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REPORT OF INVESTIGATIONS/1991

Evaluation of the Safety of the CSE SR-100 Self-Contained Self-Rescuer

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UNITED STATES DEPARTMENT OF THE INTERIOR

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

Btu/lb-mol	British thermal unit per pound-mole
°C	degree Celsius
cm	centimeter
cm^3	cubic centimeter
°F	degree Fahrenheit
ft	foot
ft^3	cubic foot
ft/s	foot per second
g	gram
gal	gallon
h	hour
in	inch
kcal/mol	kilocalorie per mole
kg	kilogram
L	liter
lb	pound
m	meter
min	minute
mm	millimeter
m/s	meter per second
oz	ounce
Pa	pascal
psi	pound per square inch
s	second
st	short ton

EVALUATION OF THE SAFETY OF THE CSE SR-100 SELF-CONTAINED SELF-RESCUER

By R. W. Watson,[1] R. L. Brewer,[2] W. J. Doyak,[3] and A. L. Furno[4]

ABSTRACT

A belt-wearable self-contained self-rescuer (SCSR) manufactured by the CSE Corp. and designated the "SR-100" was evaluated for safety in the underground mine environment by the U.S. Bureau of Mines. The evaluation consisted of laboratory tests on the chemicals contained in the unit and field trials to simulate the mine environment. This report summarizes the test results and compares the results with those from earlier tests with chemical and compressed oxygen self-rescuers. It was concluded that the new SCSR did not pose any different or more severe hazards than the earlier units. In view of the mine-proven safety record of the SCSR's now in service, no reason could be found to disallow use of the belt-wearable unit.

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INTRODUCTION

A Federal regulation (30 CFR 75.1714), which went into effect on June 21, 1981, requires that every person who goes into an underground coal mine in the United States must be supplied with an SCSR. An SCSR is a self-contained, closed-circuit, emergency breathing apparatus designed for mine escape purposes.

All SCSR's intended for in-mine use must be approved by the National Institute for Occupational Safety and Health (NIOSH) and the Mine Safety and Health Administration (MSHA) under a schedule given in 30 CFR 11, Subpart H, for 60-min-duration breathing apparatus. Both chemical oxygen and compressed oxygen SCSR's have received NIOSH-MSHA approval; as of July 1, 1982, five different SCSR's were commercially available.

In early 1989, the U.S. Bureau of Mines was requested by MSHA to evaluate a new belt-wearable SCSR for potential hazards associated with the general use of this device in underground coal mines; the self-rescuer was manufactured by the CSE Corp. and was designated the "SR-100." A test protocol was agreed at a planning meeting held on March 8, 1989, which was attended by representatives of the Government and the mining industry, including the Bureau, MSHA, the American Mining Congress, the Bituminous Coal Operators Association, the United Mine Workers of America, the R&P and Consolidation Coal companies, the CSE Corp., and the National Mine Service Co. The protocol was based on previous hazard evaluations performed on 1-h self-rescuers containing oxygen-generating chemicals (*1*)[5] or compressed oxygen (*2*).

Commercial units became available in early April 1989, and the experimental work was started shortly thereafter. This report summarizes the experimental findings with the SR-100; comparisons are made with the earlier work.

PHYSICAL DESCRIPTION OF UNIT TESTED

The SR-100 is a closed-circuit, self-contained oxygen supply system designed for use in toxic or oxygen-deficient atmospheres. The unit is 7.75 in (19.7 cm) high, 5.5 in (14.0 cm) wide, and 4.0 in (10.2 cm) thick and weighs 5.7 lb (2.6 kg). Starting oxygen is provided by a small compressed oxygen bottle, and the rest, by chemical means. The rated duration of the oxygen supply is 60 min. There are two chemical beds in the unit. A small bed at the bottom of the stainless steel housing contains 1.8 oz (50 g) of lithium hydroxide (LiOH). Above this bed and filling the remainder of the housing (which also contains the oxygen bottle) is a mixture of 20.6 oz (585 g) of potassium superoxide (KO_2) and 4.2 oz (120 g) of LiOH. Stainless steel screens and fiberglass filters separate and contain the beds in the housing.

The self-rescuer is encased in a stainless steel (AISI Type 304) housing, which has a plastic (PVC-Kydex brand)[6] wraparound (fig. 1*A*). The unit opens by means of a top latch similar to that used in existing filter self-rescuers. Opening the top latch causes the top and bottom covers to fall away, exposing the neck strap, breathing hose, mouthpiece, nose clips at the top, and the breathing bag and protective goggles at the bottom (fig. 1*B*). Pulling a fluorescent orange tag wired to the oxygen valve releases the starter oxygen into the breathing bag. Moisture in the exhaled breath activates the KO_2, releasing oxygen. Carbon dioxide (CO_2) in the exhaled breath is absorbed by the LiOH and the potassium hydroxide (KOH) resulting from the KO_2-water reaction. Figure 1*C* shows the components of a disassembled unit.

The oxygen bottle (fig. 1*D*) is 3.625 in (9.21 cm) long and 1.25 in (3.18 cm) in diameter; it contains 0.25 to 0.28 ft^3 (7 to 8 L) of oxygen at a working pressure of 2,250 psi (15.5×10^6 Pa). It has, as a safety device, a frangible disk soldered into the valve end of the bottle. This disk is designed to fail at 125% of the working pressure, 2,812 psi (19.4×10^6 Pa).

The SR-100 can be stored in the temperature range from 32° F (0° C) to 130° F (55° C). Its service life is 5 years as long as the color in the moisture indicator at the top of the unit remains blue. If the indicator color changes to pink or white, the unit is no longer suitable for use. Service life extensions may be offered contingent on field sampling.

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[5] Italic numbers in parentheses refer to items in the list of references at the end of this report.

[6] Reference to specific products does not imply endorsement by the U.S. Bureau of Mines.

Figure 1.—Construction features of SR-100. *A*, Complete unit; *B*, unit ready for use; *C*, disassembled canister; *D*, oxygen bottle.

TEST PROCEDURES AND RESULTS

The test protocol consisted of some preliminary experiments designed to provide a quick estimate of the potential hazards of the SR-100 in order to assure operational safety in conducting more realistic destructive tests to follow. The preliminary experiments consisted of drop weight impact and burning rate tests on the KO_2-LiOH mix used in the SR-100, and bullet impact and bonfire tests with complete units. A few tests involving the reaction of the KO_2-LiOH mixture with water and the injection of water into complete units were also conducted.

The preliminary experiments were followed by experiments involving various forms of mechanical abuse anticipated for the units when deployed in a hostile mine environment. These included roof falls, heavy equipment runover, and accidental encounters with a feeder-breaker.

The results of these experiments are discussed in this report; comparisons with the earlier work reported in references 1 and 2 are made where possible.

PRELIMINARY EXPERIMENTS

DROP WEIGHT IMPACT TESTS

The main chemical bed in the SR-100 consists of a physical mixture of KO_2 and LiOH. The older chemical SCSR units contained a single bed of KO_2 and depended on the formation of KOH (from KO_2 and exhaled moisture) for scavenging CO_2. KO_2 is a yellow solid having a specific gravity of 2.14 and a melting point of 380° F (193° C). It is a very strong oxidizer, and while it has no inherent explosive properties it can form explosive or rapidly burning mixtures when combined with any combustible material. The chemistry of KO_2 is more fully described in reference 1.

LiOH is a colorless (or white) chemical that has a specific gravity of 1.46 and a melting point of 462° F (239° C). It is not self-reactive and does not react with KO_2 at ordinary temperatures. It is a strong caustic agent, and its principal use is as an electrolyte in storage batteries and as an absorber of CO_2 in self-rescuers, space vehicles, etc.

The mechanical sensitivity of the KO_2-LiOH mixture alone and combined with various combustibles that would be found in coal mines was determined using the drop weight test that had been used in previous work (*1*). In this test, an 0.28-oz (8.0-g) sample of the material is distributed in a uniform layer over a 4.0-in (10-cm) diameter circular steel anvil. The sample is then struck by a 187-lb (85-kg) steel drop weight released from various heights to determine a go or no-go condition. Data from tests on the KO_2-LiOH mix alone and with crushed coal (through No. 8 and on No. 14 sieves), hydraulic oil, and No. 2 diesel fuel added to the mix are presented in table 1. For comparison purposes, results from similar tests with lump KO_2 separated from the KO_2-LiOH mix are also presented, along with the results of tests with 5010 smokeless powder.

As expected, the KO_2 and the KO_2-LiOH failed to react at the maximum drop height of 8 ft (2.44 m). The KO_2-LiOH and combustible mixtures all failed to react at 1 ft (0.305 m) but gave off smoke and sparks at 2 ft (0.61 m) and above. None of these reactions were judged to be explosions inasmuch as they did not produce audible reports. The KO_2 combustible mixes all failed to react at 0.5 ft (0.15 m) but exploded with loud reports at 1 ft (0.305 m). Thus, the KO_2-LiOH combustible mixtures were less sensitive to drop weight impact than the KO_2 combustible mixtures. This is probably due to a cushioning effect provided by the LiOH. The smokeless powder exhibited about the same sensitivity as the KO_2-LiOH combustible mixtures but produced an explosion rather than just smoke and sparks at the critical drop height.

BURNING RATE MEASUREMENTS

Burning rates were measured using the United Nations test method for readily combustible solids (*3*). In this test, a 10-in (250-mm) long train of sample with a triangular cross section 0.4 in (10 mm) high by 0.8 in (20 mm) wide is placed on a plate of low heat conductivity and ignited with a small flame at one end. Burning times are then recorded over a 4-in (100-mm) length of the sample starting 3 in (80 mm) from the ignition end.

Table 1.—Results of 187-lb (85-kg) drop weight tests

Test sample	Drop height, ft	Results	Remarks
KO_2-LiOH mix	8	No reaction	None.
50% KO_2-LiOH mix, 50% crushed coal.	1	do.	Do.
Do.	2	No explosion	Some smoke, sparks.
Do.	3	do.	Do.
Do.	4	do.	Do.
91% KO_2-LiOH mix, 9% hydraulic oil.	1	No reaction	None.
Do.	2	No explosion	Some smoke, sparks.
Do.	3	do.	Do.
Do.	4	do.	Do.
91% KO_2-LiOH, 9% diesel fuel.	1	No reaction	None.
Do.	2	do.	Do.
Do.	3	do.	Do.
Do.	4	No explosion	Some smoke, sparks.
KO_2	8	No reaction	None.
50% KO_2, 50% crushed coal.	.5	No explosion	Some smoke.
Do.	1	Explosion	Loud report.
91% KO_2, 9% hydraulic oil.		.5 . No reaction	None.
Do.	1	Explosion	Loud report.
91% KO_2, 9% diesel fuel.	.5	No reaction	None.
Do.	1	Explosion	Loud report.
Smokeless powder	1	No explosion	Some smoke.
Do.	2	Explosion	Loud report.

Burning rates are calculated and expressed as inches (or millimeters) per second. Burning rate measurements for the KO_2-LiOH mixture combined with crushed (through No. 8 and on No. 14 sieves) and dried Pittsburgh Seam coal are presented in table 2 along with comparison data for KO_2 and ammonium perchlorate (NH_4ClO_3) mixed with dried crushed coal. As will be noted, the KO_2 and coal mixture burned about four times as fast as the KO_2-LiOH and coal mixture. This is due to the fact that there was less KO_2 available in the latter mixture and possibly to the presence of LiOH, which would serve as a heat sink.

