

R E P O R T
on the SHOP TRIALS of
PARSONS'
SIMPLEX UNIT SYSTEM
of GEARED TURBINES
for CARGO BOATS

BY

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REPORT
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SIMPLEX UNIT

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OF
THE PARSONS' SIMPLEX UNIT.

At the request of The Parsons Marine Steam Turbine Co., Ltd., Turbinia Works, Wallsend-on-Tyne, I supervised a series of trials of their Simplex Turbine Unit at the Works on 14th, 16th and 17th November, 1934.

The principal object of these trials was to ascertain the steam consumption of the turbines over a range of powers. The nominal full power of the Unit is 2,000 B.H.P. at 80 R.P.M.

BRIEF DESCRIPTION OF THE ENGINE.

The Unit consists of two turbines, H.P. and L.P., working in series. The H.P. ahead turbine is of the impulse-reaction type, consisting of two impulse-velocity stages and three reaction expansions fitted with end-tightened blading. The L.P. ahead turbine is of the ordinary reaction type with fourteen expansions. The turbines drive, through expansion couplings, a common primary pinion gearing with a primary reduction wheel. The secondary pinion, which is on the same shaft as the primary reduction wheel, drives the main wheel, which is directly connected to the brake shaft. When the brake shaft speed is 80 R.P.M. the speed of the turbines is 3,993 R.P.M., i.e., the total reduction is about 50 to 1. The gearing is of the single helical type, with involute teeth; and thrust blocks are fitted to each turbine, to the primary pinion, to the intermediate gearing shaft and to the main shaft. The end thrust of the main gear wheel will, in practice, be opposed to the propeller thrust, which will reduce the load on the main thrust block.

For astern working, a H.P. astern impulse wheel is incorporated in the H.P. ahead turbine casing, working in series with a L.P. astern impulse wheel situated in the exhaust casing of the L.P. ahead turbine.

The condenser is of the three-pass type and it is mounted with the turbines, on the gear case—making a very compact arrangement.

During the trials saturated steam was supplied by an oil-fired Babcock and Wilcox boiler, and the steam was then superheated in a separate oil-fired superheater. The boiler, which was recently installed, is capable of generating 40,000 pounds of saturated steam per hour at a pressure of 600 lbs. per sq. inch, and the superheater can raise the steam temperature to 850°F.

The main steam pressure to the turbines was controlled by a stop valve placed in the pipe line at the point where it entered the testing bay from the boiler house.

A special auxiliary unit—comprising the circulating, condensate, forced-lubrication, bilge and sanitary pumps—has been designed which will be embodied in the Simplex Unit at a later date. This auxiliary unit will be driven by chain drive and friction clutch from the main-wheel shaft when the turbines are running at full power ahead, and by an auxiliary steam engine, through a friction clutch, under all other conditions. With this arrangement a three-stage air ejector will be used.

The auxiliary unit was not in use during the trials; and the three-stage air ejector and condensate pump were replaced by a single-stage augmentor and a Weir's monotype air pump. Steam circulating and forced-lubrication pumps were employed. The steam pumps were supplied with saturated steam and they exhausted to a winch condenser. The steam consumption of these auxiliaries is not recorded.

Saturated steam was admitted as necessary to the turbine glands; and all the turbine drains were led to the condenser.

Figure 1 shows the lay-out of the plant as tested.

It is understood that the plant was built in accordance with the requirements of Lloyd's Register of Shipping and the British Corporation.

METHODS OF MEASUREMENT EMPLOYED.

STEAM CONSUMPTION.

The air-pump discharge—which consisted of the condensate from the turbines, from the turbine glands and from the augmentor—was led to the measuring tanks. Two tanks were employed, each capable of holding about 650 gallons of condensate. The tanks, shown at L in Figure 1, which were fitted with the necessary change-over supply and drain cocks, were calibrated before the trials at a temperature of 45°F. The temperature of the water entering the measuring tanks was recorded during the trials, and the slight adjustments necessary on account of temperature have been included in the recorded results.

