Mechanical Assistance Equipment Test and Evaluation Program

Volume 4 – Equipment Evaluation (ProMac BDM48)

Geoff Coley
Defence Research Establishment Suffield

Denis M. Bergeron
Defence Research Establishment Suffield

Russ W. Fall
Canadian Centre For Mine Action Technologies

Canadian Centre for Mine Action Technologies

Le Centre canadien des technologies de déminage

Defence Research Establishment Suffield

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Author

Geoff Coley

Approved by

Dr. Robert Suart

Director, CCMAT

Approved for release by

Dr. Robert Herring

Establishment Information Security Officer

Abstract

In a program conducted by the Canadian Centre for Mine Action Technologies in the summer of 2000, four machines were evaluated for their potential as Mechanical Assistance Equipment in humanitarian demining operations. This program also developed test and evaluation protocols and highly realistic but inert "reproduction mines" for use in such tests. This report is prepared in 8 separate volumes. While each volume is intended as a stand-alone document, there are important interdependencies between some of the volumes. One of the machines included in the program was the ProMac BDM48 Brush-Deminer, detailed in this volume.

Résumé

Dans le cadre d'un programme mené par le Centre canadien des technologies de déminage à l'été 2000, on a évalué quatre systèmes de déminage pour en connaître le potentiel en tant qu'équipement d'assistance mécanique pour les opérations de déminage humanitaire a été évalué. Des protocoles d'essai et d'évaluation, ainsi que des mines de reproduction très réalistes mais inertes ont été conçues pour effectuer les essais. Le présent rapport compte huit volumes distincts. Bien que chaque volume soit conçu comme un document indépendant, certains volumes révèlent d'importantes interdépendances. Une des machines essayées dans le cadre du programme était la débroussailleuse démineur ProMac BDM4, décrite dans le présent volume.

Executive summary

The Mechanical Assistance Equipment Test and Evaluation Program sought (i) to develop meaningful, standardized test and evaluation protocols and tools for mechanical assistance technology, and (ii) to identify promising technologies and procedures that could be proposed to the humanitarian demining community. In support of these goals a test facility was designed and constructed, test procedures were drafted, standardized test targets were designed, constructed and installed in the test area, and finally, machines were tested.

The ProMac BDM48 had no difficulty with any of the vegetation, and it destroyed over 99% of all Mechanical Reproduction Mines it encountered.

This report is divided into multiple volumes to adequately deal with the subject matter. This volume describes the Test and Evaluation of the ProMac BDM48. At a minimum, Volume 1 (which contains the overall program summary) should be read in combination with this volume.

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Sommaire

Le Programme d'essai et d'évaluation d'équipements d'assistance mécanique visait (1) à élaborer des outils et des protocoles d'essai et d'évaluation normalisés et utiles pour la technologie d'assistance mécanique et (ii) à déterminer les technologies et les procédures prometteuses qu'on pourrait proposer pour le déminage humanitaire. Dans la poursuite de ces objectifs, on a construit une installation d'essais, élaboré des procédures d'essais, conçu des cibles d'essai normalisés, construit et installé l'aire d'essais et, enfin, essayé les machines.

Le démineur ProMac BDM48 n'a été entravé par aucune des végétations et il a détruit plus de 99 % des mines de reproduction mécanique sur son chemin.

On a divisé ce rapport en volumes multiples pour que le sujet en question soit bien traité. Ce volume-ci décrit l'essai et l'évaluation du ProMac BDM48. Le volume 1 (qui contient le sommaire global du programme) devrait être lu au moins en conjonction avec le présent volume.

Coley G, Bergeron D M, Fall R W. 2001. Mechanical Assistance Equipment Test and Evaluation Program, Volume 4. DRES TR 2001-078 Defence Research Establishment Suffield.

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Acknowledgements

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Other key personnel from the Defence Research Establishment Suffield (DRES) provided vital assistance throughout the program. Scott Trebble and Randy Linde provided excellent photographic capability. Maj. Kent Hocevar, Mr. Wayne Sirovyak, and Mr Jack Toews each provided much needed assistance and advice in construction of the test area, surveying the test plots before and after the trials, assisting with the scanning and documentation of the test area, and also in picking up the slack in other activities while the authors were immersed in this program.

Finally, special mention is given to some of the people who assembled, identified, documented, and buried the Mechanical Reproduction Mines and then located and removed the remains of these devices following the trials. Mr. Jim Roseveare, Mr. Dan Roseveare, Mr. Doug Roseveare, Mr. Paul Schile, Mr. Blair Mullen, Mr. Corry Milner, Mr. Gary Milner, and Mr. Erin Milner all performed these tedious and largely invisible duties with good humour and the greatest co-operation.

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1. Document Overview

The documentation of this program has been divided into a number of separate volumes. While each volume listed below is intended as a stand-alone document, there are important interdependencies between some of the documents. For example, the evaluation of the performance of any of the machines is tightly tied to the facilities and types of test pieces used. As each of the machines are intended to perform completely different tasks, no attempt has been made at direct comparisons between the machines. The volumes that make up this document include:

- Volume 1 – Summary
- Volume 2 – Mechanical Reproduction Mines
- Volume 3 – Test and Evaluation Procedures and Facilities
- Volume 4 – Equipment Evaluation (ProMac BDM48)
- Volume 5 – Equipment Evaluation (Loken Mine Disker)
- Volume 6 – Equipment Evaluation (Schulte Extractor Mine Picker)
- Volume 7 – Equipment Evaluation (Omega 5 Aegis Slapper Flail)
- Volume 8 – Equipment Evaluation (Miscellaneous Equipment)

2. Introduction

The Mechanical Assistance Equipment (MAE) test program proposed two main activities for each machine. The first activity, Phase 1, was a set of preliminary tests which would be conducted in Humboldt, Saskatchewan at a site owned by the Prairie Agricultural Machinery Institute (PAMI). This preliminary testing was to examine the machine's operation in a qualitative sense and to help revise the test procedures that would be used in the detailed, quantitative tests to follow. In addition, this was a training period during which the machine operators would become familiar with the use of the machine against something approaching real mines. This is important in that many machinery manufacturers and their respective machine operators have no experience in any kind of demining.

The second activity in the MAE test program, Phase 2, was the testing of each machine in a detailed, quantitative set of trials at DRES. With its procedures suitably modified via the preliminary tests, each machine would be "put through its paces" on the standard test lanes at DRES. The performance of the machine would be quantified in terms of number of mines engaged (extracted, triggered, broken, or otherwise influenced as specific to the machine), area covered per unit time, soil conditions (include soil profile and/or tillage depth) before and after the operations, and any other parameter relevant to the machine.

It was expected that the combination of results of the preliminary tests and the detailed tests would allow the performance of the machines to be evaluated and reported in an objective and consistent manner.

It is critically important that there be some means of evaluating whether a machine or a technology is (i) worth testing, and (ii) mature enough to undergo testing. Regardless who is paying for the MAE testing of a given machine, it is very expensive in terms of time, labour, equipment, and facilities. As constructed for this set of trials at DRES, a test lane for one machine costs well in excess of $30,000. Premature testing of a machine can destroy in minutes what it took many weeks and tens of thousands of dollars to prepare, all without producing any useful data.

It is also critical that everyone be <u>absolutely clear</u> from the start as to what the machine is supposed to accomplish and how the machine is supposed to accomplish it. In this first-of-type program there was considerable slack in establishing the definition of what a machine was to accomplish. It became very clear that any program which seeks to test machines in a fair, consistent, unambiguous manner must <u>first</u> establish the definition of the machine's intended task. In addition, it is necessary to identify the data that define the machine's performance. Is the machine's purpose to eliminate all live mines from an area? Does it succeed in this task if it simply moves them intact to another (controlled) location? Does it succeed if it destroys the mines but leaves large numbers of fuzes, detonators, and other potential Explosive Ordnance Disposal (EOD) hazards behind? Does it make a difference whether those EOD hazards are in the processed area or in the other "controlled" location? Does it succeed in the task only if it leaves "smoking holes" where mines used to be? These and other questions need to be addressed before testing commences, and it should be largely the responsibility of the machine manufacturer to establish exactly what the machine is supposed to do, and how it is supposed to go about doing it. If this has not been done by the manufacturer, the exercise must be undertaken prior to formal Test and Evaluation (T&E) activities in order to interpret the test results in a fair, unbiased manner.

PAMI was contracted to assist with these equipment trials, and to report on their findings. Annex A provides a copy of the PAMI report dealing with the ProMac BDM48.

2.1 Machine Description

One of the four candidate machines selected for the CCMAT MAE T&E program was the ProMac BDM48. Figure 1 and Figure 2 show the system as tested.

As supplied for testing in this program the ProMac BDM48 System is a machine that is intended for brush cutting and for grinding into the ground to destroy anti-personnel landmines. The operator sits in a host vehicle (in this case a tracked-hoe) which is always kept in a known "safe" area, previously cleared of landmines. A specially built tool on the end of the tracked-hoe's arm is stretched into the suspected minefield and engages brush or soil as required. Strictly speaking, the ProMac BDM48 is just the tool or working head which engages the soil and mines. In theory, the BDM48 could be mounted on a variety of host machines including a log skidder, or a tracked-hoe as done for these MAE tests. It is only necessary to ensure that the host vehicle has the necessary hydraulic power and physical characteristics to allow the working head to be adequately manoeuvred. Clearly it is also necessary to ensure that the host vehicle and operator be properly protected from the effects of exploding mines or UXOs. For the purposes of this report, the following terminology will be used:

- "Host Vehicle" refers to the vehicle used to operate or manipulate the tool. In this case, the host vehicle is a Case 9040B tracked-hoe, although almost any other make and model of tracked-hoe could have been used. Alternately a completely different vehicle such as a logging skidder might have been selected.

- "BDM48" refers to the tool, "working head," or "end-effector" part of the system.

- "BDM48 System" refers to the combination of the host vehicle and the BDM48 tool as tested in this program. It is possible that a different host vehicle might impact on the effectiveness of the BDM48 tool if, for instance, the vehicle's arm were less able to manipulate the tool in the desired manner.

Figure 1. *ProMac BDM48 System as tested*

Figure 2. *ProMac BDM48 equipped with chisel teeth*

The BDM48 was derived from a commercial brush cutter. Stump grinders and brush cutters are used around the world for construction, maintenance of highways and railways, etc. Whereas brush cutters are not normally used in contact with the ground, the BDM48 has been modified to allow it to clear above-ground vegetation and also to grind into the soil to encounter and destroy anti-personnel land mines.

The BDM48 working head is very heavily built. This is partly a holdover from the design of heavy duty tree and brush cutters, but it is also partly due to the manufacturer's intentional design to blast harden the machine. For the most part, the blast hardening seemed to have been well done. The design had emphasized the machine's ability to contain the blast and shrapnel. The blast hardening done on the machine prior to the tests was intuitive, and did not have the benefit of actual blast tests or data to guide or confirm the design. Figure 3 shows an exploded assembly view of the BDM48's construction. Annex B contains much more detail in a manual from the manufacturer. Note that this manual was developed after additional testing and development and shows a slightly different configuration than was tested in this program. The differences relate mostly to a shock suppression device between the BDM48 and the host vehicle; the differences are not expected to have any impact on the results discussed in this report.

The BDM48 uses hydraulic connections to its host vehicle to operate a hydraulic motor driving the drum or roller seen in Figure 2. Also seen in this image are one of the types of teeth that can be installed on the BDM48. When the drum is brought up to speed (about 1800 rpm) it is used in debrushing operations to remove vegetation. It can also be used against landmines directly by engaging the drum/teeth with the ground and grinding suspected areas or targets. The system was designed to grind to a depth of 200mm.

The main drawback of the BDM48 system is that it is a relatively large machine requiring significant infrastructure. Heavy equipment parts, maintenance, operators, fuel, and suitable roads would all be required. This might negate its application in certain locations.

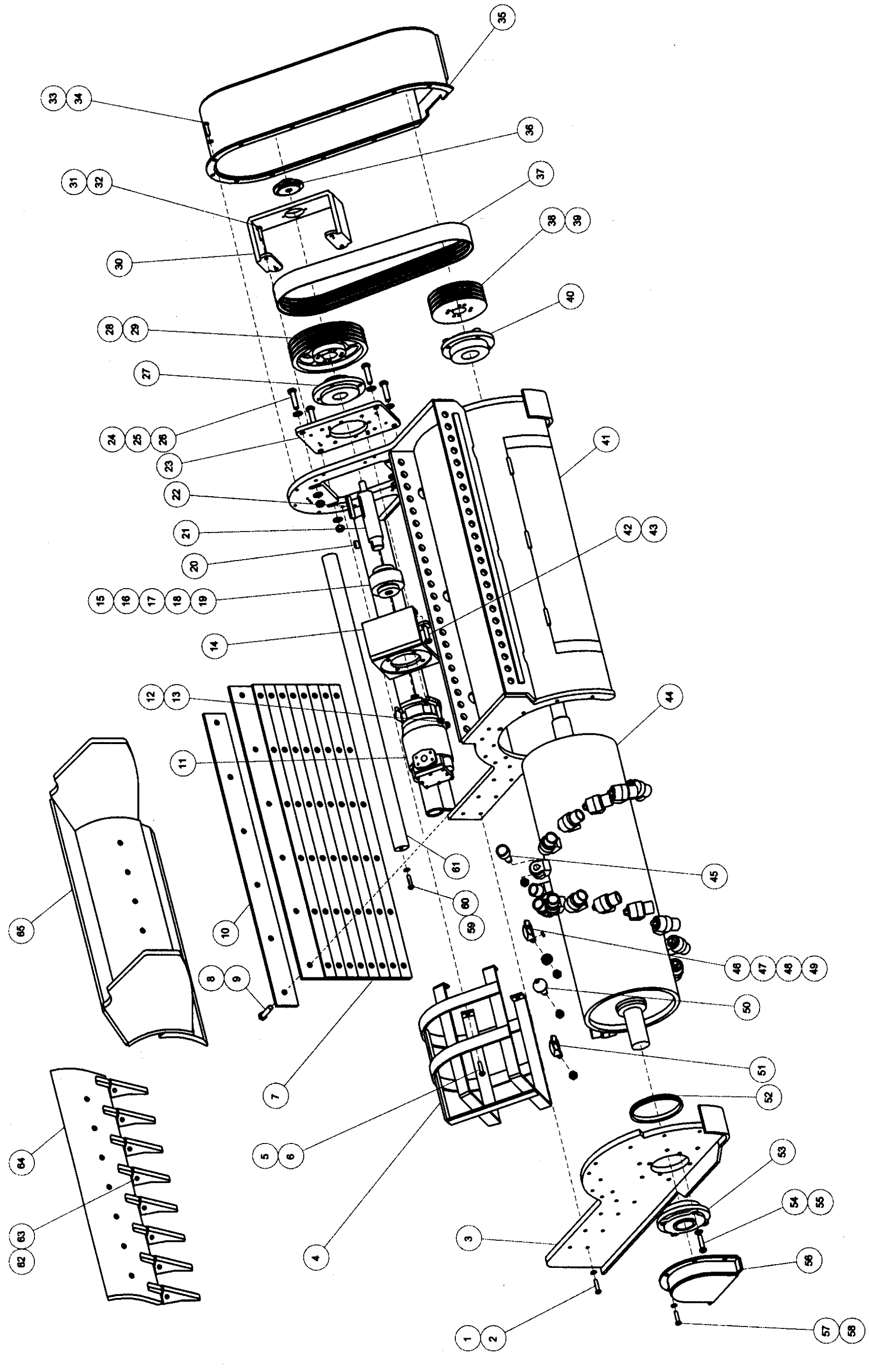


Figure 3. *ProMac BDM48 components*

3. Phase 1 Testing – Humboldt Saskatchewan

The rationale behind the phase 1 testing is detailed in Volume 3 of this report, along with the goals, procedures, etc. For convenience, these are briefly summarized below.

Phase 1 testing was conducted in sand, clay soil, black earth, prairie sod, and in poplar and willow groves. This testing was intended to train the operators, revise the test procedures if necessary, evaluate the machine against trees/brush as appropriate, and to act as a filter to eliminate any machines that were clearly not mature or capable enough to warrant the more expensive phase 2 testing at DRES.

As shown in Figure 4 and Figure 5, test patches were laid out in each soil/environment for each machine. In each test patch MRMs were buried at depths ranging from 0mm ("flush" buried) to 200mm. The machines were then allowed to operate on each test patch in whatever manner (within certain limitations) seemed most appropriate to the manufacturer. Following each "operation" by the machine, the MRMs were checked to determine the effectiveness of that operation, and a decision was made whether to repeat the operation or to declare that test patch "finished."

Figure 4. *Placement and Marking of MRMs for Phase 1 Testing*

Figure 5. *MRMs Were Located Around Trees And Roots In Poplar Grove*

3.1 ProMac BDM48 T&E Results (Phase 1)

3.1.1 Technique

Once testing commenced it became apparent that the BDM48 would generate a significant amount of loose soil. This would have at least two possible negative effects in this program:

- The loose soil would obscure the base of the cut area, making it difficult for the operator to gauge the depth and uniformity of the cut.

- The loose soil, being much looser and more voluminous than the original soil had been, would be much deeper than the original soil. This could make mine detection using conventional means even more difficult.

To address the loose soil problem in the MAE trials, it was decided that the machine would be operated in a specific manner. Whether this method of operation would be used in actual field use was not addressed; this method was to facilitate evaluation of the machine.

- With the host vehicle outside of the area to be processed, the system would be used to cut and grind the soil in whatever manner the operator found most effective.

- Exposed MRMs could be intentionally attacked by the operator since any real mines exposed using the BDM48 would certainly be attacked until they were detonated or completely broken up.

- The loose soil would then be pushed aside into a berm using the working head's exhaust curtain. Any MRMs discovered in the loose soil could be attacked again for the reasons stated above.

- Having pushed the loose soil into a berm, the operator or a supervisor could examine the cut area to determine whether more processing was required. This examination was to be conducted visually from outside of the cut area since it was potentially still an "uncleared" area.

- Once the operator/supervisor declared the area "complete," the area would be examined for MRMs, both live and dead. The berm would be examined separately to determine what sort of mine/EOD problem had been left in the berm.

- At this point testing in that area would be finished. It was observed that there might be some benefit to having a second machine to sift through the berm.

3.1.2 Findings

Prior to actual testing, the BDM48 was operated in a sod area to familiarize the machine operator with the tool. It was also used in a part of the poplar grove in tree and brush cutting mode. The system was then tested in tilled black earth, soft clay, and undisturbed prairie sod. In addition, MRMs were placed near and under tree roots in both the willow grove and the poplar grove. A brief experiment shown in Figure 6 demonstrated that the system is capable of working slopes, hills, and transition zones without any apparent difficulty.

Figure 6. *ProMac BDM48 Easily Works a Sloped Area*

As discussed above, the Phase 1 testing was not intended to provide quantitative data about each machine's performance against Mechanical Reproduction Mines. The more important information gathered during this part of the program is listed below:

- There are three main types of teeth available for the BDM48. For brush cutting, the cup shaped tooth is the most commonly used and was the starting point for the PAMI tests. This tooth, while excellent in brush cutting, did not cut well through soil. Part way through the tests, every second tooth was replaced by a chisel tooth which provided better soil results. A cone shaped tooth is also available; different combinations of these three teeth might provide optimal ability under different soil conditions but insufficient tests were done at PAMI to confirm this.

- The hydraulic motor used to drive the BDM48 cutting head was originally selected based on the machine's heritage in tree and brush cutting. Activities in the willow and poplar groves demonstrated that the machine has been well designed and the components carefully selected for such tasks. It quickly became clear however, that there was insufficient torque for the cutting head to maintain rotation during extended soil cutting operations, and the head had to be allowed to come back up to speed after each ground engagement. This did not prevent the machine from doing its job, but it did mean that operation was considerably slower than it could have been. Midway through the PAMI tests, the ProMac representatives were making inquiries to have the hydraulics reworked prior to the Phase 2 tests at DRES.

- MRMs which were visible at the surface were immediately attacked with the BDM48 working head. Similarly, as soil cutting and grinding exposed MRMs, they were attacked until they were clearly broken into small pieces. Soil processing continued until the marked area had been taken down to what appeared to be the required depth.

- The first area to be worked was the tilled black earth (see Figure 7) in which one MRM was missed on the first attempt but was successfully engaged on the second pass. This was followed by the clay soil in which two MRMs were missed on the first pass and broken up on the second pass. In the prairie sod two MRMs were missed on the first pass and missed again on the second pass but were broken up on the third pass. In the willow grove one MRM took two passes while the others were broken up on the first attempt. The last area processed was the poplar grove where all MRMs were broken on the first attempt. The fact that some MRMs were missed on the first or second attempt may or may not be significant; this was the first ever use of the machine in this application by this (or any other) operator, so it should really be considered a training exercise.

Figure 7. *ProMac BDM48 In black earth*

- It was discovered that there had been a misunderstanding of the depth requirements for this machine. The manufacturer had assumed that there was a requirement to dig an area out to 200mm depth, whereas the intention was that the MRMs would be buried to 200mm (to the top of the MRM). Hence, a 200mm deep cut by the machine might leave some MRMs untouched. This may have been another cause for some MRMs having been missed in these trials.

- After a few attempts, the operator was able to gauge cut depth and uniformity; subsequently all MRMs in the areas were successfully broken up and moved to the berm. It became apparent that the ability of the system to engage and destroy mines (or MRMs) was chiefly dependent on the machine operator's competence, and not so much on limitations of the machine itself. Even the manufacturer's misunderstanding of depth could be overcome by a good operator. Given time for the hydraulics to spin back up to speed, the working head could penetrate to any reasonable depth; the resulting processed area, once cleared of loose soil was smooth, uniform, clear of debris, and easy to inspect with metal detectors or other equipment.

