***EXPT NO: 01*** ***DATE*****:**

## *Flash and Fire Point Temperature*

***Object:*** Determination of flash and fire point of a given lubricating oil using Cleveland's open cup apparatus

### *Theory:*

**Definition of flash point**: It is the temperature at which the oil forms enough vapour to form a combustible mixture with the atmospheric air and gives out a moment airy flash when a test flame of standard size is brought over it.

**Fire point**: It is the temperature at which the oil forms sufficient vapour to form a combustible mixture with the atmospheric air, catches fire and burns for a specific period of time when a test flame of standard size is brought over it.

### *Procedure:*

1) Suspend the thermometer in vertical position such that the bottom of the bulb is at a height of 6.4 mm from the bottom of the cup.
2) The container is filled with oil up to the filling mark.
3) The electric heater is switched on.
4) Bring the test flame over the surface of the oil at every $5^oC$ rise in the beginning and at every $2^oC$ rise towards the end.
5) The flash point shall be taken as the temp. at which a momentary flash occurs.
6) After obtaining the flash point, continue the heating and continue the test. The fire point is taken as the temperature at which the oil ignites and continues to burn at least far 5 sec.
7) Repeat the test twice or thrice to get accurate values.

## *Observation Tabular Column*

Trial No 1: ……….

| Sl. No. | Temp $^oC$ | Flash/fire occurred or not |
|---|---|---|
| 01 | | |
| 02 | | |
| 03 | | |
| 04 | | |
| 05 | | |
| 06 | | |
| 07 | | |
| 08 | | |
| 09 | | |
| 10 | | |
| 11 | | |
| 12 | | |

Trial No 2: ……….

| Sl. No | Temp $^oC$ | Flash/fire occurred or not |
|---|---|---|
| 01 | | |
| 02 | | |
| 03 | | |
| 04 | | |
| 05 | | |
| 06 | | |
| 07 | | |
| 08 | | |
| 09 | | |
| 10 | | |
| 11 | | |
| 12 | | |

## ***Result**:*

| *Particulars* | *Trial No 1* | *Trial no 2* |
|---|---|---|
| Flash point temperature in $^oC$ | | |
| Fire point temperature in $^oC$ | | |

***EXPT NO: 02*** ***DATES:***

## *Bomb Calorimeter*

***Object:*** Determination of Calorific Value of solid Fuel Using Bomb Calorimeter

### *Theory:*

i) Definition and scope of fuels.
ii) Calorific value, HCV and LCV
iii) Classification of fuels

### *Description of apparatus*

The apparatus consists of a sealed vessel called the bomb. It has three parts; namely bomb body, lid and the cap. The lid is provided with two terminals. Two metallic rods pass through these terminals one of which i024444444445s provided with a ring for placing the sample crucible and the other with a groove. The bomb is placed in a calorimeter or water jacket which is made of copper and is chromium plated. The top of the water jacket carries a rod to hold the stirrer unit and an adapter to support the Beckman thermometer. A small pipe is also provided to fill the calorimeter with water.

**Pellet press**: It has a 12.5 mm diameter punch and die. Coal or other solid fuel powders are compressed into pellets using the press.

**Crucible:** It is used to keep the pellet or the powdered fuel.

**Ignition wire:** Platinum or Nichrome wire is used.

**Standard sample:** benzoic acid is commonly used as the standard sample. It burns easily and completely and can be made into pellets.

### *Procedure:*

1) Accurate weight of 1 kg of coal powder is made into a pellet using the pellet press.
2) The fuse wire is tied around the pellet and placed in the crucible.
3) The ends of the fuse wire are connected to the electrodes in the bomb.
4) The lid is then tightly screwed on to the bomb body. The bomb is then charged with the oxygen slowly so as not to disturb the pellet until the pressure 25 atm. The valve is closed and the bomb is detached from the oxygen supply.
5) Sufficient quantity of water (2000 C.C) is weighed into the calorimeter so that when the bomb is immersed, the water will be at least 2cm above the lid or the bomb.
6) The bomb is carefully lowered into the calorimeter vessel. The bomb is connected to the ignition circuit and the charge is fired.
7) The water in the calorimeter is continuously stirred. The rise in temp of water is noted down.

### *Standardizing the calorimeter:*

The energy equivalent of the calorimeter is the mass of water which will produce the same temperature rise as is produced by the calorimeter vessel containing a definite quantity of water along with the bomb and the stirrer. It is determined by burning a known quantity of benzoic acid (whose calorific value is known) in the bomb calorimeter under identical conditions and noting down the temperature rise.

Calculations are made as follows

| | | |
|---|---|---|
| Mass of fuel taken, | $m_f$ = 1 | g |
| Mass of water taken in the calorimeter | = 2000 | g |
| Energy equivalent of calorimeter | = | WJ/ °C |
| Initial temperature | $T_1$ = | °C |
| Final temperature | $T_2$ = | °C |
| Temperature correction | Tc = | °C |

Then energy released by 1 g of coal Temperature rise.=Energy equivalent of calorimeter x

$1 \times C.V. = W \times (T_2 + T_1 - T_{c1})$

Calorific value of coal = $(W \times 4.187 \times (T_2 - T_1 + T_{c1})$ J/Kg or kJlkg

To find energy equivalent of the calorimeter and its contents ( W )

Mass of benzoic acid taken, $m_b$ = 0.955g

Calorific value of benzoic acid = 6319 x 4.187 Jig

| | | |
|---|---|---|
| Initial temp of water | $T_3$= | °C |
| Final temp of water | $T_4$= | °C |
| Temperature correction | $T_{c2}$= | °C |

Then energy released by benzoic acid = 0.955 x 6319 x 4.187 J

i.e $0.955 \times 6319 \times 4.187 = W \times (T_3 - T_4 + T_{c2})$

Energy equivalent of calorimeter, W=

Then calorific value of the fuel= $W \times (T_2 - T_1 + T_{c1})$

$= 0.955 \times 6319 \times 4.187 \times (T_2 + T_1 - T_{c1}) / (T_3 - T_4 + T_{c2})$

=……………….J/Kg

=……………….KJ/Kg

***EXPT NO: 03*** ***DATE:***

## *Redwood Viscometer*

***Object:*** To determine the redwood number, the kinematic viscosity and the absolute viscosity of the given lubricating oil.

***Apparatus Required*:** Redwood Viscometer, Thermometer, Stop watch and 50 cc measuring flask etc.

***Theory:*** Write the definitions of

i. Viscosity
ii. Kinematic viscosity
iii. Absolute viscosity
iv. Unit of absolute viscosity
v. Unit of Kinematic viscosity

### *Procedure:*

1) The oil cup is cleaned with a suitable solvent such as $CCl_4$ and then dried. Using a spirit level, the viscometer is set up such that it is level.
2) The water bath is filled with water to a level not less than 10mm below the rim of the oil cup.
3) The bath is heated to a temperature a few degrees above the desired temp for the test.
4) A filtered sample of oil is poured into the oil cup. Stir the water in the bath and the oil in the cup such that the temperatures are steady.
5) Allow the oil to flow out until the surface of the oil just touches the filling mark.
6) The oil cup cover is then placed and the thermometer fixed in the slot is swung towards the closed end of the cover.
7) A clean and dry standard 50 cc flask is taken and is weighed accurately. It is then placed centrally below the gate jet such that the top of the neck is just a few mm below the jet.
8) Now the ball valve is lifted and simultaneously a stopwatch is started.
9) When the oil level reaches the 50 cc mark, the stop watch is stopped. The temperature of the oil is noted down both at the beginning and at the end of the run.
10) The weight of the flask with 50 cc of oil is accurately measured.
11) The experiment is repeated for different values of temperature and the readings are tabulated.

### *Description of the apparatus*

This apparatus is used for determining the viscosity of oil expressed as time of flow in seconds through a specified hole made in an agate piece. It is possible to convert the redwood viscometer readings into standard units by applying the appropriate equations.

### *The components of the apparatus are as follows:*

i) A heavily silver plated brass cup fitted with agate jet at the bottom and a vertical standard fitted on the rim of the cup to support the thermometer clip. An oil level indicator is also provided.

A brass cup cover having a slot for oil cup thermometer and valve wire.

### *Tabulation of readings*

| Sl. No. | Particulars | Symbol | Units | Trials | | | |
|---|---|---|---|---|---|---|---|
| **1** | Trial no | - | - | 1 | 2 | 3 | 4 |
| **2** | Weight of empty 50 cc flask | $W_1$ | gms | | | | |
| **3** | Weight of flask with 50 cc of oil | $W_2$ | gms | | | | |
| **4** | Weight of 50 cc of oil | $W = W_2 - W_1$ | gms | | | | |
| **5** | Time taken for 50 cc of oil to flow | t | Sec | | | | |
| **6** | Temperature of oil during the test | T | º C | | | | |

## *Specimen calculation:-*

Trial No.1

1. Weight of empty 50cc flask = $W_1$ = ............................................gms
2. Weight of flask with 50cc of oil = $W_2$ = ............................................gms
3. Weight of 50cc of oil $W = (W_2 - W_1)$ =……………………gms
4. Specific gravity of oil = $S = W_2 - W_1 / 50$ cc =…………………
5. Time taken for 50cc of oil to flow, t = …………….Sec.
6. Temperature of oil during the test T=……….. $^oC$
7. Redwood number of the oil = $\frac{(100 \times t\,S)}{(535 \times 0.915)}$ =………………

*Where, 535 is the time in sec for 50cc of rape oil to flow through the same jet at 15$^o$c and 0.915 is the Sp. Gr. of Rape oil at 15$^o$C.*

7. Kinematic viscosity = $\nu$ = (0.16 t-180 / t) =………………………centistokes.

8. Absolute viscosity = $\mu$ = S× (0.16 t-180 / t) =……………………... centipoises.

## *Tabulation of results*

| Sl. No. | Particulars | Symbol | Units | Temperature °C | | |
|---|---|---|---|---|---|---|
| | | | | $T_1$ | $T_2$ | $T_3$ |
| 1 | Redwood number | RN | | | | |
| 2 | Kinematic viscosity | $\nu$ | | | | |
| 3 | Absolute viscosity | $\mu$ | | | | |

## *GRAPHS*

Redwood number Vs Temperature

Absolute Viscosity Vs Temperature

***EXPT NO: O4*** ***DATE*:**

## *Saybolt Viscometer*

***SCOPE:***

(a) This method of test shall be used to determining the say BOLT, Viscosity of petroleum products and Lubricants.

(b) The say bolt universal viscometer shall be used only for oils with times of flow more than 32 seconds. There are no maximum limits to viscosity to be measured by the say bold universal viscometer but in general liquids having an out flow time of the order of 1000 secs. And higher, say bolt viscometer is tested more conveniently by means of say bolt furol viscometer.

(c) The say bolt Furol viscometer shall be used only for oils with time of flow more than 25 seconds. The out flow time of Furol Instrument in Approx, one tenth that of the universal.

**NOTE:** The word Furol is the contraction of the phrase fuel and road oils.

***TEMPERATURE OF TESTING:***

(a) With the say Bolt universal viscometer determinations shall be made at 21 °C, 37.5°C, 54°C, 99°C.

(b) With the say Bolt Furol determination shall be made at 25°e, 37.5°C, $50^{o}$C or 98°C. In tests on road and paving material, determinations may also be made at $60^{o}$C and 82°C.

***PROCEDURE:***

(a) Viscosity determinations shall be made in a room free from drafts and rapid changes in temp. for standardization and refree tests the room shall be between $20^{o}$C or $30^{o}$C and the actual temperature shall be recorded. For routine tests temperature upto 37°C may be employed.

(b) The oil tube shall be first be cleaned with an effective solvent, such as benzol and excess solvent shall be removed from gallery.

