Palestine Polytechnic University

College of Engineering & Technology

Mechanical Engineering Department

Graduation Project

Solar Adsorption Ice Maker (Building and Testing)

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ABSTRACT

Refrigeration is a major energy consumer in our world. Today because of the world warming, the world should be aware to this point. In this project solar energy used adsorption cycle in order to produce ice without any effect to the nature.

This project can used in poor areas which are not able to use electricity to have the refrigerating effect and its real and exciting possibility.

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symbol	Meaning	Unit
A.C	Activated carbon	Kg
A_a	aperture area	cm^2
A_r	receiver area	cm^2
A_o	Cross section area of generator	m^2
A_i	Cross section area of inner pipe in generator	m^2
COP	Coefficient of performance	Dimensionless
c_p	Pressure constant	kJ/kg.c
G_t	Irradiance	W/m^2
Δh	Enthalpy change	kJ/kg
n_o	optical efficiency	Dimensionless
q_{gene}	Amount of heat on generator	MJ/m^2
ρ	reflectance density	 Kg/m^3
α	absorptance	
Δh	Enthalpy change	kJ/kg

CHAPTER ONE

INTRODUCTION

Chapter one

Introduction

1.1 General outlook

As the world becomes more self aware of changing climate conditions caused by global warming; it is vital to reassess our dependence on the burning of fossil fuels to gain energy. The alternatives for gaining this energy can be found in the sources of renewable energy such as solar, wind, biomass and wave etc.

In particular, the solar energy alternatives is now being more closely examined in an attempt to utilize this as a source of energy for both domestic and commercial; and users such as refrigerators, air conditioners, hot water heaters and desalination for water recycling etc.

In recent years, increasing attention is being given to the use of waste heat and solar energy in energizing refrigerating systems. Solar powered refrigeration and air conditioning have been alternative during the last twenty years, since the availability of sunshine and the need of refrigeration both reach maximum levels in the same season.

One of the most effective forms of solar refrigeration is in the production of ice, as ice can accumulate much latent heat, thus the size of the ice maker can be made small.

In this project methanol and active carbon in solar adsorption cycle and use a parabolic trough to reach high temperature on surface of generator is used.

Figure 1.1: general sketch of the project

1.2 Previous Studies

Solid adsorption refrigeration makes use of the unique features of certain adsorbent – refrigerant pairs to complete refrigeration cycles for cooling or heat pump purposes. Zeolite and activated carbon were used as absorbents in many systems. In early 1980's, Tcherncr carried out an investigation of adsorption refrigeration with the Zeolite and water pair. Also, Pons and Genier worked on solid adsorption pair of Zeolite and water, to produce refrigerating effect achieving a coefficient of performance of only about 0.1.

Later, in 1987, Critoph demonstrated that activated Carbon and Methanol can be served as a suitable pair for a solar powered, solid – adsorption ice maker. Critoph had studied the performance limitations of adsorption cycles for solar cooling and concluded that, in general, activated Carbon - Methanol combination was preferable for solar cooling which giving the best coefficient of performance achievable in a single – stage cycle.

In this project solar adsorption cycle with methanol and active carbon to produce ice is used.

1.3 Project Objectives

- Design a solar adsorption ice maker that uses methanol and active carbon as refrigerant and adsorbent respectively, which use the sun rays to produce the energy needed to complete the refrigeration cycle.
- Design a parabolic trough to reach high temperature on generator tube.
- Determined coefficient of performance for solar adsorption cycle.

1.4 Project Layout

The project consists of the following chapters:

Chapter 1: Introduction

Introduction contents general outlook about project, previous studies of a solar adsorption cycle, project objectives, time table and budget.

Chapter 2: Refrigerant and adsorption cycle

This chapter discuss three basic point, the first point discussed adsorption cycle and its stages. The second point included explaining the components of cycles "generators, parabolic trough, condenser, evaporator, ice box". The third point show type of refrigerant and adsorbent material.

Chapter 3: Selection and design component

In this chapter the component of the adsorption cycle designed, also pipe selection.

Chapter 4: Experiment and calculation

Experiments are very important to obtain amount of cooling value that necessary to calculate coefficient of performance of cycle.

Chapter 5: Conclusion and recommendations.

Conclusions that concluded from the experiments and calculated from the experimental values of the project and what problems face the project and the recommendations which recommended increasing the efficiency of the cycle.

1.5 Budget

Table 1.1 budget

TASK	COST (NIS)
Researches and Internet	600
Transportations	1000
Printing papers	450
Equipments	1200
Refrigerant and adsorbent	420
TOTAL	3670

1.6 Time Planning

The project plan follows the following time schedule, which includes the related tasks of study and system analysis.

The following time plan of first semester

Table 1.2 the first semester time plan

Task/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Collecting Information																
Reading																
Introduction																
Cycle components																
Project Documentation																

The following time plan of second semester

Table1.3 the second semester time plan

Task/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Design of project																
Building the project																
Obtained refrigerant and adsorbent																
Calculation and experiment																
Conclusion and recommendation																
Project Documentation																

Chapter Two

Refrigeration and Adsorption cycle

Chapter Two

Refrigerant and Adsorption Cycle

2.1 Refrigerant and Adsorbent

2.1.1 Refrigerant (Methanol)

It is also known as methyl alcohol, wood alcohol is a chemical compound with formula $CH3OH$ It is toxic drinking 10 ml will cause blindness, and as little as 100 ml will cause death. It is the simplest alcohol, and is a light, volatile, colorless, flammable, and liquid with a distinctive odor that is very similar to but slightly sweeter than ethanol (drinking alcohol). At room temperature it is a polar liquid and is used as an antifreeze, solvent, fuel, and as a denaturant for ethanol.

Methanol is produced naturally in the anaerobic metabolism of many varieties of bacteria, and is ubiquitous in the environment. As a result, there is a small fraction of methanol vapor in the atmosphere. Over the course of several days, atmospheric methanol is oxidized by oxygen with the help of sunlight to carbon dioxide and water. Methanol is therefore biodegradable

Thermal and physical properties of methanol:

The freezing and boiling points at atmospheric pressure are (-97°C) and (64.7°C), respectively, the density of methanol and viscosity at 20°C (0.7918 g/cm^3) and (0.59 mPa.sec), respectively.

Application of methanol:

The largest use of methanol by far is in making other chemicals. About 40% of methanol is converted to formaldehyde, and from there into products as diverse as plastics, plywood, paints, explosives, and permanent press textiles. Derivatives of methanol include dim ethyl ether, which has replaced chlorofluorocarbons as an aerosol spray propellant, and acetic acid. Dim ethyl ether or "DME" also can be blended with liquefied petroleum gas (LPG) for home heating and cooking, and can be used as a diesel replacement transportation fuel. Methanol is also used as a solvent, and as antifreeze in pipelines and windshield washer fluid.

2.1.2 Adsorbent (Activated Carbon)

It is also called activated charcoal or activated coal, is a form of carbon that has been processed to make it extremely porous and thus to have a very large surface area available for adsorption or chemical reactions.

2.1.2.1 Applications

Adsorption refrigeration, gas purification, gold purification, metal extraction, water purification, medicine, sewage treatment, air filters in gas masks and filter masks, filters in compressed air and many other applications.

Carbon adsorption has numerous applications in removing pollutants from air or water streams both in the field and in industrial processes such as, Spill cleanup, Groundwater remediation, Drinking water filtration and Air purification volatile organic compounds capture from painting, dry cleaning, gasoline dispensing operations.

2.3 Adsorption cycle

2.3.1 Introduction

Adsorption is the use of solids for removing substances from gases and liquids.

The phenomenon is based on the preferential partitioning of substances from the gaseous or liquid phase onto the surface of a solid substrate.

This process is reversible.

