Section 01

ORIENTATION
GENERATION-OAHU DIVISION &
OPERATOR TRAINEE TRAINING PROGRAM

OBJECTIVES:

Trainee will be able to:

1. State the mission and purpose of the Generation-Oahu Division
2. List the organizations that make up the Generation-Oahu Division and state their contribution as related to Operations.
3. Follow an Organization Chart and identify personnel on the Generation-Oahu Division Organization Chart.
4. Provide an overview of the Operator Trainee Training Program.
5. State what is contained in the OPERATOR TRAINEE TRAINING PROGRAM.
6. List the jobs in the Operations job progression.
7. List and describe selected locations on the station.
8. Describe the basic characteristics of the Hawaiian Electric Company electrical distribution system.
9. List the purpose and general content of the
    a. Generation-Oahu Division's OPERATING MANUAL.
    b. EMERGENCY OPERATING MANUAL.
10. List the major functions and responsibilities called out in Operator Trainee and Equipment Operator Job Descriptions.
11. List the major job tasks of the Equipment Operator.

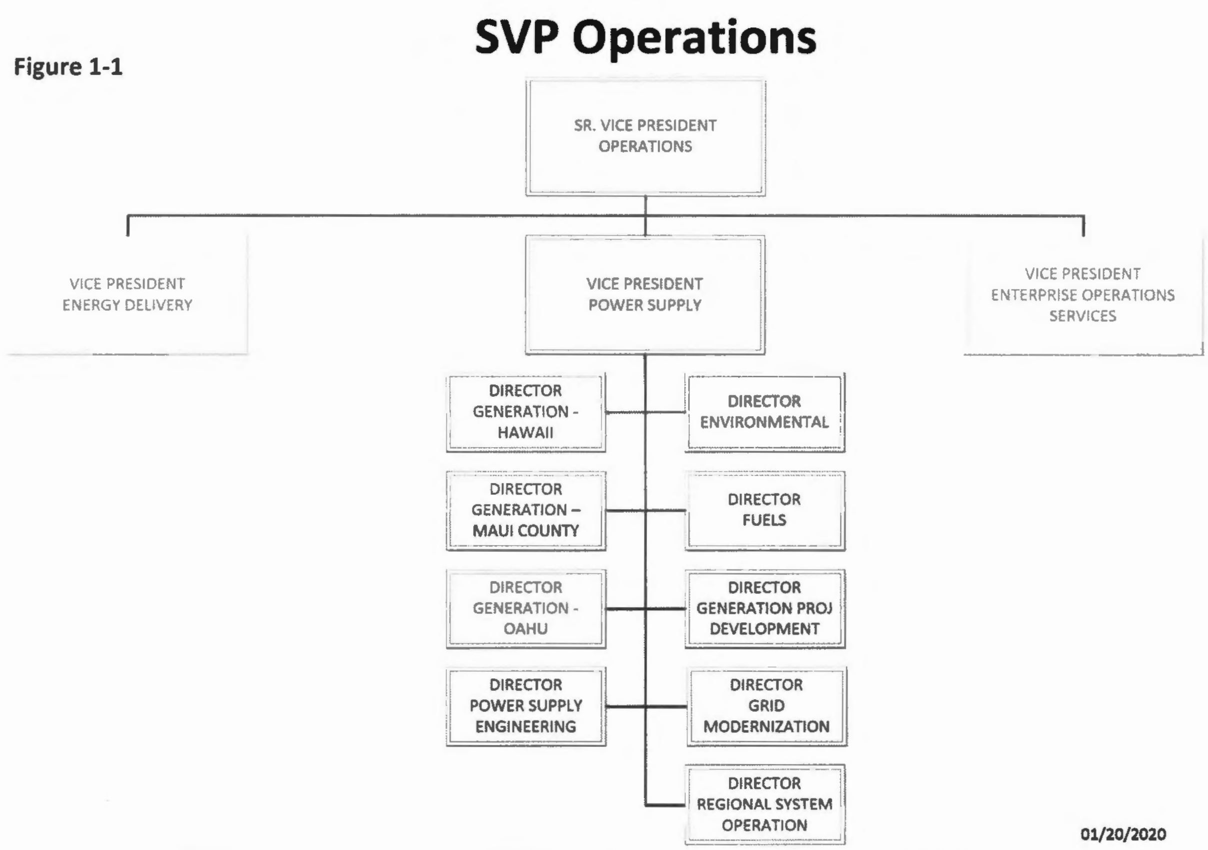
Section 01

ORIENTATION TO THE GENERATION—OAHU DIVISION AND THE OPERATOR TRAINEE TRAINING PROGRAM

Welcome to the Generation–Oahu Division! Our division is part of the Power Supply Process Area which is one of three areas that makes up the Operations group of Hawaiian Electric Company. The Power Supply area is comprised of Generation—Oahu, Generation—Hawaii, Generation—Maui County, Power Supply Engineering, Environmental, Fuels, Generation Project Development, Grid Modernization and Regional System Operation Divisions (See Figure 1-1)

All of these departments play a crucial role in the generation of electricity for our islands. The Generation—Oahu Division is responsible for the generation of electricity to supply the needs of the island of Oahu.

Figure 1-1



MISSION AND VISION

"Securing Oahu's Clean Energy Future"

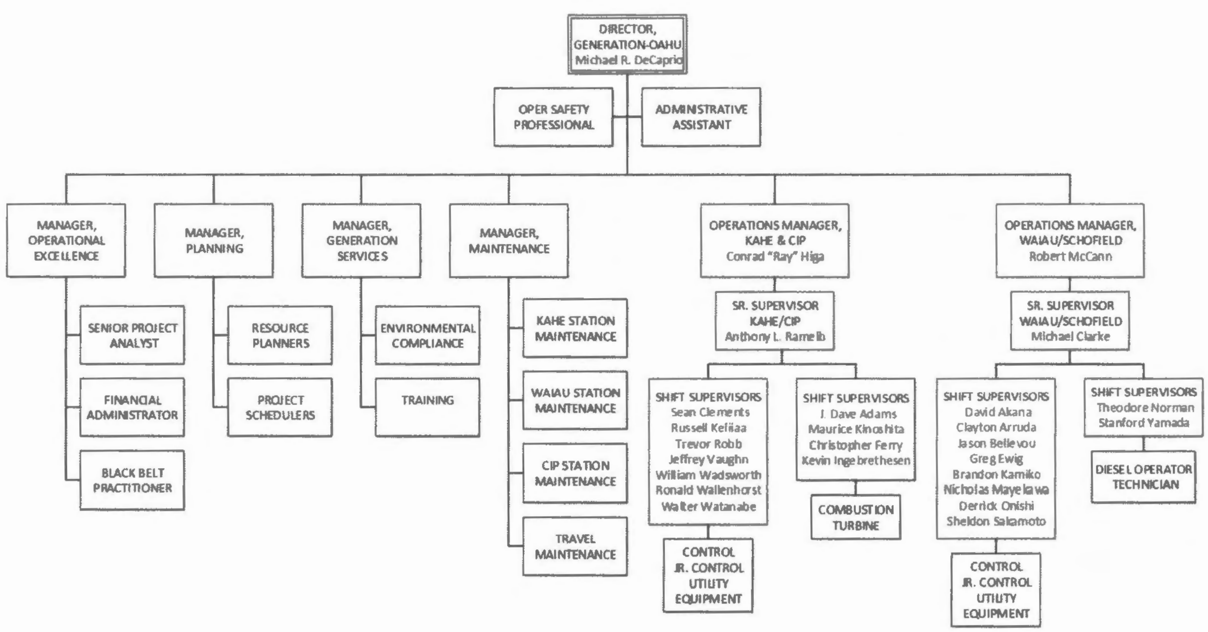
Safely operate, maintain, design, construct, and retire Hawaiian Electric Company's generation and fuel resources with a skilled workforce to enable renewable generation to be maximized, while meeting reliability standards, meeting energy security and sustainability objective, reducing environmental impacts, achieving a fair return for the investors that justifies the business risks, providing benefits to the local economy, and minimizing cost to customers.

Generation—Oahu Division Organization (see Figure 1-2)

- Administration
- Generation Services Department
- Generating Station Operations Department
- Maintenance Department
- Operational Excellence Department
- Planning Department

Figure 1-2

GENERATION-OAHU DIVISION



Operator Training Program Overview

Part 1—Basic Power Plant

This part involves this *manual,* a *classroom lecture, review,* and a *final test.* The manual is to be used for self study. Read a section and attempt to answer the Study Questions at the end of the section. You will also receive classroom instruction and be verbally quizzed on each section. The classroom lecture will follow the manual subject material and be used to clarify information, make the information relevant to the job/power plant, and answer any questions you may have. After a predetermined set of sections have been covered, you will be given a short review period followed by a Final Section Test. The questions for the test will be taken from the Study Questions at the end of the sections covered. Training will then move to the next series of sections. Should a trainee fail a section, it is up to them to study for a re-test. This is done by rereading the failed section(s) and reviewing the RedVector Courses or other assigned reading or viewing program. A makeup test will then be scheduled at the instructor's convenience.

Part 2—Plant specific layout and operations

Follows a similar format to Part I. You will have a plant specific manual to use as a study guide/reference, classroom lectures, field or plant training or tours, and final tests, prior to moving on to your On the Job Training assignments. The classroom lectures will cover a description of the purpose/function of the system and how it relates to the other systems; a flow and component trace of each system, followed by a tour of the plant to trace the system flow; a detailed component/equipment description using appropriate references, followed by a tour of the plant to identify the equipment and components; and detailed lecture/discussion and demonstration or simulation of routine and core tasks and procedures to be performed by the equipment operator.

Part 3—On the Job Training

You will be trained in the performance of selected job procedures in a systematic way under the Shift Supervisor's direction. The Shift Supervisor will evaluate and document the established training and required performance evaluations.

Program Expectations

The controlled classroom portion (Parts 1 & 2) of the Training Program should last approximately seven (7) weeks. No vacation time will be granted for the duration of this portion of the training and absence for any reason is discouraged. Trainees are expected to attend, prepared to learn and to actively participate in the program. It is imperative that trainees have their manuals and note taking materials with them each day. If a trainee is having a difficult time and needs extra assistance at any point during the training it is his/her responsibility to notify the instructor as soon as possible.

Operations Job Progression

WAIAU GENERATING STATION

- Operator Trainee
- Equipment Operator
- Utility Operator
  - Inside (Regular)
  - Outside
- Jr. Control Operator
- Control Operator

KAHE GENERATING STATION

Operator Trainee

Equipment Operator

Utility Operator

Jr. Control Operator

Control Operator

CIP GENERATING STATION

Combustion Turbine Operator

SCHOFIELD GENERATING STATION

Diesel Operator Technician

LOCATION ORIENTATION

The following is a check list of topics which will be covered with you during the first few days of the program. In order for you to feel comfortable in your new surroundings and to insure that all important questions are answered, look over the list and make sure that your instructor(s) covers each of the topics to your satisfaction.

- Introduction to co-workers
- Site/station map & HECO buildings & grounds
- Parking sticker and policies
- Security briefing
- Where and how to enter and exit buildings
- Off-limit areas
- Smoking policy
    - Location of smoking areas
- Location of employees' official bulletin boards
- Restrooms/ water fountain, coffee and vending machine locations
- Locker location and assignment
- Attendance expectations
- Sick/military and family leave
- Call-in policies
- Vacation time, selection, call back, splitting
- Start/Lunch/Stop times
- Familiarization of power plant - units, locations, names of equipment and functions.
- Watch schedule, letter assignment, relieving of watch, watch turn over
- Swapping of watch
- Job documentation and reporting of problems (daily log of station data)
- Military time / Civilian time
- New employee Onboarding
    - Explain direct deposit
    - Code of Conduct
    - Union contract
    - EEO Policy
- New Employee Safety Training
- Operator Safety Training
    - Fire Brigade
    - Self-Contained Breathing Apparatus (SCBA)
    - Location and use of Fire Fighting Equipment
- Emergency Response expectations
    - Fire
    - Oil or Chemical Spill
    - Disaster plan
- Lockout Tag-out Procedure
- Issue of tools, including protective equipment
- Location of materials and supplies section

- Safety program, reporting injuries, medical treatment
- Credit Union
- Disciplinary offenses and penalties; Grievance Procedures
- Mission of Division
- Date of first paycheck, Pay periods
- Welfare and recreation activities
- Generating Station, Department, Division, Company Policies

SYSTEM DESCRIPTION

Hawaiian Electric Company provides electrical power to the island of Oahu by means of 12 steam turbine generators, 3 combustion turbines, and 6 reciprocating internal combustion engines located at four Hawaiian Electric owned generating stations; 3 Independent Power Producers (IPPs); and power from renewable energy sources—utility scaled photovoltaic and wind farms.

The total system generating capability unit breakdown is shown in Table 1-1.

Rooftop solar is also a contributor to the electrical grid as the state moves toward a 100% renewal energy goal.

Power provided by Hawaiian Electric and IPP Generating Stations provide firm power. Descriptions of Hawaiian Electric's generating stations follow.

1. Waiau Generating Station—on Pearl Harbor, between Pearl City & Aiea Waiau Units # 3 through #10. Units #3 through #8 are steam units whereas Units #9 & 10 are combustion (gas) turbines.
2. Kahe Generating Station—on the Leeward Coast at Kahe Valley near Nanakuli. Kahe Units #1 through #6, all are steam units.
3. Campbell Industrial Park (CIP) Generating Station—in the Campbell Industrial Park in Kapolei. CIP Unit #CT1 which is a combustion turbine.
4. Schofield Generating Station—located on the Schofield Army Base in Wahiawa. Units #1 through #6, all Reciprocating Internal Combustion Engines (RICE).

Table 1-1 (December 2018)

Unit	MW Capability	Unit	MW Capability
K1	86	W8	90
K2	86	W9	53
K3	90	W10	50
K4	89	CIP1	120
K5	142	Schofield	49.8
K6	142	**HECO Total**	**1295.08**
W3	49	HR	68.5
W4	49	KL1	104
W5	57	KL2	104
W6	56	AES	180
W7	87	**IPP Total**	**456.5**

Units on the system are either base loaded, cycling or peaking units. Base loaded units operate continuously and are the most efficient units. Units W7, W8; and K1 through K4 are base load units.

Cycling units are designed for daily starts and stops and are used to supplement the base load units as system load increases during times of higher usage. W3 through W6, and K6 are used as cycling units.

Peaking units are normally operated only during the morning and/or evening load peak periods. These units are quick starting units and have short run times. Our peaking units are W9, W10, CIP1, S1 through S6.

Units W3 through W6, W9, W10, and CT1 are non-reheat units, whereas W7, W8, and all the Kahe units are of the reheat type.

All our turbine generator units were manufactured by Westinghouse with the exception of K3 & K4, and W9 & W10, which are General Electric.

Fuel oil for the generating stations is a residual fuel oil supplied by Island Energy Services from their refinery in Kapolei. Waiau and Kahe steam units utilize a Low Sulfur Fuel Oil (LSFO). W9&10 and CT1 use diesel oil as fuel and Schofield's S1 through S6 burn bio-diesel oil.

The generating stations are electrically interconnected by means of high voltage "tie-lines" (138 Kv or 46 Kv).

One of the unique features of the generating, transmission, and distribution system is that each generator is "feeding" the whole island simultaneously with the other generators. In other words, the Kahe Generating Station does not feed only West Oahu or the Waiau Generating Station does not feed only Pearl City and Aiea; rather an increase or decrease in demand anywhere on the island raises or lowers the load on the whole system. This change in system load will result in a change of output for a generator at Waiau or Kahe or CIP or Schofield.

All the generating units can be loaded or unloaded (raised or lowered in electrical output) by means of the turbine "governor". This governor has two modes of operation:

1. Manual. The Control Operator manipulates the governor control switch for the respective unit at the control room console.

2. Automatic. By means of the Energy Management System (EMS) which, through a computer at Ward Avenue, sends signals over a microwave telemetry system to the governor switch (same as in 1 above) which loads and unloads the units automatically. When the unit is on "Automatic," the Control Operator cannot exercise "manual" control of the governor. Conversely, when the unit is on "Manual" control, the EMS control is out.

The automatic loading and unloading of units is done in accord with an economic dispatch computer program. This program operates the various units at their most efficient load points in order to obtain the best possible system efficiency. This efficiency can be simply described as generating the electrical energy required while burning the least amount of fuel oil.

GENERATION-OAHU DIVISION OPERATING MANUAL

The division has established written policies for its employees in the following areas:

System Operation

- Load Requirements and Communications
- EMS Control
- Risk Condition

Unit Capabilities

- Turbine Operating Limitations
- Generator Nameplate Data
- Unit Capabilities Under Various Conditions
- Unit Capability Testing and Reporting
- Quick Load Pickup Summary

Unit Operation

- Normal Start-up and Cool Off Times for Cycling Units
- Generator Excitation and Voltage Regulation
- Transfer of Generator Exciters
- Kona Wind Operation
- Combustion Turbine Operation
- Generator MVAR Optimization
- Throttle Pressure Protection

Emergency Operation

- Severe System Frequency Depression
- Operation of Honolulu Emergency 2Switches
- System Capacity Defect

Safety

- Holdoff Request Procedures
- Generator MOS Visual Inspection

EMERGENCY OPERATING MANUAL

Unit Trips

- Electrical
- Mechanical
- Boiler

Boiler Emergencies

- Low Water in Boiler
- High Level in Boiler
- Boiler Tube Failures
- Fuel Oil Trip
- Burner Tip Failures
- Furnace Explosion
- Excessive Salt Contamination
- Stuck Soot Blowers
- Air Heater Fire
- Loss of Fuel Oil Booster Pumps

Turbine Emergencies

- Turbine Vibration and Loud Noises
- Loss of Lube Oil
- Low Vacuum in Condenser
- High Exhaust Hood Temperature
- High Condenser Outfall temperature
- Loss of Turning Gear

Generator Emergencies

- Seal Oil/Hydrogen Gas System Emergency

Auxiliary System Emergencies

- Loss of Auxiliary Cooling Water
- Loss of Service Water
- Loss of Service/Instrument Air
- Boiler Feed Pump Discharge Check Valve Stuck Open

General Emergencies

- Fire Fighting
- Severe Illness or Injury
- Tsunami Alert
- Major Earthquake
- Airplane or Vehicle Crash
- Oil Spill
- Severe System Frequency Depression

JOB DESCRIPTION

OPERATOR TRAINEE

Function: Trains to perform duties of Equipment Operator. Performs unskilled manual tasks as directed.

Job Content:

⇒ Attends classes and studies on company time to prepare for passing examinations to qualify for Equipment Operator position.

⇒ Trains to perform the following operations:

- Determine operating status of equipment from previous shift personnel and log book entries.
- Carefully monitor all equipment for normal operation; report any unusual conditions to the Shift Supervisor.
- Operate pumps (e.g. circulating water pumps, feed pumps, auxiliary cooling water pumps, condensate pumps, condensate booster pump, vapor extractor pump, distilled water make-up pumps, generator air cooler pumps, sump pumps, various other pumps) & systems equipment, and demineralizers.
- Operate the hydrogen and seal oil systems; the feed water heaters, controls, traps and drain pumps; the HP drip receiver; the traveling screens, which include the proper disposal of any trash caught; the lubricating oil storage and purifying system, which includes the periodic change of filter bags and strainer cleaning and various other strainers, pumps and systems equipment. Cuts -in and cuts-out one-half of condenser for cleaning.
- Regulate the steam to the air ejector and the turbine steam seal as required. Inspect the generator winding for oil and/or moisture. Watch for condenser leaks; notify the Shift Supervisor if leak occurs. Feed sawdust into the traveling screen pit when necessary.

⇒ Take complete log sheet readings.

⇒ Keeps equipment and floor clean

⇒ Maintains watch until relieved

⇒ Performs similar and incidental duties as required

EQUIPMENT OPERATOR

Function: Tends and operates Hydrogen and seal oil system and the auxiliary equipment on units as assigned. Tends and operates turbines and accessories. Trains to perform duties of other classifications in Operating Department as assigned.

Job Content:

⇒ Attends instruction classes, when scheduled, on Company time to prepare to pass examination to qualify for next higher job.

⇒ Determines operating status of equipment from previous shift personnel and log book entries.

⇒ Carefully monitors all equipment for normal operation; reports any unusual conditions to the Shift Supervisor.

⇒ Operates circulating water pumps, feed pumps, auxiliary cooling water pumps, condensate pumps, condensate booster pump, vapor extractor pump, distilled water make-up pumps, generator air cooler pumps, and sump pumps.

⇒ Operates the hydrogen and seal oil systems; the feed water heaters, controls, traps and drain pumps; the H.P. drip receiver; the traveling screens, which include the proper disposal of any trash caught; the lubricating oil storage and purifying system, which includes the periodic change of filter bags and strainer cleaner. Cuts-in and cuts-out one-half of condenser for cleaning.

⇒ Regulates the steam to the air ejector and the turbine steam seal as required. Inspects the generator winding for oil and/or moisture. Watches for condenser leaks; notifies the Shift Supervisor if leak occurs. Feeds sawdust into the traveling screen pit when necessary.

⇒ Takes complete log sheet readings.

⇒ Keeps equipment and floor clean.

⇒ Maintains watch until relieved.

⇒ Performs similar and incidental duties as required.

JOB TASKS

Various job tasks assigned to the Equipment Operator involve the following equipment:

1. Stilling Basin
2. Lube Pump
3. Traveling Screens
4. Sand Pump
5. Pump Wells
6. Circulator pit area
7. Screen Wash Pump
8. Circulating Water Pumps
9. Station Service Water Pumps
10. Chillers
11. Lube Water back up system
12. Auxiliary Cooling Water return tank
13. Auxiliary Cooling Water Pumps
14. Auxiliary Cooling Water chemical feed
15. Bowser Filtering System
16. Lube Oil Sup tanks and pumps
17. Seal Oil System
18. Hydrogen System
19. Hydrogen Gas Dryers
20. Boiler Feed Pumps
21. Condensate System
22. Gland Steam Exhauster
23. Heater Drip Pump
24. Surface Condensers
25. Air System
    - Service Air
    - Instrument Air
26. Air Dryers
27. Distilled Water Tanks
28. Sump Pumps
29. Primary and secondary Fuel Oil Pumps
30. Fuel Oil booster pumps

31. Primary and secondary Fuel Oil Strainers
32. Reboiler pump and condensate tank
33. Fuel Oil hot water heaters and pump
34. High and Low speed forced draft fans
35. Gas recirculating fan
36. Transformers
37. Diesel Generator
38. Preferred Bus
39. Battery Room
40. Exciter, Main and Spare
41. Annunciator Panel
42. Boiler wash pump
43. Fire pump
44. Atmospheric blow off tank
45. Nitrogen bottle for gland water head tank
46. Soda ash system tank and pumps
47. Chemical room feed tanks pumps and chemical
48. Fire hoses and extinguishers

WATCHSTANDING—KAHE

Watchstander Rounds – Minimum Inspection Requirements
Equipment Operator
(Kahe)

Inplant -

TT-03-27-06 R10

Boiler Feed Pumps:
- ✓ Check bearing temperatures
- ✓ Check shaft seals for leakage
- ✓ Listen for unusual noises or vibration
- ✓ Instrumentation – Gages operational/calibrated
- ✓ Related local alarms functional/bulbs OK
- ✓ Check recirc control valve leakage
- ✓ Bearing oil flows and oilier ring operation normal
- ✓ Inspect piping for leaks – seals/lube oil
- ✓ Structural - Foundation/brackets/pipe hangers
- ✓ Manual valves - condition/operation/packing leak
- ✓ Motor temperatures/vibration feel normal

Turbine Lube Oil:
- ✓ Check for normal operating temperatures
- ✓ Check shaft seals/packing for leakage
- ✓ Standby cooler priming oil flow normal
- ✓ Listen for unusual noises or vibration
- ✓ Instrumentation – Gages operational/calibrated
- ✓ Related local alarms functional/bulbs OK
- ✓ Motor temperatures/vibration feel normal
- ✓ Sump pressure normal – adjust vapor extractor
- ✓ Bearing oil flows and oilier ring operation norm.
- ✓ Check motor bearing oil levels normal
- ✓ Control oil CUNO filter rotated 1-2 turns
- ✓ Structural - Foundation/brackets/pipe hangers
- ✓ Manual valves - condition/operation/packing leak
- ✓ Inspect system/component piping for leaks
- ✓ Portable purifier operation normal – Dirty?
- ✓ Return screen/strainer OK – needs cleaning?

Turbine Lube Oil Bowser filtration System:
- ✓ Precipitation compartment water level normal
- ✓ Check return pump shaft seals leakage
- ✓ Bag compartment oil level not too high/dirty
- ✓ Final compartment oil level normal
- ✓ Listen for unusual noises or vibration
- ✓ Instrumentation – Gages operational/calibrated
- ✓ Related local alarms functional/bulbs OK
- ✓ Vapor extractor running
- ✓ Oil flows from LO reservoir adequate
- ✓ Check pump/extractor motor operation normal
- ✓ Return pump oil pressure normal (less than 25)
- ✓ Structural - Foundation/brackets/pipe hangers
- ✓ Manual valves - condition/operation/packing leak
- ✓ Inspect system/component piping for leaks
- ✓ Inlet CV operation normal (closes on high level)
- ✓ High level switch/control valve operation OK

Feedwater Heaters:
- ✓ Sightglass level
- ✓ Relief valves steam/water not leaking
- ✓ Bleeder trip (non return) valves position (test daily)
- ✓ Related local alarms functional/bulbs
- ✓ Level controllers position
- ✓ Manual valves - condition/operation/packing leak
- ✓ Instrumentation - gages operational/calibrated
- ✓ Structural - foundation/brackets/pipe hangers

Forced Draft / Gas Recirc Fans:
- ✓ Check for normal operating temperatures
- ✓ Check shaft seals/packing for leakage
- ✓ Clean fan inlet screens of debris, as necessary
- ✓ Bearing oilier ring operation normal
- ✓ Check motor/fan bearing oil levels normal/report dirty sight glasses to SS for cleaning

- ✓ Sealing air supplied to all necessary areas
- ✓ Damper positioners/vanes operating smoothly
- ✓ Listen for unusual noises or vibration
- ✓ Instrumentation – Gages operational/calibrated
- ✓ Related local alarms functional/bulbs OK
- ✓ Motor temperatures/vibration are normal
- ✓ Bearing cooling water /air flow normal
- ✓ Fan casings/expansion joints/insulation intact
- ✓ Structural - Foundation/brackets/pipe hangers
- ✓ Manual valves - condition/operation/packing leak
- ✓ Inspect system/component piping for leaks

Service / Instrument Air Compressors:

- ✓ Check for normal operating temperatures
- ✓ Check shaft seals/packing for leakage
- ✓ Cylinder lube operation/drops per minute normal (service air only)
- ✓ Unloader operation normal
- ✓ Interstage/final discharge pressure/temp. normal
- ✓ Listen for unusual noises or vibration
- ✓ Instrumentation – Gages operational/calibrated
- ✓ Related local alarms functional/bulbs OK
- ✓ Blowdown instrument air filters
- ✓ Bearing oil pressure normal
- ✓ Check crankcase oil levels normal
- ✓ Cooling water flow normal
- ✓ Blowdown receivers/compressor discharge drains
- ✓ Compressor crankcase/cylinder leakage OK
- ✓ Structural - Foundation/brackets/pipe hangers
- ✓ Manual valves - condition/operation/packing leak
- ✓ Inspect system/component piping for leaks
- ✓ Motor temperatures/vibration feel normal
- ✓ Check coolant/oil levels – Run donkey compressor weekly

Seal Oil System:

- ✓ Check for normal operating temperatures
- ✓ Supply header pressure (corrected for height) normal
- ✓ Drain regulator tank level normal (half sightglass)
- ✓ Vacuum tank level/pressure normal
- ✓ Backup regulator lined up/not leaking through
- ✓ Listen for unusual noises or vibration
- ✓ Instrumentation – Gages operational/calibrated
- ✓ Related local alarms functional/bulbs OK
- ✓ Drain vacuum pump discharge separator – record volume drained
- ✓ Drain the Generator (TE/CE) water detectors every watch
- ✓ Gear box/motor/separator oil levels normal
- ✓ Check vapor extractor motor/fan operation normal
- ✓ Compressor/outlet cooler cooling water normal
- ✓ Check shaft seal/packing for leaks
- ✓ Structural - Foundation/brackets/pipe hangers
- ✓ Manual valves - condition/operation/packing leak
- ✓ Inspect system/component piping for leaks
- ✓ Motor temperatures/vibration feel normal
- ✓ Vacuum pump separator oil level indication OK
- ✓ Drip pans and empty every watch

Fuel Oil Pumps:

- ✓ Check casing temperatures on standby pumps
- ✓ Standby pumps rotating slowly – adjust warm-up valves as necessary
- ✓ Listen for unusual noises or vibration
- ✓ Instrumentation – Gages operational/calibrated
- ✓ Related local alarms functional/bulbs OK
- ✓ FO pump motor/pump bearing oil levels OK
- ✓ Standby pump motor space heater on/motor feels warm
- ✓ Check shaft seals for leakage
- ✓ Inspect piping for leaks – seals/instrument/steam tracing
- ✓ Structural - Foundation/brackets/pipe hangers
- ✓ Manual valves - condition/operation/packing leak
- ✓ Motor temperatures/vibration feel normal
- ✓ Bearing oil cooling ACW cut in – as applicable
- ✓ Drip pans and empty every watch

Fuel Oil Strainers:

- ✓ Check casing temperature on standby strainer
- ✓ Strainer cover leakage OK
- ✓ Related local alarms functional/bulbs OK
- ✓ Shifting mechanism/indicators operation OK
- ✓ Instrumentation – Gages operational/calibrated
- ✓ Check shifting valve shaft packing for leakage
- ✓ Inspect piping for leaks – seals/instrument/steam tracing
- ✓ Structural - Foundation/brackets/pipe hangers
- ✓ Manual valves - condition/operation/packing leak

Fire / Boiler Wash Pumps:

- ✓ Check bearing temperatures (when operating)
- ✓ Check shaft seals for leakage
- ✓ Listen for unusual noises or vibration
- ✓ Instrumentation – Gages operational/calibrated
- ✓ Related local alarms functional/bulbs OK
- ✓ Pump casings at expected temperatures
- ✓ Discharge / Suction pressures normal
- ✓ Bearing oil levels and oilier ring operation norm.
- ✓ Inspect piping for leaks
- ✓ Structural - Foundation/brackets/pipe hangers
- ✓ Manual valves - condition/operation/packing leak
- ✓ Motor temperatures/vibration feel normal (when operating)
- ✓ Monthly / Weekly test fire pump start switches – 1st & 2nd floors

Boiler Wash/Oily Waste Water Sump Pumps

- ✓ Bearing oil levels/temperatures normal
- ✓ Level controls operating correctly
- ✓ Pump casings at expected temperatures
- ✓ Related local alarms functional/bulbs OK
- ✓ Motor temperatures/vibration feel normal (when operating)
- ✓ Pumps not running dry
- ✓ Inspect piping, valves, and expansion joints for leaks/deterioration and report discrepancies to SS

Auxiliary Cooling Water Pumps / Inplant System:

- ✓ Check bearing temperatures (when operating)
- ✓ Check shaft seals for leakage
- ✓ Listen for unusual noises or vibration
- ✓ Instrumentation – Gages operational/calibrated
- ✓ Related local alarms functional/bulbs OK
- ✓ Motor temperatures/vibration feel normal (when operating)
- ✓ Bearing oil levels norm.
- ✓ Inspect piping/expansion joints for leaks
- ✓ Structural - Foundation/brackets/pipe hangers
- ✓ Manual valves - condition/operation/packing leak
- ✓ Return tank level makeup rate normal
- ✓ Corrosion inhibitor chemical additions made as scheduled

Reboiler Feed Pumps:

- ✓ Check bearing temperatures (when operating)
- ✓ Check shaft seals for leakage/cooling water
- ✓ Listen for unusual noises or vibration
- ✓ Instrumentation – Gages operational/calibrated
- ✓ Related local alarms functional/bulbs OK
- ✓ Motor temperatures/vibration feel normal (when operating)
- ✓ Bearing oil levels norm.
- ✓ Inspect piping for leaks
- ✓ Structural - Foundation/brackets/pipe hangers
- ✓ Manual valves - condition/operation/packing leak
- ✓ Reboiler chemical additions made as scheduled
- ✓ Condensate tank level and makeup/reject valve operation normal

Gland Seal Condenser / Vapor Extractors:

- ✓ Check bearing temperatures (when operating)
- ✓ Check shaft seals for leakage
- ✓ Listen for unusual noises or vibration
- ✓ Bearing oil levels norm.
- ✓ Inspect piping for leaks
- ✓ Structural - Foundation/brackets/pipe hangers

- ✓ Instrumentation – Gages operational/calibrated
- ✓ Related local alarms functional/bulbs OK
- ✓ Motor temperatures/vibration feel normal (when operating)
- ✓ Check the Gland Steam exhauster vacuum gage (normal ~ 15" of water)
- ✓ Manual valves - condition/operation/packing leak
- ✓ Drain regulator to condenser operation normal
- ✓ Inlet/outlet damper positions normal

Emergency Generators:

- ✓ Fuel tank / Propane supply normal
- ✓ Crankcase oil level / condition normal
- ✓ Engine coolant levels normal
- ✓ Battery charger on / charging rate normal

Battery Rooms:

- ✓ Battery room conditions normal – No visible cell water / gel leakage / cell swelling
- ✓ Battery room exhaust fan running

Chemical Rooms:

- ✓ Chemical tank levels normal / going down during pump operation at expected rates
- ✓ Test Eye wash/shower station - water pressure OK
- ✓ Timed pumps shut off / tank drop as expected
- ✓ Chemical pumps normal – no oil leaks / chemical piping leaks
- ✓ Notify Chemist if boiler chemicals need to be ordered

Outside Plant-

Chillers:

- ✓ Check inlet/outlet temperatures normal
- ✓ SSW inlet strainer differential pressure normal
- ✓ Listen for unusual noises or vibration
- ✓ Instrumentation – Gages operational/calibrated
- ✓ Structural - Foundation/brackets/pipe hangers/preservation OK
- ✓ Check inlet/outlet pressures normal
- ✓ Inspect piping for leaks/cracks/deterioration
- ✓ Manual valves - condition/operation/packing leak
- ✓ Related local alarms functional/bulbs OK
- ✓ Minimum number of chillers in service – SSW pumps lined up for backup auto- start (as applicable)

Station Service Water Pumps:

- ✓ Check bearing temperatures
- ✓ Check shaft seal leakage/lube water pressure normal
- ✓ Listen for unusual noises or vibration
- ✓ Instrumentation – Gages operational/calibrated
- ✓ Related local alarms functional/bulbs OK
- ✓ Cathodic protection system turned on/operational
- ✓ Check sand pump – Operate periodically
- ✓ Bearing oil levels normal
- ✓ Inspect piping for leaks/cracks – flanges/expansion joints
- ✓ Structural - Foundation/brackets/pipe hangers
- ✓ Manual valves - condition/operation/packing leak
- ✓ Motor temperatures/vibration feel normal

Circulating Water Pumps:

- ✓ Check bearing temperatures
- ✓ Check shaft seal leakage/lube water flow/pressure normal
- ✓ Listen for unusual noises or vibration
- ✓ Instrumentation – Gages operational/calibrated
- ✓ Related local alarms functional/bulbs OK
- ✓ Cathodic protection system turned on/operational
- ✓ CWP MOV operation smooth – when observed
- ✓ Bearing oil levels normal
- ✓ Inspect piping for leaks/cracks – flanges/expansion joints
- ✓ Structural - Foundation/brackets/pipe hangers
- ✓ Manual valves - condition/operation/packing leak
- ✓ Motor temperatures/vibration feel normal
- ✓ Pump shaft cathodic brush runner operation OK

Screen Wash System:

- ✓ Check pump bearing temperatures (when operating)
- ✓ Check shaft seal leakage normal – Lube water pumps operating normally (as applicable)
- ✓ Listen for unusual noises or vibration
- ✓ Instrumentation – Gages operational/calibrated
- ✓ Related local alarms functional/bulbs OK
- ✓ Cathodic protection system turned on/operational
- ✓ Inspect piping and strainer for leaks/cracks – flanges/expansion joints
- ✓ Bearing oil levels normal – motors/gear box
- ✓ Structural - Foundation/brackets/pipe hangers
- ✓ System valves – Manual and control valve condition/operation/packing leak OK
- ✓ Motor temperatures/vibration feel normal
- ✓ Traveling screen operation normal

Chlorine Dioxide System (CLO2):

- ✓ Check for leaks – Inside/outside plant: Chemical pumps and tanks
- ✓ Is the system making "yellow water" during operation
- ✓ Bleach pump suction lined up to full tank
- ✓ Check chemical pumps are not air-bound
- ✓ Note take level lights – report any low levels to Shift Supervisor
- ✓ System condition – Report any discrepancies to the Shift Supervisor

Lube Water system:

- ✓ Check pump bearing temperatures (when operating)
- ✓ Check shaft seal leakage normal
- ✓ Listen for unusual noises or vibration
- ✓ Instrumentation – Gages operational/calibrated
- ✓ Related local alarms functional/bulbs OK
- ✓ Backup systems in standby/not supply header
- ✓ Lube water system trouble alarm clear
- ✓ Inspect piping for leaks/cracks – flanges/expansion joints/strainers
- ✓ Bearing oil levels normal
- ✓ Structural - Foundation/brackets/pipe hangers
- ✓ Manual valves - condition/operation/packing leak
- ✓ Motor temperatures/vibration feel normal
- ✓ Backup system water supply available

Transformers:

- ✓ Inspect main and aux transformers for oil leaks
- ✓ Transformer fans in auto – operation as expected based on load and air temperatures
- ✓ Check N2 bottle pressure and transformer pressure to be OK – Report discrepancies to SS

Lube Oil / Igniter Oil/Condensate Tanks:

- ✓ Inspect tanks/piping for leaks
- ✓ Review valve lineups to as expected and consistent with plant conditions
- ✓ Check transfer pump bearing oil levels (as applicable)
- ✓ Inspect lube oil/ignitor oil berm integrity – Drain valve closed, no debris – clean out as necessary
- ✓ Inspect pumps for shaft leakage
- ✓ Level indicators functional and indicate levels consistent with plant conditions
- ✓ Log beginning/ending oil levels when transferring lube oil
- ✓ Drain berm standing water after inspection / sample indicate OK to do so

General -

General Watchstation:

- ✓ Ensure conditions of watchstation meet safety and environmental compliance
- ✓ Perform housekeeping every shift
- ✓ Empty Drip pans every shift to prevent spills
- ✓ Note burned out light bulbs – Complete on-line burned out light bulb report
- ✓ Identify/correct/report safety/environmental issues
- ✓ Perform scheduled Preventive Maintenance items
- ✓ Using sight, smell, hearing, and feel, investigate for abnormalities while taking readings and making rounds

Logs and Log books:

- ✓ Examine logs for trends
- ✓ Review logbook entries since last time on watch
- ✓ Troubleshoot unusual conditions identified by log reading
- ✓ Record main and aux transformer parameters per required schedule
- ✓ Review logs for readings outside expected range for a given load
- ✓ Midnight shift – Log equipment out of service, any unusual conditions
- ✓ Record appropriate midnight logbook readings

WATCHSTANDING—WAIAU

Watch Stander Rounds - Minimum Inspection Requirements
Equipment Operator
(Waiau)

TT 3-27-06

Boiler Feed Pumps:
- ✓ Bearing temperatures
- ✓ Shaft seals for leakage
- ✓ Listen for unusual noises or vibration
- ✓ Instrumentation - gages operational/calibrated
- ✓ Related local alarms functional/bulbs
- ✓ Recirc control valve leakage
- ✓ Motor and pump bearing lube oil sightglass for oil flow and oil color
- ✓ Motor bearing oilier ring operation normal
- ✓ Inspect piping for leaks - seals/lube oil
- ✓ Structural - foundation/brackets/pipe hangers
- ✓ Manual valves - condition/operation/packing leak
- ✓ Motor temperatures/vibration feel normal
- ✓ Lube oil reservoir level
- ✓ Check ACW flow from oil cooler, mechanical seal and coolers

Condensate Pumps:
- ✓ Bearing oil level normal
- ✓ Motor temperatures/vibration feel normal
- ✓ Shaft seals for leakage
- ✓ Listen for unusual noise and feel for vibration
- ✓ Instrumentation - gages operational/calibrated
- ✓ Related local alarms functional/bulbs
- ✓ Gland water to standby pump
- ✓ Manual valves - condition/operation/packing

Turbine Lube Oil:
- ✓ Normal operating temperatures
- ✓ Lube oil reservoir level
- ✓ Standby cooler priming oil flow normal
- ✓ Listen for unusual noises or vibration
- ✓ Instrumentation - gages operational/calibrated
- ✓ Related local alarms functional/bulbs OK
- ✓ Motor temperatures/vibration feel normal
- ✓ Reservoir vapor extractor pressure
- ✓ Lube oil pump operation
- ✓ Motor bearing oil levels normal
- ✓ Control oil CUNO filter rotated 1-2 turns
- ✓ Structural - foundation/brackets/pipe hangers
- ✓ Manual valves - condition/operation/packing leak
- ✓ Inspect system/component piping for leaks
- ✓ Delaval and PALL purifier operation, test overflow alarm

Turbine Cooperheat:
- ✓ Normal operating parameters - temperatures, amperes, zones auto on/off operation
- ✓ Inspect cables/wiring

Turbine Lube Oil Bowser Filtration System:
- ✓ Storage compartment oil level normal
- ✓ Bag compartment oil level not too high
- ✓ Listen for unusual noises or vibration
- ✓ Listen for unusual noises or vibration
- ✓ Inspect system/component piping for leaks
- ✓ Pump/extractor motor operation normal
- ✓ Overflow sight glass for oil flow and color (NOTE: W4 bowser filter, ensure inlet valves are shut after unit shutdown—bowser filter compartment will overflow if these valves are not closed)
- ✓ Instrumentation - gages operational/calibrated
- ✓ Filter pump operation, pump shaft seal leakage, pump discharge < 15 psi
- ✓ No water in precipitation compartment sightglass
- ✓ Related local alarms functional/bulbs
- ✓ Structural - foundation/brackets/pipe hangers
- ✓ Manual valves - condition/operation/packing leak

Forced Draft/Gas Recirc Fans: (W5/6, W7/8)

- ✓ Normal operating temperatures
- ✓ Shaft seals/packing for leakage
- ✓ Motor temperatures/vibration feel normal
- ✓ Damper positioners/vanes steady
- ✓ Related local alarms functional/bulbs
- ✓ Listen for unusual noises or vibration
- ✓ Instrumentation - gages operational/calibrated
- ✓ Inlet vane guard screen secure/no trash
- ✓ Bearing oilier ring operation normal
- ✓ Motor/fan bearing oil levels normal
- ✓ Bearing cooling water flow normal
- ✓ Fan casings/expansion joints/insulation intact
- ✓ Inspect system/component piping for leaks
- ✓ Structural - foundation/brackets/pipe hangers
- ✓ Manual valves - condition/operation/packing leak

Air Heater: (W5/6)

- ✓ Listen for unusual noises or vibration
- ✓ Inspect system/component piping for leaks
- ✓ Related local alarms functional/bulbs
- ✓ Test air drives
- ✓ Instrumentation - gages operational/calibrated
- ✓ Normal operating lube oil pressures, temperatures, and levels

Service/Instrument Air Compressors/Air Dryers:

- ✓ Normal operating temperatures
- ✓ Shaft seals/packing for leakage
- ✓ Forced feed lubricator operation
- ✓ Blow instrument air filter drains
- ✓ Unloader operation normal
- ✓ Interstage/final discharge pressure/temp. normal
- ✓ Listen for unusual noises or vibration
- ✓ Instrumentation - gages operational/calibrated
- ✓ Related local alarms functional/bulbs
- ✓ Coolant level
- ✓ LED display for compressor status
- ✓ Bearing oil pressure normal
- ✓ Crankcase oil levels normal
- ✓ Cooling water flow normal
- ✓ Blowdown receivers/compressor discharge drains
- ✓ Compressor crankcase/cylinder leakage
- ✓ Structural - foundation/brackets/pipe hangers
- ✓ Manual valves - condition/operation/packing leak
- ✓ Inspect system/component piping for leaks
- ✓ Motor temperatures/vibration feel normal
- ✓ Reducing station pressures normal

Seal Oil System:

- ✓ Normal operating temperatures
- ✓ Supply header pressure normal
- ✓ Vacuum separator tank oil level normal
- ✓ Drain regulator tank level normal (visible in sightglass)
- ✓ Vacuum tank level/pressure normal
- ✓ Backup regulator lined up/not leaking through
- ✓ Listen for unusual noises or vibration
- ✓ Instrumentation - gages operational/calibrated
- ✓ Related local alarms functional/bulbs
- ✓ Drain the Generator (TE/CE) water detectors every watch
- ✓ Drip pans and empty every watch
- ✓ Gear box/motor/separator oil levels normal
- ✓ Check vapor extractor motor/fan operation normal
- ✓ Compressor/outlet cooler cooling water normal
- ✓ Motor temperatures/vibration feel normal
- ✓ Shaft seal/packing for leaks
- ✓ Structural - foundation/brackets/pipe hangers
- ✓ Manual valves - condition/operation/packing leak
- ✓ Inspect system/component piping for leaks
- ✓ Rotate seal oil CUNO filter
- ✓ Drain vacuum pump discharge separator – record volume drained every watch

Fuel Oil Pumps:

- ✓ Casing temperatures on standby pumps
- ✓ Standby pumps rotating slowly - adjust warm-up valves as necessary
- ✓ Listen for unusual noises or vibration
- ✓ Shaft seals for leakage
- ✓ Inspect piping for leaks - seals/instrument/steam tracing
- ✓ Structural - foundation/brackets/pipe hangers

- ✓ Instrumentation - gages operational/calibrated
- ✓ Related local alarms functional/bulbs
- ✓ Drip pans and empty every watch
- ✓ Manual valves - condition/operation/packing leak
- ✓ Motor temperatures/vibration feel normal

Fuel Oil Strainers:

- ✓ Casing temperature on standby strainer
- ✓ Strainer cover leakage
- ✓ Related local alarms functional/bulbs
- ✓ Shifting mechanism/indicators operation
- ✓ Instrumentation - gages operational/calibrated
- ✓ Shifting valve shaft packing for leakage
- ✓ Inspect piping for leaks - seals/instrument/steam tracing
- ✓ Structural - foundation/brackets/pipe hangers
- ✓ Manual valves - condition/operation/packing leak

Boiler Wash Pumps:

- ✓ Bearing oil levels/temperatures normal
- ✓ Shaft seals for leakage
- ✓ Listen for unusual noises or vibration
- ✓ Instrumentation - gages operational/calibrated
- ✓ Related local alarms functional/bulbs
- ✓ Discharge/suction pressures normal
- ✓ Pump casings at expected temperatures
- ✓ Inspect piping for leaks
- ✓ Structural - foundation/brackets/pipe hangers
- ✓ Manual valves - condition/operation/packing leak
- ✓ Motor temperatures/vibration feel normal (when operating)

Boiler Wash Sump Pumps:

- ✓ Bearing oil levels/temperatures normal
- ✓ Shaft seals for leakage
- ✓ Listen for unusual noises or vibration
- ✓ Instrumentation - gages operational/calibrated
- ✓ Related local alarms functional/bulbs
- ✓ Discharge/suction pressures normal
- ✓ Pump casings at expected temperatures
- ✓ Level controls operating correctly
- ✓ Manual valves - condition/operation/packing leak
- ✓ Motor temperatures/vibration feel normal (when operating)
- ✓ Pumps not running dry

Auxiliary Cooling Water Pumps:

- ✓ Bearing oil levels/temperatures normal
- ✓ Shaft seals for leakage
- ✓ Listen for unusual noises or vibration
- ✓ Instrumentation - gages operational/calibrated
- ✓ Related local alarms functional/bulbs
- ✓ Motor temperatures/vibration feel normal (when operating)
- ✓ Pump casings at expected temperatures
- ✓ Inspect piping/expansion joints for leaks
- ✓ Structural - foundation/brackets/pipe hangers
- ✓ Manual valves - condition/operation/packing leak
- ✓ Return tank level makeup rate normal
- ✓ Corrosion inhibitor chemical additions made as scheduled

Gland Seal Condenser/Vapor Extractors:

- ✓ Bearing oil levels/temperatures normal
- ✓ Shaft seals for leakage
- ✓ Listen for unusual noises or vibration
- ✓ Instrumentation - gages operational/calibrated
- ✓ Related local alarms functional/bulbs
- ✓ Motor temperatures/vibration feel normal (when operating)
- ✓ Check the Gland Steam exhauster vacuum gage (normal ~ 15" of water)
- ✓ Pump casings at expected temperatures
- ✓ Inspect piping for leaks
- ✓ Structural - foundation/brackets/pipe hangers
- ✓ Manual valves - condition/operation/packing leak
- ✓ Drain regulator to condenser operation normal

Chillers:

- ✓ Inlet/outlet temperatures normal
- ✓ Inlet strainer pressure normal
- ✓ Inlet/outlet pressures normal
- ✓ Inspect piping for leaks/cracks/deterioration

- ✓ Listen for unusual noises or vibration
- ✓ Instrumentation - gages operational/calibrated
- ✓ Structural - foundation/brackets/pipe hangers/preservation
- ✓ Manual valves - condition/operation/packing leak
- ✓ Related local alarms functional/bulbs

Station Service Water Pumps:

- ✓ Bearing oil levels/temperatures normal
- ✓ Check shaft seal leakage
- ✓ Listen for unusual noises or vibration
- ✓ Instrumentation - gages operational/calibrated
- ✓ Related local alarms functional/bulbs
- ✓ Motor temperatures/vibration feel normal
- ✓ Pump casings at expected temperatures
- ✓ Inspect piping for leaks - flanges/expansion joints
- ✓ Structural - foundation/brackets/pipe hangers
- ✓ Manual valves - condition/operation/packing leak

Circulating Water Pumps:

- ✓ Bearing oil levels/temperatures normal
- ✓ Shaft seal leakage/lube water flow/pressure normal
- ✓ Listen for unusual noises or vibration
- ✓ Instrumentation - gages operational/calibrated
- ✓ Related local alarms functional/bulbs
- ✓ Cathodic protection system on/operational
- ✓ Pump casings at expected temperatures
- ✓ Inspect piping for leaks - flanges/expansion joints
- ✓ Structural - foundation/brackets/pipe hangers
- ✓ Manual valves - condition/operation/packing leak
- ✓ Motor temperatures/vibration feel normal
- ✓ Chlorine system on/operational (W5/6, W7/8)

Screen Wash System:

- ✓ Pump bearing temperatures (when operating)
- ✓ Traveling screen operation normal
- ✓ Shaft seal leakage
- ✓ Listen for unusual noises or vibration
- ✓ Instrumentation - gages operational/calibrated
- ✓ Related local alarms functional/bulbs
- ✓ Cathodic protection system on/operational
- ✓ Wash nozzles/spray pattern
- ✓ Inspect piping and strainer for leaks/cracks - flanges/expansion joints
- ✓ Bearing oil levels normal - motors/gear box
- ✓ Structural - foundation/brackets/pipe hangers
- ✓ Manual valves - condition/operation/packing leak
- ✓ Motor temperatures/vibration feel normal
- ✓ Wash trough and dump flap for debris
- ✓ Raw water screen operational (EO5/6)

Lube Water System:

- ✓ Bearing oil levels/temperatures normal
- ✓ Motor temperatures/vibration feel normal
- ✓ Shaft seal leakage normal
- ✓ Listen for unusual noises or vibration
- ✓ Instrumentation - gages operational/calibrated
- ✓ Related local alarms functional/bulbs
- ✓ Backup systems in standby/not supply header
- ✓ Inspect piping for leaks - flanges/expansion joints/strainers
- ✓ Structural - foundation/brackets/pipe hangers
- ✓ Manual valves - condition/operation/packing leak
- ✓ Lube water system trouble alarm clear
- ✓ Backup system water supply available

Feedwater Heaters:

- ✓ Sightglass level
- ✓ Relief valves steam/water not leaking
- ✓ Bleeder trip (non return) valves position (test daily)
- ✓ Related local alarms functional/bulbs
- ✓ Level controllers position
- ✓ Manual valves - condition/operation/packing leak
- ✓ Instrumentation - gages operational/calibrated
- ✓ Structural - foundation/brackets/pipe hangers

DMR Chemical Storage Tanks/Pumps:

- ✓ Berm integrity intact
- ✓ Manual valves - condition/operation/packing

- ✓ Pump operation, noise/vibration
- ✓ Pump casing for leaks
- ✓ Piping and valves for leak
- ✓ Levels and log
- ✓ Drain valves closed
- ✓ Eye wash station, water supply
- ✓ Shower station, water supply
- ✓ Lighting to area

DMR/EDR:

- ✓ Inspect system/components piping for leaks
- ✓ Instruments - gages operational/calibrated
- ✓ Chemical tank levels
- ✓ Related local alarms functional/bulbs
- ✓ Eyewash station, water supply
- ✓ Shower station, water supply
- ✓ Valve lineup - consistent with operating conditions

Emergency Generators (Onan):

- ✓ Fuel tank/Propane supply normal
- ✓ Crankcase oil level/condition normal
- ✓ Complete "running log" as required
- ✓ Engine coolant levels normal
- ✓ Battery charger on/charging rate normal

Chemical Rooms:

- ✓ Chemical pumps normal - no oil leaks/chemical piping leaks
- ✓ Timed pumps shut off/tank drop as expected
- ✓ Chemical tank levels normal/going down during pump operation at expected rates
- ✓ Test eye wash station - water pressure OK

Chlorine Systems: (W5/6 and W7/8)

- ✓ Check for leaks - chemical pumps/piping/tanks
- ✓ Check chemical pump operation

General:

- ✓ Ensure conditions of station meet safety and environmental compliance
- ✓ Identify/correct/report all safety and environmental issues immediately
- ✓ Review prior shifts logbook entries
- ✓ Logs and logbooks (examine for trends)
- ✓ Troubleshoot unusual conditions
- ✓ Trains "trainees" as required
- ✓ Station lighting in-plant/outdoors
- ✓ Note station cleanliness and perform housekeeping duties
- ✓ Empty drip pans every watch to prevent spills

NOTES:

GENERATION (OAHU) DIVISION
OPERATOR TRAINEE TRAINING PROGRAM

Section 02
INTRODUCTION TO STEAM POWERED PLANTS

OBJECTIVES:

1. Describe and diagram the teapot theory of a fossil fuel power plant.
2. List the basic principles and properties of steam.
3. Describe the various cycles involved in the process of converting fossil fuel to electrical power.
4. List and describe the functions of selected equipment which make up a simple reheat plant.
5. State the basic operating principles of a combustion turbine.

Generation (Oahu) Division
Operator Trainee Training Program

Section 02
INTRODUCTION TO STEAM POWERED PLANTS

Steam electric generating plants have been in existence for a good many years. During this time, there have been tremendous advances in technology and equipment design. Despite all these advances, the basic principles involved in generating electricity in a steam power plant have changed very little. Further-more, it is not likely that these principles will change in the foreseeable future. For these reasons, if one has a good understanding of the basic principles involved, one can walk into any HECO steam plant and understand the operation. The purpose of this training manual is to provide the opportunity for a person to gain this knowledge.

Steam electric generating plants are really energy conversion plants. They take in chemical energy in the form of fuel and convert this energy to electrical energy which is the product sold to the customer. Sub-sequent sections of this manual will cover in detail the theory, equipment, and systems used to accomplish this objective. This section will cover some of the fundamentals of steam engineering and the basic steam plant cycle.

When water is heated sufficiently it boils or turns to steam. The commonest example of this is the kitchen tea kettle. The temperature at which this boiling takes place is 212° F at normal atmospheric pressure at sea level. This boiling temperature of the water will become lower at a higher altitude where the atmospheric pressure decreases. In the opposite way, if the kettle is in a mine several thousand feet deep the boiling point would be higher than 212° F due to the increased atmospheric pressure. The higher the pressure on the surface of the water in the kettle, the higher the boiling temperature of the water.

An example of this is the ordinary pressure cooker which has a sealed cover and a pressure gauge on the top. When the cooker is placed on the stove and the temperature inside the cooker goes up, the liquid begins to boil. When most substances are heated, they expand. If they are confined when they are heated so that they cannot expand, they create a pressure. As the steam cannot escape it builds up a pressure inside the vessel and as the pressure goes up the temperature goes up. For example, when the internal pressure reaches 10 lbs. per square inch gauge the temperature of the liquid will be 240° F. In other words, the steam and the liquid will both be at a temperature of 240° F. For each pressure there is a corresponding boiling temperature or steam temperature. The table listing these corresponding temperatures is called a

Steam Table and will be discussed in a later section. The creation of pressure by heating water and converting it to steam is particularly important in the operation of power plants.

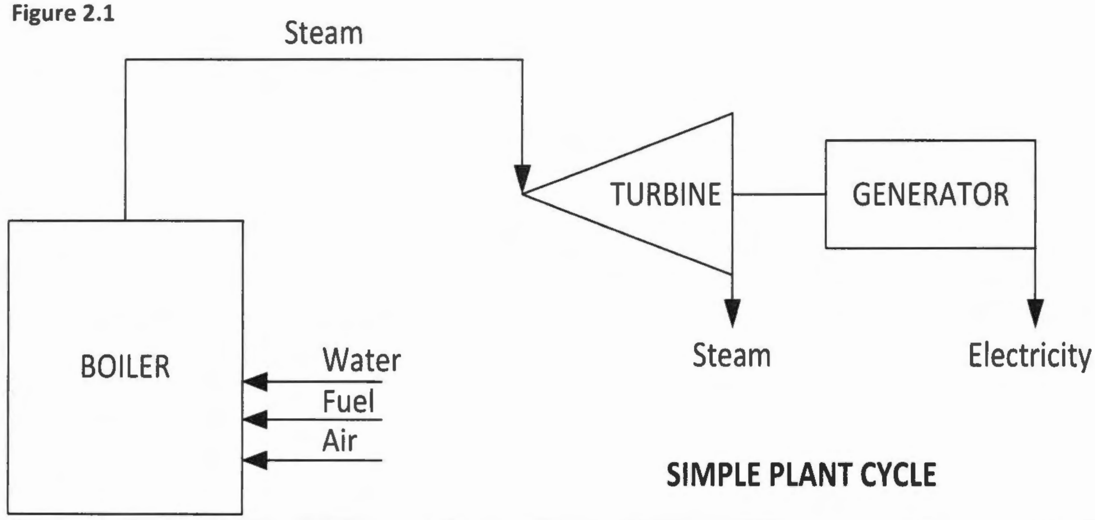
The steam that first comes out of the teakettle spout is a colorless vapor. This is dry saturated steam. A short distance from the spout it turns white. This is because some of the vapor has given up its heat and condensed into tiny particles or water which give the steam its white color. This steam contains less heat per pound and is called wet steam. Wet steam always has less heat in it per pound than dry steam. More work is accomplished heating with a pound of dry steam than with a pound of wet steam. It is always desirable to deliver steam as dry as possible to the point where it is to be used. If steam is sent to its destination through a bare steel pipe, it is evident that a lot of heat will be radiated from the pipe to the surrounding atmosphere. This means the steam will cool down and when it arrives at its destination it will not be dry steam, but wet steam, and the efficiency of the operation is reduced. Insulation is used to effectively slow down the radiation of heat from the pipe.

No insulation is 100% effective so there is always some heat loss along the steam mains and steam supply lines. This loss of heat forms little droplets of water or condensate all along the inner surfaces of the pipes. If this condensate is allowed to collect it will eventually fill up the steam mains and supply lines and prevent the hot steam from reaching its destination. This will gradually slow down the process and the production and efficiency of the operation will be seriously hampered. In order to deliver the steam as dry as possible to its destination, it is desirable to drain off this condensate by means of drip legs or drains at the low points in the steam lines.

In the simplest plant cycle, there are three major pieces of equipment: the steam generator, or as it is more often called the boiler; the steam turbine; and the electric generator. These components are connected as shown in Figure 2.1.

In the boiler, the chemical energy of the fuel is converted to heat energy by burning the fuel. The process of burning fuel is known as combustion. The proper amount of air must be supplied with the fuel in order to have proper combustion. The heat of combustion is transferred to the water in the boiler. When sufficient heat has been added, the water boils and is converted to steam. The rate at which fuel is supplied to

Figure 2.1



SIMPLE PLANT CYCLE

the boiler is adjusted either manually or automatically to maintain a constant steam pressure. High pressure steam is supplied to the turbine by the boiler. As steam is removed from the boiler, it must be replaced by an equal amount of water or the boiler will soon run dry. The water supplied to the boiler is known as feedwater. The high pressure steam entering the turbine has considerable energy due to its high pressure and temperature. The steam expands through the turbine giving up its energy to the turbine blades. This causes the shaft of the turbine to rotate. The turbine then has converted the energy in the steam to mechanical energy. When the steam has expanded as far as it can, it is exhausted from the turbine. The turbine shaft is directly connected to the generator shaft. When the turbine shaft rotates, it causes the generator shaft to rotate also. Rotation of the generator shaft causes electrical energy to be produced by the generator. The energy conversion process in this simple plant can be summarized as follows:

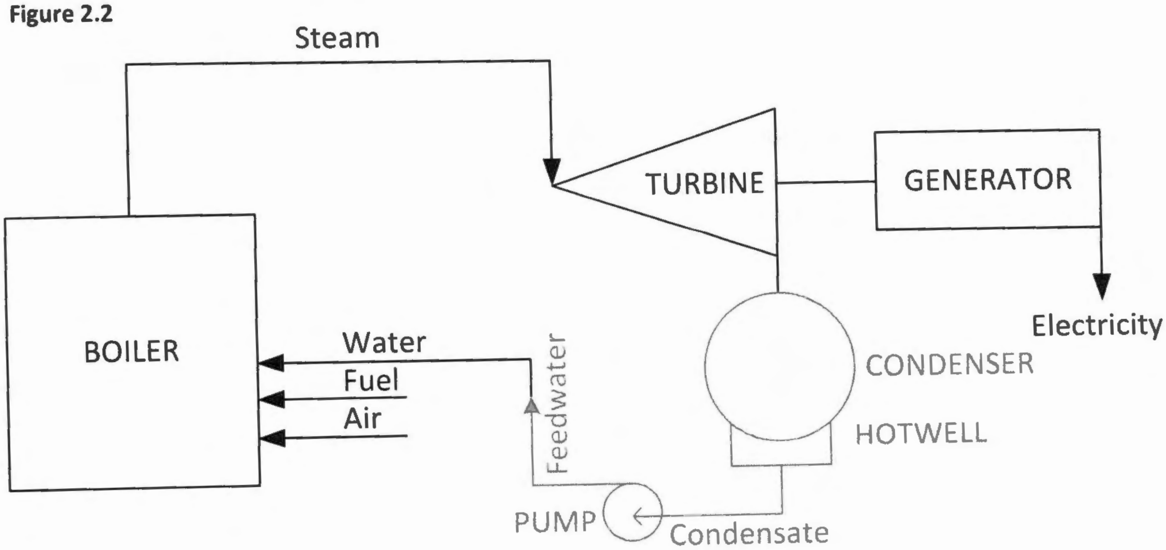
- The chemical energy in the fuel is converted to heat by the combustion process.
- The heat of combustion is transferred to the water in the boiler converting it to steam.
- The heat energy of the steam is converted to mechanical energy by the turbine.
- The generator converts the mechanical energy from the turbine to electrical energy.

The cycle shown in Figure 2.1 and discussed above is not actually used in power plants; it is too inefficient.

The cycle shown in Figure 2.2 represents a simplified actual system. It is important to have very pure water in the boiler. If there are any impurities in the water, they will form a scale on the boiler tubes.

This scale will reduce heat transfer from the fire and cause overheating of the boiler tubes. Once a supply of pure water has been obtained, it is desirable to conserve it

Figure 2.2



SIMPLIFIED ACTUAL CYCLE

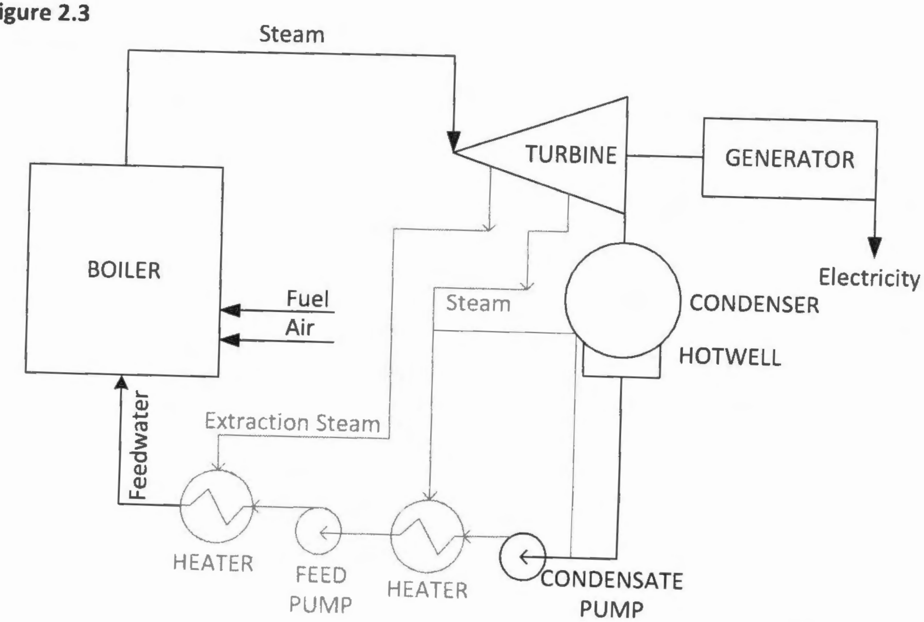
and use it over and over.

The cycle in Figure 2.2 shows how this is accomplished by the addition of two more pieces of equipment. The steam leaving the boiler is pure; if this steam is converted back to water, it would be pure water. If sufficient heat is removed from the steam; or, in other words, if the steam is sufficiently cooled, it can be converted back to water. The process of converting steam into water by cooling is known as condensing. The equipment that performs this function is known as a condenser. The water that is produced by condensing action is known as condensate. A large amount of cooling water is required to cool the steam and condense it. For this reason, power plants are always located near a large body of water. The condensed steam is collected in a tank, usually directly connected to the condenser. This tank is known as the condenser hotwell. The hotwell provides storage for the condensate and provides a supply of water to the feedwater pump. The feedwater pump takes the condensate from the hotwell and feeds it to the boiler. This completes the cycle and it can be seen that the same water is used over and over again. It is not meant to imply that the only reason for using a condenser is to permit reusing the water. The condenser performs another and equally important function. When steam condenses to water, there is a great reduction in volume. This results in the condenser being in a vacuum or an extremely low pressure. This condition allows the steam to expand much more in the turbine and greatly improves the efficiency of the plant. The condenser then has two major purposes, to create a low pressure at the turbine exhaust and to reclaim the steam for reuse in the cycle.

More equipment is actually used in plants to improve the efficiency of the cycle. Figure 2.3 shows our cycle.

In this system, condensate is removed from the hotwell by the condensate pump. The condensate is pumped through the air ejectors, gland steam condenser and three (3) feedwater heaters to the feedwater pump. This pump supplies water to the boiler through two (2) more feedwater

Figure 2.3



ACTUAL PLANT CYCLE

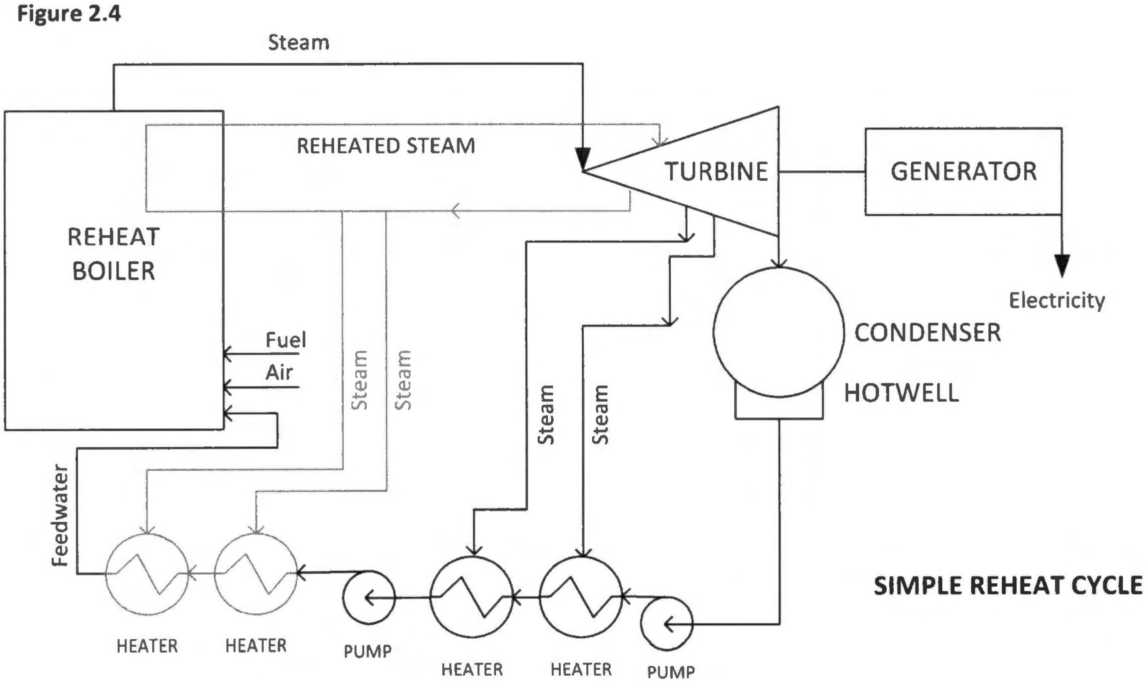
heater. The heaters receive heating steam from the turbine. This steam is used to heat the feedwater before it gets to the boiler. A small portion of the steam flowing through the turbine is extracted and supplied to the heaters. The steam removed for this purpose is known as extraction steam. There are several types of feedwater heaters in use in various power plants.

In some plants after the steam has passed part way through the turbine, it is returned to the boiler to absorb more heat and have its temperature increased. This process is known as reheating and a plant that uses this system is known as a reheat plant. Waiau units 7 and 8 and Kahe units 1 through 6 are reheat units. Figure 2.4 shows a simplified reheat cycle.

Frequently, sections of the power plant cycle are assigned names or specific terminology. Two of these are the condensate system and the feedwater system. The condensate system includes all the equipment from the condenser hotwell to the boiler feed pump suction. The feedwater system includes the equipment from the boiler feed pump suction to the boiler inlet.

In a typical power plant, the overall thermal efficiency is approximately 35 percent. This relatively low value results primarily from two conditions or losses which cannot be prevented, only minimized through proper operation. The fuel which is burned in the boilers forms certain products of combustion which are known as flue gases. After passing completely through the boiler, these gases are discharged to the atmosphere through the stack. It is not practical to reclaim all the heat energy in the flue gas and approximately 15 percent of the energy in the fuel is lost up the stack. When the steam leaves the turbine and enters the condenser, it still contains considerable energy. In order to condense, the steam must reject a considerable amount of heat energy to the circulating or cooling water in the condenser. Approximately 50 percent of the total energy input to the plant is rejected to the

Figure 2.4

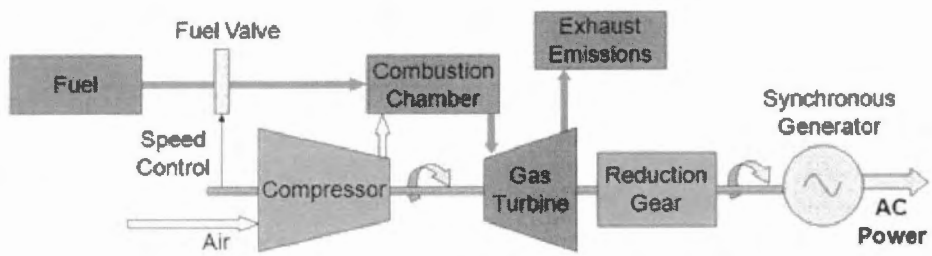


cooling water. This discussion can be summarized as follows: If the total energy in the fuel entering the plant is considered to be 100 percent, then 15 percent is lost up the stack, 50 percent is lost to the cooling water and the remaining 35 percent is converted to electrical energy.

One system for electric generation where the steam cycle is not used and the heat energy is converted directly to rotary motion is the gas turbine.

A gas turbine is a simple rotating machine that consists typically of a compressor, one or more combustion chambers where liquid or gaseous fuel is burned, a turbine to drive the compressor, and a power turbine to drive the generator. Air is introduced to the compressor where the pressure is increased. Fuel is mixed with a portion of the air in the combustion chamber where it is burned. After leaving the burner, the hot gases pass to the power turbine to drive the generator. See Figure 2.5a-c.

Figure 2.5a



Gas Turbine Electric Power Generation

Figure 2.5b

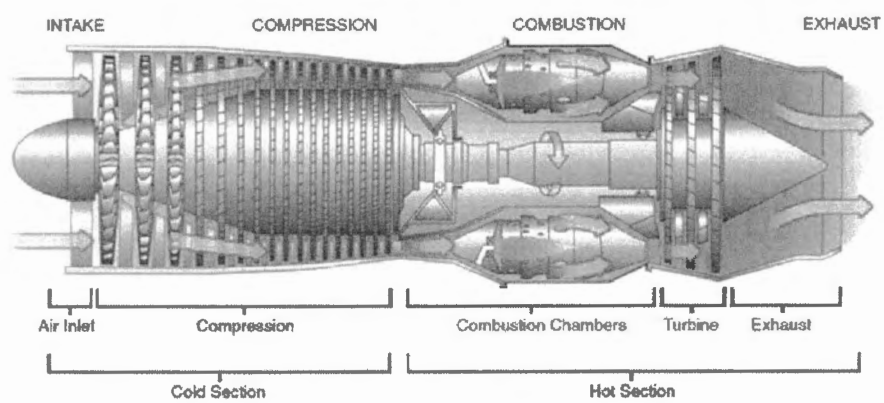
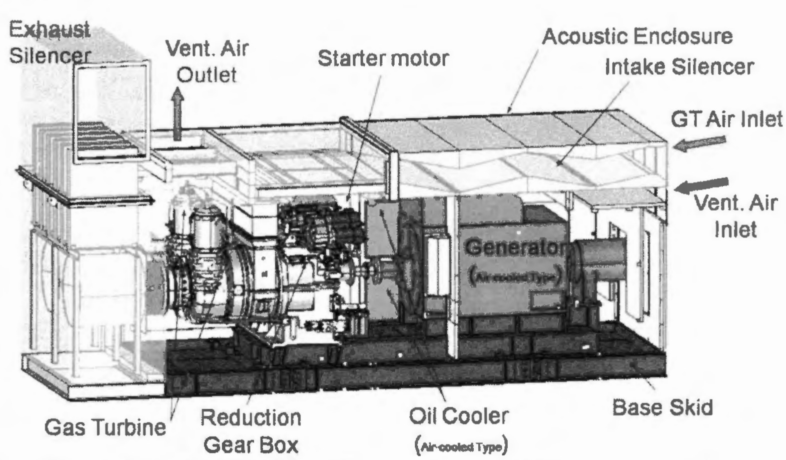


Figure 2.5c



Section 02

INTRODUCTION TO STEAM POWERED PLANTS

Study Questions

1. Most power plants throughout the world operate with use of the same basic principles? True \ False

2. Power plants can be categorized as __---__________________ conversion plants.

3. Simply put, "power plants convert chemical energy (fuel) to --__________________ energy (product)".

4. The _____________ (higher/lower) the pressure on the surface of boiling water, the higher the temperature of both steam and the water.

5. If we know the pressure of the steam and the boiling water, we can identify the temperature of the steam by using the _________________ _________________.

6. Visible steam contains water droplets which have ___________________________ from the steam.

7. We can obtain more energy from ______________________ (wet\superheated) steam.

8. Wet steam has ___________________ (more/less) heat per pound than dry steam.

9. Which type of steam is most desired for power plant operation?

10. As the energy is consumed from dry steam it becomes _________________ and eventually converts back to ____________________.

11. In the simplest electrical power plant, the 3 major pieces of equipment are the _________________, _________________ and the _________________.

12. Where is chemical energy converted to heat?

13. How is a constant steam pressure maintained in the boiler?

14. What does the boiler supply to the turbine?

15. What would happen if feedwater was not supplied to replace water that has turned to steam?

16. What causes the shaft of the turbine to rotate?

17. What causes the shaft of the generator to rotate?

18. Why is it important to have very pure water in the boiler?

19. Explain what happens to the water in a power plant after it has become steam and is returned to water again?

20. What is condensate? Where does it come from? Where is it cooled? and Where is it collected?

21. How does the condensate get from the condenser Hotwell to the boiler?

22. The condenser does not only provide the condensate for boiler feedwater. What other function does it serve?

23. Compare figure 1 (Simple Plant Cycle) in your text with figure 2 (Simplified Actual Cycle). List and describe the differences between the two.

24. Compare figure 2 (Simplified Actual cycle) in the text with figure 3 (Actual Plan Cycle). List and describe the differences between the two.

25. Describe a "Reheat" unit.

26. Compare figure 3 (Actual Plan Cycle) in the text with figure 4 (Simple Reheat Cycle). List and describe the differences between the two.

27. Using figure 4 (Simple Reheat Cycle), list all equipment to be found in the condensate system.

28. Using figure 4 (Simple Reheat Cycle), list all equipment to be found in the feedwater system.

29. Explain how a gas turbine works.

Power Generation Division
Operator Trainee Training Program

Section 03
POWER PLANT PHYSICS

OBJECTIVES:

1. List and describe selected measurement associated with Power Plant Physics
2. Describe and differentiate between the different forms of energy associated with power production
3. Detail the properties of water and steam and explain steam tables
4. Describe the processes of three (3) different heat transfer methods

Section 03

POWER PLANT PHYSICS

Before proceeding with further study of steam power plant equipment and cycles, it is necessary to have an understanding of the technical terms and physical laws involved. The following material is important and will be useful throughout your career in steam power plants.

PRESSURE is usually defined as the force acting on a unit of area. The normal measure of force is the pound and the normal measure of area is the square inch. The common unit of pressure then is pounds per square inch which is abbreviated as psi. Whenever something is measured, it must be referenced from zero or another reference point. There are two common reference points for measuring pressure. The atmosphere around the earth exerts a pressure on everything on the earth. This pressure is known as atmospheric pressure and has a value of about 14.7 psi at sea level. Atmospheric pressure changes slightly with elevation above sea level and with weather conditions. Since atmospheric pressure is always with us, it is used as the most common reference point for measuring pressure. Pressure measurements using atmospheric pressure as zero are called gauge pressure. In this system pressures below atmospheric are called vacuum. The abbreviation for gauge pressure is psig. The other pressure measuring system is known as absolute pressure and is abbreviated as psia. This system uses the complete lack of any pressure as its zero point. The difference between these two systems is atmospheric pressure. For example, a gauge attached to an automobile tire may indicate a pressure of 24 pounds per square inch. This is 24 pounds per square inch gauge, written 24 psig. This term is used when it is necessary to measure pressure relative to atmospheric pressure. When the pressure of air in an automobile tire is 24 psig, the pressure inside the tire is 24 pounds per square inch more than it is outside the tire. If atmospheric pressure is considered, which is about 14.7 psi, the total or absolute pressure of the air in the tire is 38.7 pounds per square inch absolute, written 38.7 psia. The following chart shows the relationship between the two systems.

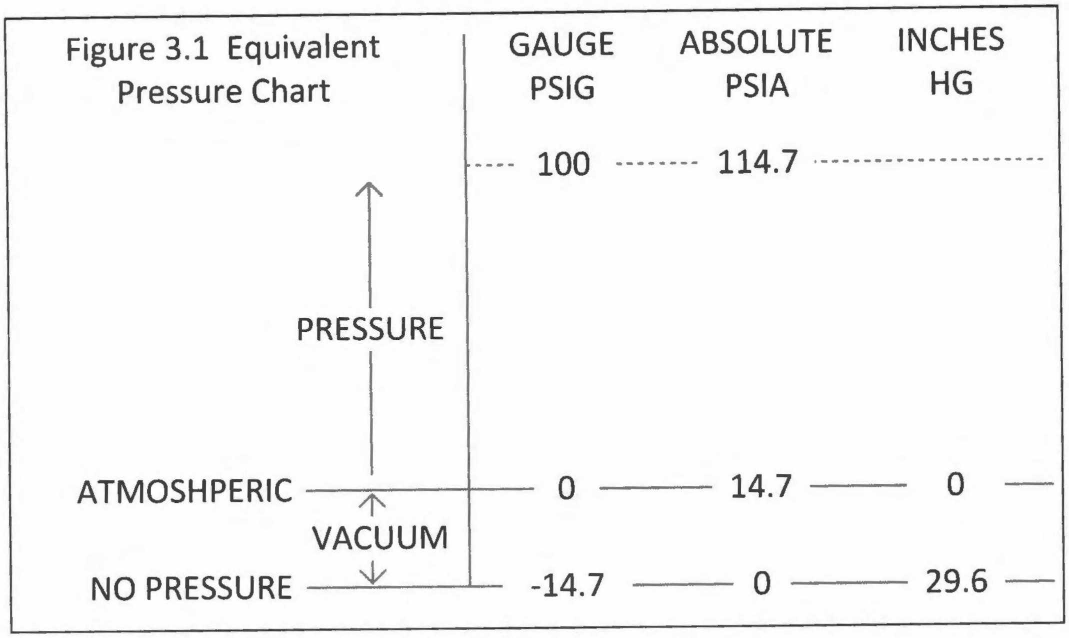


Figure 3.1 Equivalent Pressure Chart

There is one other common method of measuring pressure. This method converts pounds per square inch into the equivalent height of a column of liquid. The common units are feet of water, inches of water, and inches of mercury.

TEMPERATURE is a measure of how hot or how cold a body is. In order to measure temperature, an arbitrary scale has been set up. This scale is called the Fahrenheit Scale and is based on two fixed points. The temperature at which pure water under atmospheric pressure boils is arbitrarily said to be 212F. The temperature at which it freezes is said to be 32F. For some scientific work and in foreign countries another arbitrary scale is used. This scale is called Centigrade or Celsius. It has as its two points 0C for the freezing point of water and 100C for the boiling point.

DENSITY is usually defined as the weight of a unit volume of any material. The common unit of weight is the pound and the common volume unit is the cubic foot. The measure of density is, therefore, pounds per cubic foot which is abbreviated lb/ft^3. These are also the units of a term known as specific weight. There is a fine technical difference between density and specific weight; however, they will be used interchangeably in this program.

VOLUME is a measure of space or the capacity of a vessel. There are many different units of volume and the one that is used depends on the substance involved. For example, the volume of a car's gas tank is measured in gallons while engine oil is measured in quarts. Fuel oil for a power plant is measured in barrels while compressed air and natural gas are measured in cubic feet. A term which is frequently used in steam measurements is specific volume. This is the volume occupied by one pound of material. The usual units are cubic feet per pound. Its abbreviation is ft^3/lb.

SPECIFIC GRAVITY is a measure of the relative density of a substance referred to some standard. The standard reference for liquids and solids is the density of water. By definition the specific gravity of water at 60F is 1.0. Materials that are heavier or more dense than water have a specific gravity greater than one and materials that are lighter or less dense than water have a specific gravity less than one. The standard reference density for gases is air at 60F and atmospheric pressure. The specific gravity of air is 1.0 by definition. Gases lighter than air have a specific gravity less than one.

FLUID is a general term that is applied to substances which flow or tend to take the shape of the particular container they are in. Fluids may be of three general types: Liquids such as water, Gases such as air, and Vapors such as steam. Many of the laws of physics apply to all fluids and the study of these laws is known as fluid dynamics. Fluids can be divided into two groups; liquids are generally considered to be incompressible fluids while gases and vapors are considered as compressible fluids.

VISCOSITY is a measure of the internal friction in a fluid. The viscosity of gases and vapors is of little interest to us; however, the viscosity of liquids is important. It is the magnitude of the internal friction in the liquid that determines whether it flows easily like water or poorly like fuel oil or molasses. The higher the viscosity of a liquid the more internal friction and the slower it flows. The viscosity of a liquid can be lowered by raising the temperature of the liquid. The units of viscosity are quite complicated and will not be discussed here. There is a simple method of determining the relative value of viscosity. This consists of measuring the time required for a specified amount of liquid at a specified temperature to drip through a given size hole.

VELOCITY is a frequently misused term. Many people consider velocity and speed to be the same and for normal use this presents no problem. However, in discussing some technical aspects, it is necessary to use the correct definition. Velocity is made up of two parts, speed and direction. In order to know the velocity of something, it is necessary to know both of these quantities. Also, the velocity of a body can be changed by changing either its speed or its direction.

ENERGY

The term energy implies that a capacity for action is present. It is broadly defined as the ability to produce a change from the existing conditions. You can see from this that the term energy is not easy to define accurately. We will look at some of the different kinds of energy which are encountered in a power plant. This is important since we said earlier that a power plant is basically an energy conversion plant. The types of energy to be discussed are:

Mechanical Energy (Potential and Kinetic)
Internal Energy (Chemical and Nuclear)
P-V Energy
Flow Energy
Heat
Electrical Energy

MECHANICAL ENERGY or as it is sometimes called, Work, is usually measured in foot-pounds. For example, it requires 50 foot-pounds of energy to raise a 5 pound weight 10 feet. Mechanical energy can be further broken down into two types, potential and kinetic energy. Potential energy is energy possessed by a body due to its position or elevation. For example, water spilling over the top of a dam has potential energy relative to the bottom of the dam. Anything that is above a reference elevation has potential energy due to its position. Kinetic energy is energy possessed by a body due to its motion. It is proportional to the weight of the body and the square of its velocity. Using the previous example, the water at the top of the dam had potential energy. As the water spills over the top and falls, it converts its potential energy to kinetic energy.

INTERNAL ENERGY is due to the rotation, vibration, and movement among the molecules of a substance. Temperature is one outward sign of this form of energy. A hotter body has more of this form of energy than a colder body. When water is heated, the internal movement of molecules in the water increases and, as a result, the temperature and internal energy of the water increase. All substances have some internal energy because their molecules or atoms are in motion. In addition to this general type of internal energy, there are two other specific types; these are Chemical Energy and Nuclear Energy. Chemical energy results when a substance is able to undergo a chemical reaction and release energy. An example of this is the burning of fuel in a boiler. The fuel has chemical energy which is released by the combustion process. Nuclear energy can be released from the nuclei of atoms in certain substances by causing them to split. This relatively new energy source will become more important in the future. The amounts of chemical and nuclear internal energy in a substance do not change. The internal energy due to molecular motion does change and varies depending on the temperature of the substance.

P-V ENERGY arises from the pressure and the volume of a substance. Steam under pressure possesses this form of energy. P-V energy is numerically equal to the product of pressure and volume.

FLOW ENERGY is the term given to a specific kind of energy that exists when a fluid is in motion or has the ability to be put into motion. This is not the same as the kinetic energy of the fluid. Flow energy results from the fact that some force must have been exerted on the fluid in order to make it flow. It can be shown that flow energy is proportional to the pressure and the specific volume of the flowing fluid. Flow energy can be expressed in either work units (foot-pounds) or heat units (BTU). In power plant work we are frequently involved with flowing fluids and flow energy is an important factor in this work.

HEAT is a separate and distinct form of energy. Heat is the name given to the kind of energy that is transferred from a hot body to a cold body. In some respects heat is similar to flow energy in that there must be a flow involved. It is not correct to speak of heat contained in a body because heat by definition is energy that is being transferred. The normal unit of heat is the British thermal unit (BTU or Btu). This is the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit. When heat is transferred from one body or substance to another what actually happens is that the internal energy of the hot body decreases and the internal energy of the cold body increases. Another term that is frequently used is specific heat or heat capacity. These two terms will be used interchangeably in this manual although the term specific heat is preferred. The specific heat of any material is defined as the amount of heat required to raise the temperature of one pound of the material one degree Fahrenheit. It should be noted that for gases and vapors the specific heat depends on the process or the manner in which heat is added. For example, when heating steam at constant pressure the specific heat is 0.445 while for heating steam at constant volume the specific heat is 0.335.

ELECTRICAL ENERGY is produced when electrons, each of which possesses a unit negative charge of electricity, are made to flow in a circuit. We can use this flow of electrons to do useful work of many kinds. The units of electrical energy are kilowatt-hours or megawatt-hours. These are abbreviated KW-HR and MW-HR. Electricity and electrical energy will be discussed in more detail in another section of this manual.

There are two other terms which are frequently used that are closely related to energy. These are Power and Enthalpy.

POWER is frequently confused with work and energy. Power is the rate at which work is done or energy is expended. If we wish to raise a 10 pound weight 100 feet, it will require 1000 foot-pounds of energy. It requires this same amount of energy regardless of how fast we wish to raise it. However, it requires more power to raise the weight faster. The normal units of power are foot-pounds per second. By definition one horsepower is equal to 550 foot-pounds per second. Power can also be expressed as BTU per minute or in terms of electrical units as kilowatts or megawatts.

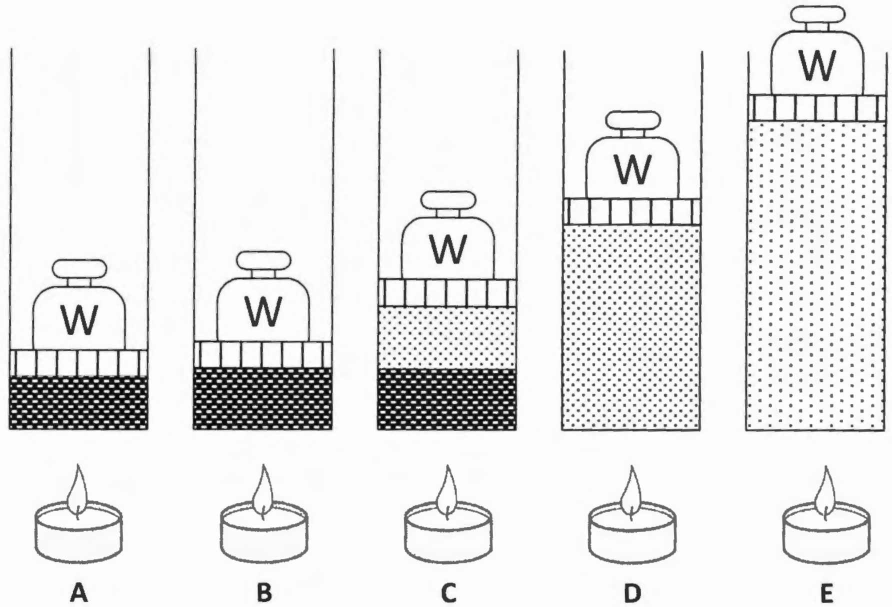
ENTHALPY is the name given to a

combination of some particular types of energy. Enthalpy can only be used with fluids because it is the sum of the flow energy and the internal energy expressed in heat units. The normal units are BTU per pound of the fluid involved. Since enthalpy is normally evaluated in heat units, it has become common practice to consider enthalpy as the total heat contained in a fluid. This is incorrect. From the definition of heat it can only be evaluated when it is being transferred and it is incorrect to speak of heat contained in a body. It is not possible to calculate the absolute amount of internal energy in a pound of fluid. This does not cause any problem since we are really only interested in the change in internal energy and enthalpy. To accomplish this, an arbitrary reference point has been selected. This reference makes the enthalpy of saturated water at 32°F equal to zero.

PROPERTIES OF WATER AND STEAM

Now that the various terms and units have been discussed, it is pertinent to take a detailed look at the properties of water and its vapor which is steam. Water and steam are the working fluids in a power plant and it is necessary to have a good understanding of them. Let us first look at the liquid state - water. When water is heated so that its temperature increases, it expands or to be more correct its volume increases. When water is cooled or its temperature lowered, it contracts or its volume decreases. If pressure is applied to water, its volume does not change and it is said to be incompressible. In the vapor state - steam, the same response occurs for changes in temperature. Increasing the temperature increases the volume. For a similar temperature change the change in steam volume will be much greater than the change in water volume. The volume of steam will change when pressure is applied and steam is therefore said to be compressible. Increasing the pressure will cause the volume to decrease.

Now let us consider the situation where water is being heated while the pressure remains constant. Assume there is one pound of water in a cyl-inder with a weight (W) applied to the piston so that the pressure on the water is 100 psia. See Figure 3.2. Let us further assume that the water is at a temperature of 60F. The volume occupied by one pound of water at this temperature is 0.01604 cubic feet. If we now start adding heat to the water, its temperature will increase and its volume will increase. The increase in volume will be rather small because most of the heat we add is used for raising the temperature and therefore the internal energy of the water. As we keep adding heat the temperature of the water reaches a point where boiling starts. The temperature at which any liquid boils depends on the pressure on it. For each pressure there is a precise tem-perature at which water or any liquid boils. This temperature is called the saturation temperature and when a liquid is



	A	B	C	D	E
Pressure PSIA	100	100	100	100	100
Temperature °F	60.00	327.81	327.81	327.81	500.00
Volume FT^3	0.01604	0.01774	2.225	4.432	5.589
Heat Added	0	270.34	714.70	1159.10	1251.00
Quality %	0	0	50	100	100
State	Subcooled Liquid	Saturated Liquid	Wet Mixture	Saturated Vapor	Superheated Vapor

Figure 3.2 Properties of Steam and Water

at this temperature it is called a saturated liquid. Water boils at 212.00°F at atmospheric pressure while at 100 psia it boils at 327.81°F. Water that is at a temperature below the saturation temperature is known as a subcooled liquid.

Figure 3.2-B shows the saturated liquid before any boiling has taken place. The volume occupied by this water is 0.01774 cubic feet. This is not a very big increase over the volume at 60°F. As we added heat to raise the temperature of the water from 60°F to the saturation temperature of 327.81°F there was a definite rise in temperature for each BTU that we added. Whenever a change in temperature results from the addition of heat, then this amount of heat is known as sensible heat. In the case of the pound of water in the cylinder, the sensible heat required to raise its temperature from 60F to 327.81°F was 270.34 BTU.

If we continue to add heat to the water, it starts to boil and turn into steam. Figure 3.2-C shows the conditions when one half the water has been converted to steam. Notice that there are two important changes. First, there has been a great increase in volume and second, there has been no change in temperature even though a considerable amount of heat has been added. Whenever a substance is converted from a solid to a liquid or a liquid vapor it is known as a change of state. The state of a substance then describes the condition it is in. Whenever there is a change of state from liquid to vapor or to be more specific from water to steam, it is accompanied by a large change in volume. At atmospheric pressure, the volume of an equal weight of steam is approximately 1600 times larger than the volume of water. At higher pressures the increase in volume is not as large. When boiling starts there is no further increase in temperature because all the heat added is used for changing the state from water to steam. Whenever there is a flow of heat, to or from a substance, and there is no temperature change then there must be a change of state. Heat flow that does not result in a change of temperature is known as latent heat. Whenever steam and water are in contact they must be at the same temperature and this temperature will be the saturation temperature corresponding to the pressure the system has on it. There is a term known as quality which is used to express the percentage of a steam-water mixture that is in the steam state. Liquid is 0% quality and pure steam with no water present is 100% quality. In Figure 3.2-C the quality is 50% because 1/2 pound of the water has been converted to steam. This state is known as a wet mixture since both steam and water are present.

As we continue adding heat to the mixture the remaining water boils and turns to steam. This condition is shown in Figure 3.2 -D. At the time when the last drop of water has turned to steam the temperature of the vapor is still the saturation temperature. Steam which is at the saturation temperature and 100% quality is known as saturated vapor or saturated steam. Under these conditions steam is sometimes referred to as being dry because there is no water present. As the rest of the water was boiled or evaporated there was another large increase in volume and no change in temperature. It is interesting to compare the quantities of heat required for raising the temperature and changing the state. It took about 270 BTU to raise the temperature from 60F to the saturation point of 237.81°F. However, it took 888.8 BTU to convert the one pound of water to steam. From this we can see that one pound of steam contains much more energy than one pound of water.

If we continue to add heat to the saturated vapor, its temperature will start to increase again and the volume will continue to increase. Steam that is heated to a temperature above its saturation temperature is known as superheated vapor or superheated steam. Figure 3.2-E shows the conditions when the steam has been heated to 500°F. Since the heat added to superheat the steam causes a change in temperature, it also must be sensible heat. Sometimes we speak of the degrees of superheat which is the difference between the actual temperature of the superheated steam and the saturation temperature for the existing pressure. In Figure 3.2-E the actual temperature is 500°F and the saturation temperature is 327.81°F so the degrees of superheat are 500°F - 327.81°F = 172.19°F.

It is important to understand that in all the previous discussion whenever we say saturation temperature we mean the saturation temperature corresponding to the existing pressure. It is the pressure that determines what the saturation temperature is. In the figures we just picked 100 psia as an example. If we had picked another pressure, the results would have been similar but all the values would be different. It should be realized that the sequence shown in Figure 3.2 can be reversed. That is, if we start with superheated steam and remove heat from it the steam will end up right where it started as subcooled water at 60°F. Complete calculations have been made of the values of the various properties of steam and water for a wide range of pressures and temperatures. These values are arranged in tabular form and are known as steam tables.

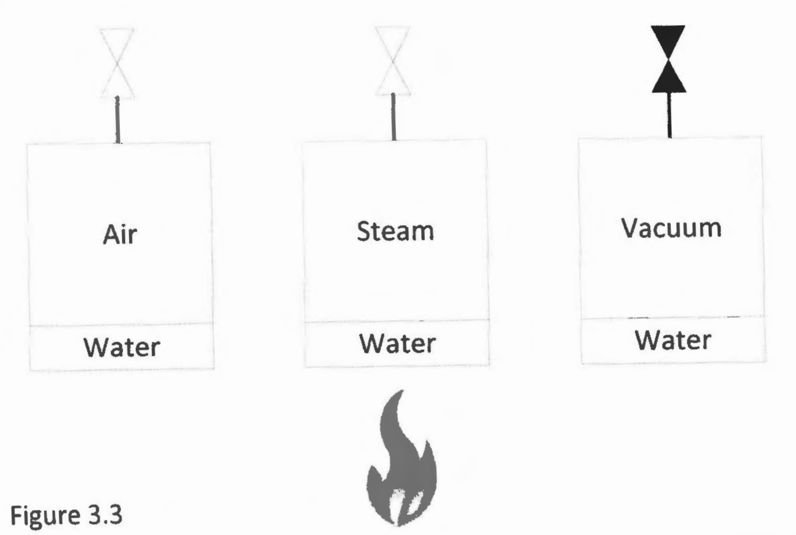


Figure 3.3

Each variable such as specific volume and enthalpy has three values for each pressure. One of these is for the saturated liquid, one for the saturated vapor and the third is the change in quantity when going from liquid to vapor. Steam tables are always given in terms of absolute pressure. This provides a constant reference point and makes the tables universally acceptable. Gauge pressure cannot be used this way because its reference point is atmospheric pressure which changes with location.

The change in volume between liquid and vapor gets smaller at higher pressures. At a pressure of 3206.2 psia there is no longer any change in volume. This is known as the critical pressure. Pressures above this value are known as supercritical pressures. The saturation temperature at the critical pressure is 705.34°F. At pressures above the critical there is no difference in any of the properties between water and steam. For any pressure and temperature above critical the specific volume, density, internal energy and enthalpy of water and steam are the same.

Another situation can be illustrated by a simple container that has a valve connecting it to atmospheric pressure. The container has some water in it. This situation is shown in Figure 3.3.

With the valve open, there will be air in the container. If we now add heat to the container and boil the water, the steam will drive all the air out of the container through the valve. If the source of heat is removed and the valve closed, the steam will condense back to water. As the steam condenses there is a considerable reduction in volume and since the valve is closed a vacuum will result in the container. This may be a harmful condition since some containers are designed to allow a high pressure inside them but cannot stand a vacuum. To prevent this type of a situation whenever a container is being cooled down its vent valve should be opened to allow air to fill the space and prevent the formation of vacuum.

HEAT TRANSFER

In the preceding discussions we have been talking about adding heat to a body and removing heat from it. It is desirable to take a more detailed look at the actual process of heat transfer. There are three separate types of methods of heat transfer; these are known as conduction, convection, and radiation. Almost all heat transfer applications use a combination of two or more of these methods. All methods of heat transfer have one thing in common, a temperature difference must exist and heat will always flow from the higher temperature area to the lower temperature area. On the other hand the three methods differ completely in the physical mechanism by which they work.

HEAT TRANSFER BY CONDUCTION is due to the ability of materials to allow the passage of heat through them. If we take a long rod of some material and place one end of it in a high temperature area, heat will flow through the rod and raise the temperature of the other end of the rod. The rate at which heat flows or is transferred through the rod depends on three factors: 1) the temperature difference between the two ends of the rod, 2) the length of the rod, and 3) the material the rod is made out of. Every material has a different ability to transfer heat by conduction. This ability is measured by a factor known as the thermal conductivity. Materials such as most metals, are good conductors of heat and have high values of thermal conductivity. Materials that are used for thermal insulation are poor conductors of heat and have low values of thermal conductivity. Values of the thermal conductivity of several materials are given below.

Material	Thermal Conductivity
Copper	2640
Steel	312
Fire Brick	4.5
Insulation (85% Magnesia)	0.5

From these values you can see that copper is about 5000 times better than ordinary insulating material at conducting heat. Any material that has a lot of air spaces or pockets is a good insulator.

HEAT TRANSFER BY CONVECTION results from the ability of a moving fluid to carry heat with it. Convection may be classified as either natural or forced depending on whether the fluid is moved naturally by a difference in densities or is forced into motion by a pump or fan. Regardless of the type of convection there is one rule that applies. Whenever a fluid comes in contact with a solid there is a thin layer or film of the fluid next to the solid that does not move. This thin film acts as an insulator and slows down the rate of heat transfer. Anything that can be done to reduce the thickness of this film will improve the performance of the heat exchange equipment. Some of the things that can be done are: increasing the velocity of the fluid, roughening the surface, and lowering the viscosity. In general the rate at which heat is transferred by convection depends on the temperature difference and the quantity known as the coefficient of film conductance. The value of this coefficient depends on the particular fluid and the thickness of the film.

HEAT TRANSFER BY RADIATION is due to the property of materials to emit and absorb waves or rays of heat. Radiant heat does not need any material to carry it; in fact, it will pass through a vacuum. The most common example of radiation is the heat we get from the sun.

When radiant energy strikes a piece of material there are three things that can happen: 1) the radiant energy (heat) can be reflected, 2) it may be transmitted right through the material, or 3) it may be absorbed in the material. In general we are interested in the third possibility. The rate at which radiant energy is absorbed by material depends on the temperature of the heat source and a factor known as the absorptivity. Black or dark materials absorb more heat than white or light colored materials. The white materials reflect more heat than they absorb. The only area of a power plant in which radiant heat transfer plays an important part is in the boiler furnace.

Boiling can be either nucleate or film boiling. In nucleate boiling the steam bubbles form slowly and are removed from the surface as quickly as they form. In film boiling, steam is formed faster than it can be removed from the surface. This results in the heat transfer surface becoming blanketed with a film of steam. In general film boiling should be avoided since the layer of steam acts as an insulator and restricts heat transfer. Condensation can be either dropwise or film type. This is comparable to the boiling situation. Filmwise condensation creates an insulating film on the surface and restricts heat transfer. Dropwise condensation results in coefficients of heat transfer that is approximately 6 times better than those for filmwise condensation.

THE COMBUSTION PROCESS

Combustion is the name given to the process of burning any fuel. More exactly it is a chemical reaction between fuel and oxygen that converts the chemical energy in the fuel into heat. This section will deal only briefly with the combustion process, it will be covered in greater detail later.

The fuels used in most of the steam plants are natural gas and No. 6 fuel oil. The fuel is supplied directly to the furnace where it is mixed with air. The air supplies the oxygen required for combustion. To have satisfactory conditions it is essential to have good mixing of the fuel and air. This insures that there will be sufficient oxygen around each particle of fuel. Maintaining the correct ratio of fuel to air is very important and automatic control systems are used for this purpose. The hot gases that result from the combustion process are known as flue gas. The flue gas is usually sampled and analyzed automatically to insure that the correct air - fuel ratio is being maintained. Insufficient air can cause an extremely hazardous condition while too much air causes a considerable loss of efficiency.

To summarize this short discussion the requirements for proper combustion are:

- Fuel and air must be supplied in the proper ratio.
- The fuel and air must be adequately mixed.
- The combustion temperature must be maintained high enough for continued ignition of the fuel - air mixture.

Section 03
POWER PLANT PHYSICS
Study Questions

1. Pressure caused by the weight of air pressing down upon the Earth is known as ____________________________ pressure.

2. Psig is the abbreviation for ______________ pressure.

3. Psia is the abbreviation for ______________ pressure.

4. A partial vacuum is a pressure less than _________________ pressure.

5. The temperature at which pure water boils under atmospheric pressure at sea level is said to be ________°F.

6. The three (3) general types of fluids are ___________________, ___________________, and _______________________.

7. Velocity is made up of two parts, __________________ and ______________________.

8. Water at the top of a dam has ____________________ energy. When it spills over the top and falls, the energy is converted to ____________________ energy.

9. ____________________ energy is due to the rotation, vibration, and movement among the molecules of a substance. Temperature is an outward sign of this type of energy.

10. Burning of fuel in a boiler is an example of ______________________energy. This energy is released by the ______________________ process.

11. Explain the terms incompressible and compressible with regard to water and steam.

12. What happens to its temperature and volume when water is heated?

13. For each pressure there is a precise temperature at which water or any liquid boils. This temperature is called the ___________________ temperature.

14. What are the three methods of heat transfer?

15. The ability of materials to allow the passage of heat through them is called _____________________________ .

16. The heat we get from the sun is the most common example of heat transfer by _____________________________ .

17. The only area of a power plant in which this type of heat transfer plays an important part is in the ______________________________.

Power Generation Department
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Section 04
POWER PLANT CHEMISTRY

OBJECTIVES:

1. Identify and distinguish the various types of matter involved in power plant chemistry.
2. Discuss compounds and their behavior when dissolved in water.
3. List five water systems and reasons for chemically controlling them.

Section 04
POWER PLANT CHEMISTRY

The subject of chemistry is quite important in power plant operation. This section will include a brief discussion of some of the principles involved and the particular chemical problems associated with power plant operation.

To recognize, identify and distinguish the various types of matter which make up our world certain definite descriptive and characteristic terms which are called the ***properties*** of the substance are used. By the use of these properties any substance can be described so that it can be recognized anywhere in the world. These properties can be divided into two general classes, physical and chemical.

PHYSICAL PROPERTIES are those that can be stated without reference to any other substance and include such things as density, color, size, melting point.

CHEMICAL PROPERTIES are those characteristics of a substance which describe its behavior with reference to other substances. For example, hydrogen reacts with oxygen to form water. This is a chemical property of hydrogen and also of oxygen.

At first consideration our universe seems to be made up of an enormous amount of different kinds of matter. Further consideration reveals, however, that all matter can be divided into three categories: elements, compounds and mixtures.

Elements are pure substances which cannot be broken down into simpler substances by any chemical reaction or change.

Compounds are substances which have uniform composition and structure however, they may be broken down or resolved into two or more simpler substances by a chemical reaction. For example, mercury oxide (a solid) is decomposed by heat into mercury (a liquid) and oxygen (a gas) both of which are more simple or less complex than the original compound. The two products cannot be broken down further by chemical action and are therefore elements. From this we can see that compounds are made up of two or more elements and can likewise be broken down into these elements. The elements that make up a compound are always present in a fixed and uniform proportion.

Mixtures are made up of distinct parts differing from each other in physical properties and with definite surface boundaries. The individual constituents can usually be recognized visually and can often be separated by simple mechanical means.

To further understand the basic small particles that make up the various elements and compounds, we can state three general rules that govern the structure of matter.

1. Elements are made up of tiny particles called atoms which cannot be divided by any chemical means.
2. The atoms of different elements have different weights and properties.
3. A compound is formed by a definite combination of the atoms of two or more elements in simple numerical proportions, resulting in the formation of the basic particle of the compound called the molecule.

These rules can be summarized by stating that elements are made up of atoms while compounds are made up of elements which in turn are made up of atoms.

For simplicity in chemical work each element is represented by a symbol which is often the first letter or first two letters of its name. (Some symbols are derived from Latin or other languages.) A list of the elements which occur in nature with their symbols and relative weights is given in Table 4.2. A compound is represented by a formula consisting of the symbols of its constituent elements followed by subscript numbers that indicate the number of atoms of that element which make up the compound molecule. For example, water is written as H_2O which shows that it is composed of two elements and furthermore that each molecule of water contains two atoms of hydrogen and one atom of oxygen. It should be noted that when writing a chemical symbol the first letter of each elements symbol should be capitalized and the second letter if used should not be capitalized. For example, the symbol for sodium is Na. If this were incorrectly written as NA it could mean either sodium or a compound of nitrogen (N) and argon (A). If the second letter of any symbol is never capitalized this problem does not arise.

In addition to the elements listed in Table 4.1 there are some compounds or groups of elements that occur frequently in plant chemical work. A list of some of the more frequently encountered ones and their symbols is given in Table 4.2.

It is not intended that the operator should try to memorize the material presented in Tables 4.1 and 4.2. It is provided for information and as a possible reference. As you work with this part of the job you will learn the common symbols.

In the power plants we are primarily interested in the chemistry of water. In this area we are really concerned with material that is dissolved or suspended in the water rather than the water itself. In order to understand what happens when a compound dissolves in water it is necessary to review the process of compound formation. As an, example, consider the metal sodium (Na) coming in contact with the gas chlorine (Cl). These two elements combine to form the compound sodium chloride (NaCl) which is ordinary salt. This

TABLE 4.1 – List of Naturally Occurring Elements

ELEMENT	SYMBOL	RELATIVE WEIGHT	ELEMENT	SYMBOL	RELATIVE WEIGHT	ELEMENT	SYMBOL	RELATIVE WEIGHT
Actinium	Ac	227	Holmium	Ho	165	Radium	Ra	226
Aluminum	Al	27	Hydrogen	H	1	Radon	Rn	222
Antimony	Sb	122	Indium	In	115	Rhenium	Re	186
Argon	A	40	Iodine	I	127	Rhodium	Rh	103
Arsenic	As	75	Iridium	Ir	193	Rubidium	Rb	85
Barium	Ba	137	Iron	Fe	56	Ruthenium	Ru	102
Beryllium	Be	9	Krypton	Kr	84	Samarium	Sm	150
Bismuth	Bi	209	Lanthanum	La	139	Scandium	Sc	45
Boron	B	11	Lead	Pb	207	Selenium	Se	79
Bromine	Br	80	Lithium	Li	7	Silicon	Si	28
Cadmium	Cd	112	Lutecium	Lu	175	Silver	Ag	108
Calcium	Ca	40	Magnesium	Mg	24	Sodium	Na	23
Carbon	C	12	Manganese	Mn	55	Strontium	Sr	88
Cerium	Ce	140	Mercury	Hg	201	Sulfur	S	32
Cesium	Cs	133	Molybdenum	Mo	96	Tantalum	Ta	181
Chlorine	Cl	35	Neodymium	Nd	144	Tellurim	Te	128
Chromium	Cr	52	Neon	Ne	20	Terbium	Tb	159
Cobalt	Co	59	Nickel	Ni	59	Thallium	Tl	204
Copper	Cu	64	Niobium	Nb	93	Thorium	Th	232
Dysprosium	Dy	162	Nitrogen	N	14	Thulium	Tm	169
Erbium	Er	167	Osmium	Os	190	Tin	Sn	119
Europium	Eu	152	Oxygen	0	16	Titanium	Ti	48
Fluorine	F	19	Palladium	Pd	107	Tungsten	W	184
Francium	Fr	223	Phosphorus	P	31	Uranium	U	238
Gadolinium	Gd	157	Platinum	Pt	195	Vanadium	V	51
Gallium	Ga	70	Polonium	Po	210	Xenon	Xe	131
Germanium	Ge	73	Potassium	K	39	Ytterbium	Yb	173
Gold	Au	197	Praseodymium	Pr	141	Yttrium	Y	89
Hafnium	Hf	179	Promethium	PM	147	Zinc	Zn	65
Helium	He	4	Protoactinium	Pa	231	Zirconium	Zr	91

TABLE 4.2 – List of Compounds Commonly Found In-Plant

COMPOUND	SYMBOL	COMPOUND	SYMBOL
Ammonia	NH_3	Molybdate	MoO_4
Bicarbonate	HCO_3	Nitrate	NO_3
Bisulfite	S_20_5	Permanganate	MnO_4
Borate	B_40_7	Phosphate	PO_4
Carbonate	CO_3	Silica	SiO_2
Chromate	CrO_4	Sulfate	SO_4
Hydroxide	OH	Sulfite	SO_3
Iodate	IO_3	Thiosulfate	S_2O_3

combination process is due to the structure of the atoms. Every atom has a heavy central core with a positive electrical charge and circulating around this core are negatively charged electrons.

Atoms which have an electrical charge due to gaining or losing one or more electrons are called ***ions***. Ions that are positively charged are known as cations while those that are negatively charged are known as anions.

There are two types of solutions that are of particular interest, these are acids and alkalis. In discussing these solutions it is necessary to first re-examine water itself. The formula for water is H2O, however, this can also be written as HOH. This second form is of more interest for it reveals that water consists of some positive hydrogen ions and an equal number of negative hydroxide ions. As long as the number of hydrogen ions and the number of hydroxide ions are equal the solution is neutral, that is it is neither acidic nor alkaline. If we now add a material such as hydrogen chloride (HCl) the hydrogen and chloride will separate and form ions. There will now be more hydrogen ions than hydroxide ions in the solution. This makes the solution acidic. An acid then is any solution that contains more hydrogen ions than hydroxide ions. The strength of the acid depends on how many extra hydrogen ions are present. The exact opposite of an acid is known as a base. A base is a material that when dissolved in water produces a solution that has more hydroxide ions than hydrogen ions. An example of such a material is sodium hydroxide (NaOH). A solution that contains excess hydroxide ions is also known as an alkaline solution, however, these are not the only ions that cause a solution to be alkaline. The alkalinity of a solution is a measure of its ability to take up or neutralize acids. Some of the more common ions that contribute to alkalinity are; carbonate (CO3), phosphate (PO4) and bicarbonate (HCO3). Any of these, as well as the hydroxide ions will tend to combine with, and use up, the excess hydrogen ions in an acid solution and they are therefore known as alkalis. Since these ions use up some hydrogen ions the degree of alkalinity of a solution is a measure of the deficiency of hydrogen ions. In order to more easily describe the degree of acidity or alkalinity of a solution a scale has been developed. This scale consists of numbers from 0 to 14 and is known as the ***pH of the solution***. On this scale a pH of 7 is pure or neutral water. Numbers proceeding in the lower direction from 7 toward zero indicate increasing acidity and values above 7 represent increasing alkalinity. Each full number on the pH scale represents a difference of ten times concentration of the solution. For example, a solution with a pH of 5 is ten times more acidic than a solution with a pH of 6. Meters are available to automatically determine and indicate the pH of a solution.

It is frequently desirable and/or necessary to know if there are any dissolved materials in a water system. The most common method of making this determination is to measure the electrical resistance of the solution. The value is usually expressed in terms of the reciprocal of resistance which is ***conductance***. Pure water is a very poor conductor of electricity; however, when dissolved material is present the ions permit a greater current to flow and the conductance increases. In actual practice we use the specific conductance or as it is more commonly known the ***conductivity*** of the solution. The correct units of conductivity are ***mhos per centimeter***. The mho is the reciprocal of the ohm or mhos = 1/ohms. For normal operation the value of conductivity expressed in mhos per centimeter is a relatively small number. For ease in use we usually report conductivity in terms of ***micromhos per centimeter***. This just means that we have multiplied the very small value in mhos by 1,000,000 to get a number that is easier to handle. It should be noted that the value of conductivity that results from a given amount of dissolved chemicals is not constant, but depends on the chemical involved.

It is often necessary for control purposes to know the exact amount of a particular chemical that is in solution. This relation is normally expressed in parts per million. The abbreviation for this unit is PPM. This is a weight relationship, for example, one pound of sodium chloride (NaCl) dissolved in one million pounds of solution results in a concentration of one part per million.

Different materials have varying solubility in water. Some are highly soluble while others are practically insoluble. The solubility of any particular substance is affected by both the pressure and temperature of the solution. In general, the amount of a gas that can be dissolved in water decreases with an increase in temperature and increases with an increase in pressure. The amount of a solid that can remain dissolved in water usually increases with an increase in temperature. There are other factors that affect solubility and not all materials follow the general rules given above, however, as long as their limitations are recognized they may prove helpful. It is possible to have material dissolved in water and then add to this solution a second chemical. These two chemicals may react to form a new compound which is not soluble in water. This new substance will come out of solution and appear as a solid material known as a ***precipitate***.

CHEMICAL CONTROL OF PLANT SYSTEMS

In power plants we are primarily concerned with the chemical control of five water systems. These are: make-up water, condensate and feedwater, boiler water, closed cooling water and circulating water. The methods used for the control of these water systems vary considerably due to local water conditions and equipment design. This discussion will therefore be confined to the aims or goals of treatment rather than considering the detailed treatment practices. Additional information is provided in the sections dealing with the particular system.

MAKE-UP WATER TREATMENT

The aim of the chemical control program for make-up water is twofold. First and foremost is to insure high quality pure water for use in the plant cycle. Secondly is to maintain satisfactory heat transfer surfaces by either restricting the formation of scale or promoting the formation of a hard scale that can be easily cracked off. In locations where the raw water has a relatively high concentration of dissolved calcium and magnesium ions the water is said to be ***hard***. Frequently the raw water is treated or ***softened*** to remove these impurities before being supplied to the heat exchanger. If this were not done the exchanger tubes would scale up very quickly and require frequent cleaning.

DEMINERALIZER

Part of the make-up water system takes minerals from the water using an ion exchange method to remove impurities and solids.

ELECTRODIALYSIS REVERSAL PROCESS (EDR)

This method employs electrochemical and membrane cell technologies to perform separations of ionic materials in aqueous solutions.

CONDENSATE AND FEEDWATER TREATMENT

The purpose of condensate and feedwater treatment is to insure a high quality water supply to the boiler and to minimize corrosion in the system. Corrosion of the feedwater system usually results from dissolved gases in the water. The primary treatment for this condition is ***deaeration*** either in a deaerating heater or a special deaerating design in the main condenser. The main gases to be removed are oxygen (O_2) and carbon dioxide (CO_2). In most of the newer plants an oxygen scavenging agent called hydrazine (N_2H_4) is pumped into the condensate to eliminate any dissolved oxygen that remains after deaeration. The corrosion rate of steel exposed to water is dependent upon the pH of the water. The corrosion rate is lowest when the pH is maintained in the range of 10-12. In plants where the entire condensate and feedwater system are steel, liquid ammonia solution is frequently added to the water to provide pH control. This method cannot be used in a system where brass heater tubes are used because ammonia dissolves the copper from the brass and damages the tubes.

Dissolved solids usually enter the condensate from condenser tube leaks. This leakage is usually monitored by conductivity instruments. There is usually no treatment for this condition other than fixing the leak. In plants requiring extreme high purity water, demineralizers are used to remove any dissolved solids from the condensate.

BOILER WATER TREATMENT

Boiler water treatment is prescribed to control the dissolved material in the boiler water in order to minimize scale formation, corrosion and carryover. Scale formation results in reduced heat transfer through the boiler tubes with resultant overheating and possible rupture of the tube. Corrosion due to dissolved gases results in pitting and deterioration of the boiler drum and the tube metal. Carryover results in deposits in the superheater which can cause tube ruptures due to reduced steam flow and overheating. Carryover can also cause deposits in the turbine with resultant loss of efficiency or in an extreme case damage to the machine.

Scale formation results from the presence in the boiler water of calcium and magnesium salts. These materials form a hard scale on the boiler tubes. The principle of scale prevention is relatively simple. It involves adding to the water one or more highly soluble chemicals such as sodium hydroxide (caustic, NaOH) and disodium phosphate (Na_2HPO_4). These chemicals react with the scale forming materials (calcium and magnesium) and form a precipitate or soft sludge that can easily be removed by boiler blowdown.

Corrosion results mainly from dissolved oxygen and low pH. The dissolved oxygen is frequently controlled by adding an oxygen scavenging chemical such as sodium sulfite (Na_2SO_3) to the water. In the newer plants this method of control has been replaced by adding hydrazine to the condensate as discussed previously. Control of pH is not required in most plants because the normal boiler water treatment with caustic and phosphate for scale control results in required pH values. Again in the newer high pressure plants pH control is a very important factor because no caustic is used. In these cases pH is controlled as previously described by ammonia addition to the condensate.

CARRYOVER is the term used to describe the condition where droplets of water are carried along with the steam leaving the boiler drum. These water droplets may contain large amounts of solids. The main causes of carryover are: high dissolved solids in the water, high alkalinity and the presence of oil in the boiler water. Total dissolved solids in the water are controlled by blowing down the boiler whenever the concentration gets too high. The total concentration of solids results from contamination such as condenser leaks and from the chemicals added for scale and corrosion control. Excess alkalinity usually results from improper treatment and can only be corrected by blowing down the boiler. Blowing down removes contaminated water from the boiler and replaces it with pure distilled water. This is basically a dilution process. Oil in the boiler water mixes with the caustic to form soap which will create foam or soap suds and cause carryover. Oil should never be allowed to enter the boiler water supply. Any residual oil remaining after construction is removed from the boiler by a special boil out procedure. There is one special boiler water control that involves both scale formation and carryover. This is the amount of dissolved silica in the boiler water. Silica may form complex scale in the boiler that cannot be controlled in the ordinary manner. The best defense against this is to remove all the silica in the makeup water so that it never gets into the boiler. In addition, under the correct conditions silica will vaporize and carryover with the steam and condense on the turbine blades. This can seriously affect turbine efficiency. The amount of silica that vaporizes depends on the boiler pressure, the boiler water pH and the concentration of silica in the water. Maximum allowable boiler pressures are specified for various silica concentrations and pH values. These pressures must not be exceeded. Silica can only be removed by boiler blowdown.

CIRCULATING WATER TREATMENT

It is not economically feasible to prescribe much treatment for this water system because it just makes one pass through the plant and is discharged. The usual treatment is periodic injection of chlorine dioxide to eliminate algae and slime formation in the condenser tubes. The feed rate is adjusted so that small chlorine residual remains in the circulating water discharge. This insures that sufficient chlorine has been injected.

Section 04

POWER PLANT CHEMISTRY

Study Questions

1. All matter can be divided into three categories; (1) ____________________________, (2) ____________________________, and (3) ____________________________.

2. Compounds are made up of two or more ____________________________.

3. The chemical symbol for water is ________________. It shows that water is composed of what two elements? ________________ ____________________

4. When a compound dissolves in water, it breaks down into its basic ____________________________________(s).

5. ________________________ are atoms which have an electrical charge due to gaining or losing one or more electrons.

6. Negatively charged ions are known an ____________________, positively charged ions are known as ________________________.

7. A solution (water) that contains more hydroxide ions than hydrogen ions is _________________________ (acidic/alkaline)?

8. A solution (water) containing more hydrogen ions than hydroxide ions is __________________________ (acidic/alkaline)?

9. The alkalinity of a solution is a measure of its ability to take up or neutralize ___________________________.

10. The pH of a solution is determined by a scale describing the degree of acidity or alkalinity. The scale consists of numbers from ______ to ______. A pH number of ______ is pure or neutral water.

11. On the pH scale, numbers higher than neutral indicate increasing ________________ while numbers proceeding lower toward 0 indicate increasing ________________.

12. Define *conductance*.

13. Define the abbreviation *PPM*

14. The solubility of a particular substance is affected by the ______________________ and _____________________ of the solution (water).

15. Power plants are primarily concerned with the chemical control of five water systems. They are:

    1.

    2.

    3.

    4.

    5.

16. Identify at least one goal of chemically controlling each of the five water systems.

17. Scale usually results from a high concentration of dissolved ___________ and ___________________ ions in the water. This water is said to be hard.

18. Corrosion is mainly the result of low _____ and dissolved _____________ in the water.

19. When water droplets are carried along with the steam leaving the boiler drum the condition is referred to as_______________________________.

20. Define corrosion.

21. Define erosion.

Power Generation Department
Operator Trainee Training Program

Section 05
BASIC ELECTRICITY

OBJECTIVES:

1. Provide a definition for electricity
2. State two (2) basic laws governing electron flow
3. Describe the properties of magnetism
4. Describe the properties of electromagnetism
5. Describe the relationship between electromagnetic fields and current flow
6. List five (5) methods for producing electric current
7. Define and describe direct current
8. Define and describe alternating current
9. Explain the operating principle of a simple transformer
10. Describe the process and associated problems with opening and closing loaded circuits.
11. Describe the operating characteristics of a switch
12. Describe the operating characteristics of selected types of circuit breakers
13. Describe how a control relay works
14. Describe the purpose and application of selected protective devices

Power Generation Department
Operator Trainee Training Program

Section 05
BASIC ELECTRICITY

The purpose of a steam power plant is to produce electrical energy. The purpose of this section of the manual is to provide the operator with some basic electrical knowledge. More will be said about electrical machinery and how it works in a later section.

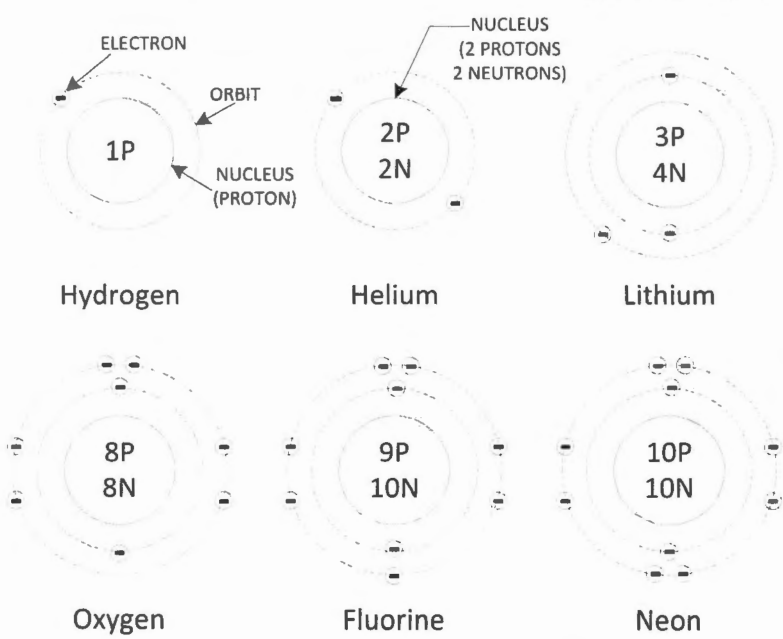
Electricity is difficult to explain because we can't see it. By looking at a piece of wire there is no way to tell whether electricity is flowing through it or not. From this we can surmise that the flow of electricity must be associated with the internal structure of the wire. Before exploring this point any further, it is necessary to understand the basic structure of any material.

Every single thing on earth is made up of combinations of elements. There are 92 elements that occur in nature. Examples of elements are hydrogen, oxygen, iron, copper, and uranium. Every element and, therefore, all matter is composed of tiny particles called atoms. The atom is the smallest particle that an element can be divided up into and still retain all the properties and characteristics of the element. Since the atom retains all the element's properties, it follows that the atoms of different elements are different from each other. That is, an atom of hydrogen, for example, is different from an atom of iron. On the other hand, all the atoms of any one element are the same. Originally, it was felt that the atom was the smallest particle of matter. Later research, however, showed that even the tiny atom is composed of small particles. These small particles are the basic building blocks of nature, and all atoms are composed of the same particles. The thing that makes atoms different is the number and combination of these particles. The basic or elementary particles we are talking about are the electron, the proton, and the neutron. The electron is a small lightweight particle that carries a negative electrical charge. The proton is a small but very heavy particle that carries a positive electrical charge. The neutron is quite similar to the proton except that it has no electrical charge.

Let us now look at how these particles are combined to form the various atoms. An atom can be considered to be like a small solar system. In our solar system the sun is at the center and the various planets including the earth are in orbit around the sun. The atom is similar, it has a center called the nucleus that is made up of protons and neutrons. These particles are packed closely together and, therefore, the nucleus is very heavy and has a strong positive charge. The electrons are in orbit around the nucleus. There are definite rings or orbits in which the electrons travel. In a normal atom there is the same number of orbiting electrons as there are protons in the nucleus. This results in the atom being electrically neutral since the positive charge of the nucleus is canceled by the negative charge of the electrons. Figure 5.1 shows a schematic diagram of the structure of various atoms.

The number of protons in the nucleus determines which element an atom belongs to. Every atom of a particular element will have the same number of protons in the nucleus.

Figure 5.1
Atomic Structure of Different Elements



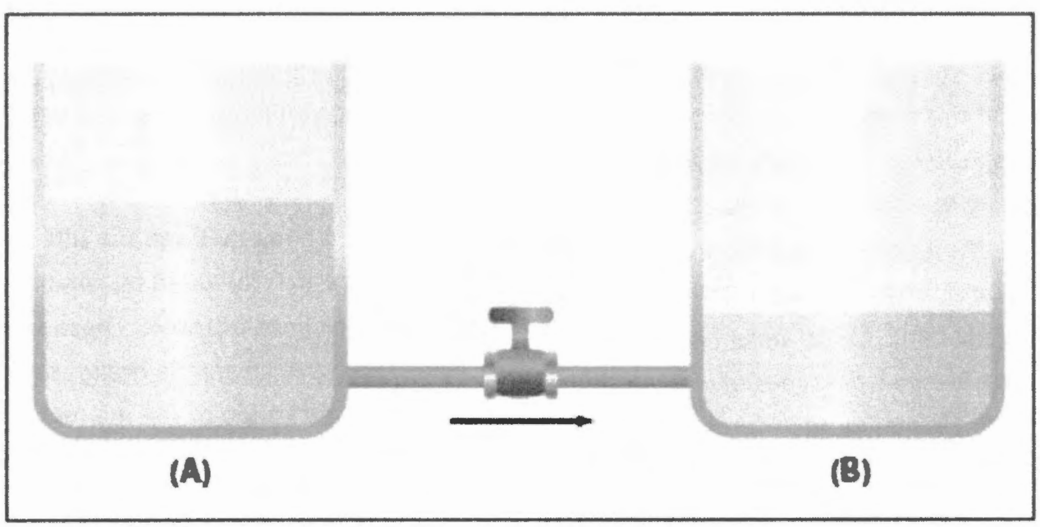
Using this information we can define electricity and take a look at how it works. Electricity may be defined as a flow of electrons. Working from this definition we can look at what makes a good conductor or a good insulator of electricity. A material which allows electricity to flow through it easily is known as a conductor. Such a material must have the ability to permit some of its orbiting electrons to break free of their orbit and move away. Most metals have this ability and are, therefore, good conductors. A material that does not permit the flow of electricity is known as an insulator. This kind of material does not have any electrons that can easily be freed.

The force that causes electrons to move or flow in a conductor is known as a potential difference and its unit of measurement is the volt. Other names given to this force which are frequently used: electromotive force and voltage. The term potential difference is preferred and will be used most frequently in this manual. When a difference of potential exists between two bodies that are connected by a conductor, electrons will flow through the conductor. The electrons will flow from the negative body to the positive body until the charge on each body is equal and there is no longer any potential difference. In much of our discussion of electricity we will compare electrical circuits with hydraulic or water circuits. There is a considerable similarity between the two and since water can be seen and is more familiar to the operator it may help in understanding electrical circuits. The previous discussion on difference of potential can be illustrated by a hydraulic system. Refer to the system shown in Figure 5.2.

At first the valve is closed and all the water is in tank A. Since the water in tank A is at a higher elevation, it has some potential energy with respect to tank B. There is a difference in potential between tanks A and B. When we open the valve, the water flows from tank A to tank B until the levels are equal. At this time there is no difference in potential energy and the flow stops. This is just what happened in the previously described electrical circuit. The difference in potential that causes electrons to flow can be thought of as a difference in pressure that causes water to flow. The rate at which electrons flow is known as electric current and is measured in amperes. This is similar to the flow rate of water in pounds per hour or gallons per minute. In any flow situation there is always some type of resistance to flow. In electron flow this resistance depends on the ease of making free electrons in the conductor. The unit that is used to measure electrical resistance is the ohm. The three basic units of electricity then are the volt, the ampere, and the ohm. These three units are related in the following manner: It takes a difference in potential of one volt to force a current of one ampere through a resistance of one ohm.

There are two basic laws about electricity that we can state now. The first is that in order to have electron flow there must be a

Figure 5.2



difference in potential. The second law is that the current in any electrical circuit is directly proportional to the difference in potential. This means that when we increase the voltage the current will also increase.

The next logical step in this discussion is to look at the methods which are used to create or produce a difference in potential. Before we can do this, however, it is necessary to discuss a topic that is very closely related to electricity. This subject is magnetism. The principles involved are applied in practically all electrical equipment.

A magnet is a body that has the properties of polarity and attraction and repulsion. Every magnet has at least two opposite poles, one positive and one negative or, as they are more commonly known, one south and one north pole. The portions of a magnet where its attractive power is the greatest are known as its poles. If a bar magnet is rolled in iron filings, they will cling in big clusters to each end of the bar. There will be few or no filings attached near the center of the bar. Obviously, the attractive power of the magnet is concentrated near its ends. We can then say that a bar magnet has a pole at each end. Magnets can be divided into two general classifications: natural and artificial. Natural magnets are no longer of any importance; however, in ancient times certain types of iron ore were discovered which were naturally magnetic. It was found that when free to move, one end would always point north and the other end south. The ends of these natural magnets were then called a north pole and a south pole. This terminology is still used today.

One of the basic laws of magnetism is that similar or like poles repel each other while dissimilar or unlike poles attract each other. This means that one south pole will repel or push away any other south pole, while a north pole and a south pole will attract each other.

The exact nature of magnetism is not fully understood. The accepted theory is that the individual atoms or molecules of a material are themselves tiny magnets. These atoms combine to form small areas known as domains which have all the properties of a magnet. In some materials it is possible to arrange all these domains so that their forces add up and produce a magnet. In a material that is non magnetic, the atoms are held so tightly that they cannot be moved and arranged to produce a magnet. The magnetic properties of a magnet can be destroyed or removed by disorganizing the lineup of its domains. This can be accomplished in several ways such as heating the material or striking it a sharp blow.

The strength of a magnet and the direction in which it acts are explained by what are called magnetic lines of force. These are imaginary lines which can be drawn to show the intensity and shape of the magnetic field produced by a magnet. This concept of lines of force and magnetic fields is very important since it will be used in other volumes of this manual to explain the operation of electrical equipment such as generators and transformers. Figure 5.3 shows a drawing of a simple bar magnet and the magnetic lines of force associated with it. Notice that the lines are drawn leaving the north pole and entering the south pole of the magnet. Also, the only area where the lines enter or leave the magnet are at the ends. This provides another definition of a magnetic pole.

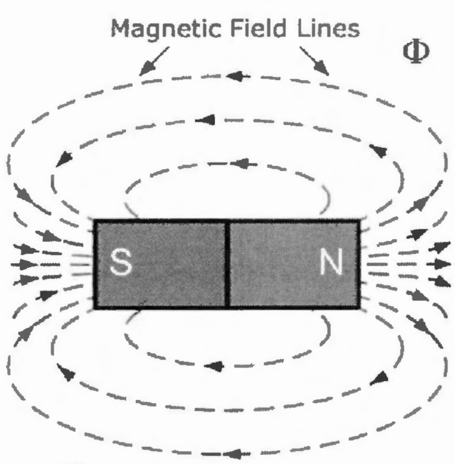


Figure 5.3

Magnetic poles are formed only where lines of force enter or leave a magnet. The lines of force are more concentrated or closer together near the poles. This shows that the force of attraction of the magnet is strongest in these areas. Where the lines of force are further apart, the strength of the magnet is weaker. The lines of force which leave the north pole travel through the surrounding area and enter the magnet at the south pole. The lines continue through the magnet itself back to the north pole. Each line of force is then a complete circuit or loop. Each loop is known as a magnetic circuit. The magnetic field of a magnet is the area around the magnet through which the lines of force travel.

The lines of force associated with a magnet will travel unhindered through non magnetic material. For example, a piece of glass will not change the direction or intensity of magnetic lines of force. Materials such as soft iron which are easily magnetized will deflect the lines of force, so that they flow through the iron rather than around it. The magnet circuit flows more easily through iron than through air, so it changes its normal direction to go through the iron. In other words, the lines of magnetic force follow the path of least resistance.
Figure 5.4 shows how a piece of iron can deflect the lines of force.

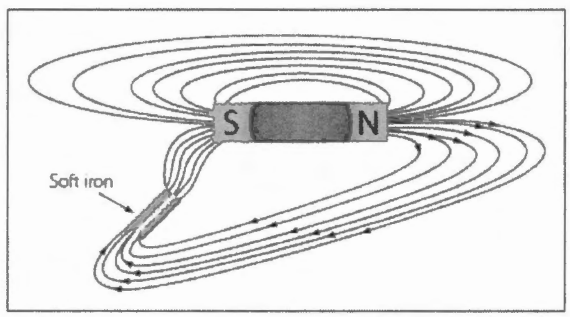


Figure 5.4

A material that is easy to magnetize, such as iron, is said to have a high permeability. This is the ability to deflect lines of force or concentrate them. Materials with high permeability usually do not maintain their magnetism. A permanent magnet is one that retains its magnetism. These are usually made out of hardened steel or special alloys such as alnico.

ELECTROMAGNETISM

Up till now we have been considering the basic laws of magnetism and simple permanent magnets. Now we must consider the important relationships between electricity and magnetism. The importance of these relationships cannot be overemphasized. Unless this material is well learned it will not be possible to understand the principles of operation of generators, transformers, and motors. Under electromagnetism we will discuss magnetism as it is affected by electricity and electricity as it is affected by magnetism.

Whenever electric current flows through a conductor it creates a magnetic field around the conductor. The strength or intensity of this magnetic field depends on the amount of current flow. When the current is increased, the magnetic field also increases. The magnetic field produced in this manner has a circular shape surrounding the conductor.

Figure 5.5 shows the field produced by a conductor. The direction of the lines of force depend on the direction of current flow. When two parallel conductors carry current in the same direction, their magnetic fields combine and exert a force trying to pull the conductors together. If the current flow is in opposite directions in the two conductors, their magnetic fields will tend to push them apart. The magnetic field around a current carrying wire exists all along its length. If we now take this wire and wind or wrap it into a coil, the magnetic field interacts and takes a different shape. The combined influence of all the turns produces a two pole magnetic field similar to that of a simple bar magnet. One end of the coil will be a north pole and the other end a south pole. If a material with high permeability such as iron is placed inside the coil, it will concentrate the field and make this magnet stronger. A magnet formed in this manner is known as an electromagnet. When the current flow is stopped, the electromagnet loses its magnetic properties. This principle is extensively used in power plants for generators, motors, solenoids, and relays. The strength or intensity of the magnetic field produced by a coil depends on the following factors:

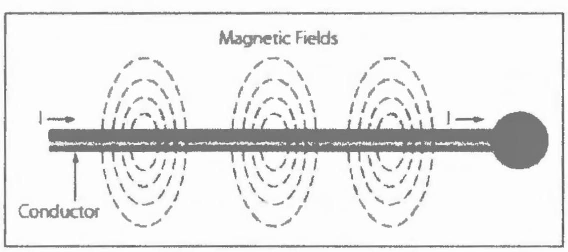


Figure 5.5
Magnetic Field Around a Conductor

- The number of turns of conductor
- The amount of current flow
- The type of material in the core
- The ratio of the coil's length to its width

The number of turns of conductor and the amount of current flowing are frequently combined into a term known as ampere-turns.

There are two basic relationships that determine the effect of a magnetic field on a conductor. A thorough understanding of these relations is required in order to understand the operation of electrical machinery.

Whenever a current carrying conductor is placed in a magnetic field other than its own, the two magnetic fields will interact and exert an actual force on the conductor. If the conductor is not physically restrained it will move. This is the basic principle involved in an electric motor. The direction of the force depends on the direction of current flow in the conductor and the direction of the lines of force of the magnetic field. The value or magnitude of this force depends on the intensity of the magnetic field, the amount of current flowing, and the length of the conductor.

Whenever a conductor which has no current flow is moved through a magnetic field, a potential difference will be developed in the conductor. It is important to understand that the motion must be such that the conductor cuts across the lines of force of the magnetic field. No difference in potential will be developed if the conductor moves parallel to the lines of force and does not cut across them. The magnitude or value of the potential difference produced in this manner depends on the strength of the magnetic field, the length of the conductor within the field, and the speed with which the lines of force are crossed by the conductor. This principle is used in all generators and transformers. The difference in potential produced in this manner will continue to be produced as long as the relative motion continues.

Now, let's return to the topic of electricity and look at the various methods used to produce a potential difference. There are a great many methods available; however, only a few have application in a power plant.

FRICTION

A potential difference can be produced by the friction of one body rubbing against another. We have all experienced this at one time or another, particularly after sliding across plastic seat covers in an automobile. This is known as static electricity since the charge that is produced stays put or is static. There is no useful application of this method in a power plant.

PRESSURE

There are some special crystalline materials that have the ability to produce a difference in potential when subjected to pressure. The size of this potential difference is very small, and the use of this method is usually limited to communications equipment or precision instruments. Some telephones use a crystal to convert the mechanical motion caused by a voice to electrical signals.

HEAT

When a piece of metal such as copper is heated at one end, the electrons in the copper try to move away from the high temperature end. This condition holds true for most metals. There are, however, a few materials that have an opposite effect when heated. In these materials, such as iron, the electrons flow toward the high temperature area. If we join a copper wire to an iron wire and apply heat to the junction, electrons will flow from the iron to the copper due to the potential difference. The voltage produced by this method is small. The main use for this system is for instrumentation. For the correct type of metals there is a known relation between the temperature of the junction and the resulting difference in potential. This device is known as a thermocouple and is commonly used for measuring temperatures in a power plant.

CHEMICAL ACTION

Just as the chemical action between fuel and air in the boiler furnace is used to produce heat, an appropriate chemical action can be used to produce a potential difference. A device of this type is generally known as a battery. This is not strictly correct; the proper name is a cell. A battery actually consists of two or more cells connected together. There are two basic types of cells, primary and secondary. All cells have some common parts, two conductors known as electrodes through which the electrons leave and enter the cell, a container, and a suitable chemical solution.

A primary cell is one in which one of the electrodes is eaten away by the chemical action. A secondary cell is one in which the electrodes and the solution (known as the electrolyte) are altered by the chemical action when the cell delivers current. There, cells may be returned to their original condition by forcing an electric current through them in the opposite direction to that of discharge.

PHOTOVOLTAICS

These modules have made reliable power beyond powerlines possible. Photovoltaics is the most widely used alternative power source. A PV module produces electrical current when exposed to sunlight.

A single PV cell consists of two very thin wafers, generally made of very pure silicon, which have been doped with elements that produce a surplus of electrons in one layer (called the n-layer) and a deficit of electrons in the other (called the p-layer). When the photons in sunlight bombard these electrons, some are liberated and begin to flow. Electricity results from millions of these liberated electrons flowing away from the n-layer. Some electrons make their way to metallic conductors on the silicon surface, then flow on through the electrical circuit. The PV cell acts like an electron pump.

PRIMARY CELLS

Primary cells can be further divided into two types known as dry and wet. The type depends on the condition of the chemical solution. In the dry cell it is a paste, while in the wet cell it is a liquid. Primary wet cells are seldom used; however, primary dry cells are very common, the regular flashlight battery being a good example. This dry cell consists of a zinc container which is also used as the negative electrode, a carbon positive electrode, and a chemical paste (usually ammonium chloride). As this cell supplies current, the zinc is eaten away by the chemical paste. When the zinc is used up, the cell is dead and must be thrown away.

SECONDARY CELLS

Secondary cells can also be divided into wet and dry classes. In this instance, however, it is the wet cell that is commonly used. The usual example is the automobile storage battery. The cells in this battery usually use lead peroxide as the positive electrode and lead as the negative electrode. The electrolyte is sulfuric acid. Actually, the name storage battery, as given to this equipment, means that it stores chemical energy which can be converted to electrical energy. In the power plants a group of these cells are connected to form the station battery with a nominal voltage of 125 volts. This battery is used to supply critical services and is kept fully charged at all times. A battery charger is used to supply the normal load and keep the battery charged. When being charged, a storage battery generates hydrogen and oxygen. As hydrogen is explosive, care must be used to prevent an explosion.

Another advantage of a wet cell battery is that the state of charge or storage can be easily determined. The specific gravity of the solution changes with the state of storage. By measuring this property the condition of the battery is known.

MAGNETISM

The production of a potential difference due to the relative motion between a conductor and a magnetic field was discussed previously. This is a principle used in all modern generators. The actual methods used in generators will be discussed in a subsequent section.

DIRECT AND ALTERNATING CURRENT

The way in which current flows in an electrical circuit can be divided into two general classes. These are known as direct current (DC) in which the direction of the flow is always in the same direction, and alternating current (AC) in which the direction of flow continually reverses or alternates. Remember that current flow is produced by a difference in potential, so for direct current the potential difference or voltage must remain in the same direction, while for alternating current the potential difference must change direction to cause the direction of current flow to reverse.

DIRECT CURRENT

Direct current flow can be represented by a piping system with a centrifugal pump. A system such as this is shown in Figure 5.6. The pump produces a pressure that causes water to flow in the circuit. The pressure at the pump discharge is always greater than the suction pressure, and the water always flows in the same direction. The equivalent electrical circuit is also shown. Batteries always produce direct current; however, it may also be produced by a generator.

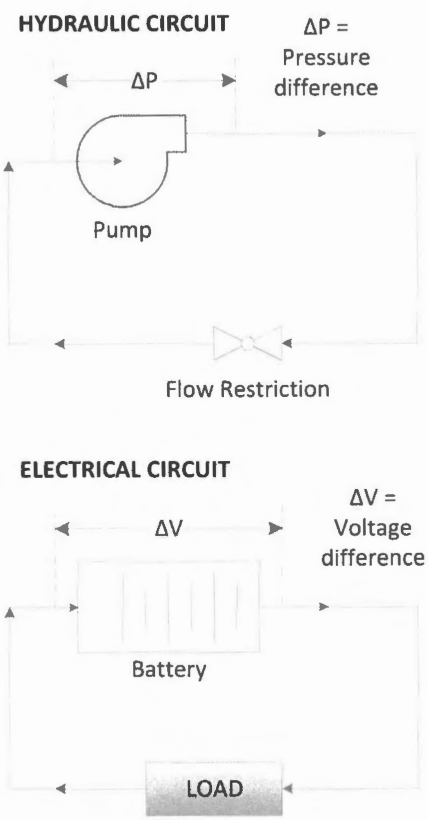


Figure 5.6—Direct Current

ALTERNATING CURRENT

Alternating current can also be represented by a piping system and pump. In this case, however, a reciprocating pump must be used. Figure 5.7 shows a circuit of this type. The equivalent electrical circuit is shown for comparison. As the piston moves toward the right, water pressure at point A increases and water flows in the pipe from A through the resist-ance R and into the pump at B. The pressure at point B is low because the piston is moving away from it. When the piston reaches the end of its travel or stroke, it reverses and now moves toward the left. The pressure at point B now increases while the pressure at A decreases and the flow of water is reversed.

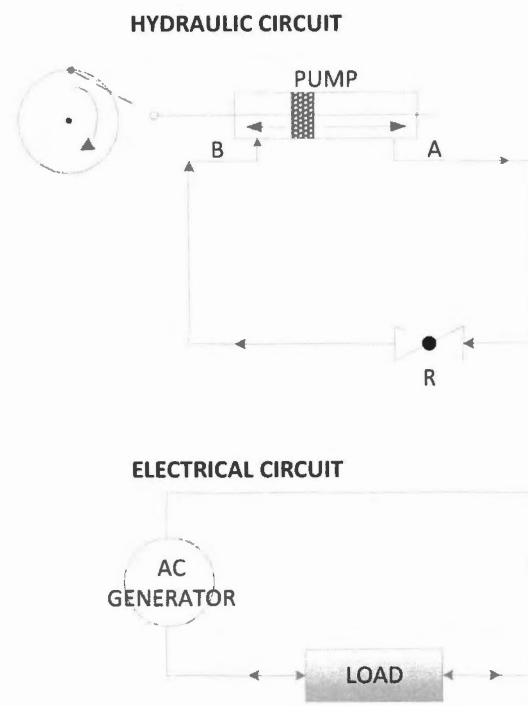


Figure 5.7—Alternating Current

If we installed a pressure gauge at point A and made a graph of the pressure versus the piston position, it would show the pressure continually varying. A graph such as this is shown in Figure 5.8.

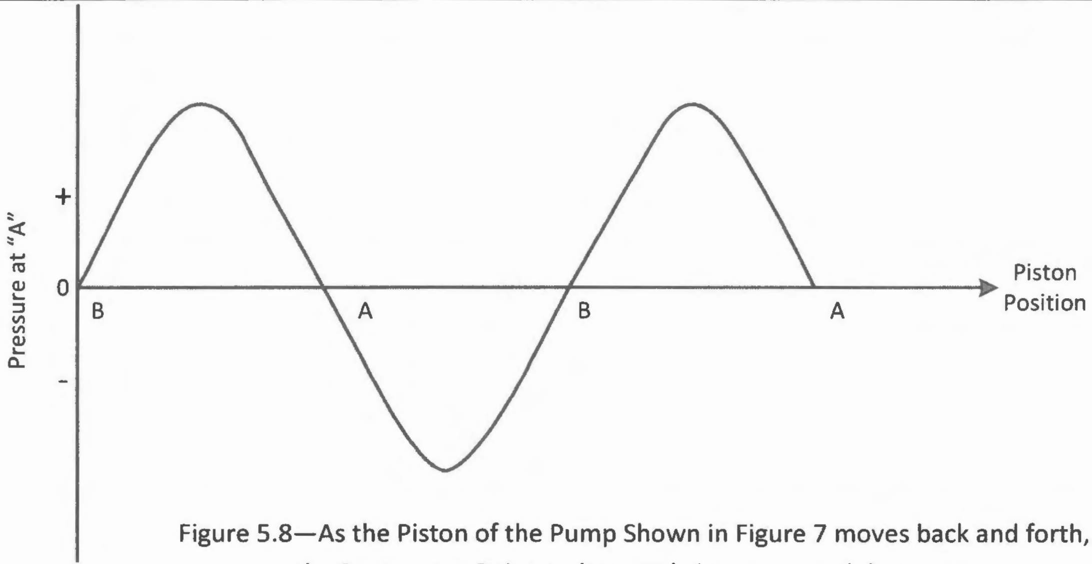


Figure 5.8—As the Piston of the Pump Shown in Figure 7 moves back and forth, the Pressure at Point A alternately increases and decreases

Since pressure in the water system is equivalent to voltage in the electrical system, a voltage graph for the electrical circuit would look the same. In fact, since current flow is produced by a difference in potential or voltage, it follows that the current flow must also have this shape. Generators are designed to produce a particular shape of curve. This shape is known as a sine wave.

GENERATORS

The topic of generators will be covered in detail in a later section. At this time it is sufficient to say that all generators on this system produce alternating current electric power. These generators produce a potential difference by the relative motion between a magnetic field and a conductor. For all main generators the conductor is stationary while the magnetic field is in motion. The mechanical power required to produce this motion is supplied by the steam turbine. The magnetic field is produced by passing a direct current through a circuit known as the generator field. This direct current is supplied by a small DC generator which is known as an exciter.

Due to economic considerations it is highly desirable to design all large electrical equipment for three phase operation. This means that each piece of equipment has three complete, separate circuits, each of which is known as a phase. Normally, three phases are used and are known as A, B, and C.

All main generators produce three phase power and all large electrical equipment utilizes three phase power. For small low voltage applications in the plant, office, or home, single phase power is used. For this use, just one of the three separate circuits or phases is used.

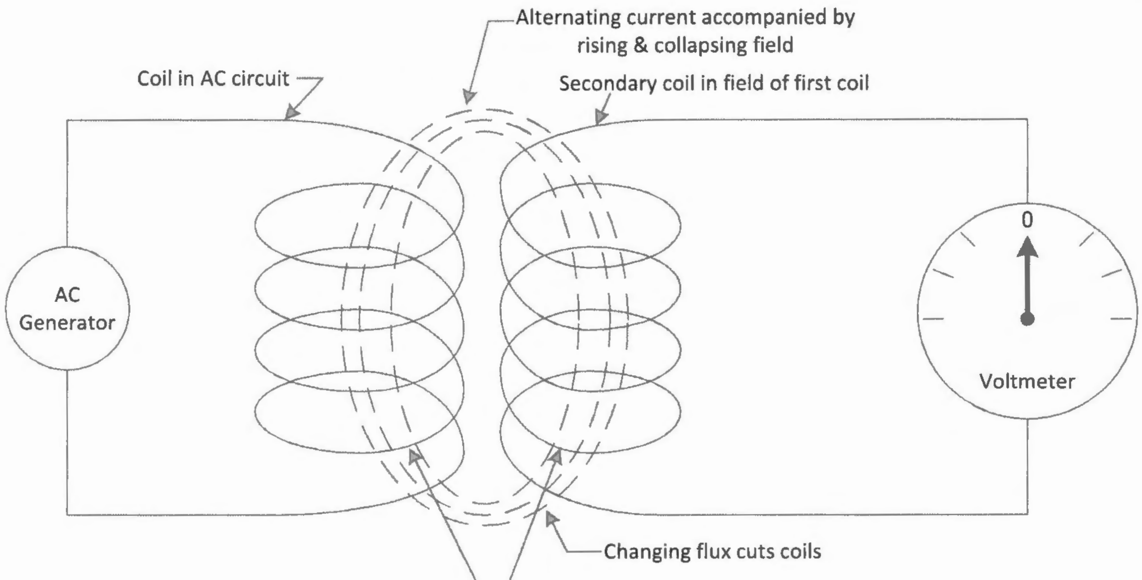


Figure 5.9
Voltage Induced in Coils in AC Field

TRANSFORMERS

Transformers are one of the most important pieces of electrical equipment. It is desirable to generate or produce power at relatively low voltages, transmit it at high voltages, and use it at low voltages. These voltage changes are accomplished by the use of transformers. A power transformer is a device whose primary function is to change the voltage level of a system.

