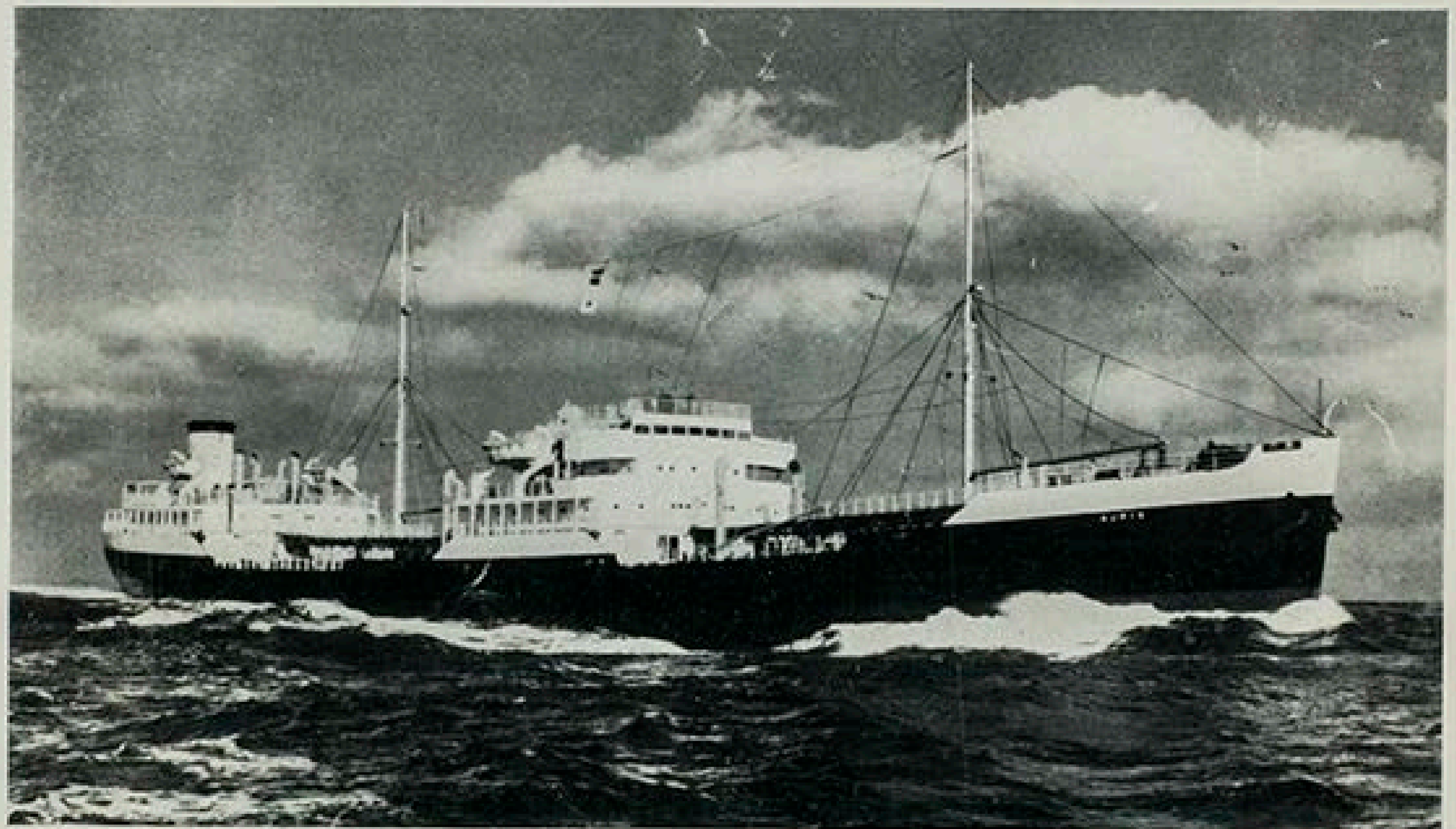
GAS TURBINE-ALTERNATOR SET
FOR
D.E.S. *AURIS*
(The Anglo-Saxon Petroleum Co., Ltd.)



THIS gas turbine-alternator set has been built mainly for obtaining operating experience with a main propulsion gas turbine set under service conditions at sea.

D.E.S. *Auris* was built specially by The Anglo-Saxon Petroleum Company for the purpose of installing an experimental gas turbine set. Her present machinery comprises four diesel engine-driven alternators which supply current for a main motor driving the propeller. One of the diesel sets has been removed, and replaced by the gas turbine unit. The space available is sufficient for the installation of a gas turbine set of adequate size for the purpose, the ship having been specially built with this in view. This space, particularly the narrow width, however, had a considerable influence on the general arrangement of the set, and led to the adoption of vertical compounding, and also restricted the heat recovery in the heat exchanger.

In view of the small mass flow of air, intercooling during compression was found to be out of the question. The set was designed for a moderate initial gas temperature to ensure an adequate length of life. The design conditions limited the thermal efficiency obtainable, but a low fuel consumption was, however, considered to be of secondary importance for this installation, the principal task being to ascertain if the gas turbine could meet the marine requirements in regard to reliability, rather than thermal efficiency.

Until the reliability of the gas turbine under sea-going conditions has been proved, adequate alternative power must be available should it be necessary to shut down the gas turbine set at sea. This will be provided by the three diesel sets which are retained.

