Thermal Engineering Laboratory Manual
(UMCH0332)

Second Year – III Semester
(Under Graduate Programme)

Department of Mechanical Engineering

Kolhapur Institute of Technology's
COLLEGE OF ENGINEERING, KOLHAPUR
(Autonomous Institute)
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Expt. No.	Name of Experiment	Page No.	Date	Evaluation Marks			Total Marks out of 10	Faculty Signature
				Neatness (3)	Timely Submission (3)	Understanding (4)		
1	Test on Carbon Residue Apparatus							
2	Determination of Flash and Fire Point of Lubricating Oil							
3	Test on Dropping point Apparatus							
4	Test on Aniline Point Apparatus							
5	Study and Demonstration of Steam condensers							
6	Study and Demonstration of Steam Boilers							
7	Study and Demonstration of Boiler mounting and Accessories							
8	Study and Demonstration of Calorimeters							
9	Trial on Reciprocating Compressor Test Rig.							
10	Industrial visit to Steam Power Plant							
						Total Marks out of 100		
						Final ISE Marks out of 25		

CERTIFICATE

***This is to Certify that Mr./Ms*____**

***Class Roll No*___________ *of S.Y.B.Tech – Mechanical Engineering, Division:*_______*has completed satisfactorily Laboratory Course in* "THERMAL ENGINEERING" *(UMCH0332) of Semester* III *during Academic Year 20*____*/20*____.**

PRN No.:-________________________

Department Stamp

Faculty Incharge
Name & Sign.

Head of the Department
Signature

THERMAL ENGINEERING PRACTICAL/ORAL EXAMINATION

Instructions to all students:

**** You should wear simple Formal Dress. (No T-shirts, Jeans etc,.)***

**** You should wear Academic College ID Card .***

**** You should carry pen, pencil, eraser, calculator, stapler to the exam; Sharing is not allowed.***

**** You should carry ID card, pen ,pencil, calculator to oral room without fail.***

**** You should answer all oral questions in English language only.***

**** You should not prompt your friend while answering the questions and raise your hand and take prior permission if you want to answer in between.***

Common Oral Questions for all Experiments:

- Explain the experimental setup with the sketch included in journal. *(See that the sketch included in journal should not have any mistakes for which you can verify the same by actually seeing the setup in the lab.)*
- Explain the procedure for the experiment conducted.*(Any mistake in the procedure will attract many questions right from fundamentals of the topic)*
- Questions related to the SI units of the parameter observed ,measured and calculated in the observation table. *(Any mistake in the answer to this question will deduct more marks)*
- *What are the SI units of the* observed ,measured and calculated values? *(See that you have written the correct units wherever required)*
- What are specifications of the setup?
- What measuring instruments are used for the setup? and why?
- What are the precautions you should take during the experiments?

Title of the Course: Thermal Engineering Lab Course Code:	L	T		P	Credit
	0	0		2	1

Course Pre-Requisite: Basic Mechanical Engineering, Physics

Course Description: Basic Concepts in Thermodynamics, Working of Steam generator and Condenser, Working Principle of Reciprocating compressor, Working Principle of Gas Turbine

Course Objectives:

1. To Understand types and working of Steam Boilers and steam condensers.
2. To Demonstrate working of Steam calorimeters.
3. To Determine Thermo physical properties of Lubricating oil and Grease
4. To estimate efficiency of Reciprocating Compressor

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	Bloom's Cognitive	
		level	Descriptor
CO1	Explain fundamental knowledge of Thermodynamics	II	Understanding
CO2	Compare different Thermodynamics Systems	II	Understanding
CO3	Make use of Mollier chart and Steam Table	V	Evaluating
CO4	Analyze performance parameters of Thermodynamic systems	V	Evaluating

CO-PO Mapping:

CO	PO1	PO2	PO3	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3												2			
CO2	3												2			
CO3	3		2										2			
CO4		2	3										2			

Assessments :

Teacher Assessment:

One component of In Semester Evaluation (ISE) and one End Semester Examination (ESE) having 50%, and 50% weights respectively.

Assessment	Marks
ISE	50
ESE	50

ISE are based on practical performed/ Quiz/ Mini-Project assigned/ Presentation/ Group Discussion/ Internal oral etc.

ESE: Assessment is based on oral examination

Course Contents:

Experiment No. 1:--- Test On Carbon Residue Apparatus **Aim and Objectives:** To determine the percentages of carbon residue after evaporation of oil.	CO4	2 Hrs
Experiment No. 2:--- Determination of Flash and Fire Point of Lubricating Oil **Aim and Objectives:** Determination of flash and fire point of given lubricating oil.	CO4	2 Hrs
Experiment No. 3:--- Test on Dropping point apparatus **Aim and Objectives:** To determine the dropping point of lubricating grease	CO4	2 Hrs.
Experiment No. 4:--- Test on Aniline Point apparatus Aim and Objectives: To determine the aniline point of given lubricating oil.	CO4	2 Hrs.
Experiment No. 5:--- Study and demonstration of Steam condensers **Aim and Objectives:** To Classify and explain working of Steam Condenser and calculation of performance parameters of condenser. **Outcomes:** Students are able to Classify and explain working of various steam Condenser and determine performance parameters.	CO2	2 Hrs.
Experiment No. 6:--- Study and Demonstration of Steam Boilers **Aim and Objectives:** To Classify and explain working of Steam Boilers **Outcomes:** Students are able to Classify and explain working of various Steam Boilers	CO2	2 Hrs.
Experiment No. 7:--- Study and demonstration of Boiler mounting and Accessories **Aim and Objectives:** To Classify and explain working of Boilers Mounting and accessories **Outcomes:** Students are able to Classify and explain working of various Boilers mountings and accessories	CO1	2 Hrs
Experiment No. 8:--- Study and demonstration of calorimeters **Aim and Objectives:** To Classify and explain working of Steam Calorimeter **Outcomes:** Students are able to Classify and explain working of various steam Calorimeter	CO3	2 **Hrs.**
Experiment No. 9:--- Trial on Reciprocating Compressor **Aim and Objectives:** To determine thermal and volumetric efficiency of reciprocating compressor. **Outcomes:** Students are able to determine thermal and volumetric efficiency of Reciprocating Compressors	CO4	2 **Hrs.**
Experiment No. 10:--- Industrial visit to steam power plant. **Aim and Objectives:** To Classify and explain working of Steam Boilers, mounting and accessories **Outcomes:** Students are able to Classify and explain working of various steam Boilers, mounting and accessories.	CO1	2 **Hrs.**

Textbooks:

1.Thermodynamics: An Engineering Approach, 3rd Edition, Yunus Çengel and Michael, Boles, Tata McGraw Hill.

2.Basic and Applied Thermodynamics, 2nd Edition, Nag P. K., Tata McGraw-Hill.

References:

1.Fundamentals of Thermodynamics, 5th Edition, Richard E. Songtag, Claus Borgnakke and Gordon J. Van Wylen, John Wiley and Sons, Inc.

