Examining these results it can be easily understood that in practically every case a pump with a characteristic similar to type No. 1 is preferable. A considerable change in the pressure will only slightly change the quantity with only slight change in the horsepower required to drive the pump.

It is quite possible to construct a pump which will not under any condition overload the motor. The horsepower required is a function of the product of the quantity pumped, the head developed and the efficiency. If the characteristic curve is so steep that the head drops quickly with increased quantity and the efficiency remains high, then with careful design the point of maximum efficiency can be made the point of maximum load on the motor. Such a pump is very valuable, as fluctuations of the pressure cannot overload or injure the motor.

In case No. 3, the load on the motor increases from 1,000 h.p. to 2,740 h.p. with only a drop of less than 8% in the pressure. Such a pump is a menace in any plant and under no condition should be installed; yet it is a very common type.

CHARACTERISTIC CURVES OF TWO PUMPS, SHOWING WORKING AREAS

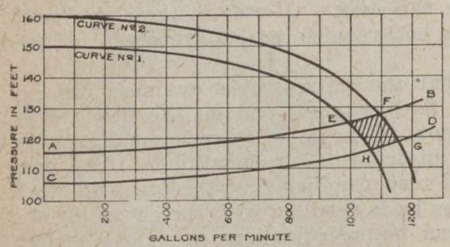

FIG. 4—DROPPING CHARACTERISTIC TYPE

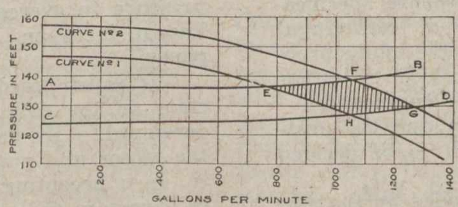

FIG. 5—FLAT CHARACTERISTIC TYPE

The pump in type No. 2 would also overload the motor unless the motor selected was large enough to meet the extreme demands of the pump. A bad feature of case No. 2 is that the pressure when the pump is discharging no water is less than the pressure when the pump is discharging at the rating of the pump.

Suppose the outside pressure in the main when the pump is not running were over 240 ft., then it would be impossible to start the pump discharging water, as the pump would only develop 240 ft. when no water was flowing, and as the outside pressure was higher than this, the water would flow back into the pump. To overcome this difficulty, it has been found necessary in the past to place a by-pass on the main and relieve the pressure on the pump until the pump gets up to its rating. Such a pump is an unstable, unsatisfactory proposition.

The next consideration the engineer has to face, having decided on the type of pump required to meet the conditions, is the selection of a suitable type of motor. The head developed by a pump varies directly as the square of the speed at which the pump is run. Suppose that the motor driving a pump fluctuates 5% in speed either way, then the head developed will fluctuate approximately 10%.

Figs. 4 and 5 represent characteristic curves of two pumps. In each case curve No. 1 represents the curve for minimum motor speed and curve No. 2 represents the curve for maximum motor speed.

To clearly understand the effect of speed fluctuation, suppose a pump is started up with the discharge valve closed and the valve is gradually opened up, then the curve showing the pressure on the pump side of the valve and the quantity pumped is the characteristic curve of the pump. A curve showing the pressure on the opposite side of the valve can also be plotted against the flow. Such a curve (A B) is shown on Figs. 4 and 5. The difference between the characteristic curve and curve A B at any point, represents the head lost in passing through the partially opened valve.

Due to variations in service demand, the pressure outside the valve will vary. If the demand increases, the pressure will fall.

Let curve A B represent the maximum outside pressure, and curve C D represent the minimum outside pressure, then the area E F G H intercepted between characteristic curves Nos. 1 and 2 and curves A B and C D, will show the total variations in pressure and flow which can be caused by variations in motor speed and variations in service demand.

It is desirable that this area be kept as small as possible, otherwise the motor will require to be of very large capacity to meet the maximum demand, and as the average demand is usually very much lower than the maximum, then the motor will usually be very much under loaded.

The area of fluctuation shown under Fig. 4 is much less than that indicated in Fig. 5. This again shows the importance of the characteristic curve of the pump.

If a synchronous motor be used, then the speed will not vary and only outside variations in the demand will affect the load. Unfortunately, a synchronous motor is not self-starting and requires to be started by some other source, such as an induction motor, bars in the pole pieces of the motor or otherwise. Even with auxiliary starters, it is out of the question to attempt to develop a large starting torque and this fact limits the design of pump, as a pump which requires a low starting torque must be designed. Such a pump will not develop as high an efficiency at full load as a pump which is designed without regard to the necessary starting torque.

The reason for this is that for high efficiency a fairly wide impeller, through which the water will flow slowly, is necessary. Naturally the wider the impeller, the greater is the power required to start the impeller rotating. Therefore, for high efficiencies, where it is not desirable to install a synchronous motor much larger in capacity than actually required at full load, the selection of an induction motor is recommended.

An induction motor will vary in speed through variations in line voltage, frequency, etc. However, if the pump is designed so that the area enclosed by the minimum and maximum characteristic curves and the minimum and maximum outside pressure curves is kept small, variations in speed of the motor are not of much importance.

An induction motor is self-starting and can develop full load torque at starting. By using such a motor, the pump designer does not need to consider the starting torque and can concentrate on full load conditions for design.

If the pump is of the non-overloading type, it is possible to use a motor which will operate at practically its maximum capacity without danger of overloading the motor.

An induction motor running considerably under its full load rating has a very deleterious effect on the power factor of the service. The power factor is lowered, thus requiring extra current to operate the motor. This lowering of the power factor also affects the regulation of the generators on the system and increases the line losses.

For the above reasons, it is bad practice to use an induction motor which is too large for the service demanded. A non-over-loading type of pump is essential for good service in order that the motor may be kept small.

No attempt is made in this paper to indicate the most suitable detailed design of pump, but the engineer should pay particular attention to the class of pumps and service in which the manufacturer tendering on his specifications has had experience.

After examining the characteristics of the pump, the engineer should examine the detailed designs to ascertain the accessibility of all interior parts of the pump, the kind of materials to be used, the efficiency guaranteed and all mechanical details.

The corporate title of Gunn Richards, Ltd., efficiency engineers, Montreal, has been changed to W. B. Richards & Co., Ltd.