71-9251

FRAMATOME ANP

An AREVA and Siemens Company

FRAMATOME ANP, Inc.

Mr. John D. Monninger
Chief, Licensing Section
Spent Fuel Project Office – NMSS
U.S. Nuclear Regulatory Commission
One White Flint North
1155 Rockville Pike
Rockville, MD 20852-2738

October 8, 2002

Subject: **Submittal of Consolidated Application for Renewal of Certificate of Compliance No. 9251 for the BW-2901 Shipping Package**

Enclosure I Justification for Requested Change
Attachment I Consolidated application for renewal of BW-2901

Dear Mr. Monninger,

Framatome ANP formally transmits the attached consolidated application for renewal of the Certificate of Compliance (C of C) for the above referenced shipping package. On August 16, Framatome ANP requested timely renewal in accordance with 10 CFR 71.38.

Due to some outstanding questions related to Confirmatory Action Letter (02-8-001), submittal of the consolidated application were delayed until physical testing of the package could be performed. Tests were conducted in early September with the appropriate additional protective measures applied to the package to ensure all concerns related to the CAL were addressed.

The attached transmittal was updated to reflect the most recent revision, corporate name changes, correction of typographical errors, and to include the updated sections on the recent hypothetical accident testing. The significant changes in the documentation include removal of the references to fissile class types and the data supporting fissile class III shipments and the inclusion of the new test data. Attempts were made to minimize the changes to other sections to facilitate your review.

Similar to the request made by Framatome ANP for the DHTF certificate, it is requested that the requirements on the gasket on the internal container be changed on the certificate to require replacement if any defect is found during inspection rather than every 12 months, whichever comes first. The technical justification for this request is included in Enclosure I.

FRAMATOME ANP, Inc.
1724 Mount Athos Road PO Box 11646 – Lynchburg VA 24506-1646
Tel 434-832-5000 Fax 434-832-5025 www.us.framatome-anp.com

NMSS01

It is also requested that the contents listed in Section (b)(l)(i) and (b)(l)(ii) of the certificate of compliance be evaluated since the latter contents bounds the former requirements.

If you have any questions concerning this submittal, please call me at (434) 832-5268.

Sincerely,

Robert S. Freeman
Manager, Environmental, Health,
Safety and Licensing

EHSLL-02-020
EHSLR-02-036

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Enclosure I

**Justification for Requested Change
To Docket 71-9251**

Section 7.1 Procedures for Loading the Container

This section cites overly specific requirements for the internal gasket. During normal transportation mode, containment of the solid ceramic UO2 pellets is accomplished by enclosing the pellets within closed cardboard boxes. The boxes, up to six per package, are then contained within the inner container. The inner container is secured using a metal lid with twelve perimeter bolts. Located between the lid and the inner container flange is the silicon rubber gasket.

Since the gasket is assumed not to be available to prevent water intrusion, and was not credited in the criticality safety accident analysis, the requirement to replace the inner container gasket, if during inspection it shows any signs of defect <u>or every 12 month whichever comes first</u> is unnecessary. Based on the reasons stated below, the sentence has been reworded to continue to require inspection and replacement if necessary, but remove the 12 month interval. The specific statement requested in the renewed certificate is: ***Prior to each shipment the containment vessel gasket must be inspected. The gasket must be replaced if the inspection shows any defects or signs of degradation.***

1) Experience and historic data shows no damage or defects due exclusively to time in service.
2) The gasket was not credited in the criticality analysis performed as part of the safety demonstration.
3) The primary purpose of the gasket is for product quality.
4) The gasket is robust in construction and located internal to the package and therefore not as subject to the potential damaging effects of the environment as an external gasket.
5) This requirement contributes to an unnecessary addition of contaminated waste generation.

FRAMATOME ANP

APPLICATION FOR THE

BW-2901

USA/9251/AF

Docket 71-9251

1.0. GENERAL INFORMATION

1.1 INTRODUCTION

The BW-2901 container is designed for shipment of uranium oxide pellets manufactured, inspected and certified in accordance with reactor fuel specifications. It can also be used for the shipment of dry uranium compounds such as uranium oxide powder and rejected pellets and pieces (hard scrap).

The maximum number of containers per shipment shall be limited to:

Fissile Class - Maximum 72 containers

1.2 PACKAGE DESCRIPTION

1.2.1 Packaging

The BW-2901 container consists of a standard steel drum (see Drawing 1215599E) with a square inner container centered in the drum. The inner container is centered by hardboard, support rings Asbestos or ceramic sheet, plywood and Fiberlite insulation provide thermal protection to the inner container. The inner container closure is fitted with a gasket capable of withstanding temperatures up to at least 500°F. The BW-2901 containers may be shipped in either the horizontal or vertical orientation, but are usually shipped in the horizontal position.

1.2.1.1 Package for Pellets

U02 fuel pellets are shipped from the selected vendor's manufacturing facility (currently Framatome ANP, Inc. in Richland, WA) to the FRAMATOME ANP Lynchburg, Virginia facility on clean, corrugated stainless steel trays. Trays of pellets are packaged in quantities not exceeding a slab height of 4 inches, in clean polyethylene sheeting and enclosed in cardboard boxes. In cases where the quantity of pellets (end of a lot) is too few to completely fill a box, empty SST trays will be used to maintain tray stack height at 4 inches. Usually, 10 OR 12 trays of pellets are loaded into each box. The boxes are stapled closed and sealed, without the use of adhesives or tape, in plastic film to insure the box integrity during normal handling and storage (nominal box size: 9⅛ x 8¼ x 4¼) . Pellet

surfaces may contact stainless steel and polyethylene during shipping. A typical arrangement is depicted in FRAMATOME ANP Drawing 1215600D.

1.2.1.2 **Package for Reject Pellets**

Rejected uranium oxide pellets and pieces may be packaged in the pellet shipping package configuration described above in Section 1.2.1.1; sealed in polyethylene bags and enclosed in a cardboard box, then sealed with tape or staples and wrapped in polyethylene sheeting.

1.2.2 **Operational Features**

The BW-2901 shipping container is of relatively simple design, and does not incorporate cooling systems, cooling, etc. Operation of the container is typical of 55 gallon drums. The cylindrical drum is an 18gauge steel full open head shipping drum, sealed with a 16-gauge steel lid and secured by a 12-gauge closure ring with a 5/8" bolt and nut through drop forged closure ring lugs. Loading of the BW-2901 is accomplished by placing the package configuration (described in Section 1.2.3) inside the container insert; unloading is accomplished in reverse fashion.

1.2.3 **Contents of Packaging**

The BW-2901 will carry a payload of up to 6 cardboard boxes of U02 pellets, having 3 boxes per layer and 2 layers per container. Pellets are packed in one of two methods, either neatly stacked on corrugated stainless steel trays, or randomly placed into a polyethylene bag within the cardboard box. If pellets are packed on corrugated trays, the BW-2901 is limited to a total payload of 168 kgs U02 for nuclear safety purposes. No nuclear safety limit exists if pellets are bagged, but physical dimensions of the cardboard box and inner container limit the payload to a similar quantity of pellets.

Uranium dioxide pellets have a maximum theoretical density of 10.70 grams per cubic centimeter. In practice, densities of 10.4 to 10.6 grams per cc are typically achieved. Enrichment is limited administratively to 5.05% w/o U-235. The BW-2901 will only be used for shipping unirradiated materials, which will not generate heat or cause pressure buildup within the inner container, and do not require radiation shielding.

1.2.3.1 **Pellets or Rejected Pellets**

Maximum Enrichment 5.05 wt

Type Material: Sintered (high fired) uranium oxide pellets, rejected pellets or pieces.

Maximum quantity per container:

a) Maximum net weight - Maximum net weight of pellets: 370 pounds

   Pellets and packaging material (contents of inner container) 427 pounds.

b) Gross Weight- Gross weight of the container as assembled for shipment shall not exceed 660 pounds.

1.2.3.2 **Packaging Materials**

Exterior plywood or hardwood boards shall be used for materials enclosing the pellet boxes (See Drawing 1215597C). A poison plate shall be placed on bottom of the wood box, one in between the 2 layers of pellets and one on top. See section 1.3 for associated drawings.

Solid pellet box spacers made of aluminum or wood shall be used to replace boxes in less than full containers (less than 6 boxes).

1.3 **ASSOCIATED DRAWINGS**

Details of construction and assembly are shown on drawings:

1.3.1 1215599E, BW-2901 Shipping Drum Assembly & Details

1.3.2 1215597D, BW-2901 Container Loading Box Packaging Method

1.3.3 1283759D, Method of Packaging UO2 Fuel Pellets

1.3.4 1215598B, Suggested Assembly of 2901 Plywood Insert

FIGURE WITHHELD UNDER 10 CFR 2.390

TOLERANCES UNLESS OTHERWISE SPECIFIED FRACTION UP TO 6" ±1/16 OVER 6" THRU 24 ±1/8 OVER 24" ±1/4 DECIMAL: 2-PLACES - XX ± 02 3-PLACES - XXX ± 005 ANGLE ±1° ANGULAR DIM FOR CHAM & C SINKS 5° FILLET RADII 03 R MAX BREAK CORNERS 02 MAX R OR CHAM ALL MACHINED SURFACES 125/AA FINISH	DWN BY R W GOOCH CHKD BY AR SHUMAKER PASSED BY LG DIDEON APPVD BY FS LESTER DATE 06 04-92 CONTRACT NO FS/91-1/2/D10	BW-2901 SHIPPING DRUM ASSEMBLY & DETAILS	THIS DRAWING IS THE PROPERTY OF FRAMATOME ANP DO NOT SCALE USE DIMENSIONS ONLY SCALE NONE DRAWING NO 1215599 E REV NO 5

FIGURE WITHHELD UNDER 10 CFR 2.390

TOLERANCES UNLESS OTHERWISE SPECIFIED				
FRACTION UP TO 6" ±1/16 OVER 6" THRU 24" ±1/8 OVER 24" ±1/4 DECIMAL: 2-PLACES - .XX ±.02 3-PLACES - .XXX ±.005 ANGLE ±1° ANGULAR DIM FOR CHAM & C'SINKS 5° FILLET RADII .03 R MAX BREAK CORNERS .02 MAX R OR CHAM ALL MACHINED SURFACES 125/AA FINISH	DWN BY R W GOOCH CHKD BY A R SHUMAKER PASSED BY C G DIDEON APPVD BY K S LESTER DATE 06-04-92 CONTRACT NO FS/91-7/2/08	BW-2901 CONTAINER LOADING BOX PACKAGING METHOD	THIS DRAWING IS THE PROPERTY OF B & W FUEL COMPANY DO NOT SCALE USE DIMENSIONS ONLY SCALE NONE DRAWING NO 1215597 D	REV NO 5

FIGURE WITHHELD UNDER 10 CFR 2.390

FIGURE WITHHELD UNDER 10 CFR 2.390

TOLERANCES
UNLESS OTHERWISE SPECIFIED

FRACTION	UP TO 6"		±1/16
	OVER 6" THRU 24"		±1/8
	OVER 24"		±1/4
DECIMAL:	2-PLACES -	XX	± 02
	3-PLACES -	XXX	± 005
ANGLE	±1°		

ANGULAR DIM FOR CHAM & C SINKS 5°
FILLET RADII 03 R MAX
BREAK CORNERS 02 MAX R OR CHAM
ALL MACHINED SURFACES 125/AA FINISH

DWN BY	M RYAN
CHKD BY	[illegible]
PASSED BY	[illegible]
APPVD BY	[illegible]
DATE	3/26/99
CONTRACT NO	
	FS\91-7\2\D17

METHOD OF PACKAGING
UO2 FUEL PELLETS

THIS DRAWING IS THE PROPERTY OF
FRAMATOME COGEMA FUELS

DO NOT SCALE USE DIMENSIONS ONLY | SCALE NONE

DRAWING NO 1283759 D | REV NO 0

2.0 STRUCTURAL EVALUATION

The BW-2901 shipping container was subjected to the hypothetical accident test condition in accordance with 10 CFR 71.36 and 49 CFR 173.398(c). The actual tests and results provided in this section are from the report "Design and Structural Evaluation of a Low Enriched U02 Pellet and Powder Shipping Package, Model UNC 2901", dated April 1970.

Structural Evaluation Reference: Combustion Engineering, Inc. Certificate of Compliance No. 6294, NRC Docket No. 71-6294, UNC-2901 Shipping Container, Application Amendment Date: July 27, 1990.

2.1 SUMMARY

A shipping package was designed for shipment of low enriched U02 pellets and powder. The package consisted basically of a square metal inner container supported and insulated inside a 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.

2.2 DESCRIPTION OF SHIPPING PACKAGE

Details of the BW-2901 shipping container are illustrated on drawings no. 1215599E. The shipping container is to be identified as a Model BW-2901. The basic components of the shipping package are:

1. A square inner container with a flange and cover.
2. Twelve bolts securing the cover to the flange.
3. A full-faced gasket on the inner container.
4. Three hardboard support rings.
5. Angle iron welded completely around inner container for securing the hardboard.
6. A high temperature sheet on top and bottom of outer drum.
7. Plywood on bottom and on top of drum.
8. Fiberlite insulation between inner and outer container.

2.3 STRUCTURAL EVALUATION

2.3.1 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 (Ref. Certificate of Compliance No. 6294, NRC Docket No. 71-6294), 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	228
Net Weight(Pellets & Packaging)	313	427
Equiv. Pellet Weight	227	302
Equiv. Pellet Packaging Weight	86	125
Total Gross Weight	544	655

*All units are in pounds.

2.3.2 Discussion of Results

Pictures of the package in its various stages of assembly and test are included in the Appendix 2-1 of this report.

2.3.2.1 Thirty Foot Drop Test

Original Tests 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 of 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 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.

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 hardwood, 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 on top of 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 in tact and securely tightened. There was no deformation of the flange closure.

The conditions 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 arrangement in the first test, it was not necessary to reevaluate its stability and, therefore, the load was composed solely of the 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 following the drop test.

Supplemental Tests Conditions - As a direct result of concerns raised by the NRC in Confirmatory Action Letter (02-008)related to low angle 30 foot drop tests, supplemental physical testing was performed. The specimen tested was 660 lbs gross weight, loaded with solid blocks of dunnage. The package was oriented 17.5 degrees from horizontal with the initial impact on the lid. The

Results - The

2.3.2.2 **Piston Drop Test**

conditions - For both loading configurations, the drum was dropped five feet onto a concrete piston. The piston was six inches in diameter by eight inches long. 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 hold and no damage was incurred by the inner container.

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 stripped 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.

2.3.2.3 Fire Test

Conditions - *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.

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 outer most 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. Original tests (Structural Evaluation Reference: Combustion Engineering, Inc. Certificate of Compliance No. 6294, NRC Docket No. 71-6294, UNC-291 Shipping Container) indicated that 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 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 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.

2.3.2.4 **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.

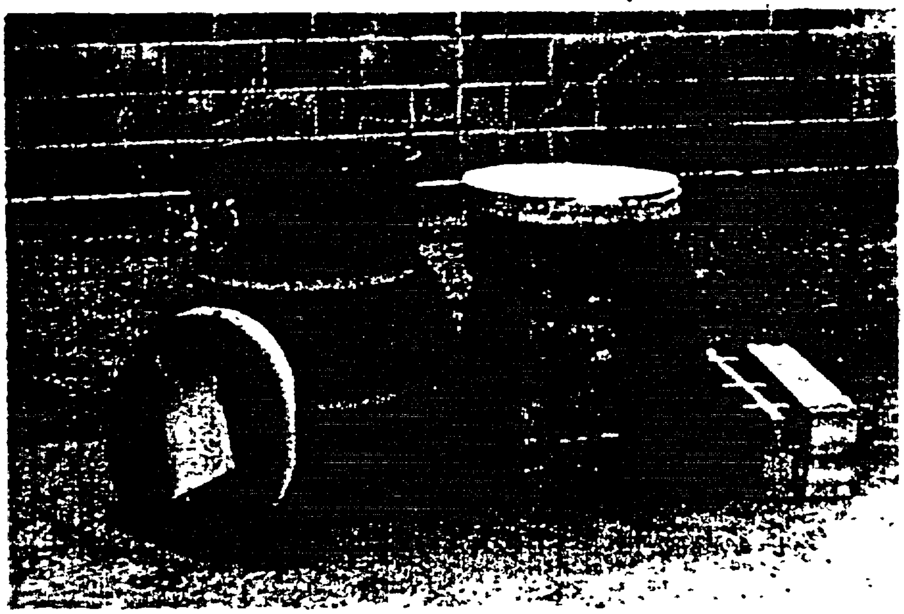
Results - Since the outer container has been punctured in the piston drop, the outer drum was thoroughly flooded. However, the inner container did not show any evidence of leakage after immersion for 8 hours. Some of the Ethafoam cushioning material had been crimped under the asbestos gasket during assembly,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

2.3.2.5 **Conditions of Pellet Package**

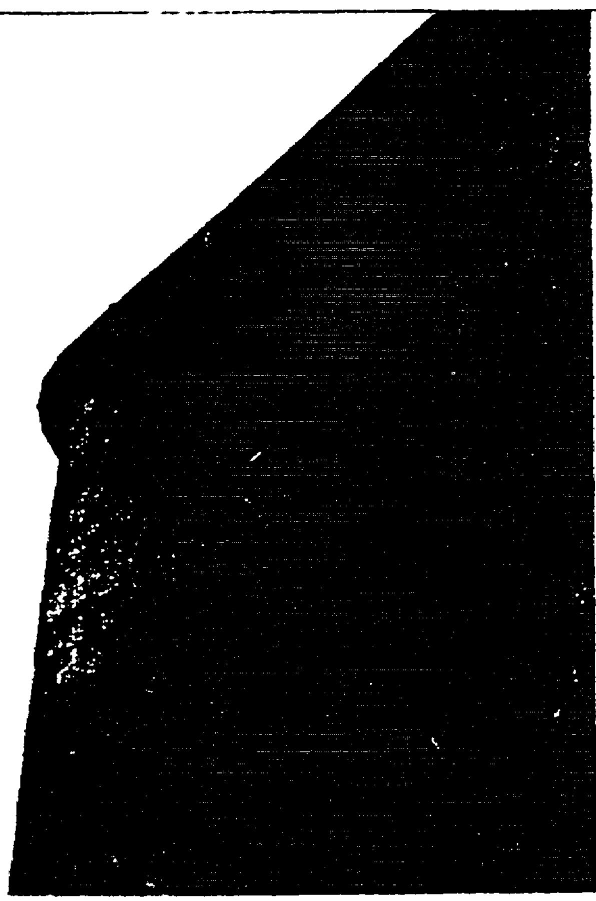
The condition of the inner container contents after the completion of the tests is shown in pictures 16-22. Although about 25% of the pellets were cracked or broken, (picture 22), the pellet package remained intact, (Pictures 19 and 20), and less than 1/20 of the pellets became dislodged (picture 21). 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 assembled 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.

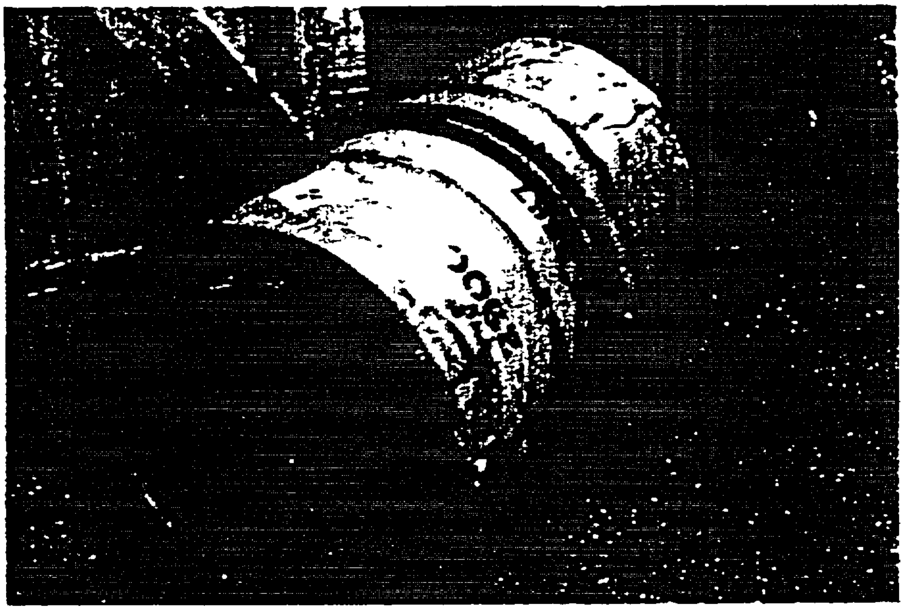
New write-up on recent drop tests



PICTURE 1 - Assembly of shipping package for Test #1.

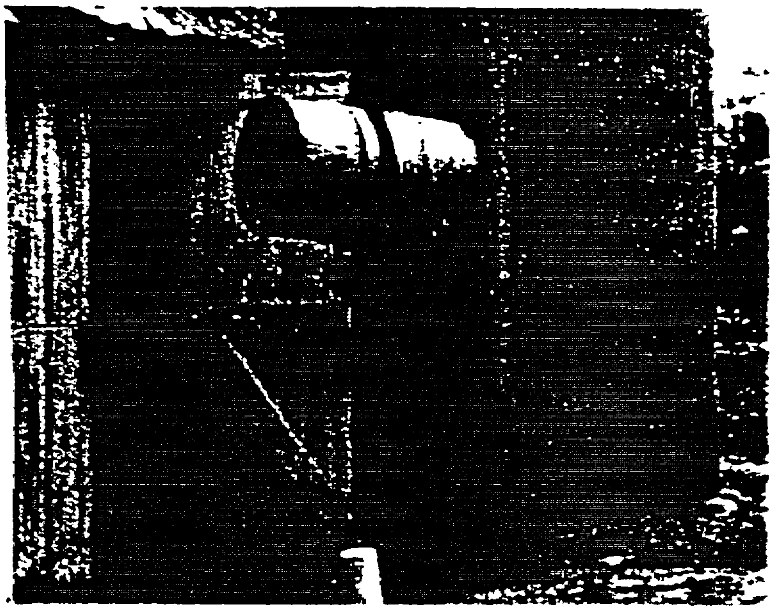


PICTURE 2- Shipping package in upper position for 30' drop test.