2. Thermodynamics, 4th Edition, J.P. Holman, McGraw-Hill.

3. Engineering Thermodynamics, 2nd Edition, Jones J.B. and Hawkins G.A., John Wyley and Sons.

4. Fundamentals of Engineering Thermodynamics, Moran M.S. and Shapiro H.N., John Wyley and Sons, 1988.

5. Thermodynamics, 5th Edition, K. Wark, McGraw-Hill.

Experiment wise Measurable students Learning Outcomes :- At the end of each experiment the students will be able to

1. **Determine Percentage of Carbon Residue in Lubricating Oil.**
2. **Determine Flash and Fire point of Lubricating oil**
3. **Determine Dropping point of Lubricating oil**
4. **Determine Aniline point of Lubricating oil**
5. **Demonstrate working of Steam Condensers**
6. **Demonstrate working of Steam Boilers**
7. **Demonstrate working of Boiler mountings and accessories.**
8. **Demonstrate working of Steam Calorimeter**
9. **Determine Efficiency of Reciprocating Compressor.**

Mr. Amit R. Kopardekar	**Prof. Sangram S. Shinde**	
Technical Lab. Assistant	Laboratory Incharge	Head,
Thermal Engineering Lab.	Thermal Engineering Lab.	Dept. of Mechanical Engineering

Thermal Engineering Laboratory Manual

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KOLHAPUR INSTITUTE OF TECHNOLOGY'S
COLLEGE OF ENGINEERING
(AUTONOMOUS),
KOLHAPUR

Experiment No. 01

Experiment on Carbon Residue Apparatus

Second Year - Bachelor of Technology
III Semester

Department of Mechanical Engineering

Experiment No. 01 **Date of Conduct** / /2

Experiment Name : Experiment on Carbon Residue Apparatus

AIM: To determine the percentages of carbon residue after evaporation of oil.

THEORY: Carbon residue term is used to designate the carbonaceous residue formed during evaporation & pyrolysis of petroleum product.

This residue is not entirely of carbon is but a coke which can further changed by residue is called carbon residue.

DESCRIPTION OF EQUIPMENTES:

1) Metal furnace: It is a metal cylindrical block having six projection of diameter that as of coking bulb & one at center for thermocouple.

2) Temp. Measuring instrument it is an electronic device, which measure temp. with help of thermocouple connected with a block.

3) Coking bulb: coking bulb is somewhat cylindrical in shape at upper side a narrow hole say capillary is provided.

PROCEDUER:

1) Firstly metal furnace is heated at temp.550 °c or above.

2) During heating prepare bulb with a sample.

3) Take 5 ml of sample injected is in bulb with help of injection.

4) Before filling with sample take empty weight & note as w1.

5**)** After filling with sample take weight of bulb & note as w2.

6) At 550 °c put it in projection in metal block.

7) Kept it inside for 20 minutes fuel will bulb out & carbon residue remains inside.

8) Cool it up to room temp. & Weight it & note as A1

9) By using formula % carbon residue = $\frac{A}{W}$ X 100 calculated %carbon residues.

, Where,

A = W1 – A1 (carbon residue in gms)

W = W1 – W2 (wt.of sample in gms)

[Note : Draw Setup or Experimental Diagram on Left side Page]

OBSERVATION & CALCULATIONS :-

Weight of empty bulb (w1) :- ---------------- gm

Weight of bulb with oil (w2): --------------------- gm

1) Weight of sample oil = w2 – w1
2) Weight of bulb with carbon residue (A1) = ------------- gm.

% Carbon residue: $$\frac{A1 - W1}{W2 - W1} \times 100$$

CONCLUSION:

Rams botlom carbon residue for given sample is -------------- %

QUESTIONS :

1. What is significance of carbon percentage in oil?

2. Which oil is used in this experiment?

3. What is effect of carbon on Automobile engine?

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KOLHAPUR INSTITUTE OF TECHNOLOGY'S COLLEGE OF ENGINEERING (AUTONOMOUS), KOLHAPUR

Experiment No. 02

Determination of Flash and Fire Point of Lubricating Oil

Second Year - Bachelor of Technology
III Semester

Department of Mechanical Engineering

Experiment No. 02 **Date of Conduct** / /2

Experiment Name : Flash and Fire Point of A Lubricating Oil

AIM : Determination of Flash and Fire Point of A Lubricating Oil

DESCRIPTION:

There is a test open type cup in which oil is taken for experiment. Arrangement is made for thermometer to measure the temp oil. A blowpipe is provided flame over the oil. To heat heating arrangement is provided.

PROCEDURE:

1) Oil is taken in to the open type cup & heated by means of heating arrangement with electric current.
2) As temperature up to below flash point lower the temperature for increasing temperature with slow rate.
3) Flame from blowpipe is kept moving over oil surfaces to get burned the oil vapor at temperature which flash o°c

THEORY:

1) Flash point is the temperature of oil at which the flame of oil is burnt for momentarily.
2) Fire point is the temperature of oil which the oil starts to burn continuously.
3) Cur it noted as flash point.
4) Still heating kept continuous until surface of oil is burned.
5) This temperature is noted as fire Point.

CONCLUSION:

For given sample,

1) Flash point = ____________________ º c

2) Fire point = ____________________ º c

Questions :

1. Write significance of Flash and Fire point?
2. Which oil is used in this experiment? Give specification
3. What is difference between Gear oil and Engine oil?
4. What is difference between oil used in Two wheeler and Heavy Vehicles.
5. How SAE No is assigned to Engine Oil.

[Note : Draw Setup or Experimental Diagram on Left side Page]

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Experiment No. 03

Test on Dropping Point Apparatus

Second Year - Bachelor of Technology
III Semester

Department of Mechanical Engineering

Experiment No. 03 **Date of Conduct** / /2

Experiment Name : **Test on Dropping Point Apparatus**

AIM: To Determine the Dropping Point of Lubricating Grease.

THEORY: The dropping point the temperature at that the grease paas a semisolid to liquid state under the condition of the test.

PRESCRIPTION OF EQUIPENT:

1) There is a heater closed in a box & coils are heated by means of electric current.
2) Grease cup in which grease whole dropping point has to measure is place in test tube.
3) Oil with b.p move than grease placed in flats in which thermometer & test tube are inserted.
4) For stirring purpose of oil electro-mechanical stirring is used.

PROCEDURE:

1) Kept the cup filled with grease in test tube & with thermometer whole bulb is 3mm above from grease level.
2) Test tube is then in serried in oil bath which is kept on heating arrangement & with stirrer.
3) Stirrer the oil bath providing electric current.
4) Same instance bath is heated at a cont. Temp.
5) Reduce temperature below the expected dropping point so we can get exact temp.
6) When temperature is reach to dropping point grease melts & liquid falls in a vessel from hole provided at bottom of cup.
7) Note the temperature as dropping point of grease.

CONCLUSION:

The dropping point obtained for given sample of grease is ------------- **°c**

QUESTIONS :

1. Which type of grease is used in this experiment?
2. Give application of Grease?
3. How the grease is manufactured?
4. What is specification of grease?

