COMPLEX ENGINNERING PROBLEM

2024

INDUSTRIAL AUTOMATION

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Boiler Automation System for steam flow, water flow & drum level control.

1. Abstract:

A boiler automation system for steam flow, water flow, and drum level control is essential for efficient and safe operation in steam generation processes. This system utilizes sensors, control algorithms, and actuators to monitor and regulate key parameters. The system focuses on maintaining optimal steam flow by adjusting fuel and air inputs, ensuring a steady water supply through control of the water inlet valve, and controlling the drum level to prevent overflows or dry running. A centralized control unit processes sensor data, initiates control actions, and incorporates safety features to protect personnel and equipment. Overall, the system optimizes energy usage, maintains water level, and prevents hazardous situations, enhancing boiler reliability and performance.

2. Literature Review:

2.1 Boiler:

A boiler is a closed vessel or container in which water or other fluids are heated to produce steam or hot water. It is a key component in various industrial and commercial applications, as well as residential heating systems. Boilers are commonly used in power plants, refineries, chemical plants, and heating systems for buildings.

Boilers are used in power plants in order to produce high pressured steam, so that the plant can generate electricity. The process that does this is known as the Rankine cycle. The boiler takes in energy from some form of fuel such as coal, natural gas, or nuclear fuel to heat water into steam.

The primary function of a boiler is to generate steam by transferring heat energy from a fuel source, such as natural gas, oil, coal, or biomass, to the water within the boiler. This heat transfer is typically achieved through combustion processes or by utilizing electric heating elements. The generated steam can be used for a wide range of purposes, including power

generation, heating, process heating in industrial facilities, and driving various mechanical processes.

Boilers come in different types, such as fire-tube boilers and water-tube boilers, each with its own design and operational characteristics. They also have various components, including burners, heat exchangers, control systems, and safety devices, which work together to ensure efficient and safe operation.

2.2 Three Element Drum Level Control System:

In most drum level control applications, the two-element drum level control will maintain the required water/steam interface level – even under moderate load changes.

If an unstable feed water system exists exhibiting a variable feed header-to-drum pressure differential, or if large unpredictable steam demands are frequent, a three-element drum level control scheme should be considered. As implied from the previous information, this control strategy supplies control of feed water flow in relationship to steam flow.

The performance of the three-element control system during transient conditions makes it very useful for general industrial and utility boiler applications. It handles loads exhibiting wide and rapid rates of change. Plants which exhibit load characteristics of this type are those with mixed, continuous, and batch processing demands. It is also recommended where normal load characteristics are fairly steady; but upsets can be sudden, unpredictable and/or a significant portion of the load.

2.2 Working of Three Element Drum Level Control System:

The Three Element Drum Level Control System is a commonly used method for maintaining the desired water level in a boiler drum. It consists of three main components: the level transmitter, the flow transmitter, and the controller. Here's an overview of how the system works:

1. **Level Transmitter:**

The level transmitter continuously measures the water level in the boiler drum. It can be a differential pressure transmitter or any other suitable level sensing device. The transmitter converts the level measurement into an electrical signal and sends it to the controller.

2. **Flow Transmitter:**

The flow transmitter measures the feedwater flow rate entering the boiler drum. It monitors the rate at which water is being added to the drum. This flow rate information is also converted into an electrical signal and sent to the controller.

3. **Controller:**

The controller is responsible for analyzing the signals received from the level and flow transmitters. It compares the actual water level with the desired setpoint level and calculates the required control action.

Operation:

The Three Element Drum Level Control System operates as follows:

1. **Measurement:**

The level transmitter continuously measures the water level in the drum, while the flow transmitter measures the feedwater flow rate.

2. **Comparison:**

The controller compares the actual water level with the desired setpoint level. It calculates the level deviation (difference between actual and setpoint levels) and the rate of change of the level (based on the flow rate).

3. **Control Action:**

The controller determines the required control action to maintain the desired water level. It adjusts the control valve position that regulates the flow of feedwater into the boiler drum. The control valve opens or closes to increase or decrease the water flow rate accordingly.

