Engineering Notes

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Scaling of VTOL Aerodynamic Suckdown Forces

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THIS note presents a comparison of some of the aerodynamic suckdown results obtained in a recent full-scale VTOL ground-proximity effects investigation with the results from small-scale tests presented in Refs. 1 and 2. For the purpose of this comparison, a single jet issuing from the center of a square plate attached to the nozzle exit was selected (see Fig. 1). The ratio of the plate area to the jet area, A_p/A_j, was 142 for both the full-scale test and the small-scale tests.

In the full-scale test, the jet was produced by the exhaust of a J-85 turbojet engine issuing from a 11.8-in.-diam nozzle. The temperature of the exhaust gas ranged from approximately 900° to 1200°F. In the small-scale tests of Refs. 1 and 2, the nozzle exit diameters were nominally 4.4 and 1.0 in., respectively, and were supplied by air at approximately ambient temperature.

Figure 2 shows the variation in thrust ratio T/T_0 (defined as the ratio of the installed thrust in ground effect to the momentum flux of the isolated jet) with the nondimensional height of the plate above the ground plane, H/D, for a nozzle pressure ratio of 1.45. Data from the full-scale test and the small-scale tests of Ref. 2 are presented along with an empirical equation based on a rigorous correlation of the data of Ref. 1 in which the effects of A_p/A_j, plate planform shape, nozzle pressure ratio, and jet Reynolds number were successfully correlated for numerous single-jet configurations. For the case of a square plate with a centrally located jet, the

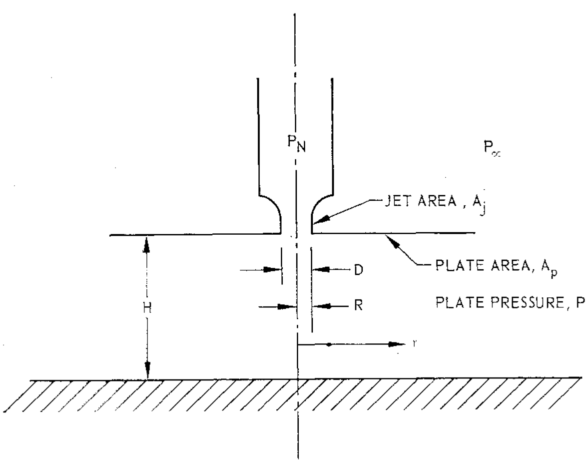

Fig. 1 Test configuration and nomenclature.

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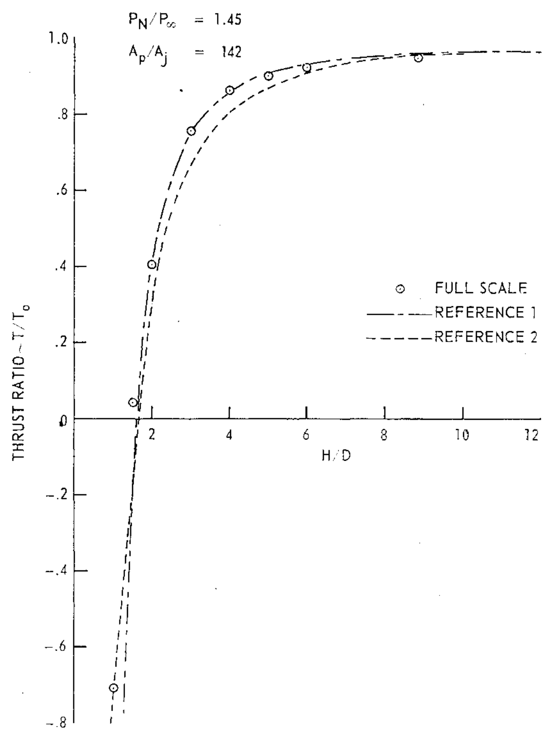

Fig. 2 Thrust ratio as a function of H/D.

empirical equation of Ref. 1 reduces to

$$\frac{T}{T_0} = \frac{T_{H/D=\infty}}{T_0} - 0.012\left(\frac{H/D}{0.994\,(A_p/A_j)^{1/2} - 1}\right)^{-2.30}$$

The full-scale values of T/T_0 shown in Fig. 2 were obtained from integration of the measured pressure distribution over the plate area along with the calculated value of jet momentum flux based on the measured nozzle pressure ratio. On the other hand, the data of Ref. 2 and the empirical correlation from Ref. 1 were obtained from direct thrust measurements, although pressure distributions were also measured in the tests of Ref. 2. The data from Ref. 2 have been reduced by 2% to reflect the "base loss" difference in the reference thrust T_0 used in this note compared to the reference thrust T_∞ (installed thrust out of ground effect) adopted in Ref. 2.

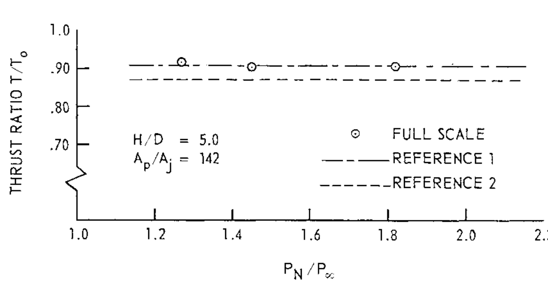

Fig. 3 Thrust ratio as a function of nozzle pressure ratio.