[Note : Draw Setup or Experimental Diagram on Left side Page]

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KOLHAPUR INSTITUTE OF TECHNOLOGY'S
COLLEGE OF ENGINEERING (AUTONOMOUS), KOLHAPUR

Experiment No. 04

Experiment on Aniline Point Apparatus

Second Year - Bachelor of Technology
III Semester

Department of Mechanical Engineering

Experiment No. 04 **Date of Conduct** / /2

Experiment Name : Experiment on Aniline Point Apparatus

AIM: To determine the aniline point of given lubricating oil.

THEORY: Aniline point is the temp at which the aniline & sample forms separated layers. Firstly during heating it becomes homogenous mixture and a cooling it gets separated at particular temp. & It is called as aniline point.

DESCRIPTION:

1) Test tube & cork: - test tube of 25mm diameter & 150mm length in which thermometer is fitted with help of cork.
2) Jacket: - it is glass flask with scale on at bottom ring shape is made to still the oil.
3) Stirrer: - it is of metal rod & at bottom ring shape is made to still the oil.
4) Thermometer: - Pipette, which is used to take aniline required.
5) Heating and cooling bath.

PROCEDURE:

1) Clean & dry the apparatus thoroughly.
2) Pipette 5ml of the dried sample & 5ml of aniline into the test tube.
3) Assemble the cork: stirrer & thermometer so that the bottom of thermometer bulb is 5mm is from the bottom of test tube & and central with respect to ring of stirrer.
4) Test tube should be approximate 20mm above the bottom of jacket.
5) Still the mixture rapidly.
6) These two sample heat at room with heating bath until complete miscibility is obtained.
7) Remove bath & allow cooling in cooling bath.
8) Note the aniline point at which the mixture becomes so cloudy as to observe the thermometer bulb by reflected light.

SPECIFICATION & SAMPLE USED FOR EXPERIMENT :

1) Liquid Paraffin : Colorless & Heavy
Weight per ml at 20^0C = 0.860 to 0.890 gm
Kinematic Viscosity at 37.8^0C = min. 64cS
Melting point :-24 °C
Boiling point :300 °C
Density 0.85 g/mL at 20 °C
Refractive index n20/D 1.467(lit.)
Flash point:>300°C

Liquid paraffin, also known as paraffinum liquidum, is a very highly refined mineral oil used in cosmetics and for medical purposes

[Note : Draw Setup or Experimental Diagram on Left side Page]

Solubility : Practically insoluble in ethanol (95%), glycerin, and water; soluble in acetone, benzene, chloroform, carbon disulfide, ether, and petroleum ether. Miscible with volatile oils and fixed oils, with the exception of castor oil.

2) Liquid Aniline : Molecular Formula =**C_6H_7N or $C_6H_5NH_2$**
Molecular Weight = 93.13
Weight per ml at 20^0C = 1.020 to 1.025 gm

Aniline is a clear to slightly yellow liquid with a characteristic odor. It does not readily evaporate at room temperature. Aniline is slightly soluble in water and mixes readily with most organic solvents. Aniline is used to make a wide variety of products such as polyurethane foam, agricultural chemicals, synthetic dyes, antioxidants, stabilizers for the rubber industry, herbicides, varnishes and explosives.

Aniline, phenylamine or aminobenzene is an organic compound with the formula C6H5NH2. Consisting of an amine attached to a benzene ring, aniline is the prototypical aromatic amine. Being a precursor to many industrial chemicals, its main use is in the manufacture of precursors to polyurethane. Like most volatile amines, it possesses the somewhat unpleasant odour of rotten fish. Aniline is colorless, but it slowly oxidizes and resinifies in air, giving a red-brown tint to aged samples.

3) Lubricating Oil : SAE 15W-30 **OR** SAE 20 w 40 / 50

Lubricating oil creates a separating film between surfaces of adjacent moving parts to minimize direct contact between them, decreasing heat caused by friction and reducing wear, thus protecting the engine.

The ***Society of Automotive Engineers*** (SAE) has established a numerical code system for grading motor oils according to their viscosity characteristics. The original viscosity grades were all mono-grades, e.g. a typical engine oil was a SAE 30. This is because as all oils thin when heated, so to get the right film thickness at operating temperatures oil manufacturers needed to start with a thick oil. This meant that in cold weather it would be difficult to start the engine as the oil was too thick to crank. However, oil additive technology was introduced that allowed oils to thin more slowly (i.e. to retain a higher viscosity index); this allowed selection of a thinner oil to start with, e.g. "SAE 15W-30", a product that acts like an SAE 15 at cold temperatures (15W for winter) and like an SAE 30 at 100 °C (212 °F).

Therefore, there is one set which measures cold temperature performance (0W, 5W, 10W, 15W and 20W). The second set of measurements is for high temperature performance (8, 12, 16, 20, 30, 40, 50). The document SAE J300 defines the viscometrics related to these grades.

CONCLUSION:

Sample Reading 01= Aniline Point of given sample of oil is --------------------------

Sample Reading 02= Aniline Point of given sample of oil is --------------------------

QUESTIONS

1. What is Aniline Point?
2. What is significance of Aniline point?
3. Why aniline oil is used in this experiment
4. What is effect of aromatic compounds on aniline point?
5. Which oil is used in this experiment give specification?

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KOLHAPUR INSTITUTE OF TECHNOLOGY'S COLLEGE OF ENGINEERING (AUTONOMOUS), KOLHAPUR

Experiment No. 05

Study and Demonstration of Steam Condensers

Second Year - Bachelor of Technology
III Semester

Department of Mechanical Engineering

Experiment No. 05 **Date of Conduct** / /2

Name of Experiment : Study and Demonstration of Steam Condensers

Aim: - Study and demonstration of Steam condensers

Objectives: -

1) Define condensers & cooling towers.
2) Different types of condensers & cooling towers.
3) Neat sketches of condensers & cooling towers.

Theory: -

The steam condensing plant mainly consists of following elements.

1) Condensers in which condensation of exhaust steams take place.
2) Supply of cooling water from cooling tower or cooling plant.
3) A pump for circulating cooling water.
4) Wet air pump or dry air pump, which is required for extracting the non-condensable gases.
5) Extraction pump for removing condensate from condenser.
6) Hot well where condensate can be discharge.

Introduction: -

A steam condenser is a closed vessel in to which the steam is exhausted & condensed after doing work in an engine cylinder or turbine. A steam condenser has following objects.

(1) The primary object is to maintain a low pressure (below the atmospheric pressure) so as to obtain the maximum possible energy from steam & thus to secure a high efficiency.

(2) The secondary object is to supply pure feed water to the hot well from where it is pumped back to the boiler.

Classification of Condensers: -

Condensers are generally classified under two groups.

(1) Jet condenser or mixing classified under two groups.

(2) Surface condenser or non- mixing type condenser.

JET CONDENSERS: -

Jet condenser is used at the place where water of good quality is easily available in sufficient quality

☞ **TYPES OF JET CONDENSERS: -**

☞ **(1) Parallel flow condenser: -**

In parallel flow jet condenser, both the steam & water enter at the top & the mixture is removed from the bottom. Parallel flow jet condenser is as shown in fig. The exhaust steam is condensed when it mix up with water the condensate, cooling water & air flow down ward & are removed by two separate pumps is called as air pump & condensate. The condensate pump delivers the condensate to the cooling water tank through an over flow pipe.