THE
BRITISH THOMSON-HOUSTON
COMPANY LIMITED, RUGBY, ENGLAND
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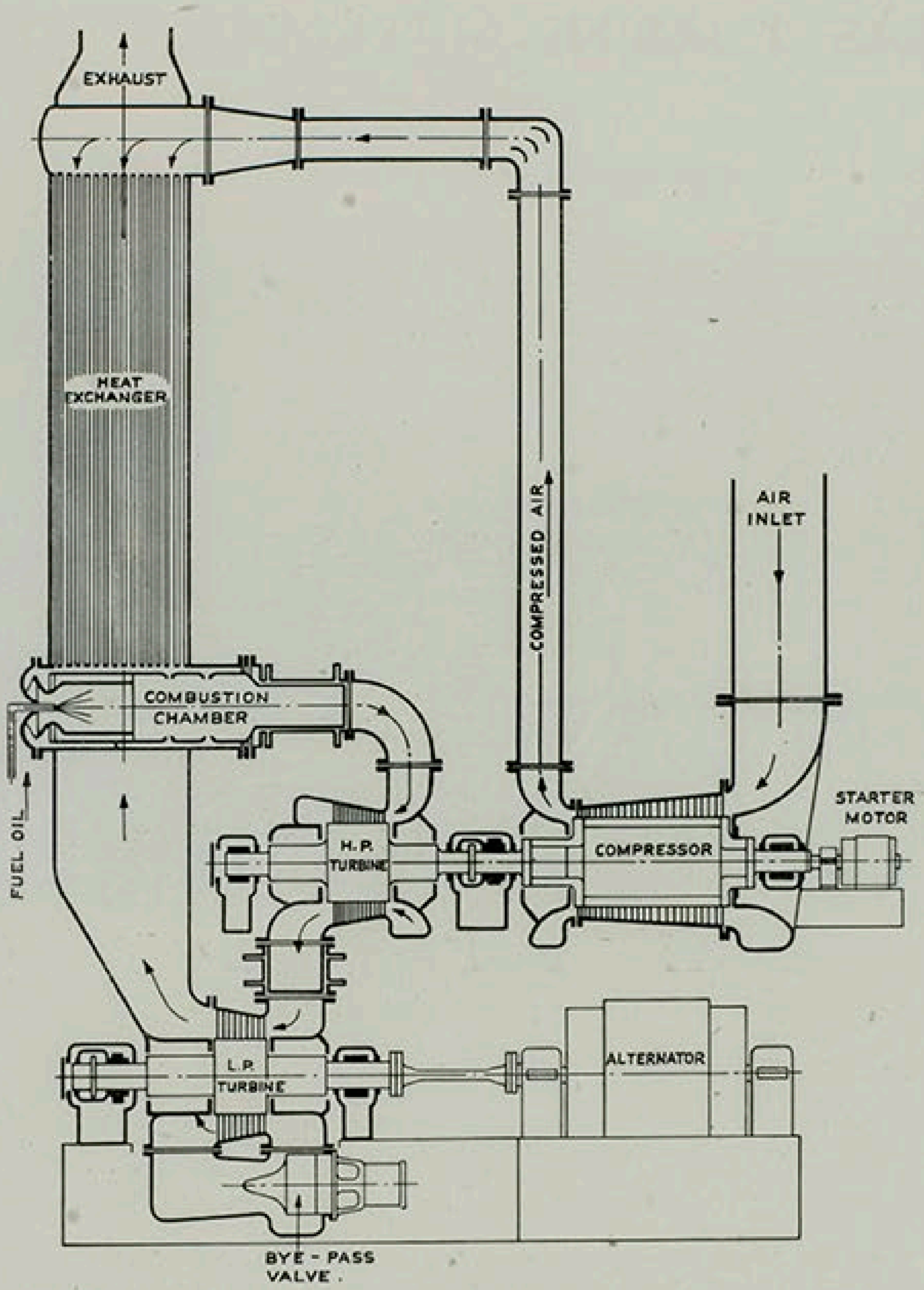

Fig. 1. Diagrammatic layout of gas turbine set.

Fig. 1 shows a diagrammatic layout of the set. In this diagram the various components of the plant are shown approximately in accordance with actual construction. Atmospheric air is inhaled through the inlet duct by the compressor. The compressed air passes through the air delivery pipe to the heat exchanger air inlet drum, and then through the tubes to the heat exchanger air outlet drums, of which there are two, one on either side of the turbine exhaust.

The combustion chambers are incorporated in the heat exchanger air outlet drums. The hot gases from the combustion chambers pass through short pipes to the high-pressure turbine, which drives the compressor ; and from the high-pressure to the low-pressure turbine, which drives the alternator.

After leaving the low-pressure turbine the gases pass through the heat exchanger, flowing outside the tubes longitudinally, and substantially in contra-flow to the compressed air inside the tubes. The gases are eventually discharged to the atmosphere.

The gas turbine is started up by means of an electric motor. A bye-pass valve is provided through which the gas may pass direct from the high-pressure turbine exit to the atmosphere, via the heat exchanger. This bye-pass valve has two functions. First, it is a safety device ; should the speed of either turbine shaft reach the trip speed, the valve opens, and at the same time the fuel supply is shut off, thus preventing over-speeding of the alternator shaft in the event of sudden failure of the electrical load. Secondly, it is an accessory for starting ; by keeping the valve open during the starting period the pressure behind the high-pressure turbine is reduced. The high-pressure turbine will then assist in driving the compressor at starting speeds, and thus the power demand and the time required for starting are both reduced.

