12p.

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GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

Memorandum

CCN

Mr. Andrews, 876-6044

TO [illegible] Distribution

DATE July 10, 1961
REF: M-AERO-E-3-61

FROM M-AERO-E, Experimental Projects Section

Cy 1

SUBJECT Experimental [illegible] Longitudinal Stability and Drag Characteristics of SATURN Configuration SA-7 [redacted]

(C) INTRODUCTION

In order to determine the static longitudinal stability and drag characteristics of a 0.006809 scale SATURN configuration SA-7, wind tunnel tests were conducted in the Marshall Space Flight Center's 14-inch Trisonic Wind Tunnel. The test Mach number range was from 0.70 to 4.96 while Reynolds number was varied between 4.34×10^6 and 6.90×10^6 per foot of body length. Three component data were obtained through an angle of attack range from -3 to +6 degrees by means of electric strain gage balances which were located within the model. The geometrical details of the test configuration are presented as Figure 1 while a photograph of a typical wind tunnel model setup is presented as Figure 2. Test Reynolds number (per foot) and Mach number are tabulated on Figure 3 with corresponding stagnation pressures for the MSFC 14-inch tunnel.

2. (U) COEFFICIENTS AND SYMBOLS

[redacted] are presented in a body system of axes. Coefficients and symbols are defined as follows:

α	Angle of attack, degrees
C_{D_b}	Base drag coefficient, $\frac{P_s - P_b}{q}$
C_{D_F}	Fore drag coefficient, $(C_{D_T} - C_{D_b})$
C_{D_T}	Total drag coefficient, $(\frac{X}{q\,S})$, $C_{D_T} = C_X$ at $\alpha = 0$ degrees
C_{m_g}	Pitching moment coefficient, referred to vehicle station 100 (Gimbal Station), $(\frac{M}{q\,S\,D})$
C_Z	Normal force coefficient, $(\frac{Z}{q\,S})$
C_X	Axial force coefficient, $(\frac{X}{q\,S})$
$C_{m_{\alpha_g}}$	Rate of change of pitching moment coefficient with angle of attack, [illegible] $\alpha = 0$ degrees

CLASSIFICATION CHANGE
TO - UNCLASSIFIED
By authority of T.D. No. 74-136
Changed by [illegible] Date 11/07/[illegible]

MSFC - Form 480 (October 1959)

(NASA-TM-X-69458) EXPERIMENTAL STATIC LONGITUDINAL STABILITY AND DRAG CHARACTERISITICS OF SATURN CONFIGURATION SA-7 (NASA) 12 p

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C_{Z_α}	Rate of change of normal force coefficient with angle of attack, $\frac{\partial C_Z}{\partial \alpha}$ $\alpha = 0$ degrees
$\frac{CP}{D}$	Center of pressure location, calibers forward of vehicle station 100 (Gimbal Station)
D	Reference diameter, 257 inches full scale, (See Figure 1)
γ	Ratio of specific heats, 1.40 for air
m_g	Pitching moment, inch pounds
M	Mach number
P_b	Base pressure, psi
P_s	Free stream static pressure, psi
q	Free stream dynamic pressure, psi, $\frac{\gamma}{2} P_s M^2$
S	Area based on reference diameter, $\frac{\pi D^2}{4}$
X	Axial force, pounds
Z	Normal force, pounds

3. (C) RESULTS

The results from this investigation have been presented in the form of summary data which were derived from the basic data. Slopes of normal force and pitching moment, center of pressure, and drag coefficient at approximately zero degree angle of attack are presented as a function of Mach number for the SATURN configuration SA-7 with and without escape tower. Some difficulties were encountered in obtaining these static longitudinal stability and drag characteristics in the Mach number range above M = 3.50. These difficulties are attributed to boundary layer flow separation along the model upper stages. An example of this phenomenon can be seen in the upper half of Figure 4. It is felt that the flow separation is only a characteristic of the low Reynolds number test conditions; therefore, in order to simulate higher Reynolds number flow conditions, a carborundum grit strip was applied to the nose of the escape rocket for the SA-7 configuration and to the nose cone of the escape tower off configuration. The effect of the transition strip on the flow may be seen in the lower half of Figure 4 for the SA-7 test configuration. It will be noted that on

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SUBJECT: Experimental Static Longitudinal Stability and Drag Characteristics of SATURN Configuration SA-7 (U) 7/19/61

Figures 5 through 8 flagged symbols indicate data points which were obtained through the use of boundary layer tripping devices. Previous test results from similar configurations indicate that data obtained in this manner are valid within reasonable limits ($\approx$ 2 percent). Tests are expected to continue, however, in a Reynolds number range comparable to the prototype local values.

