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Self-Contained Self-Rescuer Long Term Field Evaluation Combined Eighth and Ninth Phase Results

Department of Health and Human Services
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

NIOSH

Report of Investigations

Self-Contained Self-Rescuer Long Term Field Evaluation: Combined Eighth and Ninth Phase Results

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

October 2006

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Contents

Abstract

The National Institute for Occupational Safety and Health (NIOSH) National Personal Protective Technology Laboratory (NPPTL) and the Mine Safety and Health Administration (MSHA) conduct a Long Term Field Evaluation (LTFE) program to evaluate deployed self-contained self-rescuers (SCSRs). The objective of the program is to evaluate how well SCSRs endure the underground coal mining environment with regard to both physical damage and aging when they are deployed in accordance with Federal regulations (30 CFR 75.1714). This report presents findings of the combined eighth and ninth phases of the LTFE. For these phases, over four hundred SCSRs were evaluated. The units tested include the CSE SR-100, Draeger Oxy K-Plus, MSA Life-saver 60, and the OCENCO EBA 6.5. The OCENCO M-20 was evaluated only in Phase 9. Testing was performed between December 2000 and April 2004. Results of the evaluation indicate that all SCSRs experience some performance degradation due to the mining environment. Observed degradation varies from elevated levels of carbon dioxide, high breathing resistance, and reduced capacity. Mechanical degradation to the SCSR components included breathing hoses, chemical beds, outer cases and seals. The LTFE tests discussed in this report are different from tests performed for SCSR certification to the requirements of 42 Code of Federal Regulations, Part 84 (42 CFR, Part 84). LTFE tests reported here are conducted to an end point, oxygen depletion, to enable comparison of the duration of new and deployed SCSRs. The method for obtaining deployed SCSRs for this evaluation was not a random selection from the deployed population of SCSRs. Although the results of these tests are useful for observing performance of the tested SCSRs, they are not representative of all deployed SCSRs. A new evaluation protocol, with revised sampling strategies, test methods, and reporting procedures, is currently being designed to enhance the generalizability of the results. This program will be implemented following completion of Phase 10 of the current LTFE protocol.

Introduction

On June 21, 1981, U.S. coal mine operators were required to make available to each underground coal miner a self-contained self-rescuer (SCSR). The regulations (30 CFR 75.1714) require that each person in an underground coal mine wear, carry, or have immediate access to a device that provides respiratory protection with an oxygen (O_2) source for at least 1 hour, as approved according to the requirements found at Title 42, Code of Federal Regulations, Part 84 (42 CFR, Part 84). The SCSRs are sealed to protect them from the underground mining environment. The sealed case that protects the apparatus from environmental and physical damage also makes it difficult to inspect. Unlike general industry open-circuit, self-contained breathing apparatus, no functional assessment can be made prior to actual use. For these reasons, the National Institute for Occupational Safety and Health (NIOSH) National Personal Protective Technology Laboratory (NPPTL) in cooperation with the Mine Safety and Health Administration (MSHA) conducts an ongoing, long term field evaluation of SCSRs deployed in underground coal mines. NPPTL locates mines willing to participate in the study and acquires deployed SCSRs by supplying new replacement units in cooperation with MSHA. The NPPTL then tests the deployed SCSRs. Approximately 90% of tests are performed using a breathing and metabolic simulator (BMS), while 10% are evaluated by human test subjects with MSHA inspectors among those serving as human subjects. The objective of this program is to evaluate how well SCSRs endure the underground coal mining environment with regard to both physical damage and aging. This report presents results from Phase 8 and Phase 9 testing conducted between December 2000 and April 2004. Previous reports describe Phases 1 through 7 of the Long Term Field Evaluation (LTFE) program [Kyriazi et al. 1986; Kyriazi and Shubilla 1992, 1994, 1996, 2000, 2002].

Mines must conduct regular inspections of deployed units to ensure SCSR readiness. The criteria for these inspections are established by the manufacturers and include damage assessments of specific components by either visual inspection or non-destructive testing. Among the visual inspection criteria are evaluating the use indicators or gauges provided on the unit, checking the service life date, and visually assessing physical indications of wear. Users must comply with the manufacturer's specified conditions of use. SCSRs failing inspection or not complying with the conditions of use no longer meet the NIOSH/MSHA approval and should be removed from service.

The tests performed as part of the LTFE are focused on detecting any changes in deployed respirators. NPPTL tests to endpoints and under conditions to facilitate performance comparison between new and deployed units. These tests are different from the tests used in respirator certification. The LTFE tests are consistent with SCSRs performing at a constant work rate in an underground escape scenario. The test data from LTFE testing should not be used to predict actual respirator performance for a miner in an emergency where work rates can vary based on escape route conditions, miner fitness level, etc. As stated earlier, many tests are conducted using a BMS instead of human test subjects. The machine provides a reproducible measure to enable comparison of new and deployed units. Although certification tests using human subjects and simulator testing using the BMS can produce similar results, they are different tests, and the data reported from BMS testing cannot be considered equivalent to certification tests using human subjects.

The suspected problems and nonconformities identified in the LTFE program are reported for investigation under the Certified Product Investigation Program (CPIP). These investigations and their outcomes are reported in Appendix 1. However, the method for obtaining deployed SCSRs for this evaluation was not a random selection from the deployed population of SCSRs. Although the results of these tests are useful for observing performance of the tested SCSRs, they are not representative of all deployed SCSRs. Redesign of the LTFE to address sampling strategies, test methods, and reporting procedures is under development by NIOSH NPPTL and will be implemented following peer review, stakeholder input, and completion of Phase 10 testing in the current LTFE program.

Evaluation Procedure

Over 400 SCSRs were tested in the eighth and ninth phases of the study conducted December 2000 – April 2004. Ninety percent of the apparatus were tested on a BMS (Figure 1) and 10% were tested using human subjects on a treadmill (Figure 2). MSHA provides human test subjects from its Mine Emergency Unit for treadmill testing.

Figure 1. Breathing and Metabolic Simulator

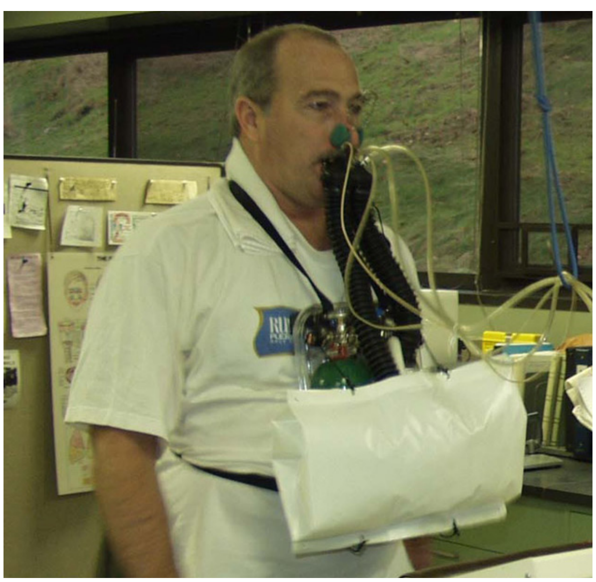

Figure 2. Treadmill Testing

MSHA assisted in selecting the participating mines from mines indicating a willingness to participate in the LTFE program by considering the type of mining operation, coal bed height, and SCSR deployment mode, so as to represent a wide range of conditions that could impact SCSR performance. NIOSH staff, accompanied by MSHA inspectors, applies the manufacturers' inspection criteria on units currently deployed at each mine during an on-site visit to acquire sample SCSRs for testing. New units are exchanged for deployed units judged to meet the manufacturer's criteria, and the mines are advised to remove rejected units from service. Mines selected for participation in Phase 8 and Phase 9 are identified in the Acknowledgements. Deployment modes included permanent storage on the mine floor, storage on a man-trip or mining machine, daily carry-and-store, and belt-worn. The number collected for each phase is indicated in Table 1.

Table 1. SCSRs Collected for Evaluation

Apparatus	Number Collected Phase 8	Number Collected Phase 9
CSE SR-100	90	98
Draeger OXY K-Plus	24	20
MSA Life-Saver 60	35	20
OCENCO EBA 6.5	80	57
OCENCO M-20	0*	20
Total	229	215

*Not included in Phase 8 because new models were not available

Units were prescreened by visual inspection in accordance with the manufacturer's inspection criteria during the collection procedure to reject units with evidence of potential damage.

Evaluated SCSRs were manufactured by CSE Corp., Drägerwerk AG (Draeger), Mine Safety Appliances Co., Inc. (MSA), and OCENCO, Inc. Units were sampled according to estimated distribution of the various models and are shown in Figures 3 through 7. By the end of Phase 9, the MSA Life-Saver 60 was no longer being manufactured or distributed. The devices evaluated represent all NIOSH/MSHA certified SCSRs available and in use in United States coal mines. The devices vary in size and weight. Some can be worn on the miners' work belts, others cannot.

Figure 3. Uncased and Cased CSE SR-100 Self-rescuer

Figure 4. Cased and Uncased Draeger OXY K-Plus Self-rescuer

Figure 5. Cased and Uncased MSA Life-Saver 60 Self-rescuer

Figure 6. Cased and Uncased Ocenco EBA 6.5 Self-rescuer

Figure 7. Partially Uncased and Uncased Ocenco M-20 Self-rescuer

Results and Discussion

The depletion times for the deployed and new units are shown in Figures 8a and 8b for Phases 8 and 9 respectively.

Figure 8. Depletion Time for All Models Tested

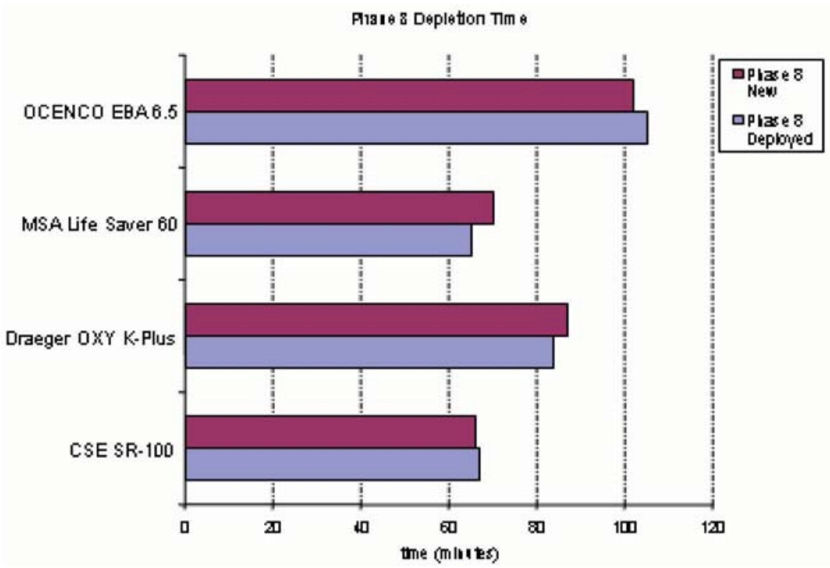

Figure 8a. Depletion Time for All Models Tested–Phase 8

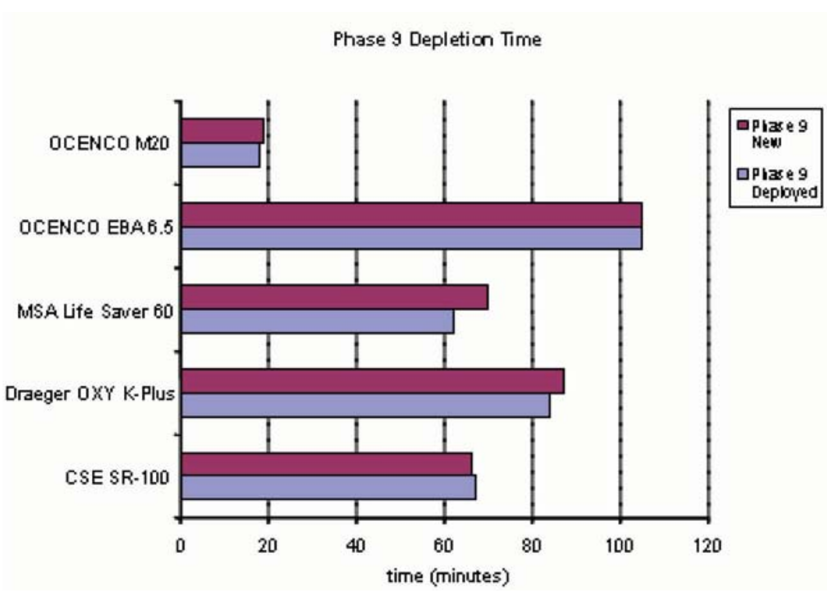

Figure 8b. Depletion Time for All Models Tested–Phase 9

Table 2 summarizes the number of units with testing terminated for reasons other than oxygen depletion. Both LTFE Phase 8 and Phase 9 results are indicated in the table. The table includes units demonstrating decreased oxygen (O_2) levels, increased carbon dioxide (CO_2) levels, high breathing resistance (pressure), and coughing.

