NBSIR 74-614

Mechanical Tests of Flammable Liquid Containers

Nixon Halsey, Arthur F. Kirstein, and Robert E. Snyder

Engineering Mechanics Section
Mechanics Division
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U. S. DEPARTMENT OF COMMERCE, Rogers C.B. Morton, Secretary
NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, Director

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ABSTRACT

Because of the concern for safety in the storage and use of gasoline and other flammable liquids around the home, this study was made to determine if standards can be established to minimize the flammable liquid hazard by controlling or standardizing the containers. Attention was focused on performance standards for stability, leakage, carrying handle strength, and pour spout strength. In general, it was found that the technology involved in existing voluntary standards for safety cans could be applied to flammable liquid containers for home use for all of the above factors except pour spout strength.

Key words: Consumer products; flammable liquid containers; gasoline cans; mechanical tests; product standards; safety.

1. INTRODUCTION

The Consumer Product Safety Commission (CPSC) has suggested that a significant number of accidents in and around the home involving flammable liquids may be related to the faulty design or misuse of flammable liquid containers. Since there are many gasoline-powered devices used around the home, there is a need to keep gasoline available to operate them. Therefore, this study examined the kinds of containers available on the market to determine if reasonable specifications, for controlling or standardizing the containers, can be established to reduce the gasoline hazard.

Attention was primarily focused on performance standards. This approach was believed to be one which would not hamper future innovations in the construction and design of containers, but would produce information useful to CPSC in their preparation of standards and specifications for flammable liquid containers for home use. Since voluntary standards and specifications are already available for metal gasoline safety cans [1, 2, 3] and for plastic containers (jerrycans) for petroleum products [4], the objective was to ascertain whether the technology involved in safety can standards could be used to provide this information. To test this hypothesis, thirty-six randomly selected gasoline containers were subjected to mechanical tests for stability, leakage, handle strength, and spout strength in accordance with these standards. While it is possible

*Numbers in brackets indicate references listed at the end of this report.

that the voluntary standards for safety cans may be too strict for containers for home use, CPSC may wish to regard these standards as an upper limit when evaluating the results from this study.

2. TEST PROCEDURES AND RESULTS

This study was an experimental investigation into the feasibility of utilizing the technology involved in voluntary standards for safety cans to provide information for the preparation of standards for flammable liquid containers for home use. Basically, the experimental program incorporated the testing of a random selection of thirty-six gasoline containers (described in Table 1) for stability, leakage, handle strength, and spout strength in accordance with existing standards for metal and a safety can voluntary product standard for plastic jerry-cans. Modifications of these tests were made to accommodate the test specimens when, due to the geometry or design of the specimens, they could not be tested in accordance with the available standards.

2.1 Stability

Stability is an important consideration from the standpoint of accidental spillage. Available standards recognize the possibility of accidental spillage and some [3, 4] require that the filled container shall not overturn on an inclined plane, while others [1, 2] require that the container return to a normal upright position when released from a tilted position. The following are excerpts from these standards:

Federal Specification

3.7.2 Stability. The relationship between can height and diameter shall be such that when the filled can is placed on a surface and inclined 30° from horizontal the can shall not tip when tested in accordance with 4.4.3.

4.4.3 Stability. To determine compliance with the stability requirement in 3.7.2, the can shall be filled to its rated capacity. A stability test will be made by tipping the can to an angle of 30° with the horizontal and releasing it. Failure of the can to return to the normal upright position shall constitute failure of this test.

Factory Mutual

Stability

After filling the container to its rated capacity, a stability test will be made by tipping the container to an angle of 30° with the horizontal and releasing it. It shall return to the normal upright position.

Underwriters' Laboratories

Stability Tests

64. Safety cans shall retain their stability when filled with liquid and placed -- facing in any direction -- on an inclined plane forming an angle of 30 degrees with the horizontal.

Voluntary Product Standard

3.5. Stability - Each container shall be so designed that it shall not upset when placed facing any direction on a plane inclined at 20° with the horizontal when filled to its nominal capacity.

As can be seen, the Federal Specification and the Factory Mutual Standard require that the container return to a normal upright position when released from a tilted position. This is referred to as the "tilt test" in this report. The Underwriters' Laboratories Standard and the Voluntary Products Standard require that the container shall not overturn on an inclined plane. This is referred to as the "inclined plane test" in this report. An additional test, described later, was developed to determine the angle of instability for containers filled to capacity.

2.1.1 Tilt Test

The equipment used for the stability tests is shown in Figure 1. Figure 1a shows the arrangement for the tilt test. The container was filled to capacity with water, capped, and placed on the horizontal bed of the test fixture. The container was tilted to an angle of 30° to the horizontal and released. This test was performed for three orientations (long, short, and diagonal axes of the base) of the containers having rectangular bases, and for one orientation of containers having circular bases. The data from these tests are given in Table 2. The S indicates that the specimen returned to a stable upright position, and the U indicates that the specimen was unstable and overturned.

2.1.2 Inclined Plane Test

Figure 1b shows the stability test fixture as it was used for the inclined plane test. For this test, the bed of the fixture was inclined to an angle of 30° from the horizontal, and coated with an abrasive material to prevent the container from sliding down the plane. The containers were filled to capacity with water, capped, and placed on the inclined plane. As with the tilt test, this test was also performed for three orientations of the containers having rectangular bases and one orientation for containers having circular bases. The data from the inclined plane tests are given in Table 2. The S indicates that the specimen remained in a stable position on the inclined plane, and the U indicates that the specimen was unstable and overturned.

2.1.3 Angle of Instability

To develop additional information on the stability of the specimens, a test procedure was developed to determine the angle of instability. The stability test fixture was used in a manner similar to that shown in Figure 1b. For this test procedure, the bed of the fixture was raised to approximately 20° with a laboratory jack. The filled containers were placed on the bed against a 1/16-inch thick metal strip, which was attached to the bed to restrain the container from sliding down the inclined plane. The angle between the bed and the horizontal was increased slowly with the jack until the container began to overturn. The angle at this point is referred to as the angle of instability, and the data are given in Table 2.

The results given in Table 2 apply to all thirty-six containers of the type used in and around the home and to one specimen (SWM3C-A) which is a safety can of the industrial type. Note that the same seventeen containers which failed to pass the 30° tilt test failed to pass the 30° inclined plane test. It appears significant that all of the specimens that failed these tests were rectangular in shape and failed parallel to the short axis (see Table 1). The angle of instability, for the short axes of the containers that failed, ranged from 20° to 29°. Note that the plastic containers that failed these tests would have passed the less-stringent stability requirements of the Voluntary Product Standard.

2.2 Handle Strength

Carrying-handle strength has been considered in the safety can standards and in the voluntary product standard in different ways. Underwriters' Laboratories Standard treats the problem from a design standpoint instead of performance requirements as follows:

> Handles
>
> 49. Each safety can shall be provided with a handle having a comfortable hand grip arranged for carrying the can conveniently.
>
> 50. In the absence of a support ring at the bottom, and if the bottom is not set up a sufficient distance to serve as a hand grip

in pouring, a bottom handle shall be provided on cans having a capacity of two gallons and over.