Figure 9 presents the effect of the escape tower on the variation of C_{Z_α} and CP/D with Mach number for SATURN configuration SA-7. These data are faired values obtained from Figures 5 and 7. It will be noted that the tower effect becomes more pronounced as Mach number increases. In general, above Mach = 1.50, the tower produces a forward shift in center of pressure and a increase in normal force curve slope, C_{Z_α}. At Mach = 4.96, the effect of the tower is a 0.35 caliber forward shift in center of pressure and approximately 8 percent increase in normal force curve slope. Also, a comparison of Figures 6 and 8 shows that, above Mach = 1.20, the tower causes a decrease in fore drag coefficient as Mach number increases while base drag remains the same for both configurations. At Mach = 4.96, the fore drag coefficient is approximately 7 percent lower with tower on than with tower off.

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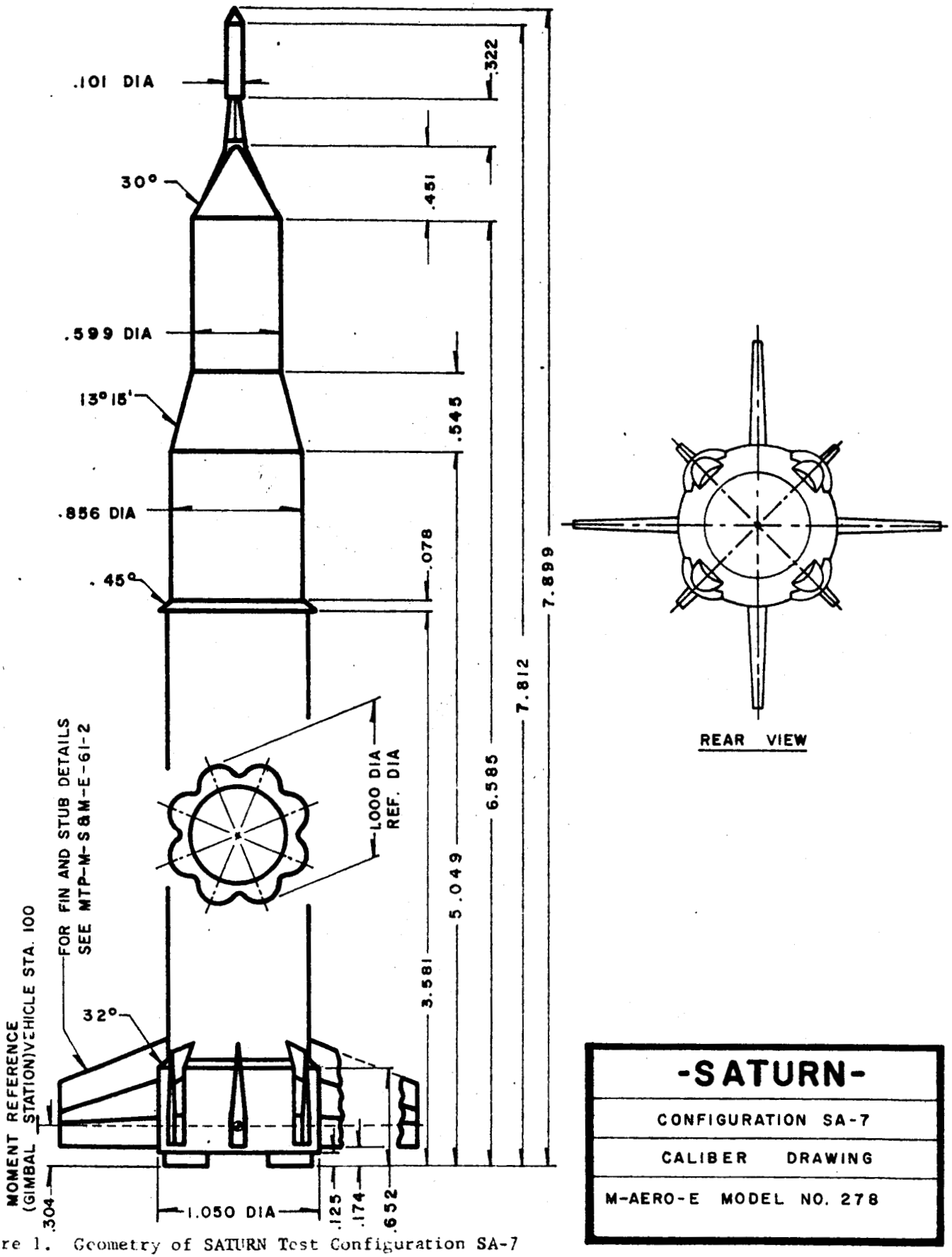


