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MATERIALS RESEARCH LABORATORY

MELBOURNE, VICTORIA

REPORT

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DEVELOPMENT OF A LOW COST, LOW HAZARD 81 MM PRACTICE MORTAR CARTRIDGE

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ABSTRACT

The development of a low-cost, low-hazard practice 81 mm mortar projectile incorporating a bursting/spotting charge that functions from a Plastic Compression-Ignition Fuze (PCIF) is described. The mortar casings were made from normalized AISI 1340 steel, and were made to fracture in a ductile manner along pre-machined grooves under the influence of a small high explosive burster charge. A spotting signature was provided by a pellet of pyrotechnic composition.

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DEVELOPMENT OF A LOW COST, LOW HAZARD 81 MM PRACTICE MORTAR CARTRIDGE

1. INTRODUCTION

At the present time, two alternatives are available for 81 mm mortar practice ammunition, these being the high explosive cartridge and an inert cartridge which is used for training in the firing procedure. Both cartridges are expensive to manufacture, whilst the inert cartridge, as the name suggests, provides no signature upon ground impact.

This report outlines the work undertaken at Materials Research Laboratory to develop a practice cartridge which is significantly cheaper to manufacture than the high explosive cartridge, but which still provides a noise, smoke and flash signature at ground impact. Whilst meeting these requirements, a number of other design criteria also had to be met, as follows.

2. ARMY REQUIREMENTS

(a) The use of a practice mortar cartridge in place of the high explosive cartridge should not result in 'negative training', whereby operations are carried out in the practice cartridge firing procedure which are not standard practice. Just as importantly, the practice cartridge should allow training in all operations currently required in firing the high explosive cartridge.

(b) Upon impact, significant audial and visual signatures should be produced.

(c) The practice cartridge must satisfy safety standards for operational munitions.

(d) The spent practice projectile must be easily distinguishable from an unexploded high explosive filled projectile or smoke projectile. The projectile should also function reliably to reduce the incidence of unexploded projectiles.

(e) The practice projectile should be ballistically comparable to the M374 high explosive filled projectile.

(f) The practice cartridge should provide substantial cost savings over projectiles currently employed for practice and training.

3. PRACTICE PROJECTILE COMPONENTS

3.1 Mortar Projectile Bodies

Bodies examined for use in the practice cartridge were of the design M374 and were filled with a paraffin wax based High Explosive Substitute (HES) of density 1.69 g/cc. In order to assess the suitability of body materials, the fragmentation behaviour of each body type was examined by subjecting it to the influence of a small explosive charge. The aim of experimentation was to disrupt the body (identifying it as expended) whilst minimizing fragmentation to reduce safety hazard.

Bodies were fitted with the fuze DA162 MK.II which had been modified for remote firing using an Exploding Bridge Wire (EBW) detonator. The adapter TV184 was used to fit this modified fuze to the bodies.

The following body materials were examined.

(a) Cast Pearlitic Malleable Iron (CPMI)

Bodies made from CPMI were obtained from Small Arms Factory Lithgow, NSW. These are currently used exclusively for proof of propellant and during the early stage of training of mortar crews.

Projectile bodies containing Tetryl (high explosive) pellets of 10, 16 and 21 grams were detonated in an enclosed chamber to allow fragment recovery. In all three cases, the body shattered into many small high velocity fragments (Fig. 1), as could be expected due to the low ductility (3% elongation to failure) of the cast iron. Because of the potentially high fragment hazard presented to the gun crew, testing on bodies made from this material was halted.

(b) AISI 1340 Steel (Australian Standard Designation)

Bodies made from AISI 1340 steel were supplied by Ordnance Factory Maribyrnong. These bodies are currently used for the high explosive projectile.

The manufacturing process used to produce a body from this steel includes a quench and temper heat treatment designed to provide acceptable strength and toughness and to enhance fragmentation performance. Two bodies in this condition were assembled incorporating 10 and 16 gram Tetryl pellets respectively. In both cases the bodies fragmented unacceptably, in a manner similar to the CPMI bodies tested.

Bodies were prepared which had undergone a normalizing heat treatment. Using this treatment a more ductile body can be produced, whilst maintaining sufficient strength to withstand launch forces.

Tetryl charge w .ghts of 10 and 16 grams were fired in two of these normalized bodies. Both of these bodies bulged around the nose section but failed to rupture (Fig. 2).

3.2 Body Fracture Groove

On the basis of the behaviour of the normalized AISI 1340 body, a range of machined grooves in the mortar body was investigated with the aim of weakening the body and promoting controlled fracture. Use of such grooving allows fracture to be achieved from a small burster charge, thereby minimizing body fragmentation and fragment velocity.

Two types of grooving were considered as viable alternatives; longitudinal grooving (Fig. 3c, 3e and 3f) and circumferential grooving (Fig. 3a, 3b, 3d and 3g).

3.3 Fuze

The fuze developed for use in the practice cartridge [1] is based upon a modified version of the Australian developed Plastic Compression Ignition Fuze [2] shown in Fig. 4. The fuze consists of an in-line compression-ignition element which contains PETN high explosive, a small high explosive Tetryl burster charge and a pyrotechnic pellet, all of which are housed in a plastic fuze body. The fuze is configured such that the bursting pellet is located adjacent to the weakening groove in the mortar body.

The basic mechanism of this fuzing is the use of a cylindrical striker which upon ground impact breaks a shearing element and impacts against the nose of an initiator. The gas contained in the initiator nose is compressed, producing a rapid temperature rise sufficient to initiate the explosive stemming in the initiator core. The stemming then burns to detonation, resulting in a substantial explosive output from the base of the initiator. This in turn detonates the burster pellet and ignites the pyrotechnic spotting charge.

Because the mechanism is simple and the plastic fuze body is injection molded, this fuze is much less expensive than the fuzing currently used for high explosive filled cartridges.

3.4 High Explosive Burster Charge

The high explosive selected for use as the practice cartridge burster charge was Tetryl (2,4,6 trinitrophenyl methylnitramine) mixed with 2% w/w lithium stearate. The pellets produced for the final practice cartridge design featured an indentation at the base of 1.5 mm depth and 12 mm diameter, facing to the rear of the projectile. This directs a pressure wave toward the centre of the pyrotechnic, assisting in the ignition of the composition.

3.5 Spotting Charge

Pyrotechnic photo-flash compositions were selected as the most suitable agents to produce the required signal. A number of photo-flash compositions were selected for evaluation, as shown in Table 1.

4. PERFORMANCE RESULTS

A total of five trials were conducted at the Army Proof and Experimental Establishment at Graytown to field test practice cartridge configurations. The contents and groove types of these cartridges and a comparative evaluation of the signatures produced at ground impact are listed in Table 2.

Whilst it was found that rupture of the body was necessary to produce a good spotting signature, the development of the rupture groove was generally independent of the development of the high explosive and pyrotechnic payload. Consequently, for sake of clarity, these two aspects of the practice cartridge development are dealt with independently in the following two sections.

