www.SlaythePE.com

MECHANICAL ENGINEERING
P.E. HVAC&R
PRACTICE EXAM

(version 1.0: July 26, 2023)

001. The efficiency (ratio of energy utilized in cooking to energy input to the appliance) of residential cook-top ranges is 73% for electric units and 38% for gas units. An electric unit with a maximum input of 2 kW is used at a location where electricity costs \$0.09/kWh and gas costs \$0.55/therm. The electric unit will be replaced with a gas unit to produce the same energy output. The heat input of the replacement gas cook-top (Btu/h) is most nearly:

(A) 2,593

(B) 4,981

(C) 6,824

(D) 13,200

002. The graph shows the variation of total pressure (p_t) and static pressure (p_s) along a horizontal segment of duct with no branches. Select ALL the statements that are most nearly correct:

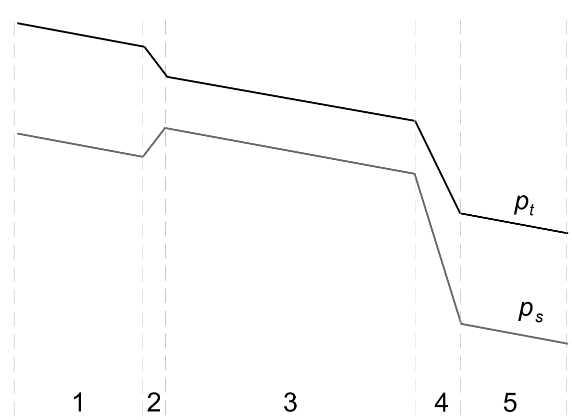
(A) The flow of air is from right to left, in the direction of increasing total pressure.

(B) Section 3 has a constant cross-sectional area.

(C) Section 2 is convergent (cross-sectional area decreases)

(D) The flow velocity in section 3 is lower than in section 5.

(E) Section 4 is convergent (cross-sectional area decreases)



003. An ice-cream manufacturer is considering purchasing a 50-ton refrigeration system for a new production line. The system will run with ammonia evaporating at -10°F and condensing at 100°F, operating for 8,600 hours per year. The system may be modeled as an ideal vapor compression single-stage refrigeration cycle. The purchase and installation cost for this system is estimated at $1,500 per ton. The cost of power consumption is $0.04 per hp-h based on fluid power for the first five years, and $0.06 per hp-h for the remainder of the equipment lifetime. The system is expected to have a life of 25 years with negligible salvage value. Assuming an annual interest rate of 8%, the present worth ($) of the first five years of power consumption costs is most nearly:

(A) $25,400

(B) $101,200

(C) $126,800

(D) $270,800

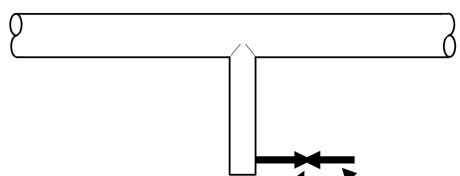
004. A large steam pipe contains steam at 200 psia with 10% moisture. A “drip leg” in a low point is installed so the liquid falls into it due to gravity. A steam trap at the bottom of the drip leg removes only the liquid and throttles it down to ambient pressure. The quality (%) at the discharge of the steam trap is most nearly:

(A) 10

(B) 18

(C) 32

(D) 90



005. A centrifugal water pump operates at a flow rate of 200 gpm and a pump head of 15 feet of water. Select ALL the statements that are correct:

(A) If a pressure gauge immediately upstream of the pump reads a vacuum of 1.5 psi, a pressure gauge immediately downstream of the pump should read approximately 8 psi.

(B) If a valve in the hydraulic system downstream of the pump is actuated so that it starts to partially close (but not fully), the flow rate through the pump will decrease and the pump head will also decrease.

(C) If a valve in the hydraulic system downstream of the pump is actuated so that it starts to partially close (but not fully), the flow rate through the pump will decrease and the pump head will increase.

(D) If a pressure gauge immediately upstream of the pump reads a vacuum of 1.5 psi, a pressure gauge immediately downstream of the pump should read approximately 5 psi.

(E) If the pump efficiency is 75%, the expected water horsepower is approximately 0.76 hp.

006. A single-effect water-ammonia absorption refrigeration system will be selected to provide a cooling load of 10 tons of refrigeration. The literature from the vendor claims the heating requirement at the desorber is 200,000 Btu/h. The waste heat from the condenser and the absorber will be collected by the same stream of water entering the machine at 70°F. If this cooling water shall be heated to no more than 85°F, the minimum flow rate (gpm) of cooling water is most nearly:

(A) 11

(B) 16

(C) 27

(D) 43

007. A vacuum of 3.5 psi is measured at a location where the elevation is 9,850 ft, and the atmospheric pressure is 10.3 psia. The absolute pressure of that measurement (inHg) at that location is most nearly:

(A) 0.014

(B) 1.8

(C) 6.8

(D) 13.8

008. In a heat exchanger, saturated steam at 15 psig is condensed to saturated liquid. The other fluid is atmospheric pressure water flowing at a rate of 6 gpm, entering at 70°F and leaving at 100°F. The mass flow rate (lbm/min) of steam is most nearly:

(A) 1.6

(B) 95

(C) 155

(D) 945

009. In a 12 in. by 24 in. duct, the static pressure is measured at 0.5 in. of water, and total pressure is measured at 0.54 in. of water. The air flow rate (cfm) is most nearly:

(A) 25

(B) 800

(C) 1,600

(D) 2,600

010. A heating coil is used to sensibly heat 5,000 SCFM of sea-level air from an initial condition of 40°F dry-bulb, 35°F wet-bulb to 110°F dry-bulb. The heating medium in the coil is water, pressurized to 30 psi, entering at 200°F and leaving at 120°F. The air volume flow rates (actual CFM) upstream and downstream of the coil respectively, are most nearly:

(A) 375 and 375

(B) 4,740 and 5,410

(C) 4,220 and 5,960

(D) 5,000 and 5,000

011. A vacuum cleaner is capable of creating a vacuum of 0.3 psi just inside the hose. The maximum velocity (ft/s) that could be expected in the hose is most nearly:

(A) 11

(B) 34

(C) 58

(D) 191

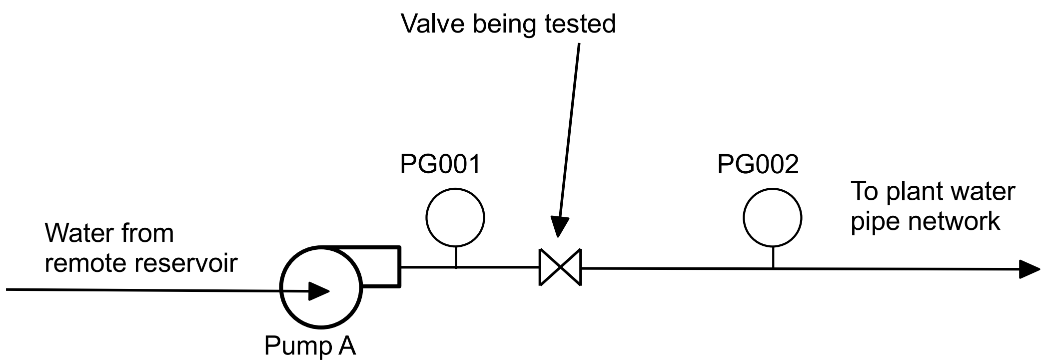
012. A valve manufacturer uses the rig shown below to test their valves. The working fluid is water (kinematic viscosity = 1.12 cSt, density = 62.4 lbm/ft^3). The flow rate is 400 gallons per minute, and all piping is 4-in, schedule 40, steel pipe (ID = 4.026 in). The test section (between pressure gauges PG001 and PG002) is 1,000 feet long of horizontal, straight pipe. For the test conditions, the Moody friction factor is known to be 0.018. Upon achieving steady state flow, the pressure readings are 70 psig for PG001 and 25 psig for PG002. For the valve being tested, the equivalent length in feet is most nearly:

(A) 0

(B) 110

(C) 220

(D) 1,000



013. A specialized refrigeration system runs with carbon dioxide and can be modeled as a single-stage, ideal vapor compression refrigeration cycle. The refrigerant enters the evaporator with a quality of 30% and is discharged as saturated vapor at 100 psia while providing a refrigeration effect of 25 tons. The temperature (°F) of the carbon dioxide at the discharge of the condenser is most nearly:

(A) -57

(B) 22

(C) 29

(D) 480

A table of saturated properties for carbon dioxide is provided here for your potential use.

		Enthalpy (Btu/lbm)	
Pressure (psia)	Temperature (°F)	Liquid	Vapor
100	-57.54	-8.36	137.5
110	-53.25	-6.33	137.8
120	-49.25	-4.43	138.1
130	-45.49	-2.64	138.3
140	-41.94	-0.93	138.5
150	-38.57	0.69	138.7
160	-35.36	2.24	138.8
170	-32.3	3.73	139
…	…	…	…
430	21.23	31.32	138
440	22.74	32.16	137.8
450	24.21	32.99	137.7
460	25.67	33.81	137.5
470	27.1	34.62	137.3
480	28.51	35.43	137.2
490	29.89	36.22	137
500	31.26	37.01	136.8

014. A 6-inch thick brick wall separates the hot gas inside an industrial furnace from the ambient air and its surroundings, which are at 77°F. The brick wall has a known thermal conductivity of 0.7 Btu·ft/(ft^2·h·°F) and a surface emissivity of 0.8. During steady operation of the furnace, the surface temperature of the outer face of the wall was measured as 212°F. Assuming a convective heat transfer coefficient between the outer face of the wall and the surrounding air of 3.5 Btu/(ft^2·h·°F), the temperature of the inner face of the wall (°F) is most nearly:

(A) 212

(B) 352

(C) 550

(D) 670

015. An exterior wall consists of 8-inch concrete (R-value = 1.95 (°F·ft^2·h)/Btu), an insulating layer providing an R-value of 12 (°F·ft^2·h)/Btu), and 1/2-inch drywall (R-value = 0.45 (°F·ft^2·h)/Btu). For the moment of interest, the indoor temperature is 72°F and the outdoor temperature is 90°F. The cooling load temperature difference (CLTD) is listed as 25°F. The instantaneous heat gain per unit wall area (Btu/(h·ft^2)) is most nearly:

(A) 1.17

(B) 1.30

(C) 1.63

(D) 1.74

016. Steam at 15 psig with 20% moisture enters a radiator. The steam is condensed as it flows through the radiator and leaves as condensate at 120°F. The heating capacity of the radiator is 9,300 Btu/h. The flow rate (lbm/min) of steam that is supplied to the radiator is most nearly:

(A) 0.175

(B) 0.205

(C) 10.5

(D) 12.3

017. An air handler processes 4,000 cfm of air with initial conditions of 50°F and 50% r.h. The air is heated with a finned heat exchanger with 78 ft^2 of heat transfer surface area and a *UA* value of 210 Btu/h·°F. Also, a steam spray uses saturated steam at 5 psig to add moisture to the air. The outlet air is at 100°F and 50% RH. The heat (Btu/h) added by the coil is most nearly:

(A) 3,450

(B) 105,500

(C) 210,000

(D) 360,000

018. A 12-in thick brick exterior wall is used in a building with no insulation or added internal finish. On a winter day, the following temperatures were measured: inside air temperature, 70°F; outside air temperature, 15°F; outside surface temperature, 20°F. Using an R-value (per inch thickness) of 0.119 (ft^2·°F·h)/(Btu·in) for the brick wall, and a convection heat transfer coefficient of 1.8 (Btu/h)/(ft^2·°F) for the inner side of the wall, the temperature (°F) of the inside wall surface temperature is most nearly:

(A) 28

(B) 56

(C) 63

(D) 68

019. A cylindrical, atmospheric-pressure tank with a diameter of 30 ft has one inlet pipe and one outlet pipe. The tank is used for the storage of fuel oil and is oriented so the axis is vertical. During simultaneous loading and unloading, liquid fuel oil is delivered to the tank at a rate of 20 ft^3/s through the inlet pipe. If the level inside the tank is to rise at a rate no greater than 20 inches/minute, the lowest flow rate (gpm) at which the fuel oil must be drawn from the tank through the outlet pipe is most nearly:

(A) Cannot be determined

(B) 22

(C) 164

(D) 8,976

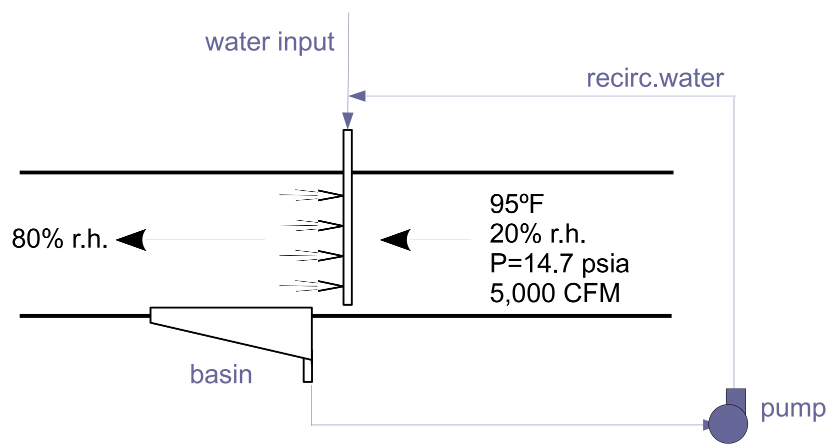
020. An air stream of 5,000 CFM enters an evaporative cooler where it is sprayed with a mist of cool water. During steady state operation, some fraction of the water sprayed evaporates and mixes with the air while the remaining water is collected in a basin and recirculated by a pump. For the conditions shown in the figure, the required input of liquid water into the humidifier (gallons per hour) is most nearly:

(A) 0.25

(B) 2.1

(C) 11

(D) 15



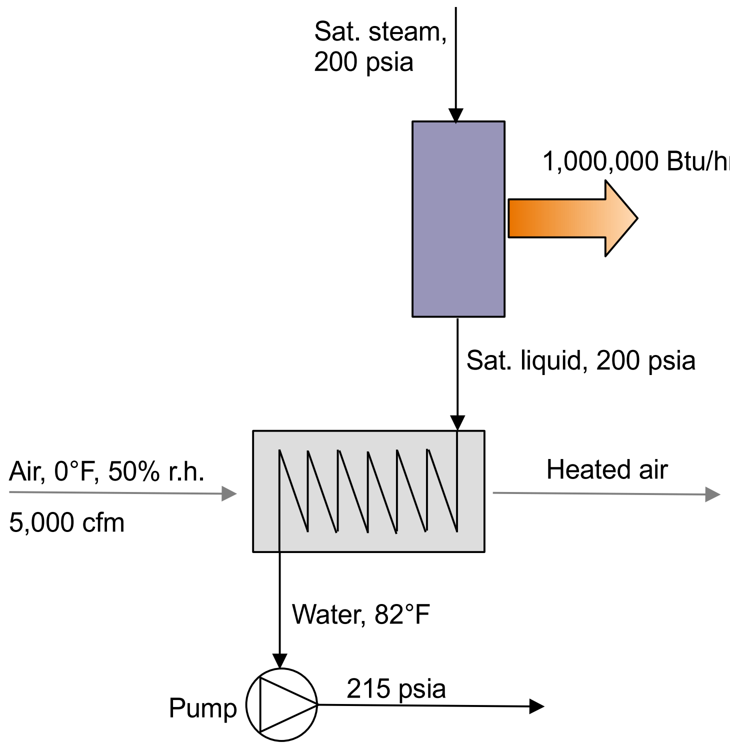
021. A stream of saturated steam at 200 psia enters a coil where it provides 1,000,000 Btu/hr of heat and is discharged as a saturated liquid. The saturated liquid then enters a secondary coil where it provides additional heating to a stream of 5,000 CFM of air at 0°F and 50% r.h. The water discharge temperature from the secondary coil is 82°F. Following the secondary coil, the water enters a centrifugal pump, which raises the pressure by 15 psi. The flow rate (gpm) of water into the pump is most nearly:

(A) 0.32

(B) 2.4

(C) 142

(D) 1,186



022. Octane is burned in a constant pressure burner and the combustion equation for the actual process is:

$$C_8H_{18} + 16.32(O_2+3.76N_2) \rightarrow 7.37CO_2 + 0.65CO + 4.13O_2 + 61.38N_2 + 9H_2O$$

The percent excess air being used is most nearly:

(A) 1475

(B) 131

(C) 16

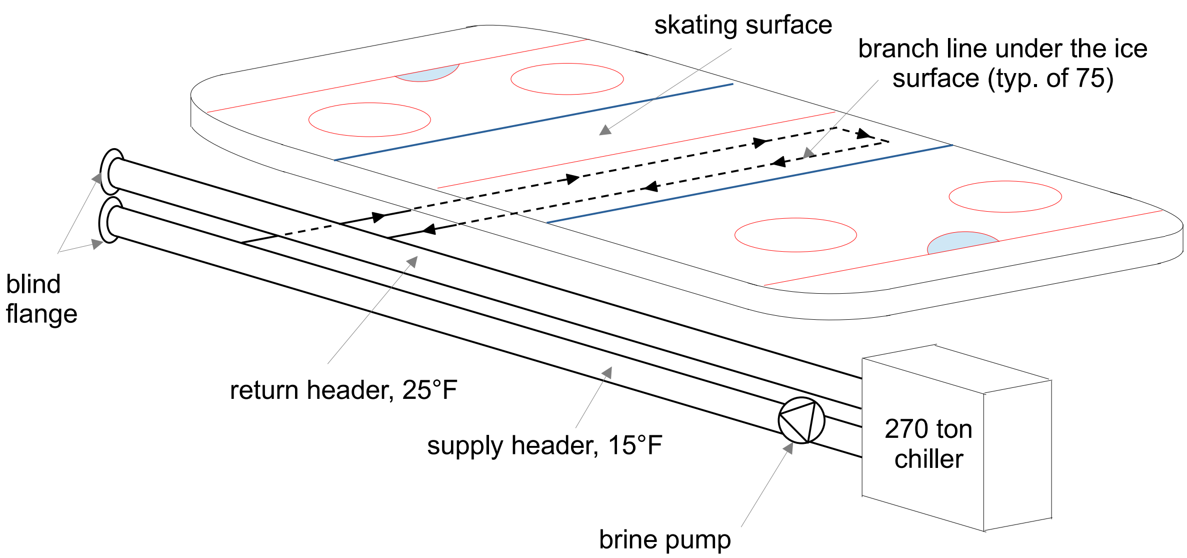
(D) 31

023. In an ideal Dual-Compression, Dual-Expansion Refrigeration Cycle with ammonia, the flash intercooler operates at a pressure of 30 psia. At the discharge of the low pressure compressor, the superheat is 160°F. The condenser pressure for the high pressure stage is 100 psia. The ammonia mass flow through the low pressure cycle is 600 pounds-mass per hour. The ammonia mass flow (pounds-mass per hour) through the high pressure cycle is most nearly:

(A) 270
(B) 365
(C) 600
(D) 786

024. The refrigeration system of an ice-skating rink consists of a brine chiller with a capacity of 270 tons of refrigeration. The chiller supplies the brine at 15°F and a pump fills a supply header with the chilled brine. From the supply header, 75 equal branches tee off and run under the skating surface, make a U-turn and run back into a return header. The branches are all 1” nominal diameter, standard weight steel pipe. In the return header, the brine is at 25°F. Assume the brine flow rate is equally divided between the 75 branches, and that the brine specific gravity and specific heat are 1.18 and 0.8 Btu/(lbm·°F), respectively. If needed, you may assume the Moody friction factor in each branch is 0.04, the equivalent length (physical length of pipe plus an allowance to account for elbows, tees, valves, etc) of each branch is 200 feet, and each header is entirely at a fixed, constant pressure. The pressure drop across the chiller is 5 psi. Assuming the chiller is running at full capacity, if the pump efficiency is 80%, the pump brake power (hp) is most nearly:

(A) 2.5
(B) 5.7
(C) 6.8
(D) 10



025. A single-stage ammonia vapor compression refrigeration system has a load of 5 tons. The evaporator temperature is 5°F. The ammonia leaves the expansion device with a quality of 30% and enters the compressor as saturated vapor. The required flow rate of ammonia (pounds-mass per hour) is most nearly:

(A) 50

(B) 75

(C) 150

(D) 200

026. A 100-ton, R-22 single-stage refrigeration system operates with a condensing temperature of 100°F and an evaporating temperature of 40°F. There is liquid subcooling of 10°F, suction superheat of 10°F and the compressor efficiency is 80%. The condenser water enters at 86°F and leaves at 95°F. The mass flow of condenser water (lbm/min) is most nearly:

(A) 312

(B) 2,600

(C) 18,720

(D) 156,130

027. A heat pump is used for heating a house during winter. The house is to be maintained at 78°F at all times. When the outdoor air temperature is 25°F the heat losses from the house are estimated to be 55,000 Btu/h. If the outdoor air is used as the heat source, the theoretical minimum power (hp) required to run this heat pump under the conditions described is most nearly:

(A) 1.5

(B) 2.1

(C) 5.4

(D) 8.0

028. An ammonia evaporator in a liquid overfeed refrigeration system with a 15-ton capacity and an evaporation temperature of 0°F must have a circulation rate of 6.5 per the manufacturer's recommendations. Under these conditions, the liquid flow (gpm) into the evaporator is most nearly:

(A) 0.064

(B) 0.96

(C) 6.2

(D) 8.5

029. A sea-level, atmospheric pressure air stream of 300 CFM at 65°F, with a humidity ratio of 55 grains of moisture per pound of dry air is to be cooled by flowing over a coil. Condensation is to be avoided, so the cooling process shall end with the air at a temperature 5°F above the dew point. Under these conditions, the maximum allowable dry-bulb temperature drop (°F) for the air is most nearly:

(A) 3

(B) 9

(C) 19

(D) 51

030. An evaporator with an overall *U*-factor of 130 (Btu/h)/(ft^2·°F) will be selected for a heat pump providing 120,000 Btu/h of heat with a coefficient of performance of 6.0. The evaporating and condensing temperatures for the refrigerant are 40°F and 100°F, respectively. The water enters the evaporator at a rate of 10 gpm at 70°F. Assuming the LMTD correction factor is 0.8, the required heat transfer area (ft^2) for the evaporator is most nearly:

(A) 11

(B) 35

(C) 53

(D) 86

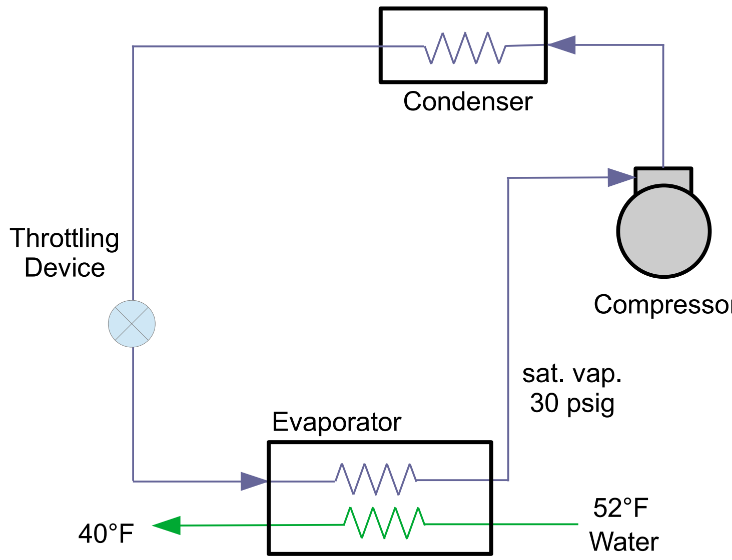
031. A stream of 3,700 pounds per hour of water at 52°F is chilled to 40°F. The evaporator heat exchanger in the chiller has an overall heat transfer coefficient of 60 (Btu/h)/(ft^2·°F). The direct expansion evaporator uses R-134a and operates at 30 psig, discharging as saturated vapor. Under these conditions, the heat exchanger effectiveness for the evaporator is most nearly:

(A) 33

(B) 48

(C) 66

(D) 71



032. An industrial boiler installation is to be performed in conformance with the ASME Controls and Safety Devices for Automatically Fired Boilers (CSD-1) Standard (relevant portion reproduced below, with permission from ASME). Per the standard, under what circumstances can a single safety shutoff valve be used in the gas supply line?

(A) If the input is greater than 5,000,000 Btu/h and it is not possible to use two valves in series.

(B) If the input is lower than 5,000,000 Btu/h and the valve has a proof of closure interlock function.

(C) If the input is greater than 5,000,000 Btu/h and the valve has a proof of closure interlock function.

(D) None. This is not allowed by the standard.

CF-180 Safety Shutoff Valves

(a) Each main burner supply line shall be equipped with a safety shutoff valve(s) that shall comply with the applicable provisions of ANSI Z21.21/CSA 6.5, Automatic Valves for Gas Appliances, ANSI Z21.78/CSA 6.20, Combination Gas Controls for Gas Appliances, or UL 429, Standard for Electrically Operated Valves.

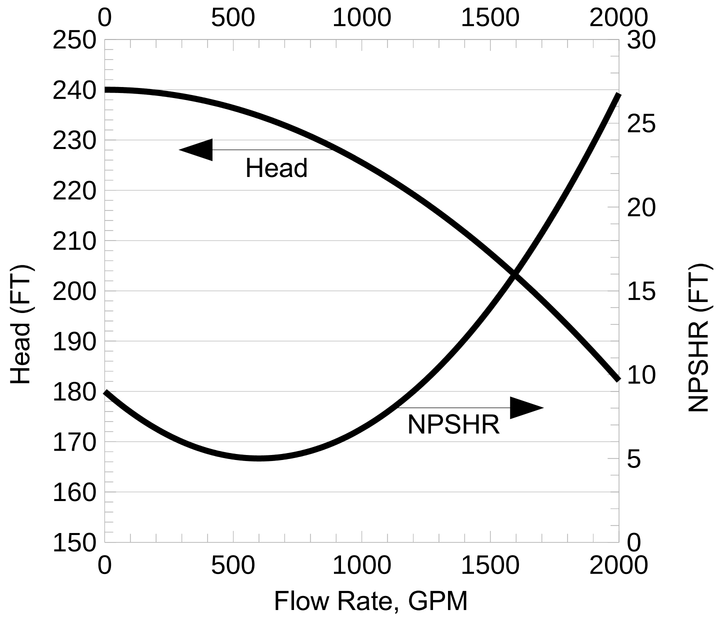
(b) The burner supply line shall be equipped as indicated below for the applicable input classification or any greater input classifications:

(1) For boiler units having inputs less than or equal to 5,000,000 Btu/hr (1 465 356 W), the main burner supply line shall be equipped with at least two safety shutoff valves in series that may be in a single valve body or one safety shutoff valve with a valve seal overtravel (proof of closure) interlock function. If the two safety shutoff valves are in a single valve body, the two safety shutoff valve seats shall be in series and shall have independently operated valve shafts.

(2) For boiler units having inputs greater than 5,000,000 Btu/hr (1 465 356 W) and less than 12,500,000 Btu/hr (3 663 389 W), the main burner supply line shall be equipped with at least two safety shutoff valves in series that may be in a single valve body. At least one of the two safety shutoff valves shall incorporate a valve seal overtravel (proof of closure) interlock function. If the two safety shutoff valves are in a single valve body, the two safety shutoff valve seats shall be in series and shall have independently operated valve shafts.

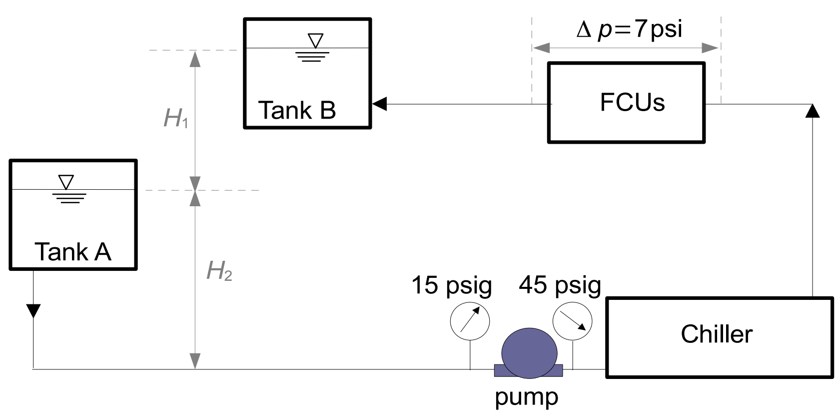
033. A pressurized, insulated hot water tank stores heated liquid water at 25 psi (absolute) and 180°F. A pump is used to take water from the tank at a rate of 1100 gpm. The pump performance curves are provided below. Neglecting friction and minor losses, the maximum height (feet) above the water surface of the suction reservoir this pump can be located without experiencing cavitation is most nearly:

(A) 8
(B) 21
(C) 34
(D) 224



034. In an office building, a pump with an efficiency of 75% circulates a 50-50 solution of water and ethylene glycol (SG for the solution is 1.08) from pressurized large storage tank "A", through a chiller, and through a network of Fan-Coil Units (FCUs) and finally to pressurized large storage tank "B". The loss coefficient for the chiller is K=5.5, the pressure drop across the network of FCUs is 7 psi, and all piping is standard weight steel, 2-inch nominal diameter. Pressure gauges at the pump suction and discharge read 15 psig and 45 psig, respectively. When the pump shaft power is 1/3-hp, the flow rate (gpm) is most nearly:

(A) 13.2
(B) 14.3
(C) 16.1
(D) 18.0



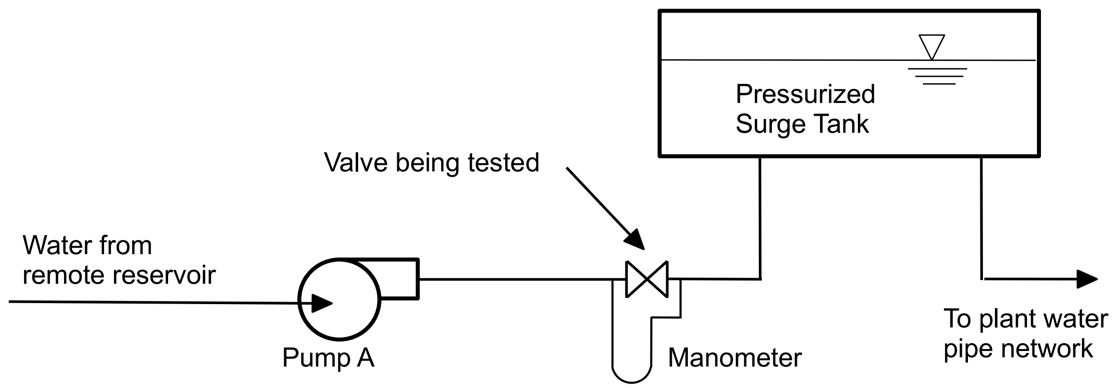
035. A valve manufacturer uses the test rig shown below to determine the loss coefficient *K* for their valves. The working fluid is water (kinematic viscosity, v = 1.12 cSt, density, ρ = 62.4 lb/ft^3). The flow rate is 400 gallons per minute, and all piping is 4-in, schedule 40, steel pipe (ID = 4.026 in). A differential U-tube manometer measures the pressure drop across the valve as 8.5 inches of mercury. The loss coefficient *K* for the valve, is most nearly:

(A) 8.5

(B) 12

(C) 6

(D) 24



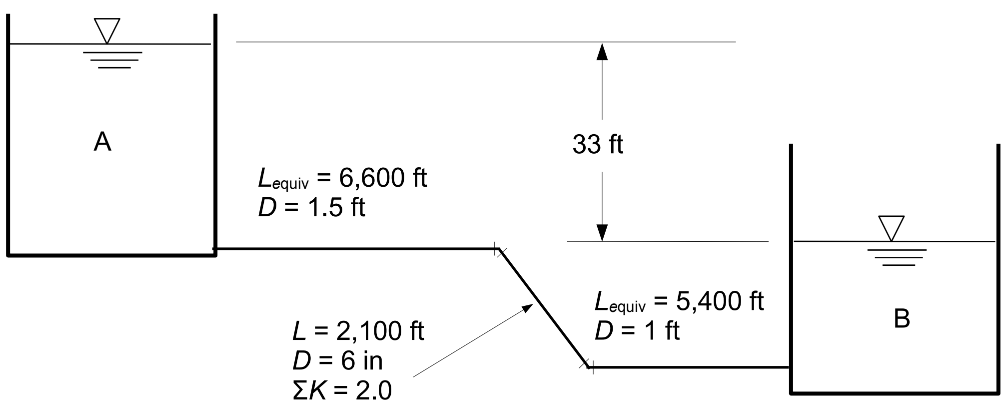
036. The two reservoirs are connected by three piping segments in series. Assume a Darcy friction factor of 0.03 throughout all piping. For the middle segment, the pipe length is 2,100 ft and the sum of the minor loss coefficients $\Sigma K = 2.0$. For the other two segments, the equivalent length is provided in the figure. The flow rate (gpm) is most nearly:

(A) Cannot be determined

(B) 0.77

(C) 165

(D) 345



037. A 15-ton, ideal vapor compression refrigeration cycle operates with R-22; evaporating and condensing at 15°F and 95°F, respectively. The flow rate of liquid refrigerant (gpm) being discharged from the condenser is most nearly:

(A) 0.61

(B) 4.59

(C) 44

(D) 2642

038. Water enters the tubes of a small parallel flow heat exchanger at 74°F at a rate of 30 gpm. On the shell side 10,700 lbm/h of a heat transfer oil enters at 175°F. The heat transfer surface area is 94 ft^2, and the overall heat transfer coefficient is 200 Btu/(h·ft^2·°F). For this heat exchanger, the number of transfer units (*NTU*) is most nearly:

(A) Cannot be determined

(B) 2.5

(C) 3.0

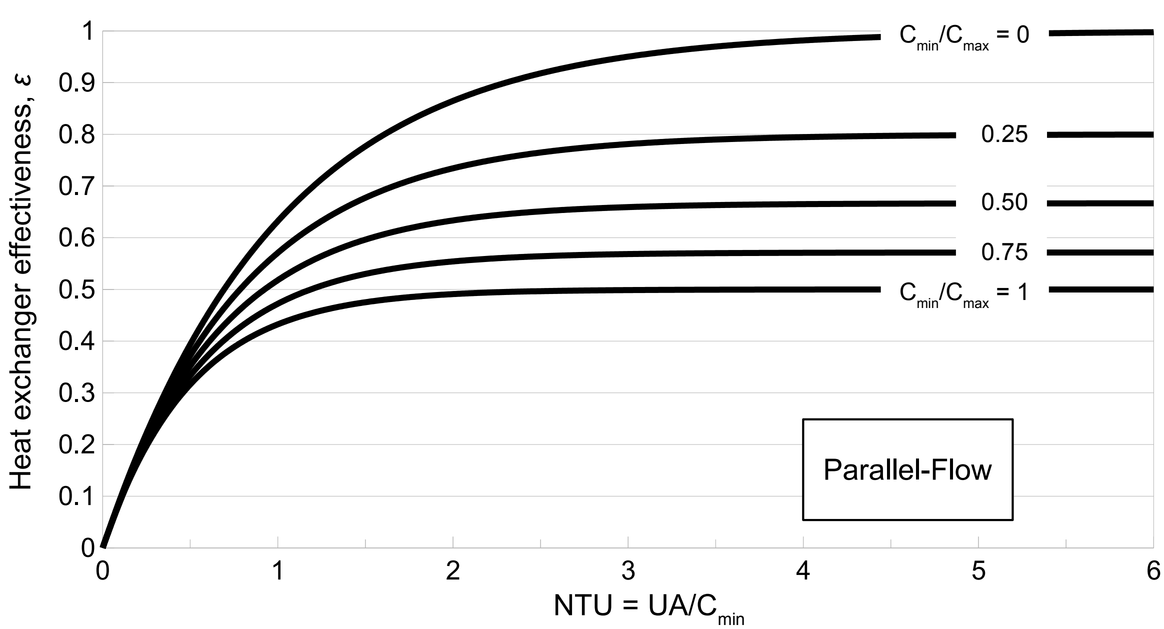
(D) 3.5

If needed, you may use the following values for specific heat *c*, and density, *ρ*:

c_{oil} = 0.7 Btu/(lb·°F) ρ_{oil} = 81.1 lb/ft^3

c_{water} = 1.0 Btu/(lb·°F) ρ_{water} = 62.4 lb/ft^3

Also, this is a plot of heat exchanger effectiveness for your possible use:



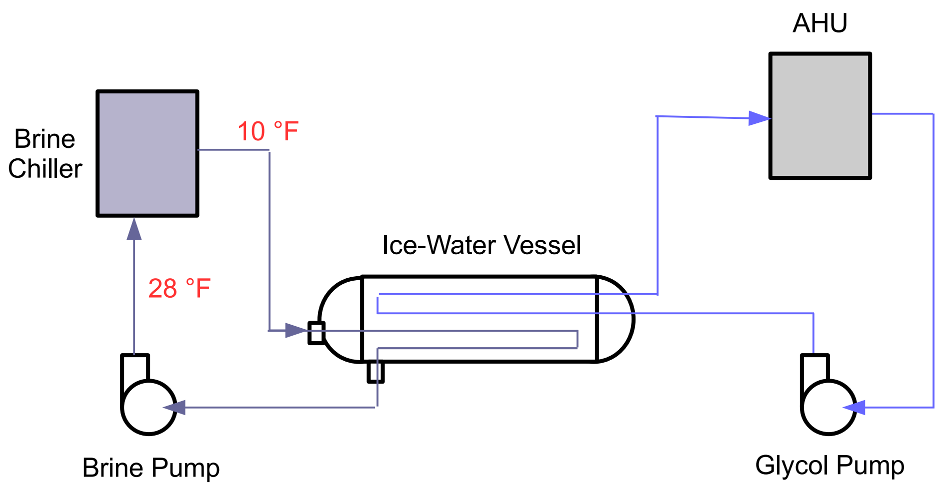
039. During the night, when electricity costs are low, an office building uses a chilled brine (specific heat, 0.88 Btu/(lbm·°F); density, 67 lbm/ft^3) to freeze water stored in a large, perfectly insulated vessel. During the freezing process, the water in the tank goes from 5% ice by mass to 95% ice by mass and it takes 5 hours of continuous operation of the brine system. During the day (as the building is occupied and the brine system is inactive) the stored ice is used to chill glycol which is pumped to the air handling unit (AHU) and provide conditioned air to the offices. The design cooling load of the AHU is 700,000 Btu/h and it must provide this continuously during a period of 10 hours. At the design condition, the water is 95% ice by mass and goes to 5% ice by mass over the 10 hours. At the design condition, the required brine flow rate (gpm) is most nearly:

(A) 15

(B) 25

(C) 95

(D) 165



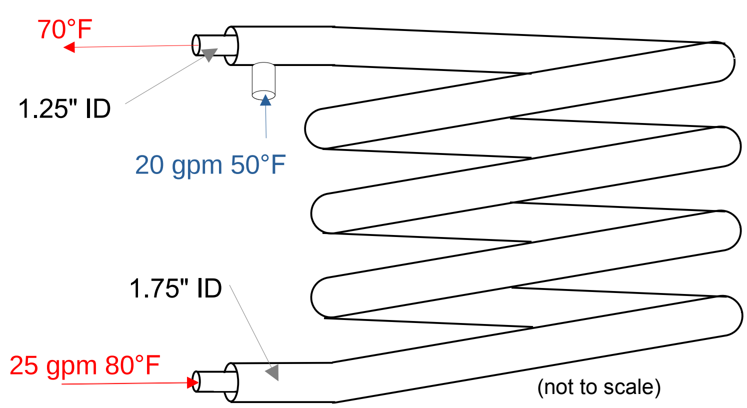
040. A stream of water flowing at 25 gpm must be cooled from 80°F to 70°F with chilled water at 50°F flowing at 20 gpm in a coaxial counterflow heat exchanger with an overall *U*-factor of 450 (Btu/h)/(ft^2·°F) and 1.25 inch diameter internal tube, with negligible tube thickness, and an outer tube of 1.75 inch ID. Under these conditions, the required length (ft) of heat exchanger tubing is most nearly:

(A) 32.3

(B) 45.2

(C) 51.0

(D) 64.3



www.SlaythePE.com

This completes the first portion of the practice test.
To purchase detailed, step-by-step solutions to all the problems in this practice test, visit www.SlayThePE.com

The second portion of the test starts in the next page.

201. A dry products analysis was performed on a combustion process where propane (C_3H_8) was burned with air at constant pressure of 15 psia. When corrected for water vapor, the analysis produced the following volumetric percentages for the composition: 8.32% CO_2, 4.16% CO, 1.04% H_2, 15.60% H_2O, 0.52% O_2, and the rest was nitrogen. The temperature of this flue gas is always 300°F. A waste heat recovery system is being considered to use this flue gas as a source of heat to raise the temperature of a stream of water from 70°F to 120°F. The temperature of the flue gas after cooling will be kept 10°F above its dew point to avoid condensation of the water vapor. Assuming the flue gas-to-water heat exchanger is a counterflow, concentric tube, the log-mean temperature difference (°F) is most nearly:

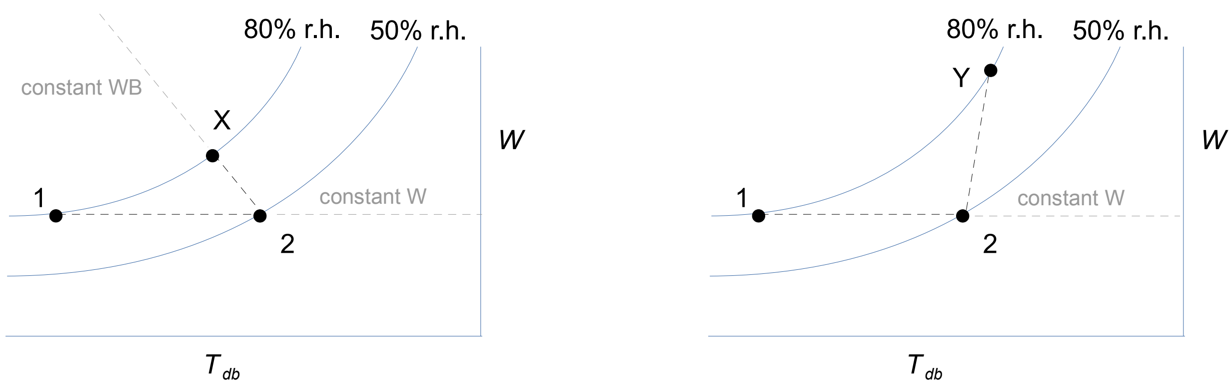
(A) 89

(B) 102

(C) 118

(D) 126

202. Two different multi-step psychrometric processes are schematically shown in the psychrometric charts below. Examine the figures and select all the statements that are most nearly correct. Conditions "1" and "2" are the same for both processes.



(A) Process 1-2-X on the left figure consists of latent heating followed by passing the air through a moist screen.

(B) Process 1-2-Y on the right figure consists of sensible heating followed by injection of hot steam.

(C) All else being equal, Process 2-X requires less mass of water/steam than Process 2-Y.

(D) If T_1 = 40°F (DB), then T_X > 54°F (DB)

(E) If T_1 = 40°F (DB) and T_Y = 65°F (DB), the dew point at State 2 will be greater than that of State 1.

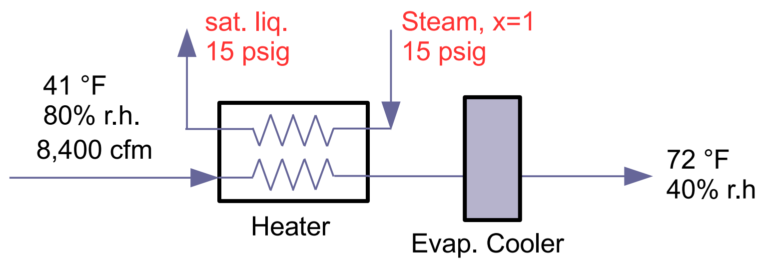
203. Sea-level air at 41°F, 80%r.h. enters a heating-humidification system at a rate of 8,400 CFM. The heating section uses a steam coil with saturated steam at 15 psig, and the humidification step is accomplished with evaporative cooling. The desired condition for the air at the system outlet is 72°F and 40%r.h. If the steam shall leave the coil as saturated liquid, the required steam flow rate (lbm/min) into the heating coil is most nearly:

(A) 5

(B) 7

(C) 415

(D) 660



204. Water leaves the condenser of a power plant at a rate of 1,600 gpm and enters a wet cooling tower at 95°F. The water is cooled in the tower down to 70°F by ambient air that enters the tower at 68°F, and 60 percent relative humidity and leaves saturated at 86°F. The required flow rate (lbm/hour) of air is most nearly:

(A) 1,600

(B) 413,500

(C) 797,000

(D) 838,000

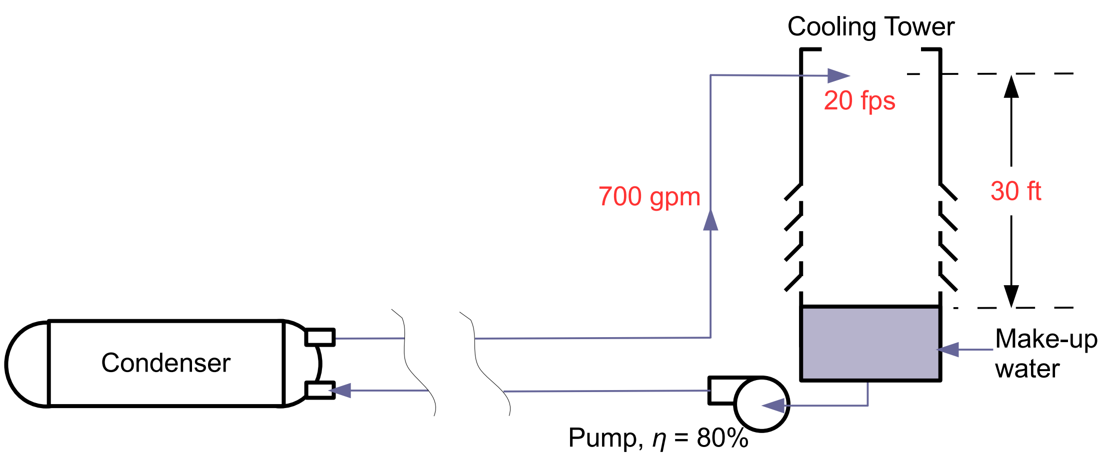
205. The pump moves 700 gpm of water from the cooling tower basin, through the condenser of a steam power plant and then to the spray nozzles at the top of the tower. All piping is schedule 40, nominal 6-in steel pipe (ID=6.065 in). The total length of pipe is 800 ft. All the elbows, tees, valves, and fittings are well represented by a total loss coefficient $\Sigma K = 20$. The water pressure drop across the condenser is 10 psi. The spray nozzles at the top of the tower are 30 ft above the free surface of the basin and the water velocity at the nozzles is 20 ft/s. Neglecting any changes in the water properties with temperature, assuming a Darcy friction factor of 0.03, and assuming a pump efficiency of 80%, the brake horsepower (hp) for the pump is most nearly:

(A) 15

(B) 22

(C) 27

(D) 32



206. When the shaft horsepower supplied to a certain centrifugal pump is 25 hp, the pump discharges 700 gpm of water while operating at 1800 rpm with a head rise of 90 ft. If the pump speed is reduced to 1200 rpm, the new head rise is most nearly __________feet

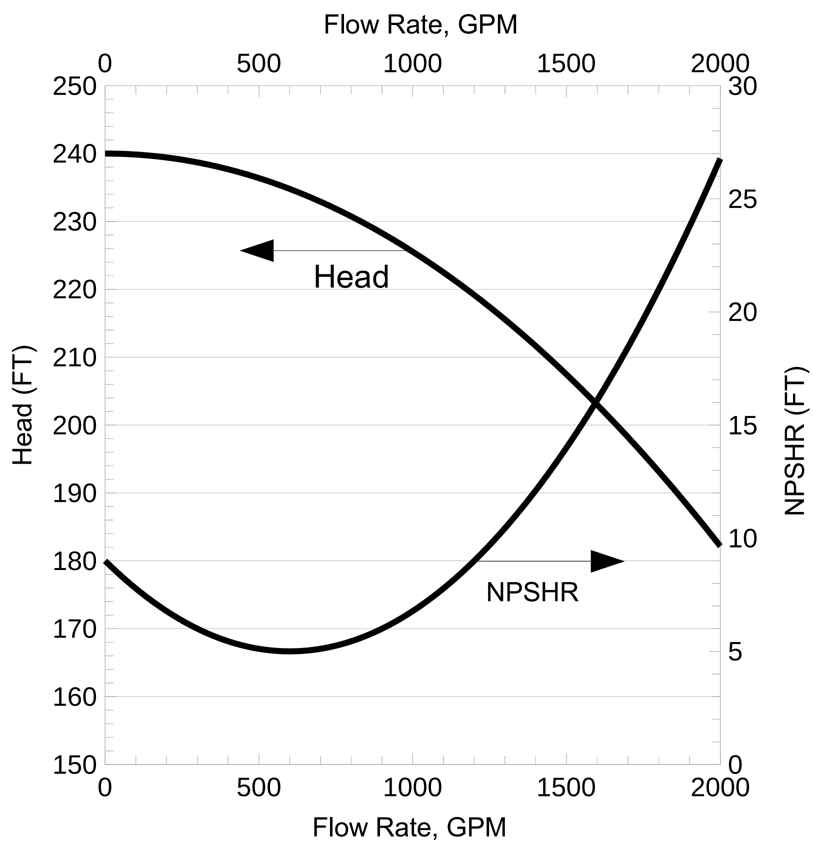
207. A pump is used to deliver water from a ground-level, atmospheric reservoir to a municipal water tower, also at atmospheric pressure. The height of the water surface in the tower is 170 feet. Normally the pump (whose performance curve is shown below) delivers a flow rate of 1,200 gpm and minor losses are negligible. For this distribution system in normal operation, the friction head loss (ft) is most nearly:

(A) 9

(B) 50

(C) 170

(D) 220



208. The sketch shows process 1-2-3 in a psychrometric chart.

Select <u>all</u> that apply:

□ A. In process 1-2 the relative humidity decreased.

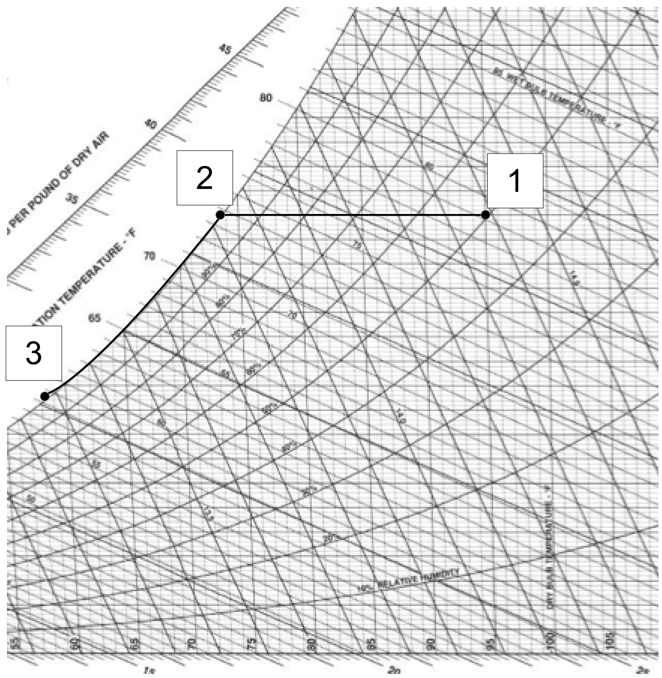
□ B. The dry-bulb temperature at State 2 is the dew-point temperature of State 1.

□ C. In process 1-2 the humidity ratio remained constant.

□ D. In process 2-3 the sensible heat ratio is less than 1.

□ E. In state 3, the wet bulb temperature is lower than the dry bulb temperature.

□ F. The amount of condensation formed in process 2-3 is approximately the same as the amount formed in process 1-2.

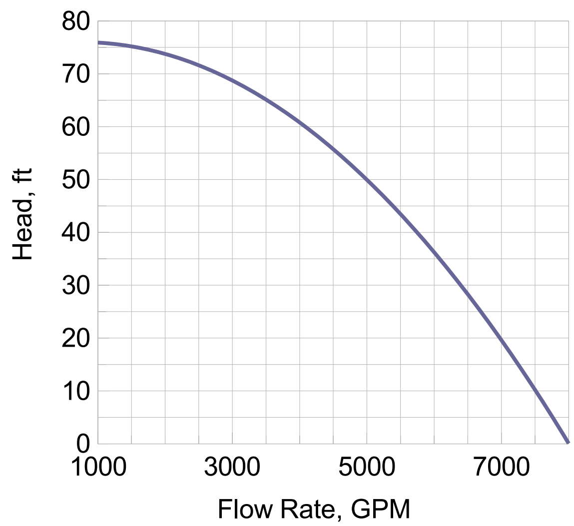


209. Water is pumped between two atmospheric pressure reservoirs in a pipeline with the following characteristics:

Pipeline Characteristics	
Pipe ID, D (in)	12
Total length, L (ft)	230
Darcy friction factor, f	0.03
Total of minor loss coefficients, ΣK	2.5
Static head, $z_{destination} - z_{source}$, (ft)	50

The system is served by two identical pumps in parallel, running simultaneously. The characteristic curve for one such pump is given below. The water flow rate (gpm) in the pipeline is most nearly:

(A) 1,000
(B) 1,700
(C) 2,200
(D) 4,400



210. A heat transfer oil at 430°F (density = 40 lbm/ft^3) flows into a manifold where the flow is divided into 4 branches labeled A, B, C, and D. All piping is schedule 40 seamless steel pipe. The flow entering the manifold is 10,000 lbm/h, and the flow rates for branches A, B, and C, are known to be 1000, 2000, and 3000 pounds per hour, respectively. If the velocity in all branches is not to exceed 5.5 feet per second, the smallest nominal pipe diameter (in) for branch D, is most nearly:

(A) ¼
(B) ½
(C) ¾
(D) 1

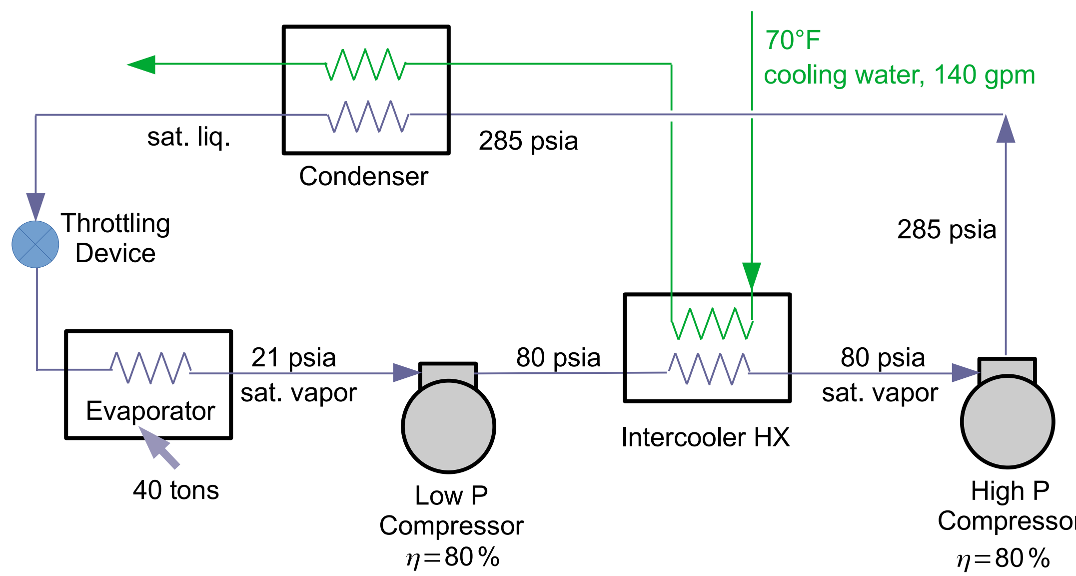
211. An ammonia vapor compression refrigeration cycle operates with two stage compression with an intercooling heat exchanger as shown in the figure. The gas at the low P compressor discharge is cooled in the heat exchanger until it becomes saturated vapor. A stream of 140 gpm of water at 70°F is used for cooling the gas between the compressors and then is routed to cool the condenser. The system capacity is 40 tons, and the isentropic efficiency of each compressor stage is 80%. With the conditions shown in the figure, the heat removed from the refrigerant (Btu/h) in the intercooler is most nearly:

(A) 69,000

(B) 91,000

(C) 115,000

(D) 480,000



212. Natural gas (which you may model as pure methane, CH_4) is burned with air during a combustion process in a furnace for a large commercial building. Assume complete combustion and a total pressure of 14.7 psia. The furnace consumes fuel at a rate of 100 pounds mass per hour. A blower will deliver combustion air at 70°F to the furnace so the combustion takes place with 30% excess air. The flow rate (cfm) of air the blower must supply is most nearly:

(A) 130

(B) 500

(C) 2,250

(D) 29,900

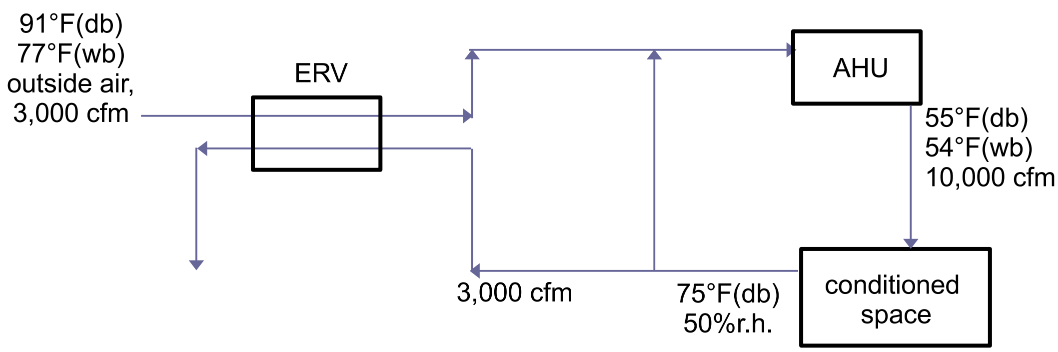
213. Octane (C_8H_{18}) is burned with dry air. The volumetric analysis of the products on a dry basis is given in the table below. Under these conditions, the gravimetric air-fuel ratio used is most nearly:

(A) 4.76
(B) 14.22
(C) 16.32
(D) 19.76

CO_2	10.02%
O_2	5.62%
CO	0.88%
N_2	83.48%

214. An air handler unit (AHU) delivers 10,000 cfm of air at 55°F (db), 54°F (wb) to a conditioned space. The return is at 75°F(db) and 50% r.h. The exhaust is 3,000 cfm which is replaced with an equal amount of outside air at 91°F(db), 77°F(wb). There is an energy recovery ventilator (ERV) between the exhaust and the fresh air streams, with latent effectiveness of 75% and sensible effectiveness of 85%. Under these conditions, the latent heat (Btu/hr) removed by the AHU is most nearly:

(A) 29,000
(B) 62,000
(C) 83,000
(D) 133,000



215. A heating section consists of a 16-in.-diameter duct that houses an electric resistance heater rated for 14,000 Btu/hour. Air enters the heating section at 14.7 psia, 50°F, and 40% relative humidity with a velocity of 25 ft/s. The air exit temperature (°F) is most nearly:

(A) 54
(B) 57
(C) 77
(D) 163

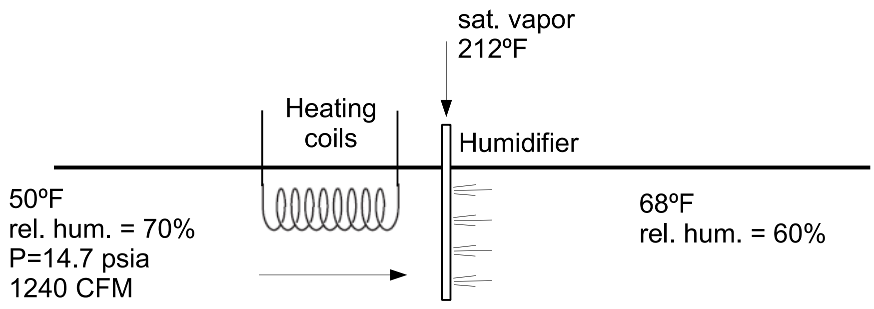
216. An air-conditioning system operates at a total pressure of 1 atm and consists of a heating section and a humidifier that supplies wet steam (saturated water vapor) at 212°F. Air enters the heating section at 50°F and 70 percent relative humidity at a rate of 1240 CFM, and it leaves the humidifying section at 68°F and 60 percent relative humidity. The rate at which water is added (lbm/h) to the air in the humidifying section is most nearly:

(A) 0.33

(B) 6.5

(C) 12.5

(D) 19.5



217. During an air-conditioning process, 900 CFM of conditioned air at 65°F and 30 percent relative humidity are mixed with 300 CFM of outside air at 80°F and 90 percent relative humidity at a pressure of 1 atm. The relative humidity of the resulting mixture is most nearly:

(A) 30%

(B) 45%

(C) 53%

(D) 90%

218. The viscosity of saturated liquid ammonia at -50°F is $6.527 \cdot 10^{-6}$ lbf·s/ft^2. If the Reynolds number is 9,000 at a location within a 3-in ID conduit, the mass flow rate (lbm/h) of ammonia is most nearly:

(A) 22.3

(B) 41.5

(C) 1,337

(D) 16,044

219. The pump for a chilled water system is located in a basement mechanical room. The expansion tank is connected very near the pump suction. The pump is the lowest point in the system and the highest point is a pipe in the penthouse, which is 130 feet above the pump. The desired pressure at this highest point is 12 psig. The head losses in the system are provided as follows:

Upwards Segment	
Piping, fittings, valves, etc.	35 ft H_2O
Chiller	25 ft H_2O
Cooling coils	15 ft H_2O

Downwards Segment	
Piping, fittings, valves, etc.	25 ft H_2O

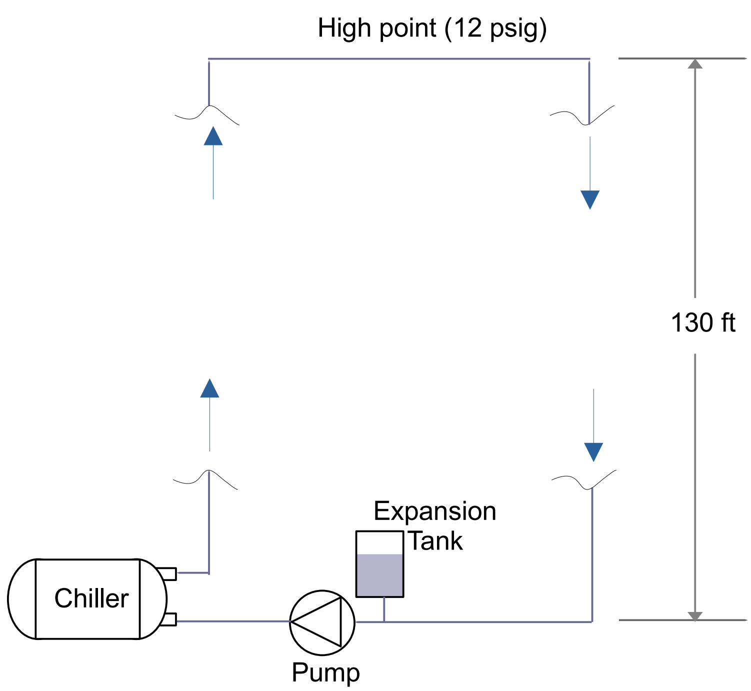
Assuming a mean operating temperature of 50°F while the pump is running, the pressure (psig) at the pump suction is most nearly:

(A) 46

(B) 58

(C) 68

(D) 75



220. A duct with a square cross section will be selected so it has equal resistance and air flow capacity as the smallest circular duct that can carry 13,200 cfm while keeping the velocity below 1600 fpm. The side length (in) of the duct is most nearly:

(A) 34

(B) 36

(C) 39

(D) 44

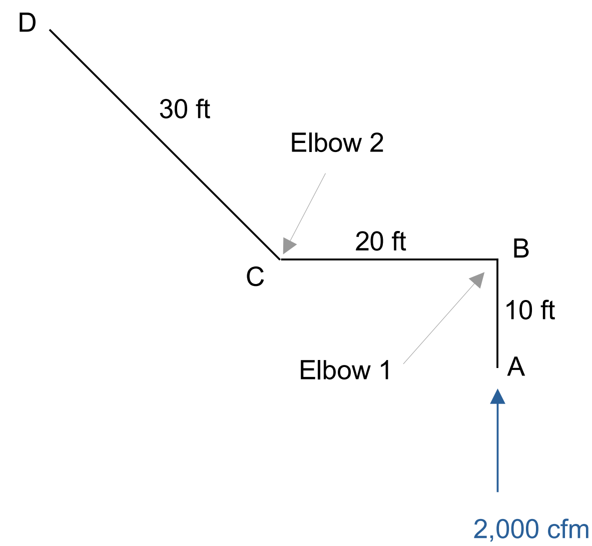
221. Duct segment A-B-C-D is 12in x 12in with a flow rate of 2,000 cfm. Elbow 1 has a center radius of 13 inches and a local loss coefficient of 0.21. Elbow 2 has a center radius of 24 inches and a local loss coefficient of 0.03. The pressure loss due to friction for straight segments can be taken as 0.45 in. w.g. per 100 feet of length. If the pressure at D is 0.25 in. w.g., the required pressure (in. w.g.) at A is most nearly:

(A) -0.09

(B) 0.27

(C) 0.34

(D) 0.59



222. A building is 85 ft wide by 120 ft long and 12 ft high. The indoor conditions are 72°F and 30% r.h., while the outdoor conditions are 5°F and saturated. For an infiltration rate of 0.8 ACH, the latent load (Btu/h) due to infiltration is most nearly:

(A) 30,000

(B) 2,680

(C) 3,440

(D) 5,110

223. During a cold winter day, wind at 35 miles per hour is blowing parallel to a 13-ft-high and 33-ft-long wall of a house. The air outside is at 0°F and the temperature of the outer face of the wall is 40°F. An engineer needs to obtain the Reynolds number of this flow, as an intermediate step in the calculation of the heat transfer film coefficient. The Reynolds number is calculated based on the long side of the wall and evaluating the properties of air at the mean temperature value of 20°F. Under these conditions, the Reynolds number is most nearly:

(A) $4.9 \cdot 10^6$

(B) $12.5 \cdot 10^6$

(C) $400 \cdot 10^6$

(D) $746 \cdot 10^6$

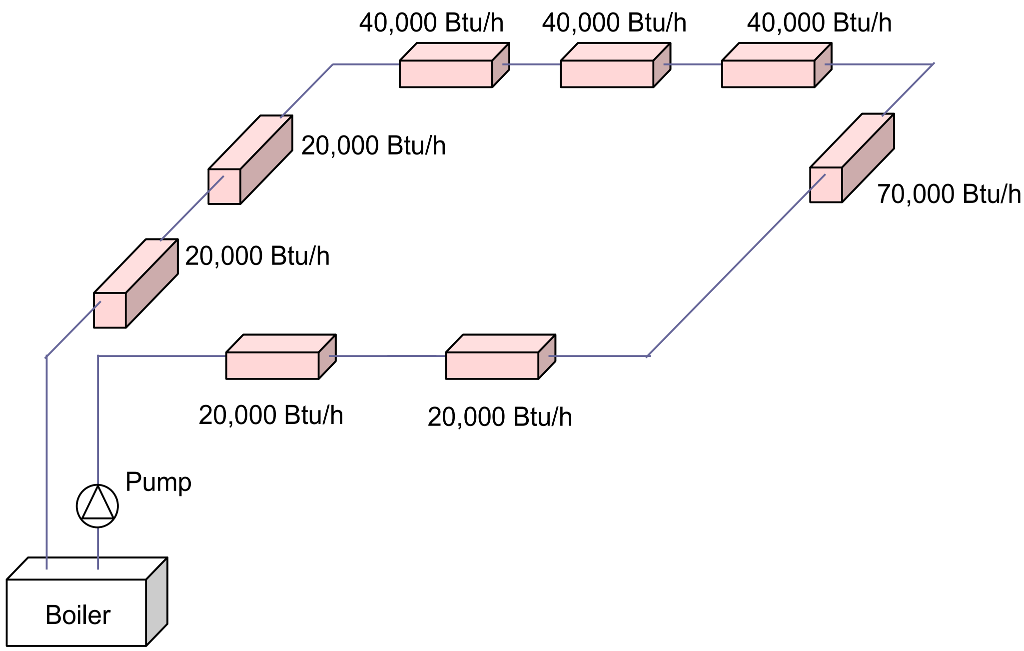
224. A boiler supplies pressurized water at 200°F to a group of convectors in the floor above as shown in the figure. The vertical risers into and out of the boiler are 6 feet long each. The total length of horizontal pipe in the upper level is 260 feet, and all elbows are regular 90°. The iron pipe will be selected as the smallest that can keep the flow velocity below 2 fps, and it is required to keep the water temperature entering the boiler at 180°F at the design condition when all convectors are active at full capacity. Assuming a friction head loss of 1 psi per 100 feet of linear length, and using the equivalent length approach, the head (ft) supplied by the pump must be most nearly:

(A) 4.6

(B) 11

(C) 22

(D) 462



225. Fluid 1 (hot) and Fluid 2 (cold) are separated by a composite wall made of two layers. Layer A is made of material A and Layer B is made of a different material, B. The thickness of Layer A is the same as that of Layer B. The red line represents the temperature distribution across the fluids at steady state.

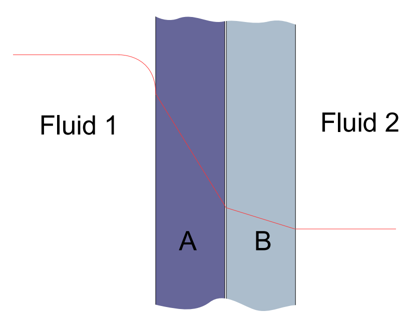
For steady state, select <u>all</u> that apply:

□ A. The convection film coefficient at the wall-Fluid 2 interface is zero.

□ B. The thermal conductivity of Material A is lower than that of Material B.

□ C. The heat transfer rate across Layer A is greater than that across Layer B.

□ D. The conduction resistance across Layer A is higher than the convective resistance between Fluid 1 and the wall.



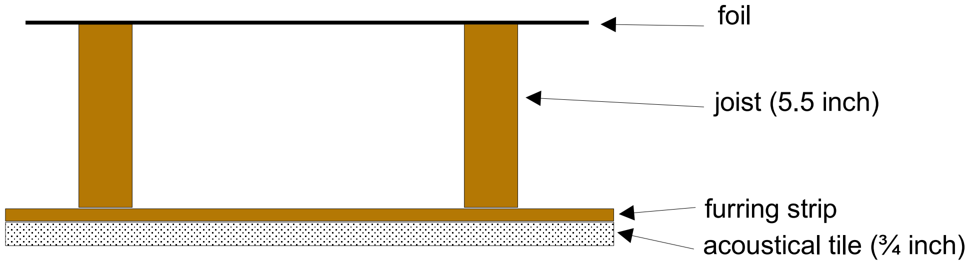
226. The ceiling of a house is 3/4-inch acoustic tile (fiberboard) on wood furring strips with highly reflective aluminum foil across the top of wood ceiling joists. Disregarding the effect of all the wood, The *U*-factor ((Btu/h)/(ft^2·°F)) for cooling load calculations is most nearly:

(A) 0.078

(B) 0.160

(C) 6.4

(D) 12.8



227. A space in an industrial building has a winter sensible heat loss of 150,000 Btu/h and negligible latent heat load. The space is to be kept at 71ºF, 50% r.h. This specific application requires 100% outside air at a rate of 6,500 cfm when measured at the room conditions. The winter design outdoor condition is saturated air at 30ºF. The air is to be conditioned in three stages: 1) preheated, 2) humidified with an adiabatic saturator to the desired humidity ratio, and 3) reheated. The temperature at the discharge of the adiabatic saturator is to be maintained at 60°F dry bulb. The heat inputs (Thousand Btu/h) supplied to the preheat and reheat coils respectively, are most nearly:

(A) 137; 460

(B) 226; 357

(C) 357; 460

(D) 357; 226

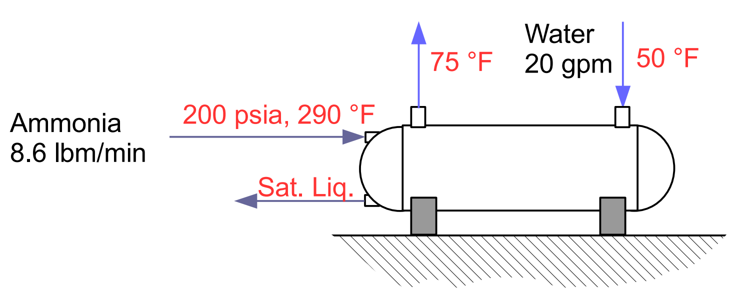
228. The figure shows a heat exchanger used as a condenser for hot ammonia gas in an industrial refrigeration plant. The coolant is a stream of 20 gpm of water at 50°F, which is then discharged at 75°F. Over the course of several years, the insulation on the heat exchanger has been degraded so the amount of heat lost to the ambient from the heat exchanger vessel is no longer negligible. The figure provides the process data. Under these conditions, the rate at which heat is lost (Btu/h) to the ambient is most nearly:

(A) 0

(B) 65,000

(C) 245,000

(D) 565,000



229. The window panels at a natatorium (a room with an indoor swimming pool) have a double glazing with a ¼ inch air gap configuration so that R-value$_{window} = 2.1(°F \cdot ft^2 \cdot h)/Btu$. The room air is at 85ºF, 60% relative humidity. The outdoor air is saturated at 5ºF. The indoor and outdoor air films may be characterized with R-values of $0.68(°F \cdot ft^2 \cdot h)/Btu$. and $0.17(°F \cdot ft^2 \cdot h)/Btu$. For these conditions:

(A) Condensation will not be expected to occur on the indoor side of the glazing, because the surface temperature there is lower than the room's dew point.

(B) Condensation will be expected to occur on the indoor side of the glazing, because the surface temperature there is higher than the room's dew point.

(C) Condensation will not be expected to occur on the indoor side of the glazing, because the surface temperature is higher than the room's dew point.

(D) Condensation will be expected to occur on the indoor side of the glazing, because the surface temperature is lower than the room's dew point.

230. The latent load in a conditioned space is 12,500 Btu/h and it is entirely due to moisture gain from internal sources. The rate of water evaporation (pounds per minute) in the space is most nearly:

(A) 0.2

(B) 1.6

(C) 12

(D) 24

231. Air at 55°F dry bulb and 53°F wet bulb is supplied to a conditioned space. The return air is at 74°F and 55% RH when the sensible gains for the space all add up to 30,000 Btu/h. Under these conditions, the total latent gain (Btu/h) for the space is most nearly:

(A) 1,435

(B) 9,000

(C) 14,000

(D) 30,000

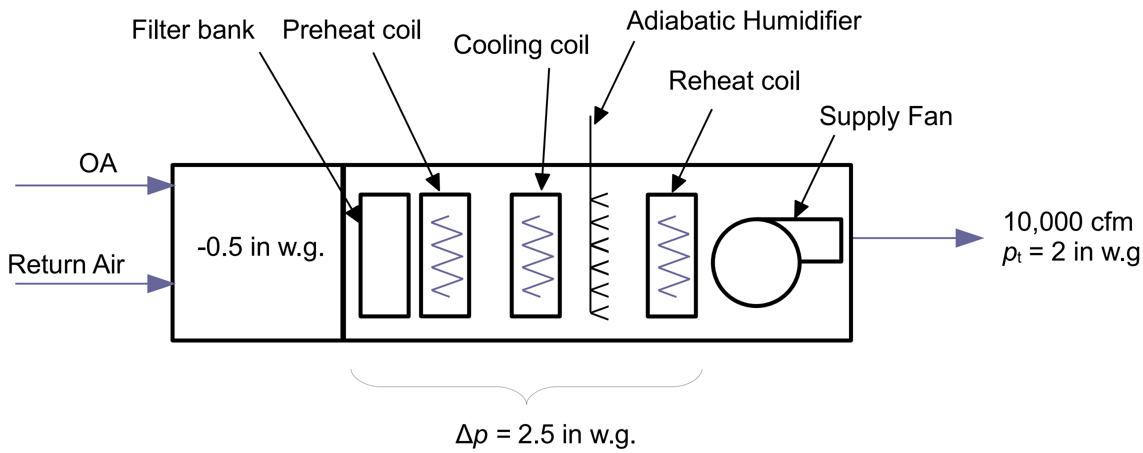
232. The supply air fan shown has to provide 10,000 cfm of air at 55°F(db), 52°F(wb) at the discharge at a pressure of 2 in. w.g. The air handler has filters, multiple heating/cooling coils, and a humidifier nozzle bank which all combine to cause a pressure drop of 2.5 in w.g. The pressure at the mixing box is -0.5 in w.g. The fan efficiency is 80% and the fan motor efficiency is 75%. Under these conditions, and noting that the fan motor is not in the airstream, the expected temperature rise (°F) across the fan is most nearly:

(A) 0.5

(B) 1.3

(C) 2.5

(D) 3.1



233. In a single-stage vapor compression refrigeration system, there is a pressure drop due to friction and minor losses in the liquid line (the piping between the condenser discharge and the inlet to the expansion valve). If this pressure drop is significant, the saturation temperature of the liquid in the line drops, causing the formation of excessive vapor bubbles, which affects the operation of the expansion valve. One solution is to provide enough undercooling at the condenser discharge so the refrigerant is still undercooled or is a saturated liquid at the expansion valve inlet. In a system operating with R-134a condensing at 110°F and evaporating at 20°F, the expected pressure drop between condenser discharge and expansion valve inlet is 4.5 psi. Assume the pressure drop along the piping occurs isothermally. Select the lowest value of undercooling (°F) at the condenser discharge that can prevent vapor formation upstream of the expansion valve:

(A) 1

(B) 2.5

(C) 5

(D) 10

234. In a large office building during the winter, the rooms near the exterior walls need heating while the rooms towards the center need cooling. In such applications, a heat-recovery chiller (HRC) may be suitable. In these systems, the evaporator chills water for the fan-coil units that need cooling and the condenser heats water for the fan-coil units that need heating. One manufacturer's catalog lists the following technical information for a particular heat-recovery chiller:

Heating Water Leaving Temperature	Heating Water Entering Temperature	Chilled Water Flow Rate	Chilled Water Leaving Temperature	Chilled Water Entering Temperature	Compressor Input Power
110°F	95°F	250 gpm	44°F	54°F	75 kW

For the conditions described above, the flow rate (gpm) of heating water, is most nearly:

(A) 177

(B) 200

(C) 265

(D) 300

235. In a waste heat recovery operation, hot exhaust gases enter a finned-tube, cross-flow heat exchanger at 660°F and leave at 250°F, are used to heat 25 psig water at a flow rate of 120 lbm/min from 86°F to 255°F. For these conditions, the overall heat transfer coefficient is known to be $U = 17.6\,(\text{Btu/h})/(\text{ft}^2\cdot°\text{F})$. If needed, you may use the following property values for specific heat *c*, and density, *ρ*, which may be treated as constants:

$$c_{gas} = 0.239\ \text{Btu/(lbm}\cdot°\text{F)} \qquad \rho_{gas} = 0.043\ \text{lbm/ft}^3$$

Under these conditions, the heat transfer effectiveness is most nearly:

(A) 72%

(B) 82%

(C) 92%

(D) Cannot be determined

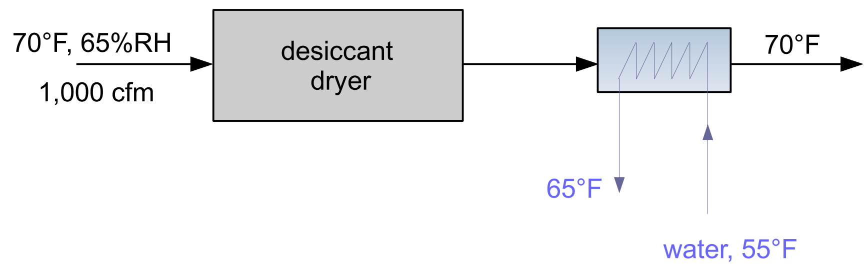
236. In a specialized manufacturing process, a stream of air at 70°F and 65% r.h. flows at a rate of 1,000 cfm. The stream enters a desiccant dryer until the humidity ratio is halved. Following the dryer, the air is sensibly cooled back to 70°F in a water cooled heat exchanger. The cooling water enters the heat exchanger at 55°F and is discharged at 65°F. The cooling water flow rate (gpm) is most nearly:

(A) 5

(B) 7

(C) 9

(D) 24,500



237. Consider the ideal vapor compression cycle running with ammonia, with saturated vapor at the compressor suction and saturated liquid at the condenser discharge. If the condenser pressure is reduced without changing the evaporator pressure, and keeping the condenser discharge as saturated liquid, select <u>all</u> that are most nearly true:

□ A. The compressor power will decrease.

□ B. The quality at the evaporator inlet will increase.

□ C. The refrigeration effect will increase.

□ D. The compressor discharge temperature will decrease.

□ E. The temperature of the liquid-vapor mixture entering the evaporator will decrease.

238. A cooling tower has a cooling capacity of 100 tons. If the tower operates at capacity in ambient conditions of 70°F and 60% relative humidity with air at 95°F and 80% relative humidity at the discharge, the amount of water evaporated (lbm/day) is most nearly:

(A) 845

(B) 9,310

(C) 14,510

(D) 20,300

239. A circular ceiling pattern diffuser will be selected as the only source of supply air to a 20 ft by 12 ft room. The load for the room is 4,800 Btu/h and the flow rate through the diffuser is 320 cfm. The throw (ft) to 50 fpm required for maximum Air Diffusion Performance Index (ADPI) is most nearly:

(A) 4.8

(B) 6.0

(C) 9.6

(D) 10

240. In a supermarket installation, the line connecting the evaporator (in a refrigerated display case) to the compressor (in the mechanical room) will have an equivalent length of 250 feet. The system capacity is 3.5 tons and it operates with R-22 evaporating at 20°F and condensing at 105°F. The line will be selected as the smallest size to have a pressure drop from friction no greater than the equivalent of about a 2°F change in saturation temperature. If a Type L copper pipe is desired, the outer diameter (OD) of the pipe should be most nearly:

(A) 7/8

(B) 1-1/8

(C) 1-3/8

(D) 1-5/8

SLAY the P.E.

www.SlaythePE.com

This completes the second portion of the practice test.

To purchase detailed, step-by-step solutions to all the problems in this practice test, visit www.SlaythePE.com