Figure 1. Geometry of SATURN Test Configuration SA-7

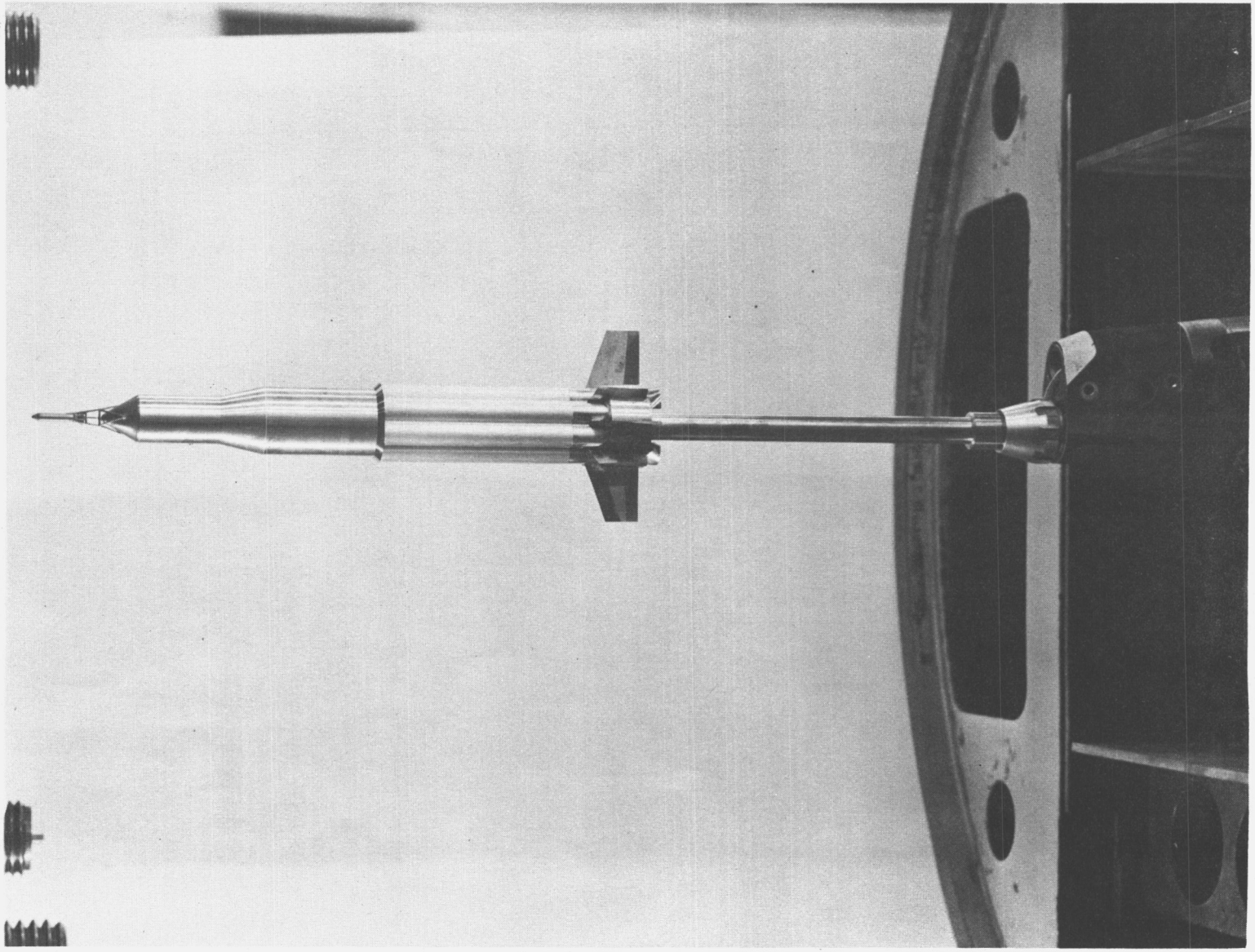
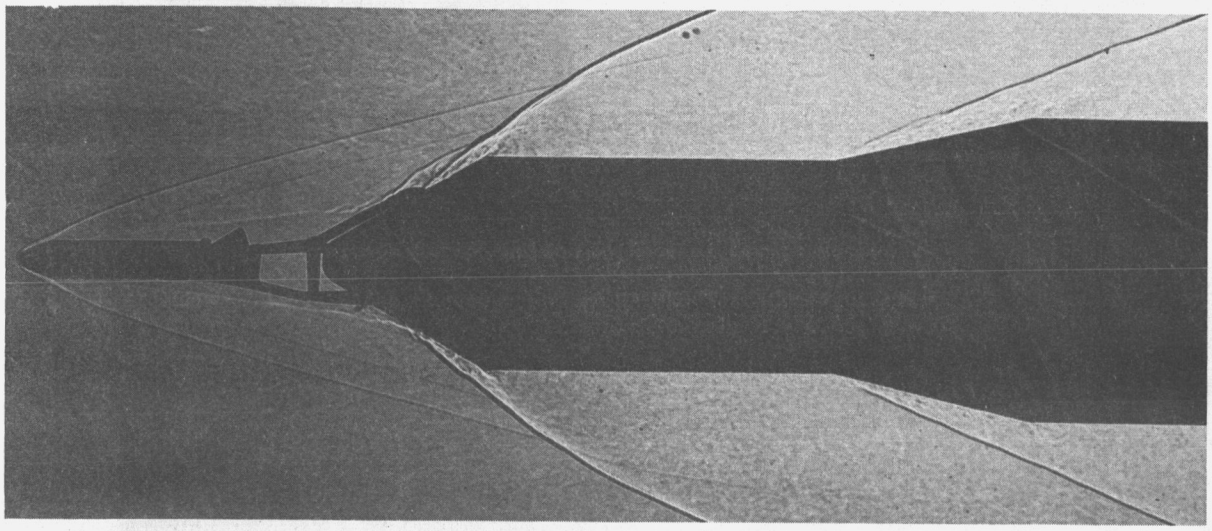


