

A. V. ROE CANADA LIMITED ...

TECHNICAL DEPARTMENT (Aircraft)

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P/WIND TUNNEL/9

C.A.L. TESTS - SEPT. 1953

COMPARISON OF ESTIMATES WITH WIND TUNNEL RESULTS

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J.A. Chamberlin	Sept. 11/53.
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1 SUMMARY

AIRCRAFT: C 105

Wind tunnel tests of the Avro C-105 were conducted in the 3' x 4' transonic throat of the Cornell variable Density Wind Tunnel to confirm the predicted performance estimates which were based on the use of a small amount of negative wing camber to reduce the elevator drag in flight at high altitudes. The basic drag, the longitudinal stability and the effect of camber were in excellent agreement with the estimates. The elevator effectiveness, hinge moments and drag were found to be more favorable than had been anticipated by a substantial margin. It is hence concluded that these tests have confirmed the validity of the assumptions used in estimating the performance and established the basic soundness of the configuration.

2 INTRODUCTION

R.C.A.F. Spec. AIR 7-3 (1) calls for a design study of a supersonic fighter meeting the detail requirements laid down therein. One of these requirements is that the serodynamic data on which the study is based be confirmed by wind tunnel tests. Accordingly, tests were conducted in the 3' x 4' transonic threst of the Cornell Variable Density Wind Tunnel from Aug. 27 to Sept. 2 on a model of the configuration which was selected by the R.C.A.F. (as the one which best met their requirements), on the basis of the data given in Avro Design Study Report No. P/C105/1 (2).

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2 INTRODUCTION (Continued)

AIRCRAFT: C 105

This report gives a summary of the results of these tests and compares them with the data used in the Design Study (2). It was pointed out in that study that one of the major features of the design was the use of negative wing camber in order to reduce elevator angles required at high altitudes and hence the elevator drag. Furthermore, it was made clear that adequate test data on which to base the effectiveness of camber did not exist and that information on elevator drag was not altogether satisfactory. The purpose of these tests was to resolve these matters, as well as to confirm the other data on which reasonably satisfactory information was already in existence.

"3 WOORT

The model was made to .03 scale for sting mounting in the 3' x 4' transcnic throat of the Cornell Variable Density Wind Tunnel. The sircraft dimensions are given on the general arrangements shown on sheet 1.9. The model was of metal construction and noused specially designed strain gauge balances within the fuselage. A free passage for air was allowed within the fuselage between the engine intake ducts and the jet notable. Two wings were made for the model; one without camber, and one campered the required amount. Only the uncambered wing was fitted with elevators. The elevator on the port side was fitted with strain gauges for measuring hinge moments.

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AIRCRAFT: C 105

.3 MODEL (Continued)

The transonic throat of the tunnel is of a type specially developed by Cornell and employs suction through the porous walls of the working section to avoid choking and incidently to avoid all tunnel constraint corrections as well as interference from reflected shocks. The present throat was originally intended as a model to establish the design requirements for modifications to the entire working section of the tunnel. However, the model has proved so successful that it is being used extensively for routine testing pending the development of the full scale throat. This will require some time, since the suction requirements are so large that special equipment will have to be provided, having a capacity greatly exceeding that of the two J 35 jet engine compressors which are used to provide suction for the small working section.

4 RESULTS

The results have been reduced to coefficient form and are compared with estimated values on the graphs given in sections II to IV of this report. The basic data from which the coefficients were derived is contained in Ref. 3.

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AIRCRAFT: C 105

5 DISCUSSION

5.1 Longitudinal Stability

5.1.1 Aerocantre

Figure 2.1 shows excellent agreement between the test and estimated positions for the aerocentre. This confirms that c.g. limits assumed are reliable. The effect of camber on this is not appreciable, as was expected.

5.1.2 Lift

The slope of the lift curve with incidence as obtained from test agrees well with the estimates as shown on Sheet 2.2. Furthermore it has been shown on Sheet 5.1.1 of ref. 3 that the low speed $C_{L_{max}}$ is in good agreement with estimates and is not affected by camber. The C_{L} 's at higher speeds were not extended above about 0.7. There was no evidence of stalling or buffeting with this range, which was more than adequate to achieve the estimated manoeuvre envelope.

