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Self-Contained Self-Rescuer Field Evaluation: First-Year Results of 5-Year Study

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

°C	degree Celsius	min	minute
h	hour	mm	millimeter
kg	kilogram	pct	percent
L	liter	s	second
lb	pound	yr	year
L/min	liter per minute		

SELF-CONTAINED SELF-RESCUER FIELD EVALUATION: FIRST-YEAR RESULTS OF 5-YEAR STUDY

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ABSTRACT

A joint effort by the Bureau of Mines and the Mine Safety and Health Administration (MSHA), U.S. Department of Labor, was undertaken to determine how well self-contained self-rescuers, deployed in accordance with Federal Regulations (30 CFR 75.1714), held up in the underground environment. This report presents findings regarding laboratory-tested breathing apparatus from the first year of a 5-yr program as well as other related findings. The SCSR's were tested on human subjects and on a breathing and metabolic simulator. These results indicate that the apparatus, if well-treated, perform as expected except for manufacturing defects or quality control problems, which are identified. However,when the apparatus are carried in and out of the mine every day and stored at the working section, they may suffer abuse that can be extreme. Physical signs of abuse, unless extremely obvious, frequently are not detected by the miners or the mine operators; this poses a danger to a potential user in case of emergency. Recommendations include improved training in inspection procedures.

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INTRODUCTION

On June 21, 1981, coal mine operators in the United States 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 self-rescuer that has an oxygen source. The Bureau of Mines is involved with the Mine Safety and Health Administration, U.S. Department of Labor, (MSHA) in a 5-yr in-mine evaluation of SCSR's now deployed in underground coal mines. In this study, MSHA's responsibility is to identify the participating mines and to procure from those mines the SCSR's to be tested. The Bureau replaces those SCSR's with new units and tests the SCSR's in the laboratories of the Life Support Group at its Pittsburgh Research Center. The objective of this 5-yr program is to evaluate the in-mine, operational durability of SCSR's. Of utmost concern is the successful performance of any SCSR that passes its inspection criteria. Such apparatus will be relied upon to function successfully in an emergency. Apparatus that fail inspection criteria are expected to be removed from service.

In a related study with MSHA, the Bureau is evaluating the performance of SCSR's that have been deployed by MSHA inspectors for 3 yr. In the first part of the MSHA inspectors' SCSR study, a sampling of four apparatus was tested in the Life Support laboratories. The second phase consisted of 14 apparatus that were worn by MSHA inspectors while they walked around a track as fast as conditions permitted in the experimental mine at the Pittsburgh Research Center.

EXPERIMENTAL PROCEDURE

This program involves testing approximately 100 SCSR's per year for 5 yr, with the first year split up into two, 6-month intervals. This report describes findings through the second 6-month period. Testing was done using human subjects on a treadmill or a breathing and metabolic simulator (BMS). In the first 6-month period, 90 pct of the tests were performed using a BMS and 10 pct using human subjects. The apparatus collected from the participating mines for the second 6-month test period were tested by human subjects on the treadmill because the BMS was unavailable.

The SCSR's tested were manufactured by CSE, Draeger, MSA, Ocenco, and PASS (table 1), and were sampled according to market share. The sampling was modified to ensure that at least 10 SCSR's from each manufacturer were sampled annually.

MSHA chose the participating mines with regard to type of mining machinery, seam height, and SCSR deployment mode in order to obtain a representative cross section of U.S. mines. The list of participating mines is shown in the appendix.

Five human subjects were used in the treadmill tests. Their weights and ages are given in table 2.

The treadmill test consisted of the treadmill-equivalent of the 1-h man-test 4 from 30 CFR 11 used by the National Institute for Occupational Safety and

TABLE 1. - Self-contained self-rescuers received for evaluation

Type of SCSR	Estimated market share, pct	1st 6 months		2d 6 months		Total tested
		Rec'd	Tested	Rec'd	Tested	
CSE AU-9A1	20	21	21	5	4	25
Draeger OXY-SR 60B	21	6	6	15	15	21
MSA 60-min SCSR	04	13	13	2	1	14
Ocenco EBA 6.5	54	24	18	20	20	44
PASS 700	01	0	0	10	6	6
Total	100	64	58	52	46	110

TABLE 2. - Weights and ages of human subjects for treadmill tests

Subject	Weight		Age,
	kg	lb	yr
A	64	141	20
B	82	181	33
C	64	141	34
D	93	205	26
E	80	176	41

TABLE 3. - BMS breathing and metabolic parameters

O_2 consumption rate.........L/min..	1.35
CO_2 production rate.........L/min..	1.30
Ventilation rate............L/min..	31.9
Tidal volume (per breath).......L..	1.21
Respiratory frequency breaths/min..	26.5
Peak flow rate.............L/min..	126

Health (NIOSH), U.S. Department of Health and Human Services, in its testing and certification program. The BMS test consisted of the average metabolic work rate exhibited by the 50th-percentile miner weighing 87 kg (191.8 lb) while performing the 1-h man-test 4. The metabolic parameters (at STPD) are given in table 3. The BMS is shown in figure 1.

