AEROSPACE PROPULSION
LAB MANUAL

Year	2019 - 2020
Course Code	AAE108
Regulations	R16
Class	VI Semester
Branch	Aeronautical Engineering

Prepared by

Dr. Praveen Kumar Balguri

Dr. V.Varun

Aeronautical Engineering

INSTITUTE OF AERONAUTICAL ENGINEERING

(AUTONOMOUS)

Dundigal – 500 043, Hyderabad

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(AUTONOMOUS)

Dundigal, Hyderabad - 500 043

Certificate

This is to certify that it is a confide record of practical work done by Mr. /Ms. ______________________________________ bearing Roll. No. _______________________ of _____________ class ____ branch in the Aerospace Propulsion Laboratory during the academic year ____________________under our supervision.

Head of the Department **Lecture In-Charge**

External Examiner **Internal Examiner**

AEROSPACE PROPULSION LAB SYLLABUS

S. No.	List of Experiments	Page No.	Date	Remarks
I	**ENGINE DISASSEMBLY AND ASSEMBLY**			
II	**FLASH POINT AND FIRE POINT TEST**			
III	**DETERMINATION OF DYNAMIC VISCOSITY OF A GIVEN SAMPLE USING REDWOOD VISCOMETER**			
IV	**MECHANICAL EFFICIENCY OF AXIAL COMPRESSOR**			
V	**GAS TURBINE PARAMETERS CALCULATION**			
VI	**GAS TURBINE EFFICIENCY AND PERFORMANCE DIAGRAMS**			
VII	**GAS TURBINE EFFICIENCY CALCULATIONS**			
VIII	**WORK OUTPUT OF AXIAL TURBINE**			
IX	**NOZZEL PERFORMECE**			
X	**CALORIFIC VALUE OF DIFFERENT FUELS**			
XI	**FREE AND FORCED CONVECTION**			
XII	**PROPELLER TEST RIG**			

AEROSPACE PROPULSION LABORATORY

OBJECTIVES:

1. Understand the basics of propulsion, working principles of reciprocating engines, flash and fire point, and kinematic and dynamic viscosity of fuels.
2. Knowledge about the mechanical efficiency of axial compressor, work, power, thrust requirements of a gas turbine and efficiency and performance diagrams.
3. Calculation of thermal, propulsive efficiency of gas turbine, work output of axial turbine and nozzle performance.
4. Understand the calorific values of different fuels, coefficient of convection heat transfer, and calculation of propeller efficiency.

OUTCOMES:

After completing this course the student must demonstrate the knowledge and ability to:

1. Understand the working mechanism and identifying various components to build an IC engine.
2. Determination of flash point and fire point for a sample using pen sky martin‘s test.
3. Determine kinematic viscosity and dynamic viscosity of given sample using a viscometer.
4. Calculation of the mechanical efficiency of axial compressor- power required, power available, compression ratio.
5. Calculation of work, power and Thrust requirement in gas turbine- combustion power input, work heat relationship.
6. Elucidate T-S, H-S diagrams for the gas turbine and compare efficiencies of non-ideal engine components.
7. Calculation of thermal, propulsive and overall efficiency of turbo jet cycle.
8. Understand the calculation of total work output of axial turbine- out put work necessary, available output.
9. Understand the calculation of various nozzle performance with airflow.
10. Analyze the calorific value of different fuels and materials using digital bomb calorimeter and optimizing astute fuels.
11. Analyze the convection heat coefficient of a plate using forced jet or free convection apparatus.
12. Analyze the propeller efficiency and thrust availability using propeller test rig at various blade pitch angles.

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PROGRAM OUTCOMES

PO1	**Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
PO2	**Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO3	**Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
PO4	**Conduct investigations of complex problems**: Use research-based knowledge and research methods, including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PROGRAM SPECIFIC OUTCOMES

AERONAUTICAL ENGINEERING	
PSO1	**Professional skills:** Able to utilize the knowledge of aeronautical/aerospace engineering in innovative, dynamic and challenging environment for design and development of new products.
PSO2	**Problem solving skills**: imparted through an understanding of experimental facilities and techniques, to solve practical, design and analysis problems of components to complete the challenge of airworthiness for flight vehicles.
PSO3	**Practical implementation and testing skills**: Providing different types of in house and training and industry practice to fabricate and test and develop the products with more innovative technologies.
PSO4	**Successful career and entrepreneurship**: To prepare the students with broad aerospace knowledge to design and develop systems and subsystems of aerospace and allied systems and become technocrats.

ATTAINMENT OF PROGRAM OUTCOMES & PROGRAM SPECIFIC OUTCOMES

Expt No.	Program Outcomes Attained	Program Specific Outcomes Attained
1	PO1, PO2,PO3	PSO1, PSO2, PSO3
2	PO1, PO2,PO3	PSO1, PSO2, PSO3
3	PO1, PO2	PSO1, PSO2, PSO3
4	PO1, PO2,PO4	PSO1, PSO2, PSO3
5	PO1, PO2,PO3	PSO1, PSO2, PSO3
6	PO1,PO3,PO4,	PSO1, PSO2, PSO3
7	PO1, PO2	PSO1, PSO2, PSO3
8	PO1, PO2	PSO1, PSO2, PSO3
9	PO1, PO2,PO3	PSO1, PSO2, PSO3
10	PO1, PO3,PO2	PSO1, PSO2, PSO3
11	PO1, PO3,PO4	PSO1, PSO2, PSO3
12	PO1, PO3,PO2	PSO1, PSO2, PSO3

EXPERIMENT- I

ENGINE DISASSEMBLY AND ASSEMBLY

Aim:

To understand the working mechanism and identifying various components to build an IC engine.

Apparatus:

ENGINE: Premiere Automobiles Limited, Premiere Padmini Engine.

MANUFACTURER: The Premiere Automobile Ltd ., India.

ENGINE TYPE: Cylinder in line Bore: 68mm

Stroke: 75mm

Capacity: 1089cc

Compression ratio: 7:3:1.

Brake power: Max 354kw at 500 RPM cylinder head AL, with seat inserts over heads valves.

Cylinder blocks: Cast Iron

Cooling: Cooling water circulated by centrifugal pump.

Lubrication: Forced lubrication with rear pumps by pass oil filters

Fuel supply: Mechanical pump down, drought, carburetor, witheconomy settings.

Ignition: Battery ignition system

The main parts of an automobile engine are:

- Cylinder block and crank case.
- Oil pan
- Gaskets
- Pistons
- Connecting rod
- Crank shaft
- Mufflers
- Cylinder head
- Manifolds
- Cylinder
- Piston rings
- Main bearing
- Valves and valve actuating mechanism.

Theory:

Components of engine and their functions are briefly described.

CYLINDER BLOCK: The cylinder block is the main supporting structure for various components. The cylinder of the multi- cylinder engine is cast as a unit called cylinder block. The cylinder head is mounted on the cylinder block. The bottom portion of the cylinder Block is called as crank case. The inner surface of the cylinder wall is called bore/face.

CYLINDER: This is a cylinder vessel or space in which the piston makes a reciprocating Machine. The varying volume created in the cylinder during the operations of the engine is filled with working fluid and subjected to different thermodynamics processes

PISTON: It is a cylindrical component fitted into the cylinder forming the moving boundary the cylinder system it fits perfectly into the cylinder providing a gas tight space with the piston rings and the lubrication. It forms the first link in the gas forces to the output shaft.

