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SECURITY INFORMATION

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THIRTY-SECOND

PROGRESS REPORT

OF

THE FIRESTONE TIRE & RUBBER COMPANY

ON

105 MM. BATTALION ANTI-TANK PROJECT

UNDER

Contract No. DA-33-019-ORD-33

ORDNANCE DEPARTMENT PROJECTS

TS4-4020-WEAPONS AND ACCESSORIES

TM1-1540-AMMUNITION

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THE FIRESTONE TIRE & RUBBER COMPANY

Defense Research Division

Akron, Ohio

MARCH 1953

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SECURITY INFORMATION

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**THIRTY-SECOND
PROGRESS REPORT
OF
THE FIRESTONE TIRE & RUBBER CO.
ON
105 MM BATTALION ANTI-TANK PROJECT**

**Contract Nos.
DA-33-019-ORD-33 (Negotiated)
DA-33-019-ORD-1202**

**RAD Nos. ORDTS 1-12383
ORDTS 3-3955
ORDTS 3-3957
ORDTA 3-3952**

**THE FIRESTONE TIRE & RUBBER CO.
Defense Research Division
Akron, Ohio
MARCH, 1953**

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ABSTRACT

An inventory is presented of the recoilless rifles and mounts manufactured by Firestone Defense Research Division for its own research and development activities.

The main revised features of a new T137 rifle are described. The rifle is to be released for manufacture in April.

An aluminum T152E4 mount is being made.

The design of a firing system for the ONTOS vehicle has been completed.

Projectiles of the T138E57 type, for evaluating the effect upon flight behavior of spin rate and center of gravity location, have been manufactured and long range firing tests are being arranged.

The fin-opening piston for the T119 projectile has been redesigned and tested. The piston is illustrated and the test data presented.

A laminated cartridge case liner for the T119 cartridge assembly has been developed and tested. The liners are shown and preliminary test results presented.

An accuracy firing with a revised T119 projectile having fins two inches shorter than normal is reported. Additional tests with short fins are planned.

Data are presented for the penetration-standoff behavior of a 90mm size cone of the DRB398 type.

The effect of standoff on drawn, recoined and machined liners is described. The inspection and penetration data are given.

A program to evaluate the performance of composite or bimetal cones has been completed and the results are presented.

The T267 superquick and delay fuze has been redesigned to improve ease of initiation. The revisions are illustrated and test results described.

Tests conducted with T223E2 mechanical superquick and delay fuzes are reported.

Functioning tests of the DRA726 nose element in T138E57 and T119 E11 HEAT projectiles were conducted at Aberdeen Proving Ground. The tests are summarized.

A summary is presented, listing the items delivered to specified government agencies for their evaluation and use.

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THE WEAPON SYSTEM

An inventory of T137 rifles and T152 mounts, manufactured by Firestone Defense Research Division for its own research and development activities, is given in Table I. Additional rifles and

mounts, manufactured by Firestone, have been delivered to other installations for their own use and these are recorded in the final section of this report.

Table I

Inventory of Recoilless Rifles and Mounts

*Manufactured by Firestone and Used in Research and Development Activities
of Defense Research Division*

<u>Rifle or Mount</u>	<u>Location</u>	<u>Comments</u>
RIFLES		
<u>T137E3 Rifles</u>		
Serial Nos. 1 & 2	Akron	Returned from Fort Benning
No. 13	Aberdeen Proving Ground	Test Facility
Nos. 21 & 22	Akron	For Spare Parts
<u>T137E2 Rifles</u>		
Serial No. 1	Akron	For Spare Parts
No. 2	Erie Ordnance Depot	Test Facility
<u>T137E1 Rifles</u>		
Serial Nos. 1, 2 & 3	Usable parts removed and remainder scrapped	
No. 4	Watertown Arsenal	Metallurgical Study
Nos. 5, 6, 7	Usable parts removed and remainder scrapped	
No. 8	Akron	Held for historical value
<u>T137 Rifle</u>		
Serial No. 1	Usable parts removed and remainder scrapped	
MOUNTS		
<u>T152E5 Mounts</u>		
Serial Nos. 1 and 2	Akron	
No. 3	Aberdeen Proving Ground	
<u>T152E3 Mounts</u>		
Serial No. 1	Usable parts removed and remainder scrapped	
Nos. 2 & 3	Converted to E4	
No. 4	Usable parts removed and remainder scrapped	
<u>T152E2 Mounts</u>		
Serial Nos. 1 and 2	Usable parts removed and remainder scrapped	
<u>T152E1 Mount</u>		
Serial No. 1	Usable parts removed and remainder scrapped	
<u>T152 Mount</u>		
Serial No. 1	Usable parts removed and remainder scrapped	

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The T137 Rifle

Drawings of a redesigned T137 rifle (described in Thirty-First Progress Report) will be released for manufacture during the month of April. The basic design features of the T137E3 rifle have been retained with the following revisions:

(1) The chamber contour has been changed in the attempt to improve gas flow in the chamber.

(2) The breakdown joint has been made selective, so the rifle may be removed from the cradle in one piece if desired.

(3) A gas seal has been incorporated into the breakdown joint.

Preliminary firings at Erie Ordnance Depot show the seal to be effective. Additional tests are planned.

The T152 Mount

A new mount is being made of aluminum. The carriage has the same basic design as the T152E4 mount but two tripods are planned. One tripod made entirely of aluminum has two wheels for man-tow on the ground; the second is the standard T152E4 light weight steel tripod. This mount has a new firing control system which requires much less trigger effort to fire either the major or minor caliber rifle.

The ONTOS Firing System

The design of the firing system for the ONTOS vehicle, outlined in the Thirty-First Progress Report, has been completed. All parts necessary to equip one vehicle for test have been ordered and are scheduled for completion by April 15. When completed the system will be installed on a vehicle at Aberdeen Proving Ground for test.

Future Program

1. Continue test firing to evaluate the gas seal at the breakdown joint.

2. Continue test firing in pressure-station rifle.

3. Prepare new design layouts of rifles and mounts for ultimate BAT system.

4. Redesign the spotting rifle mount to use a T45 spotting rifle.

5. Complete calculations, now in process, to determine the ballistic requirements for the ultimate BAT system objectives.

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T138 PROJECTILE

Projectiles for determining the effect of center of gravity location and spin rate on the accuracy of the T138 projectile (Twenty-Ninth Progress Report) have been manufactured. The future program is being amplified to include

long range accuracy tests. Adequate range facilities are available at Aberdeen Proving Ground and a request for authorization to carry out these tests at that place is being formulated.

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T119 PROJECTILE

Design of Fin-Opening Piston, P-84787C

The Thirtieth Progress Report presented data showing that the fin-opening piston, DRB198, had marginal strength when used without heat treating but was satisfactory after a suitable heat treatment. The piston has been redesigned as shown in Fig. 1. The more generous radii and greater wall thickness of the new design have increased the strength considerably and heat treatment is not required.

These new pistons were tested at Erie Ordnance Depot by firing five projectiles, T119E11, at 115% of service pressure. The pistons were not heat treated. Yaw card measurements of the fin cuts and an inspection of the recovered pistons showed them to be satisfactory. The firing data are presented in Table II.

Cartridge Case Liner Development

The cartridge case liner used at the present time in the T119E11 round consists of an inner viscose rayon sleeve and an outer polyethylene sleeve which are sewed and heat-sealed, respectively, to polyethylene end rings to form a single assembly. A study is being conducted in an effort to improve this liner, DRC479, with respect to ease of manufacture, ease of assembly to the cartridge case, better complete round sealing, and better resistance to powder abrasion. Combining the rayon and polyethylene into a single laminated sheet appeared a promising means of accomplishing these objectives. It was learned that Picatinny Arsenal had a laminated liner consisting of a sheet of viscose rayon, sandwiched between sheets of polyethylene, under development. A liner incorporating such a laminate has been prepared for the T119E11 cartridge and is shown in Fig. 2.

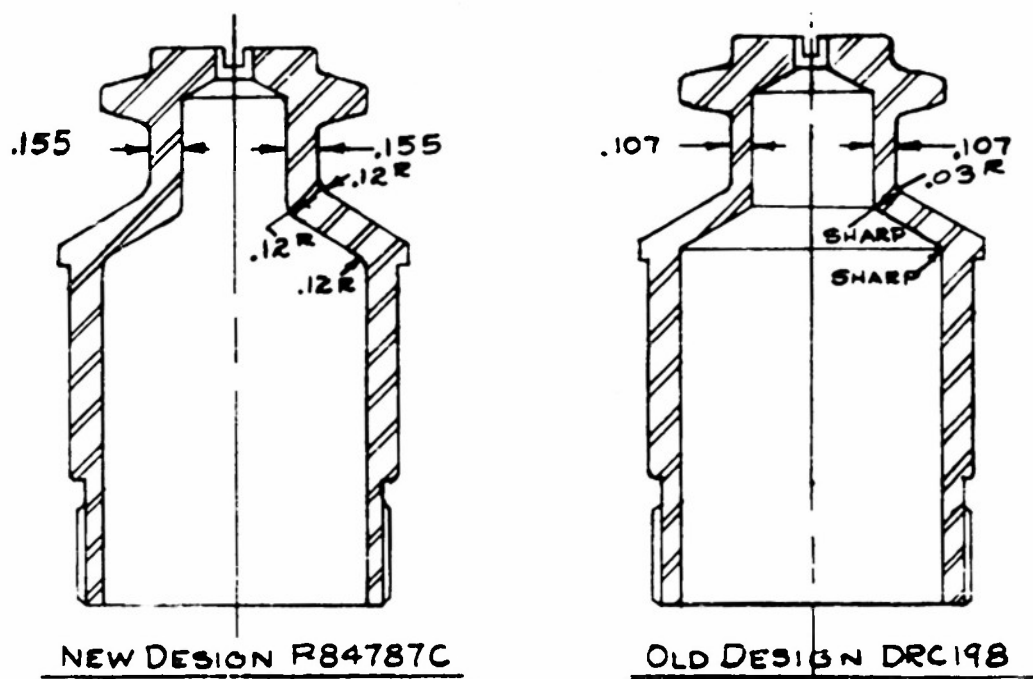


Fig. 1. Cross Sections of Fin-Opening Pistons.
For T119 Projectile.

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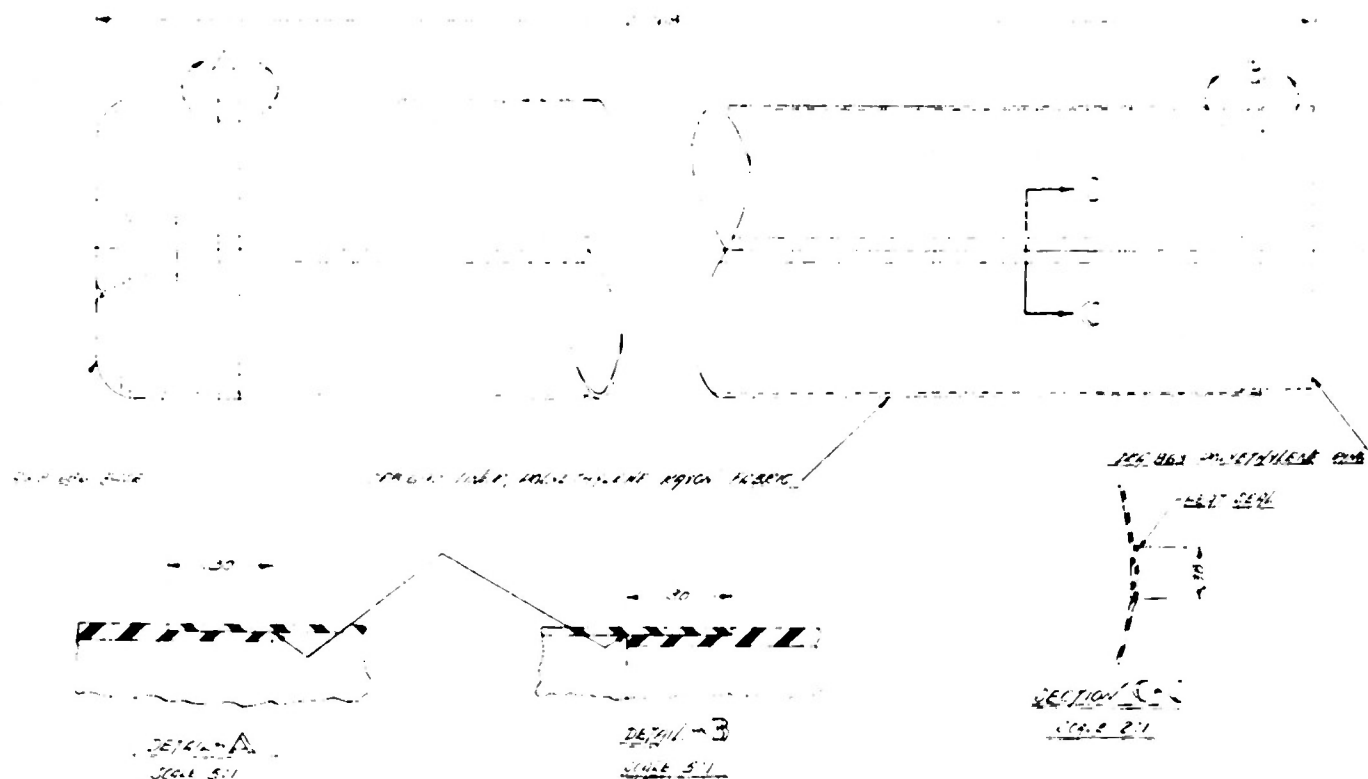


Fig. 2. Laminated Case Liner for T119E11 Cartridge.

