UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 5 Examination in Engineering: July 2017

Module Number: ME 5304 **Module Name: Refrigeration and Air Conditioning**

[Three Hours]

[Answer **all questions**, each question carries **10** marks]

Q1. a) List four thermodynamic characteristics of an ideal refrigerant. Also, briefly explain the importance of one of them.

[2.0 Marks]

b) Sketch theoretical vapor compression refrigeration cycles on p-h and T-s diagrams with the following considerations.

i) Dry saturated vapor after compression.

ii) Wet vapor after compression.

iii) Superheated vapor after compression.

iv) Superheated vapor before compression.

v) Sub cooling of refrigerant.

[4.0 Marks]

c) An ice plant with ammonia (R-717) as the refrigerant has a refrigerant capacity of 20 TR. The temperatures of brine in the evaporator and Condenser are -15°C and 25°C, respectively. The temperatures of cooling water entering and leaving the condenser are 200C and 270 C. Ammonia is cooled to 20° C, before entering the expansion valve. If ammonia enters the compressor in dry saturated condition, calculate following for one tonne of refrigeration;

i) Heat rejected at condenser.

[1.0 Mark]

ii) Power requirement of the compressors.

[1.0 Mark]

iii) The coefficient of performance (COP) of the plant.

[2.0 Marks]

Q2. a) Draw "Cascade Refrigeration System" with a neat sketch.

[2.0 Marks]

b) What are the advantages of using a cascade refrigeration system over a multi stage refrigeration system?

[2.0 Marks]

Question 2 is continued to page 2

c) Ice cream is transported by a freezer truck having a cascade refrigeration system. The freezer temperature is to be maintained at -30°C to avoid melting of ice cream. The expected cooling load, 150 kW is obtained at the evaporator of low temperature cascade circuit using R-22 refrigerant. Heat is rejected in the cascade condenser at -2°C. The cascade condenser is cooled by the high temperature cascade using R-12 refrigerant. The temperature overlap of cascade condenser is 8°C. In the high temperature cascade, heat is rejected in the air cooled condenser at 30°C. Both low and high temperature cascade circuits are operating on an ideal vapour-compression cycle. Determine;

i) Mass flow rate for both cascades.

[2.0 Marks]

ii) Power required to run the compressors.

[2.0 Marks]

iii) COP of each cascade and the combined COP.

[2.0 Marks]

Q3. a) What are the practical problems associated with a water-lithium bromide Absorption refrigeration system?

[1.0 Mark]

b) Show that maximum COP of an Ideal Vapour Absorption Cycle is the product of efficiency of a Carnot heat engine operating between T_g and T_o and COP of a Carnot refrigeration system operating between T_o and T_e. Here T_g is generator operating temperature, T_e is evaporator operating temperature, and T_o is absorber and condenser operating temperature.

$COP_{max} = \eta_{carnot} \times COP_{carnot}$

[2.0 Marks]

(c) Consider the LiBr- H2O cycle shown in Figure Q3. The fluid flow rate through the pump is 0.6 kg/s and the operating temperatures of generator, condenser, evaporator and absorber are 100 °C, 40 °C, 10 °C and 30 °C respectively. Giving all the assumption you have made, calculate the following if the solution enters to the generator is at 52 °C;

i) The flow rate of the refrigerant through the condenser and the evaporator.

[1.0 Mark]

ii) The heat transfer at the generator, absorber, condenser, evaporator and Heat exchanger.

[1.0 Mark]

iii) The COP of the cycle.

[1.0 Mark]

Question 3 is continued to page 3

iv) If condensing temperature is reduced to 34°C, is there any chance of crystallization?

[2.0 Marks]

v) An inventor claims that the heat input to the system can be reduced by 50% by improving the design of all the components, while keeping the refrigeration capacity and operating temperatures same as before. Examine the validity of the claim.

[2.0 Marks]

Note: To find the solution properties you may use Steam Tables and the P-t-x diagram and h-t-x diagram of LiBr- H2O system provided with this question paper.

