Indian Forest Service Examination-2012

D–GT–M–NFB

MECHANICAL ENGINEERING

Paper—II

Time Allowed : Three Hours

Maximum Marks : 200

INSTRUCTIONS

Candidates should attempt Question Nos. 1 and 5 which are compulsory, and any ***THREE*** *of the remaining questions, selecting at least* ***ONE*** *question from each Section.*

All questions carry equal marks.

Marks allotted to parts of a question are indicated against each.

Answers must be written in ***ENGLISH*** *only.*

If any data is considered insufficient, assume suitable value and indicate the same clearly.

Newton may be converted to kgf using the equality

1 kilonewton (1 kN) = 100 kgf, if found necessary.

All answers should be in SI units.

Take : 1 kcal = 4·187 kJ and 1 kg/cm^2 = 0·98 bar

1 bar = 10^5 pascals.

Universal gas constant = 8314·6 J/kmol-K.

Neat sketches may be drawn, wherever required.

A psychrometric chart is attached to this question paper.

Important Note :—

All parts/sub-parts of a question must be attempted contiguously. That is, candidates must complete attempting all parts/sub-parts of a question being answered in the answer-book before moving on to the next question.

Pages left blank, if any, in the answer-book(s) must be clearly struck out. Answers that follow pages left blank may not be given credit.

SECTION—A

1. (a) 0·05 kg of carbon dioxide (molar mass 44 kg/kmol) is compressed from 1 bar, 15°C, until the pressure is 8·3 bar, and the volume is then 0·004 m^3. Calculate the change of entropy. Take C_p for carbon dioxide as 0·88 kJ/kg K, and assume carbon dioxide to be a perfect gas. Represent the states on pressure-volume and on temperature-entropy diagrams. 10

(Contd.)

(b) Petrol used in SI engine is assumed to have a chemical formula C_7H_{16}. Determine :

(i) stoichiometric A/F ratio.

(ii) If 50% excess air is supplied then find the volumetric composition of dry exhaust products.

Air contains 23% of O_2 & 77% of N_2 by Mass. 10

(c) A refrigerator has working temperatures in the evaporator and condenser as – 23°C and 37°C respectively. The environment temperature is 27°C. The required refrigeration temperature is –13°C. What is the maximum COP possible ? If the actual COP of the refrigerator is 0·65 of the maximum, calculate the required power input for a refrigerating effect of 5 kW. 10

(d) List the merits and demerits of pulverized coal firing system. Differentiate between pulverized dry-bottom furnace and wet-bottom furnace. 10

2. (a) A test on a single cylinder engine, four stroke having bore 180 mm and stroke 360 mm yielded the following results :

Speed	285 rev/min.
Brake Torque	393 Nm
IMEP	7·2 bar
Fuel consumption	3·5 kg/hr
Cooling water flow	4·5 kg/min
Cooling water temp. rise	36°C
A/F ratio by mass	25
Exhaust gas temp.	415°C
Barometric pressure	1·013 bar
Room temperature	21°C

Fuel has a calorific value 45200 kJ/kg and contains 15% by mass of hydrogen.

Determine :

(i) indicated thermal efficiency.

(ii) The volumetric efficiency based on atmospheric conditions.

(iii) Draw up a heat balance in terms of kJ/min explaining clearly the content of such term.

Take R = 0·287 kJ/kgK,

C_v for dry exhaust gases = 1·005 kJ/kgK

C_p for superheated steam = 2·05 kJ/kgK. 15

(Contd.)

(b) Consider three fluids with Prandtl numbers of 0·01, 1 and 100 flowing in a circular tube. Calculate the ratio of the L_{th} and L_e. L_{th} is the length required to achieve a fully-developed temperature profile and L_e is the length required to obtain a fully-developed velocity profile. Assume that the flow is laminar and that the heat transfer takes place with a constant wall heat flux boundary condition.

