VERTICAL DIFFUSER TYPE TURBINE, MIXED-FLOW, AND AXIAL-FLOW (PROPELLER) PUMPS

by

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ABSTRACT

Vertical diffuser type pumps, their application, construction, specialties and installation are discussed. Also, system curves and pump curves are handled.

INTRODUCTION

The vertical turbine pump was developed in the late 1800s for pumping from lower levels where the centrifugal end suction pump, which had been in existence for quite a while, was not well suited. (Figure 1.)

Employing the same impeller style as used in centrifugals, the diffuser was developed. The diffuser is normally called the bowl (Figure 2).

Since its original development, the diffuser type pump has evolved into a range of pumping equipment from axial flow (propeller) to the turbine pump.

Axial flow pumps have a head range to approximately 20 ft per stage, mixed flow pumps to approximately 60 ft per stage and turbine pumps to well over 200 ft per stage. See the Hydraulic Institute Standards (14th Edition) and the 1988 Greutink handout for impeller shapes and associated specific speeds [1].

The name "turbine" still sticks, differentiating it from any other type of nondiffuser vertical pumping equipment. The diffuser type deep well pump (its best known usage) made a pretty good turbine, possibly explaining the origin of the name.

APPLICATIONS

Now one finds these pumps used anywhere a liquid needs to be pumped up. Also, vertical diffuser pumps are very well suited for

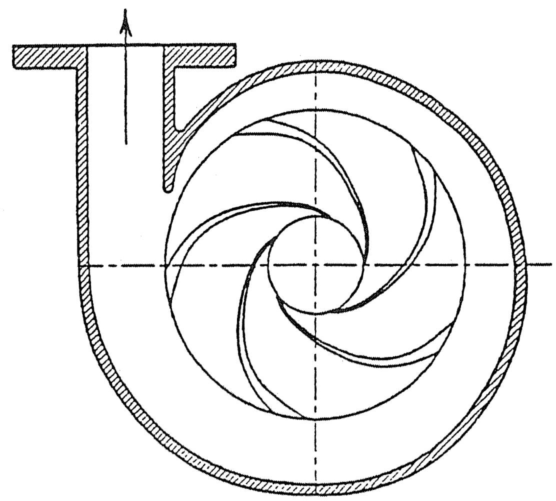

Figure 1. Centrifugal End Suction Volute Type. Fluid enters into the center of the impeller and discharges as shown.

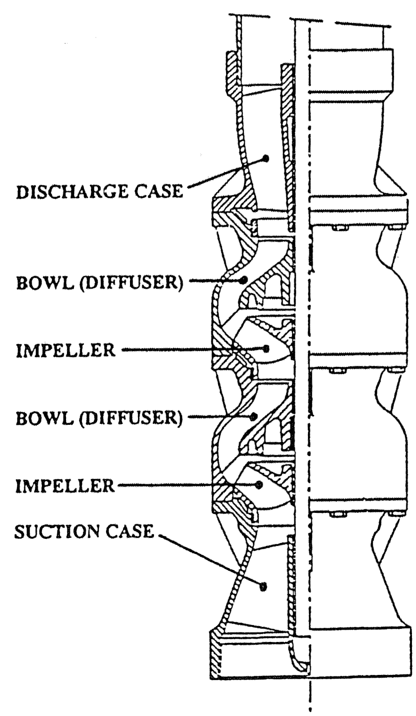

Figure 2. Bowl Assembly. The fluid is distributed evenly around through the bowl that has evenly spaced guiding vanes (two stage shown).

use in systems where the NPSH available demands that the first impeller is mounted well below the source of the liquid or the liquid level.

In saying the first impeller, it is implied that a pump can have more than one impeller. Multistaging is similar to putting individual pumps in series, in a very easy way. The head developed per impeller, or stage, is additive. Therefore, heads higher than that produced by a single stage may be satisfied easily with additional stages.