51. Carrying handles shall have a width not over 1 1/2 inches, and the hand clearance shall be not less than 1 by 3 1/2 inches.

52. Edges of sheet-metal handles shall be hemmed, rolled, or wired.

The Federal Specification, the Factory Mutual Standard, and the Voluntary Product Standard require handle strength tests as a measure of performance. The Federal Specification and the Factory Mutual Standard require static test loading of the handle. Excerpts follow:

Federal Specification

3.7.3 Carrying handle strength. Carrying handles shall withstand a test load exerting a pull in pounds not less than the load indicated in table I, without failure of the handle or fastenings and without loss of valve tightness or causing any can leakage when tested in accordance with 4.4.5.

4.4.5 Carrying handle loading. To determine compliance with the carrying handle load requirement in 3.7.3, the can shall be secured in a testing machine or jig. A pull load, equal to the applicable test load in table I, shall then be applied at the center of the normal grip position on the handle, for not less than 30 seconds. The direction of the applied load shall be parallel to the center axis of the can. Failure of handle, fastenings, loss of valve tightness or leakage shall constitute failure of this test.

Factory Mutual

The carrying handle shall withstand a test-load, as specified in Table I, exerting a pull from the center of the normal carrying grip and parallel to the vertical axis of the container. All valves shall be tight and no leakage is permissible in the seams and joints of the containers as a result of this test.

The test loads, referred to in Table 1 of these excerpts, are given in Table 3 of this report.

The Voluntary Product Standard requirement for handle strength was a drop test as shown in the following excerpt:

Voluntary Product Standard

3.7. Handle - Each container shall be provided with a handle suitable for use in carrying the filled container. The handle shall be an integral part of the container or shall be securely fastened thereto. The handle shall not crack or become loosened or detached from the container when tested in accordance with 4.7.

4.7. Handle strength - The container shall be filled to its nominal capacity with water, and the closures shall be secured. One end of a 6-foot length of 3/8-inch manila rope shall be secured to a rigid point of suspension and the other end of the rope to the handle. The container shall be suspended from this rope for 1 minute. Then it shall be raised 12 inches from the suspended position and allowed to fall freely.

2.2.1 Metal Cans

Static strength tests on the handles were performed as shown in Figure 2. A test fixture was used to aline and securely mount the empty container in a universal testing machine. A pull rod was connected to the handle of the container with an S-hook to apply the load in the manner prescribed in the Federal Specification and in the Factory Mutual Standard. During the test of the first container having a rigid handle (EM1R-A), it was noted that excessive bending would occur with the load concentrated at the center of the normal grip position on the handle. Therefore, the test procedure was modified by using a 3-inch length of 1/2-inch diameter steel rod to distribute the load along the grip position on the rigid handles.

During the test of the first container having a folding handle (EM5C-A), it was noted that the wooden grip split along the metal wire bail at a load of 157 lbf, which was less than the required test load of 250 lbf. Since all of the specimens having folding handles are constructed with wire bails and wooden grips, this test procedure was also modified to distribute the load along the grip. A 3-inch length of 3/4-inch pipe was cut in two longitudinally, and one half was used to cradle the grip and distribute the load. Specimen EM5C-A was retested, and sustained the 250 lbf test load with no further damage noted. Conclusions based on the results from the static load tests on handles are subjective in that the observer's judgement is required to determine whether failure has occurred. This can be seen in the Federal Specification requirement, "Failure of handle, fastenings, loss of valve tightness or leakage shall constitute failure of this test", and the Factory Mutual Standard requirement, "All valves shall be tight and no leakage is permissible in the seams and joints of the containers as a result of this test". For evaluating the results of these tests, deformations of the handle, top, and sides of the containers were not regarded as constituting failure. All of the containers listed in Table 1 were subjected to this test, and none were thereby observed to leak at the seams and joints. Furthermore, none of the pour spouts or caps appeared to suffer structural damage. One side of the handle on specimen HM1-1/4R-B broke loose from the container at a load of 100 lbf, which made this specimen the only one to fail the modified static load test for handles.

2.2.2 Plastic Containers

The plastic containers were subjected to the drop test for handles in accordance with the Voluntary Product Standard. No failures or permanent deformations were observed.

2.3 Pour Spout Strength

Static load tests of pour spout strength are required in the Federal Specification and in the Factory Mutual Standard. Excerpts follow:

> Federal Specification
>
> 3.7.4 Pour spout strength, styles I and II cans. The pour spout shall not deform, nor be displaced relative to the valve cap or body of can, as determined by the valve tightness test when the test load specified in table I is applied to the nozzle in accordance with 4.4.6.
>
> 4.4.6 Pour nozzle loading, styles I and II cans. To determine compliance with 3.7.4, the can shall be secured in a testing machine or jig. The applicable test load in table I shall then be externally applied as a concentrated load against the nozzle for not less than 15 seconds. The load shall be applied on the side opposite the valve opening linkage, or either side of a spout or fill fitting which has no valve opening linkage, 1/4 inch below the top of the pour opening and perpendicular to the center axis of the can. Deformation of pour spout or displacement shall constitute failure

of this test.

Factory Mutual

> A concentrated test-load, specified in Table I, below, will be applied externally against the pour-spout wall 1/4 in. below the opening on the side opposite the valve opening linkage and perpendicular to the vertical axis of the container body. Spout shall remain within the limits permitted under "Tightness of Valve".

The test loads, referred to in Table 1 of these excerpts, are given in Table 3 of this report.

Neither the Underwriters' Laboratories Standard nor the Voluntary Product Standard have comparable test requirements for pour spout strength.

It is difficult to relate the spout test devised for safety cans to gasoline containers that are available on the market and intended for home use, since the construction of safety cans is so different from that of the other containers. A photograph of a safety can (SWM3C-A) is shown in Figure 3a and typical examples of containers intended for home use are shown in Figure 3b. It can be seen from an examination of Figure 3a that the pour spout on the safety can is also the housing for the valve system. None of the containers intended for home use were equipped with pour spout valves. Since the apparent concern over pour spout strength in the Federal Specification and the Factory Mutual Standard is for valve tightness, direct application to containers intended for home use has little or no significance. However, it was felt that some sort of pour spout strength test might be useful to determine if pour spouts or caps might leak because of deformations in the spouts resulting from handling or reasonable mishandling of the containers.

Static load tests, similar to those required for safety cans, were performed as shown in Figure 4. A fixture was used to aline and securely mount the empty circular-based containers in a universal testing machine. A 3/4-inch square steel rod approximately 10 1/4-inches long was attached to the head of the testing machine to apply a concentrated load to the spout as shown in Figure 4a. Figure 4b shows how the containers having rectangular bases were tested. These were alined on the platen of the testing machine with the spout directly under a 3/4-inch square steel rod which was used to apply a concentrated load. The restraining clamp was used to hold the specimen in place during load application.

The five plastic containers were not tested because it was believed that the plastic spouts were too flexible to yield useful results.