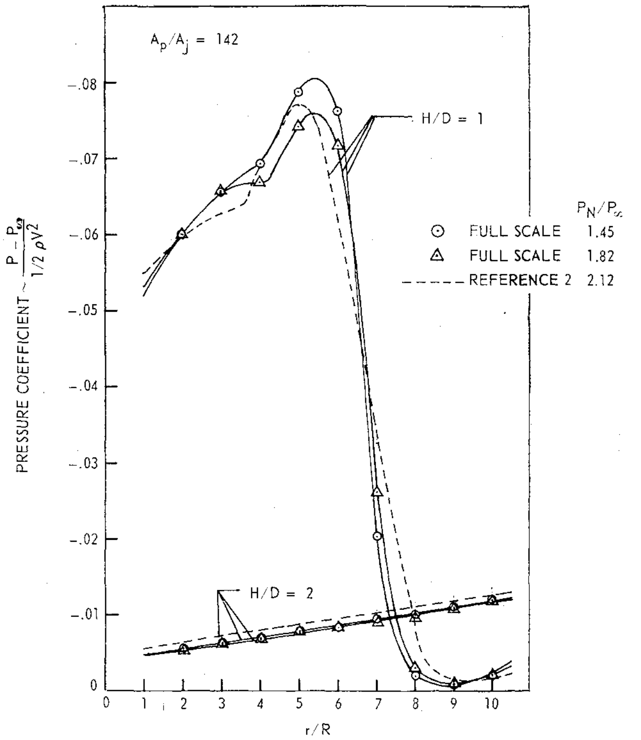

Fig. 4 Plate pressure distribution.

The value of 2% for the base loss was obtained from the experimental data of Ref. 1 for $A_p/A_j = 142$.

From Fig. 2 it is seen that the thrust loss data of the full-scale test are in excellent agreement with the generalized correlation curve of Ref. 1 in the range of practical values of H/D for VTOL aircraft (say $H/D \gtrsim 2$). On the other hand, the small-scale data of Ref. 2 indicate higher values of thrust loss than those of the full-scale test. Figure 3 shows a similar relation between the data of the full-scale test, Ref. 1, and Ref. 2 in demonstrating the independence of thrust ratio with nozzle pressure ratio.

Figure 4 shows the plate pressure distributions obtained from the full-scale test and from Ref. 2. The reference for the pressure coefficient is taken as the jet dynamic pressure $\frac{1}{2}\rho V^2$ rather than $P_N - P_\infty$ as in Ref. 2. As a result, the data correlation becomes independent of pressure ratio. The pressure ratio independence when correlated with $\frac{1}{2}\rho V^2$ rather than $P_N - P_\infty$ follows from Fig. 3, which shows the invariance of thrust ratio with pressure ratio. The data of Fig. 4 show close agreement between the pressure distributions of the full-scale tests and those of Ref. 2.

In summary, it would appear that valid aerodynamic suckdown data applicable to full-scale vehicles can be obtained from small-scale tests with cold jets for single-jet (or closely spaced multiple-jet) configurations. It should be pointed out, however, that extension of the foregoing conclusion to include multiple split-jet configurations is a dangerous extrapolation due to fundamental differences in the flow phenomena between split-jet and single-jet configurations, and therefore cannot be made on the basis of the data presented in this note. Finally, it would appear that the small-scale data correlation of Ref. 1 is an excellent representation of aerodynamic suckdown for full-scale configurations of the same family evaluated in Ref. 1.

References

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[2] Spreeman, K. P. and Sherman, I. R., "Effects of ground proximity on the thrust of a simple downward-directed jet beneath a flat surface," NACA TN 4407 (September 1958).

Response of Bare Wire Thermocouples to Temperature Variations in a Jet Engine Intake

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Introduction

Recent full-scale VTOL exhaust gas ingestion tests performed by Norair and others have indicated engine inlet air temperature histories of a highly transient character for many of the configurations tested. Considering the transient character of these data, highly responsive thermocouples are required to reproduce the actual temperature transients experienced within the inlets. In general, however, thermocouples of a small enough thermal mass to follow the actual temperature transients are costly to fabricate and may not withstand the hostile vibration and acoustic environment within an engine inlet. Considering these practical factors, along with the generally large number of thermocouples required to define the inlet temperature fields for multijet configurations, it may be necessary to accept a temperature pickup which compromises the desired thermal response.

Depending upon the particular objective of the investigation, damped thermal response may or may not represent a serious compromise in the test objective. For instance, for determining the thrust degradation resulting from exhaust gas ingestion for a particular airplane configuration, measurements of short-duration temperature pulses of the order of a few msec are not required because of the relatively slow adjustment of the engine to changes in inlet temperature. For evaluations of this type, some damping of the instantaneous temperature field is acceptable; in fact, there may be some merit to matching the response of the temperature readout circuit to the response of the engines for experimental correlations of this type.

On the other hand, for configurations in which exhaust gas ingestion is severe enough to result in engine stall caused by sharp localized temperature pulses within the engine inlet, undamped measurements of these temperature pulses are obviously important. This means selection of a highly responsive temperature pickup and a recorder with response equal to or greater than that of the temperature pickup.

Although in the foregoing an example is pointed out for a case in which instantaneous temperature determination is not important and for a case in which instantaneous temperature determination is important, it is not the purpose of this note to discuss what one should be measuring, since there is no unique answer to this question. Rather, the purpose of this note is to aid one in the selection of a particular temperature pickup once the desired response is established, or, if the desired response results in wire gage too fine to withstand the environment, to provide data from which the actual response may be determined so that the data may be interpreted accordingly. If in following the latter course, one feels that the instantaneous temperature is highly important, it is still possible to reconstruct the actual input temperature history, given the output temperature history and temperature pickup response characteristics. This can be accomplished by use of compensating amplifiers either directly in the

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