



UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 5 Examination in Engineering: July 2016

Module Number: ME5304

Module Name: Refrigeration and Air Conditioning

[Three Hours]

[Answer all questions; each question carries ten marks; provide neat sketches where necessary; make reasonable assumptions and state them clearly]

- Q1 Write answers to each section. You may use diagrams for explanations.
- a) What are the limitations of simple vapor compression refrigeration cycles? [2.0 Marks]
 - b) Briefly explain how the two-stage vapour compression refrigeration system works with flash-gas removal and intercooling arrangement. [3.0 Marks]
 - c) Explain the working principle of vapor absorption refrigeration systems. [3.0 Marks]
 - d) What are the advantages of pump less vapor absorption refrigeration systems? [2.0 Marks]
- Q2 A cascade refrigeration system for an environmental chamber is designed to operate under the following conditions;

Details	Lower stage system	High stage system
Refrigerant	R125	R22
Evaporating temperature	-51.10°C	-12.20°C
Evaporating pressure	88 kPa	327 kPa
Condensing temperature	-6.70°C	37.80°C
Condensing pressure	541 kPa	1452 kPa
Suction temperature	-28.90°C	
Sub-cooling after heat exchanger	-17.20°C	
Refrigerant load	29.3 kW	

Question continue on next page

Dry saturated refrigerant vapour (no superheating) enters the high stage compressor and saturated liquid refrigerant leaves the condenser (no sub-cooling) (refer Figure Q2). Ignore pressure losses in pipelines and valves, and assume that the compression processes for both the higher stage and lower stage systems are isentropic.

Based on the data from the properties of saturated liquid and saturated vapor of R125, the following equations can be used to calculate the enthalpies of the refrigerants;

Saturated liquid enthalpy;

$$(h_{sl}) = 48 - 1.26T_{sl} \quad \text{for temperature between } -17.8^{\circ}\text{C and } 10^{\circ}\text{C in kJ/kg}$$

T_{sl} - saturated liquid temperature in $^{\circ}\text{C}$

Saturated vapor enthalpy;

$$(h_{sv}) = 147.24 + 0.33(T_{sv} - (-62.2)) \quad \text{for temperature between } -62.2^{\circ}\text{C and } -34.4^{\circ}\text{C in kJ/kg}$$

T_{sv} - saturated vapour temperature in $^{\circ}\text{C}$

Enthalpy difference along the constant entropy line;

$$(\Delta h_{sv}) = 0.73(T_{con} - T_{ev}) \quad \text{when } T_{con} < -1.1^{\circ}\text{C and } T_{ev} > 26.7^{\circ}\text{C}$$

T_{con} - condenser temperature and T_{ev} - evaporator temperature

Specific heat of saturated vapor of R125;

$$(c_{pv}) = 586 \text{ J/kg/}^{\circ}\text{C} \quad \text{for temperature between } -62.2^{\circ}\text{C and } -40^{\circ}\text{C in kJ/kg}$$

Specific heat of saturated vapor of R125;

$$(c_{pl}) = 1256 \text{ J/kg/}^{\circ}\text{C} \quad \text{for temperature between } -17.8^{\circ}\text{C and } 10^{\circ}\text{C in kJ/kg}$$

Enthalpy of saturated vapor refrigerant R22 in the higher system is; **245.244 kJ/kg**

Enthalpy difference along constant entropy line of the higher system is; **35.0 kJ/kg**

Enthalpy of liquid refrigerant R22 at condensing temperature 37.8°C in the higher system is;

91.34 kJ/kg

Calculate the following;

- The refrigeration effect per kilogram of refrigerant in the low stage system. [3.0 Marks]
- Total work input to the compressors [3.0 Marks]
- Coefficient of Performance (COP) of this cascade system [2.0 Marks]
- Mass flow rates of the refrigerants in the higher and lower stages [2.0 Marks]

Q3 A LiBr-water based vapor absorption refrigeration system is shown in Figure Q3. If the pump delivers 0.6 kg/s and following temperatures prevail;

Generator temperature = 100°C

Condenser temperature = 40°C

Evaporator temperature = 10°C

Absorber temperature = 30°C

Temperature of weak LiBr solution enters in to the generator = 52°C.

Temperature-pressure-concentration diagram and Enthalpy of LiBr-water solutions diagram have provided.

