



National Personal Protective Technology Laboratory

Technology Evaluation Branch

Status Investigation Report of Three
Self-Contained Breathing Apparatus
Submitted by the
Pennsylvania State Fire Academy
Lewistown, Pennsylvania

NIOSH Task No. 14292

May 1, 2007

Disclaimer

The purpose of Respirator Status Investigations is to determine the conformance of each respirator to the NIOSH approval requirements found in Title 42, *Code of Federal Regulations*, Part 84. A number of performance tests are selected from the complete list of Part 84 requirements and each respirator is tested in its “**as received**” condition to determine its conformance to those performance requirements. Each respirator is also inspected to determine its conformance to the quality assurance documentation on file at NIOSH.

In order to gain additional information about its overall performance, each respirator may also be subjected to other recognized test parameters, such as National Fire Protection Association (NFPA) consensus standards. While the test results give an indication of the respirator’s conformance to the NFPA approval requirements, NIOSH does not actively correlate the test results from its NFPA test equipment with those of certification organizations which list NFPA-compliant products. Thus, the NFPA test results are provided for information purposes only.

Selected tests are conducted only after it has been determined that each respirator is in a condition that is safe to be pressurized, handled, and tested. Respirators whose condition has deteriorated to the point where the health and safety of NIOSH personnel and/or property is at risk will not be tested.

Mention of any company or product does not constitute endorsement by NIOSH.

Investigator Information

The SCBA inspection and performance tests were conducted by and this report was written by Vance Kochenderfer, Quality Assurance Specialist, Technology Evaluation Branch, National Personal Protective Technology Laboratory, National Institute for Occupational Safety and Health, located in Bruceton, Pennsylvania.

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Background

As part of the *National Institute for Occupational Safety and Health (NIOSH) Fire Fighter Fatality Investigation and Prevention Program*, the Technology Evaluation Branch agreed to examine and evaluate three Scott 4500 psi, 30-minute, self-contained breathing apparatus (SCBA). The branch also agreed to photograph a set of protective clothing to document its condition, but any further analysis or evaluation of the clothing should be done by an entity with the appropriate experience and capability.

This SCBA status investigation was assigned NIOSH task number 14292. The Pennsylvania State Fire Academy was advised that NIOSH would provide a written report of the inspections and any applicable test results.

Three complete respirators were provided. The SCBA designated as Unit #1 was the unit being worn by the victim of a fatal incident at the fire academy. It and the protective clothing worn by the victim were delivered to the NIOSH facility in Bruceton, Pennsylvania on October 28, 2005. Two additional facepieces were received on November 10, 2005; these were reportedly from the stock of equipment in use at the fire academy. On December 7, 2005, two sets of backframes, pneumatics, and cylinders were received. These were matched with the two facepieces and designated as Units #2 and #3. All of the equipment was taken to the Firefighter SCBA Evaluation Lab in building 108 and stored under lock until the time of the evaluation.

SCBA Inspection

The inspection of Unit #1 was performed on June 27, 2006. The SCBA was inspected by Vance Kochenderfer, Quality Assurance Specialist, of the Technology Evaluation Branch, National Personal Protective Technology Laboratory (NPPTL), NIOSH. The SCBA was examined, component by component, in the condition as received to determine its conformance to the NIOSH-approved configuration. Although a full inspection of Units #2 and #3 was not conducted, their facepieces were evaluated for the sake of comparison. The entire inspection process was videotaped. The SCBA were identified as the Scott Air-Pak Fifty 4.5 model.

The complete SCBA inspection is summarized in **Appendix I**. The condition of each major component of Unit #1 and the facepieces of Units #2 and #3 was also photographed with a digital camera. Images of the SCBA are contained in **Appendix III**.

Unit #1 has been exposed to extreme levels of heat. The most prominent evidence of this is the facepiece lens, the center portion of which has melted and completely separated from the facepiece. Many other plastic, fabric, and elastomeric components of this unit show similarly extreme levels of heat damage. No performance testing of Unit #1 was possible. The facepieces of Units #2 and #3 also showed signs of exposure to high heat levels, although not to the same degree as Unit #1. Both facepieces were damaged to the point where they should be repaired or replaced, but it was determined that Units #2 and #3 could be safely tested.

Personal Alert Safety System (PASS) Device

A Personal Alert Safety System (PASS) device was incorporated into the pneumatics of Unit #1. Like other components of the SCBA, it has suffered severe thermal damage and is not functional.

SCBA Testing

The purpose of the testing was to determine the conformance of Units #2 and #3 to the approval performance requirements of Title 42, *Code of Federal Regulations*, Part 84 (42 CFR 84). Further testing was conducted to provide an indication of the SCBA's conformance to the National Fire Protection Association (NFPA) Air Flow Performance requirements of NFPA 1981, *Standard on Open-Circuit Self-Contained Breathing Apparatus for the Fire Service*, 1997 Edition.

NIOSH SCBA Certification Tests (in accordance with the performance requirements of 42 CFR 84):

1. Positive Pressure Test [§ 84.70(a)(2)(ii)]
2. Rated Service Time Test (duration) [§ 84.95]
3. Static Pressure Test [§ 84.91(d)]
4. Gas Flow Test [§ 84.93]
5. Exhalation Resistance Test [§ 84.91(c)]
6. Remaining Service Life Indicator Test (low-air alarm) [§ 84.83(f)]

National Fire Protection Association (NFPA) Tests (in accordance with NFPA 1981, 1997 Edition):

7. Air Flow Performance Test [Chapter 5, 5-1.1]

Testing was conducted on July 21 and 25, 2006. All testing was videotaped with the exception of the Exhalation Resistance Test and Static Pressure Test. Both SCBA met the requirements of all tests, except that the bell alarm of Unit #2 activated at a higher pressure than that allowed during the Remaining Service Life Indicator Test. This would result in the user receiving an earlier-than-normal warning of cylinder exhaustion.

Appendix II contains the complete NIOSH and NFPA test reports for the SCBA. **Tables One through Four** summarize the NIOSH and NFPA test results.

Protective Clothing

The condition of the victim's turnout coat, bunker pants, and protective hood were documented through a series of digital photographs. These appear in **Appendix III**. An additional shirt which was worn underneath the turnout coat was included and appears in some of the photographs.

Summary and Conclusions

Three SCBA and a set of protective clothing were submitted to NIOSH for evaluation. The SCBA were identified as Scott Air-Pak 4.5 30-minute, 4500 psi, SCBA (NIOSH approval number TC-13F-76). Unit #1 was heavily damaged by heat and is unserviceable. The facepieces of Units #2 and #3 were less severely damaged and it was determined that these SCBA were in a condition safe for testing.

The two SCBA were subjected to a series of seven performance tests on July 21 and 26, 2006. The bell alarm of Unit #2 failed to meet the requirements of the Remaining Service Life Indicator Test; it activated at a higher pressure than that allowed during the test. This would result in the user receiving an earlier-than-normal warning of cylinder exhaustion. The SCBA met the requirements of all other tests.

As detailed in the analysis of **Appendix I**, these SCBA appear to have been exposed to levels of heat in excess of those encountered during normal firefighting operations. During fires in training facilities, consideration should be given to monitoring and controlling both the air temperature and the radiant heat experienced by firefighters to limit the risk to their safety.

