WATERTOWN ARSENAL LABORATORY

EXPERIMENTAL REPORT

NO. WAL 710/2[illegible]

AIRCRAFT ARMOR

[illegible] Characteristics of a [illegible] Alloy, [illegible] (Type [illegible]S)

BY

[illegible]

DATE

WATERTOWN ARSENAL
WATERTOWN, MASS.

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CORRIGENDA

Watertown Arsenal Laboratory Report No. WAL 710/265 entitled, "Aircraft Armor - Ballistic Characteristics of a Magnesium Alloy, Dowmetal (Type FS)" dated 22 October 1943.

Precise measurement of the butt setup used in this study discloses a discrepancy between the nominal and actual obliquities of testing. In Watertown Arsenal Laboratory Report No. WAL 710/265-1, now issued, the data in this report have been reviewed and figures of merit recalculated.

These recalculations show that the formula evolved in this study applies over the entire range of obliquity observed (0° to 70°) and is not restricted to obliquities of 60° and less.

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Watertown Arsenal Laboratory
Report Number WAL 710/265
Problem Number B-3.1

22 October 1943

AIRCRAFT ARMOR

Ballistic Characteristics of a Magnesium Alloy, Dowmetal (Type FS)

OBJECT

To investigate the feasibility of using Dowmetal as armor in aircraft.

CONCLUSIONS

1. Dowmetal (Type FS), while affording resistance to perforation comparable, on a weight-for-weight basis, to that of good quality non-magnetic steel armor, nevertheless exhibits severe tendencies toward spalling which do not justify its use as aircraft armor.

2. The resistance to perforation of Dowmetal (Type FS) by cal. .30 AP M2, cal. .50 AP M2 or 20 MM. AP M75 projectiles at normal incidence and at obliquities of 60° or less is well represented, by the following equation:

$$V_n = \frac{1535\,(e_1/d)^{.5}}{\cos\theta},$$

where V_n is the Navy ballistic limit in feet-per-second, e_1 is the thickness (in feet) of a piece of steel equivalent in weight per unit surface area to the subject thickness of Dowmetal, d is the diameter of the projectile (core) in feet, and θ is the angle of obliquity from the normal.

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APPROVED:

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Colonel, Ord. Dept.
Director of Laboratory

A

INTRODUCTION

As an aid to the designer and to the fabricator of aircraft armor, a study of the ballistic characteristics of various types of material which might be used as aircraft armor is being conducted at this Arsenal.

Duralumin (24ST), an aluminum alloy, has exhibited high resistance to perforation by projectiles and, on a weight-for-weight basis has even greater perforation resistance, at high obliquity, than steel armor. It is reasonable to attribute the weight-for-weight superiority of duralumin over steel at high obliquity to the greater thickness-per-unit-weight of the lighter alloy.

Inasmuch as the average aircraft fabricator is familiar with the uses of the magnesium alloy, Dowmetal, and in view of the fact that this alloy has an even greater thickness-per-unit-weight than duralumin, it was considered worthwhile to investigate its ballistic properties with a view, if they should prove satisfactory, of recommending its use as armor in combination with its various other uses in aircraft.

Accordingly, through the cooperation of the Dow Chemical Company, this Arsenal was provided with thirteen (13) samples of Dowmetal (Type FS)* which enabled the conduct of a reasonably comprehensive ballistic test of the material.

TEST PROCEDURE

Ballistic tests at normal incidence and at obliquities of 30°, 45°, 60° and 75° from the normal were conducted on a one-hundred yard indoor firing range, using a cal. .50 Browning Machine Gun barrel and a cal. .30 Mann barrel mounted on a machine rest which permitted horizontal and vertical orientation of the gun to control the placement of shots on the target and to compensate for any fluctuation in trajectory incidental to a variation in velocity. A 20 MM. gun mounted in a 3" field piece permitting similar maneuverability was used for heavier fire.

Striking velocities were determined by the use of a pair of Aberdeen Chronographs connected to screens of metal foil mounted on wooden frames. By this arrangement the average velocity of the projectile over the distance between the screens was determined, from which the striking velocity was computed from prepared correction tables.

Before firing, powder charges were estimated to produce the required striking velocity for each round and rounds were accordingly assembled from appropriate components.

*For physical properties, see Appendix B.

RESULTS

The results of the ballistic tests have been given in detail in Ballistic Data Sheets 1 to 13 of Appendix A.

These data have been summarized in Tables I to V and graphically represented in Figures 1 to 5. Values of e and e_1 in these tables are listed in terms of inches, but e_1/d values have been computed with e_1 in terms of feet.

The estimated resistance to perforation of several armor materials equivalent on a weight-for-weight basis to steel whose thickness equals the diameter of the attacking projectile is tabulated in Table VI and illustrated in Figure 7.

Figure 6 shows the agreement of the data with an empirical formula suggested by the constancy of F at normal incidence and at obliquities of 30°, 45° and 60° from the normal.

DISCUSSION

In order to afford a comparison of the ballistic efficiency of Dowmetal with that of steel, on a weight-for-weight basis, the performance of Dowmetal (Type FS) in the ballistic tests at normal incidence and at obliquities of 30°, 45°, 60° and 75° from the normal has been evaluated in terms of the Thompson coefficient[1] and plotted against $e_1/d \cos\theta$ in Figures 1 to 5. From these figures the resistance to perforation, at the various obliquities, of a thickness of Dowmetal equivalent in weight-per-unit surface area to a thickness of steel which matches the diameter of the projectile (core) has been estimated and this has been compared in Table VI and Figure 7 with available data* concerning the resistance afforded by equivalent weights of other armor materials.

*Table VI and Figure 7 are based on data collected as basis of a study of the ballistic characteristics of several materials which might be used as aircraft armor. The complete results of this study will be made available in Watertown Arsenal Laboratory Report WAL 710/506, soon to be issued.

1. The Thompson coefficient(F) is a measure of the ballistic efficiency of armor and is obtainable from the following:

$$F^2 = \frac{m\, V^2 \cos^2\theta}{e\, d^2},$$

where m is the weight of the projectile in pounds, V is the limit velocity in feet-per-second, θ is the angle of obliquity from the normal, e is the thickness of the plate in feet and d is the diameter of the projectile (core) in feet.

For the purpose of comparing the efficiency of materials of different density to that of steel on the basis of protection afforded per-unit-weight used to protect a unit of area perpendicular to the line of fire e_1 may be substituted for e in the equation, e_1 being that thickness of steel which is equivalent in weight to the subject thickness (e) of the material whose efficiency is being evaluated.

In this report $e_1 = \frac{e}{4.4}$ for Dowmetal;

$e_1 = \frac{e}{2.8}$ for duralumin;

$e_1 = e$ for steel.

Since the flexural rigidity of a material is a function of the cube of its thickness multiplied by its modulus of elasticity, Dowmetal, while its modulus of elasticity is only 0.22 times that of steel is nevertheless more than nineteen (19) times as rigid as steel of equal surface area and weight inasmuch as its thickness on a weight-for-weight basis is 4.4 times that of steel.

Thus, there has been designed successfully an aircraft fuselage of magnesium in which the rigidity of the light alloy veneer has allowed the elimination of many of the supporting members characteristic of a monocoque structure.[2] If Dowmetal would afford resistance to perforation comparable to steel or duralumin, there could be envisioned a more rigid combat aircraft structure affording greater space for the storage of armament and ammunition entailing no sacrifice of speed or armor protection.

Figure 7, however, indicates that only in comparison with non-magnetic steel armor is Dowmetal (Type FS) superior in resistance to perforation to other armor materials of equivalent weight. Thus, in order to provide resistance to perforation equal to that of face-hardened or homogeneous steel, or of duralumin, a greater weight of Dowmetal (Type FS) would have to be used with a consequent undesirable sacrifice of speed and maneuverability.

Figures 8 to 13 illustrate characteristic effects of projectile impact upon Dowmetal (Type FS). The severe gouging of the material is attributable to the fact that, even at obliquity, the small arms projectiles did not break up upon contact with such a soft material.

Ordinarily, contact by small arms projectiles with armor materials at obliquities and at striking velocities of the order experienced in this program results in breakage of the projectile due to a transverse force whose magnitude, at a given striking velocity and obliquity, may be proportional to some measure of the resistance of the plate material to plastic deformation.[3]

Since the hardness of Dowmetal is extremely low (BHN about 60), it may be assumed that material of this hardness affords insufficient resistance to plastic deformation by a small arms projectile to exert a transverse force of sufficient magnitude to break the projectile. This failure doubtless detracts from any advantage the superior thickness-per-unit-weight characteristic of this alloy may offer.

Furthermore, Dowmetal (Type FS) shows a high tendency toward back spalling. In some instances, although the projectile in its entirety was rejected by the plate, substantial sections spalled from the back

2. Beck, Adolph. The Technology of Magnesium and Its Alloys. London. 1940. F. A. Hughes & Co., Ltd. Page 447.

3. Watertown Arsenal Report No. 710/492. Mechanism of Armor Penetration. Second Partial Report. C. Zener and R. E. Peterson. 31 May 1943.

of the plate. This condition is highly undesirable in an armor material because, in addition to the immediate damage done by the detachment of such spalls (which may in some cases be lethal), the protection afforded by the armor is permanently impaired by such substantial reductions in the thickness of the armor material.

This spalling tendency may not necessarily be an inherent characteristic of all Dowmetal. It could well be the result of an attempt to harden the material in order to increase its resistance to perforation. There is perhaps a critical BHN for every type of material beyond which it cannot be hardened if it is to withstand ballistic attack successfully and resist spalling.

Whether this critical for Dowmetal (Type FS) has been exceeded or whether the material has some inherent characteristic conducive to spalling can only be determined by further testing.

An examination of Figures 1 to 4 discloses a remarkable constancy of the value of F independent of plate thickness or of obliquity up to 60°. While no ready explanation for this constancy offers itself, the opportunity to formularize the data should not be neglected.

Thus, the constancy of F at normal incidence and at obliquities up to 60° suggests that the Navy ballistic limit of Dowmetal (Type FS), under those conditions, is an inverse function of the cosine of the angle of obliquity, and the following equation is indicated:

$$V_n = \frac{K\ (e_1/d)^{.5}}{\cos\theta}$$

where V_n is the Navy ballistic limit in feet-per-second, e_1 is the thickness (in feet) of a piece of steel equivalent in weight-per-unit surface area to the subject thickness of Dowmetal (Type FS), d is the diameter of the projectile (core) in feet, θ is the angle of obliquity from the normal and K a constant to be determined empirically. Examination of the data indicates that K becomes equal to 1535, and the following equation evolves:

$$V_n = \frac{1535\ (e_1/d)^{.5}}{\cos\theta}$$

The fit of averaged data to the curve of this equation is shown in Figure 6.

If, for a certain value of $e/d \cos \theta$, the Navy ballistic limit of a material is constant over the entire range of obliquity, it would make little difference from the standpoint of protecting a unit area normal to the line of fire from the effects of projectile perforation whether a single unit of thickness of the material were installed at normal incidence (where $1/\cos \theta = 1.0$) or whether half this unit of thickness of the same material were installed at 60° (where $1/\cos \theta = 2.0$). Considerations of space economy, however, would probably dictate the use of the thicker gauge at normal.

If (as in the case of Dowmetal (Type FS) in this report at obliquities up to 60°) the F value of a material is independent of e/d and of θ, a superior protection from the same weight of armor will be afforded by increasing the obliquity of emplacement, since if F is constant the Navy ballistic limit for a given $e/d \cos \theta$ varies inversely as the square root of the cosine.

In the case of most armor materials, however, F does not remain constant, but rather, varies with obliquity and the point at which a maximum Navy ballistic limit is afforded by a given $e/d \cos \theta$ indicates the obliquity at which the material attains its maximum efficiency. This point is relevant in the design of armor installations.

Oblique emplacement of armor ordinarily improves its efficiency up to a certain critical beyond which a Law of Diminishing Returns apparently begins to operate.

This is attributable to the fact that, if, as obliquity is increased, $e/d \cos \theta$ is kept constant, e/d must diminish since a larger section of thinner material must be employed to shield the same area normal to the line of fire in order to keep the total armor weight fixed. As the material becomes thinner with increasing obliquity, a critical ratio of some dimension of the projectile to the thickness of the armor is apparently reached at which point the efficiency of the armor begins to diminish. This may readily be seen when it is realized that at a very high obliquity the ratio of plate thickness to projectile caliber must be extremely low if the weight necessary to shield a unit area normal to the line of fire is to be kept equivalent to that of a plate installed at normal whose thickness equals the diameter of the attacking projectile (for instance, at 85°, the ratio is only 2 to 23).