4. **Feedback:**

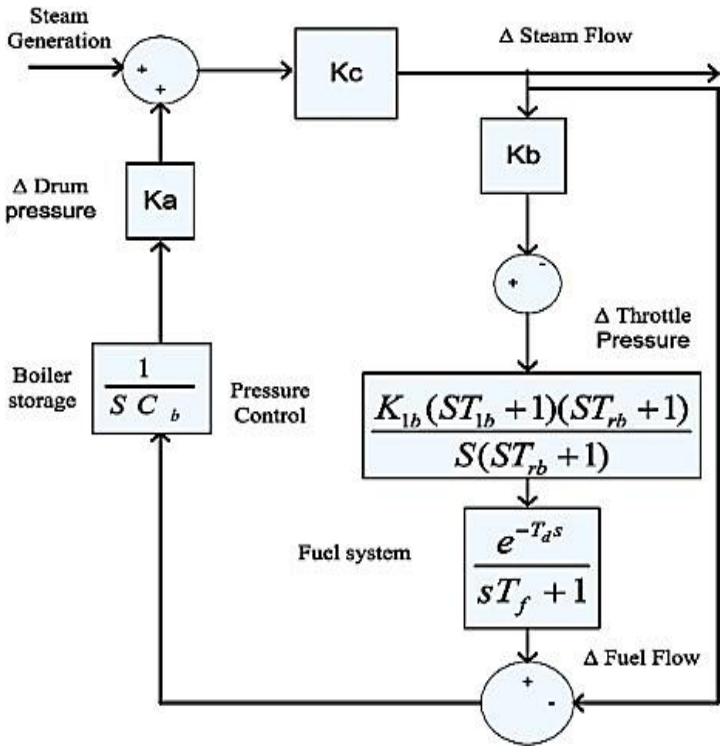
As the control valve adjusts the flow rate, the level transmitter continuously provides feedback on the actual water level. This feedback allows the controller to make further adjustments to maintain the desired level.

5. Cascade Control:

The Three Element Drum Level Control System also employs a cascade control strategy. In addition to controlling the water flow rate, it takes into account the steam flow rate. If the steam flow rate increases, indicating higher demand, the controller adjusts the feedwater flow rate accordingly to maintain the desired water level.

By continuously monitoring the water level, flow rate, and steam demand, the Three Element Drum Level Control System ensures precise control of the boiler drum level. It helps prevent issues like drum overfilling or low water level, which can lead to equipment damage or safety hazards.

2.3 Transfer Function:



2.4 Controls:

2.4.1 Steam Flow Control:

Steam flow control ensures that the boiler produces an appropriate amount of steam to meet the demand while maintaining stable and efficient operation. To achieve this, the steam flow control system typically employs the following components:

- **Steam Flow Sensor:**

Measures the rate of steam flow leaving the boiler.

- **Control Valve:**

Regulates the steam flow by adjusting the opening of the control valve in response to the steam flow sensor's feedback.

- **Control Algorithm:**

The control algorithm compares the measured steam flow with the desired setpoint and adjusts the control valve accordingly to maintain the desired steam flow rate.

2.4.2 Water Flow Control:

Water flow control is responsible for maintaining a consistent water supply to the boiler, ensuring proper steam generation. The water flow control system incorporates the following elements:

- **Water Flow Sensor:**

Measures the rate of water flow entering the boiler.

- **Water Inlet Valve:**

Regulates the water flow by adjusting the opening of the water inlet valve based on feedback from the water flow sensor.

- **Control Algorithm:**

The control algorithm compares the measured water flow with the desired setpoint and adjusts the water inlet valve to match the steam demand.

2.4.3 Drum Level Control:

Drum level control ensures the water level within the boiler drum remains within a safe and optimal range. Proper drum level control is crucial for preventing situations like low water level (dry running) or high water level (overflowing). The drum level control system includes the following components:

- **Drum Level Sensor:**

Monitors the water level in the boiler drum. Various types of level sensors, such as differential pressure transmitters, capacitance probes, or conductivity probes, can be used.

- **Control Valves:**

Control valves are utilized to regulate the water flow into the drum and the steam release to adjust the water level as needed.

- **Control Algorithm:**

The control algorithm compares the measured drum level with the desired setpoint and adjusts the control valves to maintain the water level within the specified range.

2.4.4 Temperature Control:

Temperature control is vital for maintaining the desired temperature within the boiler. It involves the following components:

- **Temperature Sensor:**

Measures the temperature of the water or steam within the boiler. Sensors such as thermocouples, resistance temperature detectors (RTDs), or thermistors are commonly used.

