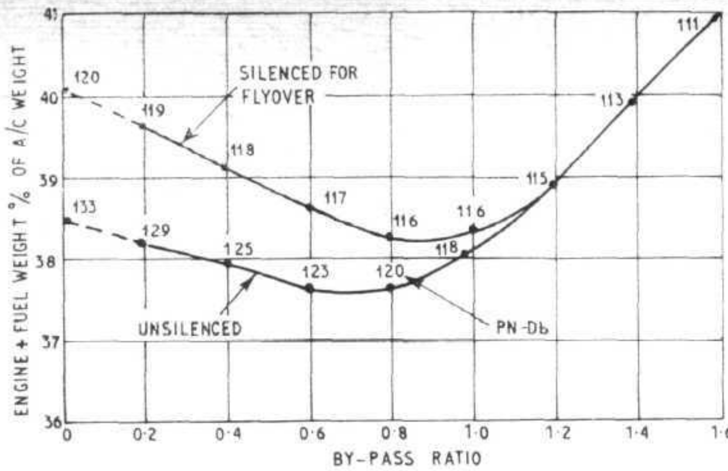
Trends in Propulsion

AN RAeS LECTURE ON ROLLS-ROYCE RESEARCH



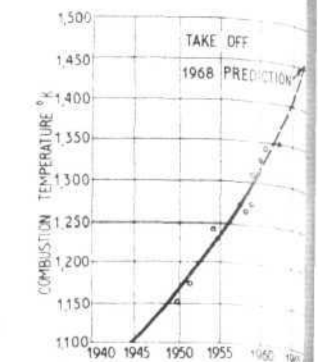


Fig 1 (left). By-pass optimization study; engine plus fuel weight for 1,500 n.m. Fig 2 (right). Increase in combustion temperatures of turbojet engines

IN the introduction to the main lecture which was to be read before the Southampton branch of the Royal Aeronautical Society yesterday, January 19, Mr Harry Pearson, chief engineer (performance and research) of Rolls-Royce, said that it was trends within the next five to seven years and not the future of aircraft propulsion which he intended to discuss.

It had been found in America, said Mr Pearson, that conversion of existing engines to fan engines was a fairly economical method of increasing thrust, particularly for take-off. Also, take-off noise annoyance acted as a catalyst in favour of the by-pass type. Almost overnight the Rolls-Royce by-pass engine was faced with competition from fan engines with by-pass ratios of something like 1.5. Rolls-Royce took leave to doubt the correctness of these conversions; they had always been of the opinion that at current operating temperature the optimum ratio was between 0.6 and unity, take-off noise being improved at higher ratios.

Specific fuel consumption diminishes as by-pass ratio increases but above unity the improvement is small and a higher ratio means a larger engine diameter. On installed s.f.c. alone 1.2 is the maximum useful by-pass ratio, while above 0.6 powerplant weight increases rather rapidly, and for ranges between 1,500 n.m. and 4,650 n.m. (London - San Francisco) 0.8 is near the optimum.

Comparing engines on a basis of noise levels, where a given cruise requirement has to be met and a given take-off is required, with a low by-pass engine take-off is achieved as a design requirement and the cruise conditions will be somewhat throttled back. For high by-pass engines the cruise becomes the design requirement, take-off being a relatively easier condition. The results of one study are shown in Fig. 1.

Reduction of take-off noise by increasing by-pass ratio is largely fruitless because compressor and other noise will become a dominating source. At present operating temperatures and speeds by-pass ratios above unity are not desirable.

But as combustion temperatures are increased somewhat higher by-pass ratios tend to rectify the situation where jet velocities increase with detriment to both propulsive efficiency and noise.

Other parameters besides by-pass ratio are changing with research and development. As compressor temperature rises or pressure ratio increases specific fuel consumption diminishes, but engine weight increases with additional compressor and turbine stages. If combustion temperature continues to rise at the present rate higher pressure ratios are worth exploiting. Within seven years a ratio of 20 could be achieved in two-shaft engines.

Supersonic aircraft act as a spur to an increase in combustion temperatures and at higher by-pass ratios a worthwhile improvement in economy occurs; in seven years a cruising temperature of about 1,350°K could be achieved and take-off combustion temperature equivalent would be about 1,450°K.

