ROLLS-ROYCE AVON (continued from page 906)

is one pipe for each of the upper groups of triple valves and further pipes for the individual bleed valves on the lower part of the compressor casing.

A serious interest in reheat was first taken by Rolls-Royce in 1946. This method of obtaining extra thrust from the unburnt air passing through a turbojet was, of course, well known, but emphasis at Rolls-Royce was placed primarily on developing the basic engine.

Reheat testing began using Derwent engines in a special installation on a Meteor. It soon became apparent that flight testing was the most important part of the development, although some major control, mechanical and combustion problems could be dealt with to some extent on the test bench. Although a larger-diameter jet pipe was used, the gas velocity of 600 ft/sec over the burner raised very difficult flame stabilization problems in spite of the high inlet temperatures of 600 to 700° C. Having started a healthy fire, the little matter of confining it to the core of the jet pipe and avoiding burning out the walls was also—and still is—a major problem. Control of the fuel supply meant the development of an entirely new and separate system from the engine, and an air-driven turbo pump driven by compressor delivery air was developed to meet the case. Some 500 hours were accumulated on three Meteors before the weight of development was transferred to the Avon. Whereas there had been no intention of using reheat on production Derwents, several proposals were made to use the system with the Avon in more advanced fighter aircraft than the Meteor.

Much of the past testing "read across" to the Avon, but changes in detail shape, air pattern and pressure level involved much more testing on the bench and in flight. A considerable amount of small-scale combustion rig work was going on in parallel during this period with a view to investigating some of the fundamental aspects of the problem and evolving a true scale-model technique to speed up the main development problem and to open up additional testing facilities. A Canberra was modified to take two reheat installations and this proved to be a very fine flying test-bed. The normal Avon engines were used and the rear end of the nacelle was opened out and suitably strengthened to take the larger-diameter reheat jet pipe. Having the advantages of an observer, ample room for instrumentation, adequate fuel tankage and extreme altitude, it fulfilled almost every requirement.

The conversion of the Canberra and the Meteors from the design to the practical work involved was undertaken by the Rolls-Royce Hucknall Flight Establishment, as also was the flight-test programme. Many hundreds of hours flying were accumulated during development of the Avon system. In spite of the successful testing on the Derwent up to 43,000ft, the Avon encountered completely new combustion troubles and lighting difficulties at altitudes below the Derwent and a great deal of work was necessary before a satisfactory performance was obtained. The problems were even then not completely solved since the identical reheat pipe and burner when used in different types of fighter installations showed up some more minor troubles which had to be solved by individual modifications relating to each aircraft.

For the purpose of description the reheat jet pipe can be conveniently divided into three sections: the diffusing section, having a burner at its outlet; a parallel, or burning, section; and a variable-area nozzle. The pipe has two concentric stainless steel skins, the inner or hot skin carrying the gas-pressure loads and being, in turn, supported by the cool outer casing. It is this casing that carries the structural loads, although axial thrust loads (rearwards non-heat and forwards on reheat) are taken on the engine exhaust unit by a flexible coupling.

An ejector on the final nozzle sucks air between the two skins, both during and without reheat. This, whilst hardly cooling the inner skin, supplies an effective insulating blanket for the outer skin. Since the aircraft nacelle construction is usually of light alloy, the reduction in temperature of the outer skin is an important point. In addition, thermal blankets are used in certain installations.

The variable nozzle is of the relatively simple two-position clamshell type and pays a small penalty in the non-reheat thrust due to side pillage of the gas stream. The reheat burner consists basically of an annular vee gutter concentric with a central cone and interconnected with it by short radial gutters of the same section. Since the wider the gutter, or cone, the greater the stability, the central cone has a greater stability than the gutter, even though its blockage area is small, and some of its margin of stability can be used to provide some piloting of the outer gutter. The blockage of the burner results in a small pressure, and hence thrust loss, both during non-reheat and reheat conditions, although it is, of course, completely masked in the latter condition by the reheat boost.

