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RESEARCH MEMORANDUM

CHARACTERISTICS OF A WEDGE WITH VARIOUS HOLDER CONFIGURATIONS FOR STATIC-PRESSURE MEASUREMENTS IN SUBSONIC GAS STREAMS

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
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CHARACTERISTICS OF A WEDGE WITH VARIOUS HOLDER CONFIGURATIONS FOR STATIC-PRESSURE MEASUREMENTS IN SUBSONIC GAS STREAMS

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SUMMARY

The characteristics of a wedge static-pressure sensing element with various holder configurations were determined and compared with the characteristics of the conventional probe.

The probes were tested over a range of Mach number from 0.3 to 0.95, a range of pitch angle from 10° to -10°, and a range of yaw angle from 15° to -15°. In order to show that moisture had no effect on the results, runs were made at dew points of 45° and -45° F at ambient pressure. Runs were also made at constant Mach numbers over a range of total pressures from 20 to 60 inches of mercury absolute.

The wedge probe is particularly useful in applications where space prevents use of the conventional probe. The wedge-type probe also finds application where the flow direction is unknown or varies greatly.

INTRODUCTION

Static pressure of a flowing fluid is measured by inserting in the stream a pressure-sensing body which is mounted on a support of suitable configuration. Where space and direction allow, the conventional static tube, reported in reference 1 and illustrated in figure 1(a), can be used. In certain applications, for example, compressor research, length in the direction of flow is limited and the probe and its support configuration must be changed to allow insertion of the probe into the stream at the proper measuring point. Some of these support configurations may introduce error in the pressure measurement.

The wedge has favorable characteristics as a sensing body in that it can be alined with the flow (in one plane) by balance of pressures on the wedge surfaces and because it is relatively insensitive to angle variation in the plane of the wedge. Although the wedge has small dimensions in the direction of flow, it also has a pressure coefficient near zero.

Two wedges with various holder configurations were tested over a range of Mach number from 0.3 to 0.95, a range of pitch angles from 10° to -10°, and a range of yaw angle from 15° to -15° to determine which configuration was most suitable for static-pressure measurement. In order to show that moisture had no effect on the results, runs were made at dew points of 45° and -45° at ambient pressure. Runs were made at constant Mach number over a range of total pressure from 20 to 60 inches of mercury absolute.

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SYMBOLS

The following symbols are used in this report:

M	free-stream Mach number
P	free-stream total absolute pressure
p	free-stream static absolute pressure
p_1', p_2'	pressure indicated by each orifice of probe
p'	pressure indicated by probe when $p_1' = p_2'$
q_c	velocity, $P - p$

APPARATUS AND PROCEDURE

The five pressure probes investigated are shown in figure 1. The relation of dimensions are given for each probe. Probes b, c, and d have the same wedge configuration with a minimum wedge angle consistent with orifice requirements and constructional limitations. Wedge probe c has a different wedge and support configuration.

The investigations were performed in two jets; one of $3\frac{1}{2}$-inch diameter discharging to the atmosphere, the other of $2\frac{1}{2}$-inch diameter discharging into a controlled-pressure receiver. The static pressure in the working region was calibrated with respect to ambient or receiver pressure by means of static-pressure orifices in an 1/8-inch diameter tube of effectively infinite length parallel to the direction of flow. The correction was less than 1 percent of the velocity head q_c for the range of Mach numbers and pressures used.

The total pressure was equal to tank pressure as determined by a total-pressure tube in the working region. Air at ambient temperature and of random moisture content was used. Runs were made at dew points of 45° F and -45° F to determine the effect of humidity on the pressure coefficient and Mach number results.

RESULTS AND DISCUSSION

In probes used for static-pressure measurement a small constant pressure coefficient is desirable. The pressure-coefficient Mach number curve for all probes investigated is shown in figure 2. The conventional subsonic probe a has a pressure coefficient of zero within 0.2 percent. Probes b, c, and d have a common wedge sensing element; wedge b is spike mounted; wedge c is "hook" mounted with
2239 relatively large distances from support to wedge; and wedge d is hook mounted with small dimensions. Probe b has a pressure coefficient of approximately -2 percent with a change of 1 percent over the range of Mach number from 0.35 to 0.95. Hook-mounted wedges having support configurations suitable for compressor research have characteristics considerably different from those of the conventional probe. Because of large dimensions between sensing orifices and support, probe c showed little change of pressure coefficient from spike-mounted wedge b. Probe d, whose dimensions from support to static orifices are less than those of probe c shows a change of 11 percent from a Mach number of 0.5 to 0.95. Probe e, which has both a different wedge and support configuration, has a pressure coefficient as low as -6 percent and the pressure coefficient curve has a steep slope at the higher Mach numbers.

The angle and total-pressure characteristics of each probe are given in figure 3. A variation of total pressure from 20 to 60 inches of mercury absolute, which corresponds to a Reynolds number change of the ratio of 1:3, causes no detectable change of pressure coefficient for all probes.