4.1 Development of Fracture Groove

Grooving of the practice projectile body was investigated through a series of tests in the field and in the firing chamber (hereafter referred to as static testing) which saw seven major variants of the groove configuration evolve. These variants are illustrated in Fig. 3a to 3g. Investigation of each variant included the testing of different explosive and pyrotechnic quantities, depths of grooving and positions of explosive relative to groove position.

The simplest option available to achieve fracture of the body was the use of the obturating ring (OR) groove already present in the projectile (Fig. 3a). Through a number of static tests it was determined that the minimum explosive weight required to disrupt the body at this point was 15 grams (Fig. 5). To locate the bursting charge adjacent to the OR groove, however, requires an explosive lead from the fuze and associated hardware, the manufacturing costs of which make this arrangement less attractive than other configurations. There is also a potential safety hazard from the high explosive substitute (HES) ejected from the body during burst.

Two arrangements were investigated in an attempt to fracture the body at the point of maximum deformation, as observed in static tests of an un-grooved body when a charge at the rear of the fuze was detonated (Fig. 2). These were a circumferential groove (Fig. 3b) and a longitudinal groove (Fig. 3c). Fracturing at these grooves could be achieved but required significantly more explosive than other arrangements investigated. The quantity of explosive required to achieve fracture could only be reduced by cutting the grooves to a depth which would make the projectile structurally unsound in regard to set back forces at launch.

In a further attempt to reduce explosive content without modifying the fuze assembly, a wider circumferential groove was machined into the body with a 45° cutting tool, producing a tapering thin walled section at the curvature in the body cavity (Fig. 3d). The high explosive bursting charge was located within the fuze adjacent to the groove.

The geometry of this groove was selected to allow detonation forces to act more effectively in aiding fracture. The difference in material thicknesses at each side of this groove allows different hoop displacements to occur promoting bending moments (and hence shear stresses) around the groove. The longitudinal forces acting on the projectile body upon ground impact would also assist with the fracture mechanism by contributing a direct moment on the groove.

The groove was rejected because of the difficulty in machining a 45° face into the body, as forces on the tool tip create problems with 'run-off' to one side. Also, this groove requires machining in the area of wide dimensional tolerance associated with forging and there would be an additional expense incurred in gauging bodies to determine the depth of cut required.

The groove configuration requiring the least amount of explosive to achieve fracture was a longitudinal 'vee' groove machined toward the nose of the body, with the depth and length of the cut controlling the final wall thickness (Fig. 3e). The bursting charge for this arrangement was located within the fuze and close to the groove.

Experimentation was carried out on bodies featuring four grooves (Fig. 6), two grooves and one groove. With a single longitudinal groove, fracture occurs along the cut notch and extends to the OR groove. At this point fracture can continue around or past the OR and separate into two fracture paths with an included angle of 90° (Fig. 7). This latter fragmentation mode can lead to free fragment formation (Fig. 8).

To alleviate this problem, an additional longitudinal groove was machined at the OR groove (Fig. 3f) to extend the fracture beyond the OR as a single fracture path, eliminating the fragment effect. Although this concept was proven in field trials, the potential problem of hazard due to ejected HES remained.

To overcome this hazard, experimentation again centred on the use of circumferential grooving. A circumferential groove was machined into the body adjacent to the cavity radius but outside the region of major dimensional variability associated with the nose forming process (Fig. 3g). By this means the wall depth at the bottom of the cut groove could be more accurately controlled. As a cost saving measure, the groove was cut using the same cutting tool as is used to cut the OR groove.

The explosive power to break this body is kept to a minimum by locating the burster charge in close proximity to the groove. This was achieved without the use of an explosive lead by modifying the fuze to move the explosive materials to the rear. This also had the effect of ensuring materials were ejected in a forward cone upon detonation of the projectile.

Field testing of this assembly proved the break-up to be satisfactory (Fig. 9).

4.2 Development of Spotting Charge

Field Trial #1

In preliminary static tests, it was found that fracture of a grooved projectile could be achieved using pyrotechnic alone. Because of the cost savings which could be achieved by omitting high explosive altogether, a range of projectiles containing pyrotechnic but no HE were field tested in addition to projectiles containing 5 grams of HE.

Three pyrotechnic compositions were evaluated at this trial, the compositions of which are listed in Table 1. For all shots, the composition was pressed to a density of 2.0 g/cc (referred to in Table 2 as hard pressed). The composition MRL(X)210 was considered to be the best performing of the three compositions, in terms of smoke, flash and noise output (Table 3).

Spotting signatures varied considerably, and the reason for this variation was evident upon recovery of the spent projectiles. In those projectiles containing pyrotechnic alone, the force produced by projectile detonation was, in all cases but one, insufficient to fracture the steel body under the additional influence of impact forces. Contrastingly, three of the four projectiles fired containing 5 grams of HE fractured successfully. It was concluded that a high explosive pellet was necessary to achieve reliable fracture.

Noise measurements were taken in conjunction with video recordings to allow a comparative evaluation of the performance of the high explosive and pyrotechnic in producing a signature.

Field Trial #2

Following a number of static tests which gave varied results, a second field trial was conducted, using CI fuzed cartridges containing a range of high explosive pellets in addition to the pyrotechnic necessary for spotting purposes. The explosive train then consisted of the CI initiator, a high explosive pellet and then a pyrotechnic pellet. Groove types employed were again either circumferential or longitudinal.

Only four of the ten projectiles fractured acceptably; two circumferentially grooved projectiles containing 10 and 15 grams of HE respectively and two longitudinally grooved projectiles containing 5 grams of HE.

Field Trial #3

It was decided that the circumferential groove should be the major path of investigation, because a fracture by this means produces fragments in a narrow cone along the line of flight. To ensure fuze body fragments were only projected forward, it was also considered necessary to move the explosive train back in the body. An additional aim of moving the explosive backward was to place the pellet adjacent to the circumferential groove, thereby best utilizing the explosive power in fracturing the case.

To achieve the set-back of the explosive train, the CI fuze body was re-designed to include a longer striker and plastic cups to locate the HE and pyrotechnic pellets to the rear [1].

Whilst most of the projectiles fired during the third trial featured circular grooves and/or a set-back payload, a number of the configurations previously tested were also fired for purpose of comparison.

After the fuze was re-designed, the 10 gram high explosive pellet used was of the more ideal dimensions of 20 mm diameter and 20 mm length, pressed to 1.57 g/cc. A 1 to 1 length/diameter ratio is the optimum configuration with respect to pellet strength, which is desirable from a storage and handling viewpoint. It is probable that efficiency of the detonation is also improved, because the pellet is more likely to be fully consumed in this configuration than in the disc-like form employed in earlier tests.

At this trial a comparison was made between the behaviour of projectiles containing both loose-pressed (1.35 g/cc) and hard pressed (2.00 g/cc) pyrotechnic (fifty grams in all projectiles). The consensus of the observers at the trial was that the loose-pressed pyrotechnic produced a far superior flash signal than the hard pressed pellet. This was confirmed by taking high speed film of test-chamber fired assemblies. A 'loose-pressed' composition produced a flash of typical duration 70 ms, whilst 'hard-pressed' compositions produced a 20 ms flash. Army expressed the opinion that a good flash signature would provide excellent day and night training performance, therefore it was elected to use a loose-pressed composition in all further testing.