Calculate followings;

- a) The flow rate of refrigerant (water) through the condenser and evaporator. [2.0 Marks]
- b) Heat released from the absorber [2.0 Marks]
- c) Heat absorbed by the generator [2.0 Marks]
- d) Heat absorbed through the evaporator [1.0 Marks]
- e) Heat released through the condenser [1.0 Marks]
- f) Now the ambient wet-bulb temperature decreases so that the temperature of the cooling water drops and therefore the condenser temperature reduce to 34°C . All other temperatures remain unchanged. Is there a danger of crystallization? [2.0 Marks]

- Q4
- a) Give some popular air conditioning types? [1.0 Marks]
 - b) Briefly discuss the importance of efficient air conditioning systems for the industries. [1.0 Marks]
 - c) List out major equipments that are being used for central air conditioning systems. [1.0 Marks]
 - d) By using suitable block diagram or sketch describe the working process of central air conditioning system. (*Hint: System has three operating cycles*). [3.0 Marks]
 - e) What is evaporative cooling? [1.0 Marks]

Question continue on next page

- f) Suppose that you are the design engineer of an air conditioning system that has to be built in upcoming hotel project in Jaffna in 2018. You are asked to select equipment for the system. Briefly mention the steps that you follow to prepare the equipment list.

[3.0 Marks]

- Q5. a) Briefly discuss the followings
- i) Psychrometric properties
 - ii) Psychrometric chart
 - iii) Sensible and Latent heat
 - iv) Apparatus dew point
 - v) Coil by pass factor
 - vi) Method to reduce coil by pass factor
 - vii) Sensible heat factor
 - viii) External and internal heat gain of a room

[4.0 Marks]

- b) Using schematic diagram of an air conditioning system of a room, mention mathematical relationships for sensible heat balance and latent heat balance

[1.0 Marks]

- c) Calculated sensible and latent heat gains of a conference hall are 400 kW and 120 kW, respectively. Central air conditioning system has been proposed to maintain the relative humidity (RH) at 50 % and temperature range between 18 °C to 25 °C of the hall. Fresh air of 10% by mass is taken from outside (RH 70% and temperature of 28°C). Supply air quantity for the space is 60kg/s at 80% RH. Calculate followings. Refer the Figure Q5 for Psychrometric chart.

- i) Exhaust air quantity.
- ii) Supply air flow rate to the space.
- iii) By pass factor of the coil, if coil apparatus dew point is 3°C.

[5.0 Marks]

