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16. Abstract

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SUMMARY

A testing technique for obtaining the static aerodynamic characteristics of twin-fuselage configurations at hypersonic speeds by using a conventional single-balance installation has been evaluated. Data from a triple-fuselage model and a single-fuselage model were summed and then halved to obtain the characteristics for a twin-fuselage model of the same scale. The three related models were evaluated experimentally at Mach 20.3 in helium and Mach 6 in air for an angle-of-attack range from -6° to 50°. The Reynolds numbers, based on model length, were 1.88×10^{6} for the Mach 20.3 tests and 2.55×10^{6} for the Mach 6 tests. The results indicate that the agreement between the longitudinal aerodynamic data obtained by the summation test technique and the data obtained by direct measurement on the twin-fuselage model is excellent except where sting effects occur.

INTRODUCTION

Wind-tunnel force and moment investigations of twin-fuselage configurations can present formidable measurement problems because of special balance mounting requirements. If, for example, a balance is mounted in one fuselage, the offset center of pressure of the configuration would probably overload the rolling-moment component of most available balances, especially at high angles of attack. On the other hand, a balance specifically constructed for large rolling moments would be too stiff for an accurate measurement of the lateral stability of a more conventional single-fuselage configuration. Moreover, a long lead time is required for the design and construction of strain-gage balances. If dual mounting is employed (a balance mounted in each fuselage supported on a forked sting), the sting would have to be tailored for the distance between the fuselages, which in a parametric study could be a variable requiring special equipment. Dual mounting also complicates data reduction by requiring a calibration of the balances as arranged and the determination of rolling and yawing moments from normal-force and axial-force couples, respectively.

To circumvent such problems and allow for the use of conventional wind-tunnel balances and mounting arrangements, a testing technique using a single-fuselage model and a triple-fuselage model was devised. This paper presents the summation test technique and its experimental evaluation at Mach 6 in air and Mach 20.3 in helium. Aerodynamic characteristics obtained by the technique are compared with measured values for the twin-fuselage model at angles of attack from -6^{o} to 50^{o}. Some lateral-directional data at Mach 6 and angles of attack from 0^{o} to 25^{o} are also presented.

SYMBOLS

b	reference span, 4.470 cm (see fig. 1(b))
C_A	axial-force coefficient, $\frac{\text{Axial force}}{qS}$
C_l	rolling-moment coefficient, $\frac{\text{Rolling moment}}{qSb}$
C_{l_β}	rate of change of rolling-moment coefficient with sideslip angle (measured at $\beta = 0^{o}$ and -4^{o}), $\Delta C_l/\Delta\beta$, per deg
C_m	pitching-moment coefficient, $\frac{\text{Pitching moment}}{qS_l}$
C_N	normal-force coefficient, $\frac{\text{Normal force}}{qS}$
C_n	yawing-moment coefficient, $\frac{\text{Yawing moment}}{qSb}$
C_{n_β}	rate of change of yawing-moment coefficient with sideslip angle (measured at $\beta = 0^{o}$ and -4^{o}), $\Delta C_n/\Delta\beta$, per deg
C_Y	side-force coefficient, $\frac{\text{Side force}}{qS}$
C_{Y_β}	rate of change of side-force coefficient with sideslip angle (measured at $\beta = 0^{o}$ and -4^{o}), $\Delta C_Y/\Delta\beta$, per deg
L/D	lift-drag ratio
l	body length
M	Mach number
q	dynamic pressure

r nose radius

S reference area, total projected planform area of twin-fuselage model

α angle of attack, deg

β sideslip angle, deg

APPARATUS AND TESTS

Tunnels

The tests were conducted in the Langley 22-inch helium tunnel at a Mach number of 20.3 and in the Langley 20-inch Mach 6 tunnel. Operational characteristics of the facilities and details of the characteristics of contoured nozzle flow are presented in references 1 and 2 for the 22-inch and 20-inch tunnels, respectively.

Models

Two sets of three models each were used in the investigation and are shown in figure 1. The models tested at Mach 20.3 in helium were approximately 12.7 cm long with a reference area of 64.19 cm^2 for the twin-fuselage model. The models tested at Mach 6 were approximately 18.85 cm long with a reference area of 136.77 cm^2 for the twin-fuselage model and were constructed with an interchangeable fuselage within which the balance was mounted. The Mach 20.3 models utilized simplified forebodies and fins as noted in figure 1(b).

Test Conditions and Methods

All models were mounted on sting-supported strain-gage balances. A balance with a large roll capability was used to test the twin-fuselage configuration at high angles of attack. Because of the limitations of the angle-of-attack mechanism in the helium tunnel, two stings (one straight and the other bent) were required to cover the complete angle-of-attack range from -6° to 50° at a sideslip angle of 0° for the Mach 20.3 tests. The angles of attack for the Mach 6 tests varied from 0° to 50° at a sideslip angle of 0° and from 0° to 40° for a sideslip angle of -4°. The lateral-directional data were obtained on a conventional balance, and the excess rolling moment of the twin-fuselage configuration limited its angle of attack to 25°. The relative sizes of the stings and models are depicted in figure 2.