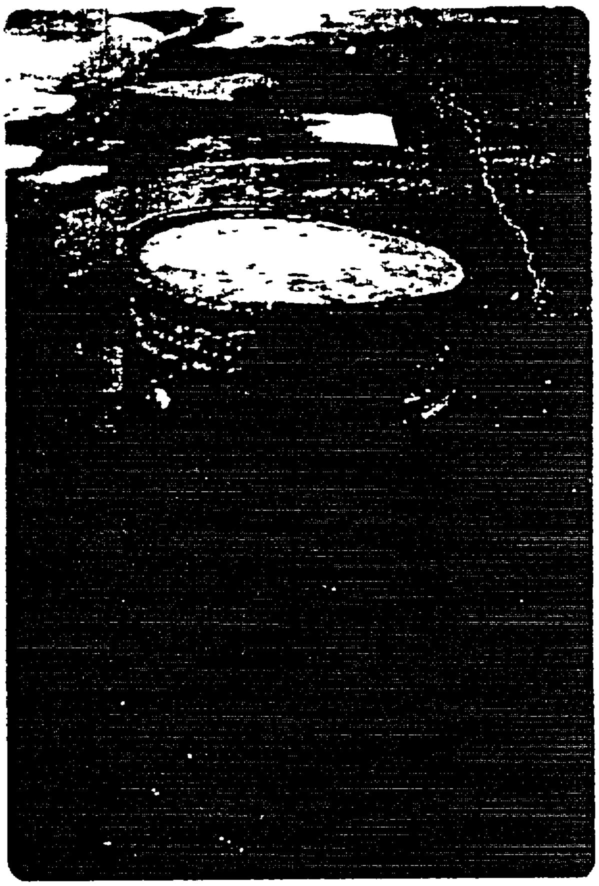
PICTURE 3 -Condition of outer drum after 30' drop test (Test #1).

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

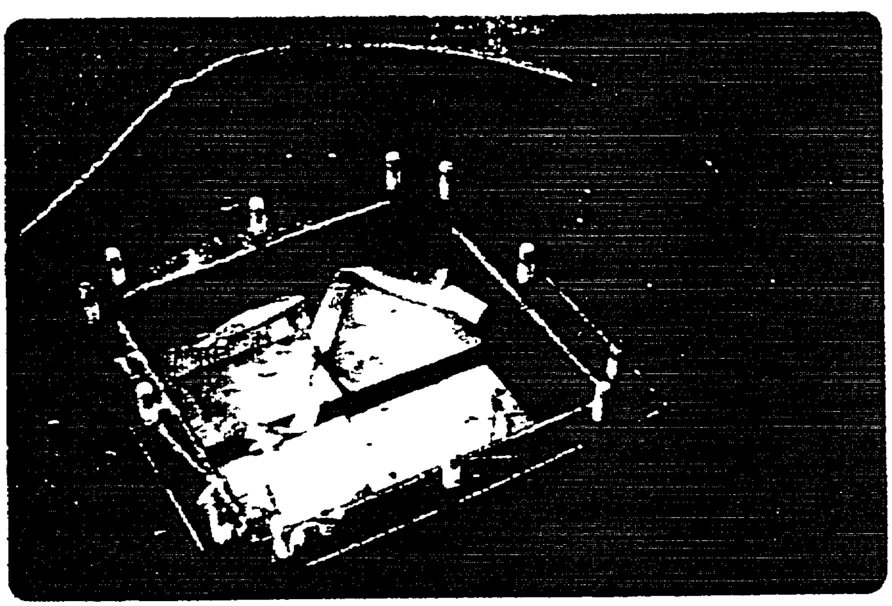


PICTURE 4 - Shipping package in upper position for piston drop.

PICTURE 5 - Condition of drum after piston drop - (Test #1).

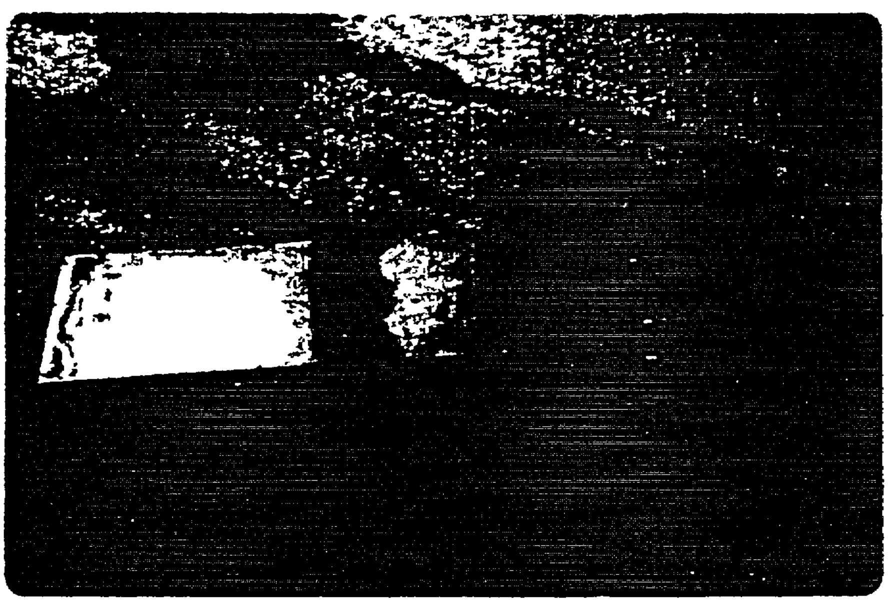


PICTURE 5A - Condition of drum after 30' drop and piston drop - (Test #2).

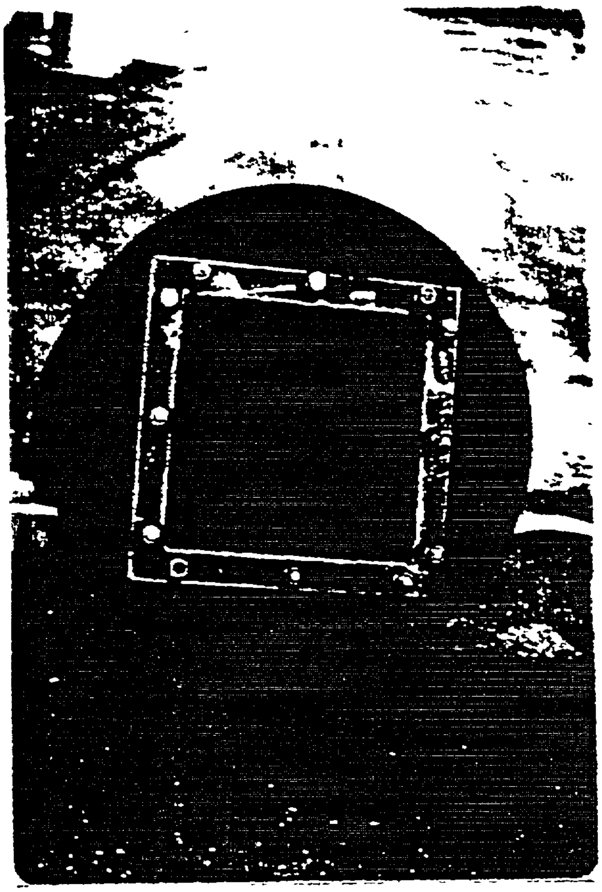


PICTURE 5B - Condition of flange after 30' drop and piston test - (Test #2).

PICTURE 5C - Condition of inner container and hard-board after 30' drop and piston test- (Test #2).

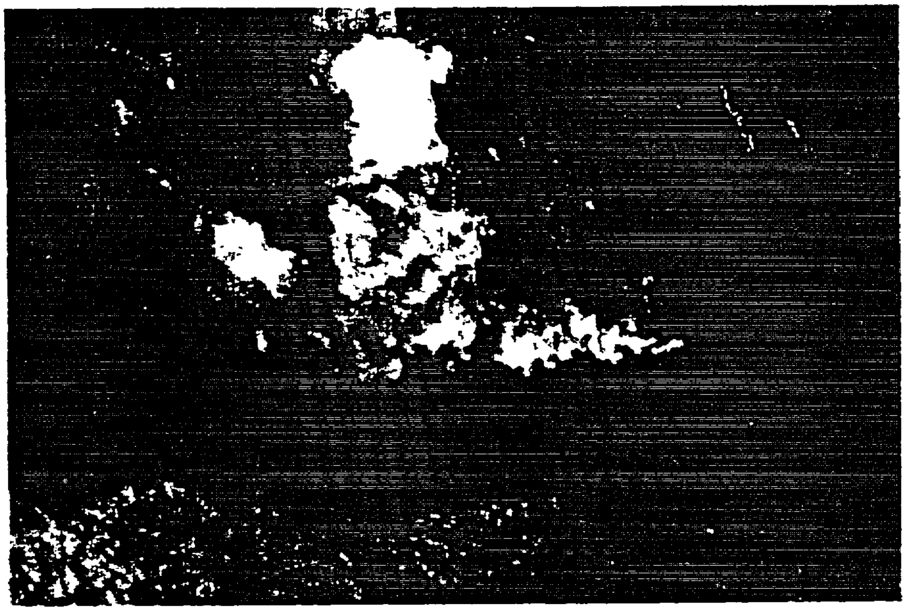


PICTURE 5D - Condition of inner container after 30' drop and piston test - (Test #2).



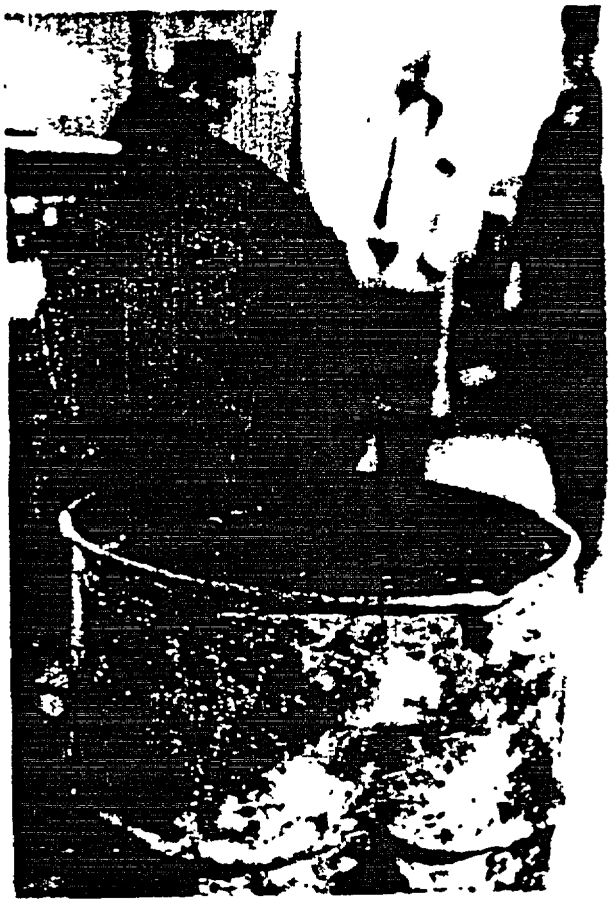
PICTURE 5E - View inside inner container after 30' drop and piston test - (Test #2).

PICTURE 6 - Shipping package in position for fire test.



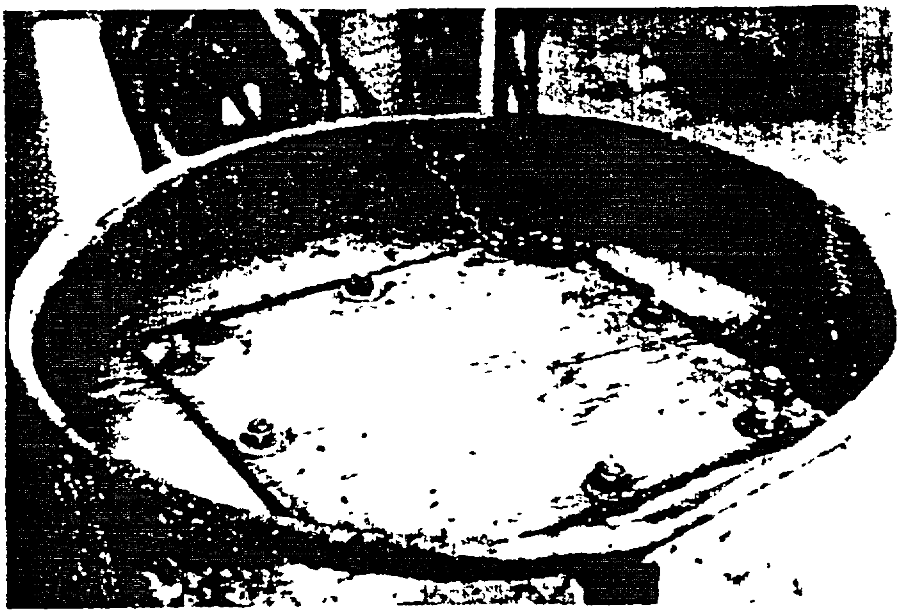
PICTURE 7 - Shipping package engulfed in flames during fire test.

PICTURE 8 - Condition of outer drum after fire test.



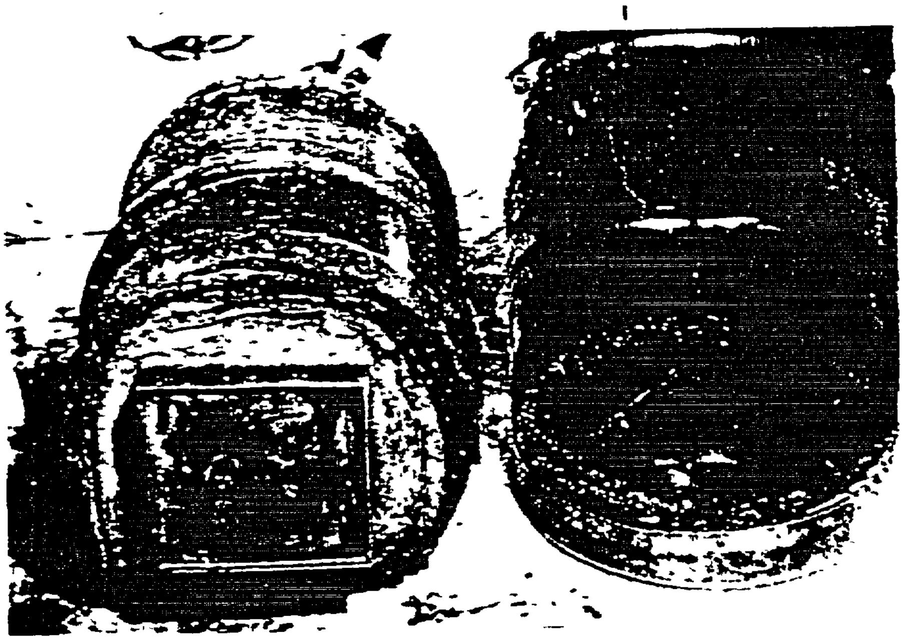
PICTURE 9 - Condition of asbestos and top plywood sheet after fire and water test.

PICTURE 10 - Condition of second plywood sheet after fire and water test.

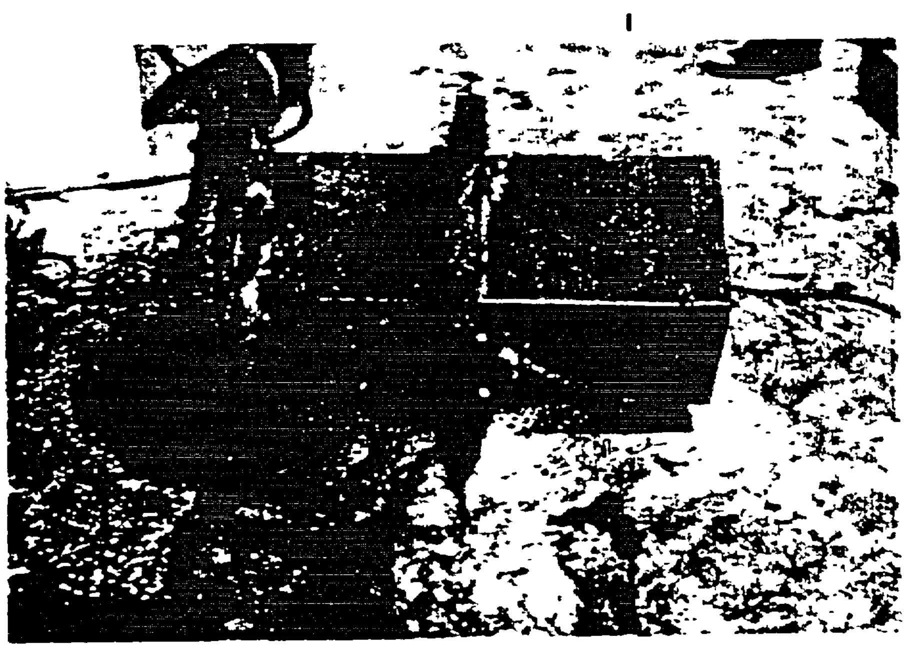


PICTURE 11 - Condition of flange cover and plywood disk around flange after fire and water test.

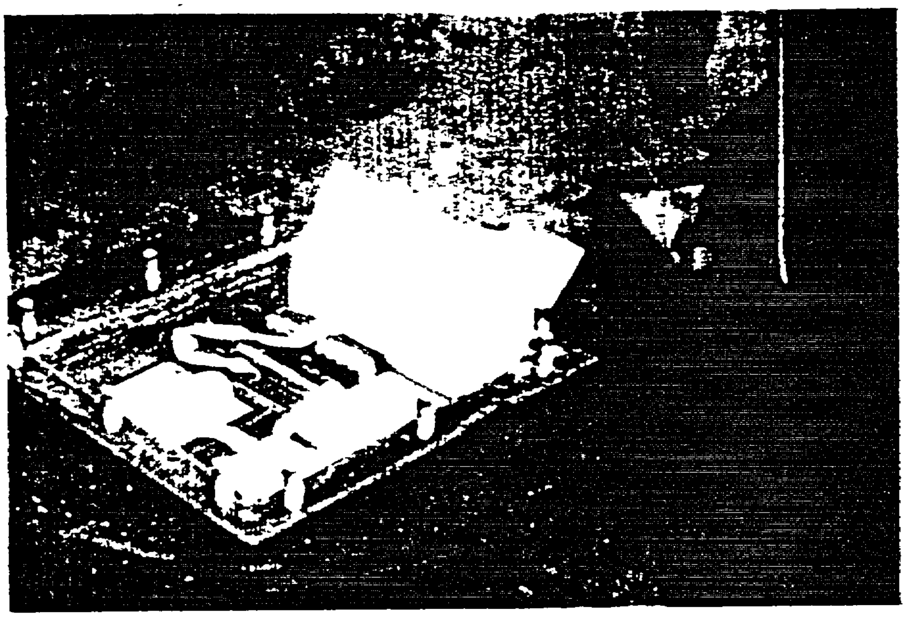
PICTURE 12 - Cut-out view of insulation and hardboard after fire and water test.



PICTURE 13 - Condition of bottom of inner and outer containers after completion of all tests.

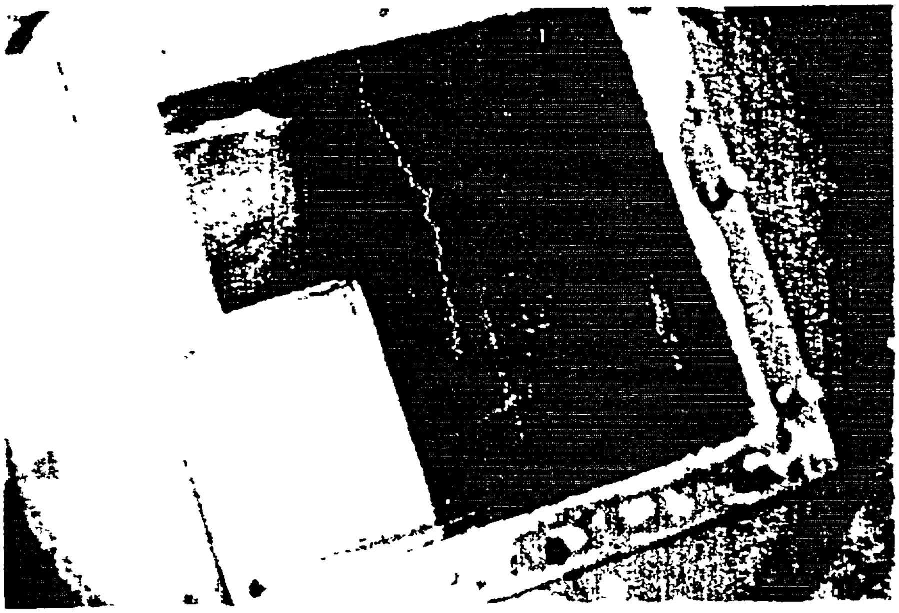


PICTURE 14 - View of inner container with insulation removed after completion of all tests.

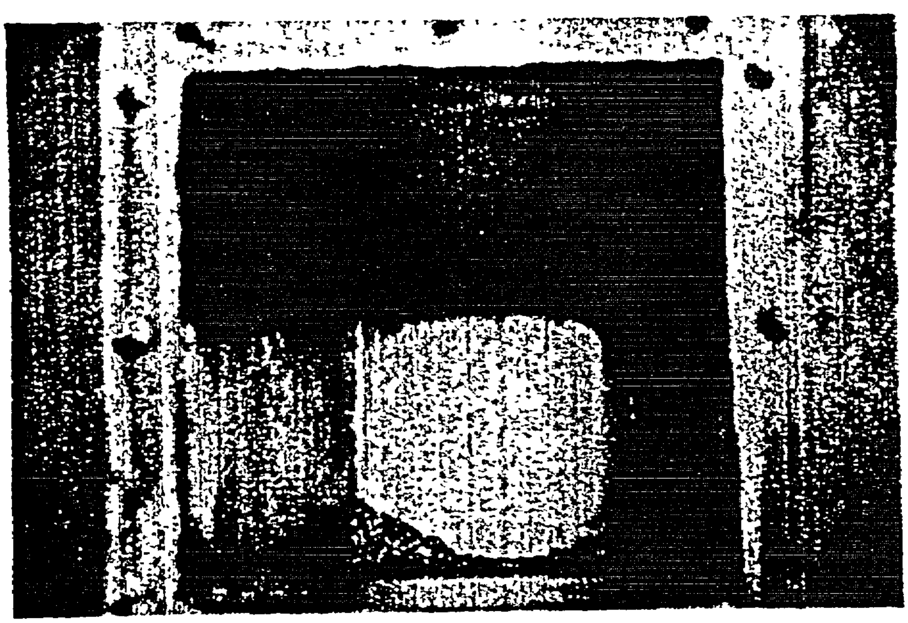


PICTURE 15 - Condition of pellet packages and cushioning material after completion of all tests.