An inverted can test was performed on all containers in the as-received condition and again on the metal containers after the pour spout tests were performed. The inverted can test was performed in accordance with the Underwriters' Laboratories Standard:

> 65. When the safety can is filled with liquid and inverted, each valve or closure shall not show leakage at a rate greater than four drops per minute (1/100 US fluid ounce). The rate of leakage per minute is considered to be the average rate of leakage over a five-minute observation.

The results of the pour spout and inverted can tests are given in Table 4. Specimen LM1R-A was inadvertently damaged during the pour spout test. Of the thirty remaining metal containers for home use, nineteen sustained visible thread damage. This damage was in the form of local flattening of the threads under the concentrated load. However, none of the pour spouts were damaged to the extent that the caps could not be replaced. The results of these tests do not show a consistent relationship between visible thread damage due to the pour spout test and leakage from the inverted can test.

Nineteen of the thirty-one metal specimens were equipped with short spouts. These were located on the top of the containers in such a way that the seams around the tops of the containers afforded the threaded spouts at least partial protection from damage due to mishandling. If containers having the above design features were equipped with suitable leak-proof caps and extension spouts, concern over damage due to mishandling would be much reduced.

In view of the foregoing, it would appear that pour spout strength tests may not be useful for a standard pertaining to flammable liquid containers for home use unless the CPSC deems it necessary to require that the containers be equipped with valves similar to those used on safety cans.

2.4 Leakage

Leakage from flammable liquid containers is one of the most important considerations in this investigation. Obviously, the previous sections of this report (stability, carrying handle strength, and pour spout strength) are all related to leakage or spillage of flammable liquids from the containers. This section of the report covers the inverted can, hydrostatic pressure, and drop tests.

2.4.1 Inverted Can Tests

The results of the inverted can tests are presented in Table 4. These tests were performed on all containers in the as-received condition, and in accordance with the Underwriters' Laboratories

Standard. The specimens were filled to capacity with water, capped, and placed inverted on a test stand. Those containers which were equipped with capped extension spouts were tested with the extension spout in place. These containers are identified in Table 4 by footnotes (b) and (c). The specimens were allowed to remain inverted for five minutes while they were observed for leakage. As shown in Table 4, eleven of the thirty-six containers failed. Following the procedure of retightening the caps on all containers that leaked during the initial inverted can tests, it was observed that only two of the eleven containers stopped leaking. Considerable torque was applied to hand tighten the caps on these eleven containers. It is doubtful that a consumer would normally tighten a cap on a container to the extend used in the laboratory tests of these eleven containers. Note that over thirty percent of the containers leaked in the as-received condition. Potentially hazardous conditions could exist if these cans were used for flammable liquid storage around the home.

2.4.2 Hydrostatic Pressure Tests

Hydrostatic pressure leakage tests and drop strength tests were also performed on the test specimens. Since these tests were more likely to cause serious damage or deformation in the containers, they were the last mechanical tests to be performed in this test series.

The hydrostatic pressure leakage tests, as related to safety cans, are primarily concerned with the strength of seams and joints. The tests of the metal containers were performed in a manner similar to that required in the Factory Mutual Standard in that the containers were air-pressure tested under water. Unlike the requirements of this Standard, however, no special effort was made to seal the openings in the containers, and the air pressure was increased until leakage occurred. Air pressure was applied to the containers through valves installed in the caps or in the tops of the containers as shown in Figure 5.

The results of these tests of metal containers are given in Table 5, and Figure 6 shows typical examples of container deformation resulting from these tests. Note that all of the specimens tested in this fashion passed the Factory Mutual requirements of no leakage at 10 lbf/in^2. Note, also, that the five containers that exhibited seam failures did not meet the 25 lbf/in^2 pressure requirements of the Federal Specification and the Underwriters' Laboratories Standard. The cap and/or vent leakage shown in Table 5 indicates the necessity for requiring that the openings in the containers be sealed against leakage to provide a meaningful test of the joints and seams.

Two plastic containers, DBP1R-A and DBP2½R-A, were tested under hydrostatic pressure in a manner similar to that required in the

Voluntary Product Standard except that the internal pressure was increased to 27.5 lbf/in^2 instead of the specified 20 lbf/in^2. These containers did not exhibit leakage at the prescribed test temperatures of 75 ± 5 °F and 140 ± 5 °F. This same test was performed on specimen DBP2½R-A filled to its nominal capacity with a mixture of equal parts of glycol and water. The specimen and its contents were cooled to 0 ±2 °F, and an internal pressure of 27.5 lbf/in^2 was maintained for two minutes without leakage.

2.4.3 Drop Strength Tests

Drop strength tests of safety cans are required by the Federal Specification and the Factory Mutual Standard but not by the Underwriters' Laboratories Standard. The tests required in the Federal Specification and the Factory Mutual Standard are essentially the same, with only minor wording differences, as follows:

Federal Specification

> 4.4.7 Seams and joints. To determine compliance with 3.7.5, the cans shall have all openings sealed and subjected to a leakage, drop, and hydrostatic test as specified in 4.4.7.1, 4.4.7.2 and 4.4.7.3. Any leakage shall constitute failure of the tests.
>
> 4.4.7.2 Drop test. Cans shall be filled with water and shall withstand a drop to a concrete floor (landing on any part of the container except the spout or spout mechanism) from a height of 3 feet without sufficient injury to cause loosening of components or leakage from any part of the container. This test may be run at any temperature in the range of -40°F. to 130°F.

Factory Mutual Standard

> The container filled with liquid, shall withstand a drop to a concrete floor (landing on any part of the container except the spout or spout mechanism) from a height of 3 ft without sufficient injury to cause leakage from any part of the container. This test may be run at any temperature in the range of -40°F and 130°F.

The drop strength test required in the Voluntary Product Standard is far more rigorous in that the plastic containers must survive three successive eight-foot drops instead of a single three-foot drop. Another difference may be seen in the prescribed test temperatures. The specific wording of the drop strength test in the Voluntary Product Standard is as follows:

> 3.8. Drop strength - The container shall show no evidence of rupture, cracks, or leakage when tested in accordance with 4.8.
>
> 4.8. Drop strength - The container shall be filled to its nominal capacity with water at 75 ± 5 °F and the closures shall be secured. It shall be dropped, free fall, onto a flat, solid surface. Drops shall be made in the following sequence: one drop on the bottom, one drop on a bottom corner, and one drop on a side. The distance of fall shall be 8 feet. The same tests shall be made with another container filled with a blend of 50 percent glycol and 50 percent water and with both the container and its contents cooled to 0 ± 2 °F. For these latter tests, the distance of fall shall be 4 feet.

The drop strength tests of metal containers were performed using the following procedure. The specimen was filled to rated capacity with water and capped. Then it was dropped from a height of three feet onto a concrete floor in three orientations to cause the specimen to strike the floor on its bottom, a side, and a bottom corner not necessarily in that order. Note that this procedure is more severe than that required by the standards for metal safety cans in that each container is subjected to three drops instead of one.