5.1.3 Camber Effectiveness

The effect of camber on C_{M_O} is shown on Sheet 2.3. It can be seen that the cambered wing gives a C_{M_O} that is in very good L, agreement with the estimate. In view of the scanty evidence on which the estimate was based, this is extremely gratifying. The fact that there is not as high a peak as estimated between M = 1.0 and 1.2 is very favorable. The agreement elsewhere should assure the validity of the previous estimates.

A. V. ROBRIGATION LIMITED MALTON ONTARIO TECHNICAL DEPARTMENT (Aircraft) AIRCRAFT: C-105 A. V. ROBRIGATION LIMITED REPORT NO. P/Wind Tunnel/9 1.5 SHEET NO. PREPARED BY DATE CHECKED BY DATE

5 DISCUSSION - Cont'd.

5.2 Longitudinal Control

5.2.1 Elevator Effectiveness

The elevator control characteristics are compared with the estimates on sheets 3.1 and 3.2 in terms of lift effectiveness & point of application of the lift respectively. These two elements are combined to give the moment effectiveness on Sheet 3.2.2 which is the primary criterion of longitudinal control. This shows that the experimental effectiveness is considerably better than the estimate below M = 1.13. Above this it is inferior. However, the experimental curve can be smoothly extrapolated to agree with the estimates above about M = 1.5.

How can Since estimated values above this speed are believed to be very they be when all experimental reliable, this seems a very reasonable extrapolation.

evidence plus

It is of very considerable interest to note that the

frecey is violated

effectiveness is linear with elevator deflections up to 30° through

the transonic region.

On the basis of these results the trim troubles near

M = 1.0 should be greatly alleviated by the very high effective
ness in this region, while the slight deficiency between M = 1.13

and M = 1.5 is not felt to be very serious, especially since its

effect will be alleviated by the fact that the aerocentre does

not move back as much as was anticipated between these Mach numbers,

and the hinge moment coefficients are lower than estimated as

noted below.

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AIRCRAFT: C 105

.5 <u>DISCUSSION</u> - Cont'd.

.5.2 Longitudinal Control

.5.2.2 Elevator Hing Moments

The elevator hinge moment coefficients are shown on Sheets

3.4 and 3.5. They are considerably lower than was forecast.

This will permit increased manoeuvrability since the maximum hinge moment that can be developed is limited by mechanical considerations

.,5.3 Drag

3,5.3.1 Basic Drag

The values of C_{D_O} given on Sheet 4.1 are in good agreement with the estimate. However the wind tunnel values cannot be considered as particularly reliable in this case, since a correction equal to about one third of the measured drag has to be applied to allow for internal flow in the ducts and for the base drag of the sting. These corrections must be estimated on the basis of a somewhat inadequate pressure measurement in the model, and hence may be subject to considerable error. The correction should not vary appreciably with C or C, so that the above reservations about the accuracy of the drag data apply only to the values of C

The induced drag efficiency factor "e" is shown on Sheet
4.2. This is slightly higher than expected at Mach numbers over
0.8. This will result in slightly lower drag at high altitudes.

1.5.3.2 Elevator Drag.

The elevator drag coefficients are given on Sheets 4.3 and

4.4. It can be seen from Fig. 4.3 that the variation of profile.

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5.5. <u>DISCUSSION</u> - Cont'd.

35.3 Drag

%.5.3.2 Elevator drag - Cont'd.

drag with elevator deflection is considerably below the estimate based on wind tunnel tests and tends more to the values obtained from rocket propelled models. The effect on the induced drag can be seen from Fig. 4.4 to be very much less than that obtained from any source previously.

This should result in a substantial reduction in the elevator drag over those used in the previous estimates which were based on N.A.C.A. wind tunnel data.

5.4 Effect of Revnolds Number

To asses Reynolds number effects, two runs were made at M = .9 at R.N. = 1.5 x 10 and 3.4 x 10^6 . Detailed results are presented in Ref. 3 Section VI. They show that the influence of Reynolds number is negligible. This is substantiated further by the fact that the present results are on the whole in excellent agreement with predictions based chiefly on free flight rocket propelled model data usually obtained at Reynolds numbers of the order of 20×10^6 .

