Notes on a Meeting to Discuss C-105 Problems at National Advisory Committee for Aeronautics 1512 H Street, N.W., Washington, D.C. December 20 and 21, 1954

1. Present:-

Dr. Hugh L. Dryden, Headquarters, NACA
Mr. John W. Crowley, Headquarters, NACA
Dr. Ira H. Abbott, Chairman, Headquarters, NACA
Mr. M. B. Ames, Jr., Headquarters, NACA
Dr. Charles W. Frick, Ames Aeronautical Laboratory, NACA
Dr. Thomas A. Toll, Langley Aeronautical Laboratory, NACA
Mr. Richard Whitcomb, Langley Aeronautical Laboratory, NACA
Mr. D. D. Wyatt, Lewis Flight Propulsion Laboratory, NACA
Air Vice Marshal J. L. Plant, Royal Canadian Air Force
Group Captain H. R. Foottit, Royal Canadian Air Force
Squadron Leader A. W. Armstrong, Royal Canadian Air Force
Dr. J. J. Green, Defence Research Board
Mr. A. W. R. Gilchrist, Defence Research Board
Mr. F. T. Smye, A. V. Roe (Canada) Ltd.
Mr. J. C. Floyd, A. V. Roe (Canada) Ltd.
Mr. J. A. Chamberlain, A. V. Roe (Canada) Ltd.
Mr. R. N. Lindley, A. V. Roe (Canada) Ltd.
Mr. J. Morris, A. V. Roe (Canada) Ltd.
Mr. J. H. Lucas, A. V. Roe (Canada) Ltd.
Mr. F. A. Woodward, A. V. Roe (Canada) Ltd.
Mr. J. Stalony Dobranski, A. V. Roe (Canada) Ltd.
Mr. R. J. Templin, National Aeronautical Establishment, Canada
Dr. D. C. MacPhail, National Aeronautical Establishment, Canada

2. Drag Coefficient at Zero Lift

2.1 As a result of previous suggestions and drag estimates offered by the NACA, Mr. Chamberlain explained the company had made, during the two weeks prior to the Washington visit, several changes to the CF-105 configuration. These included a sharpening of the intake lips and an extension to the rear fuselage between the tail pipes in order to improve the area distribution. Hence the ensuing discussion of zero-lift drag was based on an essentially different configuration than had been presented previously to the NACA at Langley and Ames.

2.2 At subsonic speeds Mr. Chamberlain estimates that C_{D_0} is equal to 0.009 of which the contribution due to friction is 0.0061.

2.3 At M = 1.5, for which the area rule has been applied to conical sections, Mr. Chamberlain has found it difficult to measure cross sectional areas and to do the computation and finds an uncertainty of 30% to 40% of C_{D_0} due to large local bumps. The work has been in progress for 3 to 4 months of which the last two weeks have been spent on intensive calculations.

2.4 The figures presented at the Ames Laboratory are not the ones presented here. $C_{d_{fr}}$ is equal to 0.0052. C_{D_w} is equal to 0.0142. Due to wave interaction on the final boat tail of the aircraft a contribution of 0.001 has been subtracted leading to a final figure of 0.0184.

2.5 In the Cornell wind tunnel, tests up to M = 1.23 have yielded C_{D_o} = 0.027, a figure which has been corrected for sting interference, duct drag, and change of Reynolds Number from the model test to the flight condition to yield a final figure of 0.016 to 0.018. The figure estimated for the Convair C-102 is C_{D_o} = 0.022 at M = 1.4.

2.6 At the Ames Laboratory the contribution of the wave drag to C_{D_o} was estimated to be 0.0192 instead of the figure of 0.0142 now proposed. This reduction had been brought about in the last two weeks by the cutting and modifying of the various nonstructural fairings, and also by the fact that the previous calculation had been made for a Mach number of 1.2.

2.7 Dr. Frick of the Ames Laboratory remarks that it is not his experience that the drag of intake ramps is taken care of by the area rule. This may add something like 10% and may be a large correction in cases where the normal shock wave is detached. He finds that calculations are good to 5 to 8%.

2.8 Mr. Chamberlain states that he expects to reduce the effect of the enlarged drag curves to the original figures by improvement in the internal ducting.

2.9 Dr. Frick does not consider that the area rule applies physically in cases where the jets cause shock wave interference on the boat tail of the aircraft.

2.10 The NACA are trying to devise techniques for investigating the jet effects on rear fairings such as that between the jets of the C-105 aircraft. In enlarging on the limitations and applicability of the area rule Dr. Frick mentioned that sudden indentations caused thickening of the boundary layer which should then be included in the area rather than the geometrical area, in a way which must be dictated by one's physical estimate of the flow. Dr. Frick emphasized that a model test must be made if one is to see where the shock waves are in order to know where to start the fairings.

