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UNITED STATES DEPARTMENT OF THE INTERIOR

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

°F	degree Fahrenheit	oz	ounce
ft	foot	pct	percent
ft^2	square foot	pt	pint
ga	gauge	psia	pound per square inch, absolute
gal	gallon	psig	pound per square inch, gauge
h	hour	psi/min	pound per square inch per minute
in	inch	s	second
in^2	square inch	wt pct	weight percent
lb	pound		
min	minute		

FIRE TESTS OF FIVE-GALLON CONTAINERS USED FOR STORAGE IN UNDERGROUND COAL MINES

By F. J. Perzak,[1] T. A. Kubala,[2] and C. P. Lazzara[3]

ABSTRACT

The Bureau of Mines conducted a study to develop a standard fire test for 5-gal containers used for storing combustible fluids in underground coal mines. A standard test method was developed which evaluates the performance of the container in a 4-min tray fire.

Bureau investigators used the standard test method to evaluate several types of closed 5-gal plastic and metal cans in outdoor tests. Each can tested contained 1 gal of nonfire-resistant (NFR) hydraulic oil. A container failed the test if it lost its contents in any of seven trials. Contents spilled either as a result of thermal rupture or melting. Fewer than 10 pct of the metal containers failed this criterion, but all the plastic containers failed. The metal container failures were usually due to tipping over during pressure relief, which spilled the NFR oil. Replacing the NFR oil in the container with kerosene resulted in failure of more than 30 pct of the metal containers. The standard tests and preliminary tests showed that plastic containers are not equivalent to metal containers in their ability to contain combustibles such as lubricants and greases in a fire. For solvents and lubricants more volatile than NFR hydraulic oil, approved metal safety containers are recommended.

[1]Research chemist.
[2]Research physicist.
[3]Supervisory research chemist.
Pittsburgh Research Center, Bureau of Mines, Pittsburgh, PA.

INTRODUCTION

An underground coal mine fire is a severe hazard to personnel and a waste of property. To minimize this risk, Title 30 of the Code of Federal Regulations (30 CFR) (1),[4] includes fire prevention, detection, and extinguishment standards for coal mines. Underground storage of lubricating oil and grease is addressed in 30 CFR 75.1104, which states,

> Underground storage places for lubricating oil and grease shall be of fireproof construction. Except for specially prepared materials approved by the Secretary, lubricating oil and grease kept in all underground areas in a coal mine shall be in fireproof, closed metal containers or other no less effective containers approved by the Secretary.

In practice, the Mine Safety and Health Administration (MSHA) requires all combustible fluids to be in closed metal containers, except for a few items such as grease cartridges and small quantities of specialty fluids. However, plastic pails are gaining wide acceptance by the manufacturers and suppliers of lubricants (2). Presently, there is no test procedure to assess the fire hazard potential of containers currently used in underground coal mines or to determine if other containers (e.g., plastic) are "no less effective" when exposed to a fire. The purpose of this study was to develop such a test for 5-gal containers. Container properties such as strength, corrosion, and impact resistance were not addressed in this work.

Nonmetallic (plastic) safety containers are approved by Factory Mutual Research Corp. (FMRC) (3) and Underwriters Laboratories, Inc. (UL) (4), for limited use with high-volatile flammable liquids. The fire tests used by FMRC and UL in approving these containers consisted of subjecting the containers, half filled with heptane, to a tray fire lasting about 8 min. If the container did not spill its contents, it passed. Metal containers easily passed these tests; however, plastic containers also passed, since they melted down to the fluid level during the test and retained the heptane after the tray fire had burned out. Other fire tests used by UL included container contact with (1) steel rods (1/2 by 6 in) heated to 500° F, until the rods cooled to room temperature; (2) 1-in-high natural gas burner flames for 75 s; and (3) a 2- by 3-ft newspaper fire lasting about 2 min. The containers were tested filled with water, and no leakage was permitted for approval of the nonmetallic safety containers.

Large-scale fire tests were conducted by the U.S. Coast Guard to compare the resistance of steel and polyethylene (PE) drums to fire exposure (5-6). The effects of fuel volatility, time to failure, and mode of failure were recorded for 5- to 55-gal drums in 25- to 90-ft^2 tray fires. Steel drums failed by jetting and/or exploding in 1-1/2 to 8 min, and the PE drums failed by melting and collapsing into the fire in less than 2 min. Failure times for materials more volatile than aircraft jet fuel, such as acetone, were about the same for both the steel and PE drums.

In this study, tests similar to the FMRC and UL tests for safety containers were used to test all types of 5-gal containers. However, materials typically used and stored in underground mines were used for the container contents instead of the highly volatile heptane contents used in the FMRC and UL tests.

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[4]Underlined numbers in parentheses refer to items in the list of references preceding the appendix.

CONTAINERS TESTED

The 5-gal containers used in the fire tests described in this report included plastic and metal safety cans and pails, metal Jerry cans and square cans, and metal pails with plastic vents or plastic closures. Metal cans are currently used in underground mines for storage of combustible fluids. Descriptions of the containers tested are included in the appendix.

EXPERIMENTAL FIRE TESTS

TEST DESCRIPTIONS

Three fire tests were deemed representative of the fire hazards that might be encountered by storage containers in underground mines: exposure to a severe (large-scale) tray fire, contact with a hot plate, and exposure to a small oil rag fire against the container wall.

Initially, the severe fire-exposure tests consisted of exposing safety containers to a burning hydraulic oil mixture (4.7 gal) for about 7 min in a nominal 10-ft^2 tray about three-fourths full of water, with the container half full of hydraulic fluid (2.5 gal). These tests were based on the UL and FMRC standard approval tests for safety containers described in the introduction to this report. For subsequent tests using other types of containers, the tray fire time was shortened to about 4 min. The containers were tested half full of fuel (2.5 gal) with a 3/8-in-deep (2.5-gal) fuel layer in the tray, using the arrangement shown in figure 1. The 7- and 4-min experimental tray fire tests are described in detail in the subsequent section "Large-Scale Tray Fire Tests."

After the experimental tray fire tests were completed, a standardized tray fire test (approximately 4 min) was developed. For the standardized tests, readily obtained kerosene and gasoline fuels were used in the tray; a commercially available mortar tray was also used. The standardized tests are described in the "Standard Tray Fire Test" section.

Plastic safety containers were tested for melting failure by heating on a 10- by 20-in hot plate. The containers, holding 2 gal of fire-resistant Pyrogard-D[5] hydraulic oil (Mobil Oil Co.), were placed upright on the hot plate, whose temperature was manually controlled. Fire-resistant oil was chosen for the hot-plate tests to prevent unwanted fires in the event of container failures. A thermocouple placed in the center of the plate under a sheet of aluminum foil protected the wiring against possible leakage of the hydraulic oil. Temperatures were controlled up to 572° F.

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

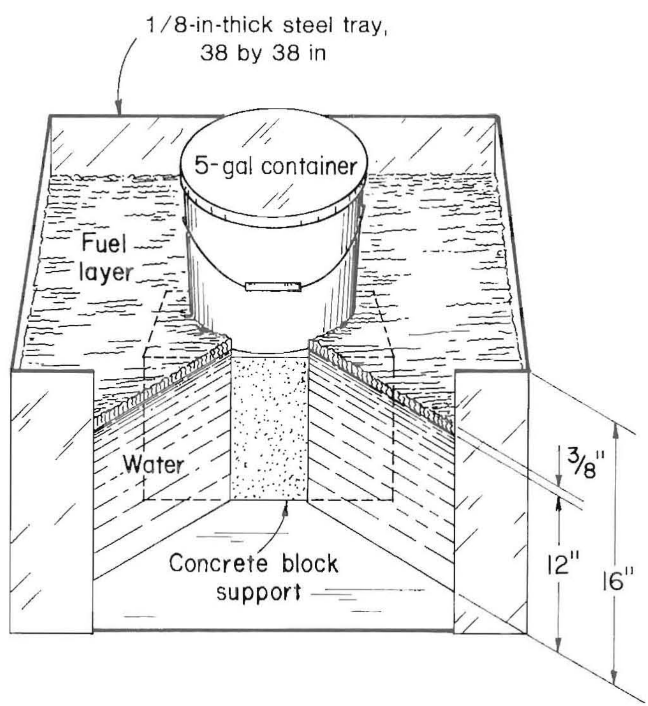

FIGURE 1. - Preliminary tray fire test arrangement.

The oily rag fire test was performed simultaneously on two containers, one metal and the other plastic. The containers were placed with their top rims touching and their bottom rims approximately 2-1/4 in apart. The test consisted of a nominal 2-min exposure to a burning grease-soaked (0.14 oz grease) cotton rag with an area of about 100 in^2. The rag was placed between the two containers and ignited with a propane torch. Open- and closed-head plastic pails, empty and containing greases and Pyrogard-D hydraulic oil, were tested in a draft-free area with the rag fire.

RESULTS

Small-Scale Oily-Rag Fire Tests

Open-head plastic containers were tested empty and filled with high-temperature, high-pressure grease and three manufacturer's closed-head plastic containers (closed tight) were tested with fire-resistant hydraulic oil. The results are given in table 1.

The empty plastic container was intact for about 1 min 45 s until a hole was observed 2 in from the bottom. The container continued to burn after the rag fire burned out. The container material melted and began to burn as a pool fire. The adjacent metal container only blackened and did not contribute to the fire. Figure 2 shows the fire damage after 5 min, at which time the fire was purposely extinguished. A cotton rag of the kind used for the source fires is also shown.

The plastic containers in about half of the tests scorched and melted but did not leak. The grease-containing pails developed holes in about 2 min; however, the resulting grease fires were confined to a small area. In one case, the leaking hydraulic oil extinguished the small rag fire. The addition of fire retardants in the plastic formulation at the maximum amounts recommended by their manufacturers did not prevent container melting, nor did it prevent the waxlike fuel from contributing to the rag fire.

TABLE 1. - Results of oily-rag fire tests of plastic containers, seconds

(Approx rag burning time: 2 min)

Contents	Leakage time	Comments
OPEN-HEAD CONTAINERS[1]		
Empty...............	105	Hole 2 in. above bottom (fig. 2).
Grease[2]............	90-390	No spread of grease out of hole at bottom.
CLOSED-HEAD CONTAINERS[3]		
Fire-resistant hydraulic oil.[2]	[4]120	3 containers did not leak; 2 leaked from hole at bottom. In 1 test, leaked oil extinguished fire.

[1]Similar containers made by two manufacturers were used; see appendix ("Open-Head Plastic Pails") for description.

[2]5 gal.

[3]Description not included in the appendix.

[4]Leakage time for containers that leaked; see "Comments" column.

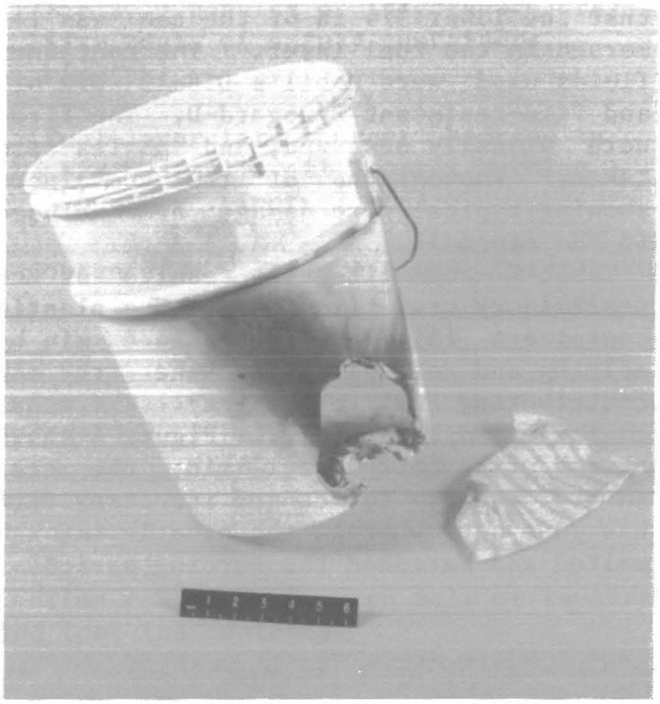

FIGURE 2. - Plastic container damaged by small burning rag.

Hot-Plate Tests

The hot-plate melting tests showed that plastic safety containers could withstand 572° F for about 1/2 h without leaking hydraulic oil. Figure 3 shows the melted bottom of a plastic container and a new container. The high-density polyethylene was stable to temperatures up to 250° F, so temperatures from 300° F to 572° F were used. At 300° F and 450° F, the containers leaked after contact times of 5 h and 2 h, respectively. These long endurance times were a result of the ribbed construction of the container bottoms and the cooling effect of the 2 gal of hydraulic oil contents, which never exceeded 170° F.

Large-Scale Tray Fire Tests

The hot-plate and the oily-rag fire tests were eventually discontinued since survival in the more severe tray fire test would imply an effective plastic

FIGURE 3. - Plastic safety container after 1/2-h contact with hot plate at 572° F (left) and a new container (right).

container. Both plastic and metal containers of several different types were tested in large-scale tray fires.

