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TECHNICAL REPORT
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# EVALUATION OF WAX IMPREGNATED CORRUGATED FIBERBOARD CONTAINERS

by

Anderson Miller
Container Engineering Branch

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Container Division
U. S. ARMY NATICK LABORATORIES
Natick, Massachusetts

## FOREWORD

In the shipment of military supplies to forward areas, one of the major problems has been maintenance of high performance of containers under adverse weather conditions. In the case of Southeast Asia, the special problem has been the effect of the combination of conditions associated with a tropical environment, especially high heat and humidity.

The study is concerned with the possibility of extending and increasing the performance of fiberboard containers through use of the principle of impregnation of the fiberboard with one of the various wax/plastic/resin impregnating compounds commercially available.

The evaluation was accomplished under the Container Development Project No. 1-M-643-324-D587 and the Packaging and Containers for Unitized Loads Task No. 01.

EDWARD A. NEBESKY, Ph.D.
Chief
Container Division

APPROVED:

DALE H. SIELING, Ph.D.
Scientific Director

W. M. MANTZ
Colonel, QMC
Commanding

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## ABSTRACT

The purpose of this study was to evaluate the performance of wax/resin impregnated fiberboards and containers for applicability for use in shipment overseas under all environmental conditions, and as a substitute for conventional weather resistant materials which may become critical and are in short supply during periods of emergency.

Sixteen different tests were performed conforming to ASTM Standards or to the requirements of Federal Specifications, utilizing up to 5 different environmental conditions: standard, arctic, hot desert, rain and tropical. Containers were given compression tests, drop tests and vibration tests. Components were tested for ply separation, water absorption, puncture resistance and stiffness, burst (Mullen), peeling, bleeding, blocking, scoreability and bending, grease resistance, solar radiation, sliding friction, printability, and flameability.

It was found that wax impregnation contributes significantly to increased compression strength through increased resistance to water absorption, and containers of wax impregnated board were superior to other grades of fiberboard in compression resistance. Differences in rough handling were negligible. This was related to the findings that wax impregnation had little effect on dry puncture resistance and on the Mullen bursting strength. Test results indicate that 275 pound test is the minimum grade which should be considered for the wax impregnation process for Military use in overseas shipment.

It is recommended that consideration be given to wider use of wax-impregnated containers in Military supply, especially for overseas shipment; that wax impregnated board of not less than 275 ~~350~~ pounds test Mullen burst dry and 175 pounds test Mullen burst wet be considered as a substitute for selected items, especially in palletized loads; that performance data for evaluation be obtained from test shipments; and that higher grade wax impregnated boards be investigated for other purposes, such as sheathing, unitizers, and consolidation type containers for overseas shipment.

## INTRODUCTION

During World War II and the Korean conflict, V2s solid fiberboard was used extensively for level A shipment of Military items of supply, particularly canned subsistence. However, since that time the limited use of V2s has resulted in a marked decrease in Industry's ability to supply the board when needed. During peace time operations, for reasons of economy, Military items for overseas shipment were usually packaged in domestic grade fiberboard or at best V3c corrugated fiberboard. These grades of fiberboard were readily available and could be acquired immediately when needed.

With the escalation of the war in Southeast Asia the need for high moisture resistance fiberboard containers is now facing the Military again. The lack of warehouses in Vietnam has resulted in supplies and equipment being exposed to high temperature, humidity and rainfall conditions in outdoor storage areas. Under these conditions the domestic type fiberboard, and in some cases the V3c fiberboard, deteriorates and delaminates in a relatively short period of time, thereby offering little or no protection to the packaged items. Under these conditions, even the V2s solid fiberboard containers lose up to 60% of their compressive strength during extended periods of storage. Therefore, in order for the packaged items to remain free from damage and serve the purpose for which they are intended, the exterior containers must resist the adverse conditions and retain a higher percentage of their compressive strength.

In order to correct the existing situation various materials are being investigated for use in container fabrication. One material which shows promise is wax impregnated corrugated fiberboard. Unlike coated fiberboards, this board is completely impregnated with wax throughout each facing and the corrugated medium.

Like any new product being introduced into the system, the wax impregnated fiberboard presented many questions that must be answered before it is accepted for use in fabricating containers for Military use. Some of these questions are:

(a) Does the material meet the requirements of the present specification on Wax Impregnated Fiberboard?

(b) How much protection will the containers offer in a hot-humid climate as encountered in Southeast Asia and how long will they offer this protection?

(c) Will they be adversely affected by high temperature? High moisture? Intense sunlight and rough handling?

(d) At what temperature will the wax begin to flow from the containers, and what effect will it have on sealability?

(e) Are they toxic when used for food items?

(f) How well do they stack in palletizing? And finally, what is their overall performance in comparison to V2s solid fiberboard?

In order to answer these questions, a study was conducted on the performance of wax impregnated fiberboard containers for level A shipment.

The study was designed to simulate any conditions that the packaged items might encounter along the supply line to Southeast Asia as well as other areas. In addition to the tests on wax impregnated containers, the component parts of the containers were also evaluated for their physical properties. These test results were compared with the results obtained in V2s, V3c and domestic containers. Some test work in the area had already been done by various Government and Industrial laboratories but the scope of their evaluation studies were not as extensive as that required to predict performance in a Military shipment to overseas areas such as Vietnam. These tests as well as preliminary tests conducted by the Container Division indicated that the wax impregnated corrugated fiberboard may have potential application for use as a weather-resistant fiberboard which might be superior in some mechanical strength properties to the standard V2s, V3c, and V3s fiberboards.

## MATERIALS AND EQUIPMENT

The materials and equipment used in this study were as follows:

Containers. -

(1) V2s solid fiberboard containers were fabricated in-house from V2s solid fiberboard conforming to PPP-F-320c.

(2) V3c corrugated fiberboard containers were fabricated in-house from V3c corrugated fiberboard conforming to PPP-F-320c.

(3) The 200 pound test and 275 pound test containers were fabricated by the Hollinger Company from corrugated fiberboard with component parts as follows:

(a) 275 pound test. -

Outer liner .023" caliper kraft, 69 pounds per 1000 sq. ft.

Corrugated medium .010" caliper kraft, 33 pounds per 1000 sq. ft.

Inner liner .014" caliper kraft, 42 pounds per 1000 sq. ft.

(b) 200 pound test. -

Outer liner .023" caliper kraft, 42 pounds per 1000 sq. ft.

Corrugated medium .010" caliper kraft, 33 pounds per 1000 sq. ft.

Inner liner .014' caliper kraft, 42 pounds per 1000 sq. ft.

The wax impregnated containers tested were fabricated from corrugated fiberboard identical to the 200 pound test and 275 pound test fiberboard described above. The amount of wax pick-up by the containers in processing was not less then 30% by weight and was evenly distributed. The wax impregnation process is accomplished by dipping the pre-cut and pre-scored sheet stock in liquid resin wax and allowing it to penetrate the board throughout. Following the dipping process the board is then passed on to a draining tank and finally to a dryer. This process was performed by the Baltimore Box Company and the resin wax used was Sealite No. 48 furnished by the Humble Oil Company. Both the control containers and wax impregnated containers were fabricated in two sizes which consisted of the Standard No. 10 can size 18-9/16" x 12-3/8" x 7" and a larger size measuring 22" x 22" x 14". The No. 10 can size was intended for use loaded in the drop test and rough handling tests; while the large size was intended for use empty in the compression test.

The bottom flaps of the containers were stapled with .103" x .023" staples with 3/8" crowns. [1] The top flaps of the containers were fastened with H. B. Fuller No. 2183 weather resistant adhesive, to insure proper bond. Number 10 cans (603 x 700) filled with water and with syrup were used for loads in the

[1]The adhesive was applied with a brush and the flaps of the empty containers for the compression test were clamped together with 2 plywood boards until dry. The loaded packs for drop test were inverted after application of the adhesive and allowed to dry.

No. 10 size containers tested, with weights from 42-1/2 to 46 pounds. The No. 10 size loaded containers were then reinforced with 3/8" x .015" flat metal bands placed 2 lengthwise and 1 girthwise. The larger containers 22" x 22" x 14" were not reinforced with strapping. Stencil ink made by Marsh Stencil Machine Company, Belleville, Illinois, was used to test the printability of the wax impregnated fiberboards.

Equipment. -

The 10,000 pound Tinius Olsen Compression Tester was used for conducting the compression tests. The LAB Vibrator was used for vibrating the packs, and drop testing was conducted using both the LAB and the Gaynes drop testers.

Burst and puncture tests were conducted on the Mullen Burst Tester and on the General Electric Beach Puncture Tester, respectively. The peel resistance tests were conducted using the S. and S. Scuff Tester. The Ohaus triple beam balance was used for determining the moisture content and the percent water absorption of the various types of fiberboard.

## ENVIRONMENTAL CONDITIONS

Environmental conditions were selected to simulate the adverse weather conditions encountered along Military supply lines with particular emphasis being given to conditions expected in Southeast Asia.

During the course of test evaluation all containers were subjected to one or more of the following conditions:

(1) Standard Conditions, 73°F., 50% R.H. for at least 48 hours.

(2) Arctic Conditions. -20°F., for at least 48 hours.

(3) Desert Conditions, 140°F., 10% R.H. for at least 48 hours.

(4) High Temperature-High Moisture Conditions, 100°F., 90% R.H. for 7 days or 30 days, as required.

(5) Water Spray, 3" per hour for 16 hours or 24 hours, as required.

(6) Water Immersion; specimen totally submerged under water for 24 hours.

## TESTS USED FOR EVALUATION

When documented procedures were available, tests were conducted in accordance with the applicable ASTM Standards, Government Specifications, or Federal Standards.

The tests used for evaluating the containers were as follows:

(1) Compression Tests (ASTM Standard 642)

The load was applied at a rate of 4 inches per minute in top to bottom compression.

(2) Drop Tests (ASTM Standard 775)

The packs were subjected to diagonally opposite corner drops from a height of 24" or 30", whichever was required.

(3) Vibration Tests (ASTM Standard 999)

Vibration tests were conducted at 268 rpm, 1G, for 1-1/2 hours.

The following tests were conducted to evaluate the component parts:

(1) Ply Separation Test, PPP-F-310c.

(2) Water Absorption Test, PPP-F-310c.

(3) Puncture Resistance and Stiffness Test, ASTM Standard 781.

