Engineering Notes

Trailing Cone Static Pressure Measurement Device

PAUL A. IKHTIARI* AND VERLYN G. MARTH†
Douglas Aircraft Company, Inc., Long Beach, Calif.

A new method for calibration of airspeed and altitude systems and measurement of free air static pressure of an aircraft in flight is presented. The detail design of the trailing cone static pressure reference system is shown, and the operational characteristics of the system are reviewed. Use of the device as a flight test tool may reduce the cost and complexity of testing where free air static pressure is required on an aircraft.

DURING aircraft flight test and evaluation, it is necessary to develop and calibrate the aircraft static pressure source used as reference for airspeed and altitude. In many other specific tests, such as performance measurement, altitude separation studies, long wave gust spectra definition, on board air data computer evaluation, etc., there is a requirement to have an accurate, readily usable, minimum error static pressure source available to an airplane in flight.

Several standard methods have been developed by industry, NASA, and the services for calibration of airspeed and altitude measurement systems and for determination of free air ambient pressure at an airplane's flight altitude. In common use are tower fly-bys, speed course runs, flights with trailing bomb extended, radar and Askania tracking at high altitude and high Mach number, pacing, and smoke-trail fly-bys. These techniques are practical and useful, but all have specific operational and accuracy limitations, and most are expensive in terms of flight time costs and auxiliary equipment requirements.

In June of 1959, the Douglas Flight Test Group at Edwards Air Force Base originated a novel concept for obtaining a near-zero error static pressure source for use by an aircraft in flight. Theoretical studies indicated that the static pressure field surrounding an aircraft in flight reverts, for all practical purposes, to atmospheric pressure within a few wing or tail chord lengths behind an aircraft. It also can be shown that orifices in an infinite-length cylindrical tube at zero angle of attack records static pressure accurately. It was reasoned that, if a relatively long length of tubing could be made stable by the drag of a nonlifting body and trailed behind the aircraft at a small angle of attack, an entirely new method of airspeed calibration could be made available.

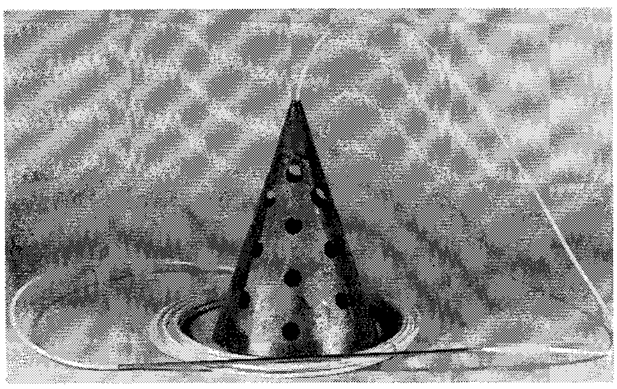

Fig. 1 Douglas trailing cone system.

Received November 4, 1963.

* Flight Test and Research Engineer, Flight Test, Aircraft Division. Member AIAA.

† Chief of Advanced Plans and Support Section, Flight Test, Aircraft Division. Member AIAA.

An experimental device incorporating these principles was designed, fabricated, and flight tested on an A3D aircraft with very encouraging results. It consisted of a 130-ft length of tubing that could be extended and retracted from the tail of the aircraft using a simple reel. The tubing was stabilized by a drag cone. Since the cone and tubing assembly was relatively light in weight compared to the drag at operating speed, the forces on the cone also served to restrict the local angle of attack on the tubing to a small angle. At a distance forward of the cone apex sufficient to avoid influence of the cone's positive pressure field, a symmetrical pattern of flight static pressure orifices was provided. The static pressure was passed to the aircraft test instruments through the hollow tubing.

Later the design was extensively refined to make it a relatively dependable, inexpensive, and accurate test tool. A configuration was established that had small static pressure error and was stable and structurally sound over a large airspeed range. The final design is shown in Fig. 1. The drag body consists of a 35° total angle, perforated cone fabricated from fiberglass. The tubing is $\frac{1}{4}$-in.-o.d. nylon material with a 0.10-in.-i.d. static pressure passage.

