AHSANULLAH UNIVERSITY OF SCIENCE & TECHNOLOGY

Department of Mechanical and Production Engineering

ME 2278: Thermodynamics and Heat Transfer 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 gm 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 the experimental setup and whether it could be improved
        iii) Discuss the different parameters that could affect the result
        iv) Discuss any assumptions 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:

The following is a list of the equipment required to conduct this application.

- DDS Calorimeter system and accessories (Crucibles, Firing cotton, Benzoic acid)
- DDS Bomb Vessel
- DDS Oxygen Filling Station
- Balance for Measuring Sample Weight

Description:

The bomb calorimeter is used to determine the calorific value of fuel, coal, food, and cosmetics when burned at constant volume. The fuel whose calorific value is desired is placed in the fuel pun (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 samples (fuel, coal, food, cosmetics). The microprocessor in the base of the vessel provides accurate results with each analysis. The complete lid assembly holds the crucible containing the sample for determination. Temperature sensors are built into the wall of the vessel for effective temperature measurement. The vessel is filled with up to 3000Kpa of oxygen for each determination.

The DDS Calorimeters:

Below is an external picture of the Calorimeter showing the major components that make up the Calorimeter. Locate and identify each component to facilitate the understanding of reference to these parts in subsequent sections. All Calorimeter systems require an external keyboard for operation (this is not included in the figures).

Figure: The DDS Calorimeters

Sample Preparation:

The sample which is used for the determination of calorific value shall be the analysis sample, ground to pass a test sieve with an aperture of 212 μm (for dry & grained sample). In some circumstances, it has been shown that a maximum particle size of 250 μm is acceptable for low and medium rank for coals.

Pellet Preparation by Pellet Die:

Arbor Press with Pellet Die Set

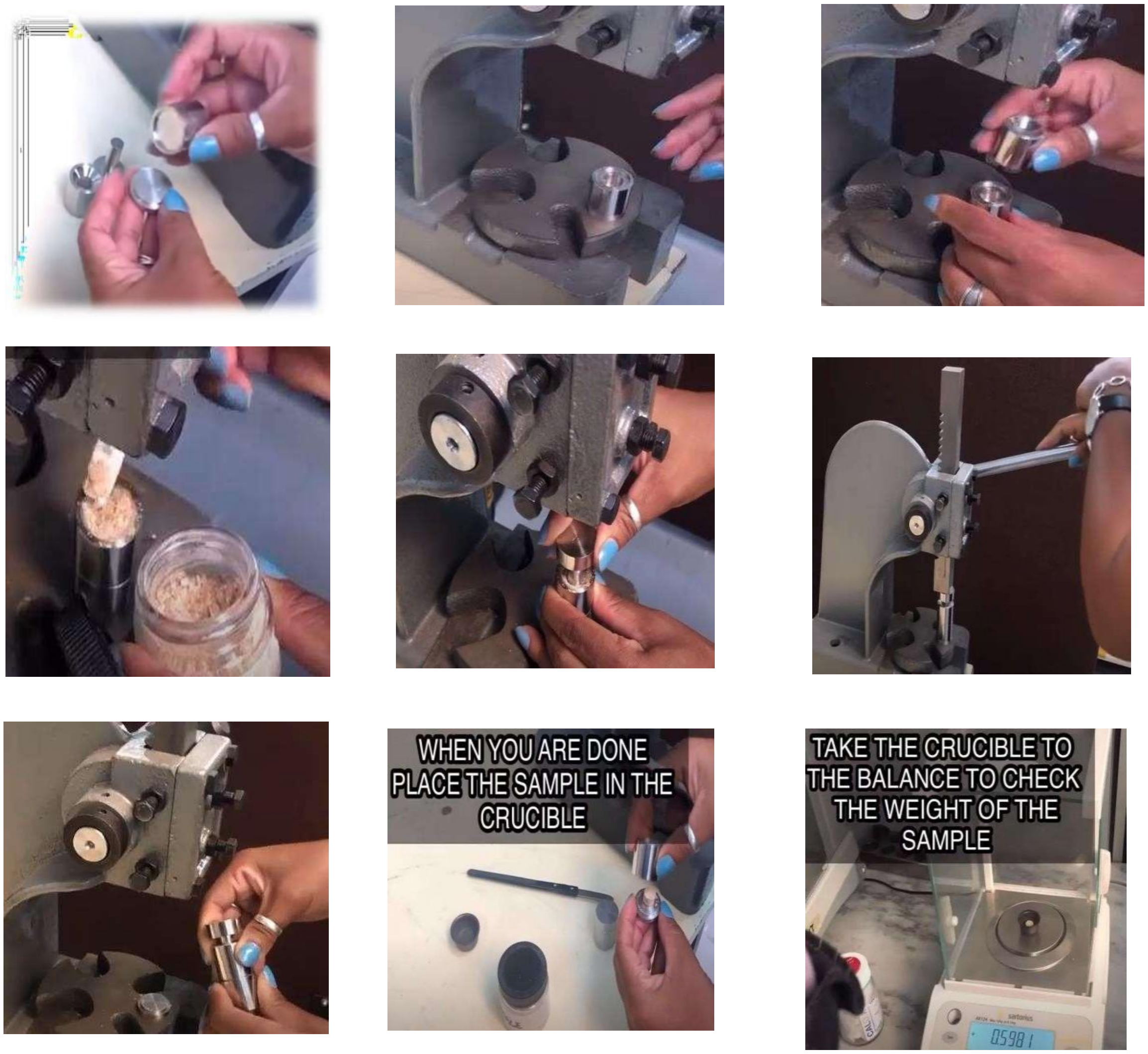

Figure: Pellet making process

Operation:

- Before running a test with unknown sample, a test is required by Benzoic Acid for calorimeter reference check
- Clean the crucible by a paper towel
- Ensure balance pan is clean
- Place crucible on balance pan & Tare it to make zero

- Weight the sample into crucible, ensure not to spill onto the pan

- Power on the calorimeter, press ESC to continue in test mode.
- Type mass to the Calorimeter through keyboard, Press F1 > Press = > Type your mass > Press ENTER
- Fit firing cotton to firing wire

- Insert crucible into outside electrode & Ensure cotton touches sample

- Then Screw down the sample to the bomb with cap & close it by hand tight

- Fill the vessel with Oxygen using the Filling station. **ALWAYS FILL THE VESSEL WITH OXYGEN TO A MAXIMUM PRESSURE OF 3000KPA (30 bar)**

  NOTE: With some applications, you may need to fill the Vessel to less than 3000KPA e.g. 1500KPA (15 bar), however, this is only applicable when you have a sample which is highly combustible, for example, with wood-related samples
  REMEMBER: You may fill the Vessel LESS than 3000KPA but NEVER more than 3000KPA.

- Select SID (Sample Identification Number) by pressing F2 in keyboard.
- Open the lid of calorimeter & place the vessel into the calorimeter chamber

- After few second, ‘’CLOSE LID’’ will show in the display and then close the lid of calorimeter
- After closing lid, wait until “Done” appears in the display
- Record the CV result of the tested sample
- Open the lid after showing ‘’ OPEN LID’’ in the display

OPEN LID: = 21.9282 KJ
M342: SUSPECT LOW TEMPERATURE RISE
04/15-08:48 21.93 KJ

- After opening lid, cooling fan will be started automatically for cooling the heated bomb and we need to wait until the processes completed

M525: WAIT. COOLING BUSY 00.2 MINUTES
04/15-09:21 22.89 KJ

- After finishing cooling process remove the vessel from the calorimeter chamber
- De-fill the vessel by using defiling cap

- After de-filling, Open vessel to clean the electrodes, cap and body
- Use a paper towel to clean the inside of the vessel body
- Clean crucible
- Ready to start another determination
- Close the LID & power of the calorimeter.

