PROJECT MANAGER – MINES, COUNTERMINE AND DEMOLITIONS [COUNTERMINE DIVISION] FORT BELVOIR, VIRGINIA

PROCEDURES FOR MATCHING THE ELECTROMAGNETIC RESPONSE OF SIMULANT MINE – INSERT COMBINATIONS TO THE RESPONSE OF SPECIFIC LAND MINES WHEN USING "SMALL METAL" TYPES OF MINE DETECTORS

NOTICE

- **These procedures apply only to the matching of SIMs and Mines by the determination of the detection distance of the small metal parts (in the fuzes of Land Mines and in the SIM Inserts) by "small metal" types of mine detectors.**
- **The procedures, which were initially formulated to support specific tests at Fort A. P. Hill, VA, have been revised to present a more generic test procedure.**
- **Any hand-held mine detector which has been designed to detect small metals [commercial or military] can be used with these procedures.**
- **Technical information on the SIMs and their inserts is available on the internet[1] at www.denix.osd.mil then go to Public Menu and UXOCOE, then go to mine target signatures. As an alternate try to go directly to the following e-mail address: http://www.denix.osd.mil/denix/Public/News/UXOCOE/Documents/Simfr/simfr.html If this does not work try: www.uxocoe.brtrc.com/Library/TecReports.htm**

APRIL 24, 2000

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PROCEDURES FOR MATCHING THE ELECTROMAGNETIC RESPONSE OF SIMULANT MINE – INSERT COMBINATIONS TO THE RESPONSE OF SPECIFIC LAND MINES

1.0 BACKGROUND AND INTRODUCTION

1.1 Background. Sets of Simulant Mines (SIMs) have been produced for the purpose of the safe and effective simulation of the response of land mines to three major techniques of land mine detection. These three techniques are mine detection based upon the electromagnetic response of the small metal parts within most land mine fuzes, mine detection using ground penetrating radar (GPR) and mine detection using thermal infrared sensors.

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- **These procedures apply only to the matching of SIMs and Mines by the determination of the detection distance of the small metal parts (in the fuzes of Land Mines and in the SIM Inserts) by "small metal" types of mine detectors.**
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2.0 OBJECTIVES AND SCOPE

2.1 Objective No 1. The first objective is to match the response, in air, of actual land mines in terms of the SIM-Insert combinations on the basis of the small metal parts contained within each. This requires the determination of the specific size SIM [of the six sizes available] fitted with the specific insert [of the six metal contents available] which most accurately matches or replicates the response of an actual land mine in air. This response is based upon the amount, type and configuration of the small metal parts within the mine and within the SIM inserts. Once a match between a mine and SIM/Insert is determined, it is expected that the close similarity of detection distances between the two will remain. If the organization performing the tests has several makes and models of mine detectors, then the actual detection distance can be expected to vary considerably between various makes and models.

2.2 Objective No 2. A second objective is to match the response of the land mines and SIM-Insert combinations in local soil to determine the degree (if any) to which the soil cover over the mine or SIM changes the detection distances compared to those in air or changes the relationship between the mine and the SIM/Insert combination.

3.0 SCOPE

3.1 Capability. The procedures apply to a wide variety and number of land mines which have low metal content and are generally in a similar configuration to that of the SIMs, when tested in air, is normal soil and in adverse magnetic and conductive soil.

3.2 Limitations. The procedures do not apply to land mines with metal cases (Very High Metal Content) or to land mines with no metal content (Zero Metal Content). These specific procedures do not apply to mine detectors operating on detection principles other than those based upon detection of small metal content (Ground Penetrating Radar, Thermal Infrared, Trace Gas or Vapor Detectors, X-Ray, Gamma Ray, etc.).

4.0 MATERIAL, EQUIPMENT AND RESOURCES.

4.1 Material. These procedures will require, as a minimum, the following materials.

- One set of Simulant Mines with six bodies [the larger 30, 25 and 20 cm diameter size simulate antitank (AT) mines, and the smaller 12, 9 and 6 cm diameter size simulate antipersonnel (AP) mines.]
- Set of Inserts for the Simulant Mines [Part of the set of SIMs]. Each of the AT SIMs will accommodate any one of the six available inserts. The six include one A Insert [no metal] plus one each G, I, K, M and O Inserts [which contain progressively increased amounts of small metal parts]. Likewise, each AP SIM includes one A Insert [no metal] plus one each C, E, G, I and K Insert [which contain small metal parts]. Only one insert can be used at a time in the SIM.
- Two ordinary carbon steel balls [not stainless steel], used to periodically calibrate the mine detectors and assure their short and long term operating condition. The balls weigh 2.032 grams [5/16 inches diameter] and 67.19 grams [1 inch diameter].
- A small plastic pin to serve as a simple reference point to mark the ground surface, for measurements of mine burial depth and mine detector search head height.
- Small containers to take soil samples, at intervals, for analysis of moisture content and soil type.

4.2 Equipment. The following is required as a minimum:

4.2.1 Mine Detectors. Tests can be performed with any mine detector [military, commercial or prototype] which is designed to interrogate and detect the small amounts of metal within most of the fuzes of the so called nonmetallic land mines. The investigators should record the make, model number and serial number of the mine detector [or detectors] being used. In addition, information on the operating principle [pulse induction, continuous wave, etc], the output frequency, expected sensitivity and other performance data should be recorded as a one time documentation of each detector.

4.2.2 Support Equipment

- Heavy duty photographic tripod such as the Bogen 3246 with a crank operated center post to raise and lower the head. A Pan and Tilt head 3039 with one Quick Change Plates for each mine detector. [or equivalent]. The tripod should have a built in bubble level on the frame. A typical tripod, with the mine detector attached is shown in figure 4.2.2-1, together with the sand bag used as a counterweight.

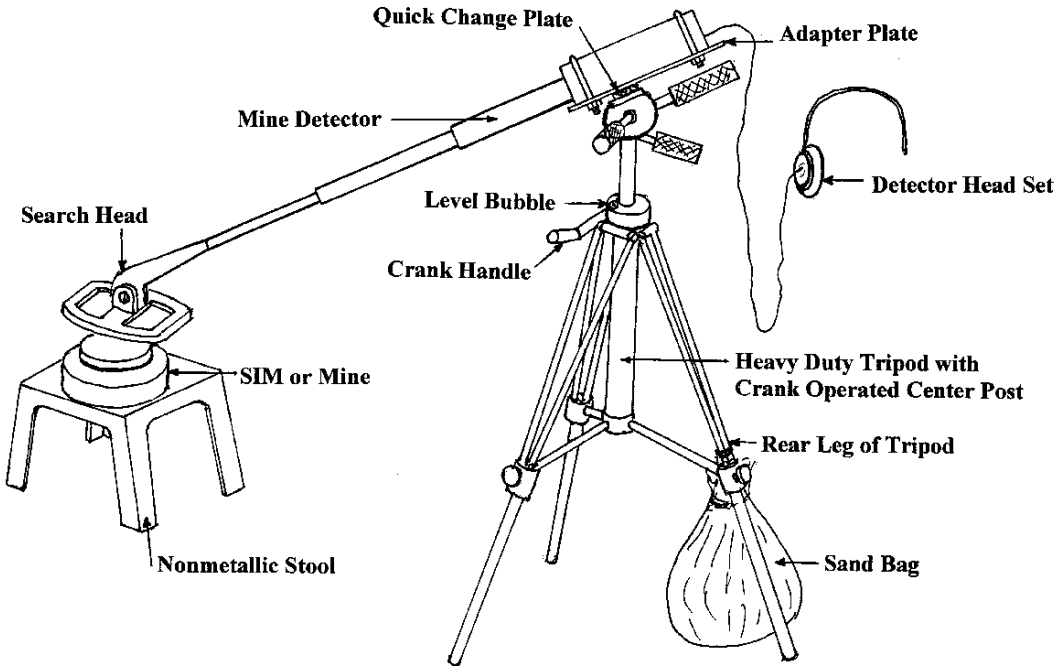

Figure 4.2.2-1 Typical Setup with Heavy Duty Tripod and Mine Detector.

- Nonmetallic stool or fixture to support the SIMs and land mines at a distance of 46 cm [18 inches] above the ground during the "in air" tests.
- Probes and clamps to measure the depth of burial of SIMs or actual land mines.
- A centimeter scale reading to at least 40 cm to measure detection distances in air.
- Shovels, picks, rakes and other related tools to dig holes and emplace the SIMs or land mines in the soil and smooth and compact the soil surface.

4.2.2 Other Resources.

- Test targets consisting of various land mines which have been rendered safe, yet have the original or accurate replica small metal parts within them. [Original parts in their original configuration are preferred]
- If and when tests involving land mines with complete fuzing trains and explosive are planned, the conduct of such tests will require a separate Set of Explosives Safety Procedures or must conform to the Explosives Safety Program and Test Procedures of the Test Site.

- A test area which is free of stray electromagnetic radiation and noise in the frequency band of the mine detectors [approximately 100 Hz to 50 Kilohertz].

5.0 DOCUMENTATION OF THE TARGETS.

5.1 Documentation of the SIMs. The characteristics of the sets of SIMs has already been extensively documented and is found on the world wide web at www.denix.osd.mil and under public menu and uxocoe and mine target signatures. The detection distances listed for each insert are the average detection distances for five specific mine detectors. These distances are to be used as a guide or starting point. Other mine detectors may achieve detection distances which are somewhat above or below those listed at the web site

5.2 Documentation of the Land Mines. The external characteristics of land mines, on a world wide basis, have been extensively documented in the DOD sponsored CD-ROM discs known as Mine Facts[2] and other CD-ROM covering Explosive Ordnance Disposal. However, these CD-ROM have limited information on the specific internal characteristics and the exact metal content and its configuration. Each land mine to be used should be identified to include the following:

- Country of origin or manufacture.
- Make and Model
- Type AT or AP
- Statement that the metal content is the same as a fully operational live mine of the same type. [or]
- Statement of the specific modifications and differences between the mine and a fully operational line mine of the same type [make and model].
- In accordance with ITOP 4-2-521[3] an audit of the small metal parts within each of the land mines will be conducted, after the tests are completed, to determine the material type, shape, weight and configuration with respect to the other parts.

6.0 MATCHING SIMs, INSERTS AND MINES IN AIR.

6.1 Test Overview. The calibration carbon steel balls, which assure that the detectors are performing properly, should be used each time a test starts with one of the five detectors. The time and distances should be recorded. This will be known as the “ball calibrating test”. The test is conducted generally as shown in Table 6.1-1

Table 6.1-1 Test Overview

Brief Description of Activity	Reference Par #
PRE TEST Actions Test the area for stray electromagnetic signals.	
1. Perform a check for stray electromagnetic signals or noise	6.2.1
2. Conduct a ball calibrating test.	6.2.2
3. An actual land mine is first item tested. It is tested in air to obtain the average detection distance of any detectors being used for test purposes.	6.2.4

4. The SIM body to be used is the nearest to the diameter (or area) of the actual land mine.	7.0
5. The Inserts must be first calibrated with the specific mine detector to be used in the tests.	6.5
6. The SIM insert to be used is the one nearest the average detection distance [determined above] plus the internal distance within the SIM. See Table 7.0-1.	7.0
7. The SIM and the selected insert are tested in air.	8.0
8. Ball calibrating tests are conducted prior to each test with a mine or a SIM or with another mine detector.	6.6.2

6.2 Sequence of Events in Testing in Air. The following is a general sequence of events and activities during the testing of mines and SIMs:

6.2.1 Tests for Stray EM Signals. The specific test site should not have stray electromagnetic radiation and noise in the frequency band of interest to the mine detectors [approximately 100 Hz to 50 Kilohertz]. The stray signals can be continuously monitored with a spectrum analyzer and a suitable low frequency antenna, However, the stray signals can also be monitored, from time to time, by setting the detectors to their maximum sensitivity and holding them high in the air to determine the presence of stray signals in the air. This may need to be done only one time, prior to the start of testing and recorded in the test log. If it is suspected that the detectors are being alarmed by unknown stimuli, the test should be performed more often.

6.2.2 The Ball Calibrating Test. At various times during this set of procedures the following directions are given: "First, give a detector the "ball calibrating test" to verify its operation and performance against the two standard carbon steel balls [2.032 grams (5/16") and 67.19 grams weight (1")]. Other carbon steel balls could be used as references. [Do not use stainless steel balls] Record the ball diameter if other than 5/16 and 1 inch. This test is vital to demonstrate that the mine detector is still working at the same level of sensitivity.

In the event that you can not obtain these carbon steel balls, use a pair of carbon steel balls of other size [one large and one small] and record their diameters. Do not use stainless steel balls.

[Normally, if all is going well, any given mine detector will, day after day or month after month, consistently produce about the same detection distance in air for the small ball and for the large ball. There are several factors which influence the performance of these detectors. These factors include temperature, moisture or debris of the search head, the presence of any ambient electromagnetic fields and the gain setting to be used. If unusual detection distances are encountered [generally lower values than expected] repeat the test and if necessary check the gain setting of the mine detector. Next repeat the calibration ball test. Low batteries generally should not result in higher readings. In the event that the problem persists, check the physical condition of the search head for dirt, excess heat or moisture. Check or change batteries. If these corrective actions do not remedy the situation, read the other material in the instruction manual for the specific detector. If the above fails, send the detector back for diagnostic examination.]

6.2.3 Index of Performance. The response of the targets [land mines or SIMs] to the mine detectors is expressed in terms of the detection distance, which is the distance, in cm, from the bottom of the search head [parallel to the ground] to the top of the land mine or the SIM at the first indication of detection of a mine or a SIM. For buried mines it is the distance, in cm, from the bottom of the search head to the plastic marker pin or disk [on the ground surface] plus the measured depth of burial of the mine or the SIM [below the ground surface].

6.4 Mines in Air.

- First give the detector a "ball calibrating test" to verify its operation and performance against the two standard carbon steel balls [2.032 grams (5/16") and 67.19 grams weight (1")].
- Place the land mine on a plastic stool or non metallic fixture so that it's bottom is at least 46 cm [18 inches] above the ground surface. See figure 6.4-1.

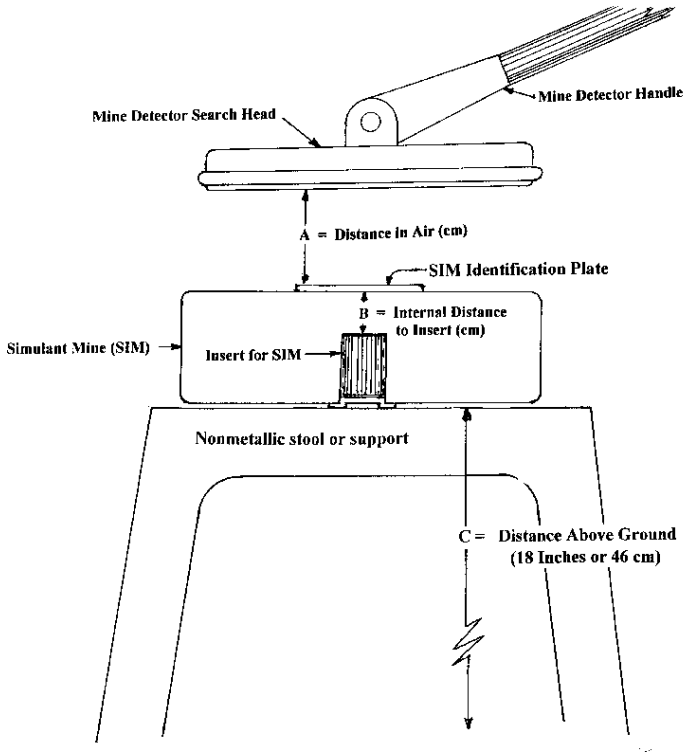

Figure 6.4-1 Tests of SIMs and Mines in Air

- Attach the mine detector to the heavy duty tripod by means of an adapter [See Appendix 1].
- Swing the mine detector over the center of the mine, so that the head moves at a speed of about 0.5 meters per second [1.5 feet per second.]
- Test the land mine, in air, to determine the detection distance, in cm, [from the top of the mine to the bottom of the search head]. The use of the tripod method results in consistent and accurate results (see Appendix 1)
- Repeat the test in air with any other the mine detectors, after giving each the ball calibrating test.
- Establish the detection distance for each mine and each mine detector.

6.5 Calibration of the Inserts of the SIMs. Repeat the above test, substituting an insert for the land mine.

- The inserts must be placed upside down on the 18 inch high non metallic stand. This is the correct orientation when the insert is placed inside of the SIM. The part of the insert, which contains the identifying letter, must be on the bottom.
- The use of the tripod method results in consistent and accurate results (see Appendix 1)
- Plot the detection distance of each insert, for the mine detector being used.

[Note: A calibration curve for the Inserts is given in the Final Report of the Development of the Simulant Mines on the Internet. This curve shows the detection distance, for the seven inserts, varying from a low of 3.5 cm to a high of 19.5 cm. This curve is an average detection distance of the five mine detectors used in the previous tests. The curve may be similar to the one you generate, but still not apply to the mine detector which you have available for testing. In fact, it is not an exact curve for any one of the five mine detectors previously used.]

7.0 SELECTION OF THE CORRECT INSERT

The Insert have previously been calibrated for detection distance against each mine detector planned for the tests. In addition the detection distance from the top of the land mine to the bottom of the detector search head has been determined.

- The correct SIM body must first be selected based upon its diameter compared to the diameter [or area] of body of the land mine.
- The inserts contain one or more small metal parts which simulate the average or composite response [or detection distance] of all five mine detectors.
- The correct Insert is then selected by adding the average detection distance in air of the mine, determined above, to the internal SIM-Insert distance [from the top of the SIM to the insert within the SIM]. For a 30 cm diameter SIM this internal distance is 4.0 cm, for a 25 cm SIM it is 2.3 cm, for a 20 cm SIM it is 0.7 cm, for a 12 cm SIM it is 1.0 cm and for the 9 cm or 6 cm SIMs it is 0.3 cm. [See Table 6.0-1 of VSE Drawing 14126 or in Table 7.0-1 below]
- For example: if the detection distance in air for a large land mine is 14.0 cm and the large 30 cm diameter SIM is used; the 4.0 cm internal distance would be added to the 14 cm detection distance giving a value of total insert detection distance of 18 cm. Thus, the M_o insert [at 18.4 cm] would be selected as the nearest insert.
- Likewise, if the detection distance in air for a small land mine is 7.0 cm and a 6 cm diameter SIM is selected, the distances of 7.0 and 0.3 would be added, giving a value of 7.3 cm for the total insert detection distance. The E_o insert [at 7.6 cm] would be selected as the nearest insert.
- Use the insert which has a detection distance which is nearest to the total distance.
- If the sum of the detection distance and the SIM internal distance is a midway between two inserts, select the lower insert, which is harder to find.

- The following table shows the average detection distance to the top of the SIM when the internal distances [which vary from 0.3 cm to 4.0 cm] are subtracted from the "in air" detection distance of the insert .

Table 7.0-1 Detection Distances to the Top of the SIMs for Various Inserts
[Base upon data from tests with the previous five mine detectors]

		Distance to SIM Top in cm WITH SMALL "AP" SIM			Distance to SIM Top in cm WITH LARGE "AT" SIM		
	SIM Diam ⇒	6 cm	9 cm	12 cm	20 cm	25 cm	30 cm
	Internal Dist *. ⇒	0.3 cm	0.3 cm	1.0 cm	0.7 cm	2.3 cm	4.0 cm
Inserts	Detection Distance In Air in cm ⇓						
C_o	3.5	3.2	3.2	2.5	-	-	-
E_o	7.5	7.2	7.2	6.5	-	-	-
G_o	10.1	9.8	9.8	9.1	9.4	7.8	6.1
I_o	13.3	13.0	13.0	12.3	12.6	11.0	9.3
K_o	16.0	15.7	15.7	15.0	15.3	13.7	12.0
M_o	18.4	-	-	-	17.7	16.1	14.4
O_o	19.5	-	-	-	18.8	17.2	15.5

* Internal Distance is distance in cm from top surface of SIM to the insert.

It is not likely that your calibration of the inserts will result in the same values as those listed on the denix web site and listed above in Table 7.0-1 For example, if the readings were significantly larger, the same procedure applies. Table 7.0-2 , below, shows a method to obtain the required data and select the correct insert to obtain the correct overall distance from the top of the mine to the bottom on the mine detector search head. In this example the detection distances vary from 6.5 cm to 30.4 cm

Table 7.0-2 Example with a Mine Detector Having Greater Detection Distances

		Distance to SIM Top in cm WITH SMALL "AP" SIM			Distance to SIM Top in cm WITH LARGE "AT" SIM		
	SIM Diam ⇒	6 cm	9 cm	12 cm	20 cm	25 cm	30 cm
	Internal Dist *. ⇒	0.3 cm	0.3 cm	1.0 cm	0.7 cm	2.3 cm	4.0 cm
Inserts	Detection Distance In Air in cm ⇓						
C_o	6.5	6.2	6.2	5.5			
E_o	10.3	10.0	10.0	9.3			
G_o	14.6	14.3	14.3	13.6	13.9	12.3	10.6
I_o	18.5	18.2	18.2	17.5	17.8	16.2	14.5
K_o	22.6	22.3	22.3	21,6	21.9	20.3	18.6

M_o	26.0				25.3	23.7	22.0
O_o	30.4				29.7	28.1	26.4

* Internal Distance is distance in cm from top surface of SIM to the insert.

8.0 SIMs IN AIR.

- First give a detector the "ball calibration test" to verify its operation and performance against the two standard carbon steel balls [2.032 grams (5/16") and 67.19 grams weight (1")].
- Place the selected SIM/Insert combination on a plastic stool or non metallic fixture (top surface facing upward) so that it is 46 cm [18 inches] off of the ground surface.
- Place the mine detector on the heavy duty tripod using the adapter.
- Swing the mine detector so that the head moves at a speed of about 0.5 meters per second [1.5 feet per second.]
- Test the SIM/Insert, in air, to determine the detection distance [from the top of the SIM to the bottom of the search head].
- Repeat the test with any other the mine detectors, after giving each the ball calibrating test.
- In the event that the insert selected for test does not provide a similar detection distance as that of the land mine, select the next nearest higher or lower insert as appropriate and repeat the test.

9.0 SEQUENCE OF TESTS IN A SOIL PIT. [OPTIONAL]

If time and resources are limited, it is recommended that only the mine or SIM with medium soil compaction be used during the test series.

- First test each detector to verify its operation and performance against the two standard steel balls [2.032 grams and 67.19 grams weight].
- Bury the land mine with the desired amount of earth cover, initially with 10 cm of cover for AT mines and with 5 cm of cover for AP mines. The relationship between the distance in air, the distance is soil and the internal distance within the SIM is shown in figure 9.0-1. The depth of the earth cover is measured by use of the slender steel probe and the 5 or 10 cm marking clamp, from the top of the mine to the surface of plastic pin or the thin plastic disk placed on the surface of the earth. This probe is illustrated in figure 9.0-2.

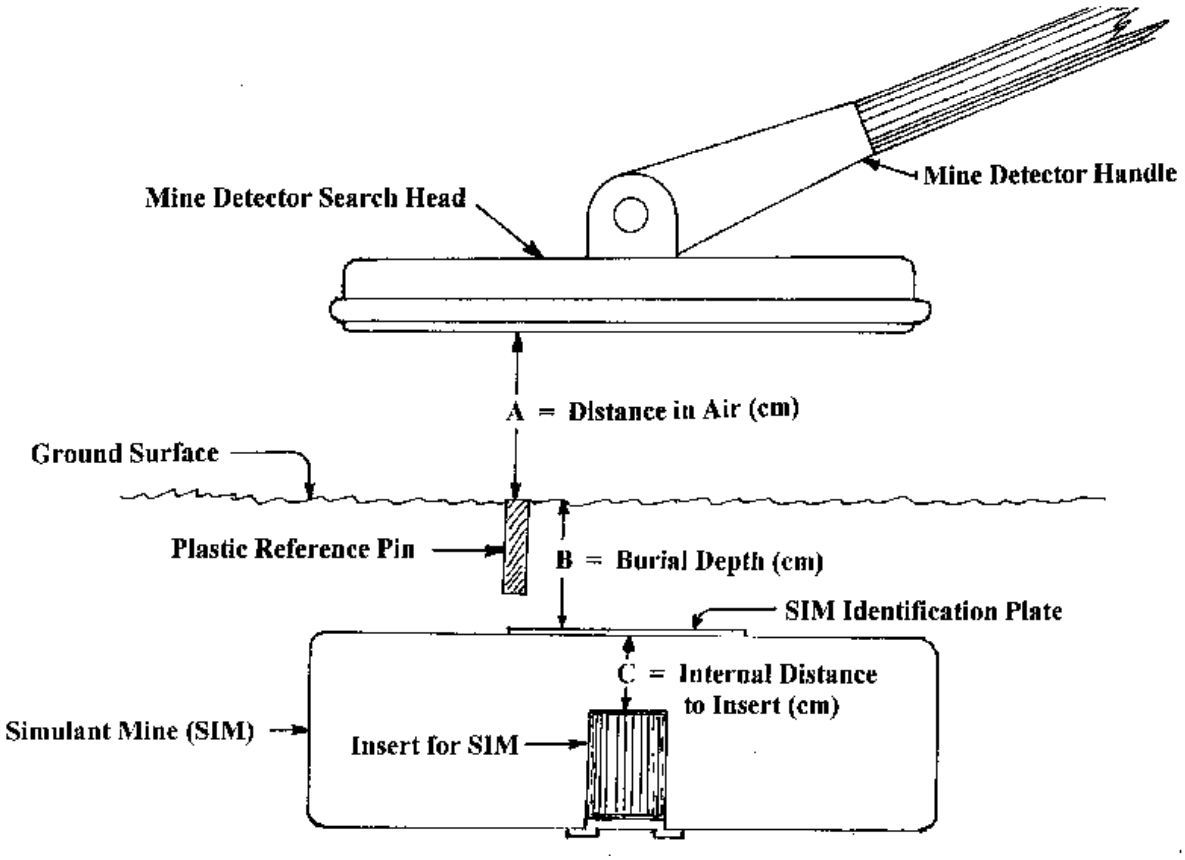

Figure 9.0-1 Relationship Between Distances in Air, Ground and Within the SIM.

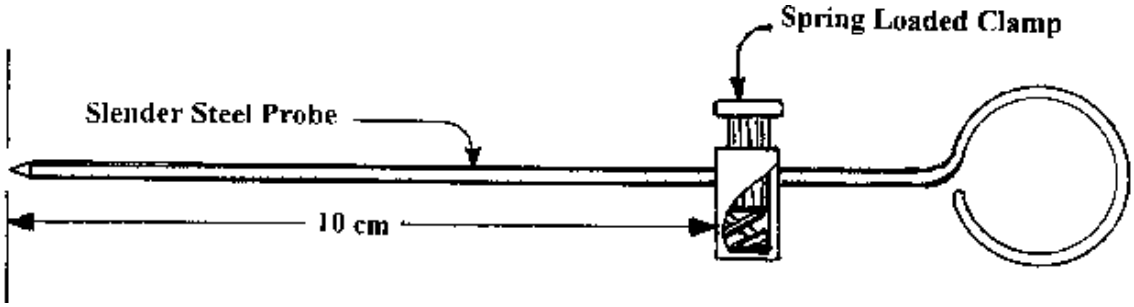

Figure 9.0-2 Slender Steel Probe and Clamp to Measure Depth of Burial

- Position the heavy duty tripod and sand bag or weight stabilization adjacent to the mine burial position. The legs are to be such that the rear leg, with the weight, is to be away from the mine position. [This increases stability and also increases the distance from the search head to the forward legs.]

- Test of the buried mine with medium compaction soil over it using a 0.5 meters per second sweep rate. The soil has been pushed over the mine with the edge of a shovel and tamped slightly. The test consists of three detection distance determinations with all mine detectors being used in the tests. [The quick change plates of the tripod facilitate easy change of detectors.]
- In the event that a detector does not detect the mine [or SIM] at 10 cm and a little soil is removed to a lesser distance [i.e., 8 or 9 cm] make a note of the removal of the soil. Record this on the data sheet**.**
- If the tests in air and the tests in soil indicate that the land mine or SIM can not be detected at a distance near 10 cm for the AT mines or near 5 cm for the AP mines, then an alternate set of distances will be used, namely 5 cm for the AT and 1 cm for the AP. Record these changes.
- Test all mine detectors over the mine target.

10.0 MINE DETECTOR CARE.

- Those mine detectors, which are not in active use, should be kept out of the direct rays of the sun. Intense sunlight could cause high internal temperatures and lead to variations in performance of some detectors.
- Search heads should be kept clean, dry and free of any foreign material.
- Batteries should checked once a day with an external battery checker.

11.DATA SHEETS

The format for the data sheet is shown in Appendix 2.

12.0 REFERENCES.

1. The Web site at denix is at the Office of the Undersecretary of Defense. It changes from time to time, but the information on Simulant Mines can be located under UXOCOE and mine target signatures.
2. The CD-ROM on Mine Facts is a Joint DOD and State Department venture. The technical Point Of Contact is Tom Reeder at the National Ground Intelligence Center, 220 7th Street, Charlottesville, VA 22902 FAX 804-980-7699
3 International Test Operating Procedure (ITOP) Final Draft ITOP 4-2-521-Target Standardization for Countermine and Humanitarian Demining Testing- Revision 3.9 Dec 1998. Four Nation Test Working Group [US, UK, Germany and France]

13.0 POINTS OF CONTACT

The following are the points of contact regarding this set of procedures.

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Appendix 1

The Heavy Duty Camera Tripod.

A heavy duty camera tripod is used in the tests to increase accuracy and stability. It had been shown in prior tests that attempting to measure detection distances, when the operator was still holding the detector by hand, resulted in excess errors. A heavy duty Bogen Tripod, with a elevating center post fitted with a hand crank, is used to accurately raise and lower the head. The tripod is also fitted with quick change replacement plates. [Normally used to rapidly change cameras] A mine detector, attached to one of the quick replacement plates, can be changed in less than one minute. The tripod is set up so that it's rear leg is away from the target and can be further stabilized with a sand bag or other weight. The level bubble, of the tripod, is adjusted so that the tripod head is level. The mine detector is attached to the plate and then to the tripod. The telescoping arm of the mine detector is extended as required and it's search head is turned until it is parallel to the ground. [See Figure 4.2.2-1 Typical Setup with Heavy Duty Tripod and Mine Detector – Page 3] The tripod's Pan and Tilt head is adjusted so that the mine detector search head is directly above the target. The Pan and Tilt head also allows the head of the mine detector to sweep the target with an accurate vertical position above the soil, without tilting the head. The mine detector is elevated by use of the center post crank. It is then lowered, while sweeping the target, until an indication of detection is noted by the audio output. At this time the cranking is raised, lowered and stopped when the detection sound is heard a second time. Then the distance between the bottom of the search head and the top of the mine, the SIM or the soil surface marking pin can be measured. Another make or model of a rugged heavy duty tripod with a crank elevating center post could have been used.

Appendix B
SAMPLE DATA SHEET

Test #		Date		Weather		Temperature	
Target Designation: Mine Type				or SIM Diameter		cm and Insert Letter	
Detector Operator				Data Recorder			
Test conducted in Air				in Soil			
Test Location and Conditions							
Mine Detector, Type, Make & Model							
		Detection Distance in cm					
Target	Time	Ball – Test Calibration	Test # 1	Test # 2	Test # 3	Average	Comments

Notes
Describe Targets [Mines or SIM –Insert Combinations] on an attached sheet if required.
If possible identify and record the type , configuration and amount of metal parts in the land mine.
Show temperature in comments column for various times [4 times a day]
One data point is the average detection distance for three individual tests.
For tests in soil, describe soil type, moisture content and depth of burial of targets