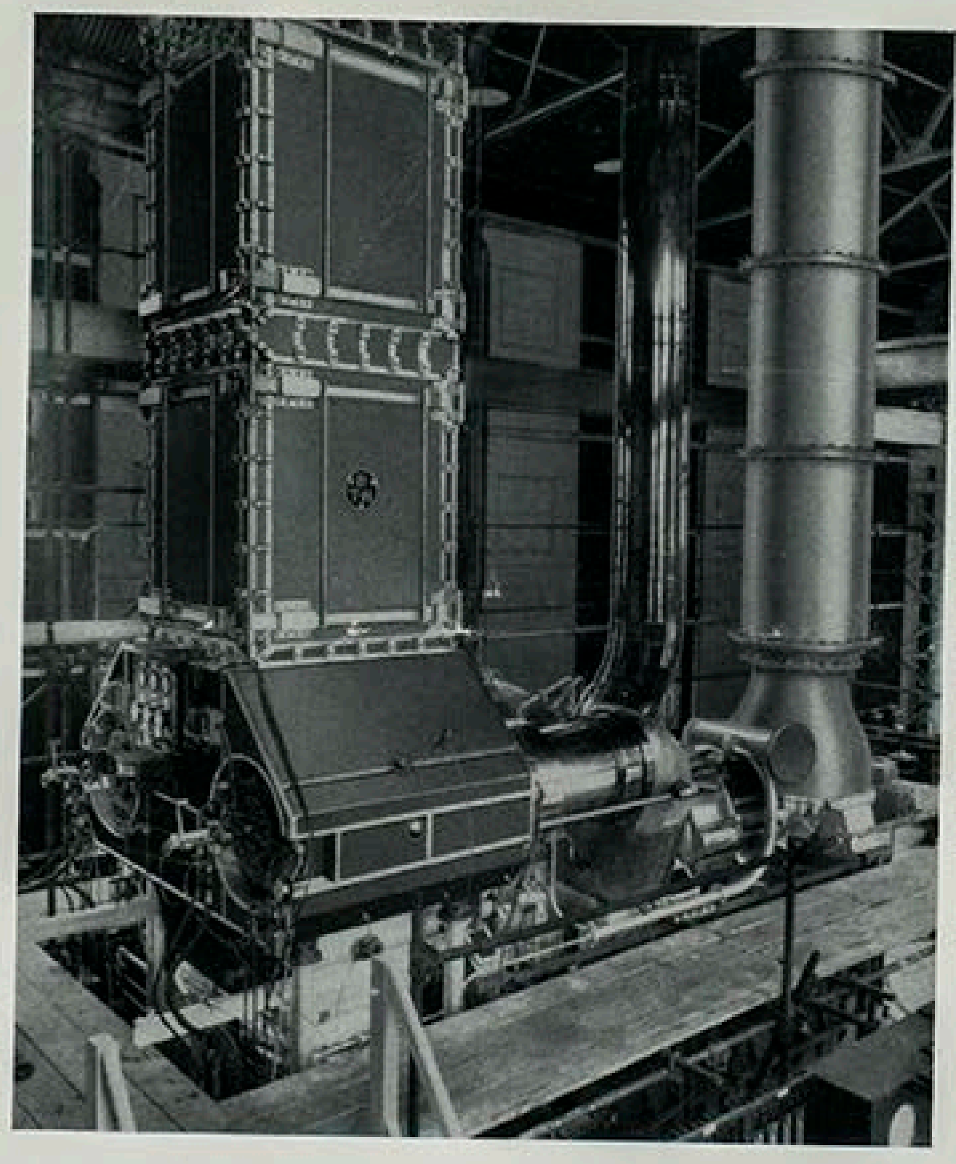

Fig. 2. Gas turbine set on test at BTH Works.

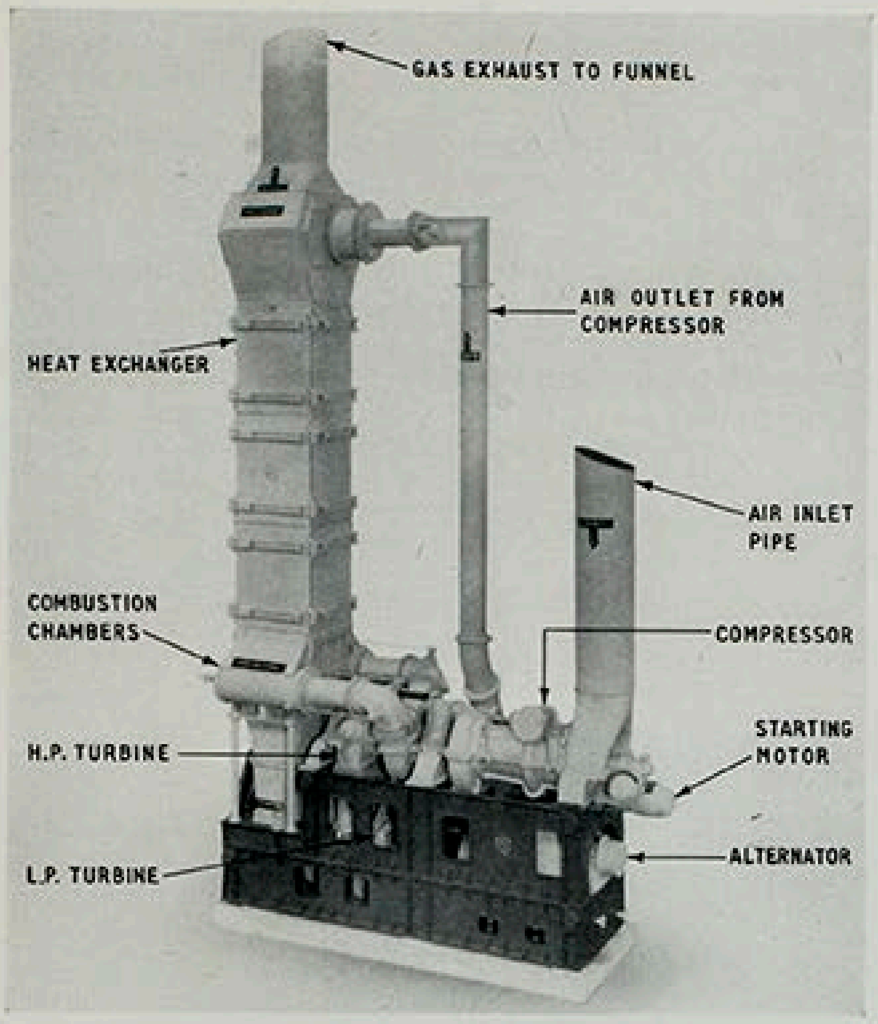

Fig. 3. Model of Gas Turbine Set.

The general construction of the set is illustrated by the photograph of the model (Fig. 3). The various working components of the plant are supported by a steel frame which is of sufficient rigidity to permit the set to be handled as one piece ; it only requires a simple seating to support it in the ship.

The equipment is made up of three sub-assemblies which may be treated as separate units during erection :—

Low-pressure turbine/alternator unit.

This unit is shown in Fig. 4, and consists of the main base on which the low-pressure turbine and the alternator are mounted direct. It also contains the alternator air cooler and a lubricating-oil tank.

Compressor/high-pressure turbine unit.

