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TWENTY-FOURTH

PROGRESS REPORT

OF

THE FIRESTONE TIRE & RUBBER CO.

ON

105 MM BATTALION ANTI-TANK PROJECT

Contract No.
DA-33-019-ORD-33 (Negotiated)
RAD ORDTS 1-12383

THE FIRESTONE TIRE & RUBBER CO.
Defense Research Division
Akron, Ohio

JULY, 1952

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ABSTRACT

Four Firestone BAT weapon systems, located at Fort Benning, Aberdeen Proving Ground and Erie Ordnance Depot (2), are being used in various tests of weapons and ammunition. The components of each system are given and the status of four weapon systems being manufactured is presented. Two direct sights have been returned to Frankford Arsenal for inspection and reconditioning. Four T46 spotting rifles were returned to Springfield Armory for installation of hardened bolt locking seats and for general overhaul.

The T138E57 rounds fired at Aberdeen Proving Ground, as a part of the BAT demonstration, held on July 23, 1952, are reported and the data presented. A test to determine the match between the spotting rifle and the major caliber rifle is discussed and results given.

The firing tests with the T119 projectile, during this report period, were associated with the demonstration of BAT weapons and ammunition at Aberdeen Proving Ground on July 23, 1952. The test results are presented and discussed. The derivation and application of a form factor and ballistic coefficient for the T119 projectile is a part of this report.

There were no tests conducted this month with the T171 projectile.

Three series of rounds were fired at Erie Ordnance Depot to investigate three phases of penetration phenom. (1) the effect of the tee of the T138E57 projectile on penetration, (2) the effect of booster cavity on penetration and (3) the effect of recoining DRB 398 copper liners. The data are presented and discussed.

Investigations involving the fuzing system were concerned with (1) the effect of shock waves upon the output of barium titanate crystals and (2) projectile retardation (T138E57) on graze impact. Tests investigating these phases are reported.

THE WEAPON SYSTEM

As reported in the Twenty-Third Progress Report, four BAT weapon systems, each consisting of a T137E1 rifle, T152E2 mount, T46 spotting rifle, M62E4 direct sight, and T183 sight mount, are mounted on M38 trucks and are in use at the following locations:

One Unit – Fort Benning Georgia, for informal evaluation tests of weapon and ammunition.

Two Units – Erie Ordnance Depot for Firestone weapon and ammunition studies.

One Unit – Aberdeen Proving Ground for ammunition evaluation.

Four additional BAT weapon systems are being manufactured. These systems will each consist of a T137E2 rifle, T152E4 mount, T46 spotting rifle, T183 direct sight mount, M62E4 direct sight and M3A1 modified indirect sight. The status of each of these units is as follows:

One Unit – Complete except for new fire control handwheels. Will be completed by August 15.

One Unit – Scheduled for completion by August 15.

Two Units – Scheduled for completion by September 15.

Sighting System

Direct Sight

One direct sight, telescope M62E4 No. 18005 and T183 mount No. 1, was returned to Frankford Arsenal on July 28 for reconditioning.

A second direct sight unit, consisting of M62E4 telescope No. 18000 and T183 mount No. 4, was shipped to Frankford Arsenal on July 31 for inspection and repair. This sight was in use on units at Aberdeen Proving Ground and became unserviceable due to the accumulation of moisture in the telescope.

Spotting Rifle

Four T46 spotting rifles, numbers 1, 19, 26 and 32, were returned to Springfield Armory in July for installation of hardened bolt locking seats and for general reconditioning.

Future Program

1. Continue stress analysis studies of T152E2 mount.
2. Continue design study of an aluminum mount.
3. Continue design layouts of semi-automatic rifles.
4. Study mounting of system on M38 truck to determine possibility of simplification in removal from truck and in installation on revised M38 truck.
5. Study fire control system and make a single fire control button to fire both major and minor caliber rifles.

T138 PROJECTILE

Test firings were made in July with T138E57 inert rounds and T138E57 HEAT rounds at Aberdeen Proving Ground. The tests were made in connection with the BAT demonstration held on July 23.

Test 1
To Determine the Match Between the Spotting Rifle and the Major Caliber Rifle.

Three lots of caliber .50 ammunition were available for use at Aberdeen Proving Ground. Samples of each were fired at a range of 1000 yards and the center of impact for each lot was estimated. Five rounds of T138E57, inert, were fired for comparison. The data are presented in Table I and are corrected for coincidence of boresights and the 1000 yard reticle marking at the center of the target.

Test 2
To Test T138E57 HEAT Rounds For Functioning and Penetration.

Sixteen T138E57 HEAT rounds, from three loading lots, were fired for penetration studies at Aberdeen Proving Ground. The projectiles were fired from a T137E1 gun at homogeneous armor plate inclined at 60-degree obliquity. The T138E57 rounds fired had thin-walled tee caps, DRA 695-3, shown in Fig. 1. A summary of these penetration firings appears in Table II.

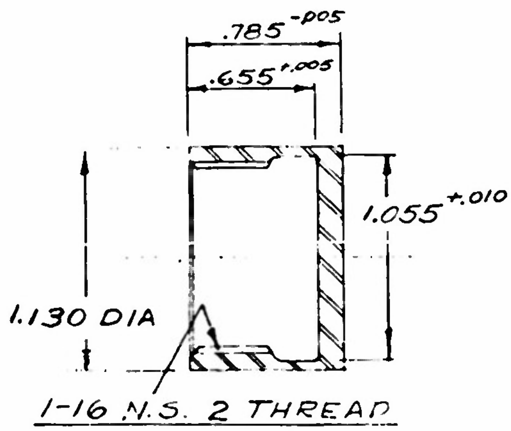


Fig. 1. Thin-Walled Tee Cap.
Firestone Drawing DRA 695-3

Table I
Firing Data
To Determine Match Between Spotting and Major Caliber Rifles

Ammunition	Muzzle Velocity (ft/sec)	No. Rds.	No. Hits	Center of Impact (mils) V	H
T138E57, inert	1737	5	5	+1.33	−1.70
T177, caliber .50 Tracer, Lot FAX-50-1710	1656 (nom)	2	1	−3.50	−
T177, caliber .50 Tracer Lot FAX-50-1675	1825 (nom)	10	10	+1.33	.25
T175 caliber .50 Spotter Lot FAX-50-1736	1908 (nom)	10	10	+2.00	− .75

The data of Table I show that the T177 tracer (Lot FAX-50-1675) and the T175 spotter (Lot FAX-50-1736) satisfactorily match.

Table II
Penetration Firing
T138E57 Projectiles at Aberdeen Proving Ground

Lot No.	No. Fired	No. Functioned	Penetration (Inches)
PA-E9604	5	3	12.4, 12.0, 10.5
PA-E9605	5	5	12.0, 10.8, 13.2, 12.0, 12.0
PA-E9616	5	4	10.5, 12.5, 15.9* plus
PA-E9616	1	1	Bursting Screen (functioned)
* Indeterminate because jet hit left bottom of plate.			

In the demonstration three T138E57 projectiles, fired against 5-inch armor plate at 60 degree obliquity, at a range of 500 yards, functioned and penetrated the target completely.

T119 PROJECTILE

The firing tests with the T119 projectile in this report period were associated with the demonstration of BAT weapons and ammunition held at Aberdeen Proving Ground on July 23, 1952. Seventeen rounds were fired prior to the demonstration for charge development purposes and to test the penetration results with live rounds. The data for these rounds are given in Tables III, IV, V and VI.

Since the sight had range scales inscribed for the T138E57 projectile it was necessary to adjust the velocity of the T119 projectile to give a reasonably good match with the reticle at the demonstration ranges of 500 and 1000 yards.

Except for one round, which gave less than 9 inches of horizontal penetration, the performance of the live rounds was satisfactory. The dispersion of the inert rounds at 500 yards and at 1000 yards was greater than anticipated.

T119 Rounds Fired On July 21, 22 and 23

On July 21 one inert T119 round was fired by the Fort Benning gun crew at a vertical plate located 500 yards distant (approximately 8 ft. by 10 ft. target). The projectile struck the target.

On July 22 one live T119 round was fired at 500 yard range by the same crew at a 5-inch thick plate of armor inclined 60 degrees to the vertical. A ¼-inch witness plate was placed a few feet behind the target and a plywood panel was placed behind the steel witness plate. The projectile struck the target and gave complete penetration.

On July 23 four T119 HEAT rounds were fired at a 5-inch plate target located 500 yards distant inclined 60 degrees to the vertical. The first round struck the target, near the center, and gave complete penetration. The second round was not observed and did not detonate. The third and fourth rounds appeared to detonate low on the target but subsequent examination of the target area revealed that these rounds struck four feet short. It was determined that the second round, not observed when fired, passed just under the armor plate, as evidenced by the position of a projectile hole found in the witness plate. Fin marks and the projectile chamber were found in a cross timber.