Pitch and yaw characteristics are shown for Mach numbers of 0.3, 0.6, and 0.9. The characteristics of the conventional subsonic probe a are given in figure 3(a). A misalinement of 5° in yaw or pitch causes a change in pressure coefficient of approximately 1 percent. The probe can be rotated to the point where maximum pressure is indicated and the error read from figure 3(a).

The characteristics of spike-mounted wedge probe b are shown in figure 3(b). Since the probe cannot be easily alined in yaw, the yaw-angle effect should be small. For yaw angles from 10° to -10°, the change in pressure coefficient is not more than 1 percent. The curve of pitch-angle pressure-coefficient difference on wedge surfaces $p_1'-p_2'/q_c$ gives the angle-measuring sensitivity of the probe. For example, with a velocity head q_c of 10 inches of mercury, the difference between the pressures indicated by the orifices, $p_1'-p_2'$; is 0.95 inch of water per degree of misalinement in pitch. The curve of pitch-angle average pressure coefficient $\frac{\frac{1}{2}(p_1' + p_2') - p}{q_c}$ is constant within 1 percent for pitch angles of $\pm 5^{\circ}$. With the wedge in a fixed pitch position, the probe indicates static pressure within 1 percent by averaging the pressures on the two surfaces of the wedge.

The change to holder configuration c causes a small change in results compared with probe b as indicated in figure 3(c). The change of holder configuration from probe c to probe d (fig. 3(d)) introduces asymmetry in the yaw angle curves. This asymmetry is caused by the close proximity of the support hook. Other characteristics of probe d are relatively similar to those of probe c.

Characteristics of probe e vary considerably from those of probes a, b, c, and d because of a change of both holder configuration and wedge configuration. An uncertainty of yaw angle of 1° in probe e causes an uncertainty in pressure coefficient of 0.8 percent at a Mach number of 0.9. The pitch-angle sensitivity of probe e is increased to a value of $p_1'-p_2'$ equal to 2.8 inches of water for a velocity head q_c of 10 inches of mercury.

The effect of a change of dew point from 45° to -45° F caused no detectable change in Mach number pressure coefficient results.

Errors in static-pressure measurement are influenced not only by the shape of the pressure-sensing element and the holder configuration, but also by the location of the sensing orifices relative to the holder. Since changes in probe geometry are reflected in the pressure coefficient, alterations of the designs presented herein will require calibration.

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CONCLUDING REMARKS

Static-pressure measurements in streams where length in the direction of flow is limited require probes of configuration different from that of the standard subsonic probe. Errors in measurement are influenced not only by the shape of the element and the holder configuration, but also by the location of the sensing orifices relative to the holder.

The spike-mounted wedge-type probe is superior to the standard probe in applications where the flow direction varies greatly. The wedge can be alined with flow in pitch and is less sensitive to variations in yaw than the standard probe. Where space limitations require the use of the hook-type or the normal-mounted probes, the static pressure may be estimated from the pressure indications by means of calibration curves; however, the errors will be greater than in the case of the standard probe or the spike-mounted wedge.

Lewis Flight Propulsion Laboratory,
National Advisory Committee for Aeronautics,
Cleveland, Ohio, June 26, 1951.

REFERENCE

1. Huston, Wilbur B.: Accuracy of Airspeed Measurements and Flight Calibration Procedures. NACA Rep. 919, 1948. (Formerly NACA TN 1605.)

