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RESEARCH MEMORANDUM

for the

Air Materiel Command, Army Air Forces

FLIGHT TESTS OF ROCKET-POWERED "TIN-CAN" MODELS

OF AAF PROJECT MX-800

By

Paul E. Purser and David G. Stone

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

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SUMMARY

Flight tests were made of six noninstrumented rocket-powered "Tin-Can" models of AAF Project MX-800. Velocity and drag data were obtained by use of CW Doppler radar. The existence of stability and adequate structural strength for flight near zero lift was checked by visual and photographic observation. Drag data obtained during the tests agreed reasonably well with estimates based on experimental data from NACA RM-2 rocket-powered drag research models.

INTRODUCTION

At the request of the Air Materiel Command, Army Air Forces, the National Advisory Committee for Aeronautics has made flight tests of six rocket-powered models of AAF Project MX-800 at the Pilotless Air-craft Research Test Station at Wallops Island, Va. The purpose of the tests was to determine the over-all drag of the MX-800 configuration and to provide a qualitative check of the aerodynamic stability and structural strength of the models. This report presents the results of the flight tests of the MX-800 models. The tests were made during the period August 1, 1947 to August 7, 1947.

SYMBOLS

M   Mach number (V/c)

V   flight velocity, feet per second

c   speed of sound, feet per second

W   weight of model, pounds

a resultant acceleration along flight path, feet per second per second

g acceleration of gravity, feet per second per second

S wing area, square feet ($b_W c_W$ for wing 2-4, fig. 1)

S_t tail area, square feet ($b_t c_t$ for tail 6-8, fig. 1)

b_W total wing span, feet

b_t total true tail span, feet

c_W wing chord, feet

c_t tail chord, feet

A_t tail aspect ratio $\left(\dfrac{b_t}{c_t} \right)$

C_D drag coefficient $\left(\dfrac{D}{qS} \right)$

D drag, pounds

q dynamic pressure $\left(\dfrac{1}{2} \rho V^2 \right)$

n_p neutral point, center of gravity for neutral stability in trimmed flight

γ flight-path angle, measured from horizontal

MODELS

Flight

The flight articles, referred to as "Tin-Can" models, were supplied by the M. W. Kellogg Company, Jersey City, N. J. Drawings of the models are presented in figures 1 and 2. Photographs of the nose cap to body, wing to body, and tail to body junctures are shown in figure 3. The "Tin-Can" model consists of a cylindrical steel body with an ogive nose and having cruciform wings and tails fabricated from duralumin. The wings and the two larger tails were symmetrical circular-arc airfoil sections approximately 8-percent-chord thick at the root. The two smaller tails were similar except that they were $9\frac{1}{2}$ percent thick. As shown by figure 2 the wing-section thickness ratio decreased as a function of a circular arc from a point 3-percent span outboard of the body to the tip. The tail-section thickness ratios decreased similarly from a point at about half the exposed span to the tip.

The models were painted with the following color scheme:

Body - International Orange

Wings, Tails, Nose Cap - Green

to provide contrast with the blue sky for taking 16-millimeter color pictures of the flights.

The steel body serves as the rocket-motor case and the propellant consists of a 69-inch length of the 6-inch-diameter "Deacon" grain developed by the Allegany Ballistics Laboratory of the Hercules Powder Company. Static firing tests of the rocket motor showed an average thrust of 4865 pounds for a burning time of 2.69 seconds. Details of the rocket-motor nozzle are shown in figure 4 and thrust-time data obtained from a static firing conducted by the Allegany Ballistics Laboratory are presented in figure 5.

Wind Tunnel

Wind-tunnel models of the MX-800 were designed and built at the Langley Laboratory to be used in obtaining low-speed stability data required for planning the flight tests. These models were $\frac{1}{4}$-scale wooden replicas of the "Tin-Can" models and were so made that interchangeable parts could be assembled to form the following configurations:

Body alone

Body + Wing

Body + Wing + Tail no. 2

Body + Wing + Tail no. 4

The tunnel is a 40-inch-diameter closed test section installed when needed in the air-supply ducting of the Langley induction aerodynamics laboratory. The test velocity used for the MX-800 models was 90 feet per second and the test Reynolds number was about 180,000 based on the 2.73-inch wing chord of the $\frac{1}{4}$-scale models.

The model was supported in the tunnel free to trim about various center-of-gravity locations, and the neutral point was determined as the center of gravity behind which the model would not weathercock into the wind. A photograph of the model mounted in the test section is shown in figure 6. The neutral points obtained in these tests are shown in figure 7 plotted against a tail-effectiveness factor which is approximately proportional to the amount of stability contributed by the tail.

FLIGHT TESTS

Program

The flight-test program for the "Tin-Can" models was so arranged that the desired configuration (T_1 with take-off c.g. at 0.74 M.A.C., fig. 1) was approached from configurations that the low-speed wind-tunnel tests indicated to be more stable. The following table shows the order of firing:

Flight number	Model number	Tail	Center of gravity at take-off (percent M.A.C.)	Low-speed[1] static margin (percent M.A.C.)	Center of[2] gravity at $M = 1$ (percent M.A.C.)	Low-speed[3] static margin (percent M.A.C.)
1	5	T_2 (large area)	30.4	106.6	15.0	122.0
2	6	T_3 (medium area, high aspect ratio)	39.9	79.1	26.9	82.1
3	4	T_1 (medium area, low aspect ratio)	40.5	60.5	28.0	73.0
4	8	T_4 (small area)	42.1	41.4	29.8	53.7
5	3	T_4 (small area)	57.8	25.7	48.7	34.8
6	2	T_1 (medium area, low aspect ratio)	73.9	27.1	68.0	33.0

[1]Determined from figure 7 and center of gravity at take-off.
[2]Determined on basis that center-of-gravity position varies linearly from take-off to burnout because of side-burning rocket propellant grain.
[3]Determined from figure 7 and center of gravity at $M = 1.0$.

