REFRIGERANT CYCLE & MOLLIER CHART

PRESSURE-ENTHALPY CHART

PREPARED BY

JASLIN BIN RASIN
NURHIDAYU BINTI AZHARI
MOHAMAD AMRI BIN MAT JUSOH

POLITEKNIK KUCHING SARAWAK
MINISTRY OF HIGHER EDUCATION
KM22, JALAN MATANG,
93050 KUCHING, SARAWAK.

Phone No. : (082) 845596/7/8
Fax No. : (082) 845023
E-mail : poliku.info@poliku.edu.my
Website : http://www.poliku.edu.my/

eISBN 978-629-7638-26-3

Published by:
Politeknik Kuching Sarawak
Ministry Of Higher Education

Cataloguing-in-Publication Data

Perpustakaan Negara Malaysia

A catalogue record for this book is available from the National Library of Malaysia

eISBN 978-629-7638-26-3

Preface

This eBook will present beyond the basic of Refrigeration Cycle and Mollier chart. Mollier charts are essential tools used in designing and analyzing the performance of vapor compression refrigeration systems. Each refrigerant has its own chart, depicting the enthalpy of the refrigerant at various pressures and physical conditions. Also known as Pressure-Enthalpy diagrams, these charts are the most frequently used graphical tools for analyzing and calculating heat transfer, compressor work, and refrigeration cycle performance.

The purpose of developing this e-book is to provide fundamental knowledge to Refrigeration and Air Conditioning Technology Diploma students about pressure and enthalpy and their significance in the industry. Additionally, this e-book aims to equip students with the knowledge and skills necessary to troubleshoot refrigeration and air conditioning systems by effectively plotting and interpreting Pressure-Enthalpy Charts (Mollier Diagrams).

Author

Jaslin Bin Rasin is a lecturer in the Department of Mechanical Engineering, specializing in Air Conditioning and Refrigeration System, at Polytechnic Kuching Sarawak. He holds a Diploma in Engineering Technology with a focus on Air Conditioning, Refrigeration, Mechanical, and Ventilation from the Advanced Technology Training Center (ADTEC) Shah Alam. Additionally, he earned a Bachelor of Engineering Technology in Air Conditioning and Industrial Refrigeration from the UNIKL Malaysian France Institute, and a Master of Engineering Management from University Putra Malaysia. His areas of interest include renewable energy and heat transfer.

Nurhidayu Binti Azhari is a lecturer in the Department of Mechanical Engineering, specializing in Air Conditioning and Refrigeration System, at Polytechnic Kuching Sarawak. She holds a Diploma in Mechanical Engineering from Polytechnic Port Dickson and subsequently earned a Bachelor's Degree in Mechanical Engineering Technology (Refrigeration and Air Conditioning System) in 2016 at Universiti Teknikal Malaysia Melaka (UTeM). She had woking experiance at Daya OCI Sdn Bhd as a ACMV Mantainence Engineer.

Mohamad Amri bin Mat Jusoh is a lecturer in the Department of Mechanical and Manufacturing at Vocational College Batu Pahat, Johor, specializing in Air Conditioning and Refrigeration. Previously, he taught in the same field at Polytechnic Kuching, Sarawak, from 2020 to 2023. He holds a Diploma in Mechanical Engineering from Polytechnic Kota Bharu and subsequently earned a Bachelor's Degree in Vocational Education (Air Conditioning and Refrigeration) from UTHM, Johor. His areas of interest also include renewable energy and heat transfer.

Table of Contents

Chapter 1

Introduction

Introduction

In the context of refrigeration and air conditioning, Mollier charts are used in designing and analyzing the performance of vapor compression refrigeration systems. Each refrigerant has its own chart which is the Enthalpy graph of the refrigerant at various pressures and physical conditions. A Mollier chart is also called a Pressure-Enthalpy diagram. The Pressure-Enthalpy Diagram is the most frequently used graphical tool for analyzing and calculating heat transfer, compressor work, and refrigeration cycle performance.

So, the purpose of developing this e-book is to provide basic knowledge to Refrigeration and Air Conditioning Technology Diploma students about Pressure and Enthalpy and their importance in the industry. Additionally, to expose students to the knowledge and skills they need to troubleshoot refrigeration and air conditioning systems by plotting Pressure Enthalpy Charts (Mollier Diagrams).

Learning Objectives

At the end of learning, students will be able to:

1. Understand the enthalpy pressure chart (Mollier diagram).
2. Plot the enthalpy-pressure chart and state the values of absolute pressure, temperature, specific enthalpy, specific volume, dryness factor and specific entropy at each point correctly.
3. Explain the theory of each process or phase that occurs at the saturated vapor line, moisture vapor region, saturated liquid line, sub-cooling region and superheat region.
4. Understand each process in the refrigeration cycle.
5. Solve refrigeration and air conditioning system problems using Mollier Diagrams (pressure-enthalpy charts).

1.1 What is a Mollier Chart

Mollier charts are used in designing and analyzing the performance of vapor compression refrigeration systems. Each refrigerant has its own chart which is a graph of the Enthalpy of the refrigerant at various pressures and physical conditions. Mollier chart are also called Pressure-Enthalpy diagram. The **Pressure-Enthalpy Chart** is the most frequently used graphical tool for analyzing and calculating heat and work transfer, as well as refrigeration cycle performance. Furthermore, the heat transfer and work of various processes can be estimated as enthalpy changes and are simply displayed on the p-h diagram.

1.2 Composition of Pressure-Enthalpy Chart

This chart is built with a graph shape that has:

1. Vertical Axis — **Absolute Pressure** axis.
2. Horizontal Axis — **Enthalpy** (heat) axis.

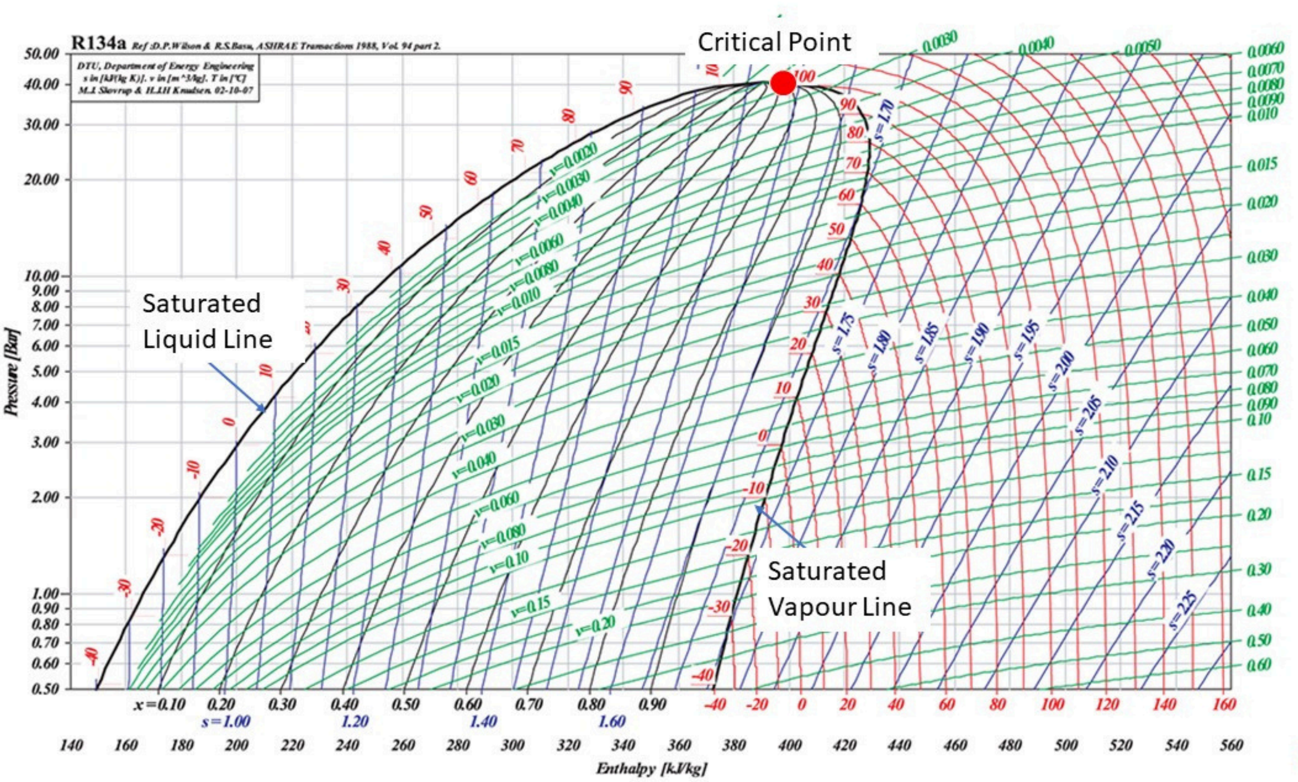


Figure 1.0: Pressure Enthalpy Chart (Mollier Chart)

3. **Saturated Liquid Line** — The refrigerant in the saturated liquid line is 100% liquid.
4. **Saturated Vapor Line** — The refrigerant in the saturated vapor line is 100% vapor.
5. **Critical Point** — The refrigerant at this point is 50% liquid and 50% vapor.

1.3 Pressure-Enthalpy Chart and the Application

The P-h chart shows the properties of refrigerants diagrammatically. The chart in Figure 2.0 Pressure Enthalpy Chart (Mollier Chart) R134a. It can be seen that refrigerant pressure on the vertical axis and enthalpy on the horizontal axis. Enthalpy is a measure of the quantity of heat, both sensible and latent, per pound[lb] or per kilogram[kg] of refrigerant. It is usually expressed in terms of Btu/lb [British unit] or kJ/kg [S.I unit]. There are **Three (3)** important regions in the basic diagram of pressure and enthalpy which are ***the subcooled region***, ***the superheated region***, and ***the mixing region (liquid and gas)***.

The subcooled region contains 100% liquid refrigerant **[metering device]**. The superheated region contains 100% vapor **[compressor]**. The mixing region, where both liquid and gas are present [occurs in the **evaporator and condenser**].

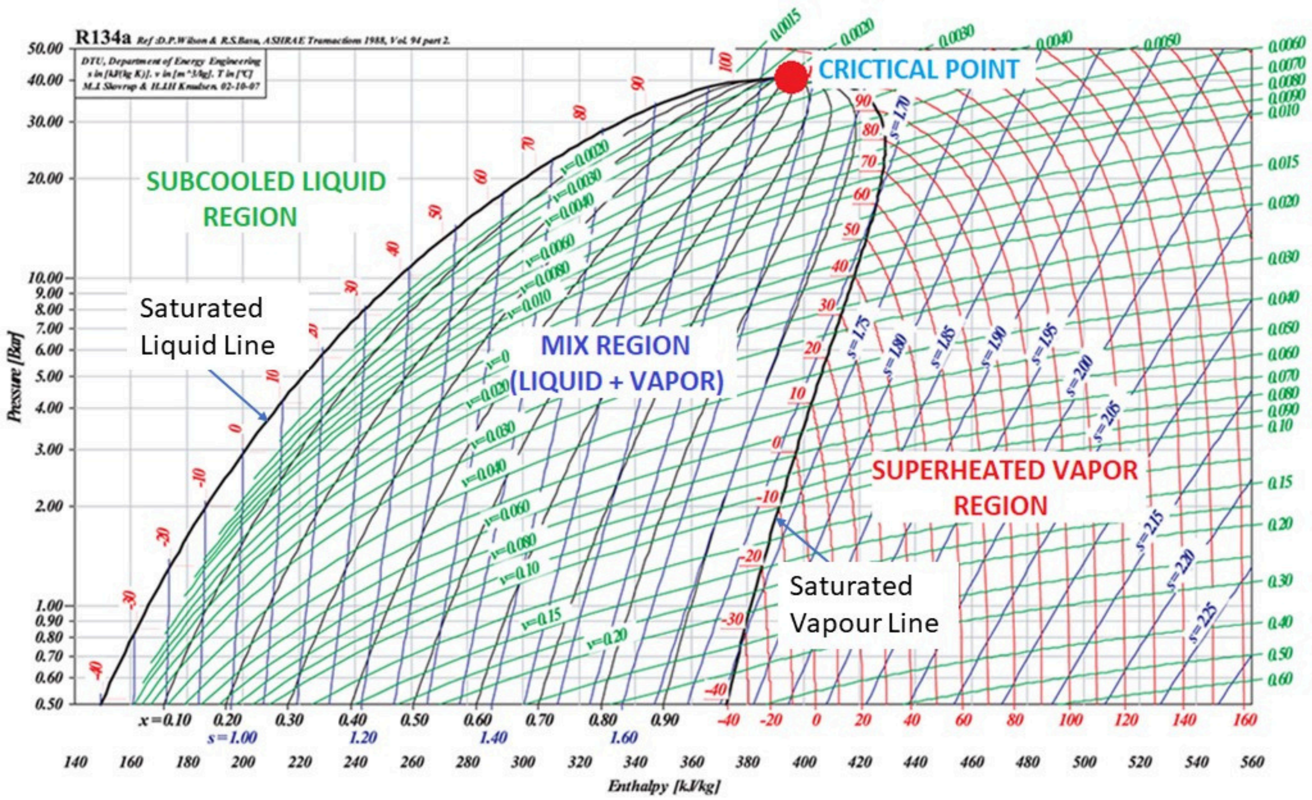


Figure 2.0: Pressure Enthalpy Chart (Mollier Chart) R134a

1.3 Pressure-Enthalpy Chart and the Application

Additionally, the P-h Chart also consists of 8 types of lines.