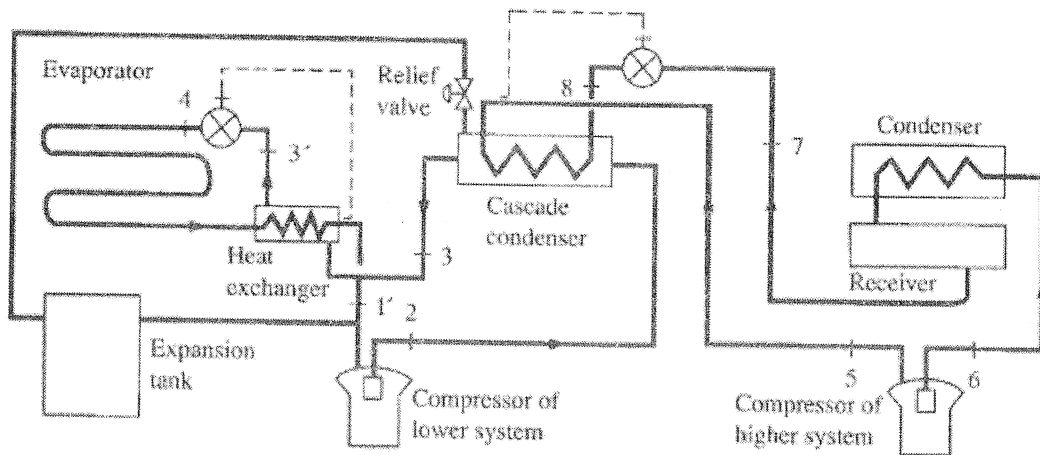


Figure Q2

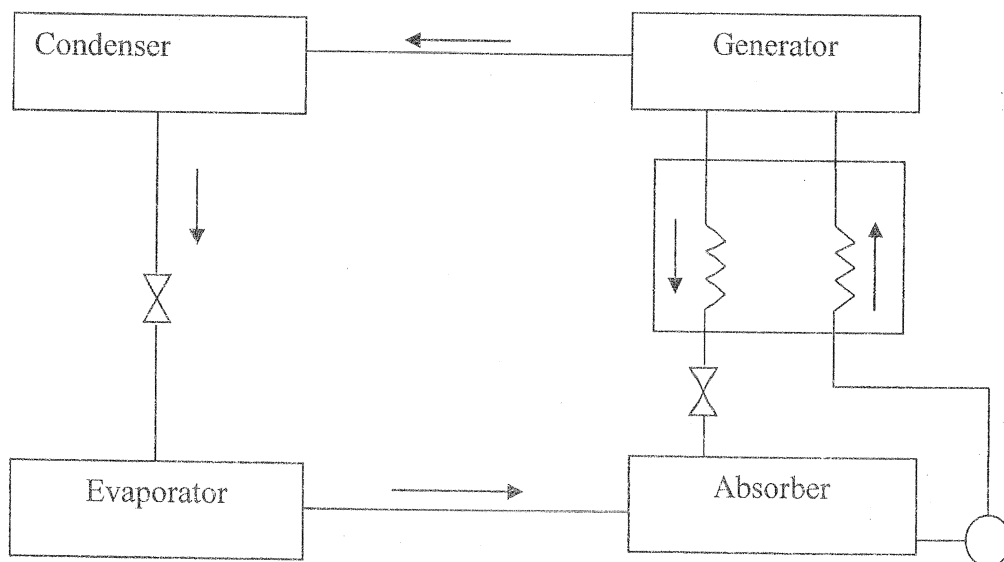
