ANNAMALAI UNIVERSITY

FACULTY OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF MECHANICAL ENGINEERING

MECP 706 – HEAT TRANSFER LABORATORY

OBSERVATION MANUAL 2021-2022

B.E. VII – SEM. MECHANICAL ENGINEERING (REGULAR)

NAME :

BATCH : **ROLL NO.** :

DEPARTMENT OF MECHANICAL ENGINEERING

VISION

The Mechanical Engineering Department endeavors to be recognized globally for outstanding education and research leading to well qualified engineers, who are innovative, entrepreneurial and successful in advanced fields of mechanical engineering to cater the ever changing industrial demands and social needs.

MISSION

The Mechanical Engineering program makes available a high quality, relevant engineering education. The Program dedicates itself to providing students with a set of skills, knowledge and attitudes that will permit its graduates to succeed and thrive as engineers and leaders. The Program strives to:

- Prepare the graduates to pursue life-long learning, serve the profession and meet intellectual, ethical and career challenges.
- Extend a vital, state-of-the-art infrastructure to the students and faculty with opportunities to create, interpret, apply and disseminate knowledge.
- Develop the student community with wider knowledge in the emerging fields of Mechanical Engineering.
- Provide set of skills, knowledge and attitude that will permit the graduates to succeed and thrive as engineers and leaders.
- Create a conducive and supportive environment for all round growth of the students, faculty & staff

PROGRAM EDUCATIONAL OBJECTIVES

1.	Prepare the graduates with a solid foundation in Engineering, Science and Technology for a successful career in Mechanical Engineering.
2.	Train the students to solve problems in Mechanical Engineering and related areas by engineering analysis, computation and experimentation, including understanding basic mathematical and scientific principles.
3.	Inculcate students with professional and ethical attitude, effective communication skills, team work skills and multidisciplinary approach
4.	Provide opportunity to the students to expand their horizon beyond mechanical engineering
5.	Develop the students to adapt to the rapidly changing environment in the areas of mechanical engineering and scale new heights in their profession through lifelong learning

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DEPARTMENT OF MECHANICAL ENGINEERING

MECP706 – HEAT TRANSFER LABORATORY

B.E. MECHANICAL ENGINEERING VII – SEMESTER (REGULAR)

LIST OF EXPERIMENTS - "A" Semester 2021-2022

1. Experiment on Emissivity measurement apparatus.
2. Experiment on composite wall apparatus.
3. Natural convection from vertical cylinder.
4. Performance test on Solar Air Heater
5. Performance test on Solar Water Heater
6. (a) Performance test on Solar Cooker

   (b) Performance test on Solar Still
7. Study and Performance Parameter Evaluation on Loco Type Boiler.
8. (a) Study and Performance Parameter Evaluation on Greenbat Turbine.

   (b) Study and Performance Parameter Evaluation on Steam Condenser (Surface)

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Ex. No. : 1

Date :

EXPERIMENT ON EMISSIVITY MEASUREMENT APPARATUS

AIM:

To determine the emissivity of the test plate

THEORY:

All substances at all temperatures emit thermal radiation is an electromagnetic wave and does not require any material medium for propagation. All bodies can emit radiation and have also the capacity to absorb all or a part of the radiation coming from the surroundings towards it.

An idealized black surface is one, which absorbs all the incident radiation with reflectivity and transmitivity equal to zero. The radiant energy per unit time per unit area from the surface of the body is called as the emissive power and is usually denoted by 'e'. The emissivity of the surface is the ratio of the emissive power of the surface to the emissive power of a black surface at the same temperature. It is denoted by 'E'.

Thus $E = \frac{e}{e_b}$

For black body absorbtivity = 1 and by the knowledge of Krichoff's Law Emissivity being a property of the surface depends on the nature of the surface and temperature. It is obvious from the Stefan Botzmann Law that the prediction of the emissive power of a surface require knowledge about the values of its Emissivity and therefore much experimental research in radiation has been concentrated on measuring the values of Emissivity as a surface temperature. The present experimental set up is designed and fabricated to measure the property of Emissivity of the test plate surface at various temperatures.

APPARATUS:

The experimental set up is having basic mechanical set-up and control panel. It consists of two circular Aluminium plates identical in size and are provided with heating coils. The plates are fitted on the base horizontally and are kept in an enclosure so as to provide undisturbed natural convection surroundings.

The heat input to the heater is varied by separate dimmerstats and is measured by using an ammeter and a voltmeter with the help of double pole double throw toggle switches. The temperature of the plats is measured by Cr-Al thermocouples. Separate wires are connected to diametrically opposite points to get the average surface temperature of the plates. Another thermocouple is kept in the enclosure to read the ambient temperature of enclo sure.

Plate 1 is blackened by a thick layer of lamp black to form the idealized black surface whereas the plate 2 is the test plate of which Emissivity is to be determined.

The Heat Energy through heater inputs to the two plates is dissipated from the plates by conduction, convection and radiation. The experimental setup is designed in such a way that under steady state conditions the heat dissipation by conduction and convection is same for both the plates. When the surface temperatures are same and the difference in the heater input readings is because of the difference in radiation characteristics due to their different emissivities. The schematic arrangement of the set up is shown in Fig.

Let,

W_B	=	Heater input to black plate (watt) = $V_1 \times I_1$
W_S	=	Heater input to test plate (watt) = $V_2 \times I_2$
A	=	Area of plates = $\frac{\pi d^2}{4} \times 2$ = m^2
T_s	=	Temperature of black plate °K
T_a	=	Ambient temperature °K
ε_B	=	Emissivity of black plate (To be assumed equal to unity)
ε	=	Emissivity of test plate
σ	=	Stefan Boltzmann Constant
	=	5.67×10^{-8} w/m^2 °K^4

By using Stefan Boltzmann Law :

$$(W_B - W_S) = (1 - \varepsilon)\, \sigma\, A\, (T_s^4 - T_a^4)$$

SPECIFICATIONS:

1. Test Plate	=	160 mm dia. = 0.16 m
2. Black Plate	=	160 mm dia. = 0.16 m
3. Heater for Test Plate	=	Nichrome, strip wound on mica sheet and sandwiched between two mica sheets – 250 watts
4. Heater for Black Plate	=	Nichrome, strip wound on mica sheet and sandwiched between two mica sheets – 250 watts
5. Dimmerstat for Test Plate	=	0 – 2 Amps., 0 – 230 V, Open type, wire wound
6. Dimmerstat for Black Plate	=	0 – 2 Amps., 0 – 230 V, Open type, wire wound
7. Digital Voltmeter	=	0 – 200 VAC
Digital Ammeter	=	0 – 2 Amps
8. Enclosure size	=	50 cm × 36 cm × 37 cm approx. with one side of Perspex sheet
9. Thermocouples	=	Chromel – Alumel type – 3 Nos.
10. Digital Temperature Indicator	=	0 – 300°C, Make – ES Point

PROCEDURE:

1. Give stabilized power supply to temperature indicator 230 V., single phase.
2. Gradually increase the input to the heater to black plate and adjust it to some value viz., 30, 50, 60 watts and adjust the heater input to test plate slightly less than the black plate 25, 45,55 watt etc.
3. After, about 45 minutes, check the temperature of the two plates and adjust Dimmerstat so that the two plates will be maintained at the same temperature.
4. This will require some trial and error and one has to wait sufficiently (more than one hour or so) to obtain the steady state condition.
5. After attaining the steady state record the readings V_B, I_B, V_T, I_T, T_1, T_2 & T_3 and fill it in the observation column.
6. The same procedure is repeated for various surface temperature in increasing order.
7. After completing the experiment, bring the **Dimmer Knobs to „zero"** position before switching off the unit.

OBSERVATION TABLE:

Sl No.	Heater Input				Temperature		
	V_B	I_B	V_T	I_T	T_1 (Black plate)	T_2 (Test plate)	T_3 (Ambient)

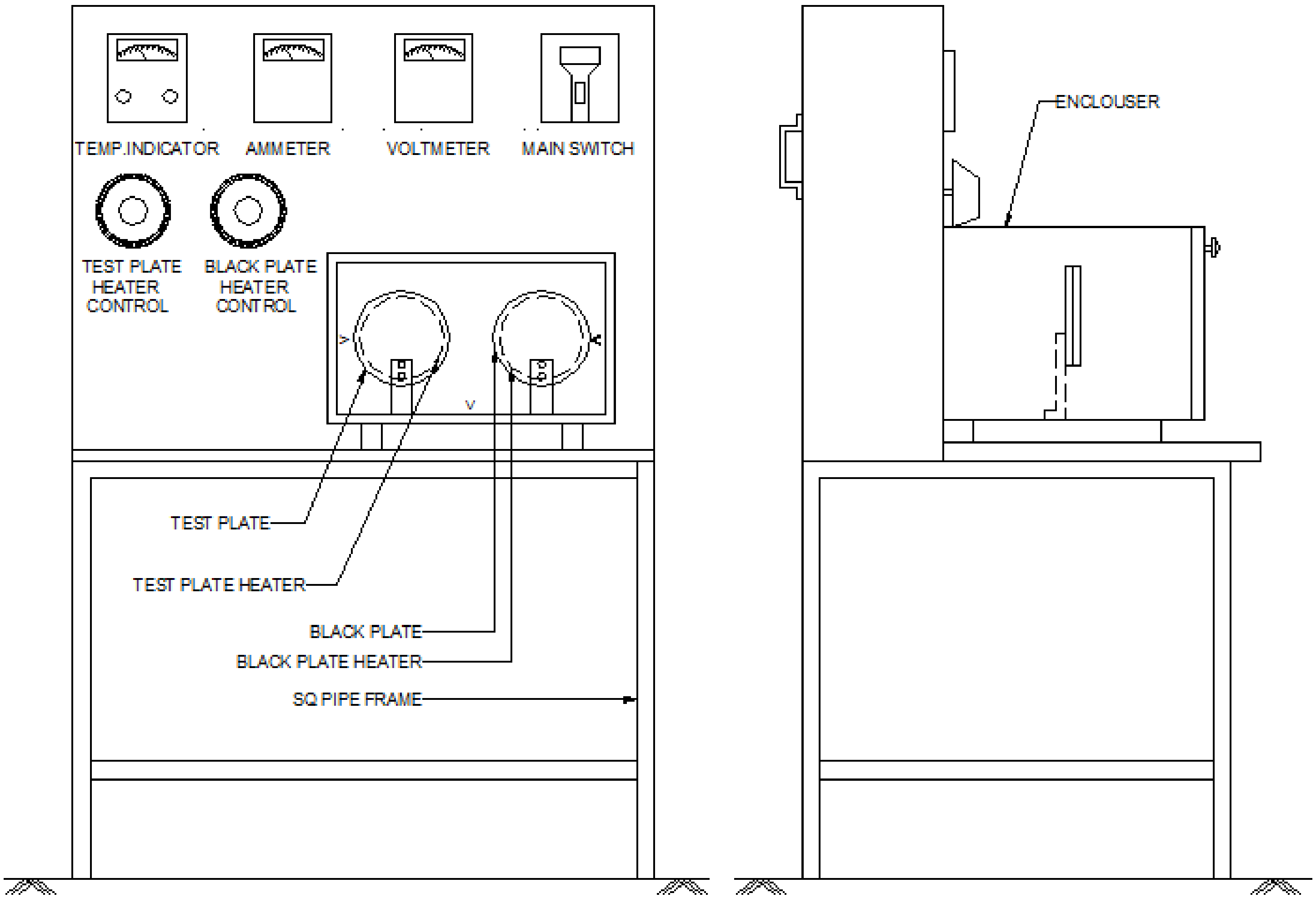


Fig. 1. Schematic diagram of Emissivity Measurement apparatus

CALCULATIONS:

1. Area of plates A = $\frac{\pi d^2}{4} \times 2$ = $\frac{\pi d^2}{4} \times 0.16 \times 2$ = 0.04 m^2

2. Heat input for Black Plate q_B

q_B = $V_B \times I_B$ Watt

3. Heat input for Test Plate q_T

q_T = $V_T \times I_T$ Watt

Now, we have

$$(q_B - q_T) = \sigma A (T_s^4 - T_a^4)(\varepsilon_B - \varepsilon)$$

where σ = Stefan Boltzmann constant.
= 5.67×10^{-8} W/m^2 K^4

A = Area of plates
ε_B = Emissivity of Black Plate = 1
ε = Emissivity of Test plate
Ts = Average temperature of the Test Plate = $\frac{T_1 + T_2}{2}$
Ta = Enclosure temperature i.e. T_3

$$\therefore (\varepsilon_B - \varepsilon) = \frac{(q_B - q_T)}{\sigma . A . (T_s^4 - T_a^4)}$$

$$\therefore (1 - \varepsilon) = \frac{(q_B - q_T)}{\sigma . A . (T_s^4 - T_a^4)}$$

$$\therefore \varepsilon = 1 - \left(\frac{(q_B - q_T)}{\sigma . A . (T_s^4 - T_a^4)} \right)$$

RESULT :

Ex. No. : 2

Date :

EXPERIMENT ON COMPOSITE WALL APPARATUS

OBJECTIVES:

To determine (i) the overall thermal conductance for a composite wall and to compare that calculated values with standard values of k for different materials of the slab. (ii) temperature distribution across the width of the composite wall.

DESCRIPTION:

The apparatus consists of a central heater sandwiched between two sheets. Three types of slabs are provided on both sides of heater which forms a composite structure. A small hand press frame is provided to ensure the perfect contact between the slabs. A Dimmerstat is provided for varying the input to the heater and measurement of input is carried out by a voltmeter, ammeter. Thermocouples are embedded between interface of the slabs to read the temperature at the surface.

SPECIFICATIONS:

1. Slab assembly arranged symmetrically on both sides of heater.
   Formation of Slab assembly:
   a. M.S. Plate - 25 mm thick × 200 mm dia .... 2 nos.
   b. Backlite Plate - 19 mm thick × 200 mm dia .... 2 nos.
   c. Press wood - 12.5 mm thick × 200 mm dia .... 2 nos.
   ** Enclosure Size - 58 cm × 35 cm × 35 cm with acrylic cover in front.

