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TECHNICAL INFORMATION

Bulletin

NUMBER ELEVEN

CONSTANT PRESSURE SYSTEMS, INITIAL COST VERSUS ACTUAL COST

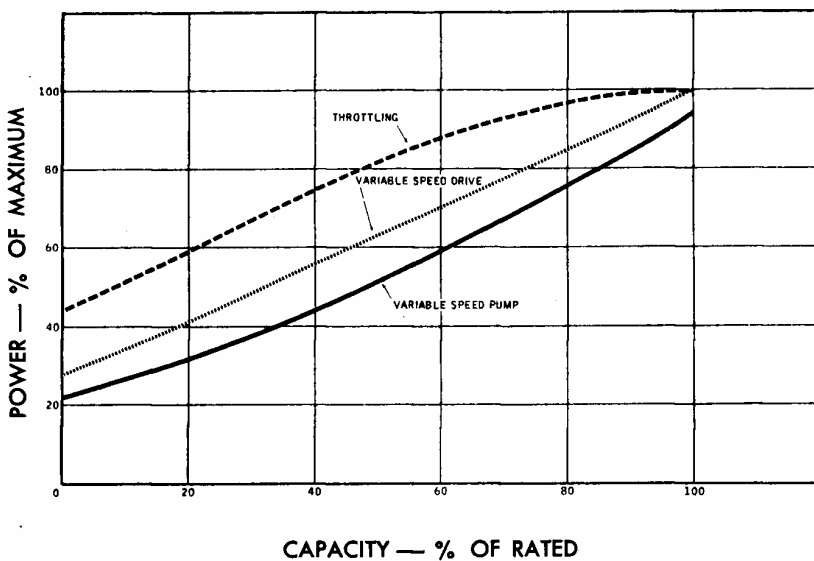
ARCHITECTS, engineers and owners are more conscious of building cost than ever. Each item must be thoroughly examined as to its function and its cost. Cost is not a one-time expenditure and therefore the initial cost must be weighed against the continuous cost of power consumption and yearly maintenance.

Many companies have touted figures that could be saved if their system for constant pressure control were utilized. In an effort to be factual in evaluation of various methods of

obtaining this desired result, an outside testing agency was contacted. This agency used the same pump for each of the following tests. By using the same pump, then the power consumed under each test can be contributed entirely to the system or method of control used.

Types of systems evaluated.

1. Throttling
2. Variable speed
3. By-passing
4. Recirculation control



This is a constant pressure application where the suction pressure is constant at all times. As the liquid requirement is reduced, the improved efficiency of the variable speed unit over the throttling method becomes quite pronounced as indicated in the percent of maximum power consumed on the curve. The line marked "Variable Speed Pump" is the power to drive just the pump. The line marked "Variable Speed Drive" is the power to drive the pump through the oil filled fluid coupling drive and the difference between the two lines is the loss in the fluid coupling.

FIGURE 1. Power requirements with constant head operation. Throttling vs. variable speed control. Rated head.

Definitions:

- 1. Throttling.** This system accomplishes constant pressure by means of a throttling valve on the discharge side of the pump. The throttling valve requires a pressure of five ft. minimum over the design head of the system. This is a constant requirement and must be added to the initial total dynamic head required of the pump at design. Variable capacity, at constant pressure, is obtained by opening and closing this valve as required. Because a valve has a limited range of accuracy, more than one valve is normally used to extend the performance range.
As can be seen, the pump operates along the normal pump head capacity curve from the design point (system head requirement plus valve loss) to shut off point. The efficiency and pump required horsepower can be read directly from the pump curve and there is no efficiency improvement as occurs through speed change.
- 2. Variable Speed** as used in this study is the oil filled fluid coupling.
- 3. By-passing** means that the pump operates continually at the maximum system design point and the excess water or liquid not wanted is by-passed back to reservoir from the discharge side of the pump. This results in sheer waste of power and the resultant horsepower curve as shown is maximum under any conditions of flow.
- 4. Variable Clearance.** This method allows the slippage of liquid within the pump case itself. It is accomplished by either:
 - a. Moving the impeller from the mating close-tolerance bushing
 - or
 - b. Moving the wear ring or close-tolerance bushing from the impeller. This method has been employed at times in raising the impellers in deep well pumps with various degrees of success. It will give appreciable reduction in power consumption.