Procedure:

DISASSEMBLY:

1. To disassembly an engine we must first begin with its basic frame work.
2. This is formed by cylinder block which houses the engine cylinder.
3. That is observed that oil holes are drilled to the cylinder block.
5. To the lower end of the cylinder block the crank case is cast, it provides support for the main journals and crank shaft.
6. Cylinder head can be disassembled by removing the stud fixing it to the cylinder.
7. In inline cylinder valves are transversely positioned and manifolds are on the either side of cylinder.
8. The manifolds are separate pipes to carry air fuel mixture and exhaust gases.
9. The exhaust manifold is made of cast iron.
10. The inlet manifolds is connected from carburetor of the cylinder with flat iron section.
11. Gaskets are located between cylinders head and block, crankcase and oil pump provide a tight fitting joint between the surfaces.
12. The piston is the reciprocating part of an engine. The top is called as a crown. The piston consists of grooves at its top cut to have piston rings.
13. The piston rings can be removed carefully by a ring spreader, which wraps around circumference of the rings.
14. The piston pin connects piston and connected rod. The piston pin retains are to be removed.
15. Using piston pin mandrels, piston pins are then driven out to remove pistons.
16. Power is taken by the crank shaft located below cylinder. Its assembly includes bearing, fly wheel and rear box drive to camshaft.

ASSEMBLY: The components are assembled in the reverse order in which they were disassembled

Precautions:

The components must be handled carefully.
Assembly the components at their respective place carefully after disassembling them.

Result:

The components of engine are disassembled and assembled.

EXPERIMENT-II

FLASH POINT AND FIRE POINT TEST

Aim:
Determination of flash point and fire point for a sample using pensky martin's test

Apparatus:
Oil cups, air bath, electric heater, current regulator, tapeonerassy, thermo meter.

Theory:
Flash point:

The flash point is defined as the lowest temperature at which lubricating oil will "flash" when a lighted match or lighted taper is passed across its surface.

Fire point:

If the oil is heated further after the flash point temperature has been reached. The lower temperature at which the oil will burn continuously is called the fire point. These two temperatures must be enough in oil so that it doesn't flash or burn in service. The flash point is mostly used.

Diagram:

Fig: flash and fire point test apparatus

Procedure:

1. Thoroughly clean up all parts of cup and dry.
2. Fill the cup with given oil is to be tested up to level indicated by a mark.
3. Lid has to be placed on cup and insert thermometer to required range.
4. Electrical supply is switched on and sample is gradually heated.
5. Oil is constantly stirred and the test flame is applied at the interval of 10 c raised is noted.
6. Heating is continued until oil vapors get ignited and burn on application of test flame continuously and temperature is noted.

Table:

Flash point	
Fire point	

Precautions:

1. Cup is cleaned and accessories are also cleaned and dried.
2. Supply of electricity is switched off after attaining flash point.
3. Gas regulators should be carefully handled.

Result:

Flash point of the given oil is ____ and fire point of the given oil ______.

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EXPERIMENT - III

DETERMINATION OF DYNAMIC VISCOSITY OF A GIVEN SAMPLE USING REDWOOD VISCOMETER

Aim:

To find kinematics viscosity and dynamic viscosity of given sample using a viscometer.

Apparatus:

Standard flask, stop watch, red wood viscometer, brake fluid, thermometer, electrical weighing machine.

Theory:

1. Viscosity is property of a given fluid by virtue of which it offers resistance to its own flow and is mainly due to cohesion between the fluid molecules.
2. Viscosity is the most important property of any lubricating oil because it determines the main operating characteristics of the lubricant.
3. If the viscosity of the oil is low, the fluid film cannot be maintained between the moving surfaces as a result of which excessive wear can take place.
4. On the other if the viscosity of the lubricating oil is too high then the viscosity of oil decreases with increase in temperature and so lubricating oil becomes thinner as the operating temperature is raised, it is therefore, necessary that viscosity of lubricating oil should not change.
5. Order fluctuating temperature is measured in terms of viscosity.

Viscometer:

- Viscometer is used to determine the viscosity of oil in which a known quantity of lubricating oil is allowed to flow a given height, through a standard capillarity tube under its own weight and time to flow is seconds is noted and time is proportional to viscosity of oil.
- The result is expressed in time taken by the oil flow through the particular viscometer.

Procedure:

1. Level the instrument with the help of leveling screws on a tripod.
2. The water bath is filled with water.
3. The orifice is sealed by keeping the brass ball in position and oil is carefully poured into the oil cup to the tip of indicator.
4. In a careful and controlled manner, heat the water in the bath and stir it continuously until the desired temperature is reached.
5. After the desired temperature is reached place the 50ml flask below the orifice left brass ball

Calculations:

Kinematic viscosity =dynamic viscosity/density

$v=\mu/density$

Kinematic viscosity measured in stokes; Dynamic viscosity measured in poise;

Density=mass/volume kg/m^3

Kinematic viscosity is given by A*t - B/t

where A=0.026; B=1.715

Table:

Temp of oil in deg	Time for collecting 50ml (Sec)	Wt of jar (w1 gms)	Wt of jar +50ml of oil(w2 gms)	Density	Kinematic viscosity	Dynamic viscosity
30						
38						

Diagram:

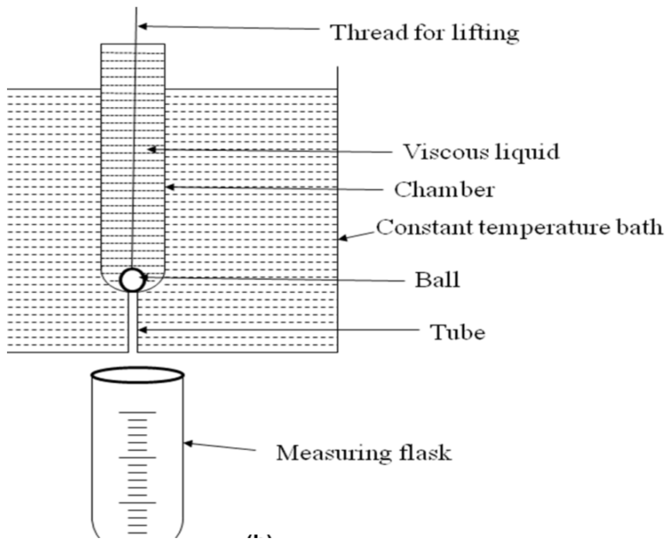

Figure 1. Scheme of Redwood viscometer experimental setup

Precautions:

1. Oil should be filtered to remove the solid particles that may clog the jet.
2. Receiving flask should be placed in manner that oil from jet strikes the neck of the receiving flask

Result:

Thus the dynamic viscosity of given sample is ______.

EXPERIMENT IV

MECHANICAL EFFICENCY OF AXIAL COMPRESSOR

Aim:
To determine efficiency of an axial flow compressor.

Apparatus:
Axial flow compressor test rig, temperature measurement instruments, pressure taps, manometer.

Theory:

Axial flow compressors are work consuming rotary machines that are intended to compress any compressible medium say air or gas to a higher pressure (compression ratio). Here the flow takes place in the longitudinal direction as the shaft exists. Often used in gas turbine engines as part of propulsion system in aeronautical applications or as part of power generation devices in mechanical engineering applications. The compressor consists of a rotating set of blades called as rotor and fixed set of blades called as stator or diffuser blades. Here the rotor imparts kinetic energy to the flow whereas the stator section decelerates the flow and converts the kinetic energy to pressure energy. A set of stator and rotor is called a stage. There could be as many stages as possible. The shape of the blades dictates the aerodynamic efficiency of the compressor system in converting shaft work to pressure energy of the flow. The type of thermodynamic process with which the gas is taken from inlet thermodynamic state to outlet thermodynamic state is the point of concern for the compressor to consume minimum amount of work for a given compression ratio. Ideally this should be an isentropic process. In reality, it deviates because of various factors like slip, shocks and boundary layer.