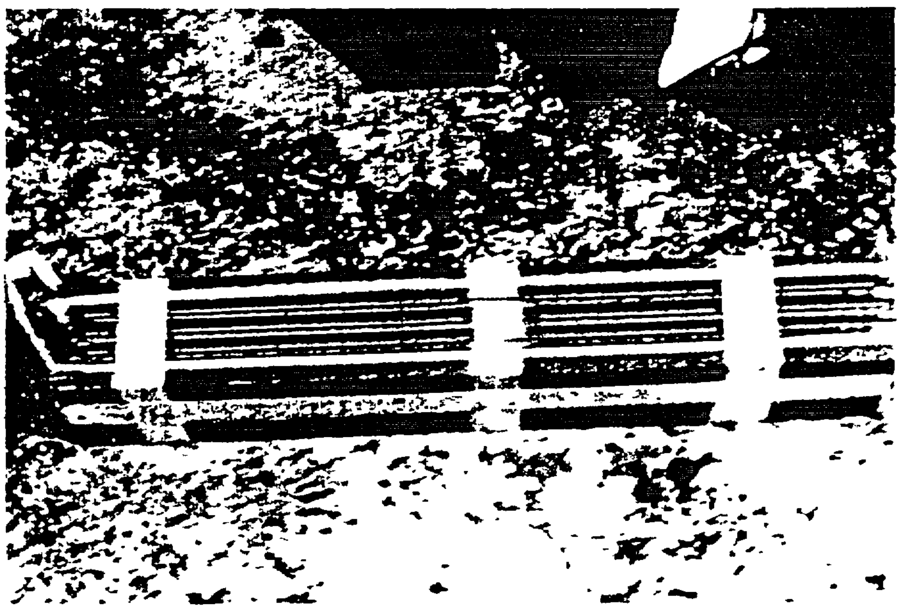
PICTURE 16 - Removal of pellet package after completion of tests.



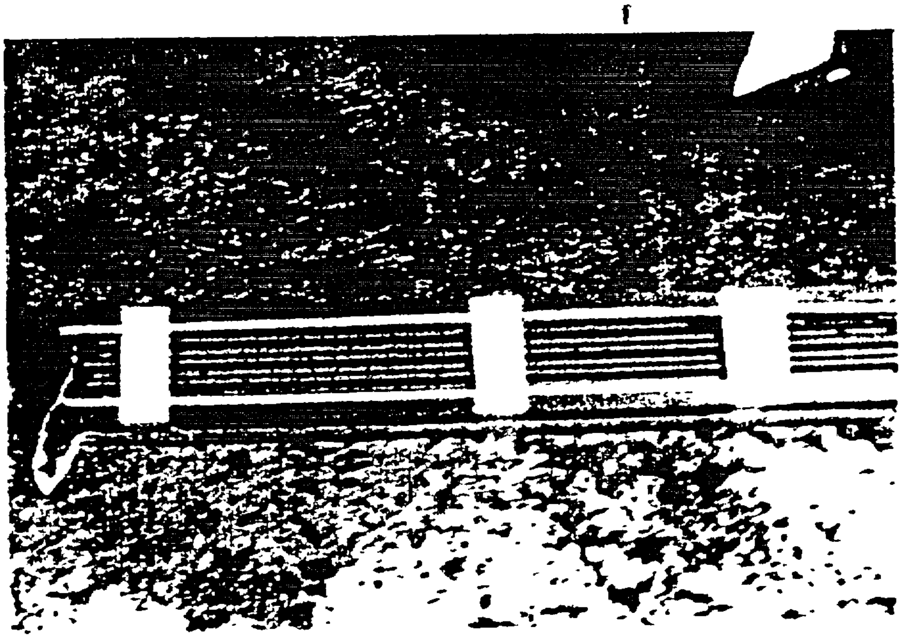
PICTURE 17 - Condition of inner container after completion of tests.



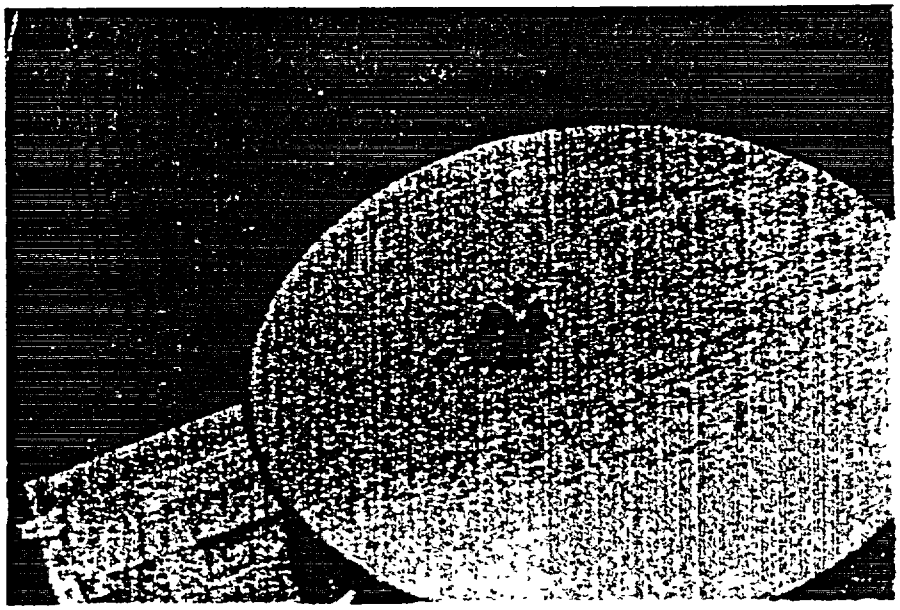
PICTURE 18 - Inner container and broken pellets after completion of tests.



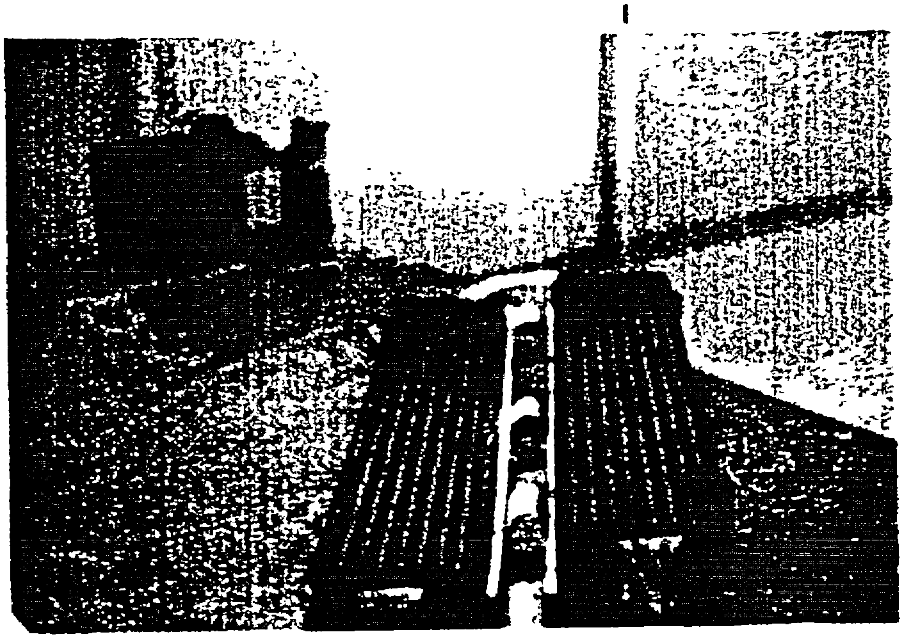
PICTURE 19 - Side of pellet package facing container wall during test.



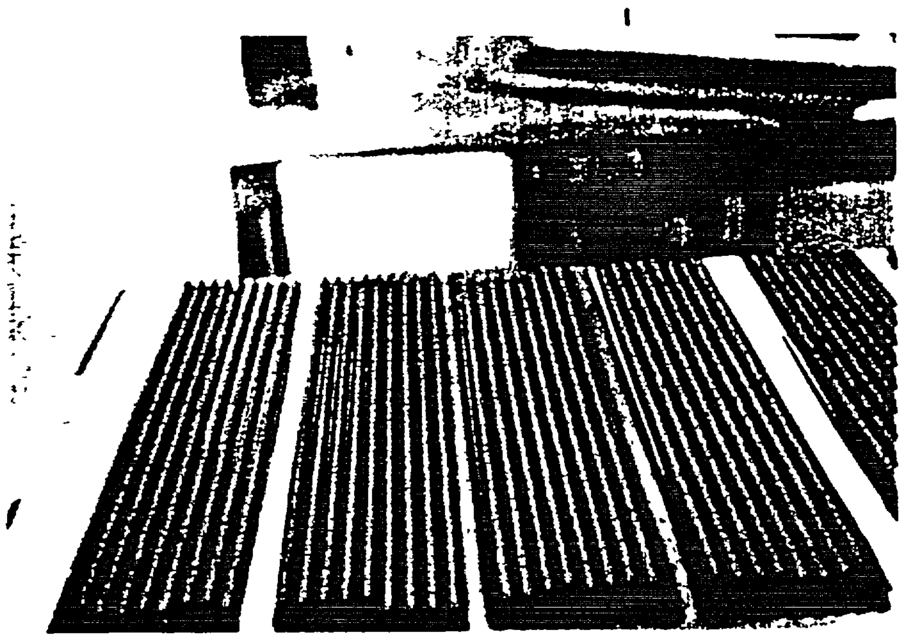
PICTURE 20 - Side of pellet package facing other package during test.



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.

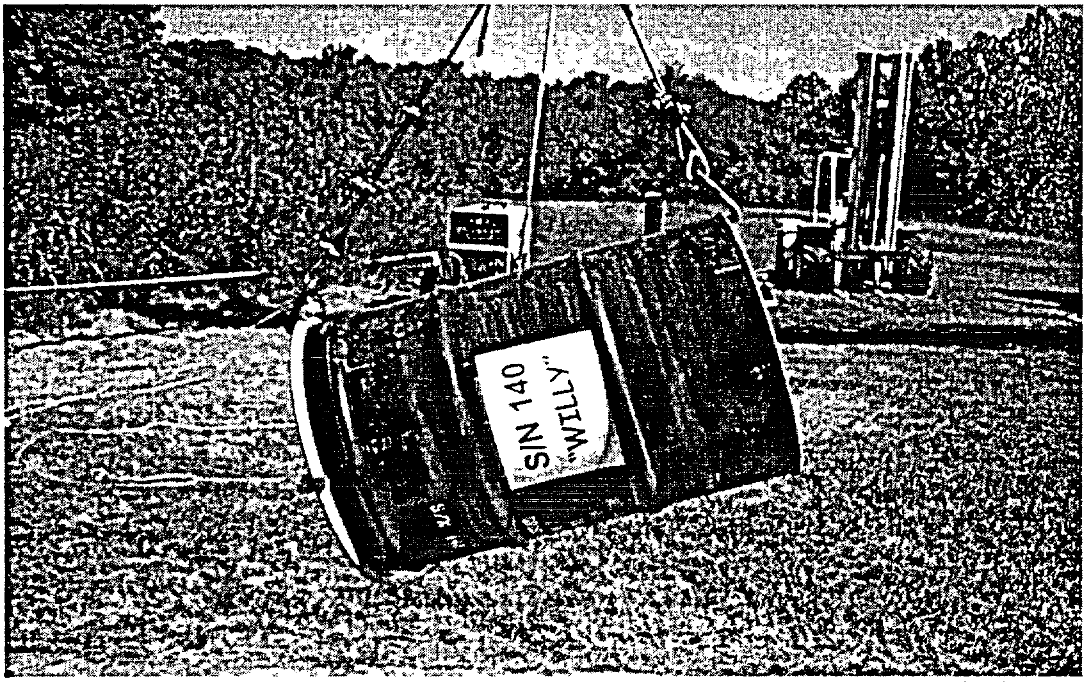


Figure 24 Supplemental low angle 30' drop tests 9/5/2002 - Example of Rigging and angle of incident.

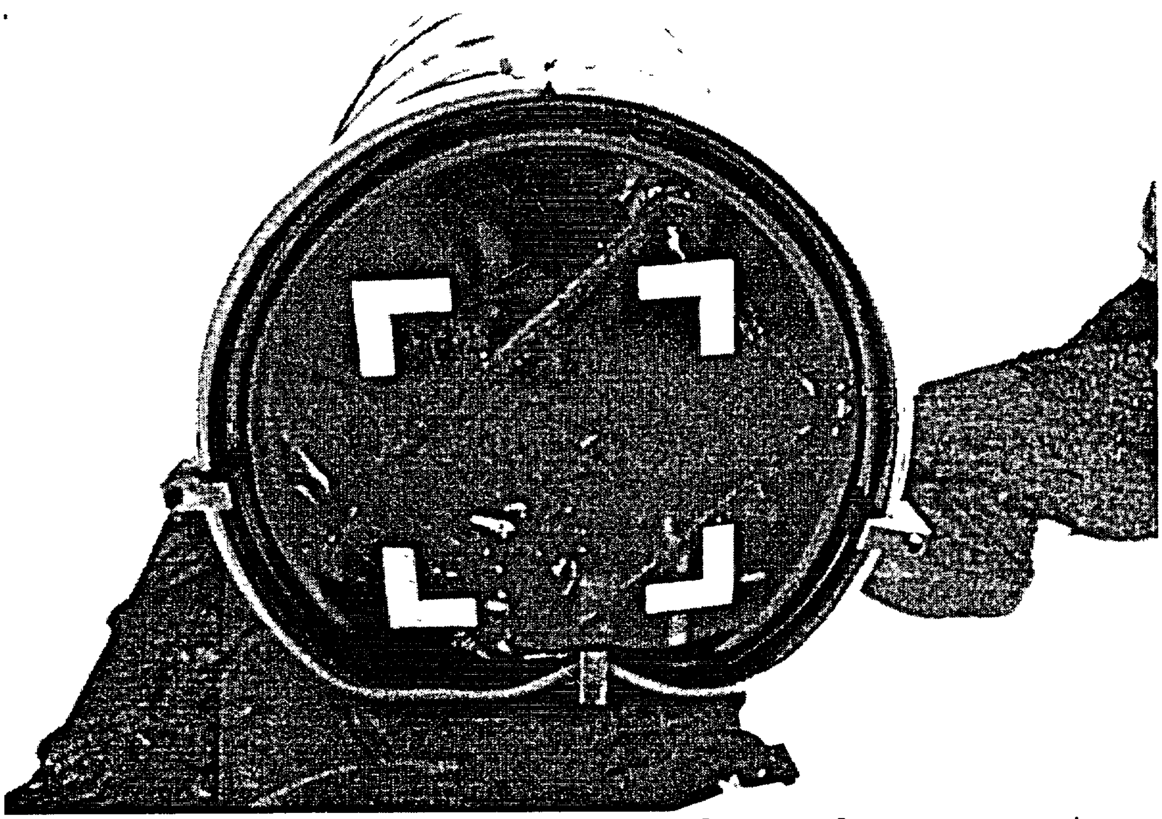


Figure 25 - Damaged package for supplemental tests specimen #139 with 3 retention clamps attached.

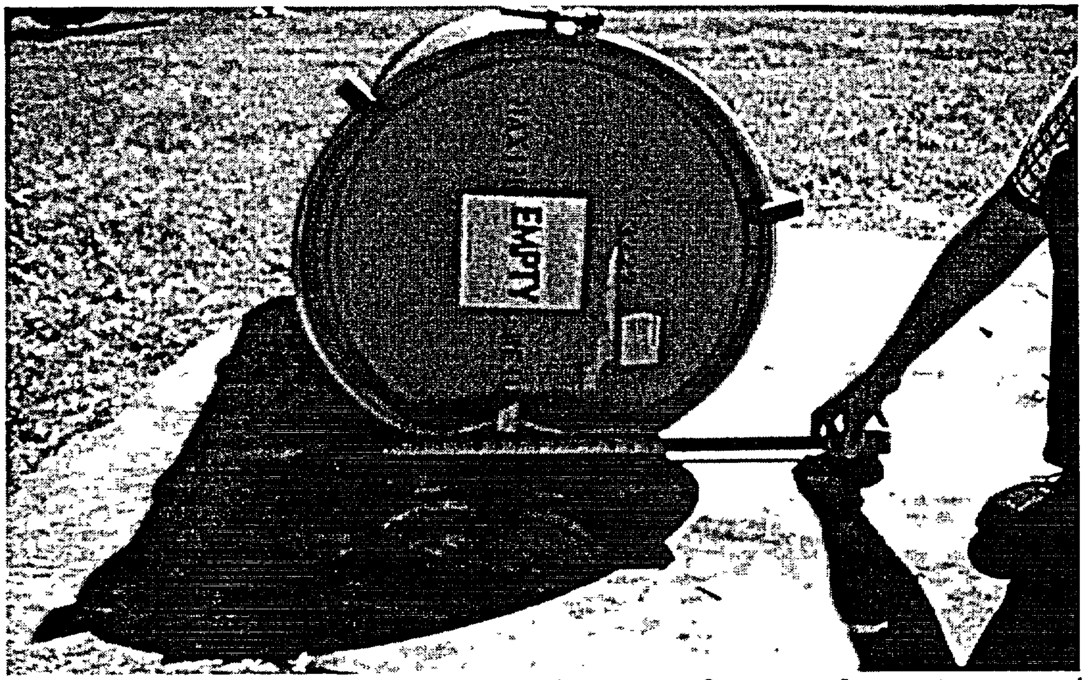


Figure 25 - Damaged package for supplemental tests specimen #139 with 3 retention clamps attached.

Figure 27 - Puncture test on suppplemental test specimen #139 with 3 retention clamps attached.

3.0 THERMAL EVALUATION

The testing and results of the thermal evaluation for the BW-2901 shipping container are discussed in Section 2 of this application.

4.0 CONTAINMENT

4.1 Containment Boundary

4.1.1 Containment Vessel

Within the BW-2901 shipping container a square inner container provides the containment boundary for the radioactive 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 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 containment vessel.

4.13 Seals and Welds

The seal of the inner container closure is formed by a gasket 0.125 inch thick 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 payload, the seal is unaffected by temperatures encountered in normal conditions of transport. Also, testing described in Section 2.0 has shown that the gasket is unaffected by the temperature attained in the Hypothetical Accident Conditions.

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

4.1.4 Closure

The inner container closure is formed by a 0.5 inch steel plate bolted to an external flange welded to the square inner container. Materials for the plate and the bolts and nuts are listed on Drawing 1215599E. The bolted inner container 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 BW-2901 shipping container to the tests specified in 10 CFR 71.71.36 and 49 CFR 173.398(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 containers subjected to the full series of spray, free drop and penetration tests showed no degradations of effectiveness of the inner container and no leakage of water into the inner container.

4.3 Containment Requirements for Hypothetical Accident Conditions

The effect on the loaded BW-2901 container of conditions hypothesized to occur in an accident was assessed during the testing as described in Section 2 0. These tests demonstrated that no radioactive material would be released. It was also demonstrated that the package would remain subcritical because the material remains confined to subcritical geometry and the geometric form of the contained material is not altered.

5.0 SHIELDING EVALUATION

The BW-2901 shipping containers are used for the shipment of oxides of low enriched uranium ($\leq$5.05 wt.% U-235) in pellet or powder form. Thus, shielding is not a consideration in the design and construction of this shipping container.

6.0 CRITCALITY EVALUATION

6.1 Discussion and Results

An analysis has been performed to determine the criticality safety of arrays of the BW2901 shipping container at an increased enrichment of 5.05% utilizing the packaging method for sintered U02 pellets as described in FRAMATOME ANP drawings 1215599E, 1215597D, 1215598B, 1215548C, and 1215600D. Each container contains a maximum of 168 kg (6 boxes with 28 kgs per cardboard box) of 5.05 wt% U235 pellets (370 lbs. U02).

The determination of the subcritical arrays has been made to establish the limits for fissile shipments as required by the regulations.

For fissile shipments, five times the allowable number of undamaged (normal) packages will be subcritical if stacked together in any arrangement with full water reflection. Twice the number of packages subjected to the accident conditions stacked in any array with optimum interspersed moderation and full water reflection will also be subcritical.

The limiting package evaluated is for 0.2 inch diameter fuel pellets (which simulate broken pellets) in the scrap container. The scrap container is most limiting because the fuel pellets are assumed optimally moderated and there are no stainless-steel pellet trays (which act as neutron absorbers) in the scrap boxes. The scrap container contains the same number of fuel boxes (6 boxes) as the pellet-tray configuration. The borated plates in the container are assumed off-center shifted by the maximum amount and 1285 gms of additional polyethylene (1435 gms total) scrap is modeled in the container. The total polyethylene limit is 1000 gms.

Minimum tolerances are assumed on all wooden dimensions of the loading box and the borated aluminum plates which maximizes the available fuel volume. An internal cavity width of 11.15 inches is assumed and bounds any as-built dimensional deviations of the internal cavity. A maximum conservative bias of 0.02 delta k was assumed. Based on the original analysis maximum reactivity occurs for the internal cavity fully flooded and all other regions in the drum and external to the drum were assumed to be dry.

The drums were loaded into a close-packed hexagonal array four drums deep (37x4 array). All drums are assumed to be deformed by the maximum amount determined from droptest results. All cardboard was assumed crushed to a minimum thickness of 0.06 inches to maximize fuel volume. The borated aluminum plates (AlB4C) have a minimum thickness of 0.365 inches and minimum areal density of 83.823 Mg/cm2. This areal density corresponds to a 25 volume % B4C content 23.702 wt%). A 25% penalty factor was applied to the B1 density per NRC requirement. The center cross-sectional view of the final model is shown in Figure 6-6.

Using this exact model the final maximum K-effective with the bias and uncertainty applied is 0.94803 for the scrap container, which satisfies the criticality limit of 0.95. Pellet diameters of 0.315 and 0.375 inches were also evaluated with the previously discussed conditions. The maximum K-effective values for these cases are 0.94720 and 0.94409, respectively.

The revised results are shown in Table 6.1-2 along with the original calculations for less limiting cases. It should be noted that the original calculations did not include borated plates or optimized fuel volumes for the pellet-tray configurations. However, the revised scrap container contents conservatively bound all other content configurations.

Both pellet and scrap package arrangements are safe for shipment. These packaging arrangements must conform to the descriptions and assumptions in this analysis and in the Certificate of Compliance. In addition to the shipping specifications already authorized, the Certificate of Compliance should contain the following specifications:

1) Weight limit will remain at 370 pounds (167.83 Kg) of UOZ with the U-235 content not to exceed 7.47 kg U23s,

2) The enrichment limit will be 5.05%.

3) The maximum allowed pellet density is 97.6% of the UOZ theoretical density (10.96%).

4) A minimum pellet diameter of 0.315" and maximum pellet diameter of .375" OD for shipments utilizing trays.

5) The pellet trays should normally be fully loaded and the boxes may have up to 10 trays for larger diameter pellets and up to 12 trays for smaller diameter pellets. There is no criticality requirement that unoccupied space in the box or on a tray of pellets contain stainless-steel or a volume displacement device since optimized fuel was used in the analysis. The use of stainless-steel trays or spacers is recommended to prevent damage to pellets.