In the following discussion, results for each SCSR model are described separately. The time to depletion for deployed versus new units is compared by phase for all units. As stated earlier, some units failed visual inspection in the laboratory. A list of SCSRs failing inspection, and the reasons for failure, is included. For each type of unit and for each phase, the proportion of SCSRs failing laboratory inspection is reported.

The minute-average values of the monitored stressors were averaged over the entire test duration, and are presented graphically for each apparatus by stressor in Appendix 2 (Figures A2-1 through A2-9). The values for new and deployed units tested on the BMS can be compared. To some extent, these values may also be compared with those for deployed units tested on human subjects on a treadmill; however, human subjects may differ from each other and from the BMS in terms of CO_2 production rate, ventilation rate, and respiratory frequency. These parameters affect apparatus duration as well as all of the monitored variables. Treadmill tests cannot be considered equivalent to the BMS tests, even though the O_2 consumption rate is the same.

Inspection Procedures

All units were inspected using the manufacturers' inspection criteria after being cleaned. If an induced noise test was required, the test was performed to the manufacturer's specifications. Despite having passed the inspection during collection, some collected units were judged to have failed the manufacturer's inspection criteria once received in the laboratory. In other words, these units should have been removed from service, and not been available for the LTFE tests. Failure could be attributed to differences in judgment as to the compliance with inspection criteria. This reflects the difficulty of inspecting units deployed in the underground coal mine environment. Units can become encrusted with dirt making a thorough inspection difficult. The test results and data analysis, therefore, include all units tested whether they passed subsequent laboratory visual inspection or not. Units that failed laboratory inspection are noted in the results.

Breathing and Metabolic Simulator (BMS) and Treadmill Testing

The BMS test consists of the average metabolic work rate exhibited by the 50th-percentile miner weighing 87 kg while performing Man-test 4 for one hour, as described in 42 CFR, Part 84. Although the average work rate is the same, LTFE testing is not equivalent to certification testing. Certification testing imposes high and

Table 2. Test Parameters for Units with Testing Terminated Prior to O_2 Depletion

TEST PARAMETER	Model Number									
	CSE SR-100		Draeger OXY K-Plus		MSA Life Saver 60		OCENCO EBA 6.5		OCENCO M20	
	Phase 8	Phase 9	Phase 8	Phase 9	Phase 8	Phase 9	Phase 8	Phase 9	Phase 8	Phase 9
Decreased 02	0	4	2	0	0	0	0	0	N/A	0
Increased CO2	9	4	0	0	0	0	0	0	N/A	0
High Breathing Resistance	7	2	0	0	0	0	0	0	N/A	0
Coughing	0	1	0	0	0	0	0	0	N/A	0
Total Number of Units	16	11	2	0	0	0	0	0	N/A	0

low work rates that the average work rate used in the LTFE does not. Also, the stressor levels are continuously monitored in the LTFE, whereas they are sampled only between work activities in certification testing. In addition, LTFE testing continues until the apparatus is empty or stressor levels exceed allowable parameters, whereas testing during certification ends at the rated duration, even if the capacity of the apparatus exceeds it.

In the LTFE treadmill testing, the human subjects walked at the speed and grade that elicited an O_2 consumption rate of 1.35 L/min. The carbon dioxide (CO_2) production rate, ventilation rate, and respiratory frequency varied in the test subjects. The metabolic parameters for both BMS and treadmill testing are given in Table 3.

the BMS were terminated upon one of three endpoints: exhaustion of the O_2 supply as indicated by inhalation pressures reaching -200 mm H_2O, coinciding with an empty breathing bag; average inhaled CO_2 levels exceeding 10%; or O_2 levels below 15%. Treadmill tests were terminated when the O_2 supply was exhausted, if minimum inhaled CO_2 exceeded 4%, if maximum inhaled O_2 fell below 15%, or if the test subject stopped because of subjectively high breathing resistances (pressures) or temperatures.

The Wilcoxon rank-sum test was performed for each monitored stressor to determine whether deployed units behaved differently from new units. The test evaluates the hypothesis that the two samples are from populations with the same mean. The values from both samples are ranked in ascending order of magnitude. If the

Table 3. BMS and Treadmill Metabolic Parameters

Metabolic workload	BMS	Treadmill
O_2 consumption rate, L/min.	1.35	1.35
CO_2 production rate, L/min.	1.15	*
Ventilation rate, L/min.	30.0	*
Tidal volume, L/breath	1.68	*
Respiratory frequency, breaths/min.	17.9	*
Peak respiratory flow rate:		
Inhalation, L/min.	89	*
Exhalation, L/min.	71	*

*Pace of treadmill test is set to maintain oxygen consumption at the stated rate.

In both BMS and treadmill testing, the monitored stressors included inhaled levels of CO_2 and O_2, end-of-inhalation wet- and dry-bulb temperatures, and peak inhalation and exhalation breathing resistances (pressures). Tests on

sum of the ranks of the smaller sample (T) (in this case, new units) falls within the acceptable range for the given sample sizes, then sufficient evidence does not exist at the specified probability level ($\alpha = .05$, two-sided) to conclude that the means of the two samples differ. The rank-sum test does not rely upon the assumptions that either the new or deployed unit data are normal distributions, or that they have identical variances, as does the T-test for two populations of independent samples. A limitation of the Wilcoxon rank-sum test is that it does not distinguish between large and small differences in values. The results of the $\alpha = .05$, two-sided, Wilcoxon rank-sum tests are presented in Table 4a for the units tested in Phase 8 and Table 4b for the units tested in Phase 9. The probability of T falling outside the given range is .05 if the populations have the same mean. Results where T falls outside the range are highlighted.

Table 4. Wilcoxon Rank-Sum Test Results

Table 4a. Wilcoxon Rank-Sum Test Results – Phase 8

	Duration		Average Inhaled CO_2		Average Inhaled O_2		Wet-bulb Temp		Dry-bulb Temp		Inhalation Pressure		Exhalation Pressure	
Apparatus	**Range**	**T**	**Range**	**T**	**Range**	**T**	**Range**	**T**	**Range**	**T**	**Range**	**T**	**Range**	**T**
SR-100	45-120	60	45-120	57	45-120	103	**43-117**	**131**	**45-120**	**133**	45-120	144	45-120	116
OXY K-Plus	26-82	67	25-79	53	26-82	70	26-82	70	26-82	56	26-82	61	26-82	48
Life-Saver 60	**12-48**	**50**	12-48	28	12-48	28	12-45	28	12-48	26	**12-48**	**52**	12-48	30
EBA 6.5	28-88	50	**28-88**	**24**	28-88	72	28-88	60	28-88	70	28-88	50	**28-88**	**22**

Note that the numbers in the table are rank numbers and do not represent test values
T=Sum of the ranks of the smaller sample (new units)

Table 4. Wilcoxon Rank-Sum Test Results

Table 4b. Wilcoxon Rank-Sum Test Results – Phase 9

Apparatus	Duration		Average Inhaled CO_2		Average Inhaled O_2		Wet-bulb Temp		Dry-bulb Temp		Inhalation Pressure		Exhalation Pressure	
	Range	T	Range	T	Range	T	Range	T	Range	T	Range	T	Range	T
SR-100	99-205	126	101-211	121	99-205	198	**99-205**	**231**	**99-205**	**236**	99-205	132	99-205	142
OXY K-Plus	24-76	58	24-76	67	**24-76**	**84**	24-72	65	24-76	49	24-76	33	24-76	32
Life-Saver 60	**13-53**	**60**	13-53	42	13-53	42	13-53	48	13-53	46	**13-53**	**7**	13-53	39
EBA 6.5	30-94	56	**30-94**	**26**	30-94	76	30-94	52	30-94	61	30-94	70	**30-94**	**23**
M-20	13-53	52	23-69	68	13-53	46	13-53	32	13-53	42	13-53	39	13-53	37

Note that the numbers in the table are rank numbers and do not represent test values
T=Sum of the ranks of the smaller sample (new units)

CSE SR-100 Discussion

Induced Noise Test

CSE developed a test to identify apparatus that have sustained internal damage, based on a correlation between loose particles in the chemical bed and CO_2 breakthrough during the last rest interval of a 1-hour Man Test #4. This was established by testing SR-100s on the CSE breathing simulator performing NIOSH variable-work rate certification tests. The Acoustic Solids Movement Detector (ASMD) analyzes the noise induced in the unit by shaking it in a controlled manner. The noise produced by the SCSR when shaken is used as an indicator of shock and vibration damage incurred by the chemical bed within the SCSR. In the field, this assessment is made using a hand-held instrument provided by CSE. A laboratory version of the ASMD test involves rotating the SR-100 in an anechoic chamber to measure the noise levels in decibels (dB). Various frequency ranges are weighted differently and result in a composite dB rating for each apparatus. A unit with a composite rating of higher than 60 dB fails the test. NIOSH performs the laboratory version of the ASMD test as part of the LTFE inspection. Excessive noise as evaluated by either of the test instruments is an indication of chemical-bed damage that may adversely affect the performance of the SCSR. SCSRs failing the ASMD test must be removed from service. The ASMD test and average inhaled CO_2 levels on CSE units on a BMS performing a constant work rate test are presented in Figures A3-1a and A3-1b.

Units failing manufacturer's inspection criteria at the laboratory are shown in Tables 5a and 5b. The failure rate in Phase 8 was 19% of the 90 units collected, and for Phase 9 it was 30% of the 98 units collected. Those failures highlighted in orange were due to ASMD test results exceeding the 60 dB limit to remain in service (test result > 60 dB).

Table 5. Lab Inspection Results for CSE SR-100

Table 5a. Lab Inspection Results for CSE SR-100–Phase 8

SN	Failure
33269	Chunk of orange case missing
34269	**70 dB**
40075	Deeply cracked orange case
42855	Cracks and holes in orange case
49088	Hole in orange case
51042	**114 dB**
53058	Cracks and holes in orange case
54954	Cracks and holes in orange case
57901	Bottom moisture indicator cracked
57942	**77 dB**
58989	Bottom moisture indicator cracked
59136	**72 dB**
61221	Cracks and holes in orange case
61303	Holes in orange case
68490	**101 dB**
69648	Bottom moisture indicator cracked
71768	Bottom moisture indicator white; seal chewed

Table 5b. Lab Inspection Results for CSE SR-100–Phase 9

SN	Failure
34167	Dent in bottom case seal
34407	Approximately 15% of orange case missing
39017	**68 dB**
40068	Large gash in orange case showing through metal
45233	**78 dB**
46971	Pieces of orange case missing
46994	**65 dB**
47009	**82 dB**
50138	**88 dB**
51152	Significant cracks and pieces missing from orange case
51297	**62 dB**
51430	**62 dB**
52048	Big dent in top corner; big crack on side
52366	**95 dB**
52480	**61 dB**
57288	**109 dB**
57430	**62 dB**
57636	**91 dB**
58929	Severely cracked orange case with pieces missing
61281	Severely cracked orange case
63804	**71 dB**
68375	**80 dB; dented bottom seal and damaged gasket**
67414	Cracked moisture lens
75576	Huge cracks in orange case with pieces missing
78338	**61 dB**
79086	**63 dB**
85247	**80 dB**
85285	**62 dB**
88252	**74 dB**
88288	**117 dB**
89282	**87 dB**
90544	**67 dB**

BMS and Treadmill Testing

The durations were comparable for both new and deployed units in both phases as shown in Figures 8a and 8b. In Phase 8, nine units had little or no starter oxygen, requiring a manual start before beginning or shortly after beginning the test. In Phase 9, 15 units had little or no starter oxygen. Manual starts consist of exhaling into the apparatus until the breathing bag is full (3 to 6 breaths). Since exhaled breath contains sub-ambient levels of O_2 (approximately 17%) the inhalation levels of O_2 started at that point, declined to below 15% within a couple of minutes, and reached a minimum at approximately 12% before rising.

