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MEMORANDUM REPORT No. 1101

OCTOBER 1957

**Drag And Stability Properties  
Of A Redstone Warhead Model (U)**

L. C. MacALLISTER

DEPARTMENT OF THE ARMY PROJECT No. 5803-03-001  
ORDNANCE RESEARCH AND DEVELOPMENT PROJECT No. TR3-0108

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**MEMORANDUM REPORT NO. 1101**

LCMacAllister/iw  
Aberdeen Proving Ground, Md.  
October 1957

**DRAG AND STABILITY PROPERTIES OF A REDSTONE WARHEAD MODEL (U)**

**ABSTRACT**

The drag and stability properties of a Redstone Warhead Model, as determined by range firings, for  $0.7 < M < 3.5$  are presented.

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**SYMBOLS**

|                        |                                            |
|------------------------|--------------------------------------------|
| $C_D$                  | Drag coefficient                           |
| $C_{M_\alpha}$         | Static moment derivative (per radian)      |
| $C_{N_\alpha}$         | Normal force derivative (per radian)       |
| $CP_N$                 | Center of pressure (calibers from base)    |
| $C_{m_q}$              | Damping derivative due to angular velocity |
| $C_{m_{\dot{\alpha}}}$ | Damping derivative due to yawing velocity  |
|                        | reference area = base area                 |
|                        | reference length = base diameter (d)       |

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### INTRODUCTION

A version of the Redstone missile Warhead was tested in the Transonic Free Flight Range<sup>1</sup> of the Ballistic Research Laboratories at the request of ABMA. The current model (Fig. 1 and 2) differed from earlier models<sup>2</sup> in that the after body was a single conical section instead of a cone section and a cylinder. The models were encased in a plastic sabot (Fig. 2) and launched through the range from a smooth bored five-inch gun. Sixteen models were launched at speeds from 800 to 4000 fps and all but one model traversed the full range of instrumentation. A summary of the initial firing data and the physical measurements of the model are given in Table I.

### RESULTS

The range data were processed by the usual techniques<sup>3</sup> and the reduction and motion parameters are given in Table II. The resulting aerodynamic coefficients are given in Table III.

The drag coefficient,  $C_D$ , is shown in Figure 3. The curve shown is for zero yaw. A value of  $C_{D\delta^2}$  of 2.5 per squared radians has been used to reduce the individual round values to a zero yaw value. This value of  $C_{D\delta^2}$  seems adequate for the supersonic data.

The moment derivative,  $C_{M\alpha}$ , (for a center of mass position 2.47 calibers forward of base) is given in Figure 4. Maximum stability occurs at about  $M = 0.9$  and decreases with increasing Mach number. In fact, extrapolation would give a neutral point at about  $M = 6$ ; however, the slope of the  $C_{m\alpha}$  curve may change at speeds above those tested. The normal force slope is shown in Figure 5 and the center of pressure of the normal force in Figure 6.

The damping moment derivatives,  $(C_{m\dot{q}} + C_{m\dot{\alpha}})$ , Figure 7, are stabilizing except at high subsonic speeds. For Mach numbers greater than about 1.1  $(C_{m\dot{q}} + C_{m\dot{\alpha}})$  is fairly constant and adequately large.

Representative shadowgraphs of the model in flight are given in Figure 8 to 16. It might be noted that even at the lowest test speed ( $M \doteq 0.7$ ) small shock waves exist at the corner of the nose cone, hence these data do not represent a fully subsonic local flow state. Also, almost all of the variations of the model's properties, except slow trends, occur in the region from the

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lowest speed tested up to about  $M = 1.2$  where full supersonic flow appears to be established over the body and the control vanes.

**REMARKS**

Normally in the processing of range data from a statically stable symmetric missile which is not spinning and has a linear force system certain equalities of the reduction parameters are preserved. Primarily these are equality in magnitude of the epicyclic rates,  $b_1$  and  $b_2$ . It can be noted in Table II that these equalities are not always present to within the probable accuracy of the data. Generally this can be ascribed to three causes:

1. Small size of one of the epicyclic modes, a degenerate fitting condition, i.e., rounds 2-4471 and 2-4476. These may be handled by computing the properties utilizing the equalities and the significant mode.
2. Small missile asymmetries where impossible, or impractical, to process by asymmetric reduction systems. The highest velocity rounds are most apt, mechanically, to have suffered some slight damage.
3. Nonlinearity of the aerodynamic force system. This is partially allowed for but may be the only logical reason why the data for the low Mach number rounds has inconsistent damping for the two modes.

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**REFERENCES**

1. Rogers, W. K., The Transonic Free Flight Range, BRL Report No. 889, 1953. AD-13 358
2. Rogers, W. K., Free Flight Tests of A Model of The "Redstone", ZSSM-A-14, Warhead, BRIM 885, 1955. AD-64214
3. Murphy, C. H., Data Reduction for Free Flight Ranges, BRL Report 900, 1956. AD-35833 ?

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TABLE I

Test Conditions

| Round<br>Number | Date<br>1957 | Mid Range<br>Test Velocity<br>fps | Weight<br>lb | C. G.<br>in. from<br>base | Remarks                                |
|-----------------|--------------|-----------------------------------|--------------|---------------------------|----------------------------------------|
| 2-4431          | 2 March      | 3450                              | 8.11         |                           |                                        |
| 2-4432          | 2 March      | 1280                              | 8.08         |                           |                                        |
| 2-4433          | 2 March      | 830                               | 8.10         | 7.413                     |                                        |
| 2-4470          | 18 March     | 1250                              | 8.11         | 7.422                     |                                        |
| 2-4471          | 18 March     | 1470                              | 8.10         | 7.515                     |                                        |
| 2-4472          | 18 March     | 1600                              | 8.11         | 7.420                     | Hit fragment shield<br>in second group |
| -4473           | 18 March     | 1600                              | 8.10         | 7.416                     |                                        |
| 2-4474          | 20 March     | 2770                              | 8.08         | 7.404                     |                                        |
| 2-4475          | 20 March     | 2430                              | 8.09         | 7.412                     |                                        |
| 2-4476          | 20 March     | 3060                              | 8.09         | 7.410                     |                                        |
| 2-4479          | 27 March     | 810                               | 8.09         | 7.414                     |                                        |
| 2-4480          | 27 March     | 810                               | 8.11         | 7.414                     |                                        |
| 2-4481          | 27 March     | 920                               | 8.10         | 7.414                     |                                        |
| 2-4482          | 28 March     | 1050                              | 8.10         | 7.414                     |                                        |
| 2-4483          | 28 March     | 1100                              | 8.09         | 7.414                     |                                        |
| 2-4484          | 28 March     | 3990                              | 8.10         | 7.413                     |                                        |

Average maximum diameter (20 measurements) = 3.000 ( $^{+.002}_{-.001}$ )

Average length (20 measurements) = 14.397 ( $^{+.006}_{-.017}$  in)

Average axial mement of inertia  
(2 measurements) = 6.39 lb-in<sup>2</sup>

Average transverse moment of inertia  
(2 measurements) = 101.50 lb-in<sup>2</sup>

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TABLES II

## REDUCTION AND MOTION PARAMETERS

| Round<br>Number | Mach<br>Number | $\overline{\delta^2}$<br><br>(deg <sup>2</sup> ) | Epicyclic Yaw<br>Rates (deg/ft) |        | Model Damping<br>Rates (1/ft) |                  | Mid-range<br>values of<br>yaw arms<br>(rad) |       | Standard Error<br>Yaw Swerve<br>Fit Fit |      |
|-----------------|----------------|--------------------------------------------------|---------------------------------|--------|-------------------------------|------------------|---------------------------------------------|-------|-----------------------------------------|------|
|                 |                |                                                  | $b_1$                           | $b_2$  | $\lambda_1 10^3$              | $\lambda_2 10^3$ | $K_1$                                       | $K_2$ | rad                                     | feet |
| 2-4479          | .717           | 11.2                                             | -1.853                          | 1.932  | - .45                         | - .05            | .0248                                       | .0529 | .0030                                   | .020 |
| 2-4480          | .720           | 9.8                                              | -1.909                          | +1.897 | +1.02                         | - .47            | .0325                                       | .0424 | .0048                                   | .041 |
| 2-4481          | .814           | 5.9                                              | -1.999                          | +2.031 | + .44                         | + .32            | .0303                                       | .0292 | .0029                                   | .020 |
| 2-4482          | .921           | 22.5                                             | -2.198                          | +2.17  | 1.21                          | +1.40            | .0291                                       | .0904 | .0045                                   | .015 |
| 2-4483          | .971           | 7.7                                              | -2.031                          | +2.058 | 1.10                          | +1.57            | .0210                                       | .0394 | .0040                                   | .015 |
| 2-4470          | 1.110          | 5.3                                              | -1.865                          | +1.848 | 1.65                          | +1.59            | .0260                                       | .0254 | .0027                                   | .018 |
| 2-4471          | 1.302          | 1.4                                              | -1.449                          | +1.785 | 1.56                          | +3.96            | .0169                                       | .0052 | .0020                                   | .016 |
| 2-4473          | 1.436          | 15.0                                             | -1.339                          | +1.371 | 1.18                          | +1.64            | .0298                                       | .0547 | .0042                                   | .031 |
| 2-4475          | 2.159          | 4.1                                              | -1.138                          | +1.116 | 1.65                          | +1.46            | .0244                                       | .0212 | .0016                                   | .022 |
| 2-4474          | 2.465          | 9.4                                              | -1.129                          | +1.032 | 1.60                          | +1.62            | .0315                                       | .0325 | .0027                                   | .012 |
| 2-4476          | 2.714          | 1.2                                              | -1.061                          | +1.000 | 2.09                          | +1.47            | .0081                                       | .0156 | .0033                                   | .025 |
| 2-4484          | 3.453          | 5.0                                              | -0.904                          | +0.904 | 2.29                          | 2.29             | .0238                                       | .0216 | .0058                                   | .061 |



