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BALLISTIC RESEARCH LABORATORY

## REPORT

EFFECT OF VARIOUS DRIVING BANDS ON THE AERODYNAMIC
PERFORMANCE OF PROJECTILES AT HIGH VELOCITIES

BY

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[redacted]

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# EFFECT OF VARIOUS DRIVING BANDS ON THE AERODYNAMIC PERFORMANCE OF PROJECTILES AT HIGH VELOCITIES


## Abstract

This report compares the drag and moment coefficients at high velocities of a series of similar projectiles with varying driving band shapes. Included is a projectile without any driving band. The data was obtained from firings in the Aerodynamics Range. A variation of $K_M$ with yaw is observed and its magnitude evaluated.

Object:

The purpose of the research reported on was to study the effect of different types of banding on the aerodynamic performance at high velocities of two particular projectile shapes. This program was carried out in cooperation with the Franklin Institute, and the basic projectile shapes and types of banding were suggested by the Institute. The firings were carried out in the Aerodynamics Range at the Ballistic Research Laboratory, using the full complement of sixteen spark photograph stations and the accompanying chronograph equipment.

Design:

The projectiles were fired from a special gun 85" long, having 0.490" diameter bore and a depth of rifling of 0.010". This is twice the depth of normal caliber 0.50 rifling. The gun uses a special 20mm breech with a large chamber, which makes it possible to get velocities close to 4000 feet per second using pre-engraved steel projectiles. All the projectiles used in this investigation were pre-engraved.

The C-28 type represents one of the shapes used in the program (Figure 1a). This projectile has a driving band one-half a caliber wide with a tapered leading edge. The C-41 type has the same body shape as the C-28, but has a band one and one-half calibers wide (Figure 1b). The leading edge of each land is sharpened to make possible the use of pre-engraved bands in automatic weapons. The performance of these two projectiles was covered in Ballistic Research Laboratory Memorandum Report No. 365, "Effects Upon the Moment and Drag Coefficient of an Increase in Width of the Driving Band" (by William A. Siljander).

The other shape used is characterized by the bandless C-43 type, which has a short tangent radius ogive with a meplat one-quarter of a caliber in diameter, and a short boattail (Figure 2a). This type was fired using a sabot to impart spin to the projectile. There are six other types based on this shape. The C-39 has a driving band which simulates the kind used in conventional artillery. The band is about one caliber wide and has a tapered leading edge (Figure 2b). The C-33 has a band one-half a caliber wide with a blunt leading edge, and is set in the normal position along the body (Figure 2c). Types C-30 and C-34 are identical except for center of gravity position. They have a band one and one-half calibers wide with sharpened lands (Figure 2d). Type LI-200 has a single narrow band (3/4 caliber) with square leading edge set forward on the body (Figure 3a). Type LI-107 combines the bands of the C-33 and the LI-200 (Figure 3b).

To determine how effective the short boattail is at these high velocities Type C-31 was fired. This projectile is the same as the C-33 except that it has no boattail.

Procedure:

The eight projectile types covered in this report were all fired at a single velocity, 3600 feet per second, with the exception of the C-34 which was also fired at 2500 feet per second, in order to give a first approximation of the variation of $K_D$ and $K_M$ with velocity. In the actual firings there was a slight dispersion around the desired velocity, but by using the results from the C-34 type $K_D$ and $K_M$ for each round were corrected to a Mach number of 3.200.

The experimental data giving time and distance throughout the range was reduced in the conventional manner. Time was considered a power series in distance with all terms past the cubic neglected. The coefficients of the series were determined by a least squares process. $K_D$ was then computed from these coefficients together with the physical characteristics of the projectiles and the air.

To find the shape of the $K_{DO}$ vs Mach number curve for type C-34 the effect of yaw was first taken out. To do this the slope of the $K_{DO}$ vs Mach number curve at M = 3.200 was estimated and all rounds brought to this common Mach number. The drag coefficients were then plotted as a function of the mean squared yaw. The following relation was obtained and used to take out the effect of yaw.

$$K_{DO} = K_D - 0.0010\,\overline{\delta^2} \qquad (1)$$

where $K_D$ is the value of the drag coefficient without any correction, $K_{DO}$ is its value at zero yaw, and $\overline{\delta^2}$ is the mean squared yaw in square degrees. The corrected drag coefficients were then fitted by a least squares process to the following expression:*

$$Q = \sqrt{1 + M^2 K_{DO}} = a + bM \qquad (2)$$

where a and b are coefficients which depend on the particular shell and are determined from two or more values of $K_{DO}$ and M. Equation (2 ) was solved for $K_{DO}$ giving

$$K_{DO} = b^2 + \frac{2ab}{M} + \frac{a^2-1}{M^2}. \qquad (3)$$

The slope of the above curve at M = 3.200 was found and used for making the velocity correction on the $K_D$ data.**

The epicyclic yawing motion of each projectile was analyzed to find the moment coefficient, which is defined as

$$K_M = \frac{\text{Moment}}{\rho v^2 d^3 \sin\delta} \qquad (4)$$

where ρ is the air density, v is the velocity, d the caliber of the projectile, and δ is the angle of yaw. The analysis is based on the theory which is given in Ballistic Research Laboratory Report No. 446, "On the Motion of a Projectile with Small or Slowly Changing Yaw" by Kelley and McShane . According to this first order theory, $K_M$ is proportional to the product of the angular rates of the epicyclic arms of the motion, and is independent of the yaw. An examination of the results, however, seemed to indicate a systematic dependence of $K_M$ on the yaw.

If the assumption is made that $K_M$ as found here is some function of δ such that the first derivative is zero when δ = 0 (in other words the theory holds at very small angles), and is independent of the sign of the angle of yaw, then the following relation suggests itself.