Safety Containers

Plastic and metal safety containers were subjected to preliminary 7-min tray fire tests, using the tray arrangement shown in figure 1. The containers were half filled with hydraulic fluids (2.5 gal) and placed upright on a concrete block in a 16-in-deep 38- by 38-in metal tray. A 4.7-gal fuel mixture of NFR hydraulic oil (Mobil DTE-13) with 14 wt pct heptane was floated on top of approximately 12 in of water to form a (3/4-in-deep) fuel layer. The container was placed on a concrete block so that the lower 3/4 in of the can was immersed in the fuel layer. The container fluids used were Mobil's DTE-13 NFR oil and fire-resistant Pyrogard-D. The fires were visually observed, and movies were taken. Photographs of the containers showing typical fire damage are included in the appendix.

Table 2 summarizes the results of the preliminary tray fire tests. The plastic containers failed in less than 4 min by melting and collapsing into the tray and contributing fuel to the tray. The metal containers did not fail. Figure 4 shows a tray fire test after 7 min; the metal safety can is intact and its tray fire has gone out, whereas the plastic one has melted and extended the burning period.

FIGURE 4. - Tray fire test showing intact metal safety container (right) after 7 min and fire-consumed plastic container (left).

TABLE 2. - Results of large-scale tray fire tests of safety containers, minutes

(Fuel-layer fire source: heptane in NFR hydraulic oil; approx burning time: 7 min)

Contents[1]	Failure time[2]	Total burn time
PLASTIC CONTAINERS		
DTE-13........	2.5	35
Do..........	3.8	26
Pyrogard-D....	3.8	36
METAL CONTAINERS		
DTE-13........	(3)	6.7
Pyrogard-D....	(3)	6.3

[1]2.5 gal.
[2]Time container took to melt or rupture and lose its contents.
[3]Did not fail.

The intensity of the tray fires in the tests of both the plastic and metal containers was about the same and was determined visually. The fire intensity was controlled by tray size, wind, and type of fuel; therefore, fluid spilled from the plastic containers only increased the burning time and not the intensity. However, considering that the spills added only 2.5 gal of fluid to the tray, the total burn times for the plastic containers were much longer than was expected. This was because the flames from the spilled fluids were relatively small (although there were periodic flareups).

Open-Head Containers

Open-head grease containers were also tested using the tray arrangement shown in figure 1, except that the fuel-layer depth was reduced to about 1/4 in. The shallower fuel layer shortened the source fire to about 4 min, which was considered adequate for nonsafety containers. The 2.5-gal fuel layer consisted of heptane or 2 gal of heptane plus 0.5 gal of No. 2 fuel oil. The 5-gal containers were either half-filled or filled with grease (Silthor lubricant, batch No. G-15K, Pennzoil Co.). The full container contents weighed about 35 lb. The plastic pails weighed 3.2 lb and were made of high-density polyethylene.

The container walls melted in less than 1 min, and the ignited grease burned as a coherent pile until both were extinguished. The plastic pails and grease probably would have continued to burn for hours; however, the fires were extinguished after 12 min. Figure 5 shows the burning grease from a melted plastic container after 12 min. Figure 6 shows burning grease in a metal container after 12 min. For this test, the container lid was removed. The test results for open-head grease containers are given in table 3.

TABLE 3. - Results of large-scale tray fire tests of open-head grease containers, minutes

(Fuel-layer fire source: heptane or heptane and No. 2 fuel oil; approx burning time: 4 min)

	Contents[1]	Failure time[2]	Total burn time
PLASTIC CONTAINERS			
With lid.	1/2 full..	0.75	>15
Do.....	Full......	.92	>15
No lid...	1/2 full..	1.17	>15
METAL CONTAINERS			
With lid.	1/2 full..	(3)	[4]4.3
Do.....	Full......	(3)	[4]4.1
No lid...	1/2 full..	(3)	[4]>15

[1]Pennzoil Silthor lubricant.
[2]Time container took to melt or rupture and lose its contents.
[3]Did not fail.
[4]In the listed tests of metal containers, flames were first observed at the tops of the containers at 1.8 min, approx 2 min, and approx 1 min, respectively; lids warped during tests or were absent.

FIGURE 5. - Remnants of plastic pail and 35 lb of grease 8 min after tray fire has self-extinguished.

Closed-Head Containers

Several types of closed-head metal containers were tested in 4-min fires with different quantities of hydraulic oil used as the container contents. A 1-gal quantity of NFR hydraulic oil was chosen as the standard container contents since quantities up to 3 gal resulted in no difference in behavior. In some tests, however, kerosene was used in the containers. Five-gallon containers usually rupture or open in less than 3 min, so a nominal 4-min fire was adequate. The test results for the closed-head containers are discussed in the appendix and below.

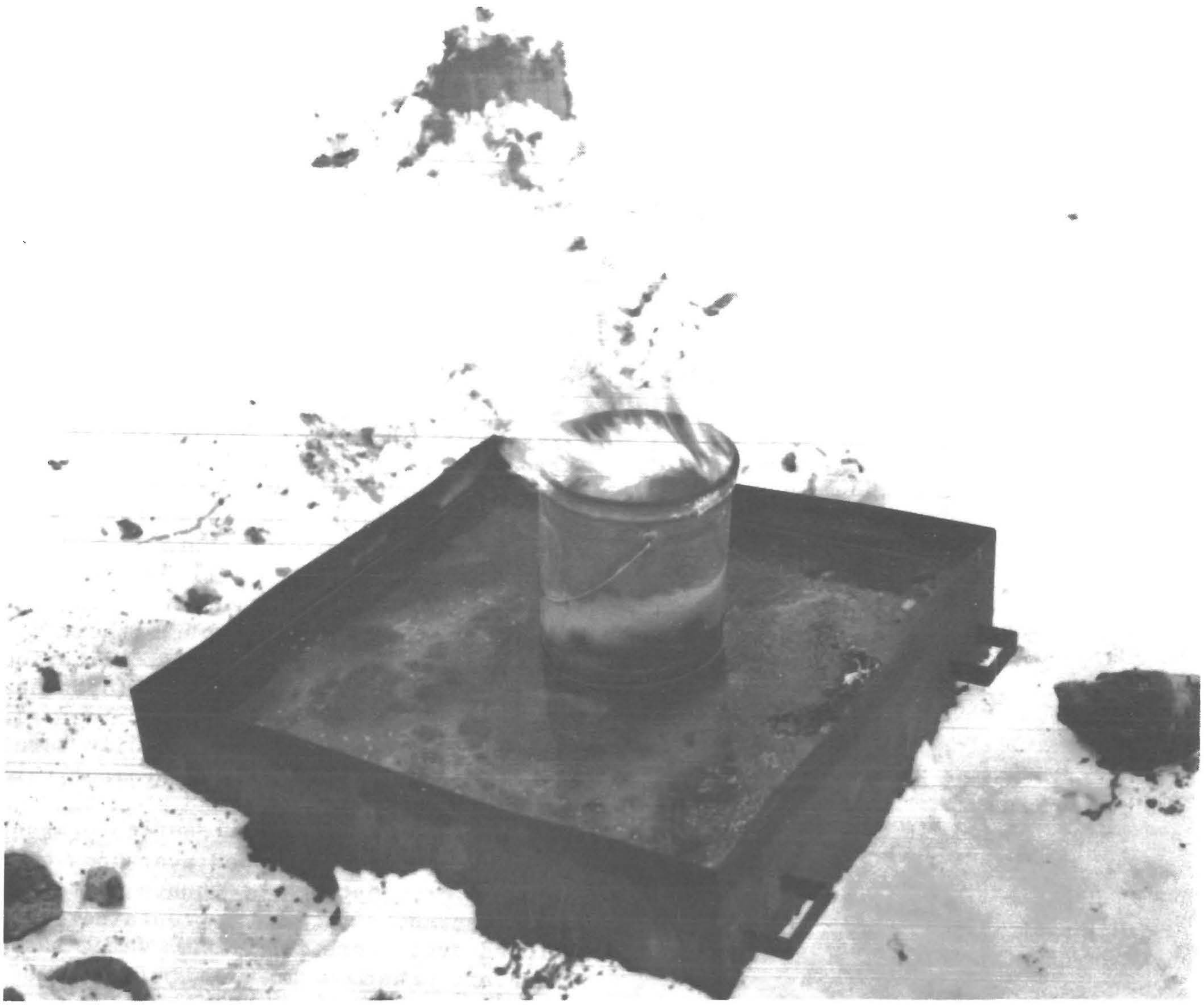

FIGURE 6. - Burning grease in open metal pail 8 min after tray fire has self-extinguished.

STANDARD TRAY FIRE TEST

In the large-scale fire tests of oil and grease containers, the tray fuel loading was finally standardized at 1 gal of kerosene and 1 qt of unleaded gasoline floating on water in a No. 1 mortar tray (11 ft^2 area). This fuel loading resulted in a 1/4-in-deep fuel layer with a burning time of 3.9±0.6 min and a maximum flame temperature of about 1,400° F. The container was supported 1 in above the water level on a concrete block, and a wind shield was constructed on one side of the tray. Figure 7 shows the standard tray fire arrangement. Figure 8 shows a black container in the tray before the fire. The standard container contents was 1 gal of NFR hydraulic oil; however, for special tests, kerosene was also used. The standard fuel loading, fire, and container contents were designed to simplify the test so that others could easily evaluate the performance of other containers. Tray fire tests should be performed at an ambient temperature of 60±20° F to obtain a 4-min burning time.

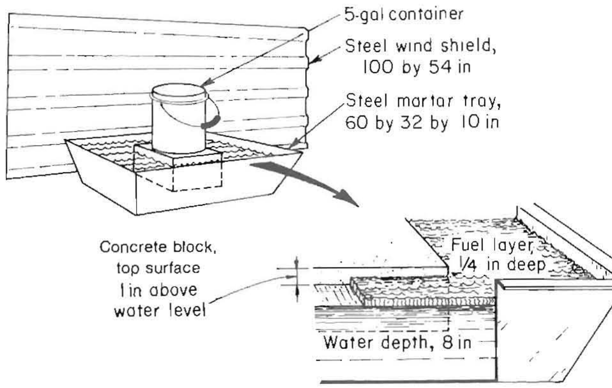

FIGURE 7. - Standard tray fire test arrangement for 5-gal containers.

FIGURE 8. - Black metal container prior to standard tray fire test.

In the standard tray fire tests with NFR hydraulic oil contents, seven containers of each type (Jerry metal, square metal, etc.) were tested. Containers of the same type were of identical construction, with identical closures, and were made by the same manufacturer. Prior to testing, 1 gal of NFR hydraulic oil (or kerosene, for the special tests) was added to each new container, and the container was sealed and weighed.

TEST CRITERION

An effective container was defined as one that did not spill its contents in seven fire trials. Containers that met this criterion passed the standard test. Weight losses equivalent to about 1 pt or less of NFR oil were permitted. These losses were determined within about 1 h from the time the fire burned out.

RESULTS FOR EIGHT DIFFERENT CONTAINERS

Eight different types of 5-gal plastic and metal cans containing 1 gal of hydraulic fluid were subjected to the standard tray fire test (fig. 7). Metal safety containers were not subjected to the standard tray fire test since they passed the more severe 7-min tray fire test (table 2). All but three of the metal containers ruptured in less than 2 min but did not spill their contents, thus meeting the test criterion. One metal container failure (open-head pail) occurred when the container lid blew off and the contents readily burned until extinguished. Two container failures (square cans) occurred when the container bottoms rounded due to pressure and the containers tipped over upon opening. Three batches of square containers were tested, and the two containers that tipped over were from the same batch. However, there were no obvious visual differences between the containers in the three batches. Replacement of the metal screw cap on three of the square containers with a 2-in-diam plastic plug allowed pressure release at about 0.5 min. These containers vented uneventfully and did not spill the hydraulic oil contents. Two plastic containers failed the standard test in the first trial. The plastic containers burned completely along with their contents. Table 4 summarizes the results of the standard tray fire tests using hydraulic oil as the container contents. Figure 9 shows the usual mode of pressure release from the black containers as flame jets from the gasket-cap area of the screw closure; rupture of the top seam occurred about 0.5 min later.

TABLE 4. - Results of standard tray fire tests using 1 gal NFR hydraulic oil in containers

(Fuel-layer fire source: kerosene and gasoline on water; burning time: 3.9±0.6 min)

Container type	Venting time,[1] min	Failure ratio[2]	Comments
METAL CONTAINERS			
Black...........	1.7±0.2	0:7	Paper gasket under cap burned.
Jerry...........	1.1± .3	0:7	Rubber gasket under cap burned.
Square:			
Batch 1.......	.6± .1	0:9	Cap usually blew off, or top seam ruptured.
Batch 2.......	.6	2:3	2 cans overturned and spilled contents.
Batch 3.......	.5	0:3	Metal screw caps were replaced with 2-in-diam plastic plugs.
Vented:			
Dark blue.....	.6± .1	0:7	Plastic vent blew off.
Black.........	.5± .1	0:7	Do.
Open head.......	.3	1:1	Head blew off and contents burned for more than 10 min.
PLASTIC CONTAINERS			
Open head.......	0.6	1:1	Container collapsed, melted, and burned.
Safety.........	2.0	1:1	Do.

[1]Elapsed time from start of tray fire to first pressure release.

[2]Ratio of failures to total trials; e.g., 0:7 indicates no failures in 7 trials.

Five of the metal containers that passed the standard tray fire test were also tested using 1 gal of kerosene in the container instead of NFR hydraulic oil. The time to rupture was about the same as before, but the violence of the rupture was striking. Figure 10 shows a black container jetting 20 ft into the air and an accompanying fire ball about 35 s after tray fire ignition.