2.3.2 Adsorption Phases

- Heating and pressurization
- Heating and desorption with condensation
- Cooling and depressurization
- Cooling and adsorption with evaporation

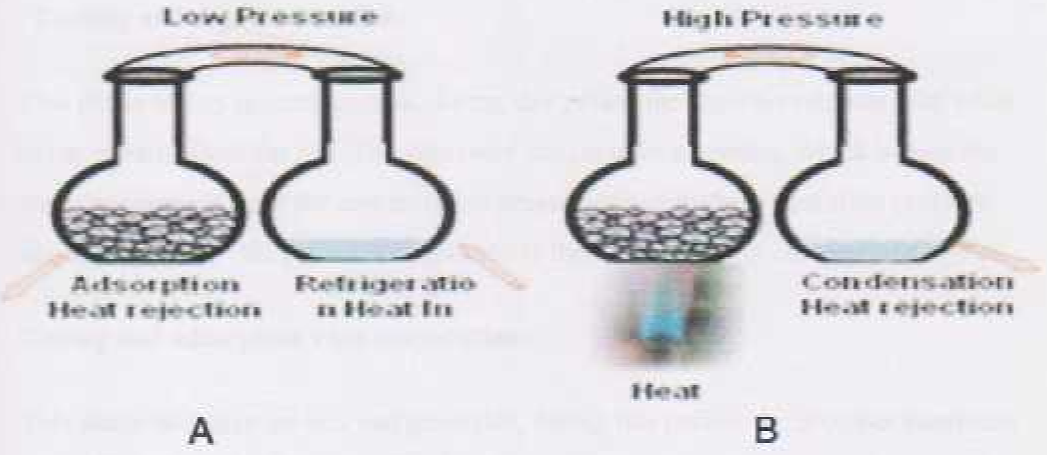


Figure 2.1 adsorption phases

Heating and pressurization:

When the cycle processes begins the methanol will be adsorbed in activated carbon and because of the increase of temperature the methanol will leave activated carbon particles, heating and pressurization process occurs in the generator, in this process the adsorbent temperature increases, which induces a pressure increase, from the evaporation pressure up to the condensation pressure see figure 2.1 (B) . This period is equivalent to the "compression" phase in vapor compression refrigeration cycles.

Heating and desorption with condensation:

This phase occurs in generator and condenser, during this period the absorber continues receiving heat while being connected to the condenser, which now superimposes its pressure.
The adsorbent temperature continues increasing, which induces desorption of vapor. This desorbed vapor is liquefied in the condenser.
The condensation heat is released to the second heat sink at intermediate temperature see figure 2.1(B). This period is equivalent to the "condensation" in compression cycles.

Cooling and depressurization:

This phase occurs in receiver tank, during this period the absorber releases heat while being covered from the sun. The adsorbent temperature decreases, which induce the pressure decrease from the condensation pressure down to the evaporation pressure, see figure 2.1(A).This period is equivalent to the "expansion" in compression cycles.

Cooing and adsorption with evaporation:

This phase occurs in ice box and generator, during this period, the absorber continues releasing heat while being connected to the evaporator, which now superimposes its pressure. The adsorbent temperature continues decreasing, which induces adsorption of vapor. This adsorbed vapor is evaporated in the evaporator. The evaporation heat is supplied by the heat source at low temperature see figure 2.1(A) .This period is equivalent to the "evaporation" in compression cycles.

2.4 The components of adsorption cycle

1- Solar collectors:

The solar collectors have many types as mentioned in table 2.1 below.

Table 2.1: classification of collectors

Motion	Collector type	Concentration ratio	Indicative temperature range (°C)
Stationary	Flat plat collector (FPC)	1	30-80
	Evacuated tube collector (ETC)	1	50-200
	Compound parabolic collector (CPC)	1-5	60-240
Single-axis tracking	Compound parabolic collector (CPC)	5-15	60-300
	Linear Fresnel reflector (LFR)	10-40	60-250
	Parabolic trough collector (PTC)	15-45	60-300
	Cylindrical trough collector (CTC)	10-50	60-300
Tow-axis Tracking	Parabolic dish reflector (PTC)	100-1000	100-500
	Heliostat field collector (HFC)	100-1500	150-2000

In this project parabolic trough has been used as solar collectors.

1-Parabolic trough:

Historically, the parabolic trough plants used in electricity generating plants. Stationary parabolic trough capable of generating temperatures nearly 240°C .The general trend is to build larger collector with higher concentration ratio to maintain collector thermal efficiency at higher fluid outlet temperature.

Thermal analysis of collectors:

Concentrating collectors:

The useful energy delivered from a concentrator is:

$$q_{gene} = G_b * A_a * \rho * \alpha * C \qquad 2.1$$

G_b : Irradiance.

A_a : aperture area.

ρ : reflectance.

α : absorptance.

C : concentration ratio.

q_{gene} : amount of heat on generator.

$C = A_a / A_r$

A_r : receiver area.

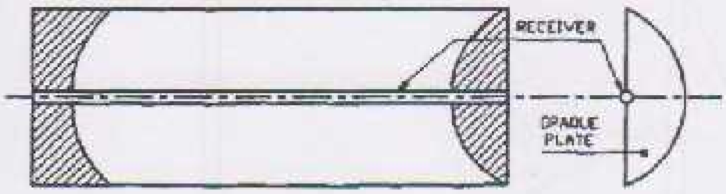


Figure 2.2 sketch of a parabolic trough

Figure 2.2 shows a sketch of parabolic trough which is built for this project.

2- Condenser

This component should have a suitable length and diameter in order to complete the condensing part in it, its position is below the generator to ensure that all condensate vapors will go to the evaporator and will not return to the generator tube, figure 2.3

and figure 2.4 shows the condenser pipe with fins welded on it and sketch of condenser.

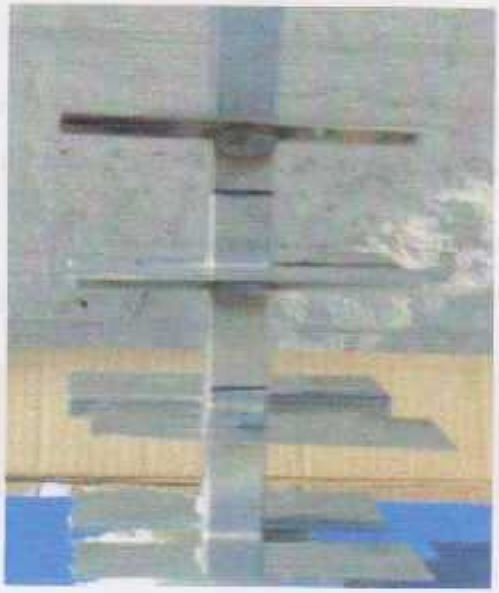


Figure2.3 condenser pipe with fins

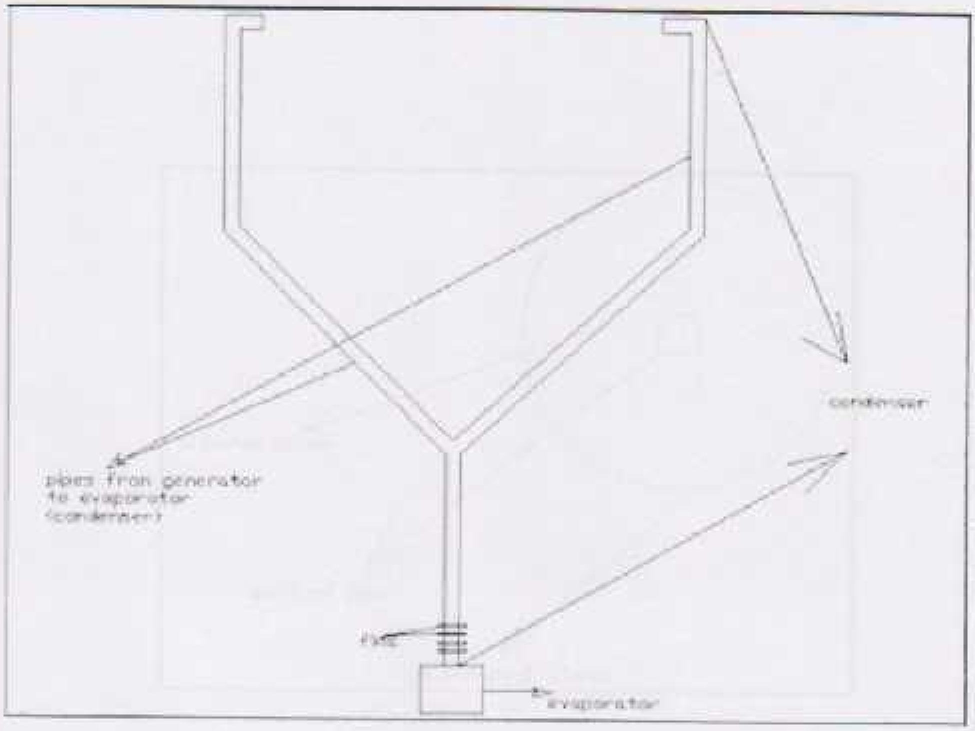


Figure 2.4: sketch for condenser

3- Generator

It is a tube that contains the adsorbent and refrigerant, this tube should have a high resistivity to the high temperature and pressure and should not be corrosive with the refrigerant and adsorbent. In this project galvanized steel was used.

Figure 2.5 show the generator tube which contains the activated carbon and methanol used in the cycle and figure 2.6 sketch of section area of generator.

