A major application area of thermodynamics engineering essay

A major application area of thermodynamics is refrigeration, which is the transfer of heat from lower temperature region to a higher temperature one. The devices that produce refrigeration are called refrigerators, and the cycles on which they operate are called refrigeration cycles. The most frequently used refrigeration cycle is a vapour-compression refrigeration cycle in which the refrigerant is vaporized and compressed alternatively and is compressed in the vapour phase. There are number of refrigerants which can be used in here, but the most commonly used on a commercial scale is a R12 (used in this experiment as well).

The thermodynamics of ideal vapour compression cycle can be analyzed on a temperature versus

entropy diagram as depicted in Figure 1. At point 1 in the diagram, the circulating refrigerant en-

ters the compressor as a saturated vapour. From point 1 to point 2, the vapour is isentropically

compressed (i. e., compressed at constant entropy) and exits the compressor as a superheated va-

pour. From point 2 to point 3, the superheated vapour travels through part of the condenser which removes the superheat by cooling the vapour. Between point 3 and point 4, the vapour travels through the remainder of the condenser and is condensed into a saturated liquid. The condensation process occurs at essentially constant pressure.

Between points 4 and 5, the saturated liquid refrigerant passes through the expansion valve

(throttling device) and undergoes an abrupt decrease of pressure. This process results in the adia-

batic flash evaporation and auto-refrigeration of a portion of the liquid (typically, less than half

of the liquid flashes). The adiabatic flash evaporation process is isenthalpic (i. e., occurs at con-

stant enthalpy).

Figure 12 Temperature – Entropy diagram

1 www. wikipedia. org/wiki/Refrigeration

2 http://upload. wikimedia. org/wikipedia/commons/f/f7/RefrigerationTS. png

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Between points 5 and 1, the cold and partially vaporized refrigerant travels through the coil or tubes in the evaporator where it is totally vaporized by the warm air (from the space being refrigerated) that a fan circulates across the coil or tubes in the evaporator. The evaporator operates at essentially constant pressure. The resulting saturated refrigerant vapour returns to the compressor inlet at point 1 to complete the thermodynamic cycle.

The area under the process curve on T-s diagram represents the heat transfer for internally reversible processes. The area under the process curve 5-1 represents the heat absorption in the evaporator, the area under the process 2- 4 represents the heat rejection in the condenser. In the ideal vapour compression refrigeration cycle all the heat losses and disruptions are being ignored, but in actual refrigeration cycle, we need to take these losses into consideration as they have been mentioned in this report later.

The Hilton refrigeration laboratory unit R714 is capable of following entities;

· Investigation of the variation in refrigerator " duty" or cooling ability for various condens-

ing temperature and the heat delivered to the cooling water with variation in condensing

temperature. We can also investigate the variation in refrigeration coefficient of per-

formance for the various condensing temperature.

· Investigation of the variation in coefficient of performance based on electrical, shaft and

indicated power, determination of the overall heat transfer coefficient for the condenser

cooling coil and performance of the thermostatic expansion valve.

· Investigation of the heat delivered to the cooling water with variation in condensing tem-

perature, coefficient of performance as a heat pump for various condensing temperature,

as well as power input based on electrical, shaft and indicated power.

The important aspect of this report is to demonstrate the two laws of thermodynamics i. e.

first and second law of thermodynamics. The first law is simply an expression of the conservation of energy principle, and it asserts that energy is thermodynamic property.

Qout = Wnet + Qin Equation (1)

In this experiment the Qin is provided by input voltage, this input is used to do the net work done on the refrigerant by compressor and motor, and the result of this produces the heat which is being removed by the condenser i. e. Qout.

The second law of thermodynamics asserts that energy has quality and quantity, and actual processes occur in the direction of decreasing quality of energy.

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Aim’s and objectives: –

The Hilton refrigeration laboratory unit R712 has been designed to allow students to fully investigate the performance of a vapour compression cycle under various conditions of evaporator load and condenser pressure.

The main objectives of this laboratory are listed below;

· The demonstration of application of the “ First and second law of thermodynamics”.

