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Marine Gas Turbine Progress

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THE year 1951 has been distinguished by an event of the greatest importance in the development of the gas turbine for marine purposes. On Oct. 28 the first ocean-going merchant ship to be powered by a gas turbine completed her sea trials off the N.-E. Coast and set out across the Atlantic on a normal commercial voyage. This ship, the tanker *Auris* (12,250 tons d.w.), owned by the Anglo-Saxon Petroleum Company, Ltd., was built in 1948 with a diesel-electric machinery installation consisting of four 1200-b.h.p. Sulzer engines, constructed by R. & W. Hawthorn, Leslie & Co., Ltd., each driving an alternator which supplied power to a single propeller motor. Now, as was intended when the ship was designed, the starboard inner diesel-alternator has been removed and has been replaced by a 1200-b.h.p. open-cycle gas turbo-alternator built by the British Thomson-Houston Company, Ltd., at their Rugby works.

Apart from this, the year has been one in which most of the progress on marine gas turbines all over the world has taken place in design offices and engine builders' workshops ashore. Interest in the gas turbine for marine purposes, both naval and mercantile, has continued to increase, but until some results of operating experience on the "first round" of gas-turbine projects are available it is not to be expected that many new ventures will be embarked upon. Furthermore, much of the development work now in progress is to the order of our own and other Navies and since release of information about such work is naturally restricted any survey must be to some extent incomplete.

The four ships which up to the time of writing are in operation are the Naval M.T.B. *5559*, powered by the Metropolitan-Vickers Gatric turbine of 2500 s.h.p. and two Packard petrol engines of 1300 h.p. each, the Naval harbour launch *3964* which made her appearance this year powered by a Rover turbine of 100 h.p., a 24-ft. United States Naval launch and the tanker *Auris*, already referred to. M.T.B. *5559* continues to be employed for trial purposes and one of the three Gatric engines built has been used for tests on boiler oil and on a light fuel with a high sulphur content (about 2.78 per cent.). As a result of these tests the Admiralty conclude that the turbine as developed for gas oil is capable of being run for a " limited period " on boiler fuel. Apart from some attack on the high-nickel-content fuel-jet shields the high sulphur fuel had no adverse effect on the engine.

The harbour launch *3964* is the successor to the *Torquil*, which was built in 1950, and may claim to be the first craft, in this country at any rate, to have a gas turbine as the only means of propulsion. The Rover turbine is of 100 h.p. and a heat exchanger is now being developed in order to improve its fuel consumption. The United States Naval launch has a Boeing turbine of 160 h.p. and is being used for development work.

THE " AURIS " TRIALS

Little information is yet available on the sea trials and first voyage of the *Auris* turbine. Extensive tests were, however, carried out earlier in the year at the maker's works at Rugby using as fuel both gas oil and a boiler oil having a viscosity of 1500 secs. (Redwood No. 1 at 100 deg. F.). The set was run for a total period of 680 hours, the final phase of the testing being a continuous trial of 270 hours on the heavier fuel, mostly at full load. The performance of the unit was not affected by the type of fuel used, and the gas temperature at full load was, when corrected to design conditions, a little below the 1200 deg. F. allowed by the designers.

The overall thermal efficiency of the set on test was 21.4 per cent., equivalent to a boiler fuel consumption of about 0.675 lb. of fuel per b.h.p. per hour at the turbine coupling. In view of the anticipated restriction placed on the design by lack of space and to the relatively low output of the unit these figures must be regarded as creditable. It should also be remembered that compared with other forms of prime mover the gas turbine needs few auxiliaries and their power requirements are small. In any case the probable fuel consumption of a gas turbine is known within a small margin at the design stage; what only an extended trial can show and what the owners of the *Auris* are anxious to find out is the general suitability of the constructionally simple gas turbine for marine use and its flexibility as regards fuel.

The period of test was not long enough to indicate definitely that no trouble would be experienced from fouling of turbine blading and heat exchanger surfaces. The rate of fouling was slightly higher for the boiler fuel than for the gas oil, but an interesting feature was the tendency for the deposits to become detached from the blade surfaces after a period of running, this tendency being encouraged by temperature fluctuations due to change of load. It is a matter for speculation whether a degree of thermal shock may become recognised as a treatment for descaling gas turbines as it is for marine evaporating plant.