Firestone Drawing No. DRC545.

Two samples of laminated polyethylene rayon, 4.60 and 4.73 ozs/sq yd, were obtained for preliminary testing. The sheets were heat-sealed to form simple tapered sleeves which conformed to the inside of the T53E1 cartridge case. The liners were tested to determine their effect on gun ballistics and to determine whether burning of the liner was complete. The present liner, DRC479, was used as a control. The tests were fired in conjunction with fuze tests and the range data are given in Table III. The internal ballistic data are summarized in Table IV.

The different case liners did not cause any appreciable difference in either muzzle velocity or peak pressure but there were slight differences in recoil.

The laminated sheets did not burn as completely as the DRC479 liners, but the few fragments which remained in the gun did not interfere with loading. A laminate with lighter rayon, 3 ozs/sq yd, is being made for additional tests.

Samples of the new laminated liners (DRC545), as shown in Fig. 2, are being manufactured and should be available for tests during April 1953.

Accuracy of T119 Projectiles With Short Fins

To evaluate the effect of fin length on projectile performance, a group of standard T119E11 projectiles were modified by cutting 2 inches off the trailing tips of the fins. The standard fin is 8.92 inches long. The short-finned projectiles were fired alternately with T119E11 projectiles at a target placed at 1049 yards. The range data are given in Table V.

The accuracy of the short-finned projectiles compared favorably with that of the T119E11 projectiles. For twelve T119E11 projectiles, the probable error of the dispersion was .35 mil vertical and .81 mil horizontal. For nine short-finned rounds, the probable error of the dispersion was .67 mil vertical and .45 mil horizontal. One short-finned round has a

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very low velocity and when the vertical impact point for this round is corrected to the mean velocity of the other eight rounds, the probable error of the vertical dispersion is reduced to .33 mil.

These results with the short-finned round are very encouraging and projectiles with still shorter fins are being prepared for tests.

Projectile Shipments

T119 projectiles manufactured by Firestone and shipped to other installations for purposes not controlled directly by Firestone Defense Research personnel and where custody is transferred are listed in the final section of this report - Manufacturing Summary.

Future Program

1. The study of the effect of fin length on T119 projectile accuracy will be continued. A group of projectiles with fins shortened four inches has been ordered.

2. The manufacture of projectiles with long and short ogives is continuing. These projectiles will be used to determine the effect of ogive length on flight characteristics.

3. Twenty multipiece cases, M32, have been obtained and some of these have been heat-treated. These cases will be tested for strength to determine if they are suitable for BAT ammunition.

4. Projectiles with fewer than six fins will be tested. Components for four-finned and five-finned projectiles are being manufactured.

Table II
Firing Test Data
Strength Test On Fin-Opening Piston
T119 Projectile, P-84787C Piston

DATE 3-9-53 Program SUPP T-119 C2

PROJECTILE T-119 **SCREEN DISTANCES** 223' **RECOVERY** 90'

PROJ. No. 4590 **Model** T-119

Type Ell. Blunt Nose **Weight (Nominal)** 17.56

C.G. Location 4.125 **Special Features** Piston

Barrel Dia (Nom.) 4.125 **Retardation Factor** 0.4 ft/sec/ft

Temperatures
Map Temp Max 75°F
Min 75°F
Pres 75°F
Loading Room 75°F
Ambient 39°F

TEST GUN
Model T-137E3 **No.** 1
Type 205mm Recoilless
Length of Tube 105'
Twist of Rifling 1-20
Sighting Equipment M-17 Adapted Telescope

Bore Dia (Lands) 4.139 **r.001**
Tube 228-849-C
Chamber 228-775-B
Vent Ring 228-81-X A
Pendulum Mount

MISCELLANEOUS DATA
Range Recovery 90'
Propellant PA3034 **M-57 Primer**
Type mm 10 web .0335m Charge Wt 81bs .500
Proof Director E. Muzzman
Observers A. Mearce
T-53 F1 Cates Rayant Polyethylene Liner

Round No	Proj. No.	Proj. Weight (lb)	Powder Charge (lb)	Recoil (in)	Chamber Pressure (psi)	Muzzle Velocity (ft/sec)	Elev. (mils)	Fired	Condition of Piston after Firing	Fin Spread (in.)			Observations
										1st Yaw Card	2nd Yaw Card	3rd Yaw Card	
4590	1	17.54	0.5	1 1/2"	15,000	1710	1761	Solenoid	No Deformation	10 1/2 x 10 1/2	10 1/2 x 10 1/2	10 1/2 x 10 1/2	Slight Yaw
4591	2	17.54	0.5	3/4"	11,000	1645	1700	Solenoid	No Deformation	10 1/2 x 10 1/2	10 1/2 x 10 1/2	10 1/2 x 10 1/2	Slight Yaw
4592	3	17.56	0.5	3/4"	12,000	1715	1758	Solenoid	No Deformation	10 1/2 x 11	10 1/2 x 10 1/2	11 x 11	Slight Yaw
4593	4	17.56	0.5	1"	12,000	1702	1745	Solenoid	No Deformation	10 1/2 x 10 1/2	10 1/2 x 10 1/2	10 1/2 x 10 1/2	Slight Yaw
4594	5	17.56	0.5	9/16"	12,000	1708	1751	Solenoid	No Deformation	10 1/2 x 10 1/2	10 1/2 x 10 1/2	10 1/2 x 10 1/2	Slight Yaw
Notes: <u>Fin spread pictures were taken of first round.</u> <u>Yaw cards were placed on the first and second screens</u> <u>and on the front of the recovery box.</u> <u>Allowable fin spread variation: 10.55 to 10.82 inches.</u> <u>Internal m-3 (w)</u>													

Signed O. Miller

Table III
Firing Test Data
To Test Laminated Case Liner, DRC545

6100' 92.25' 145 Mts. 4' Screen
 PROJECTILE 11.34 11.34 11.34
 Model T-138
 Type 5-1/4
 Weight (Nominal) 17.30
 C.G. Location Bourrelet Die (Model 4132 - 002)
 Special Features Band 500.6

TEMPERATURES
 May Temp. 70° F.
 Max. 70° F.
 Min. 70° F.
 Pres. 70° F.
 Loading Room 10° F.
 Ambient 67° F.
 Late Afternoon

TEST GUN
 Model T-137.5
 Type 105mm Recoilless
 Length of Tube 105"
 Twist of Rifling 1-200
 Sighting Equipment M-17 Adapted
 Telescope
 Bore Dia. (Lands) 3.125 inch

MISCELLANEOUS DATA
 Range 200 Yds.
 Propellant OAC 230 Armer T-3616-400
 Type M100M 230.0355 Charge Wt. 0.101 230
 1/23 21 Cases

Proof Director J. Chappay
 Observers On Line M. Russell R. Burus
 R. M. Lee

Pendulum Constant = 2.00 lbs.-sec/in.
 Lanyard fired Mechanical

Round No	Liner Type	Proj. Weight (lbs.)	Fuze No.	Recoil	Chamber Pressure (psi.)	Muzzle Velocity (ft/sec)	Powder Depth (in)	Piezo Pressure Gage No. 105	Chamber Inspection After Firing	Fuze Type	Observations
4615	1 OAC 472	17.34	6	3 1/2 R	10,300	1598	4 1/2	11,100	Chamber and Bore Clean	T-227E13 Delay	Functioned
4616	2	17.34	5	14 1/2 R	9,700	1600	4 1/2	11,100	Chamber and Bore Clean	T-227E13 Super Gun	Functioned
4617	3	17.34	4	5 1/2 R	9,700	1560	4 1/2	11,100	Chamber and Bore Clean	T-227E13 Delay	Functioned
4618	4	17.34	1	15 1/2 R	9,700	1576	4 1/2	11,100	Chamber and Bore Clean	T-227E13 Delay	Failed to Function
4619	5	17.34	5	5 1/2 R	9,700	1605	4 1/2	11,100	Chamber and Bore Clean	T-227E13 Delay	Failed to Function
4620	6	17.34	7	7 1/2 R	9,700	1608	4 1/2	11,100	Chamber and Bore Clean	T-227E13 Delay	Functioned
4621	7	17.34	2	15 1/2 R	9,700	1609	4 1/2	11,100	Chamber and Bore Clean	T-227E13 Delay	Functioned
4622	8	17.34	26	15 1/2 R	9,700	1609	4 1/2	11,100	Chamber and Bore Clean	T-227E13 Delay	Failed to Function
4623	9	17.34	21	6 R	9,700	1576	4 1/2	11,100	Chamber and Bore Clean	T-227E13 Delay	Functioned
4624	10	17.34	23	7 1/2 R	9,700	1612	4 1/2	11,100	Chamber and Bore Clean	T-227E13 Delay	Functioned
4625	11	17.34	25	11 R	9,700	1600	4 1/2	11,100	Chamber and Bore Clean	T-227E13 Delay	Not Observed
4626	12	17.34	28	6 1/2 R	9,700	1578	4 1/2	11,100	Chamber and Bore Clean	T-227E13 Delay	Missed Screen
4627	13	17.34	22	12 1/2 R	9,700	1619	4 1/2	11,100	Chamber and Bore Clean	T-227E13 Delay	Functioned
4628	14	17.34	29	10 1/2 R	9,700	1621	4 1/2	11,100	Chamber and Bore Clean	T-227E13 Delay	Failed to Function
4629	15	17.34	29	6 R	9,700	1589	4 1/2	11,100	Chamber and Bore Clean	T-227E13 Delay	Failed to Function
4630	16	17.34	21	13 1/2 R	9,700	1608	4 1/2	11,100	Chamber and Bore Clean	T-227E13 Delay	Functioned
4631	17	17.34	30	8 1/2 R	9,700	1596	4 1/2	11,100	Chamber and Bore Clean	T-227E13 Delay	Functioned

Signed O Miller

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Table IV
Internal Ballistic Data
Cartridge Case Liner Tests

Round No.	Liner	Recoil (in.)	Internal M3 Pressure	Muzzle Velocity (ft/sec)
1	T119 DRC479	3 3/4 R	9,900	1626
2	"	14 1/2 R	8,750	1628
3	"	5 1/4 R	9,700	1597
4	"	13 3/4 R	9,000	1604
5	"	3 1/2 R	10,000	1633
6	"	7 1/4 R	9,500	1636
7	"	13 3/4 R	9,550	1631
Average		8.82 R	9,500	1622
8	Type A	13 R	9,850	1632
9	"	6 R	9,600	1604
12	"	6 1/2 R	8,950	1606
13	"	12 1/4 R	9,700	1657
14	"	10 1/4 R	10,050	1649
Average		9.6 R	9,600	1630
10	Type B	7 1/4 R	9,550	1600
11	"	11 R	9,700	1628
15	"	6 R	9,500	1615
16	"	13 1/4 R	9,250	1636
17	"	8 1/4 R	--	1624
Average		9.15 R	9,500	1621
Notes: Liner DRC479 - separate sleeves - polyethylene .005 in. thick and rayon, 5.00 to 5.75 ozs/sq yd, Spec. PA-PD-29. Liner Type A - laminate of rayon, 4.73 ozs/sq yd, between polyethylene sheets, .002 in.thick. Liner Type B - laminate of rayon, 4.60 ozs/ sq yd, between polyethylene sheets, .002 in.thick.				