☞ **(2) Counter flow jet condenser: -**

In counter flow or low level jet condenser, the exhaust steam enters at the bottom, flows upward and meet the down coming cooling water

The vacuum is created by the air pump, placed at the top of the condenser shell the falling at the top of the condenser shell the falling water is caught in the trays from which it escapes in a second series

[Note : Draw Setup or Experimental Diagram on Left side Page]

of the jet & meet the exhaust steam entering at the bottom. The condensation occur, & and the condensate & cooling water descended through a vertical pipe to the condensate pump, which delivers it to the lot well.

☞ **(3) Barometric or High Level Jet Condenser: -**

These condensers are provided at a high level with a long vertical discharge pipe as shown in fig.
In this exhaust steam enter at the bottom flow up ward & meet the dowencoming cooling water in the same way as that of low level jet condenser. The vacuum is created by the air pump placed at the top of the condenser shell. The condensate and cooling water descends through a vertical pipe to the lot well without the aid of any pump the surplus water from the lot well flows to the cooling water tank through. An over flow pipe.

☞ **(4) Ejector Type Condenser: -**

In this condenser steam & water mix up whiling passing through series of metal contains water enter at the top through number of guide contain the exhaust steam enter the condenser through non-return valve arrangement. The lollow truncated contain the condensate & cooling water is the discharge to the lot well as shown in fig.

Surface Condenser: -

In the surface condenser has a great advantages as condensate doesn't mix up with the cooling water continuously the whole condensate can be reused in the boiler
fig. Shown a longitudinal section of a two-pass surface. Condenser it consists of a horizontal cast iron cylindrical vessel packed with tubes. Through which the cooling water flows. The end of condenser are cut off by vertical perforated type plates into which water tubes are fixed, the water tube pass horizontally through the main condensing space for the steam. The steam enters at the top & is forced to flow downward over the tubes due to the section of the extraction pump at the bottom.
The cooling water flows in one direction through the lower half of the tube & return in opposite direction through the upper half.

☞ **(1) Down flow surface condenser : -**

In this surface condenser the exhaust steam enter at top & flow downward. Over the tubes due to the force of gravity as well as suction of the extraction pump fitted at the bottom and then pumped by the extraction pump.
As the steam flows perpendicular to the direction of flow of cooling water
(Inside the tube) this also called as cross-surface condenser.

☞ **(2) Central Flow Surface Condenser: -**

In this central flow surface condenser, the exhaust steam enters at the top end flow down words. The suction pipe of the air extraction pump is placed in the center of steam to flow radically inward over the directed radically inward by a volute casing around the hest.

☞ **(3) Regenerative surface condenser :-**

In refrigeration surface condenser, the condensate is heated by regeneration the method
The condensate after leaving the tubes is passed through the exhaust steam from the engine or turbine thus its temperature rises.

☞ **(4) Evaporative Condenser: -**

The steam to be condensate enters at the top of the series of the pipes out side of the which a top film of cold water is falling at the same time a current of the air circulates over the water cooling water film, original temp. is restore by the radiation of the requisite quantity of cold water.
The evaporative condensers are provided when the circulating water is to be used again & again. These condensers consists of shell of gilled piping which is behind backward & forward in a vertical plane as shown in fig.

[Note : Draw Setup or Experimental Diagram on Left side Page]

☞ DIFFERENCE BETWEEN JET CONDENSERS & SURFACE CONDENSERS

JET CONDENSERS		SURFACE CONDENSER	
1	Cooling water and steam are mixed up	**1**	Cooling water & Steam Are Not Mixed
2	Less suitable for high capacity	**2**	More suitable for high capacity
3	Condensate is wasted	**3**	Condensate is reused
4	maintenance cost is low	**4**	maintenance cost is high
5	More power is required for air pumps	**5**	Less power is required for air pump.
6	High power required for water pumping	**6**	Less power required for water pumping

☞COOLING TOWERS :-

When cooling water supply is limited there is a need to circulated the water through the condenser. Cooling tower is an artificial device used to cool the hot cooling water coming out of the cool the condenser more effective, cooling towers are designed to control the temperature of the cooling tower are designed as compact as possible

In power plants the hot water from condenser is cooled in cooling tower so that it can be reused in condenser for condensation of steam in the cooling tower water is made to trickle down drop by drop so that it comes in contact with the air moving in opposite direction as result of this some water is evaporator and is taken away with air.

☞ FACTOR AFFECTING COOLING OF WATER IN A COOLING TOWER ARE :-

1) Temp. of air
2) Humidity of air
3) Temp. of air
4) Size and weight of water
5) Velocity of air entering tower
6) Accessibility of air to all parts of tower.
7) Arrangement of plant in the tower.

☞TYPES OF COOLING TOWERS: -

These are classified according to the material of which these are made.

1) Timber tower
2) Steel duct type
3) Concrete (Ferro-concrete, mutt deck concrete hyperboloid)

☞1) <u>Timber tower:-</u>

These towers are rarely used due to the following disadvantages.

1) Due to exposure to sun, wind, water etc.. timber rotes easily.
2) Short life.
3) High maintenance charge.
4) The design generally does not facilitate proper circulation of air
5) Limited cooling capacity.

[Note : Draw Setup or Experimental Diagram on Left side Page]

☞**1) <u>Concrete Tower:-</u>** advantages of following cooling towers.

1) Large capacity, some times of the order of 5x 10^3 m^3/hr.
2) Improved after draft and air circulation.
3) Increased stability under air pressure.
4) Low maintenance.

☞**2) <u>Steel Duct Type: -</u>**

Capacity of steel duct type is small, so it is hot used in large power plants.

The cooling tower may also be classified as fallows: -

a) Natural draught cooling tower.
b) Induced drought cooling tower.

1) Forced draught cooling tower.
2) Induced draught cooling tower.

☞**A) <u>Natural Draught Cooling Tower.</u>**

In cooling tower draught is required for the evaporator of water sprayed in this type of cooling water from condenser is pumped in the top portion of the tower through & nozzles. Through spray the water fall in the from of droplets into a pond situated at the bottom of the tower the enter the cooling tower from air opening provided near the of falling water. A concrete hyperbolic tower is as shown below.

This tower has following advantages: -

1) Low operating & maintenance cost.
2) Trouble free operation.
3) Less space is required.
4) Height of the tower may be 125 m & diameter the is base 100m.

This tower has following Disadvantages: -

1) High cost.
2) GTS performance varies with the seasonal changes in DBT& R.H. of air.

<u>B) Mechanical Draught Cooling Tower :-</u>

In this cooling tower, the draught is produced mechanically by the means of propeller fan. It is similar to naturally draught tower as far as interior construction is concerned, but the side of tower are closed & form an air and opening at base for the input of fresh air and out let at the top . Fans are provided for forcing the air, in to this tower

<u>C) Induced Draught Cooling Tower: -</u>

This type of tower is as shown in fig. in this type the fans are placed at the top of the town and they draw air air in through louvers from the base of the tower.