Comment on : (i) the Prandtl numbers given in this problem. Give suitable example corresponding to these Prandtl numbers. (ii) L_{th} and L_e at these Prandtl numbers and justify the same. 10

(c) Why are downcomers fewer in number and bigger in diameter, while risers are more in number and smaller in diameter in a water tube boiler ?

Describe the working principle of a modern natural circulation boiler.

What are the functions of preheater, reheater, economizer and superheaters ? Where are these located ? 15

3. (a) Discuss the process of combustion in CI engine and also explain various stages of combustion. Discuss the factors that affect the delay period. 15

(b) (A) What is fouling ? What is fouling factor ? Is fouling desirable ?

(B) Sea water below 50°C is passed through the cooling coils of a large electromagnet. The heat transfer coefficient with clean coils is 2000 W/m^{2}K. Calculate the heat transfer coefficient including the effects of fouling. What is the percentage reduction in the value of the heat transfer coefficient ? Fouling factor for sea water is 0·0001 m^2 K/W.

(C) In addition to thermal aspects of designing a heat exchanger, list other factors which need careful consideration. Which of these factors influence running cost ? What should be the basis for optimising design of a heat exchanger ?

2+6+2=10

(c) (i) What are the functions of a condenser in a steam power plant ?

How does a cooling tower operate ? Define a dry cooling tower. When is it recommended ?

(ii) Explain the meaning of draught as applied to boilers. How is it produced by various methods ? Write down the specific advantages of balance draught system.

10+5

4. (a) A 4 stroke single cylinder diesel engine develops a 36 kW when running at 800 rpm and consumes 240 gms/kWh. The pressure of the air in the cylinder at the beginning of injection and at the end of injection are 40 bar and 60 bar. The injection pressure at the beginning and end of injection are 200 bar and 600 bar respectively.

(Contd.)

Determine the diameter of the nozzle if the injection is carried out during 15° rotation of the crank. The ambient pressure and temp. are 1·013 bar and 27°C. $Cd_f = 0{\cdot}6$ and $\rho_f = 800$ kg/m³. 15

(b) A vapour compression plant uses R134-a and has a suction temperature of –5°C and a condenser saturation temperature of 45°C. The vapour is dry saturated on entering the compressor and there is no undercooling of the condensate. The compression is carried out isentropically in two stages and a flash chamber is employed at an interstage saturation temperature of 15°C. Calculate :

(i) the amount of vapour bled off at the flash chamber;

(ii) the state of the vapour at the inlet to the second stage of compression;

(iii) the refrigerating effect per unit mass of refrigerant in the condenser;

(iv) the work done per unit mass of refrigerant in the condenser;

(v) the coefficient of performance. 15

Properties of R134-a are given below.

Data for R134-a

Saturation Values							Superheat			
t	Sat.	v_g	h_f	h_g	s_f	s_g	10 K		20 K	
°C	Pressure (bar)	m³/kg	kJ/kg		kJ/kg K		h kJ/kg	s kJ/kg K	h kJ/kg	s kJ/kg K
–5	2·4371	0·081	93·46	291·77	0·9760	1·7155	302·18	1·7536	312·05	1·7884
15	4·8734	0·042	120·06	303·38	1·0709	1·7071	314·86	1·7463	325·59	1·7817
45	11·5447	0·017	162·93	319·54	1·2105	1·7028	332·87	1·7440	345·04	1·7804

(c) With the help of a sketch, discuss the working principle of boiling water reactor and explain in brief the function of main elements. 10

SECTION—B

5. (a) Given that

$$C_p = T\cdot\left(\frac{\partial S}{\partial T}\right)_p \quad \text{and} \quad C_v = T\cdot\left(\frac{\partial S}{\partial T}\right)_v$$

obtain the expressions of

$\left[\frac{\partial C_p}{\partial p}\right]_T$ and $\left[\frac{\partial C_v}{\partial v}\right]_T$ using Maxwell's and other relations.

Using the above derived equations, show that C_p and C_v for an ideal gas are functions of temperature only. 10

(Contd.)

