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TNO report

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Magnetic clutter reduction efficiency in humanitarian demining

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Magnetische valse-alarmenreductie; efficiëntie in humanitair ontmijnen

Het verminderen van het grote aantal valse alarmen van metaaldetectoren in ontmijningsoperaties kan het ontmijnen aanmerkelijk versnellen. Metaalresten zoals spijkers, blikjes en kogelhulzen zijn de grootste oorzaak van valse alarmen. In dit project is in lopende ontmijningsoperaties in Cambodja en Angola onderzocht of met een eenvoudig en goedkoop middel, namelijk een permanente magneet, een ontmijningoperatie versneld kan worden.

Probleemstelling

Metaalresten vertragen veel humanitaire ontmijningsoperaties waarbij metaaldetectoren gebruikt worden, omdat ze valse alarmen veroorzaken. De metaaldetector is nog steeds het primaire detectiemiddel in handmatige ontmijningsoperaties.
Het scannen van de bovenste laag van de grond met permanente magneten maakt eenvoudige verwijdering van een deel van die metaalresten mogelijk.
Magneten worden al zeer beperkt gebruikt in ontmijningsoperaties, maar de invloed ervan op de efficiëntie van de operatie is nooit gekwantificeerd.

Beschrijving van de werkzaamheden

Aan de hand van een enquête onder niet-gouvernementele organisaties (NGO's) die ontmijningsoperaties uitvoeren is een aantal magneten geselecteerd voor testen onder operationele omstandigheden. Naast een sterke ringmagneet en een zwakkere blokmagneet, zijn twee harkjes met magneten ontwikkeld waarmee de bovenste laag van de oppervlakte gemanipuleerd kan worden; één harkje met starre tanden en één met flexibele tanden.
Drie testseries zijn uitgevoerd door lokale ontmijners in mijnenvelden in Cambodja en Angola om de invloed van magneten op de efficiëntie van de ontmijningsoperatie te bepalen. De eerste werd uitgevoerd in samenwerking met CMAC (Cambodian Mine Action Centre) en de andere twee in Angola met NPA (Norwegian Peoples Aid). Steeds werkte één groep ontmijners volgens de vigerende standaard procedure en één groep werkte volgens een aangepaste procedure waarin het gebruik van de magneten was opgenomen. De ontruimde oppervlakte per dag per ontmijner en de hoeveelheid gevonden metaalresten zijn geregistreerd. Tevens is bijgehouden of de metaalresten met een magneet gevonden werden of op een andere wijze.

Resultaten en conclusies

De sterke ringmagneet heeft de voorkeur van de ontmijners. Het harkje met starre tanden wordt niet geaccepteerd voor gebruik in een mijnenveld, omdat men denkt dat de tanden teveel druk op de oppervlakte uitoefenen en dus een mijn tot detonatie kunnen brengen. Het harkje met flexibele tanden wordt wel geaccepteerd, maar in het algemeen zijn er bezwaren tegen het gebruik van de harkjes, omdat manipulatie van de oppervlakte niet binnen de standaard ontmijningsprocedure valt.
De ontmijners zijn er van overtuigd dat de ringmagneet de efficiëntie van de operatie verhoogt en vooral hun werk makkelijker maakt. De data van de testseries laten echter geen efficiëntieverhoging zien.
De ontmijners met magneet ontruimen 10-40% minder oppervlakte dan de ontmijners zonder magneet. Aan de andere kant vinden zij 15-50% meer metaal.
Dit kan veroorzaakt worden door niet-homogene verdeling van de metaalresten of doordat de ontmijners zonder magneet niet alle metaal gevonden en verwijderd hebben.

Toepasbaarheid

De magneten die gebruikt zijn tijdens de testseries zijn gedoneerd aan CMAC en NPA. NPA heeft besloten de ringmagneet in zijn standaard ontmijningsprocedure op te nemen. Tevens heeft NPA TNO gevraagd te assisteren bij de implementatie van deze magneet bij alle ontmijningsoperaties van NPA in Angola.

PROGRAMMA	PROJECT
Programmabegeleider -	Projectbegeleider Lkol A.F. Keijzer, MinDef/DMO/DR&D
Programmaleider -	Projectleider dr. A.J. Schoolderman, BU1-3
Programmatitel -	Projecttitel Magnetic clutter reduction efficiency
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Frequentie van overleg Met de projectbegeleider werd herhaaldelijk gesproken over de invulling en de voortgang van het onderzoek.	Projectteam dr. A.J. Schoolderman Y. Rieter-Barrell, MSc

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Summary

The aim of the project was to quantify the expected efficiency increase in humanitarian demining operations obtained by using hand-held permanent magnets(-tools) in the 'close-in' detection phase. The tools can be used to remove metallic clutter from the top layer of the ground. Although a number of organisations has experimented with such tools, the influence on demining efficiency has not been quantified within live demining operations.

A number of selection criteria for the magnet(-tools) was chosen and assessed by means of a questionnaire amongst employees of humanitarian demining organisations. The respondents indicated weight, robustness and safety as the most important criteria. A tool, which can be swept over the working lane in a kneeling position is preferable. On the capability to manipulate the top layer of the soil with the magnet(-tool), the respondents do not agree. This may be explained by the different scenarios the respondents work in. The results of the questionnaire and investigation into earlier testing of magnet(-tools) led to the selection of a number of tools: a strong ring magnet, a weaker handheld sweep magnet (HSM), a magnet-rake with rigid tines and a magnet-rake with flexible tines.

The efficiency of humanitarian demining when using the various magnet(-tools) has been analysed in three successive trials in live minefields. One trial took place in Cambodia in collaboration with the Cambodian Mine Action Centre (CMAC) and two in Angola in collaboration with Norwegian Peoples Aid (NPA). The general set-up for the trials was to have one group of deminers working according to the original standing operational procedure (SOP) of the demining organisation and a second group working with an adapted demining procedure including the use of the magnet(-tool). The amount of cleared area per day per demining lane was recorded. Moreover, the metal found during demining was gathered in plastic buckets and the method of finding (by visual detection or with the magnet(-tool) or during excavation) was recorded.

The ring magnet is the most popular magnet-tool among the deminers due to its strength. The rake with rigid tines is not accepted for use during scanning because it is believed to cause too much pressure on the surface and therefore can detonate a mine. The rake with flexible tines was only accepted for scanning during the first trial in Angola. During the second trial in Angola the deminers did not accept the rake as soil manipulation is not a part of their SOP. The deminers believe the use of the ring magnet increases the efficiency of humanitarian demining and also makes their work easier. However, the data did not show an efficiency increase. In general, the deminers in the reference group cleared a larger area than the deminers using the magnet(-tool) (10 - 40%). On the other hand, the deminers using the magnet(-tool) found a larger amount of metallic clutter than the reference group (15 - 50%). This effect may be caused by inhomogeneous metal distribution in the demining lanes. It is also possible that the deminers in the reference group did not clear all metallic clutter from their demining lanes. The endurance trial did not average out this effect.

NPA Angola has included the ring magnet for use during excavation in a revised SOP and is considering also including the ring magnet for use during scanning. Moreover, NPA has requested assistance from TNO for the delivery and implementation of the ring magnet in all its manual demining operations in Angola.

All magnet(-tools) used during the trials were donated to CMAC in Cambodia and NPA in Angola.

Contents

Appendices

1 Introduction

1.1 Aim of the project

The aim of the project 'Magnetic clutter reduction efficiency' is to quantify the efficiency increase that can be obtained by using hand-held permanent magnets or hand-held tools provided with magnets in the 'close-in' detection phase of humanitarian demining operations. Based on criteria that are set up in the project, a suitable magnet and/or tools with magnets are selected. The data that is necessary to quantify the clutter reduction by the magnet and/or these tools is not gathered in simulations or simulated demining procedures, but in representative, running demining operations, that is in live minefields. To this end a procedure is set up to train the local deminers in the use of the magnet and/or tools. Aids to support this training are developed and built as part of the project.

1.2 Framework and cause

In July 2000 the Netherlands Ministry of Defence signed the Memorandum of Understanding (MoU) of the International Test and Evaluation Program for Humanitarian Demining (ITEP). The aim of ITEP is to contribute to the solution of the world-wide landmine problem by making available information on better, safer and more cost-efficient demining methods and equipment. In the framework of the ITEP programme standards are developed and tests of demining equipment and methods are coordinated and executed. The results of these tests are made available for all interested parties. The ITEP MoU has been signed by Belgium, Canada, Germany, European Commission, United Kingdom, United States and Sweden.

The Geneva International Centre for Humanitarian Demining (GICHD)1 and the UN Mine Action Centre (UNMAS)[2] are involved in ITEP as 'observers'. In this role they are the connection between ITEP and the end-users of demining equipment, such as Non-Governmental Organizations (NGOs) and national Mine Action Centres (MACs). UNMAS recently advised[3] to focus the activities of ITEP more on operational tests ('fielding') of demining equipment, and less on research and development of this equipment.

In June 2002 the GICHD published the 'Mine Action Equipment: Study of Global Operational Needs'[4]. For this study an analysis is made of the different phases and activities that form together a humanitarian demining operation. Subsequently it is investigated how large the efficiency increase of the demining operation is when a technique or method used in one of the phases is improved. It is concluded that improvements in the 'close-in' detection phase yield 'very significant benefits'. For example a decrease of the number of false alarms of metal detectors with 50% leads to efficiency improvements of 21% to 47% in demining operations in 10 of the 12 scenario's that are defined in this study.

1 GICHD is an impartial and independent foundation supported by more than 20 governments.
2 UNMAS is the focal point within the United Nations system for all mine-related activities.
3 'UNMAS brief to ITEP ExCom', Annex 2 of the draft minutes of the ITEP ExCom Meeting, Washington, October 2005.
4 GICHD, ISBN 2-88487-004-0, Geneva, June 2002.

Between November 2004 and October 2005 two new hand-held mine detection systems, the HSTAMIDS and the Minehound, were tested in humanitarian demining scenarios in the framework of ITEP. TNO, the Netherlands Organization for Applied Scientific Research, has participated in the tests of these systems in Thailand, Namibia and Cambodia as part of the Netherlands contribution to ITEP. In both the HSTAMIDS and the Minehound a metal detector and ground penetrating radar are combined. Compared to conventional metal detectors theoretically their most important advantage is that they can be used to discriminate between buried mine-like objects and metallic clutter, such as nails, pieces of wire, shrapnel, etc. In this way the number of false alarms can be reduced drastically. Disadvantages of both systems are amongst others the high price, the high weight, causing fatigue of the operator, and the high demands to the training and experience of the operator.

In a recent study on manual demining[5], done by the GICHD, it was found that demining organizations are experimenting in their demining operations with simple tools as an addition to the standard tool set. The standard tool set consists in most cases of a metal detector, a prodder, a spoon and a wire-cutter to cut vegetation. One of the additional tools that was noticed in this study by the GICHD was a small permanent magnet. This magnet was used in a demining operation in Cambodia to remove metallic clutter on the surface of the ground by moving the magnet manually over the surface; ferromagnetic metal parts stick to the magnet. Although the added value of this tool will depend highly on the demining scenario, the use of magnets as an addition to the standard demining tool set is one of the recommendations of the study, because the use of magnets will yield an increased efficiency of the operation in many cases. We cite: ‘Perhaps most significant in terms of improving productivity in manual demining is the usefulness of a very simple and cheap tool, a small magnet, for dealing with indications from a metal detector’[6].
In the Internet newsletter ‘Mine Action technology Newsletter, issue 3’, October 2005 that is published by the UNMAS and GICHD demining organizations are asked to buy magnets and to tests these. Although many demining organizations are innovative and test procedures and tools themselves, the study on manual mine clearance notices that the results and conclusions of these tests ‘tend to be poorly reported’[7]. This is clearly a role for ITEP. Tests of tools and procedures can be executed by ITEP partners, possibly in collaboration with demining organizations, GICHD and UNMAS, in a scientific way and reports can be made available to the demining community through Internet (ITEP website: www.itep.ws).

From the perspective of the Dutch contribution to ITEP, TNO proposed a project ‘Magnetic clutter reduction efficiency’ to the Netherlands Ministry of Defence to investigate the contribution of small magnet(-tools) to the efficiency of humanitarian demining operations. The project was funded by the Netherlands Ministry of Defence. The results of this project are described in the report at hand.

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[5] A study of manual mine clearance. Book 3. Operational systems in manual mine clearance: case studies and experimental trials. GICHD, Geneva, ISBN 2-88487-039-3, August 2005.

[6] Idem, page 44.

[7] Idem, page 3.

1.3 Project phases

Initially the project consisted of the following six work packages.

WP-100 Selection of the permanent magnet and/or tools.
In this work package the following activities are distinguished.

- Criteria are set up for hand-held permanent magnets and tools equipped with magnets suitable for the intended purpose. As examples one can think of the amplitude and distribution of the magnetic induction but also of user requirements as the weight and size of the magnet and/or tool, the robustness and the price. The criteria are discussed with experts on manual demining, such as the GICHD in Geneva.
- Based on these criteria a magnet and/or tool is to be selected. Enough samples of this magnet and/or tool are purchased for the execution of the project.

WP-200 Set-up training procedure.
In this work package the following activities are distinguished.

- Because in the work packages 300 – 500 indigenous deminers use the magnets and/or tools in live mine fields during running demining operations, it is important to instruct these deminers very well on the use of these magnets and/or tools and the data acquisition procedure to be followed. For this reason an instruction procedure is set up that can be trained out of the live mine field.
- There is a need for instruction tools for the indigenous deminers in order to make the distribution of the magnet's field and dependence on the distance of the magnet visual. In this work package such a tool is designed and built.
- In preparation of the work packages 300 – 500 data acquisition procedures is set up. These procedures must obey the requirements that they can be executed, after instruction, by the indigenous deminers without guidance from others.
  Moreover, they must fit into the Standing Operational Procedures (SOPs) that are used by the local demining organizations.

WP-300 Data-acquisition in a demining operation in SE Asia.
In this work package the following activities are distinguished.

- To organize the data acquisition in a demining operation in South East Asia an NGO that is active in that region is contacted. If possible, an NGO is selected that is sponsored by the Dutch government, for example HALO Trust in Cambodia.
  Use is made of the network of GICHD.
- Instruction of the indigenous deminers in the use of the magnet and/or tools and the data acquisition sheet, on the site of the demining operation. A local interpreter and, if necessary, transport (4WD with driver) is hired.
- Monitoring of the data acquisition by the indigenous deminers in the running demining operation. It is expected that the data acquisition takes 4 to 6 weeks in order to gather enough data. Monitoring takes place during a few days at the start and the end of the data acquisition. If necessary intervening monitoring is done by ITEP partners.
- A total of three visits to the data acquisition site is foreseen; one to get familiar with the site, the NGO and its deminers, and its SOP, a second visit to instruct and train the deminers on the use of the magnets and/or tools and to start the data acquisition and a last visit to finish the data acquisition and an evaluation with the deminers.
- A concise interim report in English of the instruction and data acquisition.
  This interim report is published on the ITEP website so that the project is brought under the attention of the international mine action community.

WP-400 Data-acquisition in a demining operation in Africa.
In this work package activities are distinguished similar to those in work package WP-300 with the understanding that for the data acquisition in Africa the intention is to collaborate with the NGO Norwegian People's Aid in Angola that is sponsored by the Dutch government.

WP-500 Data-acquisition in a demining operation in SE Europe.
In this work package activities are distinguished similar to those in work package WP-300 with the understanding that for the data acquisition in South East Europe the intention is to collaborate with the NGO Norwegian People's Aid in Bosnia that is sponsored by the Dutch government.
As a result of the first trial in Angola, this work package was skipped, in order to execute a second trial in Angola.

WP-600 Data analysis and reporting.
In this work packages the following activities are distinguished.

- The data gathered in the work packages 300 – 500 are analysed. From this data the reduction of the number of false alarms of metal detectors by the use of the magnet and/or tools is calculated. It is considered whether this can be linked to the local scenario. Finally the efficiency increase of the demining operation by using magnets and/or tools is to be calculated.
- A final report of the project is written in English. This report is presented to the Netherlands Ministry of Defence and is also published on the ITEP website. Publication of the report by the GICHD is considered, or the possibility to download the report on the GICHD website. Publication of a summary of the report in the Journal of Mine Action of the Mine Action Technology Newsletter is pursued.

The work packages WP-300 and WP-400 are executed sequentially. This makes it possible to implement lessons learned from previous data acquisition phases in coming field work.

1.4 Report arrangement

In Chapter 2 the information used to select suitable magnet(-tools) for the data acquisition phases is presented. Attention is paid to open source information and the results of a survey held among a group of experts. Chapter 3 gives an overview of the set-up of the data acquisition phase including the instruction of the deminers and the demining procedure. In Chapters 4 to 7 the data-acquisition phases and the analysis of the data from the trials in Cambodia and Angola are presented. The conclusions of the study are given in Chapter 8.

2 Selection of magnets and magnet-tools

In this chapter the selection process of the magnets and magnet-tools to be used in the data-acquisition phases is described. Several organisations have already experimented with magnets or magnet-tools in their humanitarian demining procedures.
Information on these experiments has been gathered from open sources (e.g., internet) and personal communications and is summarised, without the objective to be complete, in the first section of this chapter. In the second section the results of a questionnaire held among a group of experts are presented. The four types of magnets and magnet-tools, which were selected for the data acquisition phases of the project are described in Section 2.3. The chapter is concluded with the results of research performed on the influence of a magnet on a Type72b anti-personnel mine. It has been suggested in open sources that a magnet(-tool) may be able to cause detonation of this mine type.

2.1 Information on past and present use of magnets in demining operations

As mentioned before, the GICHD study on manual demining[8] reports on the Cambodian Mine Action Centre (CMAC) using small permanent magnets in their manual demining operations. These 'doughnut' magnets are taken from the backside of a loudspeaker. The magnets are used to scan the surface after the metal detector has given an alarm thereby removing loose ferrous material from the surface. If no metal is attracted by the magnet, the deminers often attach the magnet to their CMAC trowel and scrape the top layer of the surface with it to attract ferrous material just below the surface. Finally, the surface is re-scanned with the metal detector. If the alarm remains, excavation is started, during which the magnet is used to find metal parts in the removed soil.