Figure 2.5 generator tube

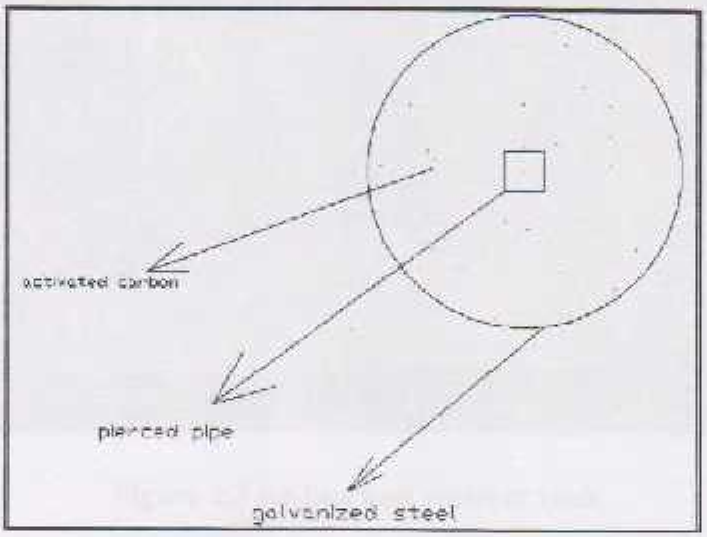


Figure 2.6: sketch for generator

4-Receiver tank and ice box

In this project receiver tank as evaporator will be used, the position of evaporator in ice box. The evaporator will be receiving a liquid methanol form condenser to maintain a suitable level to given the needs refrigeration effect.

Ice box is the refrigeration space; the wall of this box is made from two plastic layer and foam between its like sandwich to maintain suitable thermal isolation between refrigeration space and surrounding, figure 2.7 shows the ice box and receiver tank that was used in this project and figure 2.8 sketch of ice box and receiver tank.

Figure 2.7 ice box and receiver tank

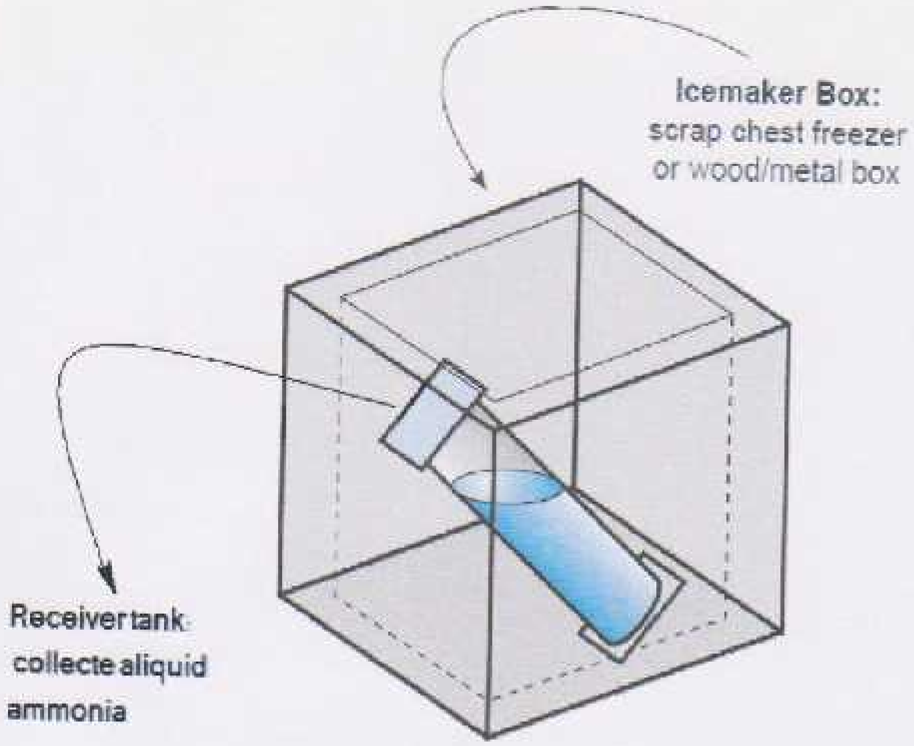


Figure 2.8 sketch of receiver tank and ice box

5- Pressure gauge:

Many techniques have been developed for the measurement of pressure and vacuum. Instruments used to measure pressure are called pressure gauges or vacuum gauges.

A manometer could also be referring to a pressure measuring instrument, usually limited to measuring pressures near to atmospheric. The term manometer is often used to refer specifically to liquid column hydrostatic instruments.

A vacuum gauge is used to measure the pressure in a vacuum which is further divided into two subcategories: high and low vacuum (and sometimes ultra-high vacuum). The applicable pressure ranges of many of the techniques used to measure vacuums have an overlap. Hence, by combining several different types of gauge, it is possible to measure system pressure continuously from 10 mbar down to 10^{-11} mbar.

Chapter Three

Selection and design cycle component

Chapter Three

Selection and design cycle component

3.1 Parabolic trough design:

Let the shape of the parabolic mirror be defined by:

$Y = mx^2$. (3.1)

The slope of any tangent line at any point on the parabola is:

Slope = $\tan \Theta = 2mx$.................. (1). (3.2)

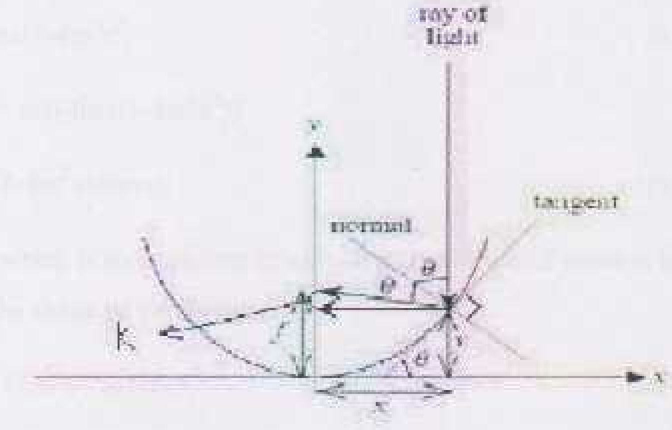


Figure 3.1: parabola

Figure 3.1 shows a sketch of the parabola that is applicable in the parabolic trough.

From the figure (3.1) the focal length (f) is:

$f = y+k$………………… (2). (3.3)

But the triangular geometry, $k/x = \tan(90 - 2\Theta)$.

$\rightarrow k - x \tan(90 - 2\,O)$………… (3). (3.4)

And $\tan(90 - 2\,O) = 1/\tan\beta$

$\beta = 2\,O$, so

$\tan(90 - 2\,O) = 1/\tan 2\,\Theta$ ……………. (4). (3.5)

Substituting (4) into (3) then in (2) gives:

$F = y+x/\tan 2\,\Theta$ …………….. (5). (3.6)

Using triangular identity

$\tan 2\,O = 2\tan\Theta / 1 - \tan^2\Theta$.

$= 2*2mx/1-(2mx)^2$.

$= 4mx/1-4m^2x^2$. (3.7)

So $f = mx^2 + x/ ((4mx/1-4m^2x^2))$

$= mx^2 + (1-4m^2x^2/4mx)$. (3.8)

So $f=1/4m$; which is independent of x. It also gives a useful relation between the focal length and the shape of parabolic mirror.

So $m=1/4f$. Then $y=(1/4f)\,x^2$.

The line $y= -f$, is called the directrix. It has the property that it is just far from any point on the parabola as the focus point is:

$x^2 + (f-y)^2 = (y+f)^2$. (3.9)

Therefore, depending on the size and shape of the autoclave device, focus point (f) will be chosen properly to fit or suit the autoclave in the focus.

So for example if the focus length is 1 meter, the parabola that will be used in the building of the parabolic mirror be:

$y = x^2/4f = x^2/4.$ (3.10)

y= 27cm.

x= 30cm.

$m = 0.27/0.3^2$ (m is amplitude so it is dimensionless)

= 3

tanΘ= 2mx.

= 2*3*0.3

= 1.8.

So the value of Θ equals to 61.

f= y + k.

k = 0.3tan (90 – 2(61)).

= -0.186 m.

f = 0.27 – 0.186.

= 0.084m.

= 8.4 cm.

3.2 Generator:

In this project the material of generator selected without any design of thickness or diameter because the pressure in the cycle it below atmospheric pressure and the main purpose of project is produce ice not specific amount of ice then the generator material is a galvanized steel pipe with a radius of 44.45 mm and a length of 960 mm, inside this pipe another pipe of rectangular shape selected with dimensions of 20*20 mm^2 this rectangular pipe have holes of diameter 1 mm and between every two holes a distance of 3 mm.