The angles of attack were set optically by the use of a point source of light and a small lens-prism combination mounted on the model. The image of the souce was reflected by the prism and focused by the lens onto a calibrated chart. Additional features of the systems can be found in reference 1 for the Mach 20.3 tests and in reference 3 for the Mach 6 tests.

The Reynolds numbers, based on model length, were 1.88×10^6 for the tests at $M = 20.3$ and 2.55×10^6 for the tests at $M = 6$. The axial force was not corrected for base pressure. All the aerodynamic coefficients were based on the geometric parameters of the twin-fuselage model. The lateral-directional stability derivatives were determined by assuming a linear variation in the characteristics between 0° and -4° sideslip angle.

SUMMATION TEST TECHNIQUE

A technique has been devised wherein the twin-fuselage configuration is divided into components, about a vertical plane, that have the following characteristics: The components together with their mirror images about the dividing plane form a configuration that is symmetrical on a balance (fig. 2(a)), and the flow fields about each half of these symmetrical models are not significantly different from those about the twin-fuselage model they represent. Figure 2(b) shows the shock intersection patterns for the three models sketched from motion pictures in which an electron beam was used to illuminate the flow at Mach 20.3 in helium. There are two differences between the shock systems of the twin fuselage and the symmetrical representations. First, the single fuselage does not have the shock intersection of the adjacent body and wing near the tail. Second, there is an additional shock intersection near the tail of the center body of the three-fuselage model. These differences are judged to be insignificant for the longitudinal data because the absence of the shock intersection over the single fuselage is compensated by the additional shock intersection over the tail of the center body of the three-fuselage configuration and because the area affected by this shock intersection and the pressure rise across the intersection (obtained from a simplified calculation) are relatively small. For the lateral-directional data, however, the differences in shock patterns were expected to have more effect because the pressure differentials act on large surfaces (fin sides). The effect of these differences in shock patterns at $\beta = 0^{\circ}$ is small; therefore, one-half of the forces and moments measured on each of the symmetrically supported models can be summed to obtain the longitudinal results for the twin-fuselage model. The base pressures were assumed to act symmetrically and were not measured. The steps in the total process are given in figure 2(c).

RESULTS AND DISCUSSION

Longitudinal Aerodynamic Characteristics

The longitudinal aerodynamic characteristics of the twin-fuselage model are presented in figure 3. The data obtained by direct measurement are represented by the symbols, and the data obtained by summing one-half of the measurements from the triple-fuselage and single-fuselage models are represented by the curve. The switch in symbols from circles to squares indicates that a change from a straight sting to a bent sting was required to cover the angle-of-attack range in the Langley 22-inch helium tunnel at Mach 20.3.

The variations with angle of attack of the aerodynamic coefficients obtained at $M = 20.3$ by direct measurement and by the summation test technique are presented in figure 3(a). With the exception of the pitching-moment coefficients obtained with the bent sting, the data obtained by the two methods are in excellent agreement. The discrepancy in the pitching-moment data appears to be due to sting effects; also, there is a difference in the axial-force coefficients as well as the pitching-moment coefficients where the two stings overlap ($\alpha = 18^{\circ}$). At Mach 6, the data obtained by the summation test technique and by direct measurement are in excellent agreement up to $\alpha = 35^{\circ}$. (See fig. 3(b).) Both sets of data ($M = 20.3$ and $M = 6$) have similar trends and inflection points at about the same angles of attack. Note especially the variation of axial-force coefficient with angle of attack. The undulating character of the curves is associated with changes in shock patterns around the bodies as the angle of attack changes.

Lateral-Directional Stability Derivatives

The flow fields about the center lines of the triple-fuselage and single-fuselage bodies do not remain symmetrical when the bodies are yawed, and the shock patterns are somewhat different from those of the twin-fuselage body; therefore, the testing technique should only be used for stability derivatives at very small angles of sideslip. Stability derivatives obtained from data at $\beta = 0^{\circ}$ and -4° by the summation test technique and by direct measurement on the twin-fuselage model are compared in figure 4.

In general, the summation test technique can be used only to determine whether a twin-fuselage configuration is directionally stable and what the trends of stability with angle of attack will be. The data of figure 4 show that the values of the stability derivatives obtained by the summation test technique are good representations of the actual values at angles of attack only up to 20°. As angle of attack increases beyond 20°, the values diverge.

CONCLUDING REMARKS

A testing technique for obtaining the static aerodynamic characteristics of twin-fuselage configurations at hypersonic speeds by using a conventional single-balance installation has been evaluated. Data obtained from a triple-fuselage model and a single-fuselage model were summed and then halved to obtain the characteristics for a twin-fuselage model of the same scale. The three related models were evaluated experimentally at Mach 20.3 in helium and Mach 6 in air for an angle-of-attack range from -6° to 50°. The Reynolds numbers, based on model length, were 1.88×10^{6} for the Mach 20.3 tests and 2.55×10^{6} for the Mach 6 tests.

