Bangladesh University of Engineering and Technology

Course Number: **ME-420** Group Number:

Course Title: **Steam and Power Plant Sessional**

Experiment Number:

Name of the Experiment(s):

Date of Performance:

Date of Submission:

SUBMITTED BY

Name:

Student ID:

Department:

Section:

Department of Mechanical Engineering, BUET, Dhaka-1000

ME 420: Steam and Power Plant Sessional

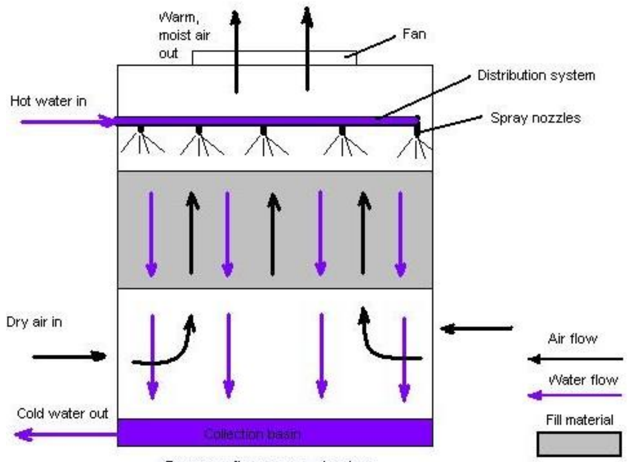
Experiment No.: 01 | Name of the Experiment: Performance Test of a Cooling Tower

Date of Performance:	**Date of Report Submission:**
Submitted by:	

1. Line Diagram of Test Set up

Draw the line diagram of the experimental set up, label important components. Also indicate the location of different test parameters

2. Schematic Diagram of the Cooling Tower



Counterflow type design

3. Data Sheet

A. Physical Dimension:

I. Cooling Tower:

a. Length, $L = 2.00$ m
b. Breadth, $b = 1.88$ m
c. Height, $h = 2.61$ m

Fill material of the cooling tower: ___________________

II. Air Duct:

a. Duct Dia, $d_d = 0.482$ m
b. Orifice Dia, $d_a = 0.216$ m

III. Water Pipe:

a. Pipe Dia, $d_p = 0.076$ m
b. Orifice Dia, $d_w = 0.032$ m

B. Ambient Condition:

I. Atmospheric Pressure, P = _______________mm of Hg = _____________kPa

II. Dry Bulb Temperature, $T_{DB,\,i}$ = ____________ °C

III. Wet Bulb Temperature, $T_{WB,\,i}$ = ____________°C

C. Operating Condition during Experiment:

No. of Obs.	Water Flow Data			Air Flow Data		
	ΔH_{Hg} (mm)	$T_{w,\,i}$ (°C)	$T_{w,\,o}$ (°C)	ΔH_w (mm)	$T_{DB,\,o}$ (°C)	$T_{WB,\,o}$ (°C)
1						
2						
3						
4						
5						

4. Calculation Sheet

No of Observations	1	2	3	4	5
Density of Air, ρ (kg/m^3)					
Mass Flow Rate of Air, m_a (kg/s)					
Mass Flow Rate of Water, m_w (kg/s)					
Water Air Ratio, m_w / m_a					
Specific Humidity of Inlet Air, ω_i (kg water vapor/kg of dry Air), corresponding to ($T_{DB, i}$, $T_{WB, i}$)					
Specific Humidity of Outlet Air, ω_o (kg water vapor/kg of dry Air) corresponding to ($T_{DB, o}$, $T_{WB, o}$)					
$\Delta\omega$(kg water vapor/kg of dry Air)					
Make-up Water (kg/s)					
% Make-up					
Actual Cooling Range, R_A (°C)					
Theoretical Cooling Range, R_T (°C)					
Cooling Efficiency					
Heat Content of Incoming Hot Water (kW)					
Heat Content of Outgoing Cold Water (kW)					
Heat Content of Dry Inlet Air (kW)					
Heat Content of water vapor in air at Inlet (kW)					
Heat Content of Dry Air at Outlet (kW)					
Heat Content of water vapor in air at Outlet (kW)					
Unaccounted Heat (kW)					

5. Equations Used for Calculation of various test parameters

Sl.	Test Parameter	Equation	Nomenclature
1.	Density of Air (kg/m^3)	$\rho_a = \frac{P}{RT_{DB,i}}$	R: Universal Gas Constant= 287 Jkg^{-1}K^{-1} $T_{DB,i}$ = Dry Bulb Temperature at ambient/inlet condition
2.	Velocity of Air @ Orifice (m/s)	$V_a = \sqrt{\frac{2g\Delta H_{air}}{\left[1-\left\{\frac{d_a}{d_d}\right\}^4\right]}}$	ΔH_w: Equivalent Air Column Height corresponding to the manometric deflection of air orifice meter
3.	Mass Flow Rate of Air, m_a (kg/s)	$m_a = C_d A_{o,a} \rho_a V_a = C_d \left(\frac{\pi}{4} d_a^2\right) \rho_a V_a$	C_d: Co-efficient of Discharge of Air Orifice meter (0.6)
4.	Velocity of Water @ Orifice (m/s)	$V_w = \sqrt{\frac{2g\Delta H_{water}}{\left[1-\left\{\frac{d_w}{d_p}\right\}^4\right]}}$	ΔH_{water}: Equivalent Water Column Height corresponding to the manometric deflection of water orifice meter
5.	Mass Flow Rate of Water, m_w (kg/s)	$m_w = C_d A_{o,w} \rho_w V_w = C_d \left(\frac{\pi}{4} d_w^2\right) \rho_w V_w$	C_d: Co-efficient of Discharge of Water Orifice meter (0.6)
6.	Water Air Ratio	m_w / m_a	
7.	Make Up Water (kg/s)	$m_{make\,up} = m_a \Delta\omega = m_a(\omega_o - \omega_i)$	
8.	% Make Up	$\frac{m_{make\,up}}{m_w} \times 100\%$	
9.	Actual Cooling Range, R_A (°C)	$R_A = (T_{w,i} - T_{w,o})$	
10.	Theoretical Cooling Range, R_T (°C)	$R_T = (T_{w,i} - T_{WB,i})$	
11.	Cooling Efficiency	$\eta_c = \frac{R_A}{R_T} \times 100\%$	
12.	Heat of Incoming Hot Water (kW)	$H_{W,i} = m_w h_{w,i}$	$h_{w,i}$: Enthalpy of incoming hot water (Assume saturated water at $T_{w,i}$)
13.	Heat of Outgoing Cold Water (kW)	$H_{W,o} = m_w h_{w,o}$	$h_{w,o}$: Enthalpy of outgoing cold water (Assume saturated water at $T_{w,o}$)
14.	Enthalpy of Dry Air at inlet (kW)	$H_{a,i} = m_a h_{a,i} = m_a(1.005 T_{DB,i})$	
15.	Enthalpy of water vapor in air at inlet(kW)	$H_{w,i} = m_w h_w = m_a \omega_i (2500 + 1.86 T_{DB\,i})$	
16.	Enthalpy of Dry Air at outlet (kW)	$H_{a,o} = m_a h_{a,o} = m_a(1.005 T_{DB,o})$	
17.	Enthalpy of water vapor in air at outlet(kW)	$H_{w,o} = m_w h_{w,o} = m_a \omega_o (2500 + 1.86 T_{DB,o})$	