* See Ballistic Research Laboratory Report No. 542, "Some Comments on the Form of the Drag Coefficient at Supersonic Velocities" (by R. N. Thomas).

** See Ballistic Research Laboratory Report No. 567, "Comparison of 155mm Shell Designs by Means of Model Firings" (by H. Stein) for a more detailed description of the procedure.

$$K_M = K_{MO} + K'_M \overline{\delta^2} \quad (5)$$

where $K_{MO}$ is the moment coefficient at zero yaw, and $K'_M$ is the yaw-moment slope.

Before the above expression could be fitted to the data the effect of velocity was taken out. To express the variation of $K_{MO}$ with Mach number, the following form has been found useful at supersonic velocities,

$$\sqrt{K_{MO}} = a + \frac{b}{M} \quad (6)$$

where a and b are coefficients which depend on the particular shell and are determined from two or more values of $K_{MO}$ and M. The data from the C-34 firings was fitted to the above expression to get the approximate slope of the $K_{MO}$ vs M curve at M = 3.2. Using this slope $K_M$ for every round was corrected to M = 3.2 and then fitted to Equation (5) by a least squares process to find $K_{MO}$.

Results:

Drag

Fitting the $K_{DO}$ data for type C-34 to the Q function (Table I) and solving for the slope of the $K_{DO}$ vs M curve at M = 3.2, gives

$$\left.\frac{dK_{DO}}{dM}\right|_{M = 3.2} = -0.021$$

Combining this with Equation (2),

$$K_{DO} = K_D - 0.0010\ \overline{\delta^2} - 0.021\ (3.200-M). \quad (7)$$

The above equation was applied to the drag data (Table II) and gives the following results:

| Type | Mean $K_{DO}$ | P.E. of Mean $K_{DO}$ | No. of Rounds |
|---|---|---|---|
| C-43 | 0.129 | 0.28% | 6 |
| C-39 | 0.132 | 0.23% | 6 |
| C-34 | 0.132 | 0.57% | 4 |
| LI-200 | 0.133 | 0.44% | 5 |
| C-33 | 0.134 | 0.51% | 5 |
| LI-107 | 0.136 | 0.32% | 4 |
| C-31 | 0.137 | 0.42% | 6 |

Moment and Stability:

Using an estimated value for $\left.\frac{dK_{MO}}{dM}\right|_{M = 3.2}$ equal to -0.20, all values of $K_M$ were corrected to this common Mach number, and fitted to Equation (5) (Table III). The following results were obtained:

| Type | $K_{MO}$ | P.E. of $K_{MO}$ | $K'_M$ | P.E. of $K'_M$ | No. of Rounds |
|---|---|---|---|---|---|
| C-43 | 1.21 | 0.36% | -0.00676 | 10.8% | 6 |
| C-39 | 1.19 | 0.63% | -0.00300 | 17.9% | 6 |
| C-33 | 1.17 | 0.38% | -0.00370 | 22.8% | 4 |
| C-30 | 1.20 | 0.29% | -0.00616 | 11.6% | 4 |
| C-34 | 1.68 | 0.73% | -0.000535 | 360.0% | 4 |
| LI-200 | 1.22 | 1.9% | -0.00416 | 26.5% | 5 |
| LI-107 | 1.20 | 0.84% | -0.00518 | 94.6% | 4 |
| C-31 | 1.15 | 0.18% | -0.00442 | 17.2% | 6 |

Reducing the $K_M$ results for Type C-34 to zero yaw, fitting to Equation (6) and solving for $\frac{dK_{MO}}{dM}$ at M = 3.2 gives -0.202 (Table I). This agrees well with the originally estimated value.

From $K_M$ for types C-30 and C-34 which differ only in center of gravity position, the following values of $K_N$ and center of pressure position were obtained:

$$K_N = 1.19 \pm 2.6\%$$

C.P. = 3.04 calibers from base.

Taking a weighted mean of the various values of $K'_M$, using

$\frac{1}{(P.E.)^2}$ as the weight of each quantity gives

$$K'_M = -0.00461 \pm 6.3\%.$$

Analysis:

Drag:

The $K_{DO}$ for the bandless C-43, which is the basic shape, is 0.129. The addition of a conventional band (C-32) or a wider pre-engraved band with sharpened lands (C-34) added 0.003 to the $K_{DO}$. If the leading edge of the band is square (C-33), LI-200), the effect is a little larger. The double band of the LI-200 increased the drag by 80% of the sum of the drags of the two bands. An examination of the spark photographs shows strong shocks off both bands so that they are both about equally responsible for the increase.

The drag coefficient for the C-31 which has no boattail is 0.003 higher than for the C-33 with boattail. This indicates that the small boattail even at this relatively high Mach number is still effective in reducing drag.

It is interesting to calculate a drag coefficient for a band alone. If drag coefficient for the band is defined as

$$K_{D_{Band}} = \frac{\text{Band Drag}}{\rho v^2 A} \tag{8}$$

where A is the frontal area of the band, then for type C-33 $K_D$ (Band) equals 0.0764. If stagnation pressure (based on the undisturbed air) were acting on the band, $K_D$ (Band) would be about 12 times this value.

It should be noted that this type of projectile has a relatively high drag coefficient compared to modern streamlined projectiles. The form factor is about 1.5 with respect to projectile type 2 (Figure 4).

Moment and Stability:

The stability varied only slightly between types. The projectiles all had stability factors around 1.7. The variation in $K_{M0}$ from one type to another may be caused by variation in center of gravity position, variation in center of pressure position, and changes in the size of $K_N$. The actual differences encountered in this program were probably caused by combinations of all three.