(4) Bursting Strength Test, ASTM Standard 774.

(5) Peeling Resistance Test, ASTM Standard 1029.

(6) Bleeding Resistance, ASTM Standard 917.

(7) Blocking Resistance, ASTM Standard 918.

(8) Scoreability and Bending Test - Conducted in accordance to requirements of PPP-F-320c.

(9) Turpentine Test for Grease Resistance, ASTM Standard 722.

(10) Solar Radiation Test, ASTM Standard E42.

(11) Friction Test - Developed for this study.

(12) Printability - Developed for this study.

(13) Flameability - Developed for this study.

## PROCEDURE

### Container Evaluation. -

#### Compression Test

Five 22" x 22" x 14" containers fabricated from each of the fiberboard types were subjected to top to bottom compression tests after exposure to the appropriate environmental conditions. V2s, V3c and wax impregnated containers were compression tested after exposure to each of the conditions cited in the above section on "Environmental Conditioning". However, the domestic grade containers were not tested at the high temperature-high humidity, and water immersion conditions. After exposure to the given conditions for the required period of time, containers were removed from the conditioning atmosphere, one at a time, and immediately tested in the Tinius Olsen Compression Machine at a platen speed of 4 inches per minute. For the set of containers conditioned at 100°F. and 90% R.H., samples were cut immediately after the compression test and weighed.[2] After the samples reached equilibrium at standard conditions, 73°F., 50% R.H., they were weighed again and the amount of moisture pick-up determined as the difference between the two weights.

#### Drop Tests

Six No. 10 can containers fabricated from each of the fiberboard types were subjected to diagonally opposite corner drop tests after exposure to the appropriate environmental conditions. A drop height of 24 inches was used for all conditions except 100°F., 90% R.H. At the 100°F., 90% R.H. conditions it was necessary to use a 30" drop height to control the failure point so that the container failure would occur instead of can rupture and subsequent leakage of contents. At conditions of 100°F.. 90% R.H., the containers become flexible and tend to sustain more drops to failure and offer less protection to the cans.

[2] The oven dry method was not used because of the relatively low melting point of the resin wax in the wax impregnated containers.

During the drop tests the number of drops to the first 1" tear, 6" tear and complete scoreline tear was recorded. Also other physical damage such as loosening of straps, or breakage and loss of straps were recorded.

Level A Cycle Test

Six each of the No. 10 can containers fabricated from V2s, V3c, 275 pound test wax impregnated and 200 pound test wax impregnated fiberboard were subjected to a level A shipping test cycle consisting of three phases which were as follows:

| Phase I | Phase II | Phase III |
|---|---|---|
| Water spray at 3" per hour for 16 hours | Exposure to -20°F. for 48 hours | Exposure to 100°F., 90% R.H. for 7 days |
| Eight diagonally opposite corner drops from 24" | Eight diagonally opposite corner drops from 24" | Eight diagonally opposite corner drops from 24" |
| Vibration for 1-1/2 hours at 268 rpm, 1G | Vibration for 1-1/2 hours at 268 rpm, 1G | Vibration for 1-1/2 hours at 268 rpm, 1G |

Component Evaluation. -

Ply Separation Test

Three samples of each type fiberboard, V2s, V3c, 275 pound test wax impregnated, and 200 pound test wax impregnated were totally submerged under water at 73°F. for 24 hours. The samples were then removed and tested for ply separation in accordance with PPP-F-320. In this test the solid fiberboard, V2s, is evaluated immediately after removal from the water, while the corrugated fiberboard is first allowed to dry at 73°F., 50% R.H. for 48 hours.

Water Absorption Test

Ten samples of each type fiberboard, conditioned at 73°F., 50% R.H. for 48 hours, were weighed on the "Ohaus" triple beam balance. The samples were then totally submerged under water at 73 ±5°F. for 24 hours. The samples were then removed one at a time and the excess water removed by wiping the outer surfaces and allowing the water to drain from the flutes of the corrugated board. The samples were then weighed and the percent water pick-up determined in accordance with PPP-F-320.

### Puncture Resistance and Stiffness Test

Five 8" x 16" samples of each type of fiberboard, conditioned at 73°F., 50% R.H. for 48 hours, were tested on the General Electric Beach Puncture Tester in accordance with ASTM Standard 781. Three punctures were made on each sample, from alternating sides of the board, and the average recorded.

With the exception of the non-impregnated domestic grade fiberboards, the puncture test was repeated on fiberboard samples subjected to total water immersion for 24 hours.

For the stiffness test five 8" x 16" samples of each of the fiberboard types were conditioned at 73°F., 50% R.H. and tested in accordance with ASTM Standard 781. The samples were pre-cut at the point where the puncture was to be received. Pre-cutting was done by making three slits 2-1/2 inches in length, meeting at one point and so spaced angularly that they coincide with the edges of the puncture point as it passed through the specimen. Two tests were made on each sample from alternating sides of the board and results recorded.

### Bursting Resistance Tests

Eight samples of each type of fiberboard conditioned at 73°F., 50% R.H. for 48 hours were tested on the Mullen Tester in accordance with ASTM Standard 744. Six bursting tests were made on each sample from alternate sides of the board. With the exception of the non-impregnated domestic grade fiberboards, the burst resistance tests were repeated on fiberboard samples after being subjected to total water immersion for 24 hours.

### Peel Resistance Tests

The peel resistance test was conducted on the S&S Scuff Tester. Eight samples were cut from each type of fiberboard. One specimen was placed in the bottom fixture of the machine and an identical specimen was placed in the moveable fixture. The two specimens were then rubbed together for 100 double strokes with a weight of 0.5 pounds per square inch applied during the scuffing action.

### Bleeding Resistance Test

Five 3 inch square test samples were cut from each of the two grades of wax impregnated board and prepared for testing in accordance with ASTM Standard 917. Each sample was placed between 4" square sheets of white bond paper. These specimens were stacked 5 high, separated with 3" square aluminum plates, and placed in an oven heated to 110°F. A pressure block producing a force of 0.5 pounds per square inch was placed on top of each stack. The test samples were allowed to stand in the oven for 5 hours and the bond paper was then observed for evidence of staining. The process was repeated using new samples at each 10°F. elevation[3] in temperature until the board showed evidence of bleeding.

## Blocking Resistance Test

Eight samples 1-1/4" x 1-3/4", were cut from each of the two grades of wax impregnated fiberboard used in fabricating the containers and tested in accordance with ASTM Standard 918. The samples were conditioned at 73°F., 50% R.H. for 48 hours. The samples were then stacked in accordance with the instructions of ASTM Standard 918. Each stack was placed between two 4" x 4" aluminum plates, and a pressure block producing 0.5 pounds per square inch was then placed on top of the stacks. Each stack was placed in a desiccator containing a solution of sodium chloride[4] after both desiccator and solution had been brought to equilibrium at 100°F. in an oven. The lid on the desiccator was allowed to remain open for 15 minutes and then closed. The desiccators containing the test specimen were then conditioned at 100°F. for 24 hours, and the specimens were examined for evidence of blocking after this conditioning.

## Scoreability and Bending Tests

Six samples, 12" x 12", were cut from the V2s fiberboard used in fabricating the containers and tested in accordance with PPP-F-320. Three each of the samples were scored parallel to the machine direction and three were scored across the machine direction on the Knowlton Scoring Machine. Each sample scored parallel to the machine direction was folded 180 degrees (toward the male side of the score). Each sample scored across the machine direction was folded 90° toward the female side of the score, returned to the original position, and then folded 90 degrees toward the male side. In each test the scorelines were observed for breakage of outer or inner facings.

[3]For this test, this deviation of temperature increments was made from the method cited in ASTM Standard 917 to determine the bleeding temperature of the wax board.

[4]The sodium chloride solution was used to raise the humidity within the desiccator to 75%.

Three each of the corrugated fiberboard samples, including the wax impregnated fiberboard, were scored parallel with the flutes and three each across the flutes on the S&S sample making machine. The samples were then folded 180° toward the female score and observed for breaks in the scoreline.

Turpentine Penetration Test

Four samples, approximately 16" x 16", of each of the fiberboard types were conditioned at 73°F., 50% R.H. for 48 hours, and then placed on white book-paper sheets 28 x 32 inches. One half of the samples were positioned with the outer liners up and the remaining half were positioned with the inner liners up. Using a tube 1 inch in diameter approximately 10 grams of sand[5] per pile was placed on the test sample, with several piles 4 to 5 inches apart on each test sample. Approximately 5 ml. of colored turpentine were then added to each pile of sand, and the white paper under each sample was examined periodically for stains in accordance with ASTM Standard 722. The time of penetration of the turpentine was recorded for each board type.

Solar Radiation Test

Two samples, 8" x 14" of each of the fiberboard types were pre-conditioned for 48 hours at 73°F. and 50% R.H., and then tested in accordance with ASTM Standard E-42. The samples were then placed in a vertical position in the revolving racks of the National Accelerated Weathering Unit Type X-1A. Using the twin carbon-arc lamps, the samples were exposed to the ultra violet radiation for 50 hours. The samples were then removed and six Mullen tests conducted on each sample from alternate sides. The results were then compared to that of samples conditioned at 73°F., 50% R.H. for 48 hours.

Sliding Friction Test (Figure 1)

A No. 10 can size container fabricated from each of the fiberboard types was loaded with 6 No. 10 cans filled with water, giving a total weight of 44 pounds. Each container was placed on a flat fiberboard surface of a material identical to that used in the fabrication of the container. and a flat metal band 3/8" x .015" was placed loosely around the side and end panels of the container to act as a harness. A 50 pound capacity Hunter type spring gage was connected to the band and the container was pulled along the fiberboard surface by applying a force parallel to the surface. The force required to start the movement as well as the force required to continue the movement of the container was recorded.

[5]A round-grained, natural silica sand graded to pass a No. 20 sieve and be retained on a No. 30 sieve.

### Printability

Stencil imprints were made on a sample of each of the two grades of wax impregnated fiberboard. The samples were totally submerged under water at 73°F. for 7 days, and the condition of the stencilled letters observed daily. The samples were removed and allowed to dry. They were then examined again for evidence of fading or blotting.

### Flameability

Samples of the various types of fiberboard were suspended from a wire rack. Using a lighted match the time required for the samples to ignite was taken with a stop watch. Another set of samples 1" square were suspended from a wire rack. The flame of a lighted match was brought in contact with each specimen for 5 seconds and removed. The time required for the entire sample to burn was recorded.