Launching

The models were ground-launched without boosters at an elevation angle of $60°$ from a short guide-rail launcher. (See fig. 8.) Photographic observation of the launchings and flights was made with the following cameras:

(a) Fixed K-24 aerial cameras focused on launcher (black and white)

(b) Fixed 35-millimeter motion-picture camera focused on launcher (black and white)

(c) 16-millimeter motion-picture cameras manually tracked to cover flight (color)

Instrumentation and Data

The primary instrumentation for the flight tests was a CW Doppler velocimeter radar unit. This radar unit provides velocity-time data that are accurate enough to allow differentiation for drag computations. (See references 1 to 3.) Radiosonde observations made at the time of firing provided temperature and static-pressure data for use in converting the Doppler velocity and deceleration data obtained during the coasting period of flight to Mach number and drag coefficient. The conversion from deceleration to drag coefficient was accomplished by means of the following formula:

$$C_D = \frac{W(a - g \sin \gamma)}{gSq}$$

where W is the weight of the model when the propellant is expended. The value of W includes the basic model weight, the propellant restrictor weight, and the steel core of the igniter. The flight-path angle γ was determined from an SCR-584 radar record of the flight path of model number 5, flight-path computations, and take-off pictures obtained with the fixed 35-millimeter motion-picture camera. Failure to obtain SCR-584 records for all flights introduces an uncertainty in the value of γ and thus an uncertainty in the values of C_D for all models except number 5. This uncertainty is of the order of ±10 percent of the weight, or expressed in terms of C_D:

±0.0018 at M = 1.4

±0.0035 at M = 1.0

Data presented in reference 4 indicate that errors inherent in the technique should provide errors in drag coefficient not greater than the following:

C_D	Mach number	Number of models of each configuration
±0.005	1.0	1
±.003	1.4	1
±.004	1.0	2
±.002	1.4	2

Approximate rolling-velocity data were obtained by counting quarter-revolutions of the models from the timed 16-millimeter color motion pictures taken with manually tracked cameras during the flights.

RESULTS AND DISCUSSION

Drag

The drag data are presented in figure 9. The drag values for the various models are listed as follows in order of decreasing drag: the large tail, the intermediate-area tail of high aspect ratio, the intermediate-area tail of low aspect ratio, and the small tail. Figure 9 also presents a comparison between the measured values of C_D and those estimated from references 1 to 3. Reasonable agreement exists despite the differences in the general smoothness of the MX-800 models (fig. 3) and the NACA RM-2 drag-research models of references 1 to 3.

In using the drag data of this report for design purposes, the base drag which was not measured in the present tests should be considered. Base-pressure data for a body similar to the MX-800 are presented, however, in reference 5.

Stability and Trim

The existence of adequate stability for all the configurations flown was evidenced by motion pictures and observers' reports, which showed that the models flew in relatively straight smooth paths. The minimum static margin of stability was about 26 percent of the mean aerodynamic chord based on the low-speed tunnel tests. (See fig. 7 and section entitled "FLIGHT TESTS.") The design configuration, tail number 1, which has 71 percent of the wing area and 104 percent of the wing aspect ratio, had a minimum static margin of about 27 percent of the mean aerodynamic chord.

The models were evidently trimmed longitudinally and directionally for zero lift, since during the roll which developed in each of the flights, the model appeared to roll about its longitudinal axis rather than describing a helical path.

Approximate roll data obtained from the 16-millimeter color motion pictures of the flights indicated the average helix angles generated by the wing tips to be between 0.6° left and 0.5° right. The construction tolerances given by the Kellogg Company for the difference in angular settings of opposite wing and tail panels were 0.50°. Inspection of data supplied by the Kellogg Company showed that although two of the 24 pairs of surfaces exceeded the tolerances slightly, the average differences were considerably less than the rates of roll indicated in the tests. The rates of roll developed were small enough, however, to indicate that the stated tolerances were satisfactory and that the wing and tail surfaces were operating at very nearly zero lift.

Rocket-Motor Performance

The rocket motors used in the "Tin-Can" models are new and as yet relatively untried. Information was desired, therefore, as to the quality and consistency of performance of these motors in order to allow more surety in estimations to be made of acceleration or maximum velocity in planning any future flights.

Sufficient data were not obtained during the first 2 or 3 seconds of flight to permit accurate evaluations of the rocket-motor performance. A study was made, however, of the motor performance in terms of maximum velocity reached by each model and these data are presented in table I and figure 10. With the assumption of zero drag, 72.42 pounds of propellant, and a constant thrust of 4833 pounds for 3.0 seconds (total impulse of 14,500 lb-sec) one obtains the following relation between maximum velocity V and average weight W:

$$V = \frac{\text{Thrust}}{\text{Weight}} \times \text{Gravity} \times \text{Time} = \frac{467,000}{W}$$

The experimental values shown in figure 10 scatter about a curve defined by:

$$V = \frac{413,000}{W}$$

The difference between these two curves is of the order of magnitude usually experienced and is due to the following factors:

(a) Finite drag of model

(b) Variations in propellant weight

(c) Finite time required for build-up and decrease of thrust at beginning and end of burning

(d) Inconsistency in rocket-motor performance, due to both propellant and nozzle construction.

The fact that the total difference between the two curves is of a normal order of magnitude and that the scatter is in the direction indicated by items (a) and (b) above (see table I and fig. 10) indicates that little inconsistency existed in the performance of the six rocket motors used.

Structures

The structural integrity of the models for flight near zero lift was evidenced by the absence of structural failure during the flights.

CONCLUDING REMARKS

Successful flights of six "Tin-Can" models of the MX-800 indicated these models to be stable longitudinally and directionally with the take-off center of gravity at 0.74 mean aerodynamic chord and with a tail having 71 percent of the wing area and 104 percent of the wing aspect ratio. That the models were structurally sound for flight near zero lift was evidenced by the absence of failures during the flights. Drag data obtained in the tests agreed reasonably well with estimates based on experimental data from NACA RM-2 rocket-powered drag research models.

Langley Memorial Aeronautical Laboratory
     National Advisory Committee for Aeronautics
          Langley Field, Va.

Paul E. Purser
Aeronautical Engineer

David G. Stone
Aeronautical Engineer

Approved:

Robert R. Gilruth
Chief of Pilotless-Aircraft Research Division

RCM

REFERENCES

1. Mastrocola, N.: Effect of Number of Fins on the Drag of a Pointed Body of Revolution at Low Supersonic Velocities. NACA RM No. L7A08, 1947.

2. Alexander, Sidney R.: Drag Measurements of Symmetrical Circular-Arc and NACA 65-009 Rectangular Airfoils Having an Aspect Ratio of 2.7 as Determined by Flight Tests at Supersonic Speeds. NACA RM No. L6J14, 1946.

3. Tucker, Warren A., and Nelson, Robert L.: Drag Characteristics of Rectangular and Swept-Back NACA 65-009 Airfoils Having Various Aspect Ratios as Determined by Flight Tests at Supersonic Speeds. NACA RM No. L7C05, 1947.

4. Katz, Ellis R.: Results of Flight Tests at Supersonic Speeds to Determine the Effect of Body Nose Fineness Ratio on Body and Wing Drag. NACA RM No. L7B19, 1947.

