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Improved Anti-Personnel Mine Neutralization Device Test Report

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IMPROVED ANTI PERSONNEL MINE NEUTRALIZATION DEVICE TEST REPORT
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1.0 INTRODUCTION

This report describes the results and analysis of the field test of the Improved Anti Personnel Mine Neutralization Device (APMINUD). This is the second test of this equipment and follows a six month design and engineering effort on the equipment to correct and improve upon deficiencies identified in the initial version of the APMINUD.

The APMINUD is a mechanical tool designed to safely detonate antipersonnel landmines as part of a peace time clearance operation. The APMINUD consists of a mobile blast and fragment containment shell, with a mechanical striker inside. It can be used in conjunction with a shielded, all terrain vehicle with crane. The vehicle is used to move and lower the shell over a marked mine location. The internal striker is released and impacts the mine or ground above the mine and actuates the pressure fuze. The blast and fragments from the detonating mine are contained within, or are directed out the top of the shell and away from surrounding personnel and equipment.

FIGURE 1. Improved APMINUD with Placement Wrecker

2.0 DESCRIPTION OF IMPROVEMENTS

The APMINUD and changes incorporated in the improved version were designed and manufactured by Israel Aircraft Industries. The goal for the APMINUD is to be capable of actuating the pressure plates on all antipersonnel mines up to the maximum normal burial depth of 2-3 inches. In order to be operationally effective the APMINUD must be relatively light and mobile, and it must be capable of remaining functional after many mine blasts. In order to be technically effective, the APMINUD must keep explosive shock and fragments from personnel, equipment, and surrounding structures. These factors along with an assessment of the original APMINUD success in meeting the goal are listed in Table One.

ISSUE	**CRITERIA**	**GOAL**	**EVALUATION**
Mine Type	Effective against all pressure fuzed AP mines	Applies 2 tons of dynamic force to the ground surface	Dead spots within the footprint of the striker reduced effectiveness
Actuation Depth	Actuates pressure fuzes at maximum depth AP mines typically buried	Actuates all AP mine pressure fuzes to a depth of 2”	Testing conducted to a depth of 4” revealed 70%-80% success on the first strike, and 100% with a second impact

Survivability	Unit is sufficiently robust to clear a large minefield without significant interruption for maintenance or repair	Shell and unit fully functional after being subjected to 50 explosive shots of .5 lbs of TNT	Shell intact after explosive testing; however weak points in the striker mechanism required 5 repairs over the 50 shot test sequence
Blast/Fragment Protection	Contains or directs explosive shock and fragments away from personnel and equipment	No primary fragments launched below 45 degrees elevation angle	This requirement was essentially met; over 6000 fragments were produced, only 8 impacted the witness boards at all, at elevation angles 40 – 60 degrees
Mission	Effectively reduces the mine threat	Can be safely and adequately positioned and has no adverse impact on mine clearing operations	Operator estimated to be capable of placing the striker within 2” of the marked location. Metallic fragments from the expendable striker face were launched at high angles and littered the minefield.

TABLE 1. Original APMINUD Success in Meeting Design Goals

The blast containment shell is cylindrical with a diameter of 28" and a height of 28". Although the shell adequately contained the blast and fragmentation in the original design, two additional cylinder sections were added to the top in order to increase the height of the cylinder to almost 44" and provide further shielding from fragments leaving the detonation center at low angles. The cylinder is constructed from 20mm European plate steel standard ST52 and the extensions added to the improved version are constructed from 5mm material. The top of the cylinder is open except for the space occupied by the plunger and its support structure. The Improved APMINUD has a blast venting umbrella supported on columns 11" above the top of the shell extension cylinders. The umbrella is constructed from perforated thin steel plate to act as a fragmentation guard and upward blast vent. It is supposed to deflect the metallic fragments which are launched out the top of the cylinder back toward the ground so that any littering of the minefield is only in the immediate vicinity of the APMINUD. Blast and detonation gases pass through the holes in the umbrella and are released.

The striker mechanism is suspended in the center of the cylinder and consists of a spring loaded "plunger" assembly which travels up and down inside a sleeve connected with the shell. The plunger assembly includes the hammer head, a spacing element, and the hollow plunger which engages the spring. Passing axially through the plunger assembly is the connecting rod which holds all of the elements of the plunger assembly together. All elements of the plunger assembly are made from 4130 chrome-molybdenum steel. The connecting rod has a flare on the bottom end which is used to pull the hammer head and spacer up tight to the plunger. The weld holding the flared section to the rest of the connecting rod broke repeatedly in previous testing with the original APMINUD. The connecting rod in the Improved APMINUD is machined from a solid round, eliminating the weak point responsible for all of the failures in the previous tests.

The spring which drives the plunger is compressed by the weight of the shell when the entire unit is lifted by the eye at the top of the plunger. The spring in the Improved APMINUD is over twice as stiff as the original version. The spring is preloaded to 300 kg when cocked and develops several tons of dynamic force when impacting the ground. This extra impact is needed to raise the first strike detonation rate for the unit, which was measured at 70%-80% in the tests performed with the original APMINUD.

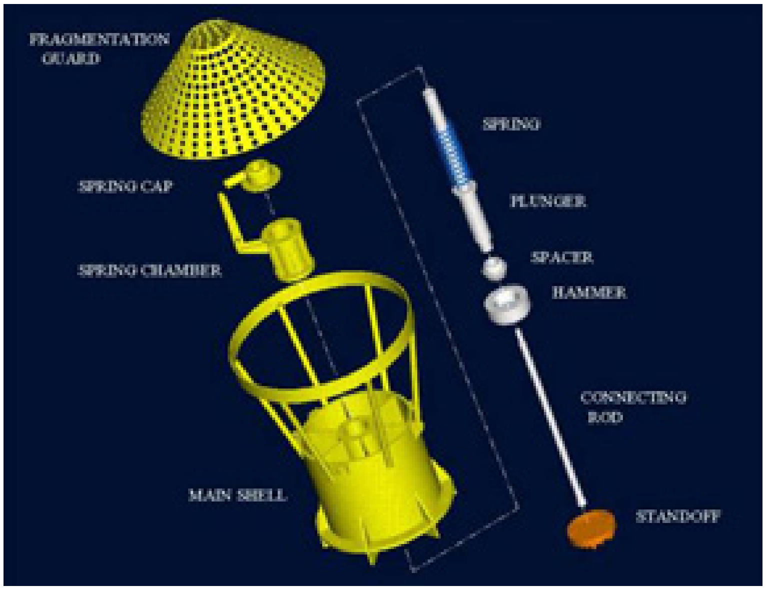

FIGURE 2. Improved APMINUD Assembly

The expendable face, or "standoff", on the hammerhead has also been redesigned. Dead spots in the effectiveness of the strike provided by the hammerhead were discovered in tests with the original APMINUD. The annular ridge pattern on the face of the standoff was causing the detonation success rate to drop significantly at certain combinations of burial depth and offset from the center of the plunger. The standoff units designed for the Improved APMINUD feature a pattern of pyramid shaped spikes protruding from the face at two inch spacing. This design is intended to give the impact footprint more uniform load while still providing the increased soil penetration that results from having protrusions on the standoff face. Israel Aircraft Industries addressed the problem of metallic pieces from the shattered standoffs cluttering the minefield by constructing the standoff elements out of cast rubber instead of aluminum used previously.

FIGURE 3. Rubber Standoff Design for the Improved APMINUD

In summary, several improvements to the APMINUD design have been incorporated. These improvements include: the fragment guard and change to rubber for the standoff element to reduce metallic minefield clutter; a stiffer drive spring and redesigned impact face on the standoff element to improve the fuze triggering success rate; shell extensions to improve the shielding performance of the APMINUD; and a one piece plunger connecting rod for better reliability. The Improved APMINUD weighs 1857 lbs. as compared to 1300 lbs. for the original version.

3.0 TEST PLAN

The purpose of this field test is to document the improvements to the capability of the APMINUD realized from the design changes described above. Most of the test elements used to document the original APMINUD were duplicated for this test. Three objective measurements for the test program remained the same as the original test and a fourth was added:

1. How effective is the Improved APMINUD at triggering mines to detonate under various emplacement conditions?

2. How effective is the Improved APMINUD at reducing the blast and fragment damage to the working environment around the mine?

3. How durable is the APMINUD when repeatedly subjected to mine blasts?

4. How effective are the fragment guard and rubber standoff element in the Improved APMINUD in reducing unwanted minefield clutter produced by the original APMINUD?

The effectiveness of the Improved APMINUD at triggering AP mines was tested by burying non explosive mines under a variety of conditions and using the Improved APMINUD to try to actuate the fuze. Italian MKII mines and US M14 antipersonnel mines were used for these tests. In each test, the mine was placed and buried, the Improved APMINUD lowered over the burial location using an automotive wrecker, and the plunger released. After the Improved APMINUD was removed and the mine body recovered, the mechanical fuzes were examined to determine whether they had "fired". Each test with the MKII mine was repeated five times, and each test with the M14 was repeated three times, to establish the repeatability of the results. The mines were buried in clay soil and in pure sand to assess the effect of soil type on the results. Tests in these soils were conducted with the mines placed with the top flush with the surface of the ground, buried in 2" deep holes, and buried in 4" deep holes in order to assess the effect of burial depth on the results. The APMINUD was placed such that the impact from the hammerhead would be centered on the mine, the impact would be centered 2" away from the mine, and the impact would be centered 4" away from the mine. The face of the standoff element on the hammerhead is 11" wide, so even with the impact centered 4" away from the mine, the mine was completely underneath the footprint. These impact offset conditions were tested in order to establish a measure of how closely the mine must be located and the APMINUD placed in order to successfully trigger the mines. A core set of tests from the above mentioned repetitions at every combination of mine type, soil type, burial depth, and burial offset from center yielded 136 individual results using the non explosive mines. This core test set provided the bases for comparison with a similar core set of results developed in previous testing on the original APMINUD and for analyzing the effect of each of these independent factors on the mine-triggering success rate.

In addition to the core set, non explosive tests were made to examine the effect produced by burying the mines in sod covered, clay soil; and the effect produced by using the APMINUD with the spikes on the face of the standoff element clogged with clay. Unlike the core tests, where every combination of variables possible was tested multiple times, only one or two combinations of burial conditions were tested in order to keep the overall number of tests manageable. In the case of the sod versus bare ground, all tests were performed at the maximum 4" burial depth, and the centered and 2" offset conditions. In the case of the investigation of the effect of soil covering the face of the standoff element, all tests were conducted with the M14 mine buried in 2" or 4" of unvegetated clay, with the mine either centered under the standoff or offset 2".

The effectiveness of the Improved APMINUD at reducing the mine blast effects to the deminer's working environment, the durability of the strengthened connection rod in the Improved APMINUD, and the effectiveness of the improvements aimed at reducing the metallic minefield clutter by using the fragment guard and a rubber standoff were all assessed simultaneously in a series of explosive tests. ½ pound blocks of TNT were used in these tests to replicate the blast effects from the large end of the range of AP mines available. 100 carbon steel balls were attached to the surface of each TNT block to replicate the fragmentation hazards from the exploding mine cases and from bounding fragmentation mines. The balls used were ¼ inch in diameter, which is in the range of the 5 to 6 millimeters reported slug size for many of the bounding type mines. The detonation site was surrounded by 3 witness towers measuring 4' wide and 16' tall. These witness towers had a 3/8" plywood face toward the blast site. The towers were placed 8' from the detonation site and were designed to indicate a fixed percentage of the fragments leaving the APMINUD at elevation angles between 0 and 63 degrees. 11 of these tests were conducted in order to repeatedly stress the system to assess its durability and to build a cumulative record of the number of fragments impacting on the face of the witness towers. The tests were conducted by placing the TNT block in a small hole flush with the ground. The APMINUD with the plunger in the released position was lowered on top of the TNT with the face of the standoff resting on the TNT. The explosive was electrically detonated with the APMINUD in place. The condition of the APMINUD was inspected and recorded as was the condition of the 3 witness towers after each shot.

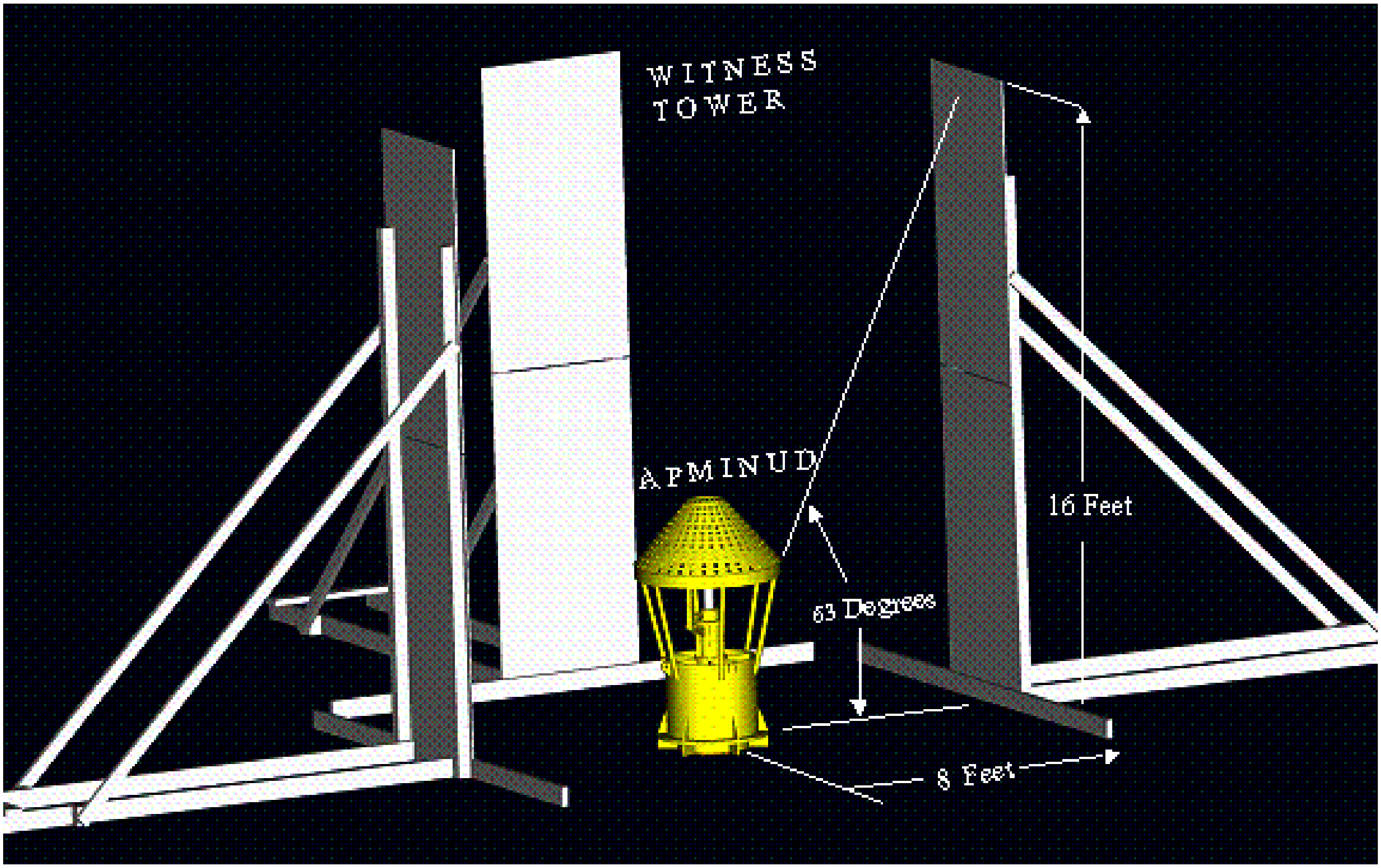

FIGURE 4. Explosive Test Set Up and Witness Tower Placement

A final explosive test was conducted to evaluate and compare the durability of the rubber standoff element and the aluminum standoff element when subjected to a small blast mines such a "toe popper" mine. Although the standoffs are intended to be expendable, there is some advantage to not having to replace them after every shot. A 30 gram charge was detonated under the Improved APMINUD with the original aluminum standoff. A second 30 gram charge was detonated under the Improved APMINUD with the rubber standoff to assess whether any durability of the standoff had been sacrificed by the new design and new material of the standoffs made for the Improved APMINUD.

4.0 TEST RESULTS AND ANALYSIS

4.1 Non Explosive "Core" Tests

Combining all test conditions, 164 non explosive mine tests were made with the Improved APMINUD. Of these, 136 tests are considered part of the "core" results in which every combination of the test variable was used. The overall rate in triggering the mine fuze under these core conditions was 93.4% in a single strike as compared with 78.9% on a similar mix of test conditions made with the original APMINUD. So the goal of raising the confidence we have in using the Improved APMINUD has been achieved. Note that these results span all of the core test conditions tried, some of which go beyond the design intent of the APMINUD (triggering a toe popper mine at 4" burial depth is not normally expected to be a requirement for the APMINUD). Also note that prior testing has shown that if the mine is not detonated on the first strike, the APMINUD can be recocked and fired again for an incremental increase in the success rate which, in the limited testing done on the original APMINUD, brought the results to 100% success. The various core test conditions used for these tests and the impact of varying each on the overall results is examined in the following paragraphs.

4.1.1 Mine Type

Variances in fuzing mechanism, pressure plate size, fuze spring stiffness etc. can have a significant effect on the amount of ground pressure and impulse required to actuate a given mine fuze. The mine types used for the non explosive core tests on this project were the US M14 and the Italian MKII. Both are "toe popper" style AP mines containing approximately 30 grams of explosive designed to damage the leg or sever the foot of the victim through blast. Although both mines can be easily triggered by holding them and applying light pressure with the fingers, there was a significant difference between the two in the success rate measured in the non explosive core tests (see table 2). The M14 mine was triggered in 100% of the core tests while the MKII was triggered 90% of the time under the same test conditions. Although both mines require approximately the same actuation force, the MKII mine is specifically designed to resist actuation from short impact forces. The MKII mine contains a pneumatic chamber that must be compressed or drained in order to allow the firing pin in the fuze to be driven home. This serves as a countermeasure against blast overpressure clearance methods (such as fuel air explosives) and apparently has some effectiveness in reducing the actuation success rate of the APMINUD. The M14 on the other hand has a simple belville spring arrangement which snaps the firing pin home when the actuation force is reached. The MKII was arbitrarily established at the baseline for these core tests, and more repetitions for each burial condition were made than for the M14.

MINE TYPE	Unvegetated Sand, Unvegetated Clay Mines Buried at a Depth of 4” to Bottom of Mine Mines buried 0” and 2” from the Center of Impact Spikes on Hammer Face Clean	
Test Results	Success Rate	
MKII	81/90	90%

M14	46/46	100%

TABLE 2. Effect of Mine Type on Triggering Success Rate

4.1.2 Burial Depth

The core tests were conducted with the mines placed at one of three depths: flush with the surface, buried in a 2" hole, or buried in a 4" hole. Paradoxically the 98% success rate at 2" depth was better than the 93% success rate of the flush buried mines. This may be attributable to normal scatter in the data or to skip zones present in the spike pattern on the standoff face. The spikes are spaced about 1.5"-2" apart and there are also vent holes in the face of the standoffs which allow detonation products of combustion to escape through ducts in the hammerhead. These spaces create gaps in the footprint where the standoff impacts the ground. It is possible that impact pressure from the standoff is more evenly distributed as one goes deeper in the soil, but at the surface, gaps in coverage may exist if the pressure plate of the mine is small enough. As the burial depth is increased to 4" the success rate in triggering the mine drops to 89%, presumably due to the cushioning effect of the additional soil overburden.

BURIAL DEPTH	M14 and MKII Mines Buried in Sand and Unvegetated Clay Mines buried 0”, 2”, and 4” from Center of Impact Spikes on Hammer Face Clean	
Test Results	Success Rate	
Top of Mine Flush with Ground	39/42	93%
2” Depth to Bottom of Mine	45/46	98%
4” Depth to Bottom of Mine	43/48	89%

TABLE 3. Effect of Burial Depth on Triggering Success Rate

4.1.3 Soil Type

In previous testing with the original APMINUD the difference between trying to neutralize mines in sand and clay was quite significant. The difference mostly disappeared in the core tests conducted with the Improved APMINUD. This may be attributable to the spike pattern on the Improved APMINUD standoff, or as a result of less care being taken in the previous test program to distinguish between results obtained with a soil clogged standoff versus a clean one (see section 4.2.2 Effect of Soil Clogging Face of Standoff). What ever the reason, the overall success rate in the sand was 94% and very close to that, 92%, in clay soil.

Soil Type	M14 and MKII Mines Mines Buried Flush and at Depths of 2” and 4” to Bottom of Mine Mines buried 0”, 2”, and 4” from Center of Impact Spikes on Hammer Face Clean	
	Test Results	Success Rate
Sand	68/72	94%
Clay	59/64	92%

TABLE 4. Effect of Soil Type on Triggering Success Rate

4.1.4 Burial Offset from Standoff Center

The final variable examined in the core testing of the Improved APMINUD was the distance the center of impact was from the center of the buried mine. The offsets used in the core tests were 0", 2", and 4". The diameter of the hammerhead is 10.4" meaning that even with a 4" offset, the mines were always completely underneath the hammerhead. The offset distance in the core tests produced the single biggest variance in the success rate in triggering the mine. 98% of the mines in the core tests were triggered when placed at 2" or less from the standoff. When we move out to 4" from center, the success rate drops to 83%, indicating less impact pressure being transmitted near the edges of the standoff.

BURIAL OFFSET FROM CENTER OF IMPACT	M14 and MKII Mines Buried in Sand and Unvegetated Clay Mines Buried Flush and at Depths of 2” and 4” to Bottom of Mine Spikes on Hammer Face Clean	
	Test Results	Success Rate

0” Offset	44/45	98%
2” Offset	44/45	98%
4” Offset	38/46	83%

TABLE 5. Effect of the Offset from Center of Impact on Triggering Success Rate

4.2 Additional Non Explosive Tests

4.2.1 Effect of Vegetation Cover

4.2.1 Effect of Vegetation Cover FIGURE 5. MKII Mine Burial in Sod

A series of tests was conducted with mines buried 4" in sod covered clay. These results were compared with results from the mines buried under similar conditions minus the vegetation from the core test program. A truly representative testing of the effect of overgrowth on the results would require burying the mines for a long period of time and allowing vegetation to develop, then performing the test. Since we were not able to create such a condition for this test, the best approximations to this were created in two ways. In most of the tests a square of sod larger than the APMINUD footprint was removed, the mine was buried in the hole left by the sod, and the sod was then replaced, and the test conducted. In some of the tests the burial hole was "drilled" into the sod exactly the size of the mine diameter. The standoff which is much larger than the hole would have to compress the sod all around the hole before impacting the ground above the mine. The method of burial didn't make much difference in the results. The vegetation produced a small reduction in the effectiveness. In these tests, all conducted at 4" burial, 89% of the mines were detonated. This compares to 94% success in the core tests with the same burial conditions except for the sod cover.

SURFACE CONDITION	M14 and MKII Mines Mines Buried at a Depth of 4” to Bottom of Mine Mines buried 0” and 2” from the Center of Impact Spikes on Hammer Face Clean	
	Test Results	Success Rate
Vegetated Clay	17/19	89%
Unvegetated Clay	15/16	94%

TABLE 6. Effect of Vegetation on Triggering Success Rate

4.2.2 Effect of Soil Clogging the Face of the Standoff

The standoffs on the APMINUD are designed to be expendable elements which are easily replaceable. Never-the-less, due to impacts which miss or fail to detonate the mine, impacts which are on false detections, or impacts causing detonation in mines too small to break the standoff in one blast, there is reason to expect that a given standoff could be used for multiple impacts. In certain conditions soil can accumulate in the spaces between the spikes on the face of the standoff and reduce the ability of the hammer to effectively transmit pressure. Clogging of the spikes in the standoffs was not observed in sand or dry clay, but was observed in damp clay. A short series of tests was made in damp clay in which the APMINUD was triggered, allowing the soil build up on the standoff, and then triggered again over a buried M14 mine. These results were compared with the results from the core tests using a clean standoff against M14 mines buried under identical conditions. The resulting decrease in triggering efficiency for the APMINUD when the standoff was allowed to become clogged was dramatic, falling from 100% with a clean face to 57% when clogged.

CONDITION OF SPIKES ON FACE OF HAMMER	M14 Mines Mines Buried at Depths of 2” and 4” to Bottom of Mine Mines buried 2” and 4” from the Center of Impact Mines Buried in Unvegetated Clay Soil

	Test Results	Success Rate
Spikes Clogged with Soil	4/7	57%
Spikes Clean	9/9	100%

TABLE 7. Effect of Soil Clogging Standoff Spikes on the Triggering Success Rate

4.3 Explosive Tests

A series of 11 explosive shots was made with ½ blocks of TNT, and two shots were made with 30 grams of TNT to assess the durability of the Improved APMINUD and its ability to protect the surrounding environment from blast and fragment damage. Both the rubber standoff design of the Improved APMINUD and the cast aluminum standoff design of the original APMINUD were used during these tests.

4.3.1 Damage Assessment to the Improved APMINUD

The Improved APMINUD unit proved survivable over the course of the 11 shots with half pound TNT blocks. These explosive charges were each covered with one hundred .25" ball bearings to simulate the fragmentation hazard associated with many AP mines. In each of these tests the explosive charge was placed flush with the ground, the Improved APMINUD plunger was released, and then the Improved APMINUD was lowered over the mine such that the standoff was resting on the explosive charge. The charge was then electrically detonated. The rubber standoffs supplied with the Improved APMINUD were used for seven of these tests. An additional four tests were performed using the cast aluminum standoffs previously tested with the original APMINUD, in order to increase the number of shots and further stress the system.

Each rubber standoff performed its sacrificial task of protecting the hammer head from damage from the detonating explosive (up to one half pound). The unit remained functional and undamaged over the course of the half pound TNT testing. After the final shot a broken weld was discovered on the retaining shoulder which holds the plunger from falling out the bottom of its bearing sleeve. This weld was determined to have been incorrectly performed and is in an area that is not highly stressed; in addition there were no problems with this weld in the original APMINUD over the course of fifty explosive blasts. Therefore the significance of this test failure on the design of the Improved APMINUD is judged to be unimportant . There was no breakage or sign of damage to the connecting rod, which had proven to be the weak link in the original APMINUD.

Two additional shots were made with 30 gram quantities of explosive to compare the damage level to the rubber standoff versus the aluminum standoff from toe popper style mines. Although the standoffs are designed to be sacrificial, there is some benefit to not having to replace them after every single detonation. The aluminum standoff remained intact after one of these smaller shots and could probably be reused multiple times against toe popper style blast mines. The rubber standoff, however, did split and would not be capable of being reused after the first detonation.

4.3.2 Damage Assessment to the Environment

Elevation angles covered by the witness plates include 0 degrees through 64 degrees. Examination of the plates after each explosion revealed that over the course of the 11 half pound shots a total of 8 fragments were captured by the witness plates. Statistically this represents about .73 fragments per shot at an average elevation angle of 57 degrees, with the lowest fragment "witnessed" being launched at 47 degrees. Considerably more fragments were launched at high angles and could be observed raining down on the areas around the APMINUD at distances up to 100 meters away. In comparing these results with those of the original APMINUD we find that the number of fragments witnessed per shot has actually risen. The original APMINUD results showed 8 witnessed fragments from 26 shots, for an average of .31 witnessed fragments per shot. Although not quantified, the number of high angle fragments which littered the area around the detonation site appeared to have been decreased (but not eliminated) from the number found with the original APMINUD. It is believed that the fragmentation guard succeeded in keeping the fragmentation litter more confined to the vicinity of the APMINUD, at the expense of launching more fragments at the intermediate angles observed by the witness plates (between 45 and 64 degrees).

As did the original APMINUD, the Improved APMINUD met its primary function of complete protection of the witness plates at low angles (below 45 degrees). The fact that the lowest fragment recorded with the Improved APMINUD was at 47 degrees versus 36 degrees with the original APMINUD is attributed to the extension of the cylindrical shell upward by 40 centimeters. The Improved APMINUD also succeeded in another important objective, that of reducing the metallic clutter introduced into the minefield. The Improved APMINUD introduces no metallic fragments to the minefield when the standoff ruptures, since the standoff units are now made from rubber.

5.0 CONCLUSIONS

The Improved APMINUD proved capable of meeting all of the design goals set for the system and the improvements made on this most recent design. Testing showed that mine type, soil type, burial depth, burial offset, and vegetation all influence, to varying degrees, the ease with which mines are triggered using the system. The improvements made have raised the overall confidence in the system significantly. In our tests the mines were triggered almost 94% of the time on the first strike. These tests included the use of blast hardened mines, burials deeper than expected, and several soil conditions. The one remaining test parameter, within the range we tested, which is still capable of degrading the trigger rate below the high eighty percent range was the offset condition. If the APMINUD is placed within 2" of the center of the target mine the overall success rate is 98%, if the APMINUD is placed 4" from the center of the target mine, the success rate drops to 83%.

Although not evaluated in this particular test, striking the target mine a second time has been shown to produce an incremental increase in the mine trigger success rate in previous testing. It is expected that allowing a double strike under field conditions would produce a confidence approaching 100% in most soil conditions, with any known AP mine type, and any offset up to 4", and burial up to 4".

The Improved APMINUD proved capable of withstanding the stress imposed by repeated mine blasts. Testing was performed at and beyond the design limit for explosive weight for the system and produced no failures of consequence. The design features of the original APMINUD which proved most susceptible to blast damage have been strengthened in the Improved APMINUD. Based on these results and previous testing with the original APMINUD, the Improved APMINUD can be expected to reliably detonate at least 50 mines with a 200 gram explosive content without maintenance or repair and perhaps in the thousands for mines with explosive content below 50 grams. The rubber standoffs designed for the Improved APMINUD performed quite well in these tests and will ensure that the minefield is not littered with unnecessary metallic debris. The only drawback of this new feature of the Improved APMINUD is that the rubber proved to be not as durable to small mine explosions(<50 gram explosive content) as the aluminum standoffs used with the original APMINUD. Although the standoffs are intended to be expendable, there is a time and monetary savings associated with not having to replace the standoff after every shot. Since the aluminum standoffs were capable of withstanding these small mine blasts without shattering or fracturing, an aluminum version could be used in situations where the mine threat is known to consist of small AP blast mines.

The rubber standoffs would then be used when larger mines are expected. Thus the user could have the advantages of reusing the aluminum standoffs when the threat allows it and still have the rubber standoffs available when the threat is such that the standoff is expected to be shattered and blasted free of the APMINUD.

The only feature present on the Improved APMINUD and not present on the original APMINUD which did not fully meet expectations was the fragmentation umbrella. It was intended to deflect toward the ground the fragments associated with the detonating mine and ruptured standoffs which are blasted out of the top of the containment shell. Although it did this with some degree of success there were still plenty of fragments leaving the Improved APMINUD at high launch angles. Although these are less of a concern since they are directed above surrounding personnel and equipment, they still must fall to the ground and end up littering the minefield. Since the rubber standoffs proved capable of doing the job required, the metallic clutter concern is much reduced and raises the question of what incremental benefit is provided by the umbrella. More of a concern however is that in deflecting the fragments down, the fragmentation umbrella also appears to have raised the number of high velocity fragments leaving the Improved APMINUD at intermediate (between 45 and 60 degrees) angles, and this is a big concern. Although we are trying most to protect the areas located between the horizon and 45 degrees elevation, we still must be concerned with what happens above 45 degrees. Anything that increases the number of projectiles in range of elevations measured by our witness plates (0 to 63 degrees) must be considered a step in the wrong direction.

We were unable to address or test many of the operational issues associated with finding the mine and bringing the Improved APMINUD to bear, since the usage and vehicle portions of an overall neutralization system featuring the Improved APMINUD have yet to be defined. In our testing we used an automotive wrecker crane to lift and place the Improved APMINUD. With guide personnel on the ground the operator was able to consistently place the footprint within 3/4" of its desired location. It is expected that, with great care, he would be capable of placing the footprint within 1-2" without live ground guidance but with proper ground marking. This would allow 1-2" of detection and marking accuracy before the confidence in triggering the mine falls off, or 3" before missing the mine completely.

These placement assumptions together with the test data suggest that the APMINUD system with the improvements developed on this program could be a reliable and valuable demining tool with the right support equipment and employment situation. The APMINUD could effectively contribute to an area clearance operation by being the first tool brought to bear on any detections the deminer makes with the hand held detector. The APMINUD could be quickly placed and triggered, several times if necessary, reducing the deminer requirement for extensive probing and limiting excavation to those detections in which the APMINUD subsequently fails to provoke a detonation. Given the high rate of success of the Improved APMINUD in causing functional mines to detonate, this should greatly increase the speed and safety for the deminer. Alternative use could be for individual neutralization of mines located in or near homes, villiages, densely inhabited areas, and other significant locations in which mines must be safely and effectively detonated in place.

In summary, the Improved APMINUD has met or exceeded every major goal set for the system. It offers an inexpensive and reliable method for clearing antipersonnel mines. It is simple to use and is capable of being employed in most situations in which one might encounter antipersonnel landmines. With the exception of the fragmentation guard, all of the improvements developed on this program unquestioningly provide a benefit to the APMINUD and should be incorporated.

APPENDIX
NON EXPLOSIVE MINE TEST DATA

Test # 	Date Time	Mine Type	Soil Type	Depth	Offset	Fuze Func ?	Remarks
1	11/30 10:40	MKII	Unveg/clay	0	0	Y	
2	10:46	MKII	Unveg/clay	0	0	Y	
3	10:49	MKII	Unveg/clay	0	0	Y	

4	10:52	MKII	Unveg/clay	0	0	Y	
5	10:54	MKII	Unveg/clay	0	0	Y	
6	11/30 10:57	MKII	Unveg/clay	2	0	Y	
7	10:59	MKII	Unveg/clay	2	0	Y	
8	11:02	MKII	Unveg/clay	2	0	Y	
9	11:04	MKII	Unveg/clay	2	0	Y	
10	11:07	MKII	Unveg/clay	2	0	Y	
11	11/30 11:13	MKII	Unveg/clay	4	0	N	
12	11:16	MKII	Unveg/clay	4	0	Y	
13	11:19	MKII	Unveg/clay	4	0	Y	
14	11:22	MKII	Unveg/clay	4	0	Y	
15	11:25	MKII	Unveg/clay	4	0	Y	
16	11/30 11:31	MKII	Unveg/clay	0	2	Y	
17	11:33	MKII	Unveg/clay	0	2	Y	
18	11:36	MKII	Unveg/clay	0	2	Y	
19	11:39	MKII	Unveg/clay	0	2	Y	

20	11:43	MKII	Unveg/clay	0	2	Y	
21	11/30 11:47	MKII	Unveg/clay	2	2	Y	
22	11:51	MKII	Unveg/clay	2	2	Y	
23	11:53	MKII	Unveg/clay	2	2	Y	
24	11:57	MKII	Unveg/clay	2	2	Y	
25	12:02	MKII	Unveg/clay	2	2	Y	
26	11/30 12:12	MKII	Unveg/clay	4	2	Y	
27	12:16	MKII	Unveg/clay	4	2	Y	
28	12:20	MKII	Unveg/clay	4	2	Y	
29	12:24	MKII	Unveg/clay	4	2	Y	
30	12:28	MKII	Unveg/clay	4	2	Y	
31	11/30 12:30	MKII	Unveg/clay	0	4	Y	
32	12:34	MKII	Unveg/clay	0	4	Y	
33	12:36	MKII	Unveg/clay	0	4	Y	
34	12:38	MKII	Unveg/clay	0	4	Y	
35	12:41	MKII	Unveg/clay	0	4	Y	

36	11/30 12:44	MKII	Unveg/clay	2	4	Y	
37	12:47	MKII	Unveg/clay	2	4	Y	
38	12:50	MKII	Unveg/clay	2	4	Y	
39	12:52	MKII	Unveg/clay	2	4	Y	
40	12:54	MKII	Unveg/clay	2	4	Y	
41	11/30 12:59	MKII	Unveg/clay	4	4	Y	
42	1:01	MKII	Unveg/clay	4	4	N	
43	1:04	MKII	Unveg/clay	4	4	N	
44	1:07	MKII	Unveg/clay	4	4	N	
45	1:11	MKII	Unveg/clay	4	4	N	

Test #	Date Time	Mine Type	Soil Type	Depth	Offset	Fuze Func?	Remarks
46	12/1 10:29	M14	Unveg/clay	0	0	Y	CRUSHED MINE
47		M14	Unveg/clay	0	0		SKIPPED
48		M14	Unveg/clay	0	0		SKIPPED

49	12/1 10:20	M14	Unveg/clay	2	0	Y	CRUSHED MINE
50	10:24	M14	Unveg/clay	2	0	Y	CRUSHED MINE
51		M14	Unveg/clay	2	0		SKIPPED
52	12/1 8:14	M14	Unveg/clay	4	0	Y	
53	8:20	M14	Unveg/clay	4	0	Y	
54	8:23	M14	Unveg/clay	4	0	Y	
55	12/1 10:34	M14	Unveg/clay	0	2	Y	CRUSHED MINE
56		M14	Unveg/clay	0	2		SKIPPED
57		M14	Unveg/clay	0	2		SKIPPED
58	12/1 10:12	M14	Unveg/clay	2	2	Y	CRUSHED MINE
59	10:15	M14	Unveg/clay	2	2	Y	CRUSHED MINE
60		M14	Unveg/clay	2	2		SKIPPED
61	12/1 8:28	M14	Unveg/clay	4	2	Y	CLEANED SPIKES REDID TEST AT 9:30 – Y
62	8:33	M14	Unveg/clay	4	2	N	CLEANED SPIKES, REDID TEST AT 9:37 – Y

63	8:37	M14	Unveg/clay	4	2	Y	CLEANED SPIKES, REDID TEST AT 9:44 – Y
64	12/1 10:43	M14	Unveg/clay	0	4	Y	CRUSHED MINE
65		M14	Unveg/clay	0	4		SKIPPED
66		M14	Unveg/clay	0	4		SKIPPED
67	12/1 8:55	M14	Unveg/clay	2	4	N	CLEANED SPIKES, REDID TEST AT 9:50 – Y
68	10:00	M14	Unveg/clay	2	4	N	CLEANED SPIKES
69	10:08	M14	Unveg/clay	2	4	Y	CLEANED SPIKES
70	12/1 8:43	M14	Unveg/clay	4	4	Y	CLEANED SPIKES, REDID TEST AT 9:22 – Y
71	8:47	M14	Unveg/clay	4	4	N	CLEANED SPIKES, REDID TEST AT 9:30 – Y
72	8:51	M14	Unveg/clay	4	4	Y	CLEANED SPIKES, REDID TEST AT 9:37 – Y
73	11/29 9:30	MKII	Unveg/sand	0	0	N	12/1 11:07 – Y
74	9:40	MKII	Unveg/sand	0	0	Y	11:10 – Y
75	9:53	MKII	Unveg/sand	0	0	Y	11:12 – Y
76	9:57	MKII	Unveg/sand	0	0	Y	11:14 – Y
77	10:01	MKII	Unveg/sand	0	0	Y	11:16 – Y

78	11/29 10:06	MKII	Unveg/sand	2	0	Y	12/1 11:20 – Y
79	10:11	MKII	Unveg/sand	2	0	N	11:22 – Y
80	10:16	MKII	Unveg/sand	2	0	N	11:24 - Y
81	10:20	MKII	Unveg/sand	2	0	Y	11:26 – Y
82	10:24	MKII	Unveg/sand	2	0	Y	11:29 – Y
83	11/29 10:30	MKII	Unveg/sand	4	0	Y	12/1 12:21 – Y
84	10:34	MKII	Unveg/sand	4	0	N	12:24 – Y
85	10:39	MKII	Unveg/sand	4	0	N	12:27 – Y
86	10:43	MKII	Unveg/sand	4	0	Y	12:29 – Y
87	10:57	MKII	Unveg/sand	4	0	Y	12:32 – Y
88	11/29 11:02	MKII	Unveg/sand	0	2	Y	12/1 12:35 – Y
89	11:07	MKII	Unveg/sand	0	2	N	12:38 – Y
90	11:10	MKII	Unveg/sand	0	2	Y	12:40 – Y
91	11:14	MKII	Unveg/sand	0	2	Y	12:42 – Y
92	11:16	MKII	Unveg/sand	0	2	Y	12:45 – Y

93	11/29 11:21	MKII	Unveg/sand	2	2	N	12/1 12:48 – Y
94	11:24	MKII	Unveg/sand	2	2	N	12:51 – N
95	11:27	MKII	Unveg/sand	2	2	Y	12:53 – Y
96	11:30	MKII	Unveg/sand	2	2	Y	12:56 – Y
97	11:34	MKII	Unveg/sand	2	2	Y	12:59 - Y
98	11/29 12:40	MKII	Unveg/sand	4	2	Y	
99	12:43	MKII	Unveg/sand	4	2	Y	
100	12:46	MKII	Unveg/sand	4	2	Y	
101	12:49	MKII	Unveg/sand	4	2	Y	
102	12:53	MKII	Unveg/sand	4	2	Y	
103	11/29 12:56	MKII	Unveg/sand	0	4	Y	
104	12:58	MKII	Unveg/sand	0	4	N	
105	1:01	MKII	Unveg/sand	0	4	N	
106	1:06	MKII	Unveg/sand	0	4	N	
107	1:16	MKII	Unveg/sand	0	4	Y	

108	11/29 1:30	MKII	Unveg/sand	2	4	Y	
109	1:35	MKII	Unveg/sand	2	4	Y	
110	1:38	MKII	Unveg/sand	2	4	Y	
111	1:42	MKII	Unveg/sand	2	4	Y	
112	1:45	MKII	Unveg/sand	2	4	Y	
113	11/29 1:48	MKII	Unveg/sand	4	4	Y	
114	1:52	MKII	Unveg/sand	4	4	Y	
115	1:56	MKII	Unveg/sand	4	4	Y	
116	2:00	MKII	Unveg/sand	4	4	Y	
117	2:03	MKII	Unveg/sand	4	4	Y	

Test #	Date Time	Mine Type	Soil Type	Depth	Offset	Fuze Func?	Remarks
118	11/30 9:41	M14	Unveg/sand	0	0	Y	
119	9:44	M14	Unveg/sand	0	0	Y	

120	9:47	M14	Unveg/sand	0	0	Y	
121	11/30 8:46	M14	Unveg/sand	2	0	Y	
122	8:52	M14	Unveg/sand	2	0	Y	
123	8:57	M14	Unveg/sand	2	0	Y	
124	11/29 2:15	M14	Unveg/sand	4	0	Y	
125	2:19	M14	Unveg/sand	4	0	Y	
126	2:23	M14	Unveg/sand	4	0	Y	
127	11/30 9:02	M14	Unveg/sand	0	2	Y	
128	9:05	M14	Unveg/sand	0	2	Y	
129	9:10	M14	Unveg/sand	0	2	Y	
130	11/30 9:14	M14	Unveg/sand	2	2	Y	
131	9:20	M14	Unveg/sand	2	2	Y	
132	9:24	M14	Unveg/sand	2	2	Y	
133	11/29 2:26	M14	Unveg/sand	4	2	Y	

134	2:29	M14	Unveg/sand	4	2	Y	
135	2:33	M14	Unveg/sand	4	2	Y	
136	11/30 9:28	M14	Unveg/sand	0	4	Y	
137	9:33	M14	Unveg/sand	0	4	Y	
138	9:37	M14	Unveg/sand	0	4	Y	
139	11/30 9:54	M14	Unveg/sand	2	4	Y	
140	9:57	M14	Unveg/sand	2	4	Y	
141	10:00	M14	Unveg/sand	2	4	Y	
142	11/30 8:19	M14	Unveg/sand	4	4	Y	8:38-N^T 10:05-Y 10:23-Y^T
143	8:24	M14	Unveg/sand	4	4	N^T	8:42-N^T 10:12-Y 10:27-Y^T
144	8:31	M14	Unveg/sand	4	4	N^T	10:16-Y 10:30-Y^T
145	12/1 2:03	MKII	Veg/clay	4	0	Y	Tests 145 – 160 peeled up 18" square of sod, buried mine flush on hole
146	2:14	MKII	Veg/clay	4	0	Y	bottom then replaced sod and conducted test
147	2:20	MKII	Veg/clay	4	0	Y	
148	2:25	MKII	Veg/clay	4	0	Y	

149	2:32	MKII	Veg/clay	4	0	Y	
150	12/2 7:53	MKII	Veg/clay	4	2	Y	
151	8:03	MKII	Veg/clay	4	2	Y	
152	8:13	MKII	Veg/clay	4	2	Y	
153	8:24	MKII	Veg/clay	4	2	Y	
154	8:39	MKII	Veg/clay	4	2	Y	
155	12/2 8:52	M14	Veg/clay	4	0	Y	
156	9:04	M14	Veg/clay	4	0	Y	
157	9:14	M14	Veg/clay	4	0	Y	
158	12/2 9:23	M14	Veg/clay	4	2	Y	
159	9:29	M14	Veg/clay	4	2	N	
160	9:34	M14	Veg/clay	4	2	Y	
161	11/29 2:08	MKII	UnVeg/clay	6	4	N	
162	12/2 9:41	M14	Veg/clay	4	0	N	Dug mine sized hole in sod

163	9:47	M14	Veg/clay	4	0	Y	Dug mine sized hole in sod
164	9:52	M14	Veg/clay	4	0	Y	Dug mine sized hole in sod

EXPLOSIVE SUBTEST DATA

Test #	EXPLOSIVE DESCRIPTION	DATE TIME	CONDITION OF APMINUD	DESCRIPTION OF WITNESS PLATES
1	.5 lb TNT 100 frags	12/2 10:50	No visible damage/fires okay/ used rubber standoff	1 Large hole at 15 feet No .25” holes
2	.5 lb TNT 100 frags	12/2 11:30	No visible damage/fires okay/ used alum. Standoff	1 Large hole at 13 feet No .25” holes
3	.5 lb TNT 100 frags	12/2 12:33	No visible damage/fires okay/ used rubber standoff	.25” hole at 9.5’ .25” hole at 8.75’ Note: charge was not under hammer head
4	.5 lb TNT 100 frags	12/2 1:06	No visible damage/fires okay/ used alum. Standoff	Mark at 14’
5	.5 lb TNT 100 frags	12/2 1:33	No visible damage/fires okay/ used rubber standoff	No fragments
6	.5 lb TNT 100 frags	12/3 8:20	No visible damage/fires okay/ used rubber standoff	No fragments

7	.5 lb TNT 100 frags	12/3 8:51	No visible damage/fires okay/ used alum. Standoff	1 Large hole at 15.5’ No .25” holes
8	.5 lb TNT 100 frags	12/3 9:10	No visible damage.fires okay/ used rubber standoff	No fragments
9	.5 lb TNT 100 frags	12/3 9:27	No visible damage/fires okay/ used alum. Standoff	1 Large hole at 10.5’ 1 Large hole at 12.5’
10	.5 lb TNT 100 frags	12/3 10:10	No visible damage/fires okay/ used rubber standoff	No fragments
11	.5 lb TNT 100 frags	12/3 10:30	No visible damage/fires okay/ used rubber standoff	No fragments
12	.5 lb TNT 100 frags No APMINUD	12/6 12:45	.25” holes at PLATE 1 / PLATE 2 / PLATE 3 13’ 3” / NONE / 15’10” 9’ 4” / / 10’10” 6’ 8” / / 8’ 5” 6’ 4” / / 7’ 6” 5’11” / / 5’10” 5’11” / / 3’ 3’ 5” / / 2’ 3” 3’ 4” / / 1’ 9” 3’ 1” / / 1’ 1” 1’11” / / 9”	

			1' 9" 1' 3" 1' 2" 1' 2" 11" 11" 9" 9" 8" 6" 6"	
13	30 grams TNT	12/6 9:50	No visible damage. Rubber standoff split.	NA
14	30 grams TNT		No visible damage Aluminum standoff intact	NA
15	1 lbs. TNT	12:15	Jammed plunger, but once freed found no damage	NA