· The introduction of to refrigeration plant and calculate the various coefficient of perform-

ance.

· Investigation of system losses, this includes motor, compressor, evaporator and con-

denser losses. These losses (friction, heat losses) occur only in practical/commercial refrigerator, there are no losses in ideal vapour compressor refrigerator.

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Apparatus

The figure shown below looks like a refrigeration laboratory unit R712 (not exactly it) and it consists of the following components;

Figure 23 Refrigeration laboratory unit

Panel: High quality glass reinforced plastic on which the following components are mounted. Refrigerant: R12

Digital Thermometer: A device that measures temperature.

Wattmeter: Allows measurement of the power input to either evaporator or motor. Voltage Controller: To vary evaporator load.

Variable Area Flow meters: Variable area types to indicator R12 and H2O flow rates. Pressure Gauges: To indicate R12 pressure in evaporator and condenser.

Spring Balance and Tachometer: These two together allow measurement of power required to drive the compressor.

Expansion Valve: Thermostatically controlled type i. e. throttling device. Evaporator: Electrically heated device i. e. heat exchanger

Compressor: (Internally mounted) Twin cylinder belt driven unit, along with spring balance force system.

Condenser: A device or unit used to condense vapor into liquid. It is also called heat exchanger.

Motor: A machine that converts electricity into a mechanical motion.

3 www. p-a-hilton. co. uk/English/Products/ Refrigeration__2_/refrigeration__2_. html

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Procedure4

In prior performing an experiment the most important things to do are, to measure the atmos-

pheric pressure, which would be added to the gauge pressure to get an absolute pressure for both

condenser and evaporator, and to balance the two tips of the spring balance force, being applied

on the compressor. In failure to do these things would cause a sufficient amount of error in the

final results.

In this experiment the condenser pressure is being kept constant i. e. 900KPa.

Step-1 Turn on the refrigeration plant using one of the control breakers, and setting the evaporator voltage i. e. 40 – 100 volts, at the same time balancing the two tips of compressor load and set the condenser pressure to 900KPa, using rota-meter.

Step-2 Record the following values; Evaporator Amps (1-2. 42A), from wattmeter, compressor speed using tachometer, water and refrigerant flow rate using flow meter.

Step-3 Record the spring balance force, reading directly from the scale.

The hot water is in the tubes is indicated by red and cold water is indicated by blue sign in the refrigeration plant.

Step-4 The flow rate is controlled by a throttling device (valve), the small changes in opening and closing the valve, effect the condenser pressure.

Step-5 The temperature values of the refrigerant at different stages in the whole cycle at constant pressure is given by temperature dialler. Now we had all the values we needed, now we changed evaporator Amps value, recorded rest of the values as mentioned earlier and repeated the whole experiment for three to four times.

The Refrigeration Laboratory Unit has three controls. Firstly a combined miniature circuit breaker and switch turns on both the compressor motor and the supply to the electrically heated evaporator. A combined variable area water flow meter and valve allow control of the condenser pressure and a panel mounted voltage controller allows control of the evaporator load from zero to full power.

Refrigerant R12 vapour is drawn into the compressor from the evaporator mounted on the front

of the panel. Work is done on the gas in the compressor and its pressure and temperature are

raised. This hot, high pressure gas discharges from the compressor and flows into the panel mounted water cooled condenser, where heat is removed from it. This liquid then flows through

a thermostatic expansion valve. Here it passes through a controlled orifice, which allows its

pressure to fall from that of the condenser to that of the evaporator. The refrigerant has a satu-

rated vapour phase at this point. The voltage across the heater elements may be varied from zero

to that of the mains supply voltage by adjustment of a voltage controller situated on the front

panel. Measurement of the power is carried out by a panel mounted digital wattmeter.

4 http://www. p-a-hilton. co. uk/R714-Edition-2-GREY. pdf

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Results

The observation table below shows all the values of different components in the refrigeration

plant along with input indices and output indices, enthalpy of the cycle and losses in the system.

The calculations required to get those results (to complete the table) are also listed after this table

below.

