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WATERTOWN ARSENAL LABORATORY

MEMORANDUM REPORT

NO. WAL 710/641

Resistance of Various Samples of Plastic Materials to Perforation by Fragment-Simulating Projectiles

BY

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DATE 25 May 1944

WATERTOWN ARSENAL
WATERTOWN, MASS.

WATERTOWN ARSENAL LABORATORY

Memorandum Report No. WAL 710/641

Eleventh Partial Report on Problem B-8.2

25 May 1944

Resistance of Various Samples of Plastic Materials

to Perforation by Fragment-Simulating Projectiles

1. As a phase of the program of development of improved body armor components, ~~requested by the Office, Chief of Ordnance~~[1], ballistic tests were ~~have been~~ conducted on several samples of plastic materials (presumably glass laminate) furnished by the Quartermaster Corp. → (to p5)

2. The resistance of these materials to perforation by caliber .45 (steel-jacketed) ball projectiles is the highest of all materials tested in this weight range (equivalent to .040" to .050" of steel) at this arsenal. Their resistance to perforation by the caliber .30 fragment-simulating projectile, G-1-S[2], is roughly equivalent to that of Hadfield manganese steel, which is the best metal tested here. Their resistance to perforation by the caliber .22 fragment-simulator, G-2[3], is however, considerably inferior to that of Hadfield manganese steel. Low temperature (-60°F) did not deleteriously affect the resistance of these materials to perforation by the caliber .45 projectile. However, prolonged (17 hours) immersion in water of a sample selected at random lowered its resistance slightly.

3. Samples of each material were rigidly mounted on wooden ballistic frames allowing an area 8"x8" to remain unsupported from the rear. Into the face of these areas there were then directed impacts of caliber .45 (steel-jacketed) projectiles and of the various fragment-simulating projectiles developed here. Ballistic limits were

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1. O.O. 422.3/71(c) - Wtn 470.5/7443(c) dated 28 September 1943.

2. WAL Memorandum Report No. 762/247(c) "Development of Projectiles to Be Used in Testing Body Armor to Simulate Flak and 20 mm. H.E. Fragment" - 17 December 1943.

3. WAL Memorandum Report No. 762/253(c) "Development of a Projectile, to Be Used in Testing Body Armor, to Simulate Fragments of a 20 mm. H.E. Projectile" - 7 January 1944.

determined by averaging the striking velocity at which a material resisted perforation and that at which it was perforated, provided these values were within 50 feet-per-second of each other and further provided that the perforation velocity exceeded the velocity of resistance to perforation.

4. Low temperature characteristics of these materials were determined by subjecting them to attack with caliber .45 (steel-jacketed) projectiles while they were at a temperature of -60°F. Samples were placed in a sheet-metal pocket which was almost totally immersed in a mixture of dry ice and acetone. Thermocouples were inserted into the body of the material and the temperature read at the report of the shot. These temperatures averaged -60°F ±3°F.

5. A sample (R-4042) was selected at random and immersed in a pail of water for 17 hours. It was then mounted on a wooden ballistic frame and tested with caliber .45 (steel-jacketed) projectiles.

6. The results of all ballistic tests appear in Table I. In Figure 1 there has been plotted the individual results of tests at room temperature with the caliber .45 projectile and with fragment-simulators F-1-S and G-2. The average resistance of Hadfield manganese steel currently procurable under Specification AXS-1170 has been estimated and appears as a solid line.

7. Under impact of caliber .45 (steel-jacketed) projectiles there appears to be a slight increase in resistance to perforation with increasing equivalence in weight which roughly parallels that of the Hadfield manganese steel and it considerably higher than it is in the range .040" to .047" of steel. Under impact of the caliber .30 fragment-simulating projectile G-1-S, there is still evident an increase in resistance with increasing weight, but the slope is much less steep than that of Hadfield steel and whereas at .040" of steel, the resistance of the plastic is equivalent to that of Hadfield, at higher thicknesses it is inferior. Under impact of the caliber .22 fragment-simulator G-2, moreover, there appears to be no improvement with weight and the resistance of all plastic materials tested is appreciably inferior to that of the Hadfield steel.