(b) (i) Discuss the three-way catalytic converter used in S.I. engines. Why isn't a normal three-way catalytic converter, as used with S.I. engines as useful, when used with C.I. engines ?

(ii) Discuss main methods used to limit No_x emissions on a modern automobile. 5+5=10

(c) A mild steel tank of wall thickness 10 mm contains water at 90°C when the atmospheric temperature is 15°C. The thermal conductivity of mild steel is 50 W/mK and the heat transfer coefficients for the inside and outside of the tank are 2800 and 11 W/m^2 K respectively. Calculate :

(i) the rate of heat loss per unit area of tank surface.

(ii) the temperature of the outside surface of the tank. 10

(d) Explain stalling and surging phenomenon in compressors with the help of head-discharge curves. 10

6. (a) An automobile has 3·2 liter five cylinder, four stroke cycle diesel engine operating at 2400 rpm. Fuel injection occurs from 20° bTDC to 5° aTDC. The engine has a volumetric efficiency of 0·95 & operates with fuel equivalence ratio of 0·80. Light diesel fuel is used. The pressure is 101 kPa, Temp. 298 K, R = 0·287 kJ/kg K. Calculate :—

(i) time for one injection.

(ii) fuel flow rate through an injector. 10

(b) (A) Define effective temperature (ET). Does it meet comfort criteria ? Justify.

(B) Define Bypass Factor (BF). Illustrate the influence of bypass factor on various parameters. Is it desirable to have high bypass factor ? Discuss extreme possible cases.

(C) Discuss evaporative cooling with the help of a schematic diagram and psychrometric chart. Discuss limitations of evaporative cooling.

(D) In an industrial evaporative cooling application with summer outdoor design conditions of 40°C DBT, 27°C WBT; the indoor is to be maintained at a maximum relative humidity of 55%. The room sensible heat is 581·5 kW. All outdoor air must be used. Find the room dry bulb temperature and supply air quantity as a function of humidifying efficiencies of 80 and 100%. Comment on the DBT in the room and supply air quantity in both these cases. 2+2+2+9=15

(c) (A) The incremental fuel costs for two generating units a and b of a power plant are given by the following relations :

$$\frac{dF_A}{dP_A} = 0{\cdot}06\,P_A + 11{\cdot}4$$

$$\frac{dF_B}{dP_B} = 0{\cdot}07\,P_B + 10$$

(Contd.)

where P is the power in MW and F is the fuel cost in rupees per hour.

(i) Find the economic loading of the two units when the total load to be supplied by the power station is 150 MW.

(ii) Find the net increase in fuel cost per hour if the load is equally shared by the two units.

(B) What are the considerations to be made while selecting the suitable site for a steam and a hydro power plant ?

10+5

7. (a) (A) You are required to predict performance of a given heat exchanger. What method would you use ? Why ?

(B) A parallel flow heat exchanger has a hot and a cold water stream running through it. The flow rates are 10 and 25 kg/min and the inlet temperatures are 70°C and 25°C on the hot and the cold side respectively. Calculate the area of the heat exchanger if (i) the individual heat transfer coefficients on both sides are 1600 W/m^2 K; (ii) effects of fouling can be neglected; and (iii) the exit temperature on the hot side is required to be 50°C.

(C) For the problem in (B) above, calculate the exit temperature of the hot and cold streams in this heat exchanger if the hot water flow rate is doubled to 20 kg/min and it is known that the individual heat transfer coefficients are proportional to the 0·8th power of the flow rates.

1+7+2=10

(b) (A) Illustrate with the help of schematic of psychrometric chart, determination of apparatus dew point (ADP) using ESHF. Discuss extreme possible cases and measures to be taken to overcome such cases.

