Mr. Templin – copy of your notes

C-105
Areas of Interest to NAE

Stability
- Aerodynamic
  - Longitudinal (1)
  - Lateral (2)
- Artificial
  - "Philosophy" (3)
  - Design (4)

Performance
- Drag Estimation
  - Min. Drag (5)
  - Lift-dependent drag in trim condition (6)
- Thrust Estimation (7)

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 rosulted only in poor but safe flying qualities, this would not be too important. In the CF-105 case, however, it could rosult in broakup of the aircraft.

(4) Artificial Stability System Dosign:

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 ordor to ensure maximum roliability, thore are actually two systems in tho aircraft. The hydraulic sorvos 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 systom comes into operation in some cases when the normal systom has not failod. This is as yet not clear to us. These other cases includo any situation (such as ono engine failure) which puts asymmetric forces on the aircraft. The switch-over to standby system is done automatically, although tho pilot always has tho choico of reselecting tho normal system. In such cases, however, it would appear that the choice of reselecting would be academic bocause if the causo of automatic switch-over is not removed, the systom would apparently continue to switch to standby. Henco it seems that double emergencios can occur. For oxample an engino failure may cause the normal stability system to go out of action. The standby, or emorgoncy system is apparently not to be designod to give completoly adoquato flying characteristics.

Another point hore is that the timing of the artificial damping system seems to be lagging considorably. We foel that the dosign 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 tho aroa of "hottest" disagreement botwoon Avro and NAE. At that time the Company estimated C_{D_o} .014 at M = 1.5. Sinco that time the aircraft has been modifiod in accordanco with the supersonic area rule, while at the same time thoir 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 ostimates that this argument has died down. We still think that both estimates are optimistic, but no great purpose is servod in further discussion. $C_{D_{min.}}$ nevor will bo known, probably.

(6) Lift-Depondent Drag in Trimmed Flight:

At the moment this is the "hot" issue. Wo do not disagree too much with Avro on drag due to lift at zero elevator angle, and we apparontly also agree with them on the drag due to elovator dofloction, 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. Wo seem to disagree by about 20% at M = 1.5 and by even larger percentages at high M. Tho two methods of estimation are basically different, although both aro to some extent empirical. Avro's method is to calculato C_m (or C_L) by linearized thoory, which is then corrected thooretically for tho finite trailing edgo angle of the control. Thoy have compared this method with available NACA data and find that it seems to agroe with experiment provided the Mach number is greator than 1.4 or 1.5. They use the method to calculate elevator effectiveness for the CF-105 in tho range 1.5 M 2.0 and fair the calculation into the Cornoll results which do not go abovo M = 1.23. Their method doos not agreo with NACA data in the Mach number rango up to about 1.5 but it always disagrees in the same direction. It always underestimates C_m or C_L in this rango.

Our own method is concerned not so much with absolute values but with the shape of the curves of C_m versus Mach number over the range 1.2 M 2.0. We find that C_m (or C_L) in general varies with M at least as rapidly as $\frac{1}{M^2 - 1}$. Hence our method depends on knowing an end point, and this we have taken to be given by the Cornell data at 1.2. Our method is thus not nearly as sophisticated as Avro's but we feel that theirs does neglect certain factors, such as boundary layer effects and carryover effects on to that part of the body behind the wing trailing edge. There is, as a matter of fact, at least one possibility of bringing the two methods nearly into coincidence. This would occur if the Cornell data in the range M = 1.1 to 1.2 were too low by almost 20%. If this were the case, both methods would give the same result at M = 1.5, and this would result in changing the NAE estimate, not the Avro estimate.

It is somewhat academic to discuss this matter at the present time, since tunnel results will soon be available in the supersonic speed range.

(7) Thrust Estimation:

There is no difference of opinion here. The NAE has not made what could be called an independent estimate. Cleveland tunnel results appear to bear out the Company estimate of pressure recovery, at least.

RJT/JVT
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