Diagram:

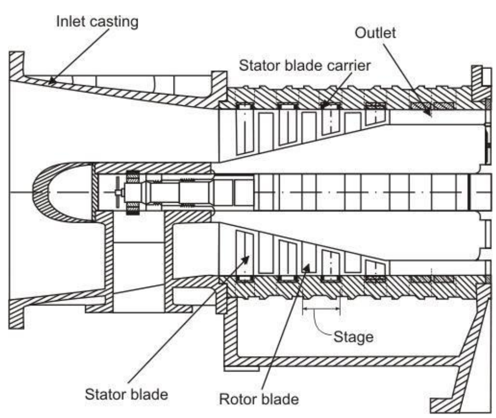

Figure 1. Scheme of compressor

Description:

A three stage axial compressor is part of the setup. The supplier provides instrumentation for calculating the isothermal efficiency of the whole setup rather than the compressor as such under isothermal assumption.

where r = pressure ratio of outlet to inlet
t = time taken (in seconds) for 'n' revolutions
Q = discharge calculated at inlet = A*v (A: area of inlet cross section; v: velocity of the flow calculated from static and total pressure heads)
n = Number of Revolutions of the meter indicator
t = time taken (in seconds) for 'n' revolutions
E = Energy meter constant= ....revolutions/kW/hr

Procedure:

1. Switch on the compressor and fix at an rpm.
2. Take down the static and total pressure readings at inlet and outlet from the multi tube manometer
3. Take the energy meter readings.
4. Repeat the same experiment for different RPMs.

Observations:

RPM = ………………………….
H_t = total inlet manometer headreading= ....mm ofalcohol
h_i = static inlet manometer headreading=........................ mm ofalcohol
h_o = static outlet manometer headreading= .... mm ofalcohol
$P_{o,i}$ = total inlet pressure = P_{atm}+ $\rho_{alcohol}$ g*H_i = ………………………….
$P_{o,i}$ = total outlet pressure = P_{atm}+ $\rho_{alcohol}$ g*H_i = ………………………….
$P_{o,o}$ = total outlet pressure = P_{atm}+ $\rho_{alcohol}$ g*Ho = ………………………….
P_i = static inlet pressure = P_{atm}+ $\rho_{alcohol}$ g*h_i = ………………………….
P_o = static outlet pressure = P_{atm}+ $\rho_{alcohol}$ g*h_i = ………………………….
$r = P_o/P_i$

Result:

The overall efficiency of the axial flow compressor test rig is calculated.

EXPERIMENT – V

GAS TURBINE PARAMETERS CALUCLATION

Aim:
To calculate the gas turbine parameters.

Apparatus:
Gas turbine test rig.

Description:

1. The engine is the compact Olympus HP E-start turbine engine, comprising a single-stage radial compressor and a low-mass, and high performance axial flow turbine.
2. The engine has been integrated into a sturdy metal frame that holds it firmly, while enabling accurate measurement of the thrust produced by the engine.
3. The engine inlet has been replaced with a custom fabricated frontal duct, to enable the air mass flow rate to be accurately measured.
4. An electronic preprogrammed controller constantly supervises the engine, ensuring safe operating conditions at all times.
5. The engine is controlled via the software, which provides uses with a friendly graphical interface for real-time monitoring and operation. This software controls the engine speed, which is electronically controlled using a high-precision fuel fear pump. This method gives a very fast engine response.

Instrumentation included:

INLET DUCT
- Inlet temperature
- Inlet pressure

COMPRESSOR
- Exit total pressure
- Exit pressure
- Exit total temperature

TURBINE
- Entry total temperature
- Entry total pressure
- Exit total temperature
- Exit total pressure

NOZZLE
- Exit total temperature
- Fuel flow

Performance specification:

1. Thrust: 200N typical
2. Typical fuel: One of the following
1. Paraffin
2. Jet A-1
3. JP-4/Kerosene
3. Exhaust gas temperature: 800oC typical
4. Mass flow:450g/s
5. Ignition system: Glow plug
6. Compressor type: Single-stage radial
7. Turbine type: Single-stage low mass
8. Engine RPM: 105,000rpm typical
9. Engine mount: Single pivot point

Specification:

An aeronautical axial flow gas turbine engine mounted in a stainless steel plinth, suitable for bench mounting. An electronic console and 51 'explo safe' fuel tank are also provided. An optional mounting frame is available for floor –standing operation
The engine has a maximum speed in excess of 100,000 rpm and generates thrust of at least 195N. Full instrumentation to measure RPM, thrust, temperature and pressure at each stage of the jet engine. Stainless steel air inlet duct to measure airflow
The engine is easy to start, without the need for propane gas or compressed air. The equipment is fully controlled form a user –supplied PC .This software includes the powerful educational features together with sophisticated graph-plotting and data logging capability. In the panel that in the mimic diagram is named 'Controls' the Watchdog button should blink. This means that the software detect the presence of the Electronic Console.

Table:

Enthalpy	h	kJ/kg
Isentropic Enthalpy	hs	kJ/kg
Ideal gas constant	R=0.2871	kJ/kg

Procedure:
Start-up:

In order to start the engine properly the following actions need to be done in the right order

- The 'Power On' button on the PC screen is clicked

- The ‘Enable’ button on the PC screen is clicked
- The ‘Start’ button on the PC screen is clicked
- The start-up sequence is initiated only on clicking on the ‘Start’ button. There is no need to do anything till the start-up sequence has finished.
- On clicking the ‘Start’ button there is a delay of several seconds, and then the electric starter tries to start the engine.
- After 30 sec ,start up sequence is complete.
- With these settings the software will sample at 1 second intervals for 15 seconds which in practice mans that the software will take 15 samples. To actually activate the automatic sampling after having clicked ‘OK’ on the ‘Sample Configuration’ window it is necessary to push the green ‘GO’ button in the main mimic diagram window. Then 15 samples will be added to the spreadsheet adjoined to those that may have been taken manually.
- For further details about how to use the Arm field software refer to its online manual.
- It is important to manage to take samples before running out of fuel from the tank and therefore it is necessary to keep track of the time the engine has been running. It is possible to consider that the average fuel flow rate at maximum speed is about **0.81 I/min** and consequently every run should be limited to about 5-7 minutes when the 5 liters fuel tank is fuel is full at the beginning of the experiment.

Power-down:

1. After having taken samples the engine must be switched off.
2. On the mimic diagram two buttons are located within the section ‘Controls’ these are named ‘Power On’ and ‘Start’ respectively.
3. The engine **must not** be switched off clicking on **‘Power On’** button unless it is an emergency. The ‘Start’ button is used to start and power down the engine instead.
4. When the engine is running and ‘Start’ button is clicked the power down sequence is initiated.
5. This sequence is supervised by the Engine Control Unit and allows for mellow cooling down of the engine in order to avoid excessive thermal stress. When this sequence is activated the Engine Control Unit runs the engine at full speed foe a brief period of time. This is done in order to allow enough lubricant in the engine and its ball bearings along with the flow.

Precautions:

1. Be careful while operating the gas turbine test rig.
2. Parameters are carefully evaluated.

Result: Gas turbine parameters are calculated.

EXPERIMENT – VI

GAS TURBINE EFFICIENCY AND PERFORMANCE DIAGRAMS

Aim:
To estimate the thrust output from the engine, using the momentum equation, and to compare this result to the measured thrust.