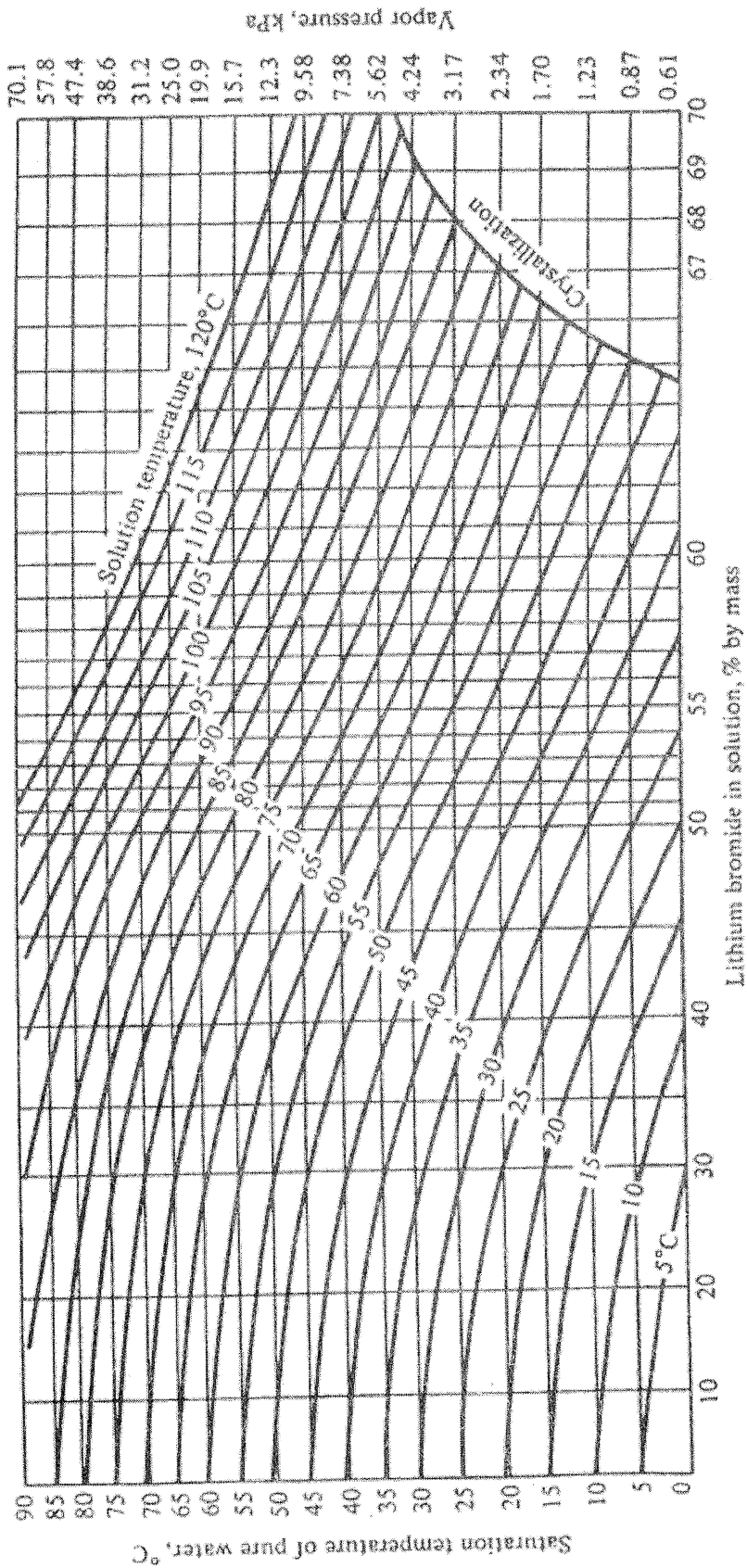
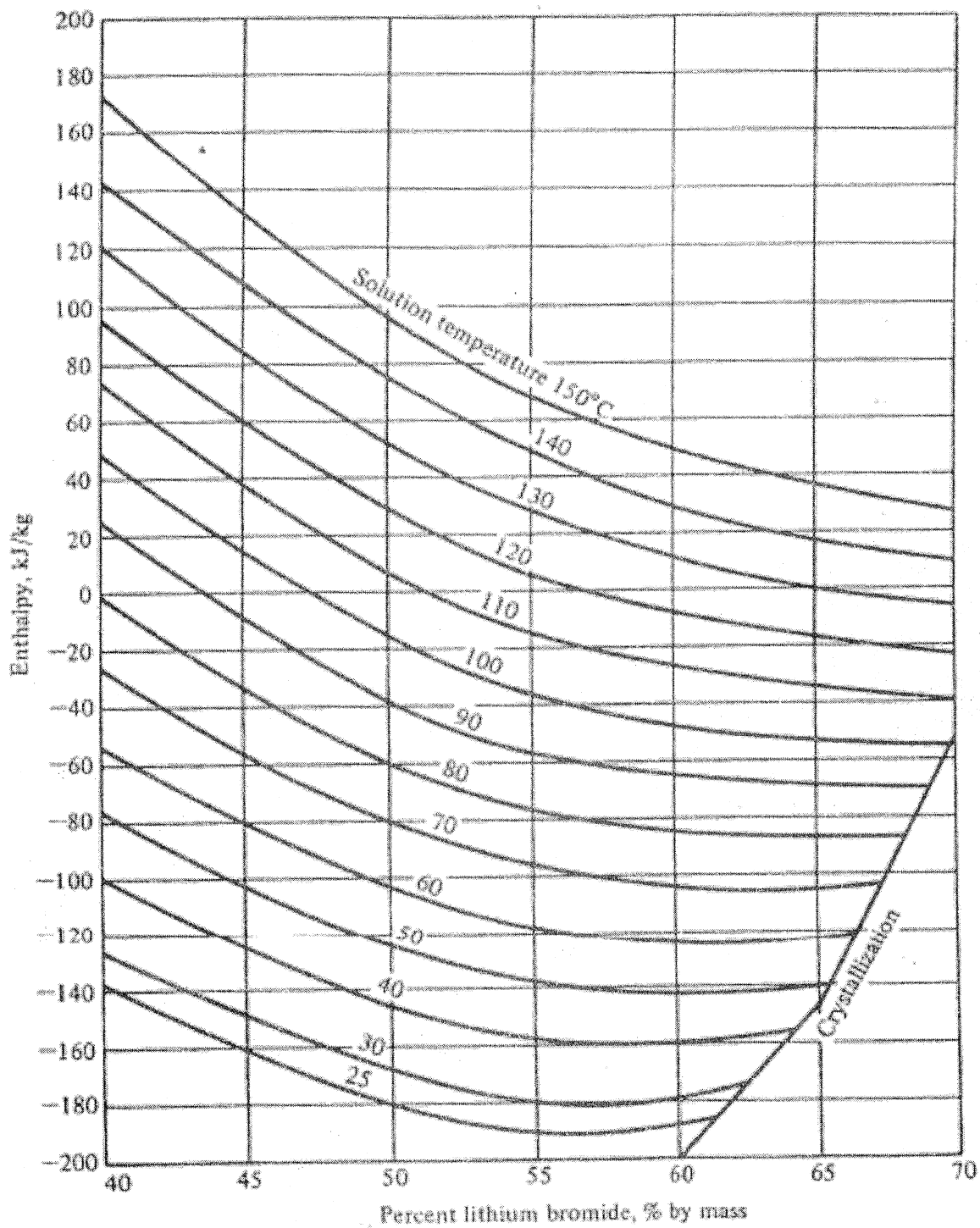