## RESULTS

### Container Evaluation. -

### Compression Tests

The 275 pound test wax impregnated containers were superior to V2s and V3c under all conditions tested. At the most severe condition, 24 hours water immersion, the 275 pound test wax impregnated containers had twice the compressive strength of V2s, and the 200 pound test wax impregnated containers had a higher compression strength than both the V2s and V3c. After exposure to 100°F., 90% R.H. for 30 days the 275 pound test wax impregnated containers had a slightly higher compression strength than V2s; and the 200 pound test wax impregnated containers had a slightly lower compression strength than V3c. The compression strength of the wax impregnated containers was increased when they were subjected to -20°F., whereas, the standard board types remained about the same. At 140°F. the wax impregnated containers showed a decrease in compression strength, whereas, the compression strength of some of the standard fiberboard containers showed an increase. An average of the compression strength of the containers under various environmental conditions is presented in Figure 2, and test data are shown in table 1 of the Appendix. The average moisture content[6] (table 13 of the Appendix) of samples taken from the containers conditioned at 100°F., 90% R.H. were as follows:

[6] Moisture content based on sample equilibrium weight at 73°F., 50% R.H.

V2s - 5.46 percent
V3c - 5.60 percent
275 pound test W.I. - 3.54 percent
200 pound test W.I. - 3.04 percent

Drop Tests

The V2s containers were superior in performance under all conditions tested. Under conditions of 73°F., 50% R.H., -20°F. and 140°F. conditioning the performance of V3c containers were approximately 10% lower than that of V2s, and the 275 pound test wax impregnated containers 15% lower than that of V2s. Under 24 hours water spray the performance of V2s was more than twice that of 275 wax impregnated, while the 275 wax impregnated was more than twice that of V3c. The 200 pound test wax impregnated performed as well as V3c under 24 hours water spray and approximately 60% as well as V3c and 275 lb test wax impregnated under 100°F., 90% R.H. The performance of both the wax impregnated containers and standard grade containers did not show any significant change when conditioned at 73°F., 50% R.H., -20°F. or 140°F. The performance of the containers subjected to drop tests under various environmental conditions is presented in Figure 3, and test data are shown in table 2 to 6 inclusive in the Appendix.

Level A Cycle Test

In the level A shipping test cycle, the performance of V2s was superior to that of the V3c and the two grades of wax impregnated boards. The V3c corrugated containers and 275 pound test wax impregnated fiberboards did not sustain scoreline failure until the final phase of the cycle. The 200 pound test wax impregnated containers failed in the first phase of the test cycle. Test data are shown in table 7 of the Appendix.

## COMPONENT EVALUATION

Ply Separation Tests. -

There was no ply separation in any of the fiberboard samples tested.

Water Absorption Tests. -

The wax impregnated samples had a lower water absorption value after 24 hours water immersion than the other types of fiberboard samples tested. Test data are shown in table 8 of the Appendix.

The average percent water absorption for each board type was as follows:

V2s solid fiberboard - 64%
V3c corrugated fiberboard - 103%
275 pound test wax impregnated - 42%
200 pound test wax impregnated - 54%

Puncture Resistance Tests. -

The average of the Puncture Resistance results[7] for each type of fiberboard tested with the General Electric Beach Puncture Tester was as follows:

Standard Conditions (73°F., 50% R.H.)

| Fiberboard Type | No. of Beach Units[8] |
|---|---|
| V2s solid fiberboard | 545 |
| V3c corrugated fiberboard | 444 |
| 275 lb. test wax impregnated corrugated fiberboard | 372 |
| 200 lb. test wax impregnated corrugated fiberboard | 266 |
| 275 lb. test standard corrugated fiberboard | 349 |
| 200 lb. test standard corrugated fiberboard | 235 |

Water Immersion (24 hours)

| Fiberboard Type | No. of Beach Units |
|---|---|
| V2s solid fiberboard | 559 |
| V3c corrugated fiberboard | 191 |
| 275 lb. test wax impregnated corrugated fiberboard | 334 |
| 200 lb. test wax impregnated corrugated fiberboard | 242 |

[7] Complete data shown in table 9 of the Appendix.

[8] Beach Unit defined as inch ounces per inch of tear.

Stiffness Test. -

The average of the results[9] of the stiffness test conducted on the fiberboard samples after conditions at 73°F., 50% R.H. was as follows:

| Fiberboard Type | No. of Beach Units |
|---|---|
| V2s solid fiberboard | 259 |
| V3c corrugated fiberboard | 182 |
| 275 lb. test wax impregnated corrugated fiberboard | 258 |
| 200 lb. test wax impregnated corrugated fiberboard | 191 |
| 275 lb. test standard corrugated fiberboard | 158 |
| 200 lb. test standard corrugated fiberboard | 115 |

Bursting Resistance Tests. -

The averages of the dry[10] and wet bursting strengths, respectively (data in table 11 of the Appendix), in pounds per square inch, of the various types of fiberboards were as follows:

Standard Conditions 73°F., 50% R.H. - (Dry)

| Fiberboard Type | lbs/sq inch |
|---|---|
| V2s solid fiberboard | 715 |
| V3c corrugated fiberboard | 496 |
| 275 lb. test wax impregnated corrugated fiberboard | 362 |
| 200 lb. test wax impregnated corrugated fiberboard | 238 |

Water Immersion (24 hours) - (Wet)

| Fiberboard Type | lbs/sq inch |
|---|---|
| V2s solid fiberboard | 513 |
| V3c corrugated fiberboard | 177 |
| 275 lb. test wax impregnated corrugated fiberboard | 192 |
| 200 lb. test wax impregnated corrugated fiberboard | 110 |

[9] Complete data shown in table 10 of the Appendix.

[10] Dry Mullen Bursting tests of domestic fiberboard types were run in the solar radiation tests and were not duplicated in this test.

Peel Resistance Tests. -

All of the samples resisted peeling of the facing during the peeling resistance tests.

Bleeding Resistance Tests. -

In the bleeding resistance test, the wax impregnated fiberboard showed signs of bleeding in the form of small blotches at 140°F.

Block Resistance Tests. -

There was no adhesion or cohesion between the surfaces of the wax impregnated fiberboard samples subjected to the blocking resistance tests. Also, the surfaces of the samples were not marred when separated.

Scoreability & Bending Tests. -

The scoreability and bending test showed that the scorelines meet the requirements of PPP-F-320 when folded in the required manner.

Turpentine Penetration Test. -

The results of the turpentine penetration test were as follows:

| Fiberboard Type | Penetration Time |
|---|---|
| V2s | 4-5 minutes |
| V3c | 12-15 minutes |
| 200 lb. test standard | 1-3 minutes |
| 275 lb. test wax impregnated | no penetration |
| 200 lb. test wax impregnated | no penetration |
| 275 lb. test standard | no penetration[11] |

Solar Radiation Test. -

The carbon-arc light did not have any significant effect on the bursting strength of any of the fiberboard samples. The average of the Mullen Tests of the control samples and the samples exposed to carbon-arc light for 50 hours were as follows:

[11] The test quantity of turpentine spread through the first liner and corrugated medium without penetrating completely through the board.

| Fiberboard Type | Irradiated lbs/in$^2$ | Control lbs/in$^2$ |
|---|---|---|
| V2s | 725 | 719 |
| V3c | 467 | 490 |
| 275 lb. test wax impregnated | 368 | 336 |
| 200 lb. test wax impregnated | 242 | 240 |
| 275 lb. test standard | 340 | 344 |
| 200 lb. test standard | 244 | 242 |

Sliding Friction Test. -

| Fiberboard Type | Force to Start Movement | Force to Sustain Movement |
|---|---|---|
| V2s | 22 pounds | 20 pounds |
| V3c | 24 pounds | 20 pounds |
| 275 lb. test wax impregnated | 5 pounds | 4 pounds |
| 200 lb. test wax impregnated | 10 pounds | 7 pounds |
| 275 lb. test standard | 21 pounds | 19 pounds |
| 200 lb. test standard | 22 pounds | 20 pounds |

Printability. -

The stencil ink on the wax impregnated containers was not affected after seven days water immersion at 73°F. When the samples became dry there was no evidence of fading or blotting of the stencilled letters.

Flameability Test. -

The results of the flameability tests were as follows:

| Fiberboard Type | Ignition Time | Burning Time for 1 sq in samples |
|---|---|---|
| V2s | 5 seconds | 1 minute 42 seconds |
| V3c | 3 seconds | 37 seconds |
| 275 lb. test wax impregnated | 2 seconds | 51 seconds |
| 200 lb. test wax impregnated | 2 seconds | 45 seconds |
| 275 lb. test standard | 3 seconds | 35 seconds |
| 200 lb. test standard | 1 second or less | 31 seconds |

## DISCUSSION

The materials selected as controls for this study represent the varieties of single wall material used in fabricating containers for both overseas and domestic shipments. The two grades of wax impregnated containers were fabricated from corrugated fiberboard similar to the standard domestic grades used. The tests show that the wax impregnation process is advantageous in increasing the compression strength of domestic grade fiberboard boxes, but provides little or no increase in rough handling resistance under most of the environmental test conditions. Especially noteworthy is the performance under simulated Arctic and tropical conditions. Even though wax impregnation generally increases the compression strength, it gives only equivalent resistance to rough handling under all severe conditions except hot desert. This equivalence in rough handling would tend to be confirmed by the fact that puncture resistance and bursting strength of both the treated and untreated 275 pound test and 200 pound test boards tested under standard conditions are about the same. It should also be noted that the resistance to rough handling under standard conditions and hot dry conditions is not increased by wax impregnation. This indicates that the wax impregnated containers might present a problem in packaging difficult loads or heavy canned subsistence items that encounter rough handling. However, easy loads or loads similar to lightweight, individually cartoned ration packs should not present any problem for 275 pound test wax impregnated containers in level A shipments. For palletized loads the wax impregnated containers will generally be equivalent to or superior to other grades of single wall boards in all severe environmental areas, except extreme desert conditions. Container unitizers fabricated as large boxes from wax impregnated fiberboard can also be expected to perform better than other grades of standard weather resistant fiberboard in a high moisture environment because of the superior compressior strength properties of the wax impregnated materials.