The parameters monitored were CO_2, O_2, temperature, and breathing resistance in the BMS and the treadmill testing. In the BMS tests, average inhaled levels of gas concentration were measured; in the treadmill tests, only minimum values of CO_2 and maximum of O_2 were able to be measured. Average inhaled gas levels take into account the effect of dead space in an apparatus, but minimum values reflect only scrubber performance and do not indicate the actual concentration of gas inhaled. The BMS measures average inhaled values by having separate paths for inhalation and exhalation in the internal flow loop and, therefore,

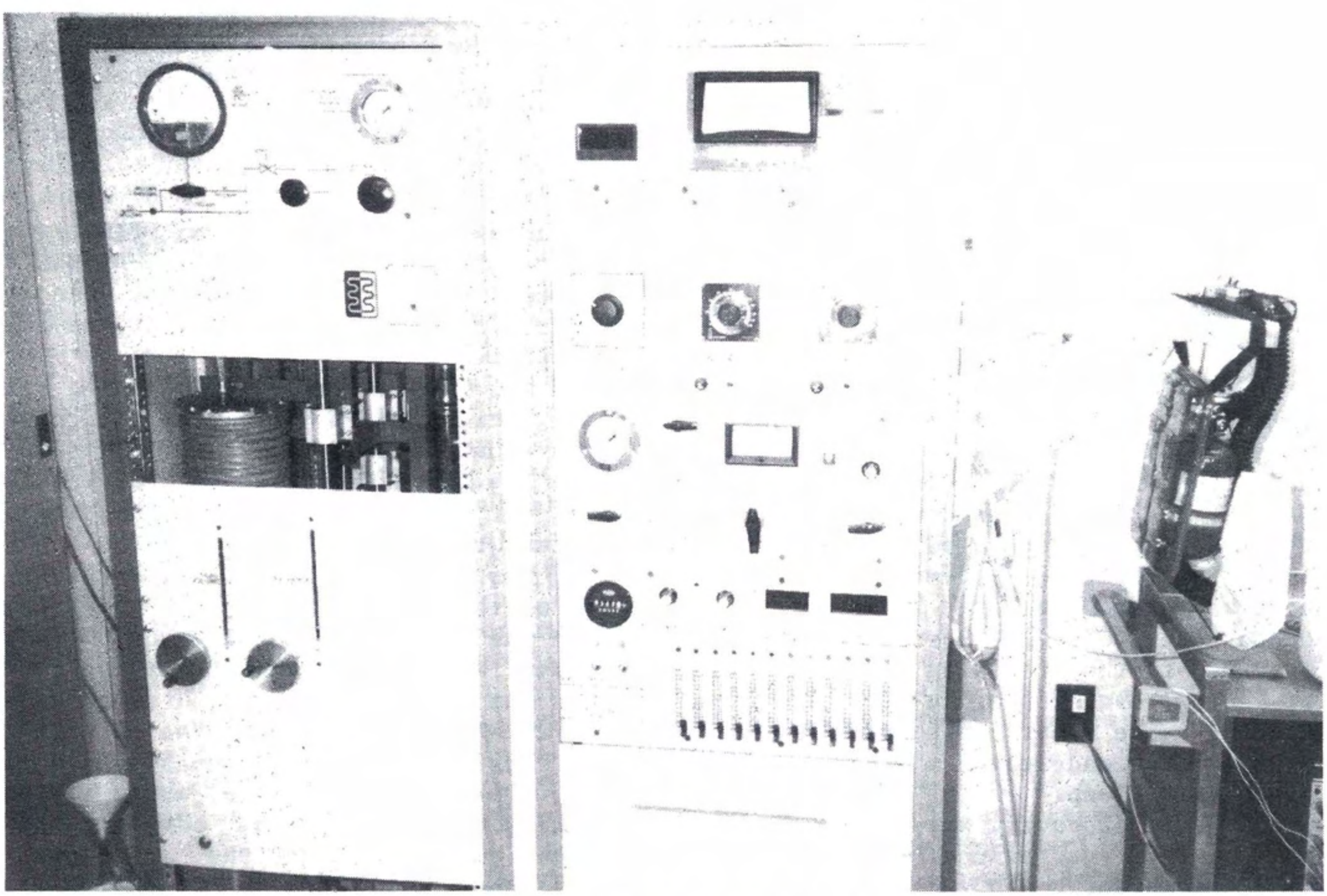

FIGURE 1.—Breathing and metabolic simulator.

collects all of the gas that is actually inhaled.

The termination criteria were a collapsed breathing bag, indicating an exhausted oxygen source or average inhaled gas levels of >4 pct CO_2 or <15 pct O_2.

RESULTS AND DISCUSSION

Problems were encountered with several of the apparatus; consequently, some were not tested. Of those not tested, some were rejected because they failed their inspection criteria; others failed while being tested. Special-case results are categorized by type of apparatus. General results are discussed later.

CSE

One CSE SCSR was rejected owing to damage (no intact lead seal and rattling of internal components). When opened, it spilled out its components and could not have been used. This unit should have been removed from service. If there is internal damage to a CSE apparatus, it rattles when shaken, or the oxygen bottle gauge has shifted and cannot be easily read.

When a CSE SCSR is dropped on the lower case latch, the case bottom is pushed in, which causes the breathing bag to be punctured. Although this can be easily seen, sometimes it is not recognized. Improved training in inspection procedures would correct this situation.

DRAEGER

In the second phase of the MSHA inspectors' SCSR study, in which SCSR's were worn by MSHA inspectors, we found two Draeger SCSR's with broken clamps around the flow-splitting valve housing, which is at the interface between the breathing hose and breathing bag. During the test, one of the two users experienced the separation of the breathing hose from the breathing bag, rendering the unit unusable. The other unit held together. Draeger has undertaken a recall to replace this clamp.

One other discovery was that a significant percentage of the Draeger SCSR's had breathing hoses that were crimped where they were folded for packaging. Uncrimping the hose is simple, but it must be mentioned in the training procedure for using the apparatus.