The detailed theory of transformer action will not be covered at this time. Some simplified basic theory will be presented to aid in understanding the operation of this equipment.

A transformer consists of two separate circuits, the input or supply circuit and the output or load circuit. To avoid confusion these two circuits should be identified as the high voltage side and the low voltage side.

Each circuit or side of the transformer consists of a number of coils or turns of wire. This is shown schematically in Figure 5.9.

The two circuits are located adjacent to each other in a common container and are not connected. An AC voltage is supplied to one side of the transformer. As the current passes through this side of the transformer, it creates a magnetic field around the coils. The coils are wound in a manner that concentrates or strengthens the magnetic field. As discussed previously, the strength and size of a magnetic field produced in this manner depends on the amount of current flowing. Since alternating cur-rent is supplied, the current flowing through the coils is constantly increasing and decreasing. The magnetic field will also be continuously increasing and decreasing. As the current increases, the magnetic lines of force build up and extend outward. As the current decreases, the lines of force collapse back inward toward the coils. This alternate buildup and collapse of the lines of force actually is equivalent to a moving magnetic field. The coils in the output circuit are located so that the expanding and collapsing magnetic field cuts across them. This action produces a potential difference and a current flow in the output circuit. The output voltage will alternate at the exact same frequency as the input voltage.

In order to concentrate the magnetic field and make more efficient use of it, the transformer is usually provided with an iron core. A schematic diagram of this type construction is shown in Figure 5.10. The core concentrates the lines of force and allows more of them to cut across the coils in the output circuit. The core is usually made up of sheets of iron which are insulated from each other. This is known as a laminated core. It's purpose is to cut down the circulating current in the core.

The magnitude or value of the voltage that is produced in the output circuit depends, among other things, on the number of turns or coils in both the input and output circuits. If it is desired to have the output voltage higher than the input voltage, there must be more turns in the output circuit than the input circuit. In general the ratio of the voltages will be the same as the ratio of the number of turns. For example, if the input circuit has 10 turns and the output circuit has 20 turns, the output voltage will be 20/10 or two times as large as the input voltage. If it is desired to use the transformer to reduce voltage, there will be less turns in the output circuit than the input circuit. It must be understood that a transformer does not generate or produce electric power, it just transforms it. In order for a change in voltage to take place, there must be a corresponding change in some other electrical quantity. In the case of a

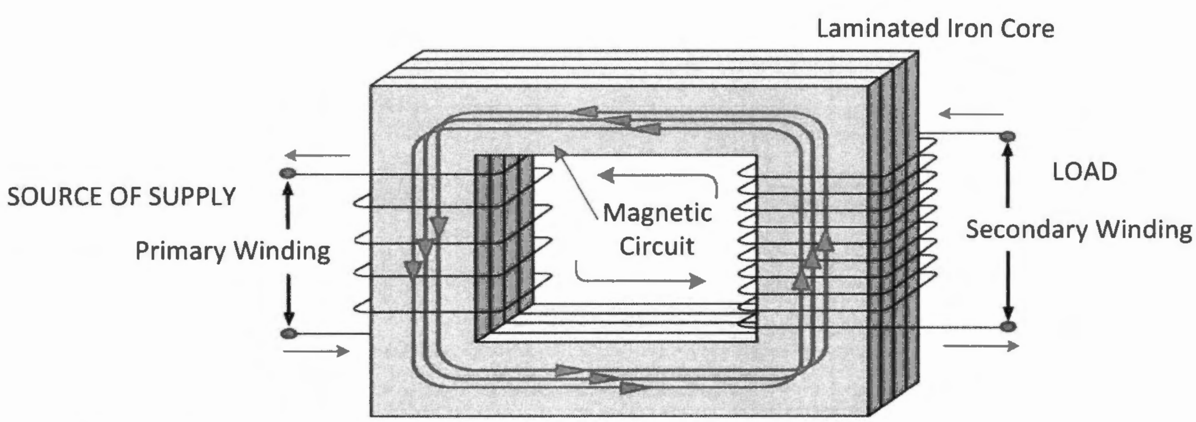
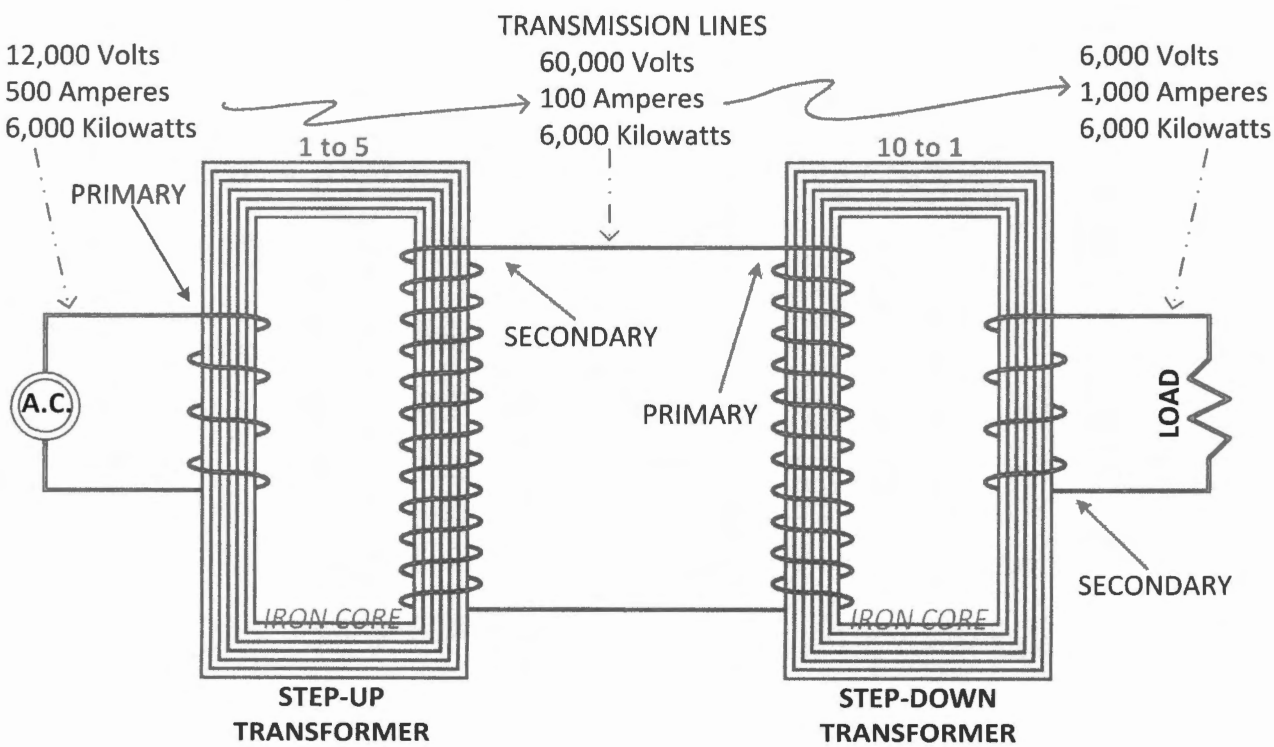


Figure 5.10
Diagram of Transformer

transformer the corresponding change is in the current. The transformer changes the voltage in direct proportion to its turns ratio and changes the current in inverse proportion to the turns ratio. This means that if the transformer is used to increase the voltage by a factor of two, the current will be decreased by a factor of two. The product of voltage times current on each side of the transformer must be equal. Whenever there is a change in one of these quantities, there must be a corresponding change in the opposite direction in the other quantity. Figure 5.11 shows a simplified diagram which illustrates the changes in the two electrical quantities in a transmission system.

Transformers are highly efficient pieces of equipment. In general their efficiency is approximately 98 - 99%. The small loss that occurs shows up as heat in the windings and core. This heat must be removed for continued operation of the transformer. Small to medium size transformers are installed dry and are cooled by air through natural convection. Larger transformers are installed in a tank filled with oil. The oil helps insulate the windings and acts as the heat transfer medium. The oil absorbs heat from the windings and core. This heat is then removed from the oil by transfer to the air. In many cases, the tank is fitted with radiators to provide more surface area for cooling the oil. The oil flow may be either natural or forced by pumps, and the air flow may also be either natural or forced by fans.

Figure 5.11
Transformer Ratio and Load



The rating of a transformer, like most electrical equipment, depends largely on the ability to remove heat from it. If the cooling equipment is shut down for any reason, the capacity of the transformer will usually be limited.

It is frequently necessary to have indication of electrical quantities shown in the control room. It is very undesirable to have large, high voltage circuits in the control room. To alleviate this condition, instrument transformers are used. There are two types of these transformers known as potential transformers and current transformers. Whenever voltage information is required, it is obtained through the use of a potential transformer. All potential transformers are designed so that the output voltage will be 120 volts when the maximum input voltage is applied. Whenever current information is required, it is obtained through the use of a current transformer. All current transformers are designed so that the output of current will be 5 or 10 amperes when maximum current flows in the input circuit.

The use of instrument transformers with standard output ratings makes it possible to have standard meters, indicators, and relays. It is only necessary to provide the correct scale for the meter.

SWITCHES AND CIRCUIT BREAKERS

It is essential in all electrical work to have a means for closing or completing a circuit and for opening or interrupting a circuit. This process is normally accomplished in the power plants by the use of switches and circuit breakers. Knowledge of the proper use and the limitations of the various devices is important for safe operation of the plant.

Before proceeding with a discussion of the actual devices involved, it is necessary to consider the process of closing and opening a circuit. Whenever a circuit which is carrying load, that is one that has current flowing through it, has to be opened, an arc will develop at the point of opening. As the contacts, which are used to open and close the circuit, start to open, a small gap develops between the contacts. If the voltage is high enough, the air in the gap becomes ionized and actually conducts from one contact to the other. Conducting through ionized air is known as

arcing. Very high temperatures are developed by the arc, and if not quickly extinguished may cause serious damage to the equipment. Many special design features are used to provide rapid arc extinguishing in actual equipment.

SWITCHES

A switch is a device for opening or closing a circuit which is not carrying any load. Switches are manually operated, slow moving devices which operate in air. Since it is slow moving and has no special arc extinguishing provisions, a switch should not be used for opening or closing a circuit which is carrying any appreciable load. The primary purpose of a switch is to positively isolate a circuit after all load has been removed. Switches are usually operated from a remote location through a mechanical linkage or by a switching stick. In this way the operator can be at a safe location in the event that an arc develops due to the circuit not being de-energized.

CIRCUIT BREAKERS

A circuit breaker is a device which is used to open or close circuits which are carrying load. In order to do this safely, the circuit breaker must have some special provisions for handling the arc. There are four basic methods used for minimizing the arc and its effect on the equipment: 1) The contacts are moved very rapidly so that they quickly reach a distance or separation across which the arc cannot jump. This keeps to a minimum the time during which the arc is present and thereby reduces the amount of burning that takes place. 2) A fluid is used to either cool the arc or force it away from the contacts into a special area which resists burning. In this manner the arc and its effect are reduced. 3) Multiple contacts are used and are adjusted to operate sequentially. The main current carrying contacts are the first to open and the last to close. In this way the auxiliary or arcing contacts handle all the arcing and burning while the main contacts are preserved for their main job of carrying the circuit load. The auxiliary contacts are designed so that they can be readily replaced. 4) A coil is installed around the contacts. The coil is energized and produces a magnetic field which forces the arc away from the contacts. In this application the ionized air acts as a conductor and is in the magnetic field produced by the coil. As discussed previously, a force is exerted on the conductor which in this case is the ionized air.

Circuit breakers are given names that describe the breaker in terms of the fluid that is used for extinguishing the arc. The commonly used names are: air circuit breaker (ACB), oil circuit breaker (OCB), and gas circuit breaker (GCB). This terminology has led to some confusion, and recently a new terminology has been developed. In this terminology all circuit breakers installed on power circuits are termed power circuit breakers (PCB) regardless of the fluid used in the breaker. It is expected that this terminology will become more common in the future. For discussion purposes it is more convenient to use the old terminology and consider each type of breaker separately.

AIR CIRCUIT BREAKERS

The simplest type of an air circuit breaker is the common light switch as used in the home. Although frequently referred to as a switch, it is really a circuit breaker since it opens and closes a circuit under load. These devices use the principle of rapid movement to minimize the arc. A snap acting mechanism is used to insure fast operation regardless of the speed with which the handle is operated.

LOW VOLTAGE ACBs

In power plants the term low voltage air circuit breaker is usually applied to 230 volt and 480 volt circuits. In general there are two classes of these breakers in common use. The type used for any particular application depends on the size of the connected load. For loads up to approximately 50 horsepower, a combination manually operated breaker and magnetic linestarter is commonly used. For loads above 50 horsepower and up to approximately 250 horsepower, an electrically operated air circuit breaker is used.

The larger 230 or 480 volt motors are supplied with electrically operated air circuit breakers. The less expensive linestarter cannot be used for this service because of its slow moving nature. These ACBs are very fast acting and are capable of interrupting large current flows. Special arcing contacts are usually provided, and arc suppression and dissipation is accomplished by a magnetic field. A breaker of this type usually has a provision for opening and closing the contacts manually by a handle on the compartment door. Remote operation of the breaker is accomplished through magnetic solenoids. A separate DC control circuit is provided for each breaker. When the breaker is closed, either manually or electrically, a strong spring is compressed. This spring stores the energy required for rapid opening of the breaker. The DC control circuit not only serves to operate the breaker but provides indication of the breaker's position through the use of indicating lamps. The red, breaker closed lamp, is frequently also used to monitor the tripping circuit. This provides visual indication that the trip circuit is available.

These ACBs are usually provided with three positions. In the fully racked in position, both the bus side and the load side of the breaker are connected. When the breaker is open, it may be partially racked out to the test position. In this position the control circuits are still connected but the bus and load side is disconnected. This allows complete testing of the breaker without actually running the connected equipment. The ACB can be further racked out to the fully disconnected position where all circuits of the breaker are disconnected. This position is used for clearance purposes and for breaker maintenance. The DC control circuit is supplied with a switch for cutting out the DC. The DC circuit must be cut out prior to racking out the breaker.

MEDIUM VOLTAGE ACBs

The term medium voltage circuit breaker is usually applied to breakers that service 2400 or 4160 volt circuits. These ACBs are much larger and stronger than the low voltage models because they must interrupt much larger currents. The speed of operation of this type breaker is extremely fast. Arc suppression is usually handled by a combination of magnetic coils and airflow. The magnetic field and airflow combine to force the arc away from the contacts and into special arc chutes. Overcurrent protection is provided by separate overcurrent relays and current transformers. Operation of these ACBs is strictly electrical through magnetic solenoids.

A separate DC control circuit is utilized and provides both operating power and indication. As discussed previously, the closed position red indicating lamp is used as a trip circuit monitor. The breakers can be racked out part way to a test position or to the fully disconnected position. Due to the size and weight of the units, some mechanical device is used for racking them out or in.

OIL CIRCUIT BREAKERS (OCBs)

Oil circuit breakers are used for practically all high voltage circuits. The voltage range involved is from 12 KV to 230 KV. These breakers are very large and are constructed so that a tank completely surrounds the mechanism. This tank is filled with oil. All contact opening and closing operations are performed in this oil bath. As the contacts open under load, an arc forms. This arc vaporizes a small amount of oil into a gas and ionizes the gas. This gas bubble is quickly replaced by fresh oil which cools and extinguishes the arc. Due to their large size, these breakers are always operated electrically.

GAS CIRCUIT BREAKERS (GCB)

In the newest very high voltage level circuits, notably the 500 KV system, gas circuit breakers are used. In these breakers a special gas, under pressure, is used to extinguish the arc. The gas used must have excellent stability and dielectric properties. The gas used at the present time is a compound of sulfur and fluorine known as sulfur hexafluorine (SF_6).

RELAYS

The subject of relays and relaying is quite lengthy and complex. In this section only a few of the more common applications will be discussed. For this discussion, relays will be divided into two general types:

1. Control or auxiliary relays.
2. Protective relays.

CONTROL RELAYS

Control relays are used for many purposes in a plant. They may open or close circuit breakers, operate lights, or initiate alarms and annunciators. In general these relays consist of a coil of wire, a movable iron core, a spring, and a set of contacts. In the normal or de-energized condition the spring holds the plunger away from the magnet. The contacts at this time may be open or closed depending on the purpose of the relay. When a voltage source is connected across the terminals

of the coil, it becomes a strong electromagnet and pulls the plunger toward its center. The plunger will stay in this position until the voltage is removed from the coil. This movement of the plunger is used to open or close the contacts. In some cases a more complex relay is used in which there are two coils. In these relays when the first coil is energized it moves the plunger as previously discussed; however, in this case the plunger is held in the energized position by a mechanical latch after the coil is de-energized. The second coil is used to open the relay by releasing the mechanical latch. In this system it is not necessary to have the coil energized continuously.

PROTECTIVE RELAYS

A protective relay is defined as a relay whose function is to trip a circuit breaker so as to remove from service a line or piece of equipment that is operating abnormally. There are a great number of different abnormal conditions that may exist, and there are specific protective relays designed for each condition. Three protective relays are overcurrent relay protection, differential relay protection, and ground relay protection.

NOTES:

Section 05

BASIC ELECTRICITY

Study Questions

1. Electricity is the movement of ______________ through a conductor.

2. How does a conductor differ from an insulator?

3. How is "potential difference" measured?

4. If the potential difference is large, what can be said about the flow of electrons?

5. If the potential difference is slight, what can be said about the voltage of the circuit?

6. Voltage is often described as ____________________ in a hydraulic system.

7. The rate of current flow is measured in ____________________ .

8. The resistance to free electron flow in a circuit is called electrical ______________ .

9. This type of resistance is measured in __________________________ .

10. It takes a difference in potential of _________ volt (s) to force a current of _________ ampere(s) through a resistance of __________ ohm (s).

11. What happens to current if the potential difference is increased?

12. Similar magnetic poles _________________________ each other.

13. Insulators usually make the best magnets. True \ False

14. Will insulation stop magnetic flux lines?

15. When current is increased the surrounding magnetic field will ________________ .

16. List 4 situations which will increase the intensity of a magnetic field produced by a coil.

    a.

    b.

    c.

    d.

17. When a conductor which has no current flow is moved through a magnetic field, an ________________ ____________________ will be developed in the conductor.

18. List 4 ways that electricity is produced.

    a.

    b.

    c.

    d.

19. Of the 4 ways, what 2 are commonly used at a power plant?

    a.

    b.

20. A Secondary cell is also called a ____________________

__________________.

21. Describe the difference between AC and DC.

22. Describe the operating principle of a generator.

23. Sketch a transformer and explain what it does and how it works.

24. What is the difference between the primary and the secondary side of a transformer?

25. What is the difference between a switch and a circuit breaker?

26. What type of breaker is generally used for low voltage applications?

27. What is the range of medium voltage when we talk about circuit breaker circuits?

28. Where might you find an Oil Circuit Breaker?

Generation-Oahu Division
Operator Trainee Training Program

Section 06
VALVES AND PIPING SYSTEMS

OBJECTIVES:

1. Discuss the basic fundamentals of fluid flow
2. Describe equipment used for power plant piping systems
3. Identify the types and parts of valves commonly used in power plant piping systems.

Section 06

VALVES AND PIPING SYSTEMS

VALVES AND PIPING

A steam power plant consists of numerous pieces of equipment which are interconnected in such a way that they can perform their function as part of the complete system. Piping, valves, and traps compose the arteries that interconnect these various pieces of equipment. This section will consider the manner in which parts of the fluid systems are interconnected and will discuss the fundamental rules or laws that govern fluid flow and the equipment that makes up the piping systems.

THEORY OF FLUID FLOW

The fundamental laws of fluid flow apply equally well to all fluids, however, these laws are more simple and easy to understand when dealing with incompressible fluids. For this reason the discussion in this section will cover the flow of liquids only. Most liquids are considered to be incompressible.

Consider the condition where water is flowing through a length of pipe. The factors which cause this flow to take place will be discussed later. As long as there are no leaks and no water is added to or removed from the system, the amount of water flowing past any one point is equal to that flowing past any other point. This holds true regardless of any changes in pipe size or shape. A mathematics statement of this fact is known as the Continuity Equation. This is one of the basic laws of fluid flow and it can be demonstrated by the following example. Consider the simple section of a piping system shown in Figure 6.1.

The continuity equation states that the flow at point 1 must be the same as the flow at point 2 and point 3 as long as no water is added or removed. The flow rate at any point in a pipe depends on the area available for flow and the velocity of the flow. The following equation expresses this relationship.

$$\mathbf{Q = AV}$$

Where Q is the flow rate in cubic feet per minute, A is the area of the pipe in square feet and V is the velocity of flow in feet per minute. The basic law states that the flow rate at any point in the system equals the flow rate at any other point. This means that the flow rate Q_1 at point 1 must equal the flow rate Q_2 at point 2. This can be expressed mathematically as:

$$\mathbf{Q_1 = Q_2 -= Q_3}$$

or

$$\mathbf{A_1V_1 = A_2V_2=A_3V_3}$$

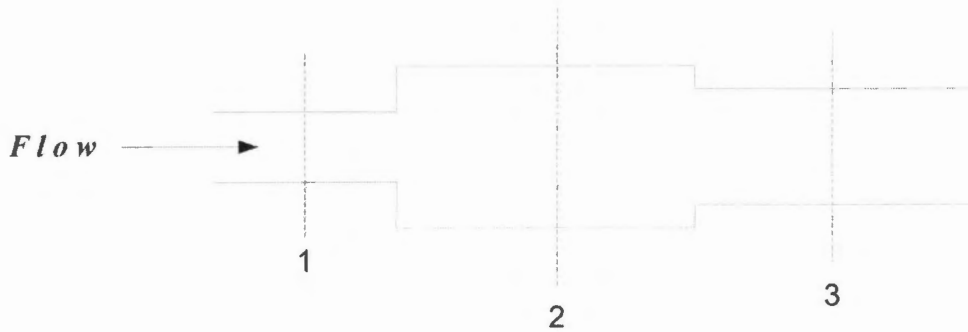


Figure 6.1

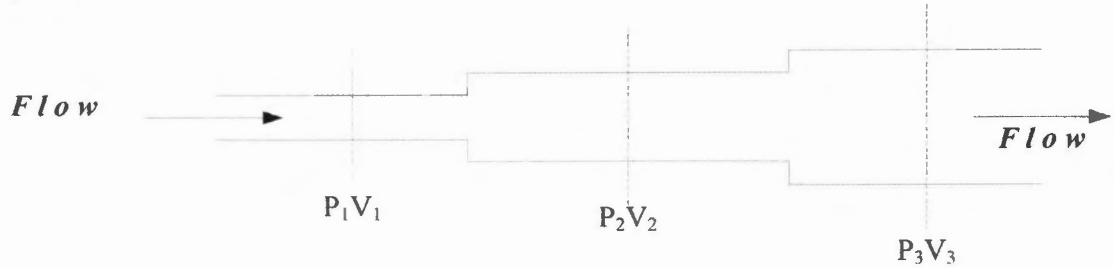
This last equation is of considerable interest. At point 1 there is a certain flow area A_1 and a certain velocity V_1. As the fluid flows toward point 2, flow area increases due to the larger pipe size. Since the product AV must remain constant and since the area (A) has been increased, the velocity (V) must decrease if the continuity equation is to hold true.

This is exactly what happens. The fluid slows down to a lower velocity the when it reaches the larger flow area. In the same manner when the fluid approaches point 3 and the flow area decreases again, the fluid will automatically speed up to compensate for the smaller flow area.

The second important law governing fluid flow is known as the General Energy Equation. This law is based on the principle that energy cannot be created or destroyed but can only be transformed from one form to another. The general energy equation states that the total energy contained in the fluid at one point in the system must be equal to the total energy contained at any other point in the system providing there is no energy added or removed between the two points. To illustrate this law, consider a simple piping system as shown in Figure 6.2. In this system no energy is added to or removed from the fluid. This requires that there is no pump in this part of the system and that there is no heat transfer to or from the system.

At point 1 the fluid contains three types of energy: Potential energy due to its elevation, kinetic energy due to its velocity and flow energy due to its pressure. The sum of these three quantities at point 1 must be equal to the

Figure 6.2



sum at point :2 and at point 3. This can be stated mathematically as:

$$PE_1+KE_1+FE_1 = PE_2+KE_2+FE_2 = PE_3+KE_3+FE_3$$

In the example in Figure 2 the pipe is horizontal and there is no change in elevation so the potential energy is the same at all three points. This term can therefore be canceled out and eliminated. Kinetic energy is proportional to the velocity squared (V^2) and flow energy is proportional to pressure (P). Using this information the general energy equation can be rewritten for the example in Figure 2 as follows:

$$V_1^2 + P_1 = V_2^2 + P_2 = V_3^2 + P_3$$

As the fluid flows from point 1 to point 2 the flow area increases, and from the continuity equation the velocity at point 2 must be leas than the velocity at point 1 due to the increase in area. Since the velocity at point 2 is lower than at point 1 it follows that the kinetic energy at point 2 is less than the kinetic energy at point 1. Since the sum of kinetic energy and flow energy at point 1 must equal the sum of these two energies at point 2 and since the kinetic energy at point 2 is less than at point 1, it follows that the flow energy and therefore the pressure at point 2 must be greater than the pressure at point 1. *What this really means is that when the flow area increased, the velocity decreased according to the continuity equation, and the decrease in velocity resulted in an increase in pressure according to the general energy equation.* In the act of slowing down the fluid converted some of its velocity energy into pressure energy. If the flow area were to decrease the opposite would take place. That is, some of the fluid's pressure energy would be converted to velocity energy. This principle is utilized in many flow meters where the flow area is deliberately restricted to cause a velocity change and thereby a pressure change. This pressure change is measured and related to flow rate.

The discussion so far has covered the ideal situation only. Actually the total energies at two points in a system are never exactly the same. There are always some losses associated with fluid flow that were not taken into account. The walls of a pipe exert a friction force on the fluid that tends to slow it down. In order to have flow continue it is necessary to overcome this friction. The amount of friction produced will depend on many factors, some of which are listed below:

- Increasing the velocity increases friction.
- Increasing the flow area decreases friction.
- Increasing the length of piping increases friction.
- Increasing the roughness of the inside of the pipe increases friction.

All of these factors must be considered when designing a piping system. It is possible to state one more general rule of fluid flow. Fluid always flows from an area of high total energy to an area of lower total energy. In many applications this can be reduced to saying that fluid flows from a high pressure area to a low pressure area. This simplification is only true when the pressure is high and the velocity is low. The correct relationship is one of total energy and not just pressure.

PIPE MATERIAL

The fluids used in power plants and their properties such as pressure, temperature and chemical composition vary widely. For this reason there is no single materia1 that is best for all uses. A great number of different materials are used in an attempt to get the best material for the lowest cost. In many instances it is better to replace a section of pipe occasionally rather than use some highly expensive material. A short list of some of the more common materials and their typical uses is given below.

Material	Typical Uses
Alloy Steel	High pressure, high temperature service.
Carbon Steel	High pressure, moderate temperature service.
Stainless Steel	Extreme high pressure and temperature or maximum corrosion and erosion resistant service.
Copper	Low pressure, low temperature where cleanliness is essential.
Brass	Low pressure, low temperature where corrosion resistance is important.
Plastic:	Low pressure and temperature where corrosion resistance is important. Plastic is replacing brass in many applications.

Pipe size is usually specified according to the inside diameter of the pipe. The wall thickness is usually specified in terms of a special numbering system known as the pipe schedule. Regular pipe is schedule 40 while pipe with a thicker wall will have a higher schedule number such as 80.

JOINING SECTIONS OF PIPE

There are three common methods of joining or connecting pipe and pipe fittings. These are screwed connections, flanged connections and welded connections.

Screwed connections are usua1ly limited to pipe 3 inches or smaller while flanged connections cover the larger sizes. Both the above methods are normally used on low to medium pressure systems. Welded connections are used on all size pipes and particularly for high pressure service. Some of the more common pipe fittings used for connecting pipe sections are shown in Figure 6.3. When sections of large, heavy walled pipe are joined by welding, the high localized temperature sets up areas of stress concentration. To eliminate this undesirable condition, the section of pipe is usually stress relieved by slowly heating

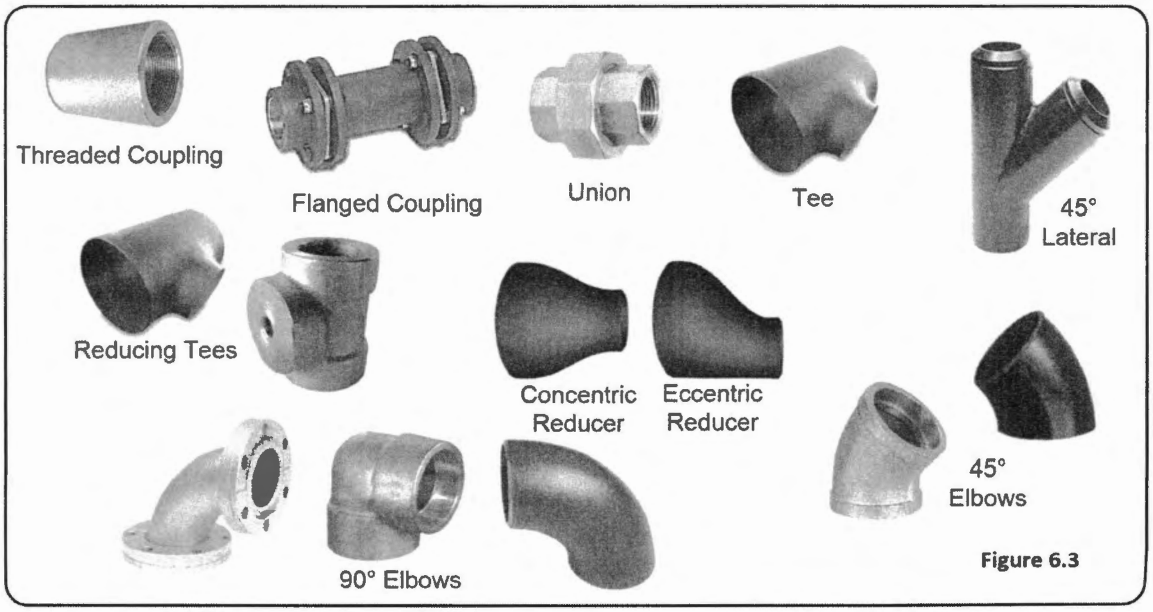


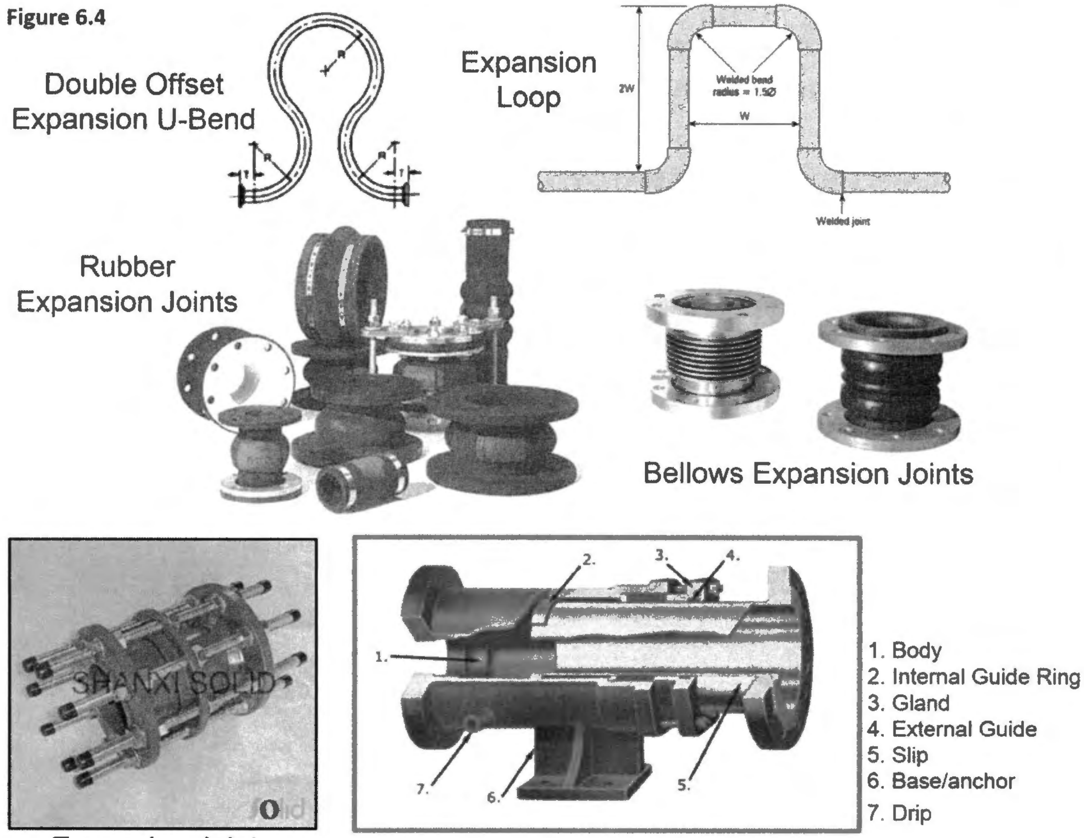
Figure 6.3

and then cooling. This procedure allows the internal stress set up by welding to be dissipated. The quality of welded joints in high pressure pipes is frequently checked by taking x-ray pictures of the weld.

PIPE EXPANSION

Many piping systems are subjected to considerable variations in pressure and temperature during routine operation of the plant. Temperature changes of 1000°F and pressure changes of 4000 psi may be experienced. The temperature changes cause expansion and contraction of the metal piping system while pressure and flow changes can exert other mechanical forces on the pipe system. Expansion joints or bends are placed in lines to compensate for the forces set up by temperature changes. A 1000°F rise in a 100 foot section of pipe will cause it to expand almost 9 inches in length. If provision is not made for this expansion, it can result in broken lines or damaged equipment. Two of the most common methods of providing for expansion and contraction are expansion joints and bends or loops. Examples of each of these are shown in Figure 6.4. The forces exerted by pressure and flow are usually overcome by the proper use of pipe hangers and supports. These are designed

Figure 6.4



Expansion Joint – Slip Type

Expansion Joint – Slip Type Packed Gland to allow the pipe to move in a specific direction to relieve the forces while restraining the pipe from moving in other directions. Hangers are frequently spring loaded while supports usually provide for sliding motion.

VALVES

Valves can be designed to provide one or more of three (3) basic functions:

1. on-off
2. control of flow rates, and
3. prevention of flow reversal.

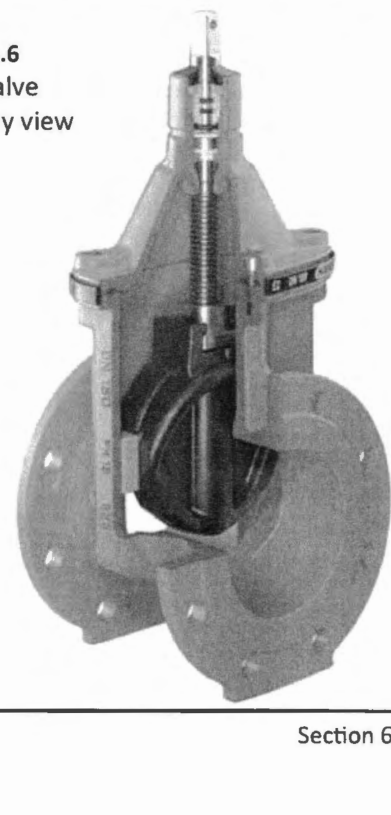
They may be classified according to their function (stop valve, throttle valve, control valve, etc.) or according to their construction. For discussion purposes it is better to classify them according to construction. The types of valves commonly used in power plants are the gate valve, globe valve, plug valve or cock, the check valve, the butterfly valve, and the diaphragm operated control valve. Figure 6.5 shows some of these types of valves.

The **gate valve** (Figure 6.6) consists of a body containing two inclined seats mounted in a plane nearly perpendicular to the line of flow and a wedge which has the same angle as exists between the two seats. The wedge is moved up and down by the stem to which it is attached. Gate valves offer very little opposition to flow when they are wide open. The wear on the seats and wedge of a gate valve is uneven when the valve is not fully open. For this reason they should not be used to throttle the flow. Gate valves are used as stop or shutoff valves where they can be either full open or closed.

The **globe valve** consists of a body containing a seat ring usually placed in a horizontal position parallel to the line of flow and a valve disc which is made to bear

Figure 6.5

Figure 6.6
Gate Valve
Cutaway view



against the seat ring. The disc is raised and lowered by the hand wheel and stem. The globe valve, because of its construction offers a considerable restriction to flow even when it is wide open. Globe valves are designed so that they can be used for controlling flow by throttling.

Check valves are automatic operating valves which allow flow in one direction only. Most check valves consist of a body containing a seat and a hinged disc balanced in such a way that the disc swings open allowing flow in one direction and swings closed preventing flow in the opposite direction. Check valves are normally installed where several pumps discharge into a common line or header. This prevents flow in the reverse direction through an idle pump. Scale, rust or other foreign material may collect above the disc preventing it from opening or under the seat preventing it from closing. The cover must be removed and the obstruction cleared whenever this occurs.

The **plug or cock valve** consists of a body in which a cylinder or plug is fitted with close tolerances. The cylinder has a slot which permits flow through the valve when it is in one position and stops or prevents flow when the cylinder is rotated 90°. The plug valve is cheaper to make and when fully open withstands the action of abrasive liquids better than globe or gate valves.

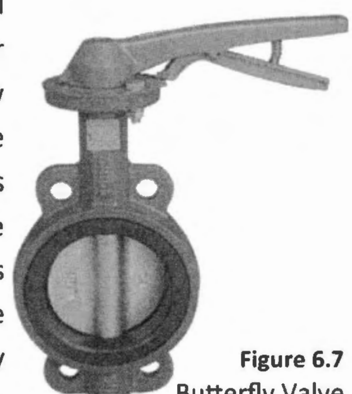
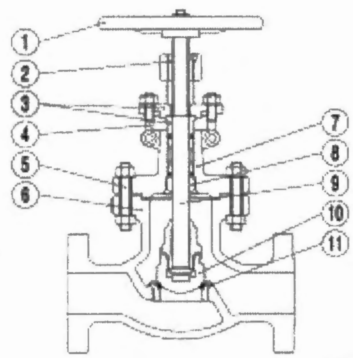


Figure 6.7
Butterfly Valve

The **butterfly valve** shown in Figure 6.7 is finding more use in the plants. This type of valve has several advantages; it is light weight, small, provides tight shutoff, can be used for throttling, and is inexpensive. The valve consists of a body, a soft resilient seat of rubber or neoprene and a handle with a notched positioning plate. The valve is operated from full closed to full open by rotating the handle 90° or 1/4 of a turn.



IT.	DESCRIPTION
1	HANDWHEEL
2	YOKE SLEEVE
3	GLAND FLANGE
4	GLAND EYE BOLT
5	BONNET BOLT
6	BODY
7	BONNET
8	BACK SEAT
9	STEM
10	DISC
11	SEAT RING

Figure 6.8—Globe Valve

Butterfly valves are relatively easy to maintain, the soft seat is held in place mechanically and can be easily replaced. This means that the valve seat does not require lapping, grinding or machine work.

Some of the parts of a globe or gate valve are the handwheel, stem, packing, gland, body seat, bonnet, stem, and disc seat. Figure 6.8 shows the parts of a typical globe valve. These valves require occasional packing or adjustment of the gland to prevent leakage around the stem.

If the threads on the stem are exposed, they should occasionally be cleaned and lubricated to prevent wear and keep the

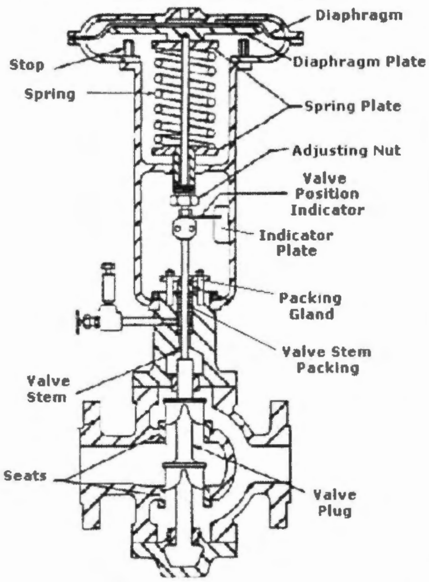


Figure 6.9a—Diaphragm Operated Double Seated Control Valve

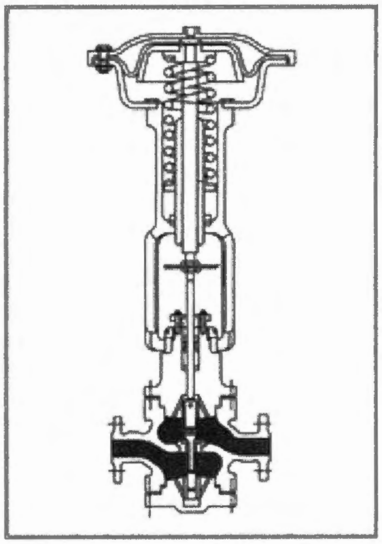


Figure 6.9b—Diaphragm Operated Single Seated Control Valve

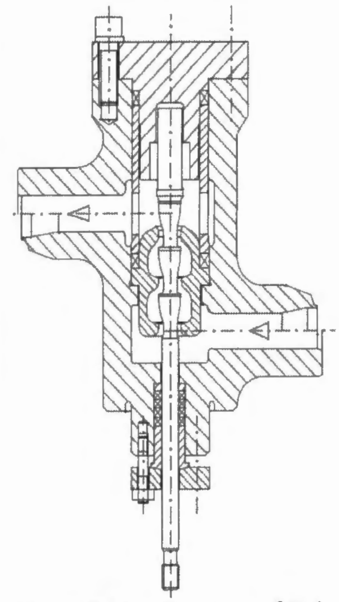
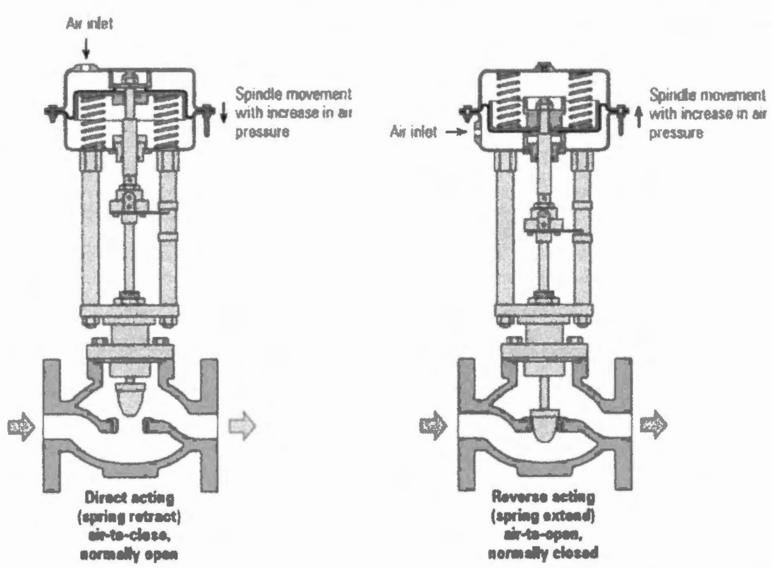


Figure 6.11—diagram of Sulzer control valve

stem operating freely. Forcing the gate or disc or a valve closed when scale or foreign material is lodged under the seat may damage the seat permanently or spring other parts beyond repair.

Diaphragm operated control valves are used for automatically controlling the flow in a piping system. There are two general types of this kind of valve which are the single seated valve and the double seated valve. The single seated valve is primarily used where tight shutoff is required. The double seated valve is used where tight shutoff is not required. See Figure 6.9a & 6.9b. In the spring diaphragm operated control valve, air is admitted to the top of the diaphragm forcing the valve stem downward. This may either open or close the valve depending on the seat

Figure 6.10
Diagram illustrates different effects of air on diaphragm operated control valve. Note position indicator on direct acting and reverse acting valves.



arrangement (Figure 6.10). As the air pressure on the upper side of the diaphragm is released, the spring raises the valve stem.

The valves have three sections; valve body, actuator, and motor or motors.

Figure 6.11 shows one of the many Sulzer valves now in use. These valves differ very little from other high pressure, high temperature valves. Each valve is equipped with a manual hand wheel which is snapped in with a mechanical lock to allow the valve to be operated remote manual and automatically. These valves are used to control pressure, flow etc. as any other high pressure, high temperature valve would be used.

VALVE OPERATION

Valves are provided with hand wheels or other devices of sufficient diameter to give the necessary leverage to close them properly. If a valve is always closed properly and used properly it should operate indefinitely without leakage. If a valve leaks when closed it may be caused by sca1e or other foreign material which has been caught between the disc and the seat. Opening the valve slightly and closing it a few times will usually remove the foreign material. This operation allows the fluid to wash the material off the seating surface. This procedure should always be tried before using any additional force on the hand wheel. More force will only result in driving the scale into the seating surface thus creating a permanent leak.

If a valve is allowed to leak through when closed, the valve seats will eventually be eroded or cut by the fluid. When this occurs it becomes impossible to prevent further leakage no matter how much force is applied.

In some cases where positive shutoff is required, two valves are provided in series. This application is usually provided on blowdown or drain lines from a pressure vessel or line. When opening these valves the first or upstream valve (Closest to the vessel or line) should be opened wide. The second or downstream valve should be opened part way and used to throttle or control the flow. In this way all the wear takes place on the second valve. When it requires repair or replacement, this can be done with the equipment in service because the first valve is still in good condition.

Large gate valves with pressure on one side can be very difficult to open. The pressure acting on the area of the gate forces it tightly against the seat. For example, an 8 inch valve with 600 psig on one side will have a force of approximately 30,000 pounds pushing it against the seat. This creates a lot of friction where the gate slides along the seat when opening the valve. To improve this condition small pressure equalizing lines are installed around gate valves in lines 8 inches and larger with pressures of 600 psig and over. The equalizing line and valve are usually 3/4 inch. This small valve can be easily opened and allows a slow buildup of pressure downstream of the large valve. When the pressure on each side of the large valve is equal, it can be opened easily. When installed, equalizing valves should always be opened prior to opening the main valve and should be closed after the main valve is open.

STEAMTRAPS

All steam lines should be adequately drained of condensate. Even superheated steam lines need drains since condensate forms during the warming up operation. The automatic removal or condensate from steam lines is accomplished by steam traps. The name comes from the fact that the unit traps steam preventing it from flowing while allowing the condensate to flow. Two of the most common types of traps used in power plants are the impulse trap shown in Figure 6.12 and the bucket trap shown in Figure 6.13a & 6.13b.

In the impulse trap shown in Figure 6.12 is a constant flow trap and allows a continuous flow of steam into the high-pressure drain line as long as its cutout valves are open. The valve disc is a piston type disc with a flange at its top and a "control orifice" drilled through it. The piston valve works up and down within a cylinder which is machined with a reverse taper and which is, at its smallest point the same size as the flange on the valve disc. The position of this cylinder is factory-adjusted so that, with the valve closed, a specific clearance between the flange and cylinder walls is maintained. The area of the control orifice is slightly greater than that of the space between the cylinder and flange. Due to the larger area of the control orifice, condensate flowing from the steam line when warming up will

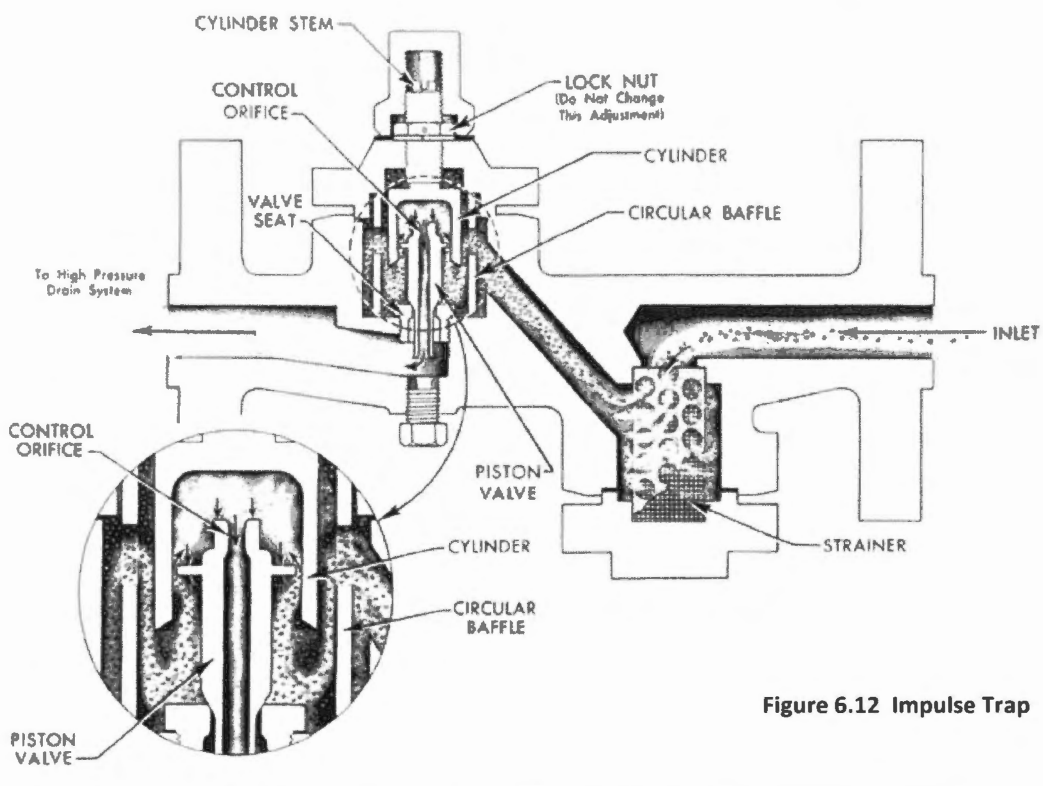


Figure 6.12 Impulse Trap

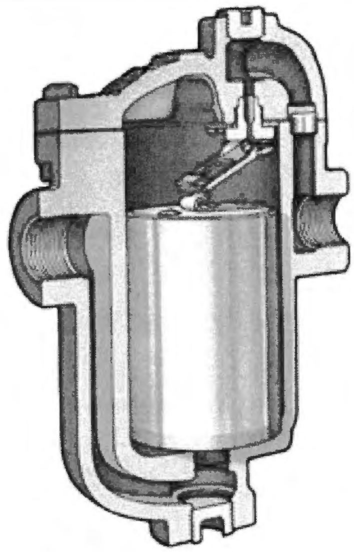
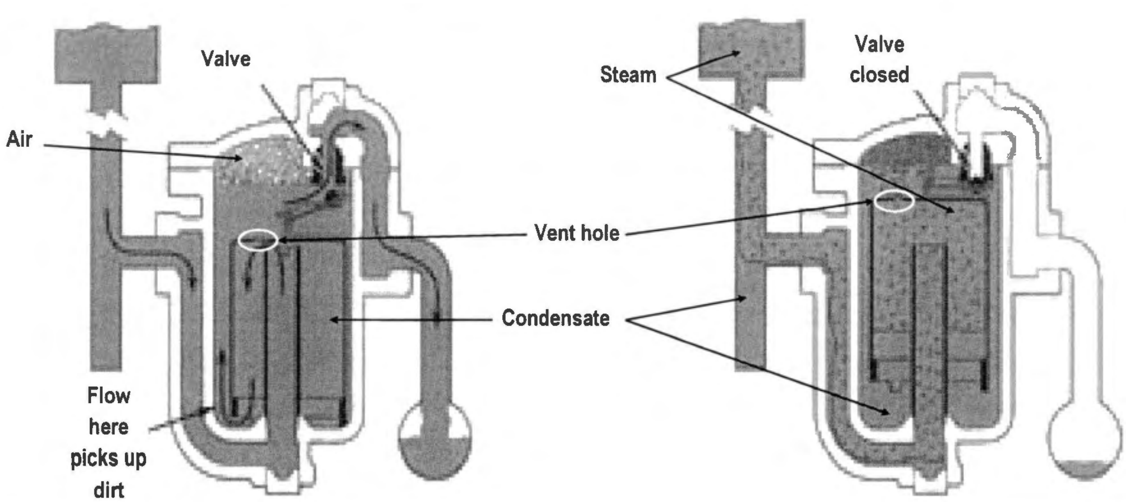


Figure 6.13a
Inverted Bucket Trap

flow through it faster than it will flow past the flange. This will cause a reduction pressure within the cylinder. When this pressure is reduced to 86 percent of the inlet pressure or less, the force on top of the valve disc is less than the force below the flange and the valve will be forced open, allowing a full flow of condensate through the valve. As the line warms up the temperature of the condensate flowing through the trap increases and as it approaches the temperature of saturated steam, the condensate flowing through the control orifice will start to flash into steam (due to the large drop in pressure through the orifice). This steam having much greater volume than the same quantity of condensate will cause the control orifice to become "choked" up and thereby reduce the flow of condensate. This will cause the pressure within the cylinder to be built up until it is greater than the inlet pressure and the trap will be closed due to the greater area of the top of the disc. With the trap closed, hot condensate or steam will continually flow through the control orifice, discharging into the high-pressure drain line. Should a shot of cool condensate enter the trap at any time, the same action will occur to drain off the condensate, with the valve closing when the condensate temperature is approximately 30 degrees F. less than the steam temperature. The stein seen attached to the cylinder can be used to raise the cylinder, catching the flange at the base of the taper and manually lifting the valve disc for the purpose of blowing through it to clean off the seat. The lock nut shown is pinned in place. It has been adjusted at the factory to provide the proper clearance between the cylinder and valve flange. The baffle shown shrouding the cylinder and

Figure 13b
Schematic of Inverted Bucket Steam Trap



valve disc is placed there to prevent direct impingement of the steam on the cylinder or disc and in addition, provide a guard against possible jet action on the flange.

The inverted bucket trap shown in Figure 6.13a & 6.13b operates as follows. When the trap is full of water, the bucket rests on the bottom of the reservoir with its open end over the trap inlet. At this time the trap discharge valve is open. Water is expelled from the trap due to steam pressure acting on the water. As the water is discharged, steam will displace the water in the bucket, causing it to rise and close the trap discharge valve. The closed end of the bucket has a vent hole for air and steam to escape. The escape of steam and air allows more water to rise into the bucket. As the water rises the bucket loses buoyancy and sinks, thereby opening the discharge va1ve again. The water is never completely discharged, thereby maintaining a seal which prevents steam from blowing through.

Traps should be checked to make sure they are operating correctly by feeling the trap body and discharge line. If the trap is warm, it indicates proper operation. Excessive temperature indicates that the trap is allowing steam to blow through and be wasted. A cold trap usually indicates that no drainage is taking place.

BYPASS AND DRAIN LINES

Bypass lines are secondary pipelines through which flow is routed while a section of the main line is out of service.

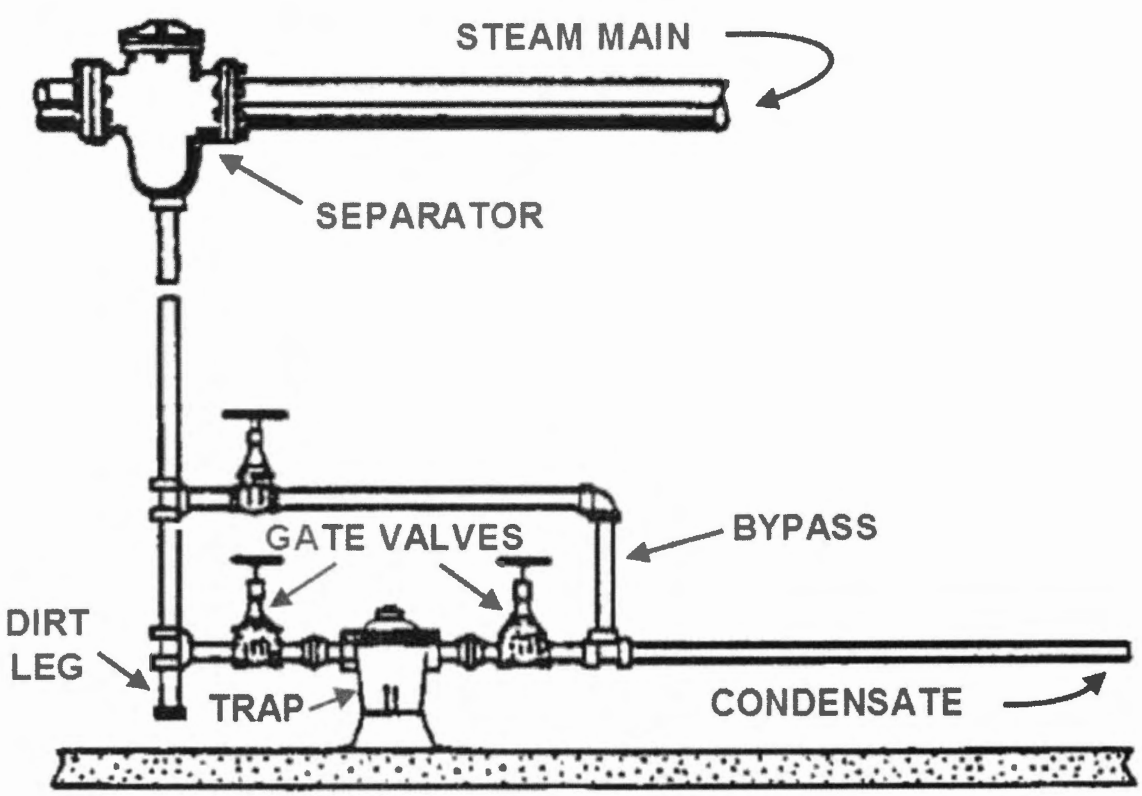


Figure 6.14: Steam Trap—Typical Installation

When lines carry steam, they are provided with drains to remove condensate formed when warming the line or while in service. Drains are also used to drain or depressurize a collection of piping when it must be taken out of service for repair.

The valve bypass and drain line, shown in Figure 6.14, serves two purposes. The drain line from the separator can be used to remove condensate from the steam or to drain the steam line when the steam flow is cut off. When the two valves next to the trap are opened and the valve in the bypass line closed, the trap automatically drains condensate from the steam line. By closing either one of the valves next to the trap, the trap is cut out of service. The valve on the bypass line can then be regulated to permit drainage around the trap.

Opening a valve suddenly where the pressures are not equal increases the likelihood of **water hammer**. A cold line should always be warmed up slowly. Adequate drainage of the line should be maintained at all times while pressures and temperatures are equalized to avoid damage due to rapid expansion and water hammer. The drain valve should be opened enough to provide drainage of condensate, yet not waste excessive amounts of steam. Water or condensate in a steam line will cause water hammer in the pipelines and, if it is permitted to progress, it can seriously damage steam driven equipment. Funnels in drain lines permit the operator to observe drainage and eliminate any possibility of back-pressure from the drain to the bypass line which might prevent drainage from taking place.

WATER HAMMER

There is one danger often present when working with high-pressure lines which all operators should know about. This danger is commonly known as water hammer. Water hammer can reach destructive proportions under certain circumstances.

Water hammer is the force or shock of confined water when its flow is suddenly arrested. Under certain conditions, a series of shock waves may be set up. These shock waves may increase or decrease in intensity, depending on conditions.

One example of water hammer which most people have probably experienced is the sudden rap sometimes heard when closing a water faucet. This hammer is not serious because the flow or force of the water suddenly interrupted by closing the faucet is small. A water line ten inches in diameter and at a given head would exert a shock or hammer, if suddenly closed, over 400 times greater than the hammer in a half-inch waterline. The larger the diameter of the line, the higher the head and the greater the velocity of flow, the greater the danger of water hammer. There is usually more danger of water hammer in vertical waterlines than in horizontal waterlines. Sudden operation of check valves sometimes causes water hammer in waterlines.

WATER HAMMER IN STEAM LINES

There is always danger of water hammer in warming up a cold steam line. Condensate which forms in the cold line may be driven up and down the line by steam with a force sufficient to wreck the line or tear it from its hangers. Hammer is more apt to happen in long horizontal steam lines or steam lines with a slight upgrade. Steam should always be admitted to cold lines slowly and the condensate drained from the line as fast as it forms.

A water hammer similar to the hammer in a steam line results when opening a valve which admits hot water into a cold line. An example of this situation would be the opening of a valve on a boiler feedwater header to fill a cold empty section of a waterline. Some of the high temperature water under high pressure will flash into steam as it passes the valve, setting up conditions identical to those in the steam line just discussed.

A good general rule to prevent serious consequences due to water hammer is to always open or close valves, which regulate the flow of any fluid, slowly. This makes it easier to close the valve if a hammer develops and in any case minimizes its effect. Where bypass valves are provided around large valves, use the bypass to equalize pressures and temperatures before opening the large valve. Keeping vents or drains open while cutting in a line, helps to prevent water hammer.

Notes:

Section 06

VALVES AND PIPING SYSTEMS

Study Questions

1. Most liquids are considered
   a) Compressible
   b) Incompressible
2. When the flow area decreases, the velocity of the fluid increases. True / False
3. A decrease in fluid velocity results in a n increase in pressure to maintain the same flow rate. True / False
4. The walls in a pipe exert friction force on fluid that tends to slow it down. The amount of friction depends on many factors. List three (3) of these factors.
   a)
   b)
   c)
5. Fluid always flows from an area of low total energy to an area of higher total energy. True / False
6. List four (4) of the more common materials used for manufacturing piping.
   a)
   b)
   c)
   d)
7. Pipe size is usually specified according to the ________________ of the pipe.
   a) thickness
   b) length
   c) Inside diameter
   d) Manufacturer's specifications
8. The three common methods of joining or connecting pipe and pipe fittings are:
   a) ______________________ connections
   b) ______________________ connections
   c) ______________________ connections

9. What are two of the most common methods of providing for pipe expansion and contraction?

   a)

   b)

10. What are three (3) basic functions provided by valves?

    a)

    b)

    c)

11. Gate valves are used as ____________________ valves.

    a) throttle

    b) control

    c) stop

12. Globe valves are used as ____________________ valves

    a) throttle

    b) control

    c) stop

13. One of the specific features of a check valve is that it _________________________.

    a) offers considerable restriction to flow even when it is wide open.

    b) allows flow in on e direction only.

    c) withstands the action of abrasive liquids better than the globe valve.

14. There are two general types of the diaphragm operated control valves, the single seated valve and the double seated valve. True / False

15. If a valve leaks when closed, one should open it slightly and close it a few times. True / False

16. Describe, briefly , what happen to a closed valve if it is allowed to leak through continuously.

17. When two valves are provided in series, the second or downstream valve should be opened wide, and the first or upstream valve (closest to the vessel or line) should be opened part way and used to throttle or control the flow. True / False

18. What is the purpose of a bypass line?

19. A general rule to prevent consequences due to water hammer is to always open or close fluid regulating valves slowly. True / False

20. List two other ways to avoid or prevent water hammer in steam lines.

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Section 07

BASIC INSTRUMENTATION

OBJECTIVES:

1. Discuss the basic devices used for pressure and temperature measurement and their principles of operation.
2. Discuss the basic devices used for flow measurement and their principles of operation.
3. Describe how measurement information is converted, transmitted, and collected.

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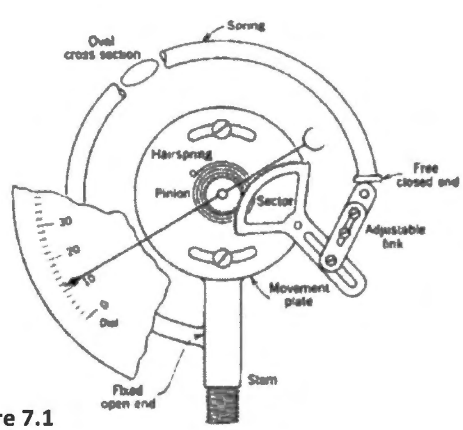
Section 07

BASIC INSTRUMENTATION

As power plants become larger and more complex, the operator must rely more and more on instruments to provide the information required for safe and efficient operation of the equipment. Some basic knowledge of how instruments function is of considerable value to the operator. This section will discuss the basic devices and their principles of operation.

PRESSURE MEASUREMENT

The range of pressures that must be measured in a power plant is quite large. The instruments required to accomplish this wide range of measurement must be designed for the specific application. As discussed in a previous section, the units commonly used for pressure measurement are: pounds per square inch for most positive pressures; inches of mercury for low positive pressures and inches of water for very low positive pressures; negative pressures or vacuum are usually measured in inches of mercury or inches of water. From the above discussion, we can see that two types of instruments are used, one for measuring pressure directly and one for measuring indirectly by the height of a column of liquid. ***Pressure gauges*** as normally used are instruments for measuring the difference between atmospheric pressure and the pressure in a pipe or vessel. The bourdon tube gauge shown in Figure 7.1 involves a curved metal tube closed at one end and with an oval cross section. When pressure is applied to the inside of this tube, it tends to straighten out causing motion of the free end. This motion is amplified and transmitted



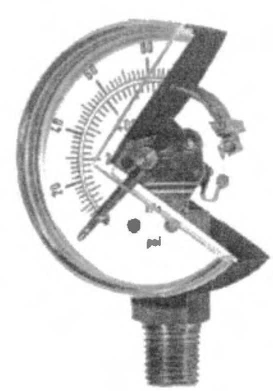


Figure 7.1
Bourdon Tube Pressure Gauge

through a linkage to the pointer.

The pointer indicates gauge pressure directly. Owing to the necessity for considerable mechanical amplification of the tube movement and the likelihood of changes in the mechanism, these gauges require periodic calibration. It is important that a gauge not be subjected to a pressure greater than the maximum scale reading. Damage to the mechanism or failure of the bourdon tube may result from overpressure. Pressure gauges should be treated as delicate instruments and cut in and out of service slowly and carefully to minimize thermal and mechanical shock.

The manometer is a pressure measuring instrument in which the measured pressure is balanced against the weight of a column of liquid. The two most common liquids used are mercury and water. Figure 7.2 shows two common types of manometers. The U tube manometer shown is the most common. The principle of this manometer is applicable to all manometers and is based on the fact that the unbalanced height of liquid is a direct measurement of the pressure. When the liquid level in the manometer reaches an equilibrium value, there must be no unbalanced forces acting upon the liquid column or it would still be in motion. If for instance the manometer is filled with mercury to its center or zero point and the left leg is connected to some pressure, the amount the left side goes down plus the amount the right side goes up will be measured pressure in inches of mercury. The disadvantage of this type of manometer is that two separate readings are necessary, one on each leg of the manometer. This condition can be overcome by using a well or single leg type manometer as shown on the right. In this type, the well actually forms one leg of the manometer; however, its area is large so that very little change in level takes place. This allows the total height of liquid to be read directly on one scale.

As with the pressure gauge, care must be used in handling manometers. The tubes are glass and can be easily broken. If subjected to pressures greater than the range of the manometer, the fluid will be forced out of the manometer, thereby making it worthless. For information, the Table 7.1 of equivalent pressure values is given.

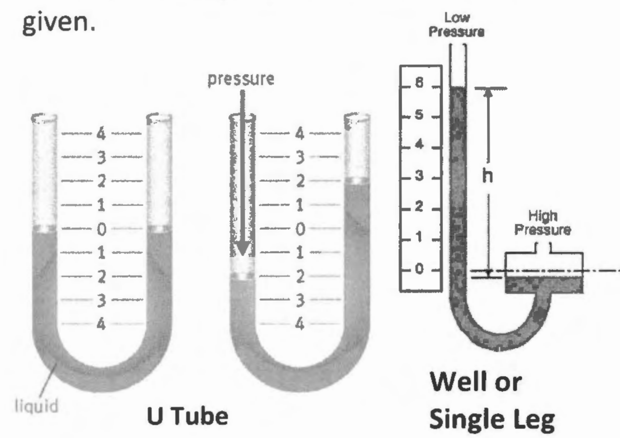


Figure 7.2 Typical Manometers

TABLE 7.1 Equivalent Pressure Values

1 inch of water	0.0734 inches of mercury
1 inch of water	0.036 pounds per square inch
1 inch of mercury	13.62 inches of water
1 inch of mercury	0.491pounds per square inch
1 pound per square inch	2.036 inches of mercury
1 pound per square inch	27.73 inches of water
1 standard atmosphere	29.92 inches of mercury
1 standard atmosphere	14.696 pounds per square inch

TEMPERATURE MEASUREMENT

The range of temperatures encountered in a power plant is also quite large, just as with pressures. As a result, there are several classes or types of instruments that are used for measuring temperature. The normal temperature scale used is the Fahrenheit scale; the Centigrade scale is used only for measuring the temperature of electrical equipment. There is no way to directly measure temperature so we must rely on measuring the effect of temperature on various other properties of substances. Some of these effects areas follows: When a solid material is heated, it expands. We can measure this expansion and convert it to temperature. A liquid behaves in much the same way and we can use its expansion as a measure of temperature. If a fluid is sealed in a container, its pressure will increase with an increase in temperature. We can measure the pressure change and convert it to temperature. Changing temperature also has an effect on the electrical properties of some metals. The resistance to the flow of electricity changes with temperature and can be used for measurement. Some dissimilar metals when joined together will produce an electrical force or voltage when heated and this voltage can be measured and converted to temperature. Each of the methods is commonly used in the power plants. A brief description of the various applications follows.

Liquid in glass thermometers utilize the difference in expansion between a liquid sealed in a glass tube and the tube. A liquid reservoir is usually located at one end of the tube. When this type of thermometer is heated, the glass tube expands very slightly while the liquid expands much more and rises in the tube. A scale is either etched onto the glass tube or a separate scale is attached next to the tube. Many liquids can be used in this type of thermometer; however, mercury is the most common due to its high boiling point and low freezing point. Liquid in glass thermometers should never be subjected to a temperature in excess of their maximum scale since the rapidly expanding liquid will fill the tube and pressurize it to the point of breaking the glass tube.

Dial thermometers are also used in the plants. These devices have a round face very similar to a pressure gauge except that it is calibrated in temperature units rather than pressure units. A moveable pointer indicates the temperature on the dial. There are two general types of these devices in use; one is mounted directly on the line or equipment whose temperature is being measured while the other is located at a convenient spot some distance away from the point of measurement. The locally mounted type generally utilizes the ***bimetallic strip*** principle. In this device, two pieces of dissimilar metal are attached to each other to form a strip. The two metals are in contact over their entire length. The metals are chosen so that they have different coefficients of thermal expansion. As the temperature of the strip is increased, one of the metals expands more than the other. This action causes the strip to bend or deflect. This motion is amplified and transmitted to the pointer by a gear and linkage arrangement. The remote mounted dial thermometers are known as ***capillary tube temperature devices.*** In these units, the indicating dial is connected to the sensing device by a length of capillary tubing. These devices operate on the principle of fluid expansion. A bulb filled with some fluid is the temperature detector which is connected by the capillary tubing to the indicator. The

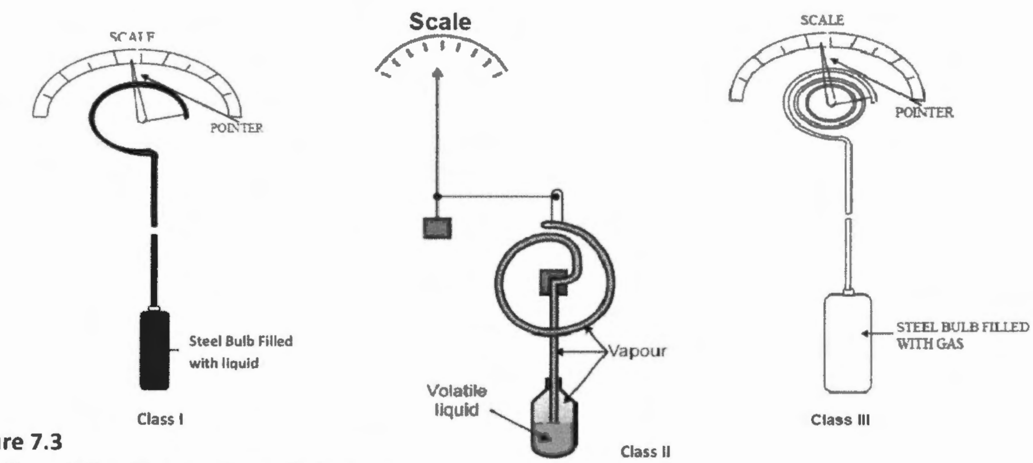


Figure 7.3
Capillary Tube Temperature Detectors

indicator is basically a bourdon tube. The bourdon tube, capillary tube, bulb combination is a completely scaled unit. When the temperature of the bulb increases, the fluid expands and since the unit is scaled a pressure rise occurs. The pressure is transmitted through capillary tubing to the bourdon tube. The pressure increase causes the bourdon tube to move, and through a linkage move the pointer and indicate the new temperature. A simplified diagram of several typical units is shown in Figure 7.3. The fluid used may be a liquid, a gas, or a mixture of these two depending on the particular application. These devices have two disadvantages: they are slow to respond, particularly when the capillary tubing is long. If the temperature being measured changes rapidly, the indication will lag behind for some time. Also, the reading may be affected by the ambient temperature through which the capillary tubing runs. These disadvantages may be overcome in part by keeping the length of capillary short and selecting the correct filling fluid.

Thermocouples are commonly used in all plants for many purposes. They are seldom direct indicating devices but are usually connected to multipoint recorders. When the fused junction of two dissimilar metal wires is heated, a voltage is produced. This voltage is quite small and a sensitive meter is required to accurately measure it. Thermocouples are frequently used since they cover a wide temperature range, have fast response, are quite accurate, and are reasonably inexpensive. Thermocouples are excellent for monitoring remote and inaccessible points since the length of the wire has very little effect on the accuracy or speed of response of the unit. A simplified diagram of a thermocouple is shown in Figure 7.4. The meter reading is proportional to the difference in temperature between the hot and cold junction. The temperature of the cold junction is known and is usually fairly constant so the meter reading indicates the temperature existing at the hot junction. For high accuracy testing, the cold junction is usually placed in an ice bath to insure that it stays at a known constant temperature. Many different kinds of wire can be used; however, the most commonly used are iron-constantan, chromelalume and copper-constantan.

Resistance Temperature Devices (RTD) make use of the principle that changes in temperature result in changes in the electrical resistance of a conductor. In these devices a coil of wire of a pure metal,

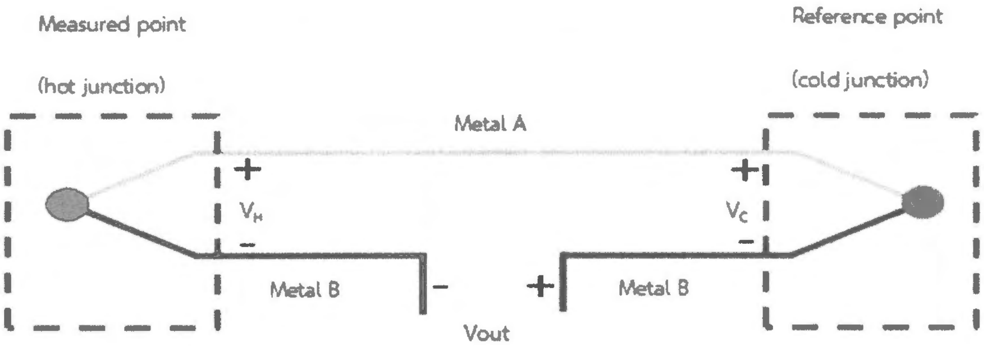


Figure 7.4
Basic Thermocouple Circuit

usually platinum, is the temperature detecting unit. The coil has a known resistance at a standard temperature. As the temperature changes, the resistance of the coil of wire changes. For any temperature, the resistance can be measured and the temperature determined. Like the thermocouple, the resistance temperature devices are seldom direct reading but are usually connected to a recorder. The change in resistance associated with a normal temperature change is quite small and a sensitive measuring device is required for accurate temperature measurements.

Most of the temperature detecting devices described above are fragile and require protection. Whenever one of these devices is installed in a line or vessel, a protective well is used. The well protects the sensing element from the erosive or corrosive action of the fluid and also allows removal and/or replacement of the sensing clement without shutting down the system. The use of a well slows down the rate of response of the detector to temperature changes; however, this disadvantage is more than compensated by the protection and replaceability that is gained.

LIQUID LEVEL MEASUREMENT

It is frequently necessary to know the liquid level existing in a closed vessel. The vessel may contain very high pressure such as the boiler or it may be under considerable vacuum such as the condenser hotwell. To cover this wide range of conditions, many types of level measuring devices are used; some of the more common are described below.

Gauge glasses are the most common level measuring device. They permit visual observation of the level in the vessel. In its simplest form the gauge glass consists of a small diameter glass tube which is connected to the top and bottom of the vessel. The liquid level inside the glass changes directly with any change in level inside the vessel. Special types of glass and construction make this device usable for practically any type of service. Provisions are usually incorporated for cutting out and draining the gauge glass for replacement or cleaning.

Float operated level indicators are commonly used on large storage tanks where it is impractical to use a gauge glass. In this type of device, the float rides on the surface of the liquid and operates through a wire and pulley arrangement to an indicator mounted on the outside of the tank. This arrangement is used on lube oil, raw water and distilled water storage tanks. On fuel oil tanks where more accurate measurements are necessary, the wire connecting the float

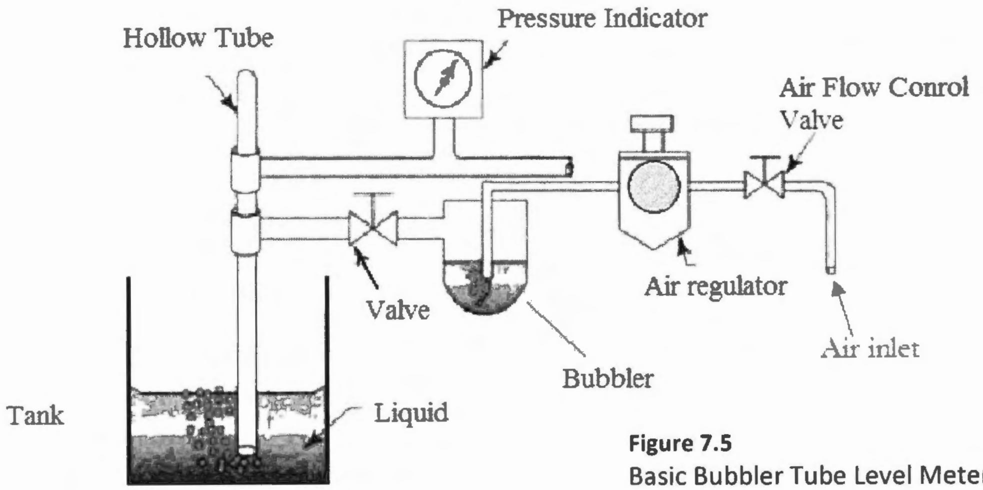


Figure 7.5
Basic Bubbler Tube Level Meter

and indicating mechanisms is replaced by a steel tape with small graduations that may be calibrated to read accurately.

Bubbler tubes are utilized for level measurement in inaccessible areas, and where the vessel or tank is below ground level. This device balances the pressure with either a manometer or a pressure gauge. Figure 7.5 illustrates the principle of operation. Air pressure is supplied to the bubbler tube which extends below the surface of the liquid. The air pressure increases and forces the liquid out of the tube; when all the liquid is out of the tube, the air bubbles pour out and no further pressure increase takes place. The air pressure is equal to the difference in level between the bottom of the bubbler tube and the surface of the liquid. The manometer or pressure gauge can be located at any convenient point and can be calibrated to read directly in any units such as feet of liquid, inches of liquid or gallons.

Level meters or as they are more correctly known, head meters, are used where considerable accuracy is required over a small range of level. They are basically used for control purposes on boiler drum level, hotwell level and deaerator level. These meters are seldom direct reading but usually transmit a signal to a remote located recorder. The meter consists of a leak proof housing which must be designed to withstand the same pressure as exists in the vessel. The housing contains a moveable float or bell that senses level changes and a sealing fluid which is usually mercury. The float or bell moves in response to changes in the mercury level which in turn responds to small changes in differential pressure. The principle is similar to a U tube manometer in which the mercury goes down in one leg and up in the other. In this case, the movement of the mercury causes a bell or float to move. This movement is vertical and is converted by a mechanical linkage to an indicator or transmitter. This mechanism is similar to that used in the head type flow meter which is discussed in more detail later in this section. This type of meter is capable of measuring differential pressure changes equivalent to one inch of water even in the presence of pressures greater than 2000 pounds per square inch. This is due to using the U tube principle where the absolute pressure on each side is balanced out and only the small differential pressure due to water level is felt by the meter.

FLOW MEASUREMENT

Measurement of the rate of fluid flow or the total quantity of flow is of considerable importance in the power plants. It is necessary to meter many different fluids such u water, steam, air, fuel oil and fuel gas. Depending on the fluid involved and the accuracy required, several methods of measurement are available. The type of flow meter used also depends on whether a continuous indication of flow rate is required or whether the total quantity of fluid passing through the meter during some time interval is required. In many instances, both of these requirements must be met. These two requirements permit dividing flow meters into two basic types known as rate meters and quantity meters.

Transducer. A transducer is an electromechanical device which changes a temperature, pressure, flow, or position to an electrical output signal. The electrical signal is then transmitted to be used as a control signal, recording signal, multi-pointer gauges, charts, and computer inputs. The transducers are placed as near the source of needed information as practical. Usually several transducers are placed in one cabinet convenient to several pickup points. The word transducer is not a trade name but a function, that is, transducing a temperature to an electrical signal. Enclosed in the case are the mechanical and electrical components used to transduce and transmit the needed information.

RECORDERS

It is frequently desirable to have a permanent record of various pressures, temperatures, levels and flows and to be able to observe how they change. This is accomplished by automatically recording this information on a chart. In most cases, the sensing device includes a transmitter which transmits either an electrical or pneumatic signal to the recorder which is located in the control room. It is desirable from a safety viewpoint to have all the signals entering the control room be low pressure pneumatic or low voltage electric. If high pressure steam and water lines are brought to the control room, a break or leak could be disastrous.

CONTROLLERS

In many instances, it is desirable to automatically control pressure, temperature, level or flow at some standard value. This can be accomplished by utilizing the same basic sensing elements as were discussed previously. As well as recording, they produce a pneumatic or electrical signal which can be used to position a valve or other final control element.

SWITCHES

The same basic sensing devices are frequently used to open and close electrical switches. The switches may be used to bring in an alarm or start and stop equipment.

NOTES:

Section 07

BASIC INSTRUMENTATION

Study Questions

1. What are the three units commonly used for pressure measurement?

   a.

   b.

   c.

2. Instruments normally used for measuring the difference between atmospheric pressure and the pressure in a pipe or vessel are called ______________________ .

3. The two most common liquids used in a manometer are _____________________ and ______________________ .

4. Balancing the measured pressure against the weight of a column of liquid is the basic principle of the manometer. True \ False

5. The normal temperature scale is the ________________________ scale, while the ______________________ scale is used for measuring the temperature of electrical equipment.

6. Changing the temperature has an effect on _________ .

   a. solid material

   b. liquid

   c. the resistance to electrical flow

   d. all of the above

7. What is the most common liquid used in a thermometer? Why?

8. State three (3) reasons for the frequent use of thermocouples.

   a.

   b.

   c.

9. What is the most common liquid level measuring device?

10. Bubbler tubes are utilized for liquid level measurement

    a. on large storage tanks
    b. in inaccessible areas
    c. for control purposes on boiler drum level
    d. none of the above

11. Level meters are used where considerable accuracy is required over a small range of level. True \ False

12. The two basic types of flow measurement meters are known as ____________ meters and __________________ meters.

13. The electromechanical device that changes temperature, pressure, flow, or position to an electrical output signal is called a ____________________________ .

GENERATION-OAHU DIVISION
OPERATOR TRAINEE TRAINING PROGRAM

Section 08
HEAT EXCHANGERS

OBJECTIVES:

1. Describe the function of a heat exchanger.
2. Discuss the two basic types of feedwater heaters and their cycles.
3. Identify and describe the two sides of condensers and their functions.
4. Discuss the theory and operation of plate heat exchangers.

Generation-Oahu Division
Operator Trainee Training Program

Section 08
HEAT EXCHANGERS

Heat exchangers play an important role in the efficient conversion of energy. The term heat exchanger can be applied to any piece of equipment designed to transfer heat. For our purposes, the term will only be applied to power plant auxiliary equipment in which heat is transferred from one fluid to another. The specific heat exchangers which will be discussed are feedwater heaters, condensers and plate heat exchangers. Miscellaneous heat exchangers such as lube oil coolers and fuel oil heaters will also be briefly discussed.

FEEDWATER HEATERS

Many heat exchangers are used in the various plants to raise the temperature of the feedwater. The term feedwater heater only applies to those heat exchangers that raise the temperature by the use of steam extracted from the turbine or reheat piping. To fully understand the gain in thermal efficiency resulting from feedwater heating, it is necessary to study the complete power plant cycle. This study is made in another section of this manual. For the present we can observe the mechanism of the gain by considering two separate conditions. Consider one pound of steam that has passed part way through the turbine. During this passage, it has transferred energy to the turbine blades and its pressure and temperature have been reduced. At this point there are two choices: the pound of steam can be allowed to proceed on through the turbine or it can be extracted from the turbine and used to heat the feedwater. If allowed to expand through the remainder of the turbine, the steam will transfer a portion of its remaining energy to the turbine but most of its energy will be rejected to the circulating water in the condenser. In the other case when the steam is extracted for feedwater heating, most of the steam's energy is transferred to the feedwater and thus returned to the system.

For each plant cycle there is an optimum or most efficient temperature to which the feedwater should be raised prior to entering the boiler. Once this temperature is determined, it is necessary to determine how many feedwater heaters should be used to produce the desired temperature rise. Actually, an improvement almost always results from using more heaters; therefore, economic considerations limit the actual number used. The installation of only one heater produces a significant gain in cycle efficiency. For each additional heater installed, the efficiency gain gets progressively smaller. At some point the cost of one more heater and its installation outweighs the saving from increased efficiency. In general, economic evaluations have led to the following pattern of feedwater heater applications.

TABLE 1

Unit Size	No. of Heaters
20 - 50 MW	4 or 5
50 - 100 MW	5 or 6
100 - 200 MW	5, 6, or 7
Over 200 MW	6, 7, or 8

The total gain in cycle efficiency resulting from utilizing feedwater heating for three typical cycles is as follows:

TABLE 2

Cycle	Gain in Efficiency
7-Heater Reheat	14.4%
5-Heater Reheat	12.8%
5-Heater Non Reheat	16.2%

Regardless of the number of feedwater heaters utilized in the cycle, the most effective use of the heater system requires that an equal rise in feedwater temperature take place in each heater. In practice, it is not possible to achieve this exactly due to the limited number of extraction points available in the turbine. There is one normal exception to this equal temperature rise per heater rule. In a reheat cycle it is most advantageous to take the extraction steam for the top heater from the cold reheat piping. In this instance the temperature rise in this heater should be about 1.8 times as great as the equal rise in the other heaters.

Feedwater heaters are divided into two basic types: (1) *open or contact heaters* in which there is mixing of the extraction steam and the feedwater; and (2) *closed heaters*, in which no mixing occurs. The effectiveness of either type of heater depends on the net loss to the cycle resulting from transferring heat from the steam to the feedwater. In general this heat transfer process becomes more efficient as the temperature difference between the steam in the heater and the feedwater leaving the heater is decreased. This temperature difference is known as the heater *terminal temperature difference* and should be kept as small as possible.

OPEN HEATERS

In the contact heater, extraction steam and feedwater are mixed and discharged from the heater at saturation conditions. This type of heater is usually designed to *deaerate* (remove dissolved gases) the feedwater and act as a storage reservoir for supplying water to the boiler feed pumps. As a heater, the contact heater is highly effective because it has a terminal difference of 0°. It approaches the ideal of a no-loss heater. For this reason a cycle composed entirely of contact heaters is sometimes called an "ideal" feedwater heating cycle. This arrangement is seldom used in practice because of the saturated condition of the feedwater leaving the heater. To prevent the feedwater from flashing, each contact heater must be followed by a pump. From an economic standpoint it is not practical to have this many pumps. A single contact heater, primarily for deaeration purposes, is used in many plants and is always followed in the cycle by a feedwater pump. The contact heater also serves as a convenient point in the cycle to collect moderate pressure drains and leakages. Collecting drains and leakages at this point ensures deaeration of these flows before they are returned to the boiler. Typical deaerating contact heaters

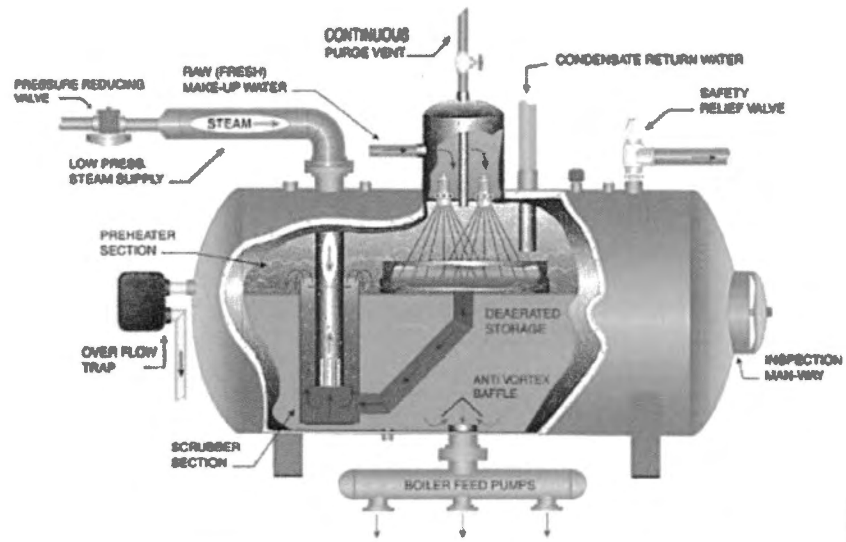


Figure 8.1a - Spray Type Deaerator

are shown in Figures 8.1a and 8.1b. The open heater accomplishes its task of deaeration of the feedwater due to an inherent property of mixtures of gases and liquids. The amount of any gas that can remain dissolved in water depends on the temperature of the water. As the water temperature increases, the amount of dissolved gas decreases. At the saturation temperature, water cannot retain gases in solution. It is not sufficient to just bring the water to its saturation temperature since the small gas bubbles that are released may still be mechanically entrained in the water. Some provision for agitation and turbulence of the water must be provided to thoroughly eliminate gas from the feedwater. In addition, some provision for venting or removing the released air must be made. This is usually accomplished by operating the heater at a slight positive pressure and venting the air and a small amount of steam to atmosphere through a vent condenser.

CLOSED HEATERS

In closed heaters, or shell and tube heaters as they are also called, no mixing of the extraction steam and feedwater takes place. This arrangement makes it possible to pass the feedwater through several heaters, one after the other, using only a single pump. In these heaters the feedwater always flows through the tubes while the steam is around the outside of the tubes in the shell. With this type of an arrangement, some provision must be made for the differential thermal expansion between the tubes and the shell. This is usually done either by the use of a separate floating head at one end of the tubes (Figure 8.2a) or by using specially bent U tubes. Most of the newer installations use the latter method. A

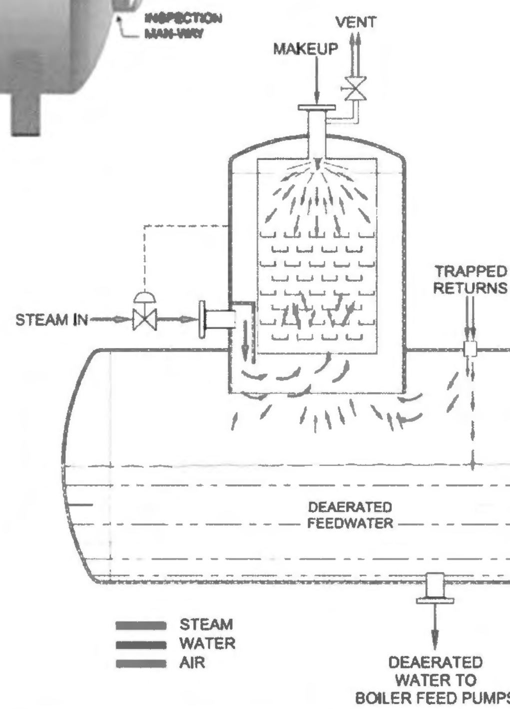


Figure 8.1b - Tray Type Deaerator

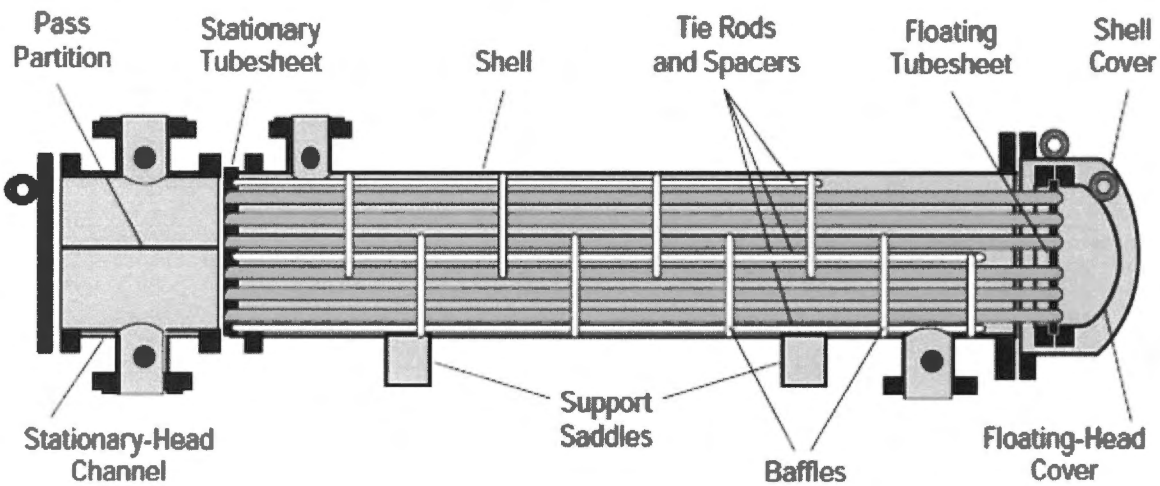


Figure 8.2a - Straight Tube Heat Exchanger

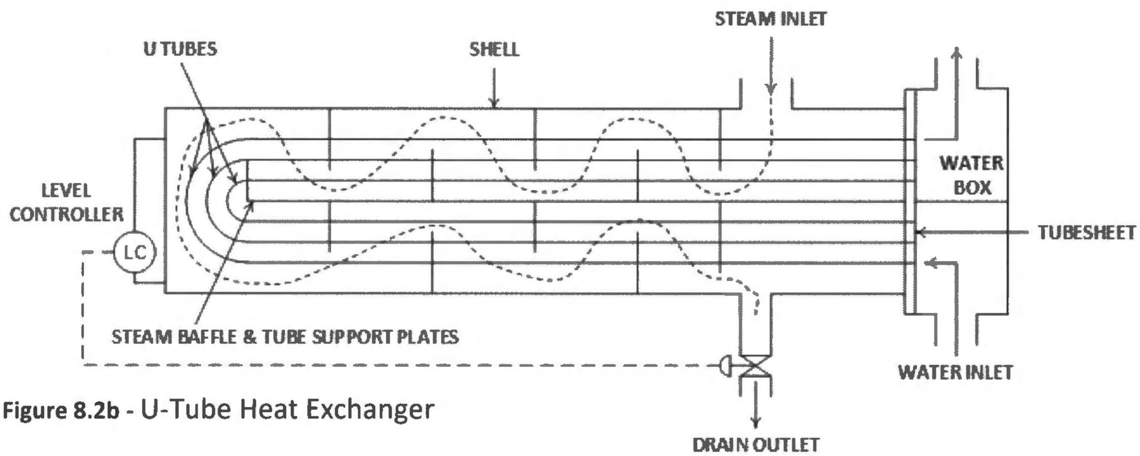


Figure 8.2b - U-Tube Heat Exchanger

simplified drawing of a U tube heater is shown in Figure 8.2b. In this drawing the water in the tubes goes the length of the heater in one direction, then makes the turn and comes back the length of the heater in the other direction. The number of times the water goes the length of the heater is known as the number of passes in the heater. Figure 8.2a & 8.2b are two pass heaters which are the most common. The divided chamber at the inlet end is known as the *water box or channel*. The heavy metal plate that divides the water box from the shell is known as the *tube sheet*. The tubes are rigidly attached to the tube sheet either by rolling (expanding) or welding or both. The steam is directed through the heater shell by baffles to insure maximum use of the heat transfer surface. As the steam transfers heat to the water, it condenses and the condensate is collected in the bottom of the shell. This condensed steam is commonly known as *drips or drains*. A control valve is used in the drain outlet to ensure that a water level is maintained in the shell. If this is not done, steam could blow right through the heater without condensing and result in greatly reduced heat transfer. A level control device is connected to the shell to sense the water level and position the control valve in the drain outlet line.

Note the direction of the steam flow through the heater as compared to the water flow. They are basically in opposite directions; this is known as *countercurrent* flow. It was pointed out earlier in this section that the most effective heater had the lowest terminal temperature difference and transferred heat with the smallest temperature difference. Countercurrent flow accomplishes this purpose by having the hot inlet steam transfer heat to the leaving or hottest feedwater. As the steam loses temperature while flowing through the heater it is transferring heat to cooler feedwater. This flow pattern maintains the minimum temperature difference between steam and water at all times. Unfortunately, at the normal extraction steam pressures and temperatures most of the heat in the steam is latent and is associated with a change of state. There is no change in steam temperature while this heat is transferred; the steam is just condensed from vapor to liquid. This reduces the effectiveness of the heater because the heat must be transferred across a larger temperature difference. This condition can be offset, if steam conditions warrant it, by dividing the heater shell into separate regions. If the extraction steam entering the heater is highly superheated, the heater can be designed with a desuperheating section to utilize this superheat. A desuperheating heater is designed to pass the incoming superheated steam over the tubes containing outgoing feedwater. In this design the temperature of the feedwater leaving the heater may be raised close to, or above the saturation temperature existing in the condensing section of the heater. This results in a small or even negative terminal temperature difference. A desuperheating section is only justified when there is considerable superheat available. This usually limits its application to the highest pressure heaters.

The effectiveness of a heater is affected by what is done with the drains leaving the heater. To get maximum effectiveness the drains should mix with steam or feedwater which is at the same temperature as the steam in the shell of the heater. In the most desirable case the drains would mix with the feedwater leaving the heater. If the drains must be disposed of to some lower pressure point, the maximum effectiveness results from keeping the drain temperature as close as possible to the temperature of the incoming feedwater. This can be accomplished by the use of a *drain cooler section* in the heater. In this design the condensed steam, or drains, are collected and brought into contact with the tubes containing the

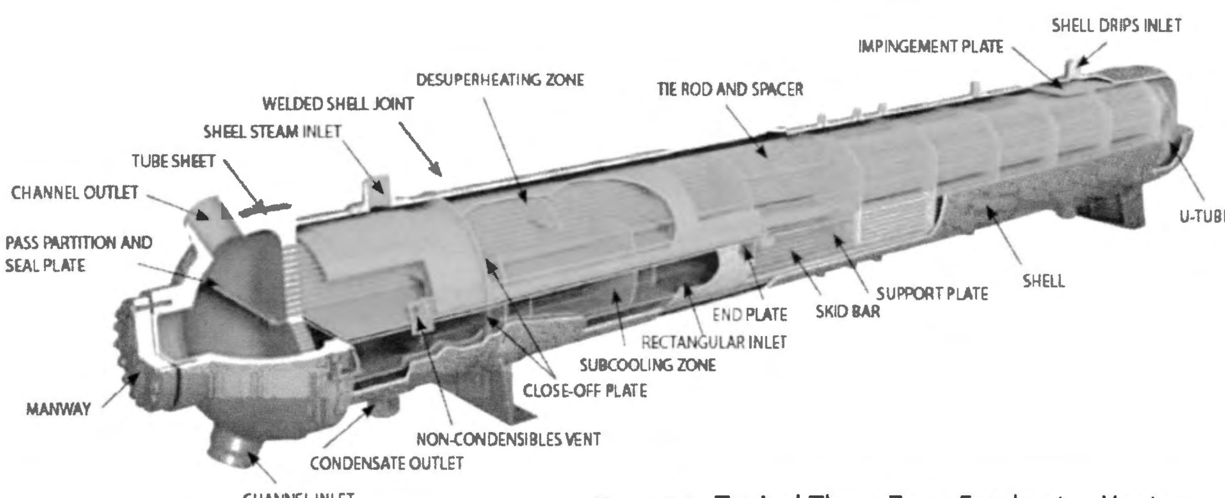


Figure 8.3 - Typical Three Zone Feedwater Heater

incoming feedwater. The temperature of the drains is lowered and made more nearly equal to the incoming feedwater temperature. Figure 8.3 shows a typical high pressure heater with three zones or sections: desuperheating, condensing, and drain cooling. The extraction steam entering the heater usually contains some *non-condensable gases* mixed with it. The origin of these gases is from two major sources:

(1) liberation in the boiler of dissolved gas in the feedwater, and

(2) gas formed by disassociation or breakdown of the chemicals used for boiler water treatment.

These gases flow along with the steam and enter the heaters. It is absolutely essential that these gases be removed and not be allowed to accumulate in the heater shell. There are two major reasons for this:

(1) enough gas can quickly accumulate to blanket the heat transfer surface and greatly reduce the effectiveness of the beater, and

(2) some of the gases if allowed to dissolve in water in the condensing zone can form highly corrosive liquids that can soon damage the tubes.

The gases are normally removed by installing one or more vents on the heater shell. The pressure in the shell forces the non-condensable gases along with some steam out of the heater. The vent is usually located at the opposite end of the shell from the steam inlet. This is done to improve the distribution of steam throughout the shell.

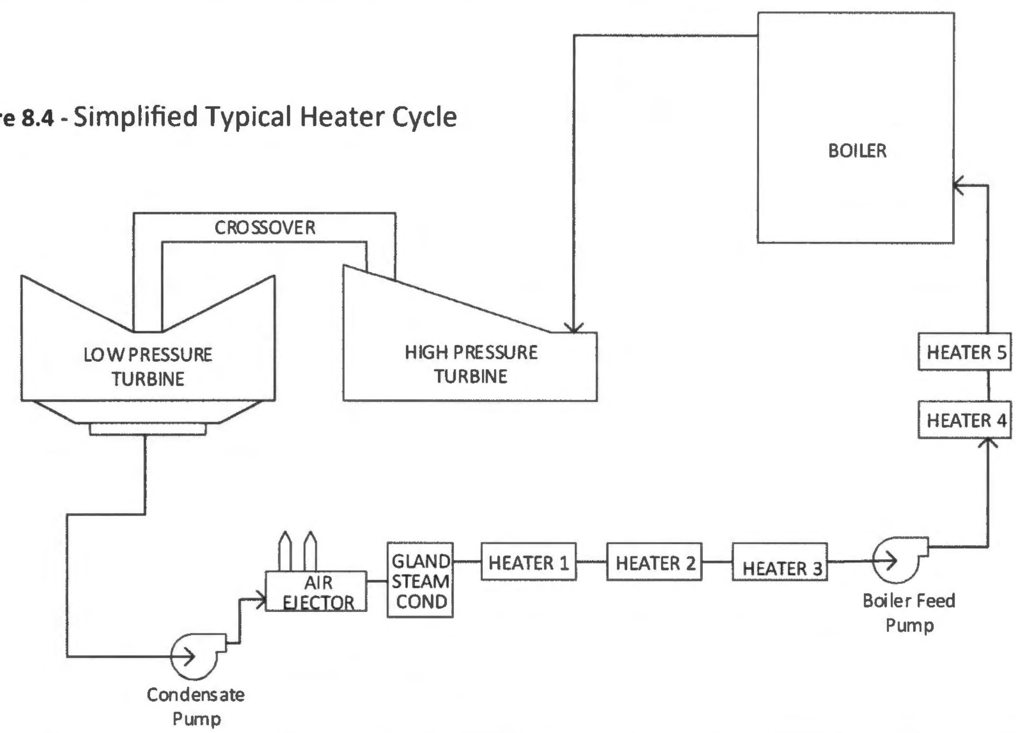
HEATERS AND THE CYCLE

The same numbering system for feedwater heaters is used throughout all plants. The heaters are numbered in reverse order in which steam is extracted from the turbine. This means that No. 5 Heater has the highest steam pressure, No. 4 the next lowest, and so forth. The feedwater flows through the heaters in the same order as the numbering system. This numbering system will be used in the following discussion. As mentioned earlier, the manner in which the drains from a closed heater are handled has a considerable effect on heater performance. The best method is to collect the drains and pump them into the feedwater leaving the heater. This requires a drain pump, or as it is more commonly known, a *drip pump* for each closed heater. In most cases this number of pumps cannot be economically justified. Usually the drains from one heater will be sent to the next lower pressure heater where, due to the lower pressure, some of the drains will flash to steam. A system where the drains from each heater are flashed to the next lower pressure heater is known as a *cascading drain system*. This type of system is used in practically all plants. Since the drains will always be a wet mixture of steam and water, they always enter a heater in the condensing zone and not in the desuperheating zone. An example of this can be seen in Figure 8.3. As we proceed down the feedwater heater chain, the drain flow from each heater gets larger and larger. Each heater not only has the drains due to its own extraction steam, but also the drains from all the heaters above it in the cascade. If this were continued down to the lowest pressure heater, the accumulated drain flow would be so large that unreasonably large size heaters would be required to handle the flow. To get around this problem, the cascade is usually stopped at some intermediate point in the heater chain, usually about half way through. If the cycle uses one open heater, the cascade is automatically stopped at this point since the extraction steam, drains, and feedwater all mix together and discharge directly to the boiler feed pump. In cycles where there is no open heater, the cascade is also stopped, and the drains are collected and pumped into the feedwater system. Regardless of the cycle, the point where the cascading drains are stopped will be before the main feed pump. This allows the drip pump to be smaller since it doesn't have to develop a head sufficient to overcome the feed pump discharge pressure. The cascade of drains is started again with the heaters below the collection point. The drains from the lowest pressure heater are either dumped to the condenser or pumped into the feedwater system. Figures 8.4 shows a simplified typical heater cycle.

An alternate method of drain disposal for each heater must be provided. If this were not done, removal from service of one heater for maintenance would stop the drain flow and therefore deactivate all heaters above it. To alleviate this condition each heater is provided with an alternate drain disposal route, usually directly to the main condenser. This alternate route is commonly known as the *high level dump*. These drains are automatically opened whenever high water level is detected in the heater shell. This alternate drain disposal route not only increases reliability by allowing maintenance but also protects against high level in a heater resulting from any source such as a ruptured tube. If high level were not protected against in this manner, a heater could completely fill with water and even back up into the extraction line and eventually into the turbine. The consequences of this could be disastrous. Additional protection against this and other turbine associated troubles is provided in the extraction line.

Disposal of the heater vents does not pose as great a problem as the drains due to the small steam flow involved. In some cases the heaters are vented directly to atmosphere. In most cases, however, the heater vent system is a closed system. Frequently, the vents are cascaded just like

Figure 8.4 - Simplified Typical Heater Cycle



the drains. In this manner the heat contained in the small amount of steam that is vented along with the gas can be reclaimed in the next lower heater. The gain from doing this is quite small and it is better to run the vent from each heater directly to the condenser. This eliminates the possibility of building up a large gas inventory in the lower pressure heaters which can happen with cascading vents.

Despite their apparent size and strength, feedwater heaters must be handled carefully to prevent thermal or hydraulic shock. When placing a heater in service, it should be warmed up slowly to its normal operating temperature. At no time should there be extraction steam supplied to a heater unless there is a flow of water through the tubes. When removing a heater from service the steam should always be secured first, and when returning a heater to service the steam supply should be opened only after a flow of water has been established. In many plants, it is not possible to remove a single heater from service. Heaters can only be cut out and bypassed in groups of two or three. When cutting out heaters in this type of installation, the steam to the highest pressure heater should always be secured first. This method produces the smallest upset in feedwater temperature.

CONDENSERS

The main condenser in a power plant serves two major functions. It creates a vacuum or low absolute pressure at the turbine exhaust, and it reclaims and collects high purity condensate for reuse in the cycle. Most condensers are designed to accomplish many other functions as well, but the above two are the major ones common to all condensers. The amount of heat transferred in the condenser is tremendous. Each pound of steam exhausted from the turbine must reject approximately 950 BTU to the circulating water in order to condense from a vapor to a liquid. Large quantities of circulating

Figure 8.5a - Single Pass Condenser

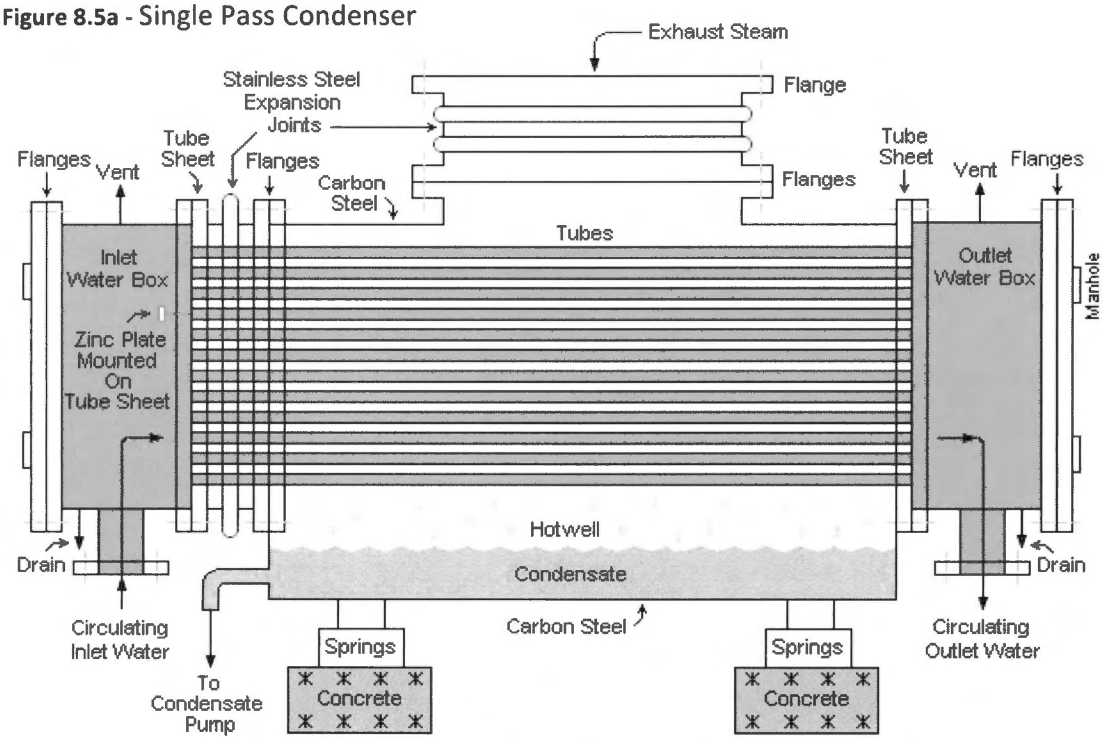
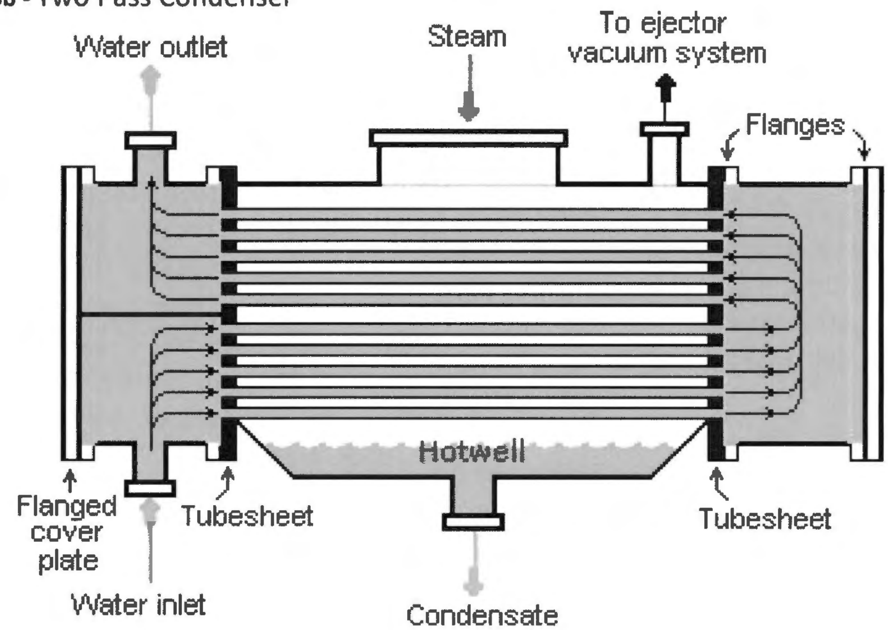


Figure 8.5b - Two Pass Condenser



water are required to remove this heat. In addition, in order to minimize thermal pollution and for other considerations, the temperature rise of the circulating water is usually limited to approximately 15°F and is never more than 20°F. From these considerations it can be shown that for each 1000 pounds per hour of steam entering the condenser, a circulating water flow of approximately 130 gallons per minute is required. Another way of stating this relation is that each megawatt of turbine capacity requires approximately 600 gallons per minute of circulating water.

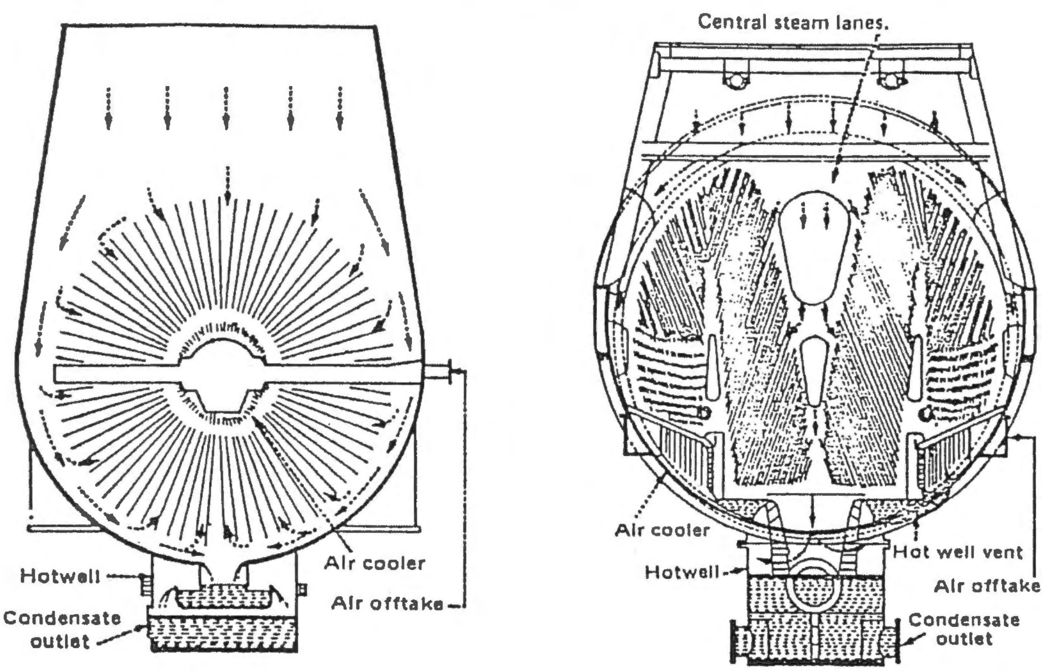
The condenser is a shell and tube heat exchanger with the circulating water passing through the tubes and the condensing steam in the shell. The condenser is located as close as possible to the turbine in order to minimize the pressure drop experienced by the steam in flowing from the turbine exhaust to the condenser. This consideration usually results in the condenser being located directly below the turbine exhaust. Some provision must be made for differential expansion between the turbine and the condenser. There are two normal methods of accomplishing this; an expansion joint may be installed in the connecting piece between the two, or they may be solidly connected with the condenser mounted on springs to allow for expansion.

Most condensers are single pass units (Figure 8.5a); however, some of the older installations use two pass condensers (Figure 8.5b). The circulating water usually enters the inlet water box from the bottom and passes through the tubes into the outlet water box from where it is discharged. The water side of the condenser is divided into two separate halves. This may be accomplished by having separate water boxes for each half or by using a common water box with an internal dividing plate. Regardless of the method, this division permits removal from service of one half of the condenser for cleaning, maintenance, or testing for tube leaks while the unit is in operation. Load must be reduced whenever one half of the condenser is out of service.

The steam side or shell of the condenser must be leak tight since any leaks will allow air to enter and result in loss of vacuum. The steam enters the condenser at the top and contacts the cold tubes. Heat is transferred from the steam through the tube wall to the water. The steam is condensed by this process of transferring heat. Drop condensation is the most effective condensing method; however, this is impractical to achieve and film condensation is the usual process. This process results in a lower overall coefficient of heat transfer and requires more tube surface. With practical tube materials, water velocities, and water temperatures, thousands of tubes are required to provide sufficient surface area for the required beat transfer rate.

The layout of the condenser tubes must be such that the steam can quickly and easily come into contact with the greatest number of tubes. This makes a much larger surface available for heat transfer. There are two usual methods of accomplishing this purpose. As previously mentioned, the steam usually enters the condenser from the top. In many designs the tube bank is designed with *steam lanes* which allow steam to flow into the center of the tube bank and thereby utilize more of the surface. The steam lanes are areas in which no tubes are installed. These open spaces or lanes permit the steam to penetrate the tube bank before contacting the cold tubes and condensing. The tube layout is such that the area of the steam lanes is largest at the top or outside of the tube bank and decreases as the lane proceeds toward the center of the tube bank. This design helps

Figure 8.6 - Typical Condenser Layouts



Deaeration and heating take place as steam rising from bottom comes in contact with falling condensate. Air is removed from the center of the condenser.

A venturi-shaped center lane allows heating and deaerating steam to pass. Note open arrangement of tubes to give steam access to all portions of the surface.

to distribute the steam and therefore the heat transfer load evenly over all the tubes.

The other common method of distributing the steam is used on the newer, larger units which have separate water boxes. In this design there are two separate tube banks, one for each condenser half. The steam completely surrounds each tube bank and flows radially inward toward the center. The tubes are arranged in a radial pattern which automatically provides more flow area at the outside of the tube bank and progressively smaller flow areas as the steam approaches the center of the tube bank.

Air and other non-condensable gases enter the condenser with the steam and from leakage. These gases must be continuously removed or a loss of vacuum will result. Most condensers have a particular section, usually near the center of the tube bank where air removal takes place. The tubes in this air removal section are placed very close together to insure that all the steam is condensed and not removed with the gas. The gases leave this section of the condenser through an *air removal line* to the *air ejectors*. The air removal line inside the condenser is usually baffled to assist in separating any entrained moisture from the non-condensable gases. When one half of a condenser is out of service for any reason. it is advisable to shut off the air removal from this half. With no cooling water through the tubes considerable steam can be drawn into the air ejector which may cause overloading and loss of vacuum.

In plants which have no deaerating heater, this function is performed in the condenser. As the steam condenses, it drips down through the tube bank and is collected in the hot well which is located directly below the condenser. Some of the incoming steam is directed around the tube bank to the bottom from where it flows upward into the tube bank. This steam heats the downward flowing condensate to its saturation temperature and releases any dissolved gases. Due to the high vacuum or low absolute pressure in the condenser, the saturation temperature is quite low and the condensate can be easily heated to this temperature. The condensate is already broken up into small drops due to its dripping through the tube bank In some designs, however, an additional agitation or break-up is provided for insurance. This is usually a form of trays similar to those used in a deaerating feedwater heater. The gas liberated by this process is carried off by the air removal system. Figure 8.6 shows some typical condenser layouts.

PLATE HEAT EXCHANGERS

A *plate heat exchanger*, or *plate and frame heat exchanger*, uses thin corrugated metal plates installed in a frame and compressed together to transfer heat between two fluids. The metal plates have gaskets for sealing around the outer edge and ports which allow fluid to flow between pairs of plates while preventing mixing of the fluid flows. The primary and secondary fluids enter through ports in the fixed cover and are directed counter-currently through adjacent channels formed by the gasketed plates (see Figure 8.7). The plates are pressed from a sheet of metal, typically stainless steel but titanium is also a common material. The gaskets can be clipped or glued to the plates depending on the service and pairs of plates can be welded instead of gasketed for high pressure or other special applications.

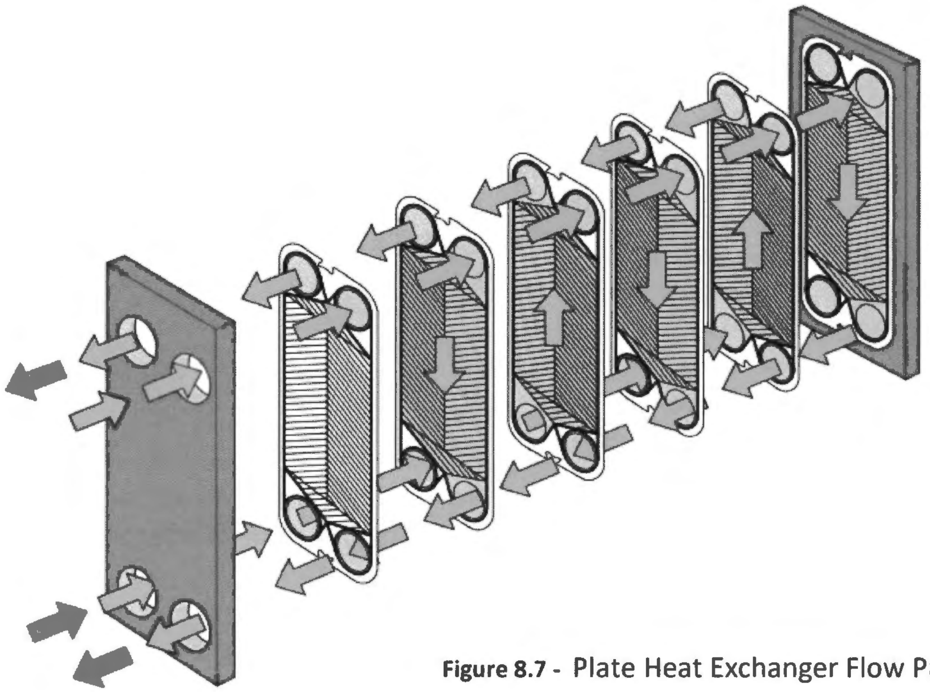


Figure 8.7 - Plate Heat Exchanger Flow Principle

Plate heat exchangers have a major advantage over shell and tube heat exchangers in that the fluid is spread out over a large surface area in a thin layer between the plates. The narrow spacing promotes turbulent flow at low velocities which results in a higher heat transfer coefficient which can allow approach temperatures to reach as low as 2°F. Because of the higher heat transfer coefficients, for the same amount of heat exchanged, the plate heat exchanger will be smaller than a shell and tube heat exchanger. Additionally, if adjustments are required in heat transfer capacity, plates can be added or removed with minimal disruption to operation.

The main components of a plate heat exchanger can be seen in Figure 8.8. These include:

Fixed Cover - Also called *Stationary Cover* or *Head*. The fixed cover has connections for the inlet and outlet piping of both fluids and provides a surface against which, the plates can be compressed.

Carrying Bar - Also called *Top Bar* or *Upper Guide Bar*. The carrying bar is what the plates and moveable cover hang from.

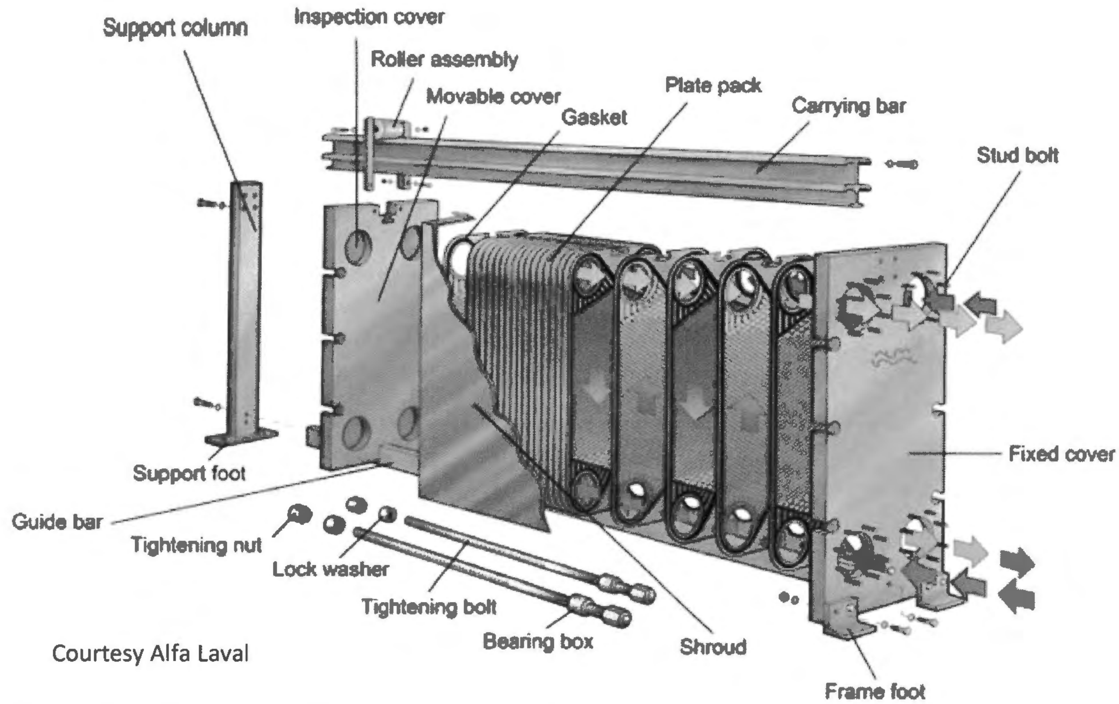
Guide Bar - Also called *Bottom Bar* or *Lower Guide Bar*. The guide bar keeps the plates aligned at the bottom.

Support Column - Also called *End Support* or *Guide Bar Support*. The support column forms the frame of the heat exchanger along with the frame plate, carrying bar and guide bar.

Moveable Cover - Also called *Follower* or *Moveable Frame*. The moveable cover hangs from the carrying bar and is allowed to move back and forth to compress the heat exchanger plate.

Tightening Bolts - Also called *Tie Bars*. The tightening bolts are used to compress the heat exchanger plates between the fixed cover and the moveable cover.

Heat Transfer Plates - The heat transfer plates transfer the heat from one fluid to another. The plates are pressed to form



Courtesy Alfa Laval

Figure 8.8 - Typical plate heat exchanger components

corrugations which create flow channels and provide additional strength.

Gasket - The gasket is used to seal between two plates to help form the flow channels for fluid movement. The gasket can be made from different material depending on fluid temperatures.

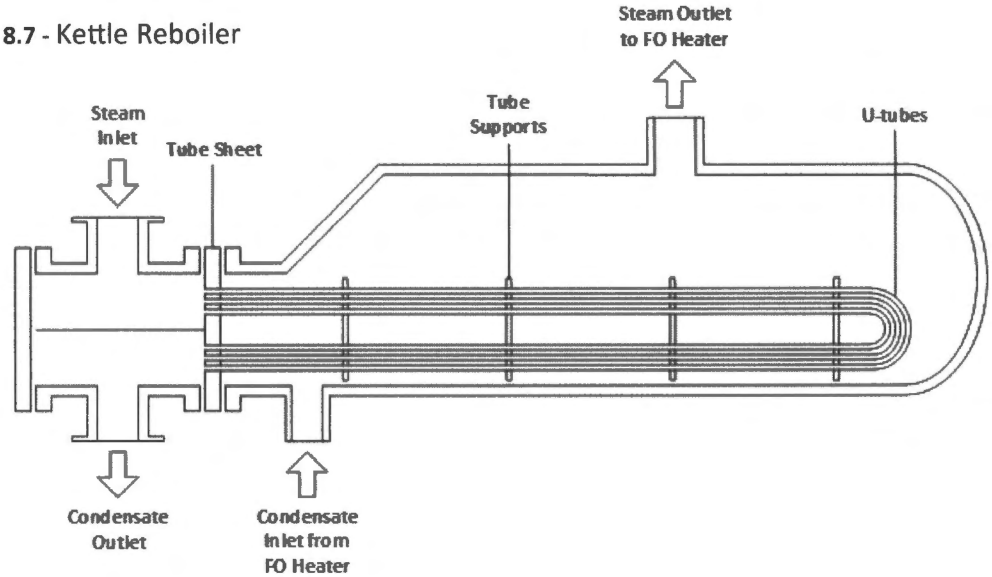
MISCELLANEOUS HEAT EXCHANGERS

Heat exchangers are used for many applications in power plants. They include: lube oil coolers, fuel oil heaters, and auxiliary cooling water heat exchangers. Most of these are shell and tube heat exchangers, but plate heat exchangers are used more widely now. Countercurrent flow is practically always used since it provides the most efficient heat transfer. In most of these applications it is necessary or desirable to control the temperature of one of the fluids exiting the heat exchanger.

There are several methods available for doing this. The primary problem is one of controlling the rate of heat transfer. Consider a fuel oil heater in which steam passes through the tubes and fuel oil is in the shell. It is desired to maintain a constant fuel oil temperature leaving this heater. This can be accomplished in several ways: The steam pressure to the heater can be varied thereby varying its temperature, or the water level in the heater can be varied which in effect changes the effective heat transfer surface. In other applications it may be possible to vary the flow rate of one of the fluids in order to control the temperature of the other fluid.

Gases are less efficient than liquids for heat transfer applications. In order to keep the size of liquid to gas heat exchangers reasonable it is frequently necessary to increase the heat transfer area by unusual means. The most common method of providing more surface in a small volume is to use tubes equipped with fins. The use of

Figure 8.7 - Kettle Reboiler



fins greatly increases the surface area. These are seldom used with liquids since the higher density of the liquid would produce a very large pressure drop through a finned tube bundle.

REBOILERS

Steam may also be used to evaporate (or vaporize) a liquid, in a type of shell and tube heat exchanger known as a reboiler. These are typically used in the petroleum industry to vaporize a fraction of the bottom product from a distillation column. These tend to be horizontal, with vaporization in the shell and condensation in the tubes (see Figure 8.9).

In power plants, the reboiler provides an isolated supply of steam for use in the fuel oil system to heat fuel oil to the correct viscosity for firing. This type of fuel oil heating system ensures that no oil leaking from the fuel oil heater can contaminate the main condensate or feedwater systems.

Some of this steam is also used for steam tracing. Steam is fed through tubing that is wrapped around fuel oil piping to prevent the oil from cooling and causing a cold plug.

In a forced circulation reboiler, the secondary fluid is pumped through the exchanger, while in a thermosyphon reboiler, natural circulation is maintained by differences in density. In kettle reboilers there is no circulation of the secondary fluid, and the tubes are submerged in a pool of liquid.

REHEATERS

In conventional plants reheating is accomplished in the reheat section of the boiler. High pressure turbine exhaust steam is reheated, mainly to remove the moisture. This reduces turbine blading erosion in the low pressure turbine.

Section 08
HEAT EXCHANGERS
Study Questions

1. The term heat exchanger can be applied to any piece of equipment designed to

   ____.

2. Feedwater heaters raise the temperature by the use of steam extracted from the turbine or reheat piping. True \ False

3. In open or contact heaters, extraction steam and feedwater are mixed, while in closed heaters, no mixing occurs. True \ False

4. Open heaters are designed to ________________________ (remove dissolved gases) from the feedwater.

5. At the saturation temperature, water cannot retain gases in solution. True \ False

6. The most effective heater has the lowest terminal temperature difference and transfers heat with the smallest temperature difference. True \ False

7. The closed heater contains which of the following features? (Circle answer)
   a. U-tubes
   b. Drain outlet
   c. Water box
   d. All of the above

8. Open heaters are more economical than closed heaters because each heater does not have to be followed by a pump to prevent the feedwater from flashing. True \ False

9. The effectiveness of a closed heater is affected by what is done with the drains leaving the heater. True \ False

10. Briefly explain the cascading drain system.

11. The cascading drain system always has to include one open heater that automatically stops the cascade. True \ False

12. Why is each heater provided with an alternate drain disposal route, and where is this route usually directed?

13. To prevent thermal or hydraulic shock in feedwater heaters during startup, the extraction steam should be supplied to the heater to warm it up before the water begins to flow through the tubes. True \ False

14. List the two major functions common to all condensers.

    a.

    b.

15. The condenser is a shell and tube heat exchanges. True \ False

16. The condenser is usually located ________________________

    a. directly after the main feed pump.
    b. directly below the turbine exhaust.
    c. as close as possible to the boiler.
    d. None of the above.

17. Why is the water side of a condenser divided into two separate halves?

18. How are non-condensable gases able to enter the condenser?

19. Describe the main components of the plate heat exchanger.

20. How is the heat exchange accomplished in a plate heat exchanger?

21. Name at least two (2) features of a plate heat exchanger that are not found in a shell and tube heat exchanger.

22. When would it be advantageous to use a plate heat exchanger instead of a shell and tube heat exchanger?

GENERATION-OAHU DIVISION
OPERATOR TRAINEE TRAINING PROGRAM

Section 9
PUMPS

OBJECTIVES:

1. Discuss the basic construction and function of postive displacement pumps
2. Describe the construction and operating principles of centrifugal pumps
3. Describe the operating principles of jet (ejector) pumps.

Section 9

PUMPS

Pumps are one of the most common pieces of mechanical equipment to be found in a power plant. Every operator is involved to some extent with the proper operation of this type of equipment.

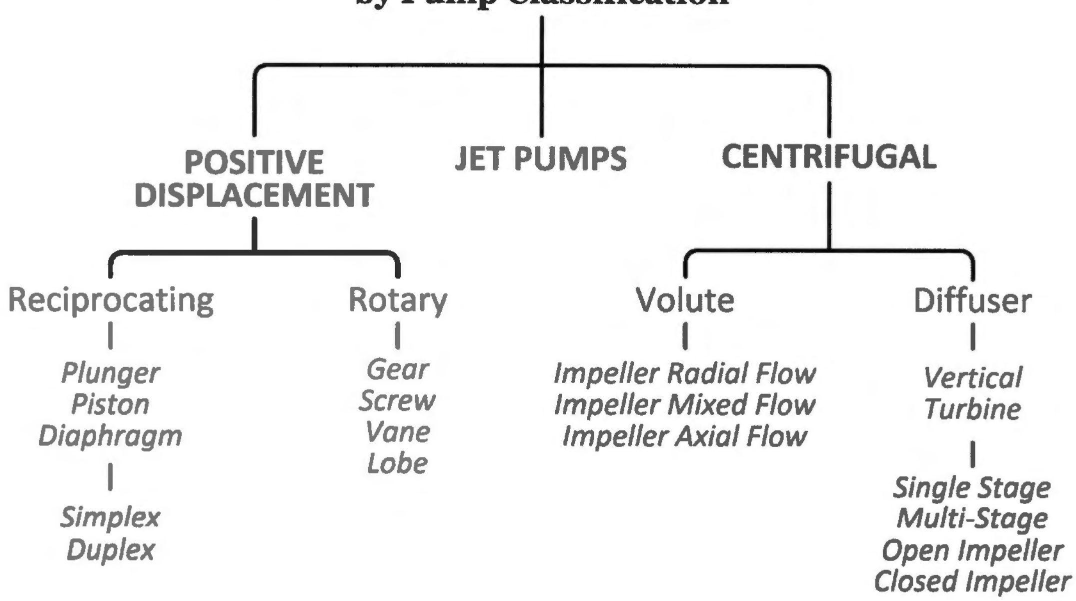
There are many different types of pumps available and they utilize different principles in their operation; however, they all have one basic purpose. The purpose of any pump is to add energy to the liquid they are handling in order to raise its pressure. The added pressure permits flow of the liquid through a piping system to some area of lower pressure.

Five of the most common types of pumps will be discussed in this section. The discussion will include their basic construction and operating principles. At the conclusion of this part, details on the centrifugal pump, which is the most common, will be given and some general operating information will be provided.

POSITIVE DISPLACEMENT PUMPS

A positive displacement pump is one in which a constant positive volume of liquid is displaced or moved during each pumping

Common Pump Types
by Pump Classification



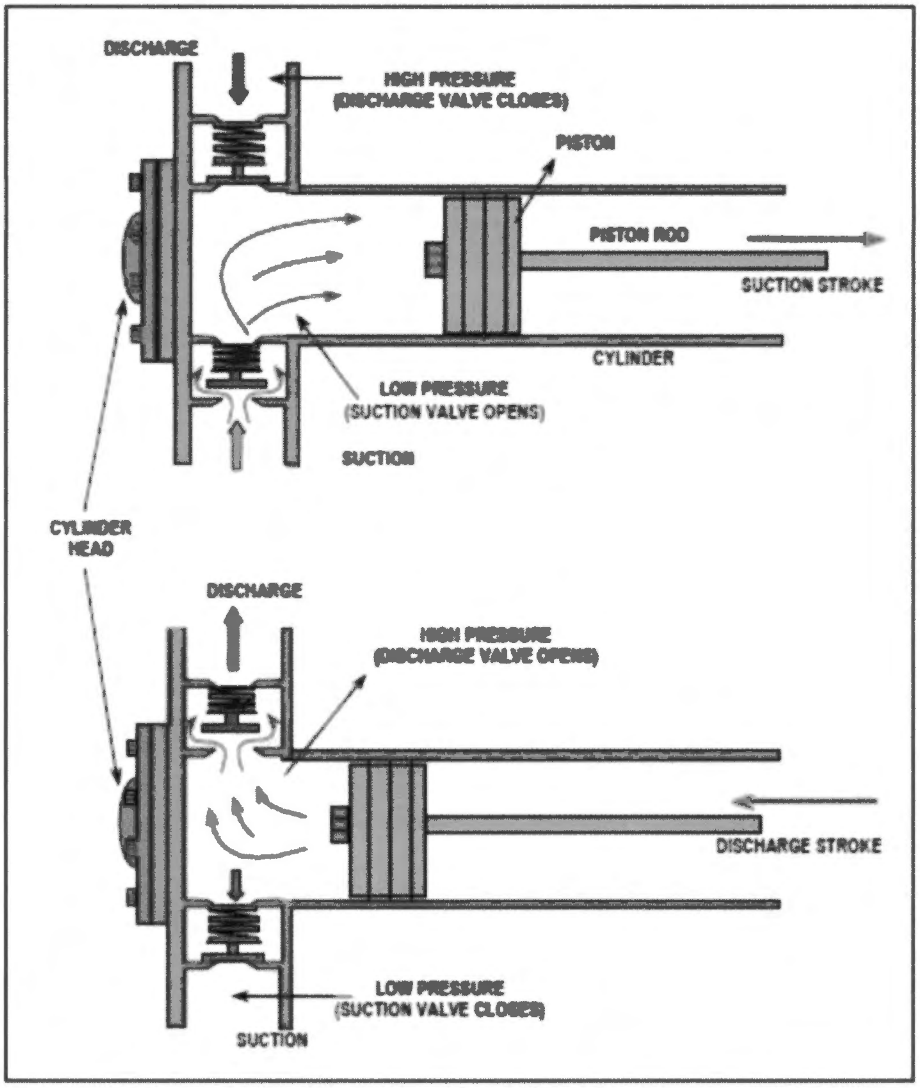


Figure 9-1a Single Acting Reciprocating Pump

cycle. The volume of liquid pumped or moved is equal to the volume displaced by the piston or other moving part. Positive displacement pumps can be further divided into two classes determined by the motion of the pumping element. These types or classes are reciprocating where the motion is back and forth and rotary where rotational motion is used. The reciprocating pump will be considered first.

In a reciprocating pump a piston moves back and forth in a cylinder. Figures 9-1a & 9-1b show diagrams of such a pump. Liquid is forced through the discharge valve as power is applied to the piston. The discharge pressure of the pump is determined by the discharge piping or head and not by the pump. The piston will develop whatever pressure is necessary to cause the liquid to flow from the cylinder through the discharge valve. The discharge pressure is limited only by the mechanical strength of the pump and the power of the driving unit. On many reciprocating pumps there is an air chamber installed on the discharge to make the flow more steady. The air in the chamber is compressed during the discharge stroke. When the piston reaches the end of the stroke, expansion of the air tends to keep the liquid in motion and the pressure up until the next stroke begins. In general, reciprocating

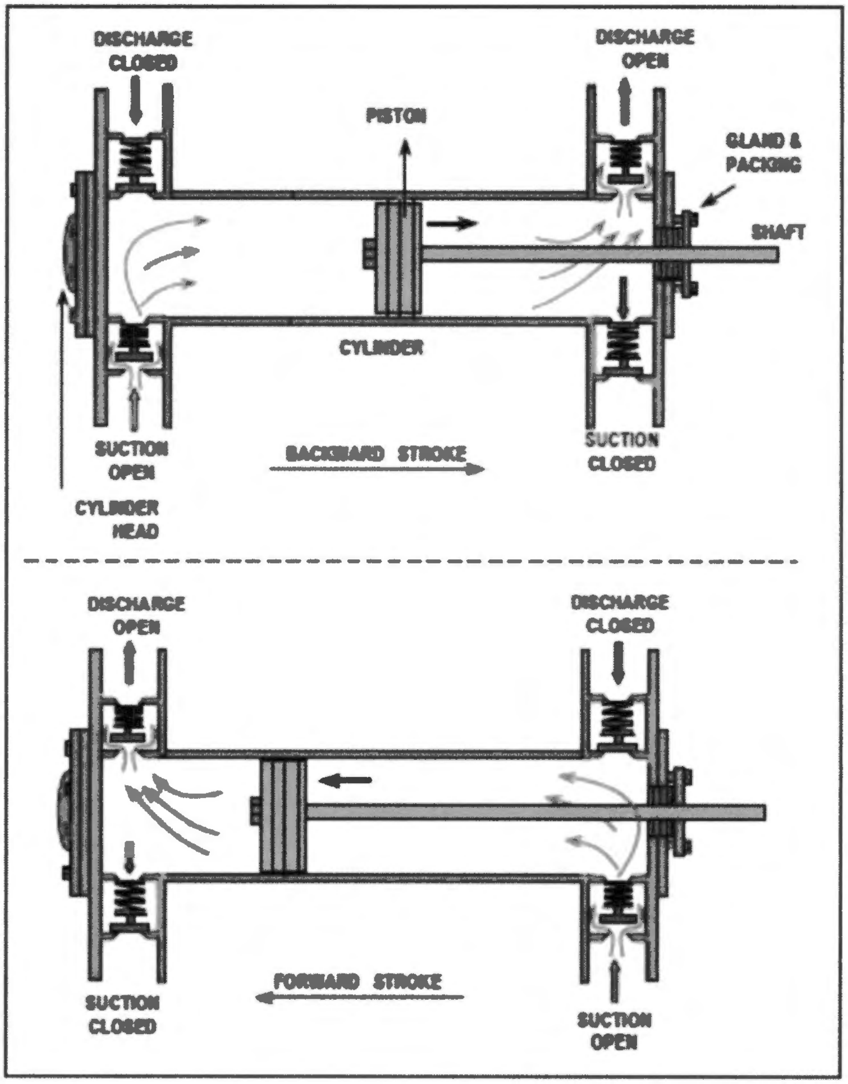


Figure 9-1b Double Acting Reciprocating Pump

pumps are most efficient for relatively small flow rates and high pressures. They are usually operated at slow speeds (40-200 crankshaft RPM) because of the reciprocating motion and the valves. These pumps may be classed as single or double action (see Figures 9-1a & 9-1b) depending on whether one or both ends of the piston are used. In addition, they may be classified according to the number of pistons used. A simplex pump has one, a duplex two, and a triplex three cylinders. The driving mechanism may be a reciprocating device or a motor or turbine in which case the rotary motion of the driver is converted to reciprocating motion by a crankshaft.

In a rotary type of positive displacement pump the action is one of rotation rather than reciprocation. The flow from a rotary pump is fairly steady whereas the flow from the reciprocating pump is pulsating. There arc many different designs of rotary pumps. A few of the more common types are illustrated. Figure 9-2 shows a gear pump. It includes a pair of meshed gears in a casing. As the gears rotate, the liquid is trapped between the gear teeth and the casing is carried around to the discharge. During each revolution of the gears a certain volume of liquid is transferred from suction to discharge. The exact amount depends on the size of the spaces between the gear teeth

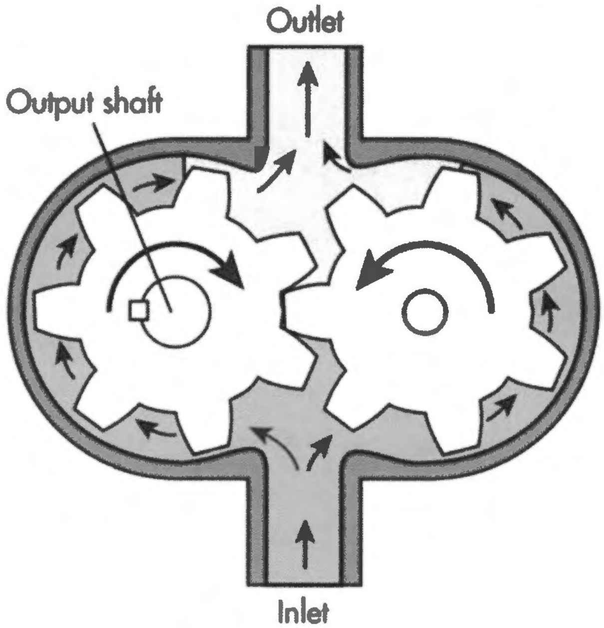


Figure 9-2 Gear Pump

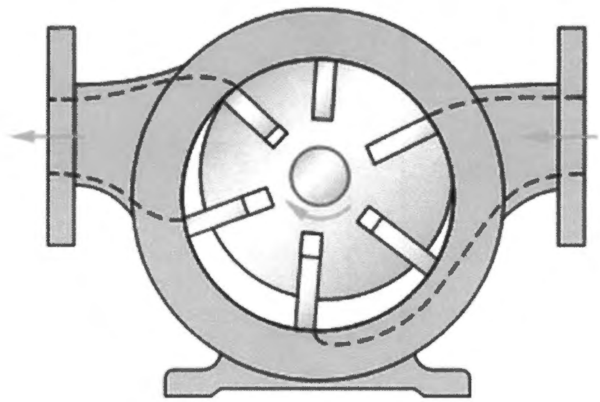


Figure 9-3 Vane Pump

and the case. The pressure developed by a rotary pump is, as with a reciprocating pump, whatever is required to force the liquid through the system. Figure 9-3 shows another type of rotary pump known as a vane pump. The rotating member with its sliding vanes is set off center in the casing. The vanes slide in and out of the rotating part and always stay in contact with the inside of the case. The entering liquid is trapped between the vanes and is carried around to the discharge. Many different designs of lobe type pumps have been devised. A two lobe model is shown in Figure 9-4. The two lobes, mounted on parallel shafts, rotate in opposite directions. A pair of timing gears, located at one end of the shafts, maintains the proper relation between the lobes throughout the rotation. Liquid is drawn into the space between the lobe and the case and is pushed from inlet to outlet.

Screw pumps, an example of which is shown in Figure 9-5, draw the liquid into one or both ends of the rotor where it is trapped in the pockets formed by the threads. It is moved along to the discharge point much like a nut on a thread. Screw pumps may have one, two, or three screws.

When only a single screw is used, liquid enters at one end and is discharged at the other end.

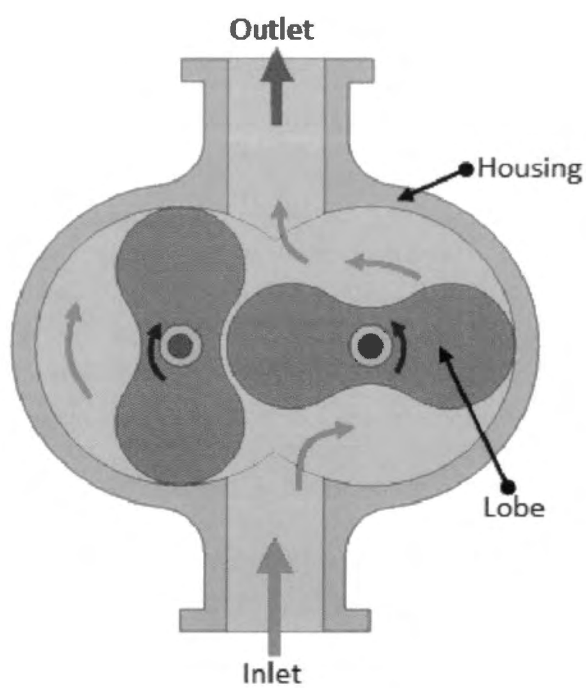
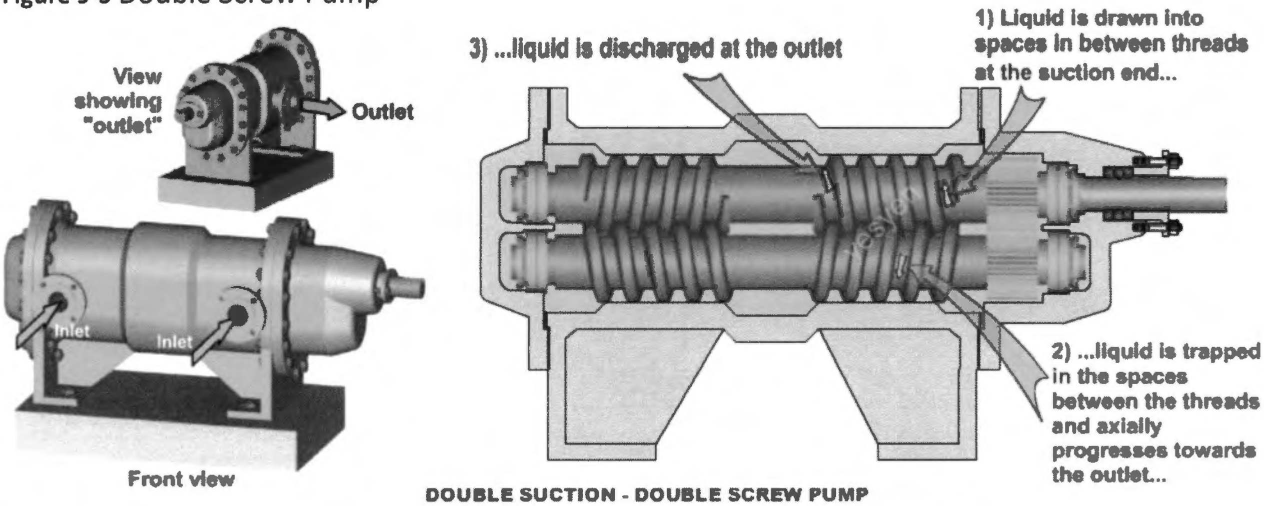


Figure 9-4 Two Lobe Pump

Figure 9-5 Double Screw Pump



JET PUMPS

In a jet pump the pressure of a fluid is increased as it flows through an arrangement of fixed channels. The jet pump has no moving parts. A so-called motive fluid is used to pump some other fluid. These pumps are frequently called by other names such as injector, ejector, evacuator, or aspirator. Figure 9-6 illustrates a simplified jet pump. It consists of a nozzle, inlet line, mixing chamber, and diffuser. The motive or actuating fluid enters the nozzle at a high pressure. The nozzle converts the pressure energy of the motive fluid to velocity. The motive fluid then leaves the nozzle with a very high velocity and low pressure. The low pressure in the mixing chamber causes the liquid being pumped to flow into the mixing chamber through the inlet line. This entering liquid is then entrained and mixed with the high velocity motive fluid. An exchange of energy takes place which in effect slows down the motive fluid and speeds up the incoming liquid. The mixture still has quite a high velocity as it enters the diffuser section. In this section, the velocity energy of the mixture is converted to pressure energy by slowing down. The discharge consists of a mixture of the two fluids at a pressure that is higher than the liquid inlet pressure but

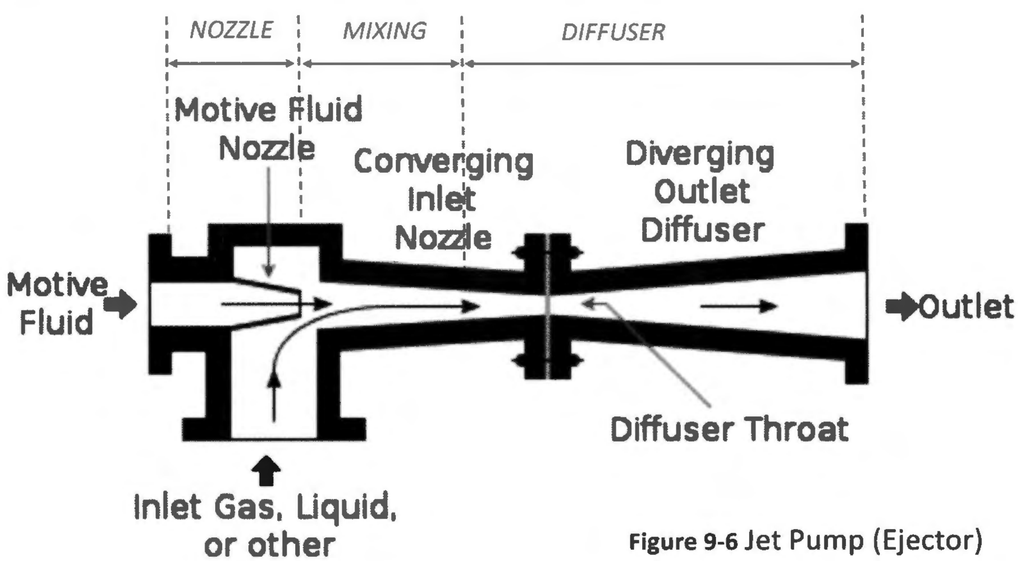
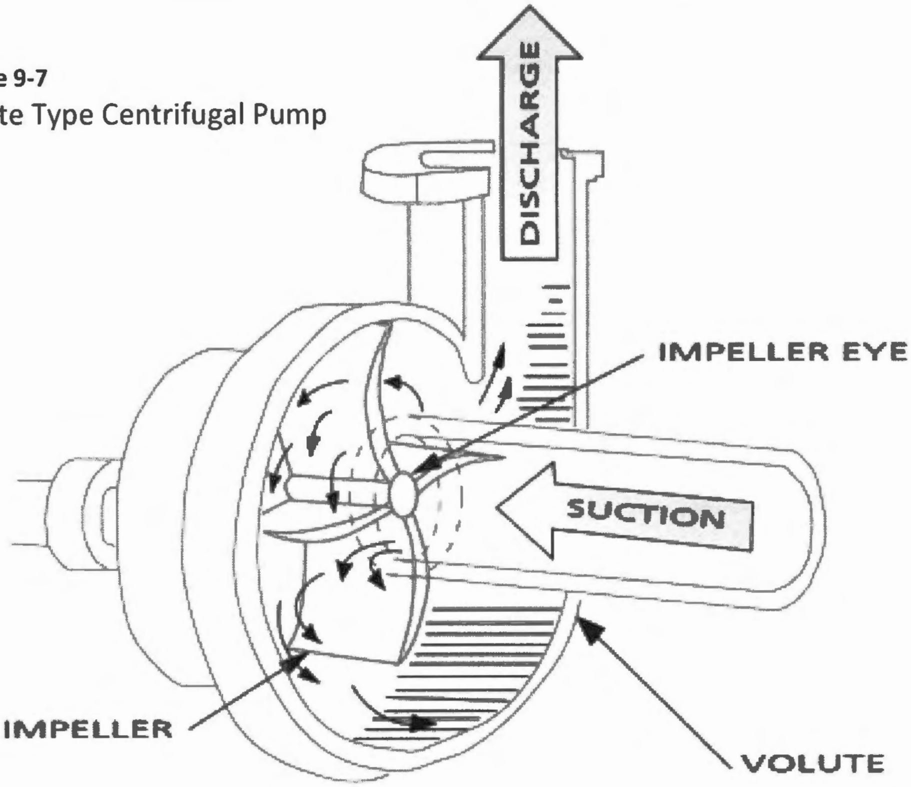


Figure 9-6 Jet Pump (Ejector)

Figure 9-7
Volute Type Centrifugal Pump



lower than the motive fluid inlet pressure. Different fluids may be used to supply the motive power and they can pump different fluids. For example, in the steam jet air ejector, steam is the motive fluid used to pump air from the condenser. In some main turbine hydraulic systems, oil is used as both the motive fluid and the pumped fluid.

