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E.O. 10501 5 Nov 1953 ; FA ltr 25 Mar 1975

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REPORT NO. R-627

HIGH SPEED X-RAY PICTURES OF THE FUNCTIONING
OF 20 L. M. H.E.I. SHELL L 97 (T23) WITH FUZE F.D. T7184.

FIRST REPORT

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To take a series of high speed X-ray pictures showing the functioning of 20mm H.E.I. Shell M97 (T23) similar to the studies carried out for the 20 mm H.E.I. Shell MK-I.

SUMMARY

A series of high speed X-ray pictures have been taken which show the functioning of 20mm H.E.I. Shell M97 (T23) with Fuze P.D. T71E4 when fired through the following thickness of target plates: .012 in., 1/16 in., .063 in., 1/8 in. and 1/4 in. The pictures show the time of function, the manner of fragmentation of the shell and the formation of the hole in the plate.

At a striking velocity of approximately 2850 f/s against target plates placed normal to the line of fire, the functioning of the shell is dependent on the thickness of the plate. Against .063 in. plate all shells functioned while passing through or after having passed through the plate. When fired against 1/8 in. and 1/4 in. plates the shells consistently functioned and ruptured before the bourrelets of the shells had passed through the plate. None of the shells fired against the .012 in. plate functioned. When fired against the 1/16 in. plate the shells frequently did not function until they were completely through the plate. Two shells out of 20 fired did not function at all.

The dependence of the functioning of the shell on the angle of impact and on velocity was observed on .063 in. plates. When fired at a striking velocity of approximately 2850 f/s against the plate inclined at 20° to the line of fire all shells functioned consistently and ruptured before having passed half way through the plate. Against a plate placed normal to the line of fire the shells frequently passed completely through the plate before functioning. When fired at 1600 f/s against the plate placed normal to the line of fire eight shells out of 35 fired did not function at all.

The shells swell to almost twice normal diameter before rupture is visible.

The explosion imparts a radial velocity of approximately 2000 f/s to the shell fragments.
I. INTRODUCTION

This Arsenal has taken high speed X-ray pictures which show the functioning of 20 mm H.E.I. Shell MK-I, with Fuze No. 253 MK-II, when fired through a mild steel target (1/16 in. and 1/8 in. thick) placed normal to the line of fire. The pictures show the manner in which the shell ruptures and the formation of the hole in the target plate. A request was received from the Office Chief of Ordnance to conduct similar studies for the 20 mm H.E.I. Shell M97 (T23).

II. METHODS

A. Weapon

A 20 mm gun tube AN-M2 was used for the firing. An adapter sleeve was screwed on the breech end of the tube. This sleeve was threaded for the "A.E.S." screw-on firing action permitting convenient single round firing.

B. Ammunition

20 mm H.E.I. Shell L97 (T23) with Fuze P.D. T71EA were used for these tests. A stationary radiograph of this shell is shown on Figure 1.

C. Targets

Mild steel plates (WD 1010 hot rolled annealed and pickled, or cold rolled, dead soft temper) were used as targets. The following target plates were used:

1. .012 in. x 12 in. x 16 in., placed normal to the line of fire.
2. 1/16 in. (.063 in.) x 12 in. x 16 in., placed normal to the line of fire.
3. .063 in. x 12 in. x 16 in., placed normal to the line of fire.
4. .063 in. x 12 in. x 36 in., inclined at 20° to the line of fire (70° between the trajectory and the normal to the plate).
5. 1/8 in. (.125 in.) x 12 in. x 16 in., placed normal to the line of fire.
6. 1/4 in. (.250 in.) x 12 in. x 16 in., placed normal to the line of fire.

The shells were fired at a striking velocity of approximately 2850 f/s through each of the above targets and also at a reduced velocity (1500 f/s) through the .063 in. target plate normal to the line of fire. A new target plate was used for each shot. The target was located 25 ft. from the muzzle of the gun.

*From evolving Arsenal Ordnance Laboratory Report No. 2-26. "High Speed X-ray Pictures of 20 mm H.E.I. Shell MK-I" by E. W. Title

**.* 27.1/2541
D High Speed X-Ray Pictures

The high speed X-ray equipment (3) was used in taking the pictures. A picture showing the arrangement of the X-ray tubes and film with respect to the target and fragment protection is shown on Figure I of Frankford Arsenal Ordnance Laboratory Report No. R-480.(4)

A number of shells were fired through each thickness of plate and high speed X-ray pictures were taken at the instant of impact and at varying times thereafter.

For the targets placed normal to the line of fire, two mutually perpendicular high speed X-ray pictures were taken of the functioning of each shell. A diagram of the set-up used in taking these pictures is shown on Figure 3 of Frankford Arsenal Ordnance Laboratory Report No. R-480. (5) The line of fire was varied from 2 in. to 4 in. above the horizontal film cassette. Maximum detail of the functioning of the shell was obtained on this horizontal film. The mutually perpendicular picture was taken on the vertical film. This film was located 9 in. from the line of fire and the pictures obtained on this film are lacking in detail. However the failure of a shell to function such as round 18 on Figure 5 was revealed by this vertical picture.

