

The rotary pumps in circulating the cooling water are direct connected to a 120 h.p. interpole motor.

The average vacuum obtained is 28 inches. The 1,500 h.p. engines are each direct connected to a generator which develops an average of about 2,000 amperes at 575 volts.

The turbine takes steam from the common exhaust main at a pressure of one pound above the atmosphere and is provided with four wheels, each with a single row of buckets.

Exhaust steam from one engine when delivering 2,000 amperes is sufficient to deliver an output from the turbine of 1,300 amperes at 575 volts, with no increase of back pressure on the engine.

As about 150 amperes are required to operate the auxiliaries the net gain from the turbine is from 1,000 to 1,200 amperes or approximately 66½ per cent.

As the maximum gain possible from the use of a condenser without the turbine would not exceed 25 per cent., it will at once be seen that the turbine produces a gain of 41½ per cent. over this arrangement.

The generator used in conjunction with this turbine is a direct-current machine, six pole, 1,200 revolutions, but the unit is not fitted with a governor.

With the turbine taking steam at atmospheric pressure with 2 inches absolute back pressure in the condenser a water rate of 36 pounds per kilowatt is guaranteed at full load. The conductors from the turbine generator are connected by common bus bars with the leads from the engine driven units.

As before stated, this turbine is peculiarly simple, consisting of nothing but the wheels, shell and generator without governor. It is prepared therefore to take all the steam delivered to it at all times from the reciprocating units, and the cycle of operation is somewhat as follows:

If the engine driven generators tend to take more than their proportion of load, the engine governors admit an additional volume of steam to produce the necessary energy, and the engines in turn deliver more steam to the turbine, tending to speed it up, thus increasing the voltage on the turbine driven generator, which tends to take more work, thereby lightening up on the engine driven generators, which makes the regulation automatic.

As the load conditions were such as required further increase, a second 800 kilowatt Curtis low pressure turbine, condenser and cooling tower was installed early in 1906 under similar conditions, taking steam from the same exhaust header and delivering current to the common bus bars.

All the auxiliaries required in connection with the turbines, condensers, and cooling towers, are motor driven, with the exception of two dry air pumps and one step bearing pump and two discharge pumps, the exhaust from which is utilized for heating the feed water, and the current required to operate them is about 14 per cent. of the output of the turbines.

The two turbines are operated about eighteen hours a day, and the only attention required is commutator attention and the usual attention given to pumps.

The coal consumption for all purposes at this station the first six months of 1905, before the turbines were installed, averaged 4.48 pounds per kilowatt-hour.

The coal consumption for all purposes for first six months of 1905, after the turbines were installed, averaged 4.08 pounds per kilowatt-hour, showing a saving of 0.4 pounds of coal per kilowatt-hour.

As the total output of the station for the first six months of 1905 was 20,346,890 kilowatt-hours, this shows a saving of 4,039 tons of coal, or 8,138 tons for the year, which figured at \$3 per ton, amounts to \$24,414.00.

As these two turbines are not using all the exhaust from the five engines, it is plain to be seen that when their load requirements necessitate further increase, the installation of additional low pressure turbines capable of utilizing all the exhaust steam will cut their coal consumption down to at least three pounds per kilowatt-hour. and pay a handsome return on the investment.

Looking at this plant from a first cost point of view, the original steam equipment cost somewhere in the neighborhood of \$100 per kilowatt, and to have increased their capacity on its original lines would have required an investment proportionately equal to the original investment; the low pressure turbines, with cooling towers, however, were installed at an expense of approximately \$50 per kilowatt, and as the turbines were utilizing the energy in the steam previously unused, the fuel consumption was not increased a pound, or in other words, considering one of the 1,500 kilowatt units operating with one of the 800 kilowatt low pressure turbines under the new arrangement, 2,300 kilowatts were made available at no more expense as regards fuel and attendance than was previously necessary to deliver 1,500 kilowatts to the distributing mains.