- **Control Algorithm:**

The control algorithm compares the measured temperature with the desired setpoint and adjusts the boiler's operation to maintain the desired temperature. It may modulate fuel and air inputs, water flow, or steam release to achieve the target temperature.

2.4.5 Pressure Control:

Pressure control ensures that the pressure within the boiler is maintained within safe and optimal limits. It involves the following components:

- **Pressure Sensor:**

Measures the pressure inside the boiler. Pressure sensors can be based on technologies such as strain gauges, piezoelectric elements, or capacitive sensors.

- **Pressure Relief Valve:**

Acts as a safety device to release excess pressure from the boiler when it exceeds a specified limit, preventing overpressure situations.

- **Control Algorithm:**

The control algorithm continuously monitors the pressure sensor readings and adjusts the boiler's operation, such as fuel and air inputs or steam release, to maintain the desired pressure range.

2.4.6 Level Control:

Level control ensures the proper water level within the boiler, preventing dry running or overflowing. It involves the following components:

- **Level Sensor:**

Measures the water level in the boiler. Various types of level sensors, including differential pressure transmitters, capacitance probes, conductivity probes, or float and displacer switches, can be used.

- **Control Valves:**

Control valves regulate the water flow into the boiler drum and the steam release to adjust the water level as required.

- **Control Algorithm:**

The control algorithm compares the measured water level with the desired setpoint and adjusts the control valves to maintain the water level within the specified range.

3. Specifications :

3.1 Comparison between different sensors

3.1.1 Pressure Sensor:

- **Hydraulic Pressure Sensor HC-Y810 in Pakistan:**

Price: 7,500 Rs – 9,500 Rs

Specifications:

- **Pressure Range**: 0-10 MPa
- **Output Signal**: Typically 4-20mA, 0-5V, or 0-10V DC
- **Accuracy**: ±0.5% to ±1% of full-scale range
- **Operating Temperature**: -20°C to 80°C or -40°C to 125°C
- **Pressure Connection**: Typically threaded or flanged
- **Material**: Stainless steel or corrosion-resistant material
- **Protection**: IP65, IP67, or IP68

- **Vacuum Pressure Sensor MPS-33:**

Price: 2500 Rs – 3500 Rs

Specifications:

Description	Unit	MPS-V33	MPS-P33	MPS-R33	MPS-C33
Fluid		Air (non corrosive, nonflammable gas)			
Diaphragm		Silicon diaphragm *1)			
Pressure range	kPa	-101.0 ~ 0kPa	-0.1 ~ 1MPa	-101 ~ 500kPa	-100.0 ~ 100kPa
Proof pressure	MPa	0.3	1.5	0.8	0.3
Operating ambient temperature	℃	0 ~ 50			
Operating humidity	%	35 ~ 85 RH(without condensation)			
Port size		Rc1/8(female), NPT1/8(female), G1/8(female)			
Power supply	V	DC12 ~ 24 ± 10%, Ripple(Vp-p) less than10%			
Power consumption	mA	less than 55			

3.1.2 Level Sensor:

- **Capacitive Level Sensor:**

Price: 6000 Rs-45000Rs

Specifications:

Technology	capacitive
Medium	for water, for oil
Applications	for storage tanks
Other characteristics	submersible, with digital display, with temperature measurement
Level range	Min.: 25 mm (0.98 in) Max.: 636 mm (25.04 in)
Process pressure	0.5 bar (7.25 psi)
Process temperature	Min.: 0 °C (32 °F) Max.: 70 °C (158 °F)

- **Boiler water level sensing probe:**

Price: 2000Rs - 2100Rs

Specifications:

Fitting size	**M14,G1/2,G3/4,M16 ,1"(customized)**
Connector material	**Bronze, sus304/316**
Rod probe size	**≤1000mm (customized)**
Probe material	**Sus304/316**
Insulation material	**PTFE / Ceramics**
Working voltage	**220~380 V AC**
Working pressure	**≤ 2.5M pa**
Working temperature	**250℃**
Fit for	**Boiler ,coffee machine etc**

3.1.3 Temperature Sensor:

- **K Type Thermocouple:**

Price: 1,850Rs – 2000Rs

Specifications:

Thermocouple: K type
Measuring temperature: -58°F-2372°F (-50°C-1300°C)
Wire diameter: 3.2mm
Total length: 215mm / 8.5 inch
Insulation length: 162 mm / 6.3 inch
Tube shape: 6 Pcs x 1 inch ceramic tube
Insulator: double hole insulator

- **Boiler Temperature Sensor:**

Price: 2000Rs – 3000 Rs

Specifications:

- Resistance @25°C: 1.0 k Ω to 100 k Ω
- Resistance accuracy: ± 0.5% - 2.0%
- Beta value: 2500 k to 5000 k
- TR 25/85°C - water: 2 .0-5.0 seconds
- Thread size: M4 TO M14
- Operating temperature: -40°C to +105°C
- Body material: SS, BRASS, AL …etc

3.2 Comparison between sensors of different companies

3.2.1 Pressure Sensor: MPS-33At

misumi-ec.com:

At comoso.com:

Specifications

	Vacuum (V)	Compound (R)	Positive (P)
Pressure range	-101.3 - 0 kPa (-14.5 to 0 PSI)	0 - 500 kPa (0 to 72 PSI)	-0.1 - 1 Mpa (0 to 145 PSI)
Proof pressure	0.3 Mpa (44 PSI)	0.8 Mpa (116 PSI)	1.5 Mpa (218 PSI)
Display resolution, Units of measure	0.1, kPa 0.001, kgf/cm² 0.001, bar 0.01, PSI 0.1, inHg 1, mmHg 0.1, mmH_2O	1, kPa 0.01, kgf/cm² 0.01, bar 0.1, PSI – – –	0.001, Mpa 0.01, kgf/cm² 0.01, bar 0.1, PSI – – –
Media	Air & non-corrosive gases, incombustible gases		
Pressure port	**(N)** 1/8" NPSF, **(G)** 1/8" BSPP female		
Operating temperature	32 to 122°F (0 to 50°C)		
Storage temperature	-4 to 140°F (-20 to 60°C)		
Humidity	40 - 85% RH (no condensation)		
Electrical connection	**(G)** Grommet open lead, 5 wire (0.15mm²)		
Power supply	12 to 24VDC ±10% or less, Ripple (Vp-p) 10% or less		

3.2.2 Capacitive Level Sensor:

At directindustry.com:

CHARACTERISTICS

Technology	capacitive
Medium	for water, for oil
Applications	for storage tanks
Other characteristics	submersible, with digital display, with temperature measurement
Level range	Min.: 25 mm (0.98 in) Max.: 636 mm (25.04 in)
Process pressure	0.5 bar (7.25 psi)
Process temperature	Min.: 0 °C (32 °F) Max.: 70 °C (158 °F)

At gemssensors.com:

3.2.3 Temperature Sensor: K type Thermocouple:

At hallroadlahore.pk:

Specifications:

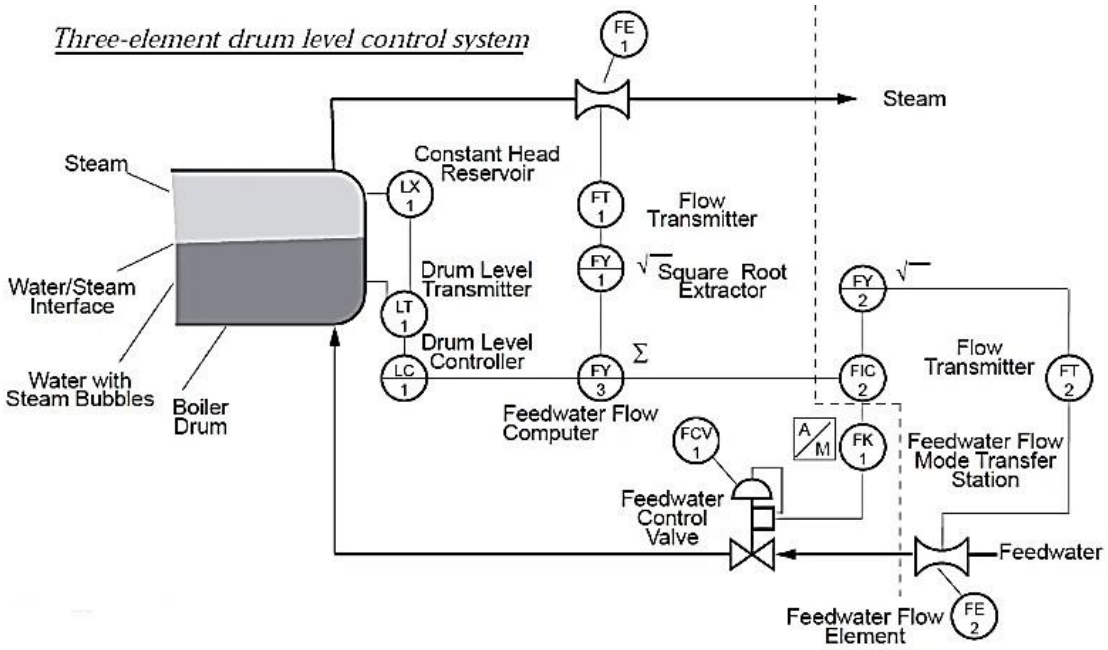
- Brand new and high quality.
- Type K Type.
- Temperature Range:0-600C
- Internal Insulation:Fibreglass.
- Thread Diameter:6mm / 0.23.
- External Shielding:Metal Shield.
- Total Length:1M / 39.
- Fork Terminal Spacing: 3.5mm / 0.13.