6) For partial shipments with less than 6 boxes of fuel, the remaining space must be occupied with aluminum or wood blocks of equal volume to prevent shifting of the fuel boxes or borated aluminum plates.

7) The wood box shall contain three borated aluminum plates with a minimum of 25 volume % B4C (23.702 wt%). The minimum areal density of B10 shall be 83.823 mg/sq cm per plate. The minimum dimensions of the borated aluminum plate shall be 24.98" x 9.24" x 0.365•'. One plate shall be located on the box bottom, the second on top of the first layer of fuel (middle plate), and the third on top of the second layer of fuel (top plate). See Figures 6-5 and 6-6 and Section 1 drawings for the arrangement.

8) The scrap and pellet-tray containers shall contain no more than 1000 gms of polyethylene.

Table 6.1-2 BW 2901 Shipping Container Results

Condition	Model Configuration	K-maximum
Normal	15X15X15 Normal Array - 0.200" Pellet Diameter Original Analysis	0.799
Accident	37X4 Hexagonal Array 0.200" Pellet Diameter Revised Analysis	0.948
Single Package	1 Flooded Drum - 0.200" Pellet Diameter Original Analysis	0.819
Normal	15X15X15 Normal Array - 0.315" Pellet Diameter Original Analysis	0.905
Accident	37X4 Hexagonal Array 0.315" Pellet Diameter Revised Analysis	0.947
Single Package	1 Flooded Drum - 0.315" Pellet Diameter Original Analysis	0.752
Normal	15X15X15 Normal Array - 0.375" Pellet Diameter Original Analysis	0.934
Accident	37X4 Hexagonal Array 0.375" Pellet Diameter Revised Analysis	0.944
Single Package	1 Flooded Drum - 0.375" Pellet Diameter Original Analysis	0.707

6.2 Package Fuel Loading[2]

The BW2901 shipping container drawings are contained in Section 1 of this document. The BW2901 shipping container consists of a nominal 10.875 x 10.875 x 29 inch high inner container constructed with a minimum of 14-gauge (.0747 inches) stainless-steel or carbon steel. The top ½ inch thick steel flange (or lid) is bolted and incorporates a gasket. The inner container is centered and supported in a 22.5 inch ID (smooth wall) x 34 inch high steel drum made of 18 gauge steel with a 16 gauge head. The inner container is supported and protected by asbestos or ceramic sheet, plywood, hardwood, and insulating material. Framatome ANP uses two different packaging arrangements with the container for the shipment of uranium dioxide fuel. These are described in the separate sections covering the evaluation of that packaging arrangement. Any packaging arrangements which vary from or alter the packages described below will require further evaluation. Table 6.2-1 describes the maximum fuel loadings and parameters for these loadings.

Table 6.2-1 Package Fuel Loading

Material	Maximum Weight, lbm/Kg UO_2; lbm/ Kg U^{235}	Restrictions	Form
U^{235}	370/167.83 16.47/7.47	Max Enrichment = 5.05 wt% U^{235} 1000 gms Poly Pellet Diameters From 0.315" -0.375"	UO_2 Pellets Pellet-tray Configuration
U^{235}	370/167.83 16.47/7.47	Max Enrichment = 5.05 wt% U^{235} 1000 gms Poly Scrap	UO_2 Pellets Scrap Configuration

6.2.1 AlB_4C Plate Specifications and Melting Point

The BW2901 shipping container contains three borated aluminum plates made from a melt of aluminum and B4C. The boron carbide content is assumed to have boron at 19.8 atom % B1° in B natural. The minimum B1° areal density of the borated plates is 83.823 mg/cm2 (without 25% transportation penalty factor applied). The borated plates must have minimum dimensions of 9.24 inches x 24.98 inches x 0.365 inches.

Model-R2 assumes a minimum of 25 vol% B_4C (23.702 wt% B4C).

Of concern in the use of borated aluminum is the potential for a fire to melt the aluminum and cause a change in the geometry of the internal container. According to the fire test conducted on the UNC2901 the internal temperature did not exceed 200 °F 6. The melting point of aluminum is 1220 °F. Therefore, the internal temperature of the cavity did not reach the melting point of aluminum nor did it reach temperatures high enough to char the cardboard or wood box

6.3 Model specification

6.3.1 Description of Calculational Model

The analysis for both packagings was performed originally using the SCALE 3 CSAS2 module with revised calculations using the SCALE4.2 CSAS2X computer code 5. SCALE 3 CSAS2 calls BON-AMI, NITWAL (to calculate the Dancoff correction factor), XSDRNPM (for flux and volume weighing of the cross-sections) and KENO IV. SCALE 4.2 CSAS2X calls BONAMI-S, NITWALII (to calculate the Dancoff correction factor), XSDRNPM-S (for flux and volume weighing of the cross-sections) and KENOVa. The 123 group cross- section library was used in the original analysis and the 27 group cross-section library in the revised calculations.

The SCALE Package was prepared by the Oak Ridge National Laboratory for the U.S. Nuclear Regulatory Commission and is widely used in criticality evaluations. The 123 group cross-section set was used because more accurate results have been obtained from benchmark calculations using Low-Enriched-Uranium (LEU) critical experiments. The revised calculations used the newer 27 group cross-section library to eliminate any concerns pertaining to pretreated U235 resonances associated with the 123 group cross-section set. A description of the bias is provided in Section 6.5.

The input data containing the atomic number densities and geometry are contained in the Section 6.6 appendix. The theoretical density was used in calculating the fuel atomic number densities in the original calculations and 97.6% TD in the Model-R2 calculations. No credit was taken for dish or chamfer factors. The measured density of the cardboard was used in calculating their atomic number densities except for the revised scrap container calculations which assumed the cardboard was compressed and the composition of wood was assumed.

According to the current Certificate of Compliance the limits for both packagings is 370 lbs U02. This limit was used as an upper limit in this analysis.

6.3.1.1 Criticality Models

Dimensioned sketches of the models used in the criticality evaluation are provided as Figures 6-1, 6-2, 6-3, 6-3A, 6-4, 6-4A, 6-5, and 6-6. Figure 6-1 shows a typical fuel pellet box. Figures 6-2 shows a combination of three fuel boxes used in various criticality models. The cardboard between boxes of fuel have been removed for conservatism. Figures 6-3 and 6-4 show the original pellet-tray model and wood spacer configuration used in the original analysis. Figures 6-3A and 6-4A reflect revisions in the wood box structure and internal cavity dimensions used in the first revised model (Model-R1) of the BW2901 container. Figures 6-3A and 6-4A reflect typical dimensions. An isometric view of Model R1 details is shown

in Figure 6-5. This model used dimensions that were based on conserving the masses of fuel, wood and other materials in the internal cavity of the drum. Therefore, minor deviations from actual minimum wood thickness exist compared to the Section 1 drawings (i.e., 0.44017 inch wall thickness versus 0.4375 inch toleranced value, a difference of 0.0026 inches). Additionally, Model-R1 is based on a average cavity dimension of 11.019 inches which was subsequently revised. Model-R1 was used in this analysis to identify limiting plate configurations and fuel parameters.

Figure 6-6 is a cross-section of the internal cavity midway along the axial length of the drum and reflects the exact dimensions of internal components less applicable tolerances. This model is referred to a Model-R2 and reflects a maximum cavity width of 11.15 inches and borated aluminum plates 0.365 inches thick (minimum). The shifting of the top borated aluminum plate is also exactly modeled. Model-R2 was used for all final scrap container calculations.

The scrap container model bounds the pellet-tray configuration since optimized fuel is assumed and no stainless-steel pellet trays are present. The following assumptions apply to the original analysis:

A. In the original analysis the computer model has two long boxes instead of the actual six smaller boxes. This is due to modeling limitations in the KENO IV computer code. The same amount of fuel is included in each long box as would be in the three smaller boxes it represents. The minute amount of moderating material(cardboard between the boxes) omitted by this model is more than adequately compensated for by the flooding of the inner container. This flooding did not occur in the tests performed per 10 CFR 71.73, therefore this is extremely conservative assumption.

B. For the accident conditions, the stainless steel trays were not included. This is very conservative for the pellet-tray containers since after the tests (referenced above) the pellet packages remained intact and the trays and pellets remained in position with no water inside the inner container.

C. All limiting calculations in the original analysis assumed fuel at 100% TD. This assumption is very conservative since FRAMATOME ANP does not fabricate fuel in excess of 97.5% TD.

D. The insulating material surrounding the inner container was not included in the computer model. This was shown to be conservative in the original evaluation by reducing cask-to-cask neutron transfer. The tests referenced above showed that the support materials did remain inside and that water might fill the outer part of the drum but that the inner container would remain dry, as opposed to the conservative assumptions made in the evaluation.

E. All fuel was assumed to be at 5.1 wt% U235 in the original analysis.

The revised scrap container computer Model-R2 contains the following conservative assumptions:

A. Limiting cases were reevaluated with the maximum internal cavity dimensions and the optimum fuel volume fraction to maximize reactivity. The optimum fuel volume fractions were determined for each geometry configuration (i.e., with and without additional polyethylene, etc.).

B. The maximum theoretical density of 97.6% was assumed. FRAMATOME ANP does not manufacture pellets above 97.5% including tolerances.

C. A maximum fuel enrichment of 5.05 wt% U235 was assumed. Therefore, the license certificate reflects a slightly reduced enrichment limit.

D. All wood box surfaces assumed an appropriate tolerances as reflected by the section 1 drawings. Application of these tolerances bound the actual measured board thicknesses. Minimum wood thickness were assumed to maximize available fuel space.

E. All wood end pieces assumed minimum wood thicknesses to maximize available fuel space in the axial direction. The Type A container was chosen since it has the largest internal cavity depth.

F. Only one bag of polyethylene was assumed in a box to maximize the available fuel volume. The normal thickness of polyethylene used is 0.006". Normally the scrap boxes have two or three bags per box. In the scrap container each box is normally wrapped with an external layer of polyethylene. Polyethylene placed near the absorber plates (other than the internal box bags) was not modeled for conservatism. The volume of the polyethylene due to a single bag was computed using dimensions of the cardboard box prior to it being crushed in the accident. Therefore, the polyethylene bag volume and weight is minimized and fuel volume is maximized. For the limiting accident scrap container case 2000 gms of additional polyethylene was placed midway in each of three major fuel volumes in Model-R1 and away from the borated plates (see Figure 6-5). For Model-R2 1285 grams of additional polyethylene was placed in two major fuel areas (see Figure 6-6). This model

resulted in an approximate 1% Δk reactivity increase. The actual limit of polyethylene per container is 1000 gms and is conservative.

G. The cardboard boxes were assumed to be entirely crushed. The nominal thickness of cardboard is 0.17" thick. The cardboard was crushed at CNFP and measured with a caliper and found to have a minimum crushed thickness of 0.06". Therefore, the crushed cardboard was modeled as wood and placed adjacent to the wood box surfaces maximizing the available fuel volume. The volume of the cardboard was computed using the crushed post-accident thickness for conservatism. In an actual accident not all cardboard surfaces would be crushed.

H. For Model-R1 the wood box volume was computed using outer box dimensions of 10.75 square inches. The length was inferred by subtracting the end spacers (with effective thicknesses that conserve wood volume) from the 29-3/8" total length of the box plus spacers for the Type A container. In this model the wood box length was assumed to be 25.625" long and the balance of wood structures had dimensions adjusted to conserve the total wood volume. Model-R2 modeled the exact minimum wood thicknesses, heights, and lengths.

The boards that make up the wood bottom, ends, and sides have a 1/16" tolerance and bound the thicknesses of the boards actually measured by CNFP. Therefore, the wood box volume was minimized by using the thinnest individual wood dimensions. The end wood spacer pieces each have a 1/16" tolerance applied to the each wood piece to maximize the fuel cavity volume. For Model-R1 the wood end spacers and the wood sides use toleranced dimensions that have been adjusted to conserve the total volume of wood box material.

I. The wood support ribs in the drum were modeled only at both ends of the drum. The Z inch steel flange that covers the front-end of the internal cavity was modeled. Other intervening materials that would reduce cask-to-cask neutron transfer (such as ceramic disks and fiberglass insulation in the drum, etc.) were eliminated for conservatism.

J. The borated aluminum plates (AlB4C) have exact minimum dimensions of 24.98" X 9.24" X 0.365" which were assumed in Model-R2. The dimensions assumed in Model-R1 are 24.98" X 9.2" X 0.365". The final model assumes 25 volt B4C (23.702 wt% B4C -areal density of 83.823 mg/sq. cm.).

K. A 25% reduction in the B1° density was made per standard NRC transportation requirement. This penalty originates with the Boral product. The borated aluminum plates (Boralyn) used in the BW2901 container are very homogeneous and do not have the problems attributed to Boral.

L. The borated plates could shift off-center if the wood box walls break apart. The top plate could shift above the wood walls and above the 1-1/4" front spacer or the 3/4" back wood box wall. The top borated plate cannot shift over the back wood spacer. A forward shifted plate offers the greatest axial movement. The off-center shifted plates in Model-R1 were conservatively modeled by truncating all three borated plates, cardboard, and polyethylene by one-half the distance that the top plate alone could shift in the Y and Z directions. This is a conservative model because all three plates are truncated when only the top plate can shift over the wood box walls and the borated plates would remain in the cavity displacing optimized fuel. The remaining area of the cavity is filled with the optimized fuel mixture. The top shifted plate is modeled exactly in Model-R2.

M. The previous analysis assumed a 1.5" reduction in the diameter of the container (from the outer hoop diameter) based on drop test results. The drop test results are for a container dropped at a 45 degree angle on the cask rim. The resulting maximum localized denting of the rim was assumed for the entire container and is very conservative since a rim dent will not influence the pitch between drums.

N. In the event the drums assumed a triangular pitch a slightly more compacted fuel volume between drums is possible. This effect was simulated by reducing the diameter of the drums by an amount in a square array that conserved the fuel volume fraction from a triangular pitched array. This model is conservative because the total mass of steel in the outer drum was reduced by reducing the diameter (the 18 gauge thickness was maintained).

To verify the above model a triangular pitch was used to develop a hexagonal close-packed lattice of drums. The lattice requires a total of 37 drums in each of 4 planes. Therefore, the hexagonal lattice models 4 drums more than the 6x6x4 square array. The hexagonal lattice (37X4) was surrounded by 12 inches of water on all sides. The results indicated that the reduced square pitch model was overly conservative by 0.005 Δk.

6.3.1.2 Package Regional Densities

The region densities and number densities for the final Model-R2 are provided in Table 6.3.1.2-1. Table 6.3.1.2-1 lists the values for non-fuel and materials. The limiting fuel enrichment is 5.05 wt% U235. Since a variety of fuel volume fractions were evaluated homogenized fuel and water densities are not provided. The CSAS2X module does not require input in this form.

Table 6.3.1.2-1 Material Number Densities

Material/Den	Element-Isotope	wt%	atom/b-cm
H_2O/ 1.0 g/cc	H O	11.1902 88.8098	6.68718-02 3.34359-02
Hard Wood/ 0.84131 g/cc	H C O	6.6247 53.1752 40.2001	3.32986-02 2.24300-02 1.27300-02
Polyethylene/ 0.92 g/cc	H C	85.63 14.37	7.90600-02 3.95300-02
Carbon-Steel/ 7.8212 g/cc	Fe C	99.0 1.0	8.34982-02 3.92503-03
Boralyn (AlB_4C) (23.702 wt% B_4C/19.8 at% B^{10} in B) 2.658 g/cc	Al B^{11} B^{10} C	76.298 15.1486 3.4016 5.1519	4.52631-02 2.20257-02 5.43776-03 [A] 6.86586-03
UO_2 5.05 wt% U^{235} in U/ 10.96 x 0.976 = 10.69696 g/cc	U^{235} U^{238} O	4.451277 83.692823 11.8559	1.22000-03 2.26486-02 4.77372-02

[A] B^{10} density does not have 25% penalty factor applied.
Avagadro's number = 0.6022138 x 102' atoms/gaw.

6.4 Criticality Calculation

6.4.1 Calculational Method

The revised criticality analysis was performed with the KENOVa Monte-Carlo code . NITAWL-II processes the 27 group cross-section set to provide cross-sections for the analysis. Cell weighting calculations are performed by the XSDRNPM-S code. The SCALE 4.2 CSAS modules are used to automate the computation of resonance treated and cell weighted crosssections and number density input. A series of benchmark cases for low enriched U^{235} arrays is described in section 6.5. The bias from these cases is conservatively bounded by the 0.02 bias assumed in this analysis.

Box type geometry options were used in the analysis for normal and accident conditions of transport. Optimization of the fuel loading within the inner cavity and moderation between packages have been examined. Input listings for several bounding cases are provided in Section 6.6.

6.4.2 Fuel Loading Optimization

The first packaging arrangement is for the shipment of fresh fuel pellets. The pellets are placed on 26 gauge (.017" thick) corrugated stainless steel trays. Each box contains either ten trays or twelve trays of pellets plus one extra tray on top (11 or 13 trays). The stack of trays is wrapped in 6 mil poly and the approximate 1/8 inch thick cardboard box (actual nominal thickness is 0.17") is constructed around the stack. In the original analysis the stack of boxes is created by placing three boxes on a 3/4 inch hardwood board, then covering them with another board, placing three more boxes and then the top board and strapping the stack together.

In the revised analysis (Models R1 and R2) for fuel in the scrap container, fuel is placed in a hardwood box with a nominal 3/4 inch bottom. A nominal 3/8 inch borated aluminum plate is placed on the wood bottom board followed by three boxes of fuel, another 3/8 inch borated plate, three more boxes of fuel, and a final 3 / 8 inch top borated plate. For the Type A container the back-end construction consists of the 3/4 inch box back, an additional nominal 3/4 inch board

followed by 1/4 inch neoprene padding and another 1 inch board. The Type B container has a similar back-end construction as the Type A container except that the 1 inch board is not necessary due to the smaller depth of the cavity. The front end spacer boards are the same for both cask types and consist of a nominal 1 inch board followed by 1/4 inch neoprene. The neoprene on both ends faces the outside of the cask.

In the revised analysis only the scrap container is modeled. The scrap container results bound the pellet-tray configuration for the following reasons:

1) The fuel boxes contain stainless-steel trays which hold a specific number of pellets in an orderly array. The presence of the stainless-steel trays reduces K-effective by approximately 2.6% Δk.

2) The pellet-tray fuel configurations allows higher loadings of uranium than for the scrap container. Fuel redistributed within the internal cavity cannot achieve the optimum fuel volume fraction modeled in the scrap container and results in a significant decrease in K-effective.

For the reevaluation of the scrap container it was not necessary to evaluate interspersed moderator cases because the initial analysis demonstrated that the internal cavity filled with 100% dense moderator with the external regions dry resulted in the maximum Keffective.

The tray of fuel pellets in the original analysis was modeled as a slab, each slab containing an equal share of the fuel (except where noted the 370 lb limit was used). In the accident scenarios any void spaces were filled with water. Each tier of three boxes was modeled as one long box with a volume equal to the three boxes. The inner container was originally modeled per drawing 1215599E. The reanalysis evaluated 13 and 14 gauge steel. Both carbon steel and stainless steel were also evaluated. The most reactive combination was found to be 14 gauge carbon steel. The space between the inner container and the outer drum was left void with the exception of the front- and

back-end wood support structure. For the accident condition, the inner diameter of the drum was reduced from 22.6 inches (O.D.) to 21.2 inches (O.D.) based on the results of the drop tests[3]. The drop tests were performed by UNC according to the requirements in the Federal regulations.

This is a conservative model because the drum area was voided (as discussed later the addition of any insulation/moderator into the area outside of the inner container reduces the drum reactivity), optimum moderation conditions were used, and the theoretical density of U02 was used (in the original model only) rather than the actual density (94-96% nominal theoretical density). The most reactive array shape was used - one with a shape factor as close to unity as possible. Also, the most restrictive pitch was used in the XSDRN calculations. The pitch is .406" between pellets on the same tray with a smaller pitch between pellets on different trays. The 406" is more conservative and was used in the evaluation.

The first step of the evaluation was to determine the most reactive drum and then to use this model to determine the size of subcritical normal and accident arrays. The names of the computer runs are listed in the Tables and are indicated by parentheses in the text for identification.

6.4.2.1 Moderator Optimization

An interspersed moderation study was performed to determine the optimum amount of moderator both inside the inner container and outside of the inner container. Table 6.4.2.1-1 demonstrates the flooding of the inner container with the outer container somehow voided is the most reactive case, with a k-effective of 0.856±.006 (UNCA2). Use of this case adds to the conservatism since accidental flooding of the sealed inner container without getting any moisture in the insulation is so improbable as to be impossible. A more realistic case, one with the outer drum flooded and the inner container dry (IMS11), shows a significant drop in k-effective.

Table 6.4.2.1-1

Results of Interspersed Moderation Study
10 Tray Model - 6X6X6 Array

Run	%IM Inner Container	%IM Outer Container	K-eff + 2 Sigma
UNCA2	100	0	0.856±.006
IMS02	50	0	0.781±.006
IMS03	10	0	0.721±.006
IMS04	5	0	0.711±.006
IMS05	1	0	0.711±.006
IMS06	0	0	not run
IMS07	100	3	0.855±.006
IMS08	100	10	0.822±.007
IMS09	100	50	0.738±.006
IMS10	100	100	0.729±.006
IMS11	0	100	0.681±.007

6.4.2.2 Pellet Size Evaluation

Early in the evaluation the effect of the pellet size was examined. Two sizes of pellets are used by CNFP depending on what fuel is to be manufactured. These fuel pellets are approximately 37 or .32" OD. The box of larger sized pellets will physically only hold ten trays, but the box of smaller sized pellets could contain twelve trays of fuel. Therefore a ten tray and a twelve tray model with each tray holding the maximum amount of fuel were run. As shown in Table 6.4.2.2-1 there is no difference in the reactivity. Next a model was created to reflect the actual pellet diameter. In this model, it was necessary to smear the void area and fuel together since this slab of fuel at actual fuel density would exceed the 370 lb limit and would not allow moderation in the void areas. This model turned out to be the most reactive model turned out to be the most reactive with a k-effective of 0.891±.006.

Table 6.4.2.2-1

Effect of Pellet Size
on K-effective of a Flooded BW2901

Run	Model	K-effective ± 2 Sigma
UNCM1	10 trays	0.840 ± 0.006
UNCM2	12 trays	0.841 ± 0.007
DIAM1	fuel slab thickness based on real pellet diameter	0.891 ± 0.006

6.4.2.3 **Wood Box Evaluation**

Wood boxes are used to support and contain the packages containing the Uo2 fuel pellets in the inner container. The effect of the wood density was investigated. The results in Table 6.4.2.3-1 show that the k-effective of a flooded container increases with the increasing wood density. Therefore, hard wood was assumed to maximize K-effective. In this analysis a conservative bounding hard wood density of 0.84 g/cc was used.