The high-pressure turbine and the compressor with starting motor are carried on a fabricated steel frame which is bolted to the main base so that the high-pressure turbine is situated above the low-pressure turbine, and the compressor above the alternator (Fig. 5).

Heat exchanger and combustion chamber unit.

This unit, shown in Fig. 6, is mounted on the exhaust of the low-pressure turbine, and is supported from the main base.

MAIN DESIGN DETAILS

At the design conditions the output is 1200 b.h.p. at the low-pressure turbine coupling or 860 kW at the alternator terminals.

The set is designed for an ambient air temperature of 68°F (20°C) and a turbine inlet temperature of 1160°F (627°C), the maximum permissible operating temperature being 1200°F (649°C). The design speed is 5750 r.p.m. for the compressor/high-pressure turbine shaft, and 3000 r.p.m. for the low-pressure turbine-alternator shaft.

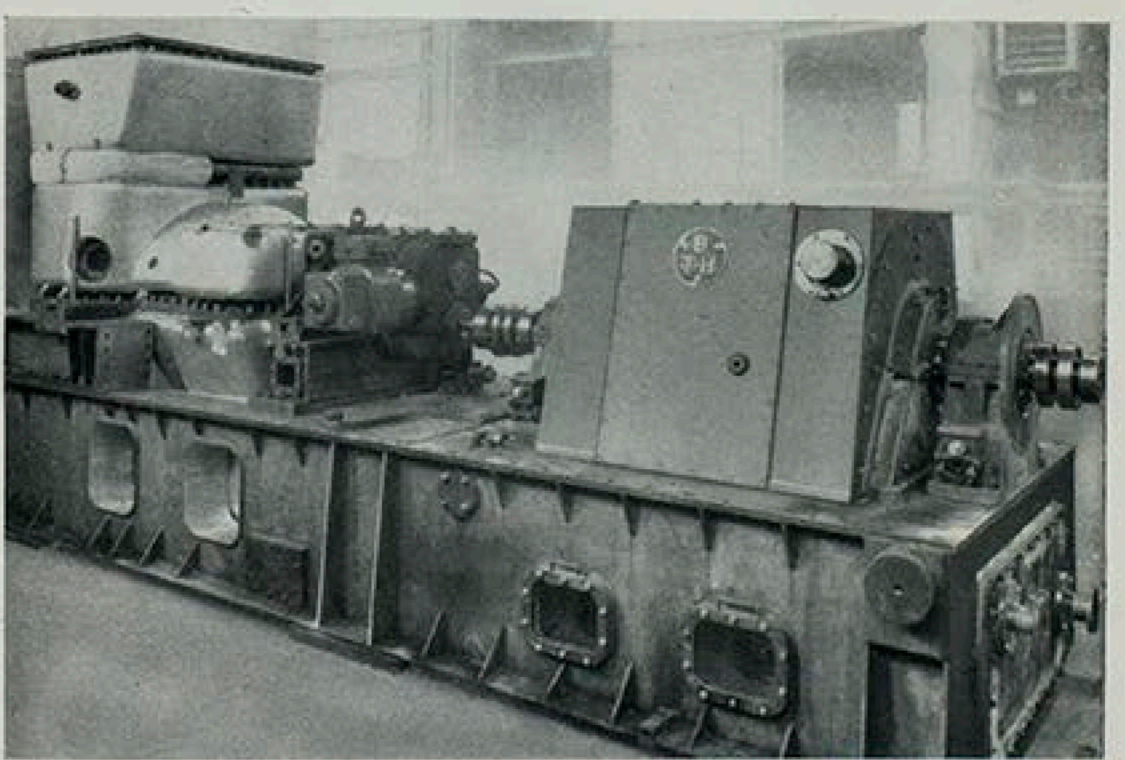

Fig. 4. Low-pressure turbine/alternator unit.

SHOP TESTING AND PERFORMANCE

Shop testing of the gas turbine set commenced in June 1950. The first series of tests, covering a total running time of 124 hours, were carried out in order to establish the soundness of the mechanical construction, obtain preliminary performance figures for the set, and establish good combustion at all loads. During this period the high-pressure turbine, which is subject to the highest temperature, was opened up twice for inspection. During the first run, when an air flow meter was fitted direct to the compressor intake inside the test building, the set had a high pitched noise which, by noise-analysis, was traced to the compressor. The provision of an intake silencer reduced the noise to an acceptable level.

At this stage the set was stripped for inspection of both turbines and re-assembled for extensive performance and endurance testing. The set was then run for 556 hours ; 193 hours running on gas oil and 363 hours on a commercial grade of heavy oil having a viscosity of 1500 seconds Redwood No. 1. The total time of testing before installation was 680 hours.