During the shop trials, purification of the boiler fuel was not carried out, but in the ship the fuel will be processed by two-stage centrifuging as in motorships using the heavier grades of fuel, and it is to be expected that fouling will be to some extent reduced. The sea trials of 48 hours were completely successful. All observers were impressed by the smooth and silent running of the gas turbine which, when working without any assistance from the diesel engines, which supply 75 per cent. of the total power, was capable of propelling the fully loaded ship at over seven knots in a sea sufficiently disturbed to make the ship unsteady.

PROGRESS IN NAVAL CRAFT

The Royal Navy's interest in gas turbines covers a wide field, for in addition to main propulsion units and full-power boost units for large and small ships it embraces also electric generating sets and lightweight plants for emergency generators and pumps. There is news of progress in all these sections. The Gatric and Rover turbines for boat propulsion have already been mentioned. The 6000-b.h.p. turbo-electric set built by the English Electric Company, Ltd., for propulsion of the frigate *Hotham* is now complete and ready for trials. A more recent development is the 6000-b.h.p. plant now under construction by Rolls Royce for the steam gunboat *Grey Goose* but no details of this have yet been released and the type of transmission to be employed is not known. The 1000-kw. gas turbo-alternator which W. H. Allen, Sons & Co., Ltd., of Bedford, have built for the Admiralty has completed one very successful series of trials and is now being rebuilt with its heat exchanger in readiness for a further period of development running which will include governing trials.

Lightweight emergency generators and portable pumps are being developed by several firms. One interesting example is the pump produced by the Solar Aircraft Company, of San Diego, California, for the United States Navy. This little unit, which develops 50 b.h.p. at a turbine speed of 40,000 r.p.m. and drives a pump with a discharge capacity of 420 gallons per minute at a pressure of 100 lb. per sq. inch, has a weight of only 165 lb. Fuel for one hour's operation with tank weighs an additional 112 lb. The turbine inlet temperature is 1140 deg. F.; since no heat exchanger is fitted the outlet gas temperature is 900 deg. F. and as the exhaust of a portable unit cannot always be directed away from working areas a water spraying device is fitted to cool the gases to about 400 deg. F. In this connection it is worth noting that the exhaust from gas turbines is, unlike that from diesel or petrol engines, non-toxic.

The 3500-s.h.p. open-cycle gas turbine built by the Parsons and Marine Engineering Turbine Research and Development Association (Pametrada) had up to the end of October a period of 120 hours' test running to its credit, mostly at or near full load. The highest sustained power so far has been 3400 s.h.p. and the fuel rate is about 0.525 lb. per h.p. hour. The fuel used has been of distillate type, but after a 100-hour endurance trial and a series of trials to establish efficiencies at partial loads it is intended to experiment with residual fuels.

THE PROBLEM OF FOULING

The possibility of vanadium attack from the heavier fuels is recognised and Pametrada is working on means of preventing it by the use of a fuel additive. Fouling of the h.p. compressor has been more rapid than was envisaged, in spite of efficient inlet air filters; it is thought that wetting of the compressor blades by atmospheric water condensed in the intercooler assists the deposition of minute particles of dirt. The fitting of an air drier after the intercooler is expected to cure the trouble.

Development in the United States of America has been sponsored solely by the Navy and the Maritime Commission and for this reason it is possible to present only an incomplete picture of progress in that country. The 2990-b.h.p. turbine built by Allis-Chalmers for the United States Navy as an experimental shore-test unit has now completed its trials and is being dismantled. The estimated thermal efficiency of 17.6 per cent. for this set appears low when considered in conjunction with the turbine inlet temperature of 1500 deg. F., pressure ratio of 4/1 and heat-exchanger thermal ratio of 60 per cent. and it must be presumed that the efficiency of the axial-flow compressor was less than that of units of more recent construction.

A willingness to adopt types of compressors other than the usual axial or centrifugal has been a characteristic of designers of marine gas turbines abroad. This has been not primarily from consideration of efficiency but because the output of positive-displacement compressors is inherently stable at all speeds and loads—a quality most desirable for marine service.

