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PCX
Avro
CF105
NAE

C-105
Areas of Interest to NAE ANALYZED

Stability

Aerodynamic | Artificial

Longitudinal (1) | Lateral (2) | "Philosophy" (3) | Design (4)

Performance

Drag Estimation | Thrust Estimation (7)

Min. Drag (5) | Lift-dependent drag in trim condition (6)

The above is a breakdown of the technical subject matter on the CF-105, in which the NAE are interested. The following notes refer to the numbered items in the diagram above. Items (1) to (4) refer to dynamic stability, and items (5) to (7) refer to performance. Other main areas, such as structural design, armament and fire control, we have paid very little attention to.

(1) Longitudinal Stability:

We are not sure that the problem of pitch-up has been satisfactorily cured by the company. They have, of course, made considerable improvement by the use of fixes (leading edge extension, notch and droop) but the C_m-C_L curve is still not completely straight.

(2) Lateral Stability:

The aerodynamic lateral stability of the aircraft is such that the aircraft can not be flown over part of its flight envelope without a very sophisticated type of artificial stability system.

We feel that it is possible that the aerodynamic stability (mainly directional stability) might be improved substantially by the use of suitable "fixes" which would have to be developed in a wind tunnel programme. The Company state that in their opinion this would not be possible or worthwhile. The only way in which directional stability could be made adequate, they feel, is by the use of "brute force" methods such as a 100 percent increase in fin size, and this they can not do because of weight and C.G. problems. Our own view, however, is that their directional stability problem may be partly due to adverse fin sidewash effects which might be changed by fixes. This view seems to be partly substantiated by the fact that directional stability was greatly improved, up to M = 1.2 at least, by the addition of wing leading edge droop, although it was not put on for this purpose.

(3) "Philosophy" of Artificial Stability:

It is probably natural that aerodynamicists should take a somewhat dim view of the idea that an aircraft should be made entirely dependent on the reliability of its "black boxes". In the present case, however, it does appear that no really concentrated effort was made to improve the aerodynamic stability picture. As a result, the type of artificial stability system required is a very sophisticated one. (It seems misleading to refer to it as a "damping" system, because it must make up for inadequate static stability). The Company argument that every effort will be made to ensure that the system is as reliable as possible seems to be insufficient. Aerodynamic static stability is as reliable as the primary structure of the aeroplane, ~~but a complex servo system~~ of the type considered is

likely to fall far short of this. If failure of the artificial system resulted only in poor but safe flying qualities, this would not be too important. In the CF-105 case, however, it could result in breakup of the aircraft.

(4) Artificial Stability System Design:

We do not seem to have had much success in obtaining a clear answer on some questions relating to the basic design of the artificial "damping" system. In order to ensure maximum reliability, there are actually two systems in the aircraft. The hydraulic servos which operate the controls are not duplicated, but the damping system itself consists of a "normal" and a "standby" system. It would appear, however, that the standby system comes into operation in some cases when the normal system has not failed. This is as yet not clear to us. These other cases include any situation (such as one engine failure) which puts asymmetric forces on the aircraft. The switch-over to standby system is done automatically, although the pilot always has the choice of reselecting the normal system. In such cases, however, it would appear that the choice of reselecting would be academic because if the cause of automatic switch-over is not removed, the system would apparently continue to switch to standby. Hence it seems that double emergencies can occur. For example an engine failure may cause the normal stability system to go out of action. The standby, or emergency system is apparently not to be designed to give completely adequate flying characteristics.

Another point here is that the timing of the artificial damping system seems to be lagging considerably. We feel that the design of the system is a very big job indeed, and that it has not progressed far as yet.

(5) Minimum Drag:

A year or more ago this was the area of "hottest" disagreement between Avro and NAE. At that time the Company estimated C_{D_o} .014 at M = 1.5. Since that time the aircraft has been modified in accordance with the supersonic area rule, while at the same time their drag estimation has gone up to 0.022. Our own estimate is not less than .023 and it is because of the similarity of the two estimates that this argument has died down. We still think that both estimates are optimistic, but no great purpose is served in further discussion. $C_{D_{min.}}$ never will be known, probably.

(6) Lift-Dependent Drag in Trimmed Flight:

At the moment this is the "hot" issue. We do not disagree too much with Avro on drag due to lift at zero elevator angle, and we apparently also agree with them on the drag due to elevator deflection, but where we disagree is on the elevator angle required to trim. The main reason is that we disagree on the value of C_m at constant C_L, for Mach numbers above about 1.3. We seem to disagree by about 20% at M = 1.5 and by even larger percentages at high M. The two methods of estimation are basically different, although both are to some extent empirical. Avro's method is to calculate C_m (or C_L) by linearized theory, which is then corrected theoretically for the finite trailing edge angle of the control. They have compared this method with available NACA data and find that it seems to agree with experiment provided the Mach number is greater than 1.4 or 1.5. They use the method to calculate elevator effectiveness for the CF-105 in the range 1.5 M 2.0 and fair the calculation into the Cornell results which do not go above M = 1.23. Their method does not agree with NACA data in the Mach number range up to about 1.5 but it always disagrees in the same direction. It always underestimates C_m or C_L in this range.