8. Thus there is a definite transition from superiority in resistance to a heavy blunt projectile through relative equivalence in resistance to a smaller, sharper projectile at the same velocity to decided inferiority in resistance to a still smaller chisel-nosed projectile at a considerably higher velocity.

9. The superior resistance to perforation by the caliber .45 projectile is doubtless attributable to the ability of these materials to distract much of the energy of the projectile into deforming itself and delaminating the plastic bonding. Its substantial equivalence under impact of projectile G-1-S is maintained because its greater thickness allows a more gradual absorption of energy during the cycle of perforation.

At higher velocities however, the shorter time of perforation cuts down the amount of deformation and energy absorption possible prior to perforation and the inherent resistance of the material itself begins to assume a greater importance. Thus as velocity increases the steel assumes superiority.

10. While the inferiority of this material under impact of the fragment-simulator, Q-2, discourages its recommendation as a body armor component, its superiority under impact of the caliber .45 projectile does encourage its recommendation as a protector against blunt projectiles, and if protection is sought against such projectiles ~~much promise is seen in the use of these materials.~~

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Table I

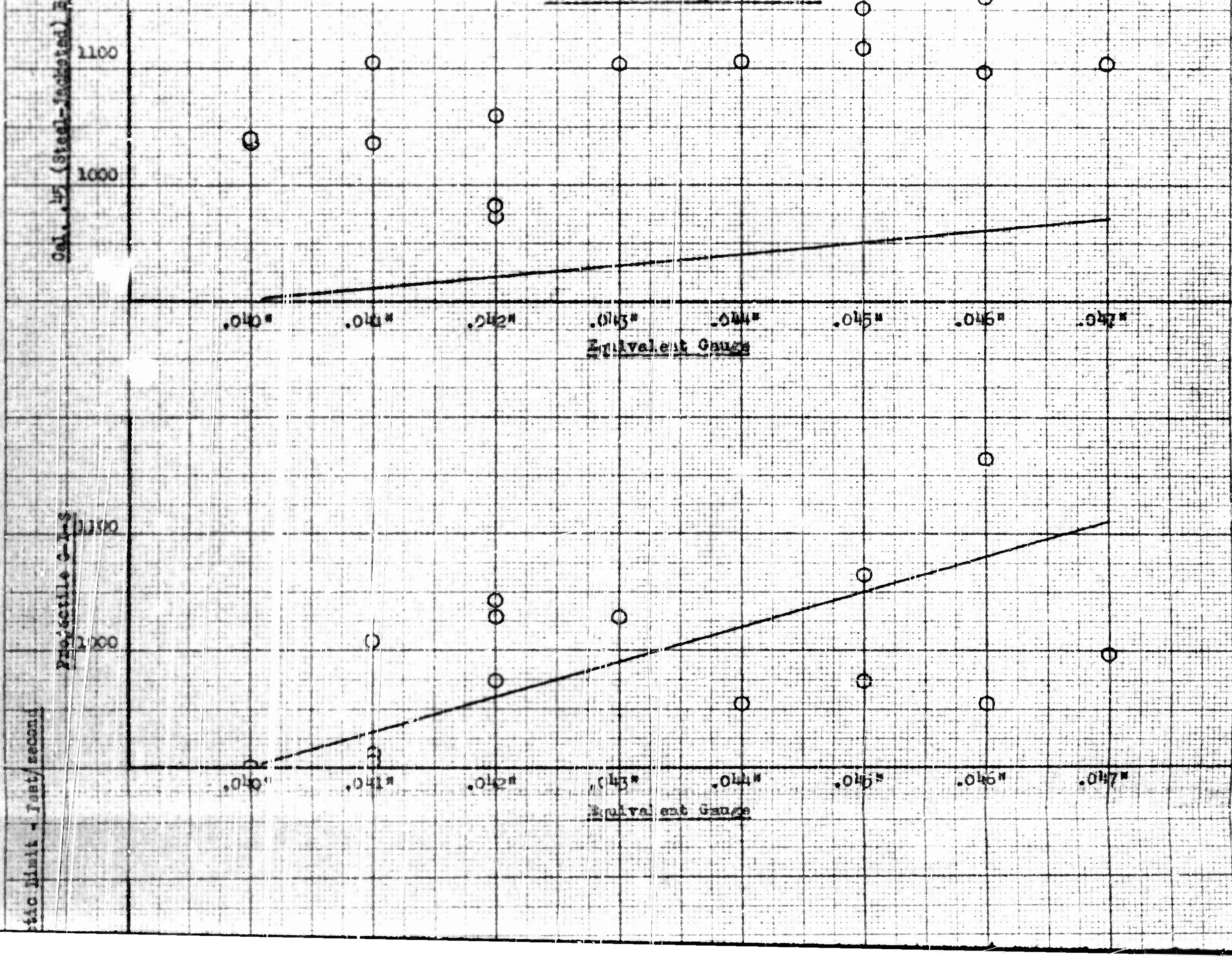
Summary of Ballistic Tests Conducted at Watertown Arsenal