2. Heater - Nichrome heater wound on mica former and insulated having capacity 400 watt maximum, 200 mm ∅, 200 Volts.

3. Heater Control Unit: Dimmerstat, 0 – 2 A, Single phase, Open type.

4. Voltmeter – Digital, range 0 to 200 V AC

5. Ammeter – Digital, range 0 to 2 A AC

6. Temperature Indicator (digital type) 0 – 199.99 ºC, 0.1ºC LC with selector switch

7. Table & Stand made up of MS square hollow pipe and Angle. Both sides laminated boards are fixed on the top and front side of the table.

PRECAUTIONS:

1. Keep the Dimmerstat to zero before starting the experiment.
2. Increase the heat input slowly. Do not exceed heat input beyond 120 watts.
3. Keep all the assembly undisturbed.
4. Remove air gap between plates by moving hand clamp gently, if disassembled for changing any specimen.
5. While removing the plates do not disturb the thermocouples from its position, if you are going to change the specimen.
6. Operate selector switch of temperature indicator gently.

PROCEDURE:

1. See that the plates are symmetrically arranged on both sides of the heater plates.
2. Operate the hand press properly to ensure perfect contact between the plates.
3. Close the box by Acrylic cover to achieve steady environmental conditions.
4. Start the supply of heater. By varying the dimmerstat, adjust the input at desired value.
5. Take readings of all the thermocouples at an interval of 10 minutes until fairly steady temperatures are achieved and rate of rise is negligible.
6. Note down the readings in observation table.

OBSERVATION TABLE:

Input (V)	Current (I)	Temperature at different point(°C)							
		t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8

CALCULATIONS:

Note: Rate of Heat Supplied Q = $\frac{(V \times I)}{2}$ =...........W.

For calculating the thermal conductivity of composite walls, it is assumed that due to large diameter of the plates heat flowing through central portion is uni-directional i.e. axial flow is assumed is considered. Accordingly, thermocouples are fixed at a close to centre of the plates.

Now

Q = Rate of heat supplied = $\frac{(V \times I)}{2}$.=

q = Heat flux = $\frac{Q}{A}$ W/m^2 =

Where A = $\frac{\pi}{4} \times d^2$ m^2 where d = dia. of walls.

Mean Reading

$$T_A = \frac{(T_1 + T_2)}{2} =$$

$$T_B = \frac{(T_3 + T_4)}{2} =$$

$$T_C = \frac{(T_5 + T_6)}{2} =$$

$$T_D = \frac{(T_7 + T_8)}{2} =$$

1. Total thermal resistance of composite slab

$$R\ total = \frac{(T_A - T_D)}{q} =$$

2. Thermal conductivity of composite slab

$$K\ composite = \frac{Q \times b}{(T_A - T_D) \times A} =$$

b - Total thickness of composite slab = 25 + 19 + 12.5 = 56.5 mm

To calculate thermal conductivity of plates.

Q = Rate of heat supplied = Heat conducted through the M.S.Wall = Bakelite = Press wood

$$Q = k_{ms} A_{ms} \frac{(T_1 - T_3)}{L_{ms}} = k_{b1} A_{b1} \frac{(T_3 - T_5)}{L_{b1}} = k_{bw} A_{pw} \frac{(T_5 - T_7)}{L_{pw}}$$

$$k_{ms} = \frac{Q \times L_{ms}}{A_{ms}(T_1 - T_3)} =$$

$$k_{bl} = \frac{Q \times L_{bl}}{A_{bl}(T_3 - T_5)} =$$

$$k_{pw} = \frac{Q \times L_{pw}}{A_{pw}(T_5 - T_7)} =$$

Where

k = Thermal conductivity of wall
A = Area of the wall = $\pi/4\ d^2$
L = Length of the wall
T = Temperature of the point

To calculate temperature (T_{x1}, T_{x2} & T_{x3}) at L_{ms}, L_{bl}, L_{pw}.

$$Q = k_{ms} A_{ms} \frac{(T_1 - T_{x1})}{L_{ms}/2}$$

T_{x1} =

$$Q = k_{ms} A_{ms} \frac{(T_1 - T_3)}{L_{ms}} = k_{b1} A_{b1} \frac{(T_3 - T_{x2})}{L_{b1}/2}$$

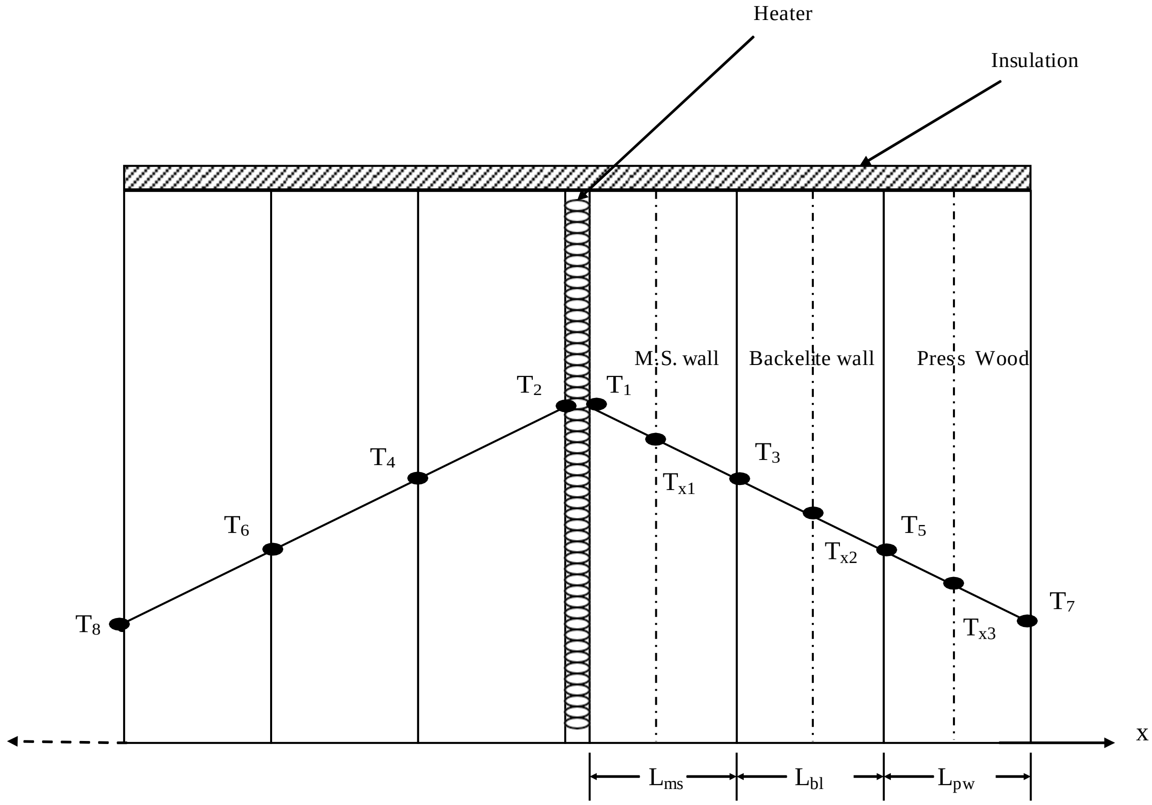
T_{x2} =

$$Q = k_{ms} A_{ms} \frac{(T_1 - T_3)}{L_{ms}} = k_{b1} A_{b1} \frac{(T_3 - T_5)}{L_{b1}} = k_{pw} A_{pw} \frac{(T_5 - T_{x3})}{L_{pw}/2}$$

T_{x3} =

Where

k = Thermal conductivity of wall
A = Area of the wall = $\pi/4\ d^2$
L = Length of the wall
T = Temperature of the point
x_1= 12.5 mm, x_2= 9.5 mm, x_3= 6.25 mm



L_{ms} = 25 mm
L_{bl} = 19 mm
L_{pw} = 12.5 mm

T_1 to T_8 - **Thermocouple locations**

Fig. 1. Thermocouple locations on composite wall

RESULT TABULATION:

Sl. No.	Experimental thermal conductivity of plates in (W/mk)	Temperatures at locations x_1, x_2 & x_3 in (^oC)
1.	M.S. Plate =	T_{x1} =
2.	Backlite Plate =	T_{x2} =
3.	Press wood =	T_{x3} =

RESULT:

Ex. No. : 3

Date :

NATURAL CONVECTION FROM VERTICAL CYLINDER[#]

AIM :

To determine the surface heat transfer coefficient and local heat transfer coefficients along the length of the tube and also to draw the graph between local heat transfer coefficient and the distance along the height of the tube.

THEORY :

When a hot body is kept in still air, heat is transferred to the surrounding by natural convection. The fluid layer in contact with the hot surface gets heated rise up due to decrease in its density and the cold fluid rushes in to take its place. The process is continuous and heat transfer takes place due to relative motion of hot and cold fluid. The surface heat transfer cofficient of a system transferring heat by natural convection depends on its shape, dimensions , orientation and also the temperature difference between the surface and the fluid.

EXPERIMENTAL PROCEDURE :

1. Switch on the supply and adjust the variac to obtain the required heat value (say 50W, 70W)
2. Note down the readings of seven thermocouples at regular intervals of 10 minutes till steady state is reached.
3. Note down the ambient temperature by means of thermocouple number 8. Repeat the experiment at different heat inputs (Do not exceed 100 W)

SPECIFICATION :

1.	Diameter of cylinder (d)	= 31 mm
2.	Length of tube (l)	= 500 mm
3.	Duct size	= 215 x 215 x 780 mm
4.	Number of thermocouples	= 8
5.	Temperature indicator range	= 0 – 300^{o}C

PRECAUTIONS :

1. Input do not exceed 100 W
2. Operate the change over selector switch gently insteps from position (1) to position (8)

[#] Note: Newton's law of cooling, Free and forced convection, heat transfer coefficient, laminar – turbulent flow. Non dimensional numbers (Reynolds, Prandtl, Nusselt, Raleigh, Grashof) normalized parametric representation , scale length, boundary layer concept (hydro dynamic and thermal)

OBSERVATION TABLE :

Sl. No.	Input (W)	Temperatures at locations (ºC)							t_s (ºC)	t_a (ºC)	t_{mf} = $t_s + t_a$ / 2 (ºC)
		1	2	3	4	5	6	7			
1.	50										
2.											
3.											
4.											
5.											
6.											
7.											
1.	70										
2.											
3.											
4.											
5.											
6.											
7.											

SPECIMEN CALCULATIONS FOR :

$$\text{Average surface temperature } t_s = \frac{t_1 + t_2 + t_3 + t_4 + t_5 + t_6 + t_7}{7} \ ^\circ C$$

$\mathbf{t_s} =$

Mean film temperature $\mathbf{t_{mf}} = t_s + t_a \ / 2 \quad =$

Where,

$t_1, t_2, .. t_7$ are the temperatures at locations 1,2,...7 respectively and t_a-ambient temp.

1. Experimental heat transfer coefficient (Average) :

$\mathbf{Q} = h A (\Delta t)$ W

$\mathbf{Q} =$

Where,

h = Experimental convective heat transfer coefficient W/m^2K

A = Area of heat transfer = π dl m^2

Δt = Temperature difference $(t_s - t_a)$ K

Q = Average rate of heat transfer by convection W

$$\mathbf{h_{ave\ (exp)}} = \frac{Q}{A_S(t_s - t_a)} \quad \mathbf{W/m^2K}$$

$\mathbf{h_{ave\ (exp)}} =$

Where,

$\mathbf{A_S} = \pi \ d L =$

$\Delta \ \mathbf{t} = t_s - t_a =$

2. Local heat transfer coefficient

$$h_{1\ local\ (exp)} = \frac{Q}{A\,(t_x - t_a)} \qquad \mathbf{W/m^2K}$$

$h_{1\ local\ (exp)}$ =

Where

t_x is the local temperature at locations 1 , 2 , ………….. 7. The local heat transfer coefficient h_1 , h_2 , ………. h_7 can be calculated from the above equation.

h_2 = **h_3 =** **h_4 =** **h_5 =**

h_6 = **h_7 =**

3. Theoretical heat transfer coefficient (Average) :

$Nu = 0.59\,(Gr\,Pr)^{0.25}$ for $10^4 \le Gr\,Pr \le 10^9$

$= 0.13\,(Gr\,Pr)^{1/3}$ for $10^9 \le Gr\,Pr \le 10^{12}$

Where

Nu - Nusselt number
Gr - Grashof number
Pr - Prandtl number

$$\mathbf{Gr} = \frac{g\,L^3\,\beta\,\Delta t}{\nu^2}$$

Gr =

Where

g = Acceleration due to gravity m/s^2
L = Characteristic dimension m
β = Coefficient of volumetric expansion for the fluid
= $1 / (t_{mf} + 273)$ (K^{-1})
=

Δt = Temperature difference = $(t_s - t_a)$ °C
ν = Kinematic viscosity of the air at mean film temperature
(from heat transfer data book)
Pr = Prandtl number of air at t_{mf}
$Nu = 0.59\,(Gr\,Pr)^{0.25}$
Nu =

$\mathbf{Nu} = h L / k$

$\mathbf{h_{(Ave)}} = (Nu\, k) / L =$

Where

h = Convective heat transfer coefficient (W/m^2K)

L = Characteristic dimension (m)

k = Thermal conductivity of air at t_{mf} **heat transfer Data book (W/mK)**

4. Theoretical local heat transfer coefficient $h_{local\,(the)}$

$$\mathbf{Gr_{1\,(local)}} = \frac{g L_1^3 \beta \Delta t}{\nu^2}$$

$\mathbf{Gr_{1\,(local)}} =$

Where

$L_X = L_1, L_2 \dots L_7$ - Distance from the bottom of tube (m)