Advantages :-

1) More efficient than induced draught
2) No problem of fan blade erosion because it handles only dry air
3) More safe

<u>QUESTIONS :</u>

1. Compare Low level and high Level condenser.
2. Give application of each condenser.
3. In surface condenser the vacuum maintained is 700 mm of Hg. The barometer reads 754 mm. If Temperature of condenser is 18^0 C, Determine 1. Mass of air per kg of steam 2. Vacuum efficiency.
4. The following data were obtained from the test of surface condenser . Condenser vacuum = 711 mm of hg , Hot well temperature =32^0 C, Inlet temperature of circulating water =12^0C, Outlet temperature of circulating water=28^0C, Barometer reading=770 mm of Hg, Calculate vacuum efficiency and Condenser efficiency.

Thermal Engineering Laboratory Manual

(UMCH0332)

KOLHAPUR INSTITUTE OF TECHNOLOGY'S
COLLEGE OF ENGINEERING
(AUTONOMOUS),
KOLHAPUR

Experiment No. 06

Study and Demonstration of Steam Boilers

Second Year - Bachelor of Technology
III Semester

Department of Mechanical Engineering

Experiment No. 06 **Date of Conduct** / /2

Name of Experiment : Study and Demonstration of Steam Boilers

Aim: - Study and Demonstration of Steam Boilers

Classifications of Boilers

A steam boiler is a closed vessel which generate steam by transferring heat produced by burning of fuel to water. The steam boiler produced is used for power generation or process heating .

Selection of Steam Boiler :

The selection of type & size of a steam generator depends on the following factors .

1. The power required & working pressure.
2. The geographical position of power house.
3. The fuel & water available.
4. The probable load factor.

The steam boilers are classified according to the following basic :

1. Flow of water & hot gases

a. Fire tube boiler
b. Water Tube boiler

2. Method of firing

a. Internally fired
b. Externally fired

3. Method of water circulation

a. Natural circulation
b. Forced circulation

4. Pressure developed

a. Low pressure boiler
b. High pressure boiler

5. Nature of service

a. Stationary boiler
b. Mobile boiler

6. Design of gas passage

a. Single phase
b. Multi phase

1) Simple Vertical Boiler

It is an internally fired, vertical, single, fire tube boiler. It consists of cylindrical shell, the greater of which is full of water (which surrounds the firebox also) and remaining is the steam space. At the bottom of the firebox is grate, on which the fuel is burnt and the ash from it falls in the ashpit. The firebox is provided with two cross tubes. This increases the heating surface and the circulation of water. The cross tubes are fitted inclined. This ensures efficient circulation of water. At the ends of each cross tube are provided the hand holes to give access for cleaning these tubes. The combustion gases after heating the water and thus converting it into steam escape to the atmosphere through the chimney. Manhole is provided to clean the interior of the boiler and exterior of the combustion chamber and chimney. The rate of production in such a boiler does not exceed 2500 Kg/hr. and pressure is normally limited to 7.5-10 bar.

[Note : Draw Setup or Experimental Diagram on Left side Page]

Applications: -

It produces steam at a low pressure and in small quantities therefore it is used for low power generation or at places where the space is limited.

2) Locomotive Boiler

It is a multi-tubular, horizontal, internally fired and mobile boiler. It consists of a cylindrical barrel with rectangular firebox at one end and a smoke box at the other end. The coal is introduced through the fire hole into the grate, which is placed at the bottom of the firebox. An arch of firebricks deflects the hot gases that are generated due to burning of the coal, so that the walls of the firebox may be heated properly. The firebox is entirely surrounded by water except for the fire hole and the ash pit that is situated below the firebox, which is fitted with dampers at its front and back ends. The dampers control the flow of air to the grate. The hot gases pass from the firebox to the smoke box through a series of fire tubes and then they are discharged into the atmosphere through the chimney. The fire tubes are placed inside the barrel. The superheater tubes are placed inside the fire tubes of larger diameter. The heat of the hot gases is transmitted into the water through the heating surface of the fire tubes. The steam generated is collected over the water surface.

The steam dome is fitted on the upper part of the barrel, from where the steam flows through the steam pipe into the chamber. The flow of steam is regulated by means of a regulator. From the chamber it passes through the superheater tubes and returns to the superheated steam chamber from which it is led to the cylinder through the pipes, one to each cylinder.

The draught here is produced by exhaust steam from the cylinder, which is discharged through the blast pipe to the chimney. When the locomotive is standing and no exhaust steam is available from the engine, fresh steam from the boiler is used for the purpose.

Applications : It is mainly employed in locomotives and may also be used as a stationary boiler. The principal feature of this boiler is to produce steam at a very high rate.

3) Lancashire Boiler :

A Lancashire boiler is a double fire tube boiler, internally fired, horizontal, natural draught, and natural circulation type of boiler. This boiler is very popular and reliable because of simplicity of design and ease of operation. The boiler has good steaming quality, and coal of inferior quality can be used. It has low maintenance and operating cost. This boiler is widely used in sugar mills and chemical industries. This boiler is used where large reservoir of water and steam are required.

Its main features and brickwork setting is shown in the figure. Several rings of steel plates we are either welded or riveted to make the cylindrical shell of suitable dimensions. This boiler has two parallel flue pipes throughout the length of boiler. Both the flue tubes, which carry hot gases, lay below the water level. To accommodate a grate of sufficient area and minimum length, these flue tubes are larger in diameter at the front of the shell. To control the gas flow and to control the amount of air entering the grate, dampers are used which are placed in path of flue gases.

Coal is fed to the grates through fire doors. Each of the flue tubes has its own furnace with grates where its combustion takes place and the flue gases rising from the furnaces pass over the fire bridge and traverse along the horizontal path. The hot gases leaving the grate pass up to the back end of the tubes and then travel back from the bottom flue passage to the front of boiler, where the gases bifurcate and pass into the two side flues. Thereafter, the gases in the two side flues enter the common flue and finally discharged to the atmosphere through chimney.

4) LaMont Boilers

The LaMont boiler is a once-through or semi-flash boiler in which the boiler water is circulated by means of a pump through long closely spaced tubes of small diameter. The tubes end in a steam separating drum where the emulsion of steam and water separates. The Lamont boilers require powerful pumps for the forced circulation of the boiler water.

[Note : Draw Setup or Experimental Diagram on Left side Page]

The LaMont boilers forced water circulation and the tubes of small diameter gives enormous freedom as far as the design of the heating surfaces concern. With its features of positive circulation, compactness, light weight, suitability for high pressure and temperature, and adaptability to limited space conditions, the Controlled Circulation can offer important advantages for advanced-designed marine boilers.

5) Babcock & Wilcox Boiler

It is a Inclined tube, stationary type water tube boiler. It consists of a drum connected to a series of front end and rear end header by short riser tube. To these headers are connected a series of inclined water tubes of solid drawn mild steel. The angle of inclination of the water tubes to the horizontal is about is 15 degrees or more. A hand hole is provided in the header in front of each rube for cleaning and inspection of tubes. A feed valve is provided to fill the drum and inclined tubes with water the level of which is indicated by water level indicator. Through the fire door the fuel is supplied to grate here it is burnt. The hot gases are forced to move upwards between the tubes by baffle plates provided. The water from the drum flows through the inclined tubes via down take header and goes back into the shell in the form of water and steam via uptake header. The steam gets collected in the steam space of the drum. The steam then enters through the anti priming pipe and flows in the superheater tubes where it is further heated and is finally taken out through the main stop valve and supplied to the engine when needed. At the lowest point of the boiler is provided a mud collector to remove the mud particles through a blow down cock.