Drag loads are carried by a high-strength steel wire installed inside the tubing. Static pressure errors induced by orifice hole distortions and local tubing "waviness" are avoided by incorporation of a steel insert in the tubing at the static pressure pickup location.

The device shown has been flown and calibrated on five aircraft models from 65 to 550 knots equivalent airspeed and has been flown transonically at approximately 30,000-ft altitude. Within this speed range it has shown excellent stability unless placed in separated wakes such as that which exists behind speed brakes, and in some aircraft configurations full flaps. The device has yielded the calibration curve shown in Fig. 2. Generally, accuracy is such that errors measured during calibrations are sufficiently small that there is a question whether the cone system is being calibrated by a given technique or vice versa. Shown superimposed upon the low-speed portion of the graph is a line indicating the pressure error equivalent to 10 ft of altitude at sea level. The data generally fall within this curve, indicating that the cone system accuracy is equivalent to scatter that may be expected from the best airborne instruments used in pressure measurements.

One interesting technique used in cross checking the trailing cone system calibration results (derived from tower-pass and trailing bomb tests) consisted of surveying the pressure field

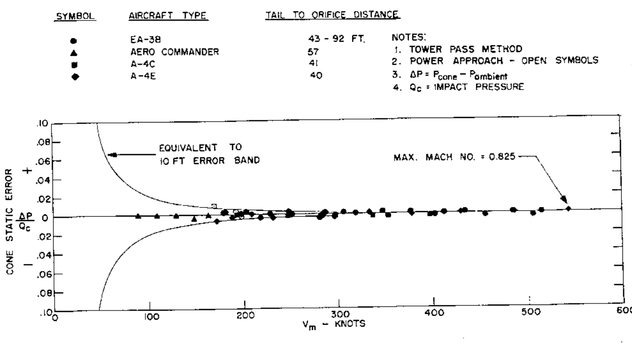

Fig. 2 Douglas trailing cone airspeed calibration.

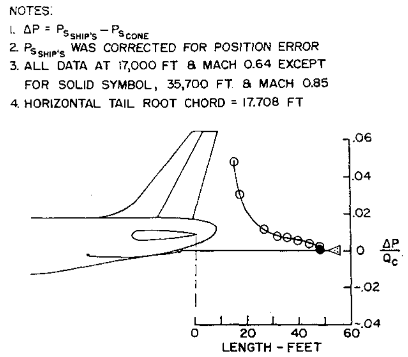

Fig. 3 Variation of $\Delta P/q$ with static tubing length on DC-8 aircraft.

behind the aircraft at constant airspeed and representing as true zero pressure the value that is asymptotically approached as a limit as the cone is extended. Figures 3, 4, and 5, showing the results of these surveys, are presented both as an indication of cone static system performance and as fundamental data concerning the extent of the pressure field of an aircraft in subsonic free flight.

In normal use the trailing cone is assumed to be a zero static pressure error source. The most desirable method for measuring static error for airspeed system static source development or calibration, is simply to use an accurate differential pressure gage or manometer between the cone source and the system being calibrated. For measurement of airspeed and altitude, the appropriate instrument is connected directly to the cone source. Lag of the system (0.2 to 1.0 sec time constant dependent on instrument volume) should be accounted for.

Several elements of trailing cone use require further study and test. Although the cone has been trailed immediately below a jet engine exhaust wake without temperature problems or power effects on static error, the unit has not been flown on an afterburner-powered aircraft where problems could arise from high temperatures and static pressure variations from under-expanded jet wakes.

The cone has been dragged during takeoff and landing on the aircraft centerline with good results, except that occasionally large-scale cone motions occur at aircraft rotation when it is emersed in the jet wake reflected from the runway.