There have not been any cases, other than the broken clamps mentioned above, in which a Draeger SCSR passed its inspection criteria and yet was not usable. Inspection of 13 Draeger SCSR's that had been subjected to the explosion forces in the McClure Mine disaster showed that even apparatus with significant damage performed normally and could have been used in attempting escape.

There have been two cases in which Draeger SCSR's were sent in from various MSHA districts with reports that they failed to function properly. Upon testing, the apparatus were found to function normally. Improper use could have caused such problems to occur. Again, improved training is recommended in both inspection and donning procedures.

MSA

Coughing occurs during the first several breaths when using many MSA SCSR's. Although the specific cause is unknown, it is attributed to one of several possibilities:

1. Talcum powder in the breathing circuit, which is used to keep the rubber parts from sticking together.
2. KO_2 fines that were not fully vacuumed out of the circuit at the time of manufacture.
3. KO_2 particles that escaped the filters of the chemical bed.

While one case can be attributed to cause 3 above, we believe that the majority of cases can probably be attributed to cause 1 or 2, since no damage to the filters or beds was found in most cases. In any case, MSA is planning to apply warning stickers to its apparatus advising that, should coughing occur, the apparatus is not defective and should not be removed, that any dust will settle promptly, and that coughing will cease.

Several early apparatus, produced for the Bureau and MSHA and now used by MSHA inspectors, had internal component structures that were dislocated from their shock mounts and were in danger of falling out of the lower case halves; this would have made them difficult to use. The condition was caused by one or more severe drops; however, no damage to the outer case was visible. This problem has been resolved in commercially available production models.

OCENCO

One Ocenco EBA 6.5 SCSR, which was used in the Greenwich Collieries escape, was found to have its check valves reversed; this made it very difficult to activate the demand valve. This was considered to be a quality control problem and was resolved by NIOSH and the manufacturer.

The major problems with the Ocenco SCSR are its stiff demand valve and its strong outer case. The pressure required to elicit 30 L/min from the demand valve is approximately 200 mm H_2O, compared with approximately 40 mm H_2O for the CSE demand valve. Upon high oxygen usage rates (over 1.8 L/min), the demand valve comes into use. Unless aware of this fact, the user is likely to think that the apparatus is malfunctioning. When 12 Ocenco EBA 6.5 SCSR's were used in Greenwich Collieries mine fire, 5 testimonies indicated that the users felt that they could not get enough air, and either removed the mouthpiece or nose clip, breathed around the mouthpiece, or slowed down. Training would remedy this problem to some degree, but the best solution is to replace this demand valve with one that is not as stiff.

The strength of the clear, outer case of the Ocenco enables it to withstand shock better than its internal components. In the case of the Greenwich Collieries mine fire, 12 of 17 units used for escape sustained internal damage sufficiently severe that they should have been removed from service. LiOH from the scrubber was found in the breathing circuits of five of these damaged units. In all the cases but one that we have seen (including Greenwich), the damage was evident, although it was not recognized by the miners, the mine operators, or the MSHA inspectors. Improved training in inspection procedures obviously is necessary. In one case, damage was not evident by inspection: the oxygen bottle was full, the bottle band was in place, and there were no cracks in the case. When the unit was opened, the breathing bag was found to contain several grams of LiOH; LiOH also was found in the mouthpiece and in the case. Upon close inspection, one could detect fine white particles of LiOH through the clear but scratched outer case. It is doubtful, however, that anyone would have noticed its presence unless one was looking for it. It is recommended that any unit with a severely scratched and gouged case be removed from service because it has suffered sufficient abuse to make it suspect.

A lesser problem is the tight-fitting case halves, which are extremely difficult to open without proper training. It is recommended that training include special mention of the opening procedure.

PASS

Two of the PASS SCSR's, for reasons still unknown, underwent a decrease in oxygen concentrations to below 15 pct, requiring termination of the tests. When these units were later dismantled and tested, the oxygen flow rates were found to be in compliance with specification. Since other apparatus were run immediately after their failures with no problems, malfunctioning measurement equipment was ruled out. One possible explanation is that the constant-flow regulators were initially clogged with some particulate matter that later freed itself. Since these incidents could not be repeated nor the causes pinpointed, they were not pursued, although they were reported to NIOSH.

One SCSR being tested by a human subject on a treadmill permitted high inhaled CO_2 concentrations during the first several breaths. It was found that the inhalation check valve was missing. This was considered to be a quality control problem and has been handled by NIOSH.

GENERAL RESULTS

All of the SCSR's that completed testing performed satisfactorily within a range of acceptable values. Performance parameters of individual units, divided by make and distinguished by test subject or type, are shown in figures 2 through 10. There are two sets of graphs, representing the first and second 6-month periods of the program. The parameters monitored are as follows: average inhaled O_2 concentration, average inhaled CO_2 concentration, inhaled gas temperature, and inhalation and exhalation breathing resistances. The parameters monitored were averaged over each test duration and are plotted on the vertical axis. Individual tests are plotted on the horizontal axis.

Average performance parameters for each type of apparatus for the first and second 6-month periods are presented in table 4. Only BMS test results were used for calculation in the first 6-month period.