Smoke signatures obtained ranged from fair to excellent, however no definite correlation with explosive/pyrotechnic content was discernible. The major factor involved appeared to be the type of grooving which was used, as a good break-up of the projectile generally produced a good smoke signature.

Consistently excellent projectile break-up results were achieved through the combination of the set back payload and a variant of the circular groove illustrated in Fig. 3g.

Noise signatures were found to be dependent upon explosive content, with an acceptable noise level being produced from an explosive mass of 10 grams.

Field Trial #4

The main aim of this trial was to prove the HE/pyrotechnic/groove combination which was successfully tested in Trial 3. These parameters were consistent over the 42 projectiles fired, with a ten gram explosive pellet, a fifty gram loose-pressed pyrotechnic (1.35 g/cc) and the groove of Fig. 3g being utilized.

40 of the 42 projectiles fired functioned at impact, in each case fracturing the projectile body and producing an excellent smoke and noise signature. Because some projectiles impacted on surface water, the flash signature was occasionally obscured. Generally speaking, however, good flash signatures were prevalent over the course of the trial.

Ground conditions for this trial were very soft; consequently the depth at which the CI fuzes functioned was about 200 mm (Fig. 14), as opposed to the surface functioning observed on the hard targets encountered in the first three field trials. Whilst this seemed to have little effect on the signature produced, the extent and nature of body break-up was altered significantly. The increased confinement afforded the projectile by the surrounding soil produced a more vigorous explosion, resulting in a more comprehensive fracture of the body than was previously experienced.

It was concluded from this trial that the configuration tested met all of the design criteria, with the exception of fuze reliability.

A fifth and final trial was conducted for two reasons;

1. To test a redeveloped fuze configuration.

The fuze was redesigned to overcome a number of perceived reliability problems; this work was carried out under a different task and the work was been documented separately [1].

2. To investigate the use of a different steel for the cartridge bodies.

5. INVESTIGATION OF THE USE OF AISI 9260 STEEL MORTAR BODIES

To date (1987), 81 mm mortar cartridges have been produced from AISI 1340 steel tubing which contains approximately (wt. %) 0.4 carbon, 1.75 manganese and 0.3 silicon. The bodies are given a quench and temper heat treatment designed to produce a martensitic microstructure. This steel is used in many conventional HE munitions because of its relatively low cost, good processing characteristics and an acceptable combination of strength and toughness.

The 81 mm mortar practice and training cartridge developed utilizes the existing 1340 steel body, but in a condition produced by normalizing from approximately

890°C. This treatment produces a pearlite/ferrite microstructure which has significantly increased toughness over the quench and temper treatment described above. By this means it was possible to achieve a controlled fracture of the body upon projectile detonation, rather than the brittle behaviour normally experienced with the hardened bodies.

Ordnance Factory Maribyrnong have recently (early 1987) been producing test batches of 81 mm mortar bodies produced from AISI 9260 steel which contains (wt. %) 0.6 C 0.9 Mn and 2.0 Si as its principal alloying elements. These bodies are given an isothermal heat treatment designed to produce optimum fragmentation performance.

OFM supplied forty 81 mm mortar bodies made from AISI 9260 steel. These were assembled in the configuration of the practice projectile shown in Fig. 12 with a range of explosive weights and a constant mass of pyrotechnic composition.

As previously experienced, the minimum explosive weight required to reliably fracture the steel body was 10 grams. Unlike the annealed AISI 1340 steel bodies, however, the 9260 bodies typically fractured into two or three large, jagged fragments and a number of small fragments. The angle of projection and velocity of these fragments was indeterminate.

This fracture mode defeats the design developed using the 1340 bodies, whereby the body fractured along a machined groove in a ductile manner, projecting fragments forward in a narrow cone. No practical heat treatment would allow the fracture toughness of AISI 9260 steel to be increased sufficiently to allow reproduceable controlled fracture using the grooving technique previously developed.

6. IN-BARREL SAFETY

Because of the lack of safe arming system in the compression ignition fuze proposed for use in the practice projectile, it was necessary to experimentally verify in-barrel safety in the event of premature detonation.

This was achieved via a trial [3] at which a fully loaded practice projectile was intentionally detonated within a mortar barrel using a specially modified fuze.

The result of the trial, in short, was that the premature detonation of the practice projectile half-way along the mortar barrel produced only a small indentation in the bore. No external swelling of the barrel was evident, and all fragments resultant from the detonation were projected forward along the axis of the barrel.

The conclusion reached from the trial was that premature detonation of the projectile was undoubtedly non-lethal, although some noise hazard would obviously be present.

7. THEORETICAL AND EXPERIMENTAL BALLISTIC EVALUATION

Because low-density plastic materials are used in the fuze assembly, the practice projectile is significantly lighter (by 380 grams, or approximately 10% of flight mass) than the M374 high explosive projectile which it is designed to emulate.

As a result of this mass difference, practice projectiles fired at charge 1 during the first field trial had a 3% higher muzzle velocity and travelled 8% further than the high explosive filled projectiles fired (Table 3).

Because it was feared that higher propellant charge loadings would result in a similar percentage range increase, a number of options were investigated in an attempt to increase the practice projectile mass to that of the high explosive projectile.

Research was carried out to determine the achievable density of the wax-based high explosive substitute which is used to fill the practice projectile. It was discovered that the maximum density which could be achieved before the mixture became un-castable was 1.80 g/cc [4]. The standard density employed is 1.69 g/cc, thus a 50 g mass increase was possible in the 470 cc of HES contained in the projectile. As the required mass increase was 380 grams, the achievable mass increase did not merit the incurred degrading of the pouring properties of the HES.

In a further attempt to increase the mass of the projectile a cylindrical steel insert was placed behind the fuze assembly, increasing the mass to that of the high explosive projectile. The cost of manufacture and assembly of this component would be high, however.

7.1 Prediction of Range and Impact Data

Before proceeding further with attempts to increase the projectile mass, a computer program was written to provide an estimate of the range of practice projectiles over the full spectrum of muzzle velocities and launch angles. The program assumes the practice projectile has the same drag coefficient-velocity relationship as the M374A2 high explosive projectile and behaves as a point-mass, affected by drag and gravitational forces.

The program made it possible to determine ranges and flight times for the proposed practice projectiles at various propellant charges and launch angles. Utilizing the practice projectile muzzle velocity figures obtained in earlier trials the ballistic data estimates in Table 4 were assembled. The figures shown include the field trial data which was recorded at a later date and which verified the computer program.

It can be seen from these figures that whilst a range difference of +26 to +76 m could be expected at Charge 1, at maximum Charge 9 range differences become smaller (+10 to +37 m). The field trial results of Fig. 11 illustrate this more effectively.

These estimates indicated that range difference problems were not solvable by use of systems which increase drag, as was thought at first. The variation between ranges for the practice and HE projectiles basically varies with flight time, because whilst a lower mass produces higher muzzle velocities resulting in extended range at lower charges, it also produces a higher rate of deceleration due to drag force which, at longer ranges, counteracts the higher initial velocity. This can be seen by Newton's law force = mass x acceleration, such that a lower mass gives a higher deceleration for a given drag force on the projectile.