Several of the metal containers were instrumented to measure the pressure in the container and the temperature of the fire, the container liquid, and the vapor-air mixture in the container. Figure 11 shows the probe arrangement that was inserted at the container bottom. The 28-ga bare thermocouples were positioned 2 in above the bottom in the liquid layer and 6 in above the bottom in the vapor. A tray fire thermocouple was also placed near the container about 6 in above the burning fuel layer. Figure 12 shows the pressure and temperature traces over time for the black container with 1 gal of kerosene as the contents. The slow pressure rise during the first half minute (less than 100 psi/min) was due to vapor-air heating. The pressure ripples were presumably due to local oxidation and cooling of marginally flammable gases accompanied by container bulging. Occasionally, pressure spikes of about 1,000 psi/min occurred, as shown at 0.6 min. The autoignition temperature of kerosene is about 410° F (7), and this temperature

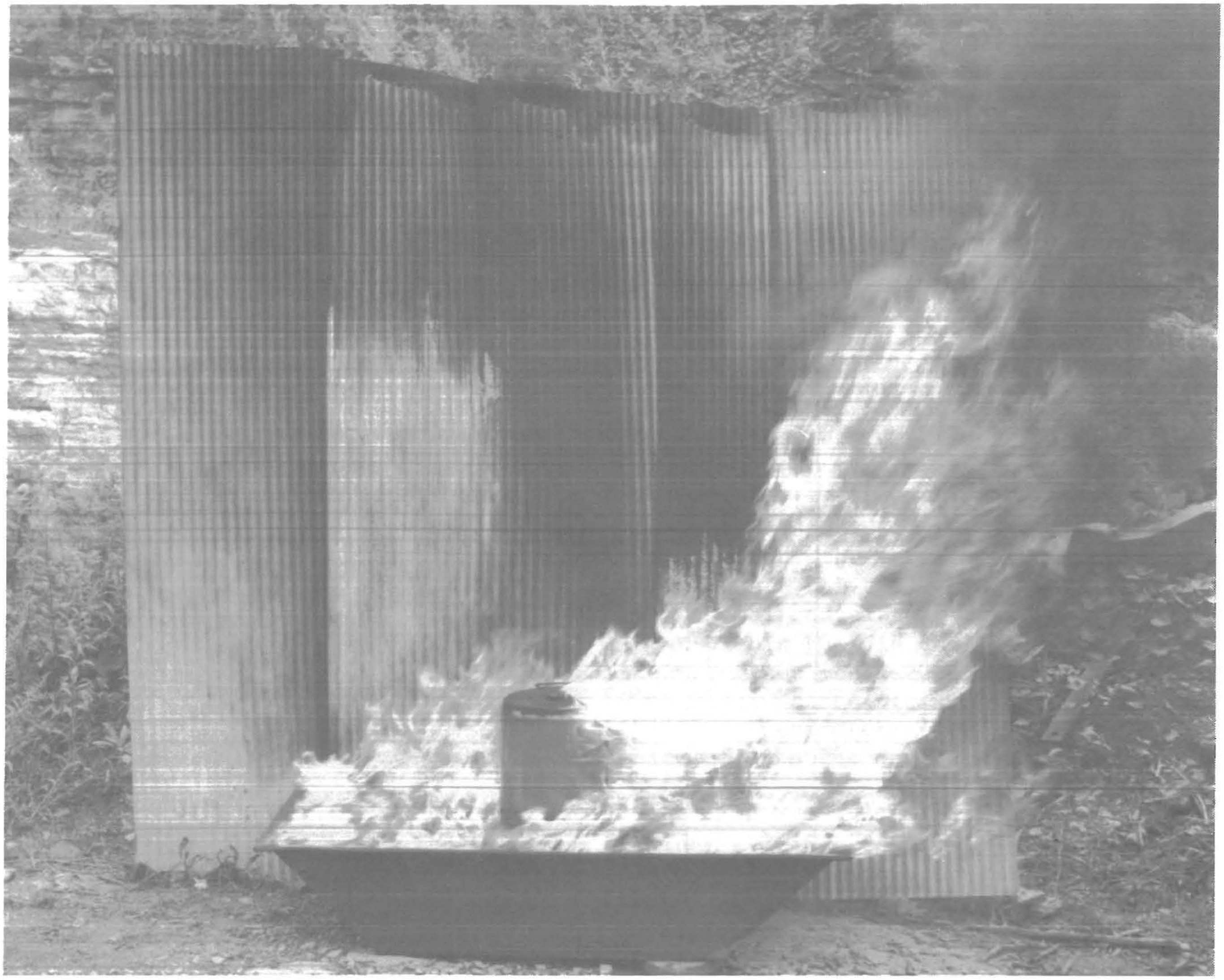

FIGURE 9. - Usual mode of pressure release from black container (flame jet near screw cap closure).

was achieved in the vapor space at about the time the pressure spikes occurred. The sharp increases in the vapor and liquid temperatures after 0.6 min were due to container rupture and exposure of the thermocouple to the tray fire.

Table 5 lists the times to rupture (venting time), maximum vapor-air pressure, and type of container damage for the five metal containers that passed the previous tests. For the tests listed in table 5, the tray used and the fuel loading were the same as in the previous standard tray fire tests, but 1 gal of kerosene was used in the containers instead of NFR hydraulic oil. (Department of Transportation (DOT) descriptions of these containers appear in 49 CFR 178 and in the appendix to this report.) Photographs of the containers before and after the fire are shown in the appendix.

TABLE 5. - Results of standard tray fire tests using 1 gal kerosene in metal containers

(Fuel-layer fire source: kerosene and gasoline on water; burning time: 3.9±0.6 min)

Container type	Venting time,[1] min	Maximum vapor-air pressure, psig	Failure ratio[2]	Comments
Black.................	1.0±0.4	23	3:10	Top seam vented and container overturned, or bottom blew off and top seam opened.
Jerry..................	1.8	19	0:1	Gasket relieved pressure.
Square.................	.5	2	0:1	Entire cap missing after test.
Vented:				
Dark blue............	.5	10	3:3	Bottoms blew off.
Black................	.4	ND	0:2	Plastic vent relieved pressure.

ND Not determined.

[1]Elapsed time from start of tray fire to first pressure release.

[2]Ratio of failures to total trials, e.g., 3:10 indicates that 3 containers out of 10 failed (and that 7 containers vented at an upper seam, gasket, or plastic vent without spilling their contents).

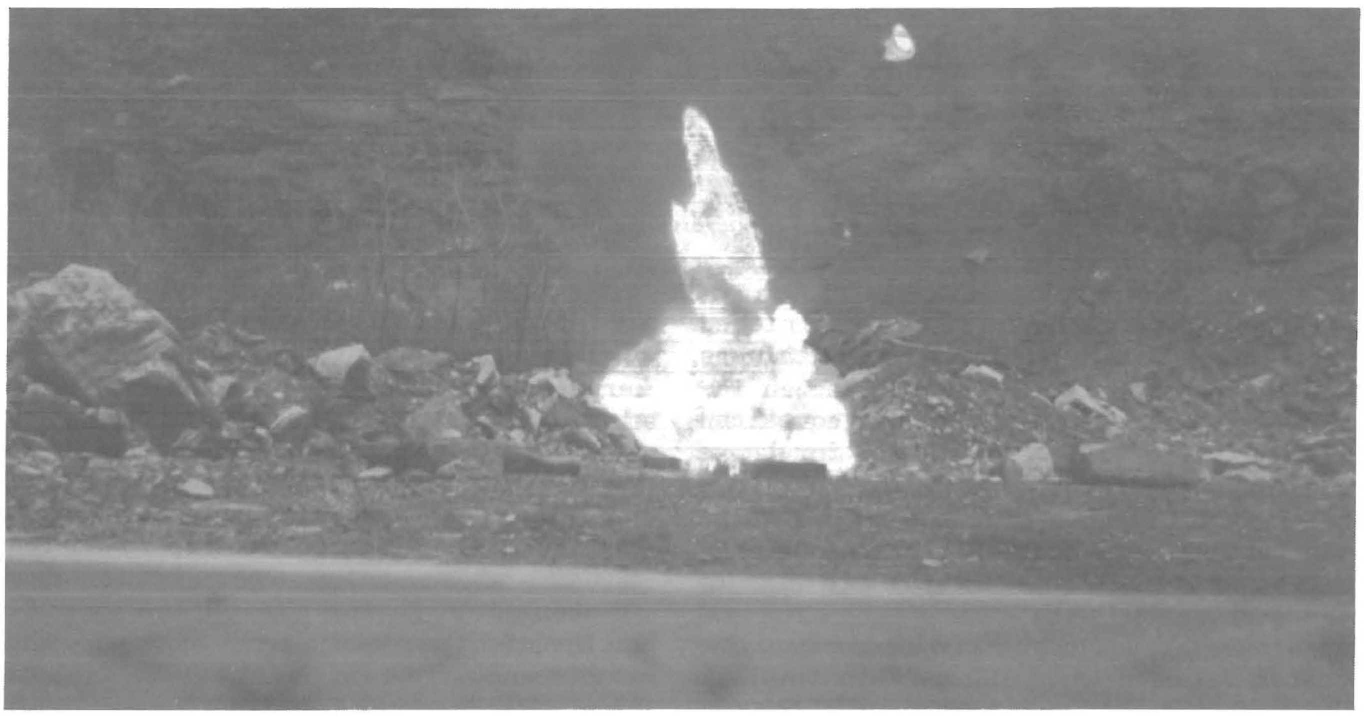

FIGURE 10. - Fire ball and black container jetting about 20 ft into the air due to explosion of kerosene vapor and air after 35-s exposure to tray fire.

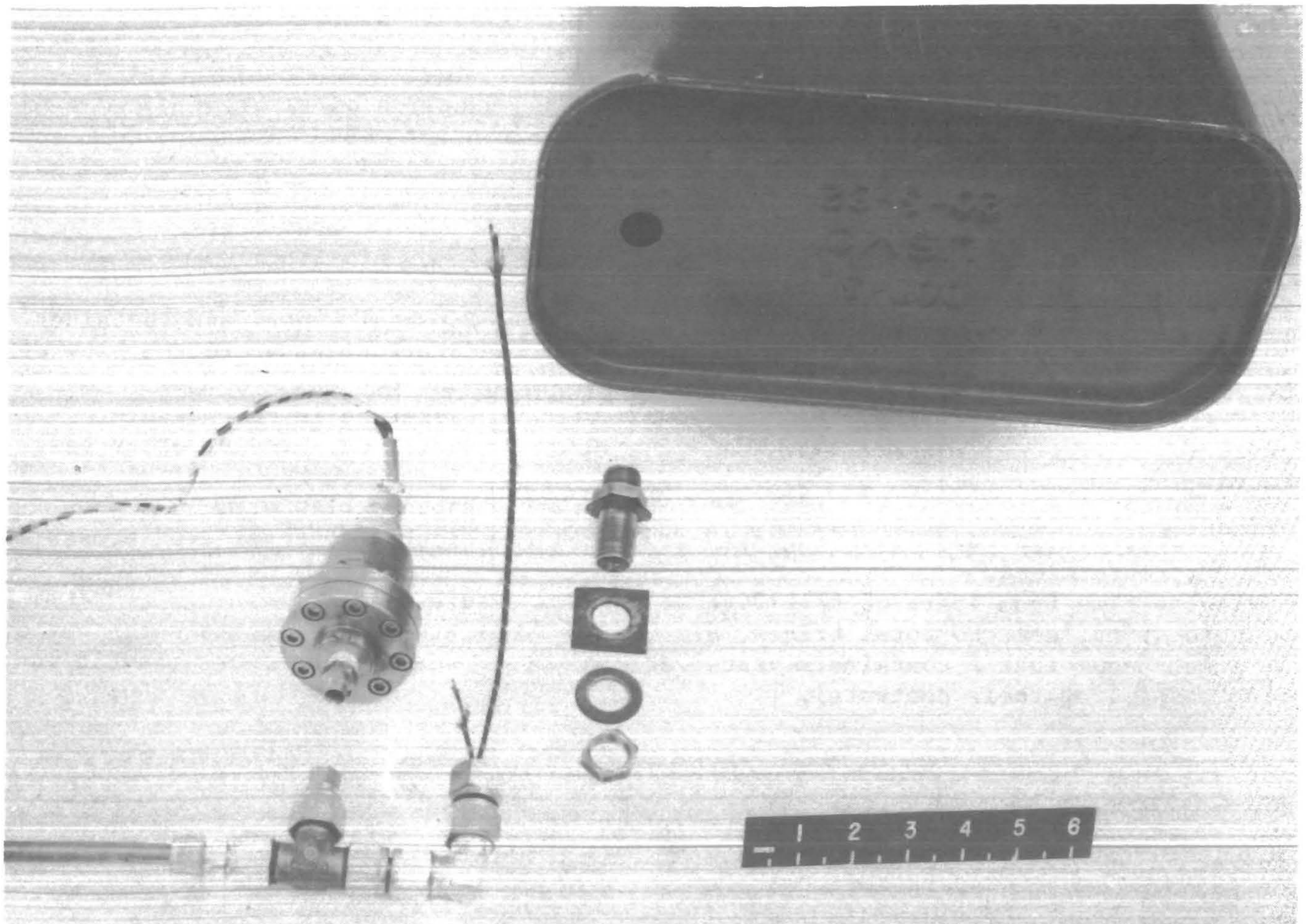

FIGURE 11. - Temperature and pressure probe arrangement used for several metal containers during tray fire tests.