1 Condenser pressure (gauge) Pc KNm-2 900 900 900

2 Evaporator pressure (gauge) Pe KNm-2 -20 20 40

3 Condenser pressure (Abs) Pc KNm-2 1001. 663 1001. 663 1001. 663

4 Evaporator pressure (Abs) Pe KNm-2 81. 663 121. 663 141. 663

5 Compressor suction t1 0 C -23. 5 -22. 6 -5. 2

6 Compressor delivery t2 0 C 59. 9 68. 5 69. 4

7 Liquid leaving condenser t3 0 C 31. 6 34. 8 33. 8

8 Evaporator inlet t4 0 C -32 -23. 6 -19. 1

9 Water inlet t5 0 C 23. 8 21. 6 21. 4

10 Water outlet t6 0 C 41. 2 38. 6 39. 5

11 Water flow rate Mw g s-1 1. 5 5. 0 6. 0

12 R 12 Flow rate Mr g s-1 0. 7 1. 5 1. 9

13 Evaporator Volts Ve V 40 70 100

14 Evaporator Amps Ie I 1 A 1. 70 A 2. 42 A

15 Motor Volts Vm V 235 232 232

16 Motor Amps Im A 3. 6 3. 6 3. 6

17 Spring balance Force F N 5. 5 7. 5 8. 2

18 Compressor speed nc rpm 477 474 473

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19 Motor Speed = 3. 17 Ã- nc Nm rpm 1512. 09 1502. 58 1449. 71

20 h1 KJ/Kg 340 345 360

21 h2 KJ/Kg 385 400 420

22 h3 KJ/Kg 225 240 250

23 h4 KJ/Kg 160 170 180

24 Qe, Elec = Ve Ã- Ie W 40 119 242

25 Qe, R 12 = Mr(h1 – h4) W 126 262. 50 342

26 Wc = 0. 0172Ã-FÃ-Nm W 143. 043 193. 832 204. 467

27 Power factor at shaft (power Wc) pf – 0. 43 0. 48 0. 52

28 Wm = Vm. Im. pf W 363. 78 400. 89 434. 31

29 W’c = Mr (h2 – h1) W 31. 5 82. 50 114. 0

30 Q cond = Mr (h2 – h3) W 112 240 323

31 Qw = Mw Ã- 4. 18 (t6 – t5) W 109. 09 376. 20 428. 87

32 CoPnet = Qe, Elec / Wm 0. 109 0. 296 0. 557

33 CoP R12 = (h1 – h4)/(h2 – h1) 4. 0 3. 1818 3. 00

34 t41 can be found by (t1 – t4) 0 C 8. 5 1. 00 13. 9

35 CoP (te-t2) = t41 / (t2-t41) 0. 165 0. 015 0. 250

36 Motor loss = Wc – Wm W -220. 73 -207. 06 -229. 84

37 Compressor loss = W’c-Wc W -111. 54 -110. 33 -90. 47

38 System loss = Qcond – Qw W 2. 91 -136. 20 -105. 87

39 System loss = Qe, R12 – Qe, Elec W 86 143. 50 100. 0

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Figure 3 A graph represents the relationship between net CoP and evaporator temperature

Figure 4 A comparison of different losses of the system in one graph against Evaporator temperature

The fluctuation and randomness in the graphs is because of the poor calibration and less

number of repeated results (less tests provide less information), and most of the recorded results are based on guessed values.

Calculations

To find absolute pressure, we need an atmospheric and gauge pressure of the component.

