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DESIGN AND DEVELOPMENT OF CARTRIDGE, 20MM, 'IT T230E1

BY

MARTIN TYSKA

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ABSTRACT

Development of a 20mm APIT cartridge capable of delivering improved terminal incendiary effects against aircraft and light-armored targets was undertaken by Frankford Arsenal. Armor piercing characteristics comparable to existing API shot were to be maintained. Approximately 2500 cartridges were fabricated for use in this development.

Vastly improved terminal incendiary effects were exhibited against aircraft and light armored vehicle type targets. Armor penetration, accuracy and ballistic match (with M56A2 HEI round) firing results were good. However, premature termination of this development resulted in a redesigned APIT cartridge which, in its present state, does not meet all of the design objectives and consequently is not suitable for service adoption.

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OBJECT

To develop a 20mm cartridge capable of delivering improved terminal incendiary effects against aircraft and light-armored targets. Included in this development was the requirement to maintain armor piercing characteristics comparable to those of existing API Shot, the application of the copper overlay welded rotating band, and the economy of fabrication by the reduction of the number of metal parts.

SUMMARY

Development of a 20mm APIT cartridge capable of delivering improved terminal incendiary effects against aircraft and light armored targets was undertaken by Frankford Arsenal. Armor piercing characteristics comparable to existing APIT shot (the T312E3 standardized as the M53) were to be maintained. Initial design and development efforts are covered in FA report R-1398. The experimental shot under development consisted of an incendiary filled, hollow, hardened shot body, an aluminum nose piece, and an aluminum tracer container. The T312E3 shot consisted of a monobloc projectile, an incendiary filled windshield and a tubular steel adapter.

Small lots of experimental APIT shot were fabricated, assembled, charged and fired at Frankford Arsenal and Aberdeen Proving Ground. A final test lot of 1000 pieces was evaluated at Aberdeen Proving Ground. The firing tests were conducted with the test barrel and the M39 automatic gun.

The tests were to determine performance with respect to sensitivity, incendiary function, armor penetration, trace, metal parts security and function in the automatic weapon.

The test results of the finalized lot were not so good as previous lots with respect to trace, metal parts security and sensitivity. It is believed that these deficiencies can be corrected with changes or closer

control of materials, tolerances, and processes. Vastly improved terminal incendiary effects were exhibited against aircraft and light armored vehicle type targets. Armor penetration, accuracy and ballistic match (with M56A2 HEI round) firing results were good.

Because of the improved terminal incendiary effects, possible cost reduction by virtue of less metal parts and reduction of possible stubbing malfunctions because of smaller soft nose area, it is recommended that development be reinitiated and completed.

INTRODUCTION

Foremost in the requirements of a 20mm Aircraft Cartridge is reliable performance in extended burst firing. However, in long burst firings, weapon barrels become worn to such a degree that excessive balloting can occur and cause metal parts separation at the juncture of the AP Core and the adapter of the API Shot. On occasion the aluminum nose piece was split on ramming the cartridge into the weapon chamber thereby causing a muzzle burst.

In January of 1956, Frankford Arsenal was directed to initiate the development of an improved APIT Shot (Reference 1).

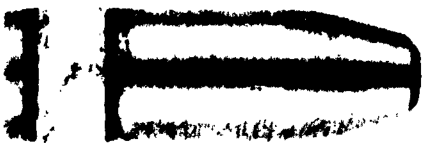
Frankford Arsenal Report R-1398 (Reference 2), dated June 1957 covers the development phase from January 1956 to June 1957 which included the design studies, fabrication and testing of prototype design shot metal parts and subsequent modifications.

The 20mm APIT shot developed under this program, designated T318E1, is a completely redesigned shot (See figures 1 and 2). It consists of a hollow, hardened steel shot body, an aluminum nose piece and an aluminum tracer container. The bulk of the incendiary charge is contained within the shot body with a narrow column of mix in the nose piece (See figure 2).

Since the shot metal parts design was essentially fixed, the development effort covered by this report was primarily devoted to the isolation and elimination of the cause of occasional premature functions, improvement of armor piercing characteristics by use of more suitable steel alloys and heat treatment techniques and the determination of an optimum incendiary mix.

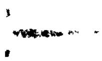
HISTORY OF DEVELOPMENT

The test firing program specified in Technical Requirements Document 21-57 and Memorandum No. 1 (Appendix A) utilized one lot of shot body metal parts with incremental increases of 10 grains in the zirconium seeded mix (IM 163), Lots 14a, 14b, 14c and 14d of Reference 2.



Shot Body with Copper Overlay Weld

Tracer Container



Nose Piece

Body - Nose Piece Assembly

Figure 1. APIT T318E1 Shot Metal Parts

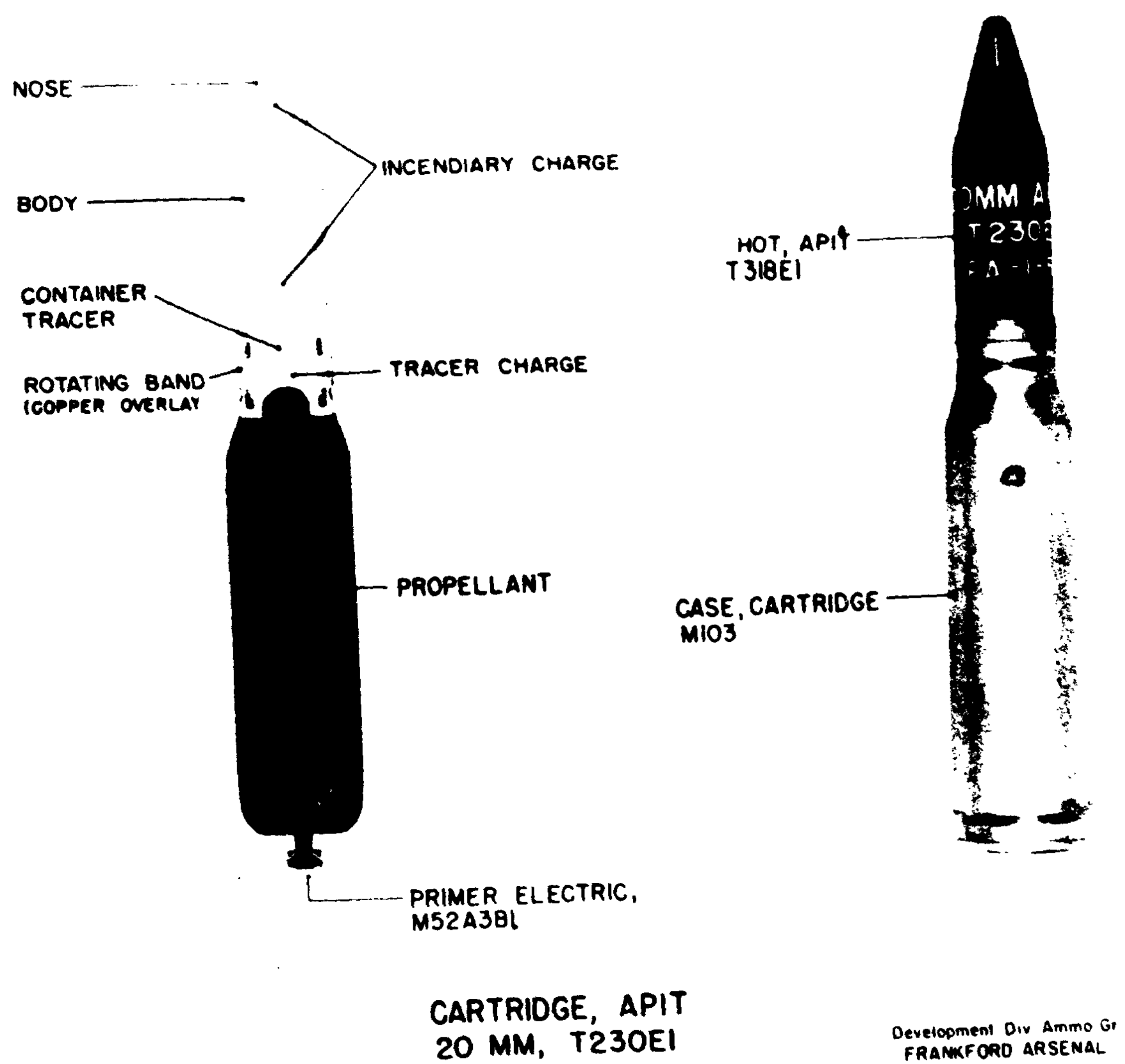


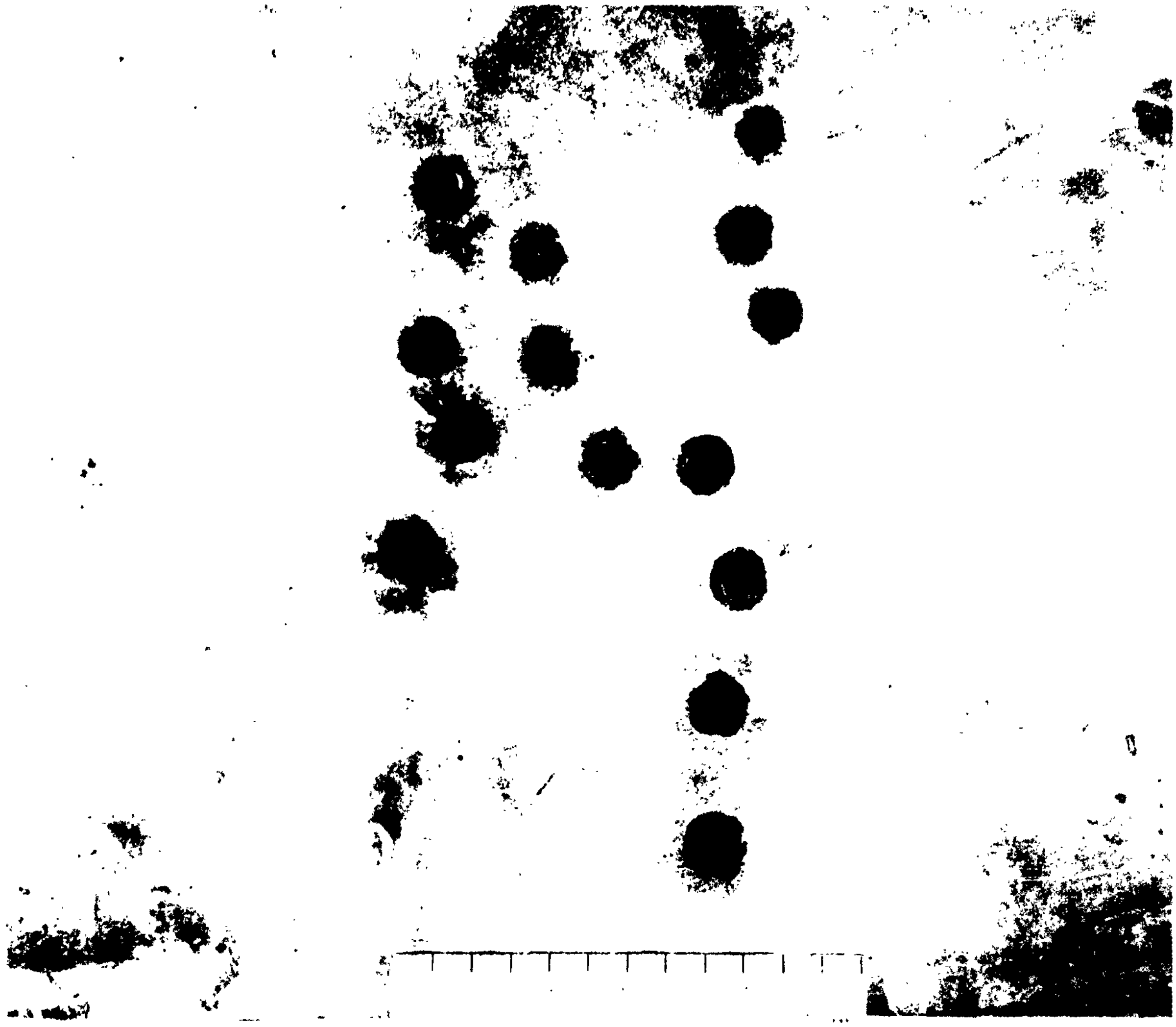
Figure 2. Cartridge, APIT 20MM, T230E1

The firing of approximately 50 rounds from each lot for sensitivity showed no appreciable difference among the various lots. The results of approximately 200 rounds fired indicated that this round would function consistently against .025 in. aluminum at 60° obliquity and would yield approximately 50% function against .025 in. aluminum at 45° obliquity.

Armor penetration tests were conducted against both 3/4 in. and 7/8 in. homogeneous armor plate at essentially service velocities. Figures 3 through 8 show photographs of the targets. For comparative purposes a lot of standard M53 API cartridges (T312E3 shot) was fired as a control (See figure 9). In these tests both the test lot and the control lot completely defeated the 3/4 in. target. However, on the 7/8 in. target the test lot yielded 50% complete penetration whereas the control lot yielded 80% complete penetrations. Of particular interest in this test was the fact that the test lot, when fired against the 3/4 in. homogeneous armor plate, carried the incendiary function through the plate with the flash occurring behind the plate. This is particularly noticeable in figure 6. It was also noted that unlike the conventional results obtained with solid bodied armor piercing cores, the test lot resulted in the breaking loose of a slug of armor plate approximately 1.5 in. in diameter. Recovery of the punched out plug revealed some portion of the shell body metal parts protruding from the entrance side of the punched out plug, figure 10.

It should be noted that the test lot of shot body metal parts assemblies was fabricated from 1036 steel which was treated to a hardness level of R_C 46 to 49, instead of 4140 steel as specified on Drawing No. FD20438, Appendix B, because of nonavailability of 4140 steel. The utilization of these rounds for armor piercing tests was conducted only to yield some basic data from which to establish design objectives.

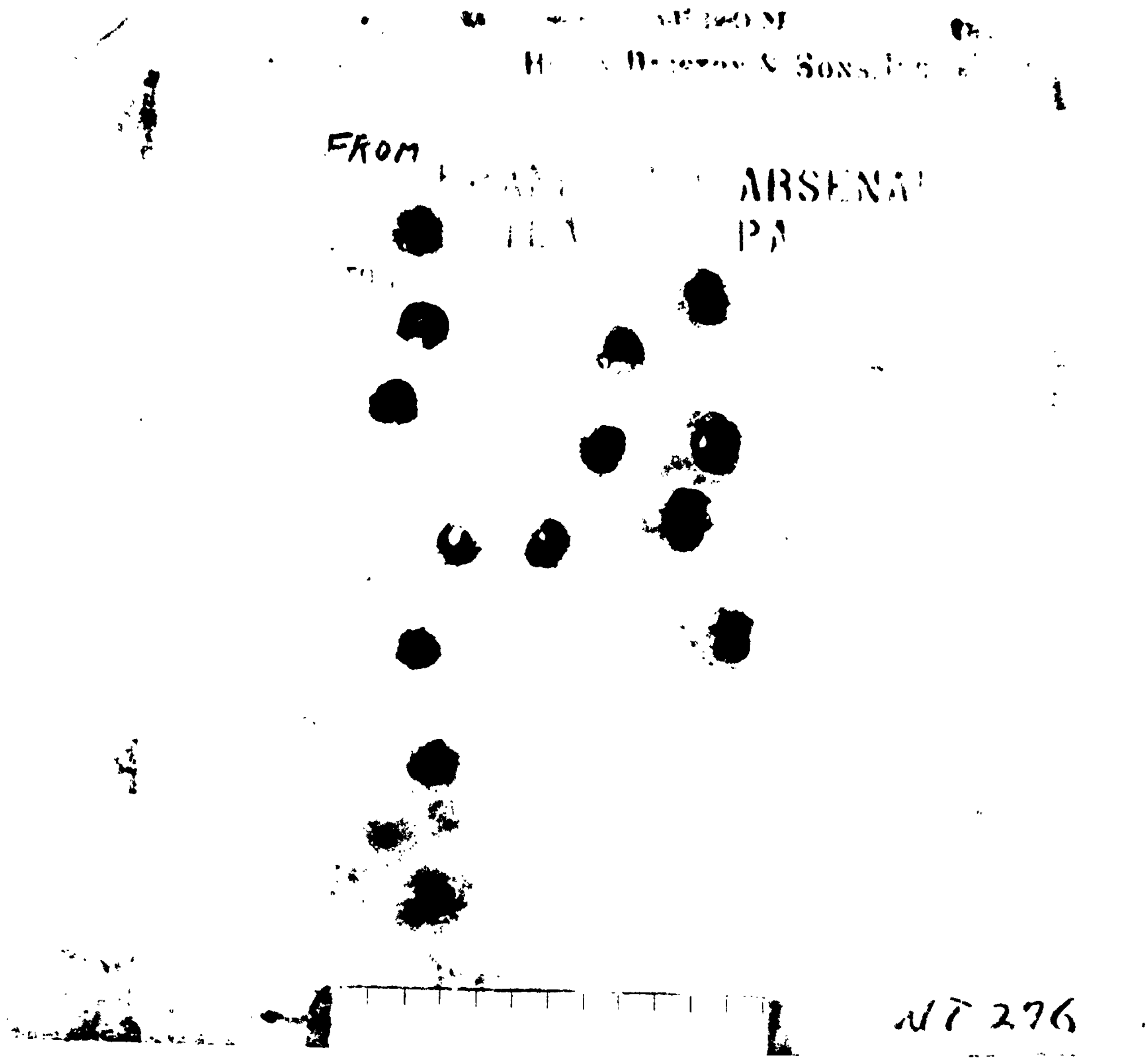
A test was fired for incendiary burst duration using 10 rounds from each of the four test lots. The results indicated that the burst duration of the test rounds, when charged with a zirconium type composition, would be significantly greater than that obtained with the control lot. Because of the difficulty in interpreting the exact burst duration of an individual round using the drum camera and photo cell, additional tests were conducted using the simulated B-29 aircraft target and a fuel spray delay, set at various increments.