The vertical dispersion of the last three T119 rounds of the preceding paragraph, when referred to a vertical plane through the target center, was 12 inches. The first round was 36 inches above the highest of the last three rounds. The dispersion, considering the four rounds, was greater than expected.

Three inert rounds (T119) were fired at a tank silhouette moving in a plane perpendicular to the line of fire and at a distance of 1000 yards. All rounds were short of the target. The spotting rifle was not used to "range in" and there was no observer to direct the fire.

Future Program

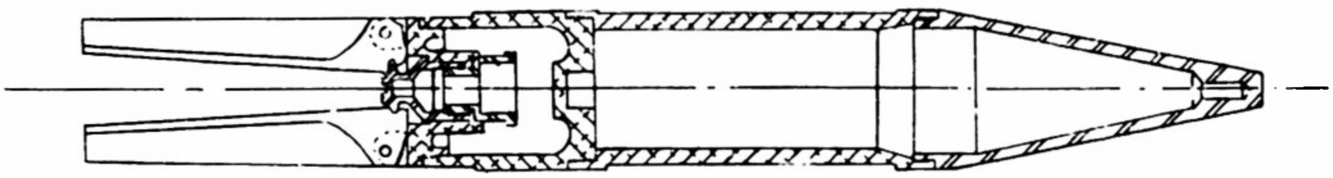
(1) Plans to fire a combined accuracy and penetration program using the T119 projectile and an M27 rifle have been deferred since the projectiles scheduled for this program were expended in the demonstration.

(2) The first shipment of forged fins for the pilot lot of 500 T119 projectiles has been received. Deliveries of projectile assemblies to Picatinny Arsenal for loading are scheduled beginning August 8, 1952.

(3) A combined accuracy and penetration program, using T119 projectiles from the pilot lot is planned for August 25, 1952.

Table III

T119E4 Projectile Specifications
See also Table VI



Component	Drawing No.	Material	Weight (lbs.)
Nose	DRB-145	SAE1020	4.00
Body	DRC-111	24ST4	3.96
Housing	DRB-169	24ST4	.98
Chamber	DRB-168	24ST4	2.21
Piston	DRB-55	SAE4140	.51
Stop	DRB-56	SAE4140	.38
Fins	DRB-49	24ST4	.98
Pins	----	Steel	.08
Assembly	DRD-103		
Inert Load		Plaster	4.40
Projectile Weight (Calculated)			17.50

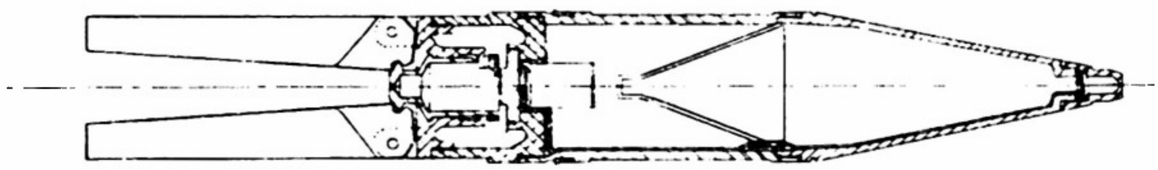
C. P. .93 Cal. From Hinge Pin Center Line, Fins Open
C. G. 2.32 Cal. From Hinge Pin Center Line, Fins Open

Total Length – Fins Closed 32.14 in.

Table IV

T119E7 Projectile Specifications

See also Table VI



Component	Drawing No.	Material	Weight (lbs)
Nose	DRC-342	SAE1020	3.75
Body	DRC-392	SAE1045	5.47
Housing	DRB-197	24ST4	.85
Chamber	DRC-393	24ST4	1.60
Piston	DRB-198	SAE4140	.52
Stop	DRA-173	SAE4140	.09
Fins – Canted	DRB-285	24ST4	.94
Pins	3/4" LG.X.2505	SAE1020	.06
Nose Cap	DRA699	SAE1030	.23
Plug	DRA288	24ST4	.11
Obturating Band	DRB420	Copper	.20
Cone	DRB398	Copper	.90
O-Ring	Ckcx3-1/8 x 3 7/8	Rubber	.01
Gas Seal	Picatinny Arsenal DWG. 75-14-38 PcMKE	Copper & Lead	.03
Base Element	DRA579	----	.33
Wire & Tape	DRA628	Nylon & Copper	
Nose Element	DRA496	Barium Titanate	.02
Pin Strip	DRA454	Bakelite	--
Grommet	DRA492	Nylon	--
Shock Pad	DRA493	Felt	--
Shock Pad	DRA491	Felt	--
Sleeve	DRA498	Turbosil Silicone Glass	--
Washer			
R.C. Assy.	DRA598	----	--
Insulator	DRA460	Felt	--
Assembly	DRD332		
Composition B			2.79
Projectile Weight (Calculated)			17.84

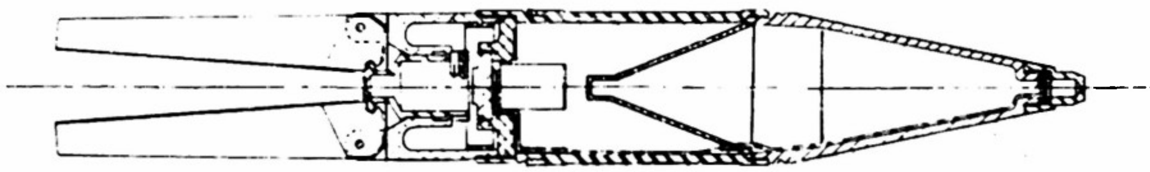
C. P. .67 Cal. From Hinge Pin Center Line, Fins Open
C. G. 1.75 Cal. From Hinge Pin Center Line, Fins Open

Total Length – Fins Closed 28.08 in.

Table V

T119E8 Projectile Specifications

See also Table VI



Component	Drawing No.	Material	Weight (lbs)
Nose	DRC342	Malleable Iron	3.49
Body	DRC341	SAE1045	5.58
Housing	DRC412	24ST4	1.76
Piston	DRB198	SAE4140	.52
Stop	DRA173	SAE4140	.09
Fins	DRD334	24ST4 Forging	1.01
Pins	DRA730	SAE1020	.06
Nose Cap	DRA699	SAE1030	.21
Plug	DRA288	24ST4	.11
Plug	DRB419	24ST4	.58
Obturating Band	DRB420	Copper	.20
Cone	DRB398	Copper	.90
O-Ring	Ckcx3-1/8"x3 7/8"	Rubber	.01
Gas Seal	Picatinny Arsenal DWG. 75-14-38 PcMKE	Copper & Lead	.03
Base Element	DRA579	----	.33
Wire & Tape	DRA628	Nylon & Copper	--
Nose Element	DRA496	Barium Titanate	.02
Pin Strip	DRA454	Bakelite	--
Grommet	DRA492	Nylon	--
Shock Pad	DRA493	Felt	--
Shock Pad	DRA491	Felt	--
Sleeve	DRA498	Turbosil Silicone Glass	--
Washer			
R. C. Assy.	DRA598	----	--
Insulator	DRA460	Felt	--
Assembly	DRD262		
Composition B			2.79
Projectile Weight (Calculated) 17.82 lbs.			

C. P. .68 Cal. from Hinge Pin Center Line, Fins Open
C. G. 1.73 Cal. from Hinge Pin Center Line, Fins Open

Total Length – Fins Closed 28.21 in.