If the actual flow around a projectile is assumed to be made up of an axial flow and a cross flow, it is clear that the increased area at the band will cause an increase in the aerodynamic force over the force on the bandless shell. This local increase in the force will effect the moment coefficient. Since the total center of pressure is ahead of the center of gravity, putting the band ahead of the center of gravity will increase $K_{MO}$ and putting it behind the center of gravity will decrease $K_{MO}$.

The present firings show this effect clearly. $K_{MO}$ for the bandless C-43 is 1.21. Type C-33 which has the band furthest back has the lowest $K_{MO}$ of the projectiles with boattails. Type LI-200 which has the band near the front of the body, ahead of the center of gravity has the highest $K_{MO}$. Type C-31 which has no boattail has the lowest $K_{MO}$.

The variation of $K_M$ with yaw is interesting. If $K_M$ and $k_m$ are defined as

$$K_M = \frac{\text{Moment}}{\rho v^2 d^3 \sin\delta} \qquad (9)$$

$$k_m = \frac{\text{Moment}}{\rho v^2 d^3} \qquad (10)$$

then $$k_m = K_M \sin\delta \qquad (11)$$

or for small angles $$k_m = K_M \delta \qquad (12)$$

and $$\frac{dk_m}{d\delta} = K_M + \delta \frac{dK_M}{d\delta} \qquad (13)$$

It has generally been assumed that for small angles of yaw the last term in equation (13) is zero, and that therefore $K_M$ is independent of the yaw. The present investigation seems to indicate that equation (12) should be,

$$k_m = K_{MO}\delta + K_M'\delta^3 \qquad (14)$$

and since $K_M'$ is negative, $k_m$ instead of being linear with yaw is concave down. A closer examination of the data from other programs seems to show this same effect. The combination of blunt projectile shapes and higher supersonic velocities may have exaggerated a condition which was small enough to escape notice in previous programs.

Conclusions:

Probably the most practical band shape would consist of a single pre-engraved band placed forward on the body similar to type LI-200. The leading edge of this band would be tapered in a manner similar to type C-39 or C-34. The shell would also have a rear bourrelet placed in the same position as the band in the C-33 type. If this rear bourrelet were faired into the body, it would not contribute materially to the drag, but combined with the front band would give good launching conditions. The forward position of the band would also provide a longer useful life for the gun as tests at the Franklin Institute have demonstrated.

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## TABLE I

C-34

| Round No. | Mach No. | $K_D$ | $K_M$ | $\overline{\delta^2}$ sq. deg. | $K_{DO}$ | $K_{MO}$ |
|---|---|---|---|---|---|---|
| 966 | 2.948 | 0.1392 | 1.748 | 3.427 | 0.1357 | 1.746 |
| 967 | 3.155 | 0.1373 | 1.678 | 2.142 | 0.1352 | 1.677 |
| 968 | 3.116 | 0.1442 | 1.693 | 11.17 | 0.1330 | 1.687 |
| 969 | 3.077 | 0.1401 | 1.687 | 5.619 | 0.1345 | 1.684 |
| 1182 | 2.078 | 0.1648 | 2.037 | 5.592 | 0.1592 | 2.034 |
| 1183 | 2.117 | 0.1725 | 2.038 | 15.70 | 0.1606 | 2.030 |
| 1184 | 2.098 | 0.1588 | - | - | 0.1588 | - |

$$Q = \sqrt{1 + M^2 K_{DO}} = \underset{(\pm 0.71\%)}{0.8671} + \underset{(\pm 1.1\%)}{0.2084M}$$

$$K_{DO} = 0.0434 + \frac{0.3614}{M} - \frac{0.2481}{M^2}$$

$$\left.\frac{d\,K_{DO}}{d\,M}\right|_{M = 3.2} = -0.021$$

$$\sqrt{K_{MO}} = \underset{(\pm 0.68\%)}{1.039} + \underset{(\pm 2.3\%)}{0.8109M^{-1}}$$

$$K_{MO} = 1.080 + \frac{1.685}{M} + \frac{0.6175}{M^2}$$

$$\left.\frac{d\,K_{MO}}{d\,M}\right|_{M = 3.2} = -0.202$$

TABLE II

C-43

| Round No. | Mach No. | $K_D$ | $\overline{\delta^2}$ | $K_{DO}$ at M = 3.200 |
|---|---|---|---|---|
| 1191 | 3.221 | 0.1361 | 8.340 | 0.1277 |
| 1192 | 3.164 | 0.1395 | 8.368 | 0.1304 |
| 1193 | 3.159 | 0.1335 | 2.287 | 0.1304 |
| 1194 | 3.173 | 0.1307 | 2.168 | 0.1280 |
| 1195 | 3.092 | 0.1349 | 5.11[illegible] | 0.1275 |
| 1196 | 3.213 | 0.1327 | 4.799 | 0.1282 |

Mean $K_{DO}$ = 0.1287
P.E. of Mean = 0.00036[illegible]6 = 0.29%

C-39

| Round No. | Mach No. | $K_D$ | $\overline{\delta^2}$ | $K_{DO}$ at M = 3.200 |
|---|---|---|---|---|
| 963 | 3.248 | 0.1388 | 6.395 | 0.1334 |
| 964 | 3.279 | 0.1545 | 24.58 | 0.1316 |
| 965 | 3.154 | 0.1408 | 9.046 | 0.1308 |
| 1166 | 3.157 | 0.1390 | 5.443 | 0.1327 |
| 1167 | 3.232 | 0.1512 | 20.40 | 0.1315 |
| 1168 | 3.156 | 0.1366 | 2.326 | 0.1334 |

