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PROJECT 'Y'

UNLIMITED

Preliminary Programme and Data for Low-Speed Wind Tunnel Tests

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December 18, 1952.

Dr. Green

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SECRET

A. V. Roe Canada Limited
Malton, Ont.
December 18, 1952.

PROJECT 'Y'

Preliminary Programme and Data for Low-Speed Wind Tunnel Tests

1. INTRODUCTION

This note outlines a preliminary plan for carrying out low speed tests on a 1/14 scale model of the A. V. Roe Canada Project 'Y' aeroplane in the N.A.E. wind tunnel at Ottawa.

The basis of the Project 'Y' design is the mating of a very large air-breathing engine with a small aeroplane. At tunnel speeds, for instance, the maximum mass flow through the engine is of the order of one quarter of the mass flow over the aeroplane; that is the mass flow theoretically washed down to produce lift. Hence the flow through the engine may well have a profound effect on the aerodynamic quantities to be measured in the tunnel and it is essential to try to simulate it at small scale.

The exhaust can be near-simulated by air flow. However, in view of the difficulty of designing a model to both suck the intake and blow the jets simultaneously it is suggested that the best method will be to try and separate the effect of jet efflux and intake flow. The jet, extending around most of the wing periphery, is probably much the most important. The proposed model, therefore, omits the intakes altogether and caters for a jet flow provided by a compressed air supply. It is hoped to introduce a 1/10 scale half-model to evaluate the intake effect and make surface pressure recordings, as a next step.

2. EQUIPMENT

At 1/14 scale the maximum mass flow required is about 1015/196 = 5.2 lb./sec. weight of air. This condition very nearly represents the maximum net thrust, but does not represent the maximum gross thrust.

Because of the large demand it is obviously impracticable to provide for a continuous flow. The scheme proposed is to use a 200 cu. ft. air receiver working at 100 psig and pump it up between test runs. If the normal compressed air supply at the N.A.E. is unable to cope with this extra demand a 500 cu. ft./min. portable air compressor unit may be brought in. This scheme is illustrated by the drawing in the rear pocket SK21056.

If the compressor is necessary then both it and the air receiver may be stationed outside and a large supply pipe bring the air in through a constant pressure valve and possibly also a flow regulator, through a heat exchanger and up to the balance platform; to feed into a 2" 1/D pipe from balance to model with a quick-acting on-off cock at the junction. Model chamber pressures would be continuous trace recorded in parallel with the standard wind-tunnel recorders. It may be possible to control the flow with the on-off cock.

A special head to the single support Balance Scheme has been designed so that air can be directed straight into the centre of the model.

3. AIR SUPPLY SYSTEM FOR SUBSONIC MODEL

The variable reducing valve will maintain any specific settling chamber pressure. With a heat exchanger inserted in the system, a constant total temperature in the delivery pipe is maintained.

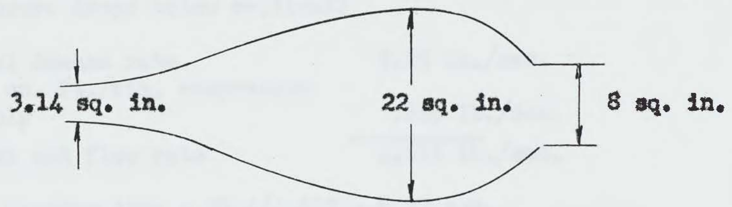
Area of pipe entering the model = 3.14 sq. in.

Area of jet nozzle = 8 sq. in.

Maximum pressure required in settling chamber for choked flow through jet nozzle = 14.7 x 1.9   28 psia.

Allowing 2 psi for friction the required maximum chamber pressure = 30 psia.

The flow through the model is schematically shown below.