In the case of the 0.83 in. target inclined at 20° to the line of fire only a single high speed X-ray picture was taken of the functioning of the shell. The horizontal tube and film cassette arranged as shown on Figure 3 (side view) of Frankford Arsenal Ordnance Laboratory Report No. R-480 (6) were used.

All high speed X-ray pictures were taken at 560 kilo-volt peak and using Paterson #445 industrial combination intensifying screens with Eastman Blue Brand Ultra Speed X-Ray Film.

III. RESULTS AND DISCUSSION

Representative prints of the X-ray pictures are shown on the figures that follow. These were selected from a large number of pictures that were processed. The descriptive material accompanying the pictures is based on an examination of the original negatives and some of the details have been lost in the reproduction process.

(3) Frankford Arsenal Ordnance Laboratory Report No. R-189, "High Speed X-Ray Equipment" by A. R. Thies and C. M. Hudson
(4) Ref. 1, loc. cit.
(5) Ref. 1, loc. cit.
(6) Ibid.

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The pictures shown on Figures 2, 5 and 19 are direct prints from the X-ray negatives. The pictures shown on Figures 3, 4, and 6 to 18 inclusive have been copied from direct prints made from the X-ray negatives. The copied pictures have been reduced to approximately 1/3 size.

Figure 18 is included for comparing the manner in which the 20 mm H.E.I. Shell MK-I functions.

Two high speed X-ray pictures showing the fragmentation of 20 mm H.E. Shell MK-II (Navy) are shown on Figure 19.

Figure 5 shows two mutually perpendicular high speed X-ray pictures of one shell exploding with a time interval of approximately 44 microseconds between pictures. The average radial velocity imparted to the fragments by the force of the explosion was approximately 2800 f/s. This value agrees well with the values reported by Major Clark of Aberdeen.

The X-ray pictures correlated with observations of the target plate revealed the following facts. Except where otherwise indicated the shells were fired at service velocity against target plates placed normal to the line of fire.

(1) .012 in. target plate (Figure 2)
   (a) The shells did not function when fired through this thickness of plate.
   (b) The windshields of the shells were not crushed up as a result of the impact.

(2) 1/16 in. (.063 in.) target plate (Figure 3, 4, 5)
   (a) The shells frequently did not function until they were completely through the plate. Two shells out of 20 fired, did not function at all.
   (b) The shells which did function while passing through the plate ruptured when more than half way through. This resulted in only small holes (2 1/8 in. maximum diameter) being formed in the plate.
   (c) The 20 mm H.E.I. Shell MK-I (Fuse #252; MK-II)
   when fired through the same thickness of plate all functioned. Rupture of the shells consistently occurred before the shell had passed more than half way through the plate. A hole approximately 4 in. in diameter was formed in the plate.

(8) Frankford Arsenal Ordnance Ballistic Research Laboratory Report No. 351, "Fla. Shell or the 'New' 18.00 H.E. Shell during the Gun Trial" by L. E. J. Wild.

(9) Frankford Arsenal Ordnance Laboratory Report No. 2457, Inc., Inc., Inc.

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(3) .083 in. target plate (Figure 6, 7)

(a) All shells functioned when fired through this thickness of plate.

(b) The time at which the shells functioned varied. Eight shells out of 32 fired passed completely through the plate before functioning.

(c) Shells which functioned and ruptured before passing half way through the plate produced large holes (6-7 ins. in diameter). The momentum imparted to the petals on the back of the plate from the force of the explosion caused them to curl back and form the large hole.

(4) .083 in. target plate, shell fired at reduced velocity (1000 f/s)(Figure 8, 9).

(a) Thirty-five shells were fired at reduced velocity through this thickness of plate. Two shells functioned after passing through the plate. Eight shells did not function at all.

(b) The other 25 shells functioned. Rupture of these shells consistently occurred before the shells had passed more than half way through the plate. These shells produced a large hole (6-7 in. diameter) in the plate.

(5) .083 in. target plate inclined at 20' to the line of fire. (Figure 10, 11)

(a) The shells all functioned consistently and ruptured before having passed half way through the plate.

(b) The explosion of the shells produced a hole approximately 4 1/4 in. in diameter in the plate. The momentum imparted to the petals on the back of the plate from the impact of the mushroomed shell base caused them to curl back and form a much larger hole (4 1/2 ins. in diameter)

(a) 1/8 in. (.125 in.) target plate. (Figure 14, 15, 16)

(a) The shells all function before passing through the plate.

(b) The shells start to swell approximately 14 microseconds after impact. Rupture of the shells takes place before the barrels of the shells have passed through the plate (approximately 45 microseconds after impact).
The momentum imparted to the petals on the back of the plate from the force of the explosion caused them to curl back and form a large hole (6 - 7 in. in diameter).

The 20 mm H.E.I. Shell MK-I (Fuze #253, MK-D) functioned in a similar manner when fired through the same thickness of plate. (10)

(7) 1/4 in. (.250 in.) target plate. (Figure 15, 16, 17)

(a) The shells all functioned before passing through the plate.

(b) The shells start to swell approximately 20 microseconds after impact. Rupture of the shells takes place before the bourrelets of the shells have passed through the plate (approximately 40 microseconds after impact).

(c) The momentum imparted to the petals on the back of the plate from the force of the explosion caused them to curl back to form a hole approximately 5 in. in diameter.

The shells swell to almost twice normal diameter before visible rupture takes place. The noses of the shells break up into fragments. In the case of the H.E.I. MK-III shell the noses of the shells remained in one piece. The fragmentation of the rest of the shells is similar to that of the MK-III shells (i.e., rupture of the shell body, mushrooming out of the base of the shell).

The fragmentation of the 20 mm H.E.I. Shell, Mk-III (hevy), is different from the H.E.I. Shell in that the nose, body, and base of the shells all break up into small fragments when the shells rupture.

The high-speed X-ray pictures show the manner in which the shell functioned, the fragmentation pattern of the shell, and the formation of the hole in the plate.

At striking velocity of approximately 1,000 ft. per second, the petals, placed normal to the axis of fire, the function of the shell is dependent on the thickness of the plate used. As the shell penetrates the plate, various parts of the fragments break up into smaller fragments as the fragments hit the target plate. The fragments of the shell remain intact as the rest of the shell passes through the plate.

The function of the shell is dependent on the size of the Petals, as well as the striking velocity of .20 mm projectile. If the petals are uniform and intact, and the striking velocity is high enough, the fragments will pass through the target plate. However, if the petals are not intact, the fragments will not pass through the target plate.
fired the shells frequently passed completely through the plate before functioning. The functioning of the shell is also dependent on the striking velocity. When fired at a striking velocity of approximately 1600 f/s against the plate placed normal to the line of fire eight shells out of 35 fired did not function at all.

In order to form a large hole in the plate the shell must function and rupture before it has passed more than half through the plate.

V. RECOMMENDATIONS

It is recommended that in the development of 20 mm Incendiary, H.E.I., and H. E. Shells that the functioning of these shells be studied by means of high speed X-ray pictures.
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Stationary X-Ray Picture of 20 mm. H.E.I. Shell M 97 (T 23) With Fuze P.D. T 71 K 4

1. Detonator, Approximately 5.0 grains Mercury Fulminate
2. Lower Detonator, Approximately 2.69 grains Lead Azide
3. Magazine Charge, Approximately 2.9 grains Tetryl
4. Tetryl, Approximately 83.4 grains Tetryl
5. Incendiary Composition, Approximately 34.0 grains

FIGURE 1

9 JUNE 1940
High Speed X-Ray Pictures of the Functioning of 20 mm. H.E.I. Shell M 97 (T 23) when fired through an .012 in. mild steel target placed normal to the line of fire. Fuzes P.D. T 71 6 4.

No crush up of the windshield as a result of the impact.

NEG. #15859-2  FIGURE 2  9 JUNE 1945
High Speed X-Ray Pictures of the Functioning of 20 mm. H.E.I. Shell M 97 (T 23) when Fired through a 1/16 in. mild steel target placed normal to the line of fire. Fuze P.D. T 71 E 4

The shell ruptured after it passed through the plate.
THE FRAGMENT OF THE BACK OF THE SHELL ARE PASSING THROUGH THE HOLE.

THE SHELL FROZE COMPLETELY THROUGH THE PLATE BEFORE IT FUNCTIONED. NO PENDA WERE FROZE IN THE PLATE.
THE PACKING MATERIAL SHOULD NOT BE COMPRESSED.
A MAXIMUM DEFORMATION OF 1 IN. IS DESIRED.
THIS SERIES X-RAY PICTURES OF THE PENETRATION OF 20 MM. H.E.1. SHELL X 97 (250) WHEN FIRED THROUGH 1 1/2 IN. WILD STEEL. TRACES PLACED NORMAL TO THE LINE OF FIRE. FROM 20 X 73 4.
HIGH SPEED X-RAY PICTURES OF THE FUNCTIONING OF 20 LB. H.E.T.
SHELL #97 (25%) ABBIN FISH THROUGH A 1/4 IN. MILD STEEL.
TARGET PLACED NORMAL TO THE LINE OF FIRE.

FIGURE 17

9 JUNE 1945
HIGH SPEF. D X-RAY PICTURES OF THE FUNCTIONING OF 20 MM HE 1 SHELL MK I WHEN FIRED THROUGH A 1 IN MILD STEEL PLATE PLACED NORMAL TO THE LINE OF FIRE

- The nose of the shell has passed through the mild steel plate.
- The head of the shell has not detonated the detonation parts of the bullet.
- The shell has swelled more than the shell pictured in the maximum swelling region of the bullet.
- The bullet has swelled in the region of the bullet hole. The booster has not detonated the plastic about the swelling can be seen. The swelling booster has swelled more than normal.
- The shell has swelled in the region of the bullet. The booster has not detonated the plastic.
- The swelling has been constrained in the region of the bullet. The booster has not detonated the plastic.
High Speed X-Ray Pictures of the Functioning of 20 mm. H.E. Shell, MK-3 (Navy) When Fired Through a 1/8 in. Mild Steel Target Placed Normal to Line of Fire