ORDRE DES INGÉNIEURS DU QUÉBEC

MAY 2014 SESSION

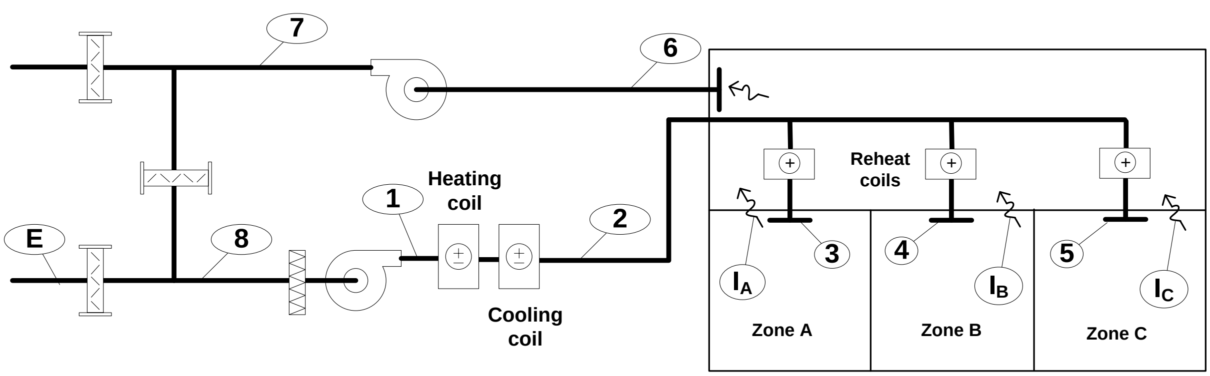
Open-book examination
Calculators : only authorized models
Duration : 3 hours

14-BA-A4
Building Environmental Control

Problem # 1 (30%)

The diagram shows a multizone constant volume air conditioning system with zonal reheat coils. The air flow rate for the design conditions and the loads of each zone for a moment out of design conditions, are as follows:

Zone	**A**		**B**		**C**	
Flow rate	2.0 m^3/s		1.5 m^3/s		1.0 m^3/s	
Load (**kW**)	sensible	latent	sensible	latent	sensible	latent
	24.0	6.0	12.6	7.43	7.2	1.5
Temperature	25 ^oC					
Ralative humidité	40 à 60 %					



Plenum heat gains	10.8 kW
Temperature rise across the return fan	$\Delta t = 1$ °C
Temperature rise across the supply fan	$\Delta t = 2$ °C
Exterior air conditions: dry bulb temperature	$t_{db} = 30$ °C
wet bulb temperature	$t_{wb} = 25$ ^oC
Exterior air flow rate	20% of design flow rate

Identify the critical zone with the relative humidity of 60%. Locate the key air states (*points 1 to 8, I_A, I_B, I_C and E*) on the psychrometric chart *(6 %)* and shown in the table *the dry bulb temperature and humidity ration of each point*. *(5 %)*

Determine:

a) Fan air flow rate *(4 %);*
b) Temperature and humidity ratio of air leaving the cooling coil; *(4 %)*
c) Cooling coil power; *(5 %)*
d) Heating capacities of the reheat coils for the zones A, B and C *(6 %)*.

Use the conditions of the standard air : ρ = 1.2 kg/m^3 c_p = 1.005 kJ/kg ^{o}C and latent heat of vaporization i_{fg} = 2500 kJ/kg

Problem # 2 (15%)

A commercial building has the following specifications:

Total heat loss coefficient K_{tot} $$K_{tot} = K_{cond} + \rho c_p \dot{V}$$

With K_{cond} = *12 000 Btu/h^{o}F* et $$\rho c_p \dot{V} = 8000 Btu/h^oF$$

Windows area	15 000 pi^2
Windows thermal resistance	R2
Building inside air temperature	72 ^{o}F
Design exterior air temperature	-16 ^{o}F
Heating degree-days for base of 64.4 ^{o}F (18 ^{o}C)	8200 (en ^{o}F)
Heat gain	130 kW
Heating system efficiency	70%

Determine:

a) annual energy consumption using degree-days method *(3 %);*
b) building balance-point temperature *(3 %);*
c) energy consumption for the exterior BIN temperature of 20^{o}F (N_{BIN} for this temperature is of 400 hours) *(3 %)*.