During trials Nos. 1 to 4 the condensate was switched over from one tank to the second tank every 15 minutes. The residual levels of water in each tank were arranged so that at the end of a recording period the water level was in the narrow portion of a tank. Owing to the reduced steam consumptions at the lower powers, the condensate discharge during trials Nos. 5 and 6 was switched over from one tank to the other every 30 minutes, but records were taken every 15 minutes. The consumption records were taken by Mr. G. F. Hardy, M.Sc., or by Mr. Talbott, B.Sc., of Armstrong College.

The diameter of the steam nozzle of the augmentor was 5/32-inch. The steam pressure to the augmentor was practically constant throughout the trials at 100 lb./sq. in.; and at this pressure the calculated steam consumption is nearly 120 lb. per hour. As it was desired to measure the steam consumption of the turbines only, the estimated steam consumption of the augmentor has been deducted from the measured condensate.

BRAKE HORSE POWER.

The B.H.P. developed by the turbines was absorbed by a Heenan and Froude hydraulic dynamometer of the compound-lever type coupled to the main gear-wheel shaft. The brake, which has a constant of 300, was supplied with water from an overhead tank in which the level was maintained constant. Before the trials the brake was balanced, and the weights were weighed on a weighing machine which had been checked with standard weights.



The procedure followed was to set the brake load at the figure fixed for the particular trial and then adjust the turbine steam and the brake valves as necessary during the stabilising period in order to balance the brake at the revolutions previously decided upon.

REVOLUTIONS OF THE ENGINE.

The revolutions of the brake shaft were recorded by a mechanical counter. Readings were taken by me every 15 minutes, at the instant the water consumption was recorded.

TEMPERATURES AND PRESSURES.

Temperatures and pressures were taken by the recording staff every 30 minutes, but I noted the principal readings every 15 minutes.

The temperatures of the steam to the H.P. nozzles and the H.P. 1st expansion were measured by platinum-platinum rhodium thermocouples (batch 6 RH) and the temperature in the L.P. 1st expansion belt by an iron-constantan thermocouple (batch 738) supplied by the Cambridge Instrument Co. These couples, which were connected to a Cambridge continuous multiple recorder, were calibrated in my presence *in situ* by means of a potentiometer and the N.P.L. charts for the batches. Mercury-in-glass thermometers were also used as a check at the positions indicated, but the thermocouple readings, after making any necessary corrections, are included in this Report.

The remaining temperatures recorded in this Report were taken with glass thermometers. These thermometers were calibrated by me after the trials, and any corrections have been included in the results given in Table 3, page 13.

The principal pressures are given in Table 2, page 12. The absolute pressures in the L.P. exhaust branch and in the condenser were obtained with Brady and Martin kenotometers. All pressure gauges were calibrated by me after the trials, and any necessary corrections have been included in the Table.

TRIALS.

It was decided to carry out trials at the full rated power of 2000 B.H.P. at 80 R.P.M., and at 2300 B.H.P., 1750 B.H.P., 1500 B.H.P., 1250 B.H.P. and 1000 B.H.P.—the respective brake loads and R.P.M. being calculated according to the usual propeller law. Preliminary tests had shown that when conditions had settled, and the temperatures and pressures were steady, trials of $1\frac{1}{2}$ hours duration were quite sufficient to give reliable records of the steam consumptions. The steadiness of the readings during the trials is clearly indicated in this Report.

There are nine nozzles in the H.P. ahead turbine, in groups of 4, 3 and 2, and each group is controlled by a valve. During the overload trial No. 1 seven nozzles were in use with the control valves full open, and the control valve to the remaining two nozzles was shut. The main steam pressure was about 270 lb./sq. in. The same combination was in use for trial No. 2, at the rated power of 2000 B.H.P. at 80 R.P.M., but the main steam pressure was reduced to about 235 lb./sq. in. For the remaining trials the steam pressure was maintained at about 260 lb./sq. in. and the nozzles in use were as follows :—

Trial No. 3—4 nozzles, control valve wide open ;
2 nozzles, control valve partly closed ;
3 nozzles, shut off.

Trials Nos. 4, 5 and 6—
3 nozzles, control valve wide open ;
2 nozzles, control valve partly closed ;
4 nozzles, shut off.

Throughout the trials the steam leakage from the glands of the turbine was, for all practical purposes, negligible ; and there were no other leaks of any kind.

MEAN OBSERVATIONS DERIVED FROM LOG SHEETS.

