Food, Agricultural, and Biological Engineering 5820

Heat Pumps, Hydronics, and Grain drying Problems

[Note: Include a GIVEN and FIND, and cite ALL references and assumptions.]

1. **Heat pump:** A vapor-compression heat pump cycle with R-22 as the working fluid maintains a building at 20°C when the outside temperature is 0°C. The refrigerant mass flow rate is 0.075 kg/s. The enthalpies of the R-22 as exits the evaporator, compressor, and condenser are 236.15, 260.31, and 77.21 kJ/kg, respectively. Determine:

   (a) compressor power in KW
   (b) heat provided to the building in kW
   (c) actual coefficient of performance
   (d) maximum coefficient of performance

(20 pts, 5 pts each)

2. **Hydronics:** A parallel-piping hydronic system network with direct return (see attached schematic) supplies the same temperature water to hot water coils in three different air handlers (shown as generic loads in the schematic). The boiler provides 1,200,000 BTU/hr with 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; and load 3 requires 500,000 BTU/hr. The hydronic system's overall temperature differential is 25°F. Assume straight runs of iron pipe (do not add 50% for elbows and fittings). Fill in the attached table using the SystemSyzer calculator wheel and complete the design by specifying:

   (a) Pump volumetric flow rate (gallons per minute, gpm)
   (b) Volumetric flow rates through each of the three loads (gpm)
   (c) Pump total pressure (head in units of feet of water)
   (d) Pump efficiency (%) using a centrifugal pump from attached pump curves
   (e) Pump impeller diameter (inches)
   (f) Pump horsepower

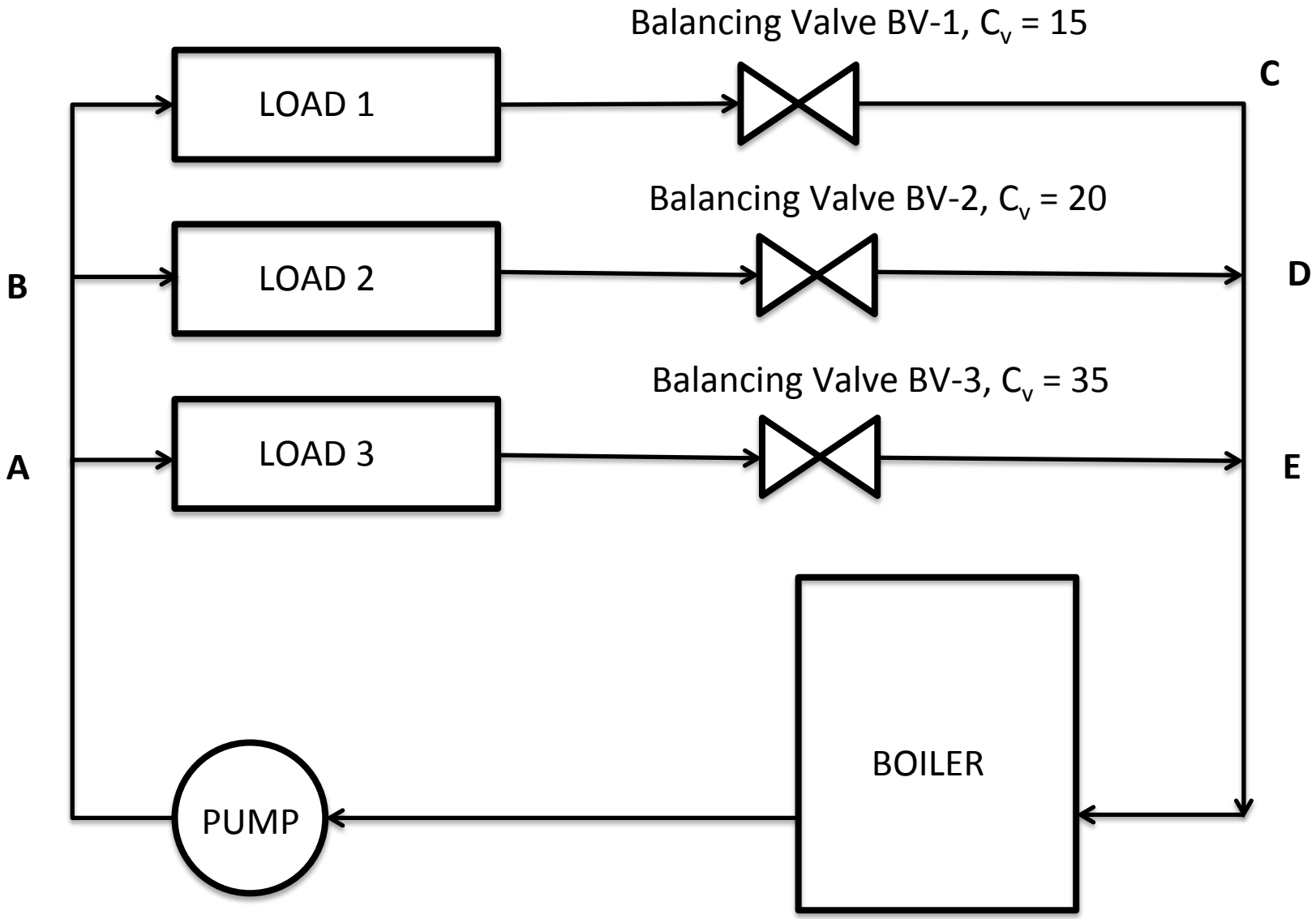
(60 pts: 5 pts each for a through f, and 1 points per item in the table)

3. **Grain drying:** There are 40,000 lbs of corn in a bin at 20% moisture content (wet basis). Outside air temperature is 40°F wet bulb and 50°F dry bulb. An in-bin drying system provides 15,000 CFM of air with a 20°F temperature rise (sensible heat).