The introduction of a magnet brush rake (i.e. a garden rake with a magnet or magnets attached to it) in humanitarian demining scenarios has been discussed on the IGEOD forum[9] and summarised by Andy Smith, AVS Mine Action Consultants on the website www.nolandmine.com/magnets.htm. The use of brush rakes without magnets has proven to be successful in Sri Lanka to expose the top of shallow mines. Here the brush rakes were used in an SOP in which no metal detectors were applied. The brush rakes are suitable for sandy areas with broken up ground without tripwires and only if the mine types are well-known. Attempts to set off the anti-personnel mines present in the operation in Sri Lanka with a brush rake intentionally failed.
Andy Smith suggested using brush rakes with magnets in addition to metal detectors, in demining scenario different from those in Sri Lanka. The experience gained by the use of brush rakes in Sri Lanka can be used to design a suitable magnet brush rake.

Andy Smith performed comparative trials of manual mine clearance techniques in Mozambique in 2004[10]. The 2 meter long magnet brush rake, Figure 2.1, was one of the methods, which was taken into account during these trials. Also a magnet attached to the standard signal-investigation tool, Figure 2.2, was added to the trials. The trials were performed in simulated mine fields with surrogate mines. It was concluded that '*the most efficient method of clearance was using a metal detector and a magnet brush rake*

[8] A study of manual mine clearance. Book 3. Operational systems in manual mine clearance: case studies and experimental trials. GICHD, Geneva, ISBN 2-88487-039-3, August 2005.
[9] Intergalactic Explosive Ordnance Disposal Forum: http://groups.google.com/group/igeod?hl=en
[10] Comparative trials of manual mine clearance techniques Mozambique, 2004. A report written for GICHD by Andy Smith, AVS Mine Action Consultants, December 2004.

in a heavily fragmented area. The use of signal investigation tools that included a magnetic attachment was the next fastest. The use of a magnet brush rake in areas with cut vegetation or leaf litter might have given an even greater speed advantage'.

Figure 2.1 Two meter long magnet brush rake tested in the comparative trials of manual mine clearance techniques Mozambique, 2004. Picture taken from [10].

Figure 2.2 Magnet attached to the standard signal-investigation tool tested in the comparative trials of manual mine clearance techniques Mozambique, 2004. Picture taken from [10].

In Croatia some experiments have been done with magnets and rakes by the Croatian Mine Action Centre (CROMAC) and are reported to be successful. However, in Croatia rakes are not always applicable due to the large number of mines with tripwires present. For the same reason large parts of Croatia are cleared mechanically. In Figure 2.3 some pictures of the CROMAC magnet-tool are shown that is mainly used during the excavation phase to pick up ferrous fragments.

Figure 2.3 The magnet-tool used by CROMAC in Croatia (pictures taken from e-mail communications with CROMAC).

At MIT some research has been performed on a 'Magrake'[11], which is a garden rake combined with ring magnets. The rake has flexible tines and the magnets are placed on the body of the rake as far away from a potential blast as possible. The rake is a hand-held rake. Experiments have been performed on various types of rakes (short or long handle, tine flexibility). The starting point of the research was the report written by Andy Smith about the trials in Mozambique.

In conclusion, there have been several initiatives by individual people, NGOs and MACs to use magnet(-tools) in their SOP or investigate the contribution of these tools to demining efficiency. However, quantification of the efficiency increase due to the magnet(-tools) has only been investigated in a simulated environment and not in a live minefield. Moreover, a tailor made magnet(-tool) for humanitarian demining is not available commercial-of-the-shelf (COTS) as of yet.

2.2 Questionnaire among an expert group

In order to investigate the selection criteria for magnet(-tools), a survey was distributed among a group of experts working for non-governmental organisations in various mine-affected countries. The survey consisted of a brief introduction to the project followed by a questionnaire with a set of multiple choice questions and three open questions. The survey format is shown in Appendix A. Since only six experts responded to the survey, the results should be regarded with care. In Appendix A the raw results of the multiple choice questions in the survey are shown. In this Section the overall results are discussed in combination with answers to the open questions and comments made by the respondents in the rest of the survey.

In Table 2.1 the results are shown for the multiple choice questions on user requirements. The respondents more or less agree that the magnet(-tool) must be light (assuming hand-held use), robust, maintenance free and easy to learn to handle although training may take a couple of hours. On the cost of the magnet the respondents do not agree. It is noted by one of the respondents that cost would become of less importance once the magnet(-tool) has proven to be an efficiency enhancing tool.

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[11] S.Raghunathen, H. Tsai, *Magrake*, March 2005, http://ocw.mit.edu/OcwWeb/Special-Programs/SP-776Spring-2005/Projects/index.htm

Table 2.1 User requirements.

User requirement	Rating
Weight of the magnet(-tool)	< 500 g
Cost of the magnet(-tool)	widely spread responses
Robustness of the magnet(-tool)	> average importance
Maintenance free: the magnet (-tool) requires little to no maintenance	> average importance
Deminer training requirements (including adaption of the SOP)	preferably 1 to 4 hours, but longer may be acceptable

In Table 2.2 the results are shown for the multiple choice questions on requirements related to the application. In this category the respondents agree that the magnet(-tool) should have a working area width of 5 to 10 cm meaning the magnet(-tool) should be swept across the complete working lane by the deminer. Large pieces of ferromagnetic material should be attracted by the magnet(-tool) from a distance larger than 5 cm but a small piece of clutter may be attracted from 1 cm. The clutter should be easy to remove from the magnet(-tool) and the magnet(-tool) would preferably be used in a kneeling position. On the possibility to manipulate the top layer of the soil with the magnet (-tool), the respondents do not agree. Several say it is not important at all and others say it is decisive. This may be explained by the different scenarios each of the respondents work in.

Table 2.2 Requirements related to application.

Requirements related to application	Rating
Coverage of the magnet(-tool): width of the working area	5 - 10 cm
Magnet strength: distance of attraction of a 10 g iron fragment	> 5 cm
Magnet strength: distance of attraction of a 1 g iron fragment	> 1 cm
Possibility of soil manipulation with the magnet(-tool)	widely spread responses
Ease of the removal of clutter from the magnet(-tool)	> average importance
Preferred position during use of the magnet(-tool)	kneeling

Finally, in Table 2.3 the results are shown for the requirements related to safety. The respondents agree the magnet(-tool) must be blast resistant and must not be able to trigger mines with anti-handling devices or magnetic sensors. The required distance between the operator and the working area is larger than 50 cm. This would indicate the magnet(-tool) should have a handle to hold.

Table 2.3 Requirements related to safety.

Requirements related to safety	Rating
Blast resistance: magnet (-tool) will not fragment due to blast	decisive importance
Impossibility to trigger mines with anti-handling devices or magnetic sensors	decisive importance
What distance between the operator and the working area is required / desired	> 0.5 m

The open questions in the survey led to the following results. Three of the respondents have experience with magnet(-tools). One respondent uses magnets from the backside of loudspeakers in manual demining, like CMAC does. No comment is given on efficiency increase due to the use of these magnets but it is noted that the magnet must be swept less than 5 cm above the ground to be effective. Two other respondents only comment that their experience with magnets is that it is a useful tool. In one case it has led to a great improvement with small pieces of clutter, especially after the metal has corroded and turned to the same colour as the soil. However, the improvement is not quantified. None of the respondents are aware of any other drills or devices in manual demining, which will remove clutter and reduce the false alarms of the metal detector.

2.3 The selected magnets and magnet-tools

Four different types of magnet(-tools) have been selected for the data acquisition phases and are shown in Figure 2.4:
1 Ring magnet.
2 Handheld sweep magnet (HSM).
3 Rake with rigid tines.
4 Rake with flexible tines.

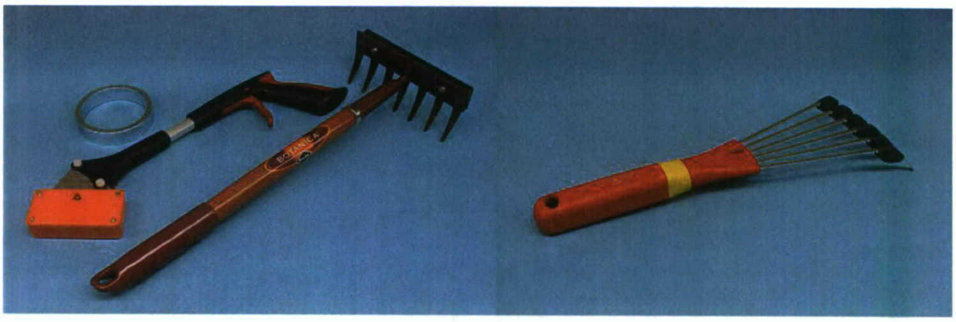

Figure 2.4 The selected magnets and magnet-tools; from left to right: the ring magnet, the handheld sweep magnet (HSM), the rake with rigid tines and the rake with flexible tines.

The ring magnet is a neodymium permanent ring magnet custom-made by NEOTEXX, Berlin, Germany. The ring magnet is coated with nickel and weighs 323 g. It has an outer diameter of 100 mm, an inner diameter of 85 mm and a width of 20 mm. It is magnetised in axial direction and the magnetic field is 1.26 T at the magnet's surface. A plastic casing has been added to the ring magnet between data acquisition phases to enable easier removal of clutter and to protect the magnet. The ring magnet and casing together weigh 586 g (see also Section 6.2).

The HSM is a magnet-tool designed and supplied by Colin King (C. King Associates Ltd, UK). The tool consists of a plastic orange cover which has a magnet inside. The tool has an aluminium handle which can be held while sweeping the working area. The trigger on the handle is used to release metallic objects, which are stuck to the orange cover. The tool is light-weight due to its construction from mainly plastic and aluminium. The exact strength of the magnet is not known but it is much weaker than the ring magnet.

The rake with rigid tines is a magnet-tool supplied by Mike O`Malley (Canica, Canada). The tool consists of a regular garden rake with rigid tines, a handle of 45 cm and a neodymium magnet which has been attached to the rake above the tines. The magnet is a block magnet and covers the complete width of the rake (16.5 cm). The weight of the rigid rake is 770 g. The exact strength of the magnet is not known but it is in between the ring magnet and HSM.

The rake with the flexible tines has been made at TNO and consists of a regular garden rake with flexible tines and diamond-shaped magnets attached to each tine separately. The length of the rake is 35 cm and the maximum width at the tips of the tines is 11.5 cm. The diamond-shape has been chosen to fit the magnet nicely underneath each tine

(see Figure 2.3). The magnets are connected to the tines with rubber socks.
The diamond-shaped magnets are custom-made neodymium permanent magnets supplied by NEOTEXX, Berlin, Germany. The magnets are shaped like a parallelogram with dimensions 20x22x5mm and are magnetised along the 22 mm side of the parallelogram. The magnetic field is 1.26 T at the magnet's surface. The weight of the complete tool is 238 g.

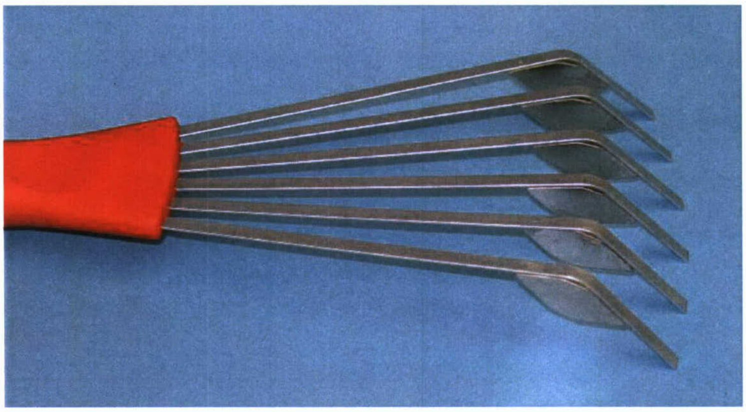

Figure 2.5 Close-up of the diamond-shaped magnets attached to the tines of the flex rake. Here the black rubber socks are removed.

In relation to the survey, the characteristics of these tools can be summarised as shown in Table 2.4. Some of the values are crude estimations.

Table 2.4 Characteristics of the magnet(-tools) in relation to the results of the survey

Requirements	Survey	Ring	HSM	Rigid rake	Flex rake
Weight	< 500 g	323 g			
Cost	-	€120			€25
Robustness	> average importance	good	medium	good	medium
Maintenance free	> average importance	good	medium	good	good
Deminer training requirements	> 1 hour	1 hour	1 hour	1 hour	1 hour
Coverage (working area width)	5 - 10 cm	10 cm	5 cm	15 cm	15 cm
Magnet strength: attraction of a 10 g iron fragment	> 5 cm	10 cm	4 cm	5 cm	5 cm
Magnet strength: attraction of a 1 g iron fragment	> 1 cm	3 cm	1 cm	3 cm	3 cm
Possibility of soil manipulation	-	no	no	yes	yes
Ease of the removal of clutter	> average importance	medium	high	medium	medium
Preferred position during use	kneeling	kneel	kneel	kneel	kneel
Blast resistance	decisive importance	N/K	N/K	N/K	N/K
Impossibility to trigger mines	decisive importance	N/K	N/K	N/K	N/K
Distance operator - working area	> 0.5 m	0.1 m	0.3 m	0.4 m	0.3 m

Since the magnet(-tool)s will be used to remove metal parts in a mine field that cause false alarms by a metal detector, there is theoretically a relation between the minimum size of the metal parts that the magnet should be able to attract and the sensitivity of the metal detector. It is not necessary to remove a metal part from the mine field if that metal part is so small that it does not give a metal detector alarm. However, this observation has no practical consequences due to the rapid decrease of the attraction force exerted by a magnet.

Finally, it is noted that the ring magnet, the HSM and the magnet with rigid tines are used during the data acquisition phase in Cambodia, and the ring magnet and the rake with flexible tines are used in Angola.

2.4 The influence of magnets and magnet-tools on mines

In open sources (e.g. the IGEOD forum) the issue has been raised that the Type72b anti-personnel mine could be set off by a magnet(-tool) even when the battery in this mine is completely depleted. In the framework of the project at hand this issue has been addressed. The complete report of this investigation can be found in Appendix B. This report concerns the analysis of the electronics circuitry of the Type72b anti-personnel mine. This type of mine contains an anti-handling device with a tilt-switch that is controlled by the electronic circuitry. The analysis aims at understanding the electronics and gives a prediction model for the magnetic induction characteristics needed to set off the detonator.

The investigation concludes that setting off a Type72b anti-personnel mine with a completely depleted battery by means of a manually moved magnet is not possible, not by charging of the detonation capacitor or by direct induced power. However, a warning is in place. When the battery is not completely depleted but is still maintaining sufficient power to keep the logic devices running and to prevent the detonation capacitor from discharging, there is a severe risk that the tilt-switch is set off. This situation can occur during a long period after deploying the mine. The components run on extreme low power and the capacitor will discharge only very little. Although the battery will soon no longer be able to provide large current, because of a high internal resistance of the battery, it will still be able to keep the circuitry operational. How long this situation will persist can not be said without elaborate measurements and analysis. One should however bear in mind that LCD clock modules run for years on one small battery that is often containing the same kind of Lithium cells as in the Type72b mine.

3 Set-up of instruction, training and data acquisition procedure

In this chapter an overview is given of the data acquisition procedure and the instruction and training of the deminers, which was used to set-up the various data acquisition phases.

3.1 Data acquisition procedure

The demining organisations chosen for the data-acquisition phases all use metal detectors in their so-called Standard Operational Procedure (SOP). The first condition for developing the data acquisition procedure including magnet(-tools) is that it should not interfere with the SOPs of the participating demining organisations. This asks for thorough agreement with these organisations and, as a consequence, it may be necessary to modify or fine-tune the proposed procedure to each demining organisation separately. Moreover, the three data-acquisition phases are executed sequentially, in order to learn from each phase and implement lessons learned in the following phase. In this section the general data acquisition procedure is presented. If some steps differ between different demining organisations, it will be noted in the following chapters on the other two data-acquisition phases.

The general set-up for the trials is to have two lanes in which the deminers work according the original SOP of the demining organisation and two lanes per magnet(-tool) in which the deminers work according an adapted demining procedure including the use of the magnet(-tool). The lanes in which the deminers work according the original SOP serve as a reference. Independent of the number of deminers working in one lane (e.g. one man – one lane procedure or two men – one lane), data will be recorded per lane every day. To this end data acquisition sheets are provided to the deminers. Moreover, metal found during demining is kept in plastic buckets marked with a colour code, depending on which phase of demining the metal was found in (see below). The trial is supervised by personnel from TNO (on a temporary basis) and by personnel from the demining organisation, e.g. a team leader or section leader.

The manual demining procedure using magnet(-tools) consists of the following steps after vegetation has been removed:

1. Visual inspection by the deminer of the part of the lane directly in front of the deminer for large pieces of metallic clutter; record if a piece of metal is found, take the piece of metal out of the lane (put in plastic box with the WHITE marking).
2. Scan the part of the lane directly in front of the deminer with the metal detector in use by the demining organisation (according to original SOP).
3. In the case of a metal detector (MD) alarm: scan that location with the magnet.
4. Record on the data acquisition sheet that a MD alarm is found and, if the magnet has found a piece of metal, take the piece of metal out of the lane (put in plastic box with the BLUE marking).
5. Scan the location again with MD; record the (non)-occurrence of an MD alarm.
6. Proceed according to the SOP:
   a. No MD alarm: step forward and scan the new area with MD and continue with step 1.
   b. MD-alarm: start prodding, excavation, etc. according the SOP.

7 In case of prodding, excavation, etc: record the result (i.e. mine or clutter found); if a piece of metal is found, take the piece of metal out of the lane (put in plastic box with the RED marking).

The data acquisition sheet supplied to the deminers is shown in Appendix C.1.
The supervisor from the demining organisation measures and records the cleared area in each lane at the end of the day and any special events, such as weather conditions and deviating working hours. To this end a data acquisition sheet is also supplied (see Appendix C.2). The metal found visually, with the magnet(-tool) and during excavation is kept in the white, blue or red box respectively. In Figure 3.1 the three boxes are shown.