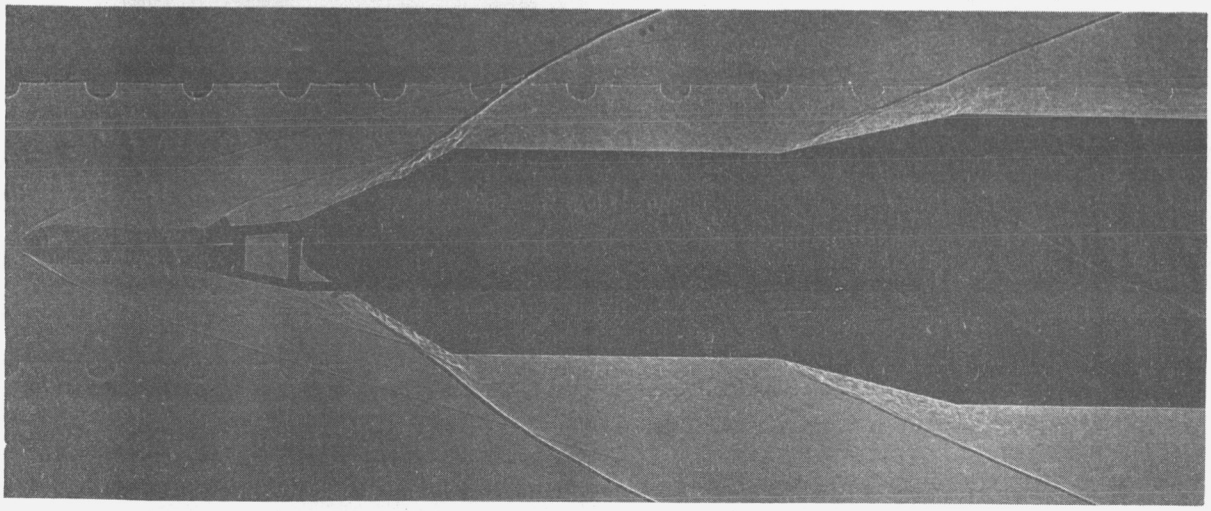
Figure 2. SATURN Configuration SA-7 Sting Mounted in the MSFC 14-Inch Trisonic Tunnel.

MACH NUMBER	P_o psia	R_e/ft x 10^{-6}
0.70	22	5.39
0.80	22	5.79
0.90	22	6.09
0.95	22	6.27
1.05	22	6.42
1.10	22	6.49
1.15	22	6.53
1.20	22	6.56
1.435	22	6.36
1.927	28	6.90
2.99	30	4.34
3.48	45	5.09
4.00	75	6.60
4.45	90	6.12
4.96	90	5.24

Figure 3. Variation of Reynolds Number Per Foot with Mach Number for Average Test Conditions, $\gamma = 1.40$



Clean Configuration



Transition Strip Applied to Nose of Escape Rocket

Figure 4. Upper Stage Shadowgraphs of SATURN Test Configuration SA-7 in the MSFC 14-Inch Trisonic Tunnel, $M = 4.45$, $\alpha = 0^{\circ}$

