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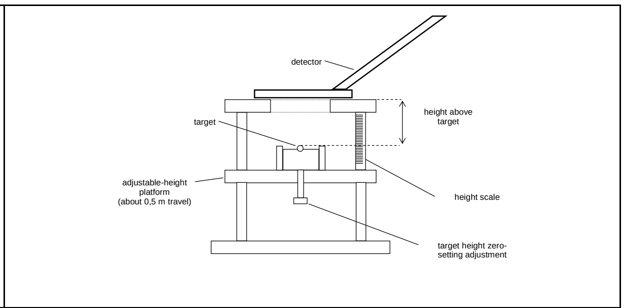
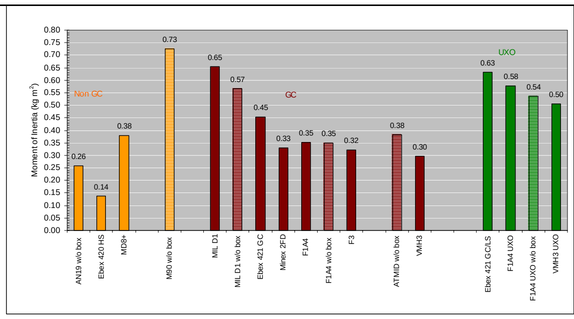
Systematic Test & Evaluation of Metal Detectors (STEMD)
Interim Report Laboratory Tests Italy





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Executive Summary

This report describes laboratory tests of the following commercial off the shelf metal detectors:

- CEIA MIL-D1 and MIL D1 DS
- Ebex 421 GC, Ebex 420 H-Solar, Ebex 421 GC/LS
- Guartel MD8+
- Foerster MINEX 2FD 4.500.01
- Minelab F3, F1A4 and F1A4 UXO
- Schiebel ATMID
- SHRIMT– Model 90
- Vallon VMH3, VMH3C UXO

The aim of the tests is to provide information to enable users to assess which detector would be best suited to their purpose, to aid manufacturers in development and to aid CEN workshop participants to frame a possible update of the standardized test protocols.

The experimental work reported here was conducted by the European Commission’s Joint Research Centre (JRC) with the assistance of staff from GICHD, BAM and Qinetiq, at the JRC’s Ispra site in northern Italy during the period November 2003 to January 2006.

Testing was conducted according to the methods of CEN Workshop Agreement 14747:2003, any minor modifications being explained and described.

Results for in-air and in soil sensitivity tests are reported, including the effects of speed, temperature, mutual interference, repeatability and drift. Tests of pinpointing and target resolution, and ergonomic and operational aspects are also reported. Very clear differences in performance may be seen between the detectors in essentially all aspects tested.

Results for sensitivity and soil compensation are broadly consistent with the results of earlier STEMD field trials in Laos and Mozambique with the following important exception. In the lab, detection capability was measured for small metal objects and results were similar when measured in-soil and in-air with the detector at the same sensitivity. This finding contrasts with the Mozambique field-trial results for real mines and simulants with full-sized mine bodies where in-soil values were often very different from in-air values at the same detector setting. Taken together, these two sets of results imply that only in-soil measurements with realistic targets with full-sized mine bodies can be trusted to give accurate indications of detection depth. Further study is recommended to confirm this finding.

No single detector performed best in all tests, so it is recommended that demining organizations assess the results according to the ERW threat that they deal with and the circumstances in which they work. e.g. for some users sensitivity may be a high priority, others may be more concerned about detector handling and ergonomics.

It is recommended that manufacturers use the results to compare their current products and prototypes with the state of the art. It is hoped that it will help them to decide priorities for research and development.

The report includes information relevant to the following specific environments and threats: low-metal mines, small UXO items, wide range of target depths, soils with uncooperative magnetic properties, high and low temperatures.

The main lesson learnt is that the methods of CWA 14747 in its current form constitute a very thorough test regime and yield a large amount of useful information but they are too lengthy and laborious to perform in their entirety.

Recommended follow-on work:
Similar testing should be repeated periodically as new metal detectors and new types of electronic mine detector, such as dual sensor ground penetrating radar/metal detectors, become available.

Experience gained should be used in an update of CWA 14747:2003 and establishment of test protocols for new types of detectors. Priority should be given to finding ways to shorten or automate the testing whilst still obtaining the critical information.

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All the work described here took place within SERAC Unit of IPSC, which is headed by Dr Alois J Sieber. The following JRC staff members assisted the authors with the measurements and the construction of the apparatus: Gareth Lewis, Philippe Viaud, Franz Muehlberger, Vitor Oliveira; grantholders Alan Gregorovic and Marco Ciano.
We acknowledge the help of partner organisations whose staff also participated and we warmly thank the individuals concerned: Steve Bowen and Dave Allsopp of Qinetiq, Al Carruthers and Mary Kelly of GICHD, Mate Gaal and Christina Mueller of BAM.
UXO detectors were loaned by CEIA SpA, Ebinger Prüf- and Ortungstechnik GmbH, Minelab Pty. Ltd. and Vallon GmbH; the GRH detector was loaned by Schiebel Elektronische Geräte GmbH; to all of these manufacturers we extend our thanks.

We also thank Al Carruthers of GICHD, Yoga Das of CCMAT and Yann Yvenic of RMA for reviewing the manuscript and making many good suggestions for improvements.

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List of Abbreviations

AIDCO	EuropeAid Co-operation Office
AP	Anti-personnnel
AT	Anti-tank
BAM	Bundesanstalt fuer Materialforschung und - pruefung
CCMAT	Canadian Centre for Mine Action Technologies
CEN	Comité Européen de Normalisation
CWA	CEN Workshop Agreement
ERW	Explosive Remnants of War
EU	European Union
EC	European Commission
GC	Ground compensation
GICHD	Geneva International Centre for Humanitarian Demining
GRH	Ground Reference Height
IPPTC	International Pilot Project for Technology Cooperation
ITEP	International Test and Evaluation Program
ITOP	International Test Operation Procedures
JRC	Joint Research Centre of the European Commission
MD	Metal detector
PVC	Polyvinyl chloride
PTFE	Polytetrafluoroethylene
SHRIMT	Shanghai Research Institute for Microwave Technology
STEMD	Systematic Test and Evaluation of Metal Detectors

Table of Contents

List of Tables

List of Figures

1. Introduction

The first objective of the STEMD project is to perform tests of metal detectors in the laboratory and in the field according to the standardized methods of CEN Workshop Agreement 14747:2003. The second objective is to provide users of metal detectors with information and training about how to apply these methods [ref. CWA].

The quality of a mine detector is determined by numerous factors: its sensitivity to different targets, its electronic stability, its immunity to disturbing and interfering factors including the soil properties, its handling, robustness, ease-of-use and battery life. Some of these factors are best tested in the laboratory, where the various physical influences on the results can be controlled; others are best measured in the field, under realistic conditions where the overall performance, including the human factor, may be assessed statistically. CEN Workshop Agreement 14747:2003 defines a comprehensive suite of tests for metal detectors in humanitarian demining, which cover all aspects of laboratory and field testing, both deterministic and statistical. Its procedures were agreed, after extensive discussion by the participants in CEN Workshop 07, on the basis of experience gained in previous tests, especially those of the IPPTC in 2000 [ref. IPPTC].

This present report describes the laboratory tests conducted within the STEMD project at the JRC's Ispra site in northern Italy. It complements the reports of the two field trials in Mozambique and Laos conducted within the same project [ref. STEMD Lao],
[ref. STEMD Moz].

2. Detectors

2.a. Rationale for Selection

The overall aim was to concentrate the trial on what we believed to be of most interest to demining organisations working in the field. The following criteria were applied in selecting the detectors:

- Current commercial models, not prototypes or old models
- Purpose-built for demining, not treasure-hunting or prospecting
- Electromagnetic induction metal detector, not radar or magnetometer
- Full-size ground-search format, not small-size for inspection of persons

Most of the detectors were from reputable marques which supply demining organisations regularly. We also included some models from manufacturers who are seeking to enter the market. Most of the manufacturers had supplied detectors to the IPPTC trial in 2000 [ref. IPPTC]. We intended STEMD to be an update of IPPTC with a new selection of detectors, so most of the models selected were ones which had either been upgraded or completely redesigned. For the purpose of providing some overlap with the previous trial we made two exceptions and included the Minelab F1A4 and, in some tests, the Schiebel AN19. The ATMID tested in STEMD is similar to that tested in IPPTC but has a new head. The MD8+ tested in STEMD is similar to the MD8 tested in IPPTC but has a new head and visual target indications by LEDs.

We added four detectors with larger formats intended for locating UXO items, of particular relevance to the clearance requirements in Laos and bordering countries.

2.b. List of detectors:

- CEIA S.p.A. – MIL-D1 and MIL D1 DS
- Ebinger GmbH – Ebex 421 GC, Ebex 420 H-Solar, Ebex 421 GC/LS
- Guartel Ltd. – MD 8+
- Inst. Dr. Foerster GmbH and Co. KG – MINEX 2FD 4.500.01
- Minelab Pty. Ltd. – F3, F1A4 and F1A4 UXO
- Schiebel Elektronische Geräte GmbH - ATMID
- Shanghai Research Institute of Microwave Technology – Model 90
- Vallon GmbH – VMH3, VMH3C with UXO head

Results for the following detectors are included for some tests, in order to make particular points of comparison.

- Adams Electronics International Ltd AX777
- Beijing Geological Instrument Factory - GTL 115-2
- Schiebel Elektronische Geräte GmbH - AN 19/2

2.c. Entry procedure

On receiving a new metal detector, the detector, case and accessories were photographed and the serial number assigned by the manufacturer was logged and cross-referenced with the number assigned for the JRC central equipment inventory. The detector was assembled, switched on and adjusted according to the instructions.
The following information was recorded:

- Content of package
- Dimensions and shape of head
- Minimum and maximum length
- Mass in transport case and in backpack, and types of case, where supplied
- Average times needed for setup
- Price paid

All this information is in Sections 10 on the ergonomic and operational aspects and Section 11, the individual detector descriptions and results.

3. Test Environment and Apparatus

3.a. Overall description of the C F Gauss Laboratory

The Carl Friedrich Gauss Laboratory is located at the JRC’s Ispra site in northern Italy. It is a purpose-built laboratory, constructed with minimal metal content, and intended for the test and evaluation of mine detectors, especially metal detectors. The laboratory building has an all-wooden main structure with non-metallic roof and windows. The laboratory has one large room with sliding exterior walls, containing a low-metal *xy* positioner over a sand pit, and a smaller room containing boxes of soil. A third room houses the necessary metal equipment: a heat-pump type heating and air-conditioning system and control system for the positioner.

The “Gauss lab” has proved to be a very good environment electromagnetically for metal detector testing. In general, the level of interference experienced is comparable with outdoor locations in the area. The sand-pit is a near-ideal neutral soil environment.

The main shortcoming of the Gauss lab is its inadequate temperature control. In both summer and winter, the lab is usually outside the temperature bounds of CWA 14747 for part of the working day. A more powerful heat pump, or additional air-conditioners and heaters, and draft proofing would be required to remedy this. Some of the bricks on the floor of the lab cause a response, albeit weak, in metal detectors and should ideally be replaced. In practice, for metal detector testing it is always possible to avoid these places. [1]

The conception and design of the Gauss lab and its scanner was carried out by John Dean, Giuseppe Nesti and Adriano Pegararo of the JRC in 1998-1999.
The heating and air-conditioning unit was added in 2001.

3.b. Scanning Machine

Fig. 3-1 View of Gauss lab main hall, showing positioner with a detector mounted

The low-metal-content *xy* positioner in the main hall has a wooden frame, shafts made from PVC tubes and PTFE sleeve bearings. Only the motors, electrical cables and some

[1] An investigation by students of Prof. Pavel Ripka from Czech Technical University in 2005 determined that the Gauss Lab is not a good neutral environment for *d.c.* magnetometry. Replacing the bricks would probably also help here.

brackets are metallic. Three-phase servomotors, one for each of the *x* and *y* axes, drive toothed belts which move two travelling frames to achieve the two-dimensional motion. The detector is held in a non-metallic clamp on the inner frame. Fibre-optic-coupled photoswitches are used to define the home position and halt the motion in the event of an overrun. An additional photoswitch can be used to trigger an oscilloscope or data acquisition board to record the detector signal.

The Gauss lab instrument is one of only two similar low-metal positioners existing in the world intended for humanitarian demining RTD, to our knowledge[2]. Its performance can be described as fair. The positioner is powerful enough to handle all types of hand-held detector, and the interference from the motors on all metal detectors is surprisingly low. Limitations are that the maximum speed obtainable is only 0.5 m/s and the area over which full speed is achieved is less than the 1m by 1m required by CWA 14747. There is significant vibration if maximum acceleration is selected.

Fig. 3-2 Pendulum used for speed and inertia measurements

3.c. Pendulum

On one wall of the Gauss Lab is fitted a bearing on which a detector can be mounted and swung as a pendulum in the vertical plane. The bearing is linked by a belt to a shaft-encoder to measure the speed of rotation. A cylindrical attachment representing a human forearm can be fitted and detectors can be mounted on the forearm at any angle . Alternatively, targets can be mounted on a rod attached to the bearing and swung past a stationary detector (Fig.3.2). In this arrangement, the speed can be adjusted by means of a moveable non-metallic weight below the pivot, and a counterweight above the pivot. Speeds greater than those obtainable using the scanner may be achieved, up to and beyond the 1 m/s specified in CWA 14747.

This simple device has proved very satisfactory and could easily be reproduced by organisations wishing to measure sweep speeds without making the larger investment necessary for a motorised scanner.

[2] The other being at the Canadian Centre for Mine Action Technologies in Suffield, now DRDC - Defence Research and Development Canada, Alberta, Canada

3.d. Soil Boxes

In the smaller room there are two 1m by 1m by 0.5m boxes filled with ferromagnetic soil (Fig.3.3)
Each box contains three acrylic tubes passing from the underside to the surface of the soil, so small targets may be inserted from underneath to a known distance from the surface, without the need to disturb the soil itself. The surface of the soil is flat and level with the top of the box, to enable detection depths in soil to be measured easily. The first box contains a grey soil from the Napoli area, which has geologically-recent volcanic activity. It has a relatively high magnetic susceptibility at all frequencies of interest. That is to say, the frequency dependence of the susceptibility is low.

Fig. 3-3 View of the soil boxes from above, with a Minelab F1A4.

The second box contains "terra rossa" soil from the Montagnola area to the west of Siena, which has a high susceptibility which falls strongly with frequency [ref. JRC soil note]. This soil is very similar to the soils of the Dalmatian coast of Croatia and Bosnia and quite similar to some "laterite" soils encountered in South East Asia and other tropical areas. The soil magnetic susceptibility properties have been measured with a Bartington MS2 soil susceptibility meter and are given in Table 1 below, together with the ground reference height (GRH) which is an empirical measure of how "noisy" or "uncooperative" a soil is. The GRH is defined as the proximity to the soil to which a calibrated detector can be brought from above, before it sounds. We have adopted the Schiebel AN19-2 Mod 7, calibrated so as to just detect its own test-piece at 50 mm, as a suitable detector for this purpose. Details of the measurement procedures for soil properties, including the GRH calibration, have been given in the Laos and Mozambique trial reports [ref. STEMD Lao], [ref. STEMD Moz] and in the JRC's Metal Detector Handbook [ref. MD Handbook].

Judged by the magnitude of the susceptibility alone, which is the main criterion used in CWA 14747, the Napoli soil is somewhat more severe than the Montagnola soil and both fall between Lanes 3 and 4 of the Mozambique soils and between Sites 1 and 2 of the Laos trial. However, judged by the frequency difference and by the GRH, which are believed to be more relevant for most detectors, the Montagnola soil is more severe than any of the other soils used in the project, except those of Test Site 3 in the Laos field trial.

Table 1 Soil magnetic properties for the laboratory test and the field trials

Soil	Magnetic Susceptibility measured with the Bartington MS2 meter (10^{-5} SI)			Low frequency suscep. minus High frequency suscep. (10^{-5} SI)	GRH (mm)	CWA 14747 classification
	MS2B (465Hz)	MS2D Loop (968Hz)	MS2B (4650Hz)	MS2B (465Hz) minus MS2B (4650Hz)	Schiebel AN19 Mod 7	
Napoli volcanic	685	555	675	10	120	Severe
Montagnola terra rossa	533	434	461.5	71.5	292	Moderate to Severe
Mozambique soils:						
Lane 1	2	2	2	0	0	Neutral
Lane 2	11	9	11	1	9	Neutral
Lane 3	130	95	124	6	83	Moderate
Lane 4	868	671	842	25	168	Severe
Lane 5	1112	890	1082	30	180	Severe
Lane 6	636	466	591	45	211	Severe
Lane 7	2885	2231	2829	57	210	Very Severe
Laos soils:						
Site 1						
Pit 1	14	22,24,23,19	14	0	20	Neutral
Pit2	29	18,17,16,16	27	2	0	Neutral
Site 2						
Pit 1	936	681,782,678,744	900	36	260, 280	Severe
Pit 2	977	679,654,668,720	918	59	250,250	Severe
Site 3						
Pit 1	1903	2238,2100, 2009,2089	1697	206	480	Severe to very severe
	1827		1638	189		
Pit 2	1767	1760,1728, 1684,1706	1647	120	350	Severe
	1654		1576	78		

With the two soils in the boxes it is possible to some degree to separate the effects of absolute susceptibility and frequency dependence of susceptibility.

The theoretical arguments for considering frequency dependence to be the more important variable may be found in [ref. Billings] and [ref. Gregorovic]. Experimental evidence showing that GRH is more closely correlated with frequency dependence than absolute susceptibility is shown in Mozambique field trial report [ref. STEMD Moz.].

3.e. Manual Jigs

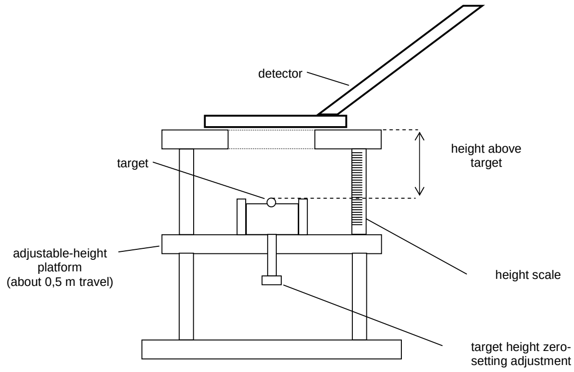


Fig. 3-4 Use of manual jig to determine detector sensitivity.

Measurement of detection capability in-air is performed using purpose-built jigs to raise and lower the target (Fig. 3.4) . The jigs are constructed out of polymer materials which have near-zero interaction with the detector so that values obtained using them are equal to those from a true in-air measurement. In a few cases we did observe small signals from the detector rubbing on the jig top-plate, possibly from microphonic effects in the detector head.

An annular top-plate provides a flat surface over which to swing the detector. It is mounted on three pillars on a base-plate. Millimetre scales are attached to the pillars. A third plate with the target mount can slide up and down the pillars and can be clamped at any intermediate height, to fix the target at a known depth below the detector. The target mount can be raised or lowered a few cm by a screw mechanism, independently of the main movement of the sliding plate, in order to fine-adjust the jig so that the top of the target is flush with the top-plate when the millimetre scales read zero.

The jigs have also proved simple but effective tools. If it were required to construct more, possible improvements would be to make the top-plate wider to provide adequate space to sweep, and to make the sliding plate much lighter so that it can be more easily raised and lowered. A more sophisticated solution would be to make a second screw mechanism to raise and lower the sliding plate.

4. Coherence of STEMD lab tests with CWA 14747

4.a. Emphasis of the lab tests

We sought to strike a balance between two priorities: to conduct as many as feasible of the CWA 14747 tests with the manpower available and to conduct thoroughly those tests which we considered to provide the most critical information needed by the user. Because of the first priority, most lab tests were performed with only one copy of the detector.

One focus was on tests concerned with the ergonomic and operational practicality of the detector. The second focus was on tests of detection capability in air and in soil, i.e. what targets can be detected at what distance.

Detection capability is used in CWA 14747 both as a basic figure of merit in its own right and also as a parameter to assess how the detector performance varies under environmental influences and according to the manner of use; so tests of this nature were included.

In cases where we were unable to comply strictly with the requirements of CWA 14747, deviations are noted and explained.

Some specific recommendations are made for possible revisions of the CWA 14747, prompted by experience gained in STEMD.

One of the basic difficulties which CWA 14747 is intended to overcome is that measurements of detection capability of metal detectors are hard to reproduce: different operators working under different conditions get different results. CWA 14747 seeks to control the various factors affecting the results in order to achieve reproducible values. We tried to comply as far as was practical with these recommendations and noted any non-compliance where unavoidable. Section 5 contains a short analysis of the estimated uncertainties in the measurements.

4.b. Structure of the report

Sections 6 to 10 of the report contain the test results and are numbered to match the chapters of CWA 14747. The subsections do not always match the CWA 14747 Test Numbers in detail and so are denoted by letters. In these Sections, results are reported test by test for all detectors, or for the mine or UXO detectors as a group. In Section 11, results of different test are reported detector by detector. Section 11 also contains tables of detector specifications and photographs.

5. Objectivity and reproducibility of detection capability measurement

5.a. Random errors

The clearest indication of the experimental uncertainty comes from the measurements on spherical targets, since their size and shape is very well controlled and the signal is not affected by target orientation. From theoretical analysis, [ref. Theory 1], [ref. Theory 2] it is known that the minimum detectable sphere diameter should always increase as a function of height, with no resonance peaks. Scatter about a smooth fitted curve may therefore be ascribed to random errors in measurement. In the data in Sections 6 and 8, it will be seen that the scatter is about ±5 mm and well within the expected precision of ±10 mm stated in CWA 14747 Section 6.3.3 .

The in-air jig has a precision of 1 mm and the diameter of the spherical targets has a precision of better than 0.1 mm, both of these factors must therefore be insignificant contributors to the random errors. Measurement of the target position in the soil box is by a ruler placed against the positioning tube, which is a somewhat less precise method but is certainly better than the observed scatter.

Other factors which can lead to uncertainty in the measurements are differences in interpretation of the signal and errors in handling of the detector e.g. tilting the head slightly or sweeping off-centre. The random error in both in-air and in-soil measurements appears to be dominated by these factors.

5.b. Systematic errors

The practice of using two operators to perform the tests as far as is possible provided a good means of avoiding systematic error due to poor handling e.g. if the operator sweeping the detector tilted the head, the second person alerted him.

Establishing an objective criterion for what constitutes detection is inherently difficult because the detectors present their signal in different ways. Some detectors indicate the presence of metal by a change in volume, some by a change in both volume and pitch etc. and the signals are perceived and judged by different operators in different ways, according to their hearing and previous experience. Some detectors also employ visual and vibrational indication. Uncertainty in interpreting the signal can therefore be a source of systematic error. It is hard to quantify how serious this is but a reasonable empirical estimate would be that it is of the same order of magnitude as the random error. As will be seen, the results show sufficiently coherent patterns that it seems unlikely that systematic differences of interpretation compromised the tests any more seriously than this.

CWA 14747 Section 6.3.2 stipulates that the detection should be confirmed five times, and this instruction was generally followed.

5.c. Feasibility of using acoustic power as a criterion for detection

CEN Workshop 7 chose to leave the decision of whether detection had occurred as a human judgement. One possibility for defining a more objective detection criterion would be to use the measured acoustic output. At present, measurement of the acoustic power is not required by CWA 14747 but some measurements were conducted within the context of Test 10.2 paragraph 10 (detector audibility). Results are reported in Section 10 Evaluation of Ergonomic and Operational Aspects.

Based on this experience, defining a criterion for detection in terms of acoustic power is feasible and could be considered in a revision of CWA 14747. A reasonable threshold would fall somewhere between 5 and 10dB above ambient. The test specification should place some limit on the acceptable ambient noise level in which the test can be conducted, which should not be much greater than 40dBA. The appropriate bandwidth for the measurement would be that for normal human hearing. It would be necessary to specify where the microphone should be placed, for internal loudspeakers and for headphones.

Whatever criterion for detection is adopted in the test protocols it should not be such as to encourage manufacturers to adopt a particular style of alarm. Currently, the alarm style is the subject of competitive development, which too rigid standardisation might have the effect of suppressing.

6. Detection Capability Testing in Air

6.a. Rationale for Selection of Tests

Tests in this section were selected from CWA 14747 Section 6 Detection Capability Testing in Air. They aim to determine: the base line detection sensitivity without the effect of soil, the quality of the soil compensation and the effect of specific influences which can reduce the sensitivity. We considered it essential to conduct this section thoroughly.

6.b. Speed tests

Method

Detector sensitivity is in general dependent on the sweep speed, so CWA 14747 specifies that the optimum must be determined as a first step. In this work, the speed dependence was measured using the scanner for low speeds and the pendulum for high speeds, with an overlap in the middle. Typical curves are as in Fig. 6.1. The speed dependence always followed a simple pattern, adequately characterised in terms of optimum speed, low-speed sensitivity loss and high- speed sensitivity loss. Table 2 summaries the results.

Similar measurements were made for the large –head UXO detectors, this time always using the pendulum, because the scanner sweep area is too small for some of the larger heads. For the MIL D1 DS, a 23 mm 100Cr6 ball was used as the target, since the 10 mm ball is not detected by it.

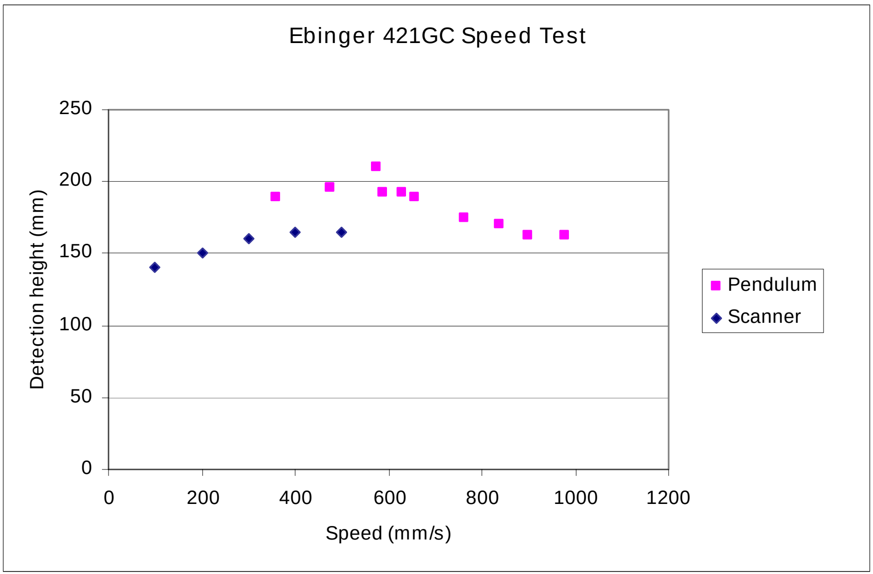


Fig. 6-1Typical results of a sensitivity versus speed measurement – conducted with a 10 mm 100Cr6 ball. In general, highest sensitivity may occur at either high or low speeds or, as here, in the mid-range.

Table 2 Effect of sweep speed on sensitivity

Detector	Optimum speed (m/s)	Loss of sensitivity at low speed 0.1 m/s	Loss of sensitivity at high speed - 1 m/s
Adams AX777	≥1.0	28%	0
CEIA MIL D1	0.1 to ≥1.0	0	0
Ebinger 420HS	0.45-0.65	61%	2%
Ebinger 421GC	0.6	30%	20%
Foerster 2FD 4.500	0.1	0	14%
Guartel MD8+	0.1	0	16%
Minelab F1A4	0.6 to ≥1.0	22%	0
Minelab F3	0.9	9%	8%
Schiebel ATMID	0.5	11%	2%
SHRIMT Model 90	≥1.0	33%	0
Vallon VMH3	0.5-0.6	19%	3%
CEIA MIL D1 DS	0-0.5	0	5%
Ebinger 421GC LS	0.4-0.8	30%	20%
Minelab F1A4 UXO	0.6	50%	10%
VMH3C UXO	≥0.9	30%	0

Where the highest sensitivity was found at the fastest speed tested, it is possible that even higher sensitivity would have been obtained at still higher speeds. This is indicated in the table by the ≥ symbol.

Discussion

Most of the detectors have optimum speeds less than 0.7 m/s and have measurably lost sensitivity by 1 m/s. This is an important observation because it limits the rate of coverage which can be achieved e.g. if the swath adequately covered[3] by the centre of the detector in one pass is 50 mm wide, the rate of coverage at 0.5 m/s is 0.025 m^2/s which is 1.5 m^2 / min. Claims of coverage rates very much greater than this should only be believed if there is evidence of the detector not losing sensitivity significantly at high speed. Of the detectors tested here, good high speed performance is shown by the CEIA MIL D1, Ebinger 420HS, Minelab F1A4, SHRIMT Model 90, Schiebel ATMID and Vallon VMH3. Results for the Adams AX777, not included in most of the tests, are included here, because it also has good performance in this respect.

[3] This swath width cannot safely be taken to be the full head-width, because the full width is only covered at the surface. It theoretically should be the width of the sensitivity profile for the targets of interest, at the required clearance depth (see Section 6h).

Very high sensitivity loss at low speeds, as exhibited by the Model 90, Adams AX777, both Ebingers and the F1A4, occurs when the detector has been designed to go silent if it is held stationary over a target, which is done by some manufacturers with the intention of improving pinpointing. Detectors having this feature are termed “dynamic”.

The CEIA MIL D1 stands out as being completely unaffected by sweep speed over the entire 0.1-1m/s range.

Recommendation

Because of the simple patterns observed, it can be argued that the speed test should be simplified in routine testing. One motive for performing this test is to know what speed to sweep at when measuring the sensitivity in subsequent tests. It is not really necessary to perform a detailed measurement for this purpose; it is sufficient to know what the general trend is e.g. by measuring at three speeds. A detailed measurement of sensitivity versus speed is also unlikely to be very interesting for field operators. A full plot, as made here, should be recommended only for design engineers.

6.c. Repeatability on Set-up (CWA 14747 Section 6.4.4)

Rationale

When a detector is switched on and set up in the same way several times, it may not always end up at the same sensitivity each time, which is potentially dangerous e.g. if a detector is switched off during a break or by mistake and then switched on, and used without a re-check that its sensitivity is still adequate.

Secondarily, non-repeatability on set-up is also a factor limiting reproducibility in testing.

This test is conducted as an in-air test. It does not address lack of repeatability in soil compensation, which may also be important.

Method

The detectors were each switched on and adjusted for maximum sensitivity in air. After three minutes warm-up a detection height measurement was performed. The detector was switched off and switched on and set up again. Another detection height measurement was made. The procedure was repeated until five detection height values had been obtained. In this test, some other detectors were included as well as the main group – see Appendix..

Results are tabulated in Table 3 below. For each of the five measurements, the percentage differences from the average of the five are also tabulated, to show the repeatability, independently of the absolute sensitivity.

Non-repeatability within ±2% may be regarded as within the experimental uncertainty.

Discussion

Superior repeatability on set-up is shown by detectors where the sensitivity has no fine adjustment (Minelabs, MD8+ and Foerster). Those detectors where the procedure involves a continuous adjustment to just below the point where the detector sounds (Ebingers, ATMID, Model 90 and GTL-115) have less repeatable set up. The Vallons, whose adjustment is digital, but in fine steps, have good or fair repeatability. The CEIA MIL D1 showed perfect repeatability, in spite of having a continuous adjustment, because in these tests it was set up to a level *below* the maximum, by backing-off the sensitivity to the position indicated by a red spot on the control, where it is less affected by small changes.

In conclusion, on the basis of these results, poor repeatability on set-up occurs when the procedure is to fine-adjust the sensitivity control to get the highest value before the detector sounds. It is the price paid for getting as much sensitivity as possible from the electronics.