Now for two individual components,

· Condenser

As we know Patm = Ïgh = 13600 kg/m3 Ã- 9. 81 m/s2 Ã- 762 Ã-10-3m

= 101. 663Ã-103 Kg / ms2 = 101. 663 KN/m2

Hence Pgauge, cond = 900 KN/m2

Pabs, cond = Patm + Pgauge, cond = 101. 663 + 900 = 1001. 663 KN/m2

· Evaporator

As Patm = Ïgh = 13600 kg/m3 Ã- 9. 81 m/s2 Ã- 762 Ã-10-3m

= 101. 663Ã-103 Kg / ms2 = 101. 663 KN/m2

i. Pgauge, Evap = -20 KN/m2

Pabs, Evap = Patm + Pgauge, Evap

Therefore = 101. 663 + (-20)= 81. 663 KN/m2

ii. Pgauge, Evap = 20 KN/m2

Pabs, Evap = Patm + Pgauge, Evap = 101. 663 + (20)= 121. 663 KN/m2

iii. Pgauge, Evap = 40 KN/m2

Pabs, Evap = Patm + Pgauge, Evap

Therefore = 101. 663 + 40 = 141. 663 KN/m2

To find Qw (Heat removal from condenser)

As we repeated the experiment three times, so water flow rate have three different values, hence we need to find Qw at three points,

Qw = Mw Ã- 4. 18 (t6 – t5)

When Mw = 1. 5 gs-1, t6 = 41. 2 0C, t5 = 23. 8 0C

Qw = 1. 5 Ã-4. 18 (41. 2 – 23. 8) = 109. 098 W

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As Qw = Mw Ã- 4. 18 (t6 – t5)

When Mw = 5. 0 gs-1, t6 = 39. 6 0C, t5 = 21. 6 0C

So Qw = 5. 0 Ã-4. 18 (39. 6 – 21. 6) = 376. 2 W

Qw = Mw Ã- 4. 18 (t6 – t5)

When Mw = 6. 0 gs-1, t6 = 38. 5 0C, t5 = 21. 4 0C

Qw = 6. 0 Ã-4. 18 (38. 5 – 21. 4) = 428. 87 W

To find Wc (work done by the compressor or a shaft loss)

The work done by the compressor depends on spring balance force and motor speed, hence to get more work done out of the compressor we need to increase any of the above mentioned parameters. Therefore

Wc = 0. 0172Ã-FÃ-Nm

i. Wc = 0. 0172Ã-5. 5Ã-1512. 09 = 143. 043 W

ii. Wc = 0. 0172Ã-7. 5Ã-1502. 58 = 193. 832 W

iii. Wc = 0. 0172Ã-8. 2Ã-1449. 71 = 204. 467 W

To find Wm (work done by the motor on a shaft to rotate)

The work done by the motor is a product of voltage provided, amount of current flowing the motor and power factor of the shaft, which gives us the following values;

Wm = Vm Ã- Im Ã- pf

i. Wm = 235 Ã- 3. 6 Ã- 0. 43 = 363. 78

ii. Wm = 232 Ã- 3. 6 Ã- 0. 48 = 400. 89

iii. Wm = 232 Ã- 3. 6 Ã- 0. 52 = 434. 31

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To find CoPnet (Total coefficient of performance of refrigerant)

CoPnet = Qe, Elec / Wm

By substituting different values of electric input heat energy (artificial input energy) and the work done by the motor, we get net coefficient of performance of the cycle,

i. CoPnet = 40 / 363. 78 = 0. 109 = 11%

ii. CoPnet = 119 / 400. 89 = 0. 296 = 30%

iii. CoPnet = 242 / 434. 31 = 0. 557 = 56%

To find CoP (te-t2)

This is the coefficient of performance of ratio of temperature values at point 1-4 and difference of it, to the temperature of the refrigerant after compression, so we get following

CoP (te-t2) = t41 / (t2-t41)

i. CoP (te-t2) = 13. 9 / (69. 4 – 13. 9) = 0. 250 = 25%

ii. CoP (te-t2) = 8. 5 / (59. 9 – 8. 5) = 0. 165 = 16%

iii. CoP (te-t2) = 1. 0 / (68. 5 – 1. 0) = 0. 015 = 1. 5%

To find Qe, R 12(Heat removal from Evaporator) The given equation is …

Qe, R 12 = Mr (h1 – h4)

By substituting different values of enthalpy, which we recorded from a pressure – enthalpy diagram, so we get

i. Qe, R 12 = 0. 7 (340 – 160) = 126. 0

ii. Qe, R 12 = 1. 5 (345 – 170) = 262. 5

iii. Qe, R 12 = 1. 9 (360 – 180) = 342. 0

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To find W’c (Input work done or compressor work loss)

The input work done by the compressor can be calculated by finding flow rate of the refrigerant R12 and the difference of enthalpy of refrigerant before and after the compression.

