71-9274

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Your ref: NRC CAL No. 02-08-002
Our ref: NFT-WES-03-005

May 15, 2003

Mrs. Osgood:

Subject: NRC Confirmatory Action Letter 02-8-002 dated June 20, 2002

Westinghouse Electric Co. hereby submits Revision 3 of the Application for Approval of Packaging of Fissile Radioactive Material (ABB-2901 Shipping Package). This revision is made in accordance with commitments made in Westinghouse letter NFT-NAK-02-022 dated July 3, 2002.

Six paper copies and one electronic copy are attached.

If you have any questions, please call Norman Kent at (803) 647-3552.

Sincerely,

WESTINGHOUSE ELECTRIC COMPANY, LLC

W. E. Stilwell
Nuclear Fuel Transport

NMSS01

WESTINGHOUSE ELECTRIC COMPANY LLC
NUCLEAR FUEL

APPLICATION FOR APPROVAL OF PACKAGING OF FISSILE RADIOACTIVE MATERIAL (ABB-2901 SHIPPING PACKAGE)

PACKAGE IDENTIFICATION NUMBER
USA/9274/AF

Initial Submittal: April 8, 1997
Revision 3: February 28, 2003
Expiration: September 30, 2007

U. S. NUCLEAR REGULATORY COMMISSION

DOCKET 71-9239

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Revision Submittal Record

Submittal Date	Reason	NRC Certificate	DOT Certificate (Corresponding NRC CoC)
28 FEB 03	License Renewal. All sections set to Revision 3 Entire document changed to revision 3 because in Header changed to Westinghouse Electric Company. The following technical changes were made: Appendix 1A ▪ Drawing L-9274-01 renamed 10004E01 and revised to include retention clamps. Changed to Rev.1 ▪ Drawing L-9274-02 renamed 10004E02 and revised to include retention clamps. Also revised to reflect only 2 sheets instead of 3.Changed to Rev.1 ▪ Drawing L9274-03 renamed 10004E03. Section 2.0 STRUCTURAL EVALUATION ▪ Paragraph added to introduce the recent HAC testing performed in response to NRC Confirmatory Action Letter No. 02-8-002 dated June 20 2002.		

Submittal Date	Reason	NRC Certificate	DOT Certificate (Corresponding NRC CoC)
	Section 2.4.2 POSITIVE CLOSURE ▪ Retention clamps added. Section 2.7.1 HAC FREE DROP ▪ Reference made to recent tests in Appendix 2D. Section 2.7.3 HAC PUNCTURE (PINNACLE TEST) ▪ Reference made to recent tests in Appendix 2D. Appendix 2A ▪ No new information ▪ Renumbered for consistency with document Appendix 2B ▪ No new information ▪ Renumbered for consistency with document Appendix 2C: ▪ No new information ▪ The section was renamed from "Appendix" to "Appendix 2C" for consistency with document. Appendix 2D: Results of Modified ABB-2901 Package Verification Drop Test ▪ New section describing recent testing done in response to NRC CAL. Section 4.3: CONTAINMENT REQUIREMENTS FOR HYPOTHETICAL ACCIDENT CONDITIONS ▪ Added reference to recent testing. Section 7.1 PROCEDURES FOR LOADING THE SHIPPING PACKAGE ▪ Added provision for installing retention clamps. Section 7.2: PROCEDURES FOR UNLOADING THE SHIPPING PACKAGE ▪ Added provision for removing retention clamps.		

1.0 GENERAL INFORMATION

1.1 Introduction

The ABB-2901 shipping package is designed for shipment of uranium oxide fuel pellets. The package evolved from the UNC-2901 shipping package and is identical to it in all respects except for the configuration (i.e., corrugated trays) in which the fuel pellets are placed into the inner compartment and the allowable tolerances for the inner compartment. The ABB-2901 fuel pellet shipping configuration was developed primarily to reduce the amount of pellet damage during shipment, as well as to provide the pellets in a configuration compatible with certain pellet-to-rod pushing operations during fuel rod fabrication, thereby minimizing pellet handling.

Based on a Transport Index (TI) of 0.50, the maximum number of shipping packages per shipment is limited to not more than 100 (50/0.50).

1.2 Package Description

1.2.1 Packaging

The ABB-2901 shipping package consists of a standard steel drum (see Drawing L-9274-01, Rev. 0) with a $10^3/_4$ inch square inner compartment centered in the steel drum. The inner compartment is centered by hardboard support rings. Asbestos or ceramic sheet, plywood and Fiberlite insulation provide thermal protection to the inner compartment which is the radioactive material containment boundary. The inner compartment is fitted with a bolted lid and gasket to assure positive closure.

The ABB-2901 container has a steel insert which holds four boxes of pellets on corrugated trays and is placed into the inner compartment. The arrangement is depicted in Drawing L-9274-02, Revision 0.

1.2.2 Operational Features

The ABB-2901 shipping package is of relatively simple design, and does not incorporate cooling systems, shielding, etc.

1.2.3 Contents of Packaging

Fuel pellets are shipped in a horizontal orientation on corrugated trays; corrugated trays are not used to ship reject pellets or pieces.

Maximum Enrichment: 5.0 wt.%

Type Material: Sintered (high fired) uranium oxide fuel pellets (≤5.0 w/o ^{235}U), various poison materials such as Gadolinia, Erbia, B4C, Stainless Steel, or Depleted Uranium (≤ 0.22 w/o ^{235}U).

Maximum quantity per shipping package:

a) Maximum net weight of fuel pellets: 227 pounds (103.0 Kg)

b) Gross weight of the shipping package as assembled for shipment shall not exceed 660 pounds.

Appendix 1A: Engineering Drawings

Details of construction and assembly for the ABB-2901 shipping package are shown on the following licensing drawings:

Drawing No.	Revision	Title
10004E01	1	ABB 2901 Shipping Drum for Pellets Assembly & Details
10004E02	1	ABB 2901 Shipping Arrangement Using Corrugated Trays (2 Sheets)
10004E03	1	Corrugated Tray

10004E01 Rev. 1 ABB 2901 Shipping Drum for pellets, Assembly and Details

10004E02, Rev. 1 ABB-2901 Shipping Arrangement Using Corrugated Trays Sheet 1

10004E03, Rev. 1 ABB-2901 Shipping Arrangement Using Corrugated Trays Sheet 2

FIGURE WITHHELD UNDER 10 CFR 2.390

FIGURE WITHHELD UNDER 10 CFR 2.390

FIGURE WITHHELD UNDER 10 CFR 2.390

FIGURE WITHHHELD UNDER 10 CFR 2.390

2.0 STRUCTURAL EVALUATION

Prior to October 2002, the ABB-2901 shipping package was not directly subjected to the test requirements set forth in 10 CFR 71. It was deemed to be structurally acceptable as a derivative of the UNC-2901 shipping package (Docket No. 71-6294) which was subjected to the hypothetical accident test condition in accordance with 10CFR71.36 and 49CFR173.398(c). The package evolved from the UNC-2901 shipping package and is identical to it in all respects except for the configuration (i.e., corrugated trays) in which the fuel pellets are placed into the inner compartment and the allowable tolerances for the inner compartment. The overall weight of the ABB-2901 shipping package is the same as or less than that of the UNC-2901 shipping package.

The actual tests and results for the UNC-2901 shipping package are discussed in detail in the report "Design and Structural Evaluation of a Low Enriched UO2, Pellet and Powder Shipping Package, Model UNC 2901", dated April 1970 and has been reproduced and is provided herewith in Appendix 2A.

The UNC-2901 shipping package was also subjected to a thirty foot drop test while loaded with simulated UO_2 powder drums. The actual tests and results are set forth in the supplement to the above referenced report entitled "Evaluation of UO2 Powder Drums for use in Model UNC 2901 Shipping Package". The supplement is dated November 1970 and has been reproduced and is provided herewith in Appendix 2B.

In October 2002, the ABB-2901 was subjected to HAC testing following a minor modification that was made in response to concerns raised by NRC in Confirmatory Action Letter CAL No. 02-8-002 dated June 20, 2002. The NRC CAL was issued after it was determined that the ABB-2901 package, when subjected to a 30-ft. (9-meter) shallow angle drop, may result in the ring clamp detaching and the lid coming off. The testing was conducted in accordance with a test prospectus that was reviewed by NRC. Appendix 2D discusses the test and results in detail.

2.1 Structural Design

2.1.1 Discussion

The ABB-2901 inner compartment serves as the containment boundary for the radioactive material contained within it and is constructed of 14 gauge stainless steel. The inner compartment is nominally 29.5 inches in length, $10^3/_4$ inches wide, and $10^3/_4$ inches high.

Design details for the ABB-2901 shipping package with respect to dimensions, component placement and material specification is provided on the engineering drawings provided in Appendix 1A.

2.1.2 Design Criteria

The ABB-2901 shipping package is designed to conform to the structural requirements delineated in 10 CFR 71. Design testing described and documented on the UNC-2901 docket,

which is reproduced in Appendices 2A and 2B, demonstrate that the structural requirements of 10 CFR 71 are satisfied for the ABB-2901 shipping package.

2.2 Weights and Centers of Gravity

The gross weight of the ABB-2901 shipping package as assembled for shipment does not exceed 660 pounds. The weight of fuel pellets does not exceed 227 pounds.
The shipping package is essentially symmetric, the center of gravity being approximately at the center of the package.

2.3 Mechanical Properties of Materials

The ABB-2901 shipping package is fabricated predominately of steel. Wood blocks are used as filler material when a full load of pellet trays is not being shipped.

2.4 General Standards for All Packaging

2.4.1 Chemical and Galvanic Reactions

There are no significant chemical, galvanic or other reactions among the package components or between the package components and the package contents. As stated above, the predominant structural material of the package is steel.

2.4.2 Positive Closure

The shipping package is equipped with a bolted closure and three retention clamps that prevent inadvertent opening.

2.4.3 Lifting Devices

The ABB-2901 shipping package has no lifting devices incorporated in the design. The package is mounted horizonally on a steel shipping pallet.

2.4.4 Tiedown Devices

The ABB-2901 shipping package has no tiedown devices incorporated in the design. The package is secured by means of a cinch cable, chain or nylon strap that is passed over the package(s) and fastened to the bed of the conveyance vehicle. The shipping packages are transported in a closed conveyance vehicle.

2.5 Standards for Type B and Large Quantity Packaging

Not Applicable. The ABB-2901 shipping package is a Type A quantity package.

2.6 Normal Conditions of Transport

The ability of the ABB-2901 shipping package to withstand conditions likely to occur in normal transport is considered to be satisified since it is a derivative of the UNC-2901 shipping package, to which it is essentially structurally identical, and which was itself subjected to the tests and assessments described in Appendices 2A and 2B of this application.

2.6.1 Heat

Materials of all components used in the manufacture of the package which are important to maintenance of structural integrity have physical and mechanical properties equivalent to or better than mild steel throughout a temperature range of -40°F to 1500°F.

Materials of all components used in the manufacture of the package which are important to maintenance of criticality safety have been addressed as discussed in the criticality analyses presented in Section 6.0 within the range of -40°F to 1500°F.

2.6.2 Cold

Materials of all components used in the manufacture of the package which are important to maintenance of structural integrity have physical and mechanical properties equivalent to or better than mild steel throughout a temperature range of -40°F to 1500°F.

Materials of all components used in the manufacture of the package which are important to maintenance of criticality safety have been addressed as discussed in the criticality analyses presented in Section 6.0 within the range of -40°F to 1500°F.

2.6.3 Pressure

The ABB-2901 shipping package is not pressurized.

2.6.4 Vibration

As previously stated, steel is the predominate structural material of the ABB-2901 shipping package. Vibration normally incident to transport will not adversely affect the structural integrity of the package or its radioactive material contents. For further discussion of structural integrity, see Appendices 2A and 2B for a reproduction of pertinent UNC-2901 test reports regarding the structural tests conducted pursuant to 10 CFR 71 and docketed in support of licensing the UNC-2901 shipping package (Docket No. 71-6294) which is essentially structurally equivalent to the ABB-2901 shipping package.

2.6.5 Water Spray

From a criticality standpoint, the results of the water spray test are not relevant. The ABB-2901 shipping package has been analyzed and shown to be safe from a criticality standpoint for all degrees of internal and external water moderation and reflection (see Section 6.0).

2.6.6 Free Drop

See Appendices 2A and 2B for a reproduction of pertinent UNC-2901 test reports regarding the structural tests conducted pursuant to 10 CFR 71 and docketed in support of licensing the UNC-2901 shipping package (Docket No. 71-6294) which is essentially structurally equivalent to the ABB-2901 shipping package.

2.6.7 Corner Drop

See Appendices 2A and 2B for a reproduction of pertinent UNC-2901 test reports regarding the structural tests conducted pursuant to 10 CFR 71 and docketed in support of licensing the UNC-2901 shipping package (Docket No. 71-6294) which is essentially structurally equivalent to the ABB-2901 shipping package.

2.6.8 Penetration

See Appendices 2A and 2B for a reproduction of pertinent UNC-2901 test reports regarding the structural tests conducted pursuant to 10 CFR 71 and docketed in support of licensing the UNC-2901 shipping package (Docket No. 71-6294) which is essentially structurally equivalent to the ABB-2901 shipping package.

2.6.9 Compression

See Appendices 2A and 2B for a reproduction of pertinent UNC-2901 test reports regarding the structural tests conducted pursuant to 10 CFR 71 and docketed in support of licensing the UNC-2901 shipping package (Docket No. 71-6294) which is essentially structurally equivalent to the ABB-2901 shipping package.

2.7 Hypothetical Accident Conditions

2.7.1 Free Drop

See Appendices 2A and 2B for a reproduction of pertinent UNC-2901 test reports regarding the structural tests conducted pursuant to 10 CFR 71 and docketed in support of licensing the UNC-2901 shipping package (Docket No. 71-6294) which is essentially structurally equivalent to the ABB-2901 shipping package. In addition, Appendix 2D gives results from the free drop test conducted in October 2002 in response to NRC's Confirmatory Action Letter CAL No. 02-8-002.

2.7.2 Crush

Not applicable. The radioactive material contents of the ABB-2901 shipping package fall outside of 10 CFR 71 requirements for crush testing.

2.7.3 Puncture (Pinnacle Test)

See Appendices 2A and 2B for a reproduction of pertinent UNC-2901 test reports regarding the structural tests conducted pursuant to 10 CFR 71 and docketed in support of licensing the UNC-2901 shipping package (Docket No. 71-6294) which is essentially structurally equivalent

to the ABB-2901 shipping package. In addition, Appendix 2D gives results from the 1-meter puncture test drop that was conducted in October 2002 in response to NRC's Confirmatory Action Letter CAL No. 02-8-002.

2.7.4 Thermal

See Appendices 2A and 2B for a reproduction of pertinent UNC-2901 test reports regarding the structural tests conducted pursuant to 10 CFR 71 and docketed in support of licensing the UNC-2901 shipping package (Docket No. 71-6294) which is essentially structurally equivalent to the ABB-2901 shipping package.

2.7.5 Water Immersion

See Appendices 2A and 2B for a reproduction of pertinent UNC-2901 test reports regarding the structural tests conducted pursuant to 10 CFR 71 and docketed in support of licensing the UNC-2901 shipping package (Docket No. 71-6294) which is essentially structurally equivalent to the ABB-2901 shipping package.

2.7.6 Summary of Damage

See Appendices 2A and 2B for a reproduction of pertinent UNC-2901 test reports regarding the structural tests conducted pursuant to 10 CFR 71 and docketed in support of licensing the UNC-2901 shipping package (Docket No. 71-6294) which is essentially structurally equivalent to the ABB-2901 shipping package.

2.8 Special Form

Not Applicable. All radioactive material shipped in the ABB-2901 shipping package is in normal form.

2.9 Fuel Rods

Not applicable. The ABB-2901 shipping package is used for the shipment of fuel pellets.

Appendix 2A: Design and Structural Evaluation of a Low Enriched UO2 Pellet and Powder Shipping Package

1.0 SUMMARY

A shipping package was designed for shipment of low enriched UO_2 pellets and powder. The package consisted basically of a square metal inner container supported and insulated inside an ~55 gallon steel outer drum. Pellets were packaged inside the inner container on Polyethylene coated corrugated trays. The shipping package was subjected to a series of drop, fire, and water tests to evaluate its structural stability. The results indicated that a structurally sound, fire-proof, leak resistant package had been developed.

2.0 DESCRIPTION OF SHIPPING PACKAGE

Details of the tested shipping container and pellet package are illustrated on drawings nos. D-5007-8086, Revision 1 and D-5008-8192, Revision 2. The shipping container is to be identified as a UNC Model 2901.

The basic components of the shipping package are:

1. A 10.75" square inner container with a $^1/_2$" thick flange and cover.
2. Twelve $^1/_2$" diameter bolts securing the cover to the flange.
3. A full-faced $^1/_8$" thick asbestos gasket on the inner container.
4. Three 1-$^1/_2$" thick hardboard support rings.
5. Angle iron welded completely around inner container for securing the hardboard.
6. A $^1/_8$" thick asbestos sheet on top and bottom of outer drum.
7. 1" thick plywood on bottom and 1-$^1/_4$" thick plywood on top of drum.
8. Fiberlite insulation, .75#/ft.^{3}, between inner and outer container.

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Low Enriched UO_2 Pellet and Powder Shipping Package
Page Two

2.0 Description of Shipping Package (continued)

The pellet package consisted of Polyethylene coated corrugated metal trays encased in gum rubber and hardboard as shown on the aforementioned drawings. The pellet loaded trays were held in compression and securely banded to insure no movement of pellets. The exact size and UO_2 capacity is dependent on the pellet diameter. The packaging design allows for one or more individual packages inside the inner container with the overall size not exceeding the 10.75" square.

3.0 STRUCTURAL EVALUATION

3.1 Conditions

The shipping package was subjected to the hypothetical accident conditions of the tests specified in 10 CFR 71.36 and 49 CFR 173.398(c). Tests were conducted at two different loading levels. One package of depleted pellets, assembled as shown on drawing number D-5008-8192 Revision 2, and three lead-filled wood boxes comprised the test load for Test #1. The second test was performed at a greater loading, but with only the lead filled boxes. The weight conditions tested were as follows:

	Test #1	Test #2
Tare Weight (Assembled Container Without Product Packages)	231 Lbs.	228 Lbs
Net Weight (Pellets & Packaging)	313 "	427 "
Equiv. Pellet Weight	227 "	302 "
Equiv. Pellet Packaging Weight	86 "	125 "
Total Gross Weight	544 Lbs.	655 Lbs.

3.2 Discussion of Results

Pictures of the package in its various stages of assembly and test are included in the Appendix of this report.

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Low Enriched UO_2 Pellet and Powder Shipping Package
Page Three

3.0 Structural Evaluation (continued)

3.2 Discussion of Results (continued)

3.2.1 Thirty Foot Drop Test

Conditions - The impact of the 30 foot drop was designed to occur at approximately 45° on the top corner of the square inner container. The selected corner for the first test condition was the corner containing the actual pellet package. These conditions were chosen as the most severe for the following reasons:

1. Experience from the same test performed on other packages indicated that maximum damage occurs from angular impact.

2. Impact on the top end was most likely to break loose the outer drum lid and expose the inner container during the fire and water tests.