Compared with Throttling

Basically the power requirements of a

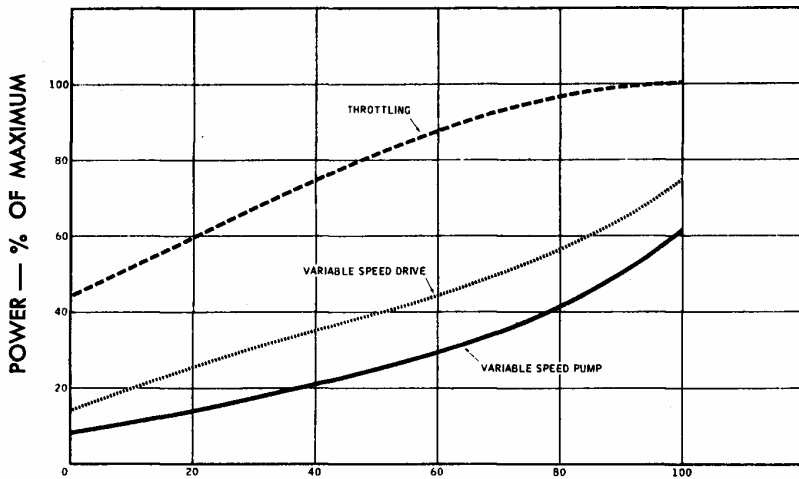
centrifugal pump vary as the cube of the speed. However, power savings in any given application will depend on a number of factors, including pump characteristics (slope of head-discharge curve, efficiency) head characteristics of system (constant head, friction head, combination) and type of control used for comparison. Throttling is the most common type of control and will be used for comparison in the first three examples.

Figure 1 shows the power requirements for throttling and variable speed control with a constant head system. Velocity head and friction losses not chargeable to pump are assumed to be negligible. Reduction in power requirements through the use of a variable speed drive is significant.

Figure 2 shows power requirements for the same conditions except that head has been reduced to half. This is the condition that would exist in a booster application if pressure in the suction line increased. Here savings with the variable speed drive become very substantial.

Figure 3 shows the power requirements for a system with friction head only. Here the savings in power with a variable speed drive are also very substantial with almost any degree of reduction in capacity. In these examples the power loss at full capacity due to slip in the fluid coupling or pressure drop through the throttling valve is assumed to be 5%. In processing applications the pressure drop in the control valve is generally greater.

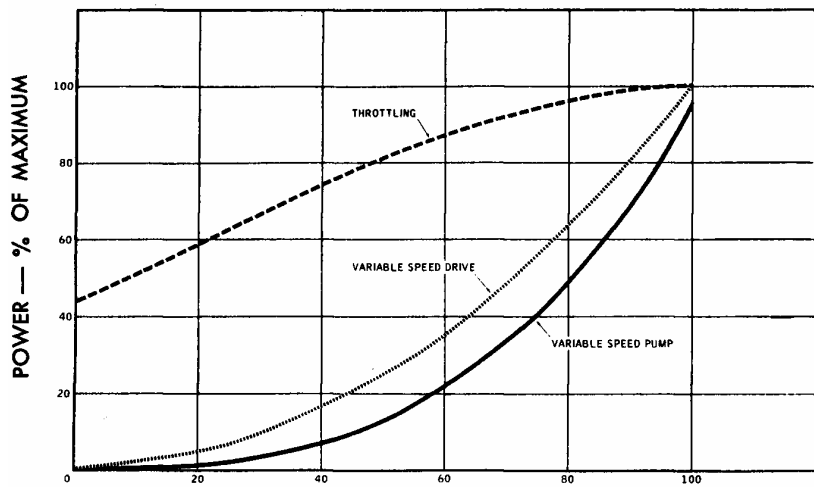
The difference between the variable speed drive and the variable speed pump curves represents the slippage loss in the coupling. This reaches a maximum of 15% (or slightly more, considering initial slip) of full power at 33% slip. At all other speeds it is less. The difference between the two curves represents the theoretical additional power that could be saved by using a non-slip variable speed drive. Considering the normal losses associated with such a drive, there would be relatively little incentive to use one in the interest of saving power, unless the non-slip drive were only a little more expensive than the comparable slip type drive.



CAPACITY – % OF RATED

FIGURE 2. Power requirements with constant head operation. Throttling vs. variable speed control. Head 50% of rated.