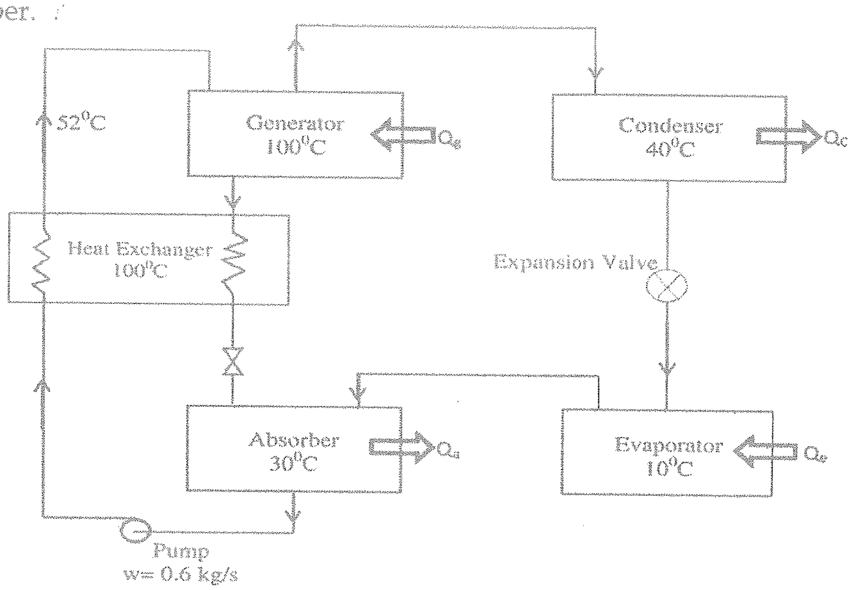


Figure Q3

Q4. (a) Discuss how Building Management System (BMS) controls the chiller and AHUs.

[1.0 Mark]

(b) Explain two reasons to use Variable Refrigerant Volume (VRV) multi split air conditioning systems in small or medium commercial applications.

[1.0 Mark]

(c) Explain working process of Air Handling Unit (AHU), by using a cross sectional view.

[2.0 Marks]

(d) Explain the working technique of Variable Air Volume (VAV) system.

[2.0 Marks]

(e) Discuss two configurations of cooling towers.

[2.0 Marks]

(f) "Efficiency of an air conditioning system will decrease with higher outside temperature" Briefly explain two possible reasons for it.

[2.0 Marks]

Q5. Total outside heat gain of a proposed conference hall is estimated to be 520kW. Maximum stage and seating capacities are 40 and 500 people respectively. Space will be maintained at 23 °C and 60 % Relative Humidity (RH) by mixing 10% by mass of fresh air at 35 °C and 60% RH. If the state of space supply air temperature and RH are 17 °C, 80 % respectively. Find the answers for following by assuming human metabolic sensible and latent heat gains are respectively 75W and 55W. You may refer Table Q5 for more details. (Clearly mention all assumptions)

(a) List out four factors that cause to generate outside heat gain for the conference hall.

[1.0 Mark]

(b) Maximum supply air flow rate.

[1.0 Mark]

(c) Maximum energy waste from fresh air systems.

[1.0 Mark]

(d) State of air entering cooling coil.

[2.0 Marks]

(e) Coil apparatus dew point (attach psychometry chat).

[1.0 Mark]

(f) Refrigerating capacity of the coil.

