REPORT ON DUTY AND CAPACITY TRIAL OF WORTHINGTON PUMPING ENGINE AT LOW LEVEL PUMPING STATION, MONTREAL WATER WORKS.

By Professor J. T. Nicolson, B.Sc., and J. Emile Vanier, C.E.

THE following report was recently presented by Messrs. Nicolson and Vanier to the Water Committee of the City of Montreal.—

Acting under your instructions, we have conducted duty and capacity trials of the new ten million gallon high duty Worthington Pumping Engine, recently installed at the Low Level Pumping Station, and have the honor to report as follows

According to the contract, the engine must be capable of pumping at the rate of ten millions of Imperial gallons of water in 24 hours, against a difference of pressure in suction and force mains of not exceeding 80 lbs. per square inch, and it must be able to perform a duty of one hundred and five million foot pounds of work for every hundred pounds of coal burnt.

In lieu of the latter stipulation, your experts agreed to accept a performance of *one hundred and five million foot pounds of work for every thousand* pounds of feed water supplied by the boilers, it being understood that the steam used by the feed pump should be counted against the manufacturers.

The engine is of the latest type of horizontal Worthington High Duty Pumping Engine, having cylinders arranged on the double tandem compound direct acting principle. The general features of construction are shown in the accompanying cuts.

The steam cylinders *are all* jacketed, both on sides and ends, with steam of boiler pressure, and reheaters are provided through which the steam passes on its way from the high to the low cylinders, which are likewise steam jacketed. The steam which is used in the jackets is that derived from the drain pipe of the separator, which belongs to the engine, and the steam from this point passes in succession through the reheaters, which are at the highest elevation, and thence through the jackets of the four cylinders, finally being delivered into a common drain pipe, which proceeds to a tank in which the water of condensation is collected. The jacket tank is drained by a small duplex steam pump, working automatically, the throttle valve being under the control of a float in the tank, and this water is pumped into the boilers. The size of the pump is 3 x 2 x 3 inches. The pipe leading from the pump to the boilers is independent of any other feed pipe. The exhaust steam discharged *from this pump* is carried to the hot well in the basement of the engine house, which serves for the supply of water to the boilers, being itself supplied by the overflow water discharged from the air pumps of the engine. The hot well tank is one which has formerly served the same purpose for the old engines in the pumping station. Its diameter is 24 inches, and its length 13 feet.

In addition to the jacket pump, there is a second steam pump connected with the engine, *which, by means* of a set of pistons, furnishes air to the top of the accumulator cylinder, and, by means of a set of plungers, furnishes water to the under side of the accumulator ram. The size of the pump, which is of the duplex type, is 4½ x 3 x 4 inches. The exhaust steam from this pump, like that from the jacket pump, is carried to the hot-well tank just referred to. This is an auxiliary piece of apparatus, as the pressure on the ram is usually kept up by a pipe supplied from the force main. The air pumps of the condensing apparatus are operated by direct connection with the main engine, the only accessories about the engine itself which consume steam, are the jackets and the two direct-acting steam pumps referred to.

The feed pump, for supplying the boilers with water, is one which has already been in use for the old plant. It is located in the cellar, under the engine room, near by the hot well tank. The exhaust steam from this pump is carried into the tank. Its size is 6 x 4 x 6 inches duplex.

The cylinders are protected from radiation by a covering of asbestos, out side of which is a layer of hair felting, and the whole is encased in black walnut lagging. The steam pipe, extending the whole distance from the boilers to the engine, is covered with magnesia, and that part within the engine-room is finished with black walnut lagging.

DIMENSIONS OF ENGINE.

Diameter of each of two high-pressure cylinders	25 inches.
Diameter of piston rods of same	5¼ inches.
Net area of high-pressure cylinders	469.11 sq. inches.
Diameter of each of two low-pressure cylinders	50 inches.
Diameter of piston rods of same	5 inches.
Net area of low-pressure cylinders	1953 68 sq.inches.
Maximum stroke of steam pistons	38 inches.
Diameter of each of two plungers	27½ inches.
Diameter of plunger rods	5¼ and 3½ ins.
Net area of plungers	583.74 sq. inches.
Average length of stroke during trial	3 157 feet.
Diameter of two double-acting air pumps	12 inches.
Stroke of same	3 157 feet.
Diameter and stroke of feed pump piston	6 inches.
Diameter of plunger of same	4 inches.
Diameter and stroke of jacket pump	3 inches.
Diameter of plunger of same	2 inches.
Vertical distance between centres of suction and force main gauges	10.66 feet.

TRIALS.

The engine was run for 55 33 hours at its full power without intermission It worked smoothly and well, without undue heating of any part, or leakage of any kind. This run began at 10.40 a.m. on Friday, July 27th On that day the temperature test was made, all the conditions of operation being retained in the proper normal state for the purpose of observing the temperatures of the various supplies of feed water to the boilers On the 28th, the duty and capacity trial lasting 10 hours was made, the feed water being supplied through suitable tanks and weighed the jackets reheaters and separator drain being also caught and weighed. At 7.22 p.m. on Saturday the trial ended, and the engine was stopped at 6 p.m. on Sunday, the 29th.

During the temperature test, the feed pump (made by Snow) exhaust was led into the hot well, the jacket pump was not worked, but the jacket tank drained into measuring tanks, its temperature being obtained before the pressure fell, the temperature of the main feed was observed close to the boilers. Readings were made every fifteen minutes of the steam pressure and vacuum gauges of the gauge on the force main, of the mercury column on the suction main, of the number and length of the strokes of each engine, in order that the engines might be kept working in exactly the state in which they would perform their rated duty and capacity.