Gr_2 = **Gr_3 =** **Gr_4 =** **Gr_5 =**

Gr_6= **Gr_7 =**

Pr = Prandtl number of air at $t_{mf\,(local)}$

Where,

$t_{mf\,x\,(local)} = (t_x + t_a) / 2$ - locations x = 1 to 7

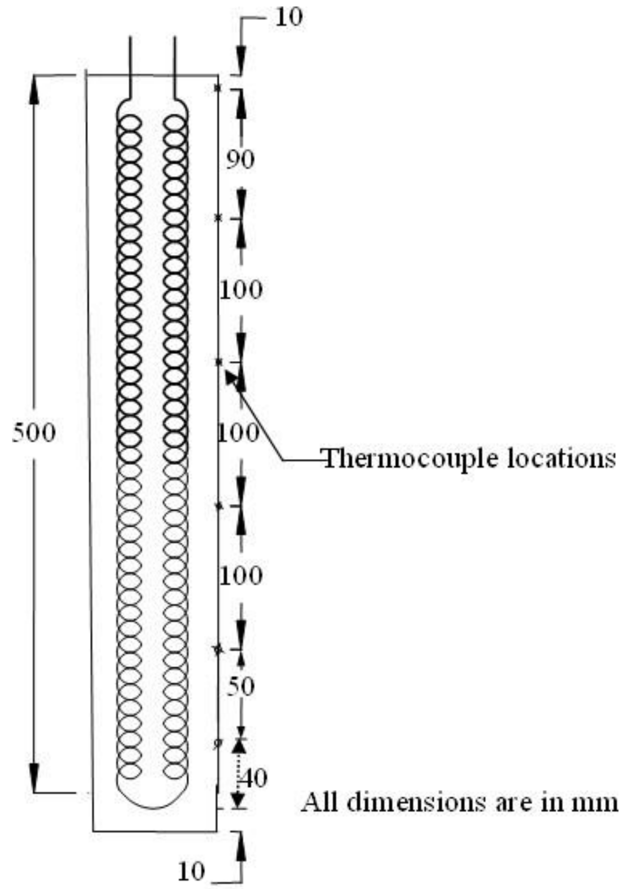
$t_{mf\,x\,(local)} =$

$t_{mf\,2}$ = **$t_{mf\,3}$ =** **$t_{mf\,4}$ =** **$t_{mf\,5}$ =**

$t_{mf\,6}$ = **$t_{mf\,7}$ =**

ν = Kinematic viscosity at t_{mf} m^2/s

Δt = Temp difference $t_x - t_a$ °C



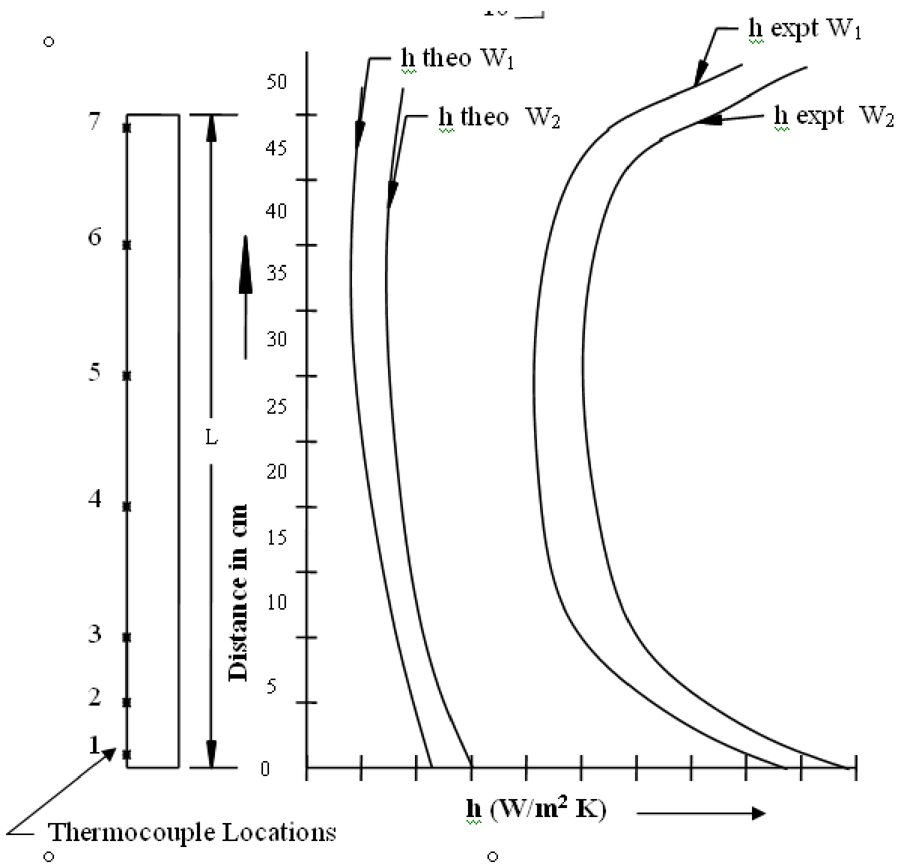


Fig. 1. Variation of local heat transfer coefficients

$$Nu = \frac{h_x \; L_x}{k}$$

$$h_x = \frac{NuK}{L_x}$$

Where,

h_x = Local convective heat transfer coefficient at points 1 to 7 (W/m^2 K)
L_x = Characteristic dimension in meter
k = Thermal conductivity of air at t_{mf} **-Heat transfer data book (W/mK)**

h_1 = **h_2 =** **h_3 =** **h_4 =**

h_5 = **h_6 =** **h_7 =**

RESULT TABULATION :

Sl. No.	**Heat Input (W)**	**Local heat transfer coeff (the) (W/m^2 K)**							**Average surface h.t. coeff. (W/m^2K)**
		h_1	**h_2**	**h_3**	**h_4**	**h_5**	**h_6**	**h_7**	

Sl. No.	**Heat Input (W)**	**Local heat transfer coeff (exp) (W/m^2K)**							**Average surface h.t. coeff. (W/m^2K)**
		h_1	**h_2**	**h_3**	**h_4**	**h_5**	**h_6**	**h_7**	

GRAPH :

Drawn a graph between local heat transfer coefficients (Theoretical and Experimental) and distance.

RESULT :

Ex. No. : 4

Date :

PERFORMANCE TEST ON SOLAR AIR HEATER

AIM:

To conduct the performance test on solar air heater.

INTRODUCTION:

Solar air heaters are used to heat the air to particular temperature by passing over a flat platesolar collector. In this system heat is transmitted by convection and radiation process.

APPRATUS REQUIRED:

1. Thermometer
2. Milli voltmeter
3. Pyranometer

DESCRIPTION:

The solar air heater is constructed with the length of 1.25m and the breadth of 0.75m. The absorber material is Aluminium sheet .The Aluminium sheets were welded together to form a rectangular box of length 1.15m and breadth of 0.65m. Aluminium sheet is enclosed in a G.I rectangular box is fitted with a glass plate, which sealed the absorber against the radiation losses The air initially enter through a slit provided at one end of the G.I rectangular box with the help of suction provided by the blower, the air passes through the absorber plate and absorbs heat.

THEORY:

Solar radiation are being shorter wavelength, they are transmitted by the glass covering and are partly absorbed by the absorber plates and of it are reradiated. These reradiated rays are of longer wavelength, the glass cover prevents these rays to pass through it. Thus heat energy is trapped between the glass covering and absorber plate. The glass covering also reduces the top losses. Bottom losses are reduced considerably by properly insulating the portion beneath the absorber plate. The heat Air is admitted at one end of the heater. A suction blower is provided at the other end, which sucks the air through the heater .As the air passes and flows over the absorber plate, it absorbs the heat and comes out of the heater with increase in temperature.

PROCEDURE:

1. Keep the solar air heater in the open yard facing south and expose it to the solarradiation.
2. Clean the glass covering and set the blower.
3. Set the pyranometer and observe Its readings at a regular interval of 10 minutes.
4. By adjusting the auto transformer, set the airflow rate at the required level.
5. Observe the glass plate temperature and absorber plate temperature using thermocouples at a regular interval of 10 minutes, and tabulate the reading as per the observation table. Determine the efficiency of the air heater as per the specimen calculation.

OBSERVATION TABLE:

Area of the collector = 1.25m x 0.75m

S.No	Time	Air velocity in m/sec	Absorber Plate temp.		Air temp		Atm.Temp in °C	Pyranometer Reading	
			°C		Tin °C	Tout °C		m.v	kJ/hr.m^2
1									
2									
3									
4									
5									

SPECIMEN CALCULATION:

1. Area of the collector = m^2

2. Total heat available

$$= \frac{\text{Pyranometer reading in m.v}}{\text{Pyranometer Constant}} \times 3600 \ \text{kJ/hr.m}^2$$

Where, Pyranometer Constant = 9.64

3. Heat available in the heater = Total heat available X area of the collector in kJ/hr.

4. Total heat gained by the air = $m C_p \Delta T$ kJ/hr

Where m = mass flow rate of air in kg/hr

C_p= Specific heat of air in kJ/kg K

ΔT= Temperature difference of air in K

5. $m = \rho \times A \times V$

Where

m= mass flow rate in kg/hr.

ρ= Density of air in kg/m^3

A= Area of flow in m^2

V= Velocity of air in m/sec

$A = \pi/4 \ d^2$ where d is the diameter of duct = 0.04m

6. Efficiency = $\frac{\text{Total heat gained by the air kJ/hr}}{\text{Heat available kJ/hr}}$ in %

RESULT TABULATION

Sl.no	Time	Mass flow rate kg/hr	Heat gain in kJ/hr	Heat available in kJ/hr	Efficiency in %

Draw the following Graph

1. Time Vs Efficiency
2. Time Vs Solar Radiation
3. Time Vs Absorber Plate Temperature

Result :

Ex.No.: 5

Date:

PERFORMANCE TEST ON SOLAR WATER HEATER

AIM:

To conduct experiment on solar flat plate water heating systemand determine the efficiency.

APPARATUS REQUIRED:

1. Thermometer
2. Milli voltmeter
3. Pyranometer

DESCRIPTION:

This flat plate water heater consists of one absorber plate coated with black board paint. One glass cover and number of 3/8 dia copper tubes are fixed on the absorber plate and their top and bottom ends are connected with outlet and inlet headers respectively. The headers are connected withstorage tank, which is provided just above the collector.

The water supply tank is provided to store and circulate the water through absorber tube. Inlet and outlet temperatures of water and the absorber tube temperature measured by thermocouples. Numbers of thermocouples are provided to measure the temperature at different locations in the collector. The collector sides and bottom portion are properly insulated for to avoid heat losses.

PROCEDURE:

1. Keep the solar water heater in the open yard facing south and expose it to the solarradiation.
2. Set the pyranometer and observe its readings at a regular interval of 10 minutes.
3. Observe the glass plate temperature, absorber plate temperature, and inlet & outlet temperature of water at a regular interval of 10 minutes.
4. Tabulate the reading as per the observation table. Determine the efficiency of the water heaters as per the specimen calculation.

OBSERVATION:

Area of the collector : 1.25 x 0.75 m

Sl No	Time	Intensity of solar radiation		Flow rate of water		Absorber plate temp.	Atm. Tem ^{O}C	Water inlet ^{O}C T_{in}	Water outlet ^{O}C T_{out}	$\Delta T = (T_{out} - T_{in})$ ^{O}C
		m.v	kJ/hr m^2	kg/min	Kg/hr	^{O}C				

SPECIMEN CALCULATION:

1. Area of the collector (A) = m^2
2. Total heat available in kJ/hr m^2

$$= \frac{\text{Pyranometer reading in m.v}}{\text{Pyranometer const}} \times 3600$$

Where pyranometer constant = 9.64

3. Heat available in the collector in kJ/hr =Total heat available x area of the collector.
4. Total heat gained by the water = m cp. ΔT

Where m = mass flow rate of water Kg/hr.

Cp = specific heat of water = 4.186 kJ/kg ^{o}k

$\Delta T = T_{out} - T_{in}$

$$5.\ \text{Efficiency} = \frac{\text{Total heat gained by the water}}{\text{Heat available}}$$

RESULT TABULATION

Sl No.	Time	Heat gain by flat plate collector KJ/hr	Heat available in flat plate collector. KJ/hr	Efficiency of flat plate collector. %

Draw the following Graph

1. Time Vs Efficiency
2. Time Vs Solar Radiation
3. Time Vs Absorber Plate Temperature

RESULT:

Ex.No.: 6 (a)

Date:

PERFORMANCE TEST ON SOLAR COOKER

AIM:

To conduct an experiment in the Solar Cooker to find the efficiency and to draw the performance curve.

INTRODUCTION:

Solar Cooker is used to heat the water and to cook foods, vegetables and eggs etc, In thisgadget conduction all modes of heat transfer is taking place.

APPRATUS REQUIRED:

1. Thermometer
2. Milli voltmeter
3. Pyranometer

DESCRIPTION:

The solar cooker is a simple flat plate type collector system. It is made up of wooden box and is having black coated Aluminum inner tray or Absorber plate. Two glass covering are provided to reduce the top losses and adjustable reflector is provided to increase the solar intensity on the absorber plate.

The space between the inner sides of the wooden box and the Aluminum tray is filled with glass wool for proper insulation. The top cover containing the two plain glasses can be opened with the help of hinges and can also be tight fitted with press wooden blocks.

THEORY:

The main principle is that the good absorbing material will also be good radiator but this is not valid in the case of those solar appliances in which glass window has been used because the absorbed and reradiated radiation are not of the same wave length. The light radiation being shorter wave length and are able to pass through glass coverings and the reradiated radiation are bring larger wave length an d are unable to pass through the glass coverings. This principle has been used very successfully for retaining the thermal radiation after being absorbed by a flat plate. The total energy incident on the solar cooker is absorbed by the flat plate and a portion of it is lost through convection, conduction and radiation.

At first the incident solar energy raises the temperature of the Air inside the box rapidly and then slowly. After some time the heat losses become equal to energy input and temperature becomes constant at equilibrium.

Energy output = Energy input – Losses

PROCEDURE:

1. Keep the solar Cooker in the open yard facing south and expose it to the solarradiation.
2. Set the pyranometer and record the intensity of solar radiation while heating the Cooker. observeIts readings at a regular interval of 10 minutes.
3. Take measured quantity (say 1 Kg) of water in the Cooker container and put one thermocoupleinside it and keep it in the solar Cooker.
4. Observe the glass plate temperature, absorber plate temperature and water temperature using thermocouples at a regular interval of 10 minutes.
5. Tabulate the reading as per the observation table. Determine the efficiency of the solar cooker asper the specimen calculation.

