amount paid to the contractor the sum of two thousand five hundred dollars ($2,500) for each one million (1,000,000) foot-pounds unperformed, and pro rata for fractional parts down to five million foot-pounds less than the guaranteed duty.

"If the duty as shown by the official test be more than five million foot-pounds below the guaranteed duty, the commissioner may, at his option, reject the unit, and in case of such rejection, the contractor shall return all moneys paid to him on account and shall, without compensation, allow the unit to remain in the service and under control of the commissioner for such a time as may be required to install a new unit, and shall fully reimburse the city for any loss or damage suffered by reason of the contractor having failed to fulfil his guarantee."

In accordance with clause 59, the contractors guaranteed a duty of 141.5 million foot-pounds of work per 1,000 pounds of steam used, and this duty was therefore inserted in the contract.

Details of the Trials.

The duty trials were run in exact conformity with the specifications, with the single exception of the duration of each, which is specified as twenty-four hours. On discussing the matter with the city's engineers, it was found that the conditions in the station made such a long run very undesirable, and it was agreed that the run should be shortened to ten hours. The contractor agreed to this. There is no doubt that the results for the ten-hour period would be practically identical with those for twenty-four hours.

The specifications require that the gauge pressure on the boilers supplying the turbines shall be 150 pounds per square inch. A battery of four boilers was used in each case, and on top of each boiler there is a stop valve bolted to the steam drum, and from the top of this stop valve the steam pipe from the boiler leads to a header which is common to all boilers. To this header the supply pipe for each pumping engine is connected by a fairly long, well-lagged pipe.

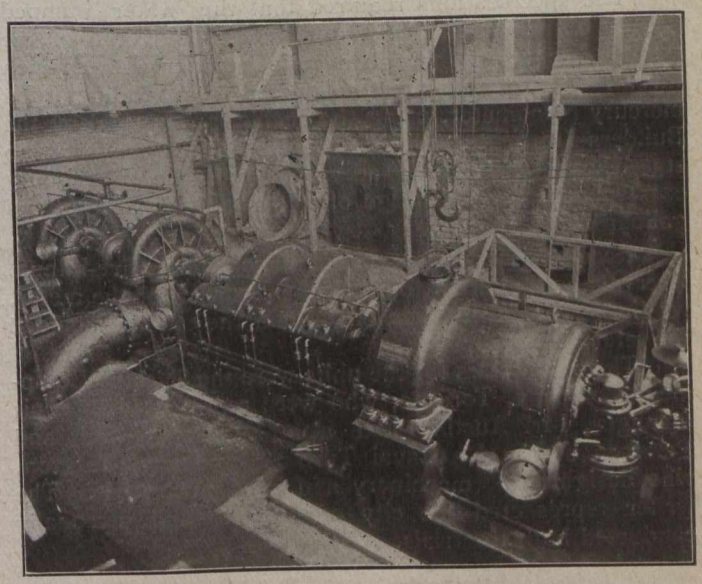
To avoid any possible sources of loss in the boiler stop valve, the gauge used on the trial was connected to the steam pipe within six inches of the stop valve. The gauge pipe was so arranged that the gauge was brought down to the level of the fireman's eye, and correction was made for water column. An observer remained constantly in the boiler room so as to keep this pressure uniform, and readings were noted every 15 minutes.

The quality of the steam was taken by throttling calorimeter attached to the steam pipe about six inches from where it entered the turbine stop valve. For the purpose of determining the quality, the engine pressure was taken and is also recorded; it was taken at the point where the calorimeter was attached. These readings were at 15-minute intervals.

To determine the exhaust steam condition, both a mercury column and a thermometer were used, the mercury column being attached to the turbine casing slightly below the level of the main shaft, while the thermometer was inserted in a cup in the exhaust pipe about half-way between the turbine casing and condenser. Much care was taken to push the thermometer well into the cup, so that the bulb was at least 9 inches in from the pipe wall, and the mercury column connections were also carefully tested for leakage. A comparison of the two readings shows that the temperature is lower than that corresponding to the mercury column, possibly due to the difference in location, and partly to the presence of air in the exhaust. Both results are quite accurate and equally reliable.

The speeds were taken with an ordinary revolution counter, or else were actually counted, those on the main pump being at 15-minute intervals; the others were not so frequent. It was not possible to get the speed of the steam turbine directly, and hence it had to be calculated from the pump speed, using the gear ratio given by the contractor of 197 teeth in the gear to 33 teeth in the pinion. The pump and turbine speeds were well below the maximum specified.

To get the steam used during the trial, the ordinary pipe for delivering the condensate into the feed tank was broken and a connection put in so that the water was delivered into a storage tank, from which it was run into a tank on scales as desired. The leakage from the air pump glands was caught and has been added to that coming directly from the air pump discharge. There was only one trap on the turbine plant, and as it was plugged no leakage occurred there.



Steam Turbine Driven Pumping Engine at John Street Pumping Station, Toronto.

On the first unit tested the gland leakage was not great, but as it was in the form of steam it could not be measured. In the second unit the leakage was much more marked, due to defective carbon rings, but the steam thus escaping would not have formed any appreciable proportion of the total, and its effect on the duty would be very slight.

The weighing tank was capable of holding a net weight of only about 1,000 pounds, and, in order to keep well within the limits, the weight of steam condensed every three minutes was taken. In order to have no error due to the storage tank, the water in it was brought to the same level at the end of the test as at the beginning. All weights were taken to half pounds. The steam used by the air pump is automatically included with that from the turbine, and the feed pump was chain-driven from the pump shaft.

For convenience and greater accuracy the pressure and suction gauges were both piped to the same point, close to the suction inlet pipe, and in the results allowance was made for the difference in levels between them.

Before the test began, considerable discussion took place between the contractors and myself regarding the position of the discharge gauge connection, and also as