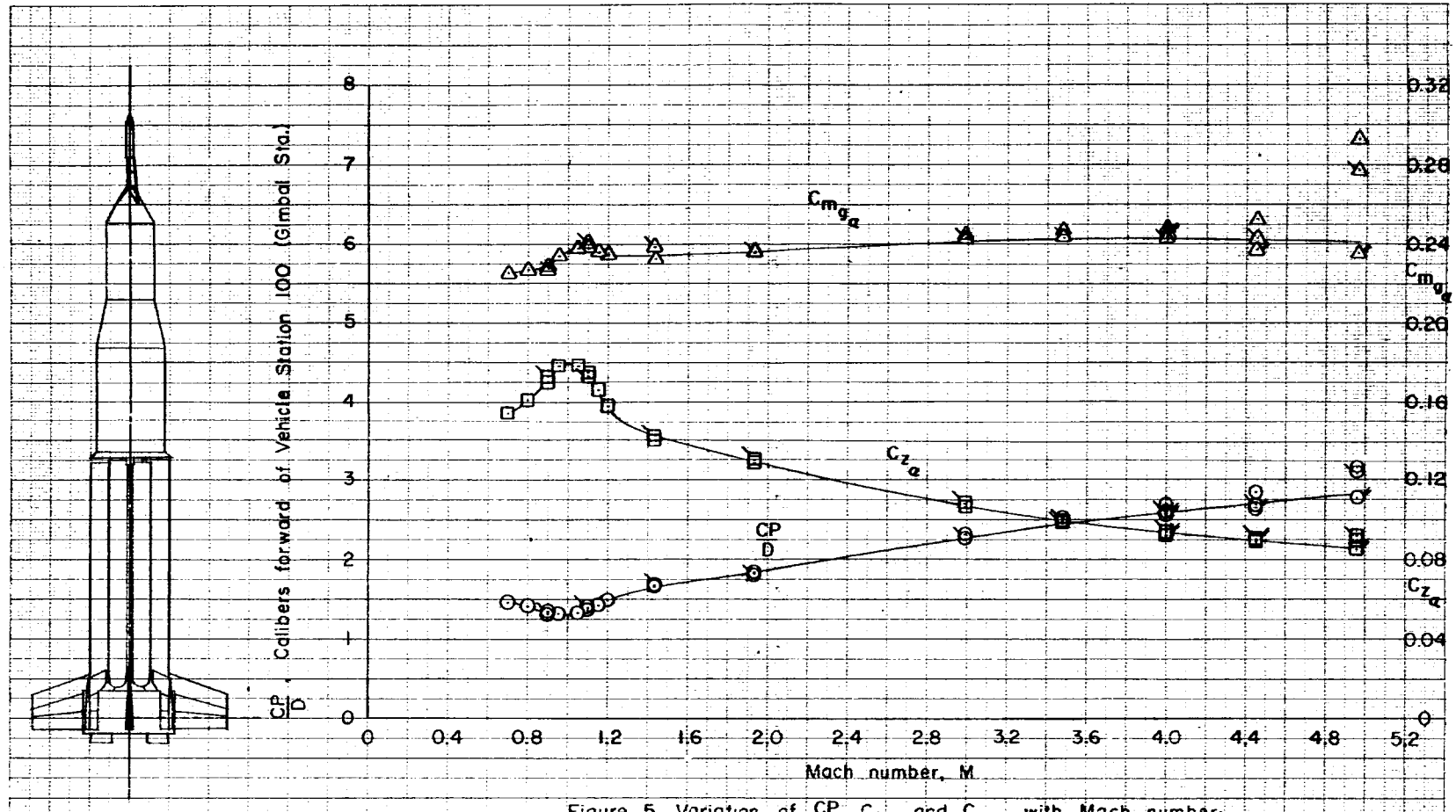


Figure 5 Variation of $\frac{CP}{D}$, C_{z_α} and $C_{m_{g_\alpha}}$ with Mach number;

