DESIGN of TURBOPROP TRANSPORTS

Mr. A. E. Russell's Lecture to the I.Ae.S. in Washington

PART I: Design Essentials Imposed by the Turboprop

T he 13th Wright Brothers Lecture was this year given before the Institute of Aeronautical Sciences in Washington on December 17th. Under the title "Some Factors Affecting Large Transport Aeroplanes with Turboprop Engines," it was presented by Mr. A. E. Russell, B.Sc., A.F.R.Ae.S., chief designer (Aircraft Division), Bristol Aeroplane Co., Ltd.

Mr. Russell opened his address by stating that, during the last few years, the Bristol Company had devoted a considerable proportion of its effort towards the design and development of large transport landplanes with turboprop power units. With the adoption of this engine and the consequent rise in cruising speed and operating altitude, together with the increasing size of aircraft, new technical problems had been introduced and old ones had been amplified.

An important condition in the effective use of turboprops was that their operating characteristics were intimately linked with the performance characteristics of the aircraft in which they were installed, for the following reasons:

(i) the compression ratio of the gas turbine was not constant, but increased with reduced temperature; this led to an improvement in efficiency with increase in altitude.

(ii) The compression ratio and peak temperature were functions of r.p.m., which resulted in deterioration in efficiency at part load.

(iii) The ram compression-ratio, besides increasing the air mass flow, enabled the working fluid to expand over a higher ratio with consequent increase in power and improved economy.

As was usual in power-plant design, once the fundamental principle had been established, improved economy and performance could be bought only at the expense of increased complexity and weight. Thus, a balance between plant weight and specific fuel-consumption had to be arranged with due consideration of other factors which might affect the overall aircraft performance. A fundamental requirement for high efficiency was to reduce the rate of energy rejection in the exhaust. It would seem that the immediate programme of development for turboprops should concentrate on the improvement of component efficiencies in order fully to exploit the potentialities of the simple cycle when optimum values were prescribed for the main parameters. This approach would result in a light, simple power unit of low frontal area and attractive fuel economy. To explore the scope in this direction, it was convenient to separate the thermal cycle from the means of propulsion and consider the compressor/turbine combination as a gas generator producing "gas horsepower."

This procedure was satisfactory for turboprops, as the propulsive efficiency was very nearly independent of the thermal efficiency; but it was not so for turbojet types, and might lead to erroneous conclusions. In Fig. 1, a plot of engine plus fuel weight against compression ratio for a range of durations, and it could be seen that, for durations above ten hours, the minimum engine plus fuel weight was achieved at a compression ratio of about 8:1. For durations up to five hours, the importance of engine plus fuel weight was critical; low-compression engines were then best from the points of view of simplicity and initial cost.

The subject of aircraft performance, Mr. Russell stated, that when reciprocating engines were employed, maximum continuous power available at low altitude was severely limited, as was also the take-off power. These conditions would often result in take-off requirements and airworthiness performance standards having an influence on the choice of wing loading and power loading; this necessary compromise might, in turn, have an adverse effect on the payload/range performance.

A different situation obtained when turboprops were employed. This arose from the fact that the power output increased continuously as the altitude was reduced from the cruising altitude to sea-level, and it was unlikely that aircraft performance at the lower levels would be important to the extent of determining gross weight or wing design. For turboprop-engined aircraft, therefore, attention would be directed toward attaining the best possible efficiency under cruising conditions.

When turboprops were used, it was essential to operate the engines at the maximum permitted continuous r.p.m. and power in order to achieve the minimum specific consumption. The only way to reduce the power available so that an economic condition was obtained was to operate at the highest altitude consistent with the maintenance of sufficient reserves for climb performance. This altitude increased as weight was reduced by the consumption of fuel and was rather nearer to the ceiling than to the altitude for maximum speed.

The lecturer considered the effects of some representative