Branch systems

Jacques Chaurette, August, 2021
www.pumpfundamentals.com

Many pump systems have only one outlet. To size the pump properly and make sure you have the flow required at the outlet requires that you calculate the friction in the lines (i.e. friction head loss), that you know the elevation difference between water tank levels and if there is any equipment in the line that you also know its friction head loss for the given flow rate. Another common occurrence is a pump system with a branch (see Figure 2).

The flow rate in a single outlet system will depend on the pressure generated by the pump at its outlet, the friction loss in the pipe and the elevation of the outlet. Pressure times volume (p x V) is the energy that the pump supplies. The energy must balance or be equal to the energy loss due to friction and the elevation change which is potential energy or the energy required to move water from a low elevation to a higher one. Think of it as sliding a block across a floor, this movement will generate friction, at the same time the block has to get to a higher elevation via a ramp, then that will require work and which will be expresses as potential energy that the block will have gained when at a higher level.

Let's take a look at just one portion of a pump system; imagine that the pump does not exist and all you have is a source of pressure, it could be a municipal water system for example. The pressure at the inlet does all the work, that work will be balanced by the energy required to overcome friction and the work required to raise the fluid to a given elevation as shown in the next figure. The work provided by the inlet pressure is the pressure times the volume displaced (p x V); the energy loss due to friction is the pressure loss due to friction times the volume displaced V (p_f x V); and the energy required to get the fluid to the required elevation is the weight of the fluid (W) times the height (W x h).

When we divide every term by the weight W, we get something we are more used to seeing such as the static head h whose unit is a unit of length or feet. We do this for fluids because we are not so interested in how much weight of fluid is transferred but how much flow, in particular the flow rate.

You will rightly notice that there is no flow, or flow rate, or even velocity in the final formula (1) of the energy balance in the next figure. However, it is there hidden within the friction head loss term. You cannot determine the friction head loss unless you know the velocity which comes from the flow rate and the pipe internal diameter (see formula 2 in Figure 2). Therefore, the procedure when designing a new system is to set your required flow rate, determine your pipe sizes based on a reasonable velocity (i.e. 9-12 ft/s); the pipe internal diameter is proportional to velocity and flow rate (see formula 2 in Figure 2). Calculate the friction loss, then add it to the static head h to obtain the head required of the pump. You could convert the pump head to pressure by using the density and the appropriate conversion constant but this is rarely required as pumps are specified in terms of their head (see formula 3, Figure 1).

Often instead of density the term specific gravity (SG) is used; this is a ratio (no units) of the density of your fluid to that of water at standard conditions SG = γ_f / γ_w. The SG of water is 1.

Returning to figure 1, the inlet pressure term (p_p x V / W) becomes p_p/γ, where γ is the Greek letter often used for density. The unit of p_p/γ is a unit length or feet. And finally, the friction term (pf x V / W) becomes p_f/γ also a unit of length and called the friction head or friction head loss. This friction loss will depend on the velocity of the fluid or the flow rate, its viscosity, the pipe internal diameter and the pipe length. It can be calculated which we will not go into here and it can be determined by the use of charts or tables readily available.

