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SUBJECT HIGH-ALTITUDE PERFORMANCE DATA FOR THE C-105 AIRCRAFT

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SUMMARY

This note presents the high-altitude performance data for the C-105 supersonic fighter aircraft in terms which will permit performance and interception studies to be carried out on an analogue computer. Four sets of data are included to allow for existing differences between Avro Aircraft Limited and the Aerodynamics Section of the National Aeronautical Establishment in the aerodynamic assessment of the aircraft, and also for uncertainties with regard to the centre of gravity position of the aircraft during combat.

1.0 INTRODUCTION

Reference 1 presents reasonably simple equations of motion for the performance of a turbojet aircraft in three dimensions in the stratosphere. The object of the present study was to provide the characteristic Mach number functions for the C-105 aircraft involved in the solution of these equations on an analogue computer. In collaboration with DRB/CARDE, who originally requested these data, it was decided to work out four sets of values to allow for discrepancies in aerodynamic estimates existing between Avro Aircraft Limited and the Aerodynamics Section, and also to provide for the effect of changes in the location of the centre of gravity of the aircraft.

In order to expedite these data to DRB/CARDE, this note does not include any description on how the values were obtained. The term "Pessimistic Values" pertains basically to the estimates obtained by the Aerodynamics Section whereas the term "Optimistic Values" is used for the values obtained fundamentally from Avro data. The forward centre of gravity position (28% M.A.C.) is somewhat forward of the position presently used by the Company for combat performance calculations (29.5% M.A.C.), but should not be considered unrealistic without fuel scheduling since the possibility of a forward shift of the centre of gravity limits may be necessary to assure good longitudinal handling characteristics during landing. The rearward position (34% M.A.C.) probably represents the extreme aft limit with optimum fuel scheduling and may be prohibitive from the point of view of directional stability.

2.0 REQUIRED MACH NUMBER FUNCTIONS

Following the notation used in reference 1:

With minor changes, the "energy height" equation presented therein is:

$$\frac{dh}{dt} + \frac{a^2}{2g}\frac{d(M^2)}{dt} = \left[f_T(M) - f_1(M)\right]\sigma(h) - f_2(M) \times n - \frac{f_3(M)}{\sigma(h)} \times n^2 \qquad (1)$$

$$\text{where } f_T(M) = f_T = C_T \frac{\rho_0}{2}\frac{S}{W} a^3 M^3 \qquad (2)$$

$$f_1(M) = f_1 = C_{D_0}\frac{\rho_0}{2}\frac{S}{W} a^3 M^3 \qquad (3)$$

$$f_2(M) = f_2 = K_1 aM \tag{4}$$

$$f_3(M) = f_3 = \frac{K_2}{\rho_0/2 \; aM} \frac{W}{S} \tag{5}$$

(Note that an error was made in reference 1 in that $f_3(M)$ is proportional to wing loading rather than to $(W/S)^2$.)

The values of these functions for various Mach numbers and for an aircraft weight of 50,000 lb., are presented in Table I. The thrust functions f_T are obtained from reference 2 and are given for full reheat and no reheat. Note that conversion to any other aircraft weight is readily obtained since f_T and f_1 are inversely proportional to weight; f_2 is independent of weight and f_3 is directly proportional to weight.

3.0 LOAD FACTOR LIMITATIONS

In addition to structural load factor limitations and pilot blackout limits, the aircraft is load factor limited by $C_{L_{max}}$ (stall and buffet), maximum elevator deflection and maximum available elevator hinge moment. At high altitudes these latter three limitations are the governing ones and in order to simulate the actual performance of the aircraft, the load factor in equation (1) must be kept within the boundaries defined by these limitations. Generally, the $C_{L_{max}}$ limitation govers at subsonic and low transonic speeds, the elevator deflection governs at high transonic and low supersonic speeds and the maximum available elevator hinge moment governs at the higher values at supersonic speeds.