Figure 3.1 The boxes in which the metallic clutter is kept; blue marking: metal found with the magnet(-tool), red marking: metal found during excavation, white marking: metal found visually.

3.2 Trial set-up and execution

As mentioned before three data acquisition phases are performed; one in Cambodia and two in Angola. The amount of metallic clutter encountered in demining operations depends heavily on the environment (i.e. the history of the area; e.g. residential or agriculture use, battle zone, etc.). For that reason it is important to identify a limited number of demining sites that are representative for these different environments.
The chosen sites in Cambodia and Angola have different environmental conditions. Details will be discussed in the following chapters.

Setting up each data-acquisition phase consists of five steps:
1 Preparation in collaboration with demining organisation including an orientation visit by TNO.
2 Instruction of the deminers by TNO.
3 Training of the deminers by TNO.

4 Approximately 5 weeks data acquisition supervised by the demining organisation.
5 Data collection and interviews with the deminers by TNO.

During the preparation of the trial a demining organisation is contacted in the country the trial will take place in using personal contacts, help from GICHD, etc. Once the demining organisation has decided to cooperate in the trial, TNO pays an orientation visit to the site. A short presentation about the project is given and the local SOP is discussed. By paying a visit before initiating the trial any special conditions in the specific country can be overseen beforehand.

Once the trial has been prepared TNO returns to the demining site to initiate the trial starting by instructing the deminers. A presentation about the project is given to the management of the demining organisation and the deminers who will be conducting the trial. It consists of a brief introduction to the goals of the project and the demining procedure is explained. The various magnet(-tools) are introduced and demonstrated using a transparent box filled with metallic clutter (see Figure 3.2).

Figure 3.2 The transparent box filled with metallic clutter, which is used to demonstrate the operation of the magnet(-tools), here with the ring magnet (see Chapter 7).

After the instruction the deminers undergo a short training on ground, which has already been cleared of mines. Several pieces of small clutter are hidden in an area of 1 m^2 and a few deminers are asked to clear the area according to the demining procedure as presented to them in the instruction including recording the results on the data acquisition sheets and putting the metallic clutter into the correct colour-coded boxes. Not all deminers do the training but watch while others do. In Figure 3.3 an example is shown of a deminer during training with the ring magnet. After the training the deminers return to their lanes and start data acquisition in the live minefield. Special attention is paid to correct execution of the demining procedure and data recording by the personnel from TNO and the supervisor(s) from the demining organisation.

Figure 3.3 A CMAC deminer during training with the ring magnet.

During a period of 4 to 5 weeks the trial is supervised by the supervisor(s) from the demining organisation and not by TNO. At the end of this period TNO returns to the demining site to collect the data acquisition sheets and interview the deminers on their experience with the magnet-tool. The question list used during the interviews is shown in Appendix C.3.

During the preparation phase of the first trial TNO discussed the project with a group of operational experts from the GICHD. Several of the issues discussed during the meeting were taken into account during the preparation. The minutes of this meeting are shown in Appendix D.

4 Data acquisition in Cambodia

4.1 The demining site

Cambodia was the country, which was chosen for the first data acquisition phase. In the preparation Norwegian People's Aid (NPA) helped to make contact with Cambodian Mine Action Centre (CMAC), which is the demining organisation responsible for a large percentage of the demining operations in Cambodia. CMAC was immediately prepared to collaborate in the trial. Therefore, TNO made an orientation trip in July 2006 visiting the CMAC headquarters in the capital of Cambodia, Phnom Penh, and Demining Units (DU) 4 and 6 in Siem Reap and Koh Ker, where the trial was planned to take place.

Koh Ker is a small village in the North of Cambodia in Preah Vihear province about 130 kilometres to the north-east of Siem Reap, the closest town. The village has a number of temples and most of the temple grounds have been cleared of mines by CMAC. However, the large parts of the area around it have not. The demining environment is characterized by large amounts of vegetation, varying moisture content of the ground due to the rain season and large amounts of metallic clutter, such as bullets, cartridges, mine and grenade rests, nails, etc. CMAC uses only manual demining techniques in this area and no machinery. As mentioned before, the SOP of CMAC is based on the use of a metal detector and includes the use of small weak 'doughnut' magnets taken from loudspeakers. These magnets are used in the excavation phase to pick up metal fragments from the removed soil. The CMAC demining toolkit is shown in Figure 4.1 (without the metal detector). The SOP is based on a 'two men / one lane' procedure but if necessary the 'one man / one lane' procedure is used.

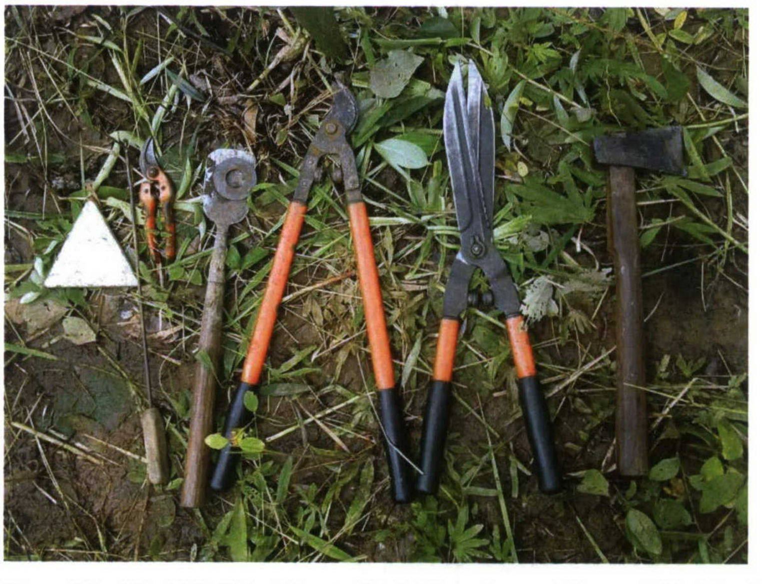

Figure 4.1 The CMAC demining toolkit (without the metal detector). The 'doughnut' magnet used by CMAC is attached to the excavation tool on the left.

4.2 The trial

The trial started in October, just at the end of the rain season. TNO visited the site in Koh Ker from 16th October to 20th October. The site, minefield 7569, was being cleared by platoon 130, DU 4. The instruction and training was performed by TNO and translated by a CMAC officer and his assistant. The latter two were hired by TNO to supervise the remainder of the trial in absence of the TNO personnel. It took one day to set up the equipment, two days for the instruction and training and the rest of the week was spent on monitoring the data acquisition in the live minefield.

The area to be cleared was a more or less rectangular area along side the main road from Siem Reap to Koh Ker. The area was divided into to two parts by a small stream of water. To the right (south) of the stream of water (looking from the roadside) the ground was more or less levelled whereas on the left hand side of the stream (north) the ground was inclined slightly. The ground was very moist because the rain season was not completely over and the vegetation was quite thick (see Figure 4.2). At the time of arrival the area had been cleared partially and several mines and UXOs had been found.

Figure 4.2 The area to be cleared by platoon 130, DU 4.

Three types of magnet(-tools) were included in the trial; the ring magnet, the HSM and the rake with rigid tines (see Figure 4.3). Note that the rake with rigid tines was used with the tines up! Hence, it was used primary as a scanning device and not as a rake. Eight couples of deminers were chosen to perform the data-acquisition meaning two couples per procedure including the CMAC SOP (reference). Each couple was supplied with a book of data acquisition sheets, three colour-coded boxes for the metallic clutter and a magnet(-tool). The officer and assistant were also supplied with a book of data acquisition sheets to record the cleared area per couple per day and three larger colour-coded boxes to collect the metallic clutter from the deminers at the end of the day.

Figure 4.3 CMAC deminers scanning the soil surface; from top to bottom: ring magnet, HSM, rake with rigid tines (note that the tines are pointing up!).

After one week of instruction and training TNO left the demining site and the officer and his assistant took over the trial. However, it turned out that the platoon had three weeks leave of absence directly after the training week due to national festivities. After this leave of absence platoon 130 did not return to the demining site due to budgetary reasons. To overcome this, the officer and his assistant repeated the instruction and training with a different platoon (platoon 141) working in the Koh Ker area about 4 kilometres away from the original demining site.

The new demining site, mine field 6465, was not located along the main road from Siem Reap but along one of its side roads behind the main Koh Ker temple leading past Koh Ker Village to a river nearby. The area to be cleared was about two kilometres down this road, past Koh Ker Village and consisted of two strips of ground on either side of the road. On the right hand side of the road (looking from the Koh Ker side) the ground was levelled apart from an occasional channel caused by erosion (rain). On the left hand side of the road the ground was inclined dropping down from the road causing demining to be more difficult. The ground was a lot drier than during the trial initiation due to the season change. The vegetation was on average also less thick than on the first site, but with some local exceptions (see Figure 4.4).

Figure 4.4 The area cleared by platoon 141, DU 4.

The return of TNO staff was delayed until the second half of December to ensure the data acquisition phase lasted at least five weeks. The data acquisition sheets were collected and interviews were held with all deminers. The ring magnets and two rakes with rigid tines were donated to the platoon.

4.3 The data

The trial involved twenty-six days of demining in total performed by eight couples of deminers. The data were collected using the data acquisition sheets shown in Appendix C. The following data are available:

- Amount of metallic clutter found per demining phase per day per demining couple.
- The type of metallic clutter found per event per day per demining couple.
- The time at which metallic clutter was found per event per day per demining couple.

- The starting and end time of each working day per demining couple.
- The area cleared per day per demining couple.
- Description of special events per day (per demining couple).
- Information on the use of the one man / one lane procedure or two men/one lane procedure per lane per day.

The following derived data are available:
- Total / Average area cleared per day per magnet(-tool).
- Total / Average amount of metallic clutter per magnet(-tool).
- Total / Average amount of metallic clutter per demining phase per magnet(-tool).

In the following chapter the data are analysed and the results are presented.

5 Data analysis and results from the Cambodian data-acquisition

5.1 Analysis of the data

In this chapter the analysis and the results of the data acquisition phase in Cambodia are discussed. The data have been analysed for each magnet(-tool) used meaning the results of two lanes where the same magnet(-tool) was used have been added together. The total area cleared for each magnet(-tool) used in five weeks is shown in Figure 5.1. As can be seen the deminers working with the standard CMAC toolkit and the HSM have cleared the largest total amount of area . The same data have been averaged per day. The results are shown in Appendix E and show a comparable result.

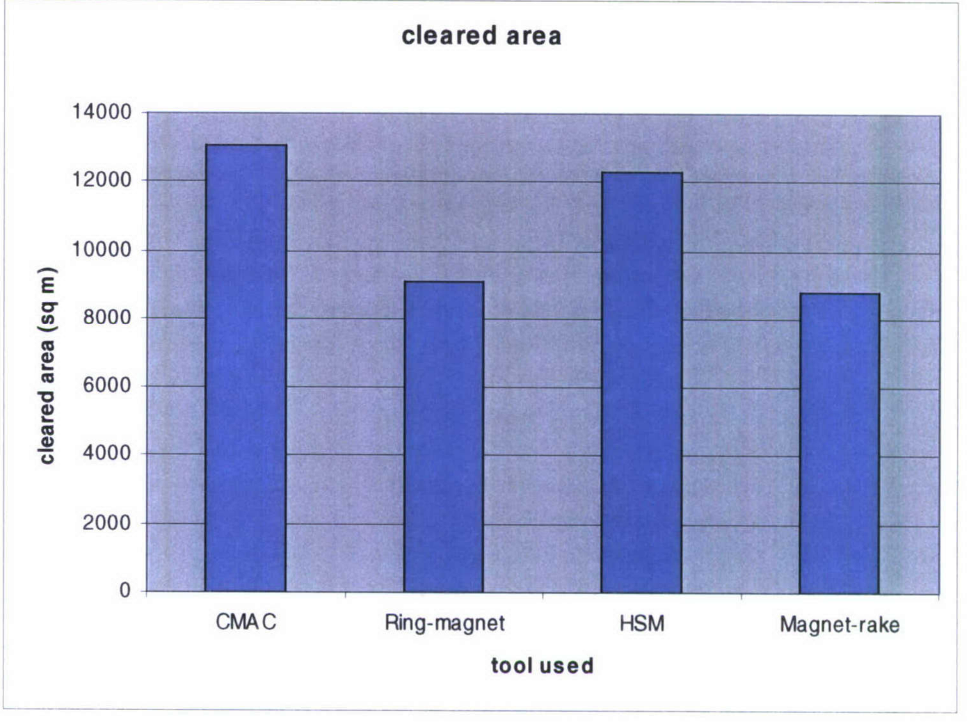

Figure 5.1 The total area cleared in five weeks for each of the magnet(-tools) used. 'CMAC' stands for the results of the deminers that used the standard CMAC toolkit.

The total amount of metallic clutter found in five weeks for each magnet(-tool) is shown in Figure 5.2. The amount of metallic clutter has also been broken down for the way in which it was found; visually, with the magnet(-tool) or during excavation. The deminers working with the ring magnet and the magnet rake found the most metallic clutter during five weeks. The same data have been averaged per day. The results are shown in Appendix E and show a comparable result.

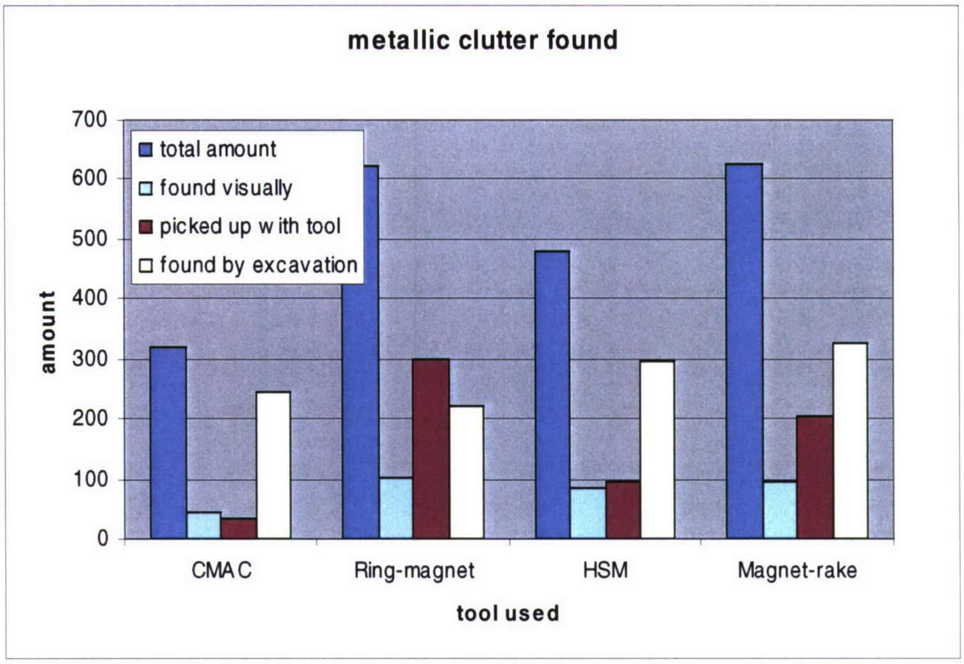

Figure 5.2 Amount of metallic clutter found for each tool, broken down for the way in which it was found: visually, picked up by the tool during scanning or found by excavation.

Combining Figure 5.1 and Figure 5.2 leads to the conclusion that although deminers working with the ring magnet and the magnet rake cleared less area in five weeks (and per day) the same deminers also found more metallic clutter and a larger percentage of the metallic clutter was found with these magnet(-tools). It is not clear whether these two tools found more metallic clutter due to a coincidence of there being more metallic clutter in their lanes or due to the deminers using the CMAC toolkit or the HSM missing some metallic clutter due to their weaker magnets. The trial was held for five weeks to rule out the first reason, however, it is possible that it was not ruled out completely. The second reason seems unlikely because the number of metal detector alarms should be the same for all lanes and the deminers using the CMAC toolkit would have the same total amount of clutter found and a larger percentage in excavation. Finally, this effect could be caused by the magnets picking up tiny metal fragments that do not give a metal detector alarm. In practise this is excluded because the magnet force on the metal fragments decreases much faster than the metal detector sensitivity. This is confirmed by a visual check of the metal clutter collected in the trial: the dimensions of the metal parts collected are such that they will have resulted in a metal detector alarm.

There are several other parameters in the trials, which were looked into to see if they had any influence on the results shown above. The first parameter taken into account is number of deminers working in a lane, in other words, whether the two men / one lane or the one man / one lane procedure was used. In principle CMAC always works with the two men / one lane procedure. However, in the case of absence of one of the deminers due to illness or other activities the one man / one lane procedure is used. The data acquisition sheets showed that one man / one lane procedure was used four, six, ten and twelve times for the deminers working with the standard CMAC toolkit, ring magnet, HSM and magnet rake, respectively. The average amount of area cleared per day and the average amount of metallic clutter found per day per tool was split up for the two procedures and is shown in Appendix E. The results show that the average amount of metallic clutter found is not influenced by the procedure. The average area cleared per day is not influenced significantly except for the deminers working with the HSM: a smaller area is cleared using the one man/one lane procedure. However, this does not clarify the results mentioned above.

A second parameter taken into account while analysing the data is the differences in working time during a day between deminers. A normal working day for a CMAC deminer starts around 6.30 am and ends around 3.30 pm. Short breaks of 10 minutes are held about every hour and the lunch break is about ninety minutes. The working times were the same every day on all lanes. On one day the all deminers stopped working at noon to cut away some vegetation, which was blocking the road. However, as all deminers stopped working at this time it does not influence the data, except the total area cleared on that specific day.

Finally, the non-levelled ground in the demining site, already mentioned in Section 4.2 is a parameter, which may have influenced the data, e.g., if the deminers using the ring magnet and magnet rake worked mainly on hilly ground it may have slowed down the clearing. However, this was not recorded on the data acquisition sheets and during the interviews all deminers indicated having worked on both levelled ground and hilly ground. This is a parameter, which is very hard to quantify and also to rule out. Having a five week trial was meant to rule these kinds of effects out. It is hard to say whether lengthening the trial may have helped.