Table V
Range Data
Accuracy of T119 Projectiles With Short Fins

PROJECTILE T 119 **SCREEN** 4500' **DISTANCES** 152.5' **DATE OF TEST** March 25, 1953

Model T 119 **TEST GUN** Model T-137 E 3 #2 **Purpose of Test** Effect of fin length on accuracy of T-119 Projectile

Type Li with standard 8.92 inch fin and Li with short 6.92 inch fin **Program** Supp. T119 C2

Weight 175.2 lbs. **Serial No.** 22.0 - 342 **Chamber** 22.0 - 342

C.G. Location 4.134" from base **Bushing (Vent)** 22.0550-0.4 **22.0 - 342 - L-4**

Barrel: Dia 4.132" dia **Tube** 22.0 - 342 - L-4 **Sighting Equipment** ASB-18 Sight on T-119 Mount

Specia. Features Variable fin length **Mount** T-153 EF **Serial** 1

MISCELLANEOUS DATA

Range 152.5 yds **Line of sight** 152.5 yds

Propellant (Cordite from Republic Arms)

Type M.P. 22 **Web** 0.645 **Weight** 8.92 lbs.

Lot No 240 21A

Primer 7-53 E

Shell Case 7-53 E

Liner ASL 422

Temperature

Muzzle Max 70° Min 70° Present 70°

Loading Room 72° Ambient 72°

Round No	Time of Flight	Proj Weight (lb.)	Proj Number	Wind Vel & Dir	Normal Wind Component	Muzzle Velocity ft/sec	Position of Hit (inches)		Corrected Position of Hit - mile	Chamber Pressure	Fin Diameter	Observations
							Vert	Horiz				
4635 1			1287	10 270	2.9	1596	39	0 23 1/2	0 100	10,420	10 1/2, 10 3/4	
4636 2			1288	13 280	11.8	1578	-72			9,971		Full shot and about 1 mile, after
4637 3			1289	14 280	12.4	1590	-72			10,290		of center, lower right
4638 4			1290	14 280	9.2	1591	-72			10,640		appeared to be slightly higher
4639 5			1291	14 275	11.7	1590	-72			10,291		than the 1st of the group
4640 6			1292	14 275	8.3	1592	-72			10,312		
4641 7			1293	14 270	5.8	1594	-72			10,133		
4642 8			1294	14 280	8.8	1592	-72			10,400		
4643 9			1295	14 280	8.3	1592	-72			9,957		
4644 10			1296	14 260	8.4	1597	-72			9,910		
4645 11			1297	14 270	3.6	1598	-72			9,729		
4646 12			1298	14 270	3.7	1600	-72			10,579		
4647 13			1299	14 270	3.8	1597	-72			10,102		
4648 14			1300	14 260	11.4	1597	-72			10,623		Omitted from PG - Low velocity
4649 15			1301	14 260	12.9	1592	-72			10,443		
4650 16			1302	14 270	5.8	1591	-72			11,771		
4651 17			1303	14 270	8.7	1599	-72			11,003		
4652 18			1304	14 270	10.7	1598	-72					
4653 19			1305	14 270	11.0	1598	-72					
4654 20			1306	14 270	13.4	1598	-72					
4655 21			1307	14 270	17.8	1591	-72					
4656 22			1308	14 270	14.1	1592	-72					

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PENETRATION STUDIES

Scaling Studies

The penetration-standoff behavior of DRB398 copper cones, modified by cutting off the base to a diameter suitable for use in a 90mm projectile, was described in the Twenty-Fifth Progress Report. This program has continued and the penetration-spin rate studies have been completed. The cones and test assemblies, Figs.

3 and 4, employed in this program are identical with those used in the standoff study. The penetration data are shown in Table VI and in Fig. 5. The behavior of the unmodified 105mm cone and charge is also shown in Fig. 5 for comparison. There is nothing unusual in these data; the loss in penetration caused by rotation is about that to be expected.

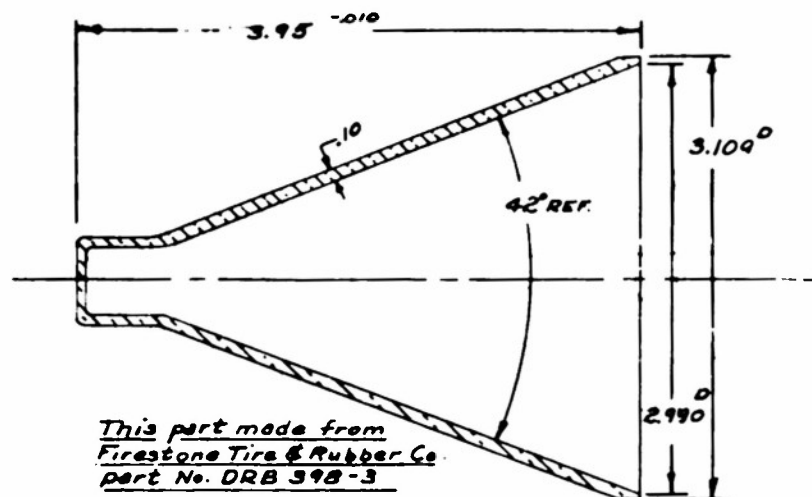


Fig. 3. Modified DRB398 Cone.

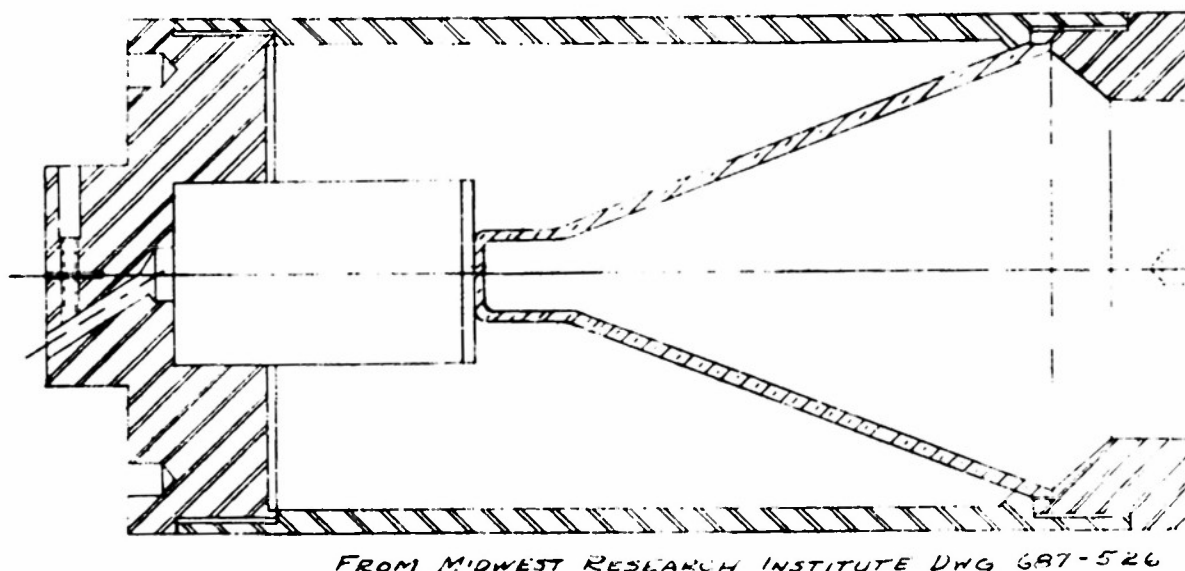


Fig. 4. Test Assembly for 90 mm. Tests.

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Table VI
Penetration Data
90 mm. Test Projectiles

Round No.	Concetricity Cone Tip T.I.R.	Lbs. Comp. B	Standoff (in.)	Rate (rev. c)	Penetration (inches M.S.)	Max. Spread (in.)	Std. Dev. (in.)
MR I 18	.007	1.76	6.5	0	16.94		
MR I 19	.004	1.78	6.50	0	16.18		
MR I 20	.017	1.76	6.50	0	16.06		
					Avg. 16.39	0.88	±.48
MR I 21	.025	1.80	6.50	15	14.75		
MR I 22	.019	1.76	6.50	15	15.94		
MR I 23	.018	1.76	6.50	15	low order		
					Avg. 15.35	1.19	--
MR I 15	.014	1.74	6.50	30	11.31		
MR I 16	.007	1.76	6.50	30	11.75		
MR I 17	.012	1.78	6.50	30	11.38		
					Avg. 11.48	0.44	±.24
MR I 12	.013	1.78	6.50	45	7.18		
MR I 13	.010	1.78	6.50	45	8.25		
MR I 14	.025	1.76	6.50	45	9.62		
					Avg. 8.35	2.44	±1.22

Notes:

1. DRB398 drawn copper cones modified to 3.109 inches base diameter.
2. Penetration Test Base Elements were used. See Fig. 12, Twenty-Third Progress Report.
3. Loaded at Ravenna Arsenal, BAT Lot No. 26, with Composition B from Holston Lot No. 3-126.
4. Tested at Erie Ordnance Depot.

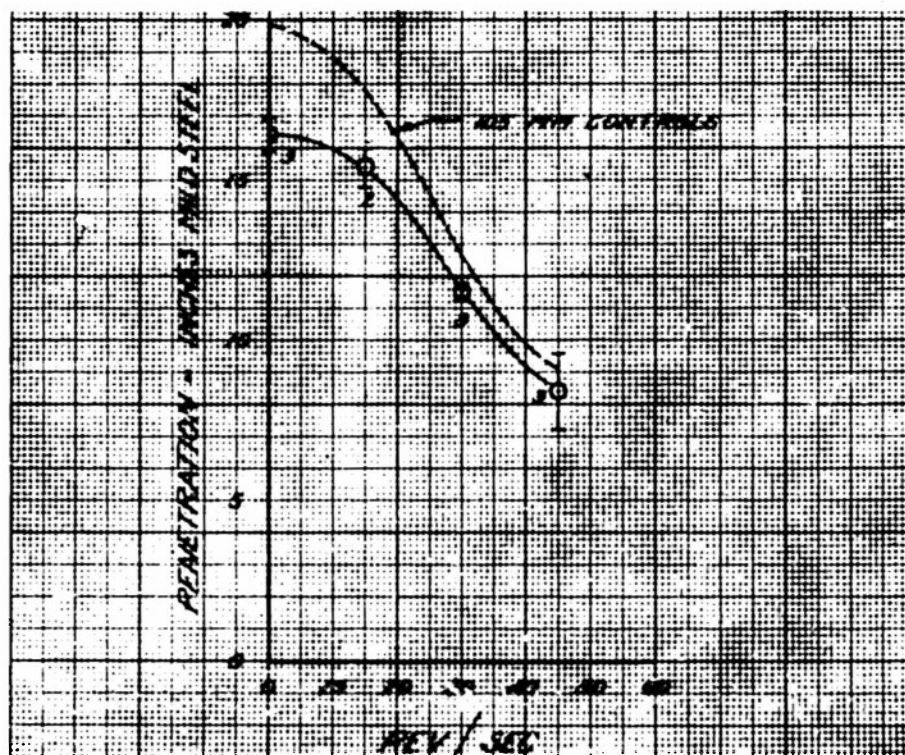


Fig. 5. Penetration Versus Rotation.
MR: 90 mm. Test Projectile; 105 mm. Controls.

