GAS-TURBINE TESTING

A Dissertation on the Extent and Practice of Power-unit Development

A NOTABLE contribution was made to a wider knowledge of the intricacies of gas-turbine testing when Mr. A. C. Lovesey, O.B.E., B.Sc., F.R.Ae.S., Chief Development Engineer, Rolls-Royce, Ltd., presented his paper, *Modern Methods of Testing Aero-engines and Power-plants,* to the Royal Aeronautical Society last Thursday, March 30th. A digest of the lecture, with a selection from the numerous illustrations, appears below.

Mr. Lovesey has been concerned with Rolls-Royce research and experimental work since 1923.

The lecturer introduced his paper with the observation that the gas turbine, as opposed to the piston engine, was readily dissectable into all its main components and much of the rapid development could be attributed to this factor. The turbojet, after the early struggles of Whittle, came into the picture as a delightfully simple engine. It had its problems, but, to those who graduated through the piston engine era, those problems, although large, seemed fewer. In striving for improved performance, the simplicity was, nevertheless, rapidly being designed out of the engine and this called for better and more specialized test equipment. For this reason, Mr. Lovesey's paper dealt exclusively with the gas-turbine aircraft power-unit.

The time from the start of design of a new engine until the start of production was usually anything from three to four and a half years, and the engine bench-testing might be between 3,000 and 5,000 hours with even more time devoted to rig-testing of the main components. In addition, there might be another 1,000 to 1,500 hours' flight-testing.

Apart from the supply of engines, the biggest item of development both in time and money was endurance testing. For example, a power unit of 7,000-lb thrust, when run on the standard M.o.S. 150-hour test, would use between 80,000 and 100,000 gallons of fuel, whereas a piston engine in the 2,000 h.p. class would use about 22,000 gallons of fuel. These two examples were not directly comparable, but did show the order of increase in expenditure entailed.

The average cost of testing components on the rig, i.e., compressor, turbine and combustion, was approximately half that of full-scale engine testing and, therefore, the aim should be to include as much of the development work as possible in the first two classes of testing. The better equipment now available and the ingenious use of better instrumentation should contribute to an economy in the third form of testing, i.e., endurance. What was probably more important, it should tend to speed up development.

The design of the testing programme was no less important than the design of the engine itself, and time devoted to careful thought in this direction was well repaid. The design of special equipment or instrumentation should run parallel with the main design so that the special test apparatus was available for the first engine run. Examples of this were such items as pressure and temperature tappings, and devices for measuring movements or loads all within the engine interior.

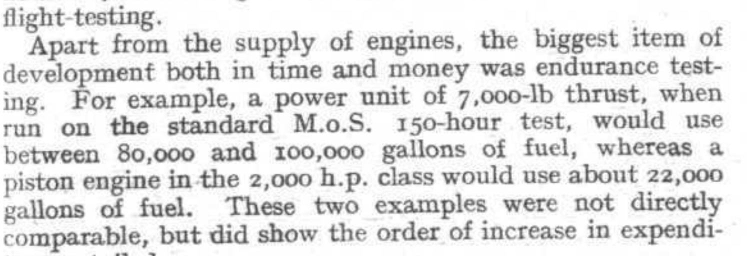

Fig. 1. The upper curves show improvement of atomization on combustion efficiency whilst the lower curves illustrate improvement in stability range obtained through better atomization.

Combustion Considerations

Usually, a new design of combustion chamber started life on a rig where air at the required pressure, temperature and quantity, together with the requisite quantities of fuel, were supplied under simulated engine operating conditions. It was, however, not infrequently found that a combustion chamber which gave excellent results on the rig left a lot to be desired on the engine. Combustion testing should really start with an examination of the airflow from the compressor outlet to make sure that this was in a satisfactory condition to be accepted by the combustion chamber.

A simple apparatus for this purpose consisted of a number of pitot tubes which could fully traverse the outlet duct of the combustion chamber annulus. By this means, a complete picture of the velocities at the head of the flame tube and in the air annulus could be obtained.

An extension of this method was also used for determining the airflow conditions within the flame tube, but these tests were run under cold conditions. They did, nevertheless, show clearly that the aerodynamics of the combustion chamber should be developed to a satisfactory state before any actual burning tests were made.

Mr. Lovesey observed that the fuel burner was one of the major factors controlling stability at high altitudes and a high degree of atomization should be aimed at over a wide flow range. For investigations of this sort, high-speed photography was a considerable aid and, in this connection, the Mullard Flash Tube, which gave a flash of one million candlepower for a millionth of a second, was a very useful tool. As a result of thorough photographic investigation of burner performance, an improvement in spray characteristics had been achieved (Fig. 1).

It was necessary to ensure that the temperature pattern at the turbine blades was the best possible to avoid heat failures, and it was usually preferable to have higher temperatures at the tip and lower temperatures at the root where, of course, the blade stress was highest. An apparatus for investigating temperature pattern consisted of nine doubly shielded thermo-couples, each of which could radially traverse the combustion chamber discharge nozzle. One method of presenting the results was by means of a celluloid model in which the ordinates represented the temperature (Fig. 2). Actual blade temperature could be determined by the Brinell hardness recovery method. In