Since it is becoming more and more difficult to obtain V2s for level A shipment, the 275 pound test wax impregnated fiberboard shows promise as being a replacement for V2s for certain items. It is being introduced into the industrial system of this country daily and will therefore be more economical than V2s in the future.

There were questions as to the adhesive bond, printability, toxic properties, and resistance to fungus growth of wax impregnated containers. To answer these questions the Food and Drug Administration and industrial firms supplying printing ink and adhesives were contacted. The Food and Drug Administration has approved the use of Sealite 48 resin wax, under an amendment to Regulation 121, 2526, for use in impregnating containers for shipping fruits and vegetables and iced poultry, meat and fish.

Various types of weather resistant adhesives and plastics base hot melts can be made available for machine sealing as well as brush and roller sealing of wax impregnated containers. To test the adhesive bond of the containers used in this study the flaps fastened with adhesive were examined during the rough handling tests after exposure to the various conditions. In almost every pack there were no failures of the glued flaps unless fiber tear occurred, and this was never a 100% failure. Usually, failure of the stapled flaps occurred before that of the flaps fastened with adhesive.

One definite advantage of wax impregnation is that it reduces the water absorption properties of the fiberboard. This accounts for the higher compression strength of the containers after 24 hours water immersion and 100%, 90% R.H. conditions.

The turpentine test shows that the wax impregnated fiberboard is also superior to standard types of fiberboard in resisting grease penetration. For this reason consideration can be given to using wax impregnated board for packaging items such as spare parts treated with various oil preservatives and for level A shipments of frozen meat items.

There was no blocking of the samples when heated to 100°F., 75% R.H. for 24 hours. However, the wax impregnated boards began to show signs of bleeding at 140°F. Based on the results of the friction test a problem may be encountered in palletizing loads of wax impregnated containers. Because of the very low coefficient of friction between two wax impregnated surfaces, such a load will definitely need a sheath or some other form of stabilization to hold the containers in place during movement, handling and shipment. The friction test showed that the wax impregnated containers are 2 to 4 times as unstable as standard containers when stacked on like surfaces. One other disadvantage of wax impregnated fiberboard is the flameability properties. The resin wax in the board tends to act as a fuel when ignited and the ignition time for wax impregnated fiberboard is about 100% faster than V2s and about 50% faster than V3c fiberboard. Just how critical this would be is not known because none of the standard fiberboards are fireproof, and precautions against fire must always be taken in warehouses and storage areas.

## CONCLUSIONS

The 275 pound test wax impregnated corrugated containers show promise as being suitable for level A shipment of certain items, especially in palletized form, where the characteristics of high compression resistance will be of advantage while the effects of rough handling on individual containers will be minimized. These items must be of a physical shape so that they will not puncture or cut the fiberboard, typical examples being individual ration packs and clothing packs. The 275 pound test wax impregnated containers will retain a higher compression strength than V2s or V3c under various environmental conditions. The 275 pound test wax impregnated containers will be superior to the currently used fiberboard in resisting stacking loads under the high moisture conditions which exist in Vietnam. Wax impregnated fiberboard considered for use in level A shipments should have a bursting strength of no less than 350 pounds/square inch dry and 175 pounds/square inch after 24 hours water immersion, and the maximum water pick-up of the 24 hour water immersion should be no more than 45%. The 200 pound test wax impregnated fiberboard containers are unsuitable for overseas shipment. However, they may be suitable for limited level B or level C shipment where the wax impregnated carton results in an economical advantage over an untreated box plus a case liner for selected items.

## RECOMMENDATIONS

It is recommended that:

(1) Consideration be given to the wider use of suitable wax impregnated containers in the Military supply lines, especially for overseas shipment.

(2) Wax impregnated board of not less than 275 pounds Mullen test dry and 175 pounds Mullen test wet be considered as a substitute for V3c and V2s for selected supply items, especially in palletized loads.

(3) Performance data be obtained on test shipments or initial shipment of items procured in wax impregnated containers for evaluation purposes.

(4) Higher grade wax impregnated corrugated containers, sheathing materials, unitizers, and consolidated type containers be investigated for use in overseas shipment.

(5) The wax impregnated 200 pound test fiberboard be considered for selected items where it results in economical advantage over the use of an untreated box plus a case liner for limited level B or level C shipment.

# A P P E N D I X

Detailed results of the container tests and component tests are tabulated as follows:

TABLE 1: COMPRESSION TEST OF 22" x 22" x 14" CONTAINERS (EMPTY)

| No. | V2s pounds | V3c pounds | 275, W.I. pounds | 200, W.I. pounds | 275, Std pounds | 200, Std pounds |
|---|---|---|---|---|---|---|
| | | | 73°F., 50% R.H. (48 hours) | | | |
| 1 | 1450 | 1470 | 2480 | 1720 | 1430 | 750 |
| 2 | 1455 | 1450 | 2500 | 1630 | 1290 | 890 |
| 3 | 1450 | 1620 | 2670 | 1690 | 1360 | 1050 |
| 4 | 1390 | 1390 | 2740 | 1500 | 1310 | 720 |
| 5 | 1430 | 1470 | 2450 | 1630 | 1380 | 770 |
| Avg | 1435 | 1480 | 2562 | 1634 | 1354 | 836 |
| | | | -20°F., (48 hours) | | | |
| 1 | 1500 | 1380 | 3205 | 1800 | 1150 | 690 |
| 2 | 1410 | 1450 | 3200 | 2090 | 1290 | 640 |
| 3 | 1360 | 1430 | 3160 | 1810 | 1230 | 760 |
| 4 | 1510 | 1360 | 3070 | 1920 | 1350 | 760 |
| 5 | 1400 | 1260 | 3120 | 1920 | 1400 | 690 |
| Avg | 1436 | 1382 | 3151 | 1908 | 1284 | 688 |
| | | | 140°F., (48 hours) | | | |
| 1 | 1200 | 1540 | 1730 | 1260 | 1960 | 1150 |
| 2 | 1280 | 1450 | 1730 | 1050 | 1620 | 1380 |
| 3 | 1260 | 1470 | 1380 | 940 | 1890 | 1430 |
| 4 | 1220 | 1590 | 1530 | 1040 | 1930 | 1320 |
| 5 | 1320 | 1470 | 1660 | 1140 | 1990 | 1220 |
| Avg | 1256 | 1504 | 1606 | 1086 | 1878 | 1300 |

TABLE 1: COMPRESSION TEST OF 22" x 22" x 14" CONTAINERS (EMPTY) (Continued)

| No. | V2s pounds | V3c pounds | 275, W.I. pounds | 200, W.I. pounds | 275, Std pounds | 200, Std pounds |
|---|---|---|---|---|---|---|
| | | | **Water Immersion (24 hours)** | | | |
| 1 | 200 | 170 | 350 | 270 | | |
| 2 | 195 | 165 | 390 | 270 | | |
| 3 | 200 | 165 | 400 | 300 | NOT TESTED | |
| 4 | 200 | 145 | 445 | 300 | | |
| 5 | 200 | 250 | 450 | 235 | | |
| Avg | 199 | 179 | 407 | 275 | | |
| | | | **100°F., 90% R.H. (30 days)** | | | |
| 1 | 890 | 690 | 1100 | 730 | | |
| 2 | 880 | 760 | 1140 | 890 | | |
| 3 | 940 | 510 | 1180 | 750 | NOT TESTED | |
| 4 | 890 | 530 | 1280 | 840 | | |
| 5 | 780 | 790 | 1130 | 750 | | |
| Avg | 876 | 656 | 1166 | 792 | | |

TABLE 2: DROP TESTS OF NO. 10 CAN CONTAINERS TESTED AFTER CONDITIONING AT 73°F., 50% R.H. for 48 HOURS - 24" DROP HEIGHT

| | | No. of drops to the 1st | | | | | No. of drops to the 1st | | |
|---|---|---|---|---|---|---|---|---|---|
| V2s | Wt | 1" tear | 6" tear | Complete scoreline tear | V3c | Wt | 1" tear | 6" tear | Complete scoreline tear |
| 1 | 45.0 | 5 | 18 | 30 | 1 | 44.0 | 12 | 20 | 22 |
| 2 | 45.0 | 9 | 17 | 26 | 2 | 44.0 | 12 | 20 | 22 |
| 3 | 45.0 | 9 | 20 | 31 | 3 | 43.5 | 10 | 20 | 22 |
| 4 | 44.5 | 10 | 16 | 23 | 4 | 44.0 | 11 | 19 | 24 |
| 5 | 44.5 | 9 | 16 | 27 | 5 | 44.0 | 14 | 20 | 24 |
| 6 | 44.5 | 9 | 17 | 23 | 6 | 44.0 | 10 | 15 | 24 |
| Avg | 44.75 | 8.5 | 17.3 | 26.6 | | 43.9 | 11.5 | 19 | 23 |
| 275, W.I. | | | | | 200, W.I. | | | | |
| 1 | 44.5 | 9 | - | - | 1 | 43.0 | 1 | 9 | 14 |
| 2 | 44.5 | 9 | 17 | 23 | 2 | 43.0 | 3 | 10 | 13 |
| 3 | 44.5 | 9 | 19 | 20 | 3 | 43.0 | 7 | 9 | 15 |
| 4 | 44.0 | 8 | 17 | 20 | 4 | 43.0 | 4 | 7 | 11 |
| 5 | 44.0 | 11 | 17 | 21 | 5 | 43.5 | 3 | 8 | 12 |
| 6 | 44.5 | 10 | 17 | 19 | 6 | 43.5 | 4 | 9 | 14 |
| Avg | 44.3 | 9.3 | 17.4 | 20.6 | | 43.1 | 3.7 | 8.6 | 13.1 |
| 200, Std | | | | | 275, Std | | | | |
| 1 | 43.0 | 3 | 7 | 11 | 1 | 43.0 | 3 | 11 | 16 |
| 2 | 43.0 | 1 | 8 | 12 | 2 | 43.5 | 9 | 16 | 20 |
| 3 | 43.0 | 1 | 6 | 9 | 3 | 43.5 | 1 | 14 | 17 |
| 4 | 43.0 | 1 | 7 | 10 | 4 | 43.0 | 16 | 16 | 24 |
| 5 | 43.0 | 1 | 8 | 13 | 5 | 43.5 | 10 | 11 | 22 |
| 6 | 42.5 | 1 | 5 | 13 | 6 | 42.5 | 8 | 16 | 22 |
| Avg | 42.8 | 1.3 | 6.8 | 11.3 | | 42.5 | 7.9 | 14.5 | 20.1 |