Apparatus:
Gas turbine test rig, Engine module, Electronic console, User PC with arm field software.

Method:
Basic application of the momentum equation.

Theory:
The momentum equation applied to the system shown in the figure above states that the engine receives a thrust which is made of the contribution of four terms. The first two terms take into account the change in momentum for the air flow and the fuel flow throughout the engine. The last two terms take into account the effect of having different pressure at the inlet and exhaust sections when $p_{exp}$is the pressure of the outside environment.

In many applications the contribution of the last two terms to the thrust is usually much less significant than the contribution of the first two terms. When this condition is satisfied it is possible to simplify the momentum equation to its first two terms.

$$T_c = \dot{m}_a(u_{out} - u_{in}) + \dot{m}_f u_{out}$$

This condition is usually satisfied when aircraft fly at a speed u_{in} called the "design speed". This speed is obviously also the speed at which the outside air is ingested at the inlet.
In this formula it is considered the vena contract effect due to the inlet nozzle geometry:

$$A_{in}^* = C_d A_{in} = 0.62 * \left(\frac{\pi}{4}\right) * (0.1m)^2$$

The cases of the minimum and maximum RPM are taken into consideration. The average air mass flow rate measured at the inlet at minimum RPM is about 0.24Kg/s and considering an average value of 1.2Kg/cube meters for the specific mass of the air flow it is possible to estimate the following speed at the inlet.

$$Min\ u_{in} = 41\ m/s$$

Equivalently, the maximum speed at the inlet is calculated knowing that the measured air mass flow rate at maximum RPM is about 0.85 Kg/s.

$$Max\ u_{in} = 145\ m/s$$

This justifies the assumption of subsonic flow at the inlet of the engine in all experimental conditions.
The presence of the compressor and the turbine does not affect significantly the axial component of the flow velocity throughout the engine and the speed of the sound is proportional to the square root of the

temperature. This allows for the assumption of subsonic flow throughout the engine up to the exit section of the turbine in all experimental conditions.
It is also clear that at the inlet the pressure equals the external pressure (ambient pressure).

$$\boldsymbol{p_{in} = p_{ext}}$$

Consequently the last term in the momentum equation can be neglected allowing for the following simplified equation to be applied.

$$\boldsymbol{T_c = \dot{m}_a(u_8 - u_{in}) + \dot{m}_f u_8 + A_8(p_8 - p_{ext})}$$

In this equation u_{out}has been renamed asu_e, the speed of the flow at the nozzle exit section. In order to estimate the thrust it is necessary to determine this velocity and the pressure at the exit section p_e of the nozzle while the exit section area is directly measurable. Moreover, the thrust produced by the fuel mass flow rate can be neglected due to the fact that this quantity is always a fraction of the air mass flow rate.

$$\boldsymbol{T_c = \dot{m}_a(u_8 - u_{in}) + A_8(p_8 - p_{ext})}$$

To determine $u_e$and p_e , it is possible to consider the isentropic model of the nozzle as approximation of the real nozzle. The equipment allows for determining the totral condition at the nozzle entrance T4 and P5 and in accordance to this model the following equations are applicable.

$$\boldsymbol{t_4\left(1 + \frac{(\gamma - 1)}{2}M_4^2\right) = t_8\left(1 + \frac{(\gamma - 1)}{2}M_8^2\right) = T_4}$$

Example, the theory does not consider friction effects, boundary layer effects and loss of homogeneity in the flow for all the variables involved I the formulation.
It is possible to investigate the thermodynamics and the fluid dynamics of the processes involved in the jet engine using simple equations that refer to the isentropic and one – dimensional flow theory. The investigations may be extended further using more sophisticated features of the theory on the experimental data obtained by operating the engine in different conditions and removing some of the simplification to the theory. For perfect gas it is possible to consider a numbr of different equations that relate the specific enthalpy to the temperature of the gas. The simplest of this equation states that: In this case C_p is considered to be constant value thereby independent from the temperature of the gas .The quantities represented with'0' subscripts are those of a reference state purposefully chosen. In this circumstance the specific enthalpy of gas is proportional to its temperature. This justify the use of a T vs. Specific Entropy diagram as a convenient substitute to the Specific Enthalpy vs. Specific Entropy diagram whenever the gas that experience the process can be assumed to behave ideally. In order to evaluate the specific Entropy of a gas the Thermodynamics provides a number of equations among which the simplest is the following. This allows for producing the Specific Enthalpy vs. Specific Entropy diagram for the flow through the engine by exploiting the measure of temperatures and pressures that are provided by the instrumentation supplied.

Procedure:
Start-up:
In order to start the engine properly the following actions need to be done in the right order
- The 'Power On' button on the PC screen is clicked
- The 'Enable' button on the PC screen is clicked

- The ‘Start’ button on the PC screen is clicked
- The start-up sequence is initiated only on clicking on the ‘Start’ button. There is no need to do anything till the start-up sequence has finished.
- On clicking the ‘Start’ button there is a delay of several seconds, and then the electric starter tries to start the engine.
- After 30 sec ,start up sequence is complete.
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4. The ‘Start’ button is used to start and power down the engine instead.
5. When the engine is running and ‘Start’ button is clicked the power down sequence is initiated.
6. This sequence is supervised by the Engine Control Unit and allows for mellow cooling down of the engine in order to avoid excessive thermal stress. When this sequence is activated the Engine Control Unit runs the engine at full speed foe a brief period of time. This is done in order to allow enough lubricant in the engine and its ball bearings along with the flow.

Precautions:

1. Be careful while operating the gas turbine test rig.
2. Parameters are carefully evaluated.

Result:

Gas turbine efficiency and parameters are studied.

EXPERIMET– VII

GAS TURBINE EFFICENCY CALUCLATIONS

Aim:

To understand the performance of the axial flow turbine.

Apparatus:

Axial turbine test rig, temperature and pressure reading equipment

Theory:

Gas turbine unit for power generation and for production of thrust primary consist of compressor, combustion chamber and turbine. The air as it passes through compressor increases pressure fed to combustion chamber leads to raise in temperature and thereafter turbine to expand and obtain power required to attain thrust.

In axial flow fluid moves essentially in axial direction through the rotor. In axial type the fluid motion is almost radial. Comparing axial and radial turbine of overall same dimensions we may say that axial is best functional for high mass flow rates capacities, on the other hand small mass flow rates flows the radial machine for higher and better efficiencies. Also the radial turbine is capable of higher pressure ratio per stage it's easier to arrange no of stages on axial flow turbine overall pressure ratios are not difficult with axial turbine. Usually the efficiency of well-designed turbine is greater to that of compressor.

Principle:

The fluid undergoes a pressure drop in the turbine and pressure raise into compressor. Thus pressure drop results in the increases in pressure differences between atmosphere and nozzle. The turbine is sufficient to keep second layer generally well below which is observes in compressor can be neglected in turbine. Offsetting this advantage, it is much more criticized to critical stress problem. Since turbine blades operate at higher temperatures. Actual blades shape are often made more dependent on stress and cooling considerations beyond velocity triangles.
Because general falling pressure in turbine flow passes much more turbine in a given blade row is possible without danger of flow separation in an axial flow compressor blade row, considering pressure ratio.