In light of the information obtained during this investigation, NPPTL has proposed no further action regarding the approval status of this SCBA model at this time. Following inspection and testing, the SCBA were returned to the packages in which they were received. They were returned to the Pennsylvania State Fire Academy on December 13, 2006.

If Units #2 and #3 are to be placed back in service, they should be repaired, inspected, and tested by a qualified service technician. The facepieces of both units should be repaired or replaced, and the bell alarm of Unit #2 adjusted to within the proper activation range.

Appendix I

SCBA Inspection Report



National Personal Protective Technology Laboratory / Technology Evaluation Branch

Respirator Field Problem
Incoming Inspection Report Summary – Unit #1

Task Number: 14292	Requestor: Pennsylvania State Fire Academy
Date Received: 28 October 2005	
Date Inspected: 27 June 2006	Description: Fatality
Manufacturer: Scott Health & Safety	Inspected by: Vance Kochenderfer
Approval Number: TC-13F-76	SCBA Type: Open Circuit, Pressure-Demand

The SCBA was received in a corrugated cardboard box (refer to **Figures 1 through 3 in Appendix III**).

Components and Observations – Unit #1

NOTE: All references to “right” or “left” are from the user’s perspective.

1. Facepiece (Refer to Figures 4 through 12 in Appendix III):

The facepiece is a Scott AV-2000 facepiece assembly which consists of a black rubber facepiece seal, lens, lens frame, and yellow mesh head harness. It has suffered serious damage as a result of heat exposure, and the portion which was not covered by a protective hood has failed catastrophically.

The central portion of the lens is missing and the edges of the remainder are melted outwards, indicating extremely severe exposure to heat. Bubbles have formed throughout the remaining portion of the lens, and it is blackened in places. The black lens frame is mostly undamaged, although the portion in the chin area is slightly melted. It is likely that this area of the frame was not covered by a protective hood. The frame still securely holds the facepiece seal to the lens.

The facepiece seal is generally in very good condition. Some of the edges which protrude from under the lens frame along the lens are charred, particularly in the chin area. Otherwise, the rubber is pliable and there are no holes, tears, or signs of degradation evident. In the exterior chin area of the seal, “2” and “SCOTT PART 10009779” are molded into the rubber as well as the letter “L,” indicating this is a large size facepiece seal. There is also a circular date code indicating the seal was molded in the **second quarter of 2001**.

The nosecup assembly is not attached to the rest of the facepiece; it remains with the portion of the lens which separated from the facepiece. It is still held partially by the plastic retaining

ring, although this has melted and distorted from exposure to heat. Strings of the melted lens material itself adhere to the nose cup. The nose cup material is pliable and does not appear to be degraded. There is a tear in the seal at the bridge of the nose. Both inhalation valves are shriveled and distorted and no longer function properly. A date code molded into the nose cup interior indicates that it was molded in the **second quarter of 2001**.

Both voicemitter tubes are no longer connected to either the facepiece or nose cup. One still has the voicemitter diaphragm assembly attached along with a portion of the lens. The rubber which is exterior to the lens is charred. The voicemitter diaphragm remains intact. The other voicemitter tube is alone and has charring both on the exterior and on the portion which interfaces with the nose cup.

The yellow mesh head harness fabric is blackened and discolored in places, but remains intact. The harness straps have not retained their elasticity. The ends of the upper strap are charred. This strap remains attached to the adjustment buckles, and these work properly. The lower head harness strap has been cut through in two places. The cut ends are not singed, indicating the strap may have been cut during rescue efforts. The lower strap is not connected to either adjustment buckle. All four head-harness attachment points remain fixed to the lens. The plastic retainer buttons on the attachment points all have bubbling and melting from exposure to heat, and pieces of the protective hood fabric are adhered to the upper two.

2. **Air Pressure Regulator** (Refer to Figures 13 through 18 in Appendix III):

The facepiece-mounted air pressure regulator assembly has been heavily damaged by heat. It is fused to the portion of the facepiece to which it is normally removably attached. The outer regulator cover is melted and flattened, and the donning mechanism lever is absent. Heat has also extremely damaged the inner cover. The walls of the regulator are blistered and distorted, especially at the bottom. The metal demand lever still operates smoothly. The number “**058031**” is marked on the interior of the regulator housing.

Because of melting and distortion of the purge valve operator, the current position of the valve cannot be determined and it cannot be operated. The facepiece latching mechanism is likewise melted and inoperable. The regulator diaphragm is no longer installed in the regulator and the silicone diaphragm is torn and appears slightly charred. The exhalation valve mechanism built into the diaphragm no longer functions and the plastic components have suffered great heat damage.

3. **Regulator Hose** (Refer to Figure 19 in Appendix III):

Most of the low-pressure hose which runs from the air pressure regulator to the pressure reducer is absent. A few inches of hose are attached to the regulator, and approximately 1½ inches of hose extend beyond the backframe assembly. The rubber hose jacket is charred and has burned away in places, exposing the inner reinforcing layers. The crimp ferrule at the end which is attached to the pressure reducer has split.

4. **Air Pressure Reducer** (Refer to Figure 20 in Appendix III):

The metal housing of the air pressure reducer is blackened by soot, but shows no obvious signs of damage. Labels on the rear and side of the housing have been burned beyond recognition, but a label adhered to the front of the reducer reads “MID ATLANTIC FIRE AND AIR” and indicates the unit was serviced in **September 2005**. The ten screws securing the reducer cover plate all appear to be tightened. The reducer is securely attached to the backframe.

5. **Remote Air Pressure Gauge and PASS Device** (Refer to Figures 21 through 23 in Appendix III):

This SCBA is equipped with a remote cylinder air pressure gauge and PASS console. Its plastic housing is severely distorted as the result of heat exposure and the gauge cannot be read. The manual alarm and reset buttons are inoperable.

The sensing line leading from the air pressure reducer assembly to the gauge is covered with a flexible spiral-wound metal sheath. The entire length of the sensing line is flexible and although blackened by soot, shows no obvious damage. The line is not routed through either shoulder strap.

Another line covered by a metal braid runs down to the sensor/alarm housing attached to the lower portion of the backframe. This line is no longer attached to the console or the electronics inside. The sensor/alarm housing is properly situated at the bottom of the backframe. Extensive charring and distortion of the housing prevents removing it from the backframe for closer inspection.

6. **High Pressure Hose and Cylinder Coupling Nut** (Refer to Figures 24 and 25 in Appendix III):

The high pressure hose which leads from the compressed air cylinder to the air pressure reducer has a black rubber jacket. There is cracking and charring of the jacket on the back side, however the front side maintains a normal appearance. The hose assembly turns freely at the reducer.

At the opposite end of the hose is an elbow stamped with the designations “56-99” and “A4Q99.” The cylinder coupling nut turns freely and the interior threads are undamaged and the sealing nipple and o-ring remain intact. The exterior of the cylinder coupling nut is blackened by soot but appears otherwise undamaged.