1. Constant pressure line (absolute pressure)
2. Constant enthalpy lines
3. Constant temperature lines
4. Constant specific entropy lines
5. Constant specific volume lines
6. Constant dryness lines
7. Saturated liquid line
8. Saturated vapor line

1.4 Constant Pressure Line

This line is indicated by the letter P. Shows the **evaporation and condensation pressure**. The pressure line is parallel to the enthalpy (h) axis. The pressure (absolute pressure) usually measured in the units **psi, kPa or Bar** . The pressure is plotted on the horizontal axis.

Absolute pressure = Gauge pressure + Atmospheric pressure

[MPa abs] = [MPa G] + 0.1 [MPa abs].

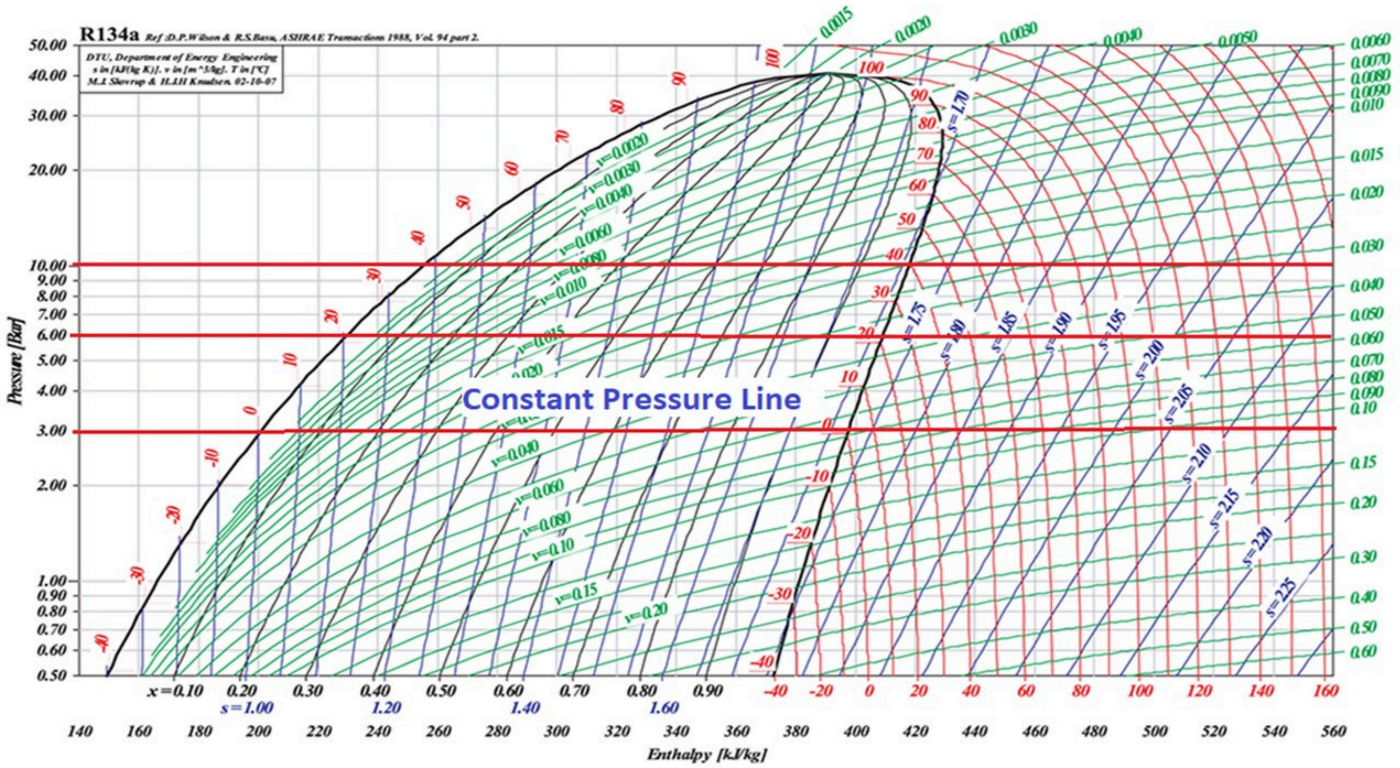


Figure 3.0: Constant Pressure Line

1.5 Constant Enthalpy Line

This line shows the heat content of the refrigerant at certain conditions. Its position is parallel to the pressure axis (P). The enthalpy is measured units like **Btu/lb, kJ/kg or kcal/kg**, the **symbol is h**. Specific enthalpy is the sum of internal and external energy: it can be defined as the amount of heat contained in a refrigerant at a given state. Specific enthalpy is plotted on the vertical axis.

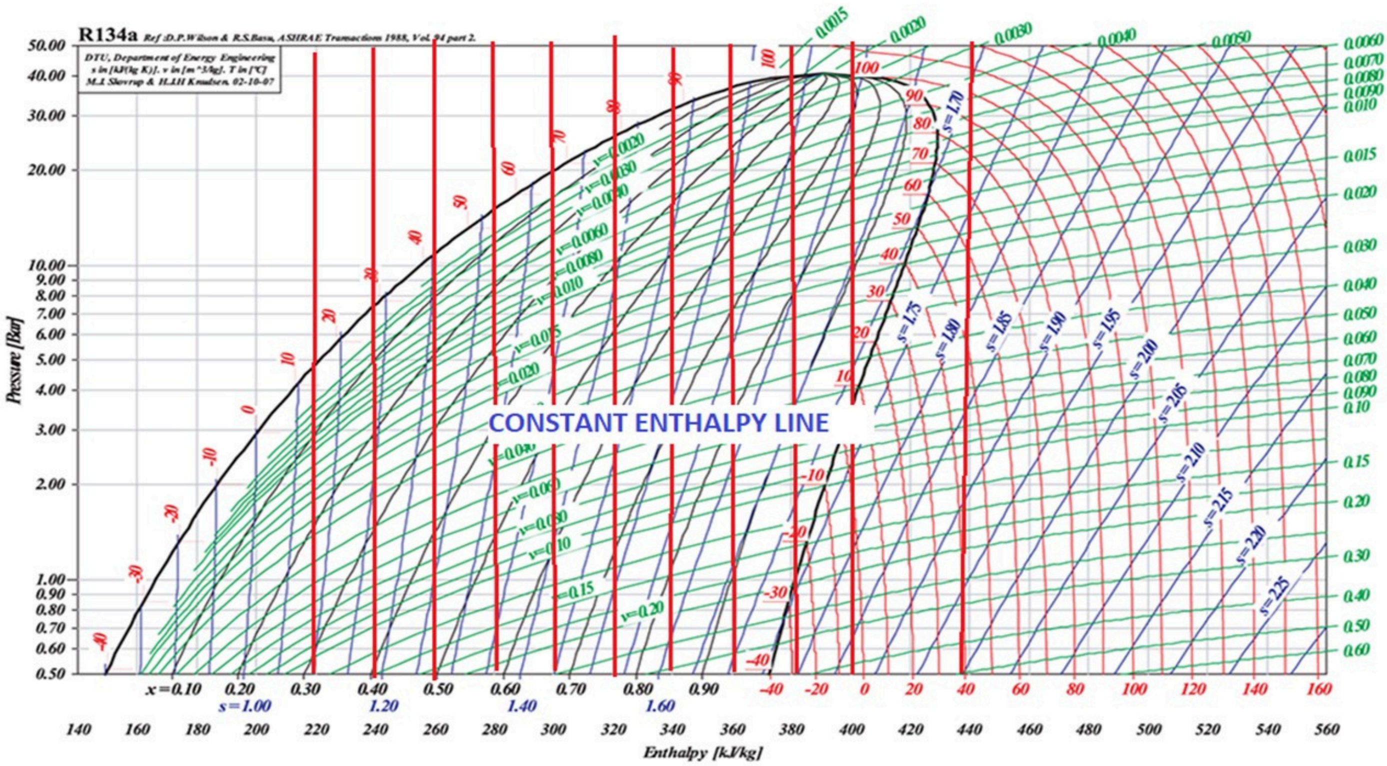


Figure 4.0: Constant Enthalpy Line

1.6 Constant Temperature Line

The temperature lines and scales are as shown below. The line is ladder-shaped with the temperature scale located on the saturated liquid and saturated vapor curves using °C units. The line of constant temperature is shown as a vertical line in the subcooled liquid region and parallel to the line of constant pressure in the moist vapor region. In the superheated vapor region, it is shown as a downward sloping curve.

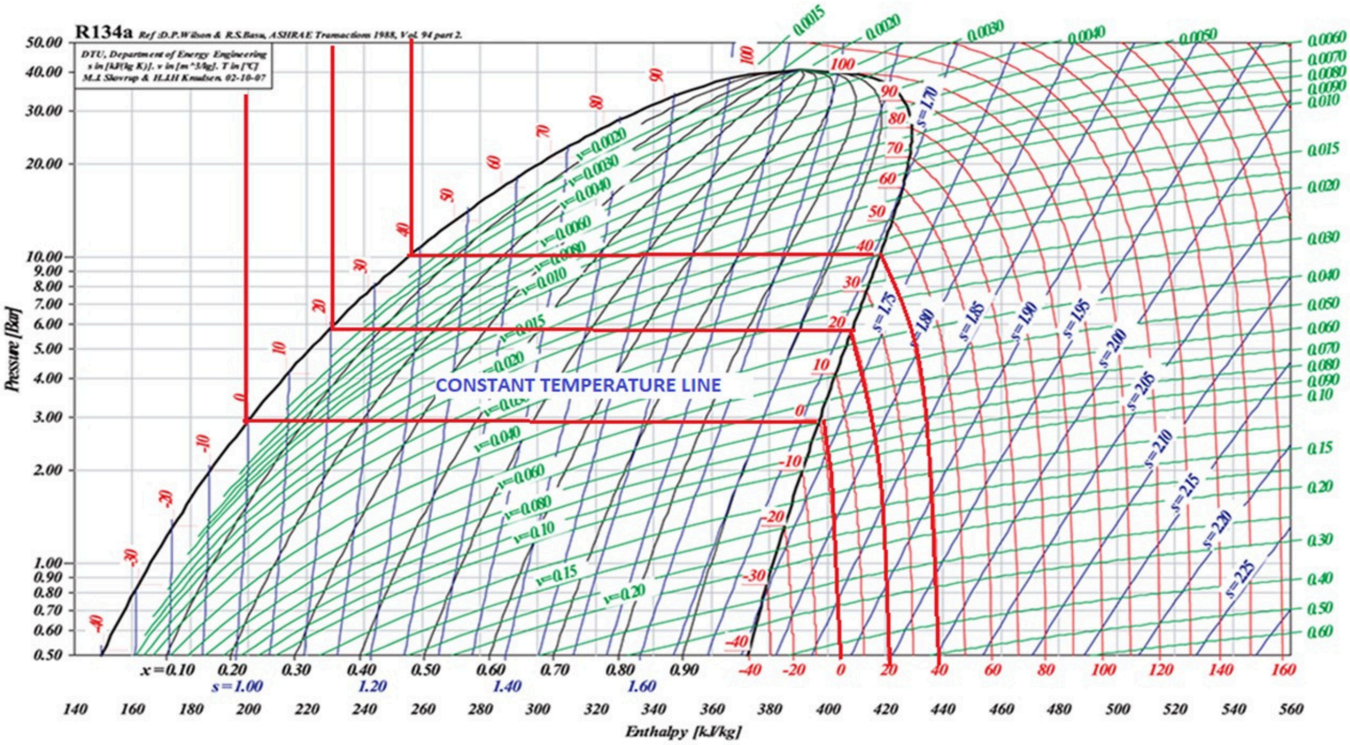


Figure 5.0: Constant Temperature Line

1.7 Constant Specific Entropy Line

The entropy line shows the ratio of the quantity of cooling heat at a certain absolute temperature. In engineering terms it is known as mechanical heat. The line starts from the saturated vapor curve and the scale can be read at the end of the line. **The unit for entropy is in kJ/kg.K and uses the symbol S**.

