101. Poisson's ratio is typically used in:

(A) heat transfer
(B) HVAC
(C) mechanical behavior
(D) vapor power cycles

102. Which of the following is used as a measure of energy efficiency of refrigeration systems?

(A) COP
(B) Carnot efficiency
(C) Latent heat
(D) SHR

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103. A system with an initial cost of \$90,000 has an operating cost of \$2.50/hr and is operated 16 hr/day for 300 days/year. After 10 years, the system has a salvage value of \$10,000. Assuming the interest rate is constant at 10%, the total annualized cost over the 10-year life is most nearly:

(A) \$12,000
(B) \$14,000
(C) \$20,000
(D) \$26,000

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104. A machining operation creates a hole for a 3/8-16NC × 0.75-in.-long countersink head screw, as shown in **Figure 1**. A cutter is used to create the countersink recess as shown in **Figure 2**. The process steps are as follows:

1. Drill through with a tap drill diameter of 5/16 in.
2. Countersink the tap drill hole to a depth of Dimension A, so that the screw head will be flush with the part surface.
3. Tap the hole 3/8-16NC.

To complete Step 2, the depth (in.) of Dimension A is most nearly:

(A) 0.202
(B) 0.234
(C) 0.269
(D) 0.313

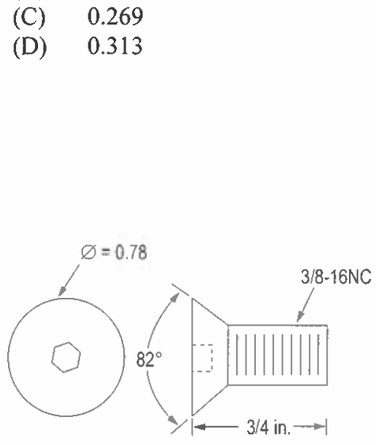

FIGURE 1

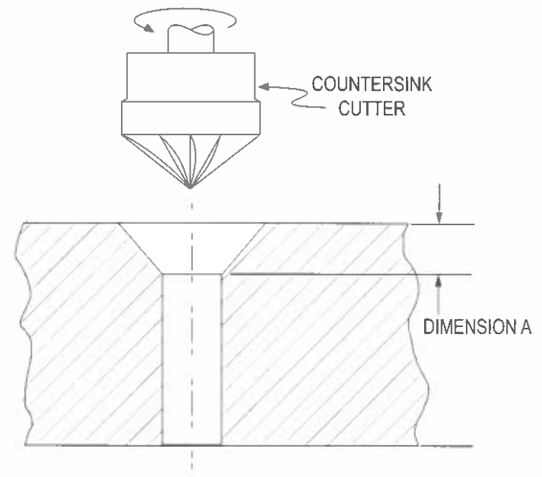

FIGURE 2

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105. A commercial product is sold in 55-gal drums. The product mixture consists of inert ingredients, to which an active ingredient is added. The active ingredient can be purchased in two different formulations as shown.

Formulation	Cost/lb	Active Ingredient (units/lb)
1	\$8	100
2	\$10	200

The amount of Formulation 1 used per drum cannot exceed 3 lb, and the amount of Formulation 2 used per drum cannot exceed 2 lb. The total cost for the active ingredient cannot exceed \$36/drum. The largest number of units of active ingredient that can be added per drum under these constraints is most nearly:

(A) 400
(B) 540
(C) 600
(D) 700

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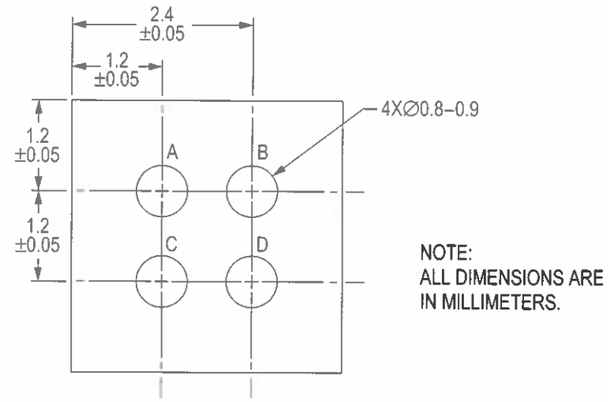
106. Referring to the figure, the minimum material thickness (mm) between Holes A and B is most nearly:

(A) 0.2
(B) 0.3
(C) 0.4
(D) 0.5



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107. A solar-thermal power system pumps and stores hot (1,000°F) liquid sodium in an insulated overhead storage tank, as shown in the figure. The pump delivers sodium at the rate of 50 lbm/sec.