In all human subject tests, the users coughed when donning the apparatus. This was thought primarily to be due to inhalation of loose corn starch particles. The manufacturer uses corn starch in the breathing hose to absorb saliva. The corn starch prevents saliva from reaching the KO_2 bed where it would speed up the chemical reaction and waste O_2. After noticing the corn starch in the breathing hoses, an attempt was made to shake out the loose particles before testing the units. This resulted in dislodging small pieces of metal (end-cuttings from the wire-mesh heat-exchanger) from the hoses. (The manufacturer has added a step during manufacture to blow out the loose metal cuttings.) The donning procedure was changed and the human subjects were instructed to dampen the loose particles by exhaling repeatedly into the units. When O_2 fell below 15%, the user was instructed to activate the starter O_2. This sometimes caused a fresh series of coughs, including one in which the test subject complained after the test that his throat burned. In some tests, instead of immediately beginning to walk on the treadmill, the test subjects stood still until the O_2 levels stabilized, usually at about 16%. However, as soon as the test subjects began walking at their target speed, the O_2 levels quickly fell below 15% and the starter O2 was activated.

Most tests were terminated when their O_2 supply was expended. In phase 9, four units were terminated for high CO_2 levels, four for low O_2 levels, two for high breathing pressures, and one for coughing. Of the four tests terminated for low O_2 levels, three of the apparatus should have failed inspection for various reasons. One, which was terminated at 73 minutes simultaneously with an empty breathing bag, had ASMD test results exceeding the criteria to remain in service (test result = 109 dB). Another, terminating at 22 minutes, also had an ASMD test result exceeding the criteria to remain in service (test result = 88 dB) plus large cracks in the orange jacket with pieces missing, and a severe side dent. It also had insufficient starter O_2. The third unit, which ran for only one minute before dropping below 15% O_2, had a badly dented metal case and a severe dent in the lower case seal, and contained no starter O_2. The low O_2 levels in these three apparatus can probably be attributed to chemical bed degradation. The fourth unit passed all inspection criteria, but had a punctured breathing hose and no starter O_2, neither of which could have been detected through inspection. It was terminated at 69 minutes. The low O_2 levels in this apparatus can be attributed to the in-leakage of ambient air through the hose puncture.

The test that was stopped for coughing was terminated after three minutes. This apparatus had severe cracks in its orange jacket with pieces missing, requiring it to be taped together. Upon opening the case, the findings exhibited coal dust migration through the case seals, and the breathing hose was punctured. The test subject coughed upon initial donning, but continued testing. However, after the starter O_2 was activated, which occurred with a popping sound, the coughing became worse, and the test subject, an MSHA inspector, declined to continue.

Increased CO_2

In Phase 8, of the 87 deployed apparatus tested on the BMS, 25 experienced CO_2 levels in excess of 4% before 60 minutes: 64 experienced CO_2 in excess of 4% before expenditure of the O_2 supply. Four of eight new units also experienced breakthrough; three before 60 minutes. The response to high inhaled levels of CO_2 will be increased ventilation rates in most users, approximately doubling with 4% CO_2. Increased ventilation rates will result in higher breathing pressures for the user. Breathing resistance in the SR-100 increases rapidly toward end-of-service-life, even in some new apparatus, and elevated CO_2 levels even could result in higher breathing resistance than normal.

In Phase 9, all four tests terminated for high CO_2 levels (10% CO_2 in the two BMS tests, and 4% CO_2 in the two treadmill tests) had noise induced sound level test dB levels higher than 60 and should have been removed from service.

Breathing Resistance

In phase 8, four BMS tests and three treadmill tests of deployed units were terminated because of high breathing pressures (exceeding the + 715 mm H_2O range of the pressure transducer in the BMS tests, or at the discretion of the human subject in the treadmill tests, ranging from + 230 to 500 mm H_2O). One BMS test of a new unit was also terminated for high breathing pressures. The breathing pressures in most tests did not reach high levels until approximately 50 minutes. However, one treadmill test did have high pressures early and was terminated at 16 minutes. Disassembly at CSE revealed a layer of fused potassium superoxide (KO_2) at the bottom of the chemical bed, possibly due to water in-leakage into the case bottom, even though the color indicator was blue (passing inspection) at the time of testing. It may be possible for an indicator to turn pink if water or humidity leaks in through a seal breach, and then revert back to blue after drying out. The damage has been done, however, showing the importance of daily inspections. Most of the other tests were terminated due to oxygen depletion or because of high CO_2 (Table 2). One test ended due to low O_2 levels.

In Phase 9, of the two tests terminated for high breathing pressures, the BMS test was terminated when the pressure reached -600 mm H_2O at 55 minutes. The treadmill test was terminated at the request of the test subject when pressures reached + 300 mm H_2O at 51 minutes. A BMS test of a new unit was also terminated for high breathing pressures at 60 minutes. Thirty-four deployed apparatus reached +200 mm H_2O, while 25 reached -300 mm H_2O. These pressures were the limits of tolerance for 80% of test subjects in a study contracted by the Bureau of Mines (Hodgson, 1993). In 10 units, the inhalation breathing pressure limit was exceeded before 60 minutes, while in 16 units, the exhalation limit was exceeded before 60 minutes

Other Observations

In one case in Phase 9, the user said his throat burned, and that it was more than corn starch, based on his previous experience. Since KO_2 was found in another SR-100, it is possible that it was KO_2 in this apparatus, also. The apparatus in which KO_2 was determined to be present had been taken to CSE and disassembled. It was found that the canister had been dented, deforming the seal that contains the chemical bed. This apparatus had passed all its inspection criteria. There was no way for a user to have detected the damage to the metal canister underneath the orange plastic case.

In Phase 8, nine units had breathing hoses with severe creases with the hose walls stuck to each other. A careful effort to open the flow path was required. In two instances, simply extending the hose resulted in tearing the hose. Even a conscientious effort in two more instances to open the flow path resulted in tearing. Similar conditions were observed in Phase 9, where breathing hoses of eighteen units were severely creased with the hose walls stuck to each other. A careful effort to open the flow path was required. In two cases the hoses tore when attempting to open the flow path. Thereafter, the hoses were left stuck and partially occluded. The manufacturer has determined that this degradation is caused by heat exposure.

In both Phase 8 and Phase 9, the breathing hose was either punctured or slit in eight units and nine units respectively, apparently from being pressed against sharp internal components. Such holes would permit toxic gases and N_2 to enter the breathing circuit in emergency use, compromising the effectiveness of the apparatus. To correct this problem, the manufacturer has changed its packing procedures.

In Phase 8, at least 10 units had evidence of dirt and/or past water leakage into the case. The color indicators were blue in all units. In spite of the apparent breach of the case seals, all apparatus performed normally. In Phase 9, 14 units exhibited evidence of dirt and/or water leakage into the case. The color indicators were blue in all units. In Phase 9, ten apparatus had some degree of performance degradation.

In Phase 8, one apparatus leaked badly from the relief valve. Another unit had a breathing bag with chemical deposits of unknown material, and the bag was stuck to itself in several places. These peculiarities did not significantly affect the performance of the apparatus. Subsequent internal examination of this unit with the assistance of the manufacturer revealed signs of electrical arcing in the area where the bag was stuck together. The chemical deposits were deemed by the manufacturer to also be related to the arcing.

In Phase 9, the lids on five apparatus were difficult to open to varying degrees. On one unit, the thumb-strap used to open the case broke; in another unit, the breathing bag was stuck to itself and had to be manually unstuck. The relief valve cap was warped on one unit and fell off during the test, with no apparent effect on performance. One human subject said that he felt light-headed immediately after activating the starter O_2, although he continued with the test until completion.

Wilcoxon Rank-Sum Test

In earlier reports (Phases 6 and 7), the Wilcoxon rank-sum test for average inhaled CO_2 showed that the new units had significantly lower values than deployed units. Using only the three new units from the last phase for comparison with the deployed units from the Eighth Phase, the same findings were observed: the deployed units had higher CO_2 values. However, the group of new units was expanded with two recently manufactured units (January 2001), which also had higher CO_2 levels. This put them more in line with the deployed units and eliminated the distinction between new and deployed units with regard to CO_2 levels. To further explore this situation, two more new units manufactured within a month of the two newer units already evaluated were tested. As in previous results, high CO_2 levels were obtained. An apparatus manufactured in January of 2002 was then tested. This apparatus showed low levels of CO_2. Given such variability of CO_2 levels in new units, the higher CO_2 levels in deployed units cannot be attributed solely to bed degradation caused by rough deployment.

In phase 9, The Wilcoxon rank-sum tests for the CSE SR-100 units show that wet- and dry-bulb temperatures were significantly higher in new units than in deployed units. Since temperature is indicative of chemical reaction, this could indicate that deployed units have lower levels of chemical reaction. Since no statistically significant difference was found with regard to CO_2 levels between new and deployed units (Table 4b), this is not considered an important finding.

Draeger OXY K-Plus Discussion

Laboratory inspection results are shown in Tables 6a and 6b. The failure rate in Phase 8 was 8% (2 units) of the 24 units collected, and for Phase 9 it was 5% (1 unit) of the 20 units collected. Because the OXY K-Plus were not collected at random, these proportions should not be viewed as representative of the entire population of Draeger OXY K-Plus in the field.

Table 6. Lab Inspection Results for Draeger OXY K-Plus

Table 6a. Lab Inspection Results for Draeger OXY K-Plus–Phase 8

SN	Failure
ARJA 0391	Belt-clip plate dented
ARJA 0393	Belt-clip plate dented

Table 6b. Lab Inspection Results for Draeger OXY K-Plus–Phase 9

SN	Failure
ARLN 0034	Belt plate dented

BMS and Treadmill Tests

Time to depletion, as shown on Figures 8a and 8b was comparable for new and deployed units. It should be noted that the sample size in both phases was small, 24 units in Phase 8 and 20 units in Phase 9.

The tests of two units were terminated for low O_2 concentration. These units exhibited leakage when evaluated and were later found to have internal damage, causing a breach of the breathing circuits. Hypoxia (low levels of O_2) can occur when ambient air (79% of which is nitrogen) is drawn into the breathing circuit and only the oxygen is removed (by the user). These two units were among three that had dents in their metal belt-clip plates. Draeger alerted inspectors to look for such dents, and has added that to its list of inspection criteria. If the metal belt-clip plate is dented, the large, hard-plastic plenum directly inside the case can be cracked or shattered, resulting in ambient air leakage into the breathing circuit (see Figures 9 and 10). Not only can this result in low O_2 levels, which may cause the user to lose consciousness, it can also result in toxic gases entering the breathing circuit. Draeger submitted a design improvement for certification.

Increased CO_2

One deployed unit showed CO_2 levels above 4% (at 65 minutes) before expenditure of the O2 supply (at 75 minutes) reaching 5.85% average inhaled CO_2.

Wilcoxon Rank-Sum Test

In Phase 8, the Wilcoxon rank-sum tests for the Draeger showed that new units could not be distinguished from deployed units in any measured parameter.

In Phase 9, the Wilcoxon rank-sum tests for the Draeger units show that new units had significantly higher O_2 concentrations than deployed units. Since the lowest test-average of the average inhaled O_2 concentrations was 68%, much higher than ambient, this is of no concern to users.

One test was terminated simultaneously for low O_2 concentration and an empty bag at 92 minutes. This is of no concern to users, since an O_2 concentration of 15%, and even lower, is tolerable for short periods of time.

Figure 9. Dented Draeger OXY K-Plus Belt-Clip

One apparatus was missing its back plate and should have been removed from service; however, it performed normally.

