



11-2673768-1

Compressed Air Breathing Apparatus T-Piece Failure

On behalf of

NSW Department of Industry & Investment

19 December, 2011



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VERITAS

Report: 11-2673768-1

Client: Department of Industry and Investment *Move Forward with Confidence*

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Order No: 185259739

Date: 19 December, 2011

Compressed Air Breathing Apparatus T-Piece Failure

EXECUTIVE SUMMARY

Failure of the T-pieces of two Self Contained Breathing Apparatus (SCBA) units at the first engaged thread at the inlets of the main stem was due to brittle overload. The first engaged thread represents a stress concentration that would intensify the effects of any imposed load. Brittle overloading of the threaded section at the first engaged thread had originated from the surface and occurred in several stages.

No evidence of prior cracking, corrosion or fatigue was found. No internal defect, porosity or any other abnormal feature was observed in the microstructure. The SCBA T-pieces had been manufactured from a manganese bronze alloy and exhibited a satisfactory structure with a hardness of 126 HV10.

It is recommended that a periodic visual inspection be carried out on the SCABA's in service to check for cracking.

The most likely cause for brittle fracture of T-pieces is the improper handling of the backpack. It is recommended that a handling procedure be developed to reduce the potential for shock loading. Some consideration might also be given to the use of a stainless steel Tee piece in place of the bronze.

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1. INTRODUCTION

The failed T-pieces from two Sabre brand self-contained breathing apparatus (SCBA) sometimes called Compressed Air Breathing Apparatus (CABA) were provided by Mr T Flowers for failure investigation.

The CABA unit is a self-contained portable breathing unit consisting of two (2), 6.8 litre bottles of compressed air positioned within a rigid harness designed to be worn as a back pack. The two bottles are positioned within the harness such that the valves of both bottles are at the bottom, and are joined by the Tee piece. Air enters the horizontal branches of the Tee piece from both gas bottles before entering a central hollow body that connects, via a flexible hose, to a face mask.

It was understood that both of the T-pieces were installed in December 2002 and were found to be failed during an escape from an incident in the Blackfield South Mine, on 5th January 2011. SCBA units service life of was understood to have been approximately 9 years up to that time. The exact time of failure was unknown, as it might have occurred before using the units during the mine incident. A safety alert has been issued following the failure of these two Sabre brand, CABA units, see Appendix 1. An inspection was also conducted following the observance of two failures on 14 units and another two units were found faulty at the same location. This was reported to be the first instance of such failures.

The T-pieces were identified as T11/00705/001 and T11/00705/002 by client. It was requested that an examination be undertaken to determine whether fracture occurred by fatigue propagation or by a single event overload. A general view of the CABA unit is shown in figure 1. Figure 2 shows the container in which the CABA units had been stored. Figure 3 shows a general photo of the failed CABA unit and the location of the compressed air bottles. Figure 4 shows the location of the fracture at the first engaged thread of bronze T-piece at both horizontal inlets. It was stated that, it is possible that the T-piece could be stressed every time the equipment was moved or bumped. No drawing or material specification was provided at the time of investigation. It was stated that the compressed air breathing apparatus was working under a pressure of 300 bar.



Figure 1- Showing a self-contained compressed air breathing apparatus combined of two air bottles, a T-piece which connects the bottles and a backpack.



Figure 2- showing the container for SCABA units.

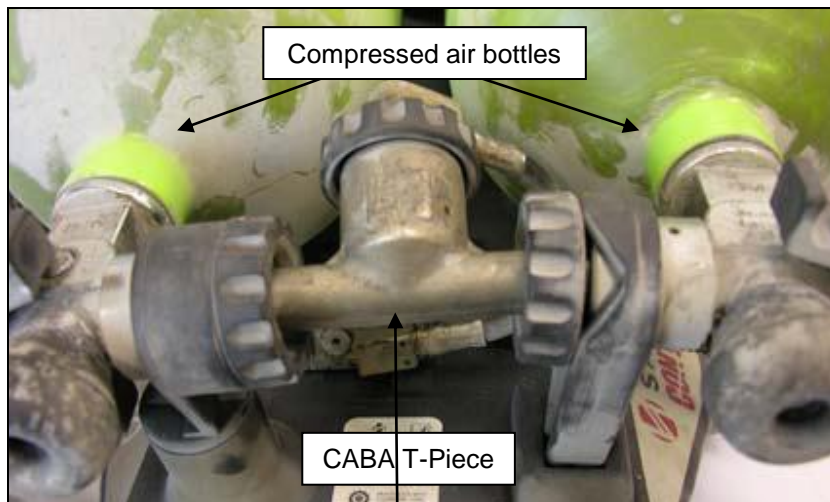


Figure 3- General photo of a failed CABA unit from 5/1/2011 showing the location of the compressed air bottles and T-piece.