For both Mach numbers, the summation test technique predicted the trends and the values of the longitudinal force and moment coefficients for the twin-fuselage configuration up to an angle of attack of about 35°. The disagreement above this angle of attack was attributed to sting effects. The summation test technique also predicted the lateral-directional stability derivatives reasonably well up to an angle of attack of 20°.

Langley Research Center,
National Aeronautics and Space Administration,
Hampton, Va., February 5, 1975.

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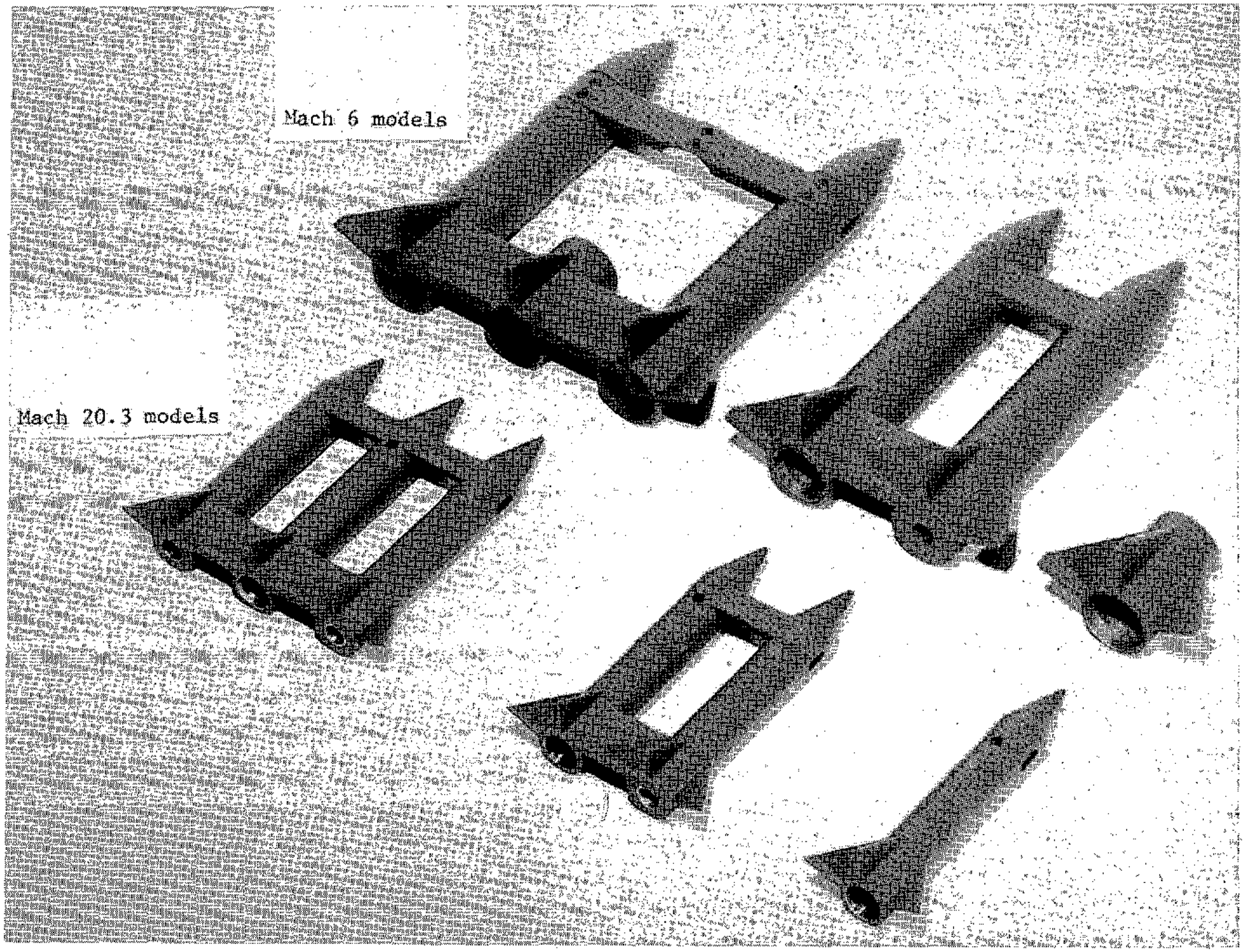
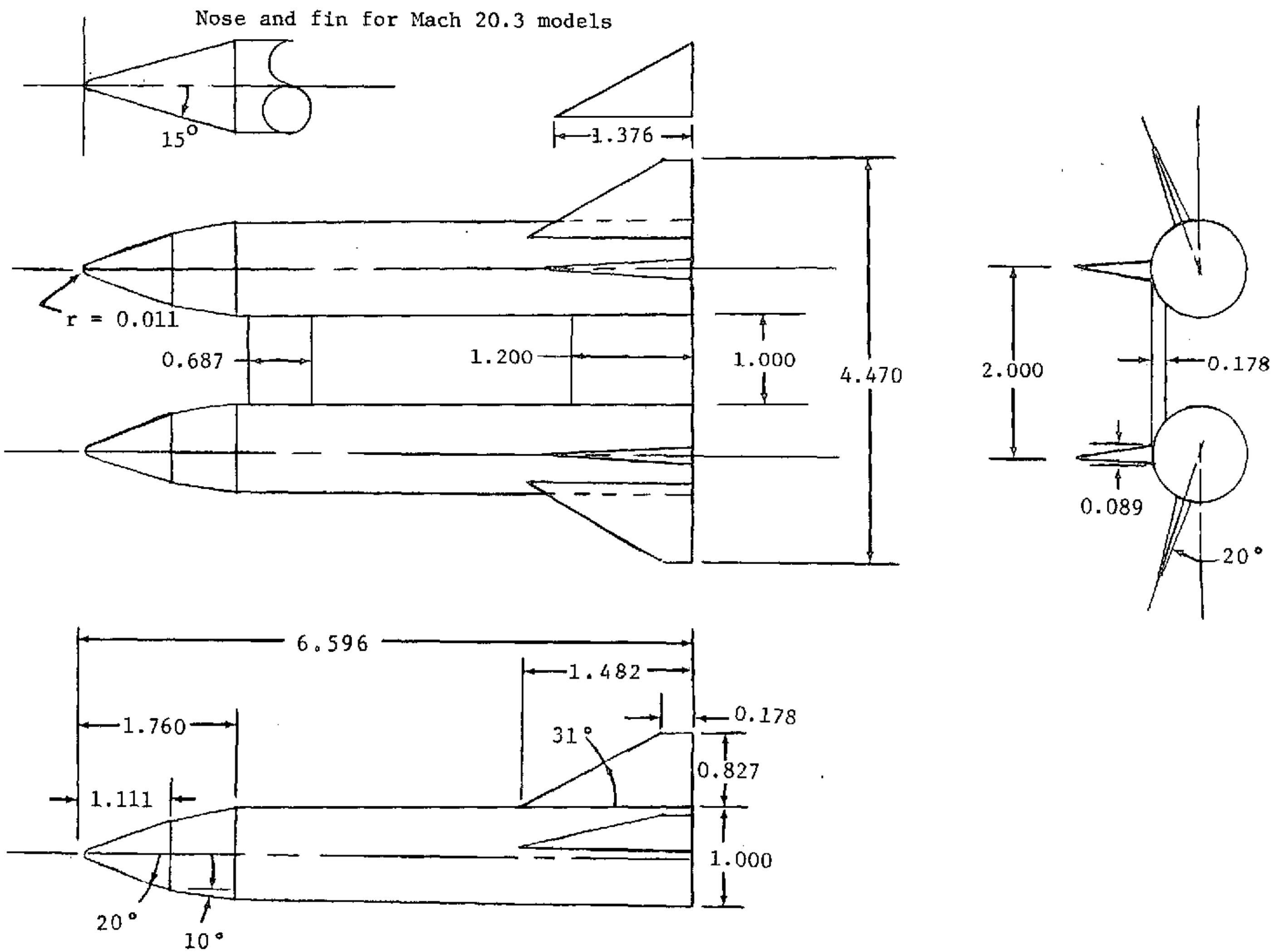


