Peerless Pump Company
2005 Dr. M.L. King Jr. Street, P.O. Box 7026, Indianapolis, IN 46207-7026, USA
Telephone: (317) 925-9661 Fax: (317) 924-7338
www.peerlesspump.com www.epumpdoctor.com

TECHNICAL INFORMATION
Bulletin

NUMBER SEVENTEEN

HORIZONTAL CENTRIFUGAL VOLUTE PUMPS
applied to constant pressure systems

By R. Volpatti – Project Engineer
L. R. Link, Jr. – Design Engineer

Economics always plays an important part in the selection of capital equipment. Initial cost, maintenance cost and energy cost whether electricity, gas, oil, etc, are the usual points of judgment for mechanical equipment. Maintenance and power costs are often overlooked in favor of lower initial cost. It is frequently possible to recoup the initial cost of the equipment in a short time by selecting a unit which will give the lowest cost in maintenance and power consumption.

Many pump applications nowadays are made for “Constant Pressure Systems.” The operational characteristics of the pump are often lost in the maze of controls required by these pumping systems. An attempt is made here to bring the pump’s operational characteristics into view, since the pump is the “heart” of a constant pressure system.

Many practical methods have been used to attain constant pressure in water distribution systems. Today, the most popular methods are pneumatic tanks, house tank, pressure reducing valves and variable speed systems. The pneumatic tanks and pressure reducing valves for many years have been the most common. In the past six to eight years the variable speed, constant pressure system has become quite popular, particularly in high rise apartment buildings, office buildings, hospitals and community water distribution systems.

When talking about “constant pressure systems” the pneumatic system is excluded. The pneumatic tank system usually maintains about a 20 psi differential pressure. The variable speed pump system and the pressure reducing valve system, however, maintain pressure within a 3-5% differential.

Constant pressure systems are sold by various companies in two basic concepts; the VARIABLE SPEED pump system, using a variable speed device between the driver and pump, and the PRESSURE REDUCING VAVLE system using a pump operated at constant speed and a pressure reducing valve between the pump and system.

The resultant effects on the pump’s mechanical life and power requirements under the two applications are herein discussed.

The life of bearings, packing and mechanical seals, and the life of close clearance parts of a pump are directly affected by the thrust loads developed by the pump. For two identical pumps, shorter mechanical life can be expected on the pump which experiences the greater thrust loads.

For horizontal centrifugal volute pumps the critical load results from radial thrust. The radial load imposed on the rotating element in a centrifugal volute pump is the result of three factors:

1. Dynamic unbalance
2. Weight of rotating components
3. Hydraulic radial thrust

Dynamic unbalance and weight are present in all types of rotating machinery. For centrifugal volute pumps they rep-resent only a small portion of the total radial load. The major portion of the radial load imposed on a centrifugal volute pump is the result of hydraulic radial thrust.

Hydraulic thrust can be expressed by the formula:

$P \cong \frac{KHD_2B_2}{2.31}$ where:

P = hydraulic radial thrust in pounds
H = total dynamic head in feet
D2 = impeller diameter in inches
B2 = impeller width including shrouds in inches
K = a constant which varies with capacity according to the following formula:

$K = 0.25\left[1-\left(\frac{Q}{Q_n}\right)^2\right]$ where Q is any capacity and QN is the capacity at peak efficiency.

For a centrifugal volute pump with fixed impeller dimensions, the two variables which affect radial thrust are K and H.

CONSTANT SPEED SYSTEM

The pump in a constant pressure system using pressure regulating valves performs to its normal constant speed head-capacity characteristics. The pressure regulating valve (PRV) maintains a constant pressure on the downstream side of the valve.

The pump and valve performance shown in figure 1 is for a design capacity of QN and a constant pressure setting of HN. HN is the maximum pressure which the pump can develop at design capacity QN, less valve loss, and is not affected by changes in suction pressure. Figure 1 also illustrates that a decrease in capacity from QN is accompanied by an increase in both H and K.