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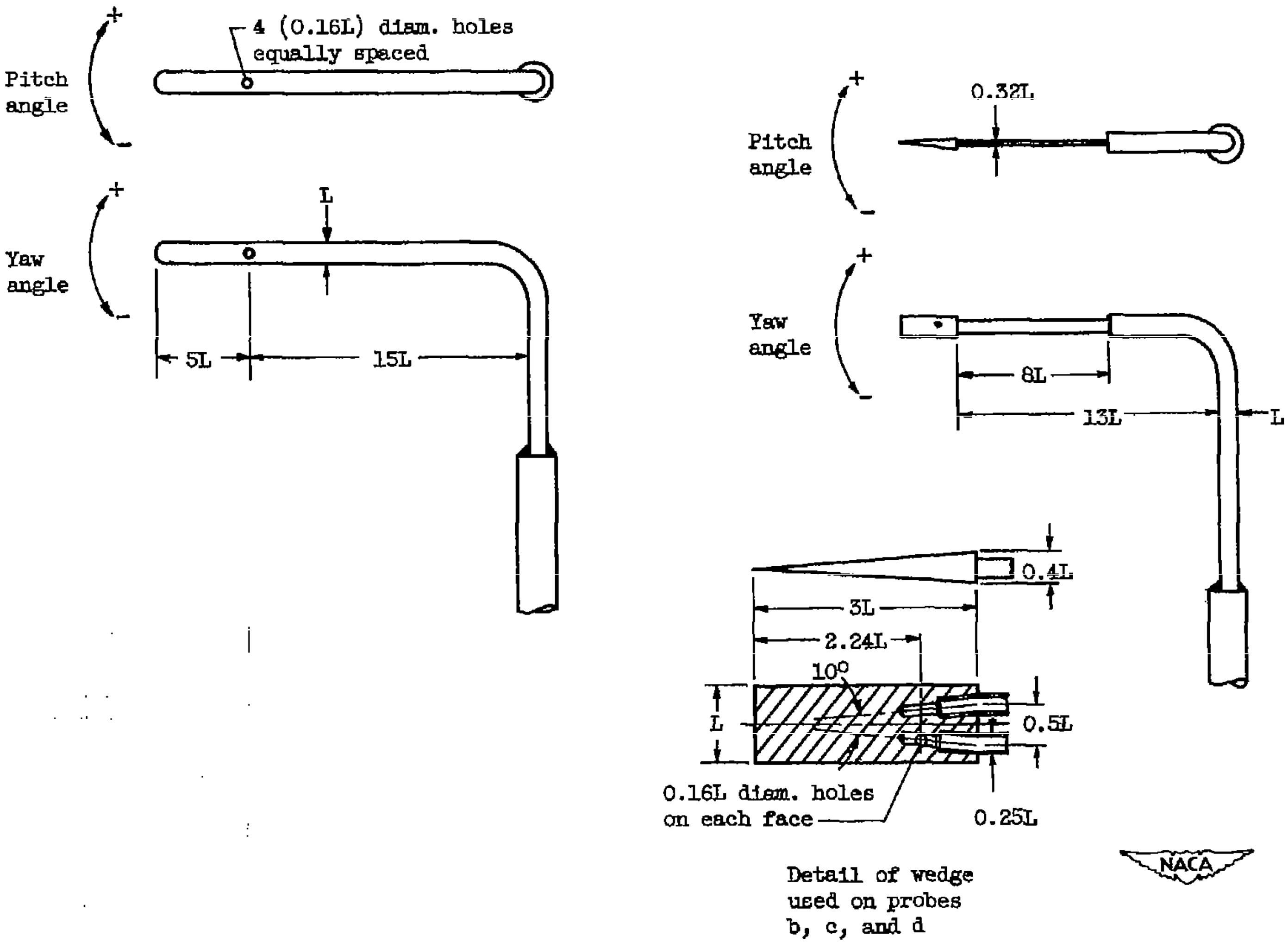
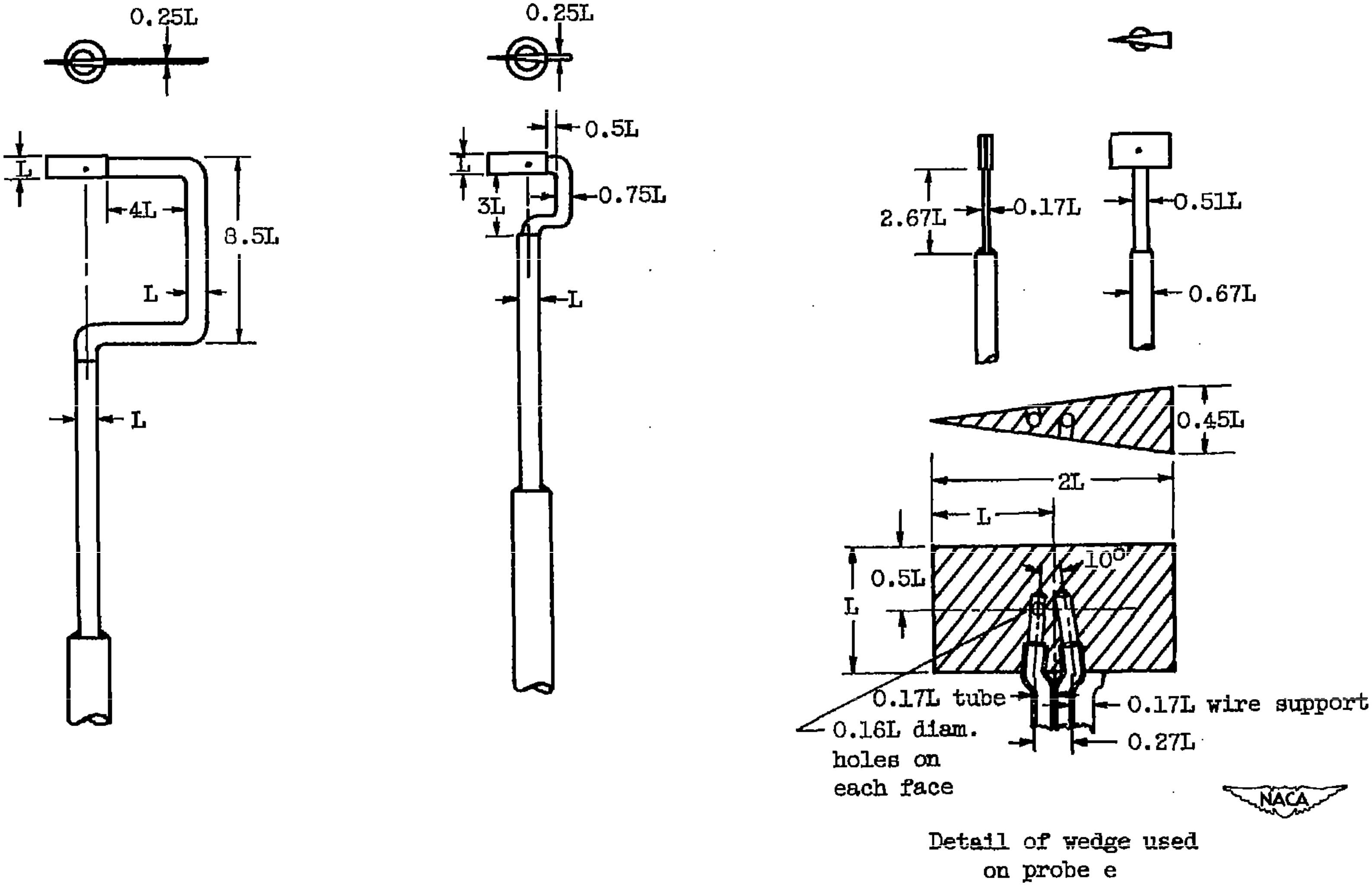


