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UNIVERSITY OF MISSOURI RESEARCH REACTOR FACILITY

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TEST REPORT

TESTING OF A RADIO-ACTIVE MATERIAL SHIPPING CONTAINER TO THE REQUIREMENTS OF THE ATOMIC ENERGY COMMISSION REGULATION 10CFR, PART 71

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Dated: September 29, [illegible]

S U M M A R Y

A shipping container designed for transporting unirradiated nuclear reactor fuel elements was tested in accordance with A.E.C. Packaging Regulations, detailed in 10 CFR, Part 71. This container was found to meet or exceed all requirements of the Commission.

The results of the tests conducted clearly indicate that this container may be expected to resist both normal transport and hypothetical accident conditions with negligible possibility of failure.

INTRODUCTION

The Engineering Department of the Nuclear Metals Division, National Lead Company, Albany, New York, was requested to conduct certain tests on a radioactive material shipping container. These tests are described in the A.E.C. Regulation, 10 CFR, Part 71, Appendices "A" and "B" for Fissile Class II shipments.

Tests to be conducted fell into two categories. The first was for normal conditions of transport and the second for hypothetical accident conditions.

Certain conditions of normal transport were not included in the testing program. No attempt was made to subject the shipping container to direct sun light at an ambient temperature of 130°F in still air and sun light, or minus 40°F in still air and shade. Atmospheric test of 0.5 times standard atmospheric pressure also was not applied. These three conditions were so thoroughly covered by design, that actual testing would have been redundant. All materials used, and the design, exceed these temperature and pressure conditions by a wide margin. As an example, Appendix "A" shows that the design analysis of the barrel has a safety factor of 4 when subjected to 5 times its own weight when treated as a simple beam. Similar conservatism was used throughout the design.

Conditions for all Testing

All of the tests performed were made in strict accordance with the applicable A.E.C. Regulations. Wherever a question of interpretation existed, a conservative, i.e., more severe, approach was adopted. Records were maintained on all tests, generally in the form of photographs, which are available for examination if copies reproduced in this report are not satisfactorily clear.

Plate #1 shows the internal and external shipping container prior to testing. This container was made in strict accordance with the following drawings:

D-34710, Container, Shipping, Fuel Elements
  NOTE: The following changes have been made to this drawing:
    a) Check valve removed
    b) Cardboard sleeves have been replaced with sheet metal sleeves containing cardboard inserts not to exceed dimensions E and D.

C-34711, Container, Outer, Shipping

C-34712, Container, Inner, Shipping
  NOTE: The check valve has been removed from container.

C-34713, Support, Internal, Shipping Container

The general design of this container is a "barrel within a barrel." The external barrel is made from sections of two 55 gallon drums, welded together, to make a drum approximately fifty inches high. Inside this barrel are two welded square frames, complete with internal insulation pads and steel hoops which are welded to the barrel itself. The inner container is bolted into these two square frames. The shipping container has neither lifting devices nor tie-down devices.

The inner container is a section of heavy walled pipe, sealed shut at one end by welding in a plate, and on the other end with a flange gasket and cover. The flange and cover are drilled and tapped for cap screws, insuring a positive closure. The nuclear fuel elements themselves are placed in four tubes constructed of cardboard and sheet metal. Vermiculite is packed around the four tubes and in the annular region between the inner and outer barrels. Each fuel element is polyethylene wrapped and is supported on both ends by transite insulate and polystyrene pads to make up excess space. The resultant container is simple, rugged, and readily fabricated. No materials are used that may result in internal reactions.

Preparation for Testing

For testing, certain changes and additions to the shipping container were necessary. Simulated fuel elements were required that had roughly the same mass, material, and dimensions as real fuel elements. This type fuel element weighs up to thirteen pounds; for conservation, fifteen pound dummy elements were used. Because this type of fuel element is basically aluminum, 2-1/2" diameter by 32" long, heavy walled aluminum pipe was used. Also, in each of the four compartments a piece of aluminum wire, 36" long, was placed. In case of a meltdown situation, the wire would go first and would simulate the thickness of a fuel plate. Also, the wire would show if there was a hot spot; the thermocouple did not show. Through the top of the inner cover, a hole was drilled and tapped for a 1/8" pipe thread. This hole was plugged except for the thermal test when it was used for a conax fitting and a thermocouple. The thermocouple location was about three inches inside the inner container.