The burning rate of the KO_2-LiOH and coal mixture was in turn about four times as high as that of the NH_4ClO_3 and coal mixture, which illustrates the strong oxidizing character of KO_2 compared with more common oxidizers.

Table 2.—Burning rate measurements, inches per second

Test sample	*Rate*
50% KO_2-LiOH mix and 50% crushed coal	0.122
50% KO_2 and 50% crushed coal	.508
50% NH_4C10_3 and 50% crushed coal	.030

BONFIRE TRIALS

The small oxygen bottle in the SR-100 is equipped with a safety relief device in the form of a frangible burst disk, which is soldered into a small recess machined around a 0.0635-in (1.6-mm) orifice in the valve end of the bottle. This disk serves to prevent the buildup of excessive pressure in the bottle as a result of heat or overfilling. To check the performance of the relief disk and to observe the general behavior of the SR-100 under fire exposure, two bonfire trials were conducted with complete units. The units were placed on a steel grate (fig. 2*A*) placed over a 3-ft (0.91-m) square by 1-ft (0.3-m) deep steel box containing 45 gal (170 L) of water on which was floated 10 gal (38 L) of kerosene with a small amount of gasoline added to promote ignition. The fuel was ignited with a 0.35-oz (10-g) black powder ignitor (fig. 2*B*) and allowed to burn to completion, which normally took about 30 min.

The two burns produced more or less identical results, which are illustrated in figure 2. Figure 2*C* shows the initial stages of the fire, including considerable black smoke generated by the liquid fuel. About 5 min into the burn, a bright jet was observed to emanate from the unit

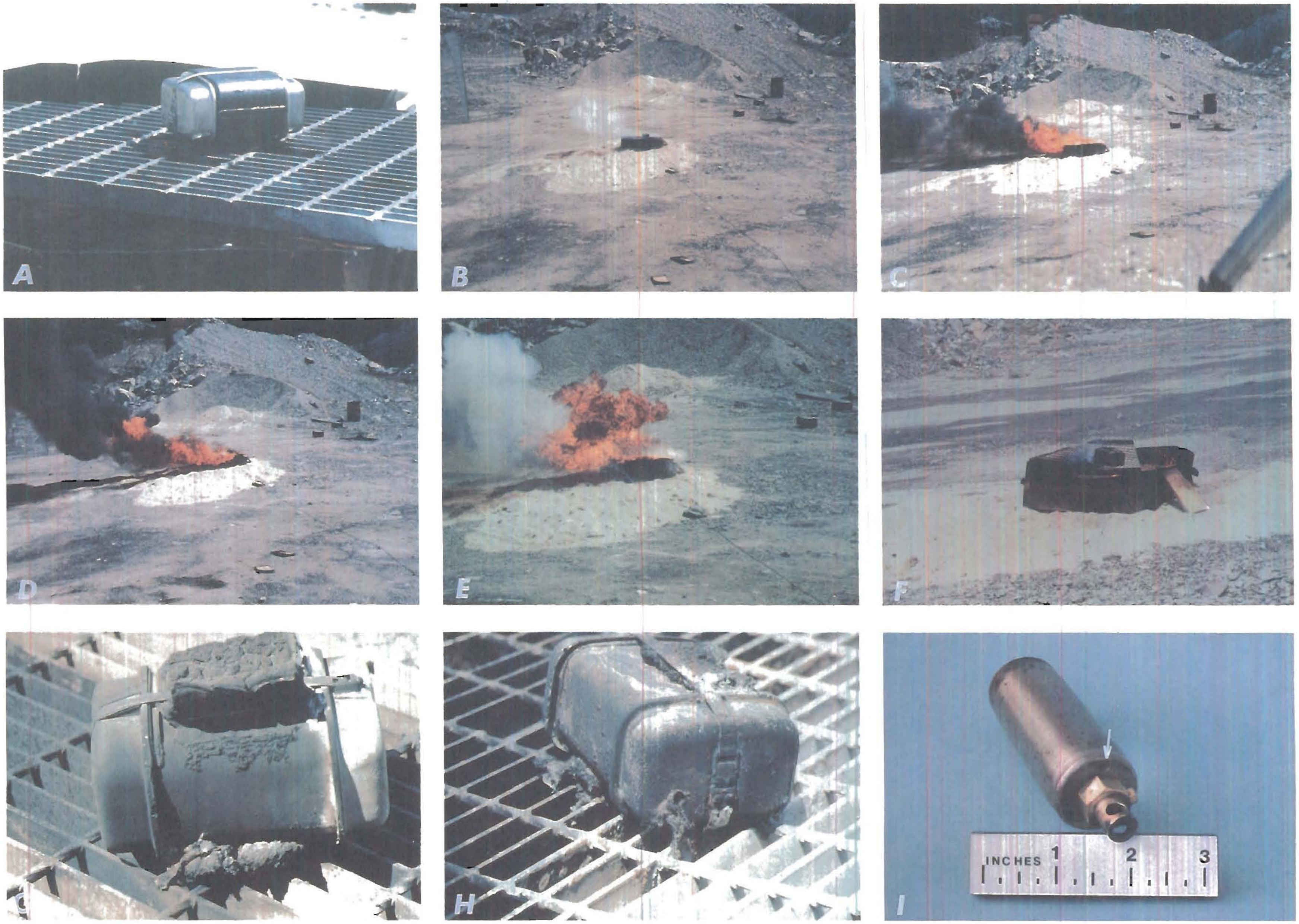

Figure 2.—Bonfire testing. *A-F*, Scenes from test 2; *G*, unit from test 1; *H*, unit from test 2; *I*, bottle from test 2 showing relief orifice.

in the vicinity of the well that contained the color moisture indicator. The jetting, which is visible near the right edge of the flames in figure 2*D*, grew in intensity for about 3 min and started to die out after 4 min. This type of jetting was observed in previous tests with chemical SCSR's and is associated with the release of oxygen generated by the thermal decomposition of KO_2. At 9 min, 45 s into the burn, there was a mild explosion, which kicked the SR-100 about 1 ft (0.3 m) toward the right edge of the grate. This event, which is believed to be associated with the operation of the pressure-relief device in the starter bottle, produced a bright flash of light and a cloud of white smoke, probably potassium oxide, a decomposition product of KO_2 and/or some LiOH. The flash was not recorded in photographs of the event, but the cloud of smoke accompanying the flash is shown in figure 2*E*. Figure 2*F* shows the end of the trial, 37 min after the start of the fire. Damage to the two units is shown in figures 2*G* and *H* and the oxygen bottle from test 2 showing the relief orifice is shown in figure 2*I*.

The bonfire trials with the SR-100 resulted in behavior very similar to that in previous bonfire tests with chemical SCSR's in terms of the observed jetting associated with the thermal decomposition of KO_2 (*1*). The violence produced by the sudden release of oxygen from the starter bottle in the SR-100 was minor compared with the reactions observed during the operation of the pressure-relief devices in the compressed oxygen SCSR's (*2*).

BULLET IMPACT TRIALS

To effect a comparison with earlier work on SCSR's (*1-2*) a number of bullet impact trials were conducted with the SR-100 and with oxygen bottles removed from SR-100 units. While bullet impact does not represent a realistic mine accident scenario, the test does provide some information on the inherent hazards of this type of device. The experimental setup (figs. 3*A* and *B*) consisted of a 30/06 rifle mounted on a portable carriage and a wooden target stand. Steel-jacketed bullets (military 0.30 caliber M2 ball) were fired at the units from a distance of approximately 85 ft (26 m); the muzzle velocity for this ammunition is reported to be 2,970 ft/s (905 m/s).

The results of four tests with complete units and two tests with oxygen bottles removed from units are summarized in table 3. Two trials in which bullets perforated the KO_2-LiOH chemical bed within the canisters (trials 1 and 4) resulted in short-lived fires. The more severe fire, which occurred in test 4, is shown in figure 3*C*. In this test, the heat-insulating band around the metal canister ignited at the exit hole (fig. 3*D*) and burned for about 1 min; it was self-extinguishing. No sign of fire was observed in the two trials (tests 2 and 3) involving perforation of the oxygen bottles within the units. However, the units were projected forward to distances of 5 ft (1.5 m) and 10 ft (3.0 m) for tests 2 and 3, respectively, presumably as a result of the rapid release of oxygen.

The exit hole generated in test 2 is shown in figure 3*E*. In the two trials with oxygen bottles alone, brief flashes of light were observed on impact but there was no sustained fire or evidence of metal burns on the recovered oxygen bottles. The bottles used in tests 5 and 6 were projected forward to distances of 15 ft (4.6 m) and 10 ft (3 m), respectively. The bottle from test 5 is shown in figure 3*F*.

The results of bullet impact tests 1 and 4 with the SR-100 closely paralleled previous bullet impact trials with the chemical SCSR's reported in reference 1, in which short-lived fires were observed. However, the SR-100 trials involving perforation of the oxygen bottles were much less dramatic than similar trials with the compressed oxygen SCSR's reported in reference 2. In the earlier tests, particularly those involving larger aluminum oxygen bottles, bullet impact produced spectacular showers of sparks and copious quantities of white smoke, as a result of metal combustion around the entrance and exit holes. There was no indication of this type of reaction with the small stainless steel bottles in the SR-100.

Table 3.—Summary of bullet impact trials

Test	Unit	Impact point	Result
1 . .	Complete unit . .	Chemical bed . .	Short-lived fire.
2 . .	. . do.	Oxygen bottle . .	Unit projected forward ≈ 5 ft, no flame.
3 . .	. . do.	. . do.	Unit projected forward ≈ 10 ft, no flame.
4 . .	. . do	Chemical bed . .	Short-lived fire.
5 . .	Bottle	Oxygen bottle . .	Impact flash; bottle projected forward ≈ 15 ft.
6 . .	. . do.	. . do.	Impact flash; bottle projected forward ≈ 10 ft.

Figure 3.—Bullet impact trials. *A-B*, Experimental setup; *C*, fire in test 4; *D*, exit hole in test 4; *E*, exit hole in test 2; *F*, oxygen bottle from test 5.

REACTION OF KO_2-LiOH WITH WATER

As described in reference 1, the reaction of KO_2 with excess water produces significant quantities of heat, primarily associated with the heat of solution of KOH, one of the products of the KO_2-H_2O reaction. The dissolution of LiOH in water is also exothermic, but the heat of solution is significantly less than that of KOH, 331 Btu/lb-mol (4.4 kcal/mol) versus 411 Btu/lb-mol (12.8 kcal/mol); the solubility of LiOH is also significantly less than that of KOH. In order to compare the heat-generating potential of the KO_2-LiOH mixture contained in SR-100 with that observed in previous water stimulation tests with KO_2 alone (*1*), a few experiments were conducted using the same experimental apparatus used in the earlier study: an insulated dewar flask equipped with a coiled metal feed tube for injecting water into a bed of KO_2-LiOH placed in the bottom of the flask. As in the previous experiments, the chemical bed was covered with a layer of crushed Pittsburgh Seam coal (minus 1/4 in) to insulate the KO_2-LiOH layer and also to determine what coal temperatures would be produced in the vicinity of the chemical bed.