5. Thompson, Jim Rogers, and Marschner, Bernard W.: Comparative Drag Measurements at Transonic Speeds of an NACA 65-006 Airfoil and a Symmetrical Circular-Arc Airfoil. NACA RM No. L6J30, 1946.

TABLE I

Model number	Model weight (lb)			Propellant weight (lb)	C_D at M = 1.0	$\dfrac{\text{Propellant weight}}{C_D}$	Measured maximum velocity (fps)
	Launching	At rocket burnout[1]	Average				
2	251.31	179.00	215.15	71.51	0.166	431	1894
3	269.69	195.87	232.78	73.02	.146	500	1830
4	290.10	217.31	253.65	71.99	.162	444	1627
5	292.25	219.98	256.12	71.47	.176	406	1555
6	293.06	220.41	256.74	71.85	.169	425	1574
8	278.38	206.25	242.38	71.33	.155	458	1703

[1]Weight at burnout computed from launching weight minus sum of propellant weight and igniter weight, assuming that propellant restrictor and steel igniter rod remain in rocket after burnout.

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24" Cone   Ballast   Propellant

Top view
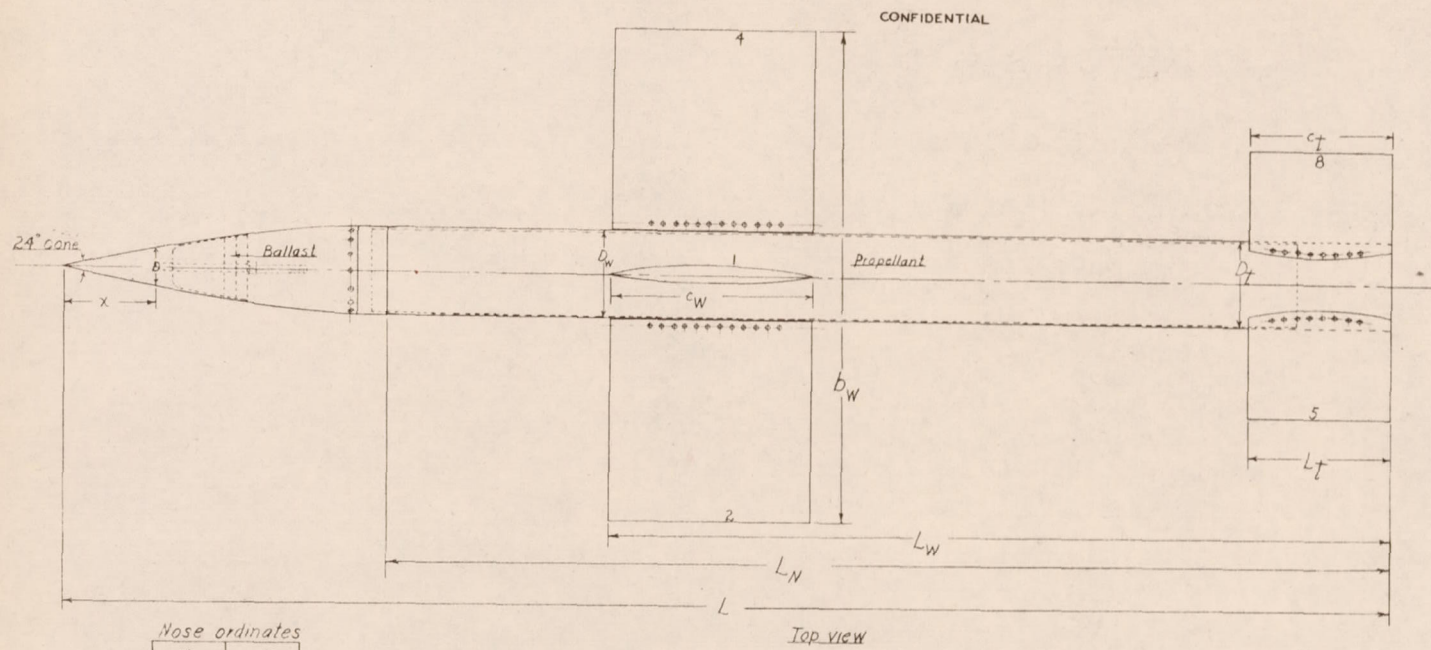
Nose ordinates

X, inches	D, inches
0	0
2.25	0.92
4.25	1.72
6.25	2.48
8.25	3.24
10.25	3.96
12.25	4.62
14.25	5.20
16.25	5.70
18.25	6.08
20.25	6.36
22.25	6.48

Dimensions measured on models, inches

Model	L	L_N	L_W	L_t	D_W	D_t	b_W 1-3	b_W 2-4	c_W 1-3	c_W 2-4	b_t 5-7	b_t 6-8	c_t 5-7	c_t 6-8	Tail
2	99.14	74.70	58.00	12.28	6.50	6.50	36.38	36.38	14.92	14.92	31.30	31.30	12.34	12.34	1
3	99.28	74.84	58.00	11.50	6.48	6.49	36.27	36.28	14.90	14.91	27.86	27.81	10.63	10.66	4
4	99.28	74.84	58.03	12.30	6.50	6.50	36.33	36.44	14.92	14.93	31.30	31.22	12.38	12.34	1
5	99.31	74.87	58.03	12.28	6.48	6.17	36.41	36.45	14.86	14.92	39.41	39.45	12.36	12.36	2
6	99.30	74.86	58.06	11.55	6.50	6.50	36.34	36.36	14.90	14.91	35.00	35.03	10.63	10.63	3
8	99.28	74.84	58.05	11.47	6.50	6.50	36.33	36.41	14.91	14.90	27.91	28.03	10.66	10.64	4

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Rear view
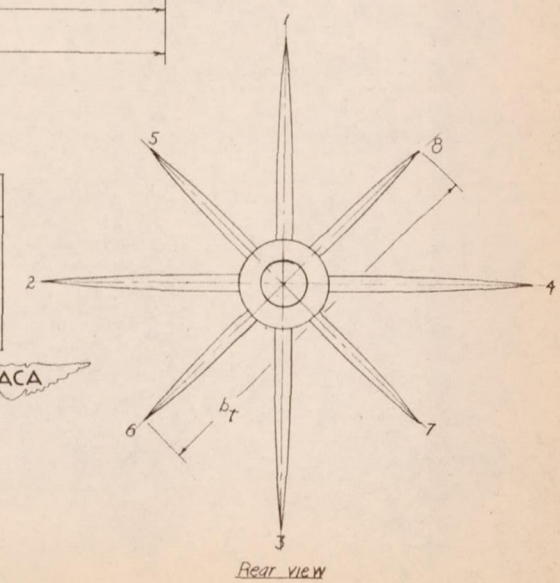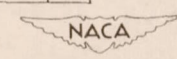
Figure 1.- Drawing of MX-800 "Tin-Can" model.