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Effect of Standoff Drawn, Machined and Recoined Cones

Three types of copper cones, each representing a different type of manufacturing history, have been tested for penetration into mild steel target placed at various standoff distances. The cone types are as follows: (1) drawn from copper strip, (2) drawn from copper strip and recoined between matching steel dies at a total load of 900 tons, and (3) machined from hard drawn copper bar. The "as drawn" copper cones are given three coining operations in the normal course of operation, but these are at a maximum load of about 125 tons. At such loads the walls are straightened but the copper does not flow and the "structure" of the cone is essentially that of the initial plate. The "recoining" operation at high pressure causes a considerable amount of flow of the copper and it is therefore assumed that the structure is considerably different from that of the initially drawn cone. The machined cones have the structure of cold drawn copper bar from which they were made and this is, of course, different from either the drawn or recoined cones. From the point of view of transverse structural symmetry, however, the machined cone should be the most uniform, followed in order by the recoined cones and the drawn cones.

The inspection data are shown in Tables VII to IX, inclusive, and the penetration data in Tables X to XII, inclusive. The penetration-standoff curves for these cones are shown in Fig. 6.

The inspection data show quite clearly that the machined cones are much more precisely made than either the drawn or recoined cones, but they do not disclose any improvement in the dimensional precision of the drawn cones as a result of

the recoining operation. However, a visual comparison of the drawn and recoined liners does disclose one difference which may be of importance. The wall waviness in the "as drawn" cones occurs as a series of more or less sharp steps, but in the recoining operation these steps are smoothed out and cannot be detected without instruments.

The penetration data show striking differences in the performance of these three series of cones at long standoff distances, but little difference at short or optimum standoff. The optimum for these cones and test assemblies is 15 inches (4.5 C.D.) and at this distance the penetration for all cones averages 21.5 inches of mild steel (6.5 C.D.). At a standoff of 42 inches (12.7 C.D.) the average penetration of the machined cones is 20.5 inches, the recoined cones, 17.5 inches and the drawn cones, 13.2 inches. As the standoff increases beyond the optimum the penetration data show an increasing scatter - the good penetrations are as high as at the optimum standoff but the number or proportion of bad penetrations increases. It is thought that slight imperfections in the symmetry of the cone geometry and structure cause the jet to waver and that at long standoffs, where the jet has broken into particles, the waver causes a scattering of the jet which in turn results in poorer penetration.

Although there is a striking difference in the performance of the drawn and machined cones it should be emphasized that at standoffs which can be built into conventional projectiles the drawn cones are as satisfactory as machined cones. If, however, some sort of proximity fuze could be developed, or if large spacings can be built into spaced armor, the perfection of the machined cone may become necessary.

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Table VII
Inspection Data For DRB398 Liners
"As Drawn" Cones

Cone No.	Wall Thickness - inches			Max.Var.Wall Thick.		Max.Wall Waviness		Concentricity (in.)	
	Max.	Min.	Avg	Trans.	Long.	I.D.	O.D.	Lower Datum	Upper Datum
Q785	.108	.104	.1062	.0015	.0030	.0025	.0015	.0065	.0070
Q786	.109	.104	.1063	.0010	.0050	.0020	.0015	.0020	.0035
Q787	.109	.105	.1068	.0010	.0040	.0015	.0010	.0020	.0015
Q788	.107	.103	.1049	.0010	.0035	.0020	.0015	.0040	.0025
Q789	.107	.102	.1056	.0010	.0040	.0030	.0015	.0040	.0025
Q790	.109	.105	.1069	.0020	.0020	.0030	.0010	.0025	.0030
Q791	.107	.103	.1059	.0025	.0040	.0040	.0015	.0015	.0020
Q792	.107	.103	.1051	.0020	.0040	.0050	.0020	.0020	.0040
Q793	.107	.104	.1051	.0015	.0030	.0020	.0005	.0040	.0010
Q794	.109	.105	.1070	.0020	.0020	.0020	.0010	.0040	.0030
Q795	.107	.103	.1052	.0020	.0025	.0020	.0005	.0040	.0035
Q796	.107	.104	.1058	.0010	.0025	.0020	.0005	.0030	.0025
Q797	.107	.104	.1052	.0010	.0030	.0020	.0005	.0025	.0080
Q798	.107	.105	.1060	.0020	.0025	.0025	.0005	.0025	.0065
Q799	.108	.104	.1057	.0020	.0040	.0040	.0010	.0020	.0015
Q800	.107	.105	.1061	.0020	.0015	.0020	.0005	.0020	.0055
Q801	.107	.104	.1058	.0025	.0025	.0020	.0010	.0025	.0030
Q802	.108	.106	.1072	.0015	.0020	.0025	.0025	.0035	.0065
Q803	.108	.104	.1063	.0025	.0040	.0030	.0030	.0025	.0015
Q804	.108	.104	.1061	.0020	.0030	.0030	.0015	.0025	.0065
Q805	.108	.105	.1067	.0030	.0020	.0010	.0015	.0040	.0015
Q806	.107	.105	.1060	.0010	.0020	.0030	.0020	.0015	.0010
Q807	.106	.102	.1039	.0015	.0040	.0030	.0020	.0020	.0035
Q808	.109	.102	.1046	.0030	.0060	.0065	.0010	.0080	.0060
Q809	.108	.105	.1069	.0015	.0030	.0020	.0020	.0020	.0085
Q810	.106	.104	.1053	.0020	.0015	.0030	.0010	.0035	.0070
Q811	.107	.103	.1048	.0015	.0040	.0030	.0030	.0020	.0050
Q812	.107	.103	.1052	.0010	.0040	.0040	.0015	.0015	.0030
Q813	.108	.105	.1068	.0025	.0030	.0025	.0015	.0050	.0060
Q814	.108	.103	.1058	.0020	.0040	.0030	.0025	.0030	.0030
Q815	.107	.102	.1051	.0025	.0035	.0035	.0015	.0055	.0070
Q816	.107	.102	.1050	.0030	.0050	.0025	.0020	.0055	.0100
Q817	.108	.105	.1068	.0015	.0030	.0025	.0015	.0025	.0070
Q818	.107	.103	.1051	.0020	.0040	.0040	.0015	.0010	.0035
Q819	.105	.102	.1038	.0020	.0025	.0030	.0010	.0020	.0050
Q820	.106	.104	.1056	.0025	.0020	.0025	.0010	.0055	.0065
Q821	.108	.106	.1071	.0005	.0010	.0020	.0010	.0015	.0035
Q822	.108	.104	.1062	.0015	.0030	.0030	.0020	.0035	.0035
Q823	.109	.103	.1063	.0040	.0030	.0035	.0010	.0030	.0035
Q824	.108	.103	.1050	.0040	.0030	.0035	.0010	.0055	.0055
Q825	.106	.104	.1054	.0020	.0020	.0020	.0020	.0045	.0035
Q826	.108	.104	.1064	.0015	.0035	.0035	.0015	.0045	.0040
Q827	.106	.104	.1049	.0010	.0020	.0040	.0010	.0025	.0065
Q828	.106	.102	.1046	.0040	.0040	.0045	.0020	.0035	.0015
Q829	.108	.105	.1064	.0010	.0030	.0020	.0020	.0040	.0045
Q830	.108	.105	.1064	.0020	.0030	.0030	.0020	.0045	.0050
Q831	.108	.105	.1066	.0020	.0020	.0020	.0015	.0035	.0010
Q832	.108	.102	.1052	.0050	.0030	.0040	.0015	.0015	.0020
Q833	.109	.105	.1074	.0040	.0020	.0030	.0010	.0025	.0045
Q834	.107	.105	.1061	.0020	.0020	.0020	.0010	.0050	.0060
Avg.	.1075	.1039	.1058	.0020	.0030	.0029	.0014	.0033	.0061
Std. Dev.	±.0009	±.0011	±.0008	±.0009	±.0008	±.0014	±.0006	±.0015	±.0029
Specifications:									
	.105	.100	--	.0020	.0060	.0060	.0060	.0030	.0030
Notes:									
1. Variation in straightness or thickness of wall shall not exceed .006 in any axial plane.									
2. Variation of wall thickness in any transverse plane shall not exceed .002.									
3. The indicated measurement at each datum is the total indicator runout of the liner's outside surface relative to the register diameter. The difference between the runout at the two datum planes is an indication of the lack of perpendicularity of the register plane and the liner axis.									
4. Lower datum is .484 inch above the base; upper datum 3.202 inches above base.									

Table VIII
Inspection Data For DRB398 Liners
Received Cones

Cone No.	Wall Thickness (in.)			Max. Variation W.T.		Max. Wall Waviness		Concentricity (T.I.R.)		Datum Diam. (O.D.)	
	Max.	Min.	Ave.	Trans.	Long.	I.D.	O.D.	Lower	Upper	Lower	Upper
DRB398 Spec	.105	.100	--	.002	.006	.006	.006	.0030	.0030	3.250 ^{±.0010}	1.164 ^{±.0010}
FS1090	.101	.097	.0993	.001	.003	.003	.002	.0045	.0030	3.218	1.154
FS1091	.102	.098	.1006	.002	.004	.004	.002	.0035	.0060	3.213	1.160
FS1092	.103	.099	.1012	.001	.004	.004	.002	.0025	.0020	3.215	1.165
FS1093	.104	.100	.1019	.002	.004	.003	.002	.0025	.0060	3.217	1.160
FS1094	.101	.099	.1000	.001	.001	.002	.002	.0030	.0030	3.215	1.164
FS1095	.105	.100	.1032	.003	.005	.006	.002	.0030	.0035	3.217	1.160
FS1096	.103	.095	.0995	.002	.008	.003	.002	.0030	.0070	3.216	1.160
FS1097	.105	.100	.1028	.002	.005	.005	.002	.0020	.0020	3.217	1.165
FS1098	.103	.100	.1016	.003	.003	.004	.002	.0030	.0035	3.215	1.161
FS1099	.100	.096	.0984	.003	.002	.002	.002	.0025	.0045	3.216	1.164
FS1100	.102	.099	.1002	.001	.003	.003	.003	.0035	.0030	3.217	1.166
FS1101	.101	.100	.1003	.001	.001	.002	.002	.0020	.0030	3.215	1.157
FS1102	.103	.099	.1009	.002	.004	.005	.002	.0035	.0050	3.216	1.165
FS1103	.102	.100	.1011	.001	.002	.003	.002	.0030	.0040	3.218	1.165
FS1104	.103	.099	.1011	.003	.003	.002	.002	.0020	.0020	3.220	1.160
Avg.	.1025	.0988	.1008	.0019	.0035	.0034	.0021	.0029	.0038	3.2163	1.1617
Std. Dev.	±.0015	±.0016	±.0013	±.0008	±.0019	±.0013	±.0026	±.0007	±.0016	±.0017	±.0035

Notes:

1. Variation in straightness or thickness of wall shall not exceed .006 in any axial plane.
2. Variation of wall thickness in any transverse plane shall not exceed .002.
3. The indicated measurement at each datum is the total indicator runoff of the liner's outside surface relative to the register diameter. The difference between the runoff at the two datum planes is an indication of the lack of perpendicularity of the register plane and the liner axis.
4. Lower datum is .484 inch above the base; upper datum 3.202 inches above base.