TABLE 4. - Performance parameters for BMS and human-subject tests

Manufacturer	Number of tests	CO_2 level, pct	O_2 level, pct	Temp., °C	Breathing resistance, mm H_2O	
					Exhalation	Inhalation
BMS TESTS (1st 6 MONTHS)						
CSE................	19	2.5±0.3	75± 8	42±1	56± 3	48±3
Draeger............	5	1.1± .1	78± 5	40±2	60±12	29±5
MSA................	12	.7± .3	77± 4	44±2	65± 3	29±2
Ocenco.............	16	.6± .2	36±11	41±1	55± 6	40±3
HUMAN-SUBJECT TESTS (2d 6 MONTHS)						
CSE................	4	2.3±0.4	59± 8	40±1	40± 4	47±6
Draeger............	15	1.7± .6	76± 4	32±1	38± 7	24±6
MSA................	1	1.1	80	34	61	21
Ocenco.............	20	1.2± .4	61±10	38±2	35± 7	24±8
PASS...............	6	1.4± .6	79± 6	38±2	43± 7	17±4

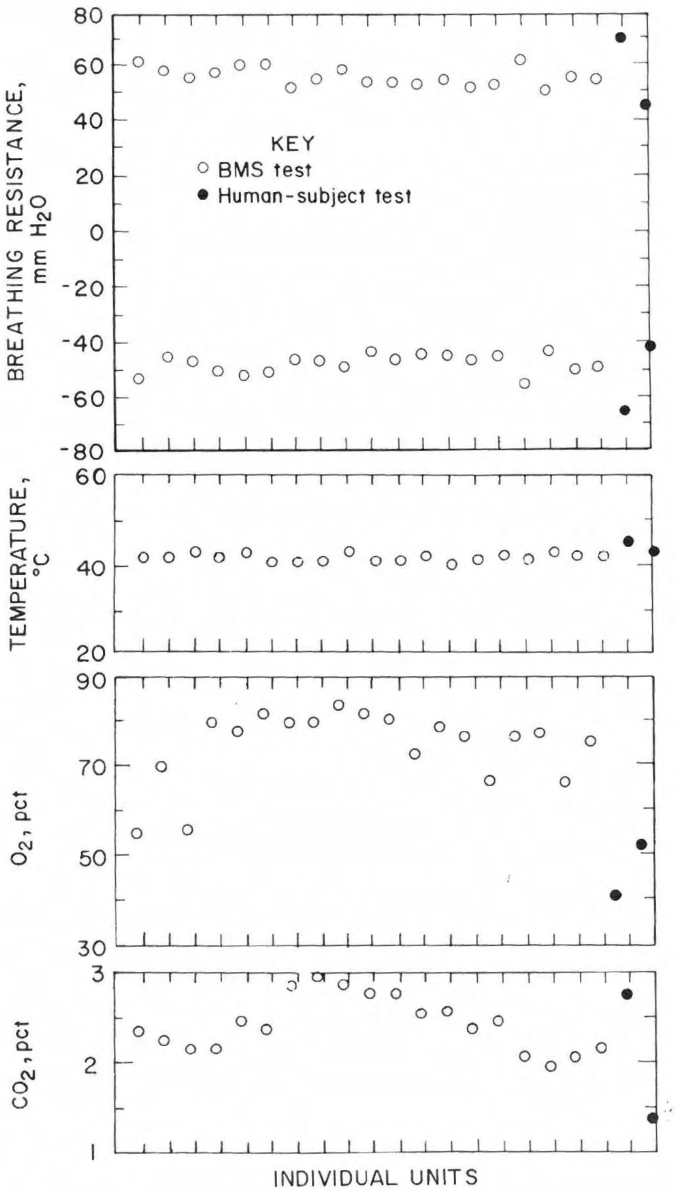

FIGURE 2.—CSE units, first 6 months.

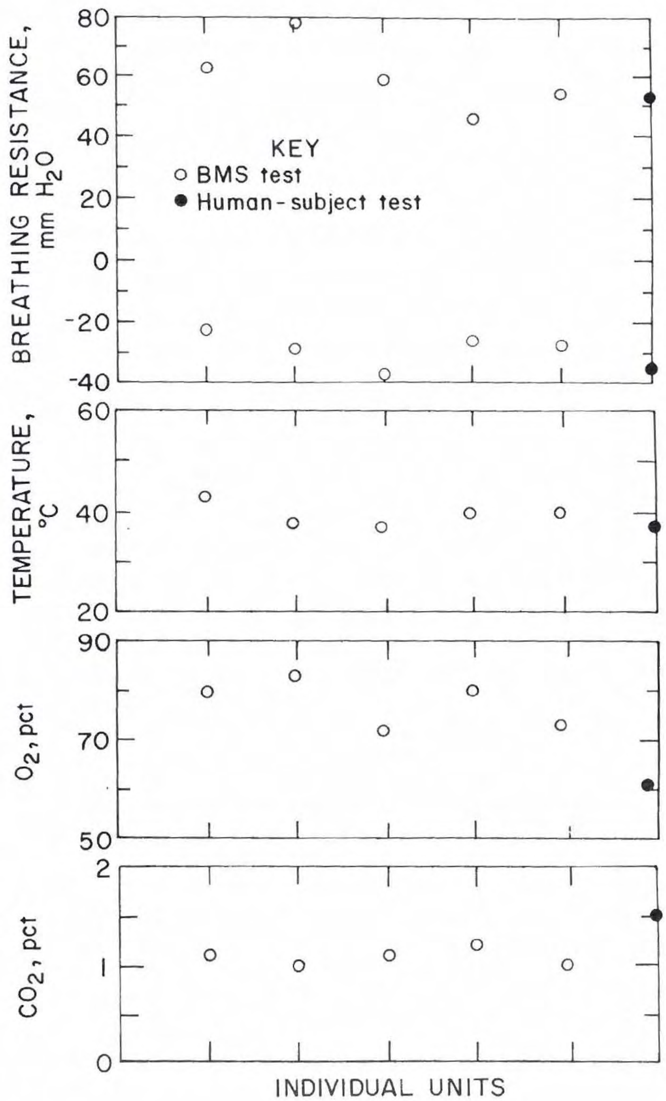

FIGURE 3.—Draeger units, first 6 months.

