If the topography is not suitable for a gravity system, there remains only the pumping system. Knowing the greatest quantity of water necessary for all purposes, design the pumping equipment with two or more units for the care of the maximum demand at normal speed and rated load. Then one unit can care for all domestic consumption and most of the smaller fires, and the other unit can be held in reserve for large fires and as a relief unit. In case of extra heavy loads for short periods, both units can be operated at a considerable overload for such emergencies. Under no conditions depend on single units in any part of the system where it is possible to install duplicates or more.

Selecting the Pumps.—The selection of type or design of pumps is so dependent upon operation conditions and power supply that it is possible only to mention here the different types, such as: direct-acting plunger pumps, steam, electrical or belt-driven; centrifugal pumps, steam, electrical or belt-driven. Each type has its advantages and its disadvantages, and local conditions of supply and demand and power supply will govern selection of type. In general, it may be said that in any type of piston pump, slow speed and long stroke should be the objects sought, as they are the more satisfactory from an operating point of view. In centrifugal pumps, not too high speed and as near as possible a constant head discharge are the desirable conditions. Too great speed causes too great friction in the pump and accentuates erosion in case there happens to be the least sediment in the water. Too irregular head lowers the efficiency curve of the pump, thereby losing overall efficiency in the plant. This, however, may be offset by the other advantages of the centrifugal pump.

The three main sources of power are steam, central station current and internal combustion engines. Here again local conditions will govern the selection of the type of power plant. Where coal is high and hard to get, with a reasonable oil rate, there may be great advantage in adopting an oil engine main drive and electric sub-drives throughout the plant. Where there are large, well-regulated central stations giving first-class service at reasonable rates, there may be advantage in central station current. Where coal is cheap and deliveries are good, then steam may be the cheapest and the best power to be had.

In any case there must be break-down or reserve service. Central station current will require steam or oil engine reserve. Oil engines will have to be in duplicate and steam will have to have duplicate equipment. With regular central station service there is the great danger of allowing the reserve plant to get in bad shape, especially in the smaller cities. This should never be countenanced, and to be sure that there is a reserve plant ready at all times the steam plant should be run at least one week in every month. No operating engineer can lay by a steam or oil engine plant for thirty, sixty or ninety days and be sure that it will operate successfully at a moment's notice, and that is all the notice that one gets from central station service, even if that much. The writer is of the opinion that with properly designed boiler settings, engines and auxiliaries and with coal at not over $4 per ton, there is small chance for the central station to carry the load at its commercial rates. If current costs less than one cent per k.w.h., there may be reason for trying the central station current.

There are the usual charges against whatever power adopted, such as interest, depreciation, operating repairs, replacement costs and general operation expense. In steam-driven pumps there are the items of valves, packings, lubricating oils, slippage, water hammer, attention, etc., that must not be overlooked. In centrifugal pumps, the items of valves, packings and lubricating oils can generally be ignored, as they are very small. Slippage also is a negligible quantity unless the water is gritty or acid or the excessive speed causes severe erosion of working parts. Each class of pump must bear its own load, and where there are necessary auxiliaries for any of the main units the operation and upkeep of these must be charged to the main unit in figuring the cost per 1,000 gallons pumped.

The Layout of the Mains.—The layout of the mains for the distribution of the water is governed mostly by the congestion of the buildings and the general direction of expansion, though the distances through which the mains have to be laid is an important factor. There have been so many cases where water plants have had to replace all small mains at great cost before the material in the lines had begun to deteriorate to any extent that it seems hardly necessary to call attention to this point, though the failure to provide against it in many cases may be caused by not giving it sufficient thought in the beginning. From the operator's point of view, mains can hardly be too large, whereas in general practice they are very seldom large enough for ordinary purposes. The difference in first cost is so little that there is no reason why they should be restricted in size. The following table, arranged by the writer for comparison purposes, when pipe and other supplies were normal, may throw a little light on the subject:—

Size main inches.	Cost foot.	Unit capacity.	Cost unit capacity.
4	$0.40	1	$0.40
6	0.60	2	0.30
8	0.80	4	0.20
10	1.00	6	0.16
12	1.50	9	0.16

The table shows that where a 4-inch main is run at a cost of 40 cents a foot the unit capacity is only one, whereas by doubling the cost per foot the unit capacity is quadrupled and the cost per unit of capacity is cut in half.

As far as the writer knows, there is no method or formula by which the proper size of main can be figured, and it is general practice to use the best judgment of the engineer or the superintendent to suggest proper sizes. This is entirely wrong; the sizes should be governed by the uses to which they are to be put. Cut the city into districts, segregate each district, calculate the maximum capacity demanded for each, and lay the mains of sufficient size to care for that demand. See that each district has feeders large enough to supply the demand, then tie all the districts together in gridiron fashion, and there will be small chance of the mains being too small. No matter if the investment is a little large at first, it will pay in the end to have mains that are large enough to stand the service and will not have to be torn out in a few years.

In the average residence section where the buildings are not congested to too great an extent and where there is a good gridiron lay-out of mains, the minimum size should be 8 inches and there should be much larger feeders, or belt lines that act as feeders. If the pressure happens to be very low and thereby calls for pumping units in the fire department, the minimum size should be 10 inches. A main of this size can generally be depended upon to furnish sufficient water in residence sections to