Sectional area of the outer pipe (A_o)

$A_o = \pi * r_o^2$.   (3.11)

$= \pi * (4.445)^2$

$= 62 \text{ cm}^2$

And the internal pipe sectional area is 4 cm^2 so the total volume of the generator can be calculated by:

$V_g = (A_o - A_i) (L_{tot})$.   (3.12)

$= (62-4) (96)$.

$= 5568 \text{ cm}^3$.

Then the total amount of activated carbon (A.C) can be calculated by the following equation:

$m_{A.C} = V_g * \rho$.   (3.13)

$= 5.568 \text{ l} * 0.7 \text{ kg/L}$

$= 3.898 \text{ kg}$.

Methanol amount can be calculated depending on the percentage of 0.26 kg methanol / kg A.C [from solar adsorption cooling project from ANnajah University]

This gives a maximum amount of methanol that can be absorbed by A.C:

$m_{methanol} = (0.26) (3.898)$

$= 1.013$ kg of methanol.

The theoretical amount of water that could be freeze is calculated by the following equation:

$m_{methanol} * \Delta h =$ sensible heat from water and ice + latent heat of water

sensible heat $= (m_{water} * \Delta T_{water} * c_{p(water)}) + (m_{ice} * \Delta T_{ice} * c_{p(ice)})$ (3.14)

$m_{water} = m_{ice} = m$

$c_{p(water)} = 4.18 \text{ kJ/kg.c}^o$

$c_{p(ice)} = 2.15$ kJ/kg.c°

At atmospheric pressure the temperature of freezing it (- .0075 c°)

$c_{p\ ice} = 2.12$ kj/kg.

$c_{p\ water} = 4.18$ kj/kg.

sensible heat = m(($\Delta T_{water} * c_{p(water)}$)+($\Delta T_{(ice)} * c_{p(ice)}$))

$\Delta T_{water} = 32-(-.0075)$

$\Delta T_{water} = 32.0075$ c°

$\Delta T_{ice} = [-0.0075-2]$

$\Delta T_{ice} = 1.9925$ c°

Latent heat of water = $m_{water} * \Delta h$ (3.15)

The value of enthalpy change (Δh) at atmospheric pressure can be given from P-h diagram of water at given temperature.

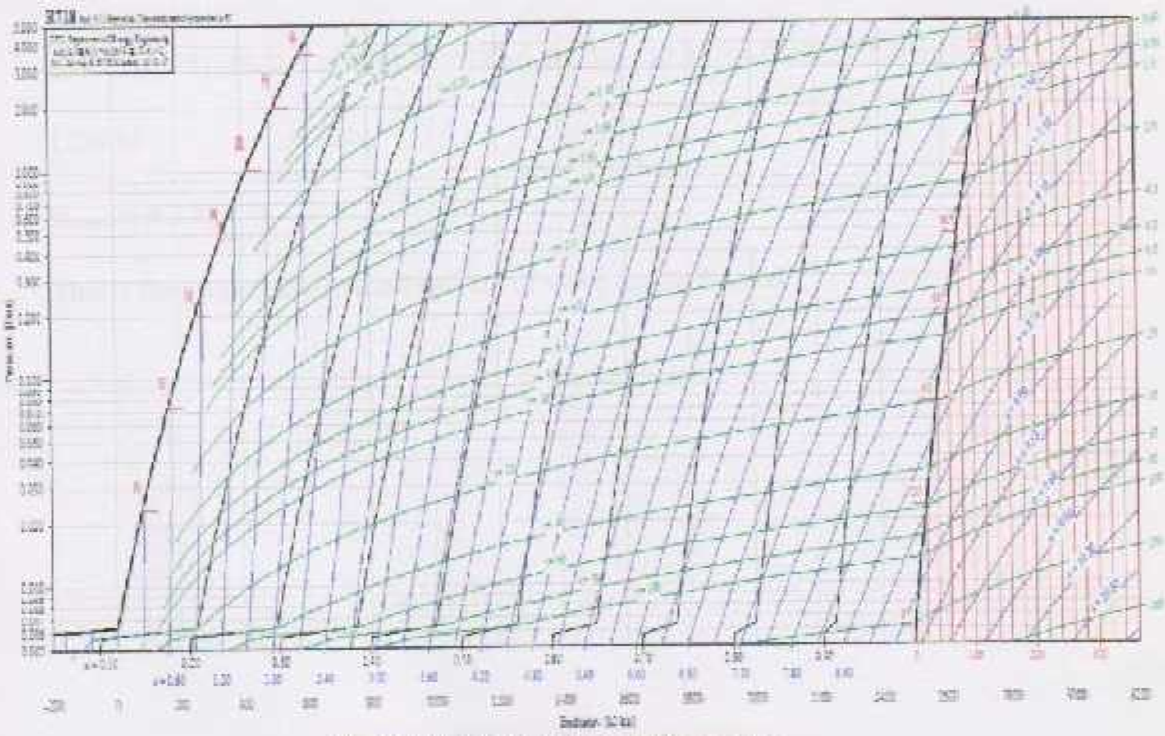


figure 3.2 P-h diagram for water

$\Delta h_{@1\ bar} = 143$ kJ/kg.

Then:

Latent heat = $m_{water} * \Delta h$

Total amount of heat = $m\ ((\Delta T_{water} * c_{p(water)}) + (\Delta T_{ice} * c_{p(ice)})) + m(\Delta h)$

$$= \ m\ ((\Delta T_{water} * c_{p(water)}) + (\Delta T_{ice} * c_{p(ice)}) + (\Delta h))$$

Referring to the figure 3.2 at saturation pressure of 2.5 kpa then $h_{f@p}$= 76.3 kj/kg and $h_{g@p}$=1281 kj/kg. $c_{p\ water}$ = 4.18kj/kg.k, t_i=30 °c , t_f=-2°c.

Substituting these values to equation (3.14) we find that:

$$m_{methanol} * \Delta h = \ m\ ((\Delta T_{water} * c_{p(water)}) + (\Delta T_{ice} * c_{p(ice)}) + (\Delta h\ )) \qquad (3.16)$$

(1.013) (1281-76.3) = m * ((4.18 * (32-(-.0075)) + (2.15 * (-0.0075 - - 2) + (143).

1220.36 = 284m

m_{water} = 4.3 kg.

This is the maximum expected amount of water can be freezed.

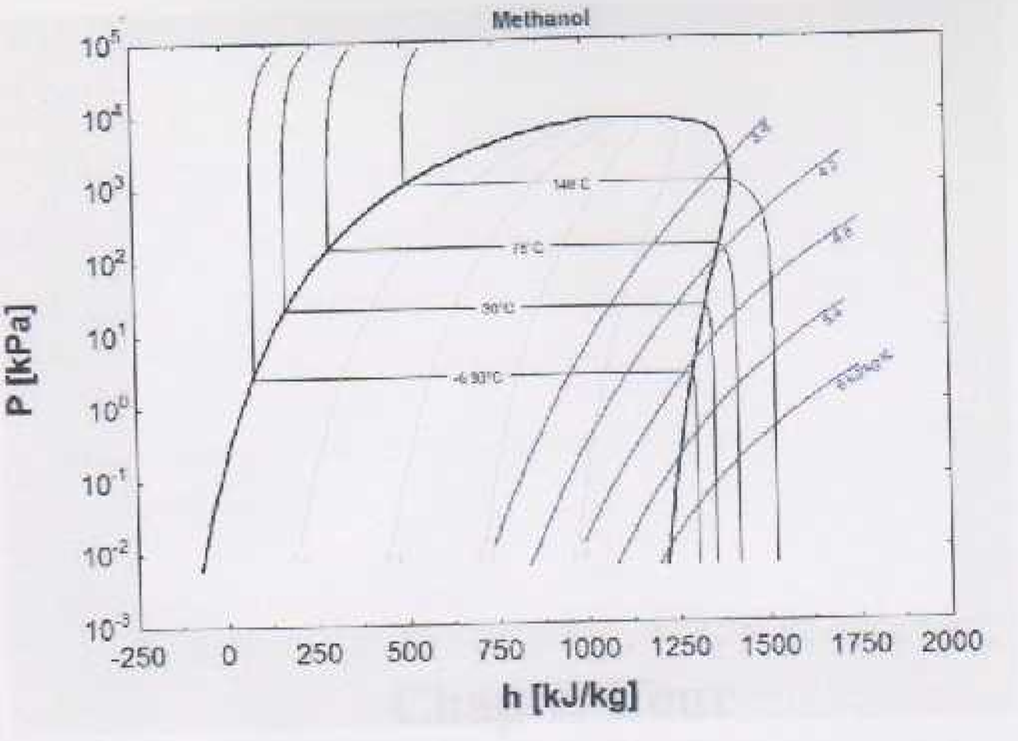


Figure 3.3 P-h diagram for methanol

Chapter Four

Experiment and Measurements

Chapter Four

Experiment and Calculations

4.1 Introduction

In this chapter the coefficient of performance (COP) of the adsorption refrigeration cycle must be calculated.