Mean $K_{DO}$ = 0.1332
P.E. of Mean = 0.0003002 = 0.23%

C-33

| Round No. | Mach No. | $K_D$ | $\overline{\delta^2}$ | $K_{DO}$ at M = 3.200 |
|---|---|---|---|---|
| 956 | 3.201 | 0.1394 | 4.847 | 0.1346 |
| 957 | 3.217 | 0.1335 | (0.5) | 0.1334 |
| 1171 | 3.172 | 0.1369 | 1.685 | 0.1346 |
| 1172 | 3.185 | 0.1355 | 8.822 | 0.1294 |
| 1173 | 3.161 | 0.1362 | 3.042 | 0.1323 |

Mean $K_{DO}$ = 0.1329
P.E. of Mean = 0.0006512 = 0.49%

C-34

| Round No. | Mach No. | $K_D$ | $\overline{\delta^2}$ | $K_{DO}$ at M = 3.200 |
|---|---|---|---|---|
| 966 | 2.948 | 0.1392 | 3.427 | 0.1305 |
| 967 | 3.155 | 0.1373 | 2.142 | 0.1342 |
| 968 | 3.116 | 0.1442 | 11.17 | 0.1313 |
| 969 | 3.077 | 0.1401 | 5.619 | 0.1319 |

Mean $K_{DO}$ = 0.1320
P.E. of Mean = 0.0005333 = 0.40%

(Table II)

LI-200

| Round No. | Mach No. | $K_D$ | $\overline{\delta^2}$ | $K_{DO}$ at [illegible] = 3.200 |
|---|---|---|---|---|
| 1177 | 3.123 | 0.1515 | 17.88 | 0.1320 |
| 1178 | 3.143 | 0.1533 | 17.10 | 0.1350 |
| 1179 | 3.153 | 0.1552 | 23.55 | 0.1307 |
| 1180 | 3.153 | 0.1589 | 24.32 | 0.1331 |
| 1181 | 3.172 | 0.1503 | 19.44 | 0.1303 |

Mean $K_{DO}$ = 0.1322
P.E. of Mean = 0.0005753 = 0.44%

LI-107

| Round No. | Mach No. | $K_D$ | $\overline{\delta^2}$ | $K_{DO}$ |
|---|---|---|---|---|
| 959 | 3.178 | 0.1396 | 1.560 | 0.1376 |
| 1174 | 3.134 | 0.1371 | 0.321 | 0.1354 |
| 1175 | 3.154 | 0.1393 | 3.586 | 0.1343 |
| 1176 | 3.169 | 0.1387 | 1.158 | 0.1369 |

Mean $K_{DO}$ = 0.1362
P.E. of Mean = 0.0004375 = 0.32%

C-31

| Round No. | Mach No. | $K_D$ | $\overline{\delta^2}$ | $K_{DO}$ |
|---|---|---|---|---|
| 953 | 3.219 | 0.1405 | 5.931 | 0.1350 |
| 954 | 3.195 | 0.1363 | 0.915 | 0.1353 |
| 955 | 3.194 | 0.1571 | 19.50 | 0.1375 |
| 1163 | 3.168 | 0.1389 | 0.536 | 0.1377 |
| 1164 | 3.203 | 0.1397 | 1.112 | 0.1366 |
| 1165 | 3.217 | 0.1405 | 5.470 | 0.1354 |

Mean $K_{DO}$ = 0.1366
P.E. of Mean = 0.0004214 = 0.31%

## TABLE III

C-43

| Round No. | Mach No. | $K_M$ | $\overline{\delta^2}$ | $K_M$ at M = 3.200 |
|---|---|---|---|---|
| 1191 | 3.221 | 1.155 | 8.840 | 1.159 |
| 1192 | 3.164 | 1.154 | 8.368 | 1.147 |
| 1193 | 3.159 | 1.199 | 2.287 | 1.191 |
| 1194 | 3.173 | 1.207 | 2.168 | 1.202 |
| 1195 | 3.092 | 1.195 | 5.112 | 1.173 |
| 1196 | 3.213 | 1.178 | 4.799 | 1.181 |

$K_M = 1.211 - 0.006764\ \overline{\delta^2}$ C.G. = 1.018" from base.
(±0.36%) (±10.8%)

C-39

| Round No. | Mach No. | $K_M$ | $\overline{\delta^2}$ | $K_M$ at M = 3.200 |
|---|---|---|---|---|
| 963 | 3.248 | 1.162 | 6.395 | 1.172 |
| 964 | 3.279 | 1.109 | 24.58 | 1.125 |
| 965 | 3.154 | 1.141 | 9.046 | 1.135 |
| 1166 | 3.157 | 1.188 | 5.443 | 1.179 |
| 1167 | 3.232 | 1.118 | 20.40 | 1.124 |
| 1168 | 3.156 | 1.203 | 2.326 | 1.194 |

$K_M = 1.188 - 0.003000\ \overline{\delta^2}$ C.G. = 0.994" from base.
(±0.63%) (±17.9%)

C-33

| Round No. | Mach No. | $K_M$ | $\overline{\delta^2}$ | $K_M$ at M = 3.200 |
|---|---|---|---|---|
| 956 | 3.201 | 1.156 | 4.847 | 1.156 |
| 1171 | 3.172 | 1.166 | 1.685 | 1.160 |
| 1172 | 3.135 | 1.141 | 8.822 | 1.138 |
| 1173 | 3.161 | 1.176 | 3.042 | 1.168 |

$K_M = 1.172 - 0.003695\ \overline{\delta^2}$ C.G. = 1.000" from base.
(±0.35%) (±22.8%)

C-30

| Round No. | Mach No. | $K_M$ | $\overline{\delta^2}$ | $K_M$ at M = 3.200 |
|---|---|---|---|---|
| 961 | 3.200 | 1.140 | 9.143 | 1.140 |
| 962 | 3.210 | 1.173 | 1.948 | 1.175 |
| 1169 | 3.182 | 1.200 | 0.728 | 1.196 |
| 1170 | 3.162 | 1.194 | 1.960 | 1.186 |

$K_M = 1.196 - 0.006162\ \overline{\delta^2}$ C.G. = 0.992" from base.
(±0.29%) (±11.6%)

(Table III)

C-34

| Round No. | Mach No. | $K_M$ | $\overline{\delta^2}$ | $K_M$ at M = 3.200 |
|---|---|---|---|---|
| 966 | 2.948 | 1.748 | 3.427 | 1.698 |
| 967 | 3.155 | 1.678 | 2.142 | 1.669 |
| 968 | 3.116 | 1.693 | 11.17 | 1.676 |
| 969 | 3.077 | 1.667 | 5.619 | 1.662 |

$K_M = 1.679 - 0.000536 \overline{\delta^2}$
(0.73%) (360%)

C.G. = 0.794" from base.