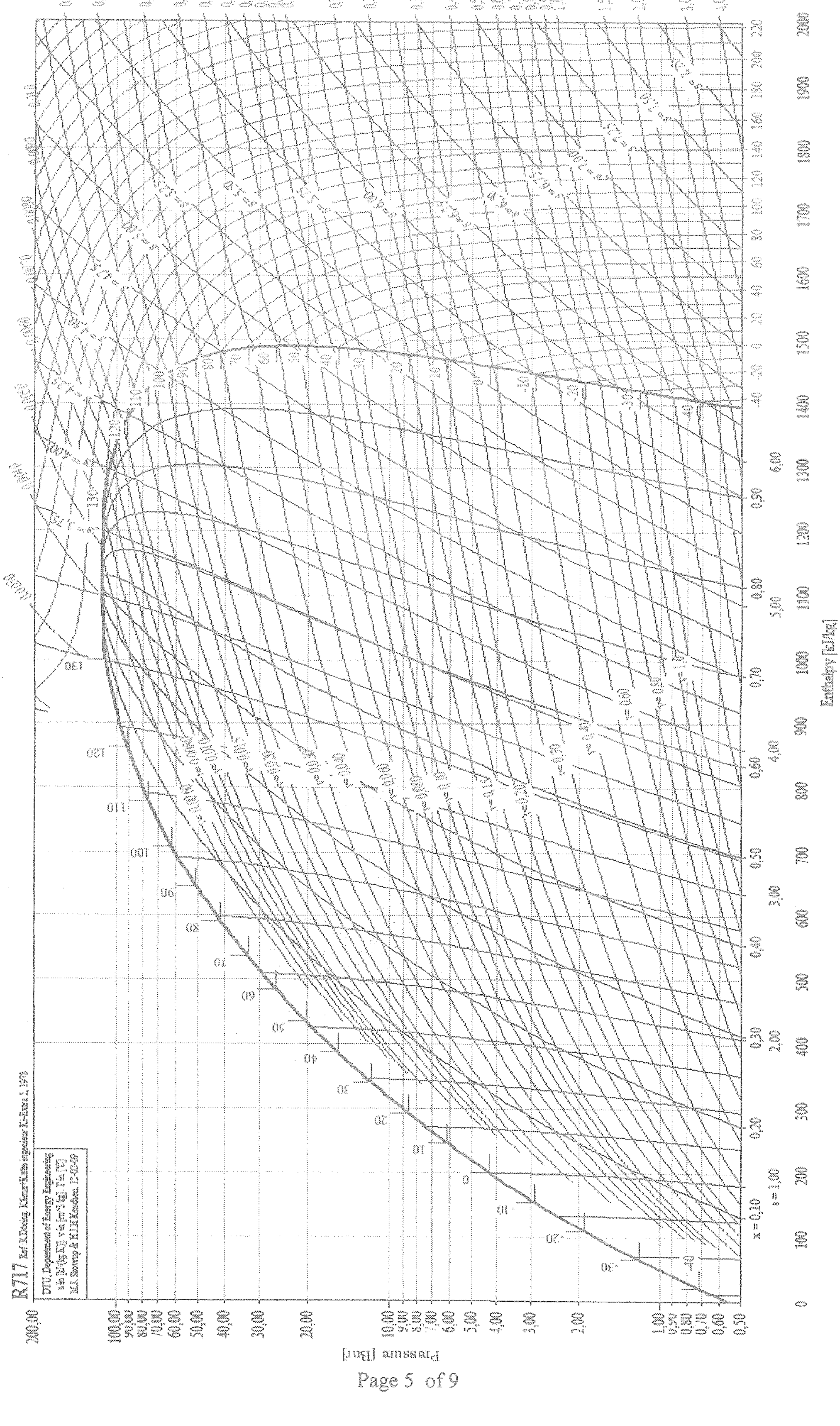
[2.0 Marks]

(g) Assuming 20% safety margin, indicate the calculated values on a clearly define systematic diagram of a central air conditioning plant.