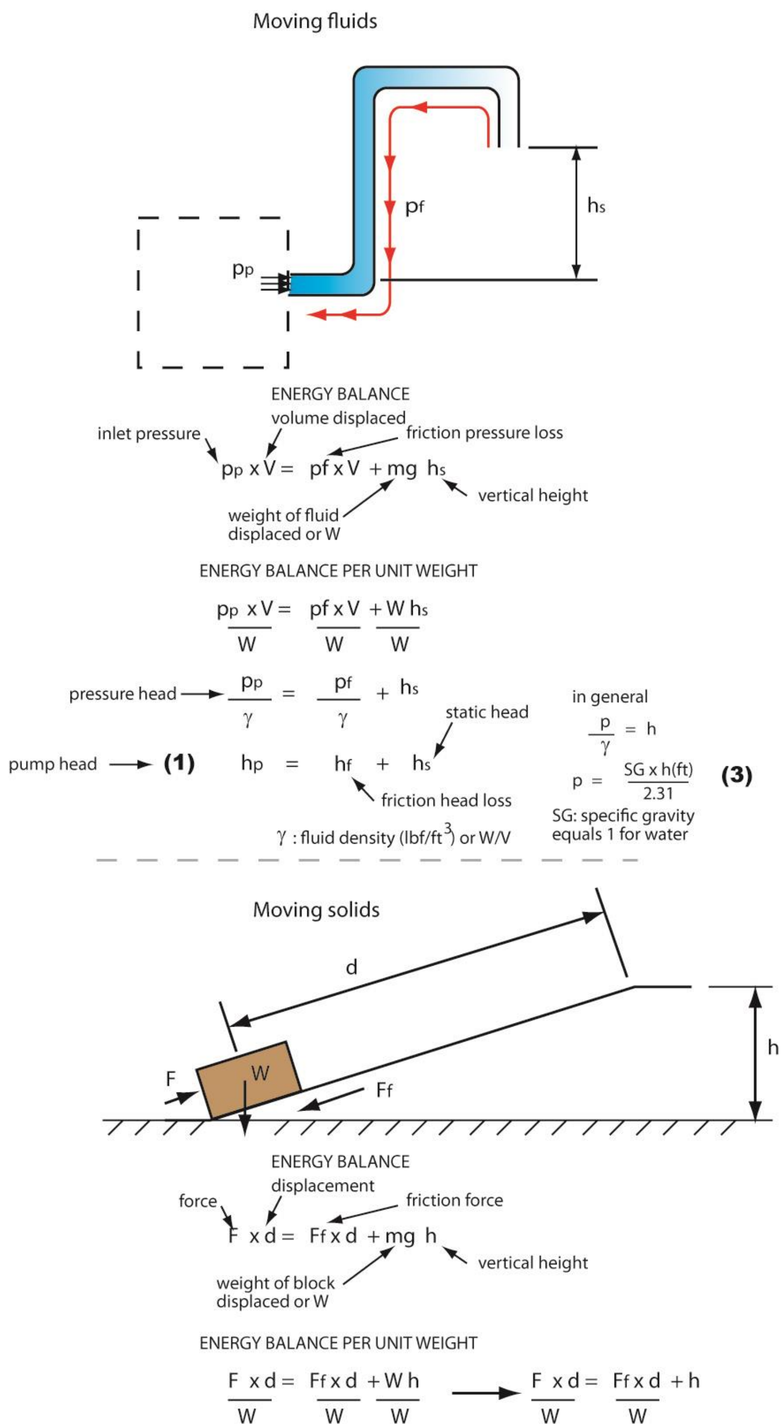

Figure 1

How can we size the pump to ensure that we get the required flow out of each branch?

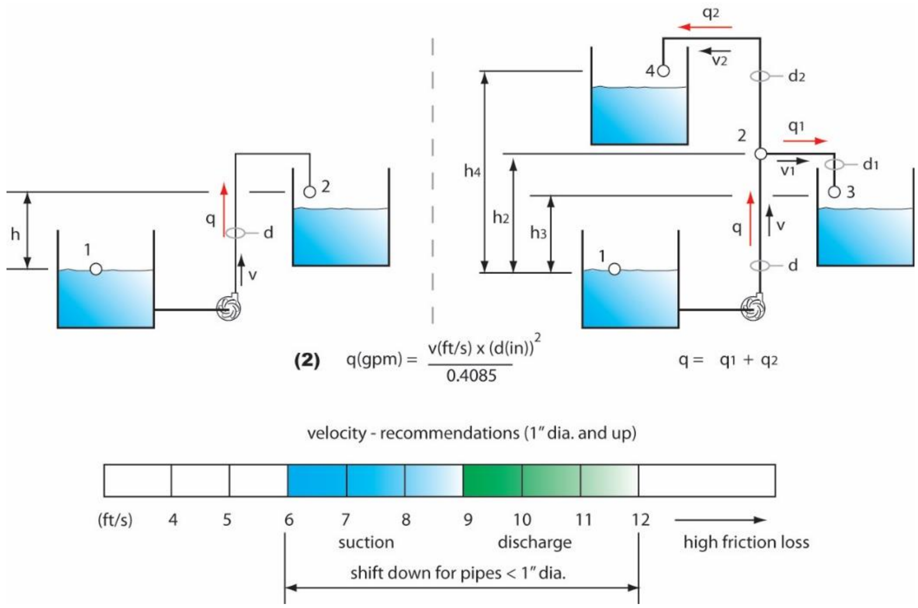

Figure 2

The key to this problem is the connection point of the two branches. The pressure at that point is the same for both branches. We set the flow requirements for both branches q_1 and q_2. The sum of the branch flows is the flow required of the pump. We determine the pipe sizes based on reasonable velocities and the required flow rates.

We know that at a minimum the pump head has to be sufficient to satisfy the flow and elevation of point 4. We have the flow going through branch 1-2 and through branch 2-4. The difference between q and q_2 will come out at point 3. Based on all this information we calculate the head at the pump discharge the first time around.

At this point we calculate the head at the branch connection point 2 knowing the length of pipe between the pump and point 2 and the height of point 2 with respect to the suction tank level. With the head at point 2 we can calculate what the flow rate in branch 2-3. If that flow rate is different than our initial requirement, we will have to change the branch pipe sizes, possibly in both branches. We then recalculate the complete system paying attention to the flow at point 4. After a few iterations you should get close enough to your flow requirements. It's a demanding task but it gets easier with practice. There is software available to do this and of course this would be particularly useful for systems with many branches.

One final word concerning velocity recommendations in figure 2. The friction loss head rises dramatically for smaller tube diameters, say less than 1". This is because the size of the diameter itself starts to have an effect on friction; for the <u>same velocity</u> the friction head is much larger for a small pipe or tube less then 1" than for say a 2" diameter pipe or larger. This can be seen clearly in the Moody diagram. So, you may want to use a smaller discharge velocity value for small tubes. Also, keep in mind that the friction head loss also depends directly on the pipe/tube length, therefore short pipes will have less friction.