

## PUMP CLINIC 17

### UNDERSTANDING THE PUMP SYSTEM CURVE

“All pump manufacturers would like to recommend the perfect pump for your application. To do this they would like you to provide an accurate system curve that would describe the capacity and head needed for your various operating conditions. Once they have your system curve, they can plot pump curves on top of the system curve and hopefully select something that will come close to your needs. Without this system curve, neither of you has much chance of coming up with the right pump.

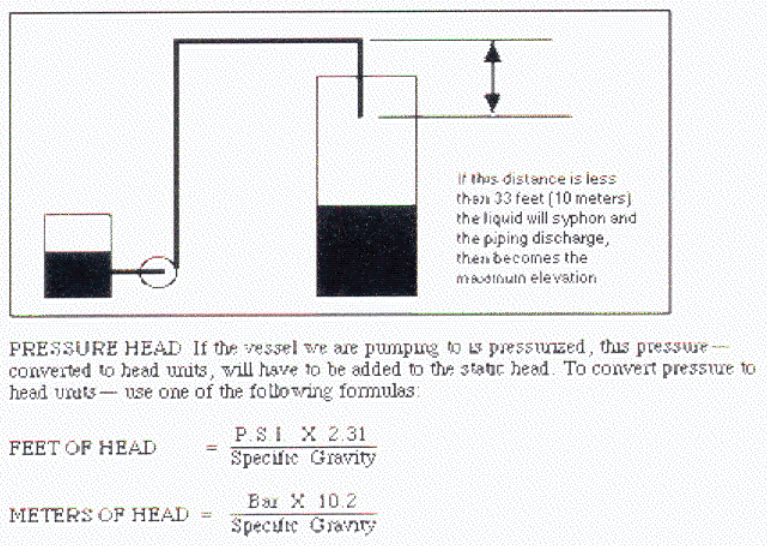
To create a system curve we plot the desired capacities against the required head over the total anticipated operating range of the pump. The head will be measured in feet or meters and the capacity will be measured in gallons per minute or cubic meters per hour.

Some of the confusion begins when we realise that there are three different kinds of head:

**STATIC HEAD** This is the vertical distance measured from the centre line of the pump to the height of the piping discharge inside the tank. Look at figure "A" and note that the piping discharge is below the maximum elevation of the piping system. We do not use the maximum elevation in our calculations because the siphoning action will carry the fluid over this point once the piping is full of liquid. This is the same action that lets you siphon petrol out of a vehicle into a storage can.

The pump will have to develop enough head to fill the pipe and then the siphoning action will take over. The pump operating point should move back towards the best efficiency point (B.E.P.) if the pump was selected correctly.

FIGURE "A"



**DYNAMIC OR SYSTEM HEAD** As the liquid flows through the piping and fittings, it is subject to the friction caused by the piping inside finish, restricted passages in the fittings and hardware that has been installed in the system. The resulting "pressure drop" is described as a "loss of head" in the system, and can be calculated from graphs and charts provided by the pump and piping manufacturers. These charts are not included with this article, you can find them in the Hydraulic Institute Manuals. This "head" loss is related to the condition of the system and makes the calculations difficult when you realise that older systems may have

"product build up" on the piping walls, filters, strainers, valves, elbows, heat exchangers, etc., making the published numbers somewhat inaccurate.

A general "rule of thumb" says that the friction loss in clean piping will vary approximately with 90% of the square of the change in flow in the piping, and 100% of the square with the change of flow in the fittings and accessories. You calculate the change in flow by dividing the new flow by the old flow and then square the number. As an example:

At 45m<sup>3</sup>/hr the piping resistance, calculated from published charts (not included) is twenty-three metres (23m). What will it be at 67.5m<sup>3</sup>/hr?

$$\frac{67.5}{45} = (1.5)^2 = 2.25 \times 23\text{m} = 51.75 \times 90\% \text{ of the change} = 46.58\text{m of resistance head}$$

In other words, when we went from 45m<sup>3</sup>/hr to 67.5m<sup>3</sup>/hr the piping resistance increased from 23m to 46.58m