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CONCLUSIONS

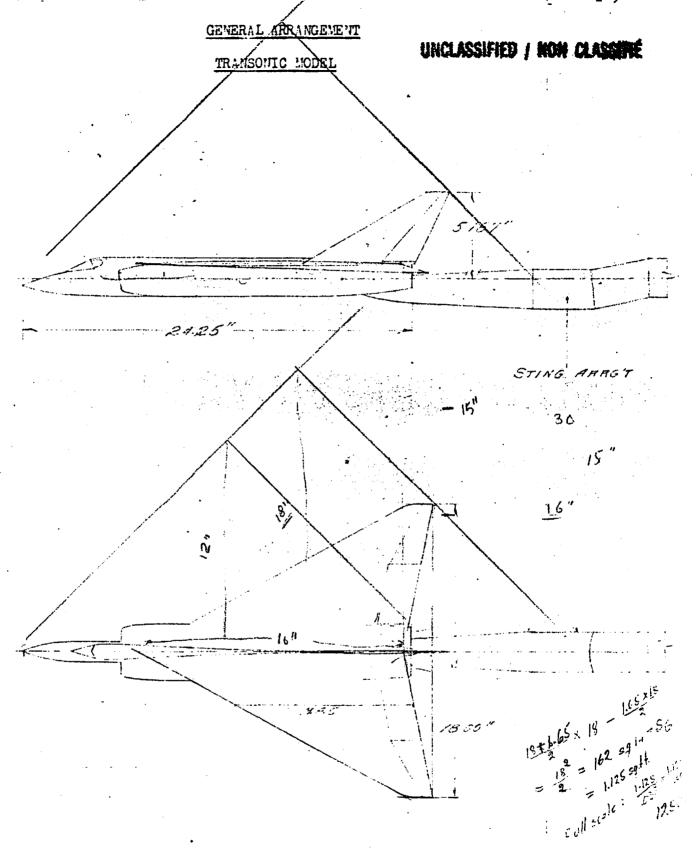
AIRCRAFT: C105

The comparison of data obtained from the transonic wind tunnel test of C-105 at Cornell Aeronautical Laboratories Inc. with the original estimates of aerodynamic characteristics indicate that:

- (1) Longitudinal stability will be entirely satisfactory and is very close to the estimate.
- Manoeuvrability will be better than expected in the entire Speed Range notably at low speed and high subsonic speeds.
- (3) Ferformance will be appreciably better than estimated.
- (4) Cornell Transonic Wind Tunnel is an excellent experimental tool, and will be of great use in the further development of the project: the data obtained being in close agreement with free flight high R.N. rocket tests.

REFERENCES

- (1) R.C.A.F. Spec. AIR 7-3 Design Studies of Prototype All-Weather Interceptor Aircraft - Issue 1, May 1953.
- (2) Design Study of Supersonic All-Weather Interceptor Alreraft - Avro Report No. P/C-105/1
- (3) Avro Report No. P/WT/7 C.A.L. Tests Sept. 1953 -Corrected Plots.



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C-105

LONGITUDINAL STABILITY DERIVATIVES AND DRAG DATA

3.5% WING

Measured in C.A.L. Wind Tunnel up to M = 1.23.

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Reference No: P/GEOM/33.

WING

AREA 1225.0 ft.

MAC 30.2177 ft.

ÿ 9.0136 ft.

VERTICAL TAIL (V3)

AREA 158.792 ft.

MAG 13.534 ft.

5.278 ft.

ELEVATOR

AREA 53.541 ft. each

RMS Chord 5.250 ft.

AILERON

AREA 33.276 ft. each

RMS Chord 3.504 ft.

RUDDER

AREA . 38.168 ft.²

RMS Chord . 3.950 ft.

N.B. Wing dimensions are projections on the horizontal. Control surface dimensions are projections on the chord plane.

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C-105 LATERAL STABILITY DERIVATIVES

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•) Cho	V8	Mach No.	1.4
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N.B. Derivatives in sections 1 to 4 measured in C.A.L. Wind Tunnel up to M = 1.23.

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SEE NAE . 07 MODEL

TEST PERIOD II AND III

PURPOSE

These tests were a continuation of the low speed tests started in test period I. The following lateral and longitudinal characteristics were investigated: effects of undercarriage with and without ground effect; effect of open canopy in yaw; rudder and aileron effectiveness with and without ground effect; the effect of rudder in yaw, the ailerons in yaw and control interference; and the effects of tanks and dive brakes.

CONFIGURATION

The model configurations used during these tests were as follows:

B₃ - area rule body (B₂) with 300 nose cone

 v_1 - fin with separate rudder

W₁ - 3½% cambered wing.

