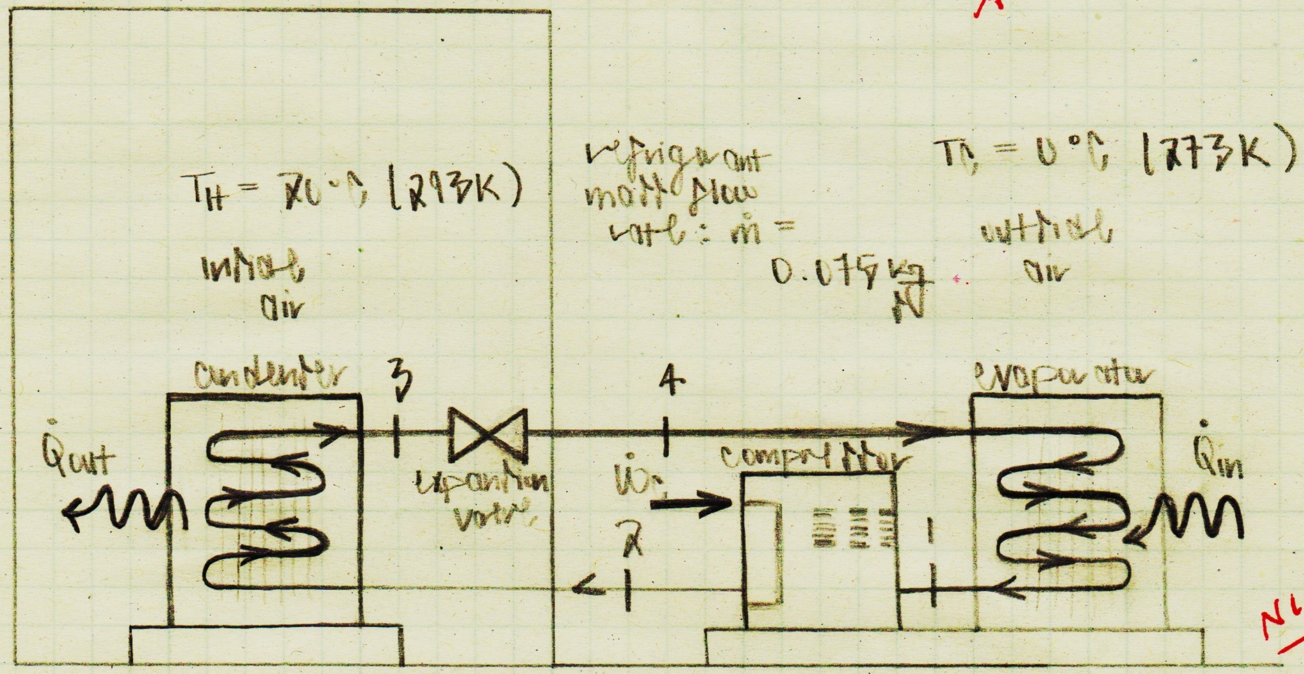
1

Known A vapor-compression heat pump cycle with R-22 as the working fluid.

Schematic and Given Data

100% AWESOME!



NICE

State 1: enthalpy of R-22 at the exit evaporator: h_1 = 234.15 kJ/kg

State 2: enthalpy of R-22 at the exit compressor: h_2 = 260.21 kJ/kg

State 3: enthalpy of R-22 at the exit condenser: h_3 = 77.21 kJ/kg

Find

(a) compressor power, $\dot{W}_c$ (kW)

(b) heat provided to the building, $\dot{Q}_{out}$ (kW)

(c) actual coefficient of performance, γ

(d) maximum coefficient of performance, γ_{max}

Engineering model

$$\dot{W}_c = \dot{m}(h_2 - h_1) \qquad \gamma = \frac{\dot{Q}_{out}}{\dot{W}_c}$$

$$\dot{Q}_{out} = \dot{m}(h_2 - h_3) \qquad \gamma_{max} = \frac{T_H}{T_H - T_C}$$

Analysis

(a) $\dot{W}_c = \dot{m}(h_2 - h_1)$

$$\dot{W}_c = 0.075\,\frac{kg}{s}\,(260.31 - 236.15)\,\frac{kJ}{kg}\left|\frac{1\,kW}{1\,kJ/s}\right| = \boxed{1.81\,kW}$$

(b) $\dot{Q}_{out} = \dot{m}(h_2 - h_3)$

$$\dot{Q}_{out} = 0.075\,\frac{kg}{s}\,(260.31 - 77.21)\,\frac{kJ}{kg}\left|\frac{1\,kW}{1\,kJ/s}\right| = \boxed{13.73\,kW}$$

(c) $\gamma = \dfrac{\dot{Q}_{out}}{\dot{W}_c}$

$$\gamma = \frac{13.73\,kW}{1.81\,kW} = \boxed{7.59}$$

(d) $\gamma_{max} = \dfrac{T_H}{T_H - T_C}$

$$\gamma_{max} = \frac{293K}{293K - 273K} = \boxed{14.65}$$

TOPS 35502

2

<u>Known</u> A parallel-piping hydronic system network with direct return supplies water to hot water coils in three different air handlers.

<u>Schematic</u> and <u>Given Data</u>

→ the boiler provides 1,200,000 BTU/hr w/ a 5 psi pressure drop

→ the three loads are characterized as having pressure drops of 3 psi each

→ load 1 requires 300,000 BTU/hr

→ load 2 requires 400,000 BTU/hr

→ load 3 requires 500,000 BTU/hr

→ the hydronic system's overall temperature differential is 25°F

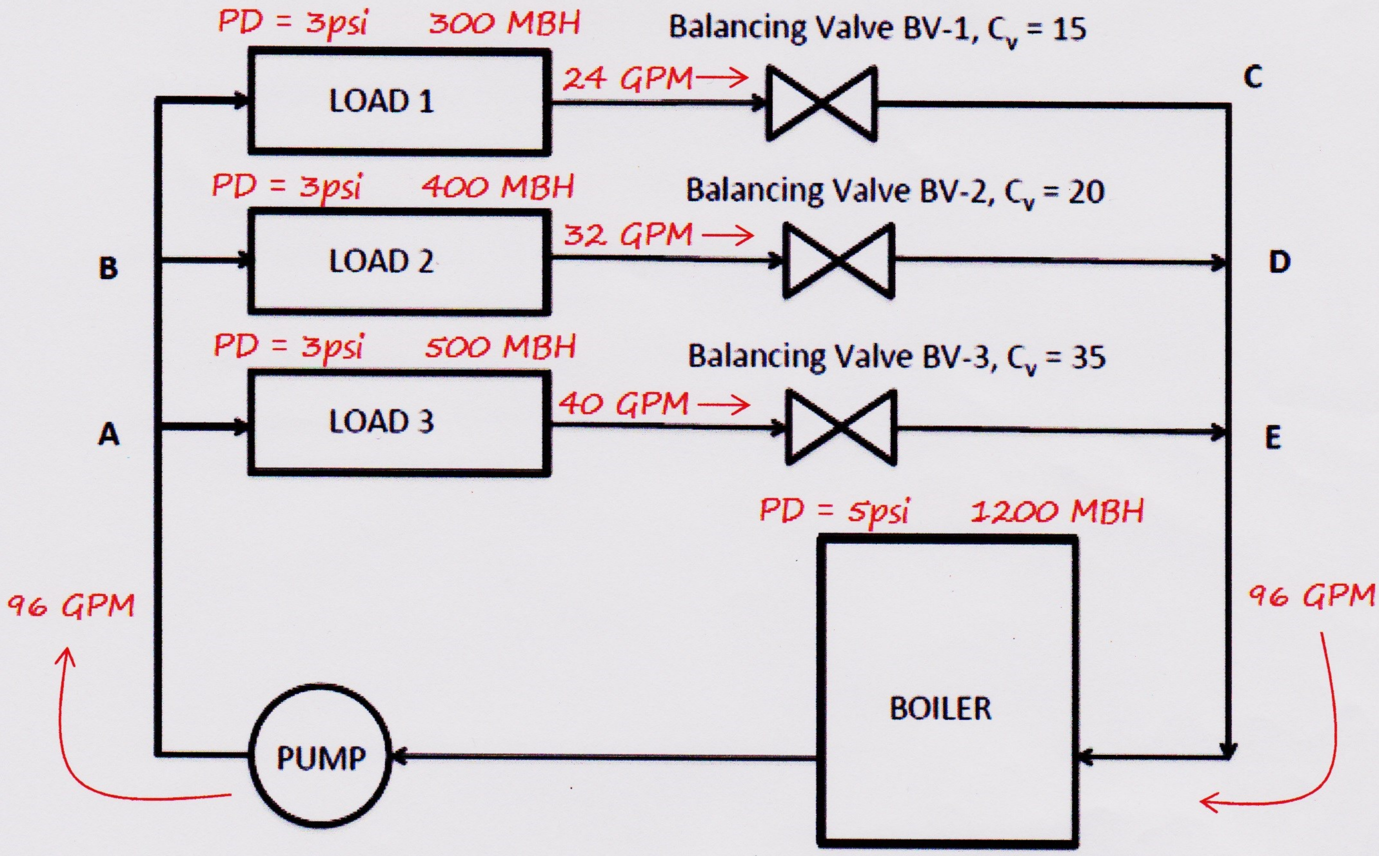
→ assume straight runs of pipe (do not add 50% for elbows and fittings)

CONTINUED →

IMPRESSIVE!

Schematic and Given Data (continued)

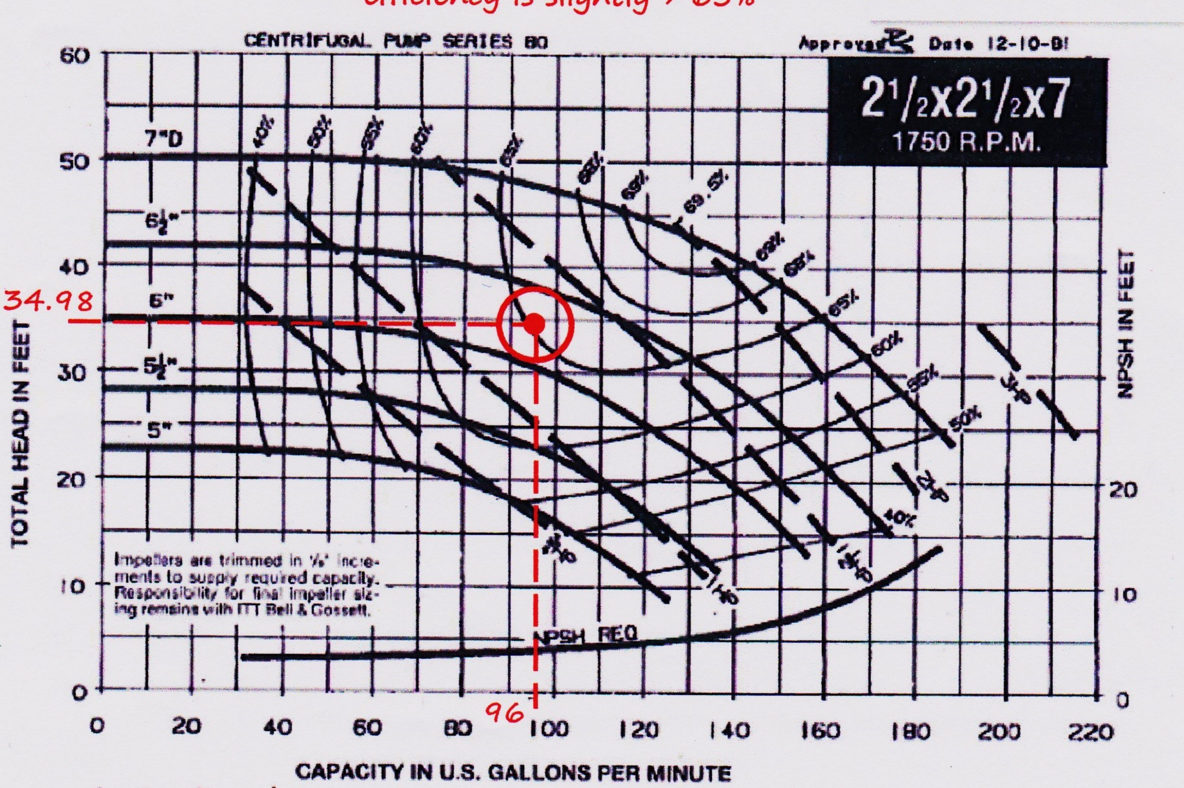
Hydronics System Schematic



Hydronics Pump Curves

1750 RPM PUMP CURVES

efficiency is slightly > 65%



Find

Fill in table on page 7 using the hydronic analyzer calculator when complete the design by specifying:

(a) pump volumetric flow rate (GPM)

(b) volumetric flow rates through each of the three loads (GPM)

(c) pump total pressure (head in ft water)

(d) pump efficiency using a centrifugal pump from pump curves on page 4 (%)

(e) pump impeller diameter (in.)

(f) pump horsepower (HP)

Engineering model

1 psi = 2.31 ft head (thermodynamic head)

$\frac{BTU}{hr}$ = (GPM)(500)(Delta T)(specific gravity)

Analysis

Design

$\Delta T = 25°F$

S.G. = 1

Boiler: $1{,}200{,}000 \frac{BTU}{hr} \rightarrow 1{,}200\ MBH$

5 psi primary drop

Load 1 circuit: $300{,}000 \frac{BTU}{hr} \rightarrow 300\ MBH$; 3 psi primary drop

Load 2 circuit: $400{,}000 \frac{BTU}{hr} \rightarrow 400\ MBH$; 3 psi primary drop

Load 3 circuit: $500{,}000 \frac{BTU}{hr} \rightarrow 500\ MBH$; 3 psi primary drop

(a) Pump volumetric flow rate

$$1{,}200{,}000 \frac{BTU}{hr} = (GPM)(500)(25)(1)$$

$$\rightarrow \boxed{96\ GPM}\ \checkmark$$

(b) volumetric flow rates through each of the three loads

Load 1 circuit: $300{,}000 \frac{BTU}{hr} = (GPM)(500)(25)(1)$

$$\rightarrow \boxed{24\ GPM}\ \checkmark$$

Load 2 circuit: $400{,}000 \frac{BTU}{hr} = (GPM)(500)(25)(1)$

$$\rightarrow \boxed{32\ GPM}\ \checkmark$$

Load 3 circuit: $500{,}000 \frac{BTU}{hr} = (GPM)(500)(25)(1)$

$$\rightarrow \boxed{40\ GPM}\ \checkmark$$

total = 96 GPM ✓

Analysis (continued)

	Pipe length (ft)	Pipe diam. (inches)	LOAD 1 circuit pressure drop (ft)	LOAD 2 circuit pressure drop (ft)	LOAD 3 circuit pressure drop (ft)	
Boiler pressure drop			11.55	11.55	11.55	unit conversion 1psi = 2.31 ft.hd
E-A (via boiler and pump)	300	3.00	6.60	6.60	6.60	
A-B	50	2.00	0.60	1.00		scale 2
B-C (via Load 1)	100	2.00	1.20			
BV-1 pressure drop			5.90			scale 5
LOAD 1 pressure drop			6.93			unit conversion 1psi = 2.31 ft.hd
C-D	50	2.00	0.60			scale 2
B-D (via Load 2)	100	2.00		2.00		
BV-2 pressure drop				5.90		scale 5
LOAD 2 pressure drop				6.93		unit conversion 1psi = 2.31 ft.hd
D-E	50	2.00	0.60	1.00		scale 2
A-E (via Load 3)	100	2.00			3.00	
BV-3 pressure drop					3.00	scale 5
LOAD 3 pressure drop					6.93	unit conversion 1psi = 2.31 ft.hd
Total pressure drop			33.98	34.98	31.08	sum

Analysis (continued)

(c) pump total pressure

maximum circuit → load 2 circuit → pump TDH = $\boxed{\text{34.98 feet of water}}$

(d) pump efficiency

see page 4 pump curves → $\boxed{65\%}$

(e) pump impeller diameter

see page 4 pump curves → $\boxed{\text{6 inches}}$

(f) pump horsepower

see page 4 pump curves → $\boxed{\text{1.5 hp}}$

3

Known: There are 40,000 lbs of corn in a bin at 20% moisture content (wet basis) using an in-bin drying system.

Given Data

→ 40,000 lbs of corn at 20% moisture content (wet basis)

→ outside air temperature is 40°F wet bulb and 50°F dry bulb

→ in-bin drying system provides 15,000 CFM of air with a 20°F temperature rise (sensible heat)

Find

(a) Sketch a psychrometric chart that shows the processes the air undergoes as outside air:
(1) enters the fan
(2) exits the heater
(3) exits the grain bin

(b) calculate the rate of grain drying, m_w (lbs water/hr)

(c) calculate the total amount of water to be removed from the grain, W (lbs)

(d) number of hours it will take for the grain to reach a final moisture content of 12% on a wet basis, drying time (hrs)

Engineering model

$m_w = m_a(W_2 - W_1)$

dry matter = constant: (1 − starting moisture content)(amount of corn in bin) = (1 − final moisture content)(amount of corn in bin − W)

drying time = $\frac{W}{m_w}$

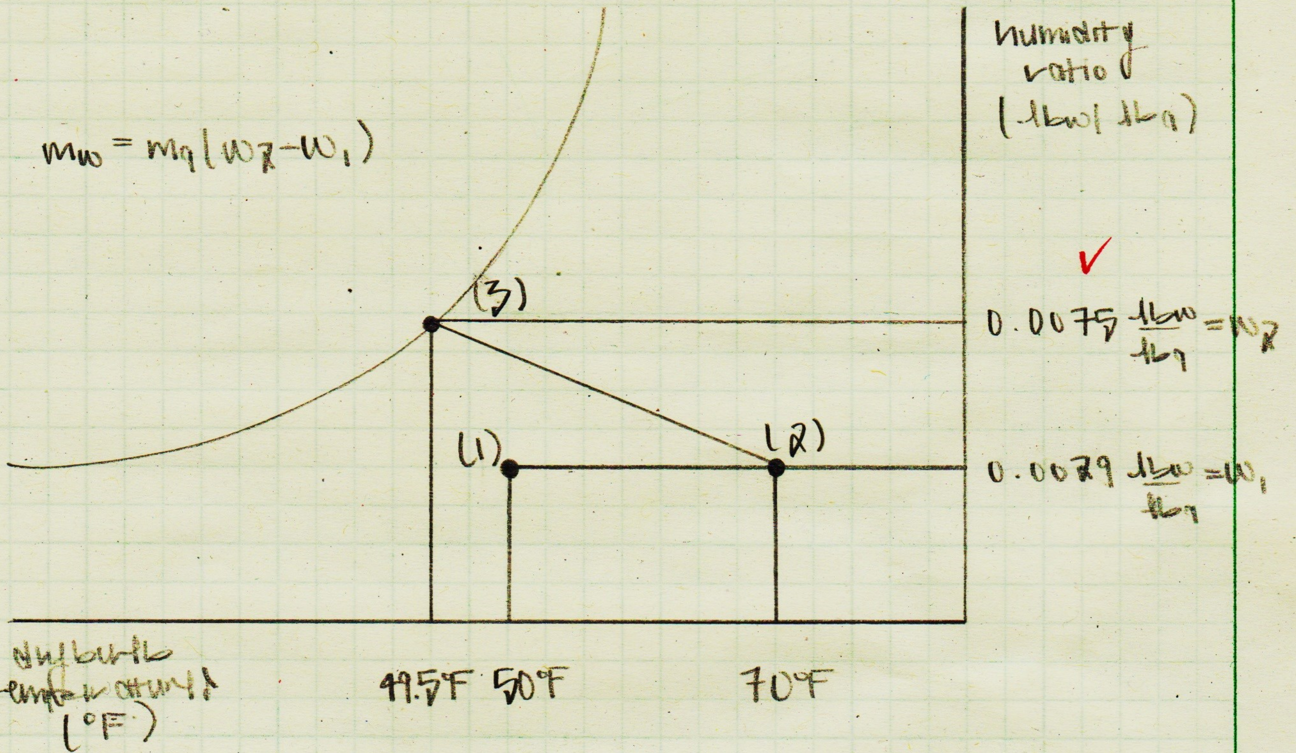
CONTINUED →

Analysis

(a) psychrometric chart that shows the processes the air undergoes of outside air:

(1) enters the fan
(2) exits the heater
(3) exits the grain bin

$m_w = m_a(w_2 - w_1)$



from psychrometric chart: initial specific volume $= 12.91\ ft^3/lb\ da$

change in humidity ratio $= w_2 - w_1$

$= 0.0075 - 0.0029$

$= 0.0046$

(b) rate of drying

$m_w = m_a(w_2 - w_1)$

$$= \frac{\left(15{,}000\ \frac{ft^3}{min}\right)\left(60\ \frac{min}{hr}\right)\left(0.0046\ \frac{lbw}{lbda}\right)}{12.91\ \frac{ft^3}{lbda}} = \boxed{321\ \frac{lbw}{hr}}$$

(c) total amount of water to be removed from the grain:

dry matter = constant: $(1-0.2)(40{,}000) = (1-0.12)(40{,}000-w)$

solve for w: $\boxed{3{,}636 \text{ lbs water}}$

✓

(d) drying time $= \frac{w}{m_w}$

$= \frac{3{,}636 \text{ lbs water}}{321 \frac{\text{lbs water}}{\text{hr}}} = \boxed{11.3 \text{ hours}}$

✓