This curve compares the “throttling” method for constant pressure against the variable speed means. In this example of constant pressure the suction pressure is allowed to change, as this is normally found in building trade applications. Since the throttling method applies the pump developed head on top of the suction head, then the total head at the pump discharge can be quite excessive on jobs where the suction head is allowed to approach normal design head. In contrast to this, the variable speed pump would continually drop in speed as the suction head increases, thus reducing the required horsepower of the pump. Not only does the variable speed pump hold a constant pressure in the system, it also holds a constant working pressure in the pump case as compared to wide variation allowed by the throttling method.



CAPACITY – % OF RATED

FIGURE 3. Power requirements friction head only. Throttling vs. variable speed control.

In many systems the total head required by the pump is chiefly to overcome the friction loss in the discharge piping. This curve is to illustrate the marked difference in the power consumption of the throttling method versus the variable speed method under this condition of operation.

The principal advantage would be to eliminate the need for auxiliary cooling.

Curves for a 4AE10 pump were used as the basis for the previous examples. These curves are shown in Figure 4 with the different system-head requirements plotted in. This figure also shows the increase in pump discharge pressure resulting from throttling as indicated by the top H-Q curve. The difference between this curve and the particular system requirements represents pressure drop through the throttling valve. **WITH VARIABLE SPEED CONTROL, THE PUMP DEVELOPS ONLY ENOUGH PRESSURE TO MEET THE SYSTEM REQUIREMENTS.**

Compared with Bypassing or Recirculation Control

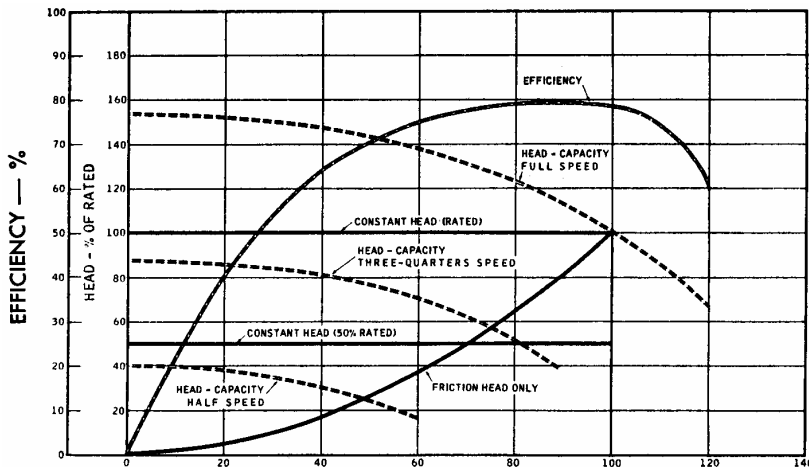
Capacity may be varied by bypassing excess fluid from the discharge of the pump back to the reservoir. In this case the pump operates at maximum power regardless of the amount of fluid delivered to the system. Capacity may also be varied by changing the clearance between the impeller and the casing to allow varying amounts of internal leakage or recirculation. A variable clearance pump using this principle was tested, shown in Figure 5. This method is also used to reduce the capacity of turbine pumps by lifting the impellers. This very appreciably reduces power requirements.

Figure 5 shows the power requirements for the variable clearance pump operating at constant head with control by throttling, variable speed, bypassing and recirculation or variable clearance. Except near maximum capacity bypass control is least efficient, followed by throttling. Variable clearance is next, with variable speed being the most efficient except near maximum capacity. In this example, the same basic pump efficiency was assumed for all cases. Actually, a closed impeller pump could be used for all types of control except the variable clearance, which would increase the efficiency of these others means of control by several percentage points.

This illustrates that the steeper the H-Q curve, the greater the savings with a variable speed drive. Also, higher specific speed pumps with rising horsepower curves at reduced capacity may be operated at reduced capacities using a variable speed drive without danger of overloading the prime mover.