TABLE 3: DROP TEST OF NO. 10 CAN CONTAINERS TESTED AFTER EXPOSURE TO -20°F., for 48 HOURS - 24" DROP HEIGHT

| | | No. of drops to the 1st | | | | | No. of drops to the 1st | | |
|---|---|---|---|---|---|---|---|---|---|
| V2s | Wt | 1" tear | 6" tear | Complete scoreline tear | V3c | Wt | 1" tear | 6" tear | Complete scoreline tear |
| 1 | 45.0 | 11 | 13 | 14 | 1 | 45.0 | 5 | 14 | 18 |
| 2 | 45.0 | 3 | 8 | 13 | 2 | 44.0 | 7 | 12 | 16 |
| 3 | 45.0 | 8 | 16 | 19 | 3 | 43.0 | 10 | 15 | 19 |
| 4 | 45.0 | 4 | 11 | 22 | 4 | 44.0 | 4 | 10 | 19 |
| 5 | 45.0 | 11 | 13 | 24 | 5 | 45.0 | 5 | 10 | 17 |
| 6 | 45.0 | 8 | 15 | 22 | 6 | 44.0 | 12 | 17 | 21 |
| Avg | 45.0 | 7.5 | 12.7 | 19.0 | | 44.1 | 7.2 | 13 | 18.3 |
| 275, W.I. | | | | | 200, W.I. | | | | |
| 1 | 44.0 | 6 | 10 | 16 | 1 | 44.0 | 2 | 7 | 9 |
| 2 | 45.0 | 4 | 10 | 16 | 2 | 44.0 | 1 | 8 | 8 |
| 3 | 45.0 | 6 | 9 | 17 | 3 | 44.0 | 2 | 7 | 11 |
| 4 | 45.0 | 4 | 8 | 13 | 4 | 44.0 | 2 | 8 | 12 |
| 5 | 45.0 | 6 | 10 | 16 | 5 | 44.0 | 1 | 7 | 8 |
| 6 | 44.5 | 4 | 10 | 14 | 6 | 44.0 | 2 | 7 | 12 |
| Avg | 44.8 | 5 | 9.5 | 15.3 | | 44.0 | 1.7 | 7.3 | 10 |
| 275, Std | | | | | 200, Std | | | | |
| 1 | 44.0 | 3 | 8 | 9 | 1 | 45.0 | 1 | 3 | 11 |
| 2 | 44.0 | 3 | 5 | 8 | 2 | 45.0 | 3 | 5 | 10 |
| 3 | 44.0 | 6 | 9 | 12 | 3 | 44.5 | 1 | 3 | 8 |
| 4 | 44.0 | 4 | 10 | 12 | 4 | 44.5 | 1 | 4 | 6 |
| 5 | 45.0 | 4 | 10 | 12 | 5 | 44.5 | 1 | 4 | 6 |
| 6 | 44.0 | 4 | 7 | 11 | 6 | 45.0 | 3 | 4 | 6 |
| Avg | 44.2 | 4 | 8.2 | 10.7 | | 44.8 | 1.7 | 3.8 | 7.8 |

TABLE 4: DROP TESTS OF NO. 10 CAN CONTAINERS TESTED AFTER EXPOSURE TO 140°F., 10% R.H. for 48 HOURS - 24" DROP HEIGHT

| | | No. of drops to the 1st | | | | | No. of drops to the 1st | | |
|---|---|---|---|---|---|---|---|---|---|
| V2s | Wt | 1" tear | 6" tear | Complete scoreline tear | V3c | Wt | 1" tear | 6" tear | Complete scoreline tear |
| 1 | 44.0 | 12 | 16 | 26 | 1 | 44.5 | 12 | 22 | 28 |
| 2 | 44.0 | 12 | 20 | 29 | 2 | 43.5 | 11 | 17 | 22 |
| 3 | 43.5 | 11 | 19 | 23 | 3 | 43.5 | 13 | 20 | 24 |
| 4 | 44.0 | 5 | 16 | 29 | 4 | 43.0 | 9 | 17 | 21 |
| 5 | 43.5 | 9 | 14 | 21 | 5 | 43.0 | 11 | 16 | 18 |
| 6 | 44.0 | 10 | 17 | 20 | 6 | 42.5 | 9 | 16 | 20 |
| Avg | 43.8 | 9.8 | 17.0 | 24.6 | | 43.3 | 10.8 | 18.0 | 22.8 |
| 275, W.I. | | | | | 200, W.I. | | | | |
| 1 | 43.5 | 9 | 15 | 21 | 1 | 43.0 | 3 | 8 | 15 |
| 2 | 43.5 | 11 | 16 | 20 | 2 | 42.5 | 2 | 8 | 13 |
| 3 | 43.5 | 10 | 15 | 20 | 3 | 42.5 | 4 | 7 | 14 |
| 4 | 43.5 | 9 | - | - | 4 | 42.0 | 3 | 9 | 15 |
| 5 | 43.5 | 9 | 15 | 19 | 5 | 43.0 | 3 | 8 | 9 |
| 6 | 43.0 | 8 | 14 | 19 | 6 | 42.0 | 2 | 7 | 14 |
| Avg | 43.4 | 9.3 | 15.0 | 19.8 | | 42.5 | 2.8 | 7.8 | 13.3 |
| 275, Std | | | | | 200, Std | | | | |
| 1 | 42.5 | 4 | 12 | 22 | 1 | 42.5 | 1 | 4 | 13 |
| 2 | 43.5 | 4 | 12 | 18 | 2 | 43.0 | 1 | 4 | 12 |
| 3 | 43.0 | 5 | 12 | 17 | 3 | 43.0 | 1 | 6 | 8 |
| 4 | 43.0 | 6 | 10 | 18 | 4 | 42.0 | 1 | 5 | 11 |
| 5 | 42.5 | 5 | 8 | 17 | 5 | 42.0 | 1 | 6 | 10 |
| 6 | 42.5 | 6 | 14 | 18 | 6 | 43.0 | 1 | 4 | 8 |
| Avg | 43.1 | 5.0 | 11.3 | 18.7 | | 42.6 | 1.0 | 4.8 | 10.3 |

TABLE 5: DROP TESTS OF NO. 10 CAN CONTAINERS TESTED AFTER EXPOSURE TO 3" WATER SPRAY PER HOUR FOR 24 HOURS - 24" DROP HEIGHT

V2s Containers - Only two of the containers sustained a 1" tear during drop tests. The packs were subjected to 36 drops from a height of 24 inches.

| | | No. of drops to the 1st | | | | | No. of drops to the 1st | | |
|---|---|---|---|---|---|---|---|---|---|
| V3c | Wt | 1" tear | 6" tear | Complete scoreline tear | 275 W.I. | Wt | 1" tear | 6 " tear | Complete scoreline tear |
| 1 | 45.0 | 3 | 4 | 7 | 1 | 45.0 | 7 | 9 | 14 |
| 2 | 45.0 | 2 | 3 | 5 | 2 | 46.0 | 9 | 12 | 17 |
| 3 | 46.0 | 3 | 5 | 7 | 3 | 46.0 | 7 | 9 | 13 |
| 4 | 45.0 | 3 | 4 | 7 | 4 | 46.0 | 7 | 9 | 15 |
| 5 | 45.0 | 1 | 3 | 6 | 5 | 46.0 | 8 | 11 | 19 |
| 6 | 46.0 | 2 | 4 | 6 | 6 | 46.0 | 8 | 10 | 15 |
| Avg | 45.3 | 2.3 | 3.8 | 6.3 | | 45.8 | 7.7 | 9.8 | 15.7 |
| 200, W.I. | | | | | | | | | |
| 1 | 45.0 | 1 | 6 | 6 | | | | | |
| 2 | 45.0 | 1 | 4 | 6 | | | | | |
| 3 | 45.0 | 1 | 4 | 8 | | | | | |
| 4 | 45.0 | 1 | 4 | 6 | | | | | |
| 5 | 45.0 | 1 | 3 | 6 | | | | | |
| 6 | 45.0 | 1 | 4 | 6 | | | | | |
| Avg | 45.0 | 1.0 | 4.1 | 6.3 | | | | | |

TABLE 6: DROP TESTS OF NO. 10 CAN CONTAINERS TESTED AFTER EXPOSURE TO 100°F., 90% R.H. for 30 DAYS - 30" DROP HEIGHT

| V2s | Wt | 1" tear | 6" tear | Complete scoreline tear | V3c | Wt | 1" tear | 6" tear | Complete scoreline tear |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 45.0 | 22 | - | - | 1 | 43.5 | 11 | 17 | - |
| 2 | 44.5 | 20 | - | - | 2 | 43.5 | 4 | 13 | 19 |
| 3 | 44.0 | 19 | 25 | 30 | 3 | 43.0 | 9 | 11 | 18 |
| 4 | 43.0 | 15 | 20 | 29 | 4 | 43.0 | 11 | 19 | 21 |
| 5 | 43.5 | 15 | 23 | 25 | 5 | 43.0 | 11 | 12 | 21 |
| 6 | 43.0 | 19 | 27 | 31 | 6 | 43.0 | 9 | 16 | 23 |
| Avg | 43.8 | 18.3 | 23.4 | 28.7 | | 43.2 | 9.2 | 14.7 | 20.4 |
| 275, W.I. | | | | | 200, W.I. | | | | |
| 1 | 43.0 | 11 | 15 | 25 | 1 | 43.5 | 3 | 6 | 12 |
| 2 | 44.0 | 11 | 14 | 18 | 2 | 43.5 | 4 | 4 | 10 |
| 3 | 44.0 | 12 | 15 | 22 | 3 | 43.5 | 4 | 6 | 12 |
| 4 | 44.0 | 9 | 16 | 20 | 4 | 43.5 | 4 | 8 | 14 |
| 5 | 43.5 | 11 | 12 | 20 | 5 | 43.0 | 4 | 6 | 10 |
| 6 | 43.0 | 11 | 13 | 21 | 6 | 43.5 | 4 | 9 | 15 |
| Avg | 43.6 | 10.8 | 14.2 | 21 | | 43.5 | 3.8 | 6.5 | 12.2 |

TABLE 7: ROUGH HANDLING TESTS OF NO. 10 CAN CONTAINERS SUBJECTED TO THE LEVEL A TEST CYCLE

Phase I: Water Spray at 3" per hour for 16 hours, eight diagonally opposite corner drops from 24", vibration for 1-1/2 hours at 268 rpm and 1G.