- The exhaust curtain on the working head, clearly shown Figure 7, was a flexible, heavy flap designed to keep debris from being thrown during soil grinding. During the PAMI tests the curtain was tried at various positions from fully open to fully closed. It was found that, while a skilful operator could minimize most of the thrown debris in most cases, the curtain should be down to prevent unavoidable accidents. Having the curtain down helped minimize but not completely eliminate flying dust, stones, and MRM pieces.

- Tests in the willow and poplar groves (see Figure 8 and Figure 9) proceeded in a similar manner except that the trees and brush were cut down to ground level before the soil was processed. Slash from brush cutting was simply ground up along with the soil. All of the MRMs in both areas were successfully broken up and moved to the berm with one exception. That exception, analyzed in detail in Volume 2 of this report, illustrated that MRM data might not necessarily be simple “live/dead” indications; other categories might be needed to be included to cover ambiguous situations or situations where the MRM had been left in a state where (had it been a real mine) a hazardous mine component might have remained. While it is technically inaccurate, such hazardous fragments are referred to herein as EOD (Explosive Ordnance Disposal) fragments.

- While the BDM48 System operation was not particularly fast, it was very thorough, and ensured that virtually all MRMs and fragments were clear of the specified area, and had been intentionally moved to a berm in a designated area. MRMs were either triggered or broken to the point where they could not function. Examples of the fragments left by the BDM48 are shown in Annex C.

Figure 8. *ProMac BDM48 mulches willow slash during soil grinding*

Figure 9. *ProMac BDM48 easily handles trees in poplar grove*

4. Phase 2 Testing – DRES

As with the phase 1 testing, the procedures, layout, and methods of conducting the tests are detailed in Volume 3 of this report. The details of the procedures which are specific to the ProMac BDM48 are described below.

The procedures worked out for the ProMac BDM48 during the Phase 1 trial were adopted with a few minor modifications. Whereas the original intent was to have the machine travel along the edge of the test lane while working the area, it was more practical for the BDM 48 to approach the lane end-on. The machine would work the soil as far as it could reach and then push the loose soil off to the side. The worked area would be checked and then the machine would advance into the "cleared" area and continue operations.

The digging or cutting pattern found to be most effective in this scenario was to begin with the working head in relatively close to the machine and on the right hand side of the test area (from the operator's point of view). After digging at this location the arm was extended slightly to dig the next location. This continued until the arm had been stretched out as far as possible. The carriage was then rotated slightly to the left and the working head gradually worked back toward the vehicle. The process was repeated until the full width had been processed as far as the machine could reach. After checking the processed area and the berm for live MRMs the machine was advanced into the newly "cleared" area and the process repeated.

It became apparent right away that it was virtually impossible to identify, collect and survey all the remains of "dead" MRMs since most had been broken into tiny, unidentifiable fragments. Live MRMs that were found right at the far edge of the machine's reach were not included in the data as "missed" since the machine would advance into the cleared area at which point these targets would be in the main part of the cleared area rather than right at the fringe. If those same MRMs were found after the machine had advanced, they were then included. MRMs found along the right and left side of the area were included however since the machine would not continue processing in that direction. MRMs found right at the leading edge of the cleared area were accepted as legitimate targets but in reality their presence was due to the operator not starting far enough back rather than being due to any limitation of the machine.

4.1 Changes to the BDM48 Before Phase 2

Between the Phase 1 and 2 tests the machine was modified in 3 main ways. The top of the BDM48 body was fitted with 3 vents which would allow explosive gases to escape in the event of anti-personnel mine sized blasts. While this was not necessary to satisfy the Phase 2 tests, the manufacturer had asked if it would be possible to do explosive trials following the Phase 2 tests. The three vents can be seen on the deck of the BDM48 in Figure 10.

The second change to the system was that the hydraulic system was changed to provide greater torque to the drum. While this did not allow a continuous grind technique (the operator still had to allow the drum to come back up to speed after ground contact), it was a significant improvement on the initial system.

The third change was the addition of a “rock picker.” Shown in Figure 11, this device was supposed to allow the operator to pick larger rocks from the soil and move them aside rather than trying to grind through them. While the specific design used here was too fragile, the concept was shown to be sound.

An additional change worth noting was one that actually occurred during the Phase 2 testing. The exhaust curtain was fitted with stiffeners to improve the system’s ability to scrape the loose soil into a berm (see Figure 12). It became clear that as the curtain became more like a blade and less like a flexible curtain, this ability steadily improved. With a little practice the operator quickly became proficient at handling the head with a “stiff” exhaust curtain

Figure 10. *Vents to minimize blast damage*

Figure 11. *BDM48 Rock picker handles larger rocks instead of grinding*

Figure 12. *BDM48 exhaust curtain stiffeners to improve berm scraping ability*

4.2 ProMac BDM48 T&E Results (Phase 2)

The performance of this machine is largely a function of the operator's skill. With a competent operator able to control the depth of the machine's ground penetration, depth of mine burial becomes effectively irrelevant (for any reasonable anti-personnel mine depth of burial).

The nature of the machine suggests that the results be discussed in two separate sections. “Neutralization results” will include the details of how well the machine triggered, destroyed or broke up the MRMs to the point where they were no longer operable. “EOD results” will consider the possible EOD fragments that might be left behind after this machine.

4.2.1 ProMac BDM48 "Neutralization Results"

The term “neutralization” can often be taken to mean that mines have been detonated, made inoperable, or simply removed from the area of interest. Whole, intact, operable mines may be completely acceptable providing they are no longer in the processed area. In the context of humanitarian demining, however, intact mines thrown from one area to another do not constitute an acceptable solution. So in this respect, the term “neutralization” may not be strictly accurate, but will be used for convenience.

As shown below in Table 1, through Table 3, and graphically in Figure 13 through Figure 16, this machine performed surprisingly well. Note that these tables list the MRMs which were intact and operational (“live”) following the machine operation, and includes MRMs found in the swept area and MRMs in the berm at the side. MRMs which were broken apart and would present EOD targets are not included in this definition. “KILL” refers to the MRMs which were broken apart, detonated, disrupted or otherwise damaged to the extent that they were no longer operational (neutralized).

- In all four soil types, neutralization, or “kill” rates exceeded 97.5%.
- All MRMs down to a DOB of 50mm were neutralized, with over 98% neutralized at 100mm DOB and over 96% at 200mm.
- Fully 100% of the PMA-1 and PMN MRMs were neutralized along with over 98% of the PMA-2 and PMA-3 MRMs.

The data appears to show that the prairie soil and obstacle course areas caused a small amount of difficulty. Without prejudice to the data as shown, the following notes are worthy of consideration:

- The prairie soil frame was the first area to be worked by this machine. It is in this area that the operator had the least experience with the machine, and was least experienced in gauging the depth of cut that he was achieving. Hence the deeply buried MRMs in this first area were more likely to be missed due to operator error. Despite this, only 2 MRMs out of 135 were missed.

- In the obstacle course 3 of the 133 MRMs were missed. This test was compromised by a poor operating decision; fuel was running extremely low, and rather than simply stopping the test and waiting for additional fuel, the remaining area was rushed to try to get it done before running out of fuel. This was clearly a poor decision, and it resulted in an apparent gap in the machine's performance.

Even with the 5 missed MRMs, an overall result of greater than 99% neutralization is unusually high for mechanical equipment.

Table 1. *ProMac BDM48 – Totals by Soil Type*

	OBSTACLE COURSE	PRAIRIE SOIL	GRAVEL ROAD	STUMP COURSE	SUB TOTALS
"Live" Before Test	133	135	133	133	534
"Live" After Test	3	2	0	0	5
After Test % Live	2.3%	1.5%	0%	0%	0.9%
After Test % KILL	97.7%	98.5%	100%	100%	99.1%

Table 2. *ProMac BDM48 – Totals by Depth of Burial (All Soil Types)*

	DEPTH OF BURIAL (DOB)					SUB TOTALS
All Types	***0mm***	***25mm***	***50mm***	***100mm***	***200mm***	
"Live" Before Test	81	120	139	115	79	534
"Live" After Test	0	0	0	2	3	5
After Test % Live	0%	0%	0%	1.7%	3.8%	0.9%
After Test % KILL	100%	100%	100%	98.3%	96.2%	99.1%

Table 3. *ProMac BDM48 – Totals by MRM Type (All Soil Types)*

	PMA-1	PMA-2	PMA-3	PMN	SUB TOTALS
"Live" Before Test	156	157	159	62	534
"Live" After Test	0	2	3	0	5
After Test % Live	0%	1.3%	1.9%	0%	0.9%
After Test % KILL	100%	98.7%	98.1%	100%	99.1%

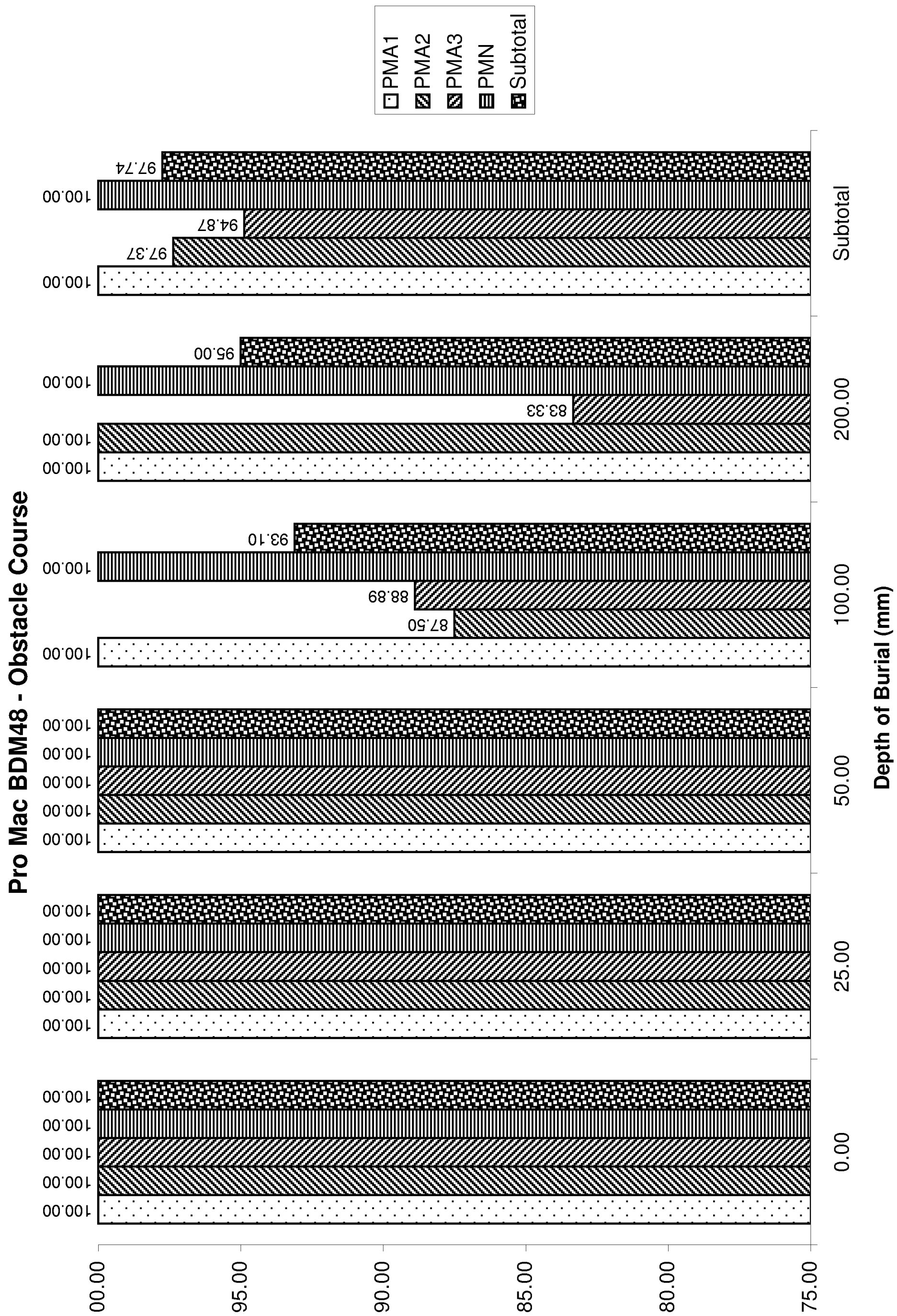


Figure 13. *ProMac BDM48 Obstacle Course Data*

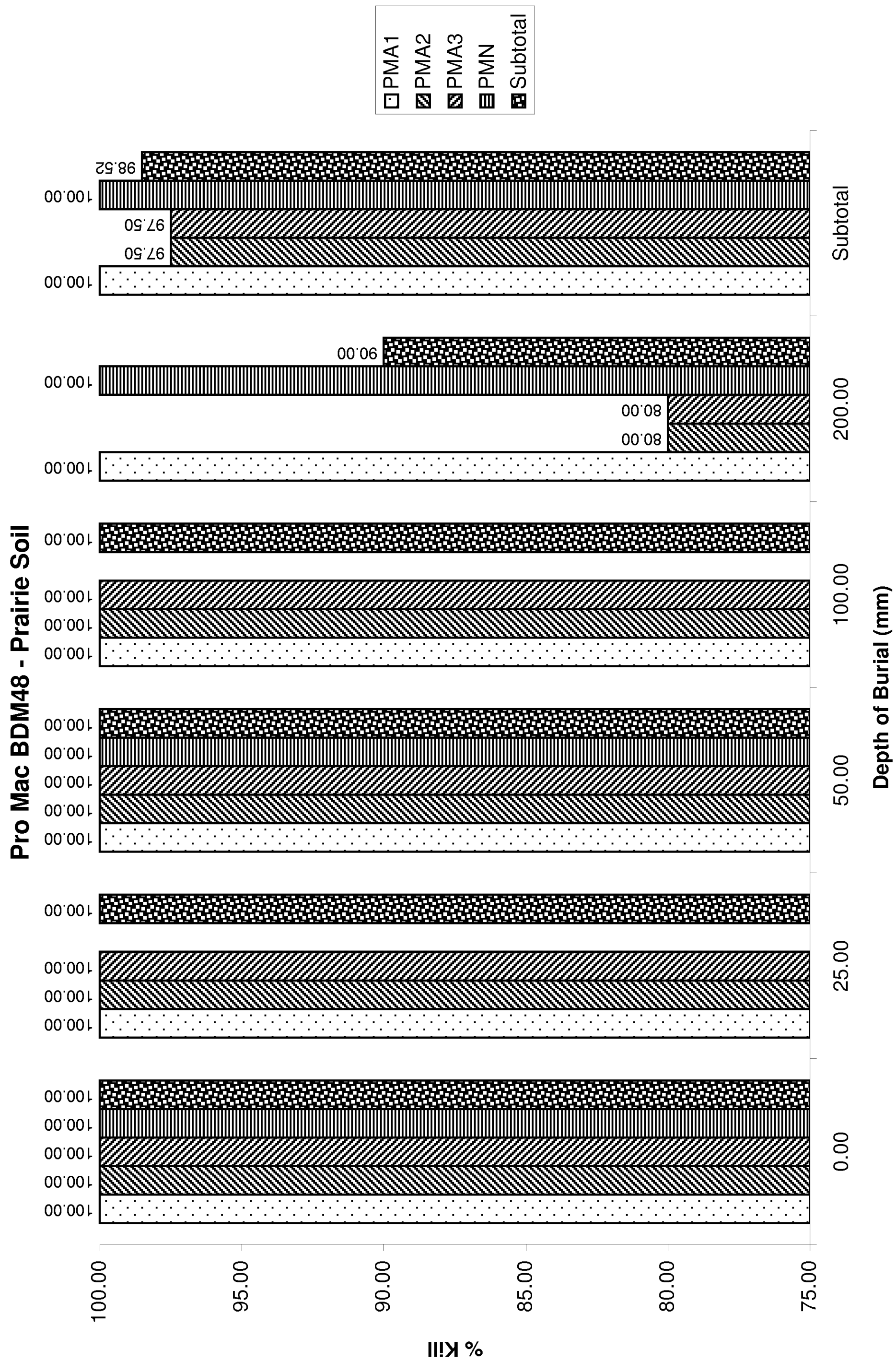


Figure 14. *ProMac BDM48 Prairie Soil Data*

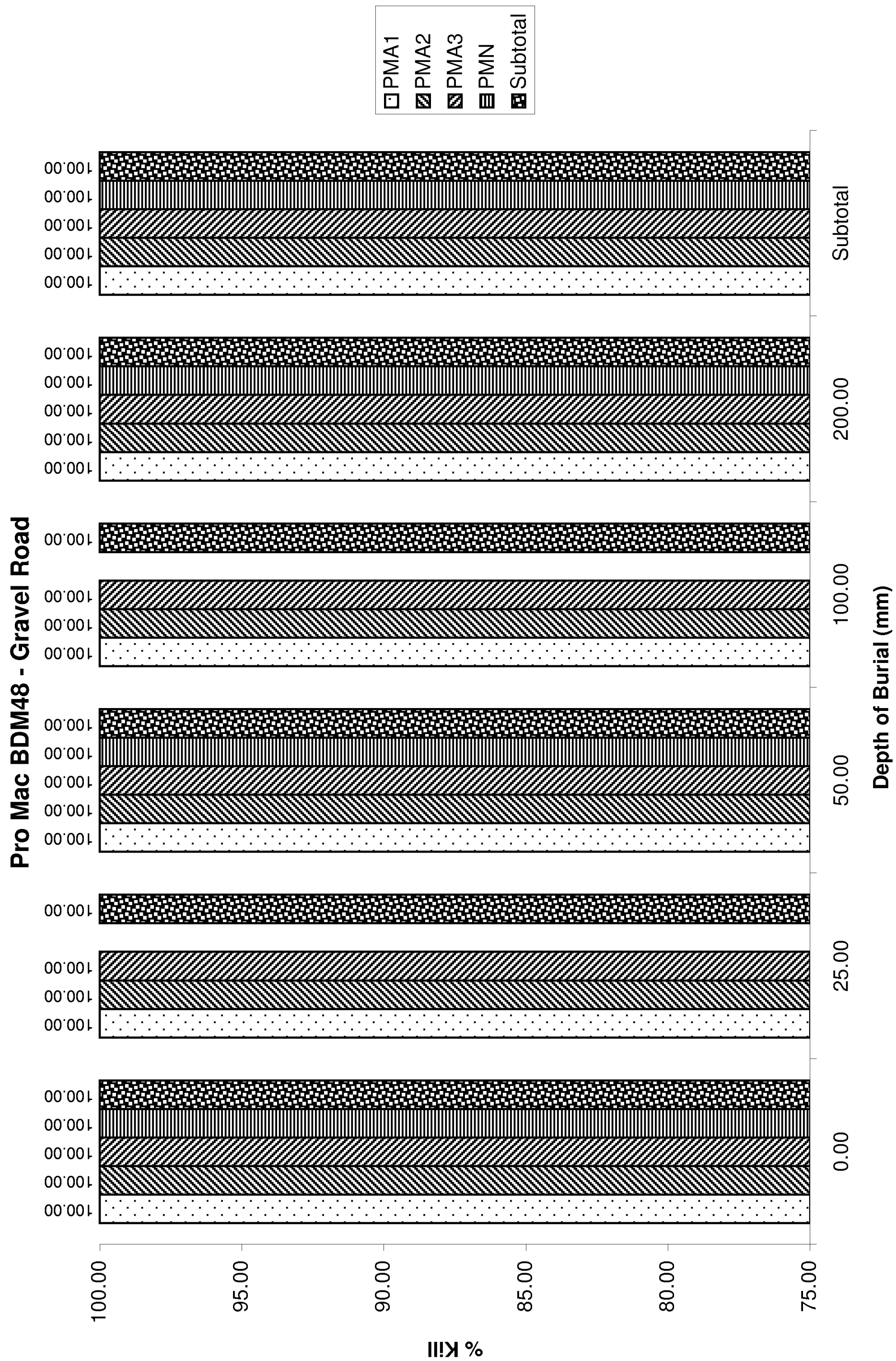


Figure 15. *ProMac BDM48 Gravel Road Data*

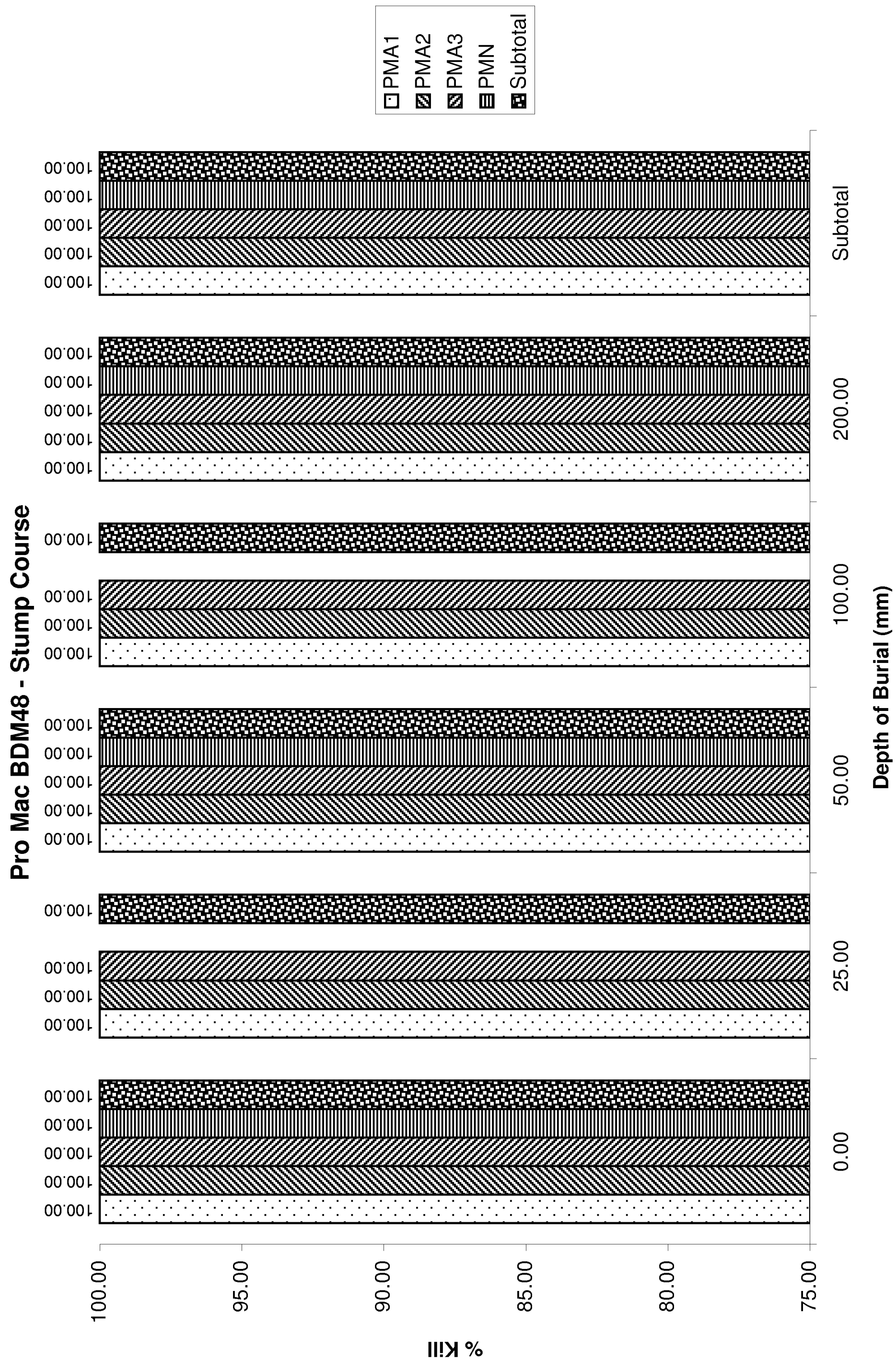


Figure 16. *ProMac BDM48 Stump Course Data*

4.2.2 ProMac BDM48 "EOD Results" (Phase 2)

As with the definition of “neutralization,” a rather loose interpretation of the term “EOD” is adopted in this report. Strictly speaking a live mine sitting on the ground should probably be considered explosive ordnance requiring appropriate disposal but for the purposes of this discussion functional mines are excluded from this category. In the context of this report, the following items are considered EOD fragments:

- Pieces of mines or fuzes that might still be triggered in the normal way but are no longer connected to their main charges: The lower body of a PMA-3 without its top plate would be an example.