By 1967 or so engines in the 10,000-20,000lb thrust class could have 18 per cent more take-off thrust than a current engine for the same airflow and 23 per cent more cruising thrust. Specific fuel consumption would be $3\frac{1}{2}$ per cent higher. The engine would be about five decibels noisier so it seems desirable to operate at constant specific thrust and a by-pass ratio of about 1.5 to 1.6; noise and pod drag would then be unaltered, specific fuel consumption four per cent greater, and specific weight ten per cent lighter. Development of noise reduction techniques—such as variable area devices within the engine—should make the next generation of jets some 12 PNdb better than at present.

For short-range jet aircraft simpler engines of higher fuel consumption but of reduced weight and cost are required.

The future of turboprops remains in doubt; they are complex and military demand has not been great. Improvements in performance should come about by raising combustion temperature and pressure ratio and from improvement in design and weight. Provided designers are not faced with designing smaller and smaller engines combustion temperatures could reach cruising values of 1,350°K towards the end of the next decade giving a seven per cent improvement in range. These improvements applied to an engine of Tyne dimensions could give an increased power of 16 per cent coupled with a reduction in s.f.c. of eight per cent. Airflow could be increased by about 20 per cent giving a power increase of 39 per cent and a net gain in specific weight of 20 per cent, although the overall specific weight of engine plus propeller would remain about the same.

Supersonic flight presents the turbo-jet in its most favourable light, overall efficiency at Mach 2 comparing with best power station practice.

But if engine size is not to become prohibitive supersonic transport success turns on the ability to run engines at high combustion temperatures. Apart from this and a bulky intake-control system the engine becomes simpler than current types. Reheat may be called for if the transition height to supersonic flight is very great.

Combustion temperatures 100-200°C higher than those current (cruising temperatures of about 1,350°K) will be necessary and blade material suitable for another 100°C must be forthcoming. This appears possible. The design of propulsion nozzles is not yet well understood; a variable nozzle of some type must be used and an ejector nozzle has possibilities, but no satisfactory solution seems yet available. Airfield noise levels will depend on climb technique but although installed thrust is high, lift/drag ratio is low, and the height of a supersonic aircraft over residential communities will not be so high as a subsonic aircraft of similar power. Landing noise will also present problems but the variable air intakes that are needed (Fig 4) should help to solve this.

No completely acceptable solution for VTOL transports has emerged from propulsion studies. Separate jets allow powerplants to be chosen to operate in the most efficient manner but a lifting engine is an additional penalty. Low jet-velocity is mandatory for low noise level and more success may be achieved by designing round a propulsion-and-lifting duct system. For supersonic interceptor aircraft propulsion powerplants will probably be capable of lifting the aircraft off vertically by powerplant rotation or jet deflection. With strike aircraft there is an advantage in the use of only one powerplant but consumption is impaired because the engine must be heavily throttled for cruise. The use of several special lift engines and a separate propulsion engine, on the other hand, has the disadvantage that a number of lift engines have to be provided. The next four years should see important developments in this field.

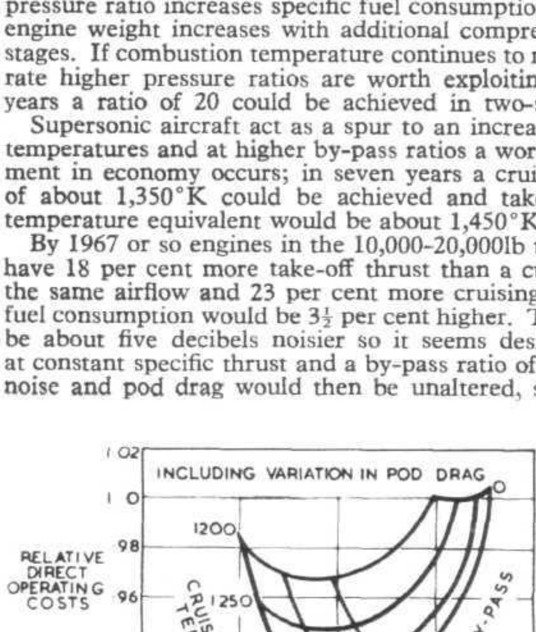


Fig 3 (left). Variation of direct operating cost and take-off noise with combustion flame temperature and design by-pass ratio

Fig 4 (right). Variable wedge-intake control arrangement for a supersonic aircraft