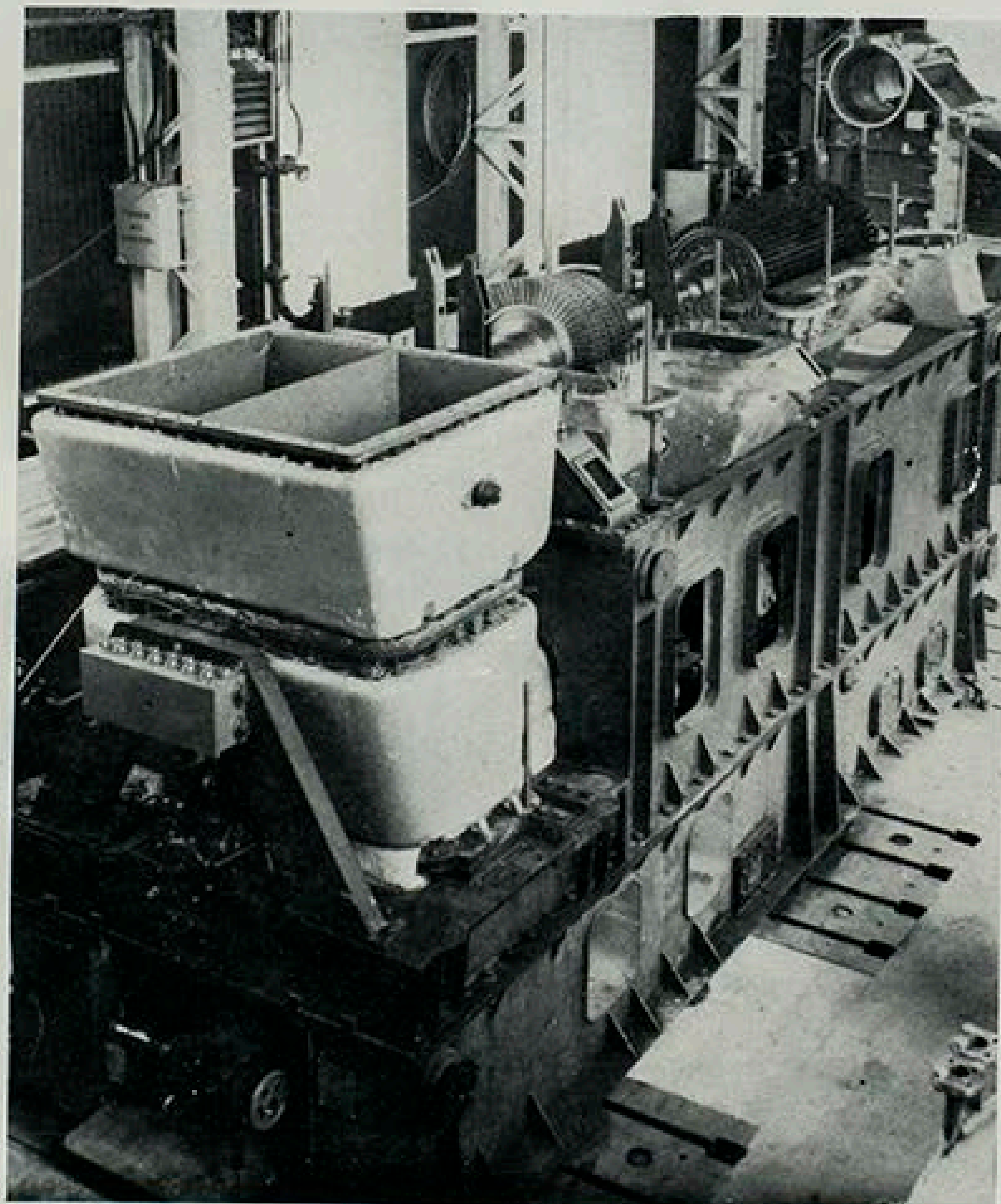

Fig. 5. Compressor/high-pressure turbine unit mounted on low-pressure turbine/alternator unit.

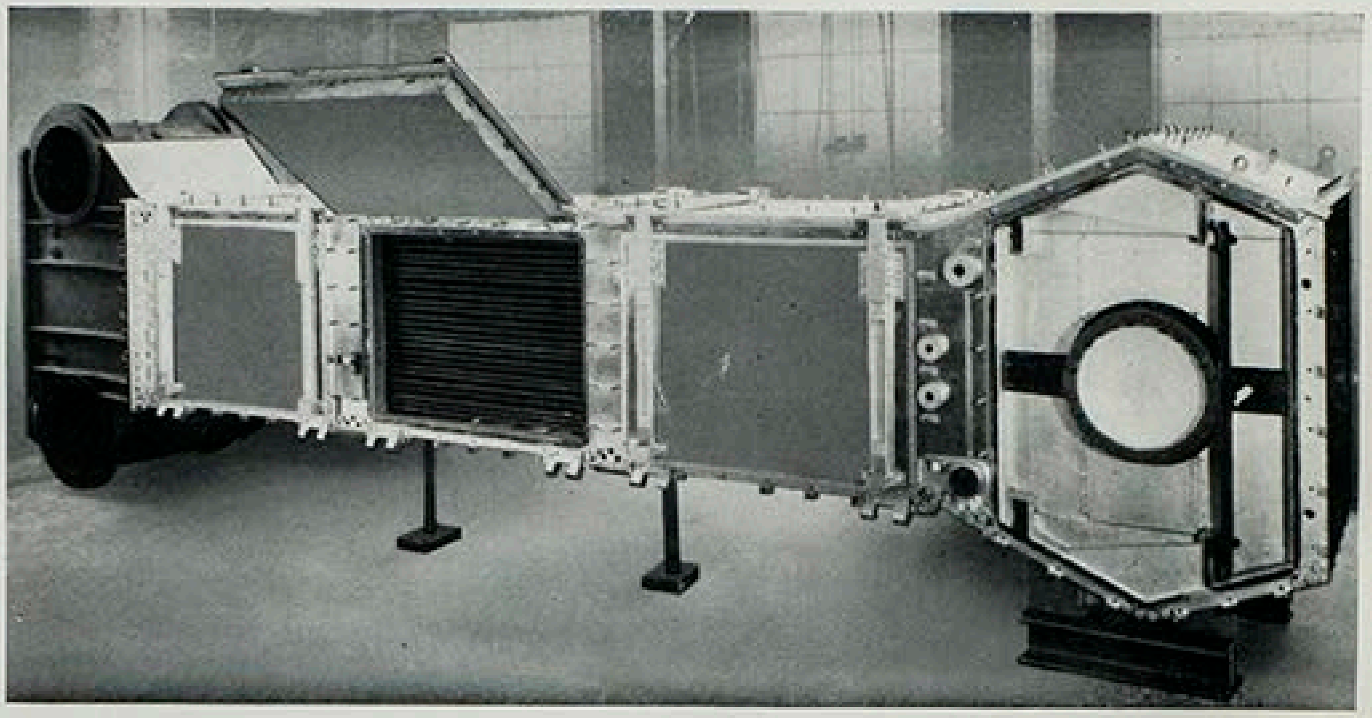

Fig. 6. Heat exchanger and combustion chamber unit. The unit is erect when fitted to the low-pressure turbine exhaust—the drum on right-hand side of photo being uppermost.