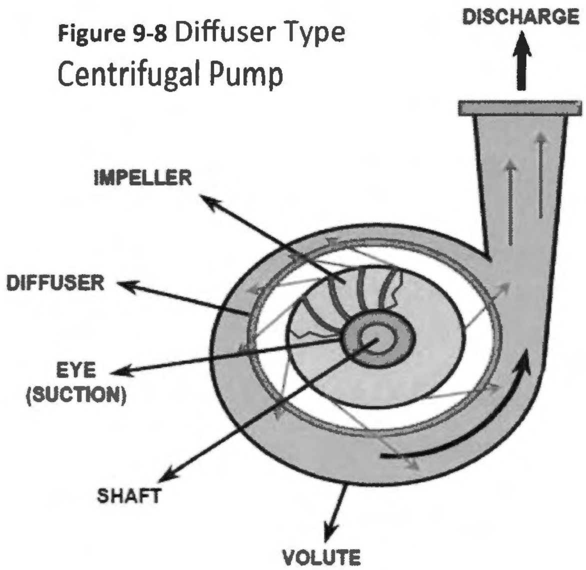
CENTRIFUGAL PUMPS

Centrifugal pumps are one of the most popular types because of their simplicity, compactness, low cost, and ability to operate under a wide variety of conditions. The action in a centrifugal pump depends mostly upon centrifugal force due to rotation. Centrifugal force is the name given to the force that tends to move a rotating body away from the center of rotation. Every piece of rotating equipment has centrifugal force acting on it. The amount of force produced depends on the weight of the body, its distance from the center rotation, and the speed of rotation.

The essential parts of a centrifugal pump are a rotating member with vanes, called the impeller, and a case surrounding it. The impeller may be driven by an electric motor, steam turbine, or internal combustion engine. Figure 9-7 shows a simple centrifugal pump. In this figure, liquid is led through the inlet or suction line to the center or eye of the rotating impeller. The rotating impeller throws the liquid out into the volute section from where it is led through the discharge nozzle to the discharge piping. The fluid leaves the impeller with a high velocity. An important function of the pump flow passages, such as the volute and nozzle, is to efficiently convert the kinetic energy of the liquid to pressure.

Centrifugal pumps are sometimes classified as volute type pumps or diffuser type pumps. Figure 9-7 shows a volute type pump in which the liquid is discharged directly into the volute from the impeller. In the diffuser type of pump, shown in Figure 9-8, there is a

Figure 9-8 Diffuser Type Centrifugal Pump



diffuser, consisting of a series of fixed guide vanes, surrounding the impeller. The function of the diffuser is to guide the liquid and reduce its velocity. There is a reduction in kinetic energy and an increase in static pressure in the diffuser. The diffuser tends to make the static pressure distribution around the impeller more uniform.

The centrifugal pump differs from the reciprocating pump in many respects. The discharge valve of a centrifugal pump can be closed without causing the pressure to rise above a certain value. If the discharge valve is closed, the rotating impeller simply chums and heats up the liquid. If the discharge valve of a reciprocating pump is closed, the pump would stop or something would burst. The discharge from a centrifugal pump is relatively smooth and steady where the reciprocating pump discharge is pulsating.

Centrifugal pumps are built with many different arrangements of impellers and with many other variations in the details of construction. In the single suction pump, liquid enters the impeller eye from one side only. In the double suction pump, liquid enters from both sides of the impeller. A pump may be staged with several impellers on one shaft, thus making it essentially several pumps in series. In a two stage pump, for example, two impellers are mounted on the same shaft. The discharge from the first impeller enters the inlet of the second impeller. Each stage of the pump increases the pressure. Very high pressures are available by the use of many stages.

AXIAL FLOW PUMPS

In axial flow pumps the flow of liquid is along or parallel to the axis of rotation or the shaft. This is completely different from the centrifugal pump which is a radial flow pump. In the centrifugal pump the flow is radially outward from the shaft or axis. Axial flow

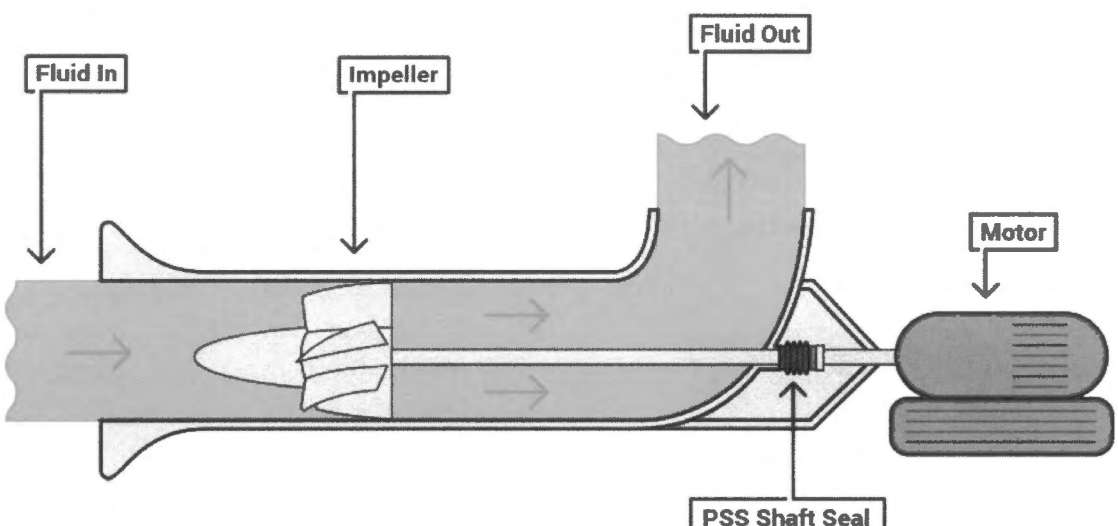


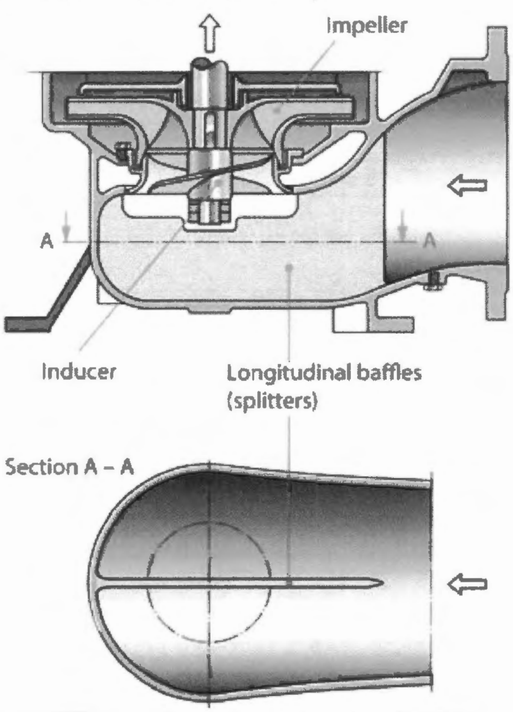
Figure 9-9 Axial Flow Pump

pumps are best suited for large volume flow rates and low pressure increases. An axial flow pump may consist of a single runner in a cylindrical case, or it may consist of a runner with one or two sets of fixed guide vanes. This type of pump develops pressure by having the runner blades shaped u air foil sections like an airplane propeller. The shape or inclined angle of the rotating blades produces a force on the liquid, thereby raising its pressure. Figure 9-9 shows a simplified schematic diagram of an axial flow pump. This type of pump is seldom used in a power plant.

MIXED FLOW PUMPS

Mixed flow is the name given to pumps that combine the radial flow of centrifugal pumps with axial flow. In the mixed flow pump the liquid enters the impeller in an axial direction and discharges in both an axial and radial direction usually into a volute type casing. The discharge pressure is developed partly by centrifugal action and partly by the dynamic lift of the impeller on the liquid. The action in a mixed flow impeller is shown in Figure 9-10. This type of pump is frequently used for circulating water pump service in power plants. In this application the pump is installed vertically with the suction submerged in the water at all times. These pumps deliver large flow rates at medium head with a low rotational speed.

Figure 9-10 Mixed Flow Pump



CENTRIFUGAL PUMP DETAILS

The basic theory and construction of centrifugal pumps has been discussed. The following discussion will cover some of the more detailed parts of the pump with which the operator is most concerned. The topics to be covered include shaft sealing, bearings, and hydraulic balance.

Shaft Sealing

Since centrifugal pumps operate with a wide range of pressures, from high vacuum to very high pressure, it is necessary to have a positive seal where the shaft penetrates the case. If the shaft is not sealed, there may be leakage of air into the pump or leakage of water out of the pump. There are many different sealing methods in use. The choice depends among other things on the pressure and temperature of the liquid being pumped and the size of the pump. The simplest type of seal is the stuffing box. This method is used on most smaller pumps and when the pressure is low. The stuffing box consists of an annular space in the casing around the shaft. Rings of packing material are placed in this space. The packing rings are compressed and held in place by a follower or gland. The gland is in turn held in place by studs with adjusting nuts. A simple stuffing box is shown in Figure 9-11. As the adjusting nuts are tightened, they move the gland in and compress the packing. This in effect squeezes the packing out radially making a tight seal between the rotating shaft and the inside wall of the stuffing box. The shaft is rotating

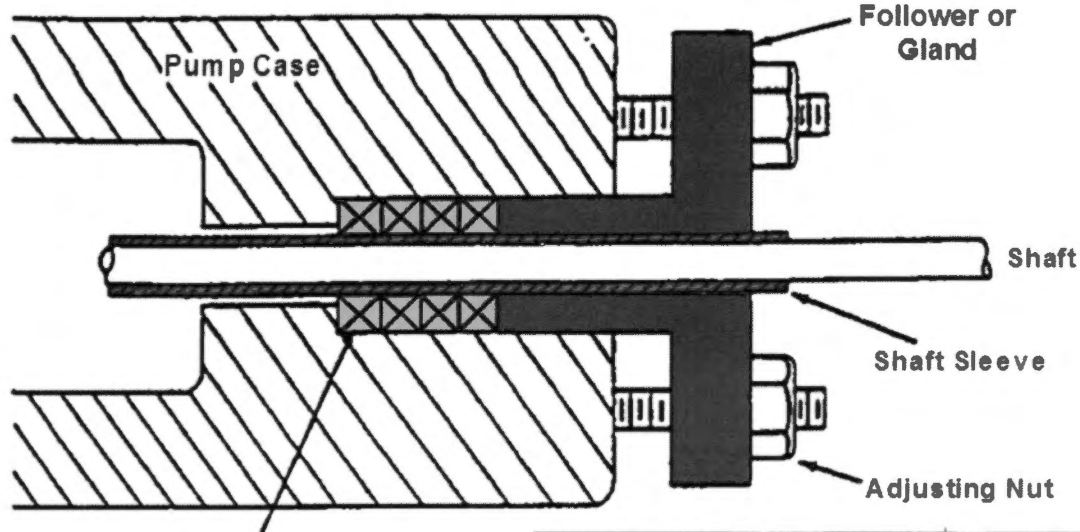
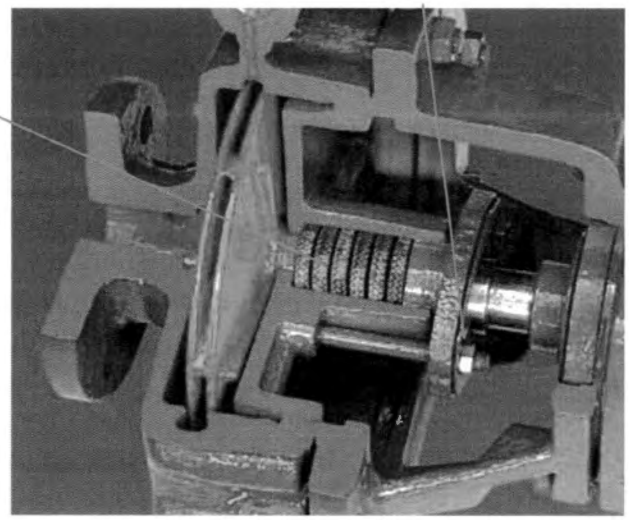


Figure 9-11 Stuffing Box



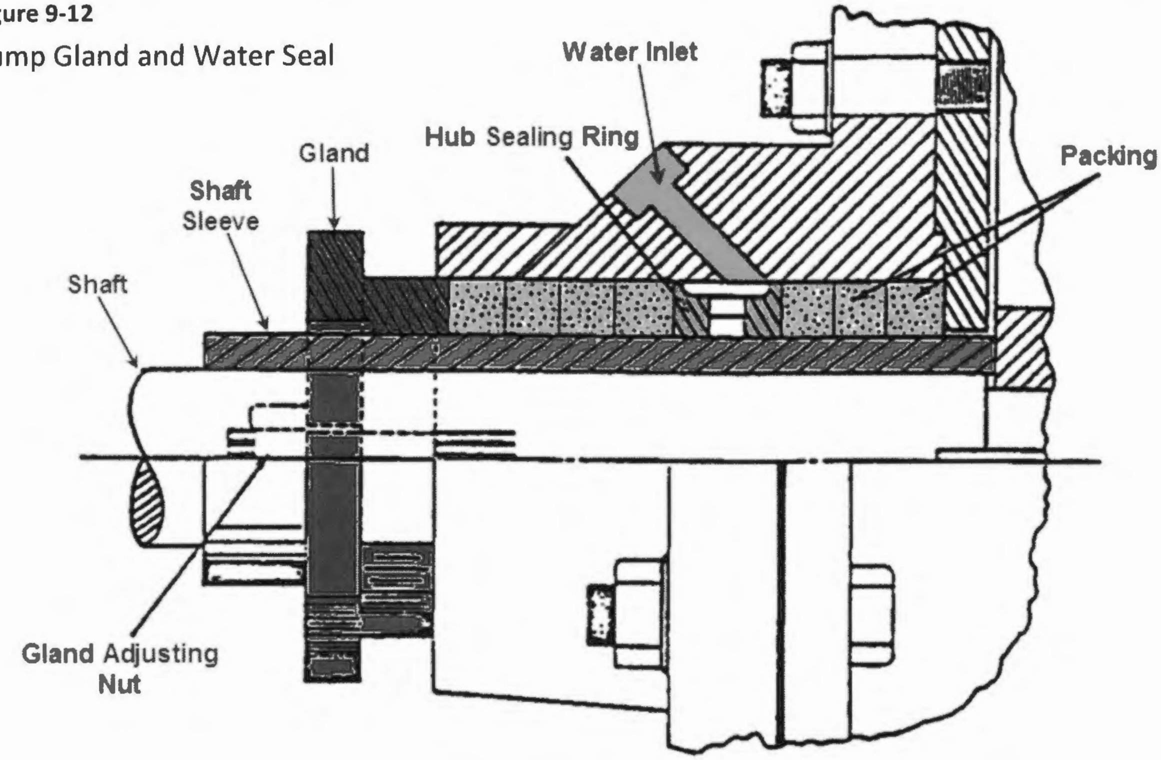
at a high speed and is rubbing against the packing which causes a lot of friction.

If there is no lubrication, the packing will quickly burn up and can seriously damage the shaft. Lubrication is normally provided by keeping the gland loose enough so that a small flow of water leaks out of the pump. The water acts as a lubricant and keeps the packing cool. The gland should only be adjusted while the pump is running so that the leakage flow can be observed. The nuts should be adjusted evenly and only a small amount at a time. This method of sealing cannot always be used.

If the pump suction is under a vacuum so that leakage outward is impossible or if the liquid is too hot to provide adequate packing cooling, a different type of seal must be used. Usually, in these cases a supply of cool, clean water is piped to the stuffing box. This water, known as cooling or sealing water, is injected through a drilled passage in the case into a ring usually located at approximately the center of the box. The ring, known as a lantern ring or sealing ring. is usually constructed of metal made in a skeleton design. The ring distributes the sealing water uniformly around the shaft. This type of seal is shown in Figure 9-12. To insure that sealing water flows in both directions along the shaft the sealing water pressure should be approximately 10 psi higher pressure than the pump suction pressure.

With pumps in the highest pressure range, namely, boiler feed pumps, the pressure is frequently too high to permit use of regular packing. To handle this situation so-called packless stuffing boxes have been developed. These are quite similar to the water injection seal shown in Figure 9-12 except that the rings of packing material are replaced by a metallic breakdown bushing. This bushing acts as a labyrinth and forces the water to travel a tortuous path, thereby reducing its pressure. Sealing water is injected into a lantern ring in this bushing. In this type of seal there is no contact between the bushing

Figure 9-12
Pump Gland and Water Seal



and the shaft. The clearance, however, is kept very small. The type of seal used on many of the newest pumps under all service conditions is the mechanical seal. This seal differs from the packless seal discussed previously in that there is definite contact between the seal and the shaft. The usual mechanical seal consists of two basic parts, one rotating and one stationary. The rotating part is attached to the shaft and is in contact with the stationary part of the seal. A slight pressure between these parts is maintained by a spring. The mating surfaces must be perfectly flat and smooth. Lubrication must be supplied at this scaling surface and it can be either the liquid in the pump or from some separate source. Frequently, a separate external supply of water is used to cool the seal. The cooling water is usually in a closed circuit and does not mix with the liquid in the pump.

Pump Shafts

One of the most important and expensive

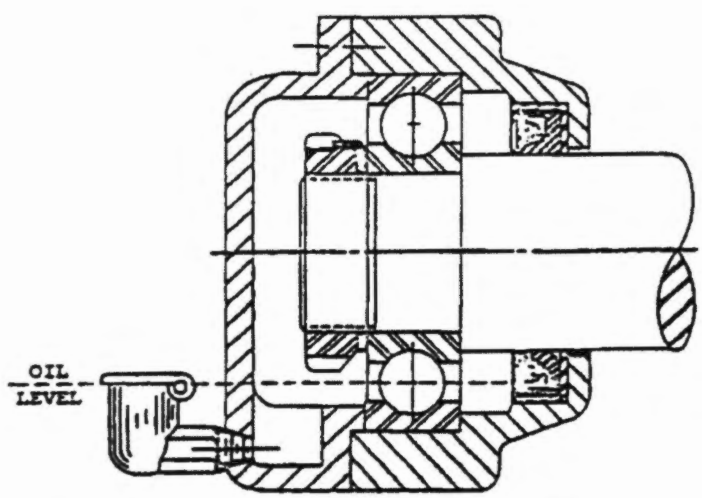


Figure 9-13—Oil Lubricated Ball Bearing

This illustration shows the application of a simple oil cup, providing a positive controlled supply of oil. The top of the oil cup should be located in such a position that the oil level will reach to the middle of the lowest ball. This type of oil cup requires frequent inspection and refilling to maintain the oil level.

parts of a large pump is the shaft. These shafts are usually protected against wear, particularly in the area of the seal by shaft sleeves. The sleeve is made of hardened steel and is installed over the shaft to protect it.

Pump Bearings

Many different types of bearings are used with centrifugal pumps. Ball and roller bearings are common in smaller pumps while babbitted sleeve bearings are used on large pumps. Any bearing will only perform its job satisfactorily if it has proper lubrication. Ball and roller bearings may be lubricated by either oil or grease. Sleeve bearings are always oil lubricated. Oil lubricated ball and roller bearings have a small storage space and level indicator as part of the bearing housing. A grease fitting is supplied for grease lubricated bearings. Figures 9-13 and 9-14 show typical oil and grease lubricated ball bearing applications. Sleeve bearings usually have a separate circulating lube oil system. The oil is circulated by a pump through the bearings and a lube oil cooler back to a reservoir. The oil pump is frequently mounted on the main pump shaft, in which case a small motor driven auxiliary oil pump is provided for startup and shutdown.

Hydraulic Balance

Since the pressure of the liquid is constantly increasing from inlet to discharge, it is possible to produce unbalanced hydraulic forces acting on the rotating shaft. The pressure on the discharge side of each impeller is considerably greater than the pressure on the inlet side. For a multistage pump these unbalanced forces can produce a large thrust toward the suction of the pump. A thrust bearing is used to compensate for this thrust; however, in large multistage pumps such as boiler feed pumps, a very large thrust bearing would be required. To reduce the load on this bearing and therefore reduce its size, other methods of balancing the hydraulic forces are used. If the pump has an even number of impellers, half of them can be mounted facing in one direction and half in the other direction thereby balancing the thrust. This method complicates the design and construction of the pump and is seldom used. The most common method is to provide a balancing disc or balancing drum at the discharge end of the pump. This device is mounted on the shaft and has one side exposed to discharge pressure while the other side is essentially at suction pressure.

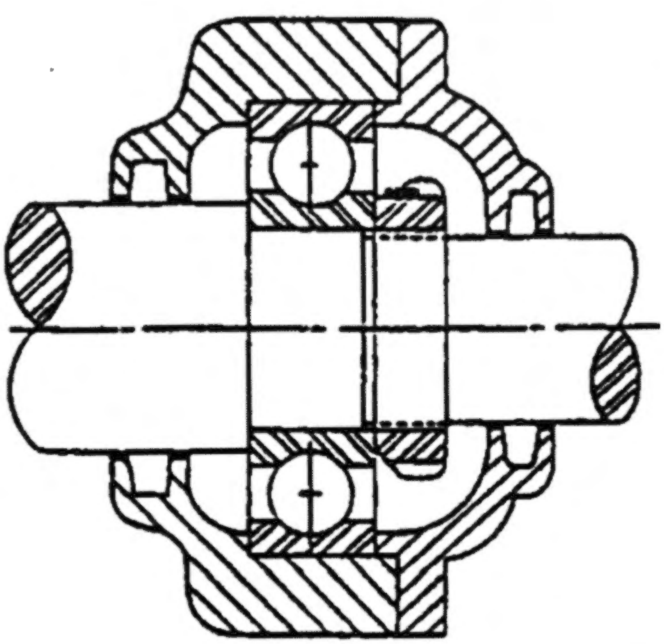


FIGURE 9-14—Grease Lubricated Ball Bearing

This housing has no provision for periodic greasing and is often used in those applications where speeds are low, the loads light and the service intermittent. Such service requires a charge of lubricant at very infrequent intervals and the bearing is therefore lubricated only when the unit is disassembled for overhaul or inspection. At such times a cleaning of housing and bearing are usually necessary.

If quite frequent lubrication is necessary it may be advisable to drill and tap the end cover for a grease fitting and drain hole during one of these disassembly periods.

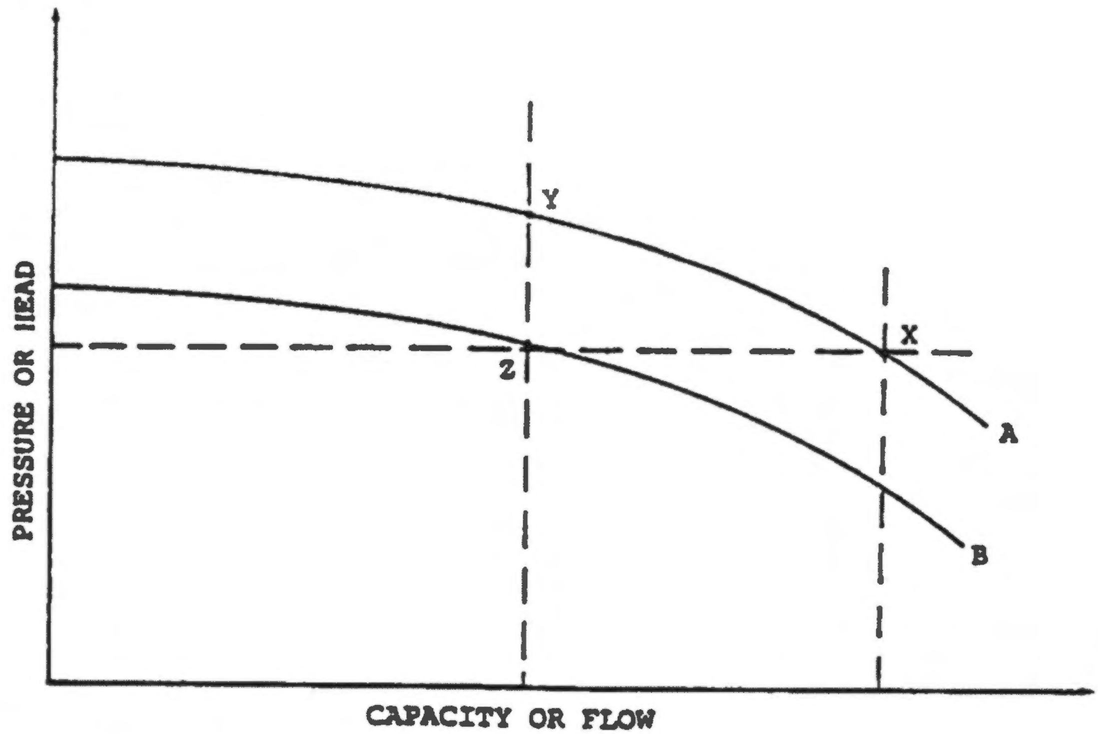


Figure 9-15 Pump Curve

The difference in pressure across the device produces a strong force toward the discharge end of the pump. This force balances out the thrust due to the impellers. The low pressure side of the balancing chamber is usually connected to the pump suction through an orifice. The pressure drop across the orifice is usually indicated and is used as a good measure of pump internal condition. Any large change in this pressure drop should be investigated. While small single stage pumps do not experience very large axial forces, they can develop quite large unbalanced radial forces. A volute type pump, particularly when operating at reduced capacity, is subjected to these forces. They result from the unequal pressure distribution around the volute.

These radial forces can be large enough to bend the pump shaft. Operation of volute type pumps at reduced capacities should be limited to as short a time as possible.

PUMP OPERATION

The operation of the various pumps in a power plant depends to a great extent on the particular pump and its related piping system. There are some general operating principles, however, that apply to all pumps. These general principles are discussed below.

Depending on its design and construction, every pump has certain characteristics. The pump characteristic curve relates the flow or capacity of the pump to the pressure or head it produces. A typical curve of this type for a centrifugal pump is shown in Figure 9-15. The curve A shows the pressure versus flow characteristic for one constant speed of the pump. Most pumps are driven by electric motors, which means they operate at essentially constant speed. As long as the speed is constant, the pump must operate at some point on this curve.

The exact operating point is determined by the pressure in the system. Flow is changed by making a change in pressure, usually by adjusting a valve in the discharge piping. If, for example, the pump is operating at point X and the discharge valve is then closed a bit, the pressure will increase. This will cause the pump's operating point to move along the curve to point Y. The flow at point Y is less than at point X. This is the most common method of flow control for centrifugal pumps. Another common method of flow control requires changing the speed of the pump. Curve B on the same figure represents a lower speed. This method is used when the pump is driven by a steam turbine or fluid coupling. If the pump is operating at point X and we wish to reduce the flow to that at point Y, we slow down the pump and it will now operate on curve B. The pressure has not changed, and the pump will now be operating at point Z on curve B. Another method of flow control which is occasionally used. This method maintains a constant flow through the pumps at all times but bypasses the unneeded portion of the flow back to the pump suction. By operating a valve in the bypass line more or less of the total flow can be bypassed, thereby controlling the flow to the system. The last method is changing the suction pressure. Increasing the suction diameter increases the discharge pressure while decreasing the suction diameter decreases the discharge pressure. Regardless of which method is used, it is this ability to change flow that makes centrifugal pumps so useful.

In order for a centrifugal pump to operate satisfactorily it must be completely filled with water prior to starting and must remain full during operation. In general, if the pump suction is under a positive pressure, there is no problem. It is only necessary to open the suction valve and the pump casing vent valve. Water from the suction supply will fill the casing and force all the air out the vent. It is helpful to close and open the vent valve several times to insure that all the air is removed. No special precautions are required while the pump is running since the entire pump casing is pressurized which precludes the possibility of air entering.

In cases where the pump suction is under a vacuum, as with condensate pumps, more precautions are necessary. The condensate pumps are always located at an elevation lower than the hotwell. The pump cannot be vented to atmosphere since this would only result in pulling air into the condenser. Condensate pumps are always vented to the main condenser. Considerable care must be exercised when filling a pump to be sure that the air vented from the casing does not upset the other condensate pumps. This is particularly important when a common vent line is used. Since it does vent back to the condenser in a closed system, it is not possible to observe when a condensate pump is filled; therefore, sufficient time should be allowed to insure that all the air is removed. While running, the pump suction remains under a vacuum and care must be taken to prevent air in leakage. This requires careful adjustment of the packing and a positive supply of sealing water. A frequent source of leakage is the pump suction valve packing which should be inspected frequently. In some cases this packing is also water-sealed. In some installations a small, operating vent to the main condenser is provided. This vent should remain open at all times to prevent the accumulation of air in the pump casing.

Another filling situation arises when the pump is located at an elevation above its suction supply. In this case the suction pipe extends down from the pump to the suction supply. Some means of getting water up into the pump casing must be provided. There are two general methods of accomplishing this requirement. On smaller pumps, an automatic valve, known as a foot valve is installed at the bottom of the suction pipe below water level. The foot valve is essentially a check valve that allows flow up the suction pipe toward the pump but prevents flow down the pipe away from the pump. A separate supply of water is provided to initially fill the suction pipe and pump for starting. This is known as priming the pump. Once the pump is running, it will maintain its own prime providing no air leaks are present since the pump suction is under a vacuum. When the pump is shut down, it will stay full of water since the foot valve prevents drainage. If the pump remains shut down for some time, it may be necessary to prime it again due to slight leakage past the foot valve. On larger pumps it is impractical to use a foot valve, and a vacuum priming system is used. This system includes a vacuum priming tank which is maintained at a high vacuum by a mechanical vacuum pump. The tank is connected to the pump casing. To fill the pump for starting, a valve in the line from the pump to the tank is opened. This puts the pump casing under a vacuum and draws water up the suction pipe and into the pump. Once the pump is full and running, it will maintain its own prime. In some cases an automatic float valve is used to provide continual removal of air from the pump casing. This valve allows air to pass freely to the vacuum priming tank from the pump but shuts off when water enters the valve.

Pumps handling hot water should always be warmed up slowly prior to starting. This prevents the possibility of high thermal stresses due to rapid temperature changes. Warmup is usually accomplished by circulating a small flow of hot water through the pump. Prior to starting the pump, metal temperature should be within 100°F of the water temperature. The warming supply usually comes from the pump discharge, flows through the pump, and returns to the pump suction. It is important that the suction valve be open while warming up to insure a flow and prevent overpressurizing the suction piping.

For any centrifugal pump there is a definite minimum flow that must be maintained. If flow is reduced below this minimum, excessive churning of the water occurs which results in heating up the water. Continued operation under these conditions can result in vaporizing the water to steam. This is known as flashing the pump and must be avoided. When a pump flashes, it becomes vapor-bound and ceases to operate. It is also very likely to overheat and result in rubbing or even seizing. A satisfactory minimum flow is best assured by providing an automatic recirculation system. This system automatically opens a recirculation valve in a line which leads from the pump discharge back to the suction. When flow decreases to the minimum allowable value, the recirculation valve automatically opens and maintains at least minimum flow. When flow to the system increases to above the minimum, the valve automatically closes. In smaller pumps where an automatic system is not practical, a permanent, always open, recirculation line is frequently provided.

Most centrifugal pumps are provided with a check valve in the discharge piping. When a pump is shut down, the check valve should close and prevent reverse flow through the pump. Reverse flow can cause the pump to rotate backwards and result in considerable damage to the pump or the driver. When shutting down a pump, it is good practice to observe the pump shaft to insure that the check valve has closed and the pump is not running backwards. If the check valve does stick and the pump starts to run backwards, it should not be restarted since this would overload and possibly damage the driver. In this case the discharge stop valve should be closed as quickly as possible.

Section 9
PUMPS
Study Questions

1. All pups have one basic purpose. That purpose is ______________________________

   ____ .

2. Two types of Positive Displacement Pumps are the Reciprocating type and the Rotary type.
   True \ False

3. In a reciprocating pump, a piston moves ____________________ .

   a. up and down c. in a circular motion

   b. back and forth d. none of these

4. The flow from a rotary pump is pulsating, while the flow from a reciprocating pump is fairly steady. True \ False

5. Name at least three (3) rotary type positive displacement pumps.

   a.

   b.

   c.

6. Reciprocating pumps are most efficient for relatively small flow rates and high pressures.
   True \ False

7. Because of their simplicity, compactness, low cost, and ability to operate under a wide variety of conditions, ____________________________________ pumps are one of the most popular types.

8. Rotary pumps may be classified according to the number of pistons used. True \ False

9. An essential part of a centrifugal pump is a rotating member with vanes called the ____ .

10. If the discharge valve of a centrifugal pump is closed, the pump will stop or something will burst. True \ False

11. In the axial flow pump, the flow of liquid is__________________ .

    a. around the axis of rotation c. both of these

    b. parallel to the shaft

12. Pumps that combine the radial flow of centrifugal pumps with axial flow and are frequently used for circulating water pump service in power plants are called __________________________________ .

13. What is the purpose of a shaft sleeve?

14. Sleeve bearings may be lubricated by either oil or grease while ball and roller bearings are always oil lubricated. True \ False

15. The most common method for maintaining hydraulic balance within a centrifugal pump is to provide a ____________________________ ________________________ at the discharge end of the pump.

16. For the centrifugal pump to operate satisfactorily, it must ______________________ .

    a. have pump suction under a positive pressure.
    b. be full of water during operation
    c. be filled with water prior to starting
    d. all of the above

17. When a pump flashes, it becomes vapor-bound and ceases to operate. True \ False

GENERATION-OAHU DIVISION
OPERATOR TRAINEE TRAINING PROGRAM

Section 10

BOILER FUNDAMENTALS

OBJECTIVES:

1. Identify the parts of a typical boiler and describe their basic function in successful boiler operation. To include assembly and construction.
2. Discuss the two separate cycles of a typical boiler, waterside and fireside.
3. Describe natural circulation and forced circulation.
4. Describe the basic functions of the superheater, the reheater, the economizer, and the furnace.

Section 10

BOILER FUNDAMENTALS

BOILER FUNDAMENTALS

The steam generator, or boiler, as it is more commonly known, is the largest and most expensive piece of equipment in a plant. The initial step in the energy conversion process takes place in the boiler. The chemical energy in the fuel is converted to heat by the combustion process and this heat is transferred to the water in the boiler, converting it to steam. This section will discuss the basic theoretical considerations in the design of a boiler.

The construction of a typical boiler lends itself to a discussion in two separate parts or cycles. The waterside, which includes all the parts that contain water and/or steam, and the fireside, which includes all the spaces and passages in which combustion takes place and through which the flue gases pass. There is never any contact or mixing between the fluids flowing through each side of the boiler.

BOILER WATERSIDE

It is essential that a continuous flow of water and/or steam be maintained throughout all parts of the boiler during operation. If flow were to cease there would be no way of removing the heat being transferred from the fireside to the waterside and severe overheating of the boiler tubes would result. Flow through the boiler may be natural or forced circulation, as in boilers provided with drums. A forced circulation system has a pump in the closed flow loop between the Boiler Drum and the lower header. The pressure difference created by the pump helps to control the flow rate. All the boilers at Hawaiian Electric (Oahu) are natural circulation boilers.

NATURAL CIRCULATION

Consider the simple boiler circuit shown in Figure 10-1. This boiler consists of a drum at the top, a downcomer, a lower header and water wall tubes that return to the drum. Heat from the fire is transferred to the fluid in the water wall tubes. No heat is added to the fluid in the downcomer and it contains water at essentially saturation temperature. The heat addition in the water wall causes the water to expand and converts or boils some of the water to steam. Conversion of water to steam

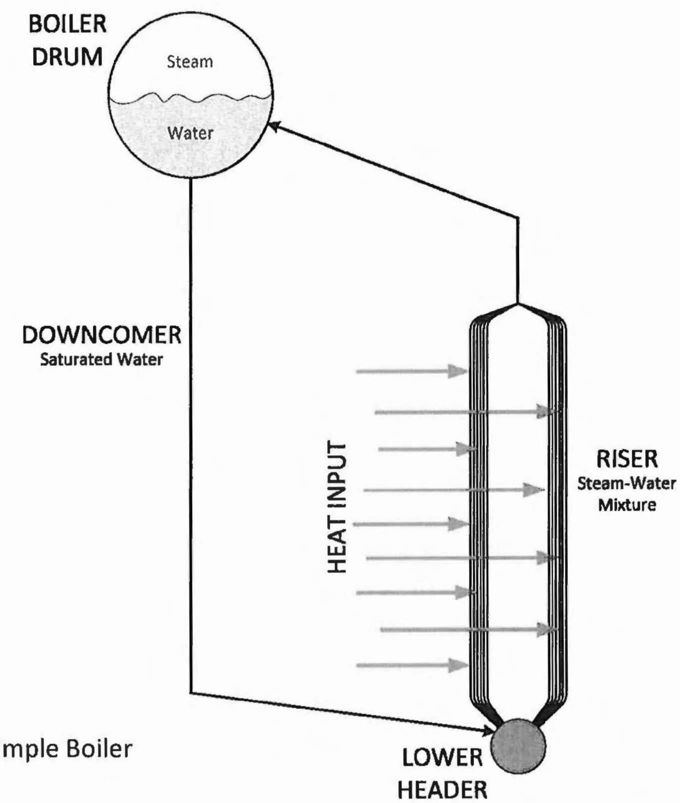


Figure 10-1 Simple Boiler

produces a large volume increase and a corresponding large density decrease.

Under operating conditions the downcomer is filled with water having a fairly high density while the water wall is filled with a water-steam mixture having a much lower density. This difference in density of the two columns times the height of the unit is a measure of the pressure available to cause natural circulation. The pressure produced in this manner must be great enough to overcome the friction losses of the system. There are several factors that influence the magnitude of the force causing natural circulation.

1) The difference in elevation between the drum and the lower headers is directly proportional to the force causing circulation. The higher the boiler the more force available. This is one reason why boilers are so tall.
2) The operating pressure of the boiler also has an important role in determining the force available for circulation. As pressure is increased the difference in specific volume and density between water and steam gets progressively smaller. This fact can be seen by looking at the steam tables shown in Section 2 of this manual.

The steam table data is presented graphically in Figure 10-2. In this figure the distance between the curves is the difference in density between steam and water. As pressure increases the difference in density gets smaller and smaller until at the critical pressure of 3206 psia there is no difference. Boilers operating above this pressure are known as supercritical units and must have forced circulation or forced flow since there is no density difference to cause natural circulation. Natural circulation boilers are normally limited to a maximum pressure of 2700 psia since above this pressure the density difference is too small to provide adequate circulation.

3) The third factor that determines the available circulating force is the rate of heat input to the water wall tubes.

   This is basically the same as the firing rate of the boiler. As more heat is added there is a greater rate of steam formation and therefore a lower density in the water wall tubes. This lower density in the water wall tubes causes a greater natural circulation rate. As the firing rate or load on a boiler increases, the circulation rate also increases. This is a very desirable condition from the heat transfer standpoint.

The three factors discussed all contribute to determining the circulating force that is available. This force must be sufficient to overcome the frictional losses resulting from the circulating flow. Under steady conditions the flow will increase until the friction losses exactly balance the circulating force and flow will stabilize at this point. Since a high rate of circulation is desirable, the boiler designer takes care to insure that the friction losses are held to a minimum.

The factors that determine the boiler circulation are the height of the unit, the operating pressure, the heat input rate and

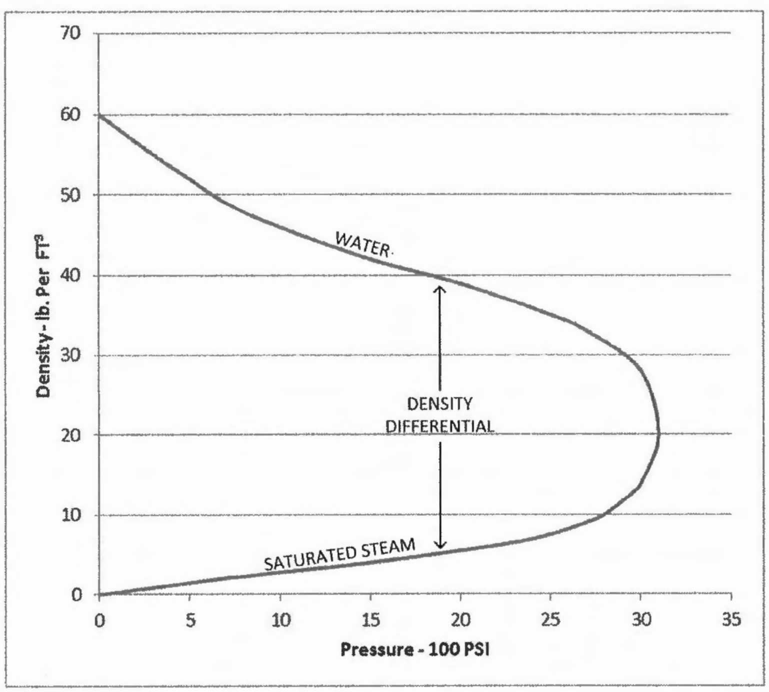


Figure 10-2 Steam-Water Density

the friction losses. Two of these, namely the height and friction losses, are fixed by the design and are beyond the control of the operator. The other two factors, operating pressure and heat input rate, have specified design values but may be operated under other conditions and are then under control of the operator. The two most common conditions under which the boiler may be operated are:

1) chemical boil out following initial installation or acid cleaning and,
2) controlled startup and shutdown operations.

During boil out, the boiler is not supplying any steam, heat input is very low and maximum circulation is required to insure that the chemicals are well mixed and contact all surfaces. To accomplish these purposes, the boil out is performed at reduced pressure where the difference in density between water and steam is much greater. In general the boil out pressure will be between 1/4 and 1/2 of normal operating pressure. It has been found, by experience, that a pressure in this range will produce sufficient circulation even at the low heat input rate.

During a controlled start-up the boiler is in service supplying steam at a pressure much lower than design. The boiler may be operated under these conditions for some time until the silica concentration is reduced sufficiently to allow raising pressure. It would appear that circulation would be quite high under these circumstances since pressure is low and heat input is high. This is not the case and it is necessary to limit the heat input rate at reduced pressures.

In this type of boiling, small steam bubbles are formed on the tube wall and are swept away as fast as they form. This allows the

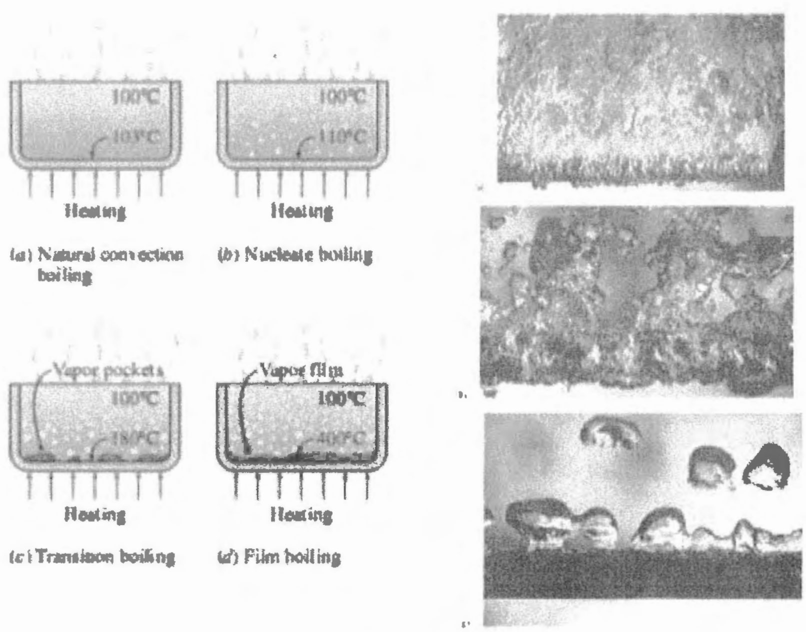


Figure 10.-3—Types of Boiling

water to continually cool the tube surface. If heat input is increased, the steam formation changes to film boiling in which the tube surface is blanketed by steam and is not adequately cooled. This type of operation can result in overheated and ruptured tubes. Film boiling will not occur if the steam flow versus pressure curve is followed. In some of the newer high pressure boilers a design error allowed film boiling to occur under normal operating conditions. In these cases, special tubes with internal rifling were installed. The rifling causes the steam water mixture to have a rotating or swirling motion which moves the steam to the center of the tube and keeps water in contact with the tube surface. The various types of boiling are illustrated in Figure 10-3.

SUPERHEATERS

The initial separation of steam and water occurs as the mixture leaves the riser and enters the drum. The steam bubbles separate at the water level in the drum. The steam bubbles carry some water along with them and several stages of mechanical separators are installed in the drum to remove this moisture. Essentially dry steam leaves the drum near the top and enters the superheater. The superheater is a once through circuit where all the steam that enters it from the drum also leaves it. The superheater usually consists of several separate banks or groups. These are given names such as primary or secondary. In general, the flow is countercurrent, with the steam flowing opposite to the direction of the flue gases. Heat transfer in the superheater is quite critical. A high velocity of flow must be maintained in order to keep the surface steam film thickness to a minimum. Special alloys which maintain their strength at elevated temperatures must be used for superheater tubes. Most boilers have thermocouples installed on the superheater tubes to indicate the metal temperature and insure that temperature limits are not exceeded. Final steam temperature is usually controlled by spraying feedwater into the steam to reduce its temperature. Spraying is accomplished early in the circuit, usually after the primary or first stage superheater. This practice reduces the temperature throughout the rest of the superheater and permits the use of less costly alloys for the tube metal. It is of utmost importance that no contamination of the steam takes place. Contamination can occur from carry-over of water droplets from the drum or from spraying for temperature control with contaminated feedwater. If a condenser tube leak occurs, it may be necessary to reduce load to a point where spraying is not required in order to prevent introducing contamination into the superheater.

There are some special operations which can result in contaminating the superheater if care is not taken. During forced cooling of the boiler, the drum is flooded to equalize temperatures. Care must be taken to insure that the drum is not overfilled and that no drum water is allowed to enter the superheater. A similar situation arises when filling the boiler for a hydrostatic test. The superheater must be filled separately with pure distilled water to insure that contamination does not take place.

When starting up a boiler there is a period of time when there are fires in the boiler and very little steam flow through the superheater. Since steam flow is what cools the superheater tubes a condition where there is no cooling results. It is quite possible to overheat and damage the tubes during this period. To prevent this occurrence, most boilers are provided with start-up furnace probes. These probes contain thermocouples which are connected to indicating or recording instruments in the control room. The probes are installed in the boiler ahead of the superheater. During start-up, the flue gas temperature leaving the furnace area as indicated by the probes should not be allowed to exceed 900°F. If this limit is adhered to it will not be possible to overheat the superheater tubes. The probes should be removed before the unit is on the line or they will be damaged by the increased temperature.

REHEATERS

The construction and operation of the reheater is essentially the same as for the superheater. The flow is usually countercurrent with the reheater arranged in banks or sections similar to the superheater. The major difference is that the reheater is handling steam at much lower pressures.

This permits the use of less expensive alloy metals or the use of larger diameter tubes to produce a lower pressure loss due to friction. The possibility of contaminating the reheater is much lower. The only normal way this can occur is through spraying for reheat temperature control. Reheat sprays are usually a backup reheat temperature control and, as such, are seldom used. The same precautions apply when spraying in the reheater as with the superheater.

ECONOMIZERS

Most boilers are provided with an economizer, the purpose of which is to reclaim low temperature energy from the flue gas and use it to heat the incoming feedwater before it enters the drum. The economizer is a counter-current flow heat exchanger which makes use of relatively small diameter tubes. Friction loss is not important since flow is insured by the feedwater pump. The flue gases have been cooled to a reasonable temperature by the time they enter the economizer section and ordinary carbon steel can be used for these tubes. Heat transfer is usually not a problem in the economizer due to the low temperature of the flue gases and the forced water flow. One exception to this occurs during start-up. At this time there are fires in the boiler, however, there is no flow through the economizer since no water is being added. It is possible to boil the economizer dry and overheat the tubes. To eliminate this possibility most units are provided with an economizer recirculation line. This line connects the economizer to the boiler water walls and permits natural circulation to take place. The recirculation line should be shut off as soon as water is being supplied to the boiler.

BOILER FIRESIDE

Air is supplied to the boiler by forced draft fans which force the air through large ducts to an enclosure on the boiler known as the wind box. The wind box is designed so that it provides essentially equal air pressure at each burner. The wind box is connected to the furnace by openings for each burner. The fuel is supplied to each burner through appropriate connections that penetrate the wind box. Each burner is usually provided with a register which gives the air a swirling motion to assist in mixing with the fuel. The register is also used to adjust or control the amount of air supplied to each burner. Proper setting of the registers is essential for safe and efficient operation of the boiler. The opening between the wind box and the furnace is known as the burner throat and is usually lined with refractory material. The throat aids in heating the air and swirling it for better mixing with the fuel.

FURNACE

Combustion takes place in the volume enclosed by the water walls and known as the furnace. The fuel and air enter the furnace through the burners. In the design of the boiler there are two primary considerations that determine the size of the furnace.

1. The furnace volume must be large enough to permit complete combustion to take place without undue impingement of the flames on the boiler tubes.

2. There must be sufficient water wall surface to insure reasonable values of heat input per unit of area to the tubes.

These considerations generally lead to very large furnace volumes and consequently very high boilers. In some of the larger boilers additional heating surface in the form of furnace division walls is installed to permit using a smaller overall boiler size.

Heat generated in the combustion of fuel appears as sensible and latent heat in the products of combustion. Approximately 50% of the total heat generated is absorbed in the furnace enclosure walls. The primary heat transfer method involved in the furnace is radiation. Approximately 75% of the heat transferred to the furnace walls is by radiation. For this reason the furnace area is known as the radiant section of the boiler. The approximate temperature in the furnace is 3000°F.

CONVECTION SECTION

The flue gases leave the furnace and pass into the convection section of the boiler. This section is so named because most of the heat transfer takes place by the convection method. Located in this section are the superheater, reheater and economizer. These three sections are located in the flue gas space so that the gases pass completely around all the tubes.

The walls which enclose the convection section are generally water walls which combine with the furnace water walls to generate the required steam flow. The flue gas temperature entering the convection section is usually about 2200°F. This temperature is reduced to approximately 700°F when the gas leaves the economizer. At these lower temperatures ash and soot can accumulate on the tube surfaces and restrict heat transfer. This results in much hotter flue gas leaving the economizer and therefore, lesser boiler efficiency. To eliminate this condition the convection section is provided with soot blowers. These blowers remove the accumulated soot and ash and thereby restore normal heat transfer.

AIR PREHEATERS

Practically all boilers are equipped with an air preheater whose function is to reclaim low temperature heat energy from the flue gas by transferring it to the incoming combustion air. Due to the relatively low temperatures involved, the air preheater must have a large surface area for heat transfer. The air preheater may be an integral part of the boiler in which case it is part of the convection section. Older air preheaters are of the tubular design. Most of the newer units have separate rotary regenerative air preheaters which are considered as boiler accessories. The flue gases leaving the air preheater are discharged to atmosphere through the stack.

BOILER CONSTRUCTION

All large boilers, such as those used in steam power plants, are shipped from the manufacturer's plant completely disassembled. The boiler is then put together or erected on the plant site. A large steel framework is erected first and the boiler is then hung or suspended from this structure. In this way the boiler is free to expand downward as it heats up. A large boiler may expand as much as 8 - l0 inches while going from cold to hot. The exterior of the boiler is referred to as the casing and usually consists of a thin layer of sheet metal backed up by 2 - 3 inches of insulation. This insulation keeps radiation to air losses to a minimum.

The furnace and convection sections of the boiler fireside may be operated either at a slight negative pressure (draft) or at a slight positive pressure (pressurized).·When designed for draft, an induced draft fan is provided to remove the products of combustion from the boiler. In this type of unit the boiler casing does not have to be air tight since any leakage will be inward. Air in leakage does result in reduced efficiency, however, it is not a hazardous condition. In the pressurized system no induced draft fan is provided and the entire boiler fireside is under a positive pressure. In this case the boiler casing must be completely air tight since leakage will consist of hot flue gas leaving the boiler which can result in damage to equipment and present a hazard to personnel. See Figure 10-4 and Figure 10-5 for examples of the furnaces.

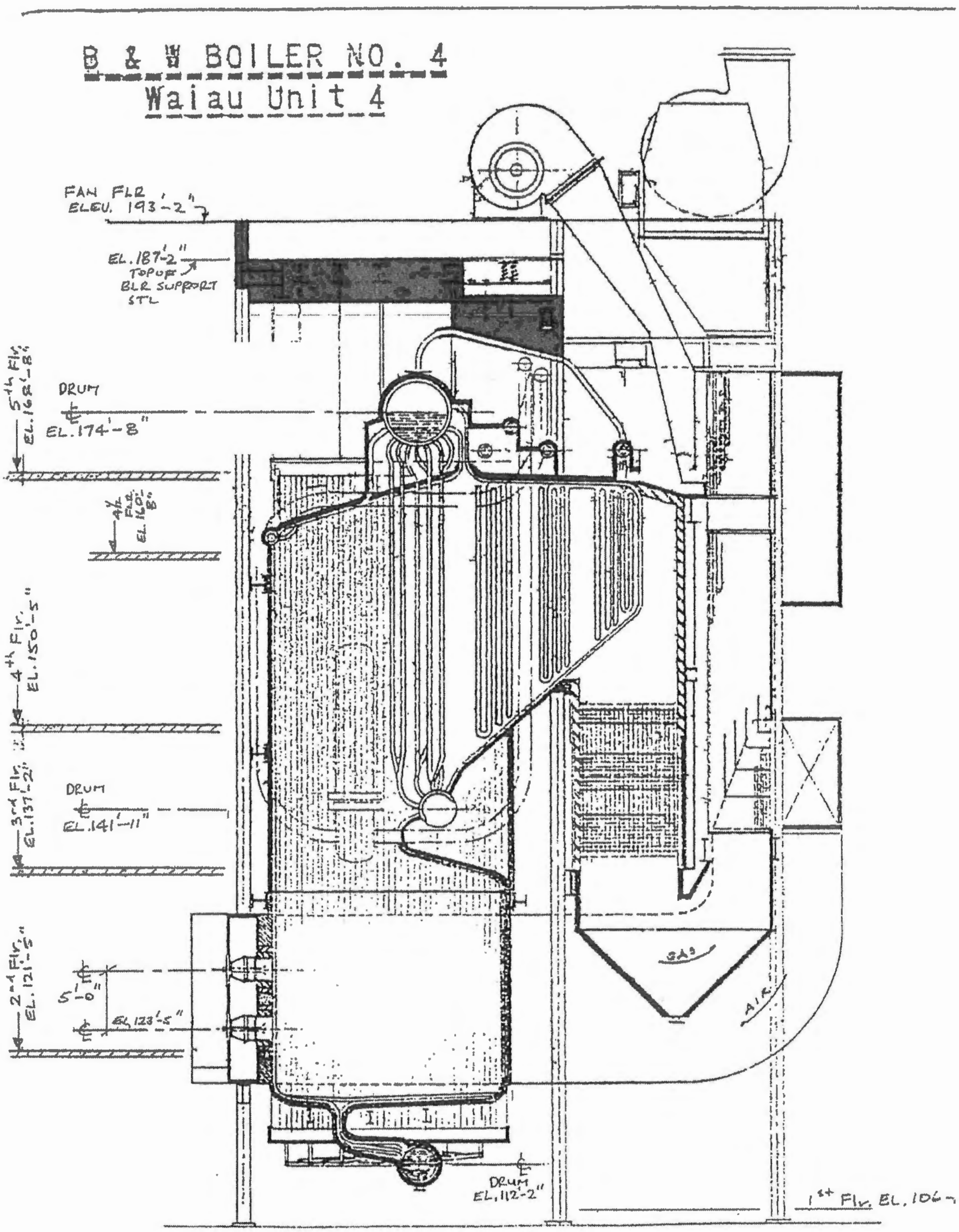


Figure 10-4—Waiau 4 operates under negative pressure.

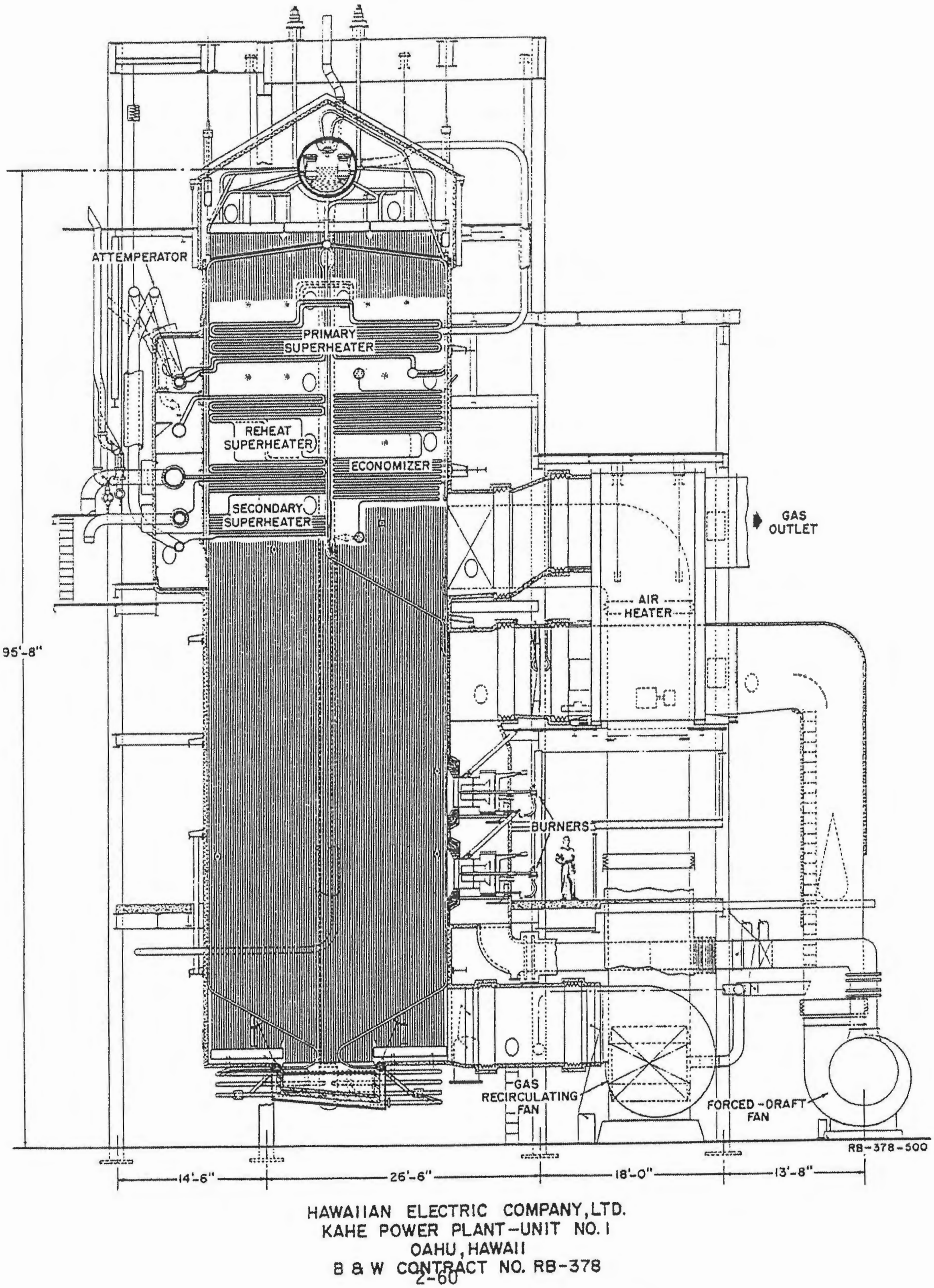


Figure 10-5—Kahe 1 operates under positive pressure.

Section 10
BOILER FUNDAMENTALS
Study Questions

1. The boiler is the first step in the ______________ ______________ process.

2. The two cycles of a typical boiler are:
   a. ______________________, which includes all parts that contain the flow of ______________________ and/or ______________________;
   b. ______________________, which includes spaces and passages where ______________________ takes place and through which ______________ gases pass.

3. Describe, briefly, what would happen should the continuous flow of water and/or steam through the boiler cease.

4. Identify the four factors that determine boiler circulation.
   a)
   b)
   c)
   d)

5. During acid cleaning and controlled startup and shutdown operations, which two of the four factors listed above would be under the control of the operator?
   a)
   b)

6. Which two are fixed by design and beyond the control of the operator?

   a)

   b)

7. How does natural circulation differ from forced circulation and forced flow?

8. Boiler walls are made up of riser tubes known as ______________________________ .

9. The construction and operation of the reheater and the superheater is essentially the same. The major difference is that the ___________________________ handles steam at much lower pressure.

10. What are some causes of steam contamination? List and describe at least two (2).

11. During start-up. the flue gas temperature leaving the furnace area should not be allowed to exceed ____________________________ .

12. Low temperature energy from the flue gas is reclaimed by the ________________.

13. This low temperature energy is used to heat the incoming _______________________ before it enters the ___________________________________.

14. Air is supplied to the boiler through large ducts to an enclosure on the boiler known as the _______________________________________ .

15. Each burner is usually provided with a ______________________ which give the air a swirling motion and adjusts the amount of air supplied to each burner.

16. The opening between the wind box and furnace is known as the _______________.

17. Combustion takes place in the area enclosed by the water walls and known as the ____________________ and the primary heat transfer method involved is ____________________.

18. The superheater, reheater, and economizer are located in the __________________ section of the boiler.

19. Why is the convection section provided with soot blowers and what is their purpose?

20. Reclaiming low temperature heat energy from the flue gas by transferring it to the incoming combustion air is the function of the _________________________.

21. When erecting a boiler on a plant site, a steel framework is erected and the boiler is suspended from this structure. Why?

22. What determines whether or not a boiler casing should be air tight?

POWER GENERATION DEPARTMENT
OPERATOR TRAINEE TRAINING PROGRAM

Section 11
STEAM TRAPS

OBJECTIVES:

1. Discuss the basic functions of a steam trap
2. Discuss the construction and operating principles of the three general classes of heavy duty industrial stem traps.

Power Generation Department
Operator Trainee Training Program

Section 11
STEAM TRAPS

Traps, along with piping and valves, compose the arteries that interconnect the various pieces of equipment in a generating station. Steam traps are installed in steam lines to remove condensate without the loss of steam. They prevent water being carried into the turbine and damaging blading. In heating systems, they remove condensate and air without the loss of steam. They improve efficiency by causing steam to condense before it is removed, increasing the rate of heat transfer. They prevent water hammer from endangering the piping and fittings.

The steam trap must serve three major functions:

1. Let out condensate but hold back steam.
2. Eliminate air and gas quickly.
3. Remove condensate, air, and gas by responding promptly to changing conditions in the line.

In general, a steam trap consists of a valve and some device or arrangement which will cause the valve to open or close, when necessary, to drain the condensate from the line without allowing the escape of steam.

The steam trap does this by either (1) responding quickly to temperature changes in the line (identifying the difference between hot steam and slightly cooler condensate); or (2) being able to tell the difference between liquid (water) and vapor (steam). In the first instance, the trap opens and closes due to temperature changes ahead of it. In the second case, it operates due to change of state of the fluid, from water to vapor.

There are many different types of steam traps, but this section will deal only with heavy duty industrial types. They are divided into three general classes:

1. **Mechanical.** These operate on change of state of the fluid coming to the trap. They open to water or condensate, but close on steam.
2. **Thermostatic.** These are actuated by the temperature of the liquid flowing to the trap. They open on cool condensate and close near steam temperature.
3. **Thermodynamic.** These operate by utilization of the differences in thermodynamic energy available from steam and hot condensate.

MECHANICAL TRAPS

Although there are several basic types of traps in this class, they all have one principle in common; all are operated by response to the difference in density between steam and water or condensate.

The Float Trap is one of the earliest types of steam traps (Figure 11.1). It consists of a closed housing containing a ball float. In the simplest form of this trap, the float is attached to the end of a rod or lever . The opposite end of the lever is attached to a discharge valve. When condensate fills the body or housing of the trap the float rises, gradually opening the discharge valve. Increasing condensate flow raises the float and opens the valve wider adjusting it to

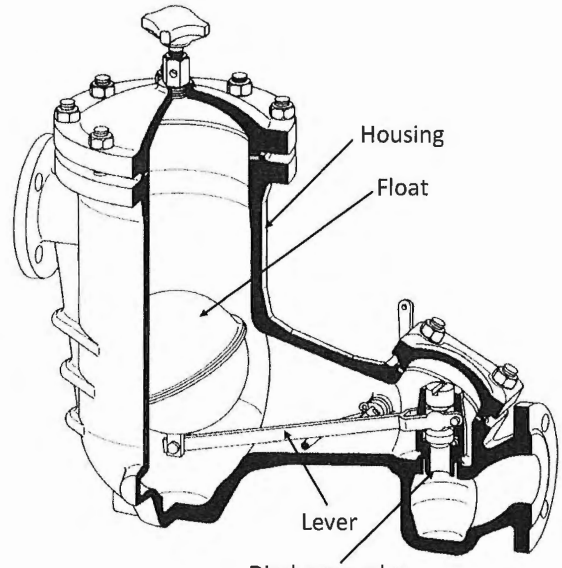


Figure 11.1—Float Trap

suit the condensate load and maintaining the proper condensate level within the trap body.

Another early type of trap is the Open Bucket Trap (Figure 11.2). This consists of a bucket or float, open at the top, operating within a housing. The bucket pivots around a fulcrum. Attached to the bucket is a valve

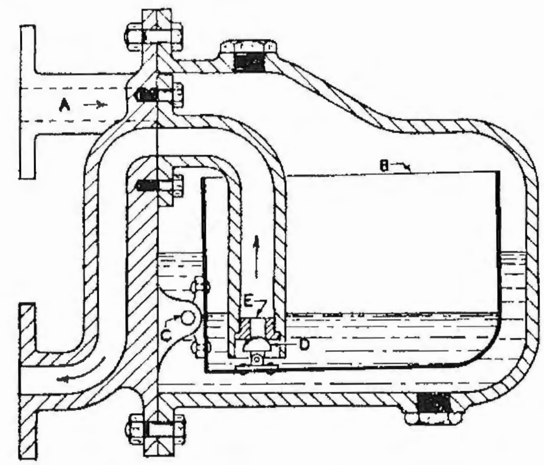


Figure 11.2—Open Bucket Trap

rod extending upward through a discharge tube. At the top of the valve rod is a discharge valve which seats in the orifice.

In some designs the bucket surrounds the discharge tube and slides up and down

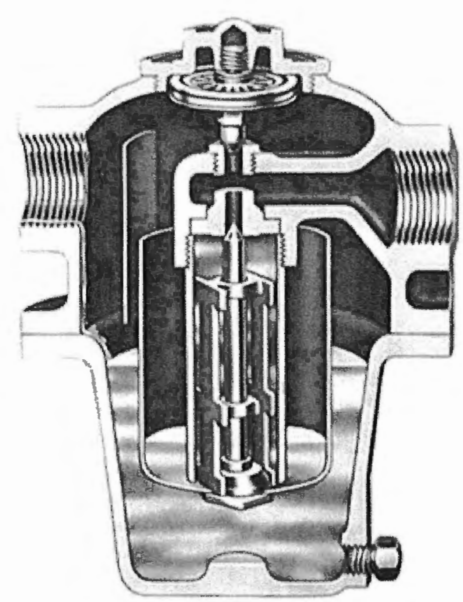


Figure 11.3—Open Bucket Trap

along the tube as shown in Figure 11.3, rather than being hinged to a pivot, but the operation is essentially the same.

When condensate reaches this trap, it gradually fills up the body and floats the bucket. This causes the bucket to rise and close the valve. Finally condensate spills over the top of the bucket and the bucket sinks. This opens the valve and the pressure inside the trap body forces the water up through the discharge tube and out the orifice. As soon as the bucket is emptied sufficiently, it floats again, closing the valve, and the cycle is repeated.

In earlier models of the float and open bucket traps, the accumulation of air in the body of the trap often became a problem. Later models were equipped with a thermostatic element, usually of the bellows type, which automatically vents the air from the trap body. As the air is cooler than the steam, the thermostatic element opens to let out the air, but closes on the steam.

A more recent and more commonly used type of bucket trap is the Inverted Bucket Trap (Figure 11.4). It is somewhat similar to the Open Bucket Trap, but in this case the bucket (A) is inverted and is open at the bottom. Attached to the top of the bucket is a valve (B) linkage mechanism which permits the air (C) discharge valve to open and close as the bucket falls and rises. When the bucket is at rest, it hangs downward with the valve open. Condensate enters the trap either from the side, flowing down the passage in the side of the trap and then

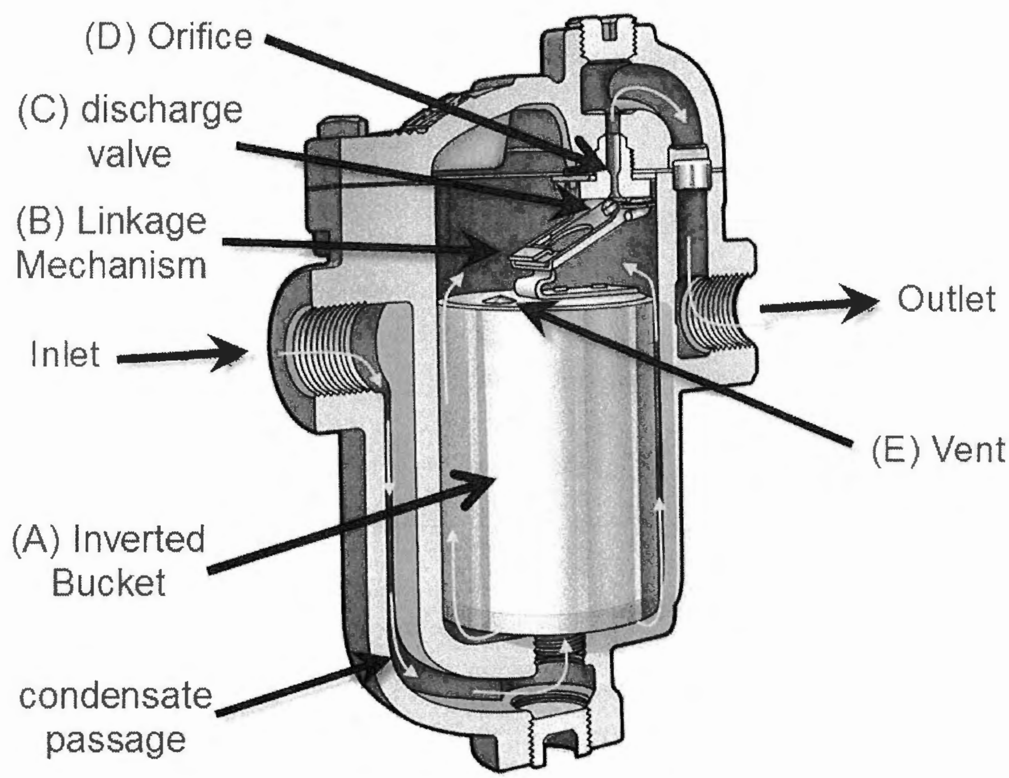


Figure 11.4—Inverted Bucket Trap

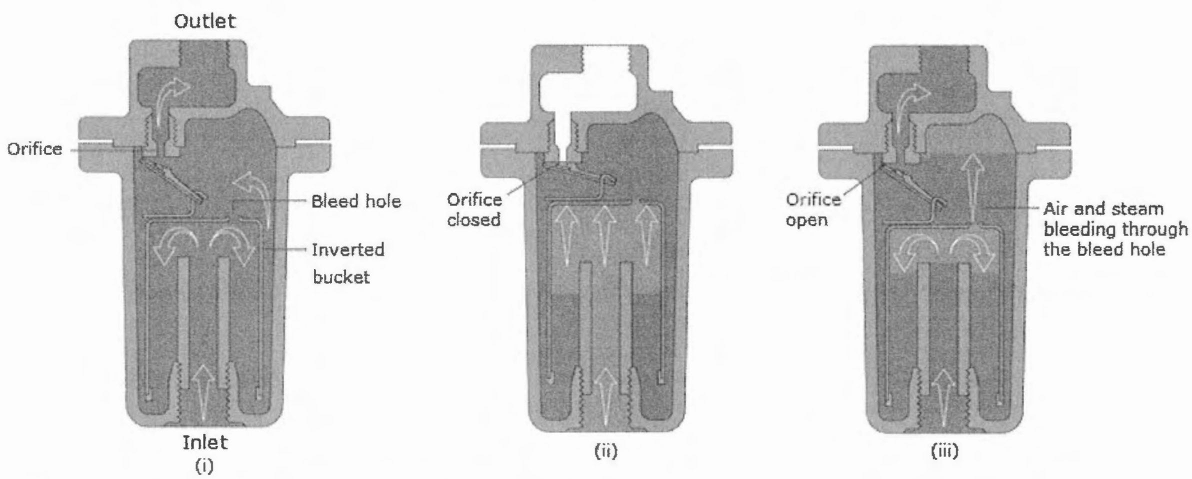


Figure 11.5—Inverted Bucket Trap with bottom inlet.

upward under the open end of the bucket, or, if the trap has a bottom inlet (Figure 11.5), the condensate will enter directly under the bottom of the bucket.

In operation, as long as condensate is flowing to the trap, the bucket stays down and flow continues out the orifice and passage (D). When steam reaches the trap, it fills the bucket, the bucket floats and rises to close the valve. The steam in the bucket slowly condenses and also bleeds off through the small vent (E) in the top of the bucket. Thus the bucket loses its buoyancy and finally sinks, opening the valve again to discharge more condensate.

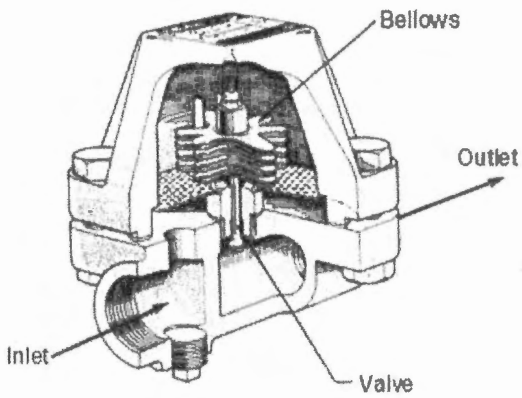
While the vent (E) (about 1/16" in diameter in a 1/2" trap) allows some of the steam in the bucket to bubble up into the body of the trap and condense, another important purpose of the vent is to permit passage of the air and non-condensable gases. If it were not for this vent the bucket would soon become filled with air and keep the valve closed all the time, rendering the trap air-bound and inoperative.

Flow of air through the vent is limited as it is due only to the buoyancy of the air in the water. The elimination of large amounts of air is handled by a bucket with a second or auxiliary vent. This auxiliary vent is much larger than the regular vent and is provided with a disc valve controlled by a thermostatic bimetallic strip. When the trap is cold the bimetallic strip bends downward opening the auxiliary vent valve. This provides quicker air elimination during the start-up period. As warmer condensate and air enter the bucket, the bimetallic strip gradually bends toward the closed position. As long as any air is present, the auxiliary vent will be at least partly open. When all air is eliminated and steam fills the bucket, the auxiliary vent closes completely leaving only the fixed vent open.

THERMOSTATIC TRAPS

All thermostatic traps work on the same basic principle. They respond to temperature changes in the line, opening to cool condensate and closing on steam.

The most commonly used is the bellows



THERMOSTATIC STEAM TRAP

Figure 11.6

type (Figure 11.6). The operating element consists of a corrugated bellows mounted within a housing. At the bottom of the bellows a valve is mounted which closes the orifice when the bellows expands. Usually the bellows is filled with a liquid, such as alcohol and water, which has a boiling point below that of water. When condensate approaching steam temperature comes to the trap, the liquid inside the bellows vaporizes, building up pressure inside that causes the bellows to expand and close the valve. The valve remains closed until radiation of heat from the body of the trap (and cooling of the condensate coming to the trap) allows the vapor within the bellows to slowly condense. The bellows then contracts, opening the valve wide again. As the valve is wide open when the trap is cool this type of trap provides quick start-up of equipment and excellent air handling ability.

Time required to condense the vapor within the bellows is dependent on a number of factors: size and material of trap body, length of pipe between trap and apparatus it is draining, and temperature of air surrounding the trap.

The bellows trap has several limitations. A sensitivity to water hammer requires that dips in the line ahead of the trap be avoided, as well as any sudden pressure changes that might allow slugs of water to strike and damage the bellows. The upper limit of pressure on which this type of trap may be used is approximately 300 psi.

A bimetallic strip is used to operate some types of thermostatic traps. As condensate cooler than the steam comes to the trap, this bimetal element bends one way, opening the valve. When hot steam comes along, the element bends the opposite way, closing the valve. (Figure 11.7).

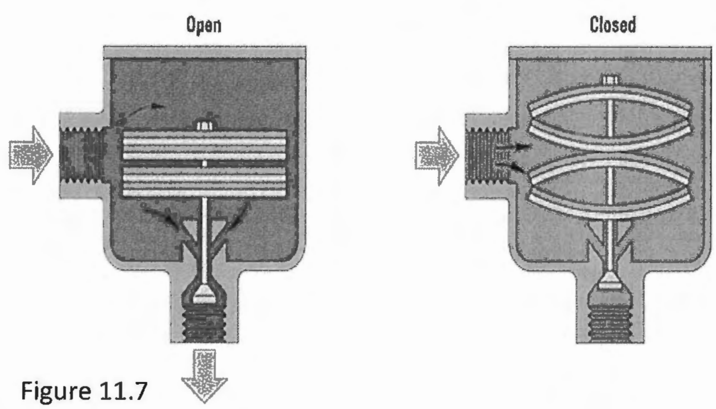
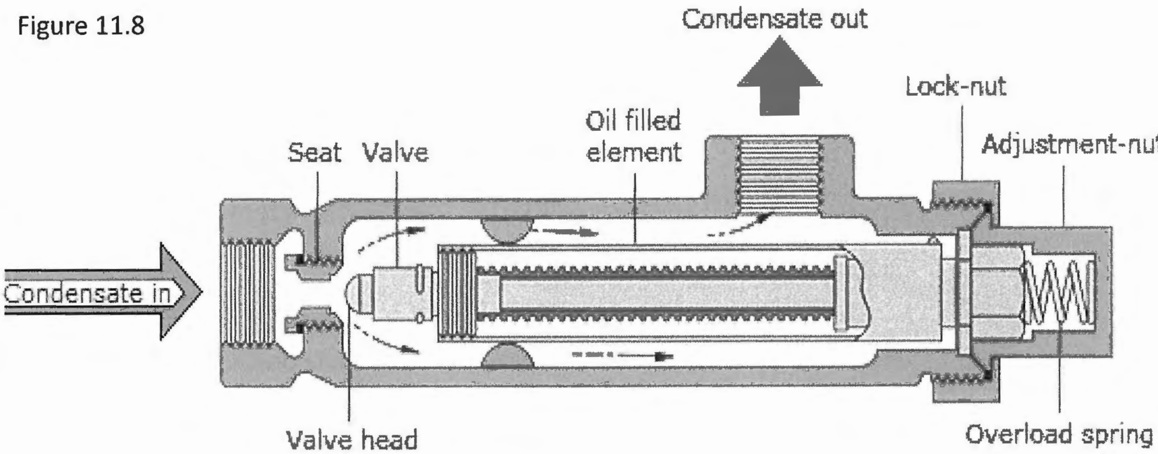


Figure 11.7

Another type of thermostatic trap is operated by the expansion of a liquid in a long enclosed tube which causes the tube to open and close a valve in the end of the trap housing. A similar type employs the expansion and contraction of a metal rod to

Figure 11.8



open and close the valve. (Figure 11.8).

FLOAT AND THERMOSTATIC TRAPS

This trap combines the float mechanism with a thermostatic element (Figure 11.9). The latter is usually of the bellows type although bimetallic elements are also used in some makes. The addition of the thermostatic element provides greater air handling ability, particularly at start-up, than the float mechanism alone, and the float

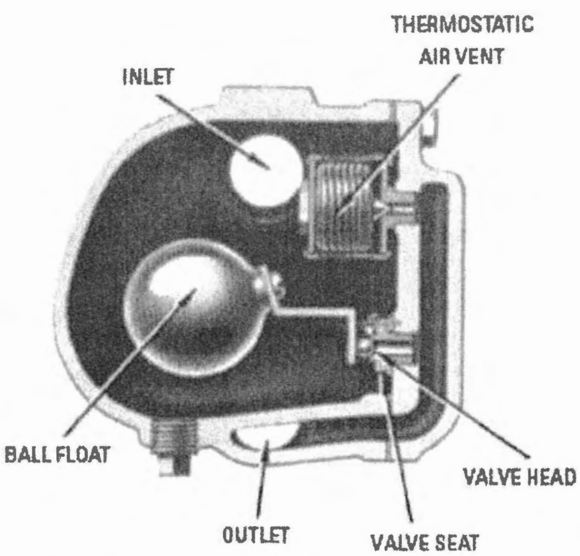


Figure 11.9 Float and thermostatic steam trap

trap portion provides variable flow according to the condensate load. All thermostatic traps have this in common, however, they are operated and controlled by the temperature in the line ahead of the trap and time must be allowed for the operating elements to either absorb heat to cause closure of the valve or dissipate heat to cause it to open.

FLASH STEAM (OR FLASH VAPOR)

Flash steam has an important bearing on the operation of Thermodynamic Traps, the third general class of steam traps. Flash steam or flash vapor is the vapor that forms when hot water at steam temperature is discharged to the atmosphere (or from a higher pressure to a lower pressure). A simple illustration of this is the cloud of vapor that rises when boiling water from a kettle is poured into the kitchen sink. If the hot water were placed in a closed vessel such as a pressure cooker and heated up, the pressure in the cooker would rise and each pound of water would then contain more heat than it held when it was boiling in the kettle at atmospheric pressure or 0 psig. As the pressure increases, the boiling temperature increases. If the safety valve from the top of the pressure cooker were removed, the contents of the cooker would be released to atmospheric pressure or 0 psig and a tremendous cloud of steam would burst out of the cooker. This is flash steam or steam at 0 psig. This flash steam expands to many times the volume it had when it was water. If the water in the cooker was at a pressure of 15 psig and the pressure is reduced to 0 psig, the portion of the water that turns to flash steam would have nearly 1600 times the volume it had before it turned to flash steam. This flashing is caused by the suddenly increased boiling of the water in the vessel as the pressure is reduced, because the water contains more heat than it can hold at atmospheric pressure. Flash steam is always formed when hot water (or condensate) is released from a higher pressure to a lower pressure.

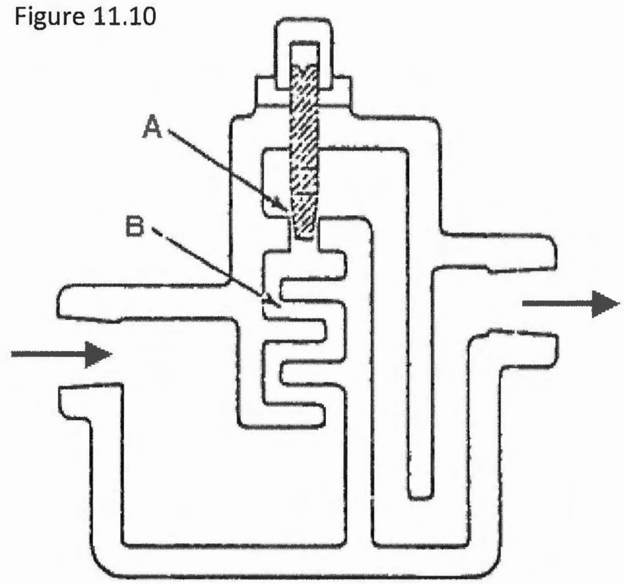
If a steam trap is discharging to the atmosphere and the trap is draining apparatus supplied with steam at 100 psig, the condensate is being discharged from a higher pressure (100 psig) to a lower pressure (0 psig). Therefore, some of the discharged condensate will reboil or turn to flash steam when it emerges from the trap. When steam first gives up its heat and turns to condensate, the condensate is at steam temperature. The closer to steam temperature a trap can discharge, the more quickly it can discharge the condensate after it forms.

THERMODYNAMIC TRAPS

This class of steam traps utilizes the heat energy in hot condensate and steam to control the opening and closing of the trap.

Orifice (Labyrinth) (Figure 11.10) was one of the earliest types of thermodynamic traps. In one form it combines an adjustable orifice (A) with labyrinth passages (B) to control the flow of condensate. Due to pressure drop through the labyrinth passages and the adjustable orifice, some condensate turns to flash steam as condensate approaches steam temperature. This provides a

Figure 11.10



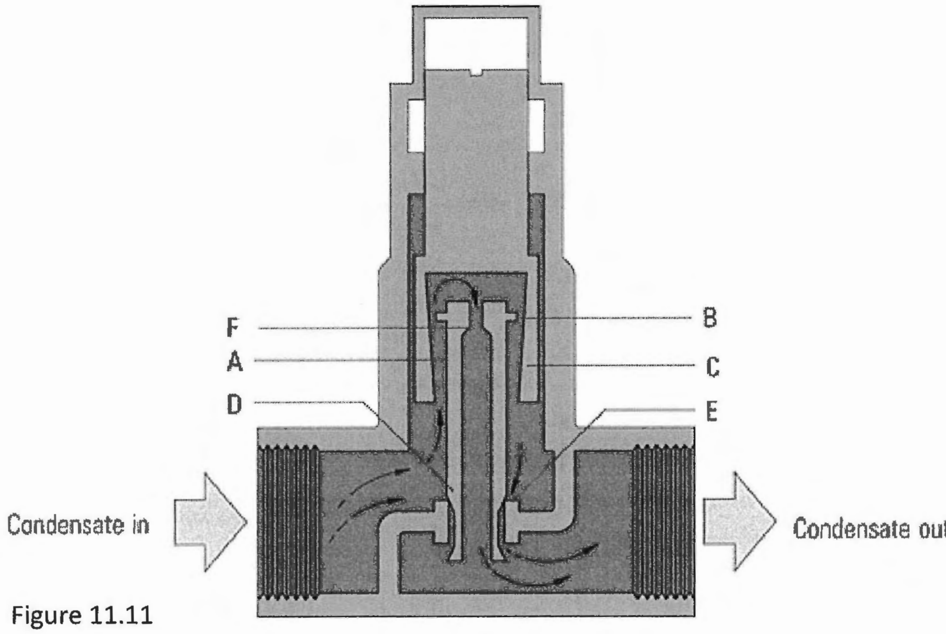


Figure 11.11

measure of automatic flow control. The nearer the condensate approaches steam temperature, the greater the flashing and the greater the choking effect of the flash steam. If the condensate load does not fluctuate to any great degree, this trap is quite satisfactory. However, if load or pressure vary considerably, it is likely to either back-up condensate or blow live steam.

The Impulse Trap is a more modern type of thermodynamic trap (Figure 11.11). Its best known form consists essentially of a piston type valve operating within a cylinder. The impulse trap has a hallow piston (A) with a piston disc (B) working inside of a tapered piston (C) which acts as a guide. At "start up" the main valve (D) rests on the seat (E) leaving a passage of flow through the clearance between piston and cylinder and hole (F) at the top of the piston. Increasing flow of air and condensate will act on the piston disc and lift the main valve off its seat to give increased flow. Some condensate will also flow through the gap between the piston and disc, through (E) and away to the trap outlet.

As the condensate approaches steam temperature some of it flashes to steam as it passes through the gap. Although this is bled away through the hole (F) it does create an intermediate pressure over the piston, which effectively positions the main valve to meet the load. The trap can be adjusted by moving the position of piston (B) relative to the seat, but the trap is affected by significant backpressure. It has a substantial capacity, bearing in mind its small size. Conversely, the trap is unable to give complete shut-off and will pass steam on very light loads. The main problem however is the fine clearance between the piston and cylinder. This is readily affected by the dirt normally found in a steam system.

The Integral Strainer Impulse Trap is for high pressure service and is made with a built- in

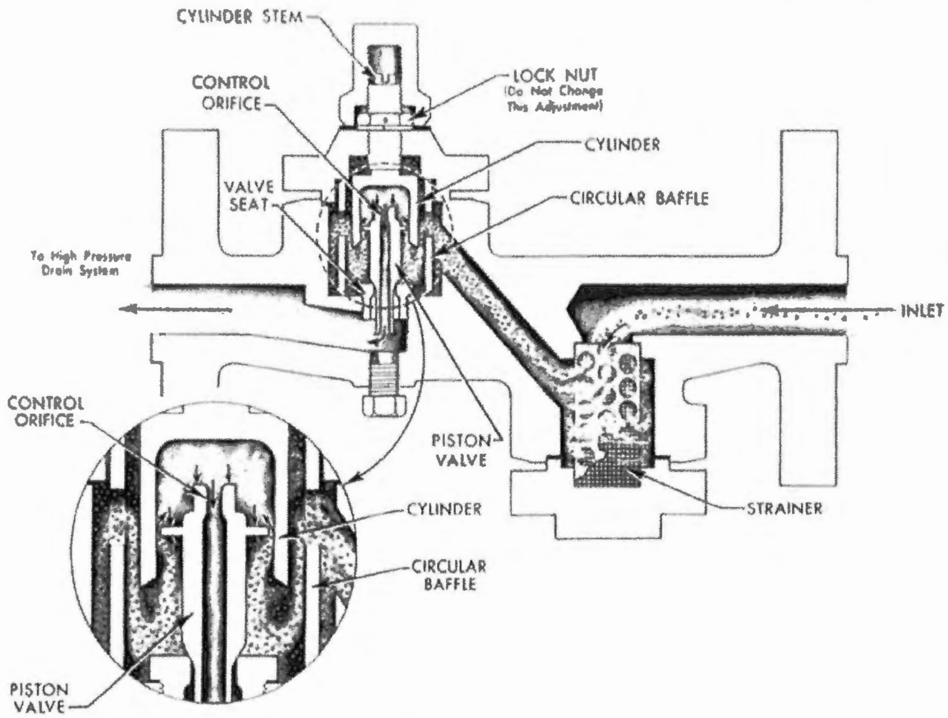


Figure 11.12 Integral Impulse Trap

or integral strainer that provides a compact and sturdy construction for such types of applications (Figure 11.12) . The Lever Valve Impulse Trap is a newer version of the Impulse Trap and is designed for extra heavy condensate loads (Figure 11.13). It operates on the same basic principle as the original type but with a lever action rather than a piston action. This trap consists of a valve disc attached to an inlet valve. The valve disc acts as an outlet valve, opening and closing the outlet orifice as the valve disc tilts up and down around the fulcrum point. A control orifice is provided in the valve disc over the center of the discharge or outlet orifice. When the valve disc is at rest there is a control flow between the inlet valve and its seat. This control flow then goes

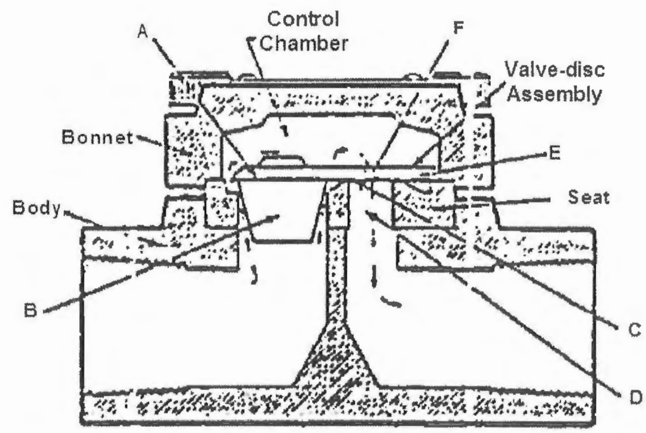


Figure 11.13

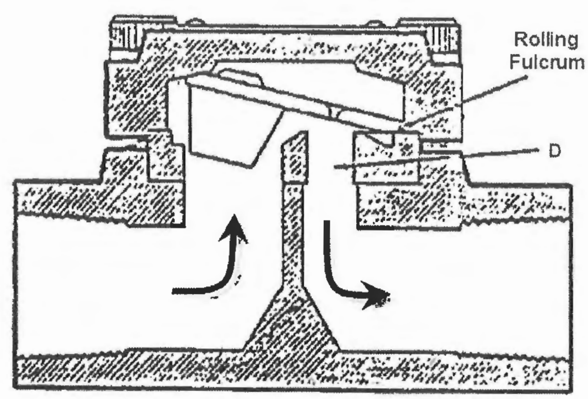


Figure 11.14

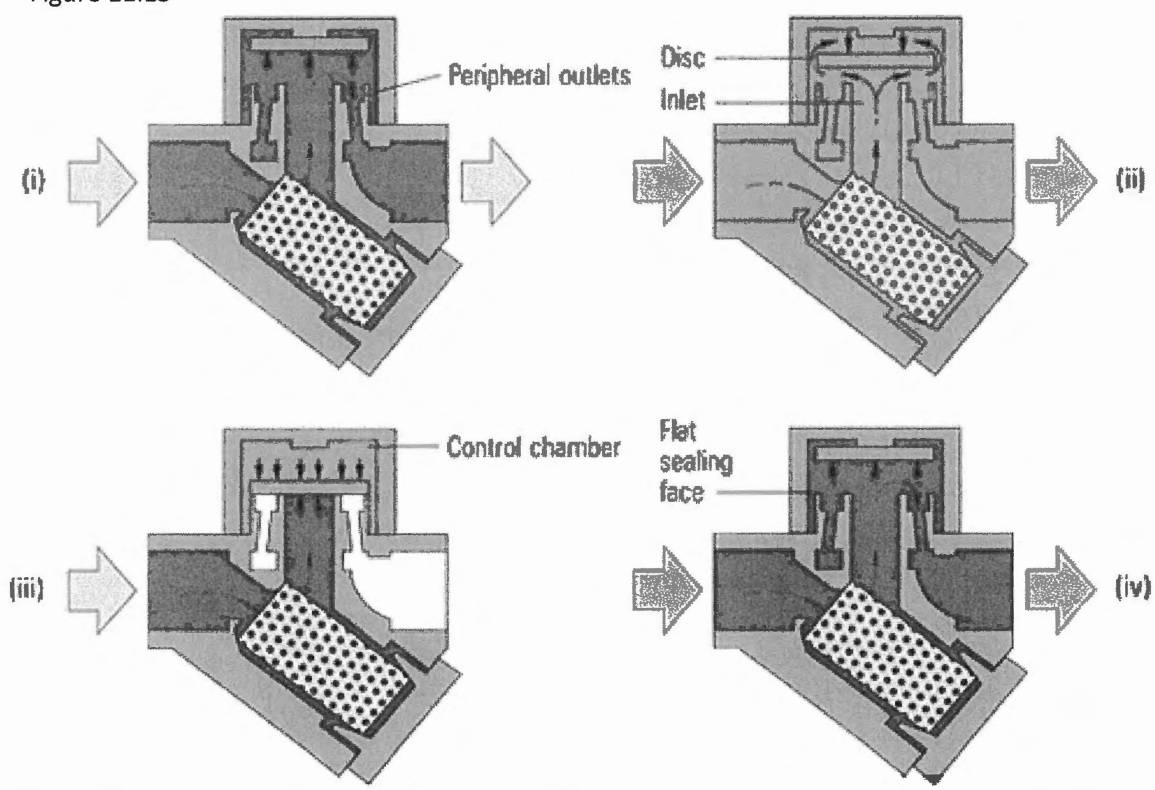
on out the control orifice. Incoming condensate and air push the disc upward with a tilting action and full flow goes out the discharge orifice (Figure 11.14).

On startup, air is handled through the control orifice. Only cool condensate or a mixture of condensate and air, will open the valve lever. As steam temperature condensate reaches the trap, flashing begins in the outlet orifice, building up pressure in the chamber above the lever. The lever closes as the chamber pressure increases. A small "control flow" permits quick response to inlet conditions. A slight drop in condensate temperature, for instance, reduces the chamber pressure, quickly opening the lever. Lever traps are designed for applications having large condensate loads and where rapid discharge of condensate is a requirement.

Operation is similar to that of the original Impulse Trap except the control flow combines with the main flow when the valve opens instead of following a separate flow path as in the earlier type. Flashing of the hot condensate controls the closing of the valve disc just as in the original Impulse type and action is governed by the same basic principle of control flow.

One of the most recently developed types of thermodynamic traps is the Disc Trap (Figure 11.15). It consists of a round flat Disc positioned over a center inlet orifice and an annular discharge leading off through a discharge port. All are enclosed within a bonnet mounted on the body of the trap. When operation starts, pressure in the inlet orifice pushes the disc up vertically off the two concentric seating surfaces surrounding the inlet and outlet pons. This allows

Figure 11.15



discharge to flow out through the peripheral outlets. Now when very hot condensate and steam come to the trap the high velocity flow outward past the rim of the disc up into the chamber tends to reduce the pressure on the under side of the disc causing some of the condensate to turn to flash steam (ii). At the same time the flashing condensate flowing outward at high velocity strikes the side wall of the chamber causing a build up of pressure in the chamber snapping the disc shut (iii). The disc remains in the closed position until the pressure in the bonnet falls due to the condensing of the steam in the bonnet. When pressure in the bonnet falls sufficiently the disc rises, condensate flows out and the cycle is repeated (iv).

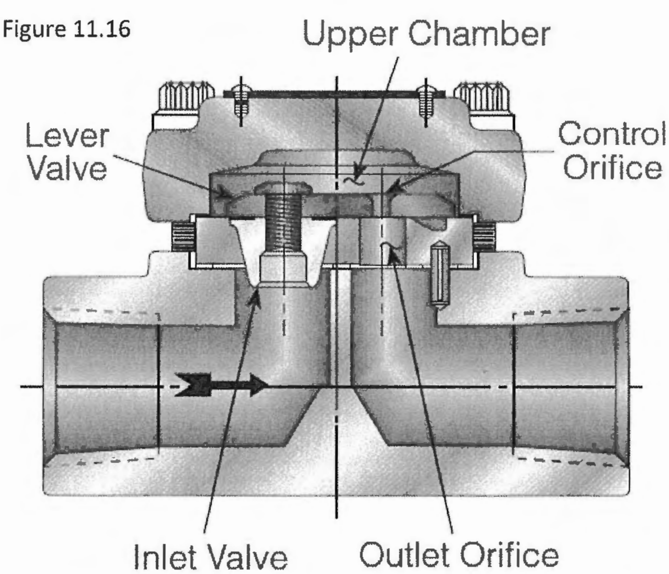
This type of trap is essentially a time cycle device. Under normal operating conditions, each time the disc closes on steam at a given pressure and temperature, it will stay closed for approximately the same length of time. This means that if condensate comes to the trap in the middle of a cycle, it will have to wait till pressure in the bonnet falls sufficiently to permit the disc to open.

The Lever Disc Impulse Trap operates in somewhat the same manner as the Disc Trap, except that the valve disc is arranged so that it opens and closes the valve with a tilting action rather than moving straight up and down. (Figure 11.16) It is designed primarily for the lighter condensate loads. When condensate enters this trap it pushes the disc upward with a tilting action because the inlet valve is off center. Discharge then goes out through the outlet orifice. When steam and steam temperature condensate come to the trap, flashing begins in the outlet orifice, the upper chamber fills with steam and the increased pressure closes the disc in a similar manner to that described for the disc trap above. The tilting or lever action of the valve in the lever disc trap insures a minimum of wear on the parts and also aids in reducing the noise from the trap discharge.

A small control flow through the control orifice allows quick response to inlet conditions.

This trap also operates on a time cycle; the time between opening and closing being relatively constant for a given set of load and pressure conditions. When the lever disc trap is closed by live steam and flash steam entering the upper chamber, it stays closed until the steam in the upper chamber condenses and also bleeds off slowly through the control orifice.

Figure 11.16



NOTES:

Section 11

STEAM TRAPS

Study Questions

1. List the three major functions that steam traps must serve.

   a.

   b.

   c.

2. Steam traps are installed in ____.

3. All basic types of__________________________traps have one principle in common; they operate on change of state of the fluid coming to the trap.

   a. Thermostatic

   b. Mechanical

   c. Thermodynamic

4. The *bellows* is one type of mechanical trap. True \ False

5. All thermostatic traps open on cool condensate and close near steam temperature. True \ False

6. What is one limitation of the *bellows trap*? ____________________________

7. The bimetallic element is instrumental in opening and closing a valve in some thermostatic traps. True \ False

8. Which of the following plays an important part in the operation of *Thermodynamic traps*?

   a. Bimetallic element

   b. Flash steam

   c. Valve rod

   d. None of the above

9. The thermodynamic trap utilizes the heat energy in hot condensate and steam to control the opening and closing of the trap. True \ False

10. The Disc trap and the Impulse trap are both essentially time cycle devices. True \ False

GENERATION-OAHU DIVISION
OPERATOR TRAINEE TRAINING PROGRAM

Section 12
BOILERS AND ACCESSORIES

OBJECTIVES:

1. Discuss the three boiler types.
2. Identify and discuss the following boiler accessories.
   a. Safety Valves
   b. Steam Drum and Internals
   c. Soot Blowers
   d. Boiler Water Treatment and Control
   e. Boiler Gauge Glasses
   f. Drum Vent and Superheat Drains
   g. Boiler Fill and Drain System
   h. Air Preheaters
   i. Steam Air Heaters
   j. Draft Equipment
   k. Boilers Sealing and Cooling Air
   l. Aspirating Air
   m. Hydrostatic Testing

Generation-Oahu Division
Operator Trainee Training Program

Section 12
BOILERS AND ACCESSORIES

All steam generators, usually referred to as boilers, are designed for a specific performance. A boiler is a device where the chemical energy in fuel is converted to heat energy in steam. When a boiler is supplied with feedwater at a specified temperature and a given amount of fuel, it is designed to deliver a specific quantity of steam to the turbine at the required pressure and temperature. How this is accomplished varies from plant to plant.

A brief description of three (3) boiler types is given before covering the accessories of a boiler which are usually fairly universal and apply to all boilers. For the purpose of this discussion the accessories include: safety valves, steam drum, soot blowers, water treatment, gauge glasses, boiler vents and drains, fill and drain system, air preheaters, steam air heaters, draft fans, boiler sealing and cooling air, aspirating air, and hydrostatic testing.

Waiau #3 & 4 boilers are Babcock & Wilcox radiant type steam generators: three drum, water tube, utilizing natural circulation, with water cooled furnace (Figure 12.1). The boilers are each designed to produce 447,000 lb/hr of superheated steam at 875 psig and 905 F.

Water enters the boiler at the economizer through the feedwater stop-check valve. Passing through the economizer, the water enters the steam drum and, due to its low temperature and high density, travels down two (2) downcomers (one on either side of the steam drum) to the mud drum.

Exposed to the radiant heat, the water forms steam and the water steam mixture rises in the water wall tubes and returns to the steam drum where the saturated steam is separated from the water and travels to the superheater.

The superheater is known as the Babcock & Wilcox continuous tube, suspended vertical type superheater in three sections arranged for counter flow. The saturated steam enters the rear of the third section, flows through this section, the intermediate section, the attemperator and first superheater section, and finally passes into the outlet header and the main steam line.

The superheater is designed to provide maximum accessibility and maximum cleanability. All sections of the superheater are supported from the water cooled roof tubes located above the superheater. Steam temperature control is provided for by the attemperator.

The economizer is of the continuous tube type, providing for counterflow of gas and water, assuring maximum efficiency of this heating surface. The gas flow is down through the economizer and the water flow is up, discharging into the steam drum.

The furnace is completely water cooled, the floor consisting of tubes lined with brickwork, and the walls in the radiant section being studded. This type of construction is gas and air tight, not dependent on insulation or a steel casing for tightness.

A vertical bank of boiler tubes is placed between the furnace and the superheater. A water cooled baffle is provided for the roof of the furnace and under the boiler steam drum.

The air heater is of the vertical tubular type with a single gas passage through the tubes and single air passage around the tubes; the gas and air being in counter flow. The forced draft fan will discharge the air into the casing around the tubes and out at the bottom into the hot air duct. From there, the air travels to the windbox and air registers and into the furnace to become combustion gas. Traveling up the radiant section, then across and down the convection section, the gas enters the air heater at the bottom and discharges at the

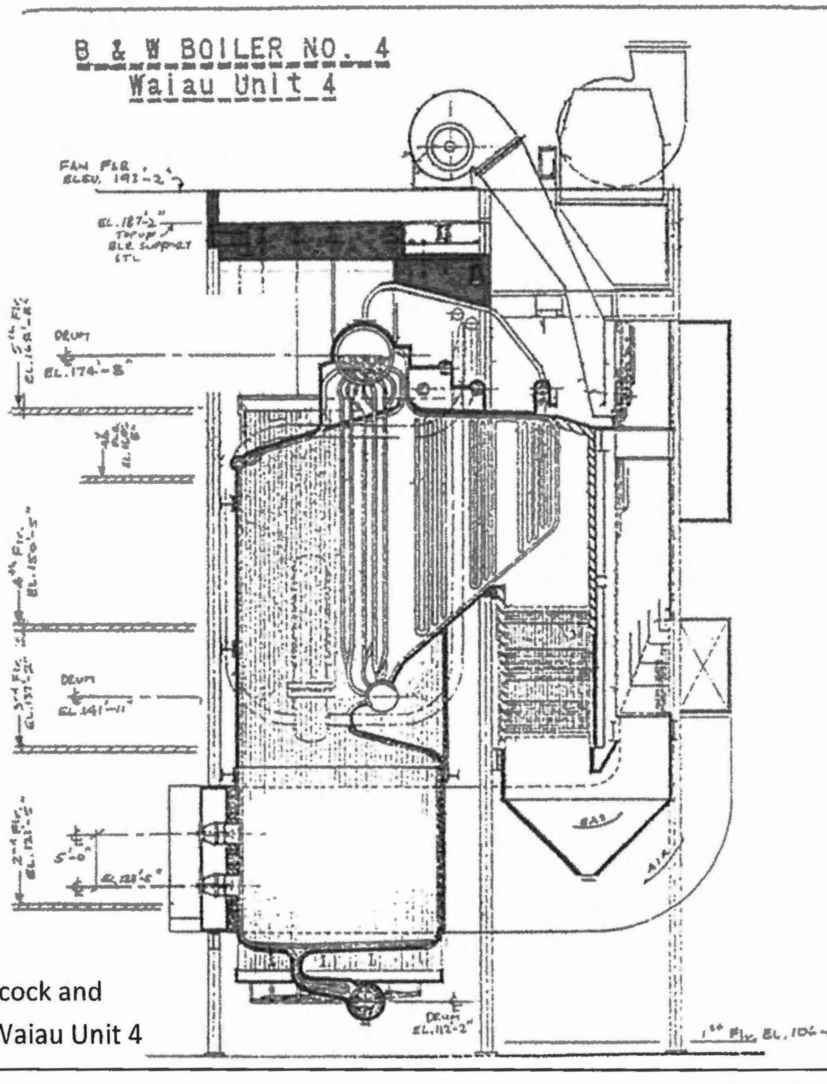


Figure 12.1 Babcock and Wilcox Boiler—Waiau Unit 4

top into an induced draft fan and out the stack.

STEAM GENERATION

The boiler is a Babcock and Wilcox single drum, radiant type with a pressurized furnace with water cooled walls, a continuous tube two-stage superheater, a continuous tube economizer, a Ljungstrom regenerative air preheater, a forced draft air system, and a single spray-type attemperator. The boiler has-a continuous rated output of 485,000 pounds of steam per hour at 1315 psig and 950°F at the superheater outlet. It is capable of producing 506,000 pounds of steam per hour. See Figure 12.2.

The boiler drum is equipped with three safety valves having a total relieving capacity of 545,000 pounds of steam per hour. In addition, there is a fourth safety valve and an electromagnetic relief valve located in the secondary superheater outlet.

The boiler drum is furnished with two water level gauges. A vision duct, using a mirror system, permits remote observation of one of these gauges in the control room. The drum is also provided with a water level recorder and indicator mounted on the control room panel. Five skin

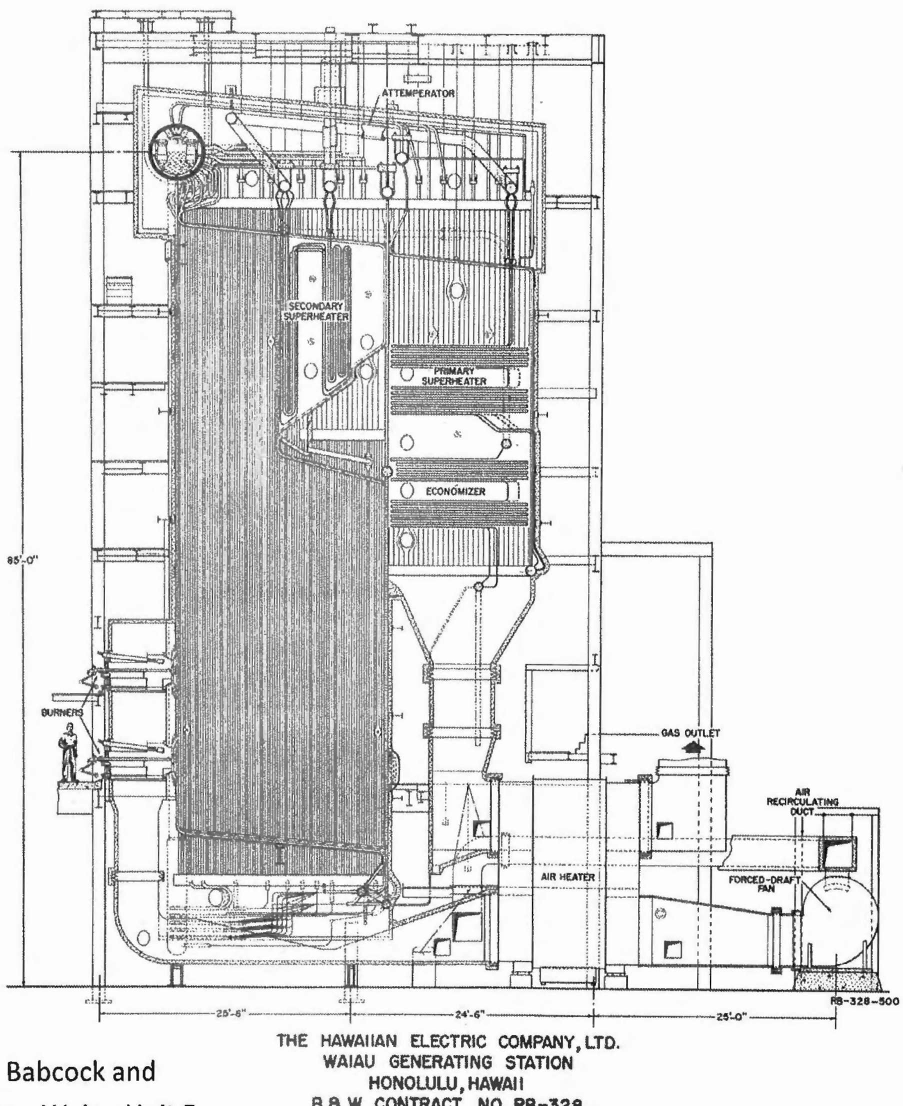


Figure 12.2 Babcock and Wilcox Boiler—Waiau Unit 5

thermocouples arc connected to the boiler drum, nine on the secondary superheater, and one on the saturated steam header for observation of the metal temperatures.

The boiler is fired with oil which is fed through six mechanical atomizing fuel oil burners. To provide for the required 10 to 1 turn down range, the oil burners are designed for an operating oil pressure of 1050 psig and up to 10 inches water gauge air pressure drop across them. As a complement to the turn down range, the forced draft fan is equipped with both inlet vane and discharge damper control. The combustion control system supplements these design criteria in that it goes directly to measurement of the fuel oil flow as a control index, with the quantity of oil fired being controlled by a valve in the return line from the burners in direct proportion to the combustion control loading pressure. In addition, the supply of oil to the burners is controlled in a predetermined relation to oil burned.

OIL FIRING SYSTEM

The furnace is fired by six Babcock & Wilcox manually retractable, air register, return flow, circular fuel oil burners mounted in two horizontal rows of three each. Design normal temperature of the oil is 235° F throughout the entire load range. Each burner is sized for a constant supply flow of 5,350 pounds of oil per hour, with the quantity of oil fired being controlled by a valve in the return line from the burners.

DRAFT SYSTEM

A forced draft fan supplies combustion air to the furnace at a pressure varying from 5 to 16 inches water gauge. The boiler requires quantities of air ranging up to 496,000 pounds per hour dependent upon load conditions. After leaving the fan, air is passed through the preheater and air flow venturi section to the windbox. To protect the cold side of the air preheater from corrosion, an air recirculation system is provided. By recirculating the warm air the average cold side temperature may be increased. The quantity of air recirculated is controlled by averaging the impulses of two thermal elements; one located in the leaving flue gas stream and one in the entering air stream. This average impulse operates a set of flow control vanes in the recirculation duct.

Air passes from the windbox through the burner registers and is mixed with the fuel oil spray to form the combustion mixture.

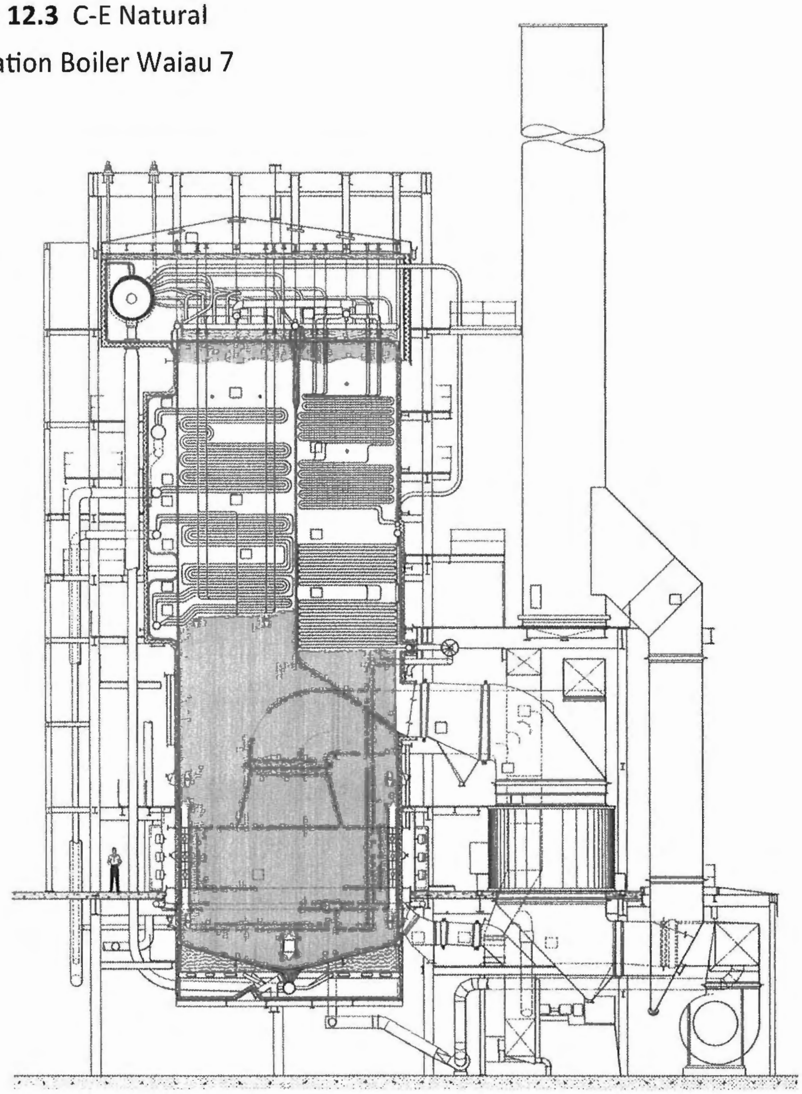
SUPERHEATER & ATTEMPERATOR

The boiler uses primary and secondary superheaters with a water spray-type attemperator located in the line connecting them. Spray water for the attemperator is taken from a point in the discharge line from the boiler feed pumps. Flow of spray water is controlled by the air flow load index readjusted by steam temperature, and with spray water flow tie-back.

ATMOSPHERIC BLOWOFF

The atmospheric blowoff tank serves as a collection point for water and steam from the several water wall header drains and the continuous blowdown line from the boiler. The amount of blowdown is regulated so that the total solids concentration in the boiler will not exceed 1000·ppm. The water entering the tank partially flashes into steam which is exhausted to the atmosphere. The

Figure 12.3 C-E Natural Circulation Boiler Waiau 7



remaining impurities and water are drained to waste.

WATER & SATURATED STEAM CYCLES

C-E Natural Circulation Boiler. The water circuits are shown on Figure 12.3.

Basically the system functions as follows:

Feedwater is supplied to the steam drum, from the economizer outlet header through the two economizer outlet links. The water side of the steam drum is connected with the furnace front and rear wall inlet header through four downtakes.

The front and rear wall inlet header feeds the front and rear furnace wall tubes; the furnace side walls are supplied by the two side wall inlet headers. The front and rear wall inlet header connects with sidewall inlet headers through supply tubes.

The furnace rear wall tubes slope forward and up to form the furnace arch and the furnace wall in back of the front horizontal superheater and reheater sections. These tubes are spread out in the upper part of the furnace to permit passage of the flue gases. The rear boiler wall, in back of the rear horizontal superheater and economizer, is formed by the superheater connecting tubes, which also form the furnace roof.

The water in the furnace side walls absorbs heat. The resulting mixture of water and steam is collected in the outlet headers and discharged into the steam drum through a series of riser tubes. Steam generated in the first two tubes in each side wall is supplied directly to the steam drum. In the steam drum, separation of water and steam takes place. The boiler water mixes with the incoming feed water. The saturated steam is led to the rear horizontal superheater via the superheater connecting tubes.

Passing through the various superheater stages, the steam is superheated to the design superheat temperature. From the front horizontal superheater outlet header the superheated steam is led to the turbine via the main steam line. From the high pressure section of the turbine, steam is returned to the Reheater to be "reheated" to the design temperature. Reheated steam is returned to the remaining turbine stages.

C-E DESUPERHEATERS

The Superheater Desuperheater. One desuperheater is installed in the link leading from the rear horizontal superheater outlet header to the front horizontal superheater inlet header. A steam assisted water spray nozzle is fitted in the entering end of the desuperheater to make it possible to reduce the steam temperature, when necessary, and maintain the same at its design value within the limits of the nozzle capacity.

The desuperheaters are positioned before the high temperature superheater and the reheater to ensure against water carryover to the turbine. This also eliminates the necessity for high temperature resisting materials in the desuperheater construction itself.

AIR AND GAS FLOW

(See Figure 12.4)

Air Flow. Total Unit air requirement is provided by one forced draft fan, which delivers air for:

- Combustion -Main Burners (oil guns)
- Combustion - Pilot Torches
- Sealing- Furnace Openings, Soot Blowers
- Sealing- Gas Recirculating Duct

Main Burner Combustion Air is pre-heated by two regenerative type air heaters which utilize the residual heat of the flue gases leaving the furnace. The combustion air is admitted to the main burner windbox compartments through individual dampers.

Pilot Torch Combustion Air is taken off the

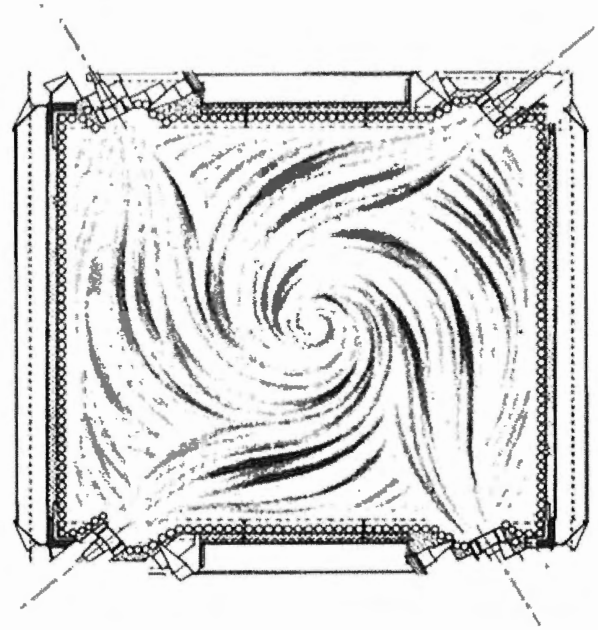


Figure 12.4 - Tangential burner arrangement - view looking down into furnace.

crossover duct connecting the F.D. Fan outlets. It is admitted to the four pilot torch windboxes through the bottom inlet connections. A booster fan with automatic control damper is provided in the pilot torch air supply manifold to maintain a constant air pressure drop across the pilot torch windboxes.

Sealing Air is required to seal off furnace openings (observation ports, soot blower wall boxes, etc.) as the furnace is pressurized. Sealing air is taken off the pilot torch air manifold upstream of the pilot torch fan.

NOTE: Sealing air is supplied continuously and is to be distinguished from aspirating air, such as used to seal off oil guns, observation ports, etc. Aspirating air, which is supplied only when used, is normally compressed air from the station air system.

Gas Recirculating Duct Sealing Air is taken off the burner air duct at the air heater outlet

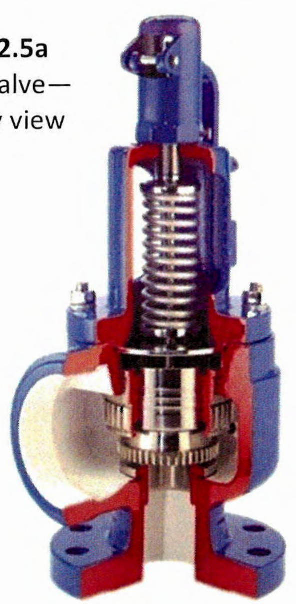
Gas Flow. Flue gases travel upward through the furnace, then downward through the boiler gas pass. From the economizer outlet, the flue gases are led to the air preheaters through two separate ducts. The air heater gas outlet ducts lead to a common stack. A portion of the flue gases leaving the gas pass can be recirculated through the furnace by means of a gas recirculating fan.

SAFETY VALVES

The safety valve (Figures 12.5a & 12.5b) is a protective device designed and set for relieving the boiler steam pressure to prevent exceeding the maximum allowable working pressure by more than 6% at maximum evaporation. At least one valve on the boiler must be set at or below the maximum allowable working pressure. If more valves are used, the highest setting shall not be more than 3% above the maximum allowable working pressure. The blowdown of each valve is set at approximately 3%.

The steam pressure control point for a plant generally maintains a relatively constant pressure at the turbine throttle. As boiler load increases the drum pressure must rise to maintain a constant turbine throttle pressure due to the increasing

Figure 12.5a
Safety Valve—
Cutaway view



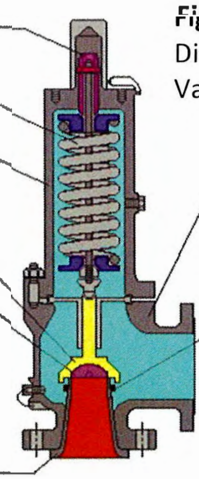


Figure 12.5b
Diagram Safety Vallve

pressure drop through superheater sections. The setting for safety valves on the superheater outlet is lower than any drum safety as it is desirable to have the superheater safety lift first and thus maintain steam flow through these sections for ample cooling.

Most installations make use of an Electromatic Relief Valve (Figure 12.6) to minimize maintenance of the regular safety valves. This valve is located on the superheater outlet and can be isolated for repairs. It is set to relieve before all other safety valves. When on automatic it is actuated electrically from a pressure sensing device with a tap to the superheater outlet or two taps, one from the superheater outlet and one from the drum. It may also be operated manually by a switch located on the boiler control panel. The drum sensor is set to relieve at a higher pressure.

OPERATION

The conventional type safety valve, as seen in Figure 12.5a, is a spring loaded valve with the compressed force of the spring being opposed by the force of the boiler steam pressure acting against the inlet face of the valve disc, Figure 12.7A.

When the pressure force becomes great enough, the load on the relatively small seating surface of the disc will overcome the spring tension and the valve will start to lift, Figure 12.7B. The slight amount of steam discharged is deflected upward. The steam now reacts against the additional area of the lower face of the disc outside of the seat and causes the valve to pop open, Figure 12.7C.

As the steam pressure decreases, the disc assembly will return to the intermediate lift position (Figure 12.7B) and as the area has decreased plus the spring tension the valve

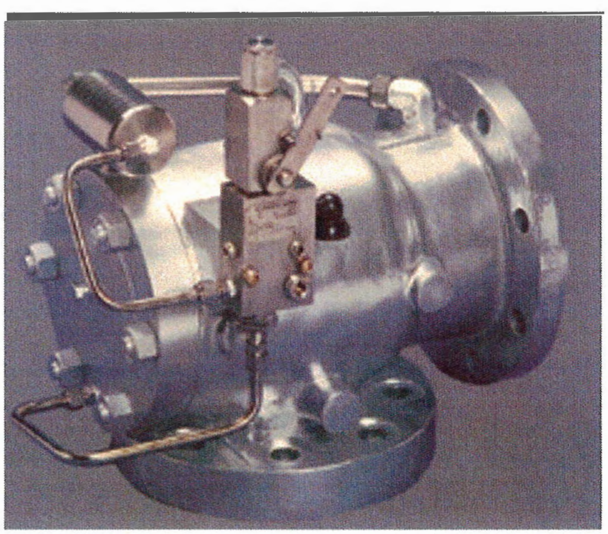


Figure 12.6a
Electromatic Relief Valve

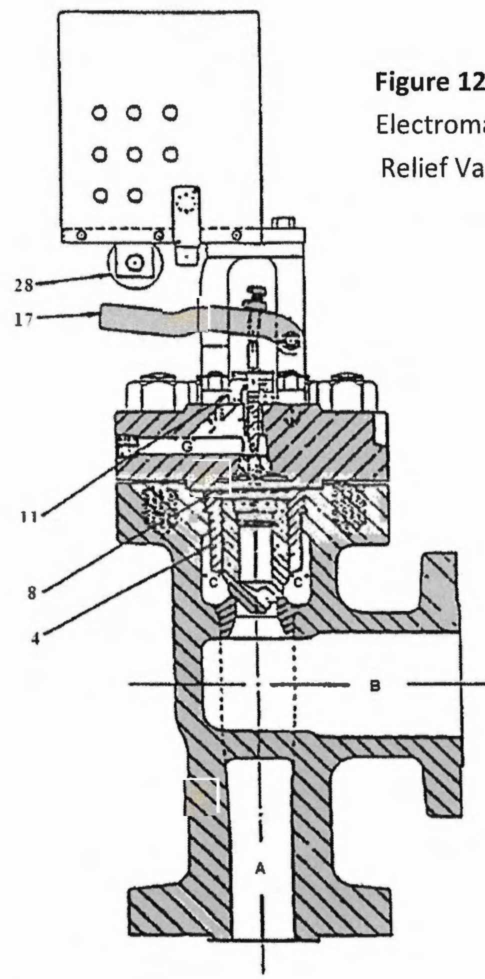
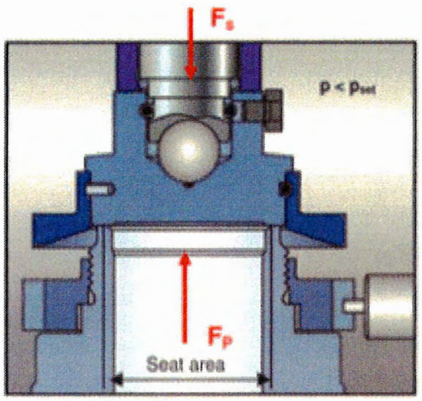


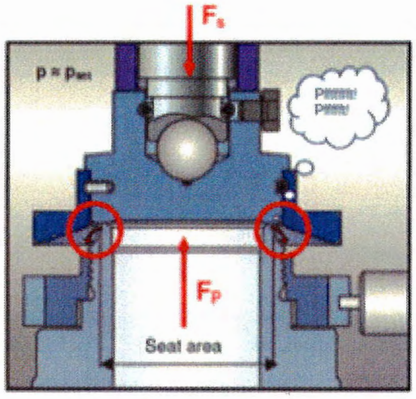
Figure 12.6b
Electromatic
Relief Valve



NORMAL OPERATION

p < p set

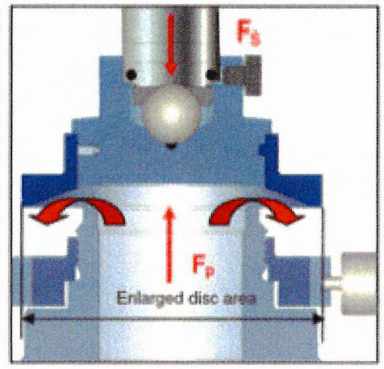
Figure 12.7a



AT SET PRESSURE

p = pset

Figure 12.7b



MAIN VALVE OPENING

p > pset

Image Credit - www.leser.com

Figure 12.7c

will snap shut. The difference in steam pressure between point of valve lift until the valve seats is called the blowdown and should be set for approximately 3% of lifting pressure.

The Electromatic Relief Valve is a pressure relief valve typically controlled by an electrical signal resulting from high system pressure or manually by closing a switch at the boiler control board. It may be set to operate from the pressure sensing line to an electrically operated solenoid which will trigger the relief valve.

Referring to Figure 12.6b, steam under pressure from the boiler enters the main valve through the inlet Chamber A and passes upward around exhaust Chamber B into Chamber C. The main valve disc is held closed by the steam pressure in Chamber E. Steam enters this Chamber E through the clearance space between the main valve disc and its guide 4. The steam pressure is equal in Chambers E and C when the escape through port G is prevented by pilot valve disc 8 being closed. The pilot valve disc is held closed by spring 11 to build up steam pressure in Chamber E. The pilot valve disc will open by operating level 17 under the action of the solenoid plunger head 28.

When the pilot valve opens, steam is released from Chamber E through port G faster than steam is supplied through the clearance space around the main valve plug. The resultant unbalance of pressures in Chamber E and C lift the main valve from its seat permitting the steam to escape from Chamber C to B.

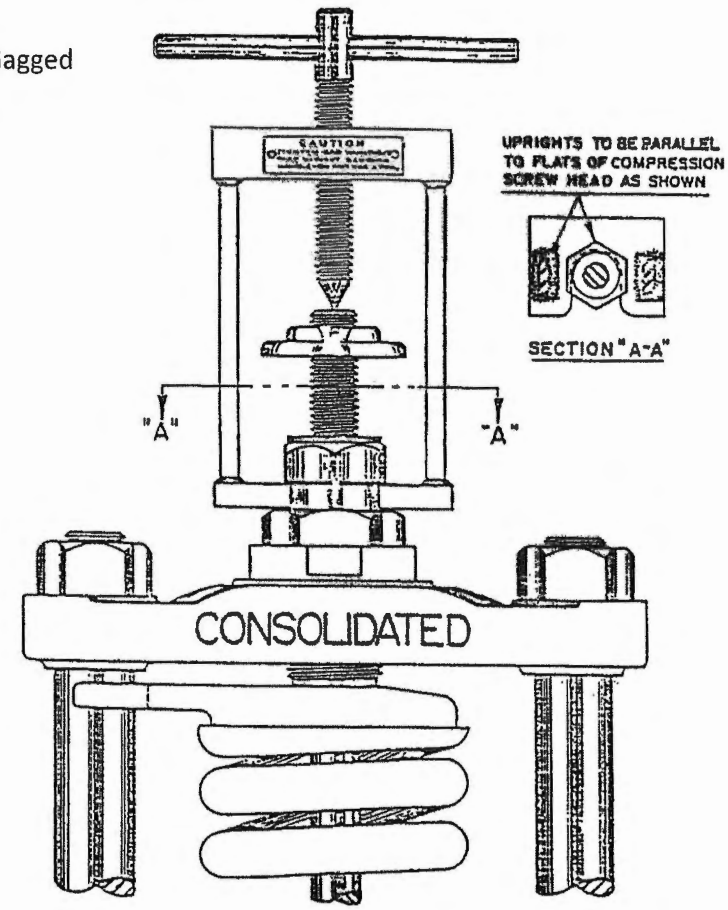
When the pilot valve closes as a result of the solenoid being de-energized (lower sensor pressure) steam is trapped in Chamber E where it builds up pressure and forces the main valve disc to seat, thereby closing the main valve.

The Electromatic Relief Valve is considered in operation when its maintenance stop valve is open and its control switch is set to the automatic position.

GAGGING SAFETY VALVES

Under certain conditions a leaking or weeping safety valve may be gagged. If a gag is not properly applied the safety valve stem may be bent which usually results in further damage to the valve seat and ultimately will cause a shutdown of the boiler.

Figure 12.8 Gagged Safety Valve



The gag must be carefully installed making certain it is straight with the safety valve stem. Without using a wrench, apply the gag load by tightening the handle with both hands using only the wrists for leverage. (Figure 12.8)

A safety valve that is gagged when the valve is hot will usually start to weep again as the valve cools and will require tension applied on the gag. Never leave a cold safety valve gagged and then start up the boiler as the valve will expand from increasing temperature and damage to the valve stem and disc will result.

STEAM DRUM AND INTERNALS

The main steam drum is the highest part of the boiler. It is in the drum where the initial separation of water and saturated steam takes place. The drum is a huge mass of steel weighing many tons. The shell can be up to approximately 6 inches thick by 6 feet in diameter and 40 or more feet long. Refer to Figures 12.9 and 12.10.

The drum generally contains internal equipment for:

- Distributing incoming feedwater.
- Adding chemicals for water treatment.
- Continuous blowdown, to control boiler water chemical limits

Separating steam from the water.

Delivering relative dry steam to the superheaters.

The steam delivered from the drum generally travels through three stages:

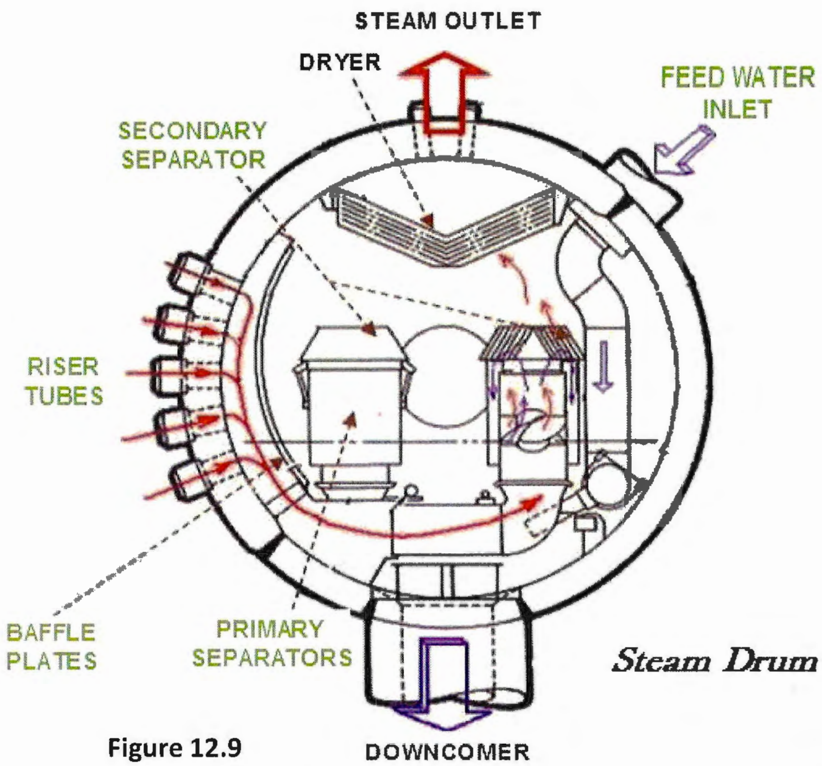
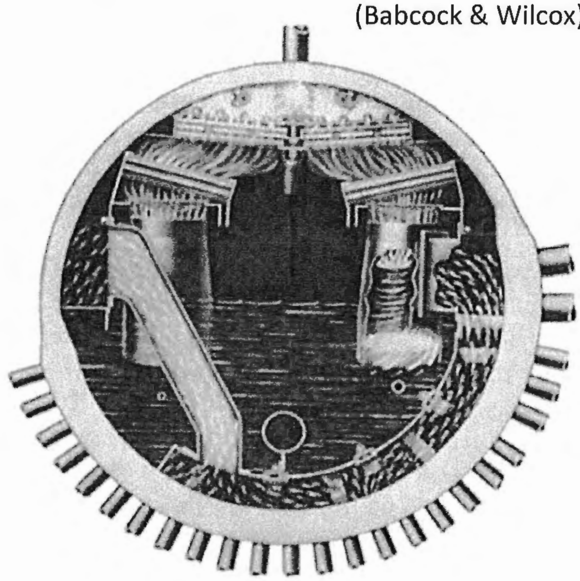


Figure 12.9

Steam Drum

Figure 12.10— Double row arrangement of cyclones steam separators for primary steam separation with secondary scrubber elements at top of drum. (Babcock & Wilcox)



1. Primary separation
2. Secondary separation
3. Dryer

CYCLE

The steam and water entering the drum from the waterwall tubes or risers is collected in an area formed by internal baffles with one or more rows of centrifugal or cyclone separators. As stated previously, the steam is released in three-stages:

Primary Separation. The cyclone separator which is the primary stage and which spins the mixture, thereby throwing the water to the outside and leaving the steam on the inside. Just above the spinner is a skim off lip which captures the water at the outer wall and returns it to the drum through the enclosed area surrounding the inner chamber. The steam then proceeds upward to the next stage.

Secondary Separation. This stage consists of two opposed banks of closely spaced, thin corrugated sheets which direct the steam·in a tortuous- path and force any remaining water against the corrugated plates. Since the velocity is relatively low in this area the water cannot be again picked up from the wetted surface and therefore runs down the plates back to the water in the drum.

Dryer. The third stage is the screen dryer which removes any water still remaining in the steam prior to entering the superheater section of the boiler.

OPERATION

The boiler drum, because of its size, must have prime consideration during its lifetime. Temperature changes must be made gradually during light-off; normal operation, or shutdown. The rate of change should not exceed 80-100°F per hour and the temperature difference between top and bottom of the drum should be limited to IOO°F or less. These figures are a rule of thumb. The boiler manufacturer's manuals have graphs that indicate actual allowable temperature vs pressure and temperature vs time limitations for heating and cooling. Unequal or too rapid heating or cooling of the drum can cause unequal thermal expansion with subsequent high stresses in the drum metal. If the heating and cooling processes are not carefully controlled these stresses can become large enough to damage the drum. Water used to fill a cold boiler drum should not be hot enough to flash. Feedwater slowly to avoid steam and water hammer.

When force cooling a boiler the drum level should be carried as high as possible without carrying over into the superheaters. This will ensure uniform cooling and very little temperature differential between the drum top and bottom.

SOOT BLOWERS

There are many different types of soot blowers used as boiler accessories. Regardless of their type they all have a few things in common, namely the ability to remove ash and soot from boiler tubes by a chilling action as well as by velocity. Usually superheated steam or air is employed in the fireside soot blowers and being cooler than the tube surface the steam will have a cracking effect in removing the soot. The force or velocity of the steam is also effective in cleaning the tubes.

On boilers provided with retractable blowers the steam must not be shut off until the blower is fully retracted otherwise the lance would be damaged due to being exposed to hot flue gas temperatures without any cooling steam flow. Routine lubrication is necessary for all blowers to operate satisfactorily. Correct steam pressure, as controlled through an orifice on each blower, is important for proper operation and area of cleaning.

Under normal conditions a soot blowing lance should remain turning as long as it is in the furnace and has steam flowing through the lance. This is to protect the boiler tubes from impingement in case the steam is striking them. Some blowers have two separate motors, one for travel and one for rotation.

Retractable blowers are provided with one and often two venturi type openings near the end of the lance, they clean a wide area by moving the lance in and out along the tube banks while turning in a 360° arc.

Stationary blowers remain inside the cooler section of the boiler, usually the economizer area, and have a row of openings along the length of the lance for cleaning. This type of lance also turns in a 360° arc.

Usually boiler loading should be between one-half and full load before blowing soot, to ensure enough draft to carry the soot out of the furnace and up the stack. Frequency of blowing soot depends largely on the type of fuel used. Generally once a day or more often when burning oil and once a month or more when burning gas fuel. Steam supply headers must be free of water before blowing soot. Steam supply header drains should be left open when not blowing soot.

Always start blowing soot in the hottest section of the boiler and blow toward the coolest section, blowing in this sequence allows the loosened soot to be carried along with the flue gas and out the stack.

Retractable soot blower carriage areas must remain free of foreign material, otherwise the blower may be damaged as it operates.

MANUALLY OPERATED BLOWERS

This type of blower is found on some of the earlier boiler installations. They may be of the chain operated type, the hand crank type or the semiautomatic, air operated type with air and steam operated manually. When the chain or hand crank is moved the steam valve opens and the blowing starts. This type of blower remains inside the cooler section of the boiler.

For best results the blower should be turned slowly and take approximately 20 seconds for each revolution. The blower should be operated until the stack exit gas is clear which indicates a clean area. With the 360° cam type blower, at the end of the blowing cycle the rotation of the blower must be reversed to permit a trigger to engage with the opening valve cam in order to close the steam valves.

The semi-automatic type of air operated retractable blower operates in the following manner. The air is turned on to the air drive and when the lance starts to move inward the steam supply is opened. The lance should be observed turning and moving steadily into the furnace. When the lance reaches the end of its travel a limit switch will reverse the air drive and retract the lance.

When the lance is fully retracted the steam supply is manually closed and the air motor stops. The air supply must then be shut off to the drive motor.

Air preheaters must be blown after all the other soot blowing is completed. Refer to the air preheater section for further details.

AUTOMATIC BLOWERS

The later installed boilers have fully automatic sequential operation of the soot blower units. Some are air motor and some electric motor driven. Individual operation of any blower is possible from the control panel or from a push-button station located near each blower. The control panel's function is to automatically operate the selected blowers in sequence, indicate normal operation and provide adequate alarms for the protection of the blower system.

Alarms associated with soot blowing are:

- Blowing header pressure low.
- Control air failure.

BOILER WATER TREATMENT AND CONTROL

Chemical control of the boiler water should be given prime consideration. The treatment specified may vary according to plant location and boiler design but the basic objectives of boiler water treatment are always the same. They are:

- To minimize corrosion.
- To keep the boiler clean, prevent or minimize scale or deposit formation.

- To keep the steam pure, minimize carry-over of solids and silica with the steam into the superheater and turbine.

CORROSION CONTROL

Oxygen Removal. It is a known fact that iron rusts in the presence of oxygen and moisture. This process speeds up as temperature rises. In boiler feedwater, most of the dissolved oxygen is removed by mechanical means either through a deaerator or a deaerating section of the main condenser. To remove the last trace of the remaining dissolved oxygen, a chemical oxygen scavenger is used. In a lower pressure boiler (below 1800 psig), sodium sulfite is injected into the boiler water. For a higher pressure boiler (over 1800 psig) a proper amount of hydrazine (according to dissolved oxygen concentration) is injected into the feedwater before it enters the boiler. Sodium sulfite will react with oxygen to form sodium sulfate and hydrazine will react with oxygen to form nitrogen and water. To illustrate the harm that can be done by a little oxygen remaining in the water after deaeration, consider that one pound of oxygen takes at least three and one-half pounds of iron from the boiler. If there were one part per million of oxygen in the feedwater of a boiler steaming at 850,000 lb/hr, every hour the .85 pound of oxygen would remove 2.97 pounds of iron. While boiler drums have thick walls the tubes do not, especially when oxygen attack usually takes the form of localized pits. It would not take too much iron removal for a pit to go through a tube wall.

Alkalinity in pure water with the absence of oxygen, iron will react with water to form iron oxide and hydrogen. The rate of reaction depends on the alkalinity of the water. To measure alkalinity, a pH scale from 0 to 14 is adopted with pH 7 as neutral. When the pH of a water is below 7, it is acidic; when it is above 7, it is alkaline. It is found that with a pH of 9-11, depending on operating pressure, the corrosion rate of iron is at the minimum. At a pH higher or lower than these values, the rate of attack increases. The pH of boiler water can be maintained, in most cases, by keeping the sodium phosphate and sodium hydroxide concentration within the established control range. For a newer boiler, pH determination with a meter is required as part of the control. The later installed boilers are provided with dissolved hydrogen analyzers on the drum steam and main steam to monitor this type of corrosion. If the dissolved hydrogen value increases without a change in boiler load, the cause should be found immediately and corrective measures should be taken.

KEEPING THE BOILER CLEAN

The danger of a scale or deposit formation is its interference with proper heat transfer in a boiler tube. Even a thin coat of scale or small patch of deposit in a high temperature zone can result in overheated metal and a ruptured tube. Most of the deposits found in a boiler are corrosion products - iron and other metal oxides. We can again see the importance of maintaining boiler chemical control to keep the corrosion rate as low as possible. Scale is formed by the impurity of feedwater. Even the best of feedwater contains minute amounts of impurities. Contamination of feedwater systems such as condenser leaks can add a large amount of scale forming materials in a short period of time.

Sodium phosphate and sodium hydroxide in the boiler water can react with the scale forming materials, calcium and magnesium salts, and form a precipitate of calcium phosphate and magnesium hydroxide, which can be removed by boiler blowdown. During the period of contamination and high blowdown rate, boiler chemical concentrations should be maintained in order to protect the boiler from scale forming and from increased rate of corrosion. The source of contamination should be found and corrected as soon as possible.

KEEPING THE STEAM PURE

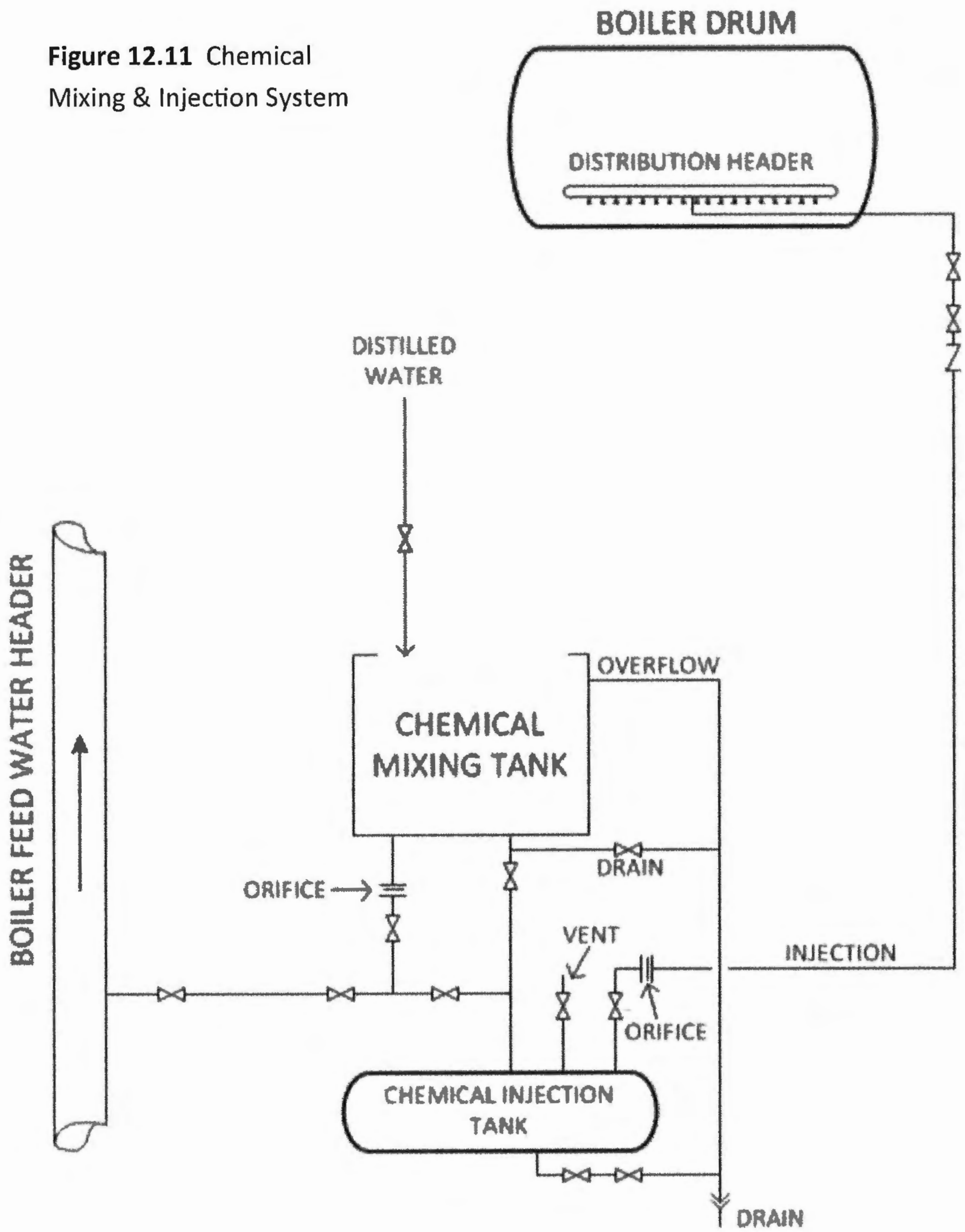
All solids that dissolve in boiler water have a tendency to be carried over with water droplets into the steam. These solids will eventually deposit on the superheater tubes and turbine blades. By controlling the total dissolved solids in the boiler water, carry-over can be minimized. The test normally used to indicate the relative amount of total dissolved solids is suppressed conductivity. It means essentially the suppressing of the higher conductivity of sodium hydroxide so that a reasonably direct relationship is obtained between total dissolved solids and conductivity. When tests indicate a high value, the boiler should be blown down.

Silica is another chemical control encountered in a power plant. Silica leaves the boiler as a vapor and condenses on the turbine blades. Since the quantity of silica that vaporizes varies with boiler pressure (temperature), silica concentration in the boiler water, and boiler water pH (alkalinity), limits are established on the various boilers consistent with these factors. In maintaining the established silica control limits, the decrease in turbine efficiency due to the deposition of silica is minimized. Control of the amount of silica in the steam below a specified amount is accomplished by establishing a maximum boiler steam drum pressure for a given silica concentration in the boiler water. A high concentration of silica in the boiler water is decreased by blowing down until silica is low enough to operate the boiler at normal operating pressure.

So far we have discussed the treatment and control, now we must find ways of actually injecting the desired chemicals into the boiler to aid in this control. The system is referred to as chemical mixing and injection system. This system consists of an open mixing tank where the chemicals are dissolved using either cool distilled water or hot boiler feedwater, Figure 12.11. Extreme care must be exercised when using the boiler feedwater because of its high pressure and temperature. A thorough mixing of the chemicals is necessary for proper injection into the boiler drum. Also if not properly mixed, the lines leaving the mixing and injection tank may plug. This not only results in inadequate injection of chemicals but also results in maintenance repairs to unplug the lines.

The chemicals are mixed in the mixing tank. The chemical injection tank must be drained of all water. The chemical solution drains from the mixing vessel to the injection tank. When the injection tank is full the tank is ready to be pressurized with feedwater. The valve to the drum may then be opened allowing the feedwater pressure to force the chemicals into the boiler drum. The injection line to the drum is provided with an orifice to ensure a slow feed and the header in the drum ensures an even distribution to all boiler circuits. Safety precautions must be adhered to when

Figure 12.11 Chemical Mixing & Injection System



handling boiler chemicals. If the concentration of chemicals in the boiler water is above limits another cycle must come into play. This is called the continuous blowdown system or just plain C.B. This system consists of a distribution header in the drum similar to the one shown in Figure 12.11.