Figure 10. Internal damage on Draeger OXY K-Plus

MSA Life-Saver 60 Discussion

Laboratory inspection results are shown in Tables 7a and 7b. The failure rate in Phase 8 was 6% (2 units) of the 35 units collected, and for Phase 9 it was 5% (1 unit) of the 20 units collected. Because the Life-Saver 60s were not collected at random, these proportions should not be viewed as representative of the entire population of Life-Saver 60s in the field.

Table 7. Lab Inspection Results for MSA Life-Saver 60

Table 7a. Lab Inspection Results for MSA Life-Saver 60–Phase 8

SN	Failure
14076	Case cracked and missing on bottom
14235	Cracks in case bottom

Table 7b. Lab Inspection Results for MSA Life-Saver 60–Phase 9

SN	Failure
14279	Missing piece of lower case

BMS and Treadmill Tests

Time to depletion, as shown in Figures 8a and 8b was different for new and deployed units, with the deployed units exhibiting about a 7% reduction in time to depletion in both phases.

Increased CO_2

In Phase 8, one deployed unit experienced CO_2 levels above 4% two minutes before depletion of the O_2 supply, while in another unit, breakthrough and depletion occurred simultaneously.

Other Observations

In phase 8, one unit was found with KO_2 in the mouthpiece. This was taken to MSA for disassembly where the presence of KO_2 was confirmed. Eighteen others of similar age and serial number were obtained from various mines and inspected. Five of these had signs of KO_2 in the base of the breathing hose. MSA revised its service life limit to account for the number of hours in mobile use; i.e., the number of shifts being worn, stored on equipment, or carried and stored. The unit in question was carried and stored on a 3-shift-per-day schedule which accelerated its degradation. A 10-year service life still is permitted for ground-storage deployment or mobile use for one 8-hour work shift per day, 5 days per week, 52 weeks per year (20,800 hours). However, the service life maximum for mobile use is now a total of 20,800 hours which would amount to as little as 2.37 years if used 3 shifts per day on a daily basis.

Chlorate candles of four units in Phase 8 and seven out of 20 units in Phase 9 activated immediately upon opening the apparatus case. In phase 9, this occurred on one of three new units, also. Although this would not necessarily compromise successful use of the apparatus, users should be made aware that it could happen.

All tests were terminated for oxygen depletion with empty breathing bags in Phase 9. However, one apparatus initially seemed to have a compromised chemical bed because the volume of the breathing bag slowly dropped after being filled by the starter O_2 such that it was empty at the end of inhalation, approximately four minutes into the test. When it appeared that the test should be aborted or the bag refilled, the unit recovered, with the bag slowly increasing in volume and behaved normally thereafter.

Wilcoxon Rank-Sum Test

In both Phase 8 and Phase 9, the Wilcoxon rank-sum tests show that new units had significantly higher durations and lower inhalation breathing resistance than deployed units. Figures 8a and 8b show that in Phase 8 and Phase 9, the difference in duration between new and deployed units is approximately 5 and 7 minutes respectively. Six units had durations of less than 60 minutes. While the nearly 50% increase in inhalation breathing resistance in deployed units is significant (an average of 64 mm H_2O in deployed units, versus 43 mm H_2O in new units), it does not present a problem as previously discussed (Hodgson, 1993).

OCENCO EBA 6.5 Discussion

Laboratory inspection results are shown in Tables 8a and 8b. The failure rate in Phase 8 was 23% of the 80 units collected, and for Phase 9 it was 19% of the 57 units collected. Because the EBA 6.5s were not collected at random, these proportions should not be viewed as representative of the entire population of EBA 6.5s in the field.

Table 8. Lab Inspection Results for OCENCO EBA 6.5

Table 8a. Lab Inspection Results for OCENCO EBA 6.5–Phase 8

SN	Failure
2F039494	Cracks in case; dented canister
91080173	Long crack in case bottom
92060171	3700 psi
92070150	Small stress cracks in top strap anchors; white dust inside case
92100277	Cracks in case
92100436	Water and mud in-leakage; lower strap shifted; clip broken
92120261	Cracks in case at top strap anchors
92120317	Cracks in case at top strap anchors
93010149	Cracks in case bottom lip
93010185	Cracks in case at top strap anchors
93020036	Top strap unattached on one side
93100033	No tamper seals
94100154	Cracks in case under one strap-mounted screw
94100320	Dented canister
96110019	Smashed case bottom under strap at demand valve
97070097	Cracks in case
97070434	Top strap unattached on one side
98110004	Top strap unattached on one side

Table 8b. Lab Inspection Results for OCENCO EBA 6.5–Phase 9

SN	Failure
93050201	Crack in case over demand valve
93110092	Crack in case over demand valve
93110095	Cracks in case at top strap anchors
93120113	Crack in case around demand valve inner-anchor
94050007	Shifted cylinder band; dented canister; loose screw, washer, and bracket from canister-mount; exhalation hose twisted on full turn
95050296	Shifted cylinder band
95050315	Stress cracks in case bottom under demand valve
98110005	Top handle strap unattached on one side
99100159	Crack in case bottom near edge of demand valve at screw socket
99100211	Mud inside case
100030147	One side of top handle strap unattached

BMS and Treadmill Testing

The oxygen (O_2) constant-flow rate is checked on the OCENCO EBA 6.5, a compressed-O_2 apparatus. The 42 CFR, Part 84 required flow rate is 1.5 L/min at ambient temperature and pressure, dry (ATPD). The large range of average inhaled O_2 levels in the Phase 8 units is due to the difference in the apparatus O_2 regulator flow rates (1.51 to 3.30 L/min ATPD). The O_2 concentration in a breathing circuit will rise if the O_2 supply rate is higher than the O_2 consumption rate. In four units, the demand valve stuck open after being activated on the first inhalation starting the test. In one case, the unit lost 400 psi in the first 30 seconds, but then dropped to a normal flow, resulting in a 92-minute duration. In another case, the flow was so high that the bag filled up and quickly began venting, causing exhalation pressures twice as high as normal. The flow rate dropped to the normal range by turning off the O_2 cylinder valve and re-opening it; and the test continued to 100 minutes. After the test, the cylinder was refilled, and the flow rates were measured. The initial flow rate was 1.57 L/min ATPD. After activating the demand valve, the flow rate jumped to between 12 and 16 L/min ATPD, eventually dropping off to around 5 L/min, until it was empty at 22 minutes. It is recommended that training on the EBA 6.5 mention that, should this happen to a user, the flow rate might be able to be reset by closing and re-opening the cylinder valve. If the user is working hard, however, and is routinely activating the demand valve, there is little that can be done to overcome the problem. The condition was reported to the manufacturer.

In Phase 9, all tests were terminated due to oxygen depletion with empty breathing bags. The wide range of average inhaled O_2 test averages is due to the difference in the apparatus O_2 regulator flow rates, which ranged in this phase from 1.15 to 3.50 L/min ATPD.

On one apparatus, the hose that connects the CO_2 canister to the breathing bag was stuck to the CO_2 canister and ripped upon attempting to unstick it. The apparatus was run on the BMS to determine what would happen if worn during an actual escape, besides the obvious effect of permitting possibly toxic ambient air to enter the breathing circuit. The demand valve was activated upon each breath, exhausting the O_2 supply in 53 minutes. Apparently, a significant portion of exhaled breath exited the tear in the connector hose and did not enter the breathing bag. Upon inhalation, the lost volume was made up through demand valve use, drawing down the O_2 in the cylinder more rapidly than normal.

Increased CO_2

In Phase 8, fifteen deployed units experienced CO_2 levels above 4% before expenditure of the O_2 supply . None of the new units did so. The apparent degradation of the CO_2-absorbent canister is mitigated by the fact that the CO_2 levels did not rise high enough to be noticeable to a user, except for one unit that reached 7.3% at 111 minutes. In this case, the user would probably have experienced some hyperventilation (deeper-than-normal breathing). This apparatus was stored on a mining machine (Getman tractor) in a 3-shift/day mine for 2 years and 4 months.

Other Observations

In Phase 8, many units had small cracks in their outer cases, some with internal damage. While units with cracks performed normally, this points out the problem with inspection of this apparatus. Small cracks in the tough outer case are evidence of severe impact likely to have had more effect on the delicate internal components. The damage eluded detection until the unit reached the testing lab.

Only after washing off the caked-on dirt and, in some cases, not until the metal straps were removed, was the damage revealed. The metal straps are normally removed only during the donning procedure. It is extremely important, then, to thoroughly examine all EBA 6.5 cases for any cracks, however small they may be. It is recommended that all SCSRs be carefully cleaned of caked-on dirt each time they are inspected.

Several apparatus had cylinder valves that were hard to open; one ultimately required pliers to do so.

One apparatus had a large tear in the exhalation hose. This was reported to the manufacturer. The effect on a user would be that a significant portion of exhaled breath would exit the hole and not go through the CO_2 canister to the breathing bag. Upon inhalation, the lost volume could come from ambient, back through the hole, and from the demand valve. Excessive use of the demand valve would quickly deplete the O_2 supply. Four apparatus had their lower connector hoses somewhat stuck together, resulting in high breathing pressures until they were discovered and opened up. The connector hose channels the exhaled air from the chemical canister to the breathing bag. A CPIP investigation was opened.

Two cylinder gages had readings over the pressure limit. This turned out to be gage inaccuracy, rather than over-filling of the cylinders. The cylinders read 450 and 700 psi when empty. One unit was missing a clamp around the exhalation breathing hose at the mouthpiece, which came apart when the mouthpiece and breathing hose assembly was extended to pull out the mouth plug for testing. It was reattached and the apparatus performed normally. These problems were reported to the manufacturer.

In Phase 9, numerous apparatus were tested that had visible damage indicating they should have been removed from service. Six units had cracks in their outer cases indicating severe impact and possibly resulting in critical internal damage, although not in these apparatus. One unit had a visible coating of mud on the inside of the case. It functioned normally, however. External handle straps were disconnected on one side of three units, making them very difficult to open. Another unit had a dented canister, a shifted cylinder band, and an exhalation hose that was apparently installed twisted one full turn. This unit had the highest test-average exhalation pressure (186 mm H_2O) ever recorded in any Phase of this study for an EBA 6.5. It is near the exhalation pressure tolerance limit of approximately 200 mm H_2O. One unit caused violent coughing upon initial donning although the test subject was able to continue with the test. One unit was found with its relief valve unseated, leaving a huge breach in the breathing circuit. Another unit's neck strap was misassembled such that it would not hold a position, and slipped to its full extension. The O_2 supply hose of one unit was not attached to the breathing bag. The O_2 supply hose of another one tore when attempting to disconnect it from the breathing bag to connect it to the flow meter to check the flow rate. This indicates material decay, although it would not likely have prevented successful use of the apparatus.

Wilcoxon Rank-Sum Test

In both Phase 8 and Phase 9, the Wilcoxon rank-sum tests show that new units, statistically, had significantly lower average inhaled CO_2 values than deployed units, and new units, statistically, had significantly lower exhalation breathing resistance than deployed units.

In phase 9, two units had high breathing pressures. These are expected to be within human tolerance limits as previously discussed.

OCENCO M-20 Discussion

Laboratory inspection results are shown in Table 9. The failure rate in Phase 9 was 30% of the 20 units collected.

Table 9. Lab Inspection Results for OCENCO M-20–Phase 9

SN	Failure
513354	Top bumpers missing
513406	One top bumper missing
513445	Ball-bearing tamper seal missing
513488	One top bumper missing
513500	Bottom bumper and one of two top bumpers missing
513502	Top bumpers missing

BMS and Treadmill Testing

Time to depletion, as shown in Figure 8b, was comparable for new and deployed units.

All tests were terminated with empty breathing bags due to oxygen depletion, with one treadmill test simultaneously reaching 4% CO_2.

Wilcoxon Rank-Sum Test

No data were collected for the OCENCO M-20 for Phase 8 testing. In Phase 9, the Wilcoxon rank-sum tests show that deployed units cannot be distinguished from new units in any performance measure.