In the case of denser materials, this critical is reached at a lower obliquity than in the case of lighter alloys. This is doubtless attributable to the fact that at equal values of e_1/d, the e/d value of the denser materials is lower (since, in the case of Dowmetal, $e_1 = \frac{e}{4.4}$; in the case of duralumin, $e_1 = \frac{e}{2.8}$; and, of course, in the case of steel $e_1 = e$). Thus the critical relationship between some dimension of the projectile and the thickness of the plate may be expected to arise at a lower obliquity.

In the case of Dowmetal (Type FS), this critical obliquity apparently lies somewhere between 60° and 75°. At 75° (Figure 5) the F value is substantially less than the constant value characteristic of this material at 0°, 30°, 45° and 60° (Figures 1 to 4), and the Navy ballistic limit for a given $e/d \cos \theta$ is less than at 60°. It may be assumed that, for this material, the critical relationship between some projectile dimension and the plate thickness is reached at some intermediate obliquity.

TABLE I

Summary of Results of Ballistic Tests of Dowmetal (Type FS)

at Normal Incidence

(See also Figure 1)

Cal.	m/d^3	θ	V_n	e	e_1	e_1/d	$e_1/d \cos \theta$	F	Data Source
.50	1275	0°	1230	1.110	.255	.595	.595	56,900	W.A. - R2455
.50	1275	0°	1218	1.118	.257	.600	.600	56,100	W.A. - R2415
.30	1355	0°	1307	.741	.170	.691	.691	57,900	W.A. - R2420
.50	1275	0°	1307	1.305	.300	.700	.700	55,800	W.A. - R2414
.50	1275	0°	1311	1.313	.301	.702	.702	55,900	W.A. - R2454
.30	1355	0°	1325	.766	.176	.715	.715	57,700	W.A. - R2439
.50	1275	0°	1433	1.495	.343	.800	.800	57,200	W.A. - R2413
.50	1275	0°	1415	1.499	.344	.803	.803	56,400	W.A. - R2453
.30	1355	0°	1541	.998	.229	.931	.931	58,800	W.A. - R2419
.30	1355	0°	1605	1.110	.255	1.037	1.037	58,000	W.A. - R2438
.30	1355	0°	1598	1.118	.257	1.045	1.045	57,500	W.A. - R2418
.30	1355	0°	1794	1.305	.300	1.220	1.220	59,800	W.A. - R2419
.30	1355	0°	1793	1.313	.301	1.224	1.224	59,700	W.A. - R2437
.30	1355	0°	1895	1.495	.343	1.394	1.394	59,100	W.A. - R2416
.30	1355	0°	1820	1.499	.344	1.398	1.398	56,700	W.A. - R2436

TABLE II

Summary of Results of Ballistic Tests of Dowmetal (Type FS) at 30° Obliquity

(See also Figure 2)

Cal.	m/d^3	θ	V_n	e	e_1	e_1/d	$e_1/d \cos \theta$	F	Data Source
.50	1275	30°	1154	.766	.176	.411	.475	55,600	W.A. - R2405
.50	1275	30°	1273	.998	.229	.534	.617	53,900	W.A. - R2452
.30	1355	30°	1343	.635	.146	.593	.6[illegible]5	55,700	W.A. - R2413
.50	1275	30°	1371	1.110	.255	.595	.687	55,000	W.A. - R2411
.50	1275	30°	1392	1.118	.257	.600	.693	55,600	W.A. - R2403
.50	1275	30°	1363	1.118	.257	.600	.693	54,400	W.A. - R2451
.30	1355	30°	1352	.675	.155	.630	.727	54,300	W.A. - R2412
.30	1355	30°	1371	.741	.170	.691	.798	52,600	W.A. - R2404
.50	1275	30°	1426	1.305	.300	.700	.808	52,700	W.A. - R2450
.50	1275	30°	1395	1.313	.301	.702	.811	51,500	W.A. - R2402
.30	1355	30°	1495	.766	.176	.715	.826	56,300	W.A. - R2410
.50	1275	30°	1511	1.499	.344	.803	.927	52,100	W.A. - R2401
.30	1355	30°	1656	.998	.229	.931	1.075	54,700	W.A. - R2446
.30	1355	30°	1776	1.110	.255	1.037	1.197	55,600	W.A. - R2409
.30	1275	30°	1832	1.118	.257	1.045	1.207	57,100	W.A. - R2408
.30	1355	30°	1989	1.305	.300	1.220	1.409	57,400	W.A. - R2445
.30	1355	30°	2084	1.313	.301	1.224	1.413	60,000	W.A. - R2407
.30	1355	30°	2124	1.499	.344	1.398	1.614	57,300	W.A. - R2406

TABLE III

Summary of Results of Ballistic Tests of Dowmetal (Type FS)

at 45° Obliquity

(See also Figure 3)

Cal.	m/d^3	θ	V_n	e	e_1	e_1/d	$e_1/d \cos \theta$	F	Data Source
20 MM.	1295	45°	1100	1.118	.257	.323	.454	48,900	W.A. - R2377
20 MM.	1295	45°	1250	1.313	.301	.384	.543	51,300	W.A. - R2378
.50	1275	45°	1334	.741	.170	.397	.561	53,500	W.A. - R2392
.30	1355	45°	1364	.425	.098	.398	.563	56,300	W.A. - R2400
20 MM.	1295	45°	1397	1.499	.344	.439	.621	53,600	W.A. - R2379
.30	1355	45°	1536	.635	.146	.593	.839	51,900	W.A. - R2399
.50	1275	45°	1744	1.110	.255	.595	.841	[illegible],100	W.A. - R2391
.50	1275	45°	1763	1.118	.257	.600	.849	57,400	W.A. - R2390
.30	1355	45°	1675	.675	.155	.630	.891	54,900	W.A. - R2398
.50	1275	45°	1949	1.305	.300	.700	.990	58,800	W.A. - R2389
.30	1355	45°	1704	.766	.176	.715	1.011	52,500	W.A. - R2397
.50	1275	45°	1903	1.499	.344	.803	1.136	53,600	W.A. - R2384
.30	1355	45°	2149	1.110	.255	1.037	1.467	54,900	W.A. - R2396
.30	1355	45°	2108	1.118	.257	1.045	1.478	53,700	W.A. - R2395, R2448
.30	1355	45°	2614	1.313	.301	1.224	1.731	61,500	W.A. - R2394
.30	1355	45°	2477	1.499	.344	1.398	1.977	54,500	W.A. - R2393

TABLE IV

Summary of Results of Ballistic Tests of Dowmetal (Type FS)

at 60° Obliquity

(See also Figure 4)

Cal.	m/d^3	θ	V_n	e	e_1	e_1/d	$e_1/d \cos \theta$	F	Data Source
20 MM.	1295	60°	1200	.675	.155	.198	.396	48,500	W.A. - R2376
.50	1275	60°	1367	.425	.098	.229	.458	51,000	W.A. - R2353
20 MM.	1295	60°	1729	.998	.229	.292	.534	57,600	W.A. - R2369
20 MM.	1295	60°	1716	1.118	.257	.328	.656	53,900	W.A. - R2375
.50	1275	60°	1696	.675	.155	.362	.724	50,300	W.A. - R2354
20 MM.	1295	60°	1994	1.305	.300	.383	.766	58,000	W.A. - R2374
.50	1275	60°	1938	.741	.170	.397	.794	54,900	W.A. - R2355
.30	1355	60°	1933	.425	.098	.398	.796	56,400	W.A. - R2353
20 MM.	1295	60°	1936	1.495	.343	.438	.876	52,700	W.A. - R2350
.50	1275	60°	2377	.998	.229	.534	1.068	58,100	W.A. - R2352
.50	1275	60°	2177	1.118	.257	.600	1.200	50,200	W.A. - R2330
.30	1355	60°	2393	.675	.155	.630	1.260	55,500	W.A. - R2354
.50	1275	60°	2702	1.313	.301	.702	1.404	57,600	W.A. - R2351
.30	1355	60°	2632	.766	.175	.715	1.430	57,300	W.A. - R2383
.50	1275	60°	2810	1.495	.343	.800	1.600	56,100	W.A. - R2351
.30	1355	60°	2913	1.110	.255	1.037	2.074	52,600	W.A. - R2382

TABLE V

Summary of Results of Ballistic Tests of Dowmetal (Type FS)

at 75° Obliquity

(See also Figure 5)

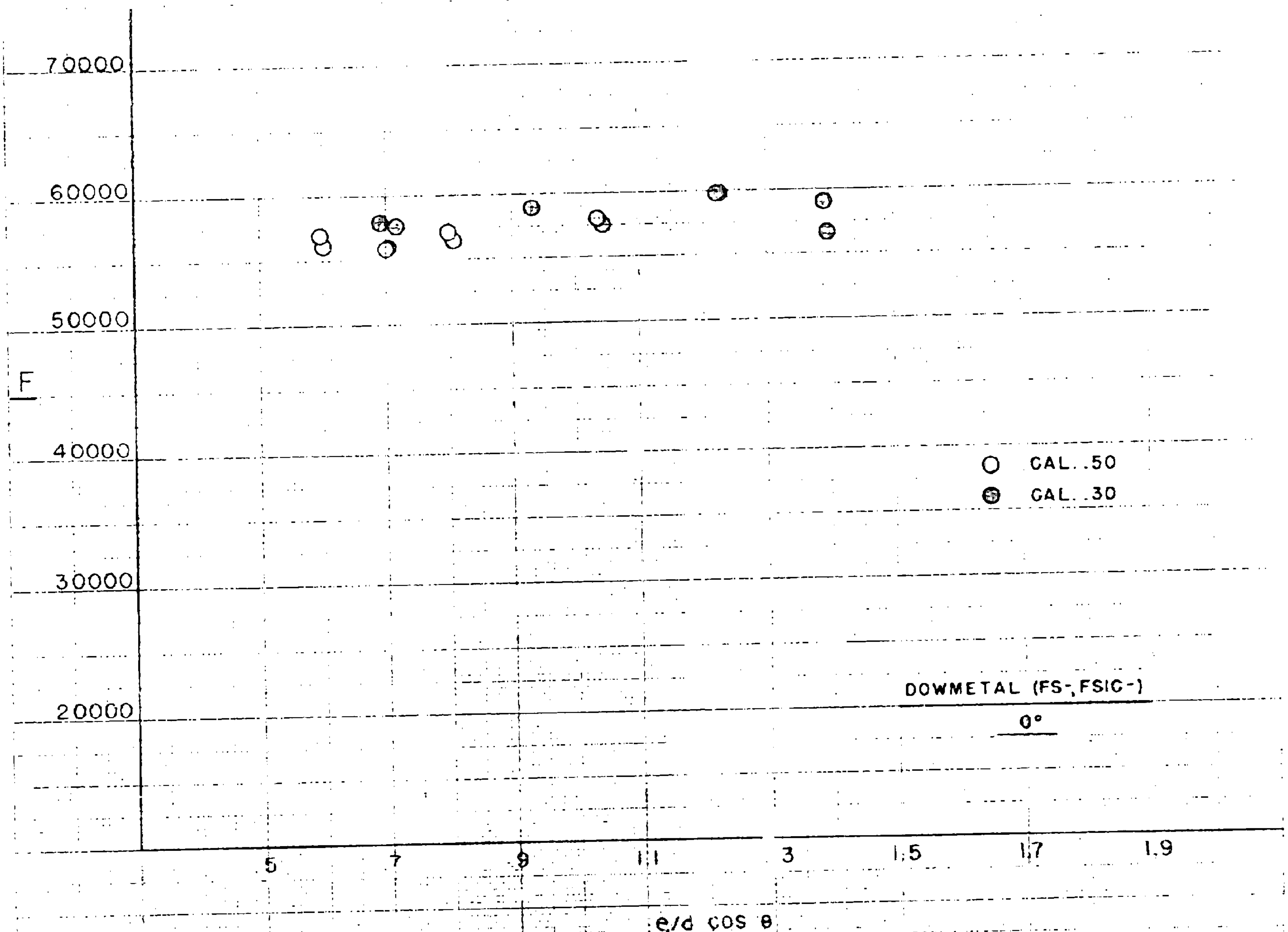
Cal.	m/d^3	θ	V_n	e	e_1	e_1/d	$e_1/d \cos\theta$	F	Data Source
20 MM.	1295	75°	1298	.425	.098	.125	.483	34,200	W.A. - R2360
20 MM.	1295	75°	1748	.741	.170	.217	.838	35,000	WA. - R2356
.50	1275	75°	1990	.425	.098	.229	.885	38,400	W.A. - R2348
20 MM.	1295	75°	2389	.998	.229	.292	1.128	41,200	W.A. - R2368
.50	1275	75°	2541	.635	.146	.341	1.318	40,200	W.A. - R2346
.50	1275	75°	2441	.675	.155	.362	1.399	37,500	W.A. - R2347
.30	1355	75°	2787	.425	.098	.398	1.538	42,100	W.A. - R2348
.50	1275	75°	2643	.766	.176	.411	1.588	38,100	W.A. - R2358