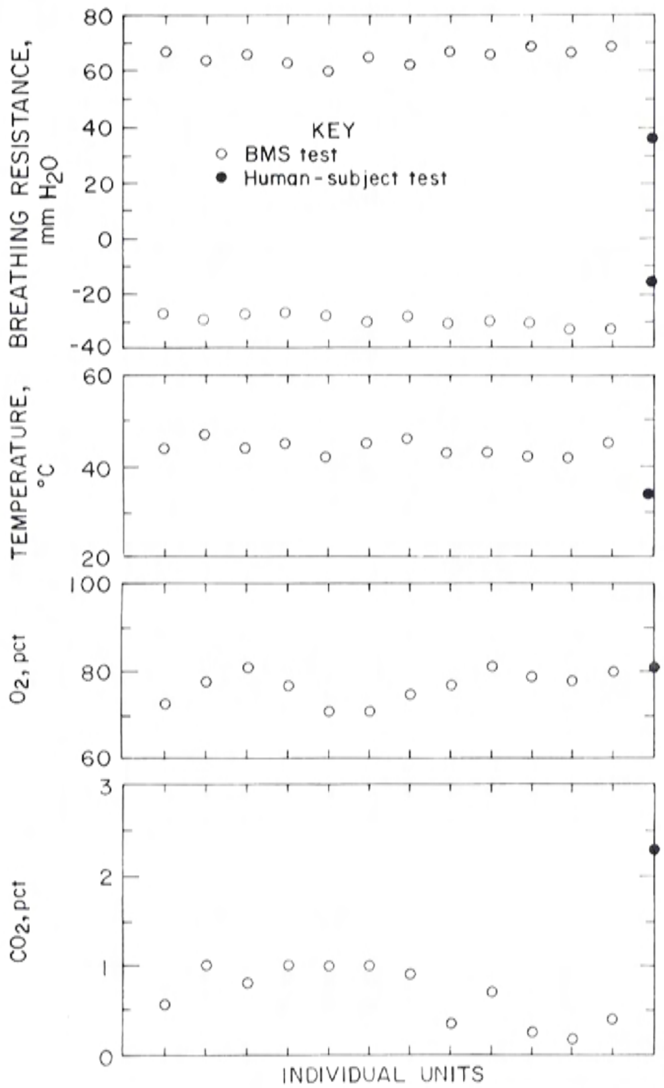

FIGURE 4.—MSA units, first 6 months.

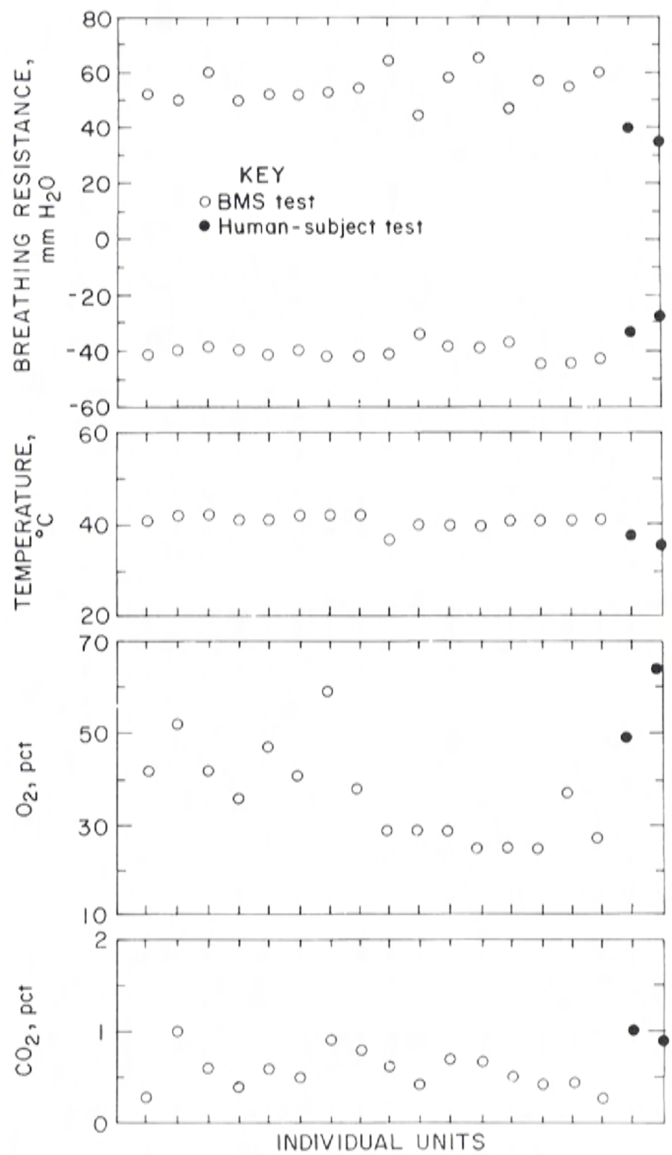

FIGURE 5.—Ocenco units, first 6 months.