The mean observations derived from the Log Sheets, and the preliminary deductions, are given in Tables 2 to 5, pages 12 to 15. A summary of the principal results are given in Table 1, page 9.



DEDUCTIONS.

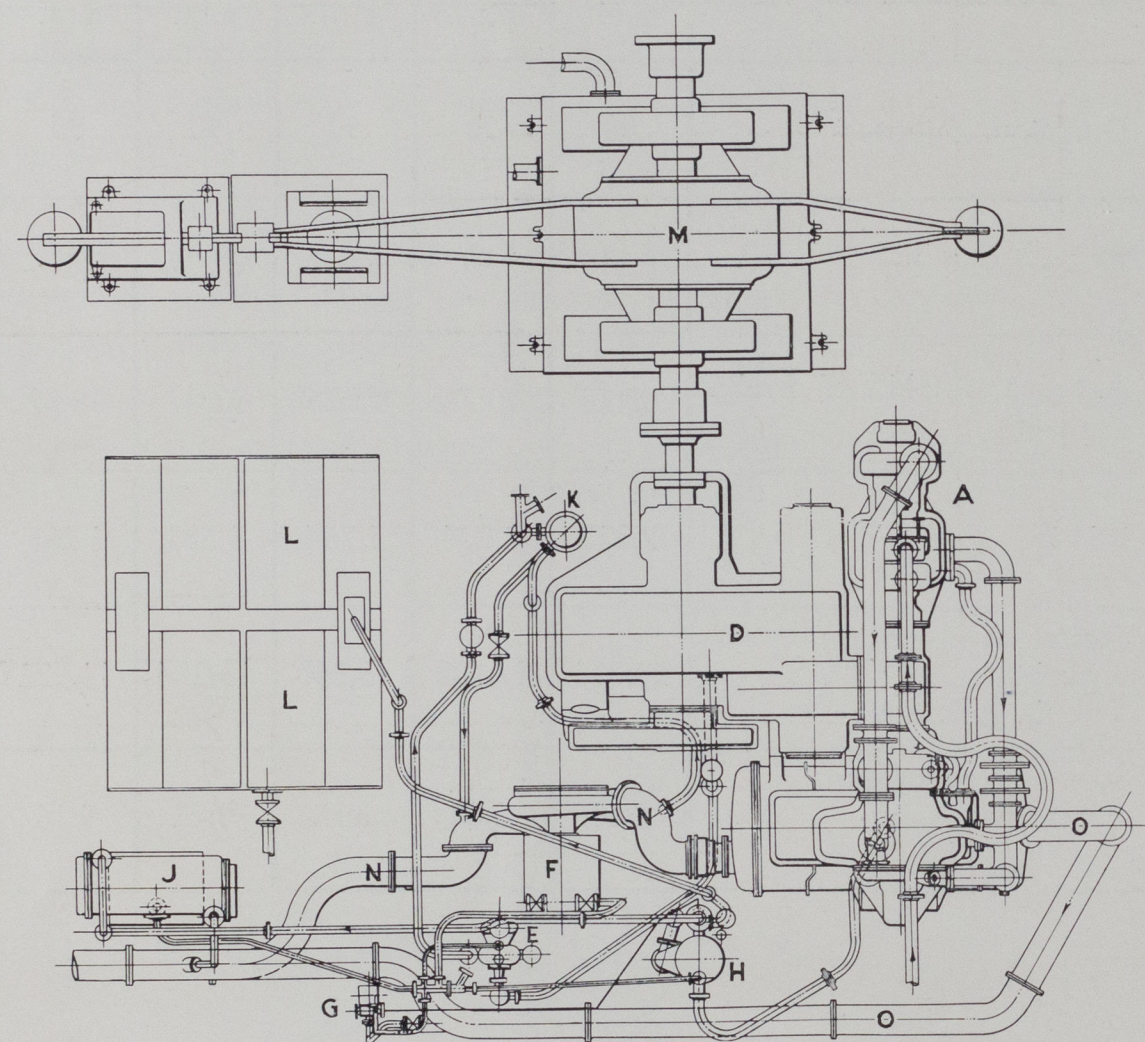
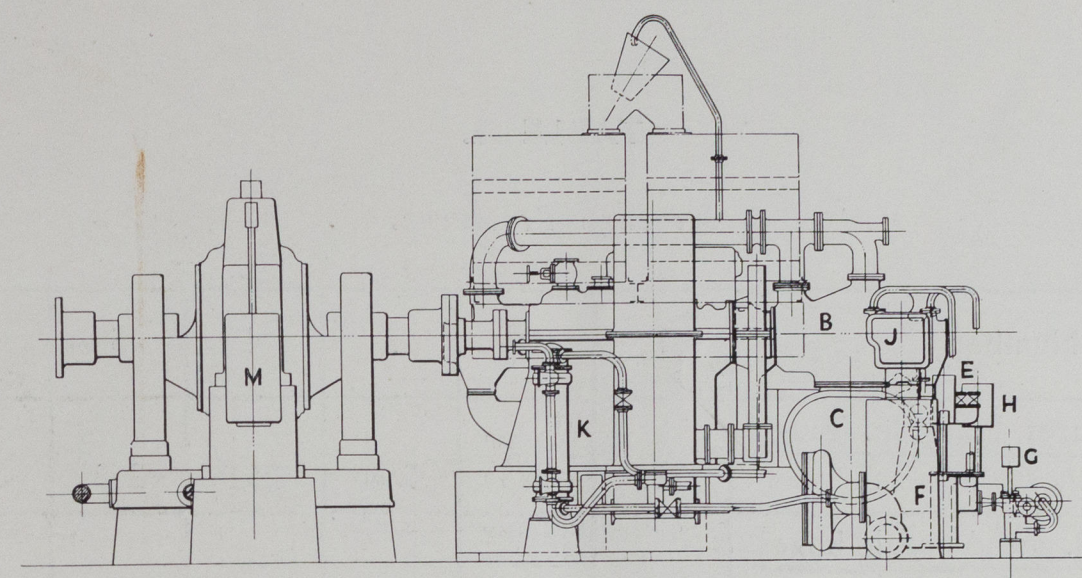
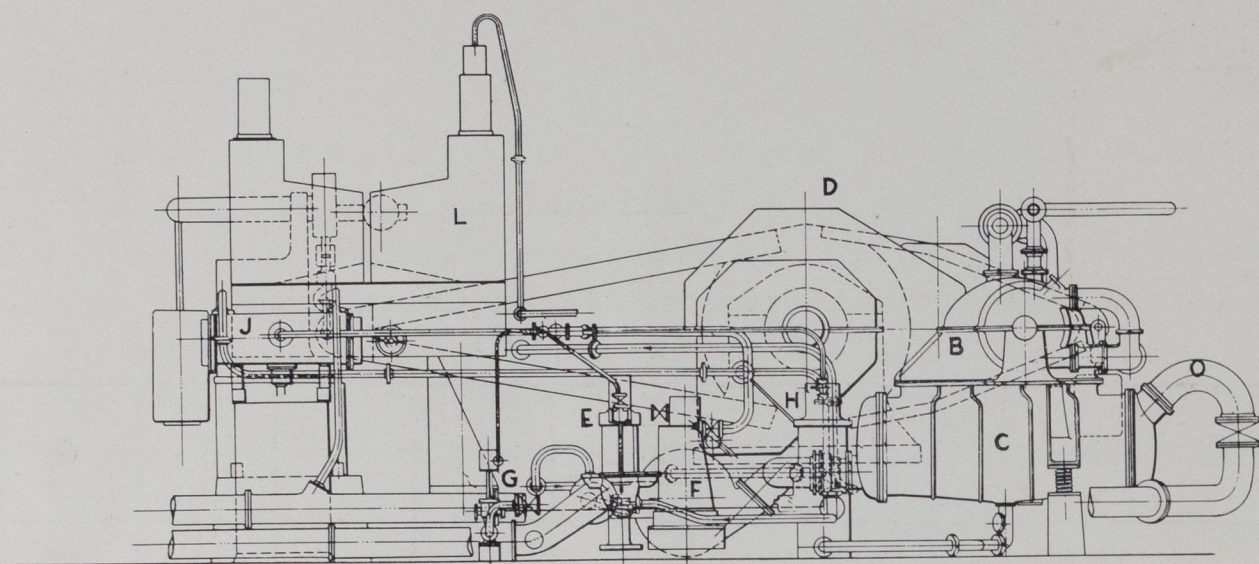
The deductions are given in Table 6, page 16. In calculating the efficiency of the plant, for the turbines only, the heat content of the steam has been reckoned from the temperature of the condensate in the wet air-pump suction. Similarly, in the calculations for the efficiencies of the turbines and the "standard of comparison" the heat content of the steam at the stop valve, obtained from Callendar's Revised Steam Tables, has been reduced by the heat content of the water at the temperature corresponding to the pressure at the exhaust flange.