LI-200

| Round No. | Mach No. | $K_M$ | $\overline{\delta^2}$ | $K_M$ at M = 3.200 |
|---|---|---|---|---|
| 1177 | 3.123 | 1.148 | 17.88 | 1.133 |
| 1178 | 3.143 | 1.162 | 17.10 | 1.151 |
| 1179 | 3.153 | 1.138 | 23.55 | 1.129 |
| 1180 | 3.153 | 1.117 | 24.82 | 1.108 |
| 1181 | 3.172 | 1.154 | 19.14 | 1.148 |

$K_M = 1.219 - 0.004155 \overline{\delta^2}$
(1.9%) (±26.5%)

C.G. = 1.013" from base.

LI-107

| Round No. | Mach No. | $K_M$ | $\overline{\delta^2}$ | $K_M$ at M = 3.200 |
|---|---|---|---|---|
| 959 | 3.178 | 1.205 | 1.560 | 1.201 |
| 1174 | 3.134 | 1.193 | 0.321 | 1.180 |
| 1175 | 3.154 | 1.180 | 3.586 | 1.171 |
| 1176 | 3.169 | 1.211 | 1.158 | 1.205 |

$K_M = 1.198 - 0.005184 \overline{\delta^2}$
(±0.84%) (±94.6%)

C.G. = 0.977" from base.

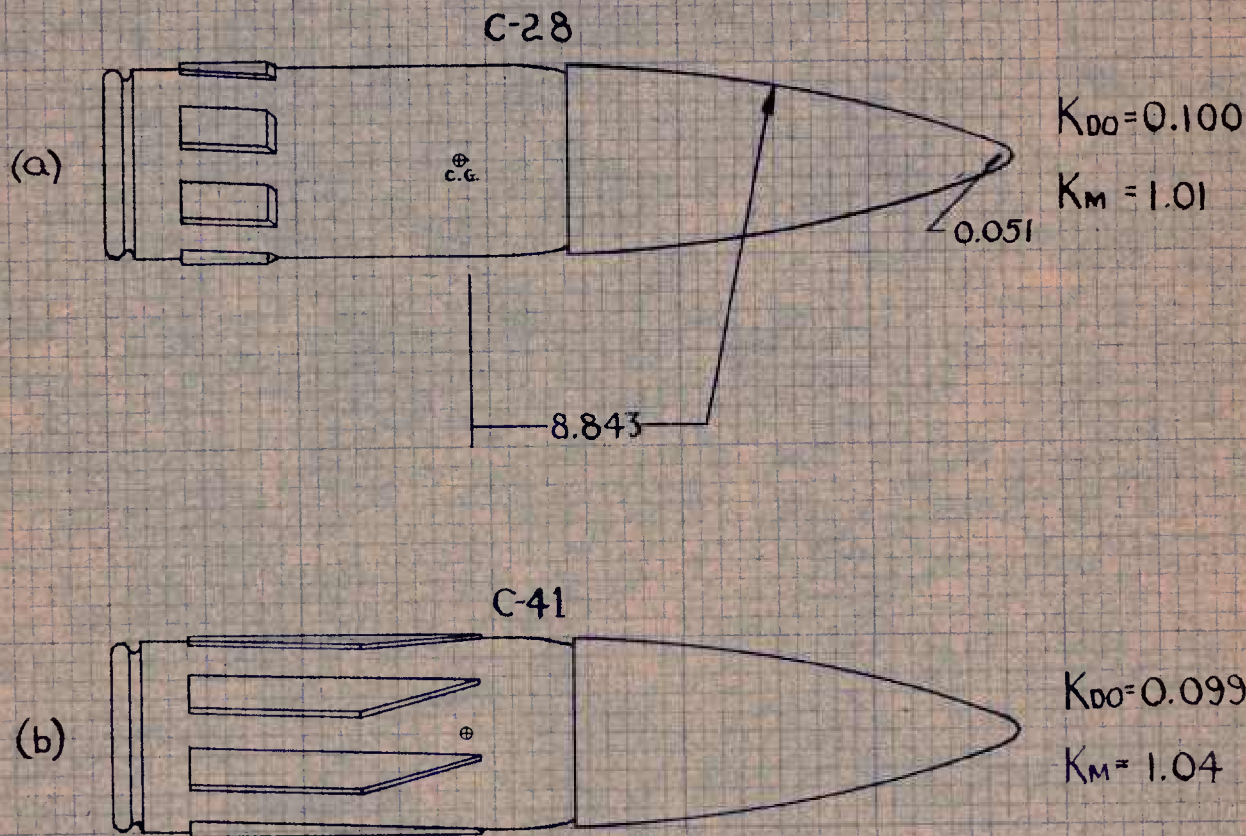
C-31

| Round No. | Mach No. | $K_M$ | $\overline{\delta^2}$ | $K_M$ at M = 3.200 |
|---|---|---|---|---|
| 953 | 3.219 | 1.097 | 5.931 | 1.101 |
| 954 | 3.195 | 1.129 | 0.915 | 1.128 |
| 955 | 3.194 | 1.063 | 19.50 | 1.062 |
| 1163 | 3.168 | 1.145 | 0.536 | 1.139 |
| 1164 | 3.203 | 1.165 | 1.112 | 1.166 |
| 1165 | 3.217 | 1.130 | 5.470 | 1.133 |

$K_M = 1.146 - 0.004421 \overline{\delta^2}$
(±0.18%) (±17.2%)

C.G. = 0.994" from base.