W’c = Mr (h2 – h1)

Substituting all three values of the above parameters (variables), we get

i. W’c = 0. 7 (385 – 340) = 31. 5

ii. W’c = 1. 5 (400 – 345) = 82. 5

iii. W’c = 1. 9 (420 – 360) = 114

To find Q cond (Heat loss by the condenser)

Similarly heat loss by the condenser is a product of refrigerant flow rate to the difference of enthalpy values of it, before entering and leaving the condenser, we get

Q cond = Mr (h2 – h3)

Now, using above stated equation…

i. Q cond = 0. 7 (385 – 225) = 112

ii. Q cond = 1. 5 (400 – 240) = 240

iii. Q cond = 1. 9 (420 – 250) = 323

To find CoPR12 (Coefficient of performance of refrigerant) CoP R12 = (h1 – h4)/(h2 – h1)

Coefficient of performance of refrigerant is a ratio of all the enthalpy values in the cycle, here note that for ideal vapour – compression refrigeration cycle h3 = h4

Hence we get...

i. CoP R12 = (340 – 160) / (385 – 340) = 4. 00

ii. CoP R12 = (345 – 170) / (400 – 345) = 3. 1818

iii. CoP R12 = (360 – 180) / (420 – 360) = 3. 00

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Systems losses

Motor loss = Wc – Wm

= 143. 043 – 363. 78 = -220. 75

= 193. 832 – 400. 89 = -207. 06

= 204. 467 – 434. 31 = -229. 84

Compressor loss = W’c-Wc

= 31. 5 – 143. 043 = -111. 54

= 82. 5 -193. 832 = -110. 33

= 114 – 204. 467 = -90. 47

System loss = Qcond – Qw

= 112 – 109. 09 = 2. 91

= 240 – 376. 20 = -136. 20

= 323 – 428. 87 = -105. 87

System loss = Qe, R12 – Qe, Elec

= 126 – 40 = 86. 00

= 262. 5 – 119 = 143. 50

= 342 – 242 = 100. 00

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Discussion of Results

The observation table of results has been listed on page 8 – 9, and it is followed by all the calculations required to complete the table or to get the results.

The experiment has been repeated three times, so all the results (values have been listed three

times. In the calculation section the system losses and heat energy are shown as negative val-

ues, it's because the work is done on the system and heat is being removed from that particu-

lar system, in this case its condenser. The positive values of system loss and heat energy

shows that heat is being add in the system and work is done by the system, and in this case its

evaporator. The condenser pressure i. e. 900 KPa, was not exactly 900 KPa. As we were set-

ting the pressure manually, so in the whole experiment the pressure was 900 KPa ± 10%, it

was because of the fluctuation in the gauge needle, so we assumed the considered pressure.

The compressor pressure applied by spring balance force, affected the work done of the com-

pressor on the refrigerant R12, because to get an accurate compressor work done, the two tips of the spring balance should be in balance (level), but during an experiment we were getting

random values (results), so then I realised that something is wrong, so I looked at all the

components of the refrigeration plant, and I found that the two tips of the spring were not bal-

ance. Hence to get right results we had to redo the experiment. The throttling device or valve

has a huge impact on condenser pressure, because by opening or closing i. e. changing a flow

rate make a considerable amount of difference on condenser pressure and evaporator tem-

perature.

Motor loss refers to the consumption of electrical energy not converted to useful mechanical

energy output, but in this case energy loss means less input energy to the compressor, which

means a refrigerant would be less compressed by a compressor, so less heat would be removed by the condenser, and even after passing through the valve the refrigerant would still

have a high temperature and pressure, hence less refrigeration would occur in a vapour com-

pression cycle. Therefore we need to take into account power losses in the electric motor.