- Pieces of mines or initiation trains that can no longer be triggered in the normal way but have fragments of the explosive charge or a booster in contact with them. A piece of the main charge from a PMA-1 with the detonator still inside but no crush capsule would be an example.

- Untriggered fuzes, ignitors, detonators , etc which can no longer be triggered in the normal way, and are no longer connected to their main charges: A PMA-2 fuze tower without its plunger would be an example.

- Pieces of explosive or boosters which have been removed from their initiation devices: A lone, undamaged PMA-3 top plate would be an example.

This list is sure to find instant criticism as some people will assert that a piece of explosive which has been removed from its initiation train is no longer a hazard and need not be considered an “EOD fragment.” Some will assert that an intact and operable detonator, removed from the main charge, while technically capable of causing injury, is so much less hazardous, and so much more difficult to accidentally initiate, that it also should be removed from the “EOD fragments” category. Still others will maintain that any such pieces have the potential to cause injury, and must therefore be removed before an area can be deemed “clear.” To take the more conservative approach, all of the above types of fragments will be included in the discussion of EOD fragments.

As described in Volume 3, it is impossible to determine with certainty the actual number of pieces which might represent EOD fragments. One very simple reason for this is that some of the apparent EOD fragments might well have come from MRMs which had been triggered before they were broken apart; there is no way to know whether an MRM was triggered first, or broken apart first. The reality is that the situation is much more complicated than this simple example suggests. Hundreds of MRMs, each broken into many pieces, some of which can be identified and some which cannot, all combine with the question of whether they were broken or triggered first. Add to this the problem that the internal construction of the MRMs is not the same as the real mines, and the fragments may not be truly representative in all cases. Clearly, any quantitative evaluation of possible EOD fragments must be viewed with a healthy degree of scepticism. Notwithstanding this reservation, it is still necessary to examine the possible EOD fragment issue.

To address the issue of EOD fragments created/left by the ProMac BDM48, all MRM fragments collected after BDM48 processing were examined. Annex C contains a representative sample of the types of fragments created by the BDM48. Those fragments which contained identification (serial number, location code, live fuze coil, etc) were catalogued against the pre-test data. Many other fragments had no specific identifying marks. Those pieces which were clearly not EOD fragments (e.g.: triggered MRMs, small plastic shards, rubber covers, PMA-1 lids, etc) were ignored. The remainder were categorized as follows (see Figure 17 for examples):

- Definitely an EOD fragment: An undamaged, untriggered PMA-3 bottom body without the top piece would be an example; in the real PMA-3 mine this would include the fuze/detonator.

- Probably an EOD fragment: A PMA-2 top cover and fuze tower with the plunger un-pressed would be an example; the lower part of the real PMA-2 mine fuze tower (not present in the MRM) might have been damaged which might have destroyed the fuze. Hence the uncertainty.

- Probably not an EOD fragment: A PMA-3 top with a moderately high level of damage would be an example; in a real PMA-3 mine, the high level of damage might well have removed the main explosive charge from the plastic.

- Unknown – it may be an EOD fragment or it may not but there is no way to evaluate it. An undamaged PMA-3 top with no indication of its bottom piece would be an example; in the case of a real PMA-3 mine the main explosive charge would probably still be present unless the mine had detonated prior to being broken apart.

Clearly, it is a very subjective matter whether a particular piece is called "probably" an EOD fragment, "probably not" an OED fragment, or is ambiguous enough to be called "unknown." This reinforces the caution about trying to quantify the EOD fragments based on MRM indications.

Definitely not EOD fragments

Definitely an EOD fragment

Probably an EOD fragment

Probably not an EOD fragment

Unknown if EOD fragments or not

Figure 17. *"Possible" EOD fragment examples*

Table 4. ProMac BDM48 EOD Fragment Summary

TYPE OF FRAGMENT	PMA-1	PMA-2	PMA-3	PMN	TOTAL
Original # of mines	159	155	160	61	535
# "Definitely" EOD Fragments	0	1	1	0	2
# "Probably" EOD Fragments	0	3	1	4	8
# "Probably Not" EOD Fragments	34	27	54	10	125
# "Unknown" EOD Fragments[1]	10	65	73	30	178
# of fragments that might be EOD fragments[2]	44	96	129	44	333

1. "Unknown" means that it is unknown whether the piece represents an EOD fragment or not. It does not mean that the piece cannot be identified.

2. Using the PMA-3 MRMs as an example, note that it is not accurate to say that 129/160 or 80% of PMA-3 MRMs became possible EOD fragments. It says that where there were 160 PMA-3 MRMs to begin with, there were 129 possible EOD fragments. Recall that a single PMA-3 could possibly yield 2 or more separate EOD fragments. Further, it is quite possible that any given MRM may have been triggered; in such a case, it is unlikely that there would have been anything left as an EOD fragment (had real mines been used).

If the data from Table 4 is normalized and presented graphically, as in Figure 18, one can make the following generalizations in round numbers with respect to the ProMac BDM48:

Assuming that no MRMs have been triggered,

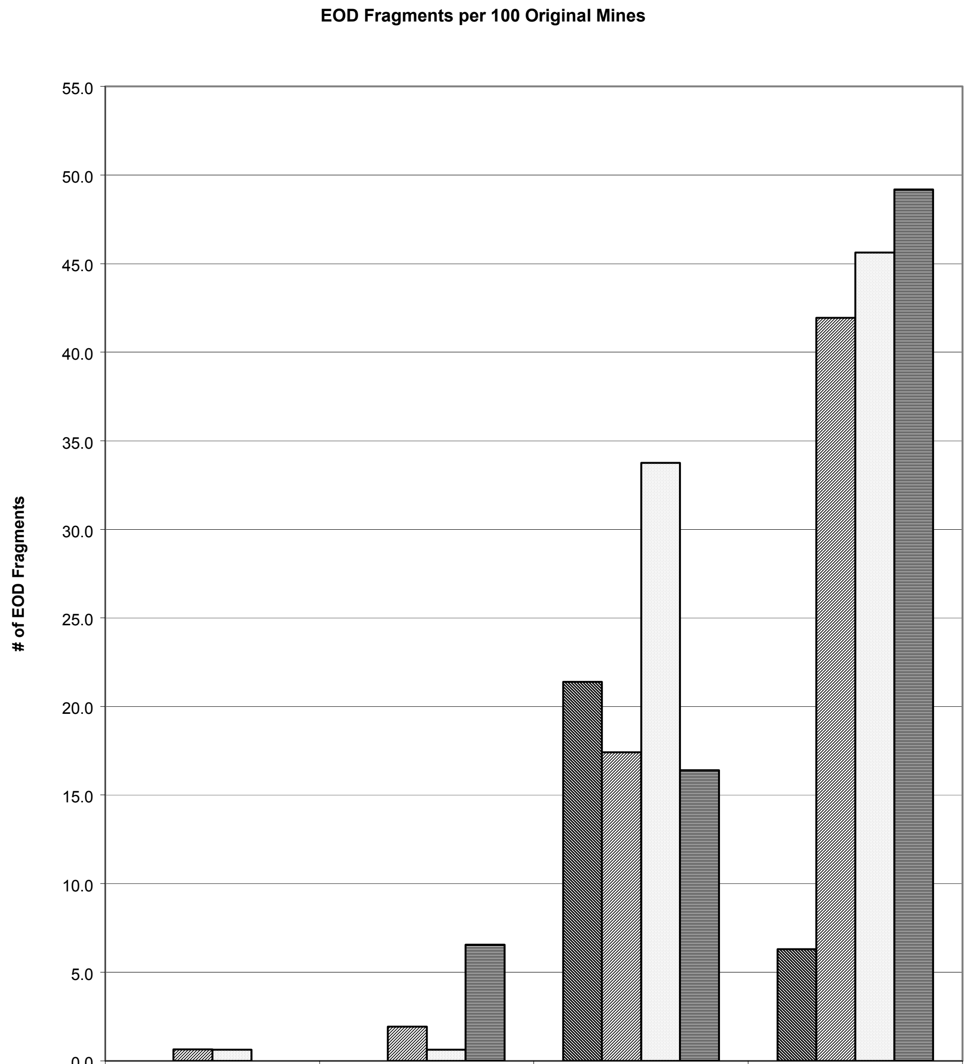
- Almost none of the MRMs will yield a piece that is "definitely" an EOD fragment.

- The only MRM type to yield any number of pieces that one might think are "probably" EOD fragments is the PMN, and even that is only a total of 7 fragments per 100 PMN MRMs.

- From an initial set of 100 of each type of MRM, something between 15 and 35 suspect fragments from each type might be found, which would "probably not" be EOD fragments.

- Beginning with 100 of each type of MRM, one might expect anywhere from 40 to 50 pieces each from the PMA-2, PMA-3, and PMN types for which they are possible EOD fragments but where one can't really make confident judgement about the probability ("unknown"). In contrast, only about 6 pieces from PMA-1 MRMs would be expected in this category.

It is critically important to keep in mind that all of these numbers relate to the MRM fragments left by the ProMac BDM48; they do not necessarily represent what the ProMac BDM48 would leave behind from real mines since the real mines might detonate first, thereby leaving no (or fewer) EOD fragments.



	Definite EOD/100	Probable EOD/100	Probably Not EOD/100	Unknown EOD/100
PMA1	0.0	0.0	21.4	6.3
PMA2	0.6	1.9	17.4	41.9
PMA3	0.6	0.6	33.8	45.6
PMN	0.0	6.6	16.4	49.2

Figure 18. *ProMac BDM48 Normalized EOD Fragment Quantities*

4.2.3 Other ProMac BDM48 Observations (Phase 2)

The BDM48 System performed the same under all of the environmental conditions used in Phase 2. The different soil types did not have any apparent effect on the machine's performance, nor did the simulated tree stumps. The uneven terrain in the "Obstacle Course" area did not create any difficulty whatsoever. Neither were system mobility or traction affected in any noticeable way. With the addition of the rock picker, the machine was able to handle rocks up to about 300mm in diameter. This capability was not tested extensively.

As noted in the PAMI report of Annex A, the system was generally capable of operating at a rate of 65-70 square metres per hour, beginning with clear ground and finishing with a scraped area at least 200mm deep. Hydraulic requirements for the system included a flow rate of up to 3.1 litres per second at 27.6Mpa (50 usgpm at 4000psi). This translates to a hydraulic power requirement of about 90kW (120hp).

There were discussions about the desirability of lowering the rotation speed of the BDM48 (from about 1800 rpm) in order to increase the torque and thus possibly allow a continuous dig through the soil. The net result of these discussions was really an academic issue but one factor to be considered was that the high rotational speed broke the MRMs up thoroughly. The effect of a lower speed was unknown. Further, a continuous high-torque operation would have put considerable additional strain on the hydraulic system.

The only other observations of note were that:

- The system could experience packing of soil inside the working head. When left to solidify, this packed soil might need to be chipped out by hand.

- Even with the exhaust curtain down, there were occasions in which MRM fragments were thrown several metres. This was due to the gap formed when the curtain flexed away from the rest of the BDM48 body.

4.3 ProMac BDM48 With Other MAE Machines

Originally the ProMac BDM48 was to be tested only as a stand-alone piece of equipment but it became evident that it might be possible, and in some cases, useful to operate the BDM48 in tandem with a second machine which could sift through the berm of loose soil created by the BDM48. In the process of Phase 2 testing, it was decided that a "sorting bucket" would be brought in to be used in conjunction with the ProMac BDM48. The Schulte Extractor Mine Picker was also evaluated as a possible companion machine for the ProMac BDM48.

The berm processing data that follows includes only qualitative data. It would be meaningless to list the number of pieces retrieved by either the Schulte Extractor or the

VRL-8 Sorting Bucket since there is no way to know how many fragments were there to begin with.

4.3.1 ProMac BDM48 Berm Processing With VRL-8 Sorting Bucket

The VRL-8 Sorting bucket and its operation are discussed in detail in Volume 8 of this report. In summary, the system included the tracked-hoe used with the ProMac BDM48 and a specially built, perforated, hydraulically vibrated excavator bucket.

The VRL-8 sorting bucket was used to sift through the berm left by the ProMac BDM48. To accomplish this the tracked-hoe was positioned at the end of the test frame as it had been in testing the BDM48 System. The track hoe reached to the side and pulled in a bucket full of the berm which was then sifted above the "cleared" test frame. Pieces of the MRMs which were collected in the bucket were dumped off to the side in a convenient area. As the cleared area filled with sifted soil in front of the vehicle, the system advanced and continued operation. This operation is shown in Figure 19 and Figure 20. In contrast to the BDM48/Schulte combination which should have had a wide, shallow berm (see below), the BDM48/VRL-8 combination benefits from a tall, more compact pile.

While the speed of berm soil sifting was not measured, the speed of the VRL-8 bucket operation alone was measured (see Volume 8). In that exercise the VRL-8 system removed and sifted an area approximately 5 x 23m to an average depth of about 0.35m in almost 105.5 minutes. This translates to a work rate of about 23 cubic metres per hour. It might be argued that the digging and sifting operation might be somewhat slower than the berm processing due to the need to dig the relatively hard soil and break it up during sifting. The other side of the argument however, is that the berm processing operation might be slightly slower due to the need to continually scrape the berm backup together; scooping up the berm tended to spread it out. The net result is that the speed of berm processing is probably very similar to the digging and sifting operation, at something between 20 and 25 cubic metres per hour.

It is very important to note that the times measured with this system depend very heavily on (i) the operator skill, (ii) the mesh size of the screen in the bucket, and (iii) the characteristics of the soil. Wet soil, highly cohesive soil, or soil containing a large amount of root mass will take much longer to process, if indeed they can be processed successfully at all. Conditions for the tests in this program were close to ideal for this machine with dry soil, and very little organic matter.

Figure 19. *Berm Processing by the VRL-8 Sorting Bucket following ProMac BDM48*

As noted above, it is meaningless to try to quantify the number of MRM pieces retrieved by the bucket. Figure 19 and Figure 20 show that the system was very effective at extracting whole and almost whole MRMs. Naturally the smallest fragments (those which could fit through the 25mm square mesh in the bucket) were often missed. On the other hand, the mesh is quickly and easily replaced; a finer mesh could be used which would capture smaller fragments, albeit at the cost of longer processing times. Photographs of the fragments collected by the VRL-8 are included in Annex C.

Figure 20. *Berm Processing by the VRL-8 Sorting Bucket following ProMac BDM48*

4.3.2 ProMac BDM48 Berm Processing With Schulte Extractor Mine Picker

The intent with this combination of machines was to use the ProMac BDM48 to grind through the soil, destroy MRMs, and pile the loose soil and fragments in a berm alongside the test area. The Schulte Extractor Mine Picker would then dig through the berm and extract MRM parts, hopefully collecting most of the EOD targets and any remaining intact MRMs.

Figure 21. *ProMac BDM48 berm*

Because of the size of the berm, there was no practical way of driving the Extractor over the pile. After the departure of the BDM48, a small skid steer loader was used to bring the pile down to about 450mm deep and relatively level. The Extractor was then operated on this flattened pile. Material in the bucket would be dumped elsewhere in the same way that had been done with the Extractor on its own.

The operation of the Schulte Extractor is dealt with in detail in Volume 6 of this report. In that volume, it is noted that the Extractor was unable to adequately deal with the berm as presented in this test; in hindsight, the berm from the ProMac BDM48 should have been spread in a wide, shallow (200mm deep) pile rather than a tall, narrow pile.

Another consideration with respect to this combination of machines is that the Schulte Extractor is poorly suited to short berms. Considerable lead-in distance is required to allow the Extractor to be properly aligned with the berm without driving its host vehicle in the uncleared areas. This contrasts with the BDM48's ability to process small, hard to access areas, creating small, irregular berms. The manner in which the BDM48 is to be used may make the Extractor an unsuitable companion to this machine.

Finally, an intentional pairing of the ProMac BDM48 and the Schulte Extractor requires that two separate host vehicles be available. If a suitable tractor is already available for the Extractor this may not be an issue, but lacking such a vehicle, this combination may not be cost effective.

This does not suggest that the Extractor would not work as a companion machine to the BDM48, but that it would be necessary to create very specific conditions before such a combination would be practical.

4.3.3 ProMac BDM48 and Schulte Extractor Mine Picker in Other Operations

Two brief tests of the Schulte Extractor following the ProMac BDM48 were conducted during the Phase 1 trials. In the first case, shown in Figure 22 and Figure 23, the Schulte Extractor was brought to an area used for practice by the BDM48. The soil here was left in place rather than being scraped into a berm. Nine intact MRMs were tossed into the loose soil and the Extractor was pulled through the area. Because this area was relatively long, flat, straight and shallow it was much easier for the Extractor than the subsequent phase 2 berm proved to be. Until such time as the bucket plugged with grass clumps, the fine, loose soil created by the BDM48 was easily sifted through the perforated floor of the Extractor leaving only the MRMs. The Extractor retrieved all nine MRMs on the first pass. This was an artificial trial in that the only targets were a few intact MRMs rather than thousands of small fragments.

The second combination test was to use the Extractor to sweep the slash from an area in which the BDM48 had debrushed a part of the willow grove (see Figure 24 and Figure 25). Again, this was a relatively long, flat, straight area with shallow debris (all above-ground in this case). While not designed for the task of raking tree slash, the Extractor did a reasonable job of cleaning the area. It is not suggested that the Extractor should be specifically purchased for this task, but the combination might be helpful if a demining organization has both the BDM48 and the Extractor.

Figure 22. *Schulte Extractor following ProMac BDM48 in field*

Figure 23. *Schulte Extractor following ProMac BDM48 in field*

Figure 24. *Schulte Extractor clearing ProMac BDM48 tree slash*

Figure 25. *Schulte Extractor clearing ProMac BDM48 tree slash*

4.4 Explosive Testing of the ProMac BDM48

The manufacturer asked whether it would be possible to do any live mine tests following the Phase 2 tests. It was determined that it would be possible to do a few explosive tests to simulate real mines. It was strongly suggested that the working head would greatly benefit from the addition of some venting to minimize blast damage. Possible venting arrangements were discussed and modifications were made by the manufacturer between the Phase 1 and 2 tests.

Following the completion of phase 2 testing, the BDM48 working head was disconnected from the host vehicle and a series of 3 explosive charges were placed under the head. After the detonation of the 3 separate 250 gram DM12 charges under the drum, the working head was reconnected to the host vehicle and brought up to speed. The system operated smoothly and without any apparent damage except to the sacrificial vent covers.

5. Conclusions and Recommendations

The ProMac BDM48 was able to successfully neutralize 99.1% of the MRMs. There was no apparent weakness with respect to a particular mine/fuze type being more difficult for the machine. There also did not seem to be any appreciable difference in performance based on soil type. To the limit tested (200mm DOB), more deeply buried mines are more likely to being missed simply due to operator error in gauging depth rather than any shortcoming of the machine.