The different types of metallic clutter found during the three demining phases have not been analysed any further. In Figure 5.3 the clutter found during the trial is shown for the three demining phases.

Figure 5.3 The metallic clutter found during the trial in Cambodia; from left to right: visual, magnet(-tool), excavation.

5.2 Interviews with the deminers

During the interviews all participating deminers reported that they were convinced that the use of magnets and magnet-tools speeds up their work, providing the magnets have sufficient strength. The deminers used the magnet-tools for scanning the soil surface for metal parts and checking the soil removed during excavation (see Figure 4.3).
The magnet-tools, including the gardening rake equipped with magnets, were not used for the manipulation of the top layer of the soil. Apart from the size and strength of the magnet-tools, the deminers mentioned robustness and low weight as important requirements for these tools.

5.3 Intermediate conclusions and lessons learned

The data recorded by the deminers show that the deminers that worked with the strong ring magnets picked up a considerable number of metal fragments by scanning the soil surface with this tool: 12.5 times more than with the small CMAC magnet (corrected for area cleared). For the HSM and the magnet rake the results are 3 times and 9 times more, respectively. However, the deminers working with the CMAC magnets, and those working with the HSM, cleared up to 45% more hazardous area than those working with the ring-magnet and the magnet-rake (Figure 5.1). This can be explained by the smaller total number of metal parts that they encountered during their operations: 301 (CMAC magnet) and 464 (Hand-held Sweep Magnet) versus 621 (ring-magnet) and 625 (magnet-rake). The number of excavations was not reduced by using the strong ring magnets. Both findings support the idea that deminers using the ring-magnets and magnet rakes coincidentally encountered more metal parts on the surface than those working with the CMAC magnet. Overall the strong magnets (both the ring magnets and the magnet rakes) were effective for removing metal parts from the surface but the speed of the operation was highly influenced by the scenario in which the deminers worked.

The overall conclusion of this first test is that strong hand-held magnets can help to reduce the number of false alarms of metal detectors significantly and thus will increase the speed of manual demining operations.

The main lesson learned in this data acquisition phase is that the rake with rigid tines is not accepted by the deminers: it was not used as a rake but as a scanning device. The soil manipulation is not included in the SOP and therefore not executed by the deminers. The rigid tines are believed to generate too much pressure on the surface. Therefore, the rake with rigid tine is replaced by a rake with flexible tines for the Angolan data acquisition phase.
Moreover, it is preferable to have a demining site which has levelled ground to rule out any influence of the inclination of the ground. If this is not possible the deminers must record this on the data acquisition sheet.
Finally, inhomogeneous distribution of metallic clutter between lanes remains a parameter to keep in mind. No changes in the trial length are made for Angola but this parameter must be taken into account.

6 Data acquisition, analysis and results in Angola

In this chapter the first data acquisition phase in Angola is discussed. The collected data are analysed and the results are presented.

6.1 The demining site

The first data acquisition phase in Angola was performed in collaboration with Norwegian People's Aid (NPA). NPA has several demining operations running in Angola and was immediately prepared to facilitate the trial. TNO made an orientation trip in May 2007 visiting the NPA headquarters in the capital of Angola, Luanda and the demining operation in Cachoeiras in the province Kwanza Sul, where the trial was planned to take place.

Cachoeiras is a small village about 300 kilometres to the south of Luanda and about 30 kilometres land inwards from the town Sumbe. The village is located close to a hillside, which was a strategic point in the war and known to be mined. Due to plans to expand the village towards the hillside by building more houses and a school, NPA has been asked to de-mine the area. Moreover, a cemetery is situated in the minefield. An impression of the demining site lay-out is shown in Figure 6.1.

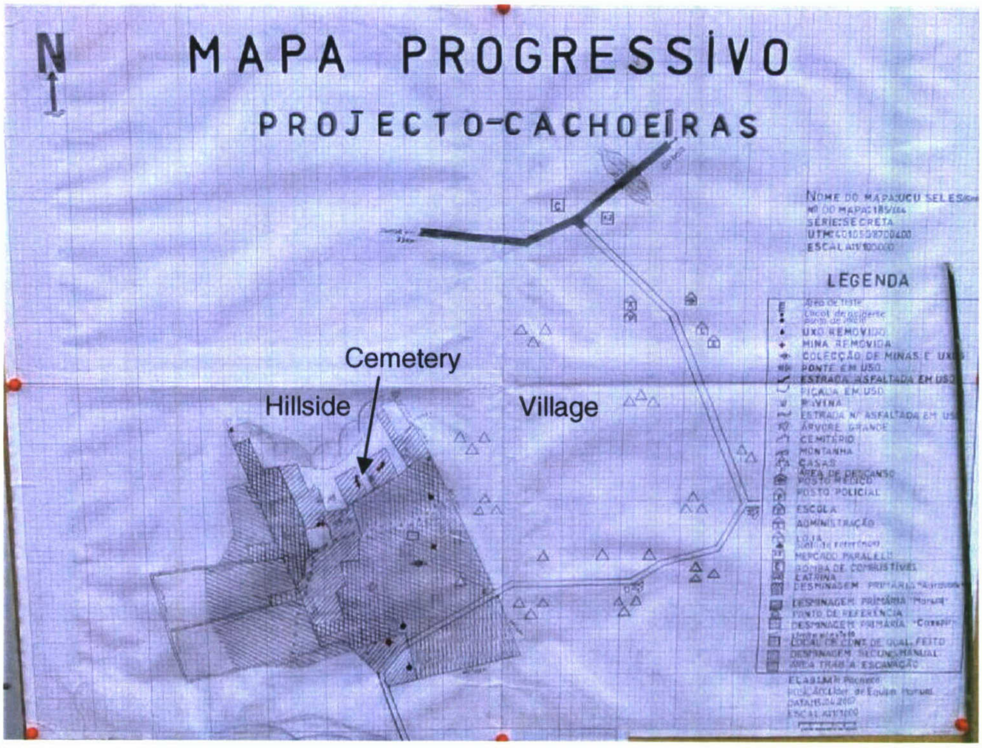

Figure 6.1 An impression of the demining site at Cachoeiras.

The demining environment is characterised by knee-high grassland with the occasional tree. The ground is dry and very hard sand ground with a large amount of metallic clutter, such as bullets and nails. The demining site stretches from levelled ground near the village and sloped ground near the hillside. Only the lower part of the hillside is demined to create a buffer preventing mines on the hillside washing down into the demined area after the operation. Several trenches descending from the war run through the minefield. Some photographs of the site are shown in Figure 6.2. Part of the minefield has been demined by means of the Aardvark or Casper demining machinery. In this case manual demining is the secondary demining phase. The NPA SOP for manual demining is based on the use of a metal detector and no magnets. Only the one man/one lane procedure is used.

Figure 6.2 Photographs of the demining site at Cachoeiras; left: sloped ground, right: cemetery.

6.2 The trial

The trial started with a visit of TNO to Cachoeiras from 21st May to 25th May. The deminers received instruction and training from TNO with the help of NPA employees who performed translation and support. After the instruction and training TNO left the site. The training was repeated the next week with the deminers by the NPA team leader and the official trial was started on 28th May and ended on the 14th June. The deminers worked for 13 days during this period. This is a shorter period of time than in the Cambodian trial but 15 deminers took part in the trial using the one man/one lane procedure instead of eight couples in Cambodia using the two men/one lane procedure.

Figure 6.3 The ring magnet with plastic casing.

Only two types of magnet(-tools) were included in the trial; the ring magnet and the rake with flexible tines (see Figure 2.4). The ring magnet was slightly modified compared to the ring magnet in Cambodia. A plastic casing was added to the ring magnet to enable easy removal of the metallic clutter by simply pulling the casing off of the magnet. The idea is that once the casing is pulled away from the magnet, all metallic clutter drops off (see Figure 6.3). The rake with the flexible tines was used as a rake in contrast to the use of the rake with rigid tine in Cambodia. Fifteen deminers were chosen to perform the data acquisition. Five deminers used ring magnets, five deminers the rakes with flexible tines and five deminers used the NPA SOP and were used as a reference group. Moreover, each deminer was supplied with a book of data acquisition sheets (as shown in Appendix C) and three colour-coded boxes for the metallic clutter. The team leader was also supplied with a book of data acquisition sheets to record the cleared area per deminer per day and five larger colour-coded bags to collect the metallic clutter from the deminers at the end of the day. The metallic clutter found by the reference group was collected separately from the rest of the clutter; hence two extra bags were necessary.

The TNO staff collected the data acquisition sheets and interviewed all deminers in the period of 19th to 21st June. The ring magnets and rakes with flexible tines were donated to the demining unit.

Figure 6.4 Deminers using the ring magnet with casing and the rake with flexible tines during the training.

6.3 Analysis of the data

The data have been analysed for each magnet(-tool) used separately. This means that the results of five deminers that worked with the same type of magnet(-tool) have been added together. The total area cleared for each magnet(-tool) used for thirteen days is shown in Figure 6.5. As can be seen the deminers working with the standard NPA toolkit and the rake with flexible tines have cleared the largest total amount of area. The same data have been averaged per day. The results are shown in Appendix F and show a comparable result.

The total amount of metallic clutter found in thirteen days for each magnet(-tool) is shown in Figure 6.6. The deminers working with the ring magnet and the magnet rake found the most metallic clutter. The amount of clutter found in the scanning phase with the ring magnet or the magnet rake is approximately the same. The amount of clutter found visually by the deminers working with the ring magnet or magnet rake is smaller than found by the deminers in the reference group. The deminers working with the rake magnets found a smaller amount of clutter during excavation than those working with the ring magnet and with only the NPA toolkit. On the other hand the deminers with the ring magnet found a larger total mount of metallic clutter than the other two groups. The same data have also been averaged per day. The results are shown in Appendix F and show a comparable result.

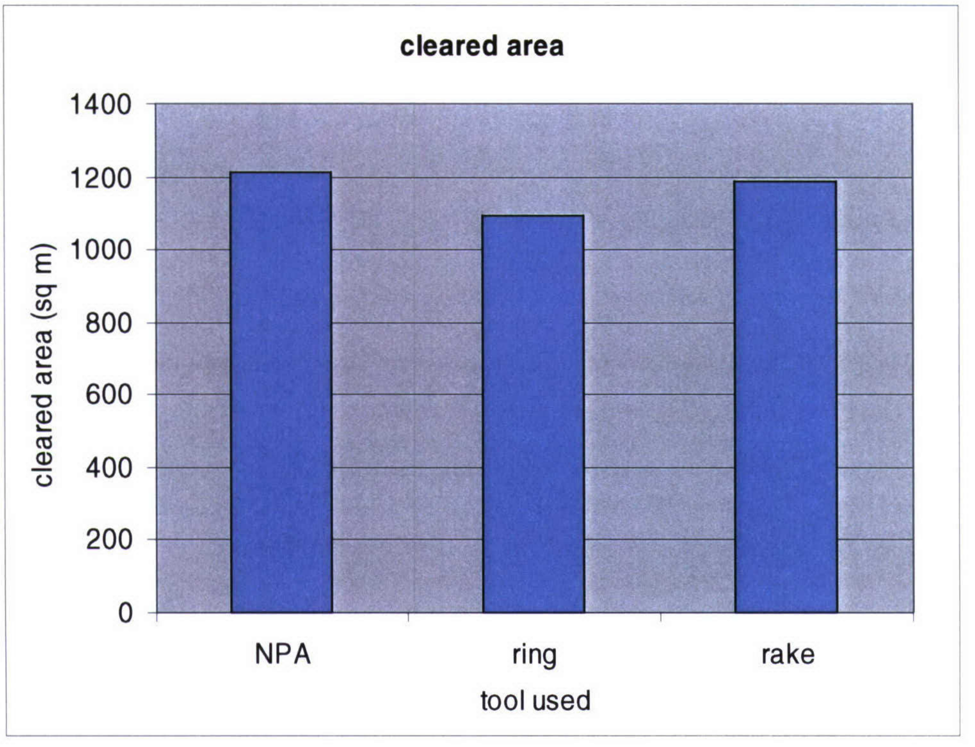

Figure 6.5 The total area cleared in thirteen days for each of the magnet(-tools) used. 'NPA' stands for the results of the reference group: the deminers that used the standard NPA toolkit.

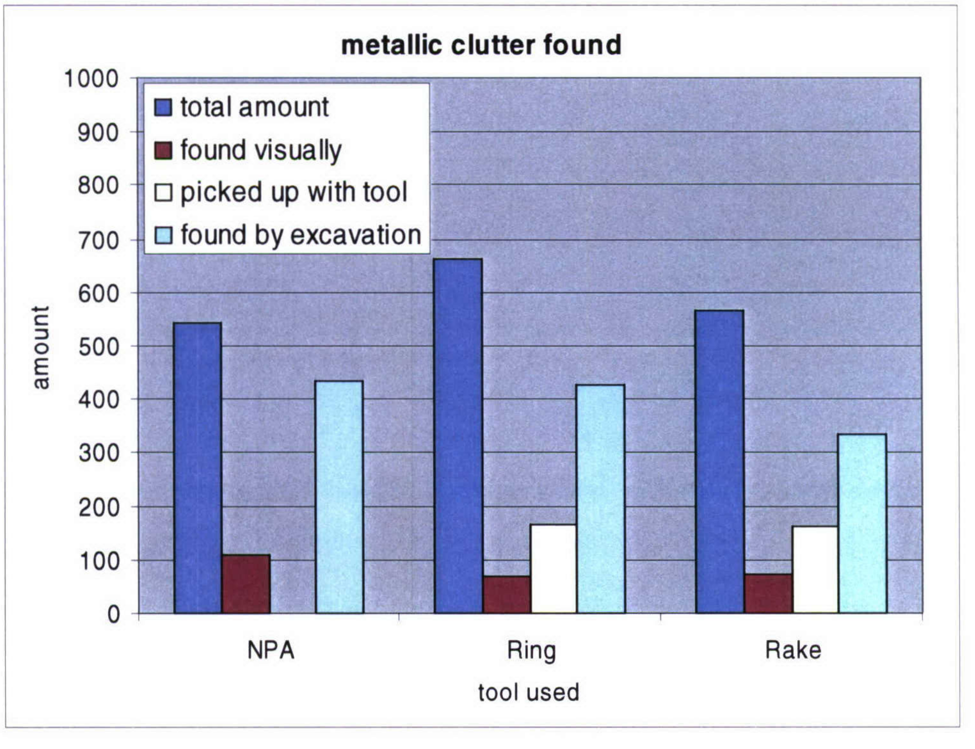

Figure 6.6 Amount of metallic clutter found for each tool, broken down for the way in which it was found: visually, picked up by the tool during scanning or found by excavation.

Combining Figure 6.5 and Figure 6.6 leads to the conclusion that although deminers working with the ring magnet and the magnet rake cleared less area the same deminers also found more metallic clutter. The inhomogeneity between lanes is not as significant as in Cambodia. In Cambodia the ring magnet users found 12.5 times more metallic clutter than the reference group. In Angola the ring magnet users found only 1.22 times more metallic clutter than the reference group.

The ring magnet users still find a significant amount of metallic clutter during excavation. There can be several reasons for this. The total amount of clutter found by the ring magnet users is higher than for the other users, as mentioned before. The ring magnet does not manipulate the soil. If large amounts of metallic clutter are found under the surface the rake will pull the clutter up during the magnet-tool phase whereas the ring magnet will not and the clutter will be found during excavation. Finally the deminers indicated that the ring magnet was also very useful during excavation and used a lot to find the clutter.

The fact that the magnet-tools have not increased the amount of cleared area seems strange as the deminers indicated having the perception that the tools speed up there work. There are a few reasons why this may be the case some of which are the same as in Cambodia. First, the demining site consisted of levelled and non-levelled ground. Most deminers worked on both types of ground. The slopes were also not as significant as in Cambodia and are thus not expected to be the cause. The working time of the deminers is also not the cause as all deminers worked the same amount of hours per day. The absence of deminers due to illness or other reasons was more or less equal for all tools; nine days absence of one deminer for the NPA toolkit, six days absence of one deminer for the ring magnet and nine days absence of one deminer for the rake.
This means the ring magnet was used the most, which could lead to the conclusion that it should have cleared more area. On the other hand, four mines were found during the trial and all mines were found by the ring magnet users (see Figure 6.7).
Moreover, these mines were found on the cemetery, which cannot be demined as fast as an area without infrastructure.

A final possible factor, which may cause the absence of speed increase is the time spent on data recording. As the deminers are not familiar to data recording, it may be the dominant factor in the demining speed. All deminers have recorded data in the trial, also the deminers in the reference group. However, if this takes a lot longer than other demining phases, it may overshadow speed differences between the different groups.

Figure 6.7 Mines found in the cemetery during the trial in Angola.

The different types of metallic clutter found during the three demining phases have not been analysed any further, although it was immediately clear that the ring magnet and magnet rake picked up many small metal fragments. In Figure 6.8 the clutter found during the trial by deminers using a magnet-tool is shown for the three demining phases.

Figure 6.8 The metallic clutter found during the trial in Angola; from left to right: visual, magnet(-tool), excavation.

6.4 Interviews with the deminers

During the interviews all participating deminers reported that they were convinced that the use of magnets and magnet-tools speeds up their work, providing the magnets have sufficient strength. The deminers used the magnet-tools for scanning the soil surface for metal parts and checking the soil removed during excavation.

The deminers seem to prefer the ring magnet to the rake although it is noted that single deminers did not work with both tools. The magnets on the rake are considered to be too weak but the manipulation of the soil is considered to be useful and not dangerous. The deminers suggested a handle should be added to the ring magnet. The casing is considered to be important for protecting the ring magnet rather than making the removal of clutter easier.