(a) Probe a.

(b) Probe b.

Figure 1. - Probe configurations.



(c) Probe c. (d) Probe d. (e) Probe e.

Figure 1. - Concluded. Probe configurations.

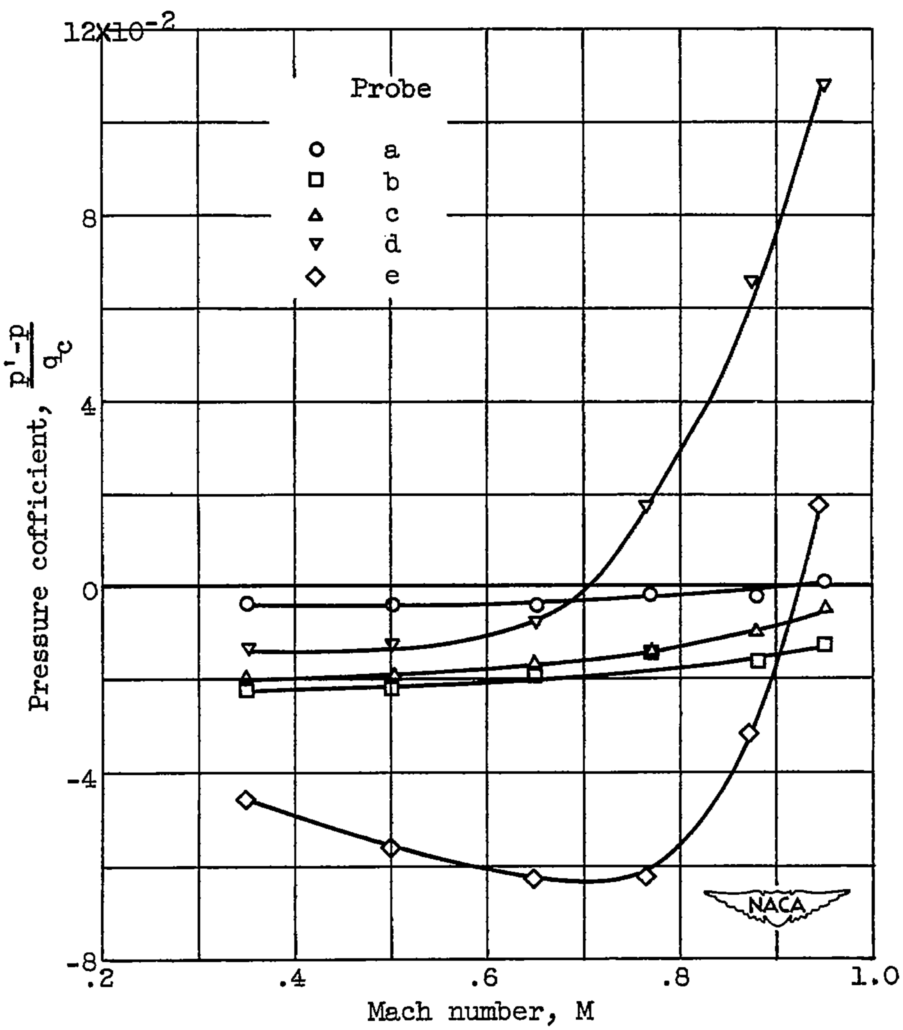
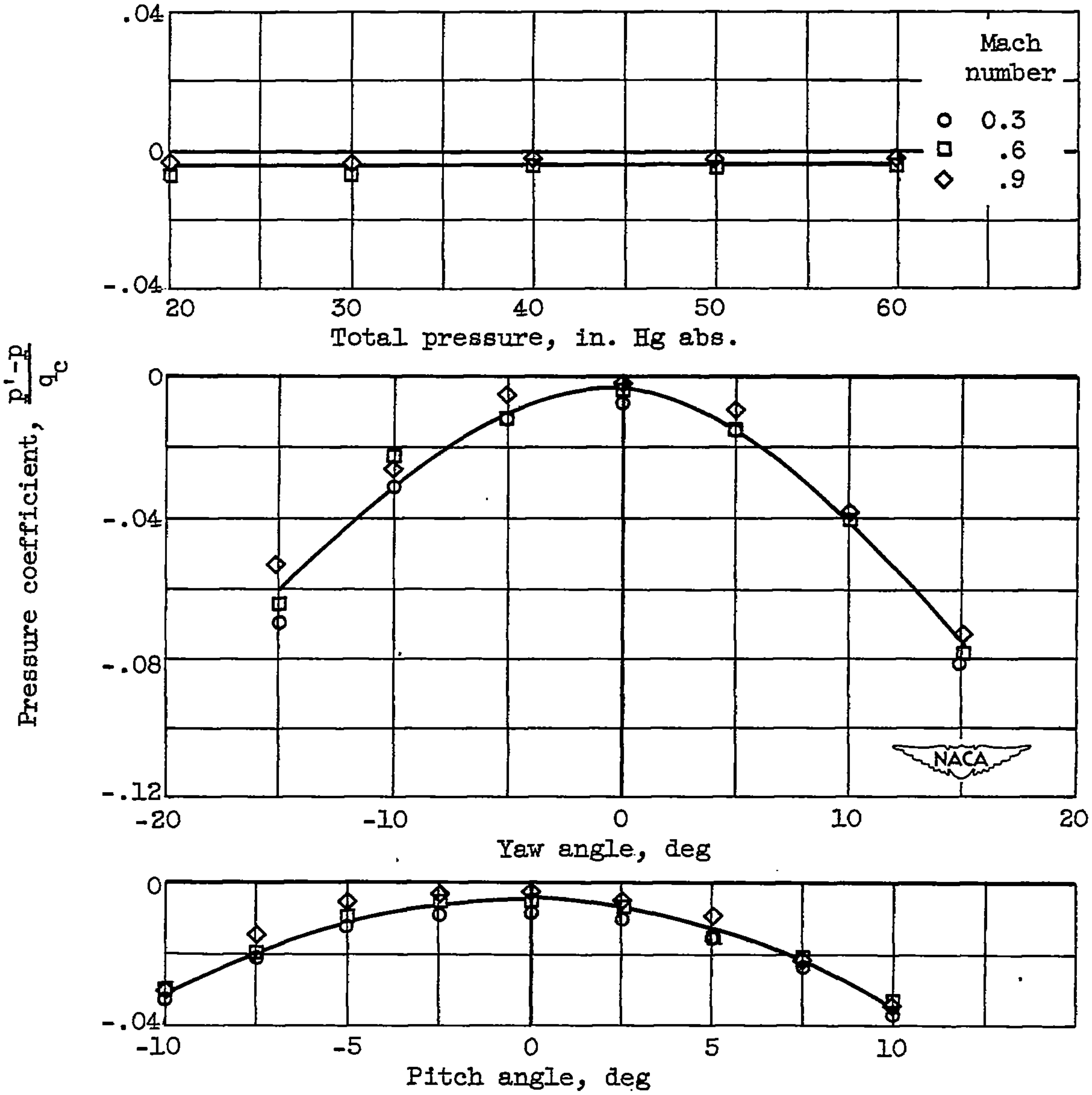
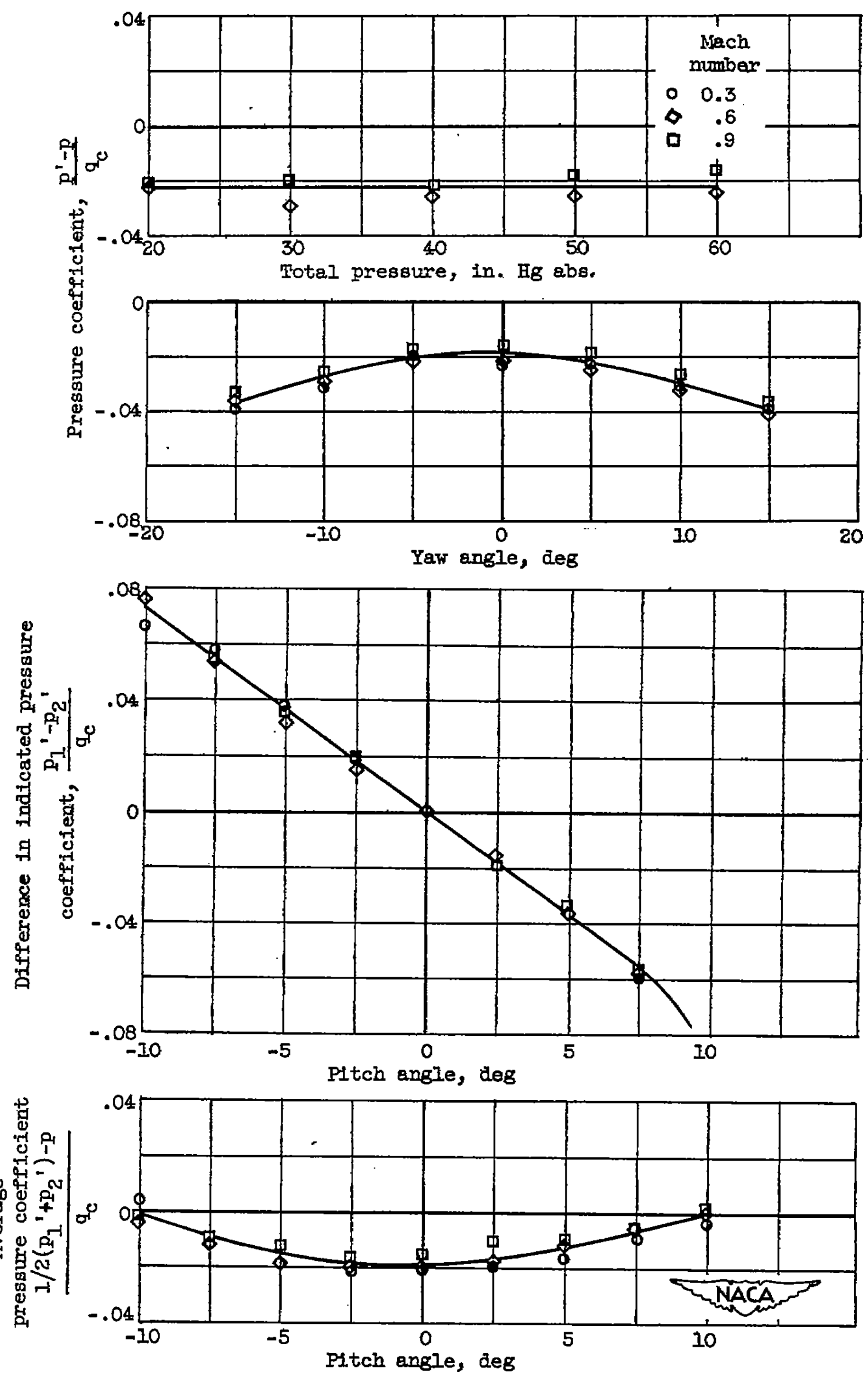