OBSERVATION TABLE:

Area of the collector = 0.3 x 0.3 m

Sl.no.	Time	Temp of water	Absorber Plate temp.	Glass cover Temp	Atm .temp in °C	Pyranometer Reading	
		°C	°C	°C		m.v	kJ/hr.m^2
1							
2							
3							
4							
5							

SPECIMEN CALCULATION :

1. Area of the collector = m^2

2. Total heat available = $\dfrac{\text{Pyranometer reading in m.v}}{\text{Pyranometer Constant}} \times 3600$ kJ/hr.m^2

   Where , Pyranometer Constant = 9.64

3. Heat available in the heater = Total heat available X area of the cooker in kJ/hr.

4. Total heat gained by food material = $m\,Cp\,\Delta T/\Delta t$ kJ/hr

   Where

   m = mass of water material Kg

   C_p= Specific heat of water in kJ/kg K

   ΔT= Temperature difference of water in K

Δt = Time difference between the readings in hr.

$$1.\ \text{Efficiency} = \frac{\text{Total heat gained by the water} \quad \text{kJ/hr}}{\text{Heat available} \quad \text{kJ/hr}} \text{ in } \%$$

RESULT TABULATION

Sl.no	Time	Mass of food material kg	Heat gain in kJ/hr	Heat available in kJ/hr	Efficiency in %

Draw the following Graph

1. Time Vs Efficiency
2. Time Vs Absorber Plate Temperature
3. Time Vs Temp of water

Result :

Ex.No.: 6 (b)

Date:

PERFORMANCE TEST ON SOLAR STILL

AIM:

To conduct a test on solar still and to determine the efficiency of the solar still.

APPARATUS REQUIRED :

1. Thermometer
2. Milli voltmeter
3. Pyranometer
4. Anemometer

DESCRIPTION:

The solar still consists of a shallow basin lined with a black, impervious material, witch contains the saline water. A sloping transparent cover is provide at the top. Solar radiation is transmitted through the cover and is absorbed in the block lining. It thus heats up the water about 10 to 20^{o} C and causes it to evaporate .The resulting vapour rises, condenses as pure water on the under side of the cover and flows in to the condensate collection channel.

PROCEDURE

1. Ensure, the dust free transparent cover at the top
2. Fill the channel with the saline water
3. Measure the quantity of condensate
4. Measure the intensity of solar radiation by using the pyranometer.
5. Measure the temperature of the glass plate and absorber plate by using thermocouples with mill voltmeter.

OBSERVATION :

S.NO	Time	Solar Intensity In kJ/hr m^2		Temperature of Glass plat		Temperature of Absorber plate		Wind Velocity m/sec	Water Collected Kg/hr
		m.v	kJ/hr m^2	^oC		^oC			

<u>SPECIMEN CALCULATION</u> :

1. Solar still efficiency $= \dfrac{m \times LH}{I_{ss} \times A_s} \times 100$

   Where

   m- Mass of Distillate Water collected in kg/hr

   L.H- Latent Heat of Evaporation (Basin Water Temperature) in kJ/kg,

   (From Steam table)

   Iss - Solar Intensity in kJ/hr $m^2 = \dfrac{\text{Pyranometer reading in m.v}}{\text{Pyranometer constant}} \times 3600$

Where Pyranometer Constant = 9.64

A - Area of the Basin in m^2=1 m^2

RESULT TABULATION

Sl no	Time	Radiation on tiltedsurface KJ/hr.m^2	Temp. of Absorber plate in ^oC	Heat Utilised KJ/hr m^2	Efficiency in %

Draw the following graphs

1. Time Vs Efficiency
2. Time Vs Absorber plate temperature
3. Time Vs Glass plate temperature
4. Time Vs Radiation on tilted surface

RESULT :

STEAM BOILER

The steam boiler is a closed vessel in which, by the application of heat, steam is generated from water at above atmospheric pressure. The pressure of steam can be varied according to the requirements. It may be produced even higher than its critical pressure and in some cases, this high pressure steam is superheated above its critical temperature by a superheater. The steam is used for driving prime movers like steam engines, steam turbines and can also be used in process industries for process heat.

DEFINITION:

A boiler is a closed vessel in which water is heated by a source of heat and converted into steam.

FUNCTION:

The function of a steam boiler is to transfer heat produced by burning of fuel to water and thus to produce steam.

BOILER CLASSIFICATIONS:

Boiler may be classified as follows,

1. Water tube and fire tube.
2. Forced circulation and Natural circulation.
3. Externally fired and internally fired.
4. Stationary, portable, locomotive and marine.
5. Horizontal, Inclined and vertical.
6. Solid, liquid and gaseous fuel boiler.
7. Heat recovery boiler.

WATER TUBE BOILER: The boilers in which water circulates through various tubes and hot gases surround these tubes so that the heat of the hot gases is transferred to water inside the tubes resulting in conversion of water into steam are called water tube boilers.

FIRE TUBE BOILER: The boiler in which hot gases pass through the tubes and water surrounding these receives the heat carried by the hot gases, and in turn gets converted into steam are called fire tube boilers.

FORCED CIRCULATION BOILERS: The boiler in which the circulation of hot gases and water are brought about by force pumps i.e., blowers and dampers for hot gases, and centrifugal pump / reciprocating pump for water etc., are called forced circulation boilers.

NATURALLY CIRCULATED BOILERS: The boiler in which the circulations of hot gases and water take place due to the difference in densities of the fluids (hot gases cold air and hot water cold water) are called naturally circulated boiler.

According to the position of the furnace the boilers are classified as externally and internally fired boilers.

EXTERNALLY FIRED BOILER:

The boiler in which the furnace is arranged for the combustion of the fuel outside the boiler shell and the hot [flue] gases thereby produced pass through the boiler to generates steam are called externally fired boiler.

INTERNALLY FIRED BOILER:

The boiler in which the furnace or grate is constructed for the combustion of fuel to take place inside the boiler shell are called internally fired boiler.

Boilers are classified according to use as stationary, portable, locomotive and marine.

They are also classified as horizontal, inclined and vertical according to the direction of the principle axis of the boiler.

SOLID FUEL BOILER:

The boilers in which combustion of the solid fuel takes place for generating heat are called solid fuel boiler. Example: Coal fired boiler

LIQUID OR GASEOUS FUEL BOILER:

The boiler in which the combustion of liquid and gaseous fuels take place for generating heat are called liquid gaseous fuel boiler. Example: Oil fired boiler

TERMS COMMONLY EMPLOYED IN THE STUDY OF BOILER

SHELL:

The shell of a boiler consists of one or more steel plates bent into cylindrical form and riveted or welded together. Each separate cylindrical ring is called a course. The shell may be made up of two or more courses. The ends of the shell are closed by means of flat or curved plates called boiler heads. The shell together with the head forms the drum.

BOILER WALL SETTINGS:

It is constructed of brick work. It may form the walls of the furnace and the combustion chamber. It confines the heat to the boiler and forms a passage through which the gases pass.

GRATE:

The grate consists of cast iron bars upon which fuel is burnt and there is a gap between the bars so as to pass air to the fuel to support combustion and to allow ashes to fall down. The area upon which the fire rests is called the grate area and is measured in sq. meter.

FURNACE:

The furnace or the fire box is the space above the grate and below the boiler shell in which the fuel is burnt. The combustion space is that part of the furnace in which the volatile matter and combustible gases are burnt.

WATER SPACE AND STEAM SPACE:

The water space is the volume of the shell that is occupied by the water, and steam space is the volume of the entire shell not occupied by water and tubes. The level at which, the water stands in the boiler shell is known as water level.

HEATING SURFACE:

It is the surface of the boiler which is exposed to hot gases on one side and water on the other.

BOILER MOUNTINGS AND ACCESSORIES

BOILER MOUNTINGS:

Boiler mountings are essential fittings generally fitted on the boiler shell for the safe and smooth running of the boiler. The important mountings are,

1. Steam pressure gauge
2. Water-Level indicator
3. Safety valve
4. Steam stop-valve
5. Blow-Off cock
6. Fusible plug
7. Feed-Check valve

PRESSURE GAUGE:

It is fitted in front of a boiler in such position that the operator can conveniently read it. It is connected to steam space by a siphon pipe. Its function is to indicate the pressure of steam in a boiler.

WATER LEVEL INDICATORS:

Water level indicators are usually two in number. They are mostly placed in front of the boiler easily visible to the attendant. The function of the water level indicator is to show the leve l of water in the boiler.

SAFETY VALVE:

A device directly attached to the steam space of the boiler shell which opens automatically to discharge some steam and does not allow the pressure of steam in side the boiler shell to exceed the pre-set maximum working pressure is known as safety valve.

STEAM STOP VALVE:

This valve is placed on the highest part of the steam space of a boiler and is connected to a steam pipe which supplies the steam to outside. The function of the steam stop valve is to stop or to allow the flow of steam from the boiler to the steam pipe. It may be operated automatically or manually.

BLOW-OFF COCK:

It is fitted at the lowest part of a boiler. It can be directly fitted to the boiler shell or to sho rt pipe which is fitted to the boiler.

Its function is to remove periodically the sediments collected at the bottom of the boiler, while the boiler is working and to empty the boiler while it is to be cleaned or inspected or shut off.

FUSIBLE PLUG:

It is fitted in the crown plate of a furnace or a fire box. Its function is to extinguish the fire in the furnace of a boiler when the water level in the boiler falls to an unsafe extent and thereby preventing the explosion which may take place due to overheating of the furnace plate.

FEED CHECK VALVE:

It is fitted to the boiler slightly below the working level of the water in the boiler. It is connected to the boiler end of the delivery pipe from the feed water pump.

Its function is to allow or to stop the supply of water to the boiler. The check valve is automatic in operation and its function is to prevent the water escaping from the boiler in case of failure of a feed pump.

MAN HOLE:

It is provided on the boiler shell at a convenient position so that a man can enter through it. Its function is to provide an opening from which a man can enter in a boiler for cleaning and inspection purposes.

BOILER ACCESSORIES:

Most of the boilers are fitted with accessories. They either increase the efficiency of the boiler plants or help in their working. The following accessories are attached to modern boiler.

1. Economiser
2. Air pre-heater
3. Superheater
4. Feed pump

ECONOMISER:

A device which utilizes he waste heat carried by exhaust gases before leaving through the chimney for heating feed water is called an economiser or feed water heater.

The advantages gained by installing an economiser are

i. Fuel economy,
ii. Long life of the boiler,
iii. Increase in steaming capacity.

AIR PRE-HEATER:

An air pre- heater is installed between the eonomiser and the chimney and it abstracts heat from the flue gases and transfers to air a portion of the heat that otherwise would pass up the chimney as waste.

SUPER HEATER:

This is one of the most important accessories of a boiler. Superheated steam effects improvements and economy in the following ways.

i. By reducing the steam consumption of the steam engine or steam turbine , by producing more work per kg of steam.
ii. By reducing the condensation losses in steam mains and in engine cylinder.
iii. By eliminating corrosion of steam turbine blades.
iv. By increasing capacity of plant.
v. By reducing the friction of the steam in the steam engine ports, while entering and leaving the cylinder.

FEED PUMPS:

Feed pumps are needed to force the water into the boiler through the feed valves. These pumps are classified as (i) Reciprocating pump (ii) Centrifugal pump. The reciprocating pumps can be classified as simplex, duplex, and triplex pumps according to the number of cylinder they are carrying. The reciprocating pump is driven by the steam engine directly connected with it or by means of electric motor. The centrifugal pump is generally driven by an electric motor.

BOILER DRAUGHT

In a boiler, draught is defined as the force required forcing air to fire and carrying away the gases produced by combustion of fuel. This force is produced by small pressure difference between the pressure of air outside the boiler and that of gases within the furnace chimney. This causes the flow of gases. Hence in a boiler, draught performs the following functions.

(i) It forces sufficient quantity of air through the furnace for proper combustion of fuel.

(ii) It draws (extracts or circulates) the hot gases produced through the system.

(iii) It removes the products of combustion to the atmosphere through the chimney after they have given their heat to water in the boiler

NATURAL DRAUGHT:

Draught produced by chimney is called natural draught. It is equal to difference between weight of column of hot gases within in the chimney and that of cold air out side it. Since the weight of hot gas is less than that of cold air, the heavier cold air rushes into the furnace and causes continuous circulation of hot gases.

ARTIFICIAL DRAUGHT:

The draught produced by some artificial means (other than chimney) is known as artificial draught.

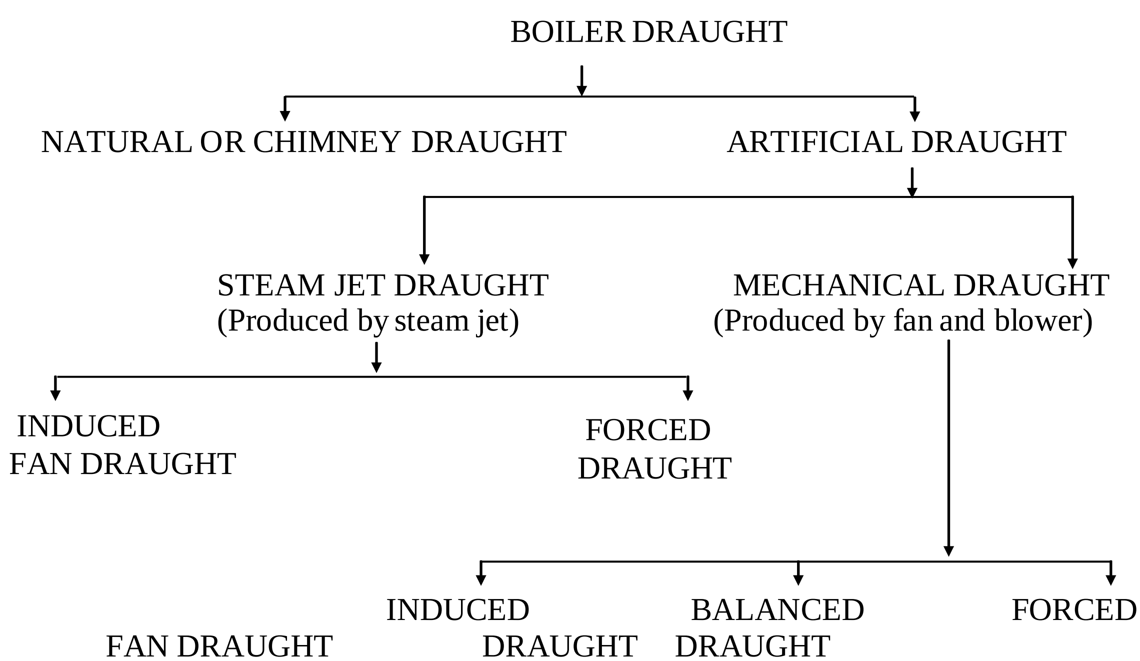
STEAM JET DRAUGHT:

The draught produced by a steam jet is called a steam jet draught. It can be produced easily and is either forced or induced.