6.5 Intermediate conclusions and lessons learned

From the analysis of the data collected, no significant change in the speed of clearance by the use of the ring magnet and magnet-rake are found. Several explanations are possible:

- The absence of speed increase of the deminers working with the ring magnet and magnet-rake may be explained by slightly higher metallic clutter density encountered by these deminers.
- All four mines found during the trial, were encountered by the deminers working with the ring magnet. The finding of a mine slows down the operation, because the deminer has to move over to another lane as long as the mine is not removed of destroyed.
- Data recording by the deminers may have been a dominant factor in the speed of demining during the trial. If the data recording takes a lot longer than the other phases in manual demining, it will overshadow possible speed difference in other demining phases.

Therefore, a second trial is planned in Angola, in which the tools will be used for a longer period of time without data recording by the deminers. The only parameters to be recorded are the area cleared by each deminer per day and the total amount of metallic clutter found. Both are measured by the supervisor at the end of the day and the measurements do not influence the demining process itself. This way, the real speed differences between the groups can be measured.

The deminers feel the tools speed up their work but also make the work easier. The rake with flexible tines is accepted to be safe and used as a rake but the ring magnet is preferred above the rake with flexible tines, because the area covered by the magnetic field of the ring magnet is larger. Small modifications to the ring magnet are suggested.

In discussions with NPA it was decided to conduct a 2-month trial with only one tool, the modified ring magnets, in Angola, starting in September 2007. This trial, in which the data acquisition effort by the deminers is reduced to a minimum, is described in the next chapter. Moreover, NPA requested support from TNO for implementing the magnet-tool in its manual demining operations in Angola (see Annex G).

7 Results from the endurance trial in Angola

From September 27 till November 21 an endurance trial of the most promising hand-held magnet tool was conducted in such a way that (1) the deminers did not have to spend time on data acquisition and (2) differences in metal distribution are expected to average out due to the number of deminers involved and the long period of the trial. The trial took place in a manual road clearance operation in Malanje province, on the road from Malanje city to Cabito (South-West of Malanje city) and in the vicinity of the village of Mucunda.

Two groups of 13 deminers were involved in the trial: one group worked according to the SOP of NPA, i.e. without the magnets and served as the reference group and one group worked with the modified ring magnet and rake with flexible tines.
The ring magnet was modified for this trial. It was equipped with a handle, according to the wishes of the deminers that were involved in the previous trial in Cachoeiras.
The magnet itself has a knob so that it is easier to remove the clutter from the magnet-tool. The modified magnet-tool is shown in Figure 7.1. The 13 deminers that worked with the magnet-tool were also provided with a small hand-held rake with flexible tines, similar to the rake with flexible tines that was equipped with small magnets in the previous trial. The idea of the current rake (without magnets) was to use it to loosen the top soil before the use of the ring magnet.

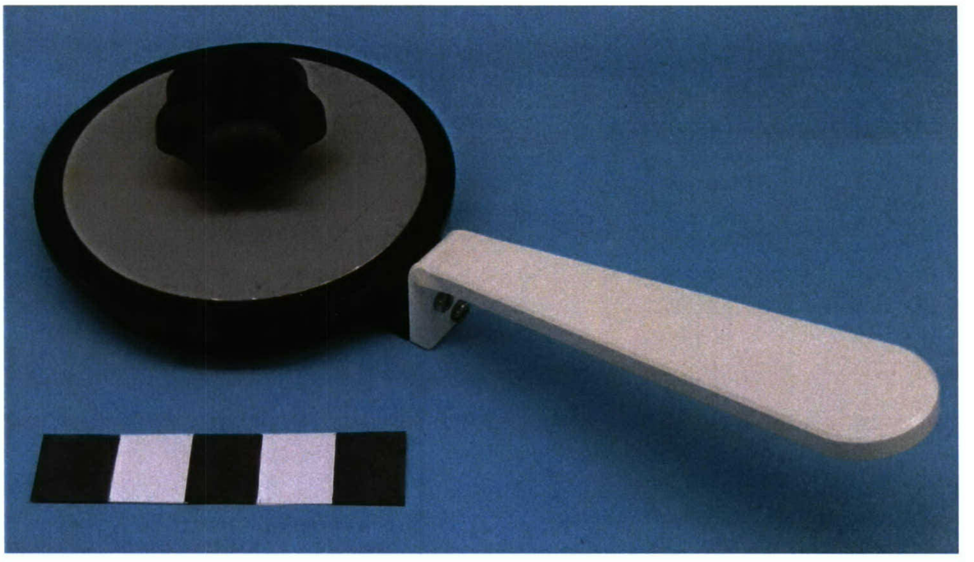

Figure 7.1 Figures of modified magnet-tool. The chequered ruler in the upper picture has a length of 10 cm. The figure below shows the opened casing with the ring magnet.

7.1 SOP used during the trial

The following modification on the NPA SOP was proposed for the trial:

- visual check on tripwires, clues of mines, etcetera, of the part of the lane directly in front of the deminer (and remove metal found);
- remove vegetation by hand after cutting;
- make top soil loose with the rake with flexible tines;
- scan the area with the magnet-tool; if metal is found remove it;
- scan the area with the metal detector:
  - in case of no alarm: proceed;
  - in case of an alarm: scan the location again with the magnet-tool;
    - if metal is found: remove it form the lane;
    - if no metal is found by magnet and the metal detector still gives an alarm: start the excavation drill;
- use the magnet-tool and the rake in excavation to find the metal easier.

The deminers had the following two objections to the proposed SOP.

1 Mine with tripwires may occur and the tripwires may be flush buried. The use of the rake will set off these mines.
2 The use of the magnet-tool on the soil surface may set off mines because of the pressure exerted.

Both objections were met to by the following modification.

1 Start the scan with the metal detector after the vegetation is removed and the rake is only used during excavation. However, it should be noted that in this demining operation no mines with tripwires were found. Only two large metal anti-tank mines were found during the current road clearance operation.
2 The magnet-tool will be used just above the soil surface and not touch the soil.

Finally NPA Angola drafted an SOP for the use of the magnet-tool. In this SOP the magnet-tool is only used during excavation.

Draft SOPHand held magnetic tool

The hand held magnetic tool will be used just when it is necessary. It will be used to collect small metal pieces to avoid spending long time for collecting them manually.

The hand held magnetic tool will just be used in verification tasks as support tool for the excavation drill. They will not be used in clearance tasks due to risk of disturbing tripwires or not visible mines.

The operational application is very simple and will be based on the procedures below:

a *The hand held magnetic tool will be included in the manual demining kit and it must always be clean before using for operations.*

b *The Deminer will hold it and pass very close to the prepared and excavated ground to attract pieces of metal.*

c *The search with hand held magnetic tool will be done without putting pressure on the ground.*

d *This drill will be repeated until the excavation is completed and there is no reading from the metal detector*

e *The attracted metal pieces will be removed from the hand held magnetic tool and put into a metal collection point.*

NPA, 19 November '07

During the trial, the operation supervisor recorded on a daily basis the amount of cleared square meters per deminer and the number of metal parts that was encountered by each deminer. The latter is the total number of metal parts, i.e. picked up by hand and magnet, and includes parts of metals that are not attracted by a magnet, such as aluminium.
The data acquisition sheet provided for the supervisor can be found in Annex C.

Figure 7.2 gives an impression of the road clearance operation where the trial was conducted. Figure 7.3 and Figure 7.4 show deminers working with the magnet-tool during the trial.

Figure 7.2 An impression of the road clearance operation in Malanje, Angola.

Figure 7.3 A deminer working with the modified magnet tool during the trial in Malanje, Angola.

Figure 7.4 A deminer working with the modified magnet tool during the trial in Malanje, Angola.

7.2 Results of the trial

The data as recorded by the operation supervisor showed that on the average 10 to 11 deminers worked in both groups, that is the reference group and the group working with the magnet-tools (more precisely: 10.44 and 10.58 deminers, respectively).

Figure 7.5 shows the average number of cleared square meters per deminer of both the reference group and the group working with the magnet-tool. Figure 7.6 shows the average number of metal parts per square meter for the areas where the deminers of the two groups worked. The deminers in the reference group cleared 11% more square meters (per deminer per day). However, they encountered nearly 27% less metal parts per square meter. The unequal distribution of the metal parts for the two groups of deminers, which was expected to average out in this endurance trial, may be the cause of the lower number of squared meters cleared by the deminers working with the magnet-tool. Another possibility is that the deminers working without the magnet-tool have not found and removed all metal parts in the areas they worked.

At the conclusion of the trial all but one deminer of the group working with the magnet-tool in the trial were interviewed and asked about their experiences with the magnet-tool (one deminer was absent due to illness). All deminers interviewed responded that they think that the use of the magnet-tool will increase the speed of the demining operation. It took very short ('seconds' was responded in some cases) to get used to working with the magnet-tool. In general the deminers were satisfied with the magnet-tool as it was used in the trial, but some answered that the handle should be round in stead of flat, and not be white ('gets dirty very soon'). One deminer noticed that the magnet can fall out of the plastic cover rather easy. This should be prevented by some sort of facility. Another deminer asked for a case for storage of the magnet-tool.
All deminers were satisfied with the working position, the weight, the way to remove the clutter from the tool ('easy') and the robustness of the magnet-tool. Inspection of the magnet-tools learned that none was damaged during the 32 working days in the trial.

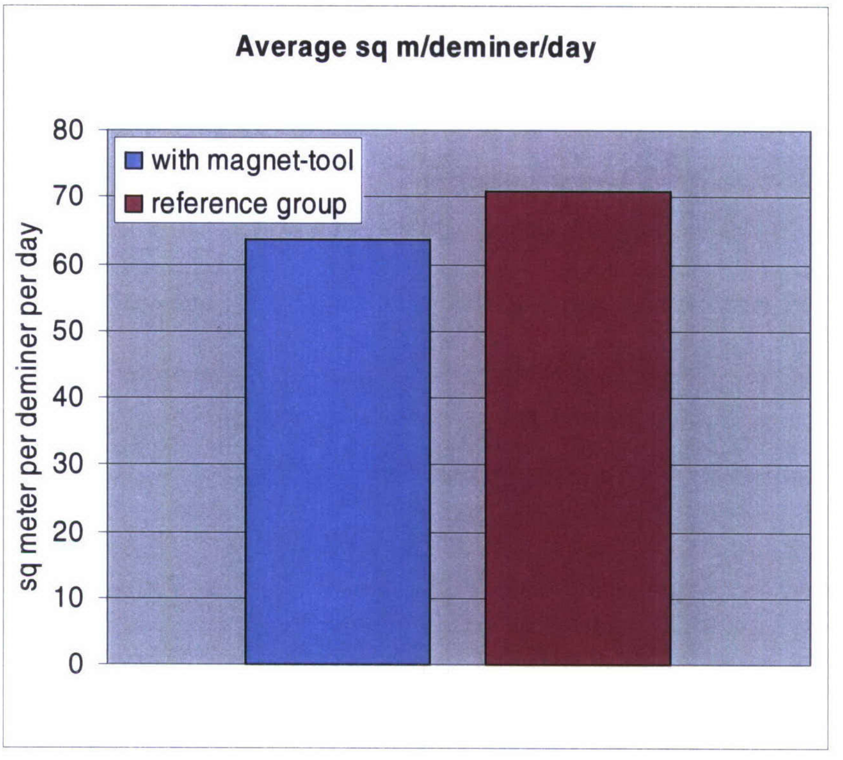

Figure 7.5 The average number of cleared square meters per deminer of both the reference group and the group working with the magnet-tool.

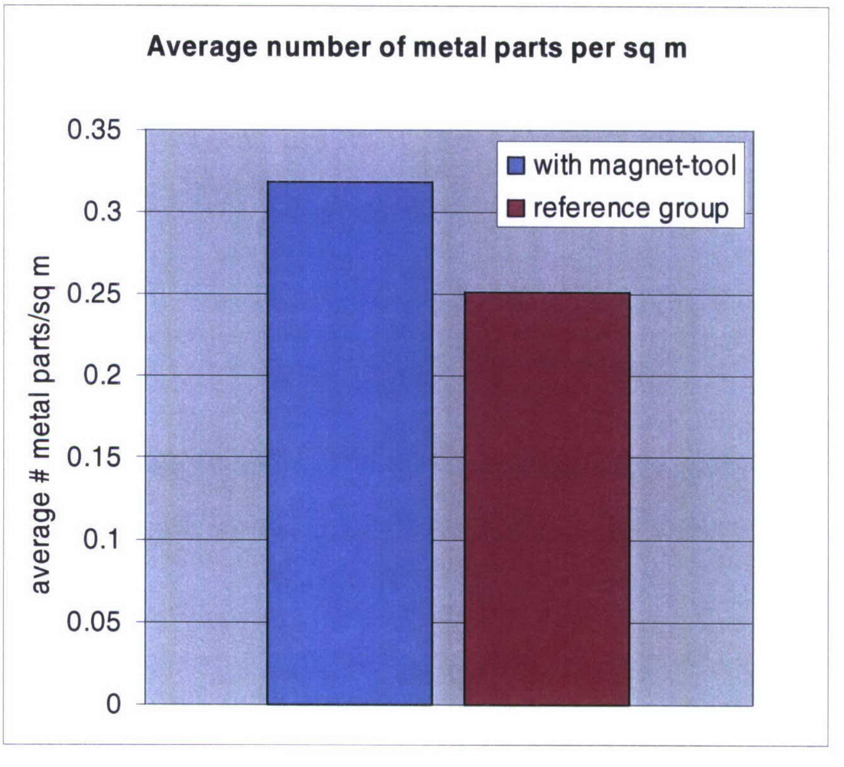

Figure 7.6 The average number of metal parts per square meter for the areas where the deminers of the two groups worked.

8 Conclusions and recommendations

Three trials have been performed successfully in live demining operations in order to quantify the effect of magnet(-tools) on the efficiency of humanitarian demining operations.

The ring magnet is the most popular magnet-tool among the deminers due to its strength. The rake with rigid tines is not accepted for use during scanning because it is believed to cause too much pressure on a mine. The rake with flexible tines, which was not tested in Cambodia, was only accepted for scanning by the deminers of NPA in the first trial in Cachoeiras, Angola. The deminers in the second trial in Angola did not accept the rake as soil manipulation is not a part of their SOP.

The deminers believe the use of the magnet increases the efficiency of humanitarian demining and also makes their work easier. The trials did not show an efficiency increase due to the use of the magnet-tools. In general, the deminers in the reference group cleared a larger area (10-40Section) than the deminers using the magnet(-tool). On the other hand, the deminers using the magnet(-tool) found a larger amount of metallic clutter (15-50Section) than the reference group. This effect may be caused by inhomogeneous metallic content of the demining lanes. It is also possible the deminers in the reference group did not clear all metallic clutter from their demining lanes. An endurance trial, that is the second trial in Angola, did not average out this effect. Finally, the effect may be caused partially by introducing an extra tool (the magnet-tool) in the manual demining procedure. This extra tool leads to extra acts by the deminer in the SOPs effective in the executed trials. Probably this effect can be reduced by introducing the so-called Crab drill12 where the deminer works laterally from the safe lane.

NPA Angola has included the ring magnet for use during excavation in a revised SOP and is considering also including the ring magnet for use during scanning. Moreover, NPA has requested assistance from TNO for the delivery and implementation of the ring magnet in all its manual demining operations in Angola.

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[12] A study of manual mine clearance. Book 3. Operational systems in manual mine clearance: case studies and experimental trials. GICHD, Geneva, ISBN 2-88487-039-3, August 2005.

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10 Abbreviations

CMAC	Cambodian Mine Action Centre
COTS	Commercial-Off-The-Shelf
CROMAC	CROatian Mine Action Centre
DU	Demining Unit
EMF	ElectroMotive Force
GICHD	Geneva International Centre for Humanitarian Demining
HSM	Handheld Sweep Magnet
IGEOD	Inter Galactic Explosive Ordnance Disposal
IC	Initial Conditions
ITEP	International Test and Evaluation Programme for Humanitarian Demining
MAC	Mine Action Centre
MoU	Memorandum of Understanding
NGO	Non-Governmental Organisation
NPA	Norwegian People's Aid
PCB	Printed Circuit Board
SOP	Standing Operating Procedure
UNMAS	United Nations Mine Action Centre

11 Signature

The Hague, February 2008

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A Survey on the selection criteria for magnet (-tools)

Survey format
The selection criteria for magnet(-tools) have been investigated by means of a survey among a group of experts. The format of the survey is shown below and consists of two parts; first an introduction explaining the project background and second the questionnaire consisting of a set of multiple choice questions and three open questions.

Survey on the selection criteria for magnet (-tools) to be used in the project 'Magnetic clutter reduction efficiency' (ITEP Workplan 2006, nr. 2.5.2.6)

The aim of the project 'Magnetic clutter reduction efficiency' (ITEP Workplan 2006, nr. 2.5.2.6) is to quantify the how well magnets can remove clutter, and thereby increase production, through the use of hand-held magnets and rakes equipped with magnets in manual demining. The project, agreed on by UNMAS and GICHD, is financed by the Netherlands Ministry of Defence (representing the Netherlands in ITEP) and is executed by TNO, the Netherlands Organization of Applied Scientific Research.
The Cambodian Mine Action Center (CMAC) will participate in a first data-acquisition phase, to be executed in a live demining operation at Koh Ker, Preah Vihear province, Cambodia, in October – November. Future data-acquisition phases will be considered in other mine-affected countries.

The first step in the project is to determine a list of selection criteria for the magnet (-tools) to be used in the trial. The survey at hand lists a number of selection criteria and asks for a rating of the importance of these selection criteria or a global quantification.

Respondents should answer the questionnaire by indicating what rating would be tolerable for their particular manual demining scenario. They should not just state that the device should be the lightest, cheapest and most robust possible.

The survey is based on the assumption that the use of magnet (-tools) could lead to a 50% time reduction of the 'close-in' detection phase in manual demining.

The survey is not anonymous in order to be able to interpret the results in relation to the background of the participants. However, all results will be presented anonymously.

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Questionnaire
User Requirements for the Use of Magnets and/or Rakes Fitted with Magnets in Manual Demining Operations.