SATURN Test Configuration SA-7

Flagged symbols indicate transition strips applied to model

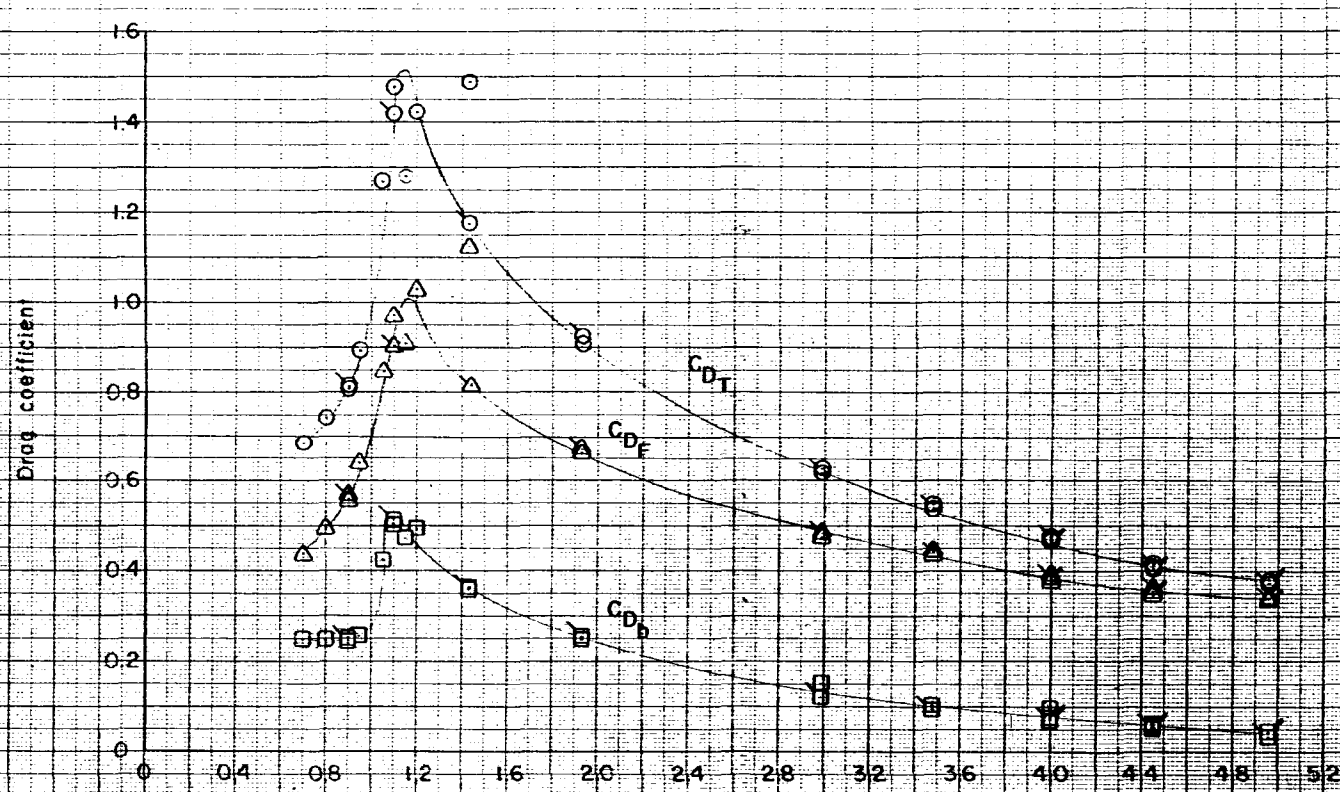


Figure 6 Variation of C_{D_T}, C_{D_F} and C_{D_b} with Mach number.

