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OFFICE, CHIEF OF ORDNANCE
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DEVELOPMENT OF 105-MM HIGH-EXPLOSIVE-PLASTIC SHELL, M327 (T81E28) (U)

Prior to our entry into World War II, it was realized that the large-caliber and more heavily armored combat vehicles being used in increasing numbers would make it necessary to furnish armor-defeating ammunition to units that heretofore had been protected by reason of their being echeloned in depth. Consequently, the development of a monobloc shot for 105-mm howitzers was approved in July 1941.

At the time authorization for this development was given, it was stated that (1) this shot should be of the same general design as that of the British 6-pounder, (2) it should not have a windshield, (3) it should have the same weight as the high-explosive (HE) shell (33 pounds), and (4) it should have a tracer. Such a projectile was designed and tested but proved to be little better than standard 75-mm armor-piercing shot against 3-inch armor plate at an obliquity of 20°. By the same authority setting up the requirement for the monobloc shot, however, work had been going on to develop a high-explosive antitank (HEAT) shell. This shell was adopted as standard in February 1942 as the M67 and retained this classification until April 1957, at which time it was replaced by the M327 (T81E28) high-explosive-plastic (HEP) shell and made limited standard.

The Ordnance Corps first became interested in HEP shell in 1947, by which time British experiments had shown the feasibility of applying this principle in their "squash-head" shell to defeat armor. Unlike kinetic-energy shot, which pierce or punch their way through armor, or HEAT shell, which use a jet of ultrahigh-velocity fragments to gain entrance, HEP shell do their damage without necessarily penetrating the plate. This is made possible by a carrier with a thin

RELATED TIR'S

1-55	TIR 1-1-2J2	105-mm Howitzer, T96E1
1-57	TIR 6-9	Development of 105-mm Ammunition
4-57	TIR 6-9-5A2(4)	105-mm HEAT Shell, T131 Series
11-55	TIR 6-9-7A5(1)	105-mm HE Shell, M1 (Double-Wall)
____	TIR 6-9-7A10	105-mm HE Shell, M1 (Cyclotol-Loaded)
11-54	TIR 6-9-8A2	105-mm Chemical Shell, M360
10-56	TIR 6-9-8A6(2)	105-mm Colored Marker HE Shell, M1
9-55	TIR 6-9-9A2	105-mm Illuminating Shell, T107
9-57	TIR 6-9-10A1(3)	105-mm Propaganda Shell, T107E2
6-56	TIR 6-9-11A3(2)	105-mm (106-mm) Canister, T310 Series

nose that crushes upon contact, thus allowing the filler to spread over the plate just prior to detonation. The explosion of the filler sets up shock waves that spall the back of the plate, thus producing a lethal missile from the very armor that is intended for defense (see TIR E). To further investigate the possibilities of this type of ammunition, in October 1948 approval was given for a subproject under a main project, which had been authorized in October 1945, for the development of armor-defeating ammunition. This same action approved the development of the T81 shell, which was to serve as a prototype that would be capable of being fired from 105-mm howitzers and the T5E2 105-mm tank gun (the development of this gun, however, was terminated in September 1949).

In June 1949 the Office, Chief of Ordnance, furnished the contractor with a suggested design and the specifications for it. This shell, the basic T81, was to have a muzzle velocity of 1,550 feet per second when fired from a howitzer, and was to be capable of withstanding a maximum chamber pressure of 30,000 pounds per square inch. The basic components were a large-diameter base plug with a central orifice for holding a base-detonating fuze; a converted M84B1 105-mm base-ejection, smoke-shell body (with the walls thinned down and the nose cut off); and a thin, drawn, ogival steel nose. The plug was screwed into the base of the projectile, into whose opposite end the nose was butt-welded. This design was agreed upon in July 1949 by representatives of Picatinny Arsenal and the contractor, who also concurred in the opinion that the investigation of the T81 should concern itself with the shape, length, material, thickness, and the hardness of the nose; also, to be considered were methods of affixing the nose and body together and the means of attaching a windshield if such an item were to be used (see accompanying chart). In addition, it was deemed advisable to make each modification differ from the basic design with respect to only one of the features listed above and to make the modifications in pairs with each of the modified designs varying from the T81 in different respects, such as a longer or a shorter nose and a longer or a shorter body.