E₁₀ - 10% extended leading edge outboard of transport joint of wing.

N₅ - 5% deep wing transport joint notch.

D₈₋₄ - 60 leading edge droop inboard of notch, 40 droop outboard of notch.

U₁ - nose undercarriage reversed

U - undercarriage.

Co - open canopy - closed canopy otherwise understood.

T - fuselage tank

S - speed brakes.



AURO	AIRCRAFT LIMITED	SHEET NO	TONNEL/119
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.07 Scale Model	WIND TUNNEL TESTS	-	0.

The ground board was located at .465 b/2 and .7 b/2 from a point .09c below the MAC at .27c.

CONTROL DEFLECTIONS

Test Period II

Elevator: -10, 0 Aileron: 10, 0

Rudder: -6, -4, -2, 0, 2, 4, 6, 10, 15, 20, 30

Test Period III

Elevator: -20, -10, 0

Aileron: -20, -15, -10, -5, -2, 0, 2, 5, 10, (both)

Aileron: -20, -15, -10, -5, 5, 10 (right only)

Rudder : 0, 15, 20, 30.

SPEED RANGE

Mach number = .21, Reynolds Number = 3.1 x 100 and Mach number = .27, Reynolds Number = 4.0 x 106

BASIC PLOTS

The curves in this report were based on the data obtained in Runs 55 to 123 (Test Period II), and 124 to 181 (Test Period III). The plots included are listed in the index by section number and sheet number.

Corrections have been applied to account for wall and blockage effects. However, since all of these tests except Runs 175 to 181 were made using the single strut support, for which no inverted or dummy runs could be obtained, strut tare and interference effects were not included. For this reason most of the plots in this report are labelled "uncorrected". Strut tare and interference corrections were estimated from the earlier twin strut data and applied to some of the curves, especially longitudinal data, but there was some doubt as to the validity of these corrections for the lateral data. Curves giving the estimated strut tare and interference corrections that can be applied to the curves are included at the end of CONFIDENTIALS.

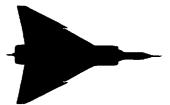
	REPORT NO P/WIND TUNNEL/11		
, MALTO	DEPARTMENT	SHEET NO	iii
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		CHECKED BY	DATE
.07 Scale Model	WIND TUNNEL TESTS		

The nose undercarriage configuration U_1 was obtained inadvertently, and the tests were repeated with the proper congiguration (U) for those conditions where the nose undercarriage was effective, e.g., basic runs in yaw. Where the effect of the reversed nose undercarriage were not predominant the U_1 data was utilized.

The data were reduced to .280 on the M.A.C., and .280, .310, and .350 at 8 inches above the fuselage datum but only the data for .280 on the M.A.C. has been completely plotted.







CONFIGURATIONS OF MODERS USED IN WIND TUNNER TESTS,

B3 - AREA RULE BODY (B2) WITH 30 HOSE CODE,

VI - FID WITH SEPARATE RUDDER

WI - 31/2% CATIBERED WING

E,O - 10% EXTENDED LEADING EDGE OUTBOARD OF TRANSPORT JOINT OF WING

M5 = 5% DEED, WING TRANSPORT JOINT WOTCH,

DB-4 = 8° DROOP INBOARD LEADING EDGE
4° DROOP OWBOARD LEADING EDGE

U, - MOSE U/C REVERSED

U - UNDERCARRAIGE RS

Co- OPEN CANOPY

T - FUSELAGE TANK

SB- SPEED BRAMES.

F - FAIRED INTAMES

W - 31/2% WING - CAMBERED

RS - RUDDER SEALED





YPS - UNCAMBERED WING SOME MODELS USED.

Aug 1954 - B'W3 V2 B'W4 V2 B'W5 V2 B'W6 V2

B' = B3 C3 R5

W3: NO DOTCH

W4= 61/2% NOTCH

W5= 8% NOTCH

W/6= 10% NOTCH

JULY 1954 - B'W/5 Y2 TI

TI FUSELAGE TANK

AUG 1954

B3 C3 R5 W/5 V2 B3 C3 R5 W/5 V2 B3 C3 R5 W/4 V2

Wy - 5% EXTENSION

W/8 - 8% EXTENSION

W/9 - 10% EXTENSION

CATTER HA Eg NAG.5

NA 8

NA 7.5

VA 5