

C King Associates Ltd



Demining Programme Office in the Falkland Islands – Technical Support 2010

Submitted by: C King Associates Ltd

Presented to the UK FCO



Foreign &
Commonwealth
Office

April 2010

TECHNICAL SUPPORT TO THE FALKLANDS DEMINING PROGRAMME

This report and the associated exploitation work was funded by the United Kingdom of Great Britain and Northern Ireland.

Aim

1. The aim of this report is to outline the technical support provided to the Falklands demining programme during the Austral summer of 2009/2010.

Technical support - general

2. The majority of the technical support provided fell into two categories:
 - a. **Detection**; activities intended to enable the contractor to establish their detection capabilities against the minimum-metal mines.
 - b. **Exploitation**; examination of recovered mines in order to observe the effects of aging and assess their implications.
3. A list of the main technical support activities undertaken is at **Annex A**.

Metal detection samples

4. Technical support to detection began with an investigation into the metallic content of the mines likely to be encountered; this would enable an assessment of detectability and allow the 'worst case' to be identified.

5. Documentary research showed that the Spanish P4B anti-personnel (AP) mine and C3B anti-tank (AT) mine had the lowest metal content of those likely to be encountered. The two mines share a similar initiation system, with a small steel spring being the sole metallic fuze component. The location of this spring, which sits lower within the AT mine, suggested that the C3B would be the harder target to detect.



Figure 1: The Spanish P4B anti-personnel mine, with safety cap to the left



Figure 2: The Spanish C3B anti-tank mine, with safety cap to the left

6. The main charge of the P4B is normally covered with a foil made from lead alloy, although there was speculation that this might have been removed from some mines as they were laid¹.
7. It was not clear to what extent – if any - the presence of the foil would make the P4B more detectable. Nor was it clear whether the orientation of the mine would effect its detectability.
8. Some sample mines had previously been made inert or 'Free From Explosives' (FFE), however, the accuracy of their detection signatures was questionable. There was, therefore, a need for accurate surrogates.
9. Examples of inert mines held by C King Associates (CKA) were dismantled and the components accurately characterised, then compared to the documentary sources. A batch of 50 springs were then sourced from a specialist company, replicating the characteristics and specifications as accurately as possible².
10. Precise measurements were taken to gauge the distance from the top surface of the mine to the spring, and a test piece designed. Since the same spring is used in both the P4B and C3B mines, and the spring is symmetrical around the horizontal axis, a single test piece could represent both mines. The off-set of the spring from each end of the test piece represented the location of the component within each mine. The resultant test piece is shown in **Figure 3**.

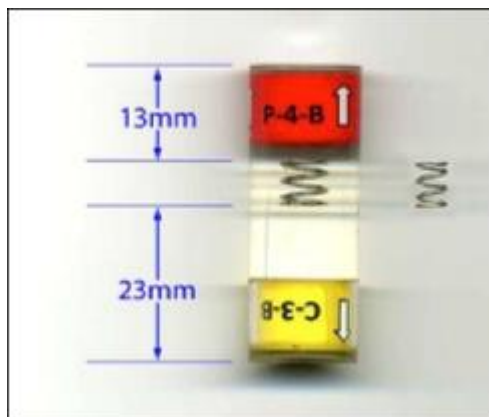


Figure 3

A detection test piece developed by CKA.

Note that in the image the spring inside the detection piece is magnified by the curve of the polymer surface making it appear larger than the free air example on the right. The two springs are actually identical

11. Eight test pieces were produced, six of which were immediately shipped to the Falklands (on 6 November 2009).
12. A number of springs were shipped direct to BACTEC UK (the clearance contractor) for incorporation into inert mines and use in their own detection testing.
13. Work on other programmes³ had shown that corrosion could reduce – or even eliminate – the detection signature of metallic components. Samples of springs were immersed in a weak saline solution to assess their susceptibility to rusting; **Figure 4** shows the results.

¹ The first P4B recovered was indeed missing most of the lead foil, however, all remaining P4Bs were found with the foil still in place.

² Accuracy included correct steel type, spring mass to within two hundredths of a gram and all dimensions to within a tenth of a millimeter.