4.2 Experiments and calculations:

On Sunday 3-01-2010, the project testing started again after fixing all problems that appeared in the project and the following values of irradiance was taken in order to complete the calculations of the cycle to get the COP of the cycle.

Table 4.1 the irradiation in Sunday (3-01-2010)

Time	Irradiance(W/m^2)
10:00 am	820
10:30 am	870
11:00 am	980
11:30 am	1100
12:00 pm	1300

And the average value of that day was : 1014 W/m^2.

The amount of heat gained in the generator could be calculated by :

$Q_{in} = G_b A_a C \alpha \rho$.

Where :

G_b : average value of irradiance (W/m^2).

A_a : Aperture area (m^2).

C : concentration ratio.

α : Absorptance.

ρ : Reflectance.

$A_a = 0.6*1 = 0.6\ m^2$.

$A_r = \pi DL$. (Receiver area)

$= 3.14*0.089*0.96$

$= 0.26 m^2$.

$C = A_a / A_r$.

$= 0.6 / 0.26. = 2.3$.

$\alpha = 0.85$.

$\rho = 0.9$.

So the value of Q_{in} will be:

$Q_{in} = 1014*0.6*2.3*0.85*0.9$.

$= 1070.48\ W$.

And the value of $Q_{evaporator}$ depends on the mass of the water and the temperature difference between temperatures of water.

$m_w = \rho_w V$.

$\rho_w = 1000\ kg/m^3$.(density of water)

V = volume of water used = 1.125 liter.

So $m_w = 1000*1.125*10^{-3}$.

$= 1.125$ kg.

$Q_{evaporator} = m\ C_p\ \Delta T$.

$C_p =$ specific heat of water = 4.18 kj/kg.

So:

$Q_{evaporator} = 1.125*4.18*(17-10)$

$= 33$ W.

And then the value of the coefficient of performance COP will be calculated by :

$COP = Q_{evaporator} / Q_{in}$.

$= 33/1070.48$.

$= 0.0308$.

Table 4.2 the irradiation in Monday (4-01-2010)

Time	Irradiance(W/m^2)
10:00 am	800
10:30 am	900
11:00 am	1027
11:30 am	1153
12:00 pm	1230

And the average value of irradiance of that day was : 1022 W/m^2.

$Q_{in} = G_b A_a C \alpha \rho.$

$= 1022*0.6*2.3*0.85*0.9.$

$= 1079$ W.

And

$Q_{evaporator} = 1.125*4.18*(17-9)$

$= 37.62$ W.

COP = 37.62 / 1079.

= 0.035.

Table 4.3 the irradiation in Tuesday (5-01-2010)

Time	Irradiance(W/m^2)
10:00 am	750
10:30 am	812
11:00 am	931
11:30 am	1017
12:00 pm	1140

And the average value of irradiance for that day was 930 W/m^2.

$Q_{in} = G_b A_a C \alpha \rho.$

$= 930*0.6*2.3*0.85*0.9.$

$= 981.8$ W.

And

$Q_{evaporator}$ = 1.125*4.18*(18-10)

= 37.62 W.

COP = 37.62 / 981.8.

= 0.0383.

Table 4.4 the irradiation in Wednesday (6-01-2010)

Time	Irradiance(W/m^2)
10:00 am	1100
10:30 am	1211
11:00 am	1403
11:30 am	1612
12:00 pm	1773

And the average value of irradiance for that day was1420 W/m^2.

$Q_{in} = G_b A_a C\alpha\rho$.

= 1420*0.6*2.3*0.85*0.9.

= 1421 W.

And

$Q_{evaporator}$ = 1.125*4.18*(18-7)

m

COP = 51.72/ 1421

= 0.0364

Table 4.5 the irradiation in Saturday (9-01-2010)

Time	Irradiance(W/m^2)
10:00 am	950
10:30 am	1127
11:00 am	1303
11:30 am	1421
12:00 pm	1551

And the average value of irradiance for that day was1270.4 W/m^2.

$Q_{in} = G_b A_a C\alpha\rho$.

= 1270.4*0.6*2.3*0.85*0.9.

= 1341W.

And

$Q_{evaperator}$ = 1.125*4.18*(20-8)

= 56.43 W.

COP = 56.43/ 1341

= 0.0420

Table 4.6 the irradiation in Sunday (10-01-2010)

Time	Irradiance(W/m^2)
10:00 am	1015
10:30 am	1102
11:00 am	1293
11:30 am	1380
12:00 pm	1470

And the average value of irradiance for that day was1252 W/m^2.

$Q_{in} = G_b A_s C \alpha \rho$.

= 1252*0.6*2.3*0.85*0.9.

= 1321.7 W.

And

$Q_{evaporator}$ = 1.125*4.18*(18-8)

= 47 W.

COP = 47/ 1321

= 0.0355

Table 4.7 the irradiation in Monday (11-01-2010)

Time	Irradiance(W/m^2)
10:00 am	1200
10:30 am	1310
11:00 am	1493
11:30 am	1617
12:00 pm	1802

And the average value of irradiance for that day was1484.4 W/m^2.

$Q_{in} = G_b A_s C \alpha \rho.$

$= 1484.4 * 0.6 * 2.3 * 0.85 * 0.9.$

$= 1567$ W.

And

$Q_{evaporator} = 1.125 * 4.18 * (18-6)$

$= 56.43$ W.

$COP = 56.43 / 1567$

$= 0.0360$

Table 4.8 Data table

Day & Date	Irradiance (average value) W/m^2	ΔT (°C)	$Q_{generator}$ (W)	$Q_{evaporator}$ (W)	COP
Sunday 3/1/10	1014	7	1070.48	33	0.0308
Monday 4/1/10	1022	8	1079	37.62	0.035
Tuesday 5/1/10	930	8	981.8	37.62	0.0383
Wednesday 6/1/10	1420	9	1421	51.72	0.0364
Saturday 9/1/10	1270.4	12	1341	56.43	0.042
Sunday 10/1/10	1252	10	1321.7	47	0.0355
Monday 11/1/10	1484.4	12	1567	56.43	0.036

So the average value of the COP equals to = 0.03628.

Chapter Five

Conclusions and Recommendations

Chapter Five

Conclusions and Recommendations

5.1 Introduction:

In this chapter all conclusions concluded from experiments and recommendations to improve the project and get better results than these reached in this project.

5.2 Conclusions:

From the experiments and data that have been reached in this project one can conclude that:

1. The COP value is low because the trough isn't tracking one so the radiations of the sun aren't vertical all the day and so the factors that affect the value of Q_{gen} will be less than that for the vertical and the amount of radiations will be samll.
2. Because the amount of the methanol isn't too large since the pressure that is to be reached is small and not want to have large pressures and not all of this amount is desorbed so the refrigerating effect will be low and then the amount of ice will be small.

3. When doing the vacuum process to have low pressure some of the methanol amount that make ice hard to be produced.
4. The pressure wasn't equal all the intervals of the project so the theoretical amount of ice wasn't reached because the methanol amount will not be adsorbed or desorbed so there is a problem in make the pressure constant all the time.
5. Not all amount of methanol will be adsorbed by the activated carbon or desorbed from the activated carbon which depends on the temperature of the day and the irradiance of that day.