Table VI

Range Firing Data
T119 Projectiles Fired at Aberdeen Proving Ground
July 21, 22 and 23, 1952

Date 7-16-52 To 7-23-52 Program T119
ABERDEEN PROVING GROUND

PROJECTILE
Model T119
Type E4, E7 & E8
Weight (Nominal) 17.60
C.G. Location ______
Bourrelet Dia (Nom.) 4.132 -.002
Special Features Bands Turned Off
E4 has fin DRB 49 not (canted) See Table III, page 6
E7 has fin DRB 285 (canted) See Table IV, page 7
E8 has fin DRB 285 (canted) See Table V, page 8
(as substitute for forged fin)

PROJECTILE ORIFICE DIAMETER
E4 - .323 in.
E7 - .220 in
E8 - .246 in

TEST GUN
Model T137E1
Type 105mm Recoilless
Length of Tube 95 in
Twist of Rifling 1-200
Sighting Equipment T128 Ballistic Reticle
Bore Dia. (Lands) 4.184 -.002 in.
Mount T152E2
T46 Caliber .50 Spotting Rifle
T81 Primer
T63 Shell Case with Polyethylene and Rayon Liners

MISCELLANEOUS DATA
Range Variable
Propellant
Type M10MP web .033 Charge Wt. Variable
PA 30175
Proof Director /s/ FARRELL
Observers Cox, Tochia, Clark

Round No.		Proj. Weight	Powder Charge (lb-oz)		Chamber Pressure[a]	Muzzle Velocity Instr.	Muzzle Velocity Actual	Elev. (yd)[b]	Azimuth	Position of Hit (mils) Vert.	Position of Hit (mils) Horiz.	Observations
	FIRED	7-15-52						INERT ROUNDS		AIMED OVER PLATE AT 400 FT		
62-E4		17.54	7-12		10,350	1624	1638					
68-E4		17.55	7-14		10,800	1665	1679					
136-E4		17.66	8-0		11,200	—	—					
	FIRED	7-16-52		LIVE ROUNDS PA-E10255			HOMOGENEOUS ARMOR PLATE INCLINED 60° FROM VERTICAL. RANGE 400 FT.					
160-E7		17.66	8-0		12,400		1684					Horizontal penetration < 9 in.
167-E7		17.61	8-0		12,100		1695					" " 15 in +
155-E7		17.53	8-0		12,400		1697					" " 15 in +
163-E7		17.64	8-0		12,600		1689					" " 14.6 in.
154-E7		17.60	8-0		11,900		1688					" " 15 in + 3/4 in witness plate
	FIRED	7-17-52		INERT ROUNDS		1000 YARD RANGE						
56 E4		—	7-11		8,450		1581	1000	0	-2½	+2½	
59 E4		17.56	7-11		10,250		1652	1000	0	+2	+2¼	Observed yaw on this round
75-E8		17.48	7-11		10,250		1657	1000	0	-½	+3	
173-E8		17.50	7-11		10,600		1661	1000	0	+¼	+1	
176-E8		17.43	7-11		10,850		1674	1000	0	-3½	+3	
	FIRED	7-18-52		INERT ROUNDS		500 YARD RANGE						
139-E7		17.50	7-13		10,650		—	500	0	—	—	Fired upon closing breech
—		—	7-13		10,850		1694	500	0	-1.17	+.84	Loaded at 70°
—		—	7-13		10,950		1702	500	0	-.61	+.22	" " "
—		—	7-13		10,950		1694	500	0	-2.62	+1.56	" " "

NOTES:-
a. Chamber pressures were obtained with M3 internal copper gages
b. Elevations are given in yards in terms of the ballistic reticle inscribed for the T138 projectile.

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The Derivation and Application of a Form Factor and Ballistic Coefficient for the T119 Projectile

Derivation

The form factor and ballistic coefficient of the T119 projectile were calculated by the use of Siacci theory and experimentally determined elevations for three different ranges.

The data shown in Table VII were obtained from firings of the T119 projectile. The projectile weight was 17.50 pounds and all muzzle velocities were corrected to 1700 ft/sec in determining the center of impact of the group of projectiles.

Table VII

Data From Test Firings

Range (Yds)	Elevation (Mils)	Vertical Center of Impact (Mils)	Elevation With Respect to V.C.I.	Firestone Report		
				Table	Page	Report No.
1029	21.5	−1.009	22.51	X	27	15
1507	37.0	− .890	37.89	XIII	21	18
2044	59.0	− .483	59.48	VII	15	19

Choice of Drag Curve

Standard drag curve G_1 had been used previously to determine elevations for firing at 1500 and 2000 yards (See Nineteenth Progress Report, page 14), but a consideration of the various shapes of the standard projectiles indicated that standard curve G_2 should give the best fit. This conclusion was based on the fact that standard projectile No. 2 has dimensions (in calibers) of body and nose similar to the T119 projectile (It is the only standard projectile with a conical nose). The $G_{2.2}$ tables were used since they are a refined version of the G_2 tables.

Formulas

THE FOLLOWING FORMULAS WERE USED:

(1) $x = \frac{c}{\sigma}(S - S_o)$

(2) $\sin 2\theta_o = \frac{c}{\sigma}\left[\frac{A - A_o}{S - S_o} - I_o\right]$

Where

$c = \frac{m}{id^2}$ = ballistic coefficient

m – mass of projectile in pounds.

i – form factor (Ratio of the projectile's drag coefficient to that of the standard projectile chosen).

d – diameter of the projectile in inches (4.134).

x – range in feet.

θ_o – angle of elevation.

σ – ratio of density of the air to the density of air under standard conditions ($\sigma = 1$ is assumed in all calculations).

S, A, I – symbols denoting certain Siacci integrals which are functions of velocity (u), subscript (o) indicates a value at muzzle velocity (u_o).

Calculation

Since range, elevation and muzzle velocity were obtained from the experimental data x, θ_o, S_o, A_o, and I_o were the known quantities in the two equations, leaving three unknowns (C,A,S) to be determined. A trial and error method was employed to obtain an approximate solution for each of the three sets of equations. Various values of $C_{2.2}$ that would give a value of θ_o reasonably near the observed value were plotted against sin $2\theta_o$. From this curve a value of $C_{2.2}$ could be obtained which agreed very closely to the observed sin $2\theta_o$. This process was carried out for each set of equations (i.e. for each range and corresponding elevation), resulting in three different values of $C_{2.2}$ each fitting its own range within ± 0.10 mil of the experimental data. By simultaneously adjusting these three values of $C_{2.2}$, a value was determined which would fit all three ranges and give minimum deviations from the experimental data.

The best result of $C_{2.2}$ was found to be .6326 and $i_{2.2}$ = 1.6187. Using these values of $C_{2.2}$ and $i_{2.2}$, the calculated and experimental elevations have a maximum deviation of .05 mil.

Application

Having obtained an optimum form factor and ballistic coefficient, the next objectives were the determination of

1. Elevations and terminal velocities for ranges from 100 yards to 2500 yards at 100-yard intervals.
2. Trajectories for 1000, 1500, 2000 and 2500 yards.
3. Time of flight for 500, 1000, 1500, 2000 and 2500 yards.
4. Angles of fall at 500, 1000, 1500, 2000 and 2500 yards.
5. Retardation factor in the region of the muzzle.
6. The effect of muzzle velocity differences on impact points.
7. The effect of projectile mass variations on impact points when muzzle velocity is constant.
8. The effect of projectile mass variations on impact points when initial kinetic energy is constant.

Elevations and Terminal Velocities

To determine the elevations and terminal velocities the mass of the E8 projectile (17.70 lb) was employed since the form factor had been found to be 1.6187, the value of $C_{2.2}$ became 0.6398. The muzzle velocity used was 1700 ft/sec.

Equations (1) and (2) were utilized in this application.

(1) $x = \frac{C}{\sigma}(S - S_0)$

(2) $\sin 2\theta_0 = \frac{C}{\sigma}\left[\frac{A - A_0}{S - S_0} - I_0\right]$

The procedure involved using the known values of x and $C_{2.2}$ to solve for $(S-S_0)$. Since the value of S_0 is taken from the $G_{2.2}$ tables, values for S at each range follow easily. Since S is the value of this particular function at a position x, interpolation in the tables gave values of u_T, the velocity remaining at the target. For the purpose of determining A, this velocity was computed to .001 ft/sec. The results of this calculation are shown in Table VIII.

Table VIII

Elevations and Terminal Velocities

T119E8 Projectile. See Table V

$C_{2.2} = .6398$ $\qquad$ $v_0 = 1700$ ft/sec

Range (Yds)	Elevation (Mils)	Terminal Velocity (ft/sec)	Range (Yds)	Elevation (Mils)	Terminal Velocity (ft/sec)
0	0.00	1700	1400	33.99	1035
100	1.69	1642	1500	37.51	1016
200	3.53	1585	1600	41.17	998
300	5.40	1528	1700	44.98	981
400	7.37	1473	1800	48.93	965
500	9.41	1418	1900	53.01	949
600	11.62	1365	2000	57.24	934
700	13.91	1314	2100	61.59	919
800	16.41	1263	2200	66.10	904
900	18.88	1214	2300	70.72	890
1000	21.57	1167	2400	75.48	876
1100	24.43	1123	2500	80.41	862
1200	27.45	1083			
1300	30.64	1056			

Trajectories

To determine the trajectories for 1000, 1500, 2000 and 2500 yards the equation (3) was used.

$$(3) \quad y/x = \tan\theta_0 - \frac{C}{2\sigma}\sec^2\theta_0\left[\frac{A-A_0}{S-S_0} - I_0\right]$$

Where

x and y are respectively the horizontal and vertical instantaneous coordinates of the projectile relative to the muzzle (measured in feet.)

All Siacci functions involved in this equation were handled as in previously explained applications.

The value of θ_0 used is the elevation for the particular range whose trajectory is to be determined.

S and A depend on the points along the range.

Other symbols agree with previous definitions.

