UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 5 Examination in Engineering: October 2019

Module Number: ME5304 **Module Name: Refrigeration and Air-Conditioning**

[Three Hours]

[Answer **all questions**; Each question carries **ten marks**; Provide neat sketches and state any reasonable assumptions made; Symbols have their usual meaning; Psychometric chart, steam tables and enthalpy concentration diagram for R12 are provided]

Q1 a) Explain the differences between theoretical and actual vapour compression refrigeration systems with the aid of clear diagrams.

[2.0 Marks]

b) What are the reasons for sub cooling the refrigerants in a refrigerator before entering in to the expansion valve? How does it affect for the coefficient of performance (C.O.P.) of the system?

[2.0 Marks]

c) A vapour compression refrigeration system is having a capacity of 50 TR, running by using R12 as a refrigerant. The evaporator and the condenser pressure of the system are 1 bar and 7 bar respectively. The vapour is dry and saturate before entering in to the compressor. Sketch P-h diagram of the refrigeration cycle and determine the following.

i) Mass flow rate of the refrigerant.

[2.5 Marks]

ii) Work input to the compressor.

[1.5 Marks]

iii) C.O.P. of the system.

[1.0 Mark]

iv) C.O.P. of the system, if the R12 is sub cooled up to 20 °C before the expansion at the throttling valve.

[1.0 Mark]

Q2 The vapour absorption refrigeration system uses heat energy, instead of mechanical energy as in vapour compression systems, in order to change the conditions of the refrigerant required for the operation of the refrigeration cycle.

a) Draw schematic diagrams of the simple vapour absorption refrigeration system and practical vapour absorption refrigeration system and briefly explain its operations.

[6.0 Marks]

b) The vapour absorption refrigeration system can be considered as a perfectly reversible system, the initial entropy of the system must be equal to the entropy of the system after change in its condition. Starting from first law of thermodynamics, show that the C.O.P. of the vapour absorption refrigeration system is given by,

$$\left(\frac{T_E}{T_C - T_E}\right)\left(\frac{T_G - T_C}{T_G}\right)$$

where,

T_E – temperature at which heat is absorbed in the evaporator

T_C – temperature at which heat is discharged to the atmosphere or cooling water from the condenser and absorber

T_G – temperature at which heat is given to the generator

[4.0 Marks]

Q3 a) In an aqua-ammonia simple vapour absorption refrigeration cycle, evaporator, absorber, condenser, and generator temperatures are -40 °C, 30 °C, 40 °C, and 100 °C, respectively. The properties of aqua-ammonia are as follows.

Particulars	Concentration (mass of NH_3/mass of solution)	Enthalpy (kJ/kg)
Strong solution leaving the absorber	0.433	67
Weak solution leaving the generator	0.387	378
Vapour leaving the generator	0.957	1925
Liquid leaving the condenser	0.957	528
Vapour leaving the evaporator	0.957	1443

i) For 1.5 TR capacity, determine the mass flow rate of solution in evaporator.

[1.5 Marks]

ii) Consider overall mass balance and material balance or partial mass balance of NH_3 in absorber. This will give two equations, solve them to determine mass flow rates of strong and weak solutions.

[1.5 Marks]

iii) Determine absorber heat rejection and generator heat transfer by considering energy balance in the absorber and generator.

[2.0 Marks]

iv) Evaluate the condenser heat rejection.

[1.0 Mark]

v) Check the overall energy balance by neglecting pump work and then find C.O.P. of the system.

[2.0 Marks]

b) Domestic electrolux refrigerator is also known as three-fluid absorption system. What are the three fluids used in domestic electrolux refrigerator system and briefly explain functions of each fluid.

[2.0 Marks]

Q4 a) Define the following terms.

i) Dry air

ii) Saturated air

iii) Degree of saturation

iv) Relative humidity
v) Dew point temperature
vi) Dew point depression

[3.0 Marks]

b) The humidity ratio of atmospheric air at 28 °C dry bulb temperature and a pressure of 760 mmHg is 0.016 kg/kg of dry air. Determine the following using steam table.

i) Partial pressure of water vapour.

[1.5 Marks]

ii) Relative humidity of air.

[1.5 Marks]

iii) Dew point temperature of air.

[0.5 Marks]

iv) Specific enthalpy of air per kg of dry air.

[1.5 Marks]

v) Vapour density.

[0.5 Marks]

Take the gas constant for air as 0.287 kJ/kg K.