3. Impact on the top end subjected the flange of the inner container to the maximum force and the seal on the gasket to the greatest potential for destruction.

4. The weld on the bottom plate was evaluated to be stronger than the parent metal, therefore, the point of failure from dropping on the bottom would have been the sides of the inner container. By dropping on the top corner, the sides were subjected to the same load and equal conditions existed.

5. The corners of the square insert had the least support. Therefore, impact at this point was directly on the weakest member.

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Low Enriched UO_2 Pellet and Powder Shipping Package
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6. Striking at an angle caused a greater rebounding effect and a minimum degree of support surface. (i.e., the top corner hit first and then the bottom as opposed to a single flat hit on side or end only.) A flat hit would allow an equal support distribution by the hardboard, plywood, cushioning, etc. and eliminate a greater concentrated force on one point.

7. The pellet package was subjected to brunt of impact from both the initial hit and the weight of the three simulated packages atop it.

Results - The damage to the outer drum for Test #1 (544 lbs.) is depicted in picture 3. The decrease in drum diameter as a result of impact was a maximum of 1-$^1/_2$" on the top corner. The small hole just below the lid retainer ring was inflicted by a small bolt which had been tied to a measuring cord used to verify the 30 foot height.

Damage to the plywood and hardboard supports for the inner container was not detrimental. The two 1" thick plywood disks encasing the inner container flange cracked on the corners but remained in position. The bottom hardboard support broke on three corners and the middle hardboard broke on the corner of impact. However, all pieces stayed in place and there was no warpage or shifting of the inner container. (See pictures 11, 13, 14, 17 and 18.) The hardboard supports remained bolted to the angle iron and all welds between the inner container and angle iron were sound. All flange bolts were intact and securely tightened. There was no deformation of the flanged closure.

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Low Enriched U02 Pellet and Powder Shipping Package
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3.0 Structural Evaluation (continued)

3.2 Discussion of Results (continued)

3.2.1 Thirty Foot Drop Test (continued)

The condition of the drum in Test #2 (655 lbs.) is shown in picture 3A. The outer drum deformed ~2" in diameter at the point of contact only, but otherwise showed no significant damage. Since the pellet package proved to uphold its tray-pellet-tray arrangement in the first test, it was not necessary to re-evaluate its stability and, therefore, the load was composed solely of lead-filled boxes.

As was the case for Test #1, a few of the plywood and hardboard supports cracked but no damage occurred to the inner container. (See pictures 5B, 5C, 5D and 5E). All welds and bolts remained intact and there was no shifting of either the inner container or the supports. The increased loading had no significant effect on the integrity of the inner container following the drop test.

3.2.2 Piston Drop Test

Conditions - For both loading conditions, the drum was dropped 5 ft. on to a 6" diameter x 8" long concrete piston. In Test #1, the point of impact was approximately midway between the center and upper hardboard support. This location was selected to determine if the outer drum would puncture and permit the piston to penetrate to the inner container. For Test #2, the selected impact point was directly on the center hardboard. This condition was evaluated to determine if the direct impact on the hardboard would drive it inward and deform the inner container.

Results - The condition of the outer drum after the piston drop for Tests #1 and #2 is shown in pictures 5 and 5A. In Test #1, a semi-circular hole was punctured through the outer drum in line with a corner of the inner container. No insulation or support material was lost through the hole and no damage was incurred by the inner container.

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Low Enriched U02 Pellet and Powder Shipping Package
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3.0 Structural Evaluation (continued)

3.2 Discussion of Results (continued)

3.2.2 Piston Drop (continued)

For Test #2 (picture 5-A), the piston hit directly on the hardboard and only a small hole, ~$^1/_2$" in diameter, was punctured in the outer drum. The hardboard was broken and chipped away for approximately a 3" x 2" area, but not completely through to the inner container (pictures 5C and 5D). The inner container suffered a minor crease ~$^1/_{32}$" high and 3" long at the point where the hardboard was supported against the insert. The inner container suffered no major damage and remained in its original position.

3.2.3 Fire Test

<u>Conditions</u> - The fire test was conducted using diesel fuel fed through piping manifolds placed lengthwise down each side of the shipping package. The flame was directed upward so it engulfed sides, top, and bottom of the package. The location and condition of the package before, during and after the fire test is shown in pictures 6, 7, and 8. The shipping package was placed with the punctured hole facing upward on a grated metal framework ~6" above the ground. The flame temperature as read on an optical pyrometer was in excess of 1650°F throughout the 30 minute test. It is probable that the flame was well above this, an intense black smoke tended to bias the reading low.

The fire test was conducted only for the Test #1 loading condition. Since the extra loading had no significant effect on the package condition after drop and piston testing, the parameters of the fire and water test were identical for both cases. Therefore, the fire and water test results of Test #1 were also applicable for the loading condition of Test #2.

3.0 Structural Evaluation (continued)

3.2 Discussion of Results (continued)

3.2.3 Fire Test (continued)

Results - Pictures 9-18 illustrate the condition of the shipping package after all the tests were completed. As shown in picture 9, the 1/8" thick asbestos sheet and top 5/8" thick plywood were completely charred. The remaining plywood disks, pictures 10 and 11, were charred only around the edges, from 2-4 inches radially inward for the outermost piece and 3/4" to 1" for the inner disk. The uniform burn completely around the periphery of the plywood indicated an even heat distribution throughout the package. The hardboard was charred slightly as indicated in pictures 12-16, but no substantial loss in strength resulted. Similar results were found on the bottom.

As shown in picture 13, the Fiberlite insulation was charred radially inward from the outer container for approximately 2 inches. However, the insulation in contact with the inner container was unimpaired. The temperatures reached on the inside wall of the inner container are indicated in figure 1, page 9. The temperature template on the underside of the container during the test registered 180°F. A template on the top side during the test showed that portion of the container reached 200°F. (These temperatures verify that the heat was well distributed from top to bottom.) This temperature range had no detrimental effect on the Ethafoam cushioning inside the inner container. Pictures 15 and 16 show the undamaged condition of the cushioning. The asbestos flange gasket and pellet package were undamaged by the fire test; which is very apparent in picture 15.

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Low Enriched UO 2 Pellet and Powder Shipping Package Page Eight

3.0 Structural Evaluation (continued)

3.2 Discussion of Results (continued)

3.2.4 Water Immersion Test

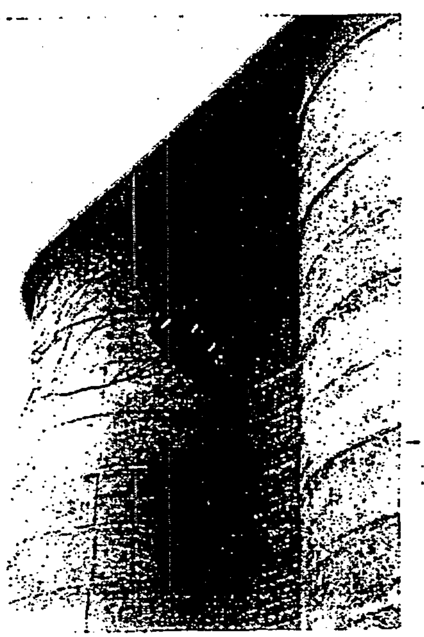
Conditions - The drum was immersed in the horizontal position so that a minimum of three feet of water completely covered the shipping package.

Results - Since the outer container had been punctured in the piston drop, the outer drum was thoroughly flooded. However, the inner container did not show any evidence of leakage after immersion for 8 hours. Some of the Ethafoam cushioning material had been crimped under the asbestos gasket during assembly, but even so, no leakage occurred. Pictures 17 and 18, which were taken immediately after the water test, show no evidence of leakage.

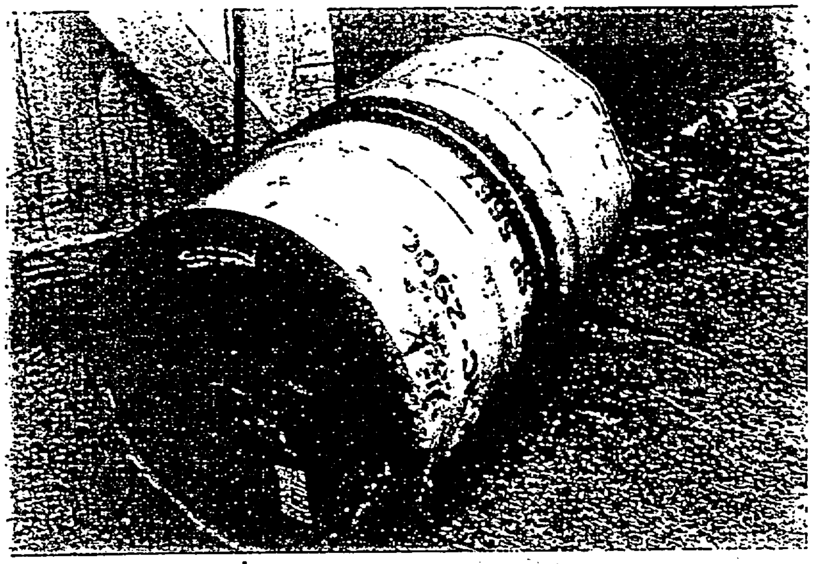
3.2.5 Condition of Pellet Package

The condition of the inner container contents after completion of the tests is shown in pictures 16-22. Although about 25% of the pellets were cracked or broken, (picture 22), the pellet package remained intact, (pictures 19 and 20), and less than 1/2% of the pellets became dislodged (picture 21). Picture 19 shows the ends and center of the trays crimped together where the hardboard supports were located. The general condition of the pellet package was "good" with the pellet-tray arrangement remaining unchanged from the original assembled configuration. Picture 23 shows the loaded pellet trays before assembly. Picture 22 shows the same general configuration after completion of the tests. All four packages remained in the exact position in which they were loaded (picture 15) and the inside of the inner container was not damaged in any manner.

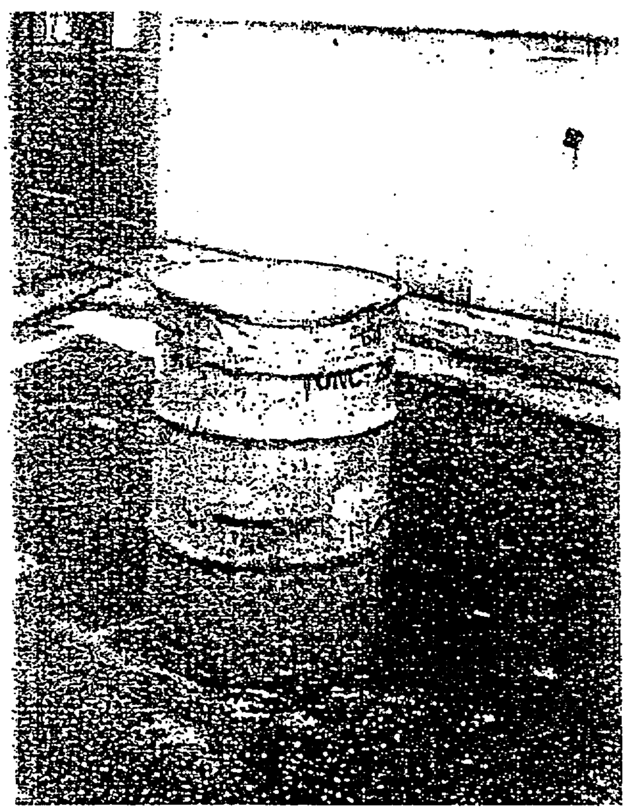
Picture 1 – Assembly of shipping package for Test #1.



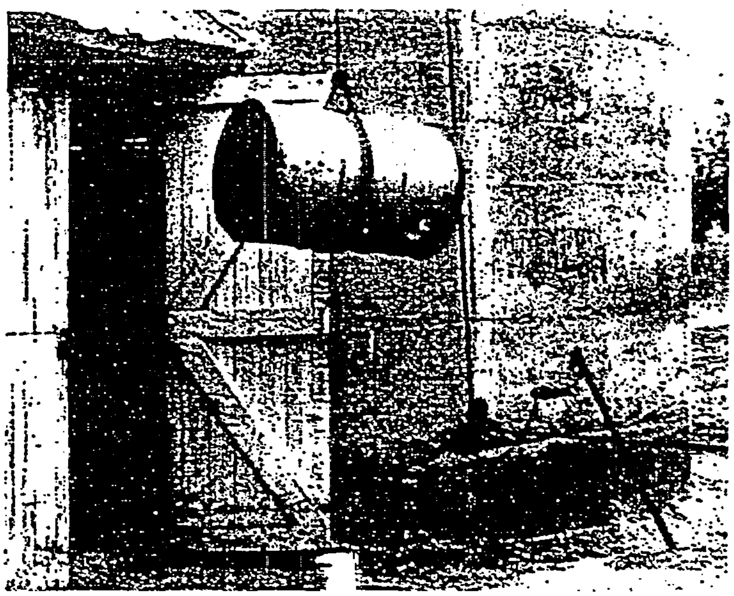
Picture 2 – Shipping package in upper position for 30' drop test



Picture 3 – Condition of outer drum after 30' drop test (Test #1).



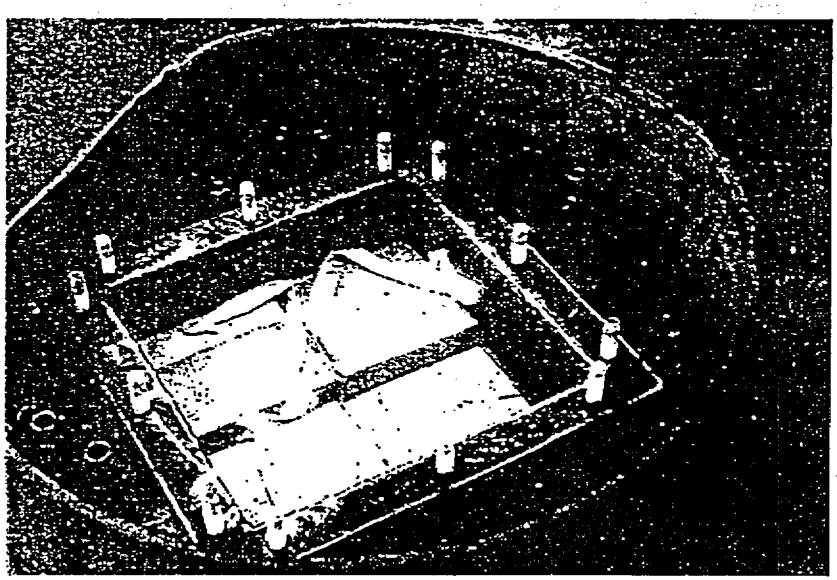
Picture 3A – Condition of outer drum after 30' drop test (Test #2).



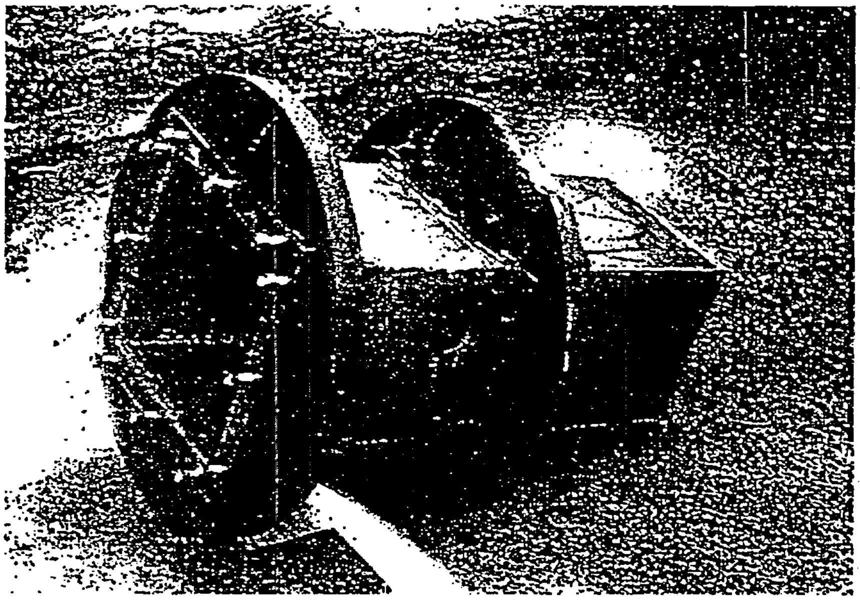
Picture 4 – Shipping package in upper position for piston drop.

Picture 5 – Condition of drum after piston drop – (Test #1).

Picture 5A – Condition of drum after 30' drop and piston drop – (Test #2).

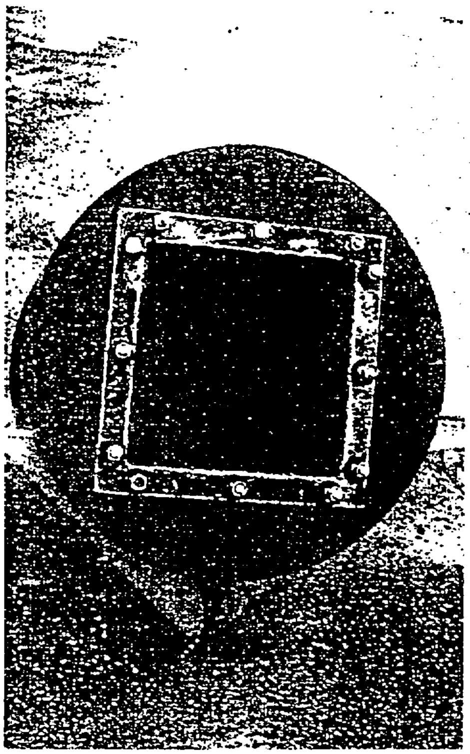


Picture 5B – Condition of flange after 30' drop and piston test – (Test #2).