Other Observations

Five units were missing one or more of their external rubber bumpers, which should have necessitated removing them from service. Two were found with LiOH (Lithium Hydroxide) powder in the breathing bag, one of which was missing both top bumpers. The LiOH powder in the breathing bag would not have prevented successful use of the apparatus. Six apparatus showed evidence of mine dust leakage into the cases, again apparently not affecting performance to a significant degree.

Long Term Field Evaluation Phase 8 Summary

The results of this study indicate that the mining environment seems to have caused some performance degradation in all the apparatus to some degree. The deployed CSE SR-100s tested in this phase exhibited CO_2 levels exceeding 4% (74% of all units tested, with 29% of these occurring before 60 minutes); stuck-together breathing hoses (10%), some leading to tearing; starter-O_2 failure (10%); breathing hose punctures and tears (9%); breathing pressures exceeding +200 mm H_2O or -300 mm H_2O (8%); and loose particulates in the breathing hose. The loose particulates caused coughing in human-subject tests. In addition, it was found that if the case had sustained an impact toward the top where the inner canister seal is located; the seal could become distorted, permitting extremely irritating bed chemicals to escape into the breathing circuit. If the orange plastic case springs back after such an impact instead of cracking, this type of damage would escape visible detection. CSE addressed these issues through the deployment of the induced noise test, improved inspection criteria, the addition of a heat indicator, and upgraded assembly and packing procedures.

The Draeger OXY K-Plus exhibited a similar problem in that impact in the area of its metal belt-clip can crack or shatter an internal component, permitting in-leaking of the ambient air. While this damage is subtle, it is detectable, because the metal belt-clip is permanently deformed from any such impact. Specific inspection for this damage has been added to the OXY K-Plus's overall inspection criteria within the user's instructions.

A 7% reduction in capacity has been observed in the MSA Life-Saver 60 among apparatus tested in this phase. In addition, bed chemical leakage into the breathing circuit was found in one unit. Upon further investigation in cooperation with MSA, KO_2 was found in the breathing circuits of five other units. MSA has now revised the expected service life of the Life-Saver 60 to be a total of 20,800 hours of mobile use (10 years of 8-hour work shifts, 5 days per week, 52 weeks per year), defined as any deployment mode other than ground storage.

The OCENCO EBA 6.5 is showing some bed degradation leading to CO_2 levels above 4%, though not to a degree affecting successful use. A small number of units had demand valves that seemed to stick open when activated. In most cases, the high flow rate quickly dropped off to normal levels. In one case, however, it would have emptied the cylinder in 22 minutes, as evidenced by actually refilling the cylinder and activating the demand valve, as would happen in actual use. Several units had cylinder valves that were very hard to open; one required pliers. One unit had a tear in the breathing hose, and another was missing an exhalation hose clamp. All of these conditions were reported to the manufacturer. Although field inspection seems to be improving, we still found many EBA 6.5 units with disqualifying cracks in the cases. It is further recommended that units having any cracks in the case be removed from service.

Because of the importance of effective visual inspection, it is recommended that deployed apparatus of all types be cleaned of mine dirt for their 90-day inspections.

An interagency agreement between MSHA and NIOSH has created Care and Maintenance Training Modules for the five currently approved SCSRs. These training modules focus on the details of proper care and maintenance for SCSRs, and emphasize the importance of critical daily inspection.

Long Term Field Evaluation Phase 9 Summary

The results of this study suggest that some performance degradation was observed. The CSE SR-100s exhibit problems with CO_2 levels exceeding 4% (65% of all units tested, with 29% of these occurring before 60 minutes); stuck-together breathing hoses (19%) which were prone to tear; starter-O_2 failure (16%); breathing hose punctures and tears (9%); breathing pressures exceeding +200 mm H_2O or -300 mm H_2O (36%); and loose particles in the breathing hose (31%). The loose particles caused coughing in all human-subject tests.

A 7% reduction in capacity was observed in the MSA Life-Saver 60 among apparatus tested in Phase 8. In this Phase 9, we observed a 10% reduction in capacity with six units having durations less than 60 minutes.

For the OCENCO EBA 6.5, evidence of degradation and mechanical integrity loss were observed. A twisted exhalation hose caused the highest exhalation breathing pressures ever recorded in an EBA 6.5. Other manufacturing oversights were an unseated relief valve, a misassembled neck strap that would not hold a set, and an unattached O_2 supply hose. Two examples of material decay were identified: a connector hose stuck to the bottom of the CO_2 canister that tore when attempting to open up the flow path, and an O_2 supply hose that tore when attempting to perform the O_2 flow test. Although field inspection seems to be improving, six EBA 6.5s had disqualifying cracks in the cases, and three units had missing external handle straps, making it difficult to open the cases.

Because of the importance of effective visual inspection, it is recommended that deployed apparatus of all types be cleaned of mine dirt for their 90-day inspections.

Redesigned Long Term Field Evaluation

The Long Term Field Evaluation (LTFE) program for self-contained self-rescuer respirators for miners was initiated more than 20 years ago by the U.S. Bureau of Mines. The objective for the LTFE program is to obtain data to compare performance of mine deployed SCSRs to new SCSRs. LTFE program results based on scientific principles can provide useful information to monitor SCSR performance degradation due to the physical stresses of mine use and can be a useful indicator for the expected performance of deployed SCSRs. However, aspects of the current LTFE program limit the generalizability of the evaluation results. These program aspects are:

- SCSR sampling,
- SCSR test procedure,
- LTFE program alignment with certification program
- SCSR LTFE reporting.

Redesign of the LTFE to address these program aspects is under development by NIOSH NPPTL and will be implemented following peer review, stakeholder input, and completion of Phase 10 testing in the current LTFE program. Considerations for the redefined LTFE are:

SCSR Sampling

A systematic stratified sampling scheme will enhance the representativeness of the evaluated SCSRs. The sampling strategy may need to account for mine size, differences in deployment strategy, carried versus stored units, and/or the manufacture date of SCSRs.

Along with stratification factors the total number of sampled SCSRs to achieve statistical significance for program results needs to be evaluated. Continued activities to increase both the total number of deployed SCSRs and mine deployment strategies will have an impact on the sampling strategy used for the redesigned LTFE program.

SCSR Test Procedure

Current LTFE program testing is different from testing used for certification of SCSRs to the requirements of 42 CFR, Part 84. SCSR evaluation testing for certification relies on a series of bench tests and human subject tests (man tests) to establish conformance with the requirements specified in 42 CFR, Part 84. Current LTFE program evaluations are based on laboratory testing to evaluate SCSR performance using a combination of machine tests and human subject tests. For the machine tests a breathing and metabolic simulator (BMS) is used to test SCSRs to an end point, oxygen depletion. The BMS operational parameters are selected to provide a constant and repeatable physiological work rate. The current LTFE program tests are expected to remain in the redefined LTFE program. BMS testing at a constant rate to obtain an operational end point is a reliable and repeatable means of evaluation. The primary test procedure difference anticipated for the redesigned LTFE program is that each phase of testing will also include testing of new SCSRs to establish a performance baseline. The baseline data may be useful for evaluating the trend of SCSR manufacturing output and for comparing deployed SCSR degradation. Evaluation test results are expected to consider only the life support capability of the tested SCSR: oxygen supply, carbon dioxide removal and capacity or duration. The life support parameters for oxygen and carbon dioxide concentrations will be established based on physiologically acceptable limits for the expected duration of the SCSR.

LTFE Program Alignment With Certification Program

The newly designed LTFE program will better align the SCSR evaluations with the respirator certification program. The certification program, in evaluating conformance with 42 CFR Part 84 requirements, requires the manufacturers to project the usable service life of deployed units and to establish quality controls in the manufacture of new units. NIOSH intends to augment existing LTFE testing with audit testing of new SCSRs to evaluate continued conformance with certification requirements, annual manufacturing site quality audits to evaluate conformance with the NIOSH certified quality plan, and documented corrective actions resulting from problem investigations.

SCSR Reporting

More regular reporting of LTFE program results is expected under the redesigned program. The new reports will include results of evaluation testing, follow-through corrective actions to address issues observed during evaluation, and verification of manufacturer site quality audits.

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Phase 8

MSHA District 1 Office, Wilkes-Barre, PA
D&D Primrose Slope, Donaldson, PA
M&M Coal Co., Mercury Slope, Hegins, PA
Rhen Coal Co., Skidmore Slope, Pine Grove, PA
RS&W Coal Co., RS&W Drift, Klinserstown, PA

MSHA District 2 Office, New Stanton, PA
Consolidation Coal Co., Mine No. 84, Eighty Four, PA
Cyprus Emerald Res. Corp., Emerald Mine No.1, Waynesburg, PA
Consolidation Coal Co., Bailey Mine, Graysville, PA
Consolidation Coal Co., Enlow Fork, West Finley, PA

MSHA District 3 Office, Morgantown, WV
BJM Coal Co., Mine No. 9A, Summerville, WV
Red Bone Mining Co., Crawdad No.1 Mine, Morgantown, WV
Coastal Coal, Whitetail Kittanning Mine, Newberg, WV
Scorpio Mining Inc., Laurel Run Mine, Fairmont, WV
Steyer Fuel Inc., Steyer Mine, Newberg, WV

MSHA District 4 Office, Mt. Hope, WV
BAR-K Inc., Madison, WV
Mountaineer Alma-A, Mingo Logan Mine, Wharncliffe, WV
Laurel Creek No. 1, Dingess, WV
Laurel Creek No. 3, Dingess, WV

MSHA District 5 Office, Norton, VA
Paramount Coal Corp., Deep Mine #28, Dante, VA
Har-Lee Mine #10, Clintwood, VA
Island Creek Coal Co., VP8, Oakwood, VA

MSHA District 6 Office, Pikeville, KY
Excel Mining LLC, Mine No. 2, Pilgrim, KY
McCoy Elkhorn Coal Corp., Mine # 21, Kimper, KY
Lodestar Energy Inc., Miller Creek Mine #1, Pikeville, KY
Consol of Kentucky, Rhoades Branch H-4, Deane, KY
South Akers Mining #8, Pikeville, KY

MSHA District 7 Office, Barbourville, KY
BR&D Enterprises Inc., BR&D #3, Middlesboro, KY
Kentucky May Mining, Kite, KY
Mallie Coal Co., Inc., Mine #4, Woodbine, KY
Minton Hickory Coal Co., Mine # 9, Corbin, KY
Blue Diamond No. 74, Slemp, KY

MSHA District 8 Office, Vincinnes, IN
White County Coal Corp., Pattiki Mine, Henderson, KY
Consolidation Coal Co., Rend Lake Mine, Sesser, IL
Wabash Mine Holding Co., Wabash Mine, Keensburg, IL

MSHA District 9 Office, Denver, CO
Energy West Mining Co., Deer Creek Mine, Huntington, UT
C W Mining CO-OP, Mine Bear Canyon #1, Huntington, UT
Bowie #2 Mine, Paonia, CO

MSHA District 10 Office, Madisonville, KY
Baker Mine, Sturgis, KY
Peabody Coal Co., Camp 11 Mine, Henderson, KY
Dotiki Mine, Henderson, KY
Cardinal Mine, Morton's Gap, KY
Island Mine #1, Madisonville, KY

MSHA District 11 Office, Birmingham, AL
North River #1 Mine, Berry, AL
Jim Walters Resources, Inc., #4 mine, Brookwood, AL
Jim Walters Resources, Inc., #5 mine, Brookwood, AL
Jim Walters Resources, Inc., #7 mine, Brookwood, AL
US Steel Mining Co., Oak Grove Mine, AL
Drummond Co., Shoal Creek Mine, Jasper, AL

Phase 9

MSHA District 1 Office, Wilkes-Barre, PA
B and B Coal Co., Rock Ridge No. 1 Slope, Tremont, PA
Buck Mt. Slope, Tremont, PA
Harmony Mine, Mt. Carmel, PA
Jordan #1 Slope, Shamokin, PA
Little Buck Coal Co., No. 2 Slope, Pine Grove, PA
No. 1 Slope, York, PA
RS&W Coal Co., RS&W Drift, Klingerstown, PA

MSHA District 2 Office, New Stanton, PA
Maple Creek Mining Inc., Bentleyville, PA
Mountain Springs Coal, Shippingport, PA