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TABLE III  
AERODYNAMICS COEFFICIENTS

| Mach<br>Number | Reynolds<br>Number | $\overline{\delta^2}$<br>(10 <sup>-6</sup> ) (deg <sup>2</sup> ) | C <sub>D</sub> | C <sub>M<sub>α</sub></sub> | C <sub>N<sub>α</sub></sub> | C <sub>P<sub>N</sub></sub> | C <sub>M<sub>q</sub></sub> + C <sub>M<sub>α</sub></sub> | Round<br>Number |
|----------------|--------------------|------------------------------------------------------------------|----------------|----------------------------|----------------------------|----------------------------|---------------------------------------------------------|-----------------|
|                |                    |                                                                  |                | (per rad)                  |                            | (from base)                |                                                         |                 |
| .717           | 1.25               | 11.2                                                             | .2801          | -1.663                     | 3.79                       | 2.03                       | 4.1                                                     | 2-4479          |
| .722           | 1.26               | 9.8                                                              | .2801          | -1.685                     | 3.63                       | 2.01                       | 8.5                                                     | 2-4480          |
| .737           | 0                  |                                                                  | .2758          |                            |                            |                            |                                                         |                 |
| .814           | 1.42               | 5.9                                                              | .2956          | -1.890                     | 3.06                       | 1.85                       | -2.3                                                    | 2-4481          |
| .921           | 1.61               | 22.5                                                             | .3998          | -2.217                     | 3.44                       | 1.83                       | -24.5                                                   | 2-4482          |
| .971           | 1.70               | 7.7                                                              | .4395          | -1.939                     | 5.14                       | 2.09                       | -20.6                                                   | 2-4483          |
| 1.110          | 1.93               | 5.3                                                              | .5485          | -1.610                     | 4.48                       | 2.11                       | -30.2                                                   | 2-4470          |
| 1.302          | 2.27               | 1.4                                                              | .5024          | -1.215                     | <u>4.08</u>                | <u>2.17</u>                | <u>-59.0</u>                                            | 2-4471          |
| 1.430          | 2.51               | 15.2                                                             | .4966          | - .858                     | 3.32                       | 2.21                       | -28.0                                                   | 2-4473          |
| 2.159          | 3.73               | 4.1                                                              | .3845          | - .601                     | 3.46                       | 2.30                       | -30.9                                                   | 2-4475          |
| 2.465          | 4.29               | 9.4                                                              | .3456          | - .547                     | 3.28                       | 2.30                       | -32.2                                                   | 2-4474          |
| 2.714          | 4.68               | 1.2                                                              | .3163          | - .504                     | 3.86                       | 2.34                       | -35.1                                                   | 2-4476          |
| 3.05           |                    | 0                                                                | .2872          |                            |                            |                            |                                                         |                 |
| 3.453          | 6.02               | 5.0                                                              | .2633          | - .388                     | 2.73                       | 2.33                       | 49.9                                                    | 2-4484          |

Underlined values are poorly determined  
due to small yaw size.

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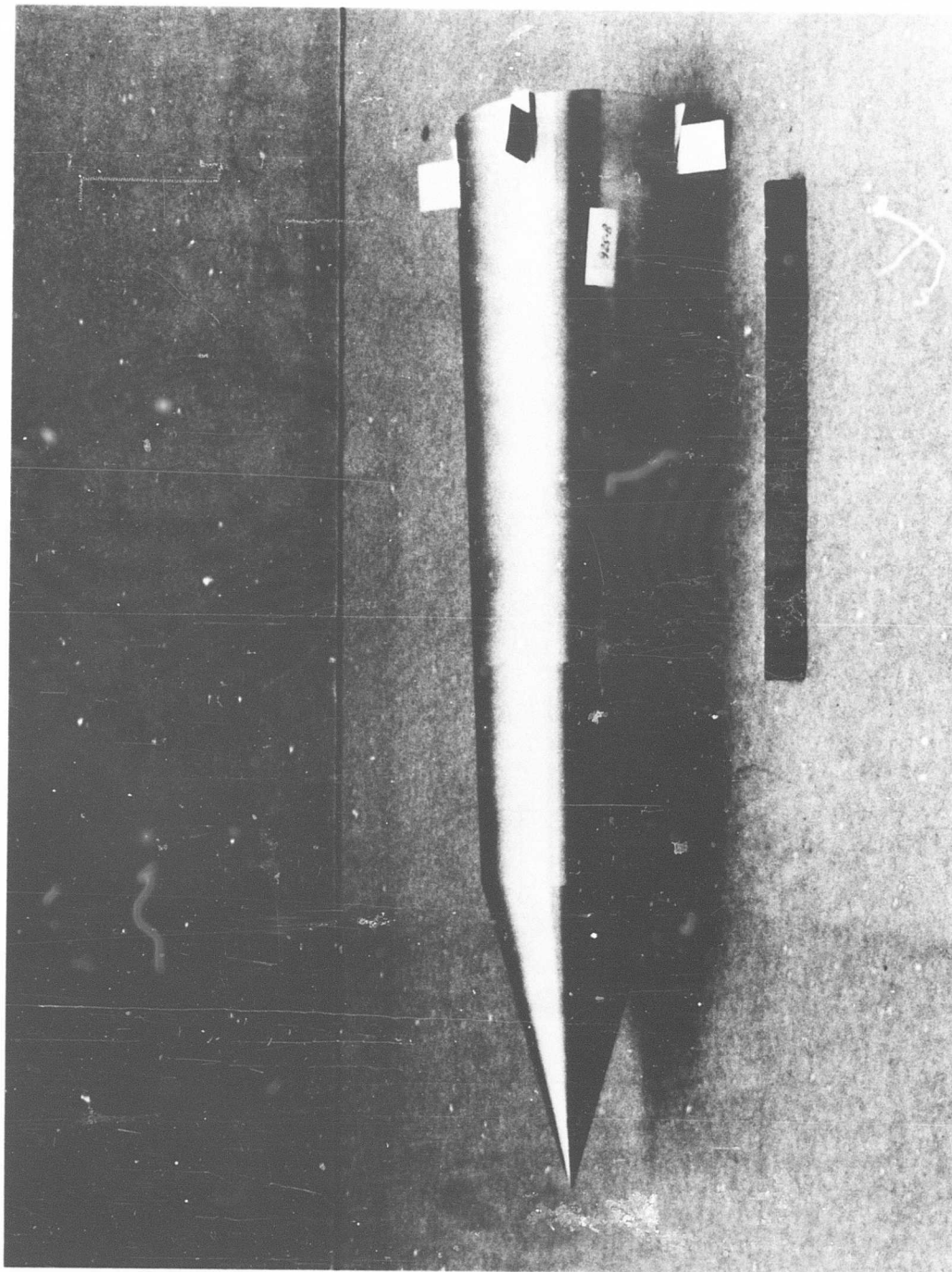
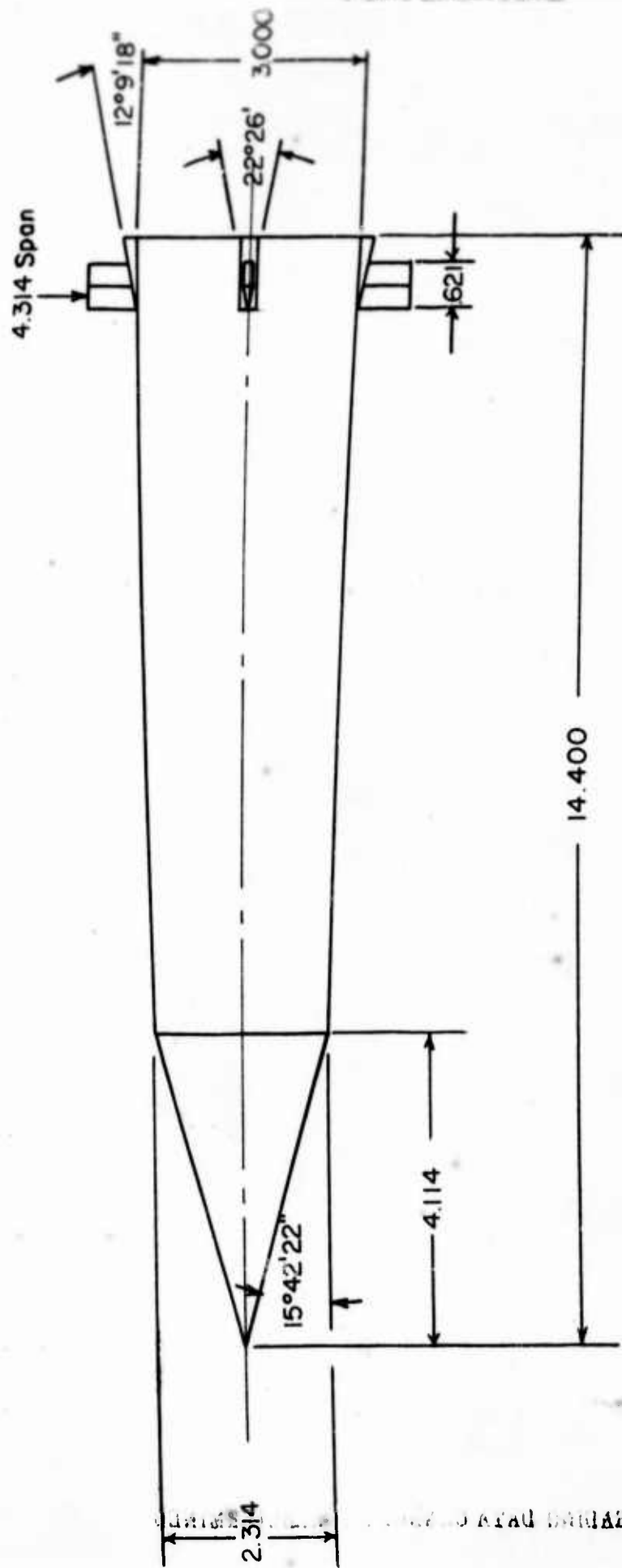