Data from two experiments are presented in table 4, which gives the amount of water added, the maximum temperature observed in the KO_2-LiOH bed, and the maximum coal temperatures measured at 1.0 in (2.54 cm) and 4.0 in (10.16 cm) above the chemical layer. In the first test, just enough water was added to react the KO_2 in the chemical bed (approximately 11 oz (330 cm^3)) and dissolve the resultant KOH. The water was added in increments over a period of 177 min. The maximum KO_2-LiOH temperature of 207° F (97° C) was observed 132 min after the start of the experiment when 9 oz (270 cm^3) of water had been added; the temperature declined after this.

In the second experiment, 22 oz (660 cm^3) of water was added over a period of 164 min. The maximum KO_2-LiOH temperature of 250° F (121° C) occurred after the addition of 11 oz (330 cm^3) of water, 25 min after the start of the experiment; the temperature gradually declined thereafter.

Table 4.—Reaction of KO_2-LiOH mix with water, maximum temperature, degrees Fahrenheit

(1.5 lb KO_2-LiOH covered by 5.5 lb coal)

Water addition .... oz ..	11	22
KO_2-LiOH	207	250
Coal:		
1 in (2.54 cm) above KO_2-LiOH layer	140	165
4 in (10.16 cm) above KO_2-LiOH layer	108	120

The maximum temperatures observed in these two tests were lower than the temperatures recorded in the earlier tests (*1*), probably because of the reduced mass of KO_2 used in these later experiments. The presence of the LiOH in the mix did not appear to contribute to observed temperature rises, presumably because of its poor solubility in water. There was no sign of any thermal reaction in the coal above the chemical bed.

WATER ACTIVATION

As discussed in an earlier investigation report (*1*), a self-rescuer can be accidentally buried in a coal pile in a wet environment. Water invasion of a self-contained chemical unit can lead to elevated temperatures having some potential for igniting the coal either directly or indirectly by inducing a self-sustained spontaneous combustion reaction. Both of these possibilities were discounted for the older chemical SCSR's on the basis of coal temperature measurements in the vicinity of SCSR's injected with water and considerations of the minimum thermal energy required for the initiation of a self-sustained spontaneous combustion reaction. Since the SR-100 differs from the earlier designs in physical size, chemical makeup, and other features that might affect its capacity to supply heat during water invasion, two experiments involving water activation of complete SR-100s were conducted.

In the first experiment, an SR-100 was opened and the top and bottom covers were removed to expose the breathing hose and mouthpiece at the top of the unit and the breathing bag at the bottom. The unit was then equipped with 11 thermocouples to monitor temperatures within and outside the unit. The internal thermocouple leads were brought out through the breathing hose and sealed into the mouthpiece with a silicone compound to keep the unit gastight. To inject water into the unit, a length of flexible plastic tubing that extended to the top of the chemical bed was brought out through the breathing hose and sealed at the mouthpiece. The instrumented unit is shown in figure 4*A*.

The unit was placed on a 3.0-in (7.6-cm) deep layer of dry crushed Pittsburgh Seam coal (3/8 in (1.0 cm) or less) at the bottom of a steel drum 24 in (61 cm) in diameter by 24 in (61 cm) high, which was then filled with coal (figs. 4*B*-*C*).

In this first experiment, the restraining link in the relief valve located at the top of the unit was not removed; this prevented normal operation of the valve. The restraining link is present to assure that the self-rescuer remains gastight until the breathing bag is inflated and is pulled

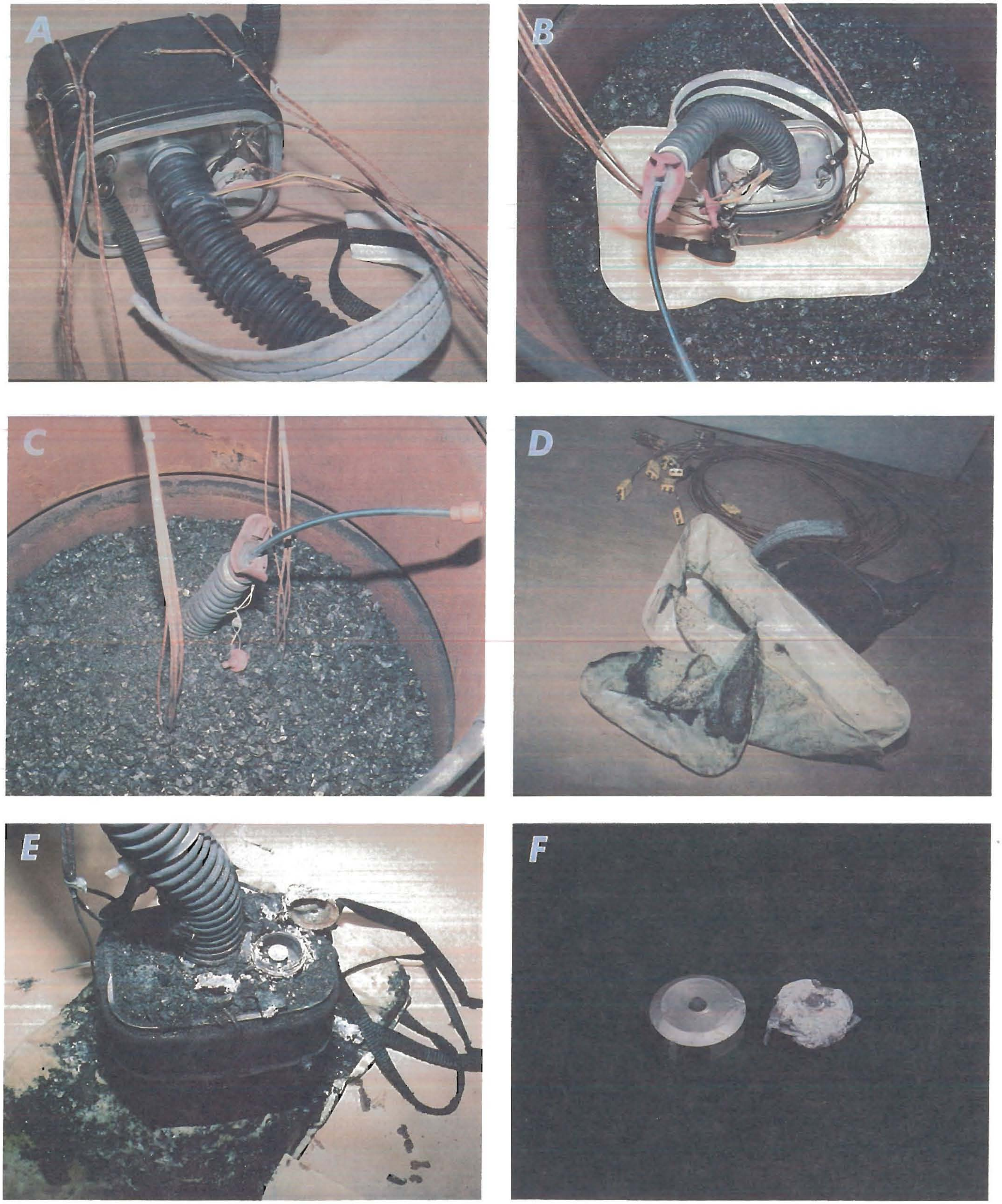

Figure 4.—Water activation experiments. *A*, Unit equipped with thermocouples; *B*, unit positioned on coalbed; *C*, unit covered with coal; *D*, unit recovered from first test; *E*, unit recovered from second test; *F*, new and disintegrated valve covers.

automatically during bag inflation by a wire connecting the link to the breathing bag.

At the start of the experiment (t = 0 min), 5 oz (150 cm^3) of water was injected into the chemical bed. As expected, the temperature at the center of the bed started to rise in 2 min, peaked in 10 min at a temperature of 221° F (105° C), and gradually began cooling. This is shown in the thermocouple records of figure 5. An additional 5 oz (150 cm^3) of water was added at t = 24 min. The immediate result of this second addition was rapid lowering of the temperature followed by a rapid temperature rise, peaking at 30 min at a temperature of 250° F (121° C).

At the start of this second addition of water, pressure began building up in the self-rescuer. The corrugated rubber hose connecting the case with the mouthpiece began to expand and extended approximately 3.0 in (7.6 cm) above the coal surface; it was difficult to force the final 3.4 oz (100 cm^3) water into the tube. With about 1.7 oz (50 cm^3) left to add, the coalbed surrounding the unit began to rise slightly, followed by a sudden release of pressure. Then the last 1.7 oz (50 cm^3) was easily injected, indicating that some component had failed and the unit was no longer gastight. Since the temperature was again dropping, another 5 oz (150 cm^3) of water was added at a time 46 min into the test. Again there was a sudden drop in temperature followed by a temperature rise in the center of the chemical bed to 203° F (95° C) at 55 min. As peak temperatures were now decreasing, no additional water was added. All temperatures were continually monitored for an additional 17 h; however, all temperatures continued to fall. Note that the highest temperature was recorded in the chemical bed following the second injection of 5 oz (150 cm^3) of water. The maximum temperatures and the times of their occurrence are summarized in table 5.

Table 5.—Maximum temperatures observed during water activation tests

Location	Relief valve inoperative		Relief valve operative	
	Temp, °F	Time into test, min	Temp, °F	Time into test, min
KO_2-LiOH layer . .	250	32	219	92
Metal case	154	50	205	97
Plastic band	113	97	136	122
Relief valve	127	46	289	93
Coal[1]	72	382	115	112

[1] 3 in above KO_2-LiOH layer.

Removal of the coal surrounding the unit revealed that the rubber breathing bag had failed. As shown in figure *4D*, it failed at one of the midseams because of the excess oxygen pressure buildup within the unit, which did not escape by way of the relief valve.

In the second experiment, the pressure-relief valve restraining link was removed before the unit was buried in the coalbed, thus allowing the relief valve to operate normally. Water was injected into the chemical bed in 5-oz (150-cm^3) increments at the beginning of the experiment (t = 0) and at t = 28, 57, 83, and 105 min. The thermocouple record from this test is shown in figure 6, and the maximum observed temperatures and the times at which they occurred are given in table 5.

In the second experiment, the observed maximum temperatures were significantly higher than in the first experiment, except in the KO_2-LiOH bed. Of particular interest was the sudden rise in the temperature of the relief valve and the metal case in the vicinity of the valve after the fourth injection of water at t = 83 min. Examination of the unit following the test showed that the aluminum cap over the relief valve had mostly disintegrated, leaving a crystalline residue (figs. *4E-F*). Analysis by X-ray diffraction showed that the crystalline residue was mostly aluminum hydroxide ($Al(OH)_3$).

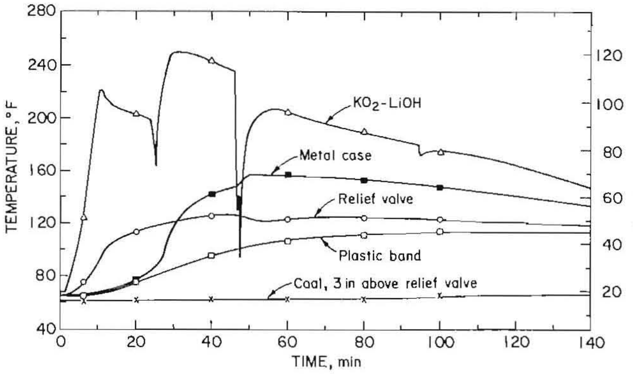

Figure 5.—Thermocouple records from first water activation test (relief valve inoperative).