Prior to the thermal test, lifting straps were welded on the outer barrel. The barrel, ready for testing, weighed 419/lbs. The contents were 60/lbs, giving a net weight for the container alone of 359/lbs.

Plate #2 shows the dummy elements and the appearance of the inner container.

TEST #1 - VIBRATION

Test Requirement: The shipping container shall be exposed to vibration normally incidental to transport.

This test was performed by shipping the container from Hicksville, Long Island to Albany, New York, by commercial carrier. The distance covered is approximately 200 miles. Examination of the shipping container on receipt in Albany indicated absolutely no damage or change in appearance in the container or contents.

TEST #2 - WATER SPRAY

Test Requirement: It is required that a water spray sufficiently heavy to keep the exposed surface of the package wet except for the bottom shall be maintained for 30 minutes minimum.

This test was performed simply by drenching the barrel with a high volume of water from a garden hose for the required 30 minutes.

Plate #3 shows the test set up. The volume of water used for this test was considerably higher than required. A simple spraying, such as would occur during a rain storm, would probably not have wet the contents at all in this time period. On removal of the lid, it was discovered that the vermiculite packed in the annular region between barrels was wet in the vicinity of the screened off water drain holes. No harm was caused to the package contents other than this dampening.

TEST #3 - FREE DROP

Test Requirement: Within 2-1/2 hours after conclusion of the water spray a free drop shall be made on to a flat, essentially unyielding horizontal surface, striking in a position for which maximum damage is expected.

Because this package weighed less than 10,000 pounds (420 pounds actual) the free fall distance was four feet. Examination of the container indicated to us that the worse position for the drop would be on a corner. Because of the possibility of the top falling off in such a test, the top corner would normally be used. Anticipating, however, that the four foot drop would not cause severe damage but could make top removal difficult, we elected to drop the barrel on a bottom corner. This allowed us to save the top of the barrel intact for the hypothetical accident condition of a thirty foot drop.

Our interpretation of a hard essentially unyielding surface, such as would most likely occur in the vicinity of such a shipment, was macadam pavement.

As shown by Plate #4, we lifted the barrel with a fork lift and a rope, on an angle, and cut the rope to drop the barrel free. The corner was dented in approximately three inches for a nineteen inch span as is evident from the photographs in Plate #4. We consider it significant that the screening over the drain hole did not tear loose in this test but remained in position and retained the vermiculite in the annular area. Examination of the barrel and contents externally and internally revealed no further damage.

TEST #4 - PENETRATION

Test Condition: Drop a thirteen pound, 1-1/4" diameter steel bar endwise on to the surface most vunerable to puncture from a height of four feet.

A study of the barrel indicated to us that the most vunerable surface to puncture would be approximately half-way up the barrels aide just off of the weld line. The bar was dropped in this position and caused a 1/8" deep dent, the same diameter as the rod. Damage was so negligible it could not be shown by photograph and we concluded that this test gave completely satisfactory results.

TEST #5 - COMPRESSION

Test Condition: A compressive load equal to five times the package weight is required, applied normally and uniformly against the top and bottom of the package for twenty-four hours.

Plate #5 shows the barrel during the compression test which we maintained for seventy-two hours. As anticipated, no change whatsoever occurred.

TEST #6 - FREE DROP

Test Condition: A free drop shall be made through a thirty foot distance on to a flat essentially unyielding horizontal surface striking the surface in a position for which maximum damage is expected.

As described previously in this report, we elected to drop the barrel on an upper corner on to macadam. We used a "cherry picker" type crane and a sling to elevate the barrel. A rope with a bow type knot connected the sling to the hook and on a signal a tug on the rope released the barrel for a free fall. Plates #6 and #7 show the test set up and results.