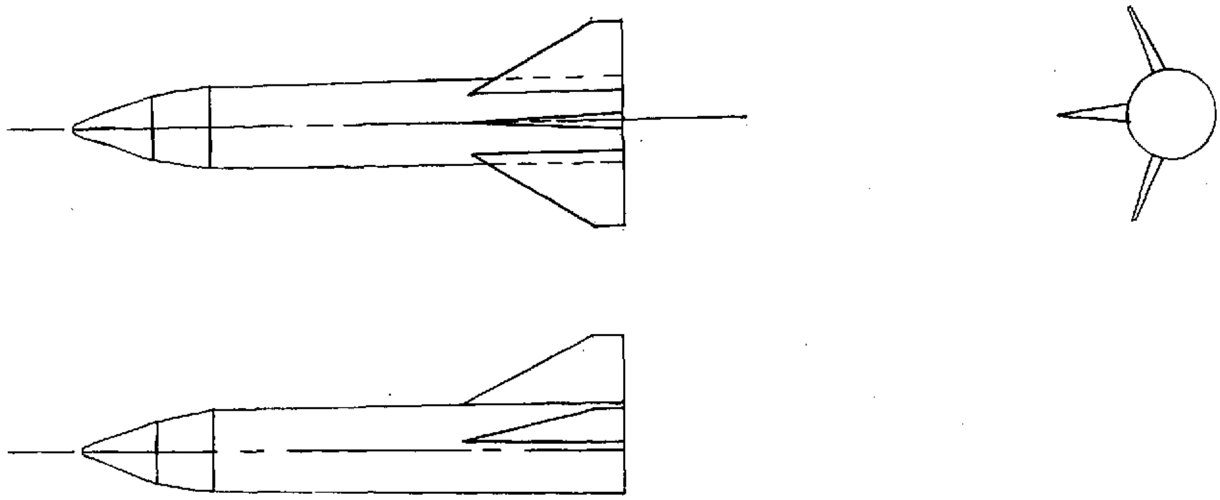
(a) Model sets. L-75-142

Figure 1.- Test models.