³ Primarily CKA studies into the effects of aging on landmines, conducted on behalf of US State Department.

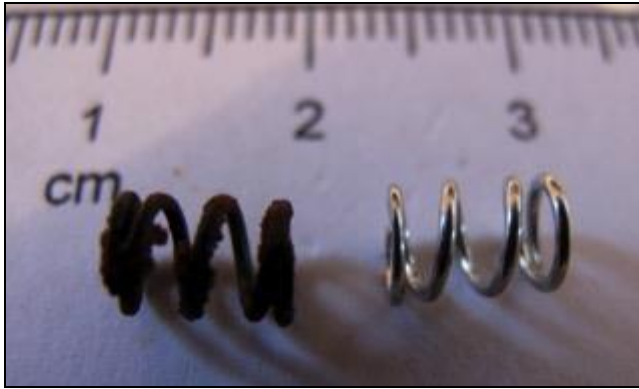


Figure 4

Corrosion testing.

Two springs of the type used in the Spanish P4B and C3B mines. The spring on the left has been immersed in weak saline solution for two weeks. The effect indicates that the spring is vulnerable to rusting, which might reduce its detectability

14. The conclusion of the corrosion test was that springs were likely to be heavily rusted if water had penetrated the fuze assembly. If so, the detection signature might be even lower, making the mine virtually undetectable⁴.

Metal detection assessment

15. An in-depth assessment of detection capabilities began with a review of previous tests⁵ - probably the most thorough and objective detection testing ever carried out and therefore provided a good overview of likely capabilities.

16. Early findings in the Falkland Islands matched the theoretical detection assessment reasonably well, however there were a number of variables that could not be taken into account. These included:

- The potential influence of the lead foil in the P4B;
- The performance of the Minelab 'yellow cap' enhancement;
- The effect of mines/components at different angles of incidence;
- The influence of an aluminised explosive filling on detection.

Radar detection samples

17. The clearance contractor had been asked to undertake some research on dual-sensor mine location using the Minehound detector. This would require targets with both the correct metallic content and an appropriate radar signature.

18. CKA had previously commissioned production of a microcrystalline wax specifically for this purpose. This wax has electrical and mechanical characteristics very similar to those of TNT, with a far higher melting point than normal wax and blue colouring to avoid any possibility of confusion with live explosive.

19. Several kilograms of the wax were carried to the Falklands, then moulded into the body of a C3B AT mine. The mine was then re-sealed and marked as inert for use in Minehound detection trials. The remaining wax was left with the Demining Programme Office (DPO) for filling AP mines, if required.

⁴ In practice, very few fuzes had been penetrated by water; meanwhile, detection by instrument was ruled out (for this contract) due to the shallow detection depth achieved during tests.

⁵ International Pilot Project for Technology Cooperation, dated October 2000

Mine exploitation

20. Samples of all three mine types recovered during clearance operations (P4B, SB-33 and SB-81) were disassembled in order to assess their condition. The examination did not encompass full exploitation, but focussed on:

- a. Ability to function;
- b. Detectability;
- c. Trends in deterioration.

21. 14 P4B AT mines had been recovered from the Sapper Hill minefield and retained for the exploitation visit, while 17 SB-33 AP mines and 15 SB-81 AT mines were lifted from the Surf Bay minefields during the course of the analysis.

22. In addition to the points listed above, lifting the mines allowed examination of the immediate location in order to assess the effect on, or action of, the ground conditions.

23. Photos showing the recovery sequence for the Surf Bay mines (SB-33 and SB-81) are at **Annex B**.

24. Key findings from the exploitation work are at the following annexes:

- a. P4B: **Annex C**
- b. SB-33: **Annex D**
- c. SB-81: **Annex E**

Creation of training aids

25. All of the mines recovered for exploitation were rendered inert, with all explosive components being sent for demolition. The inert mine casings were then marked with blue paint (the NATO colour code for inert munitions) and set aside as training aids for future operations.



Figure 5: Inert Spanish P4B AP mines, with the wax-filled C3B body to the top left



Figure 6: Inert SB-33 and SB-81 mines awaiting final safety checks and marking

Conclusions

26. The technical services provided by CKA covered a wide variety of functions, many of which had not been anticipated at the time of the original contract.