Table 3 Repeatability on set-up

Mnftcr.	Model	Meas. No.	Max. height (mm)	Diff. from average	Mnftcr.	Model	Meas. No.	Max. height (mm)	Diff. from average
CEIA[1]	MIL-D1	1	165	0.00%	SHRIMT	Model 90	1	205	-12.02%
		2	165	0.00%			2	170	7.10%
		3	165	0.00%			3	170	7.10%
		4	165	0.00%			4	185	-1.09%
		5	165	0.00%			5	185	-1.09%
Ebinger	Ebex	1	195	-4.28%	Vallon	VMH3	1	300	-6.76%
	420 HS	2	185	1.07%			2	285	-1.42%
		3	175	6.42%			3	270	3.91%
		4	190	-1.60%			4	280	0.36%
		5	190	-1.60%			5	270	3.91%
Ebinger	Ebex	1	160	2.44%	Vallon[2]	VMH3 M	1	270	-1.89%
	421 GC	2	165	-0.61%			2	265	0.00%
		3	165	-0.61%			3	265	0.00%
		4	165	-0.61%			4	265	0.00%
		5	165	-0.61%			5	260	1.89%
Foerster	Minex	1	205	-0.49%	BGIF	GTL-115	1	125	0.79%
	4.500	2	205	-0.49%			2	110	12.70%
		3	205	-0.49%			3	135	-7.14%
		4	200	1.96%			4	130	-3.17%
		5	205	-0.49%			5	130	-3.17%
Guartel	MD8+	1	120	0.00%	CEIA[3]	MIL D1 DS	1	480	-1.27%
		2	120	0.00%		(UXO)	2	465	1.90%
		3	120	0.00%			3	485	-2.32%
		4	120	0.00%			4	470	0.84%
		5	120	0.00%			5	470	0.84%
Minelab	F1A4	1	200	0.00%	Ebinger	421GC LS	1	95	3.06%
		2	200	0.00%		(UXO)	2	85	13.27%
		3	205	-2.50%			3	75	23.47%
		4	200	0.00%			4	100	-2.04%
		5	195	2.50%			5	135	-37.76%
Minelab	F3	1	170	0.00%	Minelab	F1A4	1	205	0.97%
		2	170	0.00%		(UXO)	2	210	-1.45%
		3	165	2.94%			3	205	0.97%
		4	175	-2.94%			4	205	0.97%
		5	170	0.00%			5	210	-1.45%
Schiebel	ATMID	1	225	6.64%	Vallon	VMH3 CS	1	185	-3.93%
		2	225	6.64%		(UXO)	2	175	1.69%
		3	260	-7.88%			3	175	1.69%
		4	225	6.64%			4	175	1.69%
		5	270	-12.03%			5	180	-1.12%

NOTES:
1. CEIA MIL D1 used on its red spot sensitivity setting
2. Vallon VMH3M is a firmware upgrade of VMH3
3 . CEIA MIL D1 DS was tested with its own (large) reference target

6.d. Sensitivity Drift (CWA 14747 Section 6.4.5)

Rationale

This test is conducted to reveal how much the detection capability of the detector changes over time, which is important because, if it does change significantly, the operator will have to adjust the detector frequently.

Method

The detector was switched on and the time of day recorded. In-air sensitivity measurements using an appropriate target were conducted at frequent intervals over three hours. (In this work we abbreviated the test in some cases where the trend was already clear). The percentage increases/decreases in the detection height from the starting value were plotted against time.

The drift test is conducted at constant temperature in the laboratory and assesses drift which is inherent in the electronics e.g. due to components warming up after they are switched on. Changes of sensitivity due to changing temperature of the operating environment are assessed separately in Section 7.

CWA 14747 conceives the sensitivity drift test to be a separate test from the battery discharge, essentially because the time scale is much shorter. It should be noted though that effects of overvoltage in very fresh batteries, as seen above for the 421GC, would also show up in a three hour drift test. It is a matter of definitions whether one considers this as drift or not, but the tests as a whole provide the information that the user needs.

Discussion

Significant variation is seen in drift performance. The CEIA MIL D1, Foerster Minex and Vallon VMH3M stand out as having very stable sensitivity. VMH3 and Minelab F3 are also good.

Drift may occur in either direction i.e sensitivity increases with time for some detectors and decreases for others, which is not surprising because it would be expected to depend on the details of the electronic design.

The UXO variants generally have poor drift stability, in all four cases poorer than the corresponding small head detector.

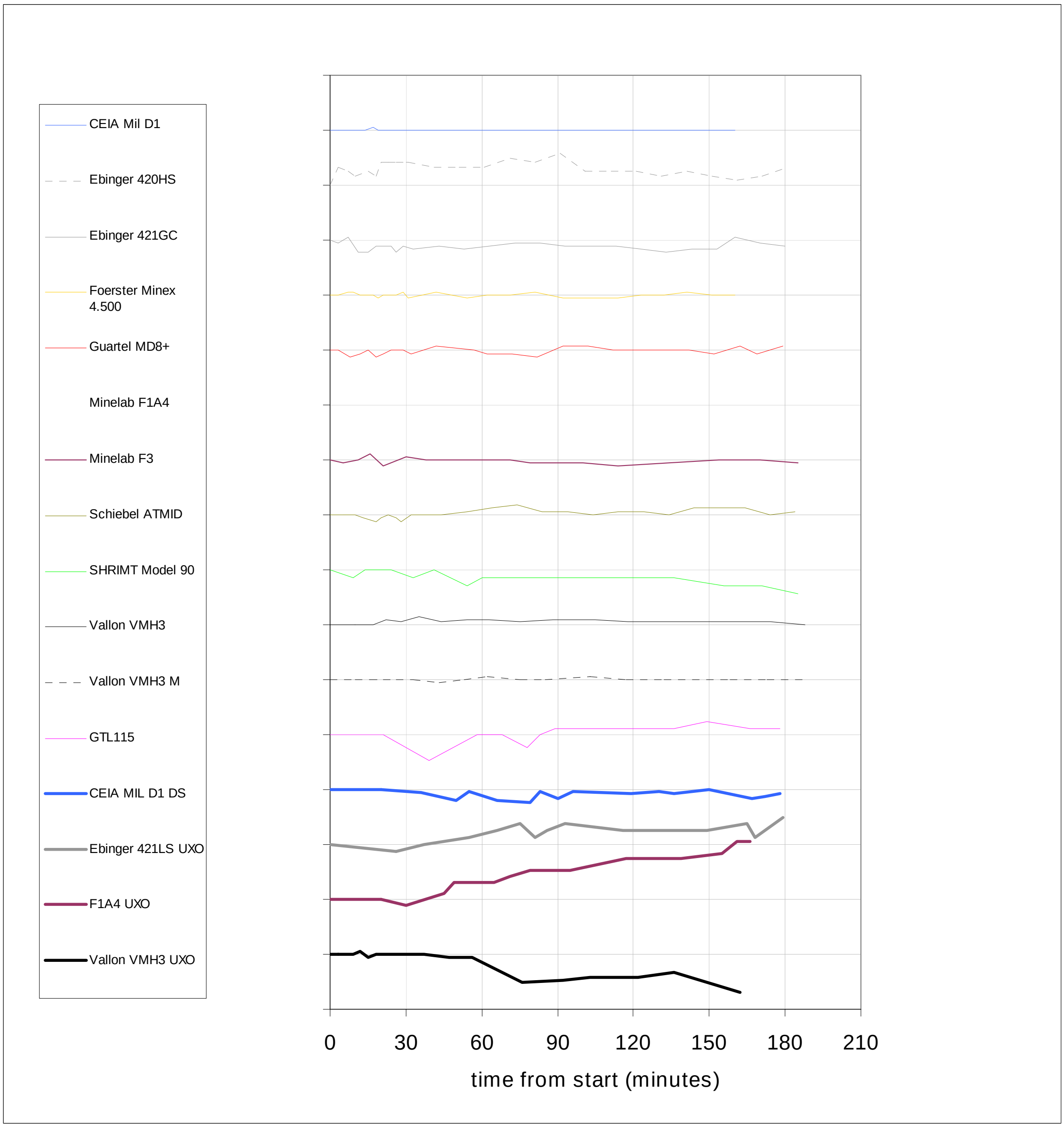


Fig. 6-2 Chart of detector sensitivity drift. The sensitivities are normalised to their starting values. For all plots, one vertical division represents 50% increase (or decrease) in the detection height from the starting value. For each plot, the starting point is offset by one division with respect to its neighbour.

6.e. Minimum target detection curves

(CWA 14747 Sections 6.5.2 and 6.5.3)

Method

In this test, the smallest sphere that the detector can detect at a given height is determined by manually sweeping the detector over the target, mounted on the jig described above and shown in fig. 3.4, first with spheres made of 100Cr6, a widely available ferromagnetic steel, and then with other metals. The measurement technique is essentially straightforward: it is sufficient to take care to keep the head horizontal and centred and to sweep at an appropriate speed. Choice of a spherical target eliminates any possible inconsistency due to target orientation.

In practice, most of the results were obtained by raising and lowering the jig for a given sphere, rather than by changing spheres at fixed height. The results below are plotted with the sphere diameter as the dependent variable, since the test is conceived in CWA 14747 as a determination of minimum detectable target size at given height. The curves are fitted cubics.

Using the jig, it is possible to achieve a precision of about 5 mm, as indicated by the error bars on the curves – for the sake of legibility shown on only a few of the curves but applicable for all. The main limit to the precision is that different operators may interpret the signals differently. CWA 14747 attempts to make the detection point more objective by defining the following criterion: a detection is confirmed if the detector signals five times in successive sweeps (CWA 14747 Section 6.3.3).

All the detectors were used at their highest stable sensitivity settings, for these measurements. The VMH3 was used in its non- soil-compensating mode, the CEIA was at maximum sensitivity (knob fully clockwise), the Foerster on setting H, the Guartel on setting III and the F3 was used with its black-coloured cap.

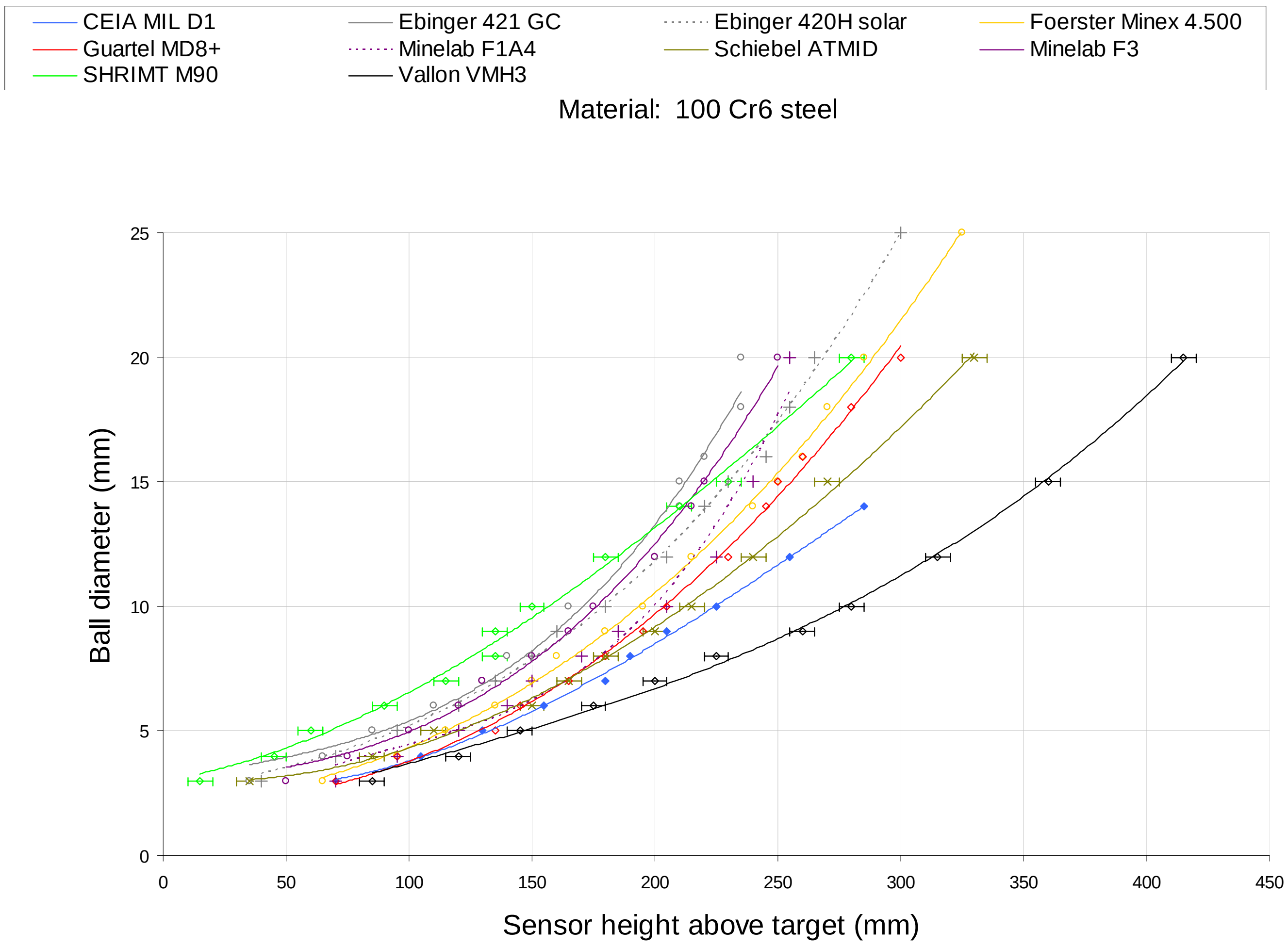


Fig. 6-3 Minimum detectable sphere diameter, versus height above target for 100Cr6 steel

Measured in air, detector set up in air

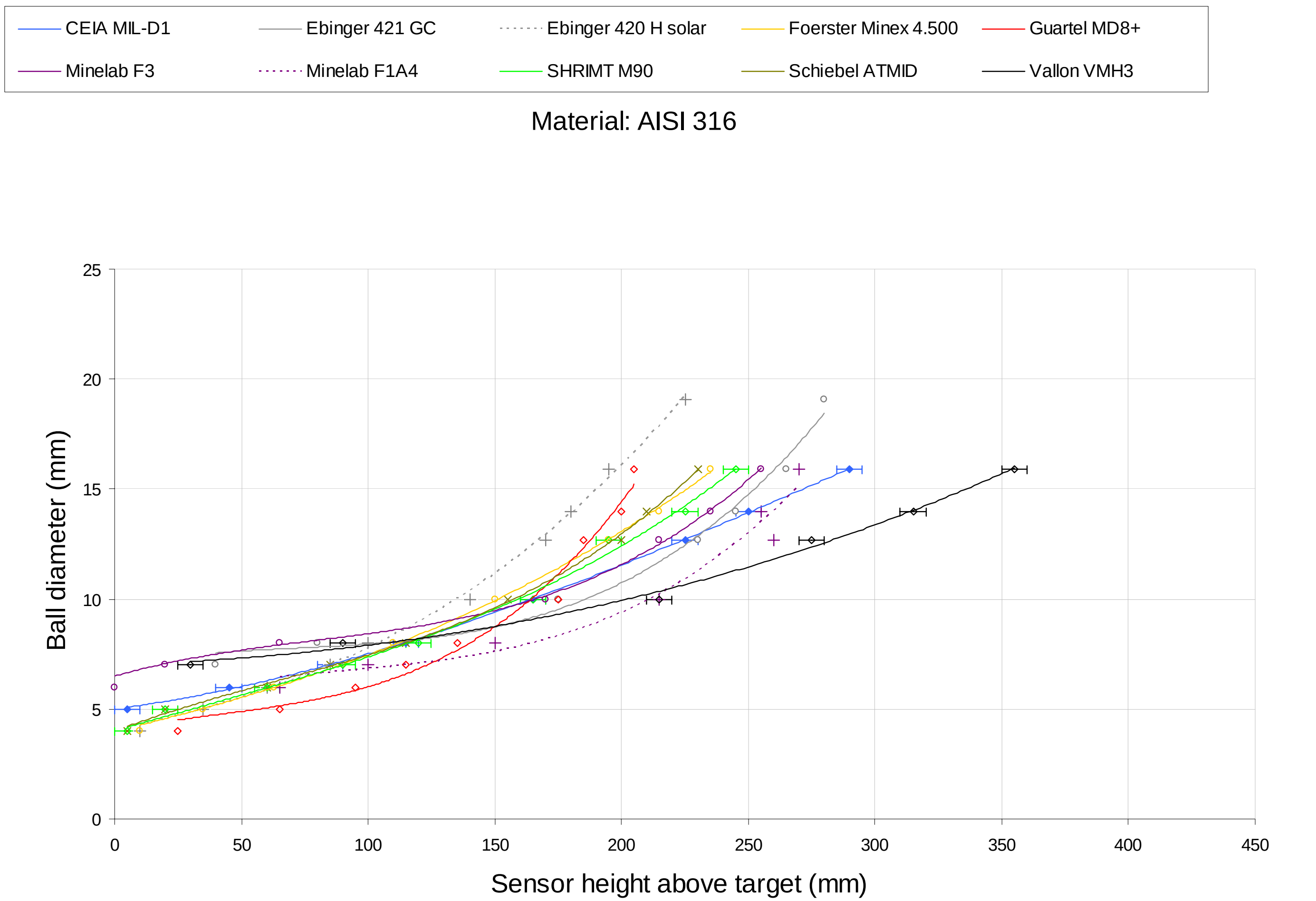


Fig. 6-4 Minimum detectable sphere diameter versus height above target for AISI 316 stainless steel
Measured in air, detector set up in air

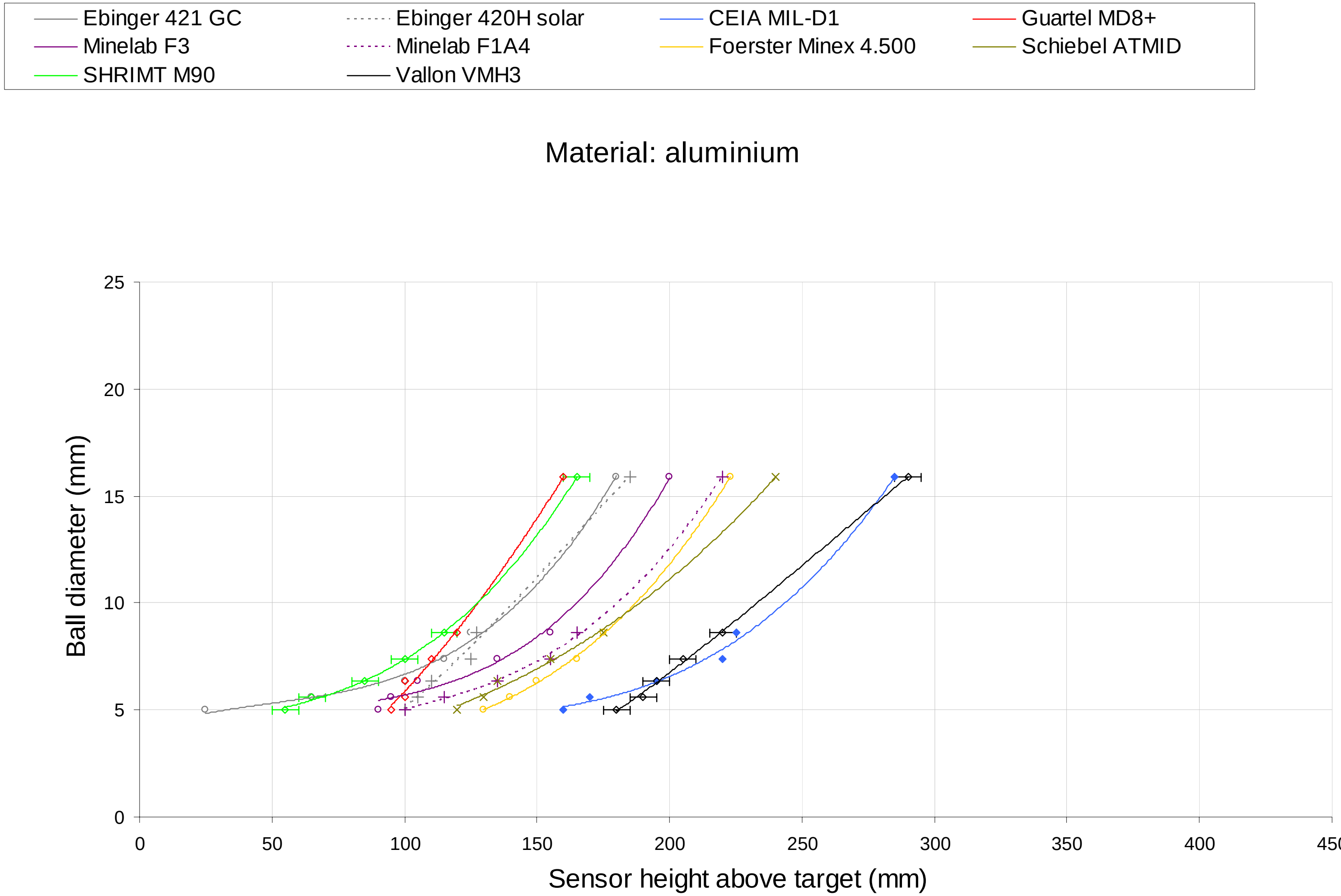


Fig. 6-5 Minimum detectable sphere diameter versus height above target for aluminium
Measured in air, detector set up in air

Discussion

All of the 100Cr6 curves display similar shapes. In all cases, the absolute minimum detectable sphere is around 1 to 3 mm in diameter. There are significant differences in sensitivity between detectors. The Vallon VMH3 is outstandingly sensitive in air, followed by the CEIA MIL D1. The detectors are generally less sensitive to the AISI 316 steel and the curves are differently shaped, some detectors having reduced sensitivity to small diameters. This behaviour is expected theoretically [ref. Theory 1], [ref. Theory 2] and is due to the low conductivity and low magnetic permeability of this material. AISI 316 is one of a class of stainless steels termed “austenitic”, which are almost completely non-magnetic in spite of iron being the largest alloy component. Such materials are found in some mines and trip wires, making them very difficult to detect.

Generally, for the small spheres, the aluminium were easiest to detect but for the larger sizes they are more difficult to detect than the 100Cr6 i.e. the curve gradient increases more quickly for aluminium. There were fewer data points but on the basis of the data available, there is no evidence of a change of curve shape at small diameters. The observed behaviour is again expected theoretically for a high conductivity but non-magnetic metal.

The comparison between the materials is also shown clearly in the individual detector results in Chapter 10.

6.f. Detection heights in air with the detector compensated for soil

Rationale

This test measures the purely electronic reduction of sensitivity caused by adjustment of the detector to the soil, separate from any residual soil/detector interaction after compensation or any effect due to the void in the soil formed by the mine body.

Inconsistency between in-soil results and in-air results with the detectors compensated to the same soil was observed in the Mozambique field trial, suggesting that either the residual interaction or the void effect is significant in practice. It is important to understand what is happening because if the in-air, soil-compensated, measurements are misleading, it may be better to remove them from CWA 14747.

Method

The detector was adjusted to the soil, using its soil compensation system where present, and reducing sensitivity as necessary. An in-air minimum detectable target measurement was then conducted using the jig. To facilitate comparison between the in-soil results reported in Sections 8, the in-air measurements at soil setting are presented here as equivalent in-soil depths, i.e. 30 mm has been subtracted from the target to head distance. (In some cases this yields a negative value for the equivalent depth, which would correspond to a target protruding above the soil surface in an in-soil measurement.)

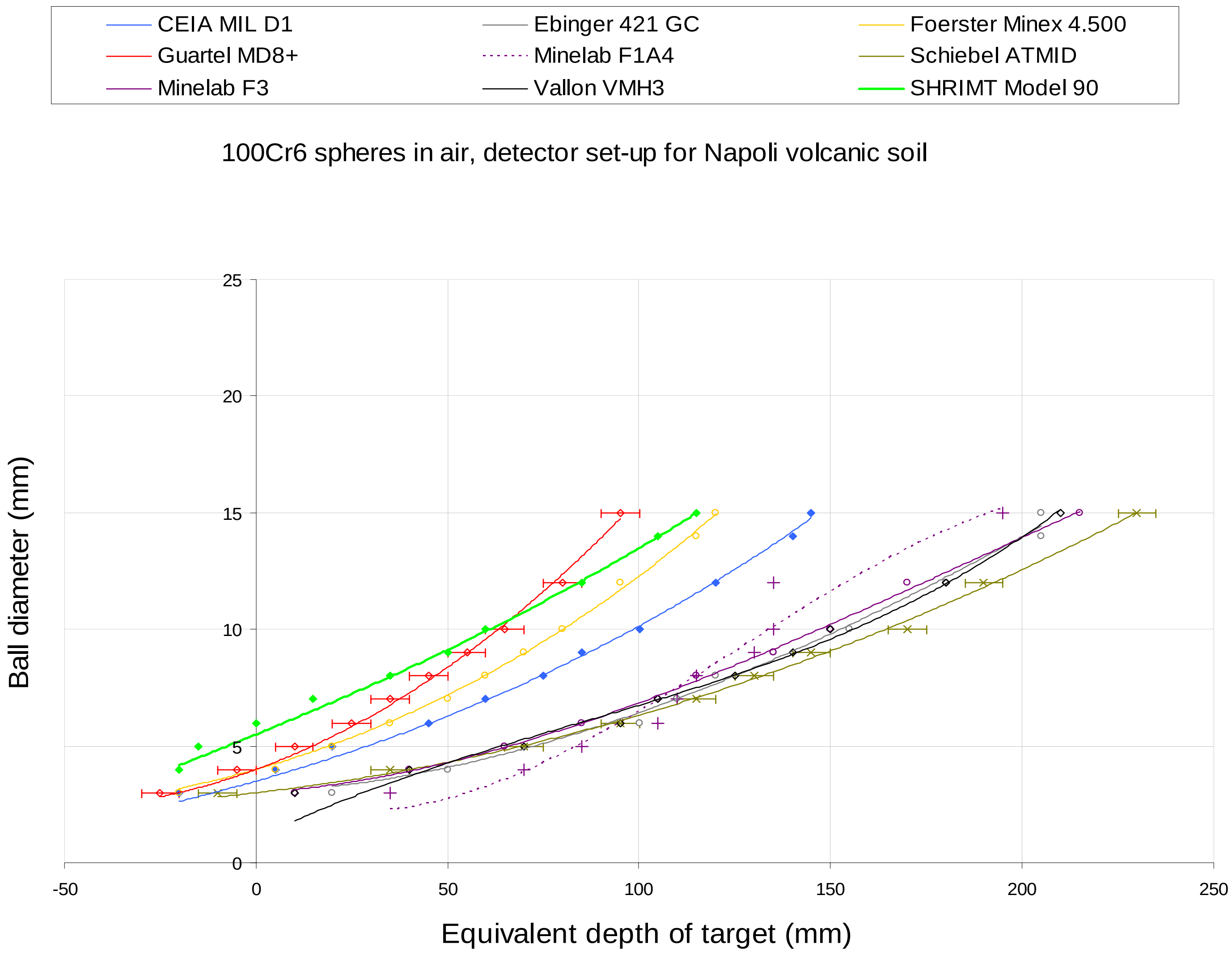


Fig. 6-6 Minimum detectable sphere diameter versus depth below soil surface for 100Cr6 steel

Napoli volcanic soil; data measured in air, detector set up on soil. The detector not shown (420HS) was unusable on this soil

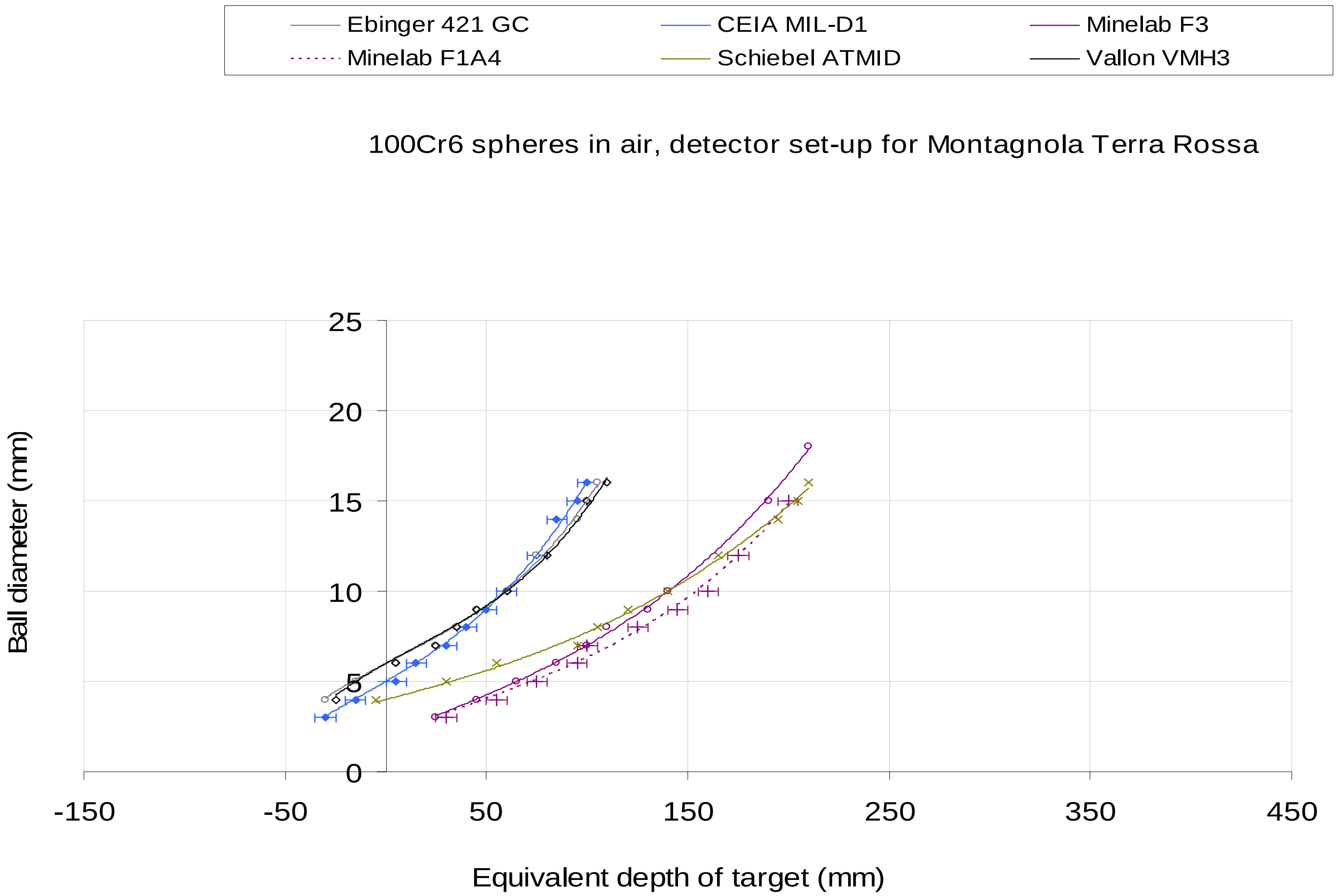


Fig. 6-7 Minimum detectable sphere diameter versus depth below soil surface for 100Cr6 steel

Montagnola terra rossa soil; data measured in air, detector set up on soil

The four detectors not shown (Minex 4.500, 420HS, Model 90 and MD8+) were unusable on this soil

Discussion

These results reveal the differences in soil-compensation performance between the detectors. The Vallon VMH3 , Minelab F3 and F1A4 and Schiebel ATMID stand out as having the best performance of the detectors tested.

The in-air results for the Vallon are again the best, but after soil compensation its performance is comparable to that of the Minelabs. There is little difference between the F1A4 and F3 in sensitivity.
The Ebinger 421GC also shows quite good performance, but not as good as the four best performing detectors.
The CEIA MilD1 mainly shows sensitivities lower than the 421GC but is capable of operating in both magnetic soils, albeit with significant degradation of performance versus its in-air performance. On the Montagnola soil Fig. 6.7 it had to be set to the reduced-sensitivity red spot position, however, in the Napoli soil Fig. 6-6 it it was at maximum sensitivity.
The Foerster Minex and Guartel MD8+ are able to be set up on the Napoli volcanic soil, with their sensitivities on the lowest setting, but are not able to operate in the Montagnola terra rossa on any setting. Of the two detectors, the Minex showed the superior sensitivity after set up to the Napoli soil. Moreover, in air, it is able to operate on its high sensitivity setting where it gives much better results, comparable to or better than those of the Minelabs.

The Ebinger 420HS was not able to be set up to either magnetic soil, even on its lowest sensitivity setting.

These findings are broadly consistent with the findings from the Mozambique field trial, which focused on the question of soil compensation.

6.g. Detection Capability for specific targets

Rationale

These targets provide detection capability measurements which correspond to real mines. Two sets of targets were used: the ITOP fuze inserts described in the CWA 14747, and a set of simulated fuzes made by CEIA SpA and verified against the real fuzes in their LACE laboratory (“Laboratorio di Compatibilità Elettromagnetica”). The CEIA simulated fuzes are fitted in perspex holders which are cut to a length such that the top of the holder corresponds to the top of the relevant mine[4].

[4] The LI-11 is the Swedish version of the German DM-11 AP mine.
The AP72 fuze simulant simulates the common mechanical fuzed version, not the electronically fuzed variant.
The length of the target holder for the SB-81 fuze simulant corresponds to the mine with its pressure plate upwards and fuze below. This mine is designed so that it can also be used upside down, in which case the fuze is higher up, making it easier to detect.

Method

Measurements were made in exactly the same way as for the spherical targets.

Results

Results are shown in Figures 6.8 to 6.10 below. For the specific targets, the target type is unambiguously the independent variable and so is plotted on the horizontal axis. That is to say, higher curves correspond to better performance.

In all cases, the results are plotted as detection depth with the convention that the head is swept at a height of 30 mm above the soil, i.e. 30 mm was subtracted from the measured detection height in air so that the results could be directly related to the in-soil values, as was done for the soil-compensated measurements with the spheres in the previous section.

