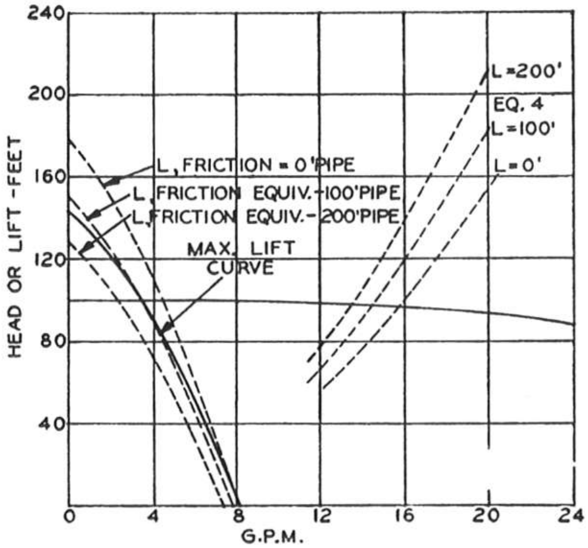

Fig. 7 Deep-Well Characteristic Lift

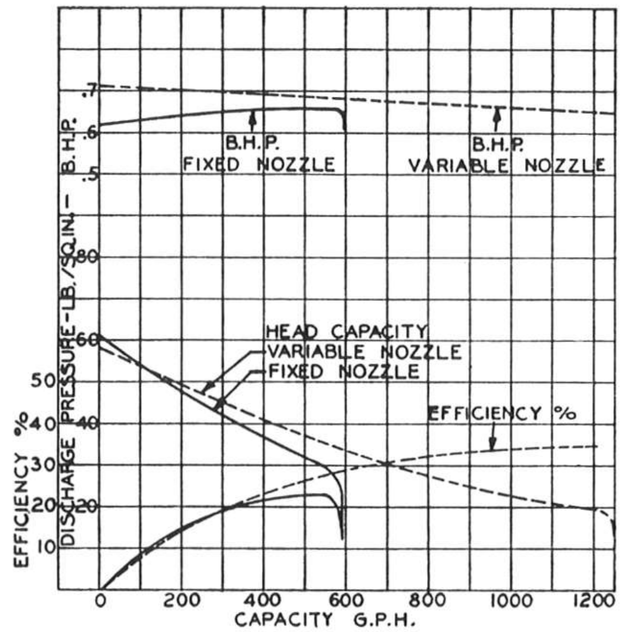

Fig. 9 Variable-Nozzle Unit Versus Fixed-Nozzle Unit

Effect of Jet Ratio

The effect of the jet ratio on the combined characteristic follows the same pattern as that of the jet, i.e., the higher jet ratios result in increased heads at lower capacities. For this reason, for the high lifts from deep wells high ratio jets will be used. Where the lifts are lower, lower ratios will be used, resulting in greater capacities.

In shallow-well service the maximum pressure is usually set at about 40 psi, and the lift at 25 ft maximum. Therefore, for a given horsepower, it is desirable to obtain maximum delivery. Owing to the operation under a lift, the largest annular area of jet nozzle to jet diffuser is desirable as discussed under suction limits. This immediately results in lower ratios which may not be high enough to allow building up the pressure at reduced capacity to operate the pressure switch.

To cover this situation, an adjustable nozzle design has been developed[5] and is illustrated in Fig. 8. Under the action of the

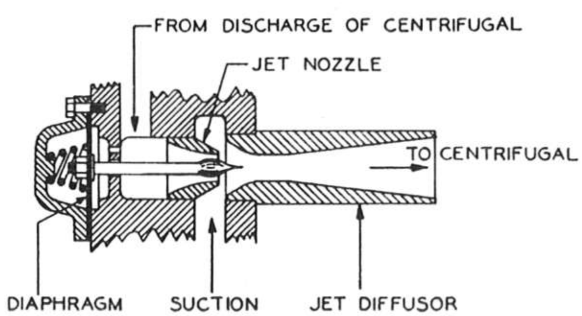

Fig. 8 Variable-Jet Nozzle

spring the nozzle areas are reduced when the pressure is low. However, as the pressure increases, the diaphragm withdraws the needle valve in the nozzle, effectively increasing the nozzle area and the jet ratio. The effect is the same as a higher ratio, and higher pressures result. The comparison of the performance of this arrangement with a fixed nozzle is shown in Fig. 9.

By suitable sizing it would be possible to bring about automatic adjustment to coincide with the peak efficiency for the various jet ratios as they are encountered during the operating cycle of this unit (refer to dotted curve in Fig. 3).

Conclusion

It is felt that the method outlined is particularly helpful in making up tables showing deep-well pump performance without resorting to extensive field testing. Pipe-friction losses have been well established so that after the jet and centrifugal characteristics are determined, the performance may be calculated readily.

The analysis also shows clearly why friction losses in the piping have such a marked effect on the output of the jet pump.

Discussion

H. W. Iversen.[6] The analysis of the centrifugal-jet pump combination, as developed by Mr. McConaghy, presents a simple solution to a three-element hydraulic system. The analysis may be extended to include a fourth element, that of the system total head.