27. Most of the three types of mine examined appeared to be fully functional, with levels of deterioration well below those expected.

28. Examination of recovered mines will be an important component of future clearance operations, particularly since many of the remaining mines (such as those with steel cases or exposed steel components) are known to have deteriorated to a far greater extent than those encountered so far.

Recommendations

29. If possible, samples of target mines should be examined, well before clearance operations commence, in order to determine the most appropriate clearance techniques and equipment.

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April 2010

LIST OF TECHNICAL SERVICES PROVIDED

Serial	Activity	Notes
1	Investigation of metallic content for the following mines: P4B, C3B, SB-33, SB-81	Involving documentary research and disassembly of inert mines to examine critical components
2	Sourcing of replica components	Procurement of springs and lead foil to replicate those used in the P4B and C3B
3	Corrosion testing	Investigating the vulnerability of P4B and C3B springs to rusting
4	Production of detection test pieces	Design and fabrication of double-ended test pieces to replicate the detection signatures of P4B and C3B mines
5	Provision of replica springs to the clearance contractor	Allowing the clearance contractor to complete their own surrogate test pieces
6	Investigation of detection capabilities against low-metal mines	Involving review of the Detection Pilot Project and discussions with detector manufacturers
7	Commissioning of report into detection capabilities	Locating an independent detection agency with access to the Minelab (yellow cap) and other detectors for comparison. Agreeing terms of reference and trial configurations
8	Provision of explosive substitute for C-3-B mine body (for Minehound trials)	Microcrystalline wax blocks were taken to the Falkland Islands and moulded into the body of an inert C3B
9	Exploitation of P4B, SB-33 and SB-81 mines	Involving the recovery, disarming, disassembly and examination of live mines
10	Creation of training aids	Removal of all explosive material from sample mines, followed by appropriate marking

THE MINE EXTRACTION PROCESS



Overview of the Surf Bay minefield



A clearance lane, with located mines to the right



Beginning extraction of an SB-81 AT mine



Turf was cut from above the mine



Cut turf was removed in blocks to expose the entire body of the mine



With the mine extracted, the underlying ground was photographed and examined



Extracted mines were disarmed immediately



A wet ditch containing a number of mines



An SB-33 AP mine under water



An SB-33 in relatively dry ground



The extraction process for the SB-33 was similar to that used for the SB-81



Disarming the SB-33 by unscrewing the detonator assembly from the base of the mine

EXAMINATION OF THE P4B



Figure 1



Figure 2

Most of the P4B mines examined showed little obvious sign of external degradation, with both the colour and the texture of the plastic casing appearing virtually 'as new' (Figure 1). However, the condition of some mines suggests that this initial visual impression may be misleading, and that all of the plastic casings are now beginning to deteriorate.

Many had some degree of root penetration between the underside of the fuze (Figure 2) and the mine body. This type of growth would not affect performance, although it is possible that further enlargement of the roots might eventually force the two assemblies apart, resulting in malfunction.



Figure 3

Throughout the course of the clearance operation, all but one of the P4B mines examined had the red lacquered lead foil present in fuze well. As the fuze assembly is fitted, this foil ruptures in unpredictable patterns (Figure 3). The shape of the ruptured foil is known to affect the return on short-wave radar and may also affect the signature with some metal detectors.



Figure 4



Figure 5

The P4B pressure plate shown in Figures 4 and 5 shows the type of long-term deterioration expected in ABS plastic. Increasing brittleness has caused fine cracks where the plastic is under stress; this has led to eventual failure, permitting the ingress of water. In most samples examined, cracking was not immediately visible; however, it is evident that the plastic is becoming more brittle and that all casings would eventually reach this stage. Previous studies have shown that such deterioration accelerates, since the effects (such as increasing the exposed surface area) make the material even more vulnerable to further degradation. Extensive tests would be required in order to assess the rate of degradation.