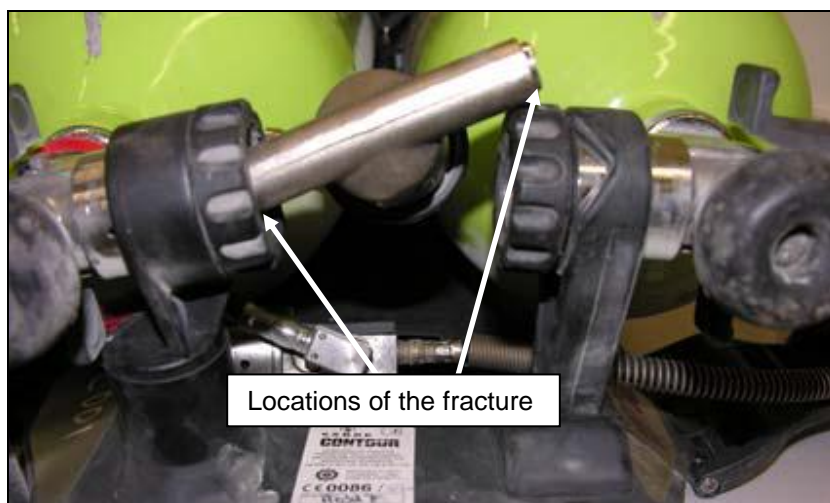


Figure 4- General photo of the failed CABA unit from 5/1/2011 showing the location of the fracture.

2. OBSERVATIONS

2.1. Visual Examination

A general view of both failed T-pieces as received is shown in figure 5. The T-pieces consisted of a pipe forming the main body terminating at one end with two branches normal to the body each of which contained an external thread at their distal end. A steel connecting piece was screwed onto both branches of the Tee piece and were in turn connected to the compressed air bottles. Both T-pieces were fractured at the first engaged thread.

Eight fracture faces from two CABA units were examined. The fracture faces from T11/00705/001 T-piece were labeled as 1-1, 1-1-T, 1-2 and 1-2-T. The fracture faces from T11/00705/002 T-piece were labeled as 2-1, 2-1-T, 2-2 and 2-2-T. The threaded section of the T-piece was nominally 8mm in diameter and 12mm long and had fractured transversely through the threaded area, at the first engaged thread at a distance of approximately 11mm from the end face.

Figure 6 shows the location of the fracture at the first engaged thread. No deformation or bending was observed around the fracture on the threaded section of both T-pieces. All four fractures had occurred at the first engaged thread location representing a stress concentration effect. The stress concentration at the thread root reaches a maximum at the first engaged thread, because this thread tends to sustain the highest load of all of the remaining threads.