5.3Recommendations:

Recommendation are recommended to be done when anyone want to redesign or rebuild the project and need to have better properties and more effective project

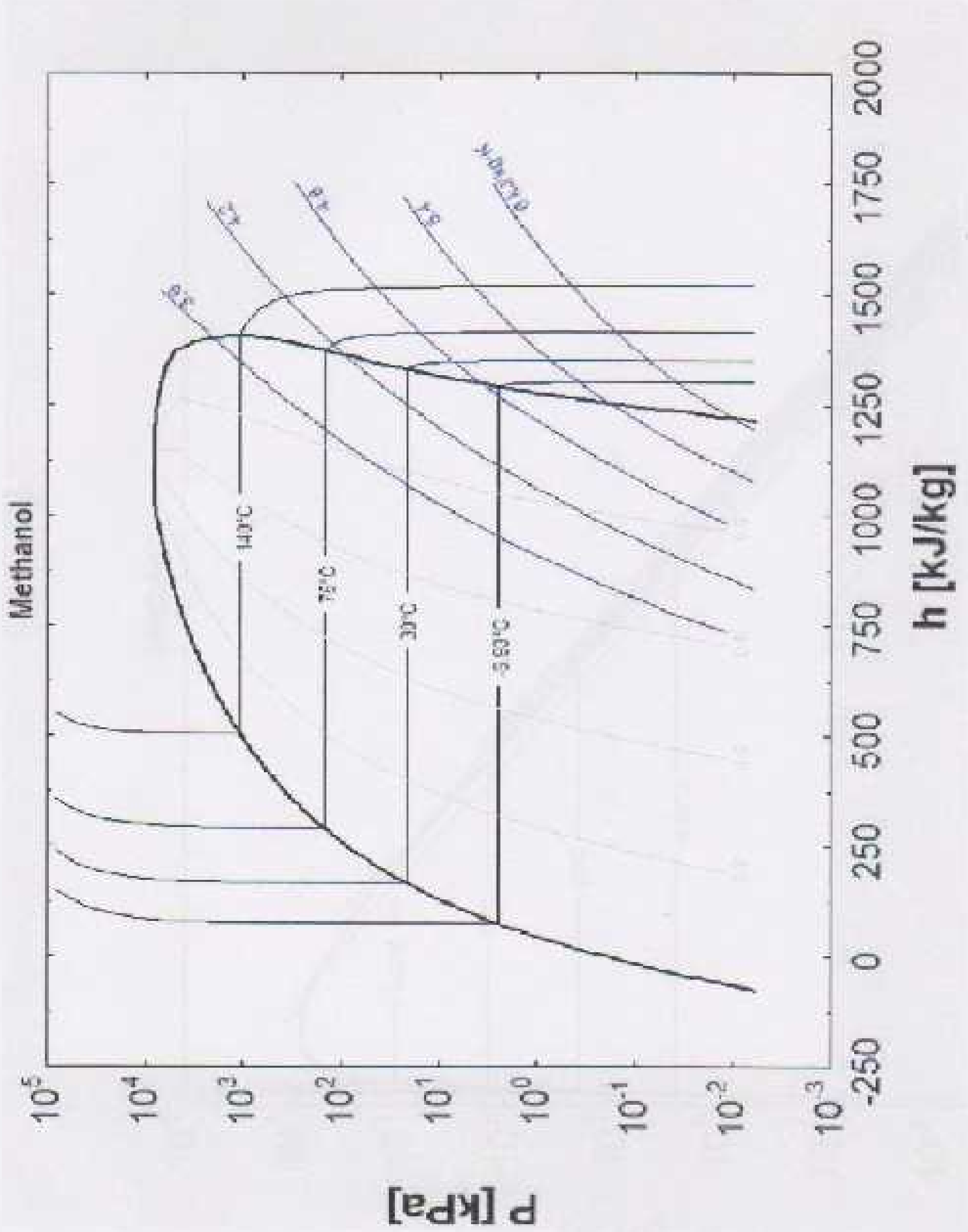
1. Covering the parabolic trough with glass that prevents air cooling the generator and lowering it temperature.
2. Evaporator can be designed in another and better way like a network of pipes to increase the heat transfer with the surrounding.
3. Another pairs can be used instead of (methanol + activated carbon):
   - Activated carbon + ammonia
   - Active carbon + R22
   - Silica gel + water
   - Silica gel + sulpher dioxide
   - Ammonia + calcium chloride.

4. Tracking parabolic trough can be used to have more sun rays.
5. Covering the generator with evacuated glass tube to increase the area of the generator.