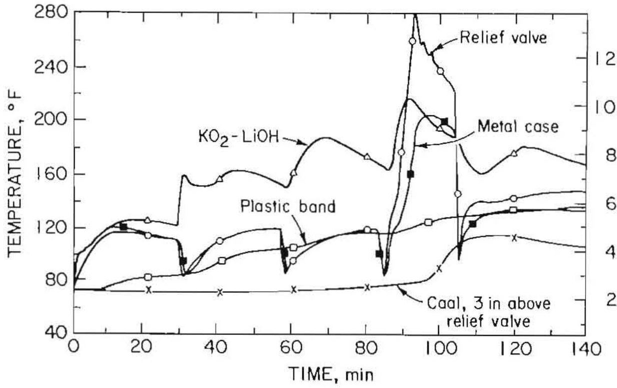

Figure 6.—Thermocouple records from second water activation test (relief valve operative).

Evidently, with the fourth injection of water, the oxygen venting through the relief valve carried with it some KOH (product of water and KO_2), which reacted with the aluminum to form $Al(OH_3)$.

The maximum temperatures observed in this test for the chemical bed and the metal case were close to those observed in previous tests with chemical SCSR's (*1*). The plastic bands on the SR-100 served to limit exterior temperatures, and the maximum coal temperature observed in this test, 115° F (46° C), was about the same as the maximum coal temperature observed in a similar test with a chemical SCSR, 104° F (40° C). On the basis of the earlier tests, it was concluded that chemical SCSR's did not present a coal ignition or spontaneous combustion problem (*1*). Since the maximum temperatures observed in this test were of the same order as those observed in the earlier tests and since the total available energy is less for the SR-100 (less KO_2), it can be concluded that the SR-100 does not pose any significant hazard in terms of direct coal ignition or induced spontaneous combustion.

MECHANICAL INTEGRITY OF UNIT

In previous work on the potential hazards of SCSR's, a number of experiments designed to simulate "worst mining conditions" were conducted in an effort to determine what level of abuse the SCSR's could sustain without releasing their contents, chemicals or oxygen, and the consequences of such release when it did occur. These experiments included drop weight tests to simulate a roof fall, runover tests with heavy equipment, and tests where individual units were fed through a feeder-breaker. Similar tests were performed with the SR-100 to measure its response for comparison with the earlier work.

SIMULATED ROOF FALL

The experimental arrangement used to simulate mine roof fall, illustrated in figure 7*A*, was the same as that used in previous tests of this type (*1*). It consisted of a 1,000-lb (455-kg) cubical block of reinforced concrete that was dropped from a height of 6 ft (1.8 m) on complete units placed in a vertical or horizontal position beneath the block. Observations were then made of the subsequent damage to the units. The results of these experiments are summarized in table 6 and shown in figure 7*B* through *G*. In the three trials conducted with the units in the horizontal position, the most severe damage occurred in test 1 where there was a small amount of KO_2-LiOH released and a slow bleedoff of oxygen from the starter bottle. In two of the tests with units in the vertical position there was a rapid release of oxygen from the starter bottles accompanied by a hissing sound (test 2) or a cloud of dust (test 5). There was no evidence of flame in any of the simulated roof-fall trials.

In previous trials with the older chemical units, no release of chemical was observed in seven experiments, but there was one test where an oxygen candle was ignited (*1*). In eight tests with compressed oxygen units using the same experimental setup as used here, there were seven instances of oxygen leakage; in five trials with a pointed rock fragment attached to the concrete drop weight there were three instances of oxygen leakage. In one test, a combustion reaction was observed when the rock shard punctured the aluminum oxygen bottle (*2*). Owing to the small size of the oxygen bottle in the SR-100, no attempt was made to duplicate this type of behavior. Overall, the SR-100 behaved pretty much like the SCSR's previously tested: They withstood the simulated roof falls with inconsequential release of contents.

Table 6.—Results of simulated roof-fall experiments

Test	Orientation	Results
1 . .	Horizontal	Small amount chemical released, slow oxygen leak.
2 . .	Vertical . .	Small amount chemical released, rapid oxygen release.
3 . .	Horizontal	No chemical release, no oxygen leak.
4 . .	. . do. . .	Small amount chemical released, no oxygen leak.
5 . .	Vertical . .	Considerable chemical released, rapid oxygen release.
6 . .	. . do. . .	No chemical release, no oxygen leak.

EQUIPMENT RUNOVER TRIALS

Two pieces of heavy equipment were available for these trials: An International TD-20 bulldozer, which weighed about 24 st (21,800 kg) and had a cleated track, and a Joy 16 CM continuous miner with an estimated weight of 50 st (45,500 kg), also with a cleated track. Complete units were run over in the forward and reverse directions (bulldozer only), with units perpendicular and parallel to the direction of motion, and with the units on a slate (bulldozer) or concrete (continuous miner) roadbed or on a small coalbed (both). Some units were repeatedly run over, from two to as many as six times. In some tests track slippage was purposely induced in order to maximize damage. The test results from the bulldozer runs are summarized in table 7. Scenes from the runs are shown in figure 8*A-C*, and the damaged units are shown in figure 8*D-F*.

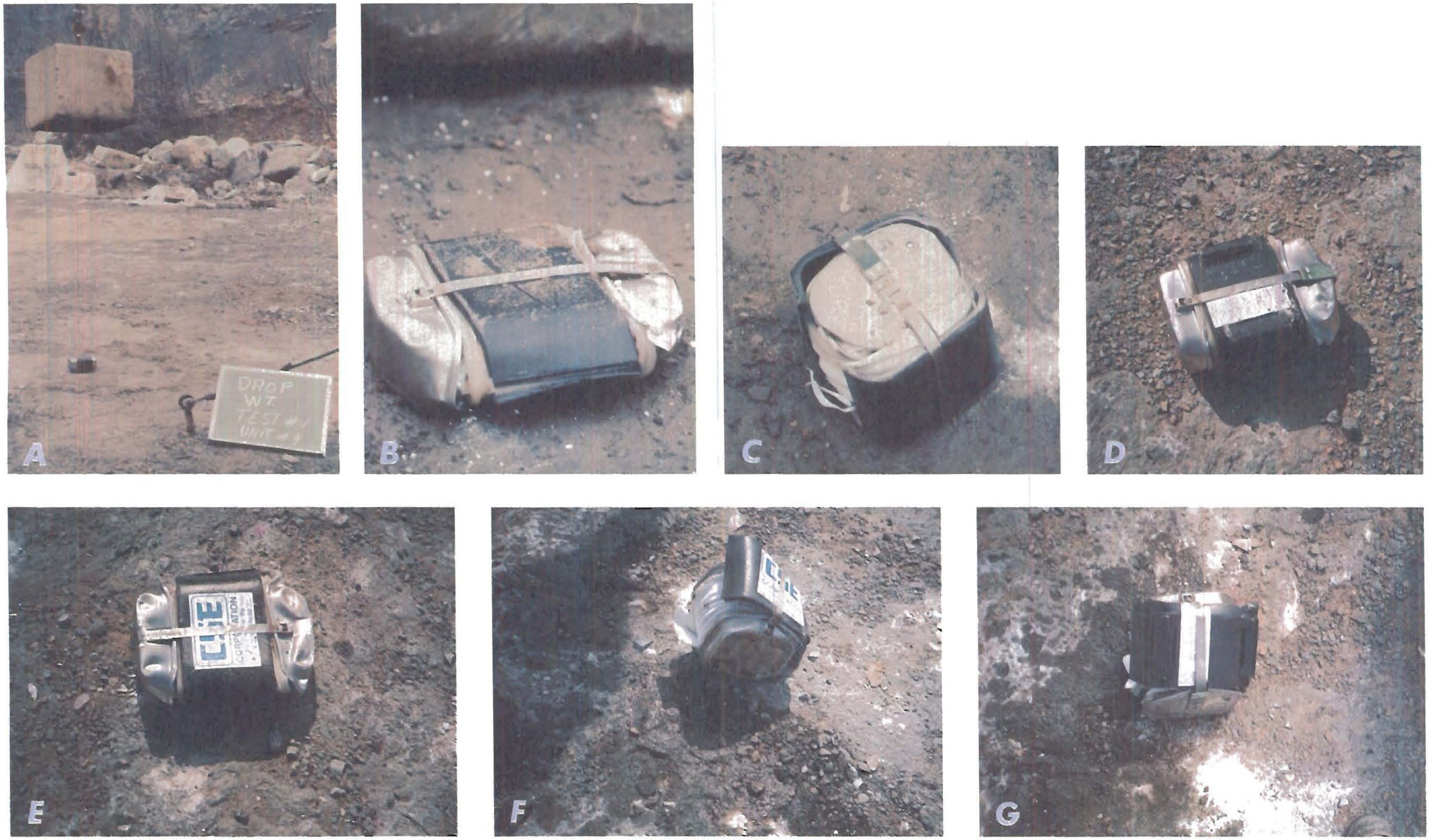

Figure 7.—Simulated roof-fall trials. *A*, Setup; *B-G*, damage in tests 1 through 6, respectively.

Table 7.—Summary of bulldozer runover trials

Run and direction	*Result*
Without coal:[1]	
Test 1:	
1, forward ..	Unit damaged, no chemical released.
2, reverse ..	Puff of dust, no chemical released.
With coal:[2]	
Test 2:	
1, forward ..	Audible pop and puff of dust, some chemical released.
2, reverse ..	More damage, no other action.
Test 3:	
1, forward ..	Unit damaged, no chemical released.
2, reverse ..	More damage, no chemical released.
3, forward ..	Do.
4, reverse ..	More damage, some chemical released.
5, forward ..	Track slippage; much more damage, more chemical released.
6, reverse ..	Track slippage; unit destroyed, some sparking.

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[1] Unit orientation perpendicular to direction of motion.
[2] Unit orientation parallel to direction of motion.

In test 1 with the bulldozer, no chemical was released after a forward and reverse pass; however, the oxygen bottle failed on the second (reverse) pass. In test 2, the oxygen bottle failed during the first pass and some chemical was released; there was more damage to the unit in the second pass but no further action. On comparing test 2 with test 1, it appeared that aligning the unit parallel (lengthwise) to the direction of travel represented the "worst case." Subsequent runs were made this way. In test 3, with the unit on a bed of fine coal, no chemical was released as a result of the first three passes but a small amount of the KO_2-LiOH mixture was released during the fourth pass. In pass 5 with track slippage more chemical was released, and in pass 6, also with slippage, some sparking was observed under the track in the vicinity of the damaged unit, as well as chemical discharge. However, there was no sustained fire. An attempt was made to produce sparking with the machine slipping on the slate roadbed alone, but no sparking was observed. It was concluded that the sparking observed in test 3, pass 6, was associated with frictional ignition of a mixture of loose KO_2 and coal. In an unofficial demonstration test, another attempt was made to reproduce the sparking observed in test 3 by repeatedly slipping the bulldozer over a unit on a coalbed; no such sparking was observed.