It can be shown that these limitations can be expressed in the following forms:

1. Limitations due to stall or buffet and maximum elevator deflection:

$$n_{max} = \sigma(h)\, f_L(M) \tag{6}$$

2. Limitations due to maximum available elevator hinge moment:

$$n_{max} = f_{HM_1}(M) + \sigma(h) f_{HM_2}(M) \tag{7}$$

The values of the functions $f_L(M)$, $f_{M_1}(M)$ and $f_{M_2}(M)$ are presented in Table II. Since $f_L(M)$ is determined by $C_{L_{max}}$ at low speed and by maximum elevator deflection at higher speeds, this function is discontinuous and the values pertaining to the point of intersection of the two limitations are presented at the bottom of Table II in the row denoted by f_{L_D}.

Both of the above load factor limitations are inversely proportional to aircraft weight.

4.0 REFERENCES

1. Templin, R.J. — The Problem of Representing the High-Altitude Performance of a Turbo-Jet Aircraft on an Analogue Computer. N.A.E. LM AE-82, 12 June 1956.

2. Avro Aircraft Limited — CF-105 Monthly Performance Report No. 8, May, 1956.

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VALUES OF THE VARIOUS MACH NUMBER FUNCTIONS FOR THE C-105 AIRCRAFT

TABLE I

Thrust and Drag Functions

Mach No.	Full Reheat	No Reheat	Pessimistic Values					Optimistic Values				
				28% c.g.		34% c.g.			28% c.g.		34% c.g.	
M	f_T	f_T	f_1	f_2	f_3	f_2	f_3	f_1	f_2	f_3	f_2	f_3
0.50	460	218	50	-39.2	39.0	-33.2	30.5	40	-37.6	36.5	-31.5	29.4
0.80	942	541	198	-56.9	24.2	-48.5	19.0	155	-55.9	22.6	-46.8	18.2
0.90	1,157	682	280	-62.0	21.3	-53.0	17.0	214	-60.0	20.1	-51.1	16.3
1.00	1,396	850	566	-69.8	20.7	-59.7	16.4	504	-72.9	19.7	-61.8	15.8
1.10	1,690	1,041	987	-88.4	23.3	-74.1	17.5	889	-94.8	21.2	-78.3	16.2
1.20	2,048	1,250	1,318	-101.3	24.5	-83.3	17.8	1,109	-117.0	24.9	-95.6	18.0
1.40	3,085	1,700	2,028	-129.4	28.0	-102.7	19.2	1,694	-139.8	22.9	-111.0	16.1
1.60	3,930	2,170	2,786	-108.7	28.4	-86.5	19.1	2,501	-169.2	22.2	-132.5	15.2
1.80	4,800	2,580	3,730	-60.0	27.0	-50.7	17.6	3,513	-193.2	21.4	-149.6	14.4
2.00	5,530	-	4,990	-38.2	24.0	-33.4	15.3	4,780	-217.5	21.9	-166.5	14.4

TABLE II

Load Factor Limitations

Mach No. M	Pessimistic Values						Optimistic Values					
	28% c.g.			34% c.g.			28% c.g.			34% c.g.		
	f_L	f_{HM_1}	f_{HM_2}	f_L	f_{HM_1}	f_{HM_2}	f_L	f_{HM_1}	f_{HM_2}	f_L	f_{HM_1}	f_{HM_2}
0.50	6.8			6.8			6.8			6.8		
0.80	12.3			12.3			12.3			12.3		
0.90	12.2			12.2			12.2			12.2		
1.00	13.7			13.7			13.7			13.7		
1.10	16.0			21.6			18.7			21.6		
1.20	15.8	4.26	2.70	22.5	6.55	4.15	17.6	4.45	2.73	25.1	6.90	4.22
1.40	16.9	3.33	3.39	24.0	5.04	5.14	20.4	4.00	3.75	30.1	6.45	6.09
1.60	18.7	2.93	2.40	27.0	4.46	3.64	23.9	3.70	4.74	35.8	6.06	7.75
1.80	20.6	2.58	0.77	30.7	3.90	1.16	27.6	3.33	5.57	41.8	5.46	9.14
2.00	24.2	2.25	0.05	36.8	3.44	0.07	30.8	2.84	6.22	46.6	4.60	10.06
f_{L_D}	16.5 @ M = 1.05			23.1 @ M = 1.12			19.2 @ M = 1.08			25.0 @ M = 1.15		