MSHA District 3 Office, Morgantown, WV
Crafts Run Mine, Dana Mining Co., Morgantown, WV
Difficult Mining Inc. Johnstown #1, Johnstown, PA
Flag Run Mining, M&J Coal Co. Inc., Bridgeport, WV
Ryanstone No. 1 Mine, Philippi, WV
Spruce #1, Buckhannon, WV
Steyer Mine, Steyer Fuel, Inc., Newberg, WV

MSHA District 4 Office, Mt. Hope, WV
Elk Run Coal Co., Black King #1 Mine, Sylvester, WV
Harmon Branch Mining, Inc., Caretta, WV
Island Fork Construction 36 Mine, Beckley, WV
Laurel Creek No. 4, Dingess, WV
Rock N Roll Coal Co., Inc., Mohawk, WV
US Steel Mining Co., # 50 Mine, Pineville, WV
MSHA District 5 Office, Norton, VA

Apollo Mining #1, Bristol, VA
Buchanan Mine #1, Mavisdale, VA
Cherokee Mine, Haysi, VA
Four "O" Mining Co., Vansant, VA
MSHA District 8 Office, Vincennes, IN

Air Quality Mine #1, Black Beauty Coal Co., Evansville, IN
Freeman United Coal Co., Crown II mine, Vinden, IL
Triad Underground Mining, L.L.C., Edwardsport, IN

MSHA District 10 Office, Madisonville, KY
Dotiki Mine, Nebo, KY
KenAmerican Resources Inc., Central City, KY

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Appendix 1—Certified Product Investigation Program (CPIP) Investigations Initiated From LTFE 8 & 9

Task Number	Date Opened	Date Closed	Mfg.	Description	Approval Number	Resolution
CSE SR-100						
11813	1/2/2001	1/16/2001	CSE	SR-100 - Two units tested at PRL did not fire when activated.	TC-13F-0239	Units cold started successfully
12022	6/22/2001	7/9/2001	CSE	SR-100 No starter oxygen in cylinder Unit S/N 57942	TC-13F-0239	Unit cold started successfully
Ocenco EBA 6.5						
12023	6/22/2001	3/21/2005	OCN	High oxygen flow rate resulting in low duration on a simulator test - Valve hard to turn	TC-13F-0104	
12202	11/8/2001	8/5/2002	OCN	EBA 6.5 High oxygen flow found during LTFE at NPPTL	TC-13F-0104	Isolated Incident. Outside condition of use/failed visual inspection
12236	12/18/2001	3/23/2004	OCN	EBA 6.5 - Torn (deteriorated) breathing hose discovered by LTFE	TC-13F-0104	Breathing hose deteriorated from exposure to strong sunlight.
12310	2/25/2002	8/5/2002	OCN	Clamp missing from hose end	TC-13F-0104	Determined to be an isolated case. Inspection criteria re-emphasized
12517	5/21/2002	2/15/2004	OCN	New unit EBA 6.5 - bulged case seal and oxygen	TC-13F-0104	Warranty issue, readily identifiabel by user