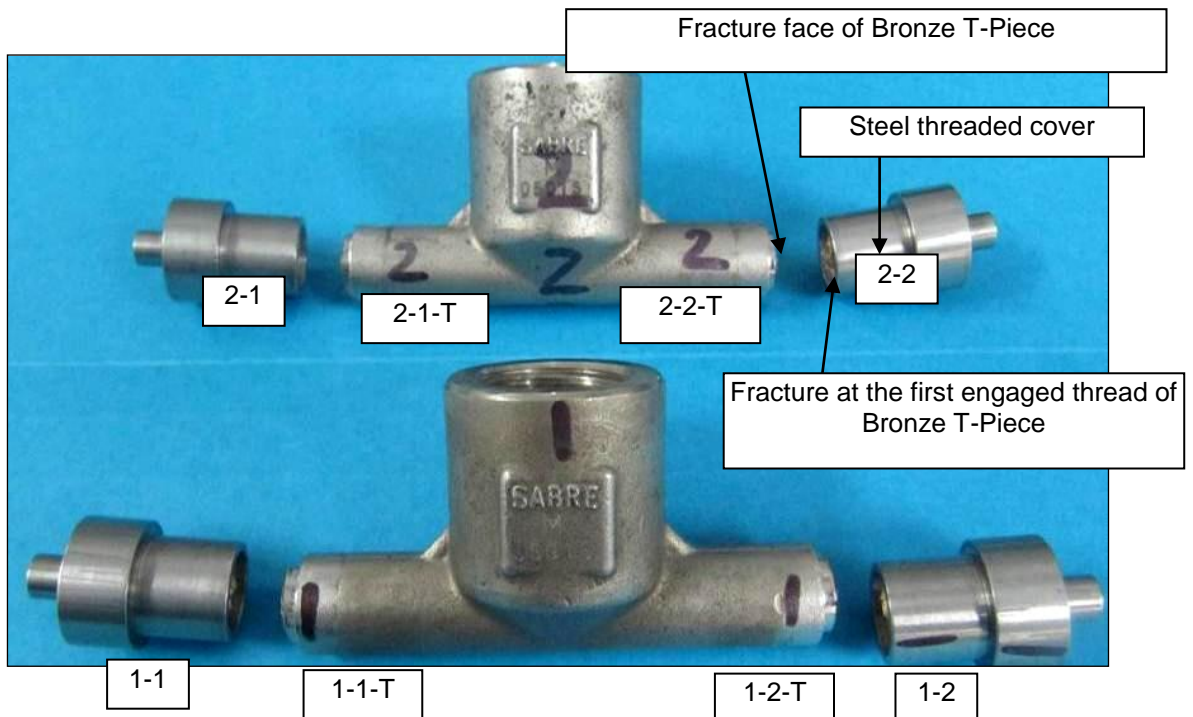


Figure 5- General view of the failed bolt and attached nut as received.

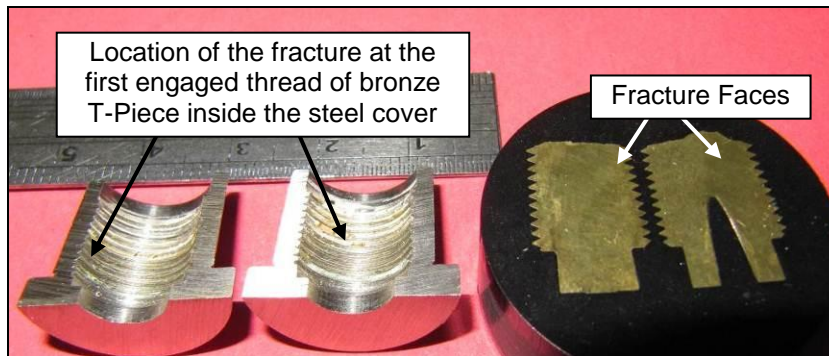


Figure 6- Showing a transverse section through the fractured bronze threaded section, inside the steel cover.

All eight fracture faces were examined by stereo microscope. All fracture faces exhibited a bright cleavage type fracture typical of brittle overload, over approximately 80-95% of the surface; see figures 7-10. No sign of prior cracking was observed.

Samples 1-1, 1-2, 1-2-T, 2-1, 2-1-T exhibited several progressive zones of fracture over the initial 30% of the fracture face, suggesting that the brittle fracture occurred in several stages.. An SEM examination of the fracture face was conducted to determine the fracture mode. There was no evidence of corrosion contributing to the failures of the provided samples.