All Data Given is for a Mach Number of 3.200

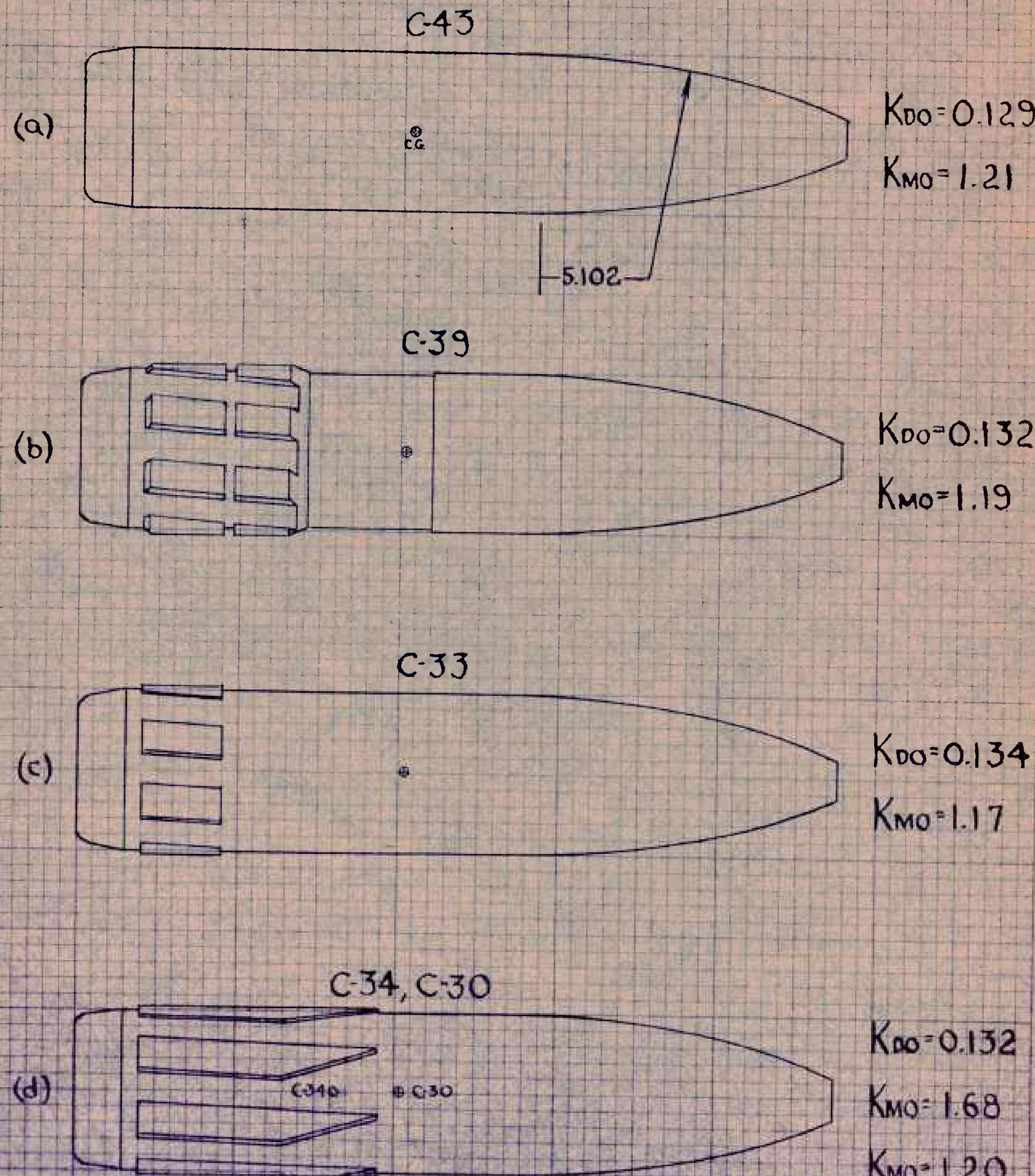



All Dimensions are in Calibers

Scale 1" = 1 Caliber

Figure 1

ALL DATA GIVEN IS FOR A MACH NUMBER OF 3.200

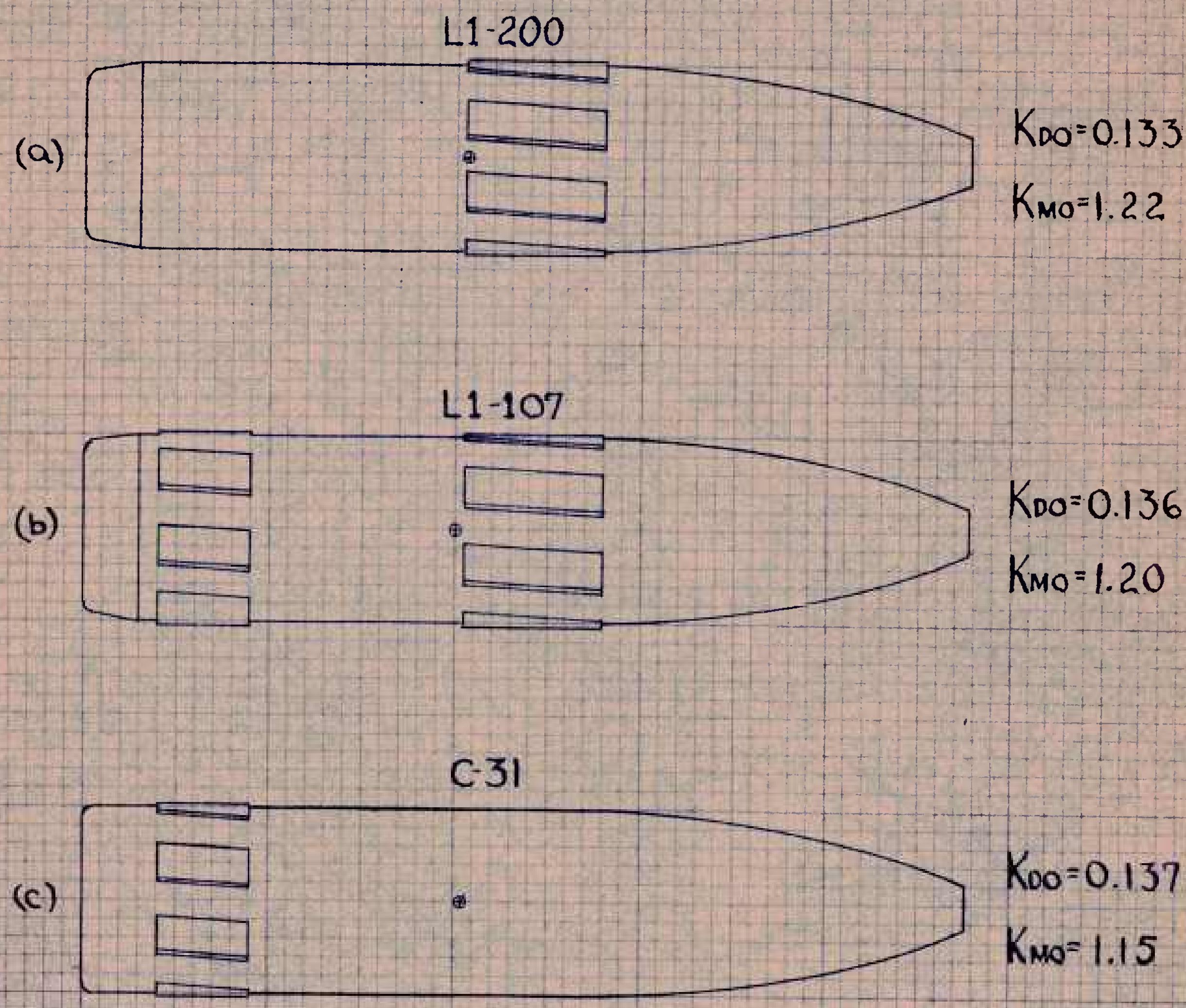



ALL DIMENSIONS ARE IN CALIBERS

SCALE 1" = 1 CALIBER