See section X

R_2

C

S

B

T

Wings~12 holes each side
Tails~ 8 holes each side

See section X

.091"

R_1

$3\frac{1}{4}$"R.

2" R.

.09375"

Formed parts

$\frac{1}{64}$" R.

Spot weld before trimming

Section X
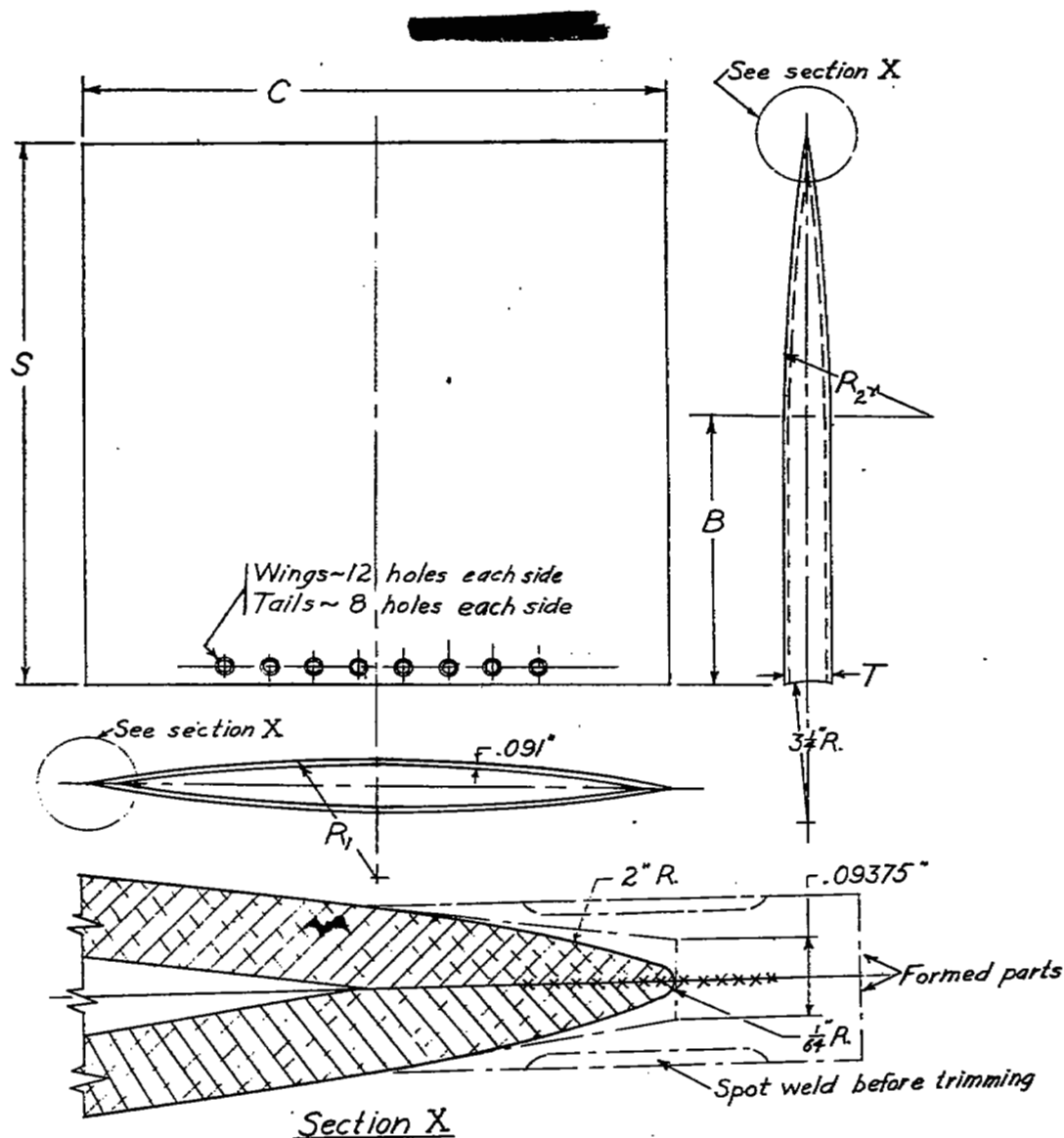
Dimensions, inches

Surface	S	C	B	T	R_1	R_2	T/C
Wing	14.88	14.88	1.0	1.2	50.3	174.4	0.081
Tail 1	12.3	12.3	6.15	1.0	42.0	42.0	.081
Tail 2	16.425	12.3	10.275	1.0	42.0	42.0	.081
Tail 3	14.2	10.65	8.875	1.0	31.61	31.61	.094
Tail 4	10.65	10.65	5.325	1.0	31.61	31.61	.094

Figure 2 .-Construction drawings for wings and tails
of MX-800 "Tin-Can" models.
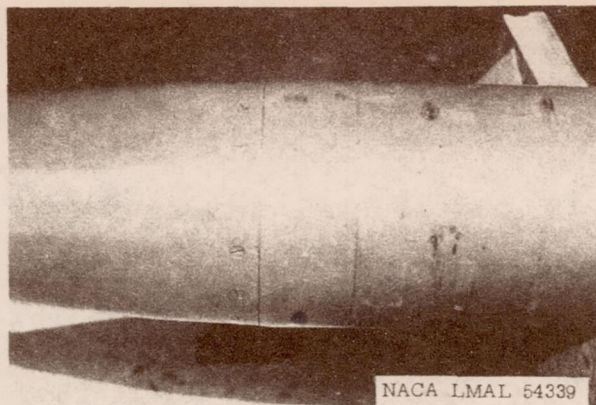
(a) Nose-body juncture.
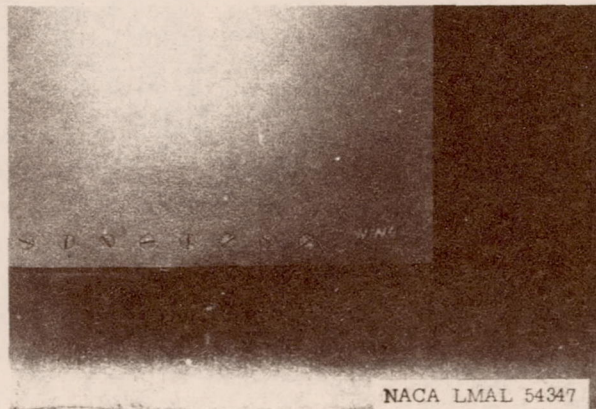
(b) Wing-body juncture.
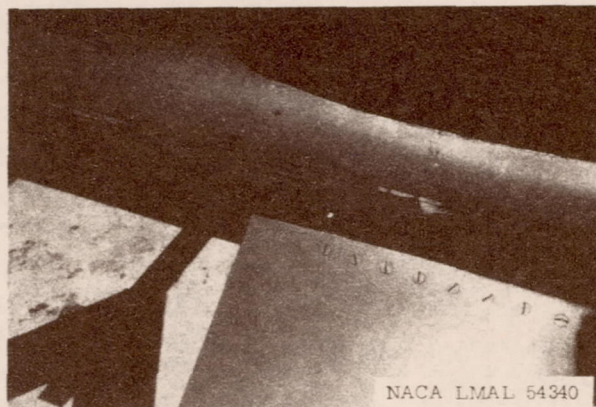
(c) Tail-body juncture.

