ANALYSING THE 727

Some Comments on Boeing's Design . . . **by the Technical Editor**

ON page 938 it is recorded that two of the largest American operators have each bought 40 of Boeing's triple-jet Model 727 airliner. Many areas of its design remain protected by Boeing, and the same is true of the powerplant; but enough is known for a technical commentary from the British viewpoint to be attempted. Throughout the design of the 727 one can see the results of the policy of reaping the maximum reward from the vast service experience gained with the 707.

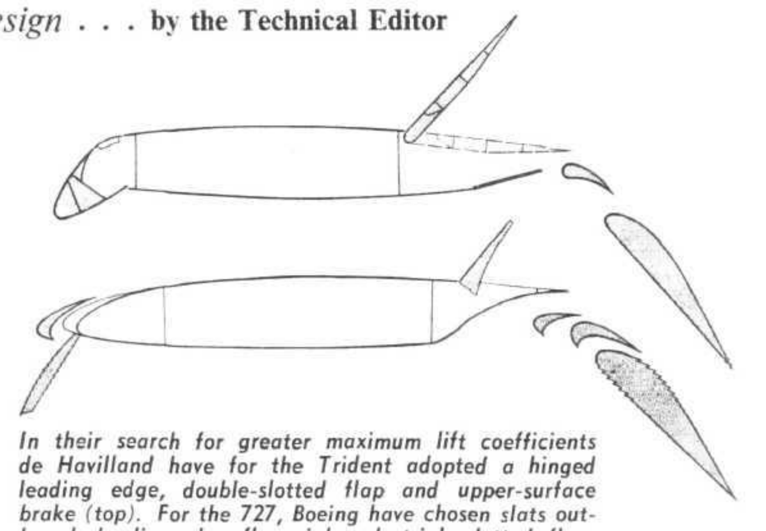
Since it is a rather larger aeroplane than the Trident 1 the 727 needs engines more powerful than the Spey, and although Boeing recently told us that the Rolls-Royce engine spectrum included a unit—which would have been marketed, and possibly manufactured, by Allison—perfectly matched to the 727, Eastern and United, the two operators to whom the company looked for the bedrock on which to base the programme, both wanted Pratt & Whitney. The engine chosen is the JT8D-1, a turbofan derivative of the J52 turbojet. The latter was planned in 1955 for an advanced version of the A4D US Navy attack aircraft; this programme was cancelled and the engine was reinstated in revised form to drive the Hound Dog air-launched strategic missile. It is doubtful if this application is of much value to the JT8D, but a special version of the J52, with tilting tailpipes, has been developed to power the Intruder US Navy attack bomber. It is surprising that Boeing should describe the J52 as being "in wide military service," since it seems to have powered only a single aeroplane (the first Intruder).

But it is increasingly obvious that military flight-time is of little importance in the development of an airline engine. Modern techniques in the Willgoos high-altitude laboratory should be able to simulate airline conditions with complete fidelity, and modern testing techniques are such that, in Britain at least, engineers feel they can develop a reliable engine without flying it at all.

Although the JT8D will look quite unlike the Spey, the engineers at Hartford have paid their counterparts at Derby the compliment of making it thermodynamically virtually identical. Three of the most important factors which determine the by-pass ratio of engines for this market are sketched on this page. The original airline Conway has the low ratio of 0.3, while the JT3D has a ratio of 1.5. Although it would be futile to deny that the two companies have spent a lot of time looking over each other's shoulders, they have made their own calculations and independently concluded that the best value is near unity (indicated by a tinted strip in the illustration).

Pratt & Whitney's first attempt to do a turbofan for this market was the JTF-10, rated at 8,250lb and intended for the defunct DC-9. This engine had a by-pass ratio of about 1.5, and also stemmed from the J52. In view of the fact that the straight turbojet has military ratings of between 7,500 and 8,000lb it seems clear that the new 727 engine is altogether larger, and it may be that no J52 parts are incorporated at all. It is worth noting that in the 727 the fan air is ducted aft, as in a Rolls-Royce engine, to pass through a single reverser and mix with the hot jet in the nozzle. Boeing have done well to fit a reverser on the middle engine.

Switching to aerodynamics, it is probably fair to comment that, while the game of finding the right wing to meet the cruising case is a straightforward slog with tunnel models and computers, the number of variables which can be introduced to meet the landing case makes the final wing design elusive. de Havilland eventually arrived at a wing with an M_{NO} of 0.875 above 24,000ft and a best-economy point of M0.87 at 32,000ft—a remarkable speed when it is considered that "maximum economy" means what it says. The Hatfield aerodynamicists probably thought they had gone far enough in adopting leading-edge flaps and double-slotted trailing-edge flaps, but Boeing have tried to go one better. Whether or not they have succeeded depends on such other factors as the first cost of the aircraft and the trouble it will give in service.