Figure 2. - Variation of pressure coefficient with Mach number when probe is alined with flow.



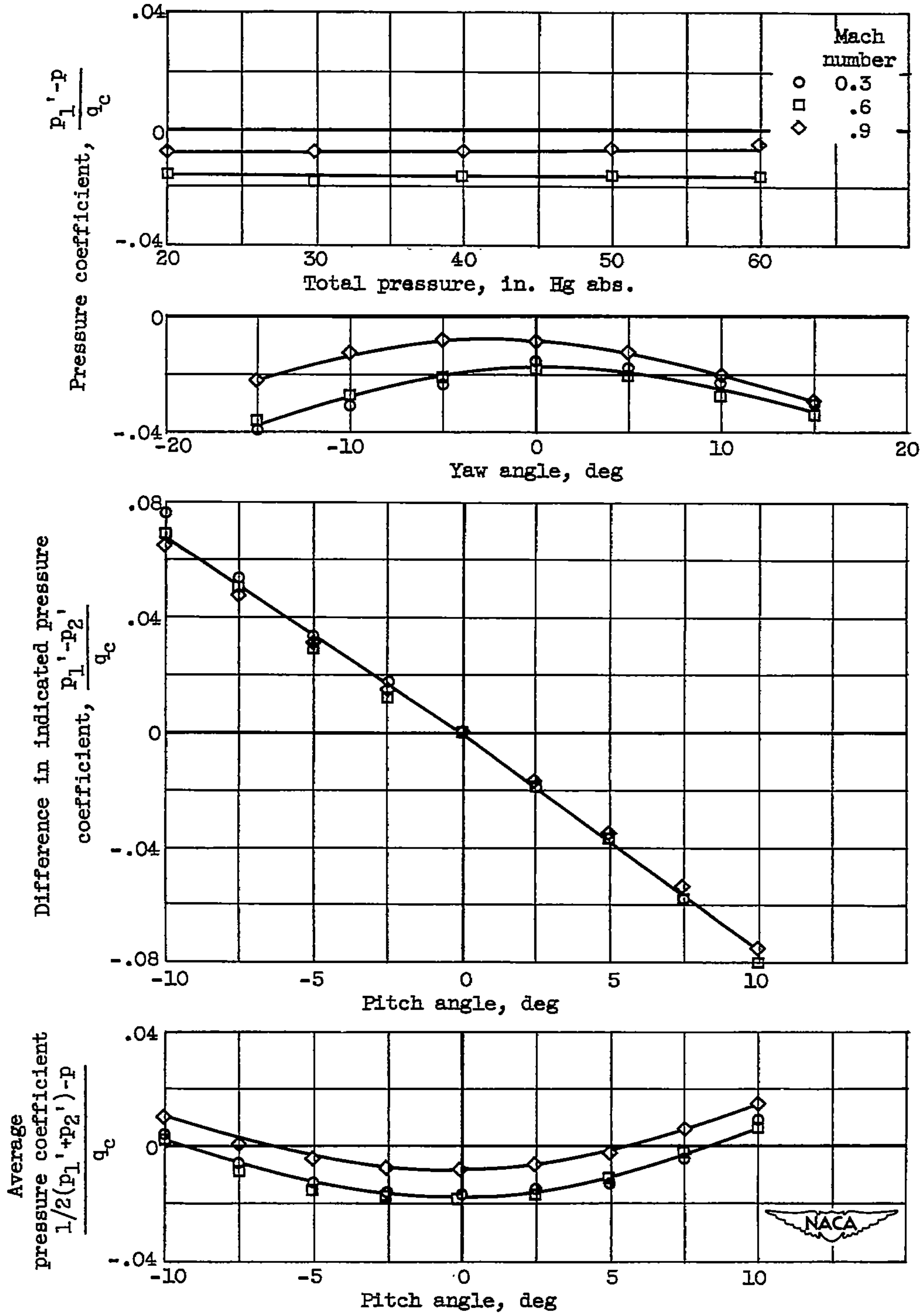
(a) Standard subsonic probe a.