7. **Backframe and Harness Assembly** (Refer to Figures 26 through 32 in Appendix III):

The SCBA has a “Fifty” style backframe. The metal backplate is intact, but the rubber trim

which is normally present around the center hole in the backframe is no longer attached and is partially burned. Two NIOSH approval labels are affixed to the back side of the backframe; while their plastic coating layer has shriveled and charred, they remain mostly legible and bear the approval numbers **TC-13F-96** and **TC-13F-212**. Two additional NIOSH labels are present on the front of the backframe, and heat and mechanical damage have obscured the approval numbers of both.

The cylinder retaining strap is blackened and appears to have been weakened by heat exposure. The plastic latch mechanism is severely melted and distorted and no longer functions. The cylinder bracket retention mechanism works normally, but the protective rubber tip is missing.

Both shoulder straps are securely fastened to the backframe at the top. The webbing is blackened, and the fabric components of each are severely charred and damaged. Both length adjustment straps are cut; it appears likely that this was done during rescue operations as the cut edges are not singed. Otherwise, the webbing remains intact and is securely fastened at the bottom to the backframe. Both adjustment buckles operate properly.

The waistbelt fabric is discolored on the side which contacts the wearer, and charred on the opposite side. The webbing portions of the waistbelt are blackened and appear to have been weakened by heat exposure although they remain intact. Attached to the left adjustment strap are a regulator storage point and the female half of the seat belt buckle. The edges of the storage point are melted. The male half of the buckle is attached to the right adjustment strap and the buckle couples and releases easily. Both length adjustment buckles operate smoothly.

8. Compressed Air Cylinder (Refer to Figures 33 through 40 in Appendix III):

The cylinder is a fully-wound composite type. Almost the entire exterior surface of the cylinder is blackened. There is evidence of heat damage to the outer epoxy layer on the dome end opposite the valve, although heat has not caused the underlying fiber reinforcement to become exposed. There are, however, a number of scratches on the back sidewall of the cylinder; discussion indicates that this likely occurred during rescue operations. There are no labels visible on the cylinder exterior, although the serial number “**90153**” is stamped into the neck.

The cylinder valve outlet threads appear undamaged. The locking-type valve handwheel was found to be fully closed and it operates properly. The valve body is blackened with soot. There is no visibility through the gauge lens on the front side; on the back side it can be seen that the gauge has a range of 4500 psi, but the gauge pointer is not visible. Upon opening the valve, the cylinder was found to be empty. The rubber end bumper is severely charred. The cylinder mounting bracket is intact and securely fastened to the valve with three screws. A burst disc assembly is installed in the valve.



National Personal Protective Technology Laboratory / Technology Evaluation Branch

Respirator Field Problem
Incoming Inspection Report Summary – Unit #2

Task Number: 14292	Requestor: Pennsylvania State Fire Academy
Date Received: 28 October 2005	
Date Inspected: 28 June 2006	Description: Uninvolved unit
Manufacturer: Scott Health & Safety	Inspected by: Vance Kochenderfer
Approval Number: TC-13F-76	SCBA Type: Open Circuit, Pressure-Demand

The facepiece was received in a corrugated cardboard box (refer to **Figures 41 and 42 in Appendix III**).

Components and Observations – Unit #2

NOTE: All references to “right” or “left” are from the user’s perspective.

1. Facepiece (Refer to Figures 43 through 46 in Appendix III):

The facepiece is a Scott AV-2000 facepiece assembly which consists of a black rubber facepiece seal, lens, lens frame, and yellow mesh head harness. Except for the lens, overall the facepiece appears to be in very good condition.

The hard coating on the facepiece lens exterior is crazed, indicating heat exposure. Bubbles have formed across the surface of the lens, although it is not clear whether these are in the coating or in the lens material itself. The lens is slightly deformed from its typical shape. There is a significant amount of soot on the exterior, particularly around the voicemitters and the regulator attachment point. The interior surface of the lens is mostly clean and has no visible scratches. Visibility through the lens is poor. There is a property label on the exterior chin area of the lens. The black lens frame is in very good to excellent condition and is tightly fitted to the facesal. There are no gaps between the frame and the facesal or between the lens and the facesal. The plastic retainer button on the top center attachment of the frame to the lens is bubbled and distorted from exposure to heat.

The facepiece seal is in very good to excellent condition. The rubber is pliable and there are no holes, tears, or degradation evident. In the exterior chin area of the seal, “1” and “SCOTT PART 10009779” are molded into the rubber as well as the letter “L,” indicating this is a large size facesal. There is also a date code indicating the seal was molded in the **second quarter of 2001**.

There is a noseclip assembly installed in the facepiece. The plastic retaining ring which normally holds the noseclip to the facepiece is absent. The noseclip is properly connected to both voicemitter ducts. There is a small gouge in the noseclip where it contacts the bridge of the wearer's nose, but otherwise it appears undamaged. Two inhalation valves are installed; the edges of these are curled so that they no longer lie flat. A date code molded into the noseclip interior indicates that it was molded in the **second quarter of 2001**.

The yellow mesh head harness is slightly dirty and worn, but has no cuts, tears, or other apparent damage. The upper harness strap has lost most of its elasticity, and the bottom strap retains none. The mesh fabric and straps are very pliable, and the four adjustment buckles operate smoothly. The head harness is secured to the facepiece assembly at four attachment points. All four attachment posts are firmly attached to the facepiece assembly. The two upper attachment assemblies in the temple regions include red, foam-rubber, anti-rotation washers. The plastic retainer buttons on the upper left and right attachment points are shiny and the surface of the plastic appears to have undergone some melting.

The two voicemitters and voicemitter ducts appear to be properly installed and undamaged. The voicemitter diaphragms as seen from inside the facepiece are clean and shiny.



National Personal Protective Technology Laboratory / Technology Evaluation Branch

Respirator Field Problem
Incoming Inspection Report Summary – Unit #3

Task Number: 14292	Requestor: Pennsylvania State Fire Academy
Date Received: 28 October 2005	
Date Inspected: 28 June 2006	Description: Uninvolved unit
Manufacturer: Scott Health & Safety	Inspected by: Vance Kochenderfer
Approval Number: TC-13F-76	SCBA Type: Open Circuit, Pressure-Demand

The facepiece was received in a corrugated cardboard box (refer to **Figures 41 and 42 in Appendix III**).

Components and Observations – Unit #3

NOTE: All references to “right” or “left” are from the user’s perspective.

1. Facepiece (Refer to Figures 47 through 50 in Appendix III):

The facepiece is a Scott AV-2000 facepiece assembly which consists of a black rubber facepiece seal, lens, lens frame, and yellow mesh head harness. Except for the lens, overall the facepiece appears to be in very good condition.

The hard coating on the facepiece lens exterior is crazed, indicating heat exposure slightly worse than that of Unit #2. Bubbles have formed across the surface of the lens, although it is not clear whether these are in the coating or in the lens material itself. The lens does not appear to be obviously deformed or distorted. There is a significant amount of soot on the exterior, particularly around the voicemitters and the regulator attachment point. The interior surface of the lens is mostly clean and has no visible scratches. Visibility through the lens is poor. There is a property label on the exterior chin area of the lens. The black lens frame is in very good to excellent condition and is tightly fitted to the faceseal. There are no gaps between the frame and the faceseal or between the lens and the faceseal. All three of the plastic retainer buttons of the lens frame/head harness attachment points across the top of the lens are bubbled and distorted from exposure to heat.