Discussion

As well as providing specific performance predictions for individual targets, these results shed light on the question of to what extent sensitivity is in practice dependent on target shape, material and configuration, as well as its overall size. In theory, one would expect that response to a target will depend on the bandwidth of the detector, whether it is single coil or double-D etc. So some detectors could be especially sensitive to certain shapes of targets.

But in both the set-up-in-air and set-up-to-soil measurements , the curves for the specific targets have similar forms for all detectors, one detector differing from another only in the vertical scale, for the most part. That is to say, the differences between detectors' responses due to the details of the target, in practice has a second order effect only.

These results also serve to deepen the evidence for the differences in soil-compensation performance between the detectors found from the sphere measurements reported in the previous section.

The performance of the ATMID after soil compensation on the specific targets does not seem to have been as good as for the spheres. This behaviour was also seen in the Mozambique field trial results, for the 10 mm diameter 100Cr6 sphere and ITOP Ko, Io and Mo targets, suggesting it is a real feature of the detector and not an artefact e.g. due to the soil compensation not being reproducible. Its in-air maximum sensitivity performance was good on both the spheres and the specific targets in the lab tests. In the Mozambique field trial, this was not really true in air but the Lane 1 non-magnetic soil performance was good on both types of target. A possible theoretical explanation for this behaviour is that the ATMID uses a sine wave signal around 8kHz, which is an unusually low frequency, giving it a high penetration depth so that it is better suited to thicker targets. This is borne out by the fact that its performance on the larger steel and aluminium spheres (Fig. 6.3 and 6.5) is especially good. Note, however, that it does not seem to apply in the AISI 316 stainless steel (Fig. 6.4).

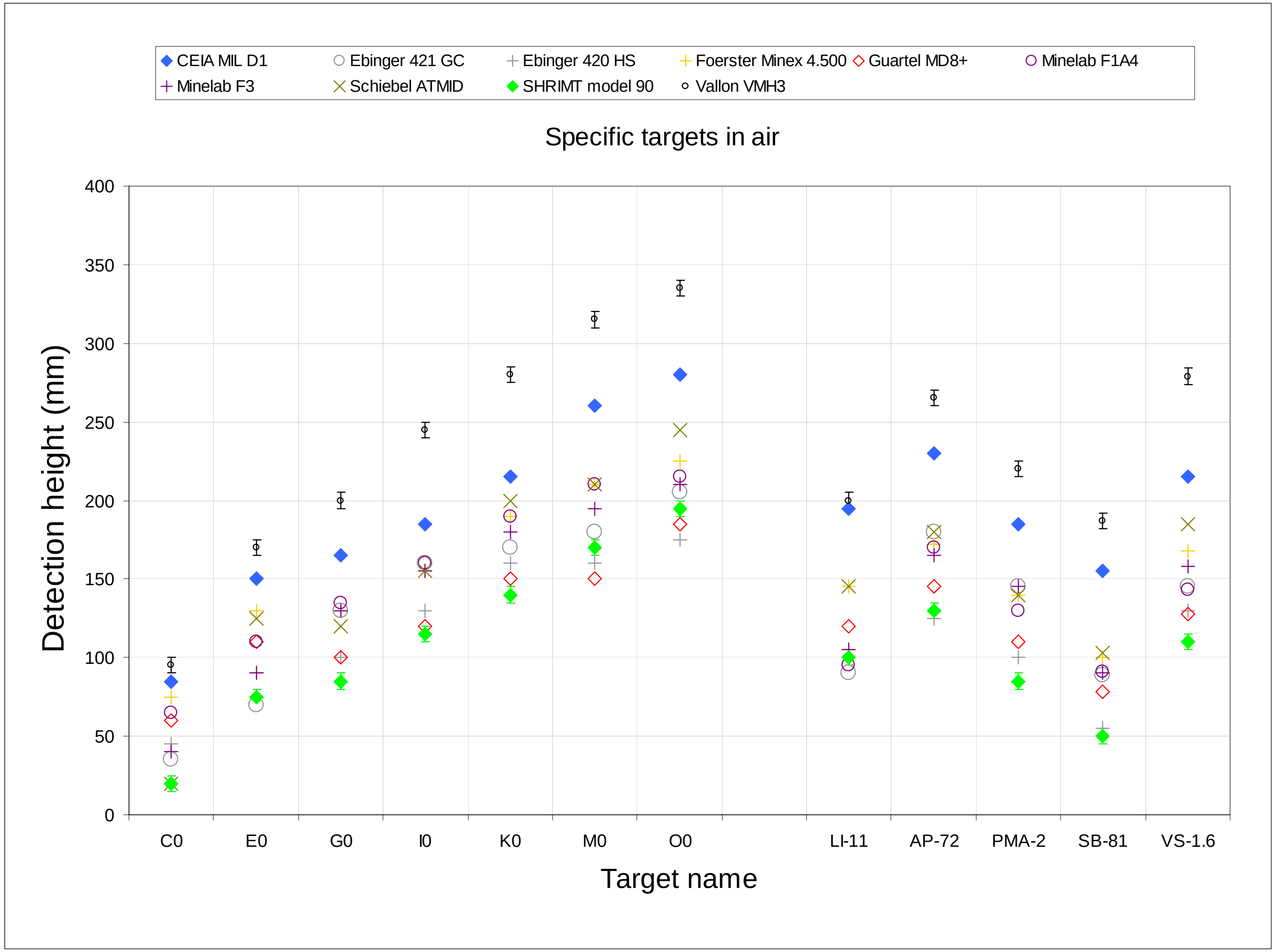


Fig. 6-8 Detection heights for specific targets measured in air, with the detector set up in air

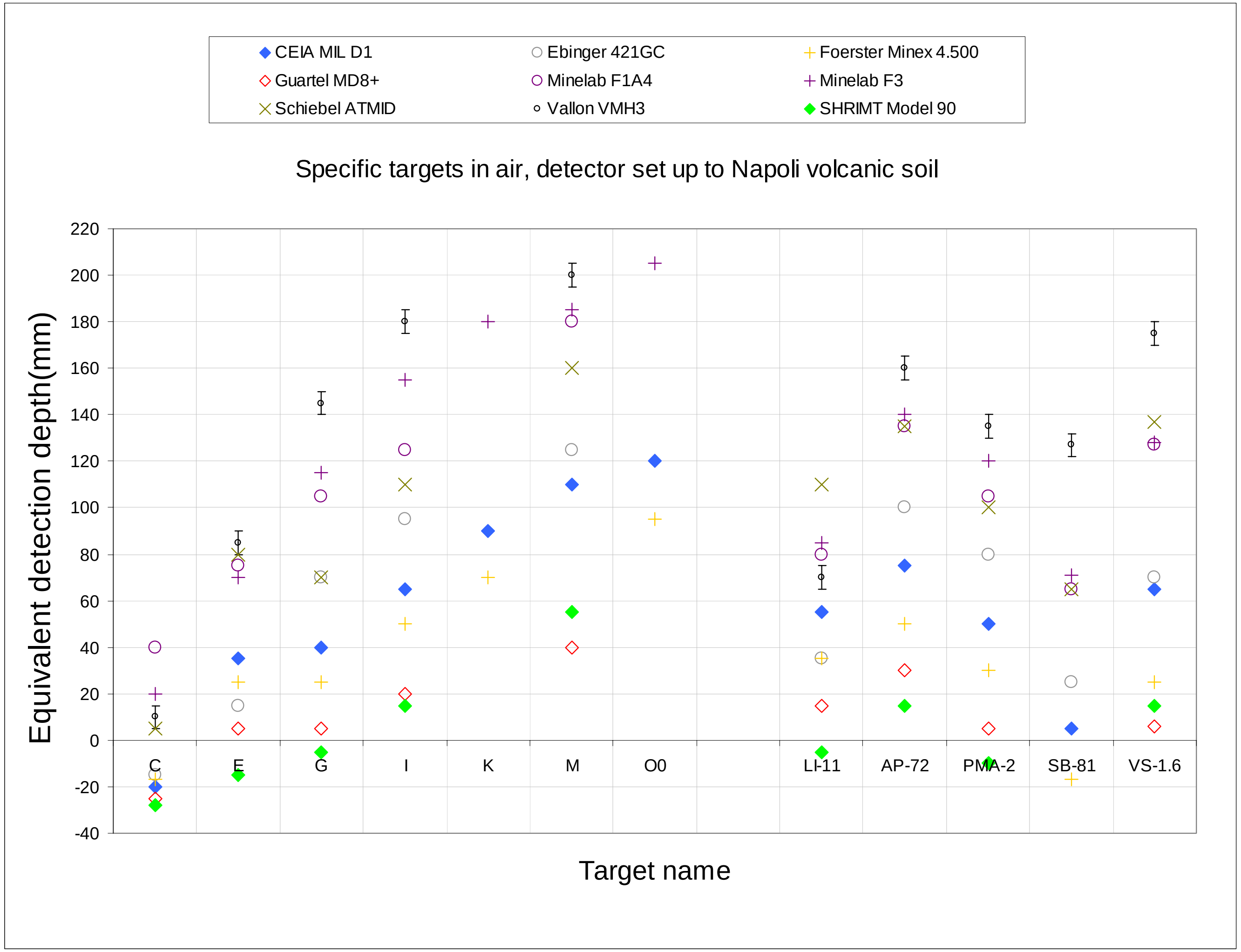


Fig. 6-9 Equivalent detection depths for specific targets

Napoli volcanic soil; measured in air, detector set up to soil

The detector not shown (420HS) was unusable on this soil

Fig. 6-10 Equivalent detection depths for specific targets
Montagnola terra rossa; measured in air, detector set up to soil
The four detectors not shown (Minex 4.500, 420HS, Model 90 and MD8+) were unusable on this soil

6.h. Sensitivity Profile Measurement

Rationale

The detection height varies across the width of the head and from front to back. Except for extremely small targets, it is greatest near the centre of the head. The sensitive region of the detector forms approximately a conical or semi ellipsoid shape.
An understanding of this shape is important in demining and should form part of the training of operators. In particular, it is important to understand that when a detector is swept across the ground at its greatest detection depth is only being achieved over a narrow strip under the centre of the head. Therefore, if the head is advanced by a whole head width at each pass, the ground is being covered to a depth much less than the maximum possible. To achieve more thorough clearance, the head should be advanced by much less than its whole width at each step.
A full understanding of this behaviour requires the sensitivity profile, i.e. the shape of the sensitive region, to be plotted out.

Method

CWA 14747 details two possible ways of performing this measurement – Method 1, using the scanner and Method 2 manually. Because these experiments are very time consuming by either method, it was considered impractical to do them by both.
Method 2 was selected. Sensitivity measurements were conducted in the normal way but with the target in front or behind the centre position of the head. A special guide frame was constructed consisting of a board with a large circular hole placed above the target jig, plastic bars on the board kept the detector at the correct horizontal position as it was swept. The profiles generated are fore-aft cross-sections through the sensitivity cone.
Some measurements reported here were made with an alternative jig, consisting of a board with grooves ("washboard") which was used to move the target at a fixed position in front or behind the head. The sensitivity cones of the UXO detectors were plotted by probing the space near the head radially with an appropriate target.

Results

Results for each individual detector are contained in Section 11. The typical form is shown in Fig. 6.11 , the profile depends on the target as well as the detector: The larger the target, the larger the footprint. The target BLU 26 is the cluster bomb submunition used in the field trial in Laos.
N.B. Because Method 2 generates fore-aft cross-sections, the double-D head format of the MIL D1 is not apparent.

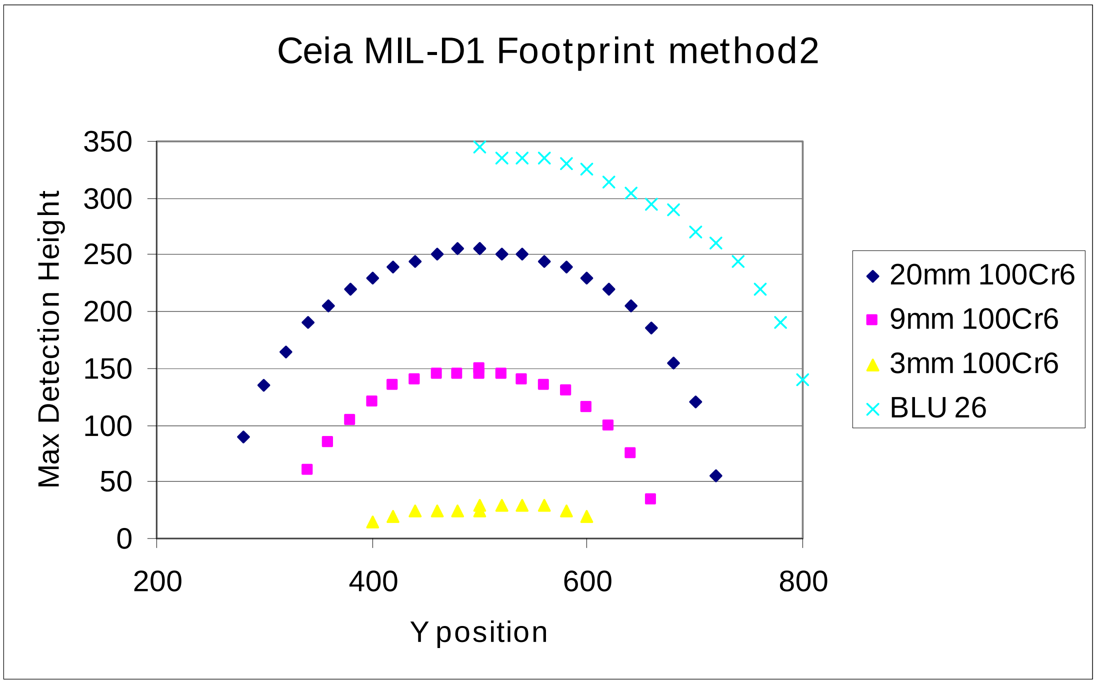


Fig. 6-11 Sensitivity profile ("footprint") for the CEIA MIl D1 measured by the manual method 2.

6.i. Comparison UXO head and standard head

Rationale

The large head UXO detectors are all based on smaller head detectors which were also tested. The two versions of the detector may be directly compared. The basic effect of an increased head diameter on the minimum detection height curve is well understood from theory: large targets may be detected at greater depth but the sensitivity to small targets decreases so that the smallest targets may no longer be detected. There may also be circuit changes introduced for UXO version detectors, which will affect the overall behaviour.

Method

As above in Sections 6e and 6g.

Results

See graphs in figs. 6.12 to 6.16 below.

Discussion

For the spherical targets (Figs. 6-12 to 6-14), as expected, the minimum target detectable at zero height is larger for the UXO detectors than for the mine detectors (solid line crosses vertical axis above broken line of same colour). In most cases, it is also visible that the minimum detectable target increases with height more quickly for the mine detectors than for the UXO. Similar trends are followed for the specific targets. Interestingly, it is only for the Minelabs that the cross–over point between the two curves is visible on these plots, but not for the other detectors. This implies that the other UXO detectors are optimized for larger targets.

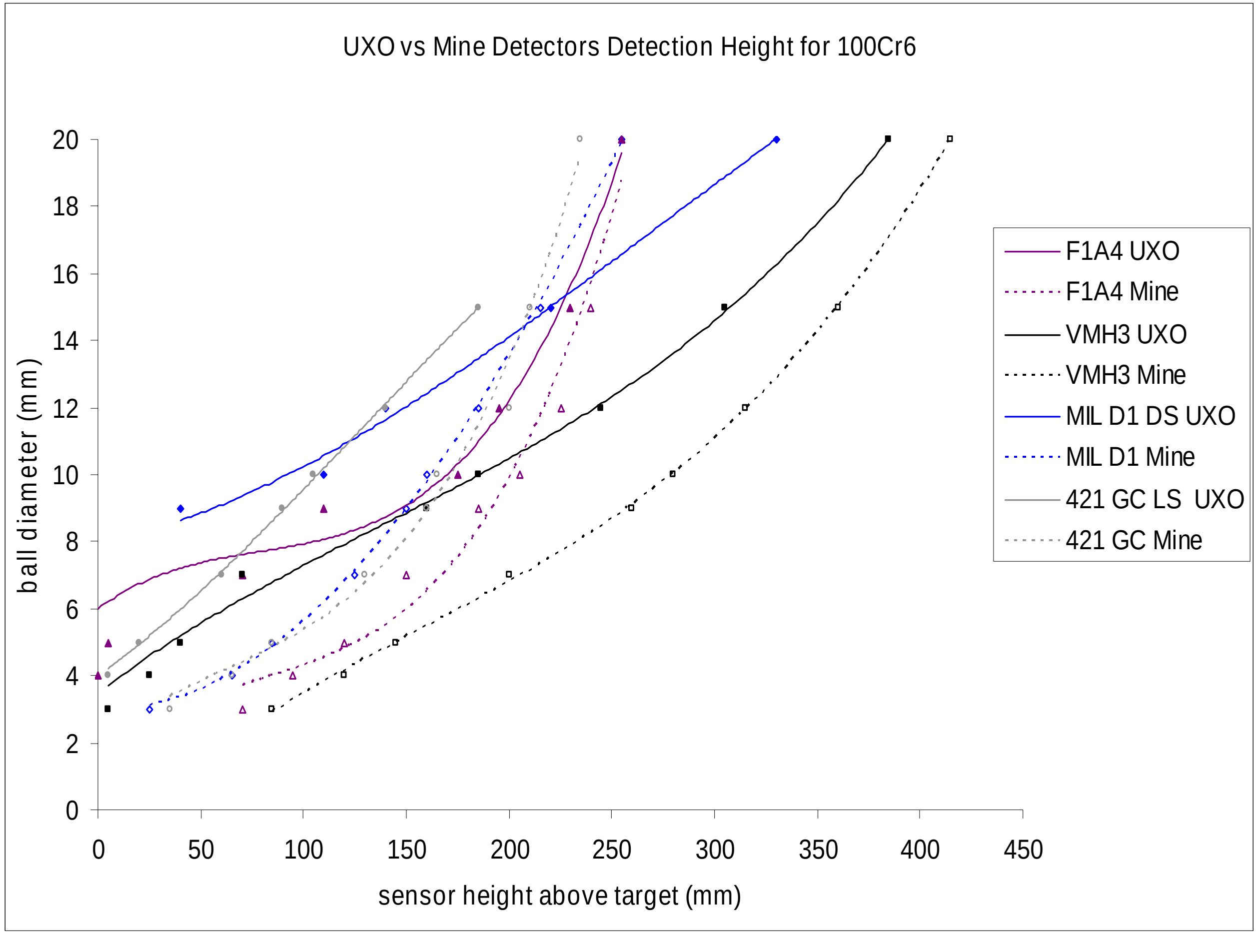


Fig. 6-12 Minimum detectable target curves for mine detectors (small head)
and UXO detectors (large head)
100Cr6 chrome steel, detectors set up in air and data measured in air.

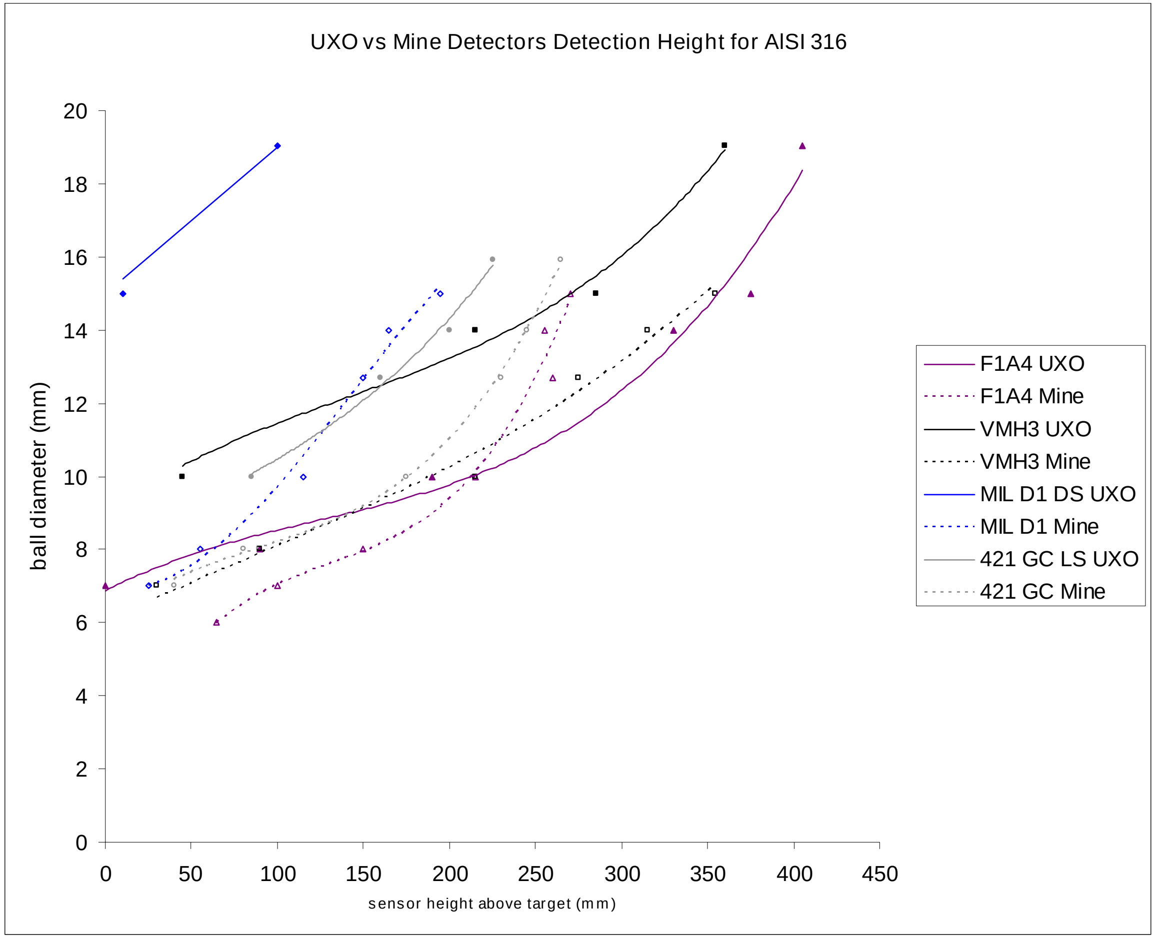


Fig. 6-13 Minimum detectable target curves for mine detectors (small head) and UXO detectors (large head)
AISI 316 stainless steel, detectors set up in air and data measured in air.

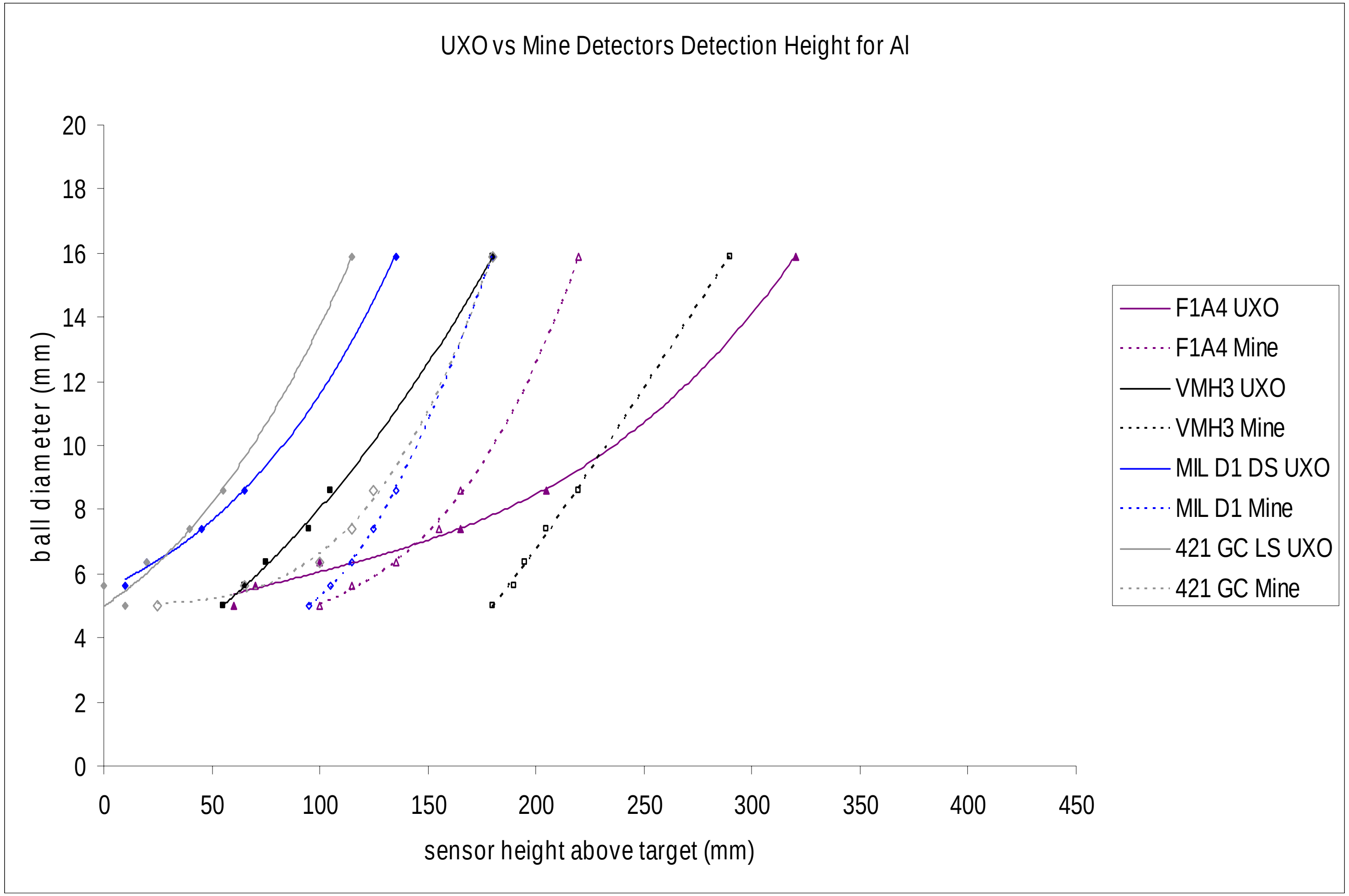


Fig. 6-14 Minimum detectable target curves for mine detectors (small head)
and UXO detectors (large head)
Aluminium, detectors set up in air and data measured in air.

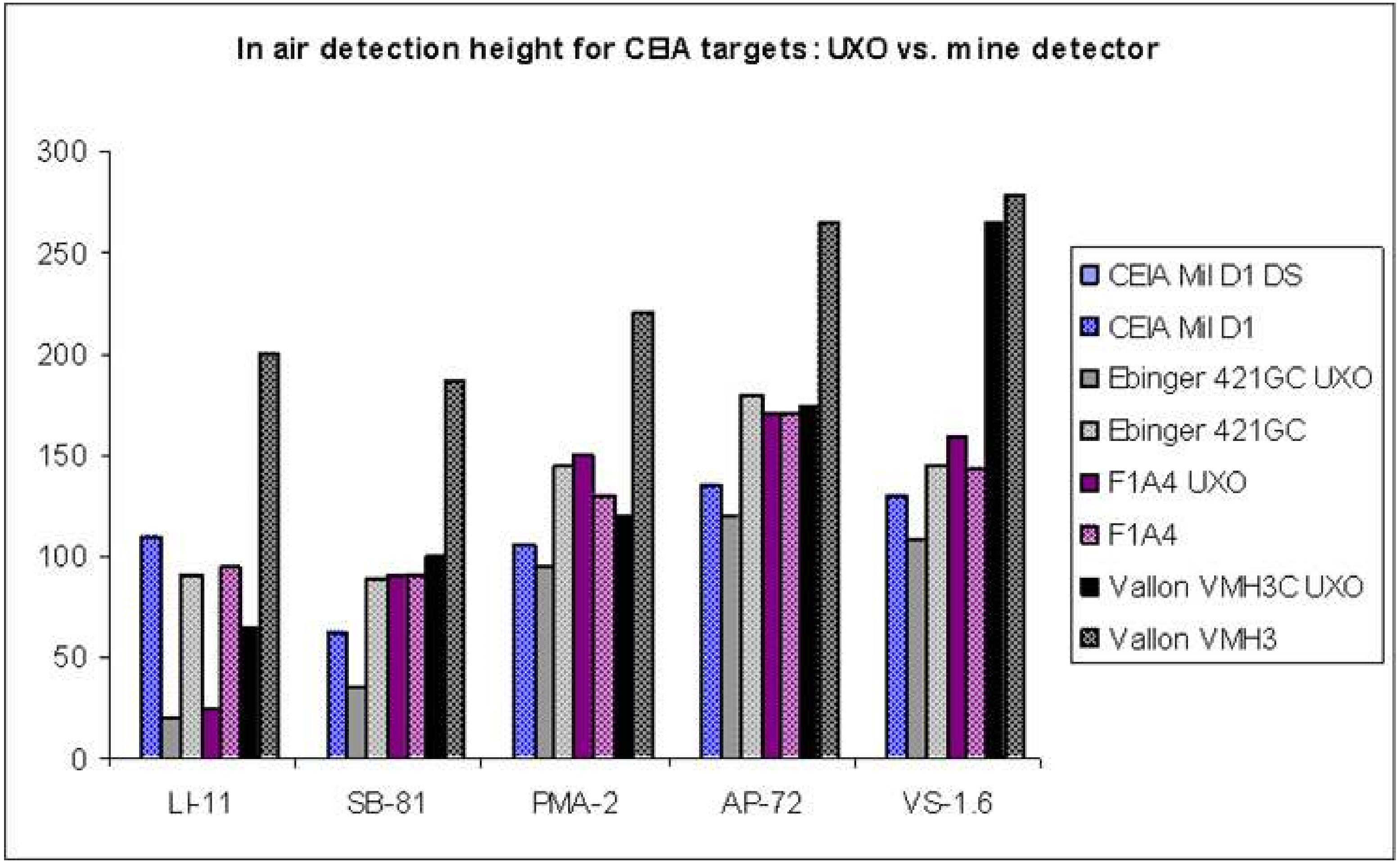


Fig. 6-15 Detection heights for mine detectors (small head) and UXO detectors (large head)
CEIA fuze stimulants, detectors set up in air and data measured in air.

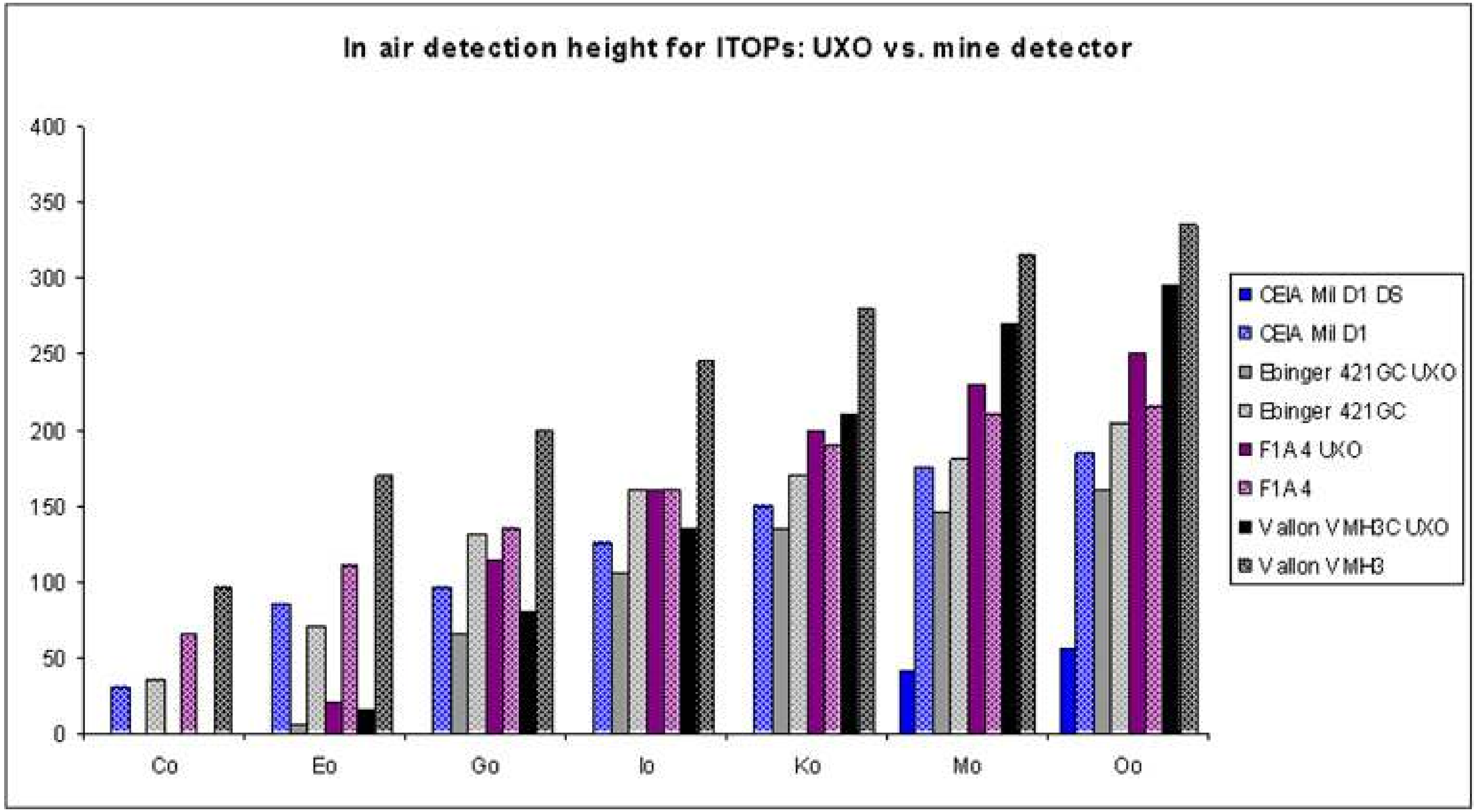


Fig. 6-16 Detection heights for mine detectors (small head) and UXO detectors (large head)
and UXO detectors (large head)
ITOP fuze stimulants, detectors set up in air and data measured in air.