Figure 3. - Angle and total-pressure characteristics of various probes.



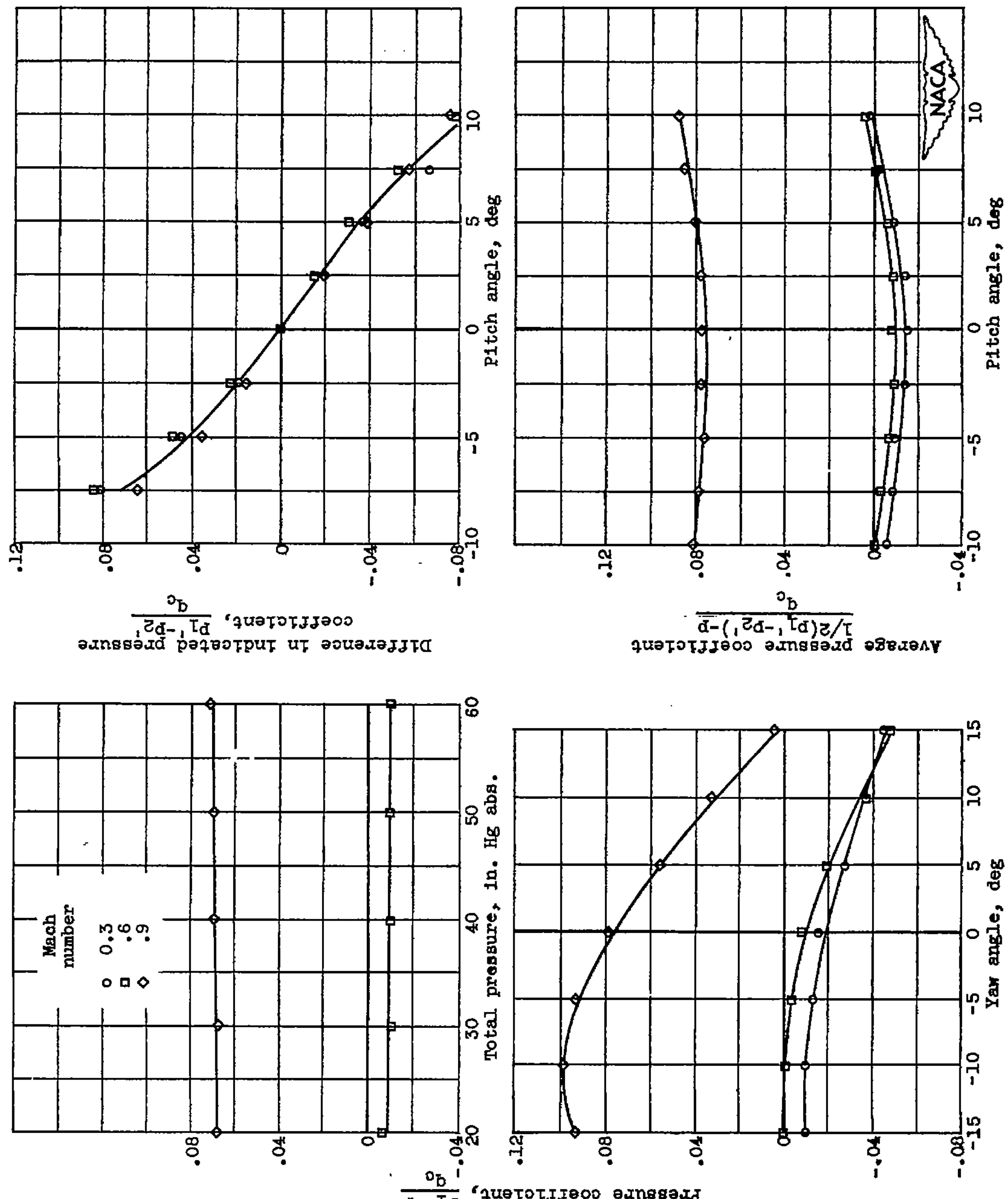
(b) Spike-mounted wedge probe b.