Figure 6

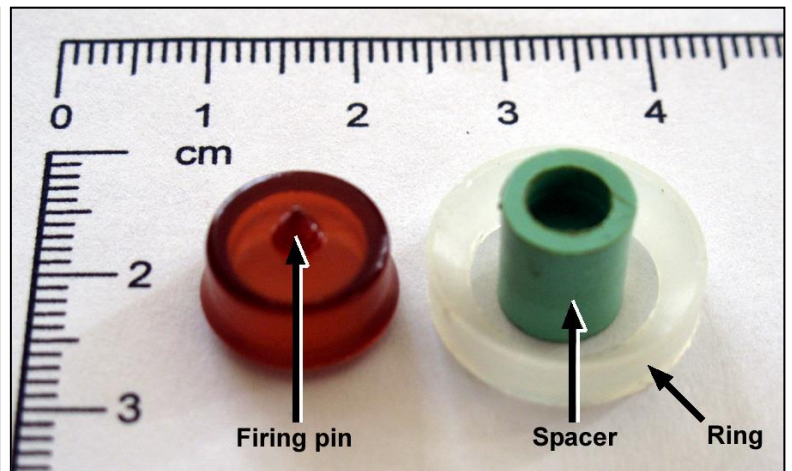


Figure 7

Even where water had penetrated the fuze assembly, the firing spring (Figure 6) was in remarkably good condition and remained fully functional. This was surprising, although, had the mines been nearer the coast, salt-water would probably have caused more extensive rusting. This would further degrade the detection signal from the small metallic mass.

It is important to note that the P4B can function regardless of the spring's condition. The firing pin is made from polymethylacrylate plastic, which is unlikely to deteriorate significantly within the foreseeable future. It is forced through a polythene ring by a spacer and this action alone may be sufficient to cause initiation without the additional impetus of the spring. These plastic components are shown in Figure 7.



Figure 8



Figure 9

The detonator assembly is bonded into the fuze body and has to be cut from the mine, as shown in Figure 8. The stab-sensitive receptor in the centre is covered by a thin plastic film (seen here having been cut using a scalpel) to keep it dry. A similar assembly, shown in Figure 9, was full of water.



Figure 10

The presence of water might prevent the stab receptor from initiating, since water-soluble compounds are used within the composition. This is likely to be the primary cause of failure for P4B mines in the near term.

As expected, the pressed TNT charges (Figure 10) were in good condition, despite many being wet. TNT is relatively stable, especially when protected from sunlight. This High Explosive (HE) content is likely to remain functional for the foreseeable future.

Conclusions

1. Most of the P4B mines examined appeared to be fully functional.
2. Deterioration of the plastic casings has begun, but – in most instances - is progressing at a far slower rate than expected. Most mines have retained their structural integrity.
3. The ingress of water into the fuze assembly has caused only minor deterioration of the striker springs. This will not significantly affect the detection signature or the mine's ability to function.
4. The ingress of water into the detonator assembly may render the mine inoperative; this would need to be confirmed by testing.
5. The lead foil was present in all but one of the mines examined. The manner in which the foil splits (when the fuze assembly is fitted) may affect the detection characteristics of the mine. Determining this would require additional trials.
6. The TNT HE content is stable and well preserved.

EXAMINATION OF THE SB-33



Figure 1



Figure 2

Seventeen SB-33 mines were recovered from a mixture of dry and wet sites (Figures 1 and 2). None of the SB-33 mines examined showed signs of significant external degradation, other than a notable increase in the profile of the rubber pressure plate; this is clear from Figures 3 and 4.



Figure 3: An SB-33 recovered from the Falklands; note the domed profile of the pressure plate



Figure 4: The normal appearance of the SB-33, with a relatively flat pressure plate

The casing of the SB-33 is made from glass-reinforced polycarbonate and showed no indication of deterioration whatsoever. However, all of the recovered mines had been buried, and it is probable that the casings and rubber pressure plates would degrade more quickly after prolonged exposure to the sunlight.

Expansion of the rubber appears to be due to the material softening when wet, although it continued to be waterproof. As the rubber dried, the height of the dome reduced noticeably, but not to the original profile.

Examination of the casing and pressure plate showed that the upper sections of all of the mines had remained watertight. Where water had penetrated, this appeared to be because the detonator plug (to the left in Figure 3) had not been tightened sufficiently.