7. Immunity to Environmental and Operating Conditions

7.a. Introduction

Tests in this section were selected from CWA 14747 Section 7. We focused on temperature which is the single most important environmental factor affecting the detectors.

Demining usually takes place in the open and it is carried out in a wide range of climates. It is an absolute necessity that the sensitivity of the detector can be relied upon to remain sufficient if the temperature rises or falls during a working session.

7.b. Low temperature extreme (CWA 14747 Section 7.4, simplified)

<u>Method</u>

In January 2005 the daytime temperature at Ispra was close to 0°C, so the low temperature test could be conveniently performed outdoors. Because of the limited number of hours in the day at the correct temperature, we were obliged to shorten the test, and the repeatability on set up test which is recommended in CWA 14747 for this test was omitted. The temperature during the time within which data was recorded remained within the range -3.9 to +3.1 °C throughout.

<u>Results</u>

See graph overleaf.

<u>Discussion</u>

The drift at 0°C is somewhat lower than that seen at room temperature (Fig. 6.2) for most detectors. In other respects, the behaviour is similar at the two temperatures, in particular that the UXO models show worse drift.

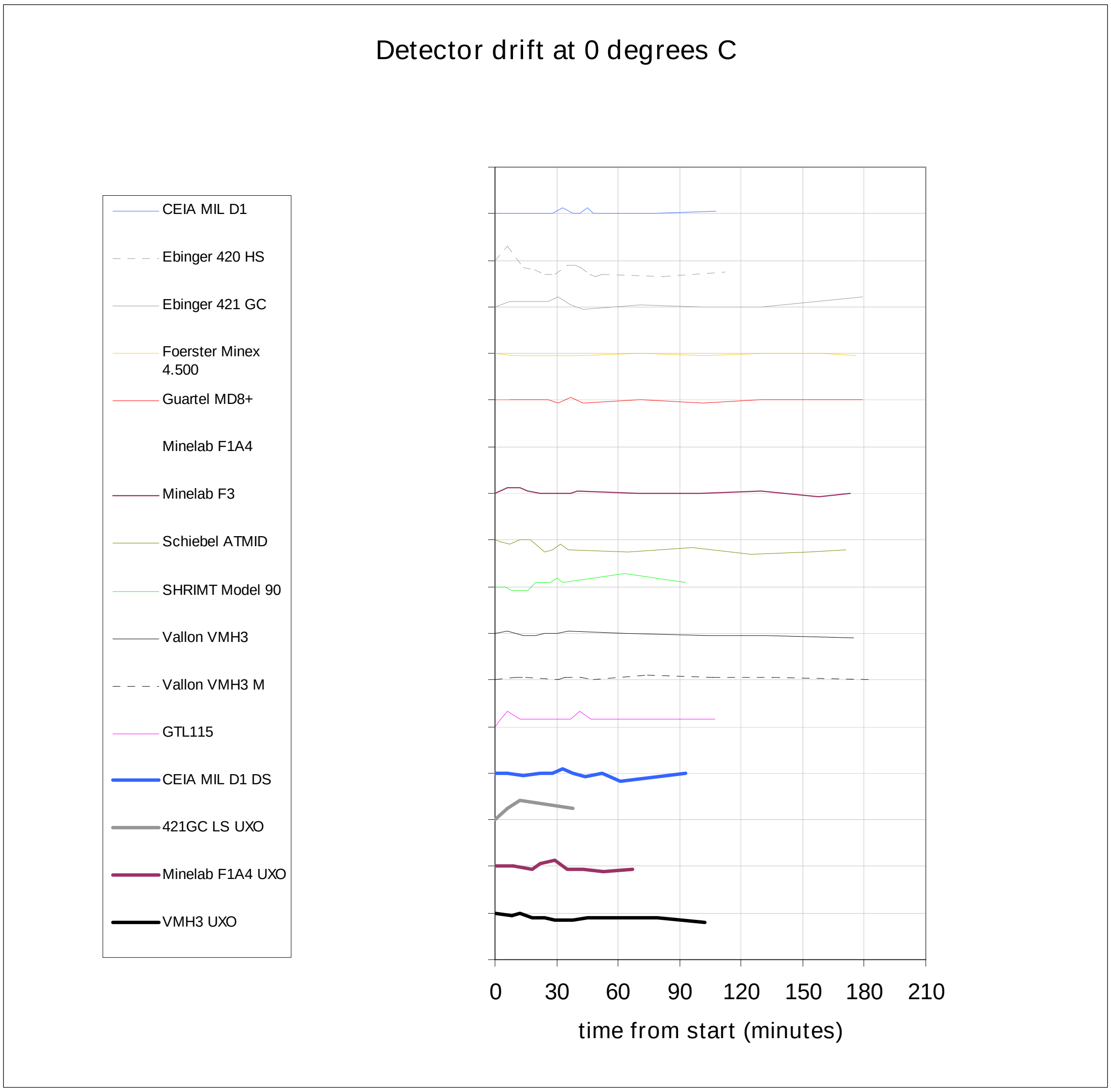


Fig. 7-1 Sensitivity drift at 0°C. The sensitivities are normalised to their starting values. For all plots, one vertical division represents 50% drift. The starting point for each plot is offset by one division with respect to its neighbour.

7.c. Temperature shock (CWA 14747 Section 7.5)

Method

This test is intended to simulate the case where a detector is brought from a cold store and has to be switched on and used immediately at ambient temperature. Again, we took advantage of the prevailing weather and cooled the detectors by leaving them outside the lab for a few hours when the temperature was near to 0°C.

Results

See graph overleaf

Discussion

For most of the detectors even this quite severe shock has only a small effect on sensitivity. The Model 90 stands out as being most seriously affected and the GTL 115 and 421GC also have some problems.

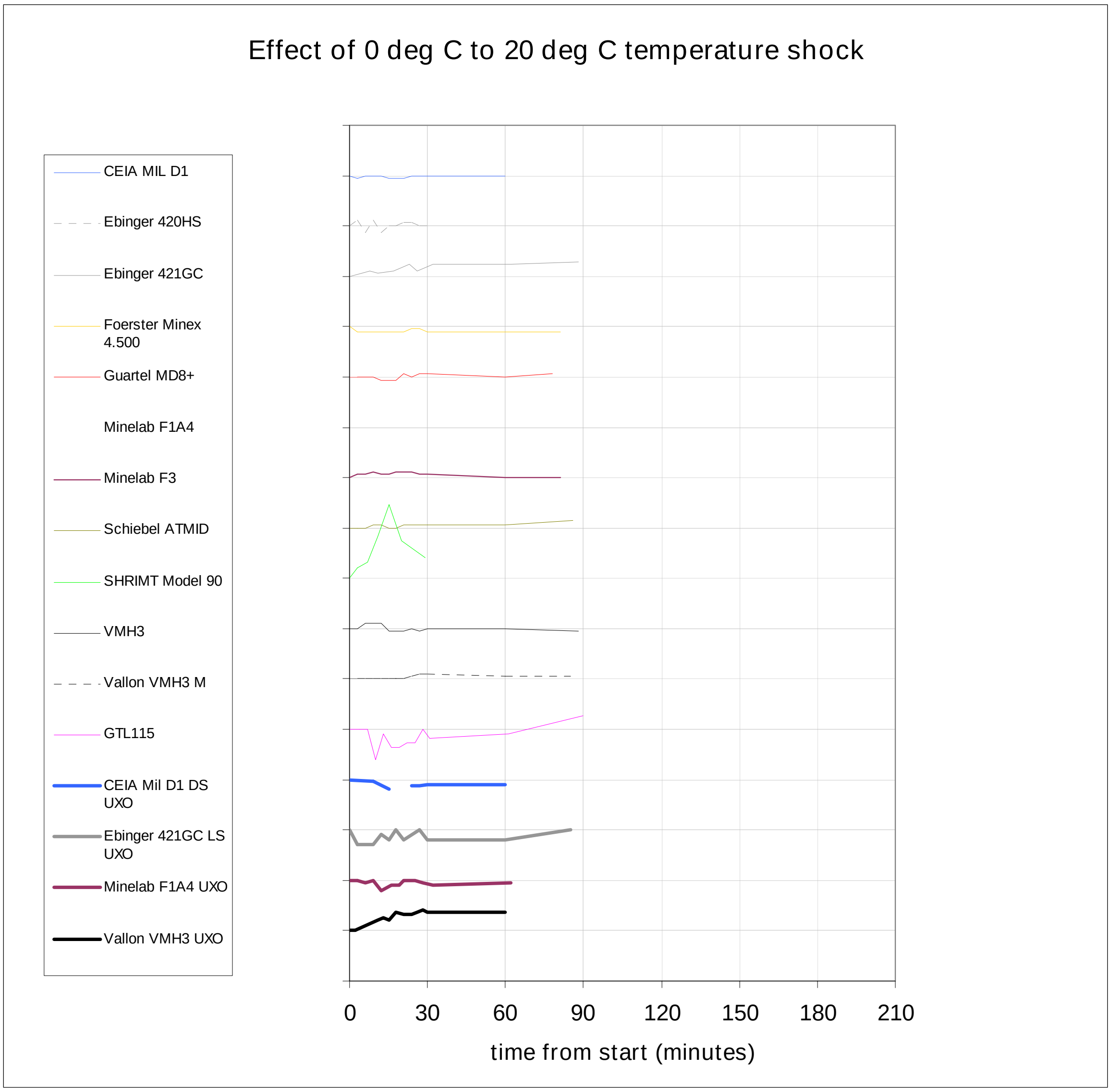


Fig. 7-2 Effect on sensitivity of a temperature shock from 0°C to 20°C. The sensitivities are normalised to their starting values. For all plots, one vertical division represents 50% drift. The starting point for each plot is offset by one division with respect to its neighbour.

7.d. High to low temperature shock (non CWA 14747)

Method
The detectors were switched off and heated to 60°C, ambient humidity, in a climatic chamber. Each detector in turn was removed from the chamber, wrapped in an insulating blanket and taken outdoors, where the repeatability on set-up test was conducted. During the test, an infrared thermometer was used to read the temperature of the search head and control box from a metre or two away.

Results
Percentage changes in the detection height, with respect to the mean, over the five repetitions are shown in table 4 overleaf, together with the temperatures.
SHRIMT Model 90 is the only detector which stopped functioning after heating in the chamber. When it was completely cool, the next day, it functioned as normal.

Discussion
As expected the range of variation is greater than for the room temperature repeatability on set up. CEIA MIL D1, Minelabs and Foerster Minex, which showed good repeatability on set up at room temperature, also show it during the temperature shock, but this is not true of the MD8+, which was much less repeatable during the temperature shock. Ebex 421GC, F3, MIL D1 DS and VMH3 M and VMH3CS UXO seem to show mainly rising sensitivity as temperature fell, Ebex 420HS and VMH3 show mainly falling sensitivity.

7.e. Recommendations for Temperature Tests

If the result seen in Section 7.b, that low temperature drift is lower than room temperature drift, is generally true, then this test is of limited use and can be removed from CWA 14747.

The temperature shock tests in 7.c and 7.d appear to yield most information and to be easiest to perform.

Consideration could also be given to shock tests simulating realistic, rather than extreme, temperature changes e.g. 40°C as the upper temperature, since these would be easier to realise and the results would be more directly applicable to field situations.

The infrared thermometer was found to be very convenient for these tests and its use should be included as a suggestion in CWA 14747, with preference for a model which has a laser-pointer to indicate the spot to which the reading refers, as was used here.

Table 4 Repeatability on set up after high to low temperature shock

	Time	T(℃) search head	T(℃) control box	Max Height (mm)		Time	T (℃) search head	T(℃) control box	Max Height (mm)
CEIA	0	42	48	160	SHRIMT	0:00	49	52	Sounds Contin-uously
Mil-D1	0:01	36	44	160	Model 90	0:11			
	0:02	33	42	165					
	0:03	28	38	160					
	0:04	26	38	160					
Ebinger	0	49	56	130	Vallon	0	43	48	185
Ebex	0:03	23	27	195	VMH3	0:01	38	44	210
420 HS	0:05	19	23	145		0:04	28	40	225
	0:07	16	20	155		0:06	18	34	245
	0:09	16	21	195		0:08	14	25	245
Ebinger	0	48	55	215	Vallon	0	53	54	240
Ebex	0:01	33	51	150	VMH3 M	0:02	42	52	240
421GC	0:04	12	40	125		0:03	38	50	245
	0:06	10	35	130		0:04	33	46	210
	0:09	8	32	130		0:05	32	42	210
Foerster	0	53	54	205	BGIF	0	42	57	80
Minex	0:01	42	52	205	GTL115-2	0:02	36	50	90
4.500	0:02	38	50	200		0:03	29	44	120
	0:03	33	46	200		0:05	15	36	75
	0:04	32	42	200		0:10	17	33	80
Guartel	0	43	52	150	CEIA	0	50	54	405
MD8+	0:03	38	47	130	MIL D1 DS	0:02	35	46	390
	0:04	34	44	120	(UXO)	0:03	28	43	360
	0:05	31	42	120		0:05	26	41	380
	0:06	27	40	125		0:06	23	41	370
Minelab	0	49	53	180	Ebinger	0	47	56	120
F1A4	0:01	40	48	175	421 GC LS	0:01	23	48	130
	0:03	34	44	175	(UXO)	0:04	18	44	135
	0:06	28	41	185		0:06	9	38	120
	0:07	24	37	185		0:09	9	36	150
Minelab	0	48	49	175	Minelab	0	48	46	215
F3	0:01	36	46	170	F1A4	0:02	29	37	215
	0:03	26	42	170	(UXO)	0:05	24	31	215
	0:04	23	38	170		0:07	18	32	215
	0:07	18	33	160		0:09	18	30	215
Schiebel	0	49	53	205	Vallon	0	47	52	160
ATMID	0:04	36	49	180	VMH3 CS	0:02	30	46	160
	0:06	27	43	190	(UXO)	0:04	26	44	170
	0:08	25	41	185		0:06	21	41	150
	0:10	23	40	210		0:08	17	36	140

8. Detection capability for targets buried in soil

8.a. Minimum detectable target as a function of depth in soil (CWA 14747 Section 8.2)

Method

In-soil detection depths were determined according to the method of CWA 14747 Section 8.2.3 using the two soil boxes with the Napoli volcanic and the Montagnola terra rossa soils. The detectors was switched on and adjusted to the soil and then swept over the surface on laths 30 mm above the soil surface in accordance with CWA 14747 . Spheres of 100Cr6 steel were introduced into the vertical tubes in the boxes from below and raised and lowered to determine the detection depth. In the boxes, the soil surface can be kept very flat so the depth is more precisely defined than in the open ground. Note that the mine body is not used, so this test does not include any interaction between the detector and the void formed in the soil by the mine body.

The measurements were also conducted for the specific targets described in Section 6: the ITOP insert metal parts and the CEIA simulated fuzes. The tubes in the soil boxes, into which the targets are inserted, are not large enough to accommodate the ITOP inserts in their housings, therefore the individual metal components were used instead. Only those ITOP inserts having a single metal piece (Co, Eo,Go, Io, Mo) were used, since the configuration of the multi-component inserts (Ko and Oo) cannot be reproduced within the space available in the tubes.

Results

See figs. 8.1-8.4 below

Discussion

In the large majority of cases, for the lab-tests, the in-soil data is similar to the in-air data with the detector set up to the same soil, which was not the case in the Mozambique field trial. However, the field trial data was for complete mines and for ITOP fuze simulants in their cylindrical cases, and the targets were actually buried in the soil, not inserted into tubes which were already present. Therefore, the differences between the in-air and in-soil data observed in Mozambique appear to have been due to detection of the soil void formed by the mine body.

There are some exceptions. The Ebinger 421GC in Napoli volcanic soil with the CEIA simulant fuzes shows results in soil which are significantly higher than those measured in-air with the detector set up to the same soil. The Vallon VMH3 data in the Napoli soil and in-air with the detector compensated for the Napoli soil are very similar and show highest sensitivity of the detectors tested. However, for the specific targets on the Montagnola terra rossa the in-soil data is considerably lower than the in-air data with the detector compensated to the same soil. These data were measured on different days so that one cannot be sure that the detector was set-up equivalently on each day. It is possible that after compensation there was still some soil noise and the first operator reduced sensitivity to remove it. The anomaly is not seen in the sphere data because in this case in-soil and in-air soil compensated data were measured one after the other, with the set-up unchanged between the two.

Important Recommendation

The results seen here and in Mozambique together imply that only in-soil measurements with realistic targets with full-sized mine bodies can be trusted to give accurate indications of detection depth. Further study is recommended to confirm this finding.

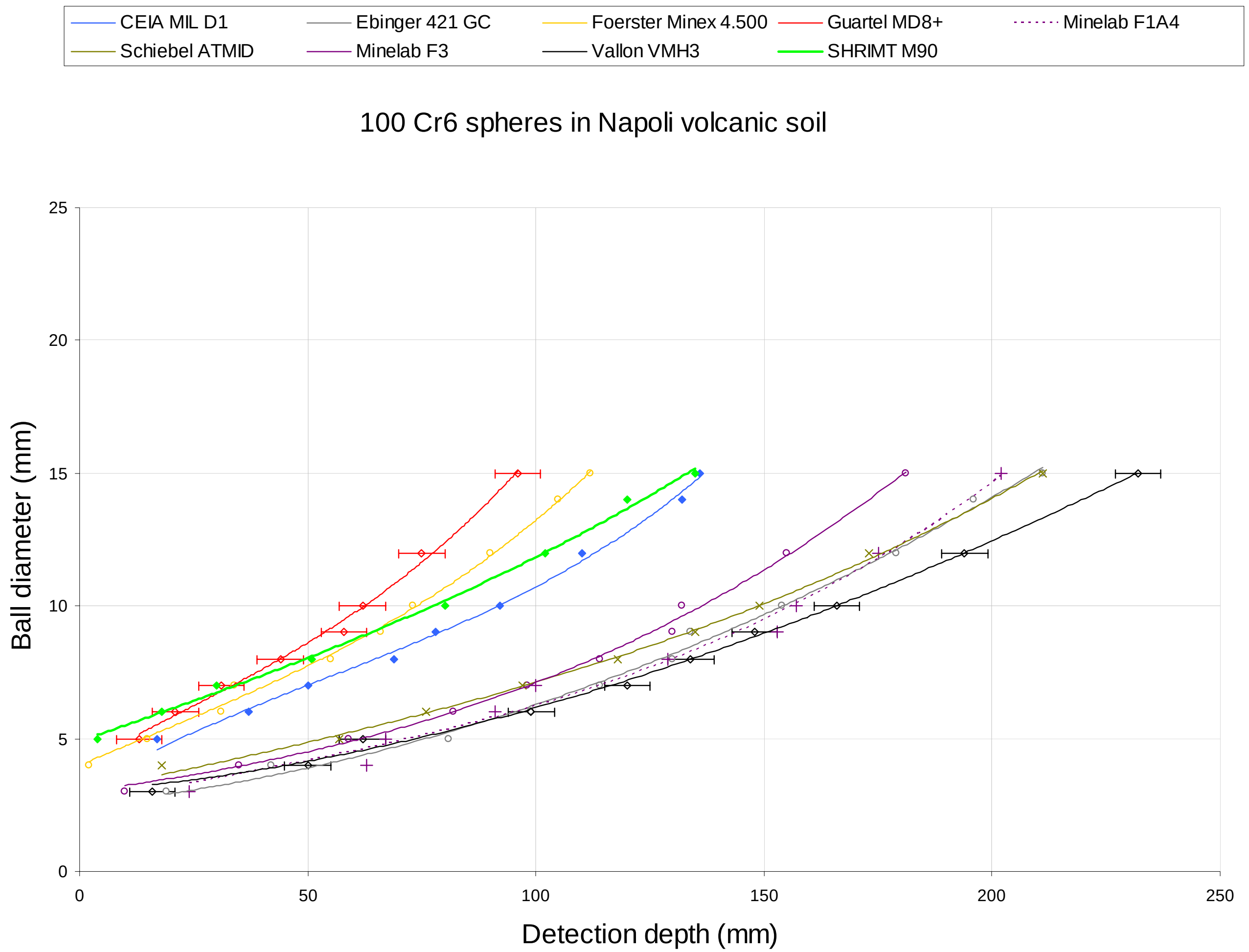


Fig. 8-1Minimum detectable sphere diameter versus depth below soil surface for 100Cr6 steel
Napoli volcanic soil; data measured in soil, detector set up to soil
The detector not shown (420HS) was unusable on this soil

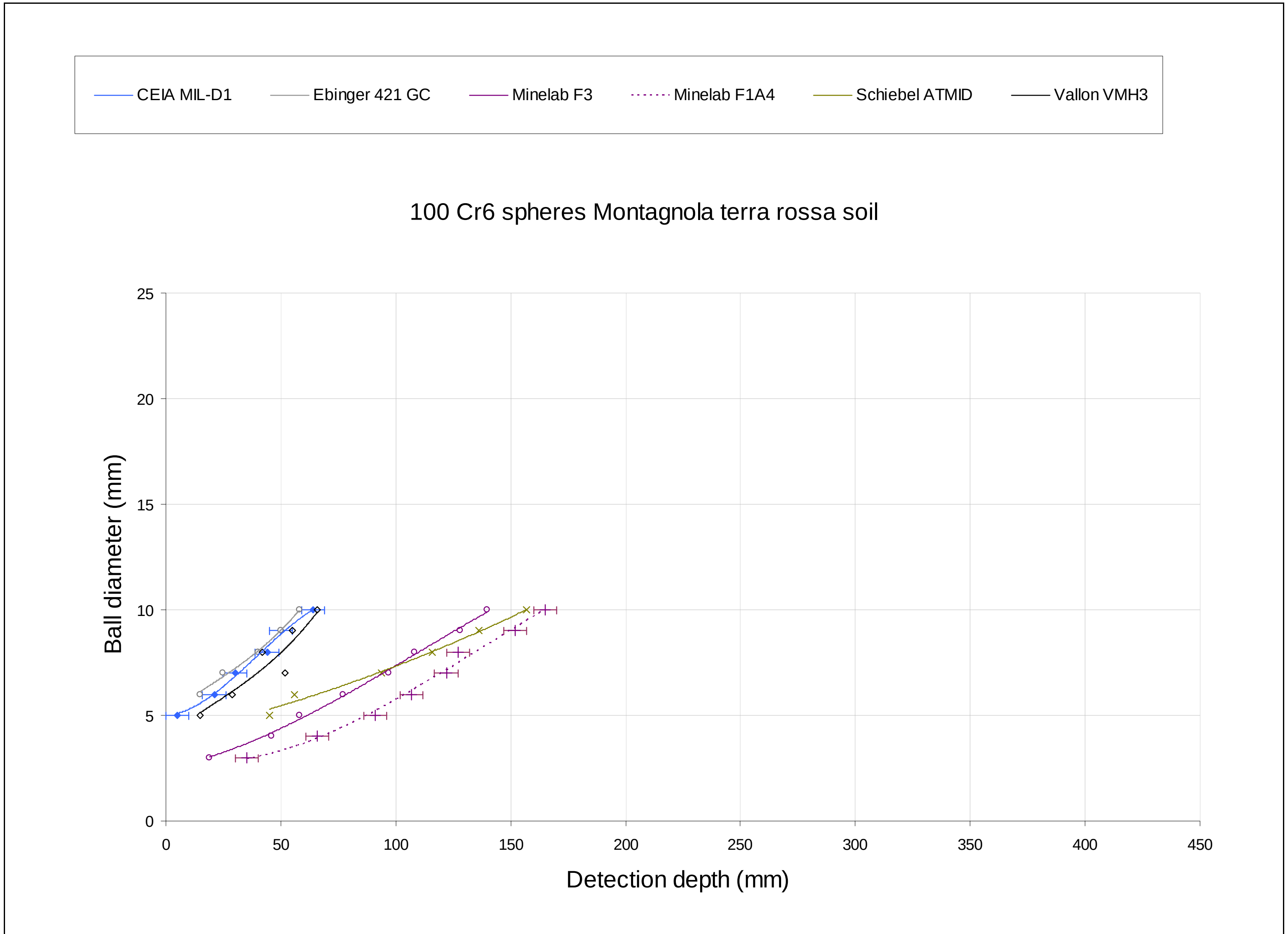


Fig. 8-2 Minimum detectable sphere diameter versus depth below soil surface for 100Cr6 steel
Montagnola terra rossa soil; data measured in soil, detector set up to soil
The four detectors not shown (Minex 4.500, 420HS, Model 90 and MD8+) were unusable on this soil

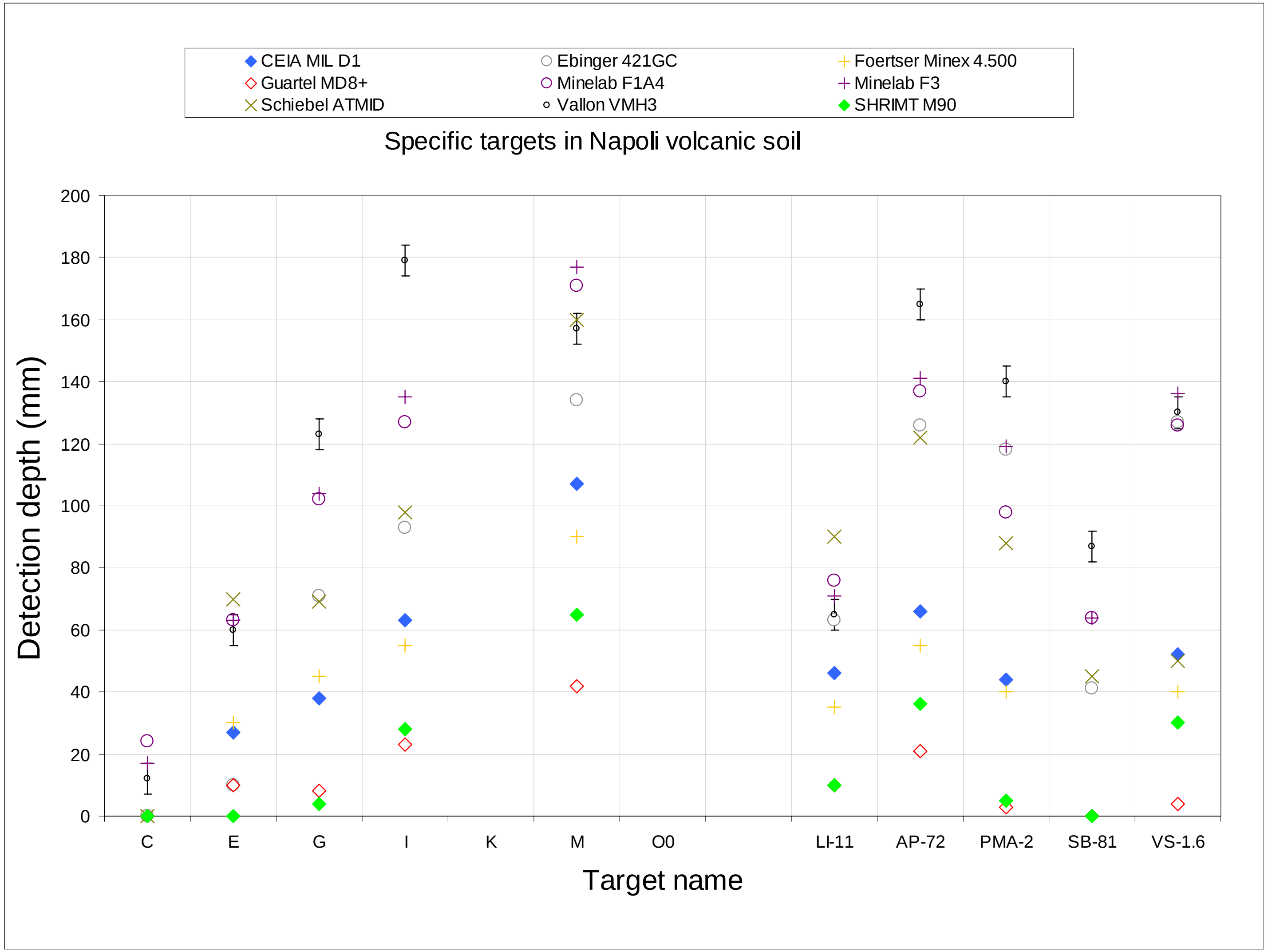


Fig. 8-3 Detection depths for specific targets
Napoli volcanic soil; measured in soil, detector set up to soil
The detector not shown (420HS) was unusable on this soil

Fig. 8-4 Detection depths for specific targets
Montagnola terra rossa; measured in soil, detector set up to soil
The four detectors not shown (Minex 4.500, 420HS, Model 90 and MD8+) were unusable on this soil

9. Operational performance characteristics

9.a. Mutual interference between detectors

(CWA 14747 Section 9.8)

Rationale

This test is mainly intended to address the circumstance where a deminer has activated a mine and been wounded. The rescue team must use detectors to search the ground as they approach the casualty because other mines could be present. In the event that the wounded deminer's detector is still operating, mutual interference between the detectors may prevent the rescue team approaching closely enough to effect evacuation.

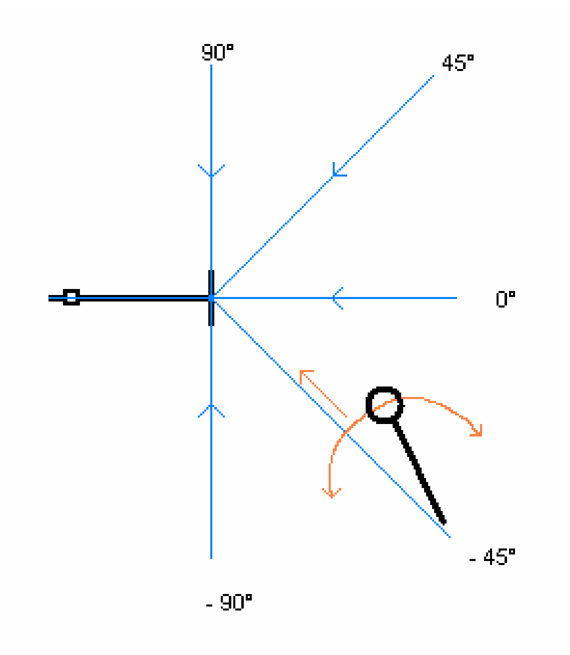


Fig. 9-1 Angles of approach for interference test

Knowledge of the interference distance can also be helpful in planning lane separations in training and tests. Contrary to what might be imagined, it is not needed for planning lane separations in real clearance operations, because the crews need to be much further apart for safety reasons anyway.

Method

The distance at which two detectors of the same model produced interference was measured. The experiment was repeated for 0, 45 and 90 degrees, in each case with the coil of one detector, representing that dropped by the injured deminer, in the vertical plane as it would most likely lie (Fig. 9.1) and the other detector, representing that of the rescue team, swept as normal during the approach.

The Minelab and Vallon VMH3CS detectors (here used with UXO head) have the possibility of interference cancellation in this context. For the Minelabs, the signal from the "dropped" detector may be treated as any other interference source. The interference cancellation circuit on the "rescue" detector is activated when the detectors approach closely enough to interfere. The VMH3CS detectors synchronise when switched on one after another when in proximity, so that their pulses fall at different times and there is reduced interference. The VMH3 with normal head, is not fitted with synchronisation.

