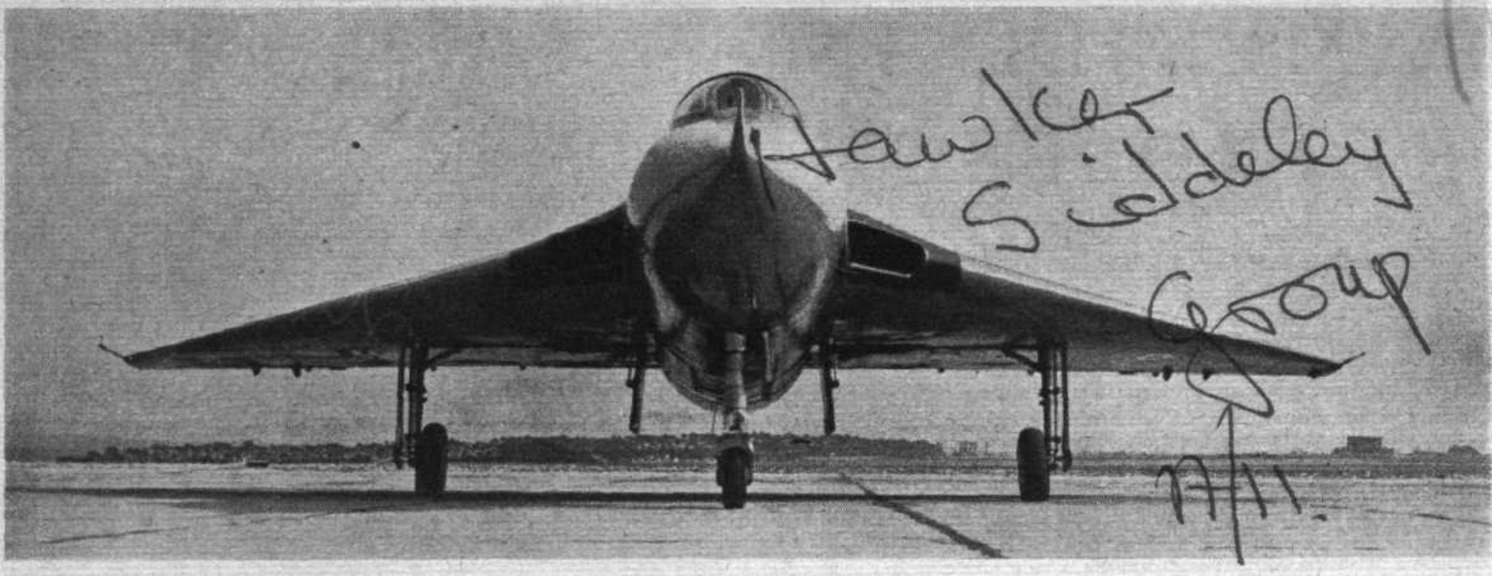

Frontal aspect of the Avro 707A research aircraft. New views of the 707B appear elsewhere in this issue.

AERODYNAMICS OF THE DELTA

Some "Background" from J. R. Ewans, Avro's Chief Aerodynamicist

SO far as can be ascertained, the idea of using a triangular plan-form for aircraft wings, now known as the delta wing, was first put forward in 1943 by Professor Lippisch, who will be remembered for his association with the Messerschmitt Company. His studies had led him to think that this form was most suited for flight at speeds in the region of the speed of sound, where conventional aircraft designs were already known to be in trouble. By the end of the war, he had a number of delta wing projects in hand, including an unpowered wooden glider intended to explore the low-speed properties of the wing. This was by then partly built, and was later completed under United States orders.

The idea of the delta wing was studied by many other aeronautical experts and a strong recommendation for its use was given, for instance, by Professor Von Karman, of U.S.A., at the 1947 Anglo-American Aeronautical Conference.

At the time of writing, three British delta aircraft and two American are known to have flown, and it is pretty certain that others are on the way. In the date order of their first flight, these are: Consolidated-Vultee XF-92, Avro 707, Boulton Paul P111, Douglas XF-3D, and Fairey FD-1.

With the exception of the last-named, which is fitted with a small fixed tailplane for the first flights, all the above aircraft are tailless.

The following notes are intended to give a logical explanation of why there is this considerable interest in the delta wing, and just what advantages it promises the aircraft designer. But consideration must first be given to the type of aircraft the designer is trying to produce.

The delta wing is of value only for very-high-speed aircraft and at the present stage of engine development this implies the use of jet engines. When projecting his high-speed aircraft, the designer will attempt to produce something carrying the greatest payload for the greatest distance, at the highest speed, and for the least expenditure of power (i.e., using the least amount of fuel). This applies to all types of aircraft, whether they be bombers in which the payload is bombs, or civil aircraft in which it is passengers or cargo, or fighters in which it is guns and ammunition.

The most fundamental factor determining the ultimate achievement is the height at which the aircraft flies. As height increases the density of the air is reduced, so that drag is less; it is possible to fly at a given speed at say, 40,000ft, for an expenditure of only one quarter of the power required at sea level.

The advent of the jet engine has enabled the aircraft designer to get his aircraft up to considerable altitudes and take advantage of the reduced drag, but a new factor is coming in to limit the speed of the aircraft. This is the speed of sound.

The speed of sound occupies a fundamental position in the speed range of aircraft. It is roughly 760 m.p.h. at sea level and falls off to a value of 660 m.p.h. at heights above 36,000ft. Because the speed of sound is of such importance, aircraft speeds are commonly related to the speed of sound, using the term Mach number (the ratio of the speed of an aircraft to the speed of sound at the same height). As an aircraft approaches the speed of sound—in fact, for conventional aircraft when a speed of about 70 per cent of the speed of sound (Mach 0.7) is reached—the effects of compressibility become important, for the characteristics of the airflow change fundamentally. There is a very large increase in the air resistance, or drag, and an excessive expenditure of power becomes necessary to increase the speed any further.

For transport and bomber aircraft the speed at which the drag starts to increase (known as the "drag rise" Mach number) becomes the maximum cruising speed, because, if the aircraft is flown at higher speeds, the disproportionally higher thrust required from the engine means excessive fuel consumption and loss of range. At a rather higher Mach number there will be changes in the stability of the aircraft and in its response to the pilot's control—leading, possibly, even to complete loss of control.

In order to progress to higher speeds it is, therefore, necessary to design aircraft so as to postpone and/or overcome these effects.

We have noted that with an "old-fashioned" type of aircraft design, i.e., that of jet-propelled aircraft current in 1945, the limiting speed in steady cruising flight is likely to be a Mach number of 0.7 (higher speeds have, of course, already been achieved and a number of aircraft have exceeded the speed of sound, but only for short periods, either by diving or by use of rocket power). However, from the knowledge now available, it appears possible, by careful aerodynamic design, to postpone the rise in drag until a Mach number in the region of 0.9 is reached, and this figure is likely to be the practical limit of cruising speed for transport aircraft of all types for many years to come. The designer of a civil aircraft, a bomber, or a long range fighter, will, therefore, bend all his energies to achieving a Mach number of this order without any drag rise. In addition, he must pay attention to the changes of stability or lack of control which might occur in this region, and this will occupy his attention to the same extent as the purely performance aspect of the drag rise.

It is quite easy to design a fuselage shape which is relatively immune from Mach-number effects. It is the design