The top of the barrel, as anticipated, came partially off of the barrel. It is believed that the strap prevented the top from falling off until the top and barrel were sufficiently crushed together so that they were essentially one unit and could not be separated by normal means. A small amount of vermiculite flew out of the barrel on impact as a fine spray for about ten feet. Loss of vermiculite by this effect was small and when the barrel was stood up, the vermiculite still covered the inner container. This vermiculite level was maintained later for the thermal test.

The corner of the barrel was smashed in as far as the inner container. No damage occurred at any point on the outside barrel other than at this corner. Examination of the inner barrel and dummy fuel element placed in the inner barrel prior to testing showed that no damage had occurred to either.

TEST #7 - PUNCTURE

Test Condition: A free drop through a distance of forty inches on to a six inch diameter cylinder shall be made in a position for which maximum damage is expected. The bar shall be eight inches long minimum and shall not have more than a one-quarter inch radius. The long axis of the bar shall be normal to the package surface.

We concluded, as in the previous penetration test, that the worst position would be the side of the barrel just off of the weld end on one of the ribs. The barrel was placed in this position with a pair of slings suspended by a rope from a fork lift as shown in Plate #8. The drop was made by cutting the rope. No puncture occurred. The outer barrel was dented in to within approximately two inches of the inner barrel. The vermiculite packing in this region undoubtedly prevented more severe damage. Examination of the contents revealed no damage to the inner barrel or its contents. Loss of vermiculite from the partially opened upper end was negligible.

TEST #8 - THERMAL

Test Condition: Exposure for thirty minutes within a source of radiant heat having a temperature of 1475°F. The package shall not be artificially cooled until the temperature at the package center has begun to fall.

This test was conducted by placing the barrel in a large furnace. A thermocouple was located in the inner barrel by means of a Conax fitting through the barrel lid. Plate #9 shows the barrel as it was being removed from the furnace. It can be noted in this plate that handling hooks were welded on the outside of the barrel for this test. For one hour from initiation of test, that is thirty minutes after removal from the furnace, there was absolutely no temperature change. Over the next two-hour period, the temperature gradually rose to a maximum of 185°F because of the large quantity of vermiculite involved. Fifteen hours later, the temperature was still 160°F in the center. Examination of the contents indicated absolutely no damage to the inner container or its contents, including the polyethylene wrapping on the dummy fuel elements and the cardboard tubes. Plate #10 shows the internal and external barrels after this test. (See Appendix A for repeat of this test with vermiculite removed from top of container.)

TEST #9 - WATER IMMERSION

Test Condition: Immersion in water for twenty-four hours to a depth of at least three feet.

This test was conducted on the inner container only because of the problem of obtaining a tank large enough to test the container at its normal configuration. The external container, of course, is not designed to exclude water and, therefore, has no value in the test. After twenty-four hours in the tank under three feet of water, the inner container was opened and the contents were perfectly dry. Plates #11 and #12 show the final test and results. (See Appendix A for repeat of this test with vermiculite removed from top of container.)

CONCLUSIONS

Based upon the tests performed, it is concluded that no significant physical damage will occur to fuel elements shipped in containers of this type. Furthermore, it is concluded that increase in possibility of a nuclear incident caused by the damage seen on this container in the various tests is zero. Change in lateral and vertical spacing of shipping containers due to test damage was absolutely nil.

It is concluded that the container under test is designed with an enormous safety factor, far beyond the original intent.

APPENDIX A

Repeat of Test #8 and Test #9 with Vermiculite Below Inner Container Flange:

This test was an exact duplicate of the previous fire test in all respects except for the vermiculite being below the inner container flange.

The container was left in the furnace for (30) minutes during which time no temperature change was noted on the inner barrel thermocouple. Approximately thirty (30) minutes after removal from the furnace, the temperature in the barrel began to rise and eventually attained a temperature of 230°F.

An examination of the contents of the inner container revealed that no structual damage had been done to either the container or the dummy fuel elements in the container. It was found that the polyethylene wrapping around the fuel elements had puckered and deteriorated in a couple of areas. It was also noted that a piece of masking tape used to close the polyethylene sleeve had turned brown.