The results of these tests are given in Table 6 and examples of damage to the containers are shown in Figure 7. The results show that only one of the specimens (HM1-1/4R-A), out of sixteen tested, failed on the first drop. The first drop would correspond to the requirements of the Federal Specification and the Factory Mutual Standard. Three other specimens (EM2R-B, EM5C-A, and SWM3C-A) failed on the third drop, while twelve specimens survived all three drops. Note that specimen SWM3C-A, which was a three-gallon-capacity safety can, leaked around the pour spout flange after a side drop in the vicinity of the pour spout.

Drop strength tests of the plastic containers were performed in a manner similar to that required in the Voluntary Product Standard except that the drops were not performed in the prescribed sequence of orientations. The results of these tests are given in Table 7. Replicate specimens DBP1R-A and DBP1R-B failed the drop tests. There was no duplicate specimen for DBP2-1/2R-A so it was tested at both 0 and 75 °F. This specimen survived the six drops without leakage from the body of the container, but the vent cap came off upon impact in each drop. While the drop strength tests are primarily concerned with the strength of seams and joints, it should be required that the container survive the drop test without leakage from any part of the container.

3. CONCLUDING REMARKS

The purpose of this study was to determine the feasibility of transferring the technology involved in voluntary standards for safety cans to standards for flammable liquid containers for home use. In general, the results of this study on the mechanical tests for stability, leakage, and handle strength indicate that reasonable performance standards for these characteristics can be developed for flammable liquid containers for home use. It remains, of course, for CPSC to establish appropriate pass-fail criteria for the tests.

The results of the pour spout strength tests did not appear to apply directly to containers for home use unless it is deemed necessary or desirable to require that these containers be equipped with valves similar to those used on safety cans. On the other hand, the results of these tests and the associated inverted can leakage tests did accent the need for leak-proof caps and extension spouts. Leak-proof caps and extension spouts are important not only because of liquid leakage in an inverted or upset position, but also because of the possibility of vapor leakage in the upright position and liquid leakage from the cap or extension spout while decanting.

The referenced voluntary standards and specifications [1, 2, 3, and 4] provide additional considerations which may be necessary to produce a meaningful standard for flammable liquid containers for home use. Further studies along these lines could address features such as air vent openings, pressure relief valves, flame arresting screens, protective coatings, material properties, capacity, fire exposure, color, and markings.

In view of present accepted practice in this technological area, U. S. customary units of measurement have been used throughout this report. It should be noted that the U. S. A. is a signatory to the General Conference on Weights and Measures which gave official status to the metric SI system of units in 1960. Readers interested in making use of the coherent system of SI units will find conversion factors in NBS Handbook 102, "ASTM Metric Practice Guide," available from the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C., 20402 for 40 cents. Conversion factors for units used in this paper are:

Length	1 in = 0.0254* meter
Area	1 in^2 = 6.4516* x 10^{-4} $meter^2$
Force	1 lbf = 4.448 newton
Stress	1 lbf/in^2 = 6895 $newton/meter^2$
Temperature	Fahrenheit to Celsius, $t_c = (t_f - 32)/1.8$
Volume	1 gallon (U.S. liquid) = 3.785 x 10^{-3} $meter^3$

*Exact values

Table 1 - Test Specimens

Specimen	Capacity	Dimensions				Materials	Handle (Rigid or Folding)(a)	Extension Spout (Rigid or Flexible)(b)
		Length	Width	Height	Diameter			
	gal	in	in	in	in			
LM1R-A	1	6-5/8	4	9-1/2		Metal	R	F
LM1R-B	1	6-5/8	4	9-1/2		Metal	R	F
LM2R-A	2	8-5/8	5-5/8	10-1/2		Metal	R	F
LM2R-B	2	8-5/8	5-5/8	10-1/2		Metal	R	F
LM2½C-A	2-1/2			6	10-1/2	Metal	F	F
LM2½C-B	2-1/2			6	10-1/2	Metal	F	F
LM5C-A	5			12	10-1/2	Metal	F	F
LM5C-B	5			12	10-1/2	Metal	F	F
HM1R-A	1	6-5/8	4	9-1/2		Metal	R	R
HM1R-B	1	6-5/8	4	9-1/2		Metal	R	R
HM1R-C	1	6-5/8	4	9-1/2		Metal	R	F
HM1R-D	1	6-5/8	4	9-1/2		Metal	R	F
HM1¼R-A	1-1/4	8-1/2	5-5/8	6-1/2		Metal	R	F
HM1¼R-B	1-1/4	8-1/2	5-5/8	6-1/4		Metal	R	F
HM2R-A	2	8-1/2	5-5/8	10-1/2		Metal	R	F
HM2½C-A	2-1/2			6-3/8	10-3/4	Metal	F	F
HM2½C-B	2-1/2			6-3/8	10-3/4	Metal	F	F
EM1R-A	1	6-5/8	4-1/8	9-1/2		Metal	R	R
EM1R-B	1	6-5/8	4-1/8	9-1/2		Metal	R	R
EM2R-A	2	8-5/8	5-5/8	10-1/2		Metal	R	R

continued

Table 1 - Test Specimens

Specimen	Capacity	Dimensions				Materials	Handle (Rigid or Folding) (a)	Extension Spout (Rigid or Flexible) (b)
		Length	Width	Height	Diameter			
	gal	in	in	in	in			
EM2R-B	2	8-5/8	5-5/8	10-1/2		Metal	R	R
EM2½C-A	2-1/2			6	10-1/2	Metal	R	F
EM2½C-B	2-1/2			6	10-1/2	Metal	R	F
EM5C-A	5			10-1/2	12	Metal	F	None
EM5C-B	5			10-1/2	12	Metal	F	None
WAM1R-A	1	6-5/8	4	9-1/2		Metal	R	R
WAM1R-B	1	6-5/8	4	9-1/2		Metal	R	R
SM2½C-A	2-1/2			7	11	Metal	F	F
SM2½C-B	2-1/2			7	11	Metal	F	F
WIM2½C-A	2-1/2			6-1/2	11	Metal	R	F
WIM2½C-B	2-1/2			6-1/2	11	Metal	R	F
DBP1R-A	1	6-1/2	5	9		Plastic	R	R
DBP1R-B	1	6-1/2	5	9		Plastic	R	R
DBP2½R-A	2-1/2	8-1/4	8	10-1/2		Plastic	R	R
GHP½C-A	1/2			6	7	Plastic	R	None
GHP½C-B	1/2			6	7	Plastic	R	None
SWM3C-A	3			10	11-1/2	Metal	R	F

