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A. V. ROE CANADA LIMITED

MALTON - ONTARIO

TECHNICAL DEPARTMENT (Aircraft)

AIRCRAFT: CF-105

REPORT NO. P/POWER/66
Abstract

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ABSTRACT FROM P/POWER/66
C105 BUZZ THRESHOLD
PRATT & WHITNEY J-75
ORENDA IROQUOIS

PREPARED BY W.B. McCarter DATE August/56.

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FORM 1316A

AVRO AIRCRAFT LIMITED
MALTON ONTARIO
TECHNICAL DEPARTMENT

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INDEX

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INTRODUCTION

At free stream Mach numbers greater than 1.76 the normal shock wave off the inlet lip separates the ramp turbulent boundary layer. This wedge-shaped separated region induces a lambda shock wave which at low inlet mass flow ratio becomes unstable.

A fluctuating static pressure within the duct results, which is defined as buzz.

DISCUSSION

The commonly accepted criterion for buzz threshold has been that the contact surface (sometimes called slip plane) coming off the intersection of the ramp oblique shock wave and the lip normal shock interacts with the turbulent boundary layer on the duct wall. This boundary layer separates choking off the duct flow, the normal shock moves upstream with explosive velocity spilling the excess air around the lip. The contact surface moves out into the turbulent duct flow giving relief from the interaction on the duct wall. The duct mass flow can then increase but contact is again made between the slip plane and duct wall and the cycle begins anew.

High speed film shows the above mechanism at work. In the case of the C105, however, it is the lambda shock fluctuation, as described in the Introduction, which gives rise to buzz. At low duct flows the fluctuation reaches explosive proportions where the normal shock itself oscillates. It is the slip plane from the intersection of the two feet of the normal shock which interacts with the duct wall triggering the final violent movement of the whole shock structure.

It is interesting to note that the value of free stream Mach number of 1.76 giving a ramp surface Mach number of 1.33 and thus a static pressure rise of 1.89 through the normal shock wave agrees exactly with the criterion for turbulent boundary layer.separation of report NACA E51L26.

From the 1/6 scale tests at Lewis Laboratory, Cleveland, the buzz threshold can be ascertained. This threshold is defined as the engine mass flow, in subcritical operation, for which the duct static pressure amplitude of fluctuation is 20% of the free stream total pressure. This is synonymous with the final violent movement of the whole shock structure as described above.

SYMBOLS

m	mass flow
mo	mass flow within the capture area
α	trimmed aircraft angle of attack
M	Mach number
T	total temperature
t	static temperature
Q(M)	function of Mach number: $M \left(1+ \frac{\gamma-1}{2} M^2\right)^{\frac{2(\gamma-1)}{\gamma+1}}$
P	total pressure
p	static pressure
γ	ratio of specific heats for air 1.400
W	gross weight of the aircraft
C.G.	aircraft centre-of-gravity
$\bar{\bar{C}}$	mean aerodynamic chord 30.218 ft.
A	area
AB	bypass inlet throat area
Aev	ramp bleed exit vent area
Ai	inlet throat area (5.60 sq.ft. for J-75 (6.00 sq.ft. for Iroquois
Acapt	capture area, the projected area of the inlet lip including the ramp 10.18 sq.ft.

SUBSCRIPTS

∞	free stream
e	engine
i	inlet
SL	sea level

METHOD OF ANALYSIS

A complete analysis,(figure 5) Ref. P/Power/65, was done at the Lewis Laboratory for what was anticipated to be the final configuration incorporating the J-75 jet engine. Unfortunately, only one test joint is available for the 90 sq.in. ramp bleed exit vent area case, to which we were subsequently limited, Ref. P/Power/69. We have bodily displaced the curves of figure 5 by the difference in mass flow for buzz between the two configurations occurring at this one test point.(Mach 2.0, α =0) i.e. $\Delta m/m_o$ = .038.

The windmilling mass flow of the J-75 has been given by Pratt & Whitney in a letter dated October 26, 1955, as follows:

$\frac{m\sqrt{\theta}}{\delta}$	M
0	0
12	.2
35	.5
77	.8
147	1.1
242	1.4
362	1.7
530	2.0

where $\theta = \frac{t_\infty}{t_{SL}}$

$\delta = \frac{p_\infty}{p_{SL}}$

To correct for duct total pressure recovery, use is made of the Pressure Recovery ~ Mass Flow Ratio curves of figure 6, Ref. P/Power/65,(the decrease in ramp bleed exit area had no effect on pressure recovery, Ref. P/Power/69, coupled with negligible angle of attack effect, Ref. P/Power/65), where:

$$\frac{m}{m_o} = \left(\frac{m\sqrt{T_o}}{P}\right) \frac{65.8}{\delta\, A_{capt}\, Q(M_\infty)}$$

$$= \left(\frac{m\sqrt{\theta}}{\delta}\right) \frac{p}{P} \sqrt{\frac{T_\infty}{t_\infty}}\ \frac{\sqrt{t_{SL}}}{p_{SL}}\ \frac{65.8}{\delta\, A_{capt}\, Q(M_\infty)}$$

Simply join a line from the value given here for 100% pressure recovery to a point at some lower value of pressure recovery (the variation of m/mo with P_c/P_∞ is linear) and where it crosses the pressure characteristic lines is the required value of m/mo and P_c/P_∞.

Superimposing the above value of m/mo (corrected for shock & duct loss) on the buzz threshold curve of figure 5 gives the flight Mach number and angle of attack for which the C105 is cleared for windmilling mass flows. Superposition, in turn, of this curve on the trim angle of attack curves of P/Control/78 gives the limiting Mach number at altitude for representative aircraft G's as shown on Figures 1 to 3.