BOILER GAUGE GLASSES

One or more gauge glasses are installed on a boiler drum to allow for visual observation of the water level. Figure 12.12 illustrates a typical glass, of an earlier designed boiler, in relation to the drum internals.

The gauge glasses are installed with lights, mirrors and ducting arrangements so the level may be observed from the control

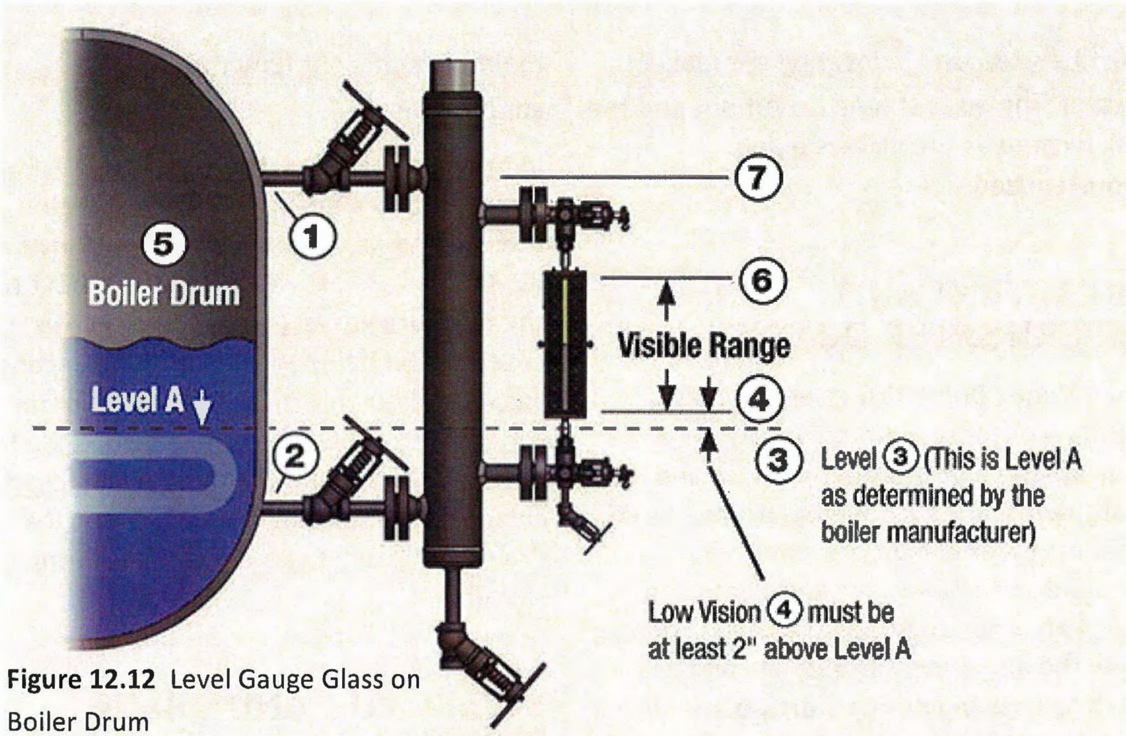


Figure 12.12 Level Gauge Glass on Boiler Drum

room area. The actual level is indicated by a light showing on the surface of the water level or by a color combination; green indicating water level and red steam space above the water level.

The gauge glass is provided with normally locked open drum stop valves to the upper (steam) and lower (water) portion of the water column or, as it is sometimes referred to, the circulating tie bar. The water column or tie bar provides circulation of steam and water and allows even temperature through the equipment external from the drum. The gauge glass is a part of or is attached by valving to the water column. This depends on the type and the manufacturer.

The gauge glass cock valves are installed so that both upper and lower valves may be operated remotely by a chain (Figure 12.13). This is necessary in case a gauge glass failure accompanied by heavy steam blowing occurs. The gauge glass can be secured from a distant point.

Chains being in place on the gauge glass cock valves are very important to assure safe operation. The only time the chains should be removed from the valve wheels is to repair the gauge glass. The only time the drum stop valves should be closed is to repair the chain operated gauge glass cock valves. If the gauge glass is leaking, caution

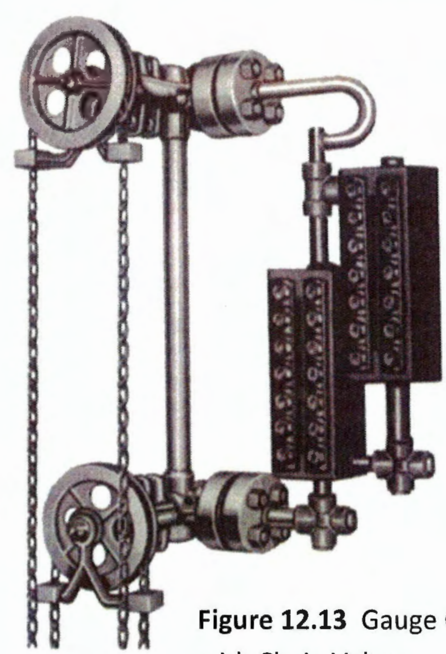


Figure 12.13 Gauge Glass with Chain Valves

must be exercised in locating the leaking section. The glass should be cut out and the leak located as the glass is being depressurized.

DRUM VENT AND SUPERHEATER DRAINS

Drum Vents. Boiler drums are provided with one or more vents to atmosphere. They are used only during start-up and shutdown. During a boiler shutdown large amounts of air will be present in the waterside of a boiler because vents and drains are open to atmosphere. In order to expel the air as soon as possible and as much as possible during start-up, the drum vents must be open as pressure is being raised on a boiler and closed when the boiler pressure reaches approximately 25 psig.

To keep the waterside of a boiler from going into a vacuum when shutting do the drum vent(s) should be open when the pressure has decayed to 25 psig. Usually unnecessary leaks develop when a boiler goes into a vacuum as header caps and drum manholes are pressure sealed and not designed to withstand a negative pressure.

Superheater Drains. These serve two distinct purposes:(1) provide a means of flow through a superheater bank when starting up a boiler and (2) provide a means of removing water or moisture from the superheater during a boiler start-up.

Normally all superheater drains are opened prior to lighting off a boiler. The drains are throttled or closed as the temperature indicates the superheater is dry. The outlet or final superheater drain, though throttled, should be left open until the boiler is supplying enough steam to the turbine to maintain sufficient flow through the superheater.

In most installations, the superheater drains are routed to a blowdown tank or well through a dual valve arrangement. Any time dual valves are provided, the valve next to the pressure vessel (superheater in this case) should be open wide and the second valve used for throttling. A plugged drain can cause trouble when starting up a boiler. Because of this, drains should be checked clear prior to shutting down a boiler. If a drain is plugged it can be opened during the shutdown.

BOILER FILL AND DRAIN SYSTEM

Boilers in general may be filled through their blowdown headers and drain lines by means of a common boiler water transfer system or directly from the distilled water system. Depending on the type of installation, the boilers may be drained using the same piping arrangement to the boiler water transfer tank, the blowdown tank, the blowdown well, the acid pond, or directly to the sewer.

Those units utilizing a boiler transfer system, consist of a transfer tank, pumps, and necessary headers to supply a number of boilers. Other units have only distilled water pumps taking suction from the distilled water tank and through headers to supply one or more boilers.

Regardless of the system, the boilers should be filled in much the same way. The drum vents must be open and the gauge glass available. If a transfer tank is used, the tank must be filled with distilled water.

In lining up the boiler valving to start filling, it is very important that valving to other boilers connected to the fill header be checked over thoroughly and properly secured. Also the fill and drain systems are usually divided in two sections, a low pressure section (transfer) and high pressure section (blowdown) because of this, proper valving is important. Usually the low pressure section is protected from over pressurizing by a relief valve. One further check that should be made, the blowdown header valving to waste must be checked closed.

Prior to filling the boiler the transfer system should be flushed. If it is possible to have contaminated water in the transfer headers, the water must be recirculated and tested. Boiler filling should always be carried out from the lowest possible point of the boiler. This is necessary as filling from the bottom forces the air upward to the drum and vent. The vent prevents trapping air in the boilers. It is also desirable to fill from the bottom as the water usually used for filling is low in dissolved oxygen. If filled from the top, the water splashing down would pick up O_2 from the air bubbling up through it. In some installations, filling would be through the Yarway blowdown valves and into a mud drum or downcomers. Other boilers are provided with lower waterwall headers that have drain and fill valves. The economizer, if installed, is provided with an individual fill line and valve connected between the fill header and the economizer.

When conditions are such that filling can start, the lower filling valves and the economizer fill valve may be opened. The boiler transfer or distilled water pumps may be started to fill the boiler to the desired level in the drum. For boiler start-up, one or two gauge glass ports are usually sufficient. The boiler setting must be patrolled periodically during the filling operation. Filling for a hydrostatic test is covered later in this section.

When the filling is complete all fill valves must be closed and the pumps shut down. When the economizer fill valve is closed the economizer recirculation· valve should be opened. This will provide assurance that the economizer stays full of water with a level showing in the drum.

In draining a boiler, the same piping and valves are used as in filling. Pressure must be otf the boiler and the drum vents open.

In earlier designed plants a boiler water transfer system is usually used. In this case, the water may be drained to the transfer tank or to waste.

On boilers designed with economizers it is possible to fill or drain only portions of the boiler. The drum and economizer may be drained through the economizer and the waterwalls not affected. Also the waterwalls may be filled or drained and not affect the economizer. This is helpful as in the case of an economizer tube leak, it is not necessary to drain the whole boiler in order to make repairs. As long as the economizer recirculation is closed and the drum and economizer is drained, no water can flow into the economizer from the waterwalls.

AIR PREHEATERS

Two types of air preheaters may be provided, a tubular type, Figure 12.14, whereby the hot flue gases pass through the tubes and the air on the outside of the tubes, thus cooling the flue gases and heating the air for combustion. As this type of preheater has no moving pans there is little to discuss other than the preheater is a heat exchanger. However, such things as acid dew point, cold end average, steam air heaters, etc., do apply and are covered in the following discussions on rotating type air preheaters. The rotating bundle type (Ljungstrom) is the most recent type, in which the bundle is revolved through the hot gas and cold air side of the boiler and the heat transfer is from heating and cooling the bundle. The following discussion will cover the Ljungstrom type as all later installed boilers are provided with these rotating air preheaters.

One or two (depending on boiler) Ljungstrom air preheaters are provided for each boiler. Combustion air from the forced draft fan passes through one side of the heater while hot flue gas from the boiler passes through the opposite side. The heater consists of a rotating cylinder with internal heating surfaces. Some are installed horizontally and some vertically. Figure 12.15 shows a vertical unit and Figure 12.16 shows a horizontal unit.

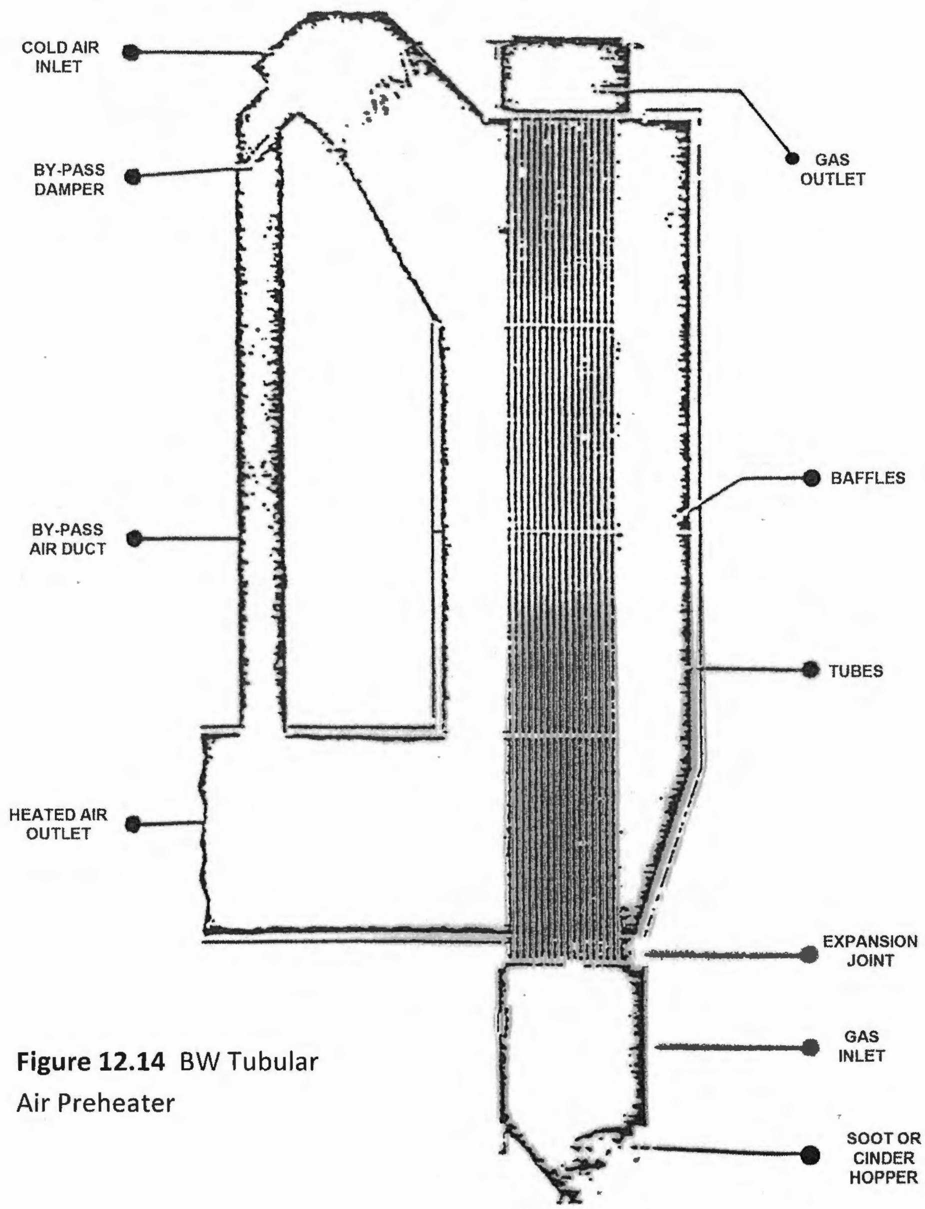


Figure 12.14 BW Tubular Air Preheater

Figure 12.15 Vertical Air Preheater

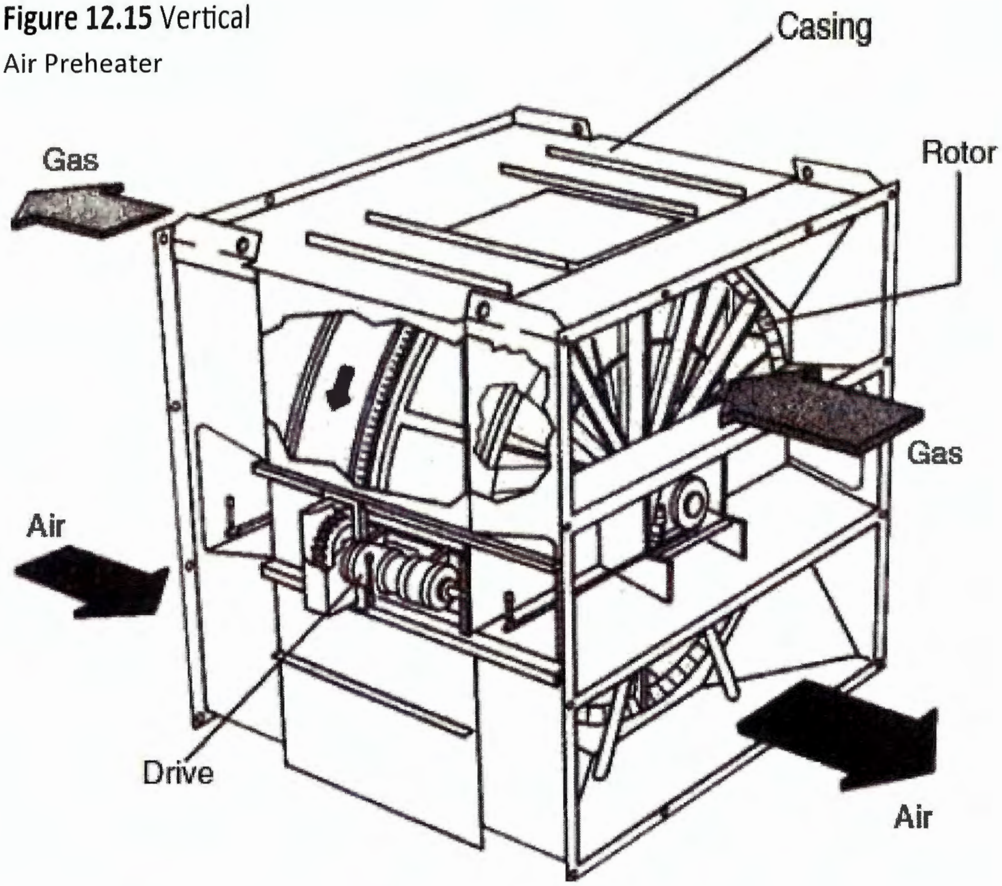
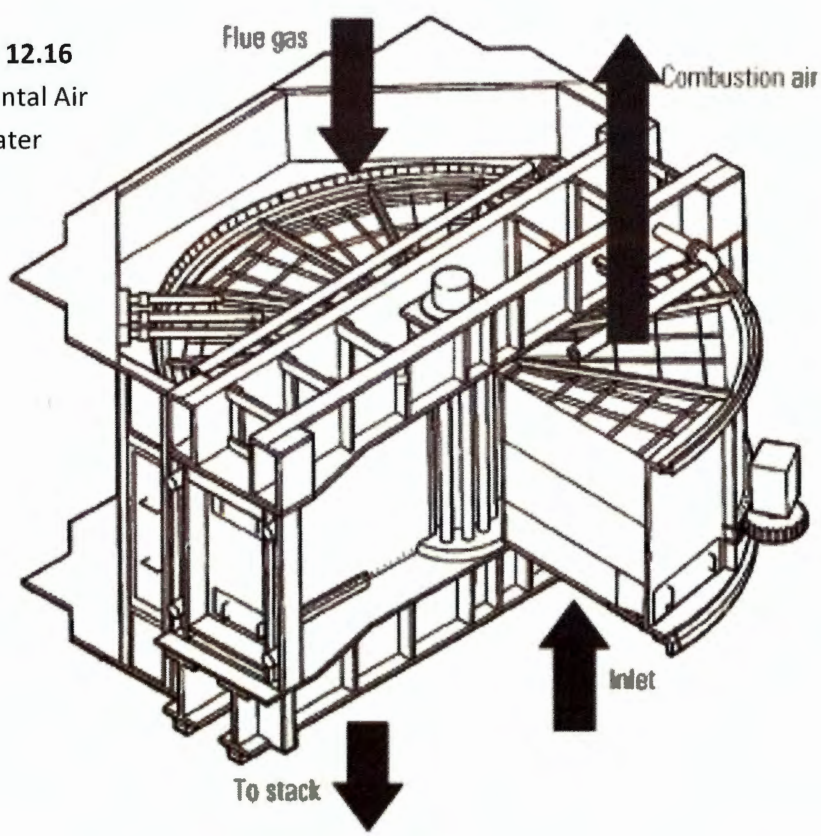


Figure 12.16 Horizontal Air Preheater



Heat transfer is by the regenerative process in which the rotating element is heated while passing through the hot gas and gives up its heat to the air as it passes through the air side.

As the flue gas is being cooled in its travel through the air preheater bundle, a practical limit of thickness of the bundle is reached in the design. Corrosion will begin if the gases are cooled to a dew point temperature. Acid is formed from the combination of sulphur products in the fuel with water vapor. Metal temperatures may be controlled above the so-called dew point of the gases by bypassing incoming air, recirculating air or by the use of steam air heaters.

If the cold end average gas temperature which is the average between the incoming air and the flue gas outlet, is controlled at 145°F while burning gas fuel and 185°F when burning oil fuel, very little or no corrosion should take place. The temperatures are approximate as the control point depends on the amount of sulphur in the fuel. The element is rotated by an electric drive motor or an air motor drive is provided for backup. The electric drive operates the unit at 1-3 rpm through a speed reducer while the air drive is approximately 1 rpm.

An interchange of hot gases and cold air within the unit is held to a minimum by radial, circumferential, and rotor post seals. These seals form a definite air passage through one-half of the heater and gas passage through the other half.

Each air preheater is further provided with manually operated water washing devices and automatic soot blowing devices.

The later designed preheaters have an oil bath plus a forced lubricating system which is automatically started or stopped by a temperature sensor. The earlier boilers have only the oil bath for lubrication with cooling water jackets.

AIR PREHEATER OPERATION

The air preheater lubricating oil systems and cooling water must be available when starting up. If the air preheaters are available for service their manual isolation dampers must be open and they should be in operation during the boiler purge.

When burning oil fuel, the air preheater must be in service and should not be shut down. This air preheater operation is different from gas burning as combustible deposits which could ignite are most likely to collect on the preheater surface when starting up a cold boiler on oil fuel.

During normal boiler operation the air preheater requires nothing more than routine inspections such as looking for oil leaks, adequate cooling water, oil temperatures normal (less than 125°F), and listening for rubs or any unusual sounds. The circumferential seal can be inspected from the inspection ports provided and should be checked periodically.

If an air preheater stops, with the boiler in operation, every attempt must be made to restore it to service with the electric or air drive. Otherwise permanent damage to the bundle can result due to expansion if the flue gas temperature is above 900°F. It is usually necessary to reduce load and/or close manual dampers to keep the flue gas temperature within allowable limits. Operation at this temperature must be limited to the time necessary to restart the air preheater.

To eliminate the possibility of an air

preheater fire, soot must be blown on a regular schedule. Any time fireside soot has been blown, the air preheaters must also be blown. When burning oil fuel, the air preheaters should be blown at least once a shift. When burning gas fuel, once a week is usually sufficient.

In shutting down a boiler, the air preheater's soot should be blown before the fuel is tripped. The air preheater normally remains in operation until the gas inlet temperature reaches 350°F or less.

If the boiler is shut down for an extended time such as an overhaul, the air preheater is usually washed with water during the outage. This further aides in maintaining clean surfaces and helps eliminate the possibility of a fire when starting up. How the air preheaters are washed differs from plant to plant.

AIR PREHEATER FORCED OIL SYSTEM

The oil system is designed to supply the support bearings with a bath of clean oil. To accomplish this, the oil is circulated by means of a motor driven pump through a filter and cooling system.

AIR PREHEATER DRIVES

The air preheaters are provided with two types of drives, an electric motor with an air motor drive as backup. The drives for turning the rotor are usually applied at the outer edge of the bundle. A pin rack mounted on the rotor engages with a pinion which is a part of the drive after the speed reducer. Operation of the electric or air motor, through the speed reducer will rotate the air preheater.

The air motor drive may also be used to control the speed of the rotor during water washing of the air preheater. The electric and the air drives should never be engaged at the same time. In the most recent installations, it is only necessary to shut down the main electric drive and start the auxiliary drive.

AIR PREHEATER CLEANING DEVICES

The air preheater soot blowing system consists of an electric or air driven blower coupled to a gear driven crank mechanism which moves the steam blowing nozzle. The arc covered by the nozzle subjects the entire area of the preheater bundle to the cleaning action of the nozzle. To maintain the desired steam pressure, usually 200-250 psig, an orifice is installed in the steam line to the blower.

The steam used for blowing the air preheaters must be dry. As the steam for the fireside blowers is usually saturated steam from the drum, it is necessary to provide a separate steam supply for the air preheaters. Dry steam from after the primary superheater section of the boiler is usually used for this purpose.

Before blowing the air preheaters, the steam headers must be drained of any wet steam and condensate. A complete blowing cycle consists of one pass across the bundle heating surface, usually adjusted for blowing from the outer edge of the bundle toward the shaft. When the arc of the nozzle reaches the center of the bundle the steam is shut off. The nozzle will change directions and move to the outer edge of the bundle before stopping.

Air preheaters are washed when the boiler is shut down and the bundle temperature is 300°F or less. The cleaning device for washing may be of three (3) types:

1) a combination steam or water device
2) a separate washing device which is no different than the steam blower
3) a header arrangement installed above the bundle with evenly spaced nozzles and the whole bundle is washed at one time.

The soot hopper blank flanges and drain valves must be open before water washing. In plants that have the boiler water transfer system, the water used for washing is usually water drained from the boiler. In other plants it is usually a convenient source such as station service, raw water, or fire water.

Water washing may be done automatically and in zones (or three sections) across the bundle or the wash system may be operated manually. The washing is done on both passes of the nozzle across the bundle. The washing is usually considered completed when the pH of the drains is higher than 6.0.

DRAFT EQUIPMENT- FANS

A fan is a pump designed to handle gases rather than liquids.· Just as with pumps, there are many different types of fans. The fans used for boiler draft applications, however, are always of the centrifugal type.

Forced Draft Fans must supply the total volume of air required for combustion at a discharge pressure sufficient to overcome the flow resistance in the ducts, steam air heaters, air preheaters, and windbox. In the newer installations the forced draft fans must also overcome the resistance of the total boiler flue gas pass to the stack.

Induced Draft Fans must create a sufficient pressure differential to cause the required quantity of flue gas at full load to pass through the resistances from the furnace to the fan and discharge to the stack at approximately atmospheric pressure. Additional capacity must be built into each fan to offset leakages and infiltrations.

Combustion air for each boiler is supplied by one or two forced draft fans. The fan(s) takes suction from the atmosphere and discharges air through the steam air heaters and the air preheater(s) to supply ducts and on to the windbox. The supply ducts contain metering orifices and in installations with dual fans and air preheaters, manual shutoff dampers are provided ahead of the air preheater.

The F.D. fan(s) is a horizontal, centrifugal unit with a constant speed of approximately 1200 rpm. The F.D. fans usually have backward curved fan blades which produce low air velocities for a given fan speed, Figures 12.17 & 12.18. Air is controlled by means of inlet vanes and aided by dampers in the discharge duct.

Flue gases leaving the boiler pass through the gas side of the air preheater(s) to an associated induced draft fan. The I.D. fan(s) discharges into the boiler stack. On some installations manual dampers are provided on the stack side of the air preheater.

The I.D. fan(s) is a horizontal centrifugal unit with a constant speed, 500-600 rpm (depending on plant). The I.D. fans are usually provided with forward curved fan blades which produce high flue gas velocities for a given fan speed, Figure 12.19. In some installations the I.D. fans may have straight fan blades which produce

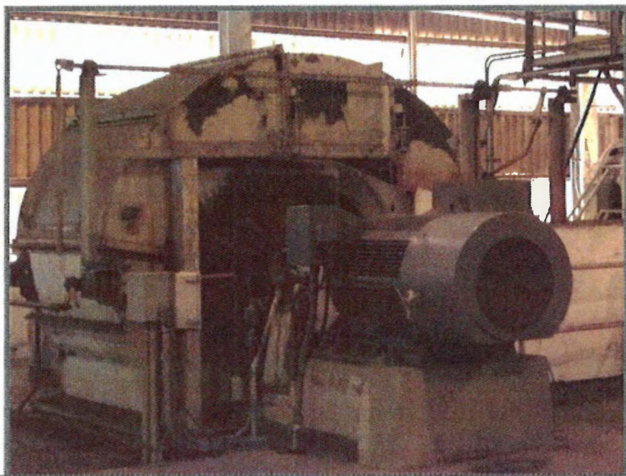
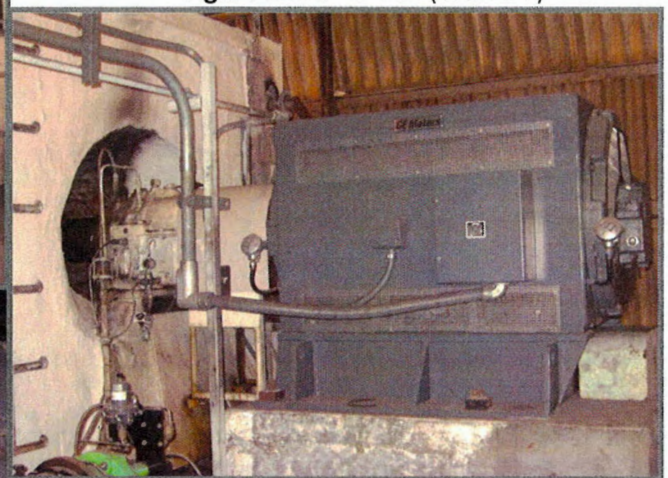


Figure 12.17 FD Fan (Waiau 3)

Figure 12.19 ID Fan (Waiau 3)



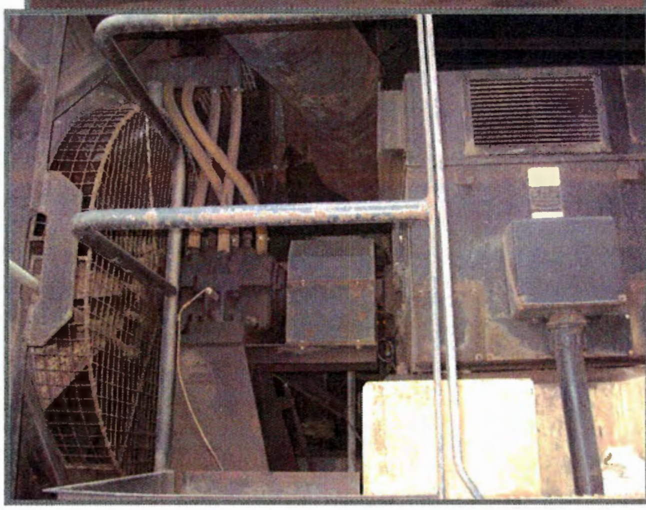


Figure 12.18
FD Fan Blades

velocities somewhere between the forward and backward curved blade velocities. Flue gas flow is controlled by means of inlet and outlet dampers. As the I.D. fan is handling hot flue gas the fan housing and duct is insulated. In later installed boilers the fan is not provided. The entire boiler setting is under a positive pressure and to prevent hot gases from leaking to atmosphere the setting is air tight.

Flue gas recirculation fans are used to control reheat temperature and assist in the control of Nitric oxide emissions from the stack. The fans operate at constant speed, approximately 900 rpm. Hot gas is diverted from the boiler outlet duct and discharged by the recirculation fan back into the furnace below the bottom row fires and also in a higher section of the furnace above the top row burners. Another way to introduce hot gas back to the furnace is to direct the gas by ductwork to the inlet side of the forced draft fan. Approximately 15% of the forced draft fan capacity is utilized to accomplish this. In some installations, leaving the top row of fires out of service but the draft registers open and reboring larger openings in the fuel burning equipment assists in Nitric oxide control. The theory behind the above mentioned conditions is the control of furnace temperature. The formation of Nitric Oxide increases very rapidly as furnace temperatures increase above approximately 2900°F. Due to changes made to assist in Nitric Oxide (NOx) control the configuration of combustion in the furnace changes. The "fire" now bums in a greater area of the furnace and so must be controlled to keep upper areas of the boiler free of flame.

The recirculation fan(s) is horizontal, centrifugal, and driven by an electric motor. Gas flow is controlled by means of inlet dampers. If the recirculation fan(s) is shut down the dampers close and sealing air is automatically admitted between suction and discharge dampers to keep from circulating hot .gases through the fan(s) and to prevent bypassing the normal furnace path if the dampers are not completely tight.

The fan bearings for all three types of fans just covered are self-lubricated and jacketed with water cooling from the closed cooling water system. The fan motors are air-cooled. The fan motors have only fibrous filters to keep the circulated air that passes across the motor rotor and windings clean.

One further part of the draft equipment worth mentioning is the boiler stack. The stack is used to discharge the products of combustion at an elevation high enough to avoid their being a nuisance to the surrounding community. The higher the stack the more draft will be available to help pull the hot gases out of the boiler.

Alarms associated with the boiler F.D. and I.D. fans are as follows:

Bearing temperatures.
Motor winding temperature.
Motor overcurrent.
Low fan speed
Undervoltage

The recirculation fan is protected by:

Bearing temperature.
Motor winding temperatures.
Motor overcurrent.
Undervoltage.
Temperature between dampers.
Temperature after dampers.
Low fan flow differential trip.
Fan dampers open.

BOILER SEALING AND COOLING AIR

Because some boilers are designed as a pressurized unit it is necessary to have cooling and sealing air. Its purpose is to keep the hot flue gases within the furnace enclosure. The various pieces of equipment and boiler sections supplied with sealing and cooling air are as follows:

Soot Blower. Air seals are provided where the blowers penetrate the furnace.

Boiler Inspection Ports. Sealing air is supplied to the ports when they are closed. For opening, the port doors are interlocked mechanically with aspirating air, supplied by the station air system.

Boiler Void or Penthouse. The boiler penthouse is the enclosed area above the furnace roof. This area usually contains the boiler steam drum, upper waterwall and division wall headers, and superheat and reheat headers. It is usually pressurized with sealing air at forced draft fan discharge pressure. This prevents flue gas from leaking through the furnace roof and filling the penthouse with possible combustible gases and prevents an accumulation of an explosive mixture in this area. The seal air pressure is approximately 3" water gauge higher than the flue gas pressure at this point. The possible points of leakage through the furnace roof are at the points where the waterwall tubes penetrate the roof.

Sealing Air to the Gas Recirculation Fans Breeching. Between the isolation dampers and the outlet dampers on the discharge side of the recirculation gas fan, a manual shutoff supply of seal air is provided. This supply is also piped to the suction of the recirculation fan.

A manual shutoff damper is provided where the seal air takes off the F.D. duct just before the steam air heaters. The seal air dampers to the recirculation fan discharge have automatically operated dampers that close if the recirculation fan is in operation and open when the fan is shut down. The seal air to the recirculation fan suction is a manually operated damper and is open only when maintenance is required on the fan and is closed during normal operation.

ASPIRATING AIR

The station air supply is normally used for furnace door aspirating service when dealing with a pressurized furnace. This service is necessary as the air will cool the door-opening, preventing hot gases from escaping the furnace and burning the individual inspecting the furnace. The inspection doors are so designed that it is necessary to turn on the aspirating air before the door can be opened.

HYDROSTATIC TESTING

In a normal operating plant a hydrostatic test (hydro) is usually applied to a boiler before a routine overhaul or after repairing a tube leak. There are exceptions to these rules and each case is studied to determine the necessity of a hydro. A hydro is applied to determine if there are leaks of any kind on the water or steam side of the boiler. Pressure is increased to the test value using the boiler feed pump.

The water and steam side of the boiler is filled with distilled water that is at a temperature no more or less than 100°F of the boiler metal temperature. The boiler must be full of water and all possible air expelled through the drum and superheat vents before pressure is applied to start the hydro.

Proper valving is very important when setting up to hydro a boiler. A nonreturn and/or a boiler steam stop valve is provided and must be closed. The allowable temperature difference mentioned earlier, between the water and boiler metal temperature, also applies to boiler or turbine stop valves.

As boiler gauge glasses have a tendency to leak from cold water and high pressure, the glasses should be cut out after filling and before increasing pressure. It is also necessary to have boiler pressure indication available. On some boilers a low pressure gauge is provided, this gauge must be cut out of service prior to exceeding the pressure rating of the gauge.

FILLING FOR HYDRO

In filling for a hydro it is first necessary to fill and establish a level in the drum gauge glass, then the fill valving to the water walls and economizer must be secured.

The superheater filling operation is very much the same as filling the water side of the boiler. The top most superheater header vent(s) must be open to expel all possible air, the superheater drain valves must be closed. With the filling pumps (boiler transfer or distilled water) in operation, the fill valve must be open into the superheater section and fill until an increase is observed in the drum gauge glass. This ensures that the superheater is completely filled with water.

When the drum level has increased and is approximately half full, the superheater fill valves may be closed and filling the waterwalls re-established. The superheater and drum vents must remain open until the boiler is full. The operation of filling will continue until fairly heavy venting is observed from all vents. Closing and reopening the vents usually helps in expelling most of the air. After all possible air is vented from the boiler, the vent valves are closed. The filling pumps remain in operation until the boiler pressure increases to the pressure capacity of the pumps. It is very important that a constant check be made around the boiler setting during the pressure increase.

Leaks of any magnitude should be noted and reported. The amount of pressure placed on a boiler is usually somewhat below the normal operating pressure. When this pressure is reached the boiler feed pump may be shut down and the boiler inspected for leaks.

At the conclusion of the hydro, the boiler drains may be cracked open and the pressure allowed to slowly decay to approximately 25 psig at which time the boiler vents must be opened to keep the boiler from going into a vacuum.

Section 12

BOILERS AND ACCESSORIES

Study Questions

1. What is the purpose of the safety valve in boiler operation?

2. If more than one safety valve is used, how is the highest setting determined?

3. The setting for safety valves on the superheater outlet is lower than any drum safety valve.

   True \ False

4. The Electromatic Relief Valve is used ____________.

   a. to minimize maintenance of regular safety valves.

   b. on the superheater outlet and can be isolated for repairs.

   c. and set to relieve before all other safety valves.

   d. All of the above.

5. The difference in steam pressure between point of valve lift until the valve seats is called the blowdown. True \ False

6. What is meant by "gagging" a safety valve?

7. The main steam drum is the highest part of the boiler. True \ False

8. The main steam drum is where the initial separation of water and saturated steam takes place. True \ False

9. Steam from the drum generally travels through three stages. They are:
   a.
   b.
   c.

10. Great care must be taken of the boiler drum. What is the major consideration to keep in mind to avoid stressing the drum metal?

11. Soot blowers commonly use a chilling action and velocity to remove ash, soot, and slag from boiler tubes. True \ False

12. Boiler loading should be less than one-half load before blowing soot. True \ False

13. When burning oil, how often should soot be blown?

14. Always start blowing soot at the coolest section of the boiler and blow toward the hottest section. True \ False

15. What are three (3) alarms associated with soot blowing?
   a.
   b.
   c.

16. What are three (3) basic objectives of boiler water treatment?
   a.
   b.
   c.

17. Why is it necessary to remove dissolved oxygen from boiler feedwater?

18. How is alkalinity measured?

19. Scale in the boiler is formed by the impurity of ___________________.

20. When test show that there is a large amount of dissolved solids in boiler water, the boiler should be ___________________________.

21. Why are gauge glasses installed on boiler drums?

22. What is the purpose of drum vents?

23. Superheater drains serve two purposes. They are:

    a.

    b.

24. When filling the boiler, the drum vents must be open and the gauge glass available. True \ False

25. Why should boiler filling be from the lowest point of the boiler?

26. What is the purpose of air preheaters?

27. What is the purpose of steam air heater?

28. Forced draft fans produce high flue gas velocities while induced draft fans produce low air velocities. True \ False

29. List two (2) reasons for boiler stacks to be as tall as possible.
    a.
    b.

30. List three (3) alarms associated with Forced Draft Fans and Induced Draft Fans.
    a.
    b.
    c.

31. Why is it necessary to have boiler sealing and cooling air?

32. List at least three (3) pieces of equipment and/or boiler sections that are supplied with sealing and cooling air.
    a.
    b.
    c.

33. Aspirating air is open before the furnace inspection doors are opened.
    True \ False

34. A hydrostatic test is usually applied to a boiler after a routine overhaul.
    True \ False

35. A hydro is applied to determine if there are leaks of any kind on the water or steam side of the boiler. True \ False

Generation-Oahu Division
Operator Trainee Training Program

Section 13
STEAM TURBINES

OBJECTIVES:

1. Identify the four fundamental parts of a steam turbine and describe the part they play in the energy conversion process
2. Detail the process for converting steam heat energy to mechanical work
3. Discuss Reaction and Impulse type turbine blades and their functions within the turbine
4. Discuss staging in turbine design
5. Identify the seals and seal systems used in turbines
6. Detail the types and purposes of turbine valves
7. Discuss the importance of bearings and lubrication in turbines
8. Discuss the controls that regulate the amount of steam to the turbine

Section 13

STEAM TURBINES

The purpose of a power plant is to generate electricity and start it on its way to the customer. In a steam power plant, the generation of this electricity is accomplished by the turbine generator. Previous sections discussed the processes necessary to efficiently and safely supply steam to the turbine. This section will deal with the steam turbine which is the prime mover in the electric generation process.

TURBINE PRINCIPLES

The usual turbine consists of four fundamental parts: the rotor which carries the blades or buckets; the casing which consists of a cylinder and bearings within which the rotor turns; the nozzles or flow passages for the steam, which are generally fixed to the inside of the cylinder; and the frame or base that supports the whole assembly.

Steam turbines take many forms but basically they are simply windmills set in a steel casing in which the heat energy in steam is converted into mechanical work by allowing expanding steam to work on the moving blades of the turbine.

In Figure 13.1, three sets of movable blades are shown mounted on a common shaft, each in a separate compartment. Each set of blades and its associated nozzles is known as a stage. Steam issuing from the nozzle in

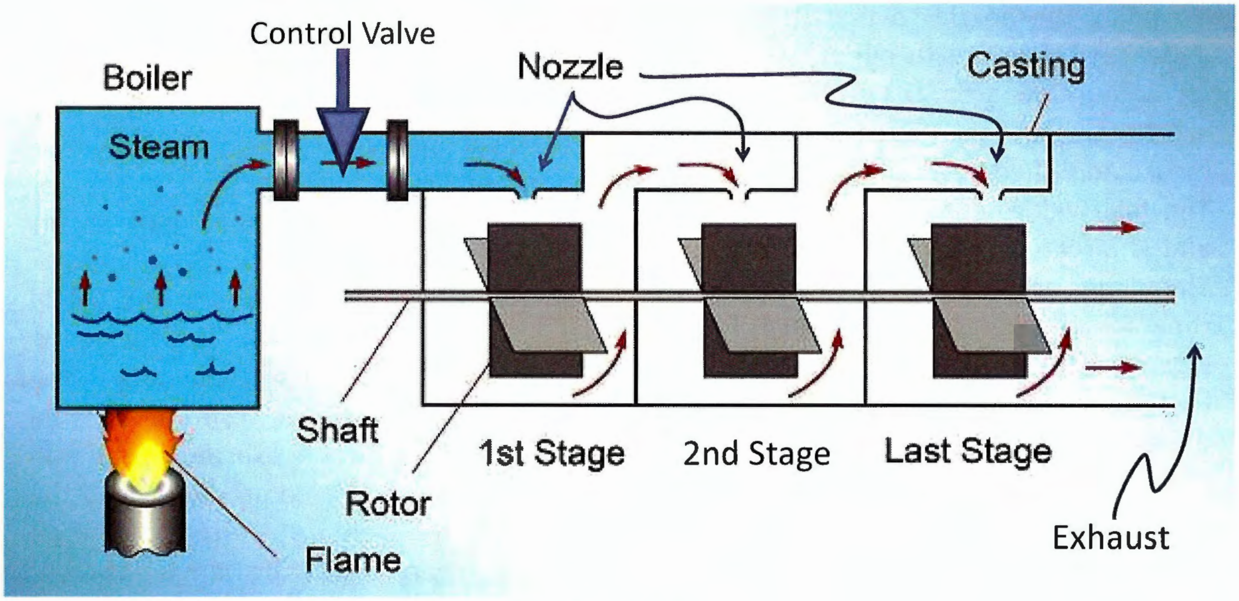


Figure 13.1

the first stage pushes against the blades and causes the entire rotor assembly to rotate. As it passes through the first stage nozzle, the steam undergoes a velocity increase and corresponding pressure decrease. With a drop in pressure there is a corresponding increase in specific volume and it is common to say that the steam expands through the nozzles. The steam at a lower pressure leaves the first stage and enters the second stage nozzles where the process is repeated. The steam expands again and then gives up more energy to the second stage blades. After passing through the third stage, the steam has given up most of its available energy to the turbine blades and leaves the turbine as exhaust steam. Note that the size of the blades in each succeeding stage is longer in order to accommodate the increased specific volume.

It is necessary now to look at the process by which the steam gives up its energy to the blades. There is very little energy loss as the steam passes through the nozzles. This is basically an energy conversion process in which some of the pressure (potential) energy of the steam is converted to velocity or kinetic energy. This is accomplished by designing the nozzle so that its flow area increases from inlet to outlet. Due to this increasing flow area, the steam must keep accelerating and this increase in speed must be accomplished by a reduction in pressure. The high velocity steam leaves the nozzle and is directed against the turbine blades. The blades are designed in such a way that they absorb energy from the high velocity steam. This energy transfer from the steam to the turbine blades is accomplished by designing the blades so that they cause a change in the velocity of the steam as it passes through them. It is not practical or necessary to discuss the detailed theory of this process in this manual. It can be said, however, that any body in motion possesses a quantity known as momentum. This quantity is equal to the mass or weight of the body times its velocity. The steam leaving the nozzle has momentum due to its weight and its velocity. In order to change the momentum of any object it is necessary to apply a force to the object. In the turbine, the momentum of the steam is changed by the blades which apply a force to the steam. A basic law of motion states that for any force acting on an object there is a corresponding force exerted-by the object. In the case of the steam turbine, the blades exert a force on the steam, but at the same time the steam exerts a force on the blades. It is this force of the steam acting on the blades that causes the turbine shaft to rotate. This process can be summarized as follows:

1. The nozzle converts the pressure energy of the steam to velocity.
2. The turbine blades exert a force on the steam to change its momentum by changing its velocity.
3. The steam in turn exerts an equal but opposite force on the blades, causing them to move and turn the turbine shaft.

The above discussion may be clarified by a simple example. Consider a car going down the street at 30 miles an hour. The car possesses some momentum due to its weight and velocity. If the car should run into the wall of a building, the wall would exert a force on the car to change its momentum by changing its velocity. The car's velocity will change from 30 miles an hour to zero. The force exerted by the wall on the car will cause some damage to the car. Since the wall has exerted a force on the car, there must be an equal but opposite force exerted by the car on the wall. This is quite evident by the amount of damage done to the wall.

As was stated above, it is essential that the turbine blades cause a change in the velocity of the steam. True velocity consists of two parts, a magnitude or speed, and a direction. Velocity can be changed by changing either of these quantities. This condition gives rise to the two distinct types of turbine blades. In the *impulse* turbine blades, the steam velocity is changed in direction only. With the *reaction* type of turbine blades, the steam velocity is changed by both changing its direction and by changing its speed or magnitude.

REACTION TYPE

When expanding steam pushes directly on the piston of the reciprocating engine, heat energy converts into mechanical work in a single step. The steam turbine takes two steps for this transformation. First, steam expands in a nozzle discharging at high velocity. In this way the potential energy or total heat (enthalpy) of the steam partly changes to velocity (kinetic energy). The force of the jet produced by this transformation in the nozzle can be used in either of two ways. If the nozzle is free to move, the reaction pushes against the nozzle and it travels in the direction opposite to the jet, lifting the weight or rotating the wheel as in Figures 13.2A and 13.2B. This is the principle used in the reaction sections of turbines. Reaction turbines expand steam in alternate rings of fixed and moving blades, both acting as nozzles.

IMPULSE TURBINE

If the nozzle is fixed and the jet is directed against a bucket, the jet's impulse force pushes the bucket forward, lifting the weight or rotating the wheel. This is the principle used in the impulse sections of turbines. Figures 13.3A and 13.3B. In each case, reaction or impulse, heat energy of the steam has been transformed into velocity energy in the nozzle and then into mechanical work.

In impulse turbines, nozzles are distributed around a ring and steam enters buckets from the side. Steam expansion occurs only in nozzles and pressure remains essentially constant in buckets. The velocity rises in nozzles and falls in buckets.

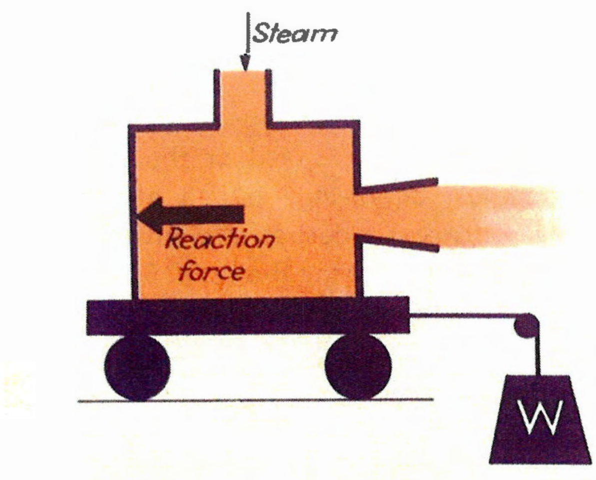


Figure 13.2A

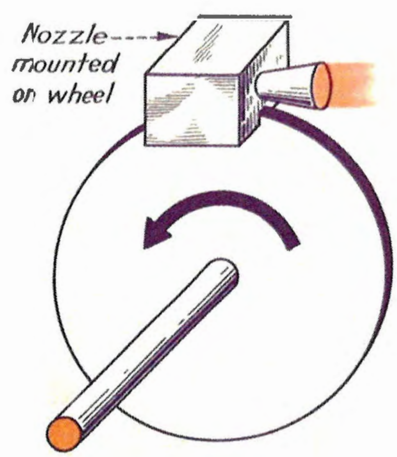


Figure 13.2B

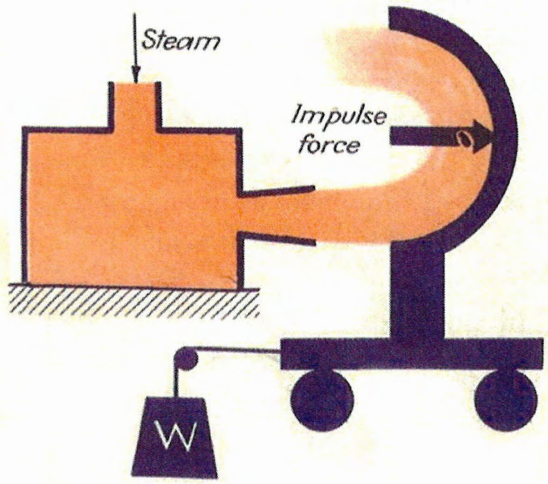


Figure 13.3A

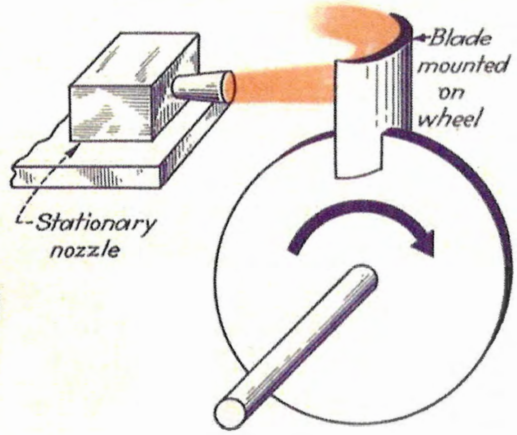


Figure 13.3B

TURBINE CONSTRUCTION

Impulse and reaction turbines are both used in power plants. Nearly all turbines use the impulse principle for the first stage or two in order to reduce losses around blade ends and to allow steam volume to increase. The steam flow in most turbines is axial, that is, the steam flow is parallel to the axis of rotation through blades which are set radially. Turbines are high pressure, condensing and may be tandem compound double flow, reheat or non-reheat, cross-compound quadruple flow reheat, and various other combinations of these steam flow arrangements.

Compound turbine is the term applied to a machine in which the steam passes in sequence through two or more separate turbine sections. As an example, a triple compound turbine would have a high pressure section, an intermediate pressure section, and one or more low pressure sections. Tandem compound is the arrangement of turbine sections in line on the same shaft and driving the same generator. Cross compound is the arrangement of turbine sections on separate shafts and driving separate generators.

Reheat turbines have been developed to meet the demand for more economical power plant operation. High pressure steam is expanded in a turbine to an intermediate pressure, then is routed back to the boiler for re-heating, thus increasing its heat energy at the lower pressure. It is then returned to the intermediate and low pressure sections to complete its expansion.

TURBINE STAGING

Maximum efficiency in a simple impulse turbine is attained by having the velocity of the steam jet, as it issues from the expanding nozzle, equal to twice the velocity of the blades upon which it impinges. In order to meet this requirement, turbines must either operate at extremely high speed or the pressure drop must be divided into a number of stages. Since it is desirable to have a direct connection for driving the usual 60 Hz two-pole generator, most turbine-generator sets operate at 3600 rpm and have a number of stages.

The higher the steam pressure, the more potential energy there is to be developed from a pound of steam at a given temperature. For this reason, steam pressure also has a bearing on the number of stages in turbine design.

Reaction turbines usually use a velocity stage or a two-row impulse wheel at the inlet end and reaction blading for the remainder of the unit. See Figure 13.4a. The advantage of this combination is a pressure and velocity decrease to a desired value in the compact impulse wheel, eliminating the need for a long high pressure straight reaction turbine section.

After the initial impulse stage there are a number of reaction stages to use up the remaining energy in the steam. The number of reaction stages designed for a turbine depends upon admission steam pressure, steam temperature and the type of turbine design, such as reheat, non-reheat, impulse, reaction, volume and number of extraction points, etc. Some large turbines use over 30 stages in their design. Wheel outside diameters start small and gradually increase as the lower pressure stages are reached. At the same time, the length of the blades is increased to give additional area to pass on the increasing steam volume due to pressure reduction.

Large turbines are provided with several extraction points to provide steam for feedwater heating. Closing off the extraction steam flow to a feedwater heater raises the pressure in the stage from which the steam was being extracted and thus increases stage differential pressure. For this reason it is important that stage differential pressures be watched when taking a heater out of service. In addition to the possibility of exceeding allowable stage differential pressures, it is possible to cause excessive rotor thrust.

In the center of Figure 13.4b is a close-up view of an actual velocity compound or governing stage for the high pressure rotor of a reaction turbine. Such stages always use impulse blades and nozzles. Shown is the row of stationary blades which are contained in the casing and which fit between the two rows of moving blades. This row of stationary blading, along with the disc upon which the blades are mounted, is known as a diaphragm or blade ring. The diaphragm partitions direct the steam flow to the adjacent buckets at the proper angle and velocity. The nozzle areas and angles of discharge are

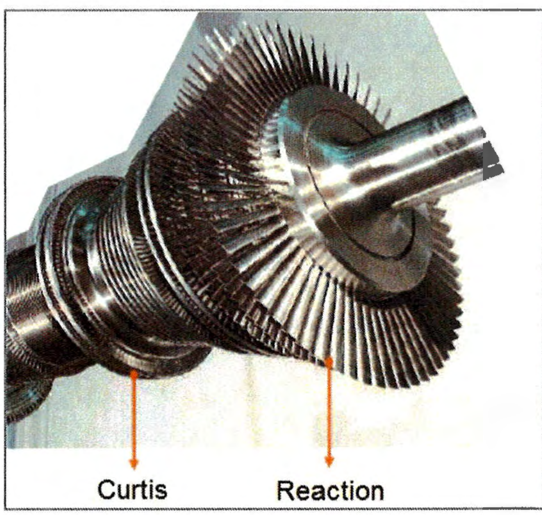


Figure 13.4a

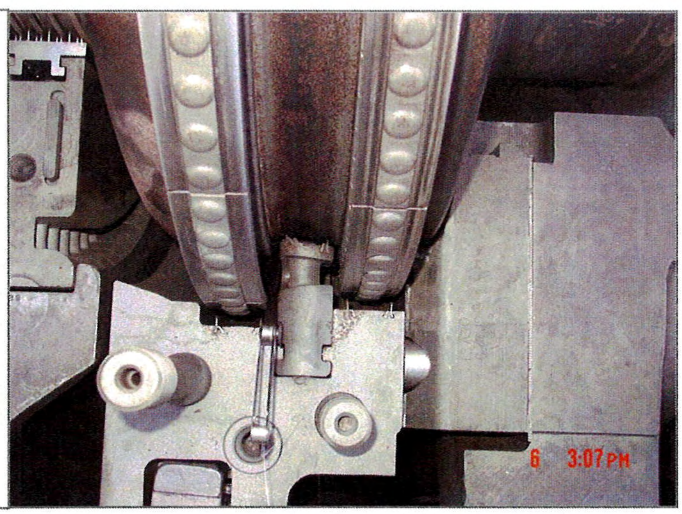


Figure 13.4b

determined by many variables, including volume of steam to be passed, speed of the adjacent bucket, and steam pressure ahead of the diaphragm.

ROTORS AND CASINGS

Impulse turbine rotors are forged steel shafts of essentially constant diameter. Discs carrying blades or blade rings may be shrunk and keyed on the shaft or forged as an integral part of the shaft. On reaction turbine rotors, the blades are usually mounted in machined grooves on the shaft.

In all turbines the blades increase in length and spacing, from the high pressure end to the low pressure end, to accommodate the increased volume of the steam as it expands. Turbine rotor shafts may be solid forgings or they may be hollow with a plug or stub shaft at the open ends.

Turbine casings are made of high-grade carbon steel or alloy steel, depending on the pressure and temperature conditions. They are divided into upper and lower halves by a horizontal, bolted, metal-to-metal joint and, in some cases, may be divided vertically by a circumferential joint. For extremely high pressures, double casings are used as shown in Figure 13.5. In these casings, exhaust steam from a lower stage of the turbine is admitted into the space between casings. This divides the total pressure differential across the casings and minimizes the temperature-caused stresses on the casing shells.

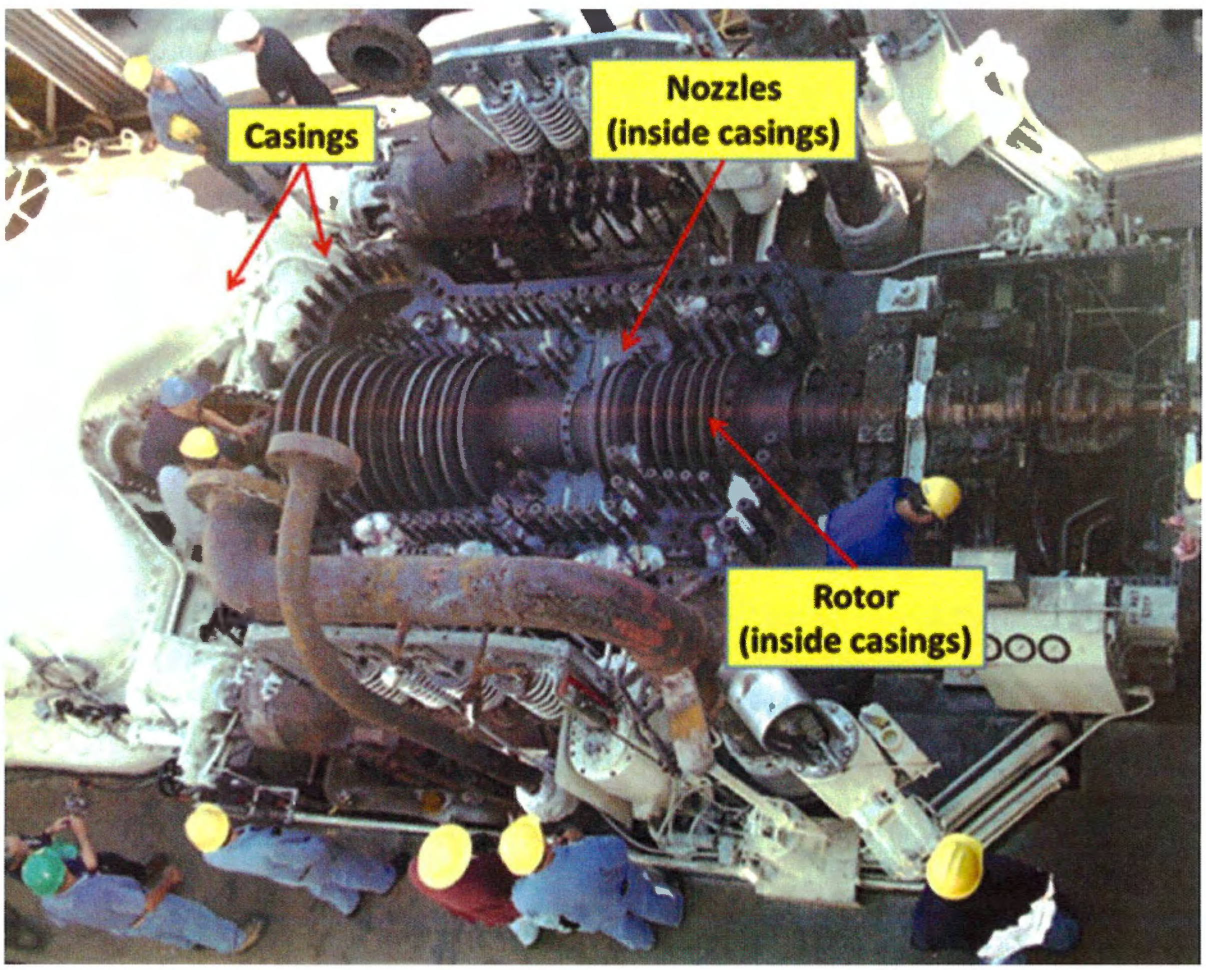


Figure 13.5

Figure 13.5 shows the high pressure element of a large modem reaction turbine. Note the heavy walled inner and outer casing necessary to withstand the high pressure and temperature.

SEALS AND GLANDS

Through the clearance between rotating and stationary parts of a turbine, steam leakage may occur, and under certain conditions, air infiltration. To reduce such leakage and infiltration to a minimum, various forms of seals or glands are installed.

The diagram in Figure 13.6 shows the location of leakage and infiltration points. At the high-pressure end, steam tends to leak out around the shaft. During starting, however, pressure in the first stage of condensing turbines may be low enough to cause an inflow of air. At the low pressure end of condensing turbines, normal tendency is toward air leakage into the machine. Steam leakage between stages may occur where the shaft passes through the diaphragms.

Steam leakage from the turbine reduces power output and increases steam consumption. Hot steam escaping from the turbine also presents a hazard to operating personnel. In addition, steam escaping will condense on nearby cooler surfaces. This could cause deterioration and faults in adjacent electrical equipment.

Air infiltration places additional load on the condenser air removal equipment and can prevent obtaining the desired vacuum in the condenser. Infiltration of air is also undesirable in that cold air can contact hot turbine parts and cause distortion, rubbing, and vibration.

The diaphragms between stages are provided with labyrinth shaft seals to minimize leakage from one stage to the next along the shaft. This is done to ensure that all of the steam passes through the turbine blading and performs useful work. For efficient operation all forms of leakage must be kept to an absolute minimum.

There are two principal types of seals or glands used in turbine practice: labyrinth steam seals and water glands. Most operators are familiar with the typical stuffing box fitted with soft metallic packing

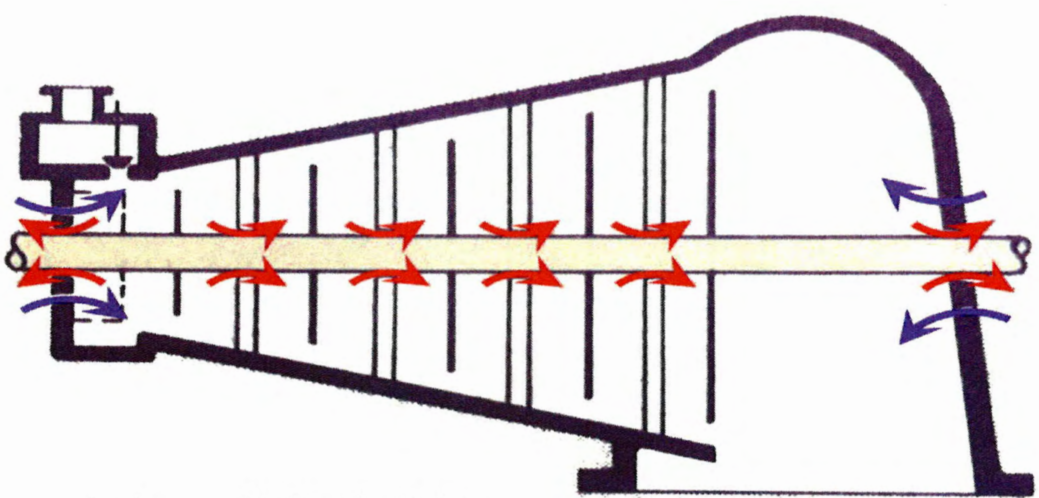


Figure 13.6 Leakage and Infiltration Points

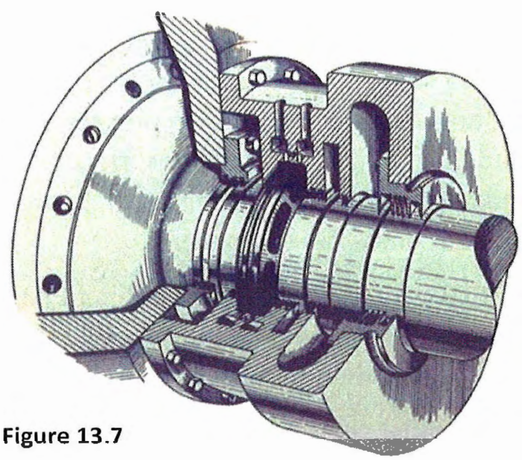


Figure 13.7

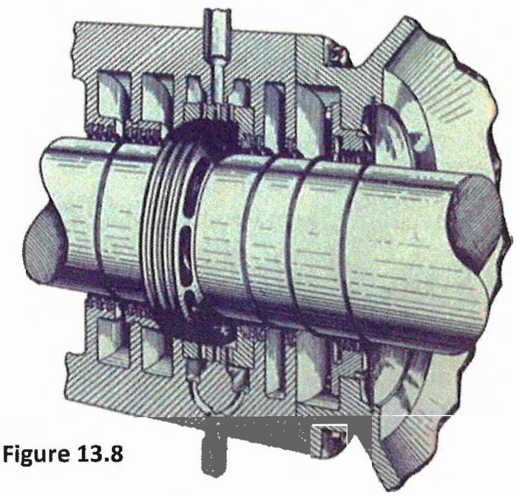


Figure 13.8

rings. This arrangement is used on some small machines for shaft sealing at the low-pressure end. However, virtually all larger units employ labyrinths or water glands or combinations of these types.

Labyrinth seals consist essentially of a number of thin circular strips fastened to the casing, or a member supported from the casing and positioned so that the clearance between the shaft and the edges of the strip are small. The resistance offered by this series of obstructions to steam flow is enough to hold leakage to a minimum. Labyrinths are sometimes used alone and frequently in combination with water glands as shown in Figure 13.7.

A water gland is merely a centrifugal pump runner rotating with the turbine shaft and confined in a housing attached to the casing. Commonly supplied with condensate, the runner holds water in a ring at its periphery, forming a positive seal. In most cases, water glands are used in combination with some other form of seal because the water gland is not effective until the turbine approaches operating speed. The additional seal also reduces the casing-side steam pressure on the water gland when used at the high- pressure end of the turbine. Figure 13.8 illustrates a water gland.

Operation of labyrinth seals is improved by the addition of steam sealing or gland leakoffs. Figure 13.9 illustrates the principles of these arrangements. Steam

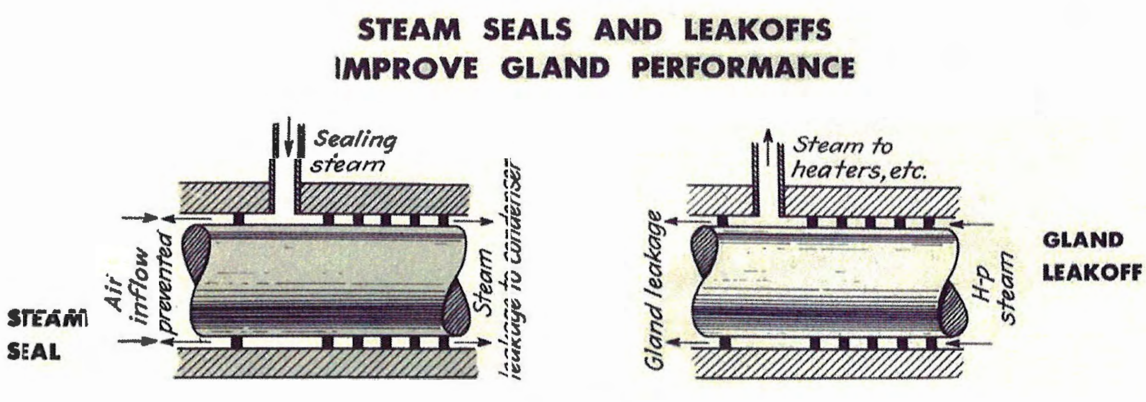


Figure 13.9*

that leaks past the gland from a region of high pressure is known as leakoff steam and is commonly led to a heater, but its heat may be recovered elsewhere in the station cycle or it may be led back to a turbine stage at lower pressure. Steam sealing positively checks air flow into the condenser at the exhaust end gland, and into the turbine at the high pressure end during starting. Steam enters an exhaust end gland as shown, some leaks to atmosphere preventing air flow, and the remainder leaks into the turbine and then to the condenser. Application of these various types of glands or seals varies considerably in actual practice. Water glands are used only at the shaft ends, usually in combination with labyrinth seals and with either steam sealing or leak-off arrangements. Labyrinth packings are commonly used as diaphragm seals and are also used, usually with steam sealing, at shaft ends.

Normal operating practice in the power plants is to place the turbine shaft sealing system in service just prior to raising vacuum for turbine start-up. Sealing steam must never be applied while the turbine is at a standstill. Applying heat to the turbine shaft while at a standstill would result in a bowed rotor. During a turbine shutdown, the shaft sealing system must remain in service until condenser vacuum has reached zero. This is done to prevent pulling air into the hot turbine through the glands.

Usually a steam seal is provided with two chambers. The chamber on the side of the seal nearest the turbine is connected to the steam seal supply and leakoff system. The outer chamber, nearest atmosphere, is connected to a gland steam condenser. Steam that leaks past the labyrinth seal toward atmosphere is collected in this chamber and then piped to the shell side of the gland steam condenser. The shell side of the condenser is provided with an air exhauster which maintains a slight vacuum in the shell. The cooling medium, which passes through the tubes of the condenser, is supplied by the main condensate pumps. The gland steam that is condensed is usually returned to a drip tank and from there to the condenser hotwell.

Water seals are usually located on the atmospheric side of the steam seals and on the low pressure turbine where the shaft emerges from the casing. Sealing water is usually supplied by gravity feed from some form of head tank. The seals on the low pressure turbine are non-circulating. They are provided with a supply line and valve and seal water leakage is drawn into the turbine. Water is circulated through the seals on the intermediate and high pressure turbines. These seals are provided with supply and return lines and valves. Adjustment of these valves permits regulation of sealing water flow, pressure, and temperature at each water seal. Normal practice is to maintain sealing water temperature leaving these seals at 165°F to 185°F. If temperature is permitted to go too high, flashing occurs at the seals. If temperature is held unnecessarily low, a large temperature differential will be created on the turbine shaft at the seal. This can result in shaft distortion and vibration.

TURBINE VALVES

Steam turbines in power plants are equipped with a variety of steam valves, each of which is designed to serve a particular purpose. In general, these valves either serve to (1) quickly shut off steam to the turbine (throttle and emergency stop

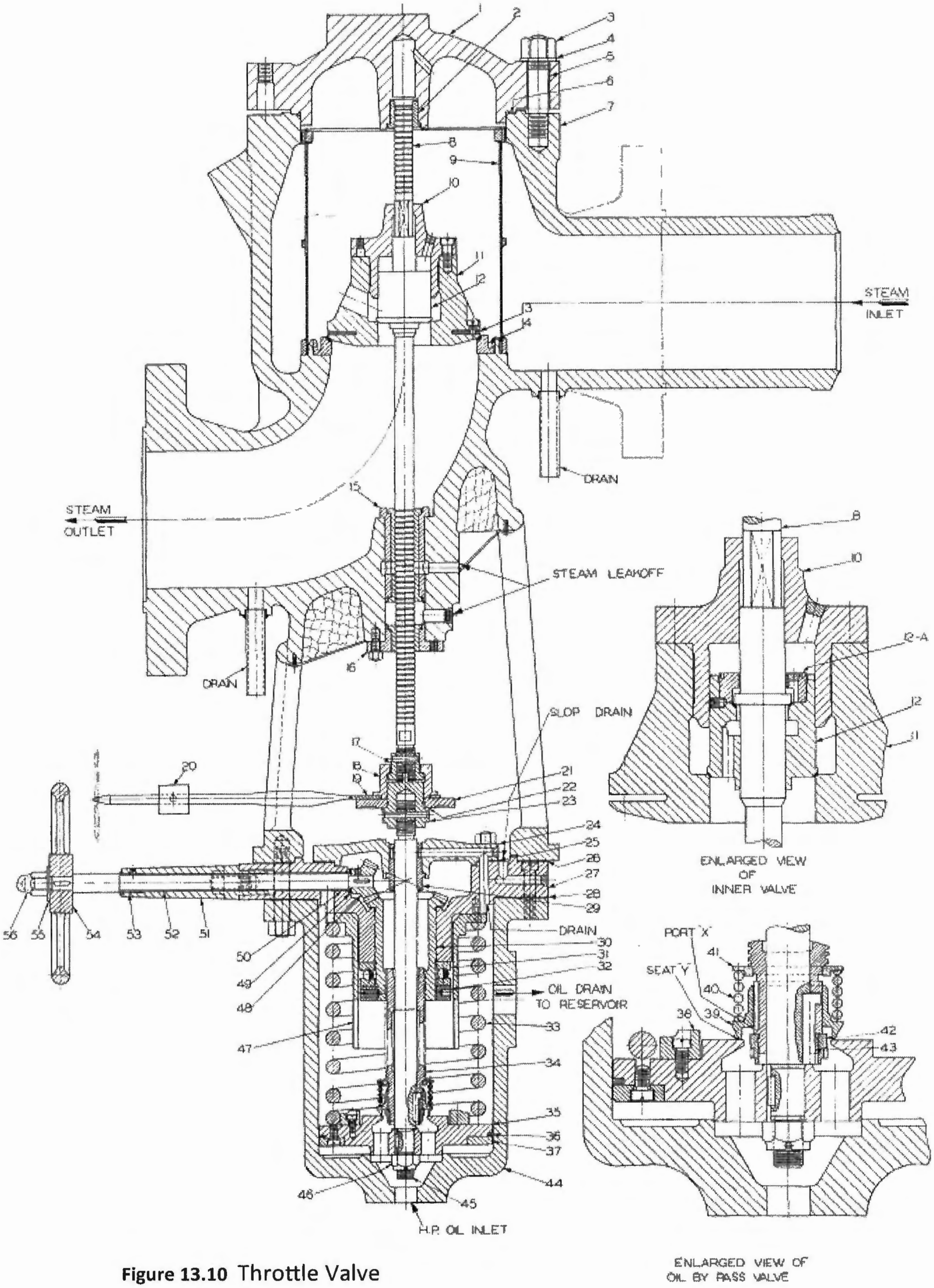


Figure 13.10 Throttle Valve

valves), or 2) control the rate of steam admission to the turbine (governing or control valves). These valves are built to handle large quantities of steam at high pressures and temperatures and are hydraulically operated. Valves to be discussed in this section are emergency stop valves and throttle valves.

Throttle valves and emergency stop valves each provide the same protection to the turbine; that of isolating the turbine from the main steam supply in the event of a turbine shutdown. The difference in these two valves is in the design application.

The **throttle valve**, Figure 13.10, is used to control the steam flow to the turbine during start-up periods. During this period the governing or control valves are in the wide open position. As the turbine approaches rated speed, the governing valves start to close and take over control of the turbine speed. The combination stop valve-throttle valve is essentially two valves in one, a small throttle valve being contained inside the larger stop valve. There is a hole or port in the disc of the stop valve which is closed off by the throttle valve when the combination stop valve-throttle valve is in the closed position. Operation of this valve is as follows: When oil pressure is increased in the throttle valve servomotor (operator) the valve stem starts to move outward. This valve stem is connected to the throttle valve only. The throttle valve starts to open, admitting steam to the turbine. The throttle valve (or valves) will pass sufficient steam to bring the turbine up to rated speed, after which the governing valves take over turbine speed control. Further opening of the throttle valve causes it to shoulder against the stop valve disc internally and further travel of the valve stem opens the stop valves. This type of valve is used on Westinghouse turbines.

The valve stem packing consists of a closely fitted bushing which is provided with suitable leakoff piping. This leakoff is routed to a zone of lower pressure, usually to the cold reheat line. When the stop valve is in the wide open position, the valve formed on the lower end of the valve bushing seats on the valve stem bushing and prevents steam leakage along the valve stem. When the valve is in the closed position, the lower end of the valve stem guide seats against the upper end of the valve stem bushing, preventing steam leakage along the valve stem. A cylindrical steam strainer is integral with the Stop valve bonnet and fits around the main valve.

During the initial operation of power plant turbines, temporary, fine-mesh strainers are installed along with the permanent strainers to prevent small particles of foreign materials from entering the turbine.

The **emergency stop valve**, Figure 13.11, is used to warm and pressurize a steam chest which accommodates the control or governing valves. During the warming period on this type of turbine, the control valves are closed to permit the warming and pressurizing of the valve chest. The stop valve will be opened wide after the chest is pressurized and the governing valves will be used to control steam flow to the turbine.

The emergency stop valve is an oil-operated, spring-closed valve. Rapid closing is accomplished by dumping the oil from under the stop valve operating piston. When the valve is closed, steam pressure holds the main valve disc closed. The main stop valve disc is totally unbalanced and cannot be opened against full pressure drop. A small internal bypass is provided

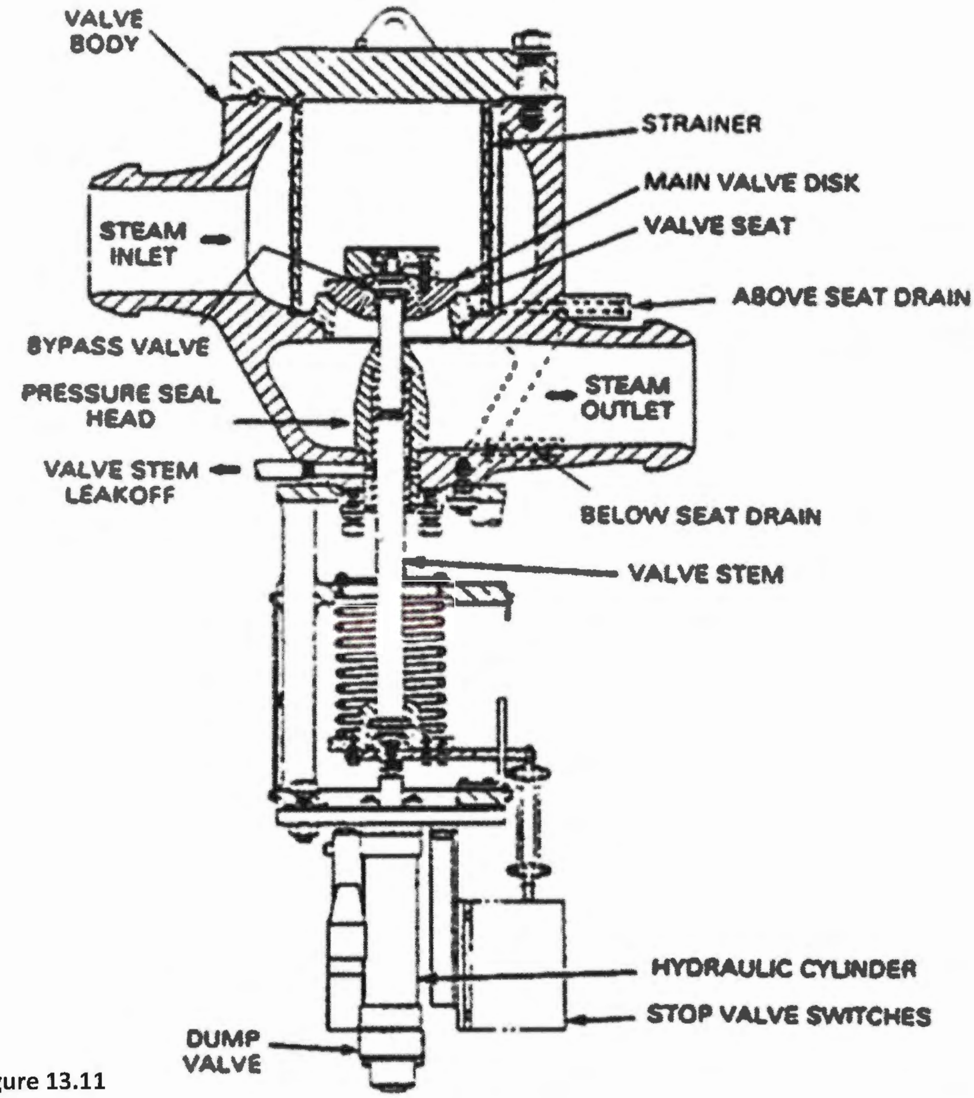


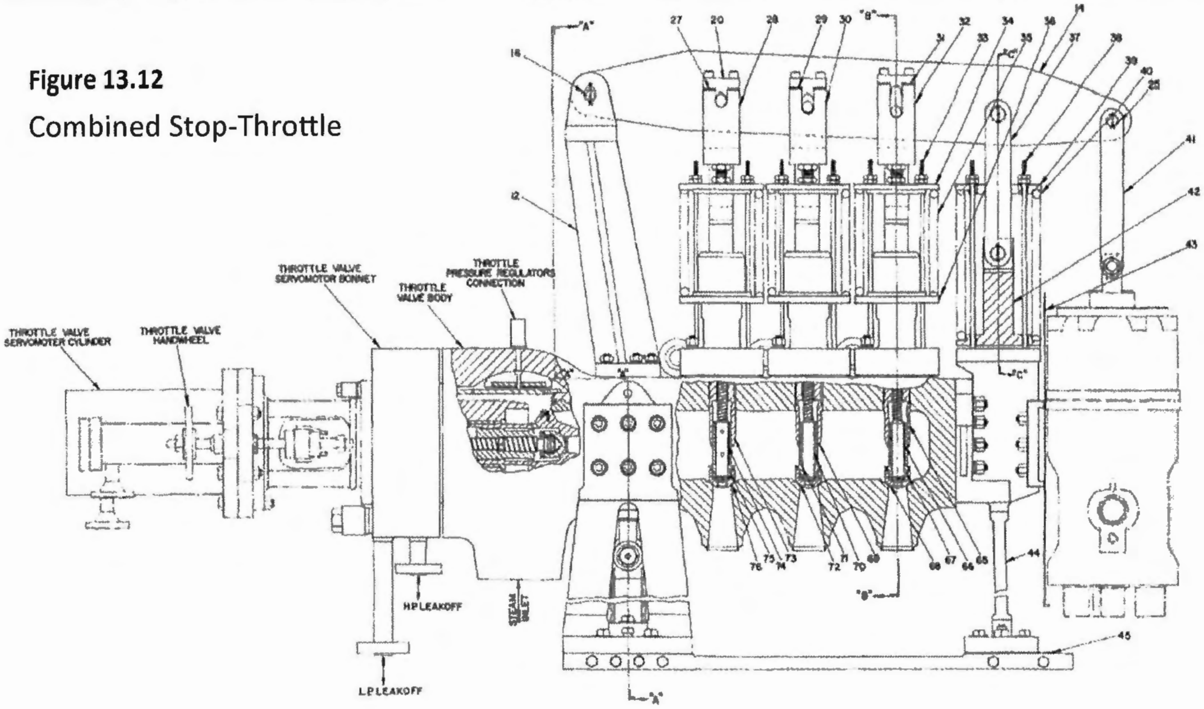
Figure 13.11
Emergency Stop Valve

inside the main disc. This bypass will pass approximately 75% of the turbine no-load steam flow. This permits slow warming of the steam lead and valve chest. When pressure downstream of the stop valve has been built up through the bypass until the pressure differential across the valve is approximately 10%, the main stop valve can be opened. This provides a safety feature in that the emergency stop valve cannot be opened unless the control or governing valves are closed. This type of valve is used on General Electric turbines.

The valve stem packing arrangement on this valve is similar to that described for the throttle valve, however the leakoff is usually piped to an open funnel. The Steam strainer arrangement is also similar to that described for the throttle valve.

Governing valves. Changes in steam flow to meet changing loads are controlled by valves located in a steam chest. These valves are variously referred to as admission valves, control valves, and governing valves. Two general arrangements are used to control these valves; 1) a bar lift mechanism camshaft or bar-lift operated steam-admission valves

Figure 13.12
Combined Stop-Throttle



may be mounted in a steam chest, or 2) the entire steam chest assembly may be separated from the casing to permit symmetrical cylinder design and reduce distortion. See Figure 13.12.

Westinghouse turbines utilize the bar-lift mechanism for governing valve control. The bar-lift mechanism opens the valves in desired sequence. Valve stems pass through holes in a bar raised and lowered by the control mechanism. Collars on each valve stem are set at different heights; as the bar rises, valves lift in a sequence determined by the collar settings. Turbines with separate steam chests have flexible inlet piping which connects the chests to separate nozzle chambers in the turbine casing. Another application of the bar-lift operation is the external hinged lever lift. The valve stems are connected to the operating lever by links. The point at which each valve starts to open is determined by the length of the slot in the links. The valves are equipped with compression springs which act downward on the spring seat to provide a positive closing force.

Cam operated steam-admission valves are usually mounted on a steam chest which may be cast integrally with the turbine casing or bolted to it. See Figures 13.13 & 13.14. Such an arrangement is found on various General Electric Company turbines. The valves control the steam flow through separate passages in the turbine shell to particular sections of the nozzles. They are raised and lowered in proper sequence through action of their levers which ride on cams mounted on a camshaft. The camshaft is rotated by the hydraulic operating mechanism through a rack and pinion. The valves have spherical seating surfaces and are fitted to the ends of the valve stem. A pin running through each valve and stem permits enough valve movement to insure proper seating with the valve seats which are peened or welded into the bottom of the valve casing. The cams are designed and arranged to open or close the control valves in a definite sequence depending upon the load requirements of the turbine. The valve stem moves in a guide against the force of a

Figure 13-13

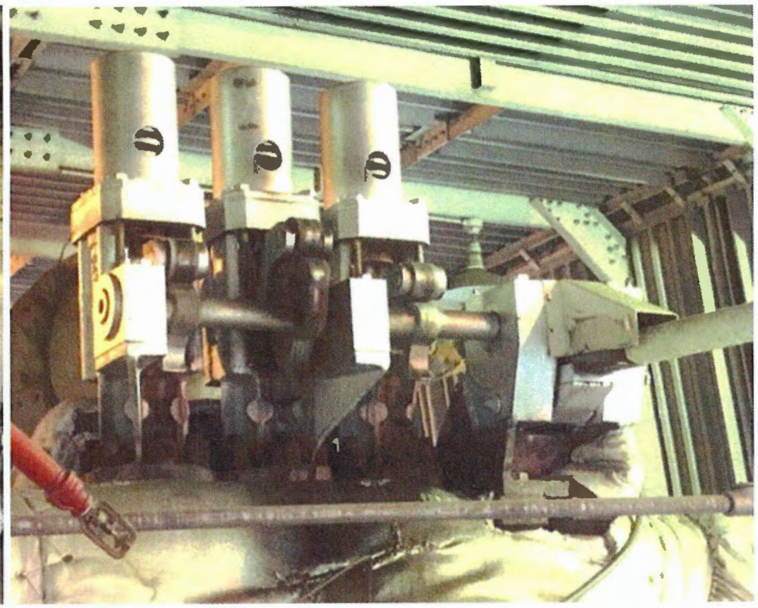


Figure 13-14

compression spring which forces the valve to its seat when the cam roller is lowered.

TURBINE BEARINGS AND LUBRICATION

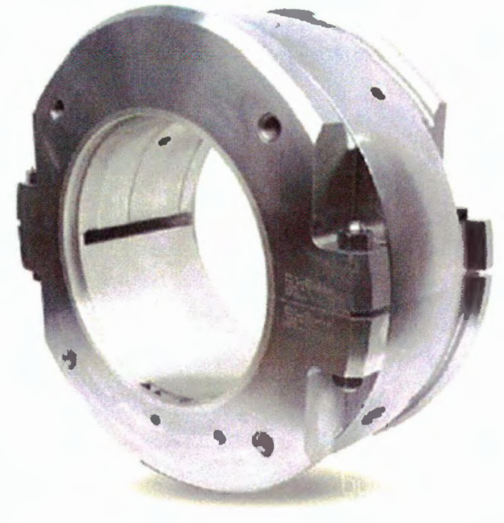
Many factors are involved in bearing and bearing lubrication design for any type of machine. All machines have one thing in common and that is moving or rotating parts which require lubrication.

Turbine lubrication is needed to minimize the friction in main bearings, thrust bearings and reduction gears. The bearings and journals pick up heat due to friction and by the shaft conducting heat from the hot pans of the turbine. Lube oil carries the heat away and keeps bearing temperatures at a safe operating level.

Oil viscosity is very important in the lubrication of bearings. The resistance to the flow of oil is affected by the temperature. The metering orifices in the turbine bearings are usually designed to pass the required flow of oil with a viscosity corresponding to a temperature of 110°F. The pressure and flow of oil to the bearings is designed to provide adequate lubrication and cooling without disturbing the design loading of the bearing or the formation of the oil wedge which supports the bearing load.

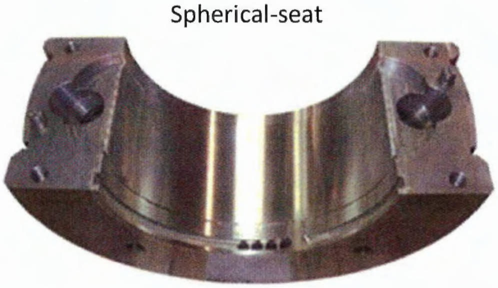
Bearings carry the full weight of turbine rotors and let them spin freely with a minimum of friction. Metal-to-metal contact would ruin the bearing lining and journal in a short time, so an oil film is forced between the two surfaces to separate them. Frictional effects take place between surfaces and the oil but mainly in the oil film. Lube oil must wet the metal surfaces it separates, yet stay cohesive enough to resist being squeezed from the area of maximum pressure.

The loads imposed upon the bearings of a turbine are mainly due to the weight of the rotor assembly. These may or may not be equally divided between the bearings, depending upon the relative location of the bearings and the center of gravity of the rotor. Bearing design varies for different sections of the grade babbitt metal and assembled in a bearing housing. Oil supply passages are provided in the housing and in



Spherical-seat

Tilt Pad



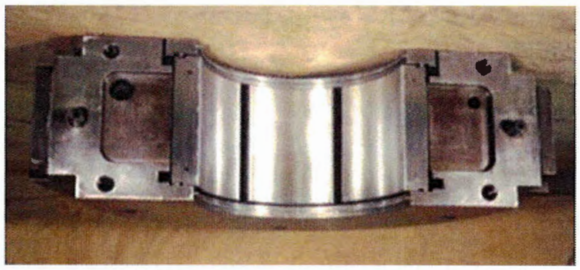


Figure 13-15 Journal Bearing

the bearing shells through which a supply of oil is furnished to the bearing from the circulation-oil system. This oil is delivered to passageways and grooves which distribute the oil along the length of the bearing which is designed in a manner to assist the formation of the oil wedge on which the journal floats. The passageways and grooves are proportioned and arranged so that considerably more oil flows to the bearing than is required for lubrication. This additional oil flow is required to remove frictional heat and the heat that is conducted to the bearing from the hot parts of the turbine. Bearings use a high-tin babbitt as the inner lining and it is cast on bronze, steel, or cast-iron backs.

The viscosity of lube oil must be selected to handle maximum bearing loads without overheating. Increased viscosity allows more loading, but higher temperatures can result from increases in fluid friction. Therefore, circulating oil systems with outside cooling become necessary.

Most journal bearings are of the spherical-seat, self-aligning type and are mounted in bearing rings which have an internal spherical surface to fit the ball seat on the bearing. This feature provides for self-alignment. See Figure 13.15.

The tilting pad bearing is also of the self-aligning type consisting of four babbitt-lined steel pads. Each pad is supported in the inner bearing ring and is located and pivoted on a spherical button with its spherical end contacting the inner liner located in the center of each bearing pad. This permits the bearing to pivot and align itself to the rotor.

Oil Wedge is formed by shaft rotation

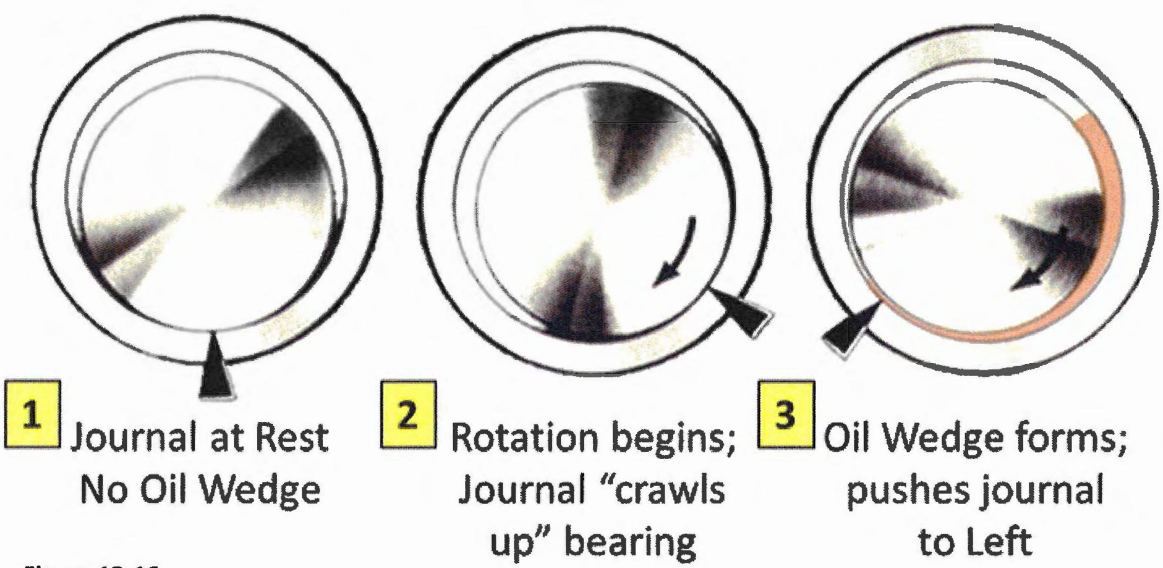


Figure 13-16

The oil wedge on which the journal (shaft) floats is formed by the working hydrodynamic oil film which involves bearing clearance, bearing grooving, point of oil application, speed, load, and viscosity of the lubricant. Refer to Figure 13.16. As the journal starts turning, it rolls uphill on the bearing surface, and since the journal is then slightly off center, the clearance becomes crescent shaped, with the wedge end of the crescent tucked into the load area. As speed increases, oil is dragged from the crescent to form a thin oil film in the bearing load area. Since the shaft and bearing converge, in effect, oil will leave the high load area at a higher average velocity than it had when it entered. There is a tendency for the fluid to back up in the wedge shaped load area, and since oil cannot be squeezed into a smaller volume, its pressure builds up instead to support the journal load. Again referring to Figure 13.16, it can be seen that as turbine speed decreases the thickness of the oil film is reduced. However, as previously stated, higher oil viscosity permits heavier bearing loading. This is one of the reasons why it is necessary to reduce lube oil temperature when a turbine generator is shut down and placed on the turning gear. Another reason is that lower oil temperature assists in removing the heat from the turbine-generator shaft.

TURBINE THRUST

Steam turbines are basically axial flow machines. This means that the flow of the steam is in the same direction as or parallel to the axis of rotation of the shaft. The blades of the turbine are designed to convert the energy in the high velocity steam into a force which causes the shaft to rotate. Some of the force produced by the steam does not act in a direction to cause rotation but instead acts parallel to the shaft. This force is known as thrust and would cause the shaft to move axially if it were not restrained by a thrust bearing.

In turbines which use reaction type blades, there is an additional thrust. This force results from the difference in pressure across each row of blades. This force is not present in impulse type blades because there is no pressure drop in the moving blades. There will always be a greater thrust force in a reaction turbine than in an impulse turbine.

Turbine designers have resorted to several methods to reduce the thrust force in order to permit the use of a reasonably sized thrust bearing. The most common method is to provide a double flow section (usually the low pressure) in the turbine. When a double flow section is used, the flow in each half is in the opposite direction so that the thrust is balanced out. This is not the main reason for using a double flow low pressure section; however, it is important from the thrust standpoint. Some designers will also change the flow direction several times, in the high and intermediate pressure sections of the turbine, in an attempt to balance out some of the thrust.

In turbines that are basically reaction (Westinghouse), it is common practice to use a dummy or balance piston to counteract some of the thrust. The dummy piston is usually an integral part of the shaft. One side of the piston is exposed to high pressure steam while the other side is connected to a much lower pressure area. The net effect is to produce a force which acts in the opposite direction from the normal thrust produced by the blades. Since there is a large pressure difference across the dummy piston it must have considerable labyrinth packing to prevent leakage of steam from the high to the low pressure area.

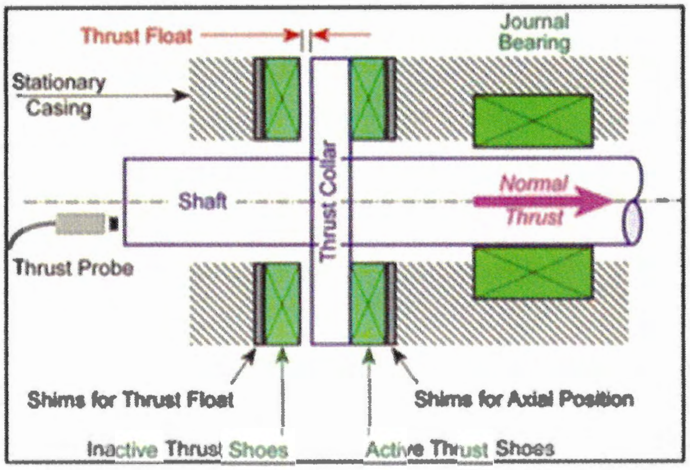
In general, turbines are designed so that the thrust load on the bearing is always in the same direction during normal operation. During abnormal conditions, however, the thrust may reverse direction. Conditions that may cause thrust reversal are low pressure operation, severe load rejection, or a rapid load application. To accommodate these conditions, thrust bearings are always designed to accept a load in either direction. The normally loaded side of a thrust bearing is known as the active side while the normally unloaded side is known as the inactive side.

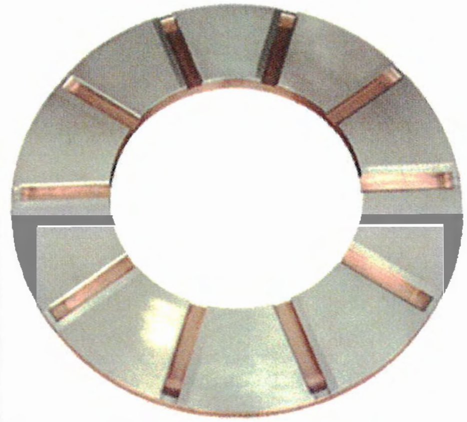
THRUST BEARINGS

Thrust bearings are provided on both impulse and reaction turbines in order to maintain the rotor in correct axial position with respect to the casing. Two types of thrust bearings are commonly used in turbines. These are the Kingsbury (Westinghouse) and the tapered land (General Electric) thrust bearings.

The Kingsbury thrust bearing consists of pivoted segments or shoes against which the thrust collar presses as it rotates. The steel thrust collar is either machined integrally or is shrunk onto the shaft. In most cases, bearings are installed on both sides of the collar to carry the thrust in either direction. The load is equally distributed among the several shoes. Since the shoes are pivoted, they have a rocking motion which allows the shoes to take a position so that the center of loading of the babbitt faces are all in the same place. Consequently, each shoe takes an equal share of the load. The thrust bearing is flooded with oil under pressure at all times. As the thrust collar rotates with reference to the shoes, the film of oil between each shoe and the loaded collar will tend to take a wedge shape, with the thick side of the wedge on the forward or entering edge of the shoes. Thus, the oil is carried between the bearing surfaces by the motion of the collar and assures proper lubrication of these surfaces.

Figure 13-17





The tapered land thrust bearing consists of a rotating collar keyed to the turbine shaft and two stationary babbitted plates supported in a housing which is bolted to the end of a journal bearing. See Figure 13.17. The tapered lands have fixed converging surfaces such that a wedge of oil will exist between the rotating collar and the thrust plates. The lands are located on each side of the thrust collar to carry the thrust in either direction. The thrust plates are split steel rings with babbitted surfaces divided into lands by radial oil feed grooves. The surface of each land is tapered so that it slopes the rotating collar both in the direction of rotation and from the inner to the outer radius at the leading edge of the land. Oil is admitted under pressure to the radial oil grooves in the thrust plates and is carried over the surfaces of the lands by the rotating collar, forming a continuous film of oil between the collar and the plates. The radial grooves are dammed at the outer ends to maintain a pressure in the groove.

TURBINE CONTROLS

Fundamentally, a turbine control system performs two principal functions: It regulates the flow of steam to the turbine and protects the turbine from operations which might damage it or the generator.

All turbine control systems use a high pressure hydraulic oil system to operate the valves that control steam flow to the turbine. The oil pressure acting on the area of a piston supplies the force required to move the valves. The source of supply for the hydraulic control system is a shaft-mounted oil pump. An auxiliary oil pump mounted on the turbine lube oil reservoir is provided as a backup for the main oil pump. The auxiliary pump may be driven by either an AC electric motor or by a steam turbine. The auxiliary pump is arranged to start automatically upon a predetermined reduction in hydraulic or bearing header oil pressure.

CONTROL SYSTEMS

Before starting a discussion of the actual control systems used, it is desirable to briefly consider some general factors of control systems.

There are two basic modes or methods of turbine control which are in common use. In one of these, the turbine valves are essentially blocked in position and will not respond to any changes in the electrical system. In the other type of control, the turbine valves are also held in position but are still responsive to changes in system conditions. The first type is known as "blocking" or load limit operation while the second type is known as governor operation. Each of these is used separately and, frequently, some combination of the two is used.

GOVERNING SYSTEMS

A governing system is primarily designed to permit controlling the speed of the unit before it is electrically connected to the system and to control the load on the unit after it is electrically connected to the system. While controlling load, the governor must still be responsive to changes in speed. Every governor must have some device for sensing speed if it is to fulfill its requirements.

The mechanical type of governor utilizes a set of weights or flyballs which are driven, usually at reduced speed, by gearing from the main turbine shaft. The weights, which are connected by a spring, respond to changes in speed due to the resulting change in centrifugal force. The mechanical movement of the weights is directly responsive to speed. It is possible to directly connect the weights to the turbine valves and make the valves move in response to speed changes. This, however, is not practical. The force required to move the turbine valves is considerable and the weights would have to be very large to develop this force. The use of large weights makes the governor very insensitive to small speed changes. To overcome this condition, the governor weights normally position a small oil pilot valve which controls the oil pressure to a piston which in tum positions the turbine valves.

The second type of speed sensing device is a pump impeller mounted on the main turbine shaft. If the pump is the centrifugal type, then its discharge pressure will be an accurate measure of speed. The pump impeller must be supplied with oil at a constant pressure and temperature for the discharge pressure to be meaningful. The discharge oil pressure can be used to position the turbine valves. In many cases, the oil pressure change for small speed changes is too small for adequate control. This oil pressure change is usually amplified by a bellows arrangement to provide a large oil pressure change for a relatively small speed change.

BLOCKING SYSTEMS

A blocking system is primarily designed to limit the opening of the governing or control valves and, therefore, the amount of electrical load the unit can carry.

In Westinghouse units, "blocking" the machine at a certain load is accomplished by adjusting and limiting the secondary governor oil pressure at a known value. This oil pressure is used to position the control valves. Therefore, if the secondary governor oil pressure is limited, then also limited or "blocked" is the opening of the control valves and the unit's load capability.

Turbine generators operating in parallel on the power system all operate at the same frequency since they are locked together electrically. All machines which are operating on the governor will respond to changes in system load demands. As an example, an additional demand on the system will tend to lower system speed or frequency. Speed-sensitive governors act to maintain a constant speed; in this case they open the turbine control valves and admit more steam to the turbines. The percentage of speed change would be the same for all units, and if they were all of the same size and had governors with the same regulating characteristic, they would divide the load demand equally among them.

In parallel operation, governor regulation is responsible for the proportions with which different units pick up or shed load with a given change in system frequency. Turbine governors on the Hawaiian Electric system are adjusted for approximately 5% regulation. The regulation of a speed governor may be defined as the decrease in turbine speed, expressed in percent of normal speed, required to open the turbine control valves from the no load position to the full load position.

Section 13
STEAM TURBINES
Study Questions

1. What are the four fundamental parts of a steam turbine?

   a.

   b.

   c.

   d.

2. Describe briefly the energy conversion process.

3. The two types of turbine blades are ________________ and _________________.

4. What is meant by a compound turbine?

5. Steam pressure and steam temperature both have a bearing on the number of stages in turbine design. True \ False

6. Nearly all turbines use the impulse principle for their first stages. True \ False

7. In all turbines, the blades increase in length and spacing from the low pressure end to the high pressure end . True \ False

8. To reduce leakage and air infiltration through the clearance between rotating and stationary parts of a turbine, ________________________ are installed.

9. The valve used to control the steam flow to the turbine during start-up periods is called the ______________________ valve.

10. Improper turbine shaft sealing will cause ____.

    a. reduction in power output
    b. increased steam consumption
    c. overload of the air ejector
    d. all of these

11. Reaction turbine blades change the direction and speed of steam. True \ False

12. As the steam passes through a turbine, the pressure drops and the steam expands.

    True \ False

13. The turbine steam stop valves are hydraulically closed and spring opened.

    True \ False

14. Valves, located in a steam chest, that control the changes in steam flow to meet changing loads are referred to as ______.

    a. admission valves
    b. governing valves
    c. control valves
    d. all of these

15. Turbine lubrication is needed to minimize the friction in the main bearings, the turbine blades, and the reduction gears. True \ False

16. Discuss briefly the function of lubricating oil in turbines.

17. The turbine control system performs several principal functions, they are ______.

    a. to regulate the flow of steam to the turbine and protect the turbine from operations which might damage it.

    b. to regulate the flow of steam to the turbine and the speed of the turbine blades.

    c. to regulate the speed of the turbine blades and protect the turbine from operations which might damage it.

18. Lubricating oil is supplied to the turbine bearings at exactly the amount of oil needed for lubrication. True \ False

19. List at least five (5) uses of the turbine oil system.

    a.

    b.

    c.

    d.

    e.

20. Give two (2) uses of the turbine throttle valve.

    a.

    b.

GENERATION-OAHU DIVISION
OPERATOR TRAINEE TRAINING PROGRAM

Section 14
GENERATORS

OBJECTIVES:

1. Understand the electrical operation of a generator
2. Identify and discuss the parts of a generator
3. Discuss hydrogen gas designs and systems in the generator

Generation-Oahu Division
Operator Trainee Training Program

Section 14
GENERATORS

GENERATOR THEORY

The name alternator is sometimes used to describe an a-c generator in order to differentiate it from a d-c generator. Since all our plants are designed to produce alternating current, the more common term, generator, may be used without any complication or misunderstanding. In this manual, the name generator always means an a-c machine unless it specifically states otherwise.

The basic purpose of this section is to provide information that will permit the operator to understand the electrical operation of a generator. In order to provide reasons for the operational characteristics of a generator, it is necessary to discuss the theory which is involved.

Throughout this discussion, there is one primary fact to keep in mind. A generator does not produce or make electricity any more than a pump produces or makes water. The generator produces a voltage or potential difference which causes current to flow just as the pump produces a pressure difference which causes water to flow.

The principle involved in producing a potential difference or voltage has already been covered and is repeated here for review purposes. Whenever a conductor which has no current flow is moved through a magnetic field, a potential difference or voltage will be developed in the conductor. The motion must be such that the conductor cuts across the lines of force of the magnetic field. The magnitude of the voltage produced in this manner depends on the strength of the magnetic field, the length of conductor in the field, and the speed with which the conductor cuts across the lines of force. It does not matter whether the magnetic field is stationary and the conductor moves, or the magnetic field moves and the conductor is stationary. The principle is the same as long as there is relative motion between the two.

In all large generators, the magnetic field moves and the conductors are stationary. The rotating member is frequently called the field. However, this is sometimes confusing and the term rotor is normally used. The term field will be used only as a short term for magnetic field. The stationary part of the machine is known as the stator although the term armature may also be used. The armature is the part of the generator which contains the conductors and since in all our machines this is the stator, the two terms may be used interchangeably.

The magnetic field on the rotor is produced by electromagnetic action. A coil of wire is supplied with direct current by the exciter to produce the magnetic field. The rotor supports the field winding, provides a steel core to concentrate the lines of force, and provides the means of rotating the magnetic field. To accomplish these purposes, the rotor is made of a large steel forging with slots cut into it to accommodate the field winding. The rotor may be constructed to provide any even number of poles; however, in practice, only two-or four-pole machines are used in steam plants. A two-pole generator must operate at 3600 rpm to produce 60 Hertz, while a four-pole generator, such as HS, operates at 1800 rpm to produce the same frequency. The relation between speed, frequency, and number of poles is:

$$N = 120\ f/p$$

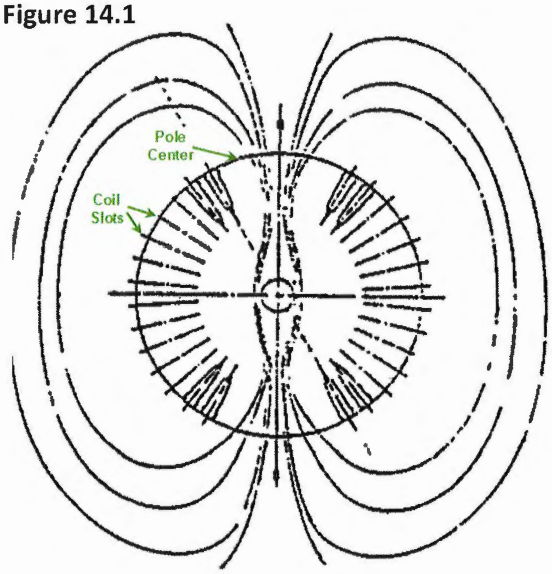
where N = speed in rpm
f = frequency in Hertz and
p = number of poles

Figure 14.1 shows the arrangement of slots and the resultant magnetic field for a two-pole and a four-pole rotor, respectively. Note that the coil slots do not go all the way around the rotor. Space is left to form the appropriate number of pole centers or faces. The large mass of metal in the pole centers provides an easy path for the lines of magnetic force.

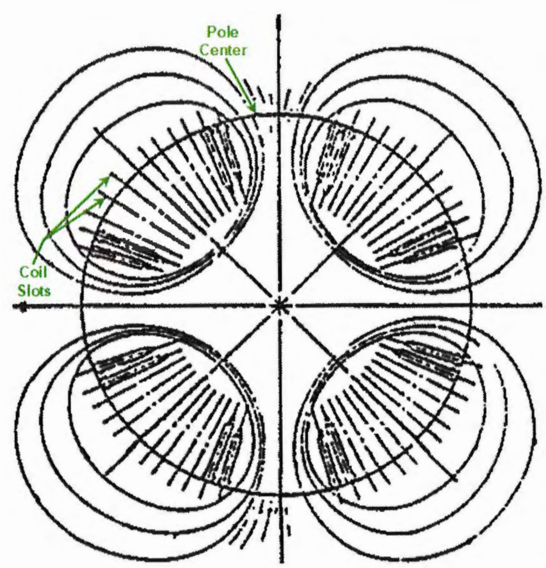
The stator is a hollow cylinder in which the rotor is located. The stator consists of a frame which supports the entire assembly and a core of steel in which there are slots for containing the stator conductors. The function of the core is to provide a return path for the lines of magnetic force from the field. The magnetic lines of force generated by the rotating field are, in effect, a series of loops which leave the north pole of the rotor, travel through the stator core, and return to the south pole of the rotor. The stator core must be made of steel which easily permits the lines of force to pass through (high permeability steel).

A simplified drawing of the rotor and stator with their respective conductors is shown in

Figure 14.1



Two Pole Field



Four Pole Field

Figure 14.2 Simplified diagram of Stator and Rotor with their respective conductors.

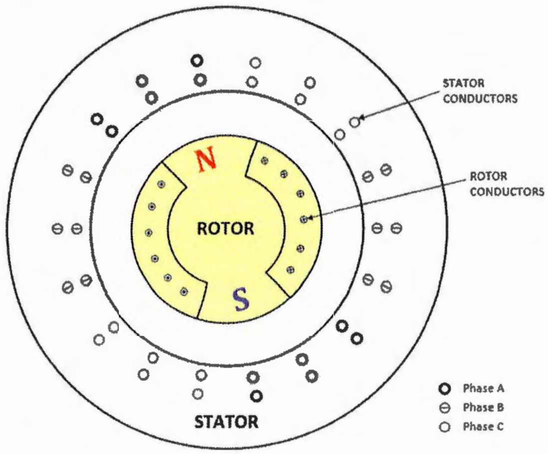


Figure 14.2. Note that there are two conductors per slot in the stator and that the stator conductors are distributed equally all around the stator. In most drawings and explanations, each phase is shown concentrated in one area as was done for the induction motor. The stator conductors are actually distributed symmetrically as shown in Figure 14.2.

As mentioned previously, the voltage produced in the stator conductors depends on the strength of the rotating magnetic field, the length of the conductor and the speed of rotation. The length of the conductor is fixed by the design of the machine and the speed is normally fixed by the requirement of producing 60-cycle power. The only variable under control of the operator then is the strength of the magnetic field. As the field rotates, a sine wave voltage is induced into the stator conductors. As long as the generator OCB is open, there is no current flow because there is no complete circuit. When the OCB is closed, the circuit is completed and current will flow due to the induced voltage.

GENERATOR CONSTRUCTION

Stator—The generator housing and enclosing ends are fabricated from steel plates rolled and welded to form the required shapes. The stator core consists of a series of iron laminations, called "punchings", pressed by a hydraulic press during the stacking process and finally clamped by insulated bolts. After assembly, the core is varnished and baked to protect it from rust and to further insulate the punchings. See Figure 14.3a.

The armature winding is formed by insulated bars of half coils assembled in the stator core slots. They are joined at the ends to form coils and connected in the proper phase belts by connection rings at the end

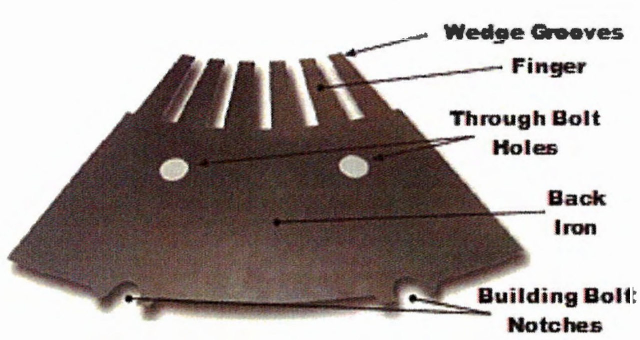
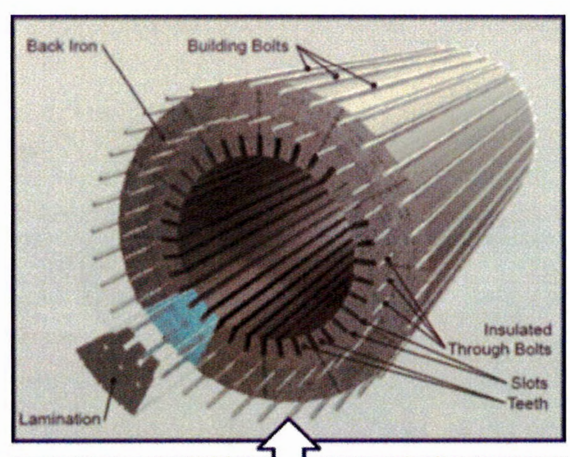


Figure 14.3a Laminate ("Punching")



Generator Stator Core with end compression assembly removed

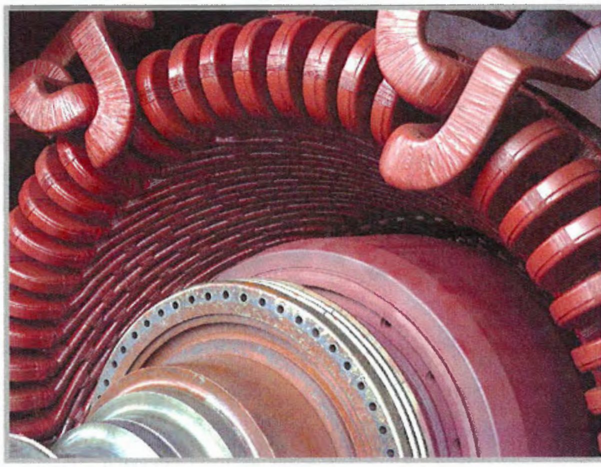


Figure 14.3b Stator Winding End Turns

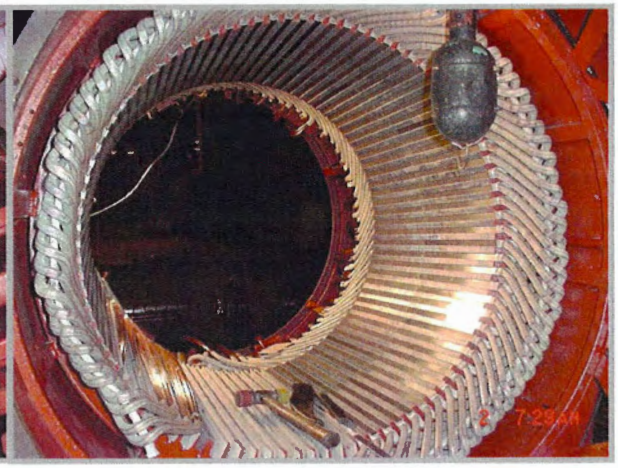


Figure 14.3c Stator Frame

of the winding. See Figure 14.3b.

The stator bars are composed of insulated copper conductors (strands) arranged in the form of rectangular bars. The bars are so assembled that each strand occupies every radial position in the bar at some point along the length of the bar. See Figure 14.3c. This arrangement causes all strands to share the load current equally and minimizes circulating current losses within the bar.

The main armature leads (high voltage and neutral) are brought out at the bottom of the generator casing through the generator terminal boards, at which point the desired connections are made. On most generators these connections are provided at the collector ring end of the generator. The armature connections are brought through the terminal boards by means of gas-tight high voltage bushings. These bushings consist of one-piece porcelain insulators containing a copper conductor. Silver-plated terminal studs are provided at each end of the bushings for making the connections.

The generator rotor bearings, the hydrogen shaft seals, and the oil passages for supplying oil to these parts, are contained in and supported by the outer generator end shields. The end shields are split on the horizontal center line to facilitate their removal.

Finned-tube coolers are provided in the stator frame to cool the hydrogen gas as it is circulated inside the generator. They may

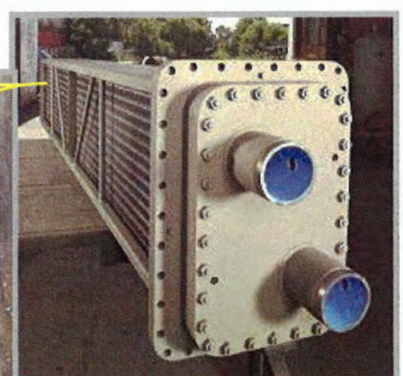


Figure 14.4 Finned coolers are inserted into the stator frame to cool the hydrogen gas.

be mounted in either a vertical or a horizontal position. See Figure 14.4. External connections are provided for cooling water supply and return piping. The cooling medium is treated water known as auxiliary cooling water.

Rotor—As previously mentioned, the rotor carries the magnetic field winding of the generator. The basic requirement of the rotor is to produce a strong magnetic field. The rotor body in which the field winding is located forms the path of the magnetic lines for part of the circuit while the stator core and air gap provide the return path for the flux.

The rotor is machined from a single solid steel forging integral with shaft ends. An axial bore hole is provided to check the properties of the forging and to carry the leads from the collector rings to the field winding. Ultrasonic test grooves are provided for examination to ensure forging soundness. Longitudinal slots are machined radially in the body to contain the field coils. See Figure 14.5. The field coils are held in the slots against centrifugal force by steel wedges. These wedges are individually fitted and driven into dovetailed openings machined in the rotor slots.

The field winding consists of rectangular bars formed into coils. Several turns in one pair of slots around one pole form a coil. Several coils are assembled around each pole to form the winding.

The end turns of windings are held in place against centrifugal force by heavy retaining rings machined from high strength, heat-treated alloy steel forgings. These rings are shrunk and keyed on centering rings on the rotor shaft.

Current is supplied to the field winding through collector rings. These rings are connected to the winding through insulated copper bars assembled in the drilled-out center of the rotor forging. At one end of the connection bars, terminal rods or studs assembled in gas-tight bushings in the rotor shaft connect the winding with bars. At the other end, similar studs connect the bars with the collector.

The generator rotor is connected to the turbine rotor through a solid bolted coupling

Figure 14.5 Generator Rotor

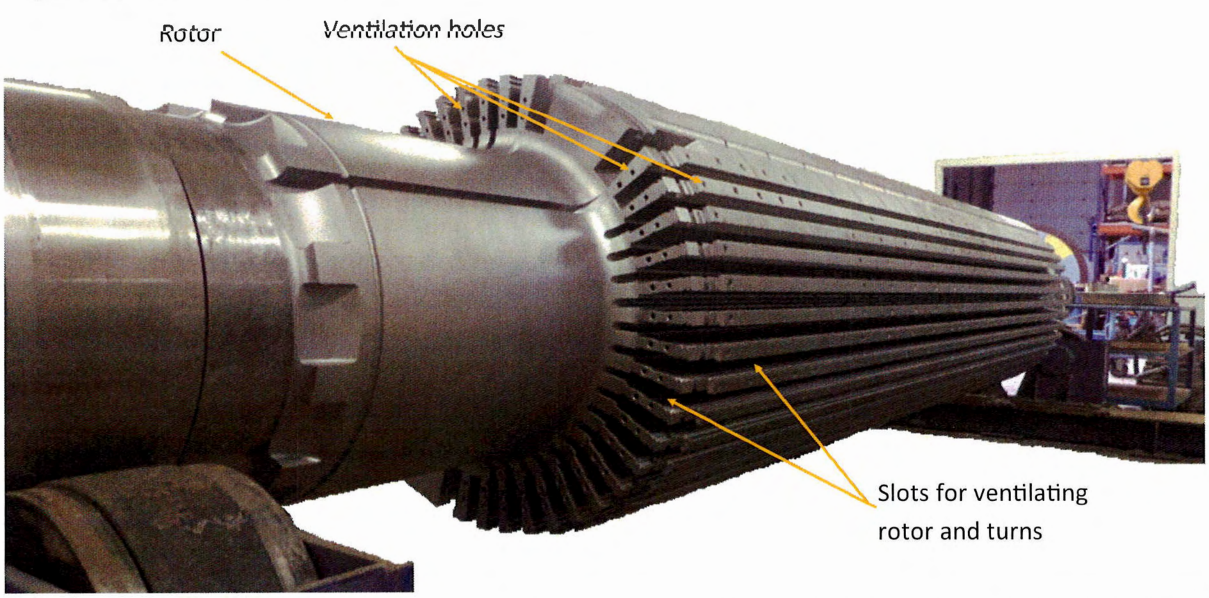
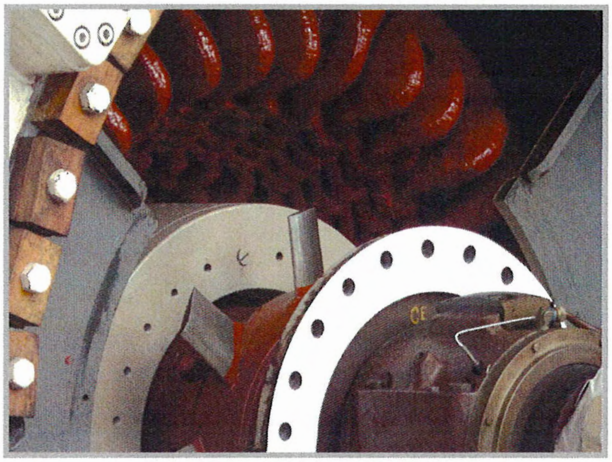


Figure 14.6 Rotor fan circulates hydrogen gas.



with an integral machined coupling half on each shaft. The rotating field, field winding, and stator core are cooled by hydrogen flow circulated through the generator by fans mounted on the rotor shaft. See Figure 14.6.

HYDROGEN COOLING

Generator losses that appear as heat must be constantly removed to avoid damaging the material of the windings. It can be said that generator size is limited by the ability of the weakest material to conduct and disperse heat without exceeding stress limits. In the case of electric machinery, including generators, this limiting material is copper. This means the major limit to generator capability is the ability of the design to cool the copper.

At one time, all turbine generators were cooled with air. Air at room temperature was circulated over the winding by fans mounted on the rotor. As the electrical industry grew, the need for higher rated generators also grew. In order to increase generator ratings with the air type cooling, it was necessary to increase the physical size of the generator to control heat losses. The weights and dimensions of the active machine parts were increased to maintain or lower the generator losses per unit of material. It soon became apparent that in order to further increase generator ratings, a better means of cooling was necessary, as the physical size of generator parts was definitely limited.

The first step to improve generator cooling was to install air coolers and air filters. In more recent installations, the air is recirculated through finned tube coolers and used over and over again, so that a minimum of dirt will be carried into the generator by the cooling air.

The next step to improve generator cooling was to use a gas which had better cooling properties than air. It had been recognized for a number of years that gases such as hydrogen and helium (the two most common gases) had the cooling properties required. Helium is inert and nonflammable, and from these considerations would be an ideal medium for ventilation and cooling purposes. However, because of its scarcity and high cost, it could not be considered feasible as a cooling medium. Hydrogen, on the other hand, could be obtained in unlimited quantities and at a relatively low cost. Furthermore, hydrogen is a more desirable cooling medium than helium because of its lower density and better thermal characteristics. Also, commercial hydrogen has the degree of purity desired and required for cooling purposes, and while it is combustible itself, it will not support combustion.

Hydrogen cooling was first used successfully on a number of synchronous condensers and frequency changers. Actual operating experience with hydrogen cooling of various types of synchronous machines demonstrated that the output of a given machine could be increased by 25% without exceeding the temperature limits specified for air cooling. This increase was based on operating in hydrogen at approximately atmospheric pressure. By using higher gas pressure, the output could be increased still further.

The principal advantages resulting from the use of hydrogen cooling for turbine generators are:

1. Reduced windage and ventilating losses because of the low density of the hydrogen gas. (Ventilating losses are proportional to the gas density.)

2. Increased output per unit volume of active material because of the high thermal conductivity and heat transfer coefficients of hydrogen. This advantage of hydrogen cooling makes it possible to build turbine generators for higher ratings than are possible with air cooling.

3. Reduced maintenance expense because of the freedom from dirt and moisture.

4. Increased life of the insulation of the stator winding because of the absence of oxygen and moisture.

5. Reduced windage noise because of the low density of the gas.

In general, it may be stated that, at present, hydrogen is the most desirable gas that can be used as the cooling medium for rotating electrical machines.

Generator Cooling Design. Large generators have cylindrical rotors with a minimum of heat dissipation surface, so they must have forced ventilation to remove the heat. Practically all large generators in use have enclosed systems with hydrogen coolant. The hydrogen cooled machine differs fundamentally from the older air-cooled machine in that the ventilating system is made gas tight and is filled with hydrogen. The gas is circulated by fans on the rotor. It flows through the machine, where it picks up heat and then through finned tube coolers where the heat is transferred to the auxiliary cooling water or treated water in the tubes of the cooler. The gas then reenters the rotor fans for another circuit through the system and may complete thirty or more such circuits in one minute (see Figure 14.7.)

Until recently generators circulated the coolant about the insulation exterior in vent ducts. The ratings of turbine generators have increased steadily by increasing hydrogen pressure, by improvement in blowers and in metallurgy, and in details of construction. It became evident, however, that this increase was limited to the rating at 30 psig hydrogen pressure, which we utilize, since beyond that point no appreciable increase in capability could be gained by a further increase in hydrogen pressure.

HYDROGEN GAS SYSTEM

The hydrogen gas system has the following principal functions:

1. To provide means for safely putting hydrogen in or taking it out of the machine, using carbon dioxide as a scavenging medium.

2. To maintain gas pressure in the

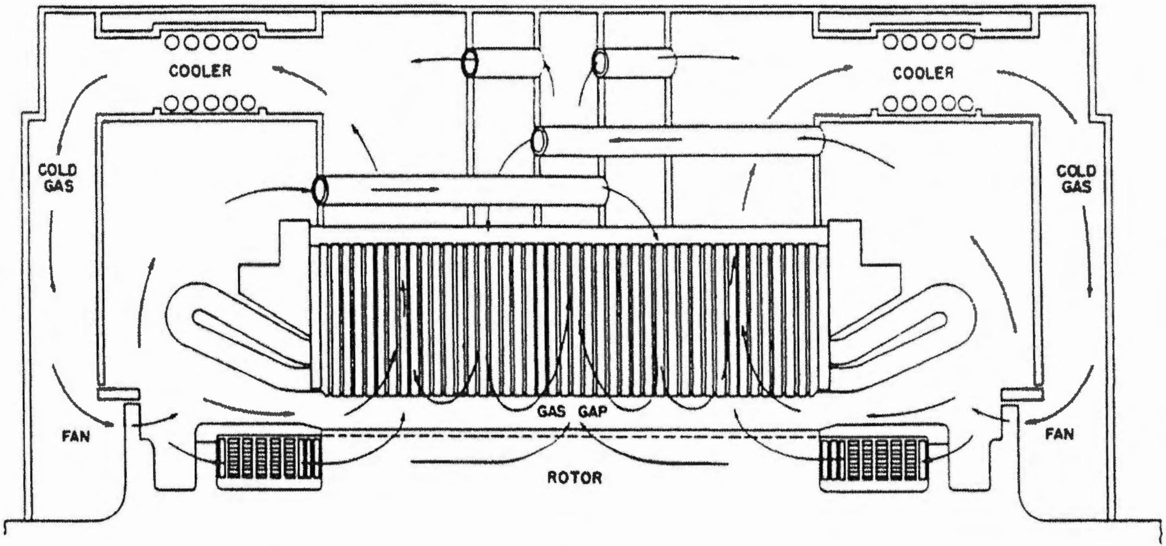


Figure 14.7 Ventilation System—gas flow through generator.

machine at the desired value.

3. To indicate to the operator at all times, the condition of the machine in regard to gas pressure, temperature and purity. The presence of water in the machine is also indicated by an alarm on the gas control panel.

4. To dry the gas and remove any water vapor which may get into the machine from the seal oil.

The hydrogen gas supply is a manifold which can be connected to a bank of commercial hydrogen bottles. Regulators are provided between the manifold and the gas connection to the machine. The hydrogen gas is distributed uniformly to the various compartments of the machine by manifolds in the top and bottom of the housing.

The carbon dioxide supply is regulated by hand at the bottle valves and a spring loaded relief valve is provided in the carbon dioxide connection. The relief valve provides protection against full bottle pressure in case other valves in this connection are closed.

A gas dryer is installed as part of the system and its main purpose is to remove water vapor from the hydrogen gas.

The gas dryer employs a desiccant which absorbs the moisture present in the gas. In some dryers, the color of the desiccant changes from a light blue to a grayish pink as the moisture content in the desiccant increases. The grayish pink coloring indicates that the desiccant has reached it's absorption limit and must be reactivated or regenerated.

In other dryer designs, measurement of the hydrogen gas dew point as it enters and exits the dryer is used to determine if the dryer needs regeneration. Regeneration involves displacement of the hydrogen gas from the dryer and then heating the desiccant to remove the moisture in the desiccant.

The desiccant dryer in the steam units currently in use is a dual tower drying system equipped with low-wattage heaters operated with microprocessor-based electronics. The eOne Generator Gas Dryer (GGD) dual tower design continuously dries and recirculates the hydrogen with one tower while the other tower is in standby or regenerating mode. The GGD uses a blower and motor assembly to continuously circulate hydrogen gas from the generator casing volume to the dryer assembly. The GGD will covered in more detail in a later section. When the GGD is in normal operation, it will manage column changeover and regeneration automatically.

Trays are provided under each gas cooler to catch any leakage or condensation from the cooler. Pipes are provided to drain water from these trays to the bottom of the machine housing. There are also openings in each frame ring so that any moisture will drain to the water detectors. These are float-operated mercury switches in small housings under the generator frame. Isolating valves are provided for draining off any accumulated water. The main lead compartments are closed off from the rest of the generator housing, so no water can drain into them.

HYDROGEN PURITY—ANALYZER

The analyzer measures the Hydrogen content based on the extreme high thermal conductivity of hydrogen gas. A sample of the gas is captured from the sensing chamber of the unit. The thermal conductivity is measured and compared against a reference gas value and the Hydrogen content calculated and its value displayed.

Gauges are provided on the gauge panel to indicate the pressure of the gas in the machine and another gauge is located near the gas bottles to aid the operator in filling the generator.

A thermometer is also provided on the gauge panel to indicate high gas temperature. The thermometer reads the temperature of the gas going to the coolers.

A pressure gauge on the high pressure manifold connected to the hydrogen bottles gives an indication of how much gas remains in the bottles.

The hydrogen is cooled by passing it through two coolers where the gas gives up its heat to the cooling water in the finned tubes of the cooler.

HYDROGEN SEAL OIL SYSTEM

Since the rotor shaft ends of a hydrogen-cooled turbine generator must be brought out of the gas-tight enclosure, means must be provided to prevent escape of gas along the shaft. Gland seals supplied with oil under pressure are used for this purpose. The function of the gland oil system is to provide oil under pressure to the seals, as free as possible from air and moisture. The same oil is used in the turbine bearing system and the gland system.

This oil in contact with air or hydrogen absorbs an appreciable volume of gas and will also absorb moisture if water vapor is present. Some of the absorbed air and moisture will come out of the oil and contaminate the hydrogen in the machine and dilute the purity. To maintain the purity, diluted gas must be exhausted and fresh hydrogen gas must be added to keep the hydrogen purity up to the required value. To minimize the need to exhaust &

replenish the hydrogen gas, a separate seal oil system was developed to help remove a large part of the absorbed gas and moisture from the oil before it is pumped back to the seals.

The main components of the seal oil system are defoaming tanks, a vacuum tank, oil pumps and a vacuum pump and separator tank.

Defoaming Tanks. Oil returning from the hydrogen side of the glands goes to two defoaming tanks which are designed to remain half full so that foam will have an opportunity to come out of the oil.

Vacuum Tank. Oil from the defoaming tanks is drawn into the vacuum tank and flows over a series of trays which provide a large area for separation of gas and water vapor. Oil level is maintained by a float valve and the tank has low & high level alarms.

Oil Pumps. The circulating pump (AC) draws treated oil from the vacuum tank and pumps part of it through a cooler to the seals, and part back to spray nozzles in the vacuum tank through a differential pressure regulator. This flow helps to maintain the desired pressure differential between the seal oil and machine gas pressure. A DC oil pump serves as a back up to the AC oil pump. Should the emergency oil pump fail, there is a valved cross section from the lubricating oil pump discharge to the seal oil system.

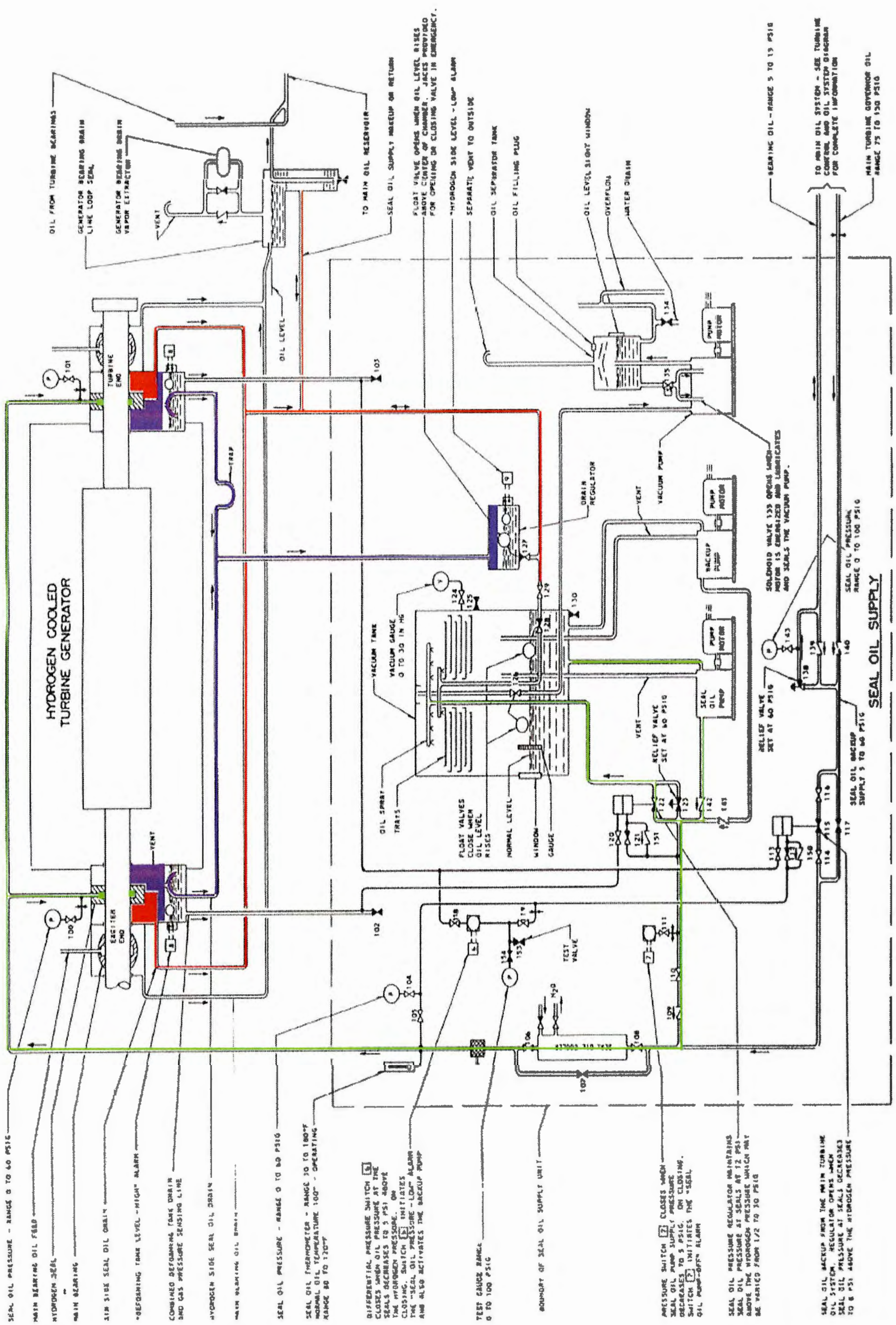
Vacuum Pump and Separator Tank. A motor-driven vacuum pump is used to remove the gases from the vacuum tank. The vacuum pump exhausts into a separator tank where any oil or water present in the gas collects. Water collecting in the separator tank must be drained off at intervals to prevent damage to the pump.

Generator bearing drain loop seal. A loop seal is provided in the combined generator bearing oil drain line before it enters the turbine bearing oil drain system. The purpose of this loop seal is to prevent the hydrogen in the generator from escaping into the main oil reservoir in the event of failure of the generator hydrogen shaft seals.

A vent located on the upstream or inlet side of this loop seal vents any hydrogen gas to atmosphere. An additional vapor extractor assembly upstream of the loop seal assembly provides the negative pressure in the generator drain system on the upstream side of the loop seal required for normal operation. Figure 14.8 is a diagram of a complete system.

The gas and seal oil systems will be covered in more detail in Section 21—Hydrogen Gas and Seal Oil Systems.

Figure 14.8 Diagram of a Westinghouse Seal Oil System



Section 14
GENERATORS
Study Questions

1. What is the major function of a generator?

2. Whenever a conductor that has no current flow is moved through a magnetic field so that the conductor cuts across the lines of force of that field, a ______________ or ____________________ will be developed in the conductor.

3. List the major components of the generator.

4. Voltage produced in the stator conductors depends on ___________________.

   a. the strength of the rotating magnetic field
   b. the length of the conductor
   c. the speed of rotation
   d. all of these

5. What is the basic requirement of the rotor?

6. List at least five (5) reasons why hydrogen is the preferred cooling medium for generators.

   a.
   b.
   c.
   d.
   e.

7. Describe how the Hydrogen gas is circulated through the generator.

8. Because of contamination problems, the hydrogen gas can only be circulated through the generator one time before it must be exhausted. True \ False

9. List the principle functions of the Hydrogen Gas System.

10. What is the purpose of the Seal Oil System?

11. Name the major components of the seal oil system.

GENERATION OAHU DIVISION
OPERATOR TRAINEE TRAINING PROGRAM

SECTION 15

READING PIPING AND INSTRUMENTATION DIAGRAMS (P&ID)

P & IDs are drawings of the process and/or flow of the mechanical systems within a given power plant unit. In addition to showing the layout of the various mechanical and piping systems throughout this unit, all of the sensing, indicating, and recording instrumentation associated with these systems is also shown. The boiler feedwater system, the fuel oil piping system, and the boiler draft system are examples of systems that would be covered by piping and instrumentation drawings.

Each set of P&I Ds for a given unit has a Legend and Index sheet, listing all of the diagrams for the unit, and a summary explanation of the various symbols, codes and related data which appear on the diagrams themselves. The information contained in this section is an expansion of this Legend data as well as information designed to assist operators in interpreting P&I diagrams and broadening their knowledge of plant nomenclature. All of the data shown on these diagrams will not be defined here however; at least 85% of the symbols and codes are addressed.

Generally, there are one or more P&I diagrams reflecting each major mechanical system. The simpler systems may be shown on one such sheet while the more extensive systems may be reflected on two or more sheets.

P&I diagrams are schematic. A schematic diagram does not reflect dimensions; i.e., size, proportion, elevation, location, distance, etc. For example, a line on a schematic representing a pipeline does not reflect the fact that this particular pipeline actually spans several levels of the unit. Similarly, two identical symbols of the same size on a schematic representing valves do not reflect the fact that one of these valves is considerably larger than the other.

Since schematics do not acknowledge dimensions, they can reflect a large complex system with a multitude of equipment, utilizing a minimum of paper, and thus are very useful to operating and maintenance personnel. As illustration, the entire Waiau 8 boiler feedwater system with all associated instrumentation is shown on two sheets (52502 - Condensate System, 52503 - Feedwater system). If an operator did not have access to these two diagrams and needed to walk through or trace this system, he would have to utilize a file of drawings which do reflect dimensions. This file consists of some 35 drawings with each drawing being 3' x 4'. The P&I diagrams for Waiau Units 3 & 4 are on 17 x 24 sheets. The diagrams for Waiau Units 5 & 6 and 7 & 8 are on 11 x 17 sheets.

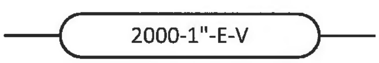
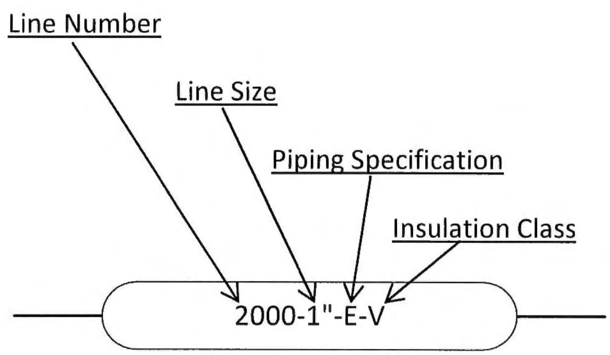
At the outset, a certain amount of basic formalized training will be furnished to the operators. However, operators will only become proficient in interpreting the diagrams for their units through practice over an extended period of time; i.e., tracing and/or walking through these systems, making a connection in their minds between the data reflected on the P&IDs and what that data physically represents in the plant.

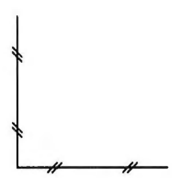
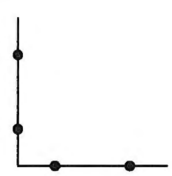
It should be noted that maintenance and other personnel also utilize these diagrams and operation do not necessarily have to interpret all of the data shown.

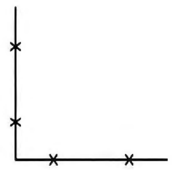
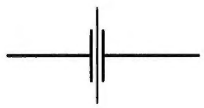
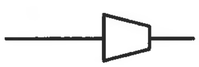
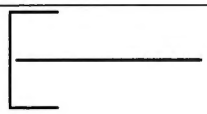
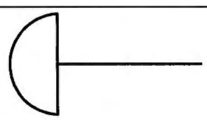
SYMBOLS

PIPELINES

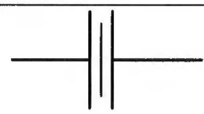
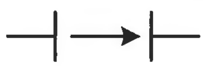
The information in this section basically pertains to the metal pipes themselves; no reference is made to any operational attachments or connection to these lines such as valves, gauges, etc.

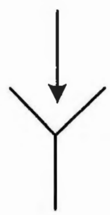
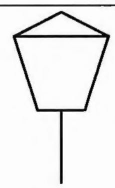
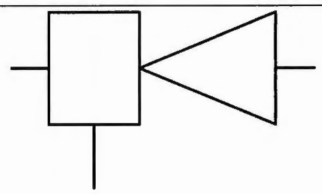
Item	P&I Code/Symbol	Explanation
1.		Line Data Code – All primary and secondary flow piping are labelled with this symbol/code. However other piping such as instrument process, control air, and capillary piping do not have this identification.  Line Number – assigned for identification and locating purposes. Line Size – size of the piping, this is a piping industry designation. Piping Specification Code – Identifies the service, schedule and material. Piping Insulation Class – Identifies service and material (usually expressed as a Roman Numeral)
2.		Primary Flow – Shown as darkened lines, and are thicker than all other lines representing piping. Primary flow lines carry

Item	P&I Code/Symbol	Explanation
		the main flow for a particular system (steam, water, air, etc.)
3.		Secondary Flow – Shown as the second thickest line. These lines serve such purposes as bypass, alternate route, and recirculation. A specific example would be a feedwater heater bypass line.
4.		Instrument Process – Shown as the third thickest line category. These are lines leading to instrumentation such as gauges which are indicating and/or recording data on various conditions of the system.
	Note: The degree of thickness between the secondary flow and instrument process piping as shown on the diagrams may be difficult to distinguish. Remember that secondary flow lines bear line data code and instrument process piping does not.	
5.		Control Air – Pipes which carry pressurized air used to operate various equipment and instrumentation such as valves, selectors, recorders, etc.
6.		Boiler Code – Piping that is constructed in accordance with the standards and requirements of the Boiler Code. P&I diagrams do not show all such piping. For example boiler tubing is not shown.

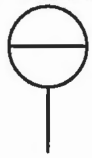
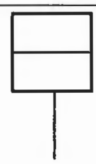
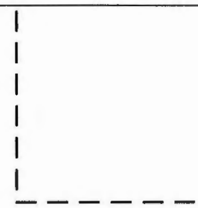
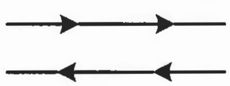
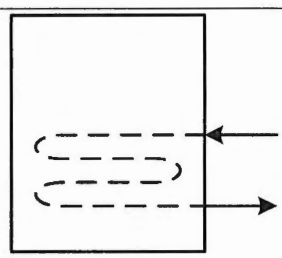
Item	P&I Code/Symbol	Explanation
7.		Capillary Tubing – Metal tubing carrying a mercury or gas power source to operate instrumentation such as temperature gauges.
8.		Union – A threaded device (similar to a standard coupling) joining two pieces of pipe. These devices are placed at various points on certain lines and are designed so that maintenance personnel can readily open the lines for inspection or repair. Regular couplings are not reflected on P&IDs.
9.		Line Size Change – At these points pips of two different sizes are connected. For example a 1" line connected to a 2" line. The larger side of the symbol reflects connection to the larger line and the smaller side connection to the smaller line.
10.		Screwed Cap – Dead-end of pipeline.
11.		Welded Cap – Dead-end of pipeline

BASIC (NON-INSTRUMENT) PIPING AND DUCT ELEMENTS OTHER THAN VALVES

Item	P&I Code/Symbol	Explanation
12.		Orifice – A metal plate within a pipeline which had an opening smaller than the normal pipe size. This opening is designed to reduce line pressure and allow a measured amount of flow.
13.		Nozzle – Generally, a constructed restriction within a pipeline or duct which is connected to instrumentation in order to measure flow. The arrow denotes flow direction.
14.		Flexible Hose – A non metal section of a piping system. It is usually comprised of a material such as reinforce rubber. It is used for applications where the line or related equipment had to be moved (such as a burner gun connection) or where the line expansion is severe due to heat (such as aspirating air for boiler observation ports).
15.		Hose Connection – A metal connector utilized to connect a hose portion to a metal portion of a line, such as service air, service water and lube oil system lines.
16.		Drain – A portion of a line, duct, or equipment designed to drain the contents.
17.		Vent – A portion of a line or equipment designed to allow air/gas removal or intake.

18.		Funnel – Basically a part of a drain system which allows visual inspection of the flow, or is utilized for feeding chemicals into a container.
19.		Exhaust Head – An ending of a cent system designed to release the contents into the atmosphere.
20.	 Or 	Injector or Ejector Injector – A device connected to a pipeline designed to inject material into the system. Ejector – A device connected to a pipeline designed to eject material from a system.

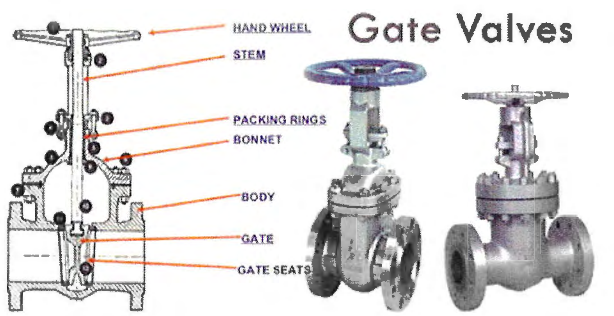
LOCAL VS. REMOTE MOUNTED APPARATUS AND INSTRUMENTATION

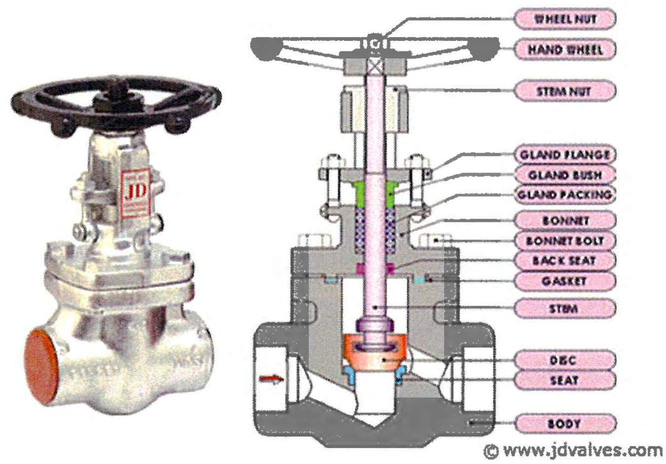
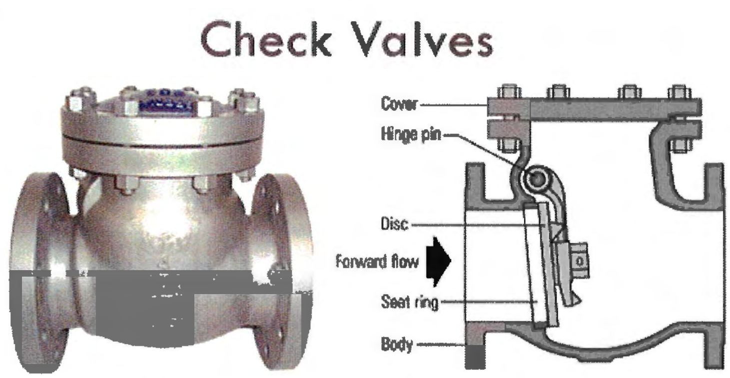
Item	P&I Code/Symbol	Explanation
21.		Local Mounted – The apparatus or instrumentation is actually located where the operation or sensing/indicating is taking place. An example would be feedwater heater temperature/pressure gauges.
21a.		Remote Mounted – The apparatus or instrumentation is located at a different location from where the operation or sending/indicating is taking place. Examples would be flow indicators and/or recorders in the control room.
22.		Instrument Electrical Leads – Wiring transmitting electrical signals to operate instrumentation and equipment such as fuel oil trip valves and alarms. These leads are normally shown on the P&ID when they are remotely located; they are normally not shown when they are locally mounted.
Directional and Reference Symbols		
23.		Arrow Heads – Flow Direction – These arrow heads indicate the flow direction in all primary and most secondary lines and may be shown on certain ducts. They are normally not shown on other lines such as Instrument Process, Control Air, Boiler Code, and Capillary Tubing.
24.		Lines/Apparatus/Elements Located Within Vessels – P&IDs do not usually reflect all such data. Where they are reflected they are shown in dotted line form.
25.		Spray Bars – Spray bars are an example of an apparatus which would be within a vessel. They are metal pipelines designed to spray water into condensers.