Figure 5



Figure 6

Mines were disarmed by unscrewing the detonator assembly from the base well (Figure 5); in most cases, this plug had been fitted tightly. Once disarmed, the two halves of the mine were unscrewed using a chain wrench (Figure 6) to access the internal components and main charge.



Figure 7

Figure 7 shows a recovered SB-33 disassembled. Most of the clear plastic internal fuze components are made from polycarbonate, and are therefore extremely strong.

Some casings were made from olive green plastic; others (including this one) were grey and merely painted green on the outside.

None of the internal components showed any mechanical damage. The main charge (RDX/HMX) was often cracked, but this would not affect performance.

Although the mines were generally well sealed, several were damp inside. In many cases this had caused very minor rusting of the striker spring (which is made from spring steel 'piano wire'). This superficial corrosion would have no effect on the performance of the mechanism, nor would it effect the detectability of the mine.

The firing pin is made from stainless steel and none of those examined showed any significant degree of corrosion.

Most of the aluminium detonator capsules were in good, functional condition (Figures 8 and 9), but some did show significant signs of corrosion; see Figures 10 and 11.



Figure 8: Most detonator assemblies were in very good condition

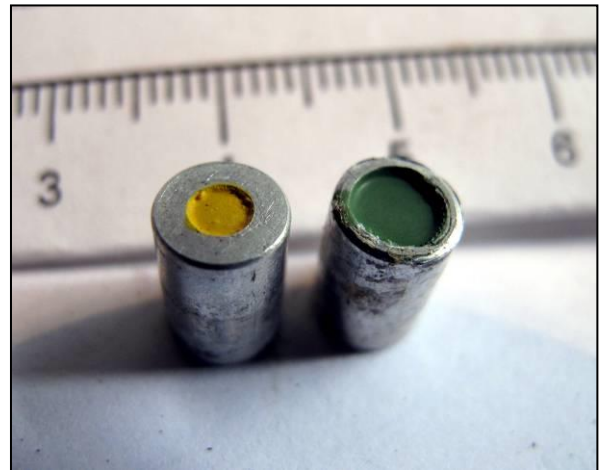


Figure 9: The end seals of these detonator capsules show no signs of deterioration



Figure 10: Some detonator capsules did show significant signs of degradation



Figure 11: The yellow seal on the stab receptor appears to have been breached

There was obvious degradation where detonator capsules had been exposed to water for prolonged periods. It is likely that this had breached the seals of the capsule, particularly the thin yellow membrane covering the stab receptor. This is significant because the stab-receptive composition is likely to be affected by water, which may cause the mine to malfunction.

Only one of the recovered SB-33 mines contained a significant quantity of water; this was caused by the detonator plug not being screwed into place sufficiently tightly. The most obvious result of the water ingress was the disintegration of the striker spring, which would probably prevent the mine's fuze mechanism from actuating and might also make the mine more difficult to detect. The detonator capsule was also substantially corroded and possibly non-functional.

The badly corroded mine (shown in Figure 12) demonstrates the longer-term fate of all SB-33 mines, as rubber seals gradually deteriorate and permit water to enter the mine.



Figure 12: Inside an SB-33 which had been penetrated by water. The most likely cause of failure would be the disintegration of the striker spring, although degradation of the detonator capsule might also prevent the mine from operating. Note that the stainless steel firing pin is virtually unaffected

Conclusions

1. Most of the SB-33 mines examined appeared to be fully functional.
2. The rubber pressure plates were distorted where the material appeared to have softened; this probably indicates the beginning of degradation that would eventually lead to failure.
3. Deterioration of the rigid mine casings was minimal and all of the mines examined retained their structural integrity.
4. Minor dampness inside the mines has caused only minor deterioration of the striker springs. This will not significantly affect the detection signature or the mine's ability to function.
5. Degradation of the detonator assembly, due to dampness, may render the mine inoperative; this would need to be confirmed by testing.
6. The HE charges are well preserved, despite some being cracked.
7. Where water had penetrated a mine, the striker spring and detonator capsule showed substantial deterioration; this would almost certainly have prevented it from functioning. In the long term, this is what could be expected to happen to all SB-33 mines in the Falklands.