The values of y were calculated at intervals of 100 yards along the range. For results see Fig. 2.

Time of Flight

To calculate the time of flight for the projectile at ranges of 500, 1000, 1500, 2000 and 2500 yards, equation (4) was used.

$$(4) \quad t = \frac{C}{\sigma}\sec\theta_0 \,(T - T_0)$$

Where

t – time of flight in seconds.

T – Siacci integral.

T_0 – Value at muzzle velocity.

Other symbols agree with previous definitions. The calculations are summarized in Table IX.

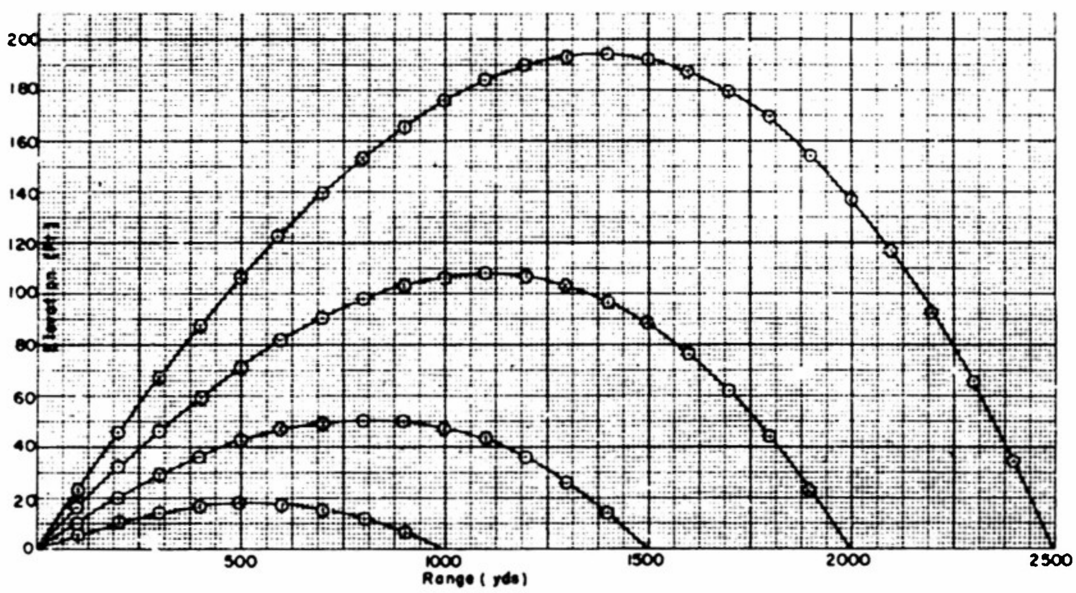

Fig. 2. Trajectories for Four Ranges.
T119 Projectile — 1000, 1500, 2000 and 2500 yards.

Table IX

Time of Flight
T119E8 Projectile

Range (Yds)	Elevation (Mils)	Terminal Velocity (Mils)	Time of Flight (Sec)	
500	9.41	1418	0.966	
1000	21.57	1167	2.132	17.6
1500	37.51	1016	3.530	49.6
2000	57.24	934	5.077	103
2500	80.41	862	6.763	184

Angle of Fall

In finding the angle of fall for ranges of 500, 1000, 1500, 2000 and 2500 yards equation (5) was used.

$$(5)\quad Tan\,\theta = Tan\,\theta_0 - \frac{c}{2\sigma} sec^2\theta_0 (I - I_0)$$

Where

I is a Siacci integral.

Io represents the value at the muzzle.

Other symbols agree with previous definitions. The calculations are summarized in Table X.

Retardation Factor

The following equation (6) can be derived from Siacci theory.

$$(6)\quad R = \sigma/c\; G\; sec\,\theta_0$$

Where

$R = \frac{U_2 - U_1}{X_2 - X_1}$ retardation factor in ft/sec.

G is a function of velocity.

The velocity used to determine G from the tables is the velocity of the projectile at the point where the retardation factor is desired. This velocity is obtained by using equation (1) as previously explained. For projectile E8, R = .1936 ft/sec/ft.

The Effect of Muzzle Velocity Differences On Impact Points

The equations previously used to determine elevations were used to determine the effect of muzzle velocity differences on impact points. Using the E8 projectile mass (17.70 lb.) and ballistic coefficient (0.6398), the elevations were determined for velocities from 1650 ft/sec to 1750 ft/sec at 10 ft/sec intervals. The differences in these elevations gave the vertical differences in impact points.

This effect was calculated at ranges of 500, 1000, 1500, 2000 and 2500 yards. The results are shown in Table XI.

The positive sign of the vertical deviation means that as the initial velocity increases, the impact point becomes higher.

Table X

Angle of Fall

T119E8 Projectile

Range (Yds)	Elevation (degrees)	Terminal Velocity (ft/sec)	Angle of Fall (degrees)
500	0 32′ 32″	1418	−0 36′ 35″
1000	1 14′ 8″	1167	−1 35′ 25″
1500	2 8′ 53″	1016	−3 4′ 24″
2000	3 16′ 33″	934	−4 52′ 22″
2500	4 35′ 50″	862	−6 58′ 18″

Table XI

Effect of Muzzle Velocity Variations

Range (yds)	Vertical Deviation (Mils/ft/sec)
500	+.011
1000	+.027
1500	+.047
2000	+.065
2500	+.083

The Effect of Projectile Mass Variations On Impact Points—Muzzle Velocity Constant

The same general procedure was followed in this calculation as in that involving muzzle velocity differences except that muzzle velocity was held constant (u_0 = 1700 ft/sec) while elevations were calculated for masses from 17.35 lb to 17.85 lb at 0.05 lb intervals. These calculations were made at ranges of 500, 1000, 1500, 2000 and 2500 yards. See Table XII.

The positive vertical deviation indicates that as the projectile mass increases, the impact point becomes higher.

The Effect of Projectile Mass Variations On Impact Points—Initial Kinetic Energy Constant

Under usual firing conditions, the amount of powder used is constant, so that other factors being uniform, it can be assumed that the initial kinetic energy of the projectiles is constant. Thus any differences in projectile mass will involve a difference in muzzle velocity.

The vertical dispersion resulting from such circumstances was calculated in the same manner as in the preceding example except the initial velocity used for each mass was a value such that the initial kinetic energy would be constant. This was the energy of a projectile of 17.60 lb with a muzzle velocity of 1700 ft/sec. Elevations were calculated for ranges of 500, 1000, 1500, 2000, 2500 yards, using masses from 17.35 to 17.85 lb. (See Table XIII).

The negative vertical deviation shows that as the mass of the projectile increases, its impact point becomes lower.

Table XII

Effect of Projectile Mass Variations
Muzzle Velocity Constant

Range (yds)	Vertical Deviation (Mil per 0.1 lb)
500	+.003
1000	+.034
1500	+.096
2000	+.162
2500	+.246

Table XIII

Effect of Projectile Mass Variations
Initial Kinetic Energy Constant

Range (Yds)	Vertical Deviation
500	−.050
1000	−.102
1500	−.136
2000	−.158
2500	−.160

Effect of Tee on Penetration

In the development of the T138E57 projectile the tee configuration has been extremely important. The exterior shape has a pronounced influence upon the flight stability of the projectile, and the interior configuration of the tee has been largely controlled by the effect of the tee cavity on the action of the jet.

The great majority of penetration firings have been made with nose rings in place of regular tees but at various stages in the development the actual tees have been checked for interference.

Data presented in the Twenty-Third Progress Report indicated that the tee on the T138E57 assembly, shown in Fig. 3, does not interfere with penetration results at a spin rate of 25 rev/sec but that it reduces penetration substantially at zero rev/sec. This investigation has continued during this report period.

Thirty rounds were fired at Erie Ordnance Depot in continuation of the study of the effect of the tee on penetration results. The data for these rounds are given in Table XIV. Two different penetration round assemblies were used and each type was fired both with and without tees. The combinations used were:

WITH NOSE RINGS (at 0 and 25 rev/sec)
- (1) DRC 376 body, ring and plug assembly, DRB 398 pressed cone. See Fig. 4.
- (2) DRC 15-6 body and plug assembly, DRB 2 machined cone. See Fig. 5.

WITH TEES
- (1) DRC 376 body and plug assembly, DRC 314 tee, DRB 398 pressed cone. See Fig. 6.
- (2) DRC 15-6 body plug assembly, DRC 314 tee, DRB 2 machined cone. See Fig. 7.

The data from the firing in Table XIV show that in the case of DRC 376 assemblies (Figs. 4 and 6) the DRC 314 tee reduces penetration by at least 3 inches at zero rev/sec, but seemed to have little, if any, effect on penetration at 25 rev/sec.