A curve showing the steam consumptions on a B.H.P. base is given in Figure 2, page 17. A similar curve, but with a very open scale for the steam consumptions, is given in Figure 3, page 18. It will be seen that the curve of steam consumption for the Unit as tested really consists of two curves, one connecting trials Nos. 1, 2, 3 and 4, and one connecting trials Nos. 4, 5 and 6. The difference in the slopes of the two curves is probably due to some extent to the nozzles in use, and the pressures in the nozzle boxes, for the various trials. It will be observed that whilst the steam pressures in the nozzle boxes were well maintained during trials Nos. 1 to 4, by varying the number of nozzles in use, no further variation was possible after trial No. 4—consequently the power developed by the turbines during trials Nos. 5 and 6 had to be controlled by reducing appreciably the steam pressure to two nozzles. The average pressure in the box supplying the two nozzles, for example, was only 40 lb./sq. in. during trial No. 6.

TABLE I.

Summary of Powers and Steam Consumptions.

Trial Number	1	2	3	4	5	6
Date, 1934	14/11	14/11	16/11	16/11	17/11	17/11
Commencement of Trial	2—1 p.m.	4—5 p.m.	1—46 p.m.	4—8 p.m.	10—48 a.m.	1—13 p.m.
Duration, minutes	90	90	90	90	90	90
Brake Load, lb.	8,319	7,537	6,893	6,222	5,510	4,746
Average R.P.M. of Brake shaft	83·75	79·76	76·36	72·47	68·89	63·77
B.H.P.	2,323	2,004	1,754	1,503	1,265	1,009
Steam consumption turbines only, lb. per hour	20,006	17,400	15,360	13,254	11,572	9,678
Steam consumption turbines only, lb./B.H.P./hr.	8·61	8·68	8·75	8·82	9·16	9·6



A	H.P. AHEAD AND H.P. ASTERN TURBINE
B	L.P. „ L.P. „ „
C	MAIN CONDENSER
D	SINGLE HELICAL REDUCTION GEARS
E	FORCED LUBRICATION PUMP
F	CIRCULATING PUMP
G	AUXILIARY CIRCULATING PUMP
H	AIR PUMP
J	AUXILIARY CONDENSER
K	OIL COOLER
L	WATER MEASURING TANKS
M	DYNAMOMETER
N	MAIN CIRCULATING INLET PIPE
O	„ „ DISCHARGE PIPE

FIGURE 1.

TABLE 2.
Average Pressures.

Trial Number	1	2	3	4	5	6
<u>Pressures, lb./sq. in. (gauge)</u>						
Main steam	269	235	258	262	263	265
<u>H.P. ahead nozzle boxes</u>						
Four nozzles	263	228	247	Not	in	use
Three nozzles	267	229	Not in use	255	259	261
Two nozzles	Not in use		193	222	130	40
H.P. 1st expansion	82	66	55	44	36	26
2nd expansion	53	44	36	29	22	16
3rd expansion	33	26	21	15	11	6
L.P. 1st expansion	17	12.7	9	5.7	2.8	0.5" vac.
Steam to augmentor	100	100	100	100	100	100
<u>Pressures, inches of Hg.</u>						
Barometer	29.86	29.89	30.15	30.13	30.2	30.2
L.P. Exhaust (corrected)	28.49	28.65	28.76	28.9	28.97	29.09
Condenser, under air baffle (corrected)	29.11	29.18	29.2	29.25	29.22	29.3

TABLE 3.
Average temperatures, deg. Fahr.

Trial Number	1	2	3	4	5	6
Main steam	759	762	768	760	756	763
H.P. 1st expansion	584	589	570	569	561	561
L.P. 1st expansion	390	390	380	366	367	365
Wet air-pump suction	75	73	72	70	71	67
Circulating water Inlet	48	47	48	48	47	48
Do. Outlet	65	62	62	60	63	60

TABLE 4.
Brake Loads, R.P.M. and B.H.P.