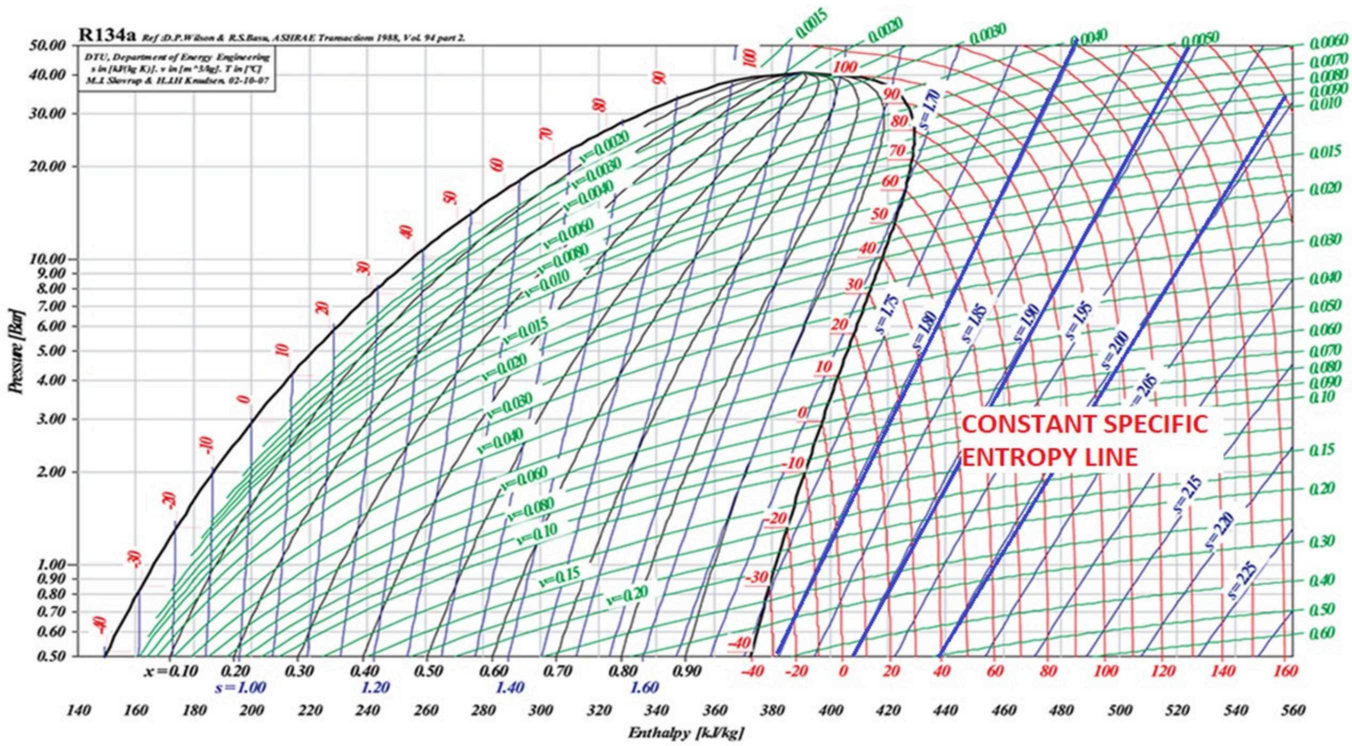


Figure 6.0: Constant Specific Entropy Line

1.8 Constant Specific Volume Line

This line shows the volume at a given pressure and temperature of the refrigerant. Starting from the saturated vapor curve and slightly horizontal from the specific entropy line. The volume value can certainly be read at the end of the line. The unit used is **m3/kg** and its symbol is **V**.

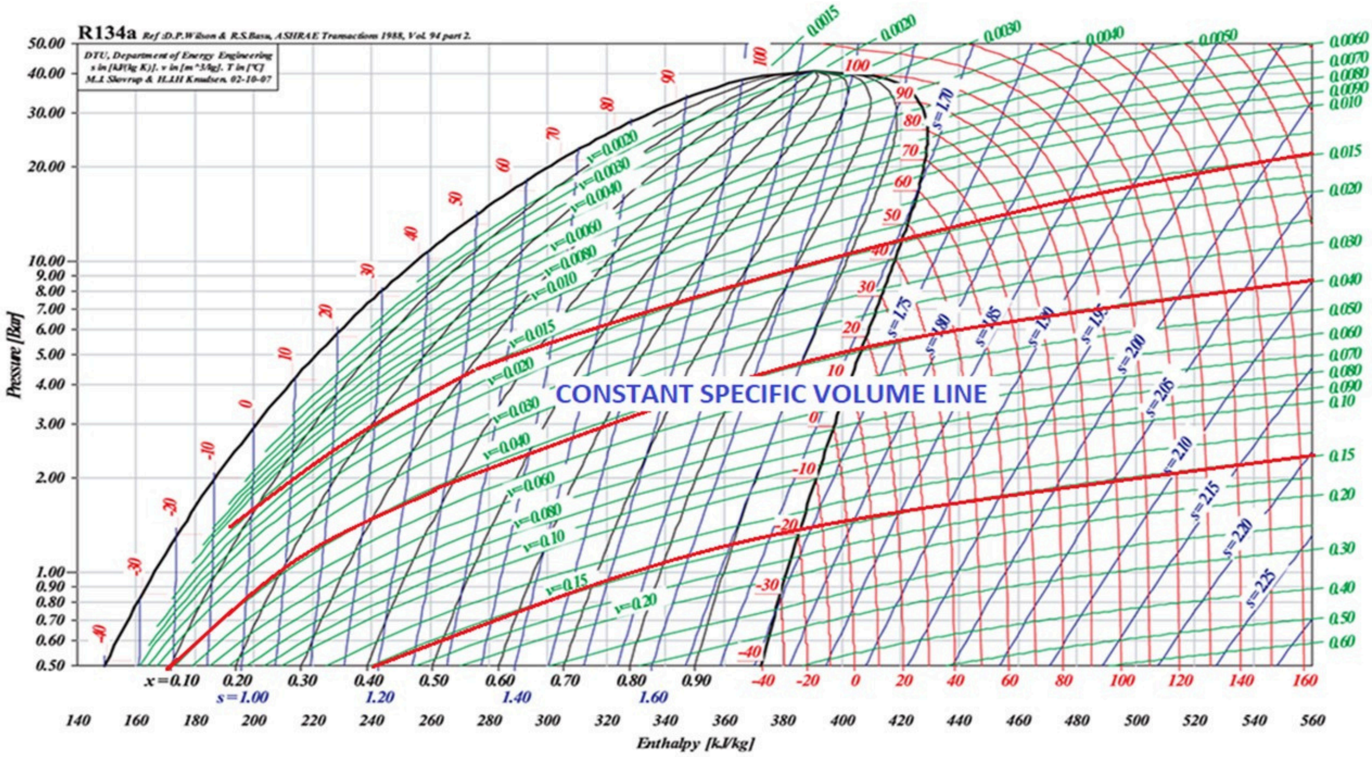


Figure 7.0: Constant Specific Volume Line

1.9 Constant Dryness Line

This line shows the form of refrigerant in the system. The line starts from the critical point to the enthalpy axis, which is between the curve of saturated liquid and saturated vapor. Fraction of the value reading in the form of liquid or vapor percentage.

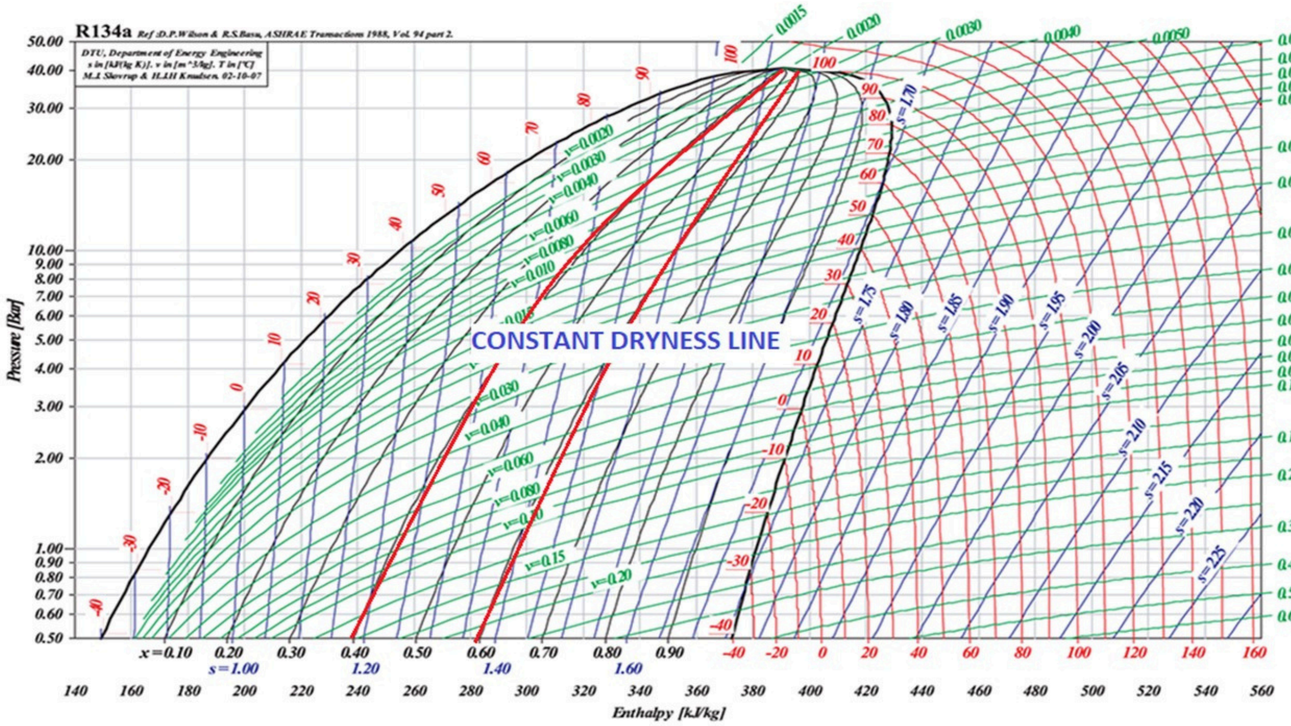


Figure 8.0: Constant Dryness Line

EXAMPLE ***What is the state of the dryness factor of R22 refrigerant at a point that has a pressure of 0.7 MPa abs and a specific enthalpy of 340 kJ/kg?***

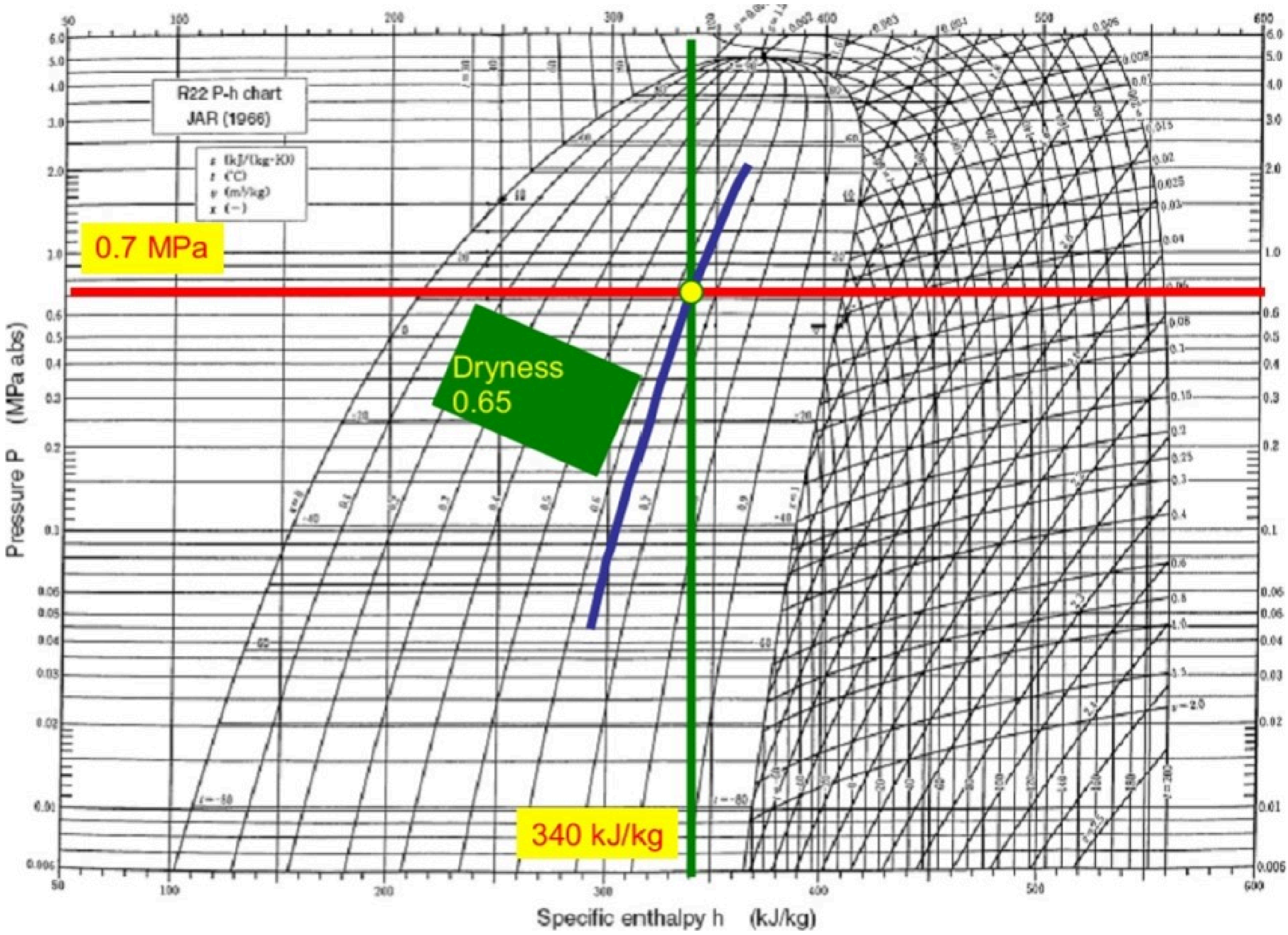


Figure 9.0: The crossed line (blue) refers to the 'Dryness factor line'

