power of velocity at low speed but with the eighth power of velocity at high speed. At that time those results were attributed to rough burning and other engine noise, but it would seem quite possible that the turbojet engine with which they were dealing possessed a turbulence level, at the exit of the turbine, sufficiently high to make the noise source we are now considering more pronounced than that of the conventional type with its dependence on the eighth power of exhaust velocity.

At the present time, this question would seem to have a particular relevance, since the turbulence levels at the nozzle exit are bound to be increased by the current trend to engines of high bypass ratio. When turbine capacities are made large enough to drive the powerful compressors that propel bypass flows, there will be a corresponding increase in the turbulence level. We see then, that there could be an important change-over in the mechanism of jet-noise production at low exhaust speeds, speeds that might be well within the range currently considered for operational aircraft. The change-over and its possible control have not been studied at all. Its significance poses an exciting new field of study that promises to be relevant to the modern jet-noise problem.

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A Miniature Strain-Gage Balance for Hypersonic Force Measurements

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1. Introduction

A MINIATURE strain-gage balance capable of measuring forces as small as 0.001 lb has been constructed at the U. S. Naval Ordnance Laboratory. A balance of this sensitivity is needed to measure the model forces in the Naval Ordnance Laboratory (NOL) Hypersonic Tunnel 4, which operates at Mach 17.5 with a supply pressure of about 100 atm. The useful testing diameter is 6 in.

The balance is an internal, three-component, water-cooled device that measures the aerodynamic force and the center of pressure of models to be tested under hypersonic flow conditions. Because of its small size, the balance is a measuring device particularly attractive in test facilities where space is at a premium. This note presents a brief description of the balance and some of the experimental results obtained with it.

2. Description of Balance

The strain-gage balance measures the axial component of the aerodynamic force and the pitching moments about two points on the model axis, the latter giving the normal component of the aerodynamic force and its location.

A schematic view of the balance and a typical cone model is shown in Fig. 1. The sting, balance, and water jacket are an integral unit. The balance is approximately 2.3 in. long and 0.6 in. in diameter at the base. The cooling water flows through the sting to and from the balance via four metal

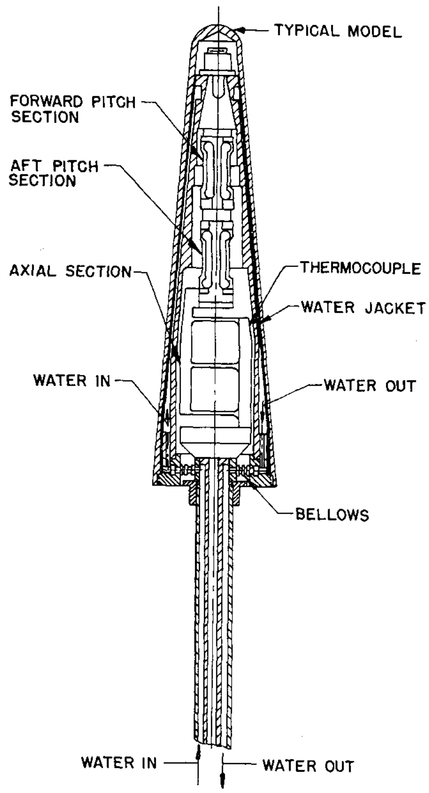

Fig. 1 Schematic view of balance and cone model.

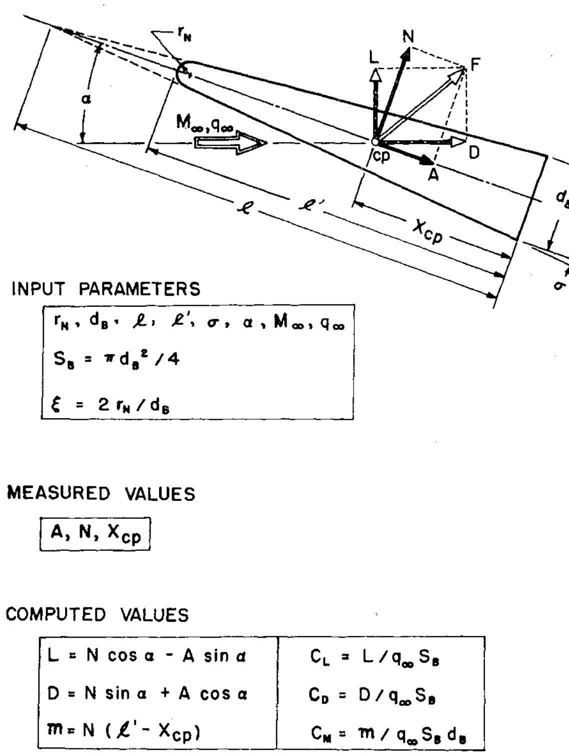

Fig. 2 Cone model geometry and nomenclature.