Trial	Brake Load, lb.	R.P.M. of brake shaft	B.H.P. (nearest whole number)
<u>Trial No. 1</u>			
First half-hour	8,319	83.76	2,323
Second half-hour	8,319	83.73	2,322
Third half-hour	8,319	83.76	2,323
Means	8,319	83.75	2,323
<u>Trial No. 2</u>			
First half-hour	7,537	79.77	2,004
Second half-hour	7,537	79.79	2,005
Third half-hour	7,537	79.71	2,003
Means	7,537	79.76	2,004
<u>Trial No. 3</u>			
First half-hour	6,893	76.31	1,753
Second half-hour	6,893	76.4	1,755
Third half-hour	6,893	76.37	1,755
Means	6,893	76.36	1,754
<u>Trial No. 4</u>			
First half-hour	6,222	72.55	1,505
Second half-hour	6,222	72.57	1,505
Third half-hour	6,222	72.28	1,499
Means	6,222	72.47	1,503
<u>Trial No. 5</u>			
First half-hour	5,510	68.88	1,265
Second half-hour	5,510	68.89	1,265
Third half-hour	5,510	68.89	1,265
Means	5,510	68.89	1,265
<u>Trial No. 6</u>			
First half-hour	4,746	63.61	1,006
Second half-hour	4,746	63.79	1,009
Third half-hour	4,746	63.91	1,011
Means	4,746	63.77	1,009

TABLE 5.
Steam Consumptions.

Trial.	Total measured steam, lb. (corrected).	Steam consumption augmentor lb.	Nett steam consumption turbines, lb.	Lb. of steam per B.H.P./hr. turbine only.
<u>Trial No. 1</u>				
First half-hour	10,051	60	9,991	
Second half-hour	10,069	60	10,009	
Third half-hour	10,069	60	10,009	
Means	10,063	60	10,003	8.61
<u>Trial No. 2</u>				
First half-hour	8,761	60	8,701	
Second half-hour	8,751	60	8,691	
Third half-hour	8,769	60	8,709	
Means	8,760	60	8,700	8.68
<u>Trial No. 3</u>				
First half-hour	7,743	60	7,683	
Second half-hour	7,733	60	7,673	
Third half-hour	7,743	60	7,683	
Means	7,740	60	7,680	8.75
<u>Trial No. 4</u>				
First half-hour	6,699	60	6,639	
Second half-hour	6,689	60	6,629	
Third half-hour	6,674	60	6,614	
Means	6,687	60	6,627	8.82
<u>Trial No. 5</u>				
First half-hour	5,852	60	5,792	
Second half-hour	5,830	60	5,770	
Third half-hour	5,856	60	5,796	
Means	5,846	60	5,786	9.16
<u>Trial No. 6</u>				
First half-hour	4,889	60	4,829	
Second half-hour	4,908	60	4,848	
Third half-hour	4,899	60	4,839	
Means	4,899	60	4,839	9.6

TABLE 6.

Deductions.

Trial Number	1	2	3	4	5	6
Steam pressure, lb./sq. in. abs.	283.6	249.7	272.8	276.8	277.8	279.8
Steam temperature, deg. Fahr.	759	762	768	760	756	763
Vacuum, L.P. exhaust inches of Hg.	28.49	28.65	28.76	28.9	28.97	29.09
Condensate temp. deg. Fahr.	75	73	72	70	71	67
Steam consumption, turbines only, lb./B.H.P./hour	8.61	8.68	8.75	8.82	9.16	9.6
Heat content of steam from condensate temp., B.Th.U. per lb.	1,360	1,365	1,368	1,366	1,364	1,371
Thermal efficiency of plant (turbines only) based on heat content of steam from conden- sate temp., per cent.	21.7	21.5	21.3	21.1	20.4	19.3
Heat content of steam from L.P. exhaust temp., B.Th.U. per lb.	1,344	1,350	1,355	1,354	1,355	1,362
Thermal efficiency of turbines, per cent.	22	21.7	21.5	21.3	20.5	19.5
Available heat between stop valve and exhaust, B.Th.U. per pound.	462	462	472	477	481	488
Efficiency of standard of comparison per cent.	34.4	34.2	34.8	35.2	35.5	35.8
Efficiency ratio of turbines, per cent.	64	63.4	61.7	61.5	57.7	54.4