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Table IX
Inspection Data For DRB398-6 Liners
Machined Cones

Cone No.	Wall Thickness (in.)			Max. Variation W.T.		Max. Wall Waviness		Concentricity	
	Max.	Min.	Avg.	Trans.	Long.	I.D.	O.D.	Lower Datum	Upper Datum
FS-627	.1040	.1020	.1033	.0010	.0020	.0015	.0005	.0030	.0040
FS-628	.1060	.1035	.1051	.0020	.0025	.0030	.0010	.0050	.0030
FS-629	.1060	.1040	.1051	.0005	.0020	.0030	.0010	.0030	.0030
FS-630	.1060	.1030	.1046	.0005	.0030	.0040	.0015	.0030	.0020
FS-631	.1060	.1010	.1036	.0010	.0050	.0040	.0015	.0025	.0030
FS-632	.1060	.1045	.1052	.0010	.0015	.0020	.0010	.0080	.0100
FS-633	.1055	.1040	.1048	.0010	.0015	.0015	.0015	.0035	.0020
FS-634	.1030	.1025	.1029	.0005	.0005	.0015	.0000	.0030	.0025
FS-635	.1050	.1040	.1046	.0010	.0010	.0015	.0000	.0020	.0010
FS-636	.1020	.1000	.1009	.0005	.0015	.0020	.0000	.0030	.0045
FS-637	.1050	.0995	.1023	.0010	.0050	.0050	.0005	.0040	.0025
FS-638	.1090	.1050	.1068	.0010	.0040	.0050	.0005	.0040	.0045
FS-639	.1050	.1040	.1046	.0010	.0010	.0015	.0000	.0050	.0030
FS-640	.1060	.1040	.1048	.0010	.0020	.0025	.0005	.0030	.0030
FS-641	.1060	.1025	.1042	.0010	.0030	.0035	.0005	.0030	.0045
FS-642	.1065	.1050	.1058	.0010	.0015	.0020	.0005	.0020	.0025
FS-643	.1040	.1020	.1030	.0005	.0020	.0030	.0005	.0045	.0045
FS-644	.1065	.1040	.1055	.0015	.0020	.0010	.0000	.0040	.0020
FS-645	.1040	.1010	.1024	.0005	.0030	.0010	.0005	.0020	.0020
FS-646	.1065	.1040	.1053	.0010	.0015	.0020	.0005	.0030	.0015
FS-647	.1020	.1000	.1014	.0010	.0020	.0015	.0005	.0030	.0030
FS-648	.1080	.1050	.1066	.0005	.0030	.0030	.0010	.0030	.0010
FS-649	.1050	.1030	.1043	.0010	.0020	.0015	.0005	.0025	.0030
FS-650	.1050	.1035	.1043	.0010	.0015	.0010	.0005	.0040	.0045
FS-651	.1065	.1050	.1053	.0015	.0015	.0020	.0000	.0055	.0050
FS-652	.1060	.1040	.1051	.0010	.0020	.0025	.0005	.0020	.0030
FS-653	.1065	.1040	.1054	.0005	.0025	.0020	.0005	.0020	.0015
FS-654	.1050	.1020	.1038	.0010	.0030	.0030	.0000	.0080	.0080
FS-655	.1080	.1070	.1077	.0010	.0010	.0015	.0000	.0015	.0025
FS-656	.1040	.1030	.1033	.0010	.0010	.0015	.0005	.0030	.0015
FS-657	.1050	.1030	.1042	.0010	.0020	.0020	.0000	.0020	.0015
FS-658	.1050	.1040	.1047	.0010	.0010	.0015	.0005	.0025	.0015
FS-659	.0980	.0950	.0966	.0010	.0025	.0030	.0005	.0050	.0050
FS-660	.1055	.1050	.1051	.0005	.0005	.0010	.0000	.0025	.0015
FS-661	.1070	.1055	.1061	.0010	.0010	.0020	.0005	.0045	.0030
FS-662	.1045	.1035	.1041	.0005	.0010	.0010	.0000	.0040	.0010
FS-663	.1060	.1015	.1039	.0005	.0045	.0050	.0005	.0030	.0015
FS-664	.1045	.1020	.1031	.0005	.0025	.0025	.0000	.0035	.0030
FS-665	.1060	.1050	.1057	.0010	.0010	.0010	.0005	.0025	.0020
FS-666	.1040	.1010	.1025	.0010	.0025	.0030	.0005	.0035	.0030
FS-667	.1070	.1040	.1056	.0010	.0020	.0020	.0020	.0030	.0020
FS-668	.1030	.1010	.1021	.0010	.0020	.0020	.0010	.0030	.0030
FS-669	.1055	.1030	.1044	.0010	.0020	.0020	.0010	.0035	.0030
FS-670	.1055	.1040	.1049	.0015	.0015	.0025	.0050	.0040	.0040
FS-671	.1050	.1040	.1046	.0005	.0010	.0010	.0005	.0030	.0020
FS-672	.1060	.1040	.1050	.0000	.0020	.0020	.0000	.0035	.0050
FS-673	.1060	.1030	.1049	.0020	.0030	.0030	.0005	.0020	.0015
FS-674	.1075	.1040	.1057	.0010	.0035	.0040	.0010	.0020	.0020
FS-675	.1050	.1030	.1043	.0010	.0020	.0025	.0000	.0020	.0005
FS-676	.1065	.1050	.1056	.0050	.0015	.0020	.0005	.0020	.0010
FS-891	.1070	.1035	.1050	.0010	.0030	.0020	.0005	.0015	.0010
FS-892	.1080	.1035	.1055	.0010	.0045	.0045	.0005	.0045	.0035
FS-893	.1060	.1020	.1040	.0010	.0035	.0035	.0010	.0020	.0025
FS-894	.1045	.1030	.1039	.0010	.0015	.0020	.0050	.0040	.0040
FS-895	.1040	.1020	.1032	.0010	.0015	.0010	.0000	.0035	.0025
FS-896	.1010	.0975	.0994	.0005	.0035	.0035	.0000	.0035	.0070
FS-897	.1035	.1010	.1026	.0010	.0025	.0040	.0010	.0025	.0015
Avg.	.1053	.1030	.1042	.0010	.0022	.0024	.0007	.0033	.0029
Std. Dev.	±.0018	±.0020	±.0018	±.0006	±.0011	±.0011	±.0009	±.0013	±.0017
DRB-398-6	.1000	.1050	.0020	.0060	.0060	.0060	.0030	.0030	

Notes:

1. Variation in straightness or thickness of wall shall not exceed .006 in any axial plane.
2. Variation of wall thickness in any transverse plane shall not exceed .002.
3. The indicated measurement at each datum is the total indicator runout of the liner's outside surface relative to the register diameter. The difference between the runout at the two datum planes is an indication of the lack of perpendicularity of the register plane and the liner axis.
4. Lower datum is .484 inch above the base; upper datum is .202 inches above base.

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Table X
Penetration Data
"As Drawn" DRB398 Cones

Round No.	Lbs. Comp B	Standoff (in.)	Penetration (inches MS.)	Max. Spread (inches)	Std. Dev (inches)
FS851	2.58	4.0	19.31		
FS852	2.58	"	19.38		
FS853	2.60	"	19.18		
FS854	2.58	"	18.25		
FS855	2.60	"	18.19		
			Avg. 18.86	1.19	±0.59
FS856	2.58	7.5	21.00		
FS857	2.58	"	18.94		
FS858	2.60	"	22.18		
FS859	2.58	"	19.38		
FS860	2.58	"	19.38		
Q761	2.60	"	20.75		
Q764	2.58	"	20.25		
Q765	2.60	"	19.62		
Q776	2.60	"	20.38		
Q777	2.60	"	19.12		
			Avg. 20.10	3.24	±1.01
FS861	2.56	15.0	22.25		
FS862	2.56	"	19.31		
FS863	2.58	"	22.06		
FS864	2.56	"	23.18		
FS865	2.60	"	20.31		
			Avg. 21.42	3.87	±1.57
FS866	2.58	22.5	18.06		
FS867	2.58	"	18.25		
FS868	2.58	"	23.75		
FS869	2.58	"	21.62		
FS870	2.60	"	20.44		
			Avg. 20.42	5.69	±2.39
Q584	2.58	31.0	14.44		
Q797	2.62	"	17.31		
Q798	2.60	"	25.06		
Q799	2.62	"	13.25		
Q800	2.64	"	15.12		
			Avg. 17.03	11.81	±4.73
Q801	2.60	37.0	23.38		
Q802	2.62	"	18.50		
Q803	2.64	"	18.31		
Q804	2.62	"	15.00		
Q805	2.62	"	11.25		
			Avg. 17.29	12.13	±4.51
Q806	2.62	42.0	14.94		
Q808	2.58	"	12.06		
Q809	2.62	"	12.18		
Q810	2.60	"	12.69		
Q811	2.62	"	14.25		
			Avg. 13.22	2.88	±1.30
Notes: 1. Cones assembled in DRC376 test assemblies. Boosters were placed in base plugs. 2. Loaded at Ravenna Arsenal, BAT Lot 22 and 27, with Composition B from Holston Lot No. 3-126 and 4-1197. 3. All rounds were tested at Erie Ordnance Depot at 0 rev/sec.					

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Table XI
Penetration Data
Recoiled DRB398 Cones

Round No.	Lbs. CompB	Standoff (inches)	Penetration (inches MS.)	Max. Spread (in.)	Std. Dev. (in.)
FS555	2.48	7.5	20.18	2.00	±.79
FS557	2.44	"	18.62		
FS558	2.44	"	19.25		
FS559	2.48	"	19.50		
FS560	2.44	"	20.62		
			Avg. 19.63		
FS1091	2.62	30.0	15.38	7.74	±3.62
FS1092	2.62	"	23.12		
FS1093	2.60	"	21.00		
FS1094	2.62	"	16.75		
			Avg. 19.06		
FS1095	2.58	36.0	22.94	12.62	±5.28
FS1096	2.60	"	21.31		
FS1097	2.60	"	12.00		
FS1098	2.60	"	24.62		
FS1099	2.60	"	15.75		
			Avg. 19.32		
FS1100	2.60	42.0	19.81	13.26	±5.16
FS1101	2.58	"	21.88		
FS1102	2.60	"	8.62		
FS1103	2.62	"	17.94		
FS1104	2.59	"	19.12		
			Avg. 17.47		

Notes:

1. Cones assembled in DRC376 test assemblies. Boosters were placed in base plugs.
2. Loaded at Ravenna Arsenal, BAT Lot No. 12 and 27, with Composition B from Holston Lot 3-126 and 4-1197.
3. All rounds were tested at Erie Ordnance Depot at 0 rev/sec.

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Table XII
Penetration Data
Machined DRB398-6 Cones

Round No.	Lbs. Comp. B	Standoff (inches)	Penetration (inches M.S.)	Max. Spread (in.)	Std. Dev. (in.)
FS627	2.58	4.0	18.19		
FS628	2.58	"	18.50		
FS629	2.58	"	18.50		
FS630	2.56	"	18.19		
FS631	2.58	"	18.56		
			Avg. 18.39	0.37	±.18
FS632	2.58	7.5	19.94		
FS633	2.58	"	20.56		
FS634	2.60	"	19.56		
FS635	2.58	"	19.12		
FS636	2.58	"	20.50		
			Avg. 19.94	1.44	±.62
FS637	2.58	15.0	21.88		
FS638	2.56	"	20.75		
FS639	2.58	"	20.81		
FS640	2.58	"	22.31		
FS641	2.58	"	21.75		
			Avg. 21.50	1.56	±.69
FS642	2.60	22.5	19.81		
FS643	2.58	"	22.25		
FS644	2.60	"	21.69		
FS645	2.58	"	22.00		
FS646	2.58	"	20.62		
			Avg. 21.27	2.44	±1.03
FS662	2.60	30.0	17.25		
FS663	2.58	"	13.18		
FS664	2.60	"	20.12		
FS665	2.58	"	22.12		
FS666	2.60	"	22.25		
			Avg. 18.98	9.07	±3.83
FS667	2.58	36.0	19.31		
FS668	2.60	"	20.06		
FS669	2.60	"	21.75		
FS670	2.60	"	18.18		
FS671	2.58	"	21.69		
			Avg. 20.20	3.57	±1.57
FS672	2.58	42.0	23.62		
FS673	2.60	"	23.69		
FS674	2.58	"	19.94		
FS675	2.60	"	15.18		
FS676	2.60	"	19.94		
			Avg. 20.47	8.51	±3.50
Notes: 1. Cones assembled in DRC376 test assemblies. Boosters were placed in base plugs. 2. Loaded at Ravenna Arsenal, BAT Lot 23 and 27, with Composition B from Holston Lot No. 3-126 and 4-1197. 3. All rounds were tested at Erie Ordnance Depot at 0 rev/sec.					