Figure 3. - Continued. Angle and total-pressure characteristics of various probes.



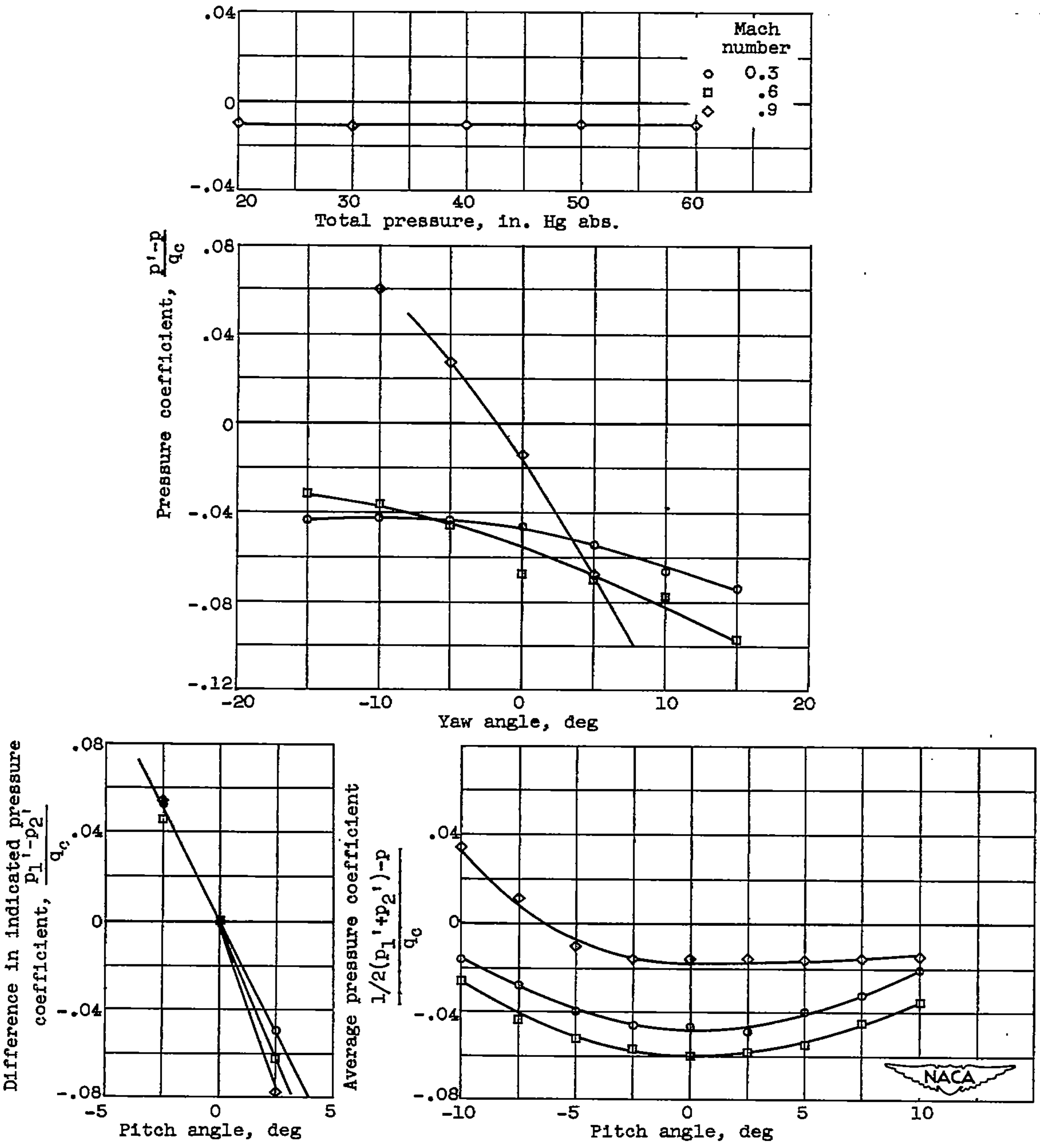
(c) Hook-supported wedge probe c.

Figure 3. - Continued. Angle and total-pressure characteristics of various probes.



(d) Hook-supported wedge d.

Figure 3. - Continued. Angle and total-pressure characteristics of various probes.



(e) Normally supported wedge e.

Figure 3. - Concluded. Angle and total-pressure characteristics of various probes.