6. Modular Cooling Tower

Draw the line diagram of the modular cooling tower in the lab and label important components.

Modular Cooling Tower

Fan Motor

Distributor System and Fill Material

7. Results and Discussion

I. Plot Cooling Efficiency and % Make-Up water against water –air ratio in plain graph.
II. Analyze the process data and obtained results and write a comprehensive discussion on construction and performance of cooling tower.

Saturated Water, Temperature Table

Table C.1b Saturated Water, Temperature Table (Metric Units)

		Volume, m^3/kg		Energy, kJ/kg		Enthalpy, kJ/kg			Entropy, kJ/(kg · K)		
T, °C	p, MPa	v_f	v_g	u_f	u_g	h_f	h_{fg}	h_g	s_f	s_{fg}	s_g
0.010	0.0006113	0.001000	206.1	0.0	2375.3	0.0	2501.3	2501.3	0.0000	9.1571	9.1571
2	0.0007056	0.001000	179.9	8.4	2378.1	8.4	2496.6	2505.0	0.0305	9.0738	9.1043
5	0.0008721	0.001000	147.1	21.0	2382.2	21.0	2489.5	2510.5	0.0761	8.9505	9.0266
10	0.001228	0.001000	106.4	42.0	2389.2	42.0	2477.7	2519.7	0.1510	8.7506	8.9016
15	0.001705	0.001001	77.93	63.0	2396.0	63.0	2465.9	2528.9	0.2244	8.5578	8.7822
20	0.002338	0.001002	57.79	83.9	2402.9	83.9	2454.2	2538.1	0.2965	8.3715	8.6680
25	0.003169	0.001003	43.36	104.9	2409.8	104.9	2442.3	2547.2	0.3672	8.1916	8.5588
30	0.004246	0.001004	32.90	125.8	2416.6	125.8	2430.4	2556.2	0.4367	8.0174	8.4541
35	0.005628	0.001006	25.22	146.7	2423.4	146.7	2418.6	2565.3	0.5051	7.8488	8.3539
40	0.007383	0.001008	19.52	167.5	2430.1	167.5	2406.8	2574.3	0.5723	7.6855	8.2578
45	0.009593	0.001010	15.26	188.4	2436.8	188.4	2394.8	2583.2	0.6385	7.5271	8.1656
50	0.01235	0.001012	12.03	209.3	2443.5	209.3	2382.8	2592.1	0.7036	7.3735	8.0771
55	0.01576	0.001015	9.569	230.2	2450.1	230.2	2370.7	2600.9	0.7678	7.2243	7.9921
60	0.01994	0.001017	7.671	251.1	2456.6	251.1	2358.5	2609.6	0.8310	7.0794	7.9104
65	0.02503	0.001020	6.197	272.0	2463.1	272.0	2346.2	2618.2	0.8934	6.9384	7.8318
70	0.03119	0.001023	5.042	292.9	2469.5	293.0	2333.8	2626.8	0.9549	6.8012	7.7561
75	0.03858	0.001026	4.131	313.9	2475.9	313.9	2321.4	2635.3	1.0155	6.6678	7.6833
80	0.04739	0.001029	3.407	334.8	2482.2	334.9	2308.8	2643.7	1.0754	6.5376	7.6130
85	0.05783	0.001032	2.828	355.8	2488.4	355.9	2296.0	2651.9	1.1344	6.4109	7.5453
90	0.07013	0.001036	2.361	376.8	2494.5	376.9	2283.2	2660.1	1.1927	6.2872	7.4799
95	0.08455	0.001040	1.982	397.9	2500.6	397.9	2270.2	2668.1	1.2503	6.1664	7.4167
100	0.1013	0.001044	1.673	418.9	2506.5	419.0	2257.0	2676.0	1.3071	6.0486	7.3557
110	0.1433	0.001052	1.210	461.1	2518.1	461.3	2230.2	2691.5	1.4188	5.8207	7.2395
120	0.1985	0.001060	0.8919	503.5	2529.2	503.7	2202.6	2706.3	1.5280	5.6024	7.1304
130	0.2701	0.001070	0.6685	546.0	2539.9	546.3	2174.2	2720.5	1.6348	5.3929	7.0277
140	0.3613	0.001080	0.5089	588.7	2550.0	589.1	2144.8	2733.9	1.7395	5.1912	6.9307
150	0.4758	0.001090	0.3928	631.7	2559.5	632.2	2114.2	2746.4	1.8422	4.9965	6.8387
		Volume, m^3/kg		Energy, kJ/kg		Enthalpy, kJ/kg			Entropy, kJ/(kg · K)		
T, °C	p, MPa	v_f	v_g	u_f	u_g	h_f	h_{fg}	h_g	s_f	s_{fg}	s_g
160	0.6178	0.001102	0.3071	674.9	2568.4	675.5	2082.6	2758.1	1.9431	4.8079	6.7510
170	0.7916	0.001114	0.2428	718.3	2576.5	719.2	2049.5	2768.7	2.0423	4.6249	6.6672
180	1.002	0.001127	0.1941	762.1	2583.7	763.2	2015.0	2778.2	2.1400	4.4466	6.5866
190	1.254	0.001141	0.1565	806.2	2590.0	807.5	1978.8	2786.4	2.2363	4.2724	6.5087
200	1.554	0.001156	0.1274	850.6	2595.3	852.4	1940.8	2793.2	2.3313	4.1018	6.4331
210	1.906	0.001173	0.1044	895.5	2599.4	897.7	1900.8	2798.5	2.4253	3.9340	6.3593
220	2.318	0.001190	0.08620	940.9	2602.4	943.6	1858.5	2802.1	2.5183	3.7686	6.2869
230	2.795	0.001209	0.07159	986.7	2603.9	990.1	1813.9	2804.0	2.6105	3.6050	6.2155
240	3.344	0.001229	0.05977	1033.2	2604.0	1037.3	1766.5	2803.8	2.7021	3.4425	6.1446
250	3.973	0.001251	0.05013	1080.4	2602.4	1085.3	1716.2	2801.5	2.7933	3.2805	6.0738
260	4.688	0.001276	0.04221	1128.4	2599.0	1134.4	1662.5	2796.9	2.8844	3.1184	6.0028
270	5.498	0.001302	0.03565	1177.3	2593.7	1184.5	1605.2	2789.7	2.9757	2.9553	5.9310
280	6.411	0.001332	0.03017	1227.4	2586.1	1236.0	1543.6	2779.6	3.0674	2.7905	5.8579
290	7.436	0.001366	0.02557	1278.9	2576.0	1289.0	1477.2	2766.2	3.1600	2.6230	5.7830
300	8.580	0.001404	0.02168	1332.0	2563.0	1344.0	1405.0	2749.0	3.2540	2.4513	5.7053
310	9.856	0.001447	0.01835	1387.0	2546.4	1401.3	1326.0	2727.3	3.3500	2.2739	5.6239
320	11.27	0.001499	0.01549	1444.6	2525.5	1461.4	1238.7	2700.1	3.4487	2.0883	5.5370
330	12.84	0.001561	0.01300	1505.2	2499.0	1525.3	1140.6	2665.9	3.5514	1.8911	5.4425
340	14.59	0.001638	0.01080	1570.3	2464.6	1594.2	1027.9	2622.1	3.6601	1.6765	5.3366
350	16.51	0.001740	0.008815	1641.8	2418.5	1670.6	893.4	2564.0	3.7784	1.4338	5.2122
360	18.65	0.001892	0.006947	1725.2	2351.6	1760.5	720.7	2481.2	3.9154	1.1382	5.0536
370	21.03	0.002213	0.004931	1844.0	2229.0	1890.5	442.2	2332.7	4.1114	0.6876	4.7990
374.136	22.088	0.003155	0.003155	2029.6	2029.6	2099.3	0.0	2099.3	4.4305	0.0000	4.4305