Test results from the continuous miner runover trials are summarized in table 8. Scenes from some of the more eventful trials are reproduced in figure 9*A-F*, and the total damage sustained by the units is shown in figure 10. In test 1, without coal, the oxygen bottle discharged on the first pass, producing a puff of floor dust (fig. 9*C*). This same behavior was noted in test 2 with coal. During the second passes of tests 1 and 2, attempts to slip the track of the continuous miner while it was passing over the units met with marginal success and only a modest twisting action was effected by varying the power fed to the opposing tracks. In an attempt to increase the violence of this maneuver, the subsequent tests (3, 4, 5, and 6) were conducted with the head of the continuous miner butted against a huge block of simulated coal located in the equipment test facility where the trials were conducted. The resistance to forward motion provided by the block of simulated coal resulted in total track slippage over the coal-covered units. This action produced much more damage, as can be seen by comparing figures 10*C*, *D*, *E*, and *F* with figures 10*A* and *B*. In fact, in test 6 enough frictional heating occurred to start a small fire in the remnants of the unit (fig. 10*F*); bright sparking of the heated chemicals and coal dust inside the damaged unit persisted for some time after the fire had died out (fig. 10*F*).

In equipment runover trials the SR-100 fared no better, or worse, than the earlier SCSR's did in similar tests. The chemical units reported in reference 1 did not release any KO_2 in normal (no slipping or tramming) runover tests with rubber-tired or tracked vehicles including a continuous miner. The older compressed oxygen units were not quite as immune to this type of abuse since fires were occasionally observed in "normal" continuous miner runover trials (*2*). The SR-100 did produce a small fire under conditions of extreme abuse that are difficult to imagine under ordinary mining conditions. Further quantifying this comparison, the SR-100 behaved more like the older chemical units than the older compressed oxygen units in the equipment runover trials. This, of course, is in keeping with the nature of their construction.

Table 8.—Summary of continuous miner runover trials

Run and direction	*Result*
Without coal:	
Test 1:[1]	
1, forward	Puff of dust, no chemical released.
2, forward, slippage	More damage, no chemical released.
With coal:	
Test 2:[1]	
1, forward	Cloud of dust, no chemical released.
2, forward, slippage	More damage, some chemical released.
Test 3:[2]	
1, forward, slippage	Cloud of dust, unit destroyed, some chemical released.
Test 4:[2]	
1, forward, slippage	Unit destroyed, some chemical released.
Test 5:[1]	
1, forward, slippage	Unit destroyed, some chemical released.
Test 6:[1]	
1, forward, slippage	Small fire, sparking, unit destroyed, some chemical released.

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[1] Unit orientation perpendicular to direction of motion.
[2] Unit orientation parallel to direction of motion.

Figure 8.—Bulldozer runover trials. *A*, Unit perpendicular to direction of travel; *B*, unit parallel to direction of travel on coalbed; *C*, puff of smoke observed in test 2, run 1; *D*, total damage to unit in test 1; *E*, total damage to unit in test 2; *F*, total damage to unit in test 3.

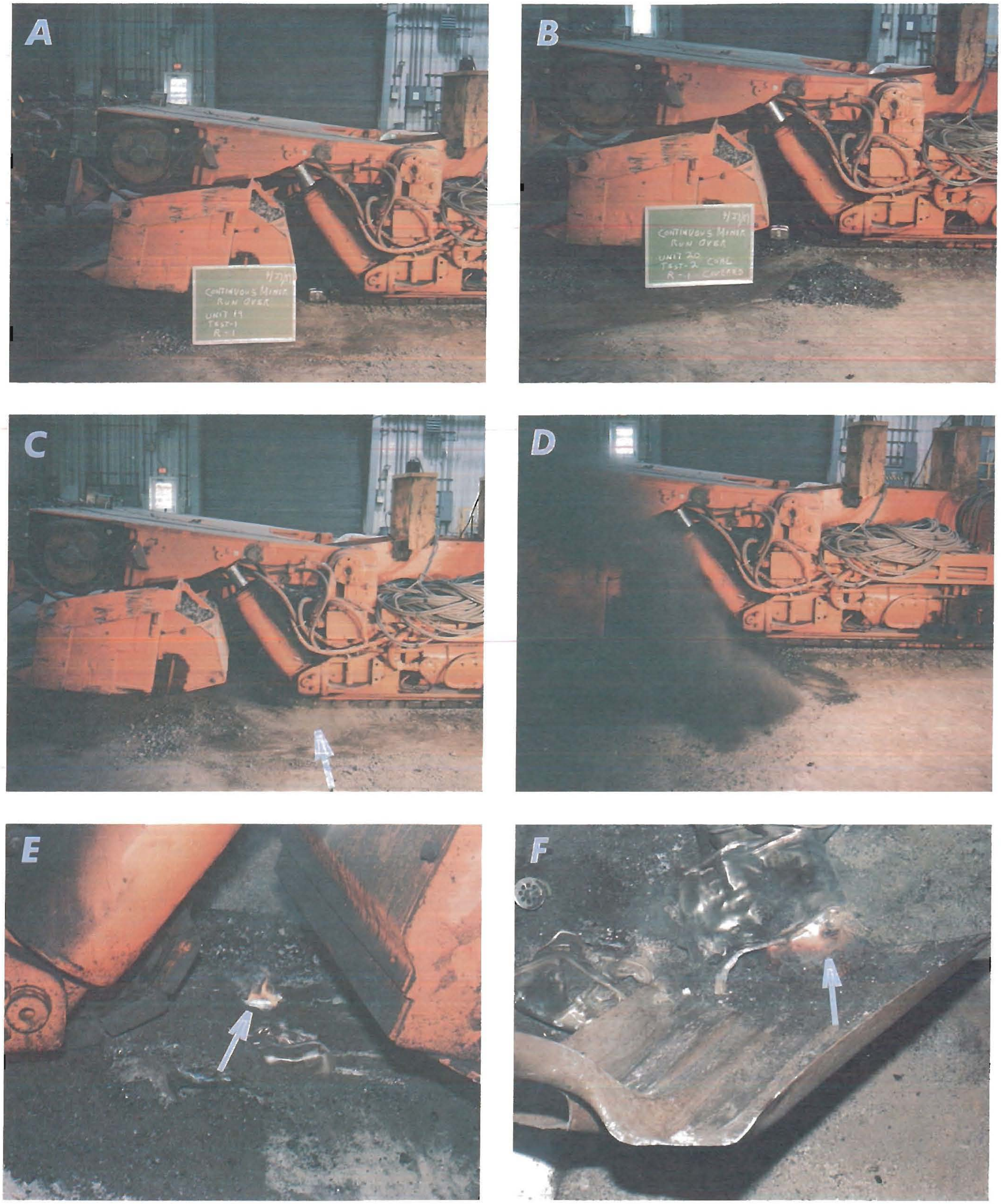

Figure 9.—Continuous miner runover trials. *A*, Unit without coal; *B*, unit with coal; *C*, puff of dust, test 1, run 1; *D*, cloud of dust, test 2, run 1; *E*, small fire in test 6; *F*, sparking in test 6.

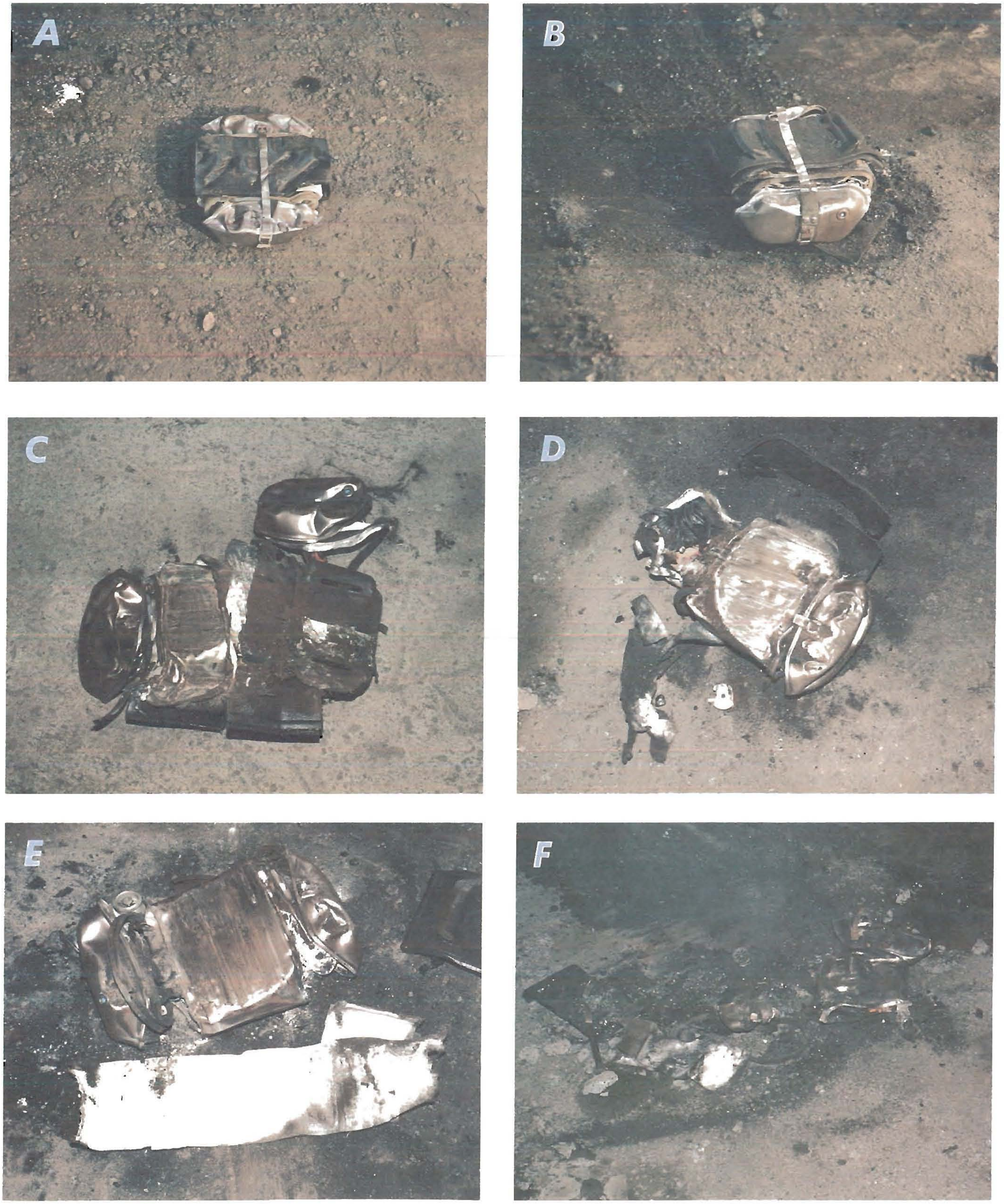

Figure 10.—Damage sustained in continuous miner runover trials. *A-F*, Tests 1 through 6, respectively.