The extreme condition of the nozzle will be that of choked condition requiring an approximate 30 psi model chamber pressure. The weight flow through the nozzle for this condition is:

$$W = \frac{57.15 \times p_o \times A^*}{T_o} = \frac{57.15 \times 28 \times 8}{16.97 \times 144} = 5.25 \text{ lb./sec. (air)}$$

The following mass flows will be considered:

(a) 5.25 lb./sec. (choked)
(b) 4.0 lb./sec. (unchoked)
(c) 2.0 lb./sec. (unchoked)
(d) 0

(a) Choked Condition W = 5.25 lb./sec. (air)

Minimum pressure, po, required to deliver the above flow through a 2" I.D. pipe

$$= \frac{W \times T_o}{57.15 \times A^*}$$

$$= \frac{5.25 \times 16.97 \times 144}{57.15 \times 3.1416}$$

$$= 72 \text{ psig}$$

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3. (a) continued

.... 72 psig

Pressure drop across reducing valve and in large supply pipe etc. = 10 psi

Pressure drop through 3 ft. of 2" pipe (see below) = 4.8 psi

14.8 psi

Critical pressure in air receiver 86.8 psig

Weight of 200 cu. ft. of air at 115 psig at 288°C = 119.8 lb.

Weight of 200 cu. ft. of air at 86.8 psi at 288°C = 90.4 lb.

Net out flow (before receiver pressure drops below critical) 29.4 lb.

Model demand rate 5.25 lb./sec.

500 cu. ft./min. compressor supply .635 lb./sec.

Net out flow rate 4.615 lb./sec.

.'. Running time = 29.4/4.615 = 6.37 sec.

Also, thrust $= \frac{WV}{g} = \frac{5.25 \times 1018}{32.2} = 166$ lb.

For this condition with a "settling chamber" temperature of 288°K jet velocity ratios are as follows:

Wind tunnel speed f.p.s.	Vj f.p.s.	Vj/Va
0	1018	
100	"	10.18
175	"	5.81
250	"	4.07

Pressure drop in 2" pipe:

The above figure of 4.8 psi drop is arrived at, as follows: (Sec. "Flow of fluids through valves, fittings and pipe" by Crane Ltd., p.82)

$$\triangle P_{100} = \frac{0.000336\, f\, W^2\, \bar{V}}{d^5}$$

where $\triangle P_{100}$ = pressure drop per 100 ft. run, psi.

f = friction factor = 0.0158 from charts.

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continued ....

where R_e = Reynolds No. = $6.32\ W/d\mu$ = 3.1×10^6
μ = Viscosity = 0.018 centipoise

W = Weight flow = 19,000 lb./hr.
V = Specific volume = 2.62 cu. ft./lb.
d = Inside dia. of pipe = 2.0 in.

ΔP_{100} = 158 psi
Hence pressure drop per ft. $\simeq$ 1.58 psi

3. (b) Unchoked condition W = 4 lb./sec.

Assume as for (a), flow being regulated by an orifice size
pressure = 72.0 psi
temperature = 288°K

$$\text{Orifice size} = A^* = \frac{W\sqrt{To}}{57.15\ po} = \frac{4 \times 16.97}{57.15 \times 72}\ \text{sq. ft.}$$

= 2.375 sq. in.

Running time = 29.4/(4.0 - 0.63) = 9 sec.

Model chamber pressure

Discharge of free air, q_s = 3150 cu. ft./min.

q_s/a_t = 3150/8 = 394 cu. ft./min./sq. in.
a_p/a_t = 22/8 = 2.75

From fig. 2(b) approach factor F_v = 1.08
Corrected q_s/a_t = 394/1.08 = 365
From fig. 2(a) upstream pressure = 6.5 psig

Jet Velocity

$\rho AV = 4.0$
$\rho V = 4.0/\rho A$ fps

where ρ = density lb./cu. ft. A = area sq. ft.

$$\rho = \frac{P}{RT} = \frac{1.5P}{T}\ \text{(P in psi)}$$

Assuming ΔT due to velocity = 17.5°C (615 fps)

$$= \frac{1.5 \times (14.7 \times 6.5)}{288 - 17.5} = 0.1172\ \text{lb./cu. ft.}$$

A = 8/144 = 0.0565 sq. ft.