In the case of the DRC 15-6 assemblies with DRB 2 conical liners (Figs. 5 and 7) the penetration results were not influenced by the presence of the tee at zero rev/sec spin rate. This confirms results obtained in earlier tests. (Tenth to Thirteenth Progress Reports).

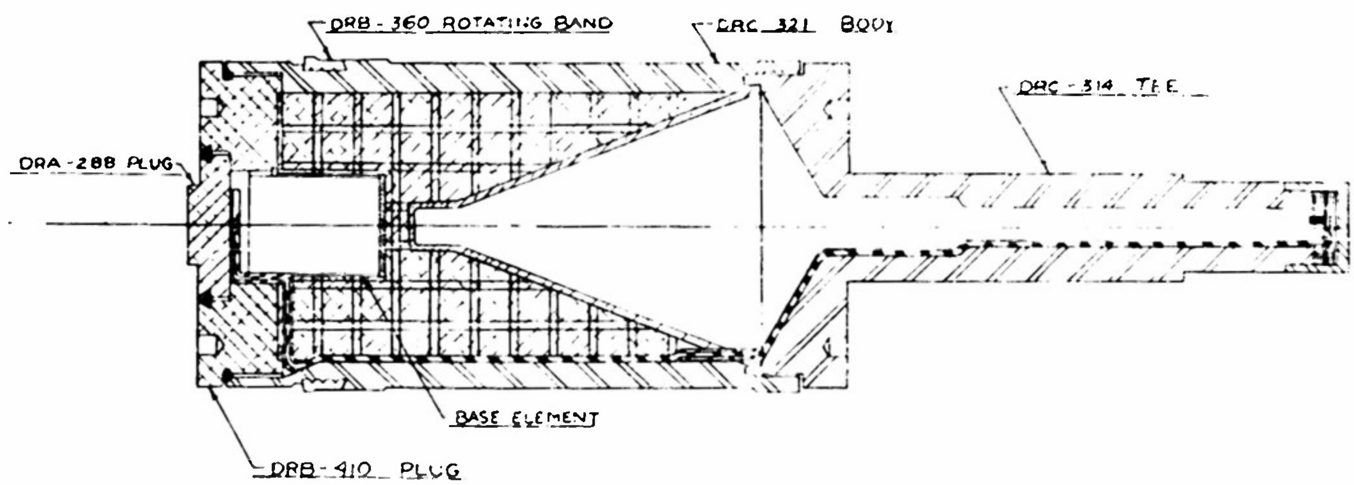

Fig. 3. T138E57 Projectile Assembly.

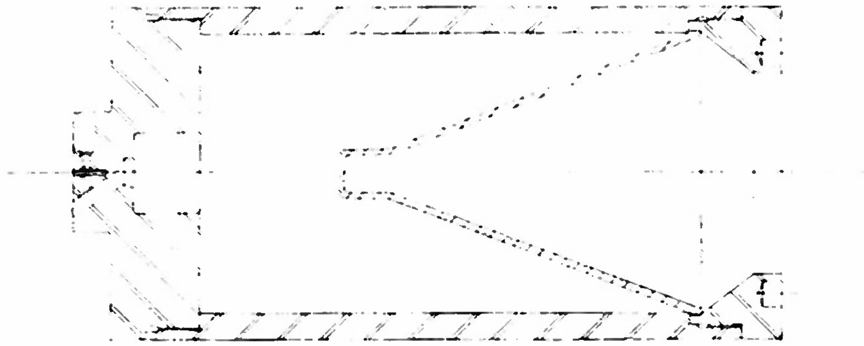

Fig. 4. Penetration Assembly.
DRC376 Assembly. DRB398 Pressed Cone.

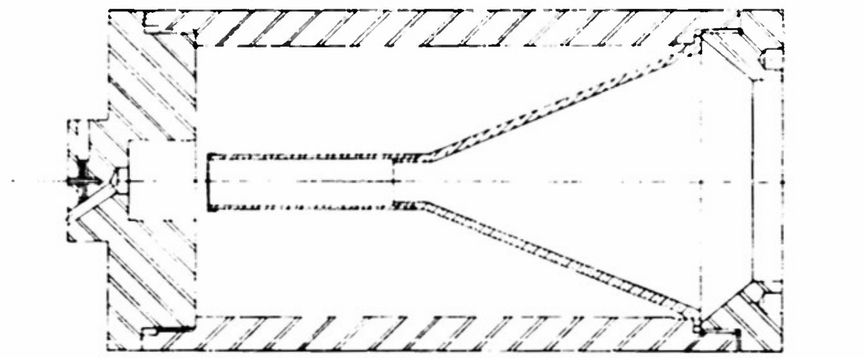

Fig. 5. Penetration Assembly.
DRC15-6 Assembly. DRB2 Machined Cone.

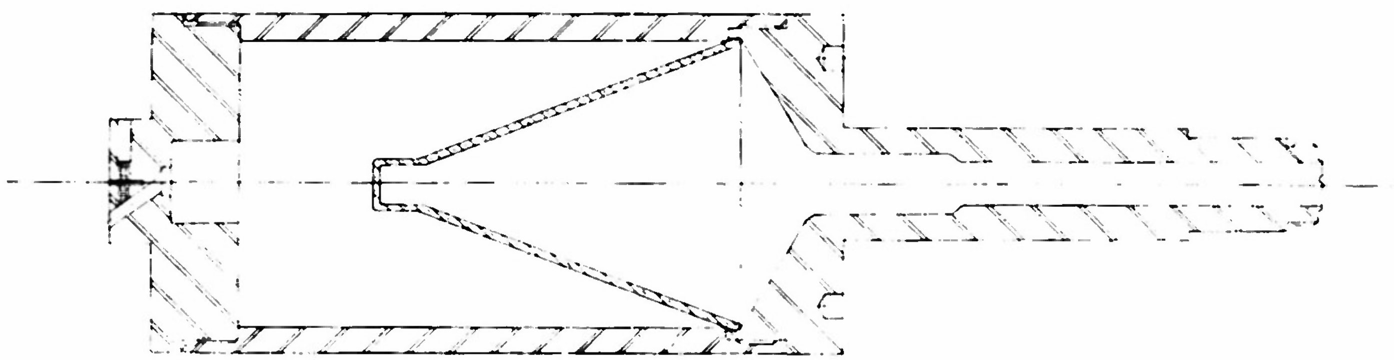

Fig. 6. Penetration Assembly.
DRC376 Assembly. DRB398 Pressed Cone.

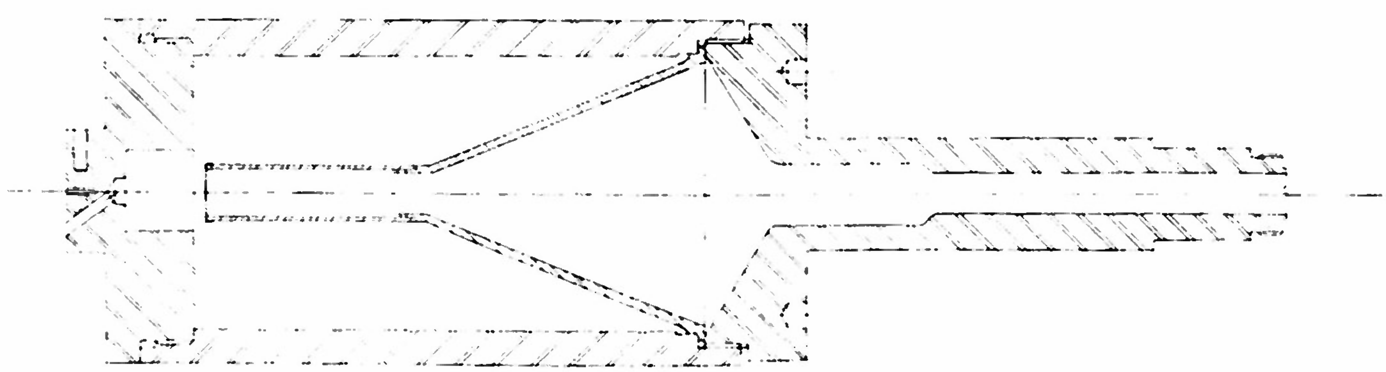

Fig. 7. Penetration Assembly.
DRC15-6 Assembly. DRB2 Machined Cone.

