OBJECTIVES

1. Define and describe the concept of refrigeration system
2. Define and describe concept of heat exchanger
3. Determine the $C.O.P_{ref}$ and $Q_{p,water}$ of the refrigeration system

THEORY

The refrigeration system is a thermodynamic cyclic process. In a cyclic process a refrigerants pass through various changes of state in cyclic manner.

1 – 2	compression process in compressor
2 – 3	condensation process in condenser at constant pressure
3 – 4	throttling process in expansion valve
4 – 1	evaporation process in cooling coil / evaporator at constant pressure

The whole process is represented by the Figure 1.

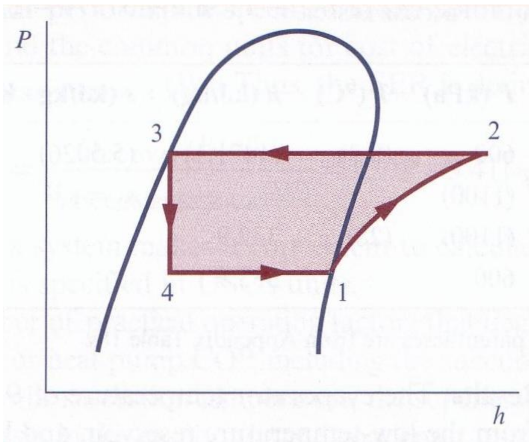

Figure 1 Refrigeration Cyclic Process

There is no difference in principle between refrigeration system and heat pump. In refrigeration, the heat from cold refrigerated space is absorbed by the evaporator or heat exchanger for cooling purposes. The evaporator is therefore located within the space to be cold, such as a cold compartment within refrigerator. The systems can be summarized as in Figure 2 and Figure 3 below.

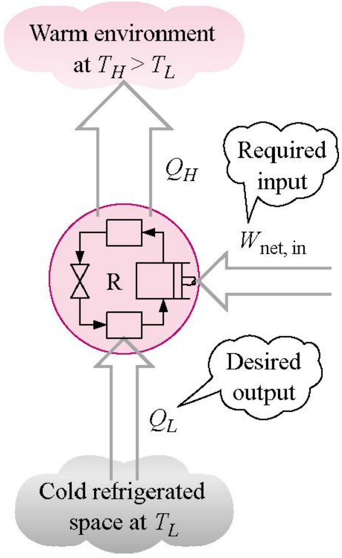

Figure 2 Refrigeration System / Air Conditioning

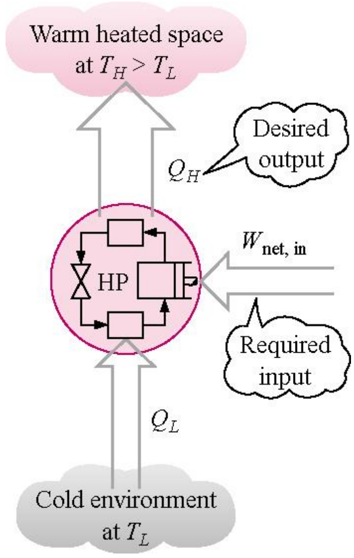

Figure 3 Heat Pump System

Refrigeration operates by the same principle as in air conditioning system, which is the control of the boiling point and condensing temperature of the refrigerant. This is done by feeding the refrigerant into an evaporator coil and compressors for raising the condensing temperatures above the temperature of the heat sink (disposing of the heat) by the aid of pressure-reducing devices. Rating of refrigeration is done by the ratio of cold output to electrical input, which is called the Coefficient of Performance (COP).

APPLICATION

Refrigeration is now part of our way of life. It would be inconceivable for it to be any other way. It has even become an essential ingredient and a "sine qua non" in improving our quality of life such as:

- the cooling chain enables the storage, transport and use of food items in ideal hygienic conditions, reducing losses and waste.
- air conditioning, particularly in hot countries, brings comfort and helps create hygienic conditions in places such as hospitals, offices, shops and public transport.
- refrigeration of essential medical products such as vaccines and blood, is often indispensable for ensuring their preservation.
- thermal insulation using high-efficiency HFC blowed foams reduces energy consumption of the installations.