(a) R-Rigid, F-Folding
(b) R-Rigid, F-Flexible

Table 2 - Results of Stability Tests

Specimen	30 - Degree Tilt Axis			30 - Degree Inclined Plane Axis			Angle of Instability (Degrees) Axis		
	Long	Short	Diagonal	Long	Short	Diagonal	Long	Short	Diagonal
LM1R-A	S(a)	U(b)	S	S	U	S	35	24	37
LM1R-B	S	U	S	S	U	S	35	24	36
LM2R-A	S	U	S	S	U	S	40	28	41
LM2R-B	S	U	S	S	U	S	39	28	42
LM2½C-A			S(c)			S			58
LM2½C-B			S			S			58
LM5C-A			S			S			41
LM5C-B			S			S			41
HM1R-A	S	U	S	S	U	S	35	24	37
HM1R-B	S	U	S	S	U	S	35	25	36
HM1R-C	S	U	S	S	U	S	35	24	37
HM1R-D	S	U	S	S	U	S	35	24	37
HM1½R-A	S	S	S	S	S	S	50	40	53
HM1½R-B	S	S	S	S	S	S	51	40	55
HM2R-A	S	U	S	S	U	S	39	29	42
HM2½C-A			S			S			56
HM2½C-B			S			S			55
EM1R-A	S	U	S	S	U	S	35	24	37
EM1R-B	S	U	S	S	U	S	34	24	37
EM2R-A	S	U	S	S	U	S	39	28	41

continued

Table 2 - Results of Stability Tests

Specimen	30 - Degree Tilt			30 - Degree Inclined Plane			Angle of Instability (Degrees)		
	Axis			Axis			Axis		
	Long	Short	Diagonal	Long	Short	Diagonal	Long	Short	Diagonal
EM2R-B	S	U	S	S	U	S	39	28	42
EM2½C-A			S			S			60
EM2½C-B			S			S			59
EM5C-A			S			S			49
EM5C-B			S			S			48
WAM1R-A	S	U	S	S	U	S	35	25	37
WAM1R-B	S	U	S	S	U	S	35	24	37
SM2½C-A			S			S			53
SM2½C-B			S			S			53
WIM2½C-A			S			S			57
WIM2½C-B			S			S			58
DBP1R-A	S	U	S	S	U	S	30	20	35
DBP1R-B	S	U	S	S	U	S	30	20	34
DBP2½R-A	S	S	S	S	S	S	30	30	37
GHP½C-A			S			S			46
GHP½C-B			S			S			46
SWM3C-A			S			S			47

(a) S = Stable
(b) U = Unstable
(c) Single entries for circular based cans

Table 3 - Handle and Spout Strength Test Loads as Specified in References 1 and 2

Container Capacity	Test Load on Pour-Spout	Test Load on Handle
gal	lbf	lbf
Up to 0.5	25	75
1	50	125
2	75	150
3	100	175
5	125	250

NOTE: Intermediate sizes will be tested as the next larger capacity.

Table 4 - Results of Pour Spout and Inverted Can Leakage Tests

Specimen	Pour Spout Test Load (lbf)	Inverted Can Leakage Test: Initial	Inverted Can Leakage Test: After Spout Test	Damage Location
LM1R-A	(a)	Fail	Fail	
LM1R-B	50	Fail	Fail	Threads
LM2R-A	75	Pass	Fail	Threads
LM2R-B	75	Pass	Pass	Threads
LM2½C-A	75	Pass	Pass	Threads
LM2½C-B	75	Pass	Pass	Threads
LM5C-A	125	Fail (d)	Pass	Threads
LM5C-B	125	Fail (d)	Pass	Threads
HM1R-A	50	Pass	Fail	None
HM1R-B	50	Pass	Fail	Threads
HM1R-C	50	Pass	Fail	None
HM1R-D	50	Pass	Pass	None
HM1¼R-A	50	Pass	Pass	Threads
HM1¼R-B	50	Fail	Fail	Threads
HM2R-A	75	Pass	Pass	Threads
HM2½C-A	75	Fail	Fail	None
HM2½C-B	75	Pass	Pass	Threads
EM1R-A	50	Pass	Pass (b)	None
EM1R-B	50	Pass	Fail (b)	Threads
EM2R-A	59	Pass	Fail (b)	Threads - spout buckled
EM2R-B	75	Fail	Fail (a)	Threads
EM2½C-A	75	Pass	Pass	None
EM2½C-B	75	Pass	Pass	None
EM5C-A	125	Pass	Pass	Threads
EM5C-B	125	Pass	Pass	None
WAM1R-A	50	Pass	Pass	None
WAM1R-B	50	Pass	Pass	None
SM2½C-A	75	Fail	Fail (c)	Threads

Continued

Table 4 - Results of Pour Spout and Inverted Can Leakage Tests

Specimen	Pour Spout Test Load (lbf)	Inverted Can Leakage Test: Initial	Inverted Can Leakage Test: After Spout Test	Damage Location
SM2½C-B	75	Fail	Fail[c]	Threads
WIM2½C-A	28	Pass	Fail	Threads - elastic buckling top of can
WIM2½C-B	75	Fail	Fail	None
DBP1R-A	-	Pass	-	
DBP1R-B	-	Pass	-	
DBP2½R-A	-	Pass	-	
GHP½C-A	-	Fail	-	
GHP½C-B	-	Pass	-	
SWM3C-A	125	Pass	Pass	None

[a] Specimen inadvertently damaged during spout test.

[b] Inverted can tests were performed with plastic extension spouts in place. When leakage occurred it was from between the plastic snap cap and the end of the extension spout.

[c] Inverted can tests were performed with flexible metal extension spouts in place. Leakage was through the side walls of the flexible metal extension spouts.

[d] Container leaked during initial inverted can test. Cap was retightened and retested and did not leak.

Table 5 - Results of Hydrostatic Pressure Leakage Tests of Metal Containers

Specimen	Leakage Pressure lbf/in^2	Location of Leak
LM1R-B	13.5	Cap
LM2½C-B	22.0	Cap
LM5C-B	17.0	Cap and vent
HM1R-B	22.0	Top seam
HM1¼R-B	17.0	Top seam
HM2R-A	18.0	Vent
HM2½C-B	20.0	Cap
EM1R-B	18.5	Bottom seam
EM5C-A	18.0	Cap and vent
WAM1R-A	14.0	Top seam
SM2½C-A	21.0	Cap
WIM2½C-A	18.0	Bottom seam
SWM3C-A	26.5	Pour spout valve[a]

[a] Vent was restrained.

Table 6 - Results of Drop Strength Tests of Metal Containers

Specimen	Orientation of Drop		
	Bottom	Side	Bottom Corner
LM1R-A	Pass	Pass	Pass
LM2R-A	Pass	Pass	Pass
LM2½C-A	Pass	Pass	Pass
LM5C-A	Pass	Pass	Pass
HM1R-A	Pass	Pass	Pass
HM1R-C	Pass	Pass	Pass
HM1¼R-A	Fail[(a)]	-	-
HM2½C-B	Pass	Pass	Pass
EM1R-A	Pass	Pass	Pass
EM2R-B	Pass	Pass	Fail[(b)]
EM2½C-B	Pass	Pass	Pass
EM5C-A	Fail[(a)]	Pass	Pass
WAM1R-B	Pass	Pass	Pass
SM2½C-B	Pass	Pass	Pass
WIM2½C-B	Pass	Pass	Pass
SWM3C-A	Pass	Fail[(c)]	Pass

[(a)] Bottom seam leaked.

[(b)] Bottom corner seam leaked.

[(c)] Pour spout flange leaked.