FIGURE 1 RANGE MODEL

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# REDSTONE WARHEAD



NOTE: All Dimensions are in Inches

FIGURE 1a

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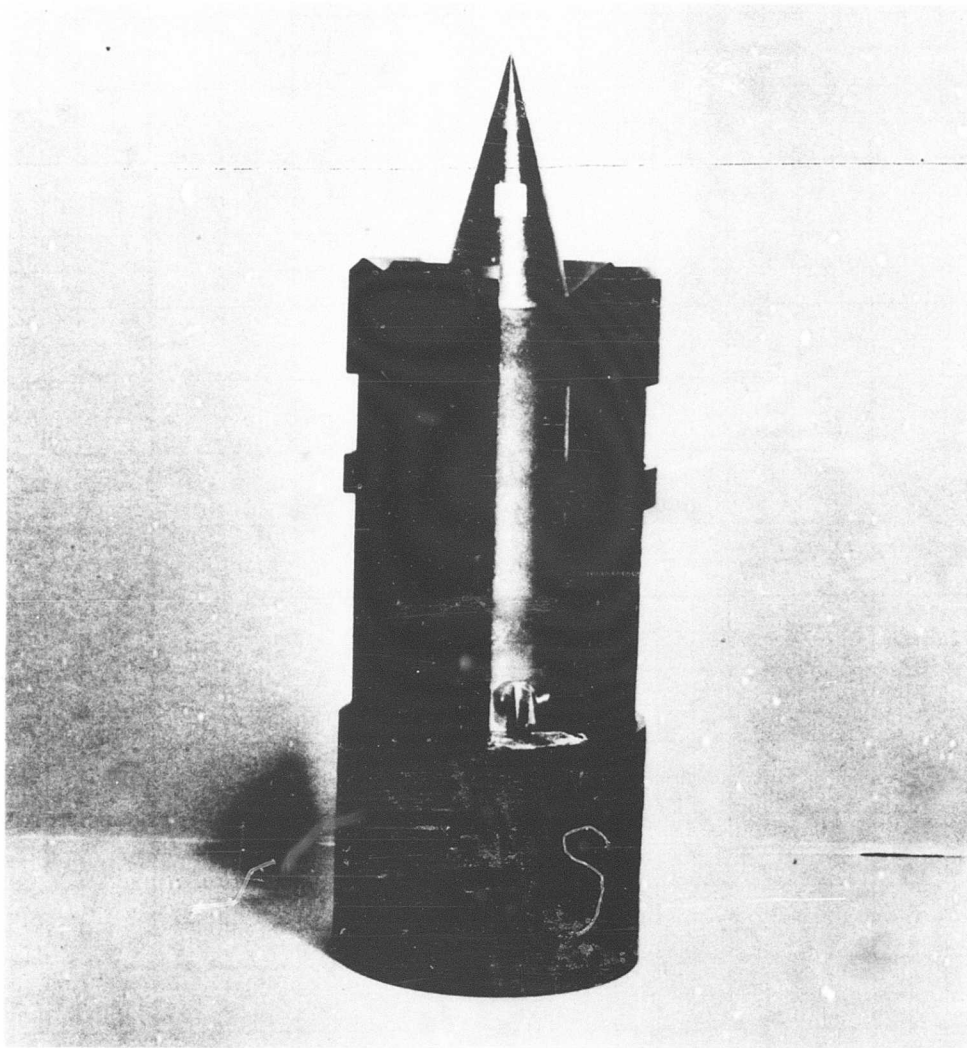


FIGURE 2 TYPICAL RANGE MODEL IN SABOT

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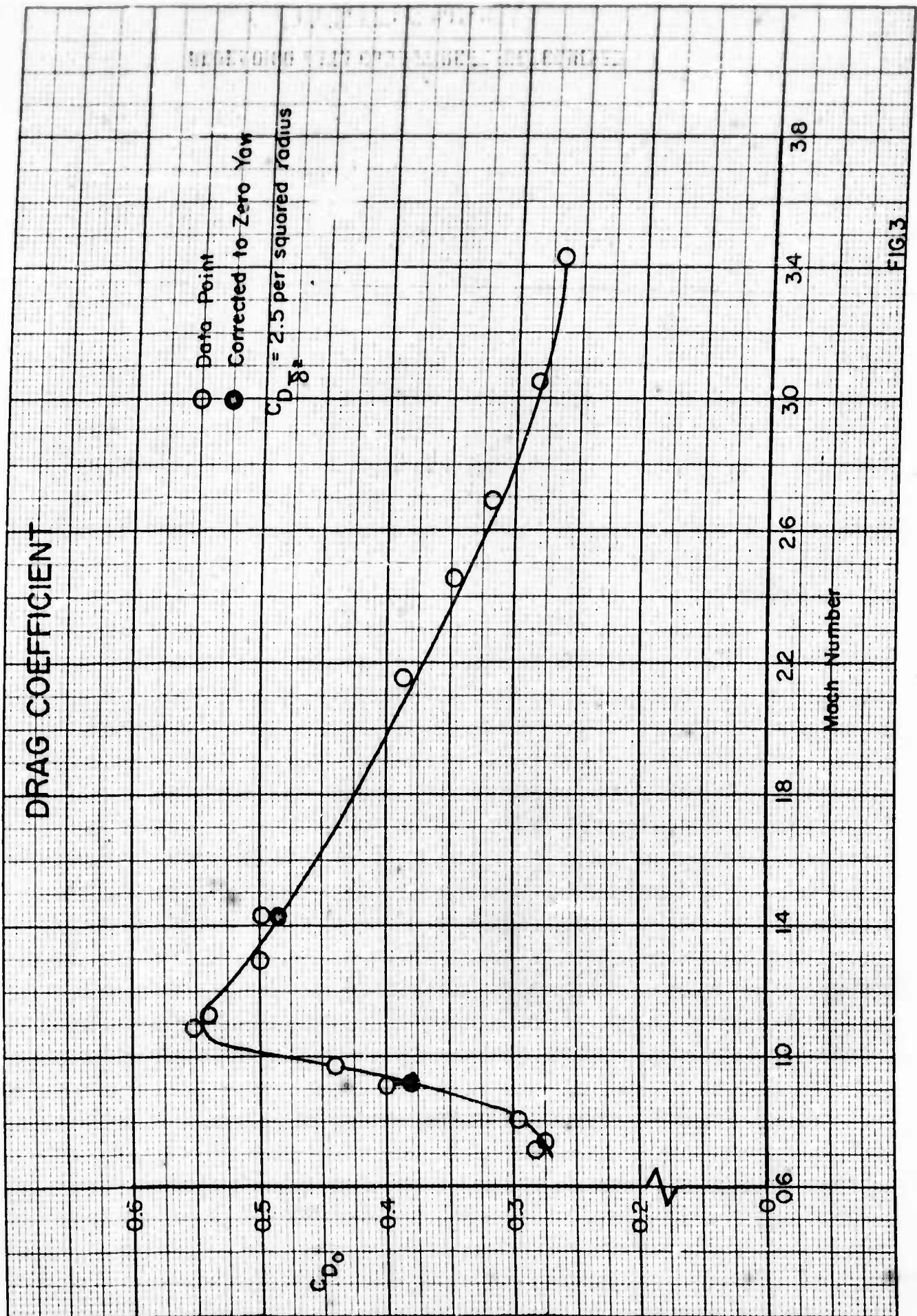
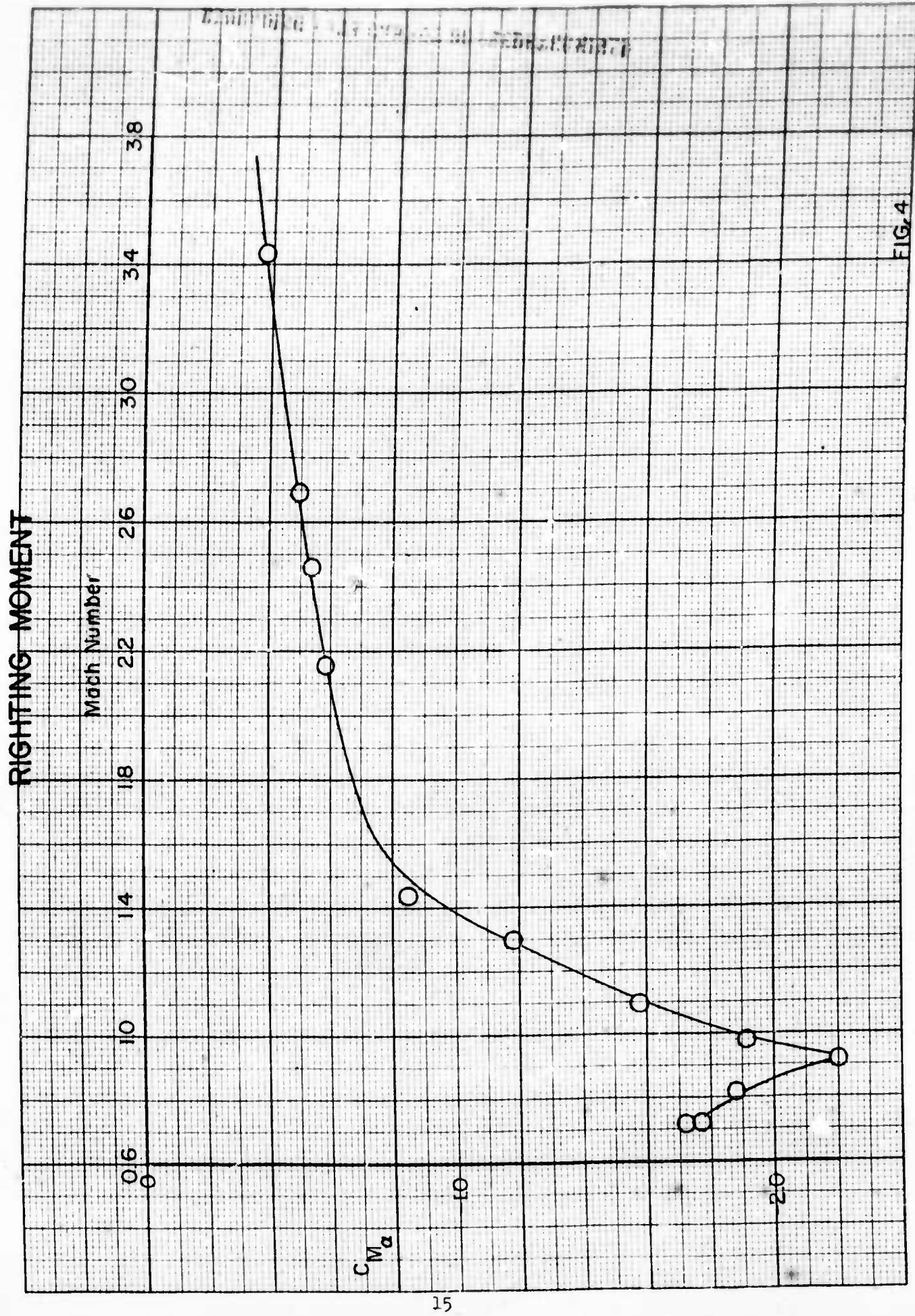