Chapter 2
Subcooling

2.1 Subcooling

Sub cooling refers to the temperature decrease of a liquid refrigerant below its saturation temperature at a given pressure. It represents the amount of sensible heat removed from the refrigerant after it has completed the phase change from vapor to liquid.

To determine the sub cooling value on a P-H chart, the sub cooling region is located below the saturation curve, where the refrigerant is in a liquid state and has a temperature lower than its saturation temperature at a specific pressure.

By monitoring sub cooling and adjusting system parameters such as condenser pressure, refrigerant flow, and condenser temperature settings, technicians can optimize the performance and efficiency of refrigeration systems.

EXAMPLE

Plotting the sub-cooled refrigerant R22 at a pressure of 0.8MPa and a temperature of 0°C.

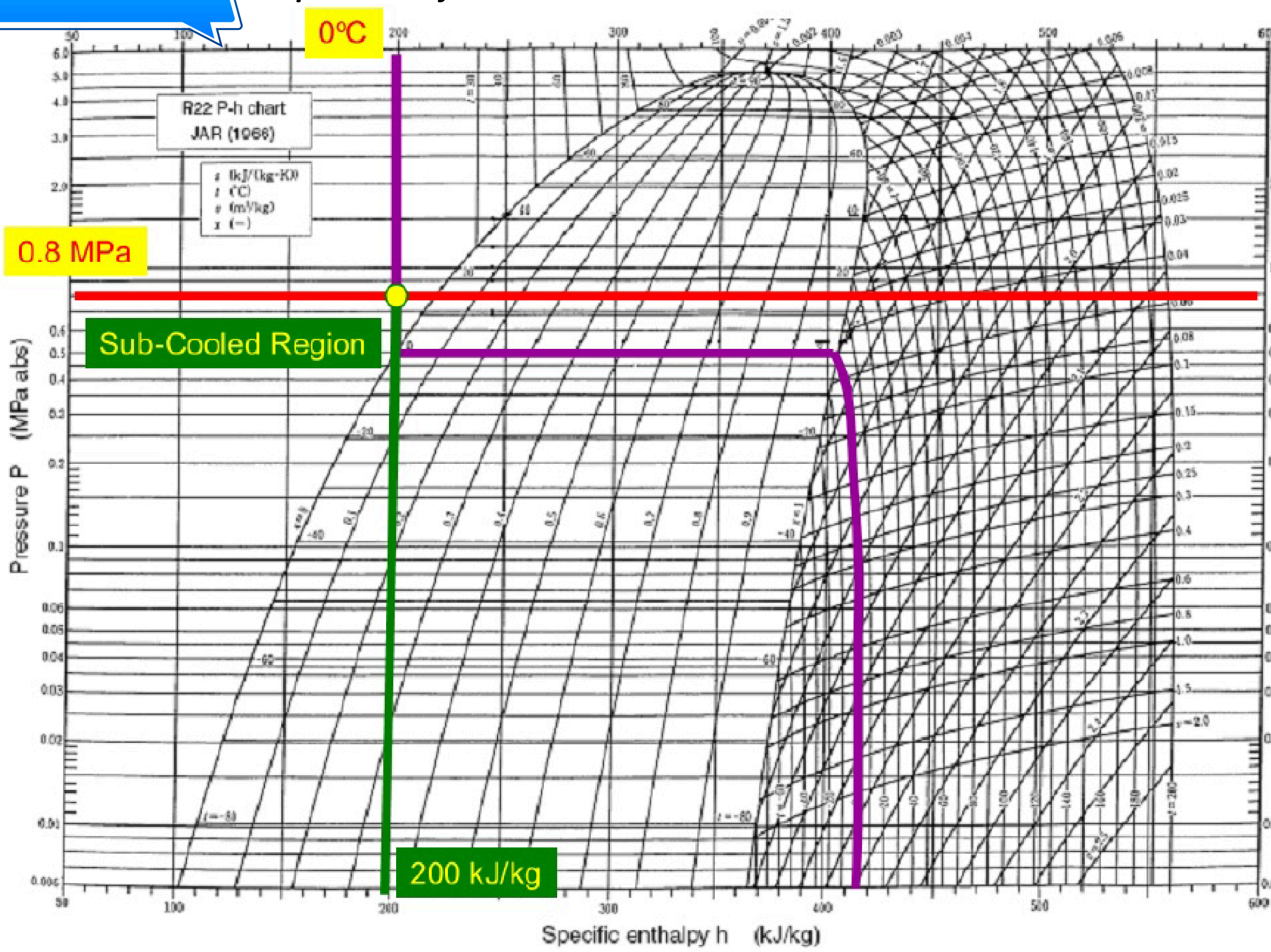


Figure 10: Sub-cooled point for refrigerant R22 at a pressure of 0.8MPa and a temperature of 0°C, enthalpy 200kJ/kg

2.2 Importance of Subcooling

Sub-cooling is important in refrigeration systems for several reasons:

1. System efficiency: Proper sub cooling ensures that the liquid refrigerant is condensed and remains in a liquid state before entering the expansion device. This maximizes the system's cooling capacity and energy efficiency.

2. Expansion device performance: Sub cooling helps optimize the operation of the expansion device (such as a thermostatic expansion valve) by providing a stable liquid refrigerant flow rate and improving the accuracy of the refrigerant metering process.

3. System stability: Sub cooling helps maintain a stable refrigerant flow and temperature control, preventing issues such as flashing or unstable operation in the evaporator.

2.3 How to measure Subcooling

S**ub cooling** is one of the best methods to determine if the refrigerant charge is correct. It is also a useful calculation for troubleshooting as it shows exactly what is happening in the condenser.

How to measure sub-cooling:

1. Take high side pressure at the receiver. (On pressure gauge)
2. **Convert the high side pressure to temperature** by using the pressure/temperature chart. **Scan QR Code below to use pressure/temperature chart.**
3. Record the actual temperature of the liquid leaving the condenser with a surface temperature probe.
4. **Subtract** the liquid pipe temperature (at the exit of the condenser) from the converted temperature (from the high side pressure using the pressure/temperature chart).
5. The difference is the **amount of sub cooling.**

EXAMPLE

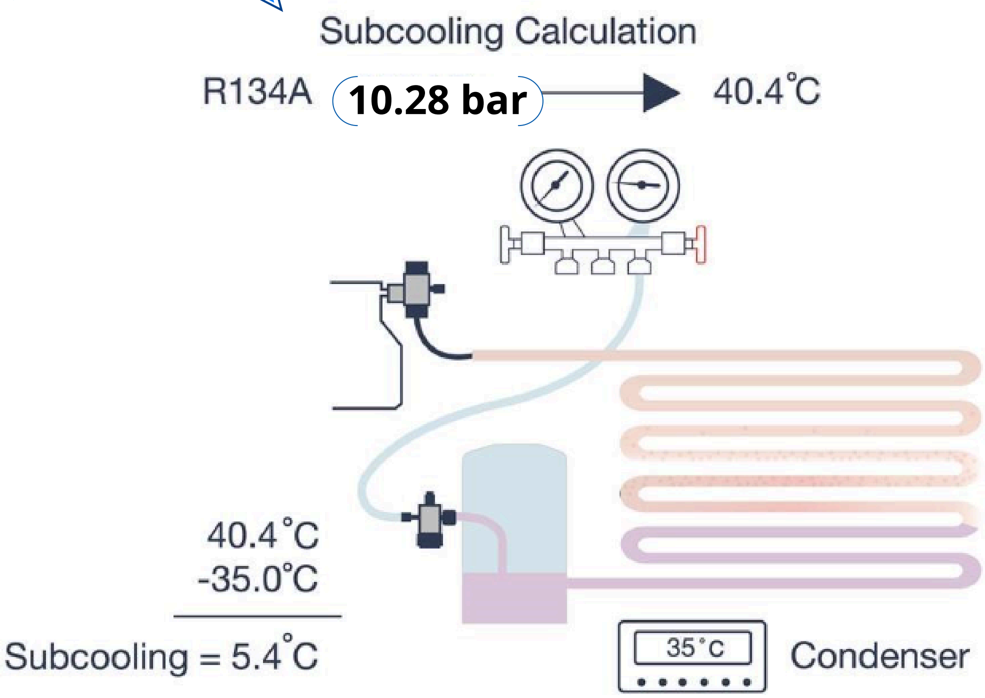


Figure 11: Sub-cooling Calculation

SCAN ME

Pressure/Temperature Chart

Chapter 3
Superheat

3.1 Superheat

Superheat refers to the temperature increase of a vapor refrigerant above its saturation temperature at a given pressure. It represents the amount of sensible heat added to the refrigerant after it has completed the phase change from liquid to vapor.

On a P-H chart, the superheat region is located beyond the saturation curve, where the refrigerant is in a vapor state and has a temperature higher than its saturation temperature at a specific pressure. The superheat region is typically represented by lines or curves that indicate constant levels of superheat.

Measuring and controlling superheat is crucial in refrigeration systems to ensure optimal performance and prevent potential issues. By monitoring and adjusting the superheat, technicians can achieve efficient and reliable operation of the system.

The concept of superheat and sub cooling is illustrated as Figure 11 for better understanding.

- Superheat is defined as the amount of heat added to a vapor above its boiling point.
- Sub cooling is defined as the amount of heat removed from a liquid below its condensing point.

