politan stations they add some heat to the feed water, which would otherwise have to be obtained from live steam in order to comply with the state law, which requires boiler feed water to have a temperature of at least 120° F.

Careful attention to methods of firing, such as depth of fire, regulation of draft, working of fire, charging and spreading of coal, makes for economy. As a general rule, charging small amounts of coal frequently and maintaining as thin a fire bed as practicable give the best results. Hand firing is the method employed, although stokers have been used and also forced draft with hand firing. There is considerable danger in using forced draft in internally fired fire tube boilers of getting a blow pipe or Bunsen burner effect, causing intense local heating which results in burning the furnace sheets or crown sheets and tube ends.

It has been found economical to burn a certain proportion of small anthracite coal, known as Birdseye, mixed with bituminous coal. From 25 to 50 per cent. of Birdseye can be burned with advantage with natural draft, depending on the draft available, load conditions and depth of fuel bed and characteristics of the coal used in regard to coking and clinkering. A larger proportion of Birdseye can be used economically by carrying a thin fire bed, taking care to avoid the formation of holes and working the fires as little as possible. If the air supply is obstructed by a thick fuel bed or formation of clinkers, imperfect combustion ensues. If the fire is sliced or shaken too much, a large proportion of the fine coal falls into the ash pit unburned.

One advantage of using a considerable proportion of anthracite is that it greatly reduces the formation of smoke; another is that mixing it with a bituminous coal having an ash of low fusibility tends to prevent the formation of a layer of melted ash, which would cut off the air supply to the fuel bed.

The boiler feed water is metered and in most cases it is necessary to use a hot water meter. Various makes of these instruments of the disc, piston or rotary type have been tried, but all are unsatisfactory as they rapidly lose accuracy and require constant repairs. A Venturi meter gives the best results, as there are no moving parts in the hot water, but the great cost of the registers makes them out of the question for most small plants.

It has been found advantageous to use as small steam pipes as will allow of the proper admission of steam to the engine, and by the use of a large separator on the engine the size may be still further reduced.

The advantages of a small pipe are low first cost of pipe, fittings and coverings, less radiating surface and consequent condensation, quicker passage of steam from boiler to engine, and greater flexibility of bends which reduces the strains due to expansion and contraction. The small size pipe is particularly advantageous when the steam is superheated.

While no large economics are possible in the engine room, care is taken to see that the valves of the engines are properly set, that cylinders and bearings are properly lubricated, that both steam and water packings are in good shape, and that the rubber pump valves are kept in good condition, otherwise there would be an excessive amount of slip. It is found that with outside packed water plungers the slip should not exceed 1½ per cent.

For packing single-acting water plungers, a packing made up in the form of a double wedge has been found satisfactory, as on the discharge stroke the water pressure forces the wedges together and prevents leakage, while on the suction stroke the packing is comparatively loose and causes but little friction.

For packing steam piston rods, metallic packing is used and it wears for years without attention.

Most of the air pumps and feed water pumps are direct connected to reciprocating parts of the main engines, and have the same length of stroke as the main plungers. This arrangement requires but little attention and has the same economy of operation as the main engine, but is not as flexible in operation as the independent steam-driven pumps. The exhaust steam from the latter can be used to heat the feed water, giving a good over-all economy and saving the boilers from strains due to cold feed water.

The action of the long-stroke pumps sets up violent strains in the piping unless it is well protected by air chambers kept filled with air.

Surface condensers are used exclusively. Some are of the so-called waterworks type, where the exhaust steam passes through the tubes and all the water pumped passes through the shell, flowing over the outside of the tubes; while in others a portion of the water pumped is by-passed through the tubes and the steam is condensed on the outside of the tubes. As a rule, the waterworks type gives better satisfaction, as the circulating water is cooler owing to the larger volume, there is no trouble with by-pass devices, and the interior of the tubes is not clogged by any material carried by the water.

The table at the bottom of the page gives the results of duty trials of some of the pumping engines.

The Arlington and Hyde Park engines are of the horizontal cross-compound crank and fly-wheel type; all others are vertical triple expansion crank and fly-wheel engines. The duties are based on plunger displacement, and where not otherwise noted on dry steam and coal.

Results of Duty Trials of Pumping Engines

Location of Engine.	Capacity. Mil. U.S. Gals. in 24 Hours.	Average Lift. Feet.	Duty. Million Foot Pounds per 1,000 Lbs. Steam.	Million B. T. U.	100 Lbs. Coal.	Efficiency Mechanical.	Thermal.
Chestnut Hill Pumping Station No. 1	20	137.48	.....	145.470	150.045	.....	.....
	30	140.35	178.497	157.002	173.869	93.29	21.63
Chestnut Hill Pumping Station No. 2	35*	44.68	157.349	140.533	156.322	88.23	20.50
	40	132.09	175.066	155.547	149.135	90.10	20.01
Spot Pond Pumping Station	20	125.27	173.620	156.592	177.961	96.53	20.85
Arlington Pumping Station	1.5	290.3	115.959†	.....	90.025‡	.....	.....
Hyde Park Pumping Station, Engine No. 14	3	.....	121.022†	111.880	113.488‡	93.2	.....

*Average of three 35-million-gallon engines tested together. †Moist steam. ‡Moist coal.