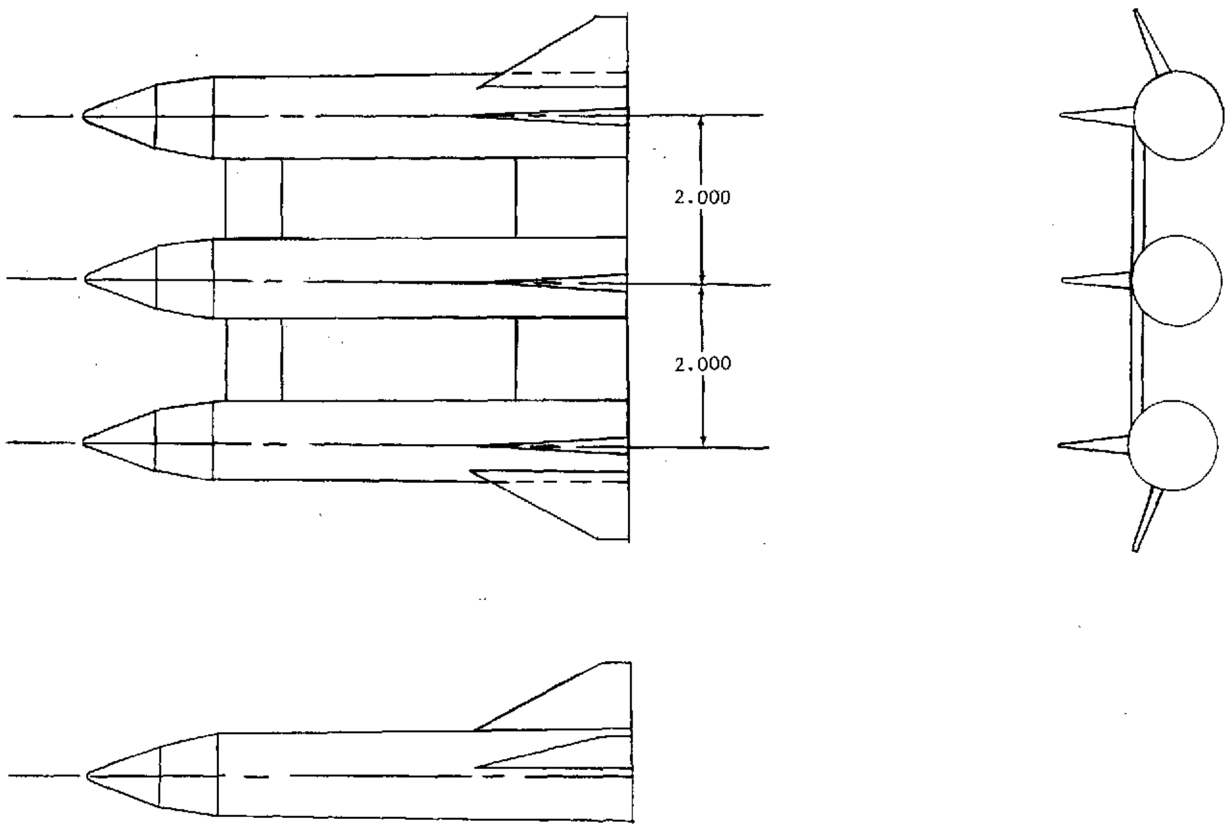


(b) Twin-fuselage model.

Figure 1.- Continued. All linear dimensions are in terms of a body diameter of 1.93 cm for Mach 20.3 models and 2.86 cm for Mach 6 models.