In the fuel system high-pressure air is tapped off the compressor to drive the turbo fuel pump. This consists of a small two-stage turbine mounted on the same shaft as a centrifugal pump and, relative to other types of pump, it has a very high flow and pressure output for a low weight. When reheat is selected a valve admits air to the turbo pump which then commences to build up fuel pressure against a closed fuel valve. When the pressure has reached a set value, a switch opens the fuel valve and reheat variable nozzle simultaneously. Ignition of reheat is by a high tension spark plug positioned in the relatively low velocity of the central cone and fed by a piloting fuel supply. Once combustion has begun in the cone, the flame propagates radially outwards along the interconnectors and lights the main gutter.

Control of the reheat fuel is by an air throttle in the line to the turbo pump. The basis of control is the fact that a normal non-reheat engine maintains a fixed pressure ratio across the turbine regardless of altitude and small variations of engine speed from the maximum conditions. This pressure ratio is used in the reheat case by means of a diaphragm and servo-control unit to alter the opening of the air throttle according to the deviation from the normal pressure ratio. This is a true "sensing" system and with a control of this type the pilot sees no difference in any of his engine flight instruments. When reheat is cancelled the nozzle and fuel valve are closed together and the engine remains at the same rotational speed. Partial reheat thrust is obtained by reducing r.p.m., and hence reducing the engine and reheat thrust together.

All the Avons so far described are direct developments of the original AJ.65, and are thus, to some extent, constrained to the theoretical approach of ten years ago. Nevertheless, various studies led Rolls-Royce to the RA.14, which represents a noteworthy advance, and can in no sense be considered as a mere "improvement" of the first Avon generation. Although really a completely new engine it was given the appellation of Avon, and appears to have founded a second generation of more advanced engines.

Considerations of security prevent a description of any of these later Avons, but certain deductions may be made with assurance from a superficial examination of them. For example, there are clearly more than the original 12 stages of compression; and this presupposes a higher pressure ratio, particularly taken in conjunction with the increased work-per-stage which can now be obtained. The annulus area at the intake is greater than on the early Avons, indicating a greater mass flow. A detail point is that the compressor bleed valves are of the sliding type, as distinct from the lift type originally fitted.

Of the superficially evident alterations introduced by the new family of Avons, the most obvious is the redesigned combustion system. This is clearly of the annular, or cannular, variety, although there seem to be eight fuel burners as before. Adoption of such a system has clearly enabled Rolls-Royce to develop a very advanced design capable not only of passing a considerably greater mass flow than that of the earlier engines, but of actually reducing the overall diameter of the engine. On previous Avons the fuel pump—a Lucas dual unit—is mounted on the right-hand side of the external wheelcase; in the new Avons the pump is attached to, and driven from, a unit combining the external wheelcase and oil sump. Another visible change is the elimination of flexible piping in favour of stainless-steel tubing, and most of the new engines carry a fuel control-unit group on the lower left-hand side, whereas these auxiliaries were separately located on the RA.7.

The experience of Rolls-Royce, coupled with much increased knowledge at the outset, has enabled development of the second generation to proceed much more rapidly than did that of the first. For example, the RA.14 prototype was first run on November 17th, 1951—the same year as that in which design started. On February 28th, 1953, RA.14s were airborne for the first time, and production deliveries were being made the following July.

Of the various branches of the second generation—such as the RA.24 and RA.28—no details may at present be published. It has been stated that commercial powerplants of this general type are being developed, and these may be expected to provide exceptionally competitive fuel consumption and overhaul life. The latest of these transport Avons is the RA.29, which has a rated thrust of 10,500 lb at 8,150 r.p.m., and is specified for the de Havilland Comet 4.

In view of the very high thrusts being achieved by late versions of Avon, it is reasonable to assume that engine operating temperatures are now considerably greater than they were when the first Avons were planned. Rolls-Royce recently stated that their Tyne turboprop incorporates "design improvements which allow high flame temperature for take-off and cruising without impairing the overhaul life of the engine. These developments have been derived from the latest military jet engines . . ." As it has been announced that the Tyne incorporates air-cooled turbine blading it is not unreasonable to infer that such blading is also fitted in the latest types of Avon.

Be that as it may, it is rarely that one can record such a story as has already been written by the Rolls-Royce Avon. In this account we have given only the first half of the story; the rest will follow in the years to come.