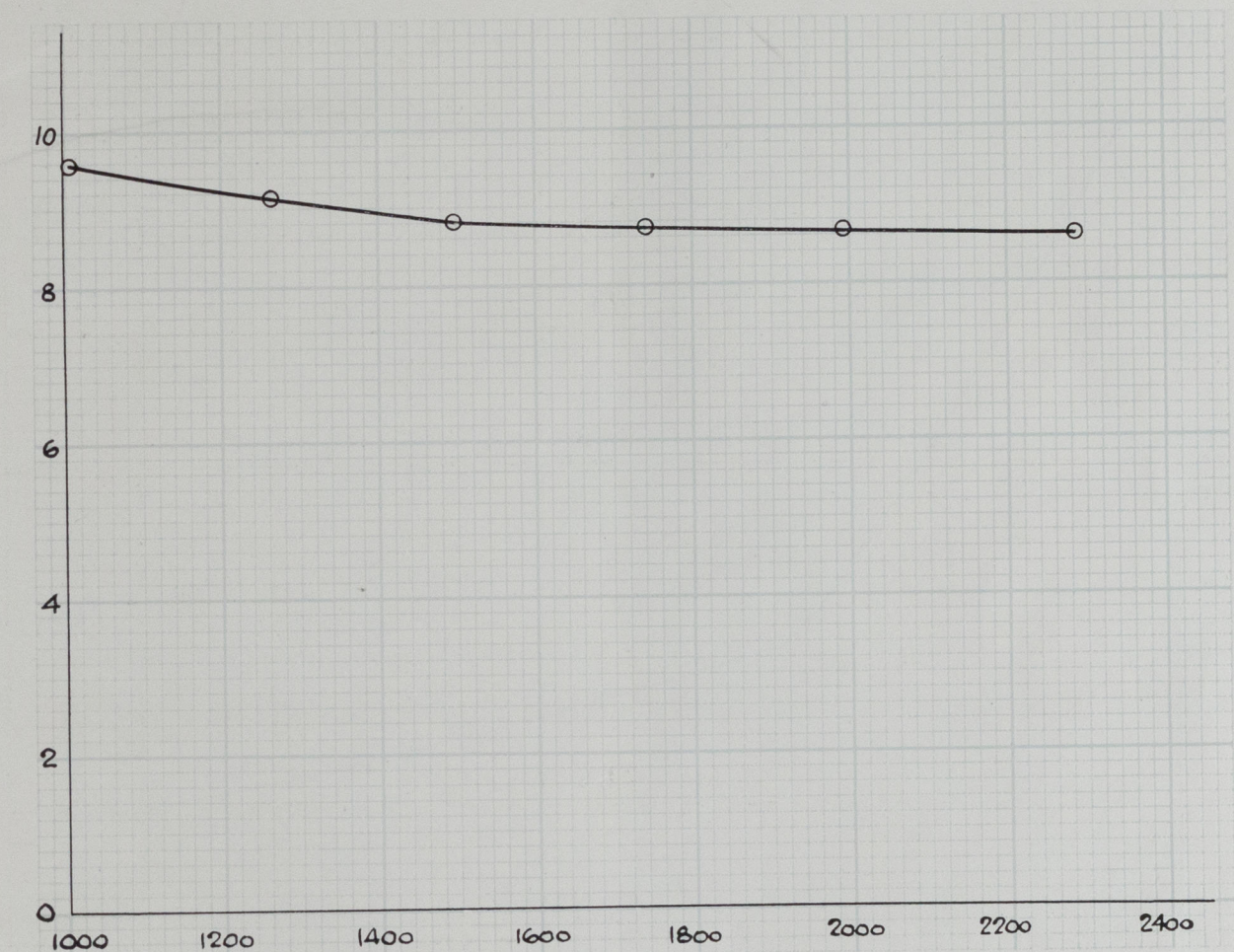


FIG. 2.