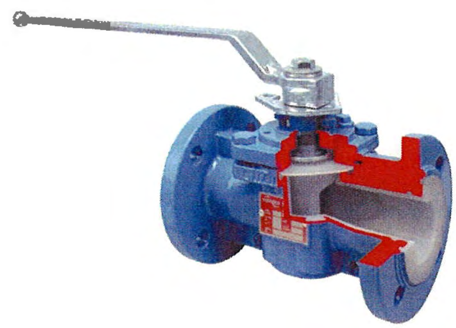
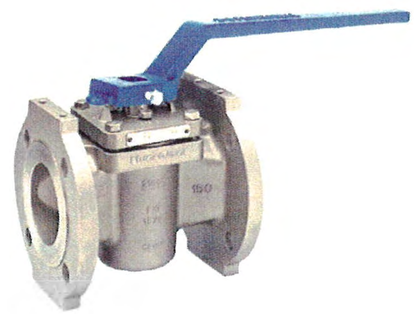
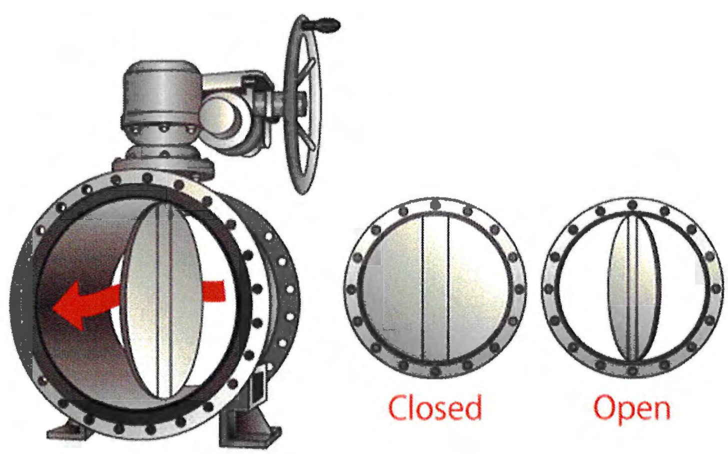
Item	P&I Code/Symbol	Explanation
26.	✳	This symbol mean that the supplier of the main equipment also furnishes all associated equipment to the main equipment as well
27.	CH. SP.	This pertains to piping only and is the abbreviation for the phrase “Change of Specification.” At these points where the code appears it is an indication that the piping has changed in some manner. For example a change from Specification Code A to B type of pipe.
28.	52503	Reference Tie-In to Another P&I Diagram or Drawing - This symbol will bear the drawing number of another P&ID which will reflect the continuance of a particular line or system. In moving from one diagram to another where primary and secondary lines are involved, the line number will normally appear close to the matching point on both diagrams; this will assist the reader in picking up the correct tie-in point. Frequently (but not always) a phrase will appear on drawings which will also assist the reader in picking up the correct tie-in point. Example: Drawing 52502 - Condensate System Drawing 52503 - Feedwater System At the end of line No. 8195 on Drawing 52502 the following is noted: "To Boiler Feed Pumps". At the beginning of line No .8195 on Drawing 52503 the following is noted: "From Condensate System".

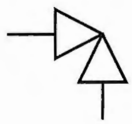
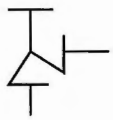
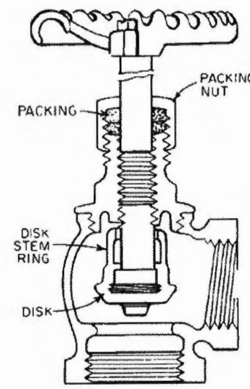
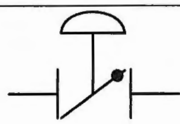
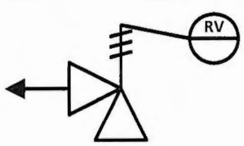
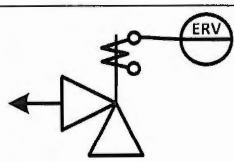
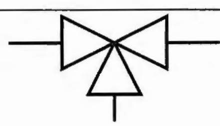
VALVES

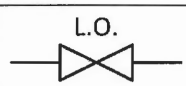
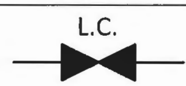
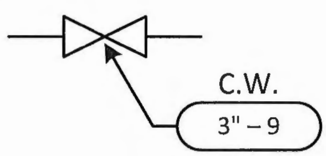
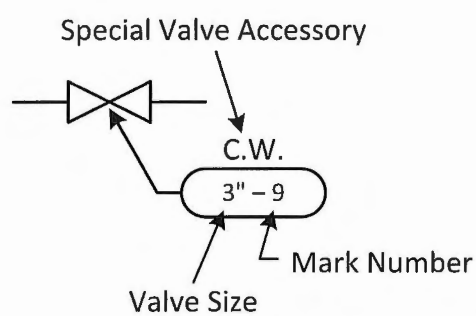
The descriptions for items 29 through 34 include cross section diagrams which are intended to reflect the basic internal composition of these valves. These diagrams reflect the valves as being manually operated. It should be noted that these diagrams cannot be used to assist in physically identifying such valves in the plant since differences between manufacturers as well as valves which are power operated may change the exterior appearance from those as shown in these diagrams.

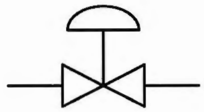
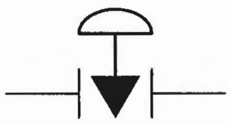
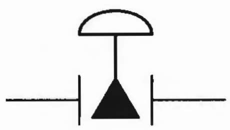
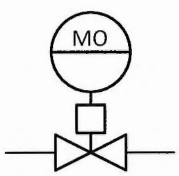
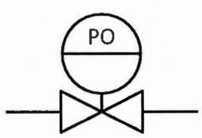
Item	P&I Code	Explanation
29.		Gate Valve – This valve is primarily for open and closed service. It is well adapted for isolation of equipment, where for long periods of time it will remain in the open or closed position and offers little or no obstruction to the flow. 

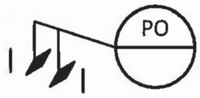
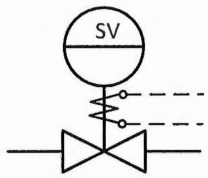
Item	P&I Code	Explanation
30.		Globe Valve – This valve provides an additional function over that of a gate valve – it can be used wide open, fully closed or in addition in an intermediate position for regulating flow. 
31.		Check Valve – This valve is entirely automatic in its operation, and is activated internally by the flow which it regulates. This valve permits the flow of fluids or gases in only one direction; if the flow stops or tries to reverse its direction the valve closes immediately and prevents a backflow. As soon as the line pressure is re-established, this valve opens and the flow is resumed. 

Item	P&I Code	Explanation
32.		Plug Valve – This valve is not restricted to one-way flow since it can be installed in either direction because it holds pressure in either direction. Flow can be reversed anytime without the danger of leakage or jamming.  
33.		Butterfly Valve – This valve is used in lines with large flow volume such as circulating water or condenser flow reversing systems. 

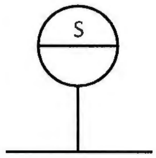
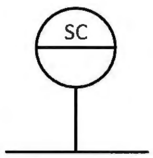
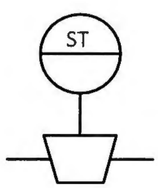
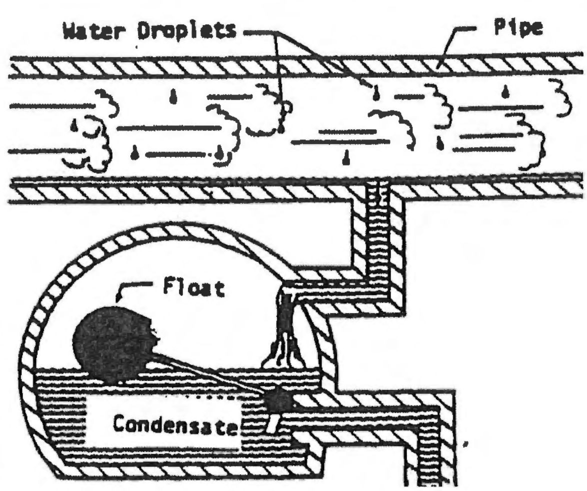
Item	P&I Code	Explanation
34.	 Or 	Angle Valve – This valve is basically a globe type valve, and is installed at a point where a line takes a right angle turn.  
35.		Bleeder Trip Valve – A check valve, operated by a pneumatic power source. It is used in such areas as turbine bleed steam lines.
36.		Relief Valve – This valve is normally closed. It is operated to open when the actual pressure in a line or vessel reaches a given point, and is designed to protect the line or vessel from an overpressure condition.
37.		Electromatic Relief Valve – Same function as a relief valve and is normally closed. Operated to open by an electrical impulse which is triggered when the pressure in a line or vessel reaches a predetermined set point.
38.		Three Way Valve – This valve allows a routing of the normal flow to 1 of 2 other directions. It is a combination of the globe and angle valve types.
39.		Gate, Globe, and Plug Valves Normally Open – When these valve types are normally open, they are shown in "lightened" form as illustrated in the symbol of a normally opened gate valve as shown here.

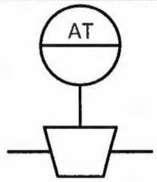
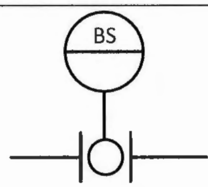
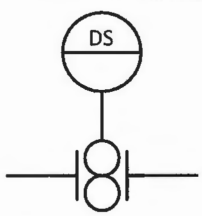
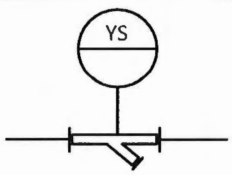
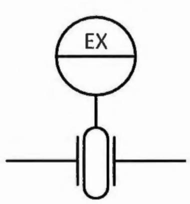
Item	P&I Code	Explanation
39a.		Gate, Globe, and Plug Valves Normally Closed – When these valve types are normally closed they are shown in "darkened" form as illustrated in the symbol of a normally closed gate valve as shown here.
	Note: Since the symbols for the gate and globe valves are very similar, it is difficult to readily distinguish which valve type is involved when this valve types are shown on the P&ID as "Normally Closed."	
40.	 	All Valves – Locked Open or Locked Closed – When a valve is locked open or locked closed the letters "L.O." or "L.C." will appear next to the symbol as illustrated here. The usual method of locking a valve is with a chain and padlock.
41.		Valve Data Code – All valves are labelled with this code as shown here.  Valve Size – Show in inches. Is a piping industry designation. Valve Mark – Refers to a valve index which is used by maintenance and engineering personnel. The index lists such data as type, service, and design data. Special Valve Accessory – These abbreviations identify additional apparatus which is installed for the operation of the valve. A list of codes appear on page ____

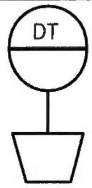
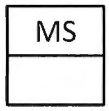
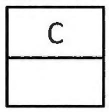
Item	P&I Code	Explanation
42.		Diaphragm – Various types of valves which employ a diaphragm operator and which are normally powered by air.
43.		Diaphragm operated control valve which will automatically open upon air failure in the line.
43a.		Diaphragm operated control valve which will automatically close upon air failure in the line.
44.		Equipment or Apparatus which is operated by an electric motor. As shown in this item, a gate valve.
45.		Equipment or Apparatus which is operated by a power source other than electric. For example by a pneumatic or hydraulic source. As shown in this item, a gate valve.

Item	P&I Code	Explanation
46.		Power Operated Damper - Dampers are utilized to control flow in air and gas duct systems. They are normally air powered.
47.		Solenoid Powered Equipment or Apparatus - A solenoid is a 2 position electric powered device, normally for the open and closed positions. As shown in this item, a solenoid operated gate valve.
48.		Float Operated Equipment or Apparatus – The level of fluid (water/oil) in a vessel raises or lowers a float which in turn operates the equipment. As shown in this item, a gate valve. (The explanation of #50 includes an illustration of float operated equipment.

OTHER APPARATUS

Item	P&I Code	Explanation
49.		Sample - A connection to a pipeline which al lows the withdrawal of content samples for inspection/analysis. An example would be a /211 pipe nipple with a 1/2" valve mounted at its end.
49a.		Sample/Cooler - Same as item 49 except that there is a cooling coil within the extension. This is utilized where the sample contents being withdrawn are at high temperatures.
50.		Steam Traps - As steam loses heat travelling through a line, droplets of water (condensate) collect on the inner surfaces of the pipe. If this water is allowed to build up in the line it will eventually fill the space needed by the steam and the flow will be blocked; also, water in the line could cause mal function of equipment to which the line is connected. These traps are designed to let condensate out of the line while retaining the steam. There are several types of steam traps in our system. The illustration below is a reflection of the operation of a float type steam trap. 

Item	P&I Code	Explanation
51.		Air Trap - Air traps serve the same purpose in airlines as steam traps (Item 50) serve in steam lines. Air traps remove liquid from air lines while retaining the air in the line.
	STRAINERS - ITEMS 52, 52a, 52b Strainers are designed to remove solid particles from pipelines which carry fluids. These particles may enter a pipeline in the fluid itself or may form within the line as the insides of the pipe walls corrode. By removing these solid particles excessive wear and equipment malfunction are minimized.	
52.		52. Single Basket Strainer - Contains 1 strainer. The line flow must be stopped when the strainer is removed for cleaning or replacement.
52a.		52a. Duplex Strainer - Contains 2 strainers. Normally the flow is through 1 strainer. However, by operating a valve, flow can be diverted through one strainer while the other strainer is being cleaned or replaced; thus line flow is uninterrupted.
52b.		52b. WYE Strainer - A single basket type strainer. This strainer can be cleaned without removal by using the line pressure, since there is a blow down valve connected to a point in the line adjacent to the strainer. As with the duplex strainer, the WYE strainer can be cleaned without interrupting line flow.
53.		53. Expansion Joint - A joint in a pipeline or duct that can expand to compensate for any one of or combination of three elements: Heat, weight, or pressure. Also in some instances these joints are utilized to compensate for piping misalignments. Such joints are usually comprised of a material such as reinforced rubber or a bellows type of construction employing stainless steel ribbing.
Item	**P&I Code**	**Explanation**

54.		54. Drain Trap - Similar function as steam traps and air traps (Items 50 & 51). Drain traps remove steam which may get into lines carrying fluids.
55.		Manual Switch - Has no provision for automatic operation. Is operated manually on a on-off basis. Is powered by air or electricity.
56.		Auto-Manual Control - A switch or other control device which can be set to be operated either automatically or manually. Has on-off and intermediate position capability.

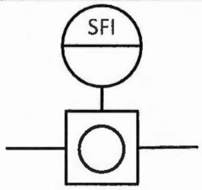
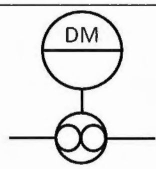
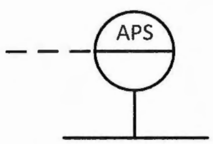
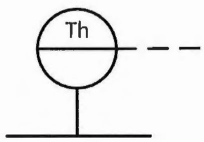
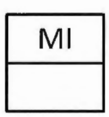
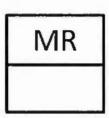
INSTRUMENTATION IN GENERAL

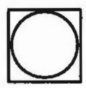
Power Plant instruments perform a wide variety of functions. However, all of these functions fall within a framework of 2 general categories, which are outlined below.

1. Sensing/Measuring - Instruments sense (or measure) a variable, such as pressure, temperature, flow, level, etc. Normally all instruments appearing on the P&IDs are shown at the point in the system where their sensing is taking place.
2. Indicating and/or Action - Instruments have an indicating and/or action function. "Indicating" is communicating the information, such as the pressure reading on a gauge. An instrument with an "Action" function is designed to automatically trigger some action in the system when it senses a given condition or conditions. An alarm is an example of the action function; Item 59, an automatic pump start, is another example.
3. Recording - This is a form of the indicating function, in that the information is permanently recorded in some manner. Item 62, a multipoint recorder is an example of this application.

Page 23 outlines the Instrument Identification Table. Proficient use of the table can be attained through practice.

INDIVIDUAL INSTRUMENT SYMBOLS SHOWN ON THE P&I LEGEND

Item	P&I Code	Explanation
57.		Sight Flow - An attachment which is part of a line carrying fluids which has a glass panel to al low visual inspection of the line flow. These devices are only utilized on low pressure lines.
58.		58. Flow Meter - An ·attachment which is part of a line carrying fluids. This attachment contains wheel s/flappers which in turn are connected to a meter which indicates the line flow rate.
59.		Automatic Pump Start - An instrument which senses abnormal pressure level s in a line carrying fluids and will automatically start a pump or pumps to restore the line pressure to normal level.
60.		Thermocouple - An instrument which electrically indicates the temperature in a line or duct. Thermocouples are installed with and without recording capability, depending on need.
61.		Multipoint Indicator - A set of gauges indicating various combinations of flow rate, pressure and temperature which are sensed at various points in lines and ducts. These indicating devices are normally located in the control room.
62.		Multipoint Recorder - Same as Multipoint Indicator (Item 61.); however the data is recorded.

Item	P&I Code	Explanation
63.	  	Two instrument devices located in the same casing, with both devices utilizing a common sensing point. In some instances this symbol is expanded to reflect 3 or more such devices instead of 2. Shared displays or shared control

INSTRUMENT IDENTIFICATION TABLE

"D"	Differential Instrument
"H"	High Variable Instrument
"L"	Low Variable Instrument
"HD"	High Variable Differential Instrument
"LD"	Low Variable Differential Instrument

PRIMARY TABLE

FUNCTION OF DEVICE (Third Letter)		CONTROLLER "C"		TRANSMITTER "T"		METER			MISCELLANEOUS			
TYPE OF DEVICE (Second Letter) / MEASURED VARIABLE (First Letter)		Indicator or Blind	Recorder	Idicator or Blind	Recorder	Direct Indicator	Pneumatic Indicator	Recorder	Switch	Primary Sensing Element	Test Point or Well	Visual Observation Device
		---	"R"	---	"R"	---	"I"	"R"	"S"	"E"	"X"	---
Pressure	P	PC	PRC	PT	PRT	P	PI	PR	PS	---	PX	P
Temperature	T	TC	TRC	TT	TRT	T	TI	TR	TS	TE	TX	T
Flow	F	FC	FRC	FT	FRT	---	FI	FR	FS	FE	FX	SFI
Level	L	LC	LRC	LT	LRT	L	LI	LR	LS	LE	---	L
Conductivity	C	---	---	---	CRT	---	---	---	---	CE	---	---
Oxygen	O2	---	---	---	---	---	---	O_2R	---	---	---	---
H+ Conc.	pH	---	---	pHT	---	---	---	---	---	pHE	---	---
Position	Po	---	---	PoT	---	---	PoI	---	PoS	---	---	---
N_2H_4 Conc.	Hz	---	---	HzT	---	---	---	---	---	HzE	---	---
PO_4 Conc.	PO_4	---	---	---	---	---	PO_4I	---	PO_4S	---	---	---
Combustibles	Cb											
Hydrogen	H2											
Smoke Density	Sm											
Speed	Sp											

ALARM

"A" When applicable this will be the last letter in the series.

BASIC DEFINITIONS

MEASURED VARIABLES – PRIMARY INSTRUMENT IDENTIFICATION TABLE

Measured Variable	Definition
Pressure	The force that is being exerted on an area. It is usually measured or indicated in terms of pounds per square inch.
Temperature	The magnitude of heat of a fluid, gas, steam, or metal. It is either measured or indicated in terms of degrees Fahrenheit or degrees Centigrade.
Flow	Flow Rate - The amount of fluid or gas that passes a point during a given time interval. It can be measured or indicated as volume per unit time such as "gallons per minute", or as weight per unit time such as "pounds per hour".
Level	The height of a fluid in a vessel.
Conductivity	The amount of dissolved impurities in water or steam.
Oxygen	The amount of dissolved oxygen in a vessel, line, or duct.
H+ Conc.	Hydrogen Ion Concentration - The amount of hydrogen ions in water at various points in the system.
Position	The degree of opened position of a given piece of equipment such as a circulating water valve or a fan damper.
N_2H_4 Cone.	Hydrazine Concentration - The amount of hydrazine in boiler feedwater.
PO_4 Conc.	Phosphate Concentration - The amount of phosphate in boiler water.
Combustibles	The amount of incomplete burning of fuel oil.
Hydrogen	The amount of hydrogen gas density in a generator.
Smoke Density	The amount of smoke density in a stack.
Speed	The number of revolutions per minute (RPM) of a given device or mechanism, such as a turbine.

INSTRUMENT IDENTIFICATION PREFIX TABLE

Code	Explanation
D	Differential Instrument - Measures a variable at 2 different points and indicates the difference.
H	High Variable Instrument - Measures and indicates a variable of a high magnitude for a given system, such as high pressure or temperature
L	Low Variable Instrument - Measures and indicates a variable of a low magnitude for a given system, such as low pressure or temperature.
HD	High Variable Differential Instrument - Measures a variable of a high magnitude for a given system at 2 different points and indicates the difference.
LD	Low Variable Differential Instrument - Measures a variable of a low magnitude for a given system at 2 different points and indicates the difference.

SPECIAL VALVE ACCESSORIES

Code	Explanation
CW	Chain Wheel - The valve hand wheel is operated with a chain. This method of manual valve operation is employed where valves are located at high elevations above the surface upon which the operator can stand.
ES	Extension Stem - The stem of a given valve is longer than the normal length utilized for that valve. Extended stems are utilized in situations where valves are located at points where operators would not have ready access to them if the stems were of normal length.
FS	Floor Stand - Valves located below floor level normally will have an extension stem passing through the floor surface. A metal casing is normally placed around the portion of the stem which is above floor level.
GO	Gear Operator - A gear attachment to the valve stem which furnishes the operator more leverage. Gear operation is normally utilized on the larger valves. The figure in the explanation of item 33 shows a gear operation attachment on the butterfly valve.
WS	Water Seal - Water is provided (by tubing) to the valve gland area, which prevents air intake. An example would be preventing air intake into a valve which is a part of the condensate system which is under vacuum.
PS	Position Switch - A switch device mounted on a valve which indicates whether the valve is currently open or closed, and in some cases partially opened/closed.

PIPING SPECIFICATION DATA

Specification Code	Type of Metal – Lines*	Pressure Range – Lbs. Per Sq. Inch (0= Vacuum)	Temperature Range (Degrees Fahrenheit)
A	Alloy Steel	1875	1005
B	Carbon Steel	1600-3300	300-650
C	Alloy Steel	580	1005
D	Carbon Steel	600-625	490-710
E	Carbon Steel	200-565	100-480
EE	Alloy Steel	5-250	800-900
	Carbon Steel	0-175	100-775
G	Carbon Steel	1100	300
H	Carbon Steel	50-150	100-300
I	Carbon Steel	5-300	70-120
J	Cast Iron	25-120	83-96
K	Galvanized Steel, or Seamless Copper Tubing, or Stainless Steel Tubing	100	120
M	Galvanized Steel	75	100
N	Alloy Steel	125	80
P	Carbon Steel	20	85
PP	Cast Iron	20	85
T	Seamless Aluminum Alloy	75	100
V	Stainless Steel	300	100
W	Stainless Steel	2500	110

*Pertains only to the line itself – frequently valves and other connections on the line are of a different type of metal.

PIPING INSULATION DATA

Insulation Class	Temperature Range (Degrees F)	General Type or Nature of Insulation
I	751-1005	Calcium silicate in blocks or molded form. Aluminum jacket on all straight pipe. On valves, fittings or bends, either aluminum jacket throughout, or canvas jacket indoors and weatherproof coating outdoors.
II	551-750	Same as Class I, except thickness or extent of insulation is less than Class I
III	351-550	Same as Class I, except thickness or extent of insulation is less than Class II
IV	251-350	Same as Class I, except thickness or extent of insulation is less than Class III
V	120-250	Same as Class I, except thickness or extent of insulation is less than Class IV
VI	135+	Same as Class I, except thickness or extent of insulation is less than Class V. Class IV insulation is for personal protection only; heat less is not a factor as it is with Classes I thru V. Also some of this piping may not be insulated in areas where the chances of personal contact are remote.

POWER GENERATION DEPARTMENT

OPERATOR TRAINEE TRAINING PROGRAM

Section 16
BOILER FUEL SYSTEMS

OBJECTIVES:

1. Discuss typical burning systems
2. Describe the function and basic problems of fuel oil burners
3. Discuss fuel oil heating, viscosity, and temperature control.

of the oil delivery.

Some plants will be able to receive, store and burn crude oil. Crude oil presents problems in handling which must be well understood. The accumulation of explosive fumes is the primary source of concern. Some crude oil storage tanks have floating roofs as a safeguard against the accumulation of fumes. There are OSHA and state requirements which must be adhered to. Primary responsibility for safe operations rests with the operators, for maintenance with maintenance force. Some of the problems we have to contend with are monitoring of suspected areas for hydrocarbon vapors, the use of power tools, mobile tools, or any tool with the ability to create a large spark to ignite the vapors. Hydrocarbon "sniffers" are the primary preventive aid. Remember, crude oil is a volatile oil. IF IN DOUBT - TAKE PRECAUTIONS.

TYPICAL BURNING SYSTEM

Oil is pumped from one or more tanks where the temperature is raised to approximately 150°F by internal steam coils. The oil pressure is raised by the transfer pumps and discharged to a header. The header pressure is controlled at approximately 66 to 70 psig by pressure control valves which recirculate oil back to the tank. The oil from the transfer fuel oil pump discharge header supplies the boilers through a secondary fuel oil heater. The oil temperature is raised to burning temperature by the secondary heaters. Oil pressure to the burner guns is controlled by a valve which can be operated by either the combustion control automatically or remote manual by the operator. Oil flow is metered and supplies the secondary fuel oil pumps.

The actual pressure in the whirling chamber of the burner tip is increased since it is essentially the burner return pressure. The higher pressure in the whirling chamber causes more oil to be sprayed into the furnace. The amount of oil being burned at any time is directly proportional to the burner return pressure. A change in boiler combustion requirements will result in a change in oil flow control valve position, increasing or decreasing the flow and

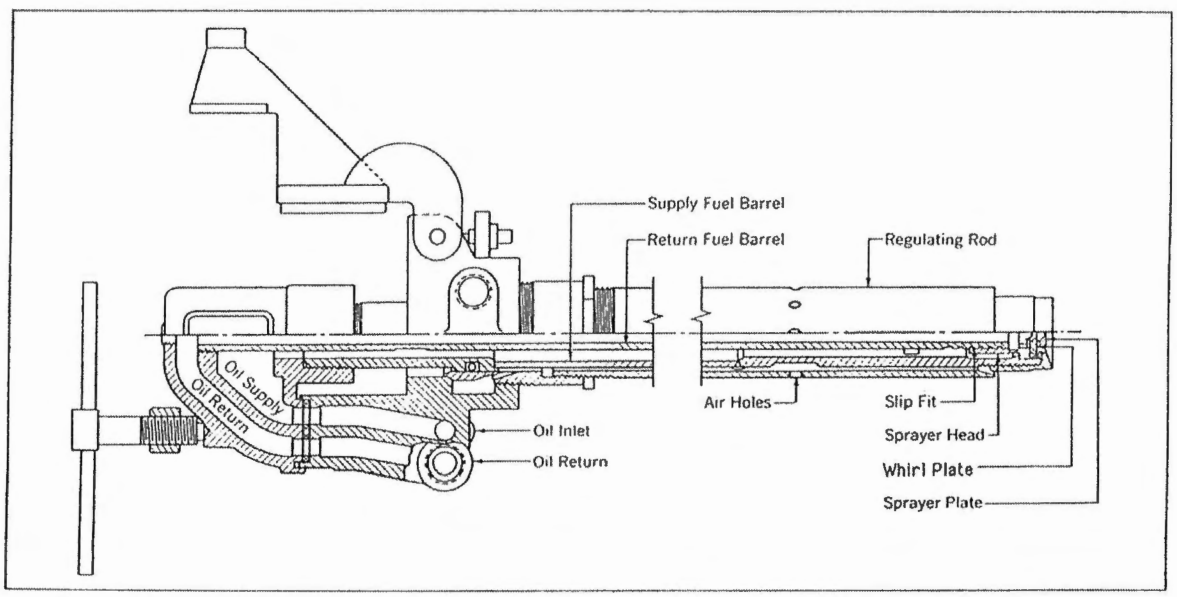


Figure 16-1

pressure of oil supplied by the secondary fuel oil pump and subsequently to the burner guns. (Figure 16-1).

This system maintains a constant circulation of oil through lines, pumps, and heaters during the periods when gas fuel is being burned. The fuel oil system remains warmed and available for service on short notice.

FUEL OIL BURNERS

The burner must prepare the fuel for combustion by atomizing, or breaking the fuel into as many small particles as possible. This exposes more surface to heat, so the oil can be vaporized for mixing with air. The motion between oil particles and air must be turbulent and sweep vapor films away, exposing fresh surfaces to heat as rapidly as possible. The resulting combustion produces more free carbon because the complete mixing of fuel vapor and air has been somewhat delayed. This delay allows the fuel to reach a higher temperature which results in more cracking. The resultant flame is short, yellow and highly luminous. It has better radiation characteristics but any chilling of the flame before the carbon is burned to completion will result in soot deposits.

The oil supplied to the burner guns is heated to reduce its viscosity. Usually the lowest temperature which produces a satisfactory operating condition for the grade of fuel used is desirable. This prevents overheating with the resultant coking or carbon formation in the equipment. Bunker "C' or more recently called No.6 Fuel Oil is the grade generally used in our system. Approximately 150°F for pumping from storage to secondary heating and approximately 200-230°F for supply to mechanical atomizing burners is desirable.

The secondary fuel oil pump supplies oil through the burner gun outside barrel to the tangential slots of the burner tip where it is given a whirling motion. A portion of the oil supplied to each burner, depending on load, is returned to the suction of the secondary pump. The degree of atomization is a function of the speed of rotation of the oil in the whirling chamber of the tip.

This speed of rotation is, in turn, a function of the difference in oil pressure across the

Table 16-1

	Problem	Probable Cause(s)	Corrected By
1	Flame separation from burner tip	Oil too hot, diffuser too close to the tip, or air flow too high.	Reduce oil temperature or reduce air flow.
2	Flame burning toward burner throat	Air flow too low, register throttled too much	Increase air flow, readjust registers.
3	Smoking Flame	Cold oil, poor atomization, dirty burner, or insufficient air.	Increase oil temperature, clean burner, increase air flow.
4	Formation of clinkers (carbon buildup)	Dirty burner, loose tip, burner retraction out of adjustment, cold oil, or incorrect air register setting.	Clean burner, check tip for tightness and tighten as needed, readjust retraction, increase oil temperature, or check and adjust register setting.
5	Fire flies or sparklers	Oil too hot or too much air.	Reduce oil temperature or reduce air flow.

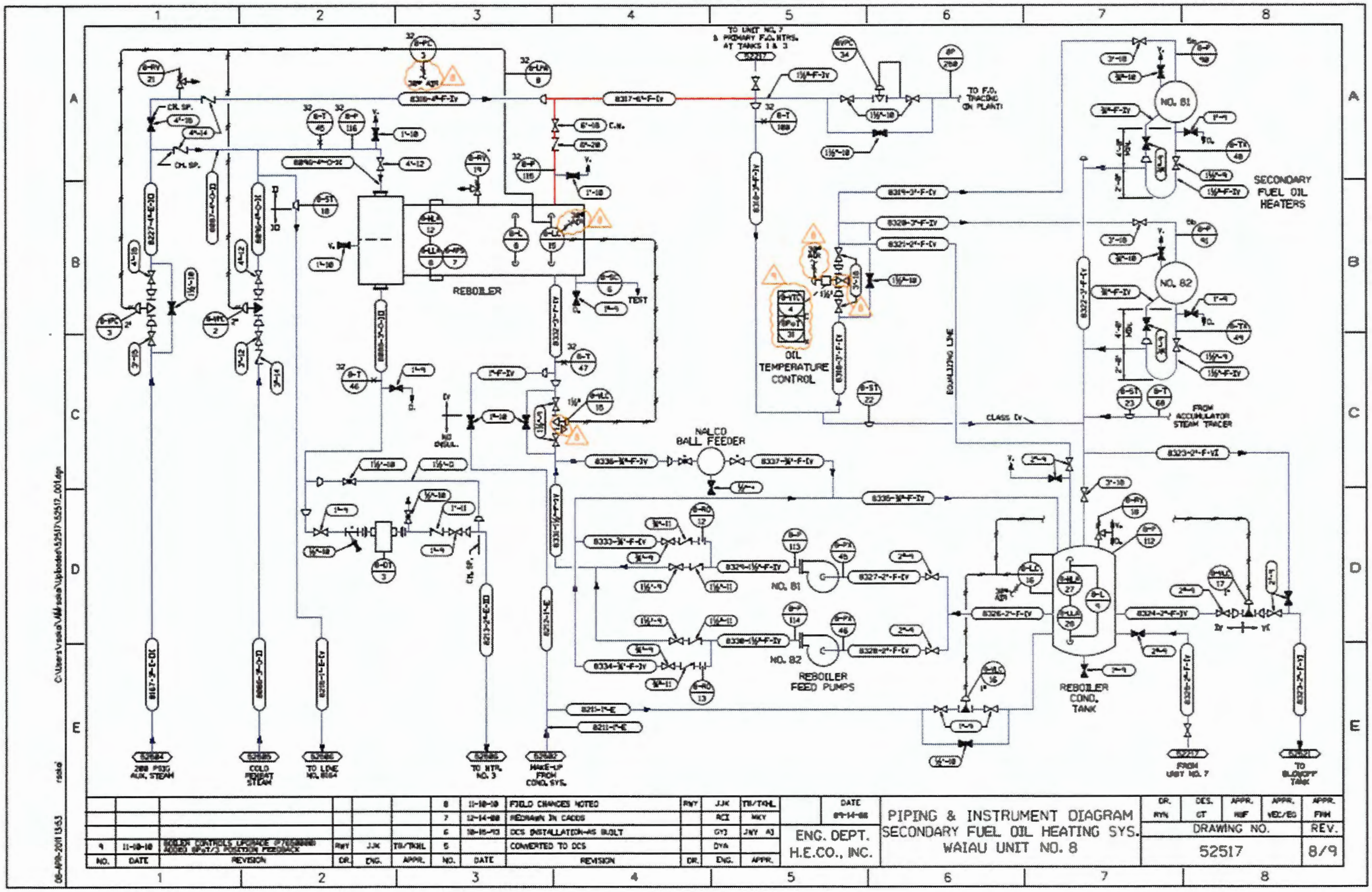
FUEL OIL PUMPS

The pumps used for moving fuel oil are generally of the screw type. They are positive displacement and able to handle relatively high viscosity oil and deliver a smooth flow at rated capacity and pressure. The primary fuel oil pumps are of this type. W3 and 4 fuel oil pumps maintain a constant differential pressure where a constant boost in pressure over a wide range of flow is desired, are the centrifugal type. In the return flow control type of system, WS-8, both primary and secondary fuel oil pumps are of the positive displacement, screw type.

Alarms associated with the fuel oil system are as follows:

- Fuel oil pump strainer high differential.
- Fuel oil pump stand-by start.
- Secondary fuel oil pump suction low pressure.
- Secondary fuel oil heater steam pressure low.
- Secondary fuel oil pump tripped
- Secondary fuel oil heater's discharge low temperature
- Secondary fuel oil discharge header high-low pressure

Figure 16-3


PIPING & INSTRUMENT DIAGRAM
SECONDARY FUEL OIL HEATING SYS.
WAIAU UNIT NO. 8
ENG. DEPT.
H.E.CO., INC.
DRAWING NO.
52517
REV.
8/9
REBOILER
OIL TEMPERATURE CONTROL
NALCO BALL FEEDER
REBOILER FEED PUMPS
REBOILER COND. TANK
SECONDARY FUEL OIL HEATERS
NO. 81
NO. 82
EQUALIZING LINE
TO F.O. TRACING ON PLANT
200 PSIG AUX. STEAM
COLD REHEAT STEAM
TO LINE NO. 8164
TO HTR. NO. 3
MAKE-UP FROM COND. SYS.
FROM UNIT NO. 7
TO BLOWOFF TANK
FROM ACCUMULATOR STEAM TRACER
TEST
8 11-10-10 FIELD CHANGES NOTED
7 12-14-00 REDRAWN IN CADDS
6 10-15-93 DCS INSTALLATION-AS BUILT
5 CONVERTED TO DCS
9 11-10-10 BOILER CONTROLS UPGRADE
NO. DATE REVISION DR. ENG. APPR.

NOTES:

Section 16
BOILER FUEL SYSTEMS
Study Questions

1. Discuss way fuel oil temperatures are maintained in fuel oil service tanks.

2. The increase or decrease in the flow and pressure of oil supplied to the burner guns is determined by boiler combustion requirements. (Circle one) True / False

3. What is the location and function of the Whirling Chamber?

4. What is meant by "atomizing"?

5. Following are five (5) basic problems encountered with fuel oil burners. Give the probable cause of each problem and the correction:

   A. Flame separation from burner tip:

   B. Flame burning toward burner throat:

   C. Smoking flame:

   D. Formation of clinkers (carbon buildup):

   E. Fire flies or sparklers:

6. Before moving the handle to manually start the igniter, the air, current and gas should be on. (Circle one) True / False

7. How is the SSU viscosity determined?

8. What factor causes the viscosity of fue oil to change?

9. The lowest temperature at which an oil will just flow is indicated by the ____________ _______________.

10. Lowering the viscosity of fuel oil for ease of handling and proper atomization is performed by various ______________________________ located at strategic points in the cycle.

11. What happens to fuel oil temperature in the secondary heat exchangers as opposed to the fuel oil tank's steam coil?

12. Oil temperature can be accomplished in two ways. These are:

A.

B.

13. When placing a fuel oil heater in service, the following operation should be observed. (Circle one)

A. Steam should not be on unless some oil is flowing through the heater.

B. Heater drips are routed into the system.

C. Both of the above.

GENERATION-OAHU DIVISION
OPERATOR TRAINEE TRAINING PROGRAM

Section 17
MAKEUP WATER TREATMENT SECTION

OBJECTIVES:

1. Discuss the supply or source of water for water purification systems.
2. Describe the pretreatment of water in water purification systems.
3. Discuss the methods used to produce high purity water.
4. Describe how purified water is stored and transferred.

Resources:

1. YouTube Video: How Does Electrodialysis Work?
   https://www.youtube.com/watch?v=wvS7jslhGBQ
2.

Section 17

MAKEUP WATER TREATMENT SYSTEM

High purity water is essential for corrosion prevention and scale control to insure continued operation of a steam plant. It is necessary to produce and maintain a supply of this water at the plant. The system for producing, storing and utilizing this water is known as the makeup water treatment system. Distillation and demineralization are two methods of purification. In the Hawaiian Electric Company power plants, pure water is made by demineralization. The systems installed in the various plants may be different; however, a general discussion can cover most of the important systems. This discussion will cover the following topics: Supply or Source of Water, Pretreatment of Water, Production of Pure Water, Storage and Utilization.

SUPPLY OR SOURCE

The water which is used to make demineralized water is referred to as raw water. This is the supply before anything has been done to it. The source for raw water may be recycled water, wells or domestic (city) water. The water may be pumped directly to the demineralizers.

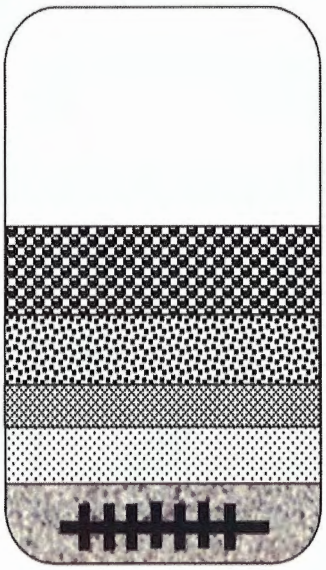
PRETREATMENT

Depending on the quality of the raw water, it may be necessary to pretreat the water before it is demineralized. When present in large amounts, suspended and dissolved solids must be removed from raw water to prevent fouling of ion exchange resins or reverse osmosis membranes.

Some of the common equipment used to pretreat water includes filters and reverse osmosis.

Filtration effectively removes suspended solids (tubidity) or insoluble solid impurities. A Multi-Media Filter (MMF) system is used to reduce the level of suspended solids in the raw water. A typical system would contain 3 layers of media which differ in size and density such as anthracite coal, sand and garnet. (see Figure 17.1) The media is arranged in layers with the largest forming the top layer and the smallest the bottom layer. In this configuration, the larger, lighter media layer near the top of the bed removes the largest dirt particles and the smaller dirt particles are trapped deeper in the bed by the finer, denser material in the lower layers. This allows the entire bed to act as a filter

Figure 17.1—Typical Multi-Media Filter



resulting in more efficient removal of the particulates. When the solids holding capacity of the media filter is exhausted, a backwash operation must be performed to remove the entrained solids from the filter. During a backwash operation pressurized feed water is directed from the bottom of the vessel and discharged through the top. The water fluidizes the media as it enters the vessel which allows entrained solids to be released and conveyed out of the filter with the backwash water. After the backwash the media settles back to the bottom of the filter. Due to the varying densities of the media the finer media settles below the lighter media. The filter media stratifies into different layers.

Reverse Osmosis (RO) is a type of filtration that uses a semi-permeable membrane that allows pure water to pass through, but rejects larger molecules such as dissolved salts or ions, and other impurities such as bacteria. (Figure 17.2a & 17.2b) This process produces highly purified water which is eventually used in our boilers.

Osmosis is the natural tendency of water with dissolved salts or ions to flow through a membrane from lower to higher salt

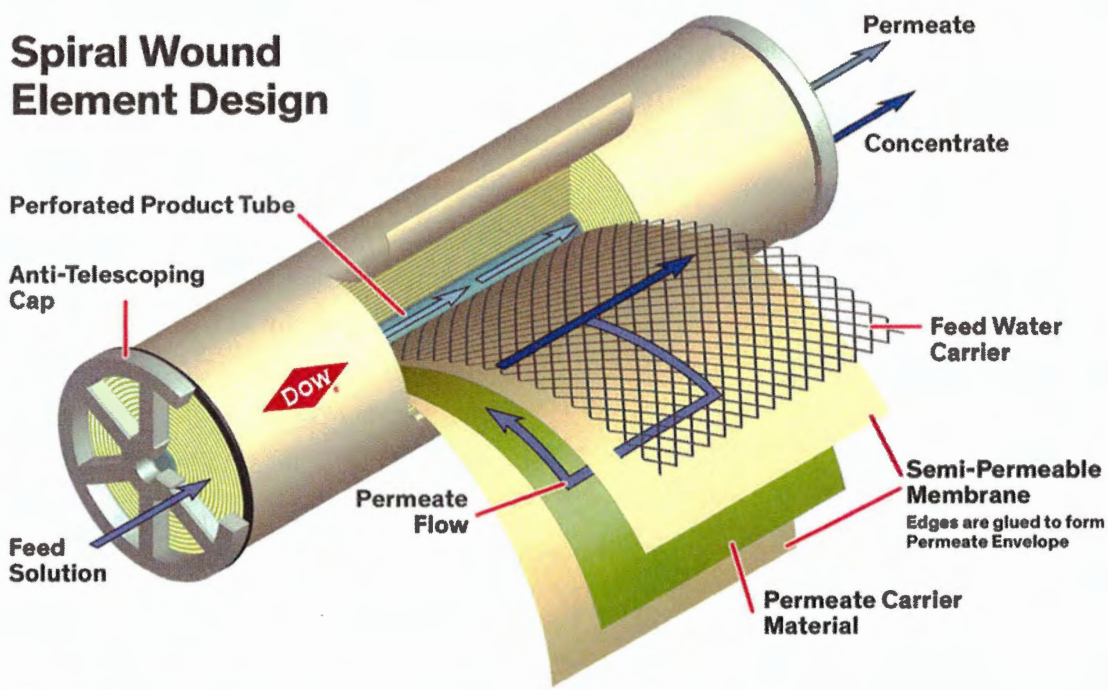


Figure 17.2 The figure above is of a typical RO membrane. Each membrane in our system is 40 in in length and has an 8 in diameter.

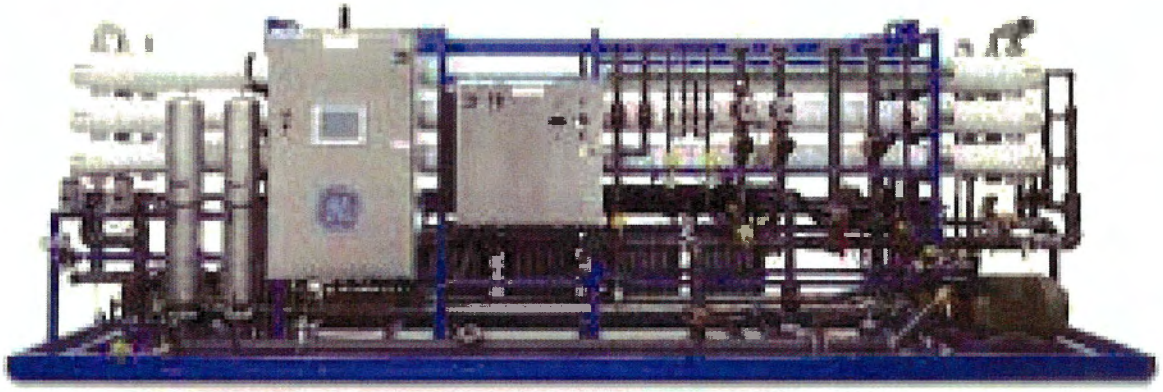


Figure 17.2b Reverse Osmosis system.

concentration. Osmosis is found in nature such as:

- Plants use it to absorb water and nutrients from soil
- In humans and other animals, kidneys use it to absorb water from blood

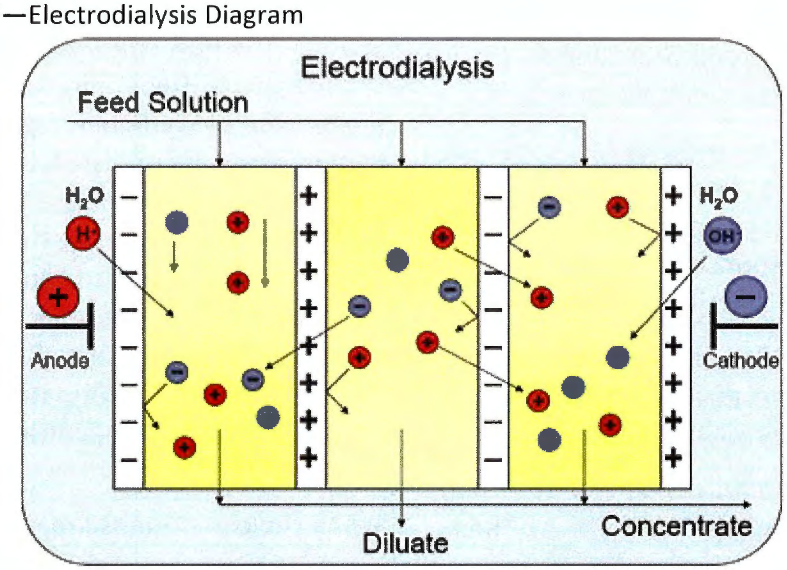
Some advantages of using an RO system:

- Simple to operate
- Energy efficient

All natural waters contain dissolved salts which dissociate in water to form particles called ions. Cations are positively charged ion, such as sodium (Na+) and calcium (Ca++). Anions are negatively charged particles, such as chlorides (Cl-) and carbonates (HC03-). Electrodialysis is an electrochemical separation process in which ions are transferred through membranes from a less concentrated to a more concentrated solution as a result of the influence of a voltage potential (DC voltage). This attraction of oppositely charged particles is the fundamental principle employed in the electrodialysis process.

Electrodialysis Reversal (EDR) is used to remove dissolved solids by attracting the

Figure 17.3—Electrodialysis Diagram



charged ions in the water to positive and negative electrodes. The basis of operation is the passage of water between paired sets of anion and cation permeable membranes with the application of an electric field. (Figure 17.3) Cation permeable membranes allow positively charged ions to pass through and the anion membranes allow negatively charged ions to pass through. Hundreds of membrane pairs make up the EDR unit. EDR units typically remove about 90% of dissolved solids from water.

The Waiau station pretreats its raw water which is drawn from a well on its property. The pretreatment is necessary because the well water contains twice as much dissolved solids as city water.

WATER CHEMISTRY

Water plays an important role in the production of electricity. Steam-electric generating stations depend on water to make steam for the purpose of producing electricity.

HECO is committed to provide continuous electricity in adequate quantity to our customers. To meet this demand and trust, presently HECO has invested in twenty-one (21) electric generators of which twelve (12) are steam turbine generators, three (3) are combustion turbine generators and six (6) are reciprocating internal combustion engines.

Because water is an indispensable material for steam-turbine generators, a basic knowledge of boiler water chemistry would certainly aid responsible operators and engineers in doing their jobs more effectively.

Water - The Ideal Material. The principal reasons why water is an ideal material for steam driven generators are fourfold:

1. Because water is capable of absorbing and releasing great quantities of heat, it is a very effective heat transfer medium. In heating one pound of water, it takes one British Thermal Unit (BTU) to raise the temperature one degree Fahrenheit (°F). Assuming the condensate temperature to start with is 100°F, it will require 112 BTU to heat a pound of water to the boiling point, at 212°F. From the boiling point, an additional 970 BTU is needed to change the pound of water to steam. Therefore, a total of 1082 BTU will be absorbed by only one pound of water starting at an original temperature of 100°F.
2. Steam has the ability to store up the great amount of heat energy absorbed by the water, and is able to release this energy at the turbine, thus converting it to useful mechanical energy.
3. After performing its useful work at the turbine, the steam can be condensed and recovered as feedwater to be used over again in the steam generating cycle.
4. Water is an abundant natural resource, and from an economic standpoint, it is cheap because of its availability.

Water - The Raw Material. All raw water is not the same. Depending on the source (lake, river, or well), natural waters contain varying amounts of dissolved and suspended solids and dissolved gases. Because water is an excellent solvent, it dissolves gases and solids that it comes into contact with. Concentrations of the solids are quantified as parts per million or ppm. The most offensive dissolved solids are compounds of calcium, magnesium, iron manganese, silica, and sodium.

When the compounds are dissolved in water,

Table 17.1—Minerals Typically Found In City Water

		Honolulu	Waiau	Kahe
Total Dissolved Solids	(micromhos)	300	265	700
Bicarbonate ions	(ppm)	80	60	110
Sulfate ions	(ppm)	10	5	50
Calcium ions	(ppm)	10	5	17
Magnesium ions	(ppm)	10	5	17
Silica	(ppm)	40	50	75
Chloride ions	(ppm)	60	30	120
Sodium ions	(ppm)	40	30	90

they separate into their component parts which carry an electrical charge. These are called ions. Positively charged ions are called cations and the negatively charged ions are called anions. This concept is the basis for most water purification processes.

The compounds calcium and magnesium constitute what is generally termed "hardness". These undesirable compounds precipitate from water and adhere to metal surfaces to form scale. Scale forms faster as the temperature of the water increases. Scale deposits form a barrier layer between water and the metal surface which retards heat transfer and even damages the metal.

Silica is another compound which, like scale, forms deposits on metal surfaces causing similar problems. Silica deposits are glasslike and very difficult to remove. Every effort is made to remove silica from waters used in our high pressure boilers.

Dissolved gases corrode metal surfaces. Even rainwater containing dissolved oxygen and carbon dioxide, although pure enough to drink, is unsuitable for critical industrial uses such as steam generation.

Some typical minerals which we normally encounter in our city water supplies are outlined in Table 17.1.

EXTERNAL TREATMENT

External treatment is used to remove impurities from raw water before it enters the boiler cycle. For all of our units, external treatment consists of demineralizers followed by deaerating condensers or feedwater heaters.

Demineralizer. Dissolved chemical compounds or salts break up or ionize into positive ions called cations and negatively charged ions called anions. Water demineralization is a process which improves the quality of the water by removing the impurities by ion-exchange. Ion exchange involves the exchange of one ion for another. This exchange takes place on tiny beads called ion exchange resins. Each bead has thousands of sites where the exchange takes place.

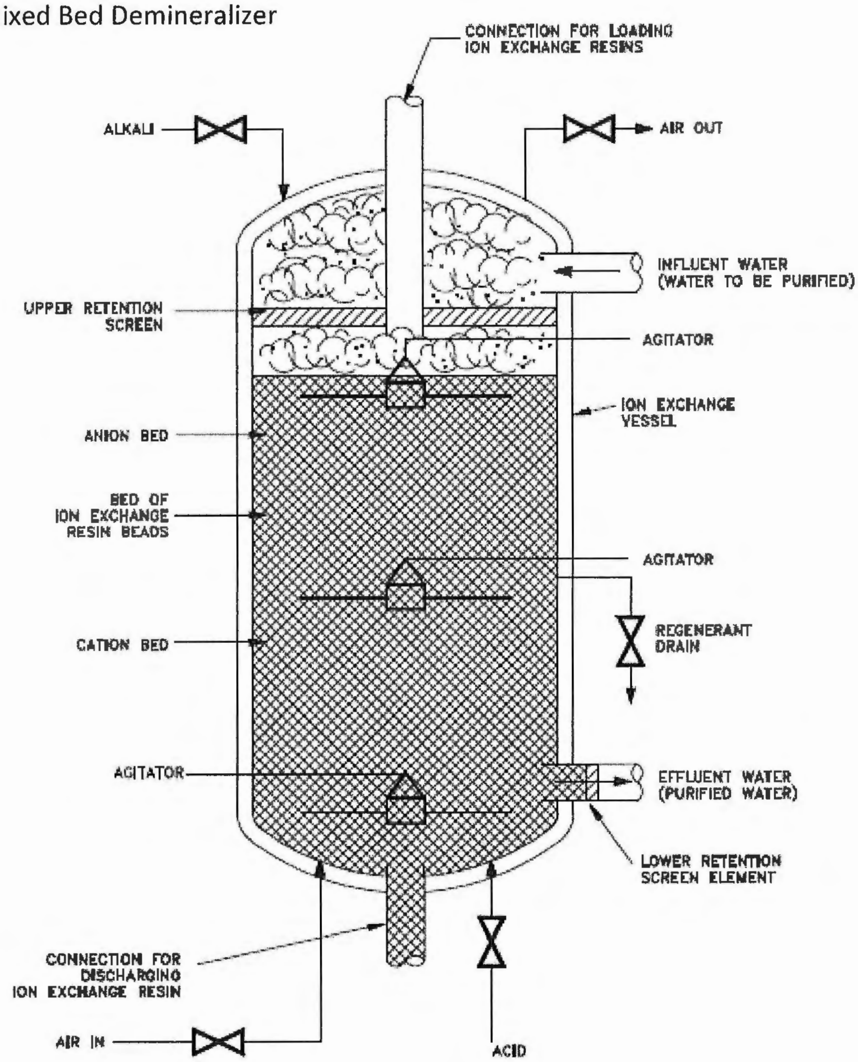
These beads are contained in vessels called resin beds.

Cation Exchangers. Cation exchanger beds contain cation resin which exchanges hydrogen ion, H^+, for calcium, magnesium, sodium, and other positively changed ions from the raw water as it enters the top of the bed. The water exiting this bed contains H^+ and negatively charged ions.

Weak Base Anion Exchangers. This exchanger contains a weak base anion resin which exchanges strongly charged negative ions such as chlorides (C_1^-), sulfate (SO_4^{++}) and nitrates ($N0_3^-$) for hydroxyl (OH^-) ions.

Deaerators and Decarbonators. This equipment removes dissolved gases from the water after it exits the weak base demineralizer bed. The removal of the

Figure 17.4—Mixed Bed Demineralizer



gases from the water eliminates the formation of the weakly charged carboxyl ion (CO_3^-) which would otherwise have to be removed by the strong base demineralizer bed.

Strong Base Anion Demineralizer. The strong base demineralizer contains strong base resin which removes the weakly charged silica ion and any negatively charged ions which passed through the preceding bed.

Mixed Bed Demineralizers. (Figure 17.4) These contain both cation and anion exchange resins in the same vessel, intimately mixed. The alternating cation and anion resin beads provide an infinite series of cation/anion exchange pairs. This produces the best quality water possible. Mixed bed units are also referred to as polishers as they remove any ions which passed through the other beds.

Regeneration of Mixed Bed Demineralizers. This regeneration depends on the difference in density and bead size of the anion and cation resins. The first step in the regeneration process is to carefully backwash the bed until the two resins separate. The heavier cation resin settles to the bottom and the anion resin forms the top layer. Caustic is injected through the upper distributor, passes through the anion resin layer and exits through the interface collector and to waste. To prevent the caustic from contaminating the cation resin, a blocking flow of water is introduced from the bottom of the vessel, through the cation resin and out to waste through the interface collector. The cation resin is regenerated with sulfuric acid which enters the vessel at the bottom, flows up past the cation layer, and out through the interface collector. Blocking flow comes from the service inlet.

The resin layers are rinsed with water, after which about 25% of the water is drained from the vessel. Air is injected from the bottom in order to mix the two resins. After the two resins are thoroughly mixed, the bed is rinsed again before putting it back into service. (Figure 17.5)

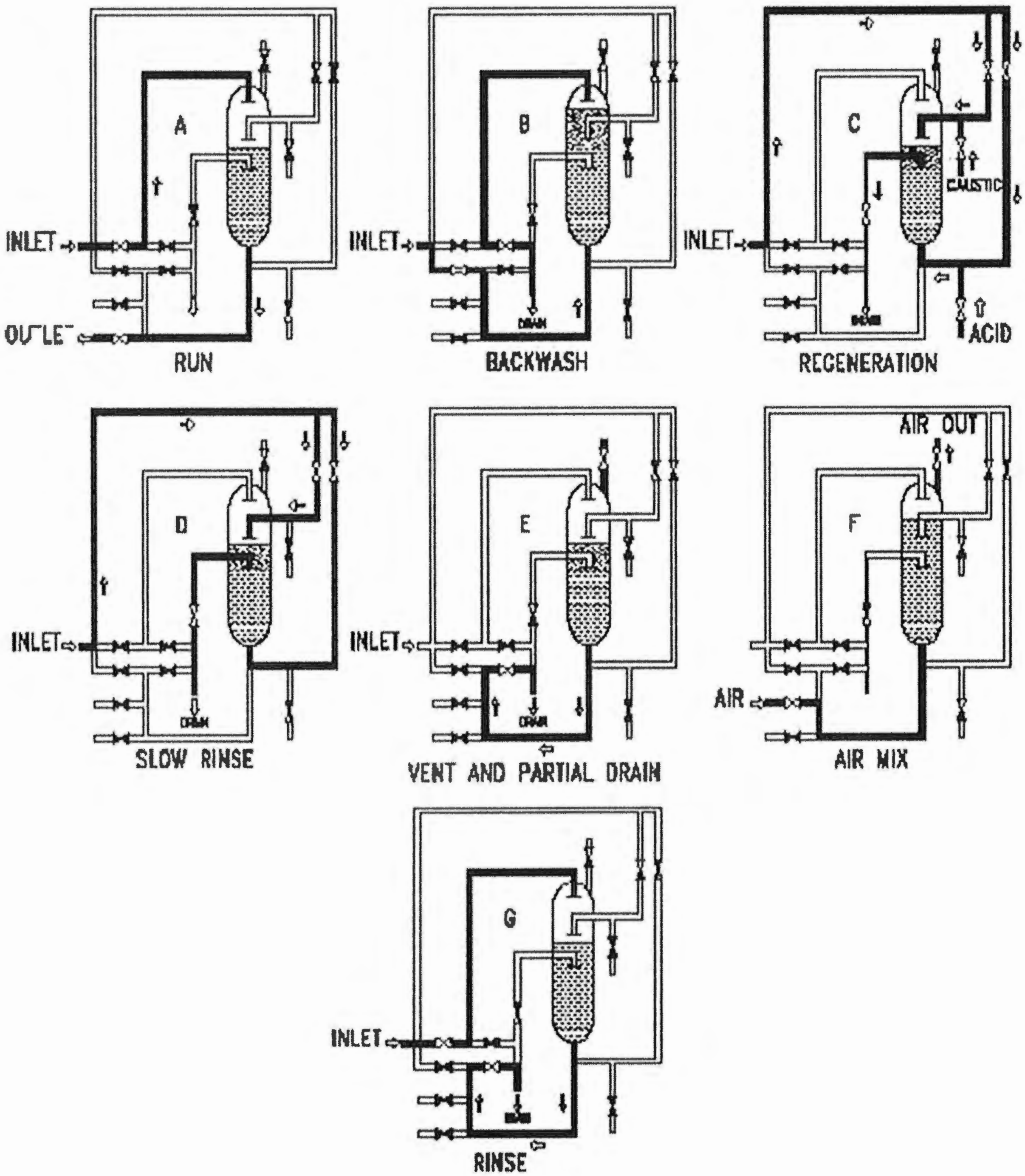
Only demineralized water or condensate is used to regenerate mixed bed demineralizers.

STORAGE & UTILIZATION

Each Generating Station has its own demineralization system which is capable of producing enough demineralized water to supply the needs of the station. Demineralized water is stored on site in sevarl storage tanks. There are usually 2 tanks for each pair of units with one in service providing the make-up water to the units and the other on standby or receiving water from the demineralizer system.

In the event of an emergency where the station is unable to generate enough demineralized water to meet the needs of the station, demineralized water must be brought in by truck.

Figure 17.5—REGENERATION OF MIXED RESIN BED



Section 17
MAKEUP WATER TREATMENT SYSTEM
Study Questions

1. Why is high purity water essential in the operation of a steam plant?

2. Why is water the ideal material for use in our steam driven generators?

3. The water that is used to make purified water is usually known as
   ____________________ ____________________.

4. Some sources of this water are: List two (2).
   a.

   b.

5. Why do we pre-treat the water used to make purified water?

6. What is the function of the Multi-Media Filter?

7. The process of filtration is the removal by chemical exchange of almost all the dissolved solids in the water. (Circle one) True \ False

8. List two (2) compounds that form scale on metal surfaces.

   a.

   b.

9. Drinking water is not pure enough for critical industrial uses. (Circle one) True \ False

10. The cation exchanger and the anion exchanger are part of the Electrodialysis Reversal (EDR) process. (Circle one) True \ False

11. Electrodialysis removes ________________________ from the water.

12. Describe the process of reverse osmosis.

GENERATION-OAHU DIVISION
OPERATOR TRAINEE TRAINING PROGRAM

Section 18
CONDENSATE & FEEDWATER SYSTEMS

OBJECTIVES:

1. Describe the major components of the Condensate System.
2. Detail the flow cycle through the Condensate System.
3. Discuss chemical control as related to the Condensate System.
4. State the purpose of and trace down lines associated with the Feedwater System
5. Trace the flow path of feedwater from the Boiler Feed Pump suction stop valve to the Steam Drum.
6. Locate and list pertinent specifications of the Feedwater System Components.

GENERATION-OAHU DIVISION
OPERATOR TRAINEE TRAINING PROGRAM

Section 18

CONDENSATE & FEEDWATER SYSTEMS

CONDENSATE SYSTEM

The condensate system provides the means for removing condensate from the condenser hotwell, raising its pressure, heating it, and supplying it to boiler feed pump suction. This system usually includes the condenser, condensate pumps, low pressure heaters, miscellaneous other heat exchangers, drip pumps, and in some cases, a deaerator. These major components and their accessories are discussed separately in this section. Simplified single line flow diagrams of two typical condensate systems are shown in Figure 18.1.

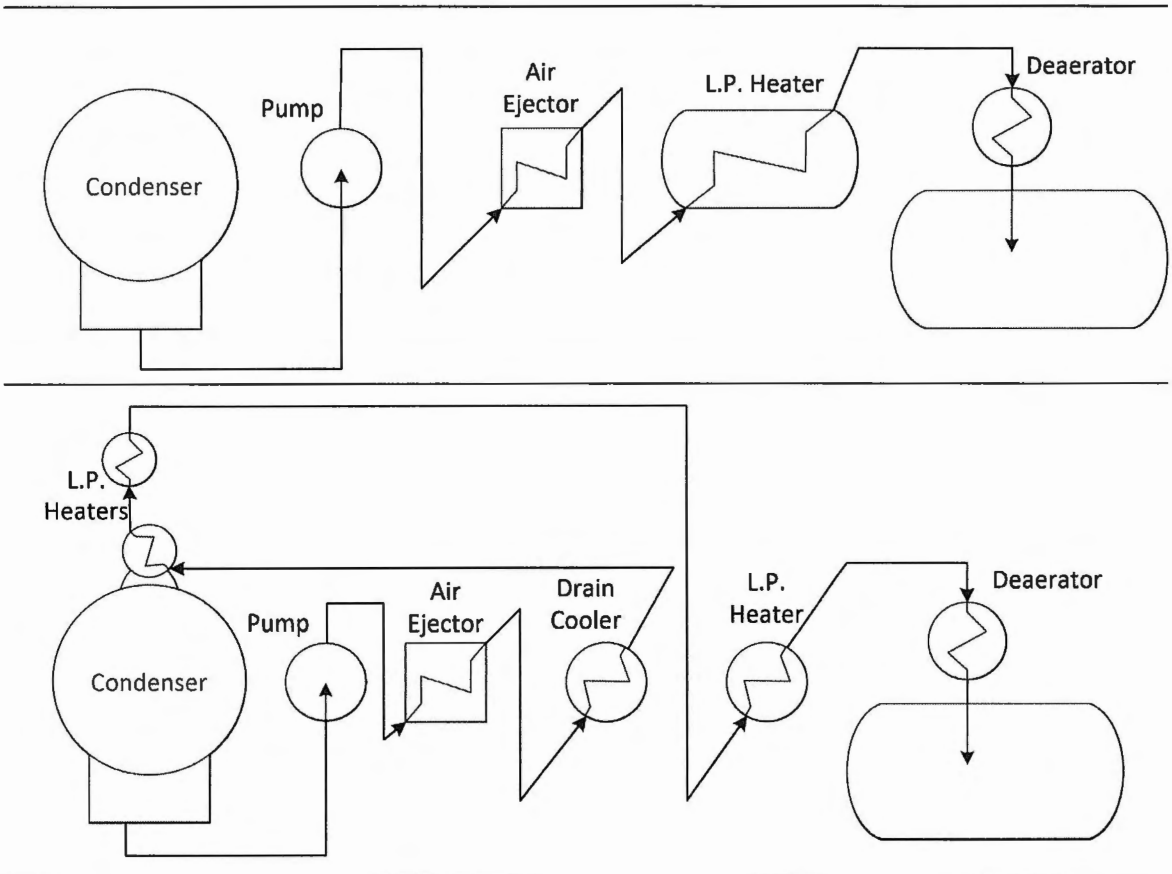


Figure 18.1 - Typical Condensate Systems

CONDENSER-HOTWELL (Figure 18.2)

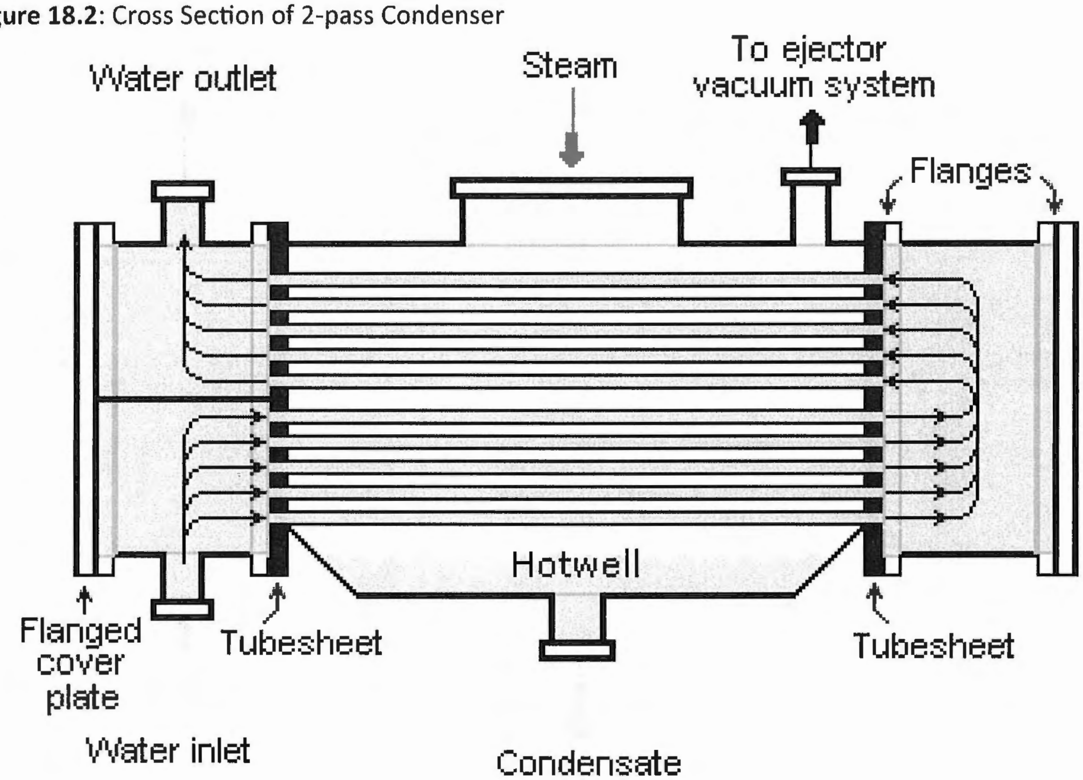
The condenser, by maintaining a low back pressure for turbine exhaust; adds greatly to the energy that can be obtained from the plant cycle. Steam can continue to expand and do work to as low as 1/2 inch Hg. back pressure. The condenser and its hotwell not only provide low back pressure and reclaim high purity water but also perform many other functions such as condensate storage space, miscellaneous drip collection, deaeration of condensate, and cycle make-up point.

The condenser has provisions for removal of non-condensable gas that may be entrained with entering steam or water, drips from feedwater heaters, vents, condensate make up, packing, and air leakage from various other points. The removal of non-condensable gases from the condenser is done with external pumps or air ejectors. The condenser design incorporates special sections where air removal connections are made. In these sections closely spaced tubes act to sub-cool the air and minimize moisture or vapor from being carried to the air removal equipment.

Internal baffles in the condenser protect tubes from direct impingement by feedwater heater spills, condensate make up, steam drain, and other spill and vapor connections routed to the condenser. These baffles should be inspected whenever the condenser is open.

Condensate recirculation, where condensate after the air ejector condenser may be partially recirculated back to the condenser for cooling, is employed on most units. The recirculation is controlled by condensate flow or condensate temperature. Its function is to hold

Figure 18.2: Cross Section of 2-pass Condenser



sufficient condensate flow through the air ejector condenser (and gland seal condenser on some units) for proper operation of this equipment. The recirculated condensate is returned to the condenser and baffled or distributed for re-cooling by flowing over the condenser tube surface. The recirculation also ensures adequate water flow through the condensate pump.

The condenser hotwell acts as a storage tank where approximately one minute operational capacity is stored. Its level is so held as to provide a sufficient suction head for the condensate pump. It acts as the point for system demineralized water make up and determines by level the cycle condensate rejection requirements.

The hotwell is divided into two halves with a vertical division plate. This is done to limit the mixing of the steam condensed in one half with that condensed in the other half. Each half is provided with a conductivity detector to facilitate the location of a tube leak.

Alarms associated with the condensate system are as follows:

- Boiler feed pump suction header low pressure.
- Condensate pump low pressure.
- Condensate pump auto start.
- Miscellaneous condensate tank level high-low.
- Hotwell level high-low.
- Conductivity.

CONDENSATE PUMPS

The condensate pumps are of the centrifugal type, Figure 18.3, and must develop enough discharge pressure to overcome atmospheric pressure, pipe friction, heat exchanger friction and the elevation of the surge tank or deaerator. Where a deaerator is not used the condensate pump must supply water to the following pump at a sufficient pressure for correct operation. The pump handles water at low absolute pressure and is located below the hotwell to receive a sufficient suction head and prevent flashing. The pumps are multistage horizontal or vertical. In the multistage horizontal type, stage inlets are generally opposed for pump balance.

The pump glands may be subjected to discharge pressure to prevent air leakage or have an external source of water injected at a lantern ring, for sealing. Others are provided with mechanical seals. Pumps can become air bound by air being sucked into the pump through the packing gland. A seal water line under pressure forms a water seal at the gland. Most condensate pumps, when running, have pump discharge pressure against the packing gland and the sealing water is not necessary. Pump casings are vented to the main condenser which insures that the idle and running pumps are full at all times. Two pumps with individual discharge check valves are usual for each installation.

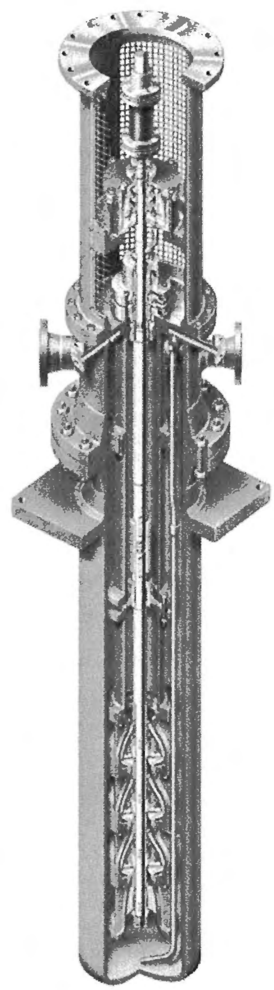


Figure 18.3 Multistage Vertical Condensate Pump

In the newer plants that operate at high boiler pressures it is not practical to raise the pressure to that required for feed pump suction using one pump. In these installations the condensate pressure is increased by the heater drip pump.

In the earlier installations, usually one pump was designed for the full load range with the second pump set up for standby.

In shutting down and clearing a condensate pump or restoring a pump to service, it is of the utmost importance to be aware of the condenser vacuum and the operating pump suction and discharge conditions.

In clearing a condensate pump, the pump vent, or equalizing line, the pump discharge and suction valving should be securely closed before closing the gland sealing water. This is to prevent air from entering the system through the seals and into the condenser which could cause loss of suction to the operating condensate pump as well as overloading the condenser air ejector.

In restoring a condensate pump to service, similar careful operating steps are necessary. Before filling commences, the pump sealing should be established and the air removed from the pump well by very carefully cracking open the vent or equalizing valve back to the condenser. This will do two things, remove the air and equalize pressure across the suction valve. The vent must be opened slowly or overloading the air ejector may occur. The pump well may be filled from the hotwell by slowly cracking open the fill valve or suction valve. This step must be done very carefully so suction will not be upset to the operating pumps. Once the suction valve is open wide the discharge may be opened.

CONDENSER AIR REMOVAL

Steam jet air ejectors are utilized to remove non-condensable gases from the condenser. For turbine start-up, when large volumes of air must be removed from the condenser, feedwater heater shells, turbine, and on reheat installations all reheat piping, large volume hogging jets are used.

The steam jet air ejector is used in the start-up operation and during normal operation for continuous removal of non-condensable gases. The ejector operates by means of the entrainment action produced by a jet of high velocity steam. Steam at 200 to 400 psig is expanded through a diverging nozzle. It leaves the nozzle at a high velocity, three to four thousand ft./sec. The gases from the condenser are entrained and given momentum by the high velocity Steam (Figure 18.4).

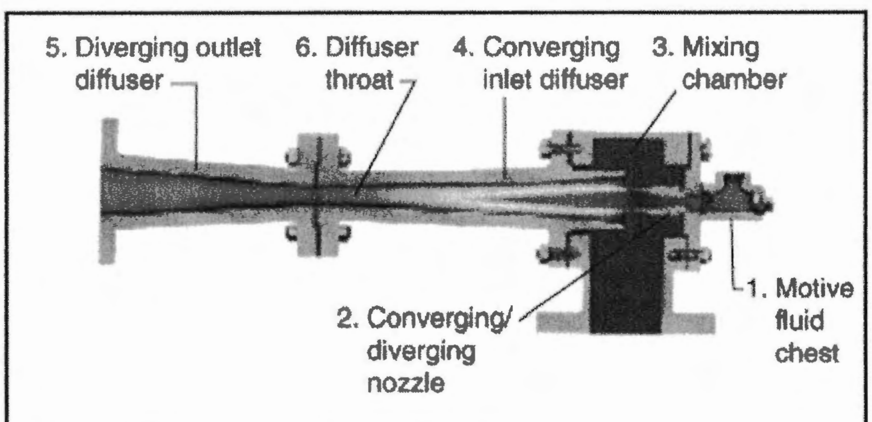


Figure 18.4 Air Ejector Jet

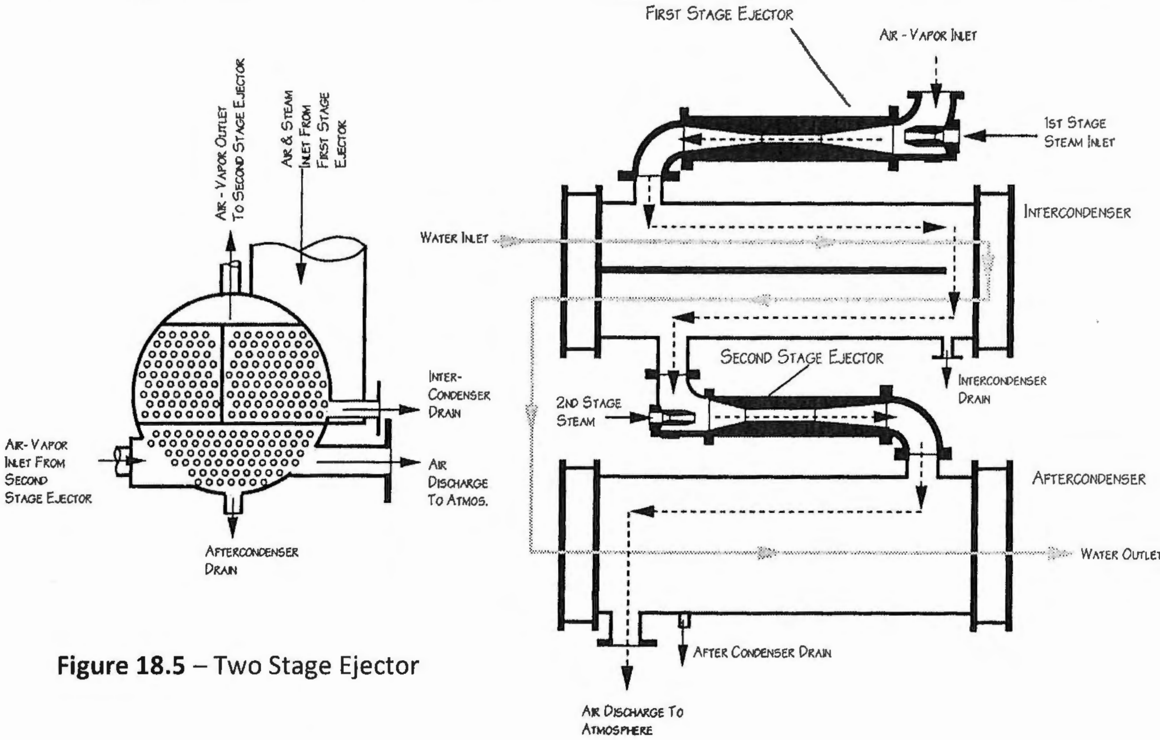


Figure 18.5 – Two Stage Ejector

The steam pressure at the nozzle is maintained by throttling the steam supply through a valve. The steam and gas mixture discharged from the ejector enters a tubed heat exchanger where the condensate passing through the tubes condenses the steam. A single stage ejector is suitable for up to 25 inches Hg. In order to hold higher vacuum, 29.3 to 29.5 inches Hg, two stages are used, with the second drawing the gas from the inter-condenser heat exchanger and discharging to an after-condenser heat exchanger where steam of the jet is condensed and gas discharged to atmosphere. (Figure 18.5)

The drips from the inter-condenser are returned to the main condenser through a loop seal and from the after-condenser to the gland seal return tank. Both inter and after-condensers are usually contained in one shell with an internal division plate separating them.

In changing over and shutting down air ejector sets the sequence in valving is very important as condenser vacuum may be lost if improper valving is used. Reference to a key question sheet should always be made as a double precaution and reminder when changing jets.

When changing over air ejector jets the operation between the secondary and primary jets is somewhat different. The steam supply to the secondary jets must be opened prior to opening the secondary jet suction valve and then the drain valve opened. If the steam supply is not opened first, entry of air to the condenser is possible through the atmospheric vent. The primary jet steam valve is opened next then the suction valve and inner condenser drain valve are opened. Correct steam pressure is important for design-operation of an air ejector so readjustments are necessary whenever steam conditions are changed.

When a set of jets are shutdown, the steps are reversed; close the primary jet suction air valve, close the steam supply to the primary jet and the discharge valve and then the drip line. The secondary jet is secured by closing the secondary suction valve, the steam supply, and then the drip line. As previously stated the steam supply must be readjusted whenever steam conditions change.

In geothermal plants air ejectors are used as in other plants for removal of non-condensable gases and assisting in maintaining vacuum. The uniqueness of these ejectors is their large size. Their length is approximately 15'. The ejectors, inter-condensers and after-condensers are insulated and then sheathed with lead to keep the noise level at a minimum. The ejectors are constructed of stainless steel while the inter-condenser and after-condenser are lined with a 1/16" thick sheet of stainless steel for corrosion protection.

CONDENSATE HEAT EXCHANGERS

The condensate, flowing through the tubes of the air ejector and acting to condense the steam used in the jets, recovers the heat from the steam. This heat together with heat transferred to the condensate from the gland seal exhauster condenser adds to plant efficiency.

The gland seal exhauster condenser creates a partial vacuum on the turbine seal leakoff points, where steam from the seals and quantities of air from the bearing side are withdrawn. The air is removed with fans and the steam condensed to form the partial vacuum. The exchanger consists of tubes for the condensate, enclosed within a shell for steam condensing. Drips flow to an atmospheric drain tank through a loop seal and return to the condenser.

Several types of heat exchangers are used on any individual plant cycle. The number and type vary with each cycle but the purpose and function remain the same, regenerative (to reuse heat or heat used once before) heating of feedwater or condensate and in some cases deaerating.

The transfer of heat between vapor and liquid or liquid and tubes in the heat exchanger involves several factors. These factors have been previously discussed but a brief review at this point should be helpful for better understanding.

The metal wall of the tube in most heat exchangers separates the two substances which are at different temperatures. The process of transferring heat from the hotter to cooler medium involves, mainly, two of the basic heat transfer methods, convection and conduction.

The steam source for heating is extraction steam from the turbine. It enters the heater shell in a slightly superheated condition. The steam is condensed and the drips cascade to another heater or are collected in a drip pot and eventually pumped back into the condensate cycle. If the heater shell level increases to a predetermined point, high level spill regulators will open and route the drips directly to the hotwell.

The turbine is protected from heater flooding by high level spills. The spills control above normal levels by opening and dumping drips to the main condenser. A non-return valve located in the extraction line on higher pressure heaters is provided for further turbine protection. The valve will close from reverse flow or turbine trip out to prevent over speeding the turbine from the energy of the steam and water in the heater. Low pressure heaters are not usually provided with a non-return valve since there is not enough energy in the water contained in the heater shells to flash and overspeed the turbine. There are three (3) precautions to be taken when dealing with turbine extraction steam:

1) where an extraction line to a heater has a back up from another

steam source and the back up pressure could exceed the extraction pressure;

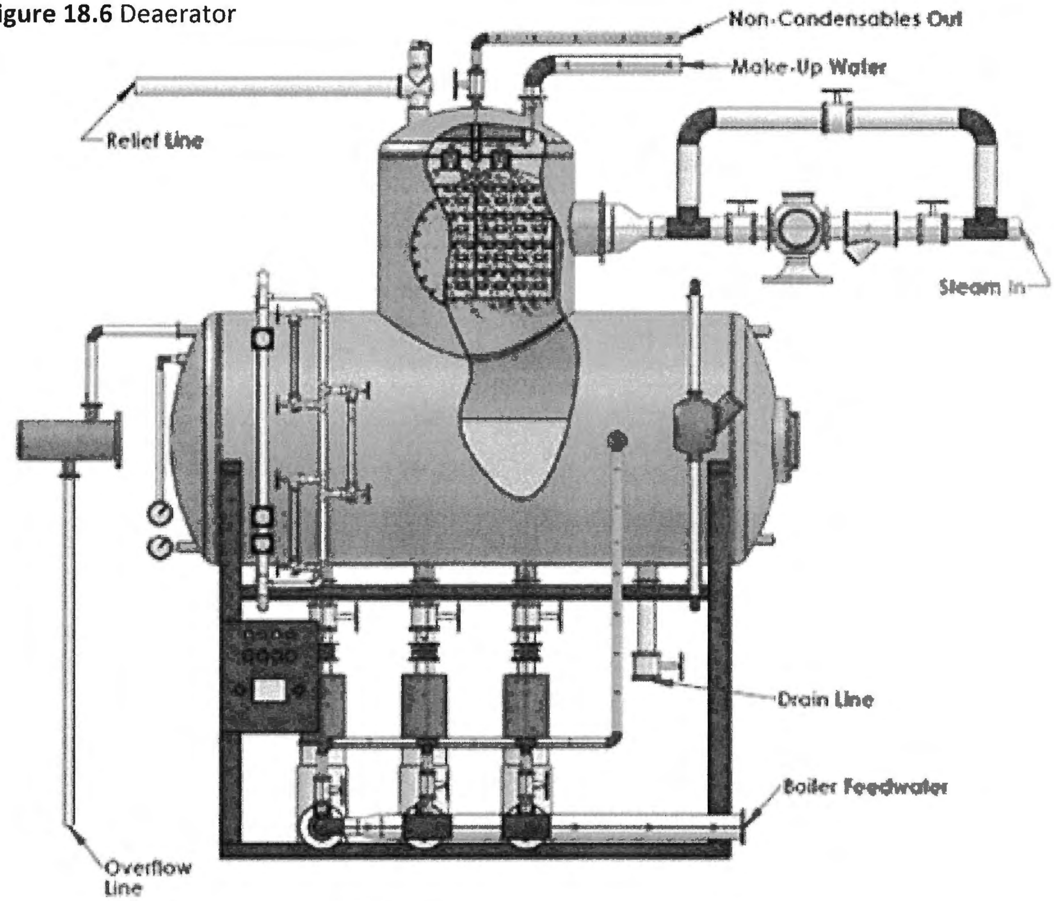
2) heater tube failure allowing water to back up into the turbine and

3) on a turbine trip it is necessary for the non-return valve to close as flashing in the extraction line and heater could possibly overspeed the turbine.

The non-return valve is a free swinging check valve and may be installed with a positive closing device. This device is a spring loaded piston that will act on the non-return valve and assure its closing if the turbine trips. When the turbine is latched up and in service the piston keeps the spring compressed by air pressure under the piston. The piston closing device and the non-return valve may be tested under way. The test device when operated bleeds the air from below the piston and the spring tension will close the valve approximately 10% of its travel. Releasing the test device will re-establish air below the piston and the extraction steam flow will reopen the non-return valve to its fully open position. On turbine trip the air is bled from below the piston and the spring tension will start closing the check valve. Its weight or reverse flow will close it completely.

Proper heater venting and heater drain level control are important for efficient performance. Venting from proper points in the heater shell not only removes non-condensable gases but also gives better distribution of steam throughout the shell. Drain level should be held at the heater

Figure 18.6 Deaerator



design point. If the level is too high, loss of condensing surface will result; if too low, steam flow through or loss of sub-cooling would occur. In a series of heaters, drains are usually cascaded to lower pressure heaters in the cycle with venting to the deaerator or main condenser completing the circuit. The drains from high pressure heaters, after a sequence of cascading, are returned to the system either by a heater drip pump into the condensate cycle or into a direct contact heater (deaerator). Low pressure heater drips cascade through the heater series to the condenser.

Low pressure heaters, including those operating at pressures below atmospheric, are designed for condensing action and drip level is usually controlled in a drip pot external to the heater. The heat exchangers may be horizontal or vertical with drips leaving the vertical heater at top or bottom depending on design. For space saving considerations and to shorten the extraction lines thereby reducing the pressure drop from the turbine to the heaters, many installations locate one low pressure heater in the exhaust trunk of the turbine.

Most installations have one heater in the cycle either surface type or direct contact type where drips from other cycles may be sent to gain maximum heat advantage from the system. In the closed type the external drip pot is large and properly baffled with piping for drip pot venting back to the heater shell. Drips from reboiler heating systems as well as the accumulated drips from the higher pressure heaters enter the drip pot and flashing that occurs, vents to the heater. The drip pot also acts as suction storage for the drip pump which returns these drips to the condensate cycle. Those systems employing the open type or direct contact heater (deaerator) utilize this heater to supply the boiler feed pump suction (Figure 18.6). The heater functions to heat the condensate by direct mixing of the condensate with heating steam. The condensate enters at the top of the heater and is sprayed or cascades over a series of trays while the steam flows through the water heating and deaerating at the same time. The shell of the heater is vented to atmosphere. Incoming condensate flowing through tubes condenses quantities of steam before release of gas and steam. This creates greater steam flow toward the top through the falling water. The heaters operate under pressure of below atmospheric to approximately 90 psig, depending on the system. The heated water collects in the bottom of the shell where sufficient volume is stored for feed pump suction considerations. Drips from various plant systems are piped to the deaerator for heat exchange and deaeration. The heater is usually located at a high elevation to maintain static feed pump suction head, and live steam for standby pressure control is usually available.

Clearing and restoring feedwater heaters to service is an important function in a power plant. Steam and water supplies must be handled carefully and slowly to keep thermal shock to a minimum and the water side (channel) valving must be performed so there is no stoppage of feedwater to an operating pump or to the boiler. All air must be expelled from both sides of the heater before placing the heater in service.

Normally, in clearing a feedwater heater the steam to the shell is closed first, then the shell vents and the normal drip regulator are closed. The heater feedwater bypass should be opened slowly, followed by closing the heater inlet and outlet valves. The shell high level spill is usually the last closed as protection against high pressure in case a tube leak should develop prior to closing the heater inlet or outlet stop valves. After all the above valves are secured, the shell and channel side drain and vent valves to atmosphere may be opened.

In placing a feedwater heater in service, a flow of water must be established through the channel side of the heater prior to opening the steam supply. The channel side of the heater must be full of water and all air expelled before allowing a flow through the heater to the system. The heater bypass valve should be closed as soon as a flow to the system has been established. If hot water is used, the filling, venting, etc. valving must be done slowly to eliminate thermal shock. Once the channel side flow is established, the steam may be slowly cut into the heater. After heavy venting to atmosphere, the atmospheric vent valve may be closed and normal shell vents valved to the condenser. The heater high level spill should be opened as soon as a level is showing in the heater gauge glass and the vents are lined up normal. The normal drip regulator may be opened when normal heater level is attained.

Alarms associated with the heaters are:

- *High Level Trip*

DRIP PUMP

The pumps handling heater drips are of the centrifugal type and, except for low volume -pressure drip pumps, are multistage to handle high volumes and discharge heads necessary to overcome condensate line pressure.

Drip pumps operating on heaters that drop below atmospheric pressure at low loads are treated in much the same manner as condensate pumps. Venting, suction head, recirculation and gland sealing must be considered to prevent air leakage at the pump glands and flashing in the pump suction.

Stuffing boxes with mechanical packing, and in some cases lantern rings for water injection, proves reliable for low pressure and temperature operation.· However, as pressures and temperatures rise, more elaborate arrangements for pump glands are needed to eliminate excessive leakage, gland and shaft erosion, and overall maintenance.

Alarms associated with drip pumps are as follows:

- *Low level suction trip*
- *Heater drip pump trip*
- *Drip receiver high level*

CHEMICAL CONTROL

The chemical control for the condensate system consists of routine sampling and testing for dissolved oxygen and sodium chloride (salt). The pH, conductivity, ammonia, and hydrazine levels are routinely sampled and tested. Conductivity and dissolved oxygen are usually recorded.

Mechanical deaeration of condensate is for the purpose of removing oxygen, carbon dioxide, and ammonia. Dissolved oxygen or carbon dioxide will cause corrosion and pitting. The complete removal of oxygen is essential in the prevention of corrosion. In the earlier built plants, the pH control solution is pumped into the condensate system proportional to unit load and the amount of dissolved oxygen.

In conjunction with the proper functioning and venting of the deaerator for chemical control, adequate venting of other heaters in the system is equally important. Insufficient venting from heaters not only results in the reduction in heater capacity due to the accumulation of air and other gases (carbon dioxide and ammonia) but can result in severe corrosion of the heater tubing due to high concentration resulting from the accumulation of these gases.

Alkalinity or pH control of the condensate system is important and ties in with other associated systems (make up) and proper venting. In some units ammonia is added to condensate to increase the pH of condensate-feedwater to provide protection for the steel heater tubes. Higher pH due to ammonia in feedwater systems containing copper-bearing materials is to be avoided due to the increased solubility of copper. Proper venting in combination with discarding drips high in ammonia will control ammonia in these systems.

Oxygen attacks steel tubed heaters very rapidly. To counteract this action when units with steel tubed heaters are shut down, a means is provided to keep oxygen from entering the heaters. This is usually controlled by nitrogen blanketing or steam blanketing. The heater is pressurized with steam which will not allow the oxygen to enter the heaters.

The measurement of conductivity of condensate is the primary method used to determine water quality. Some knowledge of the individual systems and what is going on at the time, are involved and are important to evaluate or interpret what conductivity recordings or indications show. Some things to watch for are the following:

- Proper or adequate sample flows to conductivity cells must be maintained to obtain any meaning from the recorded results.
- Some installed cells have automatic temperature compensators in conjunction with the cell and others do not. Such operations as changes in load or changing of sample flows, with resulting change in sample temperature, can change conductivity as indicated by uncompensated cells.
- Other available conductivity instrumentation should be used to evaluate an individual indication of difficulty.
- Conductivity instrumentation, like any other equipment, can fail or give erroneous results. Extra care should be taken that this is not given as a reason to ignore or minimize what properly functioning instrumentation is showing.
- Condensate conductivity can vary considerably (from approximately 1.0 - 7.0 micromhos) and still be considered as condensate. However, the conductivity at a given point in a given system should remain relatively constant. Variations normally result from dissolved carbon dioxide or ammonia.
- Chemical tests or analysis can be used to advantage in interpreting conductivity information (for example, salt test of boiler water to determine if a slight increase in conductivity is due to condenser leakage.)
- Conductivity instrumentation, in a number of cases, has established alarm points. However, alarms cannot be relied upon entirely as indications of difficulty. Alarm points are usually set high enough so that the normal expected variations in conductivity do not bring in alarms. Trends in conductivity and any unexplainable changes in conductivity should be

observed and checked out since considerable contamination can take place over a period of time even though the conductivity is well below an alarm point.

Some additional instrumentation at various plants for use in control of condensate systems include pH meters, dissolved oxygen analyzers, and hydrazine analyzers. As with conductivity, this instrumentation must have proper sample flows maintained before recorded results can have any meaning. Recorded results should be, as with conductivity, observed for trends or changes and interpreted correctly to either detect and correct indicated problems (oxygen leakage) or for adjusting controls (hydrazine feed) as required.

Alarms:

- *Dissolved oxygen high.*
- *Condensate conductivity high*

FEEDWATER SYSTEM

The feedwater system provides pure makeup water to the steam drum and maintains the water level in the drum.

The boiler feed pumps send the boiler feedwater through two high pressure heaters to preheat the feedwater. Overall unit efficiency is improved by preheating the water prior to sending it to the economizer. The feedwater system is also responsible for providing pure water to the superheat attemperators (and reheat attemperators in reheat units.) Figure 18.7 shows a typical Feedwater System.

FEEDWATER PUMPS

The Condensate system ends and the Boiler

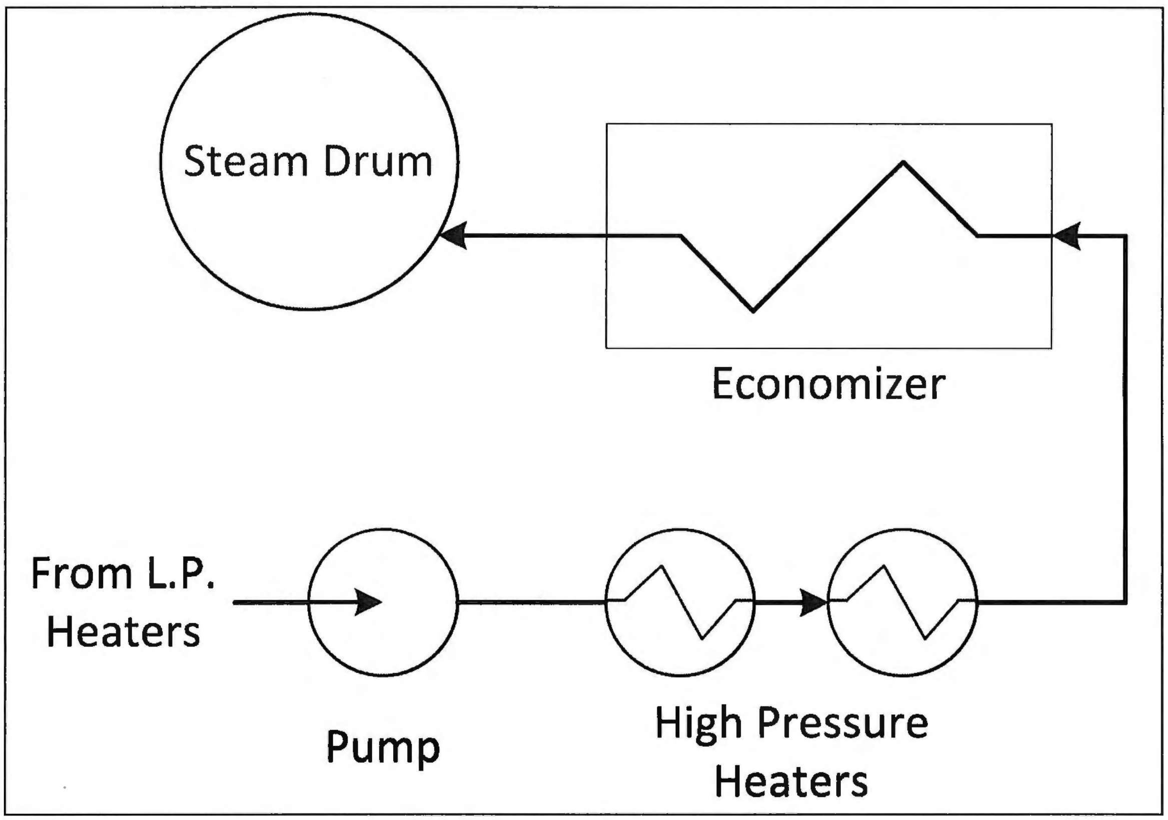


Figure 18.7: Typical Feedwater System

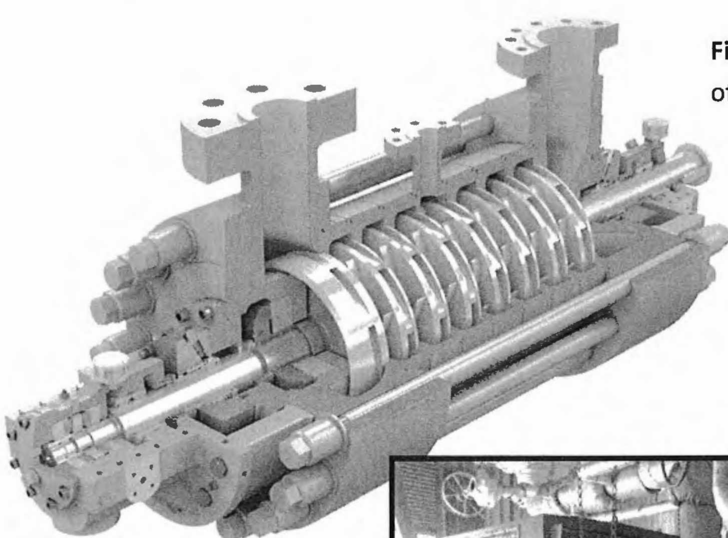


Figure 18.8a Cutaway view of multistage pump.

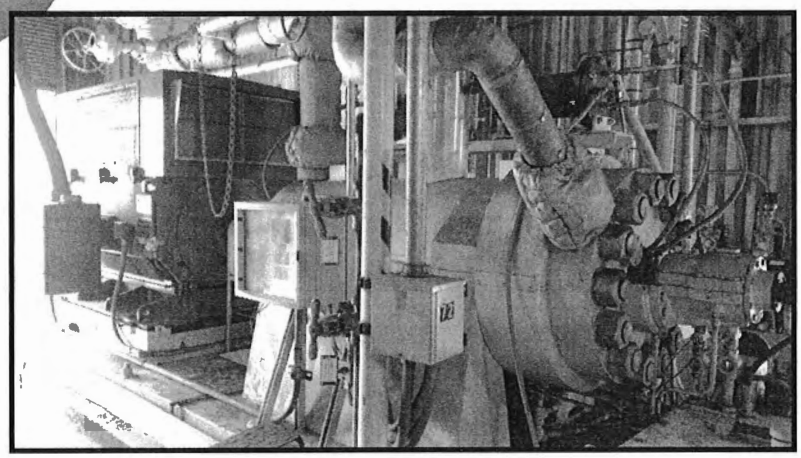


Figure 18.8b
W7 Boiler Feed Pump

Feedwater system begins after the suction valves just before the inlet to the boiler feed pumps. Feedwater must be transported from the low pressure condensate system to the high pressure steam drum located at the top of the boiler. The boiler feedwater pumps add the energy to feedwater to enable transport of the water to the boiler. The pumps take suction from the condensate leaving feedwater heater No. 3. The feedwater pumps are centrifugal pumps with each pump capable of carrying plant load when operated singly. Figures 18.8a & 18.8b. Each pump is a multi -stage unit rated to provide adequate flow to maintain steam drum levels and total dynamic head to overcome steam drum pressure.

Under normal operating conditions, one boiler feed pump is running and the other pump is on standby. The discharge line from each pump is equipped with a pressure switch, and if the discharge line from the running pump drops below a preset psi because of increased load on the plant or improper functioning of the operating pump, the pressure switch causes automatic start of the standby pump. When the pressure in the discharge from the pumps is brought back to the proper level commensurate with plant load, the pressure switch is reset but both pumps remain running. One pump can be shut down and returned to a standby condition only if the pressure switch has reset and only by manual operation of a pushbutton station in the control room.

MINIMUM FLOW

A minimum flow is maintained through each running pump by recirculating feedwater to

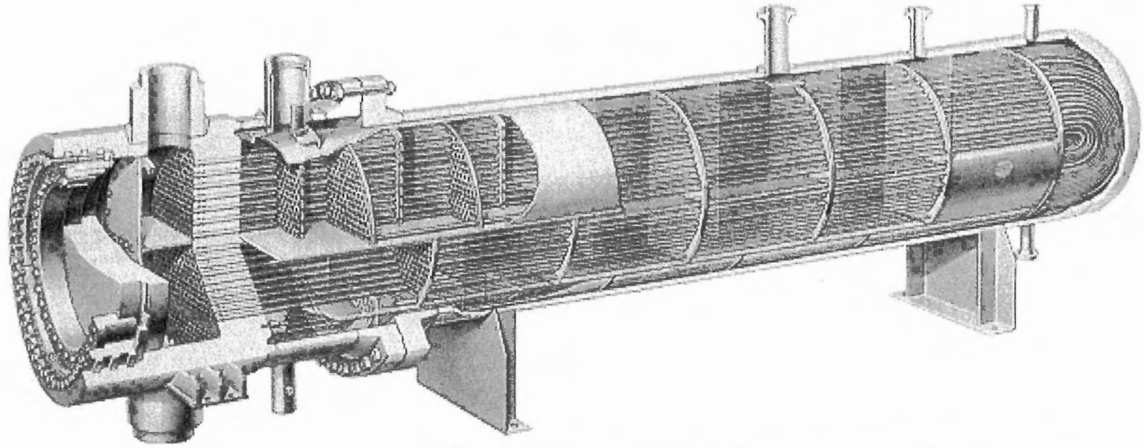


Figure 18:9 Typical High Pressure Heater Construction

the condenser through a solenoid operated control valve actuated by a flow switch located in each pump discharge line. This recirculation line also serves as a warm up line when a pump is on standby service since the recirculation control valve is always open when the pump is not operating and heated condensate flows from the pump suction thru the pump, to the condenser. Feedwater from the boiler feed pump discharge is used to supply the superheater desuperheaters. Feedwater from an intermediate stage of the pumps is used to supply the reheater attemperators to minimize reheat spray valve wear.

HIGH PRESSURE FEEDWATER HEATERS

The boiler feed pumps deliver water through the feedwater regulating valve and the high pressure heaters to the boiler economizer. The high pressure heaters are the horizontal, U- tube, removable bundle type with integral desuperheating and drain cooling sections. (Figure 18.9) These heaters take feedwater through their tube sides, and each heater may be bypassed individually. To place a heater back in service after cycle operation on the bypass, the equalizing valve must first be opened to pressurize the line through the heater. When the line is pressurized, the angle valve and the three-way bypass valve may then be opened, returning the heater to service. The high pressure heater drips and vents are normally cascaded to the heater of next lowest pressure and eventually to the main condenser.

Steam for Heater No. 5 is taken from the first extraction point which is the high pressure turbine exhaust. Heater drips are normally drained to Heater No. 4 through a control valve which maintains the condensate level in the heater shell. On high level the drips are dumped through a control valve direct to the condenser. Heater vents are normally cascaded to Heater No. 4, but may be directed to Heater No. 3 or to the main condenser through the Heater No. 3 vent line.

Steam for Heater No. 4 is taken from the second extraction point located in the intermediate pressure turbine. Drips from Heater No. 5 are normally cascaded to this vessel. Heater drips are normally drained to Heater No. 3 through a control valve which maintains the condensate level in the heater shell. On high level the drips are dumped through a control valve direct to the condenser. Heater vents are normally cascaded to Heater No. 3, but may be vented direct to the main condenser through the Heater No. 3 vent line.

EXTRACTION STEAM TRIP SYSTEM

The extraction lines supplying steam to the feedwater heaters are each provided with a shut-off valve and non-return bleeder trip valve. The bleeder trip valves prevent any backflow of steam or condensate into the turbine and are actuated by the turbine overspeed trip device or by high liquid level float switches on the individual heaters.

FEEDWATER CONTROL

Steam drum water level control is an important part the boiler system. Hawaiian Electric employs a three element feedwater control strategy (Figure 18.10) designed to provide tight drum level control that is highly responsive during rapid load changes. The controls provide a continuous mass balance, since for every pound of steam generated and removed from the boiler, a pound of water must be added to replace it.

The control logic uses drum level, drum pressure, steam flow and feedwater flow to adjust the flow through the Main Feedwater Control and Bypass Feedwater Control Valves. The control strategy includes several interlocks which would allow continued automatic operation if a sensor should fail which makes automatic control possible during abnormal operating circumstances. Failure of a sensor would generate an alarm and initiate a response based on the condition. This allows for continued operation (albeit with reduced effectiveness) of the feedwater control.

Figure 18.10 3 Element Feedwater Control

GENERATION-OAHU DIVISION
OPERATOR TRAINEE TRAINING PROGRAM

Section 19

CIRCULATING WATER

OBJECTIVES:

1. Discuss the purpose and function of the circulating water system.
2. Name the components that make up the circulating water system.
3. Detail the function of chlorine in the circulating water system.

Generation-Oahu Division
Operator Trainee Training Program

Section 19
CIRCULATING WATER

The main circulating water system supplies cooling water to the main condensers and in some installations, the plant's auxiliary cooling water system.

Salt water is drawn from the ocean or harbors and gravity flows to traveling screens. In some installations the screen structure is located on the edge of the water source. Circulating water pumps, located after the screens, pump water through the plant equipment for cooling. Water discharged from the plant flows by gravity through outfall tunnels or channels back to the harbor or bay. See Figures 19.1 and 19.2.

Provision is usually made for chlorinating the water to prevent algae and slime formation on the condenser tubes since slime will decrease heat transfer.

Stop logs on the inlet and outlet tunnels are provided to isolate tunnels and equipment for inspection and maintenance as needed.

The circulating water system discussion is divided into the following topics: bar screens, traveling screens, chlorinating equipment, circulating water pumps, condensers, and auxiliary cooling water systems.

Figure 19.1 Kahe Circulating Water—Intake & Outfall

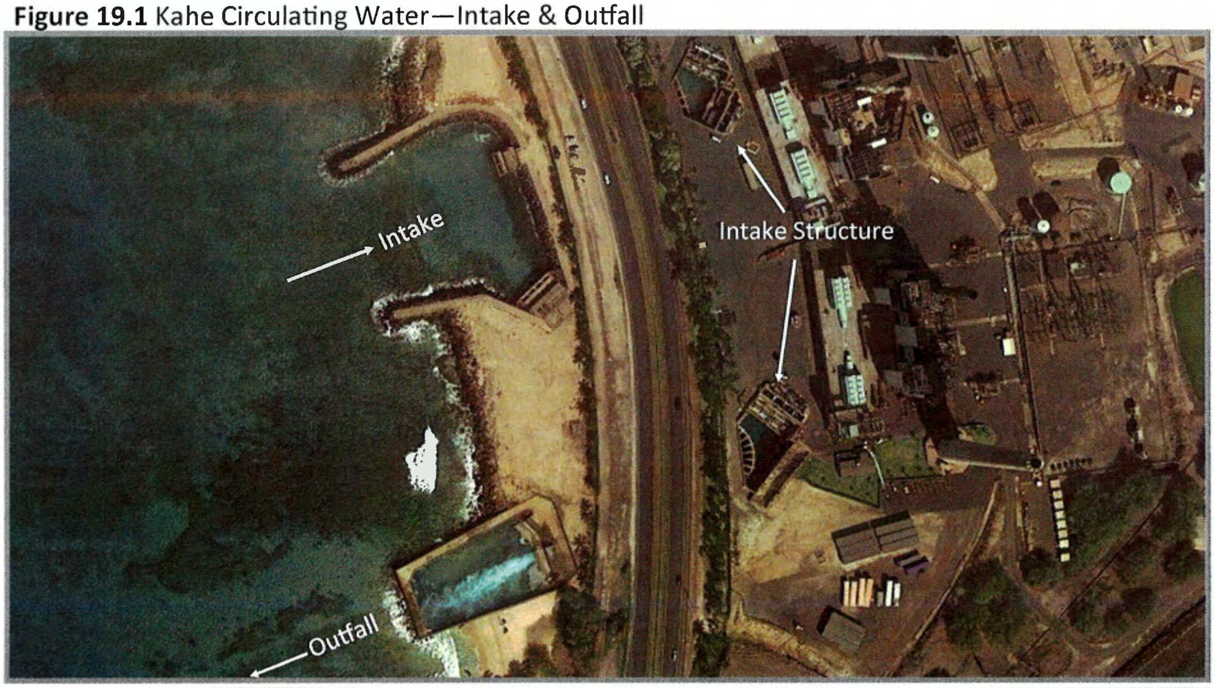


Figure 19.2 Waiau Circulating Water—Intake & Outfall

INTAKE STRUCTURE

The intake structure provides the necessary concrete foundation for mounting many components of the circulating water system. Bar screens, screen wash pumps and traveling screens are sometimes located at this structure. In more recent installations, the circulating water pumps are also located at the intake structure. Figure 19.3 shows a drawing of a typical intake structure.

BAR SCREENS—The circulating water inlet is protected from large floating debris by bar screens approximately 2-1/2 inches

Figure 19.3 Typical Intake Structure

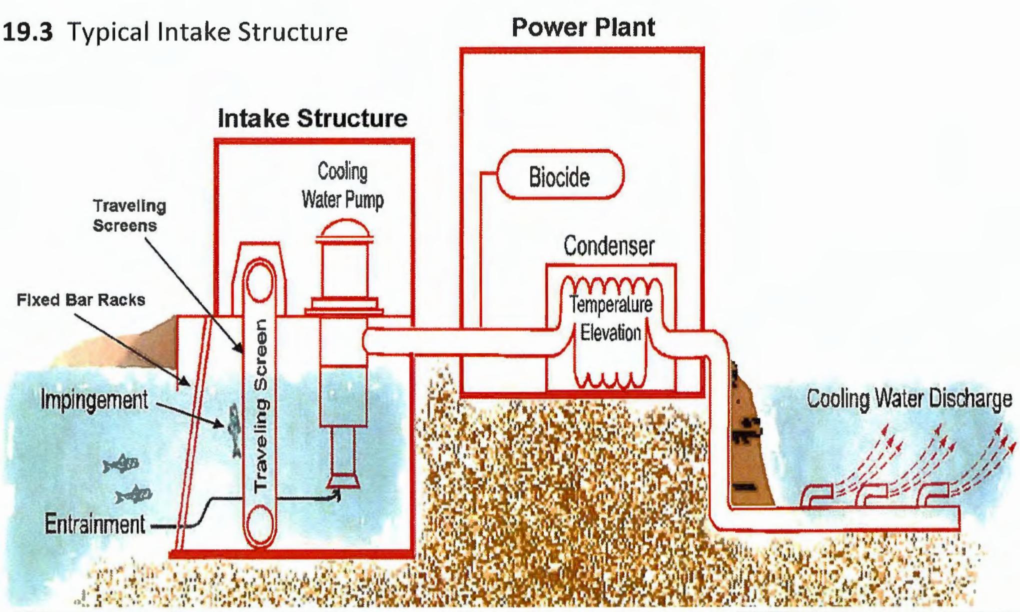


Figure 19.4—Screen wash debris is collected in a basket at the end of the troughs

apart. Debris collected on the bar racks is manually removed.

TRAVELING SCREENS—Traveling screens are provided for further cleaning of the circulating water and will not pass objects large enough to plug condenser tubes. The screens are cleaned by rotating them past fixed water sprays with the debris collected and dumped to waste.

The screen wash cycle may be manually started or automatically triggered by a pressure drop across the screen.

The screens are rotated using electric drives and reduction gears and bull gear. The screens and drives are protected from damage by shear pins on the bull gear assembly. On screens installed with shear pins, the pin is designed to break before any part of the screen. This protection is necessary as the screens are not designed to withstand a large pressure drop. One foot is a reasonable maximum but the differential should be set to start the screens when five inches differential pressure is reached . A pressure drop may be expected at any time for a number of reasons: seaweed, marine life, debris etc. If any debris causes a screen to stop or stall, it is usually necessary to secure the circulating pump in order to restore normal operation.

The screen differential is usually measured by an air bubbler device. The device operates on the principle of water level across the screen being sensed by the difference in pressure needed to bubble air through submerged feeler pipes located before and after the screens. The air pressure required to overcome the water head is in direct proportion to the depth of the water and indicates the level for alarming or automatically starting the screens due to higher differential.

SCREEN WASH—The screen wash system usually consists of wash pumps that take suction after the screens and discharge through a strainer arrangement to sprays located in front and back of the screens.

The wash pumps start automatically or can be manually started. Automatic operation of the system is controlled by an impulse from the screen differential level device. The debris which is removed is caught in basins or troughs . See Figure 19.4

The screens are interlocked and will not rotate unless the wash pump is running and there is normal wash water pressure. This is necessary since without washing the debris would fall from the screen and be carried on into the plant by the circulating water flow across the screen. In some plants the screen wash pumps are connected to the boiler wash water system which backs up the screen wash system.

Alarms associated with the screens are as follows:

Screens high differential.

CHLORINE DIOXIDE

ALGAE GROWTH AND PREVENTION—Algae growth is most effectively combated by feeding chlorine. An aqueous solution of chlorine dioxide is generated from sodium chlorite, sodium hypochlorite and hydrochloric acid. The chlorine dioxide solution is applied through up to 16 application points (condensers) as a biocidal treatment. The chlorine in liquid form and under pressure is converted to gas as the pressure is reduced and rapidly combines with water to form a chlorine solution.

The Chlorine Dioxide (ClO_2) system consists of a Chlorine Dioxide Generator and a tank monitoring and dosing control system. Human Machine Interface (HMI) screens provide the operator interface to the control the process.

Raw materials are stored in precursor tanks. The chlorine dioxide generator draws aqueous solutions of sodium chlorite, sodium hypochlorite and hydrochloric acids from these tanks into a motive water stream using an eductor.

A double walled tank with a floating roof is used to store the aqueous chlorine dioxide solution that is generated. Tank levels are monitored and the fill sequence can be automatically started based on the set points or manually initiated by pressing the tank fill button on the HMI main screen.

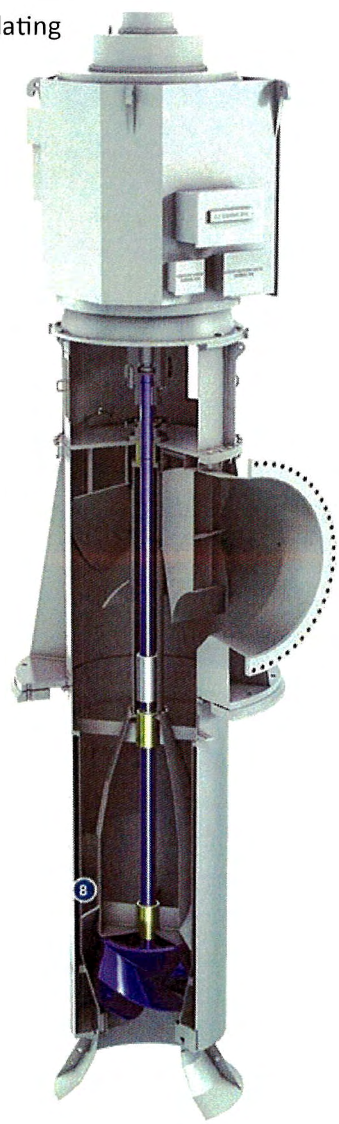
Pumps and valves are used to send chlorine dioxide from this tank to up to 16 application points. After each application point is dosed with chlorine dioxide a water flush can be used to flush chlorine dioxide from the application piping.

SAFETY PRECAUTIONS

- Chlorine Dioxide (ClO_2) gas is harmful if inhaled in high concentrations. Concentrated solutions of ClO_2 (e.g. 500 ppm) must be contained within piping or diluted (e.g. to <5ppm) before being released into areas where personnel could breathe the fumes.
- The precursor chemicals for chlorine dioxide require careful handling. Sodium Chlorite (ADOX8125) is a strong oxidizing agent and may increase the flammability of combustible, organic, or other readily oxidizable materials. If allowed to dry, this product can easily be ignited by heat or friction. Storage areas must be kept free of oxidizable materials including any wood. Any contact of sodium chlorite with worker clothing presents a hazard that is mitigated by removal of clothing and keeping wet until clothes are cleaned.

- Sodium hypochlorite and hydrochloric acid are corrosive and present a risk to eyes and skin, eyewashes must be available in handling areas.
- Hydrochloric Acid is incompatible with both sodium chlorite and sodium hypochlorite, mixing would cause the generation of chlorine dioxide gas or chlorine gas. Hydrochloric acid must be stored in a separate secondary containment area from sodium chlorite and sodium hypochlorite.

Figure 19.5—Cutaway of vertical circulating water pump



- The concentration of chlorine dioxide (ClO2) in the product must be kept within normal limits. If it is too high, it can result in an explosion, which could cause injury or death. **The sodium chlorite feed should not be increased above the recommended settings.**

PERSONAL PROTECTIVE EQUIPMENT

Eye protection is required in any area where high concentrations are expected, such as the area around the ClO_2 Generator.

Personnel should not work in any area where ClO_2 fumes are present above the odor threshold.

All spills must be flushed thoroughly with generous amounts of water.

Alarms associated with this system are:

Low-Low Level

High-High Level

High-High-High Level

Generator Not Running

Precursor Tank Low Level.

CIRCULATING WATER PUMPS

The main circulating water pumps are usually vertical, taking suction after the traveling screens and discharging through the plant condensers. See Figures 19.5 & 19.6. The discharge of the CW pump has an expansion joint and Motor Operated Valve (MOV). The pump shafts are provided with water lubricated cutlass rubber bearings. Some are protected from silt by straining the lube water. At Waiau, lube water is provided from the raw water system and is backed up by city water. Kahe lube water is sea water with city water as its back up source.

Figure 19.6—Waiau Travel Screen Structure with circulating pumps.

Pumps Serving Main Condensers. Two pumps, each rated at 50% capacity, supply the condenser through iron and concrete piping. One pump discharges to one-half of the condenser and the second pump discharges to the other half of the condenser. There may be a normally open dividing or cross-connection valve installed between the pump discharge headers to equalize flow while both pumps are in operation. This also permits either pump to serve both condenser halves. The condenser inlets and the dividing valves are usually large butterfly type valves with motor operators.

Each pump discharges through a motor operated butterfly valve to each side of the condenser. The MOV is arranged for use as either a check valve or a shut-off valve. An overboard butterfly valve is provided.

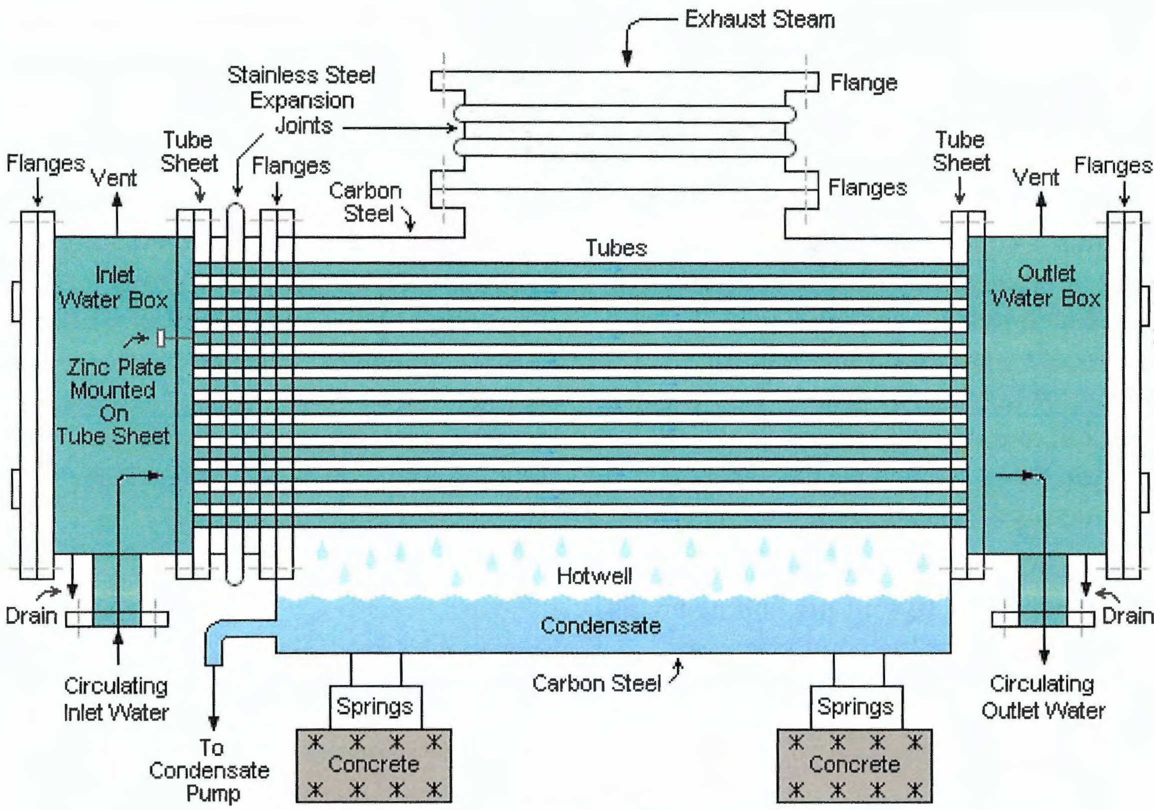
Alarms associated with the circulating water pumps are as follows:

- Lube water trouble
- Circulating water pump trip
- Circulating water pump high discharge pressure
- Travelling screen high differential level

CONDENSERS

One of the major pieces of equipment in a power plant is the surface condenser. See Figure 19.7. Condensers do two big jobs. First, they reduce back pressure on the turbine so maximum energy (expansion) can be extracted from the steam. Energy produced in expanding steam from atmospheric pressure to 29 inches Hg vacuum roughly equals that produced by

Figure 19.7—Single Pass Surface Condenser



Note: Tubes are brass, cupro nickel, titanium or stainless steel. The tubes are expanded or rolled and bell mouthed at the ends in the tubesheets.

Typical Power Plant Condenser

expanding from 200 psig, 600°F to atmospheric. Second, condensers recover low oxygen content condensate. The steam side of the condenser is covered further in the condensate section of this manual.

Surface condensers are basically vacuum tight shell and tube heat exchangers with circulating water flowing through tubes and the turbine exhaust steam flowing around the tubes. Cold tube surfaces condense the steam to water. The condensers come in various designs. Some installations are single pass, some double pass. The shell may be rigidly supported with an expansion joint connection between itself and the turbine exhaust casing; however, most installations have a rigid connection with the condenser supported on springs which accommodate the expansion.

Heat transfer from the steam to tubes and tubes to water is important in maintaining good condenser efficiency and minimum back pressure. Water temperature, marine life, mud, debris, slime from the growth of minute organisms, and chemical content of the water are among the many factors which affect condenser performance. A means of determining the pressure drop through the condenser tubes is provided. It consists of a pressure sensor/transmitter connected to pressure taps on the inlet and outlet water boxes. An increase in differential indicates the condenser is dirty.

The condenser water boxes are arranged for removing one-half of the condenser for routine cleaning and checking for tube leaks if necessary, while restricting the unit output to approximately half load.

In the newest plants if a tube leak develops, as indicated by an increase in hotwell conductivity, automatic isolation will take place. This shuts down the affected circulating water pump and restricts suction flow to the condensate pumps. At the same time the unit load will automatically be reduced to half condenser load. It will be necessary to cut out one-half the condenser to check for leaks. After the half is cut out and drained, a foam is spread over the tubes and the tube where the foam disappears is plugged.

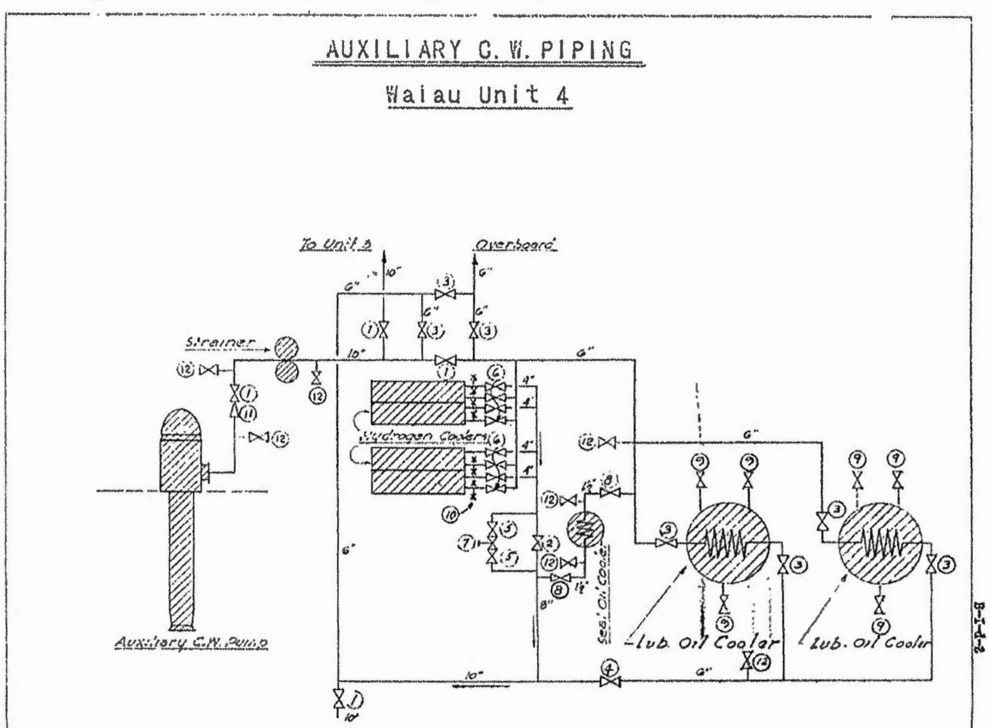
When leakage becomes excessive, it is usually necessary to shut the unit down, fill the hotwell side of the condenser with distilled water, and observe the tubes for leakage. In plants where the condenser is supported on springs, it is necessary to raise the condenser water box jacks prior to filling with water. The jacks are raised because of undue stresses placed on the exhaust trunk from the added weight of water in the hotwell. The jacks must be lowered after pumping down the hotwell and before starting up the unit. If this is not done the springs would be unable to take up the expansion as the turbine heats up.

When a leaky tube is found it must be plugged at both ends and a record maintained of how many tubes have failed. As more and more tubes leak and are plugged, the velocity through the tubes increases and will eventually call for retubing a portion or all of the condenser. This value of plugged tubes is approximately 10%.

STATION SERVICE WATER

In older power plants, auxiliary circulating water referred to circulating water that supplied equipment other than the main condensers. In the older plants (such as Hawaiian Electric's Waiau Units 3 &4—see Figure 19.8) much of the equipment, such as hydrogen coolers and lube oil coolers,

Figure 19.8—Diagram of W4 Auxiliary Circulating Water System



was directly supplied with auxiliary circulating water. This practice led to excessive maintenance due to corrosion and contamination. In the more recent plants, auxiliary circulating water was replaced with station service water and is supplied only to the closed cooling water heat exchanger. The chemically treated cooling water is what is now used for all equipment cooling in place of the auxiliary circulating water. (This closed cooling water system is the Auxiliary Cooling Water system and will be covered in the Miscellaneous Auxiliary Systems chapter.)

In Hawaiian Electric's systems, station service water pumps are provided. See Figure 19.9. These pumps are either horizontal or vertical centrifugal types and take suction from a supply located downstream of the circulating water traveling screens. In some installations no pumps are used and station service cooling water is supplied to the closed cooling water heat exchangers from the main circulating water pump discharge.

When station service cooling water pumps are provided, they are usually supplied in duplicate with provision for automatic stand-by start on failure of the operating pump or low header pressure.

Alarms associated with the station service cooling water system are as follows :

Pump stand-by start.

Cooling water low pressure.

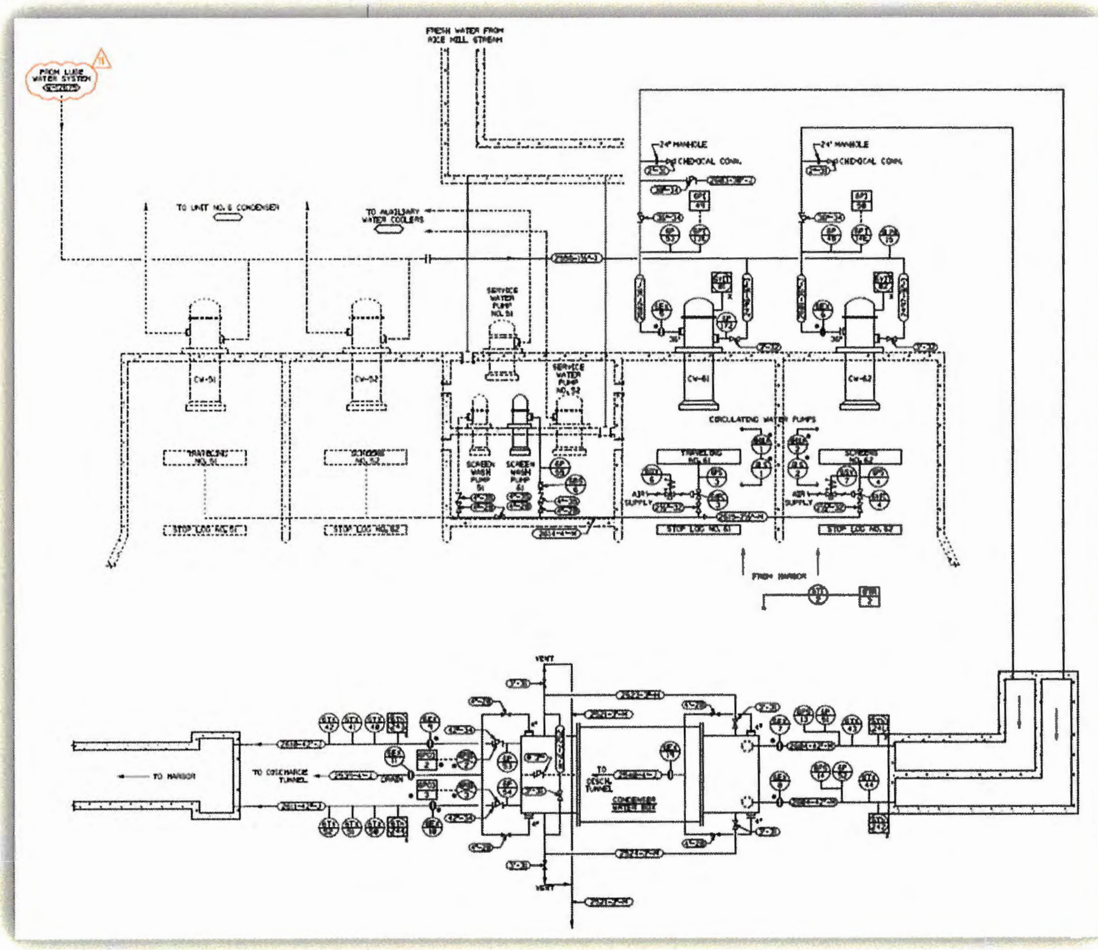


Figure 19.9—P&ID of Waiau 6 Circulating Water System (Drawing #83109) Station Service Water pumps, Screen Wash Pumps, Circulating Water Pumps, and other equipment at the intake structure are shown on this diagram.

Section 19

CIRCULATING WATER

Study Questions

1. What is the purpose of Circulating Water Systems?

2. What is the water source for circulating water systems?

3. Why is provision made for chlorinating the water?

4. The air bubbler _____.
   a. aerates the raw water.
   b. introduces chlorine into the water system.
   c. measures the screen differential.
   d. none of the above.

5. The chlorinator controls marine growth in the condenser. True \ False

6. If any debris causes a traveling screen to stop or stall, it is automatically restored to normal operation. True \ False

7. The screen wash cycle may be started _____ .
   a. by a pressure drop across the screen.
   b. manually.
   c. both of the above.

8. The pumping systems usually consist of one pump serving each condenser half. True \ False

9. Circulating water pumps take suction after the traveling screens and discharge through the plant condensers. True \ False

10. What are the two major functions of the surface condenser?

    a.

    b.

11. What are the indicators that would suggest that a condenser is dirty?

12. How would you know if a tube leak has developed?

13. Why are condensers supported on springs?

14. As more and more tube leaks are plugged, the velocity through the tubes ______ .

    a. decreases.

    b. increases.

15. Algae growth is most effectively combated by __________________ .

16. List the major components of the Circulating Water System and the purpose of each component.

17. Draw a diagram of the Circulating Water System. Include and label all major components and indicate the direction of flow.

NOTES:

GENERATION-OAHU DIVISION
OPERATOR TRAINEE TRAINING PROGRAM

Section 20
COMPRESSED AIR SYSTEMS

OBJECTIVES:

1. Describe the purpose of the Service and Instrument Air Systems.
2. Identify major components and be able to state the purpose, function and operation of the major components of the system.
   - air compressors
   - air receivers
   - air dryers
3. Identify normal flow path of the service air system.
4. Identify normal flow path of the instrument air system.

Section 20

COMPRESSED AIR SYSTEMS

INTRODUCTION

There are two separate compressed air systems in the power plant: an instrument air system and a service air system. Equipment generally associated with a compressed air system consists of an air compressor, air dryer and an air receiver fitted with a liquid drain trap. The compressor may be air cooled or water cooled.

The instrument air system furnishes air for the operation of combustion and feedwater controls and all other pneumatically operated controls throughout the plant, some of which may have a critical role in plant operation and safety. This air must be dry and free from oil for use in instruments, otherwise plugging could develop in the control devices.

The service air system furnishes air for plant cleaning services, soot blowing, burner cleaning, sealing air, air preheater auxiliary drive motors, maintenance shop and laboratory use, as well as miscellaneous general service connections located throughout the plant.

SERVICE AIR SYSTEM

The service air systems usually consist of the compressor, after-cooler, receiver, and a single air supply header. An intercooler is provided on compressors with two stages to provide cooling for the air between stages.

Fresh air is drawn through filters into compressors then discharged through after-coolers to an air receiver and routed to the service air distribution header for the units. A moisture separator is included with the aftercoolers and the moisture in the separators and receiver is drained through air traps to waste. One compressor and after-cooler normally supply the service air system. Isolating valves are located downstream of the aftercoolers for maintenance of this equipment when necessary.

The service air system usually furnishes compressed air at approximately 100 psig. The service air header usually operates in the 90-105 psig range. Service air is supplied through air supply header branch lines extending to various service connections throughout the plant. Some of the systems to which service air is supplied are:

- Back-up for instrument air
- Miscellaneous hose connections located at strategic points throughout the plant

- Auxiliary air heater motors
- Boiler aspirating air system and miscellaneous hose connections
- Burner cleaning station
- Burner ring header
- Auxiliary blowing air to air heater soot blowers
- Sootblower panel for control and air motor drives
- Chemical feed room
- Demineralized water system for regenerating the mixed bed
- Instrument room
- tanks in the waste water treatment facility for mixing of chemicals
- Circulating water pump structure

The following abnormal conditions are usually alarmed:

- Service Air Low Header Pressure
- Service Air Compressor Standby start
- Service Air Compressor Tripped
- Service Air Aftercooler High Temperature

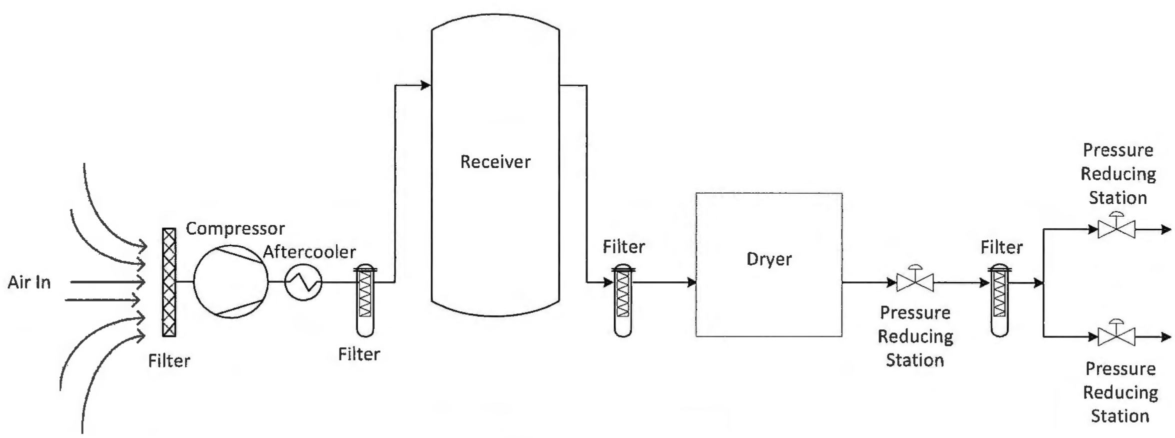
INSTRUMENT AIR SYSTEM

With few exceptions, the instrument air systems employ nonlubricated cylinder compressors with a dry silencer intake air filter. An aftercooler with moisture separator and moisture trap is provided to cool the air and remove condensate that may be formed by the cooling process. A dryer may also be included upstream of the receiver. This reduces the hazards of depositing water in the system.

Fresh air is drawn through filters to two compressors where the air is discharged through after-coolers to the air receivers and to the dryers. The air is then routed to the instrument air distribution header serving each unit. Moisture in the separator and receiver is drained through an air trap to waste. See Figure 20.1.

One compressor, aftercooler, receiver and dryer normally supply instrument air to one unit while the second set supplies the sister unit. The unit systems are cross-connected before the air receivers so that one compressor can serve the entire plant when necessary.

Each compressor is equipped with an automatic low flow switch in the cooling water line to trip the motor on insufficient



Simplified Compressed Gas System

Figure 20.1

flow while it is loaded. An automatic high temperature switch is located in the compressed air discharge line to trip the motor on high temperature. A pneumatically operated, adjustable cooling water valve is also provided to reduce inlet water flow to the compressor during unloading. This valve includes a limit stop to prevent the valve from closing tightly and allow a trickle of water to flow through.

COOLING WATER: An adequate supply of auxiliary cooling water must be available for cooling the compressor. Insufficient supply of auxiliary cooling water to the compressor reduces the efficiency of the cooling system and will cause overheating. If the compressor temperature reaches a predetermined set point, the compressor will trip to prevent further damage to the equipment from occurring due to overheating.

PRESSURE REDUCING STATIONS: In most cases at each individual instrument or air outlet a pressure reducing valve lowers the air pressure to the level required for proper operation. The main header supply pressure to the reducing station is 100 psig. The main header branches off into two separate headers. One of the headers pressure is reduced to 40 psig and the other header pressure is reduced to 30 psig.

Pressure regulators are used to reduce the pressure to the desired pressures. Air filters and moisture traps are also installed at the reducing station piping to prevent debris and moisture from passing through the compressed air system to the controls and equipment. See Figure 20.2

Automatic air failure locks are provided on certain critical service controls (such as the feedwater regulators) which lock the control in place if control air pressure

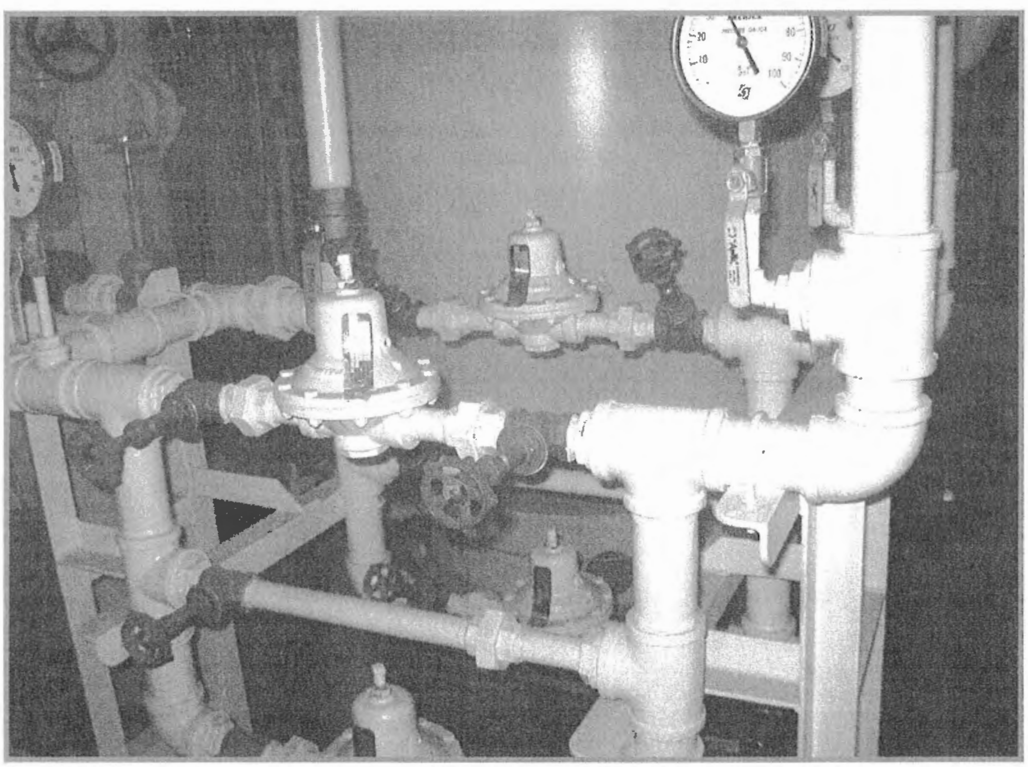


Figure 20.2 Instrument Air Reducing Station

decays to a predetermined pressure. The controls must be manually unlocked once air pressure is restored.

There are specific operating instructions for any particular compressor. However, there are some general rules that apply to all units.

- The condensate traps should be inspected and drained at least once a watch and more frequently if necessary.
- The compressor loading and unloading is important and should be checked periodically to be certain that expected pressures are maintained.
- Cooling water must be established to the compressor prior to starting and should be secured as soon as the unit is shut down.

INSTRUMENT AIR CONTROL: An air compressor that is in service runs continuously. Pressure is controlled by automatic loading and unloading of the compressor. This eliminates frequent starts on the motor. The compressor only supplies air when it is loaded and also requires jacket cooling water only when loaded. The loading and unloading of the instrument air compressors is controlled by a pressure switch which responds to changes in system pressure.

The compressors may be started manually or automatically. Some compressors are started locally at the compressor's control panel and others have the provisions to be started remotely from the generating unit control room via the Distributed Control System (DCS). A time delay prevents loading the compressor until the drive motor is up to speed. Instrument air systems operate between 85 to 100 psig of header pressure.

Instrument air systems are also protected against low system pressure by an automatic start (APS) of the standby compressor and automatic bypass features tied to the service air system.

The following abnormal conditions are usually alarmed:

- Instrument Air Compressor Tripped
- Low cooling water pressure to the aftercooler
- Instrument Air Low Header pressure
- Instrument Air Compressor standby start

COMMON COMPRESSOR MALFUNCTIONS: One problem that may occur with compressors is overheating. This is usually caused by the lack of cooling water, air inlet clogged or valve malfunction. Another problem is motor overload. This could be caused by a discharge pressure too high or discharge air line plugged.

The instrument air system furnishes compressed air through the plant as follows:

<u>100 psig air</u> is supplied to:

- the turbine bleeder trip system,
- sootblower pressure reducing station
- to the fan area
- for general usage in the instrument room and chemical laboratory
- to the demineralizer area where it's reduced as necessary for various monitoring and control systems

<u>40 psig air</u> is supplied from the filter and pressure reducing station to:

- the condenser area
- fan damper operators
- boiler area
- boiler feedwater regulator
- reboiler feed
- pump area
- demineralized water tanks level transmitters
- auxiliary cooling water tank area
- circulating water structure area
- circulating water valves and instruments
- fuel oil flow control valves
- control room

30 psig air is supplied from the pressure reducing station to:

- the control room panels
- all transmitters and controllers throughout the plant that operate on 30 psig air supply

EQUIPMENT

SERVICE AND INSTRUMENT AIR COMPRESSORS—INGERSOLL-RAND

The SSR compressor is an electric motor driven, single stage, screw compressor complete with accessories piped, wired and baseplate mounted. It is a totally self-contained air compressor package. See Figure 20.3.

The air system is composed of:

Inlet air filter
Inlet air valve
Rotors
Coolant/air separator
Minimum pressure/check valve

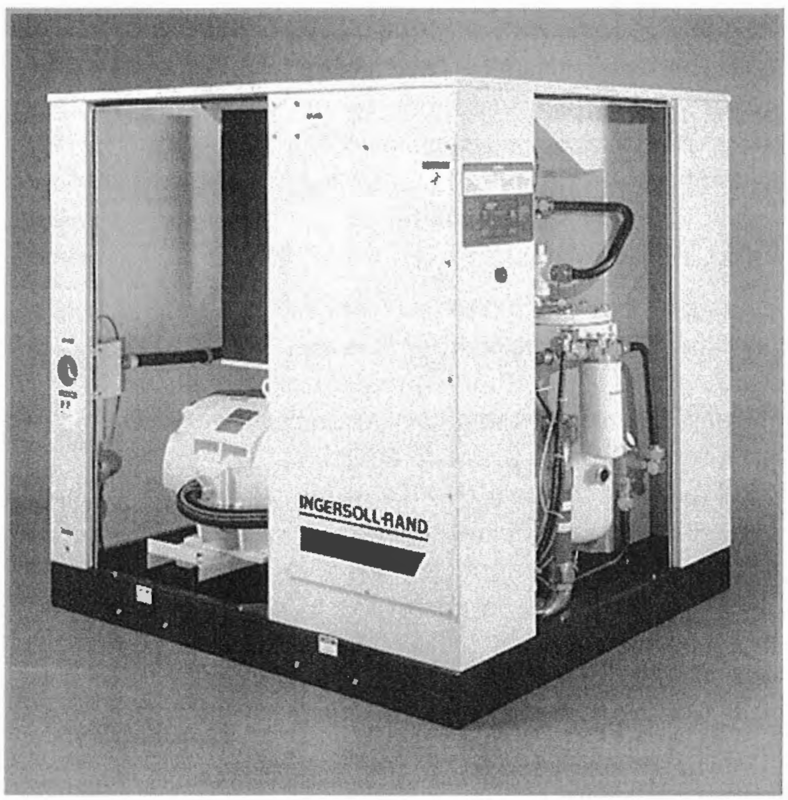


Figure 20.3 Ingersoll-Rand SSR air Compressor Package. All components come mounted on a skip.

Aftercooler
Moisture separator/drain trap

Air enters the compressor, passing through the inlet air filter and inlet valve. Compression in the screw-type air compressor is created by the meshing of two helical rotors (male and female) on parallel shafts, enclosed in a heavy duty cast iron housing, with air inlet and outlet ports located on opposite ends. The grooves of the female rotor mesh with, and are driven by, the male rotor. Tapered roller bearings at the discharge end prevent axial movement of the rotors. See Figure 20.4.

The air-coolant mixture discharges from the compressor into the separation system. This system, self-contained in the receiver tank, removes all but a few PPM of the coolant from the discharge air. The coolant is returned to the system and the air passes to the aftercooler. The aftercooling system consists of a heat exchanger, a condensate separator, and a drain trap. By cooling the discharge air, much of the water vapor naturally contained in the air is condensed and eliminated from the downstream plant-piping and equipment.

During unloaded operation, the inlet valve closes and the blowdown solenoid valve opens expelling any compressed air back to the compressor inlet.

Coolant/Air Separation System: The coolant/air separation system is composed of a separator tank with specially designed internals, a two-stage, coalescing-type separator element, and provision for return of the separated fluid back to the compressor.

Operation: The coolant and air discharging from the compressor flow into the separator tank through a tangential inlet. This inlet directs the mixture along the inner circumference of the separator tank, allowing the coolant stream to collect and drop to the separator tank sump.

Internal baffles maintain the circumferential flow of remaining coolant droplets and air. In an almost continuous change of direction of flow, more and more droplets are removed from the air by inertial action and than returned to the sump.

The air stream, now essentially a very fine mist, is directed to the separator element.

The separator element is constructed with two concentric, cylindrical sections of closely packed fibers, each held in steel

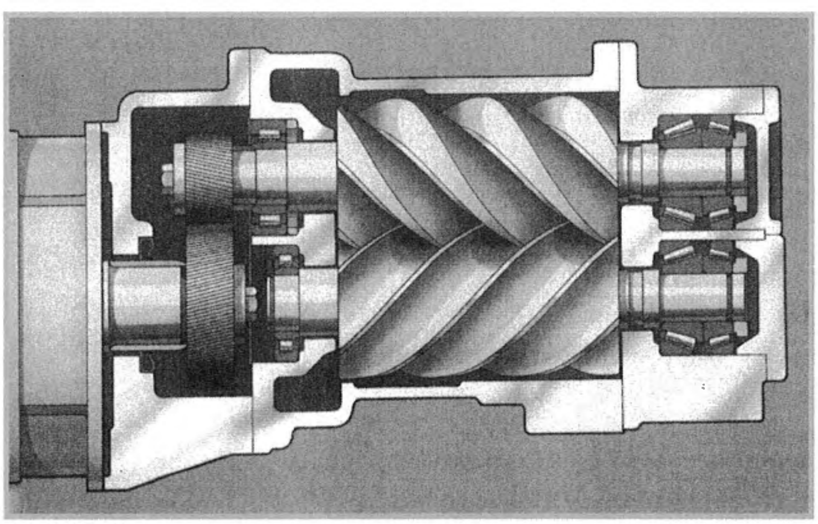


Figure 20.4—Screw type compressor. Helical rotors on parallel shafts meshes air between rotors to compress and increase air pressure.

mesh. It is flange-mounted at the receiver-outlet-cover.

The air stream enters the separator element radially and the mist coalesces to form droplets. The droplets collected on the outer first stage fall to the receiver sump. Those collected on the inner second stage collect near the outlet of the element, and are drawn back to the compressor inlet through a filter screen and orifice fitting installed in the separator scavenge line.

The air stream, now essentially free of coolant, flows from the separator to the aftercooler then to the condensate separator, and on to the plant air system.

Cooling Fan Motor: In a standard compressor, the cooling fan motors are wired at the factory. Each is protected by a fan starter/overload. The fan motor is energized at the same time the compressor drive motor is energized. The fan motor starter/overload is wired in series with the compressor drive motor overload. If an overload occurs in the fan motor circuit, both the fan motor and compressor drive motor will stop.

Aftercooler: The discharge air aftercooling system consists of a heat exchanger (located at the cooling air discharge of the machine), a condensate separator, and an automatic drain trap.

By cooling the discharge air, much of the water vapor naturally contained in the air is condensed and eliminated from the downstream plant-piping and equipment.

Coolant System: Coolant is forced by pressure from the receiver-separator sump to the inlet port of the coolant cooler and the bypass port of the thermostatic control valve. The thermostatic control valve controls the quantity of coolant necessary to provide a suitable compressor injection temperature. When the compressor starts cold, part of the coolant will bypass the cooler. As the system temperature rises above the valve setting, the coolant will be directed to the cooler. During periods of operation in ambient temperatures, all the coolant flow will be directed through the cooler.

The compressor injection minimum temperature is controlled to preclude the possibility of water vapor condensing in the receiver. By injecting coolant at a sufficiently high temperature, temperature of the discharge air and lubricant mixture will be kept above the dew point. The controlled temperature coolant passes through a filter to the airend under constant pressure.

Coolant Cooler: The cooler is an integral assembly of core, fan and fan-motor, mounted in the compressor. The cooling air flows through the left side of the enclosure, through the vertically mounted cooler core, and discharges upward through the top of the enclosure.

Intellisys Operation Controls: Refer to the INGERSOLL RAND compressor manual for the applicable unit for specific operating instructions.

Intellisys Warnings and Alarms: Warnings and alarms are displayed on the compressor control panel.

WARNINGS: When a warning occurs, the alarm indicator will flash and the display will alternate between the current message and the warning message. If multiple warnings exist, the message "SCROLL FOR WARN" will be substituted for the warning messages. The up and down arrows can be used to obtain the warnings.

A warning needs to be reset by an operator. The warning will clear when the SET button is pressed once.

ALARMS: When an alarm occurs, the alarm indicator will light and display will show actual alarm message. If alternately multiple alarms have occurred the display will show "SCROLL FOR ALARM". In this situation the up and down arrows will be used to view the alarm messages. All alarms (with the exception of the emergency stop) will be reset by twice pressing the SET button. Any exceptions to the above will be explained in the alarm description.