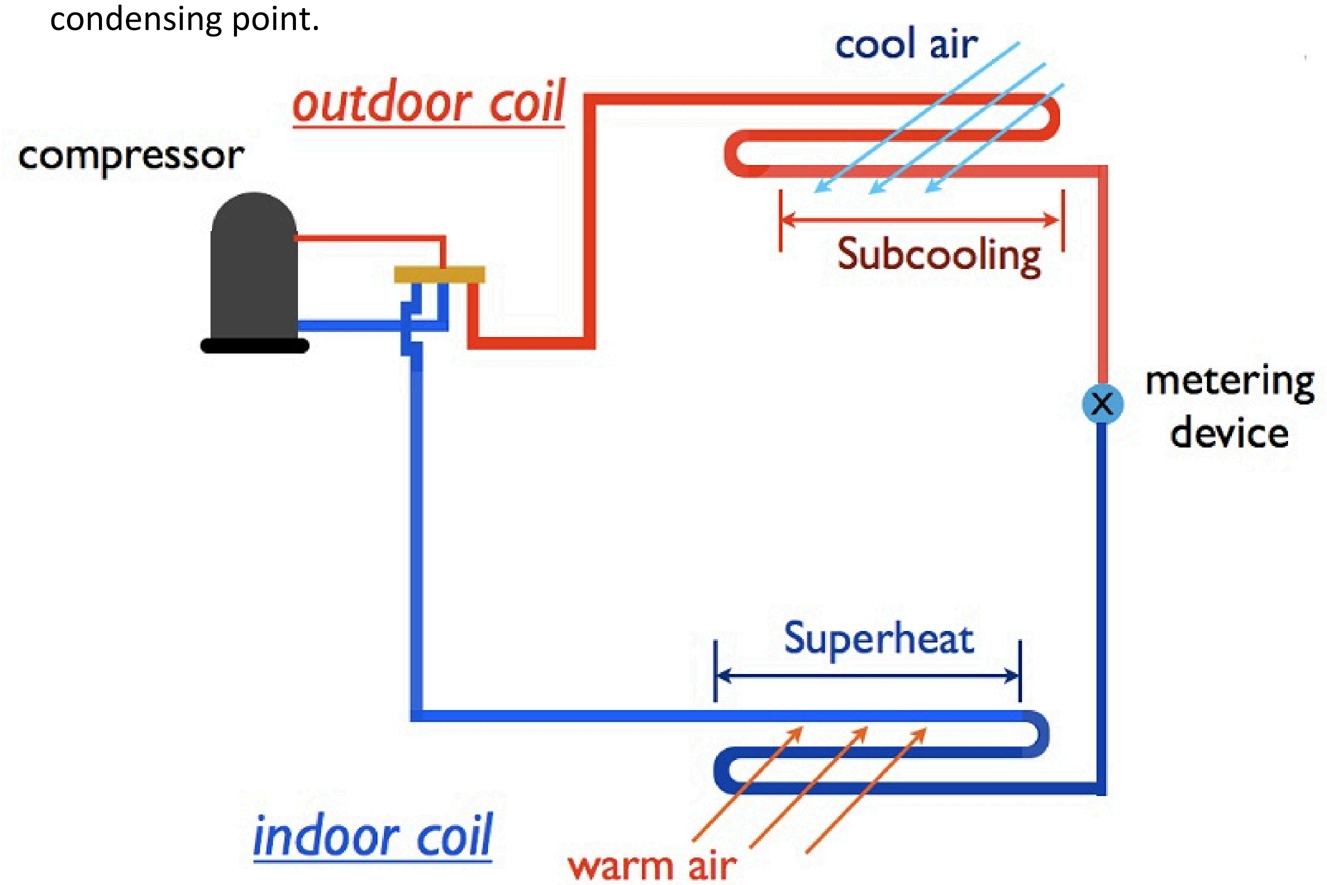


Figure 12: Concept of superheat and sub cooling

3.2 How to measure Superheat

Superheat is a very important measurement to take as it confirms **how much liquid is in the evaporator**. From an efficiency perspective, keep the evaporator fully flooded with liquid refrigerant allowing it to absorb as much heat as possible. However, be careful **not to have too much** liquid flooding back to the compressor as it will cause severe damage.

Make sure there is as much liquid in the **evaporator as possible**, but ensure it is completely boiled off **before it enters the compressor**. This can be seen by measuring the superheat.

How to measure superheat:

1. Record the **actual temperature** at the TXV bulb with a probe.
2. Record the **evaporating pressure** at the TXV bulb. (Low side gauge pressure)
3. **Convert the evaporating pressure to temperature** by using a pressure/temperature chart. **Scan QR Code below to use pressure/temperature chart**.
4. **Subtract** the temperature converted on the pressure/temperature chart from the actual temperature recorded at the TXV bulb.
5. The difference is the **actual evaporator superheat**.

- The superheat value should be 4-8K (Kelvin). If the Superheat value is too high then the evaporator is not fully flooded with cold liquid refrigerant causing the evaporator to be inefficient.
- If the superheat value is too small of even 0K (Kelvin) this means that liquid is coming out of the evaporator and back to the compressor. As mentioned above this can cause damage to the compressor.

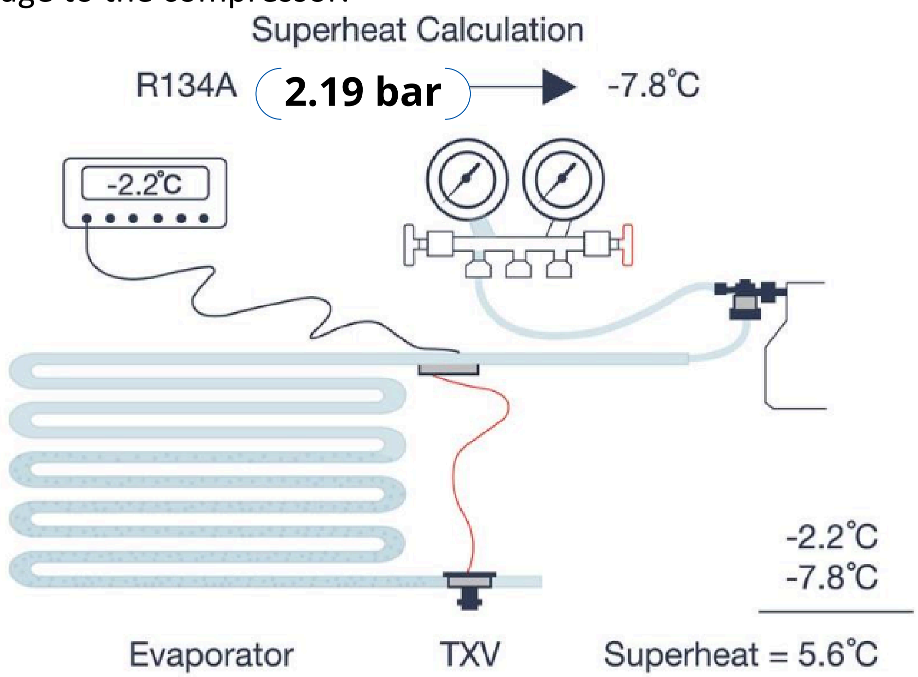


Figure 13: Superheat Calculation

SCAN ME

Pressure/Temperature Chart

3.3 Importance of Superheat

1. **System efficiency**: Proper superheat ensures that the refrigerant completely evaporates in the evaporator coil before it reaches the compressor. This maximizes the system's cooling capacity and energy efficiency.
2. **Compressor protection**: Superheat helps prevent liquid refrigerant from entering the compressor, which can cause damage due to inadequate lubrication and potential compressor failure.
3. **Temperature control**: Superheat helps maintain a consistent temperature in the evaporator coil, ensuring proper cooling and preventing frost or ice formation.

To determine the superheat value on a P-H chart, locate the point on the chart that corresponds to the operating pressure and temperature of the refrigerant in the superheated vapor state. The difference between this temperature and the saturation temperature at that pressure represents the superheat value.

By monitoring superheat and adjusting system parameters such as refrigerant flow, evaporator pressure, and temperature settings, technicians can optimize the performance and efficiency of refrigeration systems.

Chapter 4

Refrigerant Cycle Diagram

4.1 Ideal Refrigerant Cycle

Air conditioners system consist of four major components such as evaporator, compressor, condenser, and expansion valve. The refrigerant flows through these components and the **process of evaporation → compression → condensation → expansion** repeats to carry out refrigeration. This process is called the **vapour compression refrigeration cycle.** The series of graphics below shows how the refrigeration cycle is graphed onto the pressure-enthalpy chart and goes into details about how certain parameters can be determined from the chart.

The vapour compression refrigerant cycle consist of **(4) four stages** of processes:

1. **Evaporator: Heat absorbing / Evaporation process.**
2. **Compressor: Compression process.**
3. **Condenser: Heat rejection / Condensation process.**
4. **Expansion device: Expansion process**

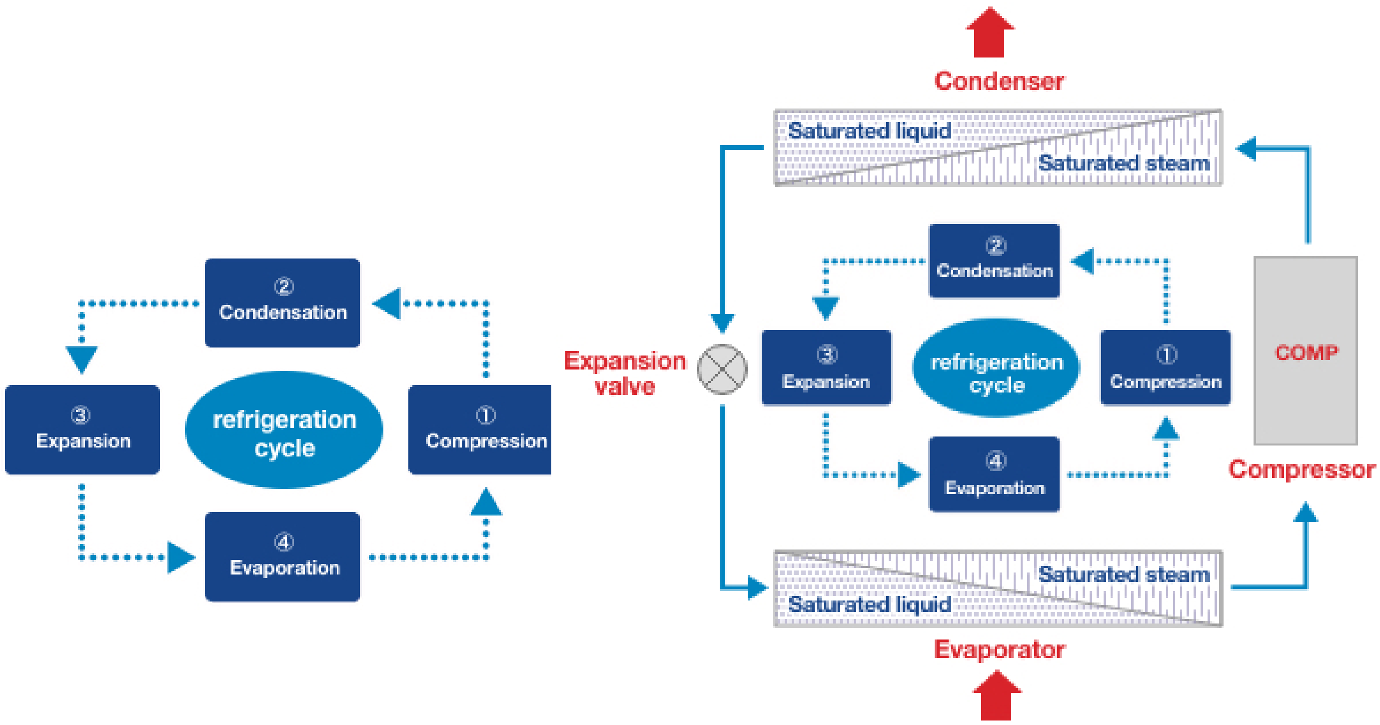


Figure 14: Concept of Refrigeration Cycle

1. Evaporator: Heat absorbing / Evaporation process

This component absorbs heat from the load/air-conditioned space (Qe) through the refrigerant evaporation process. After absorbing heat from the load, the liquid refrigerant entering the evaporator will convert to gas/vapor refrigerated.

2. Compressor: Compression process.

This component absorbs heat from the load/air-conditioned space (Qe) through the refrigerant evaporation process. After absorbing heat from the load, the liquid refrigerant entering the evaporator will convert to gas/vapor refrigerated.

3. Condenser: Heat rejection / Condensation process

The condensation is a process in which the high-temperature high pressure discharge gas from the compressor. This component works to remove heat (Qc) from the system obtained during the evaporation process and also the heat that arises during the compression process. The condenser receives refrigerant in the form of hot gas/vapour. This condensation process can occur because the temperature of the refrigerant in the Condenser is higher than the temperature of the Condenser's cooling media. Refrigerant changes from gas/vapor phase to liquid. The liquid refrigerant from the Condenser then flows to the expansion valve.

On the P-h Chart, this change of phase is represented by drawing a line from right to left with a constant pressure line, that is, a horizontal line.

4. Expansion device: Expansion process

The expansion is a process in which the pressure of the condensed liquid refrigerant is reduced through the expansion valve (or capillary tube) to an evaporation pressure required. In this process, since there is no heat transmission between the refrigerant and the surroundings, the phase changes according to the constant specific enthalpy. In general, the liquid refrigerant at the inlet of the expansion valve is sub-cooled by 5°C below the condensing temperature.

Therefore, on the P-h Chart, this change of phase is represented by drawing a vertical line from top to bottom from the left side of the saturated liquid line.

Table 1 : Summary of the refrigerant state during the refrigeration cycle

	4-element parts	Refrigerant state	Temperature	Heat transfer
(1) Compression	Compressor	Low temperature and low pressure gas → High temperature and high pressure gas	Low temperature → high temperature	+ adiabatic heat
(2) Condensation	Condenser	High temperature and high pressure gas → High temperature and high pressure liquid	High temperature (constant)	- condensation heat (= - evaporation heat - adiabatic heat)
(3) Expansion	Expansion valve	High temperature and high pressure liquid → Low temperature and low pressure liquid	High temperature → Low temperature	No heat balance
(4) Evaporation	Evaporator	Low temperature and low pressure liquid → Low temperature and low pressure gas	Low temperature (constant)	+ evaporation heat

To design and analyze a refrigeration system, you should determine the thermodynamic properties of the four main component refrigerants shown in Figure 15 involving:

- **Point 1**: between the evaporator and the compressor.
- **Point 2**: because it leaves the compressor.
- **Point 3**: when it leaves the condenser, before it enters the expansion valve.
- **Point 4**: just after the expansion valve, before it enters the evaporator.