Table 7 - Results of Drop Strength Test of Plastic Containers

Specimen	Orientation of Drop			Temperature °F	Remarks
	Bottom	Side	Bottom Corner		
DBP1R-A	(a)	Leak	-	0	Side near bottom leaked
DBP1R-B	(a)	(a)	Leak	75	Side near bottom corner leaked
DBP2½R-A	(a)(b)	(a)(b)	(a)(b)	0	Permanent dent in corner
DBP2½R-A	(a)(b)	(a)(b)	(a)(b)	75	
GHP½C-A	(a)	(a)	(a)	75	
GHP½C-B	(a)	(a)	(a)	75	Permanent dent in bottom

(a) No leakage from seams or joints.

(b) Vent cap came off upon impact.

Figure 1a - Tilt Test

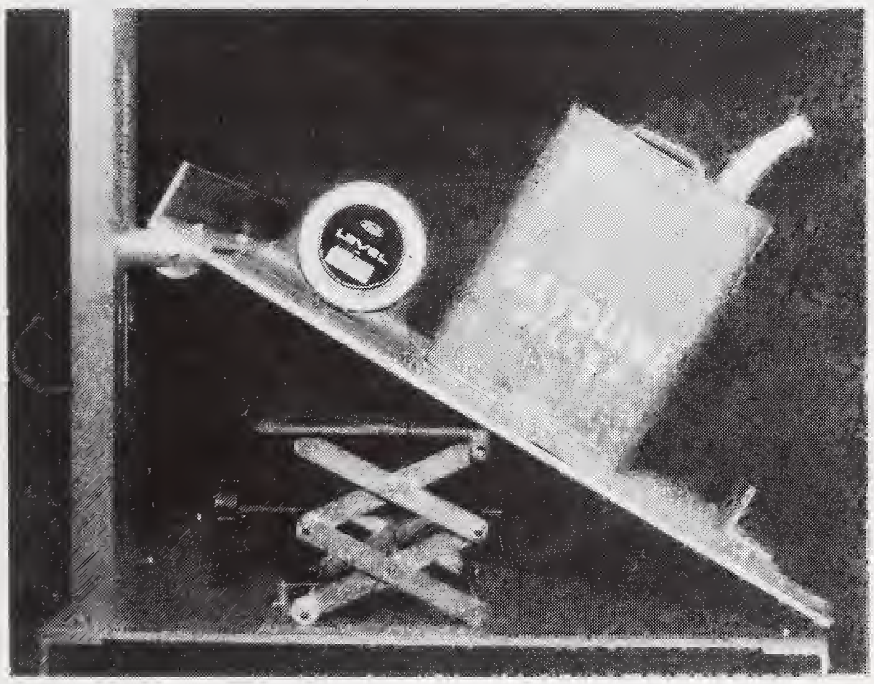


Figure 1b - Inclined Plane Test

Figure 1 - Stability Test Equipment