Carrier

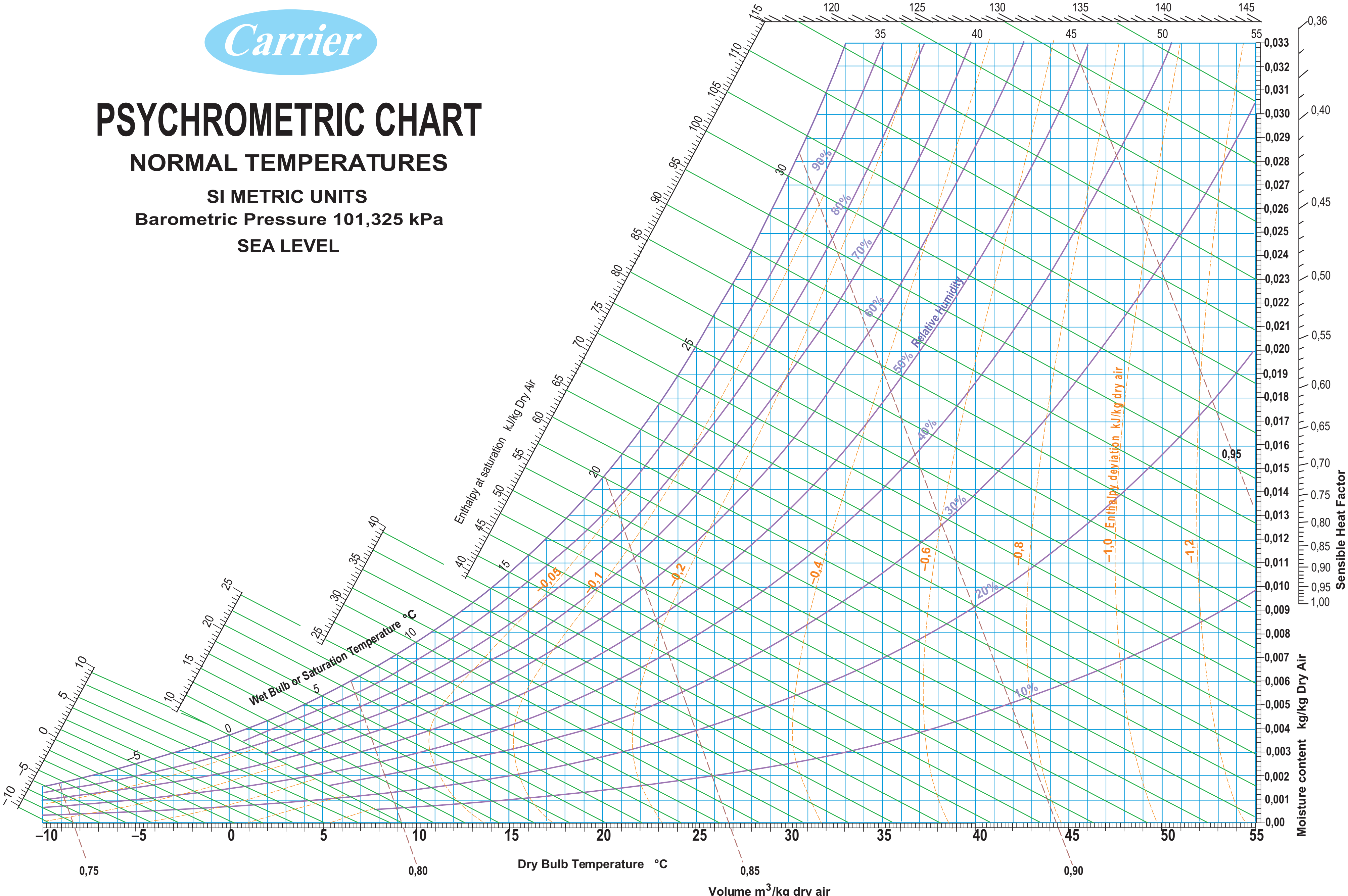
PSYCHROMETRIC CHART

NORMAL TEMPERATURES

SI METRIC UNITS

Barometric Pressure 101,325 kPa

SEA LEVEL



Below 0°C, Properties and Enthalpy Deviation Lines Are For Ice

EXPERIMENT NO. 02

STUDY OF A BOILER

1. Write down the specification of the fire tube boiler studied.

Brand Name: Model:

Country of Make: No of Tubes:

Maximum working pressure: Safety valve pressure settings:

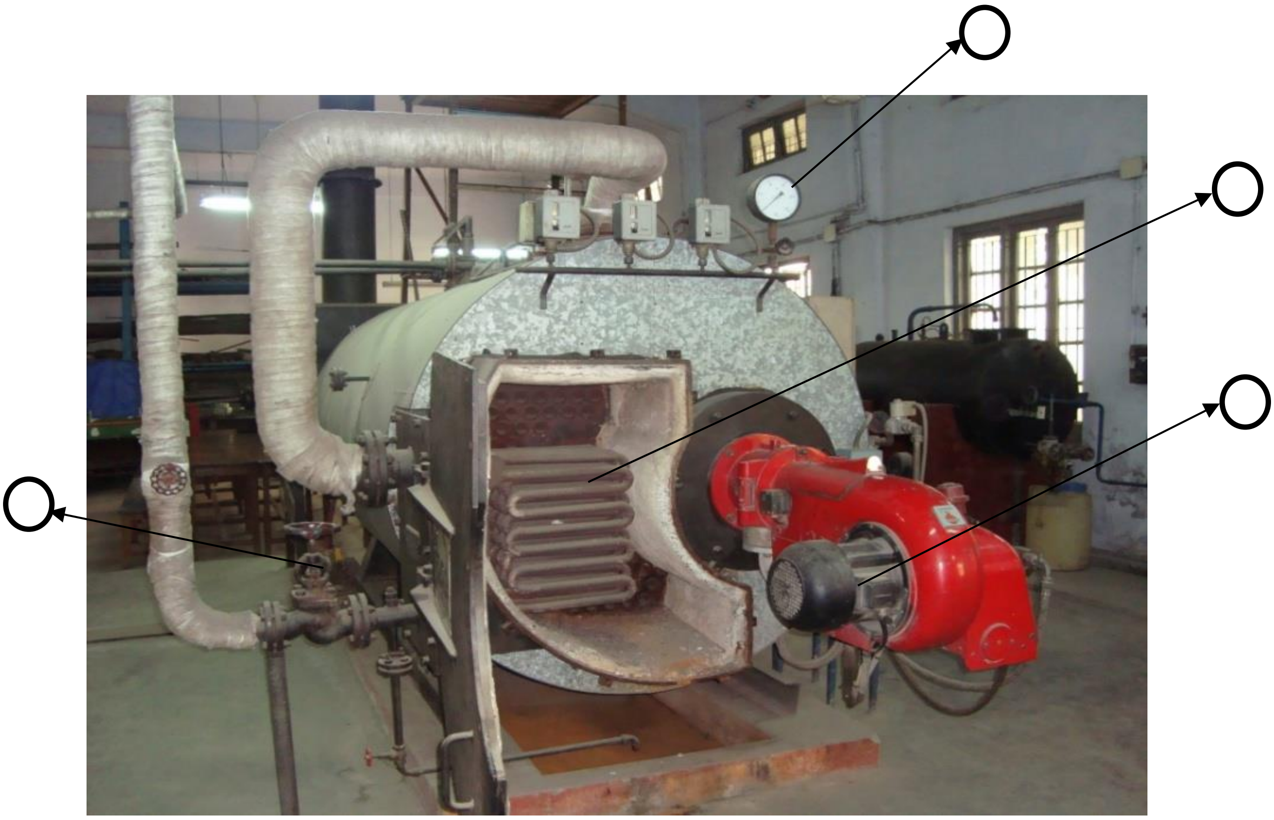
Type of Burner: Fuel/fuels used:

Capacity:__________kg/h,_________Ton No of Pass:

2. Identify different mountings & accessories on the boiler photograph shown:

1- 2- 3-

4- 5- 6-



5-

6-

7-

8-

3. Define tonnage rating of a Boiler.

4. Briefly state the control mechanism of maintaining the water level in a boiler.

5. a) Draw a line diagram of the water flow circuit which includes the water treatment plant.

b) List the parameters that are controlled by water treatment system-

6. Draw the fuel flow circuit showing both the gas and liquid fuel options.

7. Briefly state air and fuel flow conditions for Purging, Pilot flame and main flame.

8. Briefly state the functions and pressures setting of safety valve.

9. Define Hydraulic test of a boiler.

10. Study the thermal balance of the boiler.

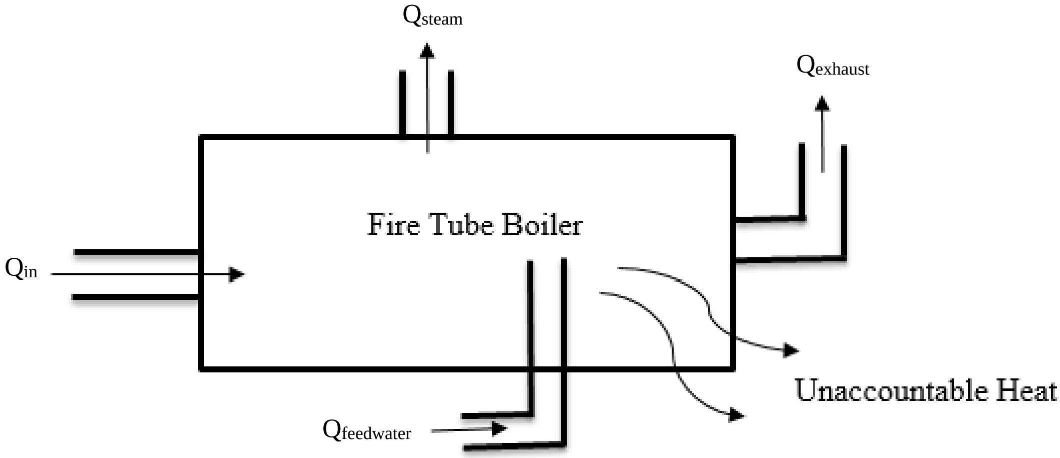


Fig. Block Diagram of heat flow of boiler

a) Equations for Thermal heat balance are as follows:

$$Q_{in}+Q_{feedwater}= Q_{steam}+ Q_{exhaust}+ Q_{unaccounted}$$

Consider,

$$\begin{bmatrix} Calorific\ value\ of\ natural\ gas = 38\, MJ\ /Nm^3 \\ Density\ of\ natural\ gas = 0.67\ \ kg/Nm^3 \end{bmatrix}$$

$Q_{in} = Q_{fuel} = \dot{m}_{fuel} \times$ HHV of fuel (Natural Gas), where $\dot{V}_{fuel} \times \rho_{fuel} = \dot{m}_{fuel}$

=

=

$Q_{steam} = \dot{m}_{steam} \times h_{steam}$ (Steam at 10° of superheating)

=

=

$Q_{feedwater} = \dot{m}_{\mathrm{feedwater}} \times h_{feedwater}$ at inlet temp.