Appendices

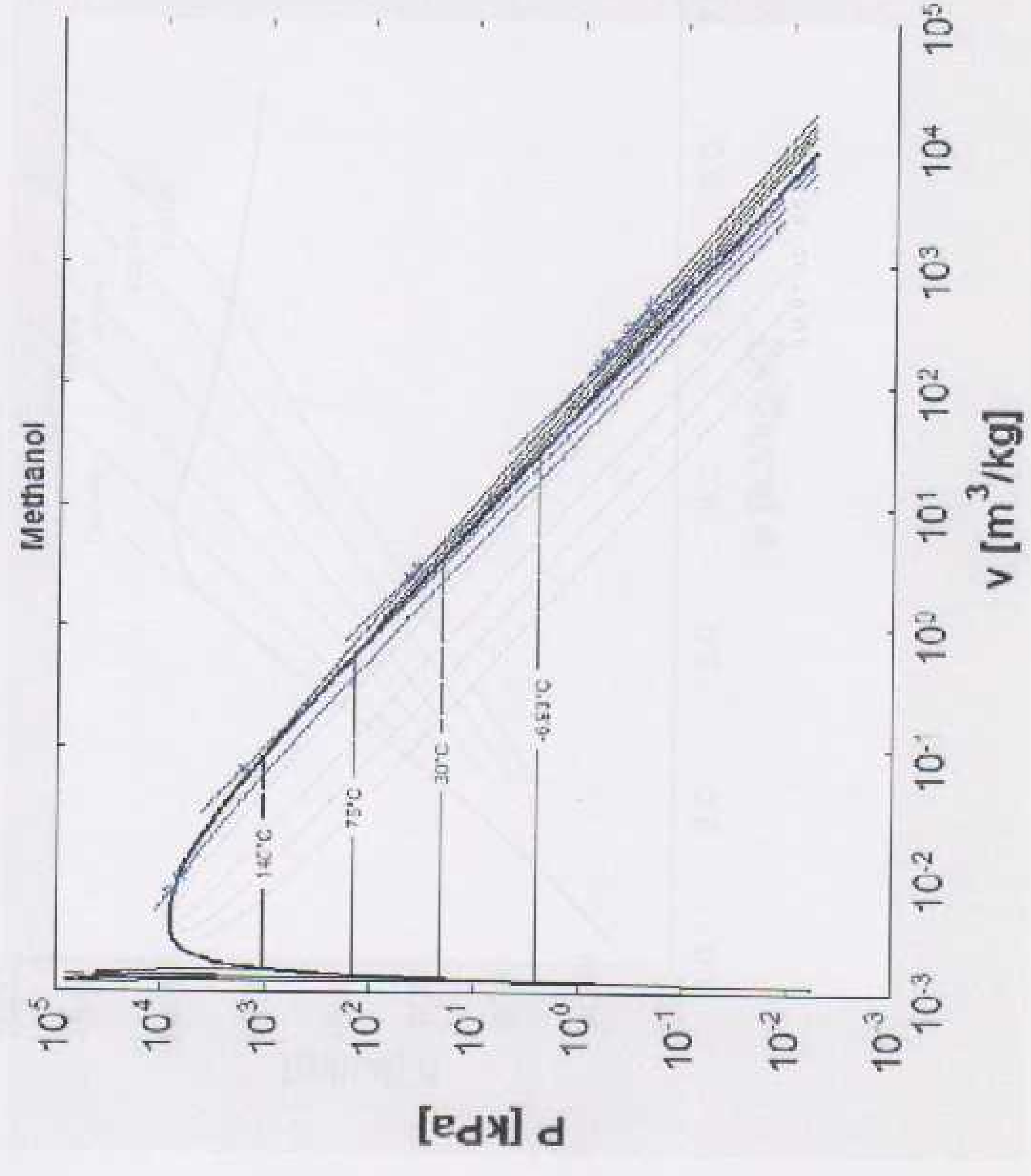
Appendix A

P-h Diagram Of Methanol



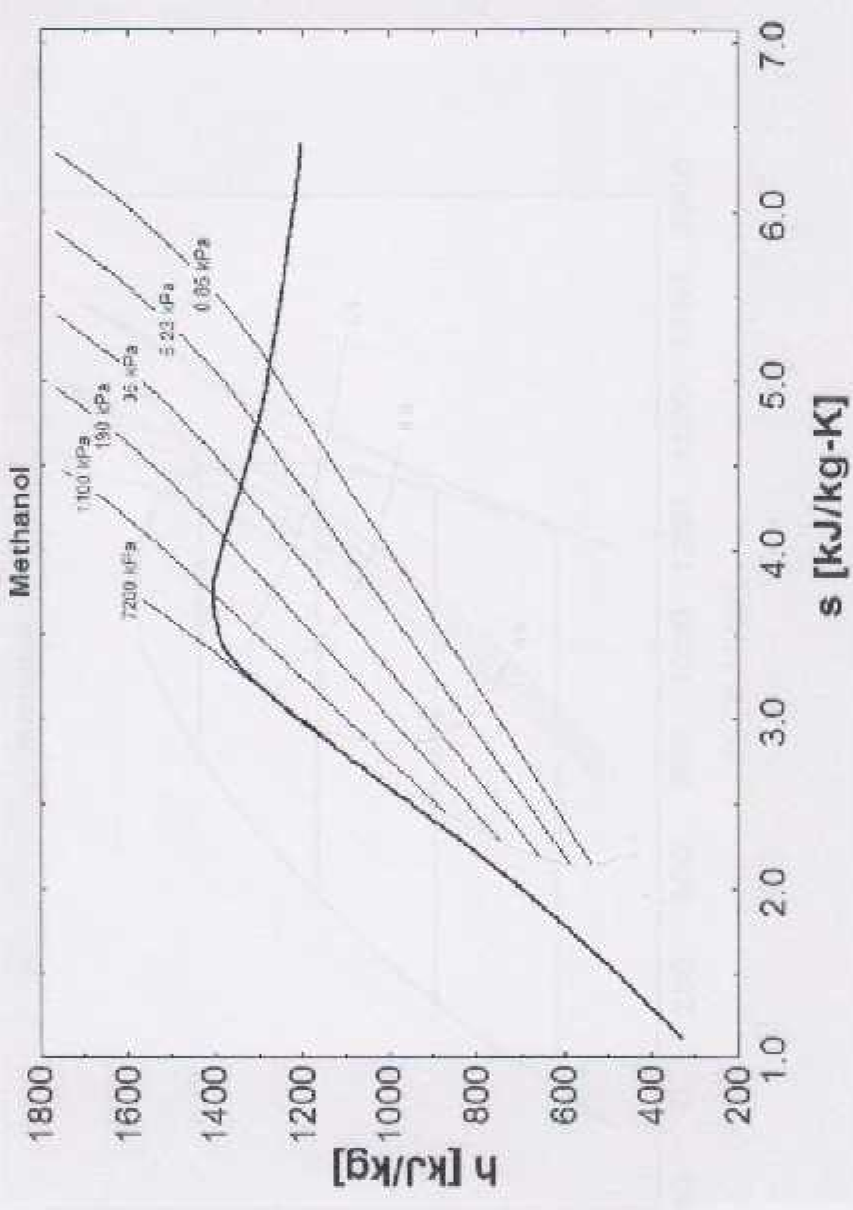
Appendix B

P-v diagram of methanol



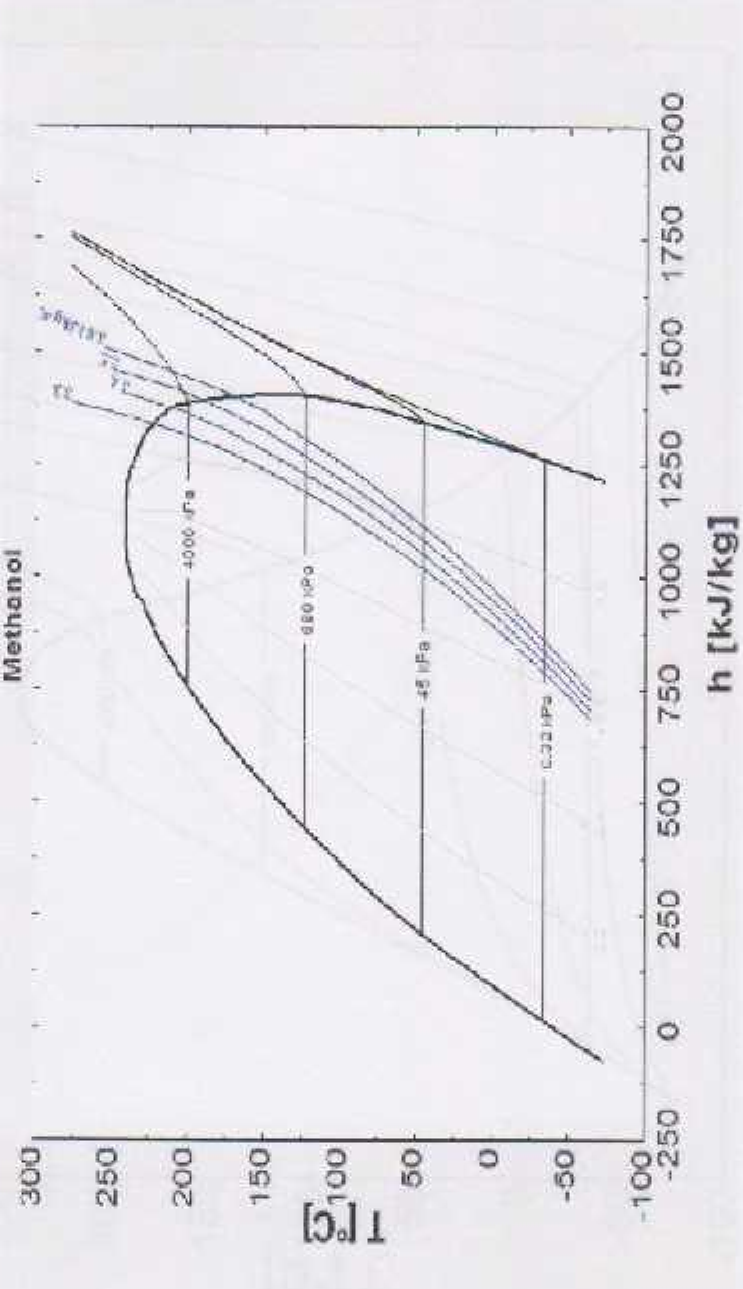
Appendix C

h-s diagram of methanol



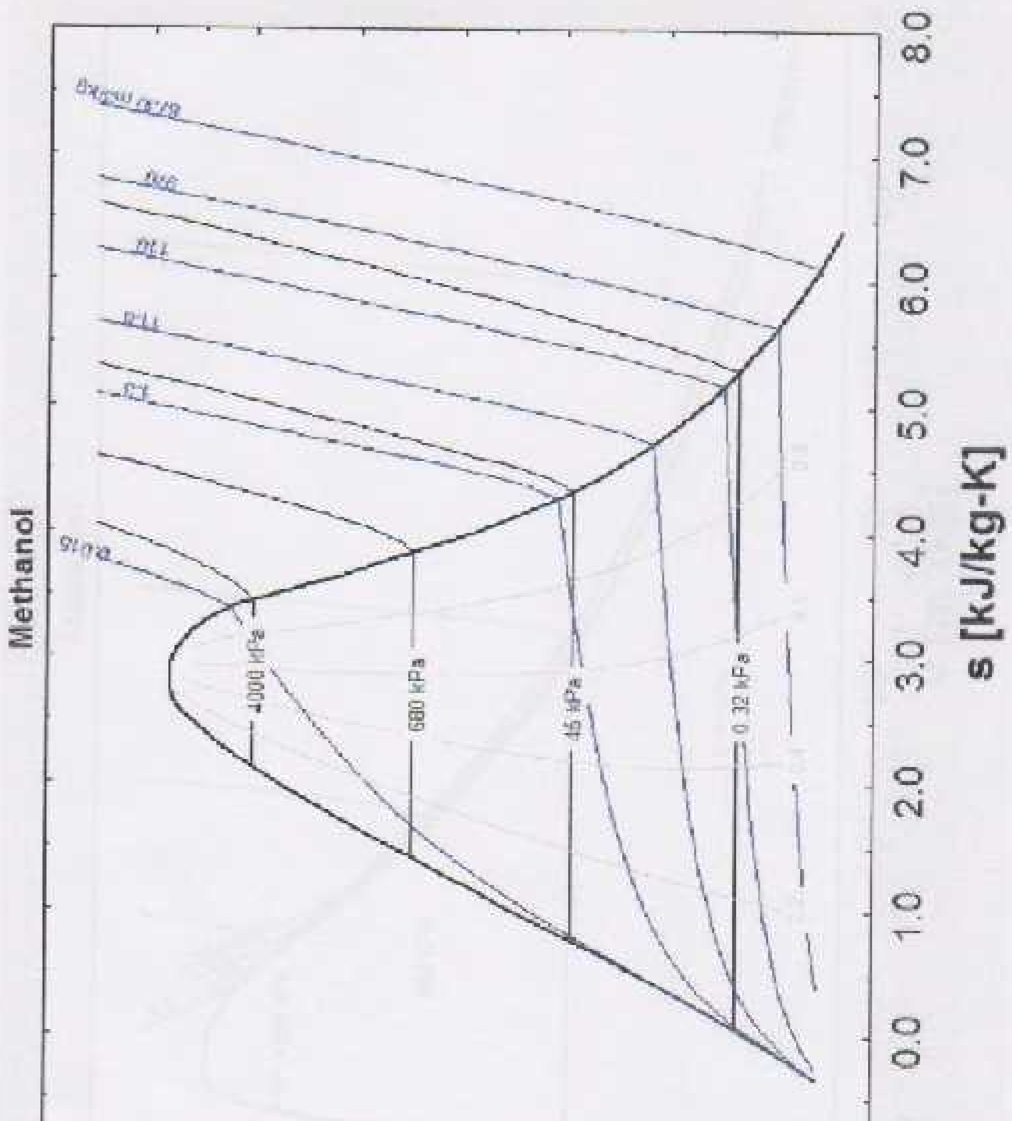