In April 1950, the first firing tests of shell with the basic design were held at Aberdeen Proving Ground. The results showed that this two-piece shell could defeat 6 inches of brittle armor with a Charpy value of 8 foot-pounds, but not an equivalent thickness of rough armor having a Charpy value of 52 foot-pounds. It was felt, however, that the test was a success because it demonstrated the desirability of devoting additional work to the development of HEP shell. All of the subsequent shell of the T81 series, up to and including the T81E17, were two-piece models made from converted smoke shell and were designed to meet the same requirements that were established for the T81.

During the course of development, it was found that, because of its ductility, the nose of the two-piece shell tended to bulge in the region adjacent to the brazed joint when fired at muzzle velocities of about 1,300 feet per second. In an effort to find a solution to this problem, a meeting was held in October 1950, at which time it was decided that one-piece shell should be fabricated. The most practicable method of manufacture, it was agreed, was to draw the shell body and nose in one piece to form the internal contour, and then spin the nose shut to form the ogive. In order to conserve time and materials, the initial work was done on the T165E11 75-mm shell, which was being developed for light tank guns. Tools and processes that proved successful were to be modified, as needed, for use in the production of 105-mm models.

After some initial one-piece shell had been fired, it was decided that such a design would be advantageous for all calibers, not only because its terminal-ballistic characteristics appeared to be at least as good as those of the best two-piece shell and its muzzle velocity higher, but also because it would cost less to produce the one-piece item; it could be fabricated with a greater degree of uniformity; the equipment on hand could be used to better advantage; and there was a larger supply of material available for its manufacture than was on hand for two-piece shell.

By November 1951 efforts were being made, wherever possible, to replace two-piece shell with the one-piece kind. The required performance characteristics for the T81E18 were as follows:

1. Chamber pressure - 30,000 pounds per square inch
2. Design pressure - 33,600 pounds per square inch (112 per cent of operating pressure)
3. Muzzle velocity - 2,000 feet per second
4. Terminal effect - the ability to defeat a minimum of 5 inches of armor plate (35 to 40 Charpy) at obliquities of 0° through 60°
5. Accuracy - comparable to that of the HE shell up to a range of 2,000 yards

The T81E18, having the same general shape as the T81E17, had an ogival nose and a square base, but, in place of a conventional, recessed base plug, it had a flanged plug with a flat copper gasket. This type of base closure had been tried on the 75-mm shell and proved to be an effective as well as an economical seal. Ballistically, this shell was to match the T131 105-mm HEAT shell, which was designed to have a muzzle velocity of 2,000 feet per second. Tests of the T81E18 indicated that it could spall 5-inch plate at 60° at striking velocities varying from 1,725 to 2,025 feet per second; no spalling occurred at striking velocities below 1,650 feet per second. Its probable error was 0.19 mil vertically and 0.50 mil horizontally at 1,000 yards when fired at a muzzle velocity of 2,050 feet per second as compared to 0.32 mil and 0.62 mil, respectively, for the M1 105-mm HE shell with a muzzle velocity of 1,550 feet per second.