Figure 3.-   Detail photographs of parts of the MX-800 "Tin-Can" rocket-powered models.
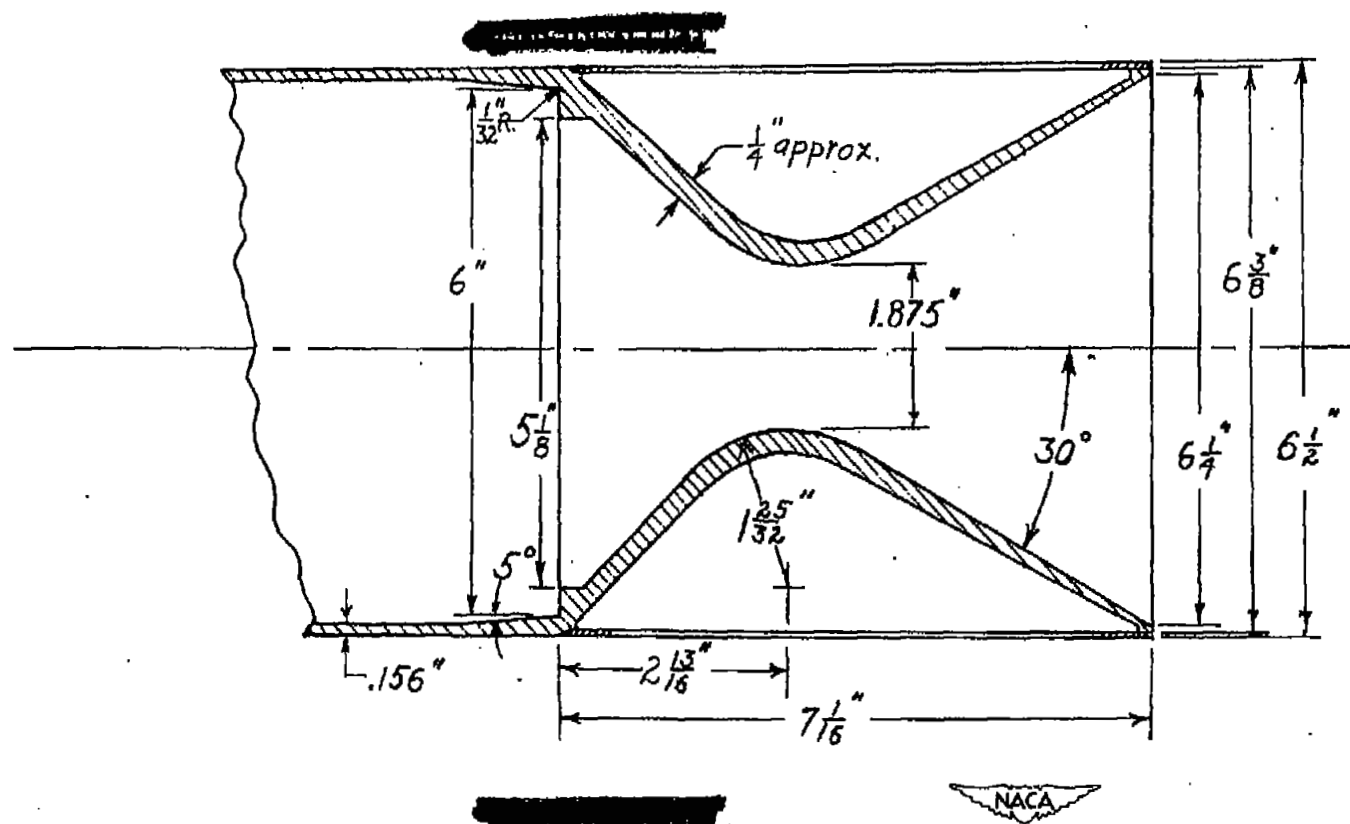
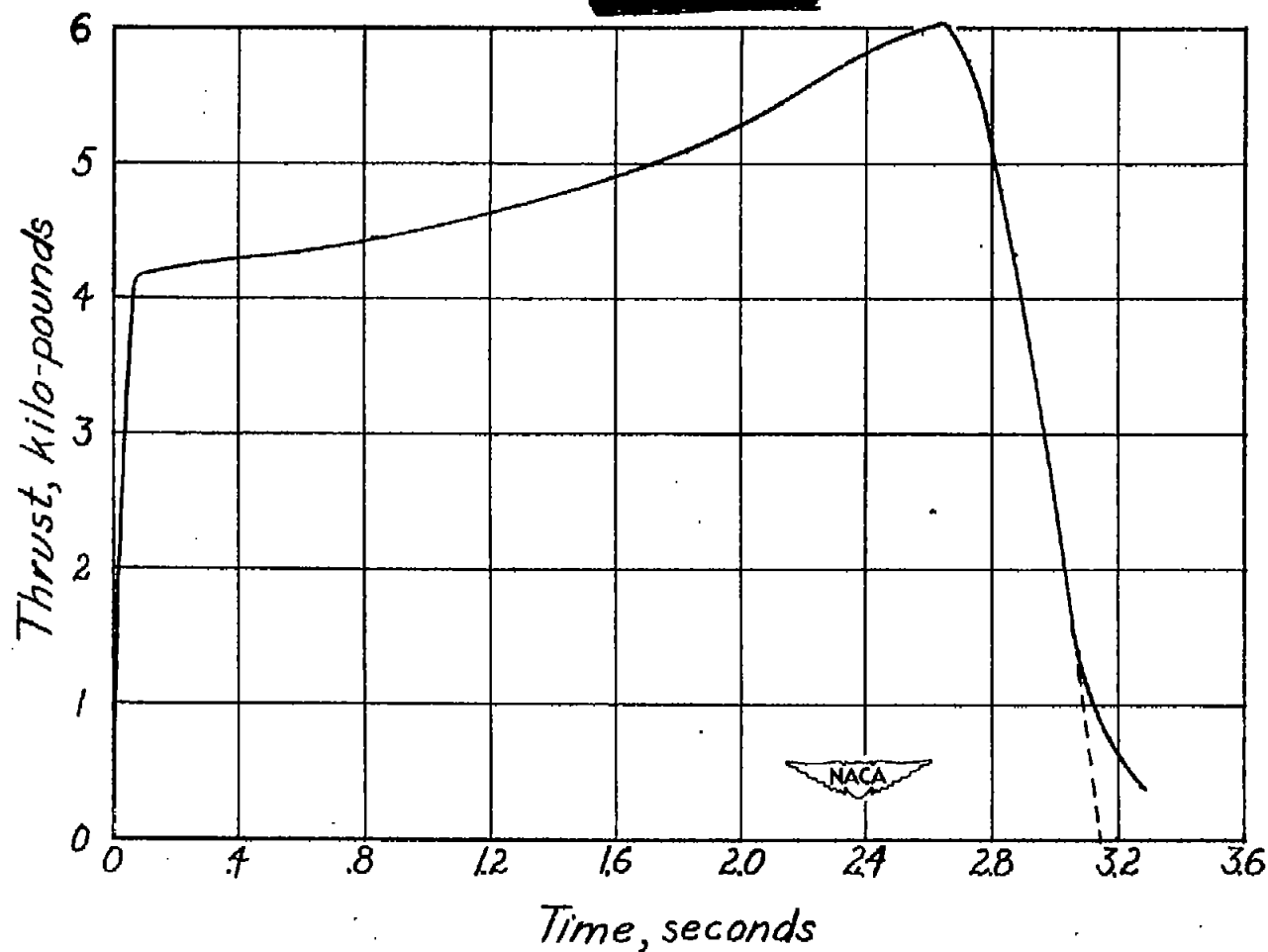Figure 4.- Section through nozzle of MX-800 "Tin-Can" rocket model.