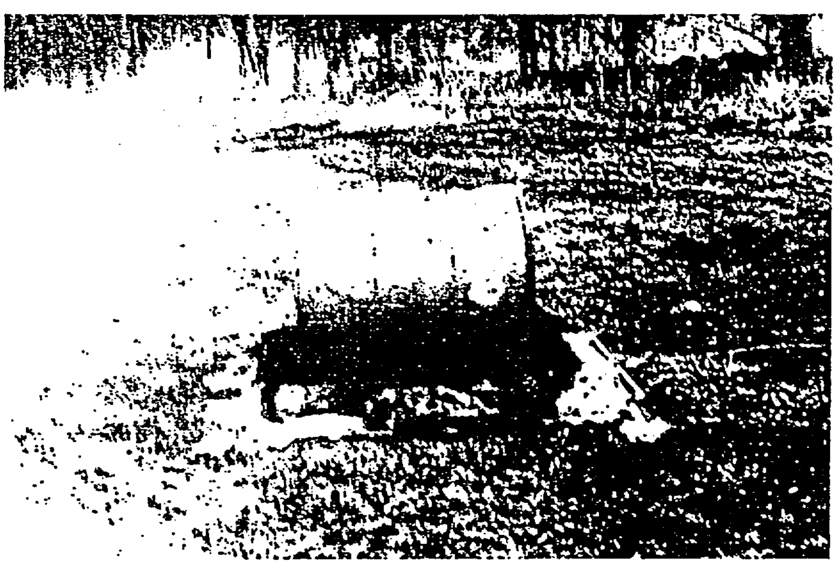


Picture 5C – Condition of inner container and hardboard after 30' drop and piston test – (Test #2)

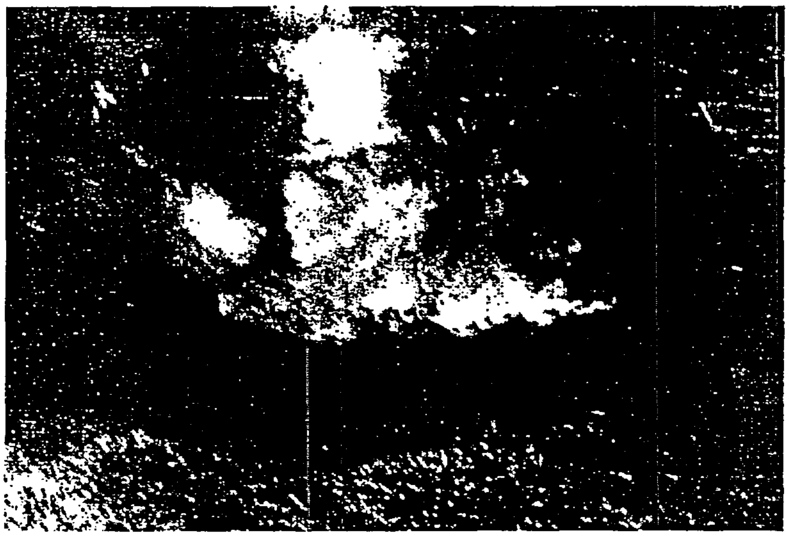
Picture 5D – Condition of inner container after 30' drop and piston test – (Test #2)



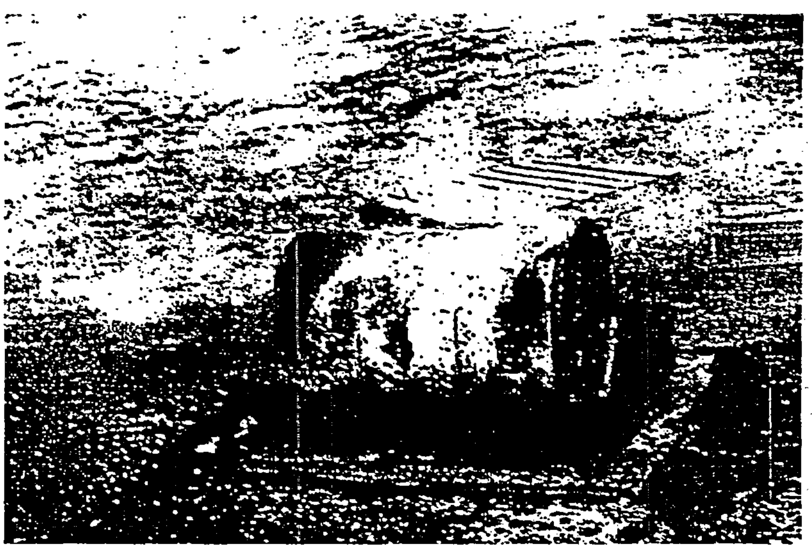
Picture 5E – View inside inner container after 30' drop and piston test (Test #2).



Picture 6 – Shipping package in position for fire test.



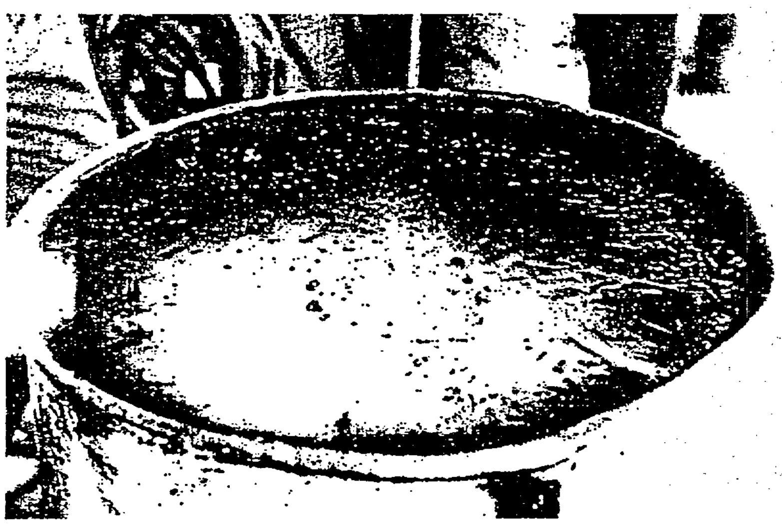
Picture 7 – Shipping package engulfed in flames during fire test.



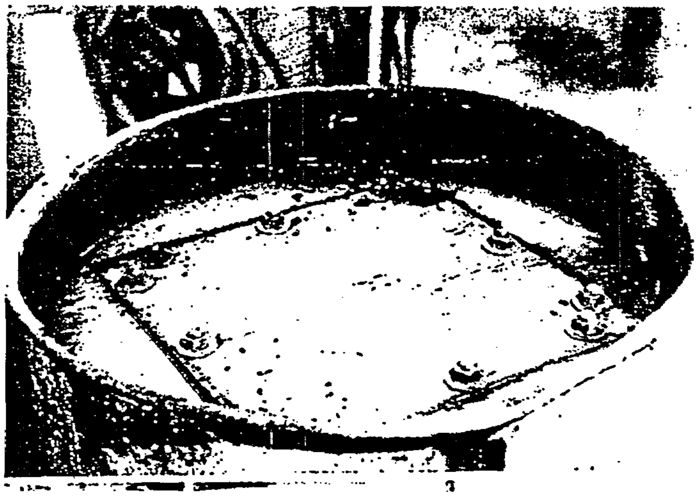
Picture 8 – Condition of outer drum after fire test.

Pictures 9 & 10

Picture 9 – Condition of asbestos and top plywood sheet after fire and water test.

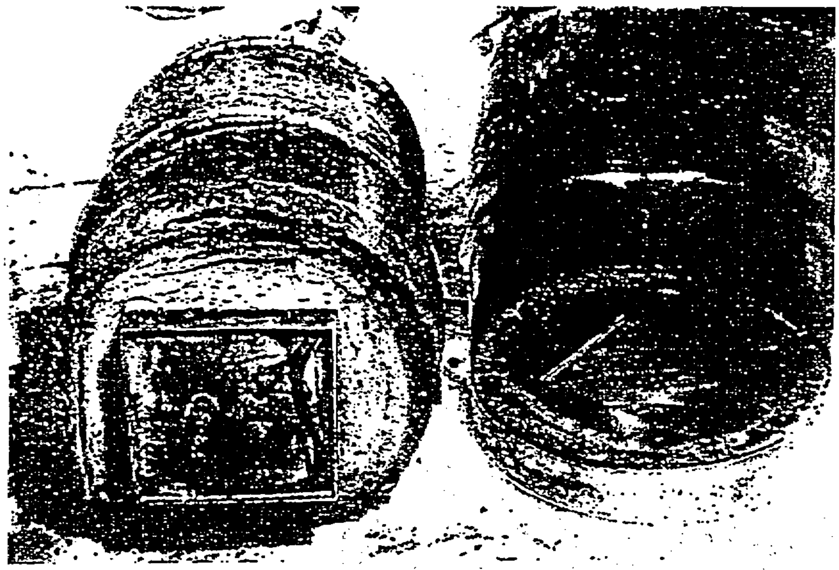


Picture 10 – Condition of second plywood sheet after fire and water test.



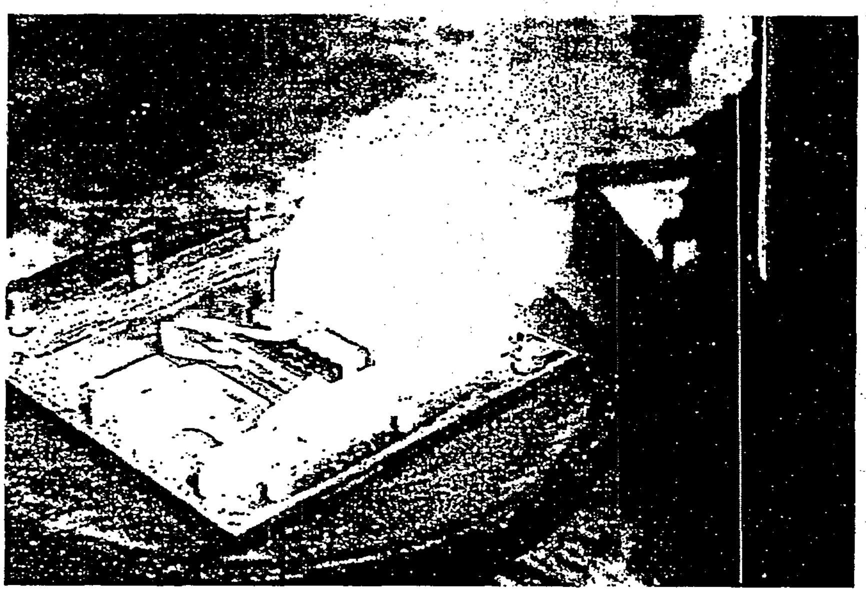
Picture 11 – Condition o flange cover and plywood disk around flange after fire and water test.

Picture 12 – Cut-out view of insulation and hardboard after fire and water test.



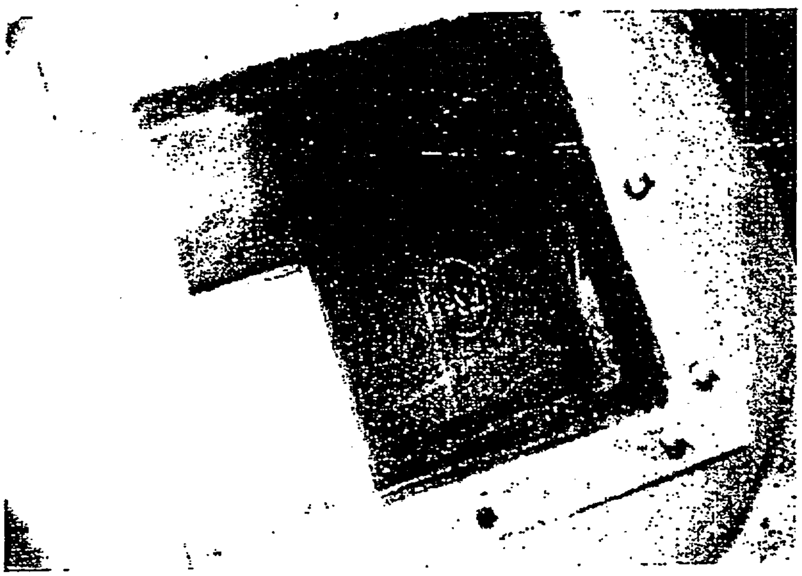
Picture 13 – Condition of bottom of inner and outer containers after

Picture 14 – View of inner container with insulation removed after completion of all tests.

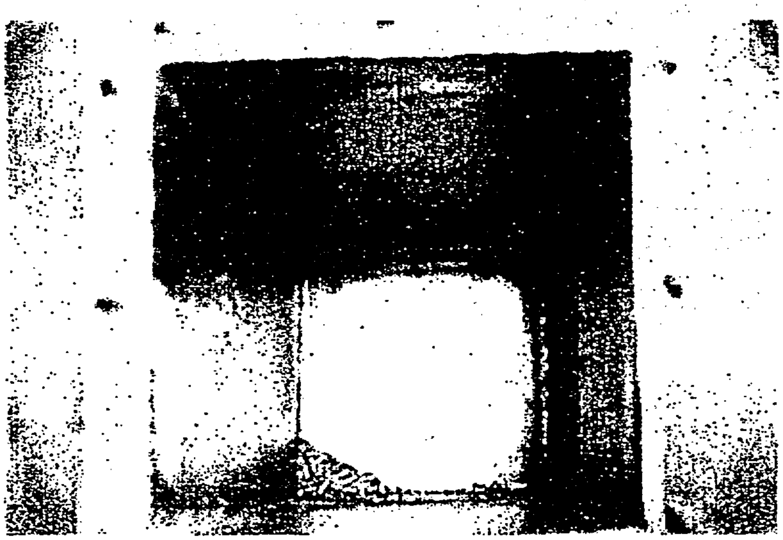


Picture 15 – Condition of pellet packages and cushioning material after completion of all tests.

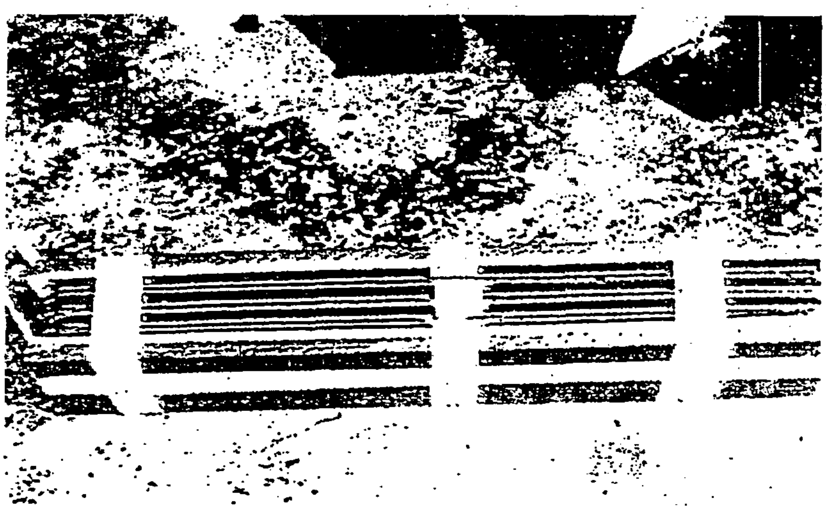
Picture 16 – Removal of pellet package after completion of tests.



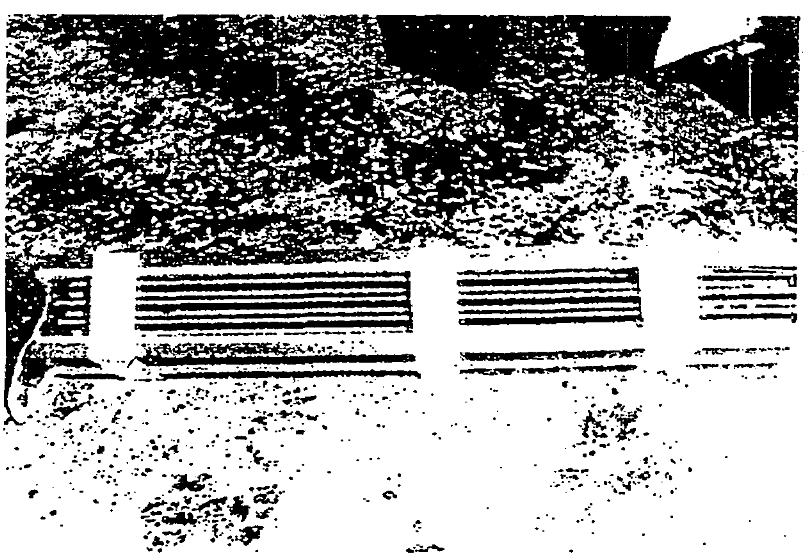
Picture 17 – Condition of inner container after completion of tests.



Picture 18 – Inner container and broken pellets after completion of tests.

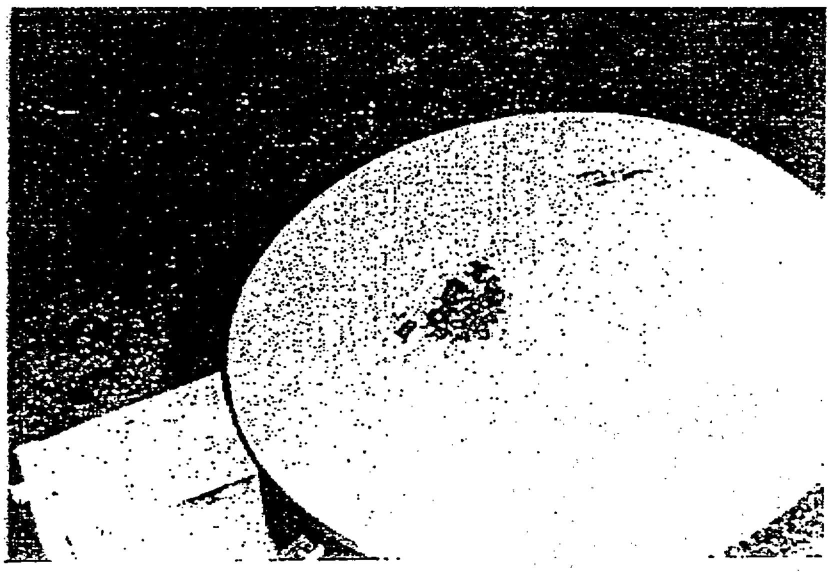


Picture 19 – Side of pellet package facing container wall during test.

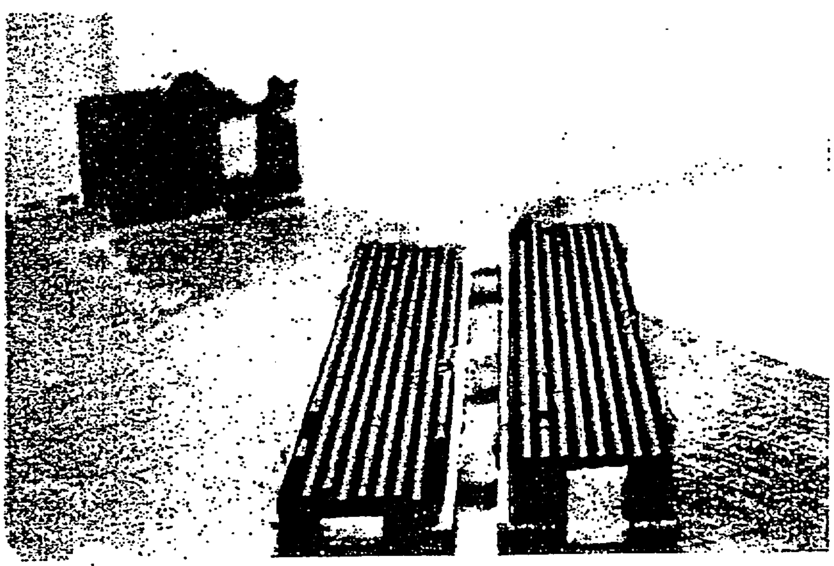


Picture 20 – Side of pellet package facing other package during test.