Use the following properties of sodium at 1,000°F:

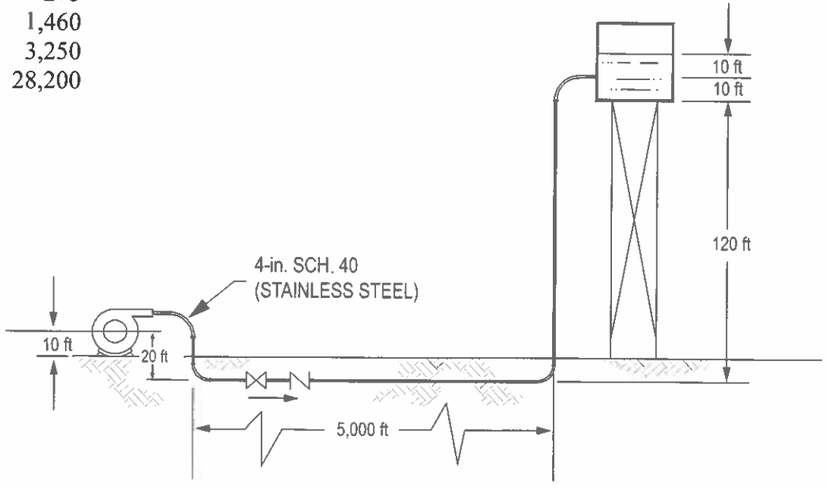
Density	51.4 lbm/ft^3
Specific heat	0.301 Btu/(lbm-°F)
Thermal conductivity	37.6 Btu/(hr-ft-°F)
Dynamic viscosity	0.000156 lbm/(ft-sec)

Use the following data for the sodium pipe:

Nominal size	4-in Sch. 40 stainless steel
Inside diameter	4.026 in.
Darcy friction factor	0.01

The convective heat-transfer coefficient [Btu/(hr-ft^2-°F)] at the inside surface of the pipe is most nearly:

(A) 275
(B) 1,460
(C) 3,250
(D) 28,200



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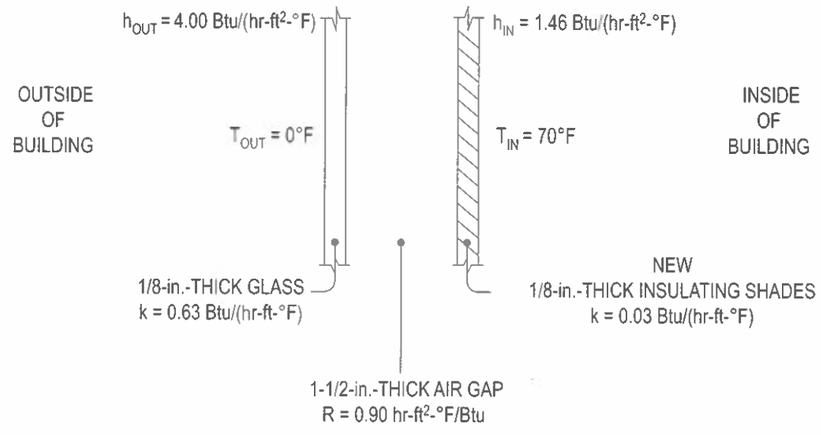
108. A 6.0-in. O.D. tube with a wall thickness of 0.10 in. and an axial length of 20 ft is located in a roofed building. The temperature of the ambient air is 65°F, and the convective heat-transfer coefficient is 5.0 Btu/(hr-ft^2-°F).

The outer surface temperature of the pipe is 450°F. The emissivity for the pipe is 0.5. The total rate of heat loss (Btu/hr) is most nearly:

(A) 93,000
(B) 77,000
(C) 62,000
(D) 16,000

109. To save on heating costs, a business is considering adding insulating shades to the 200 ft^2 of single-pane windows in its historic office building, as shown in the figure. Neglecting radiation, the reduction in heat loss (Btu/hr) that would be achieved by adding the shades is most nearly:

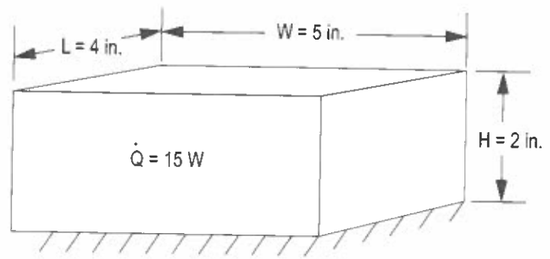
(A) 11,200
(B) 8,300
(C) 6,400
(D) 300



110. An electronic component (see figure) is mounted adiabatically at its base. The componer dissipates 15 W, and the ambient air and surroundings are at 75°F.

Assuming a constant heat flux, an average radiative heat-transfer coefficient ($h_{radiation}$) o 1.00 Btu/(hr-ft^2-°F), and an average convective heat-transfer coefficient ($h_{convection}$) of 1.2 Btu/(hr-ft^2-°F), the surface temperature of the component is most nearly:

(A) 118°F
(B) 133°F
(C) 180°F
(D) 206°F



111. A suspended vessel loses 45,000 Btu/hr to the surroundings through convection. The vessel i bare steel with a surface area of 400 ft^2. The ambient temperature is steady at 75°F. The surfac temperature of the vessel is 100°F. The film coefficient h [Btu/(hr-ft^2-°F)] is most nearly:

(A) 0.22
(B) 1.1
(C) 4.5
(D) 110

112. An insulated panel box containing electrical equipment will be located outdoors. The equipment will generate 500 W of heat. The following information is given:

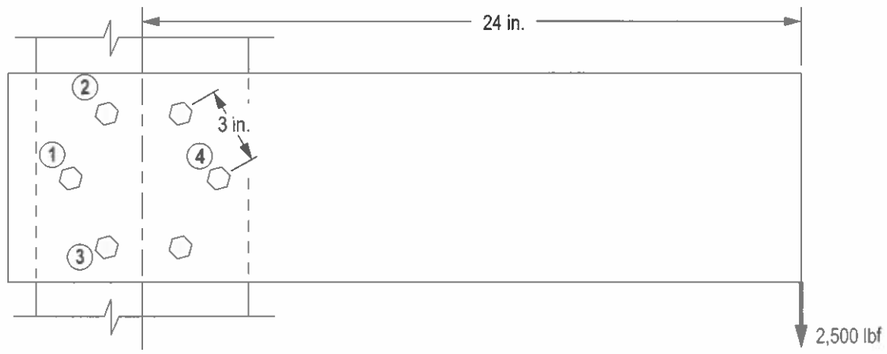
Insulation thickness	1/2 in.
Insulation thermal conductivity	0.03 Btu/(hr-ft-°F)
Heat-transfer coefficient	5 Btu/(ft^2-hr-°F)
Surface area of panel box	100 ft^2

If the outdoor temperature is 100°F, the temperature expected inside the box is most nearly:

(A) 70°F
(B) 130°F
(C) 200°F
(D) 387°F

113. The 2,500-lbf load shown in the figure is supported by a beam that is secured by six 3/4-in. diameter bolts in a hexagonal array with neighboring bolts 3 in. apart. The shear stress is greatest in which bolt?

(A) 1
(B) 2
(C) 3
(D) 4



114. Water (100 lbm/min, 60°F) and steam (100 lbm/min, 600°F), both at slightly above atmospheric pressure, enter an insulated chamber through separate inlets. After thorough mixing, 200 lbm/min of the product is withdrawn at atmospheric pressure. The quality of the steam in the product stream is most nearly:

(A) 0.12
(B) 0.43
(C) 0.52
(D) 0.60

115. Consider the following stoichiometric reaction:

$$C_9H_{18} + 13.5\ O_2 + 50.8\ N_2 \rightarrow 9\ CO_2 + 9\ H_2O + 50.8\ N_2$$

The mass fraction of water in the flue gas is most nearly:

(A) 5.8%
(B) 8.2%
(C) 10.7%
(D) 13.1%

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116. Steam (600°F, 300 psia) is expanded in an 80% adiabatic efficiency turbine to 3 psia. The enthalpy (Btu/lbm) of the resulting 3-psia steam is most nearly:

(A) 880
(B) 970
(C) 1,040
(D) 1,120

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117. An automotive air-conditioning system based on R-134a operates between 250 psia and 40 psia. A pressure-enthalpy diagram for R-134a is shown on the opposite page. If 250-psia saturated liquid R-134a is throttled to 40 psia, the change [Btu/(lbm-°R)] in entropy ($S_{final} - S_{initial}$) will be most nearly:

(A) –0.07
(B) 0.01
(C) 0.11
(D) 0.15

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117. (Continued)

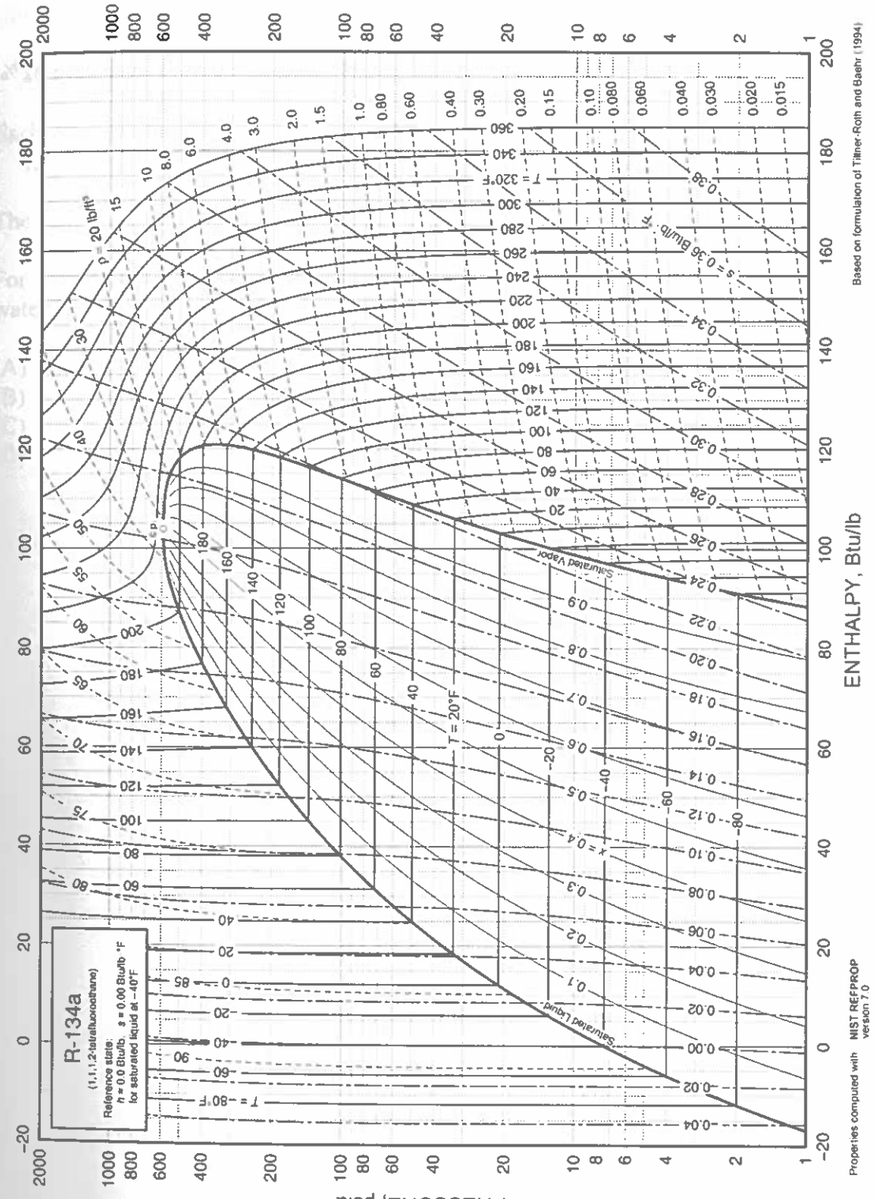

Fig. 8 Pressure-Enthalpy Diagram for Refrigerant 134a

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118. Fuel is burned in a furnace with 12% excess air to minimize the formation of partially oxidize product. The average molecular weight of the fuel is 126. The overall complete **stoichiometr** combustion reaction is:

$$C_9H_{18} + 13.5\ O_2 + 50.8\ N_2 \rightarrow 9\ CO_2 + 9\ H_2O + 50.8\ N_2$$

The mass of air (lbm) required per pound of fuel for complete combustion with 12% excess a is most nearly:

(A) 3.8
(B) 14.8
(C) 16.5
(D) 18.3

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119. A direct-pumped variable-flow chilled water system, serving three air handlers in a building, is shown in the flow schematic. AHU-3 and the system bypass are located 75 ft above the main mechanical room housing the chiller and pump.

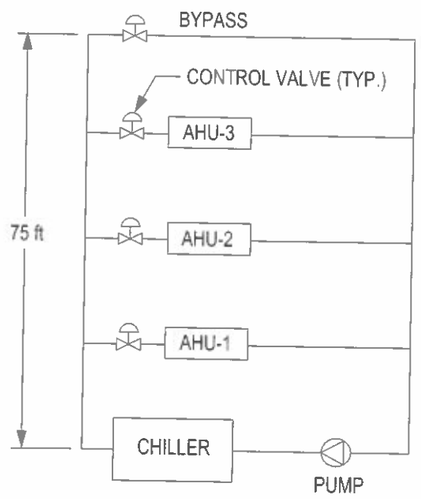
Chiller selected for:
500 gpm, 10° ΔT
20 ft of head evaporator pressure drop

Each AHU is selected for:
12° ΔT, 150 gpm, 10 ft of head pressure drop.

The control valves are selected for a maximum 5-psi pressure drop at the design flow rate.

For proper system operation, the minimum required differential pressure (psi) between the chilled water supply and return headers measured at the chilled water bypass is most nearly:

(A) 80
(B) 45
(C) 35
(D) 10



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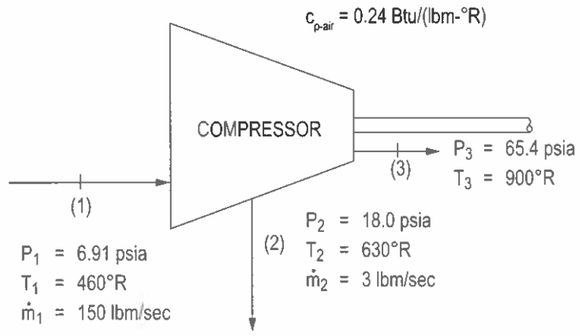
120. Below is a schematic diagram of the compressor of an aircraft gas turbine. A portion of the air th enters at State 1 is extracted at State 2, cooled, and then expanded in a turbine to be used for cab pressurization. The balance of the air leaves at State 3. Known properties (stagnation pressur and temperatures) and other data are given with the diagram. The power (hp) required to drive t compressor is most nearly:

(A) 370
(B) 15,900
(C) 16,500
(D) 22,100

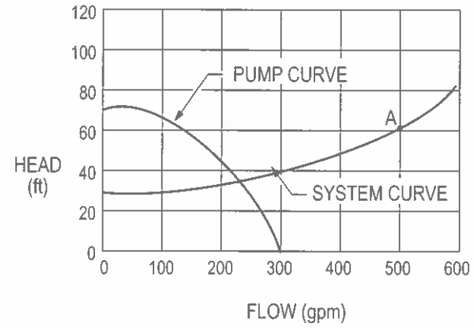


121. A centrifugal pump is used to transport 25 gpm of acetone at 78°F. The differential pressu across the pump is 50 psi. The vapor pressure of acetone at this temperature is 5.6 psia, viscos is 0.3 cP, and density is 49 lbm/ft^3 (sp gr = 0.79). The pump efficiency is 70%. The input sh horsepower (hp) to drive the pump is most nearly:

(A) 0.12
(B) 0.73
(C) 1.04
(D) 1.35

122. Given a hydronic piping system and a number of pumps, each having performance characteristics as shown in the figure, the **minimum** number of available pumps needed to supply the required flow at system operation Point A is:

(A) two
(B) three
(C) four
(D) Cannot be done with the available pumps

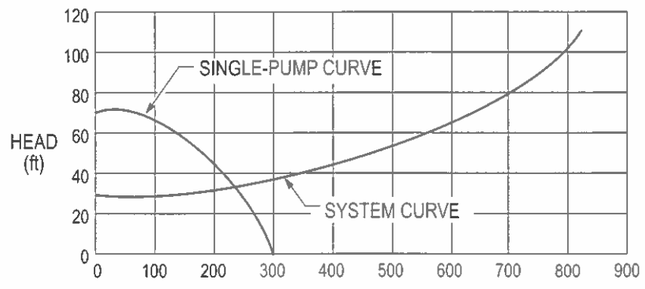


123. A centrifugal pump is sized to deliver 200 gpm at a head of 60 ft of water. It is operating 1,750 rpm. The pump efficiency is 75%. When the speed of the pump has been reduced 1,000 rpm, the head (ft of water) is most nearly:

(A) 8.5
(B) 11
(C) 20
(D) 34

124. A piping system includes three pumps, each having the performance characteristics shown the graph. The supply head (ft) that three pumps operating in parallel will deliver to t hydronic system is most nearly:

(A) 210
(B) 65
(C) 38
(D) 30



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125. A centrifugal pump is sized to deliver 200 gpm of water at 60°F against a head of 60 ft of water. It is operating at 1,750 rpm. The pump efficiency is 0.75, and the motor efficiency is 0.83. If the electricity cost is $0.06/kWh, the electrical cost to operate the pump 8,000 hr/yr is most nearly:

(A) $984
(B) $1,086
(C) $1,200
(D) $1,750

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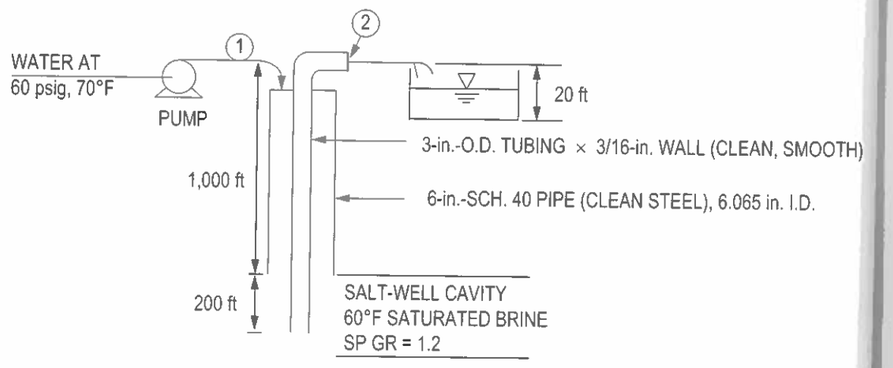
126. A salt-well cavity is 1,000 ft below grade. The cavity is filled with sodium chloride brine at 60° The well casing is 6-in. Sch. 40 pipe. There is an inner tube of 3-in. O.D. × 3/16-in. wall. Wa at 70°F is pumped into the cavity through the annular space, displacing the brine and forcing it surface through the inner tube into a storage tank. The brine discharge rate is 50 gp Neglecting velocity change, if the total friction head is 25 ft of water and the net static he $(h_2 - h_1)$ is 225 ft of water, the pump power (hp) needed to transfer 50 gpm of brine is m nearly:

(A) 1.34
(B) 2.53
(C) 3.16
(D) 10.50



127. A nuclear reactor is housed in a leak-tight containment building. The building is designed to withstand the pressure and temperature resulting from an accidental breach of the pressure boundary of the reactor. During normal operating conditions, the reactor, which has a void volume of 9,000 ft^3, contains helium at 1,000 psia and 1,340°F. The containment building normally contains air at 14.65 psia and 140°F. Use 0°R as the reference temperature for calculating thermal properties.

Property	Helium	Air
c_p, Btu/(lbm-°F)	1.24	0.241
c_v, Btu/(lbm-°F)	0.745	0.172
k	1.667	1.400
M, lbm/(lb mol)	4	29

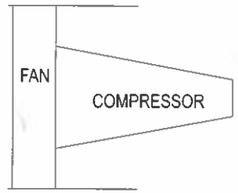
In an accident, helium from the reactor slowly leaks into the building. The operating crew of the plant is able to plug the leak before equilibrium pressure is reached. At this state, it is determined that the helium mass fraction in the building is 0.09091 and the building pressure is 30 psia (building air mass is 15,000 lbm). The mass (lbm) of helium released into the building is most nearly:

(A) 1,364
(B) 1,500
(C) 1,650
(D) 1,800

128. A turbofan engine is operating on a test stand at sea level with an ambient temperature of 80 and an ambient pressure of 14.7 psia. Known data for the fan-compressor portion are provided the figure. The input power (hp) required to drive the combined fan-compressor is most nearly

(A) 19,400
(B) 26,800
(C) 87,100
(D) 112,000

Compressor mass rate of flow	100 lbm/sec
Fan mass rate of flow	400 lbm/sec
Compressor pressure ratio	10
Fan pressure ratio	1.3
Fan and compressor efficiencies	85%
K	1.4
c_p	0.24 Btu/(lbm-°R)



129. Air with the following properties enters the compressor of an aircraft gas turbine.

P = 5.45 psia
T = 430°R
V = 600 fps
$\dot{m}$ = 150 lbm/sec

The cross-sectional area (ft^2) at the inlet is most nearly:

(A) 1.64
(B) 2.70
(C) 3.27
(D) 7.30

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130. A pitot tube measurement at a point that represents the average velocity indicates a head of 3 in. of water for air (ρ = 0.075 lbm/ft^3) flowing in a circular duct with a diameter of 12 in. The volumetric flow rate (cfm) of air is most nearly:

(A) 1,725
(B) 3,860
(C) 5,450
(D) 18,900

131. A centrifugal pump is operated at 3,500 rpm to produce a flow of 50 gpm. The pump speed (rpm) required to produce a flow of 60 gpm is most nearly:

(A) 2,920
(B) 3,830
(C) 4,200
(D) 5,040

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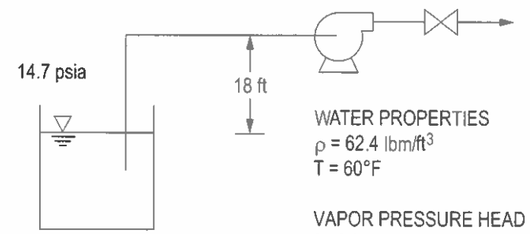
132. A centrifugal pump is sized to deliver 200 gpm of liquid with a specific gravity of 0.7 and total differential head of 60 ft of water. The hydraulic horsepower required is most nearly:

(A) 2.1
(B) 2.7
(C) 3.0
(D) 4.3

133. The net positive suction head available for the system shown is 8 ft of water. The frictional he loss (ft) is most nearly:

(A) 6
(B) 14
(C) 24
(D) 42



134. A constant volume HVAC system with a design flow of 11,500 cfm is to be designed with 3,000 cfm of outside air flow and the following parameters:

Design indoor conditions:
T = 75°F
ϕ = 50%

Design outdoor conditions:
T = 40°F
ϕ = 60%

The design mixed-air temperature is most nearly:

(A) 50°F
(B) 56°F
(C) 60°F
(D) 66°F

135. For a given set of fixed steam conditions ($\dot{m}$, P, T) at the inlet to the high-pressure turbine o fossil fuel-fired steam power plant with reheat between sections of a two-stage turbine, which the following is a result of adding reheat?

(A) Increased moisture content at the exit from the low-pressure turbine

(B) Decreased net power output

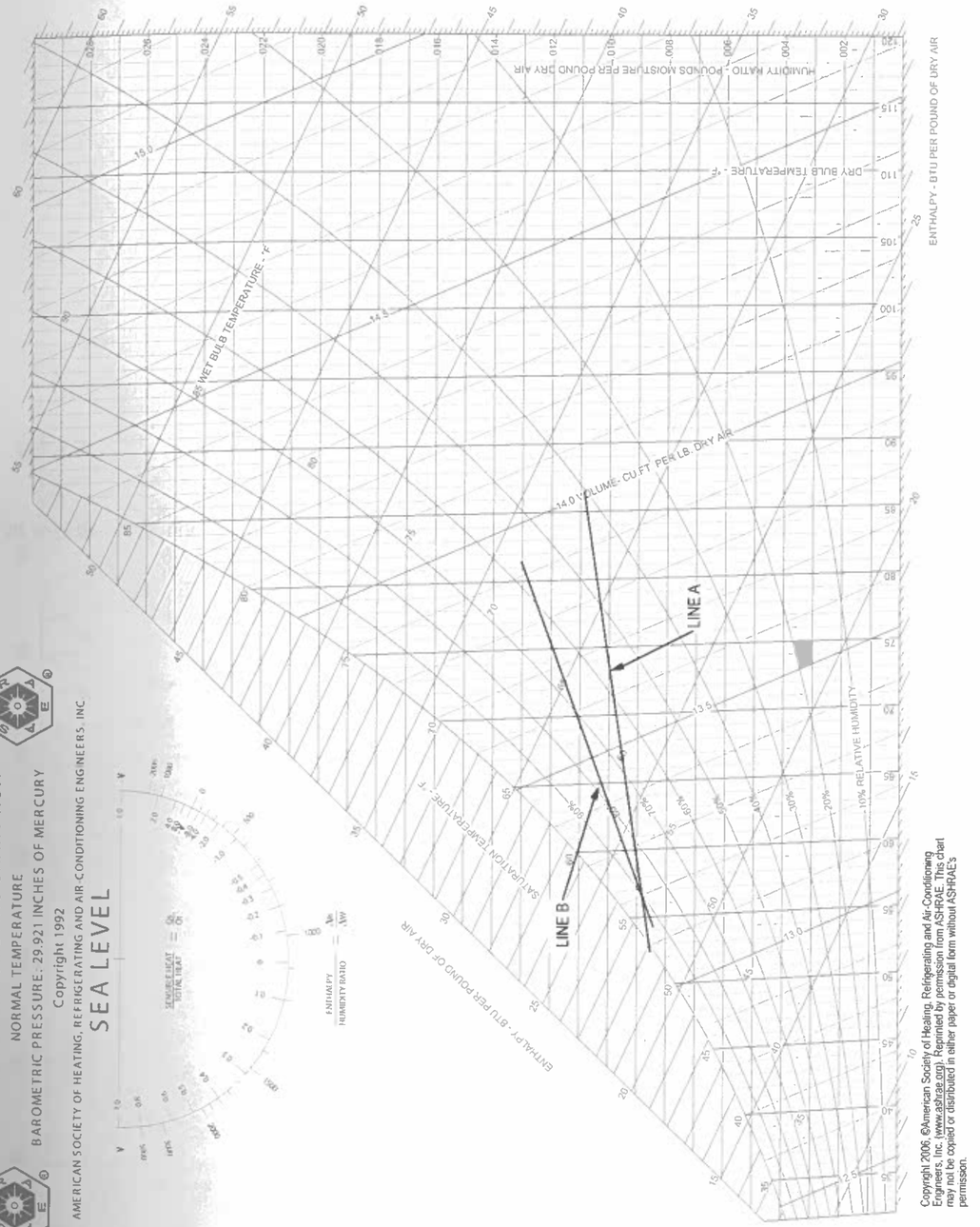
(C) Decreased amount of energy exchanged in the condenser

(D) Increased CO_2 emissions

136. The psychrometric processes for air supplied to an auditorium are represented as Lines A and on the accompanying psychrometric chart. Line A is the room load line, and Line B is the o load line. The coil apparatus dew-point temperature is most nearly:

(A) 50°F
(B) 53°F
(C) 58°F
(D) 63°F

136. **(Continued)**



137. A refrigeration system with a capacity of 1 refrigeration ton has a compressor work of 1 kW. Th coefficient of performance of the system is most nearly:

(A) 0.3
(B) 1
(C) 3.5
(D) 12

138. An expansion valve would be used in which portion of the refrigeration cycle shown in t figure?

(A) A–B
(B) B–C
(C) C–D
(D) D–A

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138. (Continued)

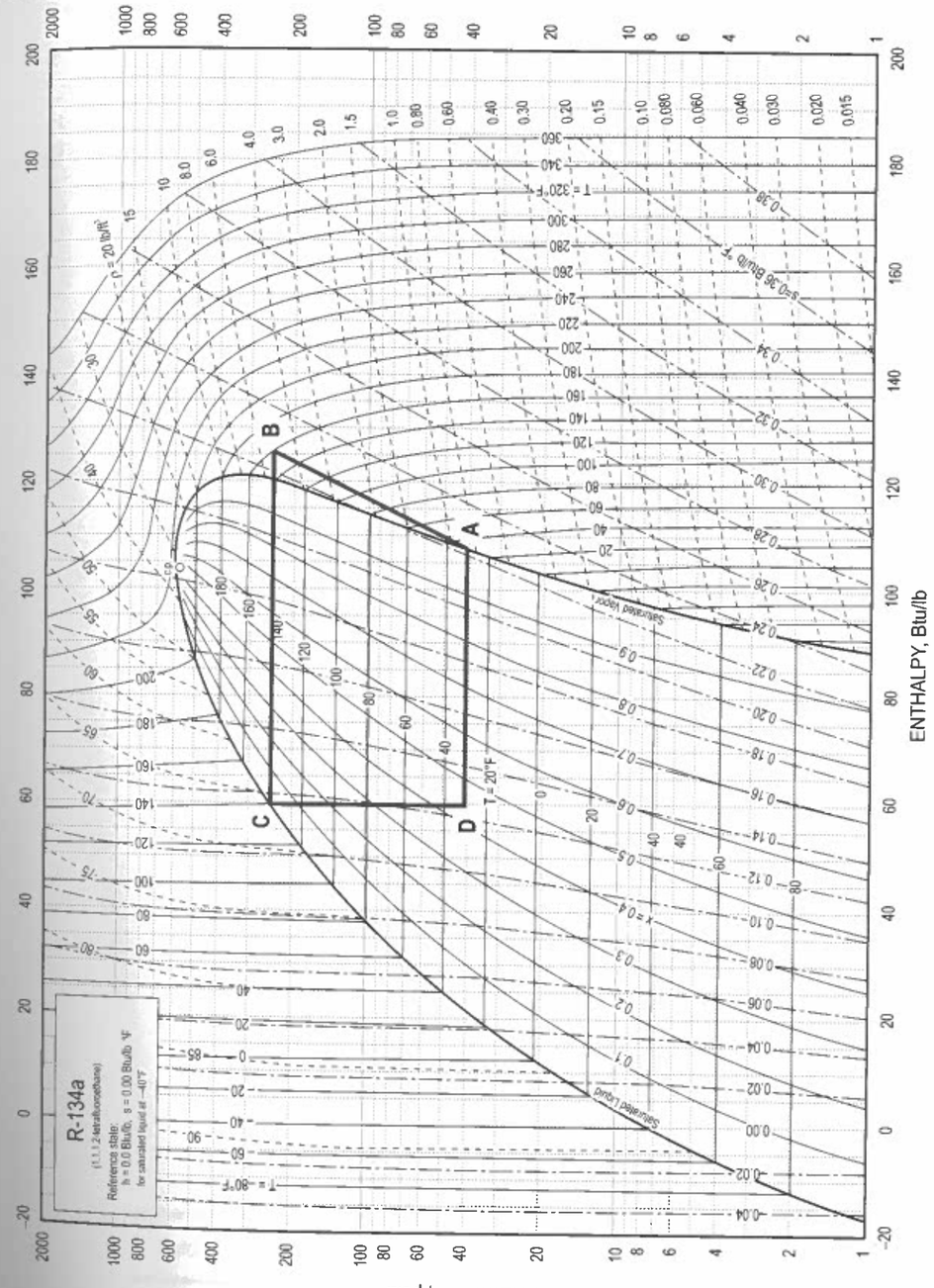

Fig. 8 Pressure-Enthalpy Diagram for Refrigerant 134a

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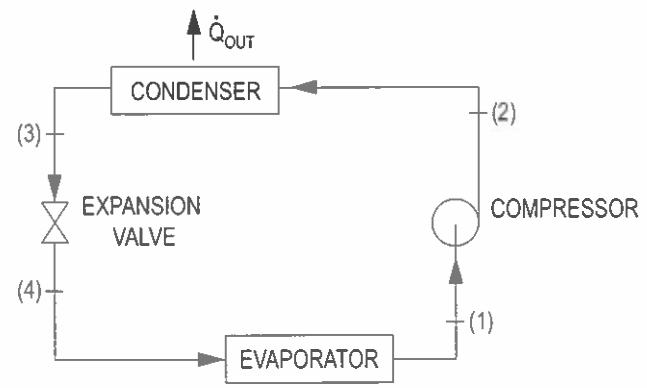
139. Known data for a vapor-compression heat pump using R-134a as the working fluid are shown in the table and figure below.

State	P (psia)	T (°F)	h (Btu/lbm)
1	16.674	−10	100.29
2	160	160	129.78
3	160	109.56	47.65
4	16.674	−10	

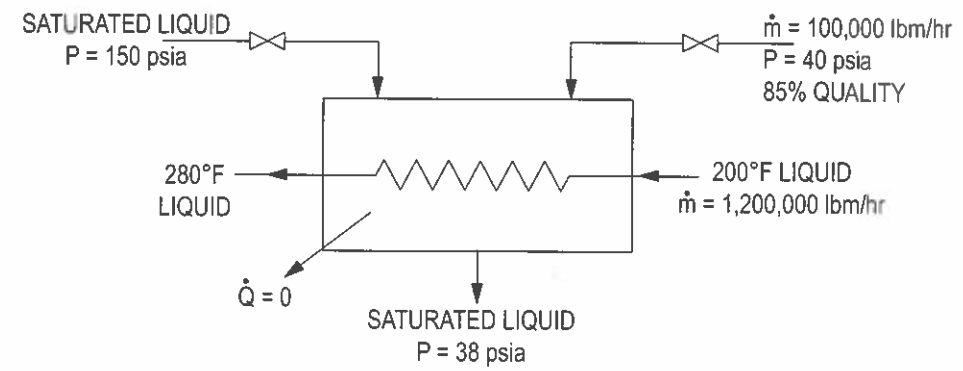
The coefficient of performance for this heat pump is most nearly:

(A) 1.00
(B) 1.56
(C) 1.79
(D) 2.79



140. In the cascading feedwater heater with data shown in the figure, all working fluids are water. The outgoing saturated liquid flow (lbm/hr) is most nearly:

(A) 280,000
(B) 180,000
(C) 137,000
(D) 37,000



This completes the morning session. Solutions begin on page 69.