Results

Table 5 Mutual interference between two detectors of same type

	MUTUAL INTERFERENCE DISTANCE (meters)						
	0°		45°		90 °		
Detector	No_Sync	Sync	No_Sync	Sync	No_Sync	Sync	Notes
CEIA Mil D1	0.45	na	0.45	Na	0.45	na	
Ebinger 420 HS	0.6	na	0.75	Na	0.73	na	
Ebinger 421GC	3.0	na	2.1	Na	2.1	na	Sensitive to tilt
Foerster 2FD 4.500	1.9	na	2.1	Na	2.1	na	
Guartel MD8+	0.3	na	0.2	Na	0.1	na	
Minelab F1A4	3.2	2.1	2.0	1.0	2.0	1.1	Cancellation takes 70 secs
Minelab F3	5.0	1.1	3.0	1.0	3.0	0.65	Cancellation takes 45s
Schiebel ATMID	3.0	na	3.0	Na	3.0	na	
SHRIMT Model 90	5.3	na	4.2	Na	3.0	na	Sensitive to tilt
Vallon VMH3	3.0	na	3.0	Na	3.0	na	Sync not implemented on this version
CEIA MilD1 DS	0.75	na	0.3	Na	0.3	na	Sense-head to sense-head - values not consistent
Ebinger 421GC UXO	3.1	na	6.9	Na	2.4	na	
Minelab F1A4 UXO	4.3	3.0	4.3	3.1	4.5	3.2	
Vallon VMH3CS UXO	2.7	0.25-0.45	3.2	0.1	1.0	0.25	

Note: “Sync” indicates either synchronisation of signals or activation of noise cancellation.

Discussion

There is a wide range of different distances. Some detectors show mutual interference at quite large distances, implying it would be difficult to reach a wounded deminer.
Activation of interference synchronisation does seem to help considerably, although in the wounded deminer scenario it would introduce extra delay in a situation where as little delay as possible was imperative.

If time had allowed, we would have liked to perform this test as a cross-test, i.e. to check interference between one type of detector and another, but the large number of combinations made this impractical.

NOTE: To simulate the dropped detector case, these measurements were made with the heads at right angles planes as indicated in Fig. 9.1. Interference at larger distances than shown in Table 5 may occur if the heads are in parallel planes.

9.b. Target Location Accuracy, “Pinpointing”

(CWA 14747 Section 9.2)

Rationale

Precise, accurate location of the metal object using the detector is of the greatest importance. When metal is detected, the deminer performs a fine scan, orientating and moving the head at different angles to improve the precision of location, an operation termed “pinpointing”. If the true position is known to within better than about 1 cm, the dangerous operation of excavating a mine becomes much safer and false alarms may be dug out more quickly, improving efficiency. Some detectors are better able to pinpoint the target than others, for example the double-D coil shape is advocated for this reason.
CWA test 9.2 is designed to assess the target location accuracy.

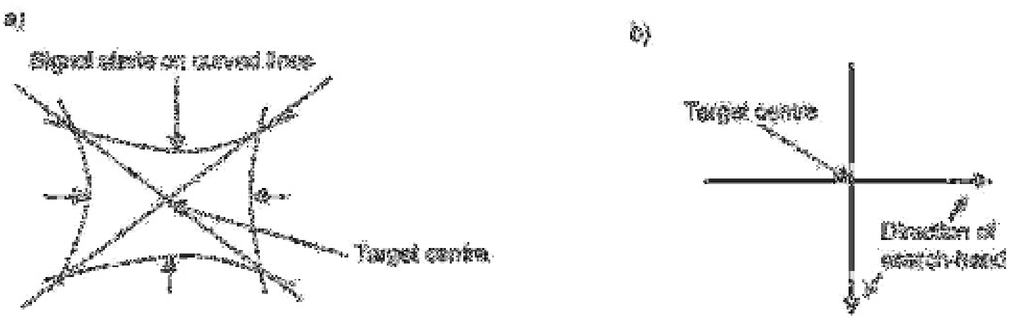


Fig. 9-2 Method used for pinpointing during laboratory tests
a) single-receive-coil detectors, b) double-D coil detectors

Method

The test technician took a 14 by 1.6 mm steel pin and embedded it at a random position in an expanded polystyrene sheet. An acrylic sheet was mounted at a fixed height above and covered with a piece of tracing paper. The detector operator, who did not know the true location of the target, which was hidden by the tracing paper, used the detector to locate it. The location so determined was marked in pencil on the paper. The paper was then folded back and the horizontal distance between the mark and the true pin location was recorded. The test was repeated ten times at 10 mm height and ten times at 50 mm height. The test technician and detector operator then swapped roles and repeated the procedure. Where practical a third detector operator also performed the test. A briefer test, only at 10 mm height and by one operator, was made on the UXO detectors.

The procedures used to locate the target (Fig. 9.2) were as follows. For the single-head detectors, the approximate position of the target was first found and then the head was advanced towards it and the leading edge of the head marked on the paper where the first sound was heard. This process was repeated for the side edges of the head, sweeping the head from each side, and then for the trailing edge, drawing the head backwards from ahead of the target. After all four operations, a curvilinear quadrilateral was marked on the tracing paper. The centre of this figure was taken as the best estimate of target location. For the double-D coil detectors, the procedure used was to draw on the paper the null lines when the head was swept in each of two perpendicular senses and take the intersection as the best estimate of target location.

Results

Values below are the average distance of the marked indication from the true target location. All values are in mm.

Mine detectors

Height	CEIA MIL D1	Ebinger 420 HS	Ebinger 421GC	Foerster Minex 4.500	Guartel MD8+	Minelab F1A4	Minelab F3	Schiebel ATMID	SHRIMT Model 90	Vallon VMH3	Vallon VMH3M
10 mm	3.3	2.1	5.8	4.1	0.5	8.0	5.6	15.9	5.9	8.0	5.2
50 mm	3.0	4.4	6.8	2.4	3.8	13.8	5.7	13.5	9.6	7.4	5.5

UXO detectors

Height	CEIA MIL D1 DS	Ebinger 421GC LS	Minelab F1A4 UXO	Vallon VMH3CS UXO
10 mm	19.8	10.5	26.8	14.9

Discussion

Of the mine detectors, only the ATMID and F1A4 failed to achieve target location accuracy better than 10 mm at both heights, and even the worst result was only 15.9 mm. The good pinpointing possible with the double-D system (Guartel, Foerster and CEIA) was evident. The 420HS also showed surprisingly good pinpointing. As expected, the UXO detectors were all less precise in pinpointing than the corresponding mine detector.

Recommendation

Since all detectors returned acceptable values, CWA 14747 Test 9.2 in its present form does not appear to be sufficiently demanding. Consideration should be given to modifying it to use larger targets at greater heights e.g. > 100 mm. Another possibility would be to adopt a more realistic pinpointing procedure: forbidding the drawing of geometric construction lines on the paper and allowing the operator to mark the estimated target location only. A further study is required to assess whether these modifications would reveal under what conditions the detectors' pinpointing ability became unacceptable.

We did find that conducting test 9.2 was an excellent means to learn how to pinpoint with each detector and would recommend it as a training procedure, independently of its value in test and evaluation.

9.c. Resolution of adjacent targets

(CWA 14747 Section 9.4)

Rationale

The objective of this test is to determine the ability of the detector to discriminate between targets that are buried close to each other. Such a situation could arise in the field either because a mine had been buried next to an innocuous metal object or because two mines had been buried close together. The deminer should be able, as far as possible, to recognise from the metal detector indications that two objects were present, not just one.

Method

The test is performed blind - the target separation was not revealed to the operator.
The "small" target was a 10 mm diameter 100Cr6 sphere.
The "large" target was a 50 mm diameter, 4 mm thick ferritic steel disc.

The test was performed in the Gauss lab sandpit, with the targets placed on the surface and at a depth of 50 mm, as applicable. The detector was swept over the pair of targets in all directions to try to resolve them. The targets were moved closer together until the minimum separation was achieved, at which two resolvable alarm indications from the targets were still produced.

For the buried target test, CWA 14747 allows either one target to be unearthed and re-buried each time to change the separation or a set of targets at various distances to be used. In the indoor sand pit it is convenient to move the buried target, so this method was adopted.

Results

Table 6 Resolution of two different targets

DETECTOR	Target 1	Target 2	Depth	Distance between edges (mm)	Distance between centres (mm)
VMH3_M	Large	Large	Flush	220	270
VMH3_M	Large	Small	Flush	300	330
VMH3_M	Small	Small	Flush	230	240
VMH3_M	Large	Small	50 mm	310	340
VMH3_M	Small	Small	50 mm	200	210
VMH3	similar results for initial setups to those of VMH3_M. Therefore discontinued				
Guartel (mode:II)	Small	Small	Flush	95	105
Guartel (mode:II)	Small	Small	50 mm	110	120
Guartel (mode:II)	Large	Small	50 mm	215	245
Guartel (mode:II)	Large	Small	Flush	160	190
CEIA	Small	Large	Flush	285	315
CEIA	Small	Small	Flush	165	175
CEIA	Small	Small	50 mm	140	150
CEIA	Small	Large	50 mm	270	300
FOERSTER	Small	Small	Flush	110	120
FOERSTER	Small	Large	Flush	165	195
FOERSTER	Small	Small	50 mm	110	120
FOERSTER	Small	Large	50 mm	220	250
F1A4	Small	Small	Flush	205	215
F1A4	Small	Large	Flush	275	305
F1A4	Small	Small	50 mm	185	195
F1A4	Small	Large	50 mm	215	245
F3	Small	Small	Flush	240	250
F3	Small	Large	Flush	255	285
F3	Small	Small	50 mm	180	190
F3	Small	Large	50 mm	185	215
421GC	Small	Small	Flush	215	225
421GC	Small	Large	Flush	385 going from large to small 295 small to large	415
421GC	Small	Small	50 mm	185	195
421GC	Small	Large	50 mm	305 (235 small to large)	335

DETECTOR	Target 1	Target 2	Depth	Distance between edges (mm)	Distance between centres (mm)
420HS	Small	Small	Flush	200	210
420HS	Small	Large	Flush	225	255
420HS	Small	Small	50 mm	180	190
420HS	Small	Large	50 mm	380 (260 small to large)	410
					0
ATMID	Small	Small	Flush	195	205
ATMID	Small	Large	Flush	310 (370 small to large)	340 (400)
ATMID	Small	Small	50 mm	130	140
ATMID	Small	Large	50 mm	330 (350 small to large)	360 (380)
Model 90	Small	Small	Flush	115	125
Model 90	Small	Large	Flush	205	235
Model 90	Small	Small	50 mm	220	230
Model 90	Small	Large	50 mm	200	230

Discussion

For the Guartel MD8+, the signal LEDs on the handle facilitate discrimination. When going over two closely spaced targets, one can see the LEDs rapidly swapping positions.

In both Large-Small combinations, a third (ghost) signal appears between the two targets for the Guartel MD8+. The same occurs for the SHRIMT Model 90 for small and large targets, flush.

The resolution ability of the Model 90 is sensitive to speed.

10. Evaluation of Ergonomic and Operational aspects

10.a. Overall Rationale for Tests

Ease of handling of detectors is of higher importance in humanitarian demining than in military demining because detectors in humanitarian operations are used more intensively. Daily use for 6 hours a day, for months at a time, is common. Good ergonomic design can do much to help. Operator fatigue will be reduced if the detector is light and well balanced, that is to say, if its centre of mass is near the operator's hand. The detector will be easier to manipulate if the mass is distributed near to the axis about which it is normally swung, that is to say, if its moment of inertia about this axis is small. The value of a detector to an organisation will be higher if it is easy to store, transport and reassemble. The tests in this section are intended to assess these factors.

10.b. Weight factors (CWA 14747 Section 10.2, parts 4, 5 and 6)

Fig. 10-1 Mounting of a detector on the pendulum for measurement of moment of inertia. The detector is first attached to the "forearm" and extended to a standard length and angle – left hand photo. The "elbow" is unlocked and moved through 90°, so that the detector coil is in a vertical plane, and re-locked – centre photo. The forearm pivot is carefully allowed to rotate 180° about the horizontal axis to the equilibrium position – right hand photo. The period of oscillations of the pendulum about this axis is used to determine the moment of inertia about what would be a *vertical* axis when the detector is in normal use.

<u>Method</u>

Each detector was weighed with an electronic suspension balance in its configuration as used and in its transport case. Where applicable, the detector was weighed in its different operating configurations such as with each choice of battery pack, with and without extensions to the handle, or with the electronic control box mounted on the handle or worn separately. Where a field backpack was provided, the mass in this was also recorded.
A representative operating configuration was adopted in which the centre of the head was 700 mm in front of the operator's wrist and 1100 mm below it. The detector was mounted on the pendulum "forearm" and set up in this configuration, as far as its design allowed. It was dismounted and its centre of mass (CoM) position was determined by hanging it from a thin

string in two approximately perpendicular orientations.[5] The detector was remounted on the pendulum and the horizontal distance from the forearm "elbow" to the CoM noted.

Its moment of inertia was then determined as follows. The forearm elbow was unlocked and the forearm was elevated through 90° so that the outward horizontal direction became the upward vertical. The elbow was re-locked and the forearm was gently allowed to rotate about the pivot so that the CoM of the forearm and detector combination was at its low point (fig.10.1) . The pendulum was swung and its period T recorded. The period is dependent on the moment of inertia (MoI), I_1, mass m_1 and CoM position l_1 of the detector, and on the corresponding quantities for the forearm I_2, m_2 and l_2, by the formula:

$$T = 2\pi\sqrt{\frac{(I_1+I_2)}{(m_1l_1+m_2l_2)g}}$$

$$I_1 = \frac{T^2 g}{4\pi^2}(m_1l_1+m_2l_2) - I_2$$

I_2, m_2 and l_2 have been determined independently so I_1 may be inferred if T and l_2 are measured. The MoI so determined is that for rotations about a vertical axis at the operator's wrist in normal use.

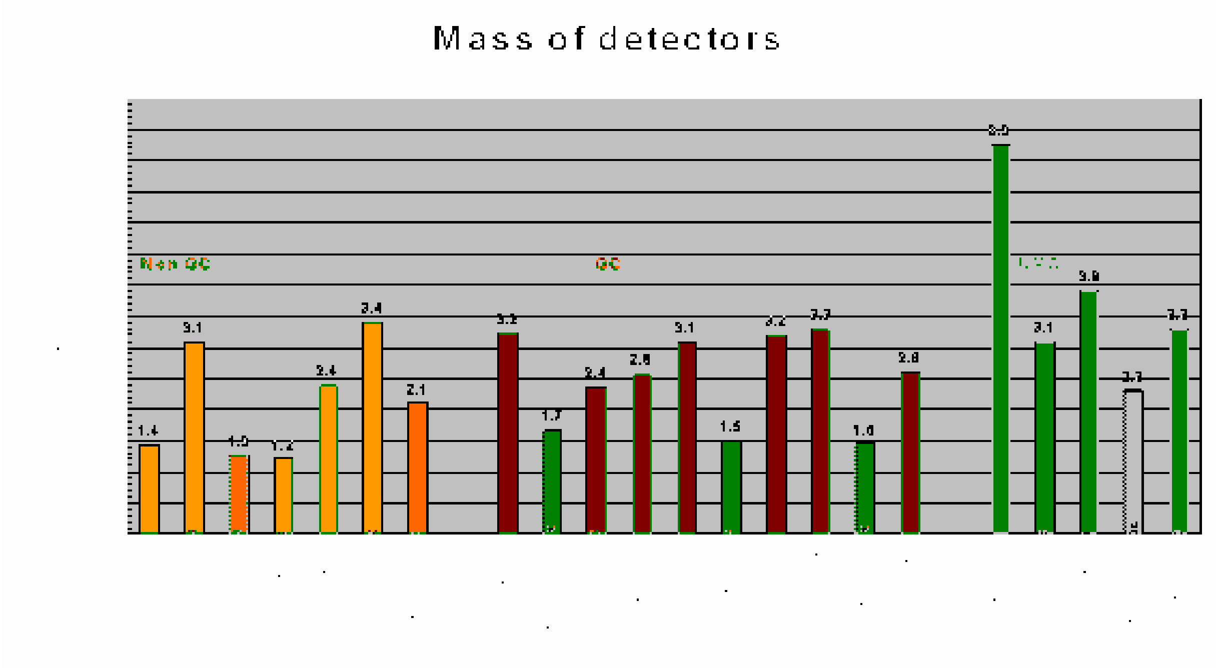


Fig. 10-2Total masses of the detectors as operated. In cases where the control box is detachable, the mass without it is shown as a hatched bar. For the Model 90 this is the only configuration possible.

Masses of the Ebinger 421 GC and 421 GC UXO include the extension bar and rechargeable battery pack.

[5] In cases where the CoM position was outside the body of the detector i.e. in the adjacent space, a piece of paper was attached to mark the position.

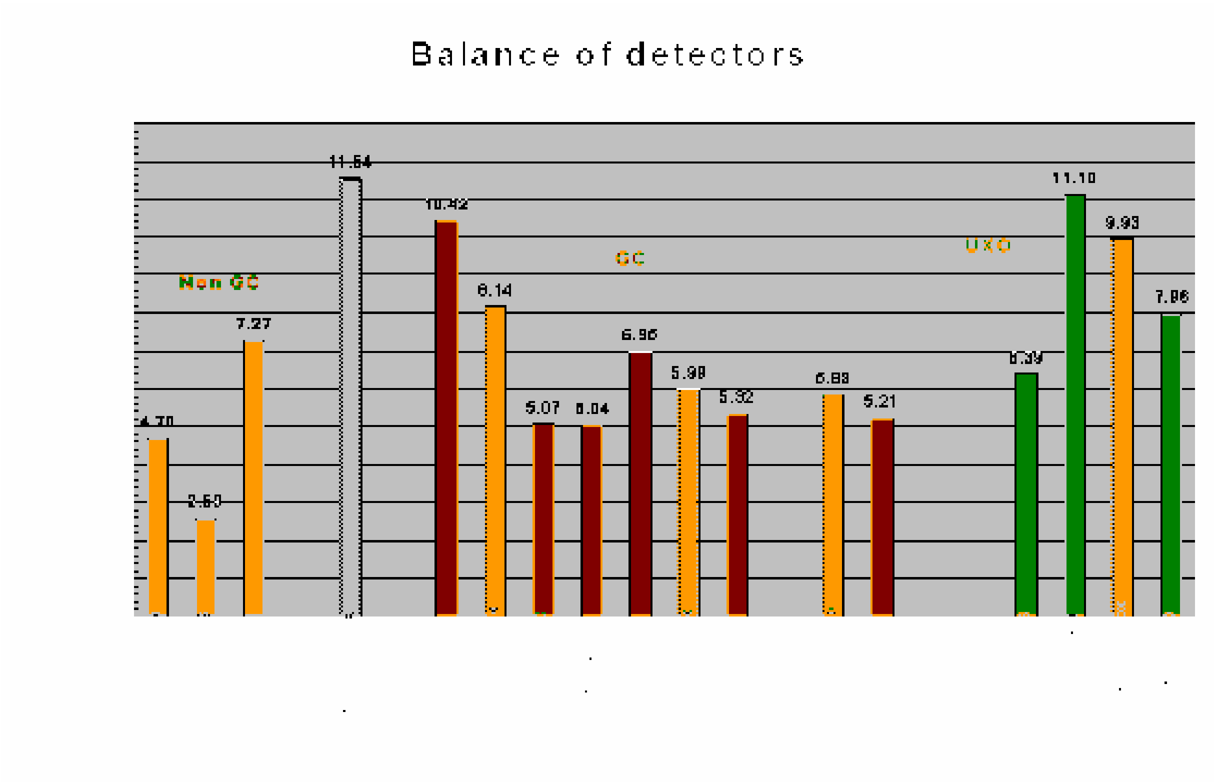


Fig. 10-3 Balance of detectors, as indicated by the first horizontal moment i.e. the weight multiplied by the horizontal distance between the operator's wrist and the centre of mass.

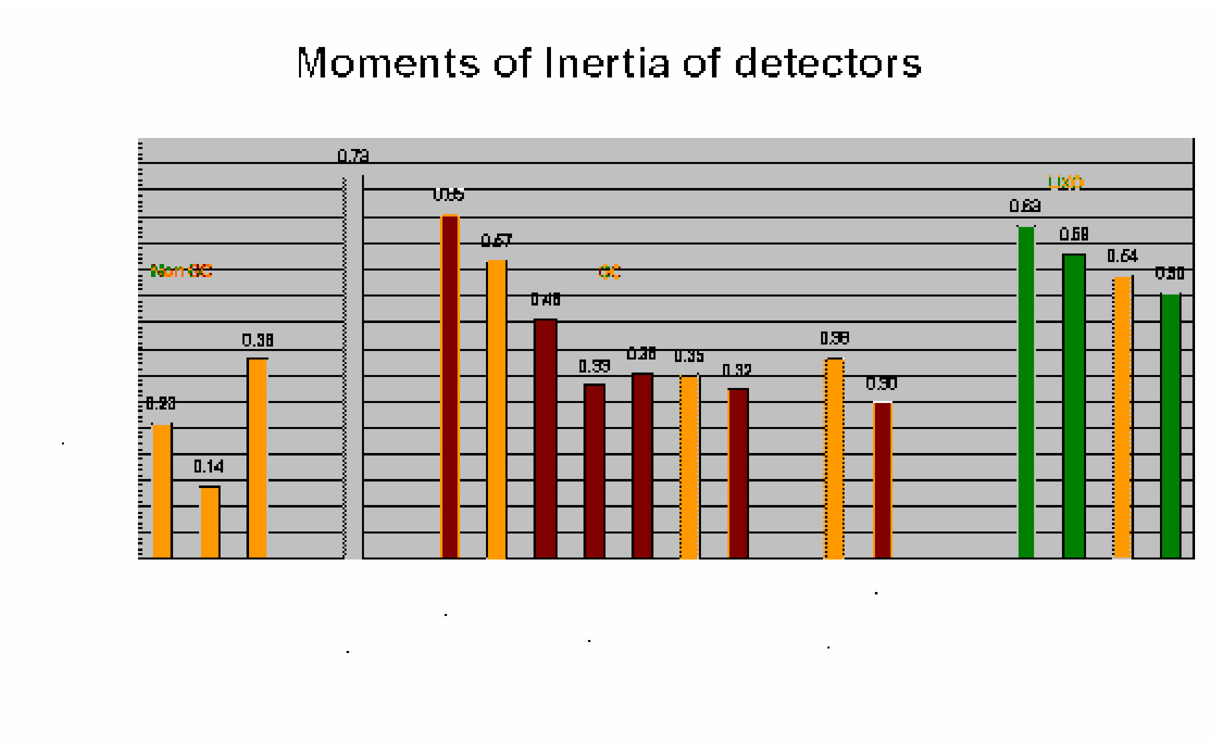


Fig. 10-4 Moments of inertia of the detectors, for rotations about a vertical axis at the operator's wrist

Discussion

The soil compensating detectors are usually heavier than the simpler non-soil compensating designs and the large head detectors are also mostly heavier, as would be expected. The Model 90 is heavy because it contains a second sensor (UHF). The double-head CEIA DS is exceptionally heavy, but it is a different class of detector, used for finding very large, deep UXO. The Ebinger 420HS is not configurable as a full length detector but only in short-format, so it is inevitably lighter than the other detectors. The masses for the Schiebel ATMID and AN19, SHRIMT Model 90, CEIA Mil D1, Minelab F1A4 and F1A4 UXO are shown in Fig. 10.2 both as total masses and as masses without the control box, because for these detectors the control box may be worn on the waist band or over the shoulder. As can be seen, wearing the control box separately reduces the mass held in the hand by about 1.5 kg. It is much less convenient though and the general trend of the industry is towards detectors with electronics integrated in the shaft or handle.

Good balance is mainly shown by detectors with small or light heads. The balance figures shown by detectors with larger heads are poorer (MD8+, CEIA MIL D1, F1A4 UXO, VMH3 UXO). Removing the control box from the shaft, for the detectors where it can be dismounted, does not alter the balance very much, because it is usually mounted under the hand-grip near the CoM.

The results for the moment of inertia show the same trends as for the balance, with the notable exception that the Ebex 421GC has large i.e. poor MoI, in spite of having quite good balance. The Model 90 has the largest MoI, because the mass of the UHF block is mounted on the head, at the furthest point from the axis of rotation.

10.c. Battery Tests (not according to CWA 14747)

Rationale for tests

Adequate battery life is of considerable importance. At minimum, it must be sufficient for a deminer to work for a whole shift without the batteries failing. The cost of batteries can also be a significant budget item, especially if non-rechargeable ones are used.[6] CWA 14747 Section 7.6 defines a procedure to measure the battery life by monitoring the sensitivity at half-hour intervals. Since the sensitivity measurement (see below) requires a human operator, this test implicitly requires the continuous presence of engineers for several days. Resources in the STEMD project were not sufficient to ensure this so, we adopted simplified procedures, not fully compliant with CWA 14747.

Test 1 : Effect of wrong insertion of the batteries

All tested detectors still function after inversion of polarity of the batteries.

Test 2 : Effect of reduction of voltage

The batteries were replaced with perspex cylinders fitted with connections to an external power supply. The supplied voltage and current drawn were monitored and the sensitivity measured i.e. the detection capability for a specific target.

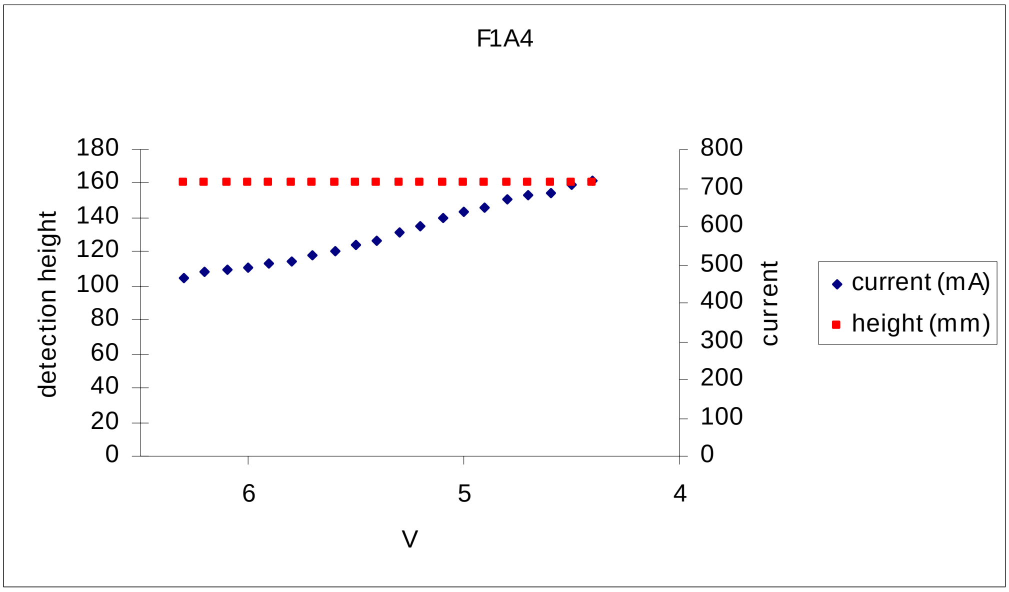


Fig. 10-5 Effect of reducing supply voltage for the Minelab F1A4. This detector takes four alkaline cells of size “D” (LR20 or MN1300).

Typical results follow the pattern shown in Fig. 10.5 for the Minelab F1A4. One surprising observation was that the current drawn from the batteries increased as the batteries discharged and their voltage dropped. This is not unique to the F1A4, a similar trend was seen for all

[6] Policy on whether or not to use rechargeable batteries at the moment varies amongst demining organisations, but their use is likely to become more common since they are becoming more widely available as consumer products. Chargers for small batteries may be damaged by power from an unfiltered portable generator. One solution is to use car batteries as an intermediate power supply.

detectors for which the test was carried out. The detectors' internal power regulators approximately draw constant power, rather than drawing constant current or presenting constant load to the battery.

Most of the detectors' sensitivities are unaffected by the initial discharge of the battery, implying that the internal power regulation is very good. In all detectors, there was little or no drop in sensitivity before the low battery alarm indication came on. The price paid for this is that a significant part of battery energy is never used – usually the alarm comes on when the batteries have discharged to about 1.1 to 1.3 V for each cell.

The Ebinger 41GC is an exception in showing higher sensitivity at the start of the discharge cycle. The Ebinger detectors begin to give a low-battery indication after about 12 hours with the C-cell pack but remain usable for a further three hours or so.

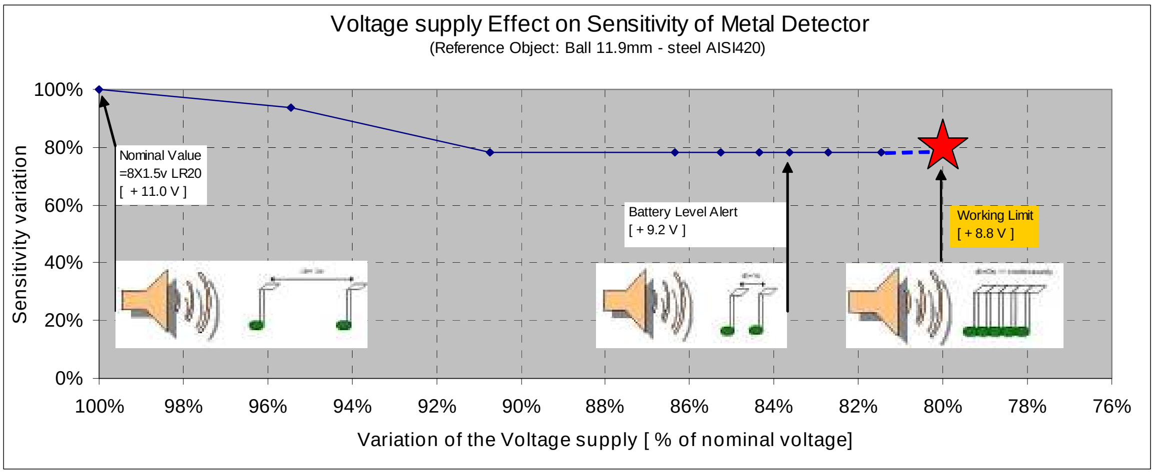


Fig. 10-6 Effect of reduced battery voltage on sensitivity of Ebinger 421GC

Test 3 : Battery life

A fresh set of high-quality, consumer-grade alkaline batteries, either Duracell Plus, Energizer or Duracell Ultra M3, was bought at a local supermarket or hardware store. The detector was switched on and left untouched until the battery had discharged.

Notes

The question of whether the battery life is affected by how frequently the detector alarms during the test was raised at the CEN Workshop. In the voltage reduction tests described above it was found that the alarm takes only a small additional current, so that it will make little difference to the battery life how frequently it sounds. The highest percentage extra current drawn by the alarm is in the F1A4, which draws 7% extra. So even in the extreme case that its alarm was sounding 15% of the time, the battery life would only fall by 1%.

The Guartel MD8+ is equipped with a motion sensor which puts it into a low-power sleep-mode if it is not moved for one minute. Therefore, for the battery life test it was mounted on the scanner, which was programmed to move periodically to prevent the detector "sleeping".

In the tests for the mine detectors, the alarm did not sound at all. The UXO detectors were passed mechanically over a target during discharge so that the alarm was sounding periodically, because the test was done before it was realised that the alarm made no significant difference.

Results

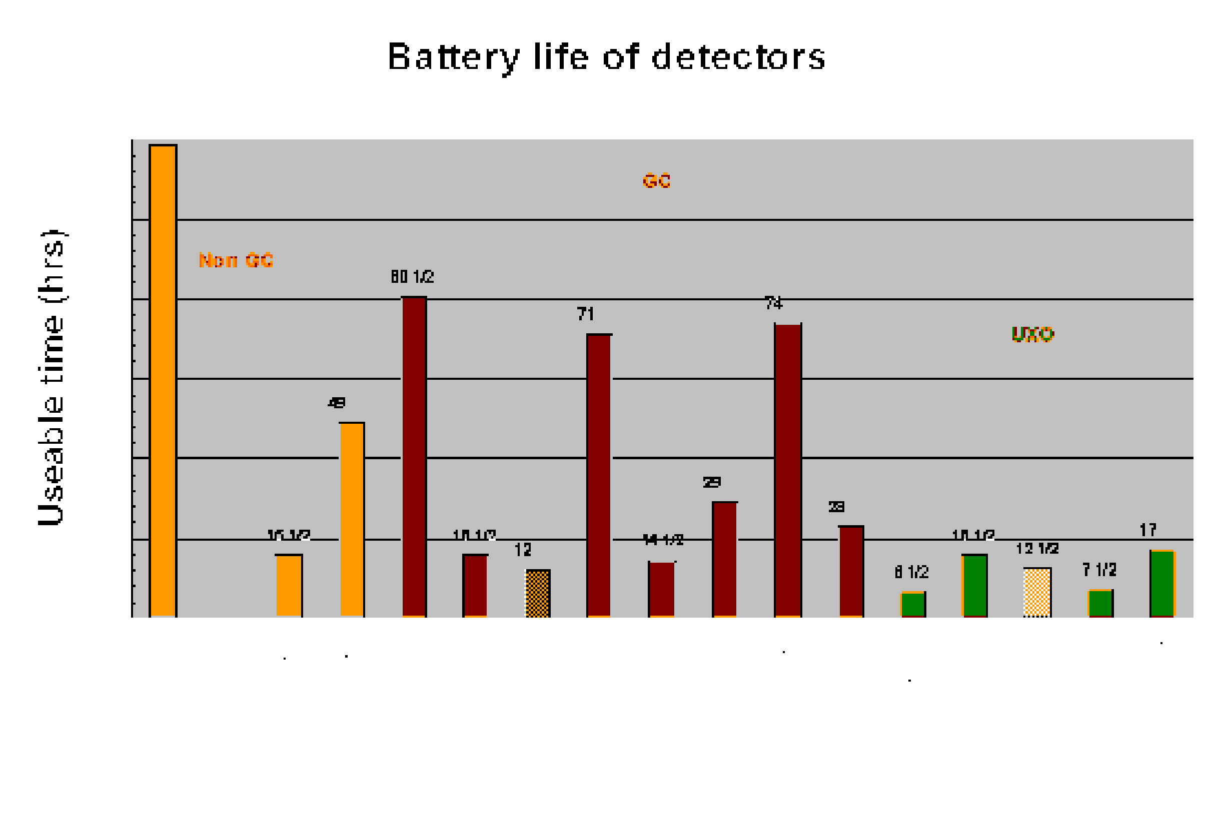


Fig. 10-7 Ultimate battery life for detectors, continuing beyond the initial alarm until detector unusable.