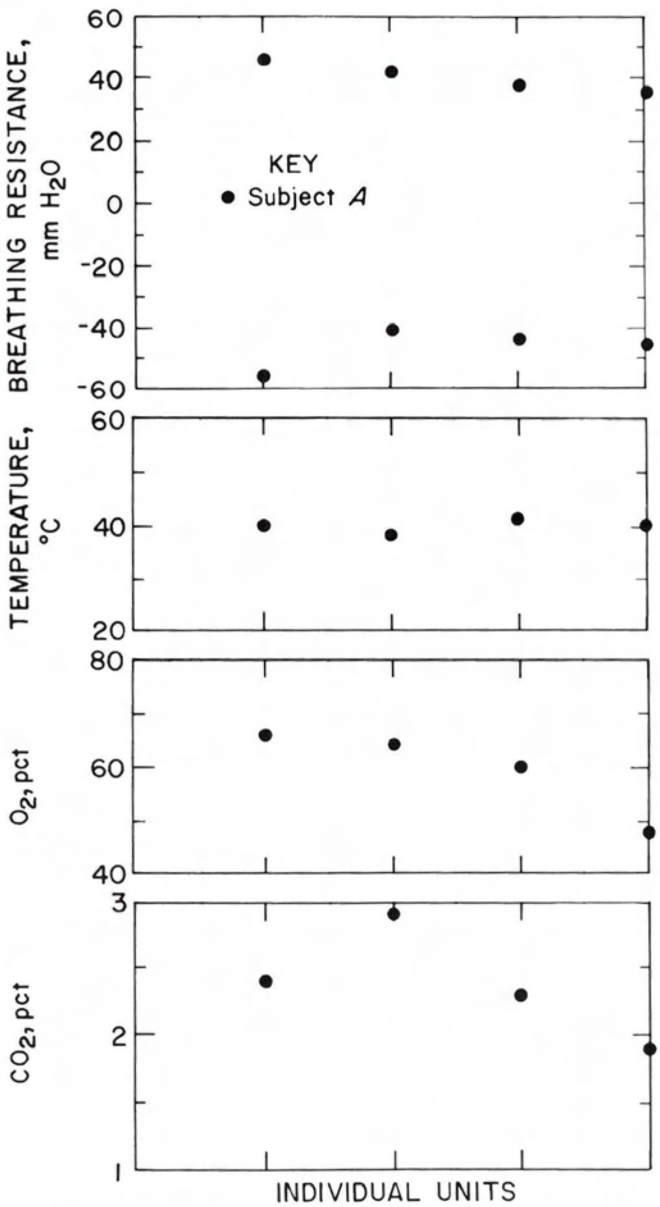

FIGURE 6.—CSE units, second 6 months.

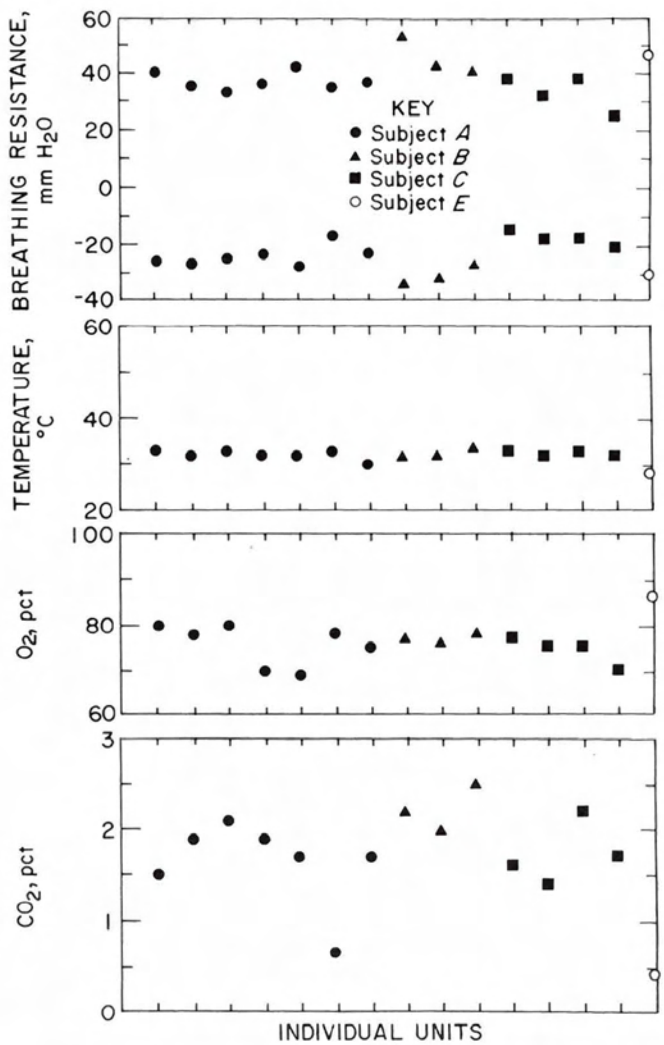

FIGURE 7.—Draeger units, second 6 months.