The pressure rates in the heated closed containers were low for the containers that were empty except for air, at an intermediate range for those that contained NFR hydraulic oil, and higher for those that contained kerosene. The pressure rates from 0 to 0.5 min of about 15 psi/min were slower than was expected for ignition of a combustible vapor-air mixture and presumably were a result of thermal expansion of the vapor-air mixtures. The faster rates of over 100 psi/min for both NFR hydraulic oil and kerosene after 0.5 min presumably were a result of hydrocarbon oxidation at the heated container surface. Pressures over time in the black container with air, NFR oil, and kerosene are shown in figure 13. The slow pressure release after the first peak for kerosene and NFR hydraulic oil most likely resulted from the venting at the gasket-cap area similar to that shown in figure 9. The abrupt drop to ambient pressure shown at 1 min for kerosene and at about 1.5 min for NFR oil was an indication of the upper seam rupture that usually occurred with these containers. (See "Black Metal Container" section in the appendix.)

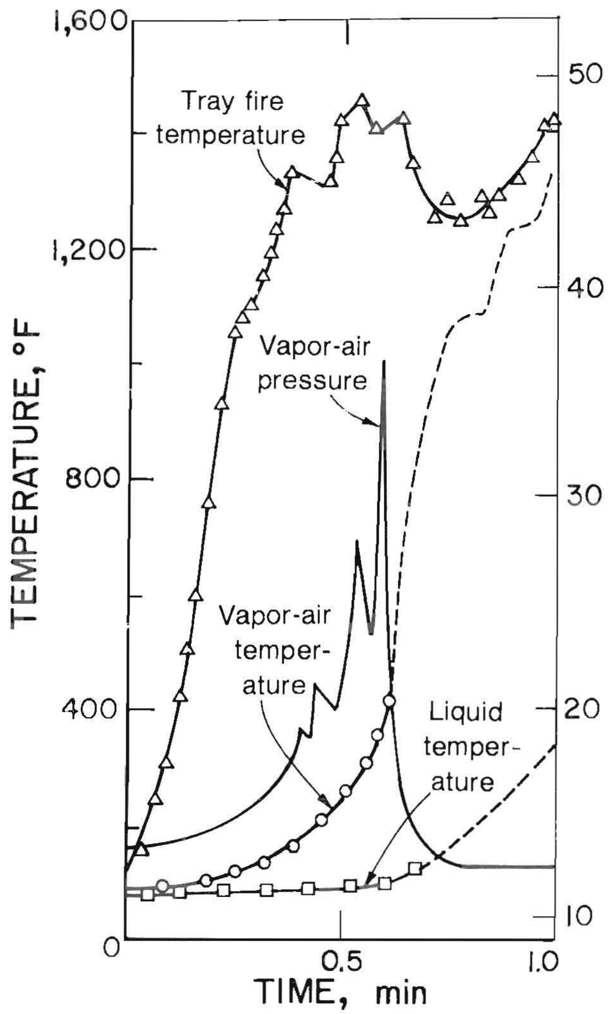

FIGURE 12. - Kerosene liquid and vapor temperatures and container pressure during tray fire test of black container. Container rupture occurred at about 0.6 min.

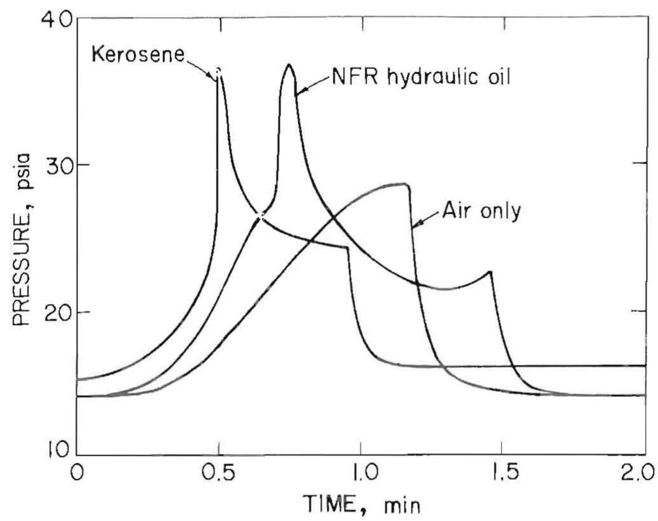

FIGURE 13. - Black container pressures during tray fires for air only (empty) and for NFR hydraulic oil and kerosene contents.

The effect of adding kerosene as a contaminant to NFR hydraulic oil (in the container) was also studied using the black containers. About 1/2 pt of kerosene in 1 gal of NFR hydraulic oil was sufficient to cause container rupture similar to that observed when kerosene was used alone.

Since 1-gal containers are widely used for handling and storing flammable and combustible fluids in underground mines, three 1-gal metal containers were also tested using the standard tray fire. (All containers tested in the previous tests were 5-gal containers.) About 1 pt of hydraulic fluid was used for the contents. In less than 23 s, the containers ruptured violently at seams in their sides and tops. Photographs of these containers are shown in the appendix.

DISCUSSION AND RECOMMENDATIONS

An effective storage container for combustible fluids is one that holds its contents in a fire situation and does not permit a small fire to become unmanageable. About 90 pct of the 5-gal metal containers tested met the test criterion of no spills in seven trials with NFR hydraulic oil as the contents; however, none of the 5-gal plastic containers passed. About one-third of the metal containers spilled or lost their contents when kerosene was used. Small plastic vent closures (3/8 in diam) appeared to be successful in relieving pressure buildup (table 5, vented black container). The containers opened in less than 0.4 min when the plastic vents softened and relieved the pressure. Similar (black) containers without plastic vents failed in about 1 min. Pressures at about 1 min were about 25 to 30 psia and easily ruptured most of the metal containers. The two usual failure modes were charring at the screw-cap gasket and rupture at an upper seam. This behavior is acceptable, however, since little fluid was lost, and when the fluids were of low volatility, the flames self-extinguished at the openings when the source fire was extinguished. With lids removed (or blown off), open-head containers allowed the contents to burn until purposely extinguished. Stronger metal containers (e.g., Jerry cans) are potentially more hazardous than light metal containers since they can hold higher pressures before they rupture. These containers should be vented or the tops purposely weakened.

Plastic friction-fit caps or plug seals are recommended for closures on metal containers. However, the use of all-plastic containers in high-fire-risk areas such as underground coal mines should be avoided since the containers readily soften, collapse, and spill their contents in less than 3 min. A small fire such as an oily rag that burns for about 4 min appears to be sufficient to ignite 5-gal plastic pails. (Figure 2 shows the container damage after a 2-min rag fire.)

Plastic tubes and pails containing high-temperature greases do not present any more of a hazard than cardboard containers, which are now permitted. The greases burn as a coherent mass and do not spread widely in a fire. (Figure 5 shows 35 lb of grease burning after the plastic pail that contained it was destroyed.)

Plastic safety containers are approved by UL and FMRC for flammable solvents that are typically highly volatile, such as heptane, gasoline, ether, and acetone, and the combustible Stoddard solvent. These volatile solvents typically allow the plastic container to burn down as a candle, and the flammable or combustible liquid does not spill. Low-volatile hydraulic oils and lubricating oils, however, allow the container to melt and collapse, spilling these combustible liquids. Plastic safety containers or other plastic pails should not be used in coal mines since combustible fluid spread is likely to occur even in a small fire.

CONCLUSIONS

A standard tray fire test was developed for evaluating the effectiveness of 5-gal containers for storage of greases and lubricants in underground coal mines. Based on the test results for typical 5-gal containers, all plastic containers, including plastic safety containers, fail the standard test. Survival times for plastic containers were about 1 min in the standard tray fire test and as short as 2 min in the small-scale oily-rag fire test. Plastic containers are not equivalent to metal containers in their ability to contain combustibles such as lubricants and greases in a fire.

Closed metal containers can violently rupture and should be weakened at their top or pressure-vented to prevent loss of fluid in a fire. Combustible fluids with volatility similar to that of kerosene should be stored in metal safety containers. Plastic vents or plug seals can prevent seam rupture of metal containers.

The use of 1-gal metal containers for storing combustibles should be kept to a minimum since these containers easily rupture in a fire.

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2. National Bureau of Standards (Dep. Commerce). Plastic containers (Jerry-Cans) for Petroleum Products. Voluntary Product Standard PS 61-74, Am. Natl. Standards MH 17.1-1974, May 1975, 6 pp.

3. Factory Mutual Research Corp. (Norwood, MA). Safety Containers and Filling, Supply and Disposal Containers. Approval Standard Class Nos. 6051 and 6052, May 1976, 6 pp.

4. Underwriter Laboratories, Inc. (Northbrook, IL). Metal Safety Cans. Standards for Safety, UL 30, June 1984, 10 pp.

5. Richards, R. C., and K. T. White. Fire Exposure Tests of Polyethylene and Fifty-Five Gallon Steel Drums Loaded With Flammable Liquids, Phase I. U.S. Coast Guard (Dep. Transportation) Rep. CG-D-116-76, Sept. 1976, 145 pp.; NTIS AD-A043 803/6ST.

6. Richards, R. C., and G. J. Munkenbeck, Jr. Fire Exposure Tests of Polyethylene and Fifty-Five Gallon Steel Drums Loaded With Flammable Liquids, Phase II. U.S. Coast Guard (Dep. Transportation) Rep. CG-D-86-77, Aug. 1977, 102 pp.; NTIS PB-283 488/5ST.

7. Zabetakis, M. G. Flammability Characteristics of Combustible Gases and Vapors. BuMines B 627, 1965, 121 pp.

APPENDIX.--CONTAINER DESCRIPTIONS AND REMARKS

This appendix describes the containers tested in this study and includes remarks concerning their behavior in the previously described tests. The following types of containers were tested:

Black metal containers

Metal jerry cans

Square metal cans

Vented dark blue metal containers

Vented black metal containers

Open-head metal pails

Open-head plastic pails

Plastic safety containers

Metal safety containers

One-gallon metal containers

With the exception of the 1-gal metal container, all containers tested were 5-gal containers.

BLACK METAL CONTAINER

Description

Five-gallon black DOT 17E[1] single-trip metal container (unvented) with pull-up metal spout and 2-1/8-in-diam screw cap; body and head metal: 24 ga. Rated at hydrostatic pressure of 15 psig for 5 min. Capable of withstanding a 4-ft drop to concrete. (Vented DOT 17E black metal containers were also tested; see "Vented Black Metal Container" section.)

[1]The designation DOT 17E is explained in 49 CFR 178.116; Part 178, "Shipping Container Specifications," describes containers for commercial transportation of hazardous materials. The DOT designation certifies that the manufacturer complies with the appropriate parts of these specifications.

Remarks

The black metal container (unvented passed the standard tray fire test with NFR hydraulic oil as the contents. The container pressure was relieved when the paper gasket under the cap burned away after about 1.7 min. Usually, the upper seam ruptured (fig. A-1), but the container nonetheless passed the test because it did not spill its contents.

Use of kerosene in this container is not recommended since 3 out of 10 containers were violently ejected when kerosene container contents were used (figs. 10 and A-2). The seven other containers opened at the upper seams and/or gaskets after about 1 min.

METAL JERRY CAN

Description

Five-gallon rectangular metal Jerry can, DOT 5L;[2] 20-ga steel. Hydrostatically tested at 15 psig for 5 min. Capable of withstanding a 6-ft drop to concrete.

Remarks

The Jerry cans survived the standard tray fire, with NFR hydraulic oil contents, for a little over 1 min. (See figure A-3.) The welded seams remained intact, but the rubber gasket at the screw cap usually burned and melted (fig. A-4). Container contents more volatile than NFR hydraulic oil could generate pressures considerably greater than those produced in the tests using this oil. On the basis of the test results, Jerry cans are not recommended for combustibles more volatile than hydraulic oils.

[2]Described in 49 CFR 178.89.

One Jerry can containing NFR hydraulic oil was ejected out of the tray fire when a bottom seam opened at 6 psig pressure after 1.45 min (fig. A-5). This occurred during a preliminary test (not included in table 4) using the arrangement shown in figure 1. This seam rupture, after a relatively brief exposure to the test fire, suggested a manufacturing defect, since the container should be able to withstand a pressure greater than 15 psig.

SQUARE METAL CAN

Description

Five-gallon standard square metal can; electro-tin plate on steel; overall body thickness: about 12 mil.

Remarks

The square cans readily opened at pressures as low as 2 psig in about 1/2 min but usually did not spill their contents, whether the contents were NFR hydraulic fluid or kerosene. Openings were usually located at the cap seams or at an upper seam (figs. A-6 and A-7); however, two out of three cans opened at a top seam and overturned.

VENTED DARK BLUE METAL CONTAINER

Description

Five-gallon DOT 37B60[3] single-trip container for gross weight less than 60 lb; 28-ga body metal, 26-ga head metal. No pressure rating test for this container, but it must withstand a 4-ft drop to concrete. Closure can be of any type. Vented DOT 17E black containers were also tested; see next section.

Remarks

The vented dark blue metal container is sold as a "kerosene" container in hardware stores. See figures A-8 and A-9, which show typical behavior of this container in the tray fire tests. The small plastic vent shown in figure A-8 (in top of container at left) relieved the pressure when NFR hydraulic oil was used as the contents (table 4). The vent plug blew off, and the paper gasket burned under the cap (fig. A-9), but the container passed the standard test. However, the use of kerosene contents resulted in a violent rupture at the bottom seam (fig. A-10) in three out of three trials (table 5). The vented dark blue metal container should not be used for kerosene and could be hazardous in a large fire.