Table 6.4.2.3-1

Effect of Wood Density
on K-effective

Run	Wood Density	K-effective ± 2 Sigma
WOOD3	0.5 g/cc	0.831 ± 0.006
WOOD1	0.7 g/cc	0.838 ± 0.006
WOOD2	0.8 g/cc	0.849 ± 0.006

6.4.2.4 **Normal Shipments**

Normal drums are undamaged drums, with no other moderation except the normal amounts of polyethylene and cardboard, loaded with up to 168 kgs of U02 (6 boxes at 28 kgs per cardboard box), and have an outer diameter of 22.6 inches. For the original computer model the outer portion of the drum was left voided. Both a single normal drum and normal array of drums were calculated. The k-effective for a single drum is .452 ± 0.005 (NORM1). For a 15x15x15 array (3,375 drums) the k-effective for the .37 inch OD pellets in the original analysis is .908 ± 0.006 (NORML) and for the .32 inch pellets is .879 ± 0.006 (NORMS).

6.4.2.5 **Limiting Arrays for Fissile Shipments**

In the original analysis the accident array was composed of drums with a reduced radius (reduces spacing in the array), voided outer container, flooded inner container (limiting case shown by the interspersed moderator study), and all the cardboard replaced by water. These assumptions are conservative. A single flooded drum containing the 0.37 inch pellets has a k-effective of .681 ± 0.006 (FLD1L), and for the 0.32 inch pellets a k-effective of .725 ± 0.007 (FLD1S).

Originally, the accident array was computed with fully loaded and overloaded containers. However, since the arrangement of fuel is under moderated, lesser loadings of fuel allow space for more moderator. It was determined that drums of the smaller pellets contain 144 kgs of fuel.

Ten trays of the normal size pellets (168 kgs UOZ) or twelve trays of smaller pellets (144 kgs U02, plus one additional steel tray fill a box. For boxes of pellets that are not completely full the remaining space is normally filled with empty stainless-steel trays or a steel spacer to prevent damage to the pellets (this is no longer a requirement for reactivity control with the revised and bounding scrap container evaluation in Section 6.4.2.6). A pellet tray may be partially full of pellets since the

optimized full study performed for the scrap container (to be discussed later) bounds the pellet-tray configuration. The computer model was altered to represent ten fuel layers of smaller size pellets, with the trays and spacer trays neglected. The 6x6x4 array of drums filled with the smaller fuel pellet (120 kgs) has a k-effective of .906 ± 0.006 (ALND2). The subcritical array for the .37 inch pellets in the accident conditions is 144 drums in a 6x6x4 cubic array, and has a k-effective of .874 ± 0.006 (ACCLP). This model had 168 kgs of UO_2.

The array of undamaged drums, as noted above, contains 3,375 drums. The limiting subcritical accident array of damaged drums is 144 (6x6x4) with 72 drums being the allowable limit for shipment,(one-half the subcritical accident array).

6.4.2.6 Scrap Pellet Shipment Evaluation

In the packaging arrangement for the shipment of scrap pellets, the pellets are placed in polyethylene bags and the bags placed in the cardboard boxes. Up to six boxes of scrap may be placed in the container. If less than six boxes are used the remaining space must be occupied by an aluminum or wooden spacer to maintain acceptable accident geometry. Three borated plates at a minimum of 25 vol percent B4C in aluminum are used to control reactivity. An additional 2000 gms of polyethylene was evaluated using Model-R1 in the container in addition to the single bag of polyethylene in each box. The borated plates were shifted offcenter to model movement in the box and the width and length of the plates were shortened in Model-R1 and replaced with fuel to simulate the top plate shifting over the top of the box walls. The scrap container was evaluated with the optimized fuel volume fraction to maximize reactivity of the system. The center cavity was flooded and the external regions of the cavity and regions outside the drum were dry. This moderator configuration was shown to maximize K-effective in section 6.4.2.1 and the results are shown in Table 6.4.2.1-1. The conservatism contained in the revised

Model-R1 scrap container analysis are described further in Section 6.3.1.1.

The results of the original scrap container analysis are shown in Table 6.4.2.6-1. These results indicated that maximum K-effective for a 0.2 inch pellet occurred for a fuel volume fraction of 0.28. With larger pellet diameters the optimum volume fraction increased slightly to 0.31 for a 0.375 inch diameter pellet.

The results of the scrap container reanalysis using Model-R1 calculations confirm previous findings. The results for a 6x6x4 accident array with 20 volt B_4C plates are shown in Table 6.4.2.6-2. If case 1 and case 3 are compared from Table 6.4.2.6-2 it is apparent that offcenter shifted borated plates cause Keffective to increase by approximately 0.011 Δk. Therefore, all subsequent cases were run with the borated plates shifted. Cases 2 through 10 evaluate the optimum fuel volume fraction for pellet diameters of 0.2, 0.315, and 0.375 inches, respectively. A pellet diameter of 0.2 inches was chosen to simulate a pellet fragment. For pellet diameters of 0.2, 0.315, and 0.375 inches, the optimum volume fractions are 0.26, 0.28, and 0.30, respectively. Note that the difference in maximum K-effective for different pellet diameters at the optimum volume fraction is decreasing as the pellet diameter is reduced. These results indicate that a 0.2 inch diameter pellet is near optimum for maximizing Keffective. The maximum K-effective occurred for a pellet diameter of 0.2 inches with a 0.26 fuel volume fraction.

Table 6.4.2.6-1

Determination of Optimum
Fuel/Water Ratio for
Scrap Pellet Shipments
9x9x6 Array

Run UO_2	Pellet Dia.	Pitch	K-eff± 2 Sigma	VF
PTCH1	.37"	1.3cm.	.897±.007	.47
PTCH2	.37"	1.4	.920±.007	.41
PTCH3	.37"	1.5	.931±.006	.35
PTCH4	.37"	1.6	.937±.007	.31
PTCH5	.37"	1.7	.928±.007	.27
PTCHA	.32"	1.0	.844±.006	.60
PTCHB	.32"	1.1	.885±.007	.49
PTCHC	.32"	1.2	.909±.006	.41
PTCHD	.32"	1.3	.932±.007	.35
PTCHE	.32"	1.4	.932±.007	.30
PTCHG	.32	1.45	.938±.006	.29
PTCHH	.32"	1.5	.933±.007	.26
PTCHI	.32"	1.6	.928±.006	.23
PTCHZ	.20"	.8	.928±.006	.35
PTCHY	.20"	.85	.932±.006	.31
PTCHX	.20"	.9	.936±.006	.28
PTCHW	.20"	1.0	.932±.006	.23
PTCHV	.20"	1.1	.923±.007	.19

Table 6.4.2.6-2
Scrap Container Volume Fraction Results With Borated Plates At 20 Volt B4C In Aluminum

Case/Dia./ Enr/VF	Microfiche ID	K-eff ± 2σ	K-maximum	Description
1/0.200/ 5.1wt%/0.26	b16494	0.90481 (0.00112)	0.92593	Center plates
2/0.200/ 5.1wt%/0.24	b16513	0.91269 (0.00114)	0.93383	Off-center plates
3/0.200/ 5.1wt%/0.26	b16512	0.91566 (0.00114)	0.93680	Off-center plates
4/0.200/ 5.1wt%/0.28	b16514	0.91365 (0.00116)	0.93481	Off-center plates
5/0.315/ 5.1wt%/0.26	b16516	0.91162 (0.00114)	0.93276	Off-center plates
6/0.315/ 5.1wt%/0.28	b16515	0.91415 (0.00106)	0.93521	Off-center plates
7/0.315/ 5.1wt%/0.30	b16517	0.91289 (0.00116)	0.93405	Off-center plates
8/0.375/ 5.1wt%/0.28	b16519	0.91131 (0.00114)	0.93245	Off-center plates
9/0.375/ 5.iwt%/0.30	b16518	0.91142 (0.00112)	0.93254	Off-center plates
10/0.375/ 5.1wt%/0.32	b16520	0.91090 (0.00110)	0.93200	Off-center plates

6.4.2.7 Limiting Arrays

From the original analysis the normal subcritical array of drums with a 65% packing fraction has 3375 drums in a 15x15x15 array (NORM2). The k-effective for this array is 0.774 ± 0.005. A single flooded drum has a k-effective of 0.792 ± 0.007 (SCRP1).

In the original analysis the accident array was composed of drums with a reduced radius, voided outer container, flooded inner container and all the cardboard replaced by water, and the optimum pitch was used. The subcritical array for the accident conditions is 144 drums in a 6x6x4 array (HTODC). The k-effective for such an array was originally calculated to be 0.912 ± 0.007 for the scrap container. The revised scrap container was evaluated with offcenter shifted plates and an optimum fuel volume fraction for the 6x6x4 accident configuration in Table 6.4.2.6-2 and results in a maximum K-effective of 0.93680 (b16512).

The array of undamaged drums, as noted above, contains 3,375 drums. The limiting subcritical accident array of damaged drums is 144 (6x6x4) with 72 drums being the allowable limit for shipment,(one-half the subcritical accident array)

6.4.2.8 Effects of Increased Polyethylene Content

There was a 600 gram limit on polyethylene for the scrap shipments and an H/X limit of 1.3 for shipments utilizing the trays. A study was originally performed to determine if these limits are still necessary.

Scrap shipments have an upper packing fraction of 65%. In the original study, the remaining area was filled with various amounts of polyethylene. The Original results are shown in Table 6.4.2.8-1.

Table 6.4.2.8-1

Effect of Polyethylene on Scrap Pellet Shipments

Run	Pckg. Frac.	GramsPolv	K-eff ± 2 Sigma
POLY4	.65	600	0.858 ± 0.005
POLY5	.65	1000	0.887 ± 0.005
POLY6	.65	2000	0.920 ± 0.007
POLY7	.65	3000	0.962 ± 0.005

The above results show for the scrap shipments that the limit for the amount of polyethylene should be kept under 2000 grams. The bags normally used weigh approximately 50 grams apiece, so it would take more than 40 bags to exceed this mass. There are normally 8 bags at approximately 50 grams per bag, so a "normal" container would have 400 grams of polyethylene, well below the prior 600 gram limit.

For shipments utilizing the pellet trays, extra polyethylene wrap was inserted into the void area inside the polyethylene wrap. An additional 380 grams of polyethylene inside the wrapper (504 grams total) gives a k-effective of .923±.006 (POLL4). Additionally, the wrap was doubled and tripled. The k-effective for the tripled wrap was .921±.006 (WRAP1). This shows that the polyethylene should not exceed three layers nor should more than 380 grams of polyethylene be allowed inside the wrap.

In the revised scrap container analysis using Model-R1 2000 additional grams of polyethylene were placed in the fuel volume and away from the borated aluminum plates. The results of this analysis are shown in Table 6.4.2.8-2 (cases 1-11). Preliminary calculations (not shown) demonstrated that additional polyethylene adjacent to the borated plates increased the worth of the borated plates causing K-effective to decrease. Therefore, the additional polyethylene was placed in the middle of

three fuel layers (see Figure 6-5) and away from the borated plates. This arrangement caused K-maximum to increase by approximately 0.01 Δk. The revised scrap container polyethylene cases indicate that the optimum fuel volume fraction is affected by the presence of the additional polyethylene. Pellet diameters of 0.2, 0.315, and 0.375 inches were evaluated and the optimum fuel volume fraction increased by 0.02 for each pellet diameter. With 2000 grams of additional polyethylene K maximum was determined for the 0.2 inch diameter pellet to be 0.94506 (b16750). Note that case 3 models the container lid with 16 gauge steel while the other cases erroneously assumed 12 gauge steel. The difference in K-maximum is less than the combined uncertainty from case 2 and case 3. For conservatism the polyethylene limit for the scrap and pellet-tray configuration is 1000 gms.

Table 6.4.2.8-2
Scrap Container Criticality Results With 2000 Additional Grams Polyethylene and 20 Volt B4C Plates

Case/Dia./ Enr/VF	Microfiche ID	K-eff ± 2σ	K-maximum	Description
1/0.200/ 5.1wt%/0.26	b16561	0.92209 (0.00112)	0.94321	Off-center plates/2000 gms poly
2/0.200/ 5.1wt%/0.28	b16566	0.92381 (0.00114)	0.94495	Off-center plates/2000 gms poly
3/0.200/ 5.1wt%/0.28	b16750	0.92392 (0.00114)	0.94506	Off-center plates/2000 gms poly/16 guage lid
4/0.200/ 5.1wt%/0.30	b16562	0.92251 (0.00116)	0.94367	Off-center plates/2000 gms poly
5/0.200/ 5.1wt%/0.35	b16565	0.91605 (0.00116)	0.93721	Off-center plates/2000 gms poly
6/0.315/ 5.1wt%/0.28	b16633	0.92183 (0.00116)	0.94299	Off-center plates/2000 gms poly
7/0.315/ 5.1wt%/0.30	b16617	0.92291 (0.00114)	0.94405	Off-center plates/2000 gms poly
8/0.315/ 5.1wt%/0.32	b16632	0.92216 (0.00120)	0.94336	Off-center plates/2000 gms poly
9/0.375/ 5.1wt%/0.30	b16631	0.91920 (0.00120)	0.94040	Off-center plates/2000 gms poly
10/0.375/ 5.1wt%/0.32	b16612	0.91974 (0.00114)	0.94088	Off-center plates/2000 gms poly
11/0.375/ 5.1wt%/0.34	b16630	0.91943 (0.00112)	0.94055	Off-center plates/2000 gms poly

6.4.2.9 Triangular Pitch Results

The results thus far have evaluated a 6x6x4 array of drums on a square pitch with the outer radius of the drum reduced to reflect drop test results. If a triangular pitch is assumed it is possible to place the fuel regions in separate drums closer together than with a square pitch. To simulate a triangular pitch the radius of the accident drum was further reduced by approximately 0.736 inches using Model-R1 to conserve the fuel volume fraction associated with the triangular pitch. This model is conservative because it allows neutrons to traverse between drums without intersecting a borated aluminum plate in two planes. Additionally, reducing the diameter of the drum reduced the steel in the outer shell since the same thickness was maintained. This result is shown in Table 6.4.2.9-1 and indicates that the triangular pitch assumption results in a 0.014 Δk reactivity increase. The increase in K-effective results in K-maximum of 0.95928 (b16742 - case 1) and exceeds the 0.95 criticality criterion. Case 1 and previous cases modeled a plate thickness of 0.355 inches with 20 volt B4C. The tolerances on the plate allow a minimum plate thickness of 0.365 inches so credit was taken in subsequent cases for the slightly thicker plate. The B4C concentration was increased from 20 to 25 Vol% in aluminum to provide the additional needed reactivity control. Case 2 is a repeat of case 1 with the previously discussed modifications and K maximum becomes 0.94698 (b16742).

To verify the validity of the square pitch model, a hexagonal triangular pitch array was constructed four drums deep. The hexagonal array contains 37 drums per plane. Therefore, there are 4 more drums being modeled than the 6x6x4 array. The array is surrounded by a 12 inch water reflector on all sides. The results of case 3 demonstrate that the reduced pitch square lattice model is conservative and the maximum final K-effective using Model-R1 from the triangular pitch result is 0.94208 (b16780).

Table 6.4.2.9-1.
Scrap Container Triangular Pitch Results With 2000 gms Polyethylene, Shifted Plates, 11.019" Cavity Dimension
0.365 in. Thick Plates @ 25 Vol% B_4C

Case/Dia./ Enr/VF	Microfiche ID	K-eff ± 2σ	K-maximum	Description
1/0.200/ 5.1wt%/0.28	b16741	0.93810 (0.00118)	0.95928	Off-center plates/2000 gms poly/ Red pitch/ 0.355 in plates
2/0.200/ 5.1wt%/0.28	b16742	0.92584 (0.00114)	0.94698	Off-center plates/2000 gms/Red Sq. pitch/ 0.365 in plates/ 25 % B4C
3/0.200/ 5.1wt%/0.28	b16780	0.92090 (0.00118)	0.94208	Off-center plates/2000 gms/Tri pitch/ 0.365 in plates/ 25% B4C

6.4.2.10 Model-R2 Development and Bulge Analysis

A revised model to be referred to as Model-R2 was developed for the following reasons:

1) Model-R1 was developed based on conserving total volumes of materials and used a simplified geometry. Model-R2 was developed to exactly model the toleranced dimensions of materials inside the internal cavity to ensure strict correspondence to the design drawings in section 1.

2) Examination of the as-built containers indicated a slight bulge in the internal cavity wall with a maximum cavity width of 11.15 inches. The bulge extends over a small region between two angle iron pieces and is not more than 9 inches in length with the worst dimension (11.15 inches) at the middle between the two angle iron pieces. The bulge is a consequence of the welding process used to attach the internal cavity to the angle iron. Because of this localized bulge the entire cavity length was modeled as having an 11.15 inch square crosssection. This assumption is very conservative because it adds more fuel to the drum than is actually allowed by the actual as-built BW2901 containers.

3) To offset the reactivity increase associated with the increase in cavity volume it was necessary to reduce the maximum enrichment from 5. 1 wt% U2 11 to 5.05 wt% U^{235}, reduce the maximum theoretical density of the fuel to 0.976 (97.5% is the maximum allowed density in the pellet specification for any FRAMATOME ANP fuel assembly design), and model the AlB4C plates exactly to take credit for the actual volume of the plates (Model-R1 conservatively truncated plates). The borated aluminum Plates were modeled with exact toleranced dimensions of 9.24" x 24.98" x 0.365". Note that assuming the

11.15 inch maximum cavity dimension along the entire length results in greater off-center shifting of the top plate and the remainder of the fuel than is actually possible with the as-built containers. Since a 1000 gm limit of polyethylene applies to the container the total mass of polyethylene was reduced to approximately 1435 gms. Therefore, the amount of polyethylene modeled remains conservative relative to the actual limit. With the previously mentioned changes from Model-R1, Model-R2 remains inherently conservative relative to the existing fabricated containers and conforms precisely to the drawings in Section 1.

A cross-sectional cut of the internal cavity at the mid-plane is shown in Figure 6-6. A more complete isometric view was not drawn due to the complexity of the KENOVa model (12 axial slices are required to define all of the internal cavity detail). Without the dimensional detail Figure 6-5 is adequate for a general understanding of the cavity contents and arrangement. Figure 6-6 shows the wood box broken apart to maximize fuel regions that are not shielded by any borated plates in the X,Y, and Z planes. The configuration maximizes K-effective and neutron transport between drums for unshielded fuel regions.

Table 6.4.2.10-1 shows the Model-R2 results. Model-R2 utilizes a triangular pitch. Cases 1-4 identify an optimum fuel volume fraction of 0.28 for the 0.200 inch diameter pellet. These results are completely consistent with Model-R1 results. Therefore, there is no shift in the optimum fuel volume fraction as a consequence of using the exact geometry. Cases 5 and 6 are the limiting cases for pellet diameters of 0.315 inches and 0.375 inches, respectively. Cases 5 and 6 were computed with their respective optimum fuel volume fractions of 0.30 and 0.32. The Model-R2 results indicate that maximum K-effective occurs for the 0.200 inch diameter pellet for a fuel volume fraction of 0.28.

The maximum K-effective for the system is 0.94803 with a 0.02 bias and 2a uncertainty applied. Therefore, with the use of optimized fuel the scrap container configuration bounds the pellet-tray configuration and satisfies the 0.95 criticality criterion.

Table 6.4.2.10-1
Scrap container Triangular Pitch Results With 1435 Total Gms Polyethylene, Shifted Plates, 11.15" Cavity Dimension, Exact Toleranced Dimensions,
5.05 wt% U^{235} With 25 Vol% B_4C in Aluminum Plates

Case/Dia./ Enr/VF	Microfiche ID	K-eff ± 2σ	K-maximum	Description
1/0.200/ 5.05wt%/0.27	b17160	0.92450 (0.00174)	0.94624	Off-center plates/ 11.15" Cavity Width
2/0.200/ 5.05wt%/0.28	b17232	0.92623 (0.00180)	0.94803	Off-center plates/ 11.15" Cavity Width
3/0.200/ 5.05wt%/0.29	b17161	0.92413 (0.00162)	0.94575	Off-center plates/ 11.15" Cavity Width
4/0.200/ 5.05wt%/0.30	b17162	0.92262 (0.00170)	0.94432	Off-center plates/ 11.15" Cavity Width
5/0.315/ 5.05wt%/0.30	b17233	0.92550 (0.00170)	0.9472	Off-center plates/ 11.15" Cavity Width
6/0.375/ 5.05wt%/0.32	b17236	0.92251 (0.00158)	0.94409	Off-center plates/ 11.15" Cavity Width

6.4.3 Criticality Results

The results of the criticality safety analysis for the BW2901 shipping container analysis are summarized in Tables 6.4.2.6-2, 6.4.2.8-2, 6.4.2.9-1, and 6.4.2.10-1. The maximum Keffective values were computed from the following formula:

K-maximum = K-effective + Bias +2σ.

where K-effective is calculated by KENOVa, σ is the uncertainty in the KENOVa calculation, and, Bias is 0.02 as described in Section 6.5.

With the number of generations equal to 500 a one-sided tolerance factor of 1.763 could be justified. However, a conservative 2-sided tolerance factor of 2.0 was maintained for conservatism. Table 6.4.3-1 shows the allowable number of drums to be shipped under the fissile classification.

Table 6.4.3-1
Summary of Limits for the BW2901 Shipping Container

Packaging Arrangements	Fissile Class Limit
Pellets on Trays	72
Bagged Scrap	72

Both packaging arrangements are safe for shipment from a nuclear criticality safety viewpoint. These packaging arrangements must conform to the descriptions and assumptions in this analysis and in the Certificate of Compliance. In addition to the shipping specifications already authorized, the Certificate of Compliance should contain the following specifications:

1) Weight limit will remain at 370 pounds (167.83 Kg) of UO_2 with the U-235 content not to exceed 7.47 kg U^{235}
2) The enrichment limit will be 5.05%.
3) The maximum allowed pellet density is 97.6% of the UOZ theoretical density (10.96%).

4) A minimum pellet diameter of 0.315" and maximum pellet diameter of .375" OD for shipments utilizing trays.

5) The pellet trays should normally be fully loaded and the boxes may have up to 10 trays for larger diameter pellets and up to 12 trays for smaller diameter pellets. There is no criticality requirement that unoccupied space in the box or on a tray of pellets contain stainless-steel or a volume displacement device since optimized fuel was used in the analysis. The use of stainless-steel trays or spacers is recommended to prevent damage to pellets.