FEEDER-BREAKER TRIALS

The feeder-breaker experiments were conducted with the same equipment that was used in the previous work with chemical and compressed oxygen SCSR's: a Long-Airdox, Rosco 1 feeder-breaker. Three types of experiments were performed. In the first series of tests, complete units were more or less randomly fed through the feeder-breaker, a possible mine accident scenario. In the second series of tests, two of three picks in a breaker pick set were cut off to allow the remaining single pick to rotate approximately 270° after machine startup before striking an SR-100 carefully positioned in the path of the single pick. In these tests, units were fixed in a short section of channel iron to prevent movement. The third series of tests was similar to the second series in that the units were fixed in the path of a single pick but the head of the feeder-breaker was locked down with chains to prevent upward movement and maximize the force of the impact.

A few preliminary tests with randomly placed units verified a previous finding (*1*) that the units had a better chance of a damaging encounter with a breaker pick if they rode on coal piled high at the restricted entrance to the rotating pick assembly. As a consequence, all subsequent "random" tests were performed in this manner. To further enhance damage, the cutterhead was held in its lowest position with the picks rotating in an arc about 2.5 in (6.4 cm) above the plates of the conveyor.

A typical test with "randomly" placed units is shown in figure 11 and the results of 20 runs with 8 separate units are summarized in table 9.

Figure 11*A* shows a unit placed on coal piled at the entrance to the rotating pick assembly; *B* shows the start of the run; and *C* shows the unit being fed out of the feeder-breaker. These scenes are from test 1, run 1, where the unit was struck by a pick and punctured, but not rotated, with no significant chemical release. In other runs, for example in test 1, run 4, the units slipped by the rotating pick assembly without encountering a pick, with little or no damage. In other runs, as in test 2, run 1, the units were impaled on a pick and rotated several turns, striking the upper crossarm or floor of the feeder-breaker. The latter event occasioned the most severe damage and chemical release. In one case, test 3, run 3, the oxygen bottle was punctured, which produced a puff of dust, but no impact flash. In another case, test 8, run 3, the chemical canister was punctured and a puff of smoke was observed. A careful examination of the television tapes of this event did not show any impact flash. However, subsequent examination of the unit showed some burn marks (charring) in the vicinity of the perforation hole in the plastic band that surrounds the metal canister, which was also punctured. This was the closest thing to a fire observed in the feeder-breaker tests with randomly placed units. The total damage sustained by the eight units used in the series of tests is recorded in figure 12.

Table 9.—Summary of feeder-breaker trials with randomly positioned units

Run	*Result*
Test 1:	
1	Unit punctured, no rotation; no significant chemical release.
2	End caps knocked off, bag exposed; no rotation, no significant chemical release.
3	Unit rotated 5 turns; no significant chemical release.
4	Unit slipped by.
5	Unit rotated 4 turns; small amount chemical released.
Test 2:	
1	Unit repeatedly punctured and rotated 4-1/2 turns; no significant chemical release.
Test 3:	
1	Unit slipped by.
2	Do.
3	Oxygen bottle punctured, puff of dust; unit rotated 19 turns to complete destruction; significant chemical released.
Test 4:	
1	Unit slipped by.
2	Unit hit, outer plastic shell punctured; no significant chemical release.
3	Unit hit; no chemical release.
4	Unit rotated 3 turns to destruction; no significant chemical release.
Test 5:	
1	Unit rotated 1 turn to destruction; small amount chemical released.
Test 6:	
1	Unit wedged between pick set and rotated; minor damage.
2	Unit rotated 2 turns to destruction; no chemical release.
Test 7:	
1	Unit rotated 1 turn to destruction; some chemical released.
Test 8:	
1	Unit slipped by; minor damage.
2	Do.
3	Chemical canister punctured, puff of smoke but no sustained fire; some burn marks on plastic band; some chemical released.

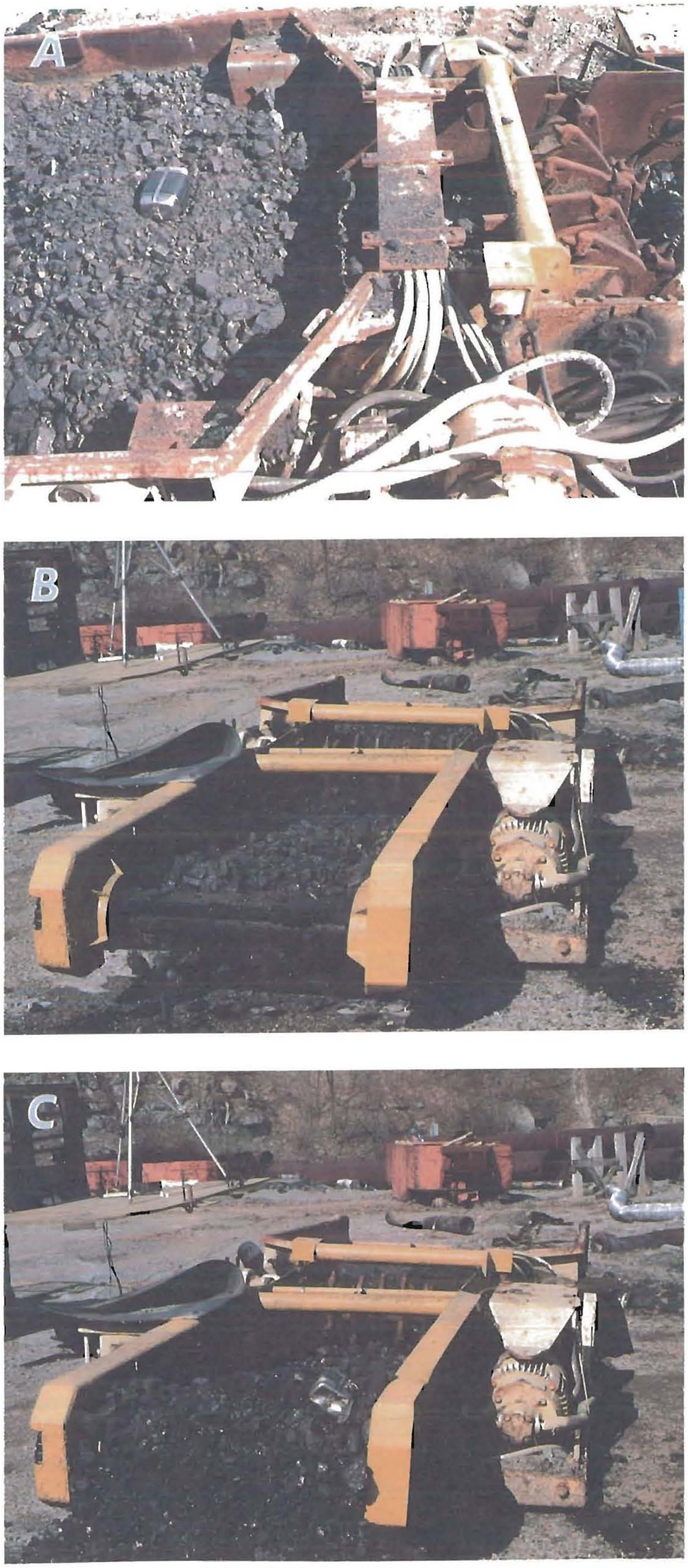

Figure 11.—Feeder-breaker trial with randomly placed units (test 1, run 1). *A*, Unit on coalbed; *B*, feeder-breaker running; *C*, unit being fed out of breaker.

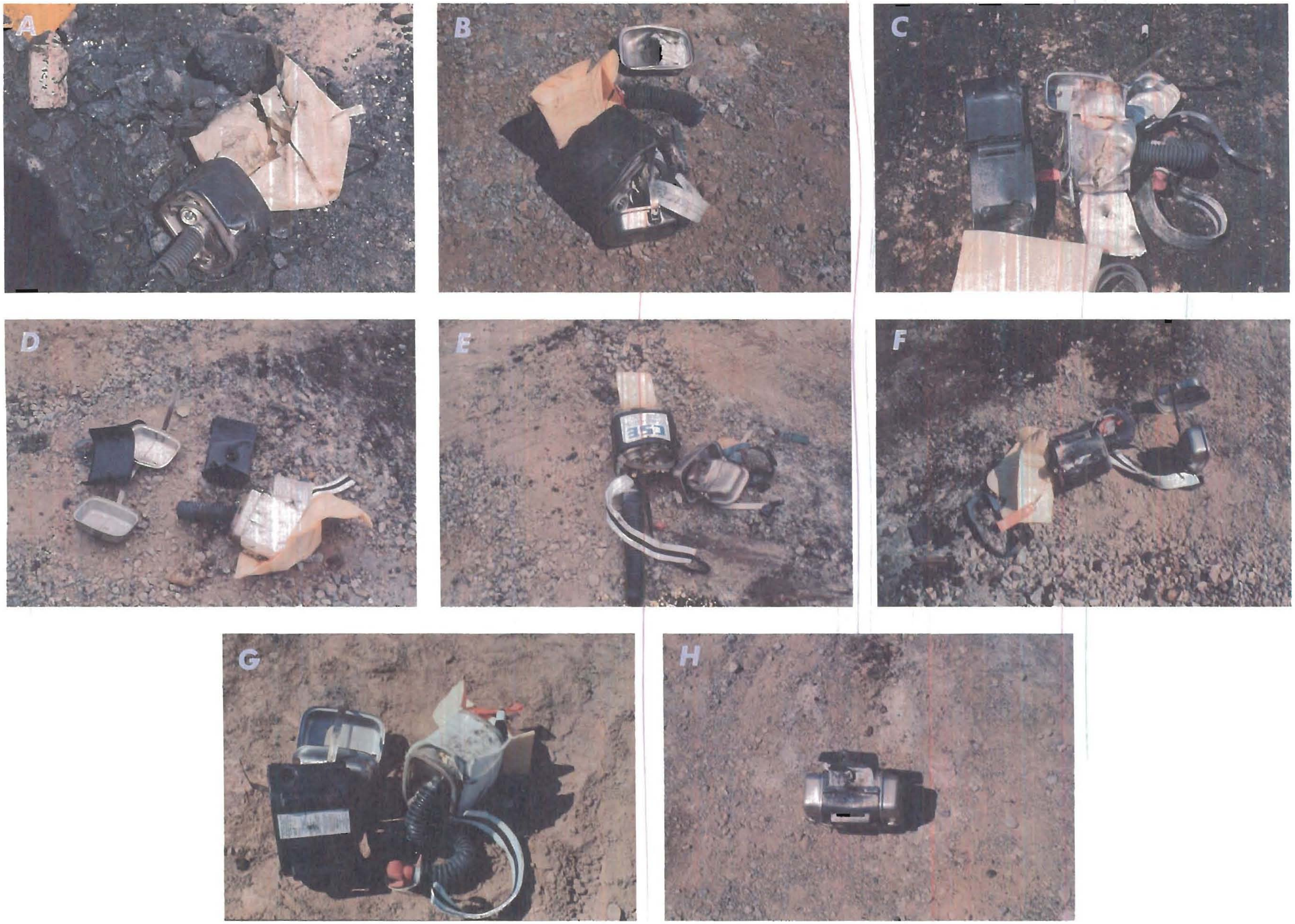

Figure 12.—Total damage to units used in feeder-breaker trials with randomly placed units. *A-H,* Tests 1 through 8, respectively.