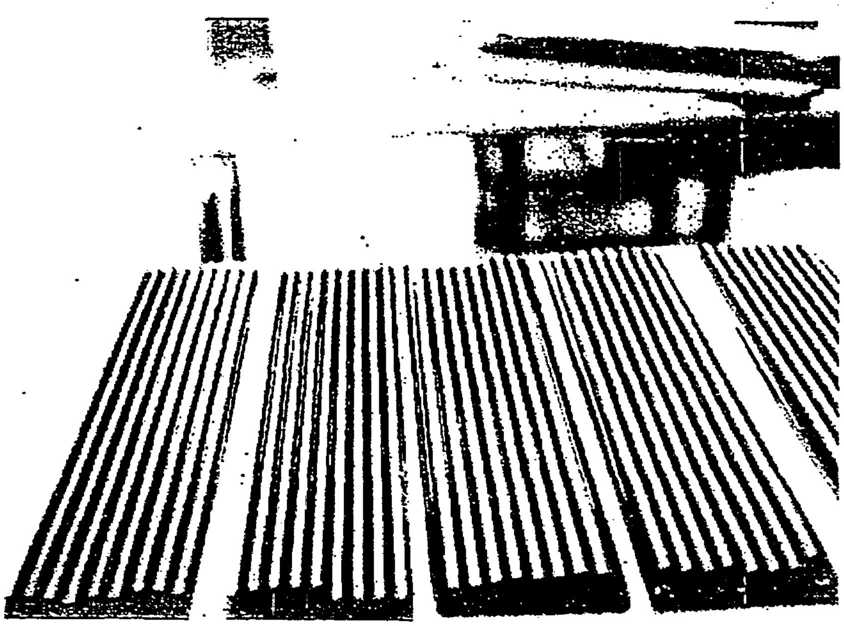
Pictures 21 & 22



Picture 21 – Amount of pellets dislodged in test.



Picture 22 – Top row of disassembled package after test.



Picture 23 – Loaded pellet trays as assembled. Before testing.

Appendix 2B: Evaluation of UO_2 Powder Drums for Use in Model UNC 2901 Shipping Package

1.0 SUMMARY

A metal drum and inner cushions were designed for the shipment of low enriched UO_2 powder in the Model UNC 2901 shipping container. The drums were filled with the maximum test weight and packaged inside the shipping container. The shipping container was subjected to a 30 foot drop test to evaluate the structural stability of the UO_2 powder drum. The results indicated that the powder drum was structurally sound for UO_2 powder shipments.

2.0 DESCRIPTION OF UO_2 POWDER DRUMS & INNER CUSHION

Details of the UO_2, powder shipping container assembly are illustrated on the attached drawing, #A-5007-2011. MIL specifications of the drum and drawing #A-5007-8111 of the inner cushion are shown in the Appendix.

The basic components of the shipping assembly are:

1. Two (2) re-usable metal shipping drums as per Specification MIL D-6055, Part No. MS 24347-8. The drum was modified in the following manner to meet UNC requirements.

    a. The inside depth was increased to 13-$^1/_4$ inches.

    b. A steel ring was added to the top lip of the container.

    c. The locking lugs were welded in addition to being rivited.

2. Three (3) 10-$^3/_4$ inches square x 1 inch thick Ethafoam.

3. Two (2) inner cushions of large bead polystyrene.

Evaluation of UO_2 Powder Drums
for use in Model UNC 2901 Shipping Package
Page Two

3.0 STRUCTURAL EVALUATION

3.1 Conditions

The shipping package was subjected to one of the hypothetical accident conditions of the tests specified in 10 CFR 71.36 and 49 CFR 173.398 (c). This test was the 30 foot drop test. Original testing performed for the pellet shipment has demonstrated structural integrity of the inner and outer container including the ability to prevent water in-leakage. The net weight of the content in that test was 427 pounds. Since the net weight of the contents for UO_2 powder is only 229.5 pounds, the original fire test, water test and "piston" drop test is applicable to this requirement; current testing was performed to demonstrate the ability of the powder drum to retain its contents.

One test was conducted. The 2901 container was assembled with two UO_2 powder drums. Each was filled with 110 pounds of lead shot and sand. The weight conditions were as follows:

Tare Weight (Assembled Container without Product Package)	227.5 pounds
Net Weight (Sand, Lead Shot, Drums & Packaging)	229.5 pounds
Equivalent Powder Weight	220.0 pounds
Equivalent Drum & Cushion Weight	9.5 pounds
Total Gross Weight	457.0 pounds

3.2 Discussion of Results

Photographs of the shipping drum and cushioning in its various stages of assembly are included in the Appendix of this report.

Evaluation of UO_2 Powder Drums for
use in Model UNC 2901 Shipping Package
Page Three

3.0 Structural Evaluation (continued)

3.2 Discussion of Results (continued)

3.2.1 Thirty Foot Drop Test

Conditions - The impact of the 30 foot drop test was designed to occur at approximately 45° on the top corner of the drum aligned with the side of the square inner container. The lugs of the powder drums were centered on that side of the inner container. The conditions were chosen as the most severe conditions for the following reasons:

1. Experience from the same test performed on other packages indicated that maximum damage occurs from angular impact.

2. The lugs on the locking ring were indicated to be the weakest structural point of the Powder drum.

3. Striking at an angle caused a greater rebounding effect and a minimum degree of support surface (i.e. the top corner hit first and then the bottom as opposed to a single flat hit on side or end only). A flat hit would allow an equal support distribution by the cushions and metal drums and eliminate a greater concentrated force on one point.

4. The top powder drum was subjected to the brunt of impact from both the initial hit and the weight of the second drum.

Results - The decrease in drum diameter as a result of impact was a maximum of 1-$^3/_4$ inches on the top corner. The drum, drum lid and the locking ring remained intact. No significant damage to the plywood discs was noted. All flange bolts were intact and securely fastened. There was no deformation of the flanged closure.

Evaluation of UO, Powder Drums for
use in Model UNC 2901 Shipping Package
Page Four

3.0 Structural Evaluation (continued)

3.2 Discussion of Results (continued)

3.2.1 Thirty Foot Drop Test (continued)

Results (continued)

The top & center 1 inch thick Ethafoam cushions were completely severed by the impact of the powder drums. Both of the polystyrene cushions were broken into two pieces. Deformation of the cushion was not severe and both powder drums were securely in place.

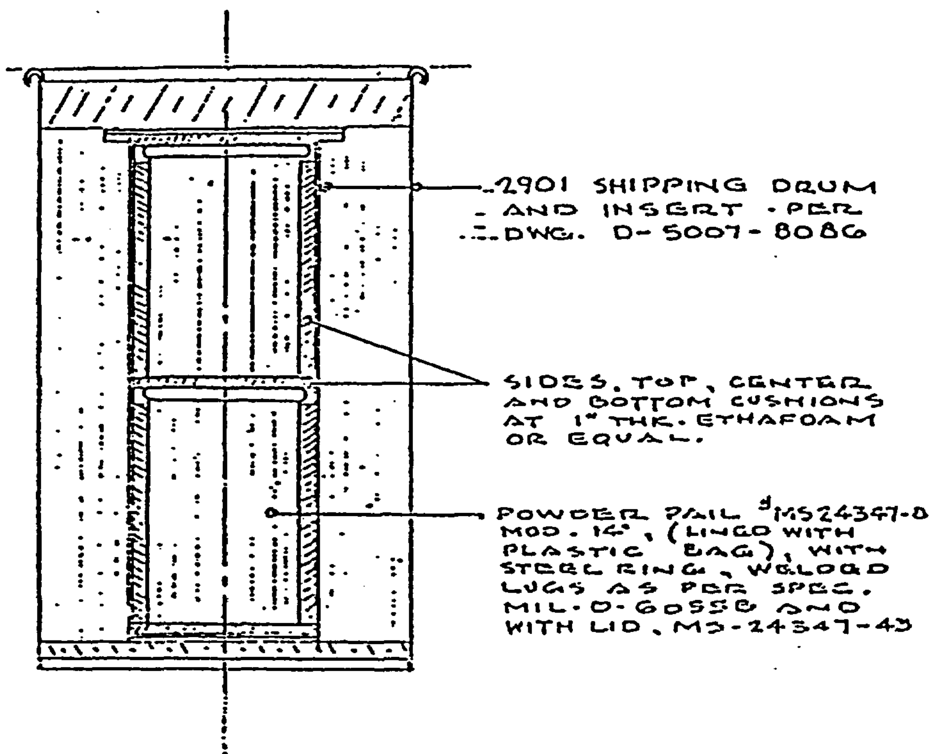
The locking ring and top flange of both powder drums were deformed. The bottom of the top powder drum was also badly defomed by the impact of the bottom powder drum. Although the drums were deformed, the locking rings and lid remained in place. There was no leakage noted at the drum lid or bottom seam.

Appendix 2C: Early Drawings and Sketches

1. UO_2 Powder Shipping Container Assembly - A-5007-2011
2. UO_2 Powder Drum Specifications - MIL D-6055
3. Insert Pail Cushion - A-5007-8111
4. Photographs - Reproducible copies are no longer available. Original photographs were submitted with the June 20, 1980 application.

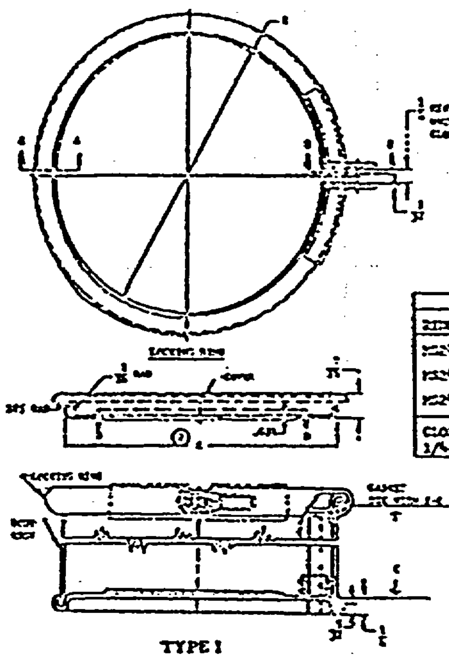
MATERIAL FOR COMPLETE ASSEMBLY

ITEM NO.	PART DESCRIPTION	NO. REQ'D	SOURCE

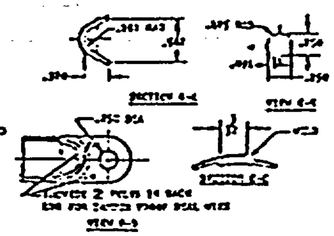


REV.	BY	DATE	APP'D.	DATE	JOB NO.	DESCRIPTION	W.O. NO.

TOLERANCES UNLESS OTHERWISE SPECIFIED FRACTIONAL ± DECIMAL ± ANGULAR ± FINISH SYMBOL ASA STD	UNITED NUCLEAR CORPORATION FUELS DIVISION HEMATITE MISSOURI UNC - 2901 ; UO_2 POWDER SHIPPING CONTAINER ASSEMBLY
SCALE ~ DWN. BY VAL APP'D. DATE 7-25-70 CHK'D BY L. Deec APP'D.	A-5007-2011 REV.



TYPE I



SPARE PARTS					
RINGS	EA.	COVERS	EA.	GASKETS	EA.
MS24347-61 (5")	.24	MS24347-41	.22	MS24347-81	.10
MS24347-62 (6½")	.26	MS24347-42	.24	MS24347-82	.12
MS24347-63 (8½")	.30	MS24347-43	.22	MS24347-83	.14
CLOSING BOLT, ROUND SLOTTED HEAD 1/4-20 X 1 1/4, WITH LOCKNUT, CAD PLATED				.06 PER SET	

				QUANTITY - PRICES PER SHIPMENT						
SIZE NO.	DRUM ASSEMBLY	DIA. -A-	INSIDE DEPTH -C-	1 TO 11	12 TO 99	100 TO 499	500 TO 2499	2500 AND OVER	UNITS PER CTN	WT. PER CTN.
1	MS24347-1	5.00"	4.50"	1.52	1.35	1.22	1.10	1.05	24	27
2	MS24347-2	5.00"	8.50"	1.70	1.56	1.37	1.24	1.18	12	20
3	MS24347-3	6.50"	4.50"	1.64	1.50	1.33	1.20	1.14	12	22
4	MS24347-4	6.50"	6.75"	1.76	1.62	1.45	1.30	1.24	12	25
5	MS24347-5	6.50"	8.50"	1.83	1.74	1.55	1.40	1.30	12	31
6	MS24347-6	8.50"	6.00"	2.00	1.87	1.74	1.60	1.52	12	36
7	MS24347-7	8.50"	7.50"	2.10	1.93	1.83	1.74	1.64	12	42
8	MS24347-8	8.50"	9.00"	2.15	2.04	1.94	1.80	1.74	12	46

INSIDE PACKING HEIGHT WITH COVER IN PLACE IS 1/4" LESS THAN INSIDE DEPTH -C-

MATERIAL: STEEL, COLD ROLLED SPEC QQ-S-698.
BODY, BOTTOM & COVER: SIZE 1 & 2 26 GAGE ALL OTHERS 24 GAGE.
LOCKING RINGS 20 GAGE AND LUGS 14 GAGE.
GASKET, SYNTHETIC RUBBER WEATHER RESISTANT, SHORE HARDNESS 60.

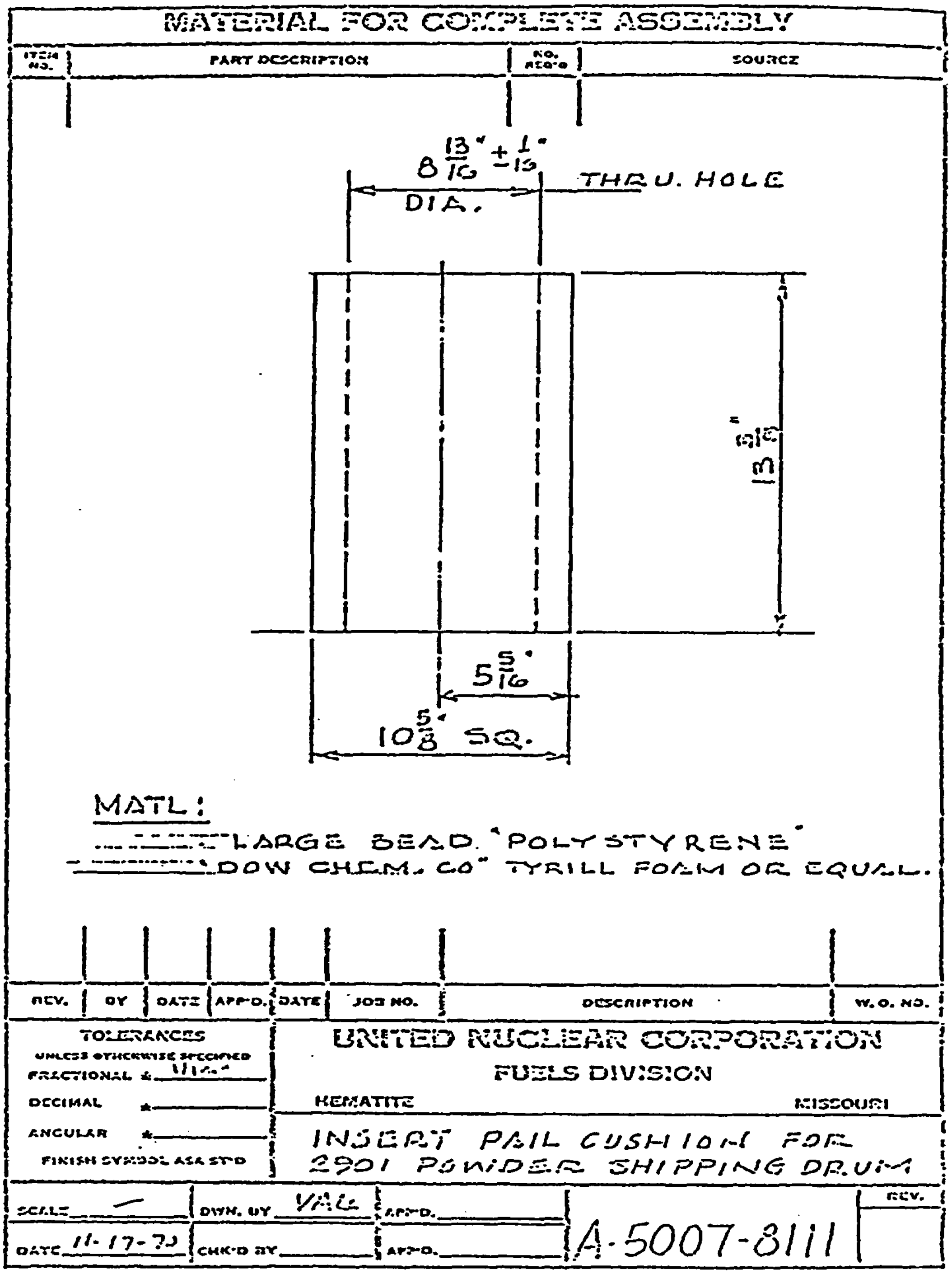
ABOVE PRICES BASED UPON DELIVERY QUANTITY PER ITEM.

PACKAGING CHARGE FOR NON STANDARD CARTON - $2.00.

Minimum Order: $5.00

Terms ½% 10: Net 30 F.O.B. St. Louis

PROCUREMENT SPECIFICATION MIL-D-6055 No. 3169 March 1, 1969	DRUM Metal Reusable Interior and Exterior Shipping and Storage MIRAX CHEMICAL PRODUCTS CORPORATION Metal Container Division 4999 TYLER AVENUE ST. LOUIS, MISSOURI 63139	MILITARY STANDARD MS24347 SUPERSEDES: AN6029



MATERIAL FOR COMPLETE ASSEMBLY
ITEM NO.
PART DESCRIPTION
NO. REQ'D
SOURCE
8 13/16" ± 1/16"
THRU. HOLE
DIA.
13"
5 5/16"
10 5/8" SQ.
MATL:
LARGE BEAD "POLYSTYRENE"
"DOW CHEM. CO" TYRILL FOAM OR EQUAL.
REV. BY DATE APP'D. DATE JOB NO. DESCRIPTION W.O. NO.
TOLERANCES
UNLESS OTHERWISE SPECIFIED
FRACTIONAL ± 1/16"
DECIMAL ±
ANGULAR ±
FINISH SYMBOL ASA STD
UNITED NUCLEAR CORPORATION
FUELS DIVISION
HEMATITE
MISSOURI
INSERT PAIL CUSHION FOR
2901 POWDER SHIPPING DRUM
SCALE —
DWN. BY VAL
APP'D.
REV.
DATE 11-17-73
CHK'D BY
APP'D.
A-5007-8111

Appendix 2D: Results of Modified ABB-2901 Package Verification Drop Test

1.0 SUMMARY

A new retention clamp design was developed to provide greater positive closure to secure the lid to the drum during structural Hypothetical Accident Condition (HAC) testing. Regulatory testing, which included a shallow angle top down impact test and a pin-puncture test, was performed in order to validate whether the new retention clamp design adequately secured the lid. Results are provided below. It was determined that the thermal test was not required for this test. The thermal test was successfully completed in earlier testing and results are reported in section 3.2.3 of the SAR. The test plan was reviewed and found to be acceptable by NRC (August 16, 2002 letter).