EXAMINATION OF THE SB-81



Figure 1



Figure 2

Fifteen SB-81 Anti-Tank (AT) mines were recovered from a mixture of dry and wet sites (Figures 1 and 2). None of these mines showed signs of significant external degradation; in fact, their appearance was virtually 'as new', as shown in Figures 3 and 4.



Figure 3: An SB-81 recovered from the Falklands



Figure 4: Base view of the SB-81

The casing of the SB-81 is made from polycarbonate and showed no indication of deterioration whatsoever. Even the pressure plate, which is made from a polyester elastomer, appeared to be in pristine condition.

All of the mines examined had been buried in the ground and were not, therefore, exposed to sunlight. Polycarbonate is known to become brittle after prolonged exposure to sunlight, so it is probable that exposed mines would show more evidence of degradation.

Examination of the casing and pressure plate showed that all of the mines had remained watertight. Where there was evidence of moisture on the inside, as with the SB-33, this appeared to be because the detonator plug (shown in Figure 4) had not been tightened sufficiently.



Figure 5



Figure 6

With the halves of the casing separated, the internal components could be examined. Figure 5 shows upper section of the mine with the pressure plate removed to reveal the top of the fuze assembly. The seal around the edge of the pressure plate is critical to the pneumatic function of the fuze; this is a common point of failure among Italian AT mines. Although small roots were present on the outside (Figure 6) all seals were intact.



Figure 7

Figure 7 shows the major components of the fuze mechanism. The fuze is similar to that used in the SB-33, with most of the clear plastic internal fuze components made from polycarbonate.

Not only were the components in perfect condition, but the thin layer of grease applied during manufacture was also present.

As with the SB-33 mines, the SB-81s were generally well sealed, but several were damp inside. In many cases this had caused very minor rusting of the striker spring (which is made from spring steel 'piano wire'). This superficial corrosion would have no effect on the performance of the mechanism, nor would it effect the detectability of the mine. The firing pin is made from stainless steel and none of those examined showed any corrosion.

The main charge (approximately 2 kg of TNT/RDX/HMX) is encapsulated in plastic, while the booster (approximately 140 g of RDX/HMX/wax) is in the form of a pressed disc. These are shown in Figure 8. Removal of the plastic showed the main charge to be in perfect condition (Figure 9).



Figure 8: The main charge and booster



Figure 9: The main charge casting



Figure 10: Some detonator capsules showed significant signs of degradation



Figure 11: The yellow seal on the stab receptor appears to have been breached

The SB-81 uses the same detonator capsule as the SB-33, albeit in a different holder (Figure 10). Most were in good condition, but some, such as the one shown in Figure 11, showed obvious signs of degradation where they had become damp. It is possible that, in some cases, this had breached the seals of the capsule, particularly the thin yellow membrane covering the stab receptor. This is significant because the stab-receptive composition is likely to be affected by water, which may cause the mine to malfunction.

Since the casings have endured so well, the deterioration of detonator capsules represents the most likely cause of failure within the next few years. In the longer term, more water can be expected to enter the mines as rubber seals gradually deteriorate. In addition to affecting the detonators, this will also corrode the striker springs and cause failure of the fuze mechanism.

Where mines are exposed to sunlight, the elastomer pressure plate is likely to become brittle, causing the seal around the shoulder to fail. When this is no longer air-tight, the pneumatic actuation system becomes incapable of operation. Deterioration of the thin diaphragm which bears on the fuze mechanism will have a similar effect, rendering the mine incapable of functioning as designed.

Conclusions

1. Most of the SB-81 mines examined appeared to be fully functional.
2. The mine casings showed no signs of deterioration; however, prolonged exposure to sunlight is likely to cause degradation that would eventually lead to failure.
3. Minor dampness inside the mines has caused only superficial rusting of the striker springs. This will not significantly affect the detection signature or the mine's ability to function.
4. Degradation of the detonator assembly, due to dampness, had occurred in some mines and might render the mine inoperative; this would need to be confirmed by testing.
5. The HE main charges and boosters were in good condition.
6. The SB-81 is one of the most resilient mines ever made, and is likely to remain a threat in the Falkland Islands for the foreseeable future.