Refer to INGERSOLL RAND compressor manual for list of warnings and alarms and their explanations.

AIR DRYERS

Liquid water occurs naturally in air lines as a result of compression. Moisture vapor in ambient air is concentrated when pressurized and condenses when cooled in downstream air piping. Moisture in compressed air is responsible for costly problems in almost every application that relies on compressed air. Some common problems caused by moisture are rusting and scaling in pipelines, clogging of instruments, sticking of control valves, and freezing of outdoor compressed air lines. Any of these could result in partial or total plant shutdown.

Compressed air dryers reduce the water vapor concentration and prevent liquid water formation in compressed air lines. Dryers are a necessary companion to filters, aftercoolers, and automatic drains for improving the productivity of compressed air systems.

Two types of dryers, refrigerated or desiccant, are used to correct moisture related problems in a compressed air system. Refrigerated dryers are normally specified where compressed air pressure dew points of 33°F (1°C) to 39°F (4°C) are adequate. Desiccant dryers are required

Figure 20.5 Ingersoll-Rand Refrigerant Air Dryers

where pressure dew points must be below 33°F (1°C).

Refrigerated dryers are used in the compressed air system at Hawaiian Electric's generating units.

The Ingersoll Rand Thermal Mass Refrigerated Air Dryer removes moisture from the compressed air by cooling the air with a refrigeration unit to a low dew point causing the moisture in the air to condense. See Figure 20.3.

Air Dryer Operation: At the air intake, air enters the dryer at a temperature usually between 18 – 27 degrees F above ambient. The air passes through the pre-cooler/ reheater. Here the temperature of the air is reduced by approximately 30 degrees F. Thus the precooler/reheater is reducing the heat load into the thermal mass heat exchanger. From here the pre-cooled air then enter the main coils of the thermal mass heat exchanger and heat exchange inwards from the air to the thermal mass takes place. The thermal mass is a solution of water with 25% glycol added.

As air passes through the main exchanger the temperature is reduced to the same level as the Thermal Mass (normally 36 degrees F), and in doing so, more water is removed from the air by the separator and drain connected to the outlet of the main exchanger.

The air is then passed through the reheater where its temperature is raised about 40 degrees F. This is done to prevent sweating on the external surfaces of the compressed air piping and as already explained to reduce the incoming heat load.

AIR RECEIVERS

An air receiver is provided to remove the pulsating effects of the compressor, act as a storage vessel and contain any moisture and oil that should happen to enter the air system. See Figure 20.6. The receiver should be checked and drained frequently as an accumulation of oil vapor in the vessel could cause an explosion. The air leaving the receiver is routed through cartridge type filters before being routed a single main header then to various equipment and control boards.

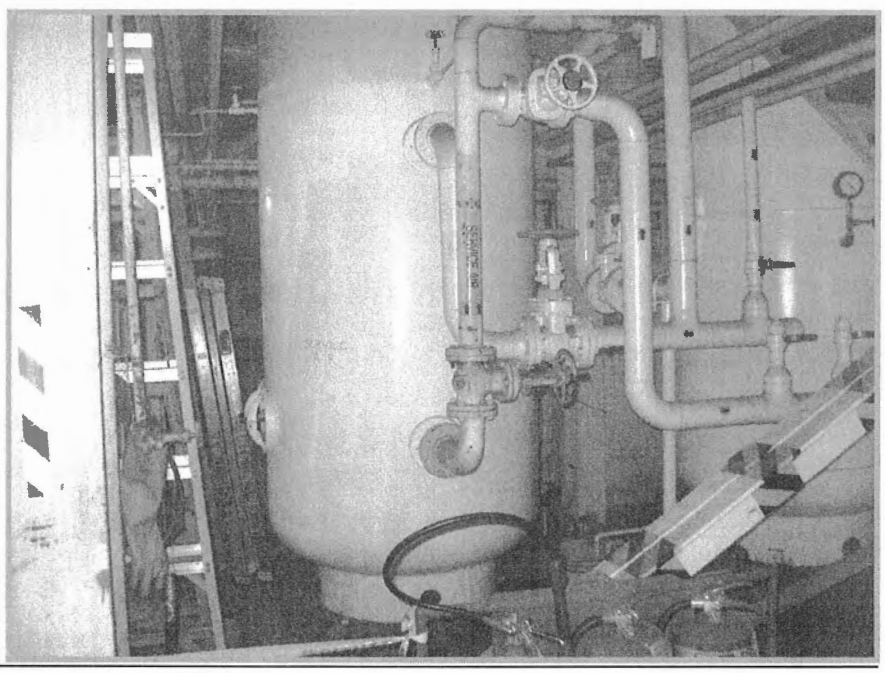


Figure 20.6 Air Receiver with associated valves and piping.

Section 20

COMPRESSED AIR

Study Questions

1. The two air systems are an ________________________________ system and a ________________________________ system.

2. What are the basic functions of these two systems?

3. An explosion could occur if an accumulation of oil vapor is not frequently drained from the ________________________________ .

4. With an air compressor, pressure is controlled by automatic ____________________ and ____________________ of the compressor.

5. Air compressors are started up ____________________________ .

   a. automatically.

   b. manually.

   c. both

6. The compressor only supplies air and requires jacket cooling water when it is ________________________________.

   a. unloaded.

   b. loaded.

7. List two causes of compressor overheating.

   a.

   b.

8. List two causes of compressor motor overload.

   a.

   b.

9. What is the purpose of the pressure reducing stations?

10. Service Air is supplied at _______________ psig.

11. Instrument Air is supplied at ______________ psig, ___________ psig, and _________ psig

12. The absorbing agent in air dryers is called a desiccant. True \ False

13. Describe how the Air Dryer dries the air stream.

14. Name the main components in a compressed air system.

GENERATION OAHU DIVISION

OPERATOR TRAINEE TRAINING PROGRAM

Section 21

HYDROGEN AND HYDROGEN SEAL OIL SYSTEM

OBJECTIVES:

1. Discuss hydrogen and its importance as a cooling medium for rotating electrical machines.
2. Describe generator cooling design.
3. Discuss hydrogen gas system.
4. Discuss hydrogen seal oil system.

Generation Oahu Division
Operator Trainee Training Program

Section 21
HYDROGEN AND HYDROGEN SEAL OIL SYSTEMS

Generator losses that appear as heat must be constantly removed to avoid damaging the material of the windings. It can be said that generator size is limited by the ability of the weakest material to conduct and disperse heat without exceeding stress limits. In the case of electric machinery, including generators, this limiting material is copper. This means the major limit to generator capability is the ability of the design to cool the copper.

At one time, all turbine generators were cooled with air. Air, at room temperature, was circulated over the generator winding by fans mounted on the rotor. As the electrical industry grew, the need for higher rated generators also grew. To increase generator ratings with the air type cooling, it was necessary to increase the physical size of the generator to control heat losses. The weights and dimensions of the active machine parts were increased to maintain or lower the generator losses per unit of material. It soon became apparent that to further increase generator ratings, a better means of cooling was necessary, as the physical size of generator parts was definitely limited.

The first step to improve generator cooling was to install air coolers and air filters. In later installations, the air was recirculated through finned tube coolers and used over and over again minimizing the dirt that would be carried into the generator by the cooling air. The next step to improve generator cooling was to use a gas which had better cooling properties than air. It had been recognized for a number of years that gases such as hydrogen and helium (the two most common gases) had the cooling properties required.

Helium is inert and nonflammable, and from these considerations would be an ideal medium for ventilation and cooling purposes. However, because of its scarcity and high cost, it could not be considered feasible as a cooling medium. Hydrogen on the other hand, could be obtained in unlimited quantities and at a relatively low cost. Furthermore, hydrogen is a more desirable cooling medium than helium because of its lower density and better thermal characteristics and commercial hydrogen has the degree of purity desired and required for cooling purposes. While hydrogen itself is combustible, it will not support combustion.

Hydrogen cooling was first used successfully on a number of synchronous condensers and frequency changers. Actual operating experience with hydrogen cooling of various types of synchronous machines, demonstrated that the output of a given machine could be increased by 25% without exceeding the temperature limits specified for air cooling. This increase was achieved operating with hydrogen in place of air at approximately atmospheric pressure. Further testing found that by using a higher gas pressure, the output could be increased even more.

The relative values of the principal characteristics of hydrogen and air, which affect the ventilating problem, are as follows:

	Air	Hydrogen
Density	1.00	0.07
Thermal Conductivity	1.00	7.00
Heat Transfer Coefficient		
From Suface to Gas	1.00	1.35
Specific Heat	1.00	0.98
Support Combustion	Yes	No
Oxidizing Agent	Yes	No

The principal advantages resulting from the use of hydrogen cooling for turbine generators are:

1. Reduced windage and ventilating losses because of the low density of the hydrogen gas. (Ventilating losses are proportional to the gas density. The density of air is over 14x that of hydrogen.)
2. Increased output per unit volume of active material because of the high thermal conductivity and heat transfer coefficients of hydrogen. This advantage of hydrogen cooling makes it possible to build turbine generators for higher ratings than are possible with air cooling.
3. Reduced maintenance expense because of the freedom from dirt and moisture.
4. Increased life of the insulation of the stator winding because of the absence of oxygen and moisture in the presence of corona.
5. Reduced windage noise because of the low density of the gas.

At present, hydrogen is the most desirable gas that can be used as the cooling medium for rotating electrical machines.

GENERATOR COOLING DESIGN

Large generators have cylindrical rotors with a minimum of heat dissipation surface, so they must have forced ventilation to remove the heat. Practically all large generators in use have enclosed systems with hydrogen coolant. The hydrogen-cooled machine differs fundamentally from the older air-cooled machine in that the ventilating system is made gas tight and is filled with hydrogen. The gas is circulated by fans on the rotor. It flows through the machine where it picks up heat and then circulates through finned tube coolers where the heat is transferred to the cooling water flowing in the tubes of the cooler. The gas then re-enters the rotor fins for another circuit through the system and may complete thirty or more such circuits in one minute.

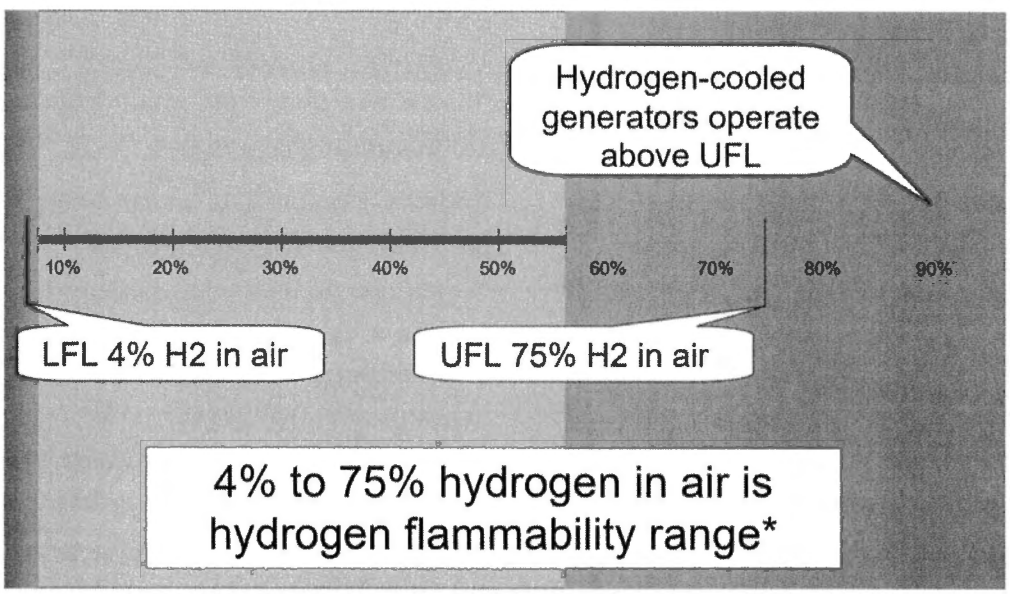
Early generator designs circulated the coolant about the insulation exterior in vent ducts. A steady increase in ratings of turbine generators had been accomplished by increasing hydrogen operating pressure, by improvement in blower design, in metallurgy, and in details of construction. It became evident, however, that the rating increase was limited to the rating at 30 psig hydrogen pressure, since beyond that point no appreciable increase in capability could be gained by a further increase in hydrogen pressure.

An improved method of cooling large turbine generation was then developed which permitted an increase in the capacities for which machines could be built. The basis of the new ventilating technique was to cool the active conductors internally by making them hollow and forcing gas at high velocities through these ducts. This method placed the coolant in direct contact with the materials in which the heat was being generated. The direct metal-to-gas heat transfer reduced the temperature differential and allowed increased generator ratings for a given quantity of copper.

SHAFT SEALING

Hydrogen, although having the desired cooling properties required, presents a problem to industry, in that if a mixture of hydrogen and air between 4% to 75% hydrogen by volume develops, an explosion of the mixture could easily occur. (See Figure 21.1.) To prevent a mixture of hydrogen and air in this explosive range to

Figure 21.1: To avoid an explosion, the mix of Hydrogen in air must be kept below Lower Flammable Limit (LFL) or above Upper Flammable Limit (UFL).



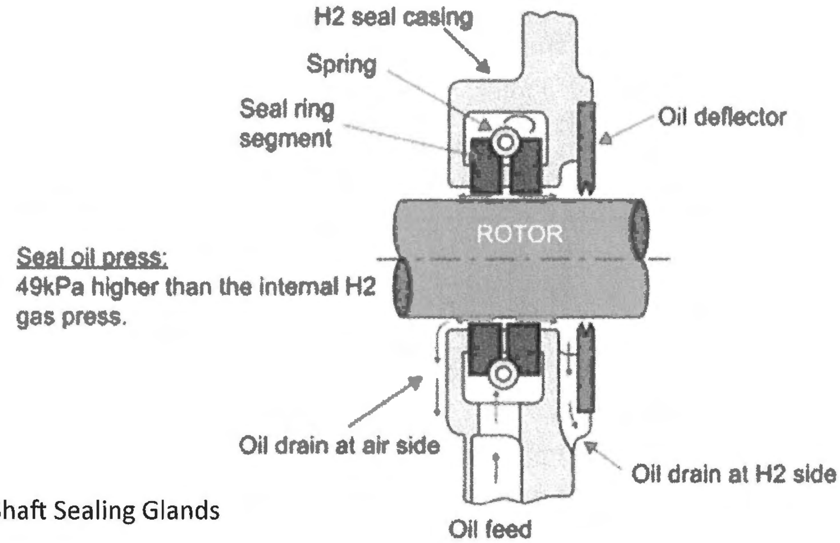


Figure 21.2—Shaft Sealing Glands

accumulate, the hydrogen must be contained in a tight enclosure above atmospheric pressure with a minimum of leakage.

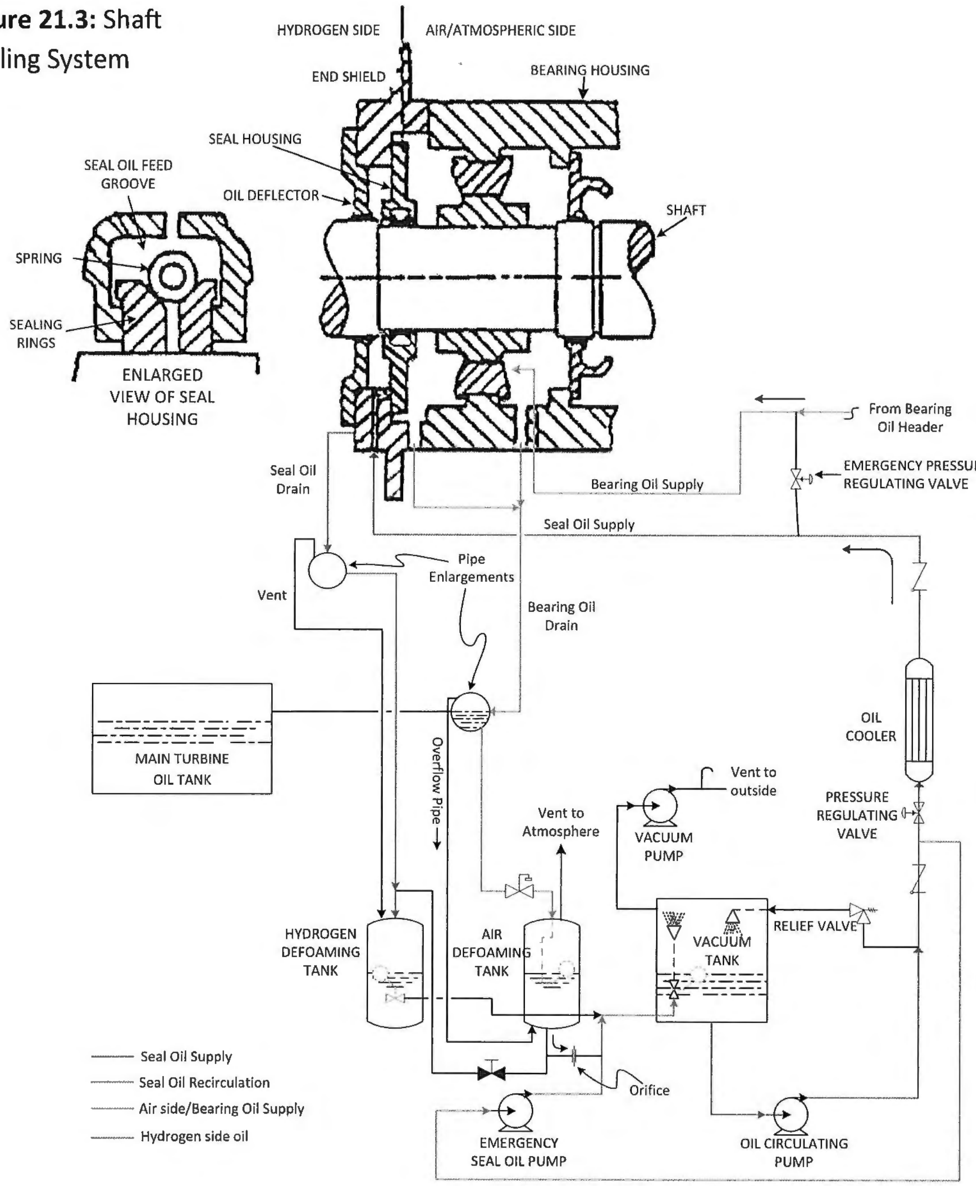
This was first accomplished in the hydrogen -cooled synchronous condensers. The bearings and all parts of the synchronous condensers are completely enclosed in a gas housing. However, in the turbine generator, it was necessary to provide a means to bring the shaft ends out through the gas tight housing. This was achieved through the use of liquid sealing glands around the shaft. (See Figure 21.2.)

Since the rotor shaft ends of a hydrogen-cooled turbine generator must be brought out of the gas-tight enclosure, shaft seals supplied with oil at a pressure above hydrogen pressure are used to prevent the escape of gas along the shaft. The shaft seals are of the oil film type where a small clearance between the rotating shaft and a stationary member is sealed by oil under pressure. The most common sealing arrangement consists of a pair of segmented rings contained in a seal housing.

The action of these seals is very simple. Oil is pumped to a feed groove between the gland rings and flows both ways along the shaft through the clearance space between the gland rings and the shaft. As long as the oil pressure in the feed groove exceeds the gas pressure in the machine, oil will flow toward the hydrogen side of the seal and prevent escape of hydrogen from the machine. The gland rings are provided to restrict the flow of oil through the seal. These rings can move radially with the shaft but are restrained from rotating by dowels in the supporting structure.

A constant supply of oil at a pressure higher than hydrogen pressure must be maintained on the seal at all times to provide adequate sealing at the shaft. To accomplish this, it is sometimes necessary to use oil directly from the turbine lube oil system. When oil from the turbine lube oil system is used, it presents a problem in the maintenance of hydrogen purity and

Figure 21.3: Shaft Sealing System



Shaft Sealing System

hydrogen usage primarily because the oil is not passed through the seal oil treatment system.

Turbine oil in contact with air or hydrogen will absorb an appreciable volume of gas and will also absorb moisture if water vapor is present. When oil with air and water absorbed in it is pumped to the hydrogen seal, some of the air and moisture will separate from the oil and contaminate the hydrogen in the machine. At the same time the oil will absorb some of the hydrogen gas. If this process of gas separation and absorption were permitted to continue, hydrogen purity would eventually decrease to the explosive range of hydrogen-air mixtures .

A reduction in efficiency would also occur due to the increased windage with the increased gas density. To maintain hydrogen purity in this operating condition, it would be necessary to exhaust low purity gas and replace the gas with high purity hydrogen to improve purity and maintain system pressure. This increases hydrogen usage considerably.

A separate shaft seal oil supply and return system was developed to eliminate this type of operation. (See Figure 21.3)

HYDROGEN SEAL OIL SYSTEMS

The seal oil system's function is to provide oil under pressure to the seals as free as possible of air and moisture. The seal oil system (aka gland oil system) is isolated from the turbine bearing oil system except for an oil level control arrangement between the turbine bearing oil drain and the seal oil reservoir to make up for slight leakage which may occur from one system to the other. A line connecting the seal oil supply line to the bearing oil drain makes up oil to the seal oil reservoir. Two (2) float valves located in the seal oil reservoir regulate flow. One valve opens on high level to supply oil from the seal oil feed to the bearing oil drain. The second float valve operates on low level to supply oil from the bearing drain to the seal oil reservoir. An overflow drain is included in the bearing drain to allow oil which backs up in the bearing oil drain to flow into the seal oil reservoir.

When the oil comes in contact with air or hydrogen it absorbs an appreciable volume of gas and will also absorb moisture if water vapor is present.

The vacuum system was the first hydrogen seal oil treatment system developed. This system consists of a supply pump, return tank, a make-up tank and a vacuum tank.

The seal oil circulating pump takes suction

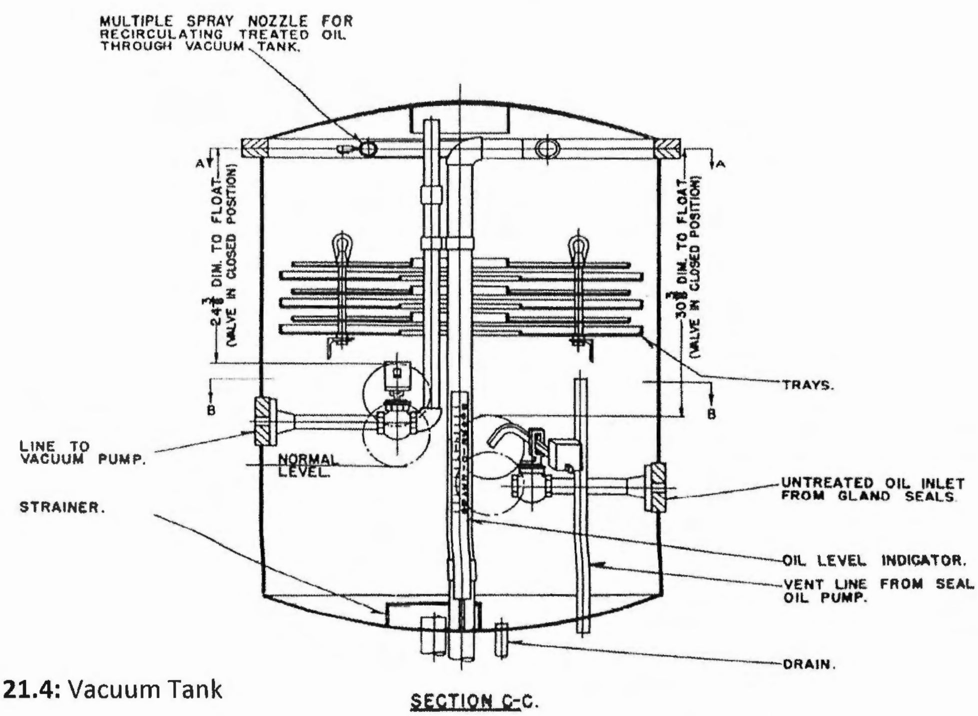


Figure 21.4: Vacuum Tank

from the vacuum tank and discharges through an oil cooler and filter to the hydrogen seal. The seal oil supply pressure is automatically maintained above hydrogen pressure by a differential pressure regulating valve.

Oil at the seal flows between the rings and then both ways along the shaft through annual clearances between the rings and the shaft. Oil leaving the seals on the gas side returns to a hydrogen defoaming tank.

Make up oil to the seal oil reservoir from the lube oil system comes into contact with air when being transferred from the lube oil tank. The air absorbed in the oil makes froth or small bubbles. Foaming occurs when the oil is injected into the bearing housing and the air is entrained in the oil. The defoaming tank allows time for the foam to come out of the oil before the oil flows to the vacuum tank (see Figure 21.4.)

Oil from the defoaming tanks is drawn into the vacuum tank through a float valve and spray nozzles. The oil flows over a series of trays which provide a large area for separation of gas and water vapor. The float valve in the vacuum tank maintains the oil level in the vacuum tank at a fixed position. Any gas and water vapor trapped in the oil tends to cause a thick layer of foam in the vacuum tank. If this foam builds up to the level of the connection to the vacuum pump, some of the foam will be drawn over to the pump and impair its operation. To prevent this, there is a large float in the vacuum tank connected to an external level indicator and three mercury switches. Two of these switches operate high and low oil level alarms. The third makes contact on rising float, energizing the solenoid valve mounted on the vacuum tank which admits a small quantity of air into the vacuum tank to "blow down" the foam.

A motor-driven vacuum pump is used to maintain vacuum and remove the gases from the vacuum tank. Normally about 1 inch of mercury absolute pressure or less is maintained in the tank. The vacuum pump exhausts into a separator tank where any oil or water present in the gas condenses and the gasses pass on out through a vent to atmosphere. The vacuum pump is automatically sealed and lubricated by the oil in this tank. Water collecting in the separator tank must be drained off at intervals to prevent damage to the pump.

The circulating pump (AC) draws treated oil from the bottom of the vacuum tank. It pumps part of it through a cooler and filter to the seals, and part back to spray nozzles in the vacuum tank through a differential pressure regulator which automatically maintains the gland pressure at a pre-set number of pounds above the machine gas pressure. (Regulators on some HECO units are set to hold 10 or 12 pounds oil pressure above the hydrogen gas pressure.) The gland oil is circulated in this way through the vacuum tank a number of times before going to the seals.

SEAL OIL BACK UP

Seal oil backup is provided from the main turbine oil system and is normally closed. If the AC driven air side seal oil pump should stop, or if the seal oil pressure at the seals should decrease to 8 psi above the hydrogen pressure the backup regulator valve will open automatically and provide oil pressure for the seals. For Waiau units 3&4, the first back-up is the DC pump. The second back-up is from the turbine main oil pump which must be opened manually.

This backup pressure may be supplied from several sources. The main oil pump on the turbine and the AC motor driven auxiliary oil pump will supply 50 psig to the back up regulator. The AC or DC motor driven turning gear oil pumps will supply 5 psig. The gas pressure that should be maintained in the generator depends upon the pressure available from the next backup source, i.e., if one of the turning gear oil pumps is the only source of seal oil backup, the hydrogen pressure in the generator should be decreased to 2 psig or less, since the turning gear oil pump can only maintain 5 psig oil pressure at the seals. When bearing oil flows to the seals through the seal oil backup, the excess oil will overflow through the seal oil return line into the main bearing oil drain.

The seal oil may be operated with the back up source but will require additional hydrogen make-up gas to maintain hydrogen purity as the make-up source is not vacuum treated and will contain more contaminants.

GENERATOR BEARING OIL LOOP SEAL

Oil leaving the seals on the air side drains into the generator bearing return header, which was originally designed to return to the turbine-lube oil tank. Makeup to the seal oil system came from a pipe enlargement in the bearing oil return header. However, the design allowed for a mixture of air and gas to accumulate above the oil in the turbine lube oil tank resulting in an explosion.

Modifications have been made in the generator bearing oil drain to protect against hydrogen accumulation in either the drain piping or turbine lube oil reservoir. The changes made included increasing drain capability and installation of vapor extractors in the vapor spaces of the lube oil reservoir and the bearing drain enlargement. A trap drain system was designed and installed on operating units in service. (See Figure 21.5.)

The trap drain system consists of an auxiliary air detraining tank and a loop seal installed in the generator bearing oil drain line. The detraining tank provides a surface which will slow down the oil and allow the foam to settle out of the oil before entering the loop. This enables the oil to flow freely through the loop without backing up the upstream side or requiring an excessive head of oil to force the oil through the loop. Vapors from the detraining tank is vented to the roof. Thus, any hydrogen which might leak past the seal casing will pass to the auxiliary air detraining tank and through the vent to atmosphere. The loop prevents gas from proceeding further down the drain.

In yet another system (Figure 21.6), no storage tank is provided in the seal oil system other than a vacuum tank. In this case, the main seal oil pump takes suction

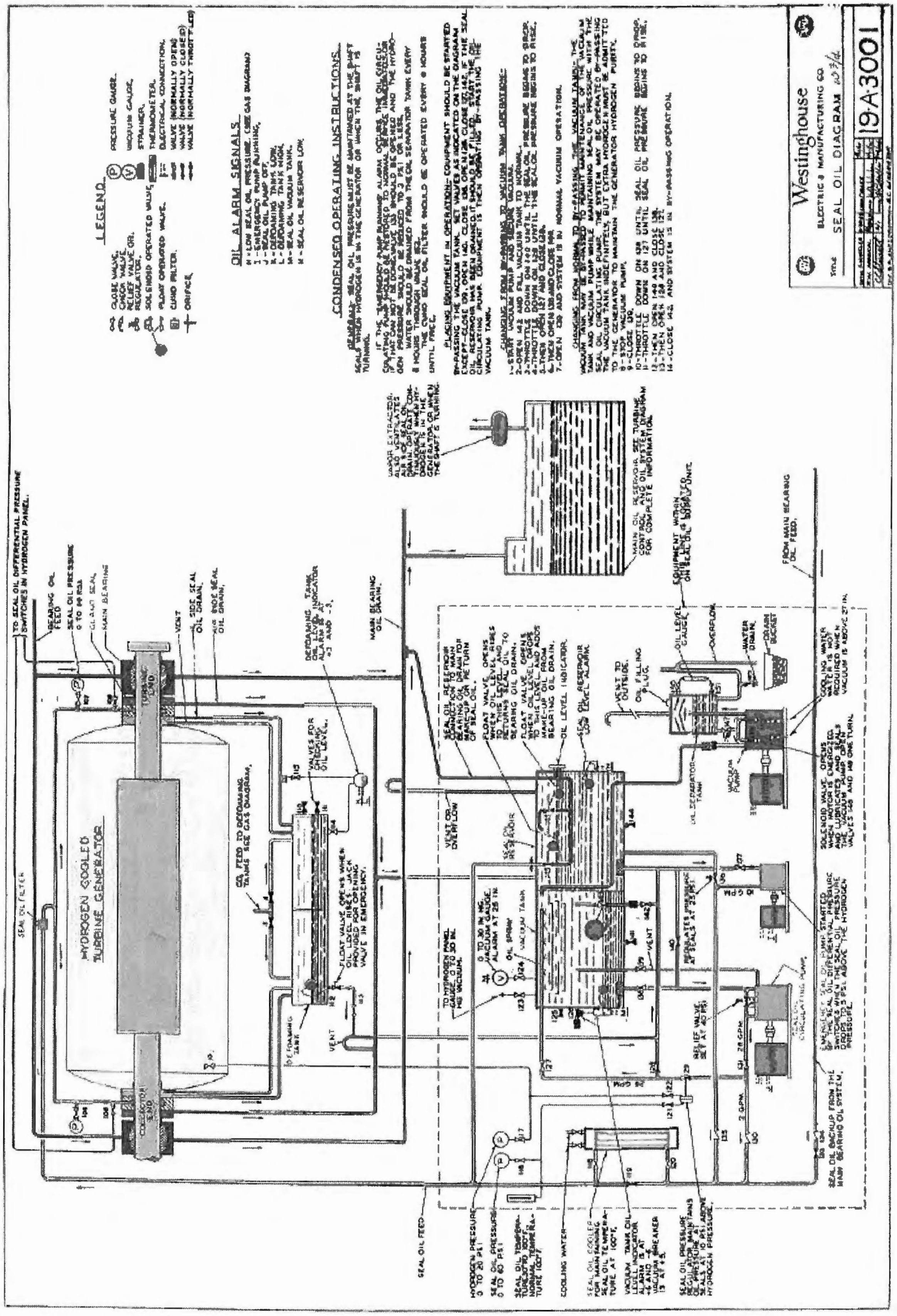


Figure 21.5: Modified Seal Oil System with trap drain system.

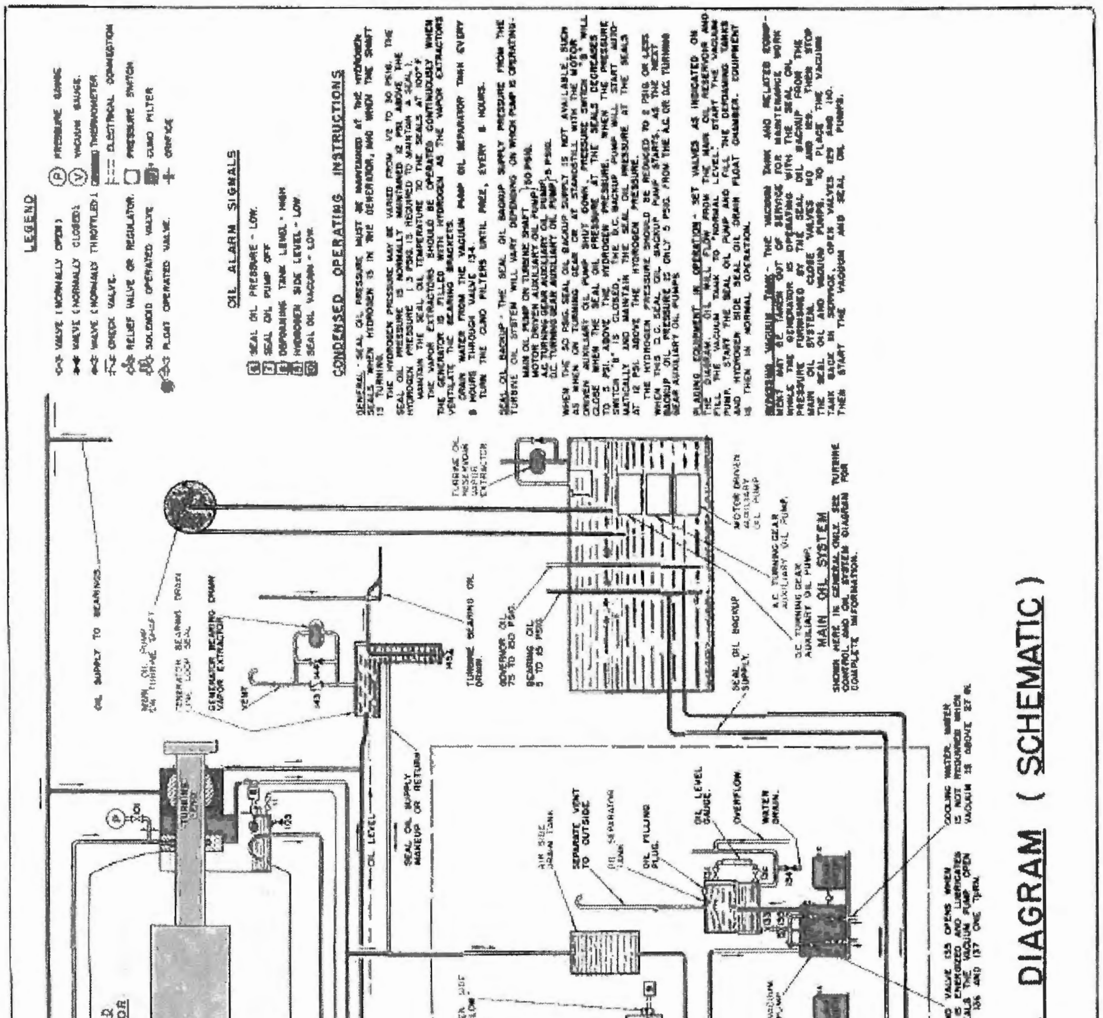


Figure 21.6: Seal Oil System—no storage tank other than vacuum tank.

from the vacuum tank and supplies oil to the seals as in other systems. The principal difference is that oil returning from the seals returns to the turbine lube oil reservoir through detraining sections, a float trap, and generator loop seals. Oil is made up to the vacuum tank from the bearing oil return header and the level in the vacuum tank is controlled by a float operated valve.

HYDROGEN LOSS IN SEALING OIL

When the seals are supplied with oil that has not been vacuum treated, air is liberated from the oil at the generator side of the shaft seals, while hydrogen from the casing is absorbed by the oil at this point.

The rate at which oil absorbs or gives up air is nearly twice the rate at which oil absorbs or gives up hydrogen. The result is, assuming there is no leakage in the system, the pressure in the generator casing would increase. There is, however, enough leakage in the system to require that hydrogen be added to maintain the correct pressure within the casing. The amount of hydrogen necessary to maintain the correct pressure is less than under normal operation when vacuum-treated oil is supplied to the seals.

From this standpoint, it would seem to be desirable to use untreated oil for the seals. But the air which enters the casing lowers the hydrogen purity continuously, and the generator must be scavenged at regular intervals to maintain the correct purity. Since the amount of hydrogen required to scavenge the casing is more than the amount of hydrogen which enters the sealing oil, the total hydrogen requirement when the set is operating with untreated oil, is much greater than when the seals are supplied with oil that has been vacuum treated.

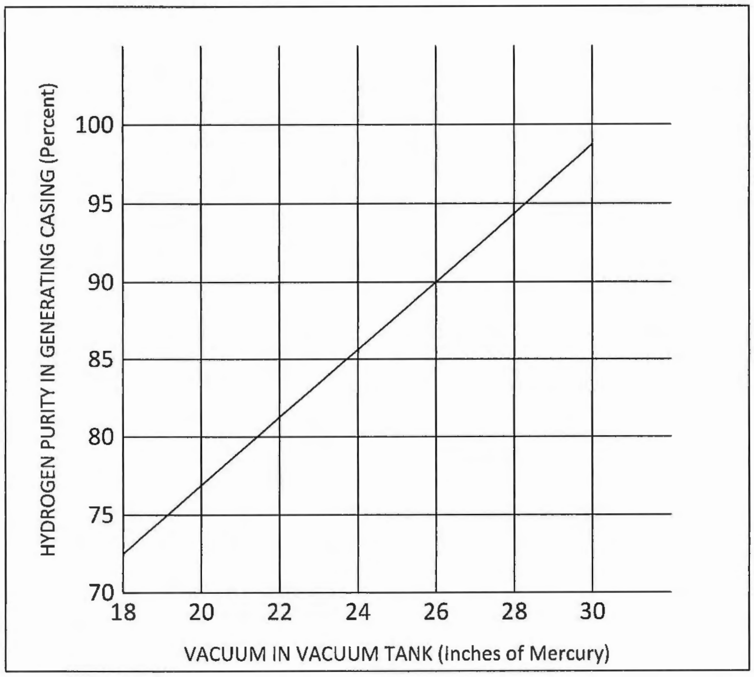
Assuming an oil flow of 3 gpm to the hydrogen side of the seals, a solubility of air in oil of 10%, and a hydrogen purity of 91% in the generator casing, the amount of air liberated from the sealing oil to the generator casing during operation at 1/2 lb. hydrogen pressure would be approximately 2.25 cu ft per hour. The amount of hydrogen required to maintain a continuous purity of 91% in the casing would be approximately 23.3 cu ft per hour.

This is about 20 times the amount of hydrogen required to maintain a purity of over 98% in the generator casing with vacuum-treated oil.

When the seals are supplied with oil that has been vacuum treated, the amount of hydrogen that is absorbed is proportional to the gas side seal oil flow and to the degree of solubility of hydrogen in oil. The larger bubbles of hydrogen in the oil are liberated in the seal-drain enlargement and the return tank. The smaller bubbles of hydrogen that go into solution in the oil, are not released until the oil reaches the vacuum tank. There the gas is released and passes to atmosphere through the separator tank.

The solubility of hydrogen in oil is about 5% by volume at 1/2 lb. hydrogen pressure. With a gas side flow of 3 gpm, the loss of

Figure 21.7: With vacuum treatment , hydrogen purity is maintained at close to that of the supply hydrogen.



hydrogen would be approximately 1.2 cu ft per hour or 30 cu ft per day. As a result of vacuum treatment, the hydrogen purity in the casing is automatically maintained at a value nearly equal to that of the supply hydrogen, which makes it unnecessary to manually scavenge the generator to maintain the proper gas purity. (See Figure 21.7.)

SCAVENGING SYSTEM

A system provided to remove air from the seal oil into the hydrogen side of the generator seal is known as a scavenging system. With the scavenging system, untreated oil containing some dissolved or entrained air is supplied to the seals. Appreciable amounts of air are released by the oil that passes to the hydrogen side of the shaft seal into a seal chamber located between the seal rings and an inside oil deflector. The amount of impurities introduced into the generator with this system is a direct function of the oil flow to the hydrogen side of the seal rings. If seal oil flow rate increases, then the entrained air liberated from the seal oil will also increase and it would result in decreased purity.

The seals are designed to fit with close radial clearances around the shaft so that a very small amount of oil flows to the hydrogen side of seals while the air side flow is large enough to provide sufficient cooling for both rings and thus limit the radial expansion.

By continuously scavenging a small amount of the gas from the seal chamber, a small flow of hydrogen is established through the oil deflector clearances and the air released from the untreated oil is removed. Proper hydrogen purity is maintained by the introduction of fresh hydrogen into the casing to replace the scavenged gas and that lost due to normal frame leakage. The scavenging rate is regulated so that the hydrogen purity in the casing is maintained at a value between 96 and 98%.

DOUBLE SHAFT SEALING SYSTEM

This system uses a gland seal ring located in a gland seal bracket and has two annular feed grooves.

Oil is supplied to the two annular grooves in the gland seal ring. Oil flows both ways along the shaft and the inner diameter of the gland ring. As long as the oil pressure in the circumferential groove exceeds the hydrogen pressure in the generator, oil will flow toward the hydrogen side of the seal and prevent the escape of hydrogen from the generator. The purpose of having two oil grooves in the gland seal ring is to provide separate hydrogen side and air side seal oil systems. When the oil pressure in these two systems is in balance, there will be no flow of oil in the clearance space between the feed grooves. Oil supplied to the hydrogen side of the seal oil system will flow inward toward the generator and the oil supplied to the air side will flow outward toward the bearing. The oil in the space between the two grooves will remain relatively stationary due to the pressure balance between the two systems. Oil leaving the gland seal rings caught in chambers on each side of the seal and drains back into the seal oil system. The air side seal drains to the generator bearing drain loop seal and the hydrogen side seal drains to the defoaming tank (See Figure 21.8.)

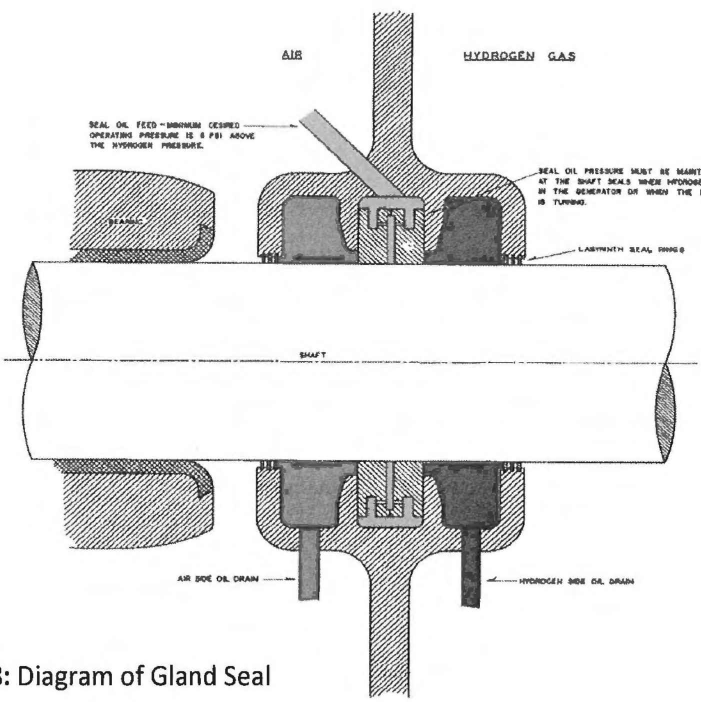


Figure 21.8: Diagram of Gland Seal

Seal oil is supplied to the air side of the gland seal ring at a pressure of 12 psig above the hydrogen pressure in the generator. The hydrogen side seal oil supply is maintained at this same pressure by means of pressure equalizing valves. As a result, the interchange of air side and hydrogen side oil at the gland rings is held to a minimum, with the interchange of seal oil toward the hydrogen side of the seal.

While the interchange of seal oil at the gland seal rings is held to a minimum, variations in pressure between the air side and the hydrogen side seals will result in an increase or decrease the amount of oil in the two sides of the seal oil system. Control of excess of deficient oil for the hydrogen side seal is provided by the seal oil float chamber. This chamber has two float valves, one which adds oil from the air side system if the oil level is low, and the other allows oil to flow from the chamber into the air side system if the level is high. The quantity of oil in the hydrogen side system is thus kept essentially constant and proper oil levels are maintained.

Oil returning from the hydrogen side of the gland seal rings drains to two defoaming tanks where most of the gas separates from the oil. These tanks are located in the bearing brackets of the generator. Oil level is maintained by standpipe overflow connections. A defoaming tank is supplied for each seal and a trap is provided in the drain line between the two tanks so that the difference in blower pressure at the two ends of the generator will not circulate oil vapor through the drain piping into and through the generator.

Oil returning from the air side of the gland seal rings drains into the generator bearing oil return, to the bearing drain loop seal. The bearing drain provides the oil supply for the seal oil system.

SEAL OIL PUMPS

The seal oil pump receives its oil supply from the vacuum tank. It pumps the oil through a seal oil cooler to both the air and gas sides of the gland seal ring and part of it returns to the vacuum tank through a differential pressure regulator. This regulator maintains the seal oil pressure at the seals at 12 psi above the generator gas pressure. A DC driven air side seal oil backup pump is provided which circulates oil in the same manner.

SEAL OIL BACKUP

Seal oil backup is provided from the main turbine oil system and is normally closed. If the AC driven air side seal oil pump should stop, or if the seal oil pressure at the seals should decrease to 8 psi above the hydrogen pressure the backup regulator valve will open automatically and provide oil pressure for the seals. For Waiau units 3&4, the first back-up is the DC pump. The second back-up is from the turbine main oil pump which must be opened manually.

This backup pressure may be supplied from several sources; the main oil pump on the turbine, the AC motor driven auxiliary oil pump, and the AC or DC motor driven turning gear oil pumps. The gas pressure that should be maintained in the generator depends upon the pressure available from the next backup source, i.e., if one of the turning gear oil pumps is the only source of seal oil backup, the hydrogen pressure in the generator should be decreased to 2 psi or less, since the turning gear oil pump can only maintain 5 psi oil pressure at the seals. When bearing oil flows to the seals through the seal oil backup, the excess oil will overflow through the seal oil return line into the main bearing oil drain.

HYDROGEN GAS SYSTEM

The degree of contamination of the hydrogen near the shaft seals is very low because of the low air and moisture content of the vacuum treated sealing oil. Proper hydrogen purity in the generator is automatically maintained by the introduction of fresh hydrogen to replace that lost by normal frame leakage and that lost by absorption to the oil. Under normal operating conditions, the hydrogen purity is maintained at a value of 98 to 99%. (See Figure 21.9.)

The hydrogen gas system has the following principal functions:

1. To provide means for safely putting hydrogen in or taking it out of the machine, using carbon dioxide as a scavenging medium.
2. To maintain gas pressure in the machine at the desired value.
3. To indicate to the operator at all times, the condition of the machine in regard to gas pressure, temperature and purity. The presence of water in the machine is also indicated by an alarm on the gas control panel.
4. To dry the gas and remove any water vapor which may get into the machine from the seal oil.

GAS SUPPLY

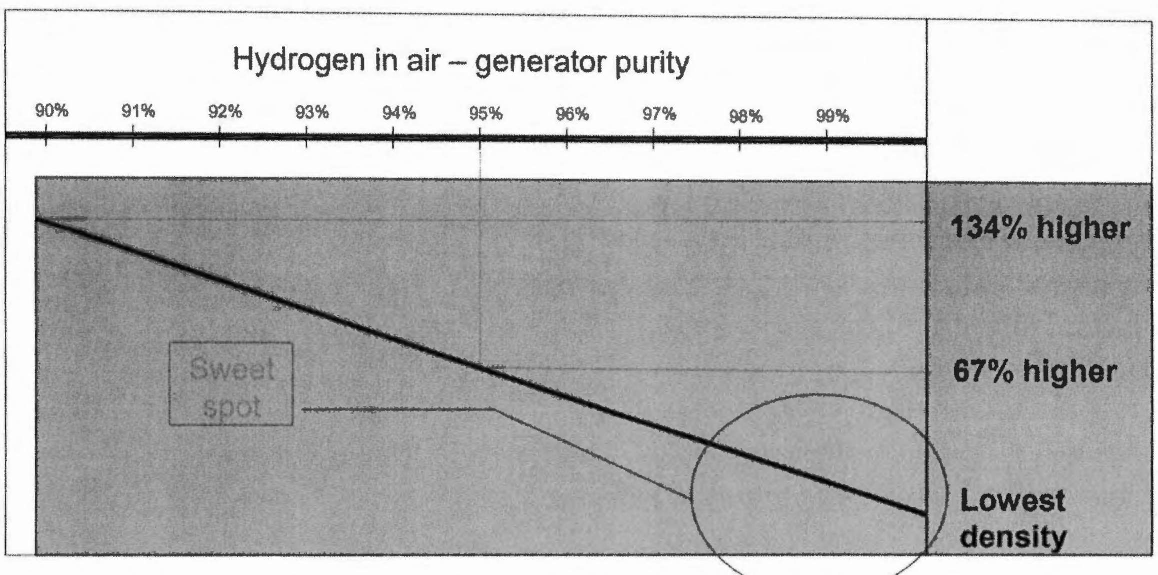


Figure 21.9: Increase in density causes increase in windage. Increased windage translates to decrease in efficiency. 98% purity or higher represents lowest density of hydrogen in the generator casing.

The hydrogen gas supply is a manifold suitable for connection to two banks of commercial hydrogen bottles. Regulators are provided between the manifold and the gas connection to the machine. The hydrogen gas is distributed uniformly to the various compartments of the machine by manifolds in the top and bottom of the housing.

GAS DRYER

Windage losses affects the efficiency of the generator. Higher dew points increase these windage losses and could also lead to winding failure due to insulation cracking and to shorted rotor turns. Keeping a lower dew point arrests corrosion and crack growth.

A gas dryer is connected into the ventilating circuit of the generator to ensure the maintenance of a dry atmosphere in the casing. Hydrogen is taken from the generator at fan pressure and circulated back to the generator fan suction.

The original dryer consisted of a chamber filled with activated alumina absorbent material (dessicant) connected across the generator fan so that the gas is circulated through the dryer whenever the machine is running and a heating coil for regenerating the agent when it became moist. A color indicator on the dryer showed when regeneration was required, the colored activated alumina in the indicator being blue when dry and changing to grayish-pink when moist. The dryer was isolated from the generator during the regeneration process, and the hydrogen scavenged with carbon dioxide and vented to atmosphere. A built-in heater was then energized and a small blower circulated air through the dryer to remove the moisture.

The original desiccant dryers have been replaced by a tower drying system equipped with low-wattage heaters operated with microprocessor-based electronics which automates the process.

The Environment One Generator Gas Dryer (GGD) is a dual tower, open regeneration type hydrogen dryer (see Figure 21.10) A dual tower dryer incorporates two vessels, one in drying mode and one in standby or regenerating mode.

The GGD uses a blower and motor assembly to continuously circulate hydrogen gas from

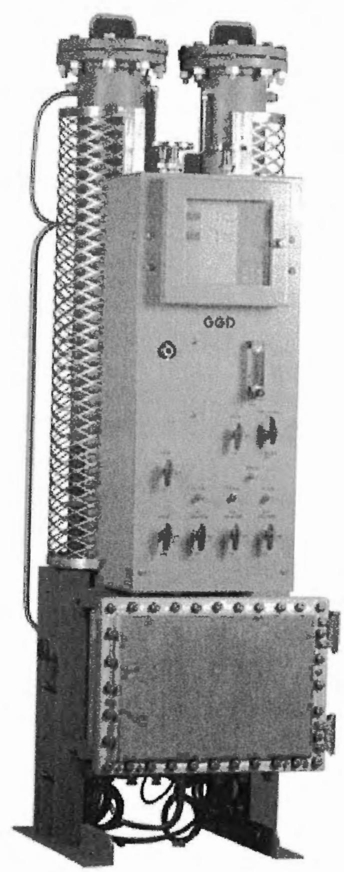


Figure 21.10: eOne Generator Gas Dryer II (GGD

the generator casing volume to the dryer assembly. This permits the dryer to remain online even while the generator is at stand still or on turning gear speed. In addition, the blower and motor assembly are rated for use with hydrogen (explosion proof).

The GGD is a microprocessor-controlled system that uses inlet and outlet dew point measurements to determine the efficiency of the dryer as well as to control if and when the "in service" tower needs to be regenerated. There is also an adjustable control timer based on elapsed time span which can control the regeneration cycle. This regeneration control guarantees that each tower is exposed to the same duty cycle, which, in turn, prolongs the life of the desiccant, motor, switching valves, etc. and further ensures proper function and efficiency of the dryer system. The GGD, as an open regeneration dryer, is the most effective method to remove moisture from the column to be regenerated and does not require the addition of a cooling water supply connection as with closed-loop regeneration dryers. Although the open regeneration uses some hydrogen from the system, the consumption of hydrogen during regeneration is very low.

The GGD incorporates a molecular sieve (desiccant) for moisture removal. The is a moisture separator (a pre-filter) on the inlet piping connection designed to remove contaminants such as liquid or mist turbine oil. Turbine lubricating oil will degrade the molecular sieve efficiency. Oil is not supposed to reach the generator hydrogen gas cooling system but it often occurs because of system malfunctions.

The GGD also incorporates an after-filter to prevent the admission of broken-down desiccant materials from entering the generator or the gas piping.

The GGD is designed for use on hydrogen-cooled generators with several protective mechanisms incorporated into the design such as:

(d) Flameproof — The system electronics are housed in a flameproof enclosure that incorporates a bolted cover or screw cap requiring tooling to remove.

(ib) Intrinsic safety — The display board represents an intrinsically safe circuit in which any spark or thermal effect produced by conditions including normal operation and specified fault conditions, is not capable of causing ignition of a given explosive gas atmosphere.

(m) Encapsulation — Solenoid valve coils are encapsulated to keep any potential flammable gas mixtures out of and away from the coil.

When the GGD is in normal operation, it will manage column changeover and regeneration automatically. It will use the values of the minimum drying time, maximum drying time and desired dew point to determine how often to change and regenerate a column.

The GGD will display the inlet and outlet dew points on the numerical displays. It will energize the dew point high relay if the inlet dew point is greater than the dew point alarm level.

On an annual basis, it is recommended that the desiccant be inspected and replaced if it appears badly broken or discolored.

LIQUID DETECTION

Trays are provided under each gas cooler to catch any leakage or condensation from the cooler. Pipes are provided to drain water from these trays to the bottom of the machine housing. There are also openings in each frame ring so that any moisture will drain to the water detectors. The detectors are float-operated switches located in small housings under the generator frame. When a significant amount of liquid is accumulated, the switch trips and activates an alarm. The presence of liquid (water or oil) could indicate a leaking tube in the gas cooler or excessive oil flow to the gas side of the shaft seals. Isolating valves are provided for draining off any accumulated water or oil. The main lead compartments are closed off from the rest of the generator housing, so no water can drain into them.

GAS PURITY

The hydrogen gas systems are all provided with some means of reading machine gas purity. Some systems use a purity meter which utilizes the changes in thermal conductivity of the gas to indicate purity. Other systems determine purity of the gas in the machine by using a density meter and density meter blower. The density meter is a differential pressure gauge measuring the pressure developed by the density meter blower. An induction motor, loaded very lightly so as to run practically at constant speed, drives the density meter blower and circulates gas from the generator housing. Thus, the pressure developed by the blower varies directly with the density of the machine gas. The scale of the density meter is graduated in percent with 100% corresponding to the density of air at atmospheric pressure.

A second differential pressure gauge is furnished on the gauge panel to show the pressure developed by the generator fans. This pressure can be used as a check on the density meter or can be used to indicate hydrogen purity if the density meter is taken out of service while the generator is running.

Regardless of which method is used to determine machine gas purity, an alternate method is available to the operator in that generator fan differential pressure may be readily converted to gas purity.

Two gauges are provided on the gauge panel to indicate the pressure of the gas in the machine. A third gauge is located near the gas bottles to aid the operator in filling the generator.

A thermometer is provided on the gauge panel to indicate high gas temperature. The thermometer is located in the bottom of the generator frame and reads the temperature of the gas going to the coolers.

A pressure gauge is provided on the high pressure manifold connected to the hydrogen bottles. This gauge gives an

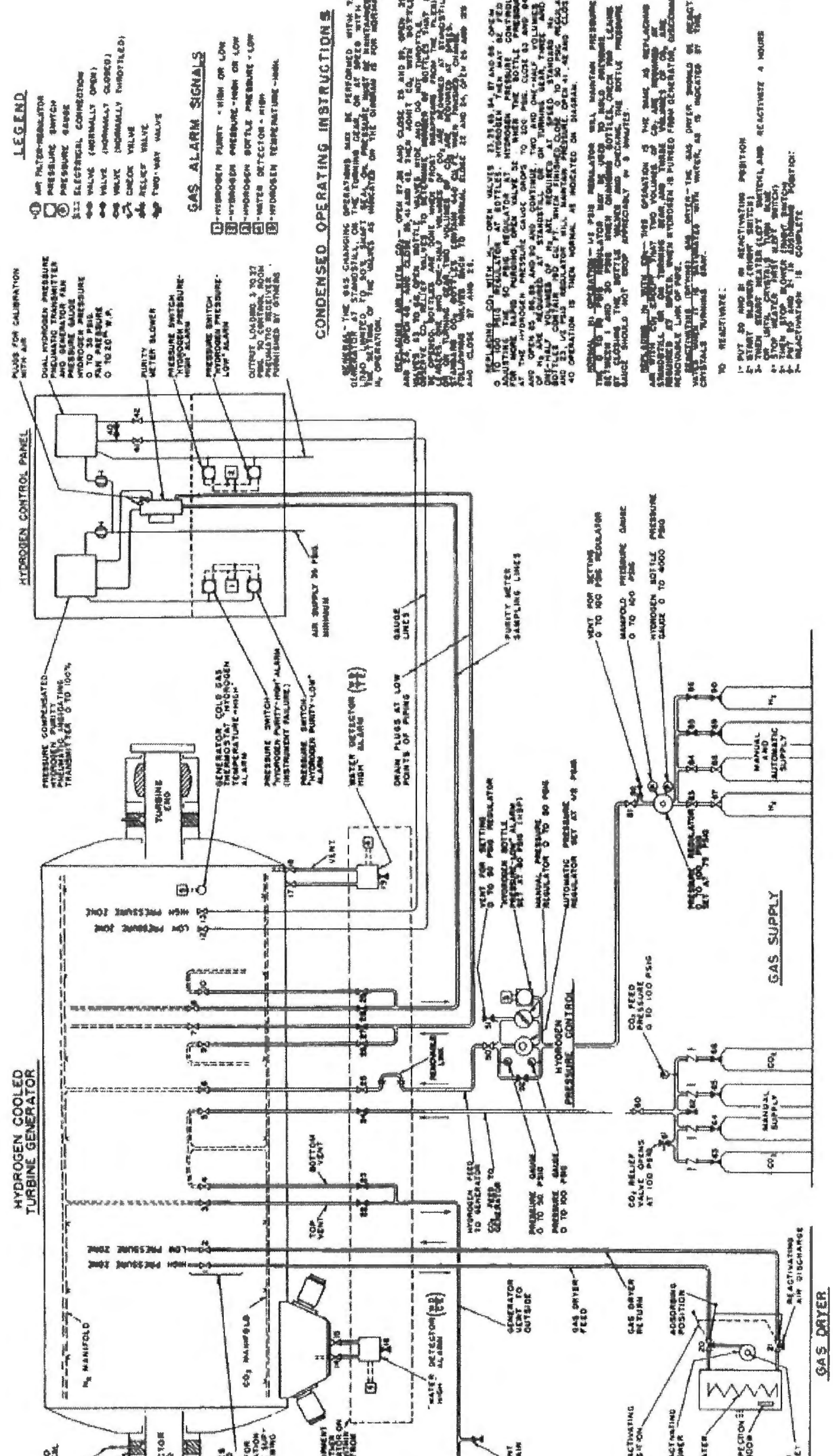


Figure 11: Hydrogen and Carbon Dioxide Gas System

indication of how much gas remains in the bottles and when new bottles will be required.

GAS COOLING

The hydrogen is cooled by passing it through two coolers where the gas gives up its heat to the cooling water in the finned tubes of the cooler. The nozzle end of the cooler is bolted solidly to the generator frame, while the rear end is permitted to move freely, expanding and contracting with temperature changes. The rear end is covered with a gas-tight steel cover which must be removed to clean the cooler tubes. With the outer cover removed at the rear end, gas is prevented from escaping by a flexible rubber diaphragm between the cooler and the frame.

CHANGING GAS

The fundamental rule to be observed in changing gas in a generator is that hydrogen and air should never be mixed. Carbon dioxide (CO2) is used as an intermediate gas when changing either from air to hydrogen or hydrogen to air. The gas changing operation may be performed with the generator at standstill, on turning gear or at speed with load limited to 50%. Shaft seal oil pressured must be maintained.

The carbon dioxide supply is regulated by hand using the bottle valve. (Use of any other valve or a regulator to control flow would result in freezing that valve or regulator as the CO2 passes through.) A spring loaded relief valve is provided in the carbon dioxide connection. In case other valves in this connection are closed, the pipes are protected from full bottle pressure by this relief valve. (See Figure 21.11.)

The lighter gas (hydrogen) should always be fed into and vented to atmosphere from the top of the machine.

ALARMS

Alarms associated with the hydrogen and seal oil systems may include:

Seal Oil System

- Emergency seal oil pump running.
- Vacuum tank low vacuum
- Differential seal oil pressure low
- Water detector high
- Oil storage tank low level
- Oil level vacuum tank high or low
- Machine gas temperature high
- Main seal oil pump failure
- Defoaming tank level high
- Seal oil pressure low

Hydrogen Gas System

- Machine gas pressure high or low
- Machine gas purity low
- Hydrogen supply low pressure
- Hydrogen density (purity) high or low
- Hydrogen temperature high

Section 21

HYDROGEN AND HYDROGEN SEAL OIL SYSTEMS

Study Questions

1. The major limit to generator capability is the ability of the design to cool which material?

2. What are the advantages of hydrogen over air with respect to generator cooling?

3. Cooling active conductors internally has allowed for an increase in the capacities of generators. True \ False

4. Liquid has better heat transfer characteristics as compared with gas. True \ False

5. An explosion could occur if hydrogen is mixed with ___________ .

6. The pumps that maintain stator cooling water circulation may be started _________ .
   a. automatically.
   b. manually.
   c. both of the above.

7. The pressure of oil maintained on the seal at all times must be higher than hydrogen pressure to provide adequate sealing. True \ False

8. Oil will absorb moisture and gas. True \ False

9. How does absorption of moisture and gas affect the hydrogen system?

10. What system provides seal oil backup?

11. In some gas dryers, the colored activated alumina is a _________ color when dry and changing to ___________ when moist.

12. Hydrogen gas systems are all provided with some means of reading machine gas purity. Two of these are:

    a. ____

    b. ____

13. What is used as an intermediate gas when changing either from air to hydrogen or hydrogen to air in a generator? Why is this gas used?

14. Under normal operating conditions, the hydrogen purity in a vacuum system is maintained at a value of 94-96%. True \ False

15. Describe the difference(s) in the oil supplied to the seals with the vacuum system in service and without the vacuum system in service.

16. Why do we have a seal oil system?

17. To prevent the escape of gas along the shaft of a hydrogen cooled turbine generator, ______________________ seals supplied with oil under pressure are used.

18. Discuss, briefly, the purpose of the defoaming tanks.

19. What is the purpose of the vacuum tank? How does the vacuum tank work?

20. Draw a diagram of the seal oil system. Include all major equipment and label each piece of equipment. Show flow, including direction of flow of oil from the generator seals through the seal oil system.

GENERATION-OAHU DIVISION
OPERATOR TRAINEE TRAINING PROGRAM

Section 22

LUBRICATING OIL SYSTEM

OBJECTIVES:

1. **Discuss the properties and functions of lubricating oil.**
2. **Describethe turbine lube oil system.**
3. Name typical lube oil impurities and describe
   a. source of those impurities
   b. how the impurities are removed
   c. conditioning systems used to remove impurities

GENERATION-OAHU DIVISION
OPERATOR TRAINEE TRAINING PROGRAM

Section 22

LUBRICATING OIL SYSTEM

All power plant equipment having moving parts is provided with some sort of lubrication. The lubrication may take the form of a sealed unit that requires no additional lubricant or a bearing that needs occasional greasing. The most important system however, is that which provides a continuous flow of lubricating oil to the bearings of major equipment.

The turbine-generator units at most power plants each have their own lubricating system. This system supplies lube oil to the bearings of the turbine and generator and supplies makeup oil to the generator shaft sealing system. This system is generally referred to as the turbine lube oil system.

Larger pumps in the plant which are required to handle hot liquids are also usually provided with their own complete lube oil systems.

In order to insure long bearing life and prevent damage to equipment, it is necessary to provide a continuous supply of oil at the correct temperature and with a minimum of impurities.

Since one important function of the lube oil is to remove heat from the bearings and journals, these systems are equipped with heat exchangers to cool the lube oil.

The following topics will be discussed in this section: Properties of Lube Oil; Storage, Receiving and Handling; Turbine Lube Oil Reservoir; Filtration and Purification.

LUBE OIL PROPERTIES

Turbine oil is a high quality refined petroleum, free from water, acid, alkali, soap, grit, resin, or anything else that might damage it or the turbine parts it contacts. Usually, in the manufacture of high quality lubricants, the crude is selected on the basis of the lubricating oil component contained and the freedom of the crude from objectionable and injurious impurities.

Some of the desired properties of the turbine lube oil are low viscosity, good demulsibility and durability. Viscosity is a measurement of relative resistance to flow. In regards to oil, it is simply the

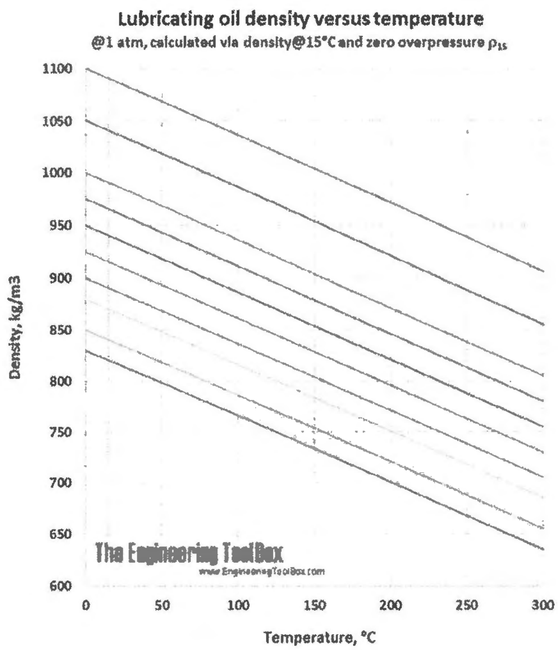


Figure 22.1 Viscosity of Oil vs Temperature

internal resistance of oil to motion. Oil with a high viscosity will not flow as easily as oil with a low viscosity. Heat will thin oil, giving it greater fluidity or lower viscosity (Figure 22.1). High viscosity oil can support a heavy load, especially at low temperatures but as the temperature rises, it thins the oil, reducing its viscosity until load forces it out of the bearing. High viscosity oil would handle heavy loads if it could get into present-day close bearing clearances. In general, thick viscous oils have greater internal friction, but can support heavier loads than thin oils.

Ideally, oil viscosity will not change with temperature. Low viscosity oil, because of improved refining methods, will not thin excessively as temperature rises. The low viscosity allows the oil to enter the small clearances of turbine bearings. As the load on the bearings increases, the oil will be squeezed between the bearing and the shaft. The oil resists any large pressure increase by increasing its viscosity as the bearing is loaded. This viscosity increase accounts for much of the high load-carrying ability of low viscosity oil.

Oil deterioration is caused ·by changes within itself plus contamination from outside. In the lubricating system of a turbine, a pump circulates oil rapidly. The oil from the reservoir flows through a cooler and is then pumped to the equipment bearings where it picks up heat as it passes through the bearings. It then is returned to the reservoir. In this circuit, oil encounters many deteriorating factors.

Water contamination is the most common cause for oil degradation. Water and air cause turbine oils to foam and emulsify. Water may enter the oil system by leakage along the turbine shaft from the steam and water seals, from water leaks in the oil cooler, or from airborne moisture, which condenses in the drain lines and reservoir.

Oxidation of oil results from reaction with the oxygen in air. How fast the reaction takes place depends on the amount of contact between oil and air, presence of catalytic materials and most important, temperature. Higher temperature means faster reaction. The product of this reaction is organic acids. Oxidation also accelerates sludge formation (precipitation from the oil of solid matter). Air and water exclusion and low operating temperatures are therefore prime objectives in lubricating systems.

High performance is required of turbine lube oils, therefore, various chemicals or additives are often mixed with the oil to provide properties it does not inherently have. Typical additives are anti-oxidants and rust inhibitors. The oxidation inhibitor deters oxygen reaction with oil. Rust inhibitors form a film on metal parts. This film prevents oxygen and moisture from attacking the metal surfaces. Since lube oil must be kept relatively free of dust, metal particles, water, etc., the design of the oil system and oil conditioning equipment must include provisions to minimize or eliminate dust, metal particles, water, and air.

Demulsibility is an important characteristic of turbine lubricating oil. It is a measure of the oil's ability to separate readily from water and is the property that guards against the formation of permanent emulsions. Emulsification will reduce lubricating value of oil and lead to corrosion.

Durability resulting from extreme purity and chemical stability, is a special qualification demanded of oils subjected to long continued service in machine lubricating systems. High chemical stability is a necessary characteristic because it helps oil to resist the destructive influence of continued circulation with solid and liquid impurities and agitation in the presence of air. This characteristic largely determines the durability of an oil and can be attained only in oils especially refined for this purpose.

STORAGE - RECEIVING - HANDLING

Power plants are generally provided with at least two turbine lube oil storage tanks, one for clean oil and one for used oil. The clean oil tank is reserved for new oil and used oil that has been centrifuged and filtered. Oil to be drained from reservoirs, Bowsers and seal oil systems is drained into the used oil tank for future conditioning (centrifuging and filtration) and subsequent storage in the clean oil tank.

New lube oil is generally purchased in smaller containers such as barrels and added to the lube oil system as needed. The smaller containers minimize exposure of the oil stock to oxygen while ensuring adequate back up quantities. Occasionally, oil may be needed in greater quantities and will be purchased in bulk. All bulk deliveries of new lube oil are received through suitable filters and samples of the filtered oil are taken. Samples are inspected and tested before use.

One or more lube oil transfer pumps are usually provided in conjunction with the lube oil storage tanks. These pumps are used to transfer lube oil from one storage tank to another or to transfer lube oil from a storage tank to various reservoirs in the plant. Along with the lube oil filling lines, lube oil drain lines are provided which permit draining the various reservoirs to either tank. Since this piping is usually common to several reservoirs in the plant, extreme care must be exercised when handling valves in this system and all drain valves should be closed when not in use.

Practically all lube oil transfer pumps are screw type pumps.

OIL PUMPS

The oil pumps in the Turbine Lubricating Oil system were provided with the Turbine Generator. It includes:

- One (1) shaft-driven main oil pump of the centrifugal type with the impeller mounted directly on the turbine shaft, providing for both high pressure control oil and bearing oil requirements.
- One (1) AC motor-driven main auxiliary oil pump with automatic regulator, used when starting or shutting down the unit and as emergency bearing oil back-up.
- One (1) DC motor-driven auxiliary back-up oil pump for emergency use when the unit is on turning gear, or for furnishing oil to the bearings during start-up or shut-down when a-c power is not available.
- One (1) AC motor-driven auxiliary oil pump for use when the unit is on turning gear.

The latter three pumps are controlled through various pressure switches in a system providing auto-start as required by the oil pressure. Annunciations or alarms are made when any of these three pumps is running.

All of the above equipment with the exception of the shaft-driven main pump are located on the turbine lube oil reservoir. The pumps provide sufficient capacity for the two separate oil systems, control oil and lubricating oil.

The high pressure oil system, supplied by the main oil pump, provides oil for the following purposes:

1. To operate the oil ejector in the lube oil reservoir which supplies oil to the main oil pump suction.
2. To operate the throttle valves, the overspeed trip valve, the governor valve emergency trip plunger and the air pilot valves.
3. To operate the servomotors which open and close the governing (control) valves.
4. As a control medium for:
    - Governor impeller
    - Governor transformer
    - Governor valve emergency trip
    - Low frequency load limit trip valve
    - Low vacuum and low pressure
    - Throttle pressure regulator oil trip cylinder

The lubricating oil system is supplied from one of the previously mentioned four pumps depending upon operating conditions. Oil is normally pumped through one of the two lubricating oil coolers to the turbine-generator main bearings, thrust bearing and turning gear.

TURBINE LUBE OIL RESERVOIR

In addition to being a combination of supply, return and storage tank, the reservoir is in effect a settling tank where impurities will tend to settle out. The reservoir and oil return system is designed to be relatively water and air tight. The bottom of the reservoir is designed to allow water that may settle out to accumulate in a low point and thus periodically be drained off. Part of the oil supply is routed through Bowser filters, removing dirt particles and water. Oil returning to the reservoir sometimes flows through screens, removing dirt or metal particles.

The top of the lube oil tank serves as a base for mounting the oil pumps which are submerged in the oil contained in the reservoir (usually includes the auxiliary oil pump (motor or steam driven), an AC motor-driven turning gear oil pump, and a DC motor-driven emergency oil pump.

Also mounted on top of the reservoir is a vapor extractor. The vapor extractor maintains a slight vacuum inside the reservoir as it removes air and oil vapor liberated by the hot oil returning to the reservoir and exhausts it to atmosphere. It is important that the vapor extractor be in service whenever there is hydrogen in the generator to prevent possible collection of explosive vapors that might be liberated from the oil. Operation of the vapor extractor to maintain a slight vacuum on the reservoir also serves to vent the turbine and generator bearings, thus minimizing the possibility of oil creeping along the shaft.

Bearing oil coolers are provided at the reservoir. These are heat exchangers with cooling water flowing through a tube bundle and oil from the bearing oil pump discharge header flowing through the shell of the cooler. Where two coolers are installed, a plug type valve is provided to permit routing the lube oil through either or both of the coolers. Each cooler is provided with a small valve and vent line to vent the oil side of the cooler back to the reservoir. This vent line helps ensure that the idle cooler is full of oil. The vent line sightglass should be checked for oil flow before transferring coolers. If coolers are transferred when not full of oil, a momentary loss of oil to the bearings will result and may seriously damage the machine. The transfer valve is equipped with a large arrow which points toward the cooler that is in service on the oil side. A locking handwheel is also provided to lock the transfer valve securely in the selected

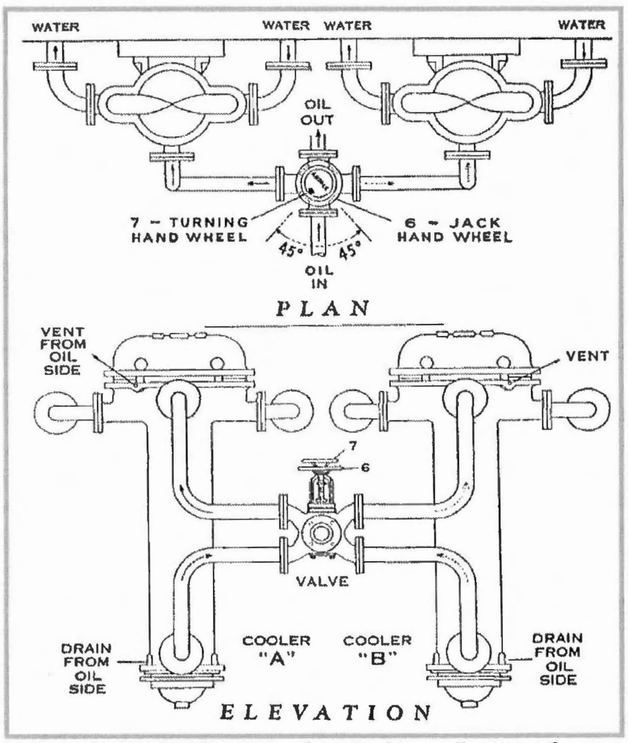


Figure 22.2 Diagram of typical installation of Ansdale 3-way valve with 2 coolers.

position.

Submerged in the oil inside of the reservoir is an oil ejector. The ejector is necessary because the main oil pump is several feet in elevation above the lube oil reservoir. The discharge from the ejector is used to furnish main oil pump suction pressure and also to supply oil to the unit bearing header. High pressure oil either from the main or auxiliary oil pump is used to power the ejector.

Also contained inside the reservoir are the gravity return oil piping from the turbine hydraulic control system, return from the unit bearings, pressure relief valves for oil pressure control, as well as the necessary piping and check valves to interconnect the various pumps.

Alarms associated with the turbine-generator lube oil system include:

- Reservoir high or low level.
- Auxiliary lube oil pump running.
- Lube oil temperature from cooler high.
- Turning gear oil pump running.
- Emergency lube oil pump running.
- Bearing oil pressure low.

LUBE OIL CONDITIONING

Oil in the Turbine Lube Oil System picks up contaminants over the course of its use. While most of our equipment is not directly exposed to the elements, our units are not fully enclosed. Dirt, debris & moisture from the air is the most

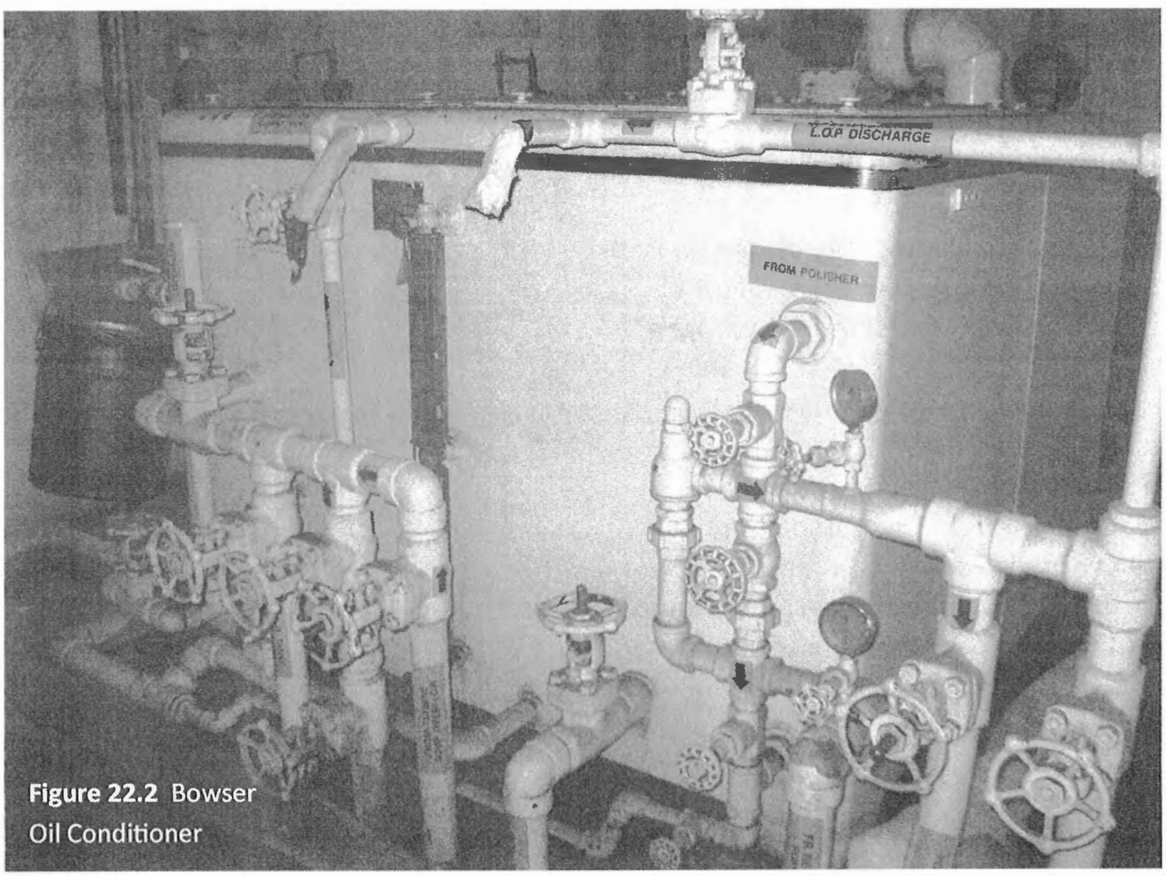


Figure 22.2 Bowser Oil Conditioner

common source of impurities. Condensation in the reservoirs, leaks from heat exchangers and shaft seals are also sources of water in the oil. Dirt, debris & moisture can be removed from the oil in various ways.

FILTRATION

Turbine oil systems are provided with a continuous bypass treatment which removes water and solid impurities from a portion of the oil while in service. The Bowser oil conditioner (Figure 22.2) is used for this purpose. This system employs a precipitation or settling compartment, a filter bag compartment, and in some cases, a polishing cartridge type filter (Figures 22.3 & 22.4).

Oil from the turbine reservoir is routed to a receiving space in the Bowser. From the receiving space the oil passes over the top of a baffle plate, then downward to the bottom of the precipitation compartment. The bottom of this compartment is sealed with water prior to placing the filter in service. This water seal is a standpipe or water overflow column. The oil flows across the water seal separating any large amounts of water and sediment from the oil. The oil then flows upward through a series of screened trays which precipitates any additional droplets of water. The water droplets collect in the bottom of the compartment where the excess water is removed by overflow from the standpipe. This removal of excess water continues until the water and oil static head pressure of the compartment and water column equalize. After passing upward through the precipitation compartment, the oil flows over a weir, then downward to enter the bottom of the filter compartment.

The filtering compartment consists of vertically mounted cloth filter bags positioned below the oil level. The oil flows inward through the cloth bag and out a nozzle which directs the oil into a tray. The oil is then directed through a downspout into the clean oil tank. The oil level in the filter compartment determines the head required to make

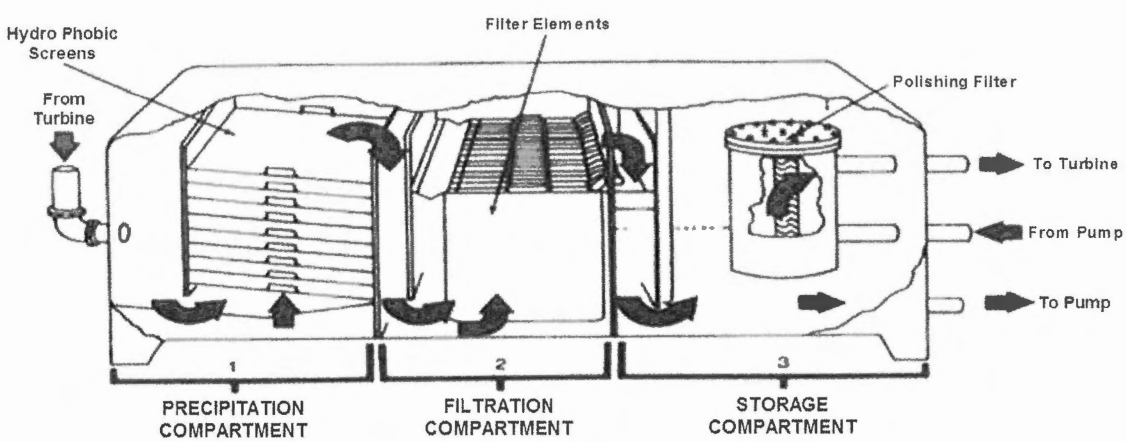


Figure 22.3 SCHEMATIC DRAWING SHOWING OIL FLOW THROUGH 832-P CONDITIONER

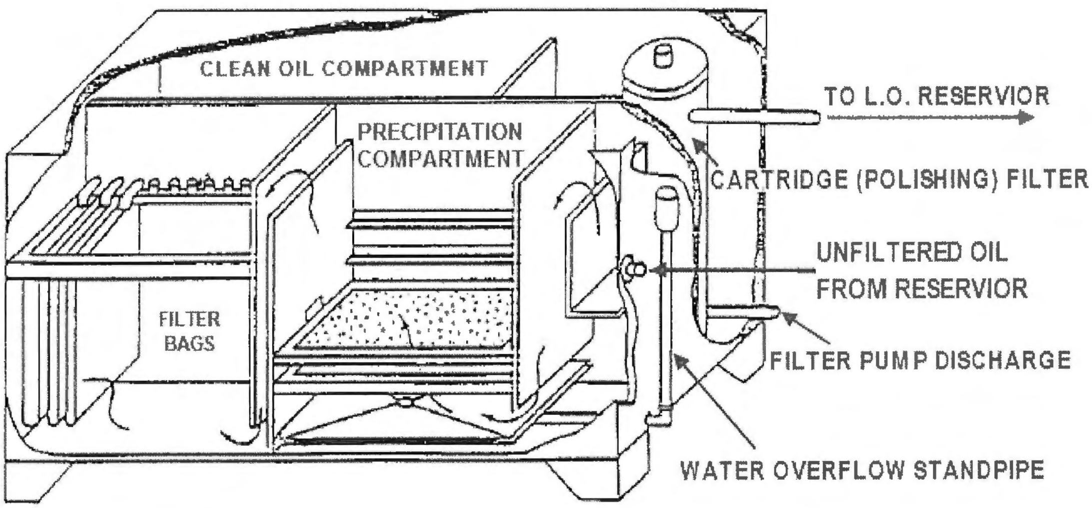


Figure 22.4 BOWSER COMPARTMENTS

the oil flow through the filter bags. When the oil level rises above the normal operating level, it indicates that the filter bags are dirty and should be removed for cleaning.

Each filter bag is mounted over a metal framework, the top of which is provided with a handle and an outlet nozzle. In operation the nozzle is contained in an orifice in a header leading to the clean oil compartment. Each of these orifices (one for each bag) contains a valve which is held open by the nozzle and automatically closes when the nozzle and bag are removed. This permits removing the bags one at a time for replacement and cleaning while the Bowser is in service.

Oil overflows from the turbine reservoir and flows by gravity to the Bowser. Filtered oil from the Bowser is returned to the turbine reservoir by a small pump. The discharge from this pump can be routed through or bypass the polishing filter (if one is provided). An air operated (air open, spring close) valve is installed in the overflow line from the reservoir to the Bowser. On high level in the Bowser or loss of power to the filter pump, this valve will trip closed to prevent overflow of the Bowser.

A vapor extractor is sometimes mounted on top of the Bowser to remove air and oil vapors.

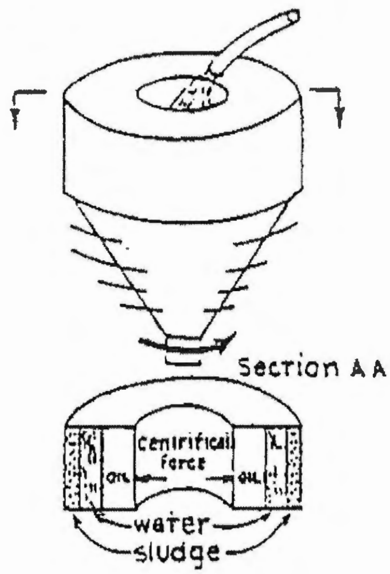
Alarms associated with the Bowser include:

- Lube oil filter high level.
- Lube oil polishing filter high differential pressure.

PURIFICATION

There are two forms of water contamination in Turbine Lube Oil Systems, dissolved water and free water. When dissolved water in oil reaches 100% saturation, any additional water added to the oil drops out as free water. By lowering temperatures on the oil stream, a portion of the dissolved water

Figure 22.5 Centrifuge Operation



in the oil can be converted to free water and removed from the oil. Free & dissolved water can be further controlled with the use of water removal equipment.

CENTRIFUGE: Routine centrifuging of the oil on an intermittent basis is carried out on all lube oil systems. Centrifugal action removes water, dust, dirt, coarse carbon particles, insoluble sludge and any other impurities which differ in specific gravity from the oil.

Figure 22.5 illustrates the general principle of operation of a centrifuge. Centrifugal force acts upon the liquid, separating the liquid into its component parts according to their relative specific gravities. The heavier parts such as solids and sludge are forced through the liquids and form a layer on the outer wall of the bowl. The heavier liquid

Figure 22.6a DeLaval Centrifuge

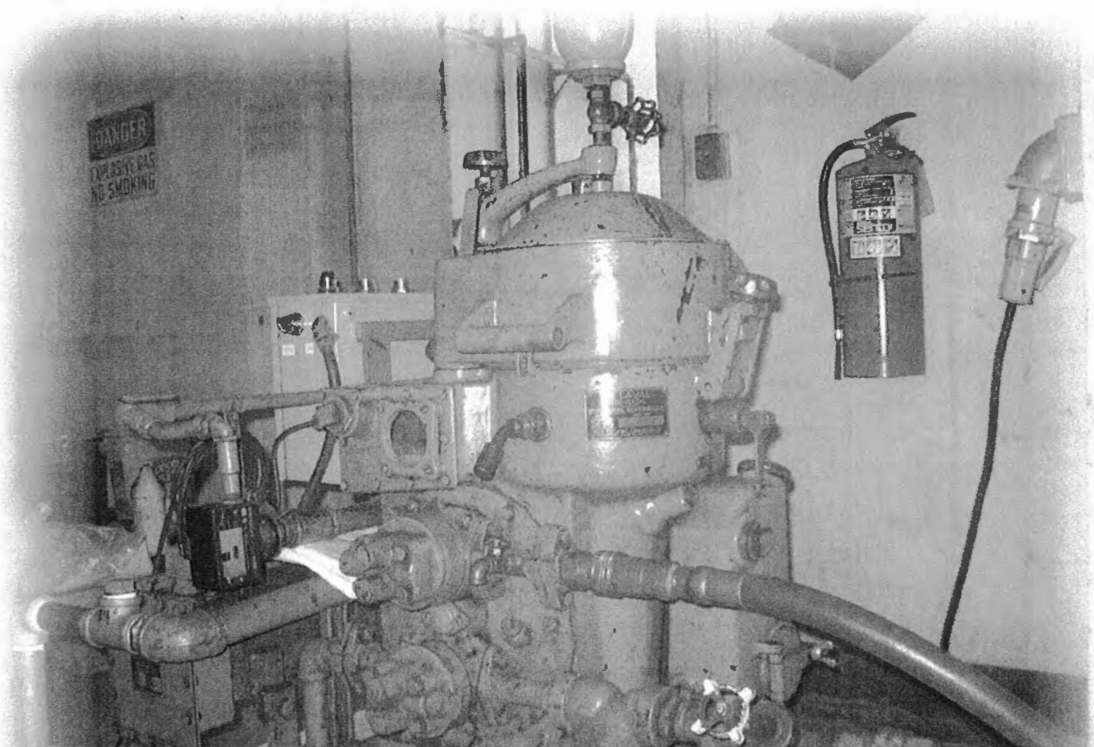
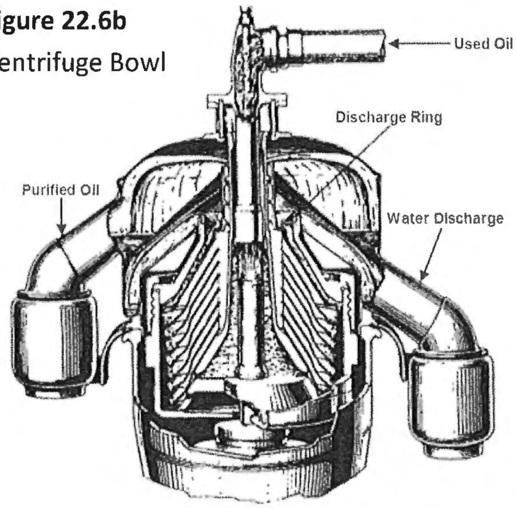


Figure 22.6b
Centrifuge Bowl



forms a cylindrical layer upon which floats a cylindrical layer of lighter liquid. What happens to the liquids as they pass through the bowl is understood if one visualizes what would happen to a mixture of oil, water, and solids if allowed to settle in a pan, with the force of gravity increased more than 13,000 times.

The DeLaval Centrifuge (Figures 22.6a & 22.6b) consists of a cylindrical bowl containing a number of conical plates through which the oil passes. Used oil enters at the top and purified oil is discharged at the second spout.

Centrifuges are equipped with an electric heater in the oil inlet to the centrifuge. The incoming lube oil is heated to a predetermined value to assure best results in purification. Centrifuges are also equipped with an inlet and discharge pump to handle the oil being purified. Figure 22.7 shows a diagram of a typical set-up for the DeLaval Centrifuge.

The DeLaval is able to handle removal of large quantities of water such as the volume a tube leak or exchanger leak would generate. The water removed with the centrifuge is free water.

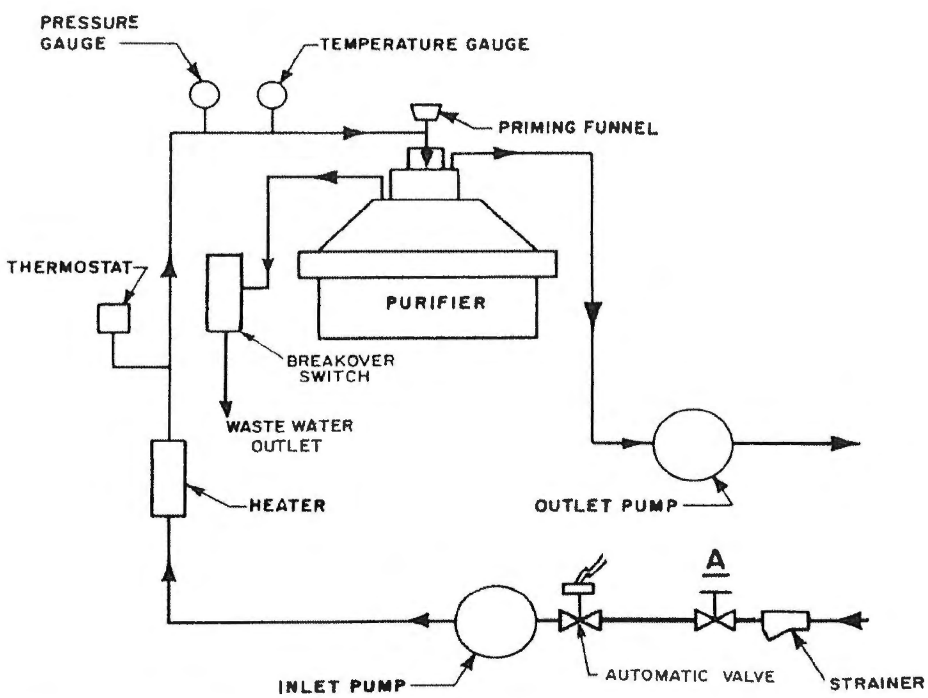


Figure 22.7 A typical set-up for the DeLaval Centrifuge

It was mentioned earlier that free water drops out of the oil when dissolved water in the oil has reached 100% saturation. It follows that if we have free water, then there is dissolved water that we have not yet removed from the oil. Removing dissolved water from the oil requires a using different method.

If we wanted to remove all of the water in the oil, we could simply heat the oil to 212 deg F and boil the water out. However, the high temperature would be detrimental to the oil and could degrade the oil.

FLASH DISTILLATION - Flash distillation is a single stage separation technique where a liquid mixture feed is pumped through a heater to raise the temperature and enthalpy of the mixture. It then flows through a valve and the pressure is reduced, causing the liquid to partially vaporize.

During flash distillation in the oil conditioning process, a portion of the oil is routed to a heater where oil is heated to between 160 and 180 degrees F. The oil then enters a vacuum chamber where the lower pressure causes the water in the oil to flash to steam. The steam then passes through a coalescer and the condensate collected from that process is routed to drain. The clean oil is then routed back to the reservoir.

The lower pressure in the vacuum chamber allows the oil to boil at a lower safer temperature to release the dissolved water and gases.

The Pall Purifier uses this concept and adds in more surface area to increase the amount of dissolved water and gases that is removed. It uses a vacuum tower with many rings within to create a greater surface area over which to "dry" the oil.

VACUUM DEHYDRATION: The PALL purifier (Figure 22.8) employs the principles of mass transfer and vacuum dehydration to achieve efficient removal of water, solvents and gases. Contaminated oil is drawn into the purifier by tower vacuum maintained via a vacuum pump driven by the drive motor. The oil enters the purifier through a 10 mesh strainer and proceeds through an inlet valve and a heater, which is thermostatically controlled to maintain the temperature of the oil.

The oil proceeds through two 2-way solenoid valves. The small solenoid, bypass valve is open whenever the purifier is running to allow a small amount of oil to always flow through the heater. The larger solenoid valve cycles to regulate the main flow of oil through the purifier, maintaining a predetermined range of oil level in the vacuum tower. This valve is controlled by high and low level float switches in the lower portion of the tower. The oil enters the top of the tower and flows downward over dispersion material which greatly increases the surface area per unit volume of oil.

Free and dissolved water and air are removed by exposing the contaminated oil to a low relative humidity atmosphere which is obtained by maintaining the tower at 15 - 22 inches Hg.

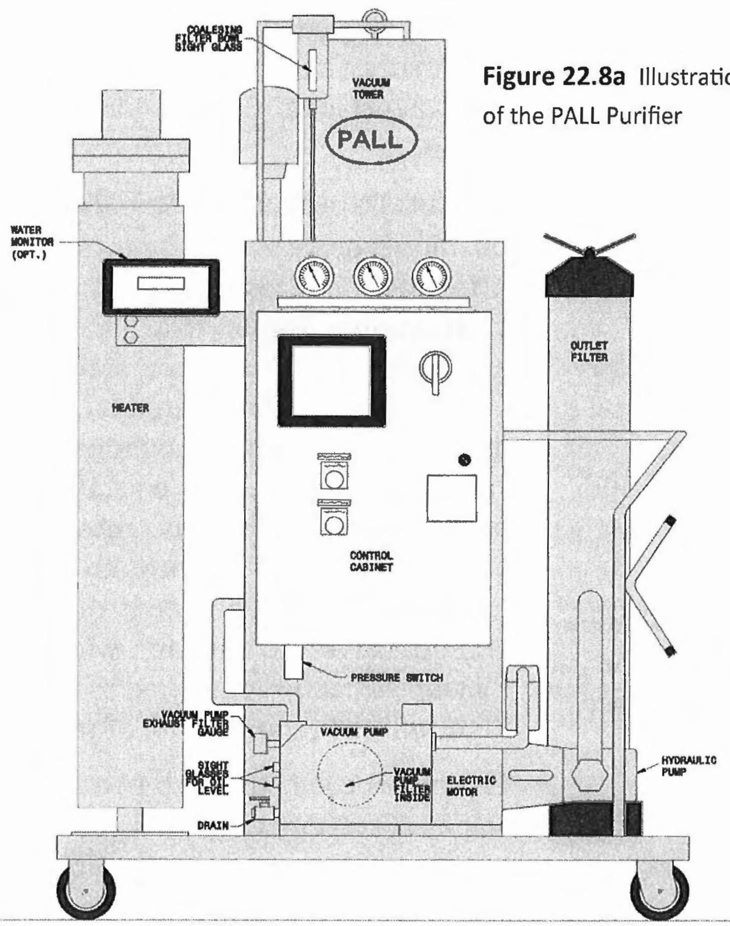


Figure 22.8a Illustration of the PALL Purifier

Ambient air is drawn into the purifier vacuum tower. Air enters near the middle of the tower and travels upward, against the downward flow of oil. Water and gases are absorbed by the upward air flow, and exit at the top of the tower through the mist eliminator which removes any excess oil mist, returning it to the inlet of the discharge pump. The air/vapor mixture then enters the rotary vane vacuum pump.

The vacuum pump is equipped with an oil reservoir which circulates lubricating oil to the pump bearings and vanes. The reservoir contains internal coalescing element(s) to minimize carryover of lubricant with the vapor flow. A final coalescing filter removes excess oil mist carryover prior to discharging the moisture laden air to the atmosphere.

Purified oil collected at the bottom of the tower is removed by a discharge pump which directs the oil through the outlet filter and back to the reservoir.

The purifier uses a programmable logic controller (PLC) which monitors and sequences its operation. The PLC monitors the level of oil in the tower, the condition of the discharge filter, the outlet coalescing filters, and the status of the electric motor (overload or short circuit conditions). The controls will start and operate the purifier, indicate operating and alarm status, and total operating hours. Automatic controls will safely shut down the purifier if internal oil levels exceed normal limits (high and low oil level monitors). This ensures a constant throughput of 15 gpm.

Section 22

LUBRICATING OIL SYSTEM

Study Questions

1. An important function of lubricating oil is to ___________ .
   a. prevent damage to equipment.
   b. remove heat.
   c. both of the above.

2. What are some of the desired properties of turbine lube oil?
   a.
   b.
   c.

3. List two causes of oil deterioration.
   a.
   b.

4. Demulsibility is a measure of oil's ability to separate from water.
   True \ False

5. High performance in oil is attained by adding various chemicals or additives.
   True \ False

6. When lube oil is subjected to pressure, it increases its viscosity.
   True \ False

7. The clean oil tank holds clean oil and the used oil tank holds used oil that has been centrifuged and filtered. True \ False

8. What is a Bowser?

9. Name the compartments in a Bowser and list the function of each.

10. When the oil level in the filtering system rises above the normal operating level, it indicates that the screened trays should be removed and cleaned. True \ False

11. Why is it important that the vapor extractor be in service whenever there is hydrogen in the generator?

12. What is the purpose of the bearing oil coolers?

13. Why is it important that a bearing oil cooler be checked for oil flow before transferring coolers?

14. An agitating action removes impurities which differ in specific gravity from the oil.
    True \ False

15. List and provide a brief description of the methods used to remove impurities from the turbine lube oil

16. List three (3) alarms associated with the Turbine Lube Oil System

17. List and briefly describe the major components of the Turbine Lube Oil system.

18. Diagram the flow of lube oil. Include and label all major components and indicate flow direction.

GLOSSARY

A

ABNORMAL OR ASSIGNABLE VARIATION	Assigned to a specific cause or problem. Process may be unstable, or it may be out of statistical control.
A-251 INHIBITOR	Used with Vertan™ in the chemical cleaning process to coat (protect) the insides of the tubes.
ABSOLUTE HUMIDITY	The actual weight of water vapor in grains or pounds per cubic foot of a mixture of air and water vapor. Often measured as ounces of water per cubic foot of air.
ABSOLUTE PRESSURE (PSIA)	Total of all exerted pressure, including atmospheric. Uses the complete lack of any pressure as its zero point reference. Begins at theoretical zero pressure, which is a condition of no pressure and a total absence of air. Difference between absolute pressure and gauge pressure is atmospheric pressure. PSIA - PSIG = 14.7 PSI. Zero pressure is equal to 30″ Hg.
ABSOLUTE ZERO	The point at which molecular motion stops, objects contain no heat, and temperature is at its lowest possible measurement.
AC MOTOR	Alternating Current Motor. Operates through the interaction between the magnetic fields of its rotor (magnet) and its stator. In most AC motors, alternating current flow causes the magnetic fields around the stator windings to increase, decrease, and change polarity.
AC TURNING GEAR OIL PUMP	A small motor driven centrifugal oil pump in the turbine lubricating oil system. Provided to supply bearing oil for operating the unit on turning gear and to serve as a backup to the auxiliary oil pump. See Turning Gear.
ACCELERATION	The rate of change in velocity in a given unit of time. A measure of how fast an object changes speed.
ACCUMULATOR	A pressure vessel divided into two chambers by means of a rubber diaphragm, having a liquid stored under pressure in one chamber and high pressure nitrogen gas in the other.
ACID	Any of a large class of substances, the aqueous solutions of which are capable of turning litmus indicators red, of reacting with and dissolving certain metals to form salts, of reacting with bases or alkalis to form salts, or have a sour taste. A substance that ionizes in solution to give up a proton. Any molecule or ion that can

	combine with another by forming a covalent bond with two electrons of the other. A liquid that contains a relatively high concentration of hydrogen ions and has a pH of less than 7.
ACIDIC	Pertaining to an acid, generally of a solution or environment having an excess of hydrogen ions of pH less than 7.0.
ACTUAL CAPACITY	Takes into account the condition of the equipment and the process variables that influence how much product a system can actually produce.
ACTUATOR	A mechanism that moves or controls a device such as a valve. Operates and positions valves in response to signals from controllers. Commonly used with valves that are designed for throttling, or regulating, flow. Actuators reduce the need for operators to go to every valve that needs repositioning and operate the valve by hand. Valves can be repositioned from a central, remote location such as a control room. Three basic types are: pneumatic, hydraulic, and electric.
ACW	Auxiliary Cooling Water
ACWP	Auxiliary Cooling Water Pump
ADDITIVES	Substances that are mixed with oils and greases to improve their lubricating abilities.
ADHESION	The physical attraction or joining of two substances, especially the macroscopically observable attraction of dissimilar substances.
ADHESIVE FORCE	A molecular force that exists between unlike molecules.
ADSORPTION	A phenomenon in which a thin layer of molecules adhere to the surface of a material. A catalyst that works through adsorption attracts and holds reactant molecules on its surface.
ADSORPTION-TYPE CATALYST	Attracts and holds reactant molecules onto it surface.
AES	Allied Energy Services; coal fired; 2 boilers; 1 turbine; 180 MW. Selected for "less largest unit" on the generating schedule because of the single turbine.
AFTER CONDENSER	The second stage air ejector condenser.
AFTERCOOLER (COMPRESSOR)	A shell and tube heat exchanger that cools the air at the outlet of an air compressor to reduce the volume and decrease the temperature of air after it leaves the compressor. As the compressed air passes through the tubes in the aftercooler, it is cooled by water flowing around the tubes. During the cooling process, any water vapor that is in the air condenses. As a result,

there may be moisture in the compressed air. Moisture must be removed to prevent it from damaging equipment that uses the compressed air. Second stage air pressure is approx. 120 psi.

AIR	A colorless, odorless, tasteless gaseous mixture, mainly nitrogen (approx. 78%) and oxygen (approx. 21%) with lesser amounts of argon, carbon dioxide, neon, helium, and other gases.
AIR BINDING	Air trapped in either the water side or the shell side of a feedwater heater as result of improper venting; causes the terminal temperature difference (TTD) to increase while the drain cooler approach (DCA) remains normal.
AIR CIRCUIT BREAKER (ACB)	A circuit breaker in which the interruption of the circuit occurs in air. The simplest type of an air circuit breaker is the common light switch as used in the home. Although frequently referred to as a switch, it is really a circuit breaker since it opens and closes a circuit under load. These devices use the principle of rapid movement to minimize the arc. A snap acting mechanism is used to insure fast operation regardless of the speed with which the handle is operated. In power plants low voltage ACB's are usually applied to 230 volt and 480 volt circuits. Medium voltage ACB's are usually applied to breakers that service 2400 or 4160 volt circuits.
AIR COOLER SECTION	A section of tubes, located above the air exit lane in a condenser that condenses nearly all of the steam in the steam-air mixture flowing through the air exit lane.
AIR EJECTOR	Jet pumps that use high velocity fluid flow to create a vacuum. Use steam to remove air and other non-condensable gases from the condenser.
AIR EXIT LANE	A low pressure area in the center of the tube sections of a condenser. The low pressure causes the steam-air mixture to flow into the low pressure region and through the tubes in the air cooler section.
AIR HEATER	A boiler efficiency device which reclaims low temperature heat energy from the stack gas by transferring it to the incoming combustion air before it reaches the furnace. This is reflected in fuel savings and an increase in boiler efficiency. Consists essentially of slightly separated metal plates arranged parallel to the gas-air flow. These plates are supported in a frame attached to a slowly rotating shaft. As these plates pass progressively through the gas stream they are heated and then, in passing through the air stream, give up heat to the air before again entering the gas

	stream, thus maintaining the regenerative cycle. The support-bearing assemblies of the air heater are provided with their own lube oil system, consisting of a pump, filter, and cooler (W5&6). Power to turn the rotor is supplied by an electric motor through a speed reducer. An auxiliary air motor is provided for operation in the event the electric motor fails. The heating element is equipped with three types of seals. The radial seals prevent intermingling of combustion air and flue gases. The circumferential seals at the inlet and outlet rotor shell restrict the flow of air or gas from by-passing the heating elements. The seal at the inlet and outlet of the rotor shaft prevents the escape of gases to the atmosphere.
AIR HEATER SOOT BLOWER	A device that cleans the air heater by sweeping across the gas outlet surface of the heating elements. An air-driven motor, with reduction gears, drives a gear and cam to operate the blower.
AIR PREHEATER	A device normally used to control the cold end metal temperature of an air heater by preheating the air before it reaches the air heater.
AIR RECEIVER	Purpose is to dampen pulsation or pressure waves in compressor discharge. It also acts as a reservoir and precipitates any moisture that may have carried over from the aftercooler.
AIR REMOVAL SYSTEM	A system that removes air and non-condensable gases and maintains the vacuum created by the volume reduction of condensing steam; also used to establish a normal vacuum in a condenser prior to turbine startup. The complete air removal system consists of a single-stage high-capacity hogger jet and two sets of primary and secondary ejectors, with associated inter and after condenser and drains.
AIR SWITCH	A switch in which the interruption of the circuit occurs in air.
ALARM	Designed to alert the operator when a process variable changes beyond an acceptable range. Can be visible, audible, or both visible and audible. Usually activated by electrical switches, which are operated by sensing devices connected to the process. Some sensing devices are mechanical, such as a pressure switch that uses a Bourdon tube to respond directly to the pressure in a tank. Other sensing devices are electrical, such as a thermocouple, which generates a voltage proportional to the temperature that it measures.
ALARM RELAY (ALARM SIGNAL)	A relay which operates an audible or visible signal to call attention to some action automatically performed or to some condition that requires operator attention.
ALGAE	A microorganism that builds up in condenser cooling water

	systems and is very difficult to remove mechanically. Chlorine or bromine are usually utilized to prevent algae buildup.
ALGEBRA	A branch of mathematics that uses letters or symbols to represent relationship between mathematical and physical concepts.
ALGEBRAIC OPERATION	Includes numbers, letters, and symbols.
ALKALI (OR A BASE)	A liquid that contains a relatively high concentration of hydroxyl ions and has a pH of more than 7.
ALKALINITY	Having a pH greater than 7. The alkali concentration or alkaline quality of an alkali-containing substance.
ALLOY	A man-made substance composed of two or more metals combined by heating.
ALTERNATING CURRENT	An electric current that reverses direction in a circuit at regular intervals.
ALTERNATOR	An electric generator that produces alternating current.
AMBIENT AIR	The air surrounding or encompassing an object. 23% oxygen, 77% nitrogen
AMMETER	An electrical device that measures current flow. The unit of measure for current flow is usually amperes, or amps.
AMMONIA	A chemical used in a steam plant for pH control of condensate and feedwater systems. Also contribute to maintaining proper steam PH to prevent acid attack (corrosion) in the superheat and turbine sections. A by-product of hydrazine.
AMPERE or AMP (I)	The basic unit of measure of an electric current. It is proportional to the quantity of electrons flowing through a conductor past a given point in one second. It is the unit current produced in a circuit by one volt acting across a resistance of one ohm.
AMPERE HOUR (Ah)	Unit of electric current over time, equal to the charge transferred by a steady current of one ampere flowing for one hour.
AMPERE-TURN	The magnetizing force produced by a current of one ampere flowing through a coil of one turn. A turn is one wrap or complete loop of wire around the core. Determined by multiplying the number of turns by the amount of electrical current in the coils.
AMPLITUDE	The maximum instantaneous value of an alternating voltage or current, measured in either the positive or negative direction.
ANALOG CONTROL SYSTEM	Does not use a computer. An analog control loop contains an analog controller that uses mechanical devices to control the value

	of a process variable. For example, an analog controller might use a pressure-sensing element, levers, and mechanical linkages. An analog controller can control the value of only one process variable at a time, so it can be part of only one control loop at a time. An analog signal can take on any value between two extreme values. In a process system, it is common to see analog signals in the form of physical properties such as pressure, current, and voltage.
ANALOG INDICATOR	Indicators that use a pointer and a scale.
ANALOG SIGNAL	A type of signal that can take on any value between two extreme values.
ANALYTICAL VARIABLE	A process variable that is based on the physical or chemical composition of materials.
ANALYZER	An instrument that measures and indicates physical or chemical characteristics that are based on the composition of a material.
ANGLE VALVE	A type of globe valve used to change the direction of fluid flow. Easy to identify because of its globe-shaped body with piping connections at a right angle.
ANION(S)	A negatively charged ion resulting from the dissociation of salts, minerals or acids in water. The negatively charged ions in a water solution such as the chloride of sodium chloride.
ANION EXCHANGER UNITS	The exchanger step in the demineralizing system in which OH (hydroxyl) ions are substituted for all the anions in the water except the bicarbonates and the silicates. PH values exiting this bank should be close to neutral (6.0 - 8.5). Conductivities can range between 1.0 and 20, depending on how well the unit is performing.
ANION MEMBRANE (EDR)	An anion exchange resin cast in sheet form through which only anions will transfer.
ANION RESIN BEADS	Resin beads in an ion exchanger that attract negatively charged ions.
ANNUNCIATOR	Audible or visible alarm or signal initiated electrically. A lighted panel that flashes when an alarm sounds to indicate the specific problem or condition.
ANODE	The electrode in a cell (voltaic or electrolytic) that attracts the negative ions and repels the positive; the positive pole.
APPARENT POWER	The amount of power that a generator would produce if inductive reactance or capacitive reactance were not present. The total power in a circuit. It results from both resistance and reactance

	and is measured in VA (volt-amperes). The result obtained from multiplying current and voltage indicated values.
APS	Automatic Pump Start. Commonly used to categorize pressure switches that will automatically start a pump or fan that is in the standby component on a high or low, pressure or flow condition.
ARCING	The flow of current through air. The discharge of electricity across a gap in a circuit. Breaking down of insulation could cause arcing.
ARCING CONTACTS	The contacts on which the arc is drawn after the main contacts of a switch or circuit breaker have parted.
AREA CONTROL ERROR (ACE)	The increase or decrease in total system MW generation.
ARMATURE	The stationary part of the generator, also known as the stator.
ARRAY	Stage; a section of a Reverse Osmosis system made up of one or more tubes. Usually an RO Bank consists of two or three Arrays.
ASH	A noncombustible form of solid waste that is essentially the residue of burned coal.
ASI	Analog Slave Input.
ASME	American Society of Mechanical Engineers
ASME POWER TEST CODE 6	A method of determining turbine heat rate that considers all turbine-related energy flows; used for acceptance testing and for establishing a benchmark for future testing.
ASO	Analog Slave Output.
ASPIRATING AIR	Supplied only when used, is normally compressed air from the station air system. A back-up to the sealing air.
ATMOSPHERIC BLOWOFF TANK	Serves as a collection point for water and steam from the several water wall header drains and the continuous blowdown line from the boiler. The water entering the tank partially flashes into steam which is exhausted to the atmosphere. The remaining impurities and water are drained to waste.
ATMOSPHERIC PRESSURE	The atmosphere, or air, is a mixture of gases that surrounds the earth to a depth of several miles. The air has weight because gravity pulls the air towards the earth. The weight of the air exerts a pressure on the earth's surface. That pressure is called atmospheric pressure. Atmospheric pressure is related to height or depth. This means that the pressure of the atmosphere varies with the height of the air above the earth's surface. Has a value of about 14.7 psi at sea level.

ATOM	Smallest division of an element that can be made while still retaining the chemical properties of an element. Made up of small particles which include electrons (neg. charge) that revolves around a nucleus. The nucleus are made up of protons (pos. charge), and neutrons (no charge). When atoms combine with other atoms, they form molecules. An atom has the same number of electrons as it has protons. When an atom has the same number of electrons as protons, the positive and negative charges are balanced. The atom is said to be electrically neutral. Many forces in nature can upset the balance of electrically neutral atoms.
ATOMIC NUMBER	The number of protons in one atom of an element.
ATOMIC WEIGHT, OR ATOMIC MASS	The weight of an element with respect to the weight of carbon. Atomic weights are expressed in atomic mass units (AMU). One AMU is approximately the weight of one proton or one neutron. Can be found in a periodic table of the elements.
ATOMIZATION	The process of dispersing fuel oil into the furnace as a mist, so that a larger surface area of the oil is exposed to the combustion air.
ATOMIZER BURNER	The atomizer steam and the fuel oil enter the gun through the upper and lower ports respectively of the stationary union, then pass through the removable union and are carried separately through the entire length of the gun by means of two concentric oil gun pipes. Steam passes through the outer pipe, oil through the inner pipe. Mixing and atomization takes place in the mixing chamber of the nozzle. The atomized oil is discharged into the furnace, in the form of a fine spray, through the holes in the spray plate.
ATTEMPERATOR	A device that sprays water into the steam flowing through a superheater or reheater to prevent the final outlet steam temperature from exceeding established limits. Spray water is taken from a point in the discharge line from the boiler feed pumps. Flow of spray water is controlled by the air flow load index readjusted by steam temperature, and with spray water flow tie-back.
ATTRIBUTE DATA (SPC)	Data that can be counted. Based on the number of items that fail to conform to some standard. An example, is the number of products that either pass or fail a standard test. Four types of chart that use these attributes as data are C charts, U charts, NP charts, and P charts. C charts and U charts deal with the number of defects in a product.
AUTOMATIC CHEMICAL	A system providing for the feeding of chemicals automatically

FEED SYSTEM	into the feed water system of a boiler in proportion to the flow and pH.
AUTOMATIC LOAD FREQUENCY CONTROLLER	A device that automatically increases or decreases generator load within a specified band to meet system demands for power.
AUTOMATIC PUMP START (APS)	An instrument which senses abnormal pressure levels in a line carrying fluids or gases and will automatically start a pump or pumps to restore the line pressure to normal level. Pressure switches monitor the bearing oil pressure. The normal bearing oil pressures is 12 to 15 psi. The auxiliary oil pump is set to start at 9 to 10 psi, the AC turning gear pump starts at 6 to 8 psi, and the DC emergency pump starts at 5 psi. The pump will start automatically, but must be manually stopped. The control switch for the pumps should have three positions; Stop, Automatic, and Run.
AUTOMATIC TAP CHANGER	A device that automatically adjusts the voltage output of a transformer to compensate for variations in the transformer's voltage; accomplished by modifying the ratio of turns in the transformer's windings.
AUTOSTOP TRIP VALVE	Designed that when it opens, the autostop oil is dumped to drain, causing the throttle valves, the interceptor valves and reheat stop valves to close. At the same time, it also causes the governing emergency trip valve to operate. The autostop pressure is connected to an emergency trip relay which directs high pressure oil into the control oil header, thus creating a high control oil pressure. Therefore, all valves capable of admitting steam into the turbine will close. An air pilot valve used to monitor the extraction non-return valves is also triggered from the autostop pressure. The autostop valve is also tripped when any one of the protective devices, such as the low bearing oil, low vacuum, solenoid, thrust bearing trip, etc., are actuated.
AUTO-TRANSFORMER	A transformer in which the primary and secondary have a common winding.
AUXILIARY CONTACTS (MCC)	An additional set of contacts usually attached to the armature and operated by it. Used to control auxiliary control functions. For example, they may provide current for indicating lights such as the lights used to indicate whether a motor is on or off.
AUXILIARY GOVERNOR	Mounted on the control block with the main governor. Hydraulically connected to the governing control oil system through a check valve and has no speed changer or speed setting. It is a hydraulically balanced governor which produces a control pressure of approx. 8 psi when the unit is operating at normal

	speed. If the turbine should accelerate due to loss of load at a rate of 120 rpm per second or faster, the auxiliary governor will assume control of the turbine. The governor run-back switch will close and run the main governor back to approx. rated speed. When the speed of the turbine levels off, the control automatically returns to the main governor. In the event of the complete or partial loss of electrical load the speed will rise sharply since the main governor speed changer is in such a position that no load speed is higher than 3600 rpm. This sudden speed rise will cause the acceleration response feature of the auxiliary governor to momentarily assume control of the turbine by increasing the control oil pressure causing the governing and interceptor valves to close rapidly. With the governing and interceptor valves closed, the speed of the unit will decrease at a rate depending upon the residual load left on the generators. As the unit reaches a speed which will be determined by the setting of the speed changer, the interceptor valves will regulate the flow of steam, holding the speed of the unit at this value. As the pressure in the reheater circuit decreases, the interceptor valves will continue to open. The speed will then tend to drop and the governing valves open to control speed at the no load speed corresponding to the setting of the speed changer.
AUXILIARY LOAD	The total amount of electrical power needed to run auxiliary components such as pumps and fans.
AUXILIARY OIL PUMP	A pump in a turbine lubricating oil system used to provide hydraulic and lubricating oil during startups and shutdowns, when turbine speed is too slow for the main oil pump to be effective. A steam driven pump (W3&4), or electrically powered motor. Under control of a separate regulator which is actuated by the pressure in the oil system and automatically starts the auxiliary oil pump if, for any reason, the bearing oil pressure in the system drops below a predetermined point (8-10 psig). The discharge from this pump provides the high pressure oil required to operate the control mechanisms and regulators, primes the main pump through a regulating check valve, and provides the bearing oil through an adjustable orifice. The regulating check valve and bearing oil orifice are adjusted on the initial start to give the desired pump inlet pressure and bearing pressure. The main oil pump suction adjustable check valve should be adjusted to maintain a pressure of 30 to 35 psig. The main oil pump will overtake the auxiliary oil pump at about 90%.
AUXILIARY POWER SUPPLY	The power required for operation of generating station auxiliary equipment.

AUXILIARY RELAY	A relay which operates in response to the opening or closing of its operating circuit to assist another relay or device in the performance of its function.
AUXILIARY STEAM	Steam used for purposes other than driving a main turbine or heating feedwater. During normal operation the auxiliary steam is taken directly from the boiler drum and a valve pressure controller reduces the pressure to 200 psi. Used in makeup water purification systems, steam tracing lines, reboilers, turbine-driven boiler feed pumps, burner front, and burner cleaning stations.
AVOIDED COST	The incremental or additional costs to an electric utility of electric energy, or firm capacity, or both, which costs the utility would avoid by.
AXIAL FLOW COMPRESSOR	An air compressor that accelerates air along the compressor shaft, causing the air to be compressed. During operation, the rotating blades spin like the blades of a fan. They draw gas in and accelerates the gas to increase its velocity. The rotating blades then push the gas towards the stationary blades. When the gas contacts the stationary blades, they cause the gas to change direction as it flows toward the compressor's discharge. This causes the gas to slow down. As the gas slows down, its pressure increases. Main parts include a shaft, bearings, seals, rotating blades, stationary blades, a suction line, and a discharge line.
AXIAL FLOW PUMP	Liquid moves along or parallel to the axis of rotation or the shaft. Main parts include a shaft, bearings, seals, rotating blades, stationary blades, a suction port, and a discharge port. May consists of a single runner in a cylindrical case, or it may consist of a runner with one or two sets of fixed guide vanes. This type of pump develops pressure by having the runner blades shaped as air foil sections like an airplane propeller. The shape or inclined angle of the rotating blades produces a force on the liquid thereby raising its pressure. Discharge pressure lower than radial flow pump, but may be able to move large quantities of liquid. This type of pump is seldom used in a power plant.
AXIAL SEAL	A type of seal used to prevent air from leaking into the gas along the shaft of an air heater.
AXIAL THRUST	A force created along the shaft of a pump that tries to push the shaft in the direction of lower pressure. End to end movement; movement that is along the axis of the shaft.

B

BABBITT METAL	A soft, silvery, antifriction alloy composed of tin with small

amounts of copper and antimony. Used on the turbine journal bearings. Melts at approx. 200°F.

BACK PRESSURE — The difference between atmospheric pressure and condenser vacuum. Condenser vacuum measured in inches of mercury absolute. One way to view back pressure is as the resistance to flow into the condenser from the turbine. It is the amount of absolute pressure the turbine is exhausting into. This should always be as little as possible when the turbine is on-line. When you deal with back pressure, barometric pressure must be taken into account. To determine back pressure we must use the vacuum reading in the condenser. This is the reading that will be in inches of mercury. If the condenser vacuum is 25″ Hg, we must subtract this reading from the barometer. Therefore, if the barometric (atmospheric) pressure is 29.09″ Hg, and the condenser vacuum is 25″ Hg, the back pressure (condenser absolute pressure) will be 4.09″ Hg.

BACK WASHING — A process of reversing the flow of water through a component such as a filter or an ion exchanger to remove trapped material. A means of removing any blockage from condenser tube sheets by reversing the flow of circulating water through the sheets.

BAFFLES — Metal plates that change the direction of the flow of exhaust gases in a silencer. Partitions that help support the tubes and increase the efficiency of heat transfer in a shell and tube heat exchanger by directing shell-side flow.

BAGHOUSE — Uses a series of porous bags installed in the gas flow path to physically filter particulates from the combustion gases. As the combustion gases are drawn through the baghouse, particulates are trapped on the surface of the bags, while the rest of the combustion gases pass through.

BALANCE LINE — A pressure equalizing line.

BALANCED DRAFT BOILER — A boiler that uses a forced draft fan, and an induced draft fan, to create a negative furnace draft.

BALANCED EQUATION (CHEMICAL REACTION) — Indicates the proportions in which the reactants will react and the proportions in which the products will be formed. The proportions of reactants and products are expressed in terms of molecules.

BALANCING DRUM LEAKOFF — A flow created by a pressure differential in a balancing line; insures that the pressure across the balancing drum will not equalize.

BALANCING PISTON, OR — A device that helps to compensate for axial thrust by creating

BALANCING DRUM	another force that opposes the axial thrust. A piston mounted on the shaft inside a chamber at one end of a multi-stage pump and used to reduce axial thrust created by the spinning impellers. Used at the high pressure end of the high pressure turbine rotor, designed so as to partially balance the thrust toward the coupling end. This piston serves a dual purpose of balancing the thrust and serving as the high pressure gland. Leakage past this piston is reduced to a minimum by labyrinth and water seals.
BALL CHECK VALVE	Consists of a valve body, a seat, and a ball. When fluid flows through the valve, the ball is pushed out of the seat. As the ball is lifted, it rotates in the fluid flow. It is difficult for solid materials in a fluid to stick to the spinning ball, so these valves are useful for handling liquids containing solid particles. This self-cleaning effect helps ensure that the valve will close properly. When flow stops, gravity pulls the ball onto the seat. Backflow will then hold the ball firmly on the seat. Ball check valves can be used in either horizontal or vertical piping runs.
BALL VALVE	A type of plug valve in which a ball with a hole pivots to allow fluid flow. Commonly used for on/off purposes requiring fast valve positioning in process systems. Consists of a valve body, a stem with a handle attached to it, a ball that has an opening straight through it, a seal around the stem that prevents leakage along the stem, and two-part, ring shaped seats, which are commonly called wipers. A ball valve can be opened or closed by turning the handle one quarter turn. The handle is usually aligned with the opening in the ball, so that valve position can be determined by the handle position. The body of a ball valve may be either cylindrical or round in shape. Used in lines less than 3 inches in diameter, and less than 300 psig pressure. Chemical systems application.
BAR GRAPH	A graph consisting of columns, or bars, that may be arranged either vertically or horizontally, to provide information such as process variable values.
BAROMETER	An instrument which measures atmospheric pressure. Consists of a sealed tube filled with mercury, and a bowl. When the bottom of the tube is unsealed, mercury flows from the tube into the bowl. The weight of the column of mercury exerts pressure, and the atmosphere also exerts pressure. As a result, the flow from the tube into the bowl stops when the pressure exerted by the weight of the mercury in the tube equals the opposing pressure exerted by the atmosphere on the mercury in the bowl. In other words, the mercury will flow until the pressure exerted by the mercury column is equal to atmospheric pressure. The amount of pressure

	exerted by the atmosphere can be determined by measuring the height of the mercury column. At sea level, atmospheric pressure can support the weight of a column of mercury that is about 30″ high. Atmospheric pressure can support a column of water about 34 feet high. Standard atmospheric pressure equals 30″ of mercury, or 14.7 psi.
BARREL (OF OIL)	A unit of measure equal to 42 gallons.
BASKET STRAINER	A strainer used to filter out large amounts of impurities from fluid in a piping system that is subject to large buildups of impurities.
BATTERY	A group of several cells connected together as a unit for furnishing electric current. A device for generating an electric current by chemical reaction (electrolytes). Before the chemical reaction begins, both electrodes are electrically neutral, that is, they have an equal number of protons and electrons. The chemical reaction that takes place in a battery causes electrons to leave one of the electrodes. When this occurs, that electrode becomes positively charged. At the same time, the electrons build up on the other electrode, which becomes negatively charged. The oppositely charged electrons in a battery create an electrical potential. If the electrodes are connected as part of a complete flow path, the electrical potential will cause a flow of electrons, or current. A group of several cells connected together as a unit for furnishing electric current.
BATTERY CHARGERS	Consist of motor-generator sets, the motor operating at 440 AC. Control of the DC output is by means of a hand-operated field rheostat.
BEARING	Turbine components designed to support the rotor and allow it to rotate while preventing metal-to-metal contact between stationary and moving parts. A bushing, sleeve, box, or shell within which the shaft rotates. Performs three functions: they carry loads, they reduce friction, and they position moving parts.
BEARING OIL PRESSURE RELIEF VALVE	Provided in the bearing oil line to compensate for moderate changes in oil requirements. Maintains the bearing oil pressure to within 12-15 lbs. If the input oil pressure to the bearings change, the output changes dramatically.
BEARING PEDESTALS (STANDARDS)	Supports for turbine bearings and turbine casings.
BELLOWS	Pressure element; basically a movable, accordion-shaped tube that converts changes in pressure to mechanical motion. A thin-walled, corrugated metal tube that expands and contracts in

	responds to changes in pressure.
BELLOWS TRAP	A thermostatic trap in which a bellows expands or compresses to open or close the outlet valve.
BENCHBOARD (CONTROL DESK)	A switchboard having a horizontal or slightly inclined section for mounting control switches, indicating lamps and instrument switches, and constructed with or without vertical instrument sections.
BENTONITE	A common additive that is a type of dried clay, used to thicken grease. Far more heat resistant than some other grease thickeners. Resist high temperatures, so it keeps grease from melting.
BERM	A structure (concrete, hollow tile, or earthen) used to retain leakage from tanks, ponds, and/or sumps.
BHP	Broken Hill Proprietaries Refinery (sold to new owner)
BIAS	A loading pressure adjustment made by the operator to balance or unbalance two or more control pressures.
BIAS	A loading pressure adjustment made to balance or unbalance two or more control pressures.
BIMETALLIC DEVICE (MCC)	A type of thermal overload device. One part of the bimetallic device is a heater, which is in the motor controller's power circuit. The bimetallic device also contains a bimetallic strip, which is a strip made up of two different metals that are bonded together; a spring-loaded mechanical linkage; contacts; which are in the motor controller's control circuit; and a reset button. The two metals in the bimetallic strip expand at different rates when the strip is heated by the heater. Under normal circumstances, the bimetallic strip holds the mechanical linkage in place, which keeps the contacts closed so that there is a complete path for current to flow to the motor controller's "M" coil. When the current level in the power circuit exceeds the rated value of the bimetallic device, enough heat is generated by the current flow through the heater to cause the bimetallic strip to bend. The strip bends because the two metals in the strip expand at different rates. When it bends, it releases the mechanical linkage. When the mechanical linkage is released, the force of the spring pulls the contacts open. Opening the contacts interrupts the current flow in the control circuit to the controller's "M" coil. The interruption of current flow in the control circuit opens contacts in the motor controller. As a result, current flow in the power circuit to the motor is interrupted, and the motor stops.
BIMETALLIC	A temperature measuring device that operates on the principle that

THERMOMETER	different metals expand and contract at different rates in response to changes in temperature. Has a bimetallic element, which is a strip that is made of different metals and formed into a coil. An increase in temperature causes the metals to expand at different rates. The unequal expansion causes the element to rotate slightly. The rotation turns a rod, which, in turn, moves a pointer. The pointer movement indicates the change in temperature. If the temperature decreases, the opposite effect occurs. Overheating, or overranging a fluid or bimetallic thermometer can damage it.
BIOCIDE	A chemical, such as chlorine, used to prevent biological organisms in water from growing into slime deposits.
BLACK START	A startup of the plant when all station power has been lost and no outside source of electricity is available.
BLADE	A rotating or fixed part of a turbine. Rotating blades convert energy in steam into mechanical energy, which causes rotation of the turbine shaft. Fixed blades direct the steam into the rotating blades.
BLEEDER TRIP VALVE	Extraction check valves (or non-return valves) are provided in most of the extraction lines from a steam turbine. Their primary function is to prevent steam from entering the turbine on loss of load and thus they comprise an important element in the control which protects the turbine against excessive destructive overspeed. Also provide some protection against water induction. Power closed on heater level. When the bleed trip is energized, a spring opens the non-return valves about 10%, with steam pressure from the heaters slamming it closed the rest of the way. Two reasons for testing are: to be sure they work properly, and to remove any binding caused by scale.
BLIND TRANSMITTER	A transmitter that does not provide a local visual indication of the value of the process variable that is being monitored.
BLOCK DIAGRAM	A drawing that uses squares or rectangles to represent major systems or components in a system. Blocks may represent the energy source, devices that perform a control function, and the load, or demand, in a system. The lines represent the transmission paths for material or energy through the system.
BLOCK VALVE	Isolation valves. On boiler bottom blowdown, valve downstream of root valve. Opened after root valve is opened, and closed before root valve is closed.
BLOCKED LOAD	Load held steadily at a fixed point.
BLOWBACK	The difference between the pressure needed to open a safety valve

	and the pressure at which the valve snaps shut; also called blowdown.
BLOWDOWN	A type of drain that may be opened during boiler operation for specific purposes, such as to remove contamination that has built up in the drum. Boiler blowdowns are used as a means of controlling boiler water concentrations (alkalinity) and to remove sludge formation. In extreme cases of sludge formation, or in cases of poorly treated feedwater with high solids contents resulting in carry-over, the boiler may be blown down intermittently through the downtake drain valves or the waterwall supply drum drains. In no case should the waterwall header drains be used for blowing down the boiler while the unit is steaming.
BLOWDOWN VALVE	A valve, usually found in a drain line, used to remove unwanted moisture or solids from a system.
BMP	Better Management Practice.
BOILER	The component in a power plant that burns fuel to produce heat and uses that heat to convert water into steam. Supplies steam at design pressure and temperature, on demand, to drive the turbine.
BOILER DRUM	Functions to separate the water from the steam generated in the furnace walls and to reduce the dissolved solids contents of the steam to below the prescribed limits. Wet steam entering the drum from the riser tubes and furnace walls is collected in a compartment, formed by internal baffles. From this compartment the steam is first led through two rows of turbo separators. Each turbo separator consists of a primary stage and a secondary stage. The primary stage is formed by two concentric cans. Spinner blades impart a centrifugal motion to the mixture of steam and water, flowing upward through the inner can, thereby throwing the water to the outside and forcing the steam to the inside. The water is arrested by a skim-off lip above the spinner blades and returned to the lower part of the drum through the annulus between the two cans. The steam proceeds up to the secondary separator stage. The secondary stage consists of two opposed banks of closely spaced thin corrugated sheets which directs the steam through a tortuous path and force remaining entrained water against the corrugated plates. Since the velocity is relatively low, this water does not get picked up again, but runs down the plates and off the second stage lips at the two steam outlets. From the secondary separators the steam flow uniformly and with relatively low velocity upward to the series of screen dryers, extending in layers across the length of the drum. These screens perform the final stage of separation. The boiler drum is equipped with three safety

	valves, two on the drum itself and one is on the superheater outlet. In addition, a fourth combination safety and electromatic relief valve is located on the superheater outlet line. The boiler drum is fitted with two water level gauges, one for normal level and one for high level. The high level gauge is for use only during shutting down and fast cooling operations. This gauge should be shut at pressures above 750 psig with its block valves. The drum is also provided with a water level recorder indicator (Bailey), two normal remote level indicators and one high level remote level indicator (Yarway) mounted on a panel outside the control room door but visible from within the control room.
BOILER ENVELOPE	A boundary that energy crosses when it enters or leaves the boiler.
BOILER FEED PUMP	Takes suction from the #3 heater (deaerator at W3&4), and discharges above boiler pressure into a common header, through a feedwater regulating valve, then through the #4 and #5 high-pressure heaters, the economizer, and finally into the boiler drum. The feedwater pumps also supply water for main steam temperature control. Contains approx. 12 stages. Lubrication for the pumps, when in service, is provided by a screw-gear type pump attached to the outboard end of the main shaft. The complete lubricating oil system consists of the main oil pump, related coolers, and a reservoir with internal strainers. A motor-driven gear-type auxiliary pump will supply oil to the feed pump bearings for starting, until the main oil pump discharge pressure exceeds the auxiliary oil pump pressure. The motors are 2,300-volt line start.
BOILER MASTER	A hand/auto station that can control several other hand/auto stations for boiler fuel flow control.
BOILING	The process of changing the state of water from a liquid to a vapor. The condition at which the molecules of a heated liquid become active enough to escape the liquid. When pressure is reduced, water boils at a lower temperature. When pressure is increased water boils at a higher temperature.
BONNET (VALVES)	Seals the top of the valve body.
BOOST	Raise or attempt to raise voltage.
BOOST FIELD	A field designed into the exciter to raise voltage. In service only when the voltage regulator is in the "regulate", or "automatic" position. One part of the voltage regulator keeps constant watch on the generator output voltage. If the generator voltage drops the regulator pushes a little current through the "boost" field which aids the main shunt field and causes the exciter output to increase.

	When you increase the voltage to your rotating field, you will make your current lag your voltage. This will add reactive power to the power system, which will tend to raise system voltage. Current lags, voltage high. VARS will be created and exported out of the generator.
BOOSTER PUMP	A pump used in some systems to supply oil to the suction of the main lube oil pump and to the turbine bearings.
BORON	A chemical used in steam plants in cooling water systems to prevent corrosion of metal surfaces.
BOURDON TUBE	A pressure sensing element. Basically a curved hollow tube that converts changes in pressure to mechanical motion. A thin-walled tube, closed at one end, that responds to changes in pressure by attempting to curl up or straighten out.
BOWSER	The trade name of a lubricating oil conditioner. Removes water and solid impurities from a portion of the oil while in service. This system employs a precipitation or settling compartment, a filter bag compartment, and in some cases, a polishing cartridge filter is included.
BOYLE'S LAW	A theory explaining the relationship between volume and pressure of gases during compression or expansion. At a given temperature, the pressure of a gas varies inversely with its volume. When the volume of gas decreases, its pressure increases. If the volume increases, the pressure decreases.
BREAK POINT	The point at which operation changes from constant drum to constant throttle.
BREAKABLE DIAPHRAGM	Mounted of the turbine exhaust cylinder cover for the purpose of providing automatic emergency relief should the internal pressure rise beyond the maximum safe value for which the cylinder is designed. It consists of a thin lead diaphragm supported against the external atmospheric pressure by a round thin diaphragm pressure disc. This pressure disc is in turn carried on a grid type support. The thin lead diaphragm is clamped between the diaphragm pressure disc and the diaphragm retaining ring. If the exhaust pressure rises above the predetermined point, the diaphragm pressure disc is forced outward causing the lead diaphragm to be sheared off between the inner edge of the retaining ring and the edge of the diaphragm pressure disc. Rupturing of this diaphragm relieves the pressure in the turbine exhaust. The turbine cylinder directs the rush of steam upward and the guard prevents scattering of the diaphragm and disc. This diaphragm is used in conjunction with an automatic low vacuum

	trip mechanism, which will normally shut the turbine down, when the exhaust pressure rises to a predetermined point, usually about 17 inches of Hg. The pressure at which the lead diaphragm will rupture is usually 5 psig. when mounted on the turbine cylinder.
BRITISH THERMAL UNIT (BTU)	The unit of thermal energy equal to the amount of heat required to raise the temperature of one pound of water at standard conditions one degree Fahrenheit. Defined as 1/180 of the amount of heat required to raise the temperature of 1 lb. of water from 32°F to 212°F, (a temperature rise of 180°F). This means that 1 lb. of water at 212°F will contain 180° BTU. This heat in the water is known as the "Heat Of The Liquid".
BRUSH	The conducting material, usually made of carbon, bearing against the commutator or slip rings through which the current flows in or out of the rotor of the machine.
BRUSH HOLDER	A device which holds the brush in position.
BRUSHLESS EXCITER	An exciter that does not have brushes or slip rings.
BT	Batch Tank
BUBBLER SYSTEM	An indirect level measurement system that measures the level in a tank based on the air pressure needed to force all of the liquid from a vertically mounted pipe. Utilized for level measurement in inaccessible areas, and where the vessel or tank is below ground level. This device balances the pressure with either a manometer or a pressure gauge.
BUCK	Lower or attempt to lower voltage.
BUCK FIELD	A field designed into the exciter to lower voltage. In service only when the voltage regulator is in the "regulate", or "automatic" position. One part of the voltage regulator keeps constant watch on the generator output voltage. If the voltage rises, the regulator pushes a little current through the "buck" field, which is so constructed that its field opposes the main shunt field and thus decreases the exciter output. When your make your current lead your voltage sine waves by reducing field voltage, you will draw reactive power from the power system, and will lower system voltage. <u>Current leads</u>, voltage low. VARS could be drawn into the generator.
BUMP	A shift at a control station between manual and automatic signals with a difference between the signals resulting in a fluctuation in the process variable. A rapid shift in a control action caused by suddenly changing instrument settings.
BURNER	A boiler component that directs the combustion air from the

	windbox and the fuel into the furnace, where combustion takes place.
BURNER REGISTERS	Components located between the windbox and the burners that regulate the amount of air flow to each burner.
BURNER THROAT	The opening between the wind box and the furnace, usually lined with refractory material.
BUS	A conductor or an assembly of conductors that receives electric current and distributes it to equipment. A bus conductor, or group of conductors, is a switchgear assembly which serves as a common connection for three or more circuits. The conductors of a bus are usually in the form of a bar. Distributes power in an electrical distribution system, and it operates at a specific voltage.
BUSHING (BEARING)	A special type of sleeve bearing. A thin-walled bearing that can be removed in one piece. The grooves in a typical bushing collect oil and keep the shaft lubricated.
BUSHING (ELECTRICAL)	A device that connects electrical equipment to electrical lines.
BUTTERFLY VALVE	A type of valve used for isolation and flow control; use is generally limited to low pressure applications. Have round, relatively thin valve bodies, and they take up less space in piping than many other types of valves. Consists of a valve body, a seating area, or seat, a disc, a stem, a stuffing box, packing, and a packing gland, with gland nuts. A handle may be attached to the stem for manual positioning of the valve. The disc of a butterfly valve is just slightly smaller in diameter than the inside of the piping in which the valve is installed. The disc is also relatively thin, and it offers little obstruction to flow when the valve is fully open. The disc is attached to the stem. The stem is used to rotate the disc when the handle is moved. The flow rate through the valve is adjusted by changing the angle of the disc. The butterfly valve requires only a ninety-degree movement, or one quarter turn, of its handle to go from the fully open position to the fully closed position. The handle is usually aligned with the disc. When the handle is in line with the valve's inlet and outlet, the valve is fully open. When the handle is perpendicular to the piping, the valve is fully closed. Used in lines with large flow volume such as circulating water/condenser flow reversing systems.

C

C CHART (Control Chart)	Used to display the actual number of defects per item. The horizontal axis represent time, and the vertical axis represents the

	number of defects per sample. The sampling size is based on the number or amount of product sample needed to determine a data point for the chart. The sampling size is constant for a particular application. Part of Statistical Process Control (SPC) charts.
CAGE (BEARING)	A metal retainer that holds the rolling elements in position and keeps them from rubbing against each other.
CAID	Customer Average Interruption Duration. Measures the average length of time, in minutes, that service was interrupted.
CALCIUM HYDROXIDE	A strong alkali commonly sold in water solution and as an ingredient of bleaching powder.
CALORIE	The amount of energy needed to make the temperature of one gram of water one degree Celsius.
CAPABILITY	The maximum load which a machine, apparatus, station or system can carry under specified conditions for a given time interval.
CAPABILITY CURVE	A chart that can be used to calculate a generator's ability to produce power safely under specific operating conditions.
CAPACITANCE	A physical property of AC circuits that opposes changes in voltage. The property of two or more bodies which enables them to store electrical energy in an electrostatic field between the bodies, which resists or opposes any change in the voltage of the associated circuit. When the applied AC voltage increases, capacitance opposes the change and delays the voltage increase across the circuit. When the voltage decreases, capacitance tends to maintain the original voltage across the circuit and delays the decrease in voltage. Measured in farads. Causes current to lead voltage.
CAPACITANCE (PROCESS SYSTEMS)	The ability to store energy. A water tank has the ability to store energy. Capacitance is determined by the size or capacity of the container.
CAPACITIVE REACTANCE	The opposition offered to the flow of an alternating current (AC) by capacitance, expressed in ohms. The frequency dependent impedance of a capacitor.
CAPACITOR	A component used to control or increase the amount of capacitive reactance in an AC circuit. Two electrodes or sets of electrodes in the form of plates, separated from each other by an insulating material called the dielectric.
CAPACITY (PUMP)	The volume of water that is moved by a pump, as measured at its discharge.
CAPILLARY ACTION	When a tube is placed into a container of liquid, the liquid tends to

	rise in the tube because of the adhesive forces between the liquid and the tube. These forces actually pull the liquid molecules up into the tube. Capillary action stops when the weight of the liquid in the tube is equal to the adhesive forces pulling the liquid into the tubes.
CARBON DIOXIDE (CO2)	A colorless, odorless, incombustible gas formed during proper combustion in flue gas; inert gas. Non-condensable gases formed in varying amounts due to chemical action taking place in the boiler water during the boiling process. These gases also tend to form in layers that act as insulating blankets. When mixed with steam, the gas lowers the temperature of the resulting mixture. A heavy colorless gas that does not support combustion, dissolves in water to form carbonic acid, is formed esp. in animal respiration and in the decay or combustion of animal and vegetable matter, is absorbed from the air by plants in photosynthesis, and is used in the carbonation of beverages.
CARBON MONOXIDE (CO)	A colorless, odorless, highly poisonous gas that burns to carbon dioxide with a blue flame and is formed by incomplete combustion of carbon or any carbonaceous material. Non-condensable gases formed in varying amounts due to chemical action taking place in the boiler water during the boiling process. These gases also tend to form in layers that act as insulating blankets. When mixed with steam, the gas lowers the temperature of the resulting mixture.
CARBON SEAL	A seal consisting of carbon rings that are held against the turbine shaft by springs.
CARDOX	Manufacturer's name for the Combustion Turbine CO2 system.
CARNOT EFFICIENCY	The ideal or highest efficiency theoretically possible from a particular cycle.
CARRYOVER	A condition existing in a steam generator in which actual droplets of boiler water containing dissolved solids are carried along with the steam leaving the boiler drum up into the steam tubes and from there into the turbine. This condition is very dangerous, the prevention of which is vital in order to have uninterrupted plant service. This condition is usually detected by checking the conductivity of the saturated and superheated steam. The main causes of carryover are: high dissolved solids in the water, high alkalinity and the presence of oil in the boiler water. Total dissolved solids in the water are controlled by blowing down the boiler whenever the concentration gets too high. Excess alkalinity usually results from improper treatment and can only be corrected by blowing down the boiler.

	Oil in the boiler water enacts with the caustic to form soap which will create foam or soap suds and cause carryover. Oil should never be allowed to enter the boiler water supply.
CASCADING DRAIN SYSTEM	A drain system associated with feedwater heaters in a string arrangement. The pressure differential from one heater to the next causes the drips to flow from one heater to another.
CATALYST	A material that can increase the rate of a reaction without becoming part of the final product.
CATHODE	A negative electrode.
CATHODIC PROTECTION	A system that induces a counter current on the piping with sacrificial anodes to maintain ionic balance in condensers.
CATION	A positively charged ion resulting from the dissociation of salts, minerals or acids in water. Positive ions in a water solution such as the sodium of sodium chloride.
CATION EXCHANGER (Water Softener)	The first exchange step in the demineralizing system, which substitutes hydrogen ions for all the cations in the water. Cation exchanger beds contain cation resin which exchanges hydrogen ion, H+, for calcium, magnesium, sodium, and other positively changed ions from the raw water as it enters the top of the bed. The water exiting this bed contains H+ and negatively charged ions. Acid Regeneration. pH values should be between 2.5 and 3.0, and conductivities between 400 and 750 μmhos.
CATION MEMBRANE (EDR)	A cation exchange resin cast in sheet form through which only cations will transfer.
CATION RESIN BEADS	Resin beads in an ion exchanger that attract positively charged ions.
CATIONS	Positive ions in a water solution such as the sodium of sodium chloride.
CAUSTIC ATTACK	Corrosion caused by an alkali.
CAUSTIC EMBRITTLEMENT	A condition caused by a combination of excessively alkaline boiler water and leaks in a boiler tube; changes the molecular structure of boiler tube metal so that the metal becomes brittle.
CAUSTIC SODA (NaOH)	Sodium Hydroxide; used to raise the PH and alkalinity of boiler water.
CAVITATION	A condition that may occur in pumps if the fluid they contain begins to boil. Vaporization of fluids due to pressure loss forms vapor pockets, and upon collapse, produces shock waves,

	vibration, noise, and destruction of the impeller and surrounding walls.
CAVITATION (PUMPS)	Usually violent, and can damage a pump. Directly related to the amount of head, or pressure, at the suction of a pump. If the suction drops below its designed value for the system, the liquid being pumped can flash to vapor. This is when cavitation occurs. Cavitation is the formation and subsequent collapse of vapor bubbles. Cavitation normally begins in the suction of a pump, where liquid is drawn into the pump and pressure is lowest. If the pressure of the liquid decreases too much, the liquid will vaporize, or boil. When the liquid boils, bubbles form and travel with the liquid in the pump. As thousands of bubbles travel towards the higher pressure areas in the pump, they are compressed until they can no longer withstand the pressure. Then they collapse, or implode, violently. As liquid rushes in to fill the spaces left by the collapsing bubbles, it strikes the inside surfaces of the pump and gradually wears away pump material. The result is a sandblasting effect on internal pump components such as the impeller. This kind of damage decreases the pump's performance. The temperature of a liquid could also be a cause of cavitation.
CEIP	Campbell Estate Industrial Park (aka CIP or Campbell Industrial Park)
CELLULOSE ACETATE	Reverse Osmosis membrane. Operates at higher pressures and are susceptible to damage from pH variances, (especially pH above 7.0). Require low levels of chlorine to reduce bacterial growth within the elements.
CEMS	Continuous Emission Monitoring System. Continuous monitoring direct to the DOH.
CENTIGRADE (CELSIUS)	Pertaining to a temperature scale that registers the freezing point of water as 0° C. and the boiling point as 100° C. under normal atmospheric pressure. °C = (°F-32) x 5/9; °C = (°F-32) ÷ 1.8
CENTIMETER	One hundredth of a meter
CENTRALIZED DIGITAL CONTROL SYSTEM	A type of process unit digital control system in which all of the system's process control functions are performed in a single location. Commonly called direct digital control, or DDC.
CENTRIFUGAL COMPRESSOR	Main internal components are an impeller and a volute. Gas that enters the compressor at the center of the impeller is swept up by vanes on the impeller and moved outward by centrifugal force. This action increases the velocity of the gas. When the gas leaves the impeller, it enters the volute. In the volute, the gas expands and gradually slows down as the chamber widens. As the gas

slows down, its velocity, or kinetic energy, is converted into pressure. The gas reaches its maximum pressure as it is discharged from the compressor through the gas discharge line.