Figure 5.– Static thrust record for MX-800 "Tin-Can" rocket. Allegany Ballistics Laboratory Record No. C-2912. Powder weight = 72.42 lb. Total impulse = 14,500 lb.-sec.
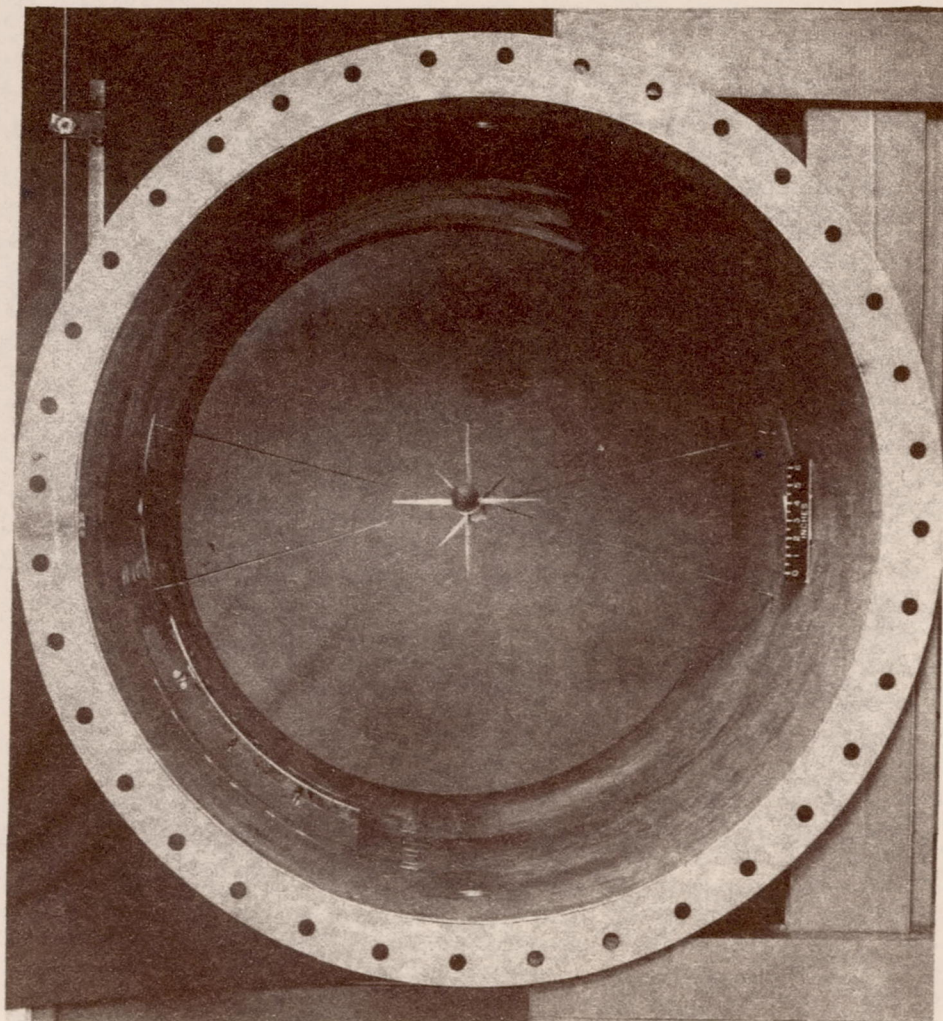
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Figure 6.