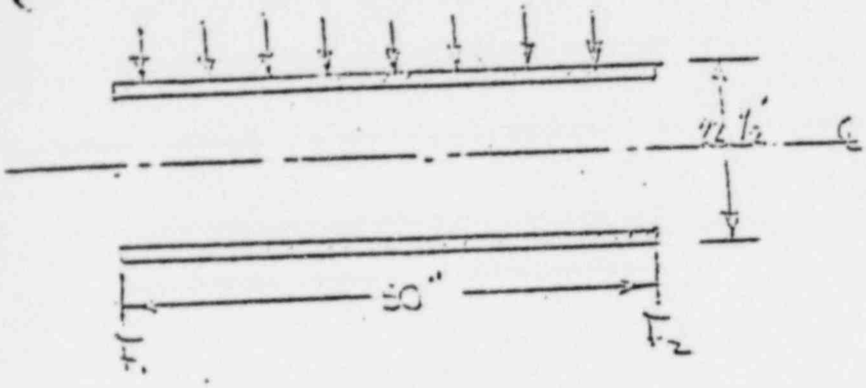
The inner container was then closed and removed from the outer container. The thermocouple was removed and the hole was closed with a pipe plug. The container was then placed in the water tank as had been done previously for the first water test. After seventy-two (72) hours the container was removed, opened, and found to be completely dry.

APPENDIX A (Cont'd)

Based on the results observed, we concluded that the shipping container and contents were structually undamaged and adequately protected the fuel elements from water and fire damage.

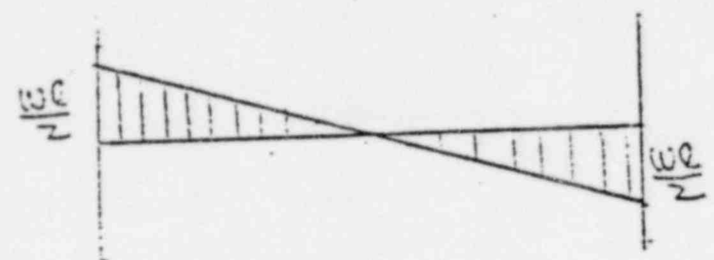
APPENDIX A

Problem: How much weight, equally distributed, can shipping container D-34710 support as a simple beam.

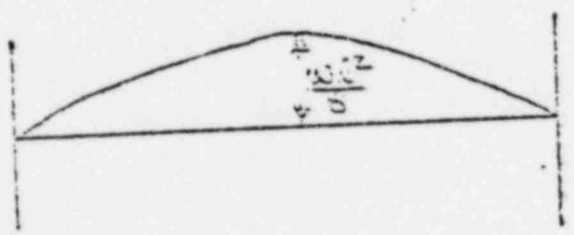


Thickness=0.040"

Weight=419# loaded



Shear Diagram



Moment Diagram

$M_{max} = \sigma \frac{I}{C}$; therefore $\sigma = \frac{C}{I}$

But $\frac{I}{C} = \frac{\pi}{32} \; \frac{D^4 - D_i^4}{D} = \frac{\pi}{32} \; \frac{[22.5^4 - 22.42^4]}{22.5} = 20.2$

And $M = \frac{wl^2}{8} = \frac{(42)(50^2)}{8} = 13{,}125$

$= \frac{MC}{I} = \frac{13{,}125}{20.2} = 650 \; \#/IN^2$

If proportional limit for carbon steel is conservatively 18,000 psi, then completely safe, i.e., (5)(650) = 3,250 $\#/IN^2$, or = 1/4 the maximum safe loading.