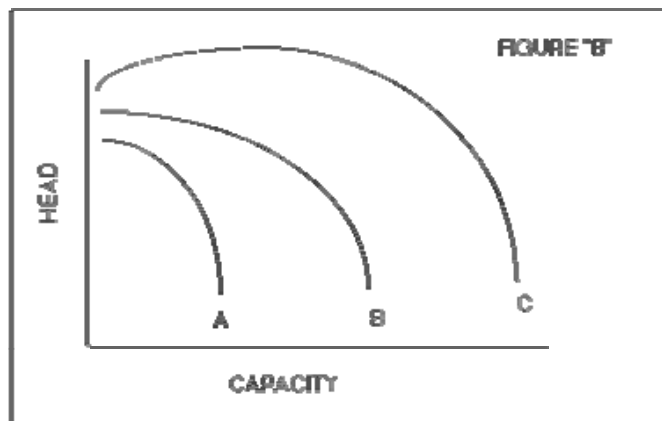
The loss through the fittings and hardware was calculated at 7.6m. What will the new loss be?

$$\frac{67.5}{45} = (1.5)^2 = 2.25 \times 7.6\text{m} = 17.1 \times 100\% \text{ of the change} = 17.1 \text{ new metres of head}$$

In the original application system, loss was a combination of the loss through the piping and the loss through the fittings for a total of 30.6 metres at 45m<sup>3</sup>/hr. When we increased the flow to 67.5m<sup>3</sup>/hr our system head changed to a total of 63.68m (46.58 + 17.1). This change would have to be added to the static and pressure heads to calculate the total head required for the new pump.

Please note that the pump is pumping the difference between the suction head and the discharge head, so if you fail to consider that the suction head will be either added to or subtracted from the discharge head, you will make an error in your calculations. The suction head will be negative if you are lifting liquid from below ground or if you are pumping from a vacuum. It will be positive if you are pumping from a tank located above ground. If the suction head is pressurized, this pressure must be converted to head and subtracted from the total head required by the pump.

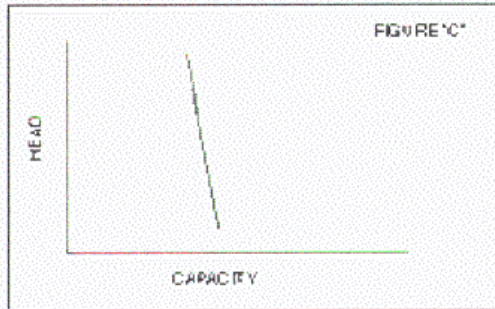
A centrifugal pump will create a head/capacity curve that will generally resemble one of the curves described in figure "B" The shape of the curve is determined by the Specific Speed number of the impeller.



Centrifugal pumps always pump somewhere on their curve, but should be selected to pump as close to the best efficiency point (B.E.P.) as possible. The B.E.P. will fall somewhere between 80% and 85% of the shut off head (maximum head).

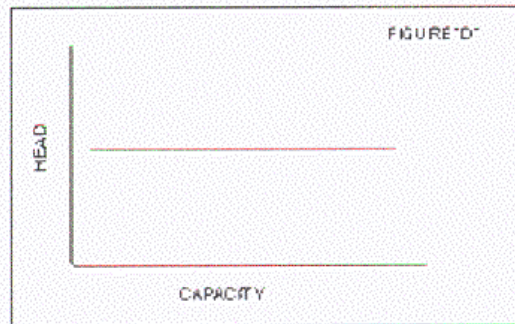
The manufacturer generated these curves at a specific R.P.M.. Unless you are using synchronous motors (you probably are using induction motors on your pumps) you will have to adjust the curves to match your actual pump speed. Put a tachometer on the running motor and record the rpm. difference between your pump and the speed shown on the pump manufacturer's published curve. You can use the pump affinity laws to approximate the change.

**POSITIVE DISPLACEMENT PUMPS** have a different shaped curve. They look something like Figure "C".



The capacity, of a positive displacement pump, will remain almost a constant as long as you do not alter the pump speed. Run it faster and it will pump more. The maximum head is determined by the strength of the pump casing and the horsepower (KW) available

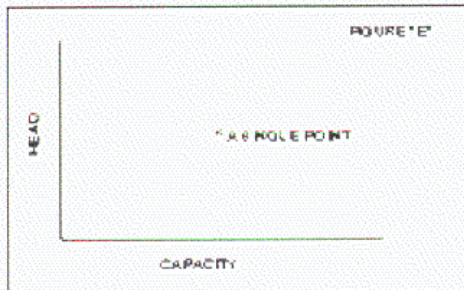
Surprisingly there are only a few system curve shapes that you will encounter. Figure "D" describes the first one :



In this system, the head remains a constant as the capacity varies. This is a typical application for:

- A boiler feed pump that is supplying a constant pressure boiler with a varying steam demand. This is a very common application in many process systems or aboard a ship that is frequently changing speeds (answering bells).
- Filling a tank from the top and varying the amount of liquid being pumped, is the normal routine in most process plants. The curve will look like this if the majority of the head is either static or pressure head.