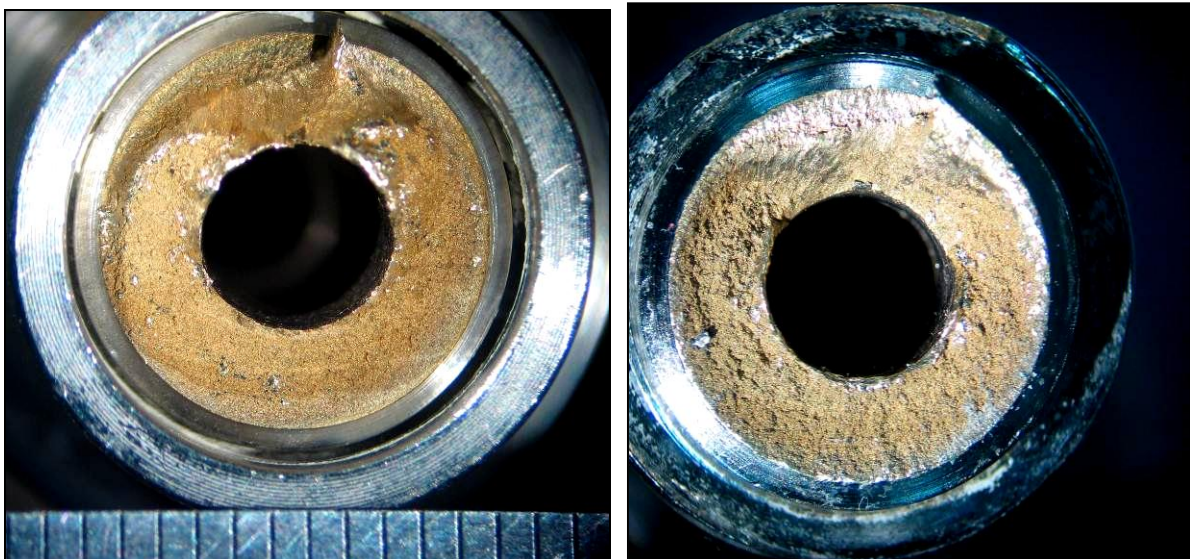


Figure 7- View of sample 1-1(Left) and sample 1-1-T(Right) fracture faces, consistent with brittle fracture over approximately 80% of the cross section followed by a shear lip.

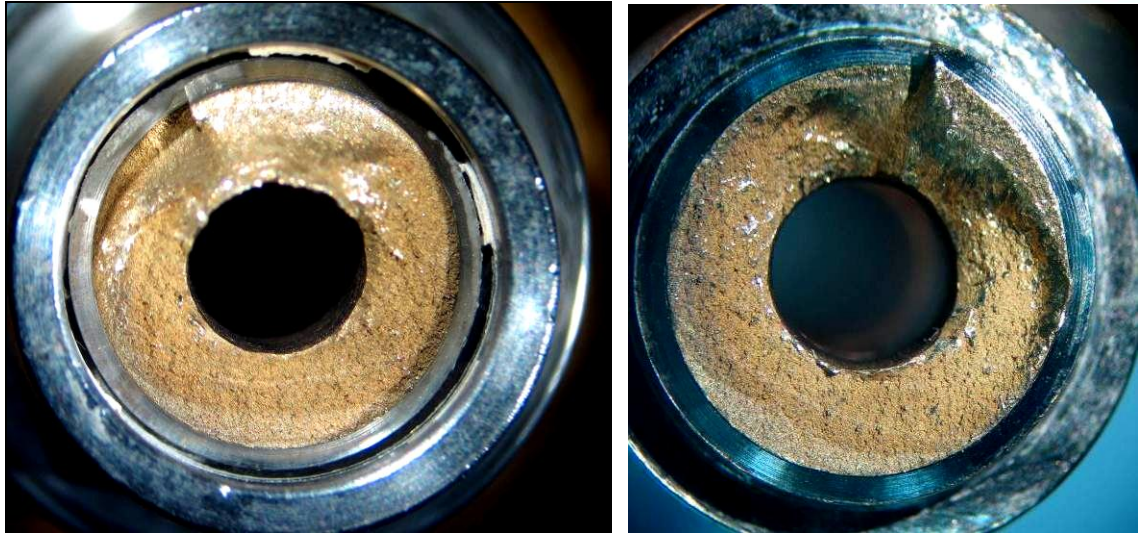


Figure 8- View of sample 1-2(Left) and sample 1-2-T(Right) fracture faces, consistent with brittle fracture over approximately 90% of the cross section followed by a shear lip



Figure 9- View of sample 2-1(Left) and sample 2-1-T (Right) fracture faces, consistent with brittle fracture over approximately 95% of the cross section followed by a shear lip.



Figure 10- View of sample 2-2(Left) and sample 2-2-T (Right) fracture faces, consistent with brittle fracture over approximately 95% of the cross section followed by a shear lip.

2.5. Scanning Electron Microscopy

Secondary Electron Imaging (SEI) of the fracture face on sample 1-2-T, intersecting the region of progressive crack advance revealed a dendritic type fracture surface, see figure 11. No sign of fatigue striations were observed, consistent with the suggestion of crack advance due to brittle fracture in several stages.

A trial fracture was created on a section through T-piece T11/00705/002. The sample was notched with a hacksaw before overloading by impacting the end with a hammer. The fracture face of the trial sample was examined under SEM. The fracture face exhibited a dendritic fracture similar to the original fracture of all T-pieces suggesting that they had also fractured under an overload situation, see figures 11 and 12.