Summary

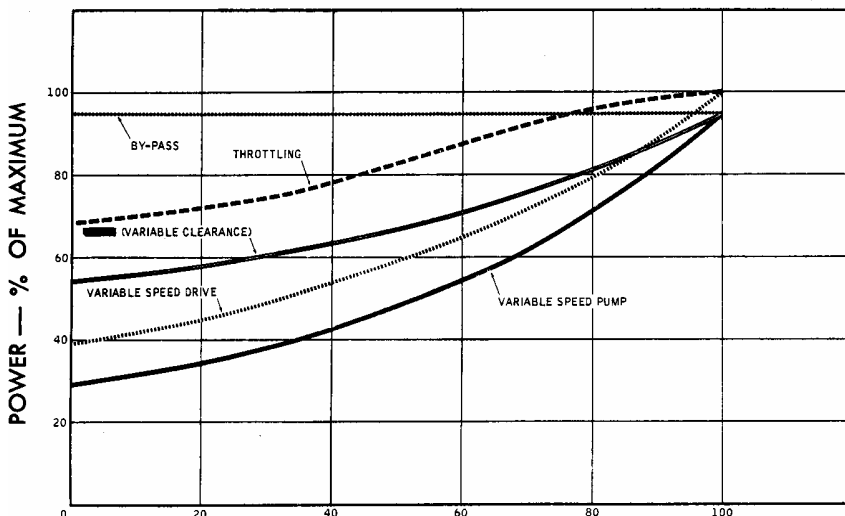
This survey should leave little doubt as to the expected operating efficiency of the various methods of obtaining constant pressure. This is a loss of efficiency and a constant drain on the horsepower consumption of the drivers and must be paid for in power costs over the entire life of the expected installation. In this case of the throttling method, not only loss of efficiency must be considered at reduced flow but the increased operating head required to overcome the pressure drop in the regulating valve must be considered. This is a minimum of 5 ft. which becomes 5% loss if the system head requirement is 100 ft. but becomes near 25% if the required head is 20 ft. and as much as 50% if the required system head is 10 ft. as in the case of a constant head circulating pump. This is loss at peak operating conditions and can never be regained.



CAPACITY - % OF RATED

FIGURE 4. Pump characteristics curves for 4AE10 pump. Curves used for plotting previous examples.

This compares all four methods of obtaining constant pressure. The least efficient drive under all conditions of operation is the "by-pass" followed in order by No. 2 - throttling, No. 3 - variable clearance, and most efficient No. 4 - variable speed.



CAPACITY - % OF RATED

FIGURE 5. Power requirements for variable capacity (internal recirculation) pump operating at constant head. Various types of control.

Efficiency is extremely important but even more so is dependable operation and low noise level. Pump manufacturers have discussed for years the possibility of limiting the operating range of their equipment to some plus or minus 20% of the design efficiency. This means that for the best operation they would like to see that the pump is selected and operated at a capacity within approximately 20% of the design point or point of maximum efficiency of the pump. There are several reasons for this line of thinking.

- 1. Mechanical Limitation.** The shaft that supports the impeller is constantly in a state of flex. This shaft deflection produces bearing loading and distortion at the mechanical seal or packing box. Manufacturers do design shaft to withstand occasional operation at points other than those at close design, however, no one will endorse sustained operation at any condition other than in the areas wherein the pump was designed to operate.
- 2. Hydraulic Limitation.** Smooth laminar flow of water is a product of a properly designed pump. When too much water is forced through an orifice, then the flow becomes erratic and cavitation becomes obvious, with its accompanying water noise. This is frequently found in pumps, valves and orifices and must be avoided. When less than design flow is allowed to pass through a pump, then a similar phenomenon occurs and the flow ceases to be laminar. The pump turning at constant speed produces a higher developed head at a smaller

capacity. The water tries to recirculate by slippage across the wear rings; the flow is not smooth through the pump and noise is frequently encountered. The same thing happens to valve operating with high pressure drop across the faces. For this reason valves are normally furnished with stainless steel seats to minimize the "wire drawing" from the water. This lengthens the life of the valve but the cause of the disturbance still exists with its disturbing noise.

Both of the described limitations result directly in higher maintenance costs. To violate either of the above limitations can result only in increased operating and maintenance expense, to all parts of the system experiencing the increased pressure, such as the valves and the pump. With this is the increased noise and vibration due to poorly operating flow patterns.

These restrictions point out very clearly the need for variable speed when variable performance is required.

No architect or engineer is willing to risk his reputation in accepting equipment just because it is cheap. Even more important than first cost is the requirement for safe dependable equipment that is noise-free and that will not be a power-hog the rest of its life.

It therefore becomes the SACRED TRUST of the architect and engineer to protect his customer from such equipment.