The testing included continuous runs of 100 hours on gas oil (for performance readings) and 270 hours on heavy oil mainly at full load. During this test the high-pressure turbine suffered to some extent from ash deposition, which was indicated by a gradually rising pressure and inlet temperature at the high-pressure turbine, as well as a slight drop in overall thermal efficiency at maintained load. After shut down and re-start, the turbine inlet pressure and temperature, as well as thermal efficiency, were almost back to original values, indicating that most of the deposit had broken loose at shut down. It should be noted that the ash content of the fuel was 0·07%.

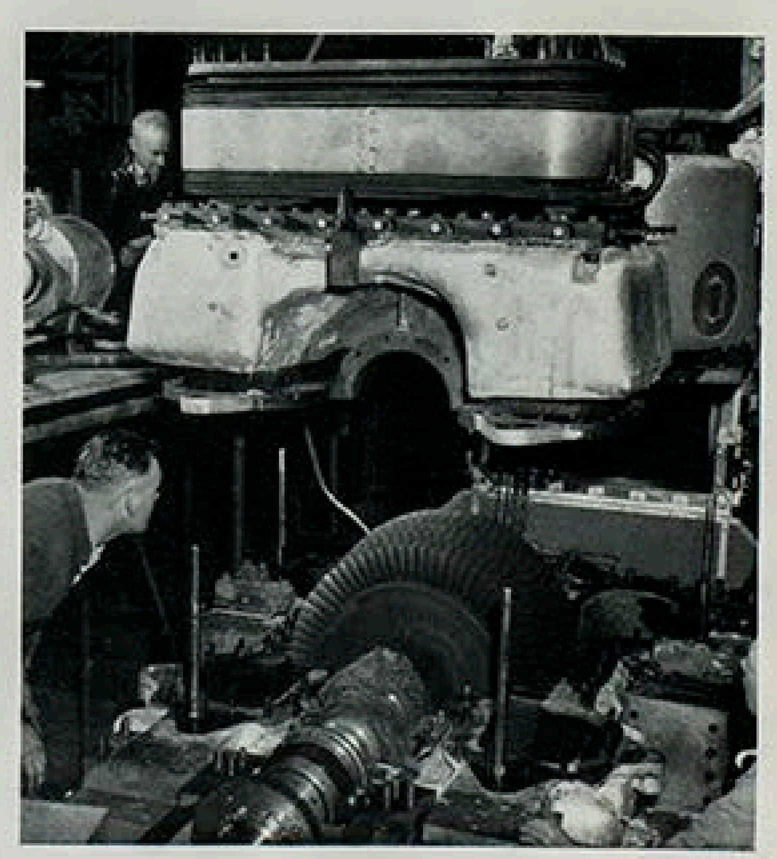

Fig. 7. Top half-casing of low-pressure unit being raised for inspection after running tests.

In appraising the performance of the gas turbine set it should be realized that the equipment went on test and was installed in the ship as designed, and that no modifications, other than adjustments to the air distribution in the combustion chambers, have been made. The test readings show that, as designed, the compressor and the turbine are not well matched, and that therefore neither the compressor or the high-pressure turbine are running at their best points.

It is of particular interest to note that, although no air intake filter was fitted, there was no falling off in the compressor efficiency at the end of the testing period of nearly 600 hours running without cleaning.

PERFORMANCE RESULTS

ITEM	Using Gas Oil: Test Readings	Using Gas Oil: Corrected to Design Conditions	Using Heavy Oil: Test Readings	Using Heavy Oil: Corrected to Design Conditions
Compressor inlet :—				
Temp. °C (°F)	6 (*43*)	20 (*68*)	4 (*39*)	20 (*68*)
Pressure lb./sq.in. abs.	14·13	14·64	14·17	14·64
Compressor outlet :—				
Temp. °C (°F)	160 (*320*)	182 (*360*)	167 (*332*)	192 (*378*)
Pressure lb./sq.in. abs.	56·17	58·24	60·03	62·02
Combustion chamber inlet :—				
Temp. °C (°F)	252 (*485*)	278 (*532*)	260 (*500*)	291 (*555*)
Pressure lb./sq.in. abs.	55·61	57·66	59·41	61·38
H.P. turbine inlet :—				
Temp. °C (°F) reading	558·5 (*1037*)	601 (*1113*)	585 (*1085*)	635 (*1174*)
Temp. °C (°F) calculated	556 (*1033*)	598 (*1109*)	589 (*1092*)	640 (*1184*)
Pressure lb./sq.in. abs.	54·10	56·09	57·83	59·75
L.P. turbine inlet :—				
Temp. °C (°F)	412 (*774*)	447 (*837*)	438 (*820*)	479 (*894*)
Pressure lb./sq.in. abs.	22·58	23·41	23·50	24·28
Isentropic efficiency % :—				
Compressor	87·0	87·0	86·3	86·3
H.P. turbine	85·2	85·2	84·3	84·3
L.P. turbine	88·4	88·4	89·5	89·5
Heat exchanger :—				
Gas inlet temp. °C (°F)	344 (*651*)	375 (*707*)	361 (*682*)	398 (*748*)
Gas outlet temp. °C (°F)	250 (*482*)	276 (*529*)	258 (*496*)	289 (*552*)
Pressure drop lb./sq.in.	0·21	0·23	0·26	0·27
H.P. turbine speed r.p.m.	5850	5996	6000	6171
L.P. turbine speed r.p.m.	2800	2870	2940	3020
Compression ratio	3·98	3·98	4·24	4·24
Air mass flow lb./sec.	27·6	27·9	29·9	30·0
Fuel consumption lb./h	773	821·5	925	983
Output (kW) at alternator terminals	875	930	1022	1087
Fuel rate lb./kWh	0·884	0·884	0·905	0·905
Overall thermal efficiency %	21·1	21·1	21·4	21·4

The table above gives the performance figures of the gas turbine unit and these were obtained from two tests taken during the running of the set. Due to the difficulty in accurately measuring the gas temperature at the inlet to the high-pressure turbine, additional values for this temperature are given in the table. These have been calculated from the crossover temperature between the high-pressure and low-pressure turbine, and the temperature rise in the compressor. Because of varying atmospheric conditions on different days, the performance figures have all been corrected to the design ambient conditions.