2.11 On the above basis the NACA consider that C_{D_o} should normally be multiplied by a factor of 1.1 or 1.2 and that this should be checked by wind tunnel tests. A figure substantially above this indicates that further experimental work is required to achieve the best possible result.

2.12 A. V. Roe propose free flight model tests to check the modifications devised from tests at Cornell.

2.13 The NACA suggest that $C_{D_{o_w}}$ as measured in a 16 inch by 30 inch wind tunnel with fixed transition is likely to be quite reliable - especially for assessing the advantage or disadvantage of modifications. They have found good agreement at reduced Reynolds numbers with the measurement in the eight foot tunnel and on free flight models. In cases where the cleanness ratio is very high, Dr. Frick considers that the adding of area rule components is not reliable and in the case of the C-105 estimated figure, he thinks the cleanness ratio has been overestimated.

2.14 The NACA advise the use of 24 terms in the area rule Fourier series analysis.

2.15 In commenting on the correction of wind tunnel skin friction drag coefficients to the flight conditions on an actual aeroplane, Dr. Toll advised against the correction on a straight Reynolds Number basis because the Langley Laboratory have often found that the improvement in drag coefficient due to increased Reynolds Number on the aircraft is almost exactly offset by imperfections of roughness, of imperfectly fitting doors, antennae, small air inlet and outlet ports, drains, etc.

2.16 Dr. Dryden and Dr. Abbott mentioned that the NACA do not, even in exceptional circumstances, achieve the smooth plate drag coefficient above a figure of $R = 40 \times 10^6$ for the standard of construction which is practicable even for a model.

3. Camber and Wing Configuration

3.1 Dr. Frick emphasized the value of conical camber to give elliptic loading. He finds that the full leading edge suction can be developed up to a Mach number of at least 1.2. There may be a very small penalty for C_L less than 0.075 but it is possible to achieve a substantial gain above. He suggests the use of wing twist to secure a favourable C_{m_0}. He does not like negative camber from an aero-elastic point of view.

3.2 He finds that the linearised theory for conical camber works O.K. and that the effect of leading edge droop is independent of Reynolds number at least from 2×10^6 to 8×10^6, a range which has been tested in the Langley Field 8 foot and 16 foot high speed tunnels.

3.3 He considers that there is little to be gained at $M = 1.5$ and load factor equal to 2 by wing camber, but there is something at subsonic speeds. A. V. Roe propose to cruise out at $C_L = 0.16$ and $M = 1.5$. Since the NACA find that the advantage of camber is greatest for subsonic speeds and $C_L = 0.25$ to 0.30 there is some possibility that a modification of the cruise out requirement, if acceptable to the R.C.A.F., might lead to some saving of fuel and improvement in the other qualities of the aircraft.

3.4 The NACA find that linearised theory is quite satisfactory for the prediction of the $C_L{}^2$ versus C_d and also for the prediction of C_{m_0}. They find that conical camber produces an improvement in the relation of C_D against $C_L{}^2$ up to $M = 0.9$ and when M exceeds 1, i.e. except between 0.9 and 0.95 or 1.

3.5 Although the NACA as well as the NAE have considered the use of canard tails for reducing trimming drag, they find that the shedding of vorticity at angles of incidence makes the vertical surfaces operate in a nonlinear way.

3.6 Dr. Frick emphasized again the NACA findings that drag estimates based on the area rule can be approached only by appropriate and intensive wind tunnel tests.

4. Intake Lips

Although Mr. Wyatt mentioned that some roundness of the lips is satisfactory up to M = 1.5 from the pressure recovery point of view, Dr. Frick strongly advised wind tunnel tests to design the lips. He mentioned that some NACA unpublished data favour thin lips.

5. Internal Ducts

5.1 In order to prevent shock waves at the entry leading to separation of the internal boundary layers, the NACA recommend maintaining the area (with allowance for boundary layer growth) for one or two diameters. They find that with the use of pressure transducers there is enough pick-up noise to show a signal equivalent to 3% of the freestream q so that "buzz" is defined as a pressure fluctuation in excess of 3%. The worst buzz so far encountered is in the neighbourhood of 20% q. The NACA have done tests over a range of 2 to 1 in scale. They find that a pilot's sensation in flight is more sensitive than either instruments or the engine in detecting buzz of this kind.

5.2 They advise against the use of free flight models for buzz investigations and urge the use of wind tunnels and the aircraft itself. Their own tests are normally done on a 1/6 to 1/4 scale, and they suggest the possibility of buying time in the Massachusetts Institute of Technology's supersonic tunnel. Mr. Wyatt thinks that the C-105 duct design is at a good starting point for experimental development.

5.3 The NACA suggest measuring local pressures on the entry for estimating agreement with the area rule.

6. Stability

6.1 Dr. Toll pointed out the use of a high wing aggravates lateral instability unless a much larger fin is put on and he is satisfied that it will require "black box control". Ventral fins are recommended since they are specially effective at high angles of incidence and high speed, i.e. M = 2. In the position of bilge keels these may be practicable from the ground clearance point of view.