Results:

| | | No. of drops to the 1st | | | |
|---|---|---|---|---|---|
| V2s | Wt | 1" tear | 6" tear | Complete scoreline tear | Comment |
| 1-6 | 44-45 lbs | - | - | - | No damage to containers during drop tests. Slight scuffing of bottom surfaces during vibration. |
| V2c | | | | | |
| 1 | 44.0 | 3 | 5 | - | Slight scuffing of bottom surfaces during vibration. |
| 2 | 44.5 | 4 | 6 | - | |
| 3 | 44.0 | 5 | 6 | - | |
| 4 | 44.0 | 3 | - | - | |
| 5 | 44.0 | 3 | 4 | - | |
| 6 | 44.0 | 4 | 5 | - | |
| Avg | 44.1 | 3.7 | 5.2 | - | |
| 275, W.I. | | | | | |
| 1 | 45.0 | 7 | - | - | Slight scuffing of bottom surfaces during vibration. |
| 2 | 44.5 | 7 | - | - | |
| 3 | 44.5 | 6 | - | - | |
| 4 | 44.5 | 8 | - | - | |
| 5 | 44.5 | - | - | - | |
| 6 | 44.0 | 6 | - | - | |
| Avg | 44.5 | 6.8 | - | - | |

TABLE 7: ROUGH HANDLING TESTS OF NO. 10 CAN CONTAINERS SUBJECTED TO THE LEVEL A TEST CYCLE (Continued)

Phase I: (Results) (Continued)

| 200 W.I. | Wt | No. of drops to the 1st: 1" tear | 6" tear | Complete scoreline tear | Comment |
|---|---|---|---|---|---|
| 1 | 44.0 | 3 | 4 | 8 | Failed, not tested further. |
| 2 | 43.5 | 4 | 6 | 8 | |
| 3 | 43.5 | 3 | 6 | 8 | |
| 4 | 44.0 | 3 | 4 | 8 | |
| 5 | 44.0 | 2 | 4 | 8 | |
| 6 | 43.5 | 1 | 5 | 7 | |
| Avg | 43.7 | 2.7 | 4.8 | 7.8 | |

Phase II: Exposure to -20°F. for 48 hours, eight diagonally opposite corner drops from 24", vibration for 1-1/2 hours at 268 rpm and 1G.

Results:

No further damage was sustained by any of the packs during drop tests and vibration after exposure to -20°F. for 48 hours.

TABLE 7: ROUGH HANDLING TESTS OF NO. 10 CAN CONTAINERS SUBJECTED TO THE LEVEL A TEST CYCLE (Continued)

Phase III: Exposure to 100°F., 90% R.H. for 7 days, eight diagonally opposite corner drops from 24", vibration for 1-1/2 hours at 268 rpm and 1G.

Results:

| | No. of drops to the 1st | | | |
|---|---|---|---|---|
| | 1" tear | 6" tear | Complete scoreline tear | Comment |
| **V2s** | | | | |
| 1 | - | 2 | - | No further damage except further scuffing of bottom surfaces during vibration. |
| 2 | - | 7 | - | |
| 3 | 3 | 5 | - | |
| 4 | - | - | - | |
| 5 | 4 | - | - | |
| 6 | - | - | - | |
| Avg | - | - | - | |
| **V3c** | | | | |
| 1 | - | - | 2 | No further damage except slight scuffing of the bottom surfaces during vibration. |
| 2 | - | - | 8 | |
| 3 | - | - | - | |
| 4 | - | - | 2 | |
| 5 | - | - | 8 | |
| 6 | - | - | 8 | |
| Avg | - | - | 5.6 | |
| **275, W.I.** | | | | |
| 1 | - | 3 | - | Slight sucffing of bottom surfaces during vibration. |
| 2 | - | 2 | 6 | |
| 3 | - | 1 | 3 | |
| 4 | - | 1 | 3 | |
| 5 | - | 1 | 5 | |
| 6 | - | - | 2 | |
| Avg | - | 1.6 | 3.8 | |

TABLE 8: WATER ABSORPTION TEST OF V2s & V3c FIBERBOARD SAMPLES AFTER 24 HOURS WATER IMMERSION

| Sample No. | V2s Solid Fiberboard Initial weight (Grams) | Final weight (Grams) | % H2O pick up | Sample No. | V3c Corrugated Fiberboard Initial weight (Grams) | Final weight (Grams) | % H2O pick up |
|---|---|---|---|---|---|---|---|
| 1 | 43.0 | 69.8 | 62 | 1 | 30.3 | 61.7 | 103 |
| 2 | 43.2 | 70.7 | 64 | 2 | 29.7 | 60.8 | 104 |
| 3 | 43.4 | 71.0 | 64 | 3 | 30.3 | 62.0 | 104 |
| 4 | 43.4 | 70.7 | 63 | 4 | 30.0 | 61.7 | 105 |
| 5 | 43.3 | 71.2 | 64 | 5 | 29.9 | 60.6 | 102 |
| 6 | 43.2 | 70.8 | 64 | 6 | 30.2 | 60.9 | 101 |
| 7 | 43.4 | 71.5 | 65 | 7 | 30.0 | 60.6 | 102 |
| 8 | 43.4 | 71.2 | 64 | 8 | 30.1 | 61.8 | 105 |
| 9 | 42.5 | 70.6 | 66 | 9 | 30.3 | 61.0 | 101 |
| 10 | 42.4 | 70.3 | 66 | 10 | 30.1 | 61.3 | 104 |
| | | Average | 64% | | | Average | 103% |
| | 275 lb. Test Wax Impregnated | | | | 200 lb. Test Wax Impregnated | | |
| 1 | 40.5 | 56.7 | 40 | 1 | 26.5 | 40.4 | 52 |
| 2 | 37.6 | 54.3 | 44 | 2 | 26.2 | 40.8 | 56 |
| 3 | 39.0 | 55.7 | 43 | 3 | 26.2 | 40.7 | 55 |
| 4 | 38.7 | 55.0 | 42 | 4 | 26.5 | 41.1 | 55 |
| 5 | 38.5 | 55.0 | 43 | 5 | 27.5 | 42.6 | 55 |
| 6 | 47.3 | 54.0 | 45 | 6 | 26.0 | 40.3 | 55 |
| 7 | 40.0 | 56.7 | 42 | 7 | 26.2 | 40.2 | 53 |
| 8 | 38.8 | 54.9 | 41 | 8 | 26.2 | 40.2 | 53 |
| 9 | 39.0 | 54.8 | 41 | 9 | 26.5 | 40.8 | 54 |
| 10 | 39.0 | 55.9 | 43 | 10 | 28.1 | 42.5 | 51 |
| | | Average | 42% | | | Average | 54% |

TABLE 9: PUNCTURE TESTS OF FIBERBOARD SAMPLES CONDITIONED AT 73°F., 50% R.H. FOR 48 HOURS & SAMPLES SUBJECTED TO 24 HOURS WATER IMMERSION

| Test No.* | V2s B.U.** | V3c B.U. | 275 W.I. B.U. | 200 W.I. B.U. | 275 Std B.U. | 200 Std B.U. |
|---|---|---|---|---|---|---|
| | | | (73°F., 50% R.H.) | | | |
| 1 | 533 | 441 | 395 | 273 | 343 | 240 |
| 2 | 458 | 450 | 377 | 252 | 352 | 235 |
| 3 | 546 | 443 | 370 | 277 | 355 | 235 |
| 4 | 552 | 443 | 347 | 268 | 345 | 230 |
| 5 | 548 | 442 | 373 | 260 | 352 | 237 |
| Average | 545 | 444 | 372 | 266 | 349 | 235 |
| | | | (24 Hours Water Immersion) | | | |
| 1 | 552 | 182 | 326 | 236 | NOT TESTED | |
| 2 | 557 | 193 | 348 | 231 | | |
| 3 | 563 | 191 | 340 | 226 | | |
| 4 | 558 | 200 | 320 | 260 | | |
| 5 | 565 | 188 | 335 | 258 | | |
| Average | 559 | 191 | 334 | 242 | | |

*Each test represents an average of three punctures.
**B.U. - Beach Units. Defined as inch ounces per inch of tear.

TABLE 10: STIFFNESS TEST OF FIBERBOARD SAMPLES CONDITIONED AT 73°F., 50% R.H. FOR 48 HOURS - TESTED WITH THE GENERAL ELECTRIC BEACH PUNCTURE TESTER

| Type V2s | Beach Units | | | Type V3c | Beach Units | | |
|---|---|---|---|---|---|---|---|
| 1 | 285 | | 275 | 1 | 195 | | 170 |
| 2 | 270 | | 265 | 2 | 210 | | 170 |
| 3 | 230 | | 275 | 3 | 190 | | 180 |
| 4 | 270 | | 230 | 4 | 185 | | 165 |
| 5 | 265 | | 220 | 5 | 190 | | 165 |
| Average | | 259 | | Average | | 182 | |
| 275 W.I. | | | | 200 W.I. | | | |
| 1 | 255 | | 260 | 1 | 195 | | 200 |
| 2 | 260 | | 265 | 2 | 195 | | 185 |
| 3 | 255 | | 255 | 3 | 190 | | 185 |
| 4 | 255 | | 255 | 4 | 190 | | 190 |
| 5 | 270 | | 250 | 5 | 195 | | 185 |
| Average | | 258 | | Average | | 191 | |
| 275 Std | | | | 200 Std | | | |
| 1 | 160 | | 160 | 1 | 130 | | 125 |
| 2 | 160 | | 155 | 2 | 120 | | 110 |
| 3 | 160 | | 160 | 3 | 110 | | 105 |
| 4 | 150 | | 160 | 4 | 110 | | 110 |
| 5 | 165 | | 150 | | | | |
| Average | | 158 | | Average | | 115 | |

TABLE 11: MULLEN TEST OF FIBERBOARD SAMPLES CONDITIONED AT 73°F., 50% R.H. FOR 48 HOURS AND SAMPLES SUBJECTED TO 24 HOURS WATER IMMERSION

| Test No.* | V2s lbs/in² | V3c lbs/in² | 275 W.I. lbs/in² | 200 W.I. lbs/in² |
|---|---|---|---|---|
| | | | (73°F., 50% R.H.) | |
| 1 | 674 | 500 | 332 | 245 |
| 2 | 698 | 510 | 396 | 242 |
| 3 | 743 | 525 | 408 | 233 |
| 4 | 740 | 490 | 385 | 263 |
| 5 | 698 | 507 | 400 | 233 |
| 6 | 728 | 498 | 343 | 244 |
| 7 | 725 | 495 | 339 | 207 |
| 8 | 710 | 490 | 294 | 238 |
| Average | 715 | 496 | 362 | 238 |
| | | (24 Hours Water Immersion) | | |
| 1 | 495 | 160 | 190 | 111 |
| 2 | 507 | 190 | 189 | 113 |
| 3 | 528 | 188 | 193 | 111 |
| 4 | 520 | 178 | 196 | 112 |
| 5 | 520 | 168 | 192 | 113 |
| 6 | 540 | 182 | 193 | 95 |
| 7 | 490 | 170 | 185 | 113 |
| 8 | 500 | 177 | 195 | 112 |
| Average | 513 | 177 | 192 | 110 |

*Each test represents an average of 6 tests.