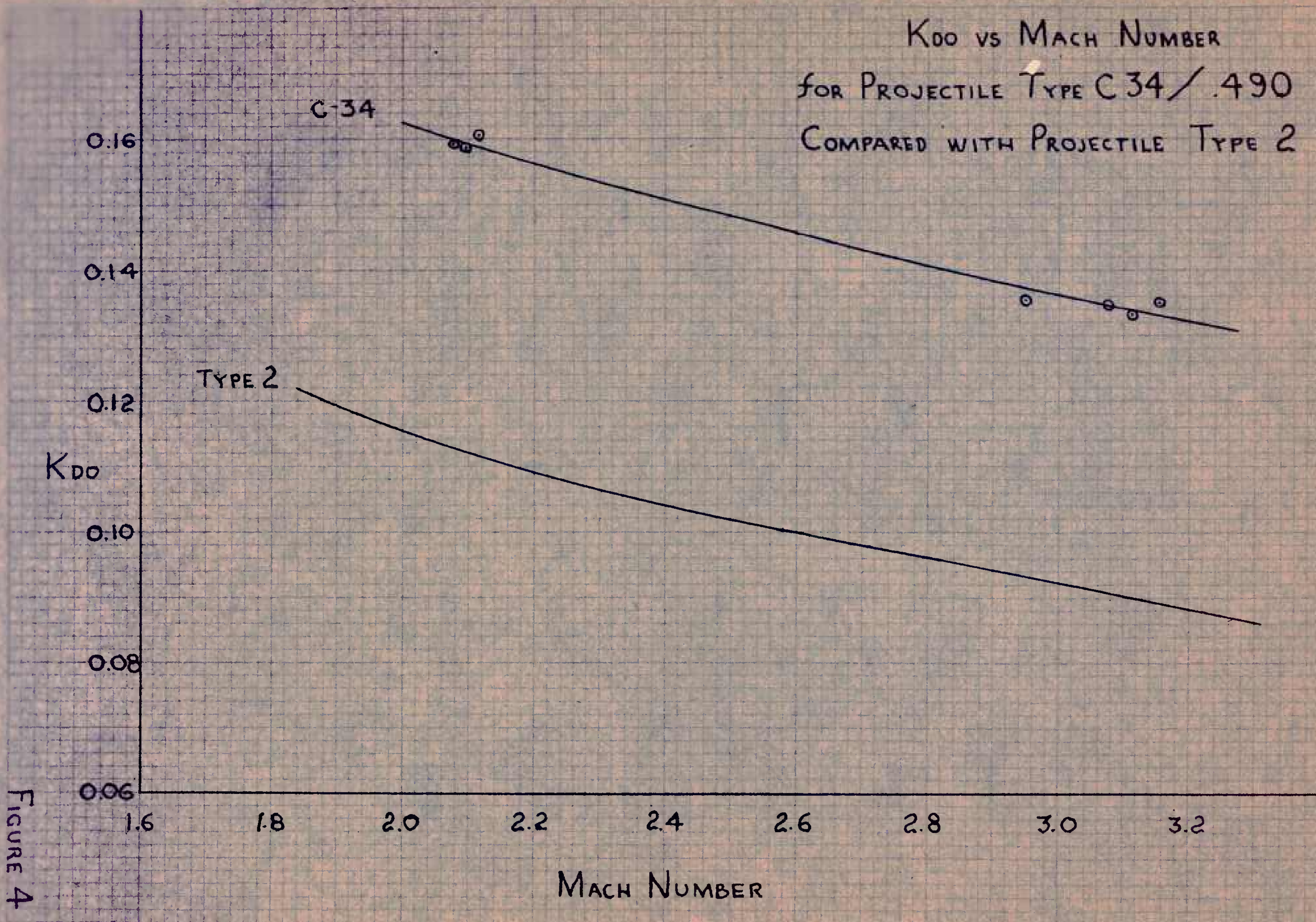
FIGURE 2

ALL DATA GIVEN IS FOR A MACH NUMBER OF 3.200




ALL DIMENSIONS ARE IN CALIBERS
SCALE 1" = 1 CALIBER

FIGURE 3



KDO VS MACH NUMBER
FOR PROJECTILE TYPE C 34 / .490
COMPARED WITH PROJECTILE TYPE 2
C-34
TYPE 2
KDO
0.16
0.14
0.12
0.10
0.08