FIG. 3

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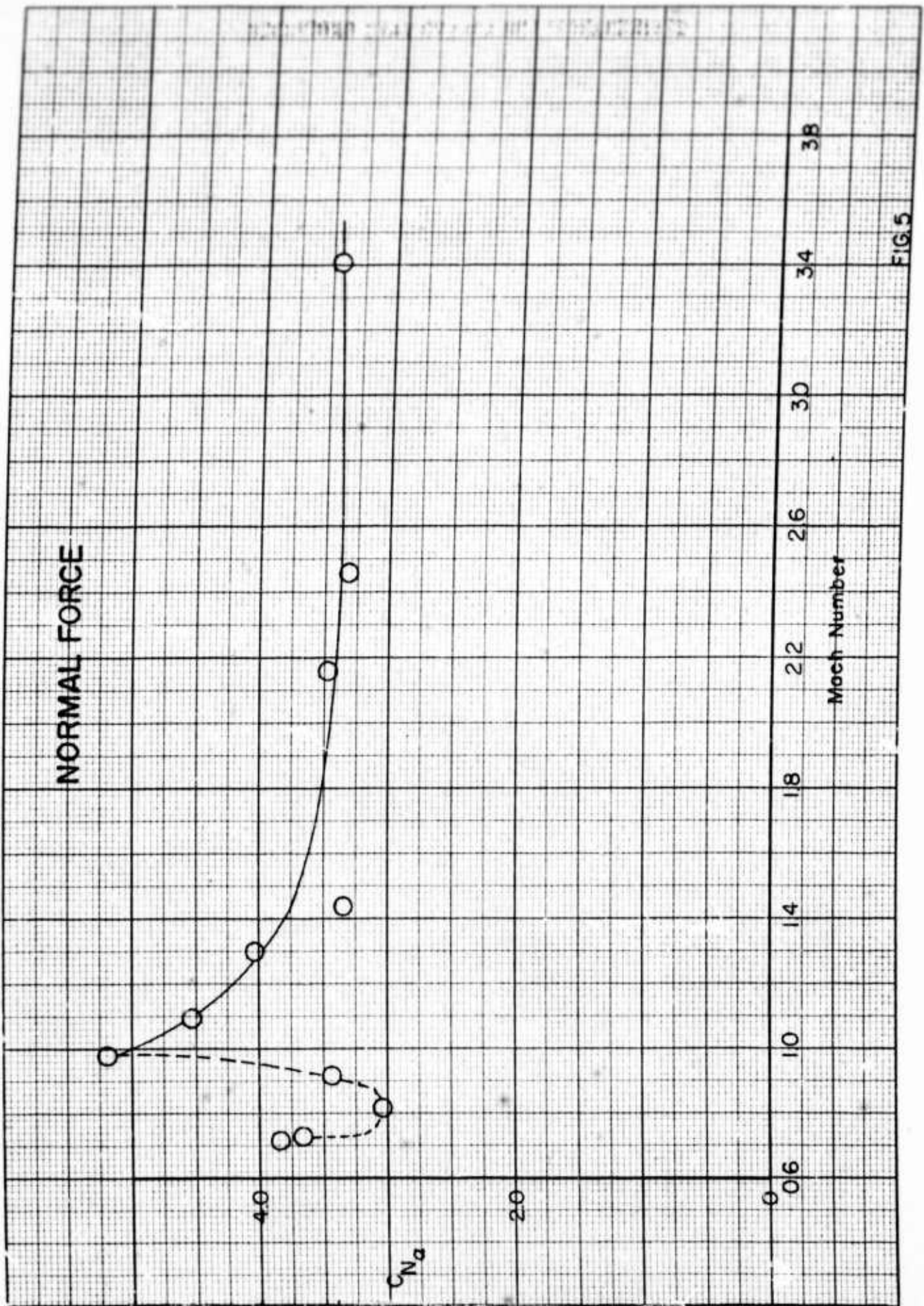
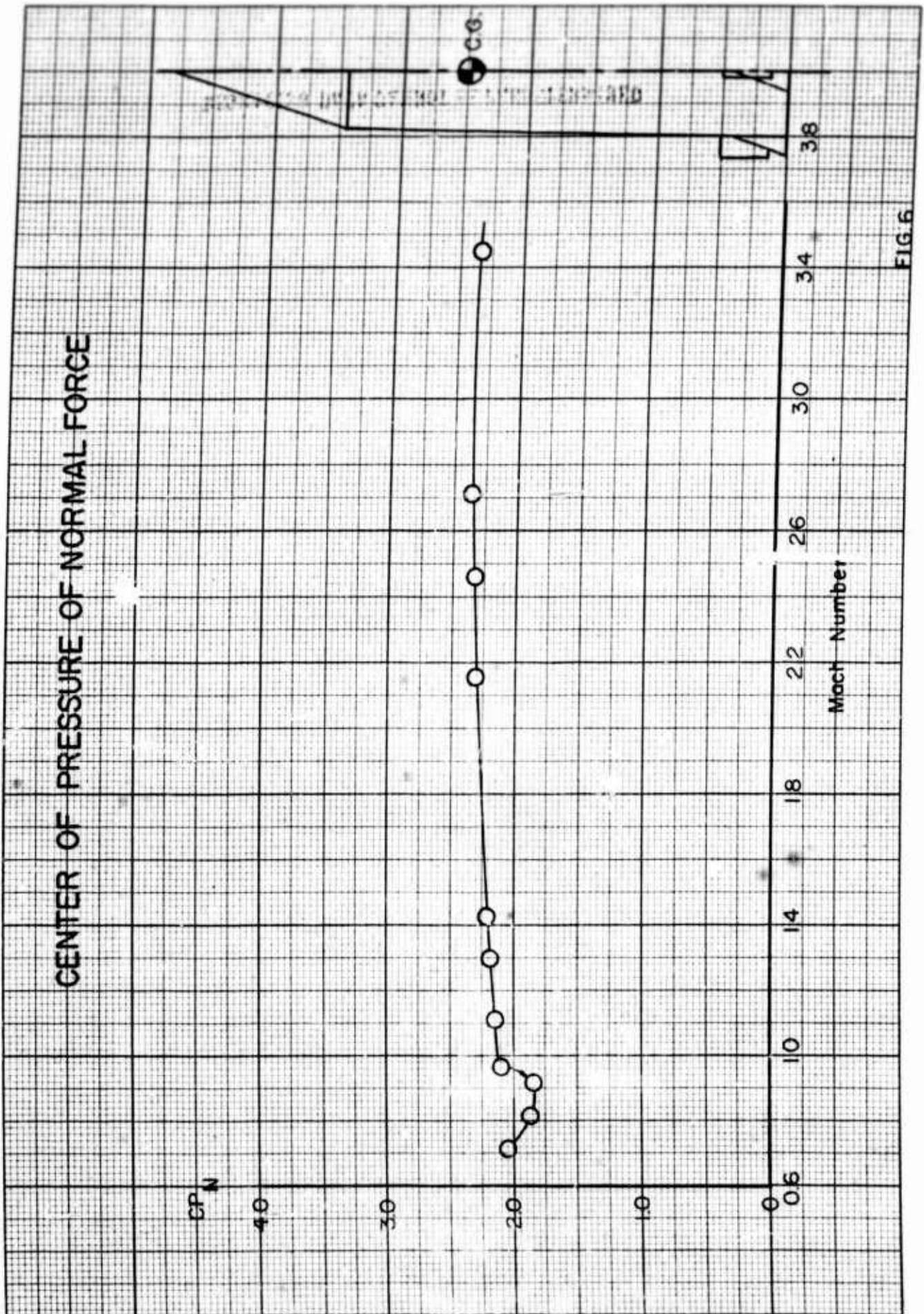