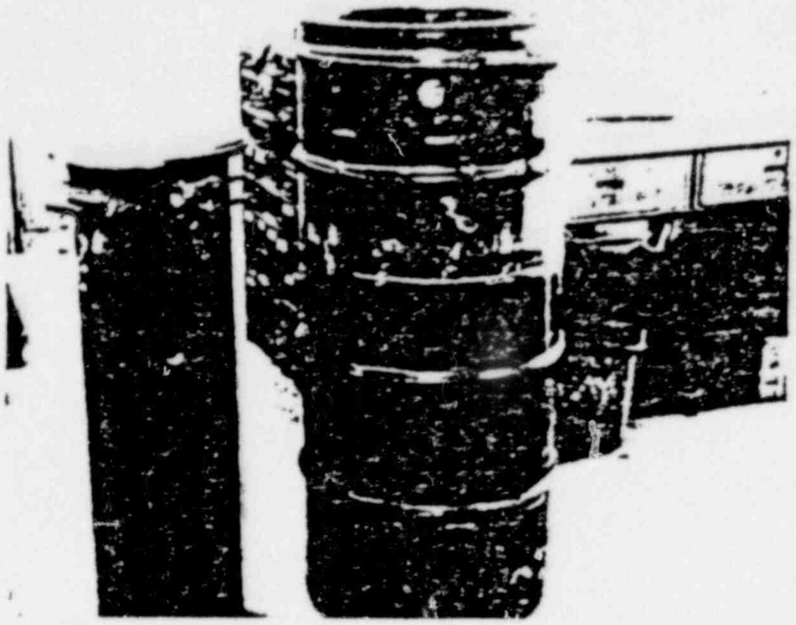


FIG. 1 HORIZONTAL VIEW

FIG. 2 VERTICAL VIEW

PLATE I TWO VIEWS OF THE INTERNAL AND EXTERNAL CONTAINERS, PRIOR TO TESTING.