=

=

Considering $\dot{m}_{\text{feedwater}} = \dot{m}_{steam}$

$Q_{exhaust} = \dot{m}_{\text{exhaust}} \times C_p \times \Delta T_{exhaust}$

Where, C_p = C_p of air at exhaust temp (T_{room} and $T_{exhaust}$ is measured)

$$\dot{m}_{\text{exhaust}} = A_{chimney} \times \rho_{exhaust} \times V_{exhaust} = \dot{m}_{fuel} + \dot{m}_{air}$$

AF for Natural Gas (mainly CH_4) ≈ 17.2 Kg of Air/Kg of NG

$\dot{m}_{air} = \dot{m}_{fuel} \times AF_{NG} \times$ %Excess Air

So,
$\dot{m}_{\text{exhaust}} = (17.2 \times 1.2 + 1) \times \dot{m}_{fuel},$ (Consider 20% excess air)

=

=

Hence, $Q_{exhaust}$ =

And $Q_{unaccounted}$ =

b) Efficiency of the boiler

$$\eta_{boiler} = \frac{\dot{m}_{steam}(h_{steam} - h_{water})}{\dot{m}_{fuel} \times HHV_{fuel}} \times 100\%$$

=

=

Here, _________ % of input heat is used in making steam, _________ % is lost with exhaust and _________ % for unaccountable loss.

c) Equivalent Steam Rate = $\frac{\dot{m}_{steam}(h_{steam} - h_{feedwater})}{2257}$, Where h in kj/kg

=

=

11. Discussion:

Experiment no.: 03

Study and Performance Test of a Refrigeration Unit

Objectives:

Apparatus:

Specifications:

1. Model	
2. Type of refrigerants	
3. Power input	
4. Compressor side maximum pressure	
5. Suction side minimum pressure	
6. Type of transducer used for measuring temperature	
7. Compressor	
8. Sub-cooling availability	
9. Super heating availability	

Experimental Set-up:

P-h Diagram:

Table 1: Enthalpy of the refrigerant at different state

State point	Temperature (℃)	Enthalpy (kJ/Kg)
1		
2		
3		
4		

Table 2: Flow rate data of Refrigerant and water

No. Of Obs.	Refrigerant			Water		
	Flow rate		Suction Specific Volume (m^3/kg)	Flow Rate (kg/s)	Temperature	
	L/min	Kg/hr			Inlet (°C)	Outlet (°C)
1						
2						

Table 3: Results

No. of Obs.	Volumetric Efficiency η_v (%)	Heat rejection capacity		Refri. Effect (kW)	Coefficient Of Performance (COP)	kW/Ton
		Based on Cooling Water (kW)	Based on Enthalpy of Refrigerant (kW)			
1						
2						

Sample Calculation:

For observation no. -

The total cylinder displacement volume = 2.57×10^{-4} m^3

Specific heat of water = 4.187 kJ/Kg°C

Flow rate of refrigerant, m_r =

Flow rate of water, m_w =

Specific volume of refrigerant, v_r =

Compressor speed, n =

Displacement volume, V_p = 2.57×10^{-4} m^3

Volumetric efficiency of compressor,

$$\eta v = \frac{m_r * v_r}{60 * n * V_p}$$

Heat rejection capacity of the compressor:

a) Based on heat extracted by condenser cooling water,

$$Q_c = C_w * m_w * (T_8 - T_7)$$

b) Based on enthalpy of refrigerant,

$$Q_C = \frac{m_r * (h_2 - h_3)}{3600}$$

Refrigeration Effect

$$Q_E = \frac{m_r * (h_1 - h_4)}{3600}$$

Coefficient of Performance

$$\text{COP} = \frac{h_1 - h_4}{h_2 - h_1}$$

$$\text{kW}/_{ton} = \frac{Wattmeter\ reading}{Refrigeration\ effect\ in\ ton}$$

Questions and Answers:

Discussion:

EXPERIMENT 4: STUDY OF GAS TURBINE SYSTEMS

a) Study of a Rover Gas Turbine
b) Study of an Turbo Jet Engine of an Aircraft
c) Performance Test of Gilkes (GT85-2) Two Shaft Gas Turbine at Constant Load

EXPERIMENT 4(a): STUDY OF A ROVER GAS TURBINE

Objectives:

1) To Study the assembled Rover gas turbine and to identify different components
2) To draw a schematic of the combustion chamber and
3) To identify the following systems with suitable block diagrams
   i. Air intake system to the turbine
   ii. Fuel supply system