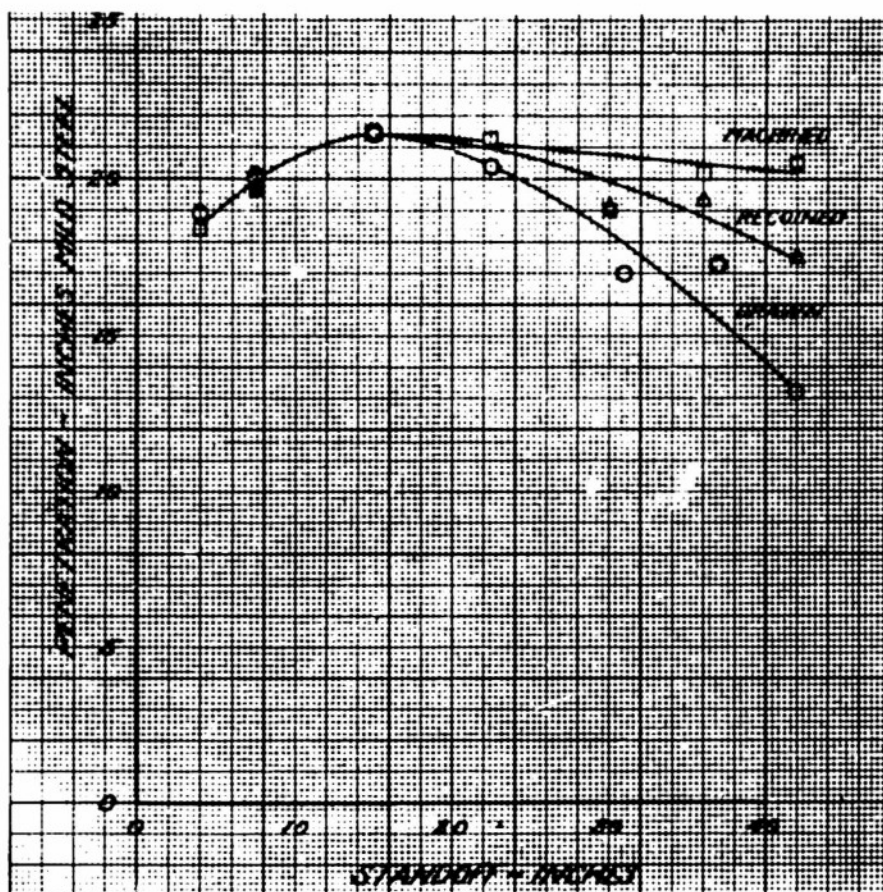


Fig. 6. Penetration Versus Standoff.
Drawn, Recoined and Machined Cones.

Composite Cone Study

The program for evaluating the performance of composite or bimetal cones has been completed. The behavior of copper cones, copper cones with thin aluminum inserts, and of both steel and aluminum cones with thin copper inserts, has been determined at 0 and 30 rev/sec. In each case, the composite cone is composed of an outer shell .080 in thick and a thin insert .020 in thick pressed and rolled into the outer shell. Fig. 7 shows the complete assembly. The copper used was hard drawn oxygen-free electrolytic copper, QQC 576; the steel was SAE 1010 cold drawn bar; the aluminum was 24S-T4 bar. Both shells and inserts were machined. The cones were assembled in modified DRC376 test assemblies, as shown in Fig. 8.

Cone inspection data are shown in Table XIII and the penetration data are shown in Table XIV. Fig. 9 shows the penetration data in a graphical form.

At 30 rev/sec the penetration differential between the types of composite cones is not large, but at 0 rev/sec substantial differences are noted. Early tests with composite cones seemed to show that the penetration achieved by the jet was determined largely by the metal comprising the jet. It was therefore anticipated that the steel and aluminum cones with copper inserts would show penetrations approximating those of the copper cones, and that the copper cones with aluminum inserts would be decidedly inferior. It is surprising, therefore, to note that these latter cones were much the best of the composite cones, and that the copper in-

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sert in the steel and aluminum cones did not alter the penetrations from those which would be normally expected for plain steel and aluminum cones without inserts. Fig. 10 illustrates a sectioned target plate and slug for round number FS762, and shows that the copper insert was sufficiently heavy to provide adequate material for the jet. The excellent penetration of the copper cone with aluminum insert is the first obtained in this laboratory in which a jet, presumably composed primarily of aluminum, has demonstrated good

penetration. This is of considerable importance in the light of the greater damage beyond the target caused by aluminum jets (NAVORD REPORT "Shaped Charge Damage Beyond Armor" presented as a part of a Symposium on Shaped Charges at Aberdeen Proving Ground, BRL Report 837, page 359). These experiments will be continued in an effort to determine a more optimum composite liner design, and to determine the relative damage beyond the armor.

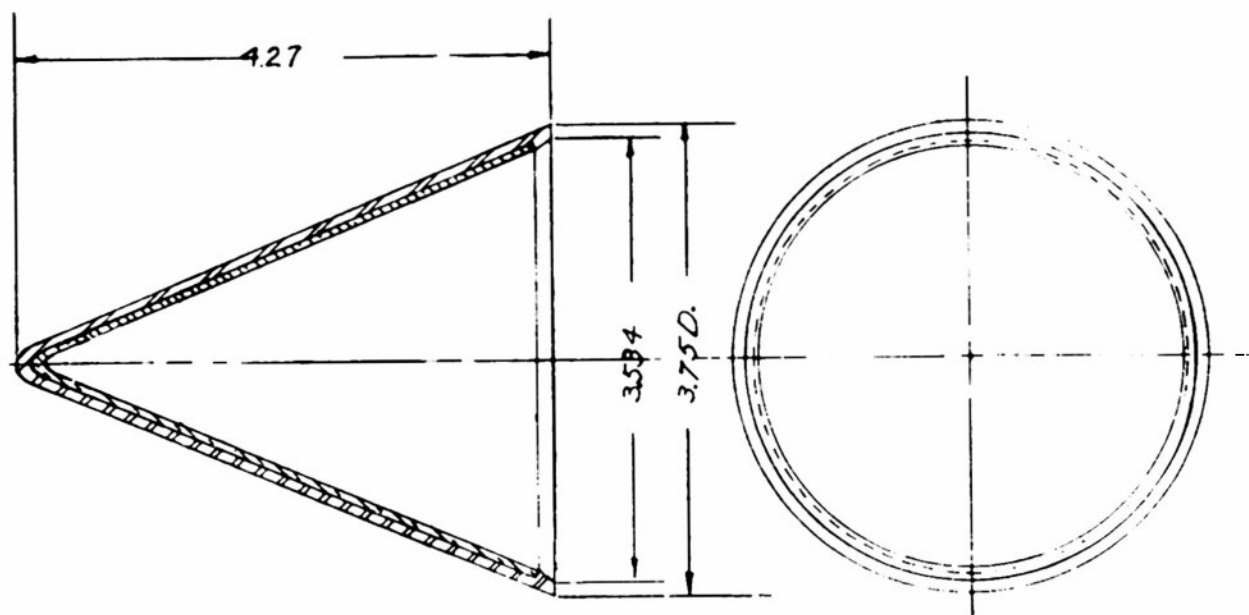


Fig. 7. Composite Cone Assembly.
Firestone Drawing No. DRB660.

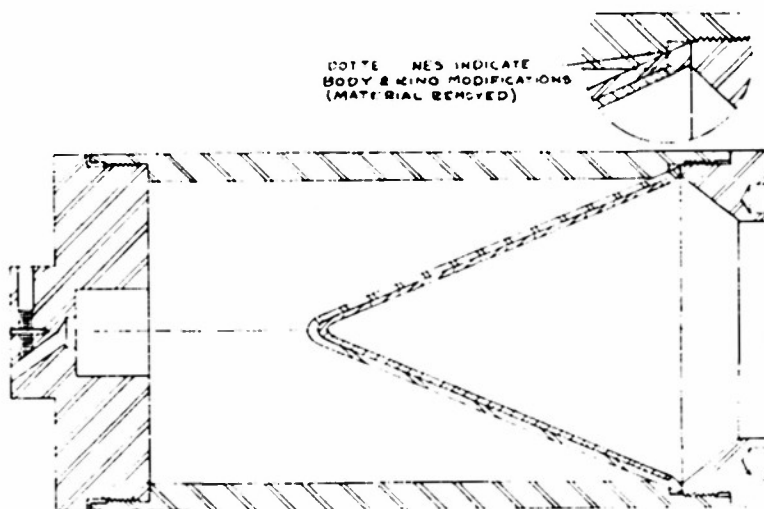


Fig. 8. Modified Test Assembly.
DRC376 Penetration Body Nose and Ring. DRB660 Cone.

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Table XIII
Inspection Data
Composite Cones, DRB660

Cone No.	Wall Thickness (in.)			Max Variation WT.		Max Wall Waviness		Concentricity ^A T I R.		
	Max.	Min.	Ave.	Trans	Long	I. D.	O. D.	Base Datum	Axis Datum	Cone Tip Body Assy
Spec.	.100	.095	--	.001	.003	.003	.003	.0030	.0030	.015 (Nom)
Solid Copper										
FS750	.099	.097	.0979	.002	.002	.001	<.001	.0030	.0030	.010
FS751	.096	.094	.0946	<.001	.001	.002	<.001	.0035	.0045	.015
FS752	.099	.096	.0973	.002	.003	.001	.001	.0020	.0020	.014
FS753	.100	.096	.0982	.001	.004	.004	.001	.0020	.0025	.007
FS754	.100	.098	.0994	.001	.002	.001	.001	.0005	.0010	.017
FS755	.100	.097	.0988	<.001	.002	.002	<.001	.0010	.0015	.007
FS756	.099	.096	.0972	.001	.003	.003	.001	.0030	.0060	.006
FS757	.101	.098	.1000	.002	.003	.002	<.001	.0010	.0020	.009
FS758	.103	.098	.1006	.002	.004	.003	<.001	.0020	.0025	.013
FS759	.100	.098	.0988	.002	.002	.002	.001	.0045	.0050	.022
Avg.	.0997	.0968	.0983	.0015	.0026	.0021	.0010	.0023	.0030	.0120
Std. Dev.	±.0018	±.0013	±.0017	±.0005	±.0010	±.0010	--	±.0013	±.0017	±.0052
Copper Insert in Steel Shell (20% Cu)										
FS760	.098	.092	.0953	.003	.004	.004	.005	.0045	.0065	.016
FS761	.096	.095	.0953	.001	.001	.001	.002	.0010	.0015	.011
FS762	.102	.097	.1001	.003	.004	.002	.003	.0040	.0045	.009
FS763	.101	.094	.0975	.002	.005	.004	.001	.0030	.0035	.028
FS764	.101	.097	.0992	.001	.003	.002	.001	.0015	.0020	.019
FS765	.106	.101	.1039	.002	.004	.005	.003	.0020	.0025	.004
FS766	.101	.098	.0994	.001	.003	.002	.002	.0025	.0020	.007
FS767	.105	.091	.0986	.003	(.014)	(.011)	.004	.0035	.0035	.020
FS768	.097	.092	.0942	.004	.00	.005	.002	.0010	.0010	.011
FS769	.102	.099	.1006	.001	.003	.003	.002	.0035	.0020	.023
Avg.	.1009	.0956	.0984	.0021	.0030	.0028	.0025	.0027	.0032	.0148
Std. Dev.	±.0032	±.0034	±.0029	±.0011	±.0012	±.0015	±.0013	±.0013	±.0016	±.0077
Aluminum Insert in Copper Shell (20% Aluminum)										
FS770	.105	.099	.1006	.007	.005	.005	.001	.0045	.0025	.030
FS771	.102	.098	.1000	.002	.003	.004	.001	.0020	.0025	.048
FS772	.102	.096	.0994	.002	.004	.004	.001	.0040	.0040	.029
FS773	.101	.098	.0990	.003	.003	.003	.001	.0015	.0010	.013
FS774	.105	.097	.1003	.005	.008	.007	.002	.0060	.0045	.029
FS775	.103	.097	.0999	.001	.006	.004	<.001	.0030	.0030	.013
FS776	.100	.095	.0966	.004	.005	.004	<.001	.0035	.0050	.023
FS777	.099	.093	.0950	.006	.006	.003	.002	.0020	.0040	.014
FS778	.100	.096	.0971	.004	.004	.003	.002	.0015	.0060	.031
FS779	.099	.095	.0970	.002	.003	.003	.002	.0015	.0030	.008
Avg.	.1016	.0964	.0985	.0036	.0047	.0040	.0014	.0030	.0036	.0232
Std. Dev.	±.0023	±.0018	±.0019	±.0020	±.0017	±.0013	±.0005	±.0016	±.0015	±.0119
Copper Insert in Aluminum Shell (20% Cu)										
FS780	.101	.098	.0996	.001	.003	.002	.002	.0010	.0010	.010
FS781	.104	.100	.1018	.004	.003	.004	.003	.0010	.0010	.016
FS782	.102	.099	.1006	<.001	.003	.002	.002	.0025	.0020	.011
FS783	.099	(.092)	(.0951)	.002	.006	.006	.004	.0015	.0010	.014
FS784	.103	.098	.1007	.001	.005	.005	.002	.0010	.0020	.018
FS785	.102	.099	.1004	<.001	.003	.003	.002	.0020	.0020	.004
FS786	.103	.100	.1015	<.001	.003	.003	.004	.0010	.0010	.006
FS787	.103	.099	.1007	.004	.002	.004	.003	.0015	.0030	.005
FS788	.102	.098	.1004	.002	.004	.003	.003	.0015	.0010	.020
FS789	.103	.100	.1006	.003	.003	.002	.004	.0020	.0025	.006
Avg.	.1022	.0990	.1007	.0020	.0035	.0034	.0029	.0015	.0017	.0110
Std. Dev.	±.0012	±.0009	±.0007	±.0013	±.0012	±.0014	±.0009	±.0006	±.0008	±.0058

Notes:

1. Brackets indicated figures are omitted from the averages.
2. The indicated measurement at each datum is the total indicator runout of the liner's outside surface relative to the register diameter. The difference between the runout at the two datum planes is an indication of the lack of perpendicularity of the register plane and the liner axis.
3. Lower datum is .484 inch above the base; upper datum 3.120 inches above the base.