.750 Homo. Steel Plate (Front)

T-318-E1 (new)	T-318 (conv.)
normal	normal
4-5-6-7	1-2-3
20°	20°
11-12-13-14	8-9-10

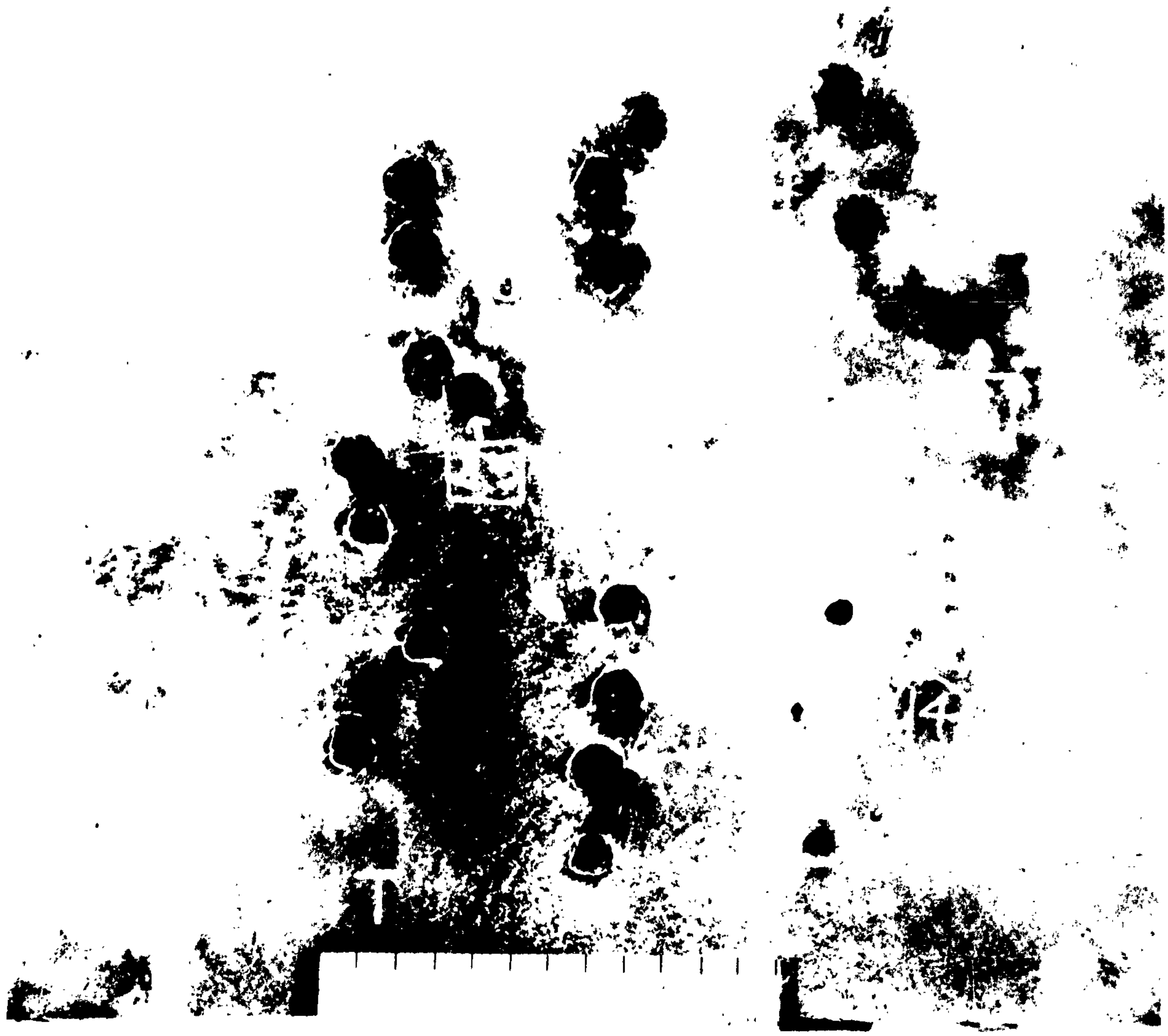
Figure 3. Comparison of armor piercing characteristics of T318 (Solid bodied Shot-conventional) vs. T318E1 (hollow cylinder shot - new)



.750 Homo. Steel Plate (Rear)

T-318E1 (new)	T-318 (conv.)
normal	normal
4-5-6-7	1-2-3
20°	20°
11-12-13-14	8-9-10

Figure 4. Comparison of armor piercing characteristics of T318 (Solid bodied Shot-conventional) vs. T318E1 (hollow cylinder shot - new)

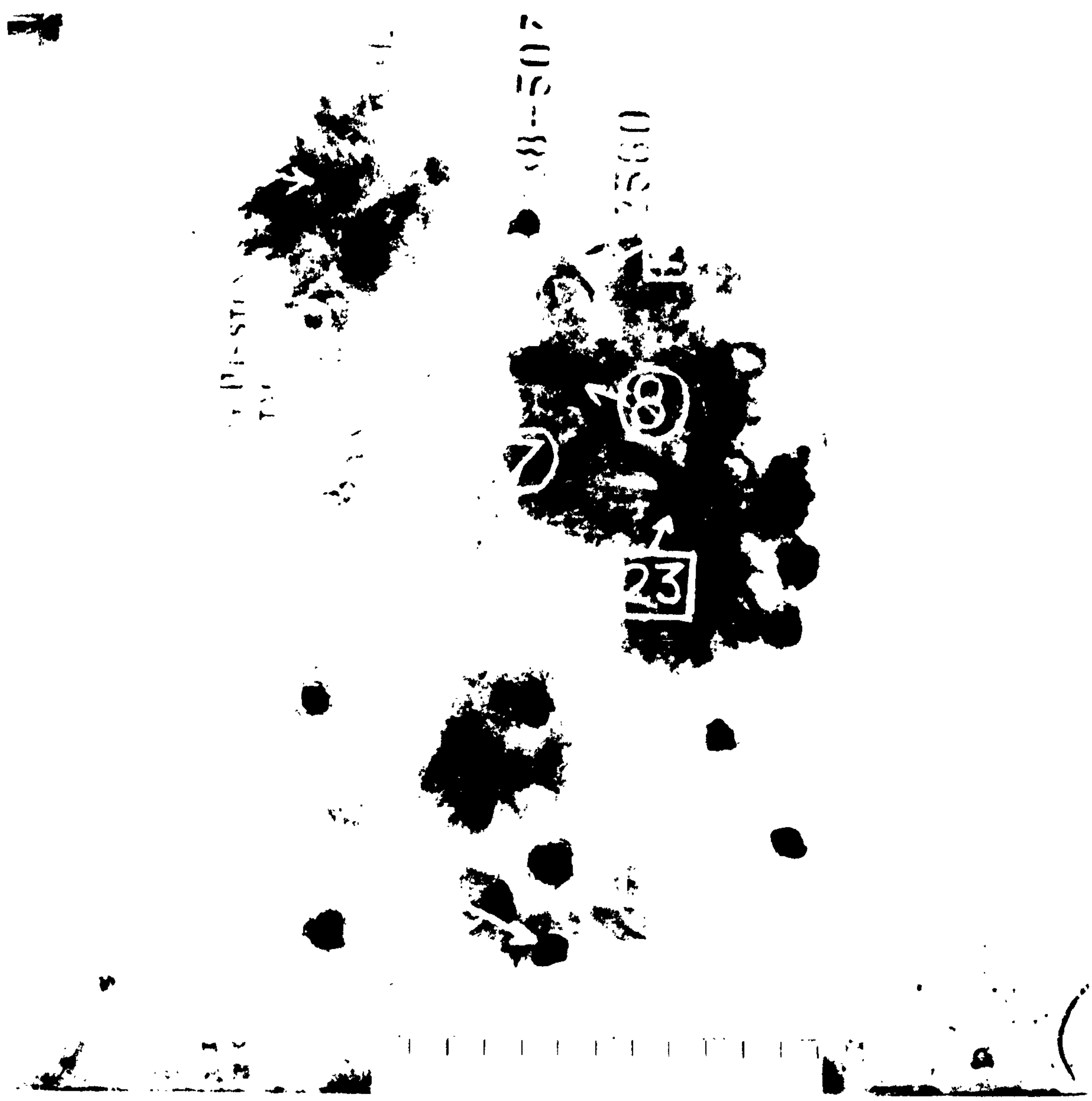


.750 Homo. Steel Plate - 30° Oblique (Front)

T-318-E1 (new)
4-5-6-10-11-12-
18-19-20-21-22

T-318 (conv.)
1-2-3-7-8-9-
13-14-15-16

Figure 5. Comparison of armor piercing characteristics of T318 (Solid bodied Shot-conventional) vs. T318E1 (hollow cylinder shot - new)

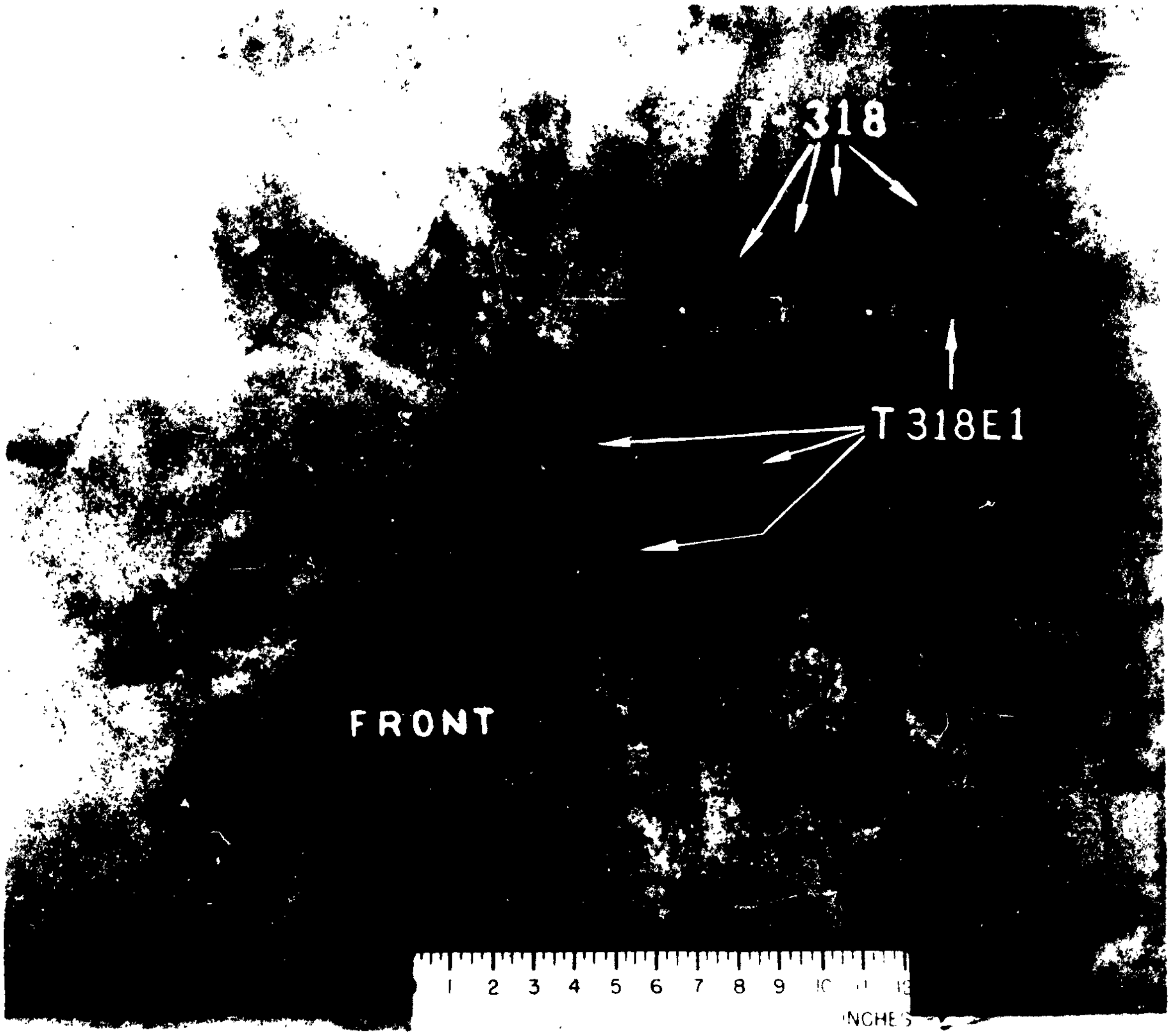


.750 Homo. Steel Plate - 30° Oblique (Rear)

T-318-E1 (new)
4-5-6-10-11-12-
18-19-20-21-22

T-318 (conv.)
1-2-3-7-8-9-13-
14-15-16

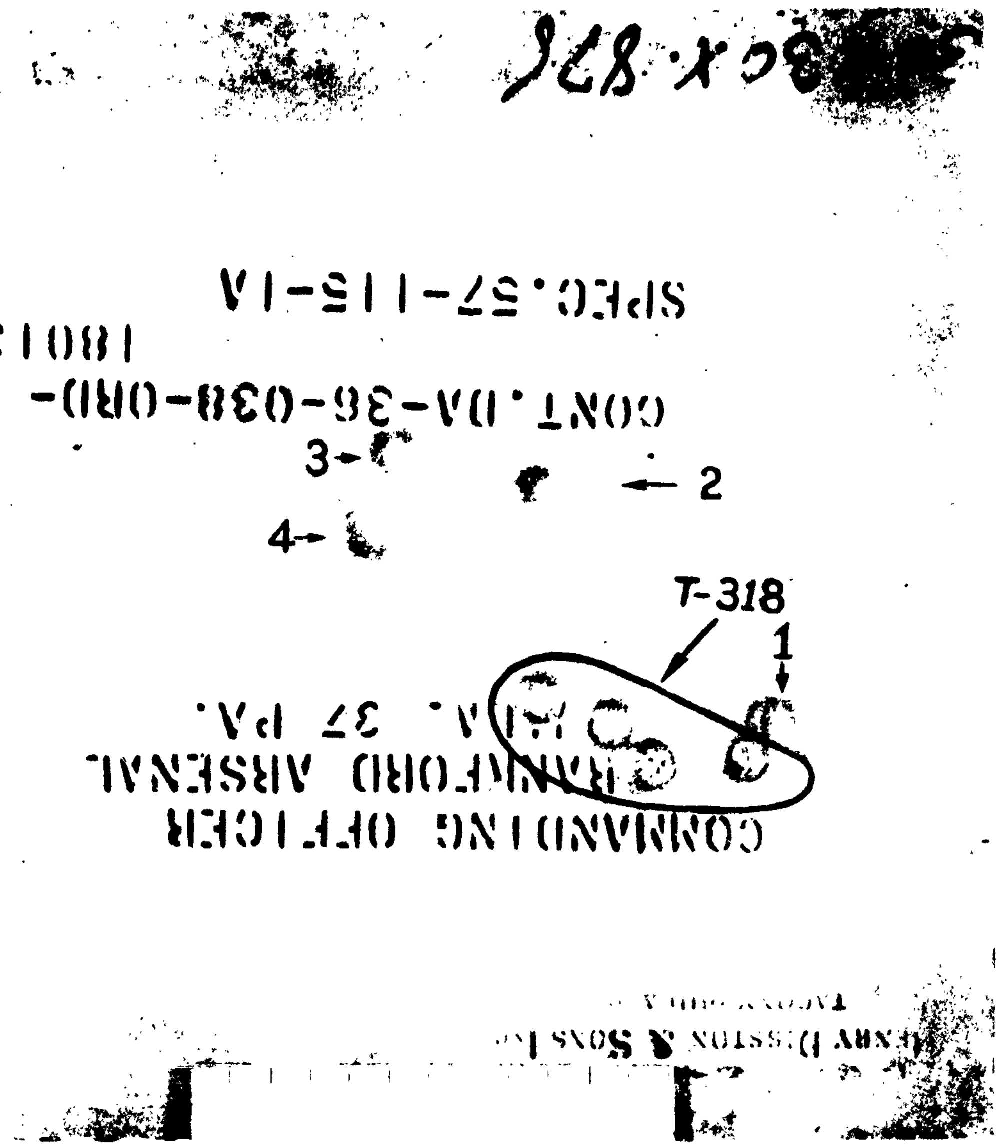
Figure 6. Comparison of armor piercing characteristics of T318 (Solid bodied Shot-conventional) vs. T318E1 (hollow cylinder shot - new)



.875 Homo. Steel Plate - Normal (Front)

T-318-E1 (new) T-318 (conv.)

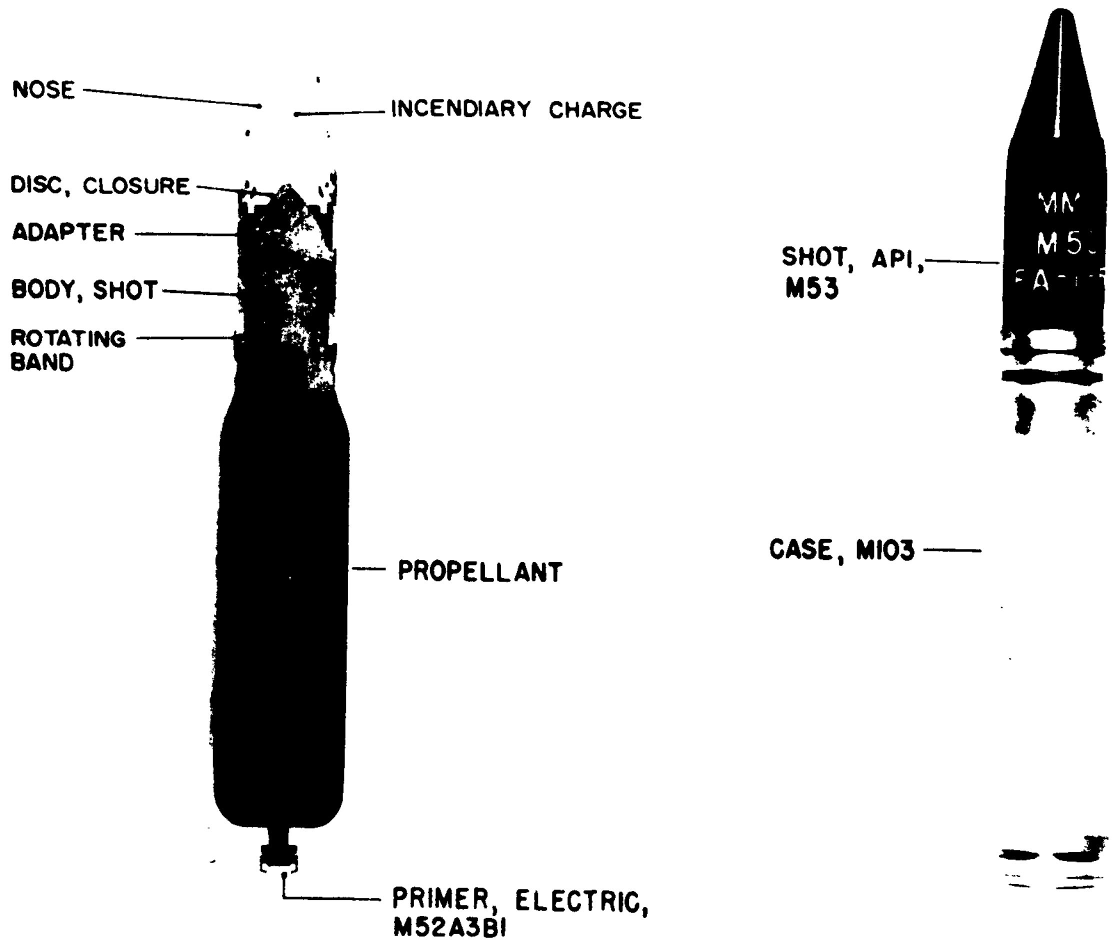
Figure 7. Comparison of armor piercing characteristics of T318 (Solid bodied Shot-conventional) vs. T318E1 (hollow cylinder shot - new)



.875 Homo. Steel Plate - Normal (Rear)

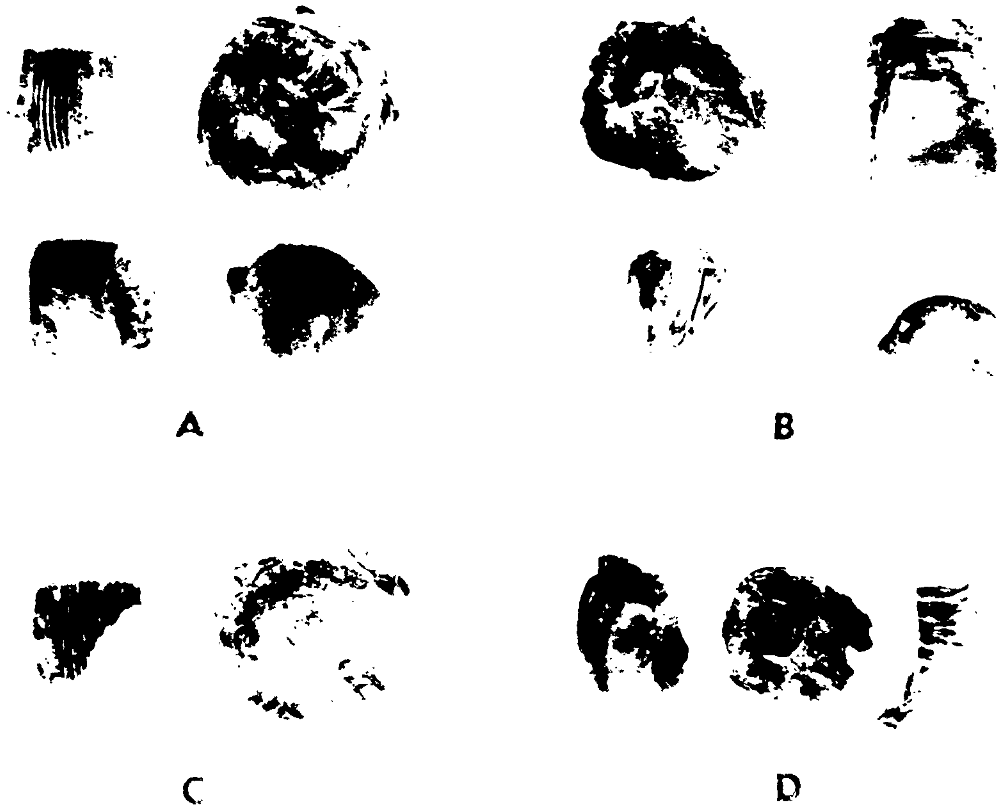
T-318-E1 (new) Shots 1-2-3-4 | T-318 (conv.)