While the ProMac BDM48 was extremely effective at neutralizing the MRMs, it did create a significant amount of contained debris, some of which might be considered as representing EOD hazards such as fuzes, detonators, ignitors, and discrete pieces of explosive; tests against real mines will be required to verify this. It may be useful or even necessary to include an additional action to locate/extract possible EOD fragments.

A machine such as the VRL-8 Sorting Bucket might be a useful companion machine to the BDM48 in humanitarian demining. The utility of such a combination would have to be determined on a case by case basis depending on cost, soil type, and the way in which the BDM48 is integrated into the demining activities. It is not expected that a device such as the Schulte Extractor Mine Picker would be practical as a companion machine to the BDM48 in most cases.

Due to the high number of neutralized MRMs, it is recommended that the ProMac BDM48 System be considered for further testing against live mines and in “real-world” scenarios. It would offer an opportunity to evaluate how the system could be integrated into existing demining operations. Prior to deployment against real mines, it will be necessary to design and test a protection package to keep the operator safe and to minimize damage to the machinery.

Annex A – PAMI "Development Report, ProMac BDM48 Mechanical Demining Trials at PAMI & DRES, May – June 2000"

Mechanical Assistance Equipment Test and Evaluation Program

Volume 4 – Equipment Evaluation (ProMac BDM48)

The document contained herein is a scanned copy of the PAMI Report, and is provided "as-is" from the contractor.

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Humboldt, Saskatchewan
1400T

Development Report

ProMac BDM48
Mechanical Demining Trials
at PAMI and DRES
May – June 2000

Leslie G. Hill, A.Sc.T.
Manager
Harvesting Technologies

Philip J. Leduc, P.Eng.
Senior Manager
Research and Development

James D. Wassermann, P.Eng.
Vice President
Saskatchewan Operations

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PAMI Report 1400T (ProMac BDM48)

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PAMI Report 1400T (ProMac BDM48)

1. Summary

The ProMac BDM48 (ProMac) brush demining implement was mounted on a Case 9040B, tracked hoe. It was operated in a wide variety of conditions. It was used to remove trees and brush and to engage various types of soil over varied terrain. It easily handled trees up to 100 mm in diameter and 6 to 7m high. It also cleared away small brush providing access to the ground. At the ground level, it engaged the soil as a high-speed tiller. Using the proper technique enabled the tool to dig down 300 mm below the surface.

Even after the drive motor was changed to a larger displacement, soil interaction with the rotor caused it to slow as each "bite" was taken. The rotor had to be lifted away from the soil to allow it to regain its operating speed. This reduced the effective work time, which was about 65 to 70m^2/h in nearly all types of soil.

When the tool teeth engaged the surrogate mines, the mines were typically broken into small pieces. Occasionally the PM3 mines, with their rubber caps, were able to survive contact. These pieces and occasionally an intact mine were shot out the discharge when the deflector door was raised.

Operating the ProMac on the host machine required a highly skilled operator, to operate the hoe and to minimise rotor slow-down. The ProMac required no special adjustments. In some soils dirt packed in the housing over the rotor which added to tooth wear. This dirt had to be cleaned by hand.

The ProMac require a substantial hydraulic supply of 2.5 to 3.1 L/s flow at 27.6 MPa pressure (40 to 50 gpm at 4,000 psi).

Like many powerful machines which operate in conditions where a working tool interacts with objects in an uncontrolled environment, there is an ever-present danger. Objects can be thrown from under the tool with sufficient force to cause serious injury to a bystander. The operator is not at any great risk when normal operating procedures are followed.

No parts were broken in the trials. The teeth wore away quite rapidly when working in abrasive soil conditions.

2. Introduction

The ProMac is made by ProMac Manufacturing Ltd. (Vendor) of Duncan, British Columbia. It is designed as brush and soil processor for the purpose of detonating and/or destroying anti-personnel land mines.

This report outlines the results of the preliminary trials conducted at PAMI and the results for soil engagement and power requirements for the trials at DRES, conducted on the ProMac.

This report outlines the results of testing conducted by the Prairie Agricultural Machinery Institute (PAMI) under contract to the Canadian Centre for Mine Action Technologies (CCMAT) in cooperation with the Defence Research Establishment Suffield (DRES), Military Engineering Section.

3. Machine Description

ProMac BDM48

The ProMac, **Figure 1**, consists of a hydraulic/belt driven, toothed drum, housed in a steel shell frame, with the bottom of the drum exposed to allow the rotor to engage trees, brush, and soil. The teeth are interchangeable. The ProMac is about 2 m long, 1.5 m wide and 1 m high. It weighs about 1730 kg.

As tested, it was mounted on a Case 9040B, tracked hoe. This combination allowed movement extending forward from the machine, on an arc sweep about the centre of the hoe and a tilt of the tool in a "heel-toe" manner.

Figure 1. ProMac Mounted on the end of the Case 9040B Hoe Boom.

4. Objectives

The objectives outlined in this report represent only the portion of the overall objectives for mechanical de-mining, which apply specifically to the ProMac.

PAMI provided a preliminary test site, different from the prepared site at DRES for the purpose of offering flexibility and diversity. A range of conditions was available on PAMI land, adjacent to the PAMI facilities in Humboldt.

The objectives for the Preliminary Test Site at PAMI included:

- Providing a range of conditions similar to where anti-personnel mines might be found.
- Providing an opportunity for the ProMac to demonstrate the range of conditions that it could operate in.
- Providing an opportunity for the Vendor to try different operating techniques and machine configurations to suit specific conditions.
- Providing an opportunity for installing instrumentation needed to measure power requirements.
- Providing an opportunity for the Vendor, DRES, and PAMI personnel to observe the machine's performance in different conditions.
- Providing an opportunity for "fine-tuning" measuring and evaluation procedures.
- Providing an opportunity to do preliminary evaluation of tool-to-soil interaction and to determine work rates.
- Providing an opportunity to assess interaction between surrogate mines and the machine tool.

At the DRES test site, where the conditions represented a "standardized test track", the objectives were similar, but focused upon the mine neutralization and work rate efficiency. At this site, many more mines were planted in each test plot, and the plots were much larger. The mine locations were not marked and the operator could not be coached from observers. The objectives were:

- For the operator to process an entire plot in a manner that was felt to be appropriate for the machine.
- To eliminate as many mines from the test plot as possible in a timely manner.

5. Test Details

5.1 Scope of Test

The Vendor was required to provide the test machine along with a host machine and any other machinery needed for operating their machine. They were also required to supply an operator for their machine as well as spare parts, tools, and fuel. All equipment was to be shipped directly to PAMI in Humboldt, Saskatchewan, for the preliminary trials and then to Canadian Forces Base (CFB) in Suffield, Alberta.

The Vendor was responsible for equipping the test machine with calibrated transducers, which would enable PAMI to record key operating functions that determined the power needed to operate their machine. However, since the machine did not come with transducers, PAMI provided suitable transducers to ensure that the test trials would produce information important for defining machine performance. PAMI provided a portable data acquisition system to measure key machine operating requirements such as hydraulic pressure and flow. The measurements were made while the machines were operating in test plots at PAMI and DRES.

At PAMI, practice areas of sod, trees, and brush were made available for the Vendor to operate their machine in, to ensure that it was working satisfactorily and to try different operating procedures and techniques.

DRES and PAMI personnel set up test plots in black soil, clay, sod, willows, and poplar trees. These plots had six mines buried in each at depths ranging from flush with the surface to 200 mm below the surface. The Vendor operated the machine in each plot. The machine's performance was evaluated based upon:

Rate of Work

- how fast the plot was processed

Quality of Work

- how deep the tool entered the soil and where was the soil moved to
- how vegetation was handled
- what the soil was like after processing
- how the tool interacted with objects in the soil such as stones
- how the tool interacted with the various types of surrogate mines

Ease of Operation

- what special skill was required to operate the machine
- what technique was required for most efficient operation
- what were the consequences of improper operation

Ease of Adjustment

- did the machine require special set up
- were adjustments required and how difficult were they to make

Power Requirements

- hydraulic pressure and flow measurements when operating

Operating Safety

- safety precautions required for the operator
- danger zone around the machine

Durability

- Wear
- Mechanical failures that occurred

At the DRES site, the test plots were much larger and were seeded with a far greater number of mines. The same basic considerations were evaluated, but with a greater emphasis placed upon the efficiency of mine neutralization.

5.2 Test Conditions

The test conditions for the ProMac provided at PAMI site included:

- Hay land sod consisting of alfalfa and tame and wild grasses that had been untilled for 20 years. The soil was very dry and quite firm. The penetrometer readings ranged from about 80 @ 25 mm depth to 160 @ 200 mm.
- A stand of willows varying in height from 1 to 4 m high, with diameters ranging from 10 to 30 mm. The soil under the willow trees was moist clay that could be formed into a ball in your hands. The soil was soft, with the soil penetrometer readings ranging from about 50 to 70 over the 200 mm range. The willows are shown in **Figure 2**.
- A poplar tree grove with trees ranging in diameter from 25 to 100 mm and about 5 to 8 m tall. The soil was quite dry and very soft. The soil penetrometer readings ranged from about 20 to 70 over the 200 mm range. The poplar test plot is shown in **Figure 3**.
- A black soil track, 5 m wide by 33 m long, with a 300 mm depth of black soil. The top, 150 mm layer of the soil had been tilled and then packed using a coil type

packer. This provided the hardest soil index with penetrometer readings that increased from 70 at a 25 mm depth to 240 at 180 mm deep. The soil was very dry.

- A packed clay track 3 m wide and 20 m long. The soil had been packed in place using a large wheeled loader. The soil index was fairly uniform at 80 to a depth of 75 mm then increased to about 170 at 150 mm. It then decreased to about 140 over the next 50 mm. This soil was also very dry.

Figure 2. Willow Test Plot at PAMI.

Figure 3. Poplar Tree Test Plot at PAMI.

Each plot had six surrogate mines buried at random depths of 50, 100, 150 or 200 mm or level with the surface. In the plots, the mine locations were marked with orange paint, to make their location visible to the operator as shown in **Figure 4**.

Figure 4. Mine Location Marked.

The standardised test plots at the DRES site consisted of four Lanes with four Frames in each lane. Lane 1 was used for the ProMac tests. Frame 1 consisted of mounds and a hole, Frame 2 was packed clay, Frame 3 was packed gravel, and Frame 4 was prairie sod with treated wood posts imbedded in it. DRES has complete specifications on the composition and construction of each frame.

The soil conditions at DRES were very dry. Frame 1 was the softest of all the frames. The soil index had readings ranging from 10 at the 25 mm depth to 50 at the 200 mm depth. The packed clay in Frame 2 increased from 90 at 25 mm to 130 at 75 mm but then remained fairly constant up to the 200 mm depth. This was slightly less packed than the clay at PAMI but otherwise quite similar. It was impossible to get readings on the gravel track in Frame 3. The penetrometer point contacted the stones and wedged preventing penetration. The sod in Frame 4 provided the highest resistance measured. The penetrometer readings increased from 80 at 25 mm to 220 at 130 mm then dropped back to about 200 over the next 50 mm.

A graphical display of the penetrometer readings are shown in **Appendix I**, Chart 1 shows a calibration comparing the downward force required to produce the penetrometer readings. Chart 2, **Appendix I**, shows the soil index for the PAMI test plots and Chart 3, **Appendix I**, shows the soil index for the soils at DRES.

5.3 Test Procedures

The Vendor provided an operator for his machine. At PAMI, practice areas were provided where the operator was free to try different operating techniques, then stop and review the performance at any time. These test areas had no surrogate mines planted in them. Test plots were set up in a variety of conditions in order to allow the machine to demonstrate how well it could handle different conditions. In the test plots, the mine locations were clearly marked to help the operator direct his machine in the right place. The Vendor was also free to coach the operator from a different vantage point.

Prior to processing, the mines were interrogated using the DRES "surrogate active mine detector" as shown in **Figure 5**, to ensure that they were functional immediately prior to testing.

Figure 5. DRES Surrogate Mine Detector Head.

The hydraulic line powering the ProMac had a Webster LTE 400 pressure and flow meter plumbed inline as shown in **Figure 6**. These were connected to a mobile Optim MegaDac data acquisition system, which recorded the hydraulic pressure and flow characteristics while the ProMac was operating.

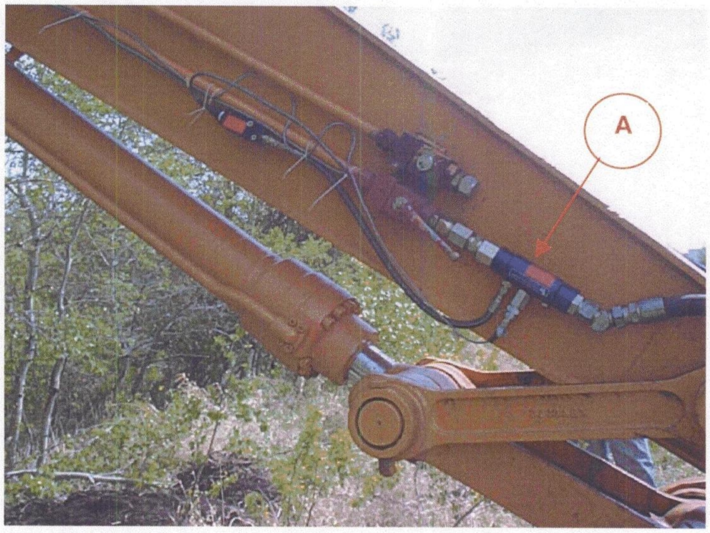


Figure 6. "A" - Hydraulic Pressure and Flow Sensors.

The operation was recorded on 8 mm video and with digital and film photos. The operating time was recorded and the area calculated in order to provide an estimate for a processing rate. Once the plot had been cleared, the area was again checked with the surrogate mine detector and a metal detector. Any signals were investigated and if a mine remained active, it was left in place for a further attempt. The deactivated mines were removed. The processed soil was also interrogated and all mines or pieces of detected mines were recovered. The loose soil was sifted through and visual pieces were collected, bagged, and identified. Movement of undetonated mines was noted.

The depth of operation was determined by scrapping away the loose soil and measuring to the firm soil from a straight edge laid upon undisturbed soil on opposite sides of the work area. At least three samples were taken across the width of the cut and three along the length of the area. Measurement accuracy was ± 2 mm.

The typical work area was about 2 m wide and 3 m long.

These tests were an experiment to discover how the machine performed.

At the DRES test site, emphasis was on the machine's ability to neutralize the mines in varying conditions. The test areas were interrogated before and after processing. Any mines left in the test area were removed. Working time was monitored, input power recorded, and the depth of soil engagement measured. At DRES, similar techniques to those developed at PAMI were used. However, an automatic level was used for checking the cut depth, where the width of cut was too wide to bridge with a straight edge. Digital and film photos were taken. DRES personnel recorded the operation on video.

6. Results and Discussion

6.1 Intended Method of Operation

The ProMac is intended to serve two specific purposes. One is to remove vegetation over a potential anti-personnel mine field by shredding it into small pieces and then to engage the soil where it will neutralise the mines either by detonating them or by detroying them.

The operation of the ProMac is dependant on the host machine that it is mounted on. The host machine must be able to deliver hydraulic flow of 2.5 to 3.1 L/s at 27.6 MPa (40-50 gpm at 4000 psi).

When mounted on a CASE 9040B tracked hoe, the machine is able to operate several metres above ground for clearing trees and can reach away from the machine in a radius extending 5 m from the tracks.

6.2 Rate of Work

At DRES, where the plots were large and the procedures were well established, the work rates for the four frames ranged from 34.5 to 52.3 m^2 per hour for an average of 46.4m^2/h. However, after the first frame, the average rate was about 50 m^2/h for the remaining three frames. This included both the digging time and the time required to scrape the processed soil off to the side, which left a clear area for checking the cut profile. The digging time typically comprised about 70 to 75% of the total time. This means that the processing rate was about 65 to 70 m^2/h.

If the processed soil was scraped to the side, additional time and equipment would be required to sift through the soil in case some unexploded mines were left in the processed soil.

6.3 Quality of Work

The final and most important aspect of quality of work is represented by the efficiency of neutralising mines. The ProMac's mine neutralization efficiency has been determined by DRES personnel.

The ProMac was operated in all conditions available at PAMI and in the four standardized conditions at DRES. At the DRES site, the mean depth of cut ranged from 230 mm in Frame 3 to 270 mm in Frame 2 with an overall average of about 250 mm. The deepest cut was typically located away from the machine. The shallowest cuts were located close to the machine and at the outer edges of the work area. The average depth of cut across the test frames in Lane 1 at DRES are shown in Chart 1 in **Appendix II**.

The ProMac demonstrated its versatility as a vegetation remover, easily clearing trees 7 m high and up to 100 mm in diameter. It shredded these trees into small pieces less that 300 mm long without the rotor slowing down. It started quite high up on the tree and chewed its way down, even into the ground to clear the stump. It handled smaller trees and brush as easily. The button and chisel teeth in combination worked well for this task.

In soil, whether grass sod, black dirt, sand, or packed clay, maintaining rotor speed was a challenge. It was difficult to determine the exact cause. It may have been the resistance on the teeth digging through the soil or it may have been the soil surrounded the drum acting as a brake. The significant mass of the drum, although providing helpful momentum when encountering short periods of resistance, also contributed to slow speed recovery once it had been slowed. A larger displacement drive motor (7.631 in^3 vs. 6.431 in^3 per rev) was installed during the time between the PAMI and DRES trials. The added torque appeared to help prevent quick drum slow down while helping to increase drum speed recovery. The cone teeth, which were installed to replace the button and chisel teeth, also helped the rotor maintain its speed. Any reduction in drum speed caused by changing the motor displacement was not enough to cause any measurable decrease in processing performance.

The soil, after processing, was very finely ground. Dry soil was left in a consistency similar to wheat flour. In damp clay, the soil left was similar to finely roto-tilled soil. In sod, after processing, there was little evidence of plant material left. Stones were usually shattered into smaller pieces. Larger stones caused considerable wear on the teeth and if frequently encountered damage may have occurred to the teeth. To help get rid of larger stones, a “stone pick”, as shown in **Figure 7,** was added to the outer end of the unit, this enabled the operator to dig out visible stones and roll them out of the way.

Figure 7. Stone Pick.

The ProMac also handled a wide range of terrain reasonably well. It was able to work on side slopes, in holes, on mounds or over berms or ditches. However, it significantly altered the terrain profile as indicated by the results in the ”mound and hole” frame at DRES. Most of the mound was levelled and the holes were much less pronounced.

Packed gravel and posts were not a serious challenge to the ProMac’s operating effectiveness.

Contact with surrogate mines usually resulted in the destruction of the mine. PMA-1 and PMA-2 mines were particularly susceptible to being pulverized into small pieces. Often it was difficult to find enough pieces to be able to be able to quickly identify the mine. The plastic cases were typically broken into several small pieces and scattered. The internal components were often separated from the body and broken into pieces. Occasionally, the coil that provided the mine identification code signal was separated from the mine without being damaged enough to deactivate it. Those would react upon interrogation as a live mine. However, it is difficult to predict whether a real mine encountered in the same manner, would be separated without detonation.

6.4 Ease of Operation

The host machine, the Case 9040B tracked hoe, required considerable operator skill in order to use the ProMac proficiently. The technique that seemed to be most effective was to slowly lower the unit onto the ground, allowing the drum to dig a trench the length of the drum. The dirt from the hole was thrown out underneath. When the flexible rear deflector was raised, the dirt was scattered over an area extending about 2 m behind the unit. Hard objects were often thrown much farther. To ensure that trench depth reached below 200 mm, the unit had to be rocked in a "heel-toe" manner, as the edge of the housing where the drive was located rested on unprocessed ground around the trench limiting the cutting depth to about 200 mm. To best accommodate the limited depth at the drive end was to create a "starter" trench, as shown in **Figure 8**. This was best done to the right of the operator, and extending away from close to the machine to the "comfortable" extended reach of the boom. To form the trench, each successive bite consisted of setting the unit at the outer end of the trench and letting it dig down, then retracting it slightly and lowering it again until the desired depth was reached. Once the trench was completed, the head was moved close to the machine and lowered so that it overlapped the left edge of the trench by about half the drum diameter. In this way the previous trench provided a cavity for the newly processed dirt and a fairly flat profile was maintained at the bottom of the "bites". This was continued until the area being worked became inconvenient or inaccessible for the operator. At that time the operator moved the entire unit to the left and continue working from right to left until the desired plot size was covered.

Figure 8. Starter Trench.

With the processed soil covering in the target area, it was difficult to determine if there were any areas missed. After modifying the discharge curtain to stiffen and reinforce it, it was used as a scraper. The boom was swung from left to right pushing the processed soil into a pile to the right of the operator, as shown in **Figure 9**. The operator then could see if there were any missed spots that required further cutting.

Figure 9. "Sweeping" Processed Soil into a Pile.

The ProMac typically cut to a depth of 300 mm in the deepest part of the work area. There was a tendency for the machine to work slightly shallower at the end nearest the power unit. Occasionally, this resulted in missing a mine that was buried at 200 mm. This appeared to be due in part to the larger shoe area below the drive. This made it critical that the edge of the work area be started well outside of the target area. In this way after the original cut the head could be moved so that the drive protection shoe was located in a cut out area.

6.5 Ease of Adjustment

There were no adjustments required for the ProMac when operating. Occasionally, the rear discharge door was opened to allow soil to be thrown clear when making initial cuts at the start of a test plot. This door was heavy and required considerable effort to raise it.