on Various Plastic Materials Submitted by Quartermaster Corp

Quartermaster Identification	Equivalent Steel Gauge	Ballistic Limits (F/S) Caliber .45[1] Room Temp.	Caliber .45[1] -60°F	Caliber .45[1] After Immersion	Room Temperature G-1-A[2]	Room Temperature G-1-S[3]	Room Temperature G-2[4]
R-141	.029"	895	—	—	340	760	1262
R-404d	.040"	1041	—	—	475	901	1380
R-404j	.041"	1037	—	1006	435	906	1460
R-158	.041"	—	—	—	508	910	—
R-148	.041"	1105	—	—	495	1009	1478
R-166	.042"	984	—	—	[illegible]	973	1283
R-150	.042"	974	—	—	513	1043	1370
R-147	.042"	1060	—	—	475	1030	—
R-117	.043"	1104	—	—	483	1030	—
R-159	.044"	1105	—	—	453	955	—
R-116	.045"	1152	—	—	498	1065	1293
R-124	.045"	1117	1124	—	540	975	1443
R-123	.046"	1098	1123	—	532	955	1430
R-120	.046"	1162	1173	—	468	1165	—
R-113	.047"	1104	1118	—	445	998	1345
For Comparison:							
	.030"	704	—	—	—	815	1215
Hadfield	.040"	900	—	—	—	900	1600
Manganese Steel	.045"	950	—	—	—	1050	1675

[1] Caliber .45 (steel-jacketed) ball projectile - 230 grains
[2] Caliber .30 fragment-simulating projectile - 150 grains
[3] Caliber .30 fragment-simulating projectile - 34 grains
[4] Caliber .22 fragment-simulating projectile - 17 grains

Comparison of Resistance to Perforation by Various Projectiles of Plastic Materials with That of Hadfield Manganese Steel