Figure 8. Comparison of armor piercing characteristics of T318 (Solid bodied Shot-conventional) vs. T318E1 (hollow cylinder shot - new)



CARTRIDGE, A.P.I., 20 MM, M53

Figure 9. Cartridge, API, 20mm, M53



A	B	C	D
0^{o} Oblique	30^{o} Oblique	20^{o} Oblique	20^{o} Oblique
Top - T-318-E-1 (new) Bottom - T-318 (conv)	Top - T-318-E1 (new) Bottom - T-318 (conv)	T-318-E-1 (new)	T-318 (conv.)

Figure 10. Comparison of armor piercing characteristics of T318 (Solid Filled Shot conventional) vs. T318E1 (hollow cylinder shot - new)

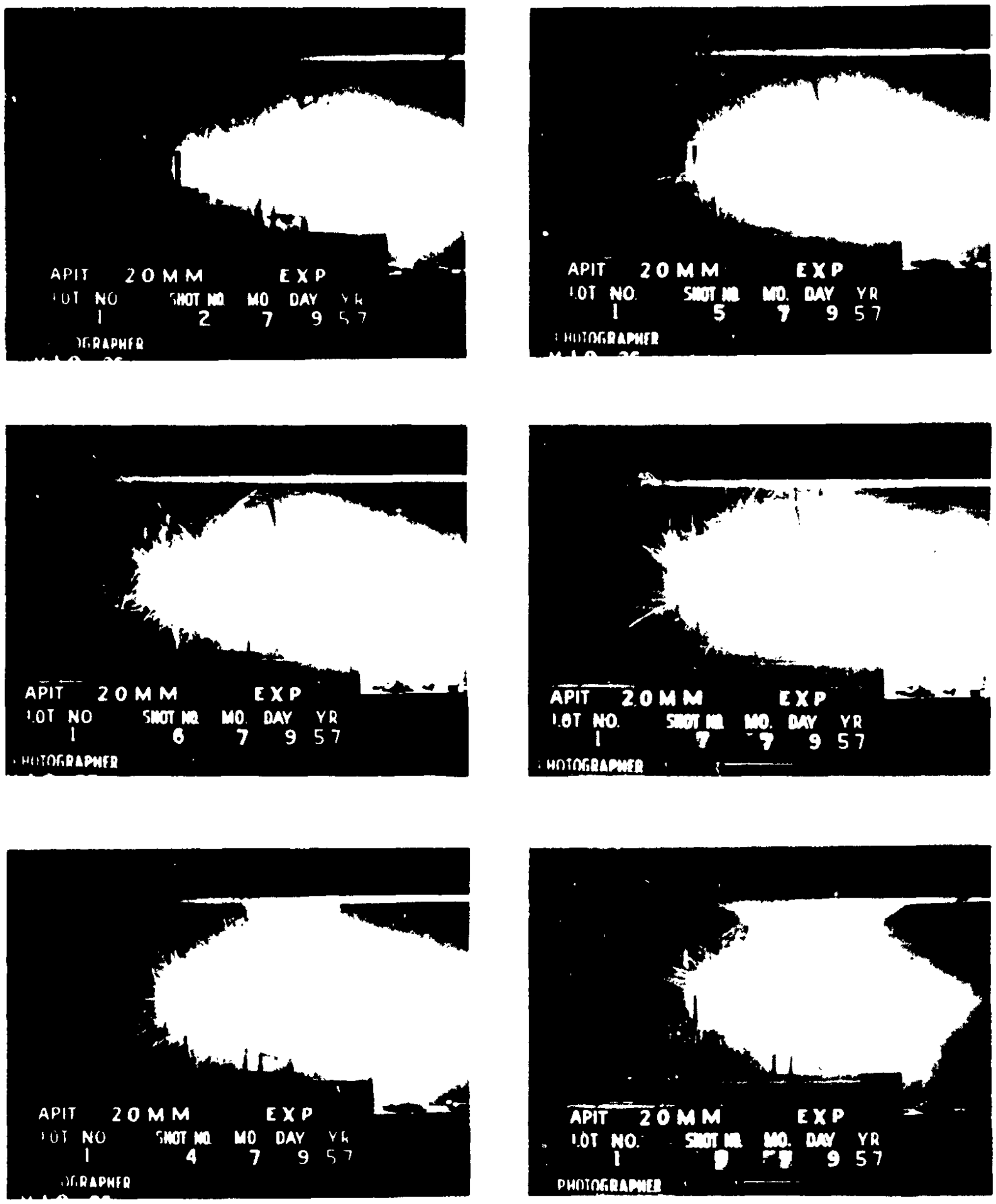
Ten rounds were fired from each of the four experimental lots and the control lot at fuel spray time delays of both 50 ms. and 150 ms. Since the ignition of the fuel spray (JP-4 fuel) adversely affected the photo cell-counter chronograph and drum camera results, five additional rounds from each lot were fired without the fuel spray. Figures 11 through 15 illustrate typical ignition characteristics of each of the lots tested. The lower pictures of each figure depict fuel spray ignitions.

The results obtained from these tests were not sufficiently accurate to enable a valid evaluation of the terminal incendiary characteristics of either the test or control lots because of difficulties encountered in instrumentation. However, an overall summation of the data indicated that a burst duration with the standard shot was approximately 50-60 ms. and approximately 200-250 ms. for the test rounds.

Because of the difficulty in obtaining the degree of performance desired of the terminal incendiary effect, several small lots were assembled using incendiary charges containing larger incremental amounts of the zirconium mix. Difficulties were encountered in the firing of the incendiary evaluation tests in which three experimental lots were loaded with the zirconium content of the mix progressively increased by 50 grain increments. Lot 1 contained 25 grains, lot 2 - 75 grains and lot 3 - 125 grains of IM 163. The tests were not completed due to premature functions in each lot.

Instrumentation reliability was questionable. The test results from the 150 ms. fuel spray delay were 10 percent ignition for the control lot, 30 percent for Lots 1 and 2. It would have been very difficult for the control lot to ignite the fuel spray at this time delay and the results of the test lots should have approached 100 percent ignition. In order to further evaluate the relative merits of the incendiary effect of the three test lots it was decided to use fastex film (high speed photograph) five rounds from each lot and measure the duration of sparks from the various test lots by means of the film strips.

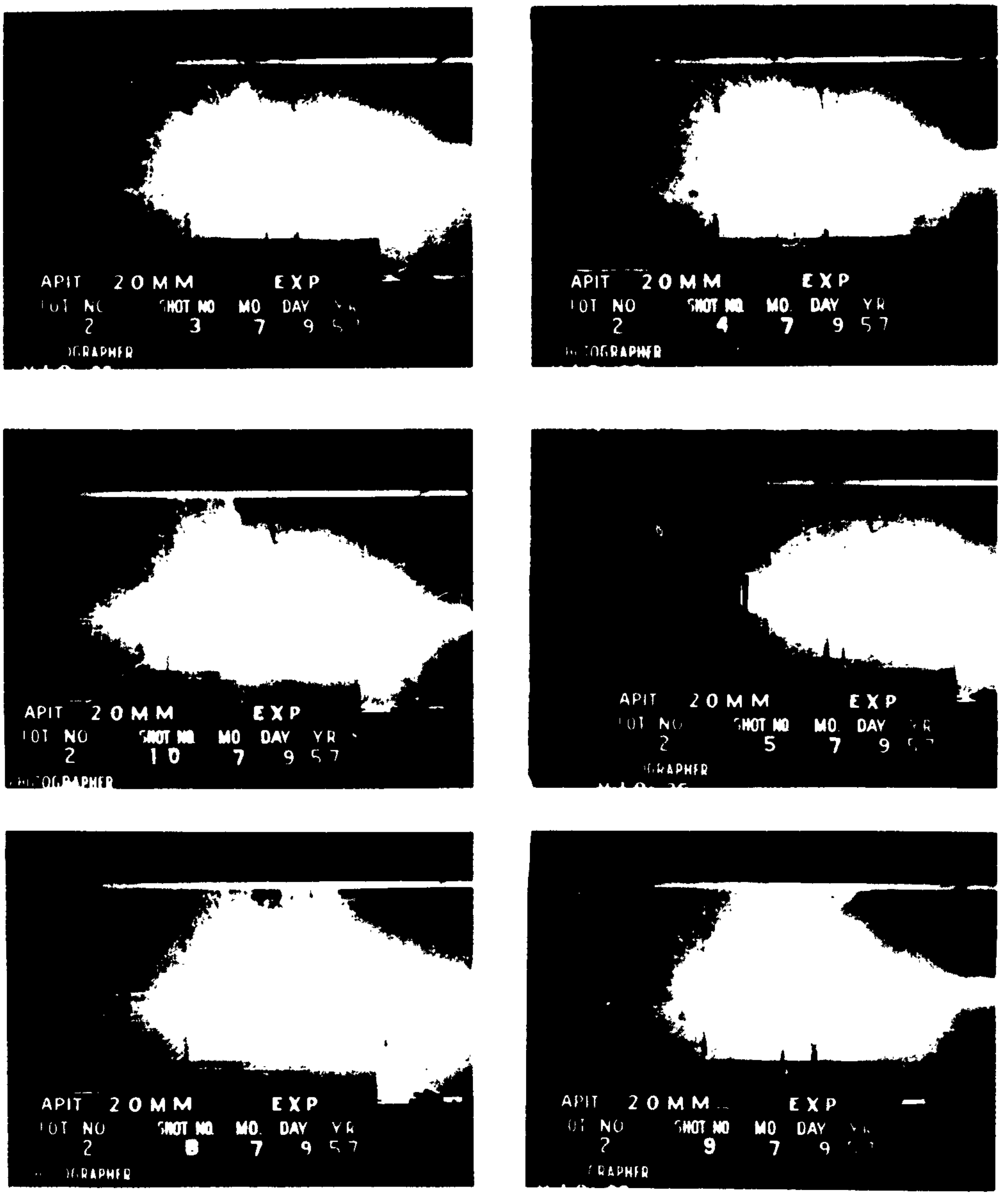
Figures 16 through 19 are prints made from the fastex film strips at various times after the initiation of the incendiary function. In the slow motion projection of the fastex films, the test rounds produced spark durations to the order of 300 ms. In some cases the sparks persisted for as long as 350 ms. There was an appreciable difference in performance noted between the 25-grain zirconium samples as compared



Fuel Spray Ignitions

T318E1 Shot 50 Grains IM163 (Zirconium)

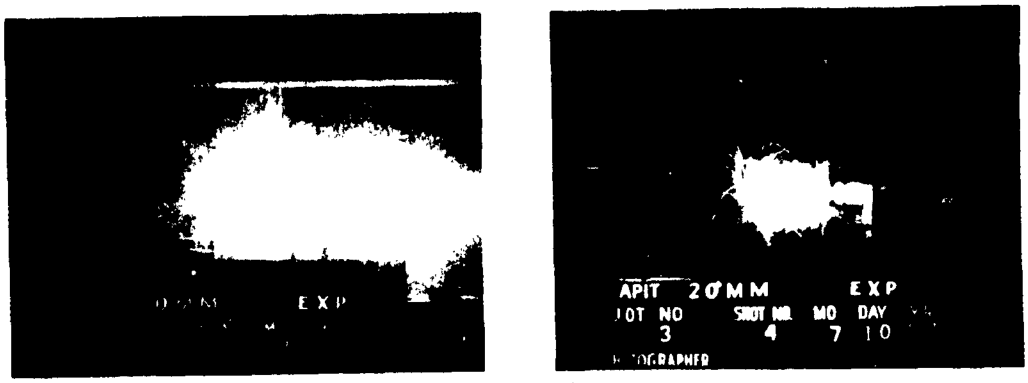
Figure 11. Simulated B-29 Target with JP-4 Fuel Spray Delay



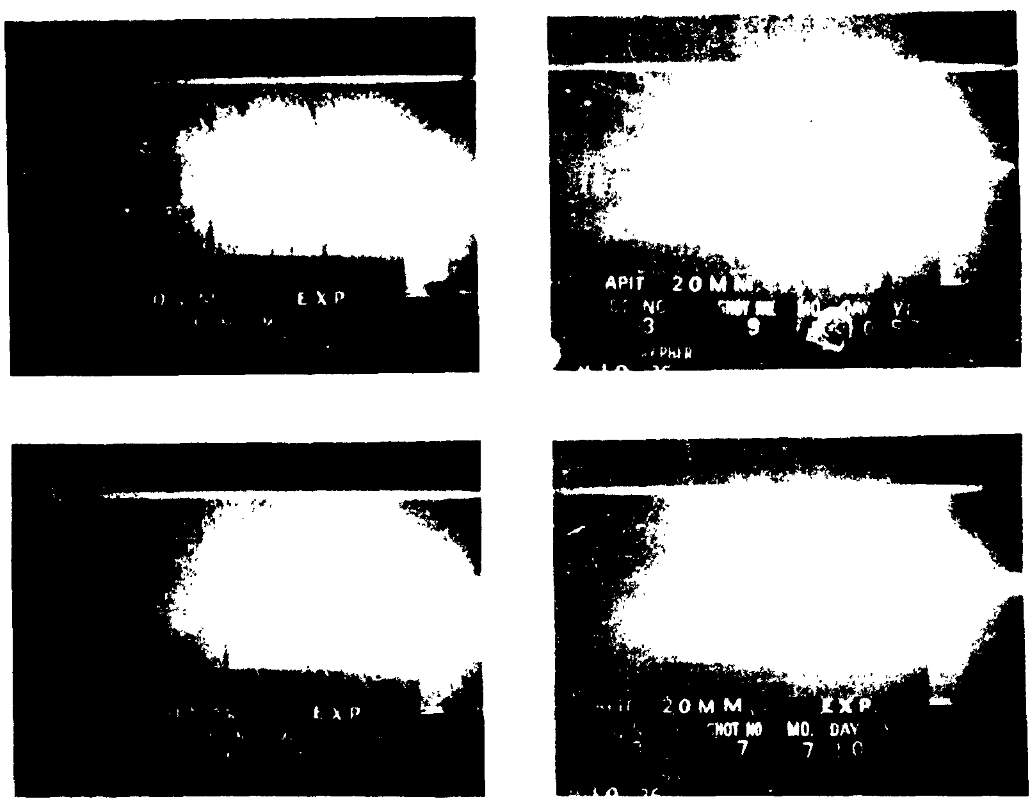
Fuel Spray Ignitions

T318E1 Shot 60 Grains IM163 (Zirconium)

Figure 12. Simulated B-29 Target with JP-4 Fuel Spray Delay



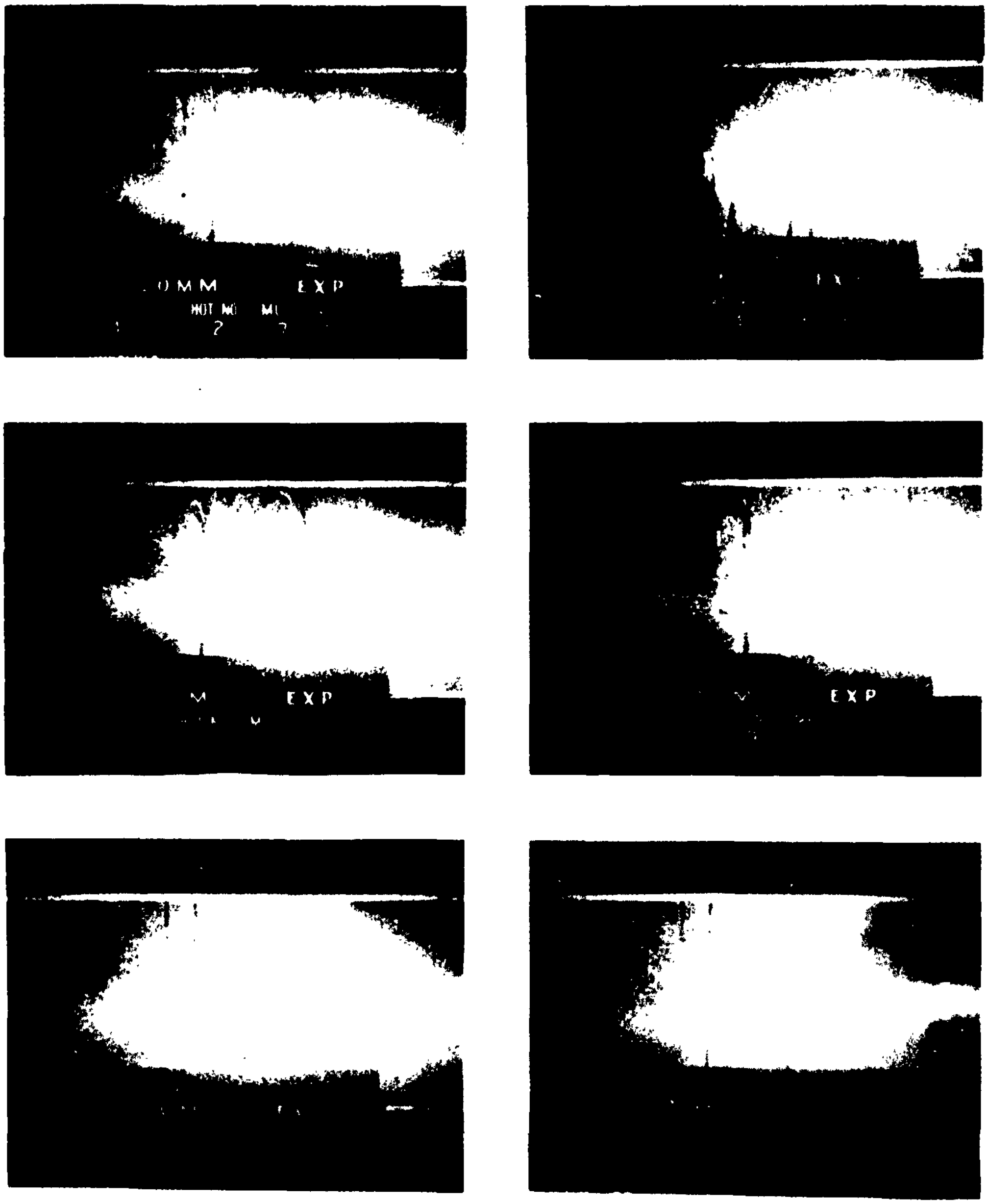
Low Order Function



Fuel Spray Ignitions

T318E1 Shot 70 Grains IM163 (Zirconium)

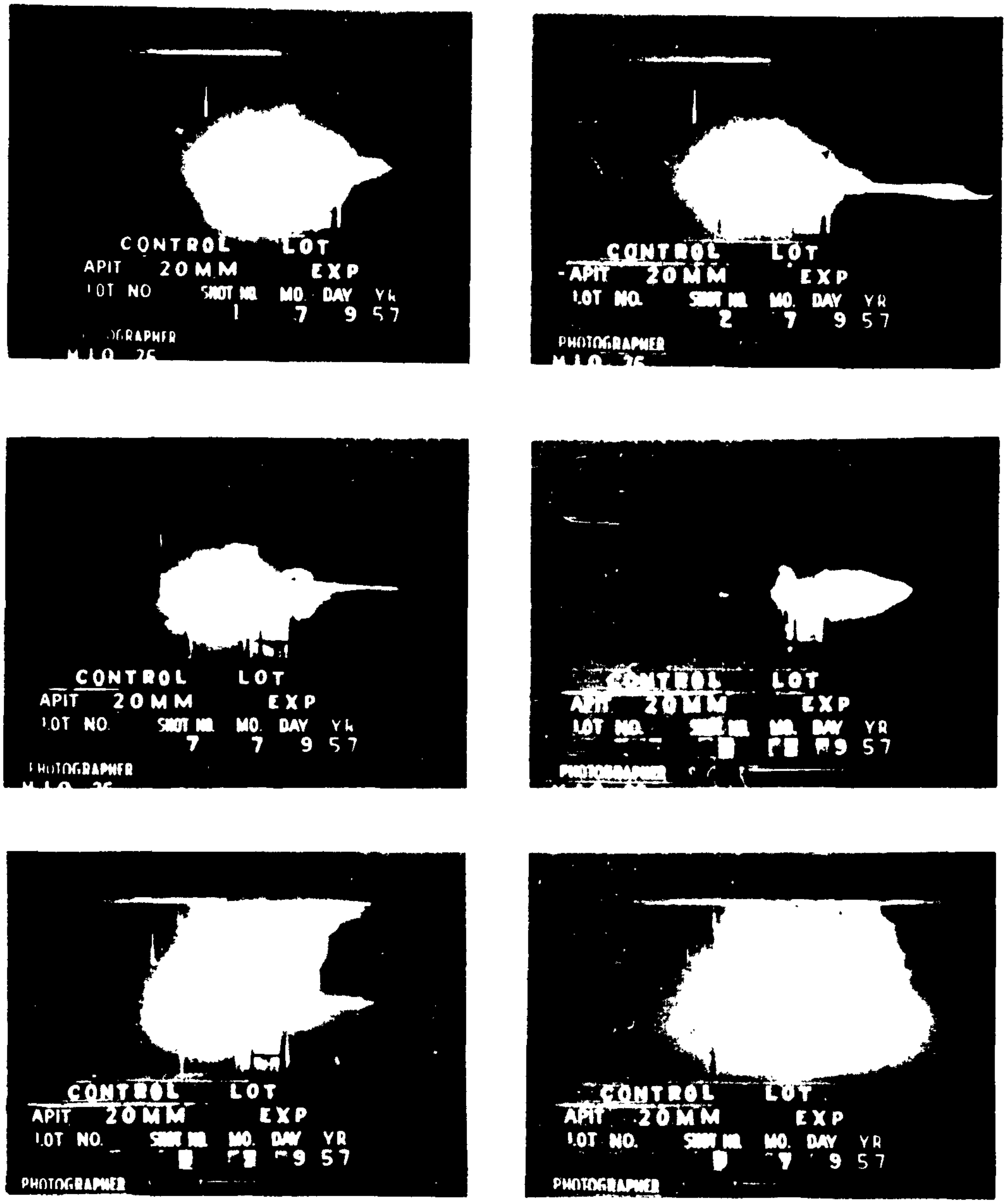
Figure 13. Simulated B-29 Target with JP-4 Fuel Spray Delay



