PROBLEM SET 12 CBE30355 DUE 12/12/24

1. In this problem you are asked to analyze the pump requirements of the Jetlev flyer jetpack. The jetpack is depicted below:

The pipe fittings on the back are fairly complex, consisting of a reducing Y-connector, a 135 degree bend, and a nozzle for each side. As a reasonable approximation, assume that the K value for the Y-connector is the geometric mean of a T straight through and through the side coupled with a smooth pipe reduction. The bend can be considered the sum of 45 and 90 degree short angle bends. The main feed pipe from the boat is 10 meters of 4" ID pipe, the pipe coming off of the Y is 3", and the final nozzle is 1.5" pipe. The dry weight of the jetpack is 30lb, and the rider weighs 200lb. The dry weight of the feed pipe is 10lb.

OK, now for the problem:

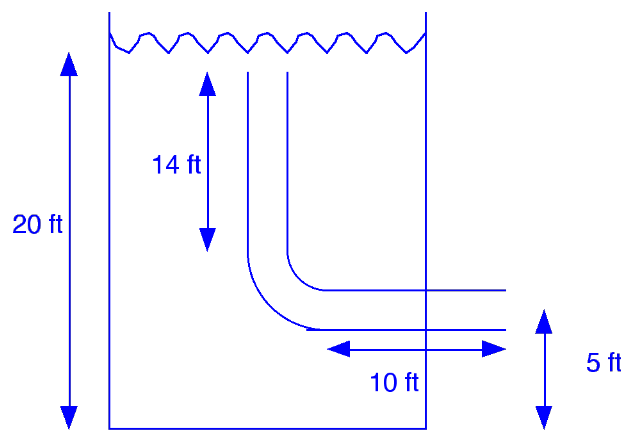
a. What is the required flow rate and pump output pressure for a flyer who is at the maximum elevation of 8.5 meters (e.g., going straight up, but some of the feed pipe is used up in making the 90 degree bend to vertical). If the pump is 25% efficient, what is the required horsepower of the pump boat engine?

b. If the flyer angles forwards so that he is just out of the water (e.g., an elevation of 2m), but the pump throttle is still at a maximum, you can get quite a bit of lateral thrust, towing the pumping boat along behind. Note that the flow rate will actually be a bit higher now, because not as much of the pump energy is used up by pumping the water to 8.5m. Also, assume that you are supporting only half the weight of the water-filled feed pipe. The drag on a boat is rather complex, and depends on the Froude number. A reasonable correlation at moderate Fr is given by:

$$C_D = \frac{\text{Resistance}}{\frac{1}{2}\rho U^2 V^{2/3}} \approx 0.035$$

where U is the velocity of the boat and V is the displaced volume. The $V^{2/3}$ scaling is a multiple of the area of water the boat is pushing against. If the pumping boat weighs in at 350kg, calculate the maximum forward velocity of the boat and jetpack.

2. You are designing an overflow drain for a tank as depicted below. It is required that the pipe must handle a flow rate of 1 gal/s. What is the minimum diameter of the drain pipe?



3. Pump Curves. It is desired to pump 80 liters/sec from a pond to a tank at an elevation of 20 meters through a 6" pipe. The pipe feeding the pump is 10m long, and the pipe leading to the tank is another 90m. There is a sudden contraction (K = 0.45) leading to the pump, and 3 45 degree elbows (K = 0.35 each) between the pump and the tank. Don't forget the acceleration of the fluid! Use the attached pump curve to answer the following:

a. Is the pump CP200 recommended for the job?

b. What is the RPM required to do the job?

c. What is the work done by the pump on the fluid per unit time?

d. What is the efficiency of the pump at the operating conditions?

e. How far up the hill from the level of the pond can we put the pump? (Note: this could actually be negative.)