Appendix 2—Test Results

APPENDIX 2 – TEST RESULTS

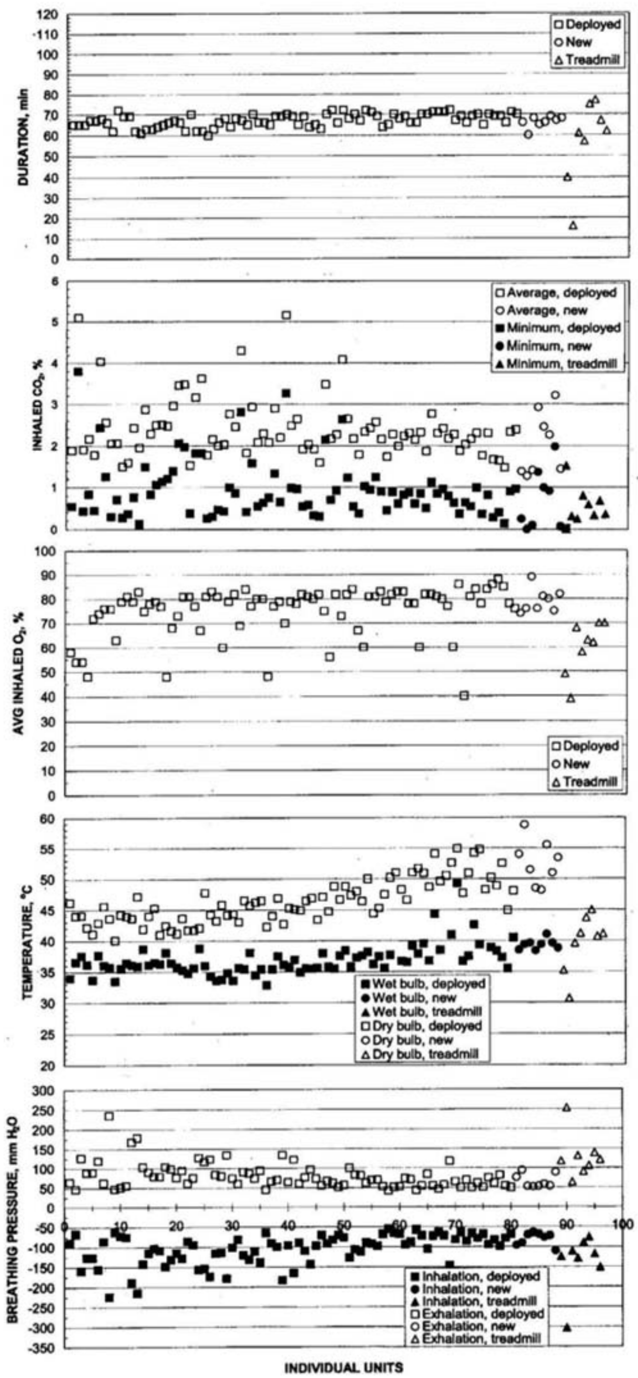

Figure A2-1. CSE SR-100 Test Results Phase 8

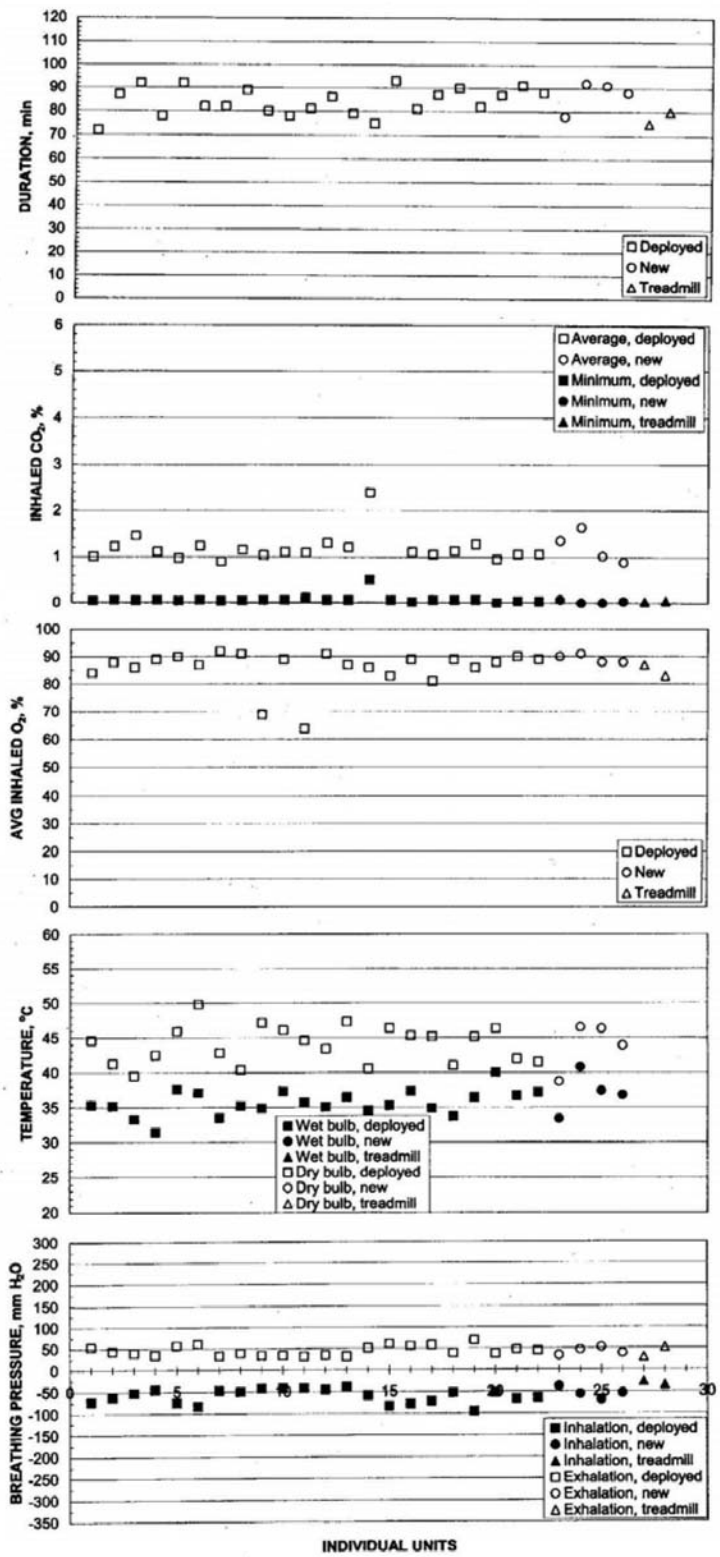

Figure A2-2. Draeger OXY K-Plus Test Results Phase 8

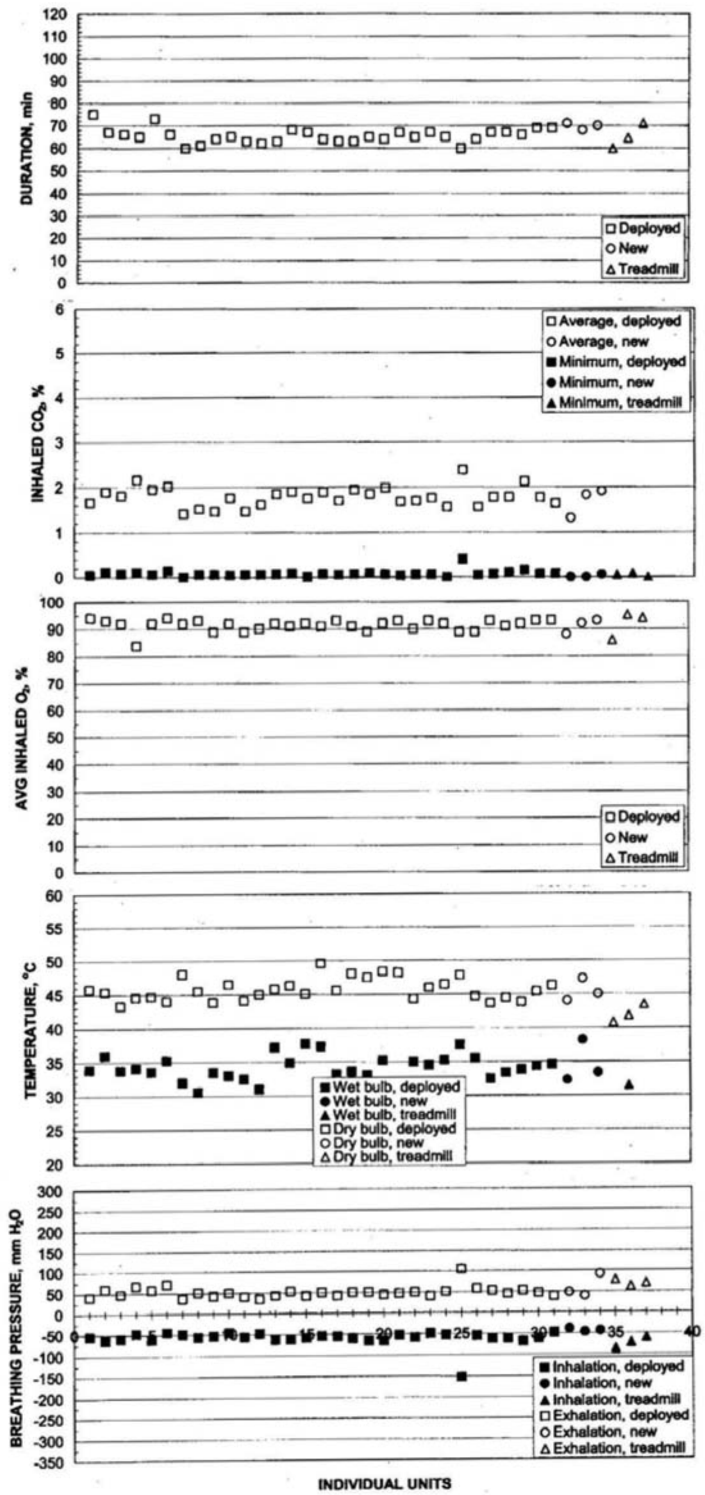

Figure A2-3. MSA Life-Saver 60 Test Results Phase 8

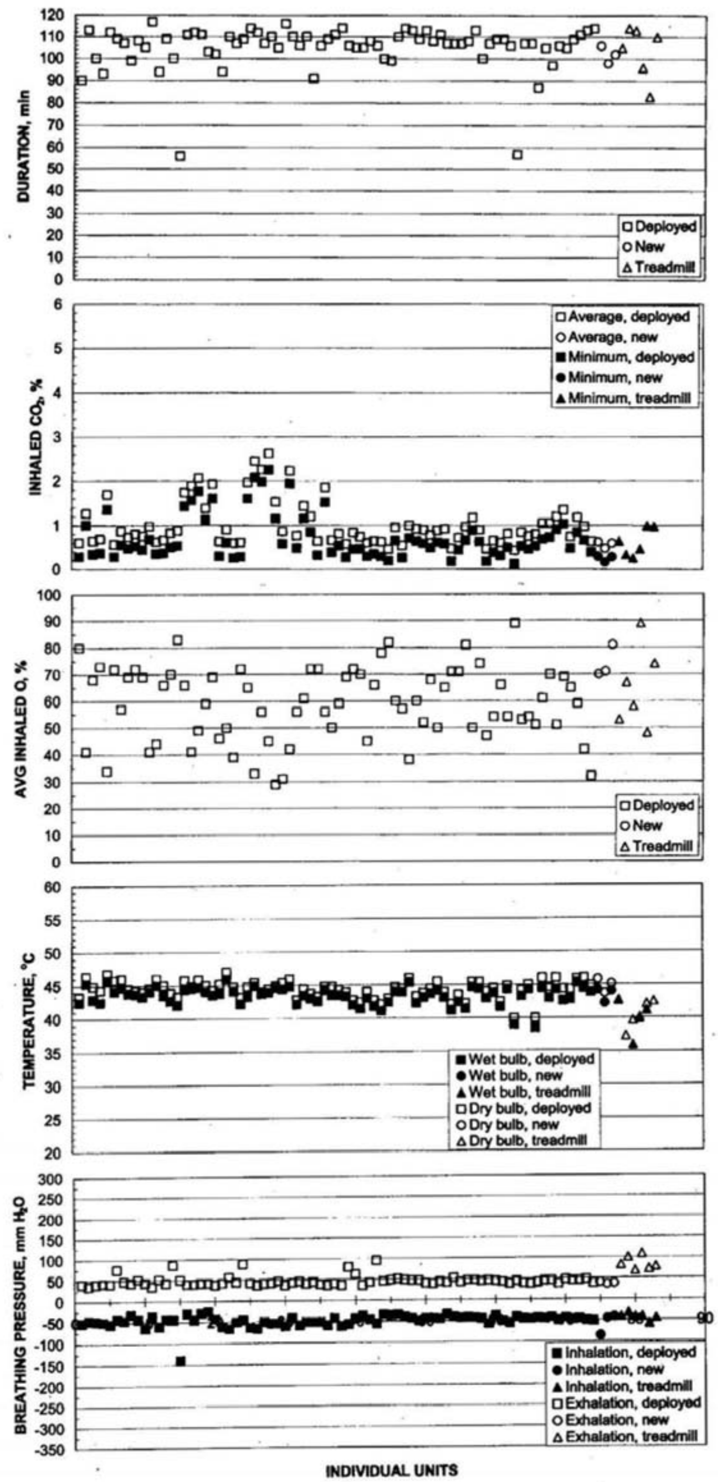

Figure A2-4. Ocenco EBA 6.5 Test Results Phase 8

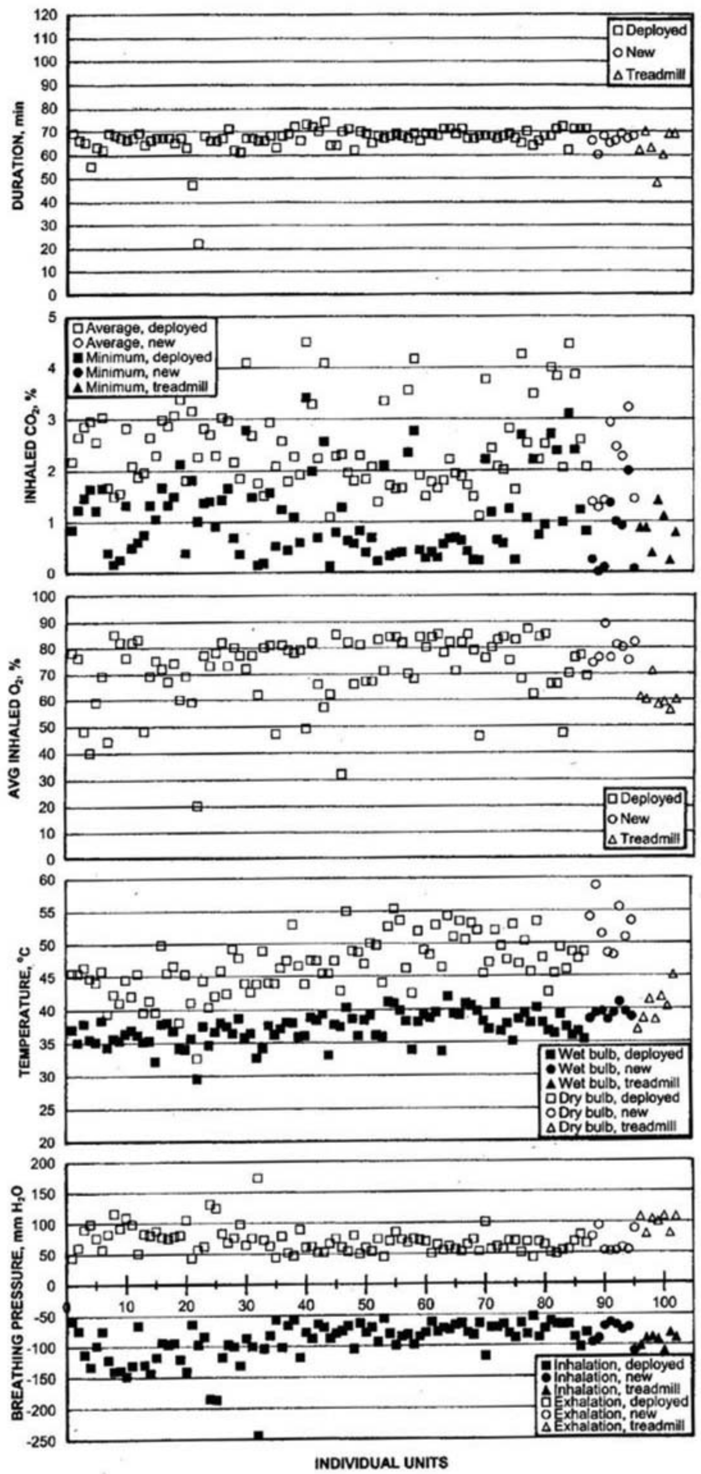

Figure A2-5. CSE SR-100 Test Results Phase 9

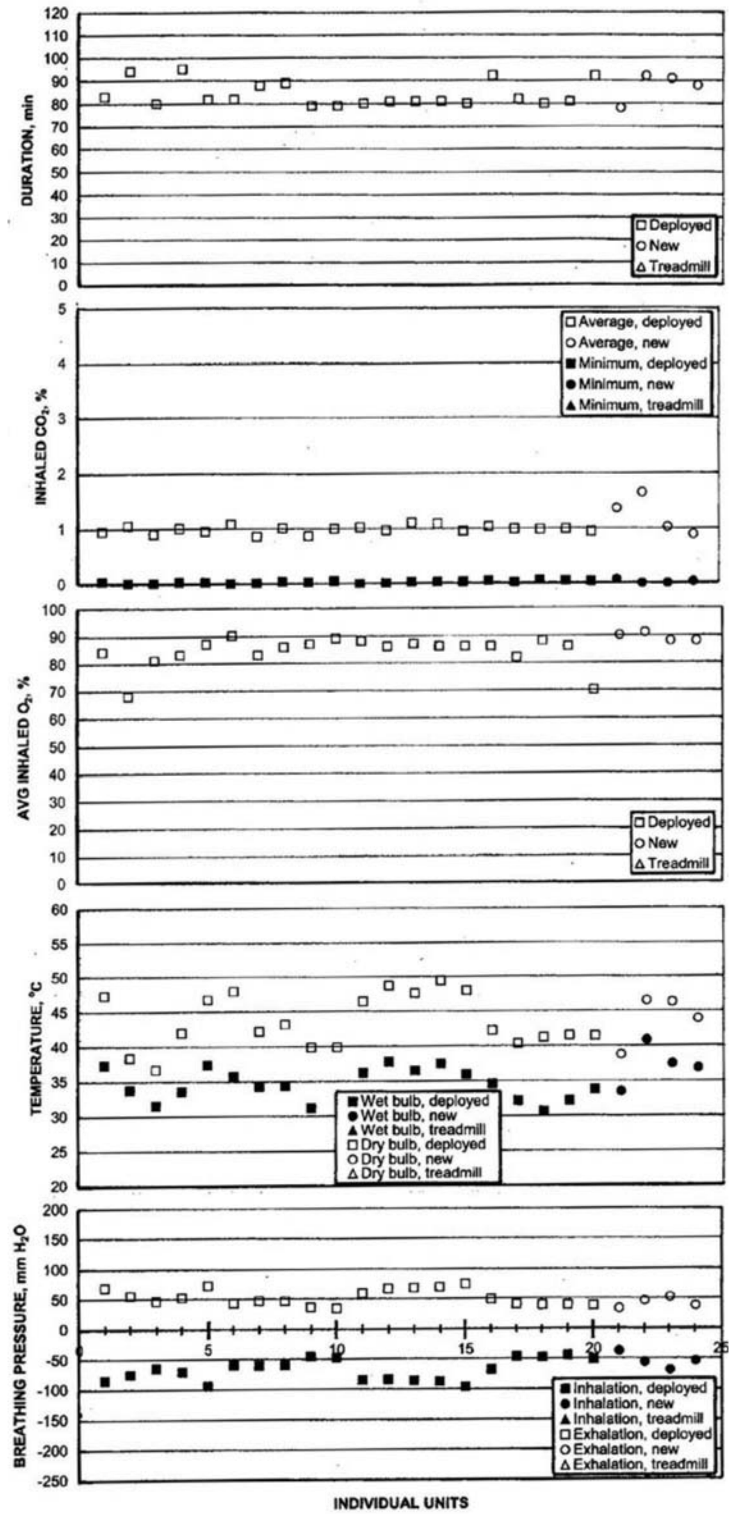

Figure A2-6. Draeger OXY K-Plus Test Results Phase 9