TABLE VI

Navy Ballistic Limits (Estimated) at Various Obliquities of Different Armor Materials Equivalent on a Weight-for-Weight Basis to Steel Whose Thickness Equals the Diameter of the Attacking Projectile (Core)

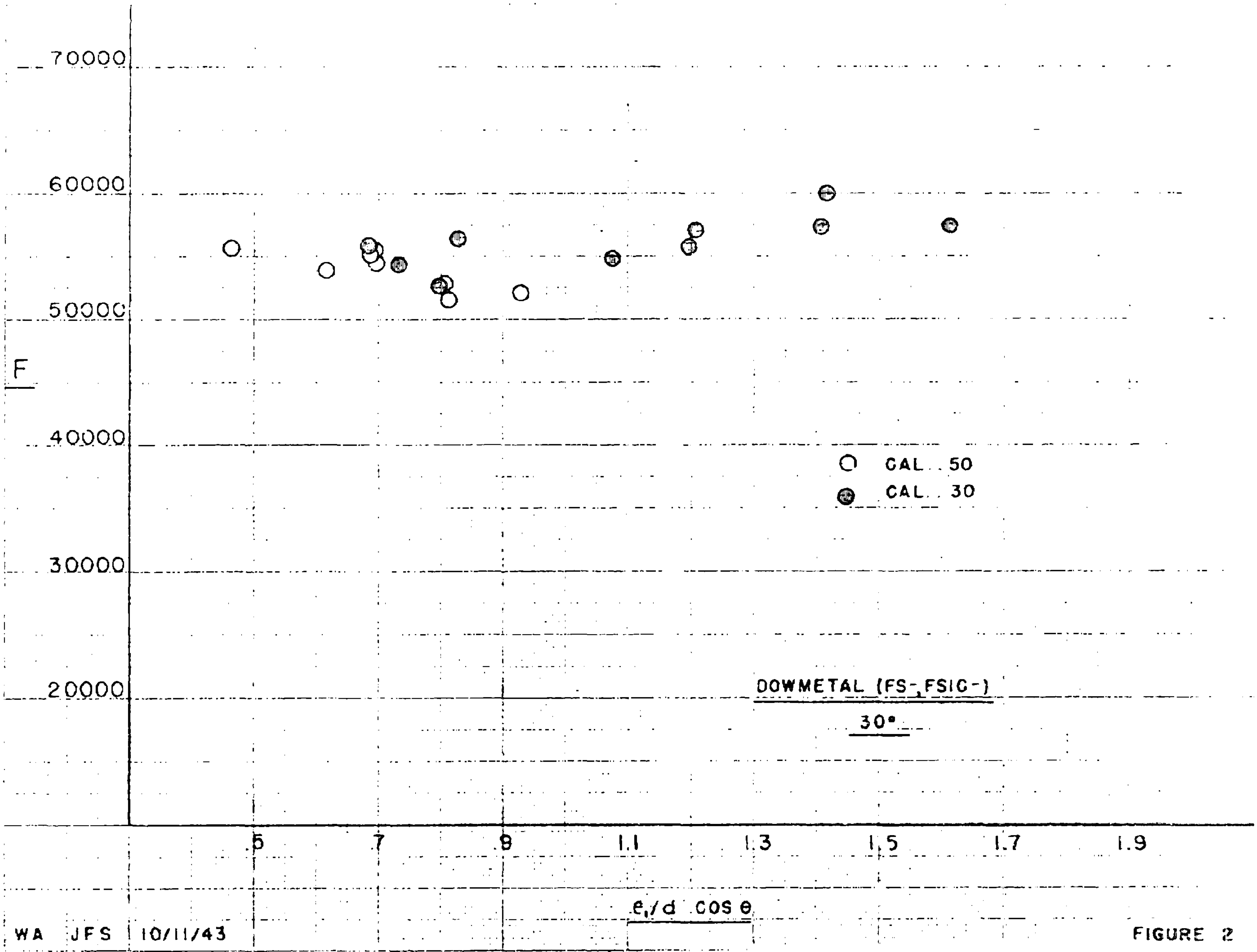
(See also Figure 7)

	0°	30°	45°	60°
Face-Hardened Steel	2130	2390	2870	3920
Homogeneous Steel (BHN 340-360)	1650	2040	2670	3530
Non-Magnetic Steel (Spec. ANOS-3)	1300	1725	--	--
Duralumin (24ST)	1820	1940	2610	4025
Dowmetal (FS)	1600	1780	2170	3045



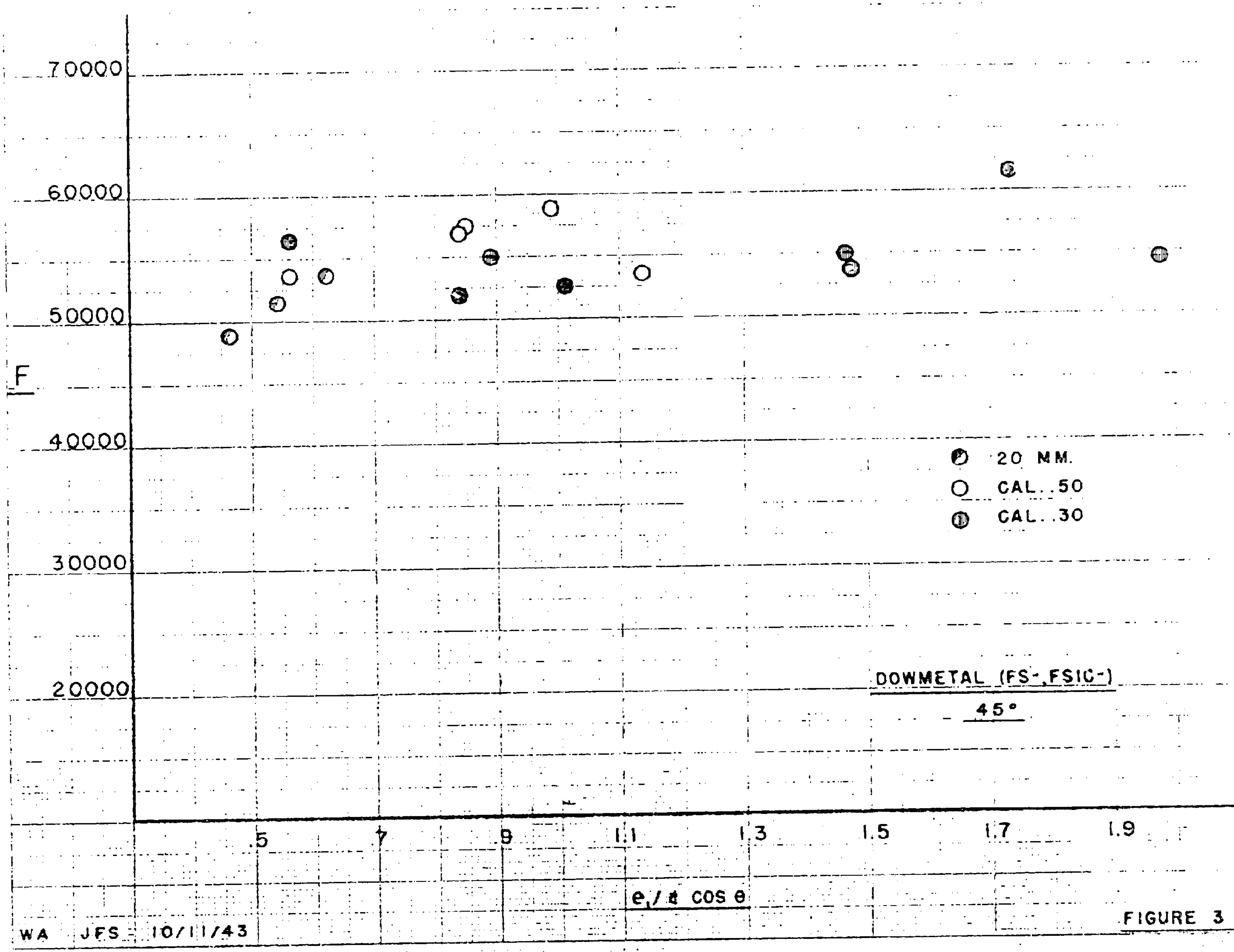
WA JFS 10/11/43

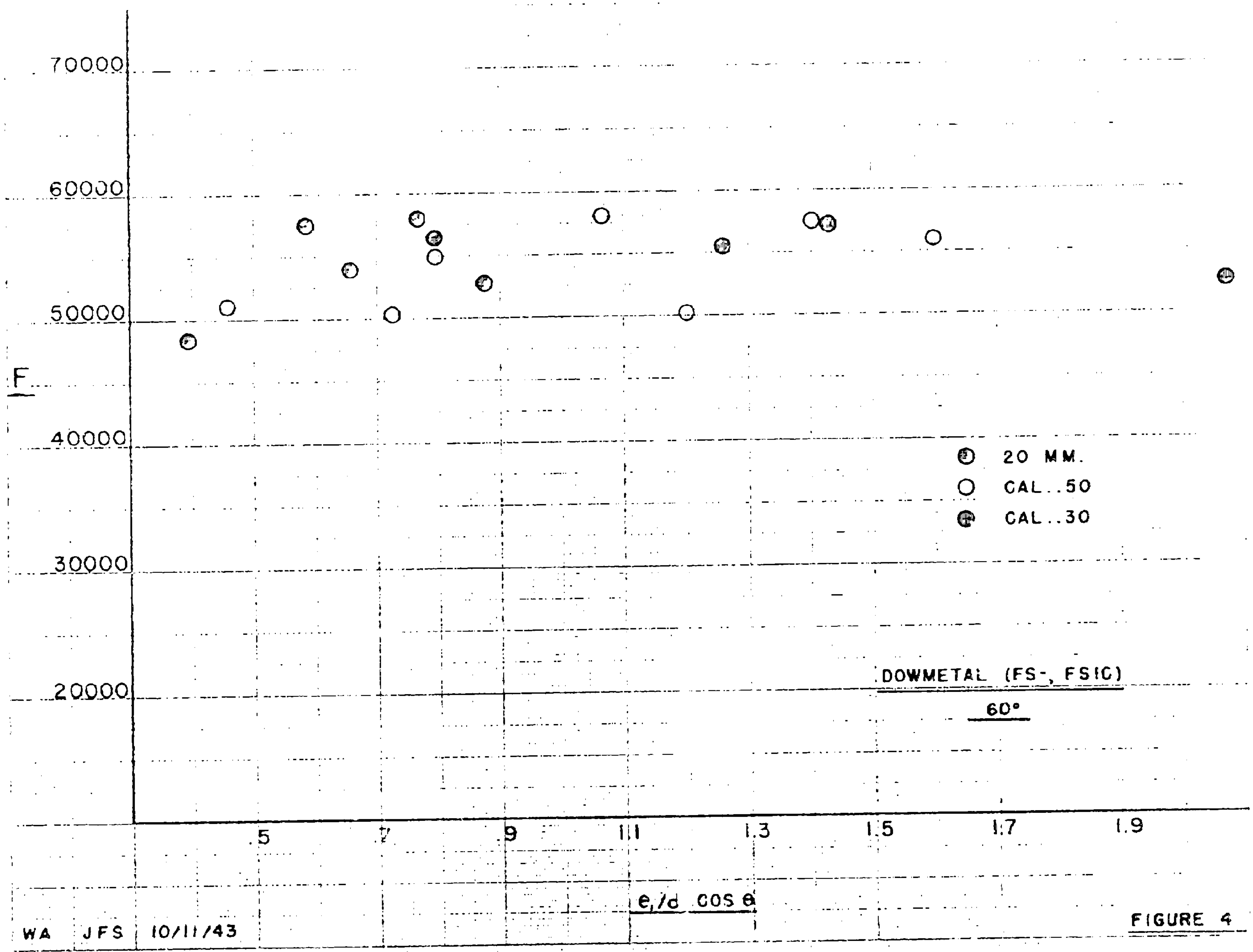
FIGURE 1



70000
60000
50000
40000
30000
20000
F
CAL. 50
CAL. 30
DOWMETAL (FS-, FSIC-)
30°
.5
.7
.9
1.1
1.3
1.5
1.7
1.9
e_1/d cos θ
WA JFS 10/11/43