(B) A laboratory having an unusually large latent heat gain is required to be air-conditioned. The design conditions and the loads are as under :

Summer outdoor design conditions	:	40° DBT, 27°C WBT
Indoor design conditions	:	25°C DBT, 50% RH
Room Sensible Heat (RSH)	:	34·9 kW
Room Latent Heat (RLH)	:	18·6 kW

The ventilation air requirement is 85 m^3/min. Determine the following :

(i) Ventilation load

(ii) Room Sensible Heat Factor (RSHF) and Effective Sensible Heat Factor (ESHF)

(iii) Apparatus Dew Point (ADP) and amount of reheat for economical design

(iv) Supply air quantity

(v) Condition of air entering and leaving coil and supply air temperature.

(vi) Grand Total Heat.

Assume a suitable bypass factor. Solve this problem using psychrometric chart.

5+10=15

(c) Explain the influence of ratio of blade speed to steam speed on blade efficiency of a single stage impulse turbine. 15

8. (a) Mention the cycles which have an efficiency equal to that of the Carnot cycle working between given temperature limits T_1 and T_2. Represent these cycles on T-s diagram. Prove for one of the cycles the expression for efficiency of the cycle is the same as that of the Carnot cycle. Comment on the work ratio (net work out divided by gross work output) of the cycle chosen and that of the Carnot cycle. 10

(b) (A) Define log mean temperature difference (LMTD.) Develop expression for LMTD in a parallel-flow heat exchanger. How is this expression modified for counter-flow heat exchanger ? Under what situations, LMTD is independent of the flow arrangements — namely : parallel-flow, counter-flow and cross-flow ? Give practical examples for such situations.

(B) Steam is condensed on the shell side of a shell-and-tube heat exchanger with the help of cooling water flowing inside the tubes. The entering steam is saturated and at a temperature of 100°C. It leaves as saturated water at the same temperature. The cooling water enters the tubes at 30°C and leaves at 70°C. Calculate the log mean temperature difference (LMTD.) 5+5=10

(c) A gas turbine power plant consists of a two stage compressor with intercooling and a single stage turbine with a regenerator. Air enters the compressor at 1 bar, 20°C. The maximum temperature of the cycle is limited to 900°C and the maximum pressure ratio is 6. The effectiveness of the regenerator is 0·7. The rate of airflow through the plant is 210 kg/s and the calorific value of fuel used is 40·8 MJ/kg. The isentropic efficiency of *both* the compressors is 0·82, the isentropic efficiency of the turbine 0·92, the combustion efficiency is 0·95.

Take for air $C_p = 1{\cdot}005$ kJ/kg K and $\gamma = 1{\cdot}4$ and for gases, $C_p = 1{\cdot}08$ kJ/kg K and $\gamma = 1{\cdot}33$. Assuming perfect intercooling and neglecting pressure and heat losses, estimate

(i) the air-fuel ratio

(ii) the cycle efficiency

(iii) the power supplied by the plant and

(iv) the specific fuel consumption of the plant and the fuel consumption per hour. 20