VENTED BLACK METAL CONTAINER

Description

The characteristics of the 5-gal vented black metal container--metal thickness, pressure rating, etc.--were the same as those of the previously described DOT 17E black metal container, except that it had a small plastic vent inserted into a 3/8-in-diam hole in its head.

Remarks

Pressure was relieved by venting at the plastic plug hole in tests using NFR hydraulic oil (fig. A-11) and kerosene as the contents. A similar unvented container failed the standard tray fire test when kerosene was used for the contents (table 5). Black metal containers vented with a plastic plug can be used to store kerosene, but unvented black containers should not be used for this purpose.

OPEN-HEAD METAL PAIL

Description

Five-gallon open-head metal pail, DOT 37A60,[4] for gross weight less than 60 lb; steel drum with removable head; single-trip container; 26-ga-steel body and head.

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[3]Described in 49 CFR 178.132.

[4]Described in 49 CFR 178.131.

Remarks

This container failed the standard tray fire test with NFR hydraulic oil contents (table 4). The metal head blew off (fig. A-12), and the contents burned for more than 10 min. The plastic folding spout melted, but the pressure was relieved in about 20 s when the lid blew off. This container was also tested with grease contents, which burned as long as the tray fire burned (table 3). The open-head metal pail can be safely used to hold greases, provided the lid is not removed.

OPEN-HEAD PLASTIC PAIL

Description

Five-gallon high-density polyethylene open-head pail weighing 3.2 lb; minimum thickness: 90 mil throughout body, bottom, and cover. Pails of similar construction made by two manufacturers were tested.

Remarks

Both manufacturers' containers failed the large-scale tray fire tests by melting, collapsing, and either allowing the grease to burn readily (table 3 and fig. 6) or spilling the NFR hydraulic oil contents (table 4). These plastic containers also failed the small-scale oily-rag test (table 1 and fig. A-13). The container fire in the oily-rag test was purposely extinguished after 4 min; the oily rag alone would have burned out in about 2 min.

PLASTIC SAFETY CONTAINER

Description

Five-gallon high-density polyethylene safety can, type I; approved by UL and FMRC.

Remarks

Containers readily melted in the large-scale fire in about 3 min (table 2) and spilled the NFR hydraulic oil contents in the standard tray fire tests (table 4). The UL and FMRC approval of this safety container limits its use to high-volatile liquids such as acetone, ether, gasoline, and kerosene. Plastic safety containers are *not* recommended for storage of combustible liquids in underground coal mines. (See figures 4 and A-14.)

METAL SAFETY CONTAINER

Description

Five-gallon metal safety container, type I; steel-terne plate; approved by UL and FMRC.

Remarks

This container passed both the large-scale fire test (table 2) and the standard tray fire test (table 4). In the 7-min tray fire (fig. 4), less than 3.5 oz of NFR oil was lost. Figure A-15 shows the metal safety container before and after the standard tray fire. Only metal safety containers are recommended for storage of combustibles such as kerosene and the more volatile flammables used in underground coal mines.

ONE-GALLON METAL CONTAINER

Description

One-gallon tin-plate oblong metal container with 1-1/4-in-diam foil-lined cap; coated white.

Remarks

One-gallon metal containers are widely used for holding combustibles and flammable fluids and satisfy the present Federal regulation 30 CFR 75.1104 concerning storage and handling of lubricating oils. However, in the standard tray fire, using 1 pt of NFR hydraulic oil, all three of the 1-gal metal containers tested exploded in less than 23 s (fig. A-16). Studies are needed on the use of purposely weakened seam tops to prevent this type of rupture.

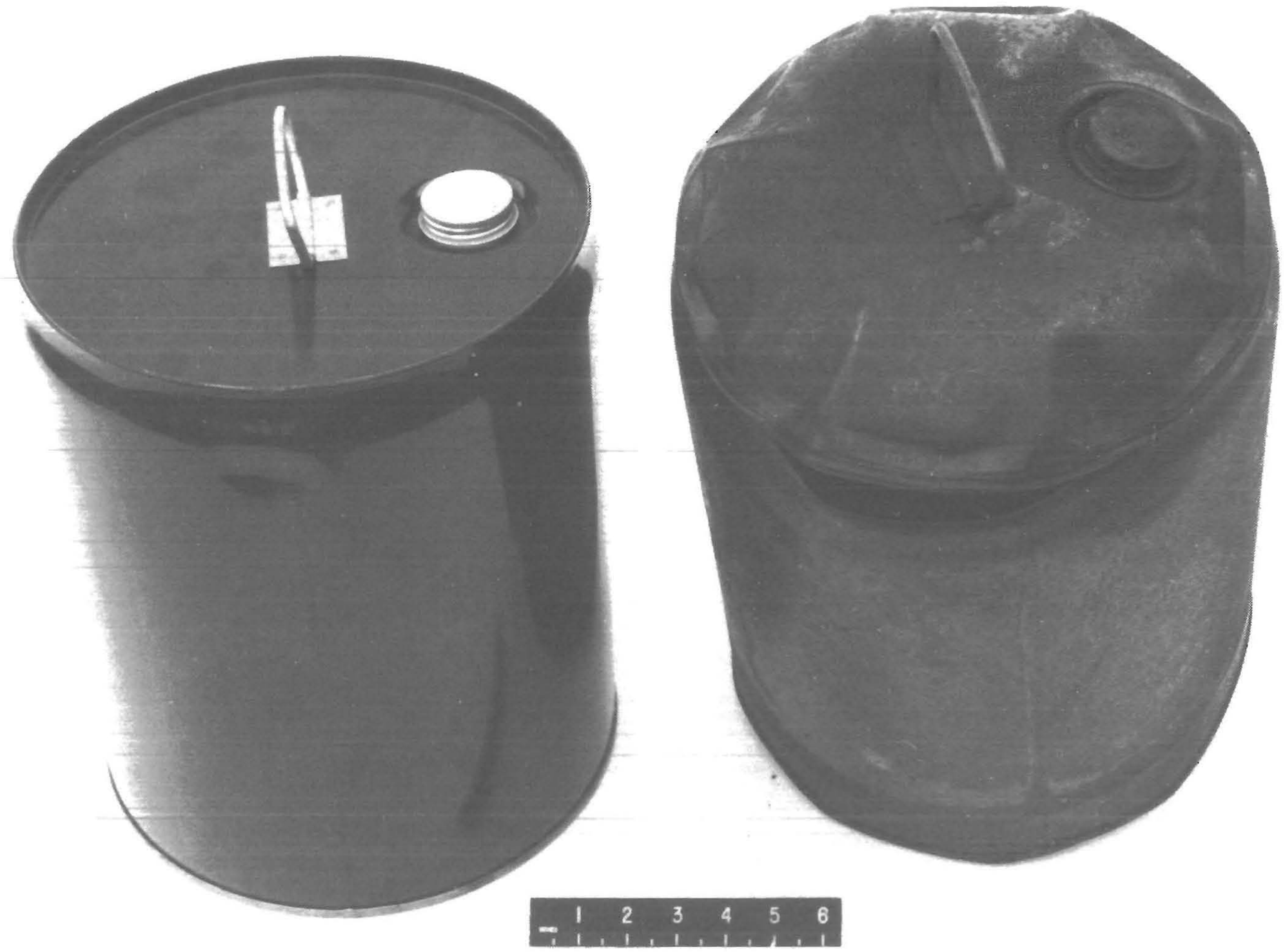

FIGURE A-1. - Black metal containers before and after standard tray fire (using NFR hydraulic oil contents) showing usual opening at upper seam (right).

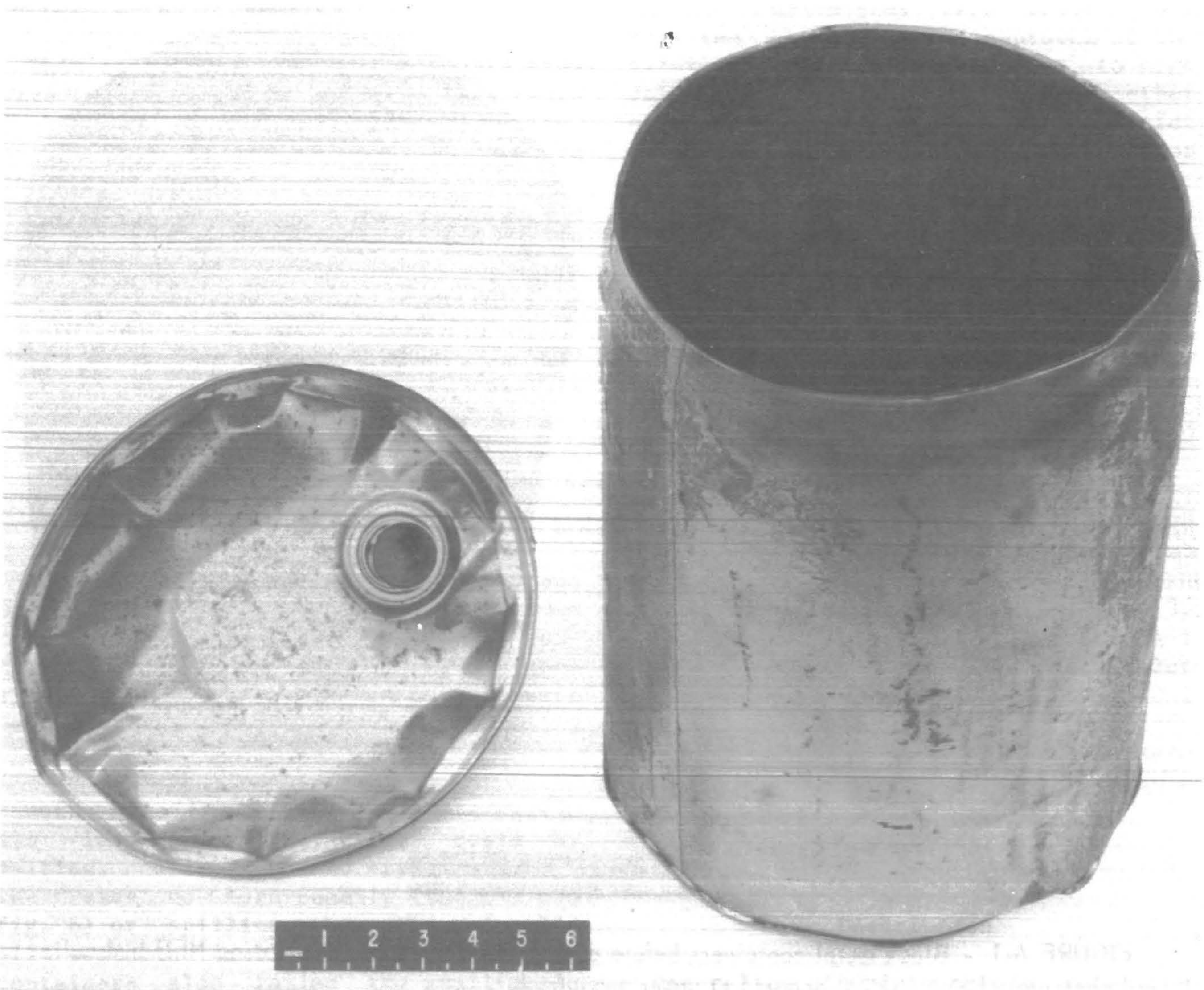

FIGURE A-2. - Black container damage after standard tray fire using kerosene contents.