FIG. 5

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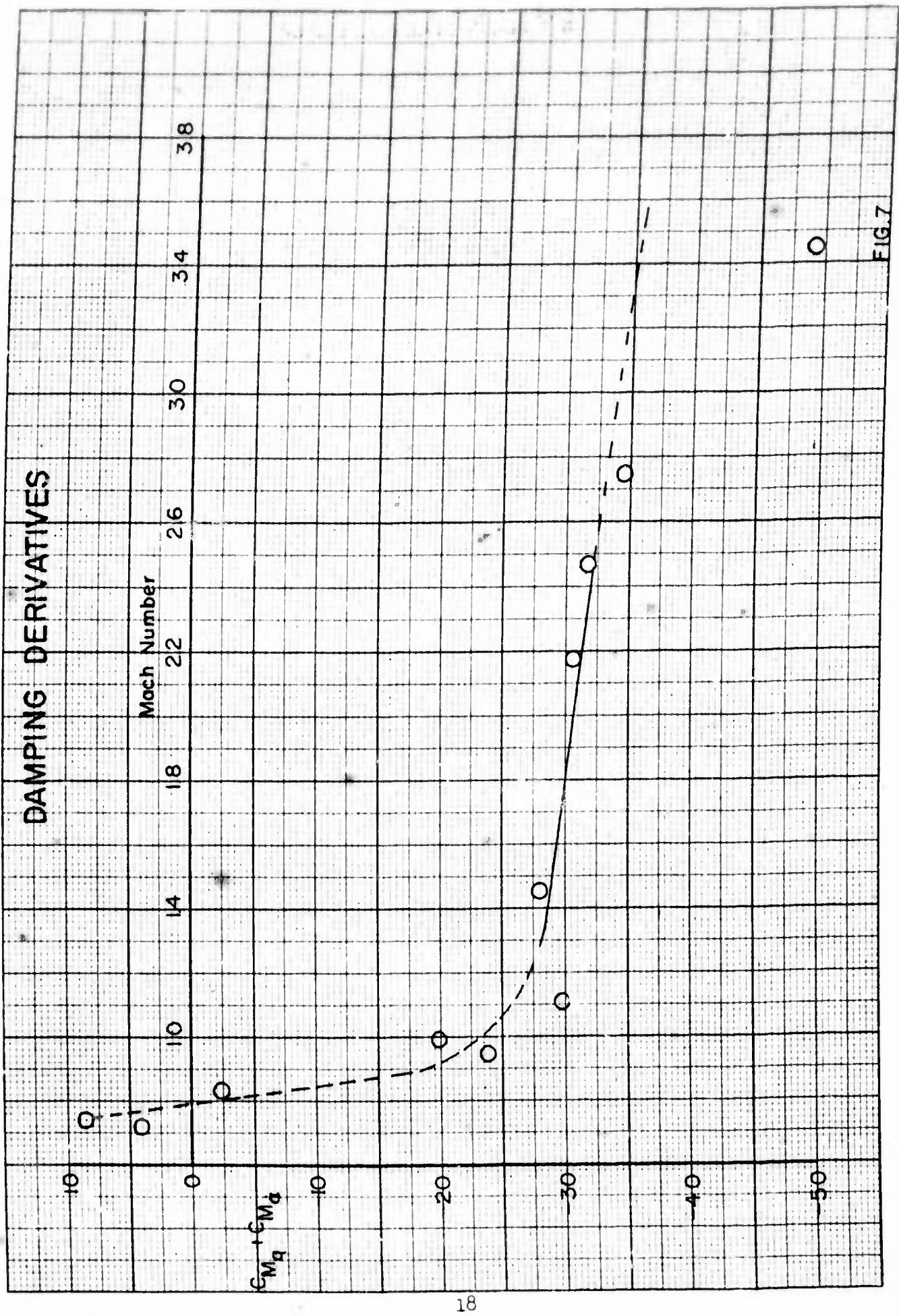


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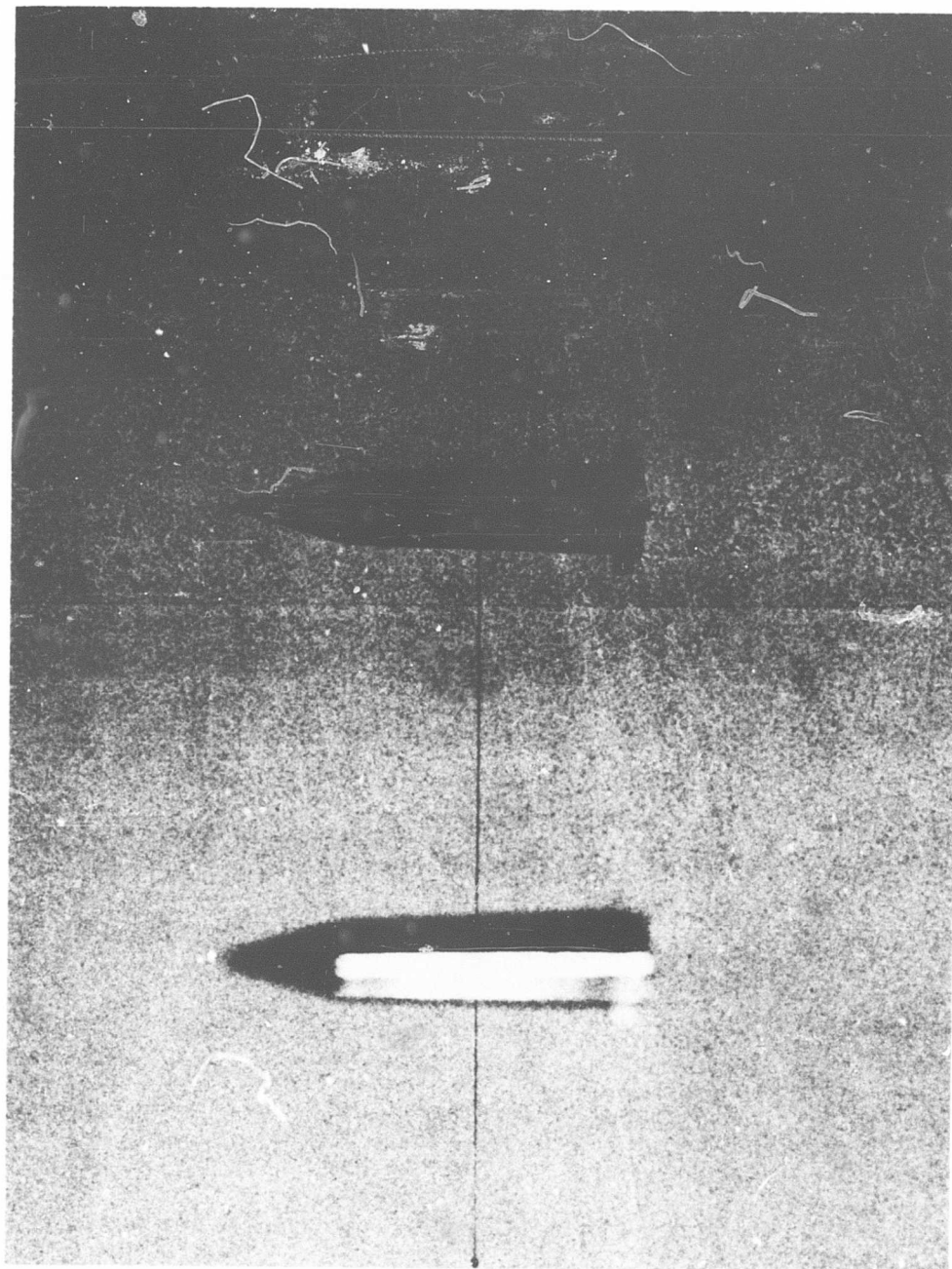


FIGURE 8 SHADOWGRAPH  $M \approx 0.72$

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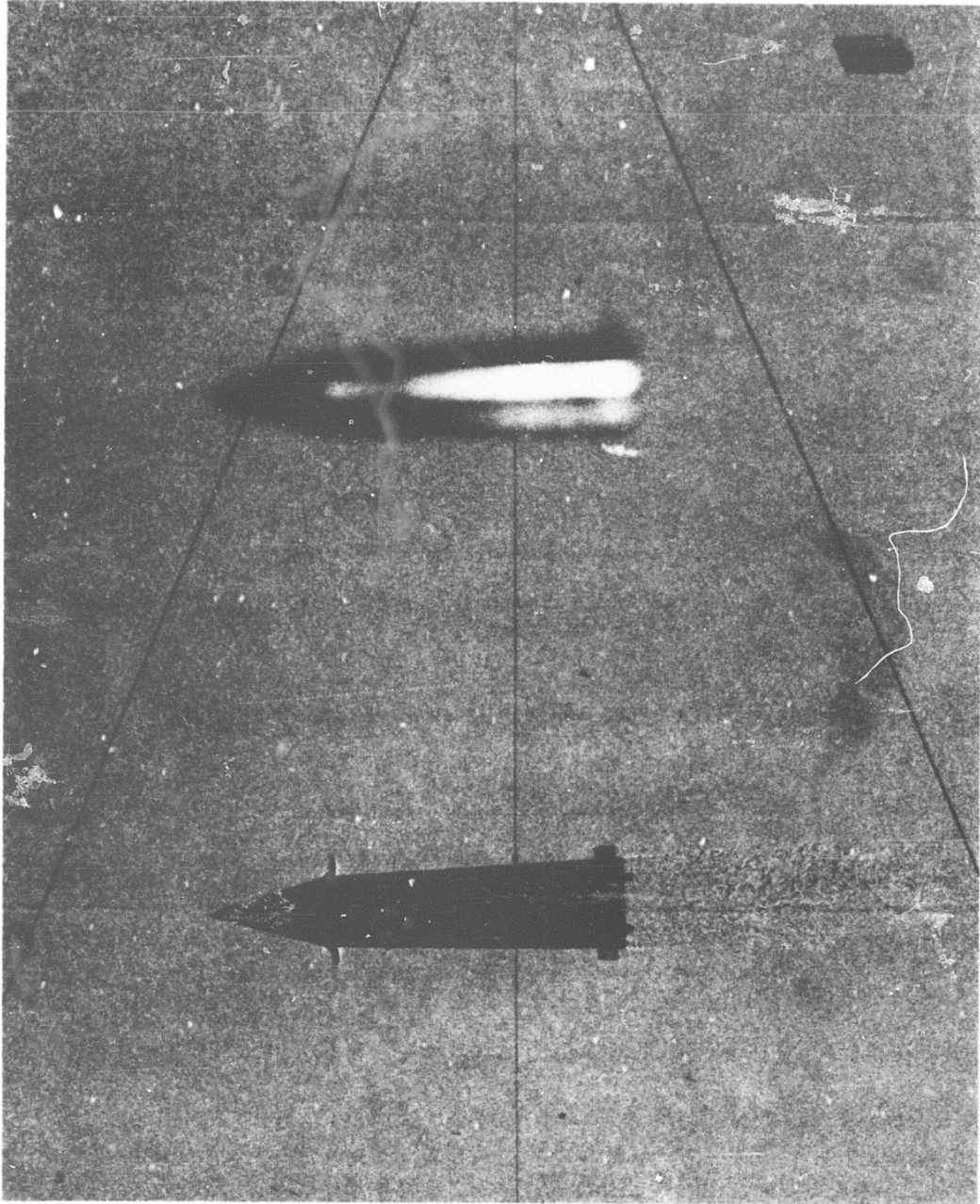


