Proposal for a Chilled Water Line for P403 Server Cooling System

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A schematic diagram of a liquid cooling system, including the requested chilled water line for the servers in Dr. Jones' lab in P403, accompanied by theoretical thermodynamic calculations, is proposed. The goal is to maintain the graphics and central processing units within the servers at acceptable temperatures by balancing the system in thermodynamic equilibrium with an external, cooler liquid line via a Brazetek BT4x12-20 heat exchanger. See Figure 1 on page 3 for the schematic diagram.

The system consists of two identical racks connected to the cooling system in parallel. Each rack contains thirteen computers with individual GPUs and CPUs. In order to cool the system, the GPUs and CPUs in each computer will be connected to tubing in series, and the computers in each rack will be connected in parallel. Because the CPUs demand a lower running temperature, they will be the first unit to be cooled within each computer. The heat exchanger will be connected to the requested external, chilled water line during the summer. In the winter, the heat exchanger will be connected to a closed line containing glycol, which will be cooled outdoors.

See Table 1 on page 2 for the pressure and temperature differences across various segments of the system. The pressure drop through each 1" full bore valve is about 5×10^{-4} PSI, which can be neglected. 1" copper pipe causes a pressure drop of about 0.01 PSI per foot due to friction; it is assumed that the cooling system will use about 60 feet of piping. See Table 2 on page 2 for flow rate, heat extraction, and system temperature information.

The same temperature and pressure drops occur across each computer, since they are comprised of similar components. In order to extract 10^4 W from the system, the flow rate through the heat exchanger must be 4 gallons per minute; this corresponds to a flow rate of 2 gallons per minute through the pumps. The pumps used for the system require a pressure differential of 9 PSI in order to maintain a flow rate of 2 gallons per minute. As seen in Table 1, the pressure difference between the inlet and the outlet of the pump is much less than this value, including pressure drops due to changes in internal energy of the water and eddy currents from reducers and pipe bends. Therefore, relief valves will be used to moderate the pressure to the desired value.

Table 1: Pressure and Temperature Changes for Cooling System

Interval	ΔP (PSI)	ΔP (Pa)	ΔT (F)	ΔT (K)
1 to 2	2×10^{-3}	20	0	0
2 to 3	0.5	3000	8	4
3 to 4	0.5	3000	30	15
4 to 5	-2×10^{-3}	-20	0	0
5 to 6	2	10^4	-40	-19
6 to 7	0	0	0	0
1"copper piping	1	10^4	0	0
7 to 1	4	3×10^4	0	0

Table 2: Flow Rates, Necessary Heat Extractions, and Temperatures for Cooling System

| Quantity	SI units	Imperial units
flow rate through pump	10^{-4} m^3/sec	2 gal/min
flow rate through heat exchanger	2×10^{-4} m^3/sec	4 gal/min
flow rate through CPU/GPU	10^{-5} m^3/sec	0.2 gal/min
power consumption per CPU	95 W	28 BTU/hr
power consumption per GPU	300 W	90 BTU/hr
total heat to extract per unit time	10^4 W	3000 BTU/hr
pre-rack water temperature	310 K	100 F
post-rack water temperature	330 K	130 F
pre-heat exchanger cool water line temperature	280 K	50 F
post-heat exchanger cool water line temperature	300 K	80 F
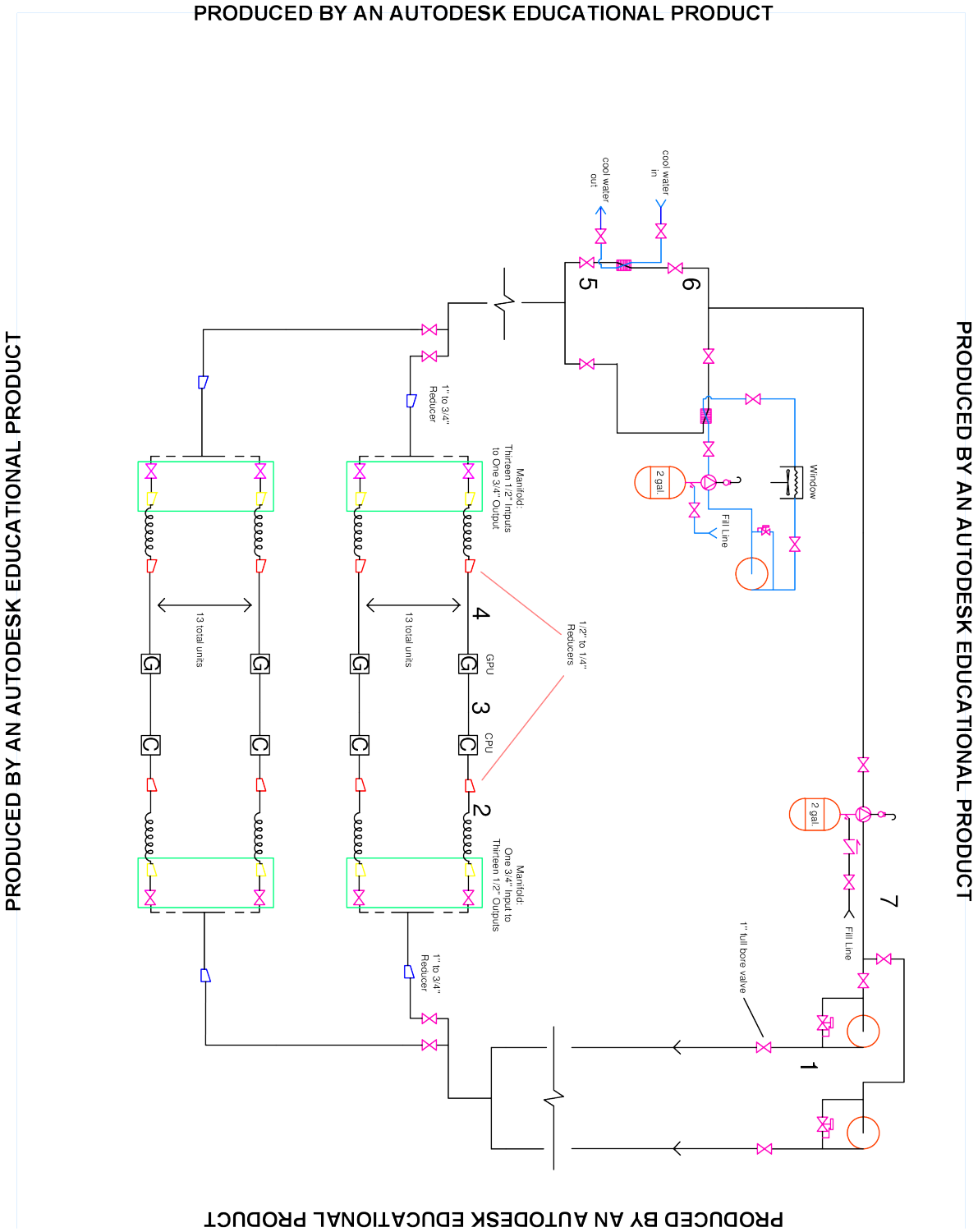
Figure 1: Schematic diagram of cooling system setup. Several segments along the cooling line have been numbered in order to express various quantities in Table 1.