Formulae:

The total-to-static turbine efficiency η_{ts} is defined by

$$\boldsymbol{\eta_{ts} = \frac{T_{01} - T_{03}}{T_{01} - T_{3s}}}$$

Total-to-total turbine efficiencyη_{tt}

$$\boldsymbol{\eta_{tt} = \frac{T_{01} - T_{03}}{T_{01} - T_{03S}} = \frac{1 - \left(T_{03}/T_{01}\right)}{1 - \left(p_{03}/p_{01}\right)^{\frac{(\gamma-1)}{\gamma}}}}$$

Procedure:
Start-up:

In order to start the engine properly the following actions need to be done in the right order

- The 'Power On' button on the PC screen is clicked
- The 'Enable' button on the PC screen is clicked
- The 'Start' button on the PC screen is clicked
- The start-up sequence is initiated only on clicking on the 'Start' button. There is no need to do anything till the start-up sequence has finished.
- On clicking the 'Start' button there is a delay of several seconds, and then the electric starter tries to start the engine.
- After 30 sec ,start up sequence is complete.
- With these settings the software will sample at 1 second intervals for 15 seconds which in practice mans that the software will take 15 samples. To actually activate the automatic sampling after having clicked 'OK' on the 'Sample Configuration' window it is necessary to push the green 'GO' button in the main mimic diagram window. Then 15 samples will be added to the spreadsheet adjoined to those that may have been taken manually.
- For further details about how to use the Arm field software refer to its online manual.
- It is important to manage to take samples before running out of fuel from the tank and therefore it is necessary to keep track of the time the engine has been running. It is possible to consider that the average fuel flow rate at maximum speed is about **0.81 I/min** and consequently every run should be limited to about 5-7 minutes when the 5 liters fuel tank is fuel is full at the beginning of the experiment.

Power-down:

- After having taken samples the engine must be switched off.
- On the mimic diagram two buttons are located within the section 'Controls' these are named 'Power On' and 'Start' respectively.
- The engine **must not** be switched off clicking on **'Power On'** button unless it is an emergency. The 'Start' button is used to start and power down the engine instead.
- When the engine is running and 'Start' button is clicked the power down sequence is initiated.
- This sequence is supervised by the Engine Control Unit and allows for mellow cooling down of the engine in order to avoid excessive thermal stress. When this sequence is activated the Engine Control Unit runs the engine at full speed foe a brief period of time. This is done in order to allow enough lubricant in the engine and its ball bearings along with the flow.

Precautions:
1. Be careful while operating the gas turbine test rig.
2. Parameters are carefully evaluated.

Result:
Gas turbine efficiency parameters are calculated.

EXPERIMET– VIII

WORK OUTPUT OF AXIAL TURBINE

Aim:
To calculate the work output of the axial flow turbine.

Apparatus:
Axial turbine test rig, temperature and pressure reading equipment

Theory:
The driving turbines used in turbo pumps are usually of the impulse type. In order to minimize the required number of stages, it is desirable to produce high power per stage. The power output per stage of an impulse turbine is greater than that of a reaction turbine for the same blade speed (given axial exhaust velocities). Figure 1indicates three turbine types. For each, the work output per unit mass flow is stated for cases in which the axial velocity is held constant through the stage and the outlet velocity has no swirl component. Thus, at a given rpm, the single-stage impulse turbine can deliver twice the power of a 50% reaction turbine of the same size.

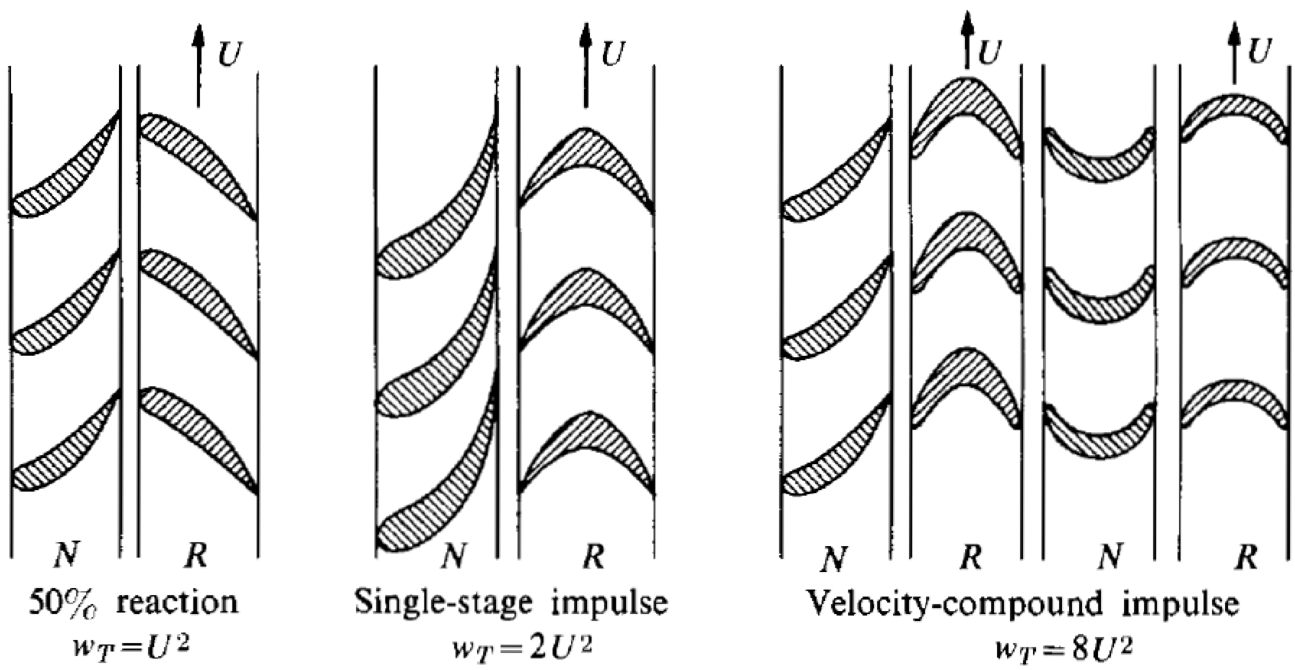

Figure 1. Blade cross sections and work outputs of three typical turbines, for constant axial velocity and axial outlet velocity

The velocity-compound impulse turbine is, in a sense, a single impulse stage since all the pressure drop occurs in the first nozzle. The fluid leaves the first rotor with swirl in the direction opposite to the rotation. This is redirected in the second "nozzle" (without pressure drop) to enter the last rotor. If the fluid leaves the last rotor without swirl, it is easily shown that the power output of the two rotors is four times that of a single-impulse rotor, and thus about twice that of an ordinary two-stage impulse turbine. For this reason the velocity-compound impulse turbine is commonly used in turbo pumps for those cases in which a single impulse stage is inadequate. For lightness, two rows of rotor blades are often mounted on a single disc that branches near the blade roots since, at typical speeds, stresses need not be intolerable. The velocity-compound turbine is, however, significantly less efficient than a single-impulse stage (which in turn is less efficient than the 50% reaction stage) owing largely to the very high fluid velocities encountered in the first nozzle and rotor blades, and to the requirement that the fluid travel through three successive blade rows without the beneficial effect of pressure drop on the boundary layer.

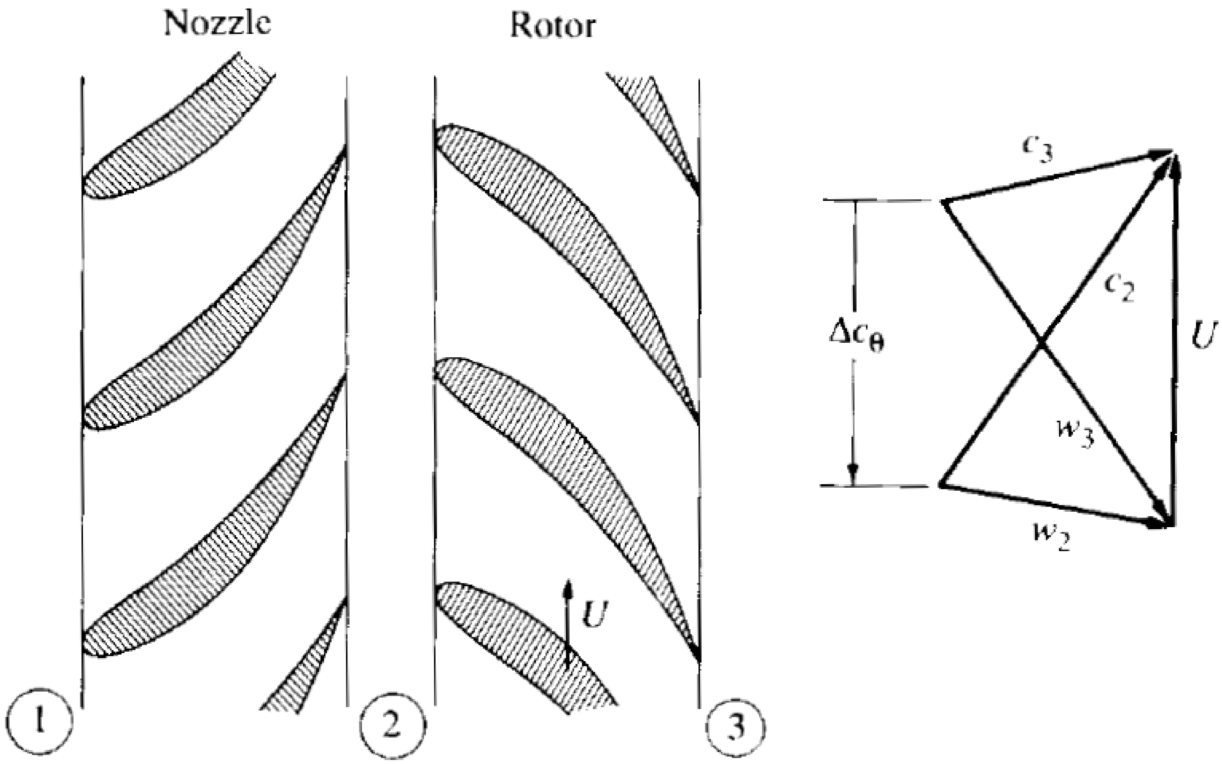

Figure 2: Turbine blading and velocity triangles.

An axial turbine stage consists of a row of stationary blades, called nozzles or stators, followed by the rotor, as Fig. 8.4 illustrates. Because of the large pressure drop per stage, the nozzle and rotor blades may be of increasing length, as shown, to accommodate the rapidly expanding gases, while holding the axial velocity to something like a uniform value through the stage. A section through the mean radius would appear as in Fig.2. One can see that the nozzles accelerate the flow, imparting an increased tangential velocity component. The velocity diagram of the turbine differs from that of the compressor in that the change in tangential velocity in the rotor, Δc_θ , is in the direction opposite to the blade speed U. The reaction to this change in the tangential momentum of the fluid is a torque on the rotor in the direction of motion. Hence the fluid does work on the rotor. The reaction to this change in the tangential momentum of the fluid is a torque on the rotor in the direction of motion. Hence the fluid does work on the rotor.

Formulae:

In an axial turbine, $U_2 \simeq U_3 = U$. The turbine work per unit mass is

$$W_T = U(c_{\theta 2} - c_{\theta 3}) \quad \text{or} \quad W_T = c_p(T_{01} - T_{03}) .$$

$$W_T = \Delta h_0 = Uc_{\theta 2} = Uc_z \tan \alpha_2 ,$$

Procedure:

Start-up:

In order to start the engine properly the following actions need to be done in the right order

- The ‘Power On’ button on the PC screen is clicked
- The ‘Enable’ button on the PC screen is clicked
- The ‘Start’ button on the PC screen is clicked
- The start-up sequence is initiated only on clicking on the ‘Start’ button. There is no need to do anything till the start-up sequence has finished.
- On clicking the ‘Start’ button there is a delay of several seconds, and then the electric starter tries to start the engine.
- After 30 sec ,startup sequence is complete.
- With these settings the software will sample at 1 second intervals for 15 seconds which in practice mans that the software will take 15 samples. To actually activate the automatic sampling after having clicked ‘OK’ on the ‘Sample Configuration’ window it is necessary to push the green ‘GO’ button in the main mimic diagram window. Then 15 samples will be added to the spreadsheet adjoined to those that may have been taken manually.
- For further details about how to use the Arm field software refer to its online manual.
- It is important to manage to take samples before running out of fuel from the tank and therefore it is necessary to keep track of the time the engine has been running. It is possible to consider that the average fuel flow rate at maximum speed is about **0.81 I/min** and consequently every run should be limited to about 5-7 minutes when the 5 liters fuel tank is fuel is full at the beginning of the experiment.

Power-down:

- After having taken samples the engine must be switched off.
- On the mimic diagram two buttons are located within the section ‘Controls’ these are named ‘Power On’ and ‘Start’ respectively.
- The engine must not be switched off clicking on ‘Power On’ button unless it is an emergency. The ‘Start’ button is used to start and power down the engine instead.
- When the engine is running and ‘Start’ button is clicked the power down sequence is initiated.
- This sequence is supervised by the Engine Control Unit and allows for mellow cooling down of the engine in order to avoid excessive thermal stress. When this sequence is activated the Engine Control Unit runs the engine at full speed foe a brief period of time. This is done in order to allow enough lubricant in the engine and its ball bearings along with the flow.

Precautions:

1. Be careful while operating the gas turbine test rig.
2. Parameters are carefully evaluated.

Results:

The work output of axial flow turbine is understood by observing the axial flow turbine.

EXPERIMENT – IX

NOZZLE PERFORMANCE

Aim:

To determine the pressure distribution of nozzle.

Apparatus:

Nozzle test rig.

Description:

- The set up consists of blower unit coupled to A.C motor.
- The pressure tapings (10Nos) is made in the nozzle surface and it is connected to multi bank manometer.
- The orifice plate is fitted in the pipeline of the blower outlet, to measure the discharge of flow and is connected to differential manometer.
- The control panel consist of the mains on indicator, console switch, A.C motor blower switch, differential manometer and multi bank manometer and whole instrumentation is mounted on a self-contained sturdy table.
- With this the whole arrangement is mounted on aesthetically designed self-sustained MS powder coated frame with a separate NOVAPAN board control panel.

Procedure:

- Switch on the MCB and then console on switch to activate the control panel.
- Switch on the blower unit first and adjust the flow of air of blower to a desired difference in manometer.
- Note down the differential manometer and multi bank manometer readings.
- Repeat the experiment for different air flow rates.