FIGURE 9 SHADOWGRAPH  $M \approx 0.81$

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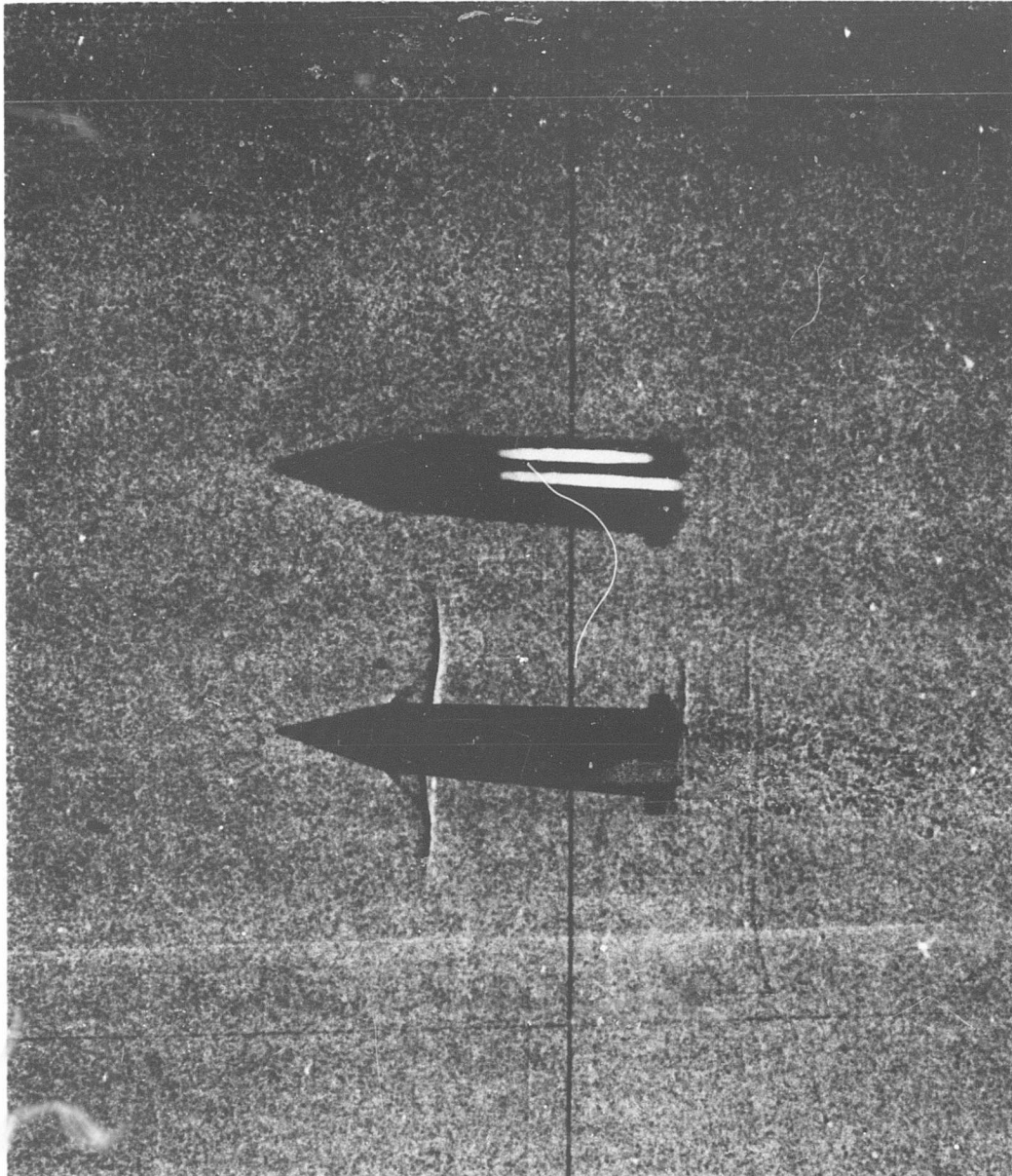


FIGURE 10 SHADOWGRAPH  $M \approx 0.92$

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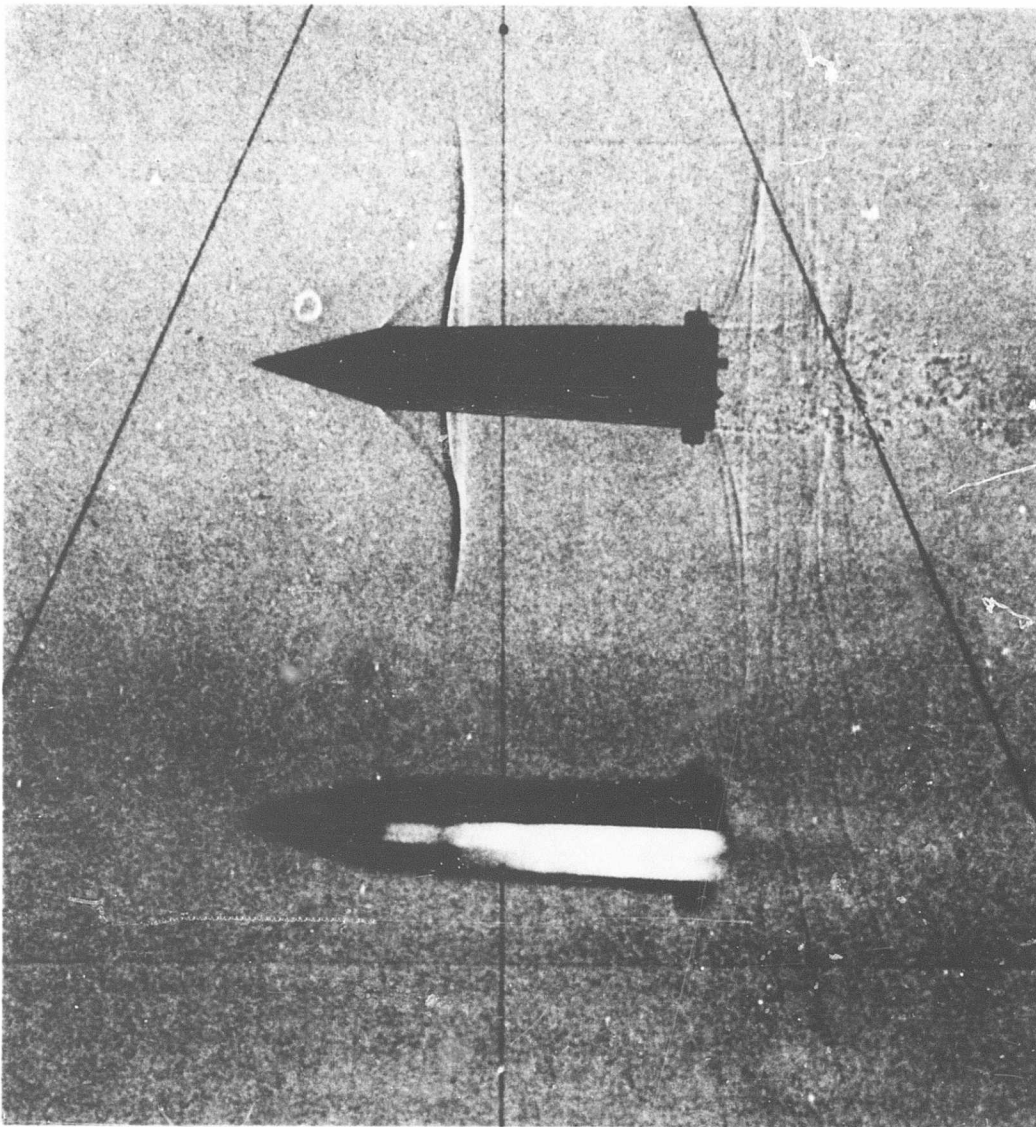