Figure Q3



temperature-pressure-concentration diagram of LiBr-water solutions



Enthalpy of LiBr-water solutions

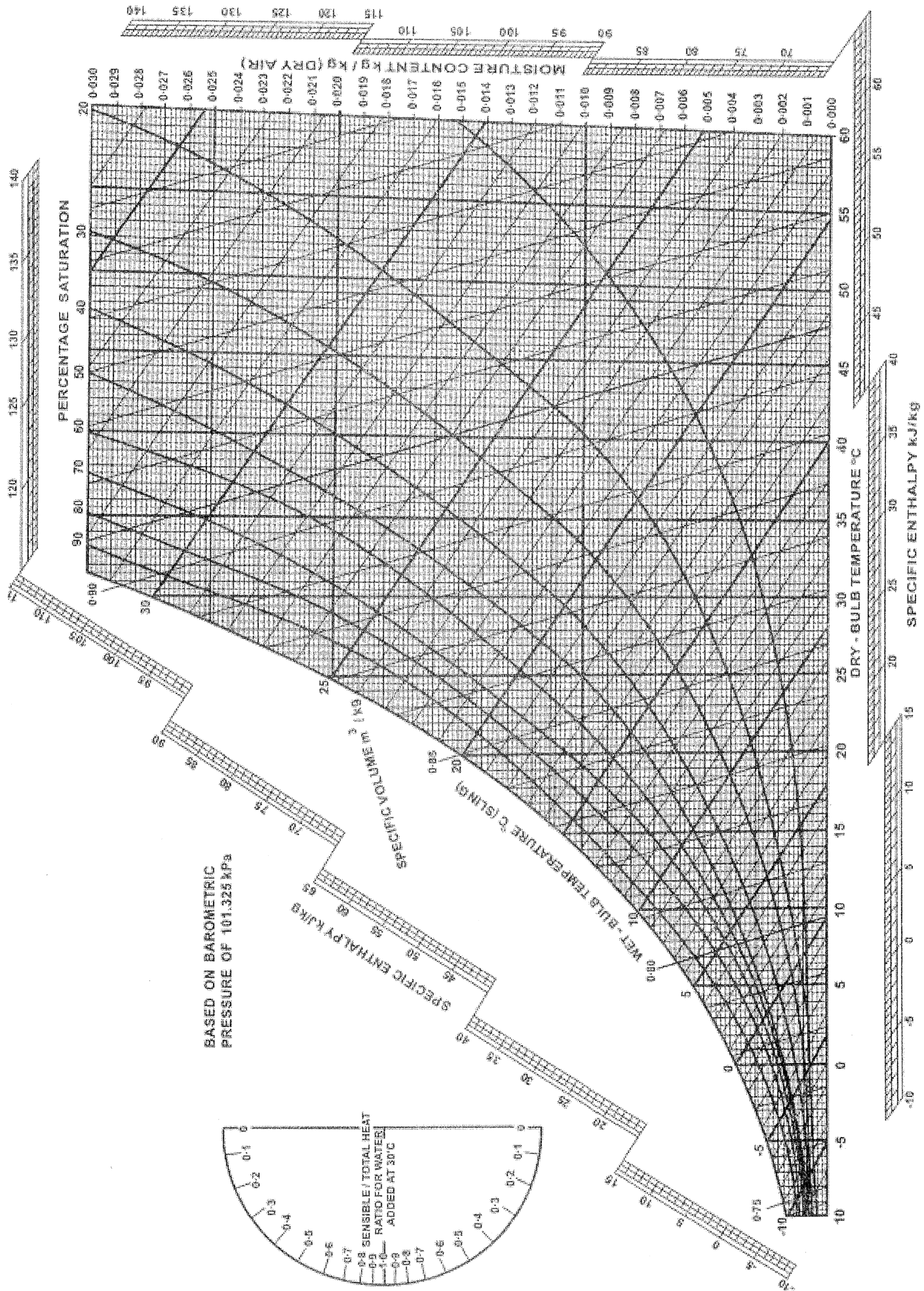


Figure Q5