At daraz.pk:

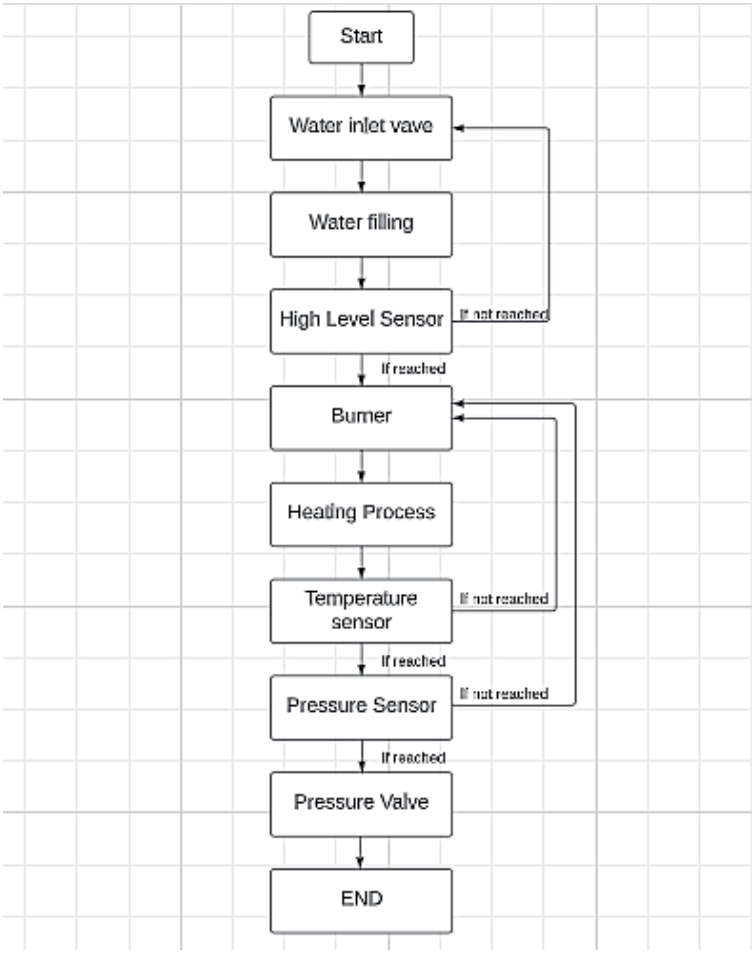
Specifications:

Thermocouple: K type
Measuring temperature: -58°F-2372°F (-50°C-1300°C)
Wire diameter: 3.2mm
Total length: 215mm / 8.5 inch
Insulation length: 162 mm / 6.3 inch
Tube shape: 6 Pcs x 1 inch ceramic tube
Insulator: double hole insulator