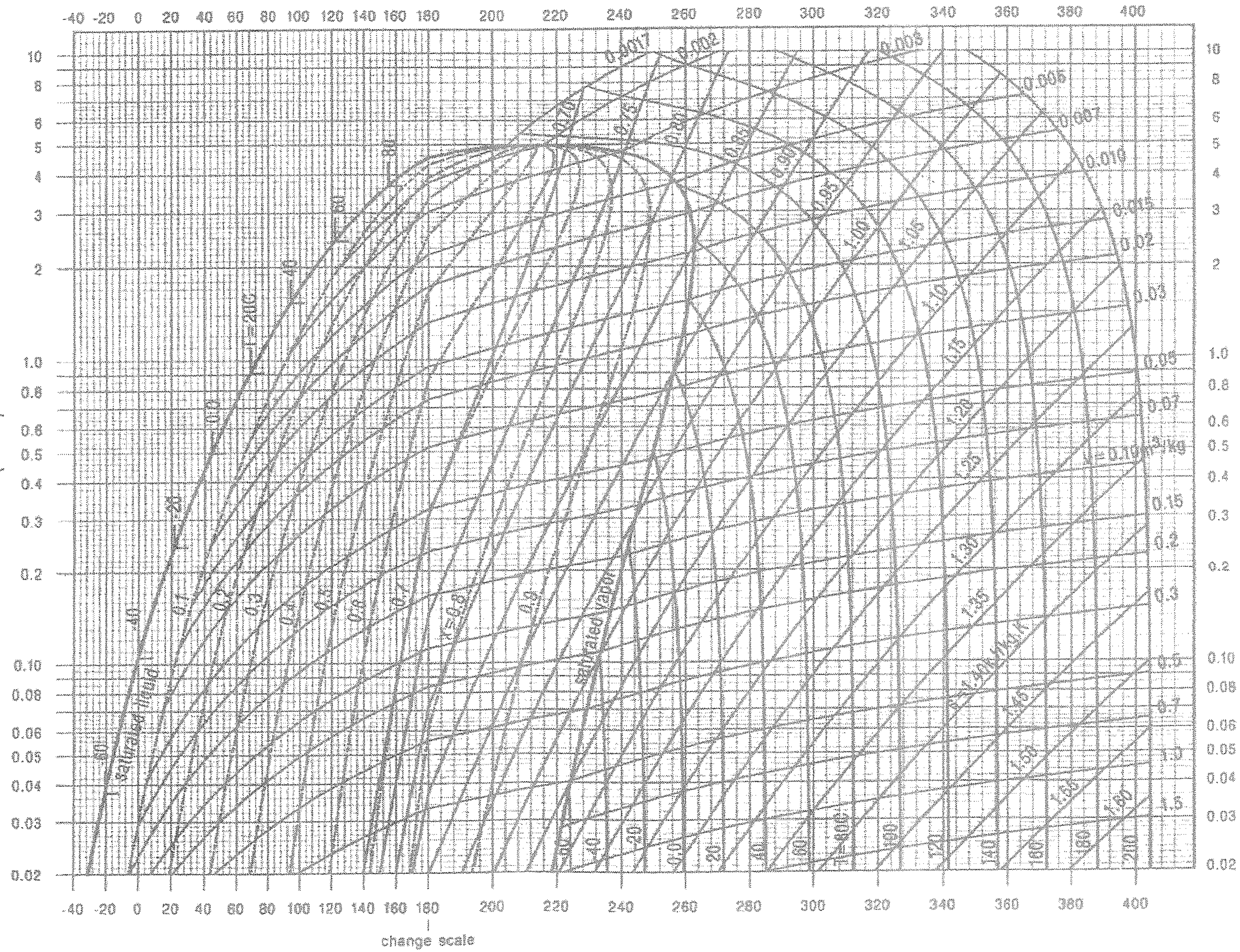
[2.0 Marks]