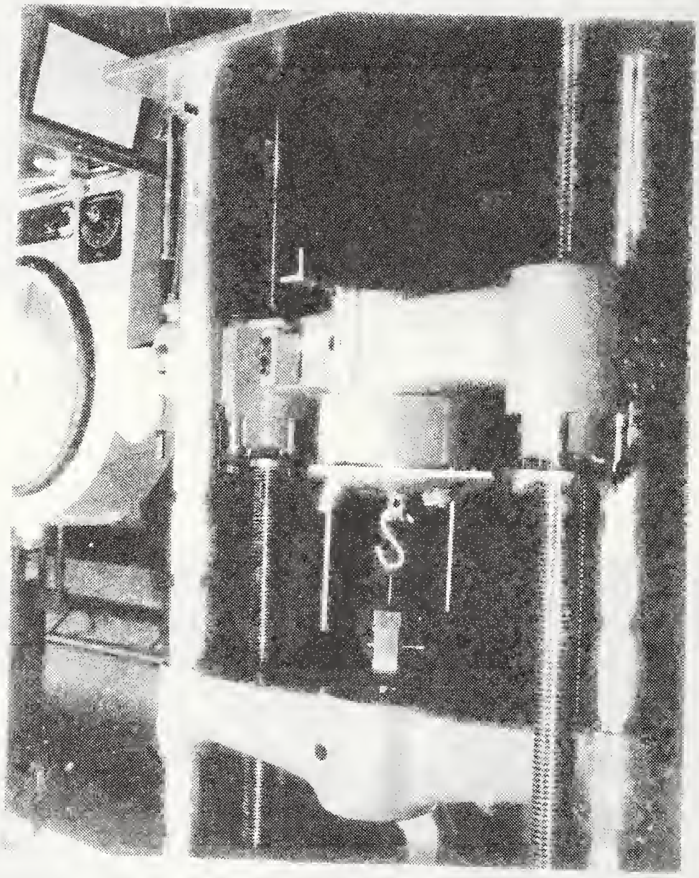


Figure 2 - Static Strength Tests of Handles

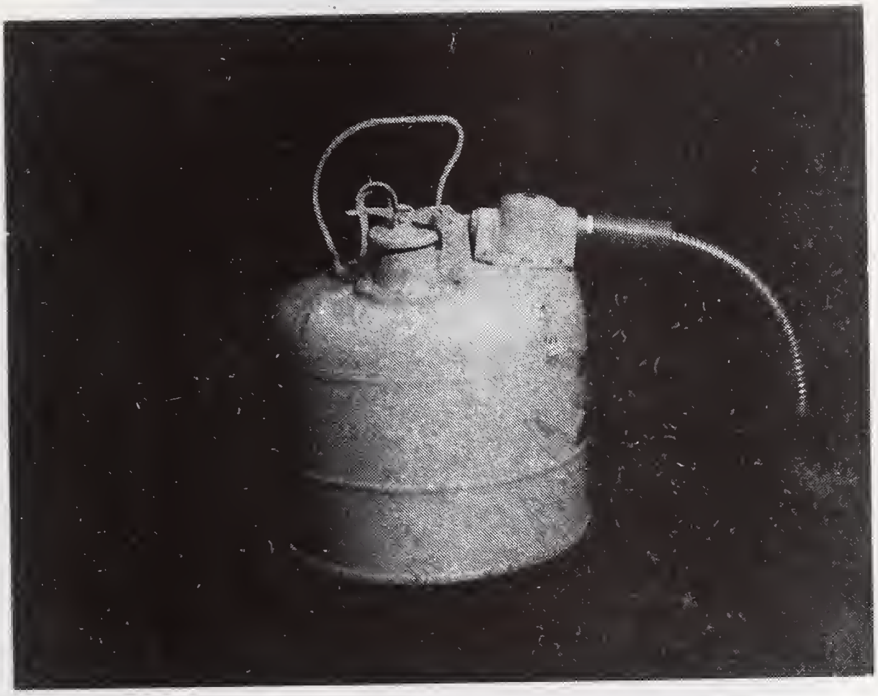


Figure 3a - Safety Can

Figure 3b - Containers for Home Use

Figure 3 - Typical Examples of Test Specimens

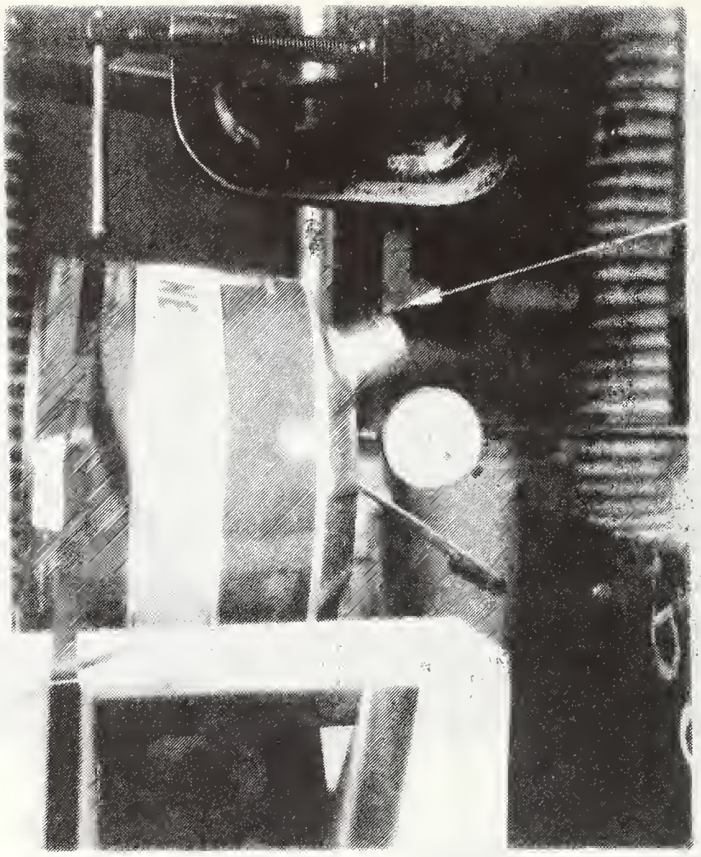


Figure 4a - Circular Based Specimen
Top arrow indicates load application
Bottom arrow indicates support fixtures

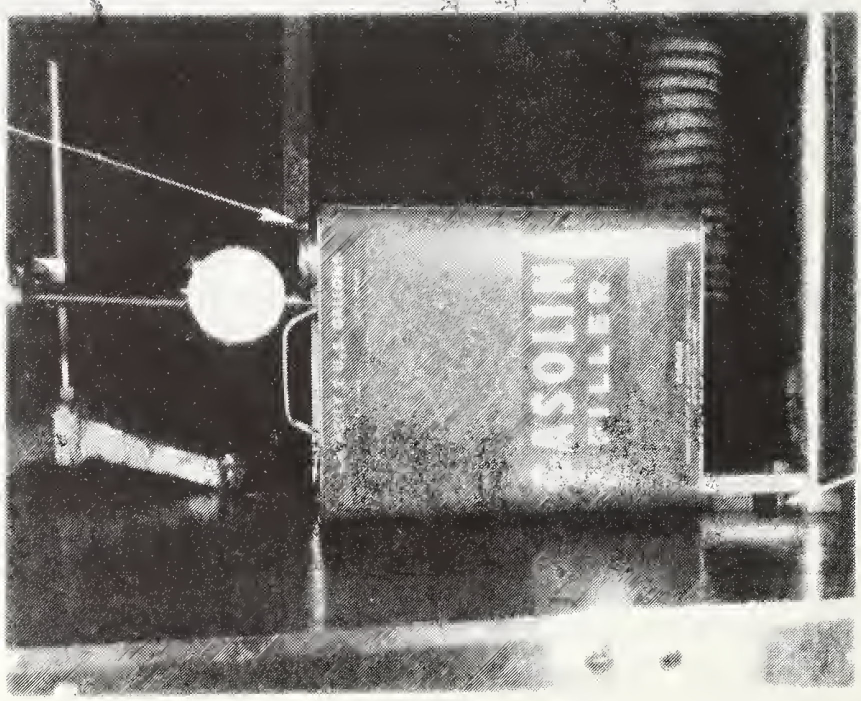
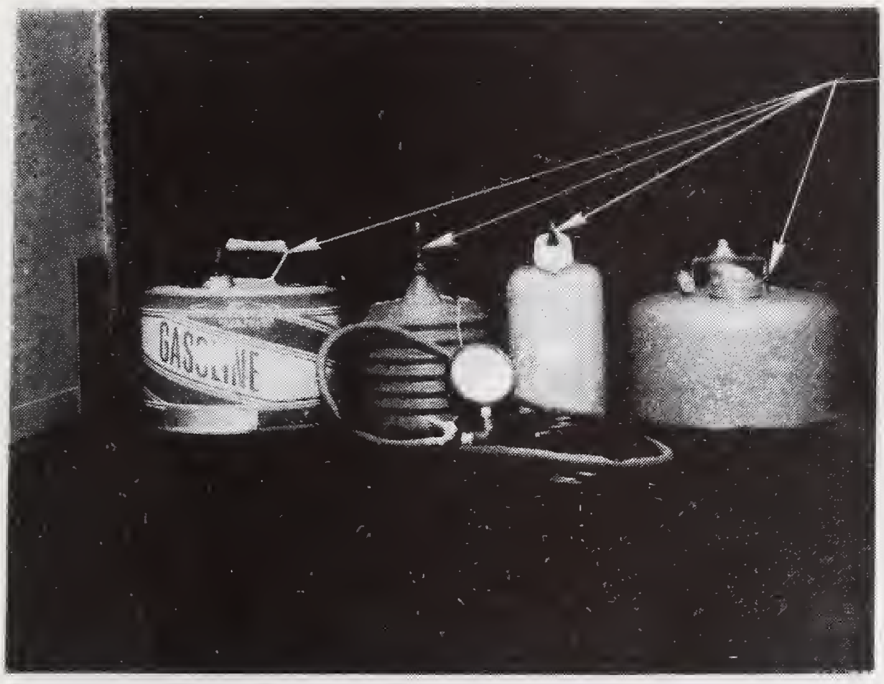


Figure 4b - Rectangular Based Specimen
Top arrow indicates load application
Bottom arrow indicates restraining clamp