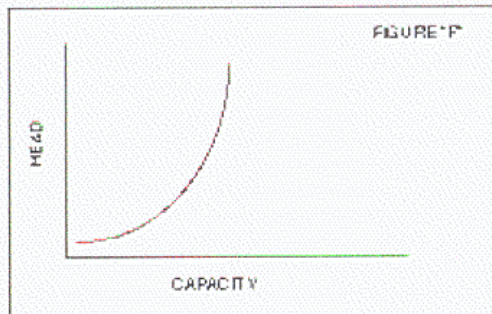
The second system is the ideal one, Figure "E" describes it:



In this system the head and capacity remain a constant as long as the pump is running, the perfect pump application! We find this condition in a couple of places:

- A boiler circulating pump—where the suction and discharge are at the same pressure. Most tank circulating pumps have a single point rather than a system curve.
- A steady state, power generating boiler is another example
- A steady state process pump operates at a single point also.

Figure "F" describes the next one. We call this an exponential curve.

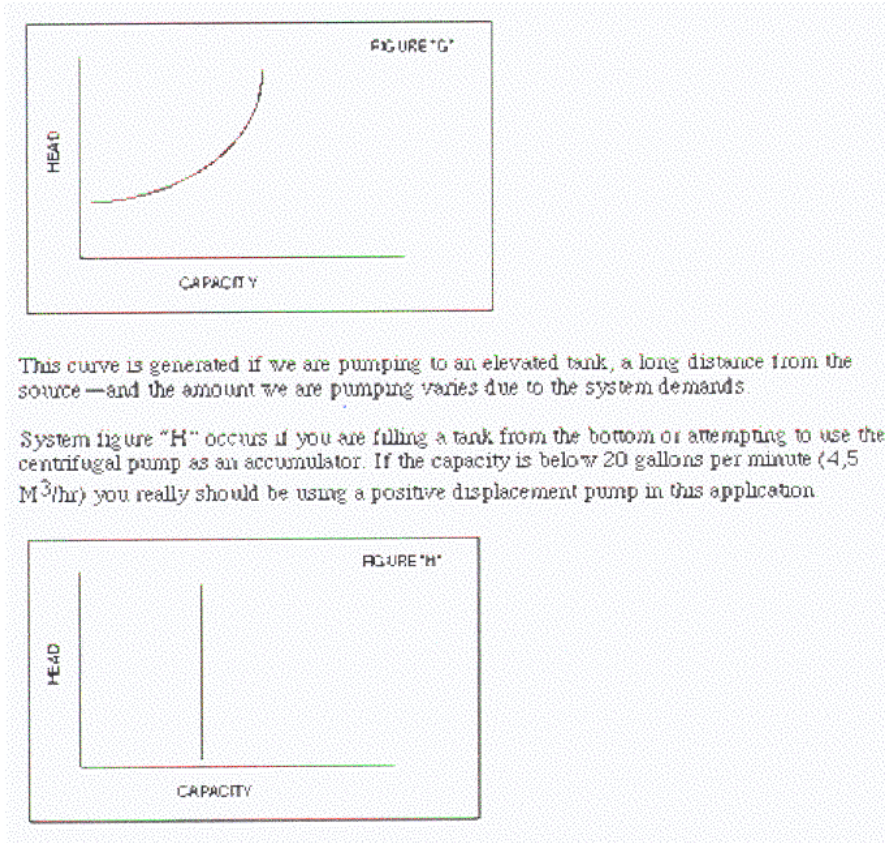


In this system the entire head is system head so it will vary with the capacity. Look for this type of curve in the following applications:

- A circulating hot or cold water heating/ cooling system.
- Pumping to a non pressurized tank, a long distance from the source with little to no elevation involved. Filling tank cars is a typical application.



System curve "G" is a common one. It is a combination of static, pressure and system heads.