The entire boiler except the furnace is hung by means of metallic slings or straps or wrought iron girders supported on pillars. This arrangement enables the drum and the tubes to expand or contract free'y. The brickwork around the boiler encloses the furnace and the hot gases.

Specifications: -

Diameter of the drum 1.22-1.83m
Length6.096-9.144m
Size of the water tubes 7.62-10.16cm
Size of superheated tubes 3.84-5.71 cm
Working pressure 40-bar max.
Steaming capacity 40000Kg/hr max.
Efficiency 60-80%

Applications:

It is an example of horizontal Inclined tube boiler and may be designed for stationary or marine purposes.

QUESTIONS :

1) Define boiler and steam generating unit?

2) Write Specification of

a) Simple Vertical Boiler

b) Locomotive Boiler

c) Lamont Boiler

d) Lancashire Boiler

e) Babcock and Wilcox boiler

f) Cochran Boiler

g) Stirling Boiler

3) Write Application of above Boilers.

[Note : Draw Setup or Experimental Diagram on Left side Page]

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KOLHAPUR INSTITUTE OF TECHNOLOGY'S
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Experiment No. 07

Study and Demonstration of Boiler Mounting and Accessories

Second Year - Bachelor of Technology
III Semester

Department of Mechanical Engineering

Experiment No. 07 **Date of Conduct** / /2

Name of Experiment : Study and Demonstration of Boiler Mounting and Accessories

Boiler Mountings

The various Boiler Mountings are discussed as follows:

1) Safety valves:

The function of safety valve is to release the excess steam when the pressure of steam inside the boiler exceeds the rated pressure. As soon as the pressure of the steam inside the boiler exceeds the rated pressure the safety valve automatically opens and excess steam rushes out into the atmosphere till the pressure drops down to the normal value. A safety valve is generally mounted on the top of the shell. As per boiler regulation every boiler must be fitted at least with two safety valves.

The various type of safety valves are enumerated and discussed as follows:

a) Dead weight safety valve:

Fig. Shows a dead weight valve. A is the vertical cast iron pipe through which steam pressure acts. B is the bottom flange directly connected to seating block on the boiler shell communicating to the steam space. V is the gunmetal valve and VS is the gunmetal valve Leat. D is another cast iron pipe for discharge of excess steam from the boiler. W are the weights in the form of cylindrical disc of cast iron. WC is the weight carrier carrying the weights W. The cover plate C covers these weights. The steam pressure acts in the upward direction and is balanced by the force of the dead weights W. The total deadweights consist of the sum of the weights W, weight of the valve, weight of the weight carrier and weight of the cover plate C. When the steam pressure is greater than the working pressure it lifts the valve with its weights. So the steam escapes from the boiler and the steam pressure thereby decreases.

b) **Lever safety valve:** –

It consists of a lever and weight. The valve rests on the valve seat, which is screwed into the valve body. The valve seat can be replaced if required. The valve body is fitted on the boiler shell. One end of the lever is hinged while at the other is suspended a weight W. The strut presses against the valve on seat against the steam pressure below the valve. The slotted lever guide allows vertical movement to the lever. When the steam pressure becomes greater than the normal working pressure, the valve is lifted with the lever and the weight. Consequently, the steam escapes through the passages between the valve and seat and the steam pressure decreases.

[Note : Draw Setup or Experimental Diagram on Left side Page]

c) Spring loaded safety valve:

II consists of two separate valves and seating having one lever, bearing on the two valves and loaded by a spring, the spring being placed between the valves. The tension of the spring can be adjusted by the nuts. By pulling or raising the lever the operator/driver can relieve the pressure from either valve separately or ascertain it is not sticking on the seating.

2) Water Level Indicator: –

The function of water level indicator is to indicate the level of water in the boiler constantly. It is also called water gauge. Normally two water level indicators are fitted at the front end of every boiler. The water gauge is often inclined to make the water level visible from any position. For proper working of the boiler, the water must be kept at safe level.

3) Pressure Gauge: –

The function of pressure gauge is to measure the pressure exerted inside the vessel. The gauge is usually mounted on the front top of the shell or the drum. It is usually constructed to indicate up to double the maximum pressure. Its dial is graduated to read pressures in kgf/cm2 or bar gauge. There are of two types:

1) Bourdon Tube Pressure Gauge

2) Diaphragm Type Pressure Gauge

4) Steam Stop Valve:

It is a valve, which is placed directly over a boiler and connected to a steam pipe, which carries steam to the engine. The larger size valve is termed as junction valves and the smaller sizes stop valves. The function of the stop valve is to regulate the flow of steam from one steam pipe to the other or from the boiler to the steam pipe. The common type of stop valve consists of a valve V that is attached to the valve spindle VS. The spindle is connected to hand wheel H and passes through a screwed portion like the nut and through a gland of stuffing box G to prevent leakage of steam. On turning the hand wheel H the spindle is raised or lowered depending upon the sense of rotation of wheel. The size of the valve is designed by the pipe diameter it connects (e.g. 5 cm, 7 cm and 10 cm stop valve).

5) Feed Check valve: –

The function of the feed check valve is to control the supply of water to the boiler and to prevent the escaping of water from the boiler run the pump pressure is less or pump is stop. The feed check valve is fitted in the water space of the boiler slightly below the normal level of water.

[Note : Draw Setup or Experimental Diagram on Left side Page]

6) Blow Off Cock:

It performs the following two functions:

1) It may discharge a portion of water when the boiler is in operation to blow out mud, scale or sediments periodically.

2) It may empty the boiler when necessary for cleaning, inspection and repair. It is fitted on the boiler shell directly or to a short branch pipe at the lowest part of the water spaces.

7) Fusible Plug:

The function of fusible plug is to protect the boiler against damage due to overheating for low water level. It is fitted on the firebox crown plate or over the combustion chamber at its appropriate place.

Boiler Accessories

The various Boiler Accessories are discussed as follows:

1) Super heater:

The function of the superheater is to increase the temperature of the steam above its saturation point. The superheater is very important accessory of a boiler and can be used both on fire tube and water tube boiler. Superheaters are of two types:

(1) Convective superheater: It makes the use of flue gases.

(2) Radiant superheater: It is placed in the furnace and wall tubes receive heat from the burning fuel through radiant process.

2) Economiser :

An economiser is a device in which the waste heat of the flue gases is utilized for heating the feed water. Economiser is of two types:

1) Independent type: It is installed in the chamber apart from the boiler settings.

2) Integral type: J is a part of the boiler-heating surface and is installed within the boiler setting.