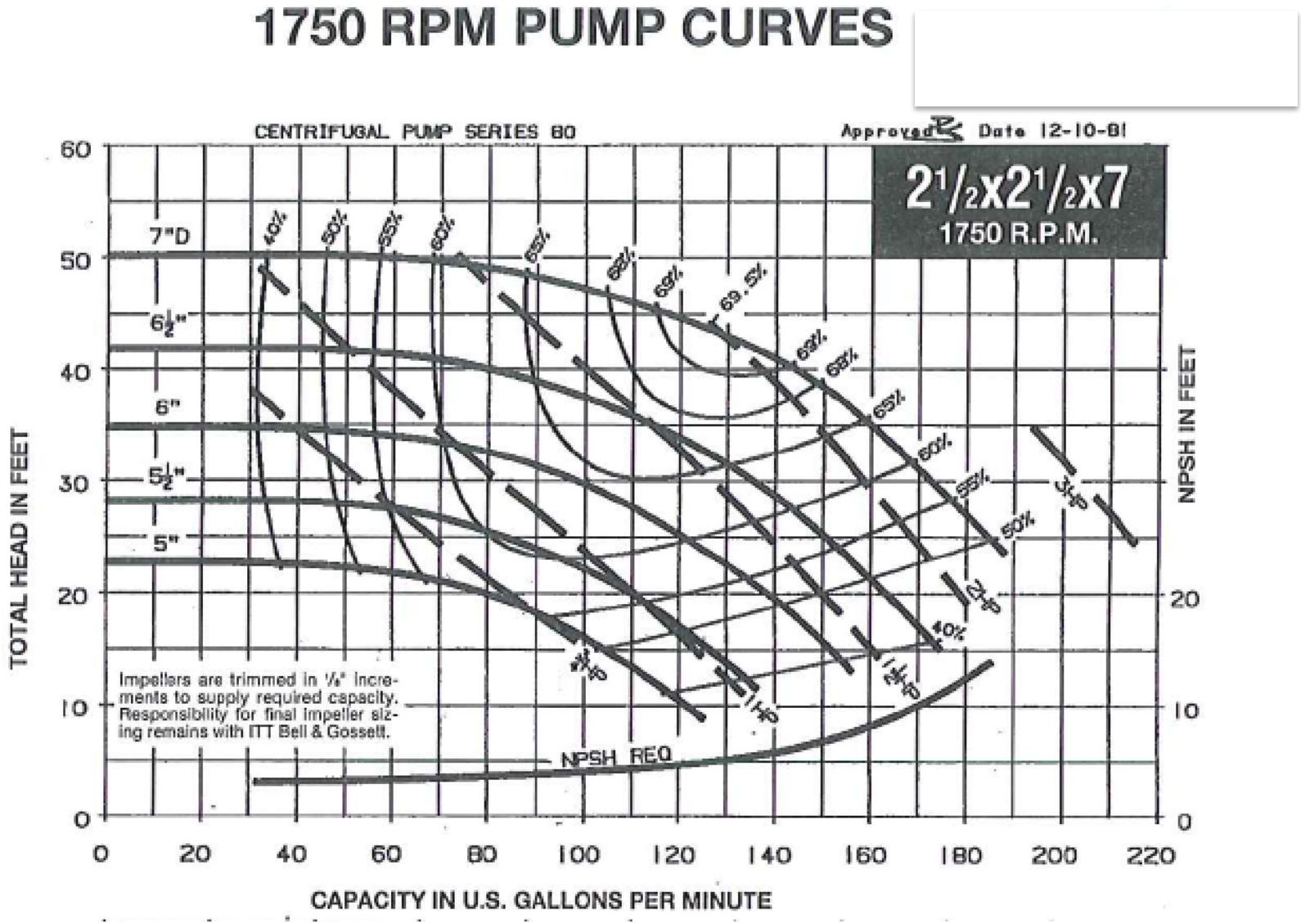
   (a) Sketch a psychrometric chart that shows the processes the air undergoes as outside air (1) enters the fan, (2) exits the heater and (3) exits the grain bin
   (b) Calculate the rate of grain drying (lbs water / hr)
   (c) Calculate the total amount of water to be removed from the grain (lbs)
   (d) How many hours will it take for the grain to reach a final moisture content of 12% on a wet basis?

(20 pts, 5 pts each)

Problem 2. Hydronics system schematic



Problem 2. Hydronics pump curves



	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					
E-A (via boiler and pump)	300				
A-B	50				
B-C (via Load 1)	100				
BV-1 pressure drop					
LOAD 1 pressure drop					
C-D	50				
B-D (via Load 2)	100				
BV-2 pressure drop					
LOAD 2 pressure drop					
D-E	50				
A-E (via Load 3)	100				
BV-3 pressure drop					
LOAD 3 pressure drop					
Total pressure drop					