6.2 Mr. Dobranski mentioned that at and in the neighbourhood of M = 1, instability if it develops will lead to structural failure of the fin under transverse load.

6.3 Dr. Abbott recommends the use of an analogue computer involving five degrees of freedom to investigate all the manoeuvres that are considered probable in service. If this is not done he points out that aircraft may be broken up during straightforward manoeuvre due to unfavourable and perhaps unknown coupling of some of the derivatives.

6.4 The NACA seem to be in favour of automatic devices to improve gunnery, but they are not inclined to depend on them for safety (except for experimental aircraft). They find little reluctance to adopt devices to improve damping but they warn strongly against the use of "black boxes" for the providing of static stability derivatives.

Continuation of Discussion on Stability, December 21st

6.5 For low subsonic speeds the static stability of the C-105 aircraft appears to be O.K. and the NACA think that the measures taken are essentially the best practicable for this wing. A. V. Roe favour 5% notches and 10% tip extensions, in which the NACA do not see any obvious faults. They do say however that there is likely to be criticism from pilots.

7. Lateral Stability

7.1 Measurements have been made up to M = 1.23 and have been extrapolated above that figure. It is expected that the lateral stability will have disappeared well below M = 2.0. Although A. V. Roe feel that the deterioration in C_{n_β} is due to the shedding of a low energy wake from the canopy or from the engine intakes, the NACA and the NAE consider that the evidence indicates that the loss of lateral stability is due more to vorticity shed over the fin from the canopy and intakes. It is essential that the ducts should have internal flow representative of the operating condition and that the tests on them should be made in a complete wind tunnel, not on isolated ducts as proposed by the firm.

7.2 The NACA recommend also that the effect of the jets on the fin and rudder be looked at closely because they have had some serious trouble on a single engine rocket aircraft with a much under expanded jet.

7.3 They recommend that the rudder effectiveness versus fin effectiveness be checked to see if the trouble at the fin is due to wakes from forward or from sidewash from the canopy and intakes. Mr. Chamberlain remarked that the rudder effectiveness is "reasonably" linear but has a queer wiggle in it, though this is based on only one point. It is nevertheless said to be "reasonably" good.

7.4 Dr. Frick disagrees that the effects are small and Dr. Abbott suggests that part of the trouble is that the coefficient C_{n_β} is too small in all cases and should be improved, and he says that the NACA would take a "dim view" of the characteristics as they stand. Mr. Chamberlain stated however that with the provision of artificial stability, the above is not of significance. At this point Dr. Abbott emphasised that a great deal more wind tunnel work should be done and much of this should be done at low speed. Dr. Toll mentioned the possibility of increasing the effectiveness of the fin by fitting a small end plate at the top.

7.5 At this point Dr. Abbott recommended strongly again that manoeuvres as well as steady flight with small disturbances be investigated on a simulator with 5 degrees of freedom. He recounted the experiences of Mr. Scott-Crossfield in the XS-3 aircraft. Although a number of rolls at 30,000 feet altitude were found to be entirely satisfactory, above a certain angular rate they led to violent yaw and pitch with a normal acceleration of -4½ g quickly followed by +8 g. At lower altitude or higher speed this would have destroyed the aircraft. It was emphasised that this manoeuvre was at low C_L and low M. It was due essentially to too small a figure of C_{n_β}, which was 0.006.

7.6 In combat, or simulated combat, a combination of roll and pitch is very dangerous, and may be brought about by the cross coupling derivatives, and especially by C_{n_β} and by the product of inertia.

7.7 Dr. Abbott again mentioned that extremely low values of C_{n_β} are peculiar to the C-105 type of configuration.

7.8 Mr. Dobranski drew attention to the necessity of limiting sideslip to ±1° for structural reasons, as a requirement of the automatic devices. He had also found that the stability is very sensitive to time lags in the hydraulics and to gain in the proposed servo system.

7.9 Dr. Abbott again replied that the NACA is very conservative about depending on gadgetry for maintaining an aircraft as an "integral unit" for return in level flight. In spite of the SX-3 trouble, C_{n_β} was the equivalent of 3 times (referred to the C-105 wing) the value of that on the C-105. Inertia and C_{n_β} are the most important cross coupling terms. It is very difficult with any configuration to get large enough and satisfactory C_{n_β}.

7.10 The wind tunnel work should include measurements of C_M against β with and without ailerons deflected.

7.11 Dr. Abbott strongly advocated a complete stability analysis (with measurements of six components) as used to be done at low M. This must be done, however, over the whole Mach number range.

7.12 Mr. Floyd's summing up took place at this point.

7.13 Finally Dr. Abbott remarked that all configurations do not require automatic stabilization as this one does.

7.14 A.V.M. Plant thanked the NACA for their outstanding help and cooperation.