3) Air Preheater:

The function of the air preheater is to increase the temperature of air before it enters the furnace. It is generally placed after the economiser; so the flue gases pass through the economiser and then to the air preheater. Preheated air accelerates the combustion and facilitates the burning of coal. There are three types of preheaters:

4) Steam Separator:

The steam available from a boiler may be wet, dry or superheated, but in many cases there will be loss of heat from it during its passage through the steam pipe from the boiler to the engine tending to produce wetness. The function of the steam separator is to remove the entrained water particles from the steam conveyed to the steam engine or turbine.

Boiler Accessories Functions

Sr. No	Name	Functions
1	Safety Valve	Do no allow boiler pressure to rise beyond its safe pressure.
2	Water level indicator	Show working level of water in the boiler.
3	Pressure gauge	Indicates workings pressure of the boiler.
4	Steam stop valve	Regulates the amount of outgoing steam.
5	Feed check valve	Checks the amount of feed water going to the boiler and does not allow its return.
6	Blow off cock	Allow to drain water from the boiler.
7	Man hole	Allow a person to go inside the boiler drum for repair etc.
8	Mud hole	Facilitates removal of heavy impurities settled in the boiler drum.
9	Fusible Plug	Stop the boiler if its heating surface if its overheated due to low water level
10	Dual Function of Safety valve high pressure and low water safety valve.	lows escape of steam in case of(1) Unsafe higher pressure

QUESTIONS :

1. Compare Mounting and Accessories

2. What is efficiency of Boiler?

3. Compare Carnot and Rankine efficiency with T-s diagram.

4. Draw P-V, T-s and h-S diagram of Rankine cycle. Write formula of Rankine Efficiency?

[Note : Draw Setup or Experimental Diagram on Left side Page]

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KOLHAPUR INSTITUTE OF TECHNOLOGY'S
COLLEGE OF ENGINEERING
(AUTONOMOUS),
KOLHAPUR

Experiment No. 08

Study and Demonstration of Calorimeters

Second Year - Bachelor of Technology
III Semester

Department of Mechanical Engineering

Experiment No. 08 **Date of Conduct** / /2

Name of Experiment : Study and Demonstration of Calorimeters

Calorimeters are the important instruments in steam plants. Calorimeters are used to determine dryness fraction of steam. Dryness fraction is nothing but ratio of amount of condensed steam and total amount of wet steam which is passed through it. Wet steam affects on metallic parts in turbines (i.e. blades & nozzles) by means of corrosion . Hence we must know what is dryness of steam i.e. condition which explains how much steam is wet.
There is no. of steam calorimeter some are explained as follows.

a) Separating Calorimeter:
It is used to determine the dryness fraction of steam by mechanically separating the water particles from the wet steam .It consists of closed chamber with inlet pipe for allowing wet steam inside There is a perforated cap in front of inlet pipe. Due to which rapid reversal of steam takes place. Outlet for dry steam is allowed from other end of chamber.

Working: - When wet steam is allowed to go inside it strikes with tray and quick reversal of directions takes place. The water particles due to inertia get separated from steam in tray. Amount of water collected is determined by graduated water gauge (m) . The dry steam separated from steam sample is separately measured by collected it from outlet pipe. Amount is noted M.
From this dryness fraction (x) can be calculated by formula,

X= M / M+m
Where, M = amount of dry steam measured.
m= amount of collected water
X = dryness fraction

This method is approximate because the separated steam may not be completely dry. Complete separation of water particles from steam is not possible in sudden reversal.

b) Throttling Calorimeter : -
A throttling calorimeter is used to determine dryness fraction of steam considers throttling process of steam. Throttling is an expansion process in which steam is passed thro' narrow space & then suddenly expanded with fall in the pressure without doing external work. So there is no exchange of heat. In these process steam becomes drier & nearly saturated becomes super heated.
Construction of throttling calorimeter is as shown in fig. ,When steam is admitted from steam main temp.& pressure are measured using thermometer & pressure gauge provided there. Then steam is throttled thro' a narrow aperture of restricted valve opening but total heat remaining constant. The at part 'B' measure pressure and tem. Of steam with manometer and thermometer provided at leaving end.

Dryness fraction is calculated by considering.
P1 = Pressure of steam before throttling
h f1 = Sensitive heat at p1
h fg1 = latent heat of steam at p1
p2 = Pressure of steam after throttling
hg2 = Total heat of dry steam at p2

[Note : Draw Setup or Experimental Diagram on Left side Page]

t = % sat. = Saturation temp. at p2.
t = Temp. of superheated steam.
X = Dryness fraction of steam before throttling
Cp = Specific heat of superheated steam.
Formula for ' x'

Total heat before throttling =Total heat after throttling.

hf1 = x . hfg1 = hg2 = Cp (t sup- t sat.)

Their calorimeter cannot be used if steam does not becomes dry saturated or superheated after throttling because at any other start above equations is not suitable

Combined separated & throttling calorimeter: -

In this calorimeter separating & throttling calorimeter are combined together in series firstly steam under study is passed thro separating & then throttling calorimeter.

A part water from steam is removed by separating calorimeter & semi dry steam is throttled in throttling calorimeter

For dryness, calculate dryness functions separately for each calorimeter and the total dryness fraction is

X= X1 * X2

Where, x1 = dryness fraction of steam considering separating calorimeter and calculated by formula.

$$X1 = \frac{M}{M + m}$$

X2= dryness fraction of steam considering throttling calorimeter and calculated by formula.

hf1 + hfg1* x1 = hg2 + Cp (t sup - t sat)

In this calorimeter drawbacks of separating and throttling calorimeter are removed . So it is very useful method of measuring the dryness fraction of steam is by a combined separating and throttling calorimeter.

d) Tank or Bucket Calorimeter:

In this calorimeter the known mass of steam sample at known pressure is condensed by passing in known mass of cold water.

Calorimeter is constructed as a cylindrical calorimeter with cover plate with holes for steam inlet and thermometer. When steam is pass thro' cold water steam gets condensed by increasing total mass of water. Temperatures as initial and final are recorded.(say t1 & t2)

Let, p = Pressure of the steam in bar.
t = Temperature of steam formation at P
hfg = Latent heat of steam at p.
mc= mass of calorimeter
ce = specific heat calorimeter
me = Water equivalent of the calorimeter
= mc * ce
ms = mass of steam condensed
mw = mass of cold water in the calorimeters
t1 = Initial temperature of water and calorimeter

[Note : Draw Setup or Experimental Diagram on Left side Page]

t2 = Final temp. of water and calorimeter
Cw = specific heat of water (4.2 KJ/ kg ºK)

X = dryness fraction of steam sample
We know that,
Heat lost by steam = heat gain by water and calorimeter.

Ms [(x.hfg) + Cw (t- t2) = [(Mw (w + mc. Cc) (t2- t1)]
From this 'x' can be calculated.

QUESTIONS :

1) In laboratory experiment on wet steam by barrel calorimeter , the following observations were recorded Mass of copper calorimeter = 1 kg, mass of calorimeter + water= 3.8 kg, mass of calorimeter + water + steam = n4 kg, Initial temperature of water = 10^0 C, Final temperature of water = 50^0 C,, steam pressure 5.5 bar, If sp. Heat of copper is 0.406 KJ/kgk, Calculate dryness fraction of Steam.