In order to study this process more closely, refrigeration engineers use this pressure – en-

thalpy diagram shown in Figure 5. This diagram is a way of describing the liquid and gas

phase of a substance. Enthalpy can be thought of as the quantity of heat in a given quantity,

or mass of substance. The curved line is called the saturation curve and it defines the

boundary of pure liquid and pure gas, or vapour. In the region marked vapour, its pure va-

pour. In the region it’s marked liquid, it is a pure liquid. If the pressure rises so that we are

considering a region above the top of the curve, there is no distinction between liquid and vapour. Above this pressure the gas cannot be liquefied. This is called the Critical Pressure. In

the region underneath the curve, there is a mixture of liquid and vapour.

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3 2

4 1

Figure 65 Pressure – Enthalpy diagram

Evaporator Pressure line Condenser pressure line

stage (Not a straight line) Isobar Condensation stage

sion valve R12 Evaporation process

5 http://www. mvsengineering. com/chapter18. pdf

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Isentropic Compression

R12 passing through Expan-

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At the inlet of the compressor the temperature (t1) is the same as temperature of refrigerant R12 at the outlet of the evaporator. So we go straight from that temperature of left side of the doom (saturated liquid) to the right side of the doom (saturated vapour line), and then following the temperature gradient line, we go down and record the enthalpy value at that temperature and pressure. Similarly for the stage 2, we find h2 on x-axis.

When the refrigerant leaves the condenser, it obtains a saturated liquid phase (left side of the

doom), so taking the reference of condenser pressure line (red line), we take a straight line

parallel to the y-axis, and wherever it meets the x-axis gives a value of enthalpy (h3) at stage

three. In actual refrigerant plant, enthalpy at stage 3 and stage 4 is not same, but for the sake

of calculation we assume that it's an ideal condition and enthalpy at these two points is same.

Test 1

As Compressor suction = t1 = -23. 5 0C and condenser Pressure (Abs) = Pc =

1001. 663 KNm-2

Hence the enthalpy h1 = 340 KJ/Kg

Compressor delivery = t2 = 59. 9 0C and Condenser Pressure (Abs) = Pc = 1001. 663 KNm-2 Hence the enthalpy h2 = 385 KJ/Kg

Here Liquid leaving condenser = t3 = 31. 6 0C

And Condenser Pressure (Abs) = Pc = 1001. 663 KNm-2 Hence the enthalpy h3 = 225 KJ/Kg

As mentioned earlier that h3 = h4 (Ideal condition) Hence the enthalpy h4 = 225 KJ/Kg

But using temperature at evaporator inlet, t4 = -32 0C, we get Actual enthalpy value, h4 = 160 KJ/Kg

Test 2

As Compressor suction = t1 = -22. 6 0C and condenser Pressure (Abs) = Pc =

1001. 663 KNm-2

Hence the enthalpy h1 = 345 KJ/Kg (from above p-h diagram)

Compressor delivery = t2 = 68. 5 0C and Condenser Pressure (Abs) = Pc = 1001. 663 KNm-2 Hence using Figure 4, we get enthalpy h2 = 400 KJ/Kg

Here Liquid leaving condenser = t3 = 34. 8 0C

And Condenser Pressure (Abs) = Pc = 1001. 663 KNm-2 Hence the enthalpy h3 = 240 KJ/Kg

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As mentioned earlier that h3 = h4 (Ideal condition) Hence the enthalpy h4 = 240 KJ/Kg

But using temperature at evaporator inlet, t4 = -23. 6 0C, we get Actual enthalpy value using figure 4, h4 = 170 KJ/Kg

Test 3

As Compressor suction = t1 = -5. 2 0C and condenser Pressure (Abs) = Pc =

1001. 663 KNm-2

Hence the enthalpy h1 = 360 KJ/Kg

Compressor delivery = t2 = 69. 4 0C and Condenser Pressure (Abs) = Pc = 1001. 663 KNm-2 Hence the enthalpy h2 = 420 KJ/Kg

Here Liquid leaving condenser = t3 = 33. 8 0C

And Condenser Pressure (Abs) = Pc = 1001. 663 KNm-2, Evaporator Pressure = 40 KPa Hence the enthalpy h3 = 250 KJ/Kg

As mentioned earlier that h3 = h4 (Ideal condition) Hence the enthalpy h4 = 250 KJ/Kg

But using temperature at evaporator inlet, t4 = -19. 1 0C, we get Actual enthalpy value at this stage, h4 = 180 KJ/Kg

6However the expansion of the high pressure liquid, process 5 – 1 above is non reversible.