Refrigeration of equipment such as large computers systems, through to the most sophisticated medical equipment (RMN for example), is also crucial.

APPARATUS

Refrigeration Training System ET 400.

Figure 4 Refrigeration Training System

PROCEDURES

1. Connect the main power.
2. Switch ON the computer ⟶ 

icon for diagram.
3. Switch ON the **compressor** and **fan.**
4. Switch ON the **circulation pump.**
5. Switch ON the **heater.**
6. Adjust the volume flow rate to 30 l/h via the flow control valve.
7. Record the value of pressure and temperature in **Table 1** when the parameters are stable.
8. Repeat step 5 to step 6 for volume flow rate of 50 l/h and 70 l/h.
9. Adjust the volume flow rate to 30l/h.
10. Switch OFF the **compressor.**
11. Switch OFF the **fan**
12. Switch OOF the **heater.**
13. Switch OFF the **circulation pump**.
14. OFF the main power.
15. Turn off computer

LAB REPORT

1. Title
2. Objective(s)
3. Introduction and Theory (Detail development and explanation of the underlying concept)
4. Apparatus
5. Procedures
6. Data and results
7. Analysis and discussion
8. Conclusion
9. References (Bibliography)

Name: ____________________ **Metric Number:** ____________________

Section / Group: ____________________ **Date of experiment:** ____________________

EXPERIMENTAL DATA

Table 1 Refrigeration System Experiment

Water flow rate [l/h]	T_1 [°C]	T_2 [°C]	T_3 [°C]	T_4 [°C]	$P_1=P_4$ [bar]	$P_2=P_3$ [bar]	T_{in} [°C]	T_{out} [°C]
30								
50								
70								

EXPERIMENTAL RESULTS

Table 2 The Results of Refrigeration System Experiments

Water flow rate [l/h]	$\dot{V}$ [m^3/s]	h_1 [kJ/kg]	h_2 [kJ/kg]	h_3 [kJ/kg]	h_4 [kJ/kg]	COP_{ref}	$Q_{p,water}$
30							
50							
70							

DISCUSSIONS

1. Write down sample calculations for the experimental results.
2. Why the temperatures of water decrease after come out from the heat exchanger?
3. Why the flow rates of water affect the difference of inlet and outlet temperatures and the COP_{ref}?

CONCLUSION

Conclude your finding in this experiment.

QUESTIONS

1. List down four (4) main components of a refrigeration system and their functions.
2. List down your findings after doing the experiment and compare it with the theory.

FORMULA

The cold output (heat input) is calculated from enthalpy of refrigerant at state 1 and state 4 as follows:

$$q_o = h_1 - h_4$$

where
- q_o = cold output (kJ/kg)
- $h_{1,4}$ = enthalpy of refrigerant at state 1 and sate 4 (kJ/kg)
- h_4 = h_3

The heat output (cold input) is calculated from enthalpy of refrigerant at state 2 and state 3 as follows:

$$q_h = h_2 - h_3$$

where
- q_h = heat output (kJ/kg)
- $h_{2,3}$ = enthalpy of refrigerant at state 2 and state 3 (kJ/kg)
- h_3 = h_4

The actual compressor work can be calculated by formula below.

$$w_{act} = h_2 - h_1$$

where
- w_{act} = actual compressor work (kJ/kg)
- $h_{1,2}$ = enthalpy of refrigerant at state 1 and state 2 (kJ/kg)

The Coefficient of Performance (COP) for refrigeration system is calculated by formula below.

$$COP_{ref} = \frac{q_o}{w_{act}}$$

where
- COP_{ref} = the coefficient of performance of refrigeration
- q_o = cold output (kJ/kg)
- w_{act} = actual compressor work (kJ/kg)

The cold load which is received by water can be calculated from the difference of water inlet and outlet temperature, flow rate, density, and specific heat of water.

$$Q_{p,water} = \dot{V} \rho C_p (T_{out} - T_{in})$$

where
- $Q_{p,water}$ = Cold load (kW)
- $\dot{V}$ = Flow rate of water (m^3/s)
- ρ = 1000 kg/m^3
- C_p = 4.2 kJ/kg K
- T_{in} = Inlet Water Temperature (°C)
- T_{out} = Outlet Water Temperature (°C)