- View of $\frac{1}{4}$-scale model of MX-800 "Tin-Can" mounted in 40-inch diameter test section.
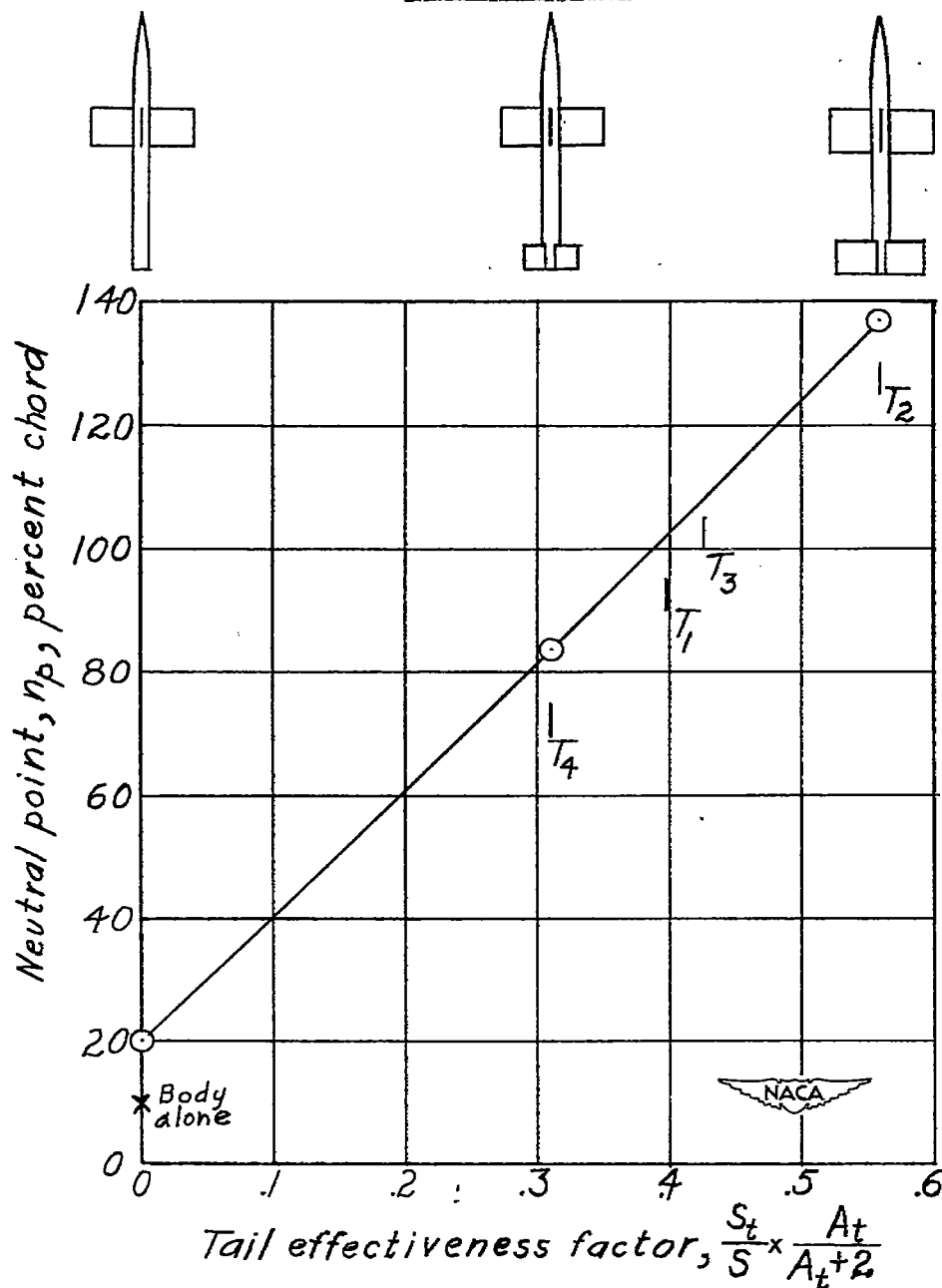
Figure 7.- Neutral points determined in low-speed tunnel tests of $\frac{1}{4}$ -scale models of the MX-800 "Tin-Can" models. Test Reynolds number approximately 180,000.
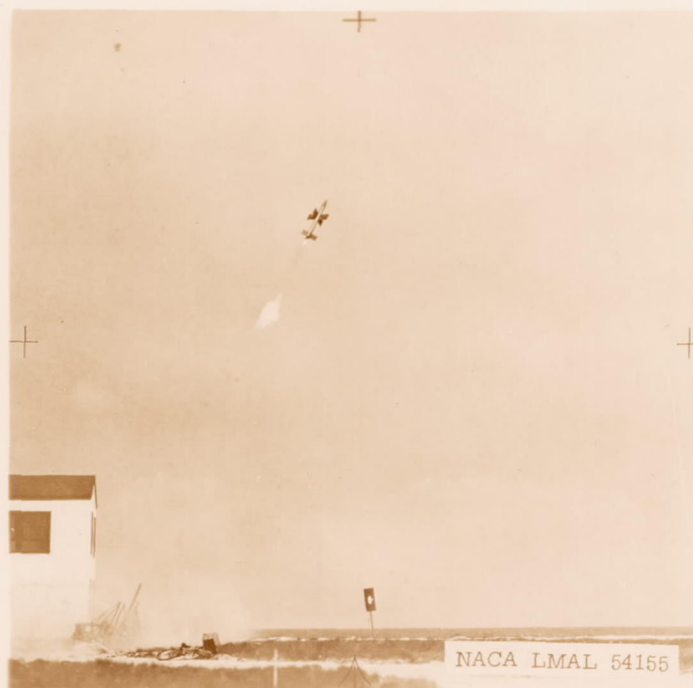
(a) Side view.