CAL3K Calculations:

The CAL3K performs the calculation to obtain a result in KJ/g by comparing the calibration data to the sample (unknown) data. The CAL3K works in Centigrade (C).

The calibration process means that:

A substance (Benzoic Acid) with a known calorific value is burned in the calorimeter.

The calibration mass is entered (from the keyboard or via balance port)

That the CAL3K is set to 'CALIBRATE'

During the calibration process, the temperature rise from firing to the end (in C) is measured.
The 'BOMB FACTOR' is calculated as follows:

Bomb Factor = Benzoic Acid value x Mass / Net Rise

= KJ/g x g / ℃

= KJ/C

The BF is vessel-specific and depends on Vessel weight and material composition.

Once the Bomb Factor (BF) is known the unknown samples can be burned. A Sample determination requires the following:

The mass of the unknown sample

Result = Net Rise x BF / Mass

= ℃ x KJ/C / g

=

Conclusion:

The above shows the principal calculations. The CAL3K obtains a high accuracy by:

Averaging the calibrations and rejecting bad calibrations

Compensating the results by measuring: Initial

Drift before firing

The ambient temperature

The temperature decline after firing

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 100m1 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 P_1, P_2 and P_3 via three cocks C_1, C_2 and C_3. Each tube is filed with its own absorbing chemical solution:

P_1: potassium hydroxide (30 % w/v) to absorb CO_2
P_2: alkaline pyrogallol to absorb 0_2
P_3: cuprous chloride in hydrochloric acid to absorb CO.

Pipettes P_1 and P_2 are partly filled with glass tubes to increase the contact surface area between liquid and glass. P_3 contains copper wire to protect acid against possible oxidation. The 3-way cock C_4 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) <u>Trapping the Gas Sample</u>

-By turning the cock C_4 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 C_4 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) <u>Absorption of Gas Constituents</u>

The following steps should be done for each pipette, one at a time, in the order P_1 then P_2 then P_3.
-Open cock C_1, and slowly raise bottle L to allow the gas to flow into pipette P_1 until water in the pipette reaches the (100)-mark.
-Slowly lower bottle L to let gas leave pipette P_1 and re-enter burette B until the chemical solution in pipette P_1 reaches the top mark on its stem. Close C_1.
-Bring the levels of water in burette B and bottle L to coincide. Read the scale on burette B to get the volume of CO_2 absorbed, measured at atmospheric pressure.
-Repeat this procedure a few times until the reading becomes constant which means that all CO_2 has been absorbed. Then close cock C_1.
-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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ME 2278: Thermodynamics and Heat Transfer Sessional

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=______KPa, T_A= ______^{O}C

Zero Reading R_o = _______ml ☐ V_{sample}= 100 – R_o =

CO_2 Reading R_{CO2} = _______ml ☐ V_{CO2}= R_{CO2} – R_o =

O_2 Reading R_{O2} = _______ml ☐ V_{O2}= R_{O2} – R_{CO2} =

CO Reading R_{CO} = _______ml ☐ V_{CO}= R_{CO} – R_{O2} =

Volume of Nitrogen ☐ V_{N2}= 100 – R_{N2} =

Teacher’s Signature

Experiment No.: 2(b)
Flash Point and Fire point of Fuel (kerosene oil)

Objectives

1. To determine the flash point and fire point of kerosene oil using a standard laboratory apparatus (such as Pensky-Martens or Cleveland open cup tester), and to record the temperatures at which vapors ignite momentarily (flash point) and sustain combustion (fire point).
2. To understand the practical significance of flash point and fire point in assessing the flammability hazard and safe storage, handling, and transportation guidelines for kerosene and similar liquid fuels.
3. To compare the measured values with standard safety specifications and evaluate the fuel's compliance with established industrial and regulatory standards for combustible liquids**.**