The usual application of a centrifugal-jet deep-well combination specifies the supply reservoir elevation and the working pressure in the pneumatic tank into which the flow, Q_2, discharges. For a given jet and piping arrangement, lines of constant discharge pressure may be determined. Equation [4] contains three variables, h_p, Q_p, and M. (N is specified by M and the jet performance, Fig. 3.) Equation [4] may be written

$$h_p = Q_p^2 A$$

For a selected value of M, A is a constant with the additional assumption of constant values of the piping head loss coefficients. The intersection of this parabolic curve with the centrifugal-pump curve determines the system operating point for the selected M. Different values of M will result in different operating points, each of which is associated with unique values of the discharge pressure and of the flow rate Q_2 into the pneumatic tank.

The total system head from the reservoir to the pneumatic tank is

[5] U. S. Patent 2457388, by K. R. Lung.

[6] Assistant Professor of Mechanical Engineering, University of California, Berkeley, Calif. Jun. ASME.

$$H = \left(\frac{p_t}{w} + z_t\right) - h_2'$$

where

h_2' = head of the supply reservoir
z_t = elevation of liquid level in the pneumatic tank above h_2'
p_t = pneumatic-tank pressure.

From Fig. 4, neglecting line loss between the centrifugal pump and the pneumatic tank

$$H = (h_1 + f_1) - h_2'$$

$$h_2 = h_2' - f_3$$

where f_3 = head loss through the jet suction pipe and strainer. Equation [2] written in the form

$$H = (N + 1)(h_p - f_1 - f_2) + h_2' - f_3 + f_1$$

permits evaluation of H for each point on the curves of constant M. Lines of constant H, or constant discharge pressure, then may be added to the previous solution. The appearance of the solution is shown in Fig. 10.

One further point should be emphasized. The curves of constant M, H, and Q_2, Fig. 10, represent the piping and jet portion of the system only. These may be matched with any centrifugal pump performance as shown in Fig. 10. Thus a centrifugal pump may be selected to meet a specified condition of both Q_2 and H (or p_t).

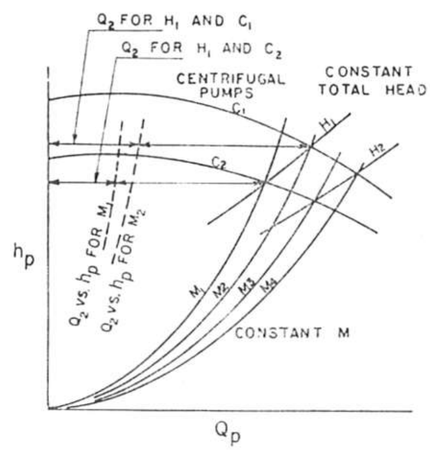

FIG. 10

Fig. 2, as shown by the author, shows one method of presentation of the jet performance. The jet suction head h_2 does not appear in the figure, nor does the text mention the suction conditions. This point should be clarified by noting that h_2 is taken as zero in Fig. 2.

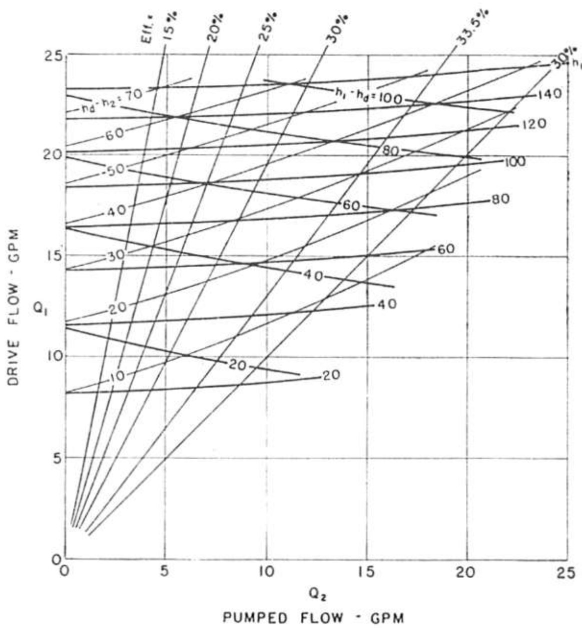

FIG. 11

Folsom[7] shows the jet performance as in Fig. 11 which has the advantage in that a single point gives the flow rates, head differences, and efficiency. Head differences are used exclusively. Thus any convenient datum may be used for pressures and elevations. Also in Fig. 11 it should be noted that lines of constant $h_1 - h_2$ do not follow lines of constant Q_1 as is implied in the author's Fig. 2. The correspondence of constant $h_1 - h_2$ and Q_1 is realized only when the hydraulic losses in the jet-pump suction are equal to zero. The effect of finite losses, while small, may be significant in many applications.

AUTHOR'S CLOSURE

For clearness in the illustrations, i.e., Fig. 6, only one set of values of N and K were used. As indicated by Fig. 10 in Professor Iversen's discussion, a series of curves for assumed values of M would be necessary to complete the determination of either the total head or lift.

In connection with Fig. 2, the value of h_2 has been taken as zero and should have so stated.

For the proportions usually encountered in domestic water-system work the assumption of zero losses in the jet suction is reasonable. As Professor Iversen points out, they should be considered in a complete analysis.

Fig. 11 is a welcome addition to this discussion.

[7] "Jet Pumps With Liquid Drive," by R. G. Folsom; *Chemical Engineering Progress*, vol. 44, no. 10, Oct., 1948, pp. 765–770.