Table XIV

Penetration Data

Effect of Tee on Penetration

Firings at Erie Ordnance Depot

Round No.	Nose	Booster Cavity	Cone	Pounds CompB	Rev/Sec	Penetration (inches M.S.)	Max. Spread(in)	Std. Dev. (in.)
Q9	Ring	Yes	DRB398	2.46	0	19.31		
Q55	"	"	"	2.50	"	18.00		
Q56	"	"	"	2.48	"	18.06		
Q57	"	"	"	2.48	"	20.56		
Q59	"	"	"	2.46	"	20.06		
						Avg. 19.20	2.56	±1.16
Q10	Ring	Yes	DRB398	2.46	25	15.69		
Q45	"	"	"	2.50	"	16.00		
Q46	"	"	"	2.48	"	15.00		
Q58	"	"	"	2.46	"	15.44		
Q74	"	"	"	2.46	"	14.00		
						Avg. 15.23	2.00	±.78
Q471	Tee	Yes	DRB398	2.48	0	16.62		
Q474	"	"	"	2.48	"	16.44		
Q579	"	"	"	2.46	"	16.06		
Q580	"	"	"	2.46	"	15.94		
Q591	"	"	"	2.48	"	16.44		
						Avg. 16.28	0.68	±.29
Q320	Tee	Yes	DRB398	2.48	25	13.81		
Q463	"	"	"	2.50	"	13.69		
Q470	"	"	"	2.48	"	14.25		
Q472	"	"	"	2.46	"	14.50		
Q473	"	"	"	2.46	"	15.75		
						Avg. 14.40	2.06	±.83
FS541	Ring	None	DRB2- with S.B.	2.52	0	18.18		
FS542	"	"	"	2.56	"	18.62		
FS543	"	"	"	2.54	"	18.69		
FS544	"	"	"	2.56	"	18.38		
FS545	"	"	"	2.54	"	17.94		
						Avg. 18.36	0.75	±.31
FS546	Tee	None	DRB2- with S.B.	2.50	0	18.06		
FS547	"	"	"	2.52	"	17.56		
FS548	"	"	"	2.52	"	17.62		
FS549	"	"	"	2.54	"	18.62		
FS550	"	"	"	2.50	"	17.94		
						Avg. 17.96	1.06	±.43

Effect of Booster Cavity On Penetration

Ten rounds were fired at Erie Ordnance Depot to determine the effect of a T208 base element cavity on penetration. The data are given in Table XV. The test assemblies used are shown in Fig. 8. The results show penetration to be approximately 2 inches better with the booster in a more rearward position.

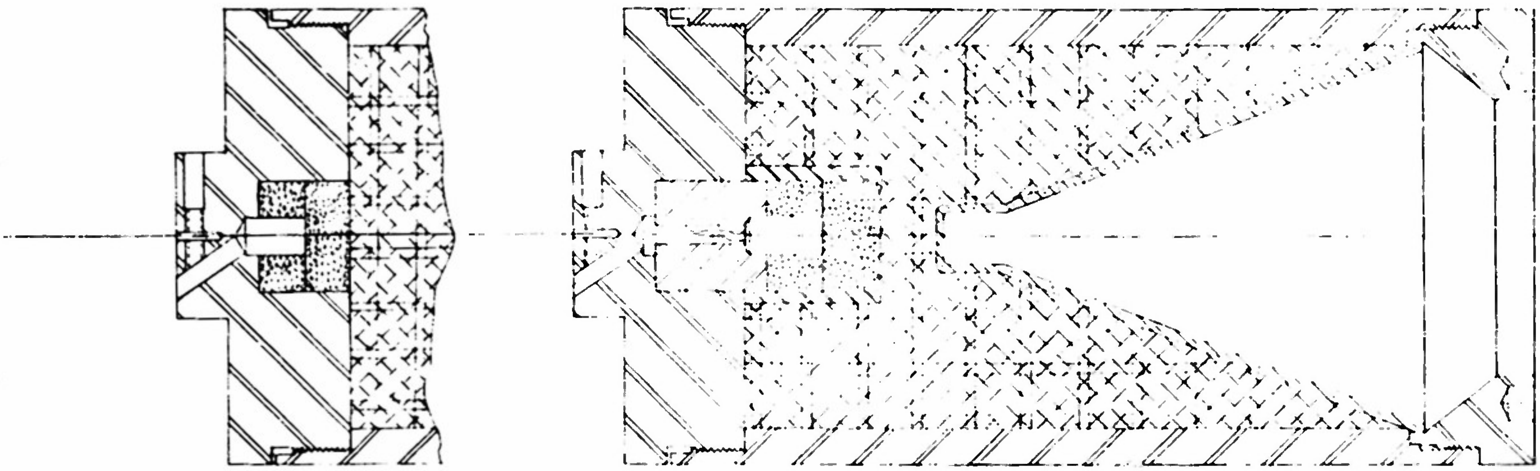

Fig. 8. Test Assemblies.
Booster Cavities.

Table XV

Penetration Data

Effect of Booster Cavity

Firings at Erie Ordnance Depot

Rd. No.	Nose	Booster Cavity	Cone	Lbs. Comp B	Rev/Sec.	Penetration (inches M.S)	Max. Spread(in)	Std. Dev. (in.)
Q9	Ring	Yes	DRB398	2.46	0	19.31		
Q55	"	"	"	2.50	"	18.00		
Q56	"	"	"	2.48	"	18.06		
Q57	"	"	"	2.48	"	20.56		
Q59	"	"	"	2.46		20.06		
						Avg. 19.20	2.56	±1.16
Q3	Ring	None	DRB398	2.58	0	20.88		
Q4	"	"	"	2.58	"	21.38		
Q5	"	"	"	2.54	"	20.50		
Q6	"	"	"	2.58	"	21.56		
Q7	"	"	"	2.56	"	21.06		
						Avg. 21.08	1.06	±.42

Penetration Results With Recoined Conical Liners

Nine test assemblies with recoined DRB 398 liners and fifteen control rounds using standard DRB 398 conical liners were fired to determine the effect of the recoining operation. In the coining operation a standard DRB 398 copper cone is pressed between matching steel dies under a load of 900 tons. The main effect of this final press is to straighten the walls and reduce the maximum waviness from about .006 inch to less than .001 inch. The penetration data are given in Table XVI.

These data indicate that under the test conditions there is no substantial difference between the performance of the standard and recoined DRB 398 liners.

Table XVI

Penetration Data

Results With Recoined Conical Liners

Firings at Erie Ordnance Depot

Round No.	Lbs. Comp.B	Spin Rate (rev/sec)	Penetration (inches M.S.)	Max. Spread (in.)	Std. Dev. (in.)
FS555	2.48	0	20.18		
FS557	2.44	"	18.62		
FS558	2.44	"	19.25		
FS559	2.48	"	19.50		
FS560	2.44	"	20.62		
			Avg. 19.63	2.00	±.79
FS551	2.46	25	14.38		
FS552	2.46	"	14.12		
FS553	2.46	"	14.06		
FS554	2.48	"	13.75		
			Avg. 14.08	0.63	±.26
Notes:					
1. Loaded at Ravenna Arsenal, BAT Load Lot No. 12, Holston 3-126					
2. DRC376 Test Assemblies					
3. Standoff = 7.50 inches					
Controls for above					
Q567	2.50	0	21.56		
Q587	2.48	0	20.88		
Q588	2.48	0	20.50		
Q589	2.50	0	20.94		
Q590	2.50	0	20.44		
			Avg. 20.86	1.12	±.45
Q441	2.48	25	14.31		
Q465	2.48	"	13.38		
Q466	2.48	"	15.69		
Q467	2.50	"	15.81		
Q475	2.48	"	14.56		
			14.75	2.43	±1.02
Q469	2.48	30	12.44		
Q539	2.46	"	11.88		
Q513	2.48	"	12.06		
Q565	2.48	"	12.00		
Q566	2.48	"	12.12		
			Avg. 12.10	0.56	±.21

Future Program

(1) Conduct penetration versus standoff tests for 45° and 20° copper cones (100-inch wall) with head of H.E. held constant at 3.63 in.

(2) Evaluate the influence of DRC 314 tees made of (a) mild steel (b) high ductility malleable iron, and (c) low ductility malleable iron.

(3) Conduct tests to determine the effect of interior tee configuration on penetration results. DRB 398 cones will be used in T138E57 test assemblies with various tee modifications.

Effect of Shock Waves Upon the Output of Barium Titanate Crystals

In further consideration of the sensitivity of barium titanate crystals a number of tests have been made in which a shock wave is allowed to pass through an unconfined barium titanate crystal and the output of the crystal is estimated. Figure 9 is a schematic drawing showing the two laboratory setups used.

Test 3

When a steel rod 4.5 in. diameter and 6 in. long replaced the rods of Tests 1 and 2, repeated hammer blows failed to function the BS28 indicator.

Test 4

A steel hoop, 10 in. I.D., made from 1-in.