2.0 DESCRIPTION OF SHIPPING PACKAGE

The original ABB-2901 package design is described in this Safety Analysis Report (SAR). The ABB-2901 consists of a standard steel drum, with a 10¾-inch square inner compartment centered in the steel drum. Hardboard support rings center the inner compartment. Asbestos or ceramic sheet, plywood and Fiberlite insulation provide thermal protection to the inner compartment, which is the radioactive material containment boundary. The inner compartment is fitted with a bolted lid and gasket to assure positive closure. The ABB-2901 packaging has a steel insert that holds four boxes of pellets.

The only modification made to the ABB-2901 packaging for this test was the incorporation of the closure ring retention clamps as shown in Figure 2D-1. The retention clamps were located at approximately the 2 o'clock, 10 o'clock, and 6 o'clock positions as oriented from the 12 O'clock position of the lug. There are no modifications to any other part of the packaging. Figure 2D-2b shows the contents of the tested package

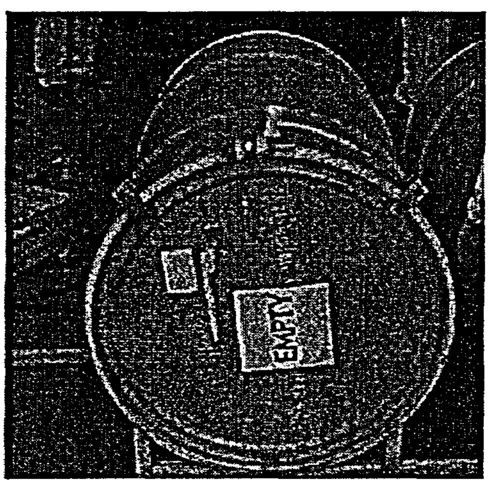


Figure 2D-1: ABB-2901 Package with Retention Clamps

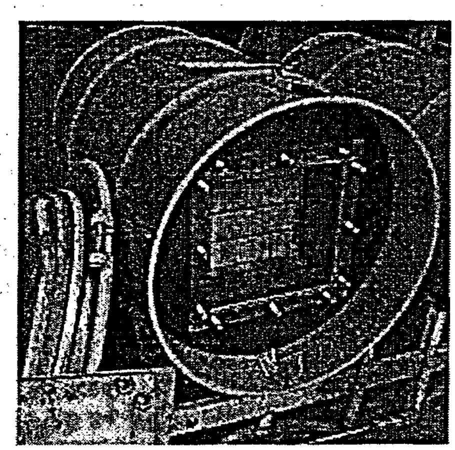


Figure 2D-2: Inner Contents of ABB-2901

3.0 STRUCTURAL EVALUATION

3.1 Conditions

The primary failure criterion was defined as the complete separation of the lid from the drum body. A secondary failure criterion was defined as the partial separation of the lid from the drum body if it can be determined that the separation produced would result in a significant reduction in the effectiveness of a generic, drum-type packaging.

After package assembly, the drum weight was determined to be 660 pounds. The drum was subsequently moved to the test site location for rigging. Westinghouse performed the 9-meter drop test followed by the 1-meter pin puncture. A summary of test particulars is shown in Table 2D-1.

Table 2D-1: ABB-2901 Test Matrix

Temperature	Ambient
Lug position	180° from Impact Point
Clamp positions	3 clamps positioned around lid at approximately 2,6 and 10 O'clock positions (relative to clamp ring lug)
Package weight	660 pounds
9 meter (30-ft) Drop Orientation	Top-Down, 17.5 ± 2.5°
Puncture*	1 meter Drop at Ring closure lug/bolt, 55°

*The impact point and orientation for the puncture test was determined from the most damaging of three drops. The impact locations included 1) The ring closure lug/bolt, 2) Most damaged section of drum lid ring, and 3) The clamp mechanism located 180° relative to clamp ring lug/bolt. Testing indicated that the maximum damage resulted from an impact to the ring closure lug/bolt, orientation 1.

3.2 Discussion of Results

The modified ABB-2901 Drum package met the acceptance criteria described above. Damage to the package resulting from the 9-meter drop included an impact footprint approximately 13-inches to 14-inches wide, 2-inches deep, and the full length of the drum. The retention clamps remained secure. The internal contents maintained their position. The 1-inch maximum separation between the lid and the drum body was not considered significant. The 1-meter pin puncture test resulted in an insignificant lid separation of 1-inch between the lid and drum for

approximately a 20-inch circumferential length. The drum lid remained attached to the drum body.

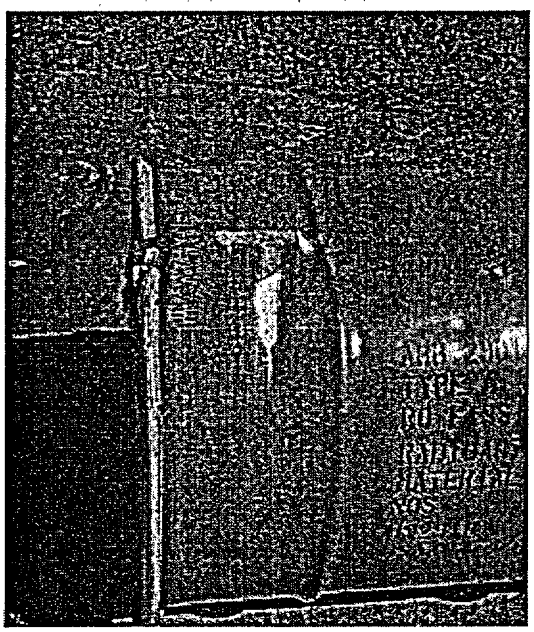


Figure 2D-3: Post-9 Meter Test Condition of ABB-2901 Package

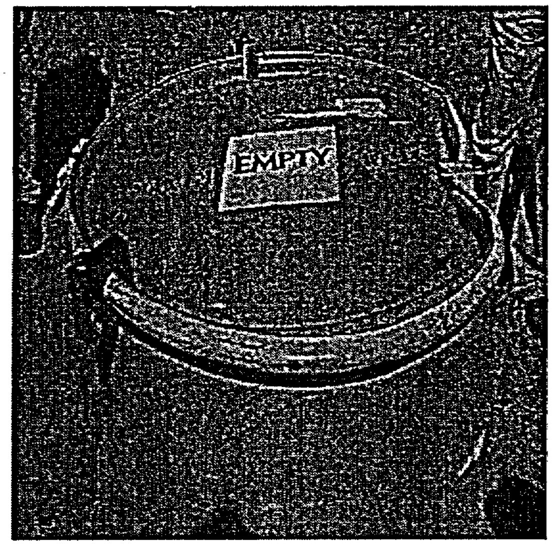


Figure 2D-4: Post-9 Meter Test Condition of ABB-2901 Package

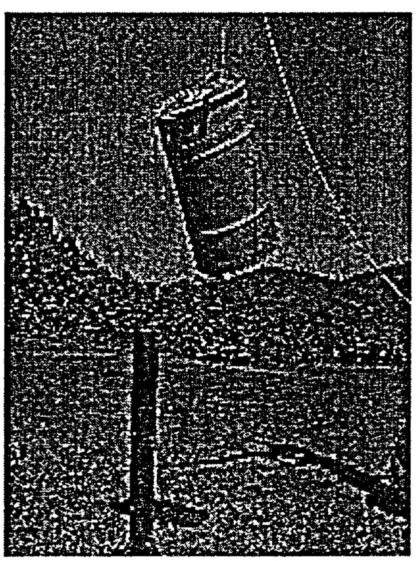


Figure 2D-5: 1-Meter Pin Puncture Test Set-Up

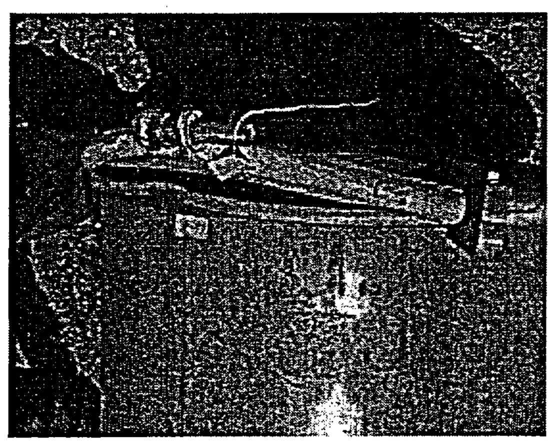


Figure 2D-6: Local Damage from Pin Drop Test

3.0 THERMAL EVALUATION

The testing and results of the thermal evaluation which are relevant to the ABB-2901 shipping package are discussed in Chapter 2.0 of this application. Testing discussed in Chapter 2.0 focuses on the UNC-2901 shipping package which is essentially identical to the ABB-2901 shipping package with regard to thermal considerations. As such, conclusions drawn relative to the UNC-2901 shipping package are also applicable to the ABB-2901 shipping package.

4.0 CONTAINMENT

4.1 Containment Boundary

4.1.1 Containment Vessel

Within the ABB-2901 shipping package, a square inner compartment provides the containment boundary for the radioactive material contents. The top closure is by means of a steel plate bolted to an external flange welded to the square body. A seal is formed between the flange and steel plate by a gasket capable of withstanding temperatures up to at least 500°F.

4.1.2 Containment Penetrations

There are no penetrations into the inner compartment.

4.1.3 Seals and Welds

The seal of the inner compartment closure is formed by a gasket 0.125 inch thickness between the surfaces of a flange welded to the outer surface of the square body and the top closure cover. The gasket is rated for at least 500°F service and, since there is no significant heat generated by the package contents, the seal is unaffected by temperatures encountered in normal conditions of transport. Also, testing described in Chapter 2.0 has shown that the gasket is unaffected by the temperatures attained in the Hypothetical Accident Conditions.

All welds are visually inspected to ensure that parent metals are well fused, and weld (or heat affected zone) is free of cracks, craters, or burnouts.

4.1.4 Closure

The inner compartment closure is formed by a 0.5 inch steel plate bolted to an external flange welded to the square inner compartment. Material specifications for the plate, bolts and nuts are provided on the engineering drawings in Appendix 1A. The bolted inner compartment closure lid with a 0.125 inch thick gasket is sufficient to maintain a positive seal during normal and accident conditions of transport.

4.2 Requirements for Normal Conditions of Transport

Submittal of the essentially structurally identical UNC-2901 shipping package to the tests specified in 10CFR71.71 and 49CFR173.398(C) has shown that there will be no loss or dispersal of radioactive contents, no significant increase in external radiation levels, and no substantial reduction in the effectiveness of the packaging. Fully loaded packages subjected to the full series of spray, free drop and penetration tests showed no degradation of effectiveness of the inner compartment and no leakage of water into the inner compartment.

4.3 Containment Requirements for Hypothetical Accident Conditions

Both the UNC-2901 and the ABB-2901 were subjected to hypothetical accident testing, as described in Chapter 2.0. These tests demonstrated that no radioactive material would be released. The tests also demonstrated that the package would remain subcritical because the material remains confined to a subcritical geometry and the geometric form of the contained material is not altered.

5.0 5.0 SHIELDING EVALUATION

The ABB-2901 shipping package is used for the shipment of oxides of low enriched uranium (≤5.0 wt.% ^{235}U) in the form of unirradiated fuel pellets. Thus, shielding is not a consideration in the design, construction, or use of the shipping package.

6.0 6.0 CRITICALITY EVALUATION

6.1 ABB-2901 Corrugated Tray Configuration

An alternative fuel pellet shipping configuration was developed for the ABB-2901 shipping package primarily to reduce the amount of pellet damage during shipment, as well as to provide the pellets in a configuration compatible with certain pellet-to-rod pushing operations during fuel rod fabrication thereby minimizing pellet handling.

The ABB-2901 tray holder is designed for maximum inner container dimensions of 11.00" x 11.00" x 29.50" (27.94 cm x 27.94 cm x 74.93 cm), with the last dimension being in the direction of the pellet column axes.

The pellet tray package consists of layers of fuel pellets separated by corrugated stainless steel trays. The trays measure 1 millimeter in thickness, 45 cm in length, and 19.3 cm in width. Each corrugation is filled with pellets along the entire length. Each overlaying tray rests directly on the pellets of the tray beneath it; each tray has a measured average center to center spacing of every other row (columns of adjacent trays are laterally offset) of 0.9968 cm based on a nominal pellet diameter of 0.818 cm, and 1.102 cm based on a nominal pellet diameter of 0.969 cm.

The trays are placed into a box which is in turn placed into one of the four designated separate locations per insert. The insert, which fits into the existing inner container, consists of a shelved open front shell comprised of 0.794 cm (5/16") thick nickel plated carbon steel with maximum outer dimensions of 26.988 cm x 26.988 cm (10.625" x 10.625"). Depending on the pellet diameter, each box contains a stack of between 69 and 92 pellet columns and between 6 and 8 corrugated stainless steel trays. Each stack of pellet trays is covered with an additional steel tray followed by a thin plastic or rubber (neoprene) pad which compresses slightly to cushion the pellets during transport.

Criticality analyses were performed for a maximum pellet diameter of 0.969 cm and a minimum of 0.818 cm. Any pellet diameter within this range will be bounded by the worst case accident analyses presented in Section 6.1.3. The range of pellet diameters analyzed was established to provide analysis results which bound the various pellet types presently manufactured.

6.1.1 ABB-2901 Pellet Tray Model

The corrugated trays are illustrated in engineering drawings provided in Appendix 1.3 along with the dimensional tolerances. Figure 6.1 shows the KENO model of the ABB-2901 with the tray configuration homogenized within the inner container. It should be noted that no structural material or Fiberlite is credited in the region between the inner container and outer shell of the ABB-2901 shipping package.

The volume of each tray was determined from the average measured weight of empty trays and the theoretical density used with the Material Input Processor (MIP LIB) used in SCALE-PC Version 4.1/0. The average measured weight per tray was 755 grams. The nominal density of SS304 is assumed to be 7.92 g/cc; therefore the average volume per tray is 95.3 cm^3. However, since the steel acts as a parasitic absorber, each of the criticality accident calculations assumed a conservative minimum tray weight of 700 grams and volume of 88.38 cm^3.

The boxes which accommodate the loaded trays have a 0.3175 cm (1/8") thick aluminum base with two 2.223 cm (7/8") thick aluminum beams running the length on the sides for support, and a 0.15 cm thick stainless steel cover which is screwed to the side beams. The boxes fit into a 0.7938 cm (5/16") thick steel insert which has four discrete locations maintained by 0.2278 cm thick nickel plated carbon steel shelving. The shelving is supported by 0.3175 cm (1/8") thick vertical steel supports which are screwed directly into the sides of the steel insert. The outer dimensions of the insert measure 26.988 cm x 26.988 cm x 46.673 cm, and the insert fits directly into the existing inner container against a 13.653 cm wood spacer block. Another 13.653 cm spacer block fills the remaining void of the inner container which is sealed with a 1.27 cm (1/2") steel cover. The wooden blocks increase structural stability and reduce the amount of free volume within the inner container.

Within each of the four boxes within the insert, certain approximations are made to represent the corrugated tray and pellet configuration. The region between the aluminum support blocks was modeled as a homogenized region with cell weighted cross sections. The cross sections were calculated with the CSAS2X sequence in the SCALE-PC (version 4.1/0) package and the standard 27 group library. Among the options for cross section calculations, the most representative was that of the triangular pitch lattice cell.
To prevent over estimating the worth of the stainless steel by direct homogenization (steel, H_2O and fuel), a more conservative approach was taken. Based on a fully loaded box, the volume of steel in the trays was converted to an equivalent clad thickness; 26 mils and 24 mils for the 0.818 cm diameter pellet columns and the 0.969 cm diameter pellet columns, respectively.

The clad thickness was kept constant around each pellet column in all cases. As the number of pellets or pellet columns was reduced, the triangular cell pitch was increased and the additional steel, no longer represented as clad, was homogenized into the moderator region of the lattice cell calculation.

Analysis confirmed that the larger pellet diameter is more reactive at all loadings due primarily to a lower steel to UO_2 ratio. A comparison of the accident scenarios for the two pellet diameters is outlined in Section 6.1.3. Since it was determined that the smaller pellet diameter is less reactive, all subsequent discussion of the pellet tray configuration pertains to the larger diameter pellet size of 0.969 cm. The safety analyses bound any pellet diameter between the two analyzed conditions, that is 0.818 cm and 0.969 cm.

Administrative controls require that if fewer than the total number of trays for each pellet diameter are to be shipped, then the void left by any missing trays will be filled with wood spacers.

6.1.2 ABB-2901 Pellet Tray Loading Limits

The maximum loading per tray is a function of the pellet diameter, the total number of rows per tray and the length of each row. The trays accommodate either 11 or 12 columns alternating on each level and measuring 45 cm in length. The trays are not used to ship scrap pellets. The following parameters have been established based on physical dimensions as well as the shipping container weight limitations.

	Small Diameter Pellet Tray Array	Large Diameter Pellet Tray Array
Number of Trays per Box	9	7
Number of Trays Filled w/ Pellets	8	6
Number of Boxes per Insert	4	4
^{235}U Enrichment	$\leq$ 5 w/o	$\leq$ 5 w/o
Pellet Diameter	0.818 cm (0.3219")	0.969 cm (0.3815")

To maintain shipping flexibility, the following materials can also be shipped consistent with the above guidelines without requiring additional analyses; Poisoning material such as Gadolinia, Erbium, B4C, Stainless Steel Pellets or depleted Uranium ($\leq$ 0.22 w/o U235). No further justification is necessary for these materials since the inclusion of any of them reduce the reactivity of the system relative to the conditions which have been analyzed.

6.1.3 ABB-2901 Pellet Tray Configuration, Accident Array

As mentioned in Section 6.1.1, certain approximations were made to represent the corrugated tray and pellet configuration. The region within each of the four boxes was modeled as a homogenized region with cell weighted cross sections. The cross sections were calculated with the CSAS2X sequence in the SCALE-PC (version 4.1/0) package using a triangular pitched lattice cell calculation and the standard 27 group library. The loading of each box in the insert was varied in order to envelope the point of maximum reactivity.

For the bounding pellet diameters the triangular lattice cell inputs are as follows:

UO_2 Pellet O.D.	0.818 cm	0.969 cm
Gap Thickness	0.00 cm	0.00 cm
Clad OD	0.9521 cm	1.0887 cm
Pitch	Varies with Loading	Varies with Loading

It was determined that if the trays were evenly homogenized within each box, their worth would be over predicted. The pellets and trays are tightly packed, and the corrugation of the tray actually touches a good portion of the pellet. Under flooded accident conditions, the steel which touches the pellet is less parasitic than the steel located at some distance away. For this reason, the amount of steel equal in volume to that of the tray separating each pellet was modeled as cladding material.

As the number of pellets or pellet columns decreases, the amount of steel representing cladding decreases, and the amount of steel in the moderator increases. This is based on the assumption that a steel tray always separates a row of pellets. Also as the number of pellets or pellet columns decrease, the equivalent unit cell pitch increases. The lattice corrected, resonance corrected, and cell weighted cross sections are then input as Nuclide 500 into the inner shell volume in KENO. This technique provides a more conservative set of cross sections than directly homogenizing the material in a mixing table.