Note:

The specific enthalpy of air and vapour density are given to be,

$$h = 1.022t_d + W(h_{fgdp} + 2.3\,t_{dp})$$

and

$$\rho_v = \frac{W(p_b - p_v)}{R_a T_d}, \qquad \text{respectively.}$$

c) Air conditioning systems can be broadly classified according to the purpose, season of the year, and arrangement of equipment. What are the sub categories of each classification?

[1.5 Marks]

Q5 a) At a certain location, the dry bulb temperature of air is 33 °C and the relative humidity is 40 %.

i) Determine the specific humidity, dew point temperature, and wet bulb temperature of air.

[4.0 Marks]

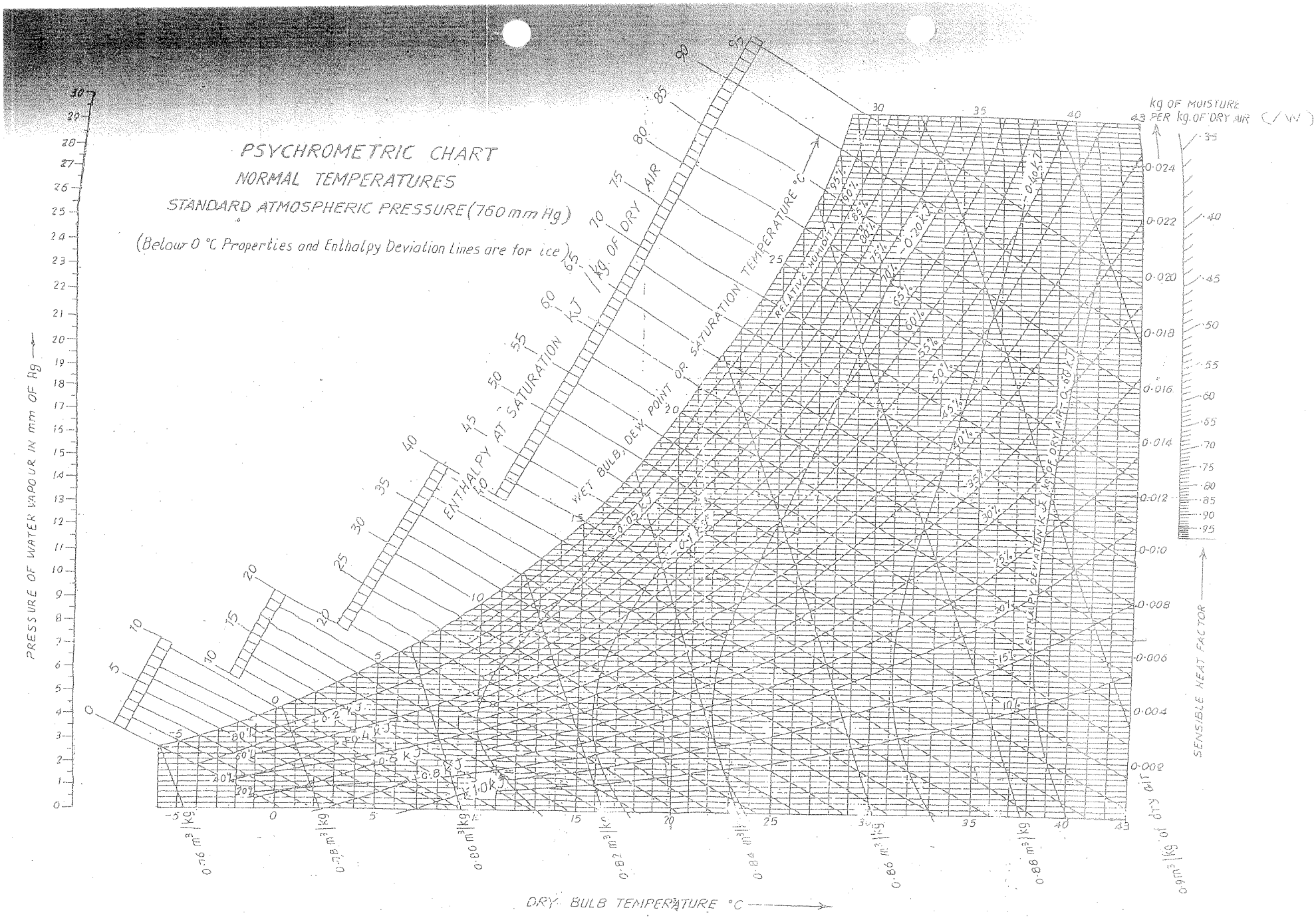
ii) If this air is cooled in an air washer using re-circulated spray water and having a humidifying efficiency of 0.92, what are dry bulb temperature and dew point temperature of air leaving the air washer?