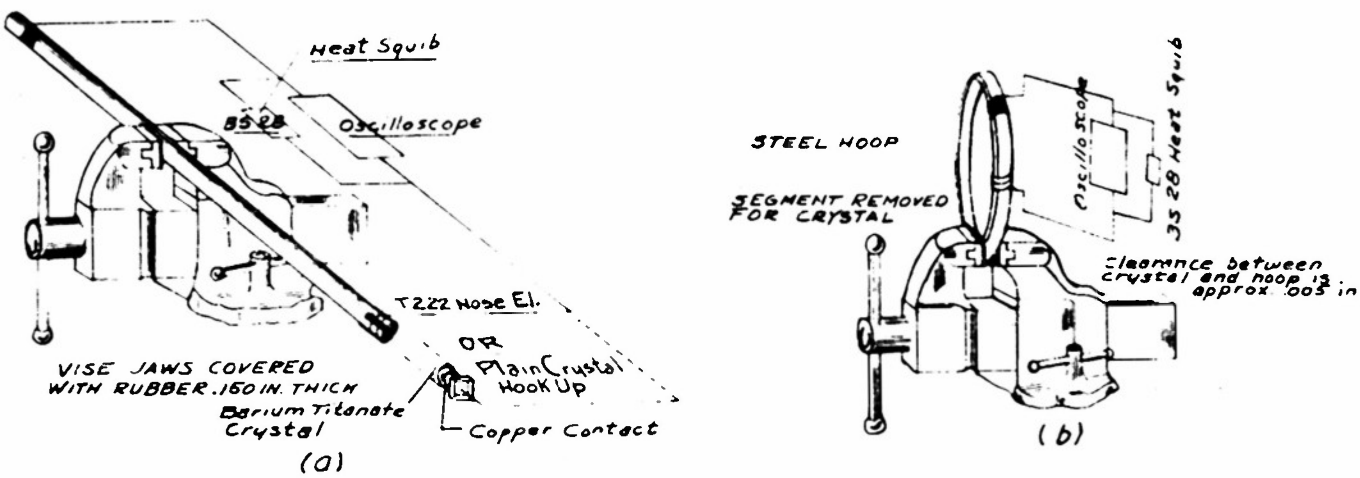

Fig. 9. Two Laboratory Test Setups.
Effect of Shock Waves on Barium Titanate Crystals.

Test 1

A steel rod, .75 in. diameter and 21 inches long was clamped in a vise as shown in Fig. 9 (a). The barium titanate crystal, 1 in. diameter and .062 in. thick, was taped to the end of the rod. A light hammer blow on the exposed end of the steel rod fired the BS28 indicator. A similar result was obtained when T222E3 nose elements (DRA 496-2, Fig. 10) were used.

Test 2

An aluminum rod, .75 in. diameter and 8 in. long was substituted for the steel bar of Test 1. Again a light hammer blow on the exposed end of the rod was sufficient to fire a BS28 indicator.

square bar was clamped as shown in Fig. 9 (b). The gap in the hoop allowed about .005 in. clearance for the T222E3 nose elements. A light blow on the ring with either a hammer or wooden rod was sufficient to fire the BS28 indicator regardless of the direction or location of the blow.

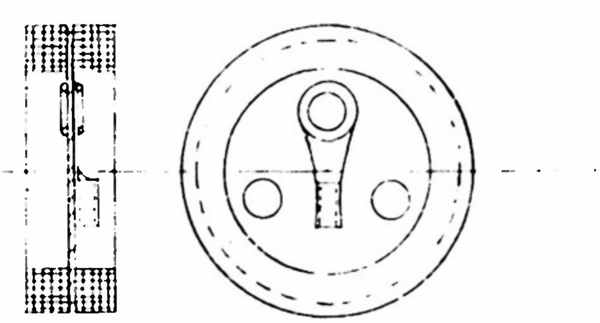

Fig. 10. Nose Element Assembly.
Firestone Drawing No. DRA496-2.

Test 5

A tee and nose element assembly from a T138E57 projectile was clamped in the vise. A BS28 indicator, connected to the leads, could be fired by light hammer blows on the rear or side of the tee.

Discussion of Tests 1 to 5

In all of these tests (1 to 5) the crystal was unconfined, that is, one side of the crystal was left unblocked. In each case the crystals remained intact, showing that the vibration did not cause large distortions of the crystals. The voltage-time curves of the output of the crystals show that the crystal is oscillating and that it is alternately compressed and relaxed during the oscillating cycle. If the amplitude of the oscillating motion is sufficiently large and if the frequency is sufficiently high the crystal would be expected to generate sufficient energy to fire the BS28 indicator.

In any event, these experiments show that the T222E3 nose element will function a BS28 indicator when vibrated, and that high pressures and gross distortions are not required.

Range Firing Tests Using T222E3 Nose Elements

Test slugs weighing fifteen pounds have been fired from a 75 mm gun at T138E57 tee assemblies having T222E3 nose elements. A BS28 indicator and an oscilloscope were connected in parallel across the output terminals of the crystal assembly. Attempts to photograph the voltage-time trace have been unsuccessful because of insufficient sensitivity of the photographic film. Attempts to obtain pictures using presensitized film were also unsuccessful. A new oscilloscope tube has been ordered which should reduce the photographic problems. The voltage-time curves could be observed visually and in each case in which the indicator functioned a voltage was also observed on the oscilloscope.

The variations of nose element mountings shown in Fig. 11, was tested. The data are shown in Table XVII. In eleven of the twelve tests the BS28 indicator functioned. In the one non-functioning case a questionable tee assembly was used. This assembly had been hammered repeatedly in earlier attempts to presensitize film and obtain photographic records of the voltage-time trace. It was used only because substitute assemblies were not available. In one test the slug barely grazed the end of the tee cap but the BS28 indicator functioned. In test 11 of Table XVII the tee was reversed so the slug struck the base instead of the nose cap and the indicator functioned.

T138E57 Projectile Retardation On Graze Impact On Grass Sod

A group of T138E57 projectiles were fired to determine the retardation or loss of velocity on graze impact with grassy sod. The projectiles were fired so as to strike the ground at nominal angles of 40 minutes, 3 degrees and 6 degrees. The velocity of the projectile was determined both before and after ground impact. The data are recorded in Table XVIII.

At each of the three angles of impact tested the projectiles dug a furrow in the ground 8 to 16 ft. long. The velocity of the rounds after graze seems to be independent of the angle of impact and averages 428 ft/sec for the eight rounds for which exit velocities were determined. Thus, it is concluded that the deceleration of the projectile upon graze impact is sufficient to permit the use of an inertia type fuze mechanism on HE or WP shell.