For each of these points, we need to know the temperature, entropy, pressure, and enthalpy of the refrigerant.

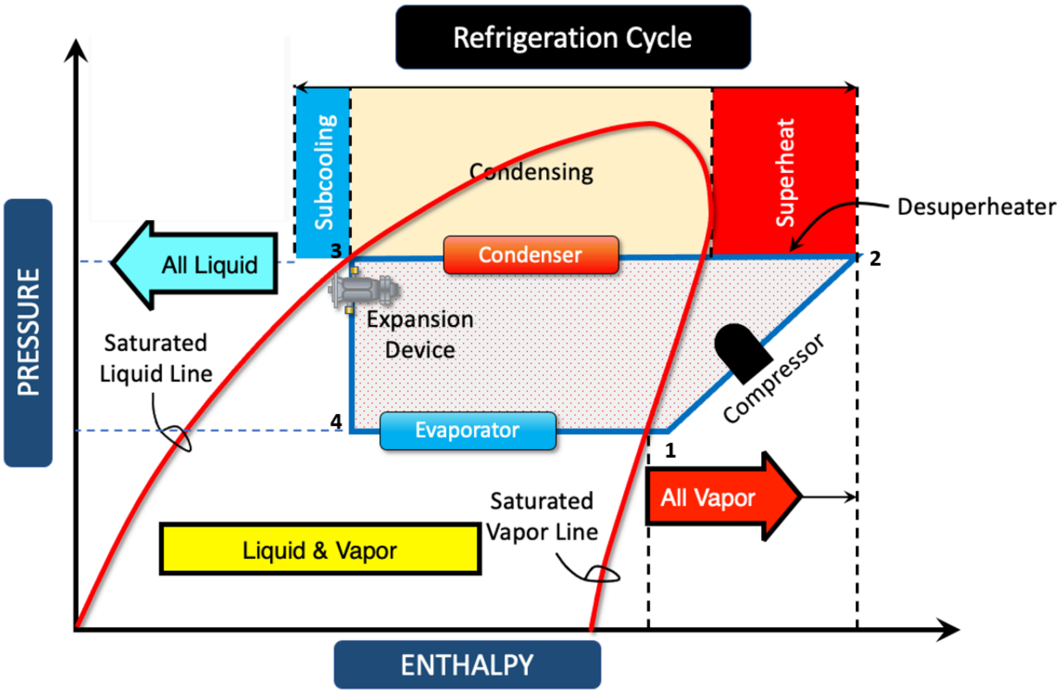


Figure 15: State of refrigerant in Refrigeration Cycle

4.2 Analyzing Refrigeration System Guided by Mollier Chart (Pressure-Enthalpy Chart)

Mollier Chart (Pressure-Enthalpy chart) have many applications in daily industrial activities. One of the most important applications of Mollier chart for pressure enthalpy includes those related to the HVAC industry (which refers to any heating, ventilation and/or air conditioning system), where knowledge of Mollier chart is essential for air conditioning design air. system. This diagram helps to optimize the performance and efficiency of different equipment. Therefore, it is used to find out which is the best condenser and evaporator in a closed system. It is also useful to know the best type of compressor for each of these systems. Finally, it is important to determine the amount of refrigerant that will be used in the system and to determine the energy efficiency of the system as a whole.

EXAMPLE

The evaporator line is at 2.8 Bar and the condenser line is at 14 Bar. Determine value of absolute pressure, temperature, specific enthalpy, specific volume and specific entropy at each point I — 4.

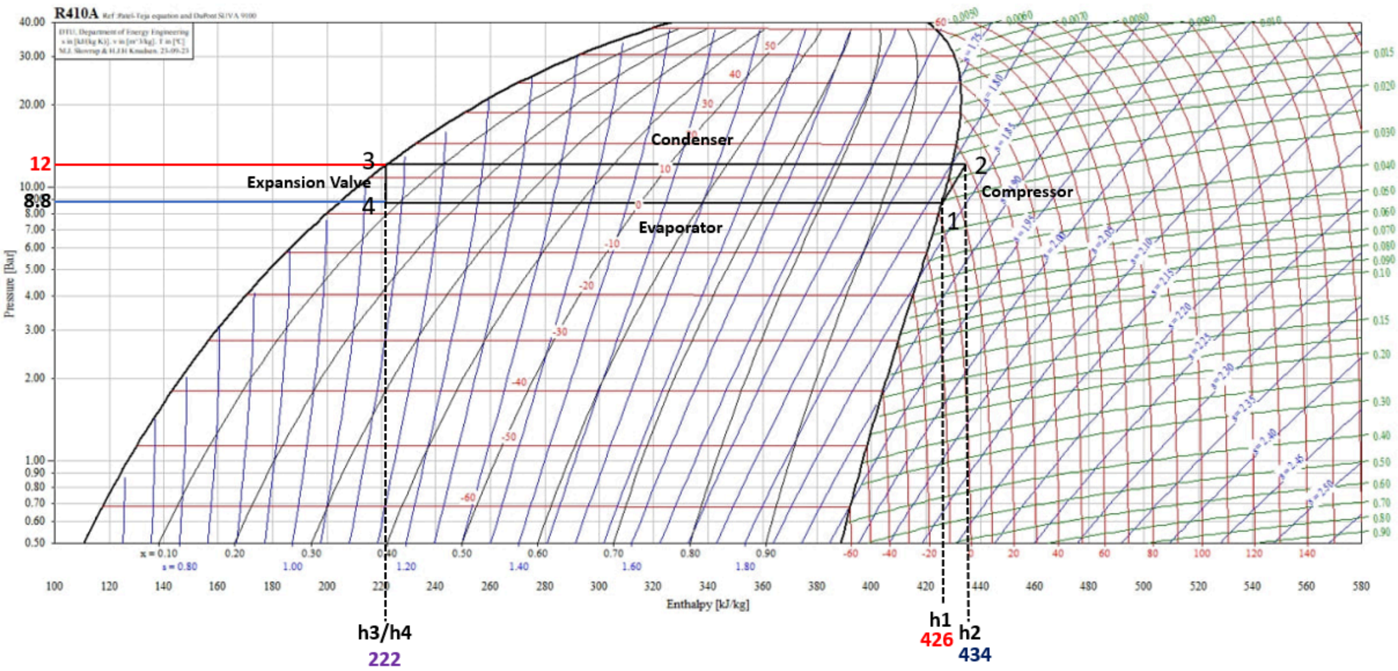


Figure 16: State of refrigerant R410a on Mollier Chart (Ph Chart)

Table 2: Value of absolute pressure, temperature, specific enthalpy, specific volume and specific entropy at each point I — 4

Point	T	P	v	h	s
	°C	Bar	m^3/kg	kJ/kg	kJ/(kg.K)
1	2.8	8.8	0.031	426	1.818
2	19	12	0.023	222	1.818
3	19	12	0.023	222	1.818
4	14	8.8	0.031	426	1.818

Chapter 5

Pressure P-h Chart Analysis

5.1 Relationship Of Mollier Chart (Pressure-Enthalpy Chart) And Refrigeration System

By applying the Mollier chart (Pressure-Enthalpy chart), the processes carried out by the refrigeraion system can be known such as the process of compression, condensation, evaporation and expansion (metering device). So, refer to the Figures 17 and Table 3 for a description of the changes in the refrigeration cycle below.

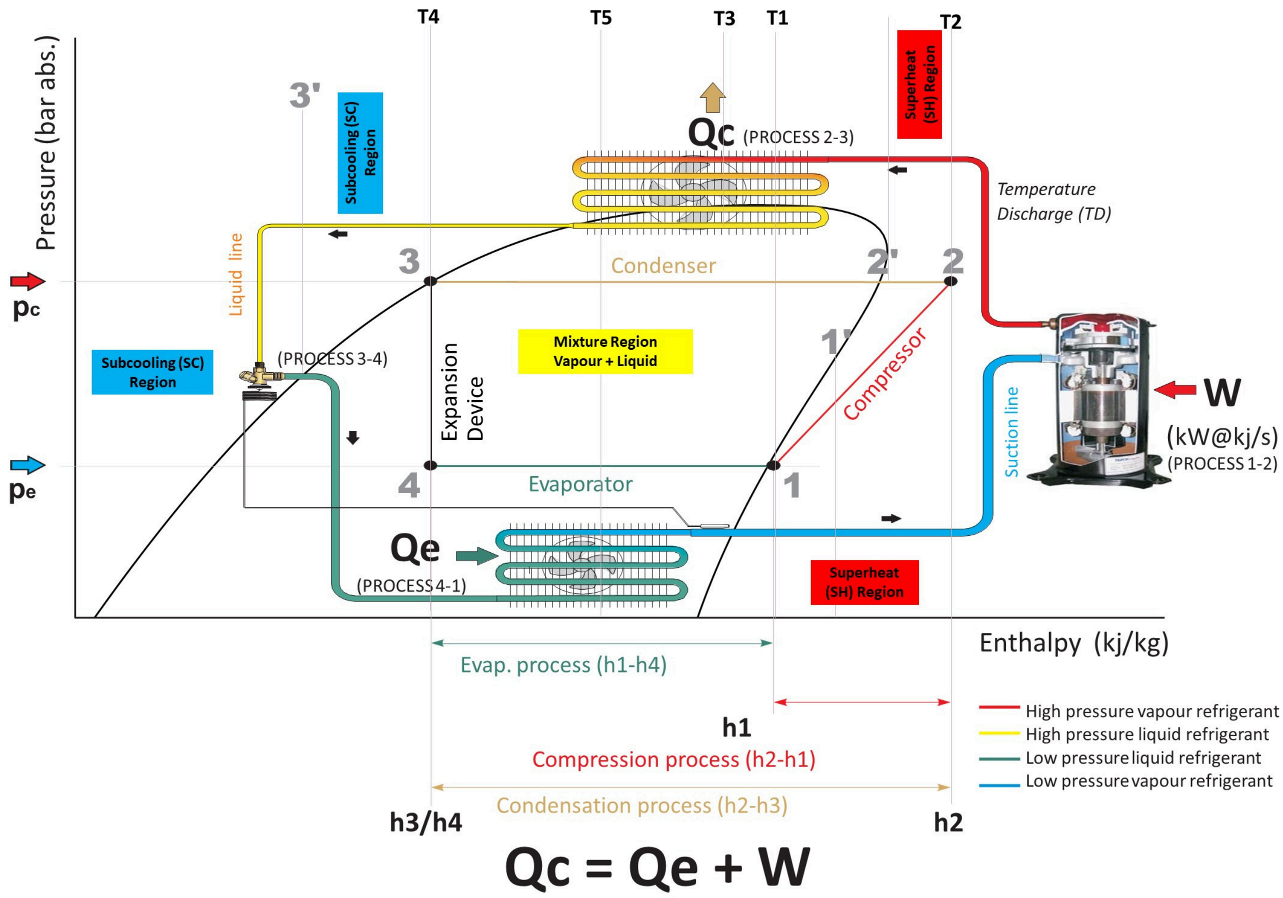


Figure 17: Analyzing Refrigeration System Guided By Mollier Chart (Ph Chart)

Table 3: Process in the operation of refrigeration system

PROCESSES IN THE OPERATION OF THE REFRIGERATION SYSTEM						
PROCESS	COMPONENTS INVOLVED	POINT	STATE OF REFRIGERANT			
			SHAPE	HEAT STATE	TEMPERATURE	PRESSURE
Compression	Compressor	1-2	Vapour	Increase from h1 — h2	Increase from T1 — T2	Increase from P1 — P2
Condensation	Condenser	2-3	Vapour + Liquid (Mixture)			
Expansion	Metering Device	3-4	Liquid			
Evaporation or Cooling Effect	Evaporator	4-1	Liquid + Vapour (Mixture)			
Superheat	Suction Line	1-1'	Vapour			
Desuperheater	Desuperheater Line	2-2'	Vapour			
Sub cooling	Liquid Line	3-3'	Liquid			

5.2 Refrigeration Cycle Analysis Guided By Mollier Chart (Pressure-Enthalpy Chart)

A Mollier chart (Pressure-Enthalpy chart) is one of the simplest ways to analyze the operation of a refrigeration cycle system. Based on some specific values of the system such as temperature and pressure, analysis can be done by plotting those values on a chart and from there the behavior of the system is obtained.