The facepiece seal is in very good to excellent condition. The rubber is pliable and there are no holes, tears, or degradation evident. In the exterior chin area of the seal, “2” and “SCOTT PART 10009779” are molded into the rubber as well as the letter “L,” indicating this is a large size faceseal. There is also a date code indicating the seal was molded in the **second quarter of 2001**.

There is a nose cup assembly installed in the facepiece. It is firmly attached to the facepiece assembly with a retaining ring and is properly connected to both voicemitter ducts. The nose cup material is pliable, has no holes or tears, and is in excellent condition. Two inhalation valves are installed; the edges of these are curled so that they no longer lie flat. A date code molded into the nose cup interior indicates that it was molded in the **second quarter of 2001**.

The yellow mesh head harness is slightly dirty and worn, but has no cuts, tears, or other apparent damage. The upper harness strap retains most of its elasticity, and the bottom strap has lost most of its. The mesh fabric and straps are very pliable, and the four adjustment buckles operate smoothly. The head harness is secured to the facepiece assembly at four attachment points. All four attachment posts are firmly attached to the facepiece assembly. The two upper attachment assemblies in the temple regions include red, foam-rubber, anti-rotation washers.

The two voicemitters and voicemitter ducts appear to be properly installed and undamaged. The voicemitter diaphragms as seen from inside the facepiece are clean and shiny.



National Personal Protective Technology Laboratory / Technology Evaluation Branch

Respirator Field Problem **Analysis**

Many components of Unit #1 have suffered severe damage from exposure to heat. The most obvious result is the extensive damage to the facepiece lens. The lens is molded from polycarbonate, which has a glass transition temperature in the range of 145-150°C (293-302°F) [Beyler and Hirschler 1995]. The glass transition temperature is the point where a thermoplastic material changes from a rigid state to a soft, rubbery state. At even higher temperatures, the material enters the melting region and begins to flow. Plastics with a low degree of crystallinity like polycarbonate melt along a relatively broad temperature range and do not have a single, well-defined melting point. The melting temperature can also be modified by differences in composition and various additives used to modify properties (such as flame resistance) of the material. For one commercially-available grade of optical-quality polycarbonate, a melt temperature of 299-316°C (570-600°F) is typically recommended for injection molding [Bayer 2002].

The lens material of the Unit #1 facepiece appears to have reached temperatures at least this high and possibly quite a bit higher. This is supported by the charring of the voicemitter tubes made of polychloroprene rubber (Neoprene), which begins to decompose around 342°C (647°F) [Beyler and Hirschler 1995]. The polycarbonate buttons on the two upper head-harness attachment points were covered by the protective hood, as were portions of the lens. These components appear to have been heated well in excess of the glass transition temperature but did not reach melting temperature.

If the Unit #2 and #3 facepieces are typical of those in use at the fire academy, the damage to the coatings of the lenses is an indicator that thermal conditions beyond the equipment's designed range are reached in training scenarios there. In particular, the distortion of the Unit #2 facepiece lens shows that it has reached temperatures beyond the glass transition point.

One approach to limit the danger to individuals and damage to equipment would be to monitor the room air temperature during training and employ countermeasures when this becomes too high. Because of the complex nature of fire dynamics, it is likely that a single temperature measurement cannot fully assess the hazard to the individuals involved. Multiple thermocouples and/or radiant heat flux sensors may be necessary to avoid unnecessary risk. One study conducted in a firefighting training facility found that radiant heat intensities were often higher than the commonly-anticipated values for the air temperature encountered [Rossi 2003]. Anecdotal evidence based on inquiries directed to NIOSH over time tends to support the notion that heat damage to equipment occurs more frequently during training and flashover simulation situations than during fires in ordinary structures. Monitoring or controlling only the ambient air temperature in a training situation without accounting for radiant heat loads may result in injury or equipment failure.

References

Bayer MaterialScience [2002]. MAKROLON LQ3187 Product Information Bulletin, October 2002. [<http://www.bayermaterialsciencenafta.com/resources/d/document.cfm?Mode=view&f=13F00037-E0C4-6D2A-E45AA7C274ABEA9F&d=14B42F5C-9A2D-43D1-B4FDAE00567895A2>]. Date accessed: October 2006.

Beyler CL and Hirschler MM [1995]. Thermal Decomposition of Polymers. In: DiNenno PJ *et al.*, eds. *SFPE Handbook of Fire Protection Engineering*, 2nd Edition. Quincy, MA: National Fire Protection Association, pp. 1-99 to 1-119.

Rossi R [2003]. Fire fighting and its influence on the body. *Ergonomics* 46(10): 1017–1033.

Appendix II

SCBA Test Results



National Personal Protective Technology Laboratory / Technology Evaluation Branch

SCBA Test Report

Task Number: 14292
Manufacturer: Scott Health & Safety
NIOSH Approval Number: TC-13F-76
Tests Performed by: Vance Kochenderfer
Date of Report: May 1, 2007

I. Background

Three self-contained breathing apparatus (SCBA) were provided to NIOSH for evaluation. Inspection was performed on June 27-28, 2006, and two of the SCBA, designated Units #2 and #3, were found to be in a condition where they could be safely pressurized and tested. It was determined that the SCBA were manufactured by Scott Health & Safety under NIOSH approval number TC-13F-76. A series of performance tests was conducted on the SCBA on July 21 and 25, 2006. All performance tests, with the exception of the Exhalation Resistance Test and Static Pressure Test, were videotaped. The Positive Pressure Test and Rated Service Time Test are conducted simultaneously.

II. Test Outlines

A. POSITIVE PRESSURE TEST – NIOSH Test Procedure No. 120 **42 CFR Part 84 Reference:** Subpart H, § 84.70 (a)(2)(ii)

Requirement:

The pressure inside the facepiece in relation to the immediate environment is positive during both inhalation and exhalation.

Procedure:

A breathing machine with a 622 kg.-m./min. cam operating at 24 RPM with a 40-liter per minute flow rate (115 liters per minute peak flow) is connected to an anthropometric head for cycling. A pressure tap in the head is connected to a transducer which in turn is connected to a strip chart recorder for determining the pressure in the facepiece.

Results for Unit #2 – Tested on July 21, 2006 with SCBA in as-received condition.

The inhalation portion of the breathing curve remained above ambient throughout the rated service time test. The SCBA met the test requirement.

Inhalation Breathing Resistance: **0.15** INWC

Results for Unit #3 – Tested on July 25, 2006 with SCBA in as-received condition.

The inhalation portion of the breathing curve remained above ambient throughout the rated service time test. The SCBA met the test requirement.

Inhalation Breathing Resistance: **0.20** INWC

B. RATED SERVICE TIME TEST – NIOSH Test Procedure No. 121

42 CFR Part 84 Reference: Subpart F, § 84.53 (a) and Subpart H, § 84.95 (a) and (b)

Requirement:

Service time will be measured while the apparatus is operated by a breathing machine as described in § 84.88. The open-circuit apparatus will be classified according to the length of time it supplies air or oxygen to the breathing machine. Classifications are listed in § 84.53.

Procedure:

A breathing machine with a 622 kg.-m./min. cam operating at 24 RPM with a 40 liters per minute flow rate is connected to an anthropometric head for cycling. A pressure tap in the head is connected to a transducer which in turn is connected to a strip chart recorder for determining the pressure in the facepiece. The breathing machine is run until the inhalation portion of the breathing curve falls below the minimum requirement.