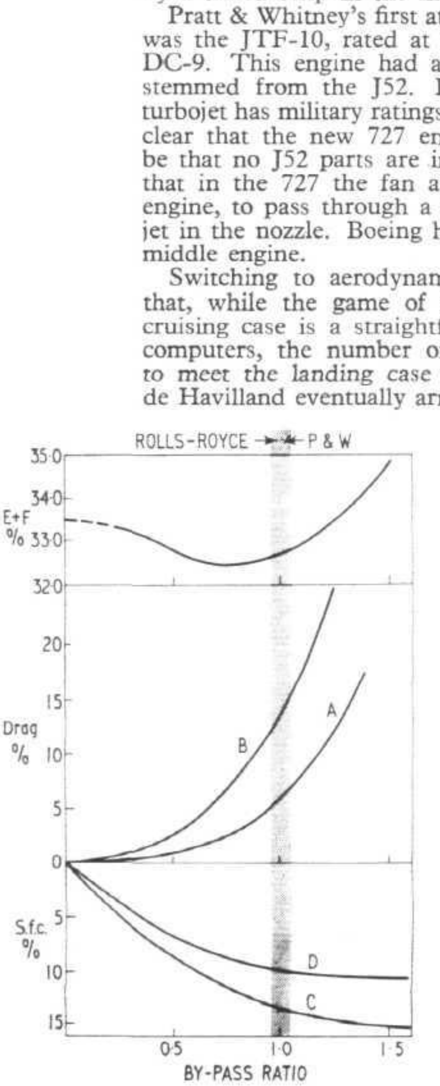
In their search for greater maximum lift coefficients de Havilland have for the Trident adopted a hinged leading edge, double-slotted flap and upper-surface brake (top). For the 727, Boeing have chosen slats outboard, leading-edge flaps inboard, triple-slotted flaps and spoilers

As we noted in our October 14 issue, Boeing have aimed at a maximum lift coefficient of 2.5 in order to meet a challenging requirement in the matter of field-length; and it is rumoured in Britain that they have achieved 2.8. The accompanying sketches of wing profiles indicate the degree of complexity necessary to achieve such a figure; and, although Boeing do not mention it, rough calculations suggest that the 727 may well have partially blown flaps. When we visited the company last month the "dash-80" prototype of the 707 family was flying with blown flaps under the wing fillets and sonic blowing around all the "dirty" areas of the main flaps, including jets intended to clean up the airflow over the flap rails. Yet another indication of the importance of the field-length limitation is the fact that the 727's sweep angle is less than that of either the 707 or the Trident.

From the early days of the Comet 1 de Havilland have been wedded to fully powered flying controls, and in the Trident a fully triplexed system is employed—three jacks on each surface—to provide a two-over-one majority rule in the event of failure. Each of three independent hydraulic supplies is served by its own engine, and the D.H./BEA/Smiths team have by specific reliability requirements of ARB been forced to apply extensive multiplication—their solution is triplex throughout—in order to meet automatic-landing safety levels. Such a situation has not yet been faced at Seattle and, as was reported in our issue of November 25 (page 840), Boeing are not trying to do anything comparable with the 727. The flying controls of the new airliner are really manual with hydraulic boost, so that effective manual reversion is possible. It may be recalled that on the 707 series not even hydraulic boost is provided on ailerons and elevators, and Boeing seem to think that fully powered controls are something one should always try to do without.

British designers, on the other hand, took the decision to apply fully powered controls without manual reversion in conjunction with an all-flying tailplane. The addition of a multiplicated automatic landing system to the 727 appears to be extremely difficult, involving as it does the application of genuine multiplication to a fundamentally split-authority control system. The addition of a set of triplicated or triplexed autopilot servos to the manual/boosted controls would raise some interesting statistical problems in reliability calculations.

From the scanty details available it appears that the accessory systems of the 727 depart hardly at all from previous practice, although doubtless one or two surprises are in store (not a word is available on ice protection). For the Trident, DH and Rolls-Royce are confident enough to pressurize the cabin by direct air bleed, as is at present proving quite successful with the Caravelle. Boeing are known to have looked at such systems for many years; but they have yet to succeed in discarding the bleed-air turbo-compressors which pump fresh air to the cabins of 707s and 720s, and the same dual-cycle arrangement will be perpetuated in at least the first 727s. Later, if it can be demonstrated that the inside of the 727 could never become filled with vapour from hot turbine oil, Boeing may adopt a direct bleed system.



Curves, plotted against by-pass ratio, of engine+fuel weight for a 1,000 n.m. stage (expressed as percentage of aircraft gross weight), increase in total engine drag (A), increase in total pod drag (B), and reduction in s.f.c. allowing for (C) accessories and air bleed and (D) for increasing pod drag also. As indicated, Rolls-Royce and Pratt and Whitney are both approaching a by-pass ratio of unity, one from below and the other from above