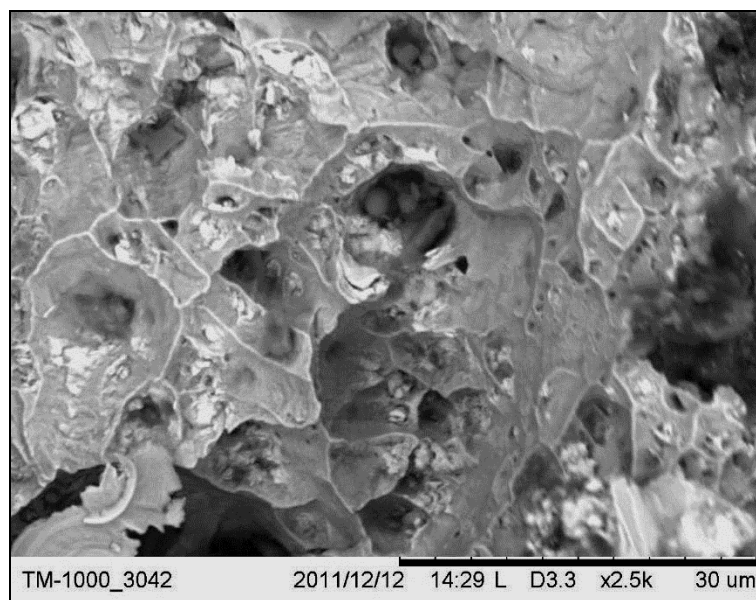


Figure 11- SEM of the original fracture of sample 1-2, fracture face shows dendritic type fracture.

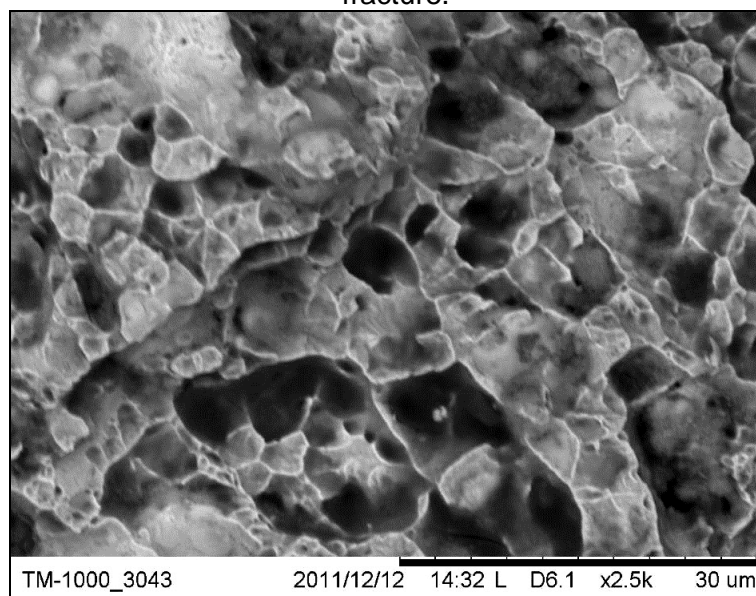


Figure 12- SEM of the fracture face of trial fracture, showing dendritic type fracture.

2.5. Metallography

A section was taken through the longitudinal axis of a fractured T-piece branch, intersecting the fracture. The sample was mounted in Bakelite and prepared for microscopic examination by polishing to a 1 micron finish and etching in acid ferric chloride.

The T-piece sample exhibited a cast structure of alpha and beta (white etching) phases with a surface coating approximately 5µm thick (see Figure 13). A shallow interdendritic crack was present in the thread roots adjacent to the fracture position, see figure 11. No abnormal feature was observed in the microstructure.

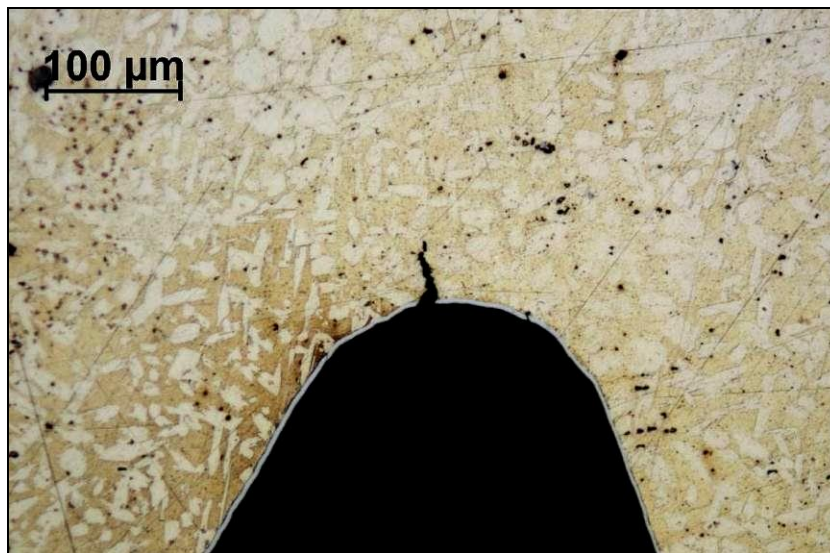


Figure 13- Showing the fractured cross section of the T-piece at the threaded region, exhibited a structure of alpha and beta phases (**Magnification x200, Etchant: Acid Ferric Chloride**).