Results for Unit #2 – Tested on July 21, 2006 with SCBA in as-received condition.

The measured service time (adjusted to correspond with the recorded breathing cycles) was greater than the rated service time of 30 minutes. The SCBA met the test requirement.

Measured Service Time: **33** Minutes **47** Seconds

Results for Unit #3 – Tested on July 25, 2006 with SCBA in as-received condition.

The measured service time (adjusted to correspond with the recorded breathing cycles) was greater than the rated service time of 30 minutes. The SCBA met the test requirement.

Measured Service Time: **34** Minutes **00** Seconds

Comment:

On Unit #2, the bell which serves as a remaining service life indicator initially activated at 22:52 then stopped at 25:09. It began to sound again erratically at 25:40, then by 26:00 sounded fully and regularly and continued that way until the end of the test.

C. STATIC PRESSURE TEST – NIOSH Test Procedure No. 122

42 CFR Part 84 Reference: Subpart H, § 84.91 (d)

Requirement:

The static pressure (at zero flow) in the facepiece shall not exceed 38 mm. (1.5 inches) water-column height.

Procedure:

The facepiece is fitted to an anthropometric head for testing. A pressure tap in the head is connected to a calibrated manometer. Full cylinder pressure is applied to the unit at zero flow and a reading from the manometer is recorded.

Results for Unit #2 – Tested on July 25, 2006 with SCBA in as-received condition.

The SCBA met the NIOSH requirement for static facepiece pressure.

Facepiece Static Pressure: 0.80 INWC

Results for Unit #3 – Tested on July 25, 2006 with SCBA in as-received condition.

The SCBA met the NIOSH requirement for static facepiece pressure.

Facepiece Static Pressure: 1.00 INWC

D. GAS FLOW TEST – NIOSH Test Procedure No. 123

42 CFR Part 84 Reference: Subpart H, § 84.93 (b) and (c)

Requirement:

The flow from the apparatus shall be greater than 200 liters per minute when the pressure in the facepiece of demand apparatus is lowered by 51 mm. (2 inches) water column height when full container pressure is applied. Where pressure demand apparatus are tested, the flow will be measured at zero gage pressure in the facepiece.

Procedure:

A pressure tap in the anthropometric head is connected to a manometer for determining when the pressure inside the facepiece is at zero. A mass flow meter is connected in line between the anthropometric head and an adjustable vacuum source to measure flow. The SCBA cylinder is replaced by a test stand which is adjusted initially to full cylinder

pressure. The vacuum source is adjusted during the test to maintain the desired pressure inside the facepiece. Once the proper facepiece pressure has stabilized, a flow reading is recorded. The procedure is then repeated with the test stand adjusted to 500 psig.

Results for Unit #2 – Tested on July 21, 2006 with SCBA in as-received condition.

The SCBA achieved the required flow rate at both test points. At a supply pressure of 4500 psig, the flow was greater than could be measured by the test equipment.

Applied pressure	Flow
4500 psig	> 459 liters per minute
500 psig	297 liters per minute

Results for Unit #3 – Tested on July 25, 2006 with SCBA in as-received condition.

The SCBA achieved the required flow rate at both test points. At a supply pressure of 4500 psig, the flow was greater than could be measured by the test equipment.

Applied pressure	Flow
4500 psig	> 450 liters per minute
500 psig	278 liters per minute

E. EXHALATION RESISTANCE TEST – NIOSH Test Procedure No. 122

42 CFR Part 84 Reference: Subpart H, § 84.91 (c)

Requirement:

The exhalation resistance of pressure-demand apparatus shall not exceed the static pressure in the facepiece by more than 51 mm. (2 inches) water-column height.

Procedure:

The facepiece is mounted on an anthropometric head form. A probe in the head form is connected to a slant manometer for measuring exhalation breathing resistance. The air flow through the apparatus is adjusted to a rate of 85 liters per minute and the exhalation resistance is recorded.

Results for Unit #2 – Tested on July 25, 2006 with SCBA in as-received condition.

The difference between the exhalation breathing resistance and static pressure for the SCBA fell within the NIOSH required range.

Exhalation Breathing Resistance:	2.20	INWC
Static Pressure:	0.80	INWC
Difference:	1.40	INWC

Results for Unit #3 – Tested on July 25, 2006 with SCBA in as-received condition.

The difference between the exhalation breathing resistance and static pressure for the SCBA fell within the NIOSH required range.

Exhalation Breathing Resistance:	2.35	INWC
Static Pressure:	1.00	INWC
Difference:	1.35	INWC

F. REMAINING SERVICE LIFE INDICATOR TEST – NIOSH Test Procedure No. 124
42 CFR Part 84 Reference: Subpart H, § 84.83 (f) and Subpart G, § 84.63 (c)

Requirement:

Each remaining service life indicator or warning device shall give an alarm when the remaining service life of the apparatus is reduced within a range of 20 to 25 percent of its rated service time or pressure.

This requirement is modified under § 84.63(c) as follows: *For apparatus which do not have a method of manually turning off remote gage in the event of a gage or gage line failure the remaining service life indicator is required to be set at 25% ± 2% of the rated service time or pressure.*

Procedure:

A calibrated gauge is connected in line between the air supply and the first-stage regulator. The unit is then allowed to gradually bleed down. When the low-air alarm is activated, the pressure on the gauge is recorded. This procedure is repeated six times. The average of the six readings is calculated and recorded.

Results for Unit #2 – Tested on July 21, 2006 with SCBA in as-received condition. As this SCBA does not have a remote gage shutoff, the test requirement is 25% ± 2%.

This SCBA contains a bell and a vibrating alarm as the remaining service life indicators. The bell alarm **did not** activate within the required range (between 1035 and 1215 psig). The vibrating alarm activated within the required range.

Run #	Bell Alarm Point (psig)	Vibrating Alarm Point (psig)
1.	1345	1070
2.	1345	1075
3.	1340	1075
4.	1345	1080
5.	1340	1070
6.	1345	1075
Avg.	1343	1074

Results for Unit #2 – Tested on July 25, 2006 with SCBA in as-received condition. As this SCBA does not have a remote gauge shutoff, the test requirement is 25% ± 2%.

This SCBA contains a vibrating alarm as the remaining service life indicator. The vibrating alarm activated within the required range (between 1035 and 1215 psig).

Run #	Alarm Point (psig)
1.	1125
2.	1120
3.	1115
4.	1120
5.	1115
6.	1115
Avg.	1118

G. NFPA AIR FLOW PERFORMANCE TEST

NFPA 1981 (1997 Edition) Reference: Chapter 5, Performance Requirements, Sec. 5-1.1

Requirement:

SCBA shall be tested for air flow performance as specified in Section 6-1, Air Flow Performance Test, and the SCBA facepiece pressure shall not be less than 0.0 in. (0.0 mm) water column and nor greater than 3½ in. (89 mm) water column above ambient pressure from the time the test begins until the time the test is concluded.

Procedure:

A breathing machine as specified in Section 6-1.12 operating at 30 ± 1 breaths/min with a 103 ± 3 L/min flow rate is connected to an anthropometric head for cycling. A pressure tap in the head is connected to a transducer which in turn is connected to a flatbed chart recorder for determining the pressure in the facepiece.

