plies not only to the design and construction but also to its operation, and it is only comparatively recently that it has been efficiently applied to pumping problems. Almost any machine shop or foundry could build a centrifugal pump that would deliver more or less water against a certain head, but little attention was given to efficiency, accessibility or operation, everything being sacrificed to low first cost. Most pumping station centrifugal pumps are driven by electric motors and consequently the operating cost is a definite and known quantity. It then becomes a question of getting the maximum efficiency from the pump under the existing conditions.

A centrifugal or turbine pump has certain fixed characteristics. For instance, in a turbine pump operating at constant speed, as it will if driven by synchronous motors, the amount of water pumped increases with the drop of pressure in contradistinction from the piston pump, which always pumps the same quantity of water, no matter what the pressure.

If, then, a turbine pump is designed to deliver a quantity of water through a pipe or a piping system of certain diameters and length at its maximum efficiency and another turbine of exactly the same characteristics is started to pump through the same piping system the frictional head from the delivery piping will increase due to the increased quantity of water and consequent increased velocity of water through it with the result that the increased head will reduce the individual deliveries, so that the total deliveries from the pumps is equal to twice the delivery of the individual pump at the increased head, instead of twice that of the original pump if pumping by itself. If these two pumps are to work together most of the time the efficiency curve for each pump should be at its maximum over the variations in head between one and two pumps working.

If two turbine pumps deliver into piping system that decreases the individual delivery of each pump by more than 10% it will have the tendency to cause the delivery to swing from one pump to the other so that one pump will be delivering water and the other practically churning. This may be remedied by increasing the sizes of the impellers.

It is usual to keep the suction tubes of all pumps under 25 feet and most pumps have their suctions at not greater than 20 feet to minimize the possibility of air leakage.

It has been found in a number of cases with turbine pumps that the tips of the impellers wear very rapidly when the suction tube is greater than 12 feet. Less than this height there is little or no wear and the reason for this is probably due to imperfections in design of the turbine pump as built to-day, although some manufacturers guarantee over 80% efficiency.

The two-stage turbine pumps that the city of Hamilton installed at its main pumping station pumps to a head of 285 feet with an efficiency of 75% under full load. The tenders for two 6½ million gallons (Imperial) turbine pumps in place varied from $5,500 to $9,800. Extra impellers capable of lifting the water to 300 feet were included and the pumps had to be successfully operated for two weeks before acceptance.

Besides the main pumping station, there was built a booster station to replace steam and air-lift pumps and to carry the water to greater elevations than possible with the main pumping station without causing excessive pressures in the lower portion of the city. This station contains four turbine pumps each of one million Imperial gallons per 24 hours capacity. Two of these pumps raised the water about 80 feet above the level of the reservoir to which the main station pumps delivered the water and two pumps raised the water 280 feet above this level. Two-stage pumps only were necessary for the lower level below the mountain plateau, but six-stage pumps were required for the higher elevation. The problem at this station was to approximately determine the heads to which the pumps would generally work so as to get the greatest efficiency out of them. The pumps were directly connected to the mains fed from the main pumping station and about 75 feet below the level of the reservoir that the main station fed.

Besides the usual annual and daily fluctuations in head with the added effect of the draft of these pumps on the static head there was the difference in level of two reservoirs on the main system to be considered. One of these reservoirs was only used in case of emergency or while cleaning or repairing the reservoir generally used, but as it was 60 feet lower in elevation and two miles distant across the city, and nearer the pumping station, it naturally produced considerable variation, and practically made the problem of obtaining maximum efficiency with turbine pumps under all working conditions indeterminate. The pumps, as built and operated, give a maximum efficiency of 60 per cent., although under certain conditions the specified efficiency of 75 per cent. is obtained.

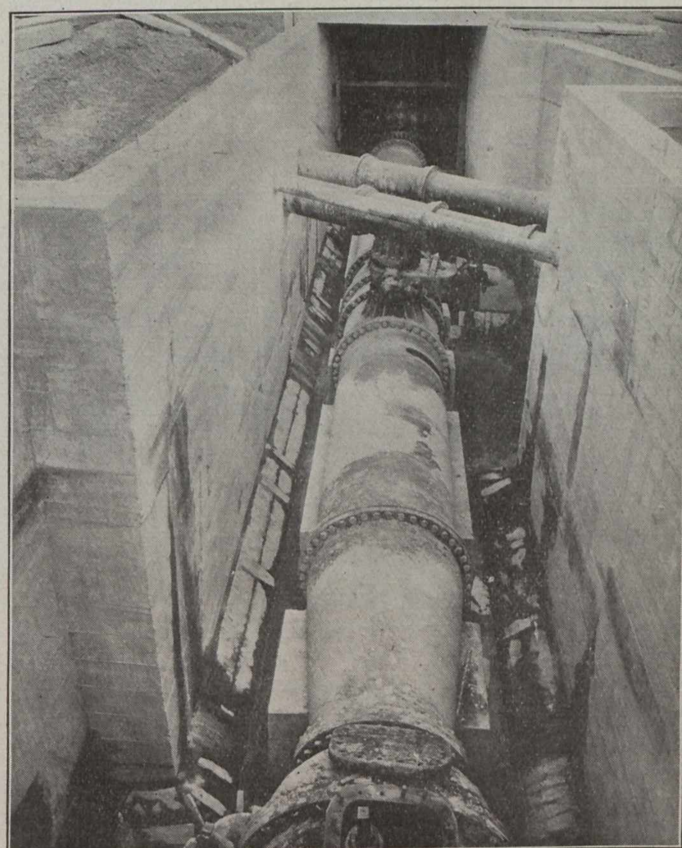

Fig. 5.—The 48-inch Header, Beach Pumping Station.

Tenders for these four pumps in place varied from $6,000 to $6,800.

The main pumps are driven by 750-h.p. motors, the lower level pumps at the booster by 50-h.p. motors and the higher level by 130-h.p. motors. All these pumps run at 750 r.p.m.