Some applications where these pumps are commonly used: water treatment plants, water supply, drainage, flood control, pipeline booster and pipeline pumping, power plant service (circulating water, condensate, cooling tower, heater drain, ash flume, service water, etc.) And again, where NPSH available is low and in closed systems such as in the petrochemical industry. Of course, the deep well applications for agricultural and other water supply purposes (municipal, service water, etc.) from aquifers should not be forgotten. Geothermal deep well pumps pump hot water (350°F is common) from geothermal aquifers, the hot water being used for power generation as well as heating. Also, all types of vertical pumps are used to pump from oceans, seas, lakes, rivers, cooling ponds, tanks and sumps. A unique application concerns pumping butane, propane, anhydrous ammonia, oil, etc., from underground storages (caverns).

CONSTRUCTION

The cross sectionals of the vertical turbine, mixed-flow and propeller pumps, as shown, are pretty much the basic construction types used today (from the 14th Edition of the Hydraulic Institute Standards).

Most of these pumps consist of a bowl assembly, a column assembly and a discharge head assembly.

Manufacturers will tend to stock impellers, bowls, bearings and threaded column, shafting, shaft enclosing tubing, and cast discharge heads based on usage. They are not, however, kept as total bowl assemblies, column assemblies or head assemblies, thus no "off the shelf" type pumps are available.

Each pump, if assembled from standard pieces, still needs at least one specially made piece. Typically, this is the head shaft, connecting the motor/driver to the pump line shaft or bowl shaft (pump shaft).

Many applications require special construction to serve the system. Various systems require nonstandard materials, flanged connections, fabrications, etc.

The variety and construction possibilities of these pumps is endless, material selections (for corrosion and abrasion resistance), length, size, fitting up to existing or designed piping, all come into the picture. They can be made to meet various codes and specifications.

The standard construction of the deep well pump is cast iron bowls, bronze impellers and rubber and bronze sleeve type bearings, steel and stainless steel shafting, steel column, tubing with bronze bearings and cast iron discharge head for the oil lubricated style (enclosed line shaft); for the water lubricated style, no tubing is used and the line shaft bearings are rubber (open line shaft type).

Pumps may be driven by vertical motors or engines, which drive the pumps through right angle gears. Steam turbines and gas combustion turbines are also used. Vertical motors are either hollow shaft or solid shaft. The hollow shaft motor allows for a head shaft with an adjusting nut on top. The solid shaft motor has a shaft extension for a coupling which in most cases has an adjusting nut for proper adjustment of the impeller(s).

One type of pump quite different from those already discussed is the submersible. On a submersible pump, the electric motor is mounted below the bowl assembly, hanging in the fluid to be pumped. Large submersibles are used to pump from deep wells or other sources. A great number of these pumps are used for domestic water supply from small wells (low horsepower). A variation of the submersible is used to pump crude oil from oil wells. Primarily, economics will dictate if a submersible is used rather than a line shaft deep well pump. Other considerations in the selection of a submersible are: no driver noise at the surface, no large protective structure and preference.

CURVES

As said before, the same types of impellers used in centrifugals are used in vertical turbine pumps, thus pump curves do not vary much from centrifugal pump curves. The vertical turbine pump (or mixed-flow and axial flow) afford a very easy medium to produce the type and shape of curve needed. For instance, if the system curve demands a steeper curve than a single stage turbine would produce, a multistage pump will produce the steeper curve. The vertical turbine pump, by its nature of being put together of "building blocks," allows readily for this variety.

Watch for total curve shape. Multistaging mixed flows or propellers, for instance, means in general, a high shutoff horsepower. Therefore, the propeller and mixed flow pumps are preferably installed in systems where they do not need to run against shutoff. See the last sheet for examples of system curves (Figures 3, 4, 5, and 6).