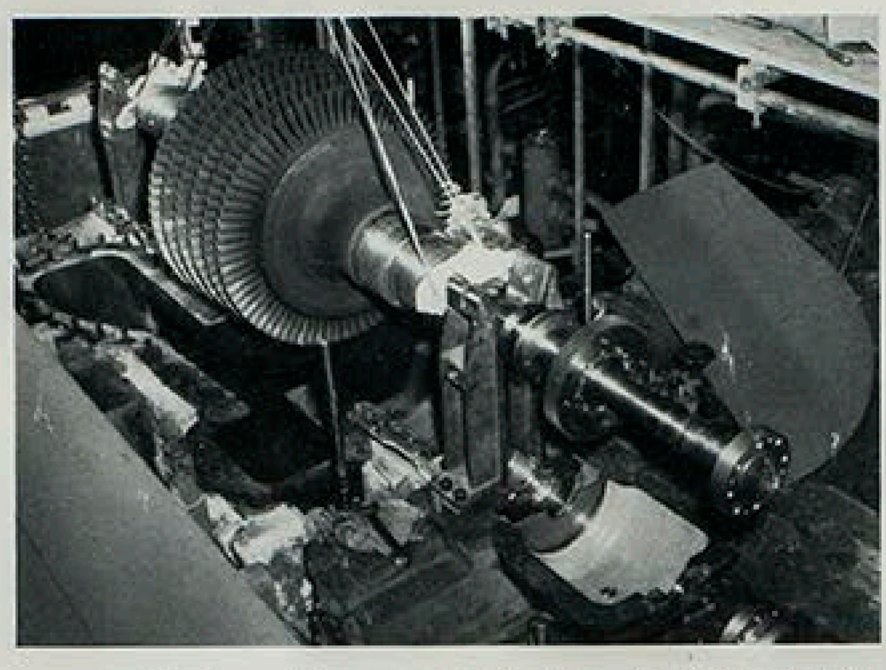

Fig. 8. Rotor of low-pressure unit being raised for inspection after running tests.

STARTING

The set is provided with a 50 h.p. starting motor which is engaged through gearing to the compressor shaft.

The normal starting procedure is to run the compressor/high-pressure turbine unit up to a speed of about 1200 r.p.m. (20% of full load speed), which requires a power input of about 30 kW. At this speed, torch igniters which throw pilot flames into the combustion chambers, are ignited electrically. The main burners are then lit from the pilot flames and the high-pressure turbine-compressor unit accelerated by the turbine with diminishing assistance from the starting motor. The motor is automatically disconnected when its driving torque falls to zero, which in this case, because of the characteristic of the starting motor, is equivalent to a compressor/high-pressure turbine shaft speed of 1800 r.p.m.

The no-load fuel consumption of the set is about 100 lb. per hour at a low-pressure turbine speed of 1500 r.p.m. and about 200 lb. per hour at an idling speed of 3000 r.p.m. These figures are approximately 12% and 24% respectively of the full-load fuel rate.

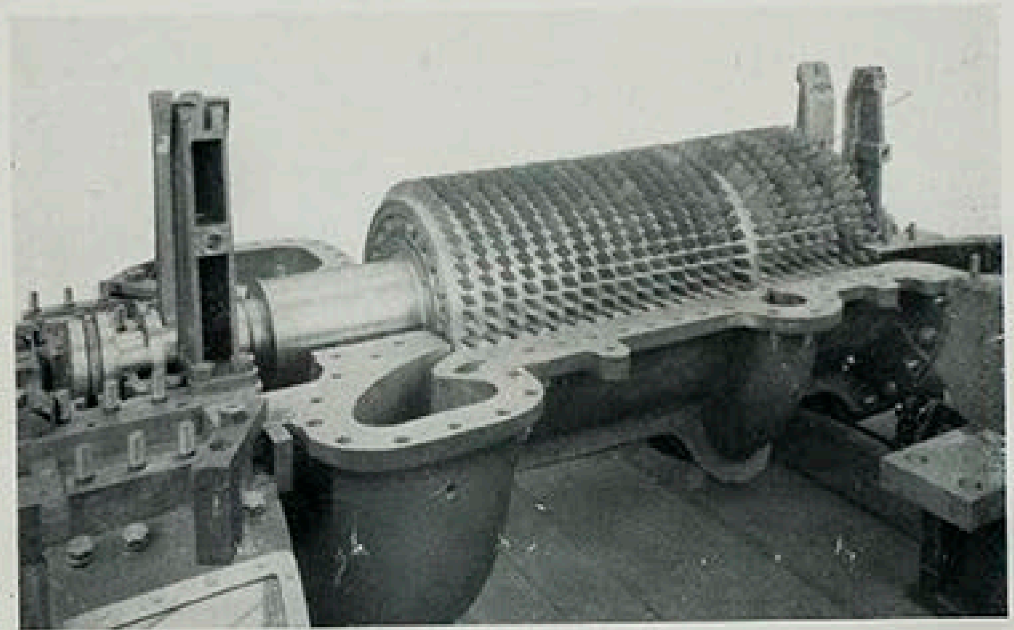

Fig. 9. Compressor unit of gas turbine.