6.6 Power Requirements

The ProMac required hydraulic flow of 2.5 to 3.1 L/s @ 27.6 MPa (40 to 50 gpm at 4,000 psi). This represents a significant hydraulic power requirement of 70 to 90 kW (90 to 120 hp). When the tool was lowered into the dirt and the rotor began to stall, the pressure went to the maximum, and the oil flow decreased. When the tool was lifted it took a few seconds for the rotor speed to recover. This slowed operation. A larger displacement motor (7.631 in^3 vs. 6.431 in^3 per rev) was installed after the PAMI trials. This change reduced the slowing effect and hastened speed recovery. Had the motor had even larger displacement, the rotor speed would have been correspondingly slower but should have slowed less under load and reduced the speed recovery time.

It is not possible at this time to suggest how low a rotor speed would still adequately cut brush. However, as a soil working tool, a much lower speed would most likely still do a very adequate job and would permit faster ground processing.

6.7 Operating Safety

The ProMac and especially it's power unit, combined to form a very large powerful machine requiring appropriate operator and bystander safety measures. Special caution was required to ensure that the rotor had come to a complete stop, the head was resting on the ground and the power unit was shut off before approaching the de-miner.

Working with real anti-personnel mines would add an entirely new dimension for safety assessment.

Working in the plot conditions demonstrated that the ProMac is a very aggressive machine capable of transferring its energy into objects above and below the soil. Objects such as stones and pieces of wood can be expelled from the rotor at speeds that could cause serious injury to a bystander. The ProMac should not be operated unless onlookers are at least 30 m away.

There did not appear to be a significant risk to the operator in the cab with a steel protective grate over the glass windshield and the ability to use the boom to keep a reasonable distance between the operator and the area being worked on. The power unit would never have to be positioned on any unworked ground.

6.8 Durability

The teeth on the drum showed some wear after a short period of operation, however, several hours of running were put on some teeth in very abrasive soil without problems. Once the wear reached the point that wear began to show on the mounting lugs, as shown in **Figure 10**, it was time to change teeth. Stones tended to accelerate wear.

Once the discharge door was reinforced, it became suitable for use as a scraper blade.

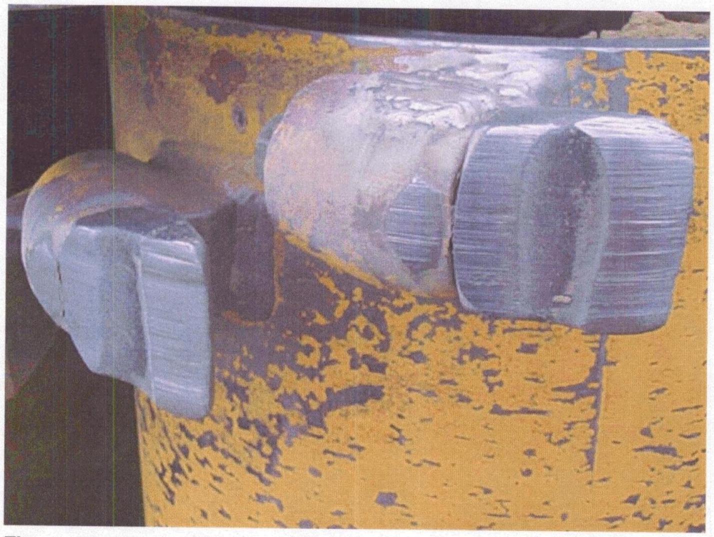


Figure 10. Wear on Teeth and Mounting Lugs.

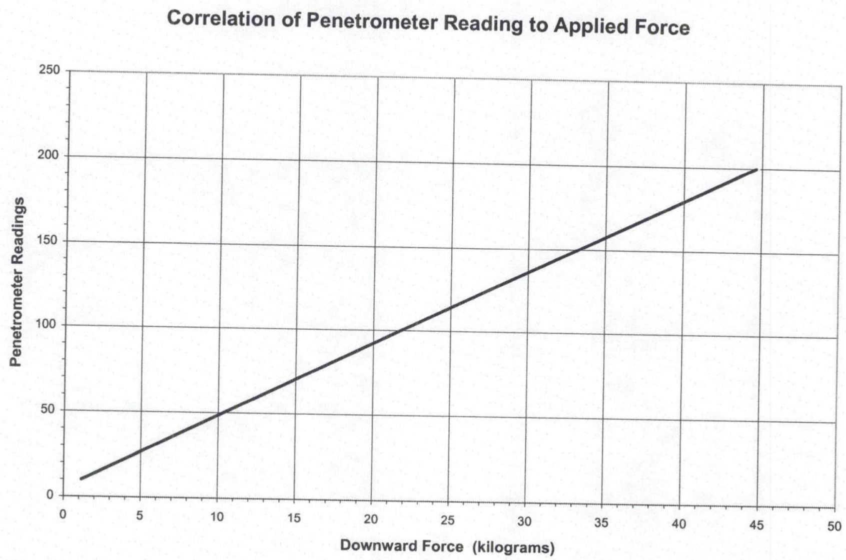
APPENDIX I

PAMI Report 1400T (ProMac BDM48)

Appendix I

Correlation of Penetrometer Reading to Applied Force

Chart 1 – Calibration Curve for Penetrometer.



PAMI Report 1400T (ProMac BDM48)

Chart 2 – Soil Index for ProMac Test Plots at PAMI.

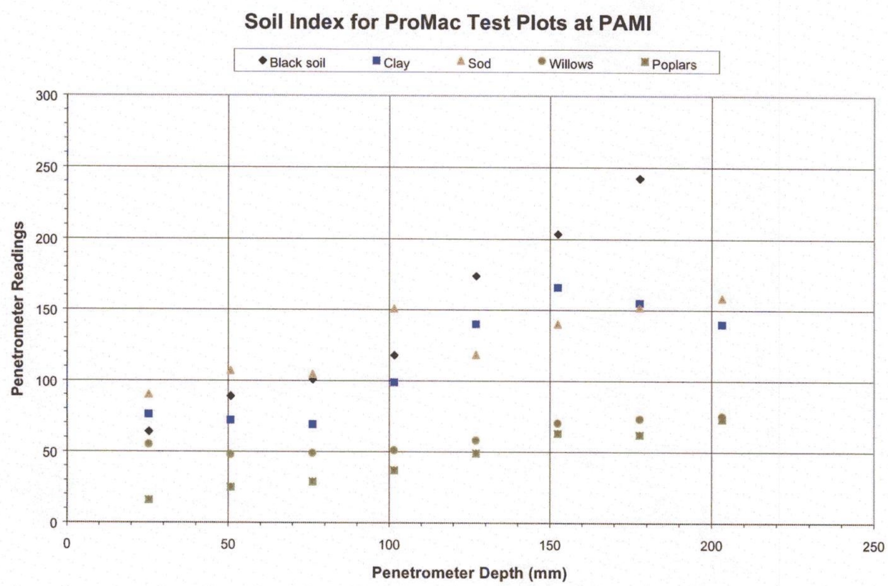
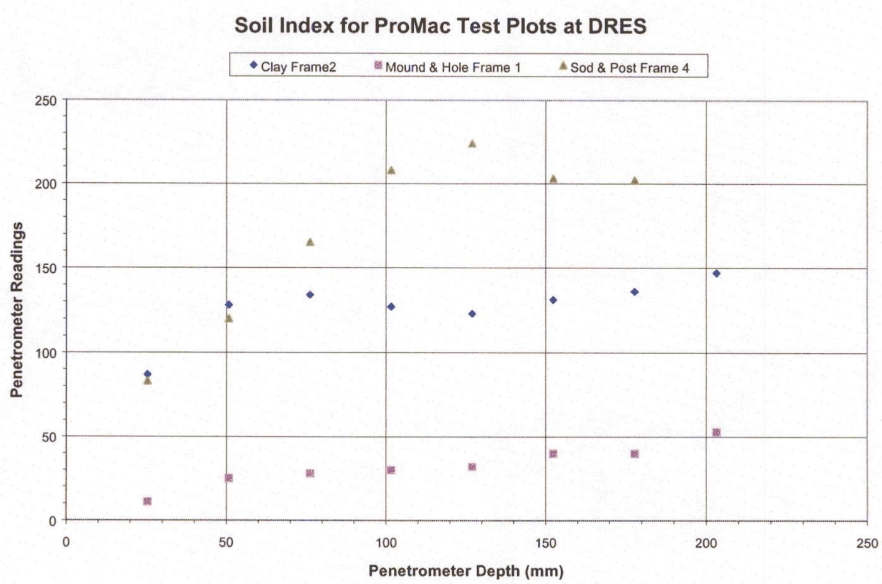


Chart 3 – Soil Index for ProMac Test Plots at DRES.



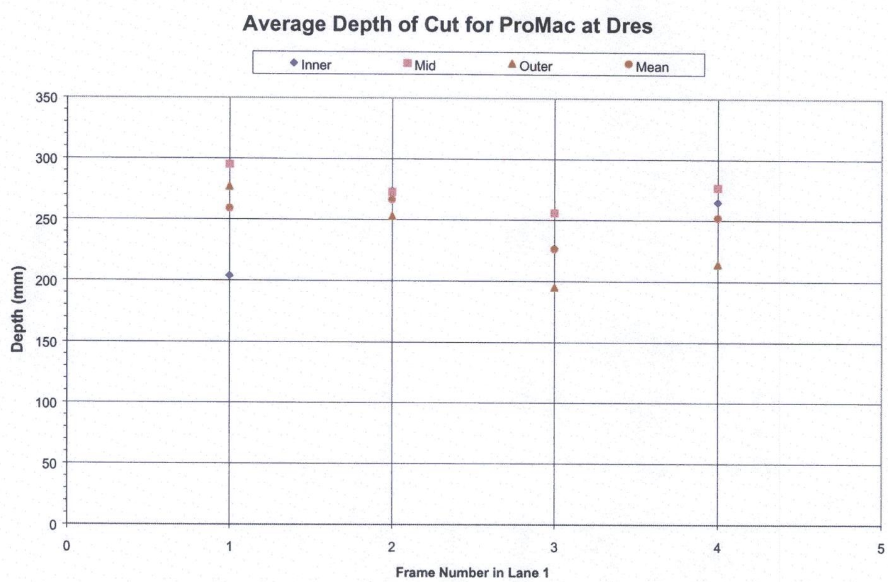
APPENDIX II

PAMI Report 1400T (ProMac BDM48)

Appendix II

Depth of Cut

Chart 1 – Average Depth of Cut Across Frames in Lane 1.



Note: Inner, Mid and Outer refer to the position of the depth measurement with respect to frame position within the field. Inner refers to the side of the frame nearest the centre of the frame, while Outer refers to the side nearest the perimeter. Mid position lies between the Inner and Outer cuts.

Prairie Agricultural Machinery Institute

Head Office:

P.O. Box 1900, Humboldt, Saskatchewan, Canada S0K 2A0
Telephone: (306) 682-2555

Test Stations:

P.O. Box 1060, Portage la Prairie, Manitoba, Canada R1N 3C5
Telephone: (204) 239-5445

P.O. Box 1150, Humboldt, Saskatchewan, Canada S0K 2A0
Telephone: (306) 682-5033

For further information with regards to this report contact:

Humboldt Test Station

For further information on other evaluations, facilities, or services contact:

Head Office

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Annex B – ProMac BDM48 Manual From Manufacturer

Mechanical Assistance Equipment Test and Evaluation Program

Volume 4 – Equipment Evaluation (ProMac BDM48)

The document contained herein is a scanned copy of the manual, and is provided “as-is” from the manufacturer. No claims are made with respect to the accuracy or validity of any statements in this manual. The manual was developed following subsequent trials, and using a machine armoured to provide the system and operator with protection against mines and UXO’s; there may be some discrepancies between the system as described in the report and as described in this manual.

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SAFE OPERATION

READ THIS CHAPTER THOROUGHLY BEFORE ATTEMPTING TO OPERATE THE DEMINER.

1.01.0 PRE-START UP

1.01.1 Walk around the Deminer and check it thoroughly for damage, loose bolts, missing cotter pins and wire or rope etc., possibly wrapped around the drum.

1.01.2 Perform the operations outlined on the Daily Check List, Chapter 1, Page 4.

1.02.0 START UP

1.02.1 Once the machine has been checked and serviced, make sure that no-one is in the vicinity of the machine.

1.02.2 Place the Deminer Control in the "OFF" or neutral position.

1.02.3 Start the machine and bring it up to operating temperature, check the hydraulic pressure to ensure it is within the operating range.

1.02.4 With the machine idling, momentarily engage the Deminer by placing the control valve to the "ON" position then immediately back to the "OFF" position. The deminer should rotate freely. If it does, the Deminer is ready for use. If it doesn't, follow Chapter 6, Maintenance Procedures to determine the cause.

1.03.0 OPERATION

DANGER: DO NOT OPERATE THE DEMINER WITHIN 25 METRES OF OVERHEAD POWER LINES!

1.03.1 Operation of the Deminer must be restricted to operators who have read and completely understood all Safety Rules, Precautions and Operating Functions of both the Tractor (Carrier) and the PRO MAC Deminer and Arm.

1.03.2 Do not operate the machine or the Deminer when tired, ill or under the influence of drugs, alcohol or medication.

1.03.3 The greatest danger when operating the machine is the possibility of the cutting head throwing debris, wood, rocks, etc., from under the shroud. To minimize this danger:

1. **Keep children, bystanders and animals a minimum of 300 metres, (1000 feet) away from the work area.**

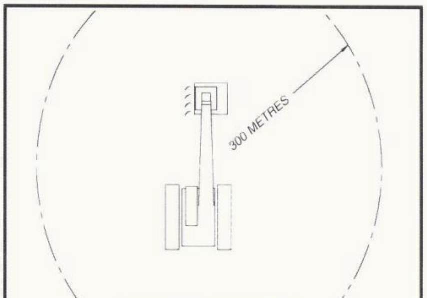

FIGURE 1.1 DANGER AREA

2. **Post "DANGER" signs as in Figure 1.2 to warn pedestrians and vehicles of the danger and to prevent them from inadvertently wandering into the area. Obey local regulations and by-laws wherever applicable.**

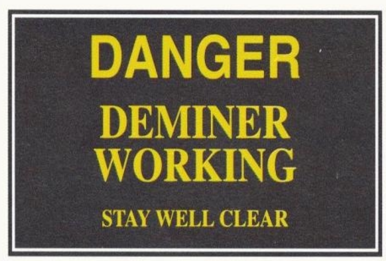

FIGURE 1.2 DANGER AREA

It is the intention of this Manual to inform owners and their operators of some of the dangers inherent in the use of this equipment. The machine is an effective, durable and simple tool and when used correctly will provide satisfactory results with minimal danger. These warnings are intended to help ensure that operators and maintenance personnel treat the machine with the respect and care that a powered, edged tool demands and enjoy trouble-free and safe usage. Do not let accidents happen through ignorance, carelessness or improper use.

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SAFE OPERATION

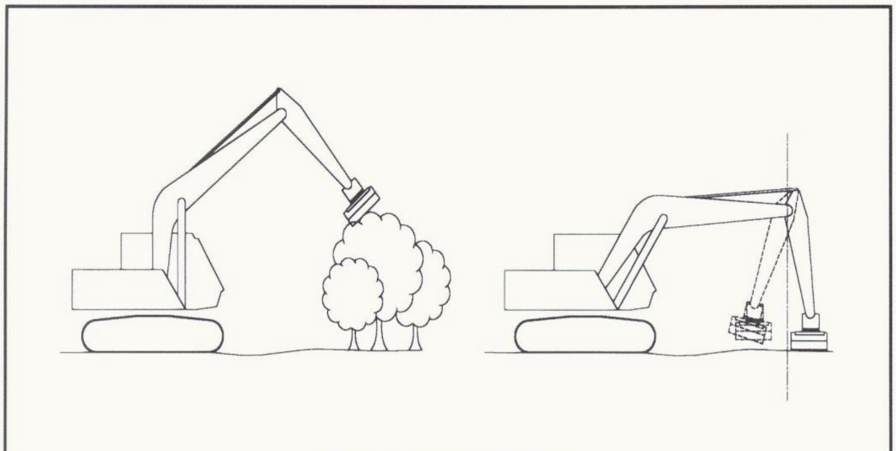

FIGURE 1.3 DEFINING THE WORK AREA

3. **An area to be cut must first be inspected for objects that could be thrown or that could damage the machine. Walk through the area looking for overgrown fences, boulders and rocks, culverts, stumps or metal objects. Mark the inspected area with flags.** If the area is dense and cannot be walked thoroughly it may be necessary to inspect a smaller area as well as possible, then trim away the part that has been inspected and can safely be removed. Walk each new again and repeat the inspection before cutting more away. Repeat as often as necessary until the area is cleared. It can be damaging and/or dangerous to work the deminer in an area that has not been visually inspected. Note that the DANGER signs should be placed at least 300 metres beyond the perimeter of the area to be worked, not just 300 metres from where the machine started operating!

4. **Once an area has been cleared, move the DANGER signs and cutting area flags and repeat step 3 above.** It is convenient in many cases to work in 10 metre sections. Move the first DANGER sign to the beginning of the freshly cleared area, place it, then take the first cutting area flag up to the end of the freshly cleared area 300 metres away. Walk and inspect the next 300 metres and place the second cutting area flag. Pick up the second DANGER sign, and take it a further 300 metres along the road or trail. **Note that in many cases the DANGER area will extend in front of and behind the machine as well as along each side. Post signs accordingly.**

5. **The operator's cab must be protected by armour material capable of withstanding blast objects thrown and pressures.**

FIGURE 1.4 OPERATOR'S ARMOUR PROTECTION

6. **Should a vehicle or pedestrian enter the defined DANGER area, immediately stop cutting until the area is clear again.**

7. Objects tend to be thrown out from under the shroud in the direction of rotation and towards the raised edge of the shroud. Avoid cutting with the head tilted at such an angle that objects would be thrown towards the operator's cab. See Figure 1.5 TILTING THE DEMINER HEAD.

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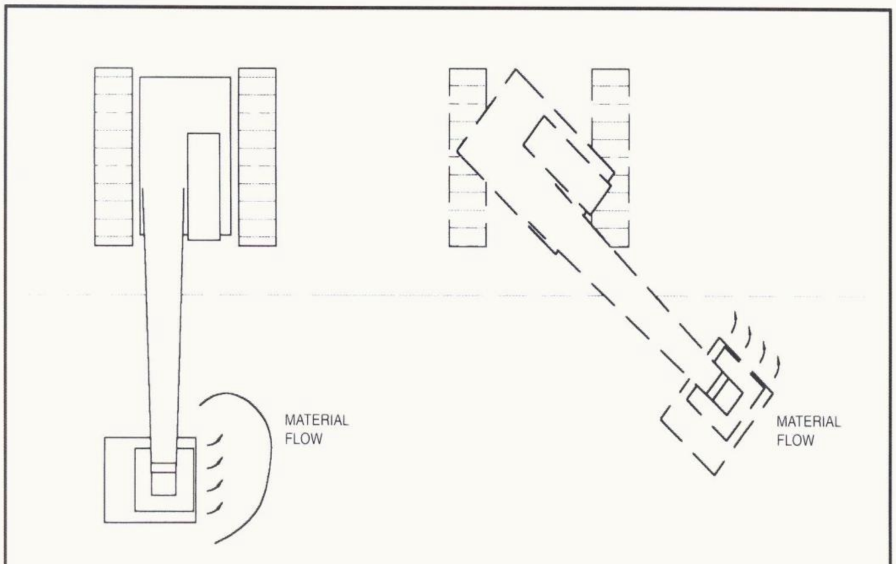

FIGURE 1.5 TILTING THE DEMINER HEAD

1.03.4 Reversing the direction of rotation of the cutting head on side opening machines increases the chances of objects being thrown out because of the position of the "gate" in relation to the flail arm.

1.03.5 When clearing brush and small trees, start at the top and then lower the head down through the brush while sweeping from right to left. This avoids clogging the flail head with mulched material.

NOTE: Keep the cutting head tilted away from the operator when it is raised to avoid throwing splinters towards the cab.

WARNING: Engage the cutting head with the tractor engine at idle. If the deminer is engaged at high rpm, severe damage to the coupling could occur.

1.03.6 Always disengage the Deminer before leaving the machine. Place the Control Valve in the OFF position and disengage the power take-off. Shut off the engine. A preventor or locking device must be installed on the control Valve handle to prevent inadvertent or accidental engagement when the operator is out of the cab.

1.04.0 NORMAL OPERATION

1.04.1 The procedure for normal operation of the Deminer is as follows:

1.04.2 Drive the tractor to the start of the inspected area, lower the deminer head close to the material to be cleared and engage the Deminer. **ALWAYS** engage the Deminer with the tractor engine at **IDLE** to avoid damage to the coupling.

1.04.3 Increase the engine speed to bring the Deminer speed up to operational level. **DO NOT EXCEED 1800 RPM shaft speed.** Lower the Deminer to the material.

1.04.4 The "GATE" on the Deminer shroud is normally on the "front" side of the shroud so the cutting swath is customarily outwards from the tractor.

1.04.5 Starting close to the tractor, cut or clear the material by sweeping the Deminer outwards, then returning over the cleared area to start the next swath. Keep the cutting head parallel to the ground as far as possible to keep the debris from spraying outwards. (See 1.03.3 - 7). **Stop immediately and shut off the engine as in 1.03.6 if the Deminer hits a solid object, or vibrates excessively, and inspect for damage.**

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DAILY CHECK LIST

CHECK THE FOLLOWING ITEMS:

1. ☐ Deminer to Carrier mounting pins for security and wear
2. ☐ Deminer frame and shroud for damage
3. ☐ Motor and motor baseplate bolts for security
4. ☐ Check all mounting adaptor bolts
5. ☐ Check all Deminer bits for condition and retention
6. ☐ Main shaft and deminers for wire, rope or other material wrapped around
7. ☐ Hydraulic lines and connections for chafing, leaks or looseness

REMOVE:

☐ Material build-up inside shroud.