6) For partial shipments with less than 6 boxes of fuel, the remaining space must be occupied with aluminum or wood blocks of equal volume to prevent shifting of The fuel boxes or borated aluminum plates.

7) The wood box shall contain three borated aluminum plates with a minimum of 25 volume % B4C (23.702 wt%) . The minimum areal density of B10 shall be 83.823 mg/sq cm per plate. The minimum dimensions of the borated aluminum plate shall be 24.98" x 9.24" x 0.365". One plate shall be located on the box bottom, the second on top of the first layer of fuel (middle plate), and the third on top of the second layer of fuel (top plate). See Figures 6-5 and 6-6 and Section 1 drawings for the arrangement.

8) The scrap and pellet-tray containers shall contain no more than 1000 gms of polyethylene.

6.4.4 Selected Input File Listings

This section contains a listing of the input decks that represent the limiting cases performed in both the original and revised analyses. They are in order:

1) 1 flooded drum with .37" OD pellets on pellet trays

2) 1 flooded drum with .32" OD pellets on pellet trays

3) 1 flooded drum with scrap pellets

4) 15x15x15 normal array with .37" OD pellets on pellet trays

5) 15x15x15 normal array with .32" OD pellets on pellet trays

6) 15x15x15 normal array with scrap pellets

7) 6x6x4 accident array with .37" OD pellets on pellet trays

8) 6x6x4 accident array with .32" OD pellets on pellet trays

9) Rev. Model-R2 37x4 hexagonal accident array with scrap pellets

6.5 Critical Benchmark Experiments

6.5.1 Benchmark Experiments and Applicability

Twenty-one Lynchburg Research Center (LRC) critical experiments were examined to quantify the KENOVa bias using both KENO-IV and KENOVa results for low-enriched uranium systems. The experiments involved three dimensional arrays of uranium fuel rods with intervening regions of either water, borated isolation sheets, or B_4C pins.

The 21 LRC critical configurations were chosen for the benchmark calculations and have the following similarities to the container configuration:

1) low-enriched systems,
2) interspersed hydrogenous moderator
3) borated aluminumisolation sheets,
4) fissile material size and shape.

Thus, the criticality experiments chosen for the benchmark calculations are directly applicable for this analysis.

6.5.2 Details of the Benchmark Calculations

The approach to defining an applicable bias is to perform benchmark calculations using the KENO-IV code with the 27 group cross-section library. Since KENOVa was used in the analysis of the BW2901, comparison cases were run between KENO-IV and KENOVa using cases from the original BW2901 license which demonstrate excellent agreement between both KENO versions. It was necessary to use KENOVa in the BW2901 analysis for several reasons:

1) The detailed geometry of the inner cavity would be very difficult to model using KENO-IV and KENO-IV does not allow modeling of a hexagonal array,

2) Use of the CSAS modules reduces the chance of errors in the treatment of resonance absorbers and in the preparation of number density input,

3) KENOVa allows treatment of P_3 scattering cross-section components. The use of the FRAMATOME ANP KENO-IV code will only allow P_1 scattering and cases performed at FRAMATOME ANP indicate that some SCALE 4.2 KENOVa results may have K-effective results that are 0.005 Δk higher than with KENO-IV. Therefore, use of the SCALE4.2 library with KENOVa is conservative relative to other available KENO versions at FRAMATOME ANP.

6.5.2.1 **LRS Critical Benchmark Results**

The 21 critical LRC benchmark calculations were evaluated using the 27 group SCALE 4.2 cross-section library in Reference 5. The KENO-IV calculations in Table 6.5.2.1-1 were performed using 625 neutrons per generation and 600 generations. The first 102 generations were skipped yielding a total of 311,250 neutron histories. Examination of Table 6.5.2.1-1 results indicates that the SCALE 27 group cross-section library with the CSASN (BONAMI-S/NITAWL-II) cross section treatment results in a maximum non-conservative bias of -0.01429 +0.00148 for core IX.

To test the adequacy of the neutron density per generation, core VI was rerun with a total of 850 generations and 2000 neutrons per generation. This case results in k-effective of 0.99781 ±0.00053 with only the first 3 generations skipped. This case is shown in Table 6.5.2.1-2 along with other core VI results and indicates that larger neutron densities and generations are required to obtain meaningful results and statistics.

Table 6.5.2.1-3 shows the calculated bias For the **eight most limiting** core configurations identified from Table 6.5.2.1-1 using 2000 neutrons/generation and 847 generations. The maximum calculated bias with uncertainty was - 0.01335 ±0.00197 for core XVI and represents a core with a water gap of 1.288 inches with borated aluminum isolation sheets in the water gap region. With the exception of core I and IX the

other cases contained B4C pins or borated aluminum isolation sheets. There is no apparent trend of the bias with separation distance or intervening materials. Therefore, the same 27 group bias and uncertainty is used for all problem types represented by these critical configurations.

Table 6.5.2.1-1
RENO-IV LRC Critical Results With CSASN 27 Group Library
(Neutrons per Generation = 625; Number of Active Generations = 498)

Spacing Between Arrays (in.)	Core Number	RENOIV On IBM 6000 w/ CSASN/27 Gp (1σ Uncertainty)	Measured (1σ Unc)	Calculated Minus Measured (1σ Uncertainty)
None	I	0.98903 (0.00127)	1.0002 (0.0005)	-0.01117 (0.00136)
	II	1.00489 (0.00104)	1.0001 (0.0005)	+0.00479 (0.00115)
0.644	111	1.00438 (0.00099)	1.0000 (0.0006)	+0.00438 (0.00116)
	IV	0.98764 (0.00120)	0.9999 (0.0006)	-0.01226 (0.00134)
	XI	1.00013 (0.00108)	1.0000 (0.0006)	+0.00013 (0.00124)
	XIII	0.99377 (0.00120)	1.0000 (0.0010)	-0.00623 (0.00156)
	XIV	0.99323 (0.00115)	1.0001 (0.0010)	-0.00687 (0.00152)
	XV	0.99266 (0.00106)	0.9998 (0.0016)	-0.00712 (0.00192)
	XVII	0.99619 (0.00113)	1.0000 (0.0010)	-0.00381 (0.00151)
	XIX	1.00027 (0.00099)	1.0002 (0.0010)	+0.00007 (0.00141)
1.288	V	0.98603 (0.00117)	1.0000 (0.0007)	-0.01397 (0.00136)
	VI	0.99602 (0.00109)	1.0097 (0.0012)	-0.01368 (0.00162)
	XII	0.99439 (0.00116)	1.0000 (0.0007)	-0.00561 (0.00135)
	XVI	0.98777 (0.00121)	1.0001 (0.0019)	-0.01233 (0.00225)
	XVIII	0.99390 (0.00112)	1.0002 (0.0011)	-0.00630 (0.00157)
	XX	0.99767 (0.00113)	1.0003 (0.0011)	-0.00263 (0.00157)
1.932	VII	0.98589 (0.00116)	0.9998 (0.0009)	-0.01391 (0.00147)
	VIII	1.01234 (0.00123)	1.0083 (0.0012)	+0.00404 (0.00172)
	X	0.99469 (0.00119)	1.0001 (0.0009)	-0.00541 (0.00149)
	XXI	0.98649 (0.00117)	0.9997 (0.0015)	-0.01321 (0.00190)
2.576	IX	0.98871 (0.00118)	1.0030 (0.0009)	-0.01429 (0.00148)

Table 6.5.2.1-2
RENO-IV LRC Core VI Results Using Variable Generations and Densities With CSASN 27 Group Library

Gen. Skipped	Act Gen/ Hist.	KENOIV On IBM 6000 w/ CSASN/27Gp (1σ Uncertainty)	Measured (1σ Unc)	Calculated Minus Measured
3	212/625	0.99322 (0.00189)	1.0097 (0.0012)	-0.01648
102	498/625	0.99602 (0.00109)	1.0097 (0.0012)	-0.01368
3	297/100 0	0.99625 (0.00126)	1.0097 (0.0012)	-0.01345
102	198/100 0	0.99806 (0.00149)	1.0097 (0.0012)	-0.01164
3	847/200 0	0.99781 (0.00053)	1.0097 (0.0012)	-0.01189
102	748/200 0	0.99736 (0.00056)	1.0097 (0.0012)	-0.01234

Table 6.5.2.1-3
KENO-IV LRC Critical Results Using CSASN 27 Group Library For Worst Eight Core Configurations
(Neutrons per Generation = 2000; Number of Active Generations = 847)

Spacing Between Arrays (in.)	**Core Number**	KENO-IV On IBM 6000 w/ **CSASN/27Gp** (1σ Uncertainty)	Measured (1σ Unc)	**Calculated Minus Measured** (1σ Uncertainty)
None	1	0.98964 (0.00053)	1.0002 (0.0005)	-0.01056 (0.00073)
0.644	IV	0.98892 (0.00052)	0.9999 (0.0006)	-0.01098 (0.00079)
1.288	V	0.98797 (0.00052)	1.0000 (0.0007)	-0.01203 (0.00087)
	VI	0.99715 (0.00049)	1.0097 (0.0012)	-0.01255 (0.00130)
	XVI	0.98675 (0.00051)	1.0001 (0.0019)	-0.01335 (0.00197)
1.932	VII	0.98689 (0.00050)	0.9998 (0.0009)	-0.01291 (0.00103)
	XXI	0.98896 (0.00050)	0.9997 (0.0015)	-0.01074 (0.00158)
2.576	IX	0.99100 (0.00051)	1.0030 (0.0009)	-0.01200 (0.00103)

6.5.2.2 Statistically, Calculated Maximum Bias

The previous calculations defined the maximum 27 group bias plus uncertainty from using the worst single core configuration. A more precise understanding of the bias is to view it in a statistical sense. It is possible that any single measured or calculated core configuration could have included larger errors than those that would actually occur if the experiment were repeated. To state the case another way, is it appropriate to penalize all future criticality results because one of twenty-one core configurations appears to indicate a larger bias which could be the result of random measurement error? This type of problem is addressed in statistical analysis by considering the determination of the expected sample mean and is a valid approach to use when groups of calculations are done at different conditions (as is the case for the different core configurations). The sample mean approach would view the core critical experiments as separate entities. If each core configuration experiment (and KENO-IV analysis were repeated a very large number of times, all core configurations would converge on the true sample mean. Furthermore, the true sample mean would be the same for each of the experiments. The true or expected sample mean is defined as:

$$E(x) = \sum_{i=1}^{i=M} w_i x_i \Big/ \sum_{i=1}^{i=M} w_i$$

where **wi** and **xi** are the weighting factors and the core bias values, respectively. E(x) is the expected sample mean. The weighting factors are defined as:

$$w = n_1/\sigma^2_I$$

where n; and *61* are the number of KENO-IV

generations (sample size) and the combined measured and KENO-IV calculated standard deviation, respectively.

The expected sample mean of the bias was conservatively computed to be -0.01159 using only the **worst eight core configurations** while for comparison the average bias of the eight worst core configurations was computed to be -0.01189. Both values are very close. The standard deviation for the expected sample mean method is the maximum standard deviation computed for any individual core. In this case the 1σ value is ±0.00197 from core XVI. The one-sided upper tolerance factor at the 95/95 confidence level is assumed to be the same as for the KENO-IV results or 1.763. For the average bias method the standard deviation is computed directly from the worst eight core configurations to be ±0.0009093 with a one-sided upper tolerance factor at the 95/95 confidence level of 3.188. To summarize; the expected sample mean method results in a bias of **-0.01159 ±0.00347 (1.763σ)**. The average bias method results in a bias of **-0.01189 ±0.00290 (3.188σ)**. For this analysis a bias of 0.02 was used (with no uncertainty) to conservatively bound any reasonable expected bias and to be consistent with the original licensed analysis.

6.5.2.3 **Benchmark Comparisons Using KENO-IV and KENOVa**

Benchmark cases were run for the container using both the 123 group and the 27 group cross-section libraries using the SCALE4.2 code package. The CSAS2X module was used which uses the BONAMI-S/NITAWL-II/XSDRNPM-S/KENOVa code sequence. Since, the Reference 1 analysis used the 123 group library with KENO-IV, a benchmark case was run with KENOVa for comparison.

The most limiting case identified in the original license analysis was for a 6x6x4 accident array of containers with the center region of the drum filled with water and uranium scrap and all external regions of the drum (and outside the drums) were void. A 2σ uncertainty and 0.02 bias was maintained as in the original license.

Table 6.5.2.3-1
Benchmark R-effectives For The
6x6x4 Accident Array

Enrich./ Microfiche	Base K-eff.	2σ Unc.	Max. K-eff.	Description
5.1 wt%/ Reference Base Case	0.912	±0.007	0.939	Reference - Base case
5.1 wt%/ b11825	0.91131	±0.00120	0.93251	27 gp Base case w/KENOVa
5.1 wt %/ b11850	0.91173	±0.00118	0.93291	123 gp Base case w/KENOVa

Table 6.5.2.3-1 results indicate that the 27 group and 123 group base K-effective results agree quite well with the base accident calculation results (compare original license base case, b11825 and b11850). K-maximum values were different because the reanalysis considered 847 active generations with 2000 neutrons per generation. Therefore, the total number of neutron histories is many more than the referenced base accident case.

6.5.3 **Results of Benchmark Calculations**

The results of the benchmark calculations and the KENOVa comparison cases suggest that a KENOVa bias of 0.01159 ± 0.00347 (1.763σ) is justifiable. However, to ensure conservatism of the bias with KENOVa the original SAR bias of 0.02 was maintained. The use of this bias implies 0.005 Δk conservatism.

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Input decks were manually cut and pasted into pages 6-51 - 6-77 due to the age and lack of availability.

1 Flooded Drum With 0.37" OD Pellets on Pellet Trays
(Original Scale3 Deck)

```
=csas2
May2-91/.3700 pellet/th.density/flooded 1drum/
123groupgmth         8        15     2 latticecell 0 0
o               1    0.0  4.89127-2  end
u-235           1    0.0  1.26241-3  end
u-238           1    0.0  2.31941-2  end
h2o             2       1.00         end
h               3    0.0  3.32986-2  end
c               3    0.0  2.243-2    end
o               3    0.0  1.273-2    end
h               4    0.0  1.27772-2  end
c               4    0.0  7.66632-3  end
o               4    0.0  6.3886-3   end
polyethylene)   5       1.00         end
ss304           6    0.001-9         end
carbonsteel     7    1.00            end
h               8    0.0  6.674-2    end
o               8    0.0  3.337-2    end
end comp
triangpitch      1.03124  0.9398   1   2      end
May2-91/.3700 pellet/th.density/6x6x4 accident array
140  150 400   5  1   1   1   0
cuboid    3   0.9525  -0.9525  10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid    8   1.58750 -1.58750 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid    5   1.60274 -1.60274 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid    6   1.64592 -1.64592 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid  500   2.58216 -2.58216 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid    6   2.62534 -2.62534 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid  500   3.56158 -3.56158 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid    6   3.60476 -3.60476 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid  500   4.54100 -4.54100 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid    6   4.58418 -4.58418 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid  500   5.52042 -5.52042 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid    6   5.56360 -5.56360 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid  500   6.49984 -6.49984 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid    6   6.54302 -6.54302 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid  500   7.47926 -7.47926 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid    6   7.52244 -7.52244 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid  500   8.45868 -7.45868 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid    6   8.50186 -8.50186 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid  500   9.43810 -9.43810 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid    6   9.48128 -9.48128 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid  500   10.41752 -10.41752 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid    6   10.46070 -10.46070 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid  500   11.39694 -10.39694 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid    6   11.44012 -11.44012 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid    5   11.45536 -11.45536 10.8432   -10.8432   29.5427   -29.5427   -0.5
cuboid    8   11.74746 -11.74746 11.1607   -11.1607   29.8602   -29.8602   -0.5
cuboid    3   13.65249 -13.65249 11.1607   -11.1607   29.8602   -29.8602   -0.5
cuboid    8   13.65250 -13.65250 13.6525   -13.6525   37.3701   -37.3701   -0.5
cuboid    7   13.84224 -13.84224 13.84224  -13.84224 37.5598   -37.5598   -0.5
cylinder  0   26.792    43.18   -43.18   -0.5
cylinder  7   26.91341 43.332   -43.30   -0.5
cuboid    0   26.91341 -26.91341 26.91341  -26.91341 45.237   -45.205   -0.5
core bdy  0   26.91341 -26.91341 26.91341  -26.91341 45.237   -45.205   -0.5
cuboid    8   57.42    -57.42    57.42     -57.42    75.74    -75.74    -0.5
end geometry
end
```

1 Flooded Drum With 0.32" OD Pellets on Pellet Trays (Original Scale3 Deck)

```
=csas2
May2-91/unc2901/one drum flooded/.32 pellets
123groupgmth      8   15  2   latticecell 0 0
o               1    0.0  4.891-2      end
u-235           1    0.0  1.262-3      end
u-238           1    0.0  2.3194-2     end
h2o             2       1.00           end
h               3    0.0  3.32986-2    end
c               3    0.0  2.243-2      end
o               3    0.0  1.273-2      end
h               4    0.0  1.27772-2    end
c               4    0.0  7.66632-3    end
o               4    0.0  6.3886-3     end
polyethylene    5       1.00           end
ss304           6    0.001-9           end
carbonsteel     7    1.00              end
h               8    0.0  6.674-2      end
o               8    0.0  3.337-2      end
triangpitch      1.03124  0.8128   1   2        end
May2-91/unc2901/one drum flooded/.32 pellets
140   150   400   5   1   1   1   1   0
cuboid   3   0.9525   -0.9525  10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid   8   1.58750  -1.58750 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid   5   1.60274  -1.60274 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid   6   1.64592  -1.64592 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid 500   2.45872  -2.45872 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid   6   2.50194  -2.50194 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid 500   3.3147   -3.31470 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid   6   3.35788  -3.35788 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid 500   4.17068  -4.17068 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid   6   4.21386  -4.21386 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid 500   5.02666  -5.02666 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid   6   5.06984  -5.06984 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid 500   5.88264  -5.88264 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid   6   5.92582  -5.92582 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid 500   6.73862  -6.73862 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid   6   6.78180  -6.78180 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid 500   7.59460  -7.59460 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid   6   7.63778  -7.63778 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid 500   8.45058  -8.45058 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid   6   8.49376  -8.49376 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid 500   9.30656  -9.30656 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid   6   9.34974  -9.34974 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid 500   10.1625   -10.1625 10.8280   -10.8280  29.5275  -29.5275 -0.5
cuboid   6   10.2057   -10.2057 10.8280   -10.8280  29.5275  -29.5275 -0.5
cuboid   0   11.44012 -11.44012 10.8280   -10.8280  29.5275   -29.5275 -0.5
cuboid   5   11.45536 -11.45536 10.8432   -10.8432 29.5427   -29.5427   -0.5
cuboid   8   11.74746 -11.74746 11.1607   -11.1607 29.8602   -29.8602   -0.5
cuboid   3   13.65249 -13.65249 11.1607   -11.1607 29.8602   -33.6702   -0.5
cuboid   8   13.65250 -13.65250 11.6525   -13.6525 37.3701   -37.3701   -0.5
cuboid   7   13.84224 -13.84224 13.84224 -13.84224 37.5598  -37.5598  -0.5
cylinder 0   26.797    43.18    -43.18    -0.5
cylinder 7   26.91341 43.332    -43.30    -0.5
cuboid   0   26.91341 -26.91341 26.91341 -26.91341 45.237   -45.205   -0.5
core bdy 0   26.91341 -26.91341 26.91341 -26.91341 45.237   -45.205   -0.5
cuboid   8   57.42    -57.42    57.42    -57.42    75.74    -75.74    -0.5
end geom
end
```

1 Flooded Drum With Scrap Pellets
(Original Scale3 Deck)

```
=csas2
05/04/91/unc scrap/30%vf/one flooded
123groupgmth    10   17   2   latticecell 0 0
o               1    0.0  4.89127-2  end
u-235           1    0.0  1.26241-3  end
u-238           1    0.0  2.31941-2  end
h2o             2      1.0           end
h               3    0.0  3.32986-2  end
c               3    0.0  2.243-2    end
o               3    0.0  1.273-2    end
h               4    0.0  1.27772-2  end
c               4    0.0  7.66632-3  end
o               4    0.0  6.3886-3   end
polyethylene    5      1.00          end
ss304           6    1.00            end
h2o             7    1.00            end
carbonsteel     8    1.00            end
h               9    0.0  6.674-2    end
o               9    0.0  3.337-2    end
al              10   1.00   end
triangpitch      0.9    0.5   1   2       end
05/06/91/unc scrap/one flooded drum
140   160   450   5   1   1   1   1   0
cuboid    6   0.635    -0.6350   11.16660  -11.16660   10.05535 -30.16605  -0.5
cuboid    7   0.9525   -0.9525   11.16660  -11.16660   10.05535 -30.16605  -0.5
cuboid    5   1.05715 -1.05715   11.16660  -11.16660   10.05535 -30.16605  -0.5
cuboid  500  11.00785 -11.00785 11.16660  -11.16660   10.05535 -30.16605  -0.5
cuboid    5  11.1125   -11.1125   11.27125  -11.27125  10.1600  -30.2707  -0.5
cuboid    7  11.4300   -11.4300   11.58875  -11.58875  10.4775  -30.5882  -0.5
cuboid   10  11.4300   -11.4300   11.58875  -11.58875  31.4325  -30.5882  -0.5
cuboid    3  13.6525   -13.6525   11.58875  -11.58875  31.4325  -30.5882  -0.5
cuboid    7  13.6525   -13.6525   11.6525   -13.6525   45.4025  -30.5882  -0.5
cuboid    8  13.84224 -13.84224 13.84224  -13.84224  45.5922  -30.7779  -0.5
cylinder  0  26.792    50.58715 -35.77285  -0.5
cylinder  8  26.91341  50.73904 -35.89426  -0.5
cuboid    0  26.91341 -26.91341 26.91341  -26.91341 52.64404 -37.79926  -0.5
core bdy  0  26.91341 -26.91341 26.91341  -26.91341 52.64404 -37.79926  -0.5
cuboid    9  57.41341 -57.41341 57.41341  -57.41341 83.14404 -68.29926  -0.5
end geom
end
```