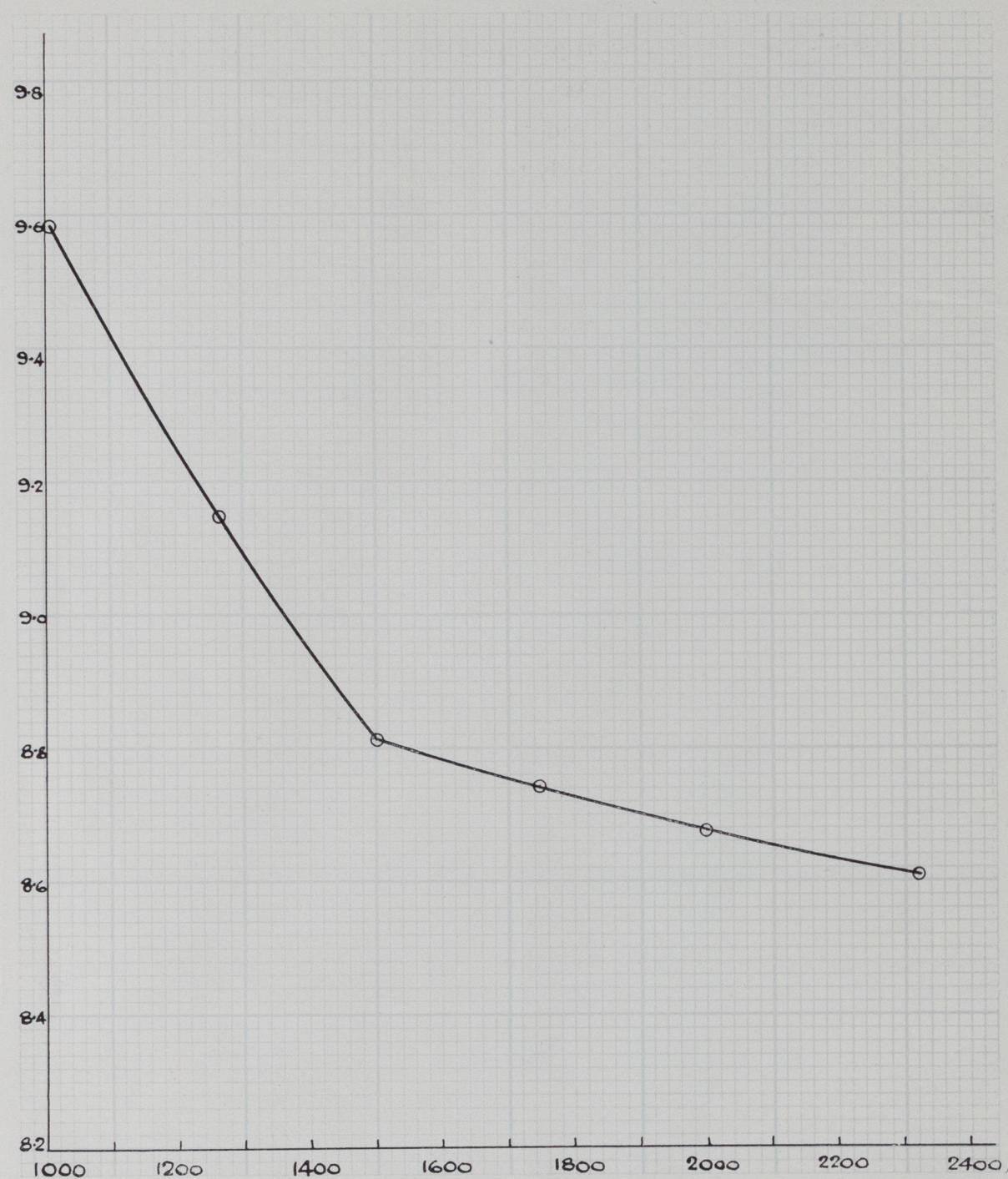


FIG. 3.

The recorded steam consumptions of the plant are exceedingly good, and it will be seen from the curves that there is little falling off in the efficiency of the turbines at the lower powers. As a result of the trials the Firm proposes to modify the blading at the exhaust end of the L.P. turbine which, it is anticipated, will have the effect of reducing slightly the steam consumption of the plant at the higher powers.

The plant, which was under my constant supervision, ran smoothly and steadily throughout the trials, without an incident of any kind.

J. Hawkes

28th November, 1934.



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