LUBRICATE:

1. ☐ Upper and Lower Bearings. Use Shell EP2 or equal. Do not over-grease, one pump of a hand gun is usually sufficient. Overgreasing will cause high bearing housing temperature
2. ☐ Deminer to Carrier hinge pin, again with ordinary, good quality grease

CHECK:

☐ Hydraulic oil level in tank, top up as necessary

Date: ______________________

Operator: ______________________

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RECEIVING & UNPACKING THE EQUIPMENT

2.01.0 RECEIVING THE SHIPMENT

2.01.1 Check the Bill of Lading against the shipment to make sure all packages are delivered.

2.01.2 Inspect the shipment for any apparent shipping damage.

2.01.3 Notify the shipping company and **PRO MAC** immediately of any damage or discrepancies.

2.02.0 UNPACKING THE MACHINE

2.02.1 Remove all packing materials but DO NOT remove plastic dust shields or pipe plugs from the hydraulic lines until ready to connect up the system.

2.02.2 Check the data plate and the machine against the original purchase order and the Data Sheet below to make sure that the correct unit has been supplied. Each Deminer is supplied with mounting fittings and hydraulic systems to suit the machine with which it is to be operated as specified by the purchaser.

NOTE: Since the Deminer may be used with a variety of models of 'Carriers', many of which have different mounting systems and hydraulic systems, it is important that the Deminer supplied be used only with the model of Carrier specified in the Data Sheet.

Unmatched systems may be both dangerous and potentially damaging to the machine. Consult PRO MAC for verification of suitability.

BDM 48 BRUSHER DEMINER

DATA SHEET AND BILL OF MATERIALS

Serial Number: ____________ Purchase Order Date: ____________

Dealer: ____________ End Use Customer: ____________

Address: ____________ Address: ____________

Contact: ________ Phone: ________ Contact: ________ Phone: ________

Carrier Make and Model: ____________

Colour: Yellow or ____________ Adaptor Dwg #: ____________

Frame: ____________ Shaft & Housing Ass'y Dwg #: ____________

Hyd. Motor: ____________

Couplings: ____________

PARTS & ASSEMBLY DWG#: ____________

HYDRAULIC SCHEMATIC DWG# A6-AM-BC034 ☐

____________ ☐

____________ ☐

____________ ☐

PRO MAC MANUFACTURING LTD.

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NOTES

SAFETY PRECAUTIONS

UNDER NO CIRCUMSTANCES WILL PRO MAC ACCEPT RESPONSIBILITY OR LIABILITY FOR PERSONAL INJURY OR PROPERTY DAMAGE RESULTING FROM OPERATION OF THIS MACHINE. DO NOT USE THIS MACHINE IN THE VICINITY OF PEOPLE, ANIMALS OR STRUCTURES. SUCH USE IS ENTIRELY AT THE RISK AND RESPONSIBILITY OF THE OPERATOR(S).

The greatest danger when operating the machine is the possibility of the cutting head throwing debris, wood, rocks, etc., from under the shroud, or from similar items ricocheting out from under the shroud.

The following notes are not intended to substitute for the instructions contained in the Manual supplied with the machine. Read and understand the Manual before working on or operating the machine. Use these notes only as a brief reminder of items described in detail in the Manual.

INSTALLATION NOTES

1. The Deminer requires a constant flow of hydraulic oil that will not be reduced when another machine function is used simultaneously.
2. Use a "Motor spool" type of control valve. If not possible, a system of recirculating check valves must be used. Circulating system and crossover relief for drive motor protection are provided with the cutter.
3. Line Sizes (Inside Diameter)
   All pressure lines are to be minimum 1 1/4" diameter. All return lines, 1 1/2" tubing.
   High pressure machines use a motor capable of operating at 4000 p.s.i. with a correspondingly lower flow rate.
4. Drive motor shaft speed must not - **UNDER ANY CIRCUMSTANCES** - exceed **1800 RPM**.
5. Secure all wear parts as per factory original installation. (Following servicing, sharpening, etc.)

OPERATION NOTES

1. Make absolutely sure that there is no-one near the machine before starting up.
2. Bring the machine up to operating temperature before commencing operation.
3. **DANGER:** Do Not operate the machine within **10 feet** of overhead power lines!
4. First, inspect the area to be cut. Walk through the area looking for rocks, boulders, culverts, stumps, etc. **Mark the area with flags.**
5. The operator's cab must be protected with protective armour plate and glass as per international standards.
6. **WARNING: ONLY** engage the cutting head with the engine at **IDLE.** Provide a locking device to prevent accidental engagement when the operator is out of the cab.
7. Give the bearings one shot of grease every day. **DO NOT OVERGREASE!**
8. **Cease operation immediately if any person or animal approaches the machine or enters the working area.**

WARNING: The consumable wear parts are constructed of specially treated steel of specific composition to withstand the stresses of operation on the Deminer. Replace ONLY with genuine PRO MAC replacement parts. Do Not repair if damaged, other than routine sharpening as described in the Manual.

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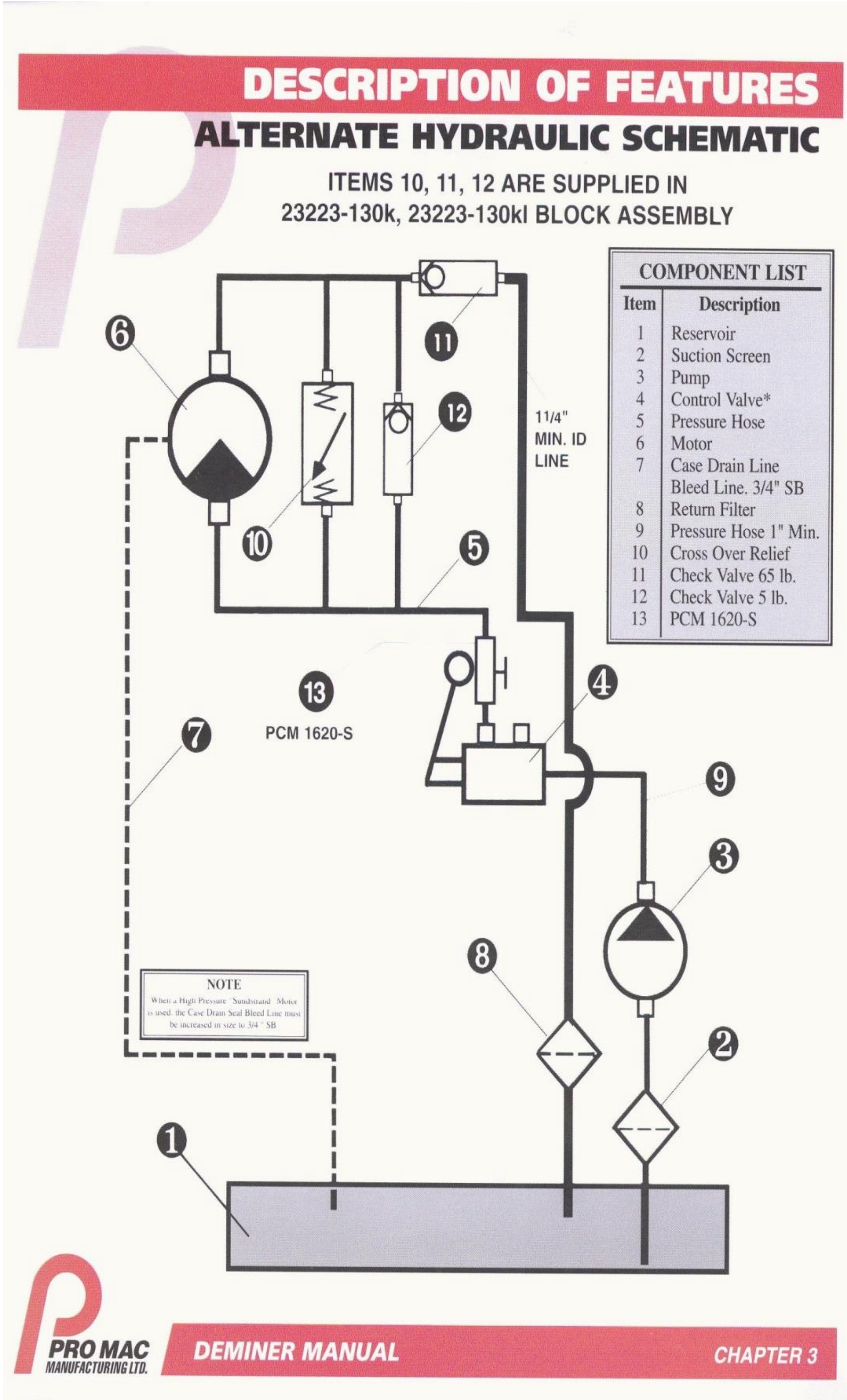

DESCRIPTION OF FEATURES

ALTERNATE HYDRAULIC SCHEMATIC

ITEMS 10, 11, 12 ARE SUPPLIED IN
23223-130k, 23223-130kl BLOCK ASSEMBLY

COMPONENT LIST

Item	Description
1	Reservoir
2	Suction Screen
3	Pump
4	Control Valve*
5	Pressure Hose
6	Motor
7	Case Drain Line Bleed Line. 3/4" SB
8	Return Filter
9	Pressure Hose 1" Min.
10	Cross Over Relief
11	Check Valve 65 lb.
12	Check Valve 5 lb.
13	PCM 1620-S

NOTE

When a High Pressure "Sundstrand" Motor is used, the Case Drain Seal Bleed Line must be increased in size to 3/4" SB

PRO MAC MANUFACTURING LTD.

DEMINER MANUAL CHAPTER 3

03/01 9073

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INSTALLATION PROCEDURES

4.01.0 PRE-INSTALLATION

4.01.1 Before starting to install the Deminer on the Carrier, check the Data Sheet on Page 1 against the machine to make sure that the combination of Carrier and Deminer is correct and as ordered.

4.02.0 INSTALLATION

4.02.1 The cutter requires a constant flow of hydraulic oil and must be provided with a supply that will not be reduced when another function of the machine is used simultaneously.

4.02.2 The control valve must be of the motor spool type that will allow the Deminer to gradually slow to a stop rather than "lock up" when the control is moved to the "OFF" position. If a motor spool equipped control valve cannot be provided then a system of circulating check valves must be used in the vicinity of the drive motor. Refer to PRO MAC Dwg.# A6-AM-BC018.

4.02.3 The control valve may be electrically operated, (HED or STANLEY type), or pressure compensated manual, (Char Lynn etc.). Some operators prefer a dual direction Parker valve, (PARKER #VS 32ACA9).

4.02.4 The Drive Motor must be provided with a cross over relief valve to protect it from pressure spikes if the blades strike a rock, stump or other immovable object.

4.02.5 If dual rotation is preferred, a dual action cross over relief valve is required.

4.02.6 A drain line must be installed from the motor case to the tank. The case drain is provided to prevent oil from building up behind the output shaft seal. This is particularly important when dual rotation is used. If possible connect the drain line to the upper part of the tank.

4.02.7 The Case Drain line must be minimum 3/4" single braid to prevent the line from being crimped thus shutting off the oil flow. There is normally very little pressure in this line, however it must remain open to allow any oil behind the seal to escape.

4.02.8 Hydraulic line sizes are important. Pressure lines should be minimum high pressure 1 1/4" ID, return line must be 1 1/2" ID.

4.03.0 PRECAUTIONS

4.03.1 The maximum oil pressure permitted with the low pressure gear type motor is 2000 p.s.i. The control valve should be equipped with a pressure relief valve set below 2000 p.s.i.

NOTE: On medium pressure machines a modified gear type motor may be used allowing pressures up to 2500 p.s.i. High pressure machines use a high pressure piston type motor. This motor is capable of operating at 3500 p.s.i. with a correspondingly lower flow rate.

4.03.2 **CAUTION:** The Deminer control valve must not be engaged at high engine RPM. When dual direction control is used, the direction of rotation must not be changed until the cutter head has slowed to a stop.

NOTE: ***RPM LIMITATION***

The shaft speed of the motor must not, under any circumstances, exceed 1800 RPM.

NOTE: This is a typical schematic only, refer to the Drawing supplied with the machine for the detailed schematic appropriate to your machine.

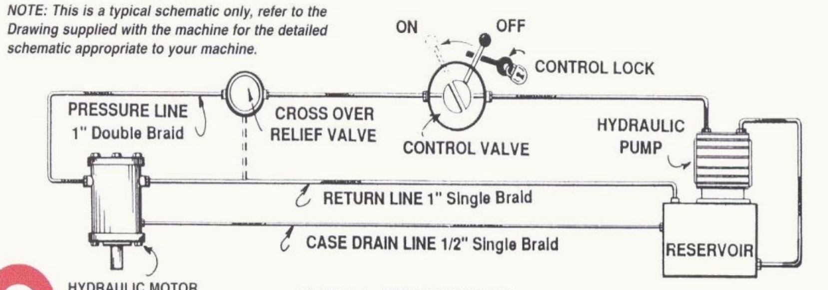

FIGURE 4.1 HYDRAULIC SYSTEM

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STARTING UP THE MACHINE

IMPORTANT

Read this section carefully and follow the instructions outlined before starting up the machine. Failure to follow the procedures outlined in this manual may result in personal injury to the operator or bystanders, or in damage to the machine.

5.01.0 PRE-STARTUP

5.01.1 Make the following checks before starting up the machine.

1. Check the attachment of the Deminer to the Carrier to ensure that all attachment point bolts and pins are in good order.
2. Check all hydraulic lines and connections for leaks and security.
3. Check the fluid level in the hydraulic tank.
4. Make sure the Control Valve is in the "OFF" position.
5. Check the Bolts holding the Flails in the brackets and make sure that the nuts are tight.
6. Check that the Flails rotate freely on the bushings and that the bushings are not excessively worn.

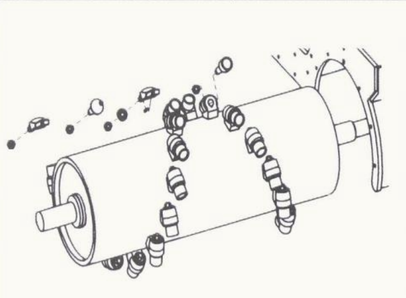


FIGURE 5.1 DRUM COMPLETE WITH HOLDERS & TEETH

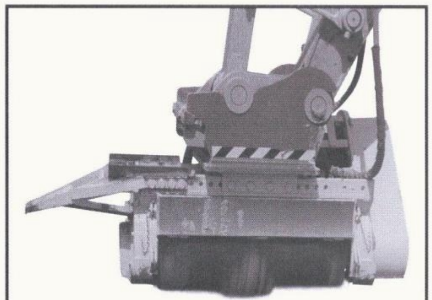
5.02.0 START UP

5.02.1 Clear all personnel, except the operator, from the vicinity of the machine.

5.02.2 With the Control Valve in the "OFF" position, start up the machine. Once it is warmed up reduce the engine speed to "IDLE".

5.02.3 With the Deminer horizontal to and about a foot or more above clear ground, momentarily move the Control Valve to the "CUT" position, then return it to "OFF". As long as no unusual noises are heard from the Deminer, tilt the Deminer towards the cab so that the operator can see the blades rotating as they slow down.

5.02.4 Note the direction of Rotation. Normal rotation is clockwise, (as observed from the cab), with the opening to the left side.



BDM 48 HEAD

NOTE: Perform the following run-up check over grass if possible to avoid raising dust.

5.02.5 Once the direction of rotation has been determined to be correct and the Control Valve notation indicates the correct direction (in the case of dual direction installations), return the Deminer to the horizontal position a foot or so above the ground and run it up to speed. It will probably be necessary to increase the engine speed to provide adequate hydraulic pressure/volume to reach maximum shaft speed. **DO NOT EXCEED 2200 RPM DRUM SPEED! (see Caution 4.03.2)**

5.02.6 Once it is verified that everything is working satisfactorily, shut the machine down and complete the Daily Check List (Chapter 1, Page 4) before proceeding.

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MAINTENANCE PROCEDURES

DEMINER – ASSEMBLY OF BDM 48

DRUM INSTALLATION

1. Install bearing 40 into frame assembly 41. Torque bolts to specified torque.
2. Install bearing 53 into side plate 3. Torque bolts to specified torque.
3. Cut felt seal material. Soak in 30w oil. Install felt seals 52 in assembly 41, assembly 3.
4. Unbolt side plate 3 from mainframe 41. Remove.
5. Slide drum assembly into bearing assembly 41. Support drum.
6. Never seize or lubricate dowel pins on plate 3. Install plate on mainframe. Bearing should slide onto shaft.
7. Bolt side frame 3 to mainframe 41. Torque bolts as specified.
8. Center drum in frame assembly. Lock bearing 40 as procedure on drive end. Do not lock bearing 53 on outboard side. Complete assembly on entire unit including installation of drive cover guard, then adjust and lock bearing 53 as described in procedure. Failure to do so may cause drum bearings to fail.
9. Install outboard bearing end cover 56.

DRIVE ASSEMBLY PROCEDURE

1. Install bearing 36 into frame assembly 30.
2. Install bearing 27 into plate assembly 23.
3. Assemble frame 30 to plate 23.
4. Slide driveshaft assembly 21 into bearings 36, 27.
5. Install taper lock 17, 18 drive assembly to driveshaft 21. Lock in place. Install washer on end of driveshaft so key 20 is retained. (Drawing does not show this retainer.)
6. Install red insert 16.
7. Install splined hub 15. Do not install dust cover assembly at this time.
8. Install motor mount bracket 14, lining up dowel holes.
9. Install drive motor 11 to mounting bracket.
10. Now unit is temporarily assembled, bottom mount splined hub 15 to the end of the motor shaft.
11. Slide driveshaft assembly 21 to allow 1/8 to 3/16" clearance between the red insert 16 and taper lock drive assembly 17, 18.
12. Tighten taper bushing. Locktite set screws and bearing no. 27, locking the bearing 27 to the driveshaft assembly 21. Bend over lock tab on timkin lock washer.
13. Remove frame assembly from plate 23.
14. On shaft 21 install key 22. Install taper bushing 29. Install sheave 28, centering assembly on driveshaft. Install belt 37, then install frame assembly 30. Torque bolts as specified.
15. Tighten taper lock in bearing number 15. Bend over locking tab.
16. Recheck clearance in drive coupling assembly.
17. Remove motor 11 from bracket 14. Install dust cover 19 onto coupling.
18. Lubricate motor splines. Install drive motor 11. Torque bolts holding motor, then lock wire bolts.
19. Torque bolts holding bracket 14 to plate 23.

ASSEMBLY OF PRIMARY DRIVE TO FRAME 41

1. Slide assembled unit through mainframe. Tighten plate 23 to frame 41 so as drive assembly will still slide freely.
2. Install sheave assembly 38, 39 and key onto drum assembly 44 stub shaft. Drawing does not show key.
3. Using straight edge, line up pulley assembly 38, 39 with drive pulley 28, 29. Tighten pulley bolts to recommended torque. You may have to repeat this procedure a couple of times (See procedure to remove pulley.) until sheaves line up with one another.
4. Once step 3. is completed, install belt 37. Tighten belt with 2 adjusting screws (not shown on drawing) until you have about 1"-1-1/2" deflection with slight thumb pressure. Note: Because of the material the belt is made of, it has superior gripping qualities to that of a standard type belt and does not have to be adjusted as tight. Overtightening the belt will cause decreased bearing life and premature failure.
5. Tighten bolt assemblies 24, 25, 26 and torque to recommended values. Recheck belt tension.
6. Pre-fill grease lines with an EP2 quality grease. Install grease lines to bearings 27, 36, 40 and connect to mainframe. Give each bearing 3-4 shots of grease. Don't overgrease bearing 36. Grease lines not shown. Records on file of grease and hydraulic lines.
7. Inspect and make sure all bolts are tight and lock-wired, then install cover 35 using bolts 33, 34.

FINAL ASSEMBLY

1. Center floating bearing 53 on drum 44 stub shaft. See bearing adjustment procedure.
2. Install dust cover 56 with bolts 57, 58.
3. Ensure grease fitting is accessible through cover 56. Give bearing 3-4 shots of EP2 grease, install 3/4" NPT plug in dust cover if supplied (not shown on drawing).
4. Install motor guard 4 with bolts 5, 6.
5. Install rear attachment option 64, 65 or 7.
6. Slide shaft 61 through rear hinged section. Tighten bolts 60, 59. Grease hinge assembly. (Drawing does not show grease points for hinge.)

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MAINTENANCE PROCEDURES

DEMINER - ASSEMBLY OF BDM 48

7. Install attachment mounting bracket depending on option.
8. Install front door.
9. BIT INSTALLATION
   Install bits using 262 locktite or equivalent retaining compound, using locking type nuts L9, Stover or better stamped nuts. If using a combination of different style bits, stagger them so that they will balance out. Drum has to remain as closely balanced as possible to keep vibration to a minimum. Excess vibration will cause premature bearing failure.
10. Motor connection: Port A will be the inlet connection from motor to relief valve block port marked motor in. Port B will be the outlet connection to the value block port marked motor out.

EXTRA NOTES:

If cam lock style bearings 53 are not available and set screw type are, assembly procedure will be basically the same, however, once bearings are in their correct locations on the stub shafts, dimple the shaft with a 1/4" drill so set screw will slightly recess into the shaft. Failure to do this will cause premature bearing failure and drum will not maintain its fixed location.