The duty and capacity trial began by a signal given when the height of water in the three boilers and in the feed tank had been simultaneously noted, the readings of the two counters in the engine being then read. At the same time the jacket tank drain was diverted, being caught and weighed throughout the trial. The main feed pump received steam from the same boilers as supplied the main engine, and was reckoned as part of the steam used by it. It exhausted to waste. The amount of steam used by feed pump was ascertained by condensing its exhaust on a subsequent day. Twelve indicators were used on the trial eight Crosby indicators on the four steam cylinders, and two Tabors, and two Thompson's on the two pump chambers

Indicator cards were taken every hour, of which average specimens are presented below The readings made every fifteen minutes included — Temperatures of engine room, jacket drain, pressure of steam, vacuum and water gauges, mercury column, engine registers and boiler gauges, and the lengths of ten successive strokes of each pump. The dryness of the steam was tested for one hour at a time, by three independent tests. The instrument used was a Peabody Throttling Calorimeter, which was attached to *the main steam pipe just before the separator. The separator drain* was estimated by means of the Calorimeter, the assumption being that all the wetness in the steam was left in the separator.

This trial ended nine hours and 46 minutes after its commencement, by a signal given in the engine room, when the boilers had been filled up to the same heights as at the beginning of the test, when the engine registers were again read. The feed tank was then filled to the hook gauge used at the commencement, and *the feed and jacket drain sheets closed. A counter on* the feed pump enabled the number of strokes made by it during the trial to be recorded. The exhaust from it was subsequently condensed and weighed, when working at the same rate of speed. The pressure against which the plungers worked being 4 57 lbs. in excess of the stipulated 80 lbs, it was mutually agreed to by your experts and Messrs. Worthingtons' representative, that the steam pressure on the boilers would be 105 lbs, instead of 100 lbs. *Acting upon instructions, the stokers accordingly kept the pressure be*tween 104 and 106 lbs, on the boiler gauges during the whole trial

All gauges, indicator springs and weigh scales were tested and calibrated by the standards at McGill College, before and after the trial.

The assistants employed on the part of your experts upon the trials were Mr. G. Sinclair Smith, B.A., Sc., Demonstrator of Thermodynamics, McGill College, Mr. J. S Cosgan, B.A., Sc., Mr. Leonard Dyer, B.A., Sc.; *Mr. Archd. Dall, B.A., Sc., Mr. Robins, Mr. Hutchinson, and Mr. Laurin,* C.E., Chief Assistant in Mr. Vanier's office.

DATA CALCULATIONS.

The following are the principal data obtained from the trials, and the calculations based thereupon

Duration of test	9 hrs. 46 mins 9 77 hrs.
Average pressure by boiler gauges (corrected)	104 8 lbs.
" " " " absolute	119 6 "
" " engine gauges (corrected)	103 35 "
" " " " absolute	118 15 "
Average pressure in steam pipe at the throttle valve (abs.)	119 0 "
" " barometer	14 8 "
" temperature of *main feed*	155 62 F
" " of jacket tank drain	330 4 F.
Total weight of water measured into boilers	740 79 lbs.
Weight of water drained from separator jackets and reheaters	8228 5 "
Weight of steam lost by Calorimeter tests	360 0 "
" " supplied to engine and feed pumps	737 19 "
" water drained from separator (73719 x .006)	442.3 "
Dryness fraction of steam supplied	99 4%
Absolute pressure in steam pipe	119 lbs.
Heat of water at temperature, 340 42 F	311.4 T. U.
Latent heat of steam at 119 lbs., abs	874 4 T. U.
Absolute pressure in Calorimeter	30 0 lbs
Temperature corresponding to same	252 .0 F
Actual temperature in Calor meter	298° 0 F
Total heat of steam at pressure 30.0 lbs.	1158 4 T. U.

$$\text{Dryness fraction} \cdot x = \frac{1158.4 - 311.0 + .48\,(298 - 252)}{874.4} = 0.994$$

MEAN EFFECTIVE PRESSURES.

North Engine —		
	High pressure, east end	41.10 lbs
	" " west end	42 18 "
	Low pressure, east end	16 52 "
	" " west end	16 88 "
	Pump, east end	85 43 "
	" west end	85.75 "
South Engine :—		
	High pressure, east end	45 45 lbs.
	" " west end	43 30 "
	Low pressure, east end	15.45 "
	" " west end	17.44 "
	Pump, east end	85.28 "
	" west end	85.68 "

HORSE POWER.

North Engine	229.05 H.P.
South Engine	233 45 "
Total	462.50 H.P.
Horse power of pump (obtained from cards)	438 97
Mechanical efficiency	94.9
Number of strokes in 9 hrs., 46 mins	53 840
Average length of stroke	3 157 ft.
Piston speed during trial (feet per minute)	145 02

PRESSURES IN PUMP

Average pressure per sq. in. on force main gauge	76 75 lbs.
" " " in suction main (mercury column)	3 21 "
Pressure due to difference of height of gauges	4 61 "
Total mean average effective pressure against plungers	84 57

WORK OF PUMP.

Work done by plungers in 9.77 hours,

$$84.57 \times 583.74 \times 53840 \times 3.157 = 8,332,600,000 \text{ ft. lbs.}$$

Steam used in performing this work	73,277 lbs.
Duty per 1000 lbs. of feed supplied	114,532,000 ft lbs

CAPACITY IN 24 HOURS.

At 145 ft. piston speed,

$$\frac{3.157 \times 583.74 \times 53840 \times 24 \times 6\,2322}{144 \times 9.77} = 10,524,300 \text{ Imp. gals.}$$

At 142 ft. per min. piston speed as per contract 10,306,500 Imp. gals.