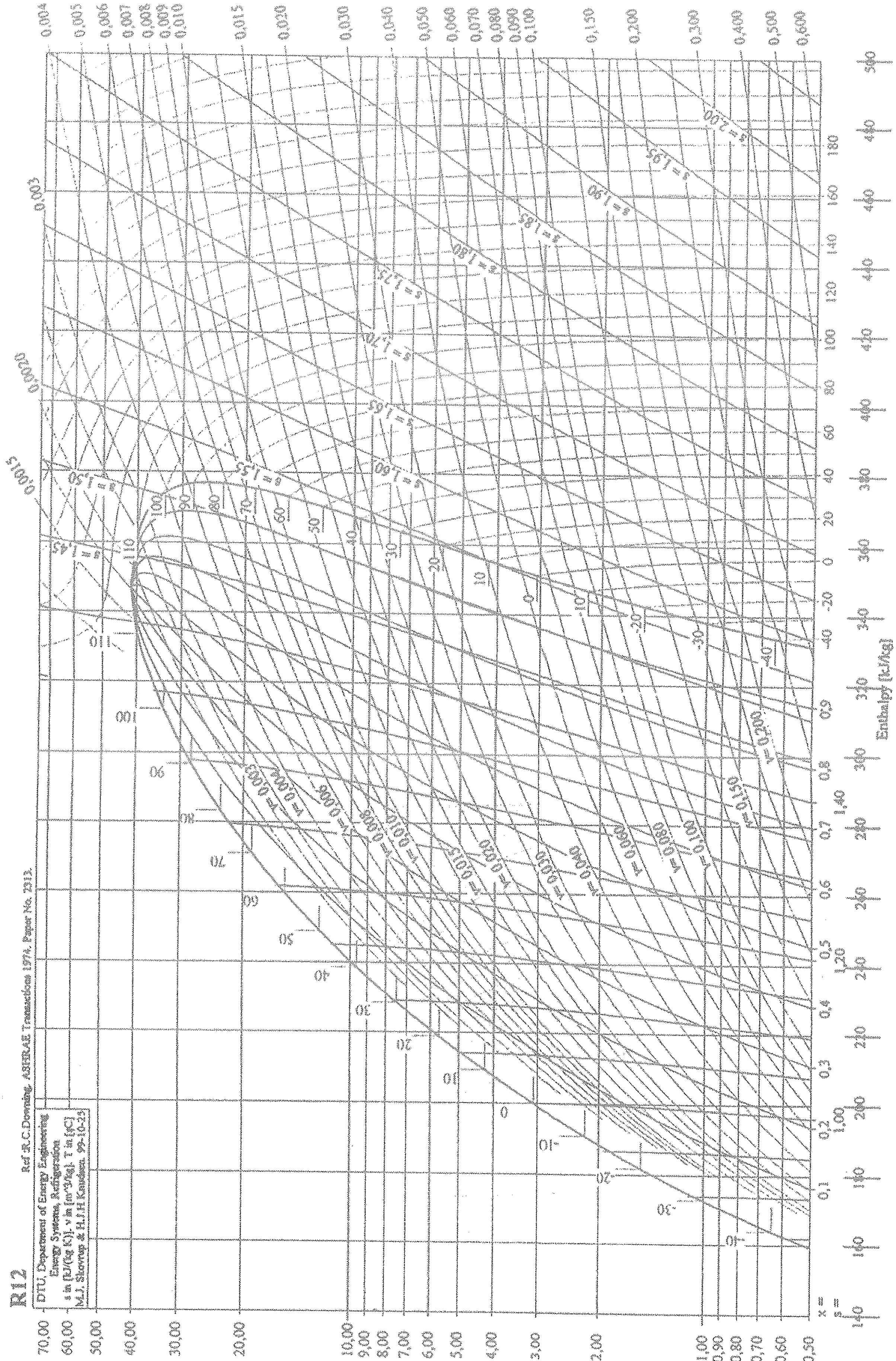
Table Q5

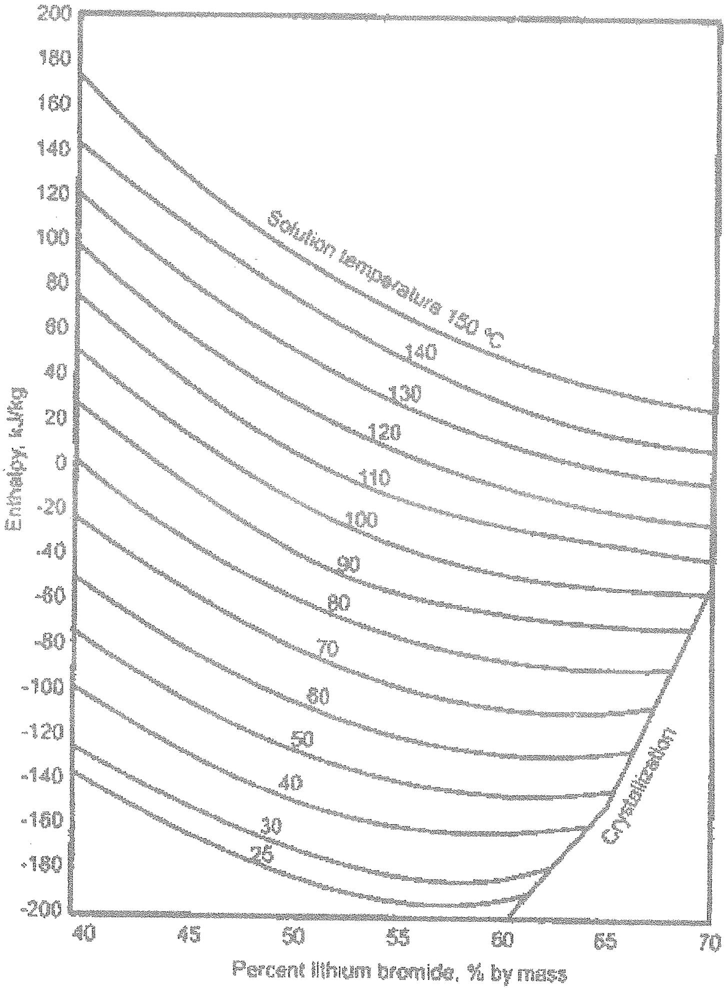
Equipment	**Quantity**	**Energy Usage**
Computer	2 Nos	200W
Flash light	20 Nos	350W
Fluorescent lamp	50 Nos	100W
Speakers	8 Nos	2800W
Ceiling fan	40 Nos	450W
LED smoke fog machine	3 Nos	600W
Portable air conditioner	5 Nos	5000BTU/hr