In FORCED STEAM JET DRAUGHT system, steam from a boiler is throttled to 1.5 to 2 bar gauge pressure. It is then made to pass through the nozzles installed at the level of ash-pit. Steam comes out of the nozzles with a large velocity and drags the air through the grate, furnace, flue paths and the chimney.

In INDUCED STEAM JET DRAUGHT system, exhaust steam from a steam engine is made to pass through the nozzles installed at the level of smoke-box under the chimney. The high velocitysteam coming out of nozzles creates a vacuum in the smoke-box. It drags the hot gases from the grate, furnace and flue paths. This draught is specially employed in locomotive boilers.

CLASSIFICATION OF BOILER DRAUGHT



MECHANICAL DRAUGHT

The draught produced by fans and blowers can be called mechanical draught and is either forced or induced type.

FORCED DRAUGHT

In forced mechanical draught system, a fan or blower is installed near the base of boiler grate or at the entrance of air-preheater. It delivers air to the furnace under pressure which forces hot gases to circulate through the grate, furnace, flue, smoke box and finally to the chimney.

INDUCED DRAUGHT

In induced mechanical draught system, a fan or blower is placed at the outlet of economizer or air-preheater. It is placed near or at the base of the chimney. This fan creates partial vacuum at the grate, furnace, and flue. It draws products of combustion from the furnace and forces them to pass through the chimney.

BALANCED DRAUGHT:

It is combination of the forced and induced draught system. Here an air fan supp lies air at a moderate pressure through the grate and also through air-preheated. An induced draught fan is placed at the bottom of the chimney to draw the flue gases through the flue-tubes, economizer and air-preheater. It sends them out through the chimney.

BOILER INSPECTION

A boiler inspector carries out periodic inspection of all boilers installed in his jurisdiction. Usually, the inspection is carried out annually. Generally the following tests are carried out for a boiler. 1. HYDRAULIC TEST 2. STEAM TEST

HYDRAULIC TEST:

Every boiler is tested hydraulically with a view to check

(i) Tightness of boiler joints and fittings.

(ii) The leakage coming out as a result of repairs of defective spots.

This test is carried out in the presence of an inspector. A boiler undergoing this test is completely filled with water and its pressure is raised according to the following specification.

(i) An old boiler will be subjected to a hydraulic pressure of 1.5 times its normal working pressure. At this pressure the boiler should not show any leakage at all. (ii) If the working pressure of the new boiler is more than 7 kg/sq.cm. It will be subjected to a pressure of 1.5 times working pressure plus 3.5 kg/sq.cm. At this pressure the boiler should not show any leakage at all.

STEAM TEST:

The boiler inspector carries out this test on every newly registered boiler. This test is carried out to check the setting of safety valve at the working pressure. The boiler (old boiler) which setting of safety valve has been tampered with the changing the working pressure is assigned by the Inspector. After performing this, the valves are properly sealed so that they are not tampered with by the owner afterwards.

STUDY AND PERFORMANCE PARAMETER EVALUATION ON LOCO TYPE BOILER.

LOCO TYPE BOILER

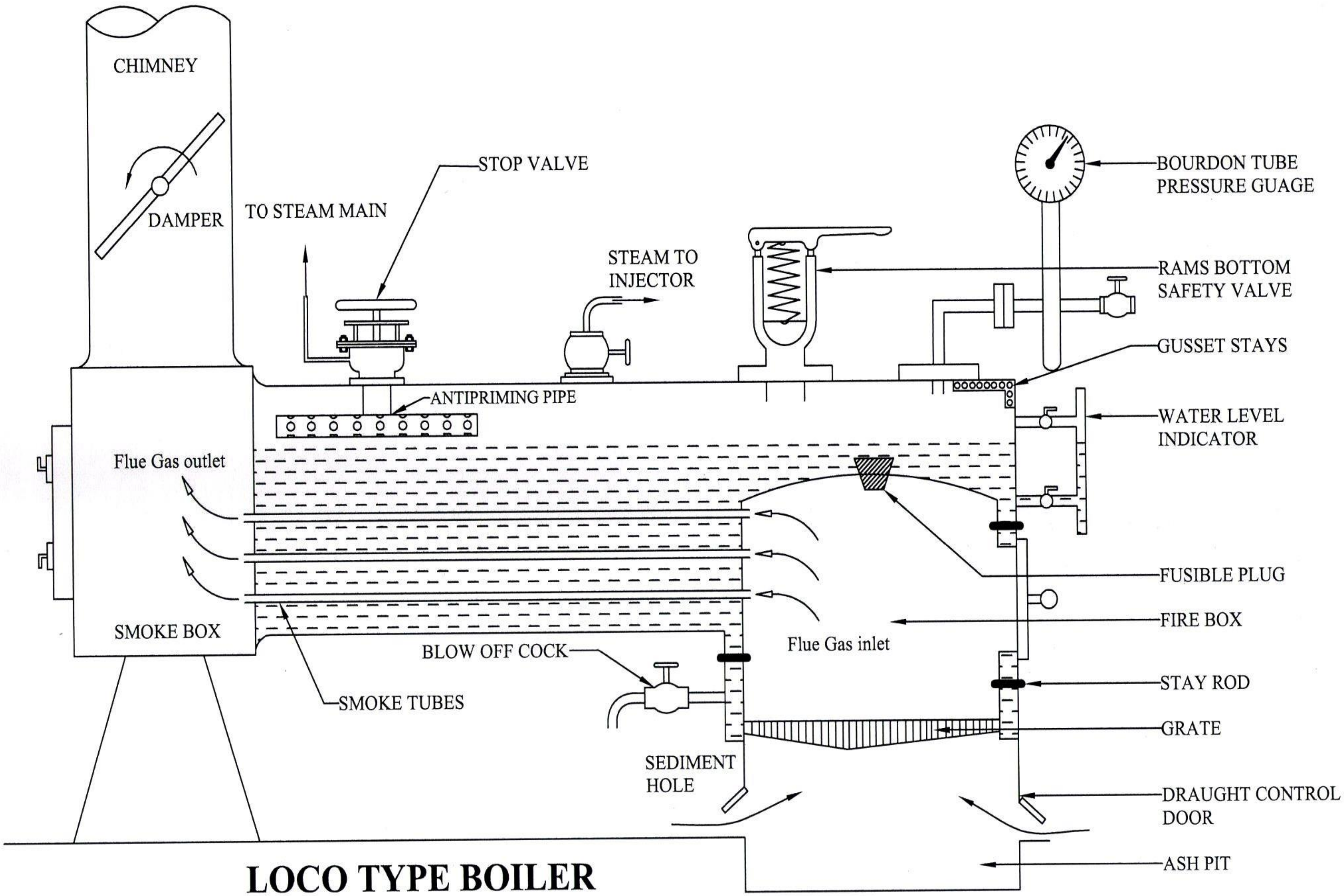
SPECIFICATIONS:

Type	: Horizontal, Fire tube
Working pressure	: 8.2 bar
Evaporating capacity	: 800 kg/hr.
Area of heating surface	: 31.9 m^2.
Grate area	: 0.88 m^2.
Diameter of boiler shell	:1.14 m.
Length of the boiler	: 4.12 m.
Number of tubes	56
Diameter of the tube	: 6.35 cm.
Diameter of chimney	: 45.7 cm.
Height of the chimney	: 8.2 m.

DESCRIPTION:

This boiler is stationary, horizontal, fire tube, loco type boiler. This has a plain grating surface and is provided with gusset stays to prevent the bulging of end plates. The water is fed initially to the boiler by means of a pump and when the boiler is in operation an injector operated by steam is used to suck the water into the boiler. Water is drawn by the suction effect produced by the steam jet provided near the water pipe. Mud if any in the water is collected at the bottom. Four hand holes are provided for removing the mud. Grate is composed of number of iron bars with a gap of about 10 mm between them.

The draught is a natural one. Since the hot air is lighter than the atmospheric air, the hot flue gases rise to the atmosphere. The draught can be controlled by adjusting a butterfly valve provided at the chimney bottom. The water level is indicated by a pair of water level indicators positioned in the front side. The water level should not fall below the marks made on the indicator. A pressure gauge and a Ramsbottom safety valve are mounted on the top of the boiler.



LOCO TYPE BOILER

A manhole is provided to inspect and clean the interior surface of the boiler. A blow- off cock is provided at the bottom for cleaning purposes. There is a fire door to feed the coal to the furnace. A damper is provided below the grate to control natural draught. The boiler is provided with a fusible plug to protect the boiler from overheating due to fall in water level. It is fitted over the crown of the furnace and is exposed to the flames.

The boiler has an anti-priming pipe to separate water particles from the out coming steam. Steam always contains some amount of water particles. The water having much higher specific gravity than the steam tends to fall back as steam ascends. The higher the steam rises in the steam space, lesser is the water particles suspended in it.

Date :

PERFORMANCE EVALUATION ON LOCO TYPE BOILER.

AIM:

To conduct a Trial on LOCO TYPE BOILER.

SPECIFICATIONS:

Working Pressure	: 8.2 bar
Evaporating Capacity	: 800 kg/hr
Area of heating surface	: 31.9 m^2
Grate area	: 0.88 m^2
Diameter of Boiler shell	: 1.14 m
Length of the Boiler	: 4.12 m
Number of tubes	: 56
Diameter of the tube	: 6.35 cm
Diameter of the chimney	: 45.7 cm
Height of the Chimney	: 8.2 m

OBSERVATIONS:-

1. Mass flow rate of water

   i) Initial flow meter reading (Q1) =

   ii) Final Flow meter reading (Q2) =

2. Time of starting the trial =

3. Mass of coal taken [Mc1] =

Installment	Coal with bucket in kg	Empty Bucket in kg	Coal in kg
1			
2			
Total mass of coal taken Mc_1			

4. Pressure of Steam at intervals of 5 Minutes.

Time from starting (Min)	O	5	10	15	20
Pressure kg/cm^2 [gauge]					

5. Average pressure of supply steam =

6. Feed Water Temperature (Tf_w) =

7. Mass of Coal Left behind (Mc_2) =

8. Time of completing the Trial [t_2] =

9. Quality of steam (X) [to be obtained from the steam calorimeter] =

10. Calorific value of coal (C.V) = 30,000 kJ/kg.

CALCULATIONS:-

1. Trial duration = Time of completion - Time of starting

2. Coal consumption rate (M_c) kg/Hr.

$$Mc = \frac{Mass\ of\ Coal\ Taken\ for\ the\ trial\ in\ Kg}{Trial\ duration\ in\ Min} X\ 60 kg/hr$$

$$Mc = \frac{Mc1 - Mc2}{(t2\ -\ t1)} X\ 60$$

3. Energy supplied by the coal in kJ/hr.

= Coal consumption rate x Calorific value of coal.

$= Mc \; X \; C.V$

Energy supplied by the coal in kJ/hr. =

4. Mass of water evaporated (M_w) in kg/ hr.

$$= \frac{\text{Mass of water actually evaporated.}}{\text{Trial duration in min.}} \times 60.$$

$$Mw = \frac{[Q_2 - Q_1]}{\text{Trial duration in min.}} \times 60$$

5. Boiler Efficiency in % (η_{boiler})

$$= \frac{\text{Energy absorbed by water in kJ per hour}}{\text{Energy supplied by coal in kJ per hour}}$$

Energy absorbed by water = $M_w (h_s - hf_w)$.

h_s = Enthalpy of steam produced(Corresponding to Ave. steam pre)

= hf+ xh_{fg} where x is the quality of steam

h_{fw} = Enthalpy of feed water.(Corresponding to feed water temp)

M_w = Mass of water evaporated per hour.

η_{boiler} =

6. Equivalent evaporation (We) kg/hr.

$$We = \frac{\text{Energy absorbed by water in kJ/hr.}}{L}$$

Where,

L = Latent heat of Evaporation at 100 °C

We =

7. Factor of evaporation per kg of coal = $\frac{h_s - h_{fw}}{L}$

8. Equivalent Evaporation per kg of Coal = $\frac{\text{We kg/hr}}{\text{Mc kg / hr}}$

9. Equivalent Evaporation per m^2 of heating surface in kg/hr m^2 = $\frac{We}{\text{Area of heating surface}}$

10. Equivalent Evaporation per m^2 of Grate area in kg /hr m^2 = $\frac{We}{\text{Grate area}}$

RESULT:

STUDY AND PERFORMANCE PARAMETER EVALUATION ON GREENBAT TURBINE

ROTODYNAMIC MACHINES

INTRODUCTION:

A Rotodynamic machine is one in which a fluid flows freely through an impeller or rotor, the transfer of energy between the fluid and the rotor is continuous and the change of angular momentum of the fluid causes , or is the result of, a torque on the rotor. When energy is transferred from the fluid to the rotor the machine is known as turbine. When the energy is transferred to the fluid from the rotor the machine is known as fan, pump or compressor.

ROTODYNAMIC MACHINES

POWER ABSORBING MACHINES POWER PRODUCING MACHINES

PUMP FAN COMPRESSOR STEAM TURBINES GAS TURBINES

AXIAL FLOW RADIAL FLOW MIXED FLOW
TURBINE TURBINE TURBINE

IMPULSE TURBINE REACTION TURBINE

[DE LAVAL'S TURBINE] [PARSON'S TURBINE]

PRINCIPLE OF OPERATION:

IMPULSE TURBINE:

The most basic turbine takes a high-pressure, high-enthalpy fluid, expands it in a fixed nozzle, and then uses the rate of change of angular momentum of the fluid in a rotating passage to provide the torque on the rotor. Such a machine is called an impulse turbine. When the static pressure at the rotor inlet is the same as that the rotor outlet, then the relative velocity of fluid flow is constant.

REACTION TURBINE:

The end of each tube is shaped as a nozzle and the steam from the supply tube expands through the nozzles to atmosphere in tangential direct ion. There is an increase of velocity of the steam, and the rate of increase of momentum is provided by a force on the steam from the nozzle walls in the direction of the steam flow. An equal and opposite force acts on the tube nozzle walls causing the tube to spin round in a direction opposite to the steam flow. In the case of reaction machines a change of static pressure occurs during the flow over each rotor stage.