The UO_2 loadings analyzed for the 0.969 cm diameter pellet are listed below:

Number of Pellet Columns per Box	Pitch (cm)	Volume Fraction of SS304 in Moderator
69	1.415	0.0000
62	1.493	0.0218
55	1.585	0.0395
48	1.697	0.0541
41	1.836	0.0664
34	2.016	0.0769
27	2.263	0.0859

Consider the case of a stack of 6 corrugated trays alternating between 11 and 12 columns of pellets per tray; a 7th tray is placed on top of the stack. The internal dimensions of the pellet tray box which houses the stack of trays were conservatively taken as 21.273 x 5.627 x 46.368 centimeters. These dimensions were established by assuming the carbon steel insert which accommodates the four boxes, as well as each of the box boundaries, breaks apart or contorts outward until it contacts the inner container wall. As demonstrated by the drop tests, the inner container was not damaged. This approach therefore does not credit the structural integrity of the carbon steel insert nor the reinforced pellet tray boxes and assumes the maximum allowable fuel volume.

The fuel was assumed to occupy the four compartments which are oversized accordingly due to the assumption of the outward expansion of the carbon steel shelved insert. The calculated planar area of fuel in each box is then represented as 21.273 x 5.627 cm and is distributed over 69 unit cells. This conservatively assumed volume over estimates the amount of fuel mixture present by approximately 7% more than would be present when the insert and box structure are intact.

Each unit cell has a hexagonal outer boundary and consists of a UO2 pellet column, a stainless steel clad tube, and a H2O moderator region. A hexagonal cell geometry is taken since it most closely approximates the fuel column array.

In this case we assume a nominal pellet radius of 0.4845 cm. The clad thickness is derived by taking the total volume of corrugated tray stainless steel per cm of UO2 and distributing it equally among the 69 cells. Thus, the clad thickness is derived as follows.

The volume of SS304 per cm of UO2 is:

$$\frac{(7 \text{ trays}) \times (700 \text{ g SS/tray})}{(7.92 \text{ g SS/cc}) \times (46.3677 \text{ cm UO2/column}) \times (69 \text{ columns})} = 0.1934 \text{ cc}$$

The outer radius of the clad, R_{clad}, is given by:

$$\Pi(R^2_{clad} - R^2_{pellet}) = 0.1934$$

$$R_{clad} = 0.5443 \text{ cm}$$

In the case of partially loaded trays, it is postulated that a given number of pellet columns are missing in a relatively uniform distribution throughout the array; assume for this example, the number of missing columns is 7. The uniform distribution is expected to give the most reactive condition. In this case it is assumed that the 21.273 x 5.627 cm cross sectional area of each box is distributed over only 62 cells. Thus, the individual cells contain more moderator and the same clad thickness as derived above. However, to preserve the stainless steel content of the array, the stainless steel associated with the missing UO2 columns is homogeneously distributed throughout the moderator of the larger unit cells. A homogenous distribution is used since this stainless steel is further removed from the UO2 than in the case of the fully loaded trays.

The volume fraction of stainless steel in the moderator region of the unit cell is derived as follows. The amount of stainless steel to be homogenized into the moderator region of each unit cell is (7 x 0.1934 cc/cm) / (62). The moderator region area is [(21.273 cm) x (5.627 cm) / (62)] - $\Pi(R^2_{clad})$. The steel volume fraction is:

$$\frac{(7) \times (0.1934)}{(21.273 \times (5.627) - 62\Pi(0.5443)^2} = 0.0218$$

The volume fraction of H2O in the moderator is 1 - 0.0218 = 0.9782

Once again, as the number of pellet columns was reduced, the pitch of the unit cell was increased. An increase in the pitch of the unit cell under flooded conditions increases the water to oxide ratio. The pitch was calculated as that of a standard hexagonal unit cell. The following description outlines the calculation for the case of missing pellet columns.

In the case of missing pellet columns, the pitch is determined based on the volume available to each of the remaining pellet columns. For example, in the case where 7 pellet columns are missing per box, the cross sectional area per remaining unit cell is as follows:

$$\frac{5{,}550.21\ \text{cm}^3 \text{ of total vol}}{46.3677 \text{ cm of length}} = 119.70\ \text{cm}^2$$

This value is then divided equally among the remaining 62 pellet columns to give a unit cell area of 1.931 cm^2. Since the SCALE 4 package cannot perform spatial weighting over non-uniform or distorted triangular pitched cells, a standard triangular pitch is assumed. Therefore the pitch is backed out from the basic equations of a hexagonal cell.

$2.59808\ S^2$ = Area of a Hexagonal Cell

Where S = Length of each side of cell

$S^2 = 1.931 / 2.59808 = 0.7431\ \text{cm}^2$

S = 0.8620

Sin 60° (0.8620) = 1/2 pitch

½ pitch = 0.7465 cm

Pitch = 1.493 cm

When fully loaded trays are stacked, adjacent pellet columns subtend a small solid angle with no intervening portion of the stainless steel corrugated tray. Since the effect of this gapping is not explicitly treated in the cross section development, the magnitude of this impact was investigated.

KENO Va cannot explicitly model steel trays at angles other than 90 degrees; therefore, a model was created based on a square pitch with 1 mm of steel representing the trays placed diametrically opposite on a bare UO_2 cylinder (Figure 6-4). This case was then compared to a cylindrical unit cell with the same amount of steel modeled explicitly as cladding, and then to an additional case which had a square cell filled with a homogenized mixture which was collapsed over the same cylindrical setup in CSAS2X (Figure 6-5). All material volumes were maintained between cases. The results shown in Figures 6-4 and 6-5 demonstrate excellent agreement between methods; each case was within one standard deviation of the others.

To evaluate the sensitivity due to the length of the steel modeled around each pellet, an additional set of cases was evaluated which assumed the steel on the corners covered only one half of the pellet (Figures 6-6 and 6-7). The results of these cases shown in Figures 6-6 and 6-7, as expected, showed a slightly larger deviation than the first set, on the order of

0.6%. Based on these studies, and the tightly packed configuration of the container, it is apparent that there is little difference between the three models, and the homogenization is a reasonable technique with little associated uncertainty.

The accident array was constructed as an array of repeating triangular pitched (i.e., close packed) shipping drums as shown in Figure 6-2 and Table 6-9. This configuration of four half containers, (two containers total) was then repeated along with the appropriate complementing hemicylinder on each of the boundaries to total 208 full containers.

This array was completely reflected with 12 inches of full density water. Flooding was assumed to occur in the inner container only. The region exterior to the inner container was assumed empty to maximize container interaction. Evaluations were also preformed to determine the sensitivity of the interaction to various possible densities of the wood spacer blocks. The wide range of wood densities examined included those of Table 6-1. As expected, as the wood density increases, the interaction between the containers decreases. The results can be seen in Table 6-2 and Figure 6-3. The maximum K_{eff} with all applicable biases and uncertainties applied as described in Section 6.1.6 was determined to be 0.88803.

The case of the smaller diameter pellet (0.818 cm) was investigated in the same manner as the larger pellet diameter accident case. As mentioned previously, the smaller pellet diameter configuration is less reactive due primarily to the increased steel to UO_2 ratio. The results can be seen in Table 6-3. The maximum K_{eff} with all applicable biases and uncertainties applied as described in Section 6.1.6 was determined to be 0.85522.

6.1.4 ABB-2901 Pellet Tray Configuration Isolated Container

The fully flooded and reflected isolated container was analyzed. The isolated condition was analyzed for a variety of loading limits for the 0.4845 cm pellet radius with all void regions inside and outside of the inner compartment filled with full density water. The resulting K_{eff}'s calculated for various fuel loadings are given in Table 6-4. The maximum K_{eff} with all the appropriate biases and uncertainties applied from Section 6.1.6 is 0.73100, which is well below the design criterion of 0.95.

6.1.5 ABB-2901 Pellet Tray Configuration Normal Transportation

The calculation supporting the normal transportation mode of operation consisted of a calculation of 512 completely dry containers stacked in an 8x8x8 array. The cross sections were calculated with CSAS2X assuming a uniform triangular lattice calculation. The pitch was calculated the same way as discussed in Section 6.1.3, with the exception of the moderator region modelled as void instead of H_2O. The containers are assumed dry and filled with fuel. The UO_2 loading is the highest achievable and therefore, under dry conditions, the most reactive. This loading was run at the more adverse maximum wood density of 0.90 g/cc. The results are listed in Table 6-5, and the maximum $K_{eff} + 2\sigma$ is 0.43614. Due to the lack of moderation under normal operating conditions, the system neutronic characteristics fall outside the scope of the validation program. Therefore, due to the sufficient margin to criticality, no additional method bias was applied to this value.

6.1.6 Methodology Validation

The accident array configuration of shipping containers is essentially a group of individually separated clusters of fuel columns sandwiched between corrugated stainless steel trays. The matter separating the fuel clusters is comprised of hydrogenous materials such as H_2O or wood blocks and layers of carbon and stainless steel. Depending on the loading assumed in each fuel cluster, the water to oxide ratio for the homogenized cluster, i.e., UO_2, H_2O, and stainless steel trays, ranges from 0.6 to 5.9. The most adverse accident conditions occur when the fuel cluster in each container is at an HO_2/UO_2 ratio of approximately 1.40, and the moderation between containers is at the lowest possible density.

To demonstrate how well the methodology can predict this type of system, and to assess the magnitude of any relative bias in the predicted effective multiplication factor of the SCALE-PC (version 4.1) code system when used with the 27 group ENDF/B-IV library distributed with the code system, three classes of critical experiments were analyzed.

The first set of 13 experiments from Reference 1 consists of various 3x3 arrays of fuel rod clusters with and without steel isolation sheets at different water separation distances. These experiments provide insight into the accuracy of the methodology to calculate the interactive properties between fuel clusters when separated by full density water with and without interposed stainless steel. A summation of the results can be seen in Table 6-6, with a best estimate multiplication factor for the 13 experiments of 0.99217 ± 0.00168. The quoted uncertainty is the standard deviation about the mean of the 13 multiplication factors.

The second set involves a subset of the "Dissolution and Storage Experiments" reported by Manaranche et al in Nuclear Technology page 148, Vol. 50, 1980 (Reference 2). In these experiments, the reactivity effects of the interpositioning of hydrogenous materials of differing hydrogen densities between four water moderated PWR type assemblies are examined. These experiments provide a measure of the ability of SCALE-PC (ver 4.1/0) to model interaction effects between heterogenous configurations of UO_2 that involve both rod cluster separation distance and hydrogenous material densities. The water to oxide ratio of the individual fuel clusters was determined to be 2.30 in all cases. Table 6-7 lists the multiplication factors for the nineteen experiments reported. The average multiplication factor for the group as a whole is 0.99838 ± 0.00643. As above, the quoted uncertainty is the standard deviation about the mean. Thus the best estimate multiplication factor for the group exhibits a negligible bias relative to unity.

The above two sets of experiments employed aluminum clad UO_2. The case of the UO_2 pellets aligned in 1 mm thick stainless steel corrugated trays is analogous to an array of stainless steel clad UO_2 pellet columns. The third set of experiments employs 16 mil stainless steel clad instead of the nearly transparent aluminum employed in the first two sets of experiments. The six fully reflected "uniform" rod lattice configurations of 2.70 w/o enriched UO_2 reported in YAEC-94 (Reference 3) and WCAP-1412 (Reference 4) are used here. These experiments contain rods with stainless steel clad UO_2 wherein the clad material composition is based on the quoted chemical analysis. The experiments range over water to oxide ratios of 1.0 to 5.0. The analysis of these experiments demonstrates the ability of the SCALE-PC (version 4.1/0) model to calculate the worth of relatively thick stainless steel clad material in UO_2 lattices. In these

lattices, approximately 8 to 10% of the fractional absorptions are within the stainless steel. The 6 cases were run using two different approaches. The first approach used the CSAS25 module of SCALE-PC and modelled the fuel pins explicitly. The resulting average k-effective and standard deviation about the mean for the 6 experiments are 0.99170 and $\pm$ 0.0044. The individual values are listed in Table 6-8. The second approach used the CSAS2X module of SCALE-PC and modelled the fuel pellet, clad, and moderator as a homogeneous mixture with cell weighted cross sections. The resulting average k-effective and standard deviation about the mean for the 6 experiments are 0.99274 and $\pm$ 0.0044. The individual values are also listed in Table 6-8. The difference between the two approaches is almost transparent, with each case being within two standard deviations.

The data in Figure 6-2 indicate that the most reactive condition for the corrugated tray configuration occurs at a water to oxide ratio of approximately 1.48. The implied bias is calculated from the 67 experiment results listed in Tables 6-5 through 6-9. The equation employed for folding the KENO calculational uncertainties and validation analyses into a value of the multiplication factor yielding a 95 percent confidence level that in 95 percent of similar analyses the validated calculational model will yield a multiplication factor less than $K_{95/95}$ is as follows.

$$K_{95/95} = K_{calc} + \Delta K_B + M_{95/95} (\sigma_m^2 + \sigma_{KENO}^2)^{1/2}$$

where:

K_{calc} is the calculated multiplication factor of interest.

ΔK_B is the calculational method bias.

$M_{95/95}$ is the 95/95 multiplier appropriate to the degrees of freedom of the n validation analyses.

σ_m^2 is the calculational method variance.

σ_{KENO}^2 is the variance for the KENO calculation of interest.

The calculational method bias is determined from the number, n, of validation analyses appropriate to the system being analyzed.

$$\Delta K_B = n^{-1} * \Sigma^n_i (K_{meas} - K_{calc})$$

$M_{95/95}$ is obtained from Reference 5 for degrees of freedom = n-1.

The calculational method variance is derived using the following equation:

$$\sigma_m^2 = \{(38 * \Sigma_i (K_i - K_{ave})^2 / \sigma_i^2) / 37 * \Sigma_i \sigma_i^2\} - \sigma^2_{ave}$$

where $\sigma^2_{ave} = (\Sigma_i \sigma_i^2 * (\text{No. Gen.})_i) / (\Sigma_i (\text{No. Gen.})_i$

and $K_{ave} = [\Sigma_i (K_i * \sigma_i^{-2})] / \Sigma_i \sigma_i^{-2}$

The average eigenvalue, K_{ave}, for the 38 experiments is determined to be 0.99451. σ^2_{ave} for the 38 experiments is $(0.00162)^2$, and the method variance, σ_m^2, is $(0.00512)^2$. The method bias, ΔK_B, is 0.004799. The number of degrees of freedom is 37 and the 95/95 multiplier is 2.149 based on Reference 5. Thus, for a given KENO multiplication factor, the magnitude of $K_{95/95}$ is:

$$K_{95/95} = K_{KENO} + 0.004799 + 2.149\,[(0.00512)^2 + (\sigma_{KENO}^2)]^{1/2}$$

In all cases presented herein, the calculated eigenvalue plus the biases and uncertainties are substantially less than the criterion of 0.95.

6.2 References

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2. J. C. Manaranche, et al, "Dissolution and Storage Experiment with 4.75 w/o U-235 Enriched UO2 Rods", Nuclear Technology, Vol 50, pg 148, September 1980.

3. "Yankee Critical Experiments- Measurement on Lattices of Stainless Steel Clad Slightly Enriched Uranium Dioxide Rods in Light Water"; P. W. Davison, et al; APD, West. El. Corp., YAEC-94, April 1, 1959.

4. "Results of Critical Experiments in Loose Lattices of UO2 Rods in H2O"; V. E. Grob, P. W. Davison, D. F. Hanlen, R. D. Leamer, F. L. Kelley, J. D. Cleary; Westinghouse Electric Corp.; WCAP-1412, March 30, 1960.

5. D. B. Owen, "Factors for One-Sided Tolerance Limits and for Variables Sampling Plans", SCR-607, Sandia Corporation Monograph, March 1963.

Figure 6-1
KENO Va Model Of ABB-2901
Inner Container Structure

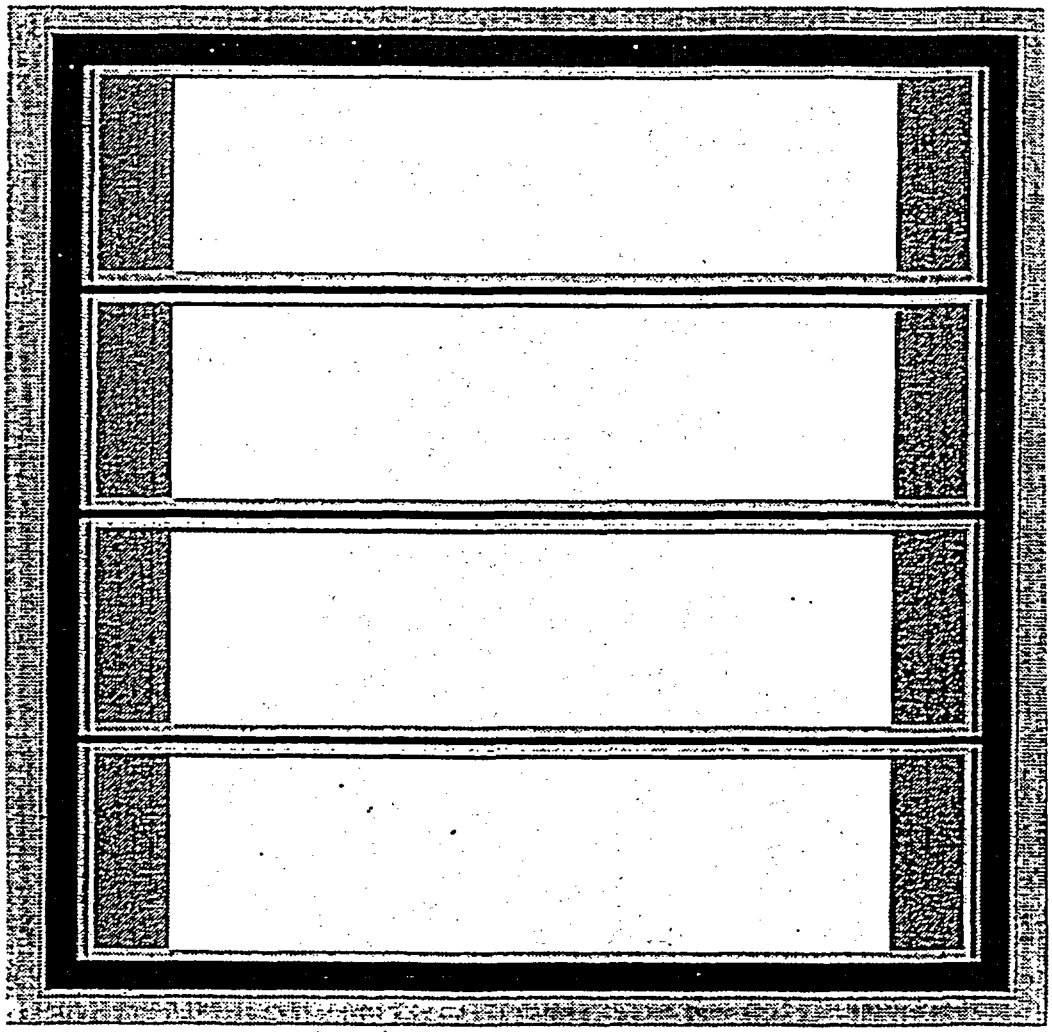


Figure 6-2
KENO Va Model Of ABB-2901
Triangular Array Setup

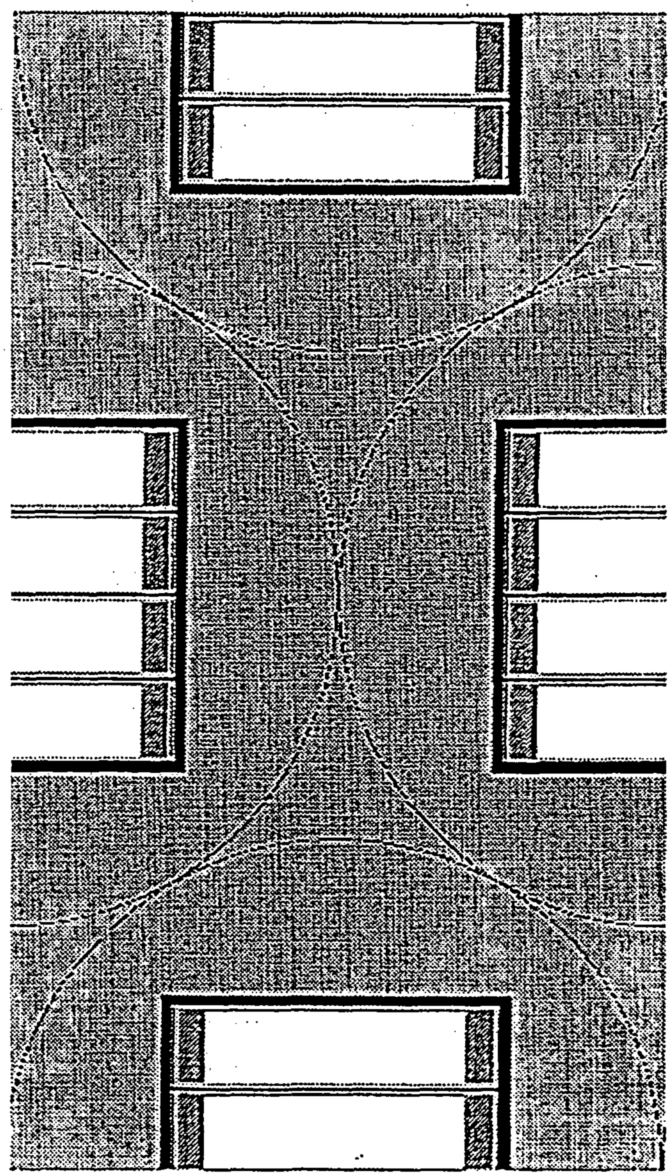


Figure 6-3
K_{eff} versus Kg UO_2
Pellet Tray Configuration, Accident Array
Large Diameter (0.969 cm) Pellet
ABB-2901