Observations:

S.No	Velocity head (pitot tube)			Air flow across orifice			Pressure tapping reading along the nozzle in mm of water									
1	h1	h2	hw	h1	h2	hw	h1	h2	h3	h4	h5	h6	h7	h8	h9	h10
2																
3																
4																
5																

Calculations:

1. Discharge Q

   $Q=Cd *a\sqrt{(2gH_a)}$

   where ,Cd= coefficient of discharge of orifice=0.62,A= area at the orifice= (3.14*(d)2/4),Ha=head in air column ,m of air

$H_a = h_w * r_{water}/r_{air}$
$r_{water} = 1000\ kg/m^3$
$r_{air} = 1.2\ kg/m^3$ @ R.T.P
h_w is the head in water column in "m" of water

2. Pressure head:
3. Pressure head = $\frac{p}{g*density}$ = h m of water

   P=r*g*h
   where, density of water = 1000kg/m^3, g= gravitational constant =9.81 m/sec^2
   h=head measured , m of water column
4. Velocity head,

   Velocity head =$\frac{v2}{g}$ m of water

   where,

   V= $\frac{Q}{a}$

   where, a=area at the particular section of the nozzle m^2
5. Verification of Bernoulli's equation:

   Bernoulli's equation is given as:

$$\frac{P}{g*density} + \frac{V2}{2g} + z = 0$$

After finding,

a. Pressure head, h
b. Velocity head

At different cross-section of the nozzle. Put the same in the above equation for different points and verify whether all the values obtained are same.
Note: consider the datum, z to be constant.

Result Table:

S.No.	Velocity of air at the exit of the nozzle (m/s)	Discharge through the orifice (m^3/s)	Maximum pressure in the nozzle (Pa)	Maximum velocity in the nozzle (m/s)

Precautions:

- Check all the electrical connections.
- Do not run the equipment if the voltage is below 180V.
- Do not obstruct flow of air while experiment is going on.
- Do not attempt to alter the equipment as this may cause damage to the whole system.

Result:

- Max press of the nozzle is………………..
- Max vel of the nozzle is ……………..

EXPERIMENT-X

CALORIFIC VALUE OF DIFFERENT FUELS

Aim:
To find calorific values of fuels

Apparatus:
Bomb calorimeter test rig.

Principle of operation:

A know amount of sample is burnt in a seal chamber (here after we shall refer to this chamber as Bomb). The air is replaced by pure oxygen. The sample is ignited electrically. As the sample burns, heat is produced. The raise in temperature is determined. Since, barring loss of heat, the amount of heat produced by burning the sample must be equal to the amount of heat absorbed by the calorimeter assembly, acknowledges of the water equivalent of the calorimeter assembly and of the raise in temperature enables ones to calculate the heat of combustion of the sample.

Characteristic requirements:

- **Bomb:** When the sample burns, the pressure of gases increases rapidly, The Bomb walls, lid and joints should be strong enough to withstand the maximum working pressures, and there should be no leaks. Normal working pressures are about 30 atmospheres and overload pressures peaks up to 100 atmospheres.
- The capacity of bomb should be large enough to store enough oxygen to ensure complete burning of the sample
- During burning the nitrogen and sulphur contents are oxidized to gases and then to nitric acid and sulphuric acid. The bomb lining must therefore be resistant to acidic or basic ash and should be corrosion proof
- The stirrer unit should not generate excessive amount of heat due to stirring. Further, motor heat should not reach the calorimeter; otherwise the calculations will leads to erroneous results.
- All surfaces should have high reflectance to minimize loses.
- Water equivalent of the calorimeter assembly should be small to ensure maximum raise in temperature of water following ignition.

Theory:
Essentially the apparatus consist of the following parts:
BOMB:

1. The Bomb consists of the three parts viz. Bomb body, Lid, and the Union nut.
2. The Bomb vessel and the lid are machined from an ultra-strong corrosion resistant stainless steel alloy rod, containing Chromium, Nickel, and Molybdenum and satisfying special ringing and bending test for inter crystalline corrosion.

WATER JACKET:

1. It is made of copper and is highly chromium plated on the outside and also inside to minimize radiative losses.
2. The top of the jacket carries a rod to hold the stirrer unit, a threaded adopter to support the Beckman thermometer holder rod, and a sample pipe through which a water is added. The pipe also supports the thermometer from measuring temperature inside this jacket.

OFFSET STIRRER:

1. It consist of stirrer with fan driven at a constant speed of 800 R.P.M by a motor through a heat insulator rubber belt.
2. The motor unit is kept at sufficient distance from the vessel to eliminate radiative heating and a heat insulator Bakelite divides the two parts of the stirrer rod.
3. The arrangement does not raise the temperature of the water by even 0.01 ℃ in ten minutes, thus easily meeting the specific requirements laid down by British Standard Institution and the Institute of Petroleum and accepted by Indian Standard Institution.
4. The electric supply for the stirrier motor is obtained through the terminals provided on firing unit.

CALORIMETER VESSEL:

1. Calorimeter vessel is made up of copper and is brightly polished outside.
2. Bomb firing unit, vibrator, timer and illuminator with magnet.
3. The firing unit is operated by A.C mains (230Volts 50Hz); and is provided with terminals for the stirrer unit.
4. Vibrator-Timer-Illuminator unit and for the bomb fuse wire. The firing unit is provided with terminals for stirrer unit, the Vibrator-Timer-Illuminator Unit and for the bomb fuse wire.

PRESSURE GAUGE STAND:

1. An accurate pressure gauge is supplied for measurement of pressure of oxygen in the Bomb. The dial is graduated from 0 to 70 kg/cm^2 (0 to about 1000 lb/in^2). Normally the oxygen is filled in the bomb at a pressure of $25 \ kg/cm^2$.

Procedure:

1. Accurately weight in the crucible of the calorimeter about one gram of the air-dried material ground to pass through IS Sieve 20(211 microns).
2. If considered desirable, the sample may be compressed into a cylindrical pallet before weighing.
3. Stretch a piece of the firing wire across electrodes within the Bomb. Tie about 10 cm length of sewing cotton around the wire; place the crucible in position and arrange the loose ends of the thread so that they are in contact with the material; use the same amount of thread in each determination. Introduce into the body of the bomb to millimeters of distilled water.
4. Resemble the Bomb, screw home with the fingers, finally tightening it as necessary, avoiding excessive pressure. Charge the Bomb slowly with oxygen from a cylinder to a pressure of 25 atmospheres without displacing its original air content. Close the valve effectively, using a little pressure as possible and detach the bomb from oxygen supply

5. Weight into the calorimeter vessel a quantity of the water sufficiently to submerge the nut of the bomb to a depth of at least two millimeters leaving the terminals projecting. Using the same weight of water in all tests. Transfer the calorimeter vessel water jacket, lower the bomb carefully into the calorimeter vessel, and having ascertained to be gas-tighten, connect it to the ignition circuit through a switch for subsequent firing of the charge. Adjust the stirrer; place the thermometer and covers in position and start the stirring mechanism, which must be kept in continuous operation at a constant speed during the experiment. After an interval of not less than ten minutes, read the temperature to 0.001 ℃ and continue the readings for five minutes, at equal intervals of not more than one minutes, tapping the thermometer lightly during 10 seconds prior to each reading. If over a period of five minutes the average deviation of the individual values of the rate of change of the temperature is less than 0.00072℃ per minute, close the circuit momentarily to fire the charge and continue the observations of the temperature at the intervals of similar durations to those of the preliminary period. If the rate of change of temperature is not constant with in this limit, extend the preliminary period until it is constant. In the chief period which extend from the instant of firing until the time after which the rate of change of temperature again becomes constant, take the earlier readings to the nearest 0.01℃ .Since it will not be possible to take earlier readings to 0.001℃ .Resume the readings in this precision as soon as possible
6. Determine the rate of change of temperature in the after period(which the chief follows period by taking readings at 1 minute interval for at least five preferably ten minutes)

Precautions:

The operation must follow the following basic points in order to operate this oxygen bomb safely:

1. Don’t use too much sample. The Bomb cannot be expected to withstand the effects of combustible charges with liberate more than 10,000 calories. This generally limits the total weight of combustible material (sample plus gelatin, firing oil or any combustion aid) to not more than 1.10gram. Do not charges with more oxygen then is necessary and do not fire the bomb if an over charge of oxygen should accidentally be admitted.
2. Keep all parts of the bomb especially the insulated electrode assembly-in good repair all times. Do not fire the bomb if gas bubbles are leaking from the bomb when it is submerged in water.
3. Stand back from the calorimeter for at least 15 seconds after firing and above all, keep clear of the top of the calorimeter. If the bomb should explode, it is most likely that the force of explosion will be directed upward.
4. Proceed with caution and use only a fraction of the allowable maximum sample when testing new materials which burns rapidly, or have explosive characteristics.