15x15x15 Normal Array With .37" OD Pellets on Pellet Trays
(Original Scale3 Deck)

```
=csas2
May02-91/.370D pellet/TH.Density/T5*3 Normal Array
123groupgmth      8   15  2   latticecell 0 0
o                1     0.0 4.89127-2 end
u-235            1     0.0 1.26241-2  end
u-238            1     0.0  2.31941-2   end
h2o              2        0.001         end
h                3     0.0  3.32986-2  end
c                3     0.0  2.243-2    end
o                3     0.0  1.273-2    end
h                4     0.0  1.27772-2  end
c                4     0.0  7.66632-3  end
o                4     0.0  6.3886-3   end
polyethylene     5       1.00          end
ss304            6     1.00            end
carbonsteel      7     1.00            end
h                8     0.0  6.674-2    end
o                8     0.0  3.337-2    end
triangpitch       1.03124  .9398  1   2       end
May02-91/.370D pellet/TH.Density/15*3 Normal Array
140   150   400   5   1  15  15  15    0
cuboid    3   0.9525   -0.9525  10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid    4   1.58750 -1.58750 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid    5   1.60274 -1.60274 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid    6   1.64592 -1.64592 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid  500   2.58216 -2.58216 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid    6   2.62534 -2.62534 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid  500   3.56158 -3.56158 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid    6   3.60476 -3.60475 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid  500   4.54100 -4.54100 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid    6   4.58418 -4.58418 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid  500   5.52042 -5.52042 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid    6   5.56360 -5.56360 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid  500   6.49984 -6.49984 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid    6   6.54302 -6.54302 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid  500   7.47926 -7.47926  10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid    6   7.52244 -7.52244 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid  500   8.45868 -8.45868 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid    6   8.50186 -8.50186 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid  500   9.43810 -9.43810 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid    6   9.48128 -9.48128 10.8280   -10.8280   29.5275   -29.5275   -0.5
cuboid  500   10.41752 -10.41752 10.8280   -10.8280   29.5275   -29.5275 -0.5
cuboid    6   10.46070 -10.46070 10.8280   -10.8280   29.5275   -29.5275 -0.5
cuboid  500   11.39694 -11.39694 10.8280   -10.8280   29.5275   -29.5275 -0.5
cuboid    6   11.44012 -11.44012 10.8280   -10.8280   29.5275   -29.5275 -0.5
cuboid    5   11.45536 -11.45536 10.8432   -10.8432   29.5427   -29.5427 -0.5
cuboid    4   11.74746 -11.74746 11.1607   -11.1607   29.8602   -29.8602 -0.5
cuboid    3   13.65249 -12.65249 11.1607   -11.1607 29.8602   -29.8602   -0.5
cuboid    0   13.65250 -13.65249 13.6525   -13.6525 37.3701   -37.3701   -0.5
cuboid    7   13.84224 -13.84224 13.84224 -13.84224 37.5598   -37.5598 -0.5
cylinder  0   28.575    43.18    -43.18    -0.5
cylinder  7   28.69641 43.332    -43.30    -0.5
cuboid    0   28.69641 -28.69641 28.69641 -28.69641 45.237   -45.205  -0.5
core bdy  0   430.4462 -430.4462 430.4462 -430.4462 678.555 -678.075 -0.5
cuboid    8   460.9462 -460.9462 460.9462 -460.9462 709.055 -709.055 -0.5
end geom
end
```

15x15x15 Normal Array With .32" OD Pellets on Pellet Trays
(Original Scale3 Deck)

```
=csas2
May07-91/unc/.32 pellet/15x15xc15 normal arrary
123groupgmth      8   15  2   latticecell 0 0
o               1    0.0  3.177-2   end
u-235           1    0.0  1.262-3    end
u-238           1    0.0  2.3194-2   end
h2o             2      0.001         end
h               3    0.0  3.32986-2  end
c               3    0.0  2.243-2    end
o               3    0.0  1.273-2    end
h               4    0.0  1.27772-2  end
c               4    0.0  7.66632-3  end
o               4    0.0  6.3886-3   end
polyethylene    5      1.00          end
ss304           6    1.00            end
carbonsteel     7    1.00            end
h               8    0.0  6.674-2    end
o               8    0.0  3.337-2    end
triangpitch      1.03124  0.8128   1   2      end
May07-91/unc/.32 pellets/15x15x15 normal array
140   150   400   5   1  15  15  15    0
cuboid    3   0.9525   -0.9525  10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid    4   1.58750 -1.58750 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid    5   1.60274 -1.60274 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid    6   1.64592 -1.64592 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid  500   2.45872 -2.45872 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid    6   2.50194 -2.50194 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid  500   3.3147  -3.31470 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid    6   3.35788 -3.35788 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid  500   4.17068 -4.17068 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid    6   4.21386 -4.21386 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid  500   5.02666 -5.02666 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid    6   5.06984 -5.06984 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid  500   5.88264 -5.88264 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid    6   5.92582 -5.92582 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid  500   6.73862 -6.73862 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid    6   6.78180 -6.78180 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid  500   7.59460 -7.59460 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid    6   7.63778 -7.63778 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid  500   8.45058 -8.45058 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid    6   8.49376 -8.49376 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid  500   9.30656 -9.30656 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid    6   9.34974 -9.34974 10.8280  -10.8280  29.5275  -29.5275  -0.5
cuboid  500   10.1625  -10.1625 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid    6   10.2057  -10.2057 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid    0   11.44012 -11.44012 10.8280  -10.8280 29.5275  -29.5275 -0.5
cuboid    5   11.45536 -11.45536 10.8432  -10.8432 29.5427  -29.5427 -0.5
cuboid    4   11.74746 -11.74746 11.1607  -11.1607 29.8602  -29.8602 -0.5
cuboid    3   13.65249 -13.65249 11.1607  -11.1607 29.8602  -33.6702 -0.5
cuboid    0   13.65250 -13.65250 11.6525  -13.6525 37.3701  -37.3701 -0.5
cuboid    7   13.84224 -13.84224 13.84224 -13.84224 37.5598  -37.5598 -0.5
cylinder  0   28.575   43.18    -43.18   -0.5
cylinder  7   28.69641 43.332   -43.30   -0.5
cuboid    0   28.69641 -26.91341 26.91341 -26.91341 45.237   -45.205  -0.5
core bdy  0   430.4462 -430.4462 430.4462 -430.4462 678.555 -678.075 -0.5
cuboid    8   460.9462 -460.9462 460.9462 -460.9462 709.055 -709.055 -0.5
end geom
end
```

15x15x15 Normal Array With Scrap Pellets
(Original Scale3 Deck)

```
=csas2
05/07/91/unc scrap/15x15x15 normal array
123groupgmth    10   17   2   latticecell 0 0
o               1    0.0  4.89127-2  end
u-235           1    0.0  1.26241-3  end
u-238           1    0.0  2.31941-2  end
h2o             2      0.001         end
h               3    0.0  3.32986-2  end
c               3    0.0  2.243-2    end
o               3    0.0  1.273-2    end
h               4    0.0  1.27772-2  end
c               4    0.0  7.66632-3  end
o               4    0.0  6.3886-3   end
polyethlene     5      1.00          end
ss304           6    1.00            end
h2o             7    1.00            end
carbonsteel     8    1.00            end
h               9    0.0  6.674-2    end
o               9    0.0  3.337-2    end
al             10    1.00   end
triangpitch      1.6      0.9398   1   2      end
05/07/91/unc scrap/15x15x15 normal array
140   160   450   5   1   15   15   15   0
cuboid    6   0.635    -0.6350   11.16660  -11.16660   10.05535 -30.16605  -0.5
cuboid    4   0.9525   -0.9525   11.16660  -11.16660   10.05535 -30.16605  -0.5
cuboid    5   1.05715 -1.05715  11.16660  -11.16660   10.05535 -30.16605  -0.5
cuboid  500  11.00785 -11.00785 11.16660  -11.16660   10.05535 -30.16605  -0.5
cuboid    5  11.1125  -11.1125  11.27125  -11.27125  10.1600  -30.2707  -0.5
cuboid    4  11.4300  -11.4300  11.58875  -11.58875  10.4775  -30.5882  -0.5
cuboid   10  11.4300  -11.4300  11.58875  -11.58875  31.4325  -30.5882  -0.5
cuboid    3  13.6525  -13.6525  11.58875  -11.58875  31.4325  -30.5882  -0.5
cuboid    0  13.6525  -13.6525  11.6525   -13.6525   45.4025  -30.5882  -0.5
cuboid    8  13.84224 -13.84224 13.84224  -13.84224  45.5922  -30.7779  -0.5
cylinder  0  28.575    50.58715 -35.77285  -0.5
cylinder  8  28.69641 50.73904 -35.89426  -0.5
cuboid    0  28.69641 -28.69641 28.69641  -28.69641 52.64404 -37.79926  -0.5
core bdy  0  430.4462 -430.4462 430.4462  -430.4462 789.661  -566.9889  -0.5
cuboid    8  460.9462 -460.9462 460.9462  -460.9462 820.161  -597.489   -0.5
end geom
end
```

6x6x4 Accident Array With .37" OD Pellets on Pellet Trays (Original Scale3 Deck)

```
=csas2x
May2-91/.370D Pellet/TH.Density/6x6x4 Accident Array
123groupmth     8   15   2   latticecell
o               1    0.0  4.89127-2  end
u-235           1    0.0  1.26241-3  end
u-238           1    0.0  2.31941-2  end
h2o             2       1.00         end
h               3    0.0  3.32986-2  end
c               3    0.0  2.243-2    end
o               3    0.0  1.273-2    end
h               4    0.0  1.27772-2  end
c               4    0.0  7.66632-3  end
o               4    0.0  6.3886-3   end
poly(h2o)       5       1.00         end
ss304           6    0.001-9         end
carbonsteel     7    1.00            end
h               8    0.0  6.674-2    end
o               8    0.0  3.337-2    end
triangpitch      1.03124  0.9398  1   2      end
may2-91/0.370d pellet/th.density/6x6x4 accident array
140 150 400 5  1    6   6   4   0
cuboid    3  0.9525    -0.9525 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid    8  1.58750  -1.58750 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid    5  1.60274  -1.60274 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid    6  1.64592  -1.64592 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid  500  2.58216  -2.58216 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid    6  2.62534  -2.62534 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid  500  3.56158  -3.56158 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid    6  3.60476  -3.60476 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid  500  4.54100  -4.54100 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid    6  4.58418  -4.58418 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid  500  5.52042  -5.52042 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid    6  5.56360  -5.56360 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid  500  6.49984  -6.49984 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid    6  6.54302  -6.54302 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid  500  7.47926  -7.47926 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid    6  7.52244  -7.52244 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid  500  8.45868  -8.45868 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid    6  8.50186  -8.50186 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid  500  9.43810  -9.43810 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid    6  9.48128  -9.48128 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid  500  10.41752   -10.41752 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid    6  10.46070   -10.46070 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid  500  11.39694   -11.39694  10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid    6  11.44012   -11.44012 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid    5  11.45536   -11.45536 10.8432  -10.8432  29.5427  -29.5427 -0.5
cuboid    8  11.74746   -11.74746 11.1607  -11.1607 29.8602 -29.8602 -0.5
cuboid    3  13.65249   -13.65249 11.1607  -11.1607 29.8602 -29.8602 -0.5
cuboid    8  13.65250   -13.65250 13.6525  -13.6525 37.3701 -37.3701 -0.5
cuboid    7  13.84224   -13.84224 13.84224 -13.84224 37.5598 -37.5598 -0.5
cylinder  0  26.792     43.18     -43.18  -0.5
cylinder  7  26.91341   43.332    -43.30  -0.5
cuboid    0  26.91341 -26.91341 26.91341 -26.91341 45.237   -45.205   -0.5
core bdy  0  161.48046 -161.48046  161.48046  -141.48046  180.948  -180.82  -0.5
cuboid    8  191.961    -191.961    191.961   -191.961  211.45   -211.32  -0.5
end geom
end
```

6x6x4 Accident Array With .32" OD Pellets on Pellet Trays
(Original Scale3 Deck)

```
=csas2x
Apr17-91/unc/120kgs/rerun with triang pitch/matrl 500/large pitch/6x6x4
123groupmth    8   15   2   latticecell 0   0
o              1    0.0  4.891-2    end
u-235          1    0.0  1.262-3    end
u-238          1    0.0  2.3194-2   end
h2o            2        1.00        end
h              3    0.0  3.32986-2  end
c              3    0.0  2.243-2    end
o              3    0.0  1.273-2    end
h              4    0.0  1.27772-2  end
c              4    0.0  7.66632-3  end
o              4    0.0  6.3886-3   end
poly(h2o)      5        1.00        end
ss304          6    0.001-9         end
carbonsteel    7    1.00            end
h              8    0.0  6.674-2    end
o              8    0.0  3.337-2    end
triangpitch     1.03124   .8128   1   2      end
Apr17-91/unc2901/120kgs/with triang pitch/matrl 500/large pitch/6x6x4
140 150 400 5   1    6   6   4   0
cuboid    3  0.9525    -0.9525  10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid    8  1.58750   -1.58750 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid    5  1.60274   -1.60274 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid    6  1.64592   -1.64592 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid  500  2.45872   -2.45872 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid    6  2.50194   -2.50194 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid  500  3.3147    -3.31470 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid    6  3.35788   -3.35788 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid  500  4.17068   -4.17068 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid    6  4.21386   -4.21386 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid  500  5.02666   -5.02666 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid    6  5.06984   -5.06984 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid  500  5.88264   -5.88264 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid    6  5.92582   -5.92582 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid  500  6.73862   -6.73862 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid    6  6.78180   -6.78180 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid  500  7.54960   -7.54960 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid    6  7.63778   -7.63778 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid  500  8.45058   -8.45058 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid    6  8.49376   -8.49376 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid  500  9.30656   -9.30656 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid    6  9.34974   -9.34974 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid  500  10.1625   -10.1625 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid    6  10.2057   -10.2057 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid    0  11.44012   -11.44012 10.8280  -10.8280  29.5275  -29.5275 -0.5
cuboid    5  11.45536   -11.45536 10.8432  -10.8432  29.5427  -29.5427 -0.5
cuboid    8  11.74746   -11.74746 11.1607  -11.1607 29.8602 -29.8602 -0.5
cuboid    3  13.65249   -13.65249 11.1607  -11.1607 29.8602 -29.8602 -0.5
cuboid    8  13.65250   -13.65250 13.6525  -13.6525 37.3701 -37.3701 -0.5
cuboid    7  13.84224   -13.84224 13.84224 -13.84224 37.5598 -37.5598 -0.5
cylinder  0  26.792     43.18     -43.18   -0.5
cylinder  7  26.91341   43.332    -43.30   -0.5
cuboid    0  26.91341 -26.91341 26.91341 -26.91341  45.237   -45.205  -0.5
core bdy  0  161.4805 -161.4805  161.4805  -141.4805  180.948  -180.820  -0.5
cuboid    8  191.99    -191.99    191.99  -191.99  211.448  -211.320  -0.5
end geom
end
```