There are large differences between one detector design and another[7].
Amongst the mine detectors (not UXO) , the continuous-wave detectors (Foerster Minex, CEIA MIL D1, SHRIMT Model 90, Schiebel ATMID) gave longer battery life than the pulsed –induction designs, with the exception of the AN 19 which displayed the longest battery life and is a pulsed induction detector.

There is no general tendency for ground-compensating detectors to give shorter or longer battery life than non ground-compensating detectors.

The Model 90 gave a much longer battery life than described in its manual, where only a life of not less than 8 hrs is claimed, but this refers to the life with R6 zinc-carbon batteries, rather than LR6 alkaline.

[7] No figures are given for the Ebinger 420 HS because in normal use its battery is kept constantly recharged by its solar panel, so it cannot be meaningfully compared with the other detectors.

The UXO detectors all have limited battery life. This seems to be an inevitable consequence of the greater power required to energise the larger coils. We are not aware of any manufacturer who has succeeded in making a large-coil detector with a battery life of 24 hrs or greater.

10.d. Sound Level

General Assessment

All the detectors subjected to full testing give sufficient sound output to be heard by a person of normal hearing. The higher of the two tones of the Foerster Minex 4.500 is hard to hear for people with impaired hearing. The GTL115-2 when operated with its external speaker is difficult to hear, even for those with good hearing.

Detailed Measurements

For some the mine detectors, we conducted a more detailed investigation, going beyond the requirements of CWA 14747 and measuring the audio power output. All detectors were used with their external speaker, except the ATMID and Model 90 which do not have one. The sound meter was placed 2m from the detector

The sound produced by the detector on passing over the 100 mm 100Cr6 ball target at different heights (50, 100, 150, 200, 250 & 300 mm) was measured. The environment was not completely quiet (ambient sound level varied between 37 and 40 dBA), it was possible to give a preliminary quantification of the alarm sound level for comparison of the different detectors. The difference in target distance between a consistent and "loud-enough" signal (above 40 dBA) and when there was no further signal was also measured.

Results

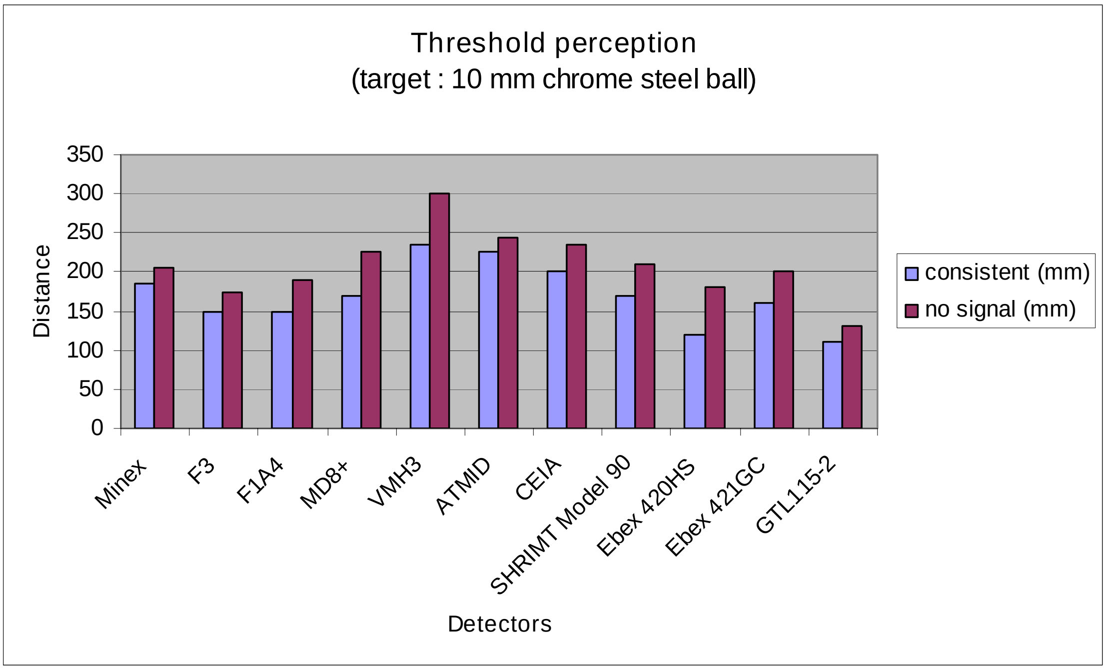


Fig. 10-8 Distances for clear and consistent signal present, and clear absence of signal. Note that not all of the detectors had been procured at the time this study was made.

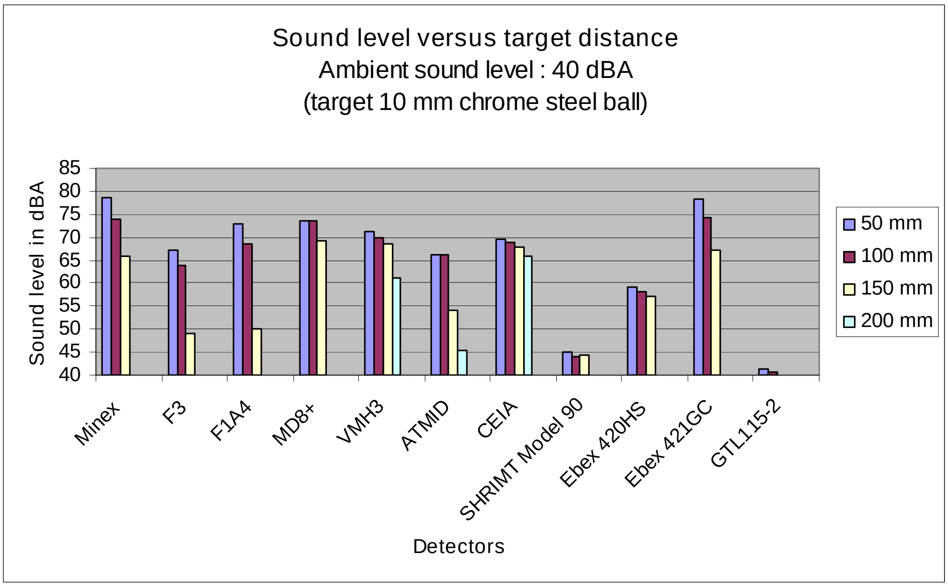


Fig. 10-9Acoustic power from alarm, at four target distances

<u>Discussion</u>
All the detectors except the Model 90 and the GTL115 gave clear and measurable sound outpout at 2 m distance.The ATMID headphone output is sufficient to be clear at this distance but the output from the Model 90 headphone is not. The GTL 115-2 gave a notably weak sound with its external speaker - the headphone is not significantly better.

For some of the detectors such as the F3, the sound level decreases rapidly with the detection height i.e. there is either a consistent and loud signal or no signal. Other detectors, such as the Ebinger 421 GC, give a smooth transition from a weak sound to a loud one[8]. But except for the detectors with weak sound output, there is a measurable and clear increase in acoustic power on passing the target. As mentioned in section 5, this result suggests that a detection criterion based on audio power output could be considered in a revision of the CWA 14747.

These measurements do not take into account pitch changes which are used by some detectors as part of the signal. A complete measurement would show the sound spectrum.

11. Individual Detector Descriptions and Results

11.a. Introduction

This section gives the individual technical specification of each participating metal detector, its results, and any special remarks based on experience acquired during the tests. A detailed discussion of detector technology may be found in the downloadable handbook published by the JRC [ref. MD handbook].

[8] The detection of the 10mm sphere at 200mm by the CEIA implies that it was set at higher sensitivity than in the test reported in Section 6, notably figure 6.3.

11.b. General remarks

One-piece detectors are considerably quicker and easy to set-up and deploy than those requiring separate parts to be screwed or locked together. This is especially important when a detector has to be unpacked quickly for a short task.

Double–D detectors have superior pinpointing, at the price of areas of reduced sensitivity in front and behind. A detector with a double-D coil behaves very differently from one with a simple circular coil and it is dangerous to confuse the two, because the shapes of the sensitive areas are different. The correct way to use a double-D is always to sweep it from side to side so that the most sensitive region encounters a mine first, it should never be pushed forwards or pulled backwards.

The Schiebel ATMID has a unique head design which has a double-D and a third small coil in the front which eliminates the problem of the region of reduced sensitivity.

Bipolar pulsed or sinusoidal fields are believed to be less likely to initiate magnetic influence fuzes than unipolar fields and are preferred by some users for this reason. In practice, few, if any, accidents have been recorded in humanitarian demining due to activation of a magnetic influence fuze by the detector. Magnetic influence fuzes are found on some anti-tank mines but not on anti-personnel mines. Since this hazard could only occur in restricted circumstances, unipolar field detectors continue to be used, in circumstances where magnetic influence fuzes are not expected to be present.

Audio indication may be by means of a loudspeaker inside the instrument, a loudspeaker which attaches separately, a headphone or an earpiece. Some detectors with internal speakers also allow an earpiece or headphone to be fitted, in which case, the internal speaker may or may not be muted when it is connected. Muting the internal speaker is mainly a military requirement, to avoid revealing one’s presence to an enemy. In humanitarian demining it is usually more useful to have a non-muting earpiece so that the supervisor may also hear the detector sounds.

The sound emitted by the detector in the presence of metal may always be the same, or may be changed to special large metal object tone if the signal is especially strong. Double-D detectors may emit the same or different tones for each side of the head.

Notes on the specifications

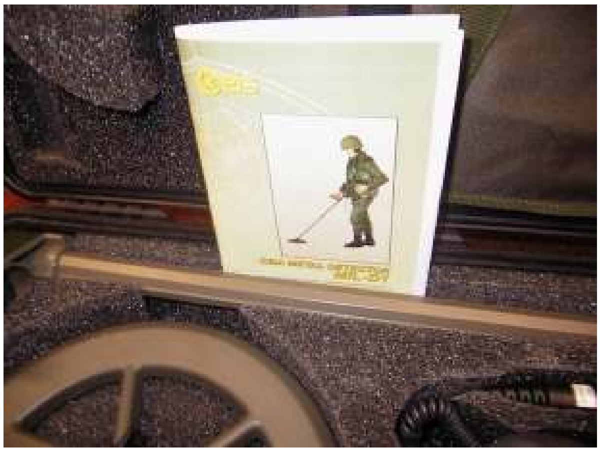
1) Masses in the case/backpack include all accessories and one set of batteries
2) Prices were as paid by JRC in 2003, except where stated otherwise. It is normal practice for detector manufacturers to negotiate unit prices with demining organisations according to the size and timing of the order
3) Assembly of the detector was always without the use of tools
4) All detectors tested are usable by either right- or left-handed operators

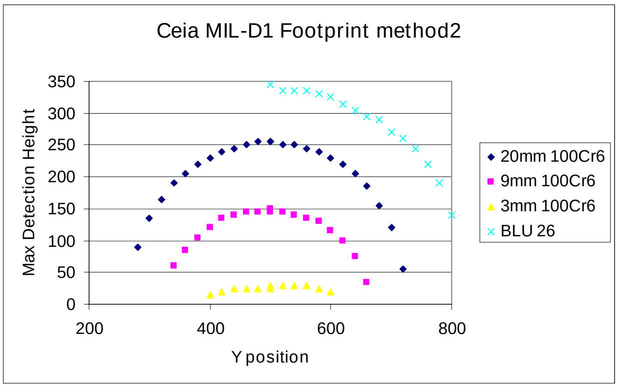
Detection capabilities in air are shown as distance from top of target to bottom of head.
Detection capabilities in soil are shown as distance from top of target to soil surface, the head being 30 mm above the soil surface. The “in-air equivalent depth” is the in-air minus 30 mm.

CEIA MIL-D1

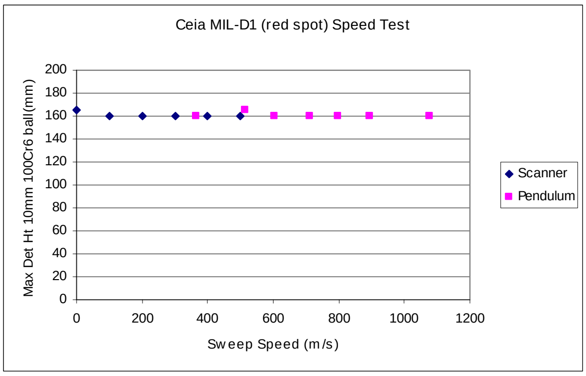
Operational aspects		
Format	Two-piece, snap-fit shaft with screw-locks, separate control box, mountable on shaft.	
Head	28 cm Ø	Circular, double D
Length in use	97-149 cm	Continuous length adjustment
Mass in use	1.6 kg / 3.2 kg	With / without control box
Ground compensation	Yes	Automatic after initiation
Mode	Static	
Audio	Internal speaker, muting headphone	
Target signals	Audio	2 tone pinpointing, small, medium and large metal object signals
System signals	Audio	Confidence click, low battery alarm
Controls	Sensitivity Volume On/Off and Reset	Continuous Continuous
Access to software	Yes	Via separate interface
Price	2700 EUR	Without VAT – Unit price
Package		
Operator manual	Yes	A5 – English – Plastic coated paper
Instruction card	Yes	Single page A5 - English/French - Plastic laminated
List of contents	Yes	Single page A5 - English/French - Plastic laminated
Test piece	Yes	
Batteries	Yes	
Transport case		
Dimensions	97 x 45 x 15 cm	
Mass (full)	12.70 kg	
Type – material	Hard case – Plastic	
Backpack	Yes	
Mass backpack (full)	4.77 kg	
Times for Set up		
Mechanical set-up	90 s	
Backpack storage	120 s	
Standing/kneeling	10 s	
Electrical set-up	15 s	
Electrical aspects		
Waveform	Bipolar triangle	3 frequency components are used
Coils	Separate send/receive	Double-D receive
Battery		
Type - Number	LR20 (D-cells) - four	Nominal voltage: 6 V
Life	80.5 hrs	

Picture details MIL-D1

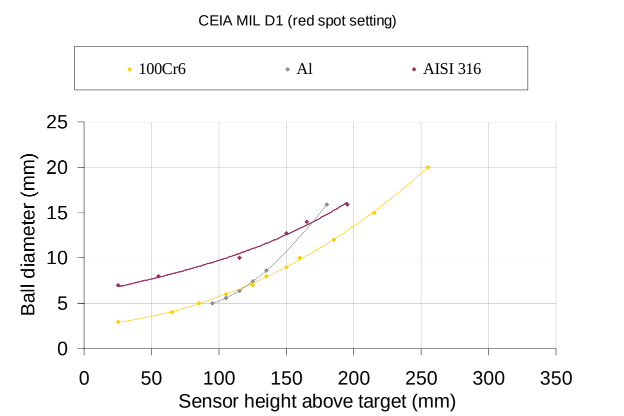




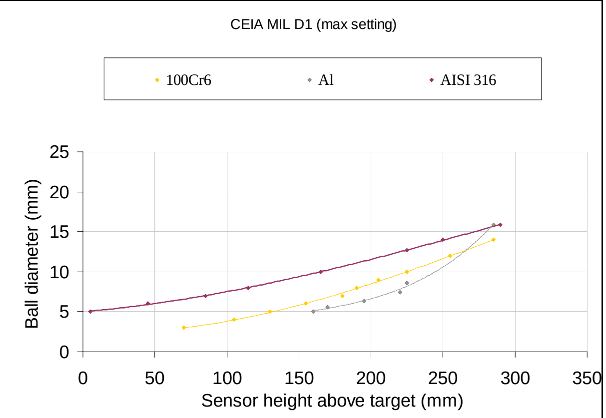
Sensitivity profile by manual method



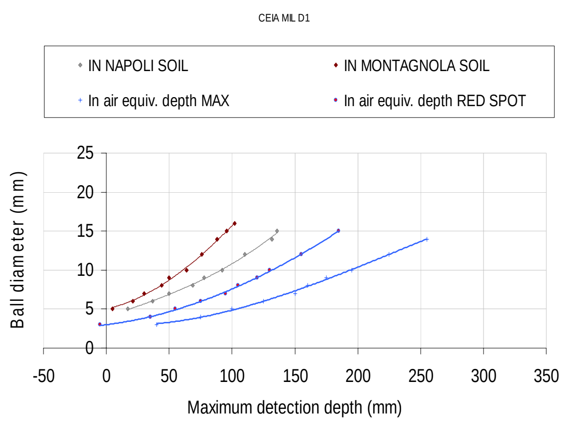
Effect of speed on detection capability



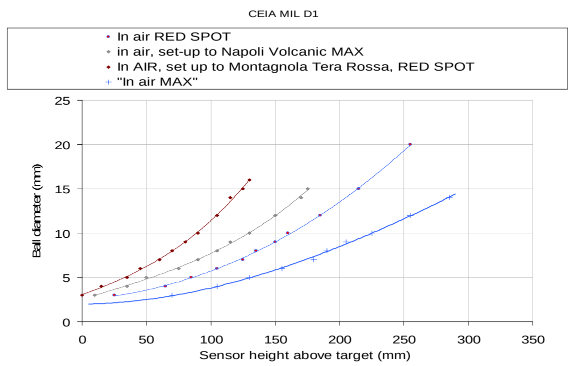
Detection capability in air for different metals at reduced senitivity setting



Detection capability in air for different metals



Detection capability in soil
(Set to "red-spot" for terra rossa,
max for volcanic)



Detection capability in-air at different settings

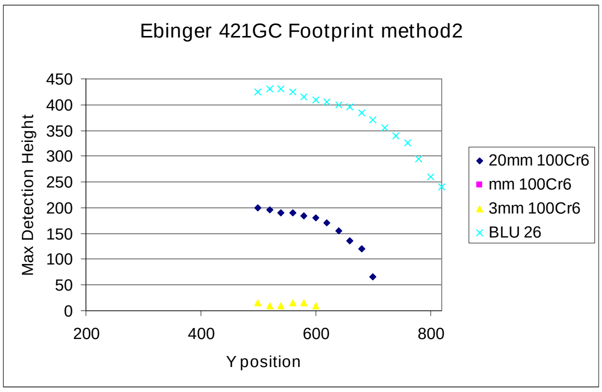
11.c. Ebinger Ebex 421GC

Operational aspects		
Format	Head, electronics cylinder, battery cylinder and optional extension, screw-fit, separate handle and arm rest. Electronics contained in shaft	
Head	23 cm Ø	Circular, others available
Length in use	88 cm /148 cm 114 cm, 174 cm	Without/with extension, rechargeable pack Without/with extension, C-cell pack
Mass in use	2.2 / 2.35 kg 2.5 / 2.7 kg	Without/with extension, rechargeable pack Without/with extension, C-cell pack
Ground compensation	Yes	Manual
Mode	Dynamic	
Audio	Detachable external speaker or headphone (not both at same time)	
Target signals	Audio	Varies according to target size
System signals	Audio	Confidence click, low battery alarm
Controls	Sensitivity, Ground comp.	Detector does not have an on/off switch, Switch on by connecting speaker/phone
Access to software	No	
Price	2360 EUR	Without VAT – at discount – 2004
Package		
Operator manual	Yes	
Instruction card	No	
List of contents	Yes	
Test piece	Yes	
Batteries	Yes	
Transport case		
Dimensions	81 x 34 x 13 cm	
Mass (full)	6.7 kg	
Type – material	Hard case plastic	
Backpack	Yes	
Mass backpack (full)	3.4 kg	
Times for Set up		
Mechanical set-up	110 s	
Backpack storage	72 s	
Standing/kneeling	50 s	
Electrical set-up	5 s	
Electrical aspects		
Waveform	Bipolar pulsed	
Coils	Single coil	
Battery		
Type –number	LR14 (C-cells) – eight Recharge pack - one	12V nominal Rechargeable pack is proprietary
Life	15.5 hrs 12 hrs	With C-cells With rechargeable pack

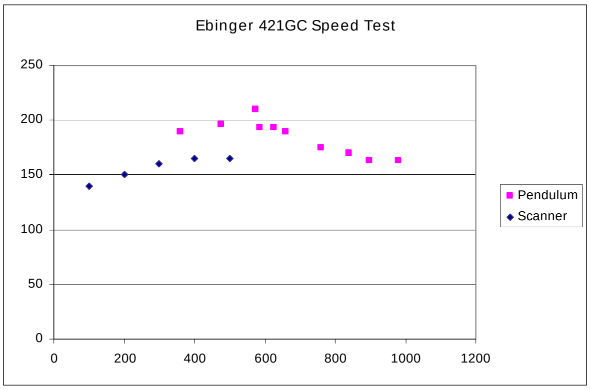
The detector with the modular extension (above) and the two possible power attachments (right).
The armrest and handle are not displayed

The detector in short configuration with the rechargeable battery pack
The armrest and handle are not displayed

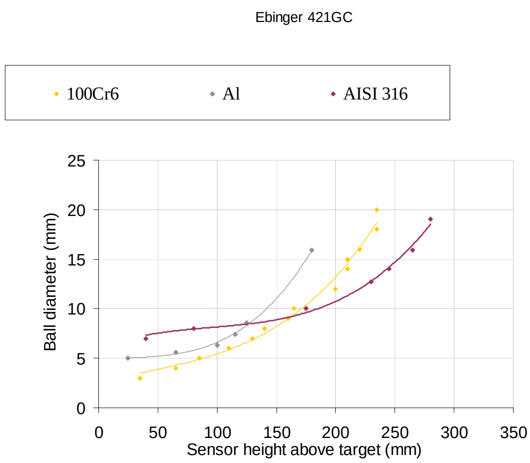
Sensitivity knob (left), soil compensation adjustment knob (middle), and loudspeaker (right) which can be covered by a protective cylinder.



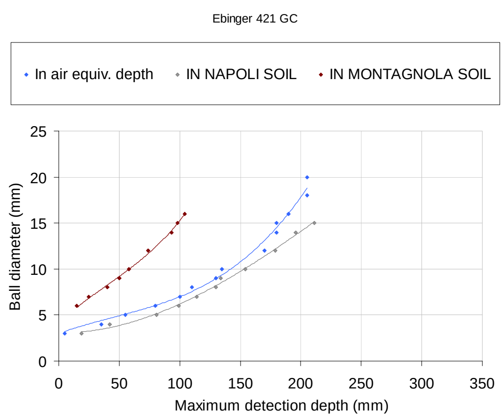
Sensitivity profile by manual method



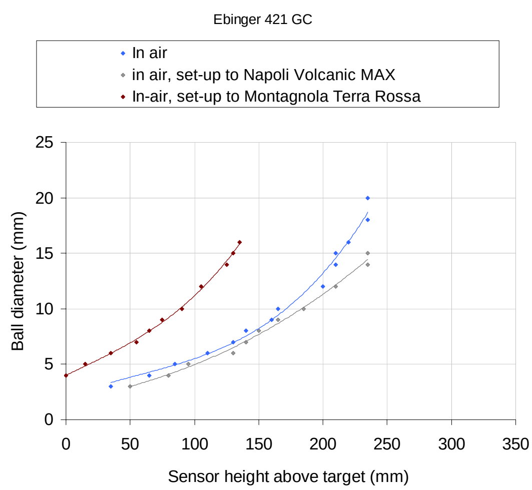
Effect of speed on detection capability



Detection capability in air for different metals



Detection capability in-soil



Detection capability in air at different settings

11.d. Ebinger Ebex 420 HS

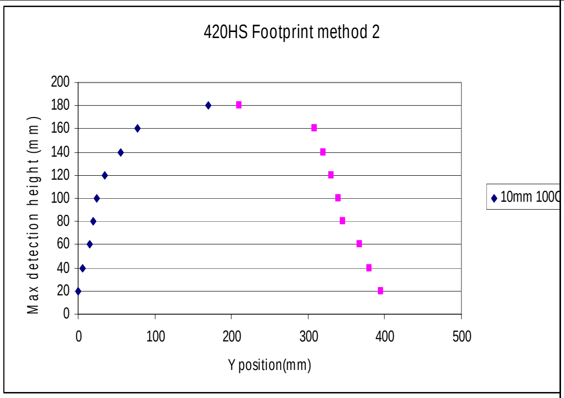
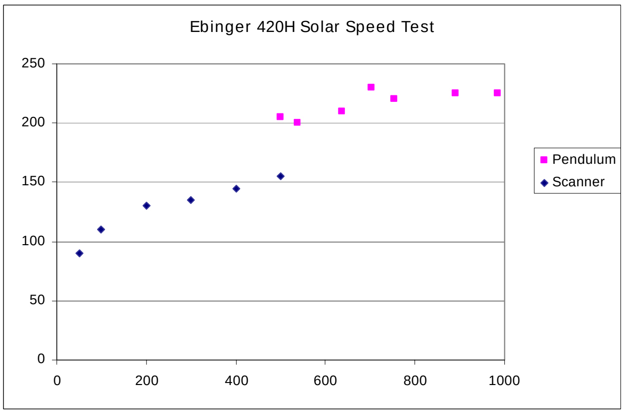
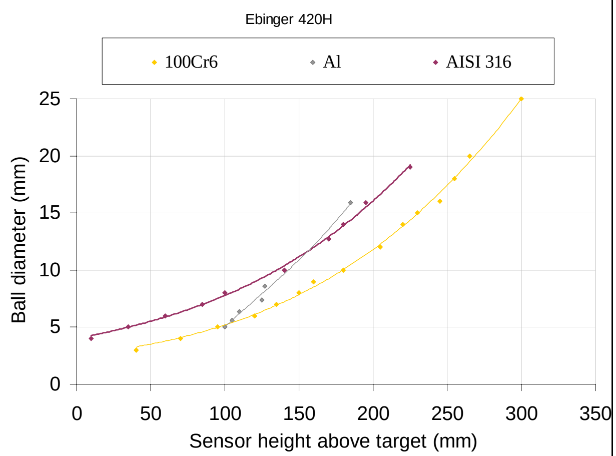
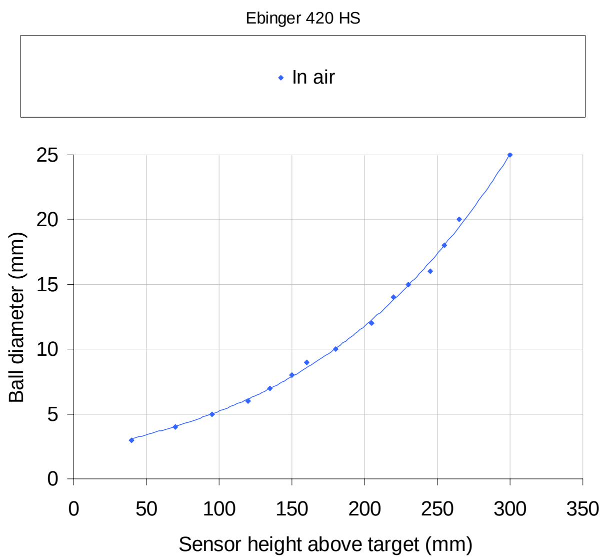
Operational aspects		
Format	Single-piece with electronics in shaft Separate handle and arm-rest	
Head	20 cm Ø	Circular
Length in use	64 cm	
Mass in use	1.2 kg	
Ground compensation	None	
Mode	Dynamic	
Audio	Internal speaker	
Target signals	Audio	Varies according to target size
System signals	Audio	Confidence click, low battery alarm
Controls	Sensitivity On/off	
Access to software	No	
Price	1899 EUR	Without VAT - with discount – 2004
Package		
Operator manual	Yes	English, paper
Instruction card	No	
List of contents	Yes	
Test piece	Yes	
Batteries	Yes	2 rechargeable batteries included
Transport case		
Dimensions	81 × 34 × 13 cm	
Mass (full)	5.2 kg	
Type – material	Hard case – Plastic	
Backpack	Yes	
Mass backpack (full)	1.9 kg	
Times for Set up		
Mechanical set-up	15 s	Only need to fit battery and adjust arm rest
Backpack storage	10 s	
Standing/kneeling	N/A	
Electrical set-up	5 s	
Electrical aspects		
Waveform	Single sine	
Coils	Separate send/receive	
Battery		
Type - Number	6KR61 (PP3) – one	To be used always with rechargeable battery
Life		Integrated solar panel for recharging

Pictures EBEX 420 HS

EBEX 420 HS in its transport case

The solar panel (right) is mounted on the search head shaft

From left: sensitivity adjustment, battery compartment, internal speaker and power knob.