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METHOD OF ANALYSIS (Continued)

Similarly for idling mass flows, as given in the Pratt & Whitney Engine Brochure for the J-75, the method follows exactly the outline as given above for windmilling mass flows.

For the Iroquois, the windmilling mass flows were given in a note dated March 28, 1956, as follows:

M_∞	$\frac{m\sqrt{T_o}}{P}$
1.0	76
1.2	98
1.4	117
1.6	131.2
1.8	140.6
2.0	144.7
2.2	146.1
2.4	145.3

The total corrected inlet mass flow is found from the method outlined in P/Power/51 in conjunction with the Pressure Recovery - Mass Flow Ratio Curves of figure 8. These were derived from the Cleveland tests with the J-75 configuration extrapolated for the enlarged throat required for the Iroquois jet engine. Buzz is assumed to occur at the same total inlet mass flow.

The idling mass flows for the Iroquois installation are governed by flame-out limitations and are sufficiently high that superposition on the buzz threshold curves of figure 7 finds the curve well outside the range of test variables. That is, there is no problem at idling r.p.m. within the complete projected flight range of the C105.

CONCLUSIONS

For the J-75 configuration as presently conceived, at the typical high speed cruise altitude of 50,000 ft., the C105 will clear in level flight a flight Mach number of 1.81 for windmilling mass flows and 1.875 for idling mass flows.

For the Iroquois installation at 50,000 ft., the C105 will clear a flight Mach number in level flight of 2.11 for windmilling mass flows and some undetermined Mach number well above the range of test variables to date for idling mass flows.

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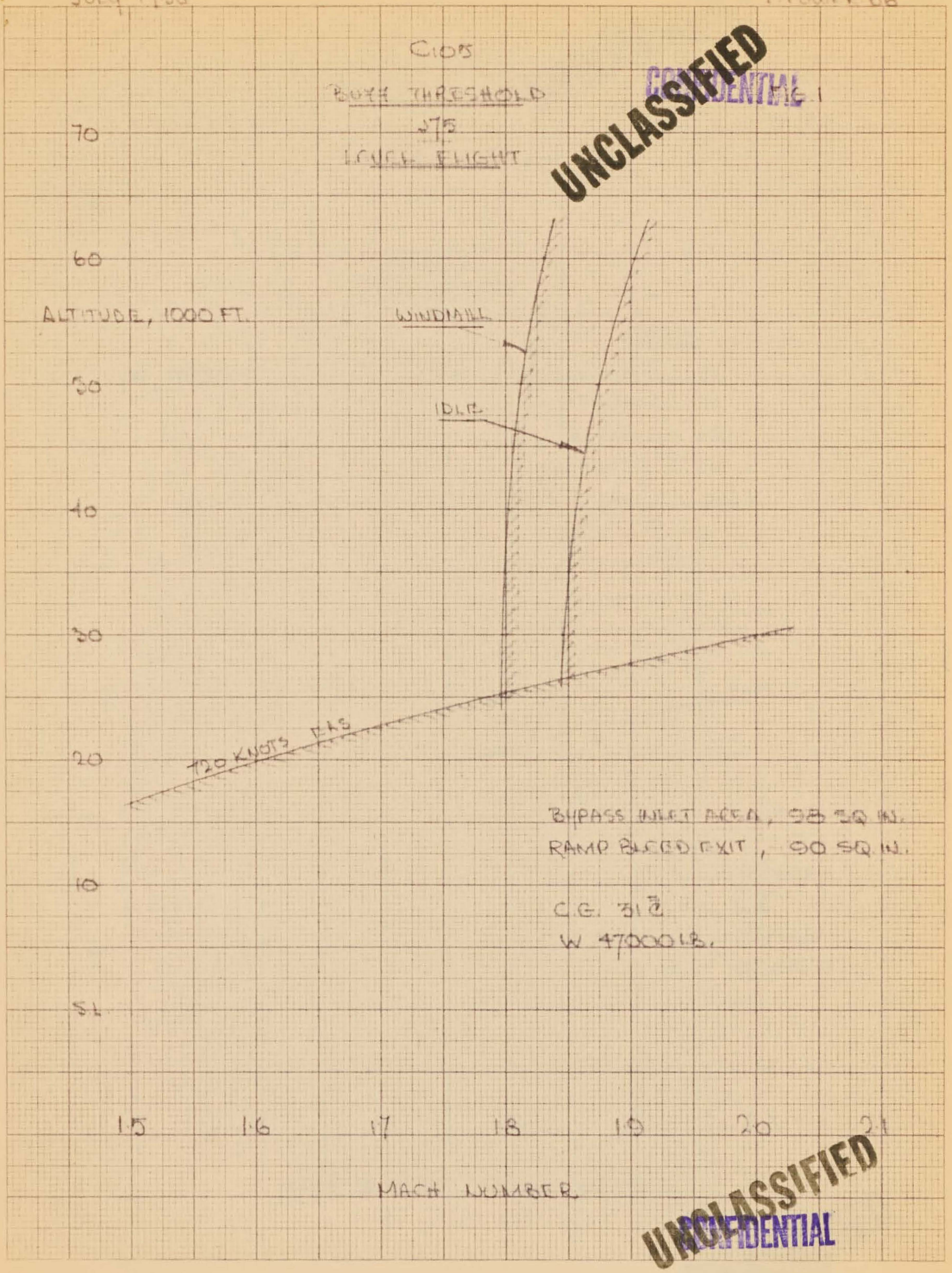
8
July 1956

F. Powell 66



9
Aug. 56

Power 66

C105

FIG 2.