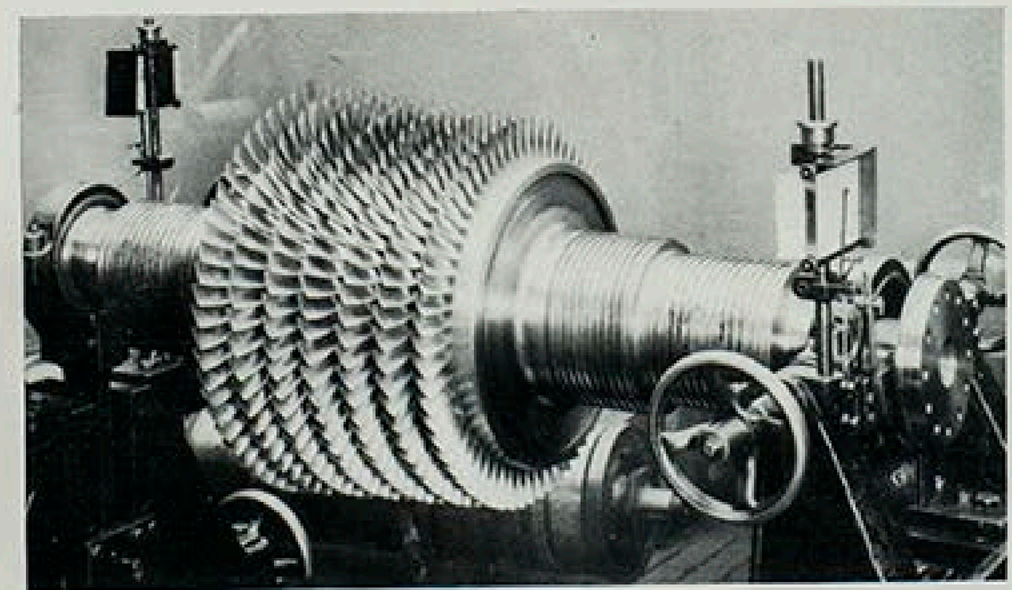

Fig. 10. High-pressure turbine rotor undergoing balancing tests.

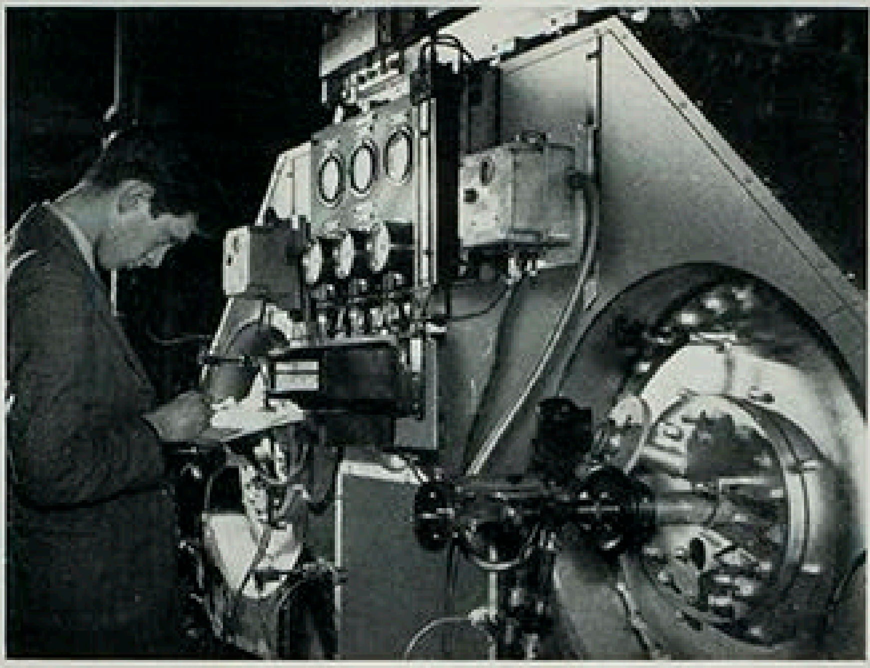

Fig. 11. View of gas turbine from combustion chamber end, showing starboard fuel burner, pressure, and temperature gauges etc.

(Photo: "Evening Chronicle," Newcastle-on-Tyne)

Fig. 12. Part of the gas turbine set arriving at the shipbuilding yard of R. & W. Hawthorn Leslie & Co., Ltd., Newcastle-on-Tyne, for installation on the Anglo-Saxon Petroleum Company's Tanker "*Auris*."

BTH GAS TURBINES

A SHORT HISTORY OF DEVELOPMENT

EARLY INVESTIGATIONS. Although the development of the gas turbine to the stage of commercial application is an achievement of recent years British Thomson-Houston began work in this field in 1933, following the success of an E.H.T. steam turbine which was built in 1929.

The higher the temperature that can be permitted the more attractive the gas turbine becomes ; this is also true of the steam turbine, although to a lesser degree. In a 10,000-kW steam turbo-alternator set built by BTH in 1929 for the Detroit Edison Company of the U.S.A., the turbine, operating at 1000°F (538°C) inlet temperature was an important advance on previous steam turbine practice. The success achieved led to the realization that the further advance of 100-200°F (55°-110°C) necessary to make the gas turbine an attractive proposition was now within sight.

The Detroit Edison extra-high temperature steam turbine was made possible only after extensive research leading to the metallurgical progress which had resulted in the production of materials capable of withstanding the "cherry red" heat at which this set is operated. Subsequent advances have made available metals which stand up to the higher temperatures necessary for efficient gas-turbine operation.

During 1933 BTH made a comprehensive study of the possibilities of the gas turbine as an alternative to established types of prime movers, and the preliminary design for a 5000-kW gas turbo-alternator was prepared. However, it was considered that the time had not yet come to develop the gas turbine, so the project was delayed.

THE JET ENGINE. In 1936 BTH was approached by Flight-Lieut., now Air Commodore, Sir Frank Whittle, *K.B.E., C.B., F.R.S.*, with regard to the development of his ideas for a jet-propulsion engine for aircraft. With the experience of extra-high-temperature steam and the knowledge of gas turbine possibilities, it was considered that an engine of the type suggested by Whittle had a very good chance of successful development. The Company accordingly co-operated with him in the design and manufacture of a jet engine.

The first experimental jet engine was completed and tested in 1937. Tests with a modified engine proved so satisfactory that an order was placed with British Thomson-Houston in 1939 by Power Jets, Ltd. for an engine for flight purposes. This new engine was fitted into an aircraft built by the Gloster Aircraft Company, and was successfully flown for the first time in May, 1941.

THE PRESENT STAGE. The accumulated experience during the foregoing period, plus subsequent research and development, is incorporated in gas turbines for commercial service now on test, under construction, or projected by The British Thomson-Houston Company.

HJ/Special

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