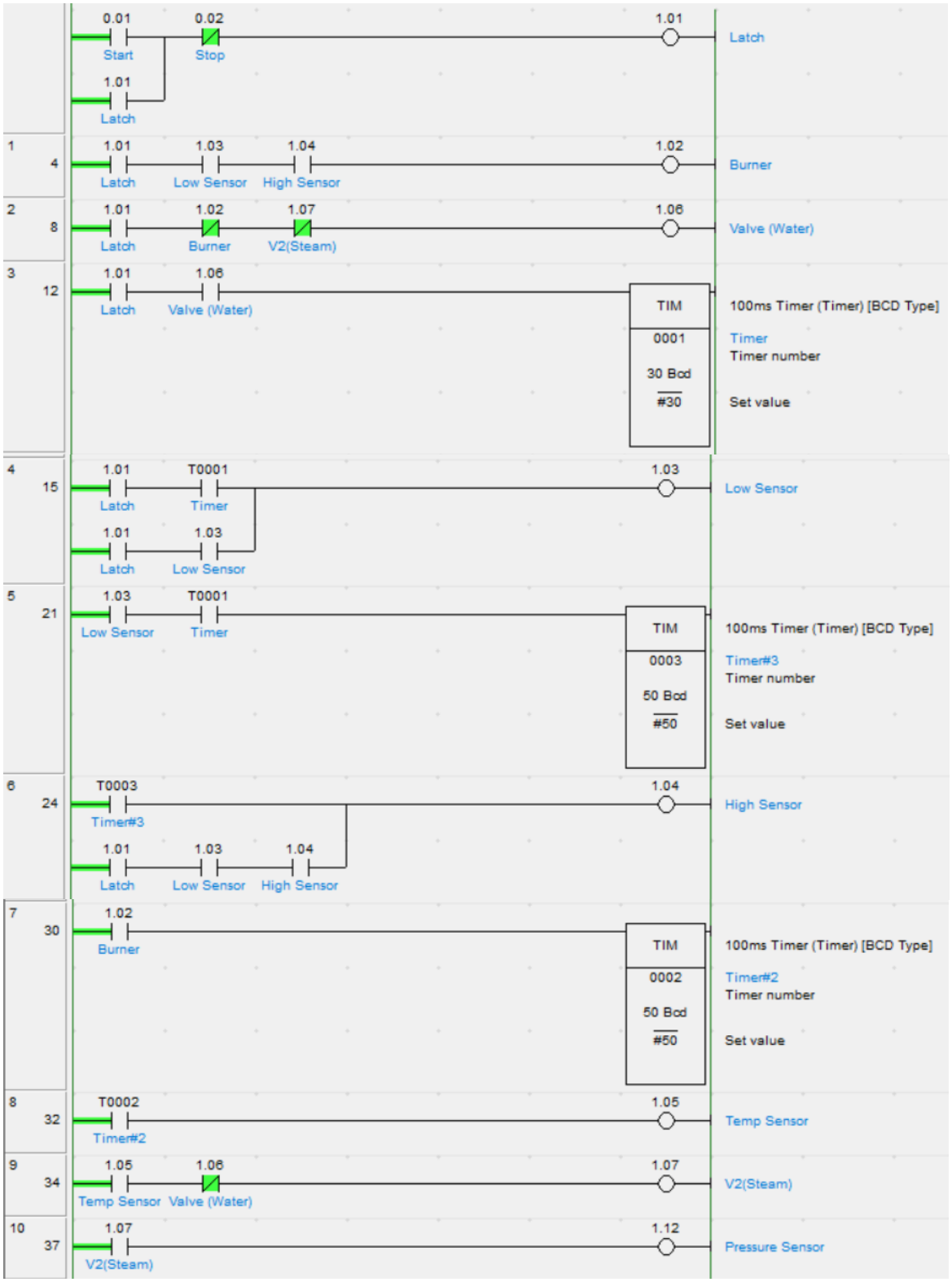
4. P & I Diagram:

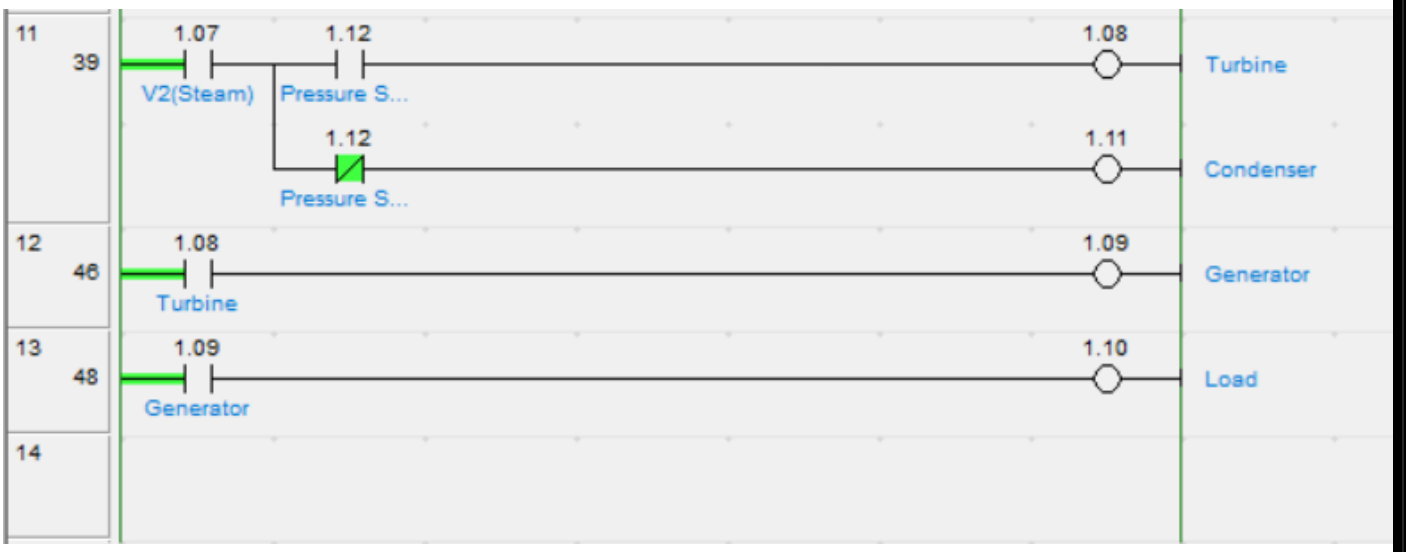


5. Flow Chart:

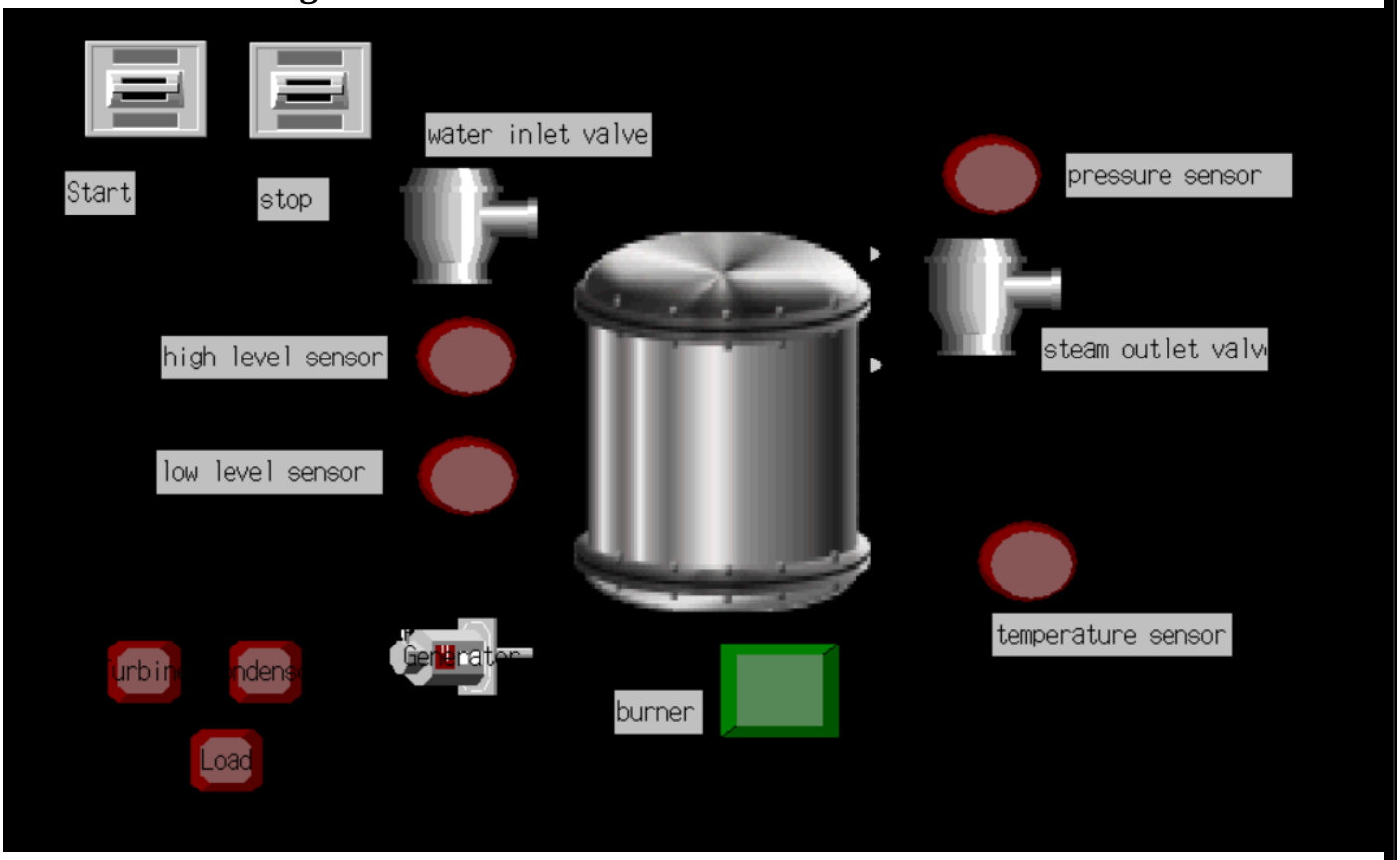


6. CX Programmer:




11
39
1.07
V2(Steam)
1.12
Pressure S...
1.08
Turbine
1.12
Pressure S...
1.11
Condenser
12
46
1.08
Turbine
1.09
Generator
13
48
1.09
Generator
1.10
Load
14

7. CX Designer:

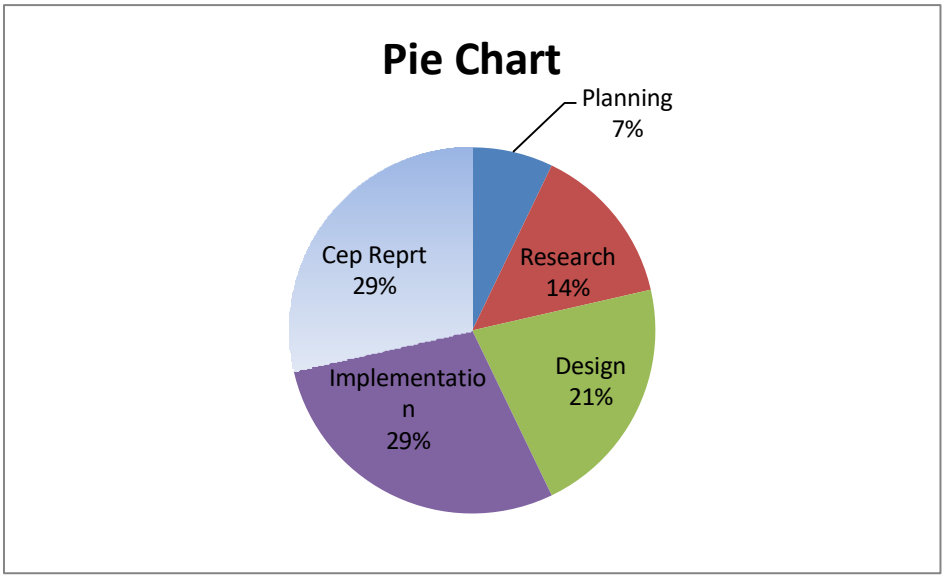


8. Gantt Chart & Pie Chart:

- **Gantt Chart:**

Activity	Week 1	Week 2	Week 3	Week 4
Planning				
Research				
Design				
Implementation				
CEP Report				
Submission				

- **Pie Chart:**



9. Conclusion:

A boiler automation system is essential for controlling steam flow, water flow, and drum level in a boiler. It utilizes sensors and actuators to monitor and adjust these parameters, ensuring safety, efficiency, and cost-effectiveness. By automating the process, the system reduces manual intervention, minimizes human error, and provides real-time monitoring and alarm capabilities. Overall, a well-implemented automation system improves boiler operation, extends equipment lifespan, enhances energy efficiency, and increases productivity in different industries.