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Table XIV
Penetration Data
Composite Cones, DRB660

Round No.	Type Cone	Lbs Comp B	Rev Sec	Penetration (inches M.S.)	Max. Spread (in.)	Std Dev (in.)
FS755	Copper	2.48	0	19.88		
FS756	Copper	2.48	0	19.81		
FS757	Copper	2.48	0	19.25		
FS758	Copper	2.48	0	19.69		
FS759	Copper	2.48	0	20.88		
				Avg. 19.90	1.63	±.53
FS750	Copper	2.50	30	13.75		
FS751	Copper	2.50	30	13.38		
FS752	Copper	2.48	30	14.18		
FS753	Copper	2.48	30	13.56		
FS754	Copper	2.48	30	14.81		
				Avg. 13.94	1.43	±.51
FS765	Cu. Insert/Steel Shell	2.50	0	14.94		
FS766	"	2.48	0	13.38		
FS767	"	2.50	0	12.62		
FS768	"	2.46	0	17.50		
FS769	"	2.50	0	17.56		
				Avg. 15.40	4.18	±1.83
FS760	Cu. Insert/Steel Shell	2.50	30	11.25		
FS761	"	2.50	30	11.06		
FS762	"	2.52	30	11.94		
FS763	"	2.52	30	11.75		
FS764	"	2.52	30	10.94		
				Avg. 11.39	1.00	±.39
FS775	Alum. Insert/Copper Shell	2.50	0	18.12		
FS776	"	2.50	0	16.88		
FS777	"	2.52	0	18.00		
FS778	"	2.50	0	16.38		
FS779	"	2.50	0	18.69		
				Avg. 17.61	2.31	±0.85
FS770	Alum. Insert/Copper Shell	2.52	30	12.06		
FS771	"	2.50	30	8.62		
FS772	"	2.50	30	13.12		
FS773	"	2.50	30	13.18		
FS774	"	2.50	30	10.88		
				Avg. 11.57	3.56	±1.70
FS785	Cu. Insert/Steel Shell	2.50	0	12.38		
FS786	"	2.50	0	11.44		
FS787	"	2.50	0	10.81		
FS788	"	2.52	0	12.38		
FS789	"	2.50	0	8.62		
				Avg. 11.13	3.76	±1.38
FS780	Cu. Insert/Alum. Shell	2.50	30	9.50	No Slugs were observed. Apparently disintegrated.	
FS781	"	2.50	30	8.94		
FS782	"	2.50	30	8.56		
FS783	"	2.50	30	9.12		
FS784	"	2.52	30	9.31		
				Avg. 9.09	0.94	±.32
Notes: 1. DRC576 test bodies, rings, and base plugs. 2. Standoff held constant at 7.5 inches. 3. All cones of the DRB660 type. Simple apex. 4. Loaded at Ravenna Arsenal, BAT Lot No. 26 with Comp B of Holston Lot 3-126.						

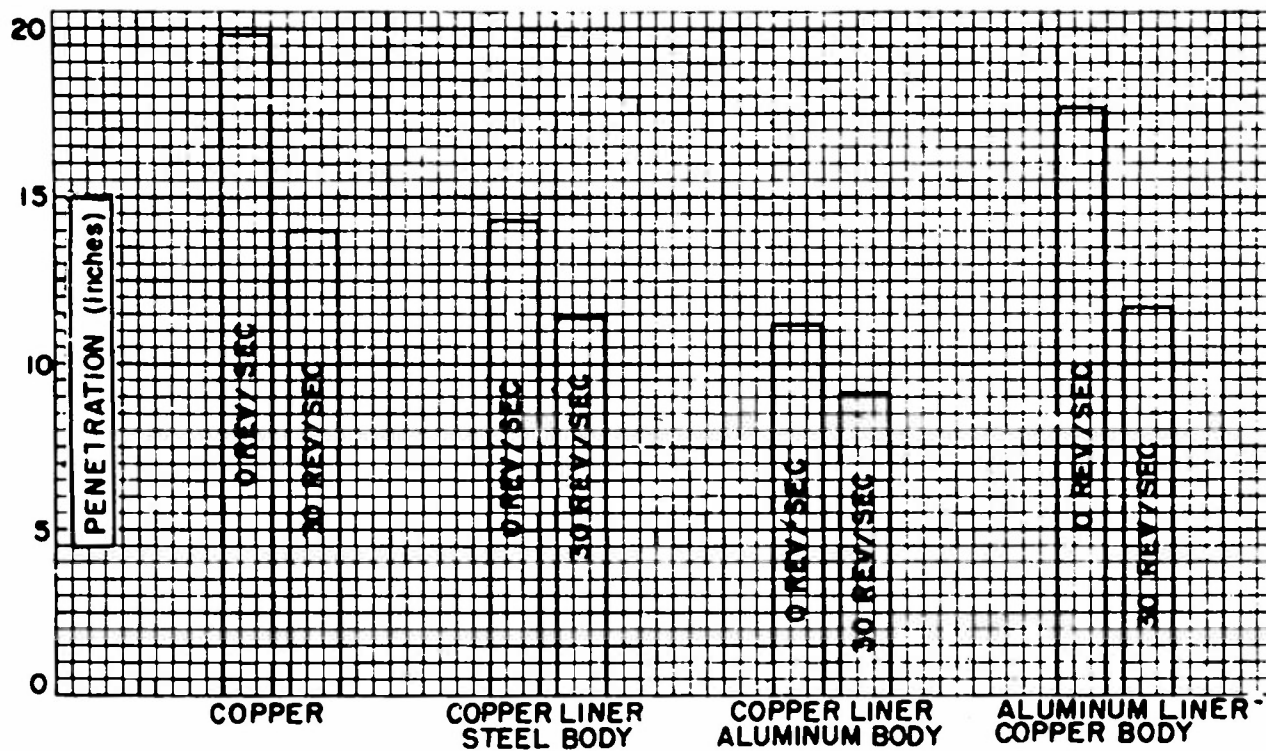


Fig. 9. Penetration Data.
Composite Liners.

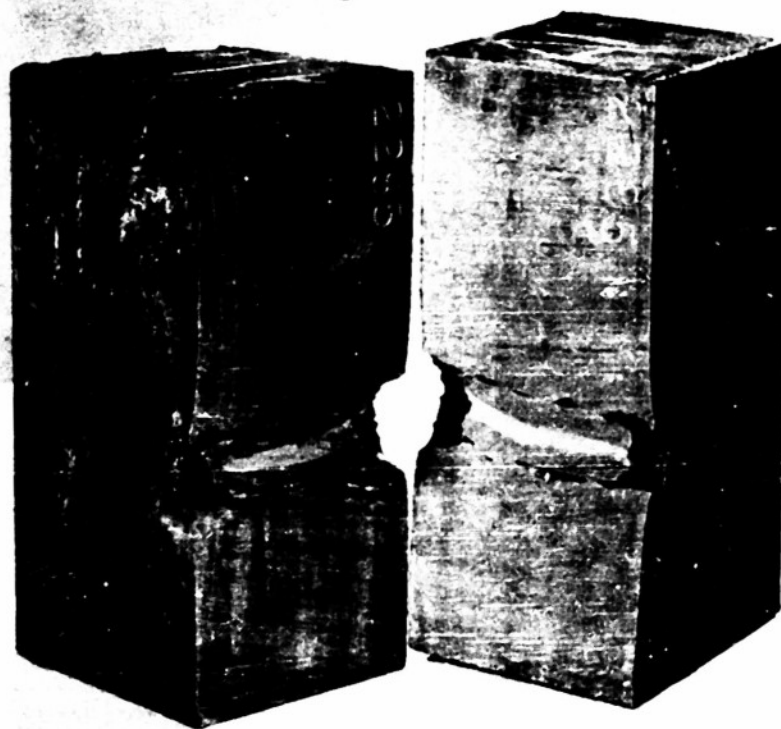


Fig. 10. Section Through Penetration Block.
Showing Copper Core in Steel Slug.

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Future Program

1. Effect of Internal Tee Contour. Three new tee designs are to be evaluated.

2. Scaling Studies. Two series of scaling studies are planned. One series with simple apex copper cones is geometrically scaled to 75, 90 and 105mm. The other series uses DRB398 cones (with short spitback of constant size) with height and wall thickness adjusted to 75, 90 and 105mm size.

3. Cones Made of Zinc and Aluminum are to be tested for penetration. Penetrations approaching those of copper cones have been reported for certain alumi-

num and zinc alloys.

4. Composite Cone Study. A series of tests using copper cones with aluminum inserts will be tested.

a. .080-inch thick copper shell and .020 and .040-inch aluminum insert (24S-T4).

b. .100-inch thick copper shell and .020 and .040-inch aluminum insert (24S-T4).

c. Same as (a) and (b) but using 2S-F aluminum instead of 24S-T4.

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FUZES

Testing of T267E13 Base Elements (Superquick and Delay)

A combination superquick and delay fuze, T267, was described in the Thirtieth and Thirty-First Progress Reports. Certain modifications, designed to improve the ease of initiation of the M21 detonator, have been made and tested. The modifications are shown in Fig. 11.

1. Drop Test on Functioning of Delay Train

Six T267 fuzes were drop-tested to study the functioning of the delay train. They were loaded with M2 delay detonators, tetryl leads and M21 detonators. Four assemblies T267E13, had .187-inch diameter holes in the M2 detonator sleeves for the escape of gases, while the remaining two fuzes, T267E11 with tetryl leads, had escape holes .0625 in. in diameter. The .187-inch diameter is larger than used in previous tests.

The four fuzes (T267E13) with the .187-inch diameter holes functioned the M21 detonator while the two assemblies with the .0625-inch diameter hole failed to function the detonator even though they did have the special tetryl lead. These

results indicate that the failure of other assemblies (T267E11) to function the M21 detonator (reported in the Thirty-First Progress Report) was due to the small size (.0625 in.) of the gas escape hole in the sleeve.

2. Field Test of T267E13 Fuzes

Seven projectiles equipped with T267E13 fuzes and spotting charges were fired against a 4-inch bursting screen at a range of 260 yards. All fuzes were set so that both the superquick and delay elements would be activated. Therefore, in the observations a superquick function would obscure a delay function. Observers reported that one fuze functioned superquick at the screen and four functioned as delay fuzes. There was some disagreement among observers as to the functioning of a sixth. One fuze did not function. This fuze had been very erratic in earlier centrifuge tests. Omitting the disputed round, five of six fuzes functioned. The failure of the rounds to function superquick is attributed to inadequate travel in the rotor contact. This condition is being corrected.