	
Sensitivity profile by manual method	Effect of speed on detection capability
	
	Detection capability in air for different metals
Cannot be used on the JRC's magnetic soils	
Detection capability in soil	Detection capability in air Cannot be set for different soils

11.e. Foerster Minex 2FD 4.500.01

Operational aspects		
Format	One-piece	
Head	L:29, W:21	Elliptical, Double D
Length in use	85-160 cm	Continuous length adjustment
Mass in use	2.6 kg	
Ground compensation	Yes	Automatic after initiation
Mode	Static	
Audio	Internal speaker / muting headphone	
Target signals	Audio	Different tones for left and right side of head
System signals	Audio Audio/visual	Confidence click Low battery alarm
Controls	Sensitivity switch Volume Control Ground compensation Reset	Three sensitivities and off
Access to software	No	Introduced in later, otherwise similar, version
Price	2990 EUR	
Package		
Operator manual	Yes	A4, paper – English
Instruction card	No	
List of contents	Yes	In manual
Test piece	Yes	Two spanners and a skid-plate are included
Batteries	Yes	
Transport case		
Dimensions	98 × 27× 33 cm	
Mass (full)	9.4 kg	
Type – material	Hard case – plastic	
Backpack	Yes	
Mass backpack (full)	3.75 kg	
Times for Set up		
Mechanical set-up	< 60 s	
Backpack storage	< 120 s	
Standing/kneeling	< 15 s	
Electrical set-up	<15 s	
Electrical aspects		
Waveform	2 sine waves	2.4 kHz and 19.2 kHz,1/8 current
Coils	Separate send-receive	Double-D receive
Battery		
Type - Number	LR20 (D-cells) -three	Nominal voltage 4.5 V
Life	71 hrs	


ZER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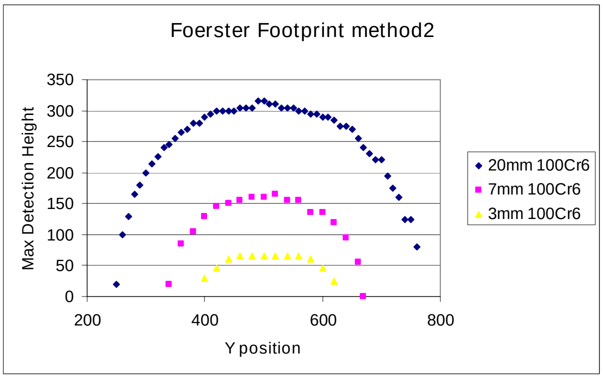
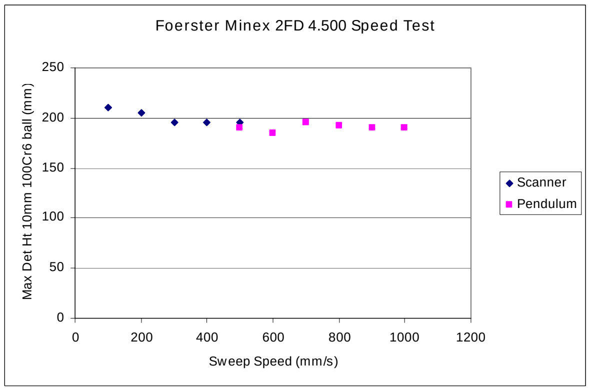
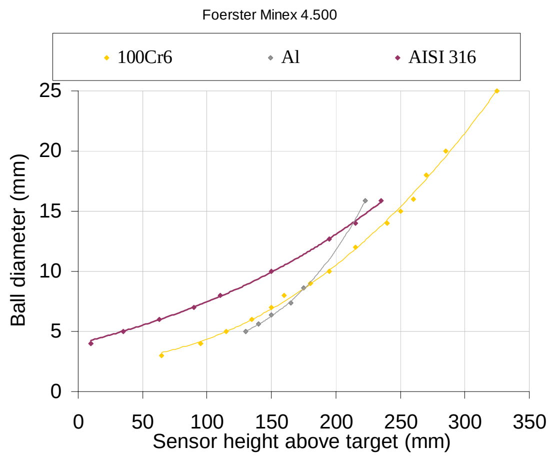
User Manual



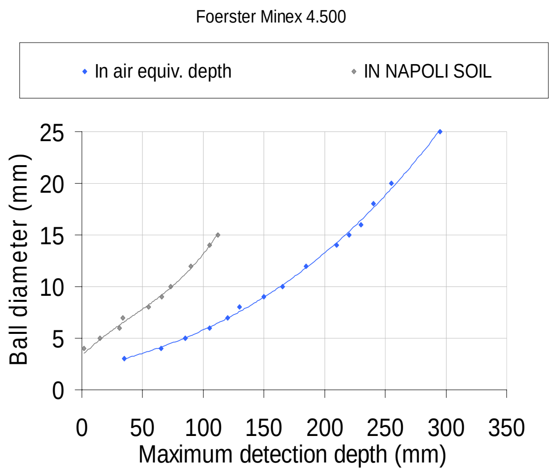
Sensitivity profile by manual method



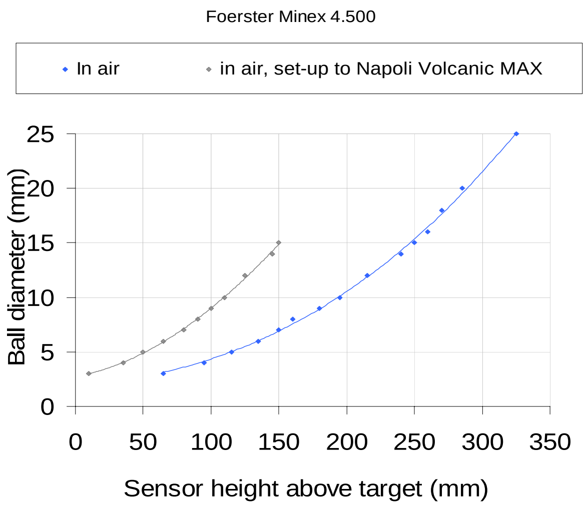
Effect of speed on detection capability



Detection capability in air for different metals



Detection capability in soil
Set up in air is on maximum sensitivity H
Set on Napoli soil is on L and with the soil compensation used
Cannot be used on Montagnola soil

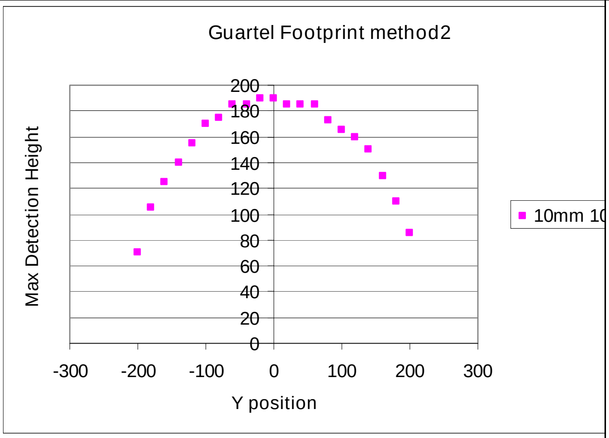


Detection capability in air at different settings
Settings as for in soil graphs

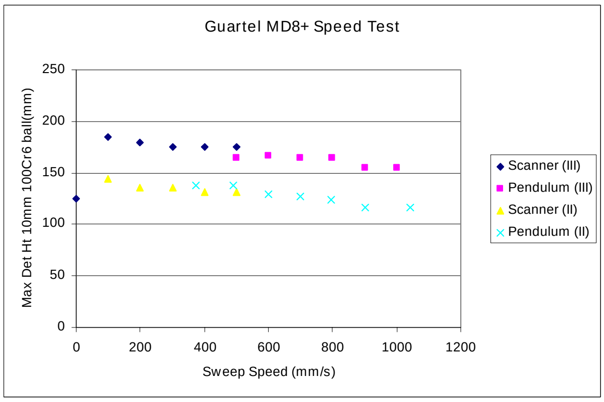
11.f. Guartel MD8+

Operational aspects		
Format	Two-piece, screw-fit shaft, electronic unit in shaft	
Head	L. cm, W. 20 cm	Oval, narrower at front, double-D
Length in use	107-132 cm	Continuously adjustable
Mass in use	2.4 kg	
Ground compensation	No	
Mode	Dynamic	
Audio	Internal speaker/ muting earpiece	
Target signals	Audio/visual	1 tone pinpointing, LEDs indicate signal strength and position
System signals	Audio/visual	Confidence click, low battery alarm
Controls	Sensitivity switch Volume control	Three sensitivities and off
Access to software	No	
Price	2199 EUR	Without VAT
Package		
Operator manual	No	
Instruction card	Yes	Single page, A4, English, plastic laminated
List of contents	No	
Test piece	No	
Batteries	No	
Transport case		
Dimensions	80 × 33× 18 cm	
Mass (full)	9.2 kg	
Type – material	Hard-metal	
Backpack	Yes	
Mass backpack (full)	3.38 kg	
Times for Set up		
Mechanical set-up	75 s	
Backpack storage	75 s	
Standing/kneeling	15 s	
Electrical set-up	5 s	
Electrical aspects		
Waveform	Unipolar pulses	
Coils	Separate send/receive	Double-D receive coil
Battery		
Type - Number	LR20 (D-cells) -three	Nominal voltage 4.5 V
Life	15.5 hrs of active use	Detector goes into “sleep-mode” if not moved

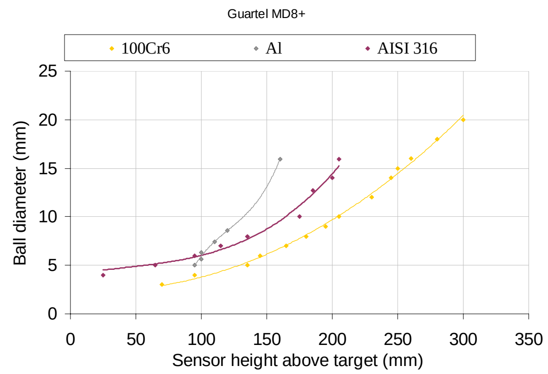
<u>Pictures Guartel MD8+</u>



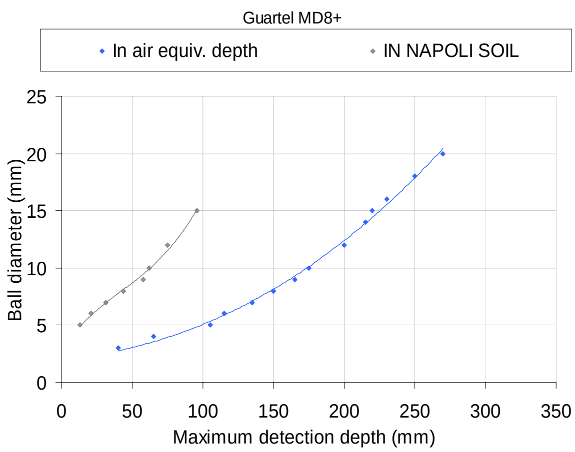
Sensitivity profile by manual method



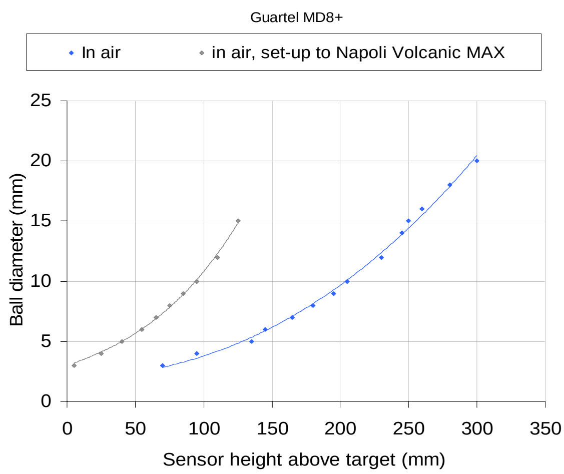
Effect of speed on detection capability



Detection capability in air for different metals



Detection capability in soil
Set up in air is at maximum sensitivity III
Set up on Napoli soil was made by reducing to setting I.
There is no explicit soil compensation.
Cannot be used on Montagnola soil



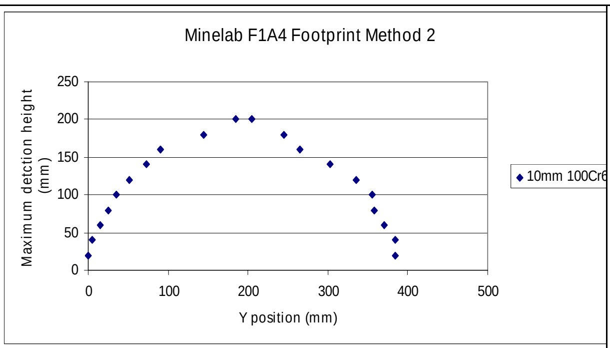
Detection capability in air at different settings
Settings as for in-soil graphs

11.g. Minelab F1A4

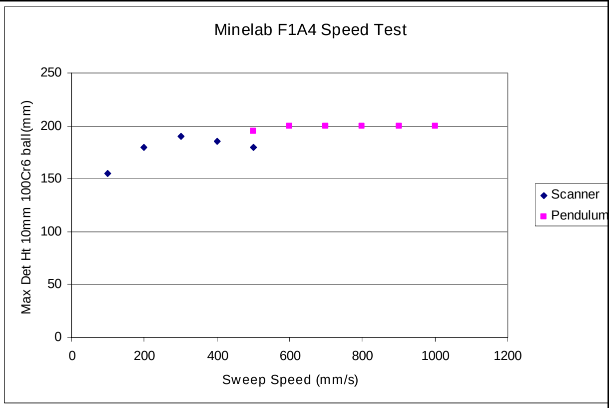
Operational aspects		
Format	Two-piece shaft, with snap-locks, separate arm-rest, separate control box, mountable on shaft.	
Head	21 cm Ø	Circular
Length in use	100-137 cm	Continuously adjustable
Mass in use	3.1 kg	
Ground compensation	Yes	Automatic after initiation Patented multi pulse-width technology
Mode	Dynamic	
Audio	Internal speaker / headphone (muting and non-muting available)	
Target signals	Audio	Varies according to target size
System signals	Audio/visual	Confidence tone, low battery warning
Controls	Switch Audio reset button Noise cancel button	3 positions: Search, ground comp. and off Fixed sensitivity
Access to software	Via RS 232 port	
Price	1969 EUR	Without VAT
Package		
Operator manual	Yes	A5, English, water and tear resistant paper
Instruction card	Yes	Single A5 page, English, plastic laminated
List of contents	Yes	On the instruction card
Test piece	Yes	Skid plate included
Batteries	Yes	
Transport case		
Dimensions	86 × 34 × 19 cm	
Mass (full)	8.6 kg	
Type – material	Hard, plastic	
Backpack	Yes	
Mass backpack (full)	4 kg	
Times for Set up		
Mechanical set-up	180 s	
Backpack storage	150 s	
Standing/kneeling	30 s	
Electrical set-up	15 s	+72 s for noise cancel
Electrical aspects		
Waveform	Unipolar	Bipolar version possible
Coils	Single	
Battery		
Type - Number	LR20 (D-cells) four	6 V nominal
Life	14.5 hrs	


F1A4 Mine Detector
OPERATIONS MANUAL
F1A4

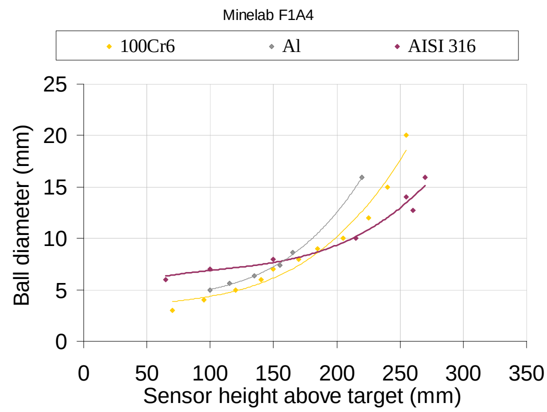

Battery
Low
Off
On
Search
Balance
F1A4
Coil



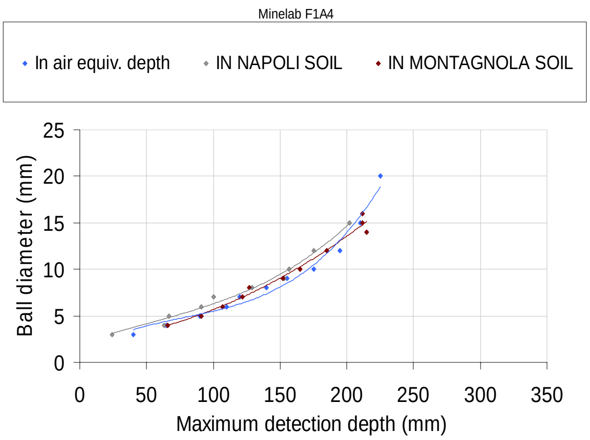
Sensitivity profile by manual method



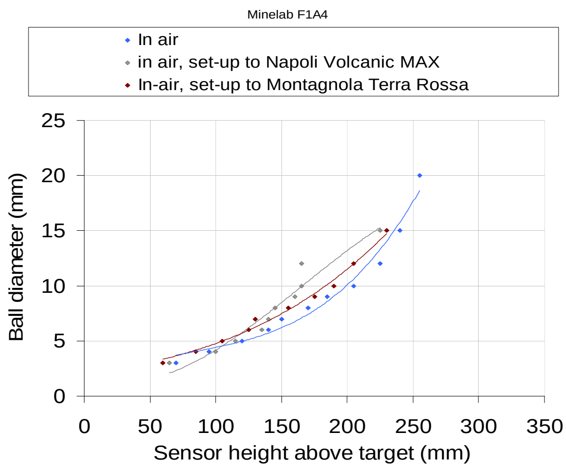
Effect of speed on detection capability



Detection capability in air for different metals



Detection capability in soil



Detection capability in air at different settings

11.h. Minelab F3

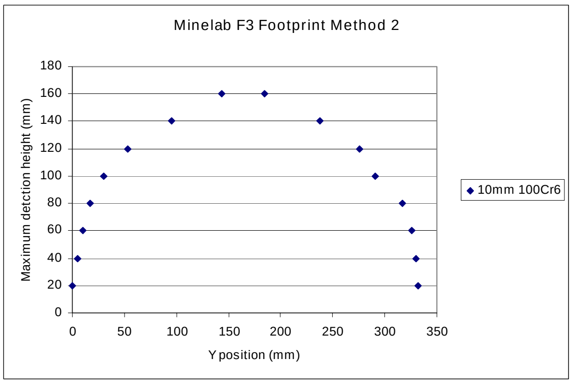
Parameters	Value	Comments
Operational aspects		
Format	One piece	
Head	21 cm Ø	Circular
Length in use	60-148 cm	Continuously adjustable
Mass in use	3.2 kg	
Ground compensation	Yes	Automatic on initiation Uses patented multi pulse width technology
Mode	Dynamic	
Audio	Internal speaker / earpiece (muting and non-muting available)	
Target signals	Audio	Varies according to target size
System signals	Audio	Confidence tone, low battery alarm, faults
Controls	Ground comp./reset	Brief press for audio reset, hold down for GC
	Elec. noise cancel On/off	Sensitivity set by means of colour-coded caps on end of handle, visible to supervisor
Access to software	Yes	Via RS 232
Price	2450 EUR	Without VAT
Package		
Operator manual	Yes	A5, English, water and tear resistant paper
Instruction card	Yes	Single A5 page, English, plastic laminated
List of contents	Yes	On the instruction card
Test piece	Yes	Skid plate included
Batteries	Yes	
Transport case		
Dimensions	86 x 46 x 19 cm	
Mass (full)	11.9 kg	
Type – material	Plastic – hard	
Backpack	Yes	
Mass backpack (full)	4.25 kg	
Times for Set up		
Mechanical set-up	30 s	
Backpack storage	120 s	
Standing/kneeling	15 s	
Electrical set-up	15 s	+ 47 s for noise cancel
Electrical aspects		
Waveform	Bipolar pulse	
Coils	Single	
Battery		
Type - Number	LR20 (D-cells) four	
Life	29 hrs	



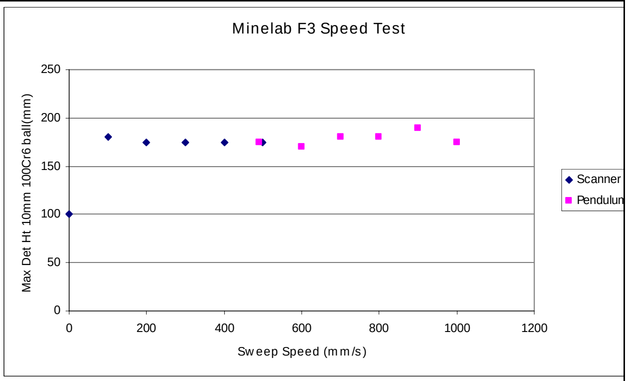




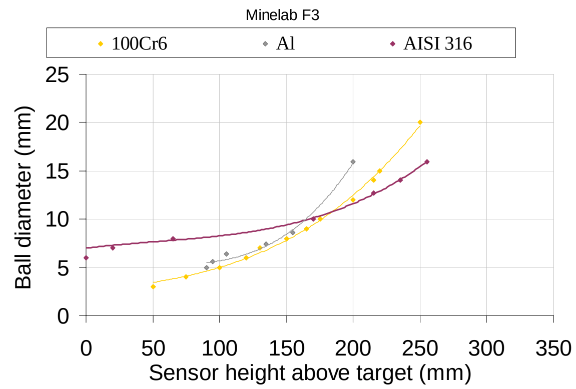
F3 Mine Detector

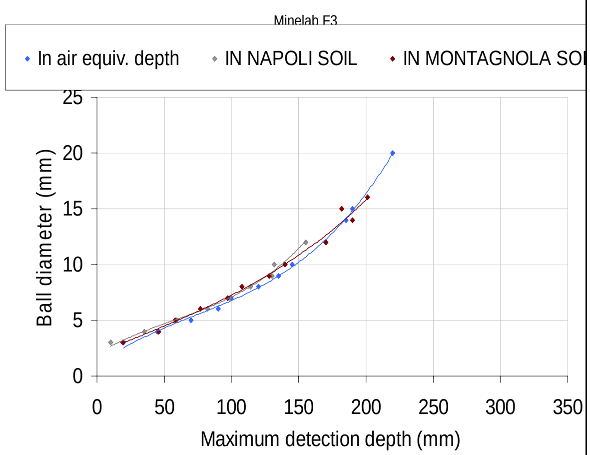
Sensitivity profile by manual method



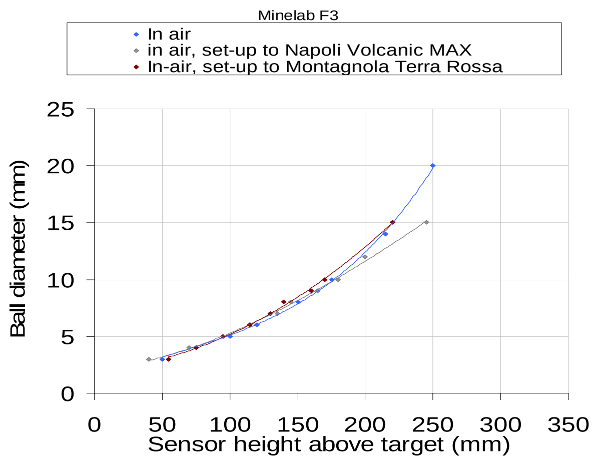
Effect of speed on detection capability



Detection capability in air for different metals



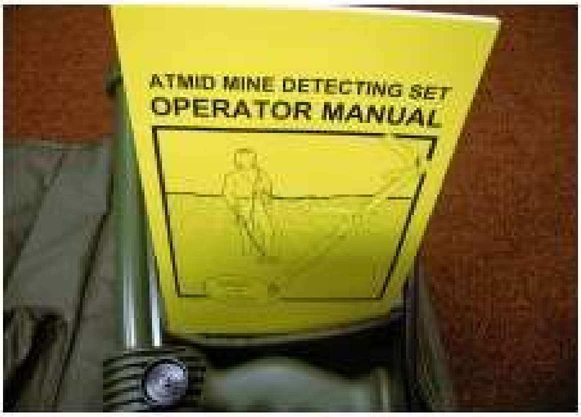
Detection capability in soil

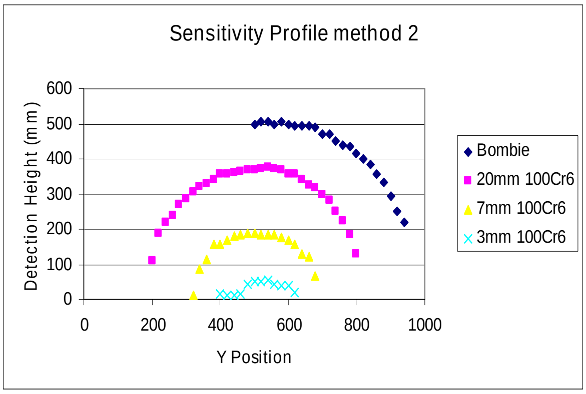


Detection capability in air at different settings

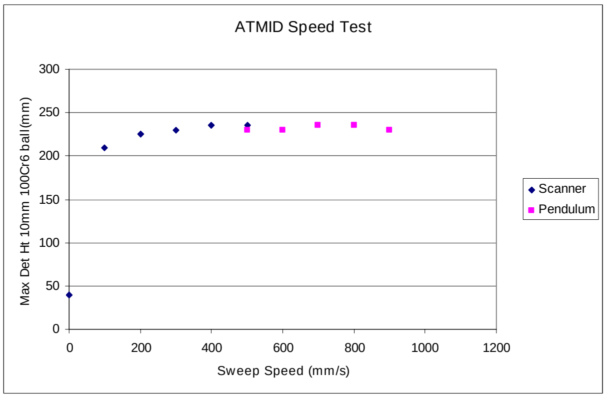
11.i. Schiebel All Terrain Mine Detector (ATMID)

Operational aspects		
Format	Two-piece shaft with snap-locks, separate handle and arm rest. External cable. Control-box can be fitted to shaft with optional clips.	
Head	26.5 cm Ø	Circular, directional
Length in use	116,126,136 cm	Three positions, fixed increments
Mass in use	3.3 kg	1.5 kg not including control box
Ground compensation	Yes	Semi-automatic after initiation
Mode	Dynamic	
Audio	Headphone – can use as loudspeaker by turning volume up	
Target signals	Audio	Large metal object signal
System signals	Audio/visual	Confidence click, low battery alarm, status tones
Controls	On/off/Ground Comp Sensitivity knob Volume knob	
Access to software	No	
Price	3050 EUR	Without VAT
Package		
Operator manual	Yes	A5, English, paper
Instruction card	Yes	Single page A5, English, plastic laminated
List of contents	Yes	
Test piece	Yes	
Batteries	No	
Transport case		
Dimensions	80 x 31 x 12 cm	
Mass (full)	7 kg	
Type – material	Hard –metal	
Backpack	Yes	
Mass backpack (full)	4.75 kg	
Times for Set up		
Mechanical set-up	120 s	
Backpack storage	120 s	
Standing/kneeling	15 s	
Electrical set-up	15 s	
Electrical aspects		
Waveform	Single sine	
Coils	Separate send/receive	Double-D and third coil
Battery		
Type - Number	LR20 (D-cells) four	
Life	74 hrs	

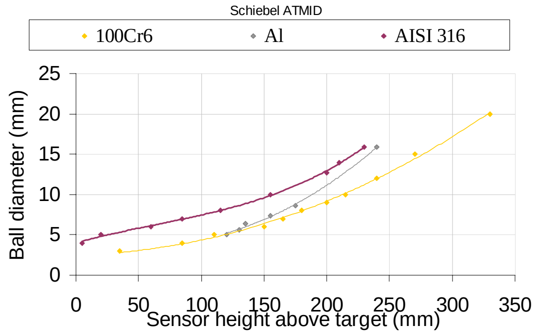

ATMID MINE DETECTING SET
OPERATOR MANUAL



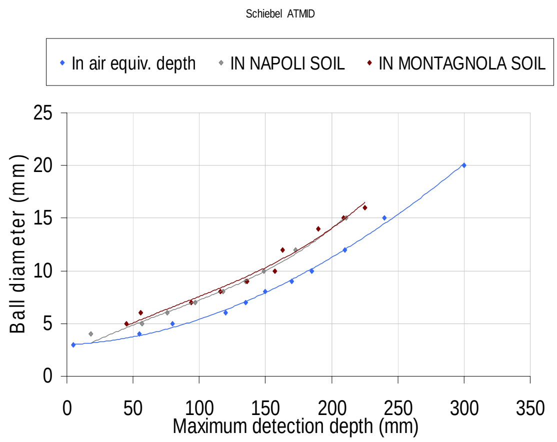
Sensitivity profile by manual method



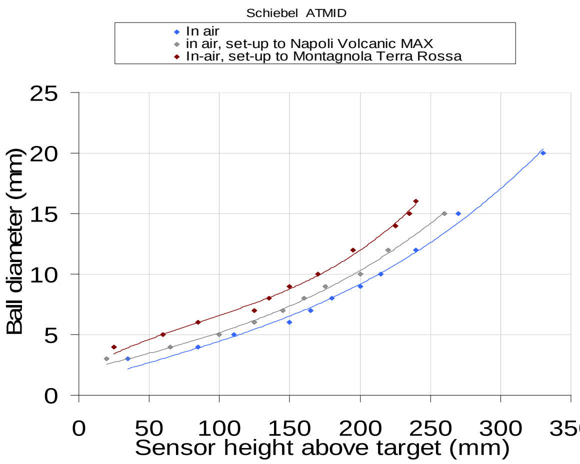
Effect of speed on detection capability



Detection capability in air for different metals



Detection capability in soil



Detection capability in air at different settings

11.j. Shanghai Research Institute of Microwave Technology, Model 90

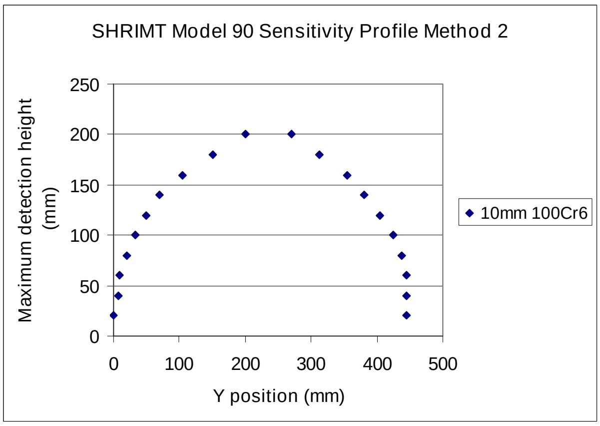
NOTE: The SHRIMT Model 90 is a dual-sensor. It has a 369.3MHz GPR as well as the metal detector. For all tests described in this report, the GPR was switched off and the instrument was operated as a metal detector only.

Operational aspects		
Format	Two-piece, screw lock, separate control box	
Head	26 cm side	Square
Length in use	73 – 156 cm	Continuously adjustable
Mass in use	3.3 kg	
Ground compensation	No	
Mode	Dynamic	
Audio	Headphone	
Target signals	Audio	
System signals	Audio	Confidence click, low battery alarm
Controls	On/off/mode select Volume	Metal detector only, two dual-sensor modes
Access to software	No	
Price	980 EUR	Without VAT – 2004
Package		
Operator manual	Yes	A5, English, paper
Instruction card	No	
List of contents	No	
Test piece	No	A prodder is also supplied
Batteries	Yes	
Transport case		
Dimensions	55 x 32 x 16 cm	
Mass (full)	9 kg	
Type – material	Hard - metal	
Backpack	Yes	
Mass backpack (full)	4.25 kg	
Times for Set up		
Mechanical set-up	130 s	
Backpack storage	70 s	
Standing/kneeling	20 s	
Electrical set-up	18 s	
Electrical aspects		
Waveform	Single sine wave	
Coils	Single (?)	Inferred from manual, not verified directly
Battery		
Type - Number	LR6 (AA) - ten	15 V nominal
Life	49 hrs	Manual states not less than 8 hrs with ZnC

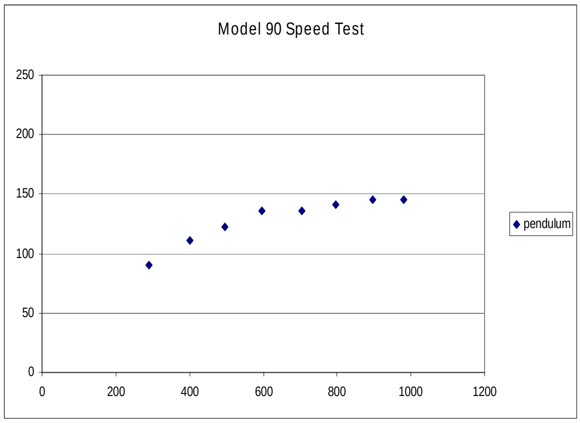
Picture details M90



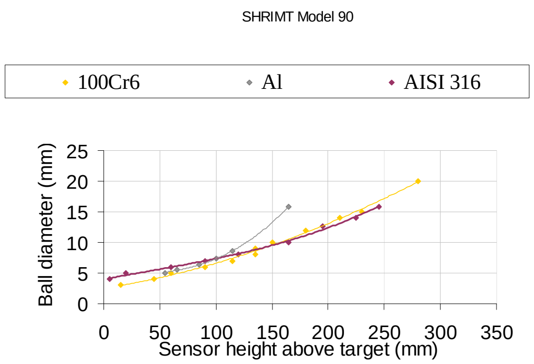


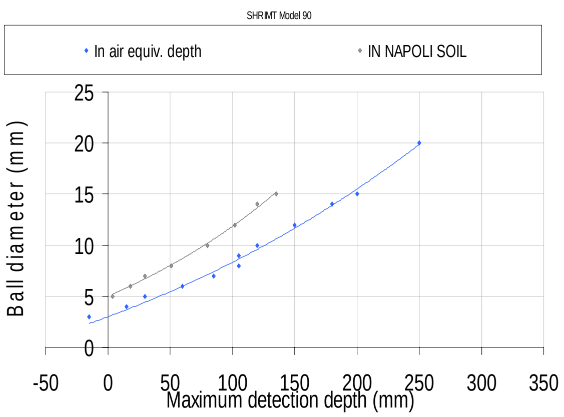
Sensitivity profile by manual method



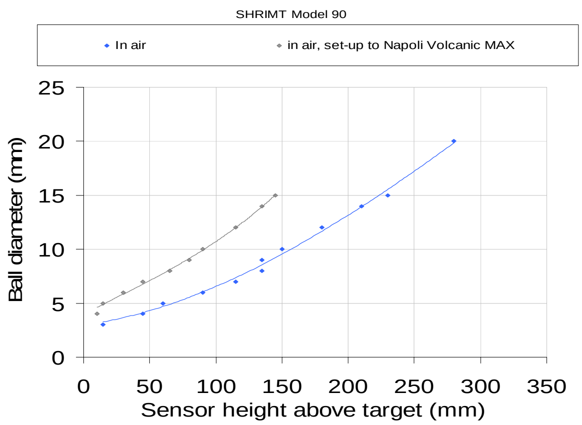
Effect of speed on detection capability



Detection capability in air for different metals



Detection capability in soil
Set up to Napoli soil by reducing sensitivity, no explicit soil compensation
Detector unusable on Montagnola soil



Detection capability in air at different settings
Settings as for in soil data

11.k. Vallon VMH3

Operational aspects		
Format	Single piece	
Head	L:31cm, W:17 cm	Truncated ellipse
Length in use	76-134 cm	Continuously adjustable
Mass in use	2.5 kg	
Ground compensation	Yes	Automatic. Setting retained when detector off.
Mode	Dynamic	
Audio	Internal speaker / headphone	
Target signals	Audio/visual/vibrator	Large target signal
System signals	Audio/visual/vibrator	Sensitivity level, low battery alarm NOTE: does not have confidence click
Controls	Mode Switch Sensitivity/vol. level Compensation/reset	Normal, mineral, volume adjust, off Digital, in fine steps
Access to software	Yes	Via RS 232. Digital output of signal also.
Price	2420 EUR	Without VAT
Package		
Operator manual	Yes	A5 – English/French Paper
Instruction card	Yes	A5- English/French – plastic laminated
List of contents	Yes	In manual
Test piece	Yes	
Batteries	Yes	NiMH and charger provided in package
Transport case		
Dimensions	84× 30× 25 cm	
Mass (full)	5.45 kg	
Type – material	Semi-rigid foam/vinyl	
Backpack	Yes	
Mass backpack (full)	4.8 kg	
Times for Set up		
Mechanical set-up	30 s	
Backpack storage	30 s	
Standing/kneeling	10 s	
Electrical set-up	10 s	
Electrical aspects		
Waveform	Bipolar pulses	
Coils	Single coil	
Battery		
Type - Number	LR20 (D-cells) three	Normally use Nigh rechargeables supplied
Life	23 hrs	With alkaline

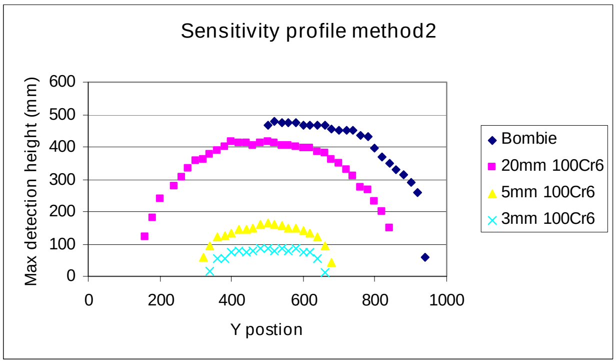
NOTE: Some tests in this report were repeated with copies of the detector which have a new version of the firmware, which we refer to as VMH3M detectors.