Results for Unit #2 – Tested on July 21, 2006 with SCBA in as-received condition.

The facepiece pressure remained between 0.0 and 3.5 INWC throughout the entire test. The SCBA met the NFPA test requirements.

Maximum Facepiece Pressure:	2.60	INWC
Minimum Facepiece Pressure:	0.30	INWC

Results for Unit #3 – Tested on July 25, 2006 with SCBA in as-received condition.

The facepiece pressure remained between 0.0 and 3.5 INWC throughout the entire test. The SCBA met the NFPA test requirements.

Maximum Facepiece Pressure:	2.50	INWC
Minimum Facepiece Pressure:	0.55	INWC

III. Disposition:

Following testing, the SCBA were returned to the packages in which they were provided to NIOSH. They were returned to the Pennsylvania State Fire Academy on December 13, 2006.

The results of all tests are summarized in Tables One through Four which follow.

TABLE ONE – Summary of NIOSH Test Results – Unit #2

Task Number: 14292
Manufacturer: Scott Health & Safety
NIOSH Approval Number: TC-13F-76
Tests Performed By: Vance Kochenderfer
Dates of Tests: July 21 and 25, 2006

TEST / 42 CFR PART 84 REFERENCE	STANDARD	RESULT	PASS	FAIL
A. POSITIVE PRESSURE TEST Reference: Subpart H, § 84.70 (a)(2)(ii)	> 0.00 INWC	0.15 INWC	X	
B. RATED SERVICE TIME TEST Reference: Subpart F, § 84.53 (a), Subpart H, § 84.95 (a) and (b)	≥ 30 min.	33 min, 47 s	X	
C. STATIC PRESSURE TEST Reference: Subpart H, § 84.91 (d)	≤ 1.50 INWC	0.80 INWC	X	
D. GAS FLOW TEST (at Full Cylinder Pressure) Reference: Subpart H, § 84.93 (b) and (c)	≥ 200 lpm	> 459 lpm	X	
D. GAS FLOW TEST (at 500 psig) Reference: Subpart H, § 84.93 (b) and (c)	≥ 200 lpm	297 lpm	X	
E. EXHALATION RESISTANCE TEST Reference: Subpart H, § 84.91 (c)	Difference ≤ 2.00 INWC	1.40 INWC	X	
F. REMAINING SERVICE LIFE INDICATOR TEST (bell alarm) Reference: Subpart H, § 84.83 (f) and Subpart G, § 84.63 (c)	Between 1035 and 1215 psig	1343 psig		X
F. REMAINING SERVICE LIFE INDICATOR TEST (vibrating alarm) Reference: Subpart H, § 84.83 (f) and Subpart G, § 84.63 (c)	Between 1035 and 1215 psig	1074 psig	X	

NOTE: The Positive Pressure Test and Rated Service Life Test are run simultaneously.

TABLE TWO – Summary of NFPA Test Results – Unit #2

TEST / REFERENCE	STANDARD	RESULT	PASS	FAIL
G. NFPA AIR FLOW PERFORMANCE Reference: NFPA 1981 (1997 Edition), Section 5-1.1	≤ 3.50 INWC Exhalation Resistance	2.60 INWC	X	
G. NFPA AIR FLOW PERFORMANCE Reference: NFPA 1981 (1997 Edition), Section 5-1.1	≥ 0.00 INWC Inhalation Resistance	0.30 INWC	X	

TABLE THREE – Summary of NIOSH Test Results – Unit #3

Task Number: 14292
Manufacturer: Scott Health & Safety
NIOSH Approval Number: TC-13F-76
Tests Performed By: Vance Kochenderfer
Dates of Tests: July 25, 2006

TEST / 42 CFR PART 84 REFERENCE	STANDARD	RESULT	PASS	FAIL
A. POSITIVE PRESSURE TEST Reference: Subpart H, § 84.70 (a)(2)(ii)	> 0.00 INWC	0.20 INWC	X	
B. RATED SERVICE TIME TEST Reference: Subpart F, § 84.53 (a), Subpart H, § 84.95 (a) and (b)	≥ 30 min.	34 min, 00 s	X	
C. STATIC PRESSURE TEST Reference: Subpart H, § 84.91 (d)	≤ 1.50 INWC	1.00 INWC	X	
D. GAS FLOW TEST (at Full Cylinder Pressure) Reference: Subpart H, § 84.93 (b) and (c)	≥ 200 lpm	> 450 lpm	X	
D. GAS FLOW TEST (at 500 psig) Reference: Subpart H, § 84.93 (b) and (c)	≥ 200 lpm	278 lpm	X	
E. EXHALATION RESISTANCE TEST Reference: Subpart H, § 84.91 (c)	Difference ≤ 2.00 INWC	1.35 INWC	X	
F. REMAINING SERVICE LIFE INDICATOR TEST Reference: Subpart H, § 84.83 (f) and Subpart G, § 84.63 (c)	Between 1035 and 1215 psig	1118 psig	X	

NOTE: The Positive Pressure Test and Rated Service Life Test are run simultaneously.

TABLE FOUR – Summary of NFPA Test Results – Unit #3

TEST / REFERENCE	STANDARD	RESULT	PASS	FAIL
G. NFPA AIR FLOW PERFORMANCE Reference: NFPA 1981 (1997 Edition), Section 5-1.1	≤ 3.50 INWC Exhalation Resistance	2.50 INWC	X	
G. NFPA AIR FLOW PERFORMANCE Reference: NFPA 1981 (1997 Edition), Section 5-1.1	≥ 0.00 INWC Inhalation Resistance	0.55 INWC	X	

Appendix III

Images



National Personal Protective Technology Laboratory / Technology Evaluation Branch

IMAGES

Three Self-Contained Breathing Apparatus
Submitted by the Pennsylvania State Fire Academy
Lewistown, Pennsylvania

NIOSH Task No. 14292

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Figure 48: Visibility through Unit #3 Facepiece

Figure 49: Crazing of Unit #3 Lens Coating

Figure 50: Unit #3 Nosecup Inhalation Valves

Figure 51: Turnout Gear in Package Received
from the Pennsylvania State Fire
Academy

Figure 52: Label on Bunker Pants

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Figure 55: Rear View of Bunker Pants

Figure 56: Right Knee of Bunker Pants

Figure 57: Left Ankle of Bunker Pants

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Figure 59: Turnout Coat and Hood in Package

Figure 60: Label on Protective Hood

Figure 61: Plastic Adhered to Collar of Turnout
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Figure 65: Shirt and Interior of Turnout Coat

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Figure 69: Damage to Moisture Barrier of
Turnout Coat

Figure 70: Rear View of Turnout Coat

Figure 71: Rear View of Turnout Coat Hem

Figure 72: Rear View of Turnout Coat Upper
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Figure 1 – Unit #1 as Received from the Pennsylvania State Fire Academy