(c) All oil shall passed through a 100 mesh wire strain before it is introduced in Oil Tube. After the tube is cleaned, a quantity of oil to be tested sufficient to wet the entire surface of the tube shall be pour into the tube and allowed to drain out. The cork stopper shall be inserted not less than 1/4 inch nor more than 3/8 inch in, into the lower and of the chamber at the bottom of oil tube. The cork shall fit tightly enough to prevent the escape of oil, as evidence by the absence of oil on the cork after it is withdrawn.

(d) If the test temperature is above that the room, the oil shall be heated more that 2°C above the temperature of test and if that temperature is below that of the room, the oil shall be cooled to not more than 2°C below the temperature of test in no case, however shall be oil be preheated to a temperature above 28°C below the flash point. The oil shall be poured into the oil tube unit, it cease to over flow into the gallery. The oil in the oil tube shall be kept well stirred with the oil tube thermometer, care being taken to avoid lifting the out flow tube. The bath temperature shall be adjusted until the oil temperature remains constant. After thermal equilibrium has been attained no further adjustments shall be made in the both temperature.
(e) After the temperature of the oil in the oil to be has remained constant within 0°C 1°C the desired temperature for 1 minute with constant stirring the oil to be thermometer shall be withdrawn and the surplus oil removed quickly form gallery by means of the withdrawal tube so that the level of the oil in the gallery is below the level in the oil to proper. The tip of the withdrawal tube shall be inserted at one point in the gallery the test shall be started over again if the tip of the withdrawal tube touches the over flow rim. Under No conditions shall be excess oil be removed by rotating the withdrawal tube around the gallery.
f) The receiving flask shall be placed in position so that the stream of oil from the out let tube will strikes the neck of the flask the graduation mark on the receiving flask shall not be less than 10cm nor more than 13 cm from the bottom of the bath. The cork shall be shaped from its position and at the same instant the timer shall be stopped when the bottom of the meniscus of the oil reaches the mark on the neck of receiving flask.

***REPORTING RESULTS:***

The time in seconds is determined by the prescribed procedure with the universal (or say bolt furol) viscosity of the oil at the temperature at which the test is made. Result shall be reported to the nearest 0.1 seconds for viscosity valve below 200 seconds and to nearest whole second for valves 200 seconds or above.

***REPRODUCIBILITY OF RESULTS:***

With; proper attention to details of method of procedure, results in different laboratories with different operators under refree or standardization condition of testing should not differ my more than 0°5 percent.

***EXPT NO: O5*** ***DATE*****:**

**Penseky - Martenzs Flash Point**

***SCOPE:***

This method covers the determination of the flash point by pensky-Martens closed cup tester of the oils, lubricating oils, viscous materials, and suspension of solids. This method is not applicable to drying oils solvent-type liquid waxes, or cut-back asphalts.

***TERMINOLOGY: FLASH POINT:***

The temperature at which a material gives so much vapour that this vapour when mixed with air forms an ignitable mixture and gives a momentary flash on application of a small pilot flame.

***OUTLINE OF METHOD:***

The sample is heated in a test cup at a slow and constant rate with continuous stirring. A small test flame is directed into the cup at regular intervals with simultaneous interruption of stirring. The flash point is taken as the lowest temperature at which the application of the test flame causes the vapour above the sample to ignite momentarily.

***PREPARATION OF SAMPLE:***

Samples of asphalt or very viscous materials may be warmed until they are reasonably fluid, before they are tested. The samples shall not be heated above a temperature 16° below their expected flash point.

Samples containing dissolved or free water may be dehydrated with calcium chloride or by filtering through suitable filter paper or a loose plug of dry absorbent cotton. Warming the sample is permitted, but it shall not be heated for prolonged periods or above a temperature of 16° below its expected flash point.

***PROCEDURE:***

Thoroughly clean and dry all parts of the cup and its accessories before starting the test, being sure to remove any solvent which had been used to clean the apparatus. Support the tester on a level, steady table, till the cup with the sample to be tested to the level indicated by the filling mark. Place the lid on the cup, and set the latter in the stove. Take care that the locating devices are properly engaged. Insert the thermometer. Light the test flame and adjust it to 4mm in diameter. Apply heat at such a rate that the temperature recorded by the thermometer increases not less than 5°C nor more than 6°C per minutes. Turn the stirrer 90 to 120 rev/ min. stirring in a downward direction.

If the sample is known to have a flash point of 105°C or below, apply the test flame when the temperature of the sample is a whole number not higher than 17°C below the flash point, and thereafter at each degree rise of temperature. Apply the test flame by operating the mechanism on the cover which controls the shutter and test flame burner so that the flame is lowered into the vapour space of the cup in 0.5 second, left in its lowered position for one second, and quickly raised to its high position. Do not stir the sample while applying the test flame.

If the sample is known to have a flash point above 105°C apply the test flame in the manner prescribed in 5.2 at each temperature, that is, a multiple of 30°C, beginning at a whole number temperature reading not higher than 17° C below the flash point

Record as the flash point the temperature read on the thermometer at the time and test flame application causes a distinct flash in the interior of the cup. Do not confuse the true flash point with the bluish halo that sometimes surrounds the test flame at applications preceding the one that cause the actual flash

***PROCEDURE FOR SUSPENSIONS OF SOLIDS:***

Bring the material to be tested and the tester to a temperature of $15^oC \pm 5^oC$ or 11°C lower than estimated flash point, whichever is lower. Completely fill the air space between the cup and the interior of the air bath with water at the temperature of the tester and sample. Turn the stirrer at 250 ±10 rev/min, stirring in a downward direction. Raise the temperature throughout the duration of the test at a rate of not less than 1°C nor more than $15^oC$ per minutes, with the exception of these requirements for rates of stirring and heating proceed as prescribed in 1.

***REPORTING:***

Round off to the whole number, the value obtained in and report the result as flash point (PMCC)

| Material | Flash point Range | Repeatability | Reproductibility |
|---|---|---|---|
| Suspension of solid | 35.0 to 43.0°C | 2°C | 3°C |
| All others | below 105°C | 2°C | 3°C |

***EXPT NO: O6*** ***DATE:***

## *Valve Timing Diagram*

***Object**: -* To draw the valve timing diagram of a 4 stroke cycle I.C. Engine.

***Theory**:* Valve timing diagram is a polar plot which shows the instant at which the inlet valve opens and closes and the exhaust valve opens and closes with respect to the piston at the Top dead centre position.

The performance of a 4 stroke cycle I.C Engine is greatly influenced by the timing and the duration of the opening and closing of the inlet and the exhaust valves. Theoretically the inlet valve opens when the piston is at the T.D.C and remains open throughout the downward stroke and instantaneously closes at B.D.C. The exhaust valve opens at the end of power stroke, remains open throughout the exhaust stroke and instantaneously closes at the end of the exhaust stroke. This is a very inefficient method of operating an I.C. Engine.

In practice as the valves cannot open or close instantaneously, the inlet valve is set to open a few degrees before the piston reaches the TDC towards the end of the exhaust stroke. This enables the valve to be fully open when the piston begins its admission stroke and the charge readily enters the cylinder. The inlet valve is set to close a few degrees after the piston reaches the B.D.C. and is moving upwards. This is to take advantage of the charge rushing in and the ram effect of the entering charge packs more charge into the cylinder before compression can begin.

The exhaust valve is set to open considerably before the piston reaches the B.D.C. during its power stroke. This allows the gases to rush out of the cylinder and the pumping work required to exhaust the burnt gases is reduced. The exhaust valve is set to close a few degrees after the piston has reached T.D.C. and is moving downwards during the admission stroke of the next cycle. This is to effectively scavenge the burnt gases from the cylinder. As can be seen the inlet and the exhaust valves are both open for a few degrees of crank rotation near the T.D.C. This is termed the VALVE OVERLAP. This enables the incoming charge to drive out the products of combustion. Care should be taken to see that the valve overlap is not excessive otherwise some of the valuable fresh charge may escape through the exhaust valve or some of the exhaust gases may be sucked back in to the cylinder.

***Observation tabular column***

| SN | Stroke | Start | End |
|---|---|---|---|
| 1 | Suction | | |
| 2 | Compression | | |
| 3 | Expansion | | |
| 4 | Exhaust | | |

| | Valve | Open | Closed |
|---|---|---|---|
| 1 | Inlet | | |
| 2 | Exhaust | | |

***Calculations***:

Circumference of flywheel = …………L cm

Length of string corresponding to inlet valve opening = ………… $X_1$ cm

Length of string corresponding to inlet valve closing = …………$X_2$ cm

Length of string corresponding to outlet valve opening = ………….. $X_3$ cm

Length of string corresponding to outlet valve closing = …………..$X_4$ cm

***Crank angle in degrees***:

$\theta_1$ = Inlet valve opening = $\frac{X_1}{L} \times 360^o$ = ……………before T.D.C.

$\theta_2$ = Inlet valve closing = $\frac{X_2}{L} \times 360^o$ =……………..before T.D.C.

$\theta_3$ = Exhaust valve opening = $\frac{X_3}{L} \times 360^o$ = ……………before T.D.C.

$\theta_4$ = Exhaust valve closing = $\frac{X_4}{L} \times 360^o$ = ……………..before T.D.C

Using these valves timing diagram is plotted
Valve overlap =

***Procedure:***

1) An arrow mark is provided on the flywheel of the engine and a vertical line on the body of the engine cylinder.
2) When the arrow head on the flywheel points to the mark on the cylinder body, it corresponds to the piston at the top dead center position.
3) A piece of twine thread is taken and the circumference of the flywheel is measured in cm. This length corresponds to $360^o$ of crank rotation.
4) Now the flywheel is rotated forward and backward and its position determined corresponding to the instant at which the inlet valve just begins to open.
5) Now a mark is made on the flywheel in line with the vertical line on the cylinder body. The arc length from this mark to the arrow mark is measured using the same twine thread.
6) This is converted into crank angle degrees.
7) The same procedure is repeated for inlet valve just closing, exhaust valve opening and closing.
8) The valve timing diagram is then plotted.

***EXPT NO: 07*** ***DATE:***

## *Planimeter*

***Object:*** To determine the area of regular and irregular surfaces using planimeter.

### *Apparatus Required:*

Drawing board, Drawing sheet, Planimeter instrument, drawing instruments

### *Theory:*

The planimeter is an instrument used to determine the area of regular and irregular surfaces, this instrument consist of two main parts i.e. two arms, one arm is fixed at one end and the other on the tracing point, both are hinged together, while using the instrument the tracing point is moved over the surface to be measured and to take the corresponding reading shown in the different scales. The area to be measure is calculated using the following formula

$$\mathbf{A = M\ [F_R - I_R \pm 10N + C]}$$

Where, $M = \Pi\ D\ L = 100$

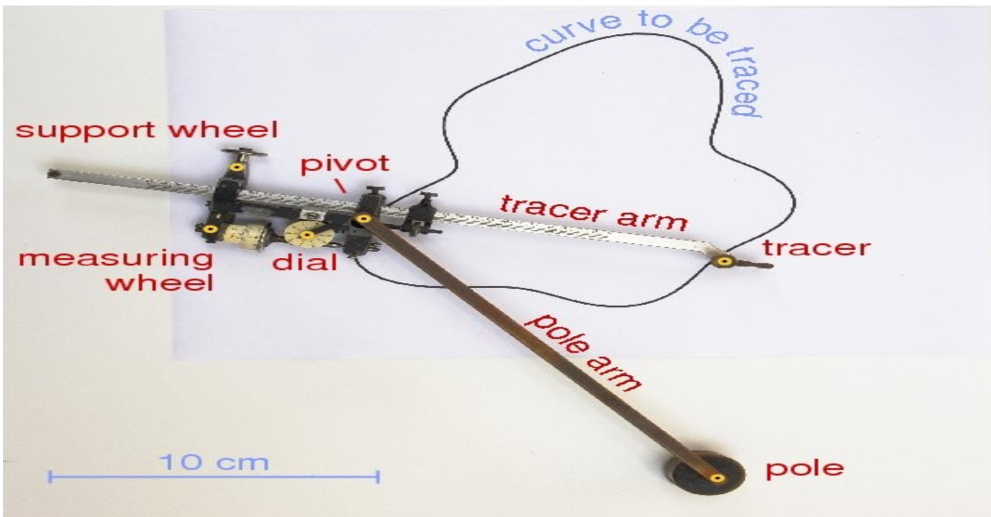
N = Number of times the zero mark of the dial passes the index mark

N is + ve for clockwise direction and –ve for anticlockwise direction

C = Planimeter constant

C= 21.4 When the pivot is kept inside the surface and zero when pivot is kept outside the surface

To use a planimeter, the user has to set up the device, zeroed the recording wheels and then traced the pointer all the way around a closed shape (typically a clockwise direction used to produce a positive result.) The area could then be read directly off the dials. Better planimeters allowed adjustments to allow the device to read in various units and scales. Other units simply read in a fixed scale such as square centimeters.



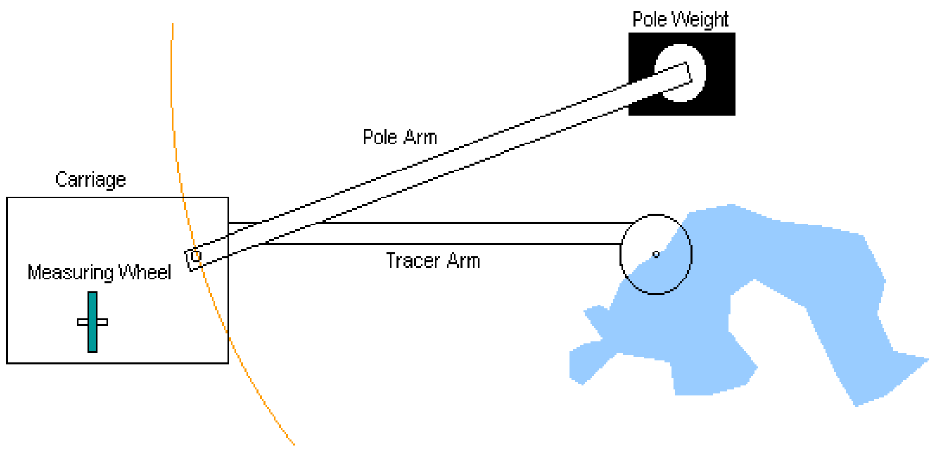
Planimeters were made in a number of ways. The devices shown above are Polar Planimeters. To use them, the user set pole weight on the desk usually outside the area to be measured. The pole weight sometimes had one or more pins in the bottom to make it stay put. The pole arm connected the pole weight to the carriage and the tracer arm connected the tracer point to the carriage. This caused the carriage to always move around a semi-circle regardless of the shape the tracer point followed.

Underneath the carriage was a measuring wheel. While the carriage always followed a circle, the angle of the tracer arm caused the measuring wheel to be anywhere between tangential to the circle and perpendicular.

## *Procedure:*

1) Firmly attach the surface whose drawing is to be measured on the drawing board.
2) If the area to be measure is small place the pivot outside the circle and if the area is large, then the pivot is kept inside the circle.
3) Adjust the verneir on the tracer arm to 1:1 ratio scale i.e. 32.6 for the arm
4) On the boundary of the one to be measured is traced and the tracing point is placed over if and the reading is noted.($I_R$).
5) Move the tracing point along the boundary which traces the initial point, now the reading is noted ( $F_R$)
6) Calculate the total final reading using the formula **$A = M [F_R - I_R \pm 10N + C]$**
7) Measure or calculate the actual area theoretically and take the difference for % error.
8) Now tabulate the reading for comparison

## *Planimeter*



## *Observations*

| | *Rectangular* | *Square* | *Triangular* | *circular* | *Irregular* |
|---|---|---|---|---|---|
| *Main drum reading* | 1x …….<br>= | 1x…….<br>= | 1x …….<br>= | 1x…….<br>= | 1x…….<br>= |
| *Main scale reading* | 0.1x…….<br>= | 0.1x…….<br>= | 0.1x…….<br>= | 0.1x…….<br>= | 0.1x…….<br>= |
| *Subdivision* | 0.01x…….<br>= | 0.01x…….<br>= | 0.01x…….<br>= | 0.01x…….<br>= | 0.01x…….<br>= |
| *Coinciding reading* | 0.001x…….<br>= | 0.001x…….<br>= | 0.001x…….<br>= | 0.001x<br>…….<br>= | 0.001x…….<br>= |
| *Final reading* | | | | | |

*Rectangular surface:* $\mathbf{A = M\,[F_R - I_R \pm 10N + C]}$ =……………………………………=……….

*Square surface* $\mathbf{A = M\,[F_R - I_R \pm 10N + C]}$ =……………………………………=……….

*Triangular surface* $\mathbf{A = M\,[F_R - I_R \pm 10N + C]}$ =……………………………………=……….

*Circular surface* $\mathbf{A = M\,[F_R - I_R \pm 10N + C]}$ =……………………………………=……….

*Irregular surface* $\mathbf{A = M\,[F_R - I_R \pm 10N + C]}$ =……………………………………=……….

| | *Rectangular* | *Square* | *Triangular* | *circular* | *Irregular* |
|---|---|---|---|---|---|
| *Measured area* ***A*** | | | | | |

## ***Actual area calculation:***

**Rectangular surface:**

*Length l=* *cm* A= cm2
*Breadth b=* *cm*

**Square surface**

*Length l=* *cm* A= cm2
*Breadth b=* *cm*

**Triangular surface**

*Height h=* *cm* A= cm2
*Breadth b=* *cm*

**Circular surface**

*Diameter d=* *cm* A= cm2

***Percentage error:*** % error = (Actual area- measured area) / Actual area x100

% error Rectangular surface :

% error Square surface :

% error Triangular surface :

% error Circular surface **:**

## ***Tabulation of results:***

| ***SN*** | ***Shapes*** | $I_R$ | $F_R$ | ***M*** | ***N*** | ***C*** | ***Actual area*** | ***Measured area*** | ***% error*** |
|---|---|---|---|---|---|---|---|---|---|
| 01 | *Rectangular* | | | | | | | | |
| 02 | *Square* | | | | | | | | |
| 03 | *Triangular* | | | | | | | | |
| 04 | *Circular* | | | | | | | | |
| 05 | *Irregular* | | | | | | | | |

*EXPT NO: O8* *DATE:*

## *Single Cylinder Four Stroke Cycle Diesel Engine Coupled to D.C. Generator*

***Object*** : To run the diesel engine at the rated speed and varying loads and to determine the following i) BP,IP and FP ii) Mech. efficiency iii) Brake thermal efficiency iv) BSFC v) Air fuel ratio and to draw energy balance sheet.

***Procedure**:* Before commencing the experiment calculate the full load current corresponding to the rated power and speed.

1) Check there is no load on the engine
2) Check the water circulation in the cylinder jacket and the exhaust gas calorimeter.
3) Checks there is enough fuel in the fuel tank and open the valve connecting the burette to the fuel supply tank.
4) Check the air box water manometer connection.
5) Open the decompression valve and crank the engine by hand briskly and close the valve
6) Once the engine starts firing and runs steadily, measure the engine speed using a tachometer.
7) Measure the rate of fuel consumption by noting down the time for 10ml of fuel consumption. While measuring the fuel consumption the valve connecting the fuel tank to the burette should be closed and as soon as the measurement is over the valve should be opened so that the engine may not be starved of fuel.
8) The engine is then loaded by switching on the lamps and the following readings are noted at each load
    a) Engine speed & Voltmeter and ammeter readings
    b) Time for 10cc of fuel consumption
    c) Water manometer reading
    d) Inlet and outlet temp of cylinder jacket circulating water
    e) Time for 1000cc of water through the cylinder jacket.
    f) Time for 1000cc of water through the E.G.C.M
    g) Inlet and outlet temp of water through the E.G.C.M
    h) Inlet and outlet temp of exhaust gases through the E.G.C.M
    i) Room temperature and pressure.

## *Data Sheet*

***Engine name plate details***

Rated Power = 5 H.P = 5× 0.7355 =3.72 kW

Rated Speed, N =1500 RPM

***Details of generator***

Rated Voltage of the generator = 200 V

Generator efficiency = 85 %

***Details of engine, orifice box and air tank***

Bore, D = 110 mm

Stroke, L = 110 mm

Compression ratio, r = 16:1

Diameter of air box orifice, do = 20 mm

Coefficient of discharge of the orifice, $C_d$ = 0.62

Room temperature, $t_a$ = ………………… $^oC$

Room pressure, $H_a$ = ……………. mm of Hg

Calorific value of the fuel used, CV = 43,100 kJ/kg

Specific gravity of fuel, SG =

### *Full load calculations:*

Rated voltage = 200 V

Rated power $= 5 \times 0.7355 \text{ kW} = \dfrac{VI_{FL}}{1000 \times \eta_G} =$

Efficiency of generator, $\eta_G = 0.85$

Full load current, $I_{FL} = \dfrac{5 \times 0.7355 \times 1000 \times \eta_G}{200} =$

=………………amps

## *Tabulation of Readings*

| **Sl. No** | **Particulars** | **Symbol** | **Units** | | | | | |
|---|---|---|---|---|---|---|---|---|
| **1** | Trial no | - | - | 1 | 2 | 3 | 4 | 5 |
| **2** | Speed | N | RPM | | | | | |
| **3** | Voltmeter reading | V | volts | | | | | |
| **4** | Ammeter reading | I | Amps | | | | | |
| **5** | Time for 10cc of fuel consumption | $t_f$ | s | | | | | |
| **6** | Manometer reading | $h_w = h_1 - h_2$ | mm of water | | | | | |
| **Cylinder jacket cooling water reading** | | | | | | | | |
| **7** | Time taken for 1000 c.c. of water from the cylinder jacket | $t_j$ | s | | | | | |
| **8** | Inlet temp of water | $T_{ji}$ | $^oC$ | | | | | |
| **9** | Outlet temp of water | $T_{jo}$ | $^oC$ | | | | | |
| **Exhaust gas calorimeter readings** | | | | | | | | |
| **10** | Time for collection of 1000cc of water | $t_w$ | Sec. | | | | | |
| **11** | Inlet temp of water | $T_{wi}$ | $^oC$ | | | | | |
| **12** | Outlet temp of water | $T_{wo}$ | $^oC$ | | | | | |
| **13** | Inlet temp of gases | $T_{gi}$ | $^oC$ | | | | | |
| **14** | Outlet temp of gases | $T_{go}$ | $^oC$ | | | | | |
| **15** | Ambient temperature | Ta | $^oC$ | | | | | |

***Specimen Calculation*** Trial No…..

1. Brake power, BP $= \frac{VI}{1000 \times \eta_G}$ = ………………

=……………kW

2. Mass flow rate of fuel, $m_f$ $= \frac{10 \times \text{Specific Gravity of Fuel}}{t_f \times 1000}$ = …………..

=…………....kg/s

3. Brake specific fuel consumption, BSFC $= \frac{m_f \times 3600}{BP} =$ ………..

=…………kg /kW hr

4. Brake thermal efficiency, B.Th. η $= \frac{BP}{m_f \times CV} \times 100$ =…………

=………… %

5. Friction power, FP =…………kW

***(To be got from plotting William's line graph of mf Vs BP)***

6. Indicated power, IP = BP + FP = ………..=…………kW

7. Mechanical η $= \frac{BP}{IP}$ =………..=………..…%

8. Indicated thermal efficiency, Ind. Th.η $= \frac{IP}{m_f \times CV}$ = ………..=………….. %

***To find the mass flow rate of air $m_a$ into the engine (from air box orifice method )***

i) Room pressure, $P_a = \frac{101.325 \times H_a}{760}$ = ……………=…………kPa

ii) Room Temp, $T_a = (t_a + 273)$ = …………… .=…………K

iii) Density of air at RTP, $\rho_a = \frac{P_a \times 10^3}{287.2 \times T_a}$ = ……………=…………kg/m$^3$

iv) Air head causing flow through the orifice,

$$h_a = \frac{\rho_w \times h_w}{\rho_w \times 1000} = \frac{1000 \times h_w}{1000 \times \rho_w} = \text{……………}$$

=………………………m of air

v) Actual volume of air drawn into the cylinder during the suction stroke,

$$V_a = C_d \times \frac{\Pi d_o^2}{4} \times 10^{-6} \times \sqrt{2gh_a} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots\ldots m^3/s$$

vi) Mass flow rate of air, $m_a = V_a \times \rho_a =$ ………………….=…………...kg/sec

9) Air fuel ratio $= \frac{\text{Mass of air}}{\text{Mass of fuel}} = \frac{\dot{m}_a}{\dot{m}_f} = \ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots$

10) Theoretical piston displacement, $V_{TH} = \frac{\Pi D^2}{4} \times L \times 10^{-9} \times \frac{N}{2} \times \frac{1}{60} = \ldots\ldots\ldots\ldots\ldots$

$= \ldots\ldots\ldots\ m^3/s$

11) Volumetric $\eta = \frac{V_a}{V_{TH}} \times 100 = \ldots\ldots\ldots = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ \%$

12) Brake mean effective pressure,

$$BMEP = \frac{BP \times 60{,}000 \times 10^{-3}}{\frac{\Pi D^2}{4} \times L \times \frac{N}{2} \times 10^{-9}} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots\ kPa.$$

## ***Energy balance sheet calculation*** (Trial No…….. )

A) Energy in fuel supplied, $Q_s = m_f \times CV =$ …………………..=……………kJ/s

B) Energy equivalent of BP, $Q_{BP} = BP$ = ………………….=……………kJ/s

C) Energy carried away by cylinder jacket cooling water,

$Q_c = m_j \times Cp_w \times (T_{jo} - T_{ji}) =$……….. ……………………..=…………….kJ/s

***(Where*** $m_j = \frac{1000}{t_j} \times \frac{1}{1000}$ ***kg/s)***

D) Energy carried away by exhaust gases,

$$Q_g = m_w \times Cp_w \times (T_{wo} - T_{wi}) \times \frac{T_{gi} - T_a}{T_{gi} - T_{go}} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

$= \ldots\ldots\ldots\ldots\ldots\ldots\ kJ/s$

***(Where,*** $m_w = \frac{1}{t_W}\ kg/s$ ***=………..Kg/Sec.)***

E) Energy lost to surroundings by radiation & convection,

$Q_{SUR} = A - (B + C + D) =$ …………………………………….=……… ……kJ/s

## *Energy balance sheet*

| Energy supplied | kJ/s | % |
|---|---|---|
| A) Energy in fuel supplied $Q_S = m_f \times CV$ | | 100 |
| B) Energy equivalent of BP, $Q_{BP}$ | | $Q_{BP}/Q_S \times 100 =$ |
| C) Energy carried away by cylinder jacket cooling water, $Q_c$ | | $Q_c / Q_S \times 100 =$ |
| D) Energy carried away by exhaust gases, $Q_g$ | | $Q_g/ Q_s \times 100 =$ |
| E) Energy lost to surroundings by radiation & convection, $Q_{SUR}$ | | $Q_{SUR}/Q_S \times 100 =$ |
| ***TOTAL*** | | |

## *Tabulation of Results*

| Sl. No | Particulars | Symbol | Units | | | | |
|---|---|---|---|---|---|---|---|
| **1** | Trial no | - | - | 1 | 2 | 3 | 4 |
| **2** | Speed | N | RPM | | | | |
| **3** | Brake power | BP | kW | | | | |
| **4** | Fuel consumption | $m_f$ | kg/s | | | | |
| **5** | Friction power(From graph) | FP | kW | | | | |
| **6** | Brake specific fuel consumption | BSFC | kg/kW hr | | | | |
| **7** | Indicated power | IP | kW | | | | |
| **8** | Mechanical efficiency | $\eta_{Mech}$ | % | | | | |
| **9** | Brake thermal efficiency | B. Th. η | % | | | | |
| **10** | Indicated thermal efficiency | I. Th. η | % | | | | |
| **11** | Brake mean effective pressure | BMEP | kPa | | | | |
| **12** | Air Fuel ratio | A/F | - | | | | |
| **13** | Volumetric efficiency | $\eta_{vol}$ | % | | | | |

***GRAPHS***

1) Total fuel consumption Vs B.P (WILLAN'S LINE)
2) IP Vs BP
3) Mech. efficiency Vs BP
4) A/F Ratio Vs BP
5) B. Th. η Vs BP } on a common base
6) BSFC Vs BP }

***EXPT NO: O9*** ***DATE:***

## *Four Stroke Single Cylinder 5 HP Diesel Engine Test Rig With Hydraulic Dynamometer Loading*

***AIM:*** To conduct a performance test on the engine and to draw the heat balance sheet.

***INSTRUMENTS REQUIRED:***

(a) Digital Temperature Indicator to exhibit different temperatures sensed by respective thermocouples.

(b) A Digital RPM Indicator to measure the speed of the engine.

(c) A differential U-tube manometer connected to an air box to measure the quantity of air drawn into the engine cylinder.

(d) A burette with 3 way manifold to measure the rate of fuel consumed during running.

***DESCRIPTION OFTHE TEST RIG:***

The engine is a Four Stroke Single Cylinder Water Cooled Vertical Diesel Engine coupled to a hydraulic brake dynamometer. A water line is connected to the inlet of the hydraulic dynamometer and a pipe to the outlet to drain water out from the sink. The engine jacket inlet and outlet are connected to a water supply line. Two thermocouples are provided at the inlet and outlet of the engine jacket water line to measure the respective water temperatures. The exhaust end of the engine is connected to a calorimeter inside which water circulates through a spiral copper tube. Two thermocouples are provided at the inlet and outlet of the exhaust gas line in the calorimeter to measure the exhaust gas inlet temperature to the calorimeter and exhaust gas outlet temperature of the calorimeter respectively. One thermocouple is mounted to measure the outlet temperature of the circulating water through the calorimeter. Two rotameters are provided to measure water flow rate through engine jacket and calorimeter, one at entry to the calorimeter and the other at entry to the engine water jacket. A digital temperature indicator, a digital RPM indicator, a U-tube manometer and a burette with 3 way manifold are provided on the panel board for measurement of various parameters.

***ENGINE SPECIFICATIONS:***

| | |
|---|---|
| BHP | : 5 |
| Speed | : 1500 RPM |
| No. of Cylinder | : 1 |
| Compression Ratio | : 16.5 : 1 |
| Bore | : 80 mm |
| Stroke | : 110 mm |
| Type of Ignition | : Compression Ignition |
| Method of Loading | : Hydraulic Dynamometer |
| Method of Starting | : Crank Start |
| Orifice Diameter | : 20 mm |

Arm length of hydraulic dynamometer = 320 mm

***TO DETERMINE THE FOLLOWING:***

| | |
|---|---|
| Weight of fuel consumed | : $W_r$ |
| Brake Power | : BP |
| Specific Fuel consumption | : SFC |
| Indicated Power (By Willan's Line Method) | : IP |
| Mechanical Efficiency | : $\eta_{mech}$ |
| Volumetric Efficiency | : $\eta_{vol}$ |
| Brake Thermal Efficiency | : $\eta_{Bth}$ |
| Indicated Thermal Efficiency | : $\eta_{Ith}$ |
| Heat Balance Sheet | : |

***BASIC MEASUREMENTS:***

To evaluate the performance of an engine following basic measurements are usually undertaken :

***FUEL MEASUREMENT*:**

The fuel is supplied from the main fuel tank through a 3 way manifold system with a measuring burette. To measure the fuel consumption of the engine at different loads allow the fuel from the burette by closing the fuel supply from the tank with the help of manifold block. By using a stop clock measure the time taken 't'sec for 'x' cc of fuel consumed.

$$Weight\ of\ fuel\ consumed, W_f = \frac{x}{t} \times Specific\ gravity\ of\ fuel \times \frac{3600}{1000}\ kg/hr$$

***AIR FLOW MEASUREMENT:***

An air drum fitted on the panel frame connected with an air hose to the engine at one end and having an orifice manifold with orifice and pressure pickup points at the up and down stream of the orifice at another end facilitates air flow measurement. The pressure pickup points are connected to the two limbs of a 'U' tube manometer. The difference in manometer reading $h_m$ is taken at different loads and the air suction by the engine is calculated by:

$$V_a = C_d\ A \sqrt{2\ g\ h_{air} \times 3600\ m^3/hr}$$

Where $C_d$ = coefficient of discharge of Orifice = 0.62

A = area of Orifice (diameter, d= 20 mm)

$$h_{air} = \frac{\rho_w - \rho_{air}}{\rho_{air}} \times h_m$$

***MEASUREMENT OF SPEED:***

The speed in rpm is measured by an RPM Sensor positioned close to the output shaft and it is indicated by the RPM indicator.

***BRAKE POWER:***

The load on the output shaft is measured by the circular scale (graduated in kg) of the hydraulic brake dynamometer. The arm length of the dynamometer is a known parameter.

$$BP = \frac{2\pi NT}{60000} = \frac{2\pi NW \times g \times r}{60000}\ kW$$

Where W = circular scale reading in kg

r = arm length

***FRICTIONAL POWER (FP)***

FP is found by using Willan's line method in which engine is run at constant speed and load is incremented. The corresponding BP and fuel consumption readings are taken. A graph is then drawn of fuel consumption against BP. The graph is extrapolated back to cut BP axis at a point whose distance from the origin will give FP.-

***THERMOCOUPLE DETAILS:***

TC1 : Inlet water temperature to calorimeter and engine jacket.
TC2 : Outlet water temperature from calorimeter.
TC3 : Exhaust gas inlet temperature to the calorimeter.
TC4 : Exhaust gas outlet temperature from the calorimeter.
TCs : Outlet water temperature from engine jacket.
TC6 : Ambient temperature.

***LOADING SYSTEM:***

The engine test rig is directly coupled to a hydraulic dynamometer which is loaded by water flow into the dynamometer. The load can be varied by operating gate valve provided on the inlet line of the dynamometer. A breather valve is provided at the bottom of the dynamometer which is to be kept crack opened throughout working range. The outlet will be connected to a valve to be adjusted depending upon the load conditions.

***EXPERIMENTAL PROCEDURE:***

1. Connect the water inlets of the engine jacket, calorimeter and hydraulic dynamometer to a constant head water source.
2. Connect the instrumentation power input plug to a 230V, single phase power source. Now all the digital meters namely RPM and Temperature Indicators display the respective readings.
3. Fill up diesel into the tank (5litre capacity) mounted on the vertical panel frame.
4. Check the lubricating oil level in the sump with the dip stick provided.
5. Open the inlet gate valves of the engine jacket and calorimeter to suitable desire~ flow rate.

6. Decompress the engine with the help of decompression lever provided on the top of the engine head (Lift the decompression lever to vertical position).
7. Start the engine by rotating the cranking handle and pulling down the decompression lever simultaneously.
8. Allow the engine to run and stabilize. Now the engine will run at 1500 rpm approx.
9. Now open the dynamometer inlet gate valve gradually to load the engine. The load is indicated on a dial type spring balance in terms of kg. The dynamometer arm having a length of r = 0.32 m gives the torque, T = r x s x g where 's' is the load indicated on

   the spring balance and g =9.81 $m/s^2$. Operate the inlet gate valve of the dynamometer and set the desired load. Allow the engine to run at the set load with the speed for a few minutes.
10. Note down all the required parameters mentioned below:

    a. Speed of the Engine (N) from digital RPM Indicator.
    b. Load (s) from Spring Balance.
    c. Fuel Consumption rate through burette.
    d. Quantity of Air from U tube manometer.
    e. Temperatures TC1, TC2, TC3, TC4, TC5, TC6 on digital Temperature Indicator by turning the selector switch provided on the meter.
    f. Water flow rate for engine jacket as well as calorimeter through the Rota meters provided (graduated in cc/sec).

11. Repeat the step no. 9 & 10 to load the engine to
    1/4 load (Le. 1.86 kg)
    1/2 load (Le. 3.73 kg)
    3/4 load (Le. 5.59 kg)
    Full load (Le. 7.46 kg)
    10% over load (i.e. 8.21 kg).
12. Draw the heat balance sheet from the parameters recorded at full load condition.

***Tabulation of Readings***

| Sl. No | Load (kg) | Speed of engine RPM | Fuel Consumption (cc) | Time take (sec) | Manometer Reading (mm) $h_1/h_2$ | Temperature Reading °C | | | | | | Water Flow rate | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $TC_1$ Engine | $TC_2$ Cal outlet | $TC_3$ Inlet exhaust | $TC_4$ Ex. Outlet | $TC_5$ En. Jacket | $TC_6$ Ambient | Engine Jacket (cc/sec) | Calorimeter (cc/sec) |
| 1 | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | |

Max. Load, $W_{max}$ = 7.46 Kg

$TC_1$ - Water Inlet temp. to calorimeter and Engine Jacket

$TC_2$ - Water Outlet temp. from calorimeter

$TC_3$ - Exhaust Gas Inlet temp. to calorimeter

$TC_4$ - Exhaust Gas Outlet temp. from calorimeter

$TC_5$ - Water Outlet from engine jacket

***FORMULAS:***

**Weight of fuel consumed**

$$W_f = \frac{X_{cc} \times Specific\ gravity\ of\ fuel \times 60 \times 60}{T_{sec} \times 1000}\ in\ kg/hr$$

Where: $X_{cc}$ is volume of fuel consumed in T secs.

**Brake Power**,

B.P = $\frac{2\pi NT}{60000}$ in KW

Where: N = Speed of the engine in RPM

T = torque = s x g x r

Where r = arm length of hydraulic dynamometer = 0.32 m

s = circular scale reading in kg

g = 9.81 m/sec2

**Specific fuel consumption**

$$SFC = \frac{W_f}{B.P.}\ in\ kg\ /\ kW\ hr$$

**Indicated Power (I.P.)**

I.P. = B.P. + F.P. ---- in kW

F.P obtained from Willan's line method

**Mechanical Efficiency**

$$\eta_{mech} \frac{B.P}{I.P} = \times 100$$

**Actual volume of air drawn into the cylinder at RTP in $m^3$/hr is calculated by**

$V_a = C_d \times A \times V_a = C_d \times A \sqrt{2gh_{air}} \times 3600\ in\ m^3/\ hr$ ,

Where $h_{air} = \frac{\rho_w - \rho_{air}}{\rho_{air}} \times h_m$ in m ($h_m$ = manometer reading)

**Swept Volume**

$$Vs = \text{Area of Cylinder} \times \text{Stroke length} \frac{\text{speed of the engine}}{2} \times 60 \text{ in m3/hr}$$

"

**Volumetric Efficiency**

$$\eta_{vol} = \frac{actual\ volume}{swept\ volume} \times 100 = \frac{V_a}{V_s} \times 100 \times$$

**Brake Thermal Efficiency**

$$\eta_{Bth} = \frac{B.P. \times 3600}{W_r \times CV} \times 100$$

Where CV = lower calorific value of diesel = 46057 kJ/kg

**Indicated Thermal Efficiency**

$$\eta_{Ith} = \frac{I.P. \times 3600}{W_f \times CV} \times 100$$

Where CV = lower calorific value of diesel = 46057 kJ/kg

**Heat Balance Sheet:**

Heat supplied by fuel, Q = Weight of fuel consumed x lower calorific value of fuel (kJ / hr)

i) Heat equivalent of B.P, $Q_1$ = B.P. x 3600 in kJ / hr.

ii) Heat carried away by engine jacket cooling water, $Q_2$

$Q_2$ = Mass of water flowing through engine jacket (kg / hr) × specific heat of water × difference in temperature inlet to outlet.

= $m_{we} \times Cp$ x (TCs - TC1) in kJ / hr.

$$Where\ M_{we} = \frac{Engine\ rotameter\ reading}{1000} \times 3600\ kg/hr$$

iii) Heat carried away by Exhaust Gas, $Q_3$

$Q_3$ = (Mass fuel + Mass of Air in Kg/hr) × specific heat of gas × temperature difference of exhaust gas inlet to calorimeter and exhaust gas outlet of calorimeter

= $(m_f + m_{air})\ C_{p(air)}\ (TC_3 - TC_4)$ in kJ / hr

Where $m_{air}$ = mass of air = volume of air ($V_a$) × density of air

$m_f$ = mass of fuel = $W_f$

iv) Heat carried away by calorimeter water, $Q_4$

$Q_4$ = Mass of water flowing through calorimeter in kg / hr × specific heat of water × temperature difference of water inlet to calorimeter and water outlet of calorimeter

= $m_{wc} \times Cp$ x $(TC_2 - TC_1)$ in kJ / hr

$$Where\ M_{wc} = \frac{Calorimeter\ rotameter\ reading}{1000} \times 3600\ kg/\ hr$$

v) Heat unaccounted for, $Q_5$

$Q_5 = Q - (Q_1 + Q_2 + Q_3 + Q_4)$ in KJ / hr

## *Heat Balance Sheet*

| Heat Item | kJ/hr | % |
|---|---|---|
| Heat Supplied by fuel Input Q | | |
| Heat equivalent of BP, $Q_1$ | | |
| Heat carried away by engine jacket cooling water, $Q_2$ | | |
| Heat carried away by exhaust gas, $Q_3$ | | |
| Heat carried away by calorimeter water $Q_4$ | | |
| Heat unaccounted, $Q_5$ | | |
| **Total** | | |

## *Tabulation of Results*

| Sl. No | Particulars | Symbol | Units | | | | |
|---|---|---|---|---|---|---|---|
| 1 | Trial no | - | - | 1 | 2 | 3 | 4 |
| 2 | Brake power | BP | kW | | | | |
| 3 | Specific Fuel consumption | $m_f$ | kg/s | | | | |
| 4 | Friction power(From graph) | FP | kW | | | | |
| 5 | Indicated power | IP | kW | | | | |
| 6 | Mechanical efficiency | $\eta_{Mech}$ | % | | | | |
| 7 | Brake thermal efficiency | B. Th. $\eta$ | % | | | | |
| 8 | Indicated thermal efficiency | I. Th. $\eta$ | % | | | | |
| 9 | Volumetric efficiency | $\eta_{vol}$ | % | | | | |

***EXPT NO: 10*** ***DATE:***

## *Single Cylinder Four Stroke Cycle Air Cooled Petrol Engine Coupled To a Prony Brake Dynamometer*

***Object***:- To run the engine at the rated speed and varying loads and to determine the following : i) B. Th. efficiency ii) Mech. Efficiency iii) BSFC iv) Air fuel ratio and also to draw an Energy balance sheet.

***Theory***: Component parts of a 4 stroke cycle petrol engine and the principle of its working Sketch and description of the experimental setup.

### *Procedure*:

Before commencing the experiment calculate the full load value corresponding to the rated power and the rated speed mentioned on the name plate.

1) Check that there is no load on the engine.
2) Check the water circulation in the EGCM (Exhaust gas calorimeter).
3) Check that there is enough fuel in the fuel supply tank and open the valve connecting fuel supply tank to the measuring burette
4) Check the air box orifice water manometer connection
5) Crank the engine by rope starter.
6) Once the engine starts firing and runs steadily, measure the engine speed
7) Measure the rate of fuel consumption on no load
8) The engine is loaded by rotating the hand wheel and forcing the brake shoes on to the brake drum.
9) The following readings are noted at each load taking care to see that the speed remains a constant.
   i) Engine speed ii) Dynamometer spring balance reading

   iii) Time for 10c.c of fuel consumption iv) Air box water manometer reading

   v) Time for 1000 C.C. of water through the EGCM vi) Inlet and outlet temperature of water through the EGCM vii) Inlet and outlet temperatures of exhaust gases through the EGCM viii) Room temperature and pressure.

### *Data Sheet*

Bore D = 70 mm, Stroke L = 67mm, Fuel used = Petrol
Rated speed N = 3000 RPM,
Rated power = 5 H.P or 5 × 0.7335 =……..KW,
Compression ratio =
Diameter of air box orifice, $d_O$ = 10mm,
Co efficient of discharge of the orifice, $C_d$ = 0.6
Room temperature, $t_a$ = ……….. $^OC$
Room pressure, $H_a$ = ……….. mm of Hg
Calorific value of the fuel. CV = 46,057 KJ/Kg
Specific gravity of fuel = Sp. Gr. = 0.74

## *Full load calculations*

Rated speed, N = 3000 RPM

Rated power = 5HP or $5 \times 0.7355$ =……… KW

Dynamometer constant, C =………………..

$BP = \frac{FN}{C}$ $\therefore F = \frac{5 \times 0.7355 \times C}{3000}$ = ……………….=………………

## *Tabulation of Readings*

| SN | PARTICULARS | Symbol | UNITS | | | | |
|---|---|---|---|---|---|---|---|
| 1 | Trial no | - | - | 1 | 2 | 3 | 4 |
| 2 | Load on the brake drum | W | kgf | | | | |
| 3 | Speed | N | RPM | | | | |
| 4 | Time for 10c.c of fuel consumption | $t_f$ | s | | | | |
| 5 | Air box water manometer reading | $h_w=h_1-h_2$ | mmof water | | | | |
| 6 | Time for 1000c.c of water through the EGCM | $t_c$ | s | | | | |
| 7 | Inlet temp of water | $T_{wi}$ | $^oC$ | | | | |
| 8 | Outlet temp of water | $T_{wo}$ | $^oC$ | | | | |
| 9 | Inlet temp of exhaust gases | Tgi | $^oC$ | | | | |
| 10 | Outlet temp of exhaust gases | Tgo | $^oC$ | | | | |

## *Specimen calculation*

1. Brake power ( BP )

   Net load on the brake drum, $F = W \times 9.81$ = …………….=………..…. N

   Brake power = $\frac{FN}{C}$ = ……………=………..….KW

2. Mass flow rate of fuel, $m_f = \frac{10 \times Sp.Gr.of\ Fuel}{t_f \times 1000}$ = …………………..=………..kg/s

3. Brake thermal efficiency, B. Th. $\eta = \frac{BP}{m_f \times CV} \times 100$ =

   =………………….

4. Brake specific fuel consumption, $SFC = \frac{m_f \times 3600}{BP}$ = =………………kg/kW - hr

5. *Friction power, F.P = Power loss in friction is assumed to be 20% of the rated power*

   i.e., F.P = 0.2 × Rated power = $0.2 \times 5 \times 0.7355$ =…………………=…………kW

6. Indicated power, I.P = B.P + F.P = ………………..=…………… kW

7. Mechanical efficiency $= \frac{B.P}{I.P}$ x 100 =…………..........=……………..%

8. Indicated Thermal efficiency $\frac{I.P}{m_f \times CV} =$ ……………………=……………%

9. *Mass flow rate of air, $m_a$*

i) Room Pressure $P_a = \frac{101.325 \times H_a}{760}$ = ……………=………. KPa

ii) Room Temp $T_a = (t_a + 273)$ = ……………=……..….. K

iii) Density of air at RTP $\rho_a = \frac{P_a \times 10^3}{287.2 \times T_a}$ =………………=……..…. kg/m$^3$

ii) Air head causing flow through the orifice

$h_a = \frac{\rho_w \times h_w}{\rho_a \times 1000} = \frac{1000 \times h_w}{1000 \times \rho_a} =$ …………………………………=………..m of air

v) Actual volume of air drawn into the cylinder during the suction stroke =

$V_a = C_d \times \frac{\Pi d_o^2}{4} \times 10^{-6} \times \sqrt{2gh_a}$ =………………………………=…………m$^3$/s

vi) Mass flow rate of air $m_a = V_a \times \rho_a$=………………………………=…………kg/s

10) Air fuel ratio $\frac{m_a}{\dot{m}_f}$ = ……………=………………..…

11) Theoretical piston displacement, $V_{TH} = \frac{\Pi D^2}{4} \times L \times 10^{-9} \times \frac{N}{2} \times \frac{1}{60}$ = …………………

=……………..…m$^3$/s

12) Volumetric efficiency $\frac{V_a}{V_{TH}} \times 100$ =……………………….=………………… %

13) Brake mean effective pressure, BMEP = $\frac{BP \times 60{,}000 \times 10^{-3}}{\frac{\Pi D^2}{4} \times L \times \frac{N}{2} \times 10^{-9}}$ = …………………

=…………………KPa.

**14) *Energy balance sheet calculation* (Trial No…. )**

A) Energy in fuel supplied, $Q_s = m_f \times CV$=…………………=…………………..kJ/s

B) Energy equivalent of BP, $Q_{BP} = BP$ = …………………=…………………kJ/s

C) Energy carried away by exhaust gases, $Q_g$

| SN | Particulars | Symbol | Units | | | | |
|---|---|---|---|---|---|---|---|
| **1** | Trial No | - | - | 1 | 2 | 3 | 4 |
| **2** | Brake Power | BP | kW | | | | |
| **3** | Mass Flow Rate of fuel | $m_f$ | kg/s | | | | |
| **4** | Brake specific fuel consumption | BSFC | Kg/kW-hr | | | | |
| **5** | Brake thermal Efficiency | $\eta_{bt}$ | % | | | | |
| **6** | Air fuel Ratio | A/F | - | | | | |
| **7** | Volumetric Efficiency | $\eta_{vol}$ | % | | | | |
| **8** | Indicated Power | IP | kW | | | | |
| **9** | Mechanical Efficiency | $\eta_{mech}$ | % | | | | |
| **10** | Brake Mean Effective Pressure | B.M.E.P | kPa | | | | |

$$Q_g = m_w \times Cp_w \times (T_{wo} - T_{wi}) \times \frac{T_{gi} - T_a}{T_{gi} - T_{go}} = \ldots\ldots\ldots\ldots\ldots\ldots$$

=……………………………..KJ/s

***(Where*** $m_w = \frac{1}{t_w}$ = …….. = …… kg / s***)***

D) Energy lost to surroundings by radiation & convection, $Q_{SUR}$

$Q_{SUR} = A - (B + C)$ = ……………………………………=…………kJ/s

***Energy Balance Sheet***

| **Energy distribution** | **KJ /s** | **%** |
|---|---|---|
| A. Energy Supplied, $Q_S = m_f \times CV$ | | 100 |
| B. Energy Equivalent of BP, $Q_{BP}$ | | $\frac{Q_{BP}}{Q_S} \times 100 =$ |
| C. Energy Carried away by exhaust gases,Qg. | | $\frac{Q_g}{Q_S} \times 100 =$ |
| D. Energy lost to surroundings<br>$Q_{sur} = A - (B + C)$ | | $\frac{Q_{sur}}{Q_S} \times 100 =$ |

***Tabulation of results***

***Graphs :*** i) BSFC Vs. BP ii) B. Th.$\eta$ Vs. BP iii) Mech. $\eta$ Vs. BP

***EXPT NO : 11*** ***DATE :***

## *Morse Test on 4 Cylinder 4 Stroke Cycle Petrol Engine*

***Object***:-To conduct the Morse test on a 4 cylinder 4 stroke cycle petrol Engine coupled to a hydraulic dynamometer and to determine i) FP ii) IP iii) Mech. η and also to draw Energy balance sheet.

***Theory***: Principle of Morse Test.

This test is based on the principle that friction losses are independent of the load on the engine and depend only on speed. As long as the speed is maintained a constant, frictional losses also remain substantially constant. In this test the engine is first run with all the 4 cylinders firing and the engine is loaded by the hydraulic dynamometer to its rated load and the speed is noted down BP is calculated.

Next one of the cylinders is cut off by short circuiting the spark plug. The engine speed drops. The speed is brought back to its original value by reducing the load on the engine. The corresponding dynamometer reading is noted and the BP is calculated.

This procedure is repeated by cutting off the cylinders in turn one at a time, bringing the speed to the original value reducing the load and calculating the B.P. the F.P. and the mechanical efficiency as follows:

Let BP = Brake power when all the 4 cylinders are firing

$BP_1$ = Brake power when cylinder No 1 is cut off

$BP_2$ = Brake power when cylinder No 2 is cut off

$BP_3$ = Brake power when cylinder No 3 is cut off

$BP_4$ = Brake power when cylinder No 4 is cut off

$BP = IP_1 + IP_2 + IP_3 + IP_4$ – F.P of all the 4 cylinders

$BP_1 = 0 + IP_2 + IP_3 + IP_4$ – F.P of all the 4 cylinders

Then $BP - BP_1 = IP_1$ = IP of the cylinder that is cut off

Similarly $BP - BP_2 = IP_2$

$BP - BP_3 = IP_3$

$BP - BP_4 = IP_4$

Then IP when all the four cylinder are firing = $IP_1 + IP_2 + IP_3 + IP_4$

Then FP=IP-BP

## *Data Sheet*

Bore, D = 73mm Stroke, L = 90mm

Number of cylinders = 4 Rated speed =1500 RPM

Rated power = 10 H.P = 10 × 0.7335 = 7.355 kW Fuel used = Petrol

Dynamometer constant, C = 26675 Diameter of air box orifice, $d_O$ = 20 mm

Co efficient of discharge of the orifice, $C_d$ = 0.62

Room temperature = $t_a$ = …………….. $^OC$

Room pressure, $H_a$ = ……………..mm of Hg

Calorific value of the fuel, CV = 46,057 kJ/kg Specific gravity of fuel, Sp. Gr.= 0.74

## *Full load calculations*

Rated speed, N = 1500 RPM Dynamometer constant, C = 26675

Rated power = 10HP or 10 × 0.7355 =7.355 kW

$$BP = \frac{FN}{C} \qquad \therefore F = \frac{10 \times 0.7335 \times 26675}{1500}$$ =……………………=………Newton's

## *Tabulation of Readings*

| S.N | PARTICULARS | Symbol | Units | | | | |
|---|---|---|---|---|---|---|---|
| 1 | Trial No. | - | - | 1 | 2 | 3 | 4 |
| 2 | Load (dynamometer spring balance reading ) | W | kgf | | | | |
| 3 | Speed | N | RPM | | | | |
| 4 | Time for 10 c.c. of fuel consumption | $t_f$ | s | | | | |
| 5 | Air box water Manometer reading. | $H_w$=$h_1$-$h_2$ | mm of water | | | | |
| 6 | Time for 1000 c.c. of water through the EGCM | $t_c$ | s | | | | |
| 7 | Inlet temp of water | $T_{wi}$ | $^oC$ | | | | |
| 8 | Outlet temp of water | $T_{wo}$ | $^oC$ | | | | |
| 9 | Exhaust gas temperature | $T_g$ | $^oC$ | | | | |

## *Morse Test Observations*

| SN | Sl. No. of cylinder cut off | LOAD ( kg) | | SPEED( RPM ) |
|---|---|---|---|---|
| | | SYMBOL | kg | |
| 1 | None | W | | |
| 2 | 1 | $W_1$ | | |
| 3 | 2 | $W_2$ | | |
| 4 | 3 | $W_3$ | | |
| 5 | 4 | $W_4$ | | |

## *Morse Test Results*

| SN | Sl.No. of cylinder cut off | Load kg | Speed RPM (N) | Brake Power ( kW ) | Indicated power of cylinder cut off |
|---|---|---|---|---|---|
| **1** | None | W | | $BP = \frac{W \times 9.81 \times N}{26675}$ =………… | |
| **2** | 1 | $W_1$ | | $BP_1$= | $IP_1 = BP-BP_1 =$ |
| **3** | 2 | $W_2$ | | $BP_2$= | $IP_2 = BP-BP_2 =$ |
| **4** | 3 | $W_3$ | | $BP_3$= | $IP_3 = BP-BP_3 =$ |
| **5** | 4 | $W_4$ | | $BP_4$= | $IP_4 = BP-BP_4$= |

TOTAL $IP = IP_1+IP_2+IP_3+IP_4$ =……………………..=…………………… KW

FP = IP-BP=…………………..……………=……………………..KW

Mech $\eta = \frac{BP}{IP}$ x100=………………………..=………………………..%

## *Specimen Calculation* Trial No…….

1. Brake power = $BP = \frac{F \times N}{26675}$ =…………………….=………….. kW

2. Mass flow rate of fuel = $m_f = \frac{10 \times \text{Specific Gravity of Fuel}}{t_f \times 1000}$ =…….. …… =………kg/s

3. Brake specific fuel consumption = $BSFC = \frac{m_f \times 3600}{BP}$ = …… =…….kg / kW- hr

4. Brake thermal efficiency = B. Th. $\eta = \frac{BP}{m_f \times CV} \times 100$ =………….. = …………..%

5. To find the mass flow rate of air $m_a$ into the engine (from air box orifice method)

i) Room pressure = $P_a = \frac{101.325 \times H_a}{760}$ =…………………….=……………kPa

ii) Room Temp = $T_a = ( t_a + 273 )$ = ……………………=……………K

iii) Density of air at RTP = $\rho_a = \frac{P_a \times 10^3}{287.2 \times T_a}$ =…………………….=…………..kg/m$^3$

iv) Airhead causing flow through the orifice, $h_a$

$$h_a = \frac{\rho_w \times h_w}{\rho_a \times 1000} = \frac{1000 \times h_w}{1000 \times \rho_a} = \text{……….. ………………………....=…………m of air}$$

v) Actual volume of air drawn into the cylinder during the suction stroke =

$$V_a = C_d \times \frac{\Pi d_o^2}{4} \times 10^{-6} \times \sqrt{2gh_a} = \text{…………………………………….=…………..}m^3/s$$

vi) Mass flow rate of air = $m_a = V_a \times \rho_a$=…………………………..=…………..kg/s

6) Air fuel ratio = $\frac{m_a}{\dot{m}_f}$ = ……………….=………………

7) Theoretical piston displacement

$$V_{TH} = \frac{\Pi D^2}{4} \times L \times 10^{-9} \times \frac{N}{2} \times \frac{1}{60} = \text{………….. ………………=…………….}m^3/s$$

8) Volumetric $\eta = \frac{V_a}{V_{TH}} \times 100$ = …………………………….=…………….. %

9) Brake mean effective pressure BMEP = $\frac{BP \times 60{,}000 \times 10^{-3}}{\frac{\Pi D^2}{4} \times L \times \frac{N}{2} \times 10^{-9}}$ =…………..…=……… kPa.

## *Tabulation of Results*

| **Sl. No.** | **Particulars** | **Symbol** | **Units** | | | | |
|---|---|---|---|---|---|---|---|
| **1** | Trial No | - | - | 1 | 2 | 3 | 4 |
| **2** | Brake Power | BP | kW | | | | |
| **3** | Mass Flow Rate of fuel | $m_f$ | kg/s | | | | |
| **4** | Brake specific fuel consumption | BSFC | Kg/kW-hr | | | | |
| **5** | Brake thermal Efficiency | $\eta_{bt}$ | % | | | | |
| **6** | Air fuel Ratio | A/F | - | | | | |
| **7** | Volumetric Efficiency | $\eta_{vol}$ | % | | | | |
| **8** | Indicated Power | IP | kW | | | | |
| **9** | Friction Power | F.P | kW | | | | |
| **10** | Mechanical Efficiency | $\eta_{mech}$ | % | | | | |
| **11** | Brake Mean Effective Pressure | B.M.E.P | kPa | | | | |

***EXPT NO: 12*** ***DATE:***

## *Single Cylinder Two Stroke Cycle Air Cooled Petrol Engine Coupled to a Hydraulic Dynamometer*

***Object***: - To run the engine at the rated speed and varying loads and to determine the following : i) B. Th. efficiency ii) Mech. Efficiency iii) BSFC iv) Air fuel ratio and also to draw an Energy balance sheet.

***Theory***: Component parts of a 2stroke cycle petrol engine and the principle of its working Sketch and description of the experimental setup.

***Procedure***:

Before commencing the experiment calculate the full load value corresponding to the rated power and the rated speed mentioned on the name plate.

1) Check that there is no load on the engine.
2) Check the water circulation in the EGCM (Exhaust gas calorimeter ).
3) Check that there is enough fuel in the fuel supply tank and open the valve connecting fuel supply tank to the measuring burette
4) Check the air box orifice water manometer connection
5) Open the decompression valve and crank the engine
6) Once the engine starts firing and runs steadily, measure the engine speed
7) Measure the rate of fuel consumption on no load
8) Take the manometer reading
9) take the EGCM reading - Inlet and outlet water temperature
   - Inlet and outlet exhaust gas temperature
   - Ambient temperature

## *Data Sheet*

Rated power = 3 H.P or 3 × 0.7335=…………..KW

Bore, D = 59mm

Stroke, L = 57mm

Rated speed N = 3000 RPM

Compression ratio = 7.4:1

Room temperature, $t_a$ = ………… $^{O}C$

Room pressure, $H_a$ = 700 mm of Hg

Calorific value of the fuel. CV= 44,000 KJ/Kg

Fuel used = Petrol

Specific gravity of fuel = Sp. Gr. = 0.74

Diameter of air box orifice, $d_O$ = 22mm

Co efficient of discharge of the orifice, $C_d$ = 0.62

## *Full load calculations*

Rated speed, N = 3000 RPM

Rated power = 3HP or 3 × 0.7355 =……… KW

Dynamometer constant, C = 26675

$BP = \frac{FN}{C}$ $\therefore F = \frac{3 \times 0.7355 \times C}{3000}$ = ……………=………………………

## *Tabulation of Readings*

| SN | PARTICULARS | Symbol | UNITS | | | | |
|---|---|---|---|---|---|---|---|
| 1 | Trial no | - | - | 1 | 2 | 3 | 4 |
| 2 | Load on the brake drum | W | kgf | | | | |
| 3 | Speed | N | RPM | | | | |
| 4 | Time for 10c.c of fuel consumption | $t_f$ | s | | | | |
| 5 | Air box water manometer reading | $h_w=h_1-h_2$ | mm of water | | | | |
| EXHAUST GAS CALORIMETER READING | | | | | | | |
| 1 | Rotameter reading | $T_w$ | cc/sec. | | | | |
| 2 | Inlet temp of water | $T_1$ | $^oC$ | | | | |
| 3 | Outlet temp of water | $T_2$ | $^oC$ | | | | |
| 4 | Inlet temp of exhaust gases | T3 | $^oC$ | | | | |
| 5 | Outlet temp of exhaust gases | $T_4$ | $^oC$ | | | | |
| 6 | Ambient temperature | $T_5$ | $^oC$ | | | | |

## ***Specimen calculation*** *(*Trial No…..)

1.Brake power ( BP )

Net load on the brake drum, F = W×9.81=…………………..= ………………. N

Brake power = $\frac{FN}{C}$ = …………………=………………..KW

2. Mass flow rate of fuel, $m_f = \frac{10 \times Sp.Gr.of\ Fuel}{t_f \times 1000}$ = ……………………...=…………..kg/s

3. Brake thermal efficiency, B. Th. $\eta = \frac{BP}{m_f \times CV} \times 100$ = ....................................... = %

4. Brake specific fuel consumption, $BSFC = \frac{m_f \times 3600}{BP}$ = ......................... = .................... kg/kW - hr

*5. Friction power, F.P = Power loss in friction is assumed to be 15% of the rated power*

i.e., F.P = 0.15 × Rated power = 0.15 ×3×0.7355 =………………=…………kW

6. Indicated power, I.P = B.P + F.P = ………………=……….. kW

7. Mechanical efficiency $= \frac{B.P}{I.P} \times 100$ =……….......=…………......%

8. Indicated Thermal efficiency $\frac{I.P}{m_f \times CV} =$ …… =……………%

9. *Mass flow rate of air, $m_a$*

i) Room Pressure $P_a = \frac{101.325 \times H_a}{760}$ = ………………. …=………….. KPa

ii) Room Temp $T_a = (t_a + 273)$ = ………………….=……………..K

iii) Density of air at RTP $\rho_a = \frac{P_a \times 10^3}{287.2 \times T_a}$ =………………… = …………..kg/m$^3$

iv)Air head causing flow through the orifice

$h_a = \frac{\rho_w \times h_w}{\rho_a \times 1000} = \frac{1000 \times h_w}{1000 \times \rho_a} =$ …………………………………..=……………m of air

v) Actual volume of air drawn into the cylinder during the suction stroke =

$V_a = C_d \times \frac{\Pi d_o^2}{4} \times 10^{-6} \times \sqrt{2gh_a}$ =………………………………….=…………….m$^3$/s

vi) Mass flow rate of air $m_a = V_a \times \rho_a$=…………….=………………….kg/s

10) Air fuel ratio $\frac{m_a}{\dot{m}_f}$ = ………………….=………………….

11) Theoretical piston displacement, $V_{TH} = \frac{\Pi D^2}{4} \times L \times 10^{-9} \times \frac{N}{2} \times \frac{1}{60}$ = ………………….

= …………………………….m$^3$/s

12) Volumetric efficiency $\frac{V_a}{V_{TH}} \times 100$ =………….. ………….=……………………%

13) Brake mean effective pressure, BMEP = $\frac{BP \times 60{,}000 \times 10^{-3}}{\frac{\Pi D^2}{4} \times L \times N \times 10^{-9}}$ =

= ………………….=..KPa.

14) *Energy balance sheet calculation* (Trial No…. )

A) Energy in fuel supplied, $Q_s = m_f \times CV$ =……………….=……………kJ/s

B) Energy equivalent of BP, $Q_{BP} = BP$ = ………………=……………kJ/s

C) Energy carried away by exhaust gases, $Q_g$

$$Q_g = m_w \times Cp_w \times (T_{wo} - T_{wi}) \times \frac{T_{gi} - T_a}{T_{gi} - T_{go}} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

= ………………………………...KJ/s

(Where $m_w = \frac{1}{t_w}$ kg / s )

D) Energy lost to surroundings by radiation & convection, $Q_{SUR}$

$Q_{SUR} = A - (B + C) =$ …………………………………..=…………..kJ/s

## *Energy Balance Sheet*

| | | |
|---|---|---|
| **Energy distribution** | **KJ /s** | **%** |
| A. Energy Supplied, $Q_S = m_f \times CV$ | | |
| B. Energy Equivalent of BP, $Q_{BP}$ | | $\frac{Q_{BP}}{Q_S} \times 100 =$ |
| C. Energy Carried away by exhaust gases,Qg | | $\frac{Q_g}{Q_S} \times 100 =$ |
| D. Energy lost to surroundings $Q_{sur}$ | | $\frac{Q_{sur}}{Q_S} \times 100 =$ |

***Graphs :*** i) BSFC Vs. BP

ii) B. Th.η Vs. BP

iii) Mech. η Vs. BP

## *Tabulation of Results*

| Sl. No | Particulars | Symbol | Units | | | | |
|---|---|---|---|---|---|---|---|
| **1** | Trial no | - | - | 1 | 2 | 3 | 4 |
| **2** | Speed | N | RPM | | | | |
| **3** | Brake power | BP | kW | | | | |
| **4** | Fuel consumption | $m_f$ | kg/s | | | | |
| **5** | Friction power | FP | kW | | | | |
| **6** | Brake specific fuel consumption | BSFC | kg/kW hr | | | | |
| **7** | Indicated power | IP | kW | | | | |
| **8** | Mechanical efficiency | $\eta_{Mech}$ | % | | | | |
| **9** | Brake thermal efficiency | B. Th. $\eta$ | % | | | | |
| **10** | Indicated thermal efficiency | I. Th. $\eta$ | % | | | | |
| **11** | Brake mean effective pressure | BMEP | kPa | | | | |
| **12** | Air Fuel ratio | A/F | - | | | | |
| **13** | Volumetric efficiency | $\eta_{vol}$ | % | | | | |

**EXPT. NO: 13** **DATES:**

# Variable Compression Ratio Petrol Engine

***Object*** **:** To study the performance of a petrol engine under varying loads for different values of compression ratio by drawing graphs of i) Efficiency Vs BP ii) BSFC Vs BP iii) Mechanical Efficiency Vs BP and by drawing an energy balance sheet.

***Theory***: i) Variation of air standard efficiency with compression ratio. ii) HUCR iii) Octane rating iv) Fuels suited for S.I. engines. v) Detonation vi) Factors affecting detonation vii) Distinction between pre-ignition and detonation viii) Anti knock agents.

## *Description of the test rig:*

The VCR Engine is a vertical single cylinder air cooled spark ignition type petrol engine. It is coupled to a loading Dynamometer, which in this case is a DC generator & resistive load bank. The overhead cylinder head, made of cast iron is water cooled externally & has an encounter piston above the original piston in the main engine. The counter piston is actuated by a screw rod mechanism.

***Air intake measurement***:

The suction side of the engine cylinder is connected to an air tank. The atmospheric air is down into the engine cylinder through the air tank. A manometer is provided to measure the pressure drop across an orifice provided in the intake pipe of the air tank. This pressure drop across the orifice is used to calculate the volume of air drawn into the cylinder (orifice dia ).

***Fuel measurement***:

The fuel is supplied to the engine from the main fuel tank through a graduated measuring fuel gauge (Burette).

***Cooling System***:

The engine cylinder jacket is air cooled & the auxiliary cylinder is cooled by water.

***Exhaust gas calorimeter***:

The exhaust gas is passed through a shell & Tube Heat Exchanger. The Temperatures of Exhaust gas at inlet & outlet of calorimeter & that of cooling water at the inlet & outlet are sensed by Thermocouples provided these points & indicated on the front panel with the help of a selector switch.

## ***Procedure:***

1. Connect the water inlet of the calorimeter to constant head water sources.
2. Open the inlet ball valve of calorimeter to suitable flow rate.
3. Fill up petrol into the tank mounted on the panel frame.
4. Check engine oil level in the engine.
5. Open petrol cock and fill the burette. Also ensure accelerator knob is in cut off position.
6. Connect the instrumentation power input plug to a 230V single phase power source. Now all the digital meters, namely RPM, Voltmeter, Ammeter & Temperature indicator display the respective reading.

***To conduct the performance test on the engine and to draw the heat balance sheet***

1. Start the engine increase the speed of engine using accelerator knob to 2800 rpm.
2. Keep the change over switch in the generator side direction.
3. Also ensure that the compression ratio of the engine is at 4.67.
4. Apply the load into 1.9 Amps (¼ load).
5. Note down all the required parameters mentioned below (with ¼ load 1.9 Amps).
   a. Speed of the engine (N) from digital RPM indicator.
   b. Load from Ammeter.
   c. Fuel consumption from burette.
   d. Quantity of air from manometer.
   e. Temperatures TC1, TC2, TC3, TC4, and TC4 on digital temperature indicator by changing the selector switch direction only at full load.
   f. Water flow rate for calorimeter through the rotameter provided graduated in cc/s.
6. Load the engine to the mentioned loads below step by step.
   ¼ = 1.9 amps/1.9 A    ½ = 3.2 amps/3.8 A
   ¾ = 4.7 amps/5.7 A    Full = 6.3 amps/7.6 A
7. Switch off the engine ignition after removing the load on the engine.
8. Change the compression ratio to 6 & take the required readings.
9. Switch off the engine & change the compression ratio to the desired point & take the respective reading.