Name:
Organisation:
Job description:

User-requirements	Rating		
Weight of the magnet (-tool)	< 500 g	500 g - 2 kg	> 2kg
Cost of the magnet (-tool)	US$0 - $10	US$10 - $20	> US$20
Robustness of the magnet (-tool)	no/little importance	average importance	decisive importance
Maintenance-free: the magnet (-tool) requires little to no maintenance	no/little importance	average importance	decisive importance
Deminer training requirements (including adaption of the SOP)	< 1 hour	1 – 4 hours	> 4 hours
...	...	...	...

Requirements related to application	Rating		
Coverage of the magnet (-tool): width of the working area	< 5 cm	5 - 10 cm	> 10 cm
Magnet strength: distance of attraction of a 10 g iron fragment	< 1 cm	1 - 5 cm	> 5 cm
Magnet strength: distance of attraction of a 1 g iron fragment	< 1 cm	1 - 5 cm	> 5 cm
Possibility of soil manipulation with the magnet (-tool)	no/little importance	average importance	decisive importance
Ease of the removal of clutter from the magnet (-tool)	no/little importance	average importance	decisive importance
Preferred position during use of the magnet (-tool)	standing	kneeling	prone
...	...	...	...

Safety	Rating		
Blast resistance: magnet (-tool) will not fragment due to blast	no/little importance	average importance	decisive importance
Impossibility to trigger mines with anti-handling devices or magnetic sensors	no/little importance	average importance	decisive importance
What distance between the operator and the working area is required/desired.	< 0.5 m	0.5 - 1 m	>1 m
...	...	...	...

Open questions

1) Are magnet (-tools) used for manual demining in your organisation?

2) If yes, what is your experience with the magnet (-tool)?

3) Are you aware of any other drills or devices that will effectively achieve the same aim, i.e. removal of clutter that causes false alarms with metal detectors?

Comments

....

Thank you for assistance by completing this questionnaire!

Questionnaire results

Six experts responded to the questionnaire and the raw results of the multiple choice questions are shown below. The overall results and conclusions are discussed in Chapter 2.

User-requirements	Rating	No. of respondents				
Weight of the magnet (-tool)	< 500 g	4	500 g - 2 kg	2	> 2kg	0
Cost of the magnet (-tool)	US$0 - $10	2	US$10 - $20	1	> US$20	3
Robustness of the magnet (-tool)	no/little importance	0	average importance	3	decisive importance	3
Maintenance-free: the magnet (-tool) requires little to no maintenance	no/little importance	1	average importance	3	decisive importance	2
Deminer training requirements (including adaption of the SOP)	< 1 hour	1	1 – 4 hours	3	> 4 hours	2

Requirements related to application	Rating	No. of respondents				
Coverage of the magnet (-tool): width of the working area	< 5 cm	1	5 - 10 cm	4	> 10 cm	1
Magnet strength: distance of attraction of a 10 g iron fragment	< 1 cm	1	1 - 5 cm	1	> 5 cm	4
Magnet strength: distance of attraction of a 1 g iron fragment	< 1 cm	1	1 - 5 cm	2	> 5 cm	3
Possibility of soil manipulation with the magnet (-tool)	no/little importance	3	average importance	1	decisive importance	2
Ease of the removal of clutter from the magnet (-tool)	no/little importance	0	average importance	3	decisive importance	3
Preferred position during use of the magnet (-tool)	standing	1	kneeling	4	prone	1

Safety	Rating					
Blast resistance: magnet (-tool) will not fragment due to blast	no/little importance	**1**	average importance	**1**	decisive importance	**4**
Impossibility to trigger mines with anti-handling devices or magnetic sensors	no/little importance	**1**	average importance	**0**	decisive importance	**5**
What distance between the operator and the working area is required/desired.	< 0.5 m	**1**	0.5 - 1 m	**3**	>1 m	**2**

B Report on the influence of magnet(-tools) on the type 72B anti-personnel mine

By Frank de Wolf, TNO Defence, Security and Safety

Introduction

In relation to International Test and Evaluation Programme (ITEP) work on magnetic clutter reduction efficiency by means of a strong magnet the issue was raised that the Type72b anti personnel mine could be set off even when the battery is completely depleted. This report concerns the analysis of the electronics circuitry of a Type72b anti personnel mine. The analysis aims at understanding the electronics and tries to give a prediction model for the magnetic induction characteristic needed to set off the detonator.

First, a short general description of the mine is given to confirm the unmodified Type72b anti personnel mine by means of a series of photos. The operation of the electronics is explained after that. To that end a circuit schematic is extracted from the printed circuit board (PCB) and its operation and characteristics are analysed. Special attention has been paid to the possible detonation caused by induced electromotive force (EMF). An estimation of the required magnetic induction with a worse case approach is added to show that it is highly unlikely that a magnet will cause a detonation.

Type 72B construction

A series of photos is added to give a view of the mine. No comment is added since the photos are self-explaining. At the end some remarks are made.

Figure B.11.1 Left: exterior Type72b top view, right: exterior Type72b bottom view.

Figure B.11.2 Type72b opened, bottom casing interior.

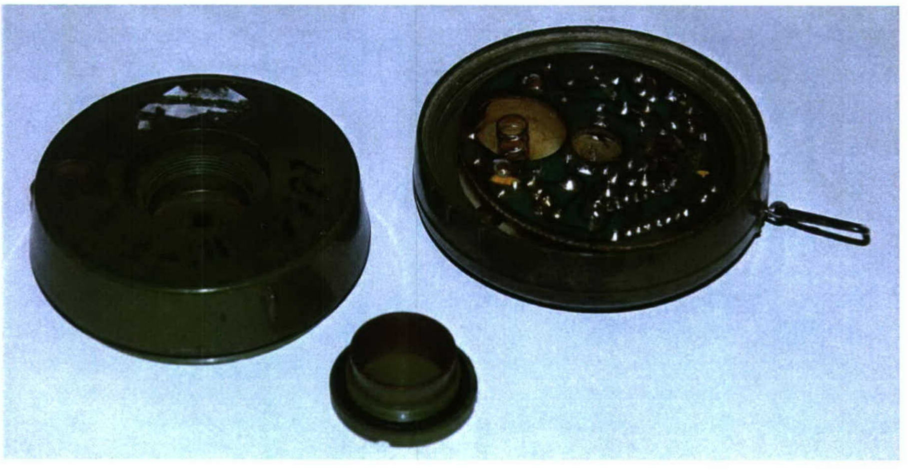

Figure B.11.3 Type72b opened, bottom casing exterior.

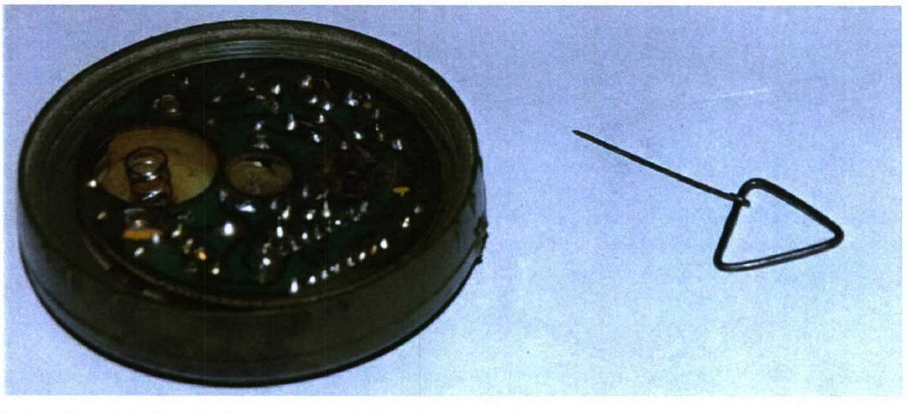

Figure B.11.4 Type72b top casing with safety pin pulled.

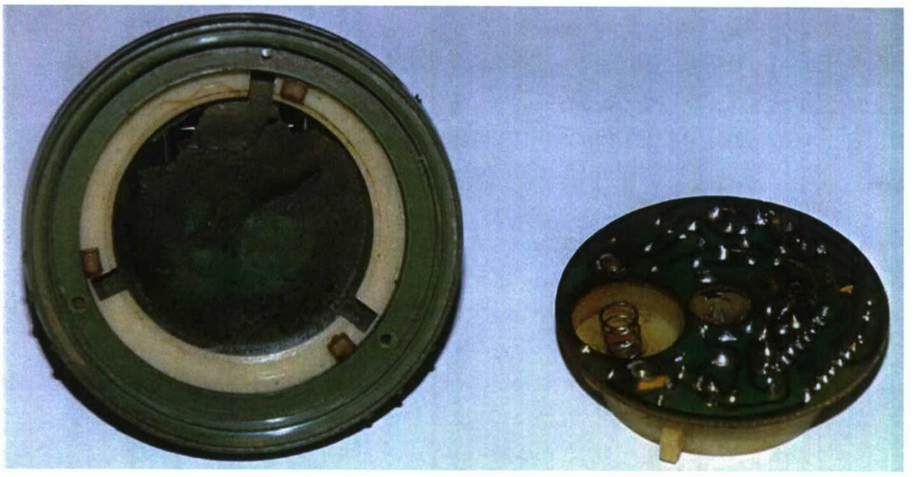

Figure B.11.5 Type72b top casing, PCB (trace side shown) removed.

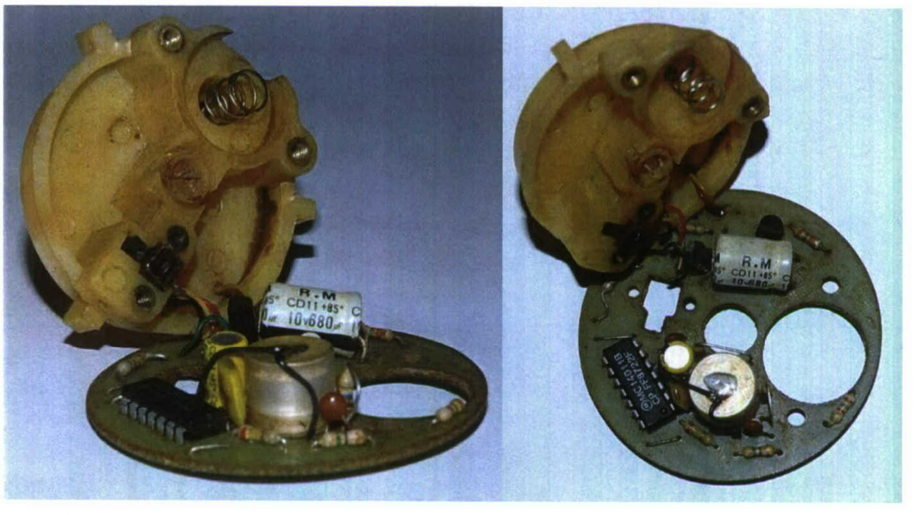

Figure B.11.6 Type72b PCB component side, plastic cap removed. The tilt switch is the component with the two black wires soldered on the top. The electrolytic capacitor (10V680μF) is C1; the DET CAP.

Figure B.11.7 Type72b printed circuit board trace side.

Although no comment is added a few remarks are in place:

- The behaviour of the electronics circuitry will depend on the resistance of the detonator, the speed of C1 discharge is also determined by this value. This speed determines the power that is needed for detonation.
- No mechanical detonation device is found nor an electrical connection to the PCB for such a device.
- Around the detonator there is a trace with two solder points that are not connected to anything, what is the use of this, is this a kind of 'grounding' for the detonator?
- It is not one hundred percent sure whether the electronics of this specimen will still function properly, it is still worth a try.
- Based on the trace there is no reason to believe that a significant magnetic induction will/can occur based on an extreme low frequency magnetic field. A direct charging of the capacitor is therefore also unlikely (maybe not impossible).

Schematics analysis

The schematics are retrieved from the printed circuit board manually. The switching capabilities have been left out. The armed status will be depicted. The circuitry is not too complicated and the schematic is found in Figure B.11.8. The whole principle is based on a sensor that detects tilting/displacement of the mine and which is basically a switch. When the amount of tilt is too much or the movement to abrupt (large acceleration) then the switch (U5) will close and cause a detonation. The switch, when not armed, shorts the upper lead of the detonator (the one connected to C1) to ground and at the same time keeps the ground disconnected from the battery.

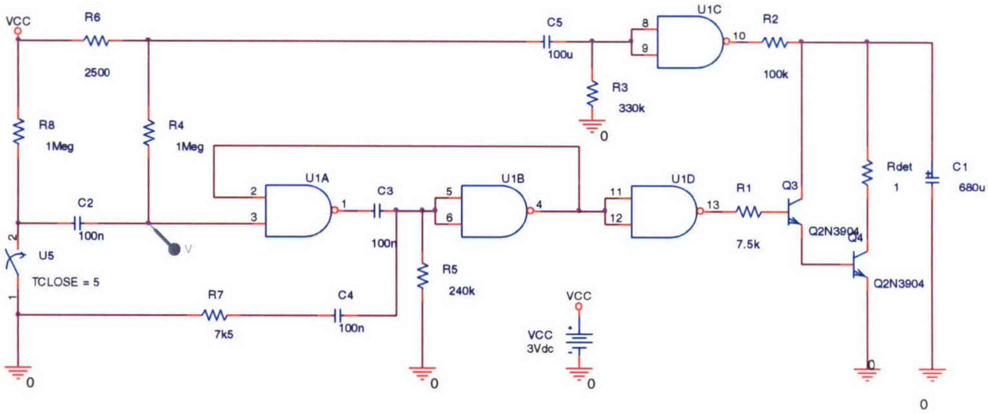

Figure B.11.8 Circuitry schematics for Type71B anti personnel mine.

From start-up, evoked by the removal of the safety pin, the mine gets into a (relatively) stable but armed condition. A short time after the circuit is activated (determined by the time constant $\tau_{C5,R3}$ = 33 seconds) the detonation capacitor C1 will be charged. Q3 and therefore Q4 will be closed and the output of gate U1D will be low. The input of the same gate therefore has to be high (this gate is switched as an inverter). Further towards the input, if the input of U1D is high then the output of U1B, used as an inverter, is high and its input is low. A high input of U1D means a high input for U1A on 2 and combined with the high input on 3 this produces a low output on U1A. C3 blocks DC signals and when the gate output of U1A changes a filtered signal will be passed on into the chain of gates towards the bipolar switching transistors. So far the stable, resting, status is described.

When switch U5 closes a short negative pulse will appear on U1A input 3 (bringing it towards ground), combined with the high input 2 the output of U1A will become high. Again a short pulse will pass C3 and make the input of the U1B inverter low.
The feedback from the inverter output towards the input 2 of U1A makes the circuit freeze into a new stable condition in which the output of U1B is kept low (as long as switch U5 does not close again). The stable condition with the input of U1D in a low condition produces a high output on the same gate. The high output switches Q3 and Q4 in de open condition thus enabling the capacitor C1 to discharge, through Rdet, to ground. When this happens fast enough sufficient power is produced to ignite Rdet (the detonator).

The stable condition could be maintained long when the battery (lithium cell) is capable of keeping C1 charged long enough and when current consumption is low (high internal impedance of the battery). Once the capacitor is charged it only needs only very little current to remain charged. The only current it looses is probably due to the leakage in its own internal resistance.

Note: C2, C3, C4 values are guesses (no clear marking). U1 is a M14001B logic NAND-gate. Q1 and Q2 are respectively a SS9011 NPN AM converter and a C2500 NPN medium power amplifier. The detonator characteristics are not known and therefore an internal resistance of 1 Ohm is chosen (this is a representative value).

Simulations
Some simulations have been carried out in MSim8 PSpice. Due to simulation limitations the simulation had to be carried out with a different supply voltage. The logical components are default supplied with a 5Volt supply voltage internally in the model.

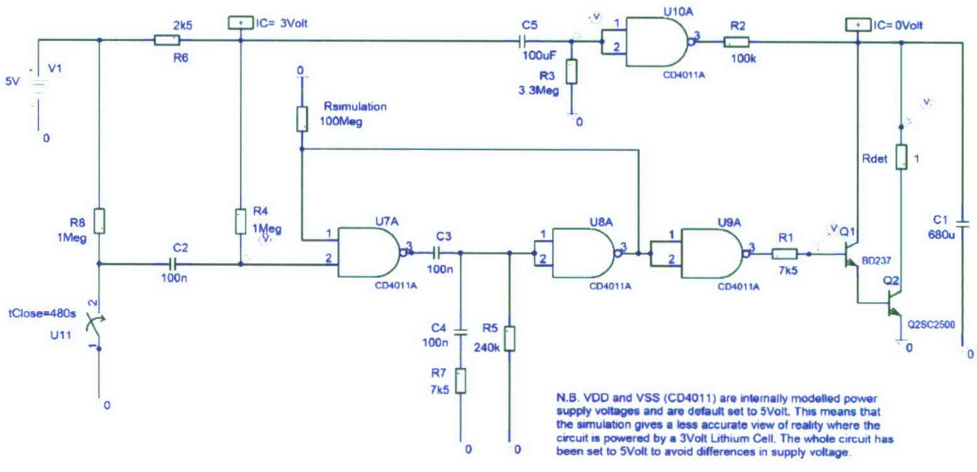

Figure B.11.9 Schematics used for simulation.

The circuit in Figure B.11.9 is used in the simulations. The IC (Initial conditions) labels are used for the simulation itself to set a certain voltage level at the start of the simulation making the start-up more realistic. The IC also help to solve convergence problems in the simulation. The pointers with V in them are probes and they designate the spots that are directly probed for their voltage and these probe voltages are shown after the simulation. The simulation results are shown in Figure B.11.10, Figure B.11.11 and Figure B.11.12. These figures give the simulation results for respectively the start up behaviour and the trigger behaviour. The trigger moment is set at t = 240 seconds.

The assumption that the circuit could remain active very long could not be simulated because of the implemented model constraints for the 4011 logic devices. A series resistance for the power supply could otherwise have been implemented. However, it is more than likely that the circuitry will remain active for a long period since none of the components uses any serious power and current consumption is extremely low (less then 0.25μAdc for the 4011 device). The battery doesn't provide the current for the detonation but C1 does, so when Q1 and Q2 are opened then C1 is discharged. Only the power needed for the opening of Q1 comes from the battery.