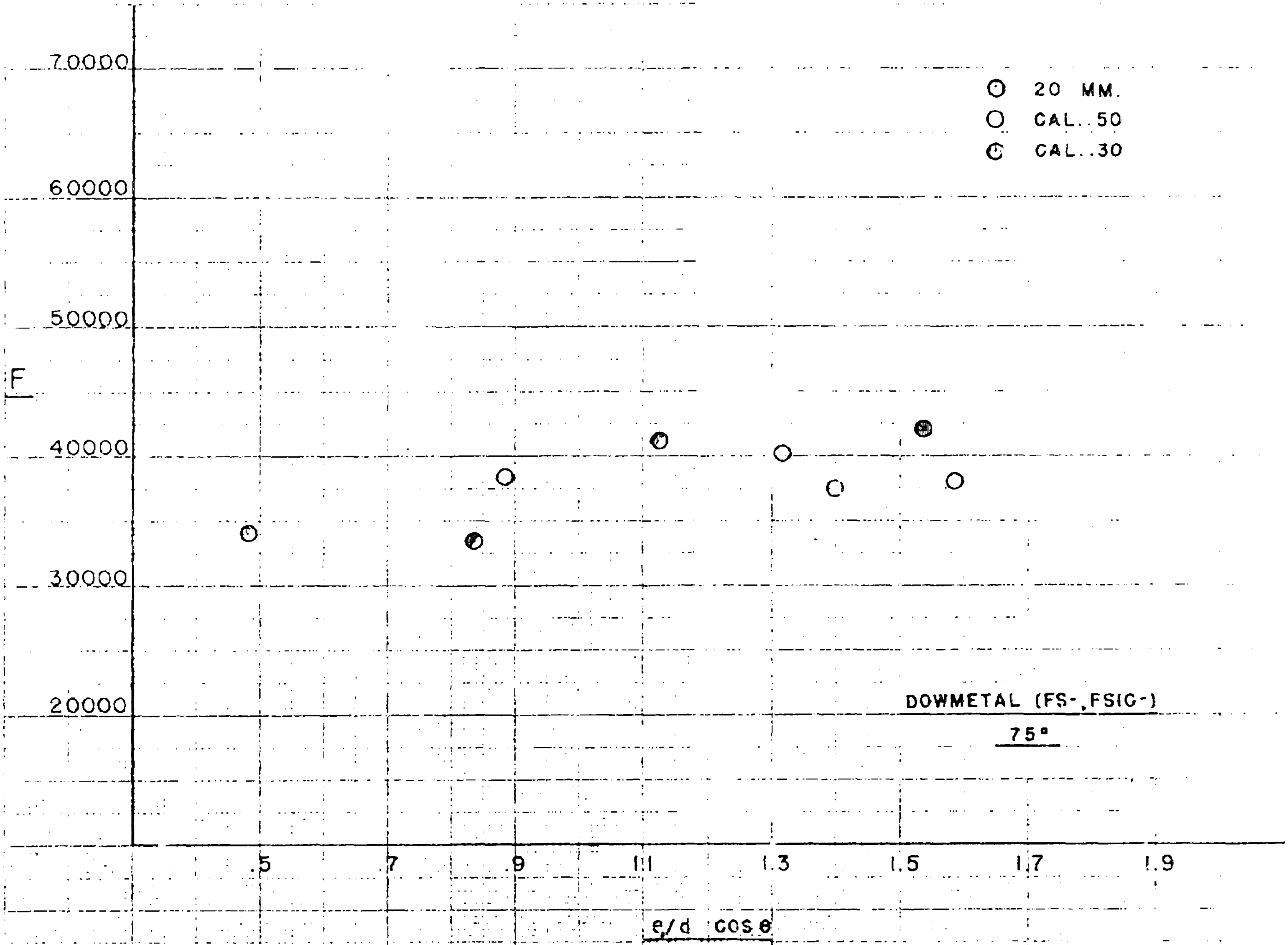
FIGURE 2


70000
60000
50000
40000
30000
20000
F
.5
.7
.9
1.1
1.3
1.5
1.7
1.9
e / t cos θ
20 MM.
CAL. .50
CAL. .30
DOWMETAL (FS-, FSIC-)
45°
WA JFS 10/11/43
FIGURE 3



70000
60000
50000
40000
30000
20000
F
.5
.7
.9
1.1
1.3
1.5
1.7
1.9
e/d cos θ
20 MM.
CAL..50
CAL..30
DOWMETAL (FS-, FSIC)
60°
WA JFS 10/11/43

FIGURE 4

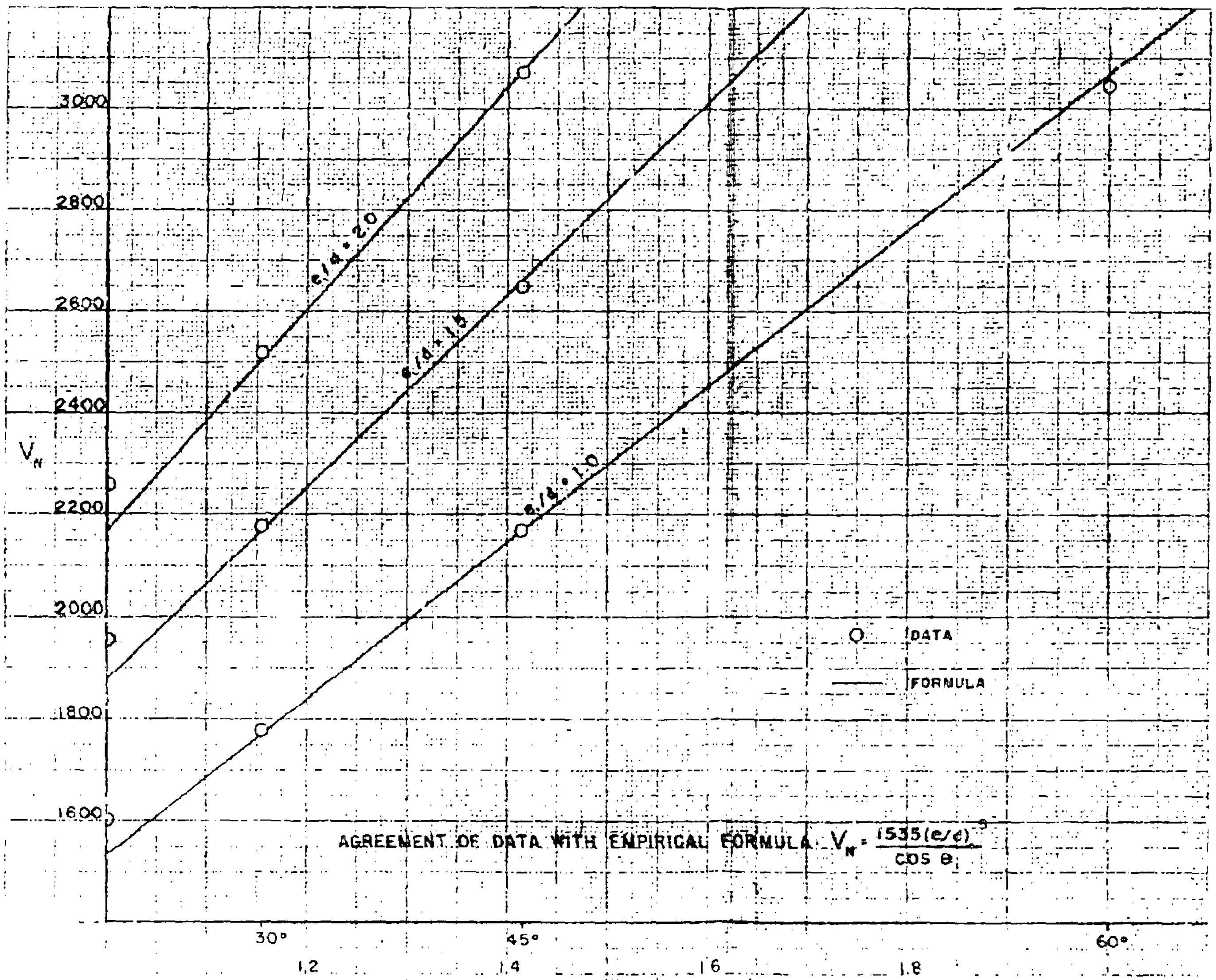


DOWMETAL (FS-,FSIC-)

75°

WA JFS 10/11/43

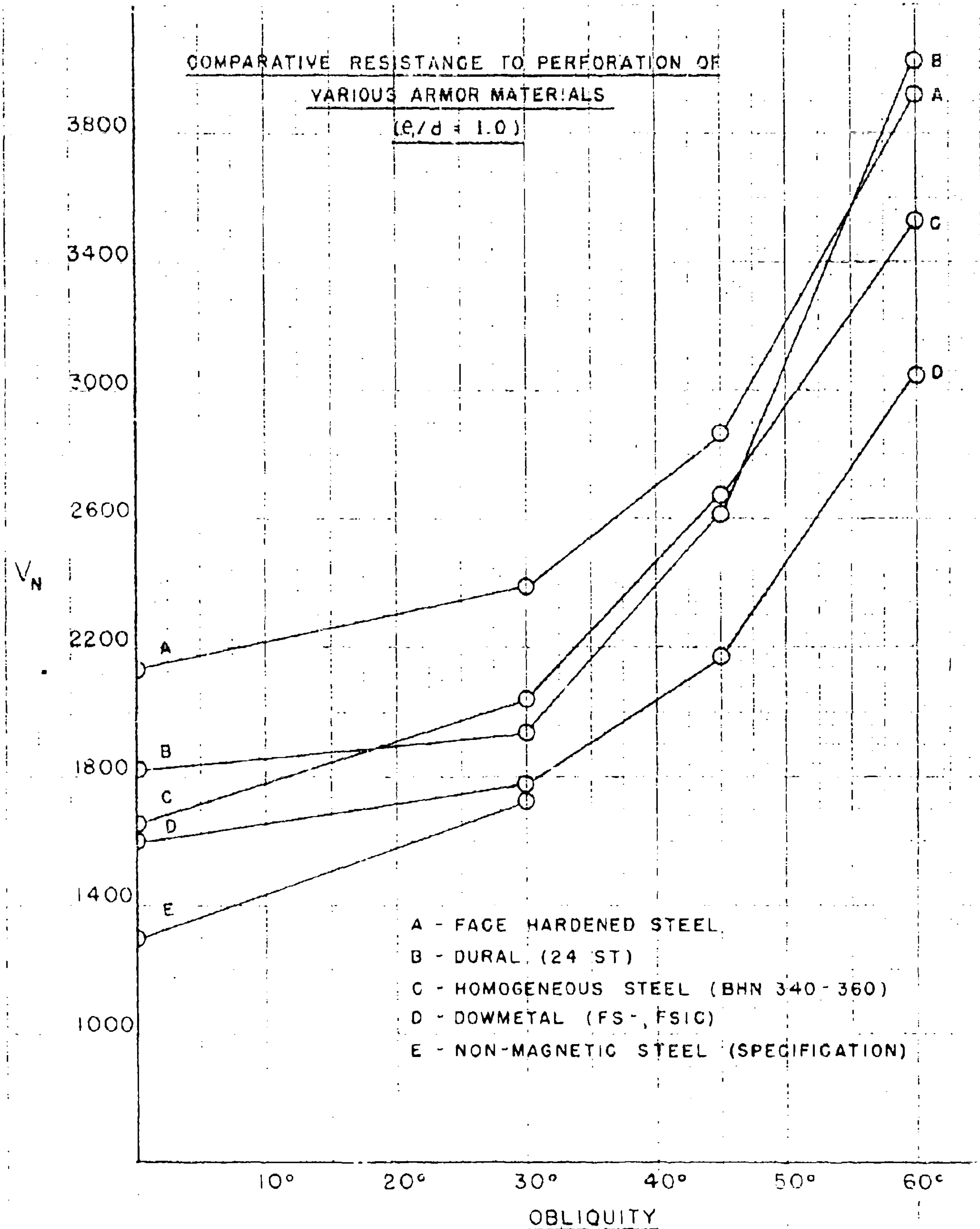
FIGURE 5



AGREEMENT OF DATA WITH EMPIRICAL FORMULA $V_N = \frac{1535(e/d)^{.5}}{\cos\theta}$

WA JFS 10/11/43

FIGURE 6



WA JFS 10/11/43

FIGURE 7

WATERTOWN ARSENAL

[illegible] ([illegible]) PLATE, [illegible] (FACE) [illegible]" X [illegible]" X [illegible]" AFTER IMPACT AT [illegible], [illegible] AND [illegible] WITH [illegible] AP [illegible], [illegible] AP [illegible] AND [illegible] AP [illegible] PROJECTILES. [illegible]

WATERTOWN ARSENAL

[illegible] ( ) PLATE, [illegible] (REAR) [illegible]" X 36" X 36" AFTER IMPACT AT [illegible], [illegible] [illegible] AP [illegible], AND [illegible] AP [illegible] PROJECTILES.