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:

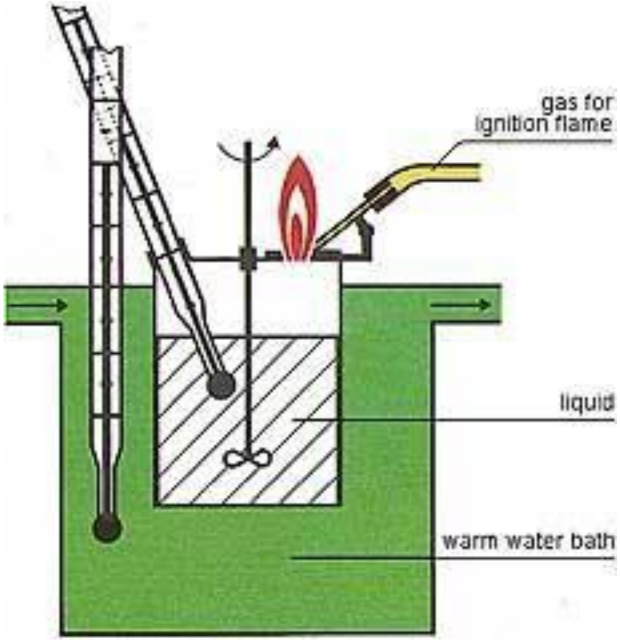


Fig: Experimental set up of fire and flash point apparatus

Experiment procedure:

1. First measure 60ml of kerosene
2. Set the two thermometers 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.: 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 thermometers 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 thermometers and wetted wick are whirled in the air. The water evaporates into the surrounding unsaturated air, causing the general conditions around the wet thermometer bulb to be similar to, and closely approximate, those of adiabatic saturation. After sufficient whirling, the thermometer reaches equilibrium conditions. Both temperatures should be read quickly in order to obtain 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 be used, since the slightest trace of oil on the wick can cause errors. The wick should be kept fully wet when readings are being taken.

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 that would exist in a saturated mixture at the temperature of the air.