DISASSEMBLY WITH DEMINER SHUT OFF

1. Move machine to a safe, level location.
2. Inspect machine for any unexploded ordinance or any dangerous potential situations.
3. Shut down excavator. Disconnect hydraulic lines to the demining head. Cap off lines to prevent dirt contamination.
4. Remove head from machine. Procedure will vary depending on attachments coupling to the prime mover.
5. Remove covers 35, 56.
6. Loosen off bearing locks on bearing 40 and bearing 53. Camlock type you will be turning the lock with a spanner hammer and punch or large pipe wrench opposite the direction of drum rotation. Back off set screws before doing the above.
7. Support the drum with adequate blocking. Deburr any damaged part of the shaft.
8. Insert 5/8 NC pusher bolts into bearing housing holes. Apply even tightening torque to the pusher bolts drawing the bearing away from the shaft and frame assembly 3 or 41, depending on bearing to be removed.
9. If removing bearing from frame 41 you will first have to remove pulley assembly 38, 39, and key (not shown).
10. To remove pulley 38, 39, remove the three 1/2" NC bolts holding it together. Reinsert the bolts into the outer threaded holes in the sheave or taper lock bushing. Tighten the 1/2" bolts evenly until the pulley separates from the taper lock bushing. It depends on whether the sheave assembly is release mount or standard mount as to what component the pusher bolts are installed. We prefer reverse mount, as it is easier to lockwire the bolts after installation.
11. Remove bolts retaining endframe 3. Draw endframe 3 away from frame 41 using 1/2" NC pusher bolts inserted into endframe 3 next to dowel pins.
12. After endframe 3 is removed, drum 44 can be removed and serviced as required.

BELT CHANGE PROCEDURE

1. Remove end cover 35.
2. Unlock tab on bearing 36 back of Timkin nut. Lightly tap end of nut to break the taper bushing loose. Do not damage threaded part of bushing.
3. Remove grease line.
4. Remove bolt assembly 31, 32, then pry off frame assembly 30.
5. Back off adjusting screws (not shown).
6. Loosen bolt assembly 24, 25, 26.
7. Remove old, install new belt. Assemble unit reversing above procedure. Do not over-tighten belt. Leave 1" to 1-1/2" deflection with slight thumb pressure.

COUPLING CHANGE PROCEDURE

1. Remove motor 11, guard 4.
2. Remove splined coupling section and cover. Install new insert. Re-assemble unit.
3. If entire coupling assembly is to be changed, remove guard 4, motor 11.
4. Remove coupling components 15, 16, 17, 18, 19. Set screws in taper lock bushing 17 may have to be warmed up with a torch as they are locktited at the factory. Remove set screws (not shown). Reinstall 1 set screw in hole between other 2 set screw holes and tighten down on this screw. Lightly tap the hub 18. This should separate the taper bushing.
5. Install new coupling assembly. Adjust taper lock bushing 17 forward or back to allow 1/8 to 3/16" clearance between insert 16 and hub 15. Motor 11 may have to be removed and installed a couple of times until proper coupling clearance is obtained.

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MAINTENANCE PROCEDURES

DEMINER

6.01.0 GENERAL MAINTENANCE

6.01.1 The importance of regular maintenance and inspection as a means of prolonging the life and maintaining the efficiency of the Deminer cannot be overemphasized.

6.01.2 For lubrication use Petro Canada Supreme EP2 grease or equal. The bearings are packed during assembly. Each bearing should be given one 'shot' of grease with a hand gun each day (8 hour shift) before starting up. **DO NOT OVERGREASE.** A hot bearing housing usually indicates overgreasing.

6.01.3 Bits may be sharpened as necessary. It is imperative, however, that the weight of each bit be the same. Maximum variation in weight must not exceed 4 oz. After sharpening, file any burrs from the bit. Clean the bolt and check the fit.

NOTE: Cutter bits may be hard surfaced providing weights are kept equal on all like bits.

WARNING

The bits are constructed of specially treated steel of specific composition to withstand the stresses of operation on the Deminer. Replace only with genuine PRO MAC bits. Do not repair if damaged other than routine sharpening as noted in 6.01.3.

6.01.4 In addition to the above warning, many other parts on the Deminer are of special construction, treatment or composition. These items, which are clearly indicated on the Parts List, **must always be replaced by genuine PRO MAC parts.** Other items may be replaced from local suppliers provided they are of equal quality and specification.

6.01.5 At some point in time the bearings will wear out sufficiently to require replacing. Since this will only occur after many hours of use it will be appropriate to carefully inspect the shaft and drum assembly for stress damage at that time when the Deminer is disassembled. If at all possible have these parts magna-fluxed. If doubtful concerning either the condition or procedure, contact PRO MAC or their authorized representative.

IMPORTANT NOTE DURING FINAL ASSEMBLY

OUTBOARD BEARING (PART No. 53) IS AN EXPANSION TYPE AND SHOULD BE ADJUSTED AFTER BOTH BEARING FLANGES AND BELT GUARD HAVE TIGHTENED TO FRAME (DRIVE END BEARING PART No. 40). LOOSEN SET SCREWS ON INNER SLEEVE TO SHAFT, CENTRALIZE COLLAR ON SHAFT, TIGHTEN SET SCREWS.

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BDM 48" EXTREME SERVICE DEMINER PARTS LIST

ITEM	DESCRIPTION	QUANTITY
1	GR.8 BOLTS - 1/2"NC X 2 1/4"	17
2	STOVER LOCK NUT - 1/2"NC	17
3	END PLATE IDLER SIDE - PRO MAC #8238	1
4	MOTOR GUARD - PRO MAC #9086	1
5	GR.8 BOLTS - 1/2"NC X 1 1/2"	4
6	LOCK WASHER - 1/2"	4
7	REAR SKIRT ASSEMBLY - PRO MAC #9089	1
8	GR.8 BOLTS - 3/4"NC X 2 1/2"	6
9	STOVER LOCK NUT - 3/4"NC	6
10	SQUEEZE PLATE - PRO MAC #9089-2	1
11	HYDRAULIC MOTOR - 'D' FLANGE	1
12	GR.8 BOLT - 1/2"NC X 1 1/2"	4
13	LOCK WASHER - 1/2"	4
14	MOTOR MOUNT BRACKET - PRO MAC #8831	1
15	HUB - PRO MAC #PBC7631 - 24ASP	1
16	RED INSERT - PRO MAC #PBC7631-24D	1
17	TAPER LOCK BUSHING - 1 15/16"Ø - PRO MAC #PBD7631-24C	1
18	HUB - PRO MAC #PBC7631-24B	1
19	COVER - PRO MAC #PBC7631-24E	1
20	KEY - 1/2" SQUARE X 1 1/2"	1
21	DRIVE SHAFT - PRO MAC #8274	1
22	KEY - 5/8" SQUARE X 4"	1
23	TAKE UP PLATE - PRO MAC #8268	1
24	GR.8 BOLT - 3/4"NC X 3"	4
25	STOVER NUT - 3/4"NC	4
26	FLAT WASHER - 3/4"	8
27	BEARING #UKFC215D1+HA2315	1
28	SHEAVE 'GATES' 4/5V 12.5	1
29	BUSHING - QD 2 7/16"Ø	1
30	DRIVE MOUNT BRACKET - PRO MAC #8267	1
31	GR.8 BOLT - 5/8"NC X 1 1/4"	4
32	LOCK WASHER - 5/8"	4

ITEM	DESCRIPTION	QUANTITY
33	GR.8 BOLT - 1/2"NC X 1 1/2"	11
34	LOCK WASHER	11
35	DRIVE GUARD - PRO MAC #8245	1
36	BEARING - #UKFC206D1+HE2306X	1
37	BELT - 'GATES' PREDATOR POWERBAND - 4/5/VP800	1
38	SHEAVE - 'GATES' 4/5V 9.5	1
39	BUSHING - QD 2 1/4"Ø	1
40	BEARING - #QMCW15J215ST	1
41	FRAME ASSEMBLY - PRO MAC #8237	1
42	GR.8 BOLTS - 1/2"NC X 1 1/4"	4
43	LOCK WASHER - 1/2"	4
44	MULCHING ARBOR - PRO MAC #8128 OR #9093	1
45	CUP BITS - PRO MAC #PBC100-12	23
46	CHISEL BIT - PRO MAC #PSM7608-4	23
47	LOCK NUT - PRO MAC #PSM7608-4	23
48	WASHER - PRO MAC #PSM7608-5	23
49	KEY - 1/4" SQUARE X 1 1/4"	23
50	BULLET BIT - PRO MAC #PBC100-9	23
51	OPTIONAL CHISEL BITS - PRO MAC #9024	23
52	FELT SEAL - 3/8" SQUARE	2
53	BEARING - #QMCW15J215SET	1
54	GR.8 BOLTS - 5/8"NC X 2 1/2"	8
55	LOCK WASHER - 5/8"	8
56	BEARING GUARD - PRO MAC #8246	1
57	GR.8 BOLTS - 1/2"NC X 1 1/2"	7
58	LOCK WASHER - 1/2"	7
59	GR.8 BOLT - 3/4"NC X 1 1/2	2
60	WASHER - 3/4"	2
61	HINGE PIN - PRO MAC #9089-5	1
62	FORGED TOOTH - #230ST	8
63	FLEX PIN - #23FP	8
64	RAKE ATTACHMENT - PRO MAC #9185	1
65	REAR BLADE ATTACHMENT - PRO MAC #9083	1

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DEMINER MANUAL CHAPTER 7

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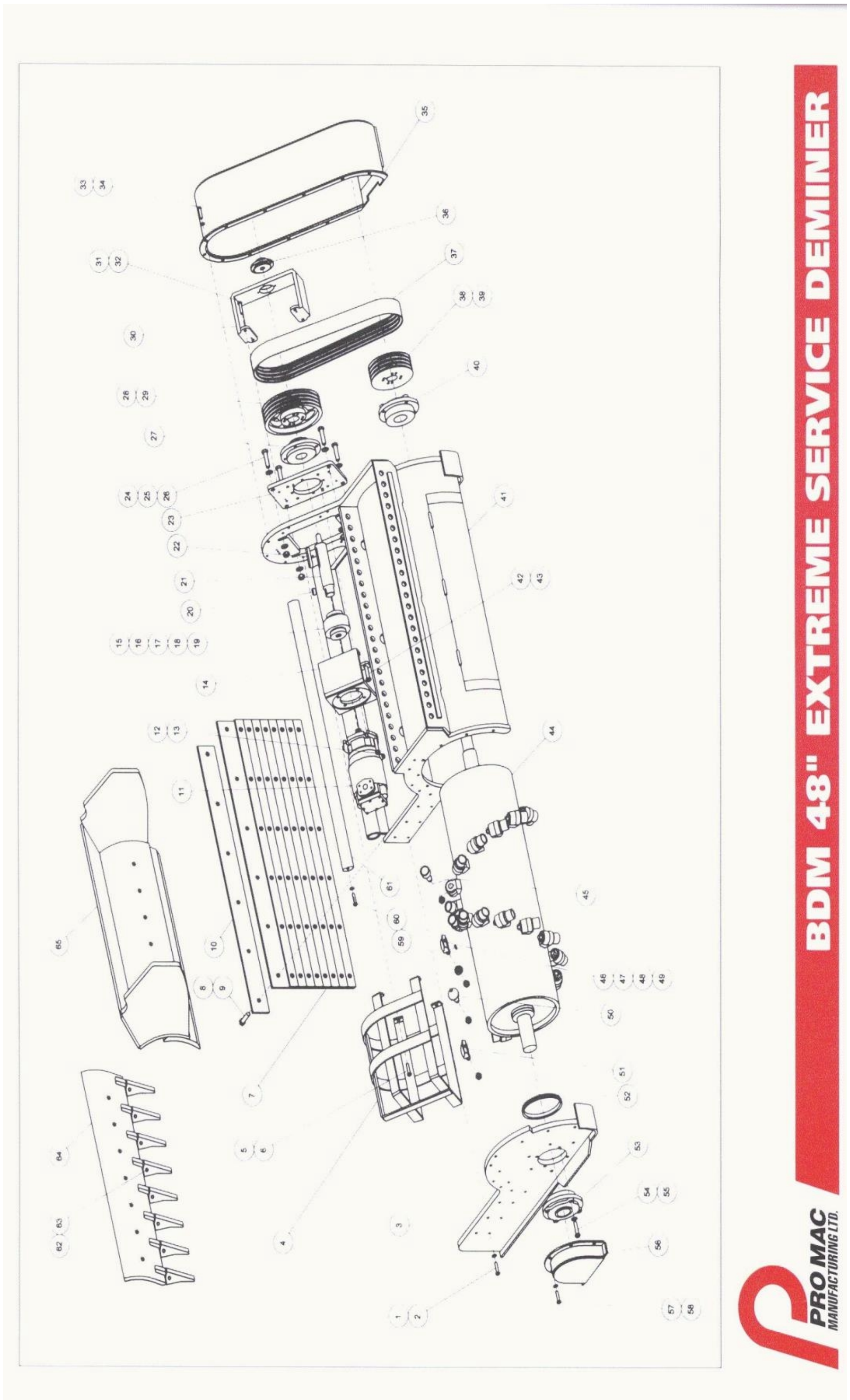

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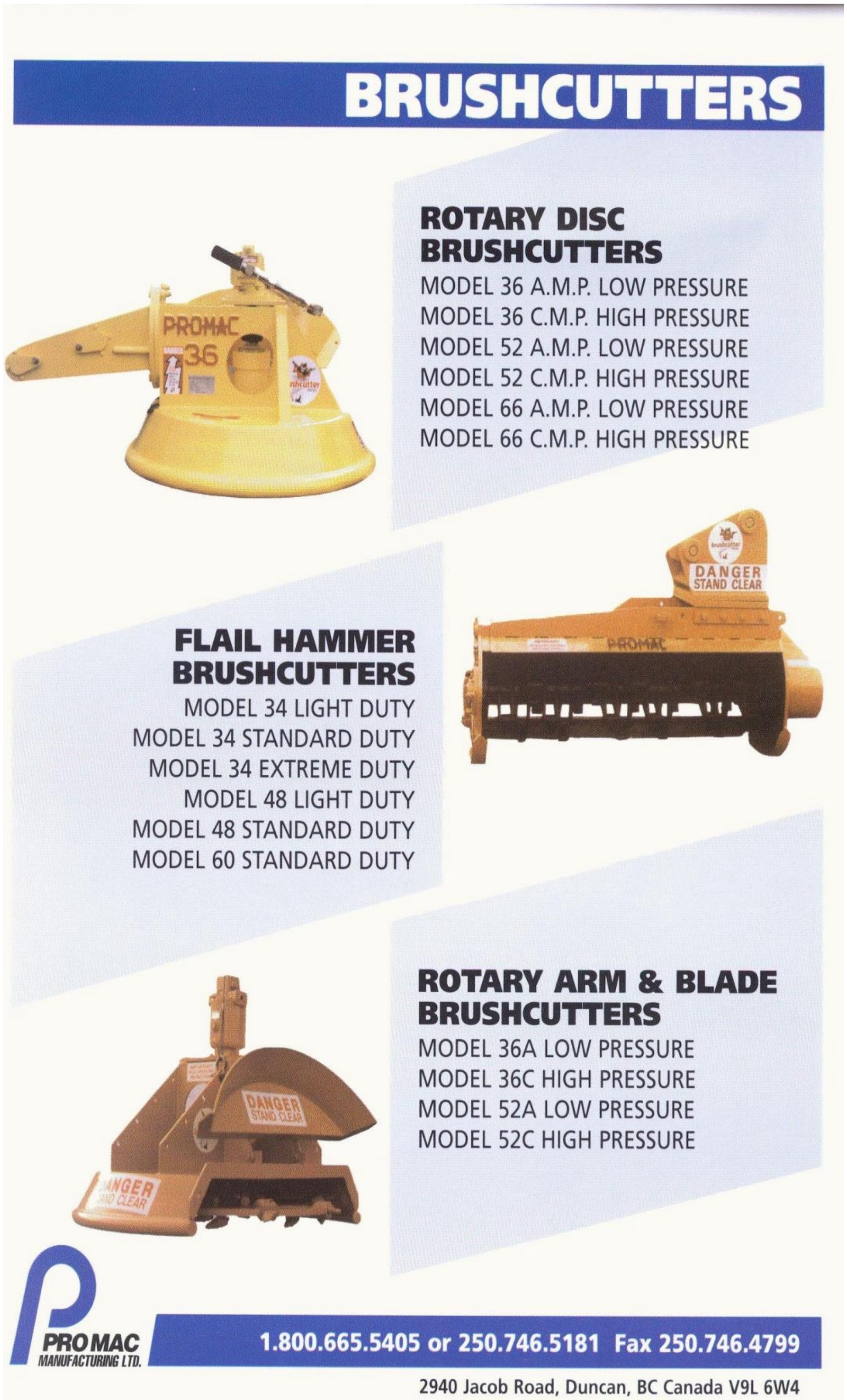

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BRUSHCUTTERS

Due to environmental problems associated with using chemicals for weed and brush control, we have designed Brushcutters that will help eliminate the problems that are becoming more and more frequent from the use of chemical defoliants.

FEATURES

- All units use sealed Anti Friction Bearings.
- All units made with Hi Alloy Steel Shafting.
- Easily mounted or adapted on various makes and models of equipment.
- Simple and efficient to operate.
- Cuts grass as well as dense bush.
- Cuts small trees.
  - MODEL 36A and 36C — 3.5" Diameter
  - MODEL 36 AMP and 36 CMP — 6" Diameter
  - MODEL 52A and 52C — 6" Diameter
  - MODEL 52A and 52 CMP — 8" Diameter
  - MODEL 66A and 66C — 10" Diameter to 12" Diameter
- Units available from 36" to 66" swath.
- Cutter blades made from Heat Treated Alloy Steel.
- Disc models with Carbide Tipped Cutters.
- Fixed displacement or variable displacement motors available.

MODEL	TYPE OF CUTTER	WEIGHT	R.P.M.	HYDRAULIC REQ.		MAX. PRESSURE
				MIN	MAX	
36A	ARM & BLADE	600 LBS/272 KG	1800 MAX	20 GPM	35	2700 PSI
36C	ARM & BLADE	600 LBS/272 KG	1800 MAX	16 GPM	35	4000 PSI
36 CMP	ROTARY DISC	1100 LBS/500 KG	1500 MAX	24 GPM	38	4000 PSI
52A	ARM & BLADE	1400 LBS/636 KG	1800 MAX	28 GPM	48	2700 PSI
52C	ARM & BLADE	1400 LBS/636 KG	1800 MAX	24 GPM	42	4000 PSI
52A	3 BLADE DISC	1700 LBS/773KG	1800 MAX	28 GPM	48	2700 PSI
52C	3 BLADE DISC	1700 LBS/773KG	1800 MAX	24 GPM	42	4000 PSI
52 CMP	ROTARY DISC	2000 LBS/909 KG	1500 MAX	30 GPM	42	4000 PSI
66 CMP	ROTARY DISC	4000 LBS/1816 KG	1500 MAX	38 GPM	48	4000 PSI
34 LFH	LIGHT DUTY FLAIL HAMMER	1250 LBS/567 KG	2300	16 GPM	35	2700 - 4000 PSI
34 SFH	STANDARD DUTY FLAIL HAMMER	1500 LBS/680 KG	2300	16 GPM	35	2700 - 4000 PSI
34 ESFH	EXTREME DUTY FLAIL HAMMER	2600 LBS/1179 KG	2300	30 GPM	48	2700 - 4000 PSI
48 LDFH	LIGHT DUTY FLAIL HAMMER	1300 LBS/590 KG	2300	30 GPM	42	2700 - 4000 PSI
48 SDFH	STANDARD DUTY FLAIL HAMMER	1800 LBS/816 KG	2300	30 GPM	48	2700 - 4000 PSI
60 FH	STANDARD DUTY FLAIL HAMMER	2400 LBS/1089 KG	2300	32 GPM	48	2700 - 4000 PSI

**NOTE: Flow requirements vary depending on type and displacement of motor used.*

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Annex C – Photographs – MRM Fragments Created By ProMac BDM48

Mechanical Assistance Equipment Test and Evaluation Program

Volume 4 – Equipment ProMac BDM48

In the photographs that follow:

- The images in Figure C-26 through Figure C-124show MRM fragments which were created by the ProMac BDM48. This collection amounts to approximately 20% of the total collection of photographic images of the MRM fragments from the BDM48 and provides a representative cross-section of the results.
- Results from the different soil types are indistinguishable.
- Fragments which could be identified to a specific MRM serial number are shown as such. Fragments which could not be attributed to a specific serial number are simply grouped together.