SATURN Test Configuration SA-7 $\alpha = 0°$

Flagged symbols indicate transition strips applied to model

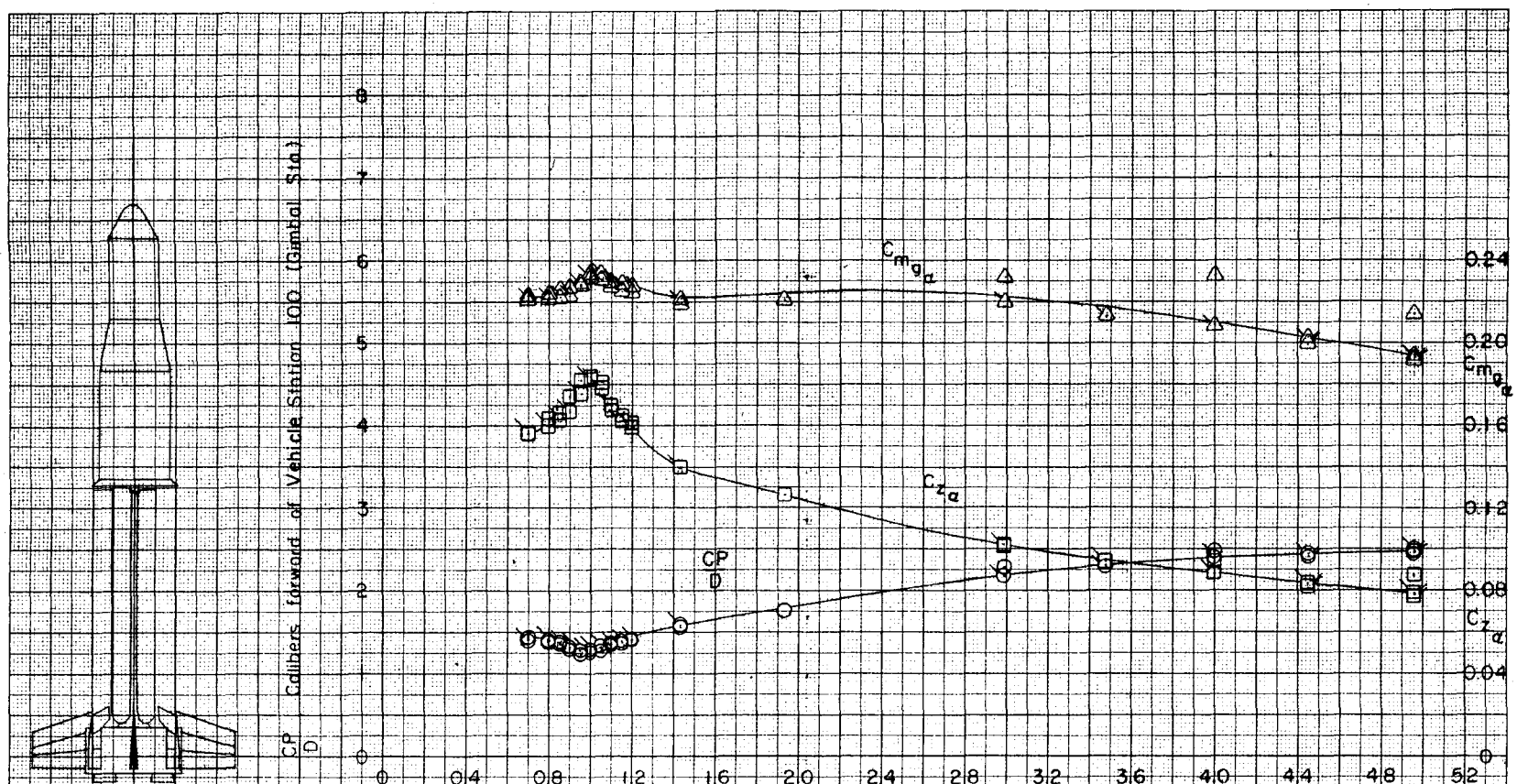


Figure 7 Variation of $\frac{CP}{D}$, C_{z_α} and $C_{m_{g_\alpha}}$ with Mach number; SATURN Test Configuration SA-7 without Escape Tower