Figure 8.- Launching of MX-800 "Tin-Can" models.

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(b) Three-quarter rear view.

Figure 8.- Concluded.

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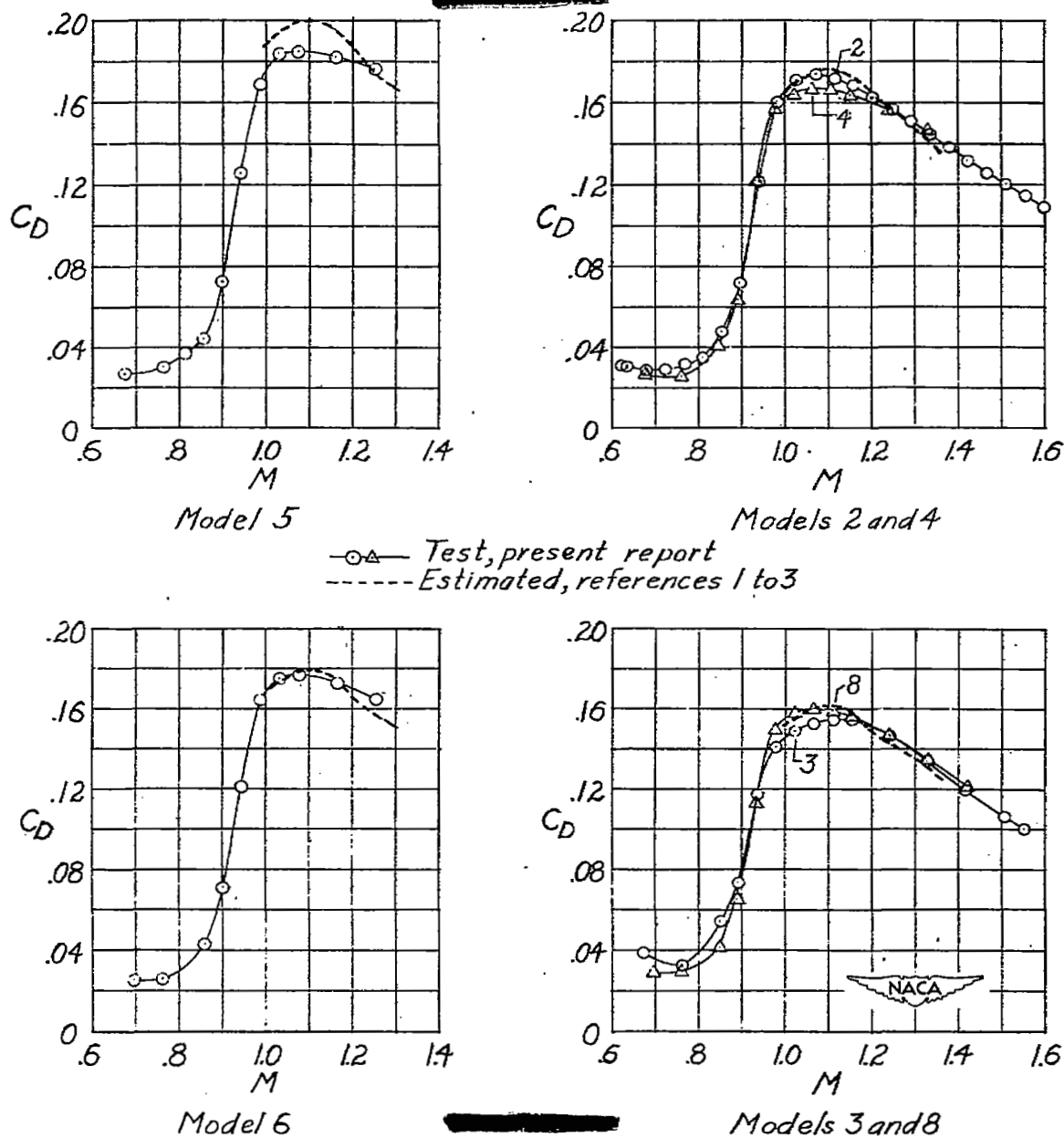LANGLEY MEMORIAL AERONAUTICAL LABORATORY - LANGLEY FIELD. VA

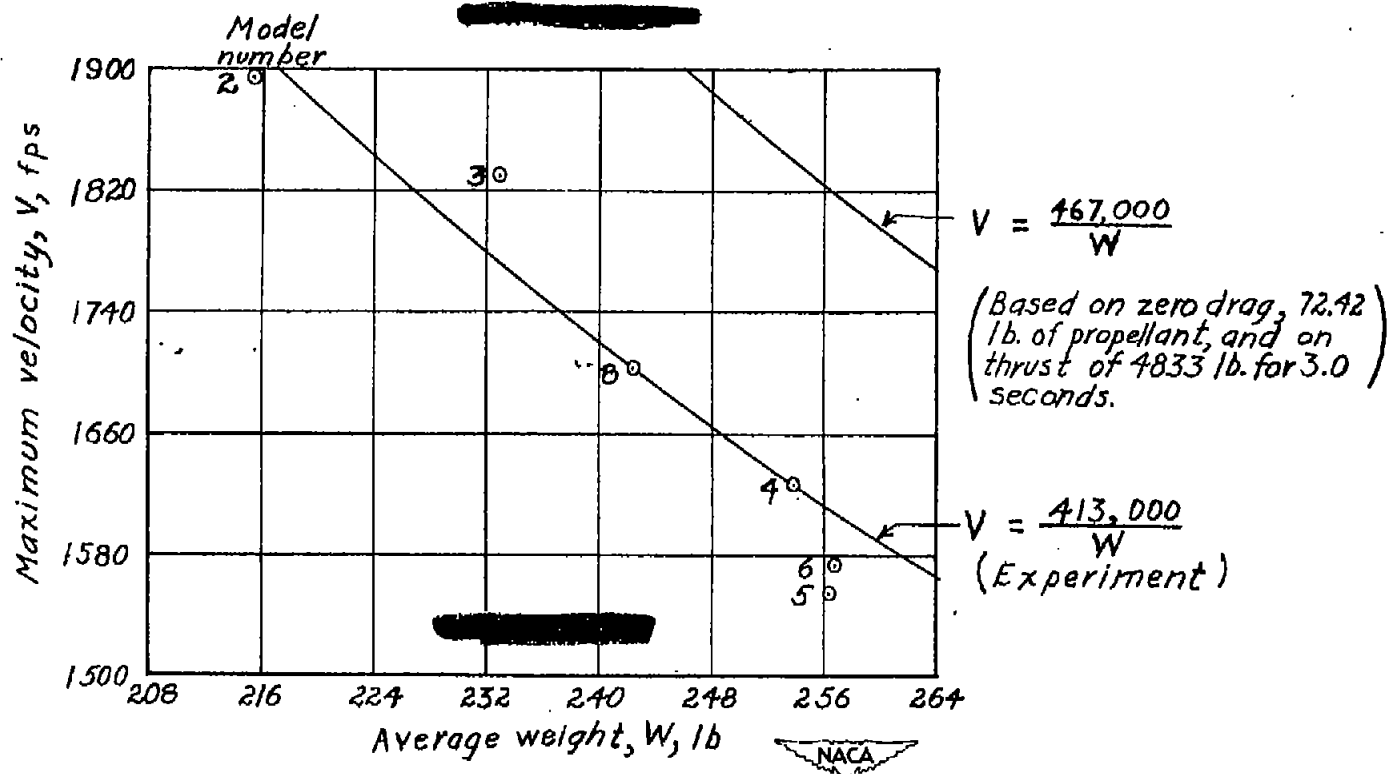Figure 9 : Drag coefficient -Mach number data for the MX-800 "Tin-Can" rocket-powered models.

Figure 10.—Variation of maximum velocity with average weight for MX-800 "Tin-Can" rocket models. Models 2, 5, and 6 have lower ratio of propellant weight to drag and Model 3 has higher ratio of propellant weight to drag than do Models 4 and 8.