**KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY**

**COLLEGE OF ENGINEERING**

# DEPARTMENT OF MECHANICAL ENGINEERING

**AIR CONDITIONING AND REFRIGERATION LABORATORY**

**DOMESTIC REFRIGERATION**

**GROUP A2**

**NAME INDEX NUMBER**

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**TITLE: DOMESTIC REFRIGERATION**

**INTRODUCTION**

Refrigeration technology is the art of cool matter below the temperature of the environment. Cooling food allows it to be preserved for longer periods of time (commercial refrigeration). Lowering the temperature of the surrounding air on hot days makes people feel more comfortable (air conditioning). To understand the process of refrigeration, we need to define some terms used in refrigeration technology and their relation to each other. Refrigeration is a technology in which energy is applied in order to reverse the normal path of heat transfer for removing heat from a cold medium and rejecting it into the hotter environment

**TEMPERATURE**

Temperature is a measure of heat intensity. Psychologically we sense temperature in comparison to our own body. Substances with higher temperature than our own are rated “hot”, substances with lower temperatures are rated “cold”. Temperatures are measured in °C or °F

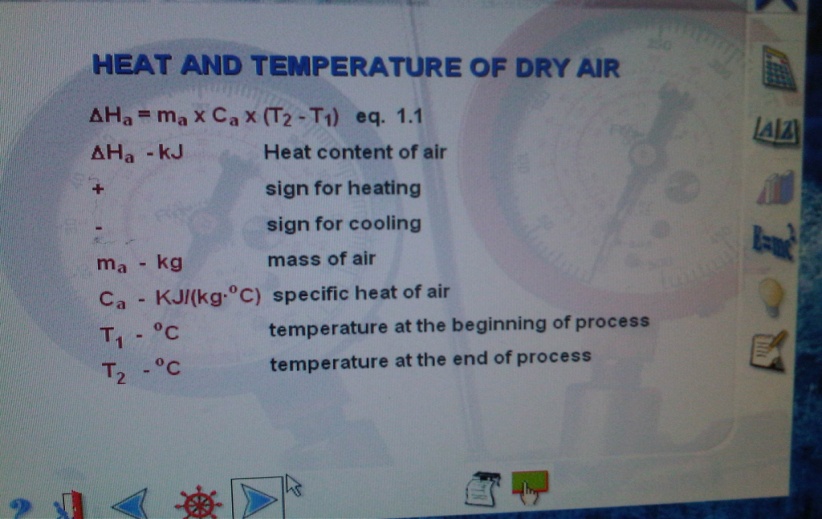
**HEAT**

Heat is a sort of energy.We apply heat in order to raise the temperature of a material or body. It’s measure in Joule kJ, Cal, or Btu. The amount of heat needed to raise the temperature of a body depends on its mass and type of material. Specific heat is the amount of heat required to raise the temperature of 1 unit of mass (kg or lb) by 1 degree (°C or °F). Specific heat depends on the type of material; and is measured in kJ/(kg. °C) or Btu/(lb.°F). When two bodies of different temperatures are in contact with each other, heat flows from the hot body to the cold body until their temperatures become equal; the hot body cools off and the cold body heats up. The flow of heat takes time. Therefore, it is measured in Joule/sec = Watt, kW or Btu/hr. Cooling is a process that lowers the temperature of a substance and heating raises its temperature. The direction of the heat transfer (marked by a positive or a negative sign) is the difference between heating and cooling. Cooling and heating power on the other hand is the amount of heat per unit time removed or added to a system. It is measured in Joule/sec=Watt, kW or Btu/hr, similar to other forms of energy (ie. Mechanical, electrical). Heating (cooling) capacity is the power a system is capable of producing.

**PRESSURE**

Pressure is the force per unit area a fluid exerts on the wall of a vessel in which it is contained. Refrigeration technology is mainly concerned with pressures of fluids called refrigerants which participate in the refrigeration process. Pressure is measured in Pa (N/m2), kPa (1000Pa), bar (1 Atm), and psi (lb/in2).

**THEORY**



Water jackets and intercoolers are used to remove heat when heat is allowed during compression

Considering the diagram below: The dotted lines show an ideal air compressor diagram from cylinder without clearance in which the air is discharged at a pressure.

Inlet valve opens at 1

Inlet valve closes at 2

Output valves opens at 4

Output valves closes at 5

42-51, equal to that in the delivery main. The supply is drawn in at atmospheric pressure along the line 61-21 and then compressed isothermally along 21-42

The actual indicator diagram varies from the ideal one as shown by the fuel lines 1-2-4-5.The friction resisting the motion of the air through inlet and outlet valves and ports necessitates a lesser pressure than that in the delivery main to discharge it.