CENTRIFUGAL FORCE	The force that exists when an object or material moves in a circular motion. This force causes the object or material to move outward, away from the center of rotation.
CENTRIFUGAL PUMP	Uses an impeller, which creates a centrifugal force to move the liquid. This force pushes the liquid away from the center of rotation and out of the pump.
CENTRIFUGE	A centrifugal separating machine used to remove water and solids from lubricating oils. Two principal makes are De Laval and Sharples.
CGS	Centimeter Gram Second
CHARLES LAW	The relationship between the temperature and volume of gas. At a given pressure, the volume of gas varies directly with its temperature. As temperature increases, volume increases, and as temperature decreases, volume decreases.
CHECK VALVE	Automatic operating valves which allow flow in one direction only. Most check valves consist of a body containing a seat and a hinged disc balanced is such a way that the disc swings open allowing flow in one direction and swings closed preventing flow in the opposite direction. Check valves are normally installed where several pumps discharge into a common line or header. This prevents flow in the reverse direction through an idle pump. Scale, rust or other foreign material may collect above the disc preventing it from opening or under the seat preventing it from closing. The cover must be removed and the obstruction cleared whenever this occurs. Three types of check valves commonly found in industrial facilities are swing check valves, lift check valves, and ball check valves.
CHELATE	Relating to, or having a ring structure that usually contains a metal ion held by coordination bonds.
CHEMICAL ENERGY	When a substance is able to undergo a chemical reaction and release energy.
CHEMICAL EQUATION	Basically a description of a chemical reaction in the form of letters, symbols and numbers. The starting materials, or reactants, and the products are separated by a yield sign. The yield sign is an arrow. It indicates that a reaction is taking place. The arrow points toward the products of the reaction. The numbers to the right of some of the element symbols in a chemical equation

	indicates how many atoms of that element are present. The absence of a number means that there is only one atom. Chemical equations must balance. In other words, whatever is represented on the left side of the equation must also be represented on the right side. The idea of a balanced equation is based on a simple principle that atoms are neither created nor destroyed in a chemical reaction. What goes in must come out.
CHEMICAL REACTION	A reaction that forms a chemical bond, breaks a chemical bond, or simultaneously forms and breaks chemical bonds. The materials that produce a chemical reaction can be called reactants, because they will react together. An interaction between the atoms of substances. Valence electrons are either transferred from one atom to another or shared between two or more atoms. By transferring or sharing valence electrons, atoms of certain elements combine, or bond, with each other to form molecules. When atoms combine, they often transfer or share valence electrons so that each atom ends up with eight electrons in its outermost shell. A smaller atom may end up with two electrons in its outermost shell.
CHEMICAL RESIDUAL	A predetermined desirable quantity of chemical remaining in a system during operation.
CHLORINATOR	A piece of equipment in a chlorine injection system that regulates the pressure of chlorine gas and controls its flow rate so that it is mixed with water in the correct proportions.
CHLORINE DIOXIDE	This chemical is generated at the point of application by mixing chlorine gas and a solution of sodium chlorite in a chlorinator. The gas is dissolved in a moving stream of water which is injected into the inlet of the condenser. Introduced to condenser cooling water in very low concentrations, controls fouling of the heat exchanger tubes. This aids in maintaining optimum heat exchange efficiency. Chlorine Dioxide effectively prevents or discourages the establishment of marine plants and animals in the condensers.
CHLORINE INJECTION SYSTEM	A system that adds chlorine to the circulating water system to retard the growth of contaminants such as algae and bacteria.
CHROMATOGRAPH	An on-line analyzer that provides the data used to plot control charts. A type of gas analyzer often used to measure the concentrations of various gases in a complex gas mixture, which is a mixture of more than two gases.
CIRCUIT	Any closed path followed or capable of being followed by an electric current. A configuration of electrically or electromagnetically connected components or devices. A

	complete flow path. The means for connecting a source of electricity to devices that use electricity to operate. A basic circuit consists of: Energy Source (battery) - Transmission Path (wires) - Control device (switch) - Load (motor)
CIRCUIT (ELECTRIC)	A conductor or a system of conductors through which an electric current flows or is intended to flow.
CIRCUIT BREAKER	A protective device for opening or closing a circuit which is carrying load to interrupt the flow of current at that particular point.

A device used to open or close circuits which are carrying load. In order to do this safely, the circuit breaker must have some special provisions for handling the arc. There are four basic methods used for minimizing the arc and its effect on the equipment.

1) The contacts are moved very rapidly so that they quickly reach a distance or separation across which the arc is present and thereby reduces the amount of burning that takes place.
2) A fluid is used to either cool the arc or force it away from the contacts into a special area which resists burning. In this manner the arc and its effect are reduced.
3) Multiple contacts are used and are adjusted to operate sequentially. The main current carrying contacts are the first to open and the last to close. In this way the auxiliary or arcing contacts handle all the arcing and burning while the main contacts are preserved for their main job of carrying the circuit load. The auxiliary contacts are designed so that they can be readily replaced.
4) A coil is installed around the contacts. The coil is energized and produces a magnetic field which forces the arc away from the contacts. In this application the ionized air acts as a conductor and is the magnetic field produced by the coil. A force is exerted on the conductor which in this case is the ionized air.

Circuit breakers protect loads from potentially damaging conditions by automatically tripping, that is, interrupting current flow. Also isolates equipment.

CIRCUIT BREAKER MECHANISM	An assembly of levers and other parts which actuates the moving contacts of the circuit breaker.
CIRCUIT RECLOSER	A line protective device usually associated with the lower voltages of a distribution system which interrupts momentary line faults.

	The circuit recloser is designed to automatically reclose after a short period of time.
CIRCULAR MIL	An area equal to that of a circle with the diameter of 0.001 inch. It is used for measuring the cross sectional area of wire.
CIRCULATING WATER PUMP	Usually, a large centrifugal pump that is capable of pumping thousands of gallons of water per minute through the circulating water system.
CIRCULATING WATER SYSTEM	Supplies sea water for condensing the turbine exhaust steam.
CIRCULATOR	Condenser circulating water pump.
CIRCUMFERENTIAL SEAL	A type of seal used to prevent air from leaking into the gas around the circumference of an air heater.
CIS	Control Interface Slave.
CIU	Computer Interface Unit
CLARIFICATION	Process of removing suspended solids by settling. A water treatment process in which chemicals are used to cause charged particles in raw water to come together in heavier clumps and settle out.
CLARITY	The measure of how clear, or transparent, a substance is.
CLEARANCE POCKETS	Small air chambers in the walls of some air compressor cylinders; used to reduce the flow of air from the compressor to the air receiver when the air receiver pressure is too high.
CLOSED CONTROL LOOP	A control loop that has a sensing element, a measuring element, a controlling element, and a final control element.
CLOSED HEATER	A shell and tube feedwater heater that does not allow extraction steam and feedwater to come into contact and mix.
CLOSED IMPELLER	Can be classified as single-suction or double-suction impeller. Has vanes that are enclosed by shrouds on both sides. The shrouds direct the flow of liquid between the vanes. Often used with low viscosity, or thin, liquids.
CLOSING COIL (Circuit Breaker)	A coil used in the electromagnet which supplies power for closing a circuit breaker.
COAGULANT	A chemical added to raw water in a clarifier to form a positively charged precipitate that attracts negatively charged particles suspended in the water.
COAGULATION	The first stage of the clarification process, in which a chemical coagulant is rapidly mixed into raw water.

COCK VALVE	See plug valve.
COGENERATION	The simultaneous production of electric energy and useful thermal energy for industrial, commercial, heating or cooling purposes.
COHESION	The mutual attraction by which the elements of a body are held together.
COHESIVE FORCE	A molecular force that exists between like molecules.
COLD END	The end of an air heater where gas exits and air enters.
COLD END METAL TEMPERATURE	The temperature of the air heater plates at the cold end of the air heater.
COLD PLUG	A restriction in a fuel oil line caused by cold fuel oil.
COLD REHEAT STEAM	Steam that flows from the exhaust of the high pressure turbine to the boiler reheater.
COLLECTOR RINGS (SLIP RINGS)	Metal rings suitably mounted on the rotor of an electric machine which conduct current into or out of the rotor by the use of stationary brushes bearing upon the rings.
COLORIMETER	An analyzer that measures the color intensity of a solution.
COMBINED CYCLE	A combustion turbine installation using waste heat boilers to capture the turbine exhaust heat energy for steam generation which is usually used to drive a steam turbine generator unit.
COMBINED CYCLE PLANT	Exhaust gases from a gas turbine are used to produce steam to drive a steam turbine. The hot exhaust gases that leave the gas turbine are routed to a heat recovery steam generator, or HRSG. In the HRSG, the exhaust gases transfer heat to water to produce steam. The steam that is produced is sent to the steam turbine, where some of the energy in the steam is converted into mechanical energy. The mechanical energy is then converted into electricity by a second generator. This process increases the efficiency of the plant, since more of the energy in the gas turbine exhaust gases is used before the gases are released.
COMBUSTIBLES	The amount of incomplete burning of fuel oil.
COMBUSTION	A chemical reaction between carbon and hydrogen contained in fuel, and oxygen contained in combustion air. Product is hot flue gas.
COMBUSTION AIR MOISTURE LOSS	Loss due to heat absorption by the moisture that enters the boiler in the combustion air supply. Most of this heat leaves the boiler in the exhaust gas.
COMBUSTION AIR	A method used to control the cold end metal temperature of an air

RECIRCULATION	heater by recirculating some of the combustion air from the discharge of the air heater back to the air inlet.
COMBUSTION AIR SYSTEM	The system that supplies the air necessary for the proper combustion of fuel in a boiler.
COMBUSTION CONTROL	Purpose is to regulate the correct ratio of fuel and air flow to the furnace throughout the boiler load range. The function of an automatic combustion control system is to maintain fuel and air input to the furnace in accordance with the demand for steam, and to proportion the fuel and air for maximum combustion efficiency. The demand for fuel and air flow is from the steam flow signal which is corrected by drum pressure. Steam flow is directly proportional to the required fuel and air flow, therefore, this signal is used as an index of boiler load. First stage pressure is proportional to the turbine steam flow, so, it is used as an indication of steam flow. The first stage pressure is calibrated to equal the feedwater flow at each division of load. But, the condition of the turbine blading will effect the relationship of 1st stage pressure to steam flow. Thus, indicating a higher steam flow per generator MW output as the turbine blading deposits increase. The basic concept of the control system is for the air flow to increase first on a load increase. Air flow increasing will increase the fuel flow. To prevent fuel enrichment, the rate of combustion is limited to the actual air available for firing. The fuel demand signal is compared to the total air flow metered. A low signal selector chooses the lesser for the fuel demand signal. Whereby, on a load reduction, the fuel and air flows are reduced together. The fuel and air flow meter feedback signals provide a method of informing the fuel and air flow controllers when the required flow conditions exist. The O2 control system corrects the air flow meter feedback signal to increase or decrease the excess air. The O2 set point adjustment biases the O2 set point which is required by steam flow. The boiler is provided with high and low speed forced draft fan motors. The fan motor speed which is selected depends upon the air flow requirement.
COMBUSTION GASES	The gases produced when fuel burns in a boiler furnace.
COMBUSTION REACTION	A exothermic reaction. A reaction between oxygen and fuel. One place that a combustion reaction occurs is in a boiler. Requires fuel, oxygen, and heat to get started. After it is started, it produces heat, which sustains the reaction as long as there is an adequate supply of fuel and oxygen. When a combustion reaction occurs, oxygen reacts with the fuel so rapidly that a fire is created.
COMBUSTION TURBINE	An electric generating unit in which the prime mover is a gas

	turbine engine.
COMBUSTOR	A chamber in a gas turbine in which combustion occurs. Where compressed air is mixed with fuel, and the mixture is ignited and burned. The burning creates gases that expand rapidly.
COMMAND KEYS (COMPUTER)	Used for operations such as changing process variable set points.
COMMUNICATION INTERFACE	A circuit in a control system that connects the equipment in the system to a communication network.
COMMUTATOR	A device in a DC exciter that changes alternating current to direct current. That part of the rotor of a motor or generator which is used to conduct electrical energy to the rotor windings from the stationary brushes with which the commutator is in contact. The conducting ring is mounted on the end of the armature. It is not a solid ring. Consists of conducting segments that are separated from each other. During operation, the commutator makes sliding contact with the brushes. Current flows from the negative side of the DC power source through one brush to a commutator segment. The current then flows through the armature, through the other commutator segment and the other brush, and to the positive side of the power source. The current flow through the armature creates a magnetic field with a north pole and a south pole. The poles are perpendicular to the armature.
COMMUTATOR AND BRUSHES	The parts of a DC motor that cause the poles on the rotor to switch. Constantly changes the direction of current flow to the rotor, which is what changes the polarity of the rotor. The change in polarity keeps the rotor rotating in the same direction. It continually moves toward opposite poles. The continuous process of switching polarity causes the magnetic fields in a DC motor to change positions. This is what causes a DC motor to operate.
COMPARATOR	An instrument that receives two different signals, compares them, and sends out a signal that is proportional to the difference between the two signals.
COMPONENT EFFICIENCY	The amount of useful energy leaving a component divided by the energy entering the component.
COMPOUND	A definite combination of the atoms of two or more elements in simple numerical proportions, resulting in the formation of the basic particle of the compound called the molecule. A product of chemical reaction. Formed when two or more elements are combined, or bonded, chemically. Each molecule of a compound consists of specific numbers of specific atoms.

COMPOUND GAUGE	A gauge that can measure both pressure and vacuum.
COMPRESSION	Occurs when external forces try to push particles of a body together.
COMPRESSOR	A mechanical device that compacts air or other gases into a smaller volume to increase pressure. Rated for discharge pressure (pounds per square inch, psi) and flow rate (units of cubic feet per minute, cfm). Drive mechanisms include electric motors, gasoline engines, and steam or gas turbines.
CONCENTRATION	Refers to the amount of solute present in the solution. The amount of one solution dissolved in another solution.
CONDENSATE	Water formed in a condenser by condensation of turbine exhaust steam. The condensate system includes all equipment from the condenser hotwell to the boiler feed pump.
CONDENSATE POLISHING MIXED-BED ION EXCHANGER	A specially designed mixed-bed ion exchanger used to remove dissolved solids from condensate; usually contains 2-3 times as much cation resin as anion resin.
CONDENSATE PUMP	Multistage vertical pit type. Its purpose is to remove the accumulated condensate from the condenser hot well and discharge it to the suction of the boiler feed pump through the air ejector and low-pressure feedwater heaters and/or deaerator.
CONDENSATE SYSTEM	A system of heat exchangers, pumps, storage tanks, valves, and piping that are usually located between the condenser and the suction of the boiler feed pumps; also includes instruments that measure flow rates, pressures, and temperatures.
CONDENSER	A shell and tube heat exchanger that condenses vapor into liquid. The purpose of a condenser is to decrease the exhaust pressure of the turbine, thereby increasing thermal efficiency, and to condense the exhaust steam from the low-pressure turbine for return to the condensate and feedwater systems. Also functions to remove air and other non-condensable gases from the steam. The exhaust steam from the turbine flows down and around the condenser tubes where its latent heat is given up through the tube walls to the circulating water. The condensed steam collects in the hot well. Make-up condensate enters near the top of the condenser and is deaerated before added to the system. Condensers used in HECO power plants are surface condensers and are so named because steam is cooled and condensed by contact with the surface of metal tubes through which the cooling water is circulated.
CONDENSER LEAKAGE	Leakage of the circulating water through the condenser tubes into the condensed steam and from there carried into the boiler. This

	condition is usually detected by the checking of the conductivity of the hotwell condensate.
CONDENSING	The process of changing the state of water from a vapor to a liquid.
CONDUCTANCE	The measure of a material's ability to conduct an electric charge. The reciprocal of electrical resistance.
CONDUCTION	A method of heat transfer in which heat is transferred from a warmer object to a cooler object when the two objects touch. The transfer of heat from one part of a body to another part or to another body by short range interaction of molecules and/or electrons.
CONDUCTIVITY	The ease with which a substance transmits electricity. A measure of a solution's ability to conduct electrical current. A means of measuring the total ionizable (dissolved) solids in the water. An electrical method of measuring the resistance of a water solution by the passage of electricity through it. The quantity of dissolved solids usually is in direct proportion to the conductivity. The greater the dissolved solids, the higher the conductivity. Certain gases, namely carbon dioxide and ammonia, also increase the conductivity. High conductivity causes foaming and priming in the steam drum, thus causing carry-over. Measured in micromhos.
CONDUCTIVITY CELL	A device that passes an electrical current through a solution to measure the solution's conductivity.
CONDUCTIVITY PROBES	Electrical probes that initiate an action, such as activating an alarm, in response to changes in the level of a liquid.
CONDUCTOR	A body so constructed from conducting material that it may be used as a carrier of electric current. A material that offers very little resistance to current flow.
CONDUIT	A protective pipe or tubing that carry power cables. Most of the cables and wires are insulated.
CONSTANT	Unchanging in nature, value, or extent; invariable. A quantity taken to have a fixed value in a specified mathematical context.
CONSTANT DIFFERENTIAL PUMP, OR BOOSTER PUMP	maintains a fixed pressure difference between the suction and discharge, irrespective of the supply pressure.
CONSTANT SPEED MOTOR	A motor that receives a constant supply of energy and operates at a constant speed.

CONTACT PYROMETER	A portable temperature-measuring instrument that uses a probe in direct contact with the surface of the object being measured.
CONTACT SEAL	Seals the opening where the shaft leaves the housing to keep lubricants from escaping and contaminants from getting in. Usually made of a relatively soft material, such as felt, synthetic rubber, cork, or a synthetic material such as silicone. The outer ring fits tightly in a bearing housing while the inner ring or lip, presses against the spinning shaft.
CONTACTOR	An electrically operated device for energizing and de-energizing electrical equipment, usually low voltage.
CONTACTOR, OR MOTOR STARTER (M)	An electromagnetic switch that is a part of a motor controller. When the contactor is operated (energized), it allows current to pass through the controller to the motor.
CONTINUITY EQUATION	Consider the condition where water is flowing through a length of pipe. As long as there are no leaks and no water is added to or removed from the system, the amount of water flowing past any one point is equal to that flowing past any other point. This holds true regardless of any changes in pipe size or shape. The flow rate at any point in a pipe depends on the area available for flow and the velocity of the flow.
CONTROL BLOCK	A preprogrammed function, or algorithm, that a control program can use to help achieve control of a process variable. Commonly referred to as control slots or computational slots.
CONTROL BUS	A bus mounted in the rear of a switchboard or in the circuit breaker structure to distribute power for operating electrically controlled devices.
CONTROL CIRCUIT	A circuit carrying a low voltage used to operate various pieces of equipment such as circuit breakers, contactors, valves, etc., usually from a remote location.
CONTROL DEVIATION, OR ERROR	Difference between the set-point and the process variable.
CONTROL FIELD	Direct current applied to magnetic coils to cause variation of output voltage.
CONTROL LOGIC PROGRAM	A set of instructions programmed into a programmable controller that determines the actions to be taken and their sequence.
CONTROL LOOP	A control scheme or logic for control system operation. A single part of a control system that uses some form of mechanical or electronic automation to balance supply against demand. A collection of devices whose function is to maintain the value of a

process variable at or near set-point.

CONTROL POINT — The value at which a process variable returns to steady state.

CONTROL PRESSURE — The operating air pressure to the final control element which in turn regulates the measured variable.

CONTROL STAGE — The first stage of a turbine, consisting of a nozzle block and a row of moving blading.

CONTROL SWITCH — A switch for controlling electrically operated devices.

CONTROL VALVES — Valves that are used to automatically throttle flow. Work basically the same way as manually operated valves. Can be either linear or rotary. A linear control valve, such as a globe valve, has a stem that moves the valve disc up and down. A rotary control valve is positioned by rotation. Butterfly valves, which open or close with a 90-degree turn, are examples of rotary control valves. A globe-type control valve has the same basic parts as a manually operated globe valve. These parts include a valve body, a disc, a seat, a bonnet, a stem, and a packing assembly. Control valves can also have parts that may not be found in manually operated valves. For example, some control valves have guides that align the valve stem and disc with the valve seat. These guides help ensure precise control when the valve is opened and closed. The upper stem guide is housed above the packing, inside part of the packing assembly. The lower stem guide is held in place by a hollow cylinder with openings, called a cage. When the valve disc is moved away from the seat, fluid flows up through the seat, through the cage openings, and out of the valve.

CONTROL VALVES (TURBINE) — Steam valves leading to a turbine's inlet that regulate the amount of steam supplied to the turbine and consequently the amount of energy that the turbine receives; valves designed to regulate the flow of steam into the HP turbine during normal operation, and to serve as a backup to the main stop valves during shutdowns, to shut off the flow of steam into the HP turbine; sometimes called governor valves.

CONTROLLED CIRCULATION — A process that uses boiler water circulation pumps to move steam and water through boiler tubes.

CONTROLLER — A device or group of devices that serves to automatically regulate, in some predetermined manner, the electric or pneumatic signal delivered to the apparatus to which it is connected.
Controlling element. Part of the instrumentation systems that monitor plant process and respond to variations in the processes. A controller receives a signal from a transmitter, that represents the value of a process variable such as temperature, pressure,

	level, or flow; compares that signal to a set-point, which is the desired value for the process variable; and sends out a corrective signal to regulate the value of the process variable.
CONVECTION	A method of heat transfer in which a fluid is heated and then moved away from the heat source, carrying heat with it as it moves. The transfer of heat by the combined mechanisms of fluid mixing and conduction. The method in which heat is transferred by the motion of a heated medium. Transfer of heat by convection can only take place in moving fluids (liquids or gases). The primary mode of heat transfer within or between fluids.
CONVERSIONS	Equivalencies between units used to measure the same quantity.
CONVERTER	A device used to change one type of signal (such as an electronic signal) to another type of signal (such as a pneumatic signal).
COOLDOWN RATES	Rates provided by the turbine manufacturer to be used when shutting down the turbine; designed to minimize turbine damage and efficiency losses during the shutdown.
COOLING FINS	The parts on air-cooled compressors that provide additional surface area for the dissipation of heat.
COORDINATE POINT	The point on a graph at which the grid lines for an x value and a y value cross.
CORE	A mass of iron placed inside a coil to decrease the reluctance to magnetic lines of force.
CORE MONITOR	A device used to measure the amount of particulate matter in the hydrogen, inside a hydrogen-cooled generator.
CORONA	An electrical discharge into space caused by an excessive electrostatic stress surrounding an electrical conductor.
CORROSION	Destruction of metal by a chemical or electrochemical attack. Electrochemical is electrons flowing from the anode to the cathode. Corrosion due to dissolved gases results in pitting and deterioration of the boiler drum and the tube metal.
CORROSION INHIBITOR	A chemical, such as hydrazine, chromates, or nitrites, that protects metal surfaces from corrosion by forming a protective coating on the surfaces or by neutralizing corrosion-causing impurities in water.
COSINE OF THETA	The ratio of the adjacent side of a right triangle to the hypotenuse.
COUNTER ELECTROMOTIVE FORCE (CEMF)	Counter electromotive force; an EMF induced in a coil or armature by self-induction that opposes the applied voltage. Voltage induced in an operating circuit that opposes the existing

applied voltage. Also called self-induction.

COUNTERFLOW	A flow pattern in a surface heat exchanger in which two fluids flow in opposite directions; also called reverse flow. A turbine cylinder arrangement in which steam flows through one cylinder in one direction and through another cylinder in the opposite direction, or from the center of one cylinder to each end.
COUPLING	A device that connects the shaft of a driver to the shaft of the driven equipment. Pump couplings are divided into two categories: fixed and variable couplings. When a fixed coupling is used, the speed of the pump is fixed by the speed of the driver. To change the speed of the pump, the speed of the driver has to be changed. When a variable coupling is used, the speed of the pump can be changed without changing the speed of the driver.
COVALENT BOND	A bond in which the atoms involved complete their outer shells by sharing electrons between them to form molecules.
CPR	Cardiopulmonary Resuscitation
CRACKING POINT	The point at which a turbine control valve is nearly closed, and frictional loss in the valve is high. Partially open governor valves have a potential of up to 3% efficiency loss. Pressure and temperature drop across the valves.
CRITICAL MASS FLOW (TURBINE)	The point at which the steam flow through the turbine, is where it was designed for at full load. Where the steam flow is most efficient; Mach .9; just before Mach l, which is supersonic. It takes 1/10 of a second for steam to pass through the turbine. Approx. 1100 feet per second.
CRITICAL POINT	The point at which the density of water and the density of steam are the same; 705 degrees Fahrenheit and 3206 psi.
CRITICAL PRESSURE POINT	A pressure of 3206.2 psia of which there is no longer any change in volume between liquid and vapor. Saturation temperature is 705.34°F. A point at which the latent heat of vaporization is zero BTU'S per pound. Above the critical point, water flashes to steam, but there is no latent heat transfer. Above this point, water exists as a superheated vapor.
CRITICAL SPEED (COMPRESSOR)	Rotational speeds that may cause severe vibration. This vibration is caused by the physical characteristics of the compressor's rotating parts. Serious damage may occur. Critical speeds occur when the compressor is at less than full operating speed.
CRITICAL SPEED (TURBINE)	A speed at which the rotor will vibrate excessively.
CROSS FLOW	A flow pattern in a surface heat exchanger in which one fluid

flows at right angles to another fluid.

CROSS-CONNECT VALVE	A valve used to continue flow through both halves of a condenser if one of the circulating water pumps is shut down. This permits the turbine to continue to operate, even though load may have to be reduced. Sometimes referred to as a tie valve.
CUNO FILTER	A metal multidisc liquid filter which is cleaned by rotating an external handle which turns the inner discs. Mounted on the lube oil reservoir to filter high pressure oil to the turbine control system.
CURRENT	A flow of electric charge, measured in amps. The movement of electrons, or electrical charges, from one place to another. Substance of electricity as to water in piping.
CURRENT TRANSFORMER (CT)	A small transformer for instrumentation, measuring heavy currents in power leads. A component that typically steps line current down to a lower current that is in direct proportion to the amount of line current. All current transformers are designed so that the output of current will be 5 amperes when maximum current flows in the input circuit. Used to supply current at a reduced value to devices such as ammeters and relays that are used to monitor and control the power in the system. The current transformer does not affect the current flowing from the main transformer to the rest of the system, but it does allow the current to be measured. Connected in series with the main circuit. Frequently the CT is made in the form of a torus or donut and is installed around the conductor whose current is to be measured. In these cases, the main conductor acts as an input circuit of one turn. The output circuit then contains sufficient turns to produce an output current of 5 amperes when rated current flows through the main conductor.
CURTIS, OR IMPULSE STAGE	An impulse stage in the high pressure turbine using two rows of moving blades with a stationary row of blades between the two rows of moving blades. Steam flows from the nozzle block to the curtis stage, then to the impulse section.
CURVE	A line used to connect points plotted on a graph, regardless of whether it is actually curved or straight. Represents the relationship between the variables on the two axis.
CUSUM (SPC)	Cumulative summation; a method of using Statistical Process Control (SPC) that typically involves a computer. The difference between the average value of the variable that is being monitored and its desired value, or “aim”. When cusum detects an out-of-control condition, it may automatically adjust the process, or it

	may simply recommend an adjustment. If a cusum system experiences problems, or if it is provided with inaccurate information, and off-aim condition can occur. Two causes of an off-aim condition are overreaction and underreaction.
CYCLE (SINE WAVE)	One complete positive and one complete negative alternation of a current or voltage wave-shape; one complete sine wave. See Hertz.
CYCLE (SPC)	A pattern that forms when data points fall above or below the process centerline in an alternating pattern. Could mean the process is being adjusted too frequently, which is called over-control. Could also mean the amount of adjustment made is too great.
CYCLING UNITS	Units which operate with rapid load changes, frequent starts and stops but generally at somewhat lower efficiencies and higher operating costs than base load units.

D

DAMPER (LOUVERS)	A device used to regulate the flow of air through a fan. A type of final control element that use a number of adjustable parallel vanes, or blades, to control the flow of air and other gases.
DC MOTOR	Direct current from a battery source flows through a conductor (rotor, or armature) and creates a magnetic field around the conductor. This magnetic field interacts with another magnetic field (stator) to produce motion. Utilizes commutator and brushes to change the polarity of the rotor. The stator is the electromagnet.
DC TURNING GEAR OIL PUMP	This pump is identical to the AC turning gear oil pump but is driven by a DC motor. This is the final back up to the bearing oil system. This pump protects the turbine in case of loss of AC power. It should have sufficient DC storage battery capacity to operate for approx. 30 minutes which is the approx. time required for a unit to coast down from 90% to 0 speed.
DCS	Distributed Control System. The DCS is the computer system (often a large computer system) which controls and monitors many aspects of a large plant's operation. The DCS often communicates with several PLC systems and is capable of providing operator control, or monitoring of these PLC systems.
DEAD TIME	The amount of time required to transfer energy from one point to another. The amount of time between an operating change and a process's initial response to the change.

DEAD ZONE	The amount of change that can occur in a process without triggering a control action.
DEAERATE	To remove dissolved gases.
DEAERATOR	A direct contact low pressure heater in the condensate-feedwater system that heats water, and also removes corrosive, non-condensable gases which are entrapped or dissolved in the condensate make-up. The main gases to be removed are oxygen (O2) and carbon dioxide (CO2). Condensate entering the deaerator flows through a spray bar at the top of the deaerator and is mixed with the steam where it receives its heating and deaerating. A type of open feedwater heater in which the steam and feedwater mix together.
DEFECT (SPC)	A product characteristic, such as color, size, or shape, that does not match design specifications.
DEFECTIVE PRODUCT (SPC)	A product that is unusable because it has one or more defects. The quality standards set by the company or by the end user determine how many defects are allowed before a product becomes unusable and is considered defective.
DEFOAMING TANK	Oil returning from the hydrogen side of the glands goes to two de-foaming tanks which are designed to remain half full so that foam will have an opportunity to come out of the oil. The oil level in the de-foaming tanks is maintained by a float valve which is located inside one of the tanks and an equalizing line between the two tanks keeps the oil in both at the same level. This float valve prevents gas escaping from the generator housing through the drain line. Separate tanks are used for each so that any slight difference in the fan suction at the two ends will not cause a circulation of oil vapor through the machine. The oil in these tanks serves as a buffer in case of an explosion and protects the main oil system in such an event.
DEGASIFIER	A component that removes carbon dioxide and other gases from water. Contains baffles that water passes over to liberate undesired gases, which is then removed by the vacuum pump.
DEGREES OF SUPERHEAT	Difference between the actual temperature of the superheated steam and the saturation temperature for the existing pressure.
DELTA CONNECTION	A type of electrical connection used in three phase circuits that is formed by connecting the three phases of a component at three separate points.
DEMAND	The amount of power needed by a power system's customers. The load at the terminals of an installation or system averaged

	over a specified interval of time. Demand is expressed in kilowatts, kilovolt amperes or other suitable units.
DEMAND-SIDE MANAGEMENT (DSM)	The planning, implementation, and monitoring of utility activities designed to reduce customer use of electricity in ways to obtain a desired change in shape of the utility's daily load curve or offset/delay the need for increased power generating capacity.
DEMINERALIZED WATER	Water from which most of the solids and gases have been removed, in order to make it chemically pure for boiler feed water purposes.
DEMINERALIZER	Takes minerals from the water using an ion exchange method to remove impurities and solids.
DEMING, W. EDWARDS	Researcher from the Census Bureau; strong supporter of SPC. Taught Japanese managers, engineers, and scientists how to use statistics to improve quality.
DEMISTER (COMPRESSOR)	Removes moisture from compressed air, sent from the aftercooler. Compressed air is swirled around inside a cylinder. The swirling action causes the heavier moisture to separate from the lighter air and collect in the bottom of the cylinder. The moisture is then drained from the system, and the dry compressed air is sent on to other components in the system.
DEMULSIBILITY	A measure of the oil's ability to separate readily from water and is the property that guards against the formation of permanent emulsions.
DENSITY	A comparison between the weight of a material and its volume. The weight per unit of volume of any material. Total mass (weight) divided by its total volume. Commonly expressed in units such as pounds per cubic foot, or grams per cubic centimeters.
DENSITY BUBBLER SYSTEM	A system that measures the density of a liquid by using different pressures. The density indication is expressed as a percent concentration of a particular substance in the liquid.
DENSITY METER	Purity of the gas in the generator is determined by use of the density meter and density meter blower. The density meter is a differential pressure gauge measuring the pressure developed by the density meter blower. An induction motor, loaded very lightly so as to run practically at constant speed, drives the density meter blower and circulates gas from the generator housing. Thus the pressure developed by the blower varies directly with the density of the machine gas. The scale of the density meter is graduated in percent with 100% corresponding to the density of air at

	atmospheric pressure.
DERATING EXTENSION (DE)	An extension of a Planned Derating (PD) or a Maintenance Derating (MD) beyond its estimated completion date.
DERATINGS	Exists whenever a unit is limited to some power level less than the unit's Net Maximum Capacity.
DESICCANT	A moisture-absorbing chemical.
DESICCANT DRYER (COMPRESSOR)	Removes moisture that may be present in the compressed air, using chemicals called desiccants. Two commonly used desiccants are silica gel and activated alumina. Located just before the air receiver.
DESUPERHEATER	A component that controls steam temperature by spraying a fine mist of water into steam pipes; also called an attemperator.
DETRAINING TANKS	Tanks in a seal oil system that remove hydrogen and air trapped in oil.
DEVIATION	The difference between the set point of a process variable and the existing value of the process variable.
DEW POINT	The temperature at which air with any given moisture content must be cooled to produce saturation of the air and begin condensation of its vapor. Air at its dew point temperature has 100% relative humidity.
DIAL THERMOMETERS	Have a round face very similar to a pressure gauge except that it is calibrated in temperature units rather than pressure units. A movable pointer indicates the temperature on the dial.
DIAPHRAGM	A stationary part of a turbine; a diaphragm contains blades or nozzles that direct steam from one set of rotating blades to the next. A row of fixed blading that consists of an inner ring, which surrounds the shaft, and an outer ring, which attaches the row to the turbine casing.
DIAPHRAGM ACTUATOR	One of the most common types of pneumatic actuators. Air pressure acts on a flexible diaphragm to position a valve.
DIAPHRAGM PRESSURE ELEMENT	A type of pressure element that has a plate, or diaphragm, that flexes in response to changes in pressure and moves a pointer through a mechanical linkage.
DIAPHRAGM VALVE	A valve in which a flexible membrane is used. Has a bell-shaped bonnet. Uses a flexible diaphragm that is positioned on or near a weir, or dam-shaped seat, to control or stop fluid flow. A stud connects the diaphragm to a plunger that is moved by the valve stem. A handwheel is sometimes used to raise and lower the stem.

	When the handwheel is turned clockwise, the stem and the plunger lower the diaphragm, which presses against the seat to stop flow through the valve. When the handwheel is turned counterclockwise, the diaphragm is moved upward, and flow through the valve can begin. A diaphragm valve can be used for both on/off and throttling purposes. The diaphragm in this type of valve also serves as a seal that keeps fluid from coming in contact with the rest of the operating parts of the valve. This design makes the diaphragm valves well suited for use in systems carrying corrosive materials such as acids and caustics. Some diaphragm valves also contain a plastic cover to help protect the body of the valve from corrosive fluids. Excessive force should never be used to close a diaphragm valve. Excessive force can cause the plunger to jam the diaphragm against the seating area, which could cut the diaphragm. If the diaphragm is cut, the valve may leak through from the valve inlet to the valve outlet, around the stem or at the body-to-bonnet joint.
DIELECTRIC	An insulator; a term applied to the insulating material that separates the parallel plates inside a capacitor.
DIESEL	An internal combustion engine that burns diesel fuel and uses the compression of air to initiate combustion.
DIFFERENTIAL EXPANSION	Difference in growth between the rotor, and turbine casing, caused by uneven heating between the rotor and casing. The difference between the rates at which a turbine rotor and a turbine shell expand or contract in response to temperature changes.
DIFFERENTIAL PRESSURE (DELTA P)	The difference in the pressure of a fluid, such as circulating water, from one point of measurement to another.
DIFFERENTIAL PRESSURE (DP) CELL	A device that measures the pressure difference across an orifice or other flow restrictor. The output of a DP cell is often used to measure flow through a flow restrictor. Measures the differential between two pressures and provides a corresponding flow rate signal. An indirect measurement.
DIFFERENTIAL RELAY	A protective relay that operates whenever there is a difference between the currents going into and coming out of electrical equipment. A relay that compares the power produced by a generator and the power leaving a transformer. If there is a significant difference, the relay opens a circuit breaker.
DIFFERENTIAL TEMPERATURE	The change, or difference, in the temperature of a substance across a system or an object.
DIFFUSER (CENTRIFUGAL PUMP)	Consists of a series of stationary vanes that surround the impeller. The distance between the outer tips of the vanes is greater than the

	distance between the inner tips. As a result, the vanes create a series of small volutes all around the impeller. This arrangement of vanes balance the radial thrust around the impeller.
DIFFUSER VANES (COMPRESSOR)	A series of plates, or vanes, designed to minimize radial thrust in centrifugal compressors.
DIGITAL CONTROL SYSTEM (DCS)	Contains one or more computers. Process control computers use data to provide the user with information, and also provide process control action. They do this either by directing the actions of controllers that control the values of process variables or by controlling the values of process variables themselves. Process computers can work with other devices to start up or shut down process systems. A digital control loop contains a digital controller. A digital controller uses a built-in computer to control the value of a process variable. The computer performs the control function by executing a set of instructions called a control program. The control program is stored in the computer's memory. Along with the control program, the computer's memory can store information associated with several control loops. The digital controller can be part of more than one control loop at a time. This means one digital controller can control the values of more than one process variable at a time. A digital signal consists of electrical pulses that, when taken in groups, represent information. An advantage of digital control systems is that they can efficiently organize large quantities of data into readily understandable information displays. These displays provide information such as the values of process variables, the status of equipment in a system, and the overall condition of a facility. Magnetic tapes and discs are used for processes that produce two or more different products. The tape or disc is used to put new values into the control systems to change from one product to another.
DIGITAL INDICATOR	Indicators that display only the number that represents the value of a process variable. The numbers are typically either electronically lighted or on rotating wheels.
DIGITAL SIGNAL	A type of signal that consists of electrical pulses, that, when taken in groups, represents information.
DIODE	A two-terminal semi-conductor device used chiefly as a rectifier.
DIRECT CONTACT HEAT EXCHANGER	A heat exchanger in which two fluids come in contact and mix with each other.
DIRECT CURRENT	Current that always flow in the same direction.
DIRECT DIGITAL CONTROL	Main component is a DDC computer. A DDC computer often has

(DDC)	a built-in control panel and display screen. The computer directly inputs and outputs data that it needs to control all of the control loops in the process. During the operation of a DDC system, input signals are sent from the process to the computer. The computer stores the input signal values in memory. Each input value is compared to the appropriate set-point value to determine a corresponding output value. The computer uses the output values to generate output signals. The output signals are sent directly to control devices that adjusts parameters within the process to keep it under control.
DIRECT FLOW MEASUREMENT DEVICE	Measures the actual flow of the fluid that passes through them.
DIRECT LEVEL MEASUREMENT DEVICE	A device that indicates level based on the position of the surface of the substance being measured. Gauge glass; plumb bob; float and tape.
DIRECT PROPORTION	A proportionality in which when one variable increases by a specific multiple, another variable increases by the same multiple; when the first variable decreases by a specific multiple, the second variable decreases by the same multiple.
DISC	A movable part of a valve that presses against a seat to stop fluid flow.
DISC TRAP	Thermodynamic trap. Consists of a round flat disc positioned over a center inlet orifice and an annular discharge leading off through a discharge port. All are enclosed within a bonnet mounted on the body of the trap. When operation starts, pressure in the inlet orifice pushes the disc up vertically off the two concentric seating surfaces surrounding the inlet and outlet ports. This allows discharge to flow out through the discharge port. When very hot condensate and steam come to the trap, the high velocity flow outward past the rim of the disc up into the chamber and tends to reduce the pressure on the under side of the disc causing some of the condensate to turn to flash steam. At the same time the flashing condensate flowing outward at high velocity strikes the side wall of the chamber causing a build up of pressure in the chamber snapping the disc shut. The disc remains in the closed position until the pressure in the bonnet falls due to the condensing of the steam in the bonnet. When pressure in the bonnet falls sufficiently the disc rises, condensate flows out and the cycle is repeated.
DISCHARGE HEAD (PUMPS)	The head at the outlet of a pump.
DISCONNECT SWITCH	A switch that can isolate a circuit from it power source by

	interrupting current flow; generally used in conjunction with a circuit breaker.
DISODIUM PHOSPHATE (DSP)	Raises PO4 levels in the boiler water. Will not contribute to raising pH, in fact it may suppress it a little. Ties up calcium and magnesium as a flocculent phosphate precipitate which can be removed through boiler blowdown. Elevates the total dissolved solids levels, therefore causing conductivity to rise. Prevention of scaling on tubes and drums.
DISPATCHING	The control of an integrated electric system to assign generation to specific generating stations, and control operation and maintenance of high voltage lines and substations.
DISPERSANTS AND DETERGENTS	Chemical additives added to oils and greases to reduce the formation of carbon deposits and sludge. These additives keep particles in the lubricant suspended, so that deposits and sludge do not form.
DISPLACER	A device used to measure level in fluid systems. The operation is based on the principle of buoyancy. This principle states that when a body is immersed in a fluid, it is lifted, or buoyed up, by a force that is equal to the weight of the displaced fluid.
DISPLAY KEYS (COMPUTER)	Used along with number and letter keys to call up information displays.
DISSOLVED SOLID	A solid that is dissolved in a solvent, usually water.
DISTILLATE	The liquid that is condensed from process vapors other than steam.
DISTILLATION	A method of separating liquid products and reactants.
DISTRIBUTED CONTROL SYSTEM (DCS)	A type of process unit digital control system in which control of a process is divided among and coordinated between various control units. Uses numerous digital controllers to control different parts of a process. These controllers can act independently.
DISTRIBUTION (MATH)	An operation in which the quantity that is outside of a grouping symbol is multiplied by each term that is inside the grouping symbol.
DOUBLE-ACTING DIAPHRAGM ACTUATOR	Called double acting because air pressure acts on both sides of a flexible diaphragm to position a valve. Consists of a casing, a flexible diaphragm, an upper air supply port, a lower air supply port, a stem, and a valve position indicator, which shows the position of the valve. The center of the diaphragm is supported by metal plates, and the outer edge is sandwiched between the rims of the upper and lower halves of the casing to form an airtight seal.

	This arrangement divides the casing into two chambers: an upper chamber and a lower chamber. The upper end of the actuator stem is connected to the metal plates and the diaphragm. The lower end is connected to the valve stem. When air pressure is applied to the upper chamber, the diaphragm and the actuator stem are pushed downward, and the valve closes. Air in the lower chamber is exhausted through the lower air supply port. When air pressure is applied to the lower chamber, the diaphragm and the stem are pushed upward, and the valve opens. Air in the upper chamber is exhausted through the upper air supply port. Stem movement and valve position are proportional to the difference between the two air pressures applied to the chambers of the actuators. Controlling the applied pressures enables the actuator to position the valve anywhere within the limits of travel for the actuator. In most applications, accurate positioning is achieved by using a device such as a positioner to add air to one side of the diaphragm and bleed it off the other side.
DOUBLE-ACTING HYDRAULIC ACTUATOR	Uses hydraulic fluid pressure to both open and close a valve. Consists of a cylinder, a fluid port at the base of the cylinder, a second fluid port at the top of the cylinder, a piston, and a piston rod, which is connected to the valve disc. Fluid can enter the cylinder through either of the two ports to move the piston to either open or close the valve. If fluid enters through the top port, it pushes the piston and piston rod and closes the valve. An equal volume of fluid is bled through the port at the base of the cylinder. When fluid flow is directed into the other port, it causes the piston and piston rod to move in the opposite direction, opening the valve. At the same time, an equal volume of fluid flows out of the top port. When the flow of fluid is stopped, fluid is trapped on both sides of the piston, and the piston is held in place by the trapped fluid. The piston can be positioned anywhere in the cylinder by controlling the amount of fluid entering the cylinder through one port and bled from the cylinder through the other port.
DOUBLE-ACTING PISTON ACTUATOR	Similar to those of a single-acting piston actuator. However, a double-acting piston actuator may not have a spring, and it may have an air supply port on each end of the cylinder. When air pressure is fed into one of the supply ports, it pushes against that side of the piston. The force of the air pressure moves the piston to open or close the valve, depending on which port supplies the air. Air on the other side of the piston is bled off through the other air supply port. When air is fed in through the supply port in the opposite end, the piston and valve disc are pushed in the other direction. Air is bled off through the other supply port. Filling

	the cylinder with air and bleeding air from the cylinder can be controlled by a device called a positioner.
DOWNCOMERS	Large diameter tubes connecting the main steam drum to the lower headers, ensuring positive water circulation. Located outside of the boiler.
DRAFT	The amount of pressure or vacuum inside a furnace, or the flow rate through the furnace. Normally expressed as "inches of water."
DRAIN COOLER APPROACH (DCA)	The difference between the temperature of the drips leaving the drain cooler section of a feedwater heater and the temperature of the feedwater entering the tubes from the inlet water box.
DRIP PUMP	The pumps, handling heater drips are of the centrifugal type and, except for low pressure drip pumps, are multistage to handle high volumes and discharge heads necessary to overcome condensate line pressure. Drip pumps on heaters that drop below atmospheric pressure at low loads are treated in much the same manner as condensate pumps. Venting, suction head, recirculation and gland sealing must be considered to prevent air leakage at the pump glands and flashing in the pump suction.
DRIPS	Condensate formed on the shell side in a feedwater heater as steam transfers its energy to the feedwater and gives up its latent heat of condensation.
DRIVER (PUMP)	Purpose is to supply the power needed to produce the pumping action. Electric motors, gasoline engines, steam or gas turbines.
DROOP	The reduction in speed of a generating unit as load increases.
DRUM-TYPE BOILER	A type of boiler that has a large steam drum located on top to collect the steam produced by the boiler.
DRY BULB TEMPERATURE	The air temperature as indicated by any sort of thermometer which is not affected by the moisture in the air.
DRY CELL	A type of battery in which the electrolyte is a paste; typically, a primary cell.
DRY GAS LOSS	Heat contained in the exhaust gas that goes up the stack.
DRY SCRUBBER	Mixes the combustion gases with a powder to remove sulfur oxides. The powder, often called sorbent powder, absorbs the sulfur oxides, removing them from the combustion gases. The combustion gas and powder mixture is then passed on to a gas collector, where the powder, along with other particulates in the combustion gases, is removed. The dust collector is often either a electrostatic precipitator, or a baghouse.

DSI	Digital Input Slave
DSO	Digital Output Slave
DUMMY BALANCE PISTON	Turbine spindle accessory for balancing axial end thrust. One located before the HP section (HP dummy piston), which connects to an equalizing line, then to the end of the IP section (LP dummy piston). Is actually a rotating blade with a solid center, and small blades on the outside. The pistons are different in size to equalize thrust.
DUPLEX STRAINER	A two-basket strainer that allows one strainer element to remain in operation while the other element is shut down.
DYNAMIC COMPRESSOR	A compressor that compresses air by accelerating it.
DYNAMIC HEAD (PUMPS)	The head that exists when a liquid is in motion.
DYNAMIC RESPONSE CURVE	Illustrates a basic fact about a system's response to operating changes. The response is gradual, not immediate.

E

EAF	Equivalent Availability Factor
ECCENTRICITY	The degree of deviation from absolute roundness; the amount that the rotor deviates from its normal center of rotation. A condition associated with a bowed turbine shaft. Measured under 600 rpm.
E-CELL STACK	The basic module of the E-Cell System. Capable of producing 12.5 gpm of deionized water (GLEGG).
E-CELL SYSTEM	Any combination of E-Cell Stacks connected together to produce deionized water.
ECONOMIZER	Preheats the boiler feedwater before it is introduced into the steam drum, by recovering some of the heat of the flue gases leaving the boiler. Located in the boiler gas pass, below the primary superheater. It is composed of a number of parallel tube circuits, arranged in horizontal rows in such a manner that each row is staggered in relation to the row above and below. The economizer tubes are provided with fins, to increase the amount of effective heating service. The fins also strengthen the economizer tube construction while their stream-lined shape prevent accumulation of fly-ash on top or bottom. Feed water is supplied to the economizer inlet header via feed stop and check valves. The feed water flow is upward through the economizer, that is, in counter flow to the hot flue gases. Most efficient heat transfer is hereby accomplished, while the possibility of steam generation within the economizer is eliminated by the upward water flow. From the

	outlet header the feed water is led to the steam drum through the economizer outlet links.
ED (ELECTRODIALYSIS)	An electrochemical separation process in which ions are transferred through membranes from a less concentrated to a more concentrated solution as a result of the flow of direct electric current.
EDR	Electrodialysis Reversal. An electrochemical separation process in which ions are transferred through membranes from a less concentrated to a more concentrated solution as a result of the flow of direct electric current.
EDR (ELECTRODIALYSIS REVERSAL PROCESS)	This method employs electrochemical and membrane cell technologies to perform separations of ionic materials in aqueous solutions. An electrodialysis process in which the polarity of the electrodes is reversed on a prescribed time cycle thus reversing the direction of ion movement in a membrane stack.
EFFECTIVE VALUE	The equivalent heating value of an alternating current or voltage, as compared to a direct current or voltage. It is 0.707 times the peak value of the alternating current or voltage sine wave. It is also called the RMS or root mean square value.
EFFICIENCY	The amount of energy expended to do work divided by the amount of energy supplied. The relationship between work and energy. The ratio of input to output power, generally expressed as a percentage.
EFFICIENCY CURVE (PUMPS)	Used to examine a pump's efficiency. The vertical axis is usually marked to indicate efficiency, from 0 to 100%. The horizontal axis indicates flow rate.
EFOR	Equivalent Forced Outage Rate. Measures the percentage of time the generating units were not available due to unplanned outages. Unscheduled unit trips (forced outages), inability to synchronize (startup failures), and unscheduled unit blocks (forced deratings) affects the EFOR. If the derating or outage can wait beyond the next weekend, it does not count against us in terms of our EFOR goal. The term "risk", as we use it, has no impact on EFOR. "Risk" has no impact on a unit's ability to make full load. The availability of blackstart generators, although critical for us, does not impact EFOR, as blackstarts are not "official" generating units.
EHC	Electro-Hydraulic Control System (electronic governor)
ELASTIC LIMIT	The point at which the force applied to a solid exceeds the ability of the solid to return to its original shape. The point at which the

	solid will remain deformed.
ELASTICITY	The ability to return to their original shape after being deformed by stress.
ELECTRIC ACTUATOR	Use electricity to produce motion. They usually fall into one of two general classifications: solenoid or motor-operated. A motor-operated actuator is often referred to as a motor operator.
ELECTRIC BOLT HEATER	Alloy steel bolt and studs in the high pressure and/or high temperature flanges, should be tightened sufficiently to produce a definite amount of stretch. The purpose of the electric bolt heater is to expand cylinder bolts by internally heating then so that they may by tightened (stretched) a specified amount, without resorting to heavy wrenching or the use of a "tensioner".
ELECTRIC FIELD	A space in which an electric charge will experience a force exerted upon it.
ELECTRIC GENERATOR	A machine which converts mechanical energy into electrical energy.
ELECTRIC MOTOR	A machine which converts electric energy into mechanical energy.
ELECTRICAL DIAGRAM	A drawing that generally uses letters, numbers, symbols and lines to identify components and show how they are connected electrically in a system. Use lines to represent flow paths for electric current, and symbols to represent equipment in the system.
ELECTRICAL ENERGY	Produced when electrons, each of which possess a unit negative charge of electricity, are made to flow in a circuit. Units are kilowatt-hours (KW-HR) or megawatt-hours (MW-HR).
ELECTRICAL POTENTIAL	Any occurrence that causes an electrical charge imbalance, or, in other words, anything that causes the number of electrons to be different from the number of protons. An electrical potential is a situation that can lead to an electrical discharge. When an electrical discharge occurs, electrons, or electrical charges, move from one place to another. One example of an electrical potential is static electricity. Three of the many sources of electrical potential are chemical action, heat, and light.
ELECTRICITY	Pumping of electrons, called current, in a conductor caused by a force called voltage.
ELECTRODE	A solid electric conductor (terminal) through which an electric current enters or leaves a medium or through which current leaves or enters an electrolytic cell, such as a battery. Generally some type of metallic material that becomes charged as a result of a

	chemical reaction.
ELECTRO-HYDRAULIC CONTROL SYSTEM	A turbine control system that uses an electronic governor and oil from an independent oil supply to monitor and control turbine speed.
ELECTROLYSIS	Chemical decomposition that results from the action of electrical current through a solution.
ELECTROLYTE	A solution which is capable of conducting electricity. An electrolyte may be in the form of either a liquid or a paste.
ELECTROLYTES	Dissolved solids that are normally present in water and are capable of conducting electricity through the water. A substance that dissociates into ions in solution or when fused, thereby becoming electrically conducting.
ELECTROLYTIC CELL	Made up of electrodes and the beaker of solution, which produces a voltage in relation to the PH of the solution.
ELECTROMAGNET	A magnet made by winding a coil of wire around a soft iron core. Current passing through this coil produces magnetic lines of force in the core. Magnets created using DC currents. The strength of the magnetic field around an electromagnet is proportional to the flow of current through the coils.
ELECTROMAGNETIC FIELD	A field around a conductor or instrument, traversed by the electromagnetic waves set up by current in the conductor.
ELECTROMAGNETISM	Magnetism that is created by current flowing through a conductor.
ELECTROMATIC RELIEF VALVE	Normally closed. Operated to open by an electrical impulse which is triggered when the pressure in a line or vessel reaches a predetermined set-point. Installed on the superheater outlet with a shut-off valve. Can be operated automatically or manually. Set to "pop" first, ahead of all other safety valves on the boiler, thus saving the need for constant overhaul of the safety valves, which would require a shutdown of the unit.
ELECTROMOTIVE FORCE	The electrical pressure that moves or tends to move electrons. Voltage; potential difference. Unit of measurement is the volt.
ELECTRON	The negatively charged particles of matter. A negatively charged particle that orbits around the nucleus of an atom.
ELECTRONIC TRANSMITTER	A device that senses and measures a process variable and produces an electronic output signal that is proportional to the value of the process variable.
ELECTROSTATIC	The movement, or flow of electrons from one place to another,

DISCHARGE	resulting from a high electrical potential. One of the most dramatic examples of an electrostatic discharge is lightning. Lightning occurs when atmospheric conditions cause a huge electrical potential to be built up between clouds and the earth. When the charge imbalance is great enough, a tremendous arc forms that we call lightning. Electrostatic discharges are situations in which there is a momentary flow of current.
ELECTROSTATIC FIELD	The field of influence between two charged bodies.
ELECTROSTATIC PRECIPITATOR	Remove particulates using an electrical charge. Has several power sources that create a positive charge on a series of metal plates, and a negative charge on a series of wires located between the plates. As the combustion gases pass through the precipitator, the particulates pick up a negative charge from the wires and are attracted to the positively charged metal plates. Devices called rappers are used to physically jar the collected particulates loose from the plates. The particulates slide into a collection hopper in the bottom of the precipitator. From there, they can be removed from the system.
ELEMENT	A basic substance consisting of atoms of only one kind. Pure substances which cannot be broken down into simpler substances by any chemical reaction or change. Made up of tiny particles called atoms which can not be divided by any chemical means. Basic building blocks of all materials. Characterized by the number of protons in their atoms. This number is called the element's atomic number.
ELEVATION DRAWING	Shows where equipment is located on different levels in a plant. Looking at an elevation drawing is like removing a wall and seeing a side view of the equipment on different levels.
EMERGENCY DRAIN VALVE	A high level dump valve in an emergency drain line from a feedwater heater to the condenser.
EMERGENCY OIL PUMP (DC)	A battery-powered pump that supplies oil to the turbine bearings while the turbine coasts down following a loss of AC power. Provided as a back-up in case all AC power is lost. Can be started by its own pressure switch that is connected to the bearing oil line when the pressure decays to somewhere between 3 to 4 psig.
EMF	Electric & Magnetic Field or Electromagnetic Field
EMS	Energy Management System. A system-wide computerized control that controls speed (frequency) and loading of all units within the range of the individual unit's set limits and efficiencies, when those units are connected thereto.

EMS INHIBITOR	Will stop EMS "raise" pulses to the governor when the throttle pressure decreases to the set-point. Pressure switches are set at 85-95% of rated throttle pressure. When the throttle pressure rises to the reset pressure, normal EMS pulsing will resume.
ENCLOSED BUS	A bus having its conductors enclosed in an insulating or metal enclosure.
END BELLS (MOTOR)	House the bearings that support the motor's shaft.
ENDOTHERMIC REACTION	Chemical reactions that must be continually provided with energy from outside in order to keep going.
ENERGY	Implies that a capacity for action is present; broadly defined as the ability to produce a change from the existing conditions. The capacity of a body to do work. Can neither be created nor destroyed, but only altered in form. That which does or is capable of doing work; electrical energy is usually measured in kilowatt-hours.
ENERGY MANAGEMENT SYSTEM (EMS)	Controls frequency and provides for economic load dispatch of generating units. Pulses the individual generating unit governor to change the generator output in response to system frequency deviation (Load/Frequency Control). Calculates the increase or decrease in total system MW generation to correct the frequency deviation.
ENTHALPY	Thermal energy or heat content of one pound of a substance. The amount of heat or energy contained in a fluid. The amount of energy that is contained in each pound of steam. Enthalpy can only be used with fluids because it is the sum of the flow energy and internal energy expressed in heat units.
ENTRAINMENT	The process by which water containing impurities is picked up and pushed along by steam.
ENTROPY	An indication of the energy in a material that is not available for doing useful mechanical work; unrecoverable energy; typically expressed in BTU's per pound per degree. A calculated property used to evaluate the efficiency of a process.
EP ADDITIVES	Chemicals added to gear oils to protect metal surfaces against wear from rubbing. The letters "EP" stand for extreme pressure. Used in greases or oils to form a protective coating on the exposed metal. The coating stays in place and prevents metal-to-metal contact even if the lubricant is rubbed away.
EPM (EQUIVALENTS PER MILLION)	A method of expressing ionic concentrations in terms of equivalent electrical charges.

EPRI	Electric Power Research Institute
EQUATION	A way to show how two mathematical expressions are equal even though they may seem to be different.
EQUILIBRIUM	A state of balance between two different concentrations.
EQUILIBRIUM REACTION	A reversible reaction; a reaction in which reactants form products and products revert back into reactants. As reactants are forming products, the products are reverting back into reactants. There is never a time when all of the reactants are gone, because some of the products are always reverting back into reactants. Equilibrium reaction reach a state of balance when the reactants are forming products at the same rate that the products are reverting back into reactants. This state of balance is called the equilibrium point. The proportions of reactants and products do not change once the equilibrium point is reached. Equilibrium reaction is both exothermic and endothermic reactions.
EQUIPMENT ARRANGEMENT DIAGRAM	Show the locations for pieces of equipment in a plant. Each type of equipment is represented by a symbol. Equipment shown on diagrams is usually labeled with its name, its equipment number, or both. For example, a pump may be labeled "P-31-A", for pump 31-A. Some diagrams may also show the distances between equipment.
EQUIPMENT CAPACITY	A system's actual production capacity.
EROSION	The wearing away of metal surfaces caused by the flow of a substance. To wear away by abrasion.
ERROR (CONTROL SYSTEMS)	The difference between set-point (requested value) and the actual value. This forms the basis of all control systems, including our governor.
EVAPORATED WATER OR DISTILLATE	Water obtained from an evaporator and used for boiler feed water purposes.
EVAPORATOR	A piece of equipment that removes suspended solids and dissolved solids from water by heating the water to produce steam. Makes distilled water through the distillation process; boiling. The boiler has to be at a high pressure in order for the proper distillation to occur. Evaporators usually do not make enough distilled water to accommodate make-up water supply.
EXCESS AIR	Air supplied to the boiler in excess of the theoretical amount required for complete combustion of the fuel. This excess amount of air is necessary to ensure complete combustion on a practical basis. Excess air, to satisfy percentage O2 versus load signals, are shaped during start-up field testing. The measured O2 value us

	compared to the desired O2 set point for each load index. Deviation from this comparison causes an integrated signal to correct the air demand feed forward signal to satisfy the pre-designed O2 curve versus load. Departure from the normal O2 calibrated set point may be biased to correct for any operational desired condition. The bias correction merely raises or lowers the calibrated curve to a new parameter position.
EXCESS OXYGEN	The term used to describe the oxygen going up the stack.
EXCITATION	Current flow that causes the field magnetic flux in motors and generators.
EXCITER	A device that produces and supplies direct current to a generator's rotor windings. A DC generator which supplies energy for the field excitation of another electric machine. Balances the flux on the generator. Matches the torque.
EXHAUST HOOD	The exhaust section of the outer casing in the LP turbine.
EXHAUST TRUNK	Turbine exhaust connection to the condenser.
EXOTHERMIC REACTION	Chemical reactions that produce energy once they are started. After an exothermic reaction is started, it continues by using the energy it produces.
EXPANSION JOINTS	Joints in steam piping that allow for movement that may result from the flow of a large volume of water or from temperature variations in a system. A joint in a piping system that takes up movement from thermal expansion and from equipment vibration.
EXPANSION LOOPS AND BENDS	Loops and bends that allow for expansion and contraction in piping due to temperature changes.
EXPONENT	A number that indicates how many times another number is to be multiplied by itself; also, the power of a number.
EXTRACTION BLOCK VALVE	A valve that isolates a feedwater heater from the turbine.
EXTRACTION NON-RETURN VALVE	A fast acting swing check valve that prevents extraction steam or water from flowing back into the turbine.
EXTRACTION STEAM	Steam that is extracted from the turbine and used by the feedwater heaters to heat the feedwater that is being sent to the boiler.

F

FACTORING	An operation used to separate a common factor from items in an expression.

FAHRENHEIT	Pertaining to a temperature scale that registers the freezing point of water as 32° F. and the boiling point as 212° F. under standard atmospheric pressure. °F = (°C 9/5) + 32; °F = (°C x 1.8) + 32
FAILURE COST (SPC)	The cost associated with producing defective products. Includes the cost of replacing defective products, the cost of scrap material from the production process, the cost resulting from returned products, and the cost associated with lost sales and customers.
FAN	A mechanical device used to move large volumes of gas.
FAN PRESSURE GAUGE	A second differential pressure gauge is furnished on the gauge panel to show the pressure developed by the generator fans. This pressure can be used as a check on the density meter, or can be used to indicate hydrogen purity if the density meter is taken out of service while the generator is running.
FARAD (F)	Unit of capacitance.
FATT	Future Appearance Transition Temperature
FAULT (Wire or Cable)	An open, ground, or short in an electrical device or system. A partial or total local failure in the insulation or continuity of a conductor.
FBS	Field Bus Slave.
FEEDBACK	Verification of information. Information updating the condition of a process variable that is fed into a control loop.
FEEDBACK CONTROL	A method of process control in which corrective action occurs after a disturbance has affected the process.
FEEDER	A conductor or group of conductors connecting (a) two generating stations, (b) two substations, (c) a generating station and a substation or feeding point, or (d) a substation and a feeding point.
FEEDER BREAKER	An overcurrent protective device that interrupts power to a distribution panel or group of smaller breakers.
FEEDFORWARD CONTROL	A method of process control that attempts to correct for a disturbance before the disturbance affects the process.
FEEDWATER	The water that is pumped into the boiler to replace the water that leaves the boiler as steam. The feedwater system includes all equipment from the boiler feed pump to the boiler economizer inlet.
FEEDWATER HEATER	A type of heat exchanger that uses turbine extraction steam to heat condensate and feedwater. Potential of up to 14% efficiency loss, 14% more fuel burned when out of service. The heaters were designed to maintain the temperature of the feedwater, even if

	another heater were to be removed from service. In other words, one heater is capable of doing two or three heaters work, (D. Miller).
FERROMAGNETIC MATERIALS	Natural magnetic materials. Ferrous stands for iron and each of the materials acts like iron with respect to magnetism.
FIELD	The region around magnet or electric charge in which the magnet or field is capable of exerting its influence.
FIELD COIL	A suitably insulated winding to be mounted on a field pole to magnetize it.
FIELD FLASHING	Since our generator and exciter both use electromagnetic fields, and not permanent magnet fields, we must have an "outside" source of power to initially "flash" or energize the field so that the entire process can be started. This is usually done by a field flashing circuit that converts AC station service from the power system to DC for an initial "blast" or "flash" of DC to the generator field. This is a momentary supply during start-up of the generator that provides the field with excitation long enough for the generator to begin producing power to sustain the excitation process.
FIELD MAGNET	A magnet used to produce a magnetic field.
FILM BOILING	Steam is formed faster than it can be removed from the surface. This results in the heat transfer surface becoming blanketed with a film of steam. This should be avoided since the layer of steam acts as an insulator and restricts heat transfer.
FILM LUBRICATION	A process that maintains a wedge of oil between a bearing and a shaft.
FILTER	A device that allows liquid to pass through it while it traps solids. The outlet pressures in a filter system.
FILTERS (COMPRESSOR)	Used in the intake line to remove foreign material from the air before the air is compressed. The filtering devices are often paper or cloth filters.
FILTRATION	Removal of suspended matter by passing the water through a filter medium.
FINAL CONTROL ELEMENT	A device that adjusts or regulates the value of a process variable; valves, dampers, motors. The element of a control system that converts a signal from a controlling element into a corrective action.
FINNED-TUBE HEAT EXCHANGER	A heat exchanger, such as an air preheater, in which steam flows through tubes inside the exchanger to heat air. The tubes are

	finned on the outside to provide a greater surface area to increase the heat transfer rate.
FIRM POWER	Power intended to have assured availability to the customer to meet the customer's load requirement.
FIXED BLADING (STATIONARY BLADING)	Turbine blading that is fixed to the casing; consists of nozzle-shaped blades that direct steam flow through the turbine and supply high velocity steam to the moving blading.
FLAMMABILITY	The degree of difficulty of a substance to drive off the combustible gases.
FLASH STEAM	The vapor that forms when hot water at steam temperature is discharged to the atmosphere (or from a higher pressure to a lower pressure). An example of this is the cloud of vapor that rises when a kettle of boiling water is poured into the kitchen sink. Flash steam expands many times the volume it had when it was water. Actually, nearly 1600 times the volume it had before it turned to flash steam. When a trap is discharging to the atmosphere it is usually quite easy to tell whether the steam formed is flash steam or live steam. If a strong jet or blast issues from the trap discharge and is colorless at first some live steam is present, but if it is all white with no clear jet it is flash steam mixed with condensate. Also when steam issues from the trap in a lazy drift or cloud it is flash steam rather than live steam.
FLASH TANK	A tank used to "flash" high pressure/temperature water into steam and water at a lower pressure. It is used to recover heat from drips and drains and to recover heat and water.
FLASHING	A rapid change of state from water to steam. The process whereby water is converted to steam by reducing the pressure.
FLEXIBLE DIAPHRAGM RECIPROCATING PUMP	Uses a flexible diaphragm to create the reciprocating motion that displaces the liquid. The flexible diaphragm is installed across the pumping area, or cavity. The diaphragm is attached to a connecting rod, which, on some pumps, is connected to a motor driven device called an eccentric. The eccentric and the connecting rod convert the rotation of the motor into a reciprocating motion. The suction and discharge valves are located underneath the pump cavity. At the start of the suction stroke, the connecting rod is in its lowest position, and the diaphragm is flexed to its maximum downward position. As the eccentric rotates, it pulls the diaphragm upward, creating a reduced pressure below the diaphragm. The reduced pressure closes the discharge valve, opens the suction valve, and draws a specific amount of liquid into the pump. As the eccentric

	continues its rotation, it forces the diaphragm downward to start the discharge stroke. The downward motion of the diaphragm exerts a force on the liquid in the cavity, which increases the pressure. The increased pressure closes the suction valve, opens the discharge valve, and pushes the liquid out of the pump. An important characteristic of all diaphragm pumps is that they do not have mechanical seals or packing. For this reason, they are often used on applications where little or no leakage can be tolerated.
FLOAT	A level sensing device that moves up or down on the surface of a liquid in response to changes in level.
FLOAT AND THERMOSTATIC TRAP	A float trap with a thermostatic bellows arrangement inside its casing.
FLOAT TRAP	A type of mechanical trap containing a float and a valve within its casing.
FLOCCULATION	Adding a flocculent to waste water which forms large, heavy clumps with particles in the water. These clumps are allowed to settle out of the water, and later removed. The second stage of the clarification process, in which a slow mixing action causes negatively charged suspended particles to come together with the positively charged precipitate formed during coagulation.
FLOCCULENT	A chemical that attracts suspended and dissolved solids and causes them to stick together.
FLOW DIAGRAM	Piping diagram. Uses lines to represent process flows, and symbols to represent process equipment in the system, including tanks, pumps, and valves. Does not show the devices used to monitor the process, and it does not show all of the devices used to control the process.
FLOW ENERGY	The term given to a specific kind of energy that exists when a fluid is in motion or has the ability to be put into motion. This is not the same as the kinetic energy of the fluid. Flow energy results from the fact that some force must have been exerted on the fluid in order to make it flow.
FLOW RATE	The amount of fluid that passes a particular point of a system at a particular time. Mass is pounds per hour; volume is gals per minute. Area x velocity = cubic feet/sec.
FLOW TRANSMITTER	A transmitter that senses and measures the rate of fluid flow.
FLUE GAS	A mixture of gases resulting from combustion and other reactions in a combustion device (boilers, combustion turbines), which is channeled through a chimney or stack into the outdoor air.

FLUE GAS RECIRCULATION	A combustion zone control system in which flue gas that is low in oxygen is added to the combustion air to expand the combustion zone and reduce the overall combustion temperature. A method of steam temperature control that involves rerouting flue gas from the outlet of the economizer to the bottom of the furnace. Provided as a means of maintaining design reheat steam temperature. The gas recirculating system should not be used for the purpose of obtaining design steam temperature below the specified control range as this may lead to overheating of superheater elements and unstable furnace conditions. Gas recirculation may be used at boiler loads below the control point to maintain a specified rate of temperature increase. However, at ratings below the control point, care must be exercised not to overheat element metal temperatures. When the boiler load decreases below the control range, the system will automatically limit the gas recirculation so that it will not exceed 30% of total gas flow. Gas recirculation must not be employed at boiler ratings below 25% of full load rating as it will lead to unstable furnace conditions. The gas recirculation fan must not be started until this boiler load is exceeded.
FLUID	A general term that is applied to substances which flow or tend to take the shape of the particular container they are in. Fluids may be of three general types: Liquids such as water, gases such as air, and vapors such as steam.
FLUID SYSTEMS BASIC STRUCTURE	Energy (source) - transmission path (pipes) - control devices (regulators, valves) - demand or load (actuators)
FLUME FLOW MEASURING DEVICE	An open channel flow measuring device that has a restriction with a downward sloping throat. The liquid level behind the restriction is converted to a flow rate.
FLUX	The magnetic lines of force existing between two opposite magnetic poles.
FLY ASH	Light, fine particles of ash that are carried out of a boiler furnace by flue gas.
FLYWEIGHT GOVERNOR	A device used to control turbine speed. It is connected to the turbine shaft and senses the speed of the turbine shaft.
FLYWEIGHTS	Parts of some mechanical governors; consisting of a set of weighted arms connected together by a spring.
FLYWHEEL	A heavy wheel of opposing and moderating by its inertia any fluctuation of speed in the machinery with which it revolves.
FOOT POUND	The English unit of work and energy.

FOOT VALVE	Holds pump priming water up in a pump.
FORCE	The total weight applied to a surface by a solid, liquid, or gas; also, any influence capable of producing movement or a change in movement. Force = Mass x Acceleration.
FORCED DERATINGS	Anything that blocks load on the unit, that isn't scheduled. Counts against our EFOR outages. The difference between "scheduled" and "unscheduled" is if the derating or outage can wait beyond the next weekend, it does not count against us in terms of our EFOR goal.
FORMULA	A mathematical expression made up of known and unknown values. An algebraic equation for a typical problem or situation. A method for describing relationships between quantities in a physical system. The relationships are usually described by words or symbols and expressed as mathematical equations.
FOULING	The buildup of deposits on the internal surfaces of a heat exchanger.
FOUR-WAY VALVE	A multiport valve commonly used to change flow through a piping system. Has two L-shaped openings in its plug.
FRAME	The supporting structure for the stator parts.
FREE ELECTRONS	Electrons which are loosely held and consequently tend to move at random among the atoms of a material.
FREQUENCY (F)	The number of cycles completed each second by a given AC voltage. The number of complete cycles per second existing in any form of wave motion; such as the number of cycles per second of an alternating current. Generator frequency is 60 cycles per second.
FREQUENCY CONTROL UNIT (FCU)	Rapid pulse frequency control. System frequency will control individual unit load.
FRICTION	A force that always acts to oppose motion. The resistance to relative motion between two bodies in contact. Produces heat and wears away surfaces.
FRICTION HEAD	Related to the level of a liquid. The difference between static head and velocity head that results from friction.
FRICTIONAL LOSS	The loss of energy due to friction that occurs when steam passes through a valve, such as a turbine control valve.
FUEL INJECTION SYSTEM	A system that delivers fuel to engine cylinders at the right time and in the proper amount to ensure smooth and efficient combustion of fuel.

FUEL INJECTOR	A device, such as a nozzle, used to spray fuel into an engine cylinder so that combustion can occur.
FULL ARC ADMISSION	A method of starting a turbine in which steam is distributed equally through the control valves to each section of the nozzle block so that the turbine is heated evenly. During start-up, when the turbine-generator unit us being brought up to speed, the governing valves are all open with the speed controlled by the throttle valve's inner plug valve. It allows steam to be admitted to all of the nozzle chambers situated around a 360 degree arc before the turbine control stage blading. This start-up method results in even heating and expansion of the nozzle chambers and reduces thermal shocking. Upon reaching a certain speed point (approx. 3400 rpm), the governing valves are positioned to take control, the throttle valves are opened wide, and then the turbine is controlled by either governor single valve or sequential valve operation. Potential of up to 7% efficiency loss. Prevents thermal stress.
FUNDAMENTAL UNITS	Length, Mass, Time
FURNACE	The open area in a boiler where fuel is burned; combustion area.
FURNACE DRAFT	The amount of pressure or vacuum inside a furnace.
FURNACE PRESSURE TRANSMITTER	Mechanically measures the furnace pressure and then converts this measurement to an electrical signal. 4 milliamp is the minimum signal, while 20 milliamp is the maximum.
FUSE	A part of a circuit made of low melting point material so that it will melt and break the circuit when a specified current is exceeded.

G

GAIN	A proportional control adjustment. Gain is the inverse of proportional band, and it is expressed as a quantity, rather than as a percent value.
GAS CIRCUIT BREAKERS (GCB)	Very high voltage level circuits, notably the 500 KV system. In these breakers a special gas, under pressure is used to extinguish the arc. The gas used must have excellent stability and dielectric properties. The gas used at the present time is a compound of sulfur and fluorine known as sulfur hexafluorine (SF6).
GAS RECIRCULATION FANS	Fans found in some generating units that are designed to recirculate furnace gas so that the boiler can be warmed more efficiently during unit startups.
GAS TEMPERING	A method of steam temperature control that involves rerouting

	flue gas from the outlet of the economizer to the top of the furnace, above the fire and below the secondary superheater.
GATE VALVE	Primarily for open and closed service; flow isolator. Used in situations where the valve position seldom changes, such as a drain valve on a tank, which would be closed most of the time. Consists of a body containing two inclined seats mounted in a plane nearly perpendicular to the line of flow and a wedge which has the same angle as exists between the two seats. The wedge is moved up and down by the stem to which it is attached. Gate valves offer very little opposition to flow when they are wide open. The wear on the seats and wedge of a gate valve is uneven when the valve is not fully open. For this reason they should not be used to throttle the flow. Gate valves are used as stop or shutoff valves where they can be either fully open or closed. Gate valves are fairly easy to identify because they have relatively long bodies and long valve stems.
GAUGE	An indicating instrument that uses a pointer and scale to display information about a measured variable.
GAUGE GLASS	A type of direct level measurement device whose use is based on the principle that liquid levels equalize in containers that are connected together. Permit visual observation of the level in the vessel. Consists of a small diameter glass tube which is connected to the top and bottom of the vessel. The liquid level inside the glass changes directly with any change in level inside the vessel. Special types of glass and construction make this device usable for practically any type of service.
GAUGE PRESSURE (PSIG)	Pressure measured from a zero reference point of atmospheric pressure. Since atmospheric pressure serves as the starting point, it is given a value of zero on the gauge scale. PSIG OR PSI; PSIG = PSIA -14.7 PSI
GEAR PUMP	Rotary pump. Consists of a casing with a suction port and a discharge port. Inside the casing are two gears. One gear is rotated by the pump's driver. This gear is often referred to as the driver, or driving, gear. The other gear moves because its teeth are meshed with the teeth of the driver. This gear is called the idler gear. During operation, liquid enters the pump through the suction port. As the gears turn and un-mesh, liquid is trapped in the spaces between the casing and the gear teeth. This liquid is moved along until it reaches the discharge port, where it is forced out of the pump. On this type of pump, each space between the gear teeth positively displaces a given amount of liquid. Therefore, on each revolution that the gear makes, a specific

	amount of liquid is pumped.
GEGWT	GE Glegg Water Technologies Inc.
GENERAL ENERGY EQUATION	A law governing fluid flow based on the principle that energy cannot be created or destroyed but can only be transformed from one form to another. The general energy equation states that the total energy contained in the fluid at one point in the system must be equal to the total energy contained at any other point in the system providing there is no energy added or removed between the two points.
GENERAL GAS LAW, OR IDEAL GAS LAW	The relationship between gas temperature, pressure, and volume. Pressure times volume, divided by temperature equals a constant value. Whenever there is a change in one of the three variables, the remaining two variables will change so that the value of the constant does not change.
GENERATING STATION	A plant wherein electric energy is produced from some form of energy (e.g. chemical, mechanical, or hydraulic) by means of suitable apparatus.
GENERATOR	A machine that converts mechanical energy into electrical energy. A generator does not produce or make electricity any more than a pump produces or makes water. The generator produces a voltage or potential difference which causes current to flow just as the pump produces a pressure difference which causes water to flow. Whenever a conductor which has no current flow is moved through a magnetic field, a potential difference or voltage will be developed in the conductor. The motion must be such that the conductor cuts across the lines of force of the magnetic field. The magnitude of the voltage produced in this manner depends on the strength of the magnetic field, the length of conductor in the field and the speed with which the conductor cuts across the lines of force. It does not matter whether the magnetic field is stationary and the conductor moves, or the magnetic field moves and the conductor is stationary. The principle is the same as long as there is relative motion between the two. In all large generators, the magnetic field moves and the conductors are stationary. The mechanical power required to produce this motion is supplied by the steam or gas turbine. The magnetic field is produced by passing a direct current through a circuit known as the generator field. This direct current is supplied by a small DC generator which is known as the exciter. The rotating member is frequently called the field, or rotor. The stationary part of the machine is known as the stator although the term armature may also be used. The armature is the part of the generator which contains the

conductors and since in all our machines this is the stator, the two terms may be used interchangeably. The generator rotor bearings, the hydrogen shaft seals, and the oil passages for supplying oil to these parts are contained in and supported by the outer generator end shields. The end shields are split on the horizontal center line to facilitate their removal. Finned-tube coolers are provided in the stator frame to cool the hydrogen gas as it is circulated inside of the generator. They may be mounted in either a vertical or a horizontal position. External connections are provided for cooling water supply and return piping. The cooling medium is treated water known as auxiliary cooling water. All main generators produce three phase power and all large electrical equipment utilizes three phase power. For small low voltage applications in the plant, office or home, single phase power is used. For this use, just one of the three separate circuits or phases is used.

GENERATOR BEARING DRAIN LOOP SEAL

A loop seal is provided in the combined generator bearing oil drain line before it enters the turbine bearing oil drain system. The purpose of this loop seal is to prevent the hydrogen in the generator from escaping into the main oil reservoir in the event of failure of the generator hydrogen shaft seals which might result in a sudden surge of hydrogen through the drain line. The generator shaft seals are especially designed to prevent the possibility of this type of failure occurring, and the service record of Westinghouse hydrogen-cooled turbine generators has proved the adequacy of this design. The loop seal, however, will provide protection against the remote possibility of shaft seal failure from any cause whatsoever, and as such represents an additional safety feature beyond normal or anticipated requirements. A vent to the atmosphere is provided on the upstream or inlet side of this loop seal so that any hydrogen flowing through the bearing drain line will be carried out of the system before sufficient pressure can be built up to blow the oil out of the loop seal and allow the hydrogen to reach the main oil reservoir. Since this loop seal presents an obstruction to uninterrupted flow in the bearing drain system, the vapor extractor on the main oil reservoir is not able to ventilate that part of the generator bearing oil drain system on the upstream side of the trap. Therefore, an additional vapor extractor assembly consisting of extractor, control by-pass, and check valve is provided as a part of the loop seal assembly to provide the negative pressure in the generator drain system on the upstream side of the loop seal required for normal operation.

GENERATOR SEAL OIL SYSTEM

The seal oil system prevents hydrogen gas from escaping from the generator at the shaft seals. Entrained hydrogen carried in the seal oil is removed and the oil is cooled before it is returned to the seals. Since the rotor shaft ends of a hydrogen-cooled generator must be brought out of the gas-tight enclosure, means must be provided to prevent escape of gas along the shaft. Gland seals supplied with oil under pressure are used for this purpose. Oil is pumped to a feed groove between the gland rings and flows both ways along the shaft through the clearance space between the gland rings and the shaft. As long as oil pressure in the feed groove exceeds the gas pressure in the machine, oil will flow toward the hydrogen side of the seal and prevent escape of hydrogen from the machine. The gland rings are provided to restrict the flow of oil through the seal. These rings can move radially with the shaft, but are restrained from rotating by dowels in the supporting structure. The function of the gland oil system is to provide oil under pressure to the seals as free as possible from air and moisture. The same oil is used in the turbine bearing system and the gland system. This oil in contact with air or hydrogen absorbs an appreciable volume of gas and will also absorb moisture if water vapor is present. When oil with air and water absorbed in it is pumped into the hydrogen compartment, some of the air and moisture will come out of the oil and contaminate the hydrogen in the machine. The hydrogen purity must be kept up to the required value by adding fresh gas. In the gland oil system a large part of the absorbed gas and moisture is removed from the oil before it is pumped to the seals. The gland oil system is isolated from the bearing oil system. However, there is a slight amount of oil interchange between the seals and the bearings, so it is necessary to have a makeup and overflow arrangement between the gland oil and the main bearing oil systems so as to maintain the proper amount of oil in the gland oil system. The seal oil makeup consists of a float valve in the seal oil vacuum tank which opens when the level drops and adds oil from the generator bearing oil system. If the quantity of oil in the gland oil system tends to increase, a float valve in the hydrogen side seal oil drain chamber opens and the excess oil is returned to the generator bearing oil system.

GENERATOR VOLTAGE REGULATOR — A regulator which functions to maintain the voltage of a generator, at a predetermined value.

GENEVA RULES — A system for naming organic chemicals. Uses different word endings, such as “ane” and “ol”, to identify different groups of molecules. For example, the letters “ane” at the end of a chemical name indicate that the molecule is part of what is called the alkane group of hydrocarbons. A hydrocarbon is a compound that contains only hydrogen and carbon. The difference between alkanes and other hydrocarbons is in the way that the carbon and

	hydrogen are bonded together. Three of the most common alkanes are methane, ethane, and propane. The first part of the name also has meaning. Within the alkane group, there is a connection between the first part of the name and the number of carbon atoms a molecule contains. Methane has one carbon atom, ethane has two, and propane has three. Another group of organic chemicals that has the same connection between the name and the number of carbon atoms is the alcohol group. Alcohols are formed by removing it with a hydrogen (OH) group. Methyl alcohol, which is also called methanol, has one carbon atom. Ethyl alcohol, which is also called ethanol, has two carbon atoms. The "ol" ending indicates that methanol and ethanol are part of the alcohol group.
GLAND	The collective term for the gland seals used at a particular sealing point. A component of the gland seal system made of grooves and ridges designed to help seal the turbine; usually supplied with steam or water, which provides sealing.
GLAND NUTS (VALVES)	Used to tighten down on the packing gland.
GLAND SEAL	A seal, usually composed of several labyrinth seals, designed to prevent leakage of air or steam around a turbine shaft. Water, steam, or oil used to prevent leakage of gases or liquids along rotating shafts.
GLAND SEAL SYSTEM	A turbine support system designed to prevent air from leaking into the turbine and prevent steam from leaking out; sealing is accomplished by supplying steam to a series of glands located along the turbine shaft. Also prevents thermal stress.
GLAND STEAM CONDENSER	Purpose is to maintain in the gland leakoff system a pressure slightly below that of sub-atmosphere, to prevent the escape of steam from the ends of the glands, and to remove and condense the vapor. Eliminates dropping and accumulation of moisture caused by slight gland leakage to atmosphere. Steam that leaks past the labyrinth seal toward atmosphere is piped to the shell side of the gland steam condenser. The shell side of the condenser is provided with an air exhauster which maintains a slight vacuum in the shell. The cooling medium, which passes through the tubes of the condenser, is supplied by the condensate pumps. The gland steam that is condensed is usually returned to a drip tank and from there to the condenser hotwell.
GLAND STEAM EXHAUSTER	A vacuum pump that draws air and steam from the turbine glands to the gland steam condenser.
GLOBE VALVE	A valve that may be used wide open, fully closed, or in an

	intermediate position for regulating flow; throttling valve. Consists of a body containing a seat ring usually placed in a horizontal position parallel to the line of flow and a valve disc which is made to bear against the seat ring. The disc is raised and lowered by the handwheel and stem. The globe valve, because of its construction offers a considerable restriction to flow even when it is wide open. Normally arranged in a piping system so that the higher pressure side of the piping system is acting under the valve's disc. This makes it easier for an operator to open the valve.
GLYCERINE	Glycerol; a sweet syrupy hygroscopic trihydroxy alcohol usually obtained by the saponification of fats and used especially as a solvent and plasticizer.
GOVERNING TRANSFORMER	A pressure transformer which, magnifies the relatively small pressure changes delivered by the governing impeller into large pressure changes which are utilized to actuate the relay of the servomotor.
GOVERNING VALVE	Valves located in the steam chest that control the steam flow to meet changing load demands. Westinghouse turbines utilize the bar lift mechanism for governing valve control. The bar-lift mechanism opens the valves in desired sequence. Valve stems pass through holes in a bar raised and lowered by the control mechanism. Collars on each valve stem are set at different heights; as the bar rises, valves lift in a sequence determined by the collar settings. Turbines with separate steam chests have flexible inlet piping which connects the chests to separate nozzle chambers in the turbine casing. Another application of the bar-lift operation is the external hinged lever lift. The valve stems are connected to the operating lever by links. The point at which each valve starts to open is determined by the length of the slot in the links. The valves are equipped with compression springs which act downward on the spring seat to provide a positive closing force.
GOVERNING VALVE EMERGENCY TRIP	Designed to admit high pressure oil to the governing control system and close the governing valves.
GOVERNOR	A device used to maintain the speed of a turbine at a desired value. Consists of a speed sensitive oil impeller mounted on the turbine shaft and an oil operated servo-motor that positions the governing valves, with oil pressure used for transmitting the speed impulse to the servo-motor element. See Main Governor.
GOVERNOR IMPELLER	Mounted on the turbine shaft and supplied with a limited amount of high pressure oil from the main oil pump, maintains a pressure

	which varies as the square of the speed thus giving a governing medium.
GOVERNOR VALVES	See control valves.
GPM	Gallons Per Minute.
GRAM	A metric unit of weight equal to approximately 0.035 ounces.
GRAPH	A diagram that represents the variations of one variable in comparison with one or more other variables. Pictorial representations of numbers and various relationships between numbers.
GRAPHIC DISPLAY	A type of display that uses symbols and lines to provide information about the present condition of a process or part of a process.
GRAPHITE	A solid lubricant; a very slippery mineral form of carbon. Because it is not sticky, it does not attract dirt. It can also resist heat and pressure.
GREASE	A mixture of oil and a thickener. Grease is measured on a scale from 0, for very soft grease, to 6, for very hard grease. There are also extra-soft 00 and 000 grades.
GRID	A network of power stations, power lines, and power users.
GROSS HEAT RATE	The heat rate of a generating unit calculated by using the total electrical output of the generator.
GROSS POWER	The total amount of power produced by a generator, measured at the generator leads.
GROUND	An electrical fault that occurs when electricity takes an undesirable path to earth or ground, usually as a result of a breakdown in insulation.
GROUND CURRENT	Any current flowing to a grounded body.
GROUND DETECTOR	An instrument used for indicating the presence of a ground on an ungrounded system.
GROUND PROTECTIVE RELAY	A protective relay that can detect excessive ground current and actuate an alarm.
GROUND RELAY	A relay that initiates an alarm if it detects abnormal current flow to ground.
GROUND RESISTOR	A protective device that provides resistance to limit the amount of fault current flowing to ground.
GROUNDED (EARTHED)	Connected to earth or to some conducting body which serves in place of the earth.

GROUNDED SYSTEM	A system of conductors in which at least one conductor or point (usually the middle wire or neutral point of a transformer or generator windings) is intentionally grounded.
GROUNDING SWITCH	A form of air switch by means of which a circuit or a piece of apparatus may be connected to ground.
GROUNDING TRANSFORMER	A transformer intended primarily for the purpose of providing a neutral point for ground.
GUIDE VANES	Devices located on the inside of a windbox that help to distribute air flow evenly.

H

H2500	See Sodium Chloride.
HAND/AUTO STATION	A control in a control loop that passes the control loop's automatic signal to a final control element, or allows an operator to assume manual control; also called a control station.
HARD WATER	Water containing a relatively high concentration of those dissolved solids that have a soap consuming property; calcium and magnesium. In the steam plant these materials correspond to the scale forming solids, which are to be avoided as much as possible.
HARDNESS	A quality of water defined by the amount of calcium and magnesium present.
HARDNESS SALTS	Compounds made of calcium or magnesium.
HAZARDOUS WASTE	Waste material which by their nature are dangerous to handle or dispose of, such as chemicals, solid materials containing heavy metals (copper, chrome, iron, etc.), or other wastes produced by industrial operations. A waste is considered hazardous if it exhibits characteristics of ignitability (ignites or burns easily), corrosivity (acid, caustics), reactivity (oxidizers), and toxicity (heavy metals).
HEAD (HEAT EXCHANGER)	The ends of the heat exchanger. The fluids that flows through the tubes enters and exits through the heads.
HEAD (PUMPS)	The pressure caused by the weight of a column of liquid as a result of its height; usually given in feet. Another way of looking at head is by relating it to pressure. For example, the amount of pressure at the discharge of a pump that's running can be viewed as the height of a column of liquid that the pump's discharge pressure will support. This imaginary column of liquid represents head.

HEAD CURVE (PUMPS)	Indicates how much head, or pressure, the pump should produce for various flow rates. The horizontal axis is often marked to indicate flow rate in units such as gallon per minute (GPM). Flow rate can also be referred to as the pump's capacity. The vertical axis is usually marked to indicate head, in feet.
HEAD PRESSURE	The pressure exerted by a column of liquid as a result of its height, or level. The amount of pressure exerted also depends on the liquid's density. Denser liquids exert more pressure for a given height than less denser liquids. Positive pressure at a given point in a liquid system, normally expressed in feet of water.
HEADER	A pipe or drum, that serves as a central connection for two or more smaller pipes.
HEAT	A form of energy called thermal energy; amount of thermal energy. A form of energy capable of raising the temperature of a substance.
HEAT EXCHANGER	A device designed to transfer heat from one fluid to another. Components used to heat, cool, condense, or evaporate fluids.
HEAT LOSS METHOD	A method of determining boiler efficiency expressed as a relationship between individual heat losses and inputs to the boiler.
HEAT OF VAPORIZATION	See Latent heat of Vaporization.
HEAT RATE	A measurement of generating station thermal efficiency. The amount of fuel, in BTU, put into the process that is required to produce 1 kilowatt-hr of electrical energy. Measured in BTU per Kilowatt-hour (BTU/Kilowatt-hr). Chemical energy in divided by electrical energy out.
HEAT SOAK	A procedure in which the speed of a turbine is held constant for a specified length of time; a method used to bring steam-to-metal temperature mismatches back to normal.
HEAT TRANSFER	Thermal energy that is moving from one substance to another, or from one part of an object to another, by means of radiation, convection, or conduction. This movement is a result of a temperature difference. Mass x specific heat x (Tf-Ti). The formula states that the amount of heat transferred equals M, the mass, or amount, of substance involved, times its specific heat, which relates to the type of substance involved, times the difference between the final temperature of the substance, Tf, and the initial temperature, Ti.
HEAT TRANSFER RATE	The amount of heat transferred from one body to another in a specific time period; often expressed in BTU's per hour.

HEATING VALUE	The BTU content of a fuel.
HEATUP RAMP RATE	The rate at which a boiler is taken from startup to normal operating temperature; generally expressed as a number of degrees or watts per unit of time.
HEAVY METALS	Metallic elements like mercury, chromium, cadmium, arsenic, and lead, with high molecular weights.
HELIUM	Inert and nonflammable, would be an ideal medium for ventilation and cooling purposes for the generator. Because of its scarcity and high cost, it could not be considered feasible as a cooling medium.
HENRY (H)	Basic unit of inductance.
HERTZ (Hz)	Basic unit of frequency, one cycle per second.
HICKEY	A tool used on valve hand wheels to increase mechanical advantage when opening valves. Also referred to as a valve wrench.
HIGH BLOCK	An adjustable turbine control device used to limit the maximum load the machine will pick up or carry.
HIGH POT	High potential applied to electrical machine or equipment normally during testing of insulation.
HIGH PRESSURE HEATER	A heater, usually located after the discharge of the boiler feed pumps, where the pressure of the water is relatively high, that uses the latent heat of extraction steam to heat the water that passes through it. Provides suitably heated water to the boiler to prevent thermal shock.
HIGH SIDE	The higher voltage electrical system of two systems connected by a transformer.
HIGH VOLTAGE	Above 600 volts.
HIGH VOLUME WASTE (HVW)	Classified waste that contains items found in the Federal Code of Regulations; metal cleaning waste. Waste that needs treatment before overboarding.
HISTOGRAM	A bar chart used to graphically display sample data. Data is plotted in the form of bars, or rectangles. The bars are called cells. A cell's height is related to the number of readings for the cell. The distance between the starting point and the ending point of a cell is called the cell range.
HOG JET	A high capacity steam air ejector utilized to assist the normal air ejectors.

HOLDING COIL	A device that, when energized, holds contacts either open or closed. When the holding coil is de-energized, the contact position changes: for example, if a contact is open, it closes.
HOLDOFF REQUEST	Purpose is to protect personnel working on a generator from injury caused by the accidental energizing of the main generator leads from the switchyard. Clarifies and communicates the isolation of equipment between Production and System Operation Department personnel and provides an electrical "clearance" on the equipment or position of the system.
HORSEPOWER	A rating of how much mechanical power a motor can be expected to produce. A unit of power in the US Customary System, equal to 745.7 watts or 33,000 foot-pounds per minute. (1.34 x KW)
HOT	Energized electrically - referring to pieces of electrical equipment, buses or lines.
HOT REHEAT STEAM	Steam that flows from the boiler reheater to the intermediate pressure turbine.
HOT REHEAT STEAM TEMPERATURE SET-POINT	The design temperature value for hot reheat steam; intended to provide as much energy as possible to the IP and LP turbines, while preventing over-heating.
HOT WELL	Condensate drain reservoir.
HRRV (H-POWER)	Honolulu Recovery Resource Venture; refuse; 2 boilers; 46 MW
HUMIDITY	The measure of how much water vapor is in the air.
HYDRAULIC ACTUATOR	A device, consisting of a casing, a piston, and a spring, that is commonly used to operate a control valve. Powered by a pressurized liquid, such as hydraulic fluid. Compared to pneumatic actuators, hydraulic actuators of the same size are usually more powerful.
HYDRAULIC COUPLING	A coupling that uses hydraulic fluid to vary pump speed while the driver speed remains constant. Uses centrifugal force to transfer the torque of a driver to the shaft of driven equipment.
HYDRAULIC GOVERNOR	A governor that typically consists of a centrifugal pump mounted on, and driven by, the shaft of a turbine. A relay connected to the hydraulic governor converts the discharge pressure of the hydraulic governor to a mechanical action.
HYDRAZINE	A chemical deoxygenating agent used to eliminate dissolved oxygen in boiler water. A chemical used in a steam plant for oxygen scavenging of boiler water.

HYDROCARBON	An almost innumerable combination of hydrogen and carbon atoms that produce combustion under proper conditions.
HYDROGEN (H)	A colorless, highly flammable gaseous element, the lightest of all gases and the most abundant element in the universe. Low density and high thermal characteristics. Has the degree of purity desired and required for cooling purposes. Hydrogen is the most desirable gas that can be used as the cooling medium for rotating electrical machines. A mixture of hydrogen and air is explosive over a wide range of proportions (from about 5% to 70% hydrogen by volume. In a generator, carbon dioxide is used as the intermediate gas when changing either from air to hydrogen or from hydrogen to air.
HYDROGEN DRYER	A device that removes moisture from the hydrogen circulating inside a hydrogen-cooled generator.
HYDROGEN EMBRITTLEMENT	A condition caused by the interaction of dissolved hydrogen and the carbon in boiler metals; loss of carbon causes the metal to become brittle.
HYDROGEN GAS COOLERS	The hydrogen is cooled by passing it through two coolers where the gas gives up its heat to the cooling water in the finned tubes of the cooler. At the water piping connections to the coolers, the nozzle end is bolted solidly to the generator frame, while the rear end is permitted to move freely with temperature changes. The rear end is covered with a protective steel cover which must be removed to clean the cooler tubes. A flexible diaphragm between the cooler and the frame at the rear end permits this movement, yet prevents the escape of gas at this point.
HYDROGEN ION (H+)	A positively charged hydrogen particle. Makes a solution acidic.
HYDROMETER	A device used to measure the specific gravity of a substance. Works on the principle that a floating object displaces an amount of liquid that is equal to its own weight. Based on the principle, the depth at which a hydrometer floats in a liquid is an indication of the liquid's specific gravity. Many hydrometers are calibrated for a standard temperature of 77°F. For temperatures above 77°F, the correction factor is added to the hydrometer readings. For temperatures below 77°F, the correction factor is subtracted. Some hydrometers are used with a thermometer, so that temperature compensations can be made.
HYDROSTATIC PRESSURE	The pressure related to the height of a column of liquid. The pressure exerted by a static, or non-moving liquid. Related to the depth and the density of the liquid. Every inch of water above a measurement point corresponds to a pressure of .0361 psi. Every

	foot of water corresponds to a pressure of .433 psi.
HYDROXYL ION (OH-)	A negatively charged particle made up of hydrogen and oxygen. Makes a solution alkaline.
HYGROMETER	A device that uses the expansion and contraction of a material, such as hair, to measure humidity.
HYPOTENUSE	The longest side of a right triangle.

I

IGNITOR	Fuel burner igniting device.
IK SOOT BLOWERS	Insertable Kinetic soot blower The air motor driven IK blower is a retracting, rotating, long lance tube type blower provided with one and often two venturi type openings near the end of the lance. They clean a wide area by moving the lance in and out along the tube banks while turning in a 360° arc. Inserted more than half the width of the boiler. Used to remove soot from superheaters and reheaters. The air motor type of power drive is provided with a sheave wheel or square lug for emergency use in case of power failure. When power air is applied to the motor, the blower is projected into the furnace, automatically reversed, and retracted to the "rest" position. The air driven motor is mounted beneath the unit carriage and travels with the assembly. Provided with a mechanically operated poppet valve which is applicable to either air or steam as the blowing medium.
IMPEDANCE (Z)	The total opposition offered to the flow of alternating current. It may consist of a combination of resistance, inductive reactance, and capacitive reactance. The combined effect of resistance and reactance. Measured in ohms. This term is very useful for making calculations but is not normally encountered in power plant operation.
IMPELLER (PUMPS)	The part of the pump that creates the centrifugal force, or pressure, to move liquid through all centrifugal pumps. Three categories: closed, open, and semi-open.
IMPULSE	An impelling force on the motion it produces; a thrust; a push; momentum. Impact reaction.
IMPULSE BLADES	Turbine blades that are shaped so that steam actually strikes the blades, causing the turbine rotor to turn. Impulse blading is more predominant in the higher pressure stages of a turbine, where the blades are shorter. Moving blading in which the space between

	blades is the same size at the blading inlet and the blading outlet. Energy transfer in impulse blading results in a decrease in steam velocity. Buckets; curve rotating blades used in HP and IP sections; 76% efficient. The temperature and pressure drop, which is fairly large, is across the stationary nozzle and not the blades. Most efficient at low loads.
IMPULSE STAGE	First stage chamber of turbine. The area between the curtis wheel and the rateau stages.
IMPULSE TRAP	Thermodynamic trap. Consists of a piston type valve operating within a control cylinder. The lower end of the valve has a tapered seating surface which opens and closes the orifice. When steam is turned on in the system ahead of the trap, pressure is exerted on the underside of the piston disc, on the valve, pushing it upward to open the orifice, so the condensate and air can flow out at full capacity. The valve opens wide on start-up for full discharge of condensate and to quickly get rid of any air that may have accumulated in the system. The valve stays wide open until condensate nears steam temperature. Opening and closing of this trap is regulated by the slight condensate flow termed the control flow, which goes up past the piston disc into the control chamber and out the small control orifice in the hollow stem of the valve. When condensate nears steam temperature it flashes in the control chamber and in the control orifice. This chokes the flow through the control orifice which increases the pressure in the control chamber snapping the valve shut to prevent the loss of live steam. As long as the condensate remains hot enough to continue the flashing the valve remains closed. When it cools slightly the flashing decreases. This reduces pressure in the control chamber allowing the valve to reopen and the cycle is repeated. The control flow continuously samples the flow coming to the trap and causes the valve to open and close quickly at the proper time, to open wide on condensate but close when steam reaches the trap. The control flow consists of only a slight percentage of the full flow through the main orifice. This means that only an amount of condensate equal to this small percentage is required to completely fill the control orifice at all times. When the main valve is closed and as long as this slight amount of condensate flow is maintained there can be no measurable flow of steam through the control orifice.
IMPULSE TURBINE	A turbine in which the force of high-pressure steam causes the rotating blades to turn.
IMPURITY	A suspended solid, dissolved solid, or dissolved gas that must be removed from water in order to make it pure.

IN PHASE	Applied to the condition that exists when two or more waves of the same frequency pass through their maximum and minimum values of like polarity at the same instant.
INDICATOR	An instrument that gives a visual indication of the current value of a process variable.
INDIRECT CONTACT HEAT EXCHANGER	A heat exchanger in which the two fluids are separated by a solid surface; also called a surface heat exchanger.
INDIRECT FLOW MEASUREMENT DEVICE	Measures process conditions that are related to flow, such as pressure. They then convert those measurements to flow indications.
INDIRECT LEVEL MEASUREMENT DEVICE	A device that measures a physical aspect of a fluid that varies in proportion to level and uses that information to provide a level measurement.
INDIVIDUAL X CHART	Plotted using single samples from a process. The actual value of each sample is plotted directly onto the chart. Used to monitor processes for which single measurements are taken some time apart. Centerline is the average value around which the process should operate.
INDUCE	To produce a force in a body by exposing it to an influence such as a magnetic force, electric force, or changing current.
INDUCED VOLTAGE (INDUCTION)	Produced by providing relative motion between a conductor and a magnetic field. The motion must be such that the conductor actually cuts across the magnetic lines of force. The magnitude and direction of this induced voltage depends on the direction and strength of the field, the speed and direction of motion, and the length of the conductor in the field.
INDUCTANCE (L)	A physical property of AC circuits that opposes changes in current flow. Measured in units known as Henrys. Causes current to lag voltage.
INDUCTION	The act or process of producing voltage by the relative motion of a magnetic field across a conductor.
INDUCTION COIL	An arrangement of two coils such that a changing current in the first produces a voltage in the second.
INDUCTION MOTOR	An AC motor whose rotor field is produced by induction. Consists of a stationary part called the stator and a revolving part called the rotor. The induction motor derives its name from the fact that the rotor is not connected electrically to the source of power supply. Current flow in the rotor conductors is not produced directly by the voltage of the power supply but result from voltages induced

	in the rotor by the action of the magnetic field set up by the stator. The motor depends, for its operation, upon the production of a rotating magnetic field. This is necessary since the relative motion is required to induce voltage in the rotor conductors. Current flow in the rotor conductors, in turn, produces the rotor field. The rotors of induction motors turn at a speed slower than the speed of alternation, or rotation, of the stator fields. The rotating magnetic field is produced by using a three-phase power supply. Three groups or sets of coils are embedded in slots in the stator. The three sets of coils are spaced 120 degrees apart. These sets of coils constitute the three phases of the winding to which the three-phase voltages, 120 degrees apart, are applied. The applied voltages will produce currents in each phase winding that are 120 degrees apart. The current in each phase will produce its own magnetic field. The three individual magnetic fields can be combined to form a single composite field.
INDUCTIVE REACTANCE (X_L)	The effect of inductance on an AC circuit. The opposition to the flow of alternating or pulsating current caused by the inductance of a circuit. Because inductive reactance opposes changes to current, it tends to cause the current in a circuit to lag the voltage. Measured in ohms.
INDUCTOR	A circuit element designed so that its inductance is its most important electrical property; a coil.
INERTIA	A property of matter by which it remains at rest or in uniform motion in the same straight line unless acted upon by some external force. A property of matter that resist changes of motion.
INFRARED MOISTURE ANALYZER	Based on the fact that water absorbs certain infrared waves. Used to measure the moisture content of a solid material.
INLET GUIDE VANES	A set of movable triangular-shaped sections, pivoted at a central hub, that control the amount of air entering some dynamic compressors or fans.
INLET VALVE UNLOADER (COMPRESSOR)	A device used to prevent overpressurizing the receiver. The unloader consists of a piston and a connecting rod. The rod is connected to the inlet valve on the compressor. A pressure sensing line is connected from the unloader to the receiver. Air from the receiver fills the pressure sensing line. As the pressure in the receiver increases, it moves the piston and the connecting rod, and opens the compressor's inlet valve. With the inlet valve open, the air that enters the compressor is pushed back out again and is not compressed.. When the pressure in the receiver decreases, the pressure in the unloader piston also decreases, allowing the inlet valve to move back and forth normally, and the compressor

resumes normal operation.

INPUT/OUTPUT METHOD — A method of determining the heat rate for a turbine generator set by comparing the net energy supplied to the set with the amount of useful work that is produced; also called heat balance method.

INSTABILITY (SPC) — Process values remain within the control limits even though abnormal variations are present. Causes could include changes in process materials, changes in sampling techniques, and changes in process variables such as temperature, pressure, and flow.

INSTANTANEOUS OVERCURRENT RELAY — A protective relay that initiates a circuit breaker trip immediately after detecting an overcurrent condition.

INSTANTANEOUS VALUE — The magnitude at any particular instant when a value is continually varying with respect to time.

INSTRUMENT — Any device used to measure, indicate, control, or transmit information about a process or system.

INSTRUMENT AIR — Air suitable for the operation of pneumatic instruments and controls; must be very clean, cool, and dry.

INSTRUMENT AIR COMPRESSOR — Supplies air needed for controlling and regulating the different systems within the power plant. Air at atmospheric pressure enters the compressor through intake filters and is compressed and passed through the aftercooler and separator. From there it goes to the air receiver. The aftercooler and air receiver are equipped with a Y strainer and air trap. Back-up source of air is supplied from the service air system through a filtering system and reducing valve which is set to open at 80 psi.
Air compressor accessories: See Service Air Compressor
Instrument air from the air receiver is supplied to the following:

1. The 100 psig air is supplied directly from the receiver to:
    a. Soot blower panel (controls)
    b. Turbine bleeder trip system
    c. Demineralizer
    d. Chemical lab and instrument rooms
2. The 40 psig air is supplied from the Bailey reducing station to:
    a. Fan damper operators
    b. Feedwater and by-pass regulators
    c. Positioners on the reheat attemperator trip valves
    d. Instruments in the circulating water pump area and fuel tank areas.
3. The 30 psig air is supplied from the Bailey reducing station to:
    a. Control room panels and all transmitters

b. Controllers and control valves throughout the plant that operate on the 3-27 psig air system.

INSTRUMENT IDENTIFICATION CHART	Defines the letters on a diagram, which designate the type of instrument, and its functions.
INSTRUMENT SWITCH	A switch used to disconnect an instrument or to transfer it from one circuit or phase to another. EXAMPLES: Ammeter switch; voltmeter switch.
INSTRUMENT SYSTEM	A group of instruments and associated devices that work together to monitor and/or control the value of a process.
INSTRUMENT TRANSFORMER	A single phase transformer that steps down high voltage or current to a value low enough to be used by instruments. A potential or current transformer.
INSULATOR	A material that offers a great deal of resistance to current flow.
INTAKE FILTER	A device that removes impurities from air before it enters a compressor.
INTER CONDENSER	The first stage air ejector condenser.
INTERCEPTOR VALVES	Controls the steam flow from the reheater to the intermediate and low pressure turbines. These valves are monitored by control oil pressure and will normally open wide when the autostop trip valve is latched. The interceptor valves remain open during normal operation, being held open by a supply of high pressure oil fed through an orifice. In case the speed rises suddenly, the auxiliary governing control oil pressure will increase rapidly and open the interceptor valve trip valve, releasing the oil pressure beneath the interceptor valve servomotor piston to drain, thus closing the interceptor valves rapidly. When the speed rise stops, the auxiliary governing control oil pressure will decrease to its steady state value and when the speed decreases the interceptor will close permitting the oil pressure to be again established beneath the interceptor valves servomotor, thus opening the interceptor valves. A handwheel is provided for manual closing to test reheat safety valves
INTERCOOLER	A cooler used to cool air leaving one compression cylinder before it enters another compression cylinder; only found in multistage compressors. A shell and tube heat exchanger located between stages. As the air passes through the tube in the intercooler, it is cooled by water flowing around the tubes. The cooled air is then routed to the second stage of the compressor. First stage air pressure is approx. 25 psi.

INTERLOCK	An electrical or mechanical arrangement that prevents one operation or sequence of operations from taking place until another prerequisite operation or condition has been satisfied.
INTERNAL BYPASS VALVE	A turbine valve that is part of the main stop valve; designed to regulate the control of steam flow into the turbine during startups.
INTERNAL ENERGY	Due to the rotation, vibration, and movement among the molecules of a substance. Two specific types; chemical energy and nuclear energy.
INTERRUPTER	A device to quickly open an electrical circuit in air.
INVERSE PROPORTION	A proportionality in which when one variable increases by a specific multiple, another variable decreases by the same multiple; if the first variable decreases by a specific multiple, the second variable increases by the same multiple.
INVERTED BUCKET TRAP	A type of mechanical trap that contains an inverted bucket connected to a valve. When the bucket is at rest, it hangs downward with the valve open. Condensate enters the trap either from the side, flowing down the passage in the side of the trap and then upward under the open end of the bucket, or if the trap has a bottom inlet the condensate will enter directly under the bottom of the bucket. As long as condensate is flowing to the trap, the bucket stays down and flow continues out the orifice and passage. When steam reaches the trap it fills the bucket, the bucket floats and rises to close the valve. The steam in the bucket slowly condenses and also bleeds off through the small vent in the top of the bucket. Thus the bucket loses its buoyancy and finally sinks, opening the valve again to discharge more condensate. While the vent allows some of the steam in the bucket to bubble up into the body of the trap and condense, another important purpose of the vent is to permit passage of the air and non-condensable gases. If it were not for this vent the bucket would soon become filled with air and keep the valve closed all the time, or in other words, the trap would become air-bound and inoperative.
INVERTER	A device that converts DC power to AC power.
ION	Atom or group of atoms which have an electrical charge due to gaining or losing one or more electrons. An atom that has too many or too few electrons, causing it to be chemically active; an electron that is not associated (in orbit) with a nucleus. Ions that are positively charged are known as cations while those that are negatively charged are known as anions. A charged particle formed when a solid dissolves in water.
ION EXCHANGE	A method of removing dissolved solids from water by exchanging

	the ions of the solids for ions that will not cause problems in the systems using the water; an example of such ions are those that combine to form pure water.
ION EXCHANGE RESIN	The medium in an ion exchanger where the ion exchange takes place; small, porous, plastic beads that contain areas called sites, which are occupied by ions.
ION EXCHANGER	A component that uses the principles of ion exchange to remove dissolved solids from water; also called a demineralizer.
IONIC BOND	The bond that holds ions together.
IPP	Independent Power Producer
IR (Soot Blower)	Insertable Rotating soot blower, aka Wall Blower
IRON HORSE	The generator hydrogen seal oil supply and purification apparatus. (Westinghouse)
ISAC	Individual System/Station Automatic Control
ISO	International Organization for Standardization; independent, non-governmental organization which develops and publishes International Standards
ISO VISCOSITY GRADING SYSTEM	The higher the ISO number, the higher the viscosity.
ISOCHRONOUS	Equal in length of time. Occurring at equal intervals of time.
ISOLATED-PHASE BUS	Conductors that connect a generator to a main transformer.
ISOTOPES	Forms of a specific atom that have varying numbers of neutrons.

J

JACKET (COMPRESSOR)	A chamber that surrounds the compressor. Water is circulated through the jacket to cool both the compressor and the gas inside it.
JET PUMP	The pressure of a fluid is increased as it flows through an arrangement of fixed channels. The jet pump has no moving parts. A so-called motive fluid is used to pump some other fluid. These pumps are frequently called by other names such as injector, ejector, evacuator, or aspirator. A simplified jet pump consists of a nozzle, inlet line, mixing chamber and diffuser. The motive or actuating fluid enters the nozzle at a high pressure. The nozzle converts the pressure energy of the motive fluid to velocity. The motive fluid then leaves the nozzle with a very high velocity and low pressure. The low pressure in the mixing

chamber causes the liquid being pumped to flow into the mixing chamber through the inlet line. This entering liquid is then entrained and mixed with the high velocity motive fluid. An exchange of energy takes place which in effect slows down the motive fluid and speeds up the incoming liquid. The mixture still has quite a high velocity as it enters the diffuser section. In this section, the velocity energy of the mixture is converted to pressure energy by slowing down. The discharge consists of a mixture of the two fluids at a pressure that is higher than the liquid inlet pressure but lower than the motive fluid inlet pressure. Different fluids may be used to supply the motive power and they can pump different fluids. For example, in the steam jet air ejector, steam is the motive fluid used to pump air from the condenser. In some main turbine hydraulic systems, oil is used as both the motive fluid and the pumped fluid.

JOCKEY PUMP

A pump used to maintain a constant water pressure in a fire protection system and to keep the system filled with water.

JOURNAL (TURBINE)

The part of the shaft that rides inside of a bearing. Normally rotates on a lubricating film of oil or grease. The lubricating film separates the journal from the bearing surface.

JOURNAL BEARING, SLEEVE BEARING, OR SHAFT BEARING

Generally made in upper and lower halves lined with high-grade babbitt metal and assembled in a bearing housing. Oil supply passages are provided in the housing and in the bearing shells through which a supply of oil is furnished to the bearing from the circulation-oil system. This oil is delivered to passageways and grooves which distribute the oil along the length of the bearing which is designed in a manner to assist the formation of the oil wedge on which the journal floats. The passageways and grooves are proportioned and arranged so that considerably more oil flows to the bearing that is required for lubrication. This additional oil flow is required to remove frictional heat and the heat that is conducted to the bearing from the hot parts of the turbine. Bearings use a high-tin babbitt as the inner lining and it is cast on bronze, steel or cast-iron backs. Most journal bearings are of the spherical-seat, self aligning type and are mounted in bearing rings which have an internal spherical surface to fit the ball seat on the bearing. This feature provides for self alignment. The tilting pad bearing is also of the self aligning type consisting of four babbitt lined steel pads. Each pad is supported in the inner bearing ring and is located and pivoted on a spherical button with its spherical end contacting the inner liner located in the center of each bearing pad. This permits the bearing to pivot and align itself to the rotor. The oil wedge on which the journal (shaft) floats is formed by the

	working hydrodynamic oil film which involves bearing clearance, bearing grooving, point of oil application, speed, load and viscosity of the lubricant. As the journal starts turning, it rolls uphill on the bearing surface, and since the journal is then slightly off center, the clearance becomes crescent shaped, with the wedge end of the crescent tucked into the load area. As speed increases, oil is dragged from the crescent to form a thin oil film in the bearing load area. Since the shaft and bearing converge, in effect, oil will leave the high load area at a higher average velocity than it had when it entered. There is a tendency for the fluid to back up in the wedge shaped load area, and since oil cannot be squeezed into a smaller volume, its pressure builds up instead to support the journal load. As the turbine speed decreases the thickness of the oil film is reduced. However, as previously stated, higher oil viscosity permits heavier bearing loading. This is one of the reasons why it is necessary to reduce lube oil temperature when a turbine generator is shut down and placed on the turning gear. Another reason is that lower oil temperature assists in removing the heat from the turbine-generator shaft.
JUMP (SPC)	Level change; when the plotted points on a control chart that are randomly falling around the process centerline suddenly shift towards the upper or lower control limit. May be a change in the materials entering a process or a change in conditions upstream.

K

KILO	A prefix used to indicate one thousand; for example, one kilowatt is equal to one thousand watts.
KILOWATT HOUR	A unit of energy equal to 1000 watthours.
KINETIC ENERGY	Energy possessed by a body due to its motion.
KPLP	Kalaeloa Partners Limited Partnership; oil fired; combined cycle; 2 combustion turbines; 1 boiler; 1 heat recovery generator; 180 MW.

L

LABYRINTH SEAL (lab-ee-rinth)	A device for restricting steam leakage along the turbine shaft. The seal must keep steam from leaking out when the pressure inside the casing is above atmospheric, and it must keep air from leaking in when the internal pressure is below atmospheric. The shaft usually has grooves in it, with matching high and low teeth on the packing rings. This forms a more zigzag path for the steam flow,

	increasing the restriction. The packing rings are usually made of a rather soft bronze alloy that will wear away without damaging the shaft in case there is rubbing. They are made in segments; two, three, or more in both the upper and lower half of the packing casing. Flat leaf-type springs that press the segments radially inward, will "give" in case the rotor should rub the packing. Controls thermal stress by maintaining a gradual temperature change on that section of the rotor, from in to out of the seal.
LAG (ELECTRICAL)	The amount one wave is behind another in time. Expressed in electrical degrees or phase angle.
LAG (LAG TIME)	The total delay in a system's response to an operating change; caused by the combined effects of factors such as resistance, capacitance, and dead time. The total amount of time from when the steam temperature changed until the water temperature reaches its maximum amount of change.
LANTERN RING	An open metal ring between rings of packing in a stuffing box used to admit a sealing or lubricating fluid.
LATENT HEAT OF CONDENSATION	The amount of heat that has to be removed from a substance to condense it without producing a change in temperature or pressure.
LATENT HEAT OF FREEZING	The amount of heat that has to be removed from a substance to freeze it without producing a change in temperature or pressure.
LATENT HEAT OF FUSION	The amount of heat required to melt a substance without a change in temperature or pressure.
LATENT HEAT OF VAPORIZATION	The amount of heat required to turn a quantity of saturated water completely into steam. The amount of heat required to vaporize a substance without a change in temperature or pressure. At atmospheric pressure or 0 pounds per square inch gauge (PSIG), 970 BTU must be added to each pound of water to turn it to steam at 0 PSIG.
LATENT HEAT TRANSFER	Heat transfer that does not cause a temperature change.
LE CHATELIER'S PRINCIPLE	If pressure is applied to a gas equilibrium system, the equilibrium will shift to lesson the pressure.
LEAD	The opposite of lag. Also, a wire or connection.
LEADS	Conductors to or from a piece of electrical equipment.
LECTRODRYER	A unit used for removing moisture from hydrogen. It contains activated alumina as the drying agent which is regenerated by heating and blowing with air.

LEFT-HAND RULE	A method for determining the direction of the magnetic field around a conductor when current is flowing through that conductor. The rule states that if the fingers of the left hand could be wrapped around a conductor with the thumb pointing in the direction of current flow, the fingers would be curled in the direction of flow of the magnetic flux lines.
LEGEND	chart on a diagram containing information about components and symbols used in the diagram.
LENZ'S LAW	The induced EMF in any circuit is always in a direction to oppose the effect that produced it.
LESS LARGEST UNIT	The sum of the capabilities of the operating units less the capability of the largest operating unit must be greater than or equal to the estimated peak load.
LEVEL	The position of a surface above or below a reference point. Measured in feet.
LEVEL CONTROLLERS	Devices that monitor level in heaters and control level by sending a signal to valve actuators to open or close valves, as necessary.
LEVEL TRANSMITTER	A transmitter that senses and measures fluid level.
LEVELTROL	Fisher Governor Company controlling device.
LIFT CHECK VALVE	A relatively small check valve that is used when a very tight seal is essential. Consists of a body, a disc, a seat, and a guide. The guide keeps the disc lined up with the seat as the valve operates. This ensures that the disc will align with the seat as the valve closes. When fluid flows through a lift check valve, the disc lifts. When flow stops, gravity pulls the disc back onto the seat. Fluid backflow will push the disc tight against the seat. Lift check valves can be used in either horizontal or vertical piping runs.
LIGHTNING ARRESTER	A device that protects equipment from high voltage surges that can occur when lightning strikes equipment, or lines or buses connected to equipment. A device which has the property of reducing the voltage of a surge applied to its terminals.
LIME	A dry white powder consisting essentially of calcium hydroxide that is made by treating caustic lime with water. Used when treating Vertan® waste to speed up the sludge forming process.
LIME SOFTENING	A process in which lime is added to water to remove hardness impurities such as calcium and magnesium by creating a precipitate that is removed from water as sludge.
LIMIT SWITCH	A simple on/off device which allows remote, electronic indication of the position of a valve, damper drive, or any moving device

	whose position needs to be known for control system purposes. A switch in an electric motor actuator that cuts off current when the final control element has reached a specific position.
LINE OF FORCE	A line in a field of force that indicates the direction of the force.
LINEAR EQUATION	Any equation whose points on a graph fall on a straight line.
LINES OF FORCE	A line in a field of force that indicates the direction of the force.
LINK	Means of opening an electrical conductor. Not used in normal switching procedures.
LIQUID RING VACUUM PUMP	A rotary vacuum pump in which a flow of liquid, usually water, forms a ring around the rotor of the pump and forms a compression chamber. A pump used to create a vacuum in a system.
LITHIUM	An oil thickener used in grease. Lithium greases are multipurpose greases. They are water resistance, and they are able to withstand high temperatures, so they can be used in applications where both heat and water are factors.
LIVE ZERO	Any minimum signal value that is greater than zero.
LJUNGSTROM AIR HEATER	Absorbs waste heat from flue gas, then transfers this heat to incoming cold air by means of continuously rotating heat transfer elements of specially formed metal plates. Protected from dew point corrosion by the recirculation of warm air from the air heater outlet to the inlet of the forced draft fan. The amount of recirculation is controlled by the average impulse of the temperature of the air entering and temperature of the flue gas leaving the air heater.
LOAD	The amount of electrical usage in a power system. A circuit or piece of equipment that uses electric power. The impedance to which electrical energy is being supplied. Can be a device, such as a motor, that uses power, or a device, such as a transformer on a motor control center, that supplies power to other circuits. The amount of electrical power being supplied by a generator to an electrical distribution system.
LOAD BLOCK	An adjustable turbine control device used to limit the minimum amount of load the machine will carry.
LOAD DISPATCHER	The individual who predicts the demand for power, monitors the condition of a power system, and coordinates the outputs of the plants in the system so that supply always equals demand.
LOAD DROP ANTICIPATOR	A device used to sense sudden loss of load above 50%. It will initiate a signal to close the interceptor and steam chest valves

	hence arresting the steam flow to the turbine, thus preventing overspeed. It consists of a pressure switch responsive to IP turbine inlet chamber pressure in series with a solenoid type current relay. The pressure switch contacts are closed above 50% and the current relay contacts are open above 20% load. These contact functions are reversed at loads below 20% and both contacts are open between 20 and 40% load. If the load is rejected above 50%, the current will drop closing the current relay contacts. However, the IP turbine inlet pressure will remain high until the interceptor valves close and the pressure dissipates. A solenoid valve will be energized to increase the control oil pressure, thereby closing the steam chest and interceptor valves. The anticipator energizes the solenoid valve until the interceptor valves are closed and the IP turbine inlet pressure decays after which time the control of the unit reverts back to the main governor.
LOAD FACTOR	The ratio of the average load over a designated period to the peak load occurring in that period.
LOAD LIMIT VALVE	A sensitive spring loaded relief valve which can be set to limit the control oil pressure in the control oil header to any value corresponding to the desired maximum load. Hydraulically connected to the governing control oil system through a ball check valve. This valve can be adjusted to maintain a control pressure corresponding to any governing control oil pressure between no load and full load. Whenever the governing control oil pressure drops below the load limit control oil pressure, the ball check valve moves off it seat permitting the load limit valve control pressure to replace the governing control oil pressure and prevent the governing valves from opening further.
LOAD REJECTION	A sudden reduction in the amount of electrical usage in the power system, which may cause a turbine to overspeed.
LOAD SHEDDING	The cutting off of electricity to specific consumers in a power system in response to load demands in excess of generating capacity; done to prevent damage to generating units. Intentional interruption of power being supplied to a utility's customer(s) for the purpose of reducing system demands as to avoid a power failure during a period of reduced generating capability.
LOADING PRESSURE	A modulated air pressure which is an index of one or more control variables.
LOBE COMPRESSOR	A positive displacement compressor. Works by trapping gas and then forcing it out of the compressor. Has two figure-eight shaped

lobes inside of a casing, an inlet port, and a outlet discharge port. The lobes rotate in opposite directions inside the compressor and are spaced to prevent gas flow from leaking back to the compressor's inlet port. During operation, the tips of the lobes alternately sweep across the inlet port. When one of the tips moves beyond the port, a volume of gas is trapped between the lobe and the casing. The trapped gas is transferred to the upper area of the casing, and then through the discharge port and into the discharge piping. As the rotation continues, each lobe packs successive volumes of gas into the discharge. Each additional volume of gas that is packed into the discharge raises the pressure of the gas at the discharge.

LOBE PUMP	A rotary pump using lobes mounted on parallel shafts that rotate in opposite directions. A pair of timing gears, located at one end of the shafts, maintains the proper relation between the lobes throughout the rotation. Liquid is drawn into the space between the lobe and the case and is pushed from inlet to outlet.
LOGIC	Control scheme. Provides the permissive and the interlocks for safe operation.
LOGIC DIAGRAM	A drawing of an electrical system that uses logic circuits. A diagram that uses symbols to represent actions in a control system.
LOUVERS	Vanes for directing and controlling air or gas flow.
LOW BEARING OIL PRESSURE TRIP	Consists of a spring loaded diaphragm exposed to bearing oil pressure. The diaphragm is connected to a dump relay through linkage. If the bearing pressure falls below a pre-set value of 5 to 6 psi it will release the oil from the overspeed trip valve through an intermediate relay.
LOW PRESSURE HEATER	A heater, usually located before the suction of the boiler feed pump, where the pressure of the water is relatively low, that uses the latent heat of extraction steam to heat the water that passes through the tubes.
LOW VACUUM TRIP	This device utilizes a pressure responsive bellows which is exposed to exhaust vacuum. When the exhaust pressure drops below a preset value, adjustable between 18 and 25 inches of mercury, a spring loaded lever is actuated which in turn causes the trip relay to release the overspeed trip valve. A means of latching the vacuum trip is provided, which when engaged prevents the device from operating during starting when the exhaust vacuum is less than the normal trip setting. However, it will function with the latch engaged should the exhaust pressure increase to 2-1/2 to 3-1/2 psig during the starting cycle. The latch will fall out of

	engagement when the exhaust vacuum has reached a value of 20 to 28 inches of mercury, and will thereafter trip at the normal value of 18 to 25 inches of mercury, unless relatched.
LOW VOLTAGE	600 volts and lower.
LOW VOLUME WASTE	Classified waste that does not exceed the limits of our NPDES permit. Does not contain items found in the Code of Regulations.
LP SECTION KEY	Secures the turbine to the foundation. Located just about in the middle of the outer LP casing. The turbine expands towards the governor pedestal (front standard).
LUBE OIL COOLERS	Heat exchangers that use a flow of water to cool turbine lube oil.
LUBE OIL TRIP	A circuit designed to activate a solenoid trip when the lubrication oil pressure falls below a certain value.
LUBRICANT	A substance used to reduce friction.
LUBRICANT OXIDATION	Occurs when a lubricant combines with oxygen. Produces acids that can cause corrosion of metal. Tends to occur more rapidly in equipment that operates at high temperatures. Can also form harmful deposits on metal surfaces, such as varnish or carbon deposits. These deposits can greatly increase friction on bearings and other machine parts and keep them from operating freely.
LUBRICATING OIL SYSTEM	A turbine support system designed to provide lubricating oil to the turbine. Lubrication prevents metal-to-metal contact between stationary and rotating parts and abnormal wear due to friction. The oil supplied to the lubrication system is taken from the main oil pump discharge, passes through the oil cooler and thence to the main bearings, thrust bearing and turning gear. A relief valve is provided in the bearing oil line to compensate for moderate changes in oil requirements. A check valve between the bearing oil header and the main oil pump discharge assures isolation of the high pressure oil system for maintenance when unit is on turning gear. A relief valve in the bearing oil line is set to maintain a pressure of 10 to 12 psig, while the orifice supplying oil to the bearing oil header is set to maintain 12 to 13 psig with no flow through the relief valve. The relief is then backed off to maintain the 10 to 12 psig bearing oil pressure required. A Cuno Filter consisting of two filter elements in parallel is mounted on the oil reservoir to filter the high pressure oil to the control system. An additional Cuno Filter is installed in the high pressure oil line to the control devices. Three other oil pumps are located in the main oil reservoir for the following purposes: **1.** Auxiliary Oil Pump - 75 HP, AC 440 V, is used during

starting and stopping periods. This pump will automatically start when bearing oil pressure drops to about 8 to 10 psig.

2. Turning Gear Oil Pump - 10 HP, AC 440 V, is used for supplying bearing oil pressure when unit is on turning gear. This pump will automatically start when bearing oil pressure drops to about 5 to 8 psig.
3. Emergency Oil Pump - 10 HP, DC 125 V, is used for back-up in case all AC power is lost. This pump will automatically start when bearing oil pressure decays to about 3 to 4 psig.

The switches controlling each of these pumps will start the pump on falling pressure but will not stop the pump on rising pressure. To stop any of these pumps after the oil pressure has risen to a point at which the pressure switch closes it is necessary to turn the switch to off position. The pump will stop but the switch will automatically return to the "auto" position and in so doing will remain under the control of the pressure switch in case of a drop in pressure. These switches are provided with a "Test" valve which can bleed off pressure on the test header to actuate the pump start for testing purposes. These tests can be carried out during normal operation without affecting the system. Another pressure switch, also connected to the bearing oil header prevents the turning gear motor from starting until bearing oil pressure has risen to somewhere above 2 to 4 psig. High and low level alarm switches are provided in the reservoir to give indications when either of these two levels has been reached. Two oil coolers are provided, and are connected by a tandem-operated three-way valve to switch from one cooler to the other. An interchange valve and sight are provided to assure that the coolers are full of oil before changing over. The interchange valve should always be open to the idle cooler except for periods during maintenance.

LVW — Low Volume Waste

M

M-268 — Used in the Vertan® treating process to isolate copper from the Vertan® waste, which is then removed along with the sludge.

MACH .9 — Speed just before supersonic.

MACHINE — Any system, usually of rigid bodies, formed and connected to alter, transmit, and direct applied forces in a predetermined manner to accomplish a specific objective, such as the performance of useful work. A device that uses applied forces

	advantageously.
MAGNETIC AMPLIFIER (MAGAMP)	A reactor of which the output is varied by changes in saturation caused by small changes from a control current coil.
MAGNETIC COUPLING	A variable speed coupling that uses magnetic force to transfer torque from the shaft of a driver to the shaft of driven equipment.
MAGNETIC FIELD (H)	The space in which a magnetic force exists. Composed of the area through which the magnetic lines of force pass. The total number of lines of force issuing from a pole.
MAGNETIC FLUX	The total number of lines of force issuing from a pole; Number of magnetic lines in a magnetic circuit. More lines ➔ more strength.
MAGNETIC OVERLOAD DEVICE, OR MAGNETIC OVERLOAD RELAY (MCC)	Operates on the magnetic field generated by current. Consists of a coil around a metal core and a set of contacts. The contacts are held together by a spring. The overload device's coil is in the motor controller's power circuit. When the power circuit is energized, current flows through the coil, creating an electromagnetic field. The strength of the electromagnetic field increases as the current flowing through the coil increases. When the current level gets too high, the strength of the electromagnetic field increases enough to overcome the force of the spring. As a result, the contacts are pulled apart, which interrupts current flow through the control circuit. The interruption of current flow through the control circuit opens contacts in the motor controller. This interrupts current flow to the motor through the power circuit, and the motor stops.
MAGNETITE	A natural magnet.
MAGNETO	An alternating current generator in which the field is supplied by a permanent magnet.
MAIN GOVERNOR	The main governor produces a governing control oil pressure which varies in accordance with the turbine speed with a fixed setting of the speed changer. When operating in parallel with a utility system or with large units in the same plant, the turbine speed is controlled by the electrical tie of the generators. Under such operating conditions the speed changer actually becomes a load changer. This is true because changing the steam flow can only change the torque while the speed of the turbine is scarcely affected. Accordingly then, there is a different load for every position of the speed changer. The main and auxiliary governors are mounted on a common housing base to the side of the thrust bearing pedestal. These two governors are similar in operation, except that the auxiliary governor is not provided with a motor driven speed changer.

MAIN GOVERNOR TRANSFORMER	The governor transformer, magnifies the relatively small pressure changes delivered by the governor impeller into larger pressure changes which are used to actuate the relay of the servomotor.

MAIN OIL PUMP

A component of the turbine's lubricating oil system. An oil pump that is attached to and driven by the turbine rotor, and whose discharge pressure is dependent on rotor speed. It is a volute type centrifugal pump with a large capacity range with very little change in discharge head. All operating mechanisms are single acting, that is, they open hydraulically, and are closed by springs. Thus there is no extra load imposed on the pump when the valve operating mechanisms are suddenly closed following a trip out or load rejection. The pump is not self-priming, and must have a positive suction pressure at all times during operation. This positive suction pressure is provided either by the auxiliary lube oil pump on startup, or by the main oil pump's ejector when the shaft is up to speed. Actually a lousy pump, because the seals are very loose. Wide clearances provide for rotor long and rotor short during startup. The main oil pump supplies all of the oil required for the control and lubrication systems during normal operation and in addition provides two sources of back up oil for the hydrogen seal oil system of the generator. Oil us supplied to the pump at about 25 psi. Oil discharge by the pump is at about 150 psi, and is used for the following purposes:

1. To operate the oil ejector which supplies the main oil pump suction. The ejector picks up a quantity of oil from the reservoir approx. equal to the amount of HP oil supplied to the ejector.
2. To operate the two steam chest servomotors which position the governing valves.
3. To provide a source of filtered HP oil to operate all the control devices and operating mechanisms.
4. To supply lubrication. An adjustable orifice is used to reduce the flow to the proper amount. The bearing oil flows through a 3 way tandem valve, and to one of two identical oil coolers. A relief valve compensates for small changes in requirements.

MAIN STEAM PRESSURE SET-POINT	The design pressure value for steam entering the HP turbine.
MAIN STEAM STOP VALVE	A specially designed, hydraulic cylinder operated valve that stops the flow of steam to the turbine to prevent possible damage.
MAIN STEAM SYSTEM	A system of pipes and valves that directs and controls the flow of steam from the boiler to the turbine.

MAIN STEAM TEMPERATURE SET-POINT	The design temperature value for main steam; intended to provide as much energy as possible to the HP turbine, while preventing over-heating.
MAIN STOP VALVES	Turbine steam valves designed to admit steam to the HP turbine during normal operation, shut off the flow of steam during shutdowns, and regulate the flow of steam during startups; also called throttle valves.
MAINTAINING CONTACTS (Ma)	Auxiliary contacts that are operated by the "M" coil.
MAINTENANCE DERATING (D4)	A derating that can be deferred beyond the end of the next weekend but requires a reduction in capacity before the next Planned Outage (PO). A D4 can have a flexible start date and may or may not have a predetermined duration.
MAINTENANCE OUTAGE (MO)	An outage that can be deferred beyond the end of the next weekend, but requires that the unit be removed from service, another outage state, or Reserve Shutdown state before the next Planned Outage. Characteristically, a MO can occur any time during the year, has a flexible start date, may or may not have a predetermined duration, and is usually much shorter than a PO.
MAKEUP WATER SYSTEM	A system connected to the condenser that adds pure water to the condensate system to compensate for water losses that may occur as a result of condensate sampling or steam and water leaks in the system.
MANIPULATED VARIABLE	The variable that is adjusted, or regulated, to maintain a controlled variable set-point. Example: make-up water into a tank to maintain the tank's water level.
MANOMETER	A liquid filled U-tube used to measure pressures. A measuring device that use columns of liquids to measure pressure. Compares pressure inside of sealed containers to that of the atmospheric pressure outside of the container. The pressure applied is determined by adding the travel in the two legs. Used to measure condenser vacuum, windbox pressure.
MANUAL OPERATION	Operation of a switch or circuit breaker by hand without using any other source of power.
MASS	Anything that has weight and takes up space. The amount of matter that a body possesses. Proportional to the weight of a substance. Flow units are pounds per hour.
MASS FLOW RATE	Measured as a unit of mass, such as pounds, per a unit of time, such as hours.

MATERIAL BALANCING	A method of calculating the amounts of substances, called reactants, that must be put into a process in order to produce the desired amounts of products. Involves the use of chemical equations, and it can be divided into two steps. The first step is to make sure the equation is balanced. Both sides having the same number of the same types of atoms. The second step is to use the balanced equation to determine the relative amounts of substances that will react with each other. For example, in the reaction between hydrogen ions and hydroxyl ions, one hydrogen ion reacts with one hydroxyl ion to form one molecule of water. This means that, in principle, 100 hydrogen ions will react with 100 hydroxyl ions to form exactly 100 molecules of water. There will be no hydrogen ions or hydroxyl ions left over.
MATTER	Anything that has weight and takes up space. Can be visible, like steel and water, or invisible, like air. Exist in three forms: solid, liquid, and gas. All matter is made up of atoms.
MCC	MOTOR CONTROL CENTER. A MCC is an assembly of one or more enclosed sections having a common power bus and principally containing motor control units. Motor control centers are in modern practice a factory assembly of several motor starters.
MCE	Motor Circuit Evaluation
MCW	Metal Cleaning Waste
MEASURING ELEMENT	The element of a control system that converts the input from the primary element into a signal representing the actual value of a process variable; transmitter.
MECHANICAL ADVANTAGE	The ratio of the output force of a machine to the input force. The ratio between the resistance force (weight) and the applied force. Resistance Force ÷ Applied Force.
MECHANICAL BURNER	The fuel oil enters the gun through the lower port of the stationary and removable unions, and passes through the inner oil gun to the nozzle. The oil passes through the back plate and tangential slots in the whirl plate to the whirl chamber. The action of the tangential slots imparts a rotary motion to the oil. From the space between the whirl plate and spray plate, part of the oil is sprayed into the furnace through the orifice in the spray plate and the remainder is returned through the outer holes in the spray plate and back plate to the outer oil gun pipe. The return oil leaves the gun through the upper ports of the unions.

MECHANICAL DRAFT COOLING TOWER	A type of cooling tower that uses large fans to create air flow through the tower to cool circulating water.
MECHANICAL ENERGY	Energy in transition, sometimes called work. Usually measured in foot-pounds. Two types; potential and kinetic energy.
MECHANICAL SEAL	Seals the area between the shaft and the casing. Does the same job as packing, but provide a more complete seal. Consists of two basic parts: a stationary element that is attached to the pump casing, and a rotating element that is attached to the pump shaft. Each element has its own seal ring. The two rings are positioned close together to form a nearly perfect seal that has virtually no leakoff. To prevent the seal rings from drying out, overheating, and becoming damaged, some type of lubricant must be supplied to them. In some applications, the process liquid being pumped is used as the lubricant. However, when the liquid being pumped could be hazardous if the seal fails, or if the liquid contains abrasives or other solids, such as in a slurry, an external liquid may be used to lubricate the seal rings.
MECHANICAL TRAP	A trap whose operation is sensitive to the difference between the density of steam and the density of condensate. Operate on change of state of the fluid coming to the trap, whether water or steam. They open to water or condensate, but close on steam. Float trap; open bucket trap; inverted bucket trap.
MECHANICAL-HYDRAULIC CONTROL SYSTEM	A turbine control system that uses a mechanical governor and oil from the turbine lube oil system to monitor and control turbine speed.
MEGA	A prefix used to indicate one million; for example, one megawatt is equal to one million watts.
MEGAVAR	One million vars.
MEGAWATT	One million watts.
MEGGER	Electrician's term for checking electrical insulation.
MEGOHM	One million ohms.
MEMBRANE (ED)	An ion exchange resin cast in sheet form which is essentially water-tight and electrically conductive.
MENISCUS	The curved upper surface of a nonturbulent liquid in a container. It is concave if the liquid wets the container walls and convex if it does not. The free surface of a column of liquid. Water and oil both form a concave meniscus, which means that the center of the column is lower than the outer edges. The level of any meniscus should be read at its center, so the level of a concave meniscus is

read at the lowest point. Mercury forms a convex meniscus, which means that the center of the column is higher than the outer edges. The level of a convex meniscus is read at the highest point.

MERCURY (Hg) — A silvery-white poisonous metallic element, liquid at room temperature. 13.6 times as heavy as water.

METAL CLEANING WASTE — This type waste includes wastewater resulting from cleaning any metal process equipment. Wastewater produced by boiler fireside and air preheater washes, condenser foam cleaning, and boiler tube chemical cleanings are generally characterized by very high suspended solids and dissolved metal concentrations. In addition to the limitation for low volume waste discharges, metal cleaning wastes must also contain less than one part per million of iron and copper.

METER ORIFICE — A primary device used for establishing pressure differentials in the measurement of flow through pipes.

MFP — Multi-function processor

MHC — Manual Hydraulic Control System

MHO — A basic unit of electrical conductivity that is used to describe a substance's ability to conduct current. A mho is the reciprocal of an ohm. An ohm is used to describe a substance's resistance to current flow.

MICROFARAD — One millionth of a farad.

MICROMHOS (μmhos) — A unit of measurement of water conductivity.

MID-SPAN SEAL — A seal between the HP and IP sections of the turbine; prevents steam from leaking between the two sections during normal operation.

MIL — One thousandth, usually of an inch or an ampere.

MILLI — A prefix used to indicate one one-thousandth; for example, one milliamp is equal to one one-thousandth of an amp.

MINIMUM NET POSITIVE SUCTION HEAD (PUMPS) — The minimum predetermined value of the amount of suction head that must be met to prevent cavitation. The pressure just above the pressure at which the liquid will boil for a given flow and temperature. Factors that influence values for minimum net positive suction head are liquid temperature and type of liquid.

MIXED BED DEMINERALIZER — These contain both cation and anion exchange resins in the same vessel, intimately mixed. The alternating cation and anion resin beads provide an infinite series of cation/anion exchange pairs. This produces the best quality water possible. Mixed bed units are

	also referred to as polishers as they remove any ions which passed through the other beds.
MIXED FLOW PUMP	Pumps that combine the radial flow of centrifugal pumps with axial flow. The liquid enters the impeller in an axial direction and discharge in both an axial and radial direction usually into a volute type casing. The discharge pressure is developed partly by centrifugal action and partly by the dynamic lift of the impeller on the liquid. This type of pump is frequently used for circulating water pump service in power plants. In this application the pump is installed vertically with the suction submerged in the water at all times. These pumps deliver large flow rates at medium head with a low rotational speed.
MIXED-BED ION EXCHANGER	An ion exchanger in which the resin bed consists of anion and cation resin beads mixed together.
MIXTURE	Consists of two or more materials that are not joined together chemically. The properties of the materials that produce the mixture do not change. The proportions of the materials in a mixture can vary. Formed mechanically, and can be separated mechanically.
MKS	Meter (length) Kilogram (mass) Second (time)
MOISTURE	Diffuse wetness that can be felt as vapor in the atmosphere or as condensed liquid on the surfaces of objects; dampness. The measurement of the amount of water in a solid material.
MOISTURE SEPARATOR	A device used to remove moisture from compressed air.
MOLECULAR WEIGHT	The weight of one molecule of a compound; can be determined by adding the atomic weights of the elements that make up the compound.
MOLECULE	The smallest particle of a chemical element or compound that retains all the properties of that element or compound. Made up of a group of atoms held together by a chemical bond. Bond is created when atoms transfer or share valence electrons.
MOLLIER DIAGRAM	A graph of entropy vs. enthalpy that indicates most of the properties of wet steam and superheated steam.
MOLYBDENUM DISULFIDE, OR MOLYSULFIDE	A solid lubricant; a powder typically blended with grease, such as lithium grease. Molysulfide powder is used because it has the ability to withstand extreme pressure.
MONOSODIUM PHOSPHATE	A chemical used for pH control.
MORPHOLINE	pH control of condensate and feedwater system. Also contribute to maintaining proper steam pH to prevent acid attack (corrosion)

in the superheat and turbine sections.

MOTION — A body changing position.

MOTOR — A device that uses electrical energy to produce mechanical energy. The motion between the stator's magnetic field and the rotor's magnetic field results from the interaction between two magnetic fields, causing the rotor to rotate. Provides the driving force to move, operate, or position components. Used in some process systems as final control elements.

MOTOR ACTION — The movement of an object, such as the rotating part of a motor, that results from the interaction between magnetic fields. All motors work because of the interaction of two or more separate magnetic fields.

MOTOR CONTROL CENTER (MCC) — A common housing for motor controllers. An MCC houses the controllers for the motors in a particular process. Basically a bus that supplies power only to motors. It may also contain other electrical devices, such as circuit breakers and switches.

MOTOR CONTROLLER — A device or a group of devices whose purpose is to control and protect a motor. Has a motor circuit, or power circuit, that provides power to the motor. It also has a control circuit that can open or close the power circuit.

MOTOR-GENERATOR SET — A machine which consists of one or more motors mechanically coupled to one or more generators, usually DC.

MOTORING — This usually refers to a generator with the driving energy removed from the prime mover but still connected to system electrically. The generator is then acting as a motor and continues to rotate.

MOTOR-OPERATED ACTUATOR, OR MOTOR-OPERATOR — Used when a valve has to be throttled or when a large amount of force is needed to position a valve. Consists of a motor and a set of gears that turn a valve stem to open or close the valve. Also has a handwheel, a lever, and switches. Two types of switches are commonly connected to the gears of a motor operator: a limit switch and a torque switch. When the motor operator is energized, the motor drives the gears. The gears move the valve stem to position the valve. The lever is used with the handwheel to position the valve manually if there is a problem with some other part of the motor operator. Depressing the lever disengages the motor from the gearing and connects the handwheel to the valve stem through part of the gearing. The limit switch and the torque switch in the motor operator ensure that the valve is positioned without damaging the valve or the motor operator. The torque switch cuts off the current to the motor when the torque, or turning force, produced by the motor operator reaches a preset

	amount. Ideally, the torque switch limits the force on the valve stem to prevent damage, while, at the same time, ensuring a tight seal between the valve disc and seat. If an obstruction blocks stem movement in a valve, a properly set torque switch can cut off the motor before damage occurs. While a torque switch cuts off current to the motor when the turning force reaches a preset amount, a limit switch cuts off current to the motor when a valve reaches a preset position. The limit switch allows the actuator to move the valve stem only within a certain desired range. For example, the limit switch on a motor operator may shut off the current to the motor when the valve is fully open.
MOVING BLADING (BUCKETS)	Turbine blading that is attached to the shaft and converts the thermal energy in steam into mechanical energy.
MOVING R CHART	Used together with other charts to give a more complete picture of what is happening in a process. Centerline sometimes called R bar. Each moving range value that is plotted on a moving R chart is determined by looking at the most recent sample reading and a specified number of previous readings, and then subtracting the lowest value from the highest value.
MOVING X BAR CHART	Used to monitor continuous processes. Centerline is sometimes called X-double-bar. Plotted using moving averages. A moving average is an average that is calculated using the most recent sample value and a specific number of previous sample values.
MULTIPLE ORIFICE AND CHECK VALVE	Control oil to each of the throttle valves, interceptor valves and the reheat stop valves is supplied from orifices in the high pressure line. These orifices and a check valve are encased in a single body.
MULTIPORT PLUG VALVE	Has additional piping connections and a different type of plug than a regular plug valve. Instead of a plug with an opening that allows fluid to pass straight through the plug, a multiport plug has an L-shaped opening. Has L-shaped markings on their handles to indicate the position that the valve is in. The "L" on the handle is aligned to the shape of the opening through the plug.
MULTISTAGE CENTRIFUGAL COMPRESSOR	A compressor in which the air is compressed in several steps. Higher discharge pressure than a single-stage centrifugal compressor. The number of stages indicates the number of times the gas is compressed. It also indicates the number of impellers and volutes that the compressor contains. For example, a multistage compressor using three impellers and three volutes is called a three-stage compressor.
MULTISTAGE PUMP	A pump that has more than one impeller mounted on its shaft; the

	fluid's pressure is increased in steps; generally used in condensate and feedwater systems.
MULTIWEIGHT OIL	Combine the properties of a lower viscosity oil for low temperature with those of a higher viscosity oil for high temperature. For example, 10W-40 oil. At higher temperatures, this oil has the properties of a 40-weight oil. At lower temperatures, it has the properties of a 10-weight oil.
MUTUAL INDUCTANCE	A circuit property existing when the relative position of two inductors causes the magnetic lines of force from one to link with the turns of the other.
MUTUAL INDUCTION	The inducing of an electromotive force in a circuit by a changing current in a nearby circuit.
MVA	Megawatt-Voltage-Amps. MVA = MW + MVAR. MW = MVA ÷ PF. Refer to the generator capability curve.

N

NAAQS	National Ambient Air Quality Standards. Protects the public health and welfare from the effects of air pollution.
NAMEPLATE RATING	The full-load continuous rating of a generator, prime mover or other electrical equipment under specific conditions as designated by the manufacturers.
NARROW PROPORTIONAL BAND	A proportional band that is less than 100%. A small change in input to the controller produces a larger change in output. Control action is rapid, and the value of the controlled variable stays close to set-point.
NATURAL CIRCULATION	The process by which water and steam move through some drum-type boilers; based on the fact that cold water is heavier than hot water or steam, so colder water in downcomers pushes hot water and steam upward through boiler tubes.
NATURAL DRAFT TOWER	A cooling tower in which the air used to cool the circulating water is forced through the tower by the difference in the temperature of the air from the bottom of the tower to the top of the tower.
NEEDLE VALVE	A type of globe valve. Usually smaller than other globe valves and are designed to give fine control of flow in small-diameter piping.
NET GENERATION	The amount of electrical energy produced per hour; also called net electrical output.
NET HEAT RATE	The heat rate of a generating unit calculated by using the electrical

	power that is fed to the grid.
NET POSITIVE SUCTION HEAD	The actual pressure at the suction eye of a pump.
NET POWER	The total amount of power that is produced by the generator (gross power), minus the auxiliary power used to run plant components.
NETWORK	Any electrical circuit containing two or more interconnected elements.
NEUTRALIZATION REACTION	A reaction in which hydrogen ions or hydroxyl ions are removed from a liquid.
NEUTRON	A particle having no charge; found in the nucleus of an atom. A neutral particle.
NIPPLE (PIPING)	Used to join two pieces of pipe. Basically a short piece of pipe with male threads, that is, it is threaded on the outside. The nipple screws into the components that it connects.
NIS	Network Interface Station.
NITROGEN OXIDES (NOX)	Pollutant gases that are produced from atmospheric nitrogen and excess oxygen when combustion takes place under conditions of high temperature and high pressure environment of the boiler furnace. NOX symbolically represents the composition of NO (nitric oxide, colorless) and NO2 (nitrogen dioxide, orange color) molecules. In the combustion process, nitrogen originates from the air (where it is molecularly stable as N2 at ambient temperatures), and from the fuel, where it is bound to the hydrogen molecules. At the high flame temperatures in the furnace (>2500°F), a small portion of the molecular nitrogen dissociates and reacts with oxygen to form NO. Similarly, as the hydrocarbon molecules react, the bound nitrogen atoms are freed to react with oxygen to form NO. NO formation increases as: **1.** gas temperature, **2.** oxygen availability, or **3.** fuel nitrogen are increased. NOX in utility boiler flue gas streams is typically comprised of 97-99% NO, with the remainder present as NO2. After, being emitted to the atmosphere for several hours, the NO reacts with atmospheric oxygen (O2) and ozone (O3) to form NO2. Scrubbers and other external pollution control devices do very little to reduce the amounts of nitrogen oxides that are released from a boiler. Considered a major air pollutant, NOX is harmful

	to the environment, causes health problems, and attacks the ozone.
NIU	Network Interface Unit
NOMOGRAPH	A graph that uses three or more different scales to represent the values of three or more variables that are related.
NON-RETURN VALVES	Valves that operate like swing check valves and function to protect the turbine from possible back flow in case the flow of steam to the turbine stops. See Bleeder trip Valve.
NORMAL DISTRIBUTION CURVE, OR BELL CURVE	Represents the natural variation that occurs in all processes, and it is the basis for SPC control charts. The center of this curve represents the mean value, or the average of the data being plotted. The downward slope is the same on each side of the mean value line. This means that there are basically as many data points to the left of the average as there are to the right of it.
NORMAL, OR RANDOM VARIATION	Occurs randomly and naturally in a process. Statistical control.
NOX CONTROL	NOX formation in utility boilers may be limited in several ways: **1.** Low Excess Air - will reduce **a.** the quantity of oxygen available for reaction with nitrogen in the burner flame zone, and **b.** flame temperature. **2.** Staged Combustion - produces fuel-rich and air-rich combustion zones. Consequently, the overall combustion zone is larger in size, peak temperatures are lower, and localized oxygen deficient regions exist. The result is lower overall NOX formation. **3.** Flue Gas Recirculation to the Windbox (FGR) - provides for an added amount of inert gas in the flame zone to absorb heat, thereby reducing peak flame temperature and reducing NOX formation. **4.** Fuel Nitrogen Limits - NOX formation from fuel-bound nitrogen is directly proportional to fuel nitrogen concentration.
NOZZLE	A set of fixed blades.
NOZZLE BLOCK	A component located at the inlet to the HP turbine section and used to increase the velocity of the steam flow so that the proper relationship between blade velocity and steam velocity can be established. The first row of fixed blading in the control stage of a turbine. The blades are usually separated into groups so that each group can be supplied with steam from an individual control valve.