Fuel Spray Ignitions

T318E1 Shot 80 Grains IM163 (Zirconium)

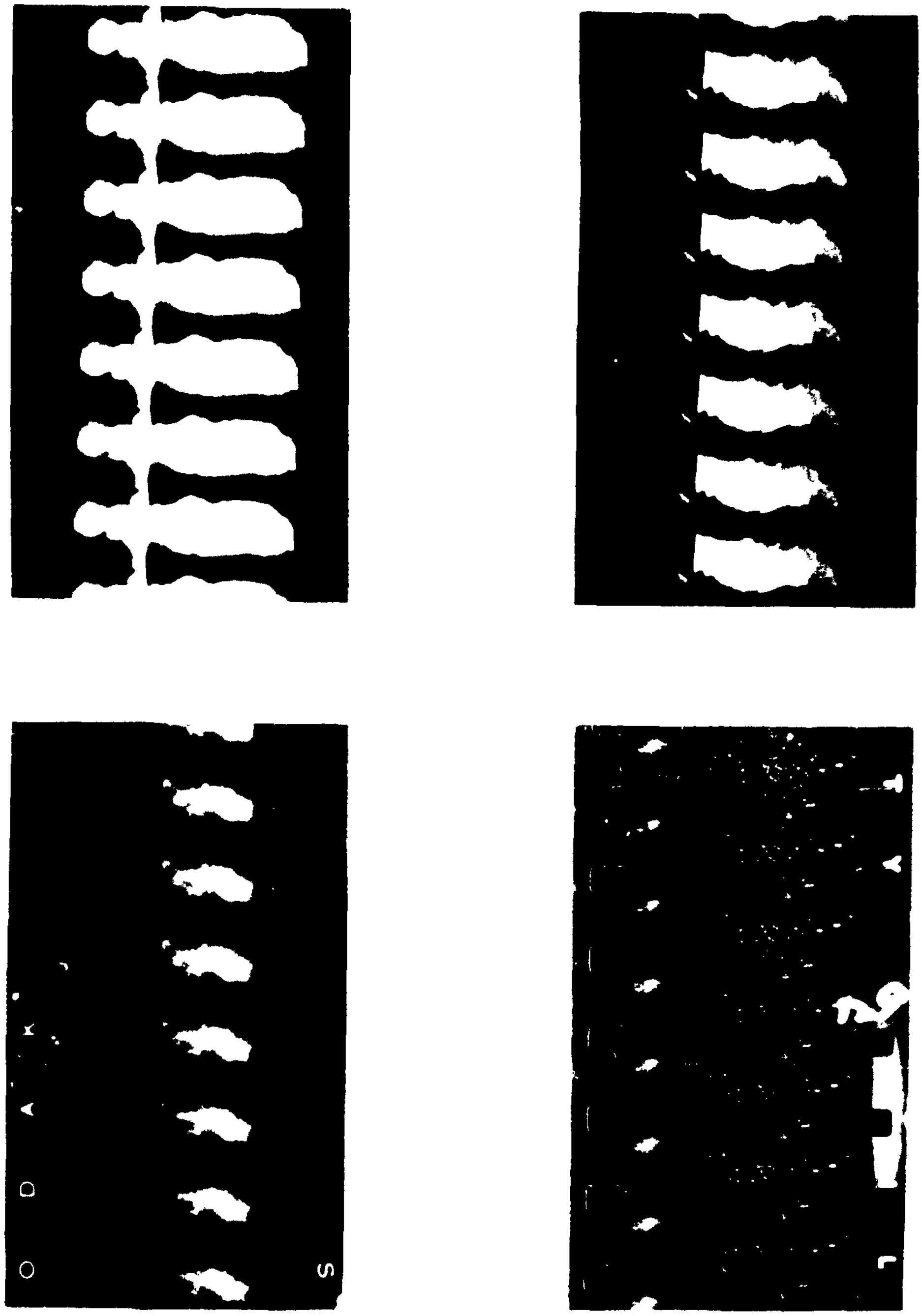
Figure 14. Simulated B-29 Target with JP-4 Fuel Spray Delay



Fuel Spray Ignitions

T312E3 Shot (Control) Standard Incendiary Mix

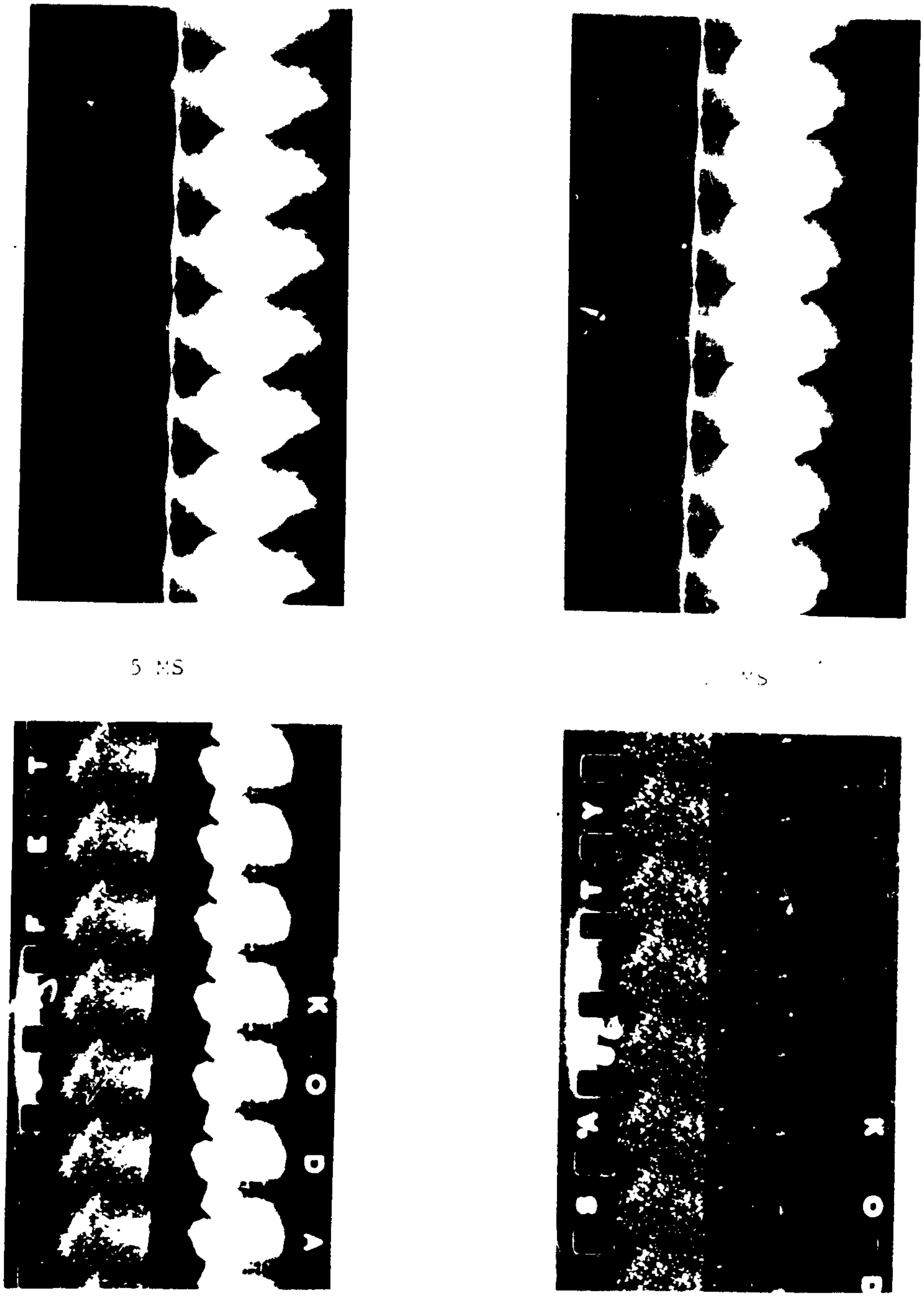
Figure 15. Simulated B-29 Target with JP-4 Fuel Spray Delay



25 MS 50 MS

T318E1 Shot 25 Grains IM163 (Zirconium)

Figure 16. Spark duration at various times after initiation of incendiary function - Taken from Fastax Film Strips

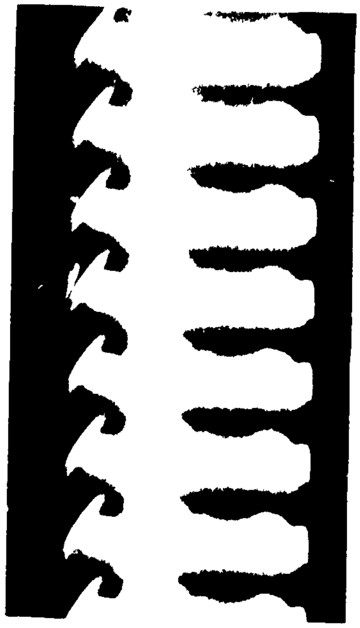


25 MS

50 MS

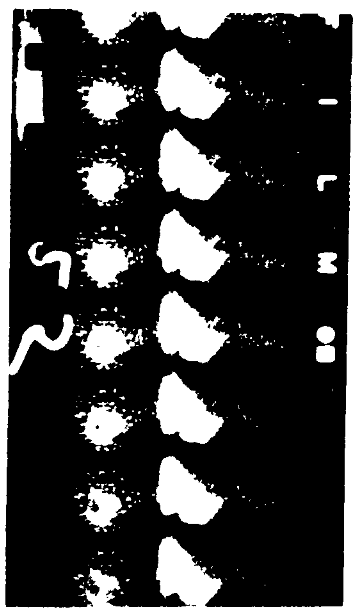
T318E1 Shot 75 Grains IM163 (Zirconium)

Figure 17. Spark duration at various times after initiation of incendiary function - Taken from Fastax Film Strips



5 MS

10 MS

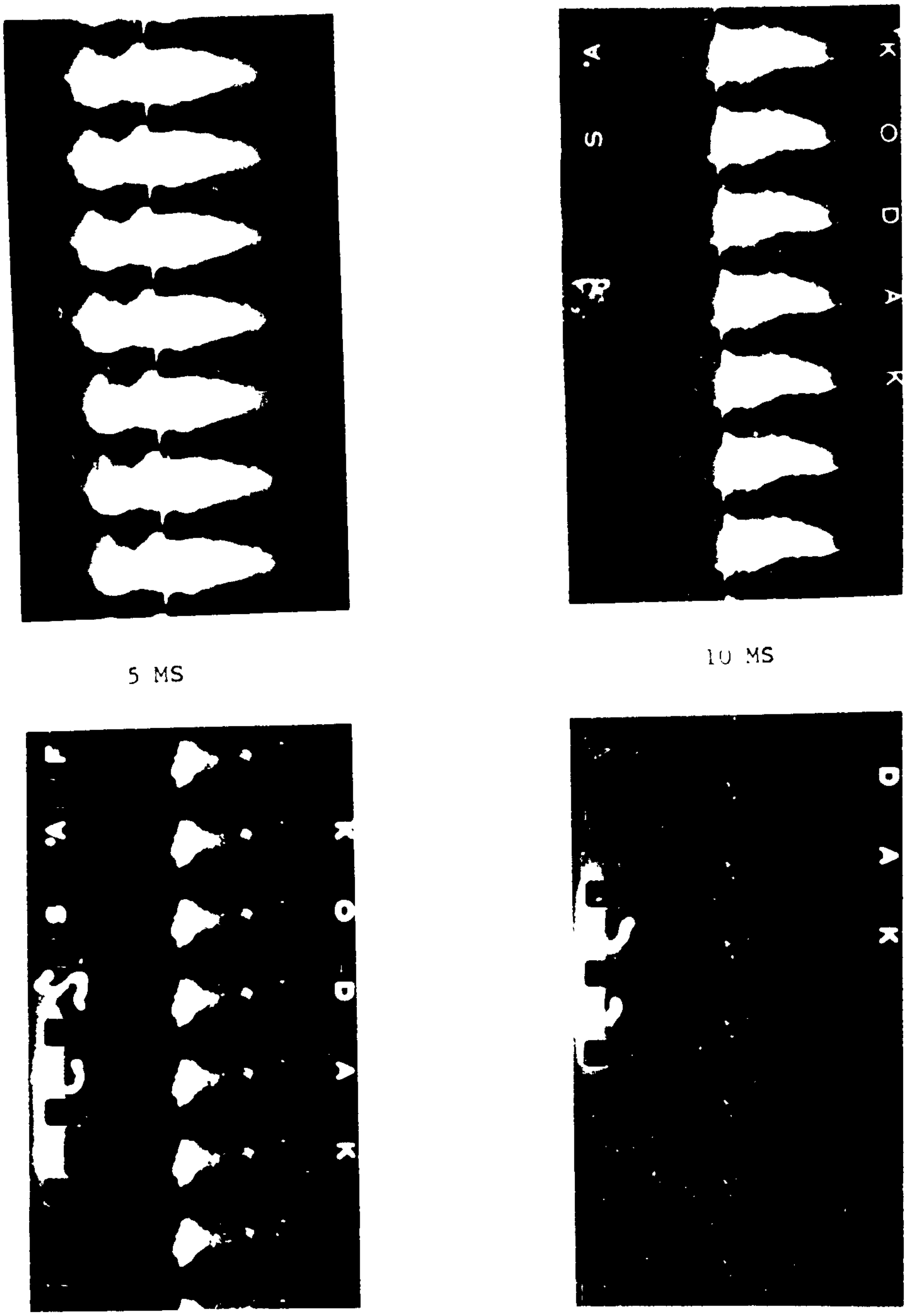


25 MS

50 MS

T318E1 Shot 125 Grains IM163 (Zirconium)

Figure 18. Spark duration at various times after initiation of incendiary function - Taken from Fastax Film Strips



5 MS

10 MS

25 MS

35 MS

T318 Shot (Control) Standard Incendiary Mix

Figure 19. Spark duration at various times after initiation of incendiary function - Taken from Fastax Film Strips

to the 75-grain and the 125-grain samples, but little difference between the 75-grain and the 125-grain samples. This was the basis for the selection of the 100-grain IM 163 charge in the incendiary content of the test round as being optimum.

Figure 20 is a still photograph of the three test lots and depict the target arrangement. It is to be noted that the pictures were not taken to be used for illustrative purposes but rather as a verification of the magnitude of the incendiary function of the round.

During the metal parts assembly of the above lots it was found in several instances that the interference fit between the nose piece and the serrated hole of the shot body was not sufficient for proper retention. A measurement survey of the metal parts on hand revealed that it was possible to have clearance between the nose pieces with minimum shank diameters and shot bodies with maximum hole diameters. To remedy this condition new nose pieces were fabricated with an increased shank diameter sufficient to produce interference fits of .006 to .008 in.

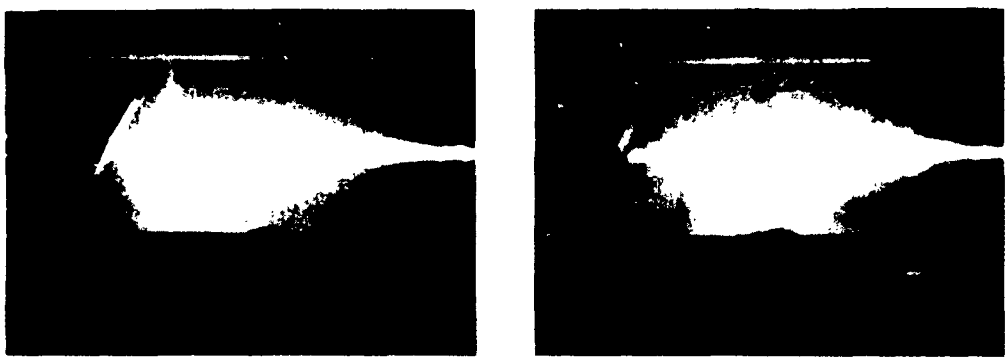
The occurrence of premature functions in the above lots, when comparable amounts of zirconium had been fired successfully in previous tests, led to detailed studies of the fits between the metal parts assemblies. Preliminary tests were conducted to determine the minimum interference fit required to prevent the nose piece from spinning in the shot body. This turned out to be .005 in. Interference fits in excess of .011 in. caused sufficient metal peeling from the O. D. of the shank of the aluminum nose piece to prevent the proper seating depth from being attained when assembled. It was also noted that the amount of collapse in the .166 in. drilled hole in the nose piece was directly proportional to the amount of the interference fit.

In an effort to produce a reliable nose piece-shot body assembly, consideration was given to:

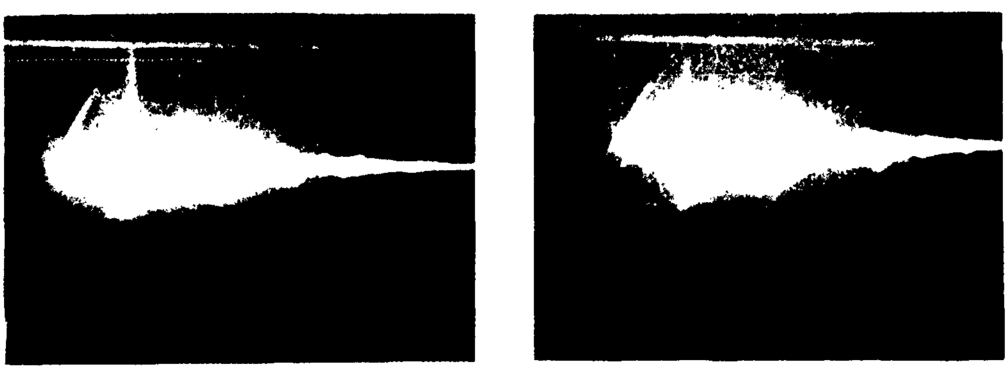
1. Increasing the number of serrations in the shot body hole from 36 to 72 so as to allow more space for the displaced aluminum to flow during assembly and thus reduce the amount of the metal peel. This would also increase the shear area of the nose piece shank.

2. Placing a taper on the forward shoulder of the broached area of the shot body which would cause a swaging rather than a cutting action on the nose piece during assembly and thus reduce metal peel.

25 Grains IM163 (Zirconium)



75 Grains IM163



125 Grains IM163

T318E1 Shot

Figure 20. Performance Comparison of Variations in Zirconium Content of Incendiary Charge

3. Drilling the .166 in. hole in the nose piece after assembly to the shot body.

To manufacture a broach that would cut 72 teeth would have been extremely difficult and costly. However, during the investigation of the nose piece-shot body assembly, it was found that the full tooth depth of the broach was not being achieved. If the full tooth depth were cut in the shot body hole it would produce the same overall effect as increasing the number of teeth. Figure 21 depicts this condition.