Figure 2 – Unit #1 in Package



Figure 3 – Unit #1 Removed from Package



Figure 4 – Unit #1 Facepiece



Figure 5 – Side View of Unit #1 Facepiece



Figure 6 – Bottom View of Unit #1 Facepiece



Figure 7 – Unit #1 Head Harness Attachment Point



Figure 8 – Unit #1 Nosecup



Figure 9 – Unit #1 Nosecup Inhalation Valves



Figure 10 – Unit #1 Voicemitter and Tube



Figure 11 – Side View of Unit #1 Voicemitter and Tube



Figure 12 – Unit #1 Voicemitter Tube



Figure 13 – Unit #1 Regulator with Nosecup and Portion of Lens



Figure 14 – Unit #1 Regulator Body



Figure 15 – Unit #1 Regulator Outer Cover



Figure 16 – Unit #1 Regulator Inner Cover



Figure 17 – Unit #1 Regulator Diaphragm



Figure 18 – Rear View of Unit #1 Regulator Diaphragm



Figure 19 – Unit #1 Low Pressure Hose



Figure 20 – Unit #1 Pressure Reducer

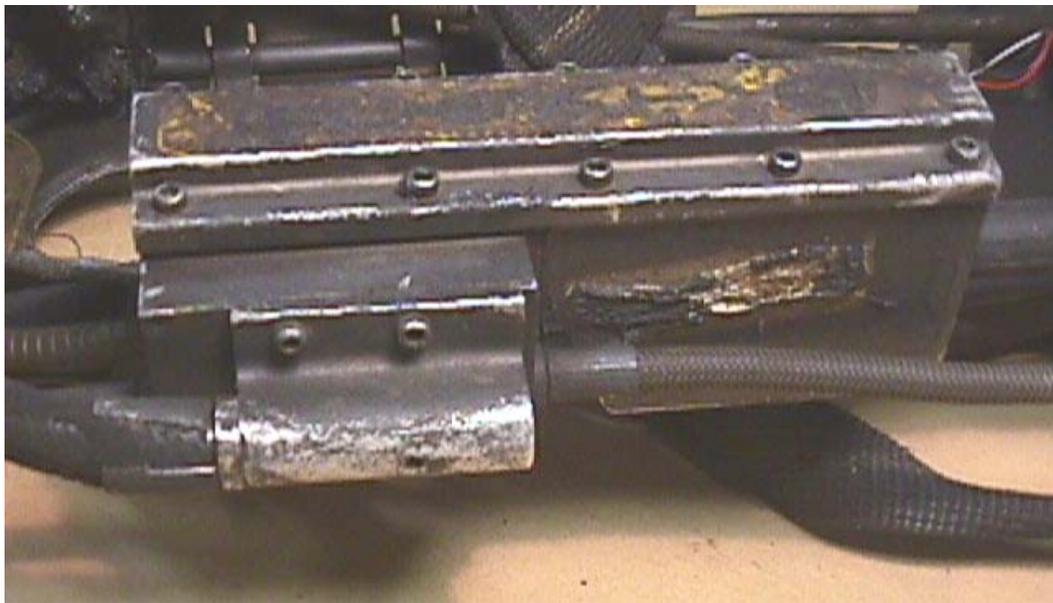


Figure 21 – Unit #1 Remote Pressure Gauge/PASS Console



Figure 22 – Rear View of Unit #1 Remote Pressure Gauge/PASS Console



Figure 23 – Unit #1 PASS Sensor Module



Figure 24 – Unit #1 High Pressure Hose

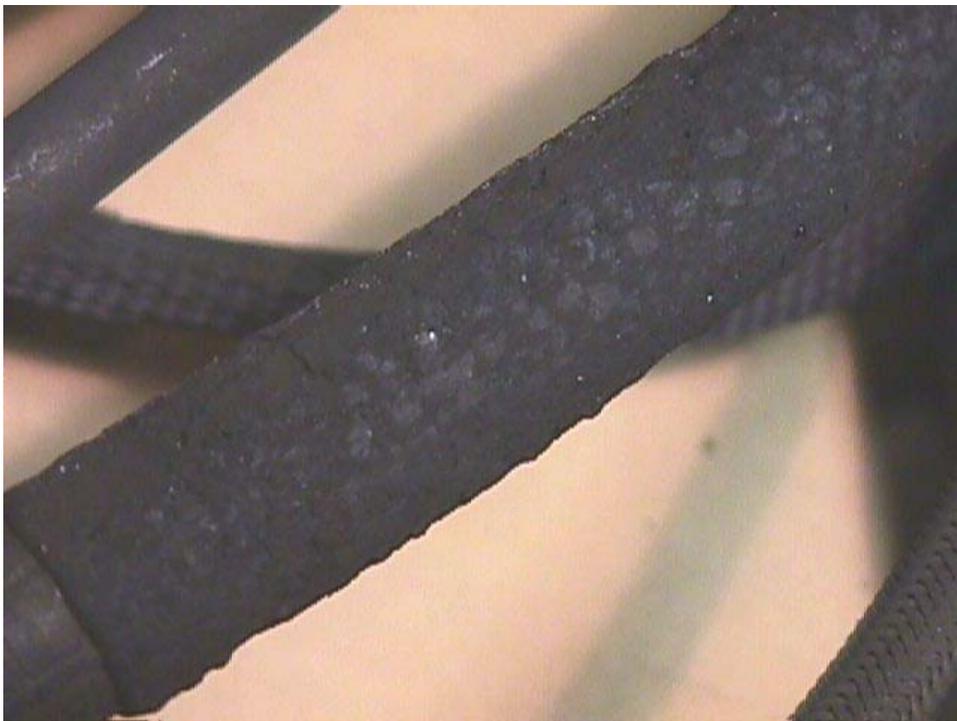


Figure 25 – Unit #1 Cylinder Connector Nut



Figure 26 – Unit #1 Backframe



Figure 27 – Unit #1 NIOSH Approval Labels on Back Side of Backframe



Figure 28 – Unit #1 NIOSH Approval Labels on Front Side of Backframe