Best Available Copy

WATERTOWN ARSENAL

COMETAL (FS) PLATE, FS10569 (FACE) — 1.110" X 18" X30" AFTER IMPACT AT 0°, 30°, 45° AND 60° WITH CAL. .30 AP M2 AND CAL. .50 AP M2 PROJECTILES. WTN.710-2166

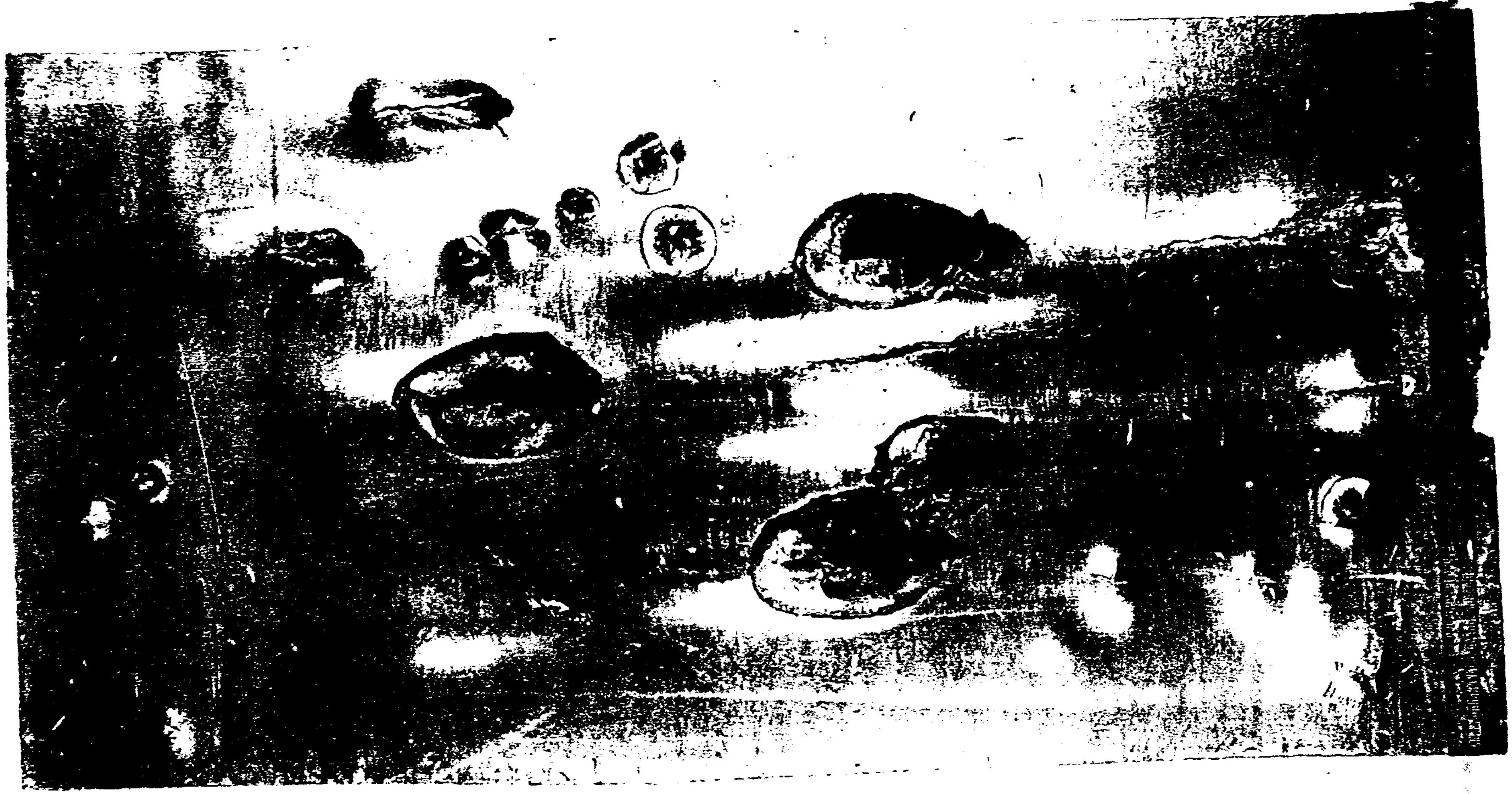
WATERTOWN ARSENAL

[illegible]METAL ([illegible]) PLATE, FS1C5[illegible] (REAR) – 1.110" x 18" x 30" AFTER IMPACT AT 0°, 30°,45° AND [illegible]
[illegible] CAL. .3[illegible] AP M[illegible] AND CAL. .50 AP M2 PROJECTILES.
WTN.710-[illegible]

WATERTOWN ARSENAL

DOWMETAL (FS) PLATE FS659-1 (FACE) 1.495" x 15" x 30" AFTER IMPACT AT 0°, 60° AND 75° WITH CAL. .30 AP M2, CAL. .50 AP M2 AND 20MM AP M75 PROJECTILES.

WTN.710-2165



WATERTOWN ARSENAL

DOLMETAL (FS) PLATE FS659-1 (REAR) 1.495" x 15" X 30" AFTER IMPACT AT 0°, 60° AND 75° WITH CAL. .30 AP M2, CAL. .50 AP M2 AND 20MM AP M75 PROJECTILES. WTN.710-2170

FIGURE

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APPENDIX A

DATA

Key to Abbreviations:

BC	Back crack
BS	Back spall
CIP	Core in plate
CL	Complete to light
CP	Complete penetration
FPTP	Failed to pass through plate
LB	Large bulge
MB	Medium bulge
PP	Partial penetration
PTP	Passed through plate
SB	Small bulge

BALLISTIC DATA SHEET NO. 1

Dow Chemical Company — Dowmetal Plate FS1C-645

.425" x 30" x 30"

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
Cal. .30 AP M2 Firings:			
45°	26	1397[a,n]	CP-PTP BS 5/8" x 5/8".
45°	27	1276	PP-SB
45°	28	1254	PP-SB
45°	29	1331[a,n]	PP-MB

[a]Army ballistic limit at 45° - 1364 f/s
[n]Navy ballistic limit at 45° - 1364 f/s

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
60°	13	2363	CP-PTP BS 1-1/4" x 7/8".
60°	14	2264	CP-PTP BS 1" x 13/16"; BC 1" x 1/16".
60°	15	2077	CP-PTP BS 1-1/8" x 3/4"; BC 1/2" x 1/32".
60	16	19[illegible][a,n]	PP BC 1-3/4" x 1/16".
60°	17	2025	CP-PTP BS 3/4" x 11/16"; BC 3/8" x 1/16".
60°	18	1945[a,n]	CP-PTP Exit hole 1/4" x 1/4"; BO 1" x 1/8".

[a]Army ballistic limit at 60° - 1933 f/s
[n]Navy ballistic limit at 60° - 1933 f/s

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
75°	7	3100	CP-PTP Exit hole 3-7/16"x7/8".
75°	8	2872	CP-PTP Exit hole 2½" x 1-1/8".
75°	9	2762[a,n]	PP-SB BC 2".
75°	10	2812[a,n]	CP-PTP Exit hole 2-1/4" x 7/8".

[a]Army ballistic limit at 75° - 2787 f/s
[n]Navy ballistic limit at 75° - 2787 f/s

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
Cal. .50 AP M2 Firings:			
60°	11	1344[a,n]	CP-CL
60°	12	1390[n]	CP-PTP Exit merged with Rd. 11 exit; BS 1-1/4" x 1"; BO 4-1/4" x 1/4".
60°	30	1285	PP-MB BC 5-3/4" x 1/16" joining crack from Rd. 23.
60°	31	1311	Passed thru Rd. 2 exit. Disregard.
60°	32	1306[a]	PP-MB BC 1¼" x 1/16" joining crack from Rd. 1.

[a]Army ballistic limit at 60° - 1325 f/s
[n]Navy ballistic limit at 60° - 1367 f/s

BALLISTIC DATA SHEET NO. 1 (Cont'd)

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
75°	1	17[illegible][a]	PP-SB BC 4-1/8" x 1/8" opening. Three minor cracks.
75°	2	1806[a]	CP-WPTP
75°	3	1850	CP-PTP Hit too near previous rd. Disregard.
75°	4	1875	CP-FPTP Back opening 4-3/4" x 3/8".
75°	5	1960[n]	CP-FPTP Back opening 4" x 1-3/4".
75°	6	2020[n]	CP-PTP Exit diameter 5½" x 2".

[a]Army ballistic limit at 75° - 1773 f/s
[n]Navy ballistic limit at 75° - 1990 f/s

20 MM AP M75 Firings:

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
75°	19	1160	Hit on rd. 8. Disregard.
75°	20	1156	Hit on rd. 5. Disregard.
75°	21	1224	CP BC 3-1/16" x 1/4".
75°	22	1299	Hit on rd. 6. Disregard.
75°	23	1275[a,n]	PP-MB
75°	24	1320[a,n]	CP-PTP Exit diameter 3-3/4" x 2-1/2".

[a]Army ballistic limit - 1298 f/s
[n]Navy ballistic limit - 1298 f/s

BALLISTIC DATA SHEET No. 2

Dow Chemical Company

Dowmetal Plate FS1C-574

.635" x 30" x 30"

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
Cal. .30 AP M2 Firings:			
30°	24	1326[a]	PP-MB BD Nose in plate.
30°	25	1420	CP-PTP BS 13/16" x 11/16".
30°	26	1341[a,n]	CP-CIP Nose protruding 1/8". BS 9/16" x 7/16".
30°	27	1345[n]	CP-PTP BS 11/16" x 11/16".
			[a]Army ballistic limit at 30° - 1334 f/s
			[n]Navy ballistic limit at 30° - 1343 f/s
45°	16	1466	PP-SB
45°	17	1559[a,n]	CP-PTP BS 5/8" x 5/8".
45°	18	1512[a,n]	PP-SB
			[a]Army ballistic limit at 30° - 1536 f/s
			[n]Navy ballistic limit at 30° - 1536 f/s
Cal. .50 AP M2 Firings:			
45°	19	1097	PP-SB
45°	20	1268	Hit Rd. 15. CP-PTP. Disregard.
45°	21	1298[a,n]	CP-PTP BS 1" x 1-1/4". Crack 1-5/8".
45°	22	1144	Hit edge of plate. Disregard.
45°	23	1170	PP-SB
45°	28	1212	PP-SB
45°	29	1254[a,n]	PP-MB
			[a]Army ballistic limit at 45° - 1276 f/s
			[n]Navy ballistic limit at 45° - 1276 f/s
75°	5	2199	Missed plate.
75°	6	2229	PP-MB. 3-7/8" back crack.
75°	7	2328[a]	PP-MB. 3-7/8" back crack.
75°	8	2358[a]	CP-CL. 5-7/16" back crack.
75°	-	2402	Missed plate.
75°	9	2407	Hit edge of plate.
75°	10	2380	PP-MB. 3-13/16" back crack.
75°	11	2427	PP-MB. 4-16" back crack. 1/4" opening.
75°	12	2481	Hit edge of plate.
75°	13	2500	PP-LB. 3-15/16" back crack; 3/16" opening.
75°	14	2564[n]	CP-PTP BS 4-11/16" x 1-11/16".
75°	15	2517[n]	PP-LB 4-3/8" crack running into Rd. 14.
			[a]Army ballistic limit at 75° - 2343 f/s
			[n]Navy ballistic limit at 75° - 2541 f/s

BALLISTIC DATA SHEET NO. 2 (CONT'D)

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
20 MM AP M75 Firings:			
75°	-	lost	Hit clamp.
75°	1	lost	CP Nose rejected, base PTP. 6-1/4" x 2-7/8" crack.
75°	2	1698	CP-PTP 3-5/8" x 1-7/8" exit hole.
75°	3	lost[a,n]	CP-PTP 4-1/16" x 1-7/8" exit hole.
75°	4	lost[a,n]	PP-MB 3½" crack; 1/8" opening on bulge.

[a]Army ballistic limit at 75° - 1385 f/s (Estimated from powder loads).
[n]Navy ballistic limit at 75° - 1385 f/s (Estimated from powder loads).