COMPOUNDING:

When expansion of steam takes place from the high initial pressure to the exhaust pressure in only one stage, the velocity of the steam will be very high and this will set up excessive blade speeds, far above the normal useful speeds. Further, “the lost velocity or the leaving loss", namely the kinetic energy of the steam leaving the turbine will also be high. Therefore, in order to restrict the rotational speed to the turbine and also to minimize the leaving loss, the exhaust steam from the first ring of moving blades is diverted to a second ring of moving blades with the help of a ring of stationary or fixed blades. There may be two or more rings of moving blades keyed to a common shaft and in between two rings of moving blades there will be a ring of fixed blades usually anchored to the turbine casing. This way of reducing rotor speed is known as*Compounding*.

METHODS OF COMPOUNDING:

1. Pressure Compounding
2. Velocity Compounding

PRESSURE COMPOUNDING

The Pressure drop available to the turbine is used in a series of small increments, each increment being associated with one stage of the turbine. The nozzles are carried in diaphragms which separate each stage from next. The steam pressure in the space between each pair of diaphragms is constant, but there is a pressure drop across each diaphragm as required by the nozzles. Precaution must be taken to prevent leakage of the steam from one section to next at the shaft and outer casing. The steam speeds and hence the blade speeds, are low if the number of stages is high. The variation of pressure & velocity through the turbine are shown in figure 3. The final pressure being that of the condenser, and the final velocity that required for the steam to leave the turbine. In figure only one set of wheels is shown, but these may be followed by another set with a larger mean radius. Each of the stages can be analysed by the method used previously for the single stage. A turbine with a series of simple impulse stage is called pressure compounded.

VELOCITY COMPOUNDING:

From, previous considerations it is seen that in the simple impulse stage the optimum condition of blade speed is hardly practical, and with the speeds actually used only a small amount of the kinetic energy of the steam can be utilized. The velocity compounded stage, called the Curtis stage after its designer, is used to employ lower blade speeds and a higher utilization of the kinetic energy of the steam. In this type all the expansion takes place in a single set of nozzles, and the steam then passes through a series of blades attached to a single wheel or rotor. Since the blade moves in the same direction it is necessary to change the direction of the steam between one set of moving blades and the next. For this purpose a stationary ring of blades is fitted between each pair of moving blades. A two row wheel version of this turbine is shown in figure.

GREENBAT TURBINE

SPECIFICATIONS:

TURBINE:

Power	: 7.36 kW (10 H.P)
Steam Pressure	: 7 bar.
Reduced turbine speed	: 2400 rpm.
No. of nozzles	5

GENERATOR:

Power	: 6.5 kW.
Voltage	: 220 Volts.
Current	: 29.5 Amps.
Loading Arrangement	: Electrical resistance type.

DESCRIPTION:

This is a single stage simple impulse turbine having the rotating element actuated by the impact of steam passing through the blades at a relatively high velocity. The whole of expansion of the steam from admission pressure to the back pressure take place in the nozzles. The heat drop is converted into the Kinetic energy. The whole of the kinetic energy of the steam is absorbed in the single row of moving blades. It is proved in turbine theory that for maximum efficiency the peripheral velocity of the blade is given by

$$V_t = \frac{1}{2} V \cos\theta$$

Where,

V_t - Velocity of blade.
V - Absolute velocity of steam from nozzle.
θ - Nozzle angle

It is obvious therefore that the rotor revolves at a very high speed for maximum efficiency. The rotor of this turbine runs at 24,000 rpm. It is made of forged, heat treated, nickel chrome steel having one row of stainless steel blades made with a shank fitted in slots drilled in the rim of the wheel. By this method, the b lades can be easily taken out and new ones inserted should an occasion arises, without damage to the wheel. The turbine wheel is mounted on a flexible shaft supported between self aligning bearings. The shaft is made of heat treated Nickel chrome molybdenum steel upon which pinion is cut. A gear meshing with this pinion gives the reduced speed of 2400 rpm to the output shaft to which it is attached.

This turbine is a condensing turbine. At the bearing, glands are provided on the rotor to prevent leakage of steam. The steam next to a gland is exhaust steam on its way to the condenser, there is no tendency for steam to escape past the gland into the atmosphere, but there will be a leakage of air inwards, as is the case here. To prevent this air leaking in, the gland is supplied with steam pressure above the atmosphere which expands through the labyrinth packing to the condenser.

This turbine is condensing turbine. Condensing turbine means condenser is attached to the exhaust of the turbine. The condensing turbine increases its power output compared with the non-condensing type.

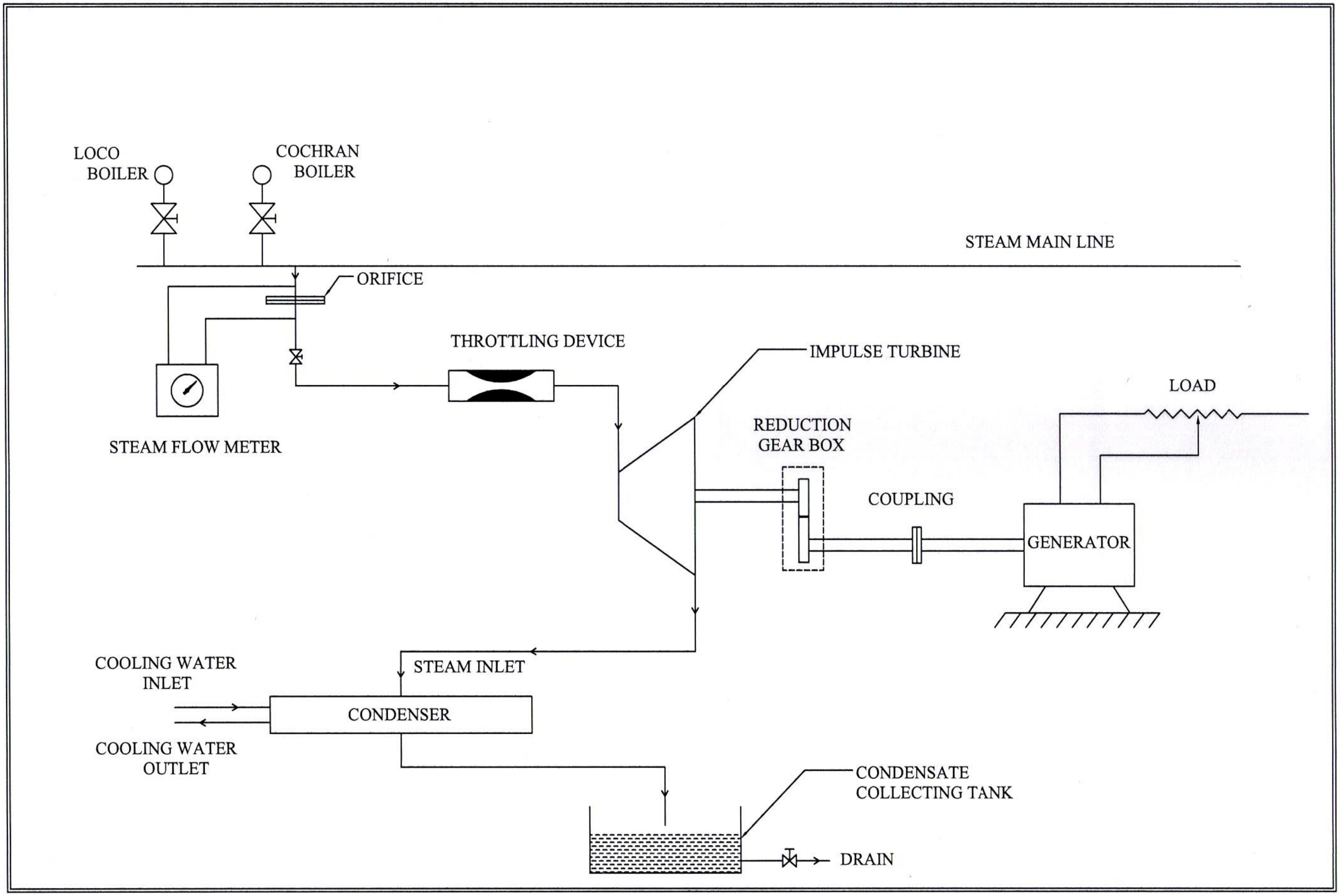
GOVERNING MECHANISM:

The turbine is fitted with 5 nozzles to achieve part load efficiency. Any nozzle is designed for a particular maximum discharge. Under part load conditions the turbine work:

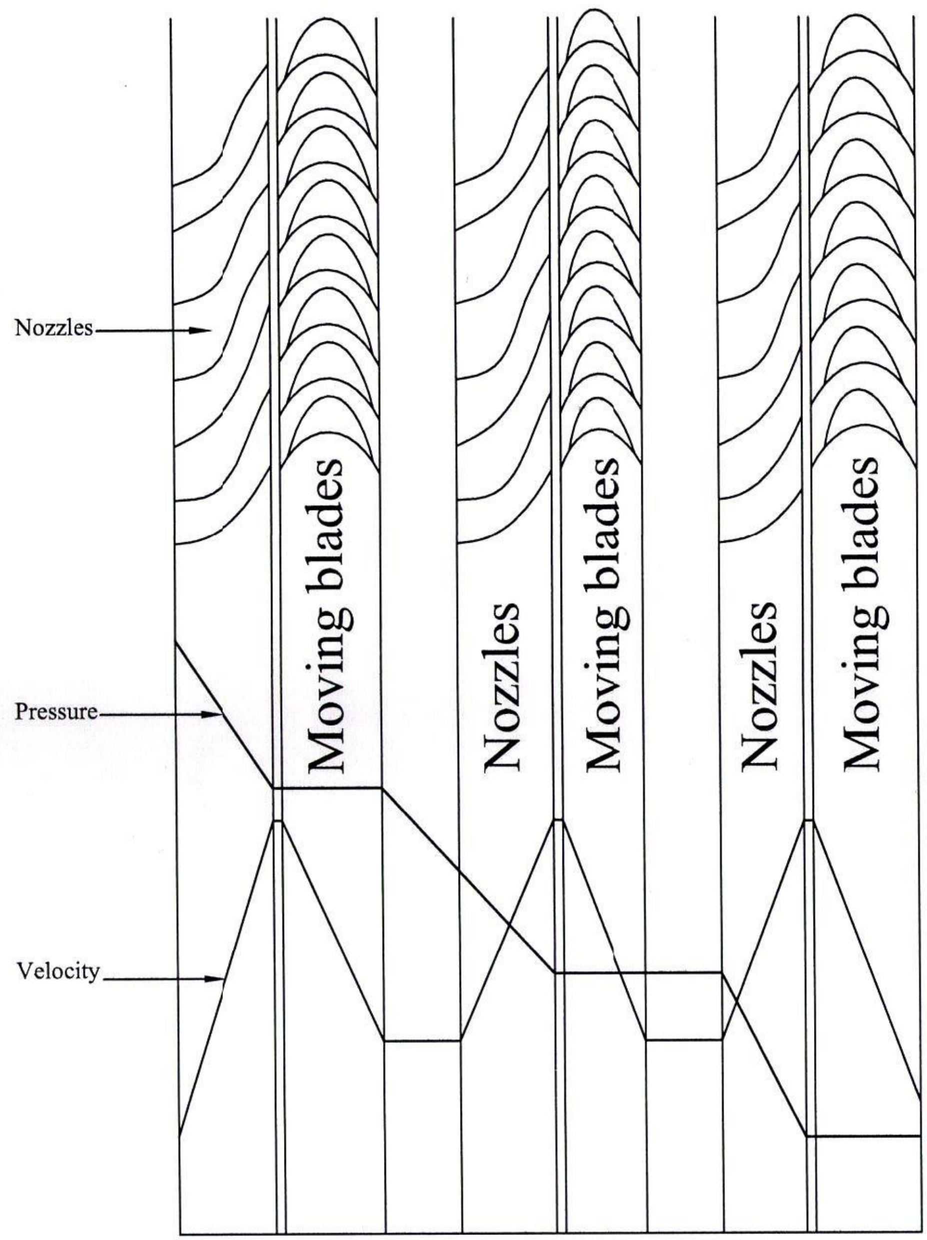
1. With the same isentropic total enthalpy drop of steam whose quantity is reduced or
2. With a lesser isentropic total enthalpy drop of same quantity of steam, or
3. With the same quantity of steam but the isentropic total enthalpy drop is reduced that is the inlet pressure reduced by throttling.

In the second case the ideal efficiency is very much lowered. However to maintain a constant speed it is impossible to keep the inlet pressure constant. Throttling has to be done to some extent.

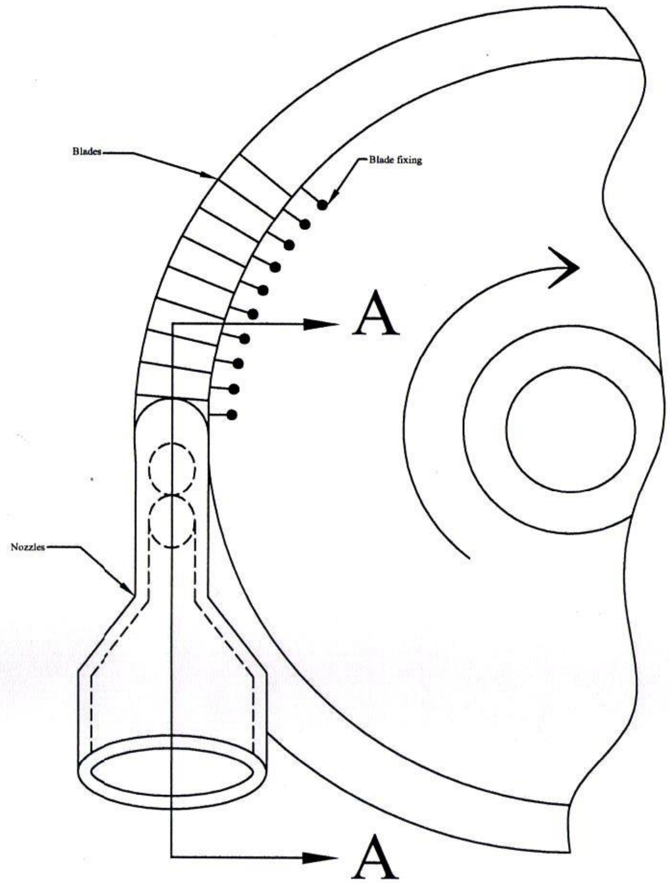
It is therefore obvious that the first method of part load operation is desirable. The reduction of the quantity of steam for part load operation is accomplished by shutting off one or more number of nozzles. In actual practice the number of nozzles open should be minimum necessarily. At this time the pressure gauge after throttling will indicate a pressure very close to the designed values which should be fully closed while in operation. Reduced opening may cause throttling at the nozzle inlet. The turbine is fitted with a constant speed governor. The governor shaft is coaxial with the out put shaft. The flying outwards or inwards of two spring loaded weights due to speed change of the turbine by a system of levers actuate a double beat throttle valve which controls the admission pressure according to the requirement. The reduction in the load on the turbine manifests itself as increase in speed of the turbine shaft, which causes the governor weight to fly outwards and this motion is communicated to the throttle valve which reduces the passage of steam ie, the inlet pressure is decreased by throttling.