The windows with thermal resistance (***R2***) are replaced by the windows with better thermal resistance and sealing:

- new windows thermal resistance is now ***R4***;
- the infiltration rate (V) is now ***0.9*** air-change per hour instead **1.5** before.

Determine:

d) new total heat loss coefficient K_{tot} *(3 %);*
e) new annual energy consumption using degree-days method *(3 %).*

Problem # 3 (20 %)

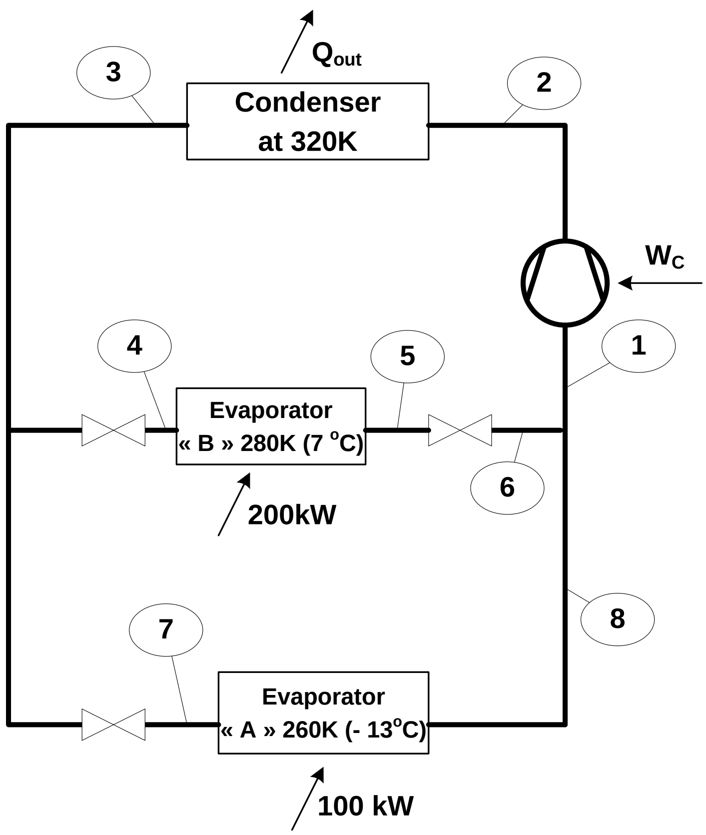


Figure shows the schematic diagram of a vapor-compression refrigeration system with two evaporators using Propane (R-290) as the working fluid. This arrangement is used to achieve refrigeration at two different temperatures 260K and 280K (-13°C et 7°C) with a single compressor and a single condenser. The evaporator « ***A*** » operates at -13°C with saturated vapor of its exit and has a refrigerating capacity of 100 kW. The evaporator « ***B*** » produces saturated vapor at 7°C at its exit and has a refrigerating capacity of 200 kW. Compression is isentropic to the condenser temperature of 320K. There are no significant pressure drops in the flows through the condenser and the two evaporators, and the refrigerant leaves the condenser as saturated liquid. Show the refrigeration cycle on the attached *p-h* diagram *(4 %)* and determine:

a) The mass flow rate of refrigerant through each evaporator and compressor ($\dot{m}_1$, $\dot{m}_4$, $\dot{m}_7$), in kg/s *(4%);*
b) The compressor power (W_c), in kW *(4 %);*
c) The rate of heat transfer through the condenser (Q_{out}), in kW *(4%);*
d) The coefficient of performance COP *(4%).*