Flagged symbols indicate transition strips applied to model

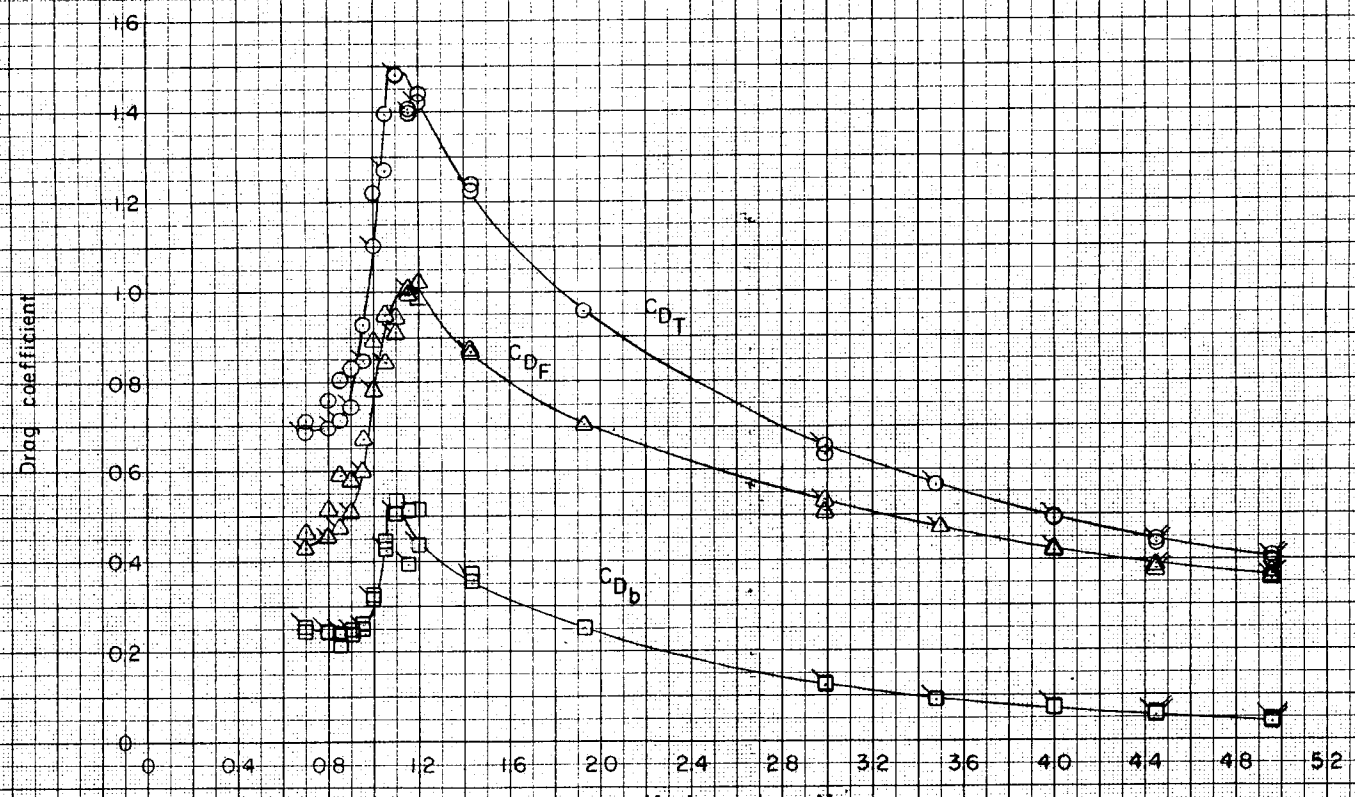


Figure 8 Variation of C_{D_T}, C_{D_F} and C_{D_b} with Mach number, SATURN Test Configuration SA-7 without Escape Tower $\alpha = 0°$

Flagged symbols indicate transition strips applied to model

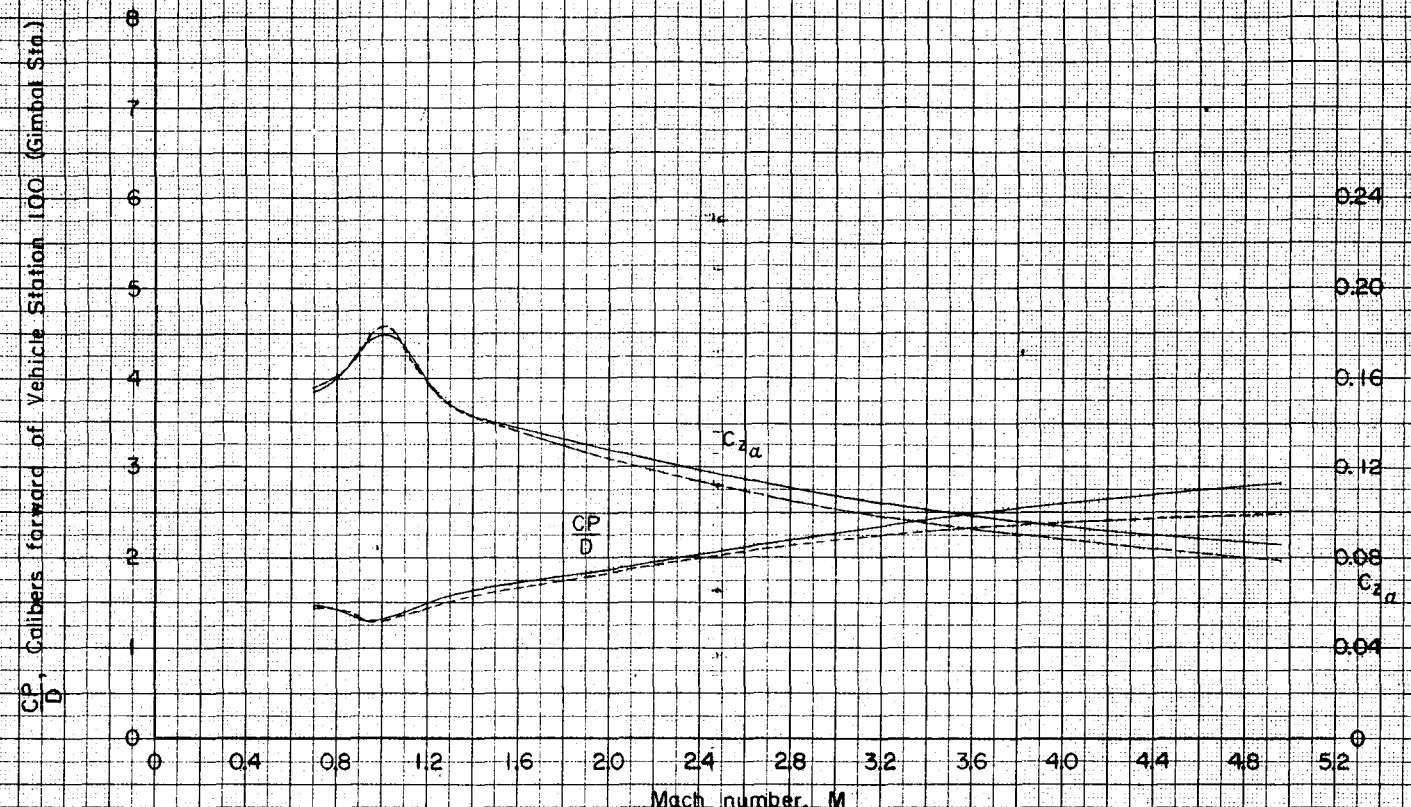


Figure 9 Effect of Escape Tower on variation of C_{z_α} and $\frac{CP}{D}$ with Mach number; SATURN Test Configuration SA-7

(Dashed lines indicate escape tower off)