Concurrent with the investigation that led to the broach modifications, alternate methods of approach for nose piece-shot body assembly reliability were attempted. With the knowledge that the greater the interference between the nose piece and shot body, the greater will be the collapse of the .166 in. hole in the nose piece, modifications were made in small lots.

1. The nose piece shank O.D. was reduced so as to produce a .003 to .005 in. interference. These assembled satisfactorily.

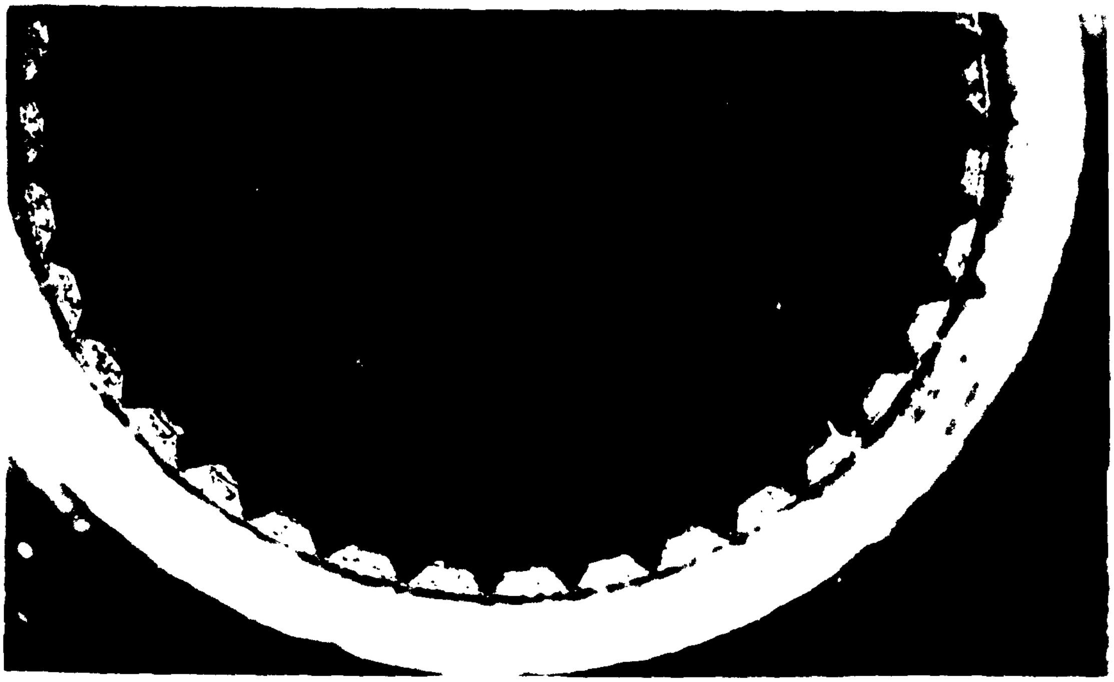
2. The nose piece shank O.D. was reduced only in the forward portion of the shank for approximately 3/16 in. to 1/4 in. which left the remainder of the shank O.D. at its original dimension (sufficient to produce .005 to .007 in. interference) for approximately 5/16 in. to 3/8 in. These also assembled satisfactorily.

3. Annealed noses as modified in step 2. These failed to assemble properly.

4. Annealed unmodified noses. These also failed to assemble properly.

Torque tests conducted on the assemblies with the noses as modified in step 1. resisted approximately 10.5 ft. lbs. torque before failure. The assemblies with the nose pieces modified as in step 2. resisted approximately 8 ft. lbs. torque before failure.

To evaluate the relative merits of 2024T4 aluminum as compared to 7075T6 aluminum for use in the nose piece fabrication, small lots of five each were assembled with interference fits ranging from .003 to .011 in. The same shot bodies were used for both the 2024T4 aluminum nose pieces and the 7075T6 aluminum nose pieces when torque tested. The tests were repeated with the nose pieces inert charged to determine



Shallow Tooth Depth - Flats

Full Tooth Depth

Figure 21. Magnified views (approx 20X) of serrations in nose piece hole of shot body.

if the charging process affected the physical properties of the nose pieces. No difference was observed. In all torque tests conducted a significant difference noted was that the 2024T4 aluminum nose pieces would fail due to the nose piece shank spinning in the serrated shot body hole at a slightly higher interference fit than the 7075T6 aluminum nose pieces.

Two lots, each containing 100 rounds live charged, were assembled. One lot was assembled with the 2024T4 aluminum nose pieces, the other with 7075T6 aluminum. The lots were subdivided according to nose piece concentricity. The torque tests revealed that eccentricity of the nose piece when assembled had a direct bearing on the amount of torque required to cause failure.

The results of the firing with respect to reliability were:

1. No premature functions in the lot assembled with the 7075T6 aluminum noses - eccentricity under .010 in.

2. Two premature functions in the lot assembled with 7075T6 aluminum noses - eccentricity over .010 in.

3. One premature function in the lot assembled with 2024T4 aluminum noses - eccentricity under .010 in.

4. No premature functions in the lot assembled with 2024T4 aluminum noses - eccentricity over .010 in.

The results with respect to sensitivity were:

1. The 7075T6 aluminum noses were approximately 80 percent effective against .040 aluminum plate - normal.

2. The 2024T4 aluminum noses were approximately 90 percent effective against .040 aluminum plate - normal, and approximately 25 percent effective against .025 aluminum plate - normal.

The conclusions drawn from the results of these firings were:

1. that the 7075T6 aluminum is more brittle and therefore more liable to fail during insertion of the nose piece into the shot body;

2. the premature encountered with the 2024T4 aluminum nose piece was believed the result of insufficient interference with this softer metal which permitted rotation of the nose in the body rather than shear type fracture. This supposition was substantiated by torque test data.

Torque tests were conducted on nose pieces fabricated from 1020 steel and phosphor bronze. The test results indicated that the torque required to cause failure to the 1020 steel noses was of the same level as that required for the aluminum. The phosphor bronze nose pieces required a torque approximately 50 percent less than that required for either steel or aluminum. Further consideration of the use of steel nose pieces was discontinued when the nose thickness required for adequate sensitivity was considered.

The effect of various heat treatment techniques and materials on the armor penetrating characteristics of the shot body was investigated and the ballistic limit of each determined. The details of these tests are contained in Reference 3.

The tracer container portion of the round was also studied to determine if the premature functions could be caused by design deficiencies in this area. Design modifications resulting in changes in dimensional tolerances, particularly those affecting the areas of thread engagement and thread relief were made. The tracer container charging technique was changed, 7075T6 aluminum replaced 2024T4 and the tracer containers were anodized.

The tracer containers were charged in a simulated die and inspected prior to "laminacing" and assembly into the live charged shot bodies. Prior to this process change the procedure had been to charge the nose piece - shot body assembly, "laminac" and assemble the tracer container, then tracer charge the assembled shot. However, an occasional tracer container would fail under the charging pressures that were applied (120,000 psi) which would require that the entire assembly be scrapped. In addition to this, there was the possibility that there were failures or fractures that were not detected when assembled according to this procedure.

Two additional modifications were found necessary in the metal parts after receipt of the new broaches which made possible the achievement of the full tooth depth in the serrated hole of the shot body. The nose piece hole was drilled after assembly into the shot body and the thickness of the front of the nose piece in the front was reduced from 0.050 to 0.040 in. to increase the sensitivity of the round.

Although the drilling of the hole in the nose piece after assembly required an additional operation, it was deemed necessary to insure a more uniform incendiary performance. The collapse of the hole in the nose piece, when assembled after drilling, required that the charging stem be of a diameter smaller than the I.D. of the hole after collapse, and the smaller stem would not produce complete compression on the incendiary mix column when it was operating in the region to the rear of the collapsed area.

At the direction of the Aircraft-Gun Ammunition Task Force, zirconium seeded mixes were eliminated entirely on the basis that they were too sensitive for use in high velocity cartridges.

The standard incendiary mix that was substituted for the zirconium type mix consisted of approximately 80 grains of IM-136 in the forward area and approximately 50 grains of IM-68 in the remainder of the cavity. Figures 22 and 23 illustrate the performance of both the standard and zirconium mixes.

Two test programs were in process when the use of the standard incendiary mix was adopted. One was to determine if strengthening the shank of the nose piece by reducing the diameter of the hole from 0.166 in. to 0.150 in. would prevent the propagation of the incendiary function because of the reduced diameter of the incendiary column in the nose piece. Seven of eleven rounds fired functioned against 0.040 in. aluminum at 0° obliquity. However, it was not necessary to adopt this modification since no malfunctions occurred when the standard incendiary mix was used.

The second program in process was to determine the merits of the anodized aluminum tracer containers. A lot of 130 cartridges was fabricated. Fifty cartridges were assembled with anodized aluminum tracer containers; the remaining 80 were assembled with uncoated tracer containers.

The initial firing test was conducted with a paper witness screen placed 15 feet from the gun muzzle and an aluminum target at 175 yards. There was evidence on the witness screen of some sort of break up with

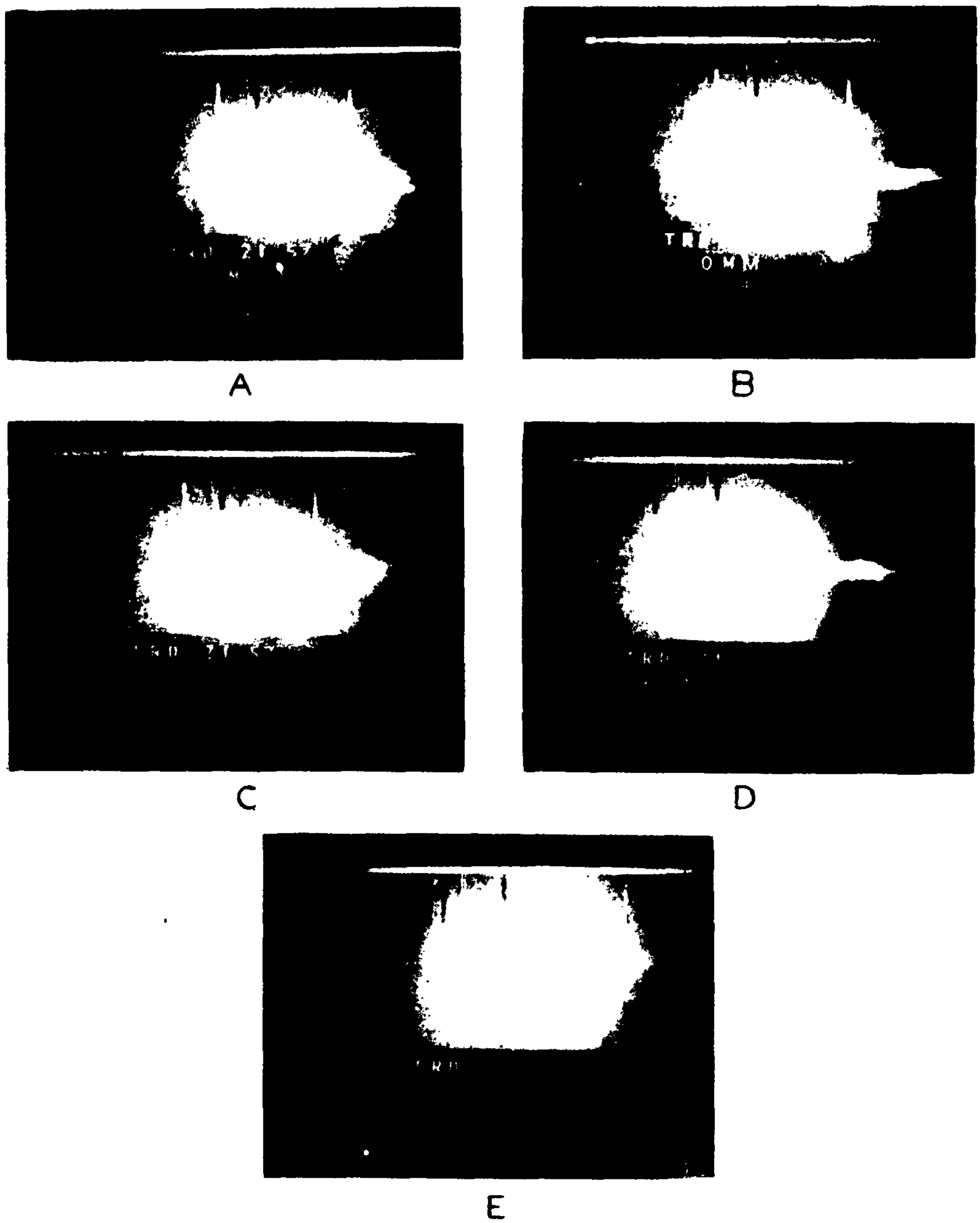


Figure 22. T318E1 Shot - 100 grain IM943 (Zirconium)

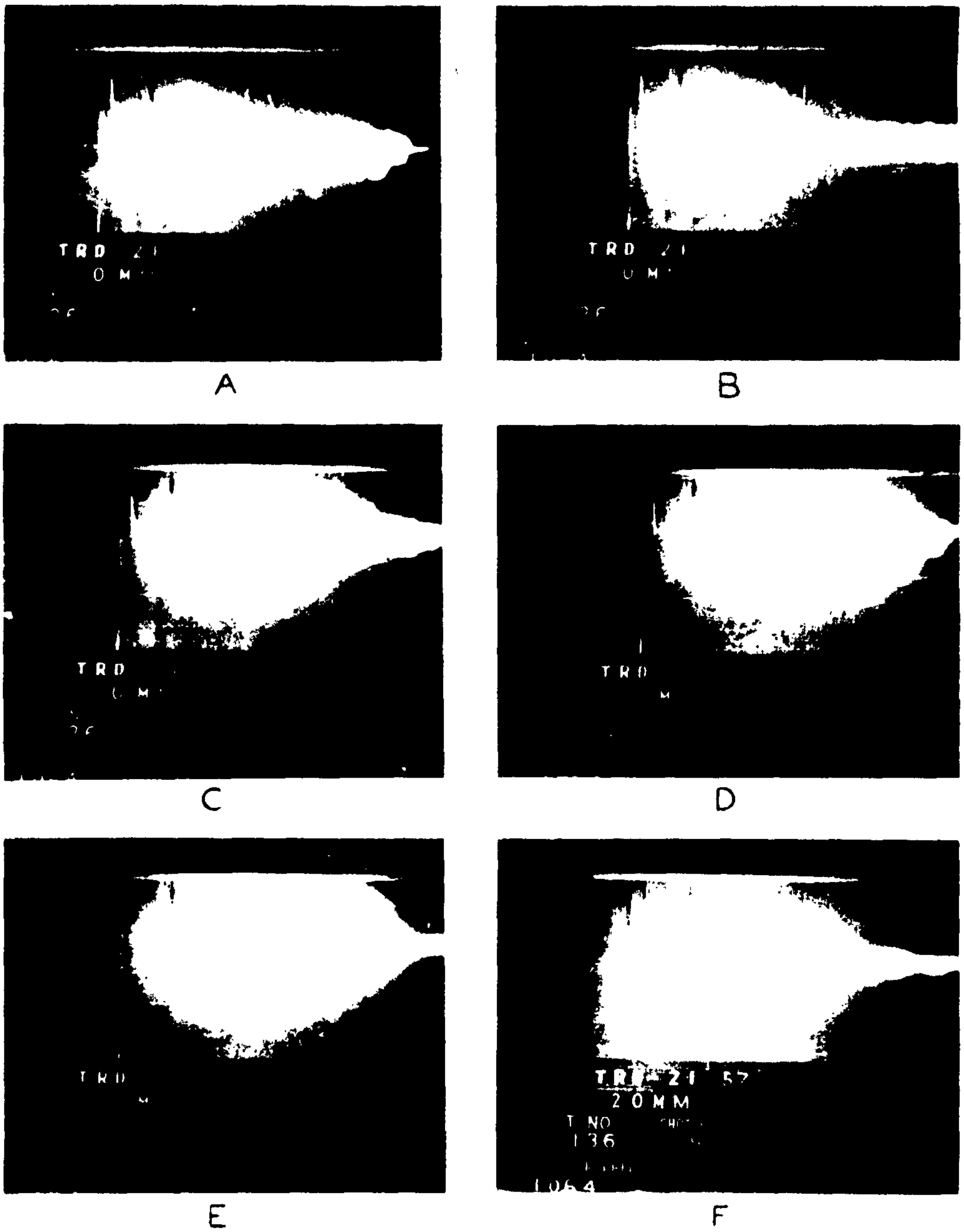


Figure 23. T318E1 Shot - Standard Incendiary Mix

the rounds containing the anodized tracer containers, however, all projectiles functioned at the target down range. A test was then conducted with X-ray coverage of the projectile approximately 5 feet from the gun muzzle. The X-rays obtained gave the first indication that the tracer column was breaking up in the gun barrel.

When the tracer charging technique was changed so that the tracer containers were charged in a die prior to assembly in the charged shot, the charging pressures were reduced to 90,000 psi because difficulty was encountered in removing the charged tracer containers from the charging die. Accordingly, the remaining cartridges were broken down and the tracer mix recompressed at 120,000 psi. The projectiles were than X-rayed to determine if the tracer containers were fractured during the recompression. Figure 24 depicts a typical X-ray of the assembled projectiles. The projectiles were assembled into cartridges and the initial test was repeated. There was no difference in the results. The rounds assembled with the anodized tracer containers still gave evidence of tracer break up on the witness screen but still functioned on the down range target. There was no evidence of a tracer break up with the rounds that were assembled with the uncoated tracer containers.

There were sufficient metal parts available to fabricate 26 rounds with anodized tracer containers and 54 rounds with uncoated tracer containers. These projectiles were assembled and sent to Aberdeen Proving Ground for tests with facilities not available at Frankford Arsenal and thus gain additional information. The tests consisted of firing rounds at both service and excess pressures for daylight and night trace, incendiary function and metal parts security (M39 gun) while observing for muzzle bursts in all phases of the firings. Detailed test results will be found in Appendix C - APG Firing Record No. S-46322.

Because of the bright sky background in all of the daylight firings, it was possible to observe the trace for a distance of only several feet in front of the gun muzzle. Accordingly, it was necessary to fire the length of trace determinations at night. One round with an uncoated tracer container and two rounds with the coated tracer containers failed to trace. These blinds occurred in the excess pressure cartridges.

The metal parts security firings from the M39 gun consisted of linking three or four test rounds to the tail end of a 50-round belt of Ball M55 rounds which were being fired on an erosion schedule. There was no evidence of metal parts separation.

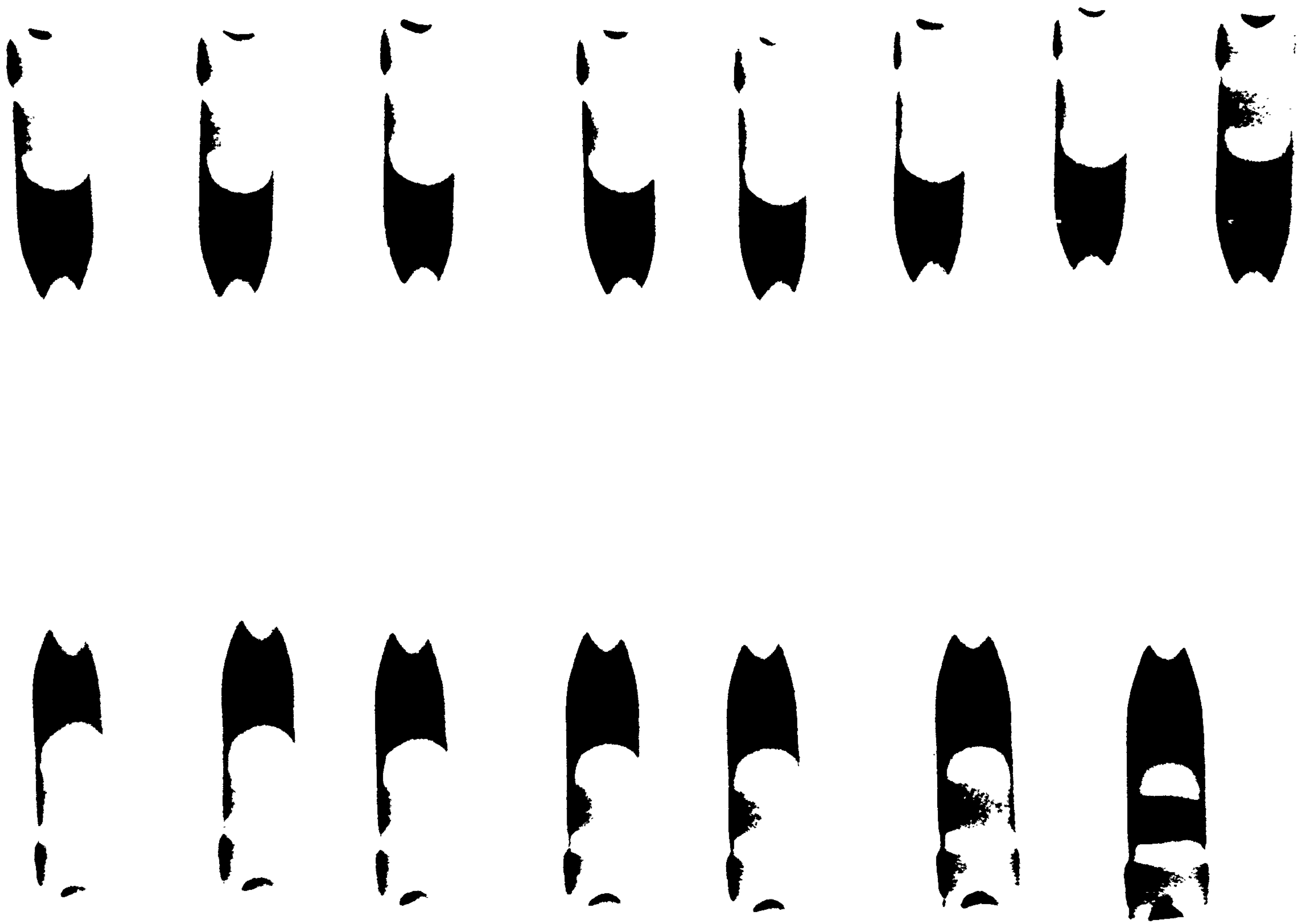


Figure 24. X-ray T230E1 Cartridges

The incendiary function phase of the tests consisted of firing against a .125 in. aluminum plate at a distance of 600 yards. Trace was observed from the gun and at the target. Three rounds failed to function on the target.

With the relatively satisfactory performance of the rounds in the above tests at Aberdeen Proving Ground, a contract was placed for a pre-engineering test lot which was to consist of 1000 sets of shot metal parts, so that advantage could be taken of the reduced costs of industrial mass production facilities and more extensive tests could be conducted.

The results of tests performed with a small sample of the purchased metal parts indicated that they were inferior to the metal parts which had been fabricated "in-house" at Frankford Arsenal with respect to both sensitivity and the amount of torque required to cause nose piece failure. However, the amount of torque required to cause nose piece failure was believed to be in excess of the torsional forces that would be incurred in firings. This was based on the fact that there were no metal parts failures in the firings conducted at excess pressure. The thickness of the forward portion of the nose piece was reduced to .010 in. in an attempt to increase the sensitivity of the round.

Incendiary charging, tracer charging, shot assembly and cartridge assembly were accomplished at Frankford Arsenal. See Appendix D for details of incendiary and tracer charging data. The cartridges that were assembled were loaded to service pressure and velocity. In addition to the assembled cartridges, a quantity of charged and assembled shot was shipped to APG to be loaded as required in the armor piercing ballistic limit determinations of the test plan.

Because of a de-emphasis in aircraft ammunition development, the improved 20mm APIT program was to be terminated with the evaluation of this approximately 1000-piece lot. Since the quantity of ammunition available for the evaluation was limited, a test plan was prepared to cover as many phases of a cartridge evaluation as possible. The test was divided into six phases: armor penetration, incendiary performance, ballistic match, accuracy, metal parts security and tracer performance. The 20mm APIT T230 cartridge, recently standardized M53, was used as a control in all phases of the test.

RESULTS AND DISCUSSION

The overall test results were not at the level that had been anticipated. See Reference 4 - APG Report No. DPS-139- Evaluation Test of Cartridge, APIT, 20mm, T230E1, for details of tests and results. In the metal parts security phase, 500 rounds, conditioned at -65° F and fired in 50-round bursts from the M39 gun, there was evidence of possibly six nose piece separations. In the trace performance phase there were 18 blinds out of 40 rounds fired. In the sensitivity firings, it was necessary to have aluminum targets at least 0.125 inch thick to insure consistent functioning.

The armor penetration, accuracy and ballistic match (with M56A2 HEI round) firing results were good. The incendiary performance of the round was excellent. It surpassed the performance of the control round in both the size and duration of the flash. There was also the added advantage of the projectile carrying the incendiary effect down range to distances in excess of 20 feet ..... how far in excess of 20 feet is not known because camera coverage ended 20 feet to the rear of the target. Figure 25 depicts comparative incendiary functions of the test and control rounds at various time increments after impact against an aircraft type target. (Prints were made from fastex film strips.)

The experimental cartridge had never been tested at -65° F. The majority of the firing tests to determine metal parts adequacy were conducted at excess pressures (65,000 to 70,000 psi) and ambient temperature. It was felt that satisfactory performance at excess pressures should insure sustained satisfactory performance at normal pressures. However, the unsatisfactory metal parts security of the final test lot fired at -65° F when compared to the satisfactory performance of preliminary lots fired at high pressures leads to the assumption that the cold temperature mechanical properties of the aluminum alloy used are sufficiently changed to require dimensional and/or alloy modifications. The decreased sensitivity of the final test lot indicates that there can be a variation in the physical and mechanical properties within an alloy (7075T6), possibly as a result of different heats, supplier or processes. Normally tracer column retention problem can be corrected by increased charging compression or increased percentage of binder in the mix. To increase the charging pressures in the aluminum tracer container, it would be necessary to reduce the tracer cavity diameter. The charging

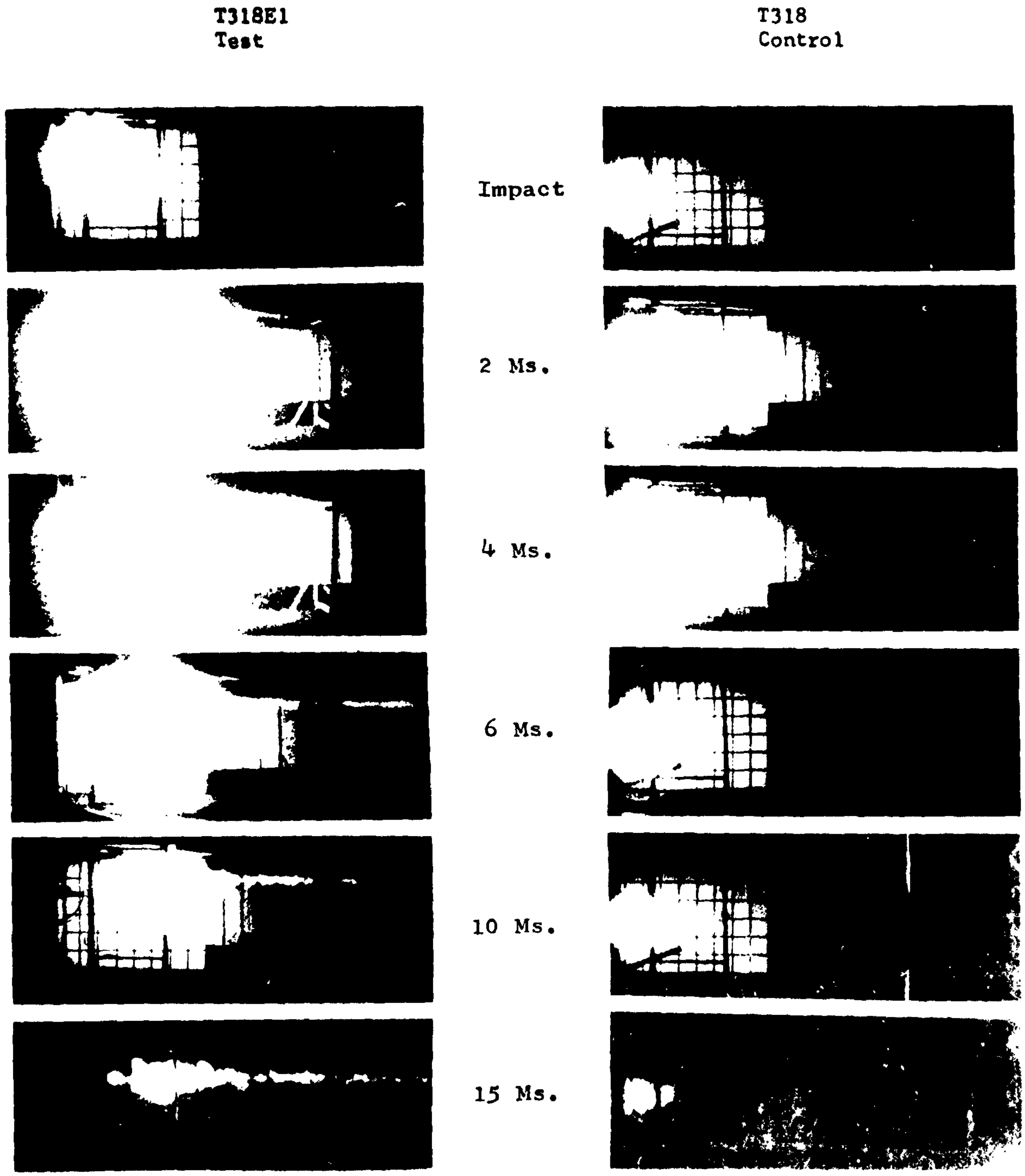


Figure 25. Comparison of functions at various times after impact.

pressures used were the maximum possible without causing deformation to the tracer container. Increasing the percentage of binder in the tracer composition could eliminate the tracer blow out without the necessity of changing the cavity dimensions or compression.

CONCLUSIONS

The development of a new 20mm APIT cartridge was partially successful and only the premature termination of the development prevented proper completion of the program. The design objectives that were not met would not require excessive development effort to correct. These are metal parts security, sensitivity and tracer performance. Performance with respect to armor penetration, accuracy, ballistic match with the M56 HEI, reduced number of metal parts and reduced area of the nose have met the design objectives that were set forth. The terminal incendiary performance by virtue of being carried through light armor and multiple thin targets was vastly improved.

RECOMMENDATIONS

It is recommended that:

1. The design objectives be reviewed and modified to reflect current or anticipated ammunition requirements.

2. Development be re-initiated and directed toward these objectives and requirements.

REFERENCES

1. Minutes of 13th Aircraft Gun-Ammunition Conference.

2. F.A. Report No. R-1398, Shot, APIT, 20mm, Experimental.

3. F.A. Report No. R-1462, Ballistic Limits of Shot, 20mm, APIT, T318 and T318E1.

4. A.P.G. Report No. DPS-139, Evaluation Test of Cartridge, APIT, 20mm, T230E1 (with T318E1 Projectile).

APPENDIX A

Ammunition Group
Development Division
Small Arms Ammunition Development Branch

17 April 1957

TECHNICAL REQUIREMENTS DOCUMENT

PROGRAM: No. 21-57

PROJECT: TS1-47

SUBJECT: Development of Shot, APIT, 20mm

PROJECT ENGINEER: Mr. B. Diaz, Ext. 6105

OBJECT: Present requirements for the 20mm APIT Shot include a high stability factor necessary for increased projectile air speed encountered in firing from modern aircraft. The present APIT shot design is inadequate for charging with a zirconium based incendiary. Preliminary tests and calculations of the experimental APIT shot, conducted under Program No. 108-56 indicate that the experimental shot satisfactorily meets the aforementioned requirements. In addition, the experimental design is such that metal parts separation should be nonexistent. Under this program, it is intended to establish incendiary charges and charging techniques that will allow the use of IM163 (zirconium based incendiary). Previous shell charges incorporating zirconium resulted in prematures; however, when IM 11 was layer charged with IM 163, it gave evidence of acting as a buffer between the tracer plug and the IM 163, effectively eliminating premature incendiary function.

INSTRUCTIONS: This program is limited to the design, development and evaluation of a maximum of 2,500 rounds.

1. MDS-M: The metal parts dimensions for the experimental, 20mm, APIT, shot have been established under Program No. 108-56. The charge for optimum terminal ballistic performance and further investigation of materials and heat treating for the armor piercing body will be determined during this phase.

2. MDE: Prepare drawings of experimental shell and components as requested by MDS-M.

3. MPC: Operations Division is requested to:

a. Manufacture tools in accordance with sketches supplied by MDS-M.

b. Manufacture metal parts assemblies in accordance with drawings supplied by MDS-M.

c. Inspect and gage metal parts and assemblies.

d. Manufacture incendiary mix in accordance with instructions from MDS-C.

e. Charge shot bodies as follows:

Initially charge 150 shell using 50 grain IM 163 in the forward section of the shell. The balance of the charge will consist of IM 11. Charge the base plugs with 17 grains of R321 and 10 grains of I280. Subsequent lot charging will be determined from test results of initial lot.

f. Prime, load and assemble into cartridges as requested by MDS-C.

4. MIQ: Industrial Engineering Division is requested to fire tests of initial experimental lot of 20mm APIT shot as follows:

Twenty-Five (25) rounds sensitivity and penetration of high obliquity aluminum targets ranging from .025 to .190 inches in thickness.

Fire ten (10) rounds, recording incendiary duration with drum camera in conjunction with chronograph.

Fire fifty (50) rounds recording, with drum camera, effect of incendiary on modified B29 target and fuel spray.

Fifty (50) rounds to determine ballistic limit against 3/4" homogeneous armor plate.

Fifteen (15) rounds fired against simulated jet fuel tanks.

Subsequent lots will be fired as requested in memorandum from MDS-M.

INSPECTOR: Report all deviations to the project engineer by telephone immediately.

BDiaz/bk

Prepared by: /s/ Benny Diaz Date 4/16/57

Reviewed by: /s/ Charles J. McGee Date 4/16/57

Concurred by: /s/ Alfred S. Hitner Date 4/17/57

Approved by: /s/ V. W. Walters Date 4/17/57

Copies to:

ORDIM, ORDTS, OAC, MDE, MIQ, MDS, MHP-File

w/Dwg:
MPC, MSN, MSR, MST, Mr. Diaz
MDS-M

3 June 1957

Memo No. 1
Technical Requirements Document - Program No. 21-57

PURPOSE: To supply the Operations and Industrial Divisions personnel with more detailed information concerning the various lots of ammunition to be assembled and evaluated under Program No. 21-57.

1. Under Program No. 21-57, four lots, numbered 1 to 4, of approximately 125 rounds each of Cartridges, APIT, 20mm, T318E1 have been assembled and partially evaluated at the Proof House. These lots have been fired for incendiary performance against various thicknesses of aluminum plate at angles of obliquity ranging from 0° to approximately 85°. The results of these limited tests have indicated that sensitivity and reliability are satisfactory. The number of rounds remaining from these four lots varies from 51 to 66 rounds.

2. It is intended that 50 rounds of each of the above mentioned lots be expended in the following tests:

a. 10 rounds against 0.025" aluminum at 0° obliquity.
b. 10 rounds against 0.025" aluminum at 45° obliquity.
c. 10 rounds for burst duration using drum camera and chronograph.
d. 10 rounds against modified B29 target with fuel spray with a time delay of 50 m.s.
e. 10 rounds against modified B29 target with fuel spray with a time delay of 150 m.s.

NOTE: Control lot of standard APIT, T230 cartridges will be used for comparison purposes under c, d and e above.

3. The remaining rounds from these four lots should be expended in a comparison test of the penetration characteristics of this round versus the standard Cartridge, APIT, 20mm, T230. For this test the rounds from the various lots may be mixed since the AP characteristics should be identical for each lot (metal parts assemblies are identical - charging technique only was varied).

Memo No. 1
Technical Requirements Document - Program No. 21-57

The targets for this test will be 3/4" homogeneous armor plate and the ballistic limit of the rounds shall be determined in terms of the angle of obliquity of this plate which the rounds can defeat.

4. An additional lot of approximately 800 shell body, metal parts have been machined and overlay banded. These metal parts have been designated as Lot 5 and have been fabricated from FS 1036 steel. The heat treatment and charging techniques used on this lot of shot will be determined based on the results obtained in the test mentioned in the preceding paragraph.

5. A quantity of approximately 650 shot are currently being machined using the remainder of the FS 1036 steel available. A few minor dimensional changes are being made in the fabrication of this lot and these shot will be designated as Lot 6.

6. A final lot of approximately 500 to 600 shot will be fabricated using FS 4140 steel. This lot will be designated Lot 7.

7. If variations in charging techniques or heat treatment are required within Lots 5, 6 and 7, these variations will be identified by letter suffixes to the lot number, such as 5a, 5b, etc. The metal parts identification will be initiated by MSN and care should be given to insure that lot identities are maintained throughout the succeeding operations.

/s/ Charles J. McGee
CHARLES J. McGEE
Supervisory Ammn
Design Engineer

CJMcGee/bk
Copies to:
Planning Section, Oper. Div.,
Planning Section, Industrial Div.,
MIQ, Tech. Administration Office,
MSN-J. Fern, MSX-G. Hadfield,
MSX-H. Harkins

APPENDIX B

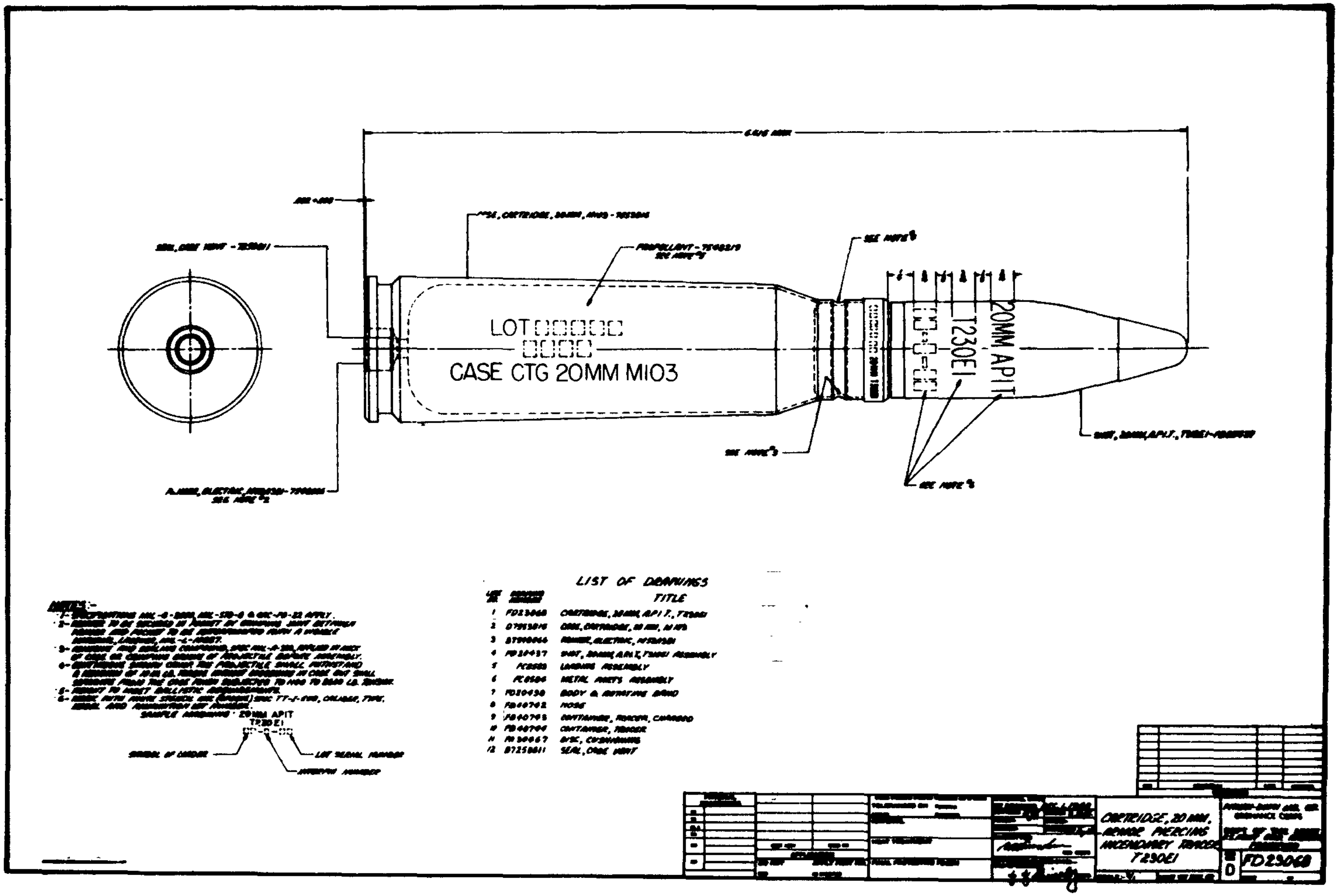


Figure B-1. Cartridge, 20mm, Armor Piercing Incendiary Tracer T230E1

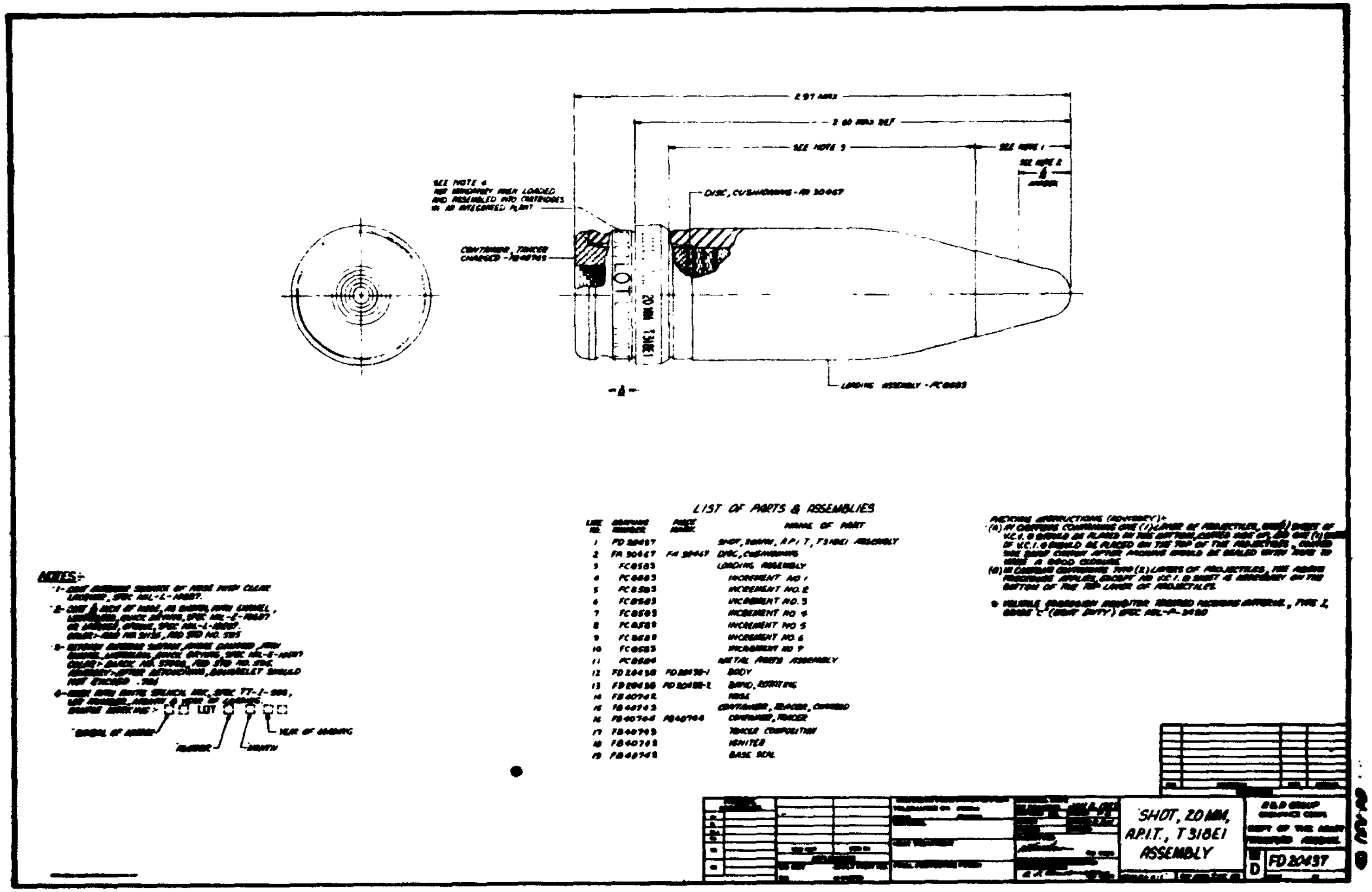


Figure B-2. Shot, 20mm, APIT, T318E1 Assembly

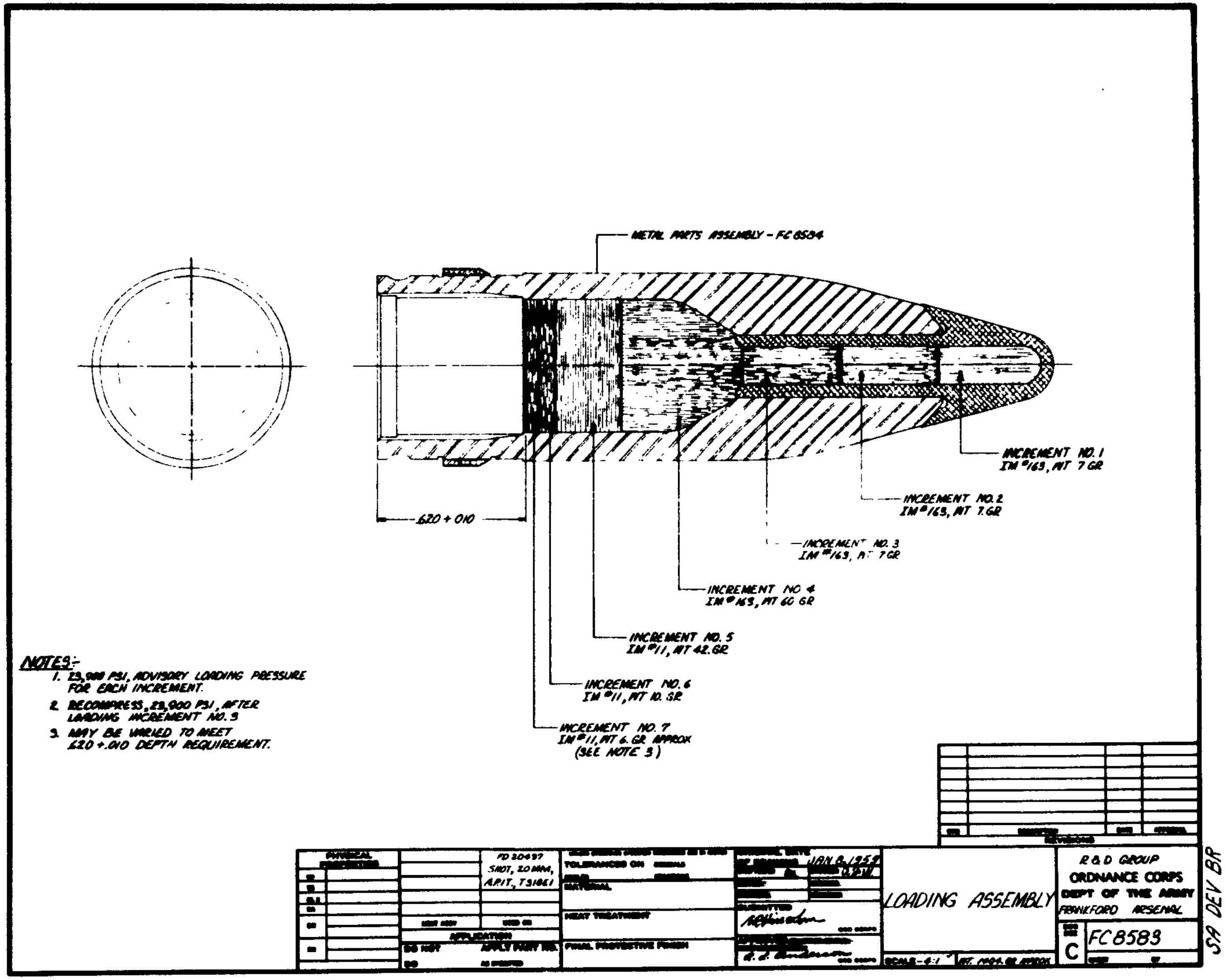


Figure B-3. Loading Assembly

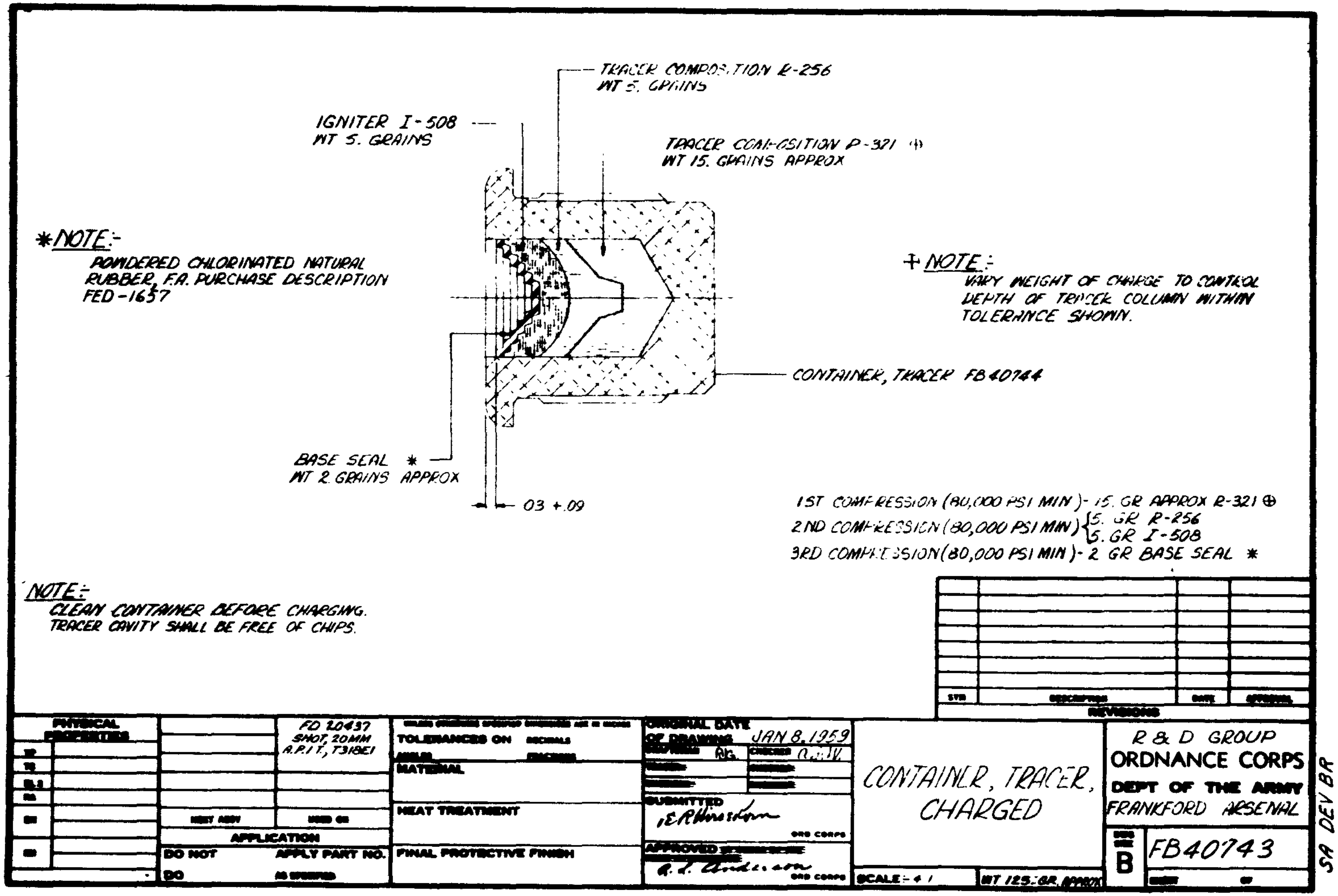


Figure B-4. Conatiner, Tracer, Charged

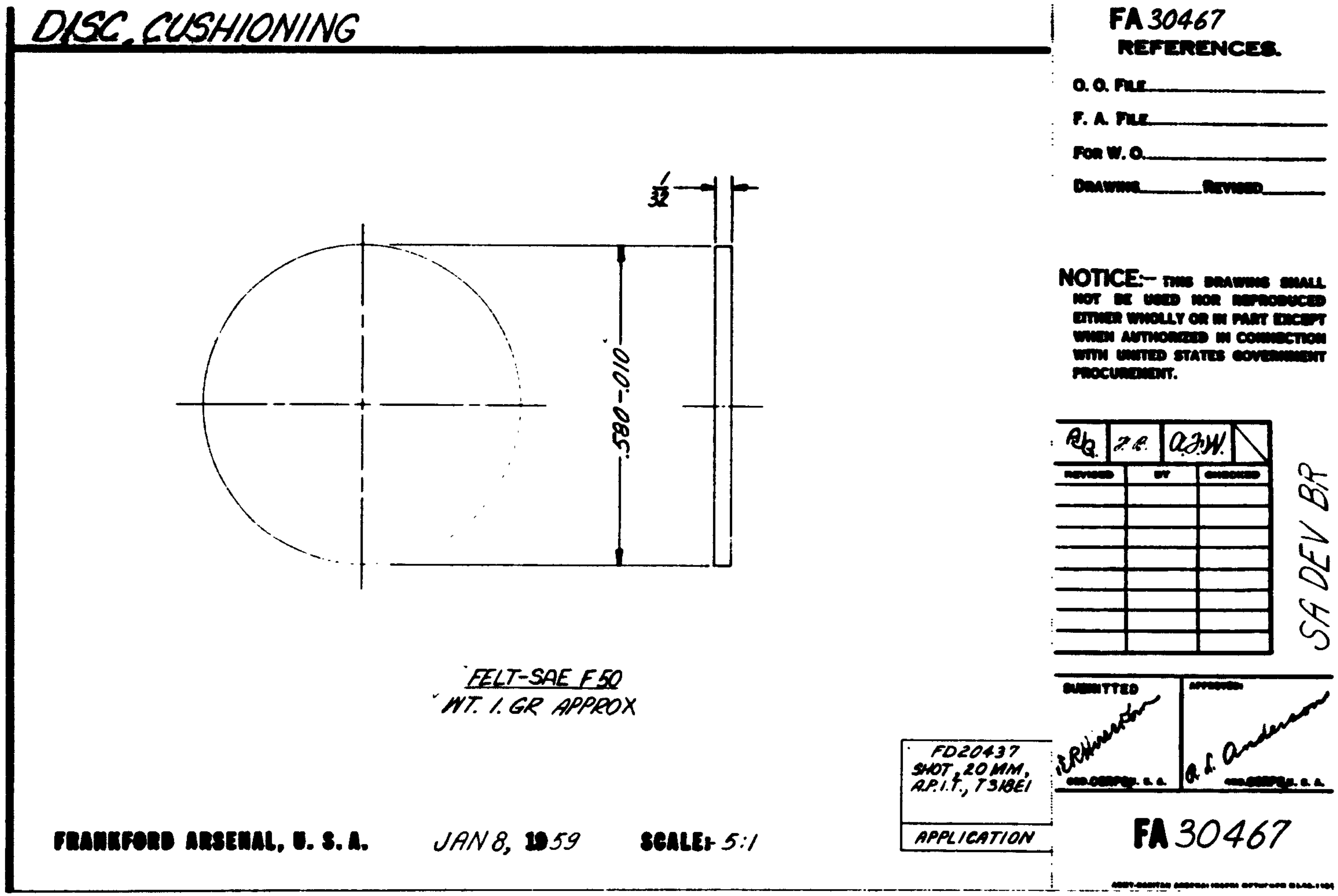


Figure B-5. Disc, Cushioning

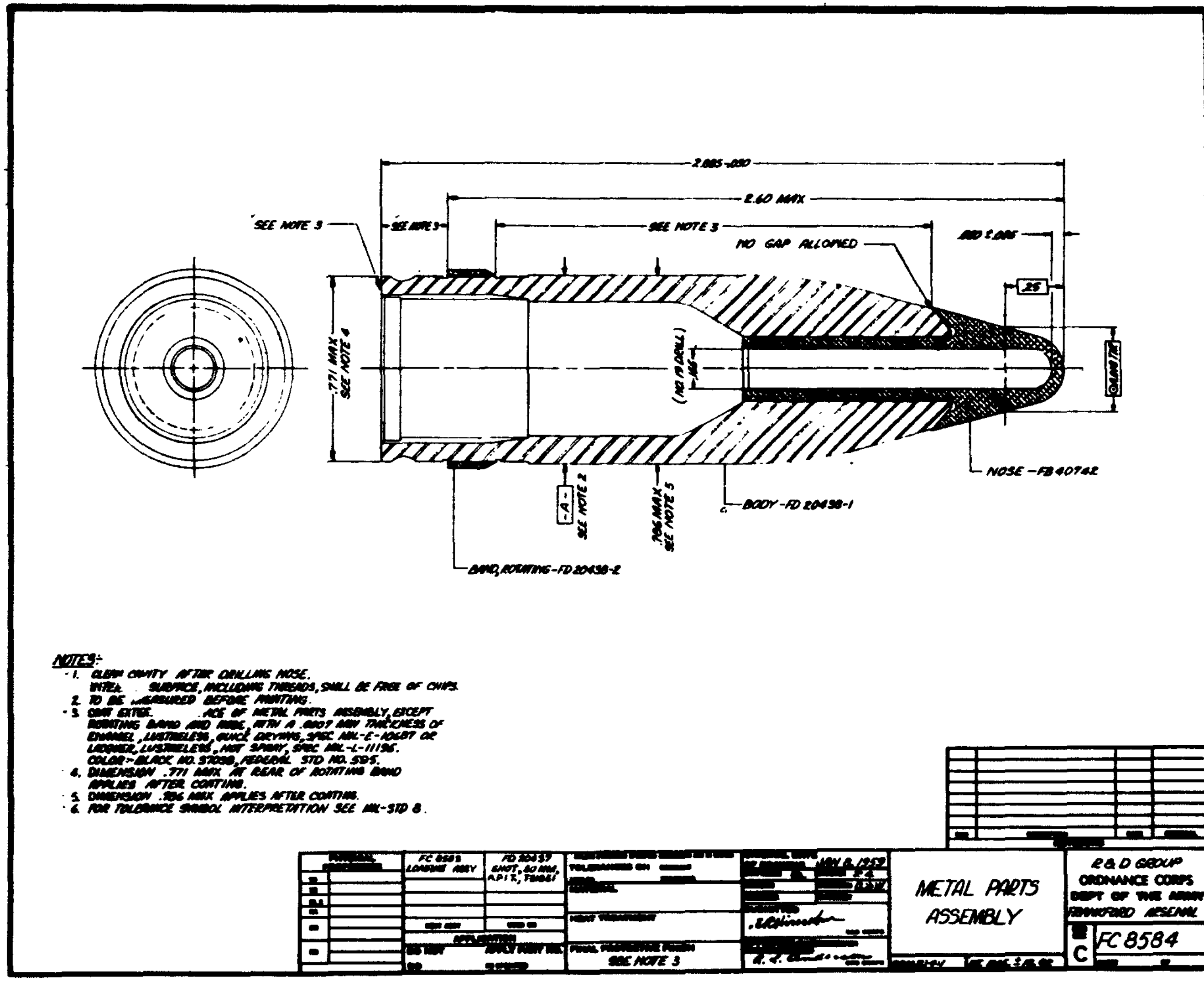


Figure B-6. Metal Parts Assembly

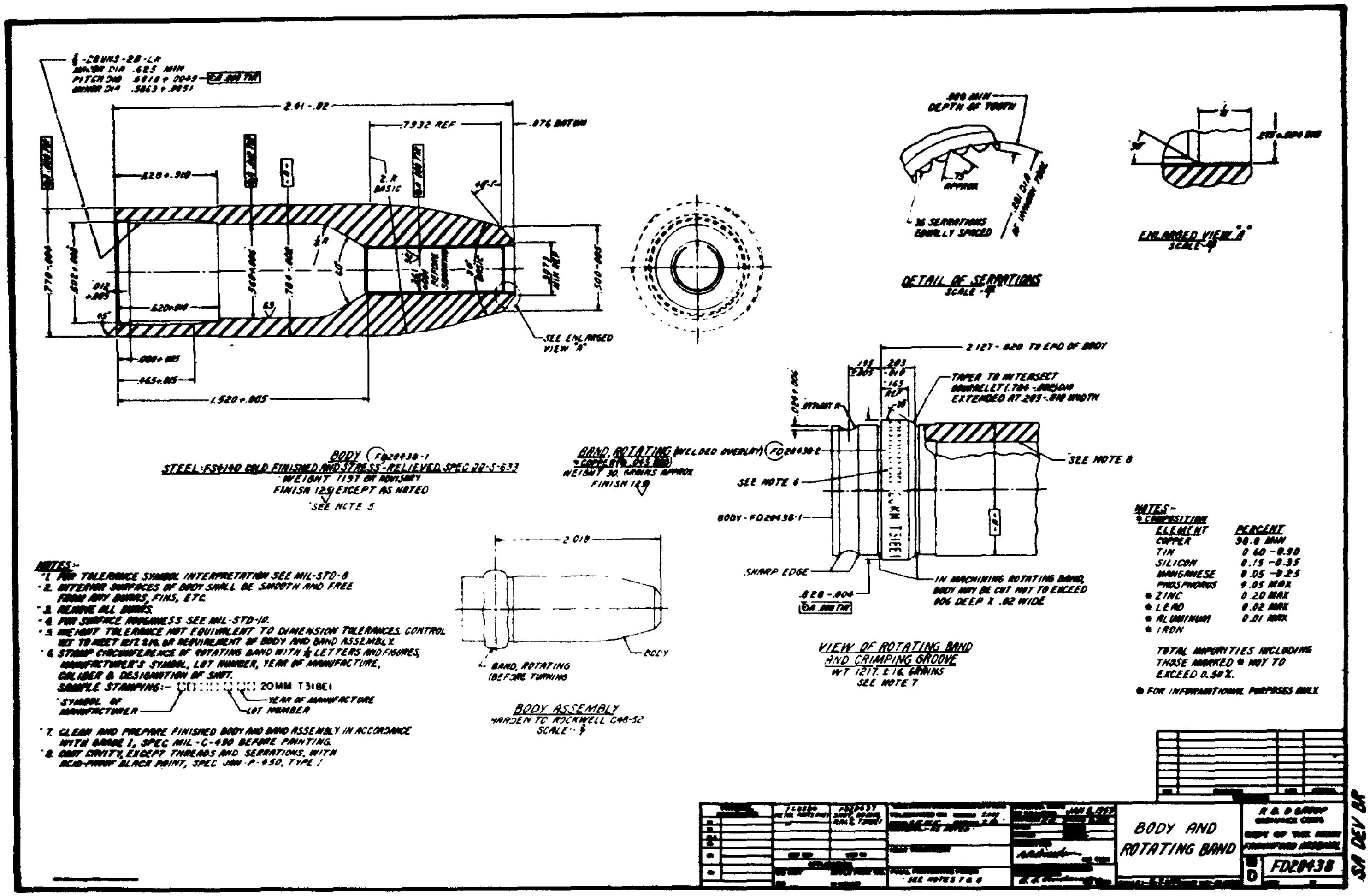


Figure B-7. Body and Rotating Band

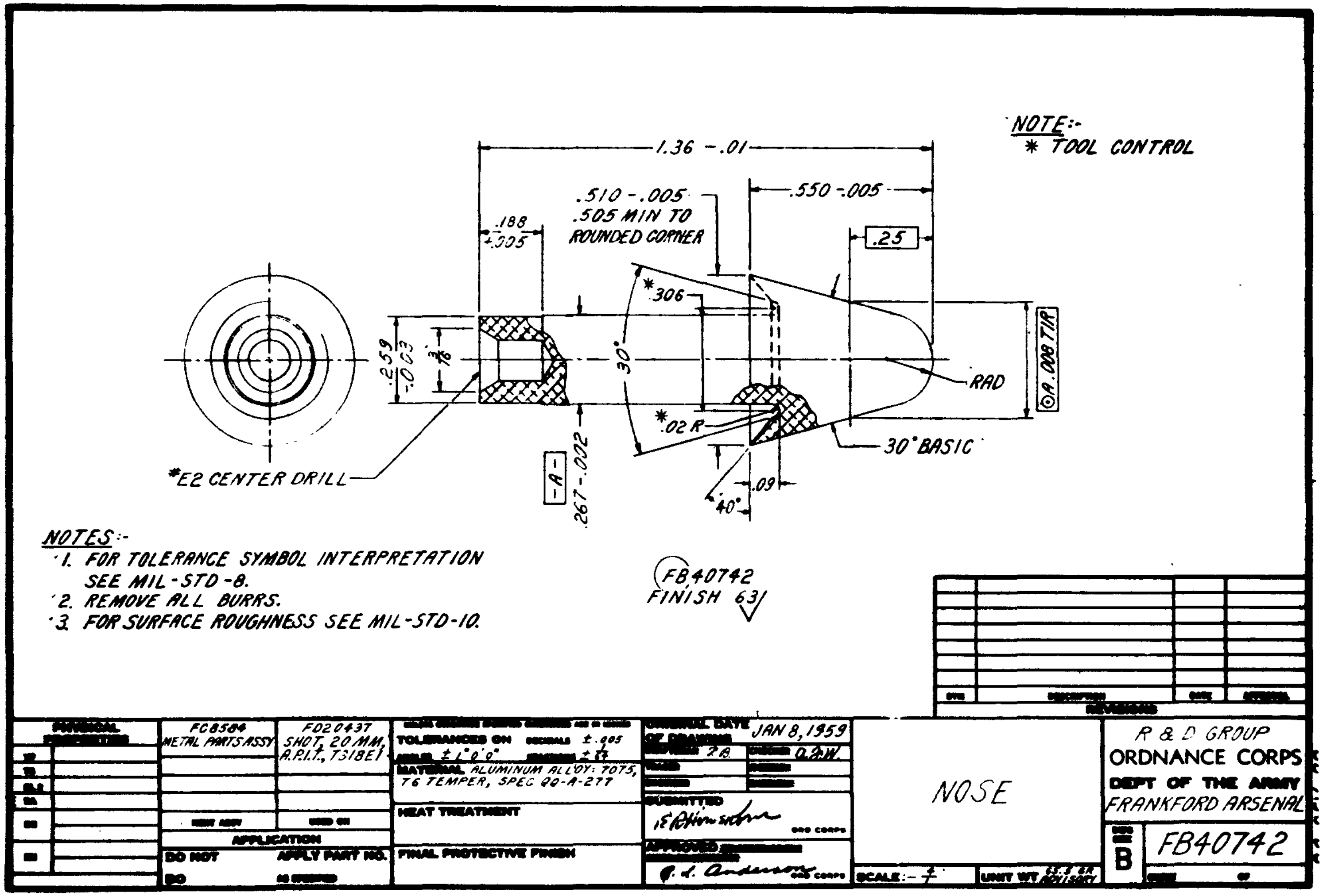


Figure B-8. Nose

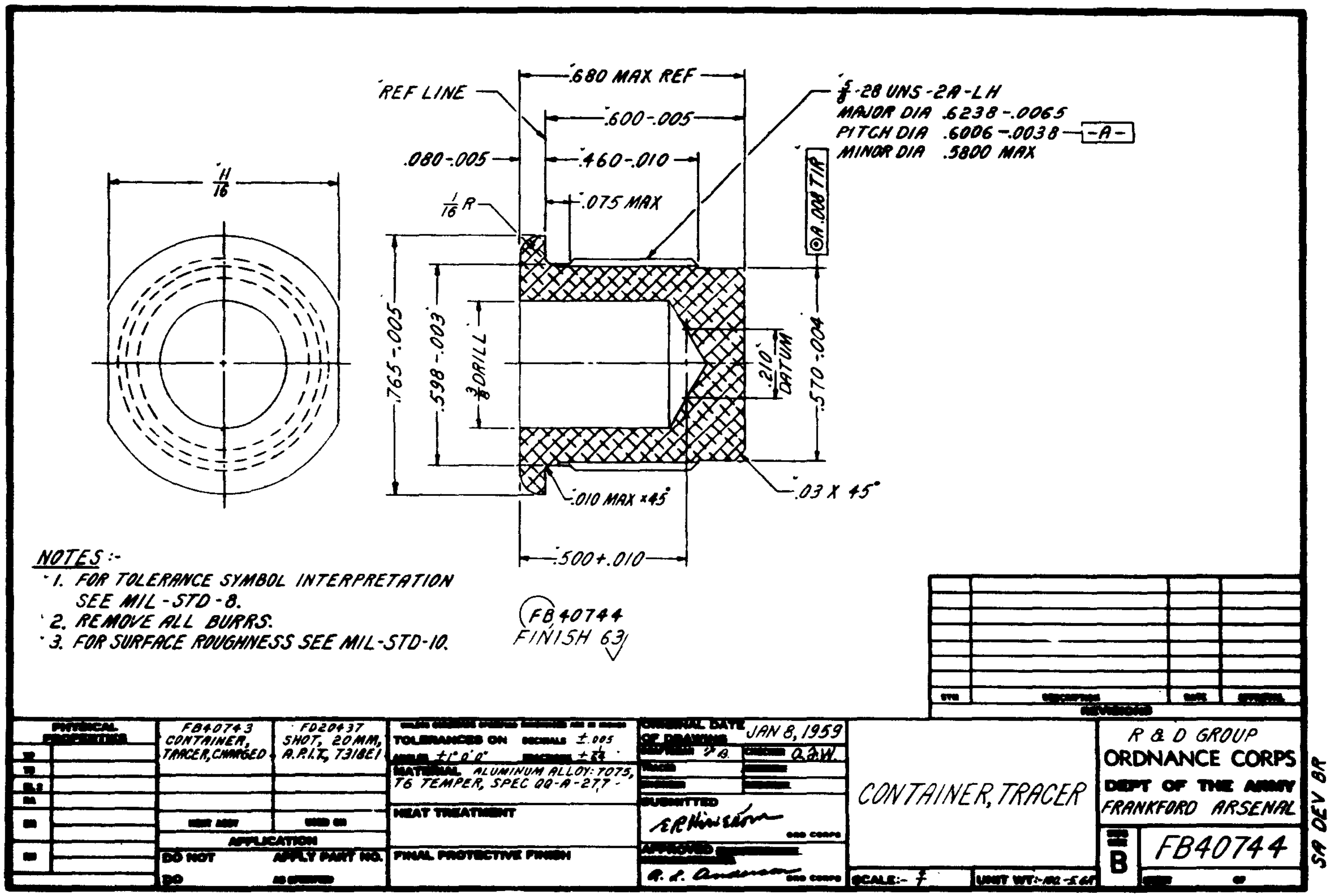


Figure B-9. Container, Tracer

APPENDIX C

DEVELOPMENT AND PROOF SERVICES
ABERDEEN PROVING GROUND, MARYLAND
FIRING RECORD

Preliminary Tests to Investigate the Performance of Shot, APIT, 20mm, T318E1

Firing Record No.: S-46322
Dates of Test: 9 & 12 Dec 1958
Authority: TT 24215 dtd 11 Nov 58, from Frankford Arsenal

Project No.: FAI/59
Development Test

W.O.No. 331-914-01 jl

ITEM UNDER TEST

Shot, APIT, 20-mm, T318E1, Lots FA-X-20-2617 and FA-X-20-2618. Details as to incendiary mixture of the test shot were not available.

SUPPORTING FACILITIES AND MATERIALS

Ammunition:

Propellant, Ball, WC-870, Lot AL-42712 (Service charge: 600 gr).
Propellant, IMR4903, Lot ALA-25750 (Excess-pressure charge: 612 gr, which produced a pressure of about 65,000 psi).
Cartridge Case, 20-mm, M103.
Cartridge, Ball, 20-mm, M55A1, Lot LC-1-4.

Weapons:

Barrels, Mann-type, 20-mm, SK-FSA 7196, No. 124 and 7196, previously fired 1090 and 2080 rounds, respectively.

Gun, Automatic, 20-mm, M39A2, No. 21810, assembled with Barrel No. 106967, which had previously been fired 500 excess-pressure rounds.

Target:

Plate, Alumium-Alloy, 2024T3, 0.125-inch thickness.

DETAILS OF TEST

During development at Frankford Arsenal of Shot, APIT, 20-mm, T318E1, some muzzle bursts have been encountered. It was desired to know, through the tests reported herein, whether these malfunctions originated in the tracer compound or where the result of premature initiation of the incendiary mixtures being investigated.

It was also desired that a superficial examination be made, with the very few shot available for test, of the daylight visibility of the tracer, the range at which tracer burnout occurred, and metal-parts security and functioning performance in automatic fire from an M39A2 gun.

A total of fifty-five shot were provided for the tests, of which seventeen were from Lot No. FA-X-20-2617 and thirty-eight were from Lot No. FA-X-20-2618. The shot were assembled into complete rounds, utilizing a service charge for thirty rounds and an excess-pressure (approx 65,000 psi) charge for the remaining rounds. The excess-pressure charges were used in an effort to increase the possibility of muzzle bursting. The firing procedures for each phase follow:

Tracer Performance

Rounds from both lots were fired from a Mann barrel placed at 6° elevation. Observers were positioned at various locations along the line of fire to observe the trace to determine the range at which tracing ended. Rounds were checked for daylight visibility and at night to observe length of trace.

Incendiary and Tracer Functioning

Rounds from both lots were fired single fire over a range of 600 yards into an 8- by 8-foot aluminum-alloy (2024T3) target, placed at approximately 0° with the projectile trajectory. Observers were positioned to observe for target functioning and tracer performance. It was hoped that, in the event of a muzzle burst, failure of the round either to trace or to function on the target would indicate the component responsible for the muzzle burst.

Metal-Parts Security

The rounds for this phase were linked into groups of six or seven rounds each. The groups consisted of three M55A1 cartridges and three or four test cartridges. To separate each of the six- or seven-round groups into bursts, a dummy round was placed between the groups. The bursts were fired from an M39A2 gun through metal-parts-security screens and a rolling yaw target. Instrumental velocities also were obtained.

ROUND-BY-ROUND DATA

Tracer Performance

Daylight Trace:

Standard Pressure.

Round Numbers	Lot No.	No. of Traces Observed	Remarks
1 to 5	2617	5	See Note.
6 to 10	2618	5	See Note.

NOTE: The trace was observed as the round left the gun; however, tracing downrange could not be observed. No muzzle bursts were observed.

Nighttime Trace:

Excess Pressure.

Round Numbers	Lot No.	No. of Traces Observed	Length of Trace, yd	Color of Trace Igniter	Color of Trace Tracer	Remarks
11 to 12	2617	1	1600	Green	Light orange.	See Note.
13 to 17	2618	5	1600	White	Light orange.	--

NOTE: One "blind". No muzzle bursts were observed.

Standard Pressure.

Round Numbers	Lot No.	No. of Traces Observed	Length of Trace, yd	Color of Trace Igniter	Color of Trace Tracer	Remarks
18 to 22	2618	5	1600	Green	Light orange.	See Note.

NOTE: Two rounds traced green, then blind and then traced from about 125 yards to 1600 yards light oragne. No muzzle bursts were observed.

Incendiary and Tracer Functioning

Plate Thickness: 0.125 inch Range: 600 yards

Standard Pressure.

Rd No.	Lot No.	Muzzle Burst	Trace at Gun	Trace at Target	Incendiary Function on Target	Remarks
1	2617	No	Yes	Yes	Yes	--
2	2617	No	Yes	Yes	Yes	--
3	2617	No	Yes	Yes	No	Functioned on ground impact.
4	2617	No	Yes	Yes	No	Functioned on ground impact.
5	2617	No	Yes	Yes	Yes	--
Excess Pressure.						
6	2617	No	Yes	Yes	Yes	--
7	2617	No	Yes	Yes	Yes	--
8	2617	No	Yes	Yes	Yes	--
9	2617	No	No	No	Yes	--
10	2617	No	No	No	Yes	--
11	2618	No	Yes	Yes	No	No function observed down-range
12	2618	No	Yes	Yes	Yes	--
13	2618	No	Yes	Yes	Yes	--
14	2618	No	Yes	Yes	Yes	--
15	2618	No	Yes	Yes	Yes	--

Metal-Parts Security

Lot No. 2618
Standard Pressure.

Burst No.	No. of Test Rds	No. of Traces Observed	Average Velocity (Instr at 42 ft, in fps)	Remarks
1	3	3	3190	See Note.
2	3	3	3156	See Note.
3	4	4	3147	See Note.

NOTE: No evidence of metal-parts separations.

Excess Pressure.

4	4	4	3245	See Note.
5	4	4	3239	See Note.

NOTE: No evidence of metal-parts separations.

SUMMARY

The fifty-five T318E1 shot received for test were fired to investigate tracer performance, incendiary functioning and metal-parts security. A primary purpose of these tests was to observe for muzzle bursting; however, no such malfunctions occurred in any of the various phases. With the following exceptions, performance of the test shot was satisfactory.

Tracer Performance

Daylight Trace.

Tracing downrange could not be observed against a bright sky background.

Nighttime Trace.

One round of Lot FA-X-20-2617, fired at excess pressure, failed to trace.

Two rounds of Lot FA-X-20-2618, fired at standard pressure, were "blind" between igniter burnout and tracer ignition.

Incendiary Performance

Two rounds of Lot FA-X-20-2617, fired at standard pressure, and one round of Lot FA-X-20-2618, fired at excess pressure, failed to function upon impact with the target.

SUBMITTED:

/s/ Herbert D. Comer
HERBERT D. COMER
Ordnance Engineer

REVIEWED:

/s/ Wm. Davis
WM. DAVIS
Chief, Small Arms and
Aircraft Weapons Branch

APPROVED:

/s/ Wm. Davis
for CLAUDE E. BROWN
Chief, Infantry and
Aircraft Weapons Division

2 Incl
1. TT 24215
2. Distribution.

APPENDIX D

TRACER AND INCENDIARY CHARGE DATA

Base Plug Charge:-

R321	16-1/2 grains	52 lbs. air	84,700 psi
R256	5 grains	None	None
I276	5 grains	52 lbs. air	79,700 psi
Recompress		52 lbs. air	79,700 psi

Cone teat punch 1st compression. Punch diam. .354 area of .0984

Step punch, balance of compression. Punch diam. .365 area of .1046

Base plugs were charged in new charging dies.

Nose Charge:-

IM-136	6-3/4 grains	3 lbs. air	23,900 psi
IM-136	6-3/4 grains	3 lbs. air	23,900 psi
Recompress		3 lbs. air	23,900 psi

Punch diam. .160 area of .0201

Shell Charge:-

IM-136	40 grains	35 lbs. air	23,900 psi
IM-68	29 grains	35 lbs. air	23,900 psi
IM-68	19 grains	35 lbs. air	23,900 psi
IM-68	3 to 9 grains	35 lbs. air	23,900 psi

Depth of Charge .620 to .630

Punch diam. .546 area of .2341

NOTE: Felt pad used under each base plug. Base plugs sealed in shells using Laminac.

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Attn: Engineering Dept.

1 - Commanding Officer
U.S. Army Munitions
Command
Dover, New Jersey
Attn: Technical Group

1 - Commanding Officer
Rock Island Arsenal
Rock Island, Illinois
Attn: Laboratory

1 - Commanding Officer
Watertown Arsenal
Watertown 72, Mass.
Attn: Tech Info Sec

2 - Commanding Officer
U.S. Army Ballistic
Research Laboratories
Aberdeen Proving Ground
Maryland
Attn: AMXBR

1 - Commanding Officer
U.S. Army Test &
Evaluation Command
Aberdeen Proving Ground
Maryland
Attn: D&PS

1 - Attn: Technical Library

1 - Commanding Officer
Raritan Arsenal
Metuchen, New Jersey
Attn: ORDJR-OML

1 - Commanding Officer
Harry Diamond Laboratories
Washington 25, D. C.
Attn: Tech Ref Branch

10 - Armed Services Technical
Information Agency
Arlington Hall Station
Arlington 12, Virginia
Attn: TIPDR

2 - Detachment #4; ASD
Attn: ASQWW
Eglin, Air Force Base,
Florida

1 - Hq, APGC (PGAPI)
Eglin, Air Force Base,
Florida