The start up is delayed by the combination of R3 and C5. V(R3:1) shows a falling voltage that crosses the input threshold for the NAND gate at approximately 3.5 Volt , this happens at t = 120 seconds. This condition is apparently a kind of meta state and lies in between the logic 0 and logic 1 thresholds. The input is nevertheless inverted at the output and the C1 capacitor starts to charge. The second start up simulation plot shows the transition to the defined logic state. A concrete step is recognised at 150 seconds towards a new level (5Volt).

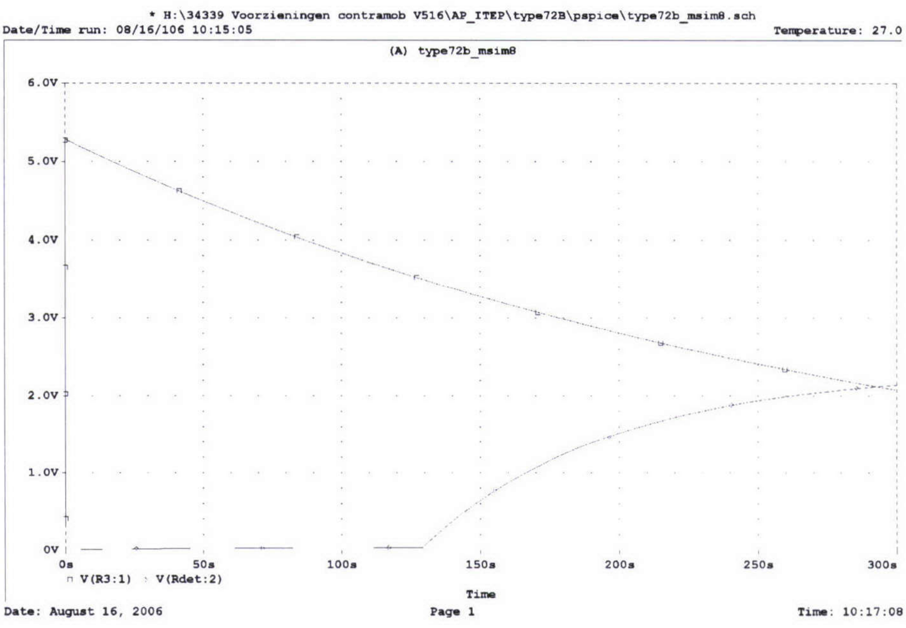

Figure B.11.10 Initialisation; Start-up with R3C5 time constant.

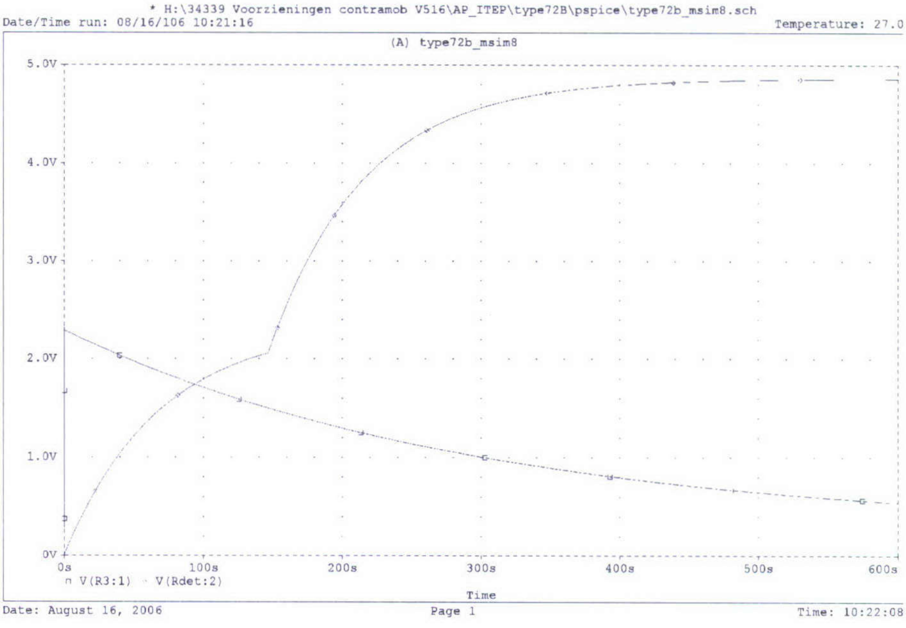

Figure B.11.11 Initialisation; Start up with R3C5 time constant, after approximately 150 seconds C1 gets charged at a different voltage.

It may be clear that the mine is only safe during the first 120 seconds after start up (based on simulation results, which therefore has to be verified). It is estimated from the simulation results that the mine can be considered to be in its (stable) operation condition after approximately 4-5 minutes. However, it is possible that the mine can go off before that in the phase between 2 and 4 minutes after removing the safety pin.

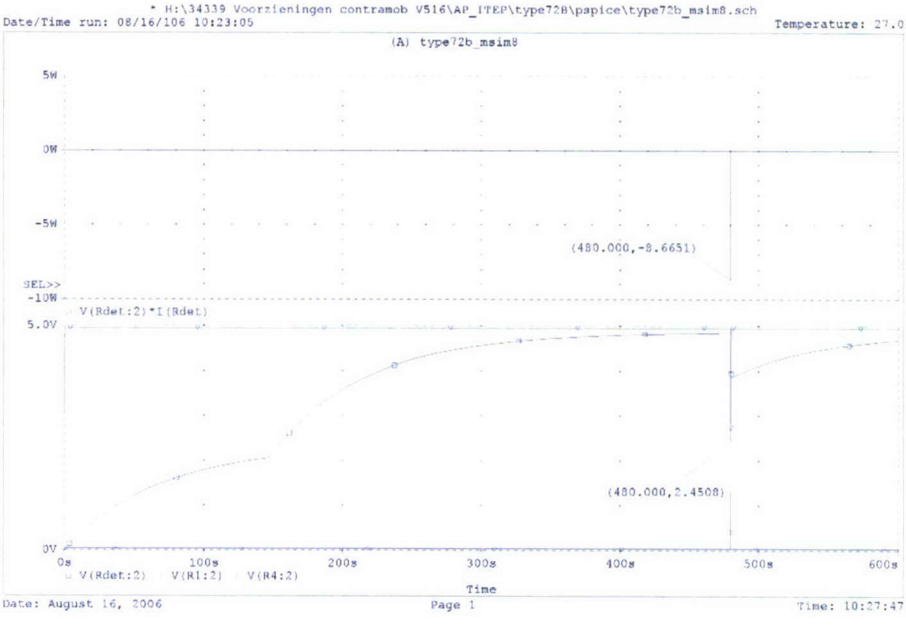

Figure B.11.12 Triggering behaviour; Top trace shows power development over Rdet, mind that the power supply voltage level is almost twice as high as in reality (due to simulation restraints).
The lower plot shows the trigger events at different locations in the circuitry.

The detonation is triggered when the switch is closed. The switching moment is set at t = 480 seconds. V(Rdet:2) clearly shows a drop in voltage, which means that C1 is shorted (through Rdet) to ground by Q2. The power peak developed for this simulation (Vcc = 5Volt!) is approximately 8 Watts. The duration of the pulse is determined by C3 and R5 (τ_{R5C3} = 2.4 msec).

The circuit impedance around C1 will become very high once the battery has run out. There is no loop and therefore it is impossible for C1 to become charged due to inductive phenomena. A worse case scenario might be considered in which a coarse reduction of the circuitry is assumed. This scenario is discussed in the next paragraph.

Field estimation (needed for detonating)
The amount of energy needed by the detonator follows from the value of the capacitor. The time constant made up by the detonator impedance and the capacitor determine the power that could result from this situation (the capacitor is shorted through the detonator to ground).
The energy stored in the capacitor follows from $E_{CAP}= ½ .C.V^2$; where C is the capacitance (680µF) and V the voltage over the capacitor (3 Volt). That makes E_{CAP} = 3.06 mJ. When this energy is released in a time span of one τ ($\tau = R_{det}.C_{det} = 1\Omega$.
680 µF = 680 µs) then $P_{det,\tau} = E.\ \tau^{-1}$ = 4.5 Watt.

If the circuitry is reduced to a single coil with a diameter of 6 cm then a worse case approach is possibly to estimate the magnetic field strength and its change that is necessary to provide sufficient power/energy to set off the detonator. Note: this scenario is assuming what could happen when a coil with the 6cm diameter is found on the PCB. If any loops are found on the PCB then they most certainly will be smaller than this worse case one and therefore less capable of picking up any fields.

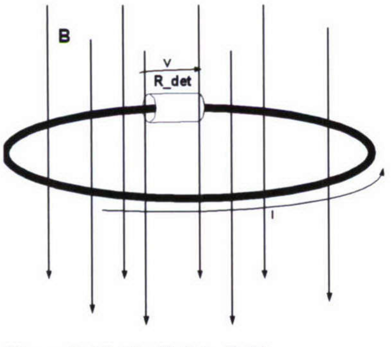

Figure B.11.13 Coil in field

The assumed situation is represented in Figure B.11.13. The homogenous field is perpendicular to the coil and Rdet is placed somewhere in the coil. For this particular situation it can be derived that $B(t) = B_o.\sin\omega t$ and $\varphi_B(t) = N.S.B_o.\sin\omega t$ with $S = 2\pi r^2$. The electromotive force (EMF) is $V_E(t) = d\varphi_B(t)/dt = -N.S.\omega.\cos\omega t$.

The power, developed over $R_{detonator}$, is $P_{det,Beff} = V_E^{\ 2}/R_{detonator} = P_{det,\tau}$ = 4.5 Watt.

Substituting N=1 and r = 0.03m we find,

$B_o = \omega^{-1}.\ (P_{det,\tau}.R_{detonator}.\sqrt{2})^{½}\ .(-2.\pi.(0.03)^2)^{-1} = -71.f^{-1}$ where f is the frequency.

The table below gives the B_o for a number of frequencies. Even for a frequency of 10kHz the required field is still 7.1mT, which is considerably large (160x the magnetic induction of the earth magnetic field).

Table B.1 B_o for given frequencies.

Frequency [Hertz]	B_o [Tesla]
1	71
10	7.1
100	0.71
1000	0.071
10000	0.0071

When a magnet is moved manually the frequency components that may be expected are smaller then 10Hz, so this means that the magnetic induction involved must be larger than 7.1Tesla. This is not very likely. Taken into account the fact that this is a worse case scenario and a stated before, the loop that is assumed is considerably large so the field needed will be consequently much larger that the ones calculated here.

The conclusion may therefore be that there is no reasonable way to set off the detonator in this circuitry by means of a manually moved magnet.

General conclusion
Setting off a Type72b anti-personnel mine of which the battery is completely depleted by means of a manually moved magnet is not possible, not by charging the detonation capacitor nor by direct induced power.

A warning is in place although: When the battery is not completely depleted but is still maintaining sufficient power to keep the logic devices running and to prevent the detonation capacitor from discharging then a severe risk is present that the tilt-switch is set off. This situation can occur during a long period after deploying the mine.
The components run on extreme low power and the capacitor will discharge only very little. Although the battery soon will no longer be able to provide large current, because of a high internal resistance of the battery, it will still be able to keep the circuitry operational. How long this situation will persist can not be said without elaborate measurements and analysis. One could however bear in mind that LCD clock modules seem to run for years on the same battery (often the same kind of Lithium cells).

C Data acquisition sheets

C.1 Trial with CMAC; data acquisition sheet for the deminers

The deminers (or couple of deminers in the case of the use of the 2 men – 1 lane procedure) are supplied with a set of data acquisition sheets. A new sheet is used every day. The sheet as used in the data-acquisition phase in Cambodia is shown below. The deminers cross out the options which are not applicable.

Procedure: 1 man, 1 lane / 2 men, 1 lane
Name deminer(s): ....
Demining procedure: CMAC / ring-magnet / HSM / magnet-rake
Date: ....
Starting time: ...h...
Finishing time: ...h...
Sheet nr: ...

Time	Detection type	Target type
	visual / magnet(-tool) scan / excavation	Mine/UXO/fragment/bullet/cartridge/.........
	visual / magnet(-tool) scan / excavation	Mine/UXO/fragment/bullet/cartridge/.........
	visual / magnet(-tool) scan / excavation	Mine/UXO/fragment/bullet/cartridge/.........
	visual / magnet(-tool) scan / excavation	Mine/UXO/fragment/bullet/cartridge/.........
	visual / magnet(-tool) scan / excavation	Mine/UXO/fragment/bullet/cartridge/.........
	visual / magnet(-tool) scan / excavation	Mine/UXO/fragment/bullet/cartridge/.........
	visual / magnet(-tool) scan / excavation	Mine/UXO/fragment/bullet/cartridge/.........
	visual / magnet(-tool) scan / excavation	Mine/UXO/fragment/bullet/cartridge/.........
	visual / magnet(-tool) scan / excavation	Mine/UXO/fragment/bullet/cartridge/.........
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	visual / magnet(-tool) scan / excavation	Mine/UXO/fragment/bullet/cartridge/.........
	visual / magnet(-tool) scan / excavation	Mine/UXO/fragment/bullet/cartridge/.........
	visual / magnet(-tool) scan / excavation	Mine/UXO/fragment/bullet/cartridge/.........
	visual / magnet(-tool) scan / excavation	Mine/UXO/fragment/bullet/cartridge/.........
	visual / magnet(-tool) scan / excavation	Mine/UXO/fragment/bullet/cartridge/.........
	visual / magnet(-tool) scan / excavation	Mine/UXO/fragment/bullet/cartridge/.........

C.2 Trial with CMAC; data acquisition sheet for the supervisors

The supervisors of the trials are supplied with a set of data acquisition sheets. A new sheet is used every day. The sheet as used in the data-acquisition phase in Cambodia is shown below. Here, a CMAC officer and assistant supervised the trial. The officer or his assistant crosses out the options which are not applicable. Comments can be made on special conditions occurring during the day such as deviating weather conditions, working hours or if a mine was found on the day.

Name officer: ....
Name assistant: ....
Date: ....
Starting time: ...h...
Finishing time: ...h...

Deminer(s)	Demining procedure	Cleared area (m^2)	Comments
	CMAC/Ring/HSM/Rake rigid/Rake flexible		
	CMAC/Ring/HSM/Rake rigid/Rake flexible		
	CMAC/Ring/HSM/Rake rigid/Rake flexible		
	CMAC/Ring/HSM/Rake rigid/Rake flexible		
	CMAC/Ring/HSM/Rake rigid/Rake flexible		
	CMAC/Ring/HSM/Rake rigid/Rake flexible		
	CMAC/Ring/HSM/Rake rigid/Rake flexible		
	CMAC/Ring/HSM/Rake rigid/Rake flexible		
	CMAC/Ring/HSM/Rake rigid/Rake flexible		
	CMAC/Ring/HSM/Rake rigid/Rake flexible		
	CMAC/Ring/HSM/Rake rigid/Rake flexible		
	CMAC/Ring/HSM/Rake rigid/Rake flexible		
	CMAC/Ring/HSM/Rake rigid/Rake flexible		
	CMAC/Ring/HSM/Rake rigid/Rake flexible		
	CMAC/Ring/HSM/Rake rigid/Rake flexible		
	CMAC/Ring/HSM/Rake rigid/Rake flexible		
	NGO/Ring/HSM/Rake rigid/Rake flexible		

C.3 Question list for interviews with the CMAC deminers

At the end of each data acquisition phase the deminers are interviewed about their experience with the magnet(-tools). The question list used for the interviews at the end of the data-acquisition phase in Cambodia is shown below.

Procedure: 1 man, 1 lane / 2 men, 1 lane
Name deminer: ....
Name partner: ....
Demining procedure:CMAC / ring-magnet / HSM / magnet-rake
Period: ....
Date of evaluation: ....

1. General impression on the use of the tool(s). Does it increase the speed of manual demining?

2. Is it easy to use?

   For scanning:

   For soil manipulation:

   For excavation:

3. How is its weight?

4. Is it robust?

   On rakes (with red rake as example):

5. Have flexible tines advantages above the tines on the heavy rake?

C.4 Cachoeiras-trial with NPA; data acquisition sheet for the deminers

Name deminer: ....
Demining procedure: No magnet / ring-magnet / magnet-rake
Date: ....
Starting time: ...h...
Finishing time: ...h...
Sheet nr: ...

Time	*Detection phase*	*Target type*
	visual / magnet(-tool) scan / excavation	Mine/UXO/fragment/bullet/cartridge/......... ....
	visual / magnet(-tool) scan / excavation	Mine/UXO/fragment/bullet/cartridge/......... ....
	visual / magnet(-tool) scan / excavation	Mine/UXO/fragment/bullet/cartridge/......... ....
	visual / magnet(-tool) scan / excavation	Mine/UXO/fragment/bullet/cartridge/......... ....
	visual / magnet(-tool) scan / excavation	Mine/UXO/fragment/bullet/cartridge/......... ....
	visual / magnet(-tool) scan / excavation	Mine/UXO/fragment/bullet/cartridge/......... ....
	visual / magnet(-tool) scan / excavation	Mine/UXO/fragment/bullet/cartridge/......... ....
	visual / magnet(-tool) scan / excavation	Mine/UXO/fragment/bullet/cartridge/......... ....
	visual / magnet(-tool) scan / excavation	Mine/UXO/fragment/bullet/cartridge/......... ....
	visual / magnet(-tool) scan / excavation	Mine/UXO/fragment/bullet/cartridge/......... ....

Etc.

C.5 Cachoeiras-trial with NPA; data acquisition sheet for the supervisor

Data recording sheet: cleared area per day per deminer

Team leader / section leader
Date: ....

Deminer	*Tool*	*Cleared area (m^2)*	*Comment: mine found; change of lane; rain; VIP visit; instruction*
	No magnet / ring / rake		
	No magnet / ring / rake		
	No magnet / ring / rake		
	No magnet / ring / rake		
	No magnet / ring / rake		
	No magnet / ring / rake		
	No magnet / ring / rake		
	No magnet / ring / rake		

Etc.