1 **Refrigerant / Cooling effect or Heat absorbed by the evaporator (Qe)**

- **The amount of heat absorbed by the evaporator, [Q evaporator]**

$$Qe = h1 - h3 = h1 - h4 \text{ (kJ/kg)}$$

2

Work value of the compressor (Work compressor)

- The heat produced during the compression process

$$Wc = h2 - h1 \ (kJ/kg)$$

3

Heat released in the condenser (Qc)

- Heat resulting from heat absorbed by the evaporator (cooling effect) and heat of compression

$$Qc = h2 - h13 \ (kJ/kg)$$

4

Compression Ratio, R

- Discharge and suction absolute pressure difference.

$$R = \frac{\text{Absolute Discharge Pressure, P2}}{\text{Absolute Suction Pressure, P1}}$$

5

Refrigerant Vapor Volume

- Can be referred directly to the Mollier chart:
- The volume of the low pressure section — V1
- The volume of the high pressure section. — V2
- Unit: m3/kg

6

Compressor Outlet Refrigerant Temperature

- Can be referred directly to the Mollier chart:

T2 = °C

7

Refrigerant Vapor Quality

- The state of the refrigerant at one point of the lamp in the form of liquid or vapor, expressed as a percentage, refers directly to the chart.

Q = %

Refrigerant Flow Rate In The System

$$m = \frac{1kW}{\text{Heat absorbed by the evaporator (Qe)}}$$

kg/sec

Compressor Power

Compressor Power = Work compressor x Refrigerant Flow Rate

kJ/sec @ kW

Coefficient of Performance (C.O.P)

The coefficient of performance indicates how much cooling capacity is obtained per motor input (thermal equivalent work). The greater the coefficient of performance, the higher the operational effectiveness is obtained. This means that operational energy savings are possible.

$$COP = \frac{\text{Heat absorbed by the evaporator (Qe)}}{\text{Work compressor}}$$

kg/sec

5.3 Tutorial Refrigeration Cycle Analysis

REMEMBER! →

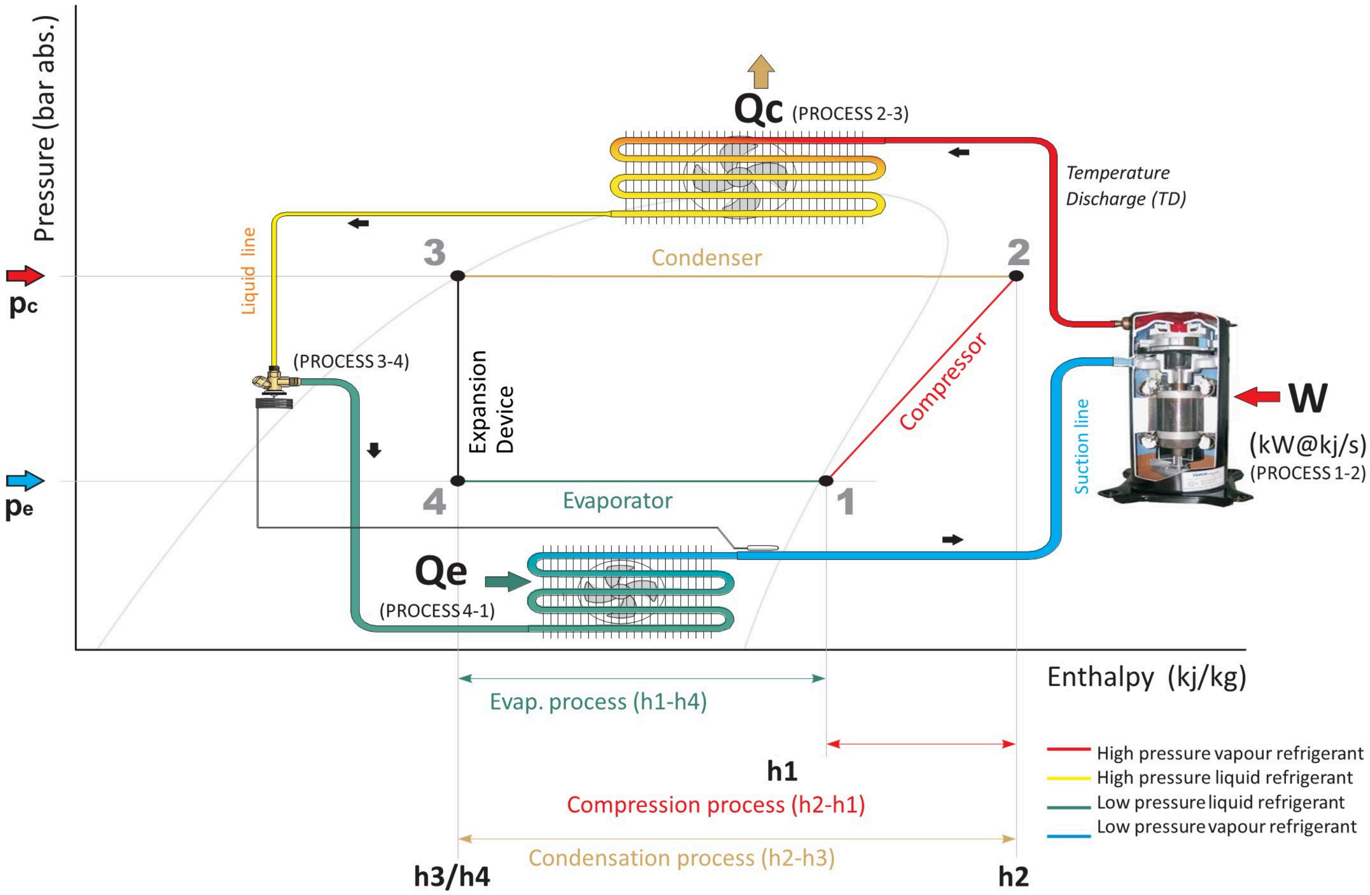
Before analyzing the following things need to be known and understood first involving:

1. **Pressure and temperature in the suction and discharge lines.**
2. **The type of refrigerant used.**
3. **System performance** such as:
   (a). Ideal refrigeration cycle condition
   (b). Superheat condition
   (c). Sub-cool condition
   (d). Superheated and sub-cooled conditions.

EXAMPLE

The refrigeration system using R-134a has a low system pressure of 1.4 Bar and a high pressure of 10 Bar. The temperature of the evaporator is -20 °C , the temperature of the refrigerant entering the compressor is -10 °C , the temperature leaving the compressor is 60 °C while the temperature of the refrigerant entering the expansion valve is 20 °C where the system is considered ideal.

a. Draw the P-H diagram of the system
b. Calculate the heat absorbed in the evaporator (Qe)
c. Calculate the value of heat released in the condenser (Qc)
d. Calculate the work value of the compressor (Wc)
e. Determine the COP value of the system



$$Qc = Qe + W$$

Based on the data, the system analysis on the R-134a refrigerant PH diagram can be described as follows:

P1 = 1.4 Bar

P2 = 10 Bars

T4 = -20 °C

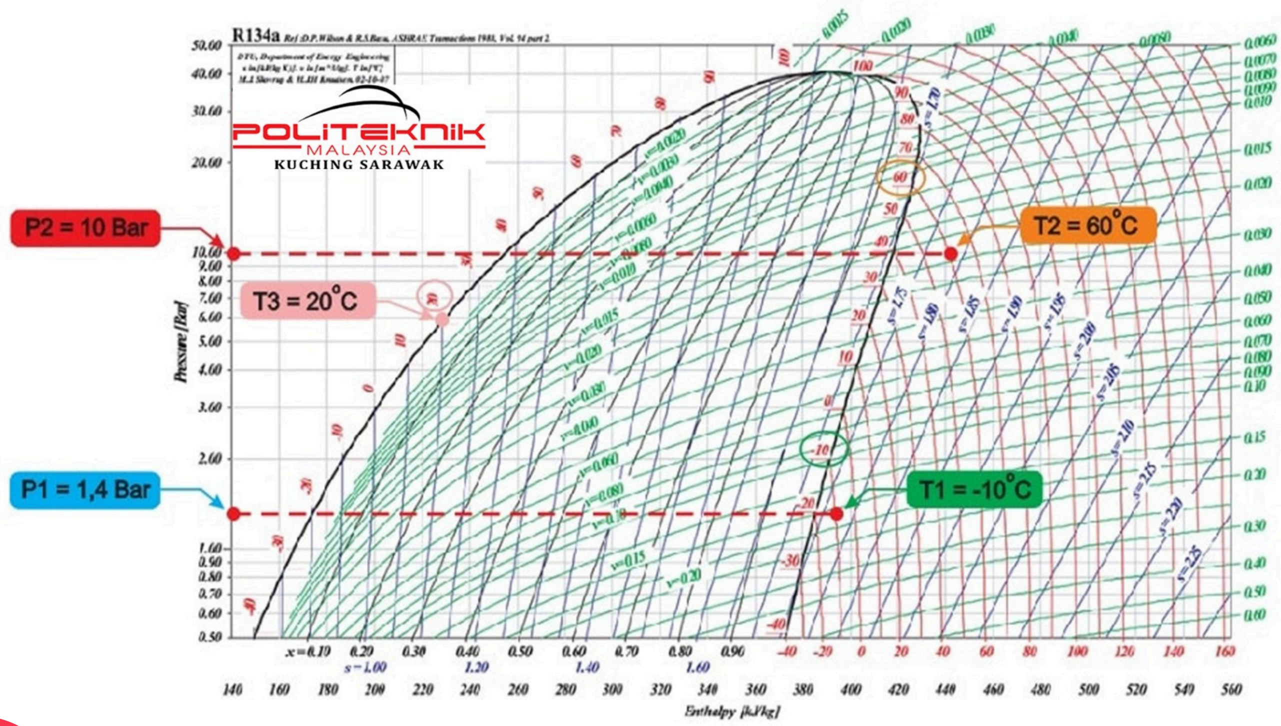
T1 = -10 °C

T2 = 60 °C

T3 = 20 °C

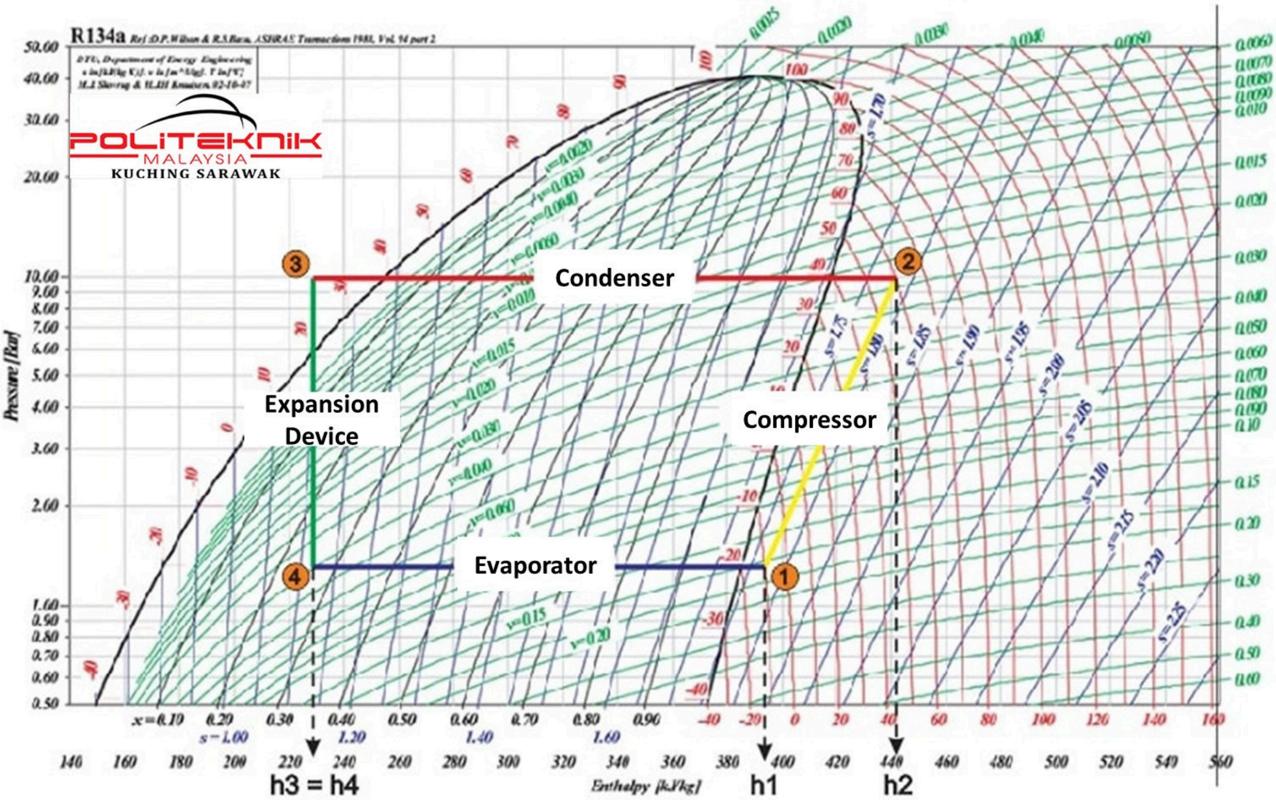
1

1. Determine the low pressure point (P1) on the diagram 1.4 Bar (blue color) and draw a pressure line horizontally up to the temperature point (T1) -10 degrees Celsius in the superheated steam region (green color).
2. Determine the high pressure point (P2) at 10 Bar (red color) and draw a pressure line horizontally to the temperature point (T2) of 60 degrees Celsius in the superheated steam region (orange color)
3. Determine the temperature point (T3) of 20 degrees Celsius (pink color) on the saturated liquid line.