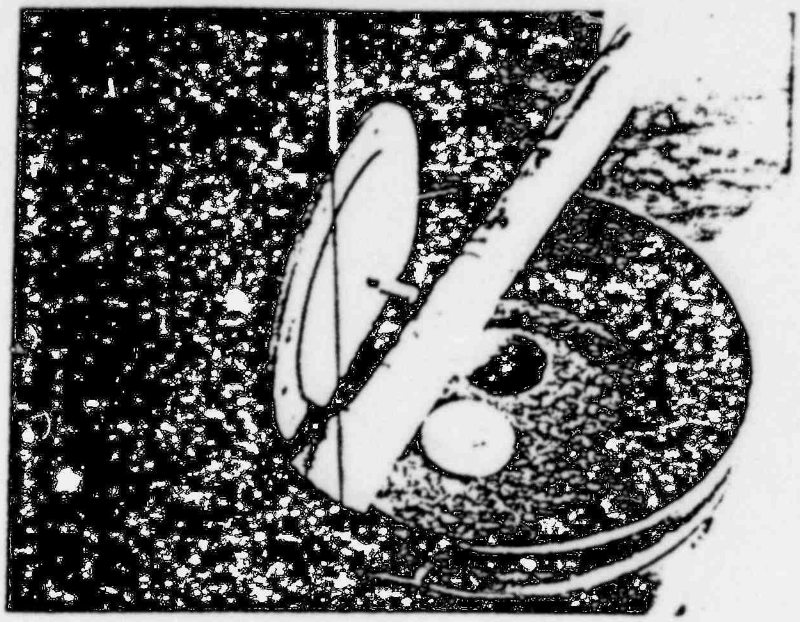


FIG. 3 NOTE PRESSURE RELIEF VALVE

FIG. 4 DUMMY ELEMENTS AND ALUMINUM WIRE

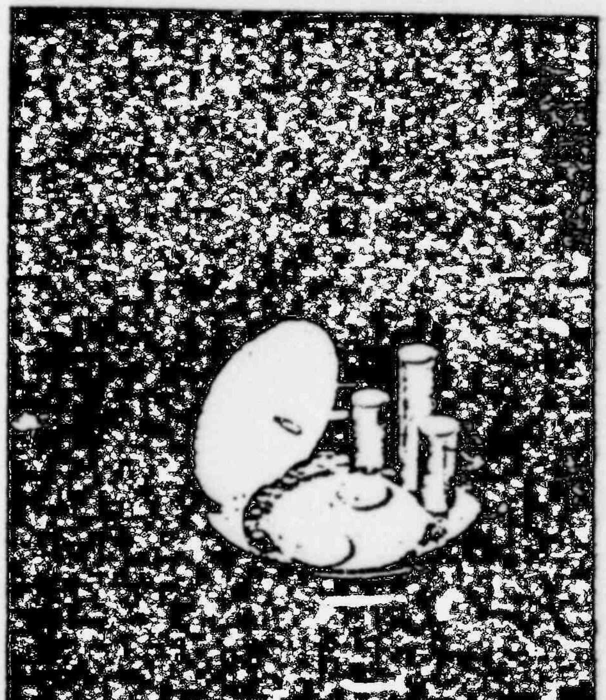


FIG. 5 ALUMINUM TUBING USED TO SIMULATE AN ELEMENT SHOWN

PLATE II VIEWS OF INNER CONTAINER BEING PACKED. DUMMY FUEL ELEMENTS AND ALUMINUM WIRE SHOWN

FIG. 6 NOTE WATER CASCADING OFF LOWER PART OF BARRELL

PLATE III WATER SPRAY TEST

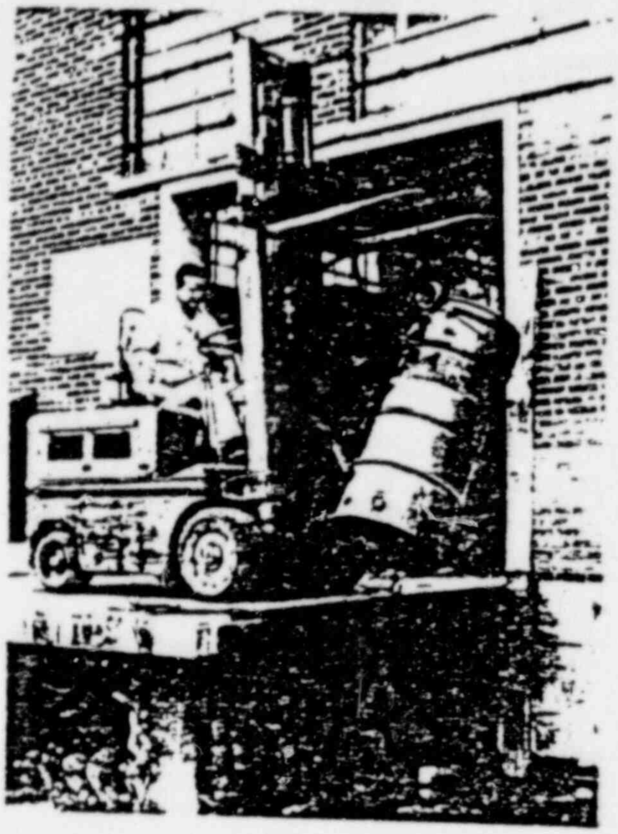


FIG. 7 BARREL SUSPENDED
READY FOR DROP

FIG. 8 DAMAGE CAUSED BY
DROP

PLATE IV 48" FREE FALL

FIG. 9 COPPER CRUCIBLES USED FOR WEIGHTS

PLATE V COMPRESSION TEST

FIG. 10 BARREL SUSPENDED READY TO DROP. NOTE RELEASE ROPE.

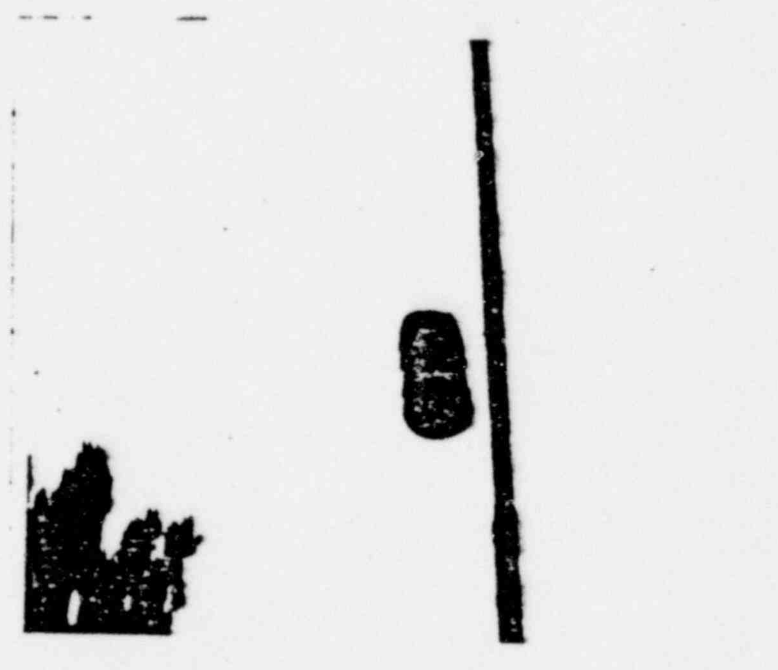


FIG. 11 BARREL IN DESCENT

PLATE VI THIRTY FOOT FREE FALL

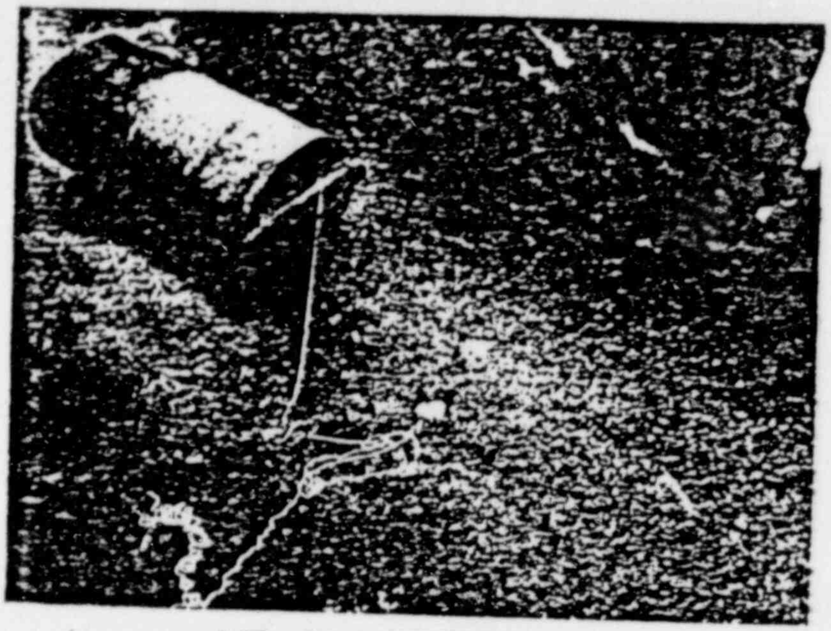


FIG. 12 BARREL AS IT LANDED. NOTE FINE SPRAY OF VERMICULITE AND LACK OF MAJOR VERMICULITE LOSS.

FIG. 13 CLOSE-UP OF DAMAGE

PLATE VII RESULTS OF THIRTY FOOT FREE FALL

FIG. 14 BARREL SUSPENDED
READY TO DROP

FIG. 15 IMMEDIATELY AFTER IMPACT
BARREL IS REBOUNDING.

PLATE VIII PUNCTURE TEST

FIG. 16 PUNCTURE TEST RESULTS. NOTE FLATTENED AREA ON SIDE.

PLATE IX RESULTS OF PUNCTURE TEST

FIG. 17 BARREL BEING LOADED INTO 1575°F FURNACE.

FIG. 18 BARREL BEING REMOVED. PICTURE DOES NOT SHOW THAT IT WAS CHERRY RED.

PLATE X THERMAL TEST

FIG. 19 INTERIOR OF EXTERNAL BARREL. NOTE COMPLETE LACK OF SIGNIFICANT DAMAGE.

FIG. 20 INTERNAL BARREL. NO VISIBLE DAMAGE OR DIMENSIONAL CHANGE.

PLATE XI APPEARANCE AFTER THERMAL TEST

FIG. 21 OLD PROC SHIPPING
CONTAINER USED FOR WATER DRUM.

FIG. 22 VIEW SHOWING SHIPPING
CONTAINER IN TANK (Bottom View)

PLATE XII IMMERSION TEST
SET-UP

FIG. 23 CONTAINER OPENED SHOWING VERMICULITE AND CARDBOARD TUBES.

FIG. 24 DUMMY FUEL ELEMENTS AND ALUMINUM WIRE.

PLATE XIII FINAL APPEARANCE OF CONTAINER AND CONTENTS