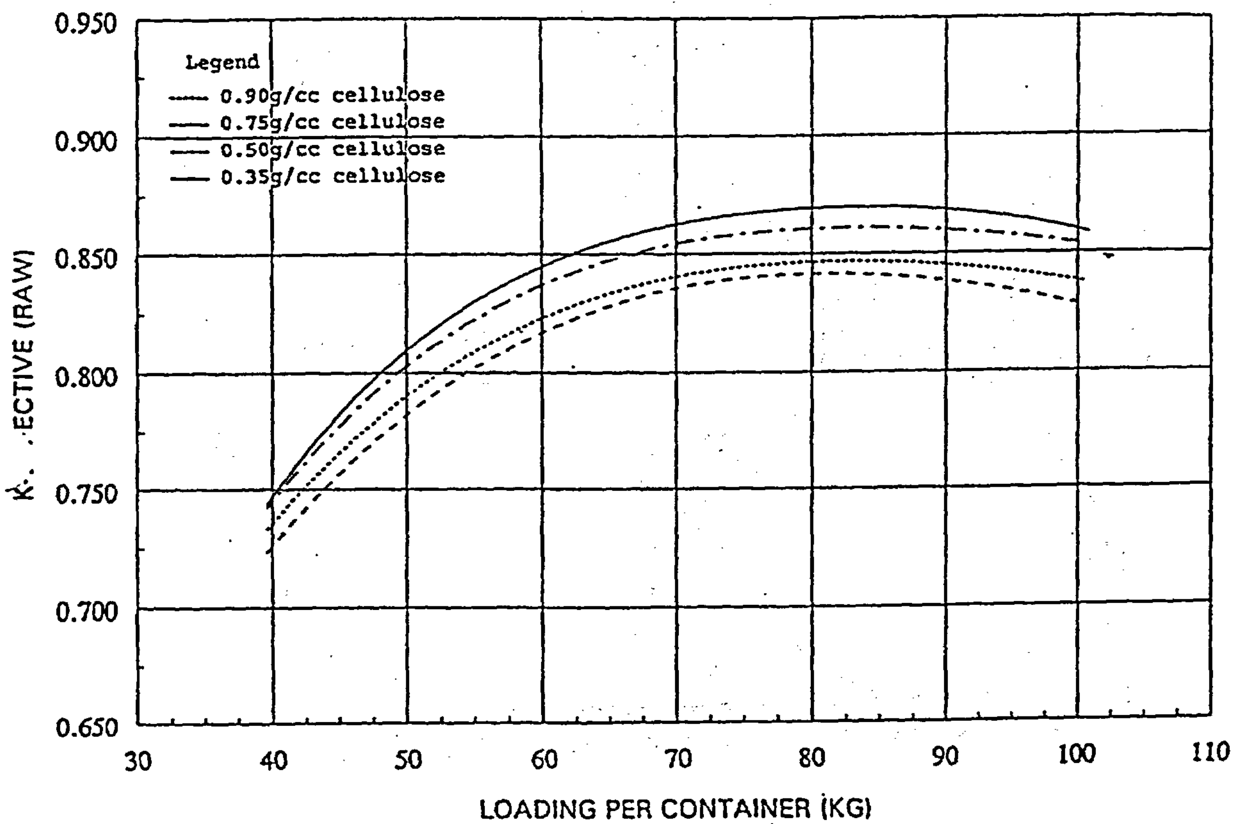
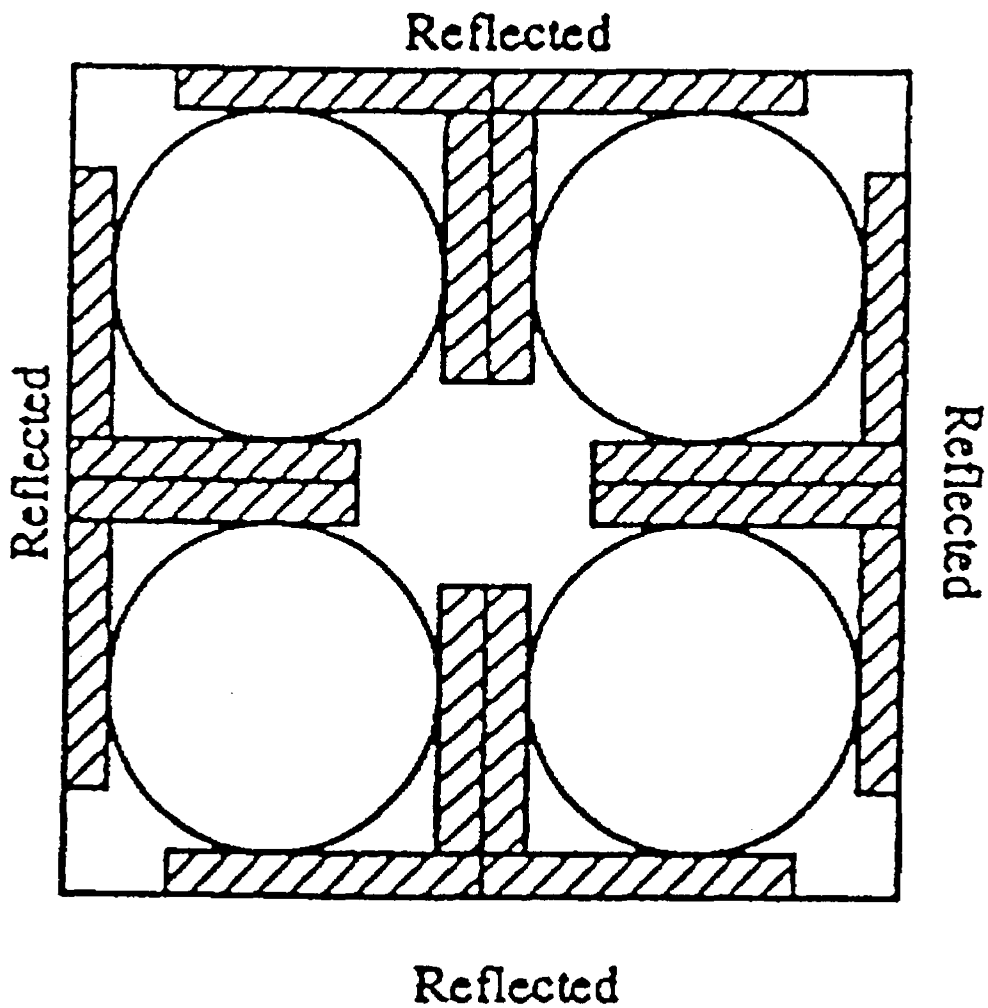
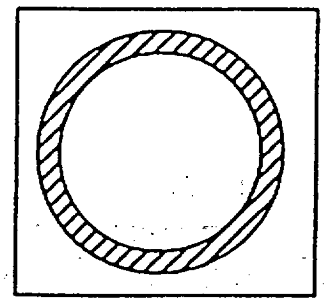


Figure 6-4
KENO Va Model of Steel Trays (3/4 length of Pellet)

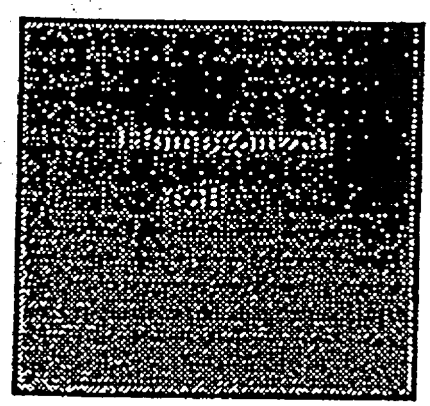


(K–effective = 1.08402 + 0.00247)

Figure 6-5
KENO Va Model Approximating Steel at 3/4 Length of Pellet

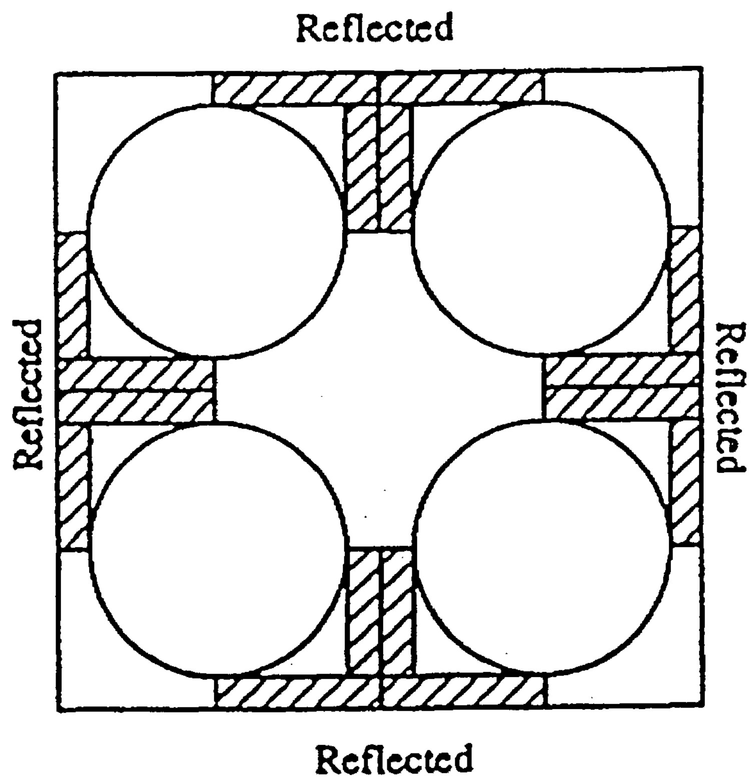


(K–effective = 1.08376 + 0.00247)



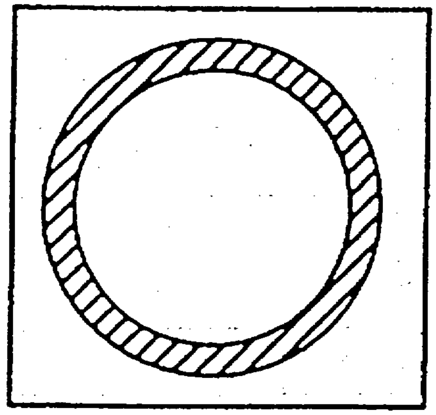
(K–effective = 1.08197 + 0.00242)

Figure 6-6
KENO Va Model of Steel Trays (1/2 length of Pellet)

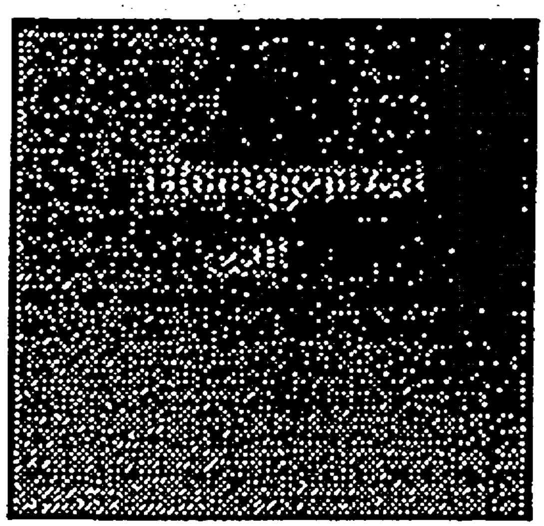


(K–effective = 1.14811 + 0.00241)

Figure 6-7
KENO Va Model Approximating Steel at 1/2 Length of Pellet



(K–effective = 1.14776 + 0.00268)



(K–effective = 1.14189 + 0.00246)

Table 6-1

Densities of Various Wood Types

Wood Type	Grams/cc
Ash	0.65 - 0.85
Birch	0.51 - 0.77
Cedar	0.49 - 0.57
Dogwood	0.76
Elm	0.54 - 0.60
Maple	0.62 - 0.75
Oak	0.60 - 0.90
Pine	0.35 - 0.60
Poplar	0.35 - 0.50

Table 6-2

Pellet Tray Configuration Accident
Case Results for Various Wood Densities
Large Diameter (0.969 cm) Pellet
ABB-2901

Kgs per Box	0.90 g/cc Cellulose	0.75 g/cc Cellulose	0.50 G/cc Cellulose	0.35 g/cc Cellulose
25.2	0.82750 ± 0.00174	0.83701 ± 0.00166	0.85262 ± 0.00165	0.85878 ± 0.00168
22.7	0.83701 ± 0.00181	0.84586 ± 0.00172	0.86133 ± 0.00173	0.86595 ± 0.00170
20.1	0.84155 ± 0.00171	0.84411 ± 0.00164	0.85734 ± 0.00177	0.87162 ± 0.00173
17.5	0.83728 ± 0.00169	0.84283 ± 0.00164	0.85564 ± 0.00151	0.86292 ± 0.00163
15.0	0.81424 ± 0.00165	0.82186 ± 0.00165	0.83791 ± 0.00162	0.84191 ± 0.00168
12.4	0.78190 ± 0.00156	0.78854 ± 0.00156	0.79978 ± 0.00146	0.80975 ± 0.00152
9.9	0.72228 ± 0.00142	0.73253 ± 0.00139	0.74220 ± 0.00135	0.74289 ± 0.00140

Table 6-3

Pellet Tray Configuration, Accident Array
Small Diameter (0.818 cm) Pellet
ABB-2901

Kilograms per Box	0.35 g/cc Cellulose
24.1	0.83274 ± 0.00201
21.4	0.83702 ± 0.00205
18.8	0.83855 ± 0.00207
16.2	0.82797 ± 0.00213
13.6	0.79828 ± 0.00208
11.0	0.75414 ± 0.00191
8.4	0.67781 ± 0.00164

Table 6-4

Pellet Tray Configuration, Isolated Container
ABB-2901

Kilograms per Box	0.90 g/cc Cellulose
25.2	0.69276 ± 0.00278
22.7	0.71000 ± 0.00304
20.1	0.71356 ± 0.00290
17.5	0.71085 ± 0.00284
15.0	0.69789 ± 0.00288
12.4	0.66765 ± 0.00256

Table 6-5

Pellet Tray Configuration, 8X8X8 Normal Transportation Mode
Fully Loaded Container
ABB-2901

Density of Cellulose	$K_{eff} \pm \sigma$
0.90	0.43629 ± 0.00193

Table 6-6

B&W Critical Experiments
Supporting Close Proximity Water Storage of
Power Reactor Fuel

B&W Experiments, 1484-7	
Experiment #	$K_{eff} \pm \sigma$
Core I	0.98938 ± 0.00157
Core II	0.99172 ± 0.00132
Core III	0.99413 ± 0.00132
Core IX	0.99120 ± 0.00156
Core X	0.99153 ± 0.00153
Core XIa	0.99091 ± 0.00142
Core XIb	0.99232 ± 0.00137
Core XIc	0.99516 ± 0.00131
Core XId	0.99439 ± 0.00118
Core XIe	0.99366 ± 0.00147
Core XIf	0.99091 ± 0.00138
Core XIg	0.99188 ± 0.00140
Core XII	0.99103 ± 0.00144

Table 6-7

Dissolution and Storage Experiments

Assembly Configuration					Calculated $K_{eff} \pm \sigma$
D cm	Interstitial Material	Compounds		Critical Water Height cm	Moderator in Cruciform at Critical Water Height
		Density g/cc	Conc H g/cc		
0	Water	1.0	0.1119	23.80	0.99723 ± 0.00180
2.5	Box + Air	0	0	29.03	0.99353 ± 0.00184
	Box + $(C_8H_8)_n$	0.0323	0.0025	28.61	0.98810 ± 0.00181
	Box + Powder $(CH_2)_n$	0.2879	0.0414	26.98	0.99754 ± 0.00186
	Box + Balls $(CH_2)_n$	0.5540	0.0800	25.54	0.99455 ± 0.00182
	Box + Water	1.0	0.1119	25.66	1.00885 ± 0.00188
	Water	1.0	0.1119	24.48	0.99824 ± 0.00177
5.0	Box + Air	0	0	34.48	0.99324 ± 0.00173
	Box + $(C_8H_8)_n$	0.0262	0.0020	34.39	0.99087 ± 0.00186
	Box + Powder $(CH_2)_n$	0.3335	0.0480	30.16	0.99774 ± 0.00176
	Box + Balls $(CH_2)_n$	0.5796	0.0833	30.73	1.00637 ± 0.00177
	Box + Water	1.0	0.1119	32.78	1.01222 ± 0.00177
	Water	1.0	0.1119	31.47	0.99485 ± 0.00178
10.0	Box + Air	0	0	48.08	0.99139 ± 0.00177
	Box + $(C_8H_8)_n$	0.0288	0.0022	45.62	0.99699 ± 0.00177
	Box + Powder $(CH_2)_n$	0.3216	0.0464	42.05	1.00423 ± 0.00178
	Box + Balls $(CH_2)_n$	0.5680	0.0816	49.94	1.00499 ± 0.00176
	Box + Water	1.0	0.1119	64.12	0.99714 ± 0.00180
	Water	1.0	0.1119	64.34	1.00114 ± 0.00186