VARIABLE SPEED SYSTEM

The pump in a variable speed constant pressure system performs along a constant pressure line from the design capacity to shut-off. The pump speed is varied to maintain the constant pressure. The pump performance, shown in figure 2, is for a design capacity of QN and a constant pres-sure setting of HN. The constant pressure setting HN is based on the maximum pressure which the pump can develop at QN with a minimum available suction pressure. An increase in suction pressure permits the constant pressure setting, HN, to be maintained with a corresponding decrease in pressure developed by the pump. For example, figure 2 shows that a 10% increase in suction pressure allows the pump to operate at 90% of HN. Figure 2 also illustrates that a decrease in capacity from QN is accompanied by an increase in K only.

In comparing thrust loads of the pump applied to the two systems it is evident that the thrust on the constant speed is the greater of the two loads. Table I shows the percent increase of thrust for the constant speed pump:

% QN	W/Min. Suction Press.	W/10% Increase in Suction Press.	W/20% Increase in Suction Press.
0	30%	40%	50%
25	26%	35%	44%
50	19%	26%	43%

TABLE I

Figure 3 compares the relative values of radial thrust for the constant speed pump and the variable speed pump, based on the minimum available suction pressure, and on an increase in suction pressure of 10% and 20%.

Excessive amounts of radial thrust or operation of a pump for a prolonged time at high thrust can result in a number of premature mechanical failures. In part, these mechanical failures are caused by the effects of radial thrust on the deflection of the pump shaft.