FIGURE II SHADOWGRAPH  $M \approx 0.97$

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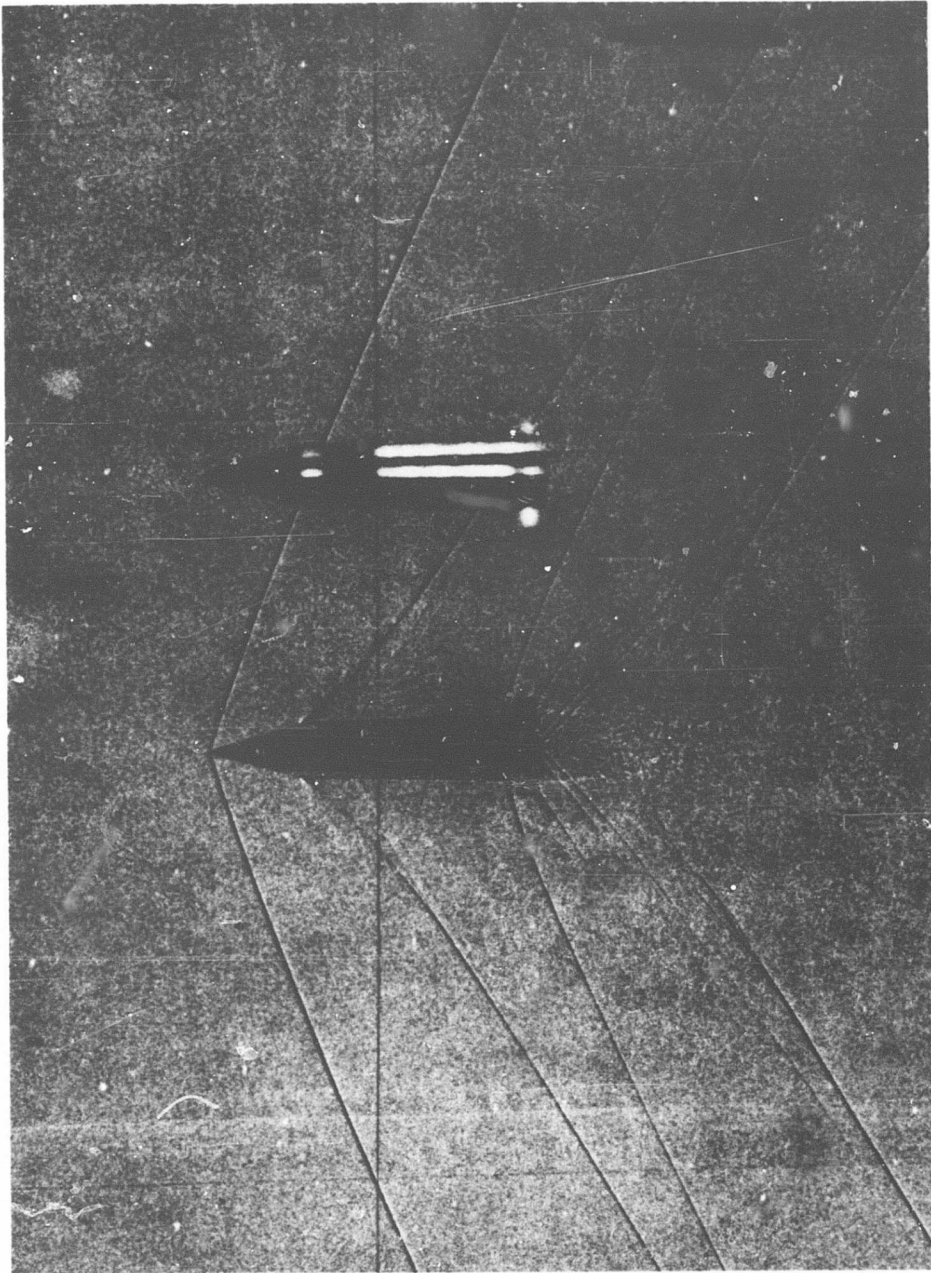


FIGURE 12 SHADOWGRAPH  $M \approx 1.11$

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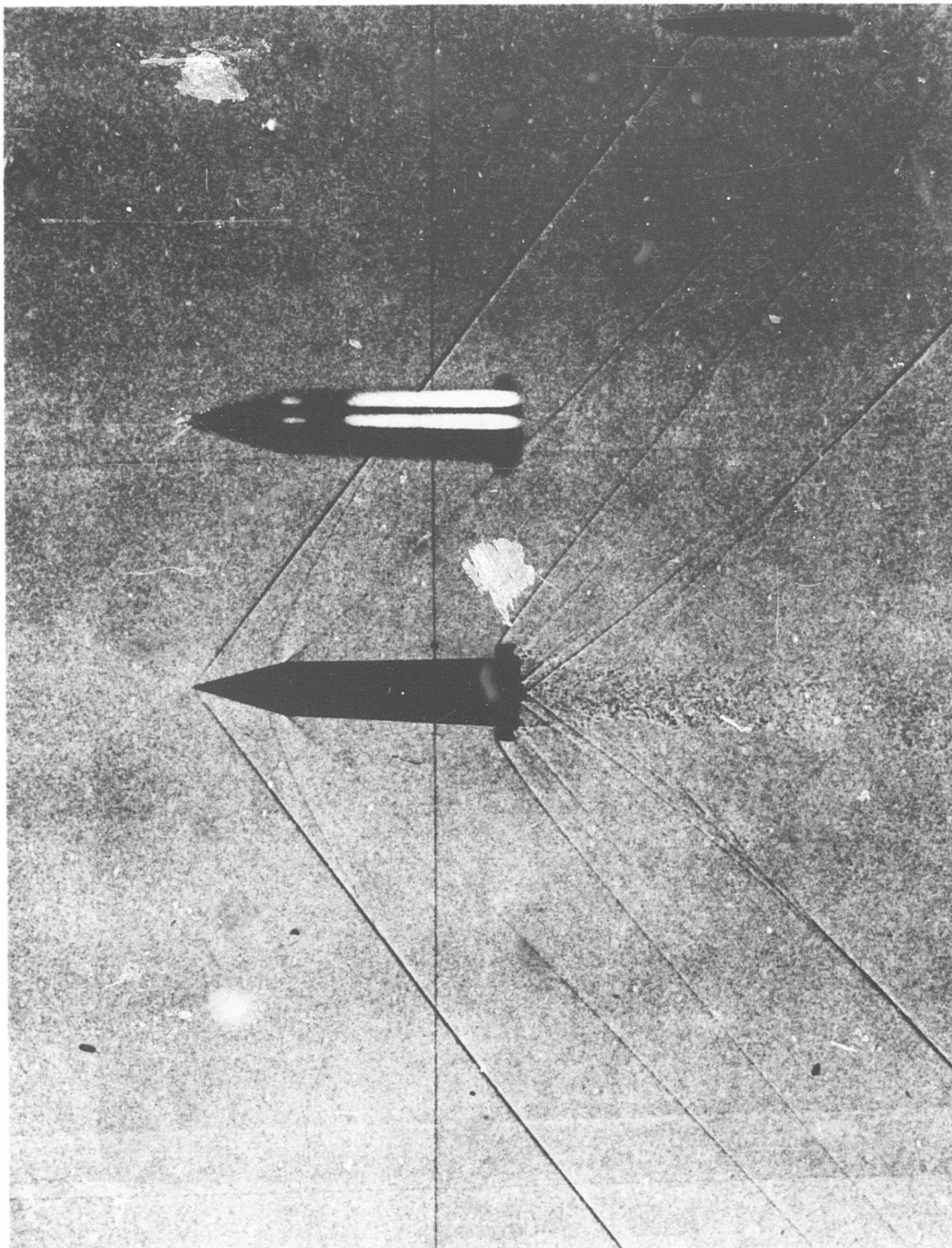


FIGURE 13 SHADOWGRAPH  $M \approx L30$

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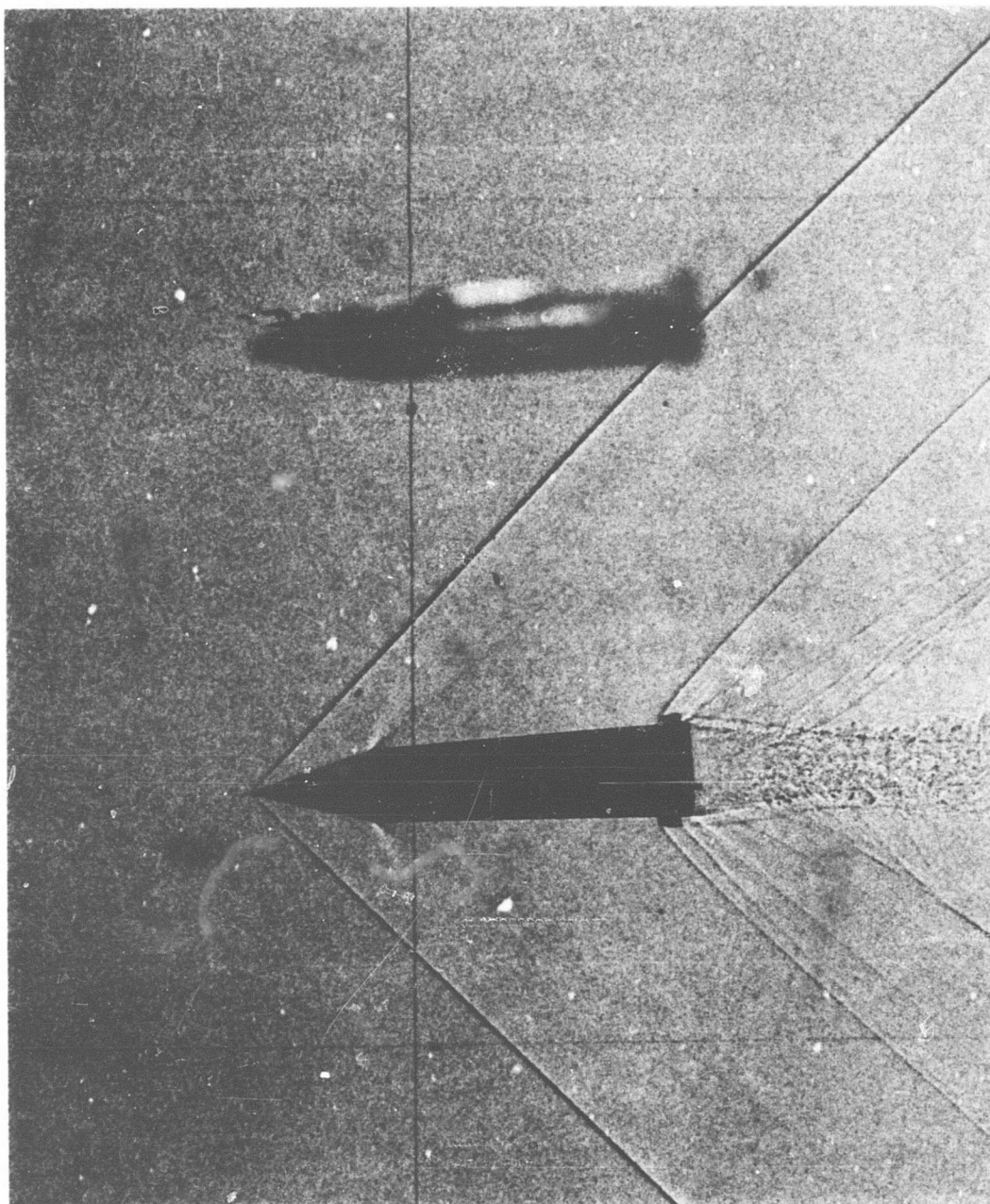