Table 6-8

WAPD/CRX Yankee Experiments

WAPD/CRX Yankee Experiments			
Experiment #	H_2O/UO_2	CSAS25 $K_{eff} \pm \sigma$	CSAS2X $K_{eff} \pm s\sigma$
1	1.048	0.98520 ± 0.00135	0.98813 ± 0.00214
2	1.405	0.98969 ± 0.00147	0.98929 ± 0.00243
3	1.853	0.98920 ± 0.00154	0.99143 ± 0.00257
4	3.373	0.99556 ± 0.00144	0.99399 ± 0.00220
5	4.078	0.99675 ± 0.00143	1.00038 ± 0.00231
6	4.984	0.99378 ± 0.00138	0.99325 ± 0.00219

Table 6-9

Sample KENO Va Input Listing - Accident Mode
25.2 Kgs per Box

```
#CSAS2X
CONTAINER ARRAY-5/16" INSERT 11X11X30 INNER CONT DIMEN BLOWN OUTWARD
27GROUPNDF4                LATTICECELL
UO2            1  DEN=10.96 1.0 293 92235 5 92238 95 END
SS304          2  1.0 293 END
POLY(H2O)      3  DEN=1.0 1.0 293 END
CARBONSTEEL    4  1.0 293 END
H2O            5  1.0 293 END
AL             6  1.0 293 END
H2O            7  1.0 293 END
SS304          8  1.0 293 END
OAK            9  DEN=0.90 1.0 293 END
CARBONSTEEL   10  1.0 293 END
CARBONSTEEL   11  1.0 293 END
END COMP
TRIANGPITCH 1.4153 .9690 1  5 1.0887 2 END
2901 PELLETS ON TRAYS IN BOXES 0.3815 PELLET DIAM 00 COLUMNS MISSING
READ PARM GEN=500 NPG=300 NSK=10 RND=67676763855 RUN=YES NUB=YES
END PARM
READ GEOM

UNIT  1
COM=!FUEL REGION OF BOX-W/ AL SIDES+BASE SS COVER+SIDE C-STEEL SUPPORTS!
CUBOID  500 1  10.6363 -10.6363  46.3677  0.000   5.626875    0.0000
CUBOID    3 1  10.6363 -10.6363  46.3677  0.000   5.794375    0.0000
CUBOID    6 1  12.8588 -12.8588  46.3677  0.000   5.794375    0.0000
CUBOID    8 1  12.8588 -12.8588  46.5201 -0.1524  5.953125    0.0000
CUBOID    6 1  12.8588 -12.8588  46.5201 -0.1524  5.953125   -0.3175
CUBOID   10 1  13.1763 -13.1763  46.5201 -0.1524  5.953125   -0.3175


UNIT  2
COM=! YHEMICYL-Z TWO BOXES W/ 5/16" C-STEEL INSERT-CENTERED TOP CELL!
ARRAY  1  -13.1763 -23.33625 -13.1763
CUBOID     4 1   13.9700 -13.9700  23.33625  -24.2888 0.0 -13.9700
CUBOID    11 1   14.1685 -14.1685  23.33625  -24.2888 0.0 -14.1685
CUBOID     9 1   14.1685 -14.1685  36.98925  -37.9418 0.0 -14.1685
CUBOID     8 1   14.1685 -14.1685  38.25820  -37.9418 0.0 -14.1685
YHEMICYL-Z  0 1 26.67 45.1232 -44.8068
YHEMICYL-Z  4 1 26.79 45.2662 -44.9498
```

```
UNIT  3
COM=! YHEMICYL+Z TWO BOXES W/ 5/16" C-STEEL INSERT-CENTERED BOTTOM CELL!
ARRAY  2  -13.1763 -23.33625 0.00
CUBOID     4 1    13.9700 -13.9700  23.33625  -24.2888 13.9700  0.0
CUBOID    11 1    14.1685 -14.1685  23.33625  -24.2888 14.1685  0.0
CUBOID     9 1    14.1685 -14.1685  36.98925  -37.9418 14.1685  0.0
CUBOID     8 1    14.1685 -14.1685  38.25820  -37.9418 14.1685  0.0
YHEMICYL+Z  0 1 26.67 45.1232 -44.8068
YHEMICYL+Z  4 1 26.79 45.2662 -44.9498

UNIT  4
COM=!FUEL REGION 1/2 BOX-W/ AL SIDES+BASE+SS COVER C-STEEL SUPPORTS!
CUBOID  500 1    0.0   -10.6363   46.3677  0.000    5.626875      0.0000
CUBOID    3 1    0.0   -10.6363   46.3677  0.000    5.794375      0.0000
CUBOID    6 1    0.0   -12.8588   46.3677  0.000    5.794375      0.0000
CUBOID    8 1    0.0   -12.8588   46.5201 -0.1524   5.953125      0.0000
CUBOID    6 1    0.0   -12.8588   46.5201 -0.1524   5.953125     -0.3175
CUBOID   10 1    0.0   -13.1763   46.5201 -0.1524   5.953125     -0.3175

UNIT  5
COM=! YHEMICYL-X TWO BOXES W/ 5/16" C-STEEL INSERT-CENTERED RIGHT CELL!
ARRAY  3  -13.1763 -23.33625 -13.1763
CUBOID     4 1    0.0 -13.9700  23.33625  -24.2888 14.2875 -14.2875
CUBOID    11 1    0.0 -14.1625  23.33625  -24.2888 14.4860 -14.4860
CUBOID     9 1    0.0 -14.1625  36.98925  -37.9418 14.4860 -14.4860
CUBOID     8 1    0.0 -14.1625  38.25820  -37.9418 14.4860 -14.4860
YHEMICYL-X  0 1 26.67 45.1232 -44.8068
YHEMICYL-X  4 1 26.79 45.2662 -44.9498

UNIT  6
COM=!FUEL REGION 1/2 BOX-W/ AL SIDES+BASE+SS COVER C-STEEL SUPPORTS!
CUBOID  500 1  10.6363  0.0  46.3677  0.000    5.626875    0.0000
CUBOID    3 1  10.6363  0.0  46.3677  0.000    5.794375    0.0000
CUBOID    6 1  12.8588  0.0  46.3677  0.000    5.794375    0.0000
CUBOID    8 1  12.8588  0.0  46.5201 -0.1524   5.953125    0.0000
CUBOID    6 1  12.8588  0.0  46.5201 -0.1524   5.953125   -0.3175
CUBOID   10 1  13.1763  0.0  46.5201 -0.1524   5.953125   -0.3175

UNIT  7
COM=! YHEMICYL+X TWO BOXES W/ 5/16" C-STEEL INSERT-CENTERED LEFT CELL!
ARRAY  4  0.0 -23.33625 -13.1763
CUBOID     4 1   13.9700 0.0  23.33625  -24.2888 13.9700 -13.9700
CUBOID    11 1   14.1625 0.0  23.33625  -24.2888 14.1625 -14.1625
CUBOID     9 1   14.1625 0.0  36.98925  -37.9418 14.1625 -14.1625
CUBOID     8 1   14.1625 0.0  38.25820  -37.9418 14.1625 -14.1625
YHEMICYL+X  0 1 26.67 45.1232 -44.8068
YHEMICYL+X  4 1 26.79 45.2662 -44.9498
CUBOID     0 1  53.58    0.0   45.2662  -44.9498 46.4100 -46.4100
HOLE       5    53.58    0.0    0.0
HOLE       2    26.79    0.0    46.41
HOLE       3    26.79    0.0   -46.41
```

```
UNIT  8
COM=!  FULL SHELF !
CUBOID     7 1  13.17630 -13.17630  46.5201 -0.1524   0.0 -0.2278
CUBOID     4 1  13.17630 -13.17630  46.5201 -0.1524   0.0 -0.3175

UNIT  9
COM=! 1/2 THICKNESS SHELF !
CUBOID     7 1  13.17630 -13.17630  46.5201 -0.1524   0.0 -0.11390
CUBOID     4 1  13.17630 -13.17630  46.5201 -0.1524   0.0 -0.15875

UNIT 10
COM=! 1/2 LENGTH SHELF!
CUBOID     7 1   0.0  -13.17630  46.5201 -0.1524   0.0  -0.2278
CUBOID     4 1   0.0  -13.17630  46.5201 -0.1524   0.0  -0.3175

UNIT  11
COM=!TOP ROW HEMICYLINDER +Z DIRECTION WITH CUBOID AROUND!
ARRAY  2  -13.1763 -23.33625 0.00
CUBOID     4 1   13.9700 -13.9700  23.33625  -24.2888 13.9700  0.0
CUBOID    11 1   14.1685 -14.1685  23.33625  -24.2888 14.1685  0.0
CUBOID     9 1   14.1685 -14.1685  36.98925  -37.9418 14.1685  0.0
CUBOID     8 1   14.1685 -14.1685  38.25820  -37.9418 14.1685  0.0
YHEMICYL+Z  0 1 26.67 45.1232 -44.8068
YHEMICYL+Z  4 1 26.79 45.2662 -44.9498
CUBOID     0 1  26.79 -26.79  45.2662 -44.9498 26.79 0.0

UNIT  12
COM=!BOTTOM ROW HEMICYLINDER -Z DIRECTION WITH CUBOID AROUND!
ARRAY  1  -13.1763 -23.33625 -13.1763
CUBOID     4 1   13.9700 -13.9700  23.33625  -24.2888 0.0 -13.9700
CUBOID    11 1   14.1685 -14.1685  23.33625  -24.2888 0.0 -14.1685
CUBOID     9 1   14.1685 -14.1685  36.98925  -37.9418 0.0 -14.1685
CUBOID     8 1   14.1685 -14.1685  38.25820  -37.9418 0.0 -14.1685
YHEMICYL-Z  0 1 26.67 45.1232 -44.8068
YHEMICYL-Z  4 1 26.79 45.2662 -44.9498
CUBOID     0 1  26.79 -26.79  45.2662 -44.9498 0.0 -26.79

UNIT  13
COM=!LEFT SIDE HEMICYLINDER -X DIRECTION WITH CUBOID AROUND!
ARRAY  3  -13.1763 -23.33625 -13.1763
CUBOID     4 1   0.0 -13.9700  23.33625  -24.2888 14.2875 -14.2875
CUBOID    11 1   0.0 -14.1625  23.33625  -24.2888 14.4860 -14.4860
CUBOID     9 1   0.0 -14.1625  36.98925  -37.9418 14.4860 -14.4860
CUBOID     8 1   0.0 -14.1625  38.25820  -37.9418 14.4860 -14.4860
YHEMICYL-X  0 1 26.67 45.1232 -44.8068
YHEMICYL-X  4 1 26.79 45.2662 -44.9498
CUBOID     0 1   0.0  -26.79  45.2662 -44.9498 46.41 -46.41
```

```
UNIT  14
COM=!RIGHT SIDE HEMICYLINDER +X DIRECTION WITH CUBOID AROUND!
ARRAY  4  0.0 -23.33625 -13.1763
CUBOID     4 1   13.9700 0.0  23.33625  -24.2888 13.9700 -13.9700
CUBOID    11 1   14.1625 0.0  23.33625  -24.2888 14.1625 -14.1625
CUBOID     9 1   14.1625 0.0  36.98925  -37.9418 14.1625 -14.1625
CUBOID     8 1   14.1625 0.0  38.25820  -37.9418 14.1625 -14.1625
YHEMICYL+X  0 1 26.67 45.1232 -44.8068
YHEMICYL+X  4 1 26.79 45.2662 -44.9498
CUBOID     0 1  26.79 0.0     45.2662 -44.9498 46.41 -46.41

UNIT  15
CUBOID     0 1  26.79 0.0 45.363 -44.853 26.79 0.0

GLOBAL
UNIT  16
ARRAY  5 3*0.0
END GEOM

READ ARRAY

ARA=1 NUX=1 NUY=1 NUZ=4
COM=!DESCR OF -Z DIR VERTICAL ARRAY OF BOXES AND SHELVES 1/2 HEIGHT!
FILL
 1 8 1 9
END FILL

ARA=2 NUX=1 NUY=1 NUZ=4
COM=!DESCR OF +Z DIR VERTICAL ARRAY OF BOXES AND SHELVES 1/2 HEIGHT!
FILL 9 1 8 1
END FILL

ARA=3 NUX=1 NUY=1 NUZ=7
COM=!DESCR OF -X VERTICAL ARRAY OF 1/2 LENGTH BOXES WITH SHELVES!
FILL
 4 10 4 10 4 10 4
END FILL

ARA=4 NUX=1 NUY=1 NUZ=7
COM=!DESCR OF +X VERTICAL ARRAY OF 1/2 LENGTH BOXES WITH SHELVES!
FILL
 6 10 6 10 6 10 6
END FILL
```

```
ARA=5 NUX=7 NUY=4 NUZ=7
COM=!FINAL TRIANGULAR PITCHED ARRAY OF CONTAINERS!
FILL 15 5R12 15
   15 5R12 15
   15 5R12 15
   15 5R12 15

   13 5R7  14
   13 5R7  14
   13 5R7  14
   13 5R7  14

   13 5R7  14
   13 5R7  14
   13 5R7  14
   13 5R7  14

   13 5R7  14
   13 5R7  14
   13 5R7  14
   13 5R7  14

   13 5R7  14
   13 5R7  14
   13 5R7  14
   13 5R7  14

   13 5R7  14
   13 5R7  14
   13 5R7  14
   13 5R7  14

   15 5R11 15
   15 5R11 15
   15 5R11 15
   15 5R11 15
END FILL

END ARRAY

READ BNDS +XB=H2O -XB=H2O +YB=H2O -YB=H2O +ZB=H2O -ZB=H2O  END BNDS
END DATA
END
```

7.0 OPERATING PROCEDURES

Uranium dioxide (UO_2) fuel pellets are shipped in the ABB-2901 shipping package. Loading and unloading of the shipping package are relatively simple, straight forward operations. However, to ensure proper and safe packaging of the special nuclear material to be transported, detailed manufacturing facility procedures are employed when executing these operations. The following general description provides a brief overview of the detailed procedures.

7.1 Procedures for Loading the Shipping Package

Pellet trays are filled and transferred to a scale area where the pellet material weight is determined by measurement and adjusted to be within the loading limit of 227 pounds of pellets (103 kgs) as listed in Section 1.2.3. From the scale area, the pellet trays are brought to the loading area or they are placed in storage to await shipment.

Prior to loading special nuclear material into the shipping package, its ring clamp, outer drum lid, circular wooden top spacer, inner compartment cover and cover gasket are removed. The outer shell of the steel drum is inspected to assure that there are no holes or tears. The shipping pallet, upon which the shipping packages rest, is also inspected to assure it is in reasonable condition prior to use (i.e., no bent legs, straps are in place, etc.). Once the shipping package and shipping pallet are determined to be acceptable for use, the corrugated pellet tray boxes of new fuel pellets can be loaded.

Initially, the first loading step is to place a wooden spacer block in the bottom of the inner container. This is followed by the insertion of the heavy steel shelved insert. Although it is removable, the shelved insert is not intended to be removed and inserted on a continuous basis due to it's weight. Therefore, following initial assembly, this step only needs to be repeated if the insert has been removed.

The shelved insert contains four locations which accommodate the corrugated pellet tray boxes. Each of the four boxes is filled with up to eight corrugated pellet trays depending on the type (i.e., diameter) of fuel pellet being shipped. An empty corrugated tray is used over the top layer of fuel pellets as a cover for the stack of pellet trays. A piece of compressible rubber material approximately the size of a corrugated tray is placed on top of the uppermost tray and the box lid is attached to the pellet box. The thickness of the rubber material is listed on the engineering drawings in Appendix 1A.

Four corrugated tray pellet boxes are placed into a steel insert. If fewer than the total number of trays for each pellet diameter are to be shipped in a box, then the void left by any missing trays shall be filled with wood spacers. If there is insufficient material to fill all four locations per insert, for structural reasons, an empty box filled with a wood spacer must occupy the unused locations.

After loading of the four corrugated tray boxes into the steel insert is complete, an additional wood spacer block is inserted which occupies the remaining volume within the inner compartment. Before installing the inner compartment cover gasket, the gasket is inspected for

acceptability and replaced if necessary. The inner compartment cover gasket and cover are installed, secured with nuts. Following this the circular wooden top spacer, lid, ring clamp and three retention clamps are installed thereby sealing the entire package. The outside surface of the shipping package is smeared and surveyed. Finally, the shipping package is appropriately labeled, a tamper-proof seal is applied, and the shipping package is removed to a storage area to await shipment or it is loaded directly on the transport vehicle, as appropriate.

The ABB-2901 shipping package is loaded, unloaded and transported in a horizontal orientation.

7.2 Procedures for Unloading the Shipping Package

Unloading the ABB-2901 shipping package is, for the most part, simply a reversal of the loading process described above. Upon arrival, the shipping packages are inspected for potential shipping or handling damage and to verify the integrity of the tamper-proof seal. If the container is found to be damaged and/or the seal has been tampered with, manufacturing facility management is informed. Following initial external receipt inspection, the ABB-2901 shipping packages, on their shipping pallet, are brought into the area of the manufacturing facility where they are to be unloaded.

Once located in the unloading area, the three retention clamps, the ring clamp, outer drum lid, circular wooden top spacer, the inner compartment cover, and gasket are removed from the shipping package. The individual corrugated pellet tray boxes are extracted by removing the two front screws and threading on the appropriate handling tool. The individual corrugated trays of pellets are accessed via complete removal of the screwed down cover. The corrugated trays are transferred to a receiving scale station and inspected. After completing receipt inspection, the fuel pellets are transferred to a storage area or they are introduced directly into the manufacturing process, as appropriate.

Once the ABB-2901 shipping package has been unloaded, the packaging material is replaced and the inner compartment cover is secured, the outer drum lid is secured with the ring clamp and an "EMPTY" notice is attached to the outside of the shipping package. The empty shipping packages are then decontaminated, if necessary, and moved to a transport vehicle or to a storage area to await return to the fuel vendor, as appropriate.

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

8.1 Acceptance Tests

The ABB-2901 shipping package will be fabricated in accordance with approved drawings and specifications. Any changes in design which fall outside of the safety envelope specified in this application will be submitted to the Nuclear Regulatory Commission for approval prior to being implemented.

The outer shell of each shipping package shall be conspicuously and durably marked with the package model number, gross weight, and the package identification number assigned by the Nuclear Regulatory Commission.

8.2 Maintenance Program

Repair and maintenance are also performed in accordance with approved drawings and specifications. The ABB-2901 shipping package has no moving parts which require periodic maintenance. Inspections of the drum and internals are performed during loading and unloading operations as specified in the loading and unloading procedures. Any unacceptable condition discovered during these operations is noted and the shipping package appropriately tagged for maintenance.