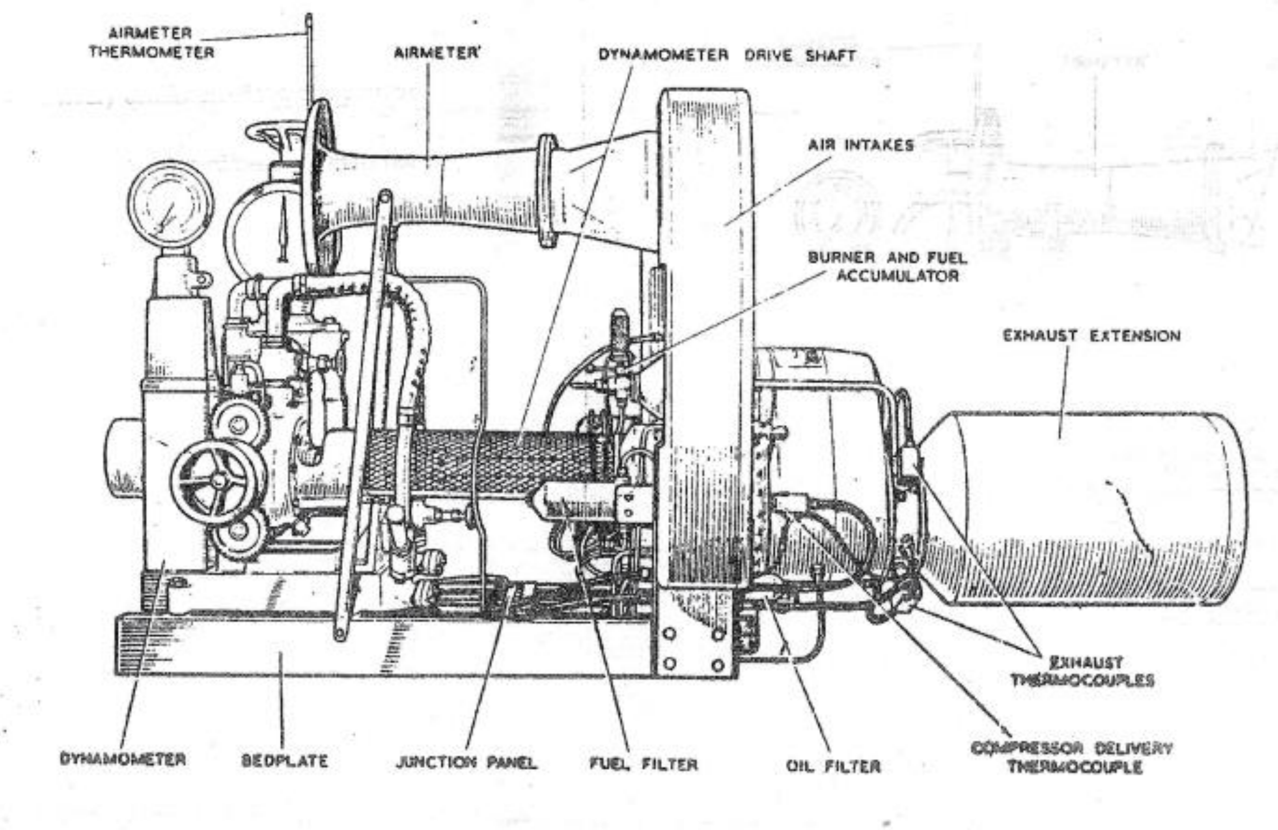


Fig. Different Components of a Rover Gas Turbine Engine

EXPERIMENT 4(b): STUDY OF A TURBO JET ENGINE

Objectives:

1) To collect specifications of the jet engine and identify why it was used
2) To become familiar with different components of the Turbo Jet Engine
3) To draw a schematic of the system
4) To draw a schematic of a combustion chamber
5) To check the following:
    i. Are the compressor and turbine on the same shaft?
    ii. Is the compressor radial flow type or axial flow type?
    iii. How many stages are there in the compressor and turbine?
    iv. How many moving blades are there at the final stage of the tu rbine?
    v. Mention the numbers of the combustion chambers, spark plug and fuel injectors in the system.
    vi. Take out a blade from the turbine on your own and fix it.
    vii. How is a Jet engine different from a Gas Turbine?

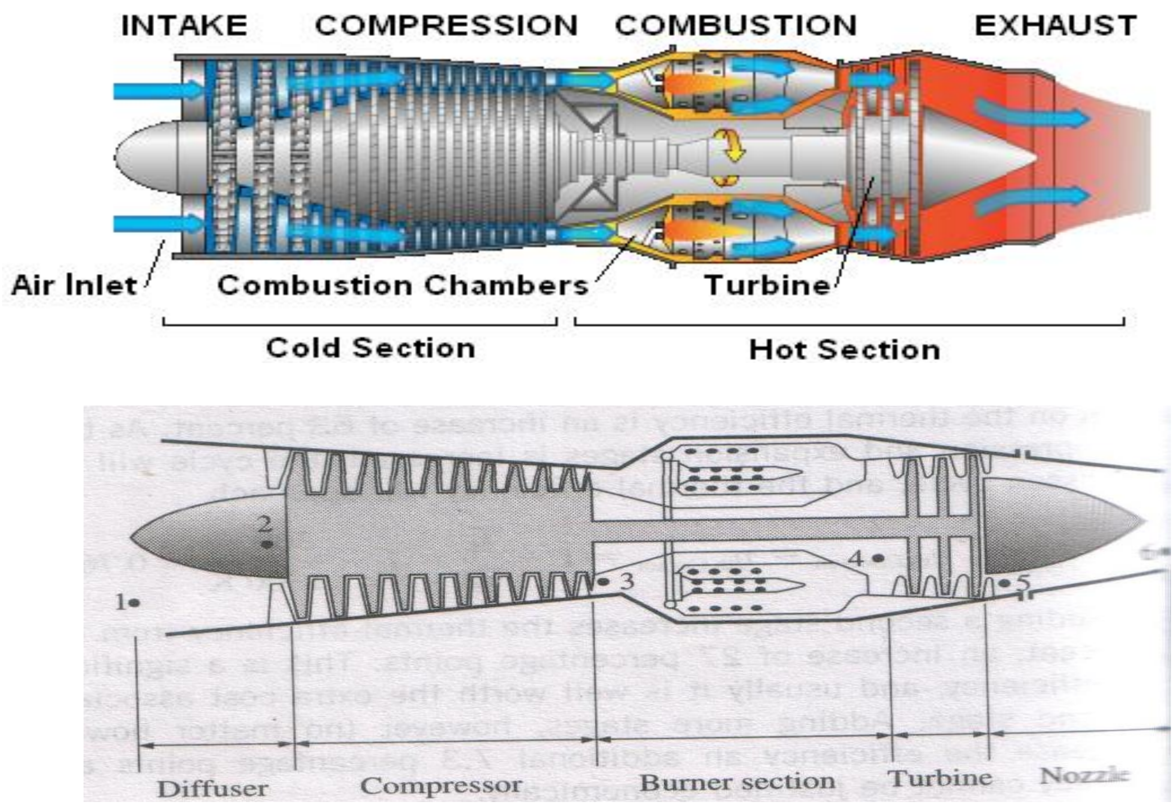


Fig.01: Turbo Jet Engine

Other Types of Jet Engine:

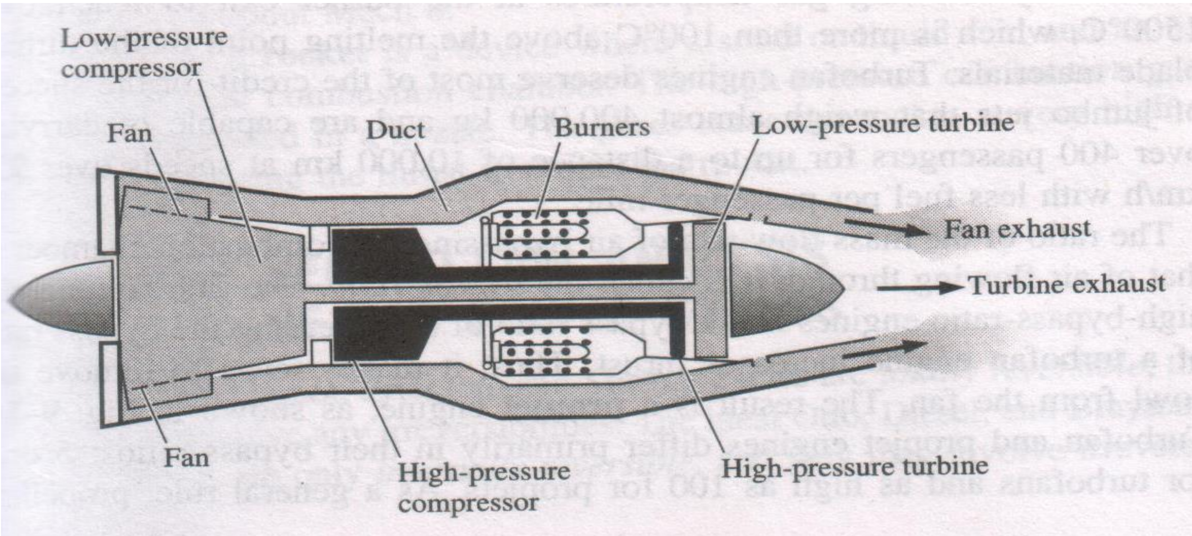


Fig.02: Turbo Fan Jet Engine

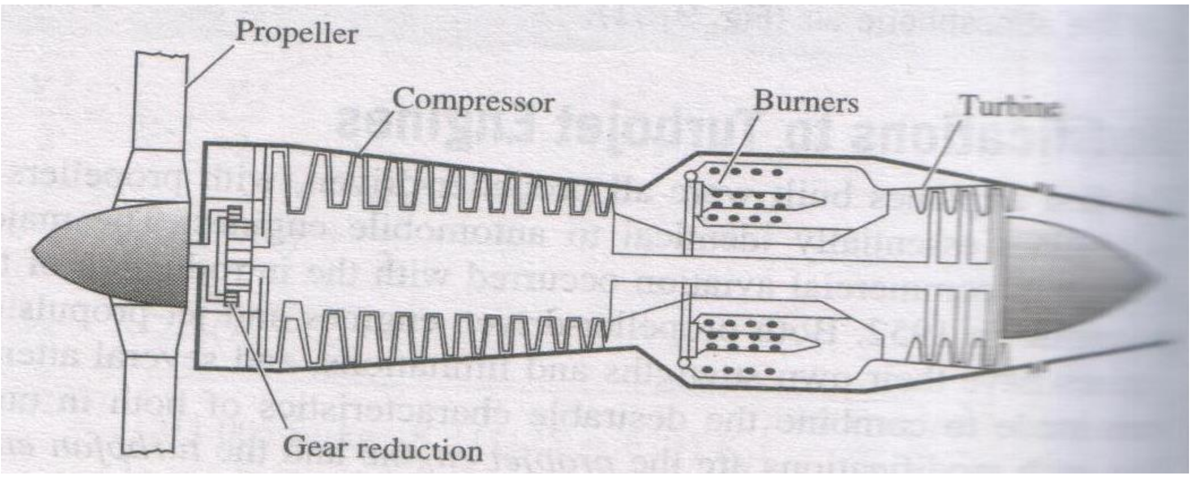


Fig.03: Turbo Prop Jet Engine

Discussion:

Experiment 4(c) Performance Test of Gilkes Two Shaft Gas Turbine at Constant Load

Objectives:

(1) To become familiar with different components of the system.

(2) To draw a schematic of the system.

(3) To calculate different performance parameters of the system.