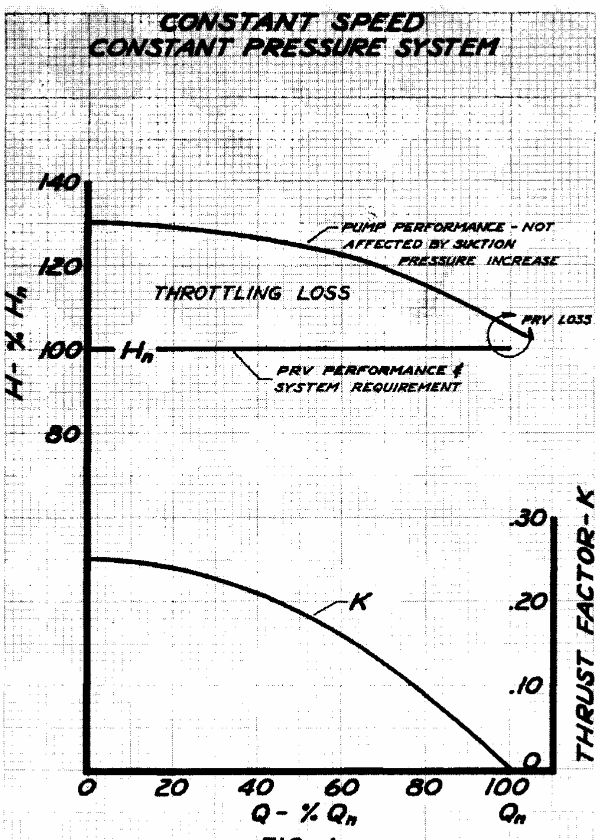

FIG. 1

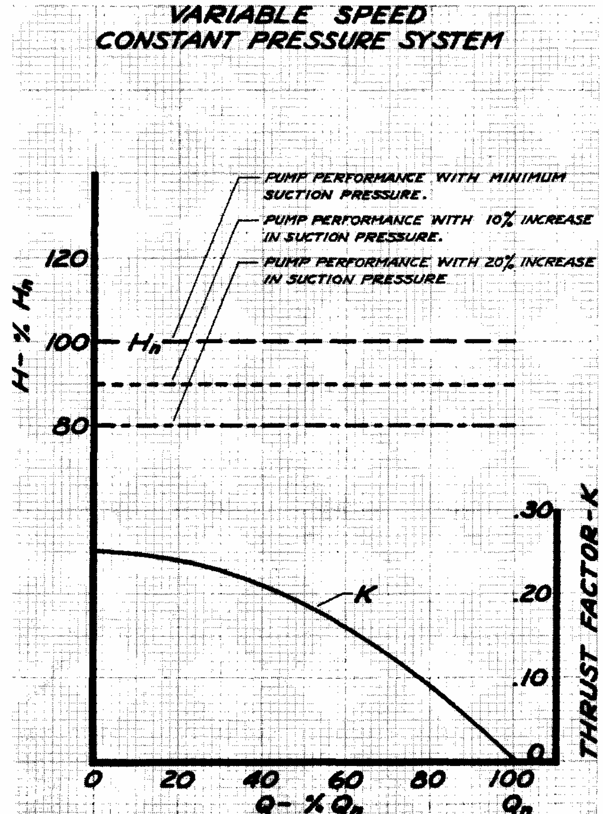

FIG. 2

Fig. 1 represents (1) the pump's head-capacity characteristic in per cent of maximum design capacity Q_N (2) the value of the radial thrust coefficient K from maximum design capacity Q_N to shut off (3) the throttling loss in the pressure reducing valve.

Fig. 2 represents (1) the pump's head-capacity characteristic in per cent of maximum design capacity Q_N at the various suction pressures (2) the value of the radial thrust coefficient K from maximum design capacity Q_N to shut off.

A pump shaft with a single concentrated load located at midpoint between the supports has an approximate deflection defined by the formula $Y = \frac{PL^3}{48EI}$.

In the example, where the comparison is made on the same pump, the value $\frac{L^3}{48EI}$ is constant.

The expression then states that the deflection of the pump shaft is directly proportional to the radial load P. Therefore, a reduction of radial load will decrease the shaft deflection and lengthen he mechanical life of the pump. The relative values of thrust for each pump application are shown in figure 3.

Power requirement is one other area of comparison. Figure 4 shows the relative values.

Pressure drop through a forced restriction is the principle of operation of a PRV constant speed pump system. The PRV maintains constant pressure on the system on the downstream side of the PRV by "burning up" excess pres-sure energy supplied to its input or upstream side. The amount of excess pressure energy the PRV dissipates depends on the head-capacity slope of the pump and the in-crease of suction pressure above minimum design conditions. Consequently, operating the constant speed pump at capacities below maximum design or having the suction pressure increase 10% to 20% from minimum does not decrease the horsepower characteristics. The horsepower requirements remain the same and the added pressure energy is "burned up" by the valve.

Impeller velocity conversion to pressure energy is the principle of operation of a variable speed pump system. The impeller speed (N) is varied to allow the pump to develop the pressure energy required by the system. The horsepower characteristics of the pump are proportional to the cube of the pump speed $\frac{HP_1}{HP_2} = \left(\frac{N_1}{N_2}\right)^3$

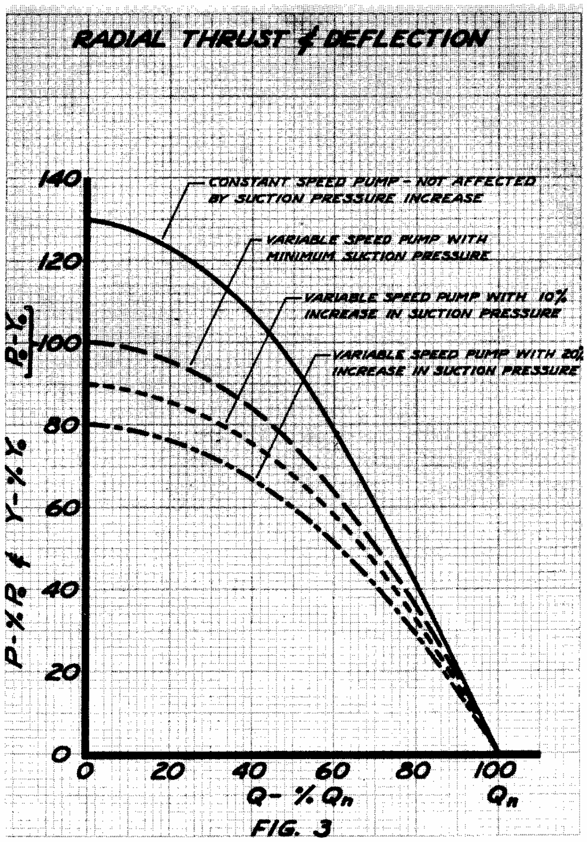

Fig. 3 represents (1) the radial thrust load P and shaft deflection Y values for a constant speed centrifugal volute pump at any suction pressure (2) the radial thrust load P and shaft deflection Y values for a variable speed pump at the various suction pressures.