An experimental shore-test unit of 2380 b.h.p. was built by the Elliott Company of America for the United States Navy using a Lysholm rotary compressor; this turbine had an inlet gas temperature of 1251 deg. F., a pressure ratio of 5.8/1, heat exchanger thermal ratio of 75 per cent., and an overall thermal efficiency of 29.4 per cent. The necessity of maintaining small clearances in the compressor led to mechanical troubles, but in the main the test results were satisfactory, and the set was dismantled in 1947. Experience gained with the first Elliott turbine paved the way for three further sets each of 3000 b.h.p., two to the order of the United States Navy and the other for the United States Maritime Commission. For these the gas temperature was to be raised to 1400 deg. F., giving an expected overall efficiency of

33.4 per cent. Construction of the first two units, however, was so delayed by mechanical and metallurgical difficulties—the welding of the turbine discs in particular proved troublesome—that their progress was outstripped by the advance of gas-turbine knowledge and accordingly they were dismantled after completion this year. Construction of the third unit was started later than the first two and is still in progress; it is not known when or whether it will be installed in a ship.

Another interesting unit has been built by the Baldwin-Lima-Hamilton Corporation for the United States Navy. In its present form it is a generating set with an output of 650 kw. The compressor is of the free-piston type and has a discharge pressure of 90 lb. per sq. inch; each piston assembly comprises three separate pistons, one for power, one for compression and one for " bounce " or cushioning.

In France two schemes of particular interest have been announced, but there is little news of their progress.

PLANT FOR LIBERTY SHIP

The Société Rateau is building a plant of 3900 h.p. to be installed in a Liberty ship. The plant comprises an H.P. turbine driving an H.P. compressor, and an L.P. turbine with its own combustion chamber driving an L.P. compressor and, through single reduction gearing, a variable-pitch reversing propeller. An intercooler is provided between the two stages of compression and a regenerator at the gas outlet from the L.P. turbine. Overall compression ratio is 8.5/1 and the maximum gas inlet temperature to both turbines is 1290 deg. F. An unusual feature is the means adopted for starting the unit; a small steam turbine is mounted on each line of shafting for the purpose. The efficiency is expected to be in the region of 32 per cent.

Separate combustion chambers are eliminated in the free-piston plants of 1100 b.h.p. under construction by the Chantiers & Ateliers Augustin Normand at Havre for two cargo ships of 850 tons d.w. The reversible-pitch propeller is driven at 108 r.p.m. through gearing by a turbine rotating at 9800 r.p.m. which is supplied with hot gas under pressure by one of two gas generators. These are of the Pescara free-piston type in which two opposed power pistons working in a single cylinder are each coupled to a compressor piston which supplies combustion and scavenge air to the power cylinder. At the end of the power stroke the mixture of products of combustion and excess scavenge air passes through ports to a gas collector and thence to the turbine.

Some indication of the direction which technical development may take can perhaps be gained by summarising the trends of the past year. It is significant that so far the potential advantages of the closed cycle have not appeared solid enough to outweigh in even a single instance, the simplicity of the open cycle for marine purposes. Gas temperatures, as is fitting for "long life" machinery of high reliability, are still relatively low and blade cooling has not yet found favour. In England the axial compressor is supreme, while abroad its nearest rival is the free-piston gas-generator; about this last some may think that whatever advantages it may possess the adoption of a component which depends on reciprocating motion is a retrograde step.

Among transmission systems electric propulsion and reversible propellers are perhaps in the lead, but the field is particularly open with several promising arrangements, notably the combination of an ahead hydraulic coupling with a hydraulic reversing torque converter and double-reduction gearing, still to be tried.

From the economic point of view one of the biggest questions is the type of fuel which the gas turbine will be capable of burning satisfactorily. At the time of writing the cost of marine diesel oil is 41 per cent. greater than that of boiler fuel and while the initial tests of new units are usually carried out with a light oil the problem of burning boiler fuel is one which is being actively pursued, and not without success, by all who are engaged in the development of the marine gas turbine.

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