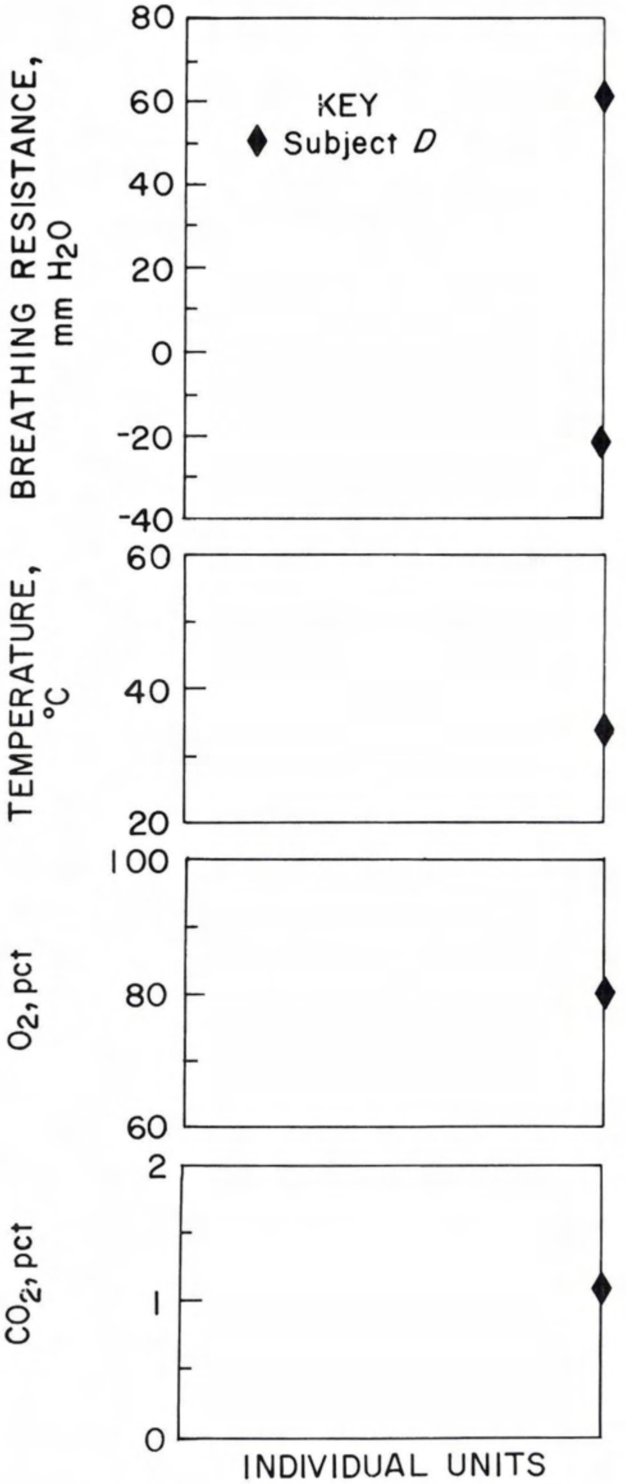

FIGURE 8.—MSA units, second 6 months.

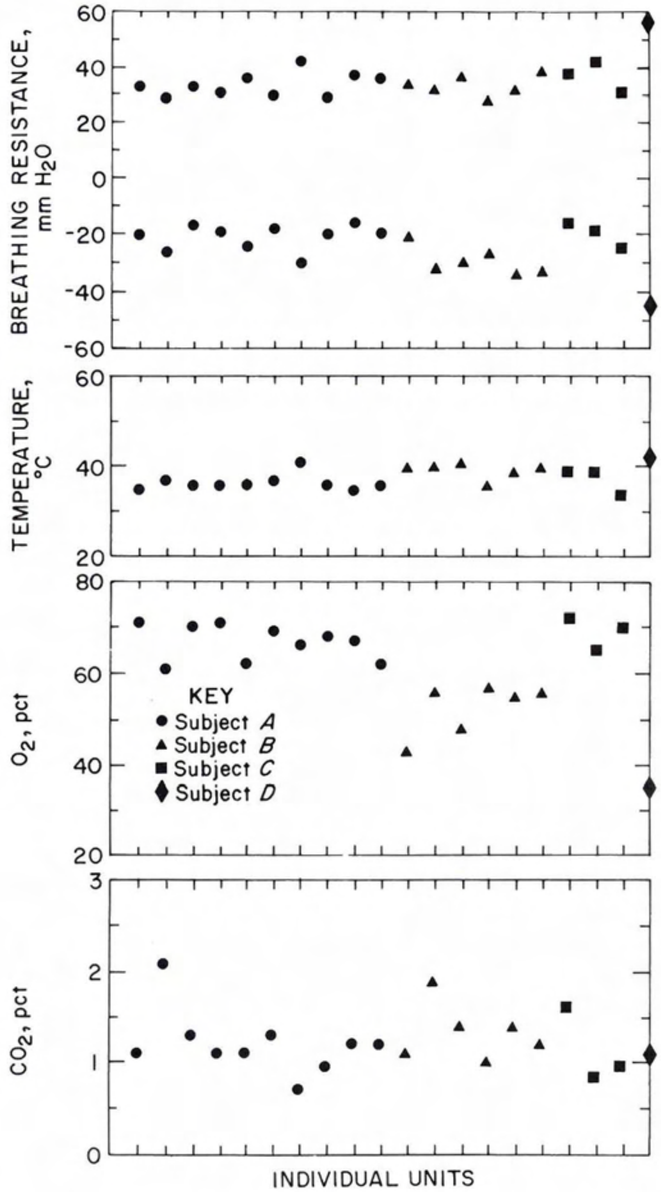

FIGURE 9.—Ocenco units, second 6 months.