TABLE 12: MULLEN BURST TEST OF FIBERBOARD SAMPLES EXPOSED TO CARBON-ARC LIGHT FOR 50 HOURS AND OF CONTROL FIBERBOARD SAMPLES CONDITIONED AT 73°F., 50% R.H. FOR 48 HOURS

| | Pounds Per Square Inch | | | | | | |
|---|---|---|---|---|---|---|---|
| V2s | | | | | | | |
| Control | | | | | | | |
| 1 | 770 | 700 | 760 | 690 | 680 | 710 | Average - 719 |
| 2 | 690 | 730 | 700 | 750 | 750 | 700 | |
| Carbon-Arc | | | | | | | |
| 1 | 870 | 660 | 730 | 700 | 680 | 680 | |
| 2 | 750 | 700 | 710 | 790 | 680 | 750 | Average - 725 |
| V3c | | | | | | | |
| Control | | | | | | | |
| 1 | 430 | 500 | 450 | 510 | 450 | 500 | |
| 2 | 570 | 520 | 450 | 520 | 490 | 540 | Average - 490 |
| Carbon-Arc | | | | | | | |
| 1 | 460 | 480 | 440 | 460 | 450 | 480 | |
| 2 | 430 | 500 | 430 | 500 | 470 | 500 | Average - 467 |
| 275 lb. Test Wax Impregnated | | | | | | | |
| Control | | | | | | | |
| 1 | 350 | 310 | 280 | 280 | 360 | 310 | |
| 2 | 380 | 350 | 370 | 340 | 340 | 360 | Average - 336 |
| Carbon-Arc | | | | | | | |
| 1 | 420 | 410 | 380 | 340 | 390 | 340 | |
| 2 | 360 | 390 | 300 | 350 | 350 | 390 | Average - 368 |

TABLE 12: MULLEN BURST TEST OF FIBERBOARD SAMPLES EXPOSED TO CARBON-ARC LIGHT FOR 50 HOURS AND OF CONTROL FIBERBOARD SAMPLES CONDITIONED AT 73°F., 50% R.H. FOR 48 HOURS (Continued)

| | Pounds Per Square Inch | | | | | | |
|---|---|---|---|---|---|---|---|
| **200 lb. Test Wax Impregnated** | | | | | | | |
| Control | | | | | | | |
| 1 | 260 | 260 | 270 | 240 | 220 | 220 | |
| 2 | 240 | 200 | 270 | 260 | 200 | 240 | Average - 240 |
| Carbon-Arc | | | | | | | |
| 1 | 290 | 190 | 250 | 260 | 200 | 280 | |
| 2 | 230 | 280 | 220 | 220 | 230 | 250 | Average - 242 |
| **275 lb. Test Standard** | | | | | | | |
| Control | | | | | | | |
| 1 | 300 | 430 | 370 | 350 | 340 | 300 | |
| 2 | 370 | 320 | 350 | - | 350 | 300 | Average - 344 |
| Carbon-Arc | | | | | | | |
| 1 | 410 | 340 | 340 | 290 | 300 | 350 | |
| 2 | 340 | 370 | 300 | 350 | 340 | 350 | Average - 340 |
| **200 lb. Test Standard** | | | | | | | |
| Control | | | | | | | |
| 1 | 250 | 220 | 230 | 230 | 270 | 250 | |
| 2 | 250 | 240 | 250 | 220 | 250 | - | Average - 242 |
| Carbon-Arc | | | | | | | |
| 1 | 200 | 230 | 230 | 240 | 250 | 270 | |
| 2 | 260 | 270 | 230 | 240 | 250 | 260 | Average - 244 |

TABLE 13: MOISTURE CONTENT OF SAMPLES TAKEN AFTER COMPRESSION [illegible] FROM CONTAINERS CONDITIONED AT 100°F., 90% R.H. FOR 30 DAYS*

| V2s | Initial weight (Grams) | Dry weight (Grams) | Percent moisture |
|---|---|---|---|
| 1 | 30.00 | 27.80 | 7.90 |
| 2 | 29.40 | 28.30 | 3.90 |
| 3 | 24.80 | 23.65 | 4.90 |
| 4 | 32.15 | 30.45 | 5.10 |
| 5 | 31.65 | 30.00 | 5.50 |
| Average | 5.46 | | |
| **275 W.I.** | | | |
| 1 | 21.15 | 20.35 | 3.90 |
| 2 | 17.35 | 16.75 | 3.60 |
| 3 | 18.41 | 17.55 | 4.90 |
| 4 | 20.50 | 19.50 | 3.10 |
| 5 | 24.88 | 24.34 | 2.20 |
| Average | 3.54 | | |

| V3c | Initial weight (Grams) | Dry weight (Grams) | Percent moisture |
|---|---|---|---|
| 1 | 19.65 | 18.85 | 4.20 |
| 2 | 29.45 | 27.90 | 5.50 |
| 3 | 25.67 | 23.70 | 8.30 |
| 4 | 23.10 | 21.75 | 6.20 |
| 5 | 27.30 | 26.30 | 3.80 |
| Average | 5.60 | | |
| **200 W.I.** | | | |
| 1 | 23.85 | 23.05 | 3.50 |
| 2 | 25.90 | 25.10 | 3.20 |
| 3 | 24.35 | 23.50 | 3.62 |
| 4 | 23.60 | 22.95 | 2.80 |
| 5 | 26.55 | 26.00 | 2.10 |
| Average | 3.04 | | |

*The percent moisture was determined as the difference between standard conditions and the conditions stated above, taken as a percent of the dry weight.

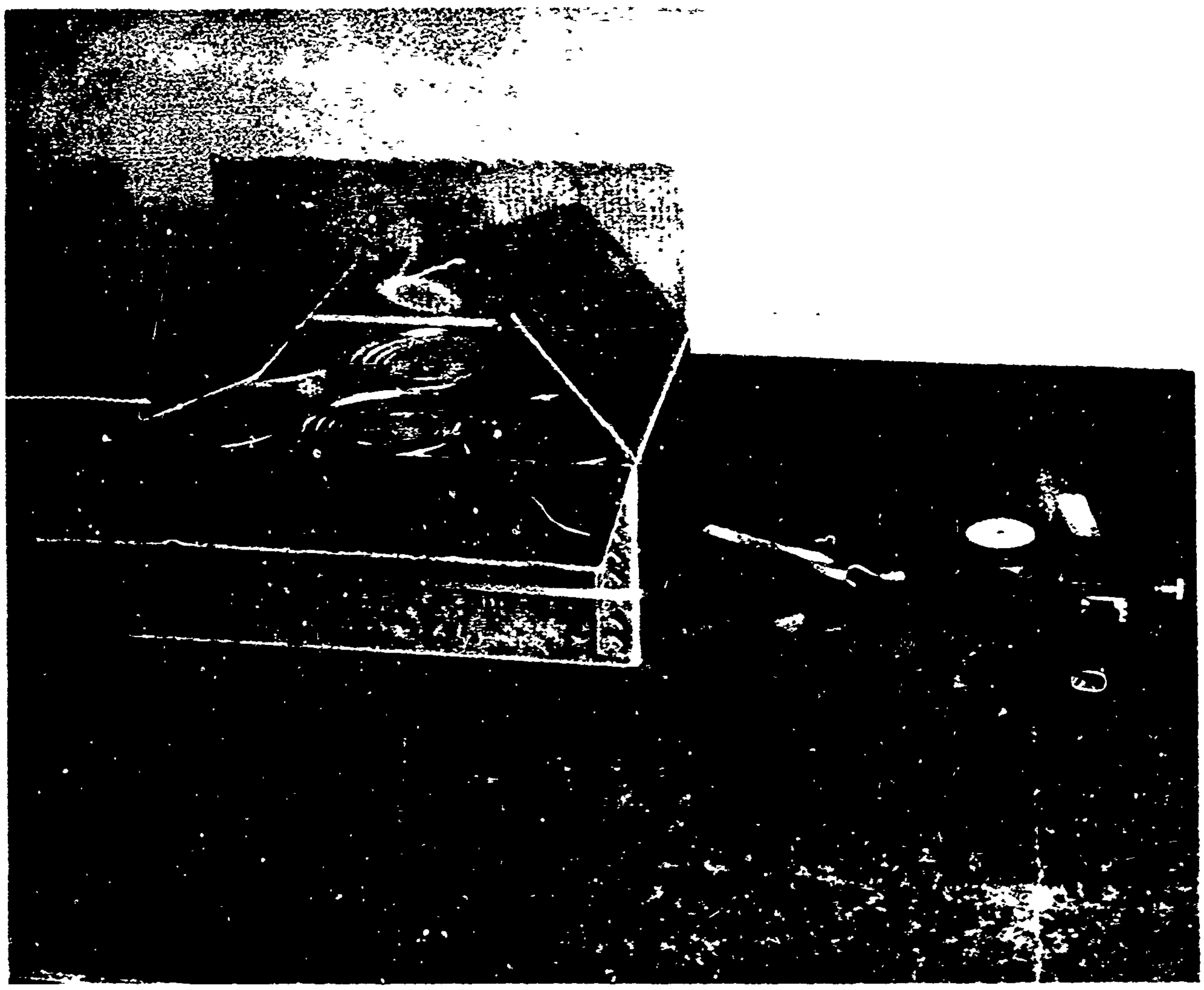


FIGURE 1

Typical Sliding Friction Test Using the Hunter Gage

FIGURE 2

Results of Compression Tests on Containers Subjected to Various Environmental Conditions