FIGURE 14 SHADOWGRAPH  $M \approx 1.52$

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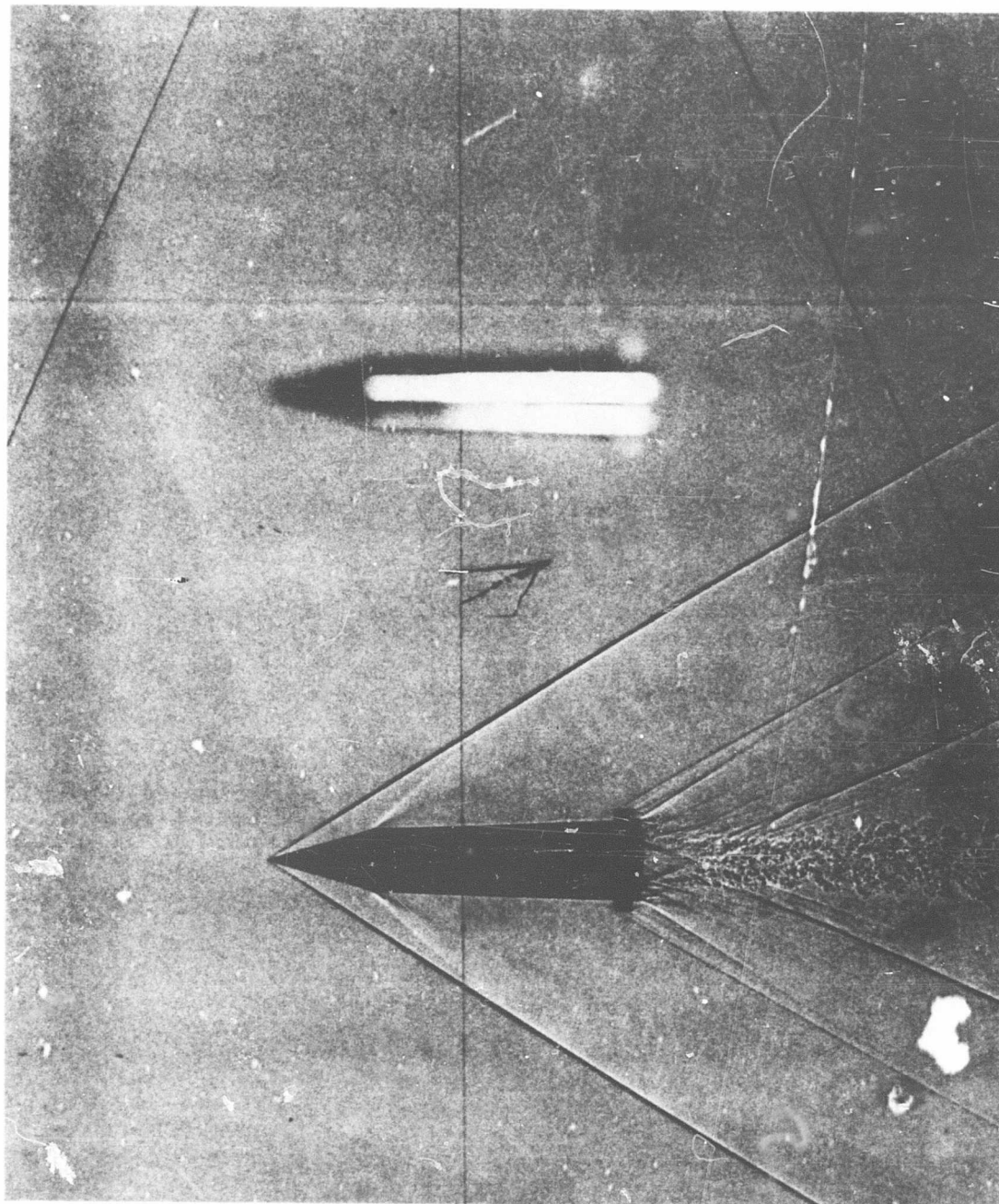


FIGURE 15 SHADOWGRAPH  $M \approx 2.16$

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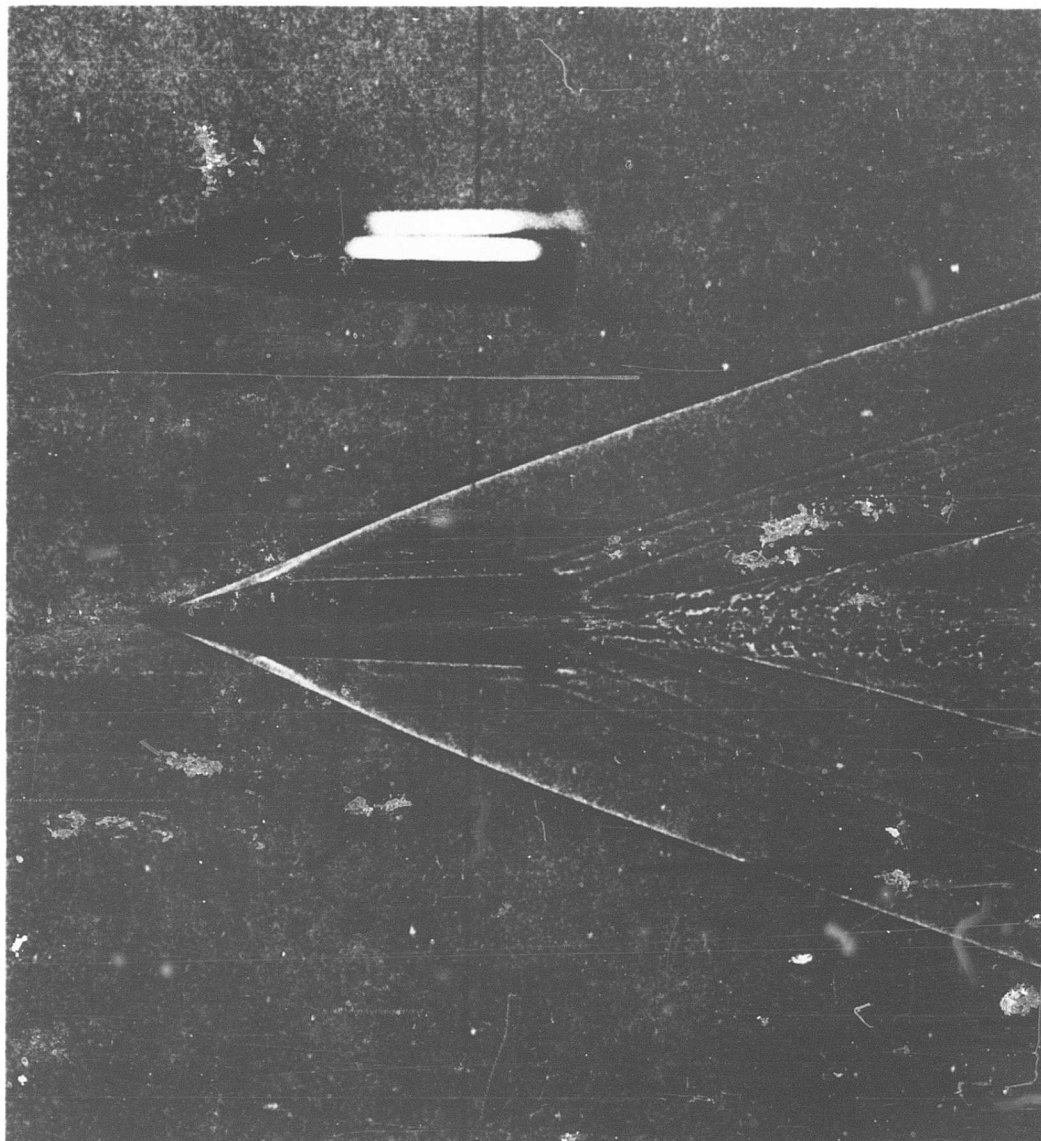


FIGURE 16 SHADOWGRAPH  $M \approx 3.45$



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