The experimental setup for the trials with SR-100s fixed in the feeder-breaker is illustrated in figure 13. Trials were conducted with bare units (fig. 13*A*) or with units covered with coal (fig. 13*B*). In some cases, the unit was positioned to effect an impact on a region of the canister containing the chemical bed, and in others to allow impact on the oxygen bottle. Data from six feeder-breaker runs under these conditions are presented in table 10. Ordinarily the units were punctured and kicked through the breaker or rotated a number of times and kicked through without significant chemical release. In test 2, the oxygen bottle was punctured, producing a cloud of coal dust but no flame. In test 3, with the unit covered with coal, a short-lived fire (2 to 3 s) was observed when the chemical canister was punctured; the fire was self-extinguishing. There was no photographic record of this event. In tests 4 and 5, the oxygen bottles were struck by the descending pick but were not punctured. Damage to the SR-100's used in tests 1 through 5 with fixed units is shown in figures 13*C* through *G*, respectively.

Table 10.—Summary of feeder-breaker trials with fixed units

Run	Impact point	Results
	WITHOUT COAL COVER	
Test 1:		
1	Chemical bed	Unit punctured, no rotation; no significant chemical release.
2	.. do.	Unit punctured, rotated 2-1/2 turns; no significant chemical release.
Test 2: 1 ..	Oxygen bottle	Bottle punctured, unit rotated 1 turn; puff of smoke but no flame.
	WITH COAL COVER	
Test 3: 1 ..	Chemical bed	Unit punctured, no rotation; short-lived fire.
Test 4: 1 ..	Oxygen bottle	Bottle not punctured, no rotation.
Test 5: 1 ..	.. do.	Do.

In tests 4 and 5 with the fixed units where attempts were made to perforate the oxygen bottles, the breaker assembly was observed to lift on impact. Therefore, several additional trials were conducted with the units fixed into position under the single pick and the breaker assembly locked with chains to prevent it from rising. This is illustrated in figure 14*A*, which shows the chains at both ends of the breaker arm. Data from six trials with the locked breaker are presented in table 11; the units were covered with coal in all six trials. Three trials were conducted with the units positioned for penetration into the chemical bed and three for perforation of the oxygen bottle.

Table 11.—Summary of locked feeder-breaker trials

Test	Impact point	Results
1	Chemical bed	Canister perforated; small flame on impact, no sustained fire.
2	.. do.	Do.
3	Oxygen bottle	Bottle perforated, fireball on impact; 17-min fire.
4	.. do.	Bottle perforated, fireball on impact; no sustained fire.
5	Chemical bed	Canister perforated, no flame.
6	Oxygen bottle	Bottle perforated, fireball on impact; 20-min fire.

Short-duration flames were observed in two of the three trials involving penetration into the chemical bed; there were no sustained fires. Coal dust fireballs were produced in tests 3, 4, and 6, in which the oxygen bottles were successfully perforated; figure 14*C* shows the fireball for test 4. Sustained fires were also observed in tests 3 and 6. These fires involved the combustibles in the SR-100 (breathing bag, goggles, straps, etc.) and lasted about 20 min. They were not intense enough to ignite the coal in the feeder-breaker and were self-extinguishing. Total damage to the SR-100's used in the locked feeder-breaker trials is shown in figure 15.

It is of interest to compare the results of the feeder-breaker trials with the SR-100 with results obtained in similar studies reported in references 1 and 2. In the 20 runs with randomly placed SR-100's there were 6 instances where the unit slipped by the pick assembly, 5 pick encounters without rotation, and 9 encounters where the unit was struck and rotated. Previous experiments with chemical units tested under similar experimental conditions (the "initial" feeder-breaker tests in reference 1) resulted in two slip-by's, one encounter without rotation, and four encounters with rotation: roughly the same frequency for the three different events as observed with the SR-100. However, in the previous tests, fires were observed in three runs out of seven: One fire was severe enough to completely destroy a chemical unit. In 20 random feeder-breaker runs with the SR-100, no fires were observed except, perhaps, the one instance where there was a puff of smoke with attendant burn marks on the plastic shell of the unit in test 8, run 3. Thus, it would appear that while the probability of a damaging encounter in the feeder-breaker is about the same for the SR-100 as for the older (larger) chemical units, the consequences of such an encounter are somewhat less severe. This can be rationalized on the basis of the relative size and conditions of the units: The larger (older) units with heavier combustible loading ordinarily suffered more damage, released

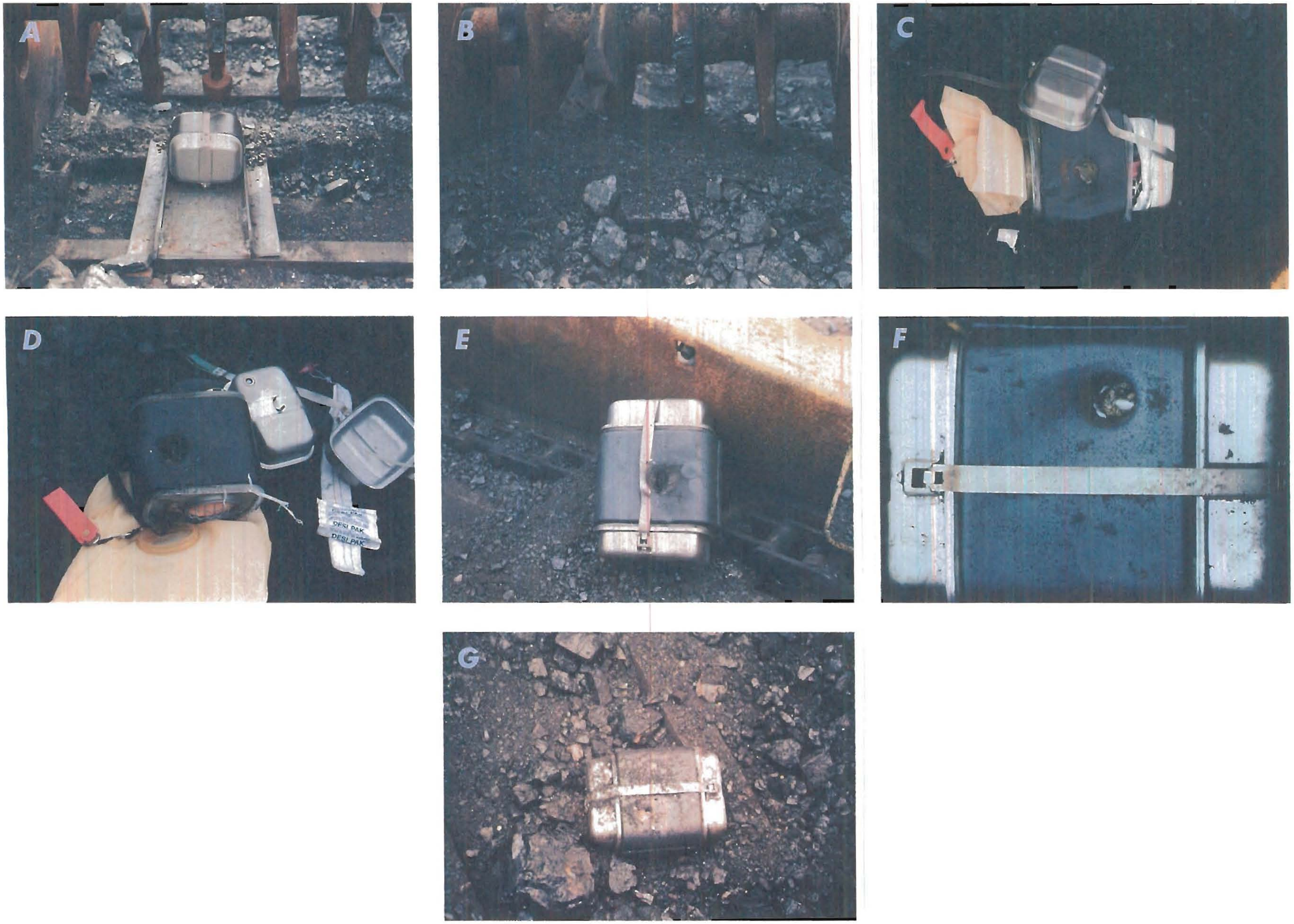

Figure 13.—Feeder-breaker trials with fixed units. *A*, Unit fixed in channel iron; *B*, fixed unit covered with coal; *C-G*, damage results in tests 1 through 5, respectively.

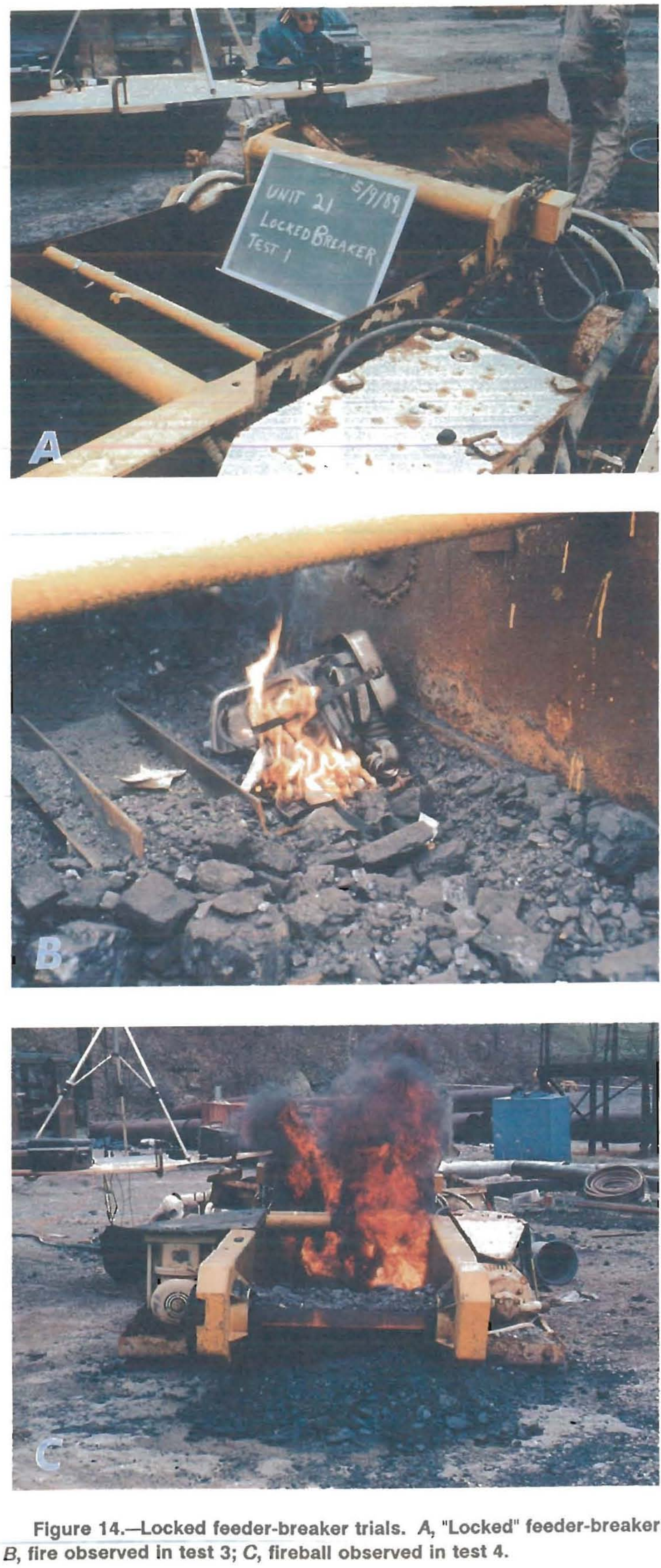

Figure 14.—Locked feeder-breaker trials. ***A,*** **"Locked" feeder-breaker;** ***B,*** **fire observed in test 3;** ***C,*** **fireball observed in test 4.**