R717
DTU, Department of Energy Engineering
Pressure [Bar]
Enthalpy [kJ/kg]

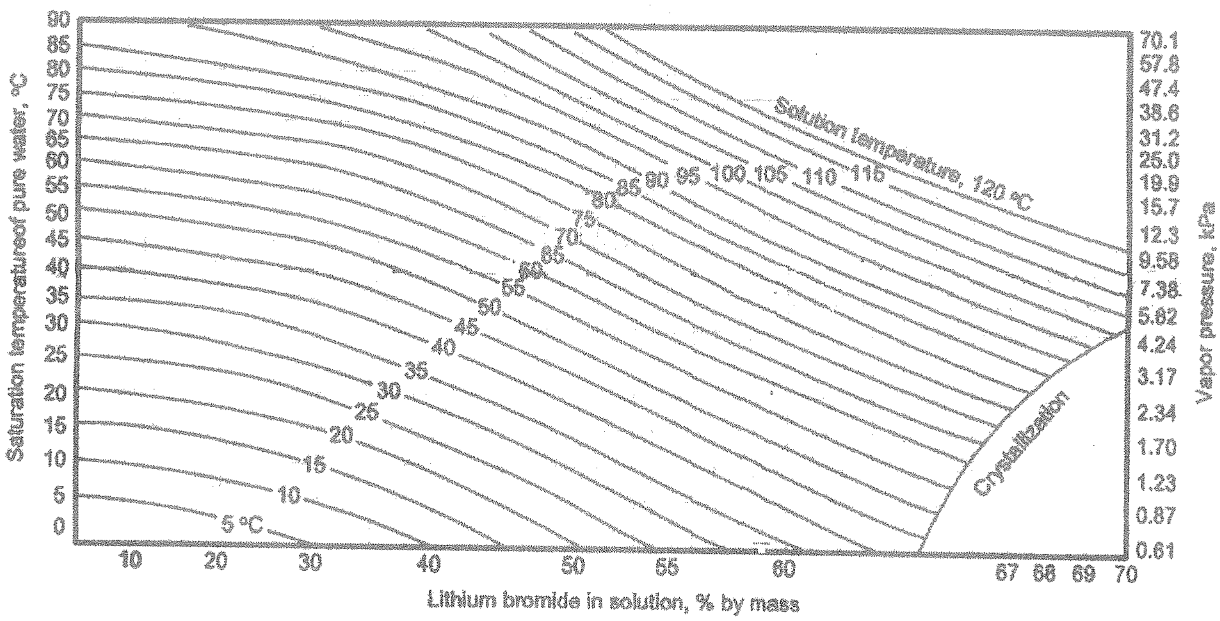
Pressure-Enthalpy Diagram for R22



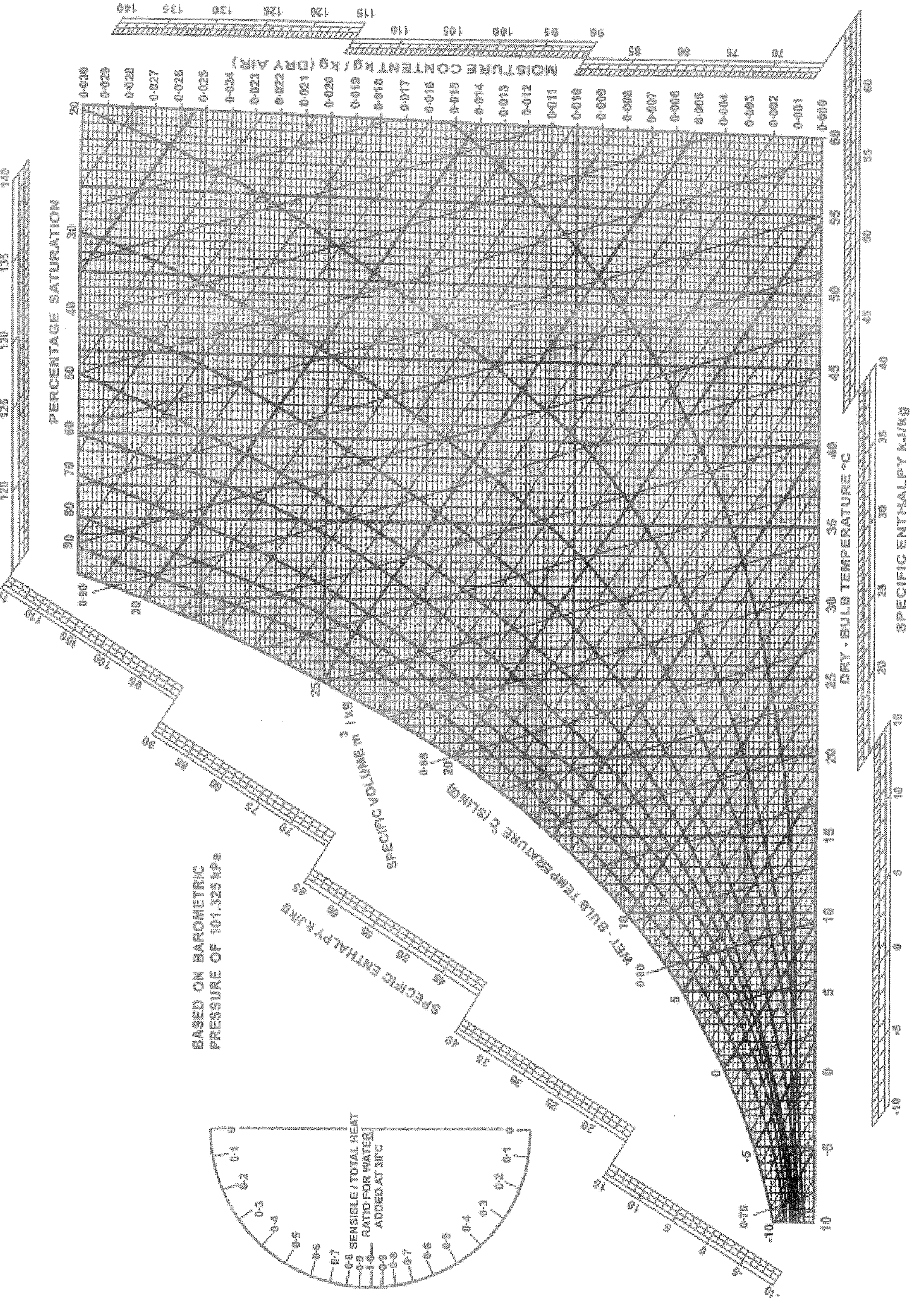

R12
DTU, Department of Energy Engineering
Energy Systems, Refrigeration
s in [kJ/(kg K)], v in [m^3/kg], T in [C]
M.J. Skovrup & H.J.H Knudsen. 99-10-25
Ref :R.C.Downing, ASHRAE Transactions 1974, Paper No. 2313.
Pressure [Bar]
Enthalpy [kJ/kg]



Enthalpy –Temperature - Concentration diagram for H2O-LiBr solution



Pressure –Temperature - Concentration diagram for H2O-LiBr solution


BASED ON BAROMETRIC
PRESSURE OF 101.325 kPa
PERCENTAGE SATURATION
MOISTURE CONTENT kg / kg (DRY AIR)
DRY - BULB TEMPERATURE °C
SPECIFIC ENTHALPY kJ/kg
SPECIFIC VOLUME m³/kg
WET - BULB TEMPERATURE °C (SLING)
SPECIFIC ENTHALPY kJ/kg
SENSIBLE / TOTAL HEAT
RATIO FOR WATER
ADDED AT 30°C