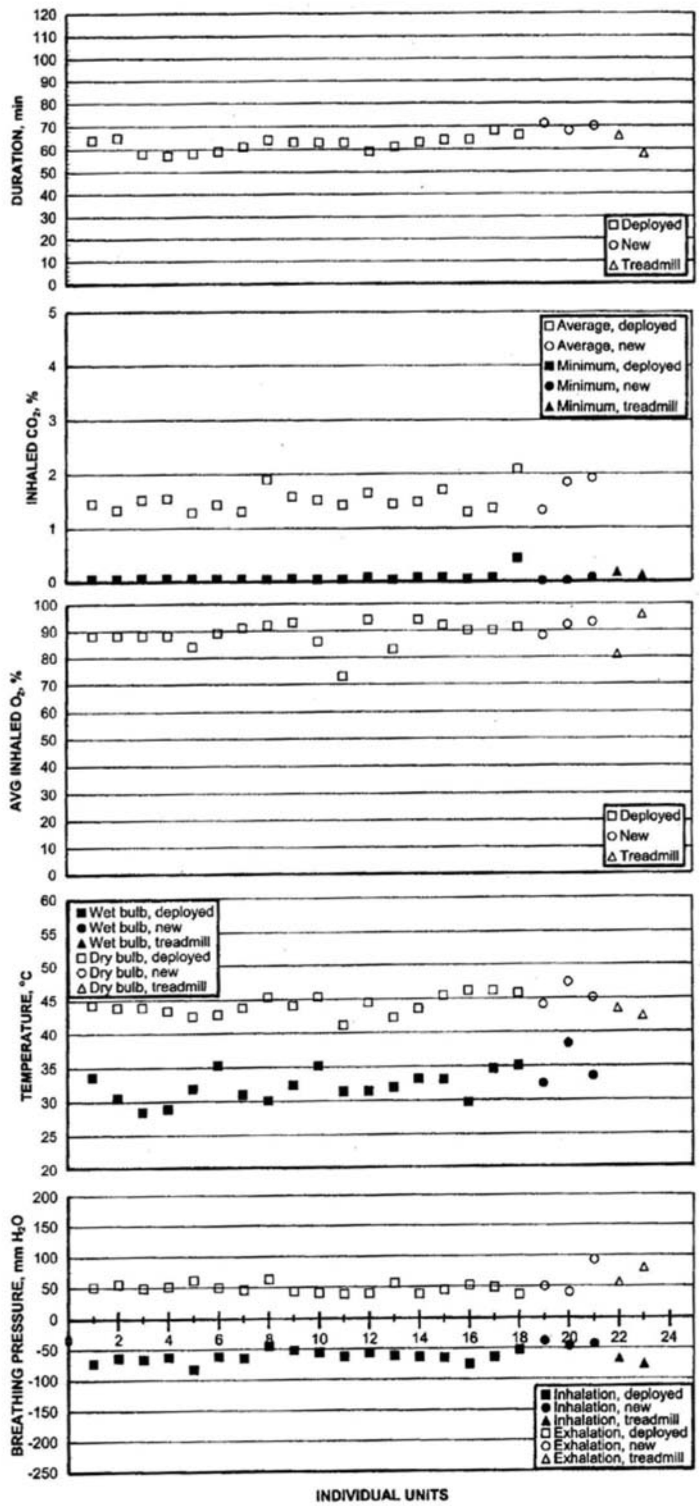

Figure A2-7. MSA Life-Saver 60 Test Results Phase 9

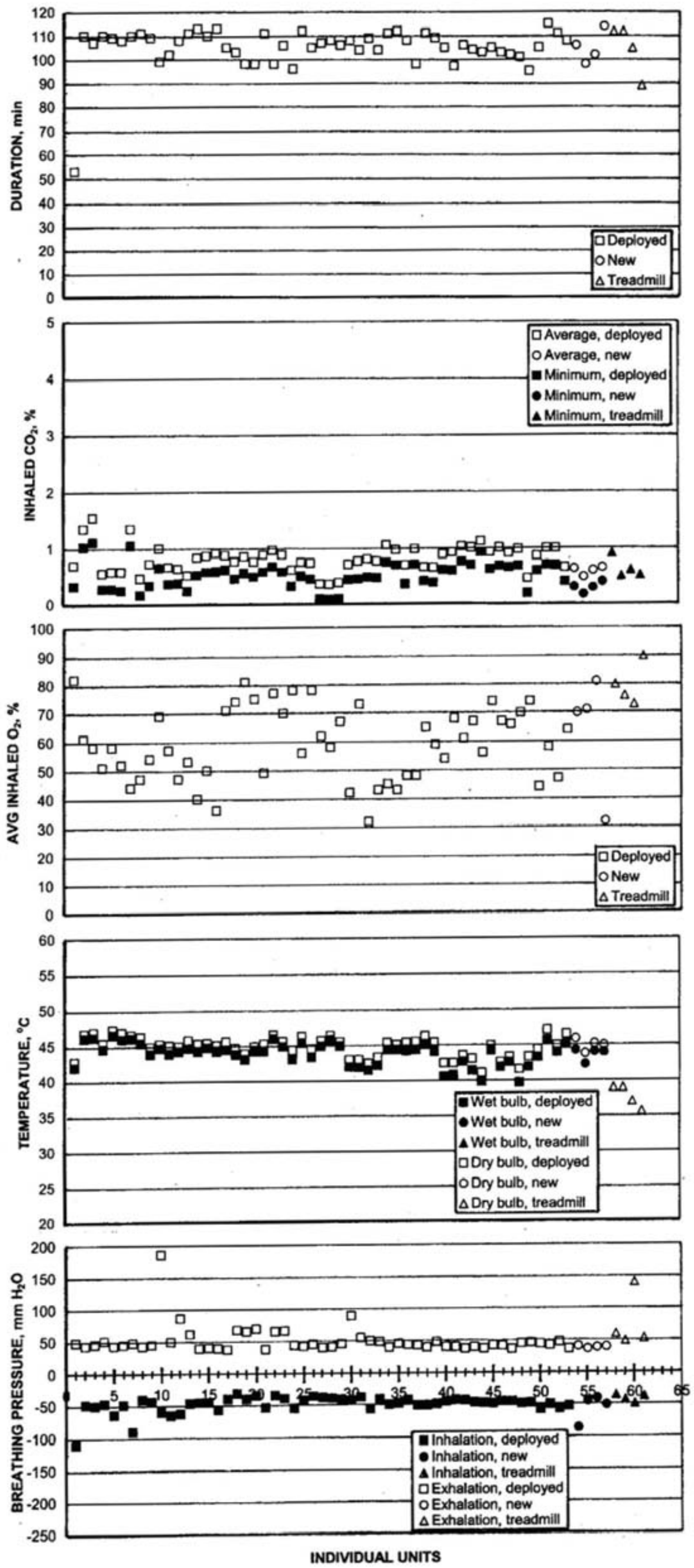

Figure A2-8. Ocenco EBA 6.5 Test Results Phase 9

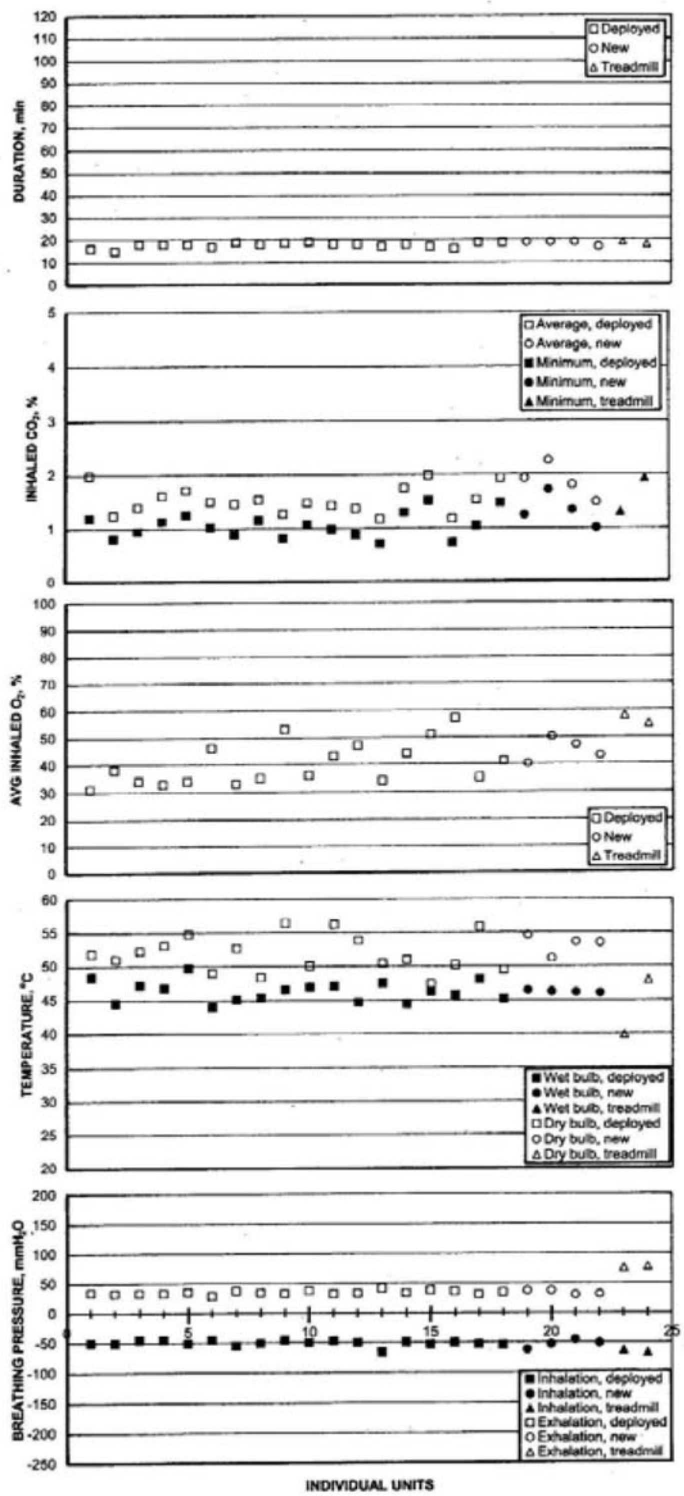

Figure A2-9. Ocenco M-20 Test Results Phase 9

Appendix 3—ASMD Test Results

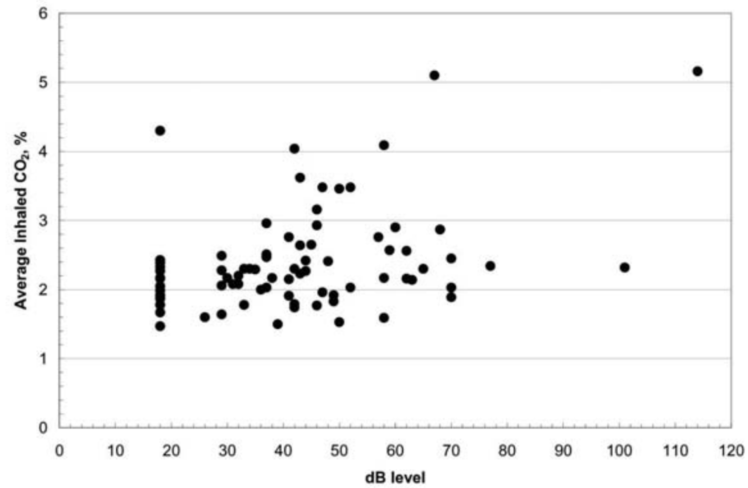

Figure A3-1a. CSE SR-100 Decibel Level versus CO_2 Level Phase 8

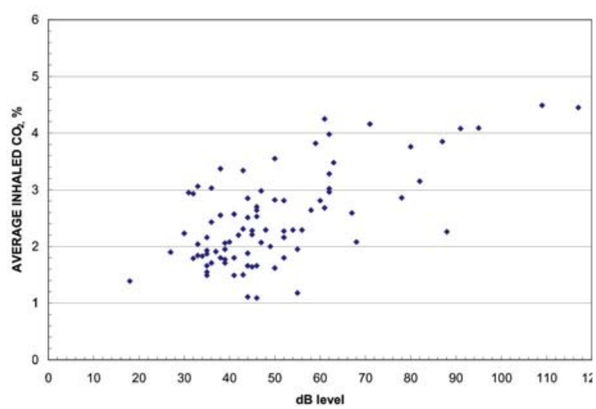

Figure A3-1b. CSE SR-100 Decibel Level versus CO_2 Level Phase 9

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