Once the pump manufacturer has a clear idea as to the shape of your system curve, and the head and capacity numbers needed he can then select the proper centrifugal pump. The shape of his curve will be pretty much determined by the specific speed number of the impeller.

In addition to specific speed he can select impeller diameter, impeller width, pump rpm., and he also has the option of series or parallel operation along with the possibility of using a multi-stage pump to satisfy your needs.

The sad fact is that most pumps are selected poorly because of the desire to offer the customer the lowest possible price. A robust pump, with a low L3/D4, is still your best protection against seal and bearing premature failure when the pump is operating off of its best efficiency point. Keep the following in mind as you select your pump:

- A centrifugal pump will pump where the pump curve intersects the system curve. This may bear no relationship to the best efficiency point (B.E.P.), or your desire for the pump to perform a specific task.
- The further off the B.E.P. you go, the more robust the pump you will need. This is especially true if you have replaced the packing with a mechanical seal and no longer have the packing to act as a support bearing when the shaft deflects. Shaft deflection is always a major problem at start up.
- When you connect pumps in parallel, you add the capacities together. The capacity of a pump is determined by the impeller width and r.p.m. The head of a centrifugal pump is determined by the impeller diameter and rpm. If the heads are different, the stronger pump will throttle the weaker one, so the impeller diameters and rpm's must be the same if you connect pumps in parallel. Check the rpm's on these pumps if you are experiencing any difficulties.



**KelairPumps**

Kelair Pumps Australia Pty Ltd ABN 28 001 308 381 215 Walters Road Arndell Park NSW 2148  
Ph: 1300 789 466 Fax: 02 9678 9455 Email: kelair@kelairpumps.com.au www.kelairpumps.com.au  
QLD Fax: 07 3808 8758 VIC Fax: 03 9569 7866 TAS Fax: 03 6331 9102 WA Fax: 08 9248 2255

PUMPS STEAM TURBINES BUILDING & FIRE WASTEWATER SERVICE

- If you connect the pumps in series, the heads will add together, so the capacities must be the same or one of them will probably cavitate. You could also have a problem operating too far to the right of the best efficiency point with a possible motor "burn out".
- When you vary the speed of a centrifugal pump, the best efficiency point comes down at an angle. The affect is almost the same as changing the diameter of the impeller. This means that the variable speed motor will work best on a system curve that is exponential (Figure "F"). Unfortunately most process and boiler feed pump system curves are not exponential.
- Pump curves are based on a speed of 1450, 1750, 2900, 3500, rpm. Electric induction motors seldom run at these speeds because of "slip". You can estimate that a 2% to a 5% slip is normal in these pumps with the "slip" directly related to the price of the motor.
- You should also keep in mind that if the motor is running at its best efficiency point that does not mean that the pump is running at its B.E.P.

Since you will be using pumps that were supplied at the lowest cost, you can do the following to resist some of the shaft displacement:

- Use a solid shaft. Sleeves often raise the L3/D4 number to over 60 (2 in the metric system), and this is too high a number for reliable seal performance.
- Try to keep the mechanical seal as close to the bearings as possible. It is the mechanical seal that is the most sensitive to shaft deflection and vibration.
- Once the seal has been moved closer to the bearings, you can install a sleeve bearing in the packing space to support the shaft when the pump is operated off of its B.E.P. This is especially important at start up, or any time a pump discharge valve is operated.
- Stop the cavitation if you are experiencing any.
- Balance the rotating assembly.
- Check that the shaft is not bent or the rotating assembly is not out of dynamic balance.
- Use a "C" or "D" frame adapter to solve pump motor alignment difficulties.
- A centre line design wet end can be used if pipe strain, due to temperature expansion, is causing an alignment problem.

Do not trust the system prints to make your calculations. The actual system always differs from that shown on the print, because people tap into the lines, using the pumped fluid for a variety of purposes and after having done so forget to change or "mark up" the original system print. You are going to have to "walk down" the system and note the pipe length, the number of fittings, etc., to make an accurate system head calculation.

Do not be surprised to find that the discharge of your pump is hooked up to the discharge of another pump further down the line. In other words, the pumps are connected in parallel and no body knows it. Pressure recorders (not gauges) installed at the pump suction and discharge is another technique you can use to get a better picture of the system or dynamic head. They will show you how the head is varying with changes in flow."