Waterworks

Back to basics with centrifugal pumps

While *World Pumps* publishes many technical features, it is always good to go back to basics. Courtesy of the Waterworks museum in the UK, we present some brief insights into the development of centrifugal submersible pumps, with some recent examples.

A pump is a machine which expends energy in order to increase the pressure of a fluid, and to move it from one point to another. The most important types are centrifugal pumps and positive displacement pumps. The fundamental difference is the method by which they impart energy to the liquid. A positive displacement pump does so simply by mechanical movement typically with a piston or diaphragm, or a screw within a close-clearance bore. A centrifugal pump imparts energy to the liquid by means of a centrifugal force produced by a rotating impeller.

So why is it that centrifugal pumps have come to replace positive displacement pumps in nearly all modern applications? History actually shows that both designs have been in existence since very early times. The Romans are known to have made primitive hand-operated plunger pumps for extinguishing fires. Equally, there is evidence that the Egyptians constructed rudimentary centrifugal pumps for irrigation. However, until the early years of the 20th Century, virtually all pumps were based on the positive displacement principle. Thereafter, centrifugal pumps took over in a very short space of time.

High speeds required

There are several reasons for this. Most of these revolve (pun intended) around the fact that in order to generate modest pressures, a centrifugal pump must rotate at a speed which is high compared with most machines in the late 19th Century. The energy is imparted to the liquid by means of centrifugal force and so the pressure generated is proportional to the square of the speed. In complete contrast, a positive displacement pump is simply pushing the liquid against whatever resistance is put in its way. The speed at which it runs is irrelevant – the pressure it can pump against is only a function of how mechanically strong the machine is.

While it was readily possible to drive positive displacement pumps at slow speeds using steam as the motive power, it was not until the turn of the 19th Century that suitable drivers became available to make the centrifugal pump a viable alternative. The first such drivers were early steam turbines, followed quickly by the electric motor. More than any other factor, the arrival of electricity changed the face of pumping. There were other problems to be solved. For example, it was necessary to develop suitable bearings for the higher speeds being achieved in both the pumps and motors. Also there was the problem of manufacturing the impellers, which are complex cast components. Engineers even now will tell you that we have still not mastered this craft.

Once these problems had been overcome, the advantages of centrifugal pumps meant that they became the pump design of choice in a very short period of time. The main benefits were size and weight — a centrifugal pump could achieve much larger flows in a compact format, and would pump without pressure and flow pulsations. Also they were easier to control – unlike a positive displacement pump for which flow rate can only be controlled by varying the speed, the flow rate of a centrifugal pump can be adjusted simply by means of discharge throttling.

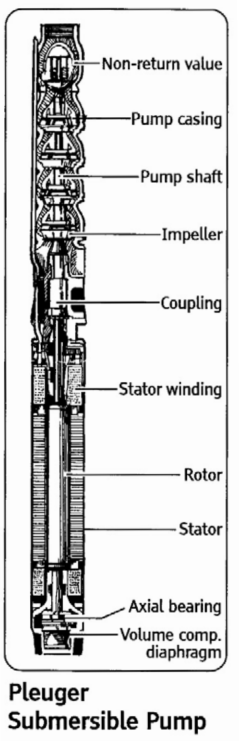

Figure 1. Basic components of a centrifugal pump.

So having established the reasons behind the rise of centrifugal pumps, what were the factors which led to the development of submersible pumps.

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Submersible pumps

Submersible pumps were first commercially available as early as 1929. They are particularly advantageous where there is a requirement for very deep or inaccessible pumping. A conventional vertical wet-pit pump features the motor at the surface, in the open air, driving the pump via a line shaft. It is clear that the deeper the pump is, the longer the line shaft must be. Long shafts are always susceptible to problems of misalignment, particularly at high speeds. Furthermore, the intermediate bearings are also prone to wear, especially if there are any abrasive particles in the liquid. With a submersible pump, there are no such problems. The motor drives the pump directly, in situ, submerged beneath the liquid. In some instances, pumps can be submerged at depths of 6,000 ft. All that is required is the electrical supply.

Power is provided by an induction motor. There are some designs which are 'dry', where the motor windings are isolated from the pumped fluid by means of mechanical sealing. However, these are confined to small sizes only. Most designs are 'wet', that is they are filled with either potable water or oil. The motors are filled with such liquids for cooling and lubrication purposes. Again, with 'wet' designs, the pumpage is prevented from entering the motors by means of mechanical sealing.

The liquid is discharged to the surface through a riser pipe. This can take the form of a flexible hose (for small pumps with low pressures) or more commonly a metallic sectional riser. For small capacity applications, such as boreholes, the pump can be lowered into the hole or caisson with its flexible riser on a rotating drum. For larger pumps with rigid risers, the pump unit is first lowered into place, and then clamped. A section of riser pipe is then added, before the assembly is lowered again, and clamped once more for the installation of the next section. The electric cable is simply clipped onto each section of the riser column as this process is carried out.

Often submersible pumps are installed in caissons only slightly larger in diameter than the pump itself. The limiting factor with regard to the minimum diameter is usually the requirement for sufficient liquid circulation around the pump in order to keep the motor cool. It is also notable that submersible motors are of a much longer and slimmer design than conventional surface motors. Hence for high power ratings and torque requirements there is often a minimum diameter for the motor, which then dictates the diameter of the borehole.

Adverse environments

One of the key applications for such pumps is in oil rigs, where they are installed in the legs of the platform in order to lift large volumes of sea water for cooling purposes. Due to the aggressive liquid environment, such pumps are not only built in increasingly exotic materials, but are also regularly fitted with anode bracelets all the way up the riser column, to corrode sacrificially.

Submersible pumps are now available for voltages up to 6600 v, and for power ratings up to 2,000 kW (2 MW.) As the developing world's requirement for clean water rises, centrifugal submersible pumps will be in continually increasing demand. ■

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