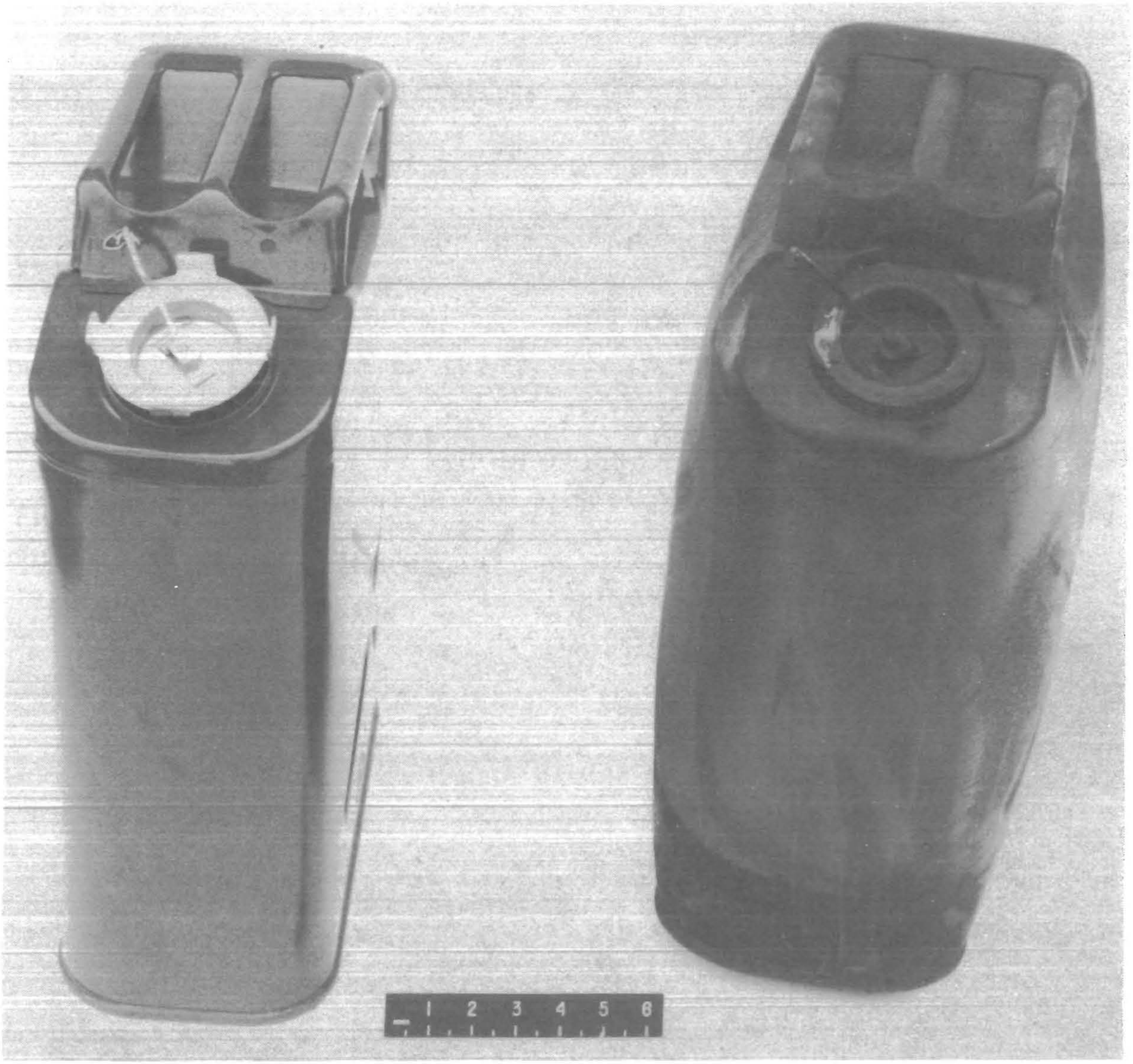

FIGURE A-3. - Metal Jerry cans before and after standard tray fire (NFR oil contents) showing container bulging.

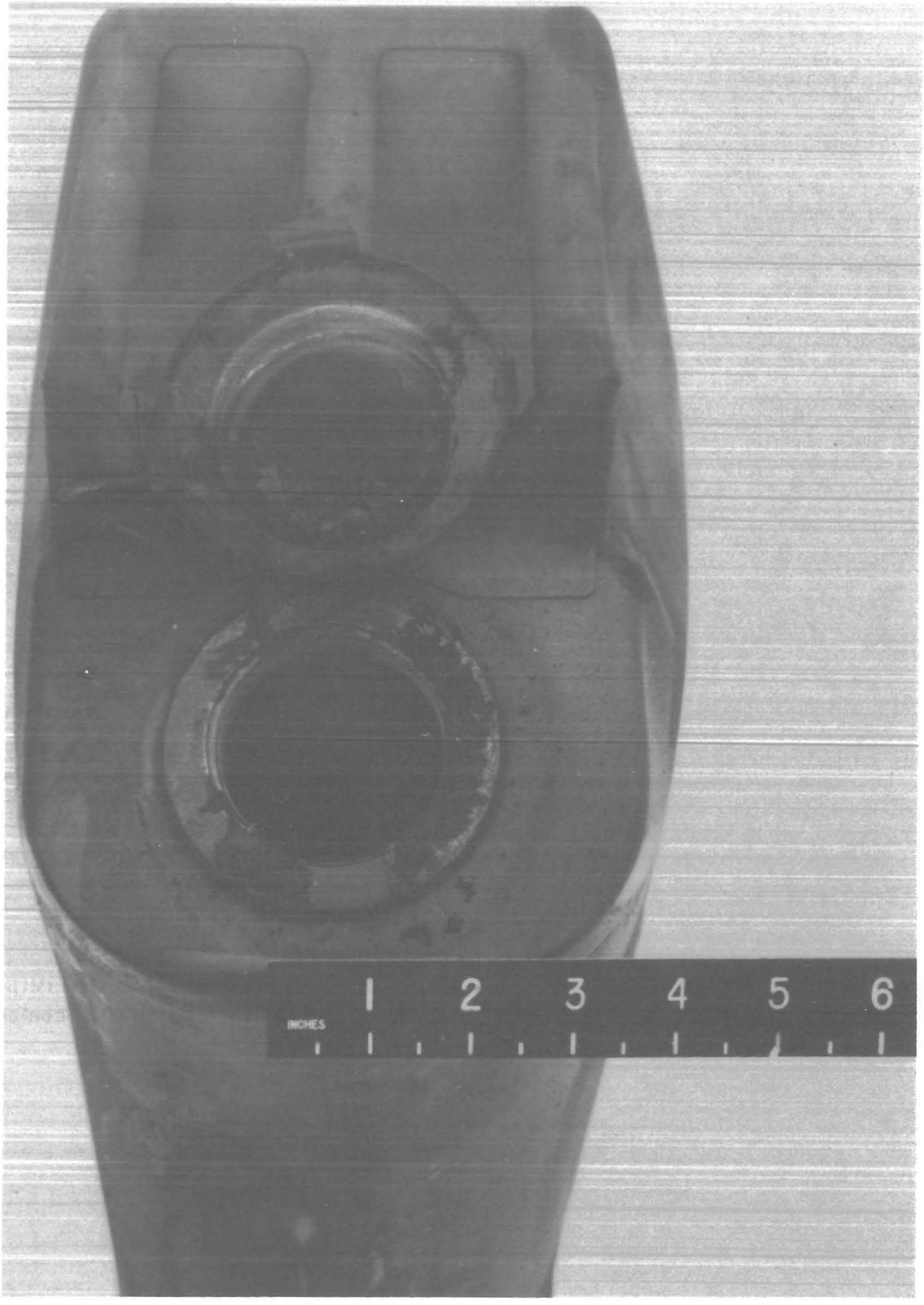

FIGURE A-4. - Jerry can after standard tray fire (NFR oil contents) showing burned rubber gasket at screw cap.

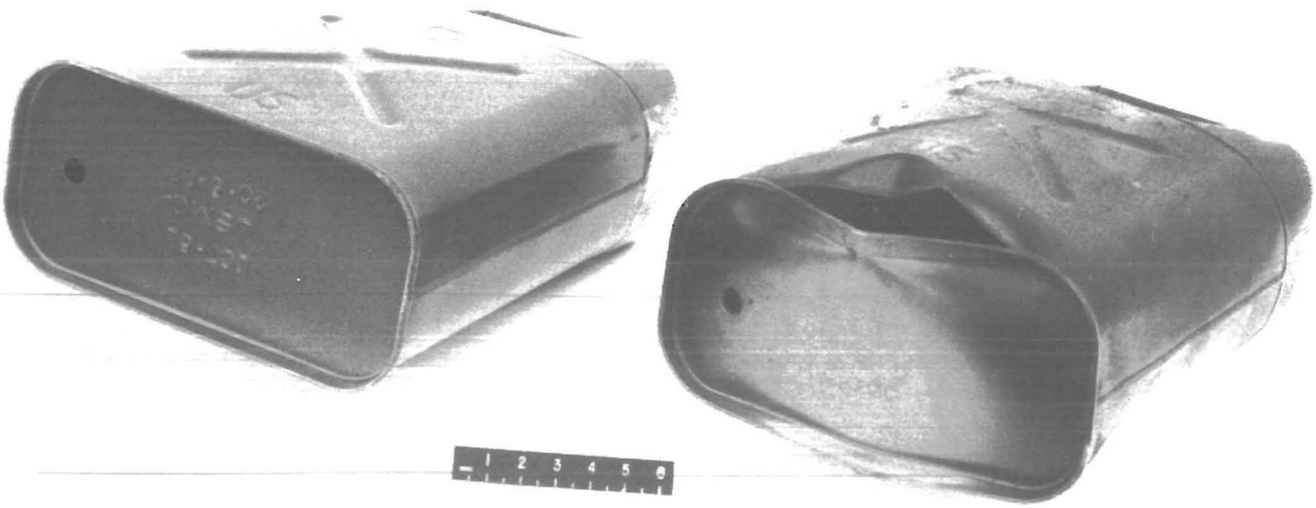

FIGURE A-5. - Jerry cans before and after preliminary tray fire (NFR oil contents) showing (atypical) early rupture at bottom seam (right).

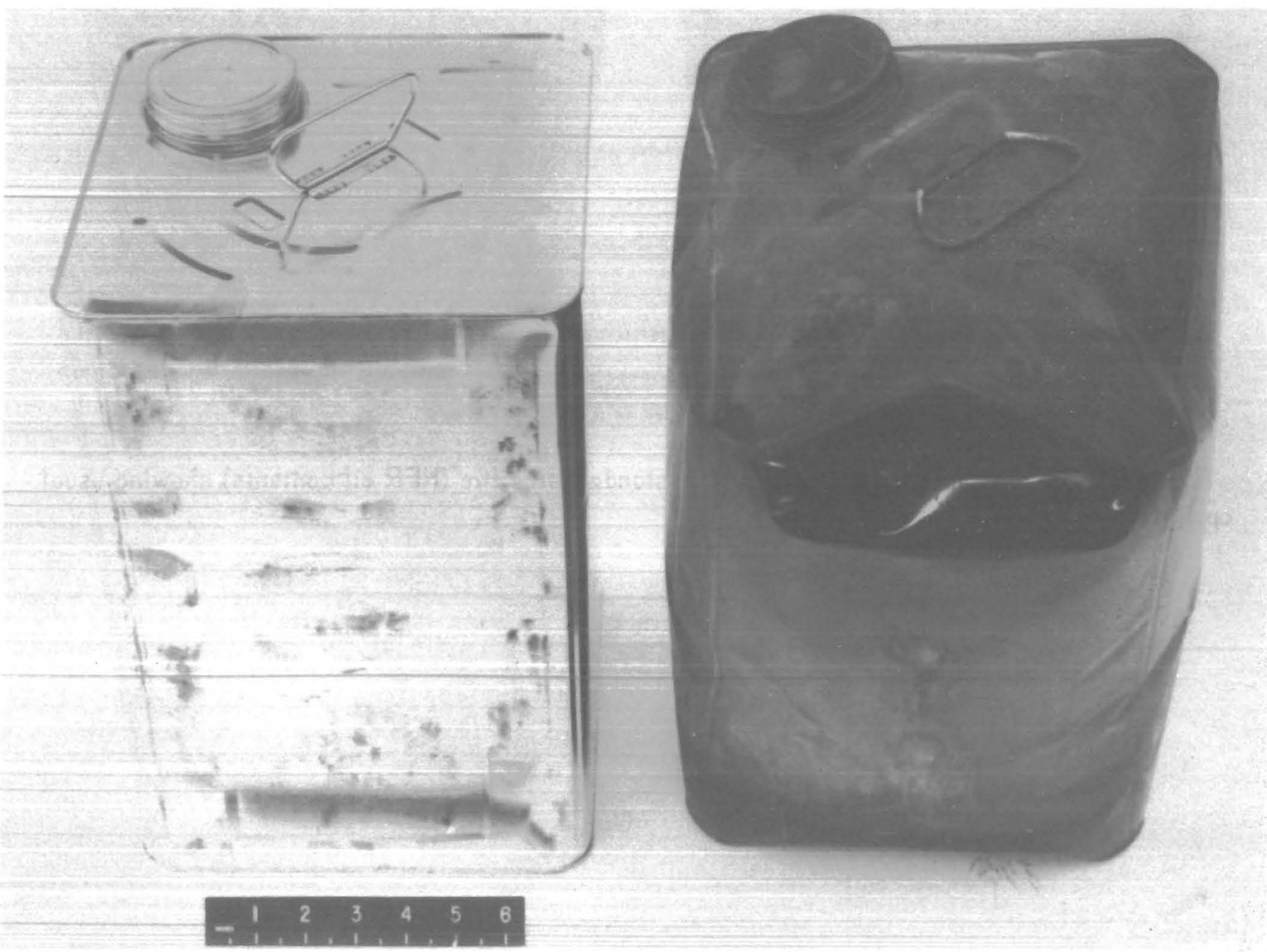

FIGURE A-6. - Square metal cans before and after standard tray fire (NFR oil contents) showing usual opening at top seam (right).