C.6 Malanje-trial with NPA; data acquisition sheet for the supervisor

Folha de registo de dados:
area limpa por dia por sapador
Data: Local:
Chefe de equipa:

Sapador	*Ferramenta*	*Area limpa (m^2)*	*Comentário: Engenhos encontrados; Mudança de linha; Chuva; visitas importante; instrução; doença, etc.*
1	Sem íman/ argola		
2	Sem íman/ argola		
3	Sem íman/ argola		
4	Sem íman/ argola		
5	Sem íman/ argola		
6	Sem íman/ argola		
7	Sem íman/ argola		
8	Sem íman/ argola		
9	Sem íman/ argola		
10	Sem íman/ argola		
11	Sem íman/ argola		

etc.

D Notes on meeting at GICHD 3rd July 2006 on ITEP project 'Magnetic Clutter Reduction Efficiency'

TNO visited GICHD on 3rd July 2006 to present their plans for the ITEP project 'Magnetic Clutter Reduction Efficiency'. The meeting is summarised briefly below.

TNO stresses that the project is not meant to be a comparison of various magnets or magnet-tools but a quantification of demining efficiency when using magnets.
TNO plans to choose one magnet and one magnet tool to perform the trials. GICHD notes that it is important to take the best tool possible because a bad tool will lead to bad results and undermine the purpose of the trials. It is suggested to perform comparison trials at TNO before selecting tools. Instead of performing trials TNO plans to select the tools based on a list of selection criteria. Important criteria mentioned at the meeting are durability, practical usage and field strength.

- GICHD notes that it is important to determine a mutual benefit before approaching an NGO for the trials. It must be clear to the NGO what the potential of using magnets is and what they can get out of such a trial.

- GICHD states that variation in fragment density across operational sites will influence the trials and complicate quantification of the demining efficiency.
  A solution for this is either gathering a very large amount of data or performing the trials in controlled test lanes. TNO prefers the first option.

- GICHD advises to have a supervisor on site to take care of data collection and observe the process of data collection rather than having the deminers do this.
  It may also be useful involving a supervisor in the preparations, e.g., by inviting him to TNO and discussing the trial.

- TNO has chosen 1 site in 3 countries to perform the trials in and a number of 4-6 deminers to gather data during a period of 4-6 weeks. GICHD suggests reducing the number of countries and expanding the trial in one country, e.g., to more sites.
  In case of extensive collaboration with one NGO, it may be possible to have all deminers (approx. 40, or at least 16) at a site performing demining sessions with and without magnets. In close collaboration with one NGO it may also be easier to discuss changing the SOP.

- GICHD notes the number of variables, which influence the efficiency of an operational trial, e.g. removal of vegetation. To determine the efficiency improvement due to the use of magnets other variables have to be corrected for. GICHD suggests using the time & motion approach as used during trials in Sudan. TNO will send the trial matrix for advice to GICHD once it has been set up completely.

- The possibility of magnets or magnet tools setting off certain mines such as the M-72B (Andy Smiths work) is not seen as a big problem by GICHD.

- HALO Trust claims to use a procedure in which the top layer of soil and thereby clutter too is removed with one sweep of the arm. It is claimed to improve demining efficiency and expected to be quicker than the magnet method. By adding this procedure to the trials too, the claims can be quantified.

- If an extensive collaboration with an NGO is realised it is also suggested to change the SOP and use the crab technique as the benchmark procedure. Especially in Cambodia, where magnets are already used, this may prevent the trial from being a test of 'just another' magnet.

- TNO has planned to have the first trials in Cambodia. TNO has contacted Avi Sakar at CMAC in Cambodia through NPA and is waiting for the results of a meeting between Avi Sakar and the director at CMAC. If CMAC falls through, TNO will go back to NPA for further actions. MAG is mentioned as a fall-back possibility. Besides NGOs, the countries are also discussed. Angola is suggested to be a good option.

- Several remarks are made on information resources:
- An engineer ('Peter') has been working for DTW in Cambodia and has written a paper on the use of electromagnets and permanent magnets in demining. Erik Tollefsen will send the paper to TNO.
- Swedec has done several trials with a vehicle mounted electromagnet.
- Roger Hess is suggested to be a good contact with operational experience.

- TNO will contact Mike 'O Malley again about the hand-held magnet tool as they have not heard from him for a while.

E Additional results from data acquisition in Cambodia

In this appendix some additional results from the analysis of the data recorded in Cambodia are shown.

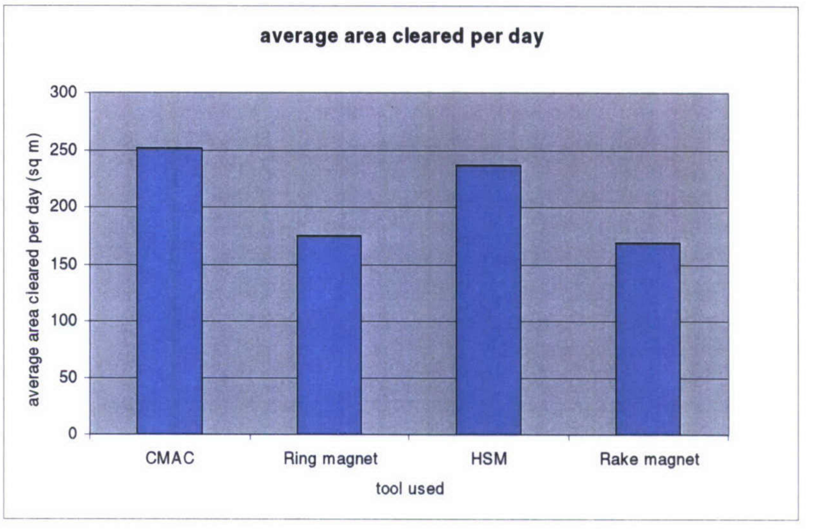

Figure E.11.14 Average area cleared per day for each tool used.

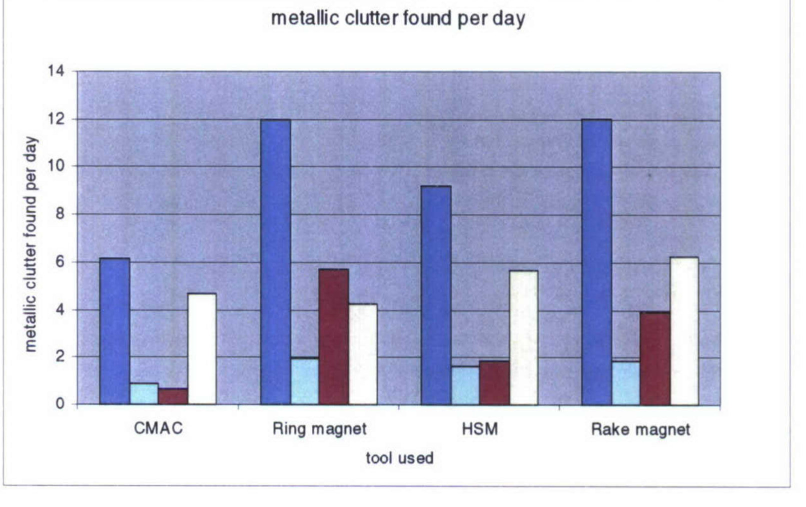

Figure E.11.15 Average amount of metallic clutter found per day for each tool used.

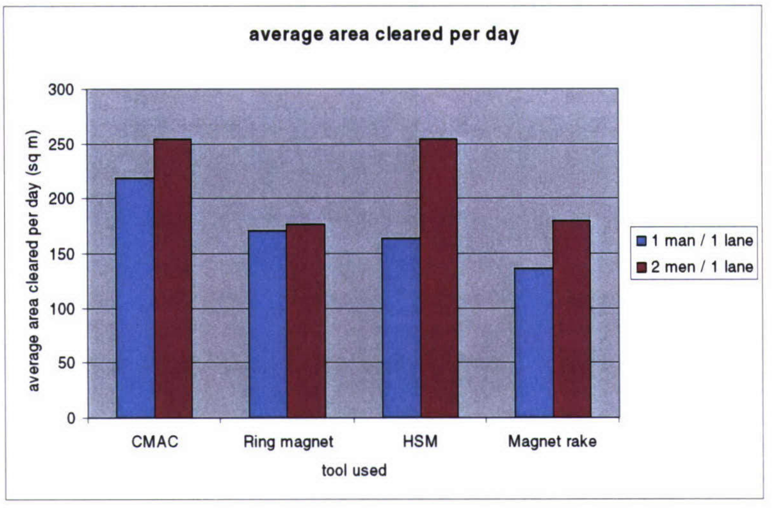

Figure E.11.16 Average area cleared per day for each tool using either the one man / one lane or the two man / one lane method.

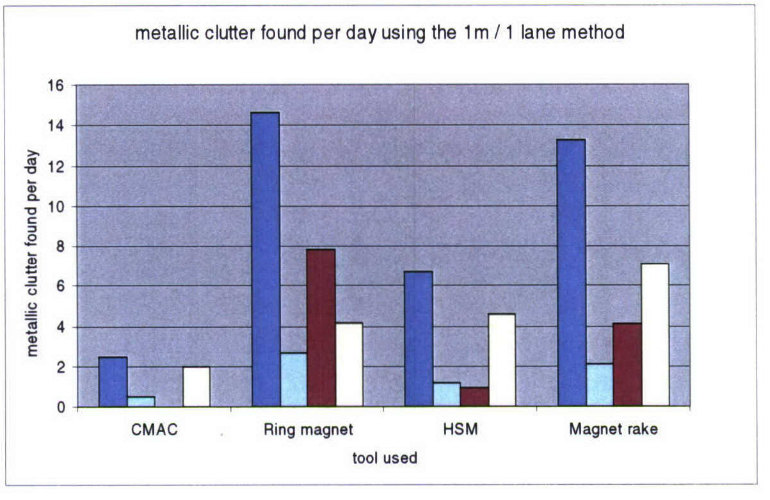

Figure E.11.17 Average amount of metallic clutter found per day for each tool used using the one man / one lane method.

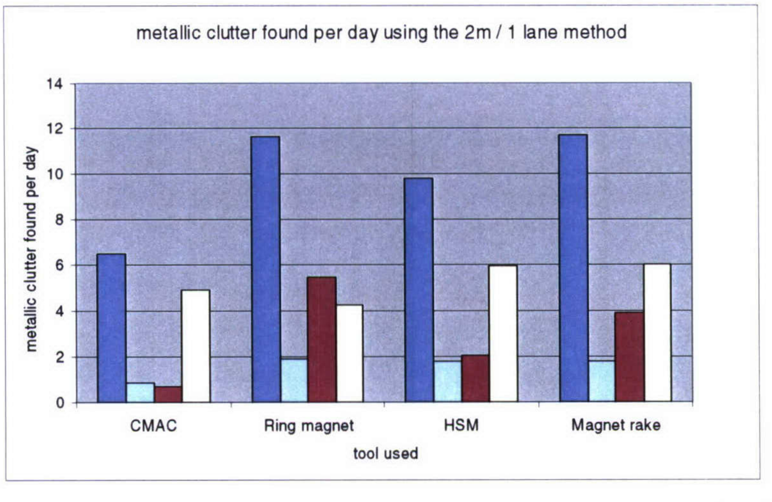

Figure E.11.18 Average amount of metallic clutter found per day for each tool used using the two man / one lane method.

F Additional results from data acquisition in the first trial in Angola

In this appendix some additional results from the analysis of the data recorded in the Cachoeiras trial in Angola are shown.

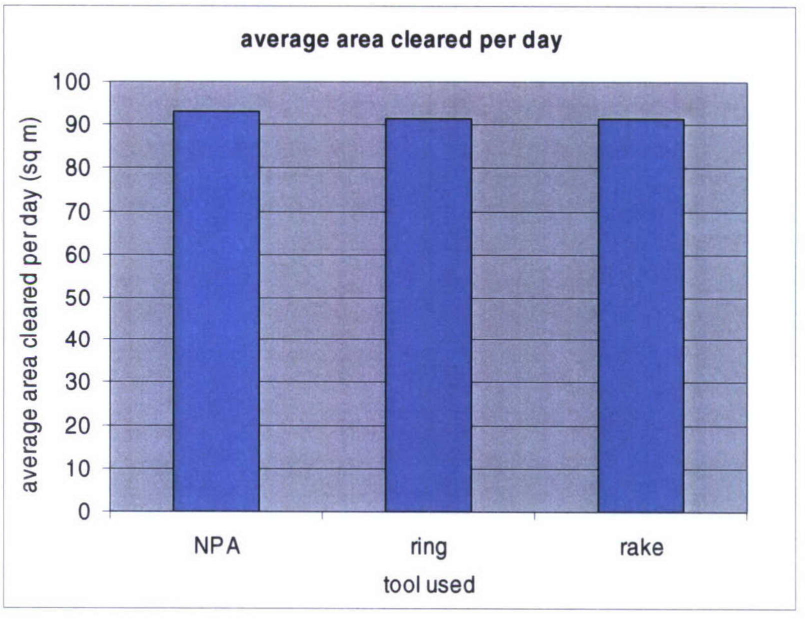

Figure F.11.19 Average area cleared per day for each tool used.

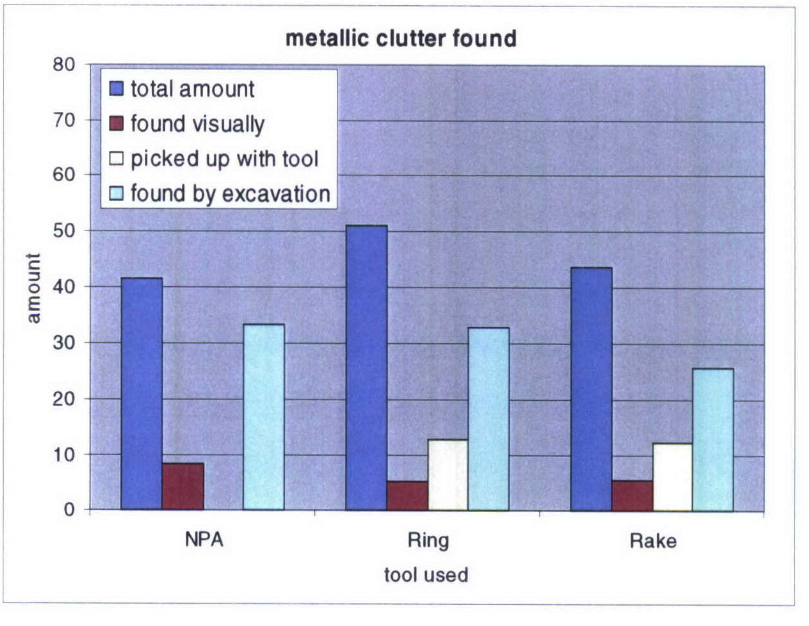

Figure F.11.20 Average amount of metallic clutter found per day for each tool used.

G Request for support from NPA Angola

NORWEGIAN PEOPLE'S AID
AJUDA POPULAR DA NORUEGA

Norwegian People's Aid
Fernão Mendes Pinto Street, 54 – 56
Tel. 222 321083/324500/324501
Fax: 222 324499
Luanda – Angola

Ref.: 287/APN/2007
Date: 2nd July 2007

Dr. Arnold Schoolderman
TNO Defence, Security and Safety
BU Observation Systems
The Hague, The Netherlands

Reference: ITEP Project; Magnetic Clutter Reduction Efficiency Project

Dear Arnold,

The Deminers of Norwegian People's Aid who were involved to the Magnetic Clutter Reduction Efficiency Project are of the opinion that the test undertaken by TNO in Angola proves that magnets are an important support tool for demining operations. The Deminers who participated to the project have shared their experiences with other Deminers who are eagerly waiting for the revised magnet to be included to the demining kit.

Norwegian People's Aid had not included the purchase of magnets within the 2007 budget as the support from NPA to the TNO administered ITEP project was only agreed in January 2007. Norwegian People's Aid would like to know if it would be possible for TNO to provide magnets to NPA in support of demining operations in Angola. In consultation with TNO, NPA would continue the Magnetic Clutter Reduction Efficiency Project, providing relevant data to TNO which would include specific Standard Operating Procedures for the use of magnets within demining operations.

Norwegian People's Aid would welcome a return visit from TNO at the end of 2007 or at the beginning of 2008 so that TNO can profit from the experience of magnets being used within demining operations. This would allow TNO to provide follow-up documentation on the Magnetic Clutter Reduction Efficiency Project to other institutions working under ITEP as well as to National Mine Action Centres.

Norwegian People's Aid is grateful to TNO for their valuable contribution in identifying tools to support ongoing demining operations.

Yours Sincerely,

Manuel João
Acting Deputy Programme Manager
Mine Action Programme
Norwegian People's Aid
Luanda – Angola

ONGERUBRICEERD

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15. ABSTRACT (MAXIMUM 200 WORDS (1044 BYTE))

The aim of the project was to quantify the efficiency increase obtained by using hand-held permanent magnets(-tools) to remove metallic clutter from the top layer of the ground in the 'close-in' detection phase of humanitarian demining operations. Therefore, three successive trials were executed in live demining operations in Cambodia and Angola. Four magnet(-tools) were chosen for the trials: a ring magnets and a block magnet and two rakes with magnets, one with rigid and one with flexible tines. The local deminers acted as operators of the magnet(-tools). The cleared area per day per deminer was compared for deminers working with and without magnet(-tools). The ring magnet is the most popular tool among the deminers due to its strength and is believed to increase the efficiency of humanitarian demining and make demining easier. However, the data did not show an efficiency increase. The deminers in the reference group cleared a larger area than the deminers using the magnet(-tool) but also found less metallic clutter. This effect may either be caused by inhomogeneous metal distributions in the demining lanes. It is also possible the deminers in the reference group did not find and clear all metallic clutter from their demining lanes.

16. DESCRIPTORS	IDENTIFIERS
Land mine detection, Mine clearance	Humanitarian de-mining, Manual techniques, Permanent magnets

17a.SECURITY CLASSIFICATION (OF REPORT)	17b.SECURITY CLASSIFICATION (OF PAGE)	17c.SECURITY CLASSIFICATION (OF ABSTRACT)
Ongerubriceerd	Ongerubriceerd	Ongerubriceerd

18. DISTRIBUTION AVAILABILITY STATEMENT	17d.SECURITY CLASSIFICATION (OF TITLES)
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