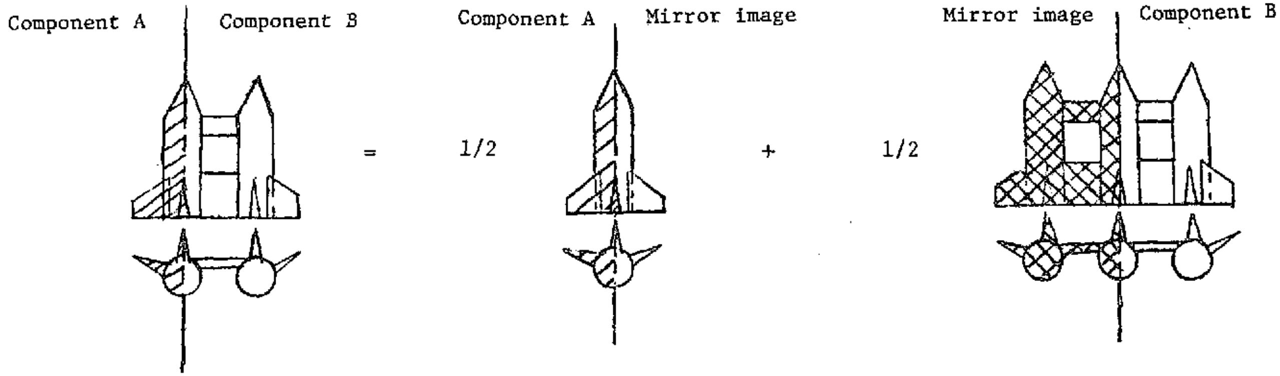


(c) Single-fuselage model.

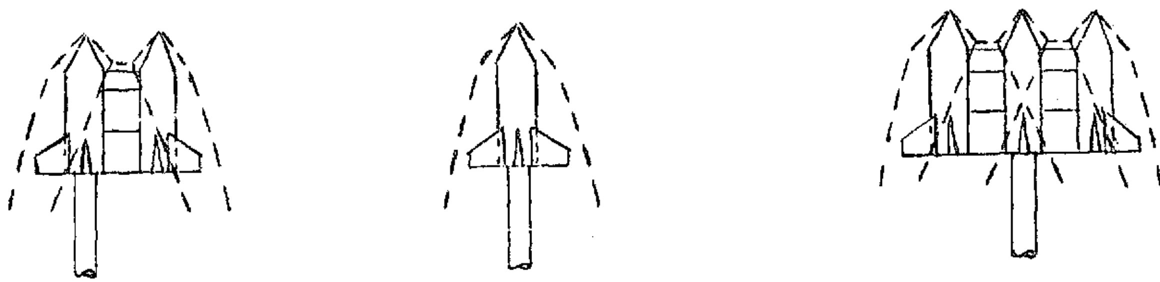


(d) Triple-fuselage model.

Figure 1.- Concluded. Dimensions are the same as those in figure 1(b).



(a) Transformation to symmetry.