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continued ....

Hence V = 4.0/0.1172 x 0.0565 = 605 fps

Velocity ratios are:

Tunnel Speed fps	Vj/Va
100	6.15
175	3.51
250	2.46

Net thrust = 75 lb.

3. (c) Unchoked condition W = 2.0 lb./sec.

Similar calculations to (b) give:

Running time	21.6 sec.
Upstream pressure	1.6 psig
Jet velocity	415 fps
Velocity ratio at 250 fps	1.66
Net thrust	26 lb.

4. PLAN FOR TESTS

The diagram on Figure 2 illustrates a suggested plan for test observations. It is drawn up in terms of lift co-efficient observations; simultaneous observations of drag and moment co-efficients are implied.

A minimum number of angles of attack would be tested, the model being mounted on a series of adaptors, one for each angle. It is suggested that 9 points at the end conditions with fewer points at the intermediate flows will be sufficient. Also only one or two points are presumably sufficient for the flaps down cases.

It will, however, be necessary to evaluate conditions to unusually high incidence. Preliminary runs will show how far to go. It is suggested that 60° is a likely maximum.

The above series of tests are designed to cover the effects of:

1. Reynolds number,
2. Mass flow ratios,
3. Velocity ratio,
4. Flap deflection,

over the full range of incidence up to the fully "stalled" condition in the subsonic region.

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FIG. 1 (a)

REF FLOW OF FLUIDS ~ CRANE HANDBOOK (p. 86 TABLE 5.)