Notice that Expansion is a constant enthalpy process. It is drawn as a vertical line on the P-h

diagram. No heat is absorbed or rejected during this expansion, the liquid just passes through

a valve, like water coming out of a tap. The difference is that because the liquid is saturated at

the start of expansion by the end of the process it is partly vapour. Point 1 is inside the curve

and not on the curve as described in the Evaporation process. At point 4 it starts to condense

and this continues until point 5 when all the vapour has turned into liquid. Point 5 is saturated liquid. If more heat is removed, the liquid cools. It is then called sub-cooled liquid. Hence h4 is on a saturated liquid line (left side of the doom), and does not appear in a vapour compression cycle, and this is the case in all three tests.

6 http://www. alephzero. co. uk/ref/vapcom. htm#ph

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As there is no moving part in the whole refrigeration plant apart from motor shaft of a compressor, so work done by them is zero, i. e. w = 0

So using steady state energy equation, we get

W – Q = h2 – h1 Equation (2)

As W = 0, so equation (1) becomes

– Q = h2 – h1

Or Q = h1 – h2 Equation (3)

The coefficient of performance or COP (sometimes CP), of a heat pump (i. e. refrigerator) is

the ratio of the change in heat at the “ output” (the heat reservoir of interest) to the supplied

work. To find Cop value of refrigeration plant as well as for the refrigerant is a good practice, because this will illustrate that how much efficient of these two are.

7It takes a lot of heat to evaporate liquid. In other words a small amount of liquid circulating

in a refrigerator can perform a large amount of cooling. This is one reason why the vapour

compression cycle is widely used. The refrigeration system can be small and compact. Also

from a practical point of view heat exchange is much better when using change of state –

evaporation and condensation. However the expansion of the high pressure liquid, process 5 –

1 above is non reversible. And so the efficiency of this cycle can never even approach Carnot

efficiency.

7 http://www. alephzero. co. uk/ref/practcop. htm

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Conclusion

8The vapour-compression cycle is used in most household refrigerators as well as in many

large commercial and industrial refrigeration systems but the efficiency of this cycle can

never even approach Carnot efficiency, because of its low coefficient of performance.

In the refrigeration plant the operating parameters can be varied by adjustment of condenser

cooling water flow and electrically heated evaporator supply voltage. Components have a low

thermal mass resulting in immediate response to control variations and rapid stabilisation.

Instrumentation includes all relevant temperatures, condenser pressure, evaporator pressure,

refrigerant and cooling water flow rates, evaporator and motor power, motor torque and com-

pressor speed.

The most of components of refrigeration plant used in this experiment (R712) are manually calibrated scales (not digital), and based on this poor calibration all the recorded results are being guessed on the base of individual judgment, which is wrong most of the time. Anyway a small amount of liquid circulating in a refrigerator can perform a large amount of cooling. This is one reason why the vapour compression cycle is widely used.

The enthalpy values which are being recorded directly from enthalpy – pressure diagram (Figure 4), and based on how unclear that diagram is, I would say it is not a great source of information, but still we use this to find enthalpy. The system (refrigeration plant) has some losses, which have described earlier in this report, this includes motor loss, condenser and evaporator loss.

In conclusion, I would like to say that by doing this experiment I learnt a great amount of

knowledge, about refrigeration plant, and how it works, what kind of cycle more often use for this, how much efficient is this and how to calculate the different losses in this system. I would

say by understanding the operation of this small scale refrigeration plant, I think I would be

able to operate on an industrial scale refrigeration plant, because the basic principle is same.

8 http://www. alephzero. co. uk/ref/vapcomcyc. htm

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