Appendix D

h-T diagram of methanol



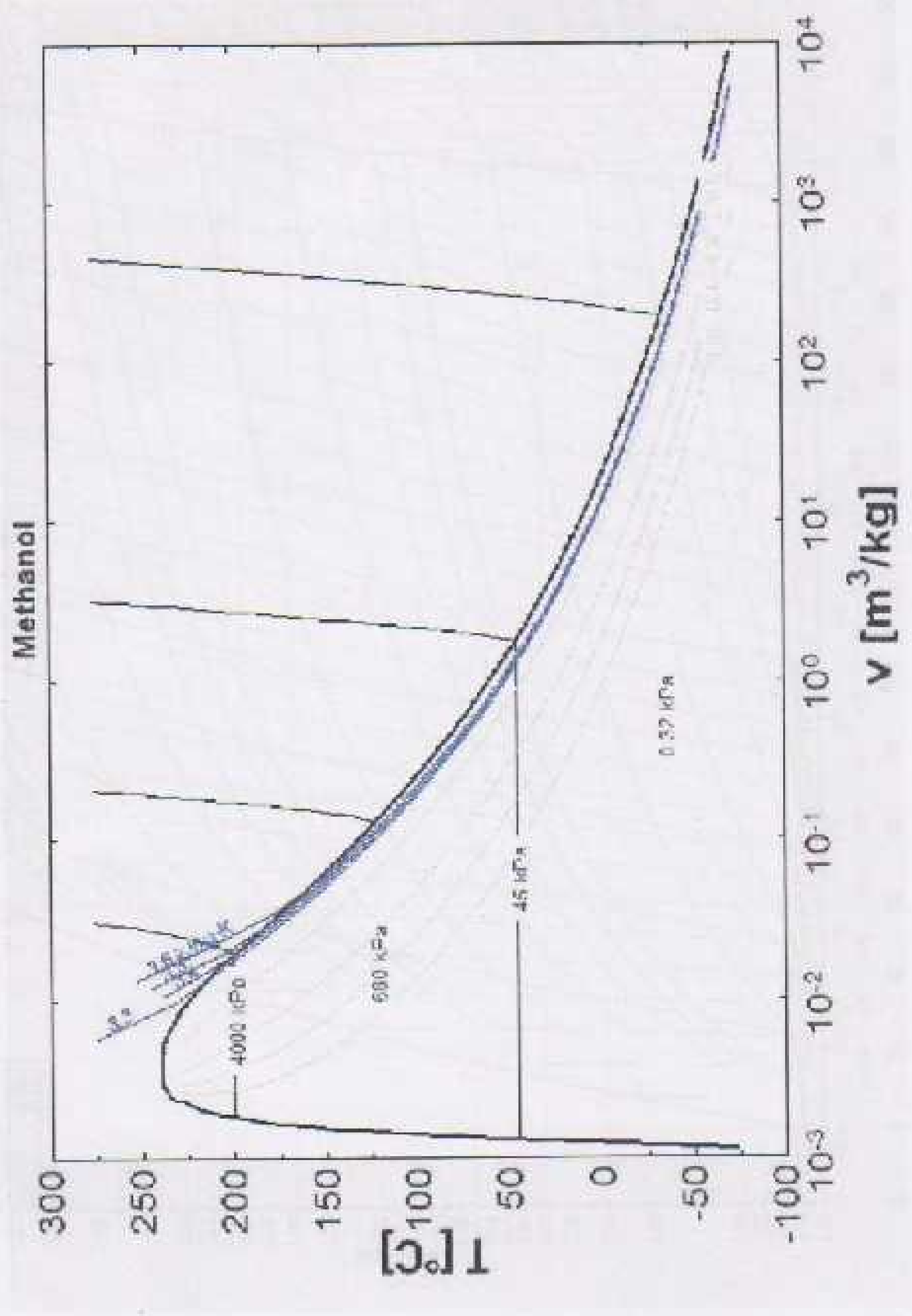
Appendix E

T-s diagram of methanol



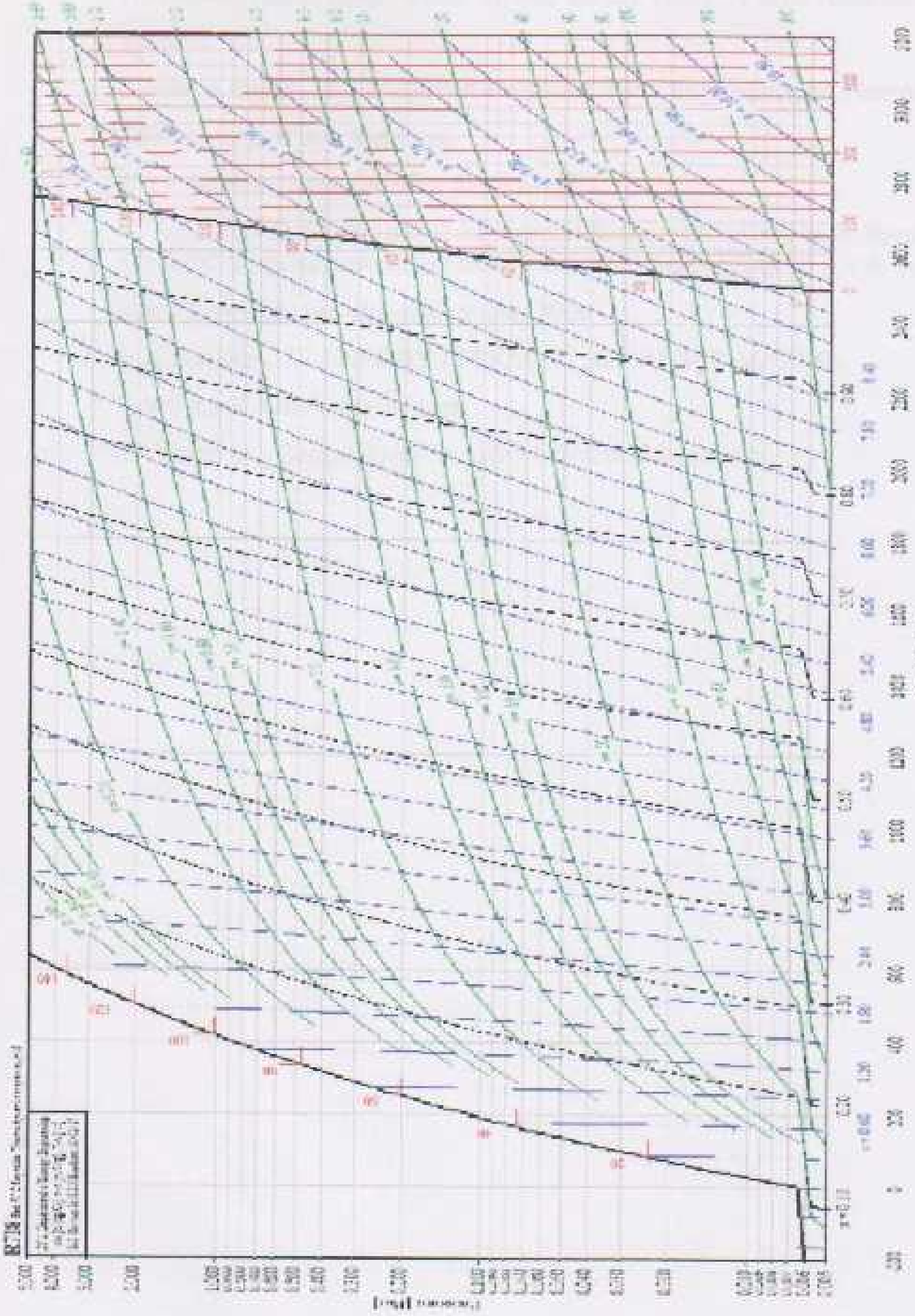
Appendix F

T-v diagram of methanol



Appendix F

P-h diagram for water



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