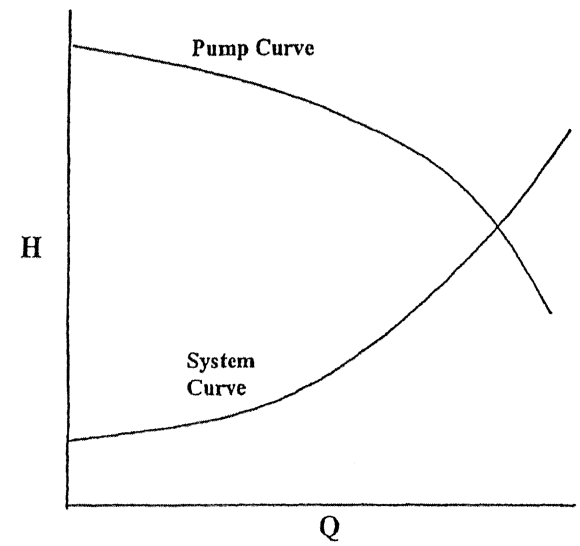

Figure 3. Mainly Friction System Curve.

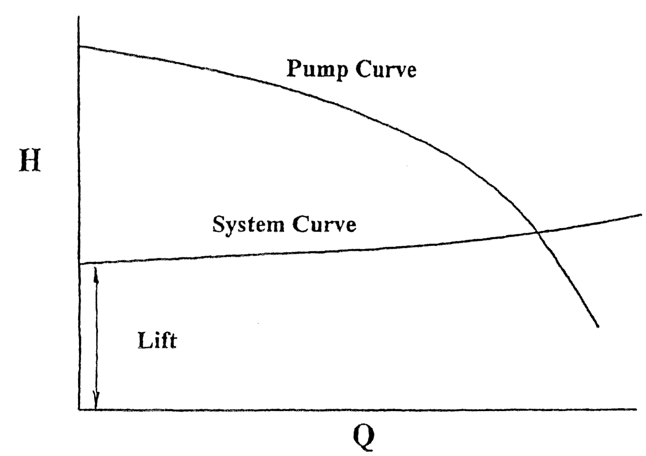

Figure 4. Mainly Lift System Curve.

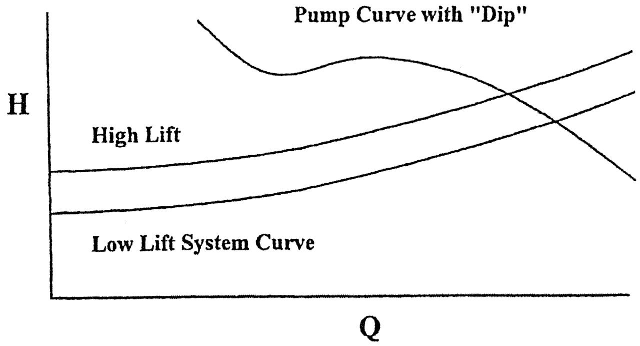

Figure 5. Dip of Pump Curve and System Curve Need to Be Separated by a Margin of Expected Wear Over Usage Time Between Repairs of the Pump.

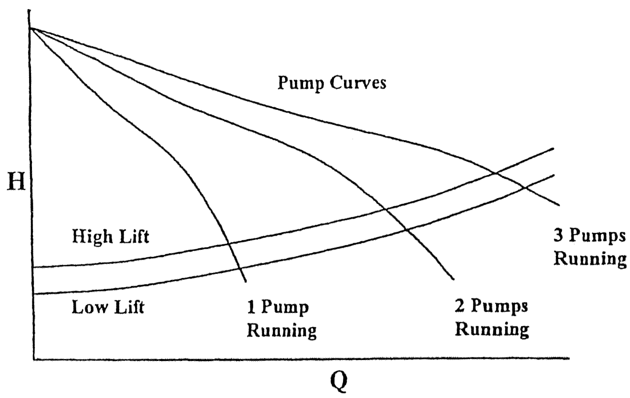

Figure 6. System Curves. Pumps in parallel.