0.06
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
MACH NUMBER


FIGURE 4

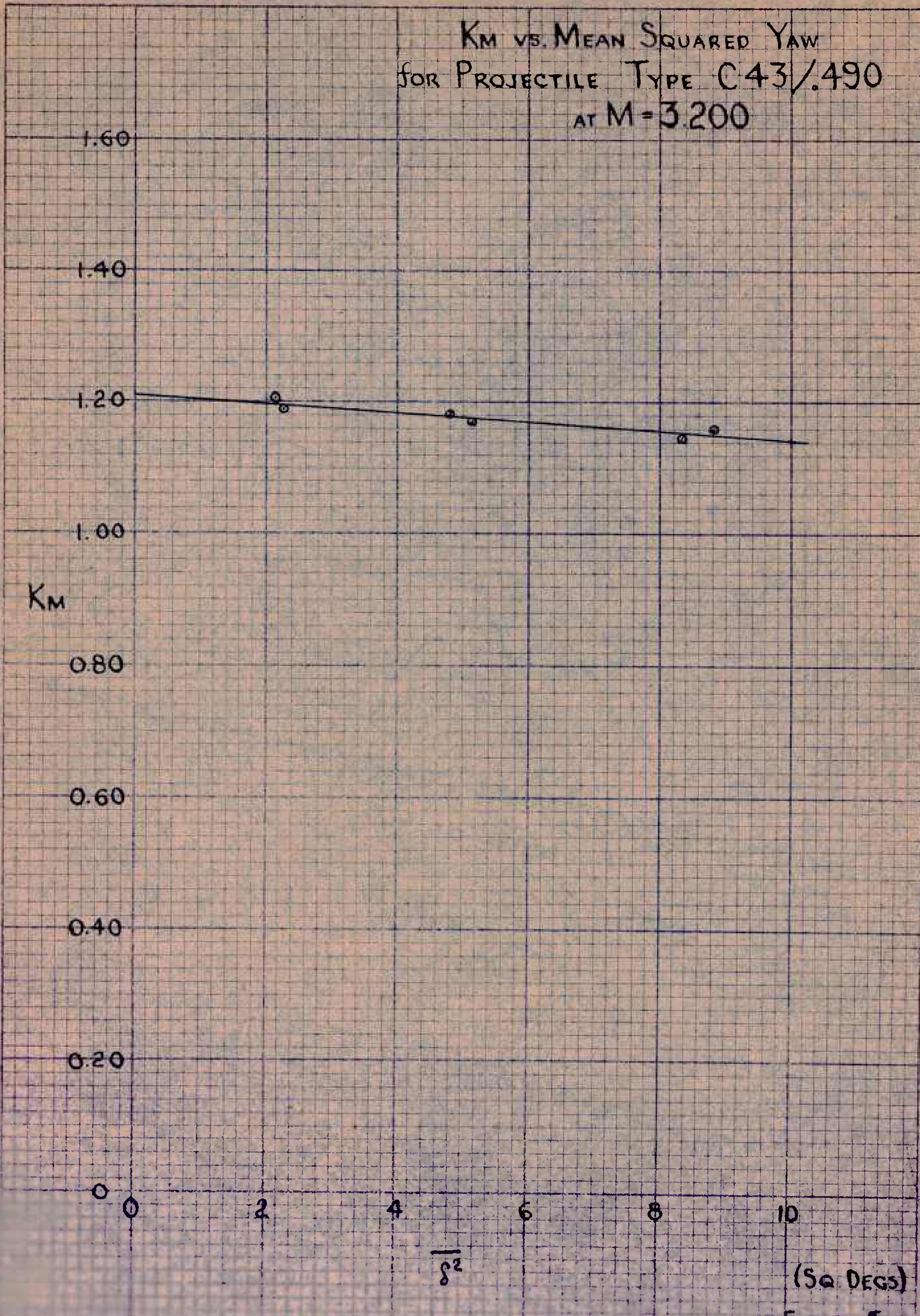

KM vs. MEAN SQUARED YAW
for PROJECTILE TYPE C43/.490
AT M = 3.200
1.60
1.40
1.20
1.00
KM
0.80
0.60
0.40
0.20
0
0
2
4
6
8
10
$\overline{\delta^2}$
(SQ DEGS)

FIGURE 5