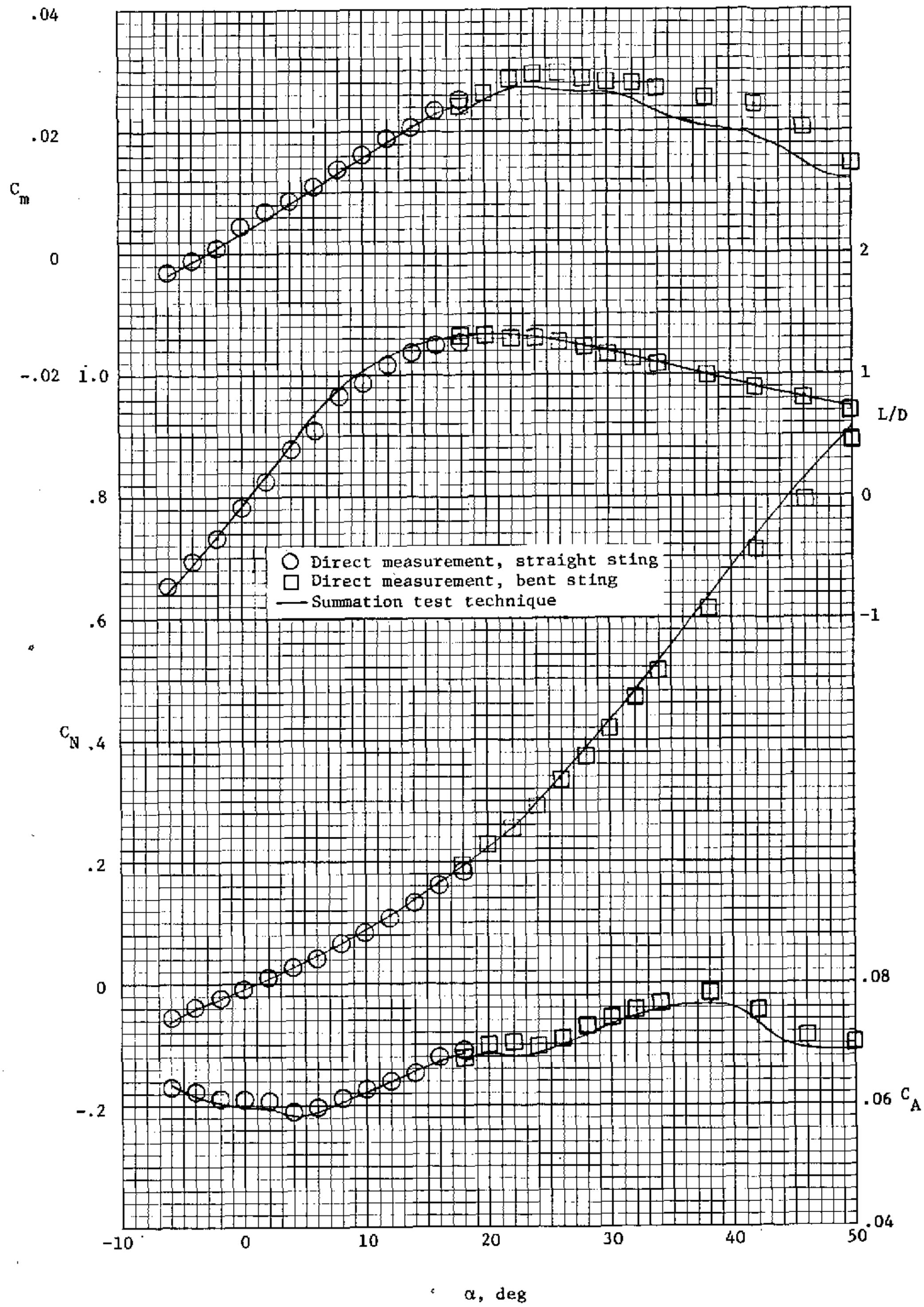


(b) Shock intersection patterns
(from $M \approx 20$ electron beam).

Total forces and moments = 1/2 forces and moments + 1/2 forces and moments

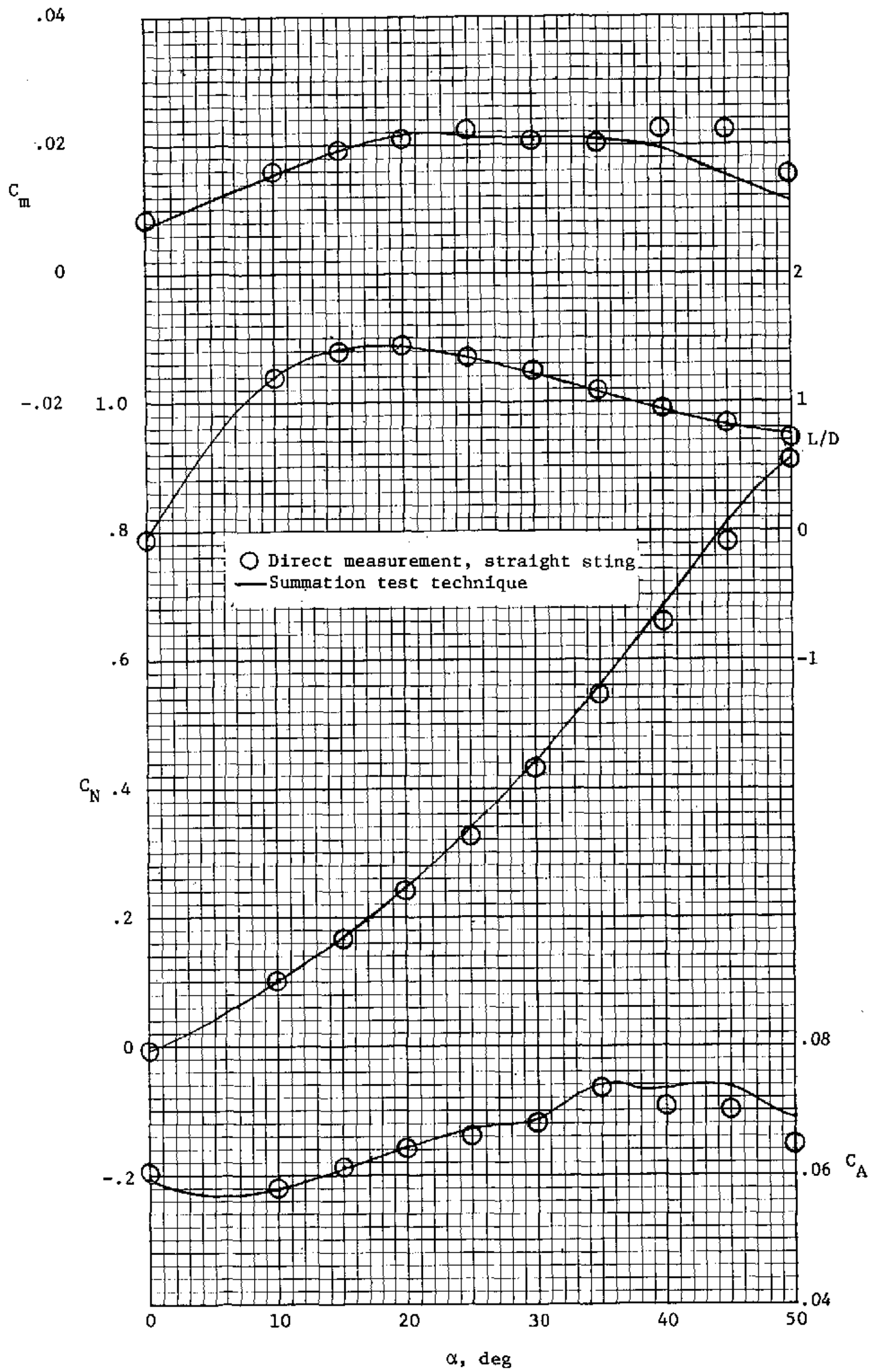
(c) Summation process.