2.6. EDS (Energy Dispersive Spectroscopy)

A sample of the failed T-piece was analysed by energy dispersive spectroscopy (EDS) using a scanning electron microscope (SEM).

The semi-quantitative EDS chemical analysis results are provided below and suggested that the T-piece had been manufactured from a manganese bronze.

Element	Weight %
Copper	52.8
Zinc	43.2
Manganese	2.4
Iron	1.6

2.4. Hardness

A Vickers hardness test was conducted on a transverse section through the failed T-piece of sample 1-1. The results are presented below.

Hardness (HV10)	Average Hardness (HV10)
132, 126, 119	126

The average hardness of sample 1-1 from the fractured T-piece was measured 126HV10.

3. CONCLUSIONS AND RECOMMENDATIONS

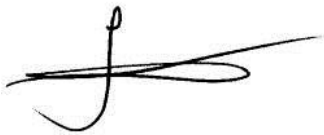
Failure of the examined compressed air breathing apparatus T-pieces at the first engaged thread connection was due to brittle overload. The first engaged thread represents a stress concentration that would be expected to intensify the effects of any shock load imposed on the connector. It was not known how many times the failed units had been used in their nine (9) years service, but assuming regular use the present failures would seem to constitute exposure to higher than normal loading.

No evidence of prior cracking, corrosion or fatigue was found. No internal defect, porosity or any other abnormal feature was observed in the microstructure. The CAB T-pieces had been manufactured from a manganese bronze alloy and exhibited a satisfactory structure with a hardness of 126 HV10.

It is recommended that a periodical visual inspection be carried out on the SCBA units in service to check for cracking.

As the most likely cause for brittle fracture of T-pieces is the improper handling of the backpack, it is recommended that a handling procedure be developed to avoid shock loading.

Some consideration might be given to the use of alternative material such as stainless steel in order to improve the material toughness of the assembly.



Sami Akbari – Investigation Metallurgist
BV Asset Integrity & Reliability Services

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Sample Disposal

Test samples and off cuts of client test samples sent to Bureau Veritas for investigation will be retained in a weather proof area for approximately one month after the issue of this report and for a further two months in external storage before disposal.

If these parts are required by you then you must contact Bureau Veritas to arrange pick up before this term has elapsed.

Appendix 1- Safety alert regarding the failure of two CABA units

SAFETY ALERT

Faulty Sabre CABA units

INCIDENT

Two dual Sabre brand BA Compressed Air Breathing Apparatus (CABA) units were delivered to the Mine Safety Technology Centre for examination. These units are reported to have been abandoned underground during an escape from an incident.

On examination, it was noted that there was flexibility in the T-piece that joins the two compressed air bottles (located near the bottle valves).

On one unit there was an obvious curve in the T-piece between the two bottles.

Both CABA units exhibited flexibility in the T-piece.

It is possible that the T-piece could be stressed every time the equipment is moved or bumped.

A failed T-piece can be easily detected as there are significant air leaks when the unit is operated.



CABA unit showing curved connection - should be straight



CABA unit with T-Piece removed from housing

Mine Safety Report No: SA11-11

ABN 51 734 124 190
www.dpi.nsw.gov.au/minesafety

Prepared by: G. Slater
Phone: 02 4924 4001
Date Created: 24 October 2011



CABA unit showing broken connection

RECOMMENDATIONS

- All mines should check this type of equipment for faults and contact their suppliers for further information.
- Review handling procedures for CABA units.

NOTE: Please ensure all relevant people in your organisation receive a copy of this Safety Alert, and are informed of its content and recommendations. This Safety Alert should be processed in a systematic manner through the mine's information and communication process. It should also be placed on the mine's notice board.

Signed



Rob Regan
DIRECTOR
MINE SAFETY OPERATIONS BRANCH
NSW TRADE & INVESTMENT

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