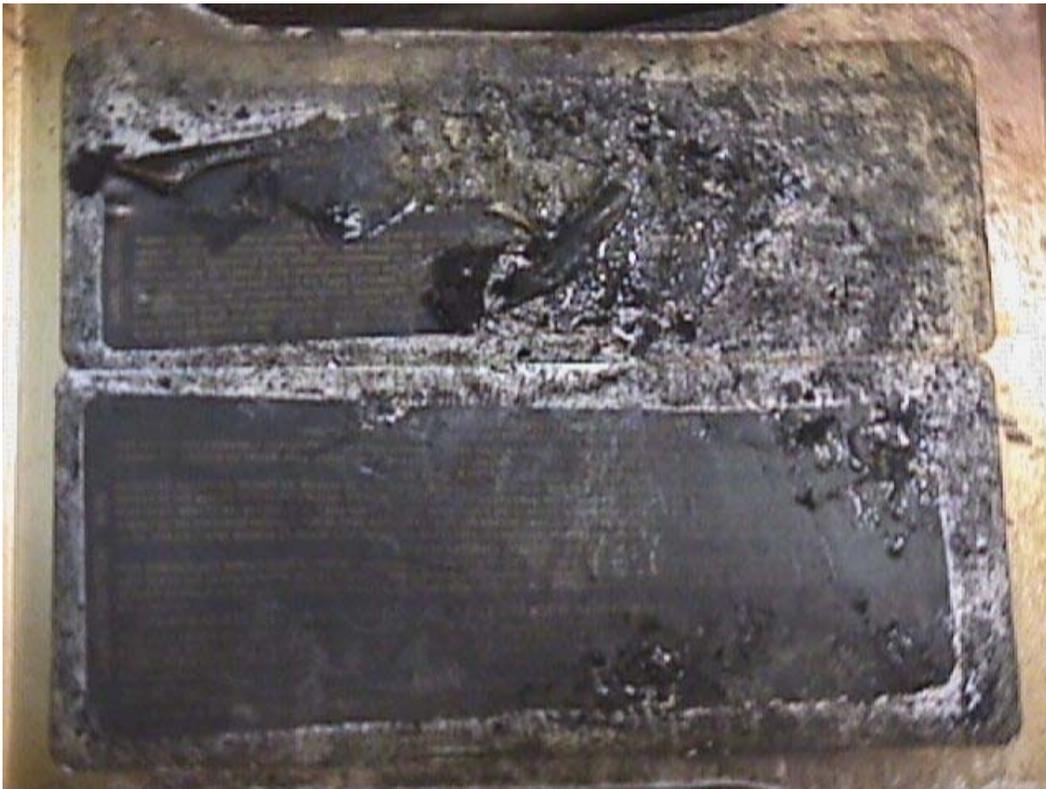


Figure 29 – Unit #1 Shoulder Straps



Figure 30 – Unit #1 Waistbelt



Figure 31 – Right Side of Unit #1 Waistbelt



Figure 32 – Unit #1 Regulator Storage Point



Figure 33 – Unit #1 Cylinder



Figure 34 – Unit #1 Cylinder



Figure 35 – Unit #1 Cylinder



Figure 36 – Unit #1 Cylinder



Figure 37 – Scrapes on Unit #1 Cylinder



Figure 38 – Heat Damage to Unit #1 Cylinder



Figure 39 – Unit #1 Cylinder Valve



Figure 40 – Unit #1 Cylinder Valve



Figure 41 – Units #2 and #3 Facepieces as Received from the Pennsylvania State Fire Academy

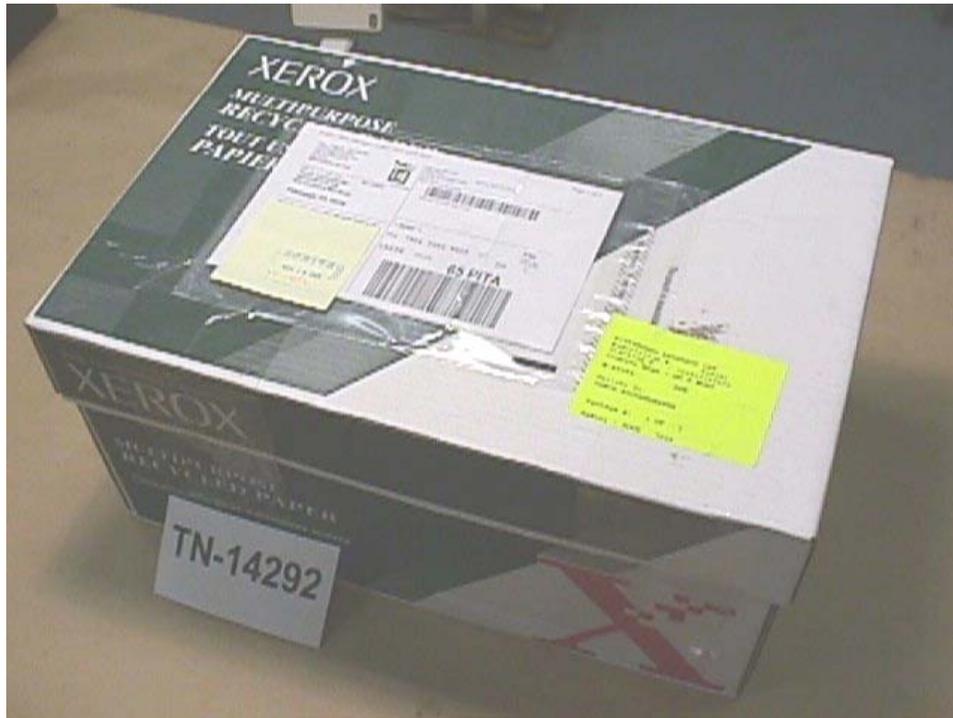


Figure 42 – Units #2 and #3 Facepieces Removed from Package



Figure 43 – Unit #2 Facepiece



Figure 44 – Visibility through Unit #2 Facepiece



Figure 45 – Crazeing of Unit #2 Lens Coating



Figure 46 – Unit #2 Nosecup Inhalation Valves



Figure 47 – Unit #3 Facepiece



Figure 48 – Visibility through Unit #3 Facepiece

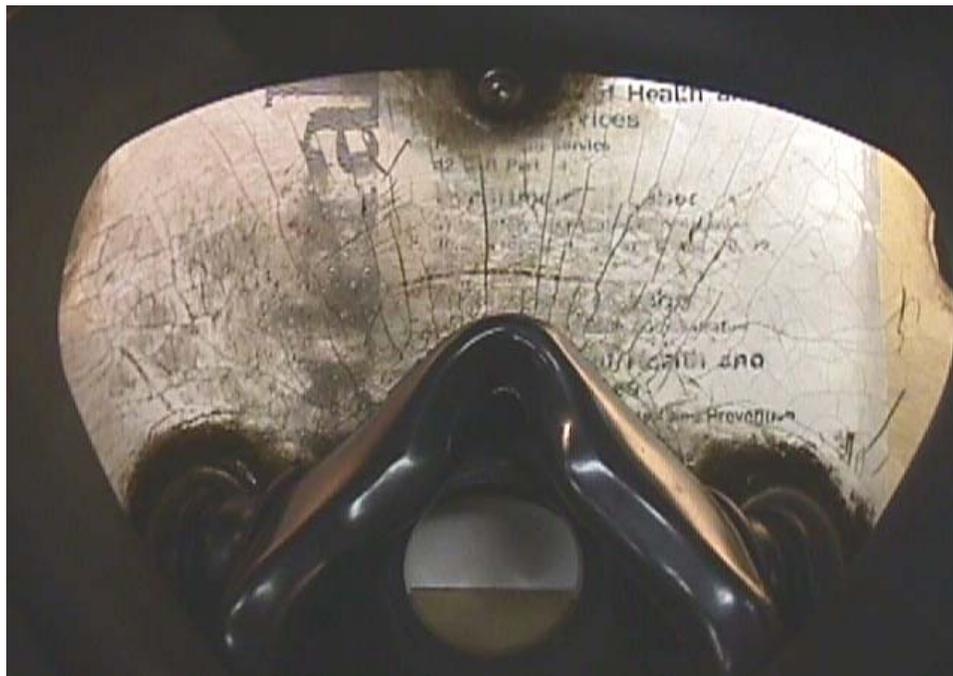


Figure 49 – Craziing of Unit #3 Lens Coating



Figure 50 – Unit #3 Nosecup Inhalation Valves



Figure 51 – Turnout Gear in Package Received from the Pennsylvania State Fire Academy



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Figure 71 – Rear View of Turnout Coat Hem



Figure 72 – Rear View of Turnout Coat Upper Torso