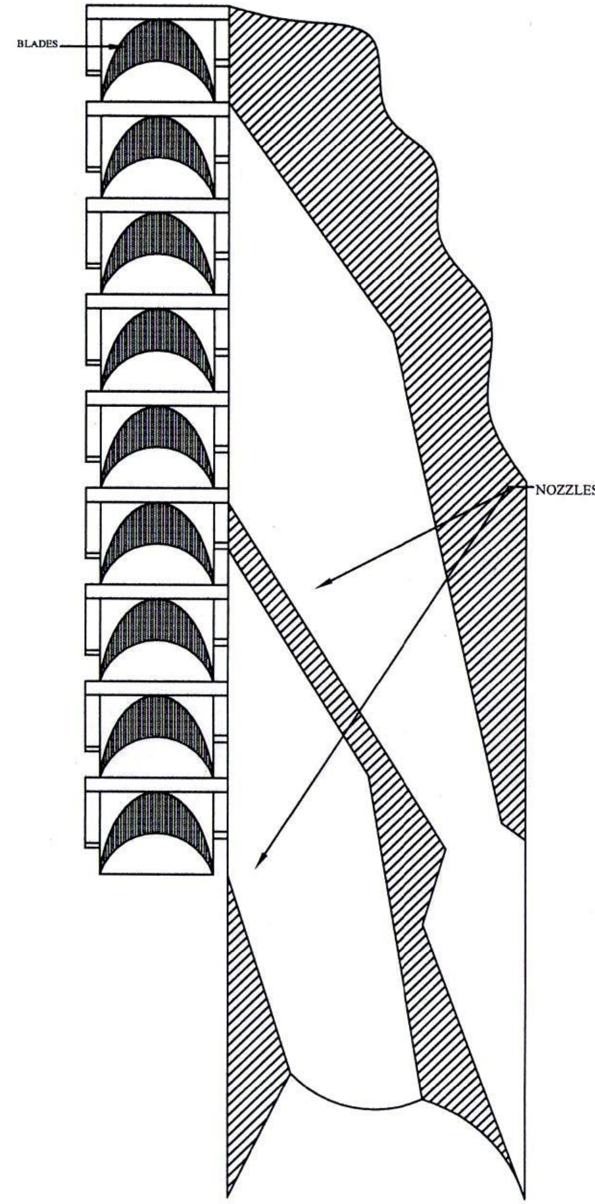
GREENBAT TURBINE AND CONDENSER



Variation in Pressure and Velocity



SIMPLE IMPULSE TURBINE



SHOWING CROSS - SECTION THROUGH BLADES AND NOZZLES

LUBRICATION AND COOLING:

The question of lubrication is very important to the satisfactory operation of all machines. All shafts are lubricated by oil supplied by a gear type pump driven by a counter shaft from the reduction gear. The oil which has lubricated and cooled all the bearings and reduction gear will be hot. Therefore it is passed through a oil collectorwhere it is cooled by circulating water. The oil pump supplies oil to the bearings and gearing at a pressure of 0.352 bar.

LOADING DEVICES:

The output shaft of the turbine is coupled to the armat ure of a DC generator. The generator is loaded by a rheostat. There is provision to measure the current and voltage and hence the output of the generator.

Date :

PERFORMANCE EVALUATION ON GREENBAT TURBINE

AIM:

To conduct a performance test on GREENBAT TURBINE and to draw various characteristics curves.

SPECIFICATIONS:

TURBINE:

Power : 7.36 kW (10 HP)

Steam Pressure : 7 bar.

Reduced turbine speed : 2400 rpm.

No. of nozzles 5

GENERATOR:

Power : 6.5 kW.

Voltage : 220 Volts.

Current : 29.5 Amps.

Loading Arrangement : Electrical resistance type.

OBSERVATIONS:-

				LOAD			
S.No	**Parameters**	**Symbol**	**Units**	**No load**	**I**	**II**	**III**
1.	Generated Voltage	V	Volts				
2.	Current	I	Amps				
3.	Speed	N	rpm				
4.	Supply Pressure[gauge]	P_1	kg/cm^2				
5.	Pressure after throttling [gauge]	P_2	kg/cm^2				
6.	Exhaust Pressure [vacuum]	P_3	cm of Hg				
7.	Time for collecting 5 kg of Condensate	t_1	sec				

Quality of supply steam (x) = __________

SPECIMEN CALCULATION:

1. Generator output in K.W = Volt x Amps.

$$= \frac{V \times I}{1000}$$

For No load

For first load

For second load

For third load

2. Steam flow rate (W) in kg/hr.

$$= \frac{\text{Mass of condensate in kg}}{\text{Time for collecting the condensate in sec.}} \times 3600$$

3. Supply steam Enthalpy (h_1) in kJ/kg._________.
[Corresponding to pressure P_1 & Quality of supply steam(X)]

4. Exhaust steam Enthalpy (h3) in kJ/kg._________.
[Using Mollier chart, Considering Throttling and Isentropic process]

5. Saturated water Enthalpy (h_{f3}) kJ/kg.________.
[From Steam table corresponding to exhaust pressure P_3.]

6. Available heat drop in kJ/kg
= Supply steam Enthalpy - Saturated Water Enthalpy.
= h_1 - h_{f3}=___________.

7. Adiabatic heat drop in kJ/kg
= Supply steam enthalpy - Exhaust steam Enthalpy.

= h_1 - h_3 =___________.

8. Specific steam rate in kg/kW hr

$$= \frac{\text{Steam flow rate in kg/hr}}{\text{Generator out put in KW}} =$$

9. Specific heat rate in kJ/kW hr

= Specific steam rate x Available heat drop

10. Overall thermal efficiency in %. ($\eta_{Overall}$)

$$\eta_{Overall} = \frac{\text{Generator output in kW}}{\dfrac{\text{Steam flow rate x Available heat drop in kJ/kg.}}{3600}} \times 100$$

11. Rankine Efficiency in % = $\dfrac{\text{Adiabatic heat drop}}{\text{Available heat drop}}$ 100

12. Relative Efficiency in % = $\dfrac{\text{Overall Thermal Efficiency}}{\text{Rankine Efficiency}}$ 100

13. Output of the Turbine or Generator input $= \dfrac{Generator\ output}{Generator\ efficiency}$

14. Specific Steam rate in terms of the output of the Turbine in kg/ kW hr

$$= \frac{\text{Steam flow rate}}{\text{Output of the Turbine}}$$

15. Specific heat rate in terms of the output of the Turbine in kJ/kW hr

= Specific steam rate in terms of the output of the turbine X Available heat drop

16. Overall thermal efficiency in terms of output of the turbine

$$= \frac{3600}{\text{Specific heat rate in terms of the output of the turbine}} \times 100$$

17. Relative efficiency in terms of output of the turbine in %

$$= \frac{\text{Overall thermal efficiency in terms of output of the turbine}}{\text{Rankine efficiency}} \times 100$$

GRAPH:

Generator output in kW Vs Overall Thermal Efficiency,
Relative Efficiency
Rankine Efficiency
Specific heat rate

RESULT TABULATION: -

			LOAD			
S.No	**Particulars**	**UNIT**	**No Load**	**I**	**II**	**III**
1.	Generator output	kW				
2.	Steam flow rate (W)	kg/hr				
3.	Supply steam Enthalpy (h_1)	kJ/kg				
4.	Supply steam Enthalpy (h_2)	kJ/kg				
5.	Saturated water Enthalpy (h_{f3})	kJ/kg				
6.	Available heat drop	kJ/kg				
7.	Adiabatic heat drop	kJ/kg				
8	Specific steam rate	kg/kW hr				
9.	Specific heat rate	kJ/kW hr				
10.	Over all Th.Efficiency	%				
11.	Rankine Efficiency	%				
12.	Relative Efficiency	%				
13.	Output of the Turbine	kW				
14.	Specific steam rate in kg/kW hr of the Turbine	kg/kW hr				
15.	Specific heat rate in terms of the output of the Turbine	kJ/kW hr				
16.	Overall Th.Effi. in terms of the out put of the turbine	%				
17.	Relative Effi. In terms of the output of the turbine	%				

RESULT:

STUDY AND PERFORMANCE PARAMETER EVALUATION ON STEAM CONDENSER (SURFACE)

STEAM CONDENSER (SURFACE)

SPECIFICATIONS:

Outer diameter of the condenser tube [D_o] = 0.0158 m
Length of condenser tube [L_o] = 0.826 m
Number of tube [Z_o] = 82

OBJECT OF CONDENSING EXHAUST STEAM:

In any heat engine the amount of work done per unit weight of working fluid depends on the range of temperature of that fluid in the engine. Efficiency is greater when the range is greater. In other words if the extent of the expansion of the fluid cannot be used over again and hence it has to be discharged to the atmosphere and the atmospheric pressure fixes the lower limit of expansion. When steam is the working fluid, it may be returned to the boiler in the form of liquid and used over again. This can be done most conveniently and most economically by pumping water rather than steam into the boiler.

ELEMENTS OF CONDENSING PLANT:

For the purpose of maintaining vacuum during condensation and removal of the exhaust steam the principal requirements are

1. A condenser in which steam is condensed.

2. Supply of cooling water.

3. A pump to circulate the cooling water.

4. A pump called the air pump for removing the condensed steam and air.

5. Atank for collecting the condensed steam discharged by the air pump.

DESCRIPTION OF THE CONDENSER:

The surface condenser consists of:

1. A horizontal shell of circular cross section.

2. Flat tube plates bolted on to ends of the shell to support the tubes.

3. Water boxes open to the tubes and surrounding them the water box at one end has a horizontal partition about half way up. The other box has only one compartment.

4. A large number of tubes extending between the tube plates and providing communication between the water boxes.

5. A large opening in the top of the shell to admit steam to the condenser.

6. A small opening at the bottom of the shell to lead the condensate.

Cooling water is pumped into the water compartment at front end which it passes through the lower nest of tubes to the water compartment at the other end. It then returns through the upper nest of tubes to the upper water compartment which then leads through the outlet at top. The steam enters the shell by the opening at the top of the shell and passing over the tube it is condensed and leaves through the opening at the bottom.

Thermometer pockets are provided to facilitate the measurement of temperatures of the cooling water at inlet and outlet and the incoming steam and condensate. A flow meter is fixed in the cooling water line so that the cooling water flow rate may be determined.

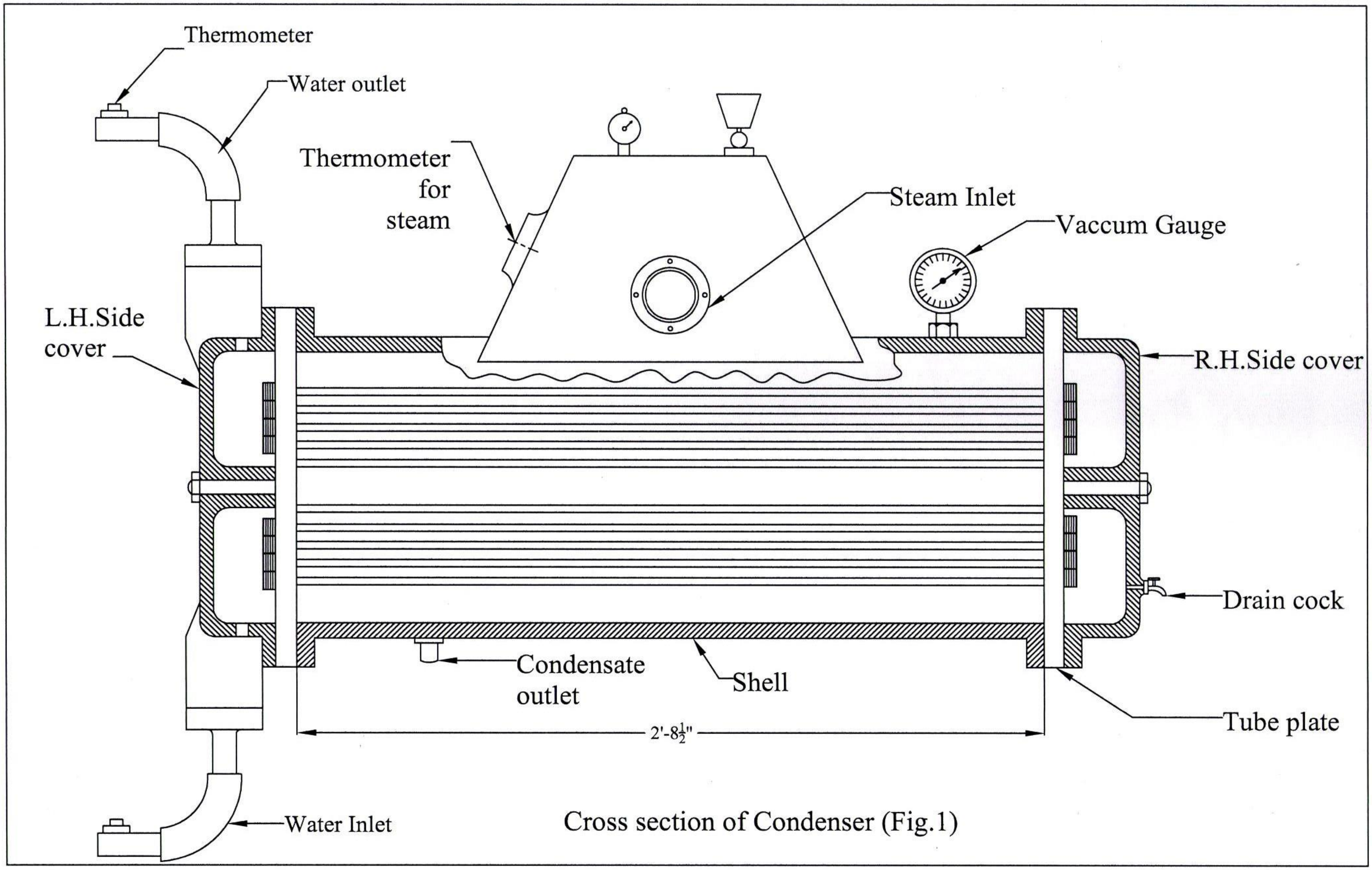
The air pump which creates vacuum as well as remo ves the condensate from the condenser is driven by electric motor through a V-belt drive. The motor is mounted on trunnions so that its output which is also the input to the air pump may be determined.