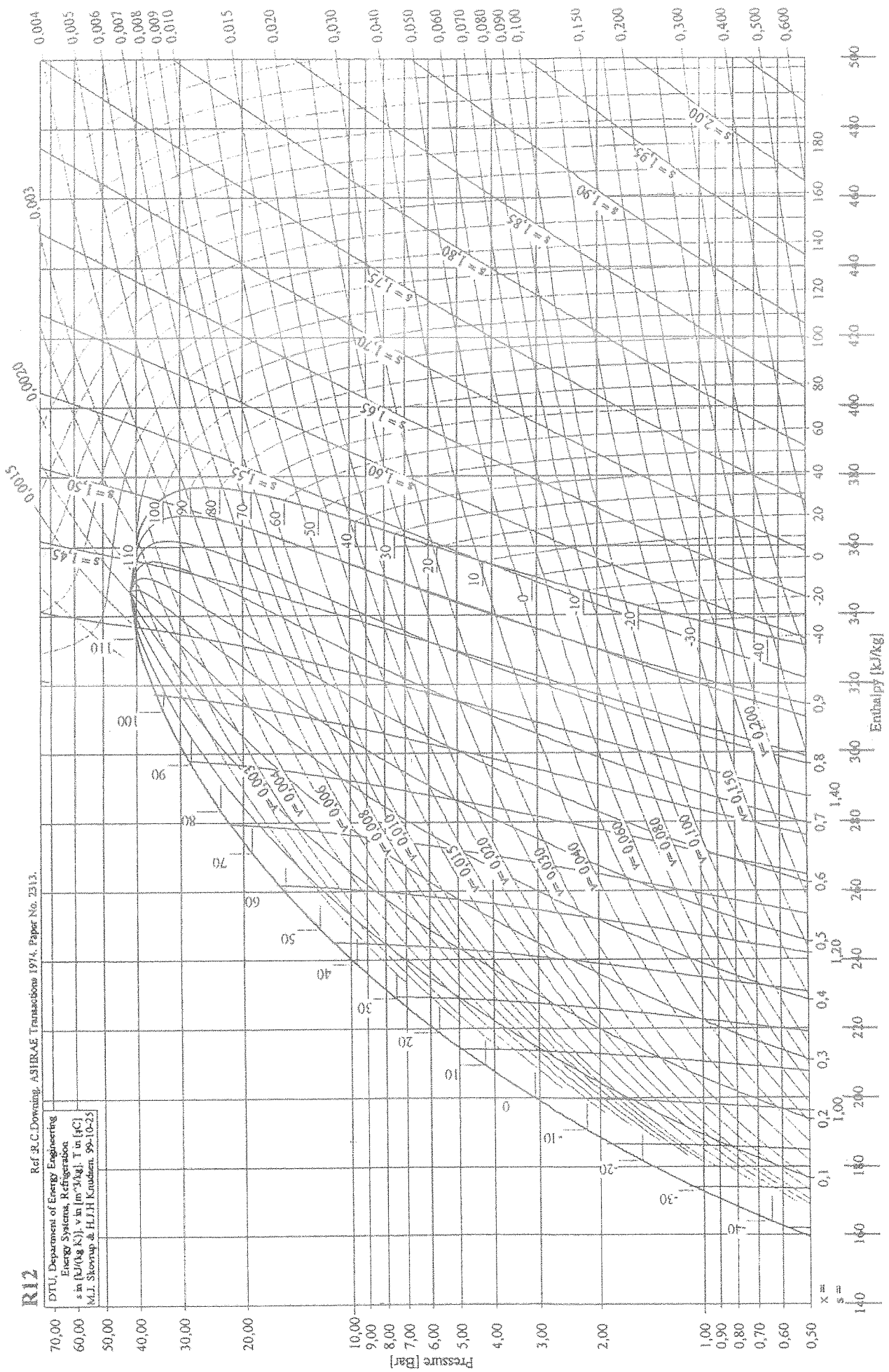
[3.0 Marks]