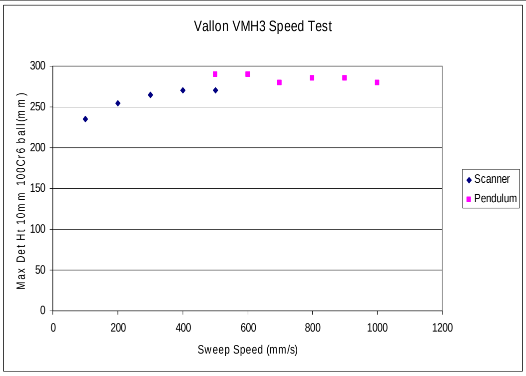




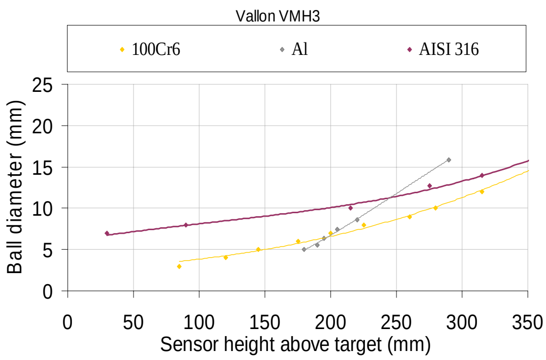
3x1,5V

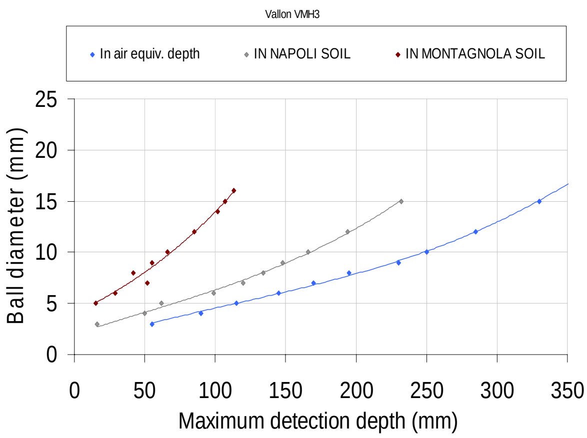
Sensitivity profile by manual method



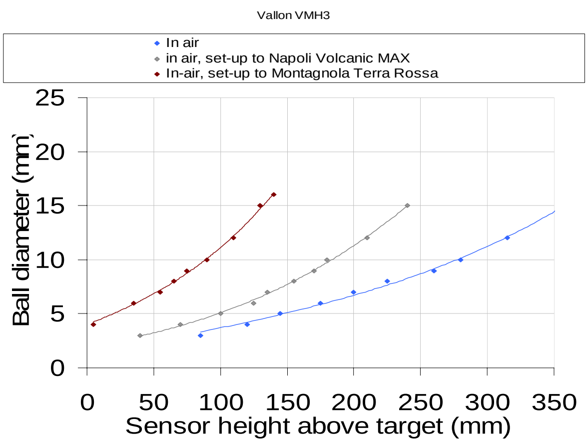
Effect of speed on detection capability



Detection capability in air for different metals



Detection capability in soil



Detection capability in air at different settings

11.l. CEIA MIL-D1/DS

The detector MIL-D1/DS is an example of a two-head design; there are separate sending and receiving coils at an adjustable distance apart. The receiving coil is set in a normal horizontal orientation but the transmitting coil is set in a vertical plane. The line of maximum sensitivity lies between the two coils.

Because of the distance between the coils, the detector covers a bigger area than the other tested detectors. The device mainly uses components from the standard MIL-D1 mine detector (coils, poles, electronics housing), adapted as necessary. Due to the weight of the detector (5.8kg), it is recommended to use it with the harness supplied.

Ordinarily, the operator walks in a serpentine pattern, advancing slowly in a direction perpendicular to the direction in which he walks so as to cover a swath several meters wide. In accordance with the target and depth for search, different extensions of the pole, and different pitches of serpentine, may be used. When an indication is encountered, a change of the search direction is used to locate the centre of the target.

Operational aspects		
Format	Three-pieces and separate control box, two-heads	
Head	28 cm Ø	Heads mounted on opposite ends of shaft
Length in use	L: 102 to 143 cm H: 29 to 61 cm	Continuously adjustable in both length and height
Mass in use	5.8 kg	
Ground compensation	Yes	
Mode	Static	
Audio	Internal speaker/ muting headphone	
Target signals	Audio/visual	Small, medium and large metal signals
System signals	Audio/visual	Confidence click, low battery, fault tones
Controls	Sensitivity volume On/off/reset	
Access to software	No	
Price	Unknown	Loaned copies used.
Package		
Operator manual	Yes	A5 English, paper
Instruction card	Yes	A5, English, plastic laminated
List of contents	Yes	A5, English, plastic laminated
Test piece	Yes	
Batteries	Yes	Optional NiMH and charger
Transport case		
Dimensions	97 x 45 x 15 cm	
Mass (full)	14.2 kg	
Type – material	Hard – plastic	
Backpack	No	
Mass backpack (full)	n/a	
Times for Set up		
Mechanical set-up	34 s	
Backpack storage	n/a	
Standing/kneeling	n/a	
Electrical set-up	13 s	
Electrical aspects		
Waveform	Triangle	
Coils	Separate send receive	In separate heads
Battery		
Type - Number	LR20 (D-cells) - four	6 V nominal
Life	6.5 hrs	With alkaline

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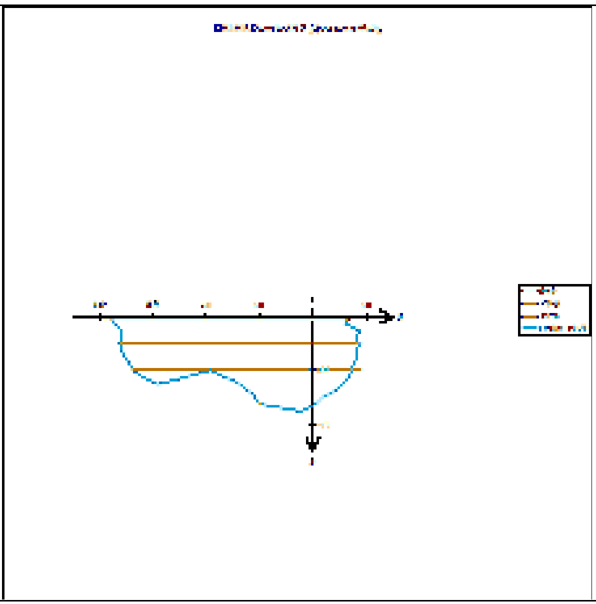
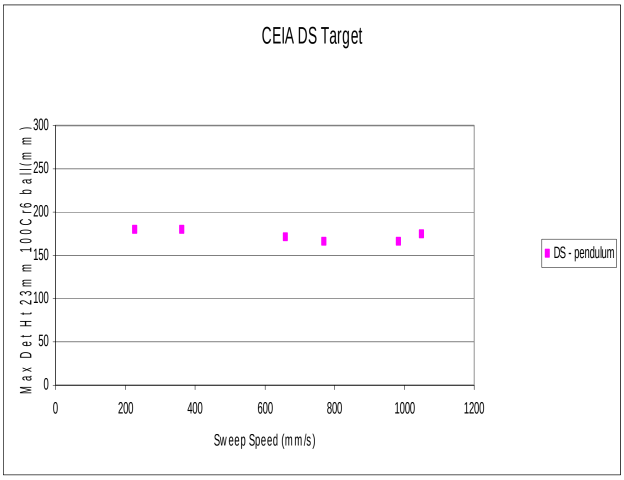
<td></td>
<td>
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<td>Sensitivity profile by manual method
Target: BLU 26B submunition</td>
<td>Effect of sweep speed on detection capability</td>
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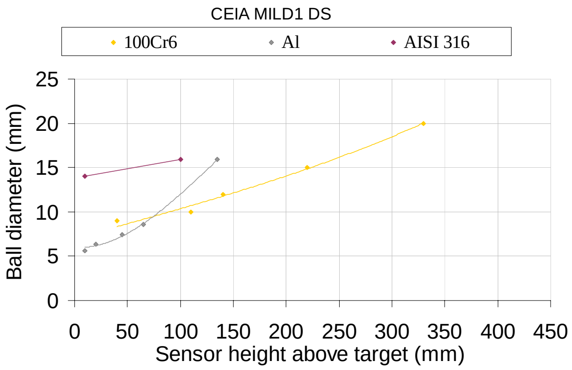
<td>
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<td>Detection capability in air for different metals</td>
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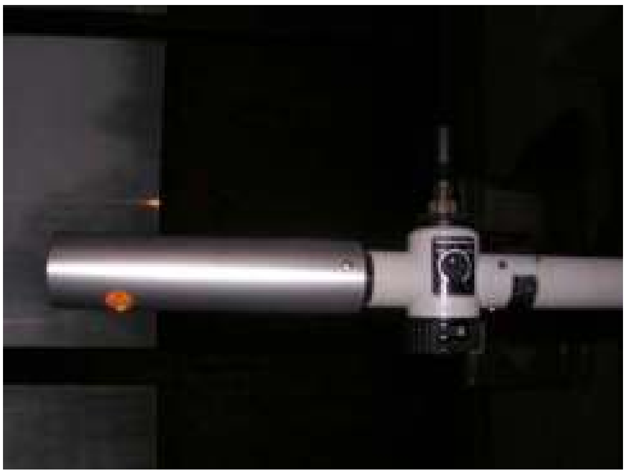
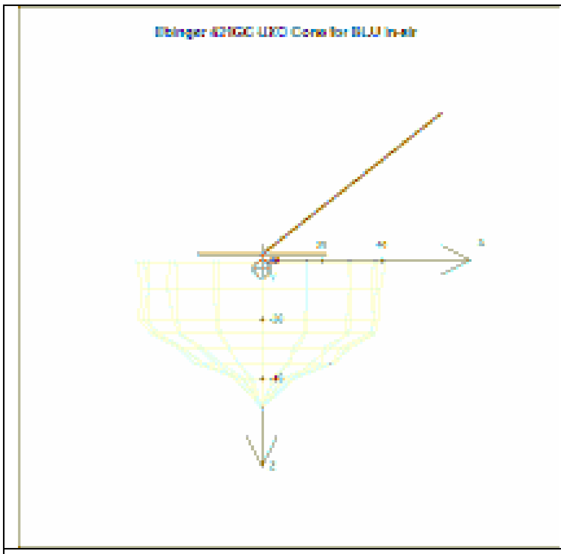
11.m. EBEX 421 GC/LS UXO

Operational aspects		
Format	Modular, two possible lengths, separate handle and arm rest Electronic unit in handle tube, external speaker or headphone	
Head	42 cm x 28 cm	Oval
Length in use	88cm /148 cm 114 cm, 174 cm	Without/with extension, rechargeable pack Without/with extension, C-cell pack
Mass in use	2.8/ 3.1 kg 3.1 / 3.4 kg	Without/with extension, rechargeable pack Without/with extension, C-cell pack
Ground compensation	Yes	Manual
Mode	Dynamic	
Speaker	Detachable external speaker or headphone	
Target signals	Audio	Varies according to target size
System signals	Audio	Confidence click, low battery alarm
Controls	Sensitivity, Ground comp.	
Access to software	No	
Price	2360 EUR	Without VAT – at discount Loaned copies used.
Package		
Operator manual	Yes	
Instruction card	Yes	
List of contents	No	
Test piece	Yes	
Batteries	Yes	
Transport case		
Dimensions	76 x 37.5 x 17.5cm	
Mass (full)	6.7 kg	
Type – material	Hard – metal	
Backpack	Yes	
Mass backpack (full)	4.7 kg	
Times for Set up		
Mechanical set-up	110 s	
Backpack storage	72 s	
Standing/kneeling	50 s	
Electrical set-up	5 s	
Electrical aspects		
Waveform	Bipolar pulsed	
Coils	Single coil	
Battery		
Type –number	LR14 (c-cells) – eight Recharge pack - one	12 V nominal Rechargeable pack is proprietary
Life	15.5 hrs 12 hrs	With C-cells With rechargeable pack

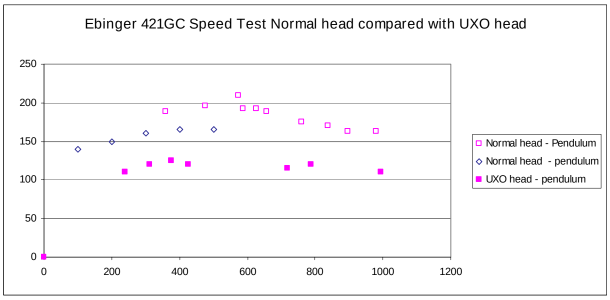

WPX
WPX



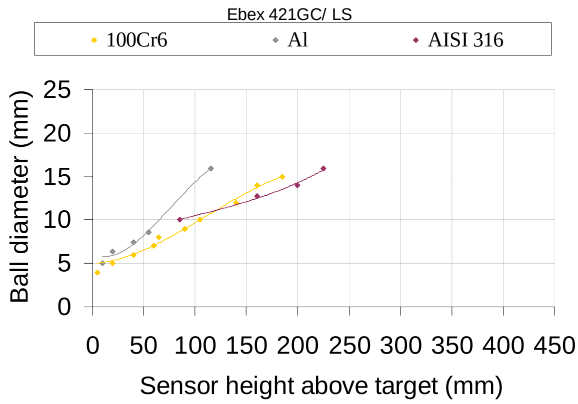





Sensitivity profile by manual method
Target: BLU 26B submunition



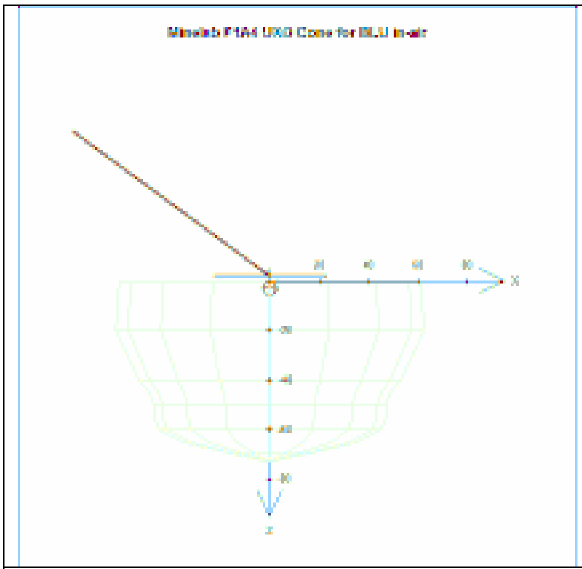
Effect of sweep speed on detection capability



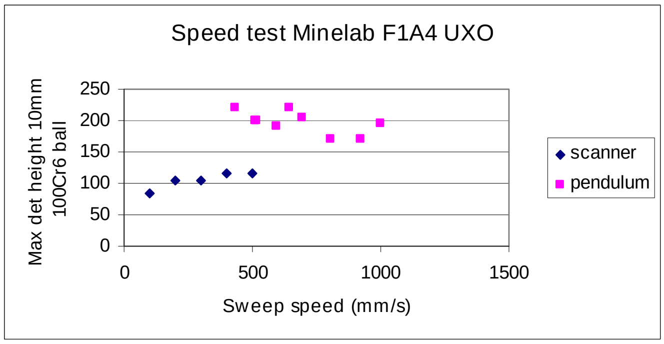
Detection capability in air for different metals

11.n. Minelab F1A4 UXO

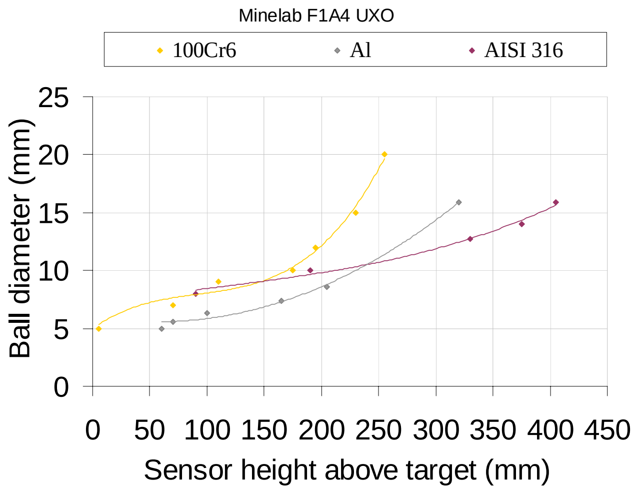
Parameters	Value	Comments
Operational aspects		
Format	Two-piece shaft, with snap-locks, separate arm-rest, Separate control box, mountable on shaft.	
Head	45 cm Ø	Circular
Length in use	110-132 cm	Continuously adjustable
Mass in use	3.9 kg	
Ground compensation	Yes	Automatic after initiation Patented multi-pulse width technology
Mode	Dynamic	
Speaker	Internal or headphone (two versions: does/does not mute speaker)	
Target signals	Audio	Varies according to target size
System signals	Audio/visual	Confidence tone, low battery warning
Controls	Switch Audio reset button Noise cancel button	3 positions: Search, ground comp. and off Fixed sensitivity
Access to software	Via RS232 port	
Price	2100 EUR	Without VAT, loaned copies used.
Package		
Operator manual	Yes	A5, English, water and tear resistant paper
Instruction card	Yes	Single A5 page, English, plastic laminated
List of contents	Yes	On the instruction card
Test piece	Yes	
Batteries	Yes	
Transport case		
Dimensions	76 × 48 × 11 cm	
Mass (full)	5.6 kg	
Type – material	Soft – fabric	
Backpack		Only soft case supplied
Mass backpack (full)		
Times for Set up		
Mechanical set-up	180 s	
Backpack storage	150 s	
Standing/kneeling	30 s	
Electrical set-up	15 s	
Electrical aspects		
Waveform	Unipolar	
Coils	Single	
Battery		
Type - Number	LR20 (D-cells) four	6 V nominal
Life	7.5 hrs	



Sensitivity profile by manual method
Target: BLU 26B submunition



Effect of sweep speed on detection capability



Detection capability in air for different metals

11.o. Vallon VMH3CS UXO

The CS variant is similar to the standard VMH3 but the head may be removed for fitting into a smaller transport case. Here it was operated with the large UXO head.

Operational aspects		
Format	Single-piece shaft and electronics unit, separate head	
Head	61.5 cm	Circular
Length in use	96 -130 cm	Continuously adjustable
Mass in use	3.3 kg	
Ground compensation	Yes	Automatic. Setting retained when detector off.
Mode	Dynamic	
Audio	Internal speaker / headphone	
Target signals	Audio/visual/vibrator	Large target signal
System signals	Audio/visual/vibrator	Sensitivity level, low battery alarm NOTE: does not have confidence click
Controls	Mode Switch Sensitivity/vol. level Compensation/reset	Normal, mineral, volume adjust, off Digital, in fine steps
Access to software	Yes	Via RS 232. Digital output of signal also.
Price	2420 EUR	Without VAT. Loaned copies used.
Package		
Operator manual	Yes	A5 – English Paper
Instruction card	Yes	A5- English – plastic laminated
List of contents	Yes	In manual
Test piece	Yes	
Batteries	Yes	Optional NiMH and charger
Transport case		
Dimensions	51.5 x 41 x 20.5 cm	UXO head goes in separate soft case, (66 x 72 cm, 3.1 kg).
Mass (full)	9.2 kg	
Type – material	Hard - plastic	
Backpack	Yes	
Mass backpack (full)	4.4 kg	
Times for Set up		
Mechanical set-up	30 s	
Backpack storage	30 s	
Standing/kneeling	10 s	
Electrical set-up	10 s	
Electrical aspects		
Waveform	Bipolar pulses	
Coils	Single coil	
Battery		
Type - Number	LR20 (D-cells) three	Normally use rechargeable NiMH supplied
Life	17 hrs	Life with alkaline. 4.5 V nominal


C
VALLON

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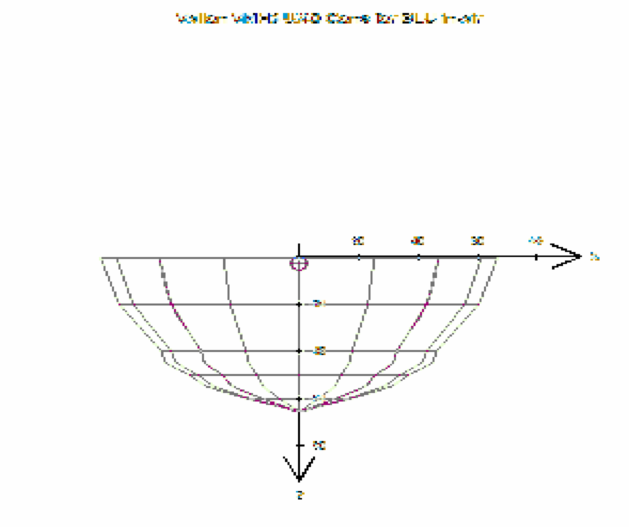
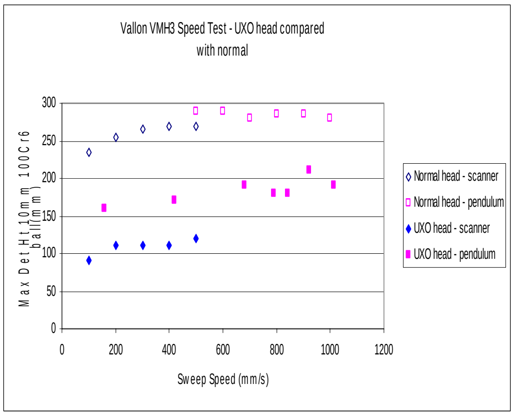
<td></td>
<td>
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Target: BLU 26B submunition</td>
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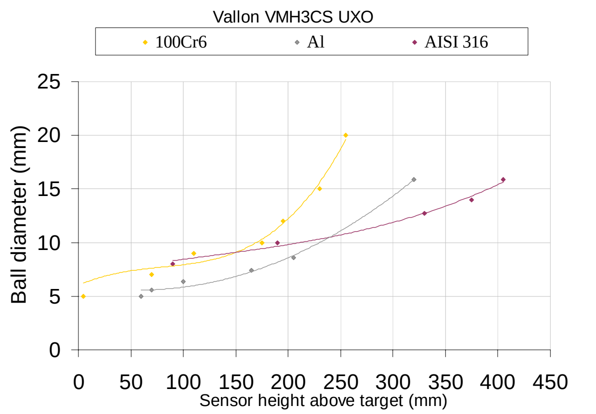
<td>
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Appendix: Additional Detectors used in certain tests

Schiebel AN19 – 2

This detector is a two-piece design with separate head and headphone, which was a predecessor of the ATMID. Unlike the ATMID, it is a pulsed induction detector and lacks soil compensation. The AN19-2 was widely used in humanitarian and military demining in the 1990's and is still obtainable. It was tested in the IPPTC and returned good results in most tests, surprisingly, outperforming the ATMID. The Ground Reference Height (GRH) measurement is performed with an AN 19-2, because it is static mode with continuous sensitivity adjustment, features which make it suitable for this purpose. Over its history, several modifications were made, that designated Mod 7 is recommended for the GRH. The AN19-2 was included in the battery test, because of its exceptionally good battery life. It was also included in the weight tests, because many users are familiar with it and may find it helpful to compare other detectors with the AN19-2 in this respect.

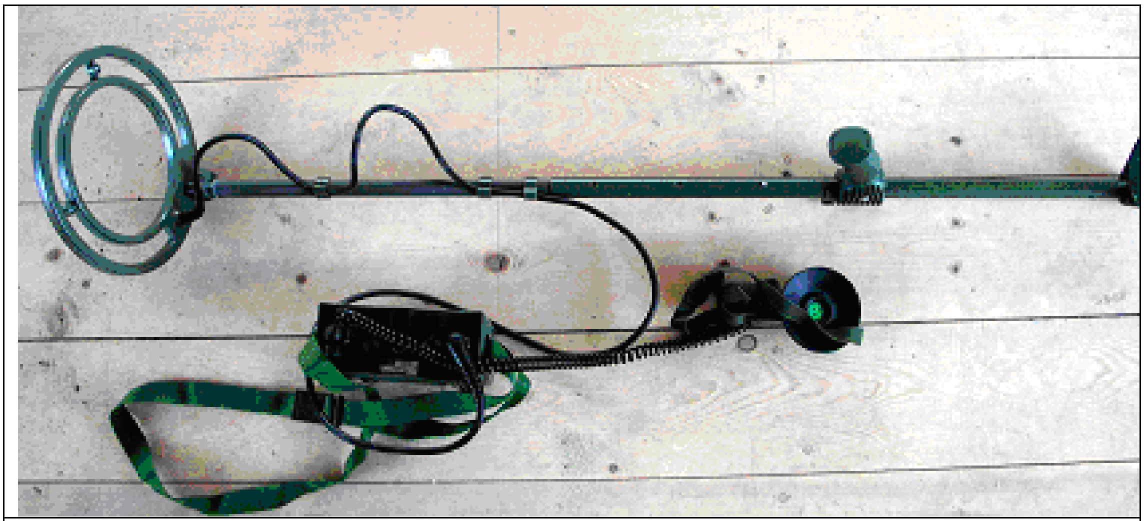

Fig. A-1 Schiebel AN 19-2

Adams Electronics AX777

Adams Electronics is a well-known manufacturer of small handheld detectors for inspection of persons. Their model AD2500 and the very similar AD2600S small detectors were included in IPPTC to see if low-cost devices of this type could be used for demining, simply by attaching them to a longer handle, but the results were generally poor. Adams does currently manufacture a detector intentionally designed for ground search, the AX777. Interesting features are low price (312 EUR), low weight (1.5 kg), vibration as well as audible alarm and long battery life (360hrs claimed, but not tested by JRC). It is not a purpose-built demining design and a preliminary assessment confirmed it to be less robust than the demining detectors: the battery compartment can come open if it is roughly handled and it lacks a transportation case or backpack. It has no soil compensation feature. Such limitations are to be expected in a device in this price bracket. For these reasons, the AX777 was excluded from STEMD but we did conduct some in-air sensitivity tests with it. Results indicated that it has the unusual feature of performing best at very high speeds. In-air detection heights for the 10 mm 100Cr6 steel up to 155 mm were found in pendulum tests, which are comparable to those of the SHRIMT Model 90 and the CEIA MIL D1 on its lower "red-spot" setting, but this performance is only achieved at sweep speeds of 1 m/s, which would be impractical to maintain in manual demining. At lower speeds, sensitivity on 100Cr6 and other metals is significantly reduced. Results of the speed test are shown in fig. A.3 below.

Fig. A-2 Adams AX777

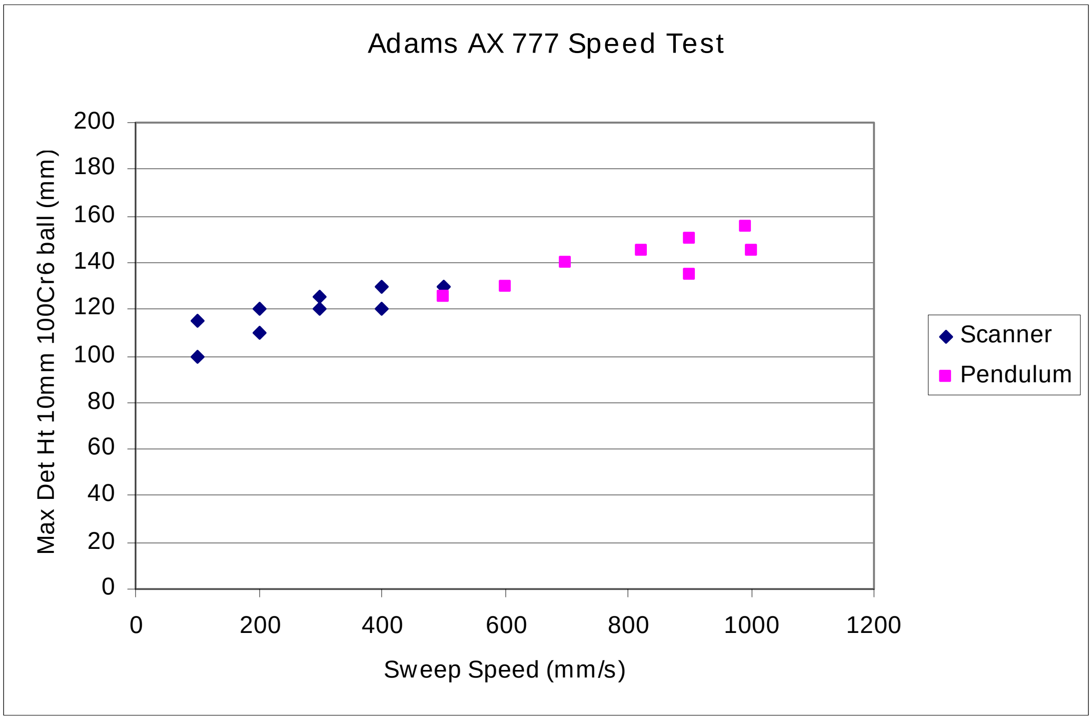

Fig. A-3 Speed test with Adams AX777

Beijing Geological Instrument Factory GTL115-2

This detector has a format which is loosely copied on the Ebinger designs but in detail it is completely different. It is of interest as an example of the entry into the market of a new company offering a device at low cost. Two copies were bought by JRC in autumn 2005. Had we been aware of its existence earlier, we would have included it in the project.

We did perform the drift, temperature shock, audio output and threshold for perception tests on it, and the results are reported above.

A preliminary assessment indicated its strengths to be its low price (823 EUR) and well-featured package, including transport case, extension tube, headphone as well as speaker, additional narrow search head, NiMH batteries and charger. No backpack is supplied. Its weaknesses are low sensitivity, lack of soil-specific ground compensation, low audibility and poor electronic stability.

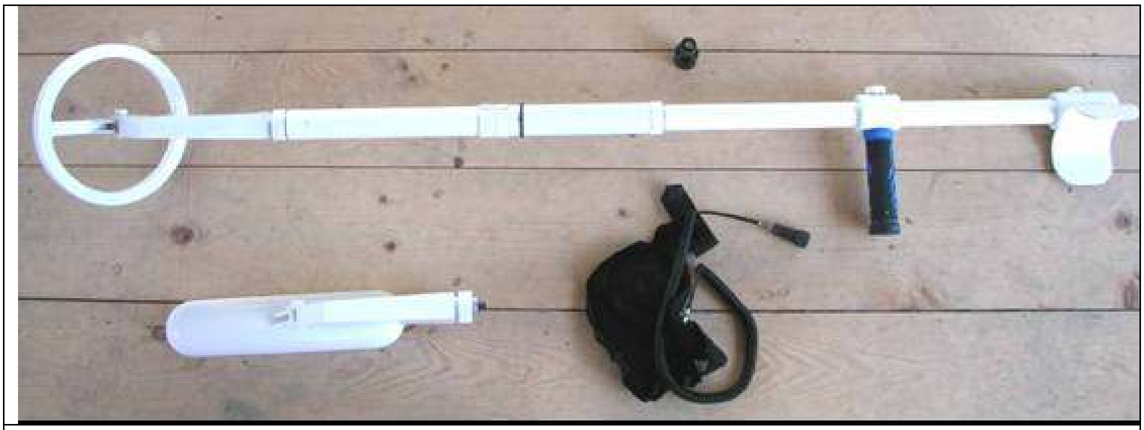

Fig. A-4 Beijing Geological Instrument Factory GTL115-2

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Luxembourg: Office for Official Publications of the European Communities
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EUR - Scientific and Technical Research series; ISSN 1018-5593

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