Figure 2.- Schematic representation of the summation test technique.



(a) M = 20.3; helium.

Figure 3.- Longitudinal aerodynamic characteristics obtained by direct measurement on twin-fuselage model and by the summation test technique. $\beta = 0^{\circ}$.



(b) M = 6; air.

Figure 3.- Concluded.

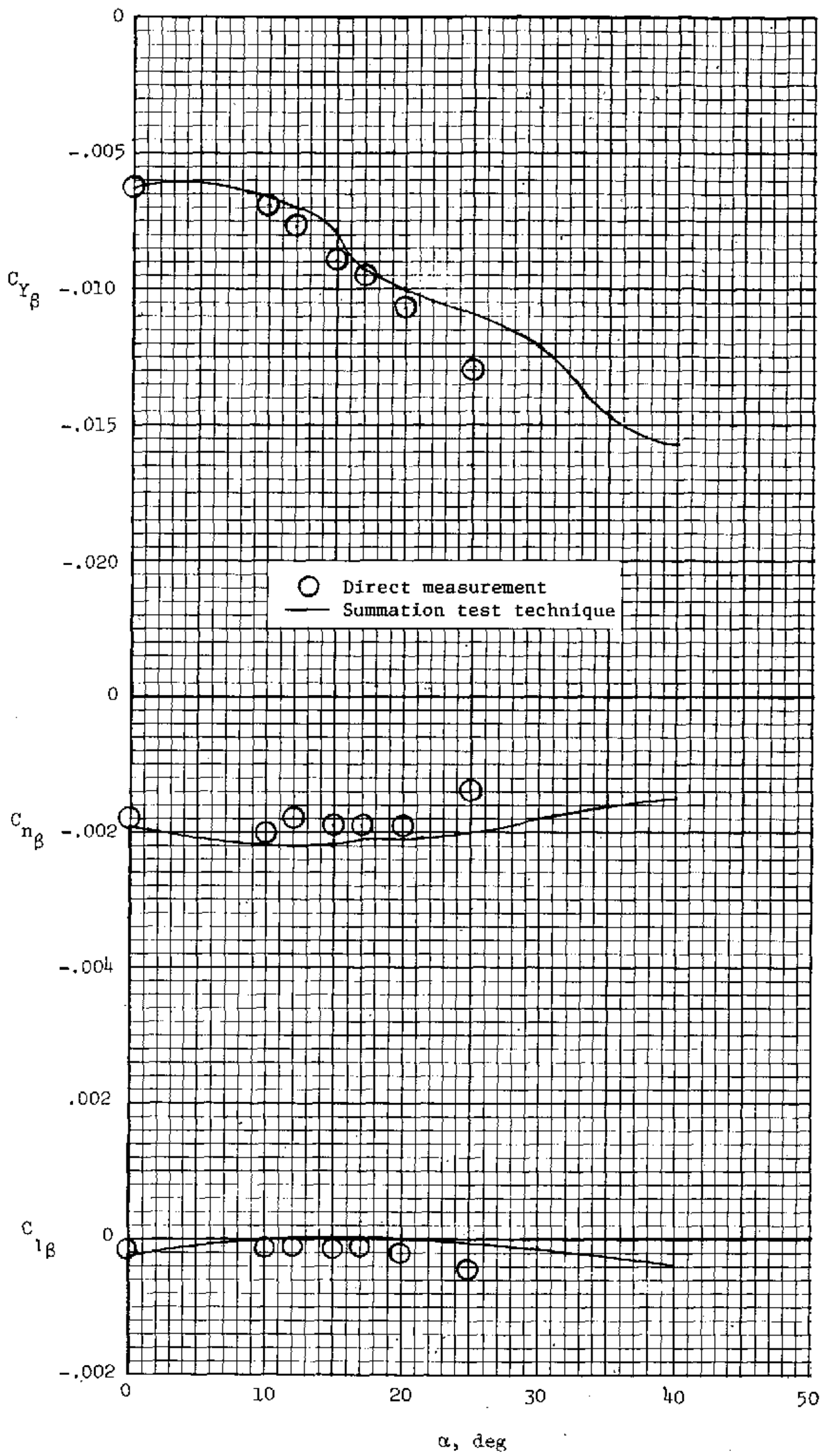


Figure 4.- Lateral-directional stability derivatives obtained by direct measurement on twin-fuselage model and by the summation test technique. M = 6 in air.