BALLISTIC DATA SHEET NO. 3

Dow Chemical Company

Dowmetal Plate FS-574-1

.675" x 30" x 30"

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
Cal. .30 AP M2 Firings:			
0°	32	1995	BS 11/16" x 3/8" (2 petals off) For information only.
30°	28	1373[a,n]	CP-PTP-BS 3/4" x 1/4". Crack 5/8" x 1/16".
30°	29	lost	PP-SB
30°	30	1350	Struck Rd. 28. CP-PTP. BS 3/4" x 5/8".
30°	31	1331[a,n]	PP-MB-CIP. Cracks 5/8" x 3/32", 5/8" x 1/16".
			[a]Army ballistic limit at 30° - 1352 f/s
			[n]Navy ballistic limit at 30° - 1352 f/s
45°	21	1454	Off the plate.
45°	21	1464	PP-SB
45°	22	1545	PP-SB
45°	23	1603	PP-SB
45°	24	lost	PP-SB
45°	25	1651[a,n]	PP-SB-CIP
45°	26	1737	CP-PTP BS 7/8" x 7/8".
45°	27	1698[a,n]	CP-PTP BS 7/8" x 1/2".
			[a]Army ballistic limit at 45° - 1675 f/s
			[n]Navy ballistic limit at 45° - 1675 f/s
60°	6	2650	CP-PTP BS 1-3/4" x 11/16".
60°	7	2445	CP-PTP BS 2-1/2" x 7/8".
60°	8	2363[a,n]	PP-SB
60°	9	2423[a,n]	CP-PTP BS 1-3/4" x 1/2".
			[a]Army ballistic limit at 60° - 2393 f/s
			[n]Navy ballistic limit at 60° - 2393 f/s
Cal. .50 AP M2 Firings:			
60°	10	lost	PP - 2¼" crack (no width)
60°	11	1822	CP-PTP BS 2" x 1-3/8".
60°	12	1711[a,n]	CP-PTP BS 2-1/2" x 1-3/8".
60°	13	1430	PP-SB
60°	14	1631	PP-SB
60°	15	1680[a,n]	PP-SB
			[a]Army ballistic limit at 60° - 1696 f/s
			[n]Navy ballistic limit at 60° - 1696 f/s

BALLISTIC DATA SHEET NO. 4

Dow Chemical Company — Dowmetal Plate FS1C569

.741" x 30" x 30"

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
Cal. .30 AP M2 Firings:			
0°	20	1331[a,n]	CP-PTP BS 3/8" x 1/4" Cracks 1/2" x 1/4", 1/2" x 1/8"
0°	21	1190	PP-CIP Crack 13/16" x 1/32"
0°	22	1240	PP-CIP Cracks 7/8" x 1/8", 1/2" x 1/8"
0°	23	1282[a,n]	PP-CIP Cracks 7/8" x 1/8", 3/8" x 1/16"
		[a]Army ballistic limit at 0° - 1307 f/s	
		[n]Navy ballistic limit at 0° - 1307 f/s	
30°	11	1196	PP-SB
30°	12	1323	PP-MB Crack 1/2"
30°	13	1430	CP-PTP BS 7/8" x 11/16"
30°	14	1402	CP-PTP BS 3/4" x 7/16"
30°	15	1177	PP-SB
30°	16	1252	PP-SB
30°	17	1400[a,n]	CP-PTP BS 9/16" x 3/8"
30°	18	1308	PP-SB
30°	19	1341[a,n]	PP-MB Cracks 3/4" x 1/8", 5/8" x 1/8"
		[a]Army ballistic limit at 30° - 1371 f/s	
		[n]Navy ballistic limit at 30° - 1371 f/s	
Cal. .50 AP M2 Firings:			
45°	9	1320[a,n]	PP-SB Crack 1-3/4"
45°	10	1348[a,n]	CP-PTP BS 1-1/4" x 15/16"
		[a]Army ballistic limit at 45° - 1334 f/s	
		[n]Navy ballistic limit at 45° - 1334 f/s	
60°	1	1600	PP-SB
60°	2	1870[a]	PP-MB Crack 3"
60°	3	1920[a,n]	CP Crack 3-1/2" x 1/4"
60°	4	1956[n]	CP-PTP BS 4-1/2" x 1-1/2"
		[a]Army ballistic limit at 60° - 1895 f/s	
		[n]Navy ballistic limit at 60° - 1938 f/s	
20 mm. M75 AP Firings:			
75°	5	1430	PP-LB Crack 5"
75°	6	1560	PP-LB Crack 6-1/2"
75°	7	1725[a,n]	PP-LB Crack 7-1/2"
75°	8	1770[a,n]	CP-PTP BS 8" x 1-5/8"
		[a]Army ballistic limit at 75° - 1748 f/s	
		[n]Navy ballistic limit at 75° - 1748 f/s	

BALLISTIC DATA SHEET NO. 5

Dow Chemical Company — Dowmetal Plate FS574-2

.766" x 30" x 30"

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
Cal. .30 AP M2 Firings:			
0°	25	1350[a,n]	CP-PTP BS 11/16" x 1/2"
0°	26	1140	PP-CIP
0°	27	1110	PP-MB
0°	28	Lost	PP-LB
0°	29	1300[a,n]	PP-LB CIP Star crack
			[a]Army ballistic limit at 0° - 1325 f/s
			[n]Navy ballistic limit at 0° - 1325 f/s
30°	18	1473	Backed by support - Disregard
30°	19	1464	Struck Rd. 17 - Disregard
30°	20	1473[a,n]	PP Crack 3/4" x 1/8"
30°	21	Lost	CP-PTP BS 3/4" x 1/2"
30°	22	1674	CP-PTP BS 3/4" x 11/16"
30°	23	1545	Struck Rd. 21 - Disregard
30°	24	1517[a,n]	CP-PTP BS 5/8" x 1/4"
			[a]Army ballistic limit at 30° - 1495 f/s
			[n]Navy ballistic limit at 30° - 1495 f/s
45°	10	1960	CP-PTP BS 3/4" x 5/8" Cracks 3/8", 1/4"
45°	11	1815	CP-PTP BS 3/4" x 5/8"
45°	12	1617	PP-SB
45°	13	1737[a,n]	CP-PTP BS 3/4" x 1/2" Crack 1/2"
45°	14	1670[a,n]	PP Crack 1-1/4" x 1/16"
			[a]Army ballistic limit at 45° - 1704 f/s
			[n]Navy ballistic limit at 45° - 1704 f/s
60°	5	2612[a,n]	PP-MB
60°	6	2872	CP-PTP BS 1-3/16" x 7/8"
60°	7	Lost	PP-SB
60°	8	2852	CP-PTP BS 1-1/2" x 5/8"
60°	9	2652[a,n]	CP-PTP BS 13/16" x 1/2"
			[a]Army ballistic limit at 60° - 2632 f/s
			[n]Navy ballistic limit at 60° - 2632 f/s

BALLISTIC DATA SHEET NO 5 (CONT'D)

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
Cal. .50 AP M2 Firings:			
30°	15	1073[a]	PP-MB
30°	16	1130[a,n]	CP-CIP protrudes 1/2" BS 1-3/16" x 3/4"
30°	17	1177[n]	CP-PTP BS 1-1/16" x 1-1/4"

[a]Army ballistic limit at 30° - 1102 f/s
[n]Navy ballistic limit at 30° - 1154 f/s

75°	1	2667[a,n]	CP-PTP BS 3-1/4" x 2-1/8"
75°	2	2542	Backed by support - Disregard
75°	3	2555	PP-MB Crack 3-1/2" x 1/8"
75°	4	2618[a,n]	PP-MB Crack 3-1/4" x 1/8"

[a]Army ballistic limit at 75° - 2643 f/s
[n]Navy ballistic limit at 75° - 2643 f/s

BALLISTIC DATA SHEET NO. 6

Dow Chemical Company — Dowmetal Plate FS16569-1

.998" x 18" x 36"

Cal. .30 AP M2 Firings:

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
0°	18	1450	PP-MB CIP Star crack 3/4", 1/2"
0°	19	1590	CP-PTP BS 11/16" x 3/4"
0°	20	1440	PP-CIP SB Hair crack 3/4"
0°	21	1560[a,n]	CP-PTP Exit 1/4" x 1/4" Star crack 7/8" x 13/16"
0°	22	1521[a,n]	PP-CIP LB Cracks 3/4" x 1/8", 1/2" x 1/8"
0°	23	2577	CP-PTP BS 1-1/16" x 1"

[a]Army ballistic limit at 0° - 1541 f/s
[n]Navy ballistic limit at 0° - 1541 f/s

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
30°	24	1680[n]	CP-PTP BS 5/8" x 3/4"
30°	25	1632[a,n]	CP-CIP BS 5/8" x 3/8", Nose protruding 1/8"
30°	26	1585[a]	PP-LB

[a]Army ballistic limit at 30° - 1609 f/s
[n]Navy ballistic limit at 30° - 1656 f/s

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
60°	1	3100est	PP-SB CIP FS 1-3/4" x 1-1/8"

Cal. .50 AP M2 Firings:

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
60°	2	1890	PP-SB
60°	3	2180	PP-SB
60°	4	2250	PP-MB Hair Line crack 2-1/2"
60°	5	2325	PP-SB Hair Line crack 3-1/4"
60°	6	2325	PP-Crack 3"
60°	7	2367	PP-Crack 4" x 1/8"
60°	8	2387	CP-PTP BS 3-3/4" x 2-14/16"

[a]Army ballistic limit at 60° - 2377 f/s
[n]Navy ballistic limit at 60° - 2377 f/s

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
30°	27	1165[a]	PP-SB
30°	28	1259[a,n]	CP-CIP Core intact. Back cracks 1-1/4" x 1/8", 1" x 1/8"
30°	29	1287[n]	CP-PTP BS 1-5/8" x 1-1/4"

[a]Army ballistic limit at 30° - 1212 f/s
[n]Navy ballistic limit at 30° - 1273 f/s

BALLISTIC DATA SHEET NO. 6 (CONT'D)

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
20 mm, AP M5 Firings:			
60°	13	1521	PP-LB
60°	14	1611	Hit Rd. 2 PP 5-1/4" crack - Disregard
60°	15	1707[n]	CP-FPTP
60°	16	1720	Hit Rd. 15 CP-PTP BS 3-3/4" x 2-3/8" (Rd.16) Crack from Rd. 10 - extended and connected to Rd. 16, Minor crack 1-7/8"
60°	17	1750[n]	CP-PTP BS 3-5/8" x 2" Minor crack 1-3/8"

[n]Navy ballistic limit at 60° - 1729 f/s

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
75°	9	1987	PP-LB Crack 5-3/16"
75°	10	2220	Off the plate
75°	10	2225	PP-LB Crack 7-9/16" x 1/16"
75°	11	2410[a,n]	CP-PTP Broke off upper right hand corner of plate (Rd. 11) 4-5/16" x 2-3/8" BS 3-15/16" x 2-1/2", connects by 2-1/4" crack with Rd. 9 Minor cracks 2", 5/8"
75°	12	2368[a,n]	PP-LB Crack 5-7/8" x 1/32"

[a]Army ballistic limit at 75° - 2389 f/s
[n]Navy ballistic limit at 75° - 2389 f/s

BALLISTIC DATA SHEET NO. 7

Dow Chemical Company — Dowmetal Plate FS617-1

1.118" x 18" x 30"

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
Cal. .30 AP M2 Firings:			
0°	21	1512	PP-LB Small star crack
0°	22	1580[a,n]	PP-LB Small star crack
0°	23	1536	PP-LB Small star crack
0°	24	1630[a,n]	CP-PTP BS 5/8" x 1/2"
			[a]Army ballistic limit at 0° - 1605 f/s
			[n]Navy ballistic limit at 0° - 1605 f/s
30°	16	1805[a,n]	CP-PTP BS 1/2" x 1/2"
30°	17	1637	Struck Rd. 14 - Disregard
30°	18	1660	PP-SB CIP
30°	19	1689	Struck Rd. 2 - Disregard
30°	20	1747[a,n]	PP- Cracks 1" x 1/8", 3/8" x 1/8", 1/4"x1/6"
			[a]Army ballistic limit at 30° - 1776 f/s
			[n]Navy ballistic limit at 30° - 1776 f/s
45°	9	2155	CP-PTP BS 3/4" x 5/8", Crack 1/2"
45°	10	2176[a,n]	CP-PTP 1/4" x 1/4" Crack 3/4" x 3/16" Circular crack 3/4"
45°	11	2121[a,n]	PP-MB
			[a]Army ballistic limit at 45° - 2149 f/s
			[n]Navy ballistic limit at 45° - 2149 f/s
60°	1	2583	PP-SB
60°	2	2792	PP-SB
60°	3	3059	CP-PTP BS 7/8" x 1/2"
60°	4	2942[a,n]	CP-PTP BS 3/4" x 1/2"
60°	5	2884[a,n]	PP-MB CIP
			[a]Army ballistic limit at 60° - 2913 f/s
			[n]Navy ballistic limit at 60° - 2913 f/s
Cal. .50 AP M2 Firings:			
0°	25	1323	CP-PTP BS 1-1/4" x 1-5/16"
0°	26	1165	CP-CIP Nose protrudes 1/4" BS 1-1/8" x 3/4"
0°	27	1060	Hit edge of plate - Disregard
0°	28	1095[a]	PP-MB
0°	29	1140[a]	CP-CIP Star crack 1-3/8" x 7/8" x 3/16"
0°	30	1193	CP-CIP Nose protrudes 3/8"

BALLISTIC DATA SHEET NO. 7 (CONT'D)