NP CHART (SPC)	Used to display the actual number of defective products produced by a process. The vertical axis represents the number of defective products, and the horizontal axis represent a percentage of the products produced, such as every tenth product.
NPDES (NATIONAL POLLUTION DISCHARGE ELIMINATION SYSTEM (1972))	Regulates the discharge of pollutants from waste streams directly into our waterways. The EPA has the authority to issue the discharge permits and to enforce the discharge limitations of the permit. Failure to comply with the permit conditions can result in fines of up to $25,000 per violation per day. Our three generating stations have their own NPDES permits which set limits on the condenser cooling volumes and temperatures for each generating unit. The iron, copper, undissolved solids, and the oil and grease content of the wastewaters are also limited. The pH of the wastewaters must be adjusted between 6 to 9. The copper and iron levels must be below 1 ppm.
NPM	Network Processing Module.
NUCLEAR ENERGY	Energy produced from Uranium. Can be released from the nuclei of atoms in certain substances by causing them to split.
NUCLEAR FISSION	The process of breaking down uranium (fuel) in a nuclear reactor.
NUCLEAR PLANT	A power plant that uses energy from uranium to produce electric power.
NUCLEATE BOILING	Steam bubbles form slowly and are removed from the surface as quickly as they form.
NUCLEUS	The central core of an atom; contains protons and neutrons.
NUTATING DISC METER	A device that measures flow directly. Gets its name from the action of a disc located in the meter. The word "nutate" means to wobble or roll about an axis of rotation. A type of flow meter with a disc that wobbles about an axis to trap and measure specific quantities of fluid.

O

O2 ANALYZER	A device, located in the flue gas flow path, used to measure the percentage of oxygen in the gas. The measurement provided by the device is an indicator of excess air.
OFF-PEAK ENERGY	Electric energy supplied during periods of relatively low system demands as specified by the supplier.
OFFSET	The amount of difference between the control point of a process

	variable and set-point.
OHM	The unit of electrical resistance.
OHM (R)	Unit used to measure electrical resistance. The electrical resistance opposes the flow or movement of electricity, and the energy dissipated in overcoming this opposition appears as heat.
OHM'S LAW	A statement of the relationship between current, voltage, and resistance in an electrical circuit. The current in an electric circuit is directly proportional to the electromotive force in the circuit. 1 volt of magnetism will push 1 amp of current, through 1 ohm of resistance. E(volts) = I(amps) x R(ohms); current equals voltage divided by resistance.
OHMMETER	A device used to measure resistance in an electrical circuit.
OHM'S LAW	The current in an electric circuit is directly proportional to the electromotive force in the circuit.
OIL CIRCUIT BREAKER (OCB)	A circuit breaker in which the interruption occurs in oil. Used for practically all high voltage circuits, ranging from 12KV to 230 KV. These breakers are very large and are constructed so that a tank completely surrounds the mechanism. This tank is filled with oil. All contact opening and closing operations are performed in this oil bath. As the contacts open under load, an arc forms. This arc vaporizes a small amount of oil into a gas and ionizes the gas. This gas bubble is quickly replaced by fresh oil which cools and extinguishes the arc. The oil also acts as an insulating media between current carrying contacts and earthed parts of the breaker. Due to their large size, these breakers are always operated electrically.
OIL RESERVOIR	Contains screens for removing all foreign matter from the oil drained back to the reservoir. The ejectors, orifices, check valves, etc. are all enclosed in the reservoir. Two identical oil coolers are provided and connected by a tandem operated three way valve which permits either oil cooler to be used. The cooler not in use can be drained and cleaned or replaced with the unit in operation. Before switching coolers, it is important that the spare cooler be filled with oil. An interchange valve is provided for this with a sight flow in the vent to observe when the spare cooler is full. The interchange valve is normally left open. A vapor extractor maintains a slight negative pressure in the oil system.
OIL SEPARATOR (COMPRESSOR)	Used to remove oil from compressed air, which could damage pneumatic instruments. The oil that is removed collects in the bottom of the separator and is drained to a waste system. Has an inlet, a series of baffle plates, a wire mesh screen, a sump, and a

air outlet. Compressed air that enters the oil separator passes around the baffle plates. As the air travels around the plates, it is forced to make rapid changes in direction. The oil, which is heavier than the air, is not able to change directions as easily. As a result, the oil droplets separate from the air, collect on the babble, and then drip down into the sump. After the last baffle, it flows through the wire mesh screen, which traps most of the small amounts of remaining oil, and also drip into the sump.

OIL WHIP — If the turbine lube oil is allowed to get too cool (less than approximately 105°F) when the turbine is rolling, the oil will build too much of a film, or wedge under the rotor. This wedge will not remain because of the spinning action of the rotor hydraulically pushing it out. Since the oil is thicker and slower moving at lower temperatures, the void under the rotor will not be replaced with oil quickly enough. The rotor "falls" due to no oil wedge, and then re-climbs the journal, creating another thick wedge. This cycle repeats itself rapidly, violently shaking the turbine. This is called oil whip.

OILER (COMPRESSOR) — An oil injector which supplies a small amount of oil to the compressor cylinder. In the cylinder, piston rings are used to maintain a seal between the piston and the cylinder. The oil lubricates the piston rings and helps seal the space between the cylinder wall and the rings.

OIS — Operator Interface Station

OIT — Operator Interface Terminal. Usually a CRT (Cathode Ray Tube) which displays graphic and text type data for the operator. Also provides the operator push buttons (membrane keys, mouse, or touch screen) to allow equipment operation selections. Also know as HMI (Human Machine Interface) or MMI (Man Machine Interface).

ON GOVERNOR — Indicates turbo-generator is at approximately synchronous speed and is under control of the turbine governor.

ON THE LINE — Synchronized and connected electrically with the system, usually referring to the main generator.

ONAN — A LPG (propane) operated DC generator providing 125 volt power to the preferred bus. Onan (aka Cummins Onan) brand of generators are built by Cummins Power Generation.

ONE MINUTE PER REPEAT (1 MPR) — When the reset part of the control action increases, or repeats, the proportional action one time in one minute.

ON-PEAK ENERGY — Electric energy supplied during periods of relatively high system

	demands as specified by the supplier.
OPACITY	Used to describe the visibility of the stack plume, and is defined as the percentage of incident light removed by a gas stream or plume due to scattering and absorption by suspended particles. Typically measured by instruments (transmissometers) that direct a light beam across the duct through the gas stream. These measurements yield real-time, continuous emissions data that can be related to stack plume visibility. Opacity is determined by four quantities: mass concentration (mass of particles per unit volume of gas), particle density, path length that the light beam travels, and light scattering characteristics of the particles (e.g., size distribution of the particles). For a given mass concentration, smaller particles will scatter more light than larger particles, and thus the gas stream with the smaller particles will be more visible (higher opacity).
OPACITY METER	An instrument that measures the concentration of suspended particles in a gas.
OPEN (CIRCUIT)	A circuit in which the resistance is so great that there is no current flow.
OPEN BUCKET TRAP	A type of mechanical trap that contains a bucket or float, open at the top, connected to a valve. When condensate comes to this trap, it gradually fills up the body and floats the bucket, causing the latter to rise and close the valve. Finally condensate spills over the top of the bucket and the bucket sinks. This opens the valve and the pressure inside the trap forces the water up through the discharge tube and out the orifice. As soon as the bucket is emptied sufficiently it floats again closing the valve and the cycle is repeated.
OPEN BUS	A bus without an enclosure.
OPEN HEATER	A heater that is classified as a direct contact heater because extraction steam and feedwater come into direct contact and mix.
OPEN IMPELLER (CENTRIFUGAL PUMP)	Has no shrouds to direct the flow of liquid. Where this design helps prevent clogging, it is less efficient at moving liquids than a closed impeller, since the flow of liquid is not directed between the vanes. Used to pump thick liquids or liquids with solids, such as slurries.
OPERATING CAPACITY	The maximum volume of fluid that is moved by a pump under normal conditions.
OPERATING COIL, OR “M” COIL	The coil inside the contactor through which current is supplied. When the “M” coil is energized, it produces a magnetic field. An

	iron core inside the "M" coil concentrates the magnetic field. When the "M" coil is energized, it becomes an electromagnet and attracts an armature. This moves a set of movable contacts against a set of stationary contacts. The armature is connected to a pack of springs, which are compressed as the armature is pulled down. When the contacts close, a complete path for current flow through the controller to the motor is established. When the "M" coil is de-energized, the electromagnetic field is removed. The springs then push the armature back to its original position, separating the two contacts.
OPERATING POINT	The specific combination of pressure and flow that is used to determine if a pump is suited for a particular application.
OPERATION	As applied to a switch or circuit breaker, is the method provided for its normal functioning.
OPERATIONS KEYS (COMPUTER)	Used to run printers and other devices.
OPERATOR CONSOLE	A component in a digital control system that allows operators to monitor and direct the activities in the system, primarily using a keyboard and a display.
ORGANIC CHEMISTRY	The study of carbon, and the chemicals that contain carbon. Inorganic is the study of everything else.
ORIFICE	A device that creates a differential pressure by restricting the flow of a liquid; often used as a component in a flow sensing element. Device for restricting flow or reducing pressure. Pressure decreases, velocity increases.
ORIGIN	Coordinate point (0,0) on a graph.
OUTAGES	Exists whenever a unit is not synchronized to the grid system and not in a Reserve Shutdown state.
OVAL GEAR METER	A type of flow meter that uses gears to trap and measure specific quantities of fluid.
OVERCURRENT RELAY	A relay that provides protection from excessive current conditions. A protective device that opens a circuit when it detects excess current flow.
OVERLOAD	A load greater than the rated load of an electrical device.
OVERLOAD RELAY	A relay that operates on excessive current.
OVER-PRESSURE (OP)	Purpose is to boost spinning reserve generation during peak hours, and meet quick load pick-up capabilities. Unit condition at maximum load with maximum throttle pressure. Off EMS, boiler

	master off cascade/on automatic.
OVERSPEED	A mechanical condition that occurs when rotating machinery exceeds its designed operating speed.
OVERSPEED TRIP (OVERSPEED GOVERNOR, AUTOMATIC STOP GOVERNOR)	An automatic device that protects a turbine from overspeed conditions; energizes the turbine trip circuits, stopping the flow of steam to the turbine. This mechanism consists of an eccentric weight transversely mounted in the end of the turbine shaft, which is balanced in position by a spring until the speed reaches 111%. Its centrifugal force then overcomes the spring and the weight flies out striking a trigger which trips the overspeed trip valve releasing the autostop pressure to drain. Operation of the overspeed governor automatically trips the throttle valve and shuts down the turbine. Set by pulling the autostop trip handle on the governor pedestal to latch position. When latched, the governing valves, reheat stop valves, and interceptor valves will open wide; the oil operated air pilot valve should operate to allow the extraction non-return valves to open. Provision is made for testing the overspeed trip mechanism without actually overspeeding the turbine. If the overspeed trip mechanism hand lever is held to prevent the trip valve from opening, it can be tested without taking the unit off line or removing load. This is accomplished by admitting oil under pressure to the chamber beneath the trip weight and noting the pressure required to move the weight outward.
OVERSPEED TRIP TEST	Set at 111% of rated speed (4000 rpm). During the test an operator should stand by prepared to trip the unit with the hand trip lever in the event that the mechanism fails to function before reaching 4100 rpm. Unit must be on a minimum of 4 hours, with a minimum of 10% rated load, to ensure equipment temperatures are normal; centrifugal stress.
OVERSPEED TRIP VALVE	Produces the auto stop oil pressure when latched.
OXIDATION	Combustion that does not produce heat or light.
OXIDATION INHIBITOR, OR ANTI-OXIDANT	Additives blended with lubricants to help control oxidation.

P

P CHART (SPC)	Similar to an NP chart, except that it indicates the percentage of defective products. The vertical axis represents percent defective, and the horizontal axis represent time. The total number of defective samples is divided by the number of samples collected. The result is then multiplied by 100 to produce a percentage

figure.

PACKING (PUMP) — Seals the area between the shaft and the casing. A flexible material that fits into the space between the shaft and casing. A small amount of process liquid is allowed to leak through. This leakoff acts as a cooling mechanism to remove heat from the packing. If too much leakoff is allowed, the efficiency of the pump may be affected. If too little leakoff is allowed, the packing will overheat, dry out, and possibly burn. The packing on a pump is held in place by a packing gland. The gland is in turn held in place by studs with adjusting nuts. As the adjusting nuts are tightened, they move the gland in and compress the packing. This in effect squeezes the packing out radially making a tight seal between the rotating shaft and the inside wall of the stuffing box.

PACKING (VALVE) — A rope-like material soaked with a lubricant such as oil, grease, or powdered graphite. The lubricant reduces friction between the packing and the valve stem. The packing fits snugly around the valve stem.

PACKING GLAND (PUMP) — Holds the packing in place. Bolted to the pump's casing, and can be adjusted to maintain the proper amount of leakoff.

PACKING GLAND (VALVE) — Fits into the top of the stuffing box, holding the packing in place.

PACKING RINGS — Seals located between the stationary blades and the rotor.

PARADIGM — model or pattern.

PARALLAX ERROR — An error that results in incorrect gauge readings; caused by reading the gauge from any position other than straight on.

PARALLEL CIRCUIT — A circuit containing two or more parallel paths through which current can flow.

PARALLEL FLOW — A flow pattern in surface heat exchangers in which two fluids flow in the same direction.

PARAMAGNETIC OXYGEN ANALYZER — An analyzer that measures the oxygen concentration of a gas mixture based on the principle that oxygen is attracted to a magnetic field.

PARAMETER — A physical property such as temperature, pressure, or flow.

PARTIAL ARC — Sequential valve control. Throttle valves wide open, with governing valves regulating. Temperature and pressure drops across the valves that are not wide open. A condition that occurs after the transfer point in a turbine startup; a state in which steam is admitted through only part of the nozzle block at a time, as a result of the sequential opening and closing of the control valves. Each governor valve will open wide, sequentially, before steam

	flow goes to critical flow (supersonic), until all valves are open. Efficiency up to 7%.
PARTICULATES	Pollutants; very fine unburned solid particles of material that are left in glue gas after combustion. Contains ash (non-combustible mineral matter), inorganic compounds (sulfates, salts, sediments), and carbonaceous organic compounds (coke residue, soot, acid smut).
PARTS PER MILLION (PPM)	Measurements that express the amount of a material per million parts of total solution. Used for measuring very low concentrations of materials. One pound of salt in one million pounds of water is one part per million of salt. Equals one ten-thousandth of one percent (0.0001%).
PCB or PCBs	Polychlorinated Biphenyls. A group of toxic, persistent chemicals used in transformers and capacitors. Further sale or use was banned in 1979 by law.
PCU	Process Control Unit
PCV	Process Control View.
PEAK LOAD	The maximum load consumed or produced by a unit or group of units in a stated period of time. It may be the maximum instantaneous load or the maximum average load over a designated interval of time.
PEAK VALUE	The amount of voltage or current at the maximum positive or negative point on a sine wave. The maximum instantaneous value of a varying current, voltage, or power. It is equal to 1.414 times the effective value of a sine wave.
PEAKING CAPABILITY	Generating capability available to assist in meeting that portion of peak load which is above base load.
PEAK-TO-PEAK VALUE	The amount of voltage or current represented by the distance between the positive peak and the negative peak on a sine wave.
PEENING	The process in which shrouding is attached to a row of moving blading by hammering tenons on the blades through holes in the shrouding to rivet the shrouding to the blading.
PERCENT MEASUREMENT	A fractional value expressed in terms on the number of parts per one hundred. Percent measurement express the amount of a material per 100 parts of total solution, either by weight or by volume. For example, if a solution of water and dye contains 10 ounces of dye and the total volume of the solution is 100 ounces, then the concentration of dye is 10 parts per 100 parts of solution. Ten divided by 100 is .10, or 10%, so the concentration of dye is

	10% by volume.
PERCENT-BY-WEIGHT	Refers to the concentration of solute in a solution expressed as a percentage of the weight of the solution. Basically, the percentage is based on the weight of the solute in relation to the weight of the solution as a whole. Helpful in understanding how solutions with different concentrations relate to each other.
PERIODIC TABLE OF THE ELEMENTS	A listing of all known elements in an arrangement designed to show some of the specific characteristics of each element. Shows the atomic weight of all atoms. The atomic weight is shown just below the element's symbol. The atomic weight is expressed in atomic mass units (AMU). Each element is represented by a block that includes the element's atomic number, chemical symbol, and atomic weight.
PERMEABILITY	A property of matter that indicates the ease with which it is magnetized. The ability to deflect lines of force or concentrate them.
PERMEATE	The portion of feedwater which penetrates (permeates) the membrane. The term product and permeates are synonymous in pure water applications.
PERMISSIVE	Usually affecting the start-up of the equipment in question.
PFOBP	Primary Fuel Oil Booster Pump
PFOP	Primary Fuel Oil Pump.
pH	The logarithm or reciprocal of hydrogen-ion concentration. A measure of the relative acidity or alkalinity of a solution.. A scale calibrated to determine the extent of the acidity or alkalinity of water, 7 being neutral, from 7 to 14 being alkaline, increasing in alkalinity as the number rises. From 1 to 7 is acid, increasing in acidity as the number decreases. pH too low or too high causes corrosion. When the relative amounts of hydrogen ions and hydroxyl ions in a solution are equal, the solution is neutral.
PHASE	A single electrical circuit.
PHASE CHANGE	Occurs during heat transfer, where there are changes in molecular energy, but these changes do not result as a temperature change. Three phases, or states of matter are solids, liquids, and gases.
PHASE DIFFERENCE	The time in electrical degrees by which one wave leads or lags another.
PHASE SHIFT TRANSFORMER	Changes the phases of voltage to match another.

PHOSPHATES (PO4)	A group of chemicals used in a steam plant. The purpose of the phosphate treatment is to precipitate any hardness (calcium and magnesium) in boiler water that may have sneaked through our external treatment system or which may have entered the feedwater system via condenser leaks. Without any internal treatment, hardness precipitates as calcium or magnesium carbonate or sulfate, and deposits on boiler metal as scale. Phosphate ties up calcium and magnesium as a flocculent phosphate precipitate which can be removed through boiler blowdown. For this reaction to take place, enough alkalinity must be present. Calcium is not precipitated properly below a pH of 9.5. This is why we use caustic, to maintain sufficient alkalinity for the proper precipitation of hardness as a phosphate flocculent. Forms of phosphate commonly used for pH control include monosodium phosphate (acid) and trisodium phosphate (alkaline). Disodium phosphate (about neutral) is used to control pH and prevent scaling on/in tubes and drums.
PHOTOELECTRIC CELL	A device that uses light to produce electricity.
PHOTOELECTRIC EFFECT	The principle of producing electricity by using light. Certain materials will generate electricity when they are exposed to light. For example, a solar cell contains this type of material. When the light intensity is increased, more electricity is generated.
PHOTOMETER	An instrument for measuring a property of light, especially luminous intensity or flux.
PHOTON	A quantum of radiant energy; light ray.
PHOTOVOLTAICS	A module that produces electrical current when exposed to sunlight.
PI	A symbol for a constant value that is approximately equal to 3.14159; a constant that is used to calculate the area of a circle.
PID CONTROL	Control action that combines a proportional response with a reset response and a rate response. Also known as proportional-plus-integral-plus-derivative control.
PIE GRAPH	A circular, or "pie" shaped, graph that is frequently used to show percentages.
PILOT EXCITER	A generator that supplies current for the electromagnet in the stator of a DC exciter. A small DC generator used to control the field of the main exciter.
PILOT LIGHT	A small light usually near the control switch to indicate the condition of the circuit being controlled.

PILOT OIL TORCH (OIL SIDE IGNITOR)	Designed to serve as an ignition torch for main oil guns and gas torches. The pilot torch is a spark ignited, oil torch with flame indication, which is operated remotely from the control board. The torch itself consists of a mounting plate, torch head, torch nozzle, atomizer assembly and spark plug assembly.
PILOT TORCH AIR SYSTEM	Designed to provide adequate combustion air to the pilot torches at all normal operating conditions.
PILOT VALVE (THROTTLE VALVE BY-PASS)	For startup control; full arc conditions; capacity is approx. 20% of full load at rated throttle pressure.
PILOT VALVE, OR SPOOL VALVE	Guides, or controls, the flow of hydraulic fluid to and from an actuator. The amount of fluid entering the cylinder and bled from the cylinder must be accurately controlled, to accurately position a valve. The pilot valve is connected to the actuator by fluid lines. Consists of a valve body, solenoids, a spool, a spring at each end of the spool, a hydraulic fluid supply port, two hydraulic fluid ports to the actuator, and two hydraulic fluid vent ports. The pilot valve is operated by the solenoids, which respond to signals from a controller to position the spool. One solenoid is attached to the top of the spool, and the other is attached to the bottom. When both solenoids are de-energized, the springs return the spool to a neutral, or centered, position. This blocks the fluid lines going to the actuator and holds the actuator's piston in place. When the lower solenoid is energized, the spool is pulled downward, and hydraulic fluid is supplied through the lower fluid line to the actuator. The fluid enters the actuator cylinder at the bottom, pushing the piston up and opening the valve. At the same time, fluid is forced out of the top of the cylinder through the upper vent port, and back to the hydraulic fluid line, back through the pilot valve, out through the upper vent port, and back to the hydraulic fluid supply. The filling and venting of the actuator's cylinder is reversed by de-energizing the lower solenoid, and energizing the upper solenoid. When the upper solenoid is energized, it pulls the spool up, blocking the upper vent line and the path for supply fluid to the lower fluid line. Hydraulic fluid is supplied to the top of the actuator's cylinder, pushing the piston down and closing the valve. The fluid below the piston is vented through the lower fluid line, back through the pilot valve, out through the lower vent port, and back to the hydraulic fluid supply. The piston can be held in place by de-energizing the upper solenoid. This allows the springs to return the spool to a neutral position and blocks the fluid lines to the cylinder, holding the piston and the valve in position.
PINCH VALVE	Sometimes used to control the flow of heavy sludge and slurries.

	The basic types of pinch valves are enclosed-body pinch valves and open-frame pinch valves. Both types are relatively easy to recognize. An enclosed-body pinch valve has a cylindrical body that encloses most of the valve parts. In an open-frame pinch valve, all of the valve parts are visible. The enclosed-body pinch valve consists of a stem, which may be attached to a handwheel; a bar, or clamp; and a flexible tube through which fluid flows when the valve is open. When the handwheel is turned to close the valve, the stem pushes the bar against the tube. This action squeezes, or pinches, the tube between the bar and the valve body, stopping the flow of fluid through the tube. In some pinch valves, the bar may be connected to the top of the tube. This connection helps the tube return to its original shape as the valve is opened. Since most of the valve's components are outside of the flexible tube, there are no components in the flow path of the fluid through the valve for materials to collect on. For that reason, pinch valves are ideally suited for handling fibrous slurries and sludge.
PIPING & INSTRUMENTATION DIAGRAM (P&ID)	Diagrams that show the components in a system and how those components are connected. A diagram that shows where components are located in the flow path of a plant system. Shows material flows, equipment in the system, and the devices used to monitor and control conditions in the system.
PISTON AND CYLINDER RECIPROCATING PUMP	Has a cylinder, which is located inside the casing, and a piston, which is attached to a connecting rod. The pump also has two valves: a suction and a discharge valve. During operation, when the piston moves back on the suction stroke, the pressure inside the cylinder is reduced. The reduced pressure closes the discharge valve, opens the suction valve, and draws a specific amount of liquid into the cylinder. When the piston moves forward on the discharge stroke, it exerts a force on the liquid in the cylinder that increases the pressure. The increased pressure shuts the suction valve, opens the discharge valve, and pushes the liquid out of the pump. After the liquid is displaced, the piston moves back, and more liquid is drawn into the pump to begin this cycle again.
PITTING	A form of localized attack that causes pits to be formed in metal. Caused by localized anodic sites that are formed by metal surface cracks, scratches, or oxygen differentials. Usually with low flow water rates.
PLANNED DERATING (PD)	A derating that is scheduled well in advance and is of a predetermined duration.
PLANNED OUTAGE (PO)	An outage that is scheduled well in advance and is of a predetermined duration, lasts for several weeks, and occurs only

	once or twice a year. Turbine and boiler overhauls or inspections, and testing are typical Planned Outages.
PLASTICIZER	Any of various liquid or solid organic substances added to modify viscosity, flexibility, or strength.
PLC	Programmable Logic Controller. The computer (usually housed in the main electrical control panel) which contains the programming through which the equipment is electrically controlled and/or monitored.
PLC PID	PLC Proportional Integral Derivative. The PLC 4-20 milli-ampere analog outputs are varied between 4 and 20 mA based on feedback from process variables i.e. flow, level, etc. The PID controller in the PLC program is the module which provides this control, based on the operator selected set-point. PID control may also be used to control the pulse rate of a discrete output which will vary from 0-100 pulses per minute.
PLUG (COCK) VALVE	A type of valve generally used in small piping systems. Consists of a body in which a cylinder or plug is fitted with close tolerances. The cylinder has a slot which permits flow through the valve when it is in one position and stops or prevents flow when the cylinder is rotated 90 degrees. Generally used for on/off purposes in situations that require quick valve operation and a tight shutoff, such as a gas line. Usually recognized by its cylindrically shaped mid-section and flat bottom. Open to close is about 1/4 turn. When the valve handle is in line with the piping, the valve is open.
PLUMB BOB	A type of direct level measurement device that consists of a weight and a measuring tape.
PLUME	A characteristically-shaped stream of materials entering the environment (air or water) from a localized source such as a stack or discharge pipe. A plume may be visible (smoke, water droplets, etc.) or invisible (heated air, colorless gas, heated water, etc.).
PLUMMET	A plumb bob. Anything that weighs down or oppresses; a float.
PNEUMATIC ACTUATOR	A actuator that uses air pressure to produce motion to position a valve. Probably the most common type of actuator used in process systems.
PNEUMATIC TRANSMITTER	An instrument that senses and measures a process variable and produces an air output signal that represents the value of the process variable.
PO4	Phosphate. Serves as a weapon to combat deposition/scaling. A

	major component in formation of the soft compound in the boiler that doesn't adhere to the boiler metal surfaces and can be blown down.
POINT OF MAXIMUM EFFICIENCY	The point at which a pump provides the maximum flow for the least amount of power.
POISONED CATALYST	A catalyst that can no longer function properly.
POLAR MOLECULE	A molecule that exhibits equal and opposite charges on opposite sides.
POLARITY	Pertaining to, or designating a pole. An indicated polar extreme: an electric terminal with positive polarity.
POLE	One of the ends of a magnet where most of its magnetism is concentrated.
POLLUTANTS	Substances that cause detrimental effects to the environment.
POLLUTION	Contamination of the environment by the discharge of harmful substances.
POSITION TRANSDUCER	Position indicating devices which provides a continuous (actual position) feedback signal as to the valve/equipment status. Provides a 4-20 milliamp signal to the control signal. 4 milliamp indicates closed, while 20 milliamp indicates 100% open.
POSITIONER	A device that use a separate supply of air to ensure that an actuator correctly positions a valve in response to a change in the air signal from a controller. A typical positioner has three gauges. One indicates the supply air pressure to the positioner, another indicates the output air pressure to the actuator, and the third indicates the input signal pressure from the controller. A mechanical linkage joins the actuator stem to the positioner. This mechanical linkage is sometimes called a feedback linkage. As the actuator stem moves up or down, it also moves the linkage. The position of the linkage indicates to the positioner when enough movement has occurred to correspond with the air signal from the controller. When a positioner is used with an actuator, the signal from the controller goes to the positioner instead of directly to the actuator. The positioner controls a source of air that is sent to the actuator through a supply line. When the controller sends a signal to close the valve, the positioner receives the signal and converts it to the appropriate air pressure using its air supply. This pressure is then applied to the actuator to close the valve. The feedback linkage indicates to the positioner how far the valve is from the desired position, which, in this case is

	fully closed. As the valve moves toward the fully closed position, the feedback linkage causes the positioner to change the air supply to the actuator so that as the valve reaches the fully closed position, actuator movement is stopped.
POSITIVE CONDUCTOR	A conductor connected to the positive terminal of a source of supply.
POSITIVE DISPLACEMENT COMPRESSOR	Work by trapping a certain amount of gas and forcing it into a smaller volume. A common type is a reciprocating compressor.
POSITIVE DISPLACEMENT PUMP	A pump in which a constant positive volume of liquid is displaced or moved during each pumping cycle. The volume of liquid pumped or moved is equal to the volume displaced by the piston or other moving parts. Positive displacement pumps can be further divided into two classes determined by the motion of the pumping element. These types or classes are reciprocating where the motion is back and forth, and rotary where rotational motion is used.
POTENTIAL	The degree of electrification of a body, voltage or electrical pressure. Electricity at rest. Static voltage or static electricity.
POTENTIAL DIFFERENCE	The force that causes electrons to move or flow in a conductor. Voltage; electromotive force. Unit of measurement is the volt. It takes a difference of one volt to force a current of one ampere through a resistance of one ohm.
POTENTIAL ENERGY	Energy possessed by a body due to its position or elevation. Energy of an object at rest. Stored energy that is waiting to do work.
POTENTIAL TRANSFORMER (PT)	A small instrument transformer for measuring voltage of a power circuit. Used in electrical power system to step down system voltage to a safe value, which is then fed to low ratings meters and relays. A component that typically steps line voltage down to a lower voltage that is in direct proportion to the amount of line voltage. The lower voltage can then be used by measuring instruments and protective devices. Designed so that the output voltage will be 120 volts when the maximum input voltage is applied. Connected in parallel with or across the main circuit. These transformers are usually fused on both the input and output sides. The output side fuses are provided to protect the PT against faults in the output circuit. The input side fuses are primarily provided to protect the main circuit in case of a fault in the potential transformer. In most cases the PT's are mounted in draw-out disconnect enclosures.

	When drawn out the PT is not only disconnected, but is automatically grounded at the same time. The use of instrument transformers with standard output ratings makes it possible to have standard meters, indicators and relays. It is only necessary to provide the correct scale for the meter.
POWER	The amount of work done in a given interval of time. The rate at which work is done or energy is expended. The unit of electrical power is the watt. Unit is foot/pounds per second. Work (ft/lbs) ÷ Time = ft-lb/sec. 1 (one) Horsepower is equal to 550 ft-lb/sec.
POWER (MATH)	A number that indicates how many times a base number is to be multiplied by itself.
POWER BLOCK	Turbine, generator, electrical equipment.
POWER CONDITIONER	The "FerroPowr" Power Line Conditioner protects the performance of the computer system and other sensitive equipment by providing: **1.** Protection from noise, voltage spikes and transients. **2.** Continuous line regulation to compensate for both brownouts and overvoltages. **3.** Instant response, with no moving parts. **4.** Reliable and maintenance-free operation with no failure-prone semiconductors. **5.** Complete isolation from the AC line for enhanced safety.
POWER CURVE (PUMPS)	Shows how much power a manufacturer expects will be used to operate a pump at given flow rates under normal conditions.
POWER FACTOR	The amount of difference (amount out of phase) between the voltage sine wave and current sine wave, on each individual stator coil. Sometimes referred to and measured as VARS (volt-ampere-reactive). The ratio of the true power of an alternating current, as measured by a wattmeter, to the apparent power, as indicated by ammeter and voltmeter readings. True power divided by apparent power. The power factor, if an indicator of capacitance or inductance, is an expression of electrical losses.
POWER FACTOR OF 1	Current sine waves are exactly the same as voltage sine waves. Voltage and current are considered to be at unity. If the current (amperage) sine waves differ from the voltage sine waves, the PF has been reduced. Current leads voltage.
POWER TRANSFORMER	The main transformer, where power comes into the plant. It converts the incoming high voltage from the distribution lines to a lower voltage that is used within the plant.

POWERLINE 1320, Nalco 7220, COAGULANTS, or DISPERSENTS	Used to gather up iron, copper, or soft sludge compounds in the boiler. It can then be blown down more efficiently. Caution should be used when injecting these chemicals. Some may suppress the pH of the boiler system.
PRECIPITATE	To chemically cause (a solid substance) to be separated from a solution. To be chemically separated from a solution as a precipitate.
PRECIPITATOR	A device used to separate particulates from flue gas leaving a boiler.
PRESSURE	Force applied over a surface, measured as force per unit of area. Measured in pounds per square inch, psi. Collision of molecules. 3 ways to create pressure: **1.** Weight of a substance - The weight of the body divided by the area on which the body rest. **2.** Mechanical force **3.** Heating a fluid in a closed container
PRESSURE BREAKDOWN BUSHING	A device used to reduce pump stuffing box pressures. It is also called a throttle bushing by some manufactures.
PRESSURE BREAKDOWN ORIFICE	A flow restriction used to reduce a pressure by limiting the flow.
PRESSURE GAUGE	Instruments for measuring the difference between atmospheric pressure and the pressure in a pipe or vessel. Bourdon Tube Gauge.
PRESSURE LOSS ACROSS	The difference between the inlet and outlet.
PRESSURE REDUCING VALVE (COMPRESSOR)	Reduces instrument air from 120 psi (service air) to a value needed for use in pneumatic instruments and devices throughout the plant.
PRESSURE SWITCH	Responds to changes in pressure by opening or closing an electrical circuit.
PRESSURE TRANSMITTER	Converts the pressure to a 4-20 milliamp signal which is read by the control system in a remote location. Only one sensing line into it.
PRESSURIZED FURNACE BOILER	A boiler in which the pressure of the incoming air from a forced draft fan pushes flue gas out through the stacks.
PRIMARY (REAR) SUPERHEATER	Low temperature elements or first stage of steam superheating. A superheater located in the gas pass, above the economizer. Heated primarily by convection.
PRIMARY CELL	A type of battery that releases energy by chemical action without

	being charged; typically, a dry cell.
PRIMARY CIRCUIT	The first, in electrical order, of two or more coupled circuits, in which a change in current induces a voltage in the other or secondary circuits; such as the primary winding of a transformer.
PRIMARY ELEMENT	The element of a control system that senses changes in a process variable; float, thermocouple. A sensing device that is located where the process variable is monitored.
PRIMARY F.O. HEATER	A heat exchanger installed on the side of the fuel oil storage tank and piped to the suction of the transfer pump. It is used to heat only that portion of fuel oil which flows to the suction of the pump.
PRIMARY WINDING	The winding of a transformer to which the electrical energy is supplied; the coil that draws power from the source.
PRIMING	The act of removing air and filling a component with fluid before putting the component into operation.
PROCESS CONTROL SYSTEM	Monitors the value of a process variable and provides actions that control the value of the variable. Two basic types are manual control and automatic control.
PROCESS DISTURBANCE	An event that causes the value of a process variable to change away from set point.
PROCESS FLOW CHART	A block diagram. The blocks represent pieces of equipment in a process system, and the lines represent flows. This type of diagram is often used to describe a process system.
PROCESS INSTRUMENTATION	Instruments that monitor and/or control process variables.
PROCESS VARIABLE	A process-related condition, such as temperature, level, pressure or flow, that is subject to change. The actual controlled process; what value you have at the moment. A physical condition whose variation can affect the operation of an industrial process. Actual value minus live zero, divided by span, equals percentage.
PROGRAMMABLE CONTROLLER	A computer-based process control device that uses a control logic program to control a process such as safety interlocks and to control operations. Commonly used to establish protective circuits in sequential process systems.
PROPORTION	An equation stating that two ratios are equal.
PROPORTIONAL BAND	The amount of controller output change (Delta Output) in relation to a given amount of input change (Delta Input); usually expressed as a percentage. PB = Input ÷ Output; PB x 100% = % PA

PROPORTIONAL CONTROL	A control's output signal is proportional to its input signal. If the input to a proportional controller changes by a given amount, the controller's output will also change by a given amount.
PROPORTIONALITY	A mathematical relationship in which a change in one variable causes a proportional change in another variable.
PROTECTIVE RELAY	A relay, the principal function of which is to protect service from interruption or to prevent or limit damage to apparatus.
PROTON	A positively charged particle contained in the nucleus of an atom.
PSIA	Pounds Per Square Inch Absolute. Indicates a pressure valve that uses a scale range where atmospheric pressure is 14.7 PSI of pressure. Zero absolute pressure is a perfect vacuum.
PSIG	Pounds Per Square Inch Gauge. Indicates a pressure valve that uses a scale where atmospheric pressure is zero gage pressure.
PTI	Power Technologies Incorporated
PULL OUT POINT	Point at which generator loses synchronism.
PUMP	A machine or device for transferring a liquid or gas from a source or container through tubes or pipes to another container or receiver. Grouped in two categories: positive displacement pumps and centrifugal pumps.
PUMP STROKE CONTROL	A method of adjusting either manually or automatically the length of stroke of a pump piston, so as to vary the quantity of chemical feed.
PURGE CYCLE	A sequence of operations involving a continuous time interval during which combustible gases are removed from the boiler and fuel cannot be admitted.
PURGE INTERLOCK	An interrelated combination of boiler safety devices which must be satisfied before the initiation of the purge cycle.
PURITY ANALYZER	A device that measures the percentage of hydrogen, in air, inside a hydrogen-cooled generator.
P-V ENERGY	Arises from the pressure and the volume of a substance. Steam under pressure possesses this form of energy. Numerically equal to the product of pressure and volume.
PVC	Poly Vinyl Chloride
PYROMETER	An instrument that measures the temperature of the substance it is in contact with.

Q

QUICK LOAD PICKUP (QLPU)	Sufficient generating unit capability must be available such that, upon tripout of any one unit, the remaining units will have sufficient quick load pick-up capability to restore system frequency to at least 58.5 Hz within three seconds after tripout.

R

R CHART	Indicates the range of the variable that is being measured. The lower control limit is often set at zero. The X axis is used to display how often samples are taken, in the appropriate units. The Y axis is used to display the range of the sample group, again in the appropriate units. Centerline sometimes called R bar.
RACES (BEARING)	Grooves in the inner and outer rings of a typical ball bearing, that the balls travel in. The inner ring fits tightly around the shaft. The outer ring is fixed in a housing.
RACK IN OR OUT	Connecting or disconnecting the control and power terminals of a circuit breaker to the external circuit.
RACKING OUT	The process of physically separating a circuit breaker from an electrical system.
RADIAL FLOW PUMP	Centrifugal pump. Main internal components are an impeller and a volute. Higher discharge pressures, but do not move as much liquid as other types of centrifugal pumps. Has a 90° liquid run.
RADIAL LOADS	Forces that act along a radius of a bearing or shaft.
RADIAL MOVEMENT	Movement that is up or down, or from side to side.
RADIAL SEAL	A type of seal that extends from the center axis of an air heater along the radius; used to prevent air from leaking into the gas.
RADIATION	A method of heat transfer in which heat is transferred directly across an open space. The transfer of heat due to the property of materials to emit and absorb electromagnetic waves. Energy radiated in the form of waves or particles.
RADIOACTIVE DENSITY ANALYZER	An analyzer that measures density without making direct contact with a process liquid.
RADIUS	The distance from the center of a circle to the edge of the circle.
RAMP RATE	For a generator, the speed at which the generator changes load. The rate at which turbine metal temperature can be increased each hour during startup or decreased each hour during shutdown.
RANKINE	Based on the fact that temperature is a measure of the average speed at which the molecules of a substance are moving. It can be

	theoretically calculated that all molecular motion stops at a temperature of -460°F. This point is defined as 0 Rankine.
RANKINE EFFICIENCY	The design efficiency of a cycle with normal values for its operating parameters.
RATE	A comparison of two quantities through division; one of the quantities is usually time.
RATE CONTROL	Control action that responds to the speed at which a process variable deviates from set point. The faster the variable changes, the greater the amount of rate change action. Normally combined with proportional control, so it is often called proportional-plus-rate control. Sometimes called proportional plus-derivative, or PD, control.
RATEAU BLADE	Turbine blades designed with a combination of impulse and reaction type blading; 80% efficient.
RATED KVA OF A TRANSFORMER	The output which can be delivered for the time specified at rated secondary voltage and rated frequency without exceeding the specified temperature limitations.
RATING	Limits placed on operating conditions of a machine, apparatus, or device based on its design characteristics. Such limits as load, voltage and frequency may be given in the rating. Designated limit of operating characteristics based on definite conditions.
RATIO	A comparison of two related quantities by division.
RATIO OF A TRANSFORMER	The turns ratio between the windings of a transformer.
REACTANCE (X)	The opposition offered to the flow of an alternating current by the inductance and/or capacitance. Used to convert inductance and capacitance into values which are equivalent to resistance. Reactance may be inductive or capacitive or the result of a combination of these. Measured in ohms.
REACTANT	The starting materials in a chemical reaction.
REACTION	A reverse or opposing action. For every action, there is an equal, opposite action.
REACTION BLADES	Turbine blades that basically act like moving nozzles, creating a reaction force that causes the turbine rotor to turn in the opposite direction from the steam flow. Reaction blading is more predominant in the lower pressure stages of the turbine, where the blades are longer. Moving blading in which the space between blades is smaller at the exhaust than at the inlet. Energy transfer in reaction blading results in a decrease in steam pressure and

	velocity. Flat stationary blades used in the LP section; 90% efficient. Small change in temperature and pressure drops, which occurs at the blades. Large blades, takes more stages, and most efficient at full load.
REACTION RATE	A measure of the amounts of reactants that are converted into products in a given period of time. Number of atoms, and efficiency of atoms colliding affect reaction rate. Four variables that can also affect reaction rate are temperature, pressure, concentration, and surface area.
REACTION TURBINE	A turbine in which the expansion of steam causes the rotating blades to turn.
REACTIVE POWER	Power that does not work; power that must be supplied to a load to compensate for the effects of inductive or capacitive reactance. The non-useful portion of the total power and results from the reactance (either inductive or capacitive) in the circuit. It is measured in units of VAR (volt-ampere-reactive). The amount it takes to get the voltage out into the system.
REACTOR	A device, the primary purpose of which is to introduce inductive reactance into a circuit, for purposes such as motor starting, paralleling transformers, and control of current.
REBOILER SYSTEM	A closed system which provides for the generation of steam to be used in the primary and secondary fuel oil heaters. Using either its normal supply from the #2 bleed (cold reheat at W7&8) or back-up supply from the auxiliary steam system, the reboiler generates steam to be used for heating the fuel oil heaters. The condensate from the fuel oil heaters returns to a drip tank. From the tank it is pumped to the reboiler where it is again generated into steam. Drips from the bleed or auxiliary steam supply to reboiler coils are normally returned to the #2 feedwater heater or condenser. W7&8 reboiler drips return to the #3 heater, and W3&4 reboiler drips return to the deaerator. If no reboiler were used, and bleed steam was admitted directly to the fuel oil heater, any tube rupture in the fuel oil heater would cause contamination of the entire condensate system. By using a reboiler, this possibility is removed, as the rupture would contaminate the reboiler system only. Inspection windows are provided in the fuel oil heater drip tank, at normal operating level, for the purpose of observing if any contamination of the system has occurred.
RECEIVER	A large tank used to store dry, filtered, compressed air until needed for pneumatic instruments and control devices. Saves the compressors from running continuously.

RECIPROCATING COMPRESSOR	A positive displacement compressor that relies on the back and forth motion of a piston within a cylinder to compress air. Gas enters the cylinder, and is trapped inside the cylinder. The gas is then forced into a smaller space by the action of the piston. Forcing the gas into a smaller space increases the pressure of the gas. The compressed gas is then discharged.
RECIPROCATING PUMP	A positive displacement pump that relies on the reciprocating motion of a solid object. A piston moves back and forth in a cylinder. Liquid is forced through the discharge valve as power is applied to the piston. The discharge pressure of the pump is determined by the discharge piping or head and not by the pump. The piston will develop whatever pressure is necessary to cause the liquid to flow from the cylinder through the discharge valve. The discharge pressure is limited only by the mechanical strength of the pump and the power of the driving unit. On many reciprocating pumps there is an air chamber installed on the discharge to make the flow more steady. The air in the chamber is compressed during the discharge stroke. When the piston reaches the end of the stroke, expansion of the air tends to keep the liquid in motion and the pressure up until the next stroke begins. In general, reciprocating pumps are most efficient for relatively small flow rates and high pressures. They are usually operated at slow speeds (40-200 crankshaft rpm) because of the reciprocating motion and the valves. These pumps may be classed as single or double acting depending on whether one or both ends of the piston are used. In addition, they may be classified according to the number of pistons used. A simplex pump has one, a duplex two and a triplex three cylinders. The driving mechanism may be a reciprocating device, a motor, or turbine, in which case the rotary motion of the driver is converted to reciprocating motion by a crankshaft. Another type of reciprocating pump is a diaphragm pump. The diaphragm is attached to a connecting rod with a motor-driven device called an eccentric.
RECIRCULATION LINES	Lines used in pumps that require a minimum flow to prevent increased friction or high turbulence that could damage the pump.
RECORDER	A device that provides a continuous, permanent record of the value of a process variable.
RECORDING PSYCHROMETER	An analyzer that is used for continuous humidity measurements.
RECTIFIER	An electronic device that allows alternating current to flow in only one direction, that is, changes alternating current into direct

	current.
RECTIFY	To change an alternating current to a direct current.
REDUNDANT PROTECTION	A type of protection associated with the use of multiple sensors; designed to ensure that a malfunctioning sensor will not initiate an equipment trip.
REGENERATION	The process of restoring an ion exchanger's capability for exchanging ions.
REGENERATION OF EXCHANGERS	A method of feeding either acid or alkali to the demineralized exchange beds in order to reactivate the capacity of the units in service.
REHEAT STEAM SYSTEM	A system that increases the energy of steam exhausted from the HP section of the turbine before it enters the IP section and thus improves plant efficiency.
REHEAT STOP VALVES	Purpose is to provide an additional safety device to prevent overspeeding of the turbine should the interceptor valve fail to close when the overspeed trip mechanism operates. These valves utilize a rotary motion thus eliminating the hazards associated with reciprocating valve stems. When the auto trip valve is latched, the reheat stop valves open and remain open during normal operation, being held open by a supply of high pressure oil fed through an orifice. The oil supply to each of these stop valves is connected to drain through the overspeed trip valve so that when the overspeed trip valve opens, the valves close preventing flow of steam from the reheater to the intermediate pressure turbine. These valves should never operate in the partially open position. The position of the valve is indicated visibly or audibly by a signal from a switch mounted on the stop valve.
REHEATER	A boiler component that adds heat to steam after it has moved through a portion of the turbine. The reheated steam then flows through the remainder of the turbine. The boiler reheater, located above the secondary superheater, raises the steam temperature back to the original level of the main steam (resuperheated). After passing through the high pressure stage of the turbine, steam is returned to the reheater, at reduced pressure and temperature, via the "cold" reheat lines. Passing through the reheater, steam is "reheated" to the superheater outlet temperature. Reheated steam is then returned to the turbine IP section via the "hot" reheat line. The reheater is equipped with three safety valves, two are on the reheat inlet piping and the third valve is on the reheater outlet line.
REHEATER DESUPERHEATER	Two desuperheaters are installed in the cold reheat lines supplying steam to the reheater inlet header from the high pressure section of

the turbine. A mechanical atomizing water spray nozzle is located at the inlet of the desuperheater to make it possible to reduce, if necessary, the temperature of the steam returning to the turbine, and maintain the same at its design value within the limits of the nozzle capacity. The desuperheaters are positioned before the reheater to ensure against water carryover to the turbine, and also to eliminate the necessity for high temperature resisting materials in the desuperheater construction itself. The source of spray water is from the feedwater circuit, and it is important that the take-off line be located upstream from any chemical injection lines. It is essential that the spray water be chemically pure and free of solids in order to prevent chemical deposition in the reheater and carryover to the turbine.

RELATIVE HUMIDITY — A ratio of the actual amount of water vapor in the air at a specific temperature to the maximum amount of water vapor that the air could hold at that temperature. Expressed as a percent of the maximum amount of water vapor that the air could hold.

RELAY — A device that is operated by a variation in the conditions of one electric circuit to effect the operation of other devices in the same or another electric circuit. Some relays sense abnormal circuit conditions and send a signal that trips a breaker. Relays convert transmitter signals to control signals.

RELIEF VALVE — Normally closed. Operated to open when the actual pressure in a line or vessel reaches a given point, and is designed to protect the line or vessel from an overpressure condition. Handles non-compressible fluids - water, petroleum products, etc. Designed to open only as far as is necessary to hold the pressure at its relief point. Generally will have an isolation valve. Consists of a valve body, a disc, a seat, a spring, a valve stem, an adjusting screw, and lock nut. The valve body, or casing, provides a path for the liquid to flow and holds the other valve parts in their proper positions. The valve body has an inlet and outlet. The disc rests on the seat and is held in place by the spring when the system is at normal pressure. The valve stem guides the disc up and down. A relief valve is set to open when the pressure in a system reaches a predetermined value, such as 200 psi. If the pressure in the system reaches 200 psi , the pressure on the disc begins to overcome the force of the spring, and the disc begins to lift off of the seat. As this happens, the pressurized fluid is released through the valve outlet. If pressure in the system continues to rise, the disc will continue to lift, until it has risen as far as it can go. As system pressure begins to decrease, the valve begins to close. When the system pressure decreases to just below 200 psi, the

	force exerted by the spring pushes the disc back onto the seat. The adjusting screw is used to change the force exerted by the spring. Tightening the adjusting screw increases the force exerted on the disc, thereby raising the pressure setting at which the valve opens, or lifts. Loosening the adjusting screw reduces the amount of force on the disc and allows the valve to open at a lower pressure. The lock nut holds the adjusting screw in position after the force exerted by the spring has been set. The top of the assembly is usually covered by a cap that protects the adjusting screw.
REMOTE INDICATOR	Indicators located away from the process variable.
REPLACEMENT REACTION	A chemical reaction in which one type of atom is replaced with a different type of atom. An example is the removal of dissolved mineral ions from water that is being treated in devices called demineralizers. An ion is an electrically charged atom.
REPOWERING	A means of increasing the output and efficiency of conventional thermal generating facilities. For example, adding combustion turbines to supplement or replace steam from fuel combustion used to power steam turbines.
RESET CONTROL	Control action in which a controller continues to adjust its output until the value of a process variable returns to set-point. Does not exist without proportional control. Reset control is actually proportional-plus-reset control, since it adds an additional corrective action to the proportional action to eliminate offset. Sometimes called proportional-plus-integral, or PI control, because it is based on a mathematical function called integration.
RESIN BEAD	A small, porous, usually plastic bead that contains electrically charged areas where ions are exchanged; may be either a cation bead or an anion bead.
RESISTANCE (I)	Opposition to current flow. Electricity flowing through conductors encounters a form of friction, and some of the electric energy is converted into heat. Resistance is that property of a circuit which limits, opposes, or resists the flow of electricity through it. Normally expressed in ohms or megohms.
RESISTANCE THERMO DETECTOR (RTD)	Works on the principle that a wire's resistance to the flow of electric current changes as the temperature of the wire changes. The greater the temperature, the higher the resistance. The amount of resistance in a circuit is usually determined by the amount of load placed on the circuit, as well as the physical properties of the materials that make up the circuit. Contains a resistor whose electrical resistance changes with temperature. The

	resistor is connected to an electronic circuit, which is connected to an indicator. As the temperature changes, so does the resistance of the resistor. This causes a change in the amount of current flowing through the resistor. The electronic circuit detects this current change and converts it to a corresponding temperature reading.
RESISTOR	A circuit element whose chief characteristic is resistance; used to oppose the flow of current.
RESONANCE	A vibration of large amplitude in a mechanical or electrical system caused by a relatively small periodic stimulus of the same or nearly the same period as the natural vibration period of the system. That condition in an alternating current circuit which exists when the capacitative reactance exactly balances the inductive reactance.
REVERSE OSMOSIS	The flow of fresh water through a semipermeable membrane when pressure is applied to a solution (as seawater) on one side of it.
REVERSE POWER RELAY	A protective relay that operates when a generator draws power from the electrical system.
RHEOSTAT	A device that control's current flow by increasing or decreasing the amount of resistance in a circuit. An adjustable resistor so constructed that its resistance may be changed without opening the circuit in which it may be connected.
RMS	Abbreviation of Root Mean Square. See Effective Value.
ROLLING CONTACT BEARING	A bearing in which one surface rolls over another surface; there is lubricant between the two surfaces to reduce friction. Contains an inner ring, rolling elements, a retainer, or cage, an outer ring, and a housing. The inner ring is attached to a shaft, and the outer ring is attached to a housing. During operation, the inner ring rotates with the shaft, and the outer ring remains stationary. As the shaft rotates, the rolling elements roll between the two rings, allowing the shaft to turn with greatly reduced friction. The rolling elements maintain an equal distance between the rings, so radial movement is prevented.
ROLLING ELEMENT BEARING, OR ANTI-FRICTION BEARING	Use rolling elements to help reduce friction. The rolling elements can be balls, cylinders, barrel-shaped rollers, or tapered rollers. The rolling elements are held in place between an inner ring and an outer ring. A metal retainer, or cage, often holds the rolling elements in position and keeps them from rubbing against each other. Many rolling element bearings have a metal shield on one side, or sometimes on both sides. The shield helps keep lubricants in and dirt out.

ROOT	The quantity that when multiplied by itself a specific number of times equals a given number.
ROOT MEANS SQUARE (RMS), OR EFFECTIVE VALUE	Refers to the mathematical method used to calculate the average of the different voltage values in a cycle. A measure of the amount of work that can be accomplished by an AC circuit in relation to an equivalent DC value; mathematically determined by multiplying the peak AC value times .707.
ROOT VALVE	Valve downstream of process. On boiler bottom blowdown, valve between process and block valve. Opened before block valve is opened, and closed after block valve is closed.
ROTAMETER	A type of flow meter, consisting basically of a tapered tube and a float, that measures and indicates flow rate. Readings are generally taken at the widest part of the float.
ROTARY COMPRESSOR	A positive displacement compressor that uses rotation to compress gases. For example, rotary screw compressors compress gases using helical, or screw-shaped, rotors. Main parts include an inlet, a discharge, and two helical rotors. One rotor is the main rotor, and the other is the secondary rotor. The two rotors mesh as they rotate. A groove on the secondary rotor passes the inlet before it meshes with the main rotor. As the groove passes by the inlet, gas enters the groove and is trapped. As the rotor turns further, a lobe rolls progressively farther into the groove, compressing the trapped gas. As the groove passes by the discharge, the compressed gas flows out.
ROTARY PUMP	A positive displacement pump in which the action is one of rotation rather than reciprocating. The flow from a rotary pump is fairly steady whereas the flow from the reciprocating pump is pulsating. There are many different designs of rotary pumps. Some use gears, vanes, lobes, or screws to move the process liquid.
ROTARY STRAINER	A strainer with several baskets or cages that rotate, allowing continuous operation while strainer elements are cleared.
ROTARY SWITCHES	Switches that are rotated to start, stop, or position equipment.
ROTOR	The rotating member of a machine.
ROTOR (GENERATOR)	The rotating part of the generator which carries the magnetic field winding. Basic requirement is to produce a strong magnetic field. The rotor body in which the field winding is located forms the path of the magnetic lines for the part of the circuit while the stator core and air gap provide the return path for the flux. The rotor is made from a single steel forging. An axial hole is

	provided to check the properties of the forging and to carry the leads from the collector rings to the field winding. Longitudinal slots are machined radially in the body to contain the field coils. The field coils are held in the slots against centrifugal force by steel wedges. These wedges are individually fitted and driven into dovetailed openings machined in the rotor slots. The field winding consists of rectangular bars formed into coils. Several turns in one pair of slots around one pole form a coil. Several coils are assembled around each pole to form the winding. The end turns of windings are held in place against centrifugal force by heavy retaining rings machined from high strength, heat-treated alloy steel forging. These rings are shrunk and keyed on centering rings on the rotor shaft. Current is supplied to the field winding through collector rings. These rings are connected to the winding through insulated copper bars assembled in the drilled-out center of the rotor forging. At one end of the connection bars, terminal rods or studs assembled in gas-tight bushings in the rotor shaft connect the winding with bars. At the other end, similar studs connect the bars with the collector. The generator rotor is connected to the turbine rotor through a solid bolted coupling with an integral machined coupling half on each shaft. The rotating field, field winding, and stator core are cooled by hydrogen flow circulated through the generator by fans mounted on the rotor shaft.
ROTOR (TURBINE)	The high-intermediate pressure turbine rotor is machined from a solid alloy steel forging. A separate stub shaft is bolted to the inlet end to form the thrust bearing collar and to carry the oil impellers and the overspeed trip. The low pressure rotor is likewise machined from a solid alloy steel forging. The entire rotors, after being completely bladed and machined, are given a running test and an accurate dynamic balance test. A flanged, rigid-type coupling is used between the high-intermediate pressure turbine and low pressure turbine rotors. The rotating element thus formed is located axially by the high pressure turbine thrust bearing. The low pressure rotor is in turn, connected to the generator by a rigid coupling. The main rotating element thus formed (consisting of high pressure-intermediate pressure turbine rotor, low pressure turbine rotor, and generator rotor) is carried in six bearing.
ROTOR END-TRAVEL GAGE	Provision is made for mounting a rotor end-travel gage in each end of the low pressure turbine cylinder cover. It is used primarily to determine the relative movements of the low pressure turbine rotor and cylinder during the initial operation of the unit, or following a general inspection or major overhaul.

ROTOR POSITION MICROMETER	A hole is provided in the overspeed trip end cover through which a standard depth micrometer can be inserted to determine the axial location of the rotor, relative to the cylinder, while the unit is in operation.
ROTOR-LONG CONDITION	A condition in which the rotor of a turbine expands faster than the shell. Raising turbine load or main steam temperature too quickly.
ROTOR-SHORT CONDITION	A condition in which the rotor of a turbine contracts faster than the shell. Reducing load or steam temperature too quickly.
RUN (SPEC)	A group of data points consistently falling above or below the process centerline.
RUPTURE DISC	See breakable diaphragm.
RUST	A destructive, continuing type of corrosion formed by the reaction of iron and oxygen under high oxygen conditions; causes equipment made of iron to weaken and deteriorate.
R-VALUE	In thermal insulation, the thermal resistance of insulation materials or constructions.

S

SAYBOLT UNIVERSAL SECONDS UNITS (SUS or SSU)	The unit of measurement for viscosity of fuel oil. The higher the SSU, the less thick it is.
SAE	Society of Automotive Engineers
SAE SYSTEM	Indicates oil viscosities with numbers referred to as weights. The higher the weight, the thicker the oil, and the higher the viscosity.
SAFETY AIR LATCH	The stationary union of the oil gun is provided with a safety latch assembly. By opening the valve on the aspirating air line, air is introduced to the air latch chamber. The aspirating air pressure overcomes the spring tension and forces the plunger to move in, away from the annular groove in the removable union. A cover, hinged to the stationary union, has been provided to close off the guide pipe after a gun has been removed. The edge of this cover is grooved to seat the plunger of the safety air latch. The cover is locked by the safety air latch. It can be unlocked by opening the aspirating air.
SAFETY VALVES	Valves that protect a system from damage due to over pressurization. Generally for compressible gases such as steam, air, etc. Contains “pop seats” and plugs relieving at full flow. Designed to open wide very quickly, and stays open until the pressure in the process system drops to a predetermined value. No

	isolation valve. Relieving capacity at a pressure not exceeding 103% of its seat pressure. Closes at 96% of it set pressure. Consists of a valve body, a disc, a seat, a spring, a valve stem, an adjusting screw, a lock nut, and a manual release lever. The manual release lever is often used to test the operation of the safety valve. The disc has a lip that is not exposed to system pressure when the valve is closed. The center portion of the disc is always exposed to system pressure. If the valve is set to open, or lift, when the system pressure reaches a preset limit, such as 200 psi, the disc will start to lift when that pressure is reached. When this happens, the lip of the disc is suddenly exposed to system pressure, as well. Since a larger area of the disc is exposed to system pressure, more force is exerted on the bottom of the disc. The increased force overcomes the force exerted by the spring and causes the disc to pop open to about 60% open position. This allows a large volume of fluid to escape rapidly. If pressure in the system continues to increase, the pressure acting on the bottom of the disc will also increase and cause the disc to lift even higher. Once the excess pressure in the system has been relieved, the system pressure begins to drop. As pressure decreases, the force acting on the bottom of the disc also decreases. Eventually, the force exerted by the spring takes over and pushes the disc down. However, when the system pressure drops to the point at which the valve popped open, which was 200 psi, the valve will not close, because the lip of the disc is still exposed to the pressure of the escaping fluid. The valve will not close until system pressure drops below the pressure needed to pop the safety valve open. The opening pressure setting can be changed using the adjusting screw. Tightening the adjusting screw increases the force exerted on the disc and raises the pressure setting at which the valve opens. Loosening the adjusting screw reduces the amount of force on the disc and allows the valve to open at a lower pressure. The lock nut holds the adjusting screw in position after the force exerted by the spring has been set.
SAIF	System Average Interruption Frequency. Measures the average number of service interruptions that our customers experienced.
SALT	An ionically bonded compound that is composed of a metal and a non-metal.
SAMPLE COOLING COIL	A coil that circulates cooling water around a hot sample in order to bring it down to approximate room temperature, so that laboratory tests can be performed on the sample.
SATURATED LIQUID	A liquid that is at its boiling point for its pressure.

SATURATED STEAM	The general power plant usage of this term indicates steam which contains no superheat for the pressure involved. The pressure/temp. relation is as shown in the steam tables for saturated steam. Saturated steam may be either "dry" or "wet", that is, it may or may not contain excess moisture.
SATURATED STEAM (DRY)	Steam or water vapor at the saturation temperature which has no water present; a colorless vapor.
SATURATION TEMPERATURE	The precise temperature for each pressure at which water or any liquid boils. The temperature at which any liquid boils depends on the pressure on it.
SCALE	A coating of a salt or an oxide deposited on a metal surface, which decrease the heat transferring ability of the metal. Results from the presence in the boiler water of calcium and magnesium salts. These materials form a hard scale on the boiler tubes. Reduced heat transfer through the boiler tubes would result in overheating and possible rupture of the tube.
SCALING	The formation of a precipitate on a surface in contact with water as the result of a physical or chemical change.
SCAN CYCLE	The sequence of a programmable controller's activities that takes place many times a second when the programmable controller is running.
SCBA	Self-Contained Breathing Apparatus
SCHEDULED OUTAGE EXTENSION (SE)	An extension of a Planned Outage (PO) or a Maintenance Outage (MO) beyond its estimated completion date.
SCHEMATIC DIAGRAM	A drawing that identifies the components in an electrical system and shows them in their proper electrical sequence.
SCIENTIFIC NOTATION (MATH)	The expression of a quantity as a decimal number times a power of ten.
SCREEN TUBES	Boiler water circulating tubes used as a screen to shield the secondary superheater from furnace radiation.
SCREW PUMP	Uses screws to create the rotary motion that displaces the liquid. Consists of a casing with a suction port and a discharge port. Inside the casing are two screws: a driver screw and a idler screw. During operation, liquid enters the pump through the suction port and is directed to the suction end of the screws. As the screws turn, liquid is trapped in the spaces between the casing and the threads on the screws. The liquid is moved along until it reaches the discharge port, where it is forced out of the pump.
SCRUBBER	A device that uses chemical processes to reduce the amount of

	pollutants such as particulates and sulfur oxides in flue gas leaving a boiler.
SCRUBBERS (BOILER DRUM)	Apparatus located in upper part of main steam drum designed to cause abrupt change in direction of steam flow to throw out moisture and entrained solids by centrifugal force.
SCRUBBING	The removal of non-condensable gases from water, for example, as extraction steam flows across the surface area in an open heater.
SEAL FLUSH	The external fluid used to lubricate the seal rings in a mechanical seal.
SEAL OIL BACKUP	The seal oil backup from the main bearing oil feed system is normally closed. If the seal oil pump should stop, or if the seal oil pressure at the seals should decrease to 8 psi above the hydrogen pressure, the back-up regulator valve will open automatically and provide oil pressure for the seals at 8 psi above the machine gas pressure. This back-up pressure may be supplied from several sources; namely: the main oil pump on the turbine shaft, the AC motor-driven auxiliary oil pump and the AC and DC motor-driven turning gear oil pumps. The main oil pump on the turbine shaft and the AC motor-driven auxiliary oil pump supply 50 psig pressure to the back-up pressure regulator valve. The AC and DC motor-driven turning gear oil pumps will provide 5 psig oil pressure at the seals. When the 50 psig seal oil back-up is not available, such as when on turning gear or at standstill with the AC motor-driven auxiliary pump shut down, pressure switch "B" will close when seal oil pressure at the seals decreases to 5 psi above the hydrogen pressure. When the pressure switch "B" is closed, the DC motor-driven seal oil back-up pump will start automatically and maintain the seal oil pressure at the seals at 12 psi above the hydrogen pressure. The hydrogen pressure should be reduced to 2 psig or less when the DC seal oil back-up pump starts unless the AC motor-driven auxiliary oil pump is placed into service, as the next back-up is only 5 psig from the AC and DC motor-driven turning gear oil pumps. Should the seal oil pump start while the DC seal oil back-up pump is operating, the seal oil back-up pump must be stopped by push-button, as it is held in by an interlock in the motor control. The generator may be operated hydrogen-cooled with seal oil supplied by the seal oil back-up from the main turbine oil pump or auxiliary oil pump, but a bottle or two of hydrogen per day will be required to maintain the hydrogen purity as the seal oil pump is the only supply that is vacuum treated.

SEAL OIL PUMP	The seal oil pump draws treated oil from the bottom of the vacuum tank. It pumps part of it through a seal oil cooler to the seals, and part back to the spray nozzles in the vacuum tank through a differential pressure regulator which maintains the seal oil pressure at the seals at 12 psi above the machine gas pressure. The seal oil is circulated in this way through the vacuum tank a number of times before going to the seals. In the vacuum tank the oil flows over a series of trays which provide a large area for the separation of gas and vapors.
SEALED BEARINGS	Bearings that do not have to be re-lubricated for the life of the motor.
SEALING AIR	Since the furnace is pressurized, sealing air is required to seal off furnace openings (observation ports, soot blower wall boxes, oil guns, etc.). Sealing air is supplied continuously via the forced draft fan.
SEALING STEAM SYSTEM	A system that supplies auxiliary steam to the turbine gland seals to protect, or seal, the turbine from air leaking into or steam leaking out of the turbine casing.
SEAT	A stationary part of a valve onto which a flow control component (disc) presses to stop flow through the valve.
SECONDARY (FRONT) SUPERHEATER	High temperature element or final stage of steam superheating. Located above the furnace, and heated primarily by radiation. From the secondary superheater outlet header the superheated steam is led to the turbine via the main steam line.
SECONDARY AIR	Combustion air; air to the burners.
SECONDARY CELL	A type of battery cell that must be charged before it can release energy by chemical action; typically, a wet cell.
SECONDARY WINDING	The winding of a transformer from which the load is supplied; the coil that delivers the energy at the transformed or changed voltage to the load.
SEDIMENTATION	The third stage of the clarification process, in which floc particles that have settled to the bottom of the clarifier form an accumulation called sludge.
SELECTOR SWITCH	A form of air switch arranged so that a conductor may be connected to any one of several other conductors.
SELF CONTAINED VALVE	Normally closed globe valve, but is self actuated for line pressure control. The line pressure triggers the valve to open or close at predetermined set-points.
SELF-INDUCTION	The production of a counter-electromotive force in a conductor

	when its own magnetic field collapses or expands with a change in current in the conductor.
SELF-PRIMING PUMP	Pumps that stay filled with liquid when they are shut down.
SEMI-OPEN IMPELLER (CENTRIFUGAL PUMPS)	Can be used for pumping thin liquids, since there is a shroud to direct the liquid between the vanes. Can also be used for heavier liquids and slurries, since they minimize clogging.
SENSIBLE HEAT	The amount of heat expended whenever a change in temperature results from the addition of heat.
SENSIBLE HEAT TRANSFER	Heat transfer that causes a temperature change.
SENSING ELEMENT	The element in a control loop that senses the value of a process variable.
SERIES CIRCUIT	A circuit with only one path for current flow.
SERIES CONNECTION	An arrangement of cells, generators, condensers, resistors, conductors, etc., so that each carries the entire current of the circuit.
SERIES-PARALLEL CIRCUIT	A circuit that contains both series and parallel current paths.
SERVICE AIR COMPRESSOR	Approx. controlled pressure is 90-105 psig. Air at atmospheric pressure and temperature enters the system through the intake filters, is compressed with the first stage compressor, passed through the intercooler and separator, the second stage compressor, the aftercooler and separator and then to the air receiver. The inter and aftercoolers are equipped with Y strainers and air traps. Air compressor accessories: **1.** Intake Air Filters - prevents dust and other impurities from entering cylinder. Dust can cause sticking valves, scored cylinder and excessive wear. **2.** Intercoolers - to lower the temperature of air entering the next stage. Also, to cool air vapor below saturation temperature corresponding to pressure and remove moisture. **3.** Separators - to remove moisture and oil from air by mechanical means. Either a change in direction, or centrifugal force. **4.** Aftercoolers - reduce temperature and moisture content of compressed air. **5.** Receivers - dampen pulsation or pressure waves in compressor discharge. Also acts as reservoirs and precipitate any moisture that may have carried over from the aftercooler.

6. Y Strainer - prevents any grit or foreign matter from entering the air trap.
7. Air Traps - used to remove condensed moisture without loss of compressed air.
8. Protective Devices - relief valves in receivers. No-flow switches shut down compressor if flow of cooling water to compressor is stopped.

From the air receiver, air is supplied to the following:

1. Soot blower panel (power)
2. Air preheater auxiliary drive motors
3. Ignitors
4. Air for burner scavenging
5. Burner cleaning station
6. Boiler aspirating air system
7. Fuel oil tank area
8. Soda ash mixing
9. Back-up for instrument air
10. Miscellaneous hose connections located throughout the plant

SERVICE WATER SYSTEM — Vertical, deep-well, turbine-type pumps, installed in the circulating water pump well structure that pump sea water to the tube side of the auxiliary cooling water heat exchangers. Service water discharged from the heat exchangers is returned to Pearl Harbor via the condenser circulating water discharge tunnel. Each service water pump well structure is designed so that it may be fed from either the circulator inlet tunnels or from the pond water.

SERVOMOTOR — A mechanism controlled by governor oil to operate steam inlet valves on a turbine.

SET POINT — A specific value at which a process variable is maintained by a control system. The desired value of a process variable.

SETTLING BASIN — A basin utilized for holding and sedimentation of particulates or coagulants in plant waste water.

SHEWHART, WALTER — Bell lab studies, 1924. Came up with a way to mathematically determine boundaries of natural variation for a process. Shewhart developed a chart to display this variation, known as the Shewhart control chart. The chart had limits for the amount of variation that should occur in a process. Walter Shewhart essentially became the father of SPC.

SHIELDING — A metallic covering used to prevent magnetic or electrostatic coupling between adjacent circuits.

SHORT CIRCUIT	An abnormal connection of relatively low resistance, whether made accidentally or intentionally, between two points of different potential in a circuit. A circuit in which the resistance drops to almost zero and current reaches an extremely high value. An electrical fault that occurs when electricity takes an unwanted path. When a portion of a complete circuit is "cut off" for some reason, bypassed. Brings the negative and positive directly together, causing heat, smoke, circuit breakers to open, fuses to blow.
SHRINK	The decrease in water level that occurs when boiling stops and the number bubbles is reduced.
SHROUD (MOTORS)	The protective covering on the end of a motor, opposite the shaft.
SHROUDING	A metal band attached to the outer edge of a turbine's moving blading to dampen blade vibration, and to provide greater strength and rigidity.
SHUNT	Parallel. A parallel resistor placed in an ammeter to increase its range.
SHUNT FIELD	The main field of the exciter; the field that the operator controls manually at the control board with the "field rheostat", which, in turn controls the strength of the field in our main generator and hence the output voltage of the power plant.
SHUT-OFF HEAD	Maximum amount of pump discharge head pressure.
SHUTTERS (AIR DOORS, REGISTERS, OR DAMPERS)	An adjusting device for controlling the air flow to each fuel burner.
SIGHT FEED	A visible means for detecting fluid flow through a pipe.
SIGNAL CONVERSION	The process of converting digital signals to analog signals, or analog signals to digital signals. Performed by devices called signal converters. Digital signals are converted into analog signals by digital-to-analog, or D-to-A, converters. Analog signals are converted to digital signals by analog-to-digital, or A-to-D, converters.
SILICA	One of the dissolved solids in raw water that is checked very closely to prevent buildup in the boiler water system. It is capable of scaling out of boiler surfaces as well as distilling over with the steam and depositing on turbine blading. Can only be removed by boiler blowdown.
SINE OF THETA	The ratio between the opposite side of a right triangle and the hypotenuse.
SINE WAVE	The curve traced by the projection of a rotating vector on a

	uniform time scale. All electrical equipment is designed to produce or utilize alternating currents and voltages of a particular shape. This shape is known as a sine wave. A sine wave may be produced by rotating an arrow about a point so that it describes a circle. If the angle that the arrow has rotated through is laid out as a horizontal line, and the vertical height of the arrow is plotted on the vertical, a sine wave will result. It takes a rotation of 360° to complete one full cycle. The same curve is repeated every 360°. Each complete curve or 360° rotation is known as a cycle. Also known as a sinusoidal wave.
SINGLE ELEMENT DRUM LEVEL CONTROL	Feedback control; Feedwater does not change until the drum level experiences changes.
SINGLE LINE DIAGRAM	A drawing of an electrical system that uses single lines to represent electrical paths and symbols to represent individual components.
SINGLE STAGE PUMP	A pump that increases fluid pressure only once.
SINGLE-ACTING COMPRESSOR	A compressor in which gas or air is only compressed on the forward stroke of the piston.
SINGLE-ACTING DIAPHRAGM ACTUATOR	Called single acting because air pressure acts on only one side of the diaphragm to position a valve. Consists of a casing, a diaphragm, an air supply port, an air vent, a spring, a stem, and a valve position indicator. The indicator shows the position of the valve. The center of the diaphragm is supported by metal plates, and the outer edge is sandwiched between the rims of the upper and lower halves of the casing to form an airtight seal. This arrangement divides the casing into two chambers: an upper chamber and a lower chamber. The upper end of the actuator stem is connected to the metal plates and the diaphragm. The lower end moves the valve disc. When the actuator receives a signal from a controller to close the valve, air pressure is applied to the upper chamber. The diaphragm and the actuator stem are pushed downward, the spring is compressed, and the valve closes. Air in the lower chamber is exhausted through the air vent. When air pressure to the upper chamber is reduced, the spring moves the actuator stem upward, and the valve opens. Stem movement and valve position are proportional to the amount of air pressure applied to the actuator. Controlling the applied pressure enables the actuator to position the valve anywhere within the limits of travel for the actuator. This type of actuator can be called an air-to-close/spring to open actuator, because air pressure moves the stem to close the valve, and a spring moves the stem to open the valve. This means that if air pressure to the actuator is lost, the

control valve that is connected to the actuator will "fail open", since spring pressure will raise the stem and open the valve. Some single-acting diaphragm actuators are designed to close a valve, or "fail closed", when air pressure is lost. During operation of a "fail closed" actuator, air pressure is fed into the lower chamber. This causes the diaphragm to lift, which expands the spring, raises the stem, and opens the valve. When air pressure is reduced, the spring pulls the diaphragm and the stem downward, closing the valve. A control valve using this kind of actuator is said to "fail closed" because if air pressure is lost, the spring in the actuator will close the valve. A diaphragm actuator with an air line to only the lower chamber is typically an air-to-open/spring-to-close type, which causes a control valve to fail closed. A diaphragm actuator with an air line to only the upper chamber is typically an air-to-close/spring-to-open type, which causes a control valve to fail open. As long as the applied pressure is properly controlled, either of these actuators can be used to position a valve anywhere within the limits of travel for the actuator.

SINGLE-ACTING HYDRAULIC ACTUATOR

Consists of a cylinder, a fluid port at the base of the cylinder, a vent, a spring, a piston, and a piston rod, which is connected to the valve disc. When there is no fluid pressure against the piston, the spring pushes against the piston to keep the valve closed. When fluid flows through the port into the cylinder, the piston moves, compressing the spring and opening the valve. The vent exhausts air from the cylinder as the piston moves. When the flow of fluid stops, the fluid pressure and the spring hold the piston and the valve at their new positions. When the hydraulic fluid pressure is decreased, the spring moves the piston to close the valve, and fluid flows from the cylinder through the fluid port. The piston can be positioned anywhere in the cylinder by controlling the amount of fluid entering the cylinder or bled from the cylinder. This type of actuator is considered to be single acting, because fluid enters the cylinder through only one port and acts on only one side of the piston. It is also described as a spring return, because a spring moves a piston to close the valve. If hydraulic fluid pressure is lost, the spring will cause the valve to fail closed.

SINGLE-ACTING PISTON ACTUATOR

A controller or similar device controls the air pressure on one side of a piston. When air is fed through the air supply port, the piston moves along a cylinder, compressing a spring, and opening the valve. Air on the other side of the piston leaves the cylinder through an air vent. When air pressure is reduced, the spring expands, moving the piston in the opposite direction and closes the valve. If air pressure drops below a predetermined value or is

	lost completely, the spring will force the piston down to close the valve. In other words, the valve will fail closed.
SINGLE-BED ION EXCHANGER	A ion exchanger that contains either anion resin or cation resin.
SINGLE-SCREW, OR PROGRESSIVE CAVITY, PUMP	Rotary pump. Contains a single screw located inside a casing. One end of the screw is normally connected to a driver. As the pump operates, process liquid is drawn into the pump through the suction port. As the screw rotates, cavities form between the casing and the screw. These cavities move, or progress, toward the discharge of the pump, carrying the process liquid along. When the liquid reaches the discharge, it is forced out of the pump. Can move extremely viscous fluids, like sludge and gels, without clogging.
SINGLE-STAGE CENTRIFUGAL COMPRESSOR	A compressor in which air is compressed in one step. Main components include a shaft, which is connected to a motor, seals, a shaft bearing, and an impeller. The compressor casing contains a volute, a suction line, and a discharge line. The shaft is used to rotate the impeller. The seals prevent gas from leaking out of the compressor, and lubricant from leaking out of the bearing along the shaft. The shaft bearing supports the shaft and allows the shaft to rotate. Single-stage centrifugal compressors produce fairly high gas flow rates, but their discharge pressures are relatively low.
SITES	Charged areas on resin beads that are occupied by ions.
SKIM TANK	A baffled tank used for separating oil from water.
SLIDING PRESSURE CONTROL	Varying main steam pressure in order to prevent turbine control valves from operating near their cracking points and to minimize frictional losses. Lowering boiler drum pressure while maintaining main steam (superheat) temperature. This avoids temperature and pressure losses at the valves; efficiency.
SLIDING SURFACE BEARING	A bearing in which two surfaces, with lubricant between them, slide over each other.
SLIDING VANE COMPRESSOR	A rotary compressor. Consists of a cylinder, a slotted rotor, and vanes that fit into the rotor slots. The vanes are free to slide in and out of the slots. The rotor is mounted off center in the cylinder, so that a crescent-shaped space is left between the rotor and the cylinder wall. Since the vanes can slide freely, centrifugal force holds them out against the cylinder wall during operation. Each pair of vanes forms a separate gas pocket. The size of each pocket varies as the vanes are moved around the cylinder. The gas pockets are largest at the inlet, where the distance between the

	rotor and the cylinder wall is greatest. As the vanes move towards the outlet, the distance shrinks, and the gas pockets become smaller. Gas flows into the pockets formed by each pack of vanes at the compressor's inlet. Once the vanes pass the inlet, the gas is trapped. As the rotor continues to turn, the volume of each gas pocket gets smaller, compressing the trapped gas. As the vanes pass the compressor's outlet, the compressed gas flows out of the cylinder.
SLIME	A deposit formed by the growth of biological organisms.
SLING PSYCHROMETER	A device that is commonly used for spot-check humidity measurements.
SLIP	The difference in rotational speed between the driver element (or impeller) and the driven element (or runner) in a variable speed coupling. The slip of an induction machine is the difference between its synchronous speed and its operating speed and may be expressed as a percent of synchronous speed.
SLUDGE	The solid substance that exist or precipitates out of a solution. The sediment at the bottom of a clarifier; made up of floc particles.
SLURRY	A mixture of solids and water. A thin mixture of a liquid, especially water, and any of several finely divided substances, such as cement plaster, or clay particles.
SMOKE POINT	The excess O2 level where a visible plume occurs (approximately 10% opacity).
SODIUM CHLORIDE (H2500)	Salt (sodium+) + (chlorine-)
SODIUM HYDROXIDE (CAUSTIC SODA, LYE)	A white brittle solid that is a strong caustic base; used to increase alkalinity and raise pH of various waters.
SODIUM SULFATE	A bitter salt; used as an oxygen scavenger
SOLDER POTS (MCC)	An alloy thermal overload device. The solder pot has a heater, a ratchet wheel, a rod, and solder. The solder is an alloy that surrounds the rod. Current that flows through the motor controller's power circuit to the motor flows through the heater. When current flows through the heater, it generates heat. If the current exceeds the rated value of the overload device, enough heat is generated to melt the solder. This will cause the overload device contacts to open, interrupting current flow in the control circuit to the "M" coil. As a result, contacts in the motor controller are opened. Opening these contacts interrupts the current flow in the power circuit to the motor, and the motor stops.

SOLENOID	A coil of wire with a movable core of soft iron or other permeable material. When current passes through the coil, the resulting magnetic field draws the core into the coil. This movement is called solenoid action. Uses a magnetic field to open circuit breaker contacts. An electrical conductor wound as a helix with a small pitch, or as two or more coaxial helices.
SOLENOID ACTUATOR, OR SOLENOID	Used for on/off control of a valve. Can position a valve from fully open to fully closed quickly, so they are particularly useful for the emergency shutoff of valves. Consists of a wire coil; a spring; an armature, or core; and a stem, which is connected to a valve. When current flows through the wire coil, it creates a magnetic field around the coil. As a result, the coil, in effect, becomes an electromagnet. The armature, which is a solid metal core, is attracted to the magnetic field. This attraction pulls the armature toward the center of the coil. As the armature moves, it compresses the spring and moves the stem, which opens the valve. When current flow through the coil stops, the magnetic field is lost. This allows the spring to push the armature and stem back to their original positions, closing the valve. When current flow through the coil starts or stops, the movement of the armature is almost instantaneous. When current flow starts, the actuator fully opens the valve, and when current flow stops, the actuator fully closes the valve. There is no intermediate, or in-between, position, so there is no way that a solenoid actuator can throttle a valve. Since most solenoids operate this way, they are typically used with on/off valves. Also, solenoid actuators do not produce a great deal of force when they operate. When more force is needed to position a valve, a different type of actuator is generally used.
SOLENOID TRIP	A solenoid is provided, which when energized, raises the protective trip dump relay releasing the auto-stop oil and high pressure operating fluid to drain. This feature permits tripping the unit from some remote point, or by means of protective relays in the generator circuit.
SOLID PARTICLE EROSION	The erosion on internal turbine components (usually the nozzle block and the turbine blades in the first few stages of the HP section) caused by solid particles that are trapped in the steam and carried into the turbine.
SOLID WASTES	Generated from electric generating systems as a result of cleaning operations such as slag and ash from boiler firesides, wastes from chemical cleaning, contaminated soils and other materials, and from oil or unusable chemicals.
SOLIDLY GROUNDED	A circuit or equipment grounded through an adequate ground

(DIRECTLY GROUNDED)	connection in which no impedance has been inserted intentionally.
SOLUTE	The material in a solution that is dissolved.
SOLUTION	A special type of mixture called a homogeneous mixture. The term "homogeneous" refers to the fact that the materials in a solution are evenly mixed. Can be a mixture of solids, liquids, or gases, or a combination of any of these, as long as the materials involved are evenly mixed.
SOLVENT	The material that the solute is dissolved in.
SOOTBLOWER (IKS & IRS)	A device that uses steam or compressed air to blow off soot that collects on boiler tubes; also used to control exit gas temperature. A system of automatic sequential steam-blowing, air-operated soot blowers is furnished to aid in keeping the gas passages of the superheaters, economizer, and air heater clear. A typical sootblower is made up of a lance tube with nozzles, a feed tube, and a poppet valve. When the poppet valve is open, a blowing medium is sent through the feed tube under pressure and discharged through the nozzles in the lance tube. High pressure steam is extracted from a point between the primary superheater outlet and the secondary superheater inlet. A pressure reducing station drops the pressure to 600 psi, and orifices at each blower reduce the pressure to the final required levels.
SORBENT POWDERS	Powders that have the ability to absorb substances.
SPC	Statistical Process Control
SPCC	Spill Prevention Control and Countermeasure Plan.
SPECIAL FUNCTION KEYS (COMPUTER)	Used to start tasks that are performed frequently.
SPECIFIC CONDUCTANCE	The specific conductance of water is a measure of the ability of the water to conduct an electric current. Specific conductance is inversely proportional to electrical resistance. Pure water is highly resistant to the passage of an electric current and therefore has a low specific conductance. However, if the water contains ions, the water becomes a better conductor of electricity and the specific conductance is increased. Therefore, the conductivity test is a means of measuring the total ionizable (dissolved) solids in the water.
SPECIFIC GRAVITY	A measure of the relative density of a substance compared to the density of water. Divide the density of the substance by the density of water. Density of water is 62.4 lbs per cubic foot, or 1 gram per cubic centimeter.

SPECIFIC HEAT	The amount of heat required to raise the temperature of one pound of the substance one degree Fahrenheit.
SPECIFIC VOLUME	The measurement of the amount of space occupied by one pound of a substance. Usual units are cubic feet per pound. Volume divided by mass.
SPEED CHANGER	The part of a turbine governor which is used to change the speed of rotation before the unit is synchronized, and to change load after synchronizing. With a fixed setting of the speed changer compression spring, the governing control oil pressure varies in accordance with the turbine speed, while with a fixed speed, the governing control oil pressure depends upon the setting of the speed changer compression spring. The position of the speed changer determines the spring force acting on the transformer cup valve. There is then a change in either turbine speed or governing control oil pressure for every change in speed changer setting. When a turbine-generator is running alone and controlling frequency, then a movement of the speed changer brings about a very small change in governing control oil pressure, a corresponding change in the position of the governing valves and a change in steam flow through the turbine. This change in steam flow, if an increase, causes the turbine speed to increase until the governor impeller discharge pressure balances the increased spring force of the spring. For parallel operation with a utility system or with large units in the same plant, the turbine speed is controlled by the electrical tie of the generator. Under such operating conditions, the speed changer actually becomes a load changer. This is true because the changing the steam flow through the turbine can only change the torque while the speed of the turbine is scarcely affected. Accordingly, then there is a different governing control oil pressure necessary to keep the transformer cup valve in equilibrium. For every value of governing control pressure there is a definite governing valve position and consequently a definite electrical load, if the system frequency remains constant. Turning the speed changer handwheel in the "Increase" direction ("Raise" on Main Governor type "W" switch at control bench) increases the force of the compression spring and hence increase the turbine speed (or load). Turning the speed changer handwheel in the opposite direction ("Lower" at type "W" switch) decrease the force on the compression spring and hence decreases the turbine speed (or load).
SPHERICAL ROLLER BEARING	Resists axial movement in two directions.
SPILL STRIP PACKING	Seals used to seal between the moving blades and the turbine

	casing.
SPINNING RESERVE	That reserve generating capability connected to the bus and ready to take load.
SPONTANEOUS COMBUSTION	Combustion that is self-starting, without outside ignition (heat source).
SQUIRREL CAGE WINDING	A permanently short-circuited winding, usually insulated (chiefly used in induction machines), having its conductors uniformly distributed around the periphery of the machine and joined by continuous end rings.
SSU	Saybolt Seconds Universal
STABILITY	Stable point above carrying capacity of wire or pull out point of generator.
STABILIZING FIELD	A small field in the exciter that is connected to the 125 volt plant DC system. Remains in service at all times under normal operating conditions. The control operator has no control over this field other than the manual breakers on the 125 volt DC panel. These breakers are opened only under special conditions for maintenance purposes.
STAGE	One row of fixed blading and one row of moving blading.
STANDARD DEVIATION	A measure of the way data points are distributed within a normal distribution. Within a normal distribution, around 68% of the plotted values should fall within a certain distance of the mean value. The distance from the mean value to each line is known as one standard deviation. About 95% of the readings should fall within two standard deviations. About 99.7% should fall within three standard deviations. The lines for three standard deviations are commonly used as control limits on SPC control charts.
STARTUP FAILURE (SF)	An outage that results when a unit is unable to synchronize within a specified startup time following an outage or Reserve Shutdown. The startup period for each unit is determined by the operating utility. It is unique for each unit, and depends on the condition of the unit at the time of startup (hot, cold, standby, etc.). A startup period begins with the command to start and ends when the unit is synchronized. An SF begins when the problem preventing the unit from synchronizing occurs. The SF ends when the unit is synchronized, another SF occurs, or the unit enters another permissible state.
STATIC	A fixed non-varying condition; without motion.
STATIC ELECTRICITY	A stationary charge of electricity. Voltage with no current;

	electrical potential. Occurs when a large number of electrons builds up on a surface. A common cause of this type of buildup is friction. The buildup of electrons on a surface results in a high electrical charge and, consequently, a high electrical potential. When the potential is great enough, the electrons move, or flow, from one place to another. This flow of electrons is referred to as an electrostatic discharge.
STATIC EXCITER	An exciter that has no moving parts.
STATIC HEAD	Related to the level of liquid. The vertical distance between the top of a column of fluid and the discharge from that column.
STATIC HEAD (PUMPS)	The head caused by a nonmoving liquid as a result of it height. The static head exerted on the inlet of a pump is measured from the centerline of the inlet to the level of the liquid.
STATION BATTERIES (125 VOLT)	Supply a reserve source of power for the operation of circuit breakers, control circuits, motors, lamps, alarms, and emergency lighting. They also feed inverters for an emergency source of alternating current for the house telephones, public address systems, and the company radios. Each plant also has a gasoline engine-generator set for emergency supply of 125-volt direct current.
STATION SERVICE	Auxiliary and other facilities for station use in a generating, switching, converting, or transforming
STATIONARY BLADES	Non-moving turbine blades, or nozzles, located between turbine stages and used to redirect the flow of steam to the next set of moving blades.
STATIONARY SOOTBLOWER (IR'S)	Remain inside the cooler section of the boiler, usually the economizer area, and have a row of openings along the length of the lance for cleaning. This type of lance turns in a 360° arc.
STATISTICAL PROCESS CONTROL (SPC)	A way of monitoring a process to maintain consistent quality and thereby reduce failure cost. Relies on using mathematical laws of statistical probability. These laws have to do with the probability of something occurring either naturally or because of an outside influence.
STATOR	The part of a machine which contains the stationary parts of the magnetic circuit with their associated windings.
STATOR OR ARMATURE	A hollow cylinder in which the rotor is located. Stationary coils which produce three phase electricity that are 120 degrees apart from each other. Consists of a frame which supports the entire assembly and a core of steel in which there are slots for containing the stator conductors. The function of the core is to provide a

return path for the lines of magnetic force from the field. The magnetic lines of force generated by the rotating field are, in effect, a series of loops which leave the north pole of the rotor, travel through the stator core and return to the south pole of the rotor. The stator core must be made of steel which easily permits the lines of force to pass through (high permeability steel). The stator core consists of a series of iron laminations, called punchings, pressed by a hydraulic press during the stacking process and finally clamped by insulated bolts. After assembly, the core is varnished and baked to protect it from rust and to further insulate the punchings. There are two conductors per slot in the stator and that the stator conductors are distributed equally all around the stator. The armature winding is formed by insulated bars of half coils and assembled in the stator core slots. They are joined at the ends to form coils and connected in the proper phase belts by connection rings at the end of the winding. The stator bars are composed of insulated copper conductors (strands) arranged in the form of rectangular bars. The bars are so assembled that each strand occupies every radial position in the bar at some point along the length of the bar. This arrangement causes all strands to share the load current equally and minimizes circulating current losses within the bar. The main armature leads (high voltage and neutral) are brought out at the bottom of the generator casing through the generator terminal boards, at which point the desired connections are made. On most generators these connections are provided at the collector ring end of the generator. The armature connections are brought through the terminal boards by means of gas-tight voltage bushings. These bushings consist of one-piece porcelain insulators containing a copper conductor. Silver-plated terminal studs are provided at each end of the bushings for making the connections. The voltage produced in the stator conductors depends on the strength of the rotating magnetic field, the length of the conductor and the speed of the rotation. The length of the conductor is fixed by the design of the machine and the speed is normally fixed by the requirement of producing 60-cycle power. The only variable under control of the operator then is the strength of the magnetic field. As the field rotates, a sine wave voltage is induced into the stator conductors. As long as the generator OCB is open, there is no current flow because there is no complete circuit. When the OCB is closed, the circuit is completed and current will flow due to the induced voltage.

STATOR WINDING — Coils of windings in the stator, that surround the rotor. Current flow through the stator windings produces magnetic fields. The

	stator windings have been dipped in an insulating varnish and then baked. The varnish insulates the windings from each other and prevents short circuits or grounds that could damage the windings.
STEADY-STATE CONDITIONS	Conditions in which the value of a process variable remains relatively constant over a period of time.
STEAM CHEST	A collection area designed to reduce the turbulence of steam before the steam enters the turbine control valves. On the new, larger utility units, the steam chests are mounted outside of the turbine casing, usually one on each side of the high pressure turbine element. Each steam chest is anchored to the foundation independently to isolate forces and moments built up by thermal expansion as components heat up. In reality, the steam chest is a manifold which provides structural support for the governing valves. It can also be described as the area where the steam pressure of the steam flowing through the throttle valve is equalized.
STEAM CYCLE	In a power plant, the complete loop from the boiler, through the turbine, through the condenser, and back to the boiler.
STEAM FLOW LIMIT VALVE	Essentially a high grade oil pressure regulating valve.
STEAM INLET VANES	Spaces, or lanes, between condenser tubes that direct steam flow around all of the circulating water tubes, thus insuring an even heat transfer throughout the condenser.
STEAM SEAL SYSTEM	Prevents leakage (steam out/air in), and controls thermal stress. Usually provided with two chambers. The chamber on the side of the seal nearest the turbine is connected to the steam seal supply and leakoff system. The outer chamber, nearest atmosphere, is connected to a gland steam condenser. Steam that leaks past the labyrinth seal toward atmosphere is collected in this chamber and then piped to the shell side of the gland steam condenser. The shell side of the condenser is provided with an air exhauster which maintains a slight vacuum in the shell.
STEAM SEAL UNLOADING VALVE	A valve in a steam seal system that dumps steam to the condenser, instead of letting it flow to a low pressure feedwater heater, when too much steam enters the system.
STEAM TABLE	Complete calculations of the values of the various properties of steam and water for a wide range of pressures and temperatures. Arranged in tabular form, each variable such as specific volume and enthalpy has three values for each pressure. One of these is for the saturated liquid, one for the saturated vapor, and the third is the change in quantity when going from liquid to vapor.

	Always given in terms of absolute pressure so as to provide a constant reference point and makes the tables universally acceptable. Gauge pressure cannot be used this way because its reference point is atmospheric pressure which changes with location.
STEAM TEMPERATURE	The boiling temperature for a given pressure. For each pressure there is a corresponding boiling temperature, or steam temperature.
STEAM TRAP	A component in a steam system that removes condensation without removing steam. Located at low points in steam lines where condensate naturally collects. Three types are mechanical, thermostatic, and thermodynamic.
STEP DOWN TRANSFORMER	A transformer in which the primary is the high voltage winding (more windings) and the secondary is the low voltage winding (less windings).
STEP INPUT (STEP CHANGE)	A sudden change in the value of a process variable.
STEP UP TRANSFORMER	A transformer in which the primary is the low voltage winding (less windings) and the secondary is the high voltage winding (more windings).
STOICHIOMETRIC AMOUNT	The exact amount of oxygen required to react with all the carbon and hydrogen, with no excess amount of oxygen, carbon, or hydrogen left unreacted. Peak flame temperature occurs when the quantity of air supplied to the burner is near the stoichiometric amount. As the quantity of air is increased above the stoichiometric amount, the excess air absorbs some of the energy released from the fuel, thereby lowering the flame temperature. On the other hand, if less air than stoichiometric requirement is supplied to the burner, there is not enough oxygen to react with the fuel. This results in incomplete combustion of the fuel and a reduction in flame temperature as less than the total energy is released from the fuel. Due to non-ideal fuel and air mixing in large furnaces with many burners, utility boilers operate with excess air to achieve complete combustion of the fuel.
STOP LOG	One of a set of timber pieces, usually square, which serve to form a dam to check the flow of water.
STOP VALVES	See main stop valves.
STRAINER (PUMP)	Used to trap and remove solids from process liquid before they can enter the pump and cause damage.
STRAPPING CHART	Conversion chart to convert the depth of oil in a tank in feet and inches to the volume in barrels.

STRATIFICATION	The formation of layers of different-temperature air in the furnace as a result of air in-leakage.
STRESS	The result of applied forces. These forces can alter the molecular structure of a solid, causing it to change shape. Tension, compression, bending, twisting.
STRIP CHART	A chart plotted on a linear strip of paper. Scales include time and process variable values.
STRONG BASE ANION DEMINERALIZER	Contains strong base resin which removes the weakly charged silica ion and any negatively charged ions which passed through the preceding bed. pH values should be in the 6.0 to 8.5 range and conductivities less than 10 μmhos.
STUFFING BOX (PUMP)	A sealing method used on most smaller pumps and when the pressure is low. Consists of an annular space in the casing around the shaft. Rings of packing material are placed in this space. The packing rings are compressed and held in place by a follower or gland. The gland is in turn held in place by studs with adjusting nuts. As the adjusting nuts are tightened, they move the gland in and compress the packing. This in effect squeezes the packing out radially making a tight seal between the rotating shaft and the inside wall of the stuffing box. The shaft is rotating at high speed and is rubbing against the packing which causes a lot of friction. If there is no lubrication the packing will quickly burn up and can seriously damage the shaft. Lubrication is normally provided by keeping the gland loose enough so that a small flow of liquid leaks out of the pump. The liquid acts as a lubricant and keeps the packing cool. This method of sealing cannot always be used. If the pump suction is under a vacuum so that leakage outward is impossible or if the liquid is too hot to provide adequate packing cooling, a different type of seal must be used. Usually in these cases a supply of cool, clean water is piped to the stuffing box. This water, known as cooling or gland sealing water, is injected through a drilled passage in the case into a ring usually located at approximately the center of the stuffing box. The ring known as a lantern ring or sealing ring is usually constructed of metal made in a skeleton design. The ring distributes the sealing water uniformly around the shaft. To insure that sealing water flows in both directions along the shaft the sealing water pressure should be approximately 10 psi higher pressure than the pump suction pressure.
STUFFING BOX (VALVES)	Holds the valve packing, which is installed around the stem.
SUBCOOLED WATER	Water at a temperature below the saturation temperature.

SUBSTATION	A facility in which electric power from several sources is combined in one location for local distribution. A network of electrical components, including transformers and circuit breakers, used to deliver power to transmission or distribution lines.
SUCTION EYE	The area in the center of the impeller; low pressure area. The pressure at the intake, or suction eye, of a pump.
SUCTION HEAD	The head at the inlet of a pump. The height of fluid above the suction of a pump.
SUDDEN PRESSURE RELAY	A protective relay that senses internal faults in a transformer and initiates circuit breaker trips to isolate the faulted transformer from the rest of the system. A relay designed to detect a rapid buildup of pressure inside a transformer.
SULFUR DIOXIDE (SO2)	A colorless, extremely irritating gas or liquid, used in many industrial processes, especially the manufacture of sulfuric acid.
SULFUR DIOXIDE AND SULFUR TRIOXIDE FORMATION	Sulfur contained in the fuel reacts with oxygen in the combustion process to form sulfur dioxide and sulfur trioxide. Typically, 97-99% of fuel-bound sulfur forms SO2, and only 1-3% of the SO2 is subsequently converted to SO3. The SO2 passes through the boiler and is emitted as a gas. The SO3 will condense to form sulfuric acid mist (and other sulfate and sulfite compounds) at temperatures below approx. 300°F. If the gas temperatures at the air heater and stack are less than 300°F, sulfuric acid deposition will lead to weak acid corrosion of metallic surfaces. If the stack temperature is greater than 300°F and a high concentration (>10ppm) of SO3 is present, a visible, "whitish colored" condensate plume may be visible depending on atmospheric conditions.
SULFUR OXIDES (SOX)	Sulfur and oxygen; pollutant gases produced in a boiler when fuel containing sulfur is burned. Can cause harm to the environment; health problems.
SULFUR TRIOXIDE (SO3)	A corrosive compound, having three solid forms that may coexist in a given sample, used in the sulfonation of organic compounds.
SULFURIC ACID	A highly corrosive, dense oily liquid, colorless to dark brown depending on purity and used to manufacture a wide variety of chemicals and materials including fertilizers, paints, detergents, and explosives. Contains hydrogen ions and sulfate ions.
SUPERCRITICAL CONDITIONS	Steam conditions above the critical point of 705°F and 3206 psi.
SUPERHEATED STEAM	Heat added to saturated steam after it is formed in the boiler. Steam that is heated to a temperature above its saturation

	temperature; 500°F and over. The higher the boiler pressure the hotter the steam and the greater will be the temperature difference between the steam and whatever is being heated, and the faster will be the flow of heat or heat transfer across the heat transfer surfaces.
SUPERHEATED VAPOR	A vapor whose temperature is higher than its boiling temperature.
SUPERHEATER	Composed of two sections, namely the primary (rear) superheater (low temperature) and the secondary (front) superheater (high temperature), through which the steam passes after it has been formed in the main boiler tubes. The hot gases of combustion come in contact with the superheater tubes and add heat to the saturated steam. It then becomes superheated steam. The purpose of a superheater is simply to get more heat (or BTU's) into each pound of steam. This also raises the temperature of the stream above the boiling or saturation temperature. Therefore when the steam gets to the apparatus it is to operate it can do more work, as in a steam turbine.
SUPERHEATER DESUPERHEATER	A desuperheater installed in the link from the primary superheater outlet header to the secondary superheater inlet header. A steam assisted water spray nozzle is fitted in the entering end of the desuperheater to make it possible to reduce the steam temperature, when necessary, and maintain the same at its design value within the limits of the nozzle capacity. Steam for assisting the atomization of the spray water flows continuously, from the steam drum, whether there is a desuperheater water flow or not. The desuperheater is positioned before the high temperature superheater to ensure against water carryover to the turbine, and also to eliminate the necessity for high temperature resisting materials in the desuperheater construction itself.. The source of spray water is from the feedwater circuit, and it is important that the take-off line be located upstream from any chemical injection lines. It is essential that the spray water be chemically pure and free of solids in order to prevent chemical deposition in the superheater and carryover to the turbine. The intermediate signal comes from the primary superheater outlet temperature, and a final signal is from the secondary superheat outlet temperature.
SUPERSONIC	Having, caused by, or related to a speed greater than the speed of sound in a specified medium. Critical flow in a turbine; just above mach .9.
SUPERVISORY COMPUTER	Directs the activities of the system's process controllers by establishing set-points. However, it does not directly control the values of process variables.

SUPERVISORY CONTROL SYSTEM	A type of digital control system in which a supervisory computer directs the activities of many process controllers.
SUPPLY PRESSURE	A constant pressure air supply piped to pneumatically operated instruments and controls.
SURFACE CONDENSER	A condenser in which circulating water or air passes through tubes, while exhaust steam passes around the tubes.
SURGE	Sudden changes of current or voltage in a circuit.
SURGE (COMPRESSORS)	When a decrease in flow below the minimum flow rate can cause a series of momentary reversals of flow through the compressor. Surging results in violent fluctuations in discharge pressure. When an electric motor is used as a driver, surging can cause extreme variations in motor current. Other symptoms include low system gas flow, excessive vibration, and a muffled banging sound inside the compressor.
SURGE TANK	A standpipe or storage reservoir at the downstream end of a closed feeder pipe to prevent sudden variations in pressure and to furnish water quickly.
SUSPENDED SOLIDS	Solids carried by water. An impurity that will not dissolve.
SWELL	The increase in water level that occurs during boiling, when the number of bubbles increases rapidly.
SWING CHECK VALVE	A type of check valve that is usually larger than a lift check valve; it can be mounted in any upright position, provided the weight of the disc is on the seat. Consists of a valve body, a seat, a disc, an arm, and a pivot pin. The disc is hinged at the top of the valve body by means of the arm. The pivot pin goes through the valve body and the arm to allow the disc to hang in place. The disc closes against the seat to block fluid flow. When pressure is under the seat and disc, the disc pivots, or swings away from the seat, opening the check valve and allowing flow through it. When flow through the valve stops, the force of gravity pulls the disc onto the seat. As fluid flow through the valve starts to reverse, backflow pressure pushes the disc against the seat to fully close the valve. On some swing check valves, the arm that holds the disc is weighted to assist in closing the valve. In other valves, a spring is used to help close the valve. The direction of flow through a check valve is commonly indicated on the outside of the valve's body. Usually, an arrow is cast into the valve's body to help ensure that the valve is installed to allow flow in the proper direction. As long as the flow through a swing check valve is constant, the disc will remain raised. However, if the flow is intermittent, the disc may repeatedly rise and fall and slam against

	the seat. This action can damage the disc and the seat and result in leakage through the valve. This condition can often be detected, because as the disc slams against the seat, noise and vibration are produced in the piping. Swing check valves are not very effective for controlling the flow of fluids containing solid particles, because solids can accumulate between the disc and seat and prevent the valves from closing. Because they may not close completely, swing check valves should never be relied on to isolate a component or system from fluid pressure in another part of a process system. Using swing check valves for isolation purposes could be extremely dangerous when a process system is about to be opened up for maintenance. In this type of situation, precautionary measures such as shutting the appropriate isolation valves should be taken to ensure that the system is isolated.
SWITCH	A device that can be opened or closed to start or stop current flow in a circuit. A device for opening or closing a circuit which is not carrying any load. Switches are manually operated, slow moving devices which operate in air. Since it is slow moving and has no special arc extinguishing provisions, a switch should not be used for opening or closing a circuit which is carrying any appreciable load. The primary purpose of a switch is to positively isolate a circuit after all load has been removed. Switches are usually operated from a remote location through a mechanical linkage or by a switching stick. In this way the operator can be at a safe location in the event that an arc develops due to the circuit not being de-energized.
SWITCHYARD	A facility that combines the output from a number of generators and transmits the combined output to different service areas. A network of circuit breakers that direct electricity to transmission lines. The area of a plant where the combined outputs of the plant's generating units are directed to a power system.
SYNCHRONISM	Matched electrical speed.
SYNCHRONIZATION	The process of matching the frequency of an off-line generator with the frequency of the grid.
SYNCHRONOUS	Happening at the same time; having the same period and phase.
SYNCHRONOUS CONDENSER	A synchronous phase modifier running without mechanical load, the field excitation of which may be varied so as to modify the power factor of the system or through such modification to influence the load voltage.
SYNCHRONOUS GENERATOR	A synchronous alternating current machine which converts mechanical energy into electrical energy.

(ALTERNATOR)	
SYNCHRONOUS MOTOR	An AC motor whose rotor field is constant. Typically, the rotor field is provided by a permanent magnet or by an electromagnet whose power is supplied from an external source. The rotors of synchronous motors turn at a speed the same as the speed of alternation, or rotation, of the stator fields.
SYNCHROSCOPE	A device used to match a generator's output voltage and frequency with that of the grid. A device that measures the difference in electrical frequency between the power system and the generator.
SYNCHROVERIFIER BYPASS (W5&6)	These switches referred to as 325/BPS and 125/BPS on the electrical drawings are to be used only during an actual blackout and should be locked in the "OFF" position during normal plant operation and blackstart tests. During an actual blackout, these switches should be turned to the "ON" position, thus bypassing the synchro-check relays which normally monitor the generator OCB's and the 2.3 KV auxiliary breakers. Bypassing the synchro-check relays during an actual blackout allows the operator to both close the running generator (Unit 5 or 6) onto a dead 138 KV bus and also to synchronize the running generator to the solar gas turbine which may be running at a frequency other than 60 Hz.
SYNTHESIZED HYDROCARBON (SHC)	A synthetic oil that is able to continue flowing at very low temperatures and to resist oxidation at very high temperatures.
SYNTHETIC	Produced by synthesis; especially, not of natural origin; man-made. Not genuine; artificial; devised.
SYNTHETIC LUBRICANTS	Designed to have the exact properties desired for specific operating conditions.
SYSTEM DIAGRAMS	Drawings and diagrams that represent parts of a system and the flows between the parts. Three types are block diagrams, piping system diagrams, and electrical diagrams.
SYSTEM LOAD	The total demand for power from the grid.

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TANGENT OF THETA	The ratio between the opposite side of a right triangle and the adjacent side.
TANK STRAPPING TABLE	A table for a specific container that lists various levels of fluid and their equivalent volumes.
TAPERED ROLLER BEARING	Bearings utilizing rollers instead of balls. Resists axial movement in one direction.

TARGET	A supplementary device used in conjunction with a relay to indicate that it has functioned.
TELEMETERING	Transmission of intelligence long distances, usually from stations to the dispatcher's office, by direct wire or carrier current.
TEMPERATURE	A measure of how hot or cold a body is in relation to a scale. Can be thought of as the degree, or intensity, of heat in a substance. At the molecular level, temperature is a measure of the average molecular kinetic energy of a substance. Molecular motion.
TEMPERING AIR	Temperature control air for the recirculating gas system.
TENON	A raised knob on the end of a moving blade that is peened over shrouding to rivet the shrouding to the blading.
TENSION	Occurs when external forces try to pull a body apart.
TERMINAL TEMPERATURE DIFFERENCE (TTD)	The difference between a feedwater heater's outlet temperature and the saturation temperature of the steam in the condensing section.
TETRAFLUOROETHYLENE, OR TEFLON	A solid lubricant that is a slippery plastic material. It can be formed into different shapes. For example, a simple sleeve bearing or a sleeve bearing with a thrust face can be made of Teflon.
THERMAL CONDUCTIVITY	The ability of materials to allow the passage of heat through them. This ability varies, depending on the material. The ability of a substance, such as a gas, to conduct heat.
THERMAL INSULATION	Insulation that prevents condensation on pipes and also prevents heat from escaping.
THERMAL OVERLOAD DEVICE (MCC)	Operate on the heat generated from current. Use a heating element, referred to simply as a heater. Current flowing to the motor first flows through the heater, where it generates heat: the greater the current flow, the more heat is produced. When the level of current flow causes enough heat to be produced, the overload device is activated.
THERMAL POLLUTION	Waste heat that can cause damage to the environment.
THERMAL STRESS	Total temperature change in a mass of metal, in a given time. Total temperature change of more than 75° F., thickness of metal, rate of temperature change.
THERMOCLINE	A naturally occurring or man-made phenomenon in which a warm layer of water floats above a layer of cooler water.
THERMOCOUPLE	A temperature sensing device consisting of a junction of two dissimilar metals which will generate a voltage proportional to the

	temperature. Converts heat into electricity to measure temperature. Consists of two wires of different metals joined at one end. The opposite ends of the wires are connected to an indicator. When heat is applied to the joined ends, a small voltage is generated in the wires. The electrical circuit detects the voltage and converts it to a corresponding temperature indication.
THERMODYNAMIC TRAP	A trap that responds to the heat energy in condensate. Operate by utilization of the differences in thermodynamic energy available from steam and hot condensate to control the opening and closing of the trap. Impulse trap; disc trap.
THERMODYNAMICS	Scientific study of heat and motion.
THERMOMETER	An instrument for measuring temperature that uses the expansion of fluids or metals to indicate a measurement.
THERMOMETER WELL	A protective tube for a temperature sensing element.
THERMOSTATIC TRAP	A trap that responds to the difference in temperature between steam, condensate, and air. Actuated by the temperature of the liquid flowing to the trap. Open on cool condensate, and close near steam temperature. Bellows trap.
THETA	Either of the angles in a right triangle that is not the 90° angle.
THREE ELEMENT DRUM LEVEL CONTROL	Drum level, feedwater flow, and steam flow. Uses the steam flow as a feed-forward signal. When steam flow changes, it changes the feedwater flow immediately, not waiting for the drum level to change. Steam flow and feedwater flow become the primary controlling factors.
THREE PHASE GENERATOR	A generator that has three sets of stator windings and produces three outputs.
THREE-WAY VALVE	A multiport valve. Allows a routing of the normal flow to 1 of 2 other directions. It is a combination of the globe and angle valve types. Has one L-shaped opening.
THROTTLE AND EMERGENCY VALVES	Each provide the same protection to the turbine; that of isolating the turbine from the main steam supply in the event of a turbine shutdown. The throttle valve is used to control steam flow to the turbine during start-up periods from turning gear operation to at or near rated speed. During this period the governing or control valves are in the wide open position. As the turbine approaches rated speed, the governing valves start to close and take over control of the turbine speed. The combination stop valve-throttle valve is essentially two valves in one, a small throttle valve being contained inside a larger valve which is the stop valve. There is a hole or port in the disc of the stop valve which is closed off by the

throttle valve when the combination stop valve-throttle valve is in the closed position. Operation of this valve is as follows: When oil pressure is increased in the throttle valve servomotor (operator) the valve stem starts to move outward. This valve stem is connected to the throttle valve only. The throttle valve (or valves) will pass sufficient steam to bring the turbine up to rated speed, after which the governing valves take over the turbine speed control. Further opening of the throttle valve causes it to shoulder against the stop valve disc internally and further travel of the valve stem opens the stop valves. This type of valve is used on Westinghouse turbines.

THROTTLE PRESSURE — The steam pressure between the boiler and the main stop valves; also called "before-seat" pressure.

THROTTLE PRESSURE REGULATOR (INITIAL PRESSURE REGULATOR) — This regulator is provided to protect the turbine against sudden failure of steam inlet pressure and possible resultant carry-over from the boiler. This device will monitor steam inlet pressure and if the pressure falls below a predetermined value it will partially close the steam chest governing valves. If the boiler pressure continues to fall, the load will be reduced to some minimum value above no load. This prevents motoring and leaves the tripping of the unit to the operator. The TPR is connected through a ball check valve to the governing control oil system. Adjusted to start closing the governor valves at approx. 80% rated throttle pressure. <u>Prevents water induction.</u>

THROTTLE VALVES — The primary function of the throttle valves is to shut off the flow of steam to the turbine in the event of overspeeding beyond the setting of the overspeed trip, which is set to operate at 11 percent overspeed. These valves are also used for controlling the steam flow to the turbine during the period when the unit is being brought up the speed. The throttle valve is designed with an inner plug valve as well as with a larger valve. This inner valve is usually big enough to get 20-25 percent load at full throttle pressure on about 60 percent effective valve travel. However, it is not used to control load on the turbine unit. One other important reason for the smaller inner valve is to permit steam pressure to be equalized on both sides of the main valve so that the servo motor can lift (open) the main valve. High pressure oil fed through an orifice located in the multiple orifice and check valve body is regulated by a relay valve for controlling the position of the throttle valve. When the auto stop trips for any reason, the throttle operating oil is automatically connected to drain and the throttle valves will trip instantaneously. After the throttle valves are tripped, it is necessary to wind the handwheel back to the closed

	position before the throttle valves can be reopened. The throttle valve is hydraulically opened and spring closed.
THRUST	A force created when moving steam strikes the blades in the turbine; the thrust is in the direction of the steam flow.
THRUST BEARING (AXIAL BEARING)	Maintains the position of the turbine rotor in correct axial position with respect to the casing. A sliding surface bearing designed to limit axial movement. With this type of bearing, a raised section, called a collar, is attached to the shaft. On both sides of the collar are bearing surfaces that fit around the shaft. These bearing surfaces are held in place by the bearing housing. The collar and the bearing surfaces are separated by a thin film of oil. Whenever the shaft tries to move axially, the collar pushes against a bearing surface, and the movement is stopped. Actual contact between the collar and the bearing surfaces is prevented by the film of oil. The bearing is flooded with oil under pressure at all times. The oil is supplied directly from the main bearing supply line. As the thrust collar rotates with reference to the shoes, the film of oil between each shoe and the loaded collar will tend to take a wedge shape with the thick side of the wedge on the forward or entering edge of the shoes. Thus, the oil is carried between the bearing surfaces by the motion of the collar and assures proper lubrication of these surfaces. The amount of oil flowing through this bearing is determined by the two orifice screws located in the discharge lines from the thrust bearing cage. Thrust bearing metal temperature (T/C at center of shoe): **a.** Up to 185°F normal **b.** Alarm at 200°F **c.** Trip at 225°F
THRUST BEARING TRIP DEVICE	A circuit designed to activate a solenoid trip when turbine movement exceeds a certain preset value. The thrust bearing trip device is to warn the operator of wearing of the thrust bearing shoes and to shut down the unit in case the wearing of the shoes increases to the point where it may cause serious damage to some other turbine parts. It consists of two small nozzles whose openings are close to the thrust collar faces. High pressure oil is supplied to each nozzle through an orifice and pressure is built up in the line through ball check valves to a spring loaded diaphragm. Should excessive thrust bearing wear occur, the thrust bearing collar will move towards one of these nozzles and the oil pressure in the line will increase. When this pressure rises to 30 psig a pressure switch will close and sound an alarm. Should wear continue, the pressure will continue to rise and when it reaches 80

	psig the diaphragm will overcome the spring load and open the dump relay through the same mechanism as the other protective devices and thus release the overspeed trip valve.
THRUST LOADS, OR AXIAL LOADS	Back-and-forth forces exerted on a bearing or shaft in a direction parallel to the axis of the shaft.
TILTING DISC TRAP	A simple type of thermodynamic trap in which the only moving part is a disc.
TIME OVERCURRENT RELAY	An overcurrent relay that initiates a circuit breaker trip after a certain pre-established time has elapsed.
TITLE BLOCK	The section of a diagram that identifies the unit and the system that the diagram represents.
TORQUE	The moment of force, a measure of its tendency to produce torsion and rotation about an axis, equal to the vector product of the radius vector from the axis of rotation to the point of application of the force by the force applied.
TORQUE CONVERTER	A variable-speed coupling that transfers rotary motion from one shaft to another through hydraulic fluid.
TOTAL FLOW	The total amount of fluid that has passed a designated point.
TOTAL HEAD (PUMPS)	The amount of head, or pressure, produced inside a pump. Can be compared to flow rate.
TRACER LINES	Any pipeline installed in or adjacent to a companion line for the purpose of heating the contents of the companion line by the passage of steam or hot condensate through the tracer.
TRAFFIC DIRECTOR	A component in a distributed control system's communication network that helps to manage the flow of data.
TRANSDUCER	A device that changes, or converts, one type of signal to another type of signal.
TRANSFER POINT	A point during startup when control of steam flow is transferred from the stop valves to the control valves.
TRANSFORMER	An electric device by which electromagnetic induction transforms electric energy from one or more circuits to one or more other circuits at the same frequency, usually with changed values of voltage and current. It is desirable to generate or produce power at relatively low voltages, transmit it at high voltages and use it at low voltages. These voltage changes are accomplished by the use of transformers. A power transformer is a device whose primary

function is to change the voltage level of a system. Consists of two separate circuits, the input or supply circuit and the output or load circuit. To avoid confusion these two circuits should be identified as the high voltage side and the low voltage side. Each circuit or side of the transformer consists of a number of coils or turns of wire. The two circuits are located adjacent to each other in a common container but are not connected. An AC voltage is supplied to one side of the transformer. As the current passes through this side of the transformer it creates a magnetic field around the coils. The coils are wound in a manner that concentrates or strengthens the magnetic field. The strength and size of a magnetic field produced in this manner depends on the amount of current flowing. Since alternating current is supplied, the current flowing through the coils is constantly increasing and decreasing. The magnetic field will also be continuously increasing and decreasing. As the current increases, the magnetic lines of force build-up and extend outward. As the current decreases the lines of force collapse back inward toward the coils. This alternate build-up and collapse of the lines of force actually is equivalent to a moving magnetic field. The coils in the output circuit are located so that the expanding and collapsing magnetic field cuts across them. This action produces a potential difference and a current flow in the output circuit. The output voltage will alternate at the exact same frequency as the input voltage. In order to concentrate the magnetic field and make more efficient use of it, the transformer is usually provided with an iron core. The core concentrates the lines of force and allows more of them to cut across the coils in the output circuit. The core is usually made up of sheets of iron which are insulated from each other. This is known as a laminated core. Its purpose is to cut down the circulating current in the core. The magnitude or value of the voltage that is produced in the output circuit depends, among other things, on the number of turns or coils in both the input and output circuits. If it is desired to have the output voltage higher than the input circuit, there must be more turns in the output circuit than in the input circuit. In general, the ratio of the voltages will be the same as the ratio of the number of turns. For example, if the input circuit has 10 turns and the output circuit has 20 turns, the output voltage will be 20/10 or two times as large as the input voltage. If it is desired to use the transformer to reduce voltage there will be less turns in the output circuit than the input circuit. It must be understood that a transformer does not generate or produce electric power, it just transforms it. In order for a change in voltage to take place, there must be a corresponding change in some other electrical quantity. In the case of a

	transformer the corresponding change is in the current. The transformer changes the voltage in direct proportion to its turns ratio and changes the current in inverse proportion to the turns ratio. This means that if the transformer is used to increase the voltage by a factor of two, the current will be decreased by a factor or two. The product of voltage times current on each side of the transformer must be equal. Whenever there is a change in one of these quantities there must be a corresponding change in the opposite direction in the other quantity. Transformers are highly efficient pieces of equipment. In general their efficiency is approximately 98-99%. The small loss that occurs shows up as heat in the windings and core. This heat must be removed for continued operation of the transformer. Small to medium size transformers are installed dry and are cooled by air through natural convection such as our lighting transformers. Larger transformers, such as our main and auxiliary transformers, are installed in a tank filled with oil. The oil helps insulate the windings and acts as the heat transfer medium. The oil absorbs heat from the windings and core. This heat is then removed from the oil by transfer to the air. In many cases, the tank is fitted with radiators to provide more surface area for cooling the oil. The oil flow may be either natural or forced by pumps and the air flow may also be either natural or forced by fans. The rating of a transformer, like most electrical equipment, depends largely on the ability to remove heat from it. If the cooling equipment is shut down for any reason, the capacity of the transformer will usually be limited.
TRANSMISSION LINE	A line used for electric power transmission.
TRANSMITTER	An instrument in a control loop that senses and measures a process variable and produces a signal representing the value of the process variable.
TRAP	A device that allows moisture to flow out of components without allowing air or other gases to escape.
TRAVELING SCREENS	Loops of screen segments that prevent leaves and debris in raw water from entering the plant.
TREND	An indication of a change in the operation of a system or an individual piece of equipment. A consistent pattern of points, that gradually move in an upward or downward direction. Could be an indication that process equipment is malfunctioning or that the proportions of the materials entering a process have changed. Could also be an indication that properties of materials, such as the purity, density, or viscosity, have changed.

TRIGONOMETRY	The study of triangles.
TRIGONOMETRY FUNCTION TABLE	A table that lists various values for theta and the corresponding values for functions such as sine, cosine, and tangent.
TRIP	An accessory or the act of divorcing a piece of equipment from its source of energy.
TRIP CIRCUIT	An electric circuit that automatically shuts down plant equipment in an emergency. **1.** Boiler - The stopping of all fuel flow to the boiler and the stopping of the ignitors. **2.** Electrical - The opening of a circuit breaker's contacts to open a circuit. **3.** Generator - The opening of a generator's circuit breakers, disconnecting the generator from the power system; will also trip the boiler and the turbine. **4.** Turbine - The shutting off of all steam flow to the turbine; will also trip the generator and the boiler. **5.** Unit - A condition in which the generator, the turbine, and the boiler in a generating unit are tripped.
TRIP COIL	An electromagnet used for opening a circuit breaker.
TRIPPING MECHANISM	An electrically or mechanically operated device which releases the holding means and permits the contacts of the circuit breaker to open.
TRISODIUM PHOSPHATE (TSP)	Raises the PO4 levels and pH values of boiler water. Ties up calcium and magnesium as a flocculent phosphate precipitate which can be removed through boiler blowdown. Elevates the total dissolved solids levels, therefore causing conductivity to rise.
TROUBLE-SHOOTING	Five major steps: **1.** Identifying the problem **2.** Taking preventive action **3.** Determining the cause of the problem **4.** Correcting the problem **5.** Returning the process to normal operation
TRUE POWER	The amount of power that is actually doing work in an AC circuit.
TU	Termination Unit.
TUBE SHEETS	Sheets that support circulating water tubes at their ends and separate the steam in the shell from the circulating water in the water boxes.
TUBE SUPPORTS	Plates that support and align the circulating water tubes in a

	condenser.
TUBING PUMP	Rotary pump. The process liquid is contained inside a flexible tubing that is part of the pump. The pump's rotor works with the tubing to force the liquid through the pump. During operation, liquid is drawn into the tubing at the suction of the pump. The rollers turn with the rotor and compress the tubing, trapping liquid inside. As the rotor continues to turn, the rollers force the trapped liquid through the tubing and out the pump's discharge. Normally do not have as high a flow rate as other types of rotary pumps.
TURBIDITY	The cloudiness or haziness of a fluid as a result of a high concentration of suspended solids that are usually invisible to the naked eye. A measure of undissolved particulate matter in a solution. The measurement of Turbidity is an important test when trying to determine the quality of water. It is an aggregate optical property of the water and does not identify individual substances; it just says something is there.
TURBIDITY METER	An instrument that measures the concentration of suspended particles in a solution.
TURBINE	A machine capable of converting thermal energy to rotating mechanical energy. Provides torque and speed. The work the turbine produces is the power required to turn a large AC generator. The turbine is one of the biggest, most powerful piece of equipment in the world, and is 40 efficient. The average clearance throughout the turbine is about 40/1000 of an inch.
TURBINE CONTROL SYSTEM	Fundamentally all controls are operated hydraulically utilizing the oil supplied by the shaft mounted main oil pump. The 150 psi pressure is used to obtain the necessary force to actuate the servomotor pistons. The same 150 psi pressure is orificed and regulated by various controllers to obtain lower pressures necessary to monitor the position of the servomotors, by means of autostop and control oil pressures. The controls of steam turbines can be divided into those for the control of the flow of steam, and those for the protection of the turbine. The main steam controls include the servomotors (operating mechanisms) for moving the governing valves and interceptor valves which determine the flow of steam into the turbine. These valves are positioned by the control oil pressure produced by the various control devices (governor, load limit valve, throttle pressure regulator, or auxiliary governor). The valves are designed to open on a decrease in control oil pressure, and close on increase in control oil pressure. The response range of the interceptor valves is higher than the response range of the governing valves. This difference in

	response range makes it impossible during normal operation to operate with the interceptor valves closed and the governing valves open. The protection controls include the throttle valves and reheat stop valves and their operating mechanisms. The throttle valves have the additional function of controlling steam for starting. The reheat stop valve is either full open or closed and should never operate in the partial open position. These valves are under the control of auto stop oil which is produced by latching the overspeed trip valve. During normal operations the steam to the turbine is regulated by the steam chest governing valves. All other valves are wide open and only during load dump operation is the interceptor valve used to regulate the steam flow. The control oil pressure ranges from 35 psi, steam chest valves closed to 10 psi steam chest valves wide open. This control pressure can originate from any of the following controllers: Main Governor, Load Limit Valve, Throttle Pressure Regulator, or Auxiliary Governor. The controller maintaining the highest pressure will assume control of the steam chest servomotors and consequently the load carried by the turbine. The speed or load of the turbine is controlled by the main governor with the conventional motor operated speed changer. This governor controls the positioning of the steam inlet (or governing) valves through servomotors one of which is connected to each steam chest. At normal frequency the governing is done by the main governor, or auxiliary governor.
TURBINE CROSSOVER PIPE ASSEMBLY	The purpose of the crossover pipe is to guide the steam from the intermediate pressure exhaust to the low pressure turbine with a minimum of pressure loss. This is accomplished by building into each mitered corner a guide vane assembly consisting of multiple vanes to smooth the steam flow as it changes direction. A manhole is provided in the top of the pipe for inspection and maintenance. When not in use it must be kept tightly covered and sealed.
TURBINE FLOW METER	A meter that uses fluid velocity to determine flow rate. Has blades that are attached to a rotor. The rotor is placed in the path of the fluid flow. As fluid passes around the blades, the rotor begins to rotate. The speed of the rotation is proportional to the speed of the fluid. The number of rotations that the rotor makes is converted to an indication of flow rate.
TURBINE INLET PIPING AND NOZZLE CHAMBERS	Inlet piping carries main steam exiting the governor valves to the high pressure turbine element. The inlet piping is a flexible piping system that allows for thermal expansion and contraction without producing higher than allowable stresses on the turbine casing. The inlet pipes are connected to nozzle chambers through an inlet

	sleeve which has a bell type, pressure seal arrangement. This permits radial movement between inlet pipes, nozzle chambers, and the inner cylinders. The high temperature steam goes through the nozzles in the nozzle block to the first row of rotating blades. This combination of stationary nozzles and rotating blading is known as the control stage. The nozzle block (containing the stationary nozzles) is bolted onto the nozzle chamber. Westinghouse utilizes separate nozzle chambers that allow maximum freedom for thermal expansion between chambers. These stationary nozzles convert the pressure energy of the main steam into velocity energy by issuing a steam jet. The jet is directed on the row of rotor mounted blading, causing the blades to rotate at high velocities.
TURBINE LOW PRESSURE CYLINDER	The steam exhausting from the intermediate turbine flows directly to the LP cylinder or cylinders. Most of the LP turbines are of the divided or double flow type. Steam is admitted to the center section of the rotor and the steam flows to both ends. The blades from the center to the ends are the same type on both halves but are opposite because of opposite steam flow. The steam is exhausted from the LP to the condenser.
TURBINE PROTECTIVE TRIP DEVICES	The trip devices operate directly to rapidly close the throttle valves and reheat stop valves. The governing valves and interceptor valves are hydraulically interlocked with the trip devices and are also closed whenever the turbine is tripped. These valves open with hydraulic pressure against a spring tension, when a trip occurs, the oil is automatically directed to drain and the valves close by the pressure from the spring. The various trip devices are: **1.** Overspeed trip valve **2.** Solenoid trip **3.** Low vacuum trip **4.** Low bearing oil pressure trip **5.** Thrust bearing trip **6.** Manual trip
TURBINE SEALS:	N1 SEALS - Seals located at the exhaust end of the HP section and used to seal between the casing and the rotor. N2 SEALS - Seals located between the HP and IP sections and used to seal between the casing and the rotor; also called midspan seals. N3 SEALS - Seals located at the exhaust end of the IP section and used to seal between the casing and the rotor.
TURBO-GRAF CASING	Measures the movement of the governor pedestal relative to a

EXPANSION RECORDER	fixed point (the foundation). In as much as one end of the unit (near the centerline of the LP turbine) is secured to the foundation, the casings will expand axially away from this anchored point. The opposite end of the unit (the governor pedestal) is designed to move freely along lubricated longitudinal keys. The recorder indicates expansion and contraction of the casings during starting and stopping periods, and for changes in load, steam temperature, etc. The recorder charts casing movement using a potentiometer type transmitter located at the governor pedestal end of the unit.
TURBO-GRAF DIFFERENTIAL EXPANSION RECORDER	When steam is admitted to a turbine, both the rotating parts and the casings will expand. Because of its smaller mass, the rotor will heat faster and therefore expand faster than the casings. Axial clearances between the rotating and the stationary parts are provided to allow for differential expansion in the turbine, but contact between the rotating and stationary parts may occur if the allowable differential expansion limits are exceeded. The purpose of the differential expansion recorder is to chart the relative motion of the rotating and stationary parts. It gives a continuous indication of the axial clearance while the turbine is in operation. The recorder charts movement using a pair of pick-up coils located between the LP turbine and the generator.
TURBO-GRAF GOVERNOR VALVE POSITION & SPEED RECORDER	This instrument with its two-scale strip chart records rotor speed or governing valve position. The selection of either valve position or speed input to the recorder is controlled by the position of the main generator breaker. A speed record is maintained with the main generator breaker open and a valve position record with the breaker closed. For operators convenience, a switch provided on the power drawer of the instrument can be energized for a speed recording with the unit on the line.
TURBO-GRAF ROTOR ECCENTRICITY RECORDER	When a turbine has been shut down, the rotor will tend to bow due to uneven cooling if the upper half of the casing enclosing the rotor is at a higher temperature than the lower half. By rotating the rotor slowly on turning gear, the rotor will be subjected to more uniform temperatures, thereby minimizing bowing. The bowing of the rotor is recorded continuously as eccentricity from turning gear to approx. 600 rpm. Two matched pick-up coils are mounted 180 mechanical degrees around the circumference of a disc which is located at the governor end of the turbine.
TURBO-GRAF ROTOR POSITION RECORDER	This instrument measures the relative axial position of the turbine rotor thrust collar with respect to the thrust bearing support and provides a second independent rotor position monitoring device as required by the Emergency Trip System. It uses the same type of rotor position pickup and power drawer as the Casing Expansion

	and Rotor Position Instrument but the power drawer contains only rotor position circuitry. There is only one set-point on this instrument. The alarm function is adjusted to the trip set-point so that any movement beyond this set-point activates trip alarm contacts and causes the turbine to trip through channel two of the Emergency Trip System.
TURBO-GRAF VIBRATION RECORDER	Measures and records vibration of a turbine rotor at speeds above 600 rpm. The vibrations are measured on the rotor near the main bearings. Excessive vibrations serve as a warning for abnormal and possible hazardous conditions in the turbine.
TURBULENCE	A swirling effect that takes place in the furnace; necessary for the mixing of fuel and air for complete combustion.
TURNING GEAR	A motor and gear arrangement that keeps the rotor turning at a constant speed during turbine shutdown to maintain uniform cooling of the rotor and thus prevent the rotor from warping or bending, minimizing rotor eccentricity. Also serves as a jacking device to turn the shaft in small increments at desired intervals for inspection. Ample power to start the rotor from rest and rotate it at approx. 3 rpm. The turning gear is an electrically-driven speed-reducing device. Driving torque is transmitted to the turbine-generator coupling spacer ring by a train of spur gears. Lubrication for turning gear operation is supplied by the turning gear oil pump. This pump can be started by a pressure switch that is connected to the bearing oil line when the bearing oil pressure recedes to somewhere between 5 to 8 psig. Another pressure switch which is also connected to the bearing oil line prevents this motor from starting until the bearing oil pressure has risen to somewhere between 2 and 4 psig. Before the turning gear motor can be started, the manually operated valve in the oil supply line must be opened. The turning gear is engaged manually at the turbine.
TWO-POSITION CONTROL	Control action in which a signal from a controller causes a final control element to move from one extreme to another, such as from on to off.
TWO-SCREW PUMP	Rotary pump. One of the screws is attached to a shaft that is coupled to the pump's driver. This screw is known as the power, or driver screw. The other screw is often referred to as the idler screw. Power is transmitted from the driver screw to the idler screw through a set of timing gears. During operation, process liquid enters the suction of the pump and is directed toward both ends of the casing. As the screws rotate, the liquid becomes trapped between the casing and the screws. The liquid is moved

	from both ends of the pump toward the center, which is also the discharge of the pump. The force that is exerted by the screws pushes the liquid out of the pump and through the discharge piping.

U

U CHART (SPC)	Used to plot the average number of defects per item. The horizontal axis represent time, and the vertical axis represents the number of defects per sample. The sampling size is based on the number or amount of product samples needed to determine a data point for the chart. The sampling size is constant for a particular application.
UNBURNED COMBUSTIBLES LOSS	Loss due to combustible material in the fuel that does not burn.
UNDERVOLTAGE RELAY	A protective relay that opens a circuit breaker when the voltage in the circuit falls below a pre-determined value.
UNGROUNDED SYSTEM (INSULATED SUPPLY SYSTEM)	A system in which no point is deliberately connected to earth except through potential or ground detecting transformers or other very high impedance devices.
UNION (PIPING)	Each end of a union is connected to a piece of pipe and held in place with a threaded collar.
UNIT SYSTEM	A system complete in itself. Normally not connected with other systems.
UNIT TRANSFORMER	A component that receives power from a generator and increases the voltage while decreasing current.
UNITY POWER FACTOR	An operating condition in which true power and apparent power are equal.
UNPLANNED (FORCED) DERATINGS:	D1 Immediate - A derating that requires an immediate reduction in capacity. D2 Delayed - A derating that does not require an immediate reduction in capacity but requires a reduction with six hours. D3 Postponed - A derating that can be postponed beyond six hours but requires a reduction in capacity before the end of the next weekend.
UNPLANNED (FORCED) OUTAGES:	U1 Immediate - Unscheduled unit trips. An outage that requires immediate removal of a unit form service, another outage state, or a Reserve Shutdown state. This type of outage usually results from immediate mechanical, electrical, or hydraulic control

	systems trips, and operator-initiated trips in response to unit alarms. U2 Delayed - An outage that does not require immediate removal of a unit from the in-service state but requires removal with six hours. This type of outage can only occur while the unit is in service U3 Postponed - An outage that can be postponed beyond six hours but requires that a unit be removed from the in-service state before the end of the next weekend. This type of outage can only occur while the unit is in service..
UPS (UNINTERRUPTED POWER SUPPLY)	Purpose is to supply uninterrupted AC power of high quality, even when the incoming commercial power is interrupted. The necessary storage of reserve electric energy is done by means of an internal battery pack. Batteries are only capable of storing DC power, whereas the critical load requires AC power. The UPS performs this important conversion from DC to pure conditioned AC. Consists of a rectifier that converts AC power to DC power to feed its own battery bank. The DC output of the rectifier in turn supplies the inverter and float charges the battery. The inverter converts the DC power back to AC power to feed the DCS (Digital Control System). The battery bank, upon loss of AC power will feed the DCS for approx. 2 hours, depending on the battery bank's condition. The system is also equipped with a static bypass switch that will transfer the critical load automatically, without any break, to the bypass source whenever the inverter fails to supply the required output. This can be due to an overload situation (more power is demanded than the inverter can deliver) or a short circuit in the load. As soon as the abnormal situation is corrected, the static switch transfers the load to the inverter again, without any interruption of power to the load.
URAL	Underexcited Reactive Ampere Limit.

V

VACUUM	Negative pressure measured from atmospheric pressure downward, usually expressed in inches of mercury.
VACUUM BREAKER	A valve connected to the main condenser that, when opened, lets air into the condenser; closed during startups and usually opened during shutdowns.
VACUUM PUMP AND SEPARATOR TANK	A vacuum pump maintains a high vacuum in the vacuum tank and draws off the gases and vapors which are liberated from the oil in the vacuum tank. The vacuum is 1 inch of mercury absolute

pressure or less. The vacuum pump exhausts into a separator tank where the vapors condense, but the gases pass on out through a vent to atmosphere. The oil in the separator tank lubricates and seals the vacuum pump. The water settles to the bottom and is drained manually every eight hours.

VACUUM TANK

Oil from the air side of the gland seals flows by gravity into the gland oil reservoir. Oil from the defoaming tanks is drawn into this tank through a float valve and spray nozzles. The oil flows over a series of trays which provide a large area for separation of gas and water vapor. The float valve in the vacuum tank maintains the oil level in the vacuum tank at a fixed position. Any gas and water vapor trapped in the oil tends to cause a thick layer of foam in the vacuum tank. If this foam builds up to the level of the connection to the vacuum pump, some of the foam will be drawn over to the pump and impair its operation. To prevent this, there is a large float in the vacuum tank connected to an external level indicator and to three mercury switches. Two of these switches operate high and low oil level alarms. The third makes contact on a rising float, energizing the solenoid valve mounted on the vacuum tank which admits a small quantity of air into the vacuum tank to "blow down" the foam.

VALENCE

The number of electrical charges, positive or negative, carried by an ion.

VALENCE ELECTRONS

Electrons in the outermost shell of an atom. They affect every chemical reaction that occurs.

VALENCE NUMBER

A number notation that expresses the number of electrons involved when an atom reacts chemically and whether those electrons are given up or accepted.

VALVE

A device used to start, stop, or regulate the flow of a fluid in a system.

VALVE STEM FREEDOM TEST (INTERCEPTOR AND REHEAT STOP VALVE)

The interceptor valves and reheat stop valves should be exercised at least weekly to detect possible valve stem sticking. This test can be carried out at any load, with no or negligible effect on the load. There is no manual control for the reheat stop valve, and the reheat stop valve can not be opened unless the corresponding interceptor valve is closed. A test panel with suitable interlocks is normally provided for testing the interceptor valves and reheat stop valves. On units with two reheat lines the interlocks prevent testing of both sets of valves at the same time. The normal test procedure is to test only one set of valves at a time, however. In addition, the test circuit is so arranged that the interceptor valve closes first. When it is closed, a limit switch energizes the test

	solenoid on the reheat stop valve causing it to close. The reheat stop valve has a limit switch that holds the interceptor valve test solenoid energized. Releasing the test switch allows the reheat stop to open first, and then the interceptor valve opens. Proper valve closing is shown by indicator lights on the test panel.
VANE ACTUATOR	Uses air pressure acting against a paddle, or vane, to position a valve. Simple in design and relatively small for the amount of force it can supply to open or close a valve. Used primarily with rotary-type valves such as a ball, plug, and butterfly valves, because the valve rotates the valve disc. When air pressure is applied through the air supply port of a valve actuator that operates a butterfly valve, it pushes against a vane, causing the vane to swing across a housing. This swinging motion turns a shaft, which opens the valve. Air on the other side of the vane is bled off through another air supply port. When air pressure is supplied to the opposite supply port, the vane is moved in the opposite direction, closing the valves. Air on the other side of the vane leaves through the other supply port. Vane actuators, like other actuators, can be spring loaded or set up with other devices so that a valve will fail in a safe position.
VANE PUMP	A rotary pump in which the rotating member, with its sliding vanes is set off-center in the casing. The vanes slide in and out of the rotating part and always stay in contact with the inside of the case. The entering liquid is trapped between the vanes and is carried around to the discharge.
VAPOR EXTRACTOR	A component of the turbine lubricating oil system designed to remove potentially dangerous vapors from the oil reservoir.
VAR	Volt-ampere reactive.
VARIABLE	Liable or likely to change or vary; subject to variation; changeable.
VARIABLE DATA	Measurements taken from the process, such as temperature, pressure, pH, or weights.
VARIABLE SPEED COUPLING	A device that allows pump speed to vary while driver speed remains constant. Allows the speed of driven machinery to be changed while in operation. Could be used as a final control element.
VARIABLE SPEED MOTOR	A motor that can be provided with varying amounts of electricity to operate at varying speeds.
VARIAC	Adjustable transformer used to change level of voltage. Similar to rheostat in its effect and mechanical operation.

VARS	Volt-ampere-reactive. The unit of reactive power. The non-useful portion of the total power, and results from the reactance (either inductive or capacitive) in the circuit; line loss. The amount it takes to get the voltage out into the system. Increasing generator rotating magnetic field voltage causes the voltage and current sine waves to disassociate, or move off each other. This creates the volt-ampere-reactive, or VARS. VARS can either be "pushed" into the system, raising power distribution system voltage, or "drawn" into the generator, lowering power system voltage.
VELOCITY	Distance traveled in a specified amount of time. Speed and direction. The velocity of a body can be changed by changing either its speed or its direction. Units of length divided by time (ft/sec).
VELOCITY HEAD	Related to the level of liquid. The pressure that results from the flow of fluid. The change in static head caused by velocity.
VENT CONDENSER	Generally, a small condenser that condenses the steam in the steam/air mixture, for example, in the vents from a deaerator.
VENTURI	A primary device used for establishing pressure differentials used in the measurement of flow through pipes.
VIBRATION VIBROMETER	An instrument used to check bearings and other components for vibration.
VISCOSITY	A measure of the internal friction in a fluid; of the thickness, or pourability of an oil; a measure of a liquid's resistance to flow. High viscosity is thick, low viscosity is thin. Viscosity is greatly affected by temperature. An oil's viscosity, or thickness, increases as the temperature drops. The colder it gets, the thicker oil becomes, and the less easily it flows. High viscosity oil which has a high resistance to flow , is generally more suitable for use at high temperatures. As the temperature rises, viscosity decreases. Oil gets thinner and flows more easily. Low viscosity oil which has a low resistance to flow, is used more with low temperatures.
VOLATILE CHEMICAL	A chemical that vaporizes easily.
VOLT (E)	The unit by which voltage is measured; unit of electromotive force. The unit used to measure the potential difference between two points. A measure of the force that causes electricity to flow.
VOLTAGE	Electrical pressure, measurement of electrical flow. Potential difference; electromotive force. The energy necessary to cause current flow.
VOLTAGE REGULATOR	A regulator which functions to maintain the voltage of a

	synchronous generator, condenser, or motor at a predetermined value. An automatic circuit that adjusts the exciter output to maintain the generator output voltage and power factor at acceptable levels, when utilizing the main exciter. It also provides for minimum excitation changes. The generator terminal voltage and current provide the sensing source for voltage regulation. The regulator uses this signal to control the field of the generator.
VOLTAGE RELAY	A relay which functions at a predetermined value of voltage. It may be an overvoltage relay, an undervoltage relay, or a combination of both.
VOLTAGE TO GROUND	The voltage between any live conductor of a circuit and earth.
VOLTAMPERE	The basic unit of apparent power. The mathematical product of the volts and amperes in an electrical circuit. The practical unit of apparent power is Kilovoltampere (KVA).
VOLTMETER	A device used to measure voltage.
VOLUME (V)	A measure of space occupied by a material body; the capacity of a vessel. Flow units are gallons per minute, or cubic feet. $V = L \times W \times H$ A measure of space or the capacity of a vessel. Product of 3 lengths, or length cubed (Length x Width x Height)
VOLUME FLOW RATE	The volume of the fluid that passes a specific point in a unit of time.
VOLUMETRIC FLOW RATE	The amount of material measured as a unit of volume per unit of time, such as cubic feet per second or gallons per minute.
VOLUTE	A continually widening chamber that is connected to a gas discharge line.

W

WASTE WATER POND	A pond, usually with large surface area, utilized for holding, transfer, evaporation, percolation, or chemical treatment of in-plant waste water.
WATER (H2O)	A tasteless, odorless, colorless liquid in its pure form. Each molecule of water is composed of two atoms of hydrogen and one atom of oxygen. Has a tremendous capacity to absorb and store heat. Absorbs more heat for a given temperature rise than any other common inorganic substance. The heat of vaporization of water is 970 Btu, indicating that 970 Btu of heat must be added to a pound of water (at boiling temperature) to change it to steam.

At normal atmospheric pressure water freezes at 32°F and boils at 212°F. Increasing or decreasing pressure changes these limits. When water evaporates at normal atmospheric pressure, its volume increases 1600 times. With a pressure increase to 3200 psig. (the critical pressure), water goes directly to steam without a volume change. Raw water has to be processed before being used for steam generation because all natural waters contain varying amounts of dissolved and suspended matter and dissolved gases. The amount of dissolved material varies from about 35,000 ppm in seawater to about 30 to 80 ppm in the best of fresh water supplies. Impurities must be removed from boiler feedwater because they cause scaling, corrosion, and carryover. Impurities are removed, or at least reduced to tolerable levels by water treatment. External treatment is done by demineralizers and deaerators. Internal boiler water treatment is the feeding of chemicals directly to the boiler or feedwater system to: precipitate impurities as a sludge in the water rather than as a scale on the boiler metal; condition the sludge to keep it from sticking to the metal so it can be removed by blowdown; and adjust the water composition to make it non-corrosive. Internal treatment compliments external treatment by taking care of any impurities entering the boiler with the feedwater (hardness, oxygen, silica, etc.). In connection with internal treatment, boiler blowdown plays an important part in maintaining a low level of impurities. All dissolved and suspended solids entering a boiler with the feedwater remain in the drum and tubes as steam is generated. Continued addition of make-up produces higher and higher solids concentration in the boiler drum. Every boiler has a limit for total solids above which priming and carryover occur. In general, the higher the boiler pressure, the less will be the tolerance of solids. The limit may be suspended solids, total solids, silica content, alkalinity, etc. To keep within these limits some of the concentrated boiler water must be removed from the drum. This is accomplished by blowdown. Internal treatment should prevent scaling and corrosion not only in the boiler itself but also in the condensate and feedwater systems.

WATER DETECTORS (GENERATOR)

Trays are provided under each gas cooler to catch any leakage or condensate from the cooler. Pipes are provided to drain water from these trays to the bottom of the machine housing. There are also openings in each frame ring so that any moisture will drain to the water detectors. These are float-operated mercury switches in small housings under the generator frame and main lead box. Isolating valves are provided so the switches can be inspected at any time, and a drain valve is provided for draining off any

	accumulated water.
WATER HAMMER	One of the conditions that cause pipes to rattle and vibrate. The force or shock of confined water when its flow is suddenly arrested. Condensate which forms in a cold line may be driven up and down the line by steam with such a force sufficient to wreck the line or tear it from its hangers. High temperature water under high pressure flashing into steam when admitted into a cold steam line is another cause.
WATER INDUCTION	The entrance of water into a turbine.
WATER JACKET	A space between the compression chamber and the casing through which cooling water circulates. The cooling water picks up heat from the compressor and removes it.
WATER SEAL SYSTEM	A turbine support system that uses water to seal air out of the turbine and seal steam in. Usually located on the atmospheric side of the steam seals and on the low pressure turbine where the shaft emerges from the casing. Sealing water is usually supplied by gravity feed from some form of head tank. The seals on the low pressure turbine are non-circulating. They are provided with a supply line and valve only, and seal water leakage is drawn into the turbine. Water is circulated through the seals on the intermediate and high pressure turbines. These seals are provided with supply and return lines and valves. Adjustment of these valves permits regulation of sealing water flow, pressure and temperature at each water seal. Normal practice is to maintain sealing water temperature leaving the seals at 165°F to 185°F. If temperature is permitted to go too high, flashing occurs at the seals. If temperature is held unnecessarily low, a large temperature differential will be created on the turbine shaft at the seal. This can result in shaft distortion and vibration.
WATERBOX PRIMING SYSTEM	A system that removes air from the condenser waterbox to insure that the circulating water tubes are completely filled with water.
WATER-STABILIZED GREASE	Protects against corrosion due to contact with water. An additive in this grease makes water and the grease mix thoroughly, thus preventing the formation of water pockets that could corrode a bearing.
WATERWALLS	Vertical tubes, filled with a water/steam mixture, that line the inside of a boiler furnace.
WATT (P)	The unit by which electrical power is measured. A unit of electrical power produced by a current of one ampere at one volt. P(watts) = E(volts) x I(amps). The rate of energy transfer equivalent to one ampere flowing due

	to an electrical pressure of one volt at unity power factor. One watt is equivalent to about 1/746 horsepower (746 watts = 1 HP).
WATTHOUR	A unit of electrical energy equal to one watt of power acting for one hour.
WAVE	An electromagnetic impulse, periodically changing in intensity and traveling through space. More specifically, the graphical representation of the intensity of that impulse over a period of time.
WAVEFORM	The shape of the wave obtained when instantaneous values of an AC quantity are plotted against time in rectangular coordinates.
WAVELENGTH	The distance traveled by a wave during the time interval of one complete cycle.
WEAK BASE ANION EXCHANGERS	This exchanger contains a weak base anion resin which exchanges strongly charged negative ions such as chlorides, sulfate and nitrates for hydroxyl ions.
WEARING RINGS	Replaceable metal rings that are mounted between the impeller and the casing of a pump, forming a seal.
WEIGHT	The result of gravitational force acting on mass.
WEIR	A flat restriction with a notch at its top that is installed across an open channel to cause fluid level to rise. The fluid's level can then be converted to a flow rate. Basically a dam with a notch at its top.
WET BULB TEMPERATURE	The wet bulb temperature of air is the lowest temperature indicated by a moistened thermometer bulb when it is exposed to a current of the air. Wet bulb temperature is important because at any given dry bulb temperature, it is indicative of the amount of moisture held in the air and also the total heat of a unit of the mixture of air and water vapor.
WET CELL	A type of battery in which the electrolyte is a liquid; typically, a secondary cell.
WET SCRUBBER	A method of controlling sulfur oxides in the exhaust gases. Combustion gases are passed through liquid sprays. Particulates in the combustion gases stick to the liquid and collect in the bottom of the scrubber. The liquid spray also separates sulfur oxides from the combustion gases by absorption. The sulfur oxides are absorbed into the liquid, which falls to the bottom of the scrubber. Both the particulates and the sulfur oxides are removed from the scrubber along with the spent liquid.
WET STEAM	Steam that contains tiny particles of water, which gives the steam

	its white color.
WETT	Whole Effluent Toxicity Test.
WETTING (SURFACE)	The result of the adhesive forces between the liquid molecules and the molecules of the container.
WHEEL	In a turbine, a round hub containing a set of rotating blades.
WIDE PROPORTIONAL BAND	A proportional band that is greater than 100%. A large change in input to the controller produces a smaller change in output. Can minimize the amount of cycling in a system, but, there is more offset.
WINDBOX	A steel box that distributes air to the burner registers. Designed so that it provides essentially equal air pressure at each burner. Connected to the furnace by openings for each burner. • With 90-95% RTP (1620-1710 psig) - control pressure is 10 psig • With 80% RTP (1440 psig) - control pressure is 30 psig • With 70% RTP (1260 psig) and 15-20% of maximum load (13-17 MW), throttle and reheat temp. drops held to 150° F. or less. If not, shut down unit. Reduced throttle pressures cause decrease in steam density and pressure drop across the turbine, ultimately resulting in heat rate degradation.
WORK	The movement of an object through a distance. The force applied to an object times the distance the object travels. Weight x distance. Basic unit is foot/pounds.
WYE CONNECTION	A type of electrical connection formed by connecting one side of each of three phases of a component to a single point.

X

X BAR CHART	The X represents the value of the variable that is being measured in a process. The bar above the X is a mathematical symbol that represents an average. An X bar chart is used to plot the average of the values taken from the sample group that is collected from a process. The Y axis displays the average value of the samples taken from the process, in the appropriate limits. The X axis displays how often samples are taken, again in the appropriate limits.
XY GRAPH	A graph consisting of a horizontal axis and a vertical axis; commonly used to show the relationship between two or more

variables.

Y

Y-TYPE STRAINER	A strainer used to filter small amounts of solid impurities from a fluid in a piping system.

Z

ZEOLITE SOFTENER	A component that softens water by removing dissolved hardness solids such as calcium and magnesium.
ZERO POINT	The level of a liquid or a solid is the position of the surface of that substance above or below a fixed reference point, often called the zero point.
ZOM	Zone of Mixing.