SHIPPING AND INSTALLATION

Typically, the manufacturer will ship pumps complete (minus driver) up to 40 ft in length (maximum truck length). If the pump is longer, it will be shipped in pieces. The bowl assembly will be shipped in one piece, the column assembly may be shipped in pieces (normally up to 20 ft in length) and the discharge head normally will be shipped with the packing box or mechanical seal arrangement separately. The 40 ft maximum shipping length is predicated upon whether or not the pump can be handled at the jobsite in one piece. Otherwise, it needs to be shipped in pieces and installed "piece meal."

A deep well pump is normally installed in pieces. The bowl assembly is hung in the well and the column assemblies are installed on top of the bowl assembly (20 ft maximum lengths for enclosed shaft type, 10 ft maximum lengths for open line shaft type). Line shaft pumps are installed to depths of 2000 ft in this manner. Proper design for such depth is critical. Manufacturers state in their publications to what depth a pump may be installed without special designs.

Vertical pumps by their nature of construction are subjected to possible natural frequency vibration problems. Although calculations can give you a good idea what needs to be done to prevent such vibrations, they are by no means failsafe. Discharge piping and foundations affect the stiffness of the assembly, which means that just equipment natural frequency calculations are not the full answer.

Some Specific Applications

The vertical barrel (can) pump is used extensively where the NPSH available is near zero and/or where the fluids cannot be exposed to the open air. For those applications (condensate, light hydrocarbons, tank farm, pipeline booster pumps, etc.), the vertical pump makes it easy to install the first impeller down far enough to satisfy the NPSH required.

Vertical barrel pumps are virtually always kept as short as possible, depending upon the NPSH available. Many of them, therefore, utilize a first stage low NPSH required impeller. It can cut the required barrel length in half. Some specifications limit suction specific speed to 10,000 or 11,000 to prevent recirculation in the pump, and as most low NPSH required impellers have suction specific speeds in excess of these values, they may not be permitted by the specification. However, limiting suction specific speed across the board is not a very good method to stay out of recirculation trouble. The system curve(s) is (are) all important and must be considered before putting a limit on suction specific speed. Various writeups of individual pump companies show calculations which may be used to determine if recirculation is possibly a problem.

The cross sectionals shown for deep well pumps indicate their purpose; all others are used for applications, as mentioned previously and must be designed for their individual application—from storm water to anhydrous ammonia.

Lubrication of the pumps is either by the fluid pumped (product or water lubricated pumps) or by oil (oil lubricated pumps with the shaft enclosing tube). There are variations on the oil lubricated type pump where force fed grease or clean fluid can be used. Presently, especially for deep well pumps, the mineral oil generally used is being replaced by biodegradable oils. The biodegradable oils can present a problem—tests and experience have shown that biodegradable oils can promote bacterial growth along with molds.

For all vertical pumps, it is necessary that the intake be designed properly. A deep well pump should be installed so that water comes up to the pump and does not cascade down. Vertical barrel pumps need a properly designed barrel, inlet and outlet; all other pumps need structures that are designed for proper flow.

For continuous duty large pumps—say over 50,000 gpm—it might be worthwhile to perform a model intake test, especially if the intake cannot be constructed to such recommendations as published by the Hydraulic Institute and the British Hydromechanics Research Association (BHRA). Flood control pump intakes are not generally modelled, but, it would be advisable to use guidelines as established by the U.S. Army Corps of Engineers. The Corps of Engineers has done excellent model testing for flood control pump intakes in their Vicksburg facilities.

REFERENCE

1. Greutink, H. A. J., "Vertical Diffuser Type Turbine, Mixed-Flow, and Axial-Flow (Propeller) Pumps—A Brief Overview," *Proceedings of the Fifth International Pump Users Symposium,* Turbomachinery Laboratory, Texas A&M University, College Station, Texas, pp. 65-71 (1988).