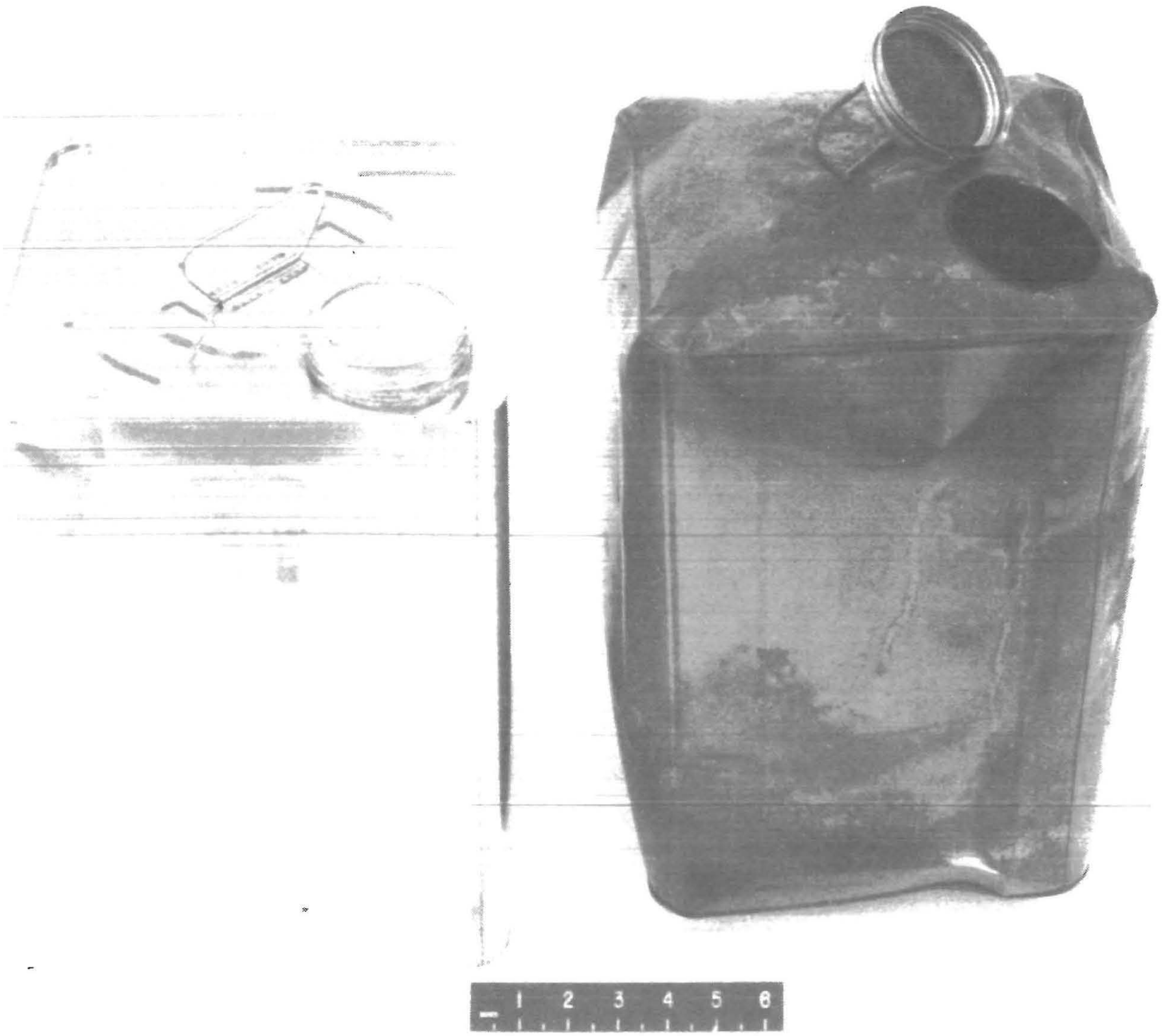

FIGURE A-7. - Square cans before and after standard tray fire (NFR oil contents) showing usual opening at top screw-cap seam (right).

FIGURE A-8. - Vented dark blue metal containers before and after standard tray fire (NFR oil contents) with blown-off plastic vent missing (right).

FIGURE A-9. - Vented dark blue container after standard tray fire (NFR oil contents) showing usual charring of screw-cap gasket.

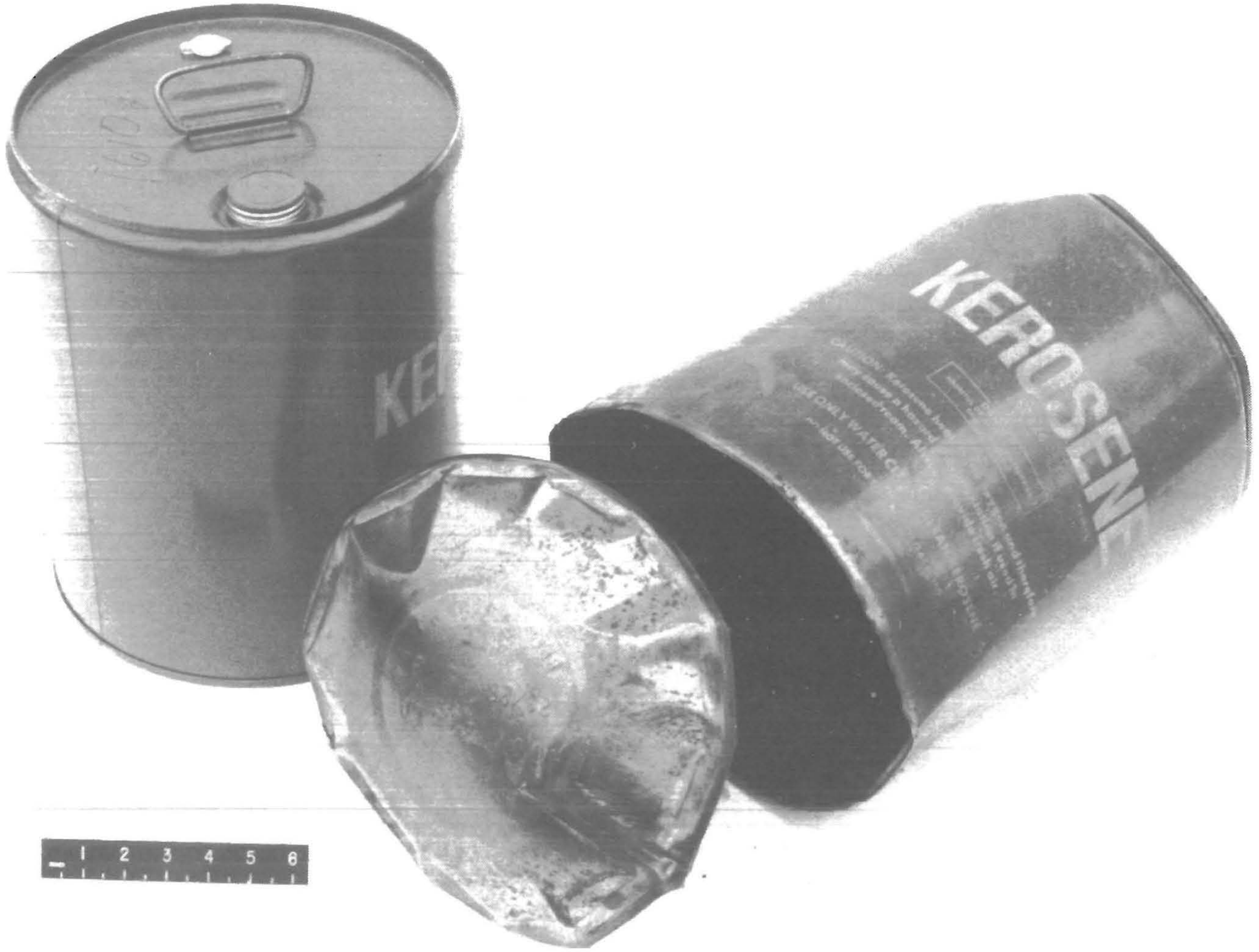

FIGURE A-10. - Vented dark blue containers before and after standard tray fire (kerosene contents) showing bottom blown off by explosion of kerosene vapor and air.

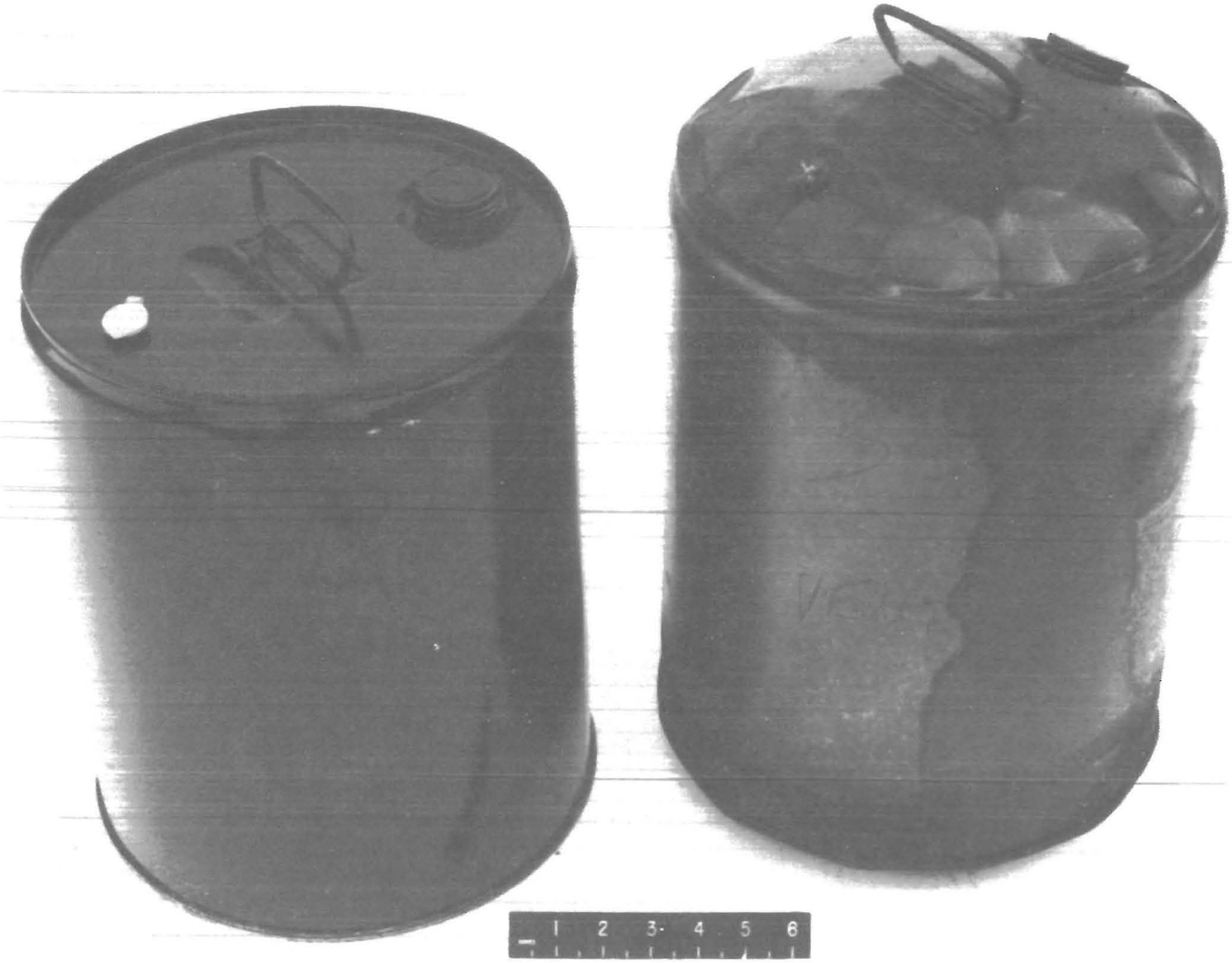

FIGURE A-11. - Vented black metal containers before and after standard tray fire (NFR oil contents).

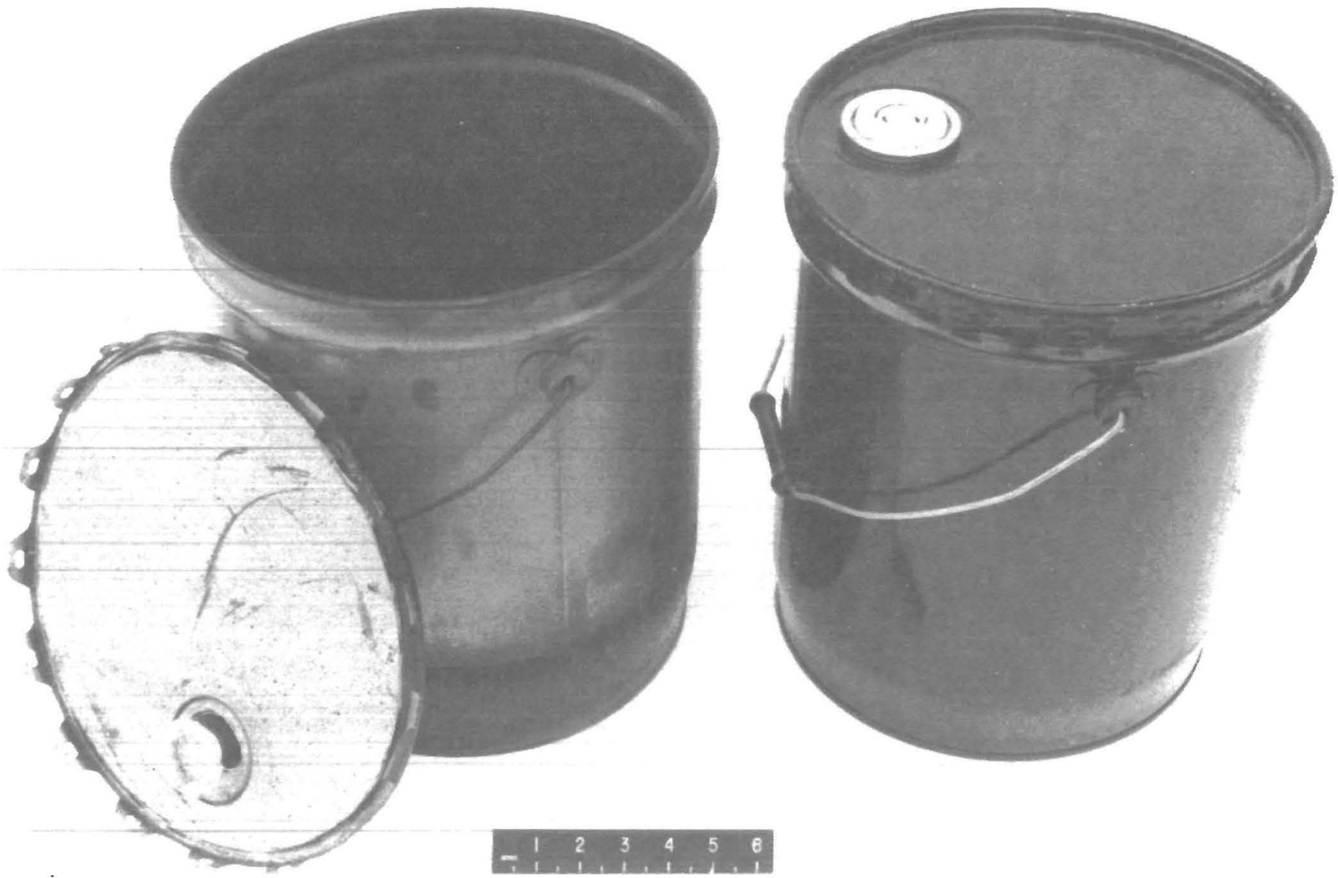

FIGURE A-12. - Open-head metal pails before and after standard tray fire (NFR oil contents). Plastic folding spout melted, but pressure was relieved when the lid blew off (left)