7.2 Evaluation of Practice Projectile Accuracy Performance

An additional aim of the fourth field trial conducted was to assess range and accuracy performance. A total of 42 practice projectiles were fired, interspersed with a total of 21 operational high explosive projectiles for comparison.

Conditions for the trial were idealized as much as possible. Practice projectiles were filled to a precise weight of 3751 grams, and all the projectiles fired were conditioned to 21^{o}C before firing. Warmer shots were fired before each firing session to ensure a consistent barrel temperature, and the barrel alignment was checked before each shot was fired. Atmospheric conditions for the two days of the trial were very good, with sparse cloud cover and wind speed peaking at one knot.

Three variations of the practice projectile were trialled, as shown in Fig. 10. The first variant was the unadjusted practice projectile, featuring the machined weakening groove. In the second variant, this groove was filled with a silicon rubber compound so that an assessment could be made of the effect of this groove, if any, on the ballistic performance of the practice projectile.

The third variant featured a small annular drag plate placed between the tail boom and the fin assembly. This has the effect of displacing the centre of drag pressure to the rear of the projectile, and would eliminate any yaw effects resultant from having a lighter fuze which moves the centre of gravity to the rear. A comparison of range figures for these and the standard projectiles would highlight any instability problems if they were present.

For each variation, seven projectiles were fired at both propellant Charge 1 and Charge 9. All projectiles were fired at a barrel angle of 45^{o}. For each projectile fired, muzzle velocity measurements were made and the range and deviation of the projectile impact points from the firing line were measured. The means and standard deviations (using a normal distribution) of the recorded results are graphically illustrated in Figs 11a and 11b.

7.3 Discussion of Results (Fig. 11a and 11b)

Range values obtained for the 'standard' and 'filled groove' projectiles fall within the same population, indicating that there is no change in ballistic performance resultant from inclusion of the weakening groove.

Use of a drag plate only had the effect of reducing practice projectile range, indicating that the only effect present was increased drag. If instability had been present in the projectile, an increased range would have been expected.

The spread of fall of shot of the high explosive and practice projectiles fired was similar, indicating that there was no significant difference in the aerodynamic stability of the projectiles.

The conclusion reached was that the ballistic match of the practice projectile to the M374 projectile was adequate and that no improvement in ballistic matching would be cost-effective.

Whilst in general the practice projectile performed adequately, there was one incidence of a practice projectile falling approximately 250 m short of the target area. This was dismissed at the time as being due to misassembly or damp propellant, however information since obtained [5] documents another two possible causes:-

1. Roll lock-in, arising because of a large amplitude yawing motion occuring as a result of launch disturbance.

2. Roll-yaw resonance, a form of dynamic instability which occurs when rolling and yawing motion of the mortar have similar frequencies.

The first mentioned phenomenon is common to mortar projectiles, hence, if this was the cause of the short-range projectile there is no cause for special concern.

The second effect is due to the inherent physical characteristics of a projectile such as centre of mass and centre of drag. If this was the cause of the short range, a change in design would be required. This possibly merits a more in-depth investigation of the ballistic properties of the projectile.

8. CONCLUSION

At this stage of development, the projectile configuration which best meets the task objectives is illustrated in Fig. 12. This configuration features the weakening groove illustrated in Fig. 3g, a ten gram high-explosive pellet and fifty grams of pyrotechnic.

This configuration has a number of points in its favor.

Because the proposed practice projectile employs the same body as is used for the high explosive projectile, the need to construct new production facilities is eliminated.

The weakening groove can be machined in the same operation and with the same tool as the obturating ring groove, at very small additional cost. The only other major deviation from the manufacturing process is the replacement of the quench and temper heat treatment with a normalizing heat treatment. Because the body is to contain an inert fill, however, a number of inspection operations can also be omitted.

In the event of a premature detonation, body fragments are projected forward in a narrow conical envelope, minimizing fragment hazard to the gun crew.

The nature of the burst upon ground impact is such that the two body fragments are nearly always left lying on the surface of the range, so that there can be little doubt that the projectile is inert (Figs 13 and 14).

The projectiles produce consis*ently excellent noise (115 dB average at 600 m) and smoke signatures on a range of target types (Figs 16 and 17), with a good flash signature being produced (Fig. 15) on all targets except water.

Fuze performance was investigated as a parallel task to the development of the projectile [1]. The fuze was refined to a point at which a 100% functioning rate was achieved from twenty projectiles fired.

In conclusion, this projectile has been optimized within the available scope for development. All task objectives listed in section 2 were met, and the practice projectile is subsequently recommended for further development. It must also be emphasised that the technology featured in this projectile is widely applicable to other items of ordnance.

9. ACKNOWLEDGEMENTS

The authors wish to thank all members of the design team, all of whom made significant contributions to the design and development of the practice projectile.

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TABLE 1

Pyrotechnic Compositions Tested

	MRL(X)206	MRL(X)210	Exp. 1	Exp. 2
Potassium perchlorate 120 to CS 5032 %	59	51	40	20
Magnesium Grade 5, cut to CS 5035A %	40			
Acaroid resin to CS 5033 %	1			
Aluminium '350-dust' %		40	59	20
Degussa Aerosil R972 %		9	1	
Potassium Nitrate %				20
Zinc %				40

In experimental composition 1 the oxygen balance has been altered to produce a fuel rich mixture. Experimental composition 2 is used as a spotting charge in US artillery shells.

TABLE 2

EXPERIMENTAL RESULTS

Field Trial #1 - 26 November 1985

PYROTECHNIC		EXPLOSIVE		PAYLOAD	GROOVE	RESULTS				#
TYPE	QUANTITY gms	DIAM. mm	QUANTITY gms	POSITION	TYPE	BREAK	SMOKE	NOISE	FLASH	RDS
							from 4 stars max.			
206 HP	42	32	5	forward	long E	***	***	**	***	1
206 HP	34	32	5	forward	long E	***	**	**	***	2
210 HP	42	32	5	forward	circ G	***	***	**	***	2
210 HP	42	32	5	forward	circ B	*	*	*	*	1
US HP	100	32	5	forward	circ B	***	*	*	*	1
US HP	34	-	-	forward	long E	*	*	*	*	2
210 HP	100	-	-	forward	long E	*	**	*	*	1
210 HP	200	-	-	forward	long E	*	***	**	**	1
FR HP	100	-	-	forward	long E	*	***	**	**	1
210 HP	30	-	-	forward	long E	*	***	*	***	3
210 HP	50	-	-	forward	long E	*	***	***	***	4
210 HP	50	-	-	forward	circ B	*	**	***	***	3
210 HP	50	-	-	forward	circ G	*	***	***	***	4
210 HP	50	-	-	forward	long F	*	***	***	***	2
210 HP	100	-	-	forward	long E	*	***	***	***	2
210 HP	100	-	-	forward	circ B	*	***	****	***	1
210 HP	100	-	-	forward	circ G	***	***	****	***	1
FR	50	-	-	forward	long E	*	****	***	***	1
FR	100	-	-	forward	long E	*	****	***	***	2

(Top half 162 fuzed rounds, bottom half CI fuzed rounds)

Ratings: **** excellent *** good ** fair * poor

Field Trial #2 - 27 February 1986

PYROTECHNIC		EXPLOSIVE		PAYLOAD	GROOVE	RESULTS				#
TYPE	QUANTITY gms	DIAM. mm	QUANTITY gms	POSITION	TYPE	BREAK	SMOKE	NOISE	FLASH	RDS
							from 4 stars max.			
210 HP	50	32	3.5	forward	long E	*	*	*	*	1
210 HP	50	32	5	back	circ G	*	***	***	***	1
210 HP	50	32	5	forward	long E	***	**	**	**	1
210 HP	50	32	5	forward	long F	***	***	***	***	1
210 HP	50	32	5	forward	long E	*	*	**	*	1
210 HP	50	32	10	back	circ G	****	***	***	***	1
210 HP	50	32	15	back	circ G	****	**	***	**	1

Field Trial #3 - 22 April 1986

PYROTECHNIC TYPE	PYROTECHNIC QUANTITY gms	EXPLOSIVE DIAM. mm	EXPLOSIVE QUANTITY gms	PAYLOAD POSITION	GROOVE TYPE	RESULTS BREAK	RESULTS SMOKE	RESULTS NOISE	RESULTS FLASH	# RDS
							from 4 stars max.			
210 LP	50	20	5	forward	long E	****	**	**	***	1
210 LP	50	20	5	back	circ G	****	****	**	****	1
210 LP	50	20	5	forward	circ G	**	**	***	***	1
210 HP	50	20	7.5	back	long E	***	***	***	**	1
210 HP	50	20	7.5	back	circ G	****	***	***	***	1
210 HP	50	20	7.5	forward	circ G	****	***	***	***	1
210 HP	50	20	10	forward	long F	****	***	****	***	1
210 HP	50	20	10	forward	circ G	****	***	****	***	3
210 LP	50	20	10	forward	circ G	****	****	****	****	2

Ratings: **** excellent *** good ** fair * poor

Field Trial #4 - 2 September 1986

PYROTECHNIC TYPE	PYROTECHNIC QUANTITY gms	EXPLOSIVE DIAM. mm	EXPLOSIVE QUANTITY gms	PAYLOAD POSITION	GROOVE TYPE	RESULTS BREAK	RESULTS SMOKE	RESULTS NOISE	RESULTS FLASH	# RDS
							from 4 stars max.			
210 LP	50	20	10	back	circ G	****	****	****	****	40

Ratings: **** excellent *** good ** fair * poor

Field Trial #5 - January 1987

*** Note - Alternative steel AISI 9260 utilized (annealed AISI 1340 in all other trials).

PYROTECHNIC TYPE	PYROTECHNIC QUANTITY gms	EXPLOSIVE DIAM. mm	EXPLOSIVE QUANTITY gms	PAYLOAD POSITION	GROOVE TYPE	RESULTS BREAK	RESULTS SMOKE	RESULTS NOISE	RESULTS FLASH	# RDS
							from 4 stars max.			
210 LP	50	20	10	back	circ G	**	****	****	****	40

Ratings: **** excellent *** good ** fair * poor

Pyrotechnic: HP = Hard Pressed (196 Pa)
LP = Loose Pressed (134 Pa)

US = United States composition
206)
210) = Experimental compositions
FR = Fuel rich 210 composition

Grooving: Per figure 3

TABLE 3

Comparison of Noise Results from Pyrotechnics Tested

Composition	Average Noise @ 600 m produced by 50 g comp. (HE full charge weight)
206	102 dB
210	115 dB
Exp. 1	113 dB
Exp. 2	100 dB
HE	125 dB

TABLE 4

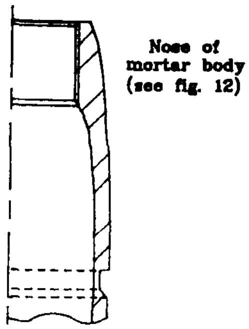
Ballistic Data Predictions and Results

PROJ. TYPE		PROPELLANT CHARGE NO.	MUZZLE VELOCITY (m/s)	MASS (kg)	BARREL ANGLE (deg.)	RANGE (m)	IMPACT ANGLE (deg.)	IMPACT VEL. (m/s)	TIME OF FLIGHT (s)
HE	(r)	1	104.0	4.137	45	978	47.6	96.3	14.9
PRAC	(p)	1	109.3	3.751	45	1056	48.1	97.7	15.3
	(r)					1054			15.3
HE	(r)	1	104.0	4.137	80	354	80.7	99.3	20.5
PRAC	(p)	1	109.3	3.751	80	370	80.8	101.2	21.1
HE	(r)	9	263.3	4.137	45	4595	54.6	181.8	33.2
PRAC	(p)	9	266.5	3.751	45	4632	55.5	179.3	33.4
	(r)					4638			33.4
HE	(r)	9	263.3	4.137	80	1579	82.3	198.8	45.5
PRAC	(p)	9	266.5	3.751	80	1579	82.5	197.2	45.8

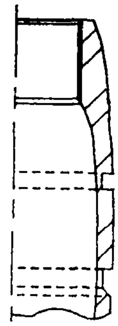
(p) = predicted results (r) = recorded results (field trials)

FIG. 1 CPMI body fractured by 10 g Tetryl Charge

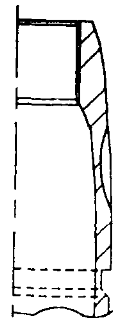
FIG. 2 Normalized AISI 1340 steel body deformed by 16 g Tetryl charge



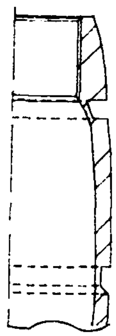
3a – obturating ring groove



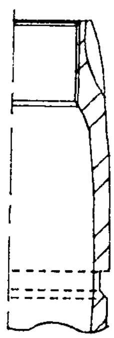
3b – circular groove at point of maximum deformation



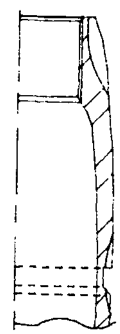
3c – longitudinal groove at point of maximium deformation



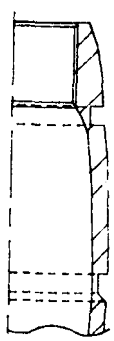
3d – 45 degree cut on cavity radius



3e – longitudinal groove at nose



3f – twin longitudinal grooves



3g – circular groove at cavity radius

FIG. 3 Groove types tested

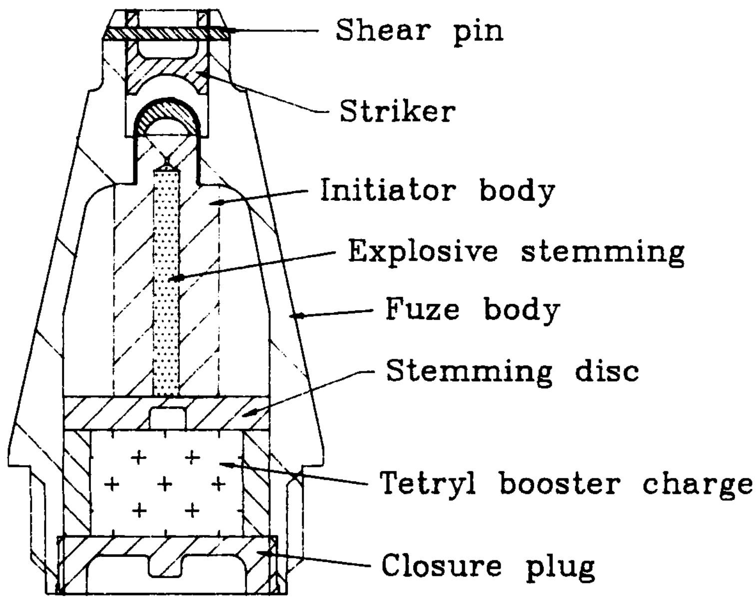


FIG. 4 **Original design, plastic compression igniticn fuze (PCIF). See Fig. 12 for final design.**

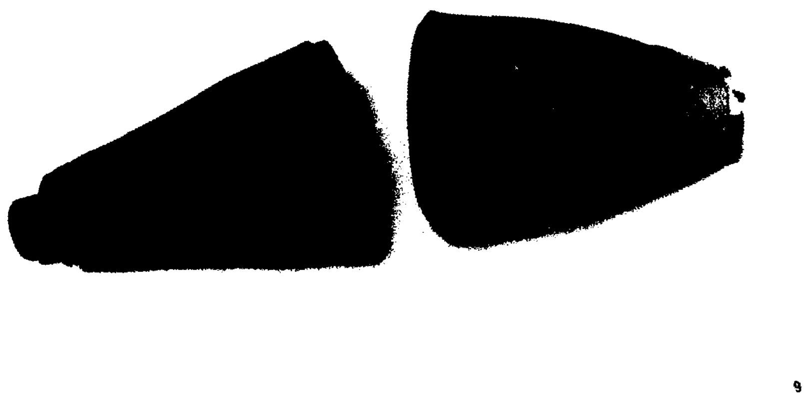


FIG. 5 Normalized AISI 1340 body fractured at obturating ring groove

FIG. 6 Normalized AISI 1340 body fractured using 4 grooves per Fig. 3e

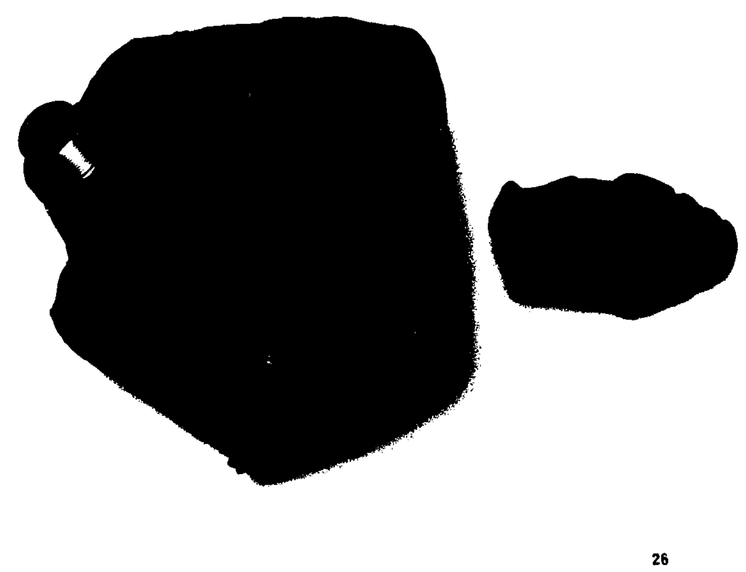


FIG. 7 Normalized AISI 1340 body split using single groove per Fig. 3e

FIG. 8 As per Fig. 6 - illustrating free fragment effect

FIG. 9 Normalized AISI steel body fractured using Fig. 3g groove

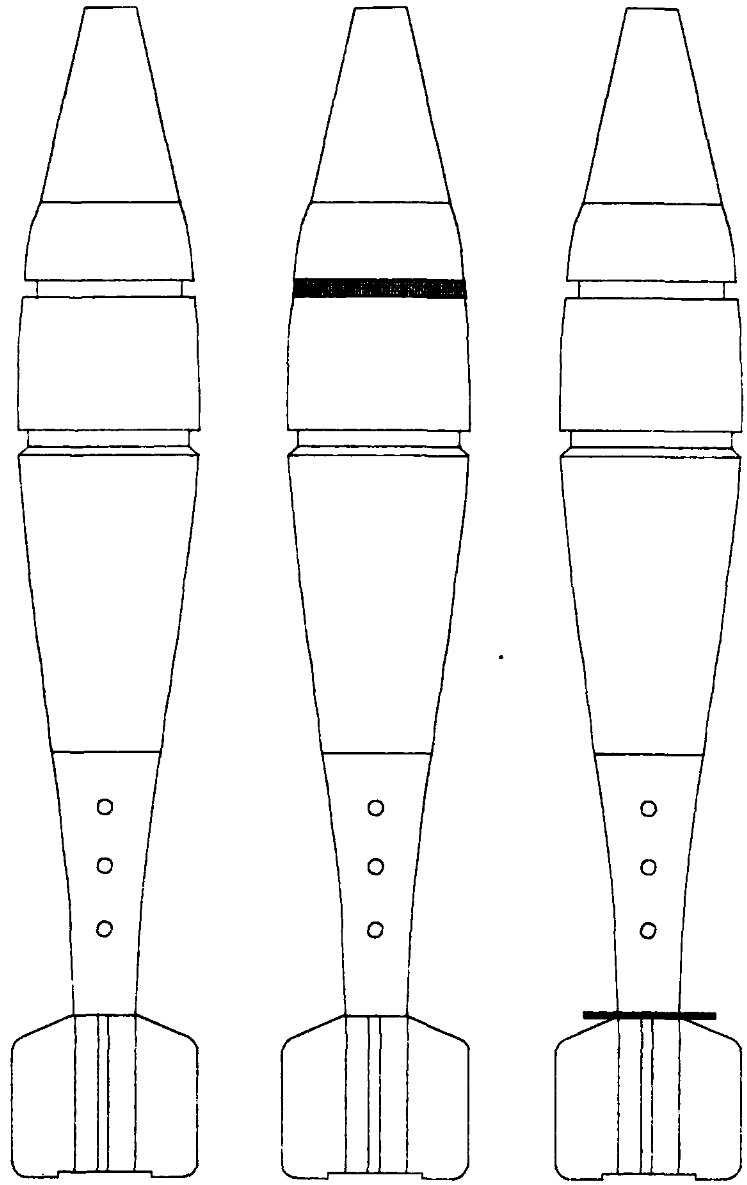
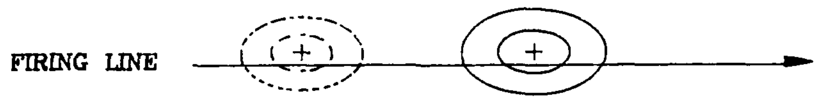


FIG. 10 Projectiles fired at trial #4.

M374 H.E. projectile –	
M.V.	104.1 m/s
M.V. S.D.	0.5 m/s
Range	970 m
Range S.D.	4 m
Dev'n	1.3 m
Dev'n S.D.	1.8 m

Standard practice projectile –	
M.V.	109.3 m/s
M.V. S.D.	0.4 m/s
Range	1054 m
Range S.D.	13 m
Dev'n	3.4 m
Dev'n S.D.	3.1 m



M374 H.E. projectile –	
M.V.	104.0 m/s
M.V. S.D.	0.7 m/s
Range	979 m
Range S.D.	11 m
Dev'n	3.7 m
Dev'n S.D.	6.6 m

Filled-groove practice projectile –	
M.V.	109.5 m/s
M.V. S.D.	0.6 m/s
Range	1063 m
Range S.D.	13 m
Dev'n	4.1 m
Dev'n S.D.	7.7 m

M374 H.E. projectile –	
M.V.	103.8 m/s
M.V. S.D.	1.0 m/s
Range	975 m
Range S.D.	13 m
Dev'n	13.2 m
Dev'n S.D.	3.2 m

Drag plate fitted practice projectile –	
M.V.	109.6 m/s
M.V. S.D.	1.0 m/s
Range	1065 m
Range S.D.	14 m
Dev'n	14.0 m
Dev'n S.D.	3.8 m

FIG. 11a Impact zones of projectiles fired at Charge 1, Trial #4.

MV - muzzle velocity
SD - standard deviation (normal distribution)
Dev'n - deviation from firing line

* Ellipses represent one and two standard deviations from mean impact point of seven projectiles fired in each group.

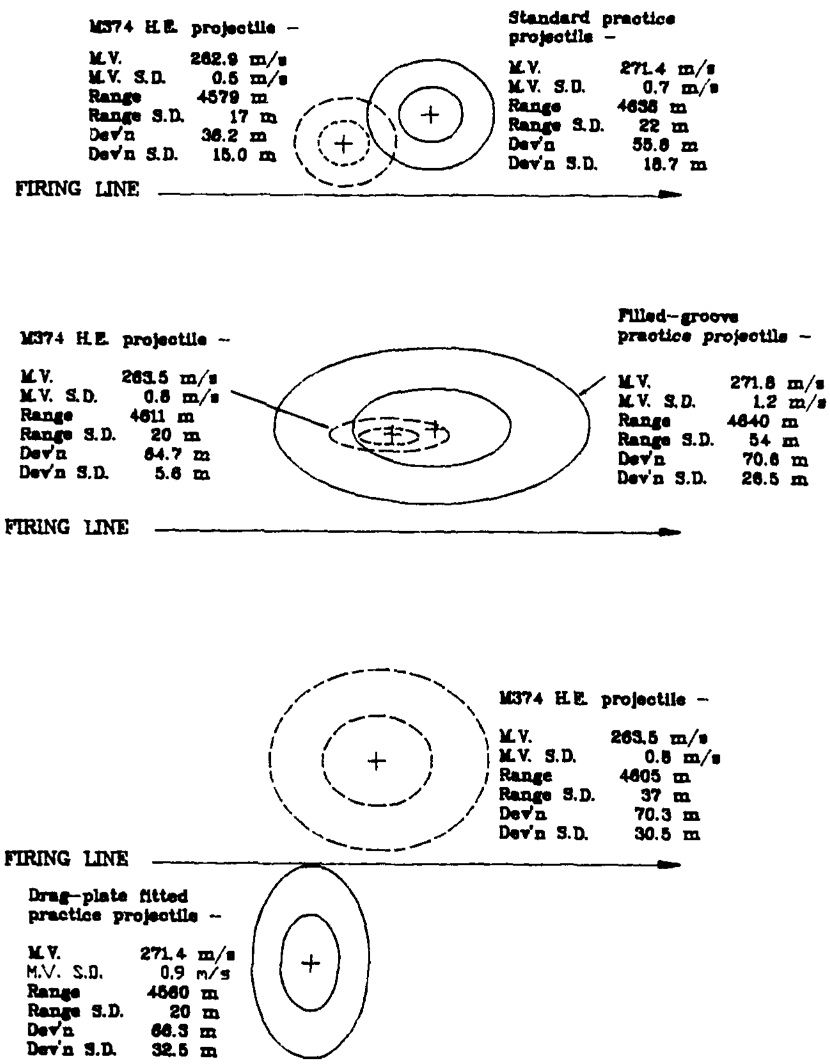


FIG. 11b Impact zones of projectiles fired at Charge 9, Trial #4.

MV – muzzle velocity
SD – standard deviation (normal distribution)
Dev'n – deviation from firing line

* Ellipses represent one and two standard deviations from mean impact point of seven projectiles fired in each group.

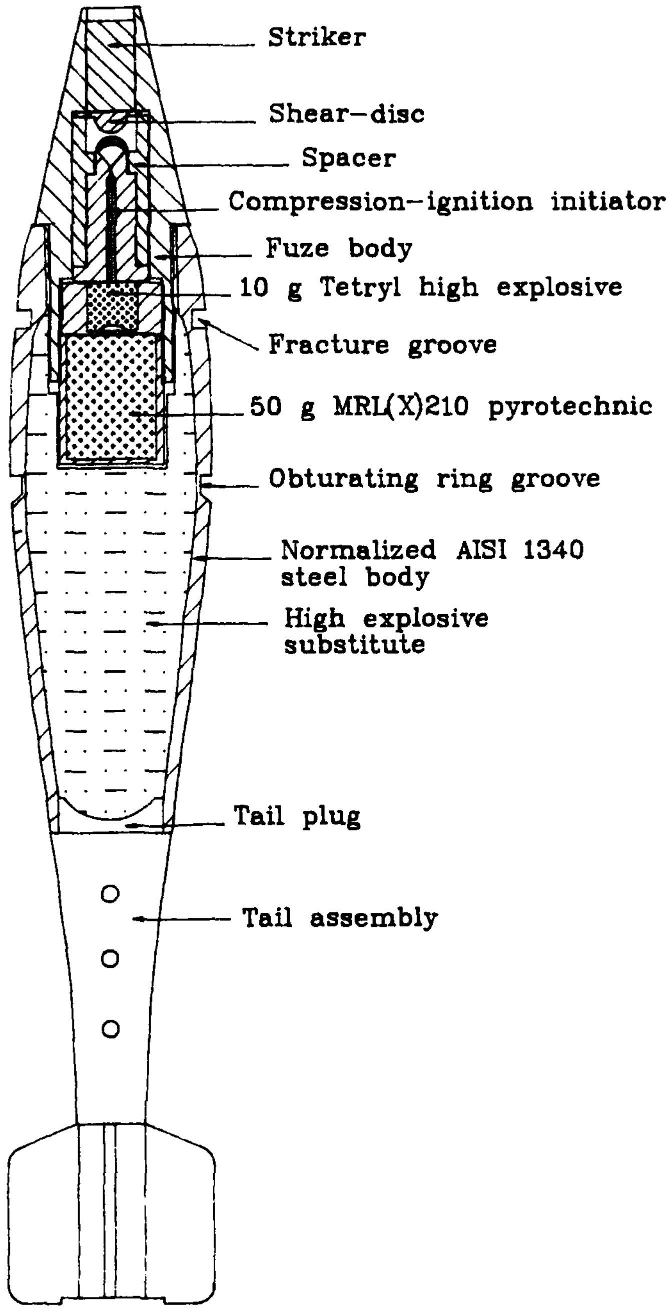


FIG. 12 MRL developed 81 mm mortar practice and training cartridge.

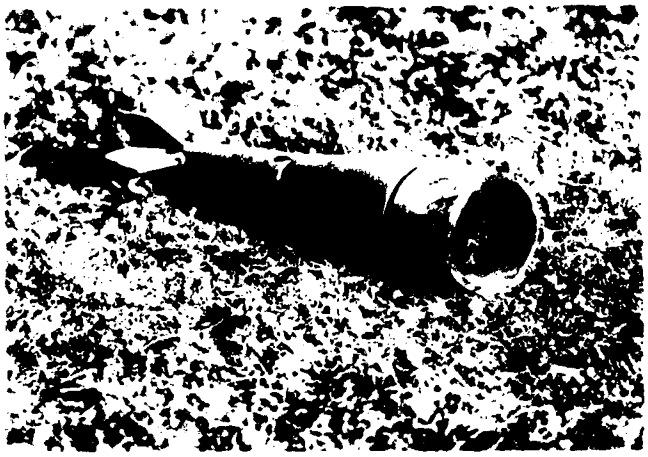


FIG. 13 Final position of practice cartridge body after impacting on hard soil

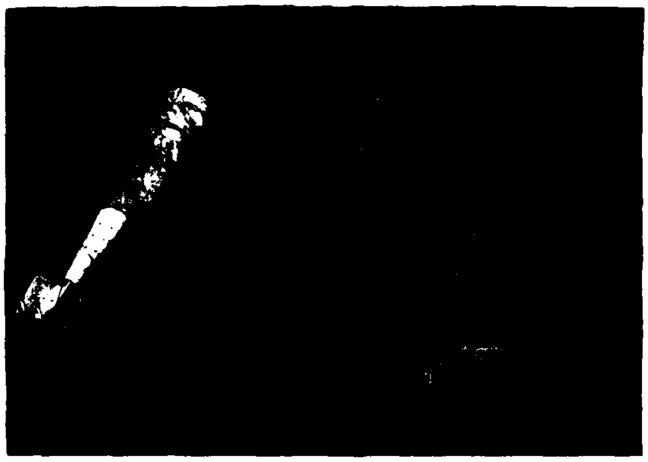


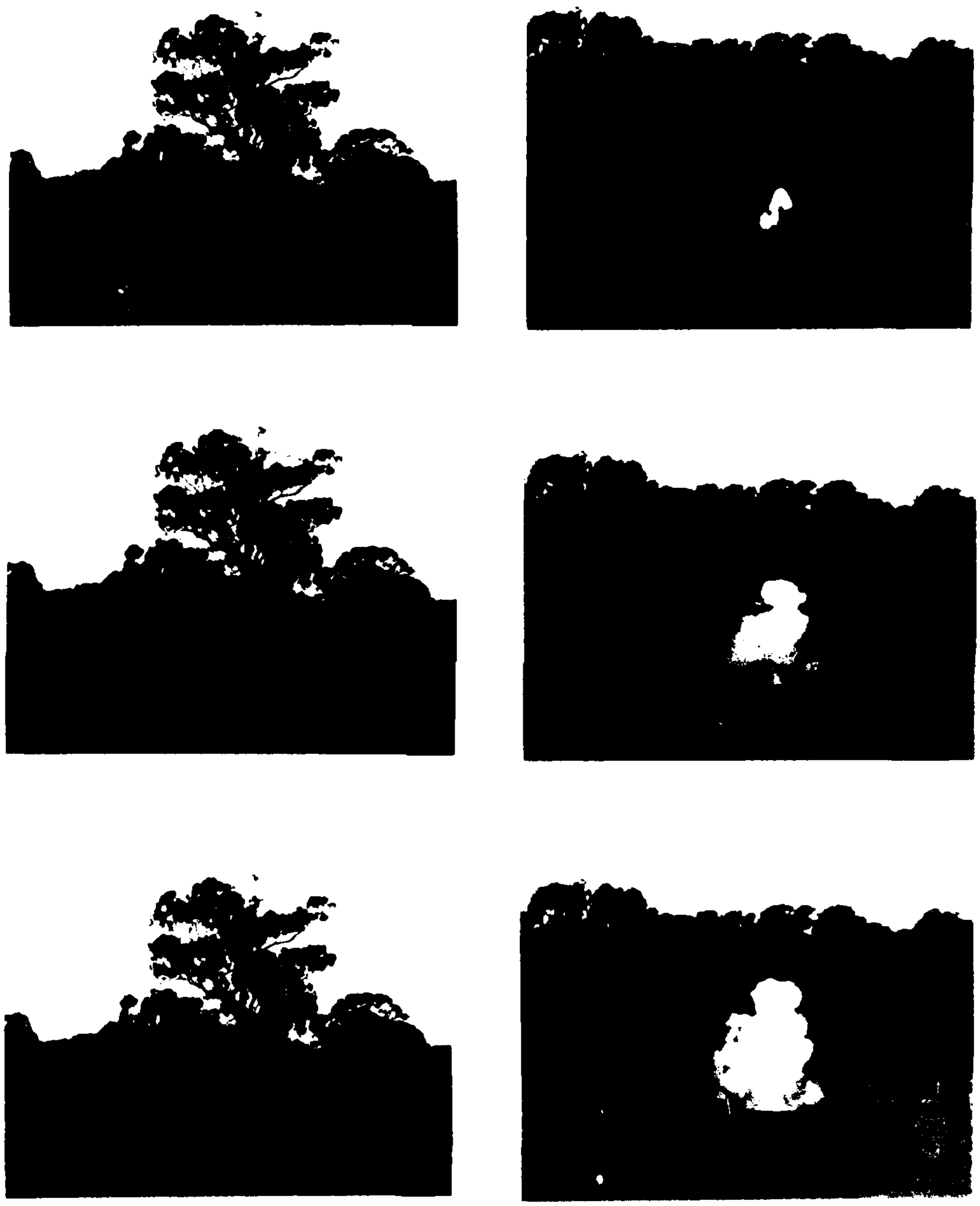
FIG. 14 Position of projectile body after impacting in marshy soil

FIG. 15 Typical flash signature produced by practice projectile at impact

Impact signature of high explosive projectile against hard dry soil

Impact signature of practice projectile (Fig. 11) against hard dry soil

FIG. 16



Impact signature of high explosive projectile against soft wet soil

Impact signature of practice projectile (Fig. 11) against soft wet soil

FIG. 17

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Development of a low cost, low hazard 81 mm practice mortar cartridge

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ABSTRACT

The development of a low-cost, low-hazard practice 81 mm mortar projectile incorporating a bursting/spotting charge that functions from a Plastic Compression-Ignition Fuze (PCIF) is described. The mortar casings were made from normalized AISI 1340 steel, and were made to fracture in a ductile manner along pre-machined grooves under the influence of a small high explosive burster charge. A spotting signature was provided by a pellet of pyrotechnic composition.

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