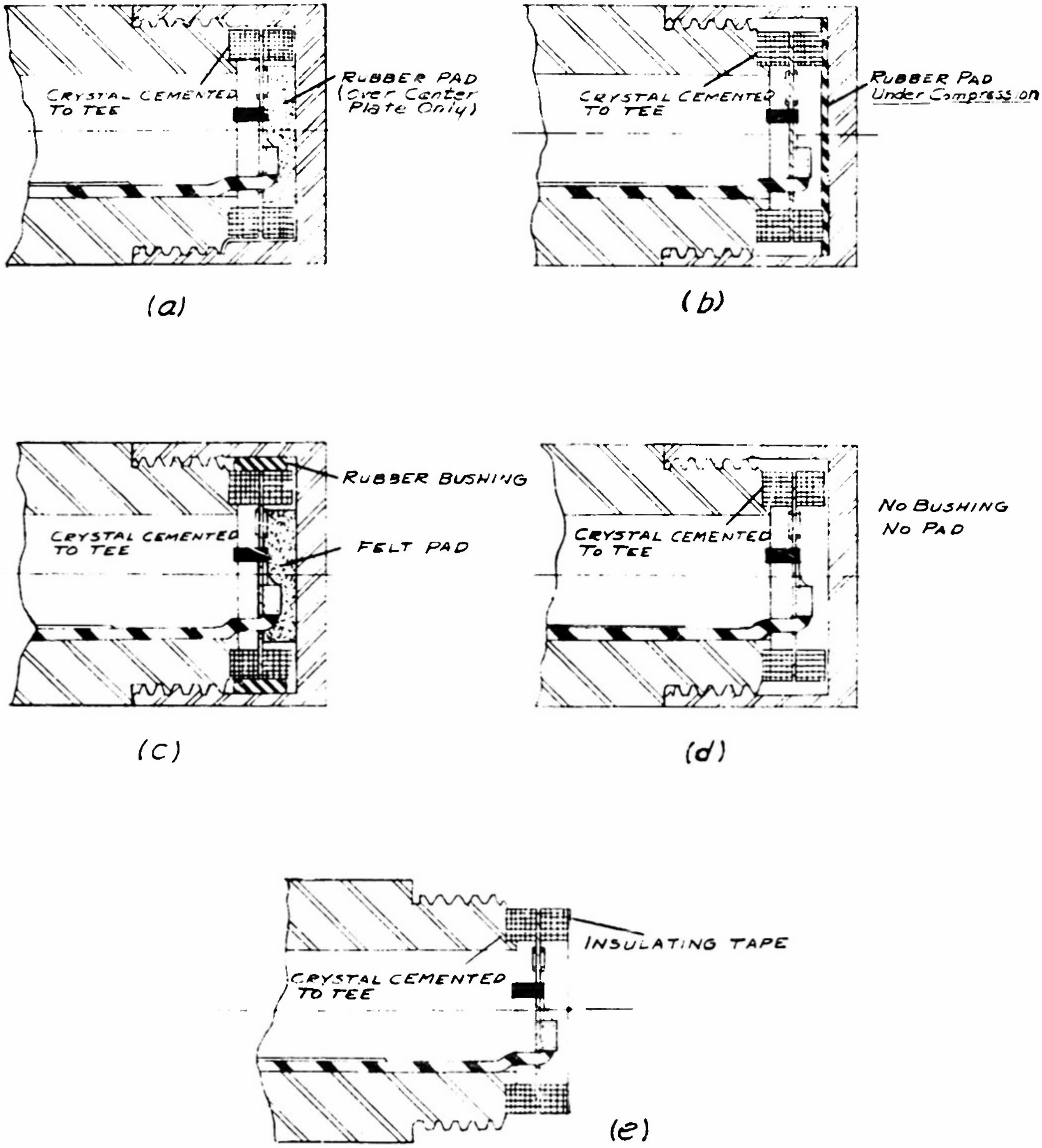

Fig. 11. Nose Element Mountings.

Table XVII

Range Firing Data

Testing T22253 Nose Elements

Round No.	Squib Resistance	Cap Wall (in)	Clearance (in)	Special Description	Results
1	–	.100	.032	Fig. 11(a)	Squib Functioned No Photo
2	–	.030	–	Fig. 11(b)	Squib Functioned No Photo
3	–	.030	.022	Fig. 11(c)	"
4	–	.030	.000	Fig. 11(d)	"
5	3000	–	–	Data Lost	"
6	1900	–	–	No tee cap. Top half of Lucky insulated out of circuit with tape Fig. 11(e)	"
7	1000	.100	.041	This Lucky had been observed as having poor activity according to electrometer reading.	"
8	3700	.030	.023	Fig. 11(d) except Lucky Not cemented down.	"
9	1250	.049	.031	Same as 8	"
10	2800	.050	.026	Same as 8	"
11	1800	.050	.037	Same as 8. Projectile shot at base.	"
12	1900	.030	.020	Same as 11. Nose had been hammered considerably. Lucky crumbling prior to firing.	Squib did not function. No photo.
Note: 75 mm projectile, weight – 15.03 lb. Velocity – 1280 ft/sec.					

Table XVIII

Range Firing Data

To Determine Retardation on Graze Impact

PROJECTILE

Model T138

Type E57A 1-9 DRB 368 Bend; 10-14 DRB 360 Bend

Weight (Nominal) 17.40 lb.

C.G. Location 5.31 in

Bourrelet Dia (Nom.) 4.132 in. -.002

Special Features ______

TEMPERATURES

	Max	Min	Proj	L Room
July 25	72	72	72	80
July 28	72	72	72	75
July 29	72	72	72	80
July 30	72	72	72	75
July 23	75	71	71	85

Date July 25, 28, 29 Rds 1-3; July 30, Rds 4-9; July 23 Rds 10-14 Program Supplementary IV Graze Test

TEST GUN

Model T19 (DR 044, 30°) For Rds 1-9; T187E1 for Rds 10-14

Type 105 mm Recoilless — Tube: 22B365-T; Breech: 22B332-U; Chamber 22B365T-A

Length of Tube 95 in.

Twist of Rifling 1-200

Sighting Equipment Adapted M17

Bore Dia. (Lands) 4.134 in. +.001

MISCELLANEOUS DATA

Range Rds 1-3 Fired at < ½°; Rds 4-9 at < 2½°; Rds 10-14 at < 5°

Propellant

Type M1CMP web .033 Charge Wt. 8 lb-1 oz (7 lb-15 oz); PA 30239; Rds 1-3, T6 cases; Rds 10-14 T-52 cases

Proof Director E. Huffman

Observers W. Brown, W. Hervey, L. Swaebly.

Round No.	Proj No	Powder Depth (in)	Powder Charge (lb-oz)	Angle of Fire Actual Graze	Chamber Pressure (External)	Muzzle Velocity Instr	Muzzle Velocity Actual	Ricochet Angle	Velocity After Graze	Graze Length & Depth	Graze Width	End of Graze To 2nd S Screen Dist (ft)	End of Graze To 2nd S Screen Height (ft)	Gun to Initial Pt of Graze (ft)	Height of Gun (ft)	Screen Meas. Openings 1st	Screen Meas. Openings 2nd	Character of Ground
FIRED AT	½° FOR GRAZE																	
2580-1	3003	5½	7-15	40 min	9370	1597	1620	6° 1 min	474	13.7'×.6'	1.7'	62.0	6.6	461	5.51	9"×12"	6"×9"	Grass Sod
2581-2	1007	5½	8-1	42 min	—	1650	1673	7°41'	390	16'×.8'	1.25'	58.0	7.75	448.33	5.51	12"×8"	12"×8"	" "
2582-3	992	6	8-1	43 min	9820	1645 est	1669	6°52'	327	15.66'×.66'	overlap	53.0	5.42	443.33	5.51	8"×4"	8"×4"	" "
								Ave.	397									
FIRED AT	2½° FOR GRAZE																	
2569-4	Slug	warm-up round																
2570-5	1014	5	8-1	3° 04'	10200	1656	1670	10°39'	—	10'×1½'	2.83'	18.92	3½	255.39	12.59	6"×6"	missed	Level Grass Sod
2571-6	1006	5	8-1	2° 56'	9800	1630	1654	11°26'	284	10.66'×1½'	overlap	17.66	3½	246.68	12.59	12"×9"	15"×7"	" " "
2572-7	1001	6	8-1	2° 52'	10360	1674	1698	6°59'	—	8.33'×1.35'	"	12.33	1½	251.92	12.59	15"×9"	15"×4"	" " "
2573-8	1019	6½	8-1	2° 53'	10360	1667	1691	11°57'	514	8.25'×1'	"	13.66	2.88	250.68	12.69	12"×8"	Hit Side	" " "
2573-9	1001	6	8-1	3° 01'	10240	1629	1653	—	—	10½'×1'	"	.83	Hit bottom of screen	239.76	12.59	Bottom Edge	11"×8"	" " "
FIRED AT	5° FOR GRAZE							Ave	399									
2575-10	997	6	7-15	6° 18'		1677	1693	10°58'	688	10'8"×14"	5'	35'1"	6'8"	119'11"	11.09	8"×6"	10"×7"	Moist Grass Sod
2576-11	998	5½	7-16	5° 15'		1656	1670	11°25'	246	10'6"×14"	6'9"	38'9"	7'8"	121'2"	11.09	8"×8"	18"×15"	" " "
2577-12	993	6	7-15	5° 10'		1661	1675	8°04'	—	8'8"×10"	2'2"	39'9"	5'7"	123'3"	11.09	12"×13"	16"×14"	" " "
2578-13	999	5½	7-15	4° 53'		1684	1700	—	—	10'4"×12"	overlap	missed	—	130'9"	11.09	8"×6½"	missed	" " "
2579-14	1000	6	7-16	5° 23'		1680	1694	7°17'	498	9'1"×10"	"	57'2"	7'3"	118'2"	11.09	10"×6"	10½"×6½"	" " "
								Ave	477									

SCREEN DISTANCES RDS 1-3

Rd	1st Vel Screen	2nd Vel Screen		1st Shorting Screen	2nd Shorting Screen
1	64.8'	62.2'	350.83'	58.9'	
2	64.67'	62.5'	350.66'	44.5'	
3 (out)	64.83'	62.0'	351.0'	34.17'	

SCREEN DISTANCES RDS 4-10

Rd				
5	65.83'	64.67'	133.76'	36.08'
6	65.83'	64.67'	133.75'	20.67'
7	65.83'	64.67'	133.75'	21.5'
8	65.83'	64.67'	133.75'	21.5'
9	65.83'	64.67'	119.75'	14.0'

SCREEN DISTANCES RDS 10-14

39.25'	50.42'	63.60'	32.83'
33'	49.60'	61.83	26.58'
33.58'	49.08'	62.83'	26.17'
38.50'	49.25'	62.66'	25.58'
38.25'	49.08'	61'	40.92'

Usually the round tumbled after graze as evidenced by size of openings. Most tees were broken off during graze. Rds 12 & 13 missed shorting screens after graze.