Dew Point Temperature

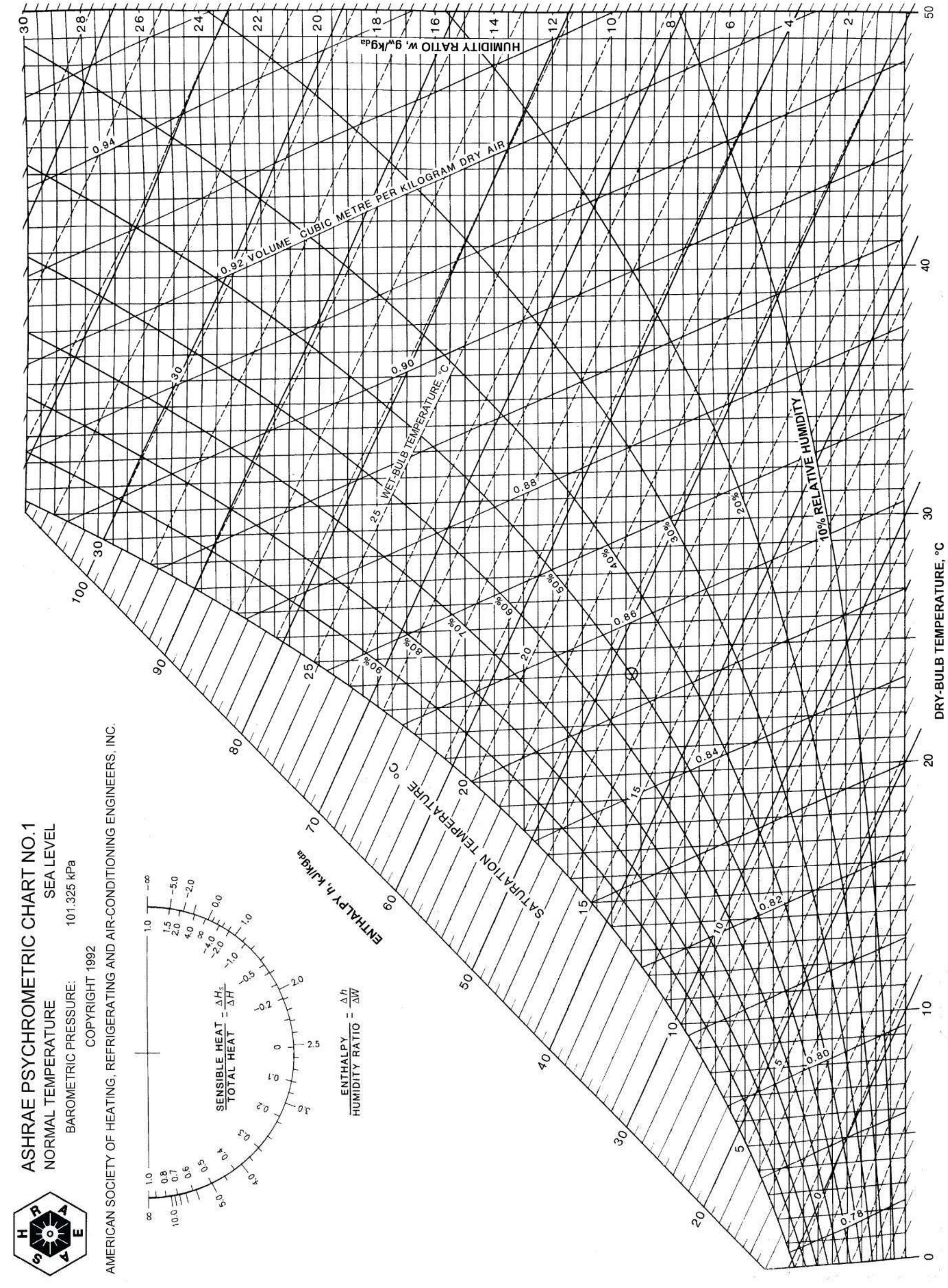
The temperature at which the water vapor in the air becomes saturated.

Operations:

1. Wet the wick of the wet bulb thermometer and whirl the psychrometer for about one 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 the air temperature.
3. Locate the point on the psychrometric chart that corresponds to the measured dry bulb temperature and wet bulb temperature.
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
COPYRIGHT 1992
AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.
SENSIBLE HEAT / TOTAL HEAT = $\Delta H_s / \Delta H$
ENTHALPY / HUMIDITY RATIO = $\Delta h / \Delta W$
∞
1.0
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.2
-0.5
-1.0
-2.0
-4.0
10.0
5.0
4.0
3.0
2.5
2.0
1.5
-5.0
0.0
ENTHALPY h, kJ/kg$_{da}$
20
30
40
50
60
70
80
90
100
SATURATION TEMPERATURE °C
0
5
10
15
20
25
30
WET-BULB TEMPERATURE, °C
VOLUME CUBIC METRE PER KILOGRAM DRY AIR
0.78
0.80
0.82
0.84
0.86
0.88
0.90
0.92
0.94
RELATIVE HUMIDITY
10%
20%
30%
40%
50%
60%
70%
80%
90%
HUMIDITY RATIO w, g$_w$/kg$_{da}$
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
DRY-BULB TEMPERATURE, °C
0
10
20
30
40
50

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ME 2278: Thermodynamics and Heat Transfer Sessional

Experiment No.: 3(a)
Name of the Experiment:
Study of Psychrometer and determination of humidity of air using Sling Psychrometer

Student ID: **Date:**

Data Sheet

Wet Bulb Temperature : ______________ºC
Dry Bulb Temperature : ______________ºC

Relative Humidity : ______________%
Absolute Humidity : ______________kg_w/kg_{da}
Dew Point Temperature : ______________ºC
Enthalpy : ______________kJ/Kg

____
Teacher's Signature

Experiment No.: 3(b)
Calibration of a Pressure Gauge

Objective:

To calibrate a pressure gauge using a dead-weight tester and to determine the accuracy of the gauge by comparing the indicated pressure with the true pressure.