The Scranton, Pa., street railways were equipped with four simple non-condensing Corliss engines, as follows:

|                                    | Rated<br>h.p. | Kilo-<br>watts. |
|------------------------------------|---------------|-----------------|
| No. 1 Allis, 42x54, at 97 rev....  | 1,400         | 1,000           |
| No. 2 Dick'n, 26x48, at 80 rev.... | 400           | 300             |
| No. 3 Cooper, 26x48, at 80 rev.... | 400           | 300             |
| No. 4 Cooper, 30x38, at 97 rev.... | 750           | 500             |
|                                    | 2,950         | 2,100           |

Engines operated at an initial pressure of 115 pounds.

No. 1 and No. 4 were connected direct, and the other two belted to individual generators of the capacities named.

The average output of this plant is 1,500 kilowatts while the maximum requirements, of short duration, taxed the entire plant to its utmost.

The exhaust of these four engines led into a common tee, from the top side of which emerges a 30-inch free outlet to the atmosphere.

Early in 1906 a 500 kilowatt Curtis low pressure turbine was installed taking steam through a 14-inch pipe connected to the 30-inch outlet, and exhausting through a condenser supplied with cooling water brought from the Lackawanna River, a distance of 450 feet, with a lift of 54 feet to the condenser head, at mean height of the river.

The turbine, therefore, works between the atmospheric pressure and 28-inch vacuum at a water rate of about 36 pounds per kilowatt hour, or less than 20,000 pounds of steam per hour at its full-rated capacity, while the engines, aggregating about 3,000

h.p., will, at 90 pounds per h.p. exhaust, when working at their rated capacity, 90,000 pounds in the same time.

There is here, therefore, an excellent opportunity for the installation of at least two or three similar low pressure units as soon as the load conditions warrant further increase. The method of using the turbine output is similar to the case previously mentioned.

#### LOW PRESSURE TURBINE WITH COMPOUND CONDENSING ENGINE.

There is a plant in East St. Louis in which is installed an 800 kilowatt low pressure turbine equipped with a 500 volt, direct current generator, which is used in multiple with the engines from which the turbines receive their steam. This equipment is utilized for operating the railroad. There is also installed in this station a 1,000 kilowatt low-pressure turbine equipped with an alternating current generator taking steam from the same exhaust header and delivering its output for an entirely different purpose, that is, the operation of light, and stationary power throughout the district.

For the benefit of those who are inclined to feel that while the advantages of the low pressure turbine may be all that are claimed for it when used in conjunction with a non-condensing engine or possibly with a condensing engine which gives poor economy, but are inclined to be extremely sceptical as regards its usefulness when used in conjunction with a first-class compound condensing engine, which by itself is producing exceptional results, I would like to familiarize you with the results of an investigation and recommendations which I recently had occasion to make in one of the most economical steam-electric power plants in New England. The general arrangement of this plant is as follows:

The boiler floor level is considerably below the engine floor level; the basement is still lower. This arrangement leaves nearly 14 feet clear height in the basement, and gives excellent space for the primary heaters, air pumps, exciter engine and the rest of the machinery there installed. Babcock & Wilcox boilers, each having 3,964 square feet of heating surface, 67.6 square feet of grate surface and 125 square feet of superheater coils, are installed. The feed pumps are Blake duplex outside-packed plunger pumps, driven by tandem compound steam cylinders.

The feed passes through a main heater in the main engine exhaust pipe, through a closed auxiliary heater where it receives heat from the feed pumps and air pump exhausts, and then through a Green economizer to the boiler. The condensers are Blake vertical twin jet condensers.

The cooling water is taken direct from a river flowing by the plant.

The engines are two McIntosh & Seymour vertical, two-cylinder, cross-compound 18 inches and 38 by 42 inches, each developing 760 indicated h.p. at 0.24 cut-off with 135 pounds initial steam pressure and 26 inches effective vacuum, and each direct-connected to 600 kilowatts, 60 cycle alternating current generators operating at a speed of 120 revolutions per minute.

Each high pressure cylinder is jacketed in the barrel, and both heads and the jackets are piped in series; the steam enters the jacket on the top head, passes into the barrel