Consequently, work is lost as represented by 4-51-5, 1-2-3-6.The actual compression line 2-4 must be above isothermal because of the possibilities of perfect cooling, and this result in the loss represented by the area between 2-4 and 2-41.These are compression loses

When the outlet valve closes at point 5, an amount of air equal to the clearance volume is entrained in the cylinder. At the beginning of a new cycle, this air expands so that the effective stroke for drawing in air begins at point 61.This point occurs later; the higher the delivery pressure is at point 5.

When the inlet valve closes at 2, the air in the cylinder is rarefied because of the suction and it is not until 3 is reached that its pressure becomes atmospheric. The effective strokes for drawing in air is therefore represented by line 6-3 instead the full length of the diagram. This is a volumetric loss since less air is delucied than would be if the full stroke were effective. Another volumetric loss not appearing in the diagram is due to leaky valves and pistons, similar to slip of a pump.

After the air in the delivery pipe has been cooled down to room temperature, it contains energy due to its pressure above atmospheric, availability for performing work. If this air could be expanded isothermally to its original pressure, there could be regained all of the energy necessary to compress it isothermally. This, however, cannot be done, the actual expansion being more nearly adiabatic. There is a final loss than due to be defined in the following, which are generally figured as air compressor test results

**MEASUREMENT OF TEMPERATURE AND PRESSURE**

Pressures up to about 80Ib/in2 (482kN/m2) are mostly conveniently measured with liquid manometers because of the high accuracy. Deformation pressures gauges using a Bourdon tube that is most suited for higher pressures must be checked before and after use.

Temperatures are measured with mercury thermometers, thermocouples or resistance thermometers .Where a thermometer pocket or well have to be used, heat transfer between the well and its surrounds and between the well and the pipe through which the gas flows must be avoided.

If high pressures are not involved, we expose the detecting element of the thermometer (mercury-filled bulb, junction of the thermocouple or resistance coil) directly in the gas stream by inserting the thermometer through a plug in the wall.

**MEASUREMENT OF THE AMOUNT OF FREE GAS DELIVERED**

The method must frequently used for measuring the gas quantity in compressor tests is by means of a standardised orifice plate or nozzle while the application of a venturi tube is comparatively rare. The amount of free gas delivered by small compressors can be obtained by pumping into large receiver.

The instruments mentioned above however gives correct results only if the flow is steady with no pulsations on either side of the instrument, which should always be located in the discharge line. Hence, large receivers must be placed between the measuring instrument and the reciprocating compressor

**MEASUREMENT OF COOLING WATER CONSUMPTION**

The rate of consumption of cooling water is measured in various was depending upon whether it is to be measured during operation as well as during a test run or whether is to be measured during guarantee tests only. Continuous measurements can be made with water flow meters or with orifice plates or nozzles

**PROCEDURE**

The main switch was turned on and the compressor was allowed to warm up for about 30minutes.The air compressor was allowed to run at a speed of 300rev/min with the air discharging to the atmosphere through a sharp edged orifice situated in the damping tank.

The air was let on through a small orifice in the tank. The valves employed in the compressor are designed to give automatic action. They are of the spring load type operated by a small difference in pressure across them, the light spring pressure giving a rapid closing action.The lift of the valve to give the required air flow was small so it operate without giving shock

Temperature readings were noted after every 20 minutes from the inserted

Thermometer inserted into various inlets and outlets of interest.

The rate of flow of water to and from the after-cooler, and that to and from the jacket were determined using stopwatches after steady flow rate were attained.

The temperature (initial) is constant at T1 for this process and there is no heat exchange with the surroundings in the ideal case. Induction commences when the pressure difference across the valve is sufficient to open it. As the piston begun its return stroke, the pressure in the cylinder rises and closes the inlet valve. The pressure rise continues with the returning piston until the pressure was reached at which the delivery valve opened. The delivery-taking place as shown is a process at constant temperature T2, constant pressure P2, and zero eat exchange and decreasing mass. At the end of this, the cycle was repeated.

The valve of the delivery temperature T2 depends upon the law of compression, which in turn depends upon the heat exchange with the surrounding during this process.

Five different valves were determined at various points of interest simultaneously. The load torque arm was also determined along side with other readings.

The following procedure was adopted in obtaining the tabulated values.