2

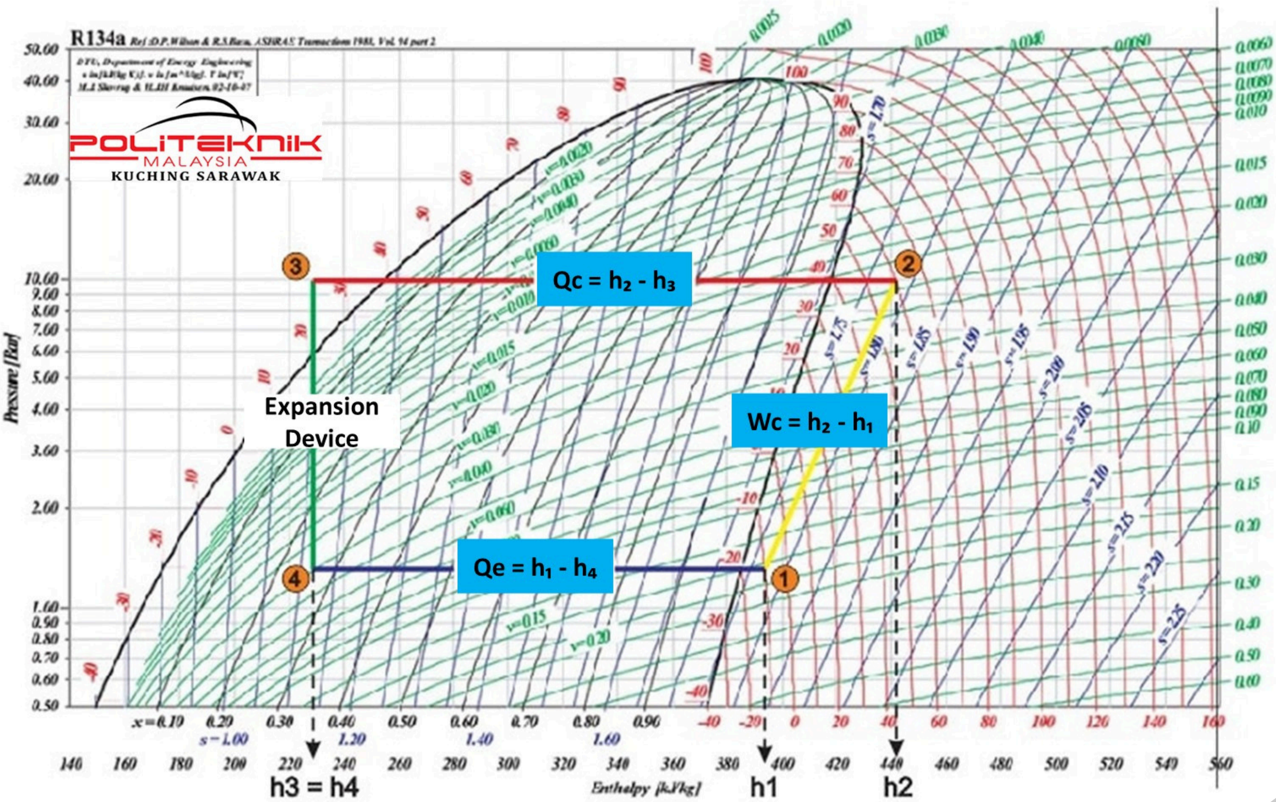
1. Draw a line from point T1 to point T2 (yellow line).
2. Draw a line from point T3 vertically until it touches the line of high pressure (10 Bar) and low pressure (1.4 Bar) (green color line).
3. A picture resembling a trapezoid is formed which depicts the condition of the refrigerant in each component (compressor, condenser, expander and evaporator).



3

Draw a dotted line from each point 1 to point 4 down to determine the value of enthalpy and get the values :

(h1 = 392 kJ/kg), (h2 = 440 kJ/kg) , (h3 = h4 = 228 kJ/kg)



4

From the example questions.

a. Draw the P-H diagram of the system

Already illustrated in the picture in step 2

b. Calculate the heat absorbed in the evaporator (Qe)

Qe = h1 - h4 = 392 - 228 = 164 kJ/kg

c. Calculate the value of heat released in the condenser (Qc)

Qc = h2 - h3 = 440 - 228 = 212 kJ/kg

d. Calculate the work value of the compressor (Wc)

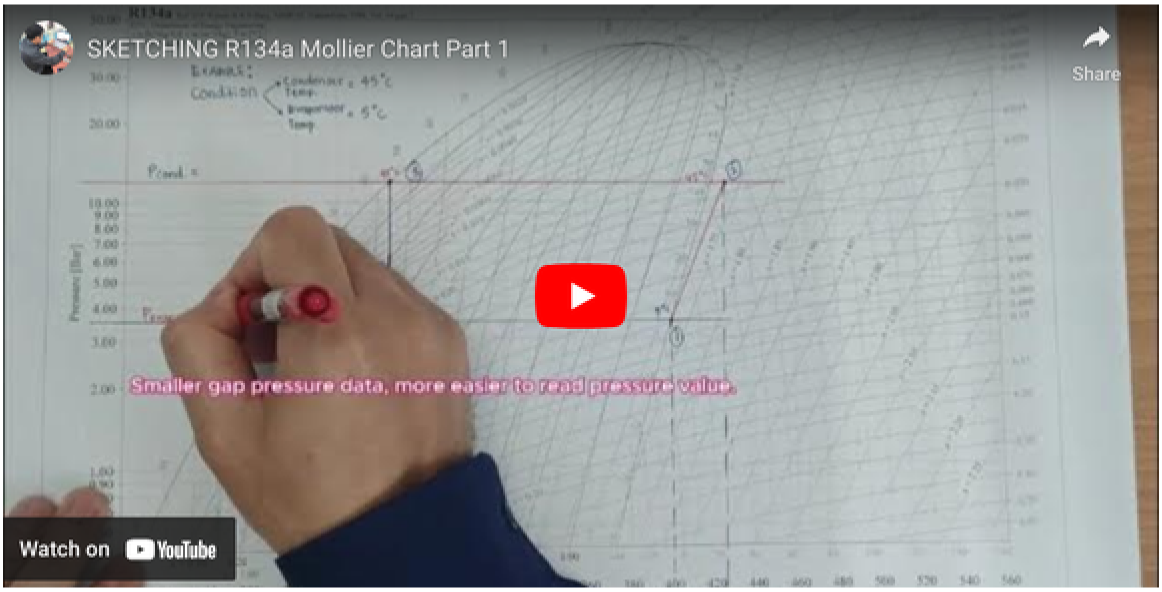
Wc = h2 - h1 = 440 - 392 = 48 kJ/kg

e. Determine the COP value of the system

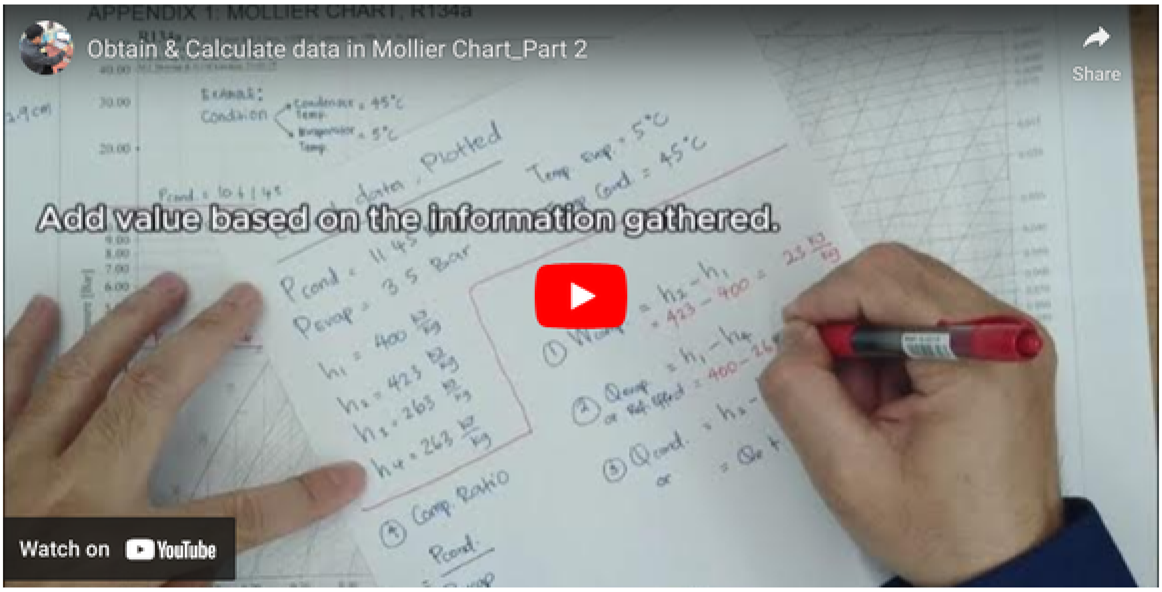
COP = Qc / Wc = 164/48 = 3,42 kJ/kg

5.4 Tutorial Sketching R134a Mollier Chart

In this tutorial video, a simple guide on how to sketch and find the parameter by using the R134a Mollier Chart.



Following the sketching video in Part 1, this Part 2 video explains how to gather and calculate data with the Moller Chart.



TEST YOUR IQ

QUIZ - Refrigeration Cycle and P-H Mollier Chart

There are EIGHT (8) objective and TWO (2) subjective question.

Answer all question

Total = 25 marks

https://forms.gle/WbwduJsmHAAaoXdCA

Chapter 6

Software P-h Chart Analysis

6.1 Software P-h Chart Analysis

Software P-h chart analysis is call as CoolPack is an older collection of simulation models for refrigeration systems and each of them has a specific purpose e.g. cycle analysis, sizing of main components, energy analysis and optimization. Student can install and used the software to analysis the data of parameter refrigeration system such as pressure, enthalpy and etc.

Figure 18: Scan and Install for Free Coolpack V150 Software.Zip

Website link to download free software

Conclusion

This e-book guides students in understanding and utilizing the enthalpy-pressure chart (Mollier diagram) comprehensively. It provides detailed instructions on how to plot the pressure-enthalpy chart accurately. Students will learn to determine and state the values of various thermodynamic properties, such as absolute pressure, temperature, specific enthalpy, specific volume, dryness factor, and specific entropy, at each point on the chart.

Furthermore, the e-book explains the theoretical concepts behind different phases and processes that occur within the refrigeration cycle. Students will gain an in-depth understanding of the phenomena at the saturated vapor line, within the moisture vapor region, along the saturated liquid line, in the sub-cooling region, and in the superheat region. This knowledge will enable them to explain the behavior and transitions of refrigerants during these processes.

Additionally, the e-book equips students with the skills to solve complex problems related to refrigeration and air conditioning systems using Mollier Diagrams (pressure-enthalpy charts). They will be able to apply this understanding to practical scenarios, enhancing their ability to design, analyze, and troubleshoot these systems effectively.

Reference

Whitman, W.C., Johnson, W.M., Tomczyk, J.A., & Eugene Silberstein. (2008). Refrigeration and Air Conditioning Technology (6th ed.). Delmar, Cemgage Learning.

Hundy, G.F., Trott, A.R., & Welch, T.C. (2008), Refrigeration and Air Conditioning (4th ed.). Butterworth-Heinemann.

Shank, K.W. (2000). Handbook of Air Conditioning and Refrigeration (2nd ed.) McGraw-Hill Inc.

Khurmi, R.S. & Gupta, J.K. (2006). A Textbook of Refrigeration and Air Conditioning. S. Chand & Company Ltd.

POLITEKNIK KUCHING SARAWAK

REFRIGERANT CYCLE & MOLLIER CHART
PRESSSURE-ENTHALPY CHART

eISBN 978-629-7638-26-3

9 786297 638263

Online