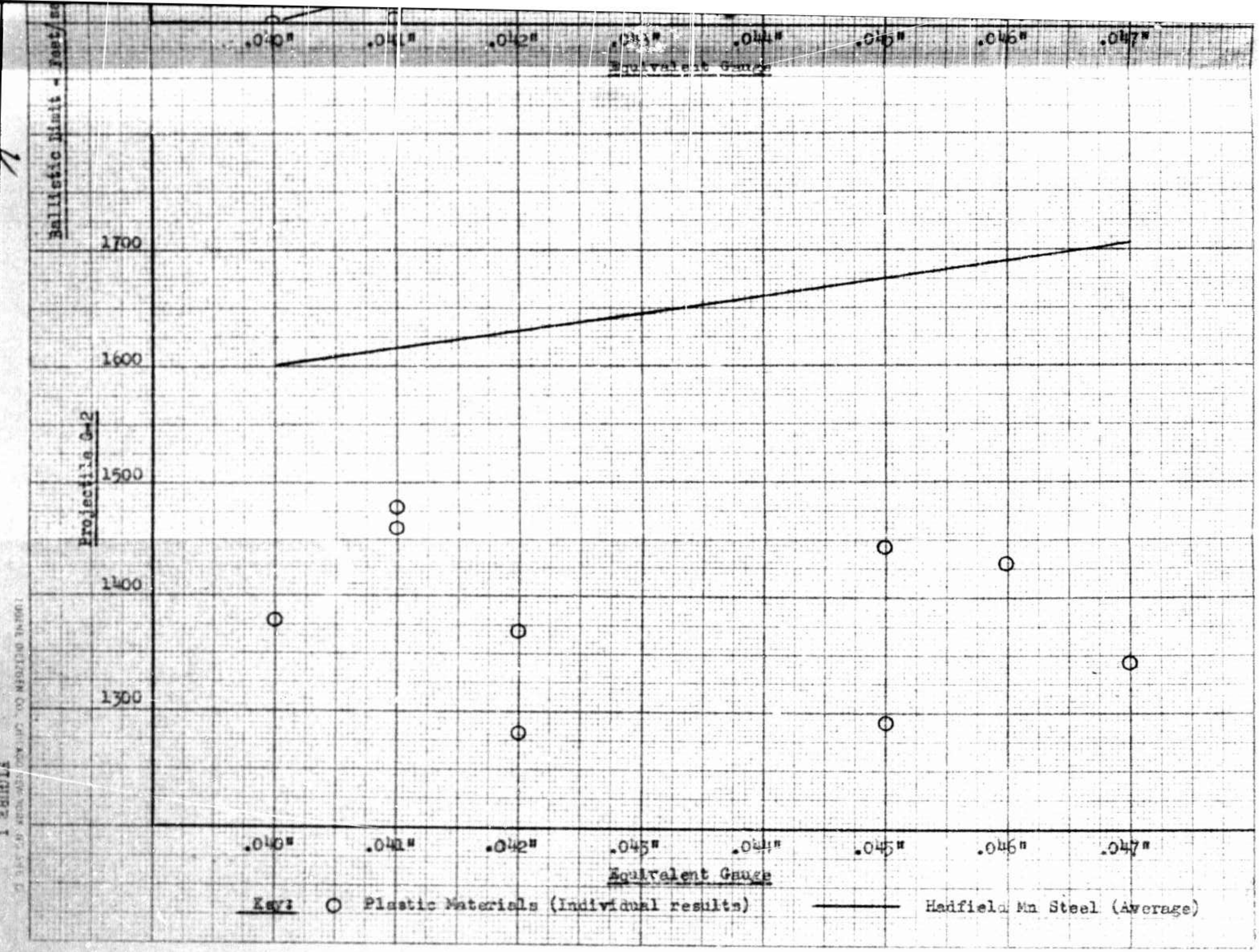

Ballistic Limit - Feet/sec
Projectile 0-2
1700
1600
1500
1400
1300
.040"
.041"
.042"
.043"
.044"
.045"
.046"
.047"
Equivalent Gauge
Key: Plastic Materials (Individual results)
Hadfield Mn Steel (Average)

FIGURE I

TITLE: Resistance of Various Samples of Plastic Materials to Perforation by Fragment-Simulating Projectiles

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ABSTRACT:

The resistance of various samples of plastic materials (presumably glass laminates) to perforation by fragment-simulating projectiles was investigated. The resistance of these materials to perforation of .45 cal. steel-jacketed ball projectiles is the highest of all materials tested in this weight range (equivalent to .040" to .050" of steel). Their resistance to perforation by the .30 cal. fragment-simulating projectile, G-1-S, is roughly equivalent to that of Hadfield Mn steel, which is the best metal tested. Their resistance to perforation to .22 cal. fragment-simulator, G-2, is inferior to that of the Hadfield Mn steel. Low temperatures did not deleteriously affect the resistance of these materials to perforation by the .45 cal. projectile. However, prolonged (17 hrs) immersion in water lowered its resistance slightly.

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