1. It was ascertained that the plant had been greased and lubricated.
2. The water circulation system was checked and water was circulated through the cylinder jacket and after- cooler.
3. It was checked that the water flow to ensure that the air delivered by the compressor flows through the after cooler and on to the damping tank.
4. The drain lock was opened on the air receiver
5. The valve on the downstream side of the nozzle full was opened for the safety conditions for the pressure gauges.
6. Valves on the upstream sides of the nozzles were closed
7. The unloader gear was set in the starting position.
8. The plant was set in motion and after a reasonable speed was attained and the unloader gear for the running conditions.
9. As the pressure increased in the receiver and water ceased to issue from the receiver drain lock, the drain lock was closed and allowed the pressure to rise to 70 ibf/in2 (482KN/m2 ) and then opened gradually the valve on the upstream side of the nozzle apparatus.
10. It is now necessary to increase the rotation speed to 300 rev/ min and the receiver pressure was adjusted to 70 ibf/in2 (482KN/m2) and have an orifice whose size limits the pressure differential to 127mm of water gauge.
11. With conditions as (x) attained, the plant is to run until settled conditions were obtained the required observations to satisfy the objects of the experiment.
12. At intervals of 5 minutes, data were recorded.

Indicator diagrams to determine the average mean effective pressure for the test was obtained.

**A SKETCH OF INDICATOR DIAGRAM**

V1 – V3 = swept volume

V1 – V4 = effective swept

volume.

From the indicator diagrams obtained in each of the five observations, the average area is given by;

Average = 1.01+1.03+1.02+1.04+1.00 = 5.10 = 1.02in2

5 5

**FUNCTIONS OF MAJOR PARTS**

* 1. Engine indicator: It gives the diagram of the area covered by the piston in compression
  2. Tachometer: It measures the speed of compressor safety valve.
  3. Damping tank: It receives the final air from the receiver.
  4. Unloader gear: It reduces pressure built up in the compressor so that a comfortable and safe pressure is maintained.

**CALCULATIONS**

L = stroke of each of the two pistons = 102mm = 0.102m

D = bore of each of the two cylinders = 102mm = 0.102m

Clearance volume for each cylinder = 25.781cm3 = 2.578 \* 10-5m

RT = torque arm = 0.5334m

Diameter of orifice, Do = 15.785cm = 0.015785m

Scale of indicator spring = 50 lb/in2 = 1.36 \* 104 KN/m2

Brake power = 2W Rt n, kW …………………………...(1)

1000

Where W = The load in Newtons

Rt = The torque arm in metres

n = The rotational speed in rev / s

Indicated power = 2D2 L Pm n, kW ……………………(2)

4000

Where Pm = mean effective pressure determined from indicated diagram.

Mechanical efficiency = Indicated power

Brake power

Rate of flow of air through orifice,

Ma = Do2 Cd (2 hww a g)

4

Where;

hw = manometer reading (mm / H2O)

w = density of water (kg / m3)

a = density of air at atmospheric temperature and pressure (kg / m3)

g = acceleration due to gravity (m / s2)

Cd = coefficient of discharge of the orifice

Pa = Po

Ra To

Where;

Po = atmospheric pressure (KN/ m2)

Ra = specific gas constant for air (kJ / kg K)

To = atmospheric temperature

**From equation (1)**

The brake power = 2W Rt n , kW

1000

= 2 (117.6)(0.533)(300)

1000\*60

= **1.97065kW**

**From equation (2)**

Indicated power = 2D2 L Pm n, kW …………………… (2)

4000

= 2(0.1022)(0.012)(18.11\*104)(300) ……………(2)

4000\*60

= **1.5094kW**

Mechanical efficiency = 1.5094 = 76.59%

1.97065

Energy to air = MaCpa(to-ta) kW

But

Pa = Po = 74.55 = 0.865N/m2

Ra To 0.287(27+273.15)

**Rate of flow of air through orifice**

Ma = Do2 Cd (2 hww a g)

4

= 0.0157852 \*0.62(2 \*0.094\*103\*9.81\*0.865)

4

= **13.687\*10-2kgs-1**

Thus

Energy to air = 13.687\*1.005(33.28-30.61)\*10-2 = **0.3673kW**

Energy to jacket water = Wj \* 4.2(tjo-tji) kW

= 0.0142\* 4.2(38.66 – 29.4) = **0.552267 kW**

Energy to after-cooler circulating water = Wc \* 4.2(tco – tci)

= 0.0122 \* 4.2(34.8 – 28.0)

= **0.34843 kW**

Energy to atmosphere from piping receiver

= MaCpa {(td-taic)+(taoc-to)}kW

= 13.687\*10-2 \*1.005{(121.8-53.16) + (30.61- 33.28)}

= **9.07446 kW**

Other unaccounted for losses

= 1.97065 – (0.03673 + 0.552267 + 0.34843 + 9.07446)

= **- 8.041237 kW**

Free air delivery = MaRa (ta + 273)