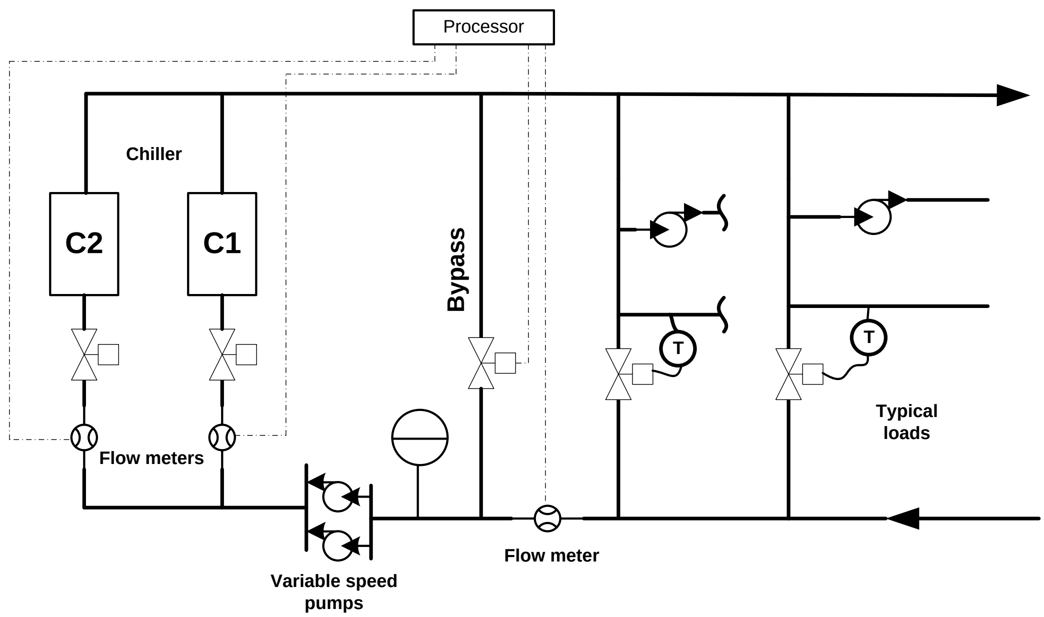
Problem # 4 (20 %)

A variable primary piping system like the one shown in Fig, has a capacity of 1200 tons (4220 kW) and is designed to operate with water supplied at 42 °F (6°C) and returned at 65 °F (18 °C). The chillers have equal capacity and there are two 3500 rpm variable speed primary pumps of equal size. Under partial load conditions the chiller flow rates may be reduced a maximum of 30 percent of full flow.

a) Compute the full load chilled water flow rate and describe the operating conditions of the system (flow rates, bypass flow, pumps speed, etc.) *(5 %);*

b) Suppose the system is operating under a load of 900 tons (3165 kW) and describe some acceptable operating conditions *(5 %);*
c) At another time the system is operating at 60 percent of full capacity. Determine satisfactory operating conditions and describe them *(5 %);*
d) At still another time the load drops to 25 percent of full capacity. Determine satisfactory operating conditions and describe *(5 %).*

Assuming no change in the temperatures.



Problem # 5 (15%)

A building has a heating load (sensible) of 200 000 Btu/hr. The sensible heat factor (SHF) for the space is 1.1 and the space is to be maintained at 72 ^{o}F dry bulb and 30% relative humidity. Outdoor air (at -16 ^{o}F dry bulb and at 0.0004 lb/lb$_{dry\ air}$ of humidity ratio) in the amount of 2000 cfm is required. Air is supplied to the space at 120 ^{o}F dry bulb. Water vapor with enthalpy of 1150 Btu/lb is used to humidify the air. Find:

a) The conditions and amount of air supplied to the space *(4%);*
b) The temperature rise of the air through the furnace using to heat the air *(3%);*
c) The required capacity of the furnace *(4%);*
d) The amount of water vapor required to humidify the air *(4%).*

Chart 1b ASHRAE Psychrometric Chart No. 1 (SI) (Reprinted by permission of ASHRAE.)

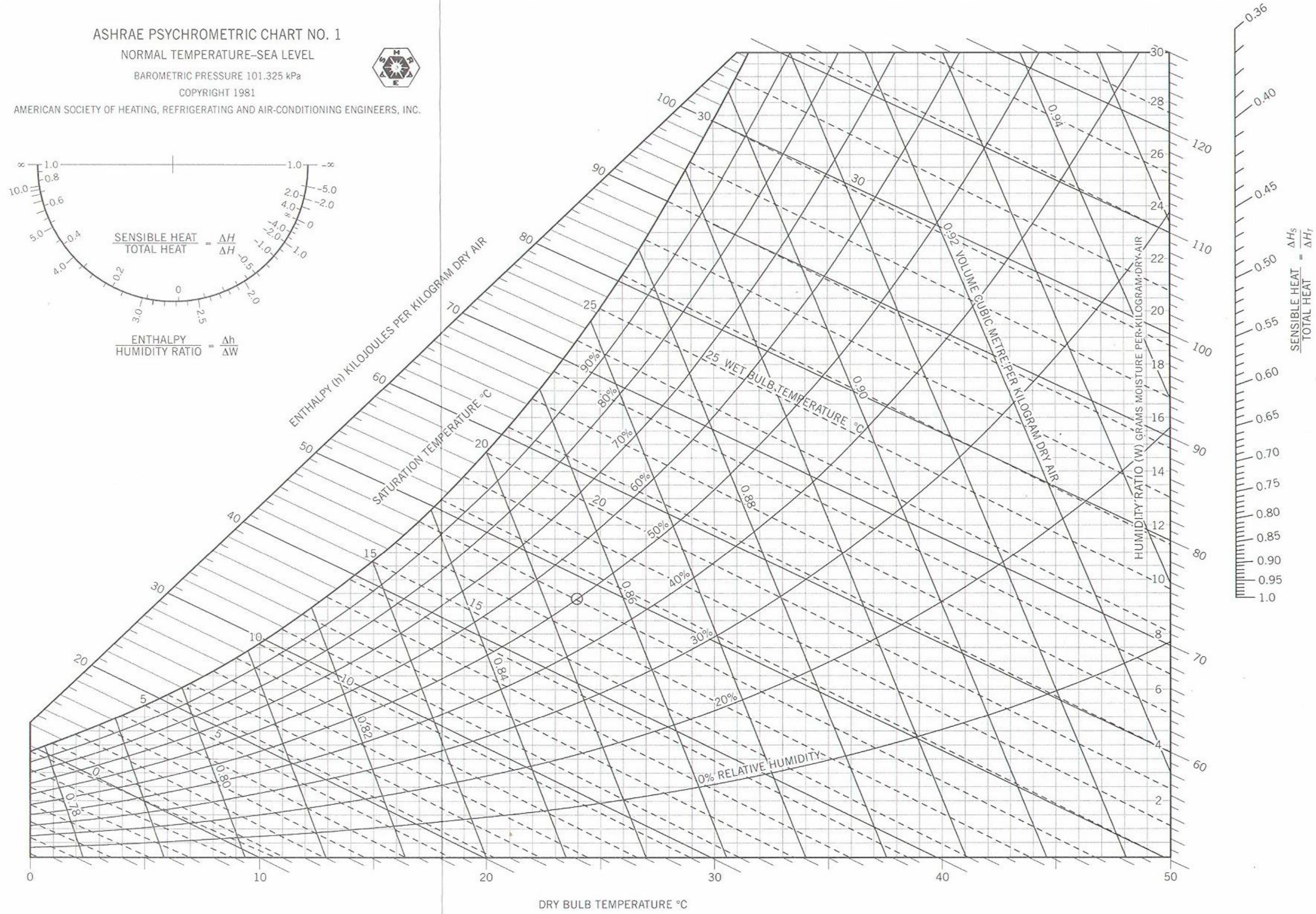