Figure C-26. MRM Fragments Created By ProMac BDM48

Figure C-27. MRM Fragments Created By ProMac BDM48

Figure C-28. MRM Fragments Created By ProMac BDM48

Figure C-29. MRM Fragments Created By ProMac BDM48

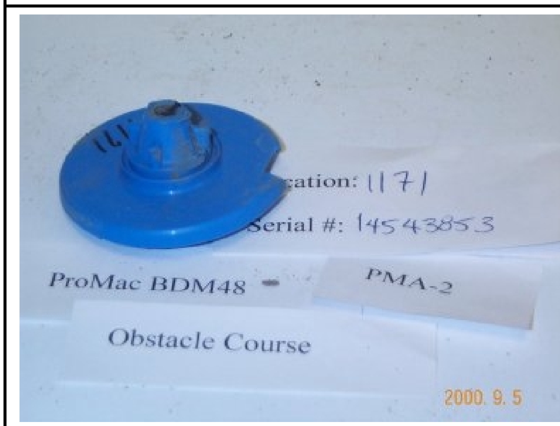

Figure C-30. MRM Fragments Created By ProMac BDM48

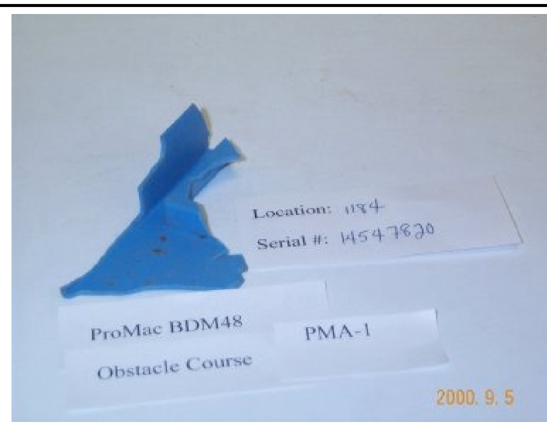

Figure C-31. MRM Fragments Created By ProMac BDM48

Figure C-32. MRM Fragments Created By ProMac BDM48

Figure C-33. MRM Fragments Created By ProMac BDM48

Figure C-34. MRM Fragments Created By ProMac BDM48

Figure C-35. MRM Fragments Created By ProMac BDM48

Figure C-36. MRM Fragments Created By ProMac BDM48

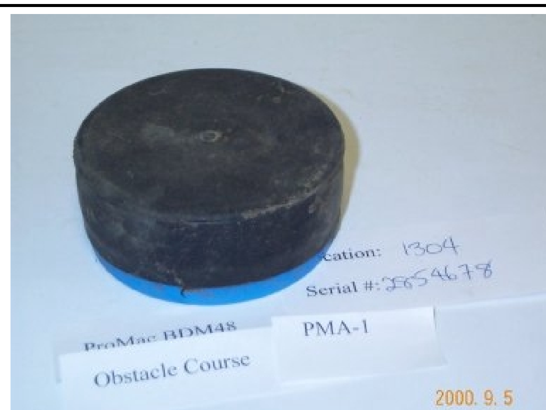

Figure C-37. MRM Fragments Created By ProMac BDM48

Figure C-38. MRM Fragments Created By ProMac BDM48

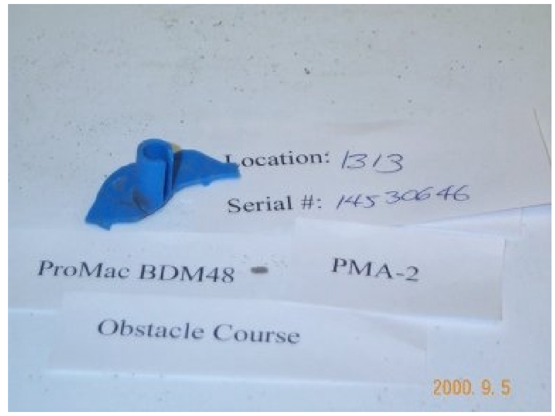

Figure C-39. MRM Fragments Created By ProMac BDM48

Figure C-40. MRM Fragments Created By ProMac BDM48

Figure C-41. MRM Fragments Created By ProMac BDM48

Figure C-42. MRM Fragments Created By ProMac BDM48

Figure C-43. MRM Fragments Created By ProMac BDM48

Figure C-44. MRM Fragments Created By ProMac BDM48

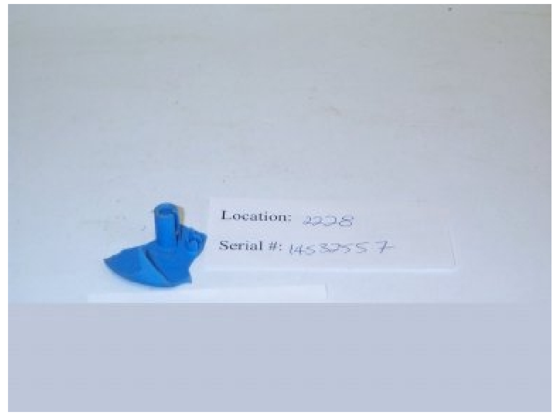

Figure C-45. MRM Fragments Created By ProMac BDM48

Figure C-46. MRM Fragments Created By ProMac BDM48

Figure C-47. MRM Fragments Created By ProMac BDM48

Figure C-48. MRM Fragments Created By ProMac BDM48

Figure C-49. MRM Fragments Created By ProMac BDM48

Figure C-50. MRM Fragments Created By ProMac BDM48

Figure C-51. MRM Fragments Created By ProMac BDM48

Figure C-52. MRM Fragments Created By ProMac BDM48

Figure C-53. MRM Fragments Created By ProMac BDM48

Figure C-54. MRM Fragments Created By ProMac BDM48

Figure C-55. MRM Fragments Created By ProMac BDM48

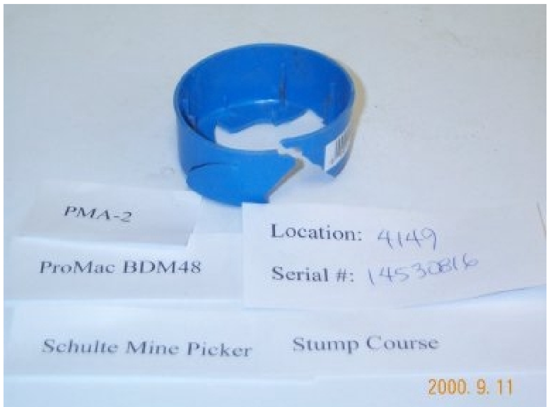

Figure C-56. MRM Fragments Created By ProMac BDM48

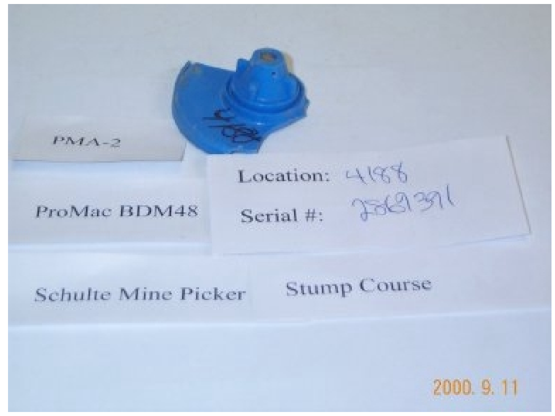

Figure C-57. MRM Fragments Created By ProMac BDM48

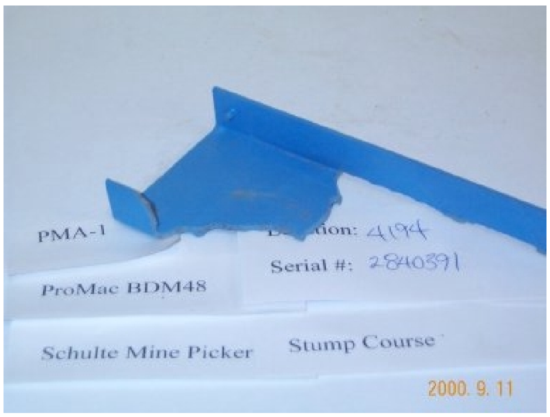

Figure C-58. MRM Fragments Created By ProMac BDM48

Figure C-59. MRM Fragments Created By ProMac BDM48

Figure C-60. MRM Fragments Created By ProMac BDM48

Figure C-61. MRM Fragments Created By ProMac BDM48

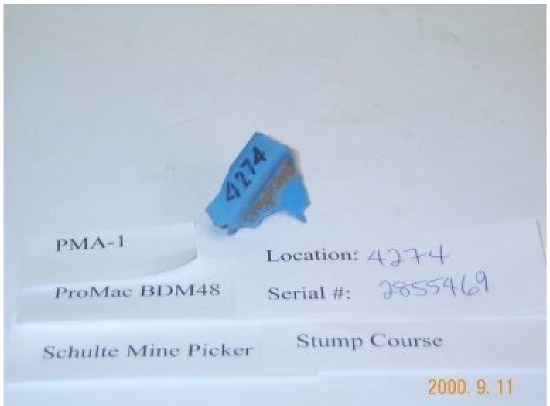

Figure C-62. MRM Fragments Created By ProMac BDM48

Figure C-63. MRM Fragments Created By ProMac BDM48

Figure C-64. MRM Fragments Created By ProMac BDM48

Figure C-65. MRM Fragments Created By ProMac BDM48

Figure C-66. MRM Fragments Created By ProMac BDM48

Figure C-67. MRM Fragments Created By ProMac BDM48

Figure C-68. MRM Fragments Created By ProMac BDM48

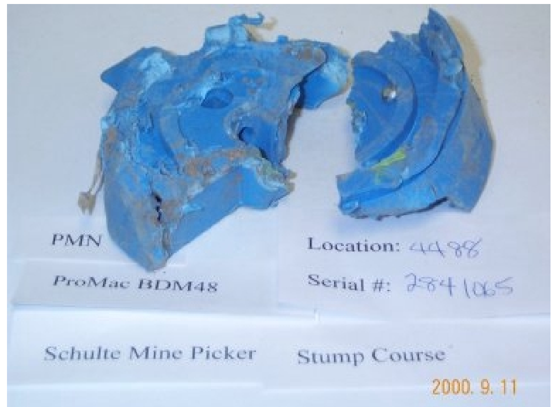

Figure C-69. MRM Fragments Created By ProMac BDM48

Figure C-70. MRM Fragments Created By ProMac BDM48

Figure C-71. MRM Fragments Created By ProMac BDM48

Figure C-72. MRM Fragments Created By ProMac BDM48

Figure C-73. MRM Fragments Created By ProMac BDM48

Figure C-74. MRM Fragments Created By ProMac BDM48

Figure C-75. MRM Fragments Created By ProMac BDM48

Figure C-76. MRM Fragments Created By ProMac BDM48

Figure C-77. MRM Fragments Created By ProMac BDM48

Figure C-78. MRM Fragments Created By ProMac BDM48

Figure C-79. MRM Fragments Created By ProMac BDM48

Figure C-80. MRM Fragments Created By ProMac BDM48

Figure C-81. MRM Fragments Created By ProMac BDM48

Figure C-82. MRM Fragments Created By ProMac BDM48

Figure C-83. MRM Fragments Created By ProMac BDM48

Figure C-84. MRM Fragments Created By ProMac BDM48

Figure C-85. MRM Fragments Created By ProMac BDM48

Figure C-86. MRM Fragments Created By ProMac BDM48

Figure C-87. MRM Fragments Created By ProMac BDM48

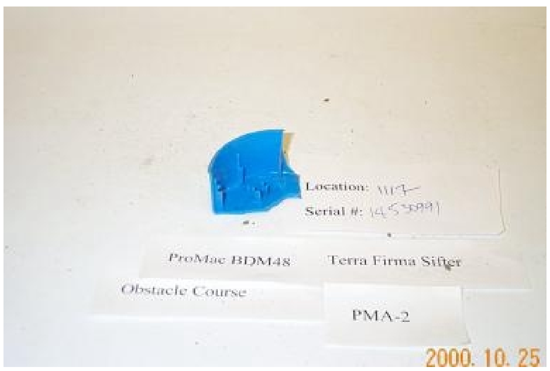

Figure C-88. MRM Fragments Created By ProMac BDM48

Figure C-89. MRM Fragments Created By ProMac BDM48

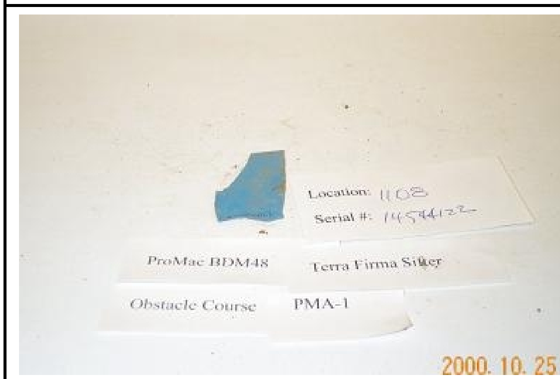

Figure C-90. MRM Fragments Created By ProMac BDM48

Figure C-91. MRM Fragments Created By ProMac BDM48

Figure C-92. MRM Fragments Created By ProMac BDM48

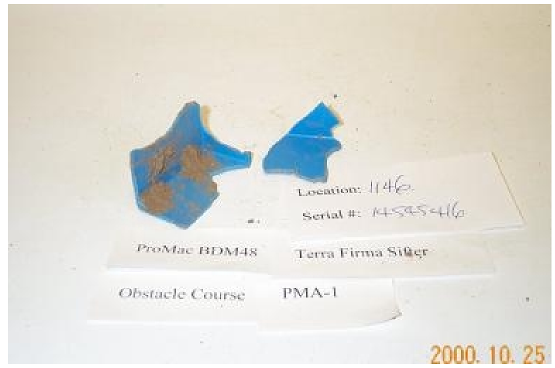

Figure C-93. MRM Fragments Created By ProMac BDM48

Figure C-94. MRM Fragments Created By ProMac BDM48

Figure C-95. MRM Fragments Created By ProMac BDM48

Figure C-96. MRM Fragments Created By ProMac BDM48

Figure C-97. MRM Fragments Created By ProMac BDM48

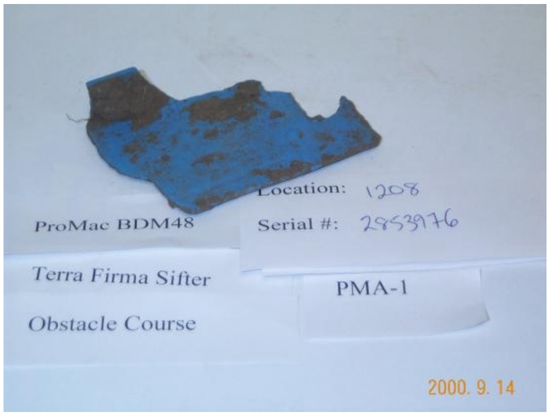

Figure C-98. MRM Fragments Created By ProMac BDM48

Figure C-99. MRM Fragments Created By ProMac BDM48

Figure C-100. MRM Fragments Created By ProMac BDM48

Figure C-101. MRM Fragments Created By ProMac BDM48

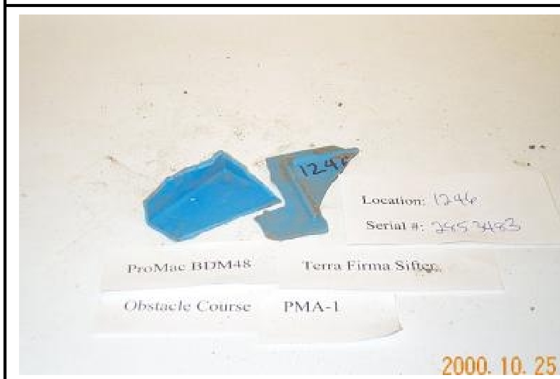

Figure C-102. MRM Fragments Created By ProMac BDM48

Figure C-103. MRM Fragments Created By ProMac BDM48

Figure C-104. MRM Fragments Created By ProMac BDM48

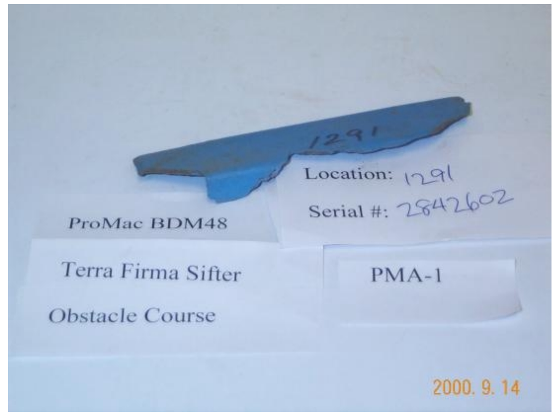

Figure C-105. MRM Fragments Created By ProMac BDM48

Figure C-106. MRM Fragments Created By ProMac BDM48

Figure C-107. MRM Fragments Created By ProMac BDM48

Figure C-108. MRM Fragments Created By ProMac BDM48

Figure C-109. MRM Fragments Created By ProMac BDM48

Figure C-110. MRM Fragments Created By ProMac BDM48

Figure C-111. MRM Fragments Created By ProMac BDM48

Figure C-112. MRM Fragments Created By ProMac BDM48

Figure C-113. MRM Fragments Created By ProMac BDM48

Figure C-114. MRM Fragments Created By ProMac BDM48

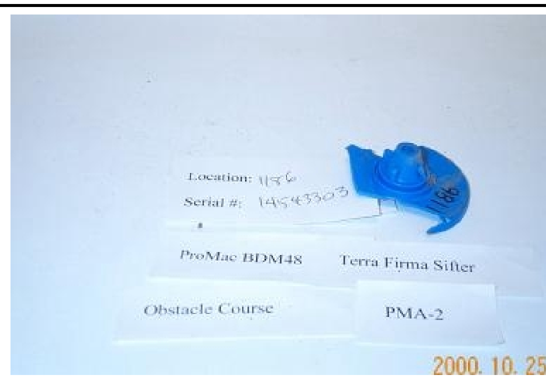

Figure C-115. MRM Fragments Created By ProMac BDM48

Figure C-116. MRM Fragments Created By ProMac BDM48

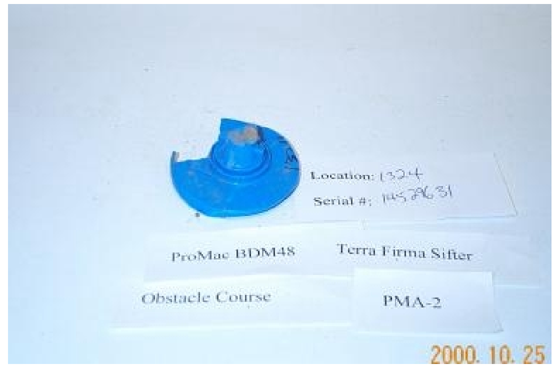

Figure C-117. MRM Fragments Created By ProMac BDM48

Figure C-118. MRM Fragments Created By ProMac BDM48

Figure C-119. MRM Fragments Created By ProMac BDM48

Figure C-120. MRM Fragments Created By ProMac BDM48

Figure C-121. MRM Fragments Created By ProMac BDM48

 Figure C-122. MRM Fragments Created By ProMac BDM48	 Figure C-123. MRM Fragments Created By ProMac BDM48
 Figure C-124. MRM Fragments Created By ProMac BDM48	Blank

Annex D – Photographs – ProMac BDM48 In Operation

Mechanical Assistance Equipment Test and Evaluation Program

Volume 4 – Equipment Evaluation (ProMac BDM48)

In the photographs that follow:

- The images show the various test conditions used in Phase 1 and Phase 2 testing. The need for removing the loose soil to a berm is observed, and the final result of the scraped area and berm is also illustrated.
- The last 2 images show the set-up and results of the unofficial blast tests in which 3 anti-personnel mine sized charges were placed under the BDM48 head.

Figure D-125. BDM48 brush cutting

Figure D-126. BDM48 brush cutting

Figure D-127. Typical Test Layout in Phase 1 (PAMI) Tests

Figure D-128. Typical Test Layout in Phase 1 (PAMI) Tests

Figure D-129. Typical test layout in Phase 1 (PAMI) tests

Figure D-130. Typical test layout in Phase 1 (PAMI) tests

Figure D-131. Flexible exhaust curtain held partially open

Figure D-132. Soil & MRM fragments thrown if exhaust curtain open

Figure D-133. Dust & dirt escapes from flexible exhaust curtain

Figure D-134. Loose soil must be scraped into a berm

Figure D-135. MRMs placed in poplar grove (Phase 1)

Figure D-136. MRM results in poplar grove (Phase 1)

Figure D-137. MRMs placed in willow grove (Phase 1)

Figure D-138. MRM results in willow grove (Phase 1)

Figure D-139. BDM48 in operation (Phase 2)

Figure D-140. Combination of cone and chisel teeth

Figure D-141. BDM48 in operation

Figure D-142. BDM48 in operation

Figure D-143. BDM48 in operation

Figure D-144. BDM48 in operation

Figure D-145. BDM48 in operation

Figure D-146. BDM48 in operation

Figure D-147. BDM48 in operation

Figure D-148. BDM48 in operation

 Figure D-149. BDM48 in operation	 Figure D-150. BDM48 in operation
 Figure D-151. Scanning for live MRMs after BDM48 operation	 Figure D-152. BDM48 berm and example of a single “bite”
 Figure D-153. MRM fragments in unscraped soil after BDM48 grinding	 Figure D-154. BDM48 scraped area and berm

Figure D-155. BDM48 scraped area and berm

Figure D-156. BDM48 scraped area and berm

Figure D-157. BDM48 scraped area and berm

Figure D-158. BDM48 scraped area and berm

Figure D-159. BDM48 blast test set-up – placing charge

Figure D-160. BDM48 blast test effects – superficial damage to vent covers only

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List of symbols/abbreviations/acronyms/initialisms

DRES	Defence Research Establishment Suffield
CCMAT	Canadian Centre for Mine Action Technologies
MRM	Mechanical Reproduction Mine
MAE	Mechanical Assistance Equipment
T&E	Test and Evaluation
EOD	Explosive Ordnance Disposal (see Glossary)
PAMI	Prairie Agricultural Machinery Institute
psi	Pounds per square inch
usgpm	(American) gallons per minute
MPa	Megapascals
hp	Horsepower
kW	Kilowatt(s)
rpm	Revolutions per minute
DOB	Depth of burial (from ground surface to the top surface of the mine)
mm	Millimetre(s)

Glossary

Technical term	Explanation of term
EOD	“Explosive Ordnance Disposal” is used herein (inaccurately) to refer to pieces or fragments of mines left after a machine’s operation which must then be handled in some manner to render an area “clear.”

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Canadian Centre for Mine Action Technologies
Mechanical Assistance Equipment
Test and Evaluation
Mechanical Reproduction Mine
Anti personnel landmine
Humanitarian demining
Neutralization
ProMac
BDM48
Vibra Ram Wack
VRL-8
Sorting Bucket