Bharath

INSTITUTE OF HIGHER EDUCATION AND RESEARCH

Declared as **Deemed-to-be-University** u/s 3 of the UGC Act, 1956

B.Tech- Aerospace Engineering

U20ASCJ05 -Aerospace Propulsion

Lab Manual

Vision of the Institute

“Bharath Institute of Higher Education & Research (BIHER) envisions and constantly strives to provide an excellent academic and research ambience for students and members of the faculties to inherit professional competence along with human dignity and transformation of community to keep pace with the global challenges so as to achieve holistic development.”

Mission of the Institute

- To develop as a Premier University for Teaching, Learning, Research, and Innovation on par with leading global universities.
- To impart education and training to students for creating a better society with ethics and morals.
- To foster an interdisciplinary approach in education, research and innovation by supporting lifelong professional development, enriching knowledge banks through scientific research, promoting best practices and innovation, industry driven and institute-oriented cooperation, globalization and international initiatives.
- To develop as a multi-dimensional institution contributing immensely to the cause of societal advancement through spread of literacy, an ambience that provides the best of international exposures, provide health care, enrich rural development and most importantly impart value based education.
- To establish benchmark standards in professional practice in the fields of innovative and emerging areas in engineering, management, medicine, dentistry, nursing, physiotherapy and allied sciences.
- To imbibe human dignity and values through personality development and social service activities.

B.Tech- Aerospace Engineering

Vision of the Department

Department of Aeronautical Engineering will endeavor to accomplish worldwide recognition with a focal point of Excellence in the field of Aeronautics by providing quality Education through world class facilities, enabling graduates turning out to be Professional Experts with specific knowledge in Aeronautical & Aerospace engineering.

Mission of the Department

- To be the state of art Teaching and Learning center with excellent infrastructure and empowered Faculties in Aeronautical & Aerospace Engineering.
- To foster a culture of innovation among students in the field of Aeronautics and Aerospace with updated professional skills to enhance research potential for sponsored research and innovative projects.
- To Nurture young individuals to be knowledgeable, skillful, and ethical professionals in their pursuit of Aeronautical & Aerospace Engineering.

B.Tech- Aerospace Engineering

Program Educational Objectives Statements (PEO)

PEO 1: Demonstrate a solid grasp of fundamental concepts in Mathematics, Science, and Engineering, essential for effectively addressing engineering challenges within the Aerospace industry.

PEO 2: Involve in process of designing, simulating, fabricating, testing, and evaluating in the field of Aerospace.

PEO 3: Obtain advanced skills to actively engage in research and development endeavors within emerging domains, while also pursuing further education opportunities.

PEO 4: Demonstrate efficient performance both as independent contributors and as valuable team members in diverse multidisciplinary projects.

PEO 5: Embrace lifelong learning and career advancement while adapting to the evolving social demands and needs.

B.Tech- Aerospace Engineering

Programme Outcomes (PO's)

PO1: Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and Engg. Specialization to the solution of complex engineering problems.

PO2: Problem analysis: Identify, formulate, research literature, and analyze engineering problems to arrive at substantiated conclusions using first principles of mathematics, natural, and engineering sciences.

PO3: Design/development of solutions: Design solutions for complex engineering problems and design system components, processes to meet the specifications with consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO4: Conduct investigations of complex problems: Use research-based knowledge including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5: Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6: The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO7: Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8: Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9: Individual and teamwork: Function effectively as an individual, and as a member or leader in teams, and in multidisciplinary settings.

PO10: Communication: Communicate effectively with the engineering community and with society at large. Be able to comprehend and write effective reports documentation. Make effective presentations and give and receive clear instructions.

PO11: Project management and finance: Demonstrate knowledge and understanding of engineering and management principles and apply these to one's own work, as a member and leader in a team. Manage projects in multidisciplinary environments.

PO12: Life-long learning: Recognize the need for and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

B.Tech- Aerospace Engineering

Program Specific Outcomes (PSO) - R2020

PSO1: Design and analyze aerospace components/systems for aerospace industries.

PSO2: Acquire the concepts of spacecraft attitude dynamics for the prediction of spacecraft motion.

Course Outcomes (COs)

CO1	**Compare** the performance characteristics of turbojet, turbofan, turboprop and propeller engines. (**Understand**)
CO2	**Discuss** the types and working and design selection criteria for inlets and nozzles. **(Understand)**
CO3	**Explain** the working principle of axial and centrifugal flow compressors. And turbines **(Understand)**
CO4	**Describe** the working, types, and design of combustion chamber with application **(Understand)**
CO5	**Summarize** the working principle, modes of operation and performance parameters of Ramjet engine and the challenges involved in scramjet design. **(Understand)**
CO6	**Acquire** the knowledge on jet engine components. **(Manipulation)**
CO7	**Carryout** calorific test on fuel to measure its properties. **(Manipulation)**
CO8	**Learn** the performance of various powerplants/engines. **(Precision)**

Mapping/Alignment of COs with PO & PSO

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	H											H		H
CO2	H									H		H		H
CO3	H											H		H
CO4	H									H		H		H
CO5	H											H		H
CO6	H							H	H	H		H		H
CO7	H							H	H	H		H		H
CO8	H							H	H	H		H		H

(Tick mark or level of correlation: H-High, M-Medium, L-Low)

LIST OF EXPERIMENTS:

S.No	Name of Experiment	Course Outcome
1.	Study the propeller Characteristics	CO6,CO7,CO8
2.	Estimation of the calorific value of the fuel using a bomb calorimeter	CO6,CO7,CO8
3.	Study of gas turbine engine components.	CO6,CO7,CO8
4.	Calculation of viscosity using a Redwood viscometer	CO6,CO7,CO8
5.	Study of the RAMJET engine working model	CO6,CO7,CO8
6.	Determination of flash point and fire point of a fuel	CO6,CO7,CO8

EXP NO : 1 DATE :	STUDY OF PROPELLER CHARACTERISTICS

AIM

To study the performance of the propeller.

BASIC PROPELLER PRINCIPLE

The aircraft propeller consists of two or more blades and a central hub to which the blades and are attached. Each blade is essentially of rotating wing. As a result of their construction, propeller blade produce forces/thrust to pull or push the aeroplane through air.
Power to rotate the propeller blades is furnished by the engines. Low powered engine propeller is mounted on the propeller shaft and that is geared to the engine crank shaft.

PROPELLER NOMENCLATURE

In order to explain the theory and construction of propellers it is necessary first to define the parts of various types of propellers and give the nomenclature associated with the propeller.
The cross section of a propeller blade is shown in the figure the leading edge of the blade trailing edge, the cambered side, or back and the flat side or face. The blade has an aerofoil shape similar to that of an aeroplane wing; it is through that it is a small wing; which has been reduced in length, width and thickness (small wing shape). When the blade start rotating, airflows around the blade fast as it flows around the wing of an aeroplane and blade is lifted forward
The nomenclature of an adjustable propeller is illustrated in the figure. This is metal propeller with two blades clamped into a steel hub assembly. The hub assembly is supporting unit for the blades, and it provides mounting structure in which propeller is attached to the engine propeller shaft. The propeller hub is split on a plane parallel to the plane of rotation of the propeller to allow for the installation of the blades. The sections of the hubs are held in place by means of clamping rings secured by means of bolts.

NOMENCLATURE FOR A CROUND ADJUSTABLLE PROPELLER

The figure shows two views of various cross sections of propeller blades. The blade shank is that portion of the blade near the butt of the blade it is usually made thick to give its strength, and it is cylindrical where it fits the hub barrel, but the cylindrical portion of the shank contributes little or no thrust. In order designs, the aero foil shape is carried to the hub by means of blade cuffs which are thin sheet metals and it function like cowling.

BLADE ELEMENT THEORY

The theory for the design of aircraft propeller was known as blade element theory. IT Is some time referred to as the DRYE WIECKI theory as the polish scientist name is DRYE WIECKI.

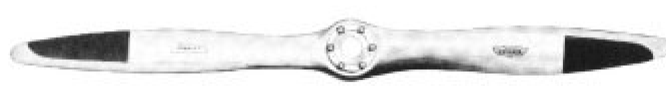
The theory assumes to the tip of the blade is divided into various mall, rudimentary aerofoil sections. For example if a propeller blade is 54 inch long and can be divided into 54 one-into aerofoil sections. Figure shows one of these aerofoil sections located at radius ‘r’, the chord ‘c’ will depend on the plan form or general shape of the blade.
According to the blade element theory, many aerofoil sections or elements being joined together side by side, unit to form an aerofoil (the blade) that can create thrust when revolving in a plane around central axis.
The thrust developed by a propeller is in accordance. With Newton’s third law of motion. In the case of propeller the first action is acceleration of a mass of air to rear of the aeroplane. This means that if propeller is exerting a force of 200 pounds in accelerating a given mass of air, it is the same time exerting at a force of 2000 pounds in pulling the aeroplane in the direction of opposite that in which the aeroplane is pulled forward. The quantitative realization slip among mass, acceleration, and force can be determined by the use of formula Newton’s second law.

F=m*a
True pitch propeller is one that makes use of the blade. In elemental theory, each element of the blade travels at different rates of speed that is tip section travels faster than the section closer to the hub.

Types of propeller:

Fixed pitch: The propeller is made in one piece. Only one pitch setting is possible and is usually two blades propeller and is often made of wood or metal.

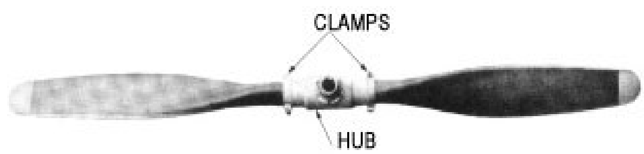
Wooden Propellers: Wooden propellers were used almost exclusively on personal and business aircraft prior to World War II .A wood propeller is not cut from a solid block but is built up of a number of separate layers of carefully selected .any types of wood have been used in making propellers, but the most satisfactory are yellow birch, sugar maple, black cherry, and black walnut. The use of lamination of wood will reduce the tendency for propeller to warp. For standard one-piece wood propellers, from five to nine separate wood laminations about 3/4 in. thick are used.



Fixed-pitch one-piece wood propeller.

Metal Propellers : During 1940 , solid steel propellers were made for military use. Modern propellers are fabricated from high-strength , heat-treated,aluminum alloy by forging a single bar of aluminum alloy to the required shape. Metal propellers is now extensively used in the construction of propellers for all type of aircraft. The general appearance of the metal propeller is similar to the wood propeller, except that the sections are generally thinner.

Ground adjustable pitch: The pitch setting can be adjusted only with tools on the ground before the engine is running. This type of propellers usually has a split hub. The blade angle is specified by the aircraft specifications. The adjustable - pitch feature permits compensation for the location of the flying field at various altitudes and also for variations in the characteristics of airplanes using the same engine. Setting the blade angles by loosened the clamps and the blade is rotated to the desired angle and then tightens the clamps.



A ground-adjustable propeller.

Full Feathering: A constant speed propeller which has the ability to turn edge to the wind and thereby eliminate drag and wind milling in the event of engine failure. The term Feathering refers to the operation of rotating the blades of the propeller to the wind position for the purpose of stopping the rotation of the propeller to reduce drag. Therefore, a feathered blade is in an approximate in-line-of-flight position, streamlined with the line of flight (turned the blades to a very high pitch). Feathering is necessary when the engine fails or when it is desirable to shutoff an engine in flight.

<u>Some of the terminologies used in propeller design :</u>

Two-position: A propeller which can have its pitch changed from one position to one other angle by the pilot while in flight.

Controllable pitch: The pilot can change the pitch of the propeller in flight or while operating the engine by mean of a pitch changing mechanism that may be operated by hydraulically.

Constant speed: The constant speed propeller utilizes a hydraulically or electrically operated pitch changing mechanism which is controlled by governor. The setting of the governor is adjusted by the pilot with the rpm lever in the cockpit. During operation, the constant speed propeller will automatically change its blade angle

to maintain a constant engine speed. If engine power is increase, the blade angle is increased to make the propeller absorb the additional power while the rpm remain constant. At the other position, if the engine power is decreased, the blade angle will decrease to make the blades take less bite of air to keep engine rpm remain constant. The pilot selects the engine speed required for any particular type of operation.

Reversing: A constant speed propeller which has the ability to assume a negative blade angle and produce a reversing thrust. When propellers are reversed, their blades are rotated below their positive angle, that is, through flat pitch, until a negative blade angle is obtained in order to produce thrust acting in the opposite direction to the forward thrust. Reverse propeller thrust is used where a large aircraft is landed, in reducing the length of landing run.
Beta Control: A propeller which allows the manual repositioning of the propeller blade angle beyond the normal low pitch stop. Used most often in taxiing, where thrust is manually controlled by adjusting blade angle with the power lever.

Blade Station

Blade stations are designated distances in inches measured along the blade from the centre of the hub the figure shows the location of a point on the blade at the 42 inches in each station this division of blade into station provides a convenient means of discussing the performance of the propeller blade locating blade marking and damage finding the proper point for measuring the blade angle and locating anti-glare areas

Blade Angle
Blade angle is defined as the angle between the chord particular blade section and the plane of rotation

Blade Pitch
Blade pitch is the distance advanced by the propeller in one revolution

Geometric Pitch
The propeller would have been advanced in one revolution

Experimental Mean Pitch
The distance traveled by the propeller in one revolution without producing thrust

Effective Pitch
Actual distance advanced by the propeller in one revolution

Pitch Distribution
The angle gradually decreases towards the tip and towards the shank

Angle Of Attack
This is the angle formed between the chord of the blade and direction of relative air flow

Propeller Slip
Slip is defined as difference between the geometric pitch and the effective pitch

Forces Acting On A Propeller

Thrust force Centrifugal force
Torsion or twisting force Aerodynamic twisting force
Aerodynamic twisting movement (ATM) Centrifugal twisting movement (CTM)

Thrust Force
Thrust force is a thrust load that tends to bend propeller blade forward as the aircraft is pulled through the air

Centrifugal Force
Centrifugal force is the physical force that tends to throw the rotating propeller blades away from the
hub

Torsion or Twisting Force
Torsion force is the force of air resistance tends to bend the propeller blade in a direction that is opposite to the direction of rotation

Aerodynamic Twisting Force
It is the force that tends to turn the blade to higher blade angle

Aerodynamic Twisting Moment
It is the force that tends to turn the blade angle towards low blade angle

Propeller Efficiency
Propeller efficiency has been achieved by use of this aerofoil section near the tips of the propeller blades and very sharp leading and trailing edge
.
Propeller efficiency id calculated = thrust horsepower / torque horse power

It is the ratio of thrust horse power to the torque horse power. Thrust horse power is the actual amount of horse power that an engine propeller transforms x thrust

Propeller Chart
For a given pitch angle B, the efficiency of the propeller is a function of dimensionless quantity T, the advance ratio such as a plot for a family of pitch angle that is valuable in a propeller can be plotted. This is called the propeller chart.

RESULT
Thus, the study of the propeller characteristics is successfully completed.

EXP NO : 2 **DATE :**	**DETERMINE THE CALORIFIC VALUE OF FUEL USING BOMB CALORIMETER.**

Aim

To determine the calorific value of the given solid or non-volatile liquid fuel using a bomb calorimeter

Theory:

A known amount of sample is burnt in a sealed chamber (bomb) the air is replaced by pure oxygen. The sample is ignited electrically. As the sample burns heat is generated. The raise in temperature is noted since baring loss of heat the amount of heat generated by burning of the sample must be equal to the amount of heat absorbed by the calorimeter assembly. By knowing the energy equivalent of the calorimeter and the temperature raise, the calorific value can be found out.

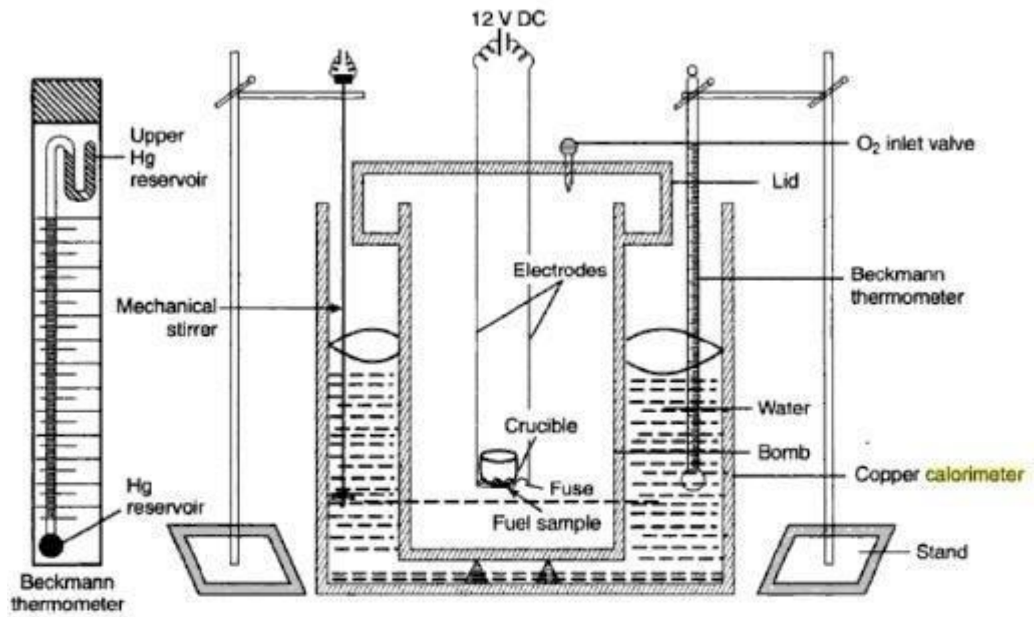


Figure 1. Bomb calorimeter setup

PROCEDURE:

Find the weight of the empty crucible using a physical balance.

- A small quantity of liquid fuel (diesel) is taken in the crucible and is again weighed with fuel in it.

- The crucible with fuel is placed over the support. A fuse wire is connected between the electrodes.

- The bomb is closed air tight and is filled with oxygen at a pressure of about 25 bars.
  - The bomb is placed inside the calorimeter vessel filled with water. Noted the initial temperature of water using the digital thermometer.
- The calorimeter water is stirred using a motor drive. The fuel is ignited electrically by passing a high voltage through the fuse wire which causes the fuse wire to burn.
- Heat liberated by the fuel causes the temperature to rise
- After steady condition is reached the temperature raise is measured using the digital thermometer provided

OBSERVATION:

Weight of the crucible without fuel (m_1) = gm

Weight of the crucible with fuel (m_2) = gm

Initial reading of the digital thermometer (t_1) = ^{0}C

Final reading of the digital thermometer (t_2) = ^{0}C

CALCULATION:

Mass of fuel burnt (m) = $m_2 - m_1$ Temperature rise (t) = $t_2 - t_1$

W = energy equivalent of the calorimeter assembly = 9735 J/.c C_v = calorific value of fuel in J/gm or

KJ/Kg

Then W * t = C_v * m C_v = W * t / m

RESULT: Thus, the calorific value of given solid or nonvolatile liquid fuel is found using bomb calorimeter.

EXP NO : 3 DATE :	**STUDY OF GAS TURBINE ENGINE COMPONENTS**.

AIM:-

Even though power produced by piston engine makes the aircraft to fly, during high altitude flying the piston engine aircraft is not efficient since the air density is very low at high altitude, and also not sufficient to meet the requirement of the engine requirement.

However, the low level (altitude) flying is very efficient by piston engine aircraft, whereas the high altitude flying is efficient by the Turbojet engine only.

JET ENGINE CONSISTS OF THE FOLLOWING:

(a) Air Intake

(b) Compressor

(c) Combustion Chamber

(d) Burners

(e) High Energy Ignition Units

(f) Nozzle Guide Vane (N G V)

(g) Turbine

(h) Exhaust unit.

(i) Lubrication System

AIRINTAKE:-

The air from the atmosphere enters through the air intake for the engine operation. The air from the atmosphere is directed to the compressor through static entry guide vane. The air is made to flow in stream lined manner to the compressor blades with out causing turbulence. Static Entry Guide Vane supports and strengthens air intake.

COMPRESSOR: -

The efficiency of the Turbojet Engine is determined by its air compressibility. There many types of compressors.

(j) Single Stage Single Entry Centrifugal Compressor

(ii) Single Stage Double entry Centrifugal Compressor.

(iii) Multistage Axial flow compressor

The compressor consist of Shaft, Drum and rotor blades. The Stator blades are fitted in the Compressor casing. The blades are made of steel/aluminum alloy as per the requirement. Each row of stator and rotor blades forms one stage. The number of stages is determined by the number of stator and rotor blades. Each row of rotor will have a row of Stator blades to direct the air to the next phase. Each set of Stator Blades row and Rotor Blades row will be called as Stage. The centrifugal compressor does not have more stages than one. The Axial Flow Compressor has many stages. The Stator blades are fitted on the compressor casing itself. The rotor blades are fitted on the rotor disc and the disc are assembled on the rotor shaft. Each blade is designed in Impulse at the root and Reaction at the tip. One third of the blade length from the root will be of Impulse design and the remaining two- third towards the tip will be of reaction design. i.e. the root will have impulse and the tip will have reaction type.

COMBUSTION CHAMBER: -

The combustion chambers are:-

(a) Can type

(b) Annular type

(c) Can-annular type

Many of the turbojet engines are fitted with Can-Annular combustion chamber only. The air after the compressor enters in to the combustion chambers through the diffuser casing for mixing with fuel. Only 30% of the air enters inside the combustion chambers and the remaining air get added up later. The air enters in side the combustion chambers for burning is called as primary air. The remaining air called as secondary air used for cooling and dilution of the burnt gas to increase the volumetric efficiency.

The combustion chambers are interconnected for flame propagation, since only two combustion chambers are fitted with igniters plug for giving initial ignition. The inter connectors helps in equalizing the pressure in all the combustion chambers and also propagates the flame to other combustion chambers. A spring loaded combustion chamber drain is located in the bottom most point of the Engine (Combustion Chamber outer casing). During wet start/ engine stops the excess unburned fuel is drained through this drain. Since it is spring loaded during engine running the internal pressure will be more and do not permit the drain to get open.

BURNERS: -

The fuel supply from the aircraft fuel tank, booster pump, reaches the fuel pump. The fuel from fuel pump enters into Fuel Control Unit (F C U). The fuel control unit only regulates the fuel supply to burner as per required operation of the engine. Each burner is connected from Fuel Control Unit by a common pipe line which is called as primary line and in addition a separate pipe line is connected to each burner from fuel control unit to supply additional fuel when RPM increases beyond 60% (Acceleration). The Fuel Pump will maintain sufficient pressure to prevent Vapor Lock in the fuel system. The fuel control unit is having a accelerator unit which supply fuel during sudden opening of the throttle to prevent starvation of fuel.

IGNITOR PLUGS: -

There are 02 ignitor plugs fitted in the 2 ‘o clock and 7 ’o clock position in the combustion chamber diagonally. The Electrical Supply from the Battery is sent to High Energy Ignition Unit (HEIU). During initial starting the ignitor plugs will ignite the fuel air mixture inside the combustion chamber. Then the flame from that combustion chamber will get propagate to other combustion chamber through inter connectors and get stabilized with pressure in all the combustion chambers. The Ignitor Switch in the Cockpit will be released after the engine attained the self-sustained RPM.

NOZZLE GUIDE VANE

The N G V is the unit located in between combustion chambers and Turbine. This will make the exhaust gases to flow uniformly to Turbine Blades, so that the gases are prevented from creating turbulence before Turbine disc.

TURBINE:-

The turbine is the main part of the jet engine which takes the rotation from compressor shaft and in turn rotates the turbine by the velocity of the exhaust gases. The high speed rotation obtained by the turbine disc due to exhaust gases in turn rotates the compressor to the selected speed. The turbine blades are retained to the turbine disc by” fir tree” method of attachment and penned for retention. The turbine blades are designed in Impulse & Reaction type.

EXHAUST UNIT:-

The exhaust unit is the attachment made to the engine rear side to evacuate the exhaust gases away from the aircraft. Further is covered with thermal Blanket to prevent the heat getting transferred to Aircraft Structure. The exhaust unit is a convergent duct (Pipe) to augment the jet velocity.At the end of the exhaust pipe trimmers may be fitted to increase the jet velocity or thrust or may be fitted thrust reversal attachment to reduce the engine thrust during aircraft landing.

LUBRICATION SYSTEM:

Dry sump lubrication system is employed in the jet engine. The lubricating oil after lubrication is taken back to the oil tank through oil filter, oil scavenge pump, oil cooler to the tank. The lubricating oil after lubrication to the rear bearing is not taken back to the oil tank since the oil might have lost its property due to high temperature. This is called as “Total Loss Lubrication”. The oil after lubrication to the rear bearing is let off to atmosphere along with exhaust gases.

RESULT: The study has given the detailed idea about construction, operation and working principle of Turbojet Engine. This basic study will help in long way to study about any other Jet-propelled Aircraft/Space craft/Space shuttle.

EXP NO: 4 DATE:	**CALCULATION OF VISCOSITY USING A REDWOOD VISCOMETER**

AIM: To determine the viscosity of given fluid using redwood viscometer at different temperatures.

APPARATUS: Redwood Viscometer, 50ml Receiving flask, thermometers, and stopwatch

DESCRIPTION OF THE APPARATUS:
Redwood viscometer Consists of a cylindrical oil cup furnished with a gauge point, agate / metallic Orifice jet at the bottom having a concave depression from inside to facilitate a ball with stiff wire to act as a valve to start or stop oil flow. The outer side of the orifice jet is convex, so that the oil under test does not creep over the lower face of the oil cup. The oil cup is surrounded by a water bath with a circular electrical immersion heater and a stirring device. Two thermometers are provided to measure water bath temp. & oil temperature under test. A round flat-bottomed flask of 50ml marking, to measure 50 ml of oil flow against time. The water bath with oil cup is supported on a tripod stand with leveling screws.

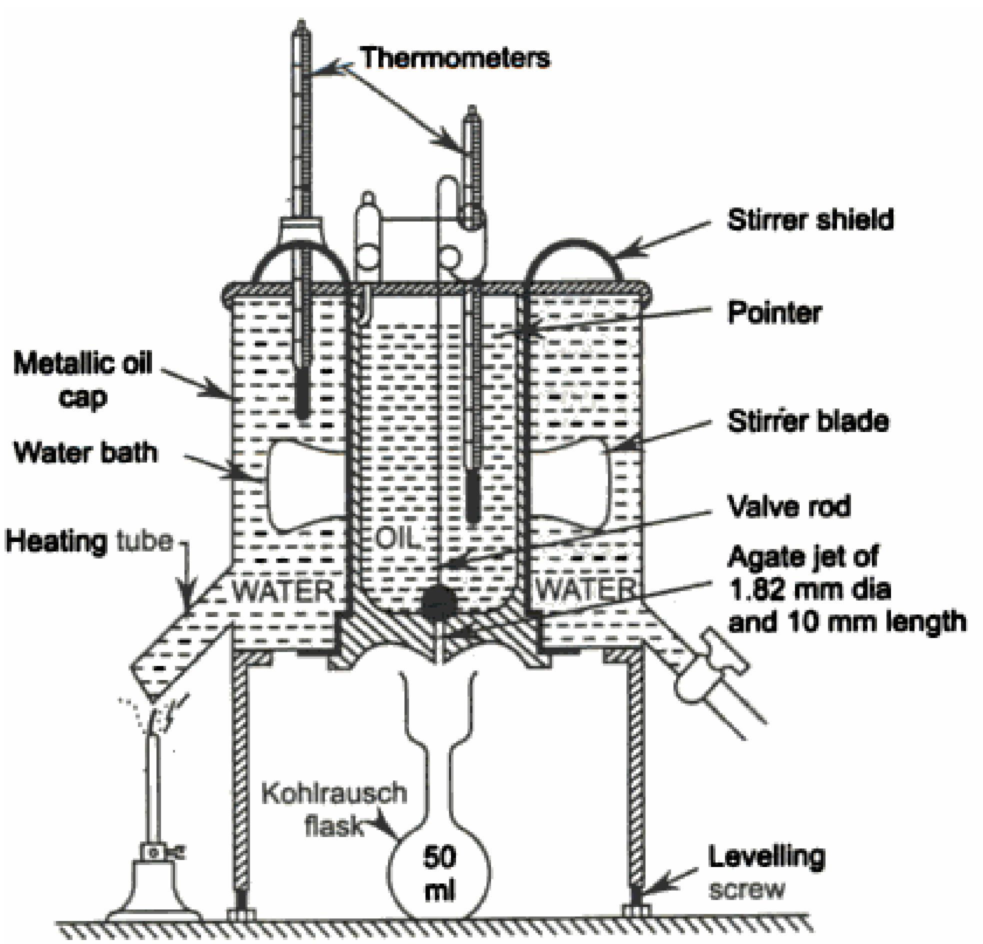


Figure: Experimental Setup

PROCEDURE:

1) Clean the oil cup with a solvent preferably C.T.C (Carbon Tetra chloride) and wipe it dry thoroughly with a paper napkins or a soft cloth (do not use cotton waste) and the orifice jet with a fine thread.
2) Keep the water bath with oil cup on the tripod stand and level it.
3) Pour water into the water bath up to 15 to 20mm below the top portion
4) Keep the ball (valve) in position and pour clean filtered oil sample (use strainer not coarser than BS 100 mesh) to be tested into the oil cup up to the gauge point and cover it with the lid.
5) Take a clean dry 50ml flask and place it under the orifice jet of the oil cup and center it.
6) Lift the ball (valve) and simultaneously start a stop watch and allow the oil into the receiving flask.
7) Adjust the receiving flask (50ml) in such a way that the oil string coming out of the jet strikes the neck of the flask to avoid foaming (formation of air bubbles) on the oil surface.
8) Wait till the oil level touches the 50 ml mark stop the watch and record the time in sec.
9) Repeat the experiment at different temperatures above ambient.
10) Plot the relevant graphs

NOTE:

For conducting experiment at different temperatures above ambient on Redwood Viscometer, connect the heater of the water bath to a 230V, 50Hz, 5amps power source through a dimmer stat. Heat the water to any desired temperature while continuously stirring the water with the stirring device and occasionally the oil sample with the thermometer. Once the temperature of the oil reaches the required temperature follow steps 6, 7 and 8.

OBSERVATION:

1. Type of oil used:

2. Weight of the empty flask:

TABULATION:

S. N	Temp. of the oil in ^0C	Time for collecting 50 ml. of oil in t (sec)	Wt. of the measuring jar (W_1) in gms	Wt. of the measuring jar + 50CC of oil (W2) in gms	Density of oil p in kg/m^3	Kinematic Viscosity (y) m^2/s	Dynamic Viscosity (μ) Pa/s

CALCULATIONS:

The viscosity of the given oil sample with the help of the Redwood viscometer at t °C = ... Redwood seconds

$$V = At - \frac{B}{t}\ s$$

Where, V = Kinematic viscosity of the oil in centistokes

t = Time of flow in seconds

A and B are instrument constants. The value of

A = 0.264 and B = 190, when t = 40 to 85 seconds

B = 0.247 and B = 65, when t = 85 to 2000 seconds

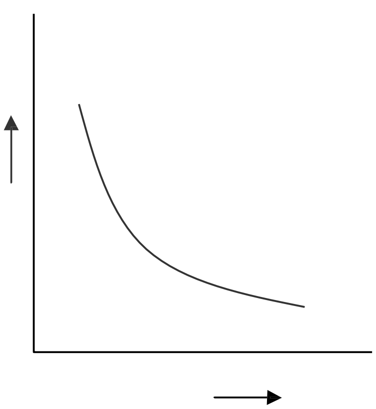
Note: 1 centistokes = 1×10^{-6} m^2/s; 1 stoke = $1 cm^2/sec$ (Kinematic Viscosity)
1 poise = $0.1 N\ S/m^2$ (Pa. S) (Absolute viscosity)

2) Density of the given oil is $\rho = \frac{(w_2 - w_1)}{50} \times 10^3$ in Kg/m^3

3) Absolute Viscosity $\mu = \nu * \rho$ in Pa.S or N S/m^2

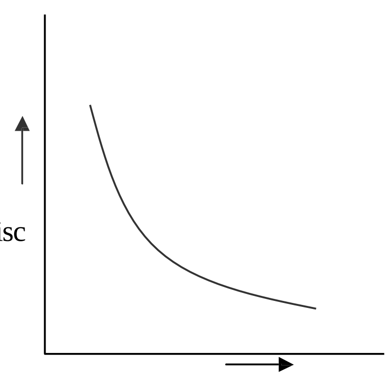
Plot the following graphs

Kine Visc



Temp

Abs Visc



Temp

RESULTS:

Mass density of given oil is_____________________ Kg/m^3
Kinematic viscosity of given oil is ______________ m^2/S Absolute viscosity of given oil is N S/m^2

CONCLUSION: Kinematic viscosity, absolute viscosity was determined, and relevant graphs were dr

EXP NO: 5 **DATE:**	**STUDY OF THE RAMJET ENGINE WORKING MODEL**

Introduction

A ramjet, sometimes referred to as a flying stovepipe or an athodyd (an abbreviation of aero thermodynamic duct), is a form of air-breathing jet engine that uses the engine’s forward motion to compress incoming air with-out an axial compressor. Because ramjets cannot pro-duce thrust at zero airspeed, they cannot move an aircraft from a standstill. A ramjet-powered vehicle, therefore, requires an assisted take-off like a rocket assist to accelerate it to a speed where it begins to produce thrust. Ram-jets work most efficiently at supersonic speeds around Mach3(2,300 mph; 3,700 km/h). This type of engine can operate up to speeds of Mach 6 (4,600 mph; 7,400 km/h).Ramjets can be particularly useful in applications requiring a small and simple mechanism for high-speed use, such as missiles. Weapon designers are looking to use ramjet technology in artillery shells to give added range; a 120 mm mortar shell, if assisted by a ramjet, is thought to be able to attain a range of 35 km (22 mi). They have also been used successfully, though not efficiently, as tip jetson the end of helicopter rotors.

Ramjets differ from pulsejets, which use an intermittent combustion; ramjets employ a Continuous combustion process. As speed increases, the efficiency of a ramjet starts to drop as the air temperature in the inlet increases due to compression. As the inlet temperature gets closer to the exhaust temperature, less energy can be extracted in the form of thrust. To produce a usable amount of thrust at yet higher speeds, the ramjet must be modified so that the incoming air is not compressed (and therefore heated) nearly as much. This means that the air flowing through the combustion chamber is still moving very fast (relative to the engine), in fact it will be supersonic - hence the name supersonic combustion ramjet - scramjet.

Description and Working Principles

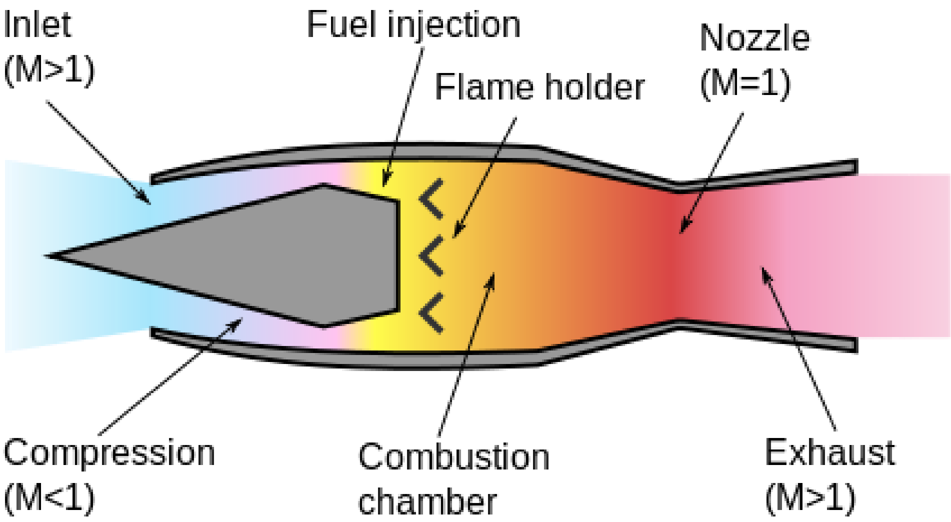
When the flight speed of a Turbojet Engine is very high, i.e. in the range of Mach no. 2 to 4, the pressure raise in the diffuser is very high. At this situation of the light speed, the discharge to the compressor, the total static pressure raise is significant. Therefore, it can be removed from the engine along with its prime moves the turbine.

Main Components of Supersonic Ramjet

- Diffuser

- Combustion Chamber
- Nozzle

The diffuser decreases the velocity of the incoming air to sufficiently low value, so that addition of required quantity of heat is possible before chocking. The diffuser consists of number of fuel inlets. The fuel gets mixed with incoming air in the diffuser and attains a very high pressure while entering the combustion chamber. On combustion the high pressure and temperature the gas expands to very high velocity while leaving the nozzle. A high thrust is developed on account of large change in momentum flux into the engine.



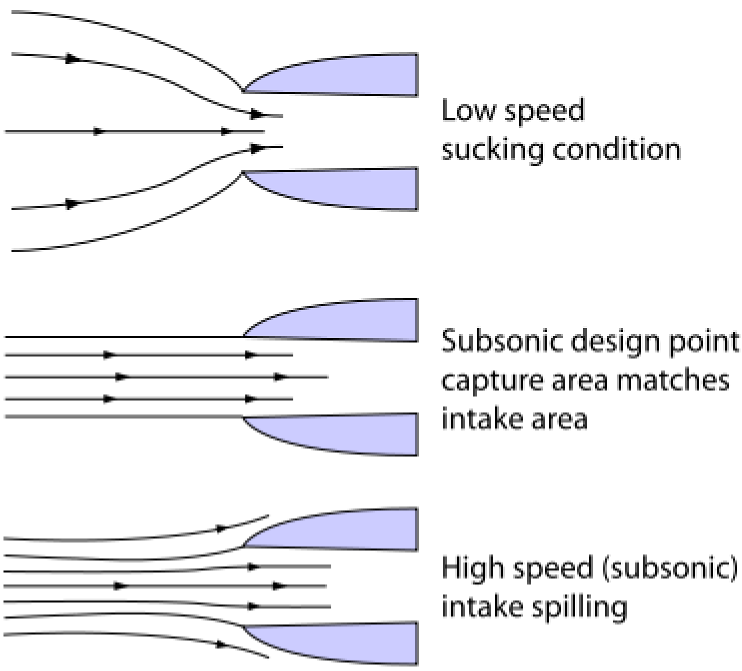


Fig. Subsonic intakes on ramjets

Engine cycle

The Brayton cycle is a thermodynamic cycle that describes the workings of the gas turbine engine, the basis of the air-breathing jet engine and others. It is named after George Brayton(1830– 1892), the American engineer who developed it, although it was originally proposed and patented by Englishman John Barber in 1791.It is also sometimes known as the Joule cycle. The ramjet is working on the Brayton cycle since it is one of the air breathing engines.

Design & Mechanism

A ramjet is designed around its inlet. An object moving at high speed through air generates a high-pressure region upstream. A ramjet uses this high pressure in front of the engine to force air through the tube, where it is heated by combusting some of it with fuel. It is then passed through a nozzle to accelerate it to supersonic speeds. This acceleration gives the ramjet forward thrust. A ramjet is sometimes referred to as a 'flying stovepipe', a very simple device comprising an air intake, a combustor, and a nozzle. normally, the only moving parts are those within the turbopump, which pumps the fuel to the combustor in a liquid-fuel ramjet. Solid-fuel ramjets are even simpler.

Diffuser

Ramjets try to exploit the very high dynamic pressure within the air approaching the intake lip. An efficient in-take will recover much of the free stream stagnation pressure, which is used to support the combustion and expansion process in the nozzle.

Most ramjets operate at supersonic flight speeds and use one or more conical (or oblique) shock waves, terminated by a strong normal shock, to slow down the airflow to a subsonic velocity at the exit of the intake. Further diffusion is then required to get the air velocity down to a suitable level for the combustor. Subsonic ramjets do not need such a sophisticated inlet since the airflow is already subsonic and a simple hole is usually used. This would also work at slightly supersonic speeds, but as the air will choke at the inlet, this is inefficient. The inlet is divergent, to provide a constant inlet speed of Mach 0.5 (170.15 m/s; 612.5 km/h)

Combustor

As with other jet engines, the combustor's job is to create hot air, by burning a fuel with the air at essentially constant pressure. The airflow through the jet engine is usually quite high, so sheltered combustion zones are produced by using 'flame holders' to stop the flames from blowing out. Since there is no downstream turbine, a ramjet combustor can safely operate at stoichiometric fuel-air ratios, which implies a combustor exit stagnation temperature of the order of 2,400 K (2,130 °C; 3,860 °F) for kerosene. Normally, the combustor must be capable of operating over a wide range of throttle settings, for a range of flight speeds/altitudes. Usually, a sheltered pilot region enables combustion to continue when the vehicle intake under-goes high yaw/pitch during turns. Other flame stabilization techniques make use of flame holders, which vary in design from combustor cans to simple flat plates, to shelter the flame and improve fuel mixing. Over-fueling the combustor can cause the normal shock within a supersonic intake system to be pushed forward beyond the intake lip, resulting in a substantial drop in engine airflow and net thrust.

Nozzle

The propelling nozzle is a critical part of a ramjet design, since it accelerates exhaust flow to produce thrust. For a ramjet operating at a subsonic flight Mach number, exhaust flow is accelerated through a converging nozzle. For a supersonic flight Mach number, acceleration is typically achieved via a convergent-divergent nozzle.

Performance and control

Although ramjets have been run as slow as 45 meter per second (160 km/h), below about Mach 0.5 (170.15 m/s; 612.5 km/h) they give little thrust and are highly in-efficient due to their low-pressure ratios. Above this speed, given sufficient initial flight velocity, a ramjet will be self- sustaining. Indeed, unless the vehicle drag is extremely high, the engine/airframe combination will tend to accelerate to higher and higher flight speeds, substantially increasing the air intake temperature. As this could have a detrimental effect on the integrity of the engine and/or airframe, the fuel control system must reduce engine fuel flow to stabilize the flight Mach number and, thereby, air intake temperature to reasonable levels. Due to the stoichiometric combustion temperature, efficiency is usually good at high speeds (around Mach 2–Mach 3 [680.6–1,020.9 m/s; 2,450–3,675 km/h]), whereas at low speeds the relatively poor pressure ratio means the ramjets are outperformed by turbojets, or even rockets.

Types of Ramjet

Ramjets can be classified according to the type of fuel, liquid or solid; and the booster. In a liquid fuel ramjet (LFRJ), hydrocarbon fuel (typically) is injected into the combustor ahead of a flame-holder which stabilizes the flame resulting from the combustion of the fuel with the compressed air from the intake(s). A means of pressurizing and supplying the fuel to the ram combustor is required, which can be complicated and expensive. The design of an LFRJ where the fuel is forced into the injectors by an elastomer bladder which inflates progressively along the length of the fuel tank. Initially, the bladder forms a close-fitting sheath around the compressed air bottle from which it is inflated, which is mounted lengthwise in the tank. This offers a lower-cost approach than a regulated LFRJ requiring a turbopump and associated hardware to supply the fuel.

A ramjet generates no static thrust and needs a booster to achieve a forward velocity high enough for efficient operation of the intake system. The first ramjet-powered missiles used external boosters, usually solid-propellant rockets, either in tandem, where the booster is mounted immediately aft of the ramjet, e.g. Sea Dart, or wraparound where multiple boosters are attached alongside the outside of the ramjet, e.g. SA-4 Ganef. The choice of booster arrangement is usually driven by the size of the launch platform. A tandem booster increases the overall length of the system, whereas wraparound boosters in-crease the overall diameter. Wraparound boosters will usually generate higher drag than a tandem arrangement of a Integrated boosters provide a more efficient packaging option, since the booster propellant is cast inside the otherwise empty combustor. This approach has been used on solid, for example SA-6 Gainful, liquid, for example ASMP, and ducted rocket, for example Meteor, designs. Integrated designs are complicated by the different nozzle requirements of the boost and ramjet phases of flight. Due to the higher thrust levels of the booster, a differently shaped nozzle is required for optimum thrust compared to that required for the lower thrust ramjet sustained. This is usually achieved via a separate nozzle, which is ejected after booster burnout. However, designs such as Meteor feature nozzle less boosters. This offers the advantages of elimination of the hazard to launch aircraft from the ejected boost nozzle debris, simplicity, reliability, and reduced mass and cost, although this must be traded against the reduction in performance compared with that provided by a dedicated booster nozzle.

Flight speed

Ramjets generally give little or no thrust below about half the speed of sound, and they are inefficient (less than 600 seconds)until the airspeed exceeds 1,000 kilometer per hour (280 m/s; 620 mph) due to low compression ratios. Even above the minimum speed, a wide flight envelope (range of flight conditions), such as low to high speeds and low to high altitudes, can force significant design compromises, and they tend to work best optimized for one designed speed and altitude (point designs). How-ever, ramjets generally outperform gas turbine-based jet engine designs and work best at supersonic speeds (Mach 2–4). Although inefficient at slower speeds, they are more fuel-efficient than rockets over their entire useful working range up to at least Mach 6 (2,041.7 m/s; 7,350 km/h).The performance of conventional ramjets falls off above Mach 6 due to dissociation and pressure loss caused by shock as the incoming air is slowed to subsonic velocities for combustion. In addition, the combustion chamber's inlet temperature increases to very high values, approaching the dissociation limit at some limiting Mach number.

Basic of scram-jet

Ramjets always slow the incoming air to a subsonic velocity within the combustor. Scramjets, or "supersonic combustion ramjet" are similar to ramjets, but some of the air goes through the entire engine at supersonic speeds. This increases the stagnation pressure recovered from the free stream and improves net thrust. Thermal choking of the exhaust is avoided by having a relatively high super- sonic air velocity at combustor entry. Fuel injection is often into a sheltered region below a step in the combustor wall. Although scramjet engines have been studied for many decades, only recently have small experimental units been flight tested and then only very briefly (e.g. the Boeing X-43).As of May, 2010, this engine has been tested to attain Mach 5 (1,701.5 m/s; 6,125 km/h) for 200 seconds on the X-51A Wave rider.

Aircraft Using Ramjet

1. Hiller hornet (a ramjet powered helicopter)
2. Lockheed D-21
3. Lockheed X-7
4. SR-71 blackbird

And many other aircraft are using ramjet for high altitude reconnaissance and may other purposes

Missiles Using Ramjet

1. Brahmos
2. MBDA meteor
3. Akash missile
4. Bristol bloodhound

Mostly 50 % of the modern missiles are working under the principle of ramjet.

Conclusion

Thus, the detailed study has been done about the subsonic ramjet.

EXP NO : 06 DATE :	DETERMINATION OF FLASH POINT AND FIRE POINT OF A FUEL

Aim :

To determine the flash and fire point temperatures of the given sample of lubricating oil using pensky –martens’ apparatus.

Apparatus Required:

1. Pensky-martens apparatus
2. Electric heater
3. Thermometer
4. Bunsen Burner

Theory and Definition:

The flash point of the lubricating oil is defined as the lowest temperature at which it forms vapours and produces combustible mixture with air. The higher flash point temperature is always desirable for any lubricating oil. If the oil has the lower value of flash point temperatures, it will burn easily and forms the carbon deposits on the moving parts. The minimum flash temperature of the oil used in IC engines varies from 200°C to 250°C. When the oil is tested using the open cup apparatus, the temperature is slightly more than the above temperatures. The flash and fire point temperatures may differs by 20°C to 60°C when it is tested by open cup apparatus. However, a greater difference may be obtained if some additives are mixed with oil. The flash and fire power point temperatures depends upon the volatility of the oil.

Description: The apparatus consists of a brass cup of 2.5” in diameter and 15/16” in deep supported is closed with a cover, a thermometer is inserted in one of the hole into the fuel to measure the temp of fuel. Fuel when heated to a sufficiently high temperature decomposes chemically. The hydrocarbon breaking upto volatile combustible gases. The flashpoint of fuel is the minimum temp of which sufficient flammable vapour is driven off to flash when brought into contact flash and fire point may vary with the nature of the original crude oil, the viscosity and method of refining. For the same viscosities and the degree of refinement the paratonic oil have higher flash and fire point oils.

Procedure:

1. A clean and dry cup is filled with given sample of oil up to the marking in the cup.

2. The lid is closed and a thermometer is inserted in the openings into the oil and the cup is placed in its position

3. The oil is heated with the help of an electric heater.

4. The oil is stirred with help of the stirring mechanism passes through the centre of the cover.

5. When the oil is at a temperature 10^{0}C below the expected lash point temperature apply the test flame at an interval of 1^{0}C.

6. Do not stir the oil when the test flame being applied.

7. The temperature at which a distinct flash is first seen on the surface of the oil through the opening is recorded as flash point.

8. The fire point is found by continuing the heating of oil at the same rate until the test flame ignites the oil continuously. If it continues to burn for at least 5sec, then this temperature is taken as the fire point temperature.

Precautions:

Before starting the experiment

1. Ensure that the cup is clean from unwanted makes
2. Carbon deposits to be removed completely.

After starting

1. Ensure that there is no air bubble in the cup.
2. Care should be taken that the operator does not breath near the cup.

When stopping

1. Hot fuel should be carefully transferred from the cup to the breaker before stopping.
2. Ensure that the flame and Bunsen burner.
3. Ensure that the workplace and apparatus are clean.

Tabulation:

S.No	Temperature of oil in ^{0}C	Flash point temp	Fire point temp

Result:

The flash and fire point temperatures of the given sample of oil was determined by using pensky-martens apparatus.

The flash point temperature of the given sample of oil is......................^{0}C

The fire point temperature of the given sample of oil is.................... ^{0}C