Po

= {3.687\*10‑2 \* (0.287)(27 + 273)}

74.55

= **0.15807**

Volumetric efficiency = Free air delivery

D2 L \* 2

4

= 0.15807

300 \* \* 0.1022 \* 0.102 \* 2

60 4

= **18.96%**

From the indicator diagram

Length of swept volume = 4 \* 10-2 m

Length of effective swept volume = 2.6 \* 10-2 m

Given a clearance volume of 2.578 \*10-5 m3

Length of clearance volume = 2.578 \*10-5 \* 4 \* 10-2

0.7854\* (0.102)3

= **1.24 \* 10-3 m**

Effective swept volume on indicator diagram

= 2.578 \*10-5 \* 2.6 \* 10-2

1.24 \* 10-3

= **0.5406 \* 10-3 m3**

Swept volume corresponding to the length of the indicator diagram

= 0.7854\* (0.102)3

**= 0.8335 \* 10-3 m3**

Volumetric efficiency = 0.5406 \* 10-3

0.8335 \* 10-3

= **64.90%**

**SOURCES OF ERROR**

**1.** Readings of temperature were not accurately taken from the thermometer since every member of the group had his or her own way of taking readings.

**2.** Due to parallax errors in the thermometer readings due to light entering whiles readings were taken.

**3**. Approximations in the readings of thermometer values also caused errors during the experiment.

**4.** Due to some wears in the compressor

**PRECAUTIONS TAKEN**

**1**. It was ascertained that the plant had been greased and lubricated.

**2**. The water circulation system was checked and water was circulating through the cylinder jacket and after – cooler.

**3**. It was checked that the water flow to ensure that the air delivered by the compressor flows through the after – cooler and into the damping tank.

**4.** Drain cock was opened on the air receiver.

**COMMENTS AND CONCLUSION**

One of the main applications of the engine is that instead of having a separate air compressor driven by an IC engine, the compressor and the engine can be combined with the result that the intermediate rotating shafts are eliminated.

Some classification of IC engine has been given but this is not exhaustive. The application for such engines are wide both in the type of duty to be performed and in the power required.

It is also comfortable to compress air isothermally as energy to be used when air is cooled. The pressure of the air supplied was increased to make available energy it contained.

**REFERENCES**

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By: T. D. Eastop

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| --- | --- | --- | --- | --- | --- | --- | --- |
| **OBSERVATION No.** | **1** | **2** | **3** | **4** | **5** | **Total** | **Average** |
| **Load on torque arm (W/Ib)** | 26.5 | 26.25 | 26.25 | 26.75 | 26.75 | 132.5 | 26.5 |
| **Rotational speed N (rev/min)** | 300 | 300 | 300 | 300 | 300 | 1500 | 300 |
| **Pressure differential across orifice (mm H2O)** | 1.8 | 1.8 | 1.75 | 1.7 | 1.72 | 8.77 | 1.75 |
| **Temperature in damping tank (to,oC)** | 32.5 | 34 | 34 | 33.1 | 32.8 | 166.4 | 33.28 |
| **Temperature of water at inlet from jacket (tjioC)** | 29.4 | 29.4 | 29.4 | 29.4 | 29.4 | 147.2 | 29.4 |
| **Rate of flow of jacket circulating water (Wj kg/sec)** | 0.0142 | 0.0142 | 0.0142 | 0.0142 | 0.0142 | 0.078 | 0.0142 |
| **Temperature of water at inlet from after- cooler (tcioC)** | 28 | 28 | 28 | 28 | 28 | 140 | 28 |
| **Temperature of water at outlet from after-cooler (tcooC)** | 32.5 | 34.5 | 35.5 | 35.5 | 36.0 | 174 | 34.8 |
| **Rate of flow of after-cooler circulating water (Wckg/sec)** | 0.016 | 0.0158 | 0.016 | 0.0159 | 0.016 | 0.0797 | 0.01594 |
| **Air temperature at discharge from compressor (td oC)** | 120.6 | 121.1 | 121.9 | 122.5 | 123.1 | 680.27 | 121.8 |
| **Air temperature at entrance to after-cooler (taic oC)** | 49.4 | 54.16 | 53.61 | 54.16 | 54.4 | 336.9 | 53.16 |
| **Air temperature at outlet from after-cooler (taoc oC)** | 30 | 30.55 | 30.83 | 30.83 | 30.83 | 153.05 | 30.61 |
| **Air inlet temperature ( ti oC)** | 33 | 33.5 | 33.8 | 34.5 | 34.8 | 169.6 | 33.92 |
| **Temperature of water at** **outlet from jacket (tjo oC)** | 38.0 | 38.5 | 38.9 | 39.0 | 39.0 | 193.3 | 38.660000 |