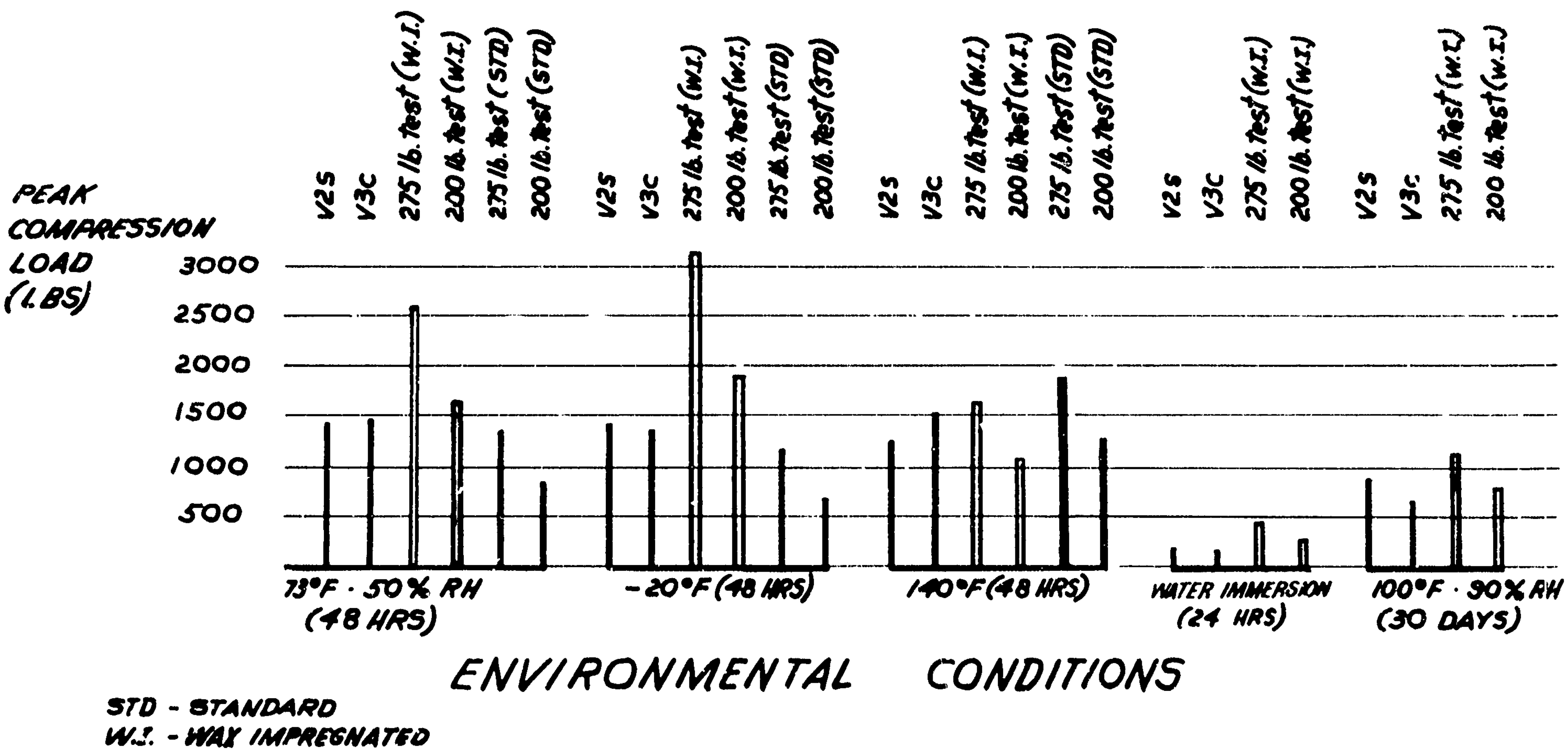
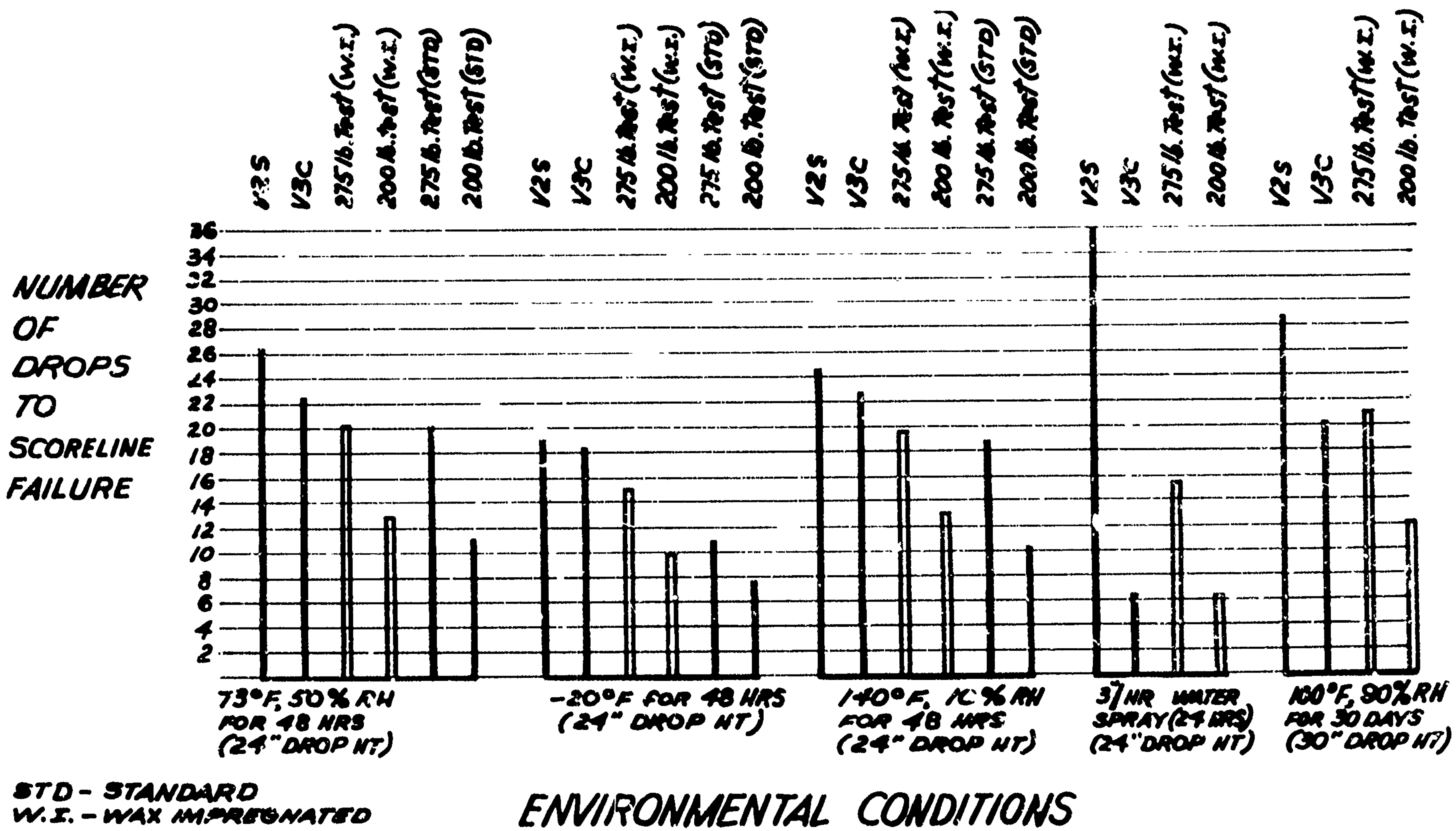


FIGURE 2

Results of Drop Tests of Containers Exposed to Various Environmental Conditions



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13 ABSTRACT The purpose of this study was to evaluate the performance of wax/resin impregnated fiberboards and containers for applicability for use in shipment overseas under all environmental conditions, and as a substitute for conventional weather resistant materials which may become critical and are in short supply during periods of emergency.

Sixteen different tests were performed conforming to ASTM Standards or to the requirements of Federal Specifications, utilizing up to 5 different environmental conditions: standard, arctic, hot desert, rain and tropical. Containers were given compression tests, drop tests and vibration tests. Components were tested for ply separation, water absorption, puncture resistance and stiffness, burst (Mullen), peeling, bleeding, blocking, scoreability and bending, grease resistance, solar radiation, sliding friction, printability, and flameability.

It was found that wax impregnation contributes significantly to increased compression strength through increased resistance to water absorption, and containers of wax impregnated board were superior to other grades of fiberboard in compression resistance. Differences in rough handling were negligible. This was related to the findings that wax impregnation had little effect on dry puncture resistance and on the Mullen bursting strength. Test results indicate that 275 pound test is the minimum grade which should be considered for the wax impregnation process for Military use in overseas shipment.


(CONTINUED)

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| 14 KEY WORDS | LINK A ROLE | LINK A WT | LINK B ROLE | LINK B WT | LINK C ROLE | LINK C WT |
|---|---|---|---|---|---|---|
| Impregnation | 8 | | | | | |
| Fiberboard | 2, 1 | | 9 | | | |
| Containers | 2, 1 | | 9 | | | |
| Waxes | 1 | | 9 | | | |
| Corrugated | 0 | | 0 | | | |
| Impact Shock | | | 8 | | | |
| Compression | | | 8 | | | |
| Vibration | | | 8 | | | |
| Tests | | | 8 | | | |
| Environmental Tests | | | 8 | | | |
| Transportation | | | 4 | | | |
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## ABSTRACT (Continued)

It is recommended that consideration be given to wider use of wax-impregnated containers in Military supply, especially for overseas shipment; that wax impregnated board of not less than ~~350~~ 275 pounds test Mullen burst dry and 175 pounds test Mullen burst wet be considered as a substitute for selected items, especially in palletized loads; that performance data for evaluation be obtained from test shipments; and that higher grade wax impregnated boards be investigated for other purposes, such as sheathing, unitizers, and consolidation type containers for overseas shipment.