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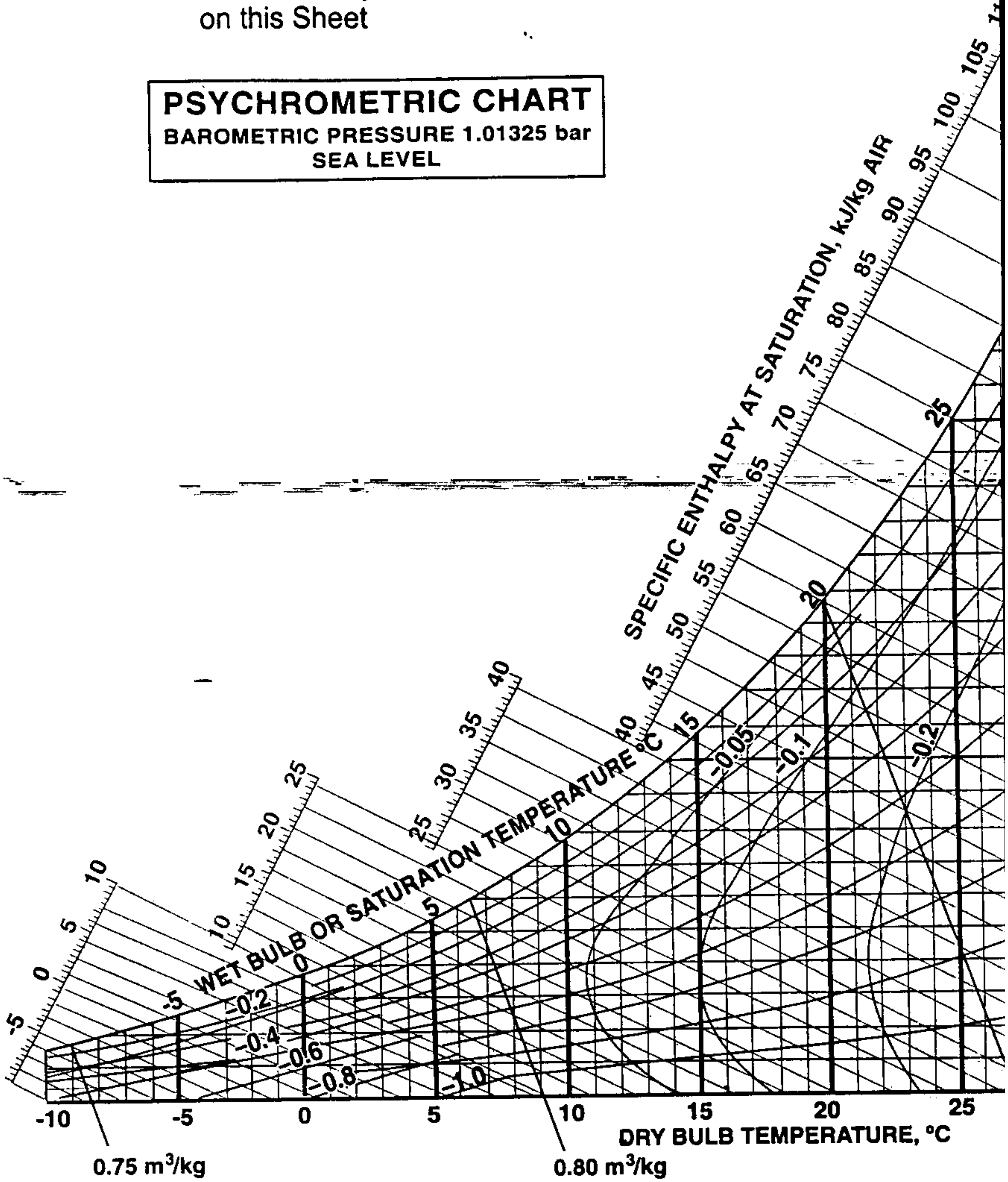
MECHANICAL ENGINEERING