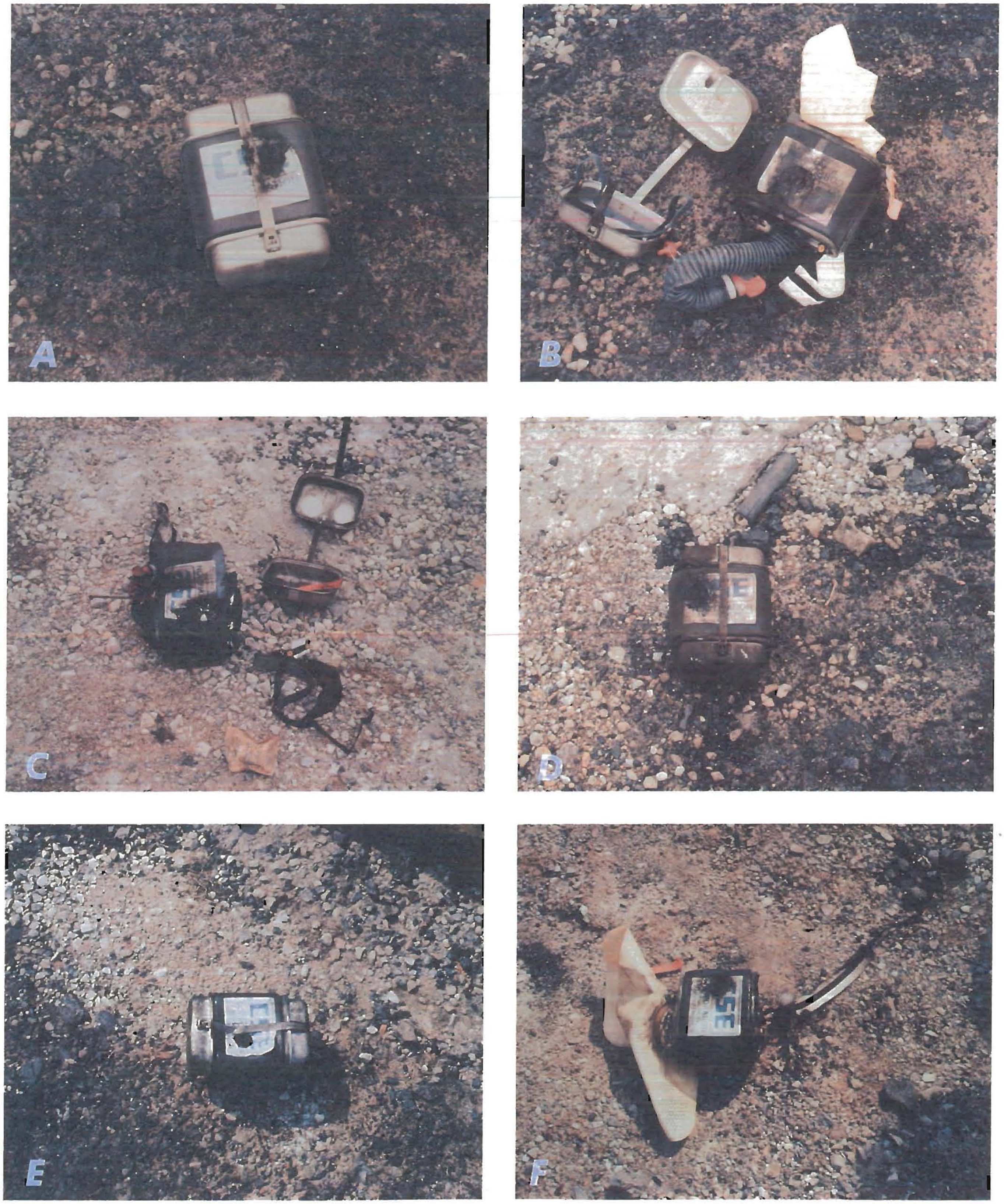

Figure 15.—Damage to units used in locked feeder-breaker trials. ***A-F*****, Tests 1 through 6, respectively.**

more chemical, and presented more opportunity for a KO_2-combustible fire. In 20 random feeder-breaker trials with compressed oxygen units (*2*), the units suffered either superficial damage with no oxygen leaks (in 13 trials) or valve-gauge damage with oxygen leakage. No fires were observed. Thus, the response of the SR-100 to random transit through the feeder-breaker lies somewhere between the response of the older chemical units and that of the compressed oxygen units in terms of violence.

In the older work, there is no direct counterpart for the SR-100 trials conducted with fixed units and free breaker bar, so direct comparisons cannot be made. However, the SR-100 trials with the locked breaker correspond to the fixed-unit, fixed-breaker trials reported in reference 2. In both cases, fireballs were ordinarily produced whenever the oxygen bottles were perforated: in three of three trials with the SR-100 and in six of six trials with the compressed oxygen units. Qualitative comparisons of photographs indicated that the fireballs were somewhat smaller in tests with the SR-100, probably because of the limited supply of oxygen in the SR-100, starter bottle as compared with the 1-h supply in the compressed oxygen self-rescuers. However, it should be pointed out that sustained fires were observed in two out of three trials with the SR-100 that produced fireballs, whereas this did not happen with the compressed oxygen self-rescuers. This is probably associated with the presence of KO_2 in the SR-100.

Overall, in the feeder-breaker trials, the SR-100's behaved pretty much like the older chemical units when the chemical bed was penetrated and like the older compressed oxygen units when the starter bottle was penetrated, resulting in fires involving combustibles in the unit or fireballs associated with the rapid burning of coal dust in an oxygen-enriched atmosphere. Because of the smaller amounts of combustible material, chemicals, and compressed oxygen in the SR-100, these events were not as violent as those observed with the older units. Of particular note is the fact that sustained fires were not observed in the feeder-breaker trials with randomly positioned units, which represents a worst case mine accident scenario, since the fixed unit and locked breaker tests are too contrived. In this respect, the SR-100 is superior to the older chemical units.

SUMMARY AND CONCLUSIONS

The overall results of the series of destructive tests performed on the SR-100 are summarized in table 12; for purposes of comparison the results of similar tests with the older chemical and compressed oxygen units are also shown.

The results of the water activation trials with the two chemical units buried in a coalbed were pretty much the same, although slightly higher coalbed temperatures were observed in the test with the SR-100. However, based on the logic outlined in reference 1, it can be concluded that the SR-100 does not pose any significant hazard in terms of direct coal ignition or induced spontaneous ignition.

The SR-100 and the older chemical units exhibited only mild burning in the bonfire trials and produced short-lived fires in the bullet impact tests. The compressed oxygen SCSR's produced more violent reactions in both of these tests because of the ready availability of pure oxygen, which enhanced the burning reactions. Neither of these tests is very realistic in terms of the mine environment.

Table 12.—Occurrence of combustion reactions in tests with various SCSR's

Test type	SR-100	Chemical	Compressed oxygen
Water activation in coal bed.	No	No	Not applicable.
Bonfire	Mild burning	Mild burning	Violent burning.
Bullet impact	Short-lived fires	Short-lived fires	Violent reaction.
Simulated roof fall	No	No	Yes.[1]
Equipment runover:			
Rubber-tired vehicle	Not tested	No	No.
Bulldozer	Sparks	No	No.
Continuous miner	Yes[2]	No	Yes.
Feeder-breaker:			
Random	Yes[3]	Yes	No.
Fixed	Yes	Not tested	No.
Locked	Yes	Not tested	Yes.

[1] With rock shard only.
[2] With severe slippage only.
[3] Smoke only.

Combustion reactions were not observed in the simulated roof-fall trials with the older chemical units or with the SR-100. Mild combustion reactions were observed in roof-fall trials with the compressed oxygen units. However, this occurred only when a carefully aimed pointed rock shard was allowed to perforate the compressed oxygen bottle.

Combustion reactions were not observed in any of the equipment runover trials with the older chemical units. However, sparks were observed in the bulldozer runover tests with the SR-100 and fires were observed in the continuous miner runover trials with both the SR-100 and the compressed oxygen units. It should be pointed out that extreme measures (continued track slippage) had to be taken to produce a combustion reaction with the SR-100. Since the older chemical units were not tested under these severe conditions and since the compressed oxygen units produced fires without track slippage, it is concluded that the behavior of the SR-100 more resembled the behavior of the older chemical units than the compressed oxygen units under these circumstances.

In the feeder-breaker trials, the SR-100 produced combustion reactions or short-lived fires in experiments where the units were randomly fed through the breaker, and in tests with fixed units and with the locked breaker assembly. The older chemical units produced more severe fires in random-feed tests and presumably would have done so in the more severe fixed and locked tests if they had been carried out. The compressed oxygen units produced violent combustion reactions only in the locked breaker trials when a well-aimed pick perforated the bottle. Again the results with the SR-100 and the older chemical units were very similar; the compressed oxygen units scored a little better because of the difficulty of perforating the oxygen bottle compared with the relative ease of producing a perforation in the chemical canisters.

Overall, the SR-100 behaved pretty much like the older chemical SCSR's in all of the destructive tests. The compressed oxygen units produced more violent reactions when the oxygen bottles were perforated, which could be accomplished only under the most extreme circumstances. None of the destructive tests indicated that the SR-100 posed any more serious hazard than the older chemical or compressed oxygen SCSR's. Since the mine-proven safety record of the older SCSR's is extremely good, the SR-100 should be able to see service in underground mines provided that the safeguards outlined in references 1 and 2 are taken into consideration.

It has been pointed out that since the SR-100 was designed to be belt wearable, personal exposure to the unit will be much more intense than with the larger chemical or compressed oxygen units, which are ordinarily stored and used only in emergency situations. The only possible hazard in the worn mode would be catastrophic failure of the starter oxygen bottle. Since the quantity of oxygen stored in the starter bottle is so small, the impulse transferred to the wearer would be negligible and the hazard would be limited to a startle effect. In view of the ruggedness of the stainless steel starter bottle as demonstrated in the destructive tests, this is not viewed as a major concern.

REFERENCES

1. Watson, R. W., W. J. Doyak, and A. L. Furno. Evaluation of the Safety of One-Hour Chemical Self-Rescuers. BuMines OFR 123-80, 1980, 190 pp.

2. Watson, R. W., A. L. Furno, W. J. Doyak, and R. L. Brewer. Evaluation of the Safety of One-Hour Compressed Oxygen Self-Rescuers—Results of Destructive Testing. BuMines RI 8890, 1984, 70 pp.

3. United Nations. Recommendations on the Transport of Dangerous Goods. Publ. ST/SG/AC.10/Rev. 5, 1988, 504 pp.

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