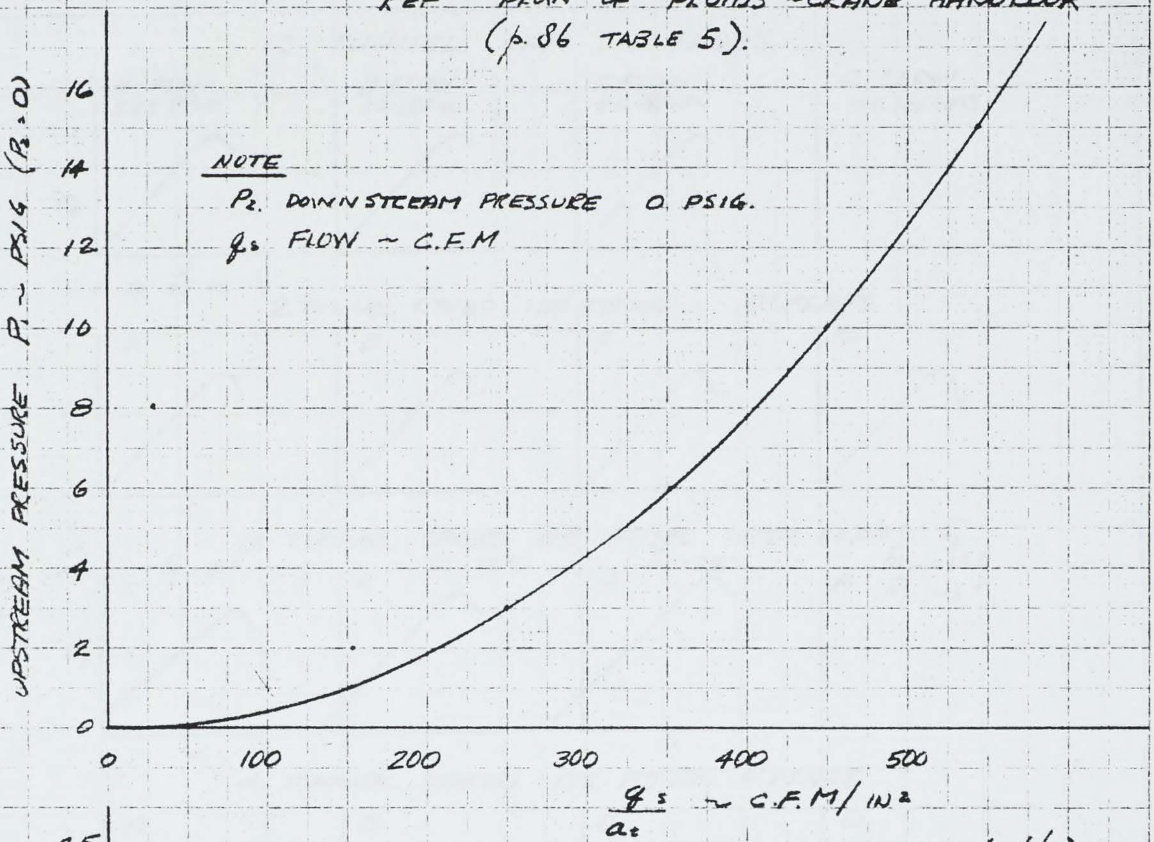

FIG 1 (b.)