AIR PUMP

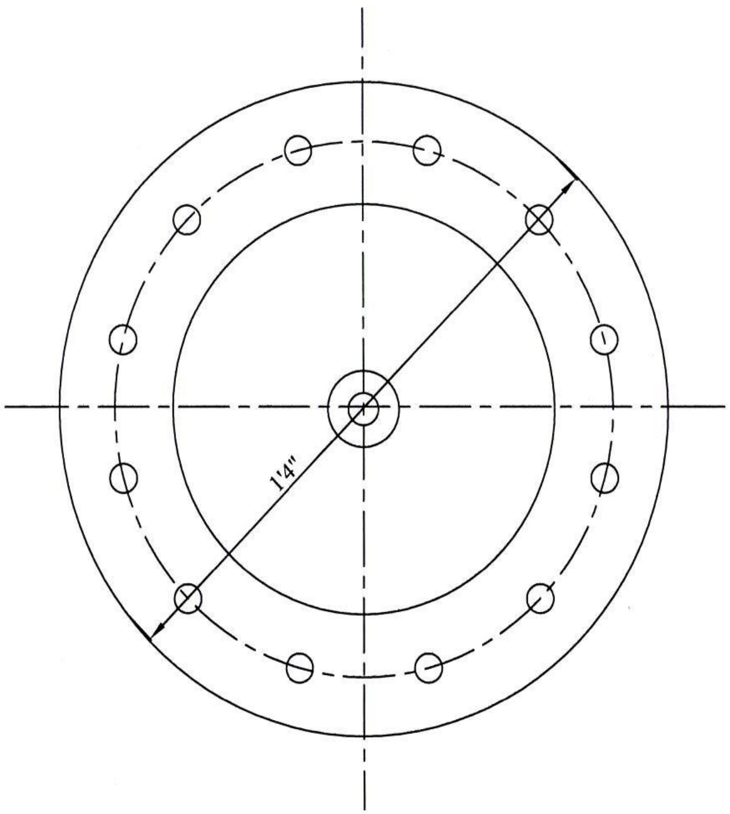
The main function of an air pump is to maintain a vacuum in the condenser as nearly as possible, corresponding to exhaust steam temperature. This is done by removing uncondensable air from the condenser. Another common, but not the essential function of the pump, is to remove both air and condensate from the condenser.

Th

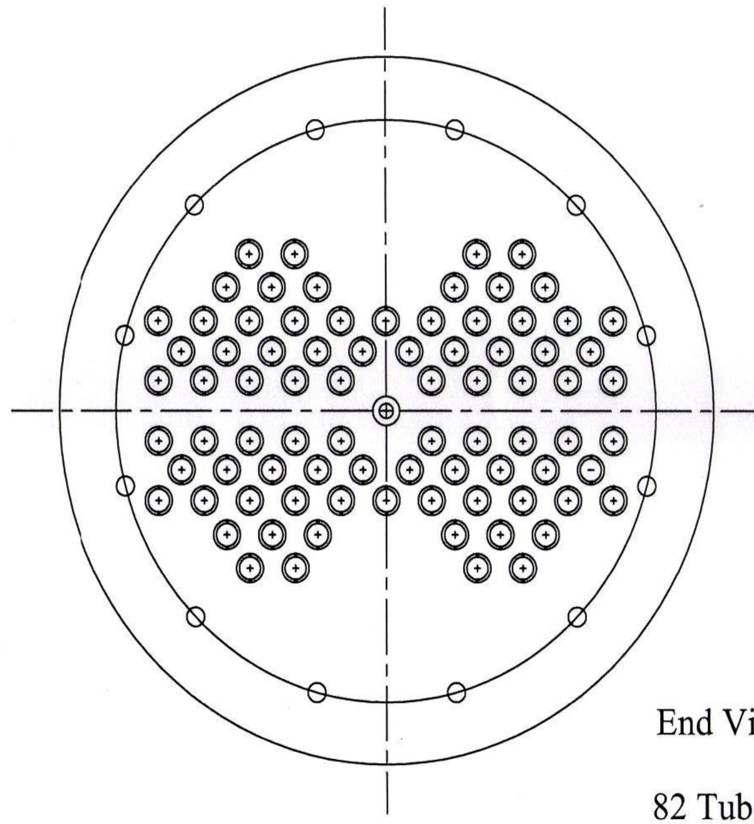
But a pump which extracts only moist air is known as dry air pump. The air pumps may be of reciprocating type or rotary type.



TWO – PASS CROSS FLOW SURFACE CONDENSOR



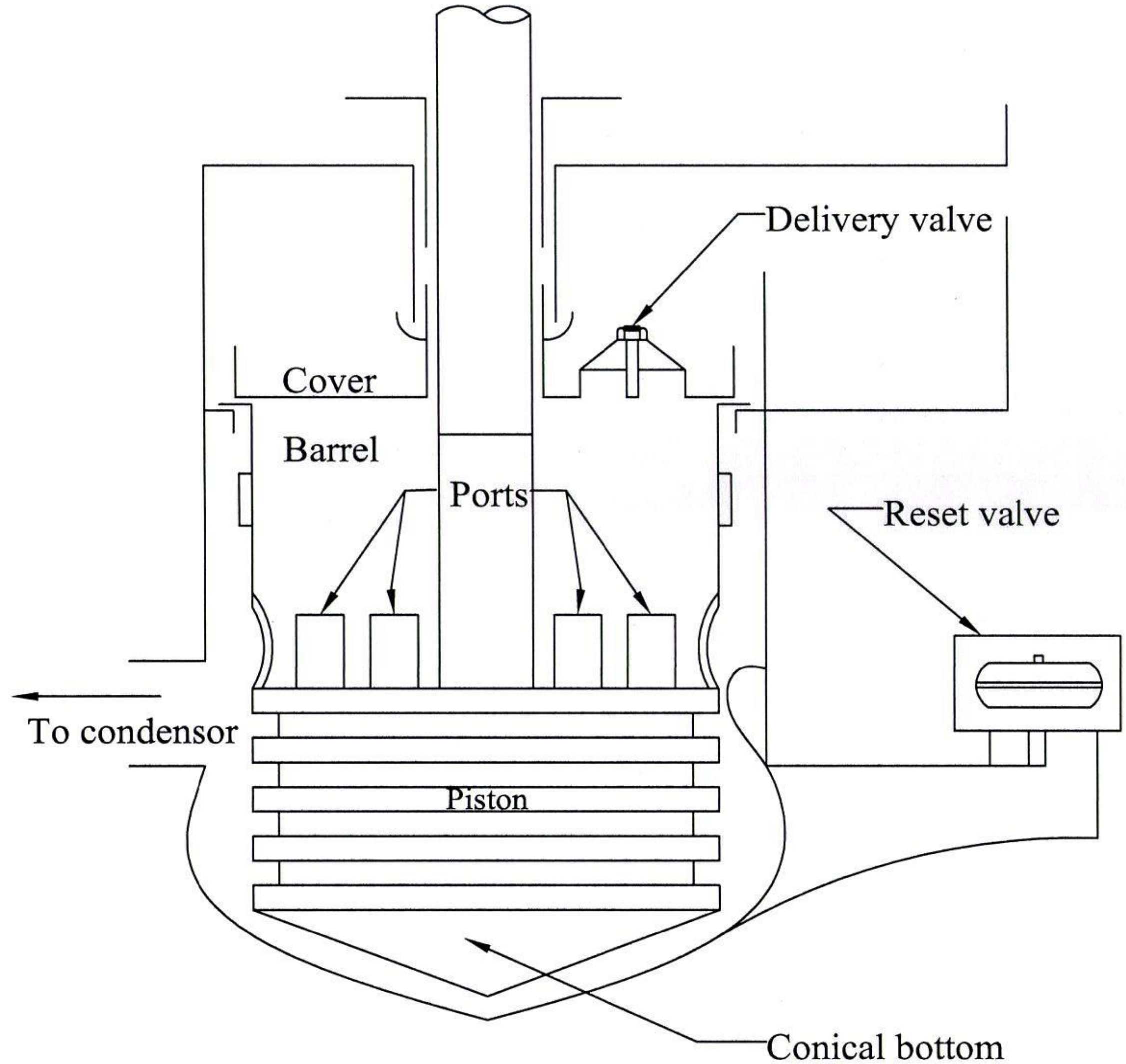
End View of R.H.Cover



End View

82 Tubes

Cross section of condenser tubes (Fig.2)



EDWARD"S AIR PUMP

Fig.3

EDWARD'S AIR PUMP:

It is a wet air pump of the reciprocating type. The Edward's air pump consists of delivery head valves as shown in figure. These valves are placed in the cover which is the top of the barrel lever. The reciprocating piston of the pump is flat on its upper surface and conical at the bottom as shown. The pump lever has a ring of ports around its lower end for the whole circumference this communicates with condenser.

When piston is at the top of the barrel, the condensate and air from the condenser are collected in the conical portion. In lower part of the barrel, through the ports on the downward stroke of the piston, the vacuum is produced above it since the head valves are closed and sealed by water. The piston uncovers the ports. When it moves downwards, the mixture of condensate, vapour and air rushes into the space above the piston. This mixture is compressed, when the piston goes to the top and raises the pressure slightly above the atmospheric pressure. The head valves are now open, which allow the mixture to pass on the weir to the hot well, which is at atmospheric pressure. A relief valve is placed in the base of the cylinder to release the pressure.

Expt.No:

Date :

PERFORMANCE EVALUATION ON STEAM CONDENSER

AIM:-

To conduct a performance test on TWO PASS CROSS FLOW SURFACE CONDENSER.

SPECIFICATIONS:

Outer diameter of the condenser tube [D_o] = 0.0158 m
Length of condenser tube [L_o] = 0.826 m
Number of tube [Z_o] = 82

OBSERVATIONS:

				LOAD			
S.No	**Parameters**	**Symbol**	**Units**	**No load**	**I**	**II**	**III**
1.	Voltage	V	Volts				
2.	Current	I	Amps				
3.	Condenser Vacuum Pressure (gauge)	P_4	cm/ hg				
4.	Inlet temp. of Steam in to condenser	T_1	°C				
5.	Inlet temp. of Coolant	T_2	°C				
6.	Temp. of Condensate	T_3	°C				
7.	Outlet temp. of Coolant	T_4	°C				
8.	Time for flow of 10 Gallons of Cooling water		sec				

Quality of supply steam (X) = __________

SPECIMEN CALCULATION: (For any one load)

1. Saturation temperature at condenser pressure P_4 abs. [Ts °C]
   (From steam table corresponding to condenser pressure [P_4 abs].

2. Condenser efficiency, % η_{Con}

$$= \frac{\text{[Temp. of coolant outlet] - [Temp. of coolant inlet]}}{\text{[Sat. temp. at condenser pr. } P_4 \text{ abs.] - [Temp. of coolant inlet]}} \times 100$$

$$= \frac{T_4 - T_2}{T_s - T_2} \times 100$$

3. Vacuum efficiency in % η_{Vacuum}

$$= \frac{\text{Condenser pressure, } P_4 \text{ bar}}{\text{Saturation pressure at temp.of steam inlet to condenser}} \times 100$$

To find saturation pressure (From steam table corresponding to inlet temperature of steam (T_1))

4. Degree of under cooling

= Sat. temp.at condenser pressure - Temp. of condensate.

$= [T_s - T_3]\ ^0C$

5. Logarithmic mean temperature difference [LMTD]

$$= \frac{\text{Temp. of coolant outlet - Temp. coolant inlet.}}{\ln\left(\dfrac{\text{Temp. of steam inlet - Temp. of coolant inlet.}}{\text{Temp. of steam inlet - Temp. of coolant outlet.}}\right)}$$

$$= \frac{[T_4 - T_2]}{\ln([T_1 - T_2]/[T_1 - T_4])}\ ^\circ C$$

6. Cooling water flow rate W_c, kg/hr.

$$= \frac{\text{Mass of cooling water, kg x 3600}}{\text{time for flow of the above mass of cooling water, sec.}}$$

7. Heat transfer rate Q in kJ/hr

= Cooling water flow rate x [temp. of coolant outlet - coolant inlet]

= W_c x C_p [T4 - T_2].

Where,

C_p = Specific heat of water in kJ / kg ^{0}C

C_p = 4.186 kJ / kg ^{0}C

8. Area of heat transfer of the condenser tubes [A_o] m^2

= Surface area of one tube x No. of tubes.

= 22/7 x D_o x L_o x Z_o

Where

D_o = Outer dia. of the condenser tube.
L_o = Length of the condenser tube.
Z_o = No. of tubes.

9. Overall heat transfer co-efficient $U_o = \frac{}{A_o (LMTD)}$

$$= \frac{\text{Heat transfer rate}}{\text{Area of heat transfer x LMTD}}$$

$$= \frac{Q}{A_o \times LMTD} \text{ kJ/m}^2 \text{ hr } ^0C$$

RESULT TABULATION:

			LOAD			
S.No	**Parameter**	**Units**	**No Load**	**I**	**II**	**III**
1.	Sat. temperature at Condenser Pr.	°C				
2.	Condenser Efficiency	%				
3.	Vacuum Efficiency	%				
4.	Deg. Of under cooling	°C				
5.	LMTD	°C				
6.	Cooling water flow rate	kg/hr				
7.	Heat transfer rate	kJ/hr				
8.	Area of Heat transfer of condenser tubes	m^2				
9.	Overall Heat transfer co-efficient	kJ/m^2 hr °C				

RESULT: