Issues in Performance Evaluation of Metal Detectors

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Abstract

Other than a mechanical prodder, a handheld metal detector is often the only available tool to detect minimum-metal landmines at the present time. Until some other technology that does not rely on metal detection becomes as routine and reliable, the situation will not change. In spite of this, the metal detector is often taken for granted and the consideration given to its performance evaluation and selection is not thorough. Matters are made worse by the commercial availability of a bewildering number of models (most of which were not developed for the specific purpose of mine detection) with various claims of performance. On the other hand, the current landmine problem demands that detectors be able to reliably detect extremely small quantities of metal under various soil and other environmental conditions. This makes proper evaluation and selection of a metal detector all the more important.

We discuss a number of issues, with emphasis on the technical ones, that should be considered in comparing performance of various detectors. These include factors such as the effects of moisture, mineralised soil, electronic drift, operator training, among others, on detector performance. The discussion is illustrated by two recent examples of detector evaluation and selection conducted by the authors - one for the Cambodian Mine Action Centre (CMAC) and the other for United Nations Mine Action Centre (UNMAC) in Bosnia-Herzegovina.

Although the paper will deal mainly with the performance evaluation and selection of handheld metal detectors in the context of landmine detection, much of the discussion will also be relevant to the role of these systems in UXO detection. As well, some of the points raised may benefit the design, conduct, and understanding the results of tests aimed at comparative evaluation of other detector systems such as various forms of vehicle-mounted sensors.

1 Introduction

An excellent account of the development and role of the metal detector for landmine detection during World War II is given in [1, 2]. Although decades of research have since been conducted worldwide into a wide range of technologies for the detection of landmines the handheld metal detector, with the possible exception of the mechanical prodder, is still the most frequently employed tool to detect landmines. Until some other technology that does not rely on metal detection becomes as routine and reliable, the situation will not change. In spite of this, the metal detector is often taken for granted and the consideration given to its performance evaluation and selection is not always as thorough as it could be.

Recent development of metal detectors has been primarily driven by commercial interests of the private sector and as a result a large number of models with various claims of performance have become commercially available. However, to the best of our knowledge, most of these were not developed to meet any specific Statement of Requirement (SOR) for mine detection. On the other hand, the current landmine problem demands that detectors be able to reliably detect extremely small quantities of metal (e.g., that found in a M14 or 72A antipersonnel landmine buried upto 10 cm) under various soil (e.g., magnetic soil) and other environmental (e.g., wet tropical) conditions. To do this reliably and effectively is extremely difficult even for the most sophisticated of the modern detectors. This makes proper evaluation and selection of a metal detector all the more important at the present time. We do not pretend to provide the “answers” to this difficult issue, but we would only like to present what we consider to be some of the important factors that must be considered when assessing the performance of a metal detector used to detect landmines. Our views are based on our own research in metal detection technology and on our experience in testing a large number of detectors from various manufacturers worldwide. We will consider our efforts successful if our views initiate a new look and discussion on the subject of metal detectors among the various stake holders, namely, the user, the manufacturers and the scientific community.

2 Performance Factors

Many countries, including Canada, and most humanitarian demining agencies do not have a Statement of Requirements (SOR) for a mine detector, that is, there is no detailed specification that a mine detector must meet. In the absence of such an end-user document, the task of an agency tasked to conduct tests and select a detector from the many available becomes very difficult. At times detectors are chosen on the basis of ad hoc and poorly controlled “field tests”. The following is not meant as a substitute for a SOR; but having been faced with the task of evaluating detectors for organisations without specific SOR’s we have come up with a number of factors that we feel should go into the evaluation of a metal-mine detector. Some of these factors are well recognized in SOR's where such documents exist and applicable military standards are available [3], [4].

2.1 In-Air Sensitivity

While a detector's ability to detect objects in air does not indicate its ability to detect objects buried in the ground, we found that such measurements are very useful. Such measurements, when done with care in a laboratory, provide baseline data that can be used to compare certain basic performance factors of the electronics of a given detector. The following are some of the issues that must be considered in conducting the measurements, evaluating the results, and comparing results of similar tests conducted by others.

2.1.1 Target

Manufacturers' specifications often indicate the maximum distance at which their detector can detect a specified quantity of metal without mentioning any other characteristics of the piece of metal. Also, most manufacturers provide a "test piece" to check the proper functioning of their detector. Sometimes a "test piece" of one vendor is not detected well by another vender's detector. It is well kown that the distance at which a metal object can be detected by a metal detector depends on the object's size, shape, material, orientation, among other parameters. Thus the selection of a suitable set of objects or targets is very important for the purpose of comparing performances of various detectors and results of tests conducted at different times and by different agencies.

The selection of a set of targets, even for a relatively well-understood sensor like a metal detector, is not simple; this is in part because various interested parties hold diverse opinions as to what the results of a test and evaluation procedure is supposed to establish. Some would like the results of a test to indicate with absolute certainty how well a given detector will perform against all landmines. Others will argue that a certain chosen target does not represent any landmine. Although it is possible to classify the hundreds of different types of existing mines into a few generic categories [5] such as antipersonnel (AP) blast, AP fragmentation, antitank (AT) blast, and so on, it will be very difficult to obtain agreement on a small selection of landmines to represent the entire population of existing mines. The situation is made worse by the fact that live mines of the desired types may not be readily available and by the safety issues involved in using live mines. As well, information on exact metal content of various mines is not readily available making the task of reproducing the metal components in a mock-up mine difficult. In all the data bases known to the authors, information on metal content of mines is very qualitative - it is usually stated as "x grms of metal", "contains a striker and a detonator (small/large)", "contains substantial amount of metal", "can be (very/extremely) difficult to detect", and so on. In some cases detailed drawings of the mines are available, but the exact type of metal is rarely specified. The metal type, if specified at all, is usually stated as steel, aluminum, etc. - no detail of chemical composition or electrical properties are given. Such information, if desired, can only be obtained by detailed chemical analysis of a real sample or from the manufacturer if they are willing to provide this information. Then there is the question of variation from batch to batch and model to model of the same mine.

Because of the difficulties just described and due to the limited time and resources available, we narrowed the scope of our target selection. Unless a company claimed and demonstrated that their detector is optimized to detect certain arrangements of metal pieces (as may be found in some mines), we felt it unnecessary to spend the resources to try and recreate these. We reasoned that for a simple baseline comparison of metal detectors, a **variety** of **small** metal targets not unlike parts (e.g., detonators, strikers) found in some minimum metal mines should be adequate. For our purpose, it really did not matter if these pieces represented any real mine at all. With this reasoning we selected, admittedly in a somewhat ad hoc manner, 8 small pieces of metal described in Fig. 1 as our basic target set and complemented it with the Schiebel Test Pin (STP) [1] because of its prevalence in earlier tests. The target set is not claimed to be any kind of "standard" and there is a lot of room for improvement in the exact pieces selected (e.g., a spring like piece is conspicuously missing). However, in situations (e.g., Cambodia and Bosnia-Herzegovina) where it was necessary to know if a particular type of mine could be detected by a certain detector, we used the real fuses in question in addition to our targets.

When we started our work there was no general discussion of standard test targets (one notable exception is [6]), and countries and agencies used targets suitable for their immediate purpose. Currently, however, there are at least six international organizations [2] that are considering mine detector test and evaluation procedures including selection of targets.

2.1.2 Drift

One basic performance factor of any electronic instrument should be its stability. In the context of metal detectors, this factor will determine the degree to which a detector's sensitivity will vary with time. A reduction in sensitivity with time without warning to the operator could be potentially dangerous. One needs to know if a detector maintains

[1] A small test piece, resembling a striker, that comes with Schiebel AN19/2 detectors.

[2] These are: International Test and Operating Procedures(ITOPS), UK/US/GE/FR; Anglo-French Defence Research Group (AFDRG), FR/UK; NATO SGE AC/243 (CET) and RSG1 US/FR/GE/NL/IT/DK/UK/CA; European Commision Joint Research Centre (JRC), EU member countries; The Technical Co-operation Program (TTCP), AU/CA/NZ/UK/US; and Information Exchange Annex (IEA) 1506, US/UK.

its sensitivity without operator readjustment over a desired period of time. We were informed by users that a detector must maintain its sensitivity within acceptable limits over a half-hour period in order to avoid the need for frequent adjustment and to gain operator confidence.

In our tests, after an initial warm-up period, we adjusted a detector according to its manufacturer's recommended procedure and measured the maximum depth at which it could detect a selected target. We then repeated this measurement, without readjusting the detector, every 2 minutes over a period of 30 minutes. This procedure revealed significant variation in sensitivity drift among the various models, including one case where the detector was considered totally useless in spite of its excellent initial performance.

2.1.3 Moisture

In 1995, we received reports from the field that the Canadian Forces' in-service mine detector suffered partial or total loss in sensitivity under certain moisture conditions. After months of investigation and following some blind alleys, we discovered the mechanism that causes the effect. The details of our study which is described in [7] is beyond the scope of this paper. Suffice it to say that if any moisture gathered on the search head, even as little as what can be expected when working over dew-covered vegetation, the detector suffered significant loss of sensitivity - the magnitude of the loss depending on the amount of moisture on the head - without warning the operator. We later established that if the operator were aware of the moisture condition he/she could readjust the detector to restore sensitivity until moisture conditions changed again. We also found that not all detectors were susceptable to moisture to the same degree, if at all.

The above experience prompted us to include a "moisture test" in our repertoire of basic tests on metal detectors. The test consists in measuring the detection distance of a target (usually one or two targets are used) as increasing but known amounts of water are sprayed on the search head from a plant spray bottle. Change in detection depth expected from drift alone has to be acounted for in interpreting results of such a moisture test.

2.1.4 Operator

The operator has a significant effect on the distance a target is detected by a given detector. An operator can influence the performance of a detector in a number of ways.

In some detectors, an operator sets the initial detection threshold by adjusting a knob attached to a potentiometer while listening to the detector's audio output. Where this threshold is set could vary wildly among operators and even among a sequence of settings by the same operator. The situation is worse in the case of detectors where a very small shift of the knob produces a large change in detection threshold. Fortunately, in an increasing number of the detectors, the operator is no longer required to make this adjustment.

An operator listens for a change in the audio output of a detector to decide if a target is present. Such a decision will depend critically on an individual operator's aural faculty, judgement, attentiveness, experience and so on, particularly in the case of a small change.

2.1.5 Sweep Speed

The speed at which a detector head is swept over a target has an effect on the distance at which the target can be detected. Sensitivity dependence on sweep speed will vary from detector to detector.

2.1.6 Ambient Noise

Obviously, the presence of ambient radio frequency interference (RFI) and other electrical noise will affect the performance of a detector. Different detectors will be affected differently by such noise.

2.1.7 Construction

Sometimes how a detector is constructed, i.e., the relative placement of various parts and their interaction, could significantly affect its sensitivity. For example, in the case of one detector, the detection depth varied by as much as 30% depending on the tilt of the search head with respect to the shaft. This was determined to be due to the interaction of connecting cable and the search head. In another, the sensitivity was reduced if the connecting cable lay close to the metal parts on the shaft. Such factors must be recognized and accounted for if one were to compare performance.

2.1.8 Battery

The performance of a detector may degrade without warning as the battery voltage goes lower.

2.1.9 Unit to Unit Variation

There will invariably be variation in performance among various units of the same detector. The extent of this variation will depend on the quality control excercised by a particular manufacturer. Often, it is not possible to test more than one or two units of a model and one has to assume that the manufacturer will meet or exceed the performance of the sample units tested.

2.2 Effect of Soil

A detector's ability to detect targets buried in soil depends, in addition to all the factors already discussed under **In-Air Sensitivity**, on the properties of the burial medium. Since there are many different types and conditions of soil, it would be very difficult to characterize, simulate or control this parameter. Hence, one must recognize the limitations and difficulties associated with indoor or outdoor laboratory "mine lanes". On the other hand, we must also recognize that although burying targets in-situ and conducting detector trials at various theatres of operation provides valuable practical information, it is very difficult to control such trials given limited resources.

The effect of soil on metal detectors was recognized during World War II and some models were fitted with a means to reduce the "pavé effect", so called for its association with road stones containing particles of magnetic iron oxides [1, 2]. During 1945-47, the effect of different rocks and soils on the performance of the U.S. SCR-625 mine detector was studied. In the intervening time since these studies were done the question of the effect of soils on metal detectors appears to have kept a low profile in the mine detection community. In the UXO detection community the soil is usually considered to be essentially transparent to electromagnetic induction sensors - a justifiable assumption based on the large target sizes involved. In cases where the effect of soil has been considered, the focus appears to have been on electrical conductivity and static magnetic susceptibility of soil. It is now known that the predominant effect of soil on induction metal detectors arises from the frequency (or time) dependence of magnetic susceptibility found in certain soils. Soil magnetism and its effect on electromagnetic induction measurements is a subject on its own [10]-[20] and it should be consulted in determing the composition of mine test lanes. However, there are unresolved issues such as: the effect of disturbing the soil or digging it up and transporting, of moisture and temperature, small-scale (order of cms) spatial variation of soil electromagnetic properties. New research into soil electromagnetism aimed specifically at understanding metal detector performance would be of great value. We should mention in passing that soil characterization for evaluation of a ground probing radar (GPR) will be much more complex than it is for the evaluation of a metal detector. Some manufacturers [20] have taken advantage of the difference in response characteristics of magnetic soil and that of metal targets to significantly reduce the adverse effect of soil on their detectors.

2.3 False Alarms

Current metal detectors cannot discriminate between metal parts in a landmine and pieces of scrap metal that are present in almost any location on earth, particularly in areas of previous conflicts. This results in a large number of "False Alarms", determined mainly by the extent of metallic contamination of a particular location and the smallest target signal being sought, and less by the design of a particular metal detector. However, false alarms caused by anomalous soil conditions have been considered by some detector designers with a view to reducing such alarms. The issue of false alarm definition, classification and characterization is a complex one, but it should be addressed in the design, conduct and evaluation of results of any field trial of detectors. The issue is just begining to be adequately addressed particularly in connection with field evaluation of multisensor vehicle-mounted systems[21, 22]. A discussion of these issues is beyond the scope of this paper.

We should also note that because of the potentially extreme variability of soil and other conditions with time, location and weather, it is very difficult if not impossible, to obtain repeatable results from field trials.

2.4 Other Selection Criteria

In addition to the detection factors discussed above, there are other factors which should go into the selection of a mine detector depending on its intended use. Fortunately, these factors are usually well considered in SORs where they exist, or in the acquisition process. We will only briefly mention them for completeness.

2.4.1 Ergonomics

Mechanical configuration, weight and size, ease of use are important factors affecting operator acceptance. Operators seem to prefer light-weight, integrated single units over the conventional detectors with their two or three subunits. A well-designed operator questionnaire should provide valuable input on the ergonomic design of a detector.

2.4.2 Ruggedness

A detector should be evaluated against any applicable military standards. It should be pointed out that many of the detectors on the market were not designed and manufactured to meet any military standards despite the fact that they are being marketed to the military user. As well, ruggedness standards for humanitarian demining will be different from those for tactical use.

2.4.3 Operational Issues

Some of the important operational factors affecting the choice of a mine detector are:(1) Likelihood of the detector setting off mines with a magnetic influence fuze. This factor may not be as important in humanitarian demining applications. In UXO detection, proximity fuzes and other electrically initiated ordnance are of concern. (2) Ability to resolve small antipersonnel mines that may be planted around a larger antitank mine. (3) Minimum separation distance between two detectors before they start to interfere with each other as well as interference from other emitters such as handheld radios will affect the concept of employment.

2.4.4 Management Issues

Since most companies currently marketing mine detectors are relatively small, one needs to consider the ability of a chosen company to provide adequate after sales technical support. The initial and maintenance cost of a detector are important considerations particularly for humanitarian demining. As well, a detector with a planned and inexpensive upgrade path to future technological improvements is highly desirable.

3 Case Studies

We will now briefly describe our involvement in evaluating and recommending mine detectors for the Cambodian Mine Action Centre (CMAC) and for United Nations Mine Action Centre (UNMAC) in Bosnia-Herzegovina. These efforts, although severely restricted due to limited time and resources available, were extremely valuable in clarifying the issues and helping these agencies make informed decisions about metal detector specifications and procurement. On the other hand, we learned a great deal and gained valuable experience in real-life application of mine detectors.

3.1 Support to CMAC

Canadian Forces personnel attached to CMAC reported, in the summer of 1995, that their primary detector, the Schiebel AN19/2, suffered a serious degradation in sensitivity in some moisture conditions. They also reported that this detector was very ineffective in detecting mines buried in mineralised soil (lateritic) which was estimated to be present in 40% of the minefields in Cambodia. A number of competing vendors, who were aware of the situation, began to apply pressure on CMAC to use their detectors instead. This prompted the Chief Technical Advisor (CTA) at CMAC to request Defence Research Establishment Suffield (DRES) to provide assistance in the following areas:(1) Investigate the moisture problem of the Schiebel detector to identify its cause and suggest possible remedies. (2) Assist CMAC in choosing a replacement for the AN19/2 by conducting and/or by teaching them how to conduct suitable comparative tests.

The first component of this work, that is , the investigation of the moisture problem of the AN19/2 became a separate investigation on its own, the details of which are described in [7]. We were able to identify and reproduce the mechanism that caused the observed behaviour in the field and suggested some measures to reduce the problems. Briefly, the responsible mechanism was electronic and not mechanical as Schiebel had believed. Proper electrostatic shielding and A.C. coupling were recommended as possible solutions. It was also pointed out that these measures, while they will reduce the adverse effect of moisture, will do nothing for the detector's ineffectiveness in a mineralised soil environment.

As regards the second, we drew up a test plan incorporating many of the performance factors already discussed, provided a set of DRES targets, trained CMAC personnel in test procedures, and conducted tests at DRES and on-site at CMAC to recommend detectors most suitable for use in Cambodia. The following mine detectors were evaluated (the number in () brackets indicates number of units of the type):Schiebel AN19/2 Mod2 (1) and Mod7 (2); Guartel MD-8 (2); Ebinger 420PB (1), 420SI (2); Forster 2000SL (3), 2000P (1); Vallon 1620B (2); Minelab F1A1 (1), F1A2 (1), F1A4 (1), F1A4C (1); and RP-507 (1). Some preliminary tests such as **in-air sensitivity** , **sensitivity drift with time** and **effect of moisture** were conducted at DRES before traveling to Cambodia. These tests were done on all detectors expect those from Minelab and the RP-507, which were not available at DRES. We used the DRES targets and the STP in these tests. On site at CMAC, we repeated these tests on a limited number of the previously tested detectors as a check of procedures and on all the detectors not seen before. The tests at CMAC was conducted over the period 5-17 June 1996 (including travel).

On arrival at CMAC, we learned that three selection criteria were of utmost importance - operation over lateritic soil, minimum performance degradation due to moisture, and the ability to detect a 72A antipersonnel landmine buried at least 10 cm deep in lateritic soil. Because of these requirements and the limited time available, we had to restrict ourselves, in spite of a previously laid out plan, to determining which detectors, if any, could meet these demands. In addition to the basic in-air tests already mentioned we conducted detectability tests in a mound of laterite that had been transported, as well as in "natural" laterite on the periphery of a real minefield. A 72A mine was included as a primary target in all these tests. Based on our findings we concluded:(1) Reported deficiencies of AN19/2 in CMAC operations were confirmed; (2) Two detectors, namely, the Minelab F1A4 and the Forster 2000SL among those tested were found to best meet CMAC requirements; and (3) There was need for improved operator training to take full advantage of mine detectors.

3.2 Support to UNMAC

Events leading to our involvement in the mine detector trials conducted under the auspices of UNMAC were similar to those for the CMAC trial. UNMAC, the organization set up to provide supervision and advice for demining in Bosnia-Herzegovina, was aware of deficiencies associated with some metal detectors in use in that country. As usual, there was pressure on UNMAC from vendors. UNMAC decided to seek outside help in the selection of suitable detector(s). Canada and the UK responded with funded offers of assistance. As a result, trials were conducted over a 3-week period in January 1997 in Bosnia-Herzegovina, by a multinational trials team consisting of 2 technical representatives from Canada, 4 UK MOD personnel, 1 Project Officer from UNMAC, and 15 detector operators from 7 countries. Canada was responsible for conducting the laboratory trials (e.g., in-air sensitivity, drift, moisture effect), while the UK accepted the responsibility to conduct the field trials. The Project Officer from UNMAC was responsible for establishing the overall trial objectives, providing logistic support, liaison with manufacturers, demining agencies and SFOR units, assistance in the final assessment of detectors. The aim of the trials was to jointly come up with a list of detectors suitable for use in the location concerned.

Prior to the in-country trial, manufacturers were requested to submit detectors for evaluation. Two units of each detector were requested. Eleven (11) manufacturers responded and provided a total of 26 detectors representing 17 different types. These were: Guartel MD8; Garrett Hunter and Sea Hunter; Forster Minex 2FD 4.400.01 (2000SL) and Metex 4.125.04; Vallon ML 1620B; Whites AF 108 and Surf Master; Schiebel AN 19/2 (Mod 7 only) and Prototype; Ebinger 420PB, 505DS and 505 PD; Minelab F1A4; Emercom UMP-1; Sentio; Reutech. Despite pre-planned thoughts on scope of the trials, field conditions necessitated substantial changes. The following separate assessments/trials were conducted. Additional details of the work can be found in [23]

1. **Sensitivity in Air:** The maximum detection distance was determined for a number of targets including the DRES targets, a Schiebel Test Pin and live fuses from the mines PMA-2, PMA-3, TMA-1A, TMA-2, TMA-3, TMA-4 and TMA-5. (TMA-1A, TMA-2 and TMA-5 use the same fuse.)

2. **Stability in Air:** The variation in detection distance in air over a 30 minute period using DRES Target No.1 (Fig. 1) was measured. Detection distances were measured at two minute intervals after an intial warm-up of 3 minutes.

3. **Stability with Moisture:** The variation in detection distance in air using DRES Target No.1 (Fig. 1), for varying degrees of moisture level on the detector search head was measured.

4.Field Trials: Field trials were conducted using a variety of sites representing poor to good conditions for detector operations. Because of the difficulty in controlling these trials and their subsequent minor impact on final selections, we will not describe them in any detail here. These trials - one on a 15 mx1 m test strip in Sarajevo, one on a 30 mX1 m strip at Mostar airport, and one at Buna Quarry - made use of 15 operators at random, used test pieces and simulated mines (except at Buna Quarry where live fuzes were buried) buried up to a depth of 200mm. These trials, in the end, only provided an ad hoc detection rate for the different detectors. However, the most valuable lesson that these trials provided was the need for more careful control and documentation of field trials in future.

5. Field Trial for Minimum Performance: Because of the low confidence in the results of the field tests already described, one final test was conducted by UNMAC under better control to establish a minimum level of performance acceptable to UNMAC. In this test, live fuzes for mines listed under Test.1 were buried just below the surface of the ground in FFE (free from explosive) cases in minefield patterns encountered in Bosnia-Herzegovina and all detectors were passed over the area with different operators to replicate minefield conditions. The soil condition was considered to be "typical" problem soil in the area. For a detector to pass this test it had to detect all the targets.

6. Operator Questionnaire: Each operator was given a questionnaire with questions requiring subjective answers. The operators could be expected to have good experience after two weeks of using the detectors and to make comments on ease of use, operation and maintenance issues, comfort, etc. Each national group of operators completed a questionnaire collectively for each type of detector. As well, each operator was asked to rank the detectors in order of preference according to their personal opinion based their experience with them over the trial period. Although operator feedback did not have direct impact on the final selection, it was of great informational value and was relayed back to manufacturers as required.

7. Manufacturers Questionnaire: Each manufacturer was requested to fill out a questionnaire on their detector model(s) presented for trial. This questionnaire allowed the manufacturers to present in the fullest detail, data for their respective detectors that assisted the evaluation team in understanding each detector's capability.

3.2.1 Selection Strategy

None of the detectors met UNMAC's requirement of detecting all mines to 200 mm depth and there was no single detector that outperformed the rest. As already mentioned, the evaluation team could not place much confidence on the outcome of the initial field trials. However, the trial team was able to jointly come up with a selection criteria based on the tests. They set pass and fail criteria for each of the tests and decided on the relative weighting to be placed on each test.

In order to pass **Test.1 In-Air Sensitivity** a detector was required to detect an antitank fuze at 140 mm, and an antipersonnel fuze at 90 mm. To pass **Test.2 Stability in Air**, the variation in detection distance over the 30 minute period could not exceed $\pm$ 20 mm. To pass **Test.3 Stability with Moisture**, the variation in detection distance with moisture on the detection head could not exceed $\pm$ 20 mm. To pass **Test 5. Field Trial for Minimum Performance**, a detector must have detected all the targets. These tests were considered mandatory, that is, for a detector to be included in the final list of suitable detectors it must have passed all these tests.

The criteria of pass for the other field trials were set, in a rather ad hoc manner, at detection of 50% of the targets. However, these tests were given low weightings and hence did not affect the final recommendation.

3.2.2 Recommendations

No detector met the UNMAC requirement of detection for all mines to 200 mm depth. However, based on the results of the tests, the evaluation team recommended (with cautionary notes) that the following detectors were more acceptable for use in the particular theatre, in a greater variety of conditions, than the others presented for the tests: Forster Minex 2000SL, Guartel MD8, Minelab F1A4, and Vallon 1620B. These findings were in general agreement with our findings in CMAC. Both Guartel and Vallon had submitted different detector configurations than those used in CMAC.

4 Lessons Learned

The trials at CMAC and UNMAC reinforced our belief that the commonplace handheld metal-mine detector must not be taken for granted, and that its specification, evaluation and selection should be given the same importance as any other piece of Engineer equipment.

The current mine problem demands that metal detectors be able to routinely detect an extremely small quantity of metal in various soil and environmental conditions. While technology has evolved to respond to this very demanding task, to get the most out of this technology we must take a fresh look at operator training and doctrine of employment of these detectors. Increased sensitivity and electronic sophistication of the modern detectors calls for more in-depth operator training for effective use of these tools.

We found that operators generally lacked confidence in the capabilities of metal detectors in detecting mines. Manufacturers and developers must work to earn their confidence.

Finally, feedback must be provided to the manufacturers on the weaknesses and strengths of their detectors so that better products can be expected in the future.

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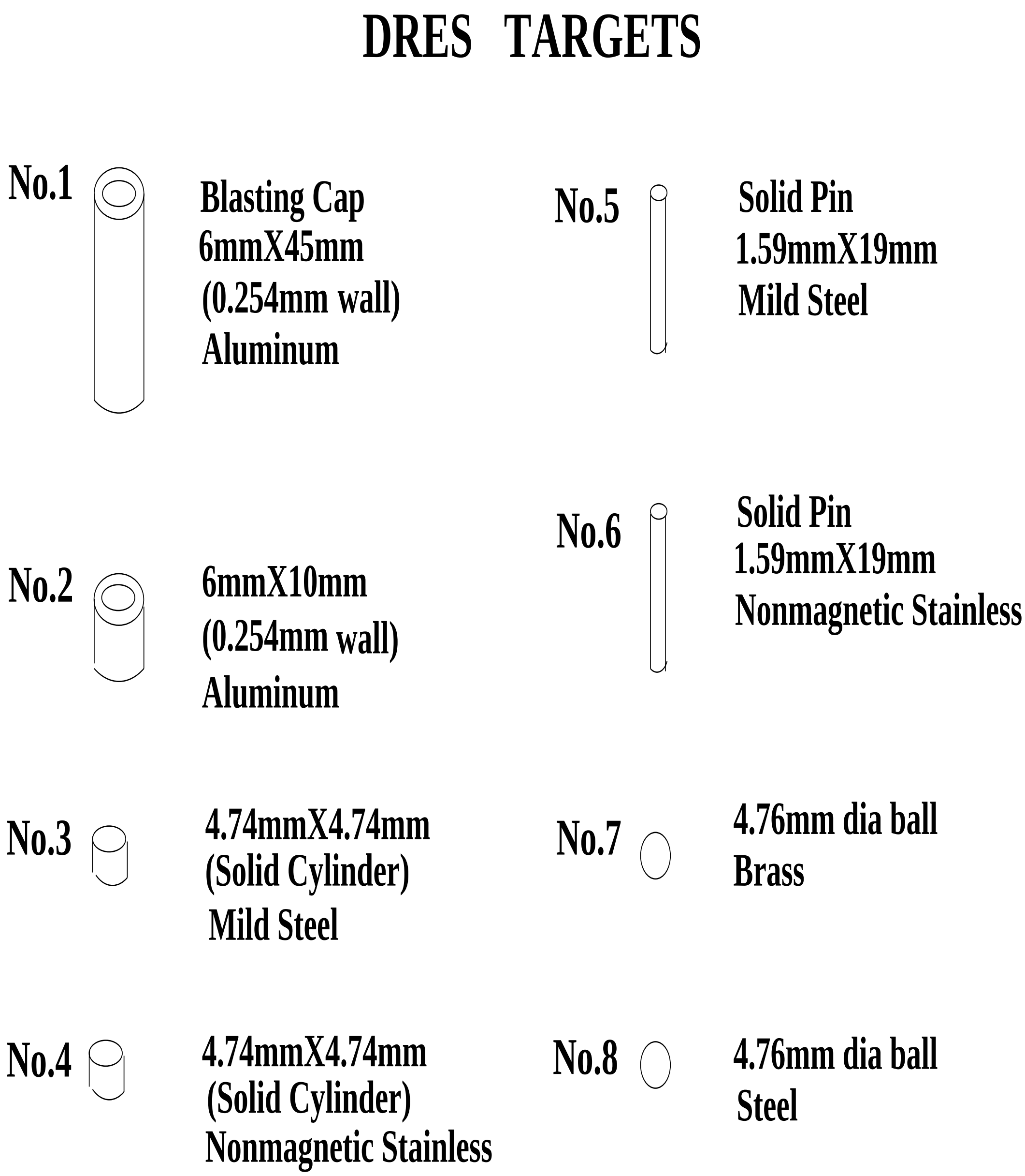

Figure 1: Sample target set.