Introduction

Many types of gauges are available for the measurement of pressure. The simplest form is a manometer tube, in which the rise in the level of a liquid indicates the static head, which is 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 electrical 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 longer, 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 that 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 time, 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 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 around 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

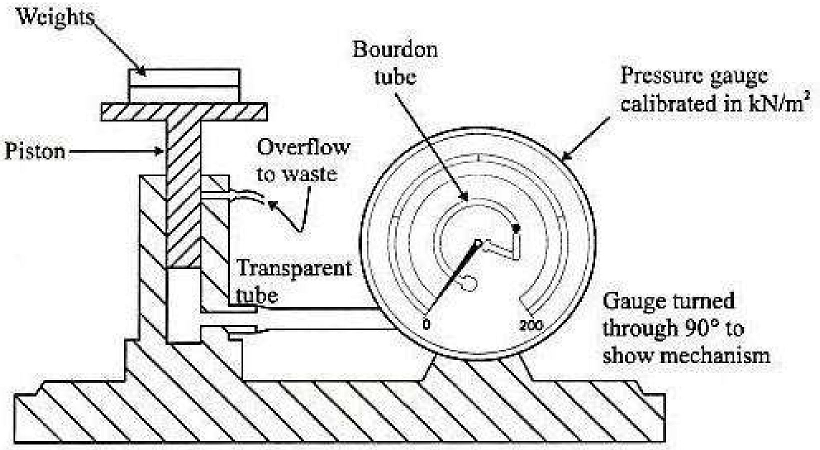

Fig 3.1 Apparatus for calibration of pressure gauge

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 practice, 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.

Calculation and Results:

Weight of piston =1 kg =9.81 N

Cross-sectional area =325 mm^2 = 0.325e-3 m^2

Table 3.1 True pressures and gauge readings

Total Load including Piston Weight		True Pressure (kN/m^2)	Gauge Reading		Mean Pressure (kN/m^2)	Error %
Kgf	N		Increasing Pressure (kN/m^2)	Decreasing Pressure (kN/m^2)		

Teacher’s Signature

Discussions:

1. What suggestions do you have for improving the apparatus?
2. No correction has been made for the difference in elevation of the piston of the dead weight tester and of the pressure gauge. If the center of the gauge were 200 mm higher than the base of the piston. Should a correction be made, and if so, how big would it be?
3. What alterations would you make to the dimensions of the piston if it were desired to calibrate a gauge with a full-scale reading of 3500 kN/m^2 using the same weights?

Experiment No.: 4
Determination of Carbon Residue of Oil (Conradson Method)

Objective:

To determine the carbon residue of High-Speed Diesel Oil

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

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 coking 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 the **Conradson carbon residue.**

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 pre-ignition period will be 10 $\pm$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 valve 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 are more important.

5. When the vapor ceases to burn and no further blue smoke can be observed, readjust the burner and hold 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 an 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 it in the desiccator, cool and weigh. Calculate the percentage of carbon residue on the original sample.

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ME 2278: Thermodynamics and Heat Transfer Sessional

Experiment No.: 4
Name of the Experiment:
Determination of Carbon Residue of Oil (Conradson Method)

Datasheet

Student ID: **Date**

Weight of the empty crucible = ________________________gm

Weight of crucible + Weight of oil, W_1 = ________________________gm

Weight of the oil, M = ________________________gm

Weight of crucible + carbon residue, W_2 = ________________________gm

Loss of oil, $X = (W_1 - W_2)$ gm = ________________________gm

Carbon residue, $A = (M - X)$ gm = ________________________gm

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

____
Teacher's Signature