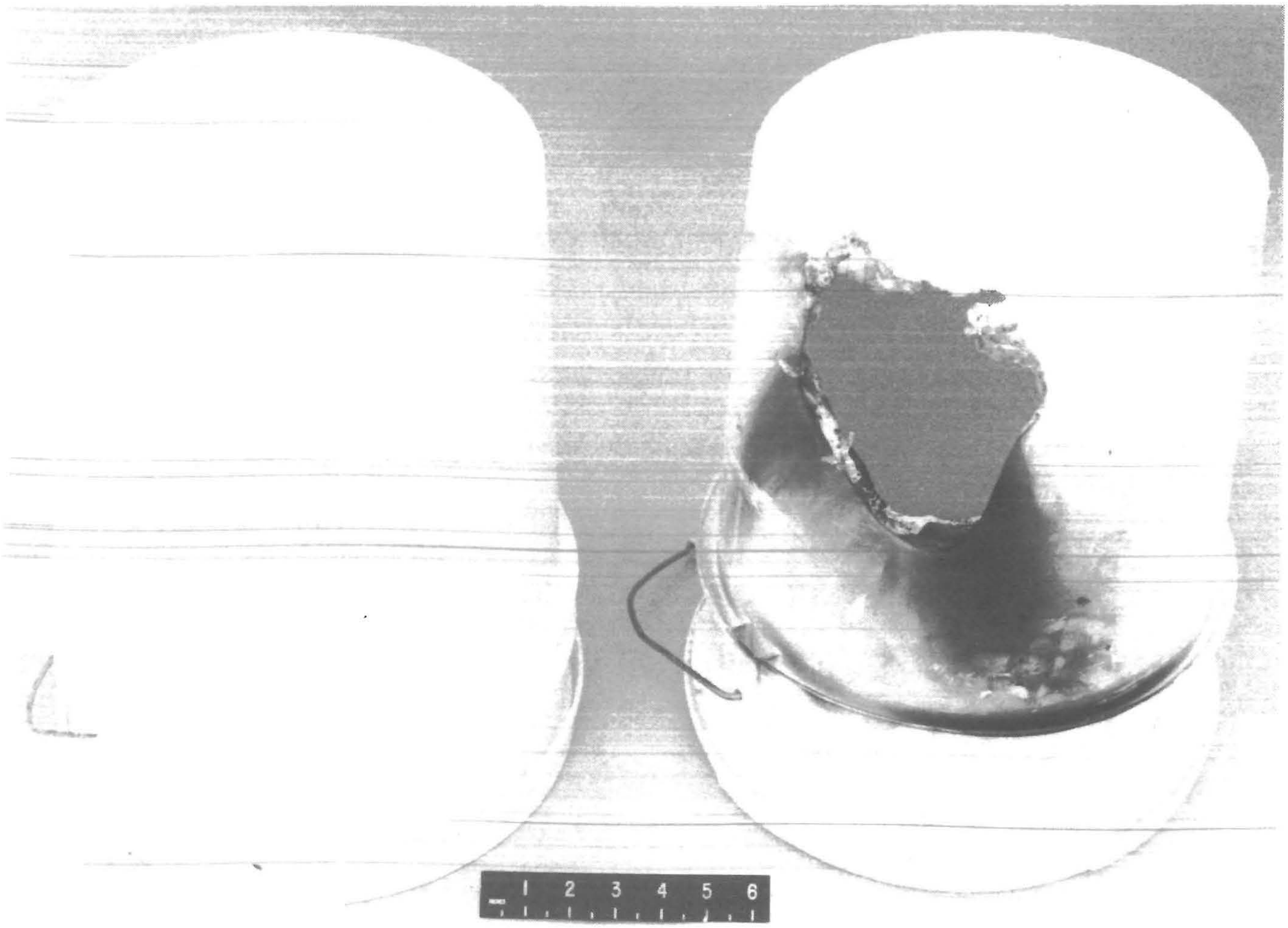

FIGURE A-13. - Open-head plastic pails before and after small-scale oily-rag fire test (NFR oil contents).

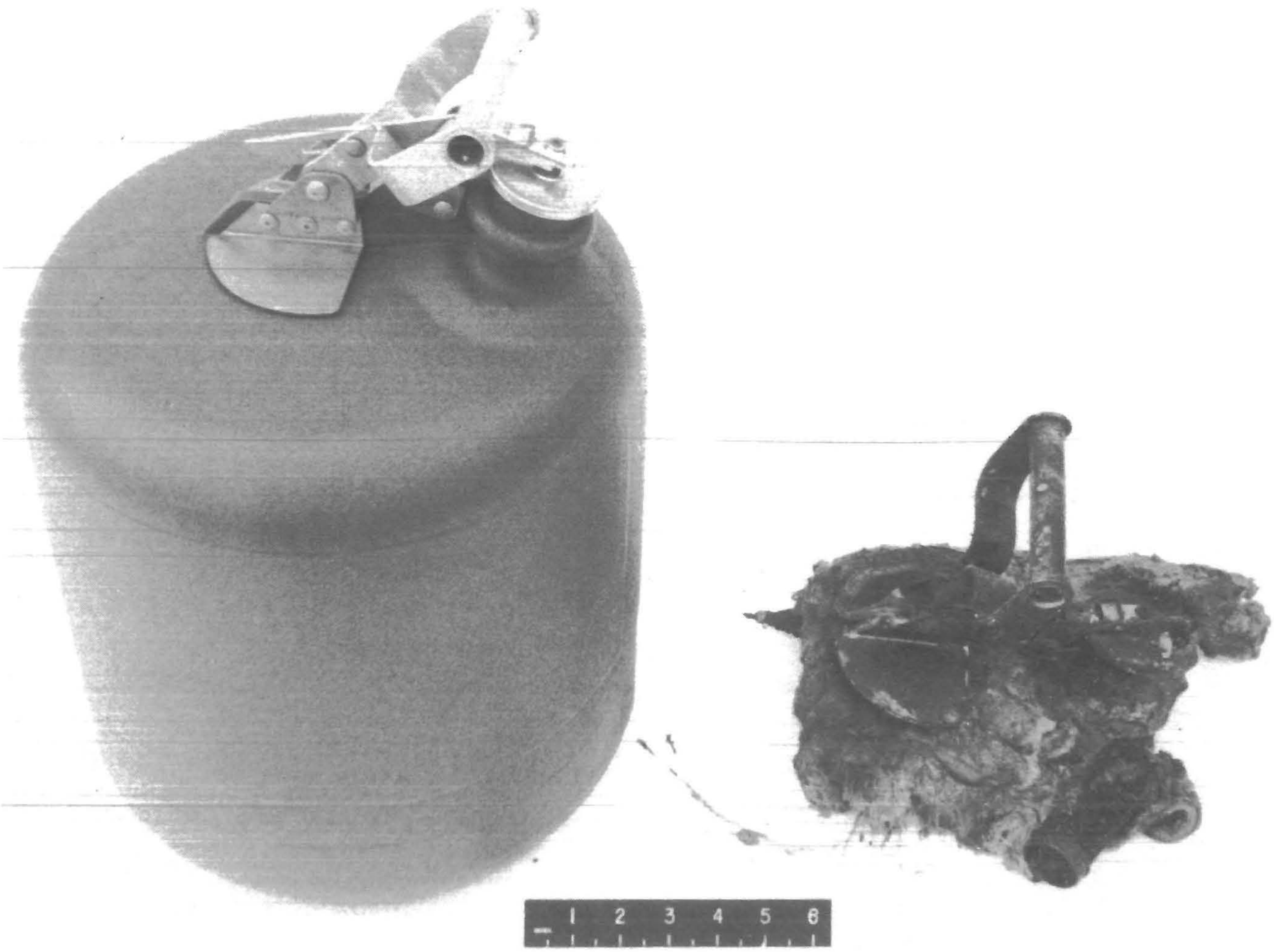

FIGURE A-14. - Plastic safety containers before and after standard tray fire (NFR oil contents).

FIGURE A-15. - Metal safety containers before and after standard tray fire (NFR oil contents).

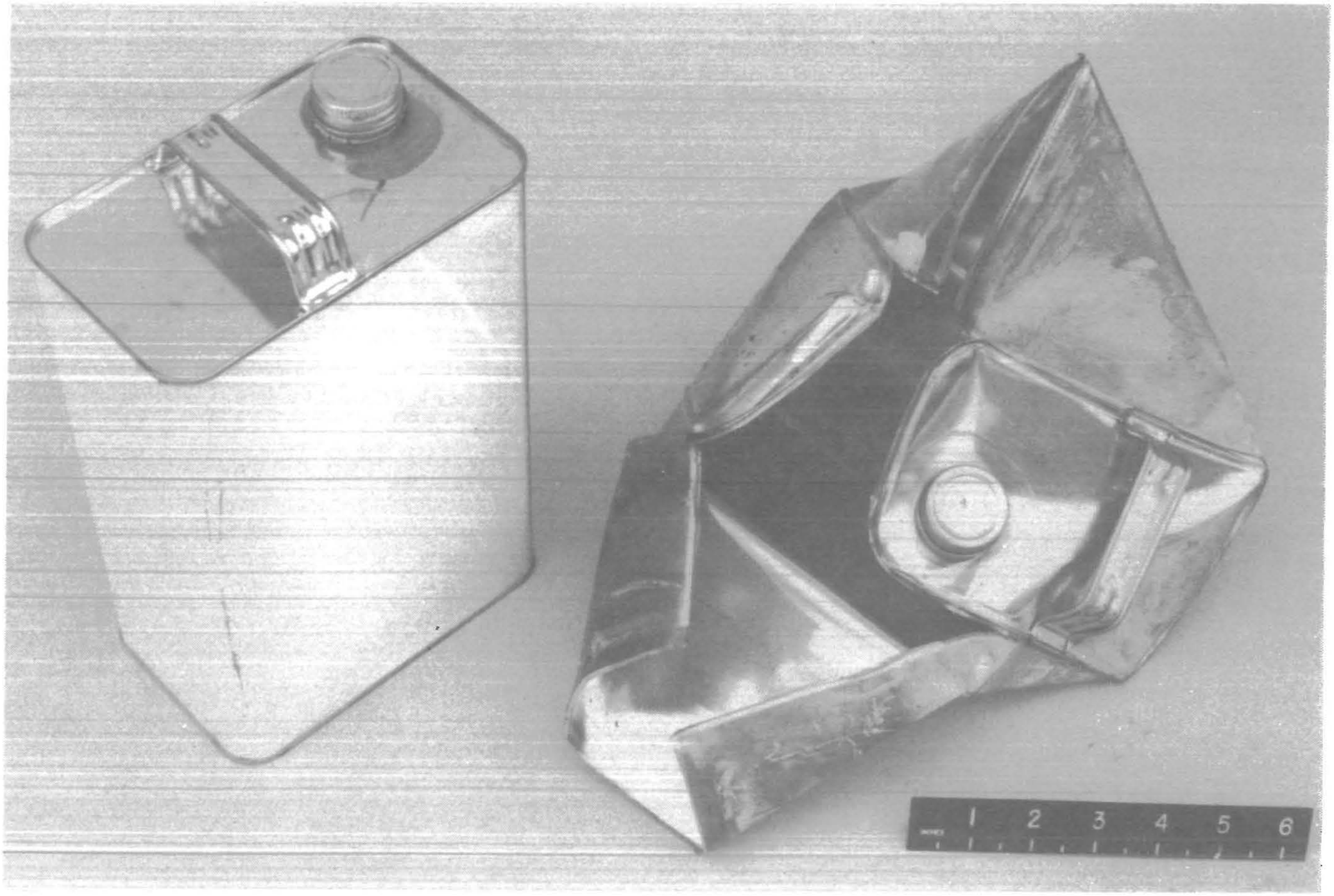

FIGURE A-16. - One-gallon tin-plated cans before and after 23 s in standard tray fire (1 pt NFR oil contents).

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