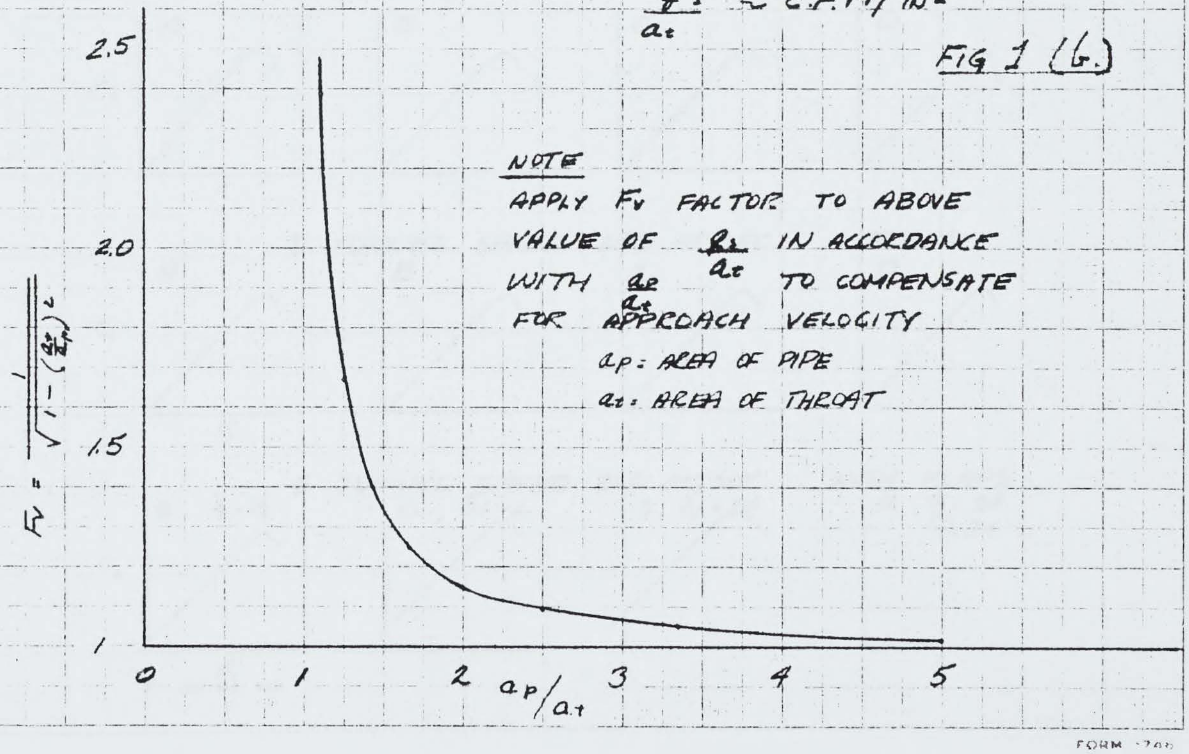

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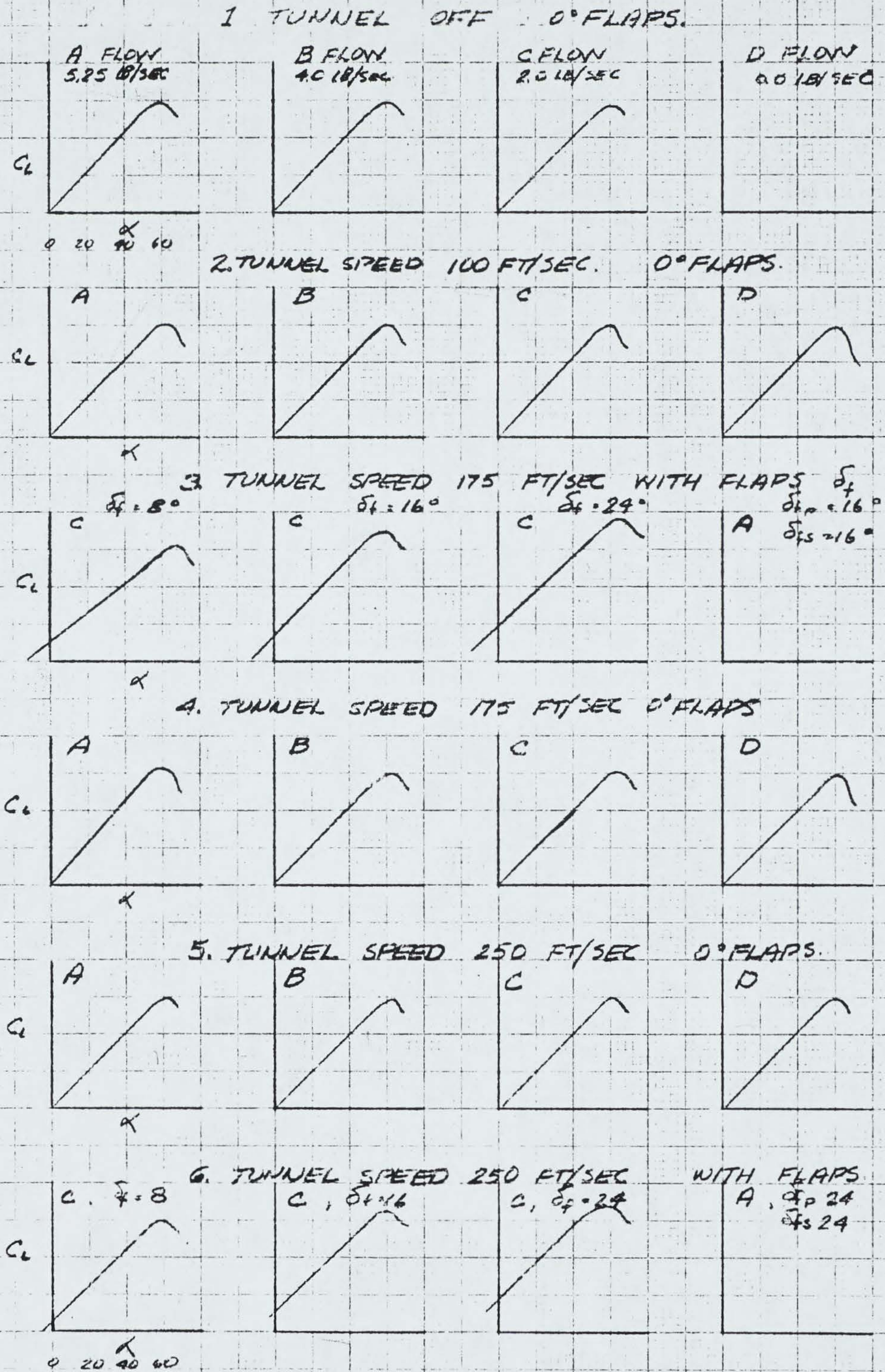
FIG. 2



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