2) In throttling calorimeter the steam is admitted at pressure of 10 bar. If it is discharged at atmospheric pressure and 110^0C after throttling , determine the dryness fraction of steam. Assume sp. Heat of steam is 2.2 KJ/kgk.

3) In laboratory experiments the following observations were recorded find dryness fraction of combined separating and throttling calorimeter
Total quantity of steam passed= 36 kg, water drained from separator= 1.8 kg, steam pressure before throttling=12 bar, temperature of steam after throttling=110^0C, Pressure after throttling=1.013 bar, Sp. Heat of steam=2.1 KJ/kgk,
Determine the dryness fraction of steam before inlet to the calorimeter.

[Note : Draw Setup or Experimental Diagram on Left side Page]

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KOLHAPUR INSTITUTE OF TECHNOLOGY'S
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Experiment No. 09

Trial on Reciprocating Compressor Test Rig.

Second Year - Bachelor of Technology
III Semester

Department of Mechanical Engineering

Experiment No. 09 **Date of Conduct** / /2

Name of Experiment : Trial on Reciprocating Compressor Test Rig.

AIM: To conduct a trial on two stage reciprocating air compressor and find its

1) Volumetric Efficiency
2) Isothermal Efficiency

THEORY:

Reciprocating air compressors are positive displacement compressors. This means they are taking in successive volumes of air which is confined within a closed space and elevating this air to a higher pressure. The reciprocating air compressor accomplishes this by using a piston within a cylinder as the compressing and displacing element. The reciprocating air compressor is considered single acting when the compressing is accomplished using only one side of the piston. A compressor using both sides of the piston is considered double acting. The reciprocating air compressor uses a number of automatic spring loaded valves in each cylinder that open only when the proper differential pressure exists across the valve. Inlet valves open when the pressure in the cylinder is slightly below the intake pressure. Discharge valves open when the pressure in the cylinder is slightly above the discharge pressure. A compressor is considered to be single stage when the entire compression is accomplished with a single cylinder or a group of cylinders in parallel. Many applications involve conditions beyond the practical capability of a single compression stage. Too great a compression ratio (absolute discharge pressure/absolute intake pressure) may cause excessive discharge temperature or other design problems. For practical purposes most plant air reciprocating air compressors are built as multi-stage units in which two or more steps of compression are grouped in series. The air is normally cooled between the stages to reduce the temperature and volume entering the following stage. Reciprocating air compressors are available either as air-cooled or water-cooled in lubricated and non-lubricated configurations, may be packaged, and provide a wide range of pressure and capacity selections. Figure 5.1 shows schematic diagram of two stage air cooled reciprocating compressor with essential components.

DESCRIPTION OF THE APPARATUS :

Figure 5.2 shows the experimental set up. It consists of tank receiver tank. An electrical motor is connected to compressor using belt and pulley arrangement. Air from atmosphere is taken to first stage compression in Low Pressure Cylinder. An air box with orifice and manometer is used at inlet of first stage for flow measurement. Thermocouples and pressure gauges are used at appropriate key points to measure temperature and pressure as indicated in figure. Energy meter is used to calculate actual energy consumed by the compressor.

[Note : Draw Setup or Experimental Diagram on Left side Page]

PROCEDURE :

1. Before starting the compressor close the delivery valve on the receiver air tank.
2. Start the compressor and wait till required pressure is reached in the receiver tank.
3. When required pressure is attained and if it increases further, open the delivery valve slowly to maintain the pressure.
4. Note down manometer, thermocouple, and pressure gauge readings in the observation table.
5. Again close the delivery valve and let the pressure in the tank increase.
6. Repeat the step 3 and enter the readings in the table.
7. Repeat the experiment for different delivery pressure.
8. Switch OFF the compressor and release the air to atmosphere.

SPECIFICATIONS :

1. **Motor:** Induction Type , Motor Power : 7.5 HP, Motor Speed : 1440 rpm
2. **Pressure Gauge on receiver tank** : 0 – 8 kg_f/cm^2
3. **Speed of compressor (N_c)** : 640 rpm
4. **Bore of LP cylinder (D_{LP})** : 100 mm
5. **Stroke of LP cylinder (L_{LP})** : 89 mm
6. **Orifice diameter (d_o)** : 15 mm
7. **Discharge Coefficient for orifice C_d** : 0.64
8. **Energy Meter Constant (EMC)** : 60 R/kWh
9. **Pipe Diameter (d_1)** : 27 mm

OBSERVATION TABLE

Trial No.	Receiver tank air pressure (Delivery Pressure)		Manometer Reading		Air temperature (^{0}C)					Energy Meter Reading (Time in Seconds for 5 Revolutions of Disc)
	P_d (kg/m^2)	P_d (N/m^2)	h_w (mm of water)	h_a (m of water)	Inlet	After first stage	After inter cooler	After Second stage	Receiver tank	
			h1	h2	T_1	T_2	T_3	T_4	T_5	
1										
2										
3										
4										
5										

Where $h_a = \left(\frac{\rho_w}{\rho_a} - 1\right) x\, h_w\ x 10^{-3}\ m\ of\ air$, ρ_a = density of air = 1.17 kg/m^3

RESULTS TABLE

Trial No	Receiver tank air pressure (Delivery Pressure) P_d (N/m^2)	Actual Volume of air Sucked, V_a (m^3/s)	Actual Power input, P_a	Isothermal Power input, P_{iso}	Volumetric Efficiency, η_{vol}	Isothermal Efficiency, η_{iso}

PLOT THE GRAPHS:

1) Delivery pressure P_d v/s Volumetric Efficiency, η_{vol}
2) Delivery pressure P_d v/s Isothermal Efficiency, η_{iso}

CALCULATIONS :

A) VOLUMETRIC EFFICIENCY (η_{vol}):

$$\eta_{vol} = \frac{Actual\ Volume\ flow\ rate\ of\ air\ sucked}{Theoretical\ Volume\ flow\ rate\ of\ air} = \frac{V_a}{V_s}$$

V_a = Actual Volume flow rate of air sucked = $\dfrac{C_d A_1 A_o \sqrt{2gh_a}}{\sqrt{A_1^2 - A_0^2}}$

Where, A_1 = Area of Pipe = $\dfrac{\pi d_1^2}{4}$ A_0 = orifice area = $\dfrac{\pi d_o^2}{4}$ $A_1^2 - A_0^2$

V_s = Theoretical Volume flow rate of air = $\dfrac{\pi D_{LP}^2}{4} \; x \; L_{LP} \; x \; \dfrac{N_c}{60}$

B) ISOTHERMAL EFFICIENCY (η_{iso}):

$$\eta_{iso} = \frac{Isothermal\ Power\ Input}{Actual\ Power\ Input} = \frac{P_{iso}}{P_a}$$

$P_{iso} = p_s V_a \ln\left(\dfrac{p_d}{p_s}\right)$ x 10^3 kW

$P_a = \dfrac{3600 \; x \; n}{EMC \; x \; t}$ kW

RESULTS:

1. Average Volumetric Efficiency of Compressor =
2. Average Isothermal Efficiency of compressor =