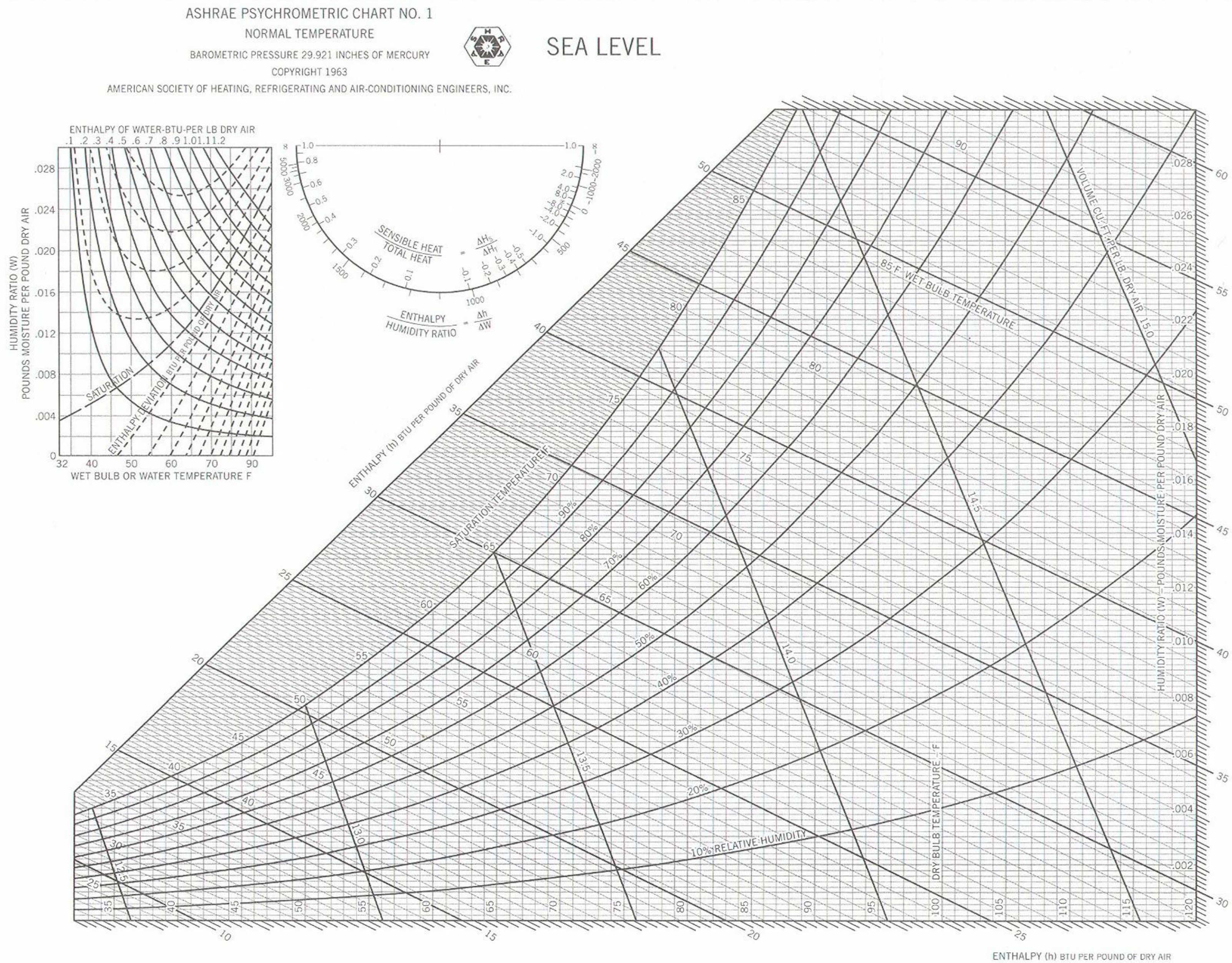


Chart 1*a* ASHRAE Psychrometric Chart No. 1 (IP) (Reprinted by permission of ASHRAE.)



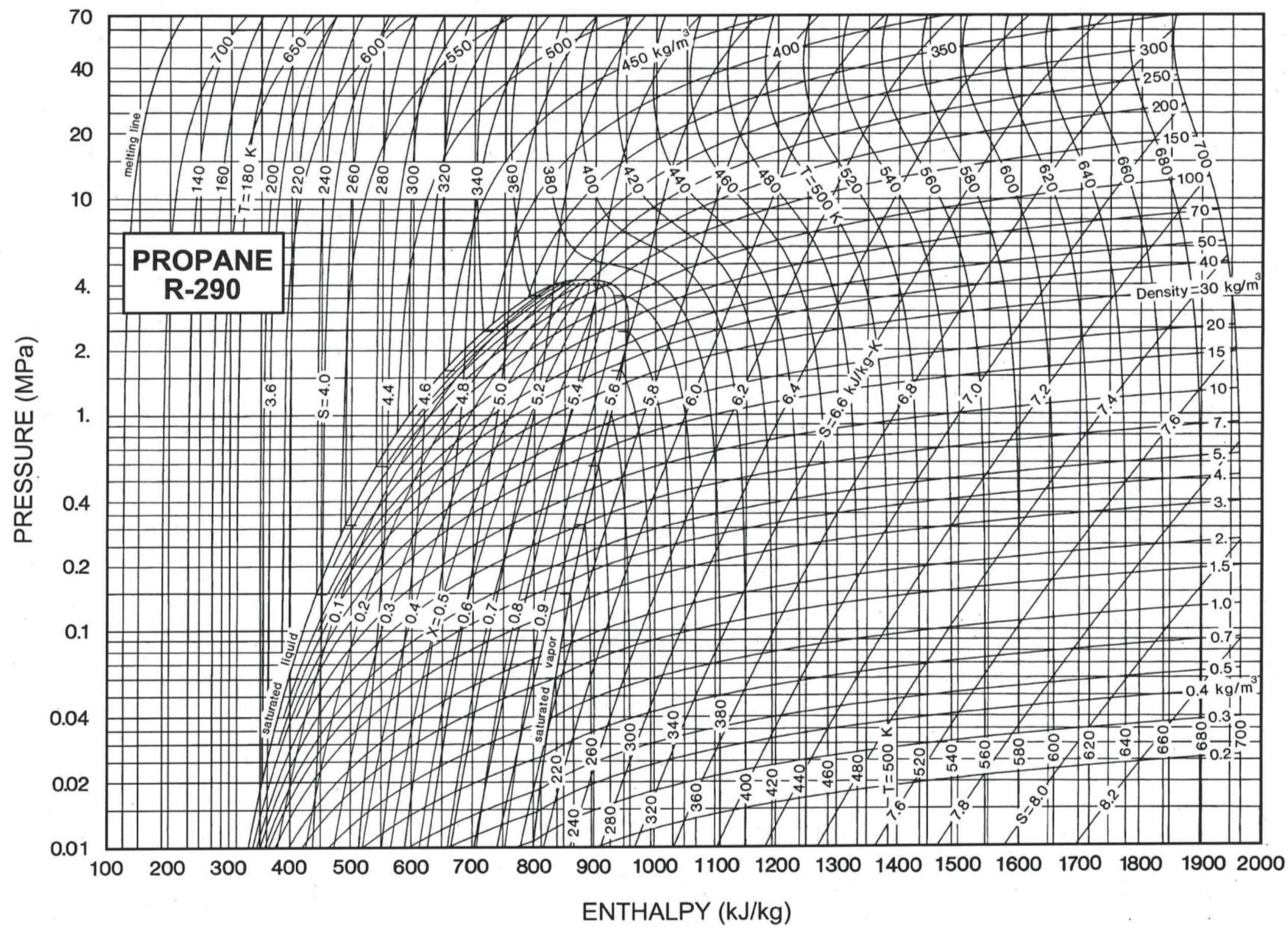


Fig. 17 Pressure-Enthalpy Diagram for Refrigerant 290 (Propane)
Note: The reference states for enthalpy and entropy differ from those in the table.