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
Cal. .50 AP M2 Firings:			
0°	31	1229	Too close to Rd. 30 - Disregard
0°	32	1202[n]	CP-CIP Core protrudes 3/4" BS 1-1/4" x 3/4"
0°	33	1258[n]	CP-PTP BS 1-1/4" x 3/4"
		[a]Army ballistic limit at 0° - 1118 f/s	
		[n]Navy ballistic limit at 0° - 1230 f/s	
30°	12	1278	PP-MB CIP Crack 1-1/8" x 1/8"
30°	13	1344[a,n]	PP-MB Crack 3/8"
30°	14	1411	CP-PTP BS 1-3/16" x 9/16"
30°	15	1397[a,n]	CP-PTP BS 1-3/16" x 1-1/4" Crack 1"
		[a]Army ballistic limit at 30° - 1371 f/s	
		[n]Navy ballistic limit at 30° - 1371 f/s	
45°	6	1729[a,n]	PP-SB
45°	7	1758[a,n]	CP-PTP BS 1-3/4" x 1-3/4"
45°	8	1794	CP-PTP BS 1-7/16" x 1-1/4"
		[a]Army ballistic limit at 45° - 1744 f/s	
		[n]Navy ballistic limit at 45° - 1744 f/s	

BALLISTIC DATA SHEET NO. 8

Dow Chemical Company — Dowmetal Plate FS617-1

1.118" x 18" x 30"

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
Cal. .30 AP M2 Firings:			
45°	19	2392	CP-PTP BS 3/4" x 1/2"
45°	20	2407	CP-PTP BS 3/4" x 3/8" Crack 7/8"
45°	21	2299	CP-PTP BS 5/8" x 3/4" Crack 3/4"
45°	22	Lost	Hit Rd. 21 - Disregard
45°	23	2244	CP-PTP BS 3/4" x 5/8"
45°	24	2146	PP-MB
45°	25	2225	CP-FPTP Crack 1-1/4"
45°	28	2135[a,n]	CP-PTP BS 1-1/16" x 7/8"
45°	29	2156	CP-PTP BS 3/4" x 13/16"
45°	30	2080[a,n]	PP-CIP Crack 1"

[a]Army ballistic limit at 45° - 2108 f/s
[n]Navy ballistic limit at 45° - 2108 f/s

Cal. .50 AP M2 Firings:

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
30°	26	1363[a,n]	CP-CIP protrudes 1/2" Cracks 1" x 3/8", 1-1/2" x 3/8"
30°	27	1421[a,n]	CP-PTP BS 1-3/8" x 1-3/8"

[a]Army ballistic limit at 30° -
[n]Navy ballistic limit at 30° - 1392 f/s

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
60°	13	2338	CP-PTP BS 2-3/4" x 1-1/16"
60°	14	2358	Hit top of plate - Disregard
60°	15	2249	Hit Rd. 10 - Disregard
60°	16	2199[a,n]	CP-PTP BS 1-3/8" x 1-1/8" Cracks 1-7/8" x 1/4" 1-3/8" x 1/8"
60°	17	2110	Backed by support - Disregard
60°	18	2022	PP-SB
60°	31	2022	PP-SB
60°	32	2179	Struck Rd. 10-15 - Disregard
60°	33	2155[a,n]	PP-MB

[a]Army ballistic limit at 60° - 2177 f/s
[n]Navy ballistic limit at 60° - 2177 f/s

20 mm, M75 AP Firings:

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
60°	10	1780	CP-PTP BS 3-1/2" x 2-1/16"
60°	11	1687[a,n]	PP-MB
60°	12	1745[a,n]	CP-PTP BS 4-9/16" x 2-1/8"

[a]Army ballistic limit at 60° - 1716 f/s
[n]Navy ballistic limit at 60° - 1716 f/s

BALLISTIC DATA SHEET NO. 8 (CONT'D)

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
20 mm. M75 AP Firings:			
75°	1	Lost	Hit top of plate
75°	2	Lost	PP-MB
75°	3	2395	PP-LB
75°	4	2476	Hit clamp
75°	5	2490	CP
75°	6	2540	PP-LB
75°	7	2590	Struck Rd. 2
75°	8	2600	PP-LB
75°	9	2690	Hit Rds. 2, 7

Due to destruction of plate by the projectile at this obliquity, firing was discontinued. No limits were obtained.

BALLISTIC DATA SHEET NO. 9

Dow Chemical Company — Dowmetal Plate FS617-2

1.118" x 1-1/8" x 18" x 30"

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
Cal. .30 AP M2 Firings:			
0°	14	1574[a,n]	CP-CIP Nose protruding 3/8" Star crack 3/4" x 7/8" x 1/4"
0°	15	1570[a]	PP-SB-CIP Star crack 3/4"x11/16"x1/8"
0°	16	1560	CP-MB-CIP Core protruding 1/8" Star Cracks 3/4" x 5/8" x 3/16"
0°	17	1750	CP-PTP-BS 7/8"x7/8"
0°	18	1622[n]	CP-PTP Jacket in plate, BS 1/2"x3/8", Crack 1/2"x1/8"
			[a]Army ballistic limit at 0° - 1572 f/s
			[n]Navy ballistic limit at 0° - 1598 f/s
30°	9	1824[a,n]	PP- Crack in back 1"x1/16"
30°	10	1990	CP-PTP Crack 3/4"x1/8" BS 3/4"x1/2"
30°	11	1839[a,n]	CP-PTP-BS 1/2"x1/2"
			[a]Army ballistic limit at 30° - 1832 f/s
			[n]Navy ballistic limit at 30° - 1832 f/s
Cal. .50 AP M2 Firings:			
0°	12	1240[n]	CP-PTP-BS 1-5/16"x7/8", Crack 1-1/8"x1/4"
0°	13	1195[n]	CP-CIP-BS 1-1/16"x7/8", cracks 1/2"x1/4", Nose protrudes 7/8"
0°	23	1107[a]	PP-LB-CIP-F Crack - Star 1-3/8"x5/8"x1/8"
0°	24	1142[a]	CP-CIP Nose protrudes 1/8", Star crack 1-3/8"x1"x1/8"
			[a]Army ballistic limit at 0° - 1125 f/s
			[n]Navy ballistic limit at 0° - 1218 f/s
30°	19	1382[n]	CP-PTP-BS 1-3/8"x7/8"
30°	20	1344[n]	CP-CIP Core intact, B cracks 1-1/4"x1/8", 1-3/8"x1/8"
30°	21	1306[a]	CP-PTP-BS 1-1/4"x7/8" crack 5/8"x1/8"
30°	22	1249[a]	PP-CIP-B Crack 1-3/8"
			[a]Army ballistic limit at 30° - 1278 f/s
			[n]Navy ballistic limit at 30° - 1363 f/s

BALLISTIC DATA SHEET NO. 9 (CONT'D)

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
45°	5	1729[a,n]	CP-BS 11/16"x5/8"
45°	6	1681	PP-MB
45°	7	1719[a]	PP-LB Core intact
45°	8	1797[n]	CP-PTP 1-5/8"x1-7/16"

[a]Army ballistic limit at 45° - 1724 f/s
[n]Navy ballistic limit at 45° - 1763 f/s

20 MM AP M75 Firings:

45°	1	1073[a]	PP-MB
45°	2	LOST	Struck edge of plate - Disregard
45°	3	11[illegible]6	PTP-BS 2-1/4"x2-1/8"
45°	4	1127[a]	PTP-BS 2-1/2"x2"

[a]Army ballistic limit at 45° - 1100 f/s
[n]Navy ballistic limit at 45° - 1100 f/s

BALLISTIC DATA SHEET NO. 10

Dow Chemical Company — Dowmetal Plate FS1C-617

1.305" x 17" x 30"

Plate Obliquity	Plate Hd. No.	Striking Velocity	Results
Cal. .30 AP M2 Firings:			
0°	13	1861	CP-PTP Jacket in plate BS 11/16"x1/2" Crack 11/16"x1/2"
0°	14	1613	PP-SB-CIP
0°	15	1786[a,n]	CP-CIP Nose protruding 3/16" Star Crack 13/16"x13/16"x1/8"
0°	16	1801[n]	CP-PTP Jacket in plate BS 3/4"x5/8"
0°	17	1645	PP-SB
0°	18	LOST	PP-LB-CIP Back crack (star)
0°	19	LOST	PP-LB-CIP BC (Horizontal 3/4")
0°	20	1665	PP-LB-CIP BC (Horizontal 1-1/2")
0°	21	1710	Struck Round #20 Disregard
0°	22	1730[a]	PP-LB BC (star)

[a]Army ballistic limit at 0° - 1758 f/s
[n]Navy ballistic limit at 0° - 1794 f/s

Plate Obliquity	Plate Hd. No.	Striking Velocity	Results
30°	23	2028[a,n]	CP-PTP BS
30°	24	1800	PP-SB
30°	25	1950[a,n]	PP-LB BC 7/8"

[a]Army ballistic limit at 30° - 1989 f/s
[n]Navy ballistic limit at 30° - 1989 f/s

Cal. .50 AP M2 Firings:

Plate Obliquity	Plate Hd. No.	Striking Velocity	Results
0°	11	1330[n]	CP-PTP-BS 1"x3/4", cracks 5/8", 1/2", 1/2"
0°	12	1283[n]	CP-CIP Nose protruding 1/4" BS 1-3/8"x11/16" Cracks 3/4", 3/8"
0°	33	1240[a]	CP-LB-BC (star 1-1/4"x1"x1/16")
0°	34	1221[a]	PP-MB Hair crack 1/2"

[a]Army ballistic limit at 0° - 1231 f/s
[n]Navy ballistic limit at 0° - 1307 f/s

BALLISTIC DATA SHEET NO. 10 (CONT'D)

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
Cal. .50 AP M2 Firings:			
45°	5	1739	PP-SB
45°	6	LOST	Struck Rd. #5. SB
45°	7	1836	PP-MB
45°	8	2022	Struck Rd. #7. CP-PTP-BS 1-5/8"x1/2". Disregard
45°	9	1973[n]	CP-PTP BS 1"x2" crack 1-1/16"
45°	10	1924[a,n]	CP-CIP BS 1-1/4"x1-1/16" crack 13/16"

[n]Navy ballistic limit at 45° - 1949 f/s

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
45°	26	1865	Too close to Rd. #1. Disregard
45°	27	1895[a]	PP-SB

[a]Army ballistic limit at 45° - 1910 f/s

20 MM AP M75 Firings:

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
60°	1	2250	CP-PTP BS 4"x1-3/16". Minor crack 1"
60°	2	2104	CP-PTP BS 3"x2-1/8". Minor crack 2-1/4"
60°	3	1962[a,n]	PP BC 7"x3/16"
60°	4	2026[a,n]	CP-PTP BS 5-3/8"x2-3/8"

[a]Army ballistic limit at 60° - 1994 f/s
[n]Navy ballistic limit at 60° - 1994 f/s

BALLISTIC DATA SHEET NO. 11

Dow Chemical Company — Dowmetal Plate FS1C-617

1.313" x 18" x 30"

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
Cal. .30 AP M2 Firings:			
0°	26	LOST	PP No B
0°	27	1790[a,n]	PP-SB Face cracks running to Rd.#12
0°	28	1844	Hit edge of plate.
0°	29	1820	Backed by support.
0°	30	1820	CP-PTP Jacket in plate petaling BS 2/8"x1/4"
0°	31	LOST	CP-PTP Jacket in plate petaling BS 1/2"x1/4"
0°	32	1795[a,n]	CP-PTP Jacket in plate petaling BS 3/4"x1/2"

[a] Army ballistic limit at 0° - 1793 f/s
[n] Navy ballistic limit at 0° - 1793 f/s

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
30°	23	1940[a]	PP-SB-CIP Hair crack 1/2"
30°	24	2087[n]	CP-PTP-BS 11/16"x5/8". Crack 3/8"x5/8"
30°	25	2080[n]	CP-CIP Crack 3/4"x1/8"
30°	33	1985	CP-PTP Thru back exit of Rd. #12. Disregard
30°	34	1965[a]	CP BC 7/8"x1/8"

[a] Army ballistic limit at 30° - 1953 f/s
[n] Navy ballistic limit at 30° - 2084 f/s

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
Cal. .30 AP M2 Firings:			
45°	14	2380	PP-MB-CIP Core intact
45°	15	2522[a]	CP Crack 3/4"x1/2"; CIP Core intact
45°	16	2547	PP-SB-CIP intact
45°	17	2642[n]	CP-PTP-BS 3/4"x3/4"
45°	18	2515[a]	PP SB
45°	19	2585[n]	CP Nose protruding 1/2"; BS 3/4"x3/4" Core intact

[a] Army ballistic limit at 45° - 2519 f/s
[n] Navy ballistic limit at 45° - 2614 f/s

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
Cal. .50 AP M2 Firings:			
0°	35	1344[a,n]	CP-PTP BS 1-1/16"x15/16"
0°	36	1278	Hit Rd. #20
0°	37	1292	Hit Rd. #36
0°	38	1278[a,n]	PP-MB-CIP Core intact BC 1-5/8"x1/16"

[a] Army ballistic limit at 0° 1311 f/s
[n] Navy ballistic limit at 0° 1311 f/s

BALLISTIC DATA SHEET NO. 11 (CONT'D)

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
Cal. .50 AP M2 Firings:			
30°	20	1416[a,n]	CP-PTP 1-1/4"x1-3/8"
30°	21	1344	PP-CIP Crack 1-1/4"
30°	22	1373[a,n]	PP-SB-CIP
			[a]Army ballistic limit at 30° - 1395
			[n]Navy ballistic limit at 30° - 1395
60°	10	2338	PP-SB
60°	11	2574	PP-SB
60°	12	2731[a,n]	CP-PTP-BS BS 1-1/8"x1" crack 2-1/2"x1/4", 9/16"
60°	13	2673[a,n]	PP-MB
			[a]Army ballistic limit at 60° - 2702
			[n]Navy ballistic limit at 60° - 2702
20 MM AP M75 Firings:			
45°	3	1107	PP-SB
45°	4	1313	Struck edge of plate.
45°	5	1306	Struck clamp - CP-PTP
45°	6	1224[a,n]	PP-MB
45°	7	1236	Struck previous Rd.
45°	8	LOST	PP-MB Partly backed by support
45°	9	1276[a,n]	CP-PTP
			[a]Army ballistic limit at 45° - 1250 f/s
			[n]Navy ballistic limit at 45° - 1250 f/s
75°	1	2690	Hit edge of plate.
75°	2	2690	PP-MB- Crack 5"x1/16"

Plate tested at this obliquity discontinued as the maximum load resulted in PP.