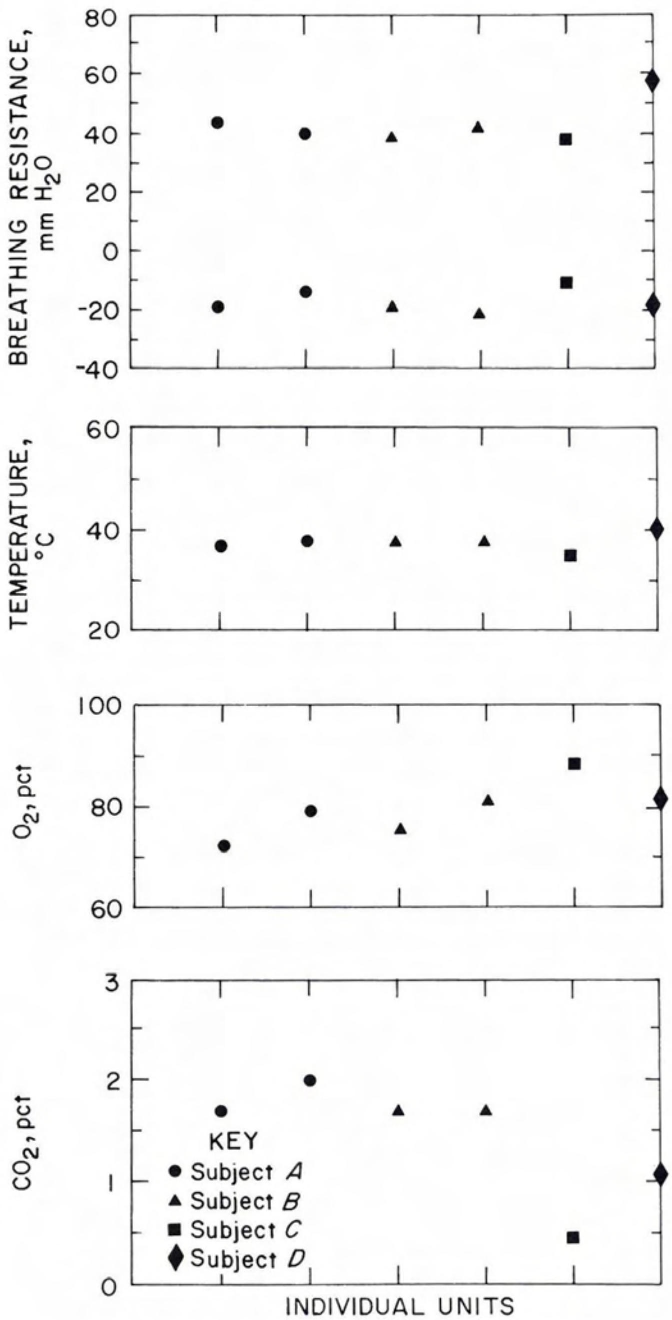

FIGURE 10.—PASS units, second 6 months.

CONCLUSIONS

A number of quality control problems were discovered in this phase of the 5-yr field evaluation. These problems were reported to NIOSH, MSHA, and the appropriate breathing-apparatus manufacturer. In each case, corrective action has been taken to solve the quality control problem.

Certain SCSR's collected during this period were damaged by daily, in-mine use and should have been removed from service. The damage was generally apparent and visible and should have been detected if the SCSR's had been properly inspected.

Coughing occurred during the first several breaths when using many of the SCSR's. According to the manufacturers, the coughing is not due to inhalation of KO_2 or LiOH; instead, it is caused by inhalation of the talcum powder used in the breathing hoses and bags to keep them from sticking together during storage. Training should include mentioning the possibility of coughing upon initial donning of an SCSR.

In general, providing that there are no quality control problems, the results of the first-year evaluation suggest that SCSR's that pass their inspection criteria can be counted on to provide a safe level of life support capability for mine escape purposes. No problems have arisen involving subtle performance degradation due to the mining environment. Rather, there have been either quality control defects or blatant abuse of the apparatus by the users. A dangerous situation occurs if the user does not recognize damage to the apparatus. This should be rectified through training.

APPENDIX.--PARTICIPATING MINES

Mine Operator	Mine
First 6 months:	
Bethlehem Mines Corp	Beth-Elkhorn No. 26
Consolidation Coal Co	Mathies
Dominion Coal Co	Young's Branch No. 15
Eastern Associated Coal Corp	Wharton No. 4
Emery Mining Corp	Deer Creek
G. M. & W. Coal Co	Grove No. 1
Mears Enterprises, Inc	Penn Hills No. 2
Do	Dixon Run No. 3
Pittston Coal Sales Co	Jewell Ridge No. 21-A
Rochester & Pittsburgh Coal Co	Emile
Southeastern Mining Co	No. 8
Valley Camp Coal Co	Valley Camp No. 1
Second 6 months:	
Bethlehem Mines Corp	Beth-Elkhorn No. 26
Consolidation Coal Co	Pursglove No. 15
Diamond Shamrock Coal Co	No. 10
Dominion Coal Co	Young's Branch No. 15
G. M. & W. Coal Co	Grove No. 3
Ike Coal Co., Inc	No. 3
Inland Steel Coal Co	No. 1
J & R Coal Co., Inc	No. 1
Jim Walter Resources, Inc	Bessie
Keystone Coal Mining Corp	Emilie No. 1
Long Flame Coal Co., Inc	No. 25-B
Peabody Coal Co	No. 10
Pyro Mining Co	Pyro No. 9
Do	Wheatcroft
S. S. Joe Burford Coal Co	Coal Bank Fork No. 8
U.S. Steel Mining Co., Inc	Maple Creek No. 2
Westmoreland Coal Co	Eccles No. 6

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