When it was found that the T131 HEAT shell could not withstand a muzzle velocity of 2,000 feet per second, the requirement was lowered

DESIGN SUMMARY

DESIGN	DESCRIPTION	REASON FOR CONSIDERATION: 1 NOSE MATERIAL	2 NOSE SHAPE	3 NOSE LENGTH	4 NOSE HARDNESS	5 NOSE THICKNESS	6 COMPARISON OF FILLERS	7 SHELL LENGTH	8 DISPERSION CONE	9 LENGTH OF NOSE ANNEAL	10 OTHER (SEE REMARKS)	REMARKS (Numbers below correspond to those to left)
T81	An M84B1 105-mm smoke shell body fitted with an annealed, 1010 steel, 12 gage, ogival shaped nose - over-all length, 15.55 inches; as-fired weight, 20.31 pounds; nose length, 5.2 inches.	X	X	X								1. Tests against armor plate indicated that the basic design gave better results than the T81E1. Thus, all later models had steel noses. 2. Tests indicated that the ogival nose was better than the hemispherical or convex noses. 3. A true comparison could not be made because of dissimilar firing conditions.
T81E1	Like the basic T81 but with a 0.115-inch thick, annealed copper, ogival shaped nose.	X										1. Tests against armor plate indicated that the basic design was superior. Thus, all later models had steel noses.
T81E2	Like the basic T81 except for a hemispherical nose - over-all length, 15.55 inches; as fired weight, 25 pounds.		X	X								2. Tests indicated that a hemispherical nose was inferior to an ogival nose. 3. There was a slight indication that, in general, the longer nose was superior to the shorter.
T81E3	Like the T81 except for a convex nose - over-all length, 15.55 inches; as-fired weight, 25.3 pounds.		X									2. Tests indicated that a convex nose was inferior to an ogival nose.
T81E4	Like the basic T81 except for a shorter nose (4.0 inches) and a longer body to give same over-all length of 15.55 inches - as-fired weight, 25.9 pounds.			X								3. There was no apparent difference in the results. This shell was not consistent in spalling 3, 4, 5, or 6-inch armor.
T81E5	Like the basic T81 except the nose length is 6 inches - over-all length, 15.6 inches; as-fired weight, 23.3 pounds.			X	X	X						3. There was no apparent difference ic the results. This shell was not consistent in spalling 3, 4, 5, or 6-inch armor. 4. There was apparently no large difference in contact areas at 60° obliquity. 5. Apparently, the T81E5 was inferior to either of the other two shell. In general, it was concluded that a thin nose gave better results than a thick nose, but hydraulic tests indicated that thinning the nose decreased the ability of the ogive to withstand filler pressure.
T81E6	Like the basic T81 except the nose length is 8 inches - over-all length, 15.55 inches; as-fired weight, 22.5 pounds.			X								3. There was no apparent difference in the results. This shell was not consistent in spalling 3, 4, 5, or 6-inch armor.
T81E7	Like the T81E2 except it has a ductile steel windshield brazed on the nose - over-all length, 22.30 inches.		X									2. No tests were conducted inasmuch as impact tests showed that the ductile steel windshield had a tendency to fold up between the filler and the armor.

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T81E8	Like the T81E5 except that the ogive is "as-drawn" - over-all length, 15.55 inches; as-fired weight, 23.3 pounds.				X							4. There was apparently no large difference in contact areas at 60° obliquity.
T81E9	Like the T81E5 except that the ogive is case-hardened to a depth of 0.005 to 0.008 inches, inside and out - over-all length, 15.55 inches; as-fired weight, 23.3 pounds.				X							4. There was apparently no large difference in contact areas at 60° obliquity.
T81E10	Like the T81E5 except it has a 7-gage ogive - over-all length, 15.55 inches; as-fired weight, 23.3 pounds.					X						5. It was apparent that the T81E10 was superior to the T81E5 but inferior to the T81E11. In general, it was concluded that a thick nose was inferior to a thin nose.
T81E11	Like the T81E5 except it has a 16-gage ogive - over-all length, 15.55 inches; as-fired weight, 22.7 pounds.					X						5. It was apparent that the T81E11 was superior to both the T81E5 and T81E10. However, hydraulic tests indicated that thinning the nose decreased the ability of the ogive to withstand filler pressure.
T81E12	Like the T81E3 except it has a cast aluminum windshield and attaching ring on the [illegible] - over-all length, 21.79 inches; as-fired weight, 25.9 pounds.		X									2. No firing tests were conducted inasmuch as tests with shell having convex noses and no windshields proved them to be not effective enough to warrant affixing windshields.
T81E14	Like the T81E5 but with internal grooves cut in the body, and a wedge ring between the body and the ogive to initiate peeling action.										X	10. This radically different design was suggested by [illegible] in an attempt to improve the spreading of the filler on impact. No firing tests were made. Only models without grooves were made because of the difficulty of making the grooves, and tests of these projectiles showed that the filler was too widely dispersed.
T81E15	Like the T81E2 except the hemispherical nose is 6-inches long - over-all length, 15.55 inches.			X								3. None of these shell were fired.
T81E16	Like the T81E2 except the nose is 6-inches long - over-all length, 17.55 inches; as-fired weight, 28.8 pounds.		X	X								2. This shell proved to be the equivalent of the T81E17 and superior to any of the previous models of the T81 series. It was felt, however, that its nose shape, although satisfactory for terminal effect, was less desirable than that of the T81E17. 3. There was a slight indication that the longer nose was generally superior to the shorter nose but more subject to telescoping, which subtracts from the area of contact.

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DESIGN SUMMARY

DESIGN	DESCRIPTION	REASON FOR CONSIDERATION: 1 NOSE MATERIAL	2 NOSE SHAPE	3 NOSE LENGTH	4 NOSE HARDNESS	5 NOSE THICKNESS	6 COMPARISON OF FILLERS	7 SHELL LENGTH	8 DISPERSION CONE	9 LENGTH OF NOSE ANNEAL	10 OTHER (SEE REMARKS)	REMARKS (Numbers below correspond to those to left)
T81E17	Similar to the T81E16 except the nose is ogival shaped - over-all length, 17.60 inches; as-fired weight, 25.4 pounds.		X				X					2. This shell proved to be the equivalent of the T81E16 and, with the exception of the latter, superior to any of the previous models with respect to terminal effect. It was chosen over the T81E16 because it was felt that its contour was superior, from the standpoint of exterior ballistics. 6. Tests showed that Composition A3 was the best filler for this shell. However, at -40°, Composition C4 proved superior in spalling effect.
T81E18	Same general shape as the T81E17 but with a flanged-type base plug and a flat copper gasket - over-all length 16.33 inches; as-fired weight, approximately 21.9 pounds.										X	10. This shell was designed to be a ballistic match with the T131 105-mm HEAT shell, which was to be fired at a muzzle velocity of 2,000 fps. It was dropped, however, after the MV of the HEAT shell was lowered because the required matching velocity of the T81E18 would not permit adequate terminal effect.
T81E18A	Like the T81E18 except the ogive is annealed - over-all length, 16.33 inches; as-fired weight, 21.9 pounds.										X	10. This shell was designed to be effective at a muzzle velocity of 1,800 fps. None spalled 5-inch plate at striking velocities of 1,275 to 1,775 fps. This item was later designated the T81E28 and was successful in meeting the required terminal effect when loaded with Composition A3.
T81E19	Like the T81E17 but with a thicker (9-gage) nose - over-all length, 17.56 inches.										X	10. This projectile was designed to investigate the possibilities of having a two-piece shell that would meet the same requirements set up for the one-piece shell. It showed evidence of deformation upon firing and could not be relied upon to spall 5-inch plate.
T81E20	Like the T81E19 except for a longer (12-inch) ogive and shorter body to achieve the same over-all length of 17.56 inches - as-fired weight, 24.3 pounds.										X	10. This shell was designed as a precaution in the event that the one-piece T81E18 proved unsatisfactory. None were fabricated since a satisfactory one-piece shell was developed.
T81E20B	Similar to the T81E20 except the boat-tail section of the converted smoke shell is removed and the ogive is thicker and shorter - over-all length, 15.52 inches; as-fired weight, 24.3 pounds; ogive length, 10.3 inches.										X	10. This shell was designed to increase the strength and stability of the T81E20. It was cancelled, however, because of the apparently poor performance of the T81E19 heavy-walled shell.
T81E20C	Design calls for cutting two T81E18 shell in half, machining a tap shoulder on the front of one half, and the rear of the other half, and brazing them together at a spot just forward of the rotating band - over-all length, 16.04 inches.										X	10. This shell was designed as the result of the poor showing of the T81E19. None were made because it was decided that the T81E18 or T81E18A would be satisfactory.

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T81E21	Like the T81E18 except for a dispersion cone in the nose.								X			8. No design study was made.
T81E22	Like the T81E20 except for a dispersion cone in the nose.								X			8. No design study was made.
T81E23	Like the T81E18 except that it is 1-inch longer - over-all length, 17.33 inches.							X				7. No test results are available.
T81E24	Like the T81E18 except it is annealed back to 5 inches from the tip of the nose.									X		9. These Composition C4 filled shell were effective against 5-inch armor plate at 60° obliquity at striking velocities of 1,475 to 1,525 fps. It appeared to be the equivalent of the T81E25.
T81E25	Like the T81E18 except it is annealed back to 7 inches from the tip of the nose.									X		9. This shell, when filled with Composition C4, could defeat 5-inch armor plate at an obliquity of 60° at striking velocities of 1,475 to 1,525 fps. When filled with Composition A3, it could defeat the same armor at velocities of 1,375 to 1,525 fps.
T81E26	Like the T81E18 except it is one inch longer and annealed for 5 inches back from the tip of the nose.									X		9. This shell was as effective against 5-inch plate as the T81E25 and T81E28. These Composition A3 loaded projectiles could defeat plate at 60° at a striking velocity of 1,375 fps.
T81E27	Like the T81E18 except it is 1-inch longer.							X				7. This shell, when loaded with Composition C4, was effective at striking velocities of from 1,175 to 1,475 fps. It was not as successful at the same striking velocities when loaded with Composition A3. It was not considered as good as the T81E25, T81E26, or the T81E28.
T81E28 (M327)	The T81E18A with a narrower flat copper gasket set in a recess in the base of the shell - loaded with Composition A3.										X	10. This shell was formerly the T81E18A, which was developed to be effective at lower striking velocities than the T81E18. When filled with Composition A3, it was found to be effective at striking velocities of between 1,375 and 1,675 fps. There is no longer a requirement that the HEP shell match the HEAT shell so that it was made standard at a muzzle velocity of 1,900 fps.

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to 1,800 feet per second. This meant that, if the two shell were to match ballistically, the velocity of the T81E18 would also have to be lowered. This was not feasible, however, since it would result in too small a spread between the muzzle velocity of 1,800 feet per second and the minimum effective striking velocity of 1,650 feet per second; this spread, in fact, was so small that it limited the effective range to about 200 yards. In an attempt to meet the requirement, the design was changed to include an annealed nose. This shell - designated the T81E18A - failed to spall 5-inch armor at 0° and 60° obliquity when striking at velocities of from 1,275 to 1,775 feet per second. As a result, consideration was given to the T81E19 and T81E20 two-piece shell and modifications of the latter (designs A, B, and C). Only the T81E19 was manufactured, and it proved to be unable to spall 5-inch armor at 55°.

To determine whether a dispersion cone might aid in increasing terminal effect, two designs - the T81E21 and the T81E22 - were considered. The T81E21 was to be like the T81E18 and the T81E22 was to be similar to the T81E20, but the two new designs called for a dispersion cone in the nose of each. No design study was made, however, so that no tests were run.

The additional models that followed the T81E22, up to and including the T81E28, were for the purpose of testing the effect of body length and nose length on terminal-ballistic performance. In addition, the noses of some of these models were to be annealed to various distances from their tips to see if terminal effectiveness was changed in any way thereby. The designation of the T81E18A was changed to T81E28 because it was felt advisable to assign new designations when the heat treatment used in the fabrication of any projectile was varied. A slight additional change was the employment of a narrower flat copper gasket, which was set in a recess in the shell base. It was found that, when loaded with Composition A3 in place of Composition C4, this projectile demonstrated a satisfactory terminal effectiveness at a striking velocity as low as 1,375 feet per second. Following user tests during the latter half of 1955, Continental Army Command (CONARC) recommended that the T81E28, having a muzzle velocity of 1,900 feet per second, be adopted as standard. This was approved by the Ordnance Technical Committee in April 1957, at which time the T81E28 was designated the M327. A muzzle velocity of 1,900 feet per second was chosen for the T81E28, because velocities higher than that affect stability adversely. It is believed that by redesigning the rotating band and by using inert nose pads developed in 1957 to prevent shock prior to the functioning of the fuze; it will be possible to fire the shell at higher velocities and improve the probability of a first-round hit. However, nothing has been done along these lines since there is now no requirement for the continued development of this shell.

Like the majority of HEP shell, the M327 differs structurally from conventional artillery shell by having a thin forward wall and ogive and by being loaded from the base end. A threaded steel base plug with a centrally threaded orifice for holding an M91A1 base-detonating fuze closes off the rear of the projectile. The filler, 7.6 pounds of Composition A3, is further protected from the propelling gases by a flat copper gasket that seals the jointure between the

CROSS SECTION OF 105-MM HEP SHELL, M327 (T81E28)

1. Cartridge case
2. Propelling-charge bag
3. Propellant
4. Primer
5. Tracer
6. Copper gasket
7. Felt washer
8. Rotating band
9. Fuze
10. Felt disk
11. Explosive charge

shoulder of the base plug and the rim of the body. The fuze is sealed by a concentric, copper-backed, lead caulking ring. A pressed felt washer, between the filler and the face of the base plug, and a pressed felt disk, between the forward face of the fuze and the filler, reduce the shock imparted to the filler by setback. A single gilding-metal rotating band is pressed into a groove about the base of the projectile to complete the assembly.

A complete M327 round is assembled as a semifixed round consisting of the projectile, an M14B1 steel cartridge case, a single bagged propelling charge containing 58.15 ounces of M6 MP propellant, and an M28B2 percussion primer.

Terminal effectiveness tests have shown that 80 per cent of the hits will defeat 5-inch rolled homogeneous plate (of 35 to 50 foot-pound Charpy value at -40° F and a Brinell hardness number varying from about 225 to 262), when striking at obliquities ranging from 0° to 60°. The remaining 20 per cent of the hits will produce hinged spalls or bulges on the rear face of the plate.

When the M327 was adopted as standard, it was stated that user tests of the T131E31 105-mm HEAT shell indicated that it may be more effective than the HEP shell for the defeat of armor but that its present degree of accuracy is unacceptable. In keeping with CONARC's findings and proposals, quantity procurement of the M327 HEP shell is being held in abeyance pending the outcome of the development of the T131 series.

The following characteristics are for the M327 (T81E28) round only.

PRINCIPAL CHARACTERISTICS

Caliber	105 mm
Models of weapon in which used	
Cannon for SP howitzers	M2A2, M4, M4A1, M49, T252
Field cannon	M2A1, M2A2
Projectile	
Weight, as fired	23.38 lb
Length with fuze	17.06 in
Charge	Comp A3
Weight	7.6 lb
Stabilization	spin
Fuze	M91A1 BD
Cartridge case	M14B1
Length	14.64 in
Weight	5.9 lb
Propellant	M6
Weight	3.64 lb
Primer	M28B2
Length of complete round	29.08 in
Weight of complete round	33.45 lb
Performance	
Spalling of homogeneous armor	
1,000 yd	5 in
2,000 yd	5 in
Probability of hit	
1,000 yd	
With range finder	0.98
Without range finder	0.31
2,000 yd	
With range finder	0.17
Without range finder	0.06
Probable error (H and V)	0.2 mil
Maximum tactical range (against armor)	2,000 yd
Muzzle velocity	1,900 fps