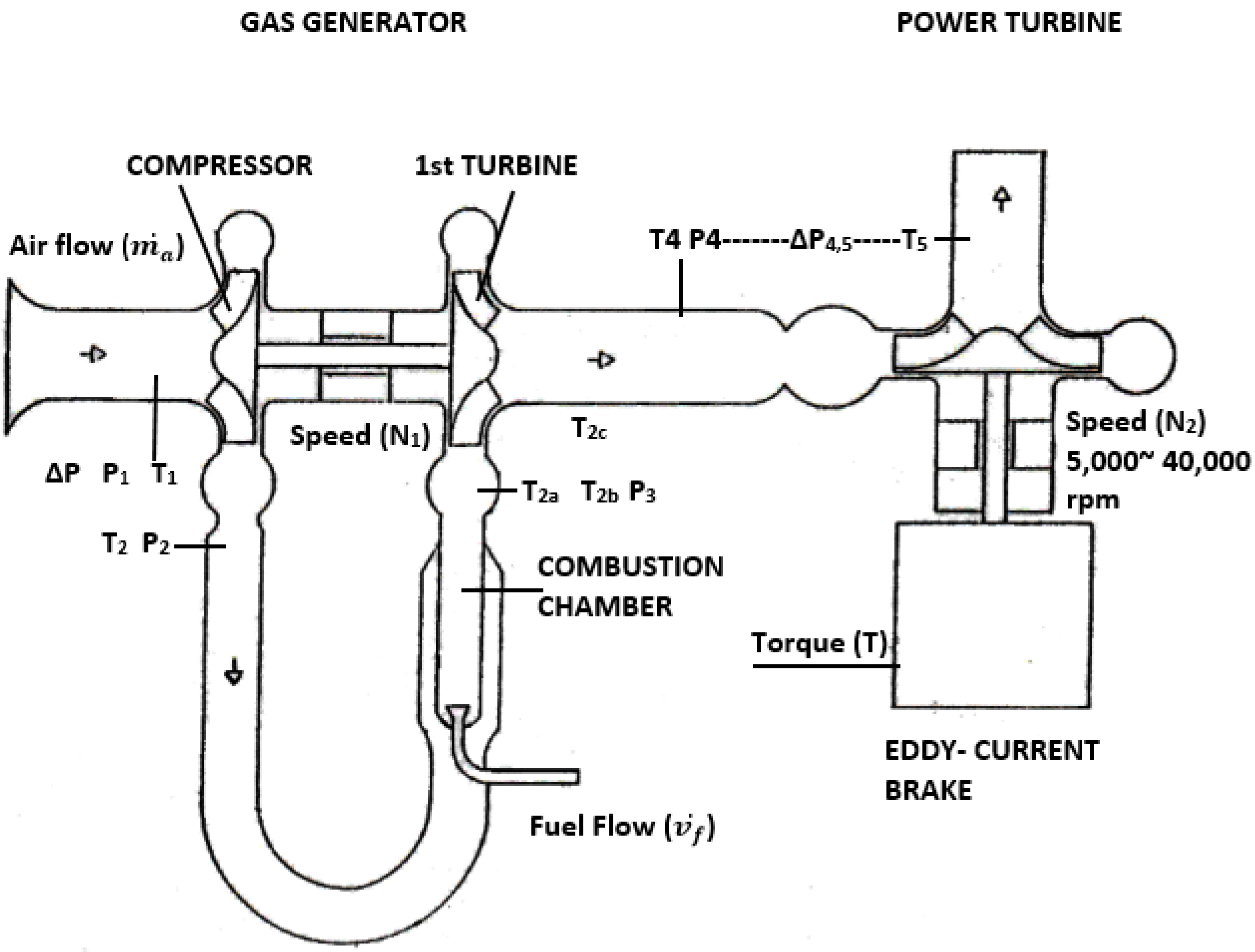


Fig. Experimental Setup of Gilkes Two-Shaft Gas Turbine

Technical Data:

Working Fuel -- Kerosene
Starting Fuel -- Methanol
Compression ratio -- 2.2:1
Gas generator speed -- 50,000 to 90,000 rpm
Power Turbine speed range -- 5,000 to 40,000 rpm
Power turbine power output -- 6 to 7 kW at 40,000 rpm
Optimal overall thermal efficiency -- 4.3%
Maximum System Temperature -- 700°C

OPERATION OF GAS TURBINE (GT 85-2)

The following sequence of operations should be used to start the gas turbine:

Warm-Up:

a) Turn on the cooling water valves.
b) Ensure that the fuel valve is closed and load control valve is in minimum position.
c) Switch on the electrical power supply.
d) Press the "START OIL" button. This starts the lubricating oil pump.
e) When the oil pressure becomes normal (3 bar), Press and release the "LOW OIL PRESSURE" button. It should switch off.
f) Press the "STOP button to switch on the fans. This is used to warm up the system to T_{3b} = 35 °C.
g) Release the "STOP" button (turn it clockwise) and ensure that all fans are stopped. If the fans continue to run, press and release the "FANS OFF" button.

Starting:

a) Make 5 turns of the fuel valve (Counter clockwise).
b) Ensure that the main fuel valve inside the cabinet is closed and the Dynamometer loading is set to minimum.
c) Press and hold "COLD START" button. Simultaneously press and hold the "IGNITION" and "ALCOHOL" buttons.
d) Release the "ALCOHOL" button after 2 or 3 seconds. Release the "COLD START" button after 30 sec (One fan will start automatically), continue to press "IGNITION" button. (Pressing the ALCOHOL button releases the primary fuel).
e) Observe the temperature rise in T_{3b} (If the temp does not rise or rises too slowly then again press ALCOHOL button for 2 or 3 seconds and release).
f) When $T_{3b} \approx$ 100 °C, release the "IGNITION" button and press "START FUEL" button.
g) The GT will now run with main fuel (Kerosene) at N_1= 48000 ~ 50000 rpm.
h) Increase the speed N_1 to 50000 rpm by increasing fuel flow rate by opening the fuel valve counter clockwise and wait 1 min to become steady.
i) Press and release the "FANS OFF" button. (Four fans will stop).

Stopping:

The following sequence of operations should be used to stop the gas turbine:

a) Release the load to minimum position rotating the load control knob.
b) Lower the speed N_1 to 50000 rpm by decreasing fuel flow rate using the fuel valve. Allow the GT to run for 2 to 3 min in this speed.
c) Depress the STOP button. (Four fans will start and fuel pump will stop).
d) Allow the GT to cool down under the action of the fans (for 3 ~5 min).
e) Release the STOP button. (Turn it clockwise).
f) Switch off the Power supply.
g) Switch off the Power supply.
h) Close the water supply line (after 5 min).

EXPERIMENT 4 (c) PERFORMANCE TEST OF GILKES TWO SHAFT GAS TURBINE AT CONSTANT LOAD

Data Table:

Compressor-Turbine Speed, N_1 (rpm)	Fuel-Flowrate, $\dot{V}_f$ (Liter/hr)	ΔP (mbar)	T_1 (ºC)	T_2 (ºC)	P_2 (bar)	T_{3a} (ºC)	T_{3c} (ºC)	P_3 (bar)	T_4 (ºC)	P_4 (mbar)	$\Delta P_{4/5}$ (mbar)	T_5 (ºC)	Power Turbine Speed, N_2 (rpm)	Load (N-m)

Formulas:

Mass flow rate of air is given by (kg/s), $\dot{m}_a\sqrt{\frac{T_1}{P_1}}=0.9597\sqrt{\frac{\Delta P}{P_1}}$	Air-Fuel ratio, $\frac{A}{F}=\frac{\dot{m}_{ac}}{\dot{m}_{fc}}$	Theoretical power output from the compressor turbine (W), $W_{t!}=(\dot{m}_{ac}+\dot{m}_{fc})C_{pg}(T_3-T_4)$
Corrected mass flow rate of air (kg/s) $\dot{m}_{ac}\doteq\dot{m}_a\frac{1.0133}{P_a}\sqrt{\frac{T_a}{288.16}}$	Specific Fuel Consumption (g/kW-hr), $sfc=3.6\times10^9\frac{\dot{m}_{fc}}{W_{t2}}$	Theoretical power output from the power turbine (W), $W_{t2}=(\dot{m}_{ac}+\dot{m}_{fc})C_{pg}(T_4-T_5)$
Mass flow rate of fuel (kg/s), $\dot{m}_{fc}=\frac{\dot{V}_f}{4500}\frac{1.0133}{P_a}\sqrt{\frac{288.16}{T_a}}$	Theoretical power output from the compressor, $W_c=\dot{m}_{ac}C_{pa}(T_2-T_1)$	Overall Thermal Efficiency, $\eta_{th}=\frac{W_{t2}}{44.3\times10^6\dot{m}_{fc}}$
Take, T_1 = atmospheric temperature (ºC), $P_1 = P_a - (\Delta P/1000)$, ΔP is in mbar, P_a = atmospheric pressure (bar), C_{pa} = 1000 J/kg-K C_{pg}=1150 J/kg-K		

Discussion: