

AHSANULLAH UNIVERSITY OF SCIENCE & TECHNOLOGY

Department of Mechanical and Production Engineering

ME 2102: Basic Thermodynamics Sessional (Applied Thermodynamics Laboratory: 8B01)

List of the Experiments

1. Determination of Heating Value of Coal by Bomb Calorimeter
2. a) Analysis of Air using Orsat Gas Analyzer
b) Flash Point and Fire point of Fuel (kerosene oil)
3. a) Study of Psychrometer and determination of humidity of air using Sling Psychrometer
b) Calibration of a Pressure Gauge
4. Determination of Carbon Residue of an Oil (Conradson Method)

General Instructions

1. Attend to the lab 5 minutes prior to the scheduled time.
2. Sessional grade will be calculated in the following way:

a) Attendance	10%
b) Lab reports	20%
c) Viva	20%
d) Quiz (End of semester)	50%
Total	100%
3. Students must bring the necessary instruments, data sheet (for particular experiment), calculator, normal graph paper.
4. Report should be submitted in the following week during the sessional time.
5. Write report on one side of an 80 gms A4 paper and follow the following format
 - a) Top sheet
 - b) Objectives
 - c) Apparatus (including technical specifications)
 - d) Figure/Experimental Setup
 - e) Data Sheets/Result
 - f) Sample calculation
 - g) Graphs
 - h) Discussion
 - i) Discuss the graphs and results
 - ii) Discuss about the experimental setup if it could be improved
 - iii) Discuss the different parameters that could affect the result
 - iv) Discuss any assumption made
 - v) Discuss any discrepancies in the experimental procedure and result
 - vi) Discuss what you have learnt and the practical application of this knowledge

Experiment No.: 1

Determination of Heating Value of Coal by Bomb Calorimeter

Objectives:

To find the heating value of coal experimentally using a bomb calorimeter

Apparatus:

Bomb Calorimeter, Thermometer, Stop Watch, Analytic Balance, Fuse Wire, Water Container etc.

Description:

The so called bomb calorimeter is used to determine the heating value of fuel when burned at constant volume. The fuel whose heating values is desired is placed in the fuel pan (crucible). A coil of fine wire dips in the pan. The bomb is charged with oxygen under pressure. When an electric current is passed through the wire, it ignites the fuel. Surrounding the bomb is a bucket containing water to absorb the heat released as the fuel burn. The bomb has an outer jacket, and a dead-air space surrounds the bucket to minimize heat losses to the surroundings. Although the water in the bucket absorbs the major portion of the heat, this heat is not the heating value of the fuel, for the following reasons:

1. The bomb itself absorbs some heat
2. There is heat exchange with the outer jacket
3. The ignition wire liberates some energy
4. The product of combustion are not cooled to the original temperature
5. Because combustion takes place in oxygen, high temperature is attained resulting in the formation of nitric and sulfuring acid, which would not be formed in the normal combustion process.

It is true that the products of combustion are not cooled to the original temperature. However, the final and original temperatures are so close that the error is only a small fraction of 1%. Furthermore the error is almost entirely offset when the bomb is standardized. The “water equivalent” of the bomb is furnished by the manufacturer. This is the amount of water having the same thermal capacity as the bomb is furnished by the manufacturer. This is the amount of water having the same thermal capacity as the bomb and its bucket (empty). When there is a doubt about the validity of this value, the bomb should be standardized.

The exchange of heat with outer jacket is minimized by maintaining a minimum temperature difference between the two. Corrections are made for small amount of heat transfer which occurs due to radiation. Corrections are also made for the heat liberated by the ignition wire by determining the amount actually burned. In the absence of exact heating value to the fuse wire, a value of 2.3 cal/cm of wire may be used.

Operations:

1. Weigh the calorimeter bucket empty. Put into calorimeter 1900 gm of water, having a temperature of about 3°C below the temperature in the jacket (It is assumed that the jacket is at room temperature)
2. Make certain that interior of the bomb is clear. Clean up the holder in the removable lining with those in the bomb. Place the lower half of the bomb in the iron plate holder.
3. Insert the tapered pin and its crucible holder.
4. Obtain a true sample of coal and place approximately 1 gm of coal in the crucible, weigh and place it in the bomb.
5. Select the proper type of fuse wire, measure the length and install it in the form of a coil. The coil should touch the coal but not the crucible.
6. Add a few drops (about 0.5 ml) of water at the bottom of the bomb to saturate the space. This will cause complete condensation of the water vapor of combustion and the heating value obtained will be the higher heating value.
7. Place the gasket in place making certain that there is no dirt present. Assemble the bomb and tighten the cap. Be careful not to spill the fuel out of the crucible by tipping or jarring the bomb.
8. Charge the bomb with oxygen to a pressure of approximately 300 psi. Open the charging valve very slowly to avoid blowing of coal from the crucible.
9. Immerse the bomb in water; preferably in a glass jar, to see whether there are any leaks. The bomb should be dried with a cloth and placed it in the bomb jacket. The thermometer and stirrer should be installed. The thermometer should be immersed in at least 3 inch. Of water and should not be no closer than ½ inch to the bomb.
10. Start the stirrer. After 3 to 4 min for temperature equalization of water in the bucket, take temperature readings every minute for 5 min. These temperature readings are required for calculating the heat exchange with the jacket.
11. Switch on the firing switch for an instant.
12. Record the temperature according to data sheet until the maximum temperature is reached. The observer of the thermometer must be alert, because a rapid temperature rise occurs shortly after firing occurs.
13. After reaching the maximum temperature, temperature should be read every minute for 5 min. These temperatures are required in accounting for the heat exchange with the jacket water.
14. Remove the bomb from calorimeter, release the gases, and disassemble bomb. Collect and measure the length of the fuse wire which remains.
15. When accurate results are required, the bomb should be washed with distilled water and the washing should be titrated to obtain the amount of acid formed.

Heat loss by radiation from the calorimeter is minimized by starting the determination with the water in the calorimeter enough below room temperature so that the final temperature after combustion will be slightly above room temperature. Thus the radiation from the room before ignition will tend to compensate that to the room after the temperature rise. Since an appreciable amount of time elapses before the rise in temperature is completed, there will be some heat transfer in spite of this precaution.

The Dickinson method of correction for radiation is prescribed by the ASTM. The rate of temperature change in degree per minute is determined over a 5 min. period just before ignition and again after ignition when the maximum temperature has been reached. The time of ignition (time a), the temperature at ignition, the thermometer reading taken when the temperature change has become uniform after attaining a maximum and the time at this maximum temperature (time c) are recorded. Time b is defined as the time at which six-tenths of the temperature rise from a to c has taken place. The ignition temperature is then corrected by adding (b-a).r₁, where r₁ is the rate in degrees per minute at which the temperature was rising before ignition. The final temperature is corrected by adding (c-b).r₂, where r₂ is the rate of temperature decrease after the maximum was reached. The temperature rise used for calculating the energy liberated is the difference between the corrected ignition and final temperatures. The corrected temperatures are to be indicated in figure.

Because a portion of the fuse wire will be found to have burnt to the oxide, a correction for the energy liberated by this reaction must be subtracted from the observed heating value of the sample. This is best accomplished by knowing the heat of combustion of the fuse wire per unit length and the length of the original and unburned portions of the wire.

When extreme accuracy is required, the ASTM test procedure should be consulted for the method to be used in correcting the observed heating value for the formation of HNO₃ and H₂SO₄.

Since the water vapor resulting from the combustion of hydrogen in the fuel sample is condensed because of the low bomb temperature, the heating value obtained is known as the higher heating value. The lower heating value is determined by subtracting from the higher heating value a quantity equal to the product of the weight of water vapor formed by combustion and the latent heat of vaporization of the water.

Calculations:

Temperature Rise

$$t = t_c - t_a - r_1(b - a) - r_2(c - b)$$

where,

t = corrected temperature rise

t_a = temperature at time of firing

t_c = temperature at time, c

r₁ = rate (temperature units per min.) at which temperature was rising during 5 min period before firing.

r₂ = rate (temperature units per min.) at which temperature was falling during the 5 min period after time, c.

Temperature at time b, t_b = t_a + 0.6 (t_c - t_a)

Heating value = Heat absorbed by calorimeter – Heat from fuse wire

$$= \frac{(1900 + 526) \text{ gm} \times 1 \frac{\text{cal}}{\text{g}^\circ\text{C}} \times t - 2.3 \frac{\text{cal}}{\text{cm}} \times 10 \text{ cm}}{m \text{ gm of fuel}}$$

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Experiment No.: 1

Name of the Experiment:

Determination of Heating Value of Coal by Bomb Calorimeter

Name of the student:

Student ID:

Date:

Data & Result Sheet

Calorimeter: Parr Oxygen Bomb Calorimeter
Manufactured by Parr Instrument Company
Moline, Illinois, USA

Weight of empty pan : _____ gm Total length of fuse wire used: 10 cm
Weight of pan + coal : _____ gm Length of remaining fuse wire: _____ cm
Weight of coal : _____ gm Fuse wire actually burnt : _____ cm
Weight of water : 1900 gm Calorimeter value of fuse
Water equivalent of Wire : 2.3 cal/cm
Calorimeter : 526 gm Room Temperature : _____ °C

Time (min.)	Thermometer Reading °C	Time (min.)	Thermometer Reading °C
0		8:30	
1		9	
2		9:30	
3		10	
4		10:30	
5 (Ignition)		11	
5:15		12	
5:30		13	
5:45		14	
6		15	
6:15		16	
6:30		17	
6:45		18	
7		19	
7:15		20	
7:30		21	
7:45		22	
8		23	

Calorific value of coal : _____ cal/gm
_____ Btu/lb

Experiment No.: 2(a)

Analysis of Air using Orsat Gas Analyzer

Objectives:

To analyze the air from surrounding using the Orsat apparatus.

Apparatus:

As shown in figure, the Orsat apparatus consists of a water-jacketed 100ml burette B connected at its top to a glass manifold M and at its bottom to a leveling bottle L. The glass manifold M is connected to three reagent bulbs called pipettes P₁, P₂ and P₃ via three cocks C₁, C₂ and C₃. Each tube is filed with its own absorbing chemical solution:

P₁: potassium hydroxide (30 % w/v) to absorb CO₂

P₂: alkaline pyrogallol to absorb O₂

P₃: cuprous chloride in hydrochloric acid to absorb CO.

Pipettes P₁ and P₂ are partly filled with glass tubes to increase the contact surface area between liquid and glass. P₃ contains copper wire to protect acid against possible oxidation. The 3-way cock C₄ is used to connect manifold M to the atmosphere (via suction pump SP), to connect it to the sampler tube or to isolate the trapped gas.

Procedure:

a) Trapping the Gas Sample

- By turning the cock C₄ connect the glass manifold M to the sampler line.
- Lower bottle L slowly until the water level in burette B is slightly below the zero mark on the scale. Then close C₄ and disconnect the sampler line.
- Slightly lift cock C₄ off its seat to equalize the pressure inside burette B with the ambient pressure. Then raise bottle L gently until water level in the burette coincides with the zero mark. This ensures that the burette now contains 100 ml of exhaust gas at atmospheric pressure.

b) Absorption of Gas Constituents

The following steps should be done for each pipette, one at a time, in the order P₁ then P₂ then P₃.

- Open cock C₁, and slowly raise bottle L to allow the gas to flow into pipette P₁ until water in the pipette reaches the (100)-mark.
- Slowly lower bottle L to let gas leave pipette P₁ and re-enter burette B until the chemical solution in pipette P₁ reaches the top mark on its stem. Close C₁.
- Bring the levels of water in burette B and bottle L to coincide. Read the scale on burette B to get the volume of CO₂ absorbed, measured at atmospheric pressure.
- Repeat this procedure a few times until the reading becomes constant which means that all CO₂ has been absorbed. Then close cock C₁.
- For the next pipettes, the volume absorbed is obtained as the difference between the current scale reading and the one just preceding it.

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Experiment No.: 2(a)

Name of the Experiment: Analysis of Air using Orsat Gas Analyzer

Name of the student:

Student ID:

Date:

Data & Result Sheet

Ambient Conditions: $P_A = \underline{\hspace{2cm}}$ KPa, $T_A = \underline{\hspace{2cm}}$ °C

Zero Reading R_o = $\underline{\hspace{2cm}}$ ml $\rightarrow V_{\text{sample}} = 100 - R_o =$

CO₂ Reading R_{CO_2} = $\underline{\hspace{2cm}}$ ml $\rightarrow V_{CO_2} = R_{CO_2} - R_o =$

O₂ Reading R_{O_2} = $\underline{\hspace{2cm}}$ ml $\rightarrow V_{O_2} = R_{O_2} - R_{CO_2} =$

CO Reading R_{CO} = $\underline{\hspace{2cm}}$ ml $\rightarrow V_{CO} = R_{CO} - R_{O_2} =$

Volume of Nitrogen $\rightarrow V_{N_2} = 100 - R_{N_2} =$

Teacher's Signature

Experiment No.: 3(a)

Study of Psychrometer and determination of humidity of air using Sling Psychrometer

Objectives:

To find relative humidity, absolute humidity, dew point and enthalpy of air using psychrometer and psychrometric chart.

Procedure:

The sling psychrometer is used to determine the humidity of air. This instrument has two similar thermometer mounted on a frame, one to read dry bulb temperature and the other wet-bulb temperature. The bulb of the wet bulb thermometer is covered with a wick wetted with distilled water. The thermometer and wetted wick is whirled in the air, the water evaporate into the surrounding unsaturated air, causing the general conditions around the wet thermometer bulb to be similar to, and closely approximate to, those of adiabatic saturation. After sufficient whirling the thermometer reach equilibrium conditions. The both temperature should be read quickly in order to get dependable readings.

The sling psychrometer should be rotated at a speed of 10 to 15 fps or 100 to 200 rpm. It is important that clean water should be used, since the slightest trace of oil on the wick cause errors. The wick should be kept fully wet when reading are being made.

Definition of Different Terms:

Absolute Humidity

This is the ratio of the mass of water vapor to the mass of dry air in a given volume of the mixture.

Relative Humidity

This is the ratio of the actual water vapor pressure in the air to the vapor pressure which would exist in a saturated mixture at the temperature of the air.

Dew Point Temperature

The temperature at which the water vapor in the air is saturated.

Operations:

1. Wet the wick of the wet bulb thermometer and whirl the psychrometer for about a minute.
2. Note the reading of the wet bulb thermometer quickly with the help of a magnifying glass. Then read the dry bulb temperature. This will correspond to thermometer temperature.
3. Located the point on the psychrometric chart which corresponds to the measured dbt and wbt.
4. Find (i) Relative Humidity (ii) Absolute Humidity (iii) Dew Point and (iv) Enthalpy using the psychrometric chart.



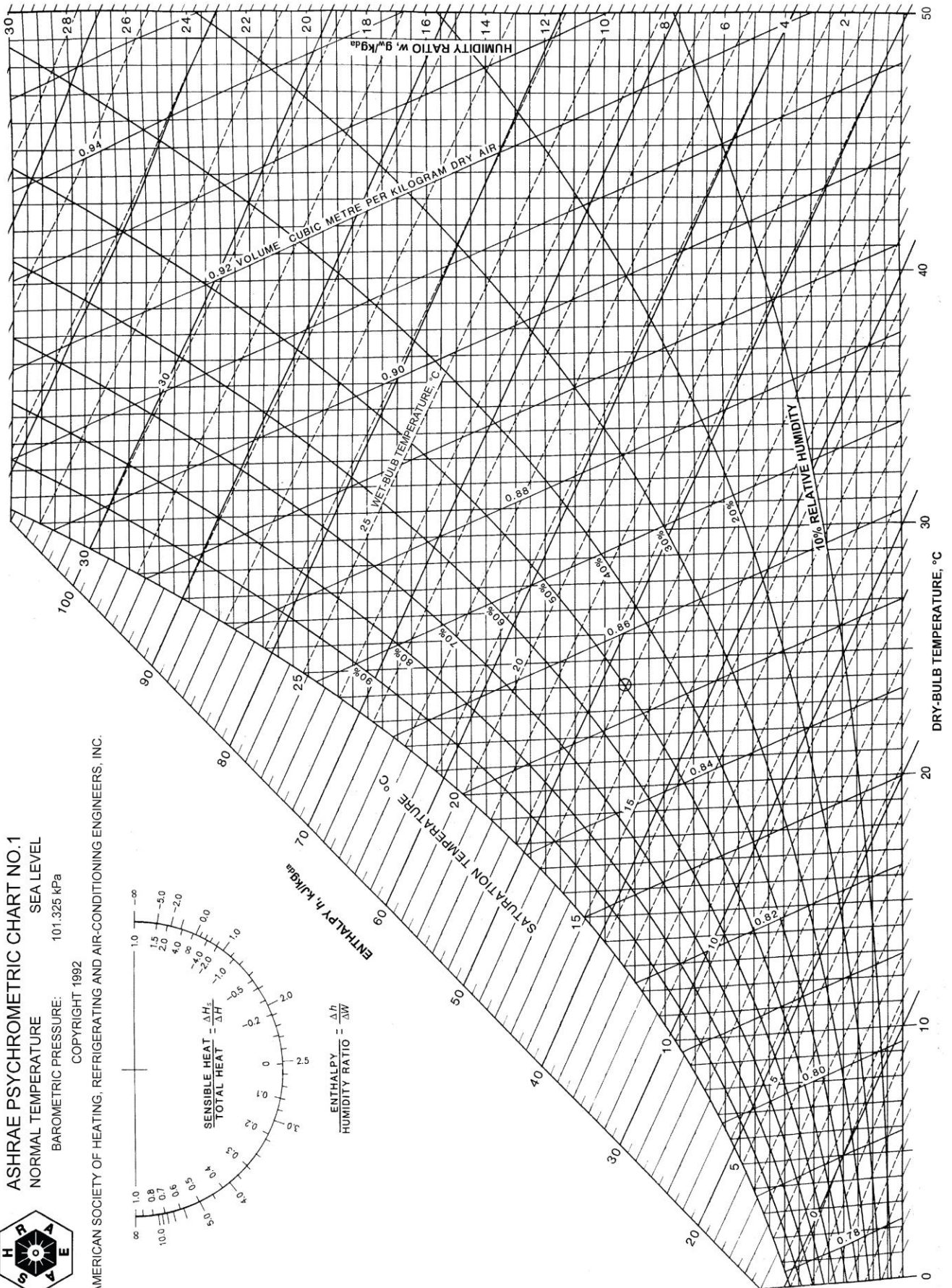
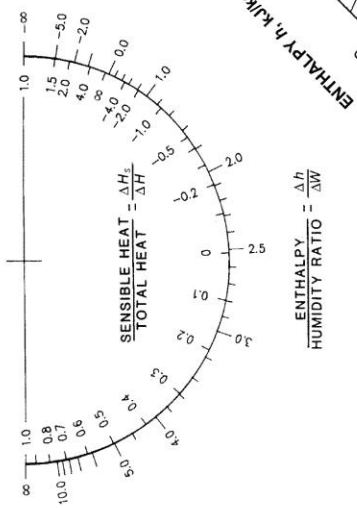
ASHRAE PSYCHROMETRIC CHART NO. 1

NORMAL TEMPERATURE
SEA LEVEL

BAROMETRIC PRESSURE: 101.325 kPa

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AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.



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ME 2102: Basic Thermodynamics Sessional

Experiment No.: 3

Name of the Experiment:

Study of Psychrometer and determination of humidity of air using Sling Psychrometer

Name of the student:

Student ID:

Date:

Data Sheet

Wet Bulb Temperature : _____ °C

Dry Bulb Temperature : _____ °C

Relative Humidity : _____ %

Absolute Humidity : _____ kg_w/kg_{da}

Dew Point Temperature : _____ °C

Enthalpy : _____ kJ/Kg

Teacher's Signature

Experiment 2(b)

Flash Point and Fire point of Fuel (kerosene oil)

Introduction:

Flash Point:

The **flash point** of a volatile material is the lowest temperature at which it can vaporize to form an ignitable mixture in air.

Measuring a flash point requires an ignition source. At the flash point, the vapor may cease to burn when the source of ignition is removed.

The flash point is not to be confused with the auto ignition temperature, which does not require an ignition source, or the fire point, the temperature at which the vapor continues to burn after being ignited. Neither the flash point nor the fire point is dependent on the temperature of the ignition source, which is much higher.

The flash point is often used as a descriptive characteristic of liquid fuel, and it is also used to help characterize the fire hazards of liquids. “Flash point” refers to both flammable liquids and combustible liquids. There are various standards for defining each term. Liquids with a flash point less than 60.5 or 37.8 °C (140.9 or 100.0 °F) — depending upon the standard being applied — are considered flammable, while liquids with a flash point above those temperatures are considered combustible.

Fire Point:

The **fire point** of a fuel is the temperature at which it will continue to burn for at least 5 seconds after ignition by an open flame.

At the flash point, a lower temperature, a substance will ignite briefly, but vapor might not be produced at a rate to sustain the fire. Most tables of material properties will only list material flash points, but in general the fire points can be assumed to be about 10 °C higher than the flash points. However, this is no substitute for testing if the fire point is safety critical. It is done by open cup apparatus

Experimental setup:

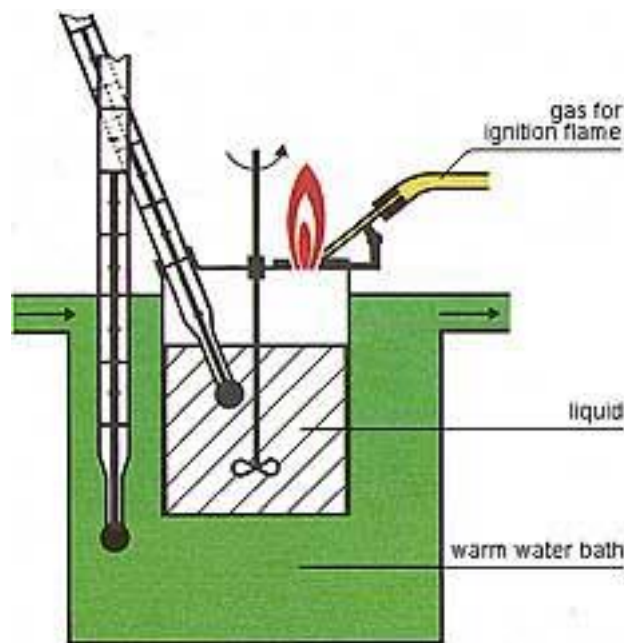


Fig: Experimental set up of fire and flash point apparatus

Experiment procedure:

1. First measure 60ml of kerosene
2. Set the two thermometer to measure the temperature of oil bath and the temperature of kerosene
3. Light the pilot light on the cover and adjust the same flame to size the of a small white bead by means of regulating the valve on the gas hose connection.
4. Switch on the electric heater.
5. Take the temperature readings of the oil bath and kerosene after every 5 minutes.
6. Every time after the temperature reading, open the cover over the kerosene oil and place the pilot light at the top.
7. If you find a flash of fire inside the bath of kerosene oil. It is the flash point of kerosene. Note down the flash point.
8. For some more temperature, it is expected to get the flash point. It is just the band of flash point.
9. After more continuous heating at one temperature, we will get the fire point where the fire inside the kerosene bath exists for some time. It is the fire point. Note down the fire point temperature.
10. For some more temperature, it is expected to get the fire point. It is just the band of fire point.

Result

Flash Point:

Band of Flash point:

Fire Point:

Experiment No.: 4

Determination of Carbon Residue of Oil (Conradson Method)

Objective:

To determination of carbon residue of High Speed Diesel Oil

Summary of the Conradson Method:

A weighed quantity of oil sample is placed in a crucible and subjected to destructive distillation. The residue undergoes cracking and cooking reactions during a fixed period of severe heating. At the end of the specified heating period the test crucible containing the carbonaceous residue is cooled in a desiccator and weighed. The residue remaining is calculated as a percentage of the original sample and reported as **Conradson carbon residue**.

Apparatus:

- Porcelain Crucible
- Skidmore Iron Crucible
- Spun Sheet Iron Crucible
- Wire Support (Triangle of bare Nichrome wire)
- Circular Sheet Iron Hood
- Insulator (Ceramic block/ refractory ring)
- Burner

Working Procedure:

1. Weigh to the nearest 10 mg sample of the oil to be tested, free of moisture and other suspended matters into a tarred porcelain crucible containing two glass beads about 0.1 inch in diameter. Place the crucible in the center of the skidmore crucible. Level the sand in the large sheet iron crucible and set the skidmore crucible on it in the exact center of the iron crucible.
2. Apply cover to both the skidmore and the iron crucible, the one on the latter fitting loosely to allow free exit to the vapors as formed.
3. On a suitable stand or, ring, place the bare Nichrome wire triangle and on it the insulator. Next, center the sheet iron crucible in the insulator with its bottom resting on top of the triangle, and cover the whole with the sheet iron hood in order to distribute the heat uniformly during the process.
4. Apply heat with a high strong flame from the gas burner. So the precognition period will be 10 ± 1.0 min (a shorter time may start the distillation so rapidly as to cause foaming or too high a flame). When smoke appears above the chimney, immediately move or, tilt the burner so that the gas flame plays on the sides of the crucible for the purpose of igniting the vapors. Then

remove the heat temporarily and before replacing adjust by screwing down the pinch cock on the gas tubing so that the ignited vapors burn uniformly with the flame above the chimney but not above the wire bridge. The period of burning the vapors shall be 10.0 to 12.0 min. If it is found impossible to meet the requirements for both flame and burning time, the requirements for burning time is the more important.

5. When the vapor ceases to burn and no further blue smoke can be observed, readjust the burner and held the heat as at the sheet iron crucible a cherry red and maintain for exactly 7.0 min. The total period of heating shall be 30 ± 2.0 min. which constitutes as additional limitation on the tolerances for the pre-ignition and burning periods. There should be no difficulty in carrying out the test exactly as directed with the gas burner of the type named using city gas (about 550 Btu) with top of the burner about 2 in below the bottom of the crucible. The time periods shall be observed with whatever burner and gas is used.

6. Remove the burner and allow the apparatus to cool until no smoke appears and then remove the cover of the skidmore crucible (about 15.0 min). Then remove the porcelain or, silica crucible with heated tongs, place in the desiccator, cool and weigh. Calculate the percentage of carbon residue on the original sample.

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Experiment No.: 4

Name of the Experiment:

Determination of Carbon Residue of Oil (Conradson Method)

Datasheet

Name of the student:

Student ID:

Date:

Weight of the empty crucible = _____ gms

Weight of crucible + Weight of oil, W_1 = _____ gms

Weight of the oil, M = _____ gms

Weight of crucible + carbon residue, W_2 = _____ gms

Loss of oil, $X = (W_1 - W_2)$ gms = _____ gms

Carbon residue, $A = (M - X)$ gms = _____ gms

Percentage of carbon residue = $(A/M) \times 100$ = _____ %

Teacher's Signature

Experiment 5

CALIBRATION OF A PRESSURE GAUGE

Introduction

Many types of gauge are available for measurement of pressure. The most simple form is a manometer tube, in which the rise of level of a liquid indicates the static head, this being converted to pressure by multiplying by the liquid density. An example of a much more sophisticated instrument is a pressure transducer, in which the pressure is used to deflect a diaphragm. The deflection causes an electrical signal to be generated by some means such as an electric resistance strain gauge, and this signal is displayed, typically in digital form, as the corresponding pressure. The response is rapid, being typically 1 ms, and the display can be remote from the point of measurement. The Bourdon gauge (named after its inventor Eugene Bourdon) uses the deflection of a tube of oval cross-section to cause a pointer to move over a scale. Its response time is therefore long, being of the order of 1 second. Moreover, the distance between the measuring point and the gauge is limited by the practicable length of the capillary line connecting the gauge to the sensing point. Nevertheless, because of its simplicity and low cost, and the large selection of pressure ranges which are available, the Bourdon gauge is widely used in engineering practice. All pressure gauges, of whatever type, need to be calibrated. If the required accuracy is low, then a standard calibration obtained from a sample of the particular model will suffice. For higher accuracy, a manufacturer will take special care and will supply a calibration certificate for an individual gauge. As the calibration may change over a period, repeat calibrations will be needed from time to time. For the highest accuracy, transducers and gauges are sometimes calibrated before each use. The normal calibration procedure is to load the gauge with known pressures using a dead weight tester using oil. The present experiment, however, works satisfactorily with water instead of oil.

Description of apparatus

The Bourdon pressure gauge shown in Fig 3.1 has a transparent dial through which the construction may be viewed. It consists essentially of a thin-walled tube of oval cross-section, which is bent to a circular arc encompassing approximately 270° . It is rigidly held at one end, where the pressure is admitted. The other end is free to move

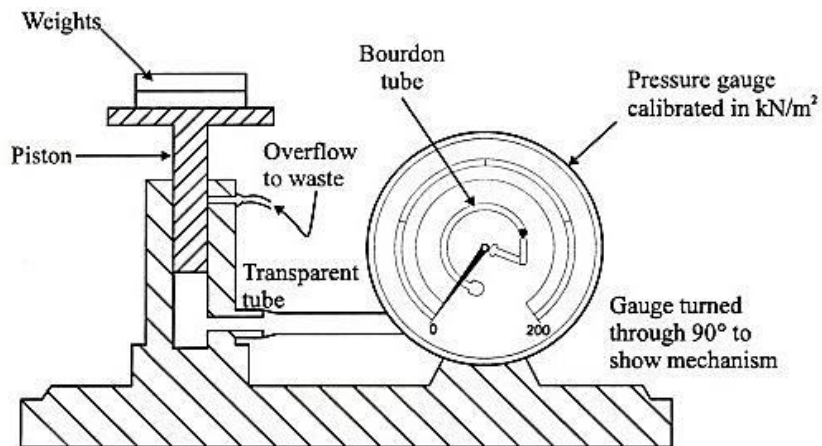


Fig 3.1 Apparatus for calibration of pressure gauge

and is sealed. When pressure is applied, the tube tends to straighten, so that the free end moves slightly. This movement operates a mechanism which drives a pointer round the graduated dial, the movement of the pointer being proportional to the applied pressure. The construction of the dead weight tester is also shown in Fig 3.1. A cylindrical piston, free to move vertically in a closely-fitting cylinder, is loaded with known weights. The space below the piston is filled with water, and the pressure is transmitted by the water to the gauge under test through a transparent hose. The pressure generated by the piston is easily found in terms of the total weight supported and the cross-sectional area of the piston.

Pressure gauge calibrated in kN/m^2 .

Procedure

The weight of the piston, and its cross-sectional area, should be noted. To fill the cylinder, the piston is removed, and water is poured into the cylinder until it is full to the overflow level. Any air trapped in the tube may be cleared by tilting and gently tapping the apparatus. In point of fact, a small amount of air left in the system will not affect the experiment, unless there is so much as to cause the piston to bottom on the base of the cylinder. The piston is then replaced in the cylinder and allowed to settle. A spirit level placed on the platform at the top of the piston may be used to ensure that the cylinder stands quite vertically.

Weights are now added in convenient increments, and at each increment the pressure gauge reading is observed. A similar set of results is then taken with decreasing weights. To guard against the piston sticking in the cylinder, it is advisable to rotate the piston gently while the pressure gauge is being read.