## ***To determine the FP of the given engine by Motoring test***

***Procedure:***

1. To conduct the motoring test first connect the rectifier to the panel board.
2. Remove the spark plug connection from the engine & switch off the ignition switch provided on the engine side.
3. Keep the change over switch in the motoring direction.
4. Now slowly increase the power using the Variac provided in the rectifier.
5. Increase the speed up to 2800 rpm and note down the armature current and voltage at this speed of the motor.

Now slowly decrease the power and turn the change over switch to off position

## *Data Sheet*

***Engine: Four Stroke, Single Cylinder***

| | |
|---|---|
| BHP | : 2.5 HP or $2.5 \times 0.7355 = 1.84$ kW |
| Rated speed | : 3000 RPM |
| No. of Cylinders | : One |
| Bore | : 70 mm |
| Stroke | : 66.7 mm |
| Starting | : Rope starter |
| Compression Ratio | : 2.5:1 to 8:1 |

***DC Generator: Shunt Wound***

| | |
|---|---|
| Rated Voltage | : 220 V DC |
| Rated Speed | : 3000 RPM |
| Rating | : 2.2 kW max. |
| Efficiency of generator | : $\eta_G = 0.85$ |

***Resistive Load Bank:***

| | |
|---|---|
| Rating | : 2 kW |
| Variation | : In 6 Steps, by DC Switches |
| Cooling | : Natural Air Cooled |

***Normal compression ratio*** **: 4.67: 1**

***Tabulation of Readings*** Compression ration, r = 4.67

| Sl. No. | PARTICULARS | | SYMBOL | UNITS | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Trial No. | | - | - | 1 | 2 | 3 | 4 | 5 |
| 2 | Speed | | N | RPM | | | | | |
| 3 | Load | Voltage | V | volts | | | | | |
| 4 | | Current | I | amps | | | | | |
| 5 | Time for 10cc of fuel consumption | | $t_f$ | s | | | | | |
| 6 | Rotameter readings Water flow rate | Cylinder jacket | $X_j$ | cc/s | | | | | |
| 7 | | Exhaust gas calorimeter | $X_g$ | cc/s | | | | | |
| 8 | Water manometer reading | | $h_w$ | mm of water | | | | | |
| ***Thermocouple Readings( EGCM)*** | | | | | | | | | |
| 9 | Gas temp. at inlet to EGCM | | $T_1 = T_{gi}$ | $^o$ C | | | | | |
| 10 | Gas temp. at exit from EGCM | | $T_2 = T_{go}$ | $^o$ C | | | | | |
| 11 | Inlet temp. of water to EGCM | | $T_3 = T_{wi} = T_{ji}$ | $^o$ C | | | | | |
| 12 | Outlet temp. of water from EGCM | | $T_4 = T_{wo}$ | $^o$ C | | | | | |
| 13 | Outlet temp. of water from cylinder jacket | | $T_5 = T_{ji}$ | $^o$ C | | | | | |
| 14 | Ambient temperature | | $T_6 = T_a$ | $^o$ C | | | | | |

## Tabulation of readings ( contd. )

Full load test at different compression ratios at constant speed.

| Sl. No. | PARTICULARS | | SYMBOL | UNITS | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Compression Ratio | | R | - | 2.5 | 3.5 | 4.67 | 6.0 | 8.0 |
| 2 | Speed | | N | RPM | | | | | |
| 3 | Load | Voltage | | | | | | | |
| 4 | | Current | | | | | | | |
| 5 | Time for 10cc of fuel consumption | | | | | | | | |
| 6 | Rotameter readings Water flow rate | Cylinder jacket | | | | | | | |
| 7 | | Exhaust gas calorimeter | | | | | | | |
| 8 | Water manometer reading | | | | | | | | |
| 9 | Gas temp. at inlet to EGCM | | | | | | | | |
| 10 | Gas temp. at exit from EGCM | | | | | | | | |
| 11 | Inlet temp. of water to EGCM | | | | | | | | |
| 12 | Outlet temp. of water from EGCM | | | | | | | | |
| 13 | Outlet temp. of water from cylinder jacket | | | | | | | | |
| 14 | Ambient temperature | | | | | | | | |

## *Motoring test at rated RPM*

Friction power loss in motor = 681 watts

| **Sl. No.** | **Compression ratio, r** | **Speed, N RPM** | **Power input to motor** | |
|---|---|---|---|---|
| | | | Voltmeter reading V (volts) | Ammeter reading I (amps) |
| **1** | 4.67 | | | |
| **2** | 6.00 | | | |
| **3** | 8.00 | | | |
| **4** | 3.5 | | | |
| **5** | 2.5 | | | |

## *Specimen Calculation*

### *Motoring test*

Speed, N = ………………………...RPM

Compression ratio, **r** =…………….

1. Power input to motor, $FP_{total} = V \times I$ = …………….=……………..watts
2. Friction power loss in motor, $FP_{motor}$ = 681 watts
3. Friction power loss in engine = $\frac{FP_{total} - FP_{engine}}{1000}$ = ………………….=……...kW

### *Load test*

*Trial No:……..*

Speed, N = **…………….**rpm

Compression ratio, **r** = …………….

1. Brake power, BP = $\frac{V \times I}{1000 \times \eta_G}$ = …………….=………………kW

2. Indicated power, IP = BP + FP = ……………=……………..…kW

3. Mechanical Efficiency = $\eta_{mech} = \frac{BP}{IP} \times 100$ =………………=……………….%

4. Fuel consumption $\dot{m}_f = \frac{10 \times Sp.Gr.}{1000 \times t_f}$ = ………………=……………..kg/s

5. Brake specific fuel consumption, BSFC = $\frac{\dot{m}_f \times 3600}{BP}$ = ……………=………... kg/kW-hr

6. Indicated specific fuel consumption, ISFC= $\frac{\dot{m}_f \times 3600}{IP}$ = ……………=…..……. kg/kW-hr

7. Brake thermal efficiency B.T.E. = $\frac{BP}{\dot{m}_f \times CV}$ = ……………=…………..…..%

8. Indicated thermal efficiency I.T.E. = $\frac{IP}{\dot{m}_f \times CV}$ =………………=…………..….%

9. Air standard efficiency = A.S.E. = 1 - $\frac{1}{r^{r-1}}$ = ……………=………..…….%

10. Relative efficiency on IP basis or I.R.E. = $\frac{I.T.E.}{A.S.E.}$ = ………………=……………..%

11. Relative efficiency on BP basis or B.R.E. = $\frac{B.T.E.}{A.S.E.}$ =……………….=……………..%

## 12. *Air flow rate (* $\dot{m}_a$ *)*

i) Room pressure $P_a = \frac{H_a}{760} \times 101.325$ =………….. ……..=……………….kPa

ii) Room temperature $T_a = t_a + 273$ =…………………=……………..... K

iii)Density of air at RTP, $\rho_a = \frac{P_a \times 1000}{RT_a} = \frac{P_a \times 1000}{287.2 \times T_a}$ = ……………………

= ……………………kg/m$^3$

iv) Water manometer reading, $h_w$ = ……………………………………mm of water

v) Air head causing flow through the orifice,

$$h_a = \frac{\rho_w \times h_w}{1000 \times \rho_a} = \frac{h_w}{\rho_a}$$ =…………………………=…………..m of air.

vi) Volume flow rate of air through orifice = Actual volume of air inhaled by engine during the suction stroke,

$$V_a = C_a \times A_o \times \sqrt{2gh_a} = C_d \times \frac{\Pi d_o^2}{4} \times 10^{-6} \times \sqrt{2gh_a}$$ =………………………

= …………… m3/s

vii) Mass of air drawn in during suction stroke,

$$\dot{m}_a = V_a \times \rho_a$$ = ………………=……………kg/s

13. Air fuel ratio = $\frac{\dot{m}_a}{\dot{m}_f}$ = ………………=…………..……

14. Theoretical piston displacement, $V_{TH} = \frac{\Pi D^2}{4} \times L \times \frac{N}{2} \times \frac{1}{60} \times 10^{-9}$ = ……………

=………………..$m^3/s$

15. Volumetric efficiency, $\eta_{vol} = \frac{V_a}{V_{TH}}$ =……………=………

16. Brake mean effective pressure, BMEP = $\frac{BP}{\frac{\Pi D^2}{4} \times L \times \frac{N}{2} \times \frac{1}{60} \times 10^{-9}}$ = ……………………..

$= \frac{BP}{V_{TH}}$ =………………………..kPa

## *Energy balance sheet*

At normal compression ratio = 4.67

Constant speed =………………RPM

And Load = ……………….kW

A) Energy in fuel supplied, $Q_s = m_f \times CV$ =…………………..=……………kJ/s

B) Energy equivalent of BP, $Q_{BP}$ = BP = ………………….=……………kJ/s

C) Energy carried away by cylinder jacket cooling water,

$Q_c = m_j \times Cp_w \times (T_{jo} - T_{ji})$ =……….. ……………………..=…………….kJ/s

***(Where*** $m_j = \frac{1000}{t_j} \times \frac{1}{1000}$ ***kg/s)***

D) Energy carried away by exhaust gases, $Q_g = m_w \times Cp_w \times (T_{wo} - T_{wi}) \times \frac{T_{gi} - T_a}{T_{gi} - T_{go}}$

=………………………………. =………………… kJ/s

***(Where,*** $m_w = \frac{1}{t_W}$ kg / s ***=………..Kg/Sec.)***

E) Energy lost to surroundings by radiation & convection,

$Q_{SUR}$ = A - ( B + C + D ) = ………………………………….=……… ……kJ/s

| Item | kJ/s | Percent |
|---|---|---|
| Energy in fuel supplied | | 100 |
| Energy equivalent of useful power output | | $\frac{Q_{BP}}{Q_s} \times 100 =$ |
| Energy carried away by cylinder jacket cooling water circulation. | | $\frac{Q_C}{Q_s} \times 100 =$ |
| Energy carried away by exhaust gases. | | $\frac{Q_g}{Q_s} \times 100 =$ |
| Energy lost to surroundings by radiation & convection | | $\frac{Q_{SUR}}{Q_s} \times 100 =$ |

***Graphs**:* At normal compression ratio and rated speed.

j) IP Vs BP  ii) Mech $\eta$ Vs BP  iii) BTE Vs BP  iv) BSFC Vs BP

ii) Vol. $\eta$ Vs BP

***For a common speed***

i) BTE Vs Compression ratio  ii) ASE Vs Compression ratio

### *Tabulation of results*

| Sl. No. | Particulars | Symbol | units | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | Trial No. | - | - | 1 | 2 | 3 | 4 | 5 |
| 2 | Compression ratio | r | - | | | | | |
| 3 | Speed | N | RPM | | | | | |
| 4 | Brake power | BP | kW | | | | | |
| 5 | Friction power | FP | kW | | | | | |
| 6 | Indicated power | IP | kW | | | | | |
| 7 | Mechanical efficiency | $\eta_{mech}$ | % | | | | | |
| 8 | Total fuel consumption | $\dot{m}_f$ | kg/s | | | | | |
| 9 | Brake Sp. Fuel consumption | BSFC | kg/kW-hr | | | | | |
| 10 | Indicated Sp. Fuel consumption | ISFC | kg/kW-hr | | | | | |
| 11 | Brake thermal efficiency | BTE | % | | | | | |
| 12 | Indicated thermal efficiency | ITE | % | | | | | |
| 13 | Brake mean effective pressure | BMEP | kPa | | | | | |
| 14 | Air flow rate | $\dot{m}_a$ | kg/s | | | | | |
| 15 | Air fuel ratio | A/F | - | | | | | |
| 16 | Volumetric efficiency | $\eta_{vol}$ | % | | | | | |
| 17 | Air standard efficiency | ASE | % | | | | | |
| 18 | Indicated relative efficiency | IRE | % | | | | | |
| 19 | Brake relative efficiency | BRE | % | | | | | |