Results: The calorific values of fuels are determined.

EXPERIMENT- XI

FREE AND FORCED CONVECTION

Aim:
To determine the convective heat transfer coefficient in forced convection.

Apparatus:
Free and forced convection apparatus test rig.

Description:
The Apparatus Consists of

- Heater regulator: supply the regulated power input to the heater.
- Thermocouples: at suitable position to measure the temperatures of body and the air.
- Digital temperature and indicator: with channel selector to measure the temperature.
- Blower: unit to blow air through the heat exchanger
- Anemometer: to measure the air flow rate from the blower.
- A control valve is provided to regulate the airflow.
- With this the whole arrangement is mounted on an aesthetically designed self-sustained ms powder coated frame with a separate nova pan board control panel.

Procedure:
- Switch on the MCB and then console on switch to activate the control panel.
- Start the blower and control it, so that the air flow is set to some desired value (3m/s).
- Switch on the heater and set the voltage (say 80V) using the heater regulator and digital voltmeter.
- Wait for reasonable time to allow temperatures to reach steady state.
- Measure the voltage, current and temperatures from T1 and T2 at known interval.
- Calculate the convective heat transfer co-efficient using the procedure given.
- Repeat the experiment for different values of power input to the heater and blower air flow rates.

Observations:

S No	Anemometer reading (V)in m/s	H heat input		Temperature (degc)						
		V	I	T1	T2	T3	T4	T5	T6	T7

where V= voltage, volts
I= current, amps

Calculations:

1. h=$\frac{Q}{A(Ti-To)}$ W/m^{2}K

   where,

   Q =heat given to the heater= V*I watts.

   A = surface area of the plate.

   = 2 side*250mm*150mm=0.025*0.015m^2

   T_i =mean temperature=(T1+T2+T3+T4+T5)/5

   To=ambient or surrounding temperature

2. Volume flow rate of air through the duct,

   Q=A*V

   where, A=area of the duct = 0.3*0.28 =0.625m^2

Theoretical:

N_u= 0.664 $Re^{1/2}$ $P_r^{1/3}$ for Re<5*10^5 ……..1

N_u=(0.037Re^{08}-870)$Pr^{1/3}$for Re > 5*10^5 …………..2

where Nusselt number : N_u=$\frac{hL}{K}$

Reynolds number =Re=$\frac{density*V*L}{\mu}$

Where L=length of the flat plate =100mm=0.01m

Prandtl number P_r=$\frac{\mu*\text{Cp}}{K}$

Properties of air are taken at T_f

At temperature T_f kinematic viscosity u, absolute viscosity μ, prandtl number P_r and thermal conductivity K are taken from properties of air from table.

Where,

V = velocity of the fluid over a flat plate in m/s.

R = density of fluid at film temperature T_f in kg/m^3

u = kinematic viscosity of fluid at film temp T_f in m^2/s

C_p = specific heat of fluid at film temp T_f J/Kg deg K.

μ = absolute viscosity of fluid at film temp Ns/m^2

K = thermal conductivity of fluid at film temp, W/Mk

All the properties of air should be taken at (Ti+T0)/2 from the data book.

Result Table:

s.no	velocity in m/s (V)	Reynolds No.(Re)	convective heat transfer coeffhth(W/m2deg k)	convective heat transfer coeffhexp(W/m2deg k)	rate of heat transfer (Q) in KW	heat carried away by the air (Q_{out}) in KW

Precautions:

- Check all the electrical connections
- Do not run the equipment if the voltage is below 180V.
- Do not obstruct flow of air while experiment is going on.
- Do not attempt to alter the equipment as this may cause damage to the whole system.

Result:

The convective heat transfer for a forced convection is ……………….

EXPERIMENT –XII

PROPELLER TEST RIG

Aim:

1. To study the performance of a propeller at different speeds and measure the thrust force.
2. To find the propulsion efficiency of the propeller.

Apparatus:

Propeller test rig.

Description:

1. The basic propeller test rig consists of a wooden propeller with two blade and with a constant pitch and it is dynamically balanced the propeller is coupled to D.C motor and mounted on a base plate and the whole unit is mounted on linear bearing and it is connected to a load cell for thrust measurement.
2. The speed of the propeller is sensed by a rpm sensor and it is connected to digital rpm indicator the power consumed by the D.C voltmeter and ammeter.
3. The experiment can be done for different speed.
4. There is an isolated control panel which houses all the measurement units like digital force indicator, digital speed indicator ,D.C motor thyristor drive and speed control knob , voltmeter and ammeter .
5. Air flow measurement before and after the propeller is done using handy digital anemometer.
6. With this the whole arrangement is mounted on a frame with a separate NOVAPAN Board control panel Aesthetically designed self-sustained MS powder coated frame with a separate NOVAPAN board control panel.

Procedure:

1. Ensure the propeller blade is firmly locked in position and mesh guard is safe enough to protect.
2. Connect the power cable and observe the "mains on" indicator to glow.
3. Ensure the speed controller knob is set to zero position.
4. Switch on force indicator and press the tare button , set it to zero and keep it in normal position.
5. Slowly increase the speed by operating the speed control knob some desired RPM value .
6. A*2000RPM (max ammeter reading A= 8amps).
7. Note down the rpm indicator reading and thrust force reading by putting the switch to peak position (keep the switch always in normal position while running the test rig).
8. Record the air flow measurement at inlet and outlet of the propeller .
9. Repeat the experiment at different speed .
10. Draw the graph of thrust vs. rotational speed, thrust vs. inlet velocity of air, thrust vs. outlet velocity of air ,rpm vs. propulsion efficiency.

Observations:

S.NO	Speed of the propeller in rpm	Thrust force in Newton Tact	Air flow measurement in m/s		Voltmeter reading (volts)	Ammeter reading(amps)
			Inlet (vin)	outlet(vout)		
1	600					
2	800					
3	1000					
4	1200					
5	1400					
6	1600					
7	1800					
8	2000					

Result Table:

S.NO	Speed in rpm	Power input to the propeller in KW	Actual thrust (Tact) in N	Theoretical thrust (Tth)in N	Propulsion efficiency(ηp)

Calculations:

1. Power input to the propeller, $P_{in}=\frac{V*i}{\eta m*1000}$ KW

   where, ηm=motor efficiency =0.75

2. Theoretical thrust generated by the propeller,

   $T_{th}= rAV_{in}(V_{out}-Vin)$
   where, r =density of air at room temperature, A=cross sectional area of duct.
   D= ………..mm

3. Propulsion efficiency, $\eta_p = \frac{2}{[1+\frac{Vout}{Vin}]}$

Precautions:

1. It is safe to run the propeller at affixed pitch and relatively low speed.
2. Before starting, ensure all the screws, bolts and nuts are firmly tight and mesh guard in secured position.
3. While doing experiment, be always little away from the propeller and control the speed of the propeller gradually by carefully observing the vibrations.

Result:

The performances of a propeller at different speeds are studied.

The efficiency of the propeller is ______