SYKES PUMPS

CURVE: CP2000108 ISSUE 3
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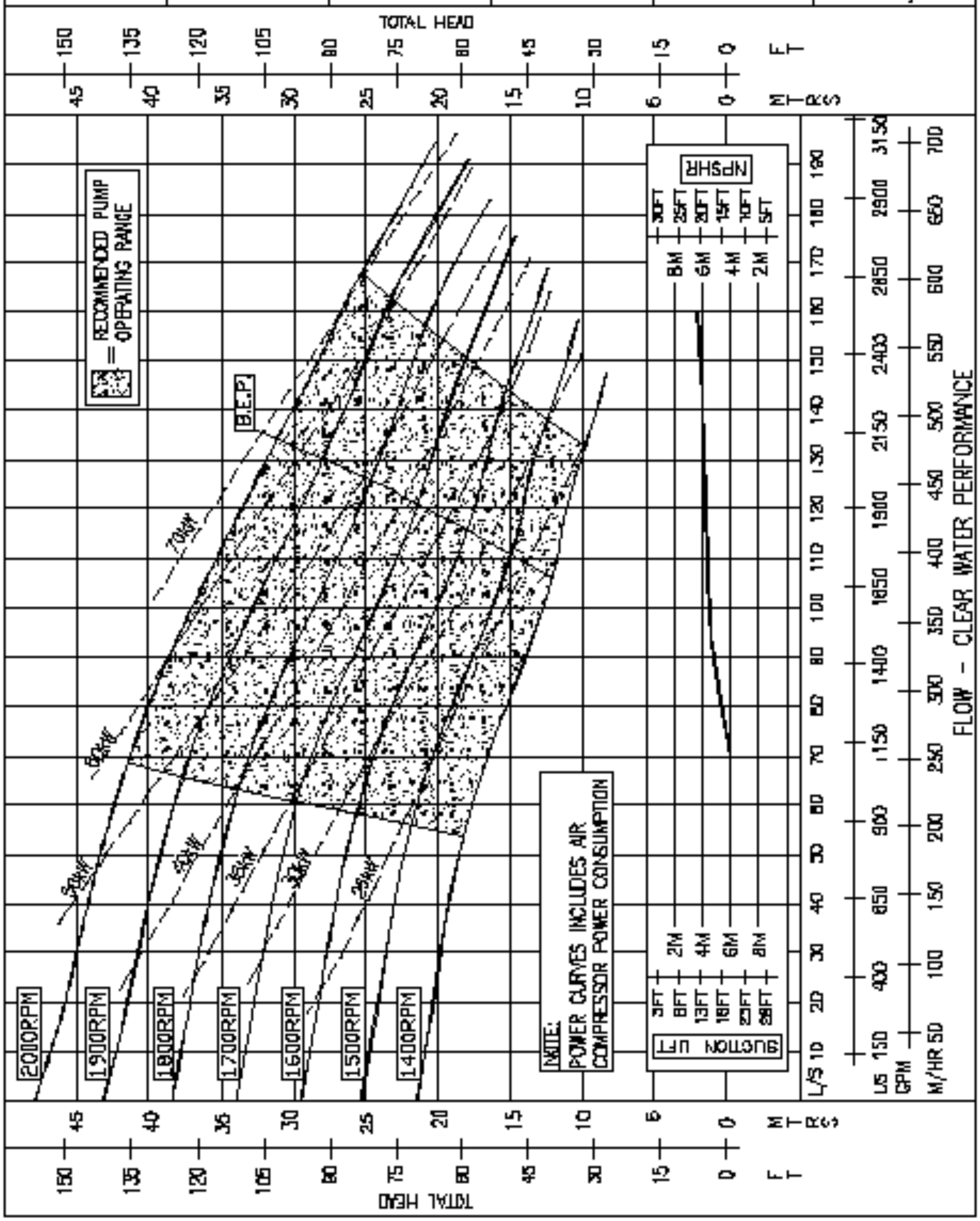
PUMP : CP-200

SUCTION	DISCHARGE	MAX. SPHERE	IMPELLER	IMPELLER	IMPELLER & WEAR PLATES
200mm	200mm	80mm	3 VANE	φ295mm	316 S/S



What you should learn from these problems:

Problem 1: The Jetlev Flyer.

a. This problem set is all about pipe flow, something you may well encounter as an engineer (or as a homeowner dealing with plumbing issues!). In the first part of this one you are to determine the flow rate necessary to achieve a desired thrust. Draw your control volume carefully!
b. Once you have a flow rate, and if you know the piping system, you just use Bernoulli's equations (plus losses!) to determine the pressure requirements at the pump. That pressure times the flow rate is the energy requirement!
c. The last bit is much trickier: Now you have to use the stuff on vectors and forces we learned at the beginning of the semester to do a momentum balance in two directions to determine the boat velocity. While you would obviously do a more careful analysis if you were designing the system (and getting paid to do so!) you actually should get pretty close to the design specs of the real system!

Problem 2: A drain problem.

a. This is a nice example of pipe sizing: If you know what the flow rate is, and the driving force, you need to figure out what sort of pipe diameter to use.
b. Pressure drops are pretty massively influenced by pipe diameter (for a fixed flow rate), so if you set up the problem right you can use functional iteration to calculate the diameter really quickly without having to use a computer...

Problem 3: Pump Curves:

a. Knowing what a pump can do is pretty important if you are designing a flow system. This problem gets you to figure out what all the lines on a standard pump diagram mean and how to use them!
b. There will be a pump curve problem on the final…