Table XV is a copy of the firing record.

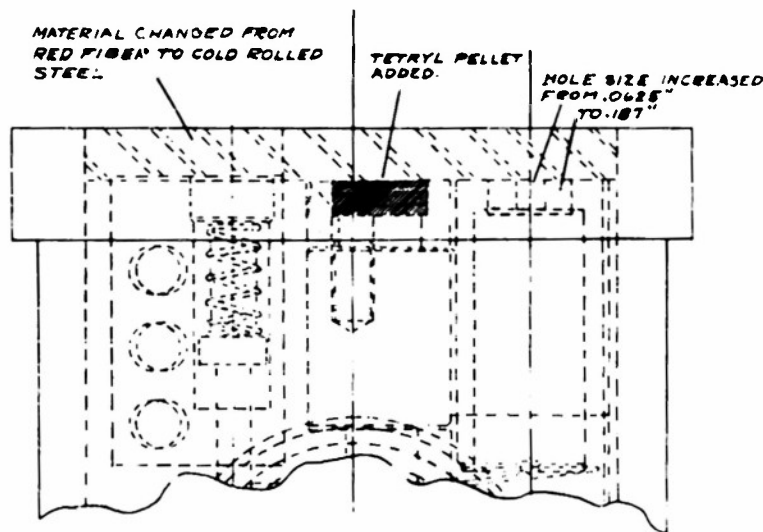


Fig. 11. Modifications to T267 Fuze Base Element.

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T223E2 Mechanical Superquick and Delay Fuze

Ten T223E2 fuzes, Twenty-Sixth and Twenty-Eighth Progress Reports, were set to function as delay fuzes and were fired against a 4-inch wooden bursting screen at a range of 200 yards. Five of the ten fuzes were observed to function. One of the rounds that failed to function went through a hole produced by a previous round. Inspection of the two-layer bursting screen after the firing was completed, revealed that the rear layer had been badly damaged (17 rounds total had been fired against it). The inertia element of the fuze is designed to use nearly the entire impulse from impact with a 4-inch thick screen. It is possible, therefore, that the impacts on the damaged screen were not adequate to actuate the fuze system. Further tests are planned.

Table XVI is a copy of the firing record.

Future Program

1. Test T222E5 base elements in live loaded HEAT shell.
2. Evaluate the "inverted" firing system using 9GA20 No. 1 rectifiers and condensers in projectiles having burster

Test of DRA726 Nose Elements in T138E57 and T119E11 HEAT Projectiles

The programs proposed in the Thirtieth and Thirty-First Progress Reports, for the testing of DRA726 nose elements in HEAT rounds have been completed at Aberdeen Proving Ground. Table XVII is a summary of the results.

Of twenty-six fair hits on the armor plate (both normal and at 64° obliquity) twenty-five functioned properly. All eight T138E57 type projectiles functioned satisfactorily against both 2-inch and 4-inch wooden screens, but none of the six T119E11 projectiles fired against wooden screens functioned. Both the nose element and the nose of the T119E11 are being redesigned for increased sensitivity.

charges.

3. Continue tests with T267E13 fuze base elements.
4. Continue tests with T223E2 fuzes.

Table XV
Firing Test Data
T267E13 Base Element

6100' 22.25' 1.45 sec 2.40 sec 4.40 sec
PROJECTILE
Model T-130
Type E-57A
Weight (Nominal) 17.50
C.G. Location
Borelet Dia (Nom) 1.22
Special Features Band 360-6

Temperatures
Mag. Temp. 70°F
Min. 70°F
Pres. 70°F
Loading Room 70°F
Ambient 67°F
Late Afternoon

TEST GUN
Model T267E13-2
Type 105mm Recoilless
Length of Tube 105"
Twist of Rifling 1:200
Sighting Equipment M-17 Adapted Telescope
Bore Dia (Lands) 1.130 nos.

Program Supp II T-267E13 Fuse Test

MISCELLANEOUS DATA
Range 200 yds
Propellant OAC IFA Primer T-36 S6 M00
Type of Fuse web 0.245 Charge Wt. 0.045. 200
Type of Fuse Cases T-53E1 Cases
Proof Director J. Chensky
Observers Dr. E. Lucas M. Russell R. Barnes
H. G. Loom

Barodulum Constant: 2.06 lbs. - sec/in.
Longer fired Mechanical

Round No.	Line Type	Proj. Weight (lbs)	Fuz. No.	Recoil	Chamber Pressure (psi)	Muzzle Velocity (ft/sec)	Powder Depth (in)	Piezo Pressure (Gage No. 05)	Chamber Inspection After Firing	Fuze Type	Observations
4015	1	17.34	6	3 1/2"	1530	1626	4 1/2"	11,100	A few shrapnel at base of chamber	Failed	Functioned Delay
4016	2	17.29	3	19 1/2"	1600	1620	4"	11,100	Chamber and base clean	Failed	Functioned Delay
4017	3	17.39	4	5 1/2"	1560	1609	4"	11,100	Chamber and base clean	Failed	Functioned Delay
4018	4	17.29	1	13 1/2"	1576	1609	3 1/2"	11,100	Chamber and base clean	Failed	Functioned Delay
4019	5	17.30	5	3 1/2"	1605	1633	3 1/2"	11,100	Chamber and base clean	Failed	Functioned Delay
4020	6	17.34	7	7 1/2"	1609	1636	3 1/2"	11,100	Chamber and base clean	Failed	Functioned Delay
4021	7	17.30	2	13 1/2"	1603	1631	4 1/2"	12,000	Chamber and base clean	Failed	Functioned Delay
All rounds were loaded and fired with one main rubber pad (as single unit) under depth action after main rubber pad inserted											
* Same as m-2 (cc)											

Signed O. Miller

Table XVI
Firing Test Data
T223E2 Mechanical Superquick and Delay Fuze

62.00' 29.38' 1.15 yds. 2nd Cal
 PROJECTILE
 Model I-138
 Type E-57A
 Weight (Nominal) 17.30
 C.G. Location _____
 Bourrelet Dia (Nom.) 4.132 - .001
 Special Features Send 360°
 1.15 yds. 2nd Cal
 Temperatures
 Mag. Temp. 70°F
 Max. 70°F
 Min. 70°F
 Pres. 70°F
 Loading Room 70°F
 Ambient 67°F
 Late Afternoon
 62.00' 29.38' 1.15 yds. 2nd Cal
 TEST GUN
 Model I-15E3 #2
 Type 45 mm Recoilless
 Length of Tube 105"
 Twist of Rifling 1-200
 Sighting Equipment M-12 Adapted
 Range _____
 Bare Dia. (Lands) 4.139 + .001
 Pendulum Constant = 2.06 lbs. - sec/in.
 Levered Fixed Mechanical

[illegible]

Signed O. Miller

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Table XVII
Test Da'a
DRA726 Nose Element Tests

	Round No.	Target	Comments
Lot 12092 LE Ti19 DRA726 Nose Element	72	2 in. Wood	Failed on wood, functioned down range.
	64	4 in. Wood	Missed target, no function down range.
	75	4 in. Wood	Missed target, functioned down range.
	70	4 in. Wood	Failed on wood and down range.
	68	4 in. Wood	Wouldn't chamber.
	78	4 in. Wood	Failed on wood and down range.
	73	4 in. Wood	Failed on wood, functioned down range.
	63	4 in. Wood	Wouldn't chamber.
	66	4 in. Wood	Failed on wood, low order down range.
	73	4 in. Wood	Failed on wood and down range.
	74	6 in. 64 Armor	Functioned high order.
	77	6 in. 64 Armor	Functioned low order (nose did not hit)
	71	6 in. 64 Armor	Functioned high order.
	80	6 in. 64 Armor	Functioned high order.
	61	6 in. 64 Armor	Functioned high order.
	69	6 in. 64 Armor	Functioned high order.
	67	6 in. 64 Armor	Functioned high order.
	76	6 in. 64 Armor	Functioned high order.
Lot 12090 Ti38 DRA726 Nose Element	59	5 in. Vertical Armor	Misfire.
	29	5 in. Vertical Armor	Functioned high order.
	24	5 in. Vertical Armor	Functioned high order.
	36	5 in. Vertical Armor	Functioned high order.
	27	5 in. Vertical Armor	Functioned high order.
	42	5 in. Vertical Armor	Functioned high order.
	51	4 in. Wood	Functioned high order.
	46	4 in. Wood	Functioned high order.
	21	4 in. Wood	Functioned high order.
	35	2 in. Wood	Functioned high order.
	28	6 in. 64 Armor	Wouldn't chamber.
	32	6 in. 64 Armor	Functioned high order.
	48	6 in. 64 Armor	Functioned high order.
	20	6 in. 64 Armor	Functioned high order.
	41	6 in. 64 Armor	Functioned high order.
	52	6 in. 64 Armor	Wouldn't chamber.
	16	6 in. 64 Armor	Functioned high order.
	31	6 in. 64 Armor	Wouldn't chamber.
	18	6 in. 64 Armor	Functioned high order.
	58	6 in. 64 Armor	Functioned high order.
	50	6 in. 64 Armor	Functioned high order.
	57	6 in. 64 Armor	Functioned high order.
	49	6 in. 64 Armor	Functioned high order.
	11	6 in. 64 Armor	Functioned high order.
	55	6 in. 64 Armor	Didn't function.
	23	6 in. 64 Armor	Functioned high order.
	15	6 in. 64 Armor	Functioned high order.
	37	6 in. 64 Armor	Functioned high order.
	47	6 in. 64 Armor	Functioned high order.
	56	6 in. 64 Armor	Wouldn't chamber.
	22	6 in. 64 Armor	Functioned high order.
	25	6 in. 64 Armor	Functioned high order.
	60	6 in. 64 Armor	Functioned high order.
	53	6 in. 64 Armor	Functioned high order.

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MANUFACTURING SUMMARY

In addition to the experimental materiel prepared for the research and development work under contracts DA-33-019-ORD-33 and DA-33-019-ORD-1202, described in preceding progress reports and in the preceding pages of this report, the following have been manufactured and shipped to the installations indicated.

Firestone's Defense Research Division, in shipping these items, transfers custody and control of the items to the receiving agencies. However, personnel of Defense Research Division will continue to collaborate with personnel of the other installations in any evaluation or engineering tests involving these items.

I Cartridges, T119E11, Metal Parts Assembly, w/o Fuze T208E7

Prior to Mar. 1, 1953	355 (Live)	Picatinny Arsenal
Mar. 1, 1953	930 (Inert)	Picatinny Arsenal
Mar. 1, 1953	30 (Inert)	Aberdeen Proving Ground
Mar. 1, 1953	50 (Inert)	Frankford Arsenal
Mar. 5, 1953	300 (Inert)	Picatinny Arsenal
Mar. 12, 1953	300 (Live)	Picatinny Arsenal
Mar. 14, 1953	25 (Inert)	Aberdeen Proving Ground
Mar. 19, 1953	<u>300</u> (Inert)	Picatinny Arsenal
Total to Mar. 31, 1953	2290	

II Rifles, T137E3, for ONTOS

Prior to Mar. 1, 1953	10 Ser. Nos. 3 to 11, 15	Allis-Chalmers
Mar. 6, 1953	4 Ser. Nos. 14, 16, 17, 20	Allis-Chalmers
Mar. 16, 1953	2 Ser. Nos. 12, 23	Allis-Chalmers
Mar. 25, 1953	<u>2</u> Ser. Nos. 24, 25	Allis-Chalmers
Total to Mar. 31, 1953	18	
Balance on Order	4	

III Mounts, T152E4, for ONTOS

Prior to Mar. 1, 1953	6 Ser. Nos. 1 to 6	Allis-Chalmers
Mar. 6, 1953	2 Ser. Nos. 7, 8	Allis-Chalmers
Mar. 16, 1953	1 Ser. No. 9	Allis-Chalmers
Mar. 25, 1953	<u>1</u> Ser. No. 11	Allis-Chalmers
Total to Mar. 31, 1953	10	
Balance on Order	2	

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