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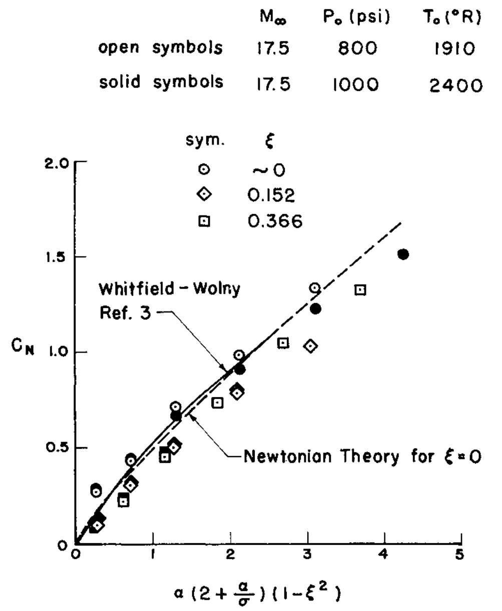

Fig. 3 Correlation of normal force coefficients.

bellows of 0.062 in. o.d. × 0.040 in. i.d. × 0.0003 in. wall thickness. Screw threads at the base of the balance allow the attachment of interchangeable models.

The axial section of the balance has three flexures. The foil strain-gages are mounted on the center flexure to reduce the pitch-on-drag interaction. The pitch sections are of the eccentrically loaded column type with the forward and the aft gages spaced longitudinally about 0.5 in. apart. An iron-constantan thermocouple is mounted on the axial section so that the effect of balance temperature on balance response can be accounted for.

Tests indicate that the balance can measure forces from 0.001 lb to 0.06 lb with an accuracy of ±0.0002 lb. A detailed description of the balance is given in Ref. 1.

3. Test Results Obtained with Cone Models

Tests were made with 10° cones of tip bluntness ratios ξ up to 0.366 (see Fig. 2 for cone geometry and nomenclature).

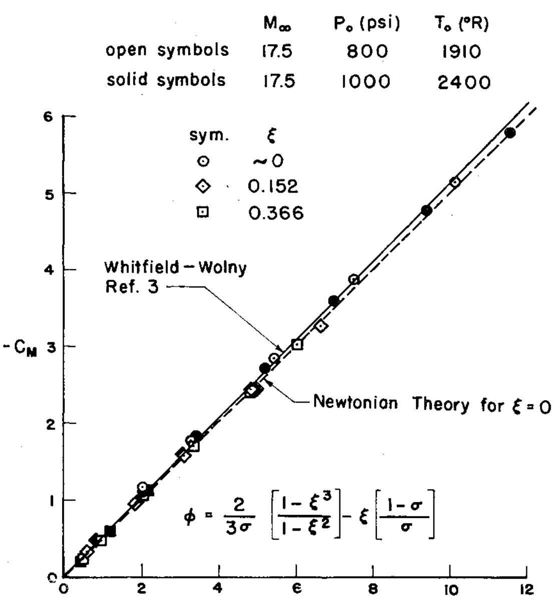

Fig. 4 Correlation of pitching moment coefficients.

The cones all have a base diameter of 0.656 in. and are 3.75 in. long when measured from the vertex. A series of force measurements has been carried out with angles of attack varying from 0° to 30°. These tests were performed in NOL Hypersonic Tunnel 4 that uses nitrogen heated by a graphite resistance heater as the test gas.[2] The gas is expanded to a test Mach number of 17.5 through a $9\frac{1}{2}°$ conical nozzle. The Reynolds number based on the length of the cones is about 25,000.

In Figs. 3 and 4 the normal force and pitching moment coefficients are correlated in terms of the parameters suggested by Whitfield and Wolny.[3] The pitching moment is defined as the moment about the nose (stagnation point at $\alpha = 0°$). The wall temperature of the cones was about 700°R for all the test results.

Since the tests were mainly for the purpose of checking out the balance, they were run at rather low supply temperatures of 1900 to 2400°R in order to extend the lifetime of the graphite resistance heater. At these temperatures the theoretical static temperature in the test section was below the condensation threshold, but no difficulties with condensation appeared to be present in the experimental results. Tests with higher supply temperatures will be reported on later.

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Sensitivity of Flow Visualization Methods at Low-Density Flow Conditions

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THE advantages of direct flow visualization methods using schlieren and interferometer techniques are obvious, provided that the differences in flow density to be visualized are large enough. Since the latter condition may not be fulfilled in some low-density hypersonic flows, sensitivity limits of optical methods for visualizing weak shock waves at low gas density conditions have been investigated (e.g., Refs. 1 and 2). Reference 2 also contains theoretical considerations for the schlieren-interferometer system. The experimental results, however, may be restricted by the quality of the respective optical systems. In this note an attempt is made to analyze theoretically the sensitivity limits for two interferometer systems and the schlieren method.

First of all, the fundamental difference between the interferometer and the schlieren methods has to be emphasized. The first method is sensitive to absolute differences in gas density, whereas the latter is sensitive to density gradients. This restricts the general validity of the results given in Refs. 1 and 2. The interferometer is capable of visualizing an ideal shock of zero thickness, whereas the schlieren method cannot detect an ideal shock with infinite density gradient. The visualization of a shock wave with the schlieren method is

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