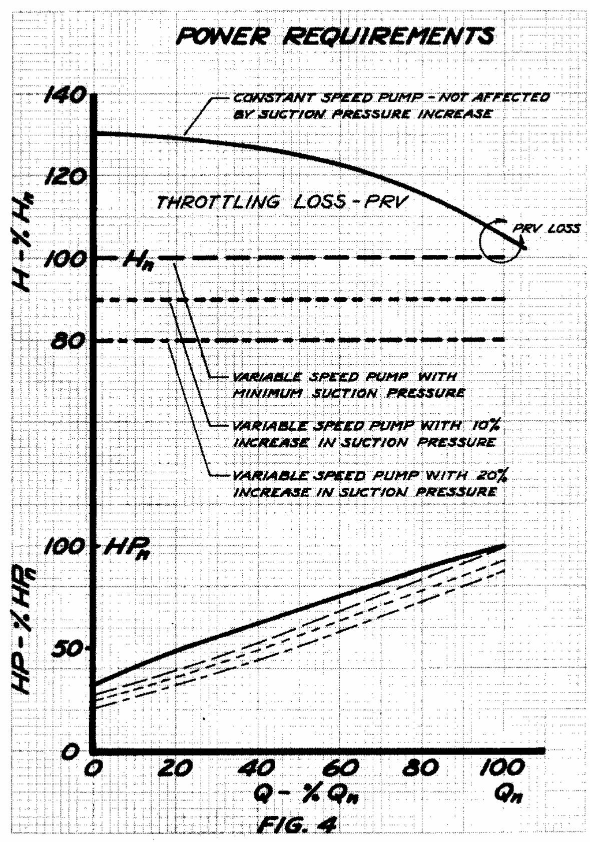

Fig. 4 primarily represents (1) the value of horsepower HP in per cent of the horsepower required at maximum design capacity Q_N (2) the head-capacity values for the constant speed and variable speed pump in per cent of the maximum design capacity Q_N.

At capacities below the maximum design capacity QN, the power requirements of the pump decrease at a rate proportional to the cube of the speed decrease. The expression HP2 = $\left(\frac{N_2}{N_1}\right)^3$ x HP, points this out.

HP1 = Power requirement at speed N1
N2 = RPM required to keep 100% HN at capacity Q1 - %QN.
HP2 = Power requirement at speed N2
N2 = RPM required to keep 100% HN at capacity Q2 - %QN.

The pump therefore does only enough work to satisfy the system requirements. Figure 4 and Table II give these relative values. These comparisons take into consideration the expected efficiency of the variable speed device, such as fluid coupling, and are based on the power requirements of the variable speed pump at maximum design point, QN and HN.

POWER REQUIREMENTS				
GPM	P.R.V. System	Variable Speed System		
	All	Suction Pressure		
% QN	Suction Pressure	Minimum	+ 10%	+20%
0%	32%	26	24	21
20%	49	40	36	33
40%	62	52	49	45
60%	73	69	64	59
80%	89	83	78	73
100%	100	100	93	87

TABLE II

The proper selection of a constant pressure pumping system is usually based on economics. The capital cost and the maintenance costs are important factors to consider. However, the power cost for a period of 5 to 10 years service is also a very important factor to consider in the final selection. The difference in power consumption between the two alternate constant pressure systems can often return the original capital investment within a relatively short period of time. The variable speed pump constant pressure system has the advantage over the PRV constant speed pump system in expected mechanical life, maintenance and power consumption.