Paper—II

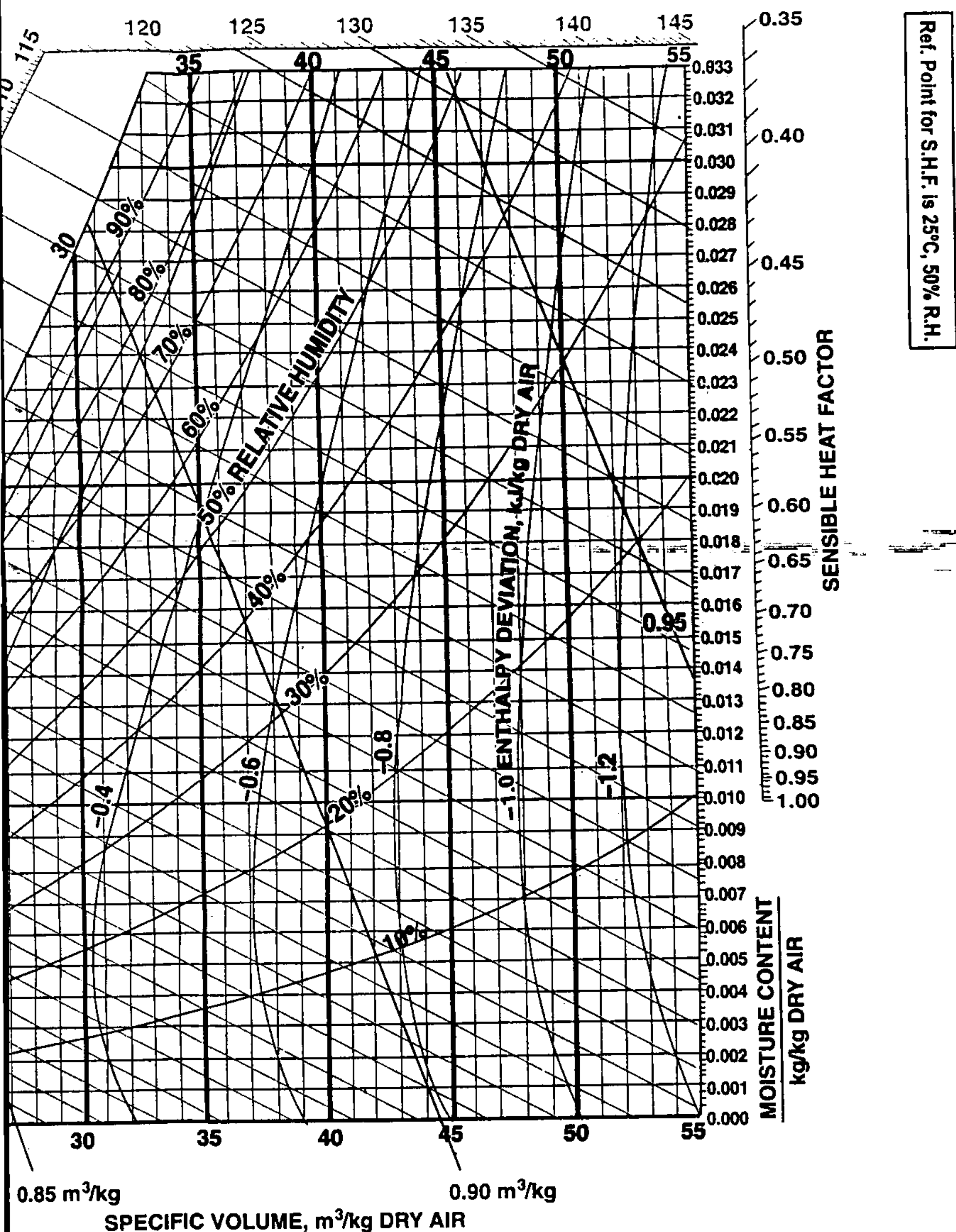
Do not write your Roll No.
on this Sheet

PSYCHROMETRIC CHART
BAROMETRIC PRESSURE 1.01325 bar
SEA LEVEL



BELOW 0 °C PROPERTIES AND ENTHALPY DEVIATION LINES ARE FOR ICE

NFB



115
120
125
130
135
140
145
0.35
0.40
0.45
0.50
0.55
0.60
0.65
0.70
0.75
0.80
0.85
0.90
0.95
1.00
SENSIBLE HEAT FACTOR
Ref. Point for S.H.F. is 25°C, 50% R.H.
35
40
45
50
55
30
90%
80%
70%
60%
50%
40%
30%
20%
10%
RELATIVE HUMIDITY
ENTHALPY DEVIATION, kJ/kg DRY AIR
-0.4
-0.6
-0.8
-1.0
-1.2
0.95
0.033
0.032
0.031
0.030
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0.009
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0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
MOISTURE CONTENT
kg/kg DRY AIR
30
35
40
45
50
55
0.85 m³/kg
0.90 m³/kg
SPECIFIC VOLUME, m³/kg DRY AIR