BALLISTIC DATA SHEET NO. 12

Dow Chemical Company — Dowmetal Plate FS659-1

1.495" x 15" x 30"

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
Cal. .30 AP M2 Firings:			
0°	21	1560	PP-SB
0°	22	1766	PP-SB Cracking in back 5/8"
0°	23	1960	Hit Rd. #15. CP-PTP-BS 3/4"x5/8". Disregard
0°	24	1930	CP-PTP BS 11/16"x7/8" cracks 3/8", 1/4"
0°	25	1824	PP-MB Cracks 3/4"x1/16", 1/2"x1/16"
0°	26	1921[a,n]	CP-PTP Exit 1/4"x1/4"; star crack 7/8"x5/8"
0°	27	1868[a,n]	PP-CIP-MB Cracks 3/4"x1/16", 1/2"x1/16"

[a]Army ballistic limit at 0° - 1895 f/s
[n]Navy ballistic limit at 0° - 1895 f/s

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
Cal. .50 AP M2 Firings:			
0°	28	1278	Struck too close to Rd. #15. PP. Disregard.
0°	29	1368	Struck too close to Rd. #28. CP-PTP-BS 1-1/8"x1"
0°	30	1392	Struck 20 MM Rd. CP-PTP. Disregard.
0°	31	1373[a]	CP-CIP Nose protruding 1/8" BC 1-3/8"x1/8", 1/4"x1/16"
0°	17	LOST	PP-CIP Cracks 1-3/8", 15/16"
0°	18	1306[a]	PP-MB Core & Jacket in plate cracks 1-1/4", 3/4"
0°	19	1411[n]	CP Nose protruding 1/4" Star cracks 1-1/8"x3/4"
0°	20	1454[n]	CP-PTP BS 1-1/4"x13/16"

[a]Army ballistic limit at 0°-1340 f/s
[n]Navy ballistic limit at 0°-1433 f/s

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
60°	12	2933	PP
60°	13	2909	CP-PTP 3-11/16"x7/8"
60°	14	2839[a,n]	CP-PTP 3-5/16"x5/8"
60°	15	2780	PP
60°	16	2780[a,n]	PP

[a]Army ballistic limit at 60° - 2810 f/s
[n]Navy ballistic limit at 60° - 2810 f/s

BALLISTIC DATA SHEET NO. 12 (CONT'D)

20 MM AP M75 Firings:

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
60°	3	2311	CP-PTP 4-5/8"x2-3/8" - Exit 4-5/8"x2-3/8"
60°	4	LOST	Hit too near Rd. #3. Crack 7-1/4"x1/4"; Exit 4-5/8"x2-3/8"
60°	5	1910[a,n]	PP-SB
60°	6	LOST	PP-SB
60°	7	2115	CP-PTP 4-1/4"x2-1/2" - BS
60°	8	LOST	CP-PTP 4-1/4"x2" - BS
60°	9	2015	CP-PTP Broke into exit of Rd. #8 (Rd. #9) Exit resulting from Rds. #8, #9 - 6-1/8"x2-5/8"
60°	10	1957	Edge of plate
60°	11	1962[a,n]	CP-PTP Near upper edge Rd. #11. Exit of Rd. #11 was thru upper edge of plate. Crack in back 2-2/3"x1/4".

[a]Army ballistic limit at 60° - 1936 f/s
[n]Navy ballistic limit at 60° - 1936 f/s

20 MM AP M75 Firings:

75°		2299	Struck clamp
75°	1	2454	PP Exit 6-1/2"x2-1/8"
75°	2	2688	CP FPTP Supported in back; Exit 6-1/2"x2-1/8"

Firings suspended due to lack of space on plate.

BALLISTIC DATA SHEET NO. 13

Dow Chemical Company — Dowmetal Plate FS659-2

1.499" x15" x 30"

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
Cal. .30 AP M2 Firings:			
0°	26	LOST	PP-SB
0°	27	2028	CP-PTP Exit thru BS of Rd. #4. Disregard.
0°	28	2087	CP-PTP BS 1"x15/16"
0°	29	1960	PTP BS 1-1/16"x1"
0°	30	1790[a,n]	PP Star crack in back
0°	31	1810	PP Struck Rd. #3. Disregard.
0°	32	1760	PP Very small star crack in back
0°	33	1730	Struck Rd. #3. Disregard.
0°	34	1856	PP Partly backed by support. Disregard.
0°	35	1850[a,n]	CP-PTP 1/4"x1/4" Petaling.

[a]Army ballistic limit at 0° - 1820 f/s
[n]Navy ballistic limit at 0° - 1820 f/s

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
30°	18	1950	PP-MB
30°	19	2028[a]	PP-SB
30°	20	1990	PP
30°	21	2092[a,n]	CP Nose protruding 1/16" crack 3/4"x1/8" Crack 5/8"
30°	22	2244	CP-PTP BS 11/16"x7/16"
30°	23	2240	CP-PTP BS 3/16"x1/4" Crack 5/8"x1/8".
30°	24	2195	CP-PTP BS 1/2"x1/2". Crack 3/8"x1/8".
30°	25	2156[n]	CP-PTP BS 1/2"x3/8". Crack 1/2"x1/16"

[a]Army ballistic limit at 30° - 2060 f/s
[n]Navy ballistic limit at 30° - 2124 f/s

Cal. .30 AP M2 Firings:

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
45°	10	2462[a,n]	PP-MB Crack 1"
45°	11	2562	PP Backed by support.
45°	12	2542	CP-PTP BS 1/2"x5/8"
45°	13	2492[a,n]	CP-PTP BS 3/4"x3/4"

[a]Army ballistic limit at 45° - 2477 f/s
[n]Navy ballistic limit at 45° - 2477 f/s

BALLISTIC DATA SHEET NO. 13 (CONT'D)

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
Cal. .50 AP M2 Firings:			
0°	36	1459	CP-PTP Hit Rd. #15.
0°	37	1436[n]	CP-PTP BS 1/2"x3/8". Crack 1-3/8"x1/4".
0°	38	1392[a,n]	CP-FPTP-CIP Core Intact; Protruding 7/8".
0°	39	1354[a]	PP Face punching 1-1/2"x15/16".

[a]Army ballistic limit at 0° - 1373 f/s
[n]Navy ballistic limit at 0° - 1415 f/s

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
30°	14	1335	PP-SB
30°	15	1617	CP-FTP BS 1-3/16"x1-1/8".
30°	16	1486[a,n]	PP-MB Crack 1". CIP.
30°	17	1556[a,n]	CP-PTP BS 1-1/4"x1-3/16".

[a]Army ballistic limit at 30° - 1511 f/s
[n]Navy ballistic limit at 30° - 1511 f/s

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
45°	5	1539	Struck Rd. #1 - PP.
45°	6	1606	PP-MB
45°	7	1748	PP-SB
45°	8	1934[a,n]	CP-PTP BS 3/4"x3/4" Rd. #8. Crack along bulge 1-3/4"x1/4". Circular crack 1-3/4"
45°	9	1871[a,n]	PP-SB

[a]Army ballistic limit at 45° - 1903 f/s
[n]Navy ballistic limit at 45° - 1903 f/s

Plate Obliquity	Plate Rd. No.	Striking Velocity	Results
20 MM AP M75 Firings:			
45°	1	1426[n]	CP-PTP BS 2-3/16"x2-1/8"
45°	2	1283[a]	PP-MB Crack 2".
45°	3	1420	Too close to Rd. #2 CP-PTP-BS Rd. #3. Combined exits of Rds. #1 & #3 - 4-1/4"x2-1/4"
45°	4	1369[a,n]	CP-FPTP Base of CIP - BS 2-5/8"x2-1/4"

[a]Army ballistic limit at 45° - 1397 f/s
[n]Navy ballistic limit at 45° - 1326 f/s

APPENDIX B

COPY

THE DOW CHEMICAL COMPANY
MIDLAND, MICHIGAN

October 22, 1943

Commanding Officer
U. S. War Department
Watertown Arsenal
Watertown, Massachusetts

Attention: Lt. Col. G. L. Cox
Laboratory (NAM)

Dear Sir:

This reply to your letters of September 14 and October 11 has been delayed because of my absence from the city. I wish to thank you for the ballistic data contained in these letters. We have now received these plates and will examine them for the type of failure. So far, we have not completed our comparison of the results of these tests with the previous work on J-1 alloy so that I will not attempt to state our opinion on that matter at this time.

As you will recall, we previously obtained some improvement in the type of fracture on J-1h with the one particular batch which had been processed differently from our regular commercial procedure. At present, in order to produce sheet and plate which is commercially flat (we endeavor to hold to 0.0001" deviation per ft.), the material is cold rolled harder than necessary to meet specifications, and then flattened under weights in a furnace at somewhat elevated temperatures. This produces exceptionally flat sheet by virtue of the creep which takes place, and leaves the material hard enough to pass specifications on hard rolled sheet. At the same time, in our aluminum containing alloys, it generally causes a certain amount of precipitate of Mg-Al compound from the supersaturated solid solution. The J-1h alloy sheet which previously showed the improvement above mentioned, was not flattened in this manner, but instead flattened cold on a press of large capacity. Its mechanical properties were not substantially superior to the other sheets, which had been furnace flattened, so we attributed the difference in behavior to the lack of precipitate.

Because of this experience, we decided to try to send you FS-1 alloy in the cold press-flattened condition wherever possible. You will recall that this sheet alloy is now being seriously considered for some applications where J-1h had been used in the past.

U. S. War Department
Watertown Arsenal -2- October 22, 1943

The designation FS-1 refers to furnace flattened material whereas FS-1C refers to cold press flattened material. In the case of batch FS-1C-569 of 1.11" thickness, the designation is in error. The material actually was furnace flattened and should have been labelled FS-1. In some cases, the designation FS has been used. This is equivalent to FS-1. The only difference between FS and FS-1 alloys is the impurity content, which affects the corrosion behavior. Actually, we make only FS-1, and sometimes carelessly refer to it as FS alloy. No such material is now being produced.

As you will see from the tensile properties of the material listed below, the furnace flattened material in the heavier gauges is quite soft and would not, in fact, pass the specifications for hard rolled material. This situation exists because of the high temperatures which had to be used to furnace flatten these materials, and because we had no press large enough to flatten them cold.

ARMOR PLATE

Batch	Gauge	Flattening	Direction	U.S.	Y. S.	%E
645	1/2"	Pressed	L	41.9	37.0	12.8
			T	42.2	33.2	14.3
574	.635"	Pressed	L	41.0	37.5	7.0
			T	40.5	32.3	8.7
574	.675"	Annealed	L	36.7	23.1	13.6
			T	35.2	23.6	14.1
569	3/4"	Pressed	L	38.4	29.6	7.2
			T	38.8	31.4	10.3
574	3/4"	Annealed	L	35.1	21.0	13.1
			T	34.8	21.7	14.6
569	1"	Pressed	L	42.0	36.8	6.5
			T	41.8	35.5	10.0
569	1-1/8"	Annealed	L	36.8	28.8	13.8
			T	36.3	24.9	12.2
617	1-1/8"	Annealed	L	36.2	23.7	14.5
			T	35.9	20.3	13.8
617	1.3"	Annealed	L	36.4	21.8	13.6
			T	35.7	21.2	15.0
659	1-1/2"	Annealed	L	31.1	25.6	14.2
			T	36.2	19.3	14.2

J. C. McDonald
Metallurgical Department

[illegible]