There has been an indication of possible negative pressure error with flaps extended on one aircraft configuration. Such error is difficult to establish with certainty, for its magnitude is generally less than 0.02 $\Delta P/q$ between 65 and 150 knots airspeed, which corresponds to a measured ΔP value equivalent in magnitude to the error that the best of airborne instrumentation experiences. If the negative pressure field exists at large distances behind an aircraft, one possible explanation of its source could be that a vortex pattern is being generated by the inboard end of each flap and that the cone static pressure orifices lie in a small magnitude negative pressure field formed by the trailed vortex cores with flaps extended.

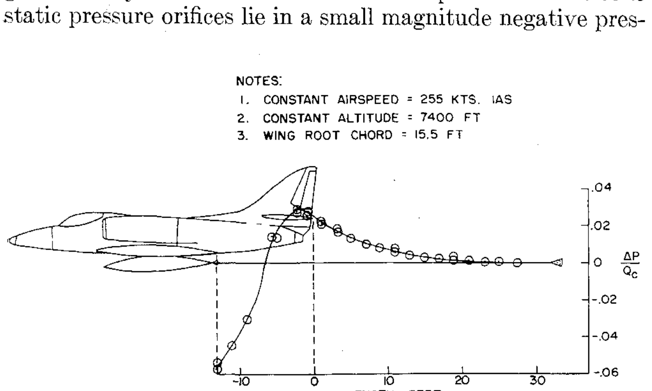

Fig. 4 Variation of $\Delta P/q$ with static tubing length on A4E aircraft.

At the present state of development, it may also be in order to avoid the area of the vortices trailing from the wing tips. These vortices generally are rolled up in approximately 2 to 4 chord lengths behind a low-aspect ratio wing and trail one-fifth to one-third of the half-span inboard from the wing tip. Periodic rotational motion of the trailing cone may be generated by the same phenomenon.

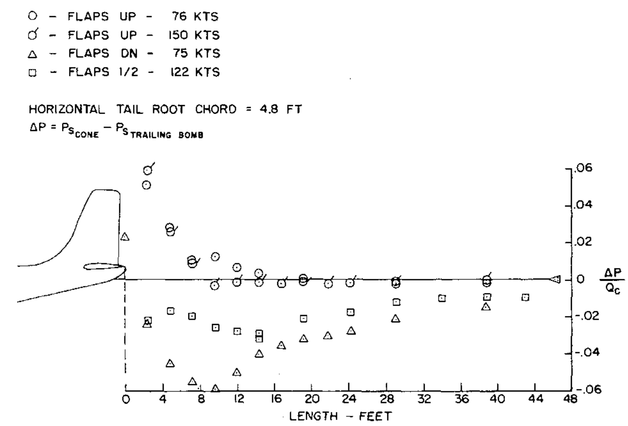

Fig. 5 Variation of $\Delta P/q$ with static tubing length on Aero Commander.

Summary

Use of the trailing cone for aircraft static system calibrations and for minimum error static reference systems can appreciably reduce the time, cost, and complication of flight test. With one system, and simplified recording and data reduction techniques, an aircraft may be completely calibrated from stall speed to dive speed in a single flight without imposing maneuvering or geographic flight area restrictions on the aircraft. Advanced developments of this device should extend the useful operational range of the calibration technique to the high Mach number regime and to slow-speed flight by helicopters and VTOL machines.

Nature and Observation of High-Level Turbulence, Especially in Clear Air

Elmar R. Reiter*
Colorado State University, Fort Collins, Colo.

Introduction

EVER since the development of fast-flying jet aircraft there has been increasing concern about clear-air turbulence (CAT). The importance of research in this field may be stressed by various considerations:

1) First of all, the aircraft engineer would like to have as detailed information as possible on gust loads to be expected with specific types of aircraft under design. From these data he will be able to compute stresses as well as aerodynamic behavior under average and extreme atmospheric conditions.

Presented as Preprint 63-81 at the IAS 31st Annual Meeting, New York, January 21–23, 1963; revision received January 27, 1964.

* Associate Professor of Atmospheric Sciences. Member AIAA.