Valves



Valve

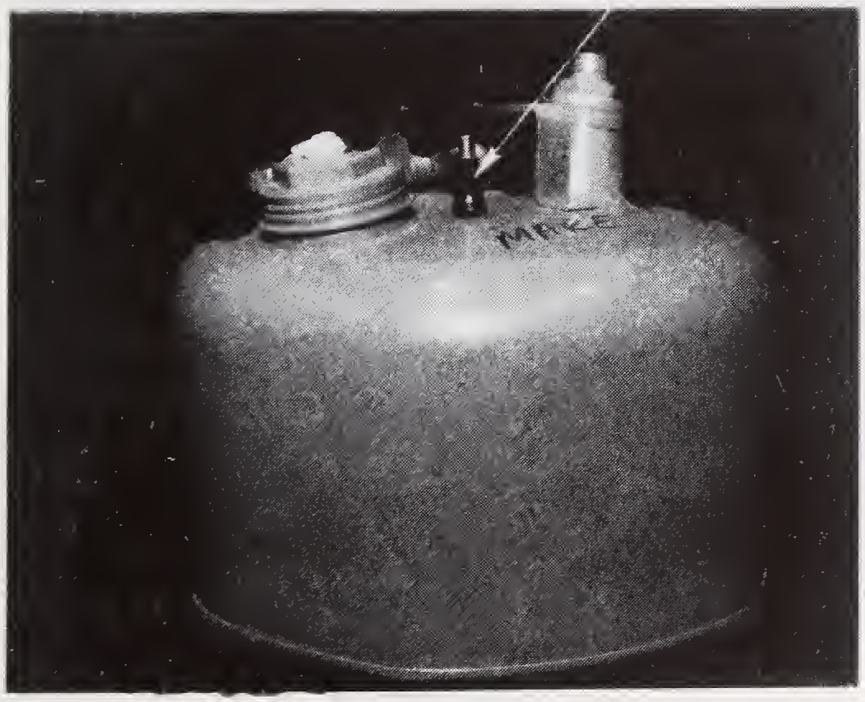


Figure 5 - Equipment Used in Hydrostatic Pressure Leakage Tests

Arrows indicate air valves

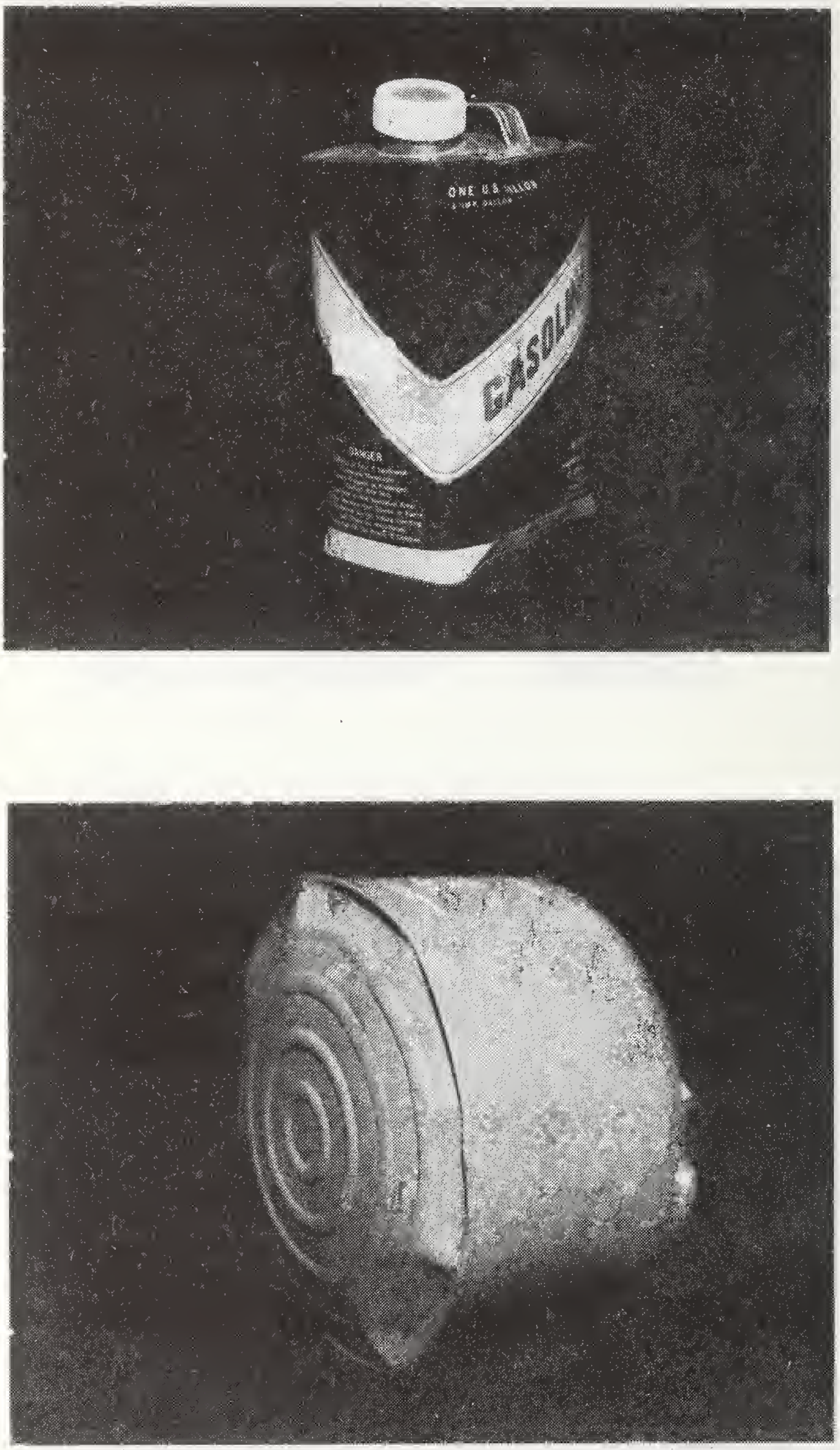


Figure 6 - Deformation of Containers Caused by Hydrostatic Pressure Leakage Tests.

Figure 7 - Damage Caused by Drop Strength Tests

References

[1] Safety Can, Spring Closing Type, Federal Specification RR-S-30E, November 2, 1971.

[2] Approval Standards, Safety Containers and Filling and Supply Containers, Associated Factory Mutual Fire Insurance Companies, Class 6051 and 6052, February 10, 1966.

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[4] Plastic Containers (Jerry-Cans) for Petroleum Products, Voluntary Product Standard 6174, May 1, 1974.

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U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBSIR 74-614	2. Gov't Accession No.	3. Recipient's Accession No.

4. TITLE AND SUBTITLE

MECHANICAL TESTS OF FLAMMABLE LIQUID CONTAINERS

5. Publication Date
January 1975

6. Performing Organization Code

7. AUTHOR(S)
Nixon Halsey, Arthur F. Kirstein, and Robert E. Snyder

8. Performing Organ. Report No.
NBSIR 74-614

9. PERFORMING ORGANIZATION NAME AND ADDRESS

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20234

10. Project/Task/Work Unit No.
2130449

11. Contract/Grant No.

12. Sponsoring Organization Name and Complete Address *(Street, City, State, ZIP)*

Consumer Product Safety Commission
5401 Westbard Avenue
Washington, D. C. 20207

13. Type of Report & Period Covered
Final

14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

Because of the concern for safety in the storage and use of gasoline and other flammable liquids around the home, this study was made to determine if standards can be established to minimize the flammable liquid hazard by controlling or standardizing the containers. Attention was focused on performance standards for stability, leakage, carrying handle strength, and pour spout strength. In general, it was found that the technology involved in existing voluntary standards for safety cans could be applied to flammable liquid containers for home use for all of the above factors except pour spout strength.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Consumer products; flammable liquid containers; gasoline cans; mechanical tests; product standards; safety.

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