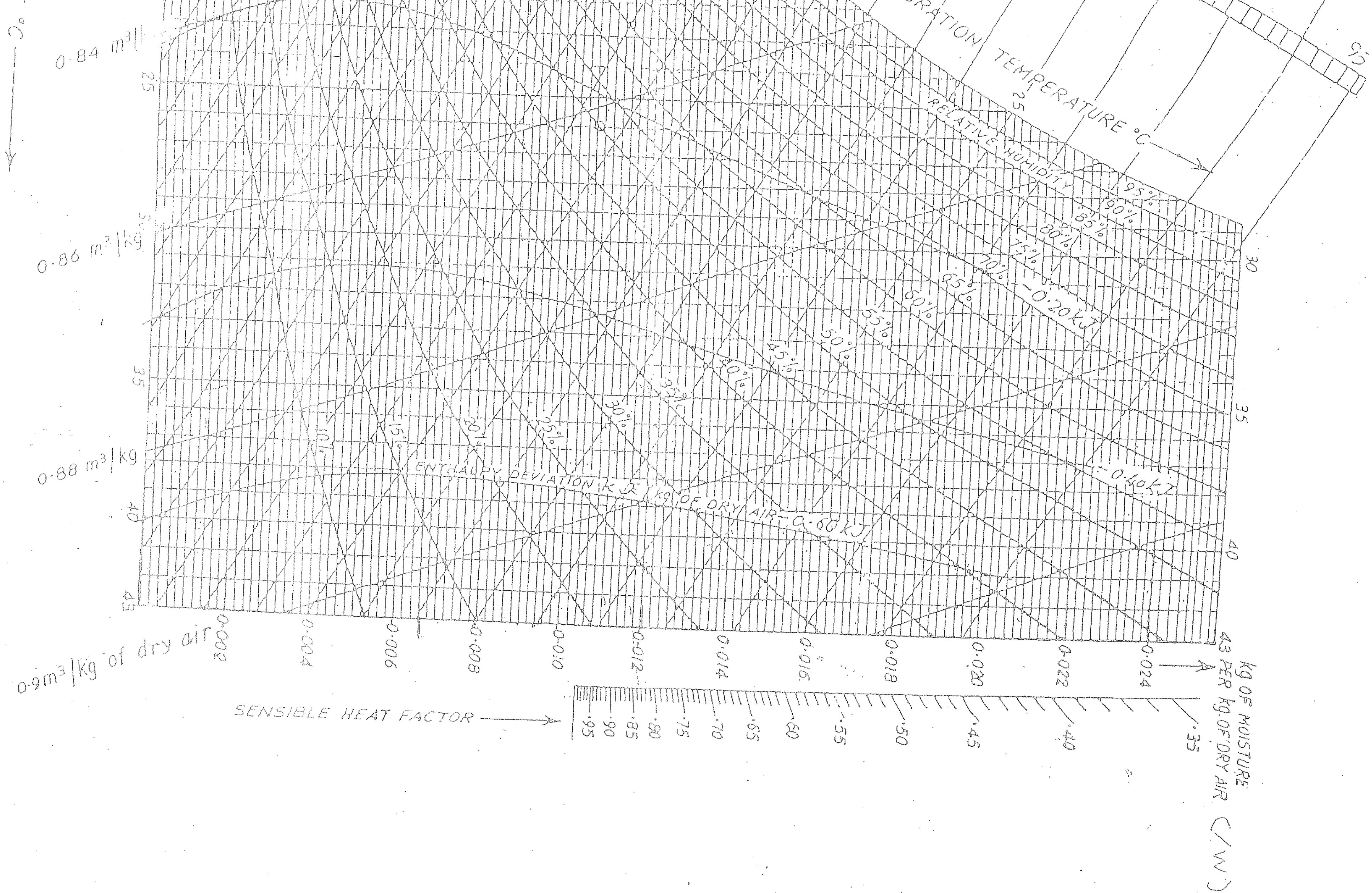
Note:

The humidifying efficiency is given to be,

$$\frac{t_{d1} - t_{d2}}{t_{d1} - t_{d3}}.$$


PSYCHROMETRIC CHART
NORMAL TEMPERATURES
STANDARD ATMOSPHERIC PRESSURE (760 mm Hg)
(Below 0 °C Properties and Enthalpy Deviation lines are for ice)
PRESSURE OF WATER VAPOUR IN mm OF Hg
DRY BULB TEMPERATURE °C
kg OF MOISTURE PER kg OF DRY AIR
SENSIBLE HEAT FACTOR
WET BULB, DEW POINT OR SATURATION TEMPERATURE °C
ENTHALPY AT SATURATION kJ / kg OF DRY AIR
RELATIVE HUMIDITY
ENTHALPY DEVIATION IN kJ / kg OF DRY AIR
m³ / kg of dry air


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



0.84 m³/kg
0.86 m³/kg
0.88 m³/kg
0.9m³/kg of dry air
ENTHALPY DEVIATION KJ/kg OF DRY AIR
-0.20 kJ
-0.40 kJ
-0.60 kJ
RELATIVE HUMIDITY
TEMPERATURE °C
SENSIBLE HEAT FACTOR
kg OF MOISTURE PER kg OF DRY AIR (W)