37x4 Hexagonal Accident Array With Scrap Pellets
(Revised Scale4.2 Deck)

```
=csas2x
27 gp .2 25 v% 0.28vf.365p tri dia poly w/bulge 5.05wt%
27groupndf4                 latticecell
uo2              1    0.976 305 92235 5.05 92238 94.95  end
h2o              2    den=1.0         end
h                3    0.0  3.32986-2  end
c                3    0.0  2.243-2    end
o                3    0.0  1.273-2    end
h                4    0.0  1.27772-2  end
c                4    0.0  7.66632-3  end
o                4    0.0  6.3886-3   end
poly(h2o)        5       1.00         end
ss304            6    1.00            end
carbonsteel      7    1.00            end
h2o              8    den=1.00        end
al               9       1.00         end
b-10            10    0.0  4.078319-3 end
b-11            10    0.0  2.202567-2 end
c               10    0.0  6.865857-3 end
al              10    0.0  4.526312-2 end
end comp
triangpitch     0.914249 0.50800  1   2      end
kenova 0.200 pellet tri pitch 5.05wt% 0.28 vf
read parm tme=4800 tba=3 gen=500 npg=1500 run=yes plt=no
end parm
read geom
unit  1
com=!5.05wt% 0.200 pellet!
cuboid    8 1  23.46960  0.0    26.19375  0.0     0.635     0.0
unit  2
cuboid    8 1   4.85140  0.0    26.19375  0.0     0.635     0.0
unit  3
cuboid  500 1  23.46960  0.0     1.20015  0.0     0.635     0.0
unit  4
cuboid  500 1   4.85140  0.0     1.20015  0.0     0.635     0.0
unit  5
cuboid   10 1  23.46960  0.0     0.92710  0.0     0.635     0.0
unit  6
cuboid  500 1   4.85140  0.0     0.92710  0.0     0.635     0.0
unit  7
cuboid    3 1  23.46960  0.0    26.19375  0.0     2.38125   0.0
unit  8
cuboid    3 1   4.85140  0.0    26.19375  0.0     2.38125   0.0
unit  9
cuboid  500 1  23.46960  0.0     1.20015  0.0     2.38125   0.0
unit  10
cuboid  500 1   4.85140  0.0     1.20015  0.0     2.38125   0.0
unit  11
cuboid   10 1  23.46960  0.0     0.92710  0.0     2.38125   0.0
unit  12
cuboid  500 1   4.85140  0.0     0.92710  0.0     2.38125   0.0
unit  13
cuboid    3 1  23.46960  0.0    26.19375  0.0     0.15240   0.0
unit  14
cuboid    3 1   4.85140  0.0    26.19375  0.0     0.15240   0.0
unit  15
cuboid  500 1  23.46960  0.0     1.20015  0.0     0.15240   0.0
```

```
unit  16
cuboid  500 1   4.85140  0.0      1.20015  0.0      0.15240  0.0
unit  17
cuboid   10 1  23.46960  0.0      0.92710  0.0      0.15240  0.0
unit  18
cuboid  500 1   4.85140  0.0      0.92710  0.0      0.15240  0.0
unit  19
cuboid    5 1  23.46960  0.0     26.19375  0.0      0.01524  0.0
unit  20
cuboid    5 1   4.85140  0.0     26.19375  0.0      0.01524  0.0
unit  21
cuboid  500 1  23.46960  0.0      1.20015  0.0      0.01524  0.0
unit  22
cuboid  500 1   4.85140  0.0      1.20015  0.0      0.01524  0.0
unit  23
cuboid   10 1  23.46960  0.0      0.92710  0.0      0.01524  0.0
unit  24
cuboid  500 1   4.85140  0.0      0.92710  0.0      0.01524  0.0
unit  25
cuboid    3 1   1.11125  0.0      1.74625  0.0     60.26531  0.0
unit  26
cuboid    3 1   0.15240  0.0      1.74625  0.0     60.26531  0.0
unit  27
cuboid    3 1   0.01524  0.0      1.74625  0.0     60.26531  0.0
unit  28
cuboid    3 1  22.35835  0.0      1.74625  0.0     60.26531  0.0
unit  29
cuboid    3 1   0.50165  0.0      1.74625  0.0     60.26531  0.0
unit  30
cuboid  500 1   1.79197  0.0      1.74625  0.0     60.26531  0.0
unit  31
cuboid  500 1   0.01524  0.0      1.74625  0.0     60.26531  0.0
unit  32
cuboid  500 1   0.15240  0.0      1.74625  0.0     60.26531  0.0
unit  33
cuboid    3 1   1.11125  0.0      1.74625  0.0     60.26531  0.0
unit  34
cuboid    3 1   1.11125  0.0      0.92710  0.0     60.26531  0.0
unit  35
cuboid    3 1   0.15240  0.0      0.92710  0.0     60.26531  0.0
unit  36
cuboid    5 1   0.01524  0.0      0.92710  0.0     60.26531  0.0
unit  37
cuboid   10 1  22.35835  0.0      0.92710  0.0     60.26531  0.0
unit  38
cuboid  500 1   0.50165  0.0      0.92710  0.0     60.26531  0.0
unit  39
cuboid  500 1   1.79197  0.0      0.92710  0.0     60.26531  0.0
unit  40
cuboid    5 1   0.01524  0.0      0.92710  0.0     60.26531  0.0
unit  41
cuboid    3 1   0.15240  0.0      0.92710  0.0     60.26531  0.0
unit  42
cuboid    3 1   1.11125  0.0      0.92710  0.0     60.26531  0.0
unit  43
cuboid    3 1   1.11125  0.0      0.22860  0.0     60.26531  0.0
unit  44
cuboid    3 1   0.15240  0.0      0.22860  0.0     60.26531  0.0
unit  45
cuboid    3 1   0.01524  0.0      0.22860  0.0     60.26531  0.0
unit  46
cuboid    3 1  22.35835  0.0      0.22860  0.0     60.26531  0.0
```

```
unit  47
cuboid  500 1    0.50165  0.0       0.22860  0.0       60.26531    0.0
unit  48
cuboid  500 1    1.79197  0.0       0.22860  0.0       60.26531    0.0
unit  49
cuboid    5 1    0.01524  0.0       0.22860  0.0       60.26531    0.0
unit  50
cuboid    3 1    0.15240  0.0       0.22860  0.0       60.26531    0.0
unit  51
cuboid    3 1    1.11125  0.0       0.22860  0.0       60.26531    0.0
unit  52
cuboid    3 1    1.11125  0.0       0.01524  0.0       60.26531    0.0
unit  53
cuboid    3 1    0.15240  0.0       0.01524  0.0       60.26531    0.0
unit  54
cuboid    5 1    0.01524  0.0       0.01524  0.0       60.26531    0.0
unit  55
cuboid    5 1   22.35835  0.0       0.01524  0.0       60.26531    0.0
unit  56
cuboid  500 1    0.50165  0.0       0.01524  0.0       60.26531    0.0
unit  57
cuboid  500 1    1.79197  0.0       0.01524  0.0       60.26531    0.0
unit  58
cuboid    5 1    0.01524  0.0       0.01524  0.0       60.26531    0.0
unit  59
cuboid    3 1    0.15240  0.0       0.01524  0.0       60.26531    0.0
unit  60
cuboid    3 1    1.11125  0.0       0.01524  0.0       60.26531    0.0
unit  61
cuboid    3 1    1.11125  0.0       5.2308633   0.0      60.26531    0.0
unit  62
cuboid    3 1    0.15240  0.0       5.2308633   0.0      60.26531    0.0
unit  63
cuboid    5 1    0.01524  0.0       5.2308633   0.0      60.26531    0.0
unit  64
cuboid  500 1   22.35835  0.0       5.2308633   0.0      60.26531    0.0
unit  65
cuboid  500 1    0.50165  0.0       5.2308633   0.0      60.26531    0.0
unit  66
cuboid  500 1    1.79197  0.0       5.2308633   0.0      60.26531    0.0
unit  67
cuboid    5 1    0.01524  0.0       5.2308633   0.0      60.26531    0.0
unit  68
cuboid    3 1    0.15240  0.0       5.2308633   0.0      60.26531    0.0
unit  69
cuboid    3 1    1.11125  0.0       5.2308633   0.0      60.26531    0.0
unit  70
cuboid    3 1    1.11125  0.0       0.4691634   0.0      60.26531    0.0
unit  71
cuboid    3 1    0.15240  0.0       0.4691634   0.0      60.26531    0.0
unit  72
cuboid    5 1    0.01524  0.0       0.4691634   0.0      60.26531    0.0
unit  73
cuboid    5 1   22.35835  0.0       0.4691634   0.0      60.26531    0.0
unit  74
cuboid  500 1    0.50165  0.0       0.4691634   0.0      60.26531    0.0
unit  75
cuboid  500 1    1.79197  0.0       0.4691634   0.0      60.26531    0.0
unit  76
cuboid    5 1    0.01524  0.0       0.4691634   0.0      60.26531    0.0
unit  77
cuboid    3 1    0.15240  0.0       0.4691634   0.0      60.26531    0.0
```

```
unit  78
cuboid    3 1   1.11125  0.0     0.4691634  0.0    60.26531   0.0
unit  79
cuboid    3 1   1.11125  0.0     5.2308633  0.0    60.26531   0.0
unit  80
cuboid    3 1   0.15240  0.0     5.2308633  0.0    60.26531   0.0
unit  81
cuboid    5 1   0.01524  0.0     5.2308633  0.0    60.26531   0.0
unit  82
cuboid  500 1  22.35835  0.0     5.2308633  0.0    60.26531   0.0
unit  83
cuboid  500 1   0.50165  0.0     5.2308633  0.0    60.26531   0.0
unit  84
cuboid  500 1   1.79197  0.0     5.2308633  0.0    60.26531   0.0
unit  85
cuboid    5 1   0.01524  0.0     5.2308633  0.0    60.26531   0.0
unit  86
cuboid    3 1   0.15240  0.0     5.2308633  0.0    60.26531   0.0
unit  87
cuboid    3 1   1.11125  0.0     5.2308633  0.0    60.26531   0.0
unit  88
cuboid    3 1   1.11125  0.0     0.01524  0.0     60.26531   0.0
unit  89
cuboid    3 1   0.15240  0.0     0.01524  0.0     60.26531   0.0
unit  90
cuboid    5 1   0.01524  0.0     0.01524  0.0     60.26531   0.0
unit  91
cuboid    5 1  22.35835  0.0     0.01524  0.0     60.26531   0.0
unit  92
cuboid  500 1   0.50165  0.0     0.01524  0.0     60.26531   0.0
unit  93
cuboid  500 1   1.79197  0.0     0.01524  0.0     60.26531   0.0
unit  94
cuboid    5 1   0.01524  0.0     0.01524  0.0     60.26531   0.0
unit  95
cuboid    3 1   0.15240  0.0     0.01524  0.0     60.26531   0.0
unit  96
cuboid    3 1   1.11125  0.0     0.01524  0.0     60.26531   0.0
unit  97
cuboid    3 1   1.11125  0.0     0.22860  0.0     60.26531   0.0
unit  98
cuboid    3 1   0.15240  0.0     0.22860  0.0     60.26531   0.0
unit  99
cuboid    3 1   0.01524  0.0     0.22860  0.0     60.26531   0.0
unit  100
cuboid    3 1  22.35835  0.0     0.22860  0.0     60.26531   0.0
unit  101
cuboid  500 1   0.50165  0.0     0.22860  0.0     60.26531   0.0
unit  102
cuboid  500 1   1.79197  0.0     0.22860  0.0     60.26531   0.0
unit  103
cuboid    5 1   0.01524  0.0     0.22860  0.0     60.26531   0.0
unit  104
cuboid    3 1   0.15240  0.0     0.22860  0.0     60.26531   0.0
unit  105
cuboid    3 1   1.11125  0.0     0.22860  0.0     60.26531   0.0
unit  106
cuboid    3 1   1.11125  0.0     0.92710  0.0     60.26531   0.0
unit  107
cuboid    3 1   0.15240  0.0     0.92710  0.0     60.26531   0.0
unit  108
cuboid    5 1   0.01524  0.0     0.92710  0.0     60.26531   0.0
```

```
unit 109
cuboid   10 1  22.35835  0.0     0.92710  0.0     60.26531  0.0
unit 110
cuboid  500 1   0.50165  0.0     0.92710  0.0     60.26531  0.0
unit 111
cuboid  500 1   1.79197  0.0     0.92710  0.0     60.26531  0.0
unit 112
cuboid    5 1   0.01524  0.0     0.92710  0.0     60.26531  0.0
unit 113
cuboid    3 1   0.15240  0.0     0.92710  0.0     60.26531  0.0
unit 114
cuboid    3 1   1.11125  0.0     0.92710  0.0     60.26531  0.0
unit 115
cuboid    3 1   1.11125  0.0     0.22860  0.0     60.26531  0.0
unit 116
cuboid    3 1   0.15240  0.0     0.22860  0.0     60.26531  0.0
unit 117
cuboid    3 1   0.01524  0.0     0.22860  0.0     60.26531  0.0
unit 118
cuboid    3 1  22.35835  0.0     0.22860  0.0     60.26531  0.0
unit 119
cuboid  500 1   0.50165  0.0     0.22860  0.0     60.26531  0.0
unit 120
cuboid  500 1   1.79197  0.0     0.22860  0.0     60.26531  0.0
unit 121
cuboid    5 1   0.01524  0.0     0.22860  0.0     60.26531  0.0
unit 122
cuboid    3 1   0.15240  0.0     0.22860  0.0     60.26531  0.0
unit 123
cuboid    3 1   1.11125  0.0     0.22860  0.0     60.26531  0.0
unit 124
cuboid    3 1   1.11125  0.0     0.01524  0.0     60.26531  0.0
unit 125
cuboid    3 1   0.15240  0.0     0.01524  0.0     60.26531  0.0
unit 126
cuboid    5 1   0.01524  0.0     0.01524  0.0     60.26531  0.0
unit 127
cuboid    5 1  22.35835  0.0     0.01524  0.0     60.26531  0.0
unit 128
cuboid  500 1   0.50165  0.0     0.01524  0.0     60.26531  0.0
unit 129
cuboid  500 1   1.79197  0.0     0.01524  0.0     60.26531  0.0
unit 130
cuboid    5 1   0.01524  0.0     0.01524  0.0     60.26531  0.0
unit 131
cuboid    3 1   0.15240  0.0     0.01524  0.0     60.26531  0.0
unit 132
cuboid    3 1   1.11125  0.0     0.01524  0.0     60.26531  0.0
unit 133
cuboid    3 1   1.11125  0.0     5.2308633  0.0     60.26531  0.0
unit 134
cuboid    3 1   0.15240  0.0     5.2308633  0.0     60.26531  0.0
unit 135
cuboid    5 1   0.01524  0.0     5.2308633  0.0     60.26531  0.0
unit 136
cuboid  500 1  22.35835  0.0     5.2308633  0.0     60.26531  0.0
unit 137
cuboid  500 1   0.50165  0.0     5.2308633  0.0     60.26531  0.0
unit 138
cuboid  500 1   1.79197  0.0     5.2308633  0.0     60.26531  0.0
unit 139
cuboid    5 1   0.01524  0.0     5.2308633  0.0     60.26531  0.0
```

```
unit  140
cuboid     3 1   0.15240  0.0      5.2308633  0.0     60.26531    0.0
unit  141
cuboid     3 1   1.11125  0.0      5.2308633  0.0     60.26531    0.0
unit  142
cuboid     3 1   1.11125  0.0      0.4691634  0.0     60.26531    0.0
unit  143
cuboid     3 1   0.15240  0.0      0.4691634  0.0     60.26531    0.0
unit  144
cuboid     5 1   0.01524  0.0      0.4691634  0.0     60.26531    0.0
unit  145
cuboid     5 1  22.35835  0.0      0.4691634  0.0     60.26531    0.0
unit  146
cuboid   500 1   0.50165  0.0      0.4691634  0.0     60.26531    0.0
unit  147
cuboid   500 1   1.79197  0.0      0.4691634  0.0     60.26531    0.0
unit  148
cuboid     5 1   0.01524  0.0      0.4691634  0.0     60.26531    0.0
unit  149
cuboid     3 1   0.15240  0.0      0.4691634  0.0     60.26531    0.0
unit  150
cuboid     3 1   1.11125  0.0      0.4691634  0.0     60.26531    0.0
unit  151
cuboid     3 1   1.11125  0.0      5.2308633  0.0     60.26531    0.0
unit  152
cuboid     3 1   0.15240  0.0      5.2308633  0.0     60.26531    0.0
unit  153
cuboid     5 1   0.01524  0.0      5.2308633  0.0     60.26531    0.0
unit  154
cuboid   500 1  22.35835  0.0      5.2308633  0.0     60.26531    0.0
unit  155
cuboid   500 1   0.50165  0.0      5.2308633  0.0     60.26531    0.0
unit  156
cuboid   500 1   1.79197  0.0      5.2308633  0.0     60.26531    0.0
unit  157
cuboid     5 1   0.01524  0.0      5.2308633  0.0     60.26531    0.0
unit  158
cuboid     3 1   0.15240  0.0      5.2308633  0.0     60.26531    0.0
unit  159
cuboid     3 1   1.11125  0.0      5.2308633  0.0     60.26531    0.0
unit  160
cuboid   500 1   1.11125  0.0      0.95631  0.0     60.26531    0.0
unit  161
cuboid   500 1   0.15240  0.0      0.95631  0.0     60.26531    0.0
unit  162
cuboid   500 1   0.01524  0.0      0.95631  0.0     60.26531    0.0
unit  163
cuboid   500 1  22.35835  0.0      0.95631  0.0     60.26531    0.0
unit  164
cuboid   500 1   0.50165  0.0      0.95631  0.0     60.26531    0.0
unit  165
cuboid   500 1   1.79197  0.0      0.95631  0.0     60.26531    0.0
unit  166
cuboid   500 1   0.01524  0.0      0.95631  0.0     60.26531    0.0
unit  167
cuboid   500 1   0.15240  0.0      0.95631  0.0     60.26531    0.0
unit  168
cuboid   500 1   1.11125  0.0      0.95631  0.0     60.26531    0.0
unit  169
cuboid     5 1   1.11125  0.0      0.01524  0.0     60.26531    0.0
unit  170
cuboid     5 1   0.15240  0.0      0.01524  0.0     60.26531    0.0
```

```
unit  171
cuboid     5 1   0.01524  0.0      0.01524  0.0      60.26531   0.0
unit  172
cuboid     5 1  22.35835  0.0      0.01524  0.0      60.26531   0.0
unit  173
cuboid   500 1   0.50165  0.0      0.01524. 0.0      60.26531   0.0
unit  174
cuboid   500 1   1.79197  0.0      0.01524  0.0      60.26531   0.0
unit  175
cuboid   500 1   0.01524  0.0      0.01524  0.0      60.26531   0.0
unit  176
cuboid   500 1   0.15240  0.0      0.01524  0.0      60.26531   0.0
unit  177
cuboid   500 1   1.11125  0.0      0.01524  0.0      60.26531   0.0
unit  178
cuboid     3 1   1.11125  0.0      0.22860  0.0      60.26531   0.0
unit  179
cuboid     3 1   0.15240  0.0      0.22860  0.0      60.26531   0.0
unit  180
cuboid     3 1   0.01524  0.0      0.22860  0.0      60.26531   0.0
unit  181
cuboid     3 1  22.35835  0.0      0.22860  0.0      60.26531   0.0
unit  182
cuboid   500 1   0.50165  0.0      0.22860  0.0      60.26531   0.0
unit  183
cuboid   500 1   1.79197  0.0      0.22860  0.0      60.26531   0.0
unit  184
cuboid   500 1   0.01524  0.0      0.22860  0.0      60.26531   0.0
unit  185
cuboid   500 1   0.15240  0.0      0.22860  0.0      60.26531   0.0
unit  186
cuboid   500 1   1.11125  0.0      0.22860  0.0      60.26531   0.0
unit  187
cuboid    10 1   1.11125  0.0      0.92710  0.0      60.26531   0.0
unit  188
cuboid    10 1   0.15240  0.0      0.92710  0.0      60.26531   0.0
unit  189
cuboid    10 1   0.01524  0.0      0.92710  0.0      60.26531   0.0
unit  190
cuboid    10 1  22.35835  0.0      0.92710  0.0      60.26531   0.0
unit  191
cuboid   500 1   0.50165  0.0      0.92710  0.0      60.26531   0.0
unit  192
cuboid   500 1   1.79197  0.0      0.92710  0.0      60.26531   0.0
unit  193
cuboid   500 1   0.01524  0.0      0.92710  0.0      60.26531   0.0
unit  194
cuboid   500 1   0.15240  0.0      0.92710  0.0      60.26531   0.0
unit  195
cuboid   500 1   1.11125  0.0      0.92710  0.0      60.26531   0.0
unit  196
cuboid     3 1   1.11125  0.0      1.74625  0.0      60.26531   0.0
unit  197
cuboid    10 1   1.11125  0.0      0.92710  0.0      60.26531   0.0
unit  198
cuboid     3 1   1.11125  0.0      0.22860  0.0      60.26531   0.0
unit  199
cuboid     5 1   1.11125  0.0      0.01524  0.0      60.26531   0.0
unit  200
cuboid   500 1   1.11125  0.0      5.2308633  0.0     60.26531   0.0
unit  201
cuboid     5 1   1.11125  0.0      0.4691634  0.0     60.26531   0.0
```

```
unit  202
cuboid  500 1   1.11125  0.0     5.2308633  0.0     60.26531   0.0
unit  203
cuboid    5 1   1.11125  0.0     0.01524  0.0     60.26531   0.0
unit  204
cuboid    3 1   1.11125  0.0     0.22860  0.0     60.26531   0.0
unit  205
cuboid   10 1   1.11125  0.0     0.92710  0.0     60.26531   0.0
unit  206
cuboid    3 1   1.11125  0.0     0.22860  0.0     60.26531   0.0
unit  207
cuboid    5 1   1.11125  0.0     0.01524  0.0     60.26531   0.0
unit  208
cuboid  500 1   1.11125  0.0     5.2308633  0.0     60.26531   0.0
unit  209
cuboid    5 1   1.11125  0.0     0.4691634  0.0     60.26531   0.0
unit  210
cuboid  500 1   1.11125  0.0     5.2308633  0.0     60.26531   0.0
unit  211
cuboid  500 1   1.11125  0.0     0.95631    0.0     60.26531   0.0
unit  212
cuboid  500 1   1.11125  0.0     0.01524  0.0     60.26531   0.0
unit  213
cuboid  500 1   1.11125  0.0     0.22860  0.0     60.26531   0.0
unit  214
cuboid  500 1   1.11125  0.0     0.92710  0.0     60.26531   0.0
unit  215
cuboid    3 1   1.11125  0.0     1.74625  0.0     3.18389   0.0
unit  216
cuboid    3 1   0.15240  0.0     1.74625  0.0     3.18389   0.0
unit  217
cuboid    3 1   0.01524  0.0     1.74625  0.0     3.18389   0.0
unit  218
cuboid    3 1  22.35835  0.0     1.74625  0.0     3.18389   0.0
unit  219
cuboid    3 1   0.50165  0.0     1.74625  0.0     3.18389   0.0
unit  220
cuboid  500 1   1.79197  0.0     1.74625  0.0     3.18389   0.0
unit  221
cuboid  500 1   0.01524  0.0     1.74625  0.0     3.18389   0.0
unit  222
cuboid  500 1   0.15240  0.0     1.74625  0.0     3.18389   0.0
unit  223
cuboid    3 1   1.11125  0.0     1.74625  0.0     3.18389   0.0
unit  224
cuboid    3 1   1.11125  0.0     0.92710  0.0     3.18389   0.0
unit  225
cuboid    3 1   0.15240  0.0     0.92710  0.0     3.18389   0.0
unit  226
cuboid    5 1   0.01524  0.0     0.92710  0.0     3.18389   0.0
unit  227
cuboid   10 1  22.35835  0.0     0.92710  0.0     3.18389   0.0
unit  228
cuboid  500 1   0.50165  0.0     0.92710  0.0     3.18389   0.0
unit  229
cuboid  500 1   1.79197  0.0     0.92710  0.0     3.18389   0.0
unit  230
cuboid    5 1   0.01524  0.0     0.92710  0.0     3.18389   0.0
unit  231
cuboid    3 1   0.15240  0.0     0.92710  0.0     3.18389   0.0
unit  232
cuboid    3 1   1.11125  0.0     0.92710  0.0     3.18389   0.0
```

```
unit  233
cuboid    3 1    1.11125  0.0       0.22860  0.0       3.18389   0.0
unit  234
cuboid    3 1    0.15240  0.0       0.22860  0.0       3.18389   0.0
unit  235
cuboid    3 1    0.01524  0.0       0.22860  0.0       3.18389   0.0
unit  236
cuboid    3 1   22.35835  0.0       0.22860  0.0       3.18389   0.0
unit  237
cuboid  500 1    0.50165  0.0       0.22860  0.0       3.18389   0.0
unit  238
cuboid  500 1    1.79197  0.0       0.22860  0.0       3.18389   0.0
unit  239
cuboid    5 1    0.01524  0.0       0.22860  0.0       3.18389   0.0
unit  240
cuboid    3 1    0.15240  0.0       0.22860  0.0       3.18389   0.0
unit  241
cuboid    3 1    1.11125  0.0       0.22860  0.0       3.18389   0.0
unit  242
cuboid    3 1    1.11125  0.0       0.01524  0.0       3.18389   0.0
unit  243
cuboid    3 1    0.15240  0.0       0.01524  0.0       3.18389   0.0
unit  244
cuboid    5 1    0.01524  0.0       0.01524  0.0       3.18389   0.0
unit  245
cuboid    5 1   22.35835  0.0       0.01524  0.0       3.18389   0.0
unit  246
cuboid  500 1    0.50165  0.0       0.01524  0.0       3.18389   0.0
unit  247
cuboid  500 1    1.79197  0.0       0.01524  0.0       3.18389   0.0
unit  248
cuboid    5 1    0.01524  0.0       0.01524  0.0       3.18389   0.0
unit  249
cuboid    3 1    0.15240  0.0       0.01524  0.0       3.18389   0.0
unit  250
cuboid    3 1    1.11125  0.0       0.01524  0.0       3.18389   0.0
unit  251
cuboid    3 1    1.11125  0.0       5.2308633  0.0       3.18389   0.0
unit  252
cuboid    3 1    0.15240  0.0       5.2308633  0.0       3.18389   0.0
unit  253
cuboid    5 1    0.01524  0.0       5.2308633  0.0       3.18389   0.0
unit  254
cuboid  500 1   22.35835  0.0       5.2308633  0.0       3.18389   0.0
unit  255
cuboid  500 1    0.50165  0.0       5.2308633  0.0       3.18389   0.0
unit  256
cuboid  500 1    1.79197  0.0       5.2308633  0.0       3.18389   0.0
unit  257
cuboid    5 1    0.01524  0.0       5.2308633  0.0       3.18389   0.0
unit  258
cuboid    3 1    0.15240  0.0       5.2308633  0.0       3.18389   0.0
unit  259
cuboid    3 1    1.11125  0.0       5.2308633  0.0       3.18389   0.0
unit  260
cuboid    3 1    1.11125  0.0       0.4691634  0.0       3.18389   0.0
unit  261
cuboid    3 1    0.15240  0.0       0.4691634  0.0       3.18389   0.0
unit  262
cuboid    5 1    0.01524  0.0       0.4691634  0.0       3.18389   0.0
unit  263
cuboid    5 1   22.35835  0.0       0.4691634  0.0       3.18389   0.0
```

```
unit  264
cuboid  500 1    0.50165  0.0      0.4691634  0.0      3.18389   0.0
unit  265
cuboid  500 1    1.79197  0.0      0.4691634  0.0      3.18389   0.0
unit  266
cuboid    5 1    0.01524  0.0      0.4691634  0.0      3.18389   0.0
unit  267
cuboid    3 1    0.15240  0.0      0.4691634  0.0      3.18389   0.0
unit  268
cuboid    3 1    1.11125  0.0      0.4691634  0.0      3.18389   0.0
unit  269
cuboid    3 1    1.11125  0.0      5.2308633  0.0      3.18389   0.0
unit  270
cuboid    3 1    0.15240  0.0      5.2308633  0.0      3.18389   0.0
unit  271
cuboid    5 1    0.01524  0.0      5.2308633  0.0      3.18389   0.0
unit  272
cuboid  500 1   22.35835  0.0      5.2308633  0.0      3.18389   0.0
unit  273
cuboid  500 1    0.50165  0.0      5.2308633  0.0      3.18389   0.0
unit  274
cuboid  500 1    1.79197  0.0      5.2308633  0.0      3.18389   0.0
unit  275
cuboid    5 1    0.01524  0.0      5.2308633  0.0      3.18389   0.0
unit  276
cuboid    3 1    0.15240  0.0      5.2308633  0.0      3.18389   0.0
unit  277
cuboid    3 1    1.11125  0.0      5.2308633  0.0      3.18389   0.0
unit  278
cuboid    3 1    1.11125  0.0      0.01524  0.0      3.18389   0.0
unit  279
cuboid    3 1    0.15240  0.0      0.01524  0.0      3.18389   0.0
unit  280
cuboid    5 1    0.01524  0.0      0.01524  0.0      3.18389   0.0
unit  281
cuboid    5 1   22.35835  0.0      0.01524  0.0      3.18389   0.0
unit  282
cuboid  500 1    0.50165  0.0      0.01524  0.0      3.18389   0.0
unit  283
cuboid  500 1    1.79197  0.0      0.01524  0.0      3.18389   0.0
unit  284
cuboid    5 1    0.01524  0.0      0.01524  0.0      3.18389   0.0
unit  285
cuboid    3 1    0.15240  0.0      0.01524  0.0      3.18389   0.0
unit  286
cuboid    3 1    1.11125  0.0      0.01524  0.0      3.18389   0.0
unit  287
cuboid    3 1    1.11125  0.0      0.22860  0.0      3.18389   0.0
unit  288
cuboid    3 1    0.15240  0.0      0.22860  0.0      3.18389   0.0
unit  289
cuboid    3 1    0.01524  0.0      0.22860  0.0      3.18389   0.0
unit  290
cuboid    3 1   22.35835  0.0      0.22860  0.0      3.18389   0.0
unit  291
cuboid  500 1    0.50165  0.0      0.22860  0.0      3.18389   0.0
unit  292
cuboid  500 1    1.79197  0.0      0.22860  0.0      3.18389   0.0
unit  293
cuboid    5 1    0.01524  0.0      0.22860  0.0      3.18389   0.0
unit  294
cuboid    3 1    0.15240  0.0      0.22860  0.0      3.18389   0.0
```

```
unit  295
cuboid     3 1   1.11125  0.0      0.22860  0.0      3.18389   0.0
unit  296
cuboid     3 1   1.11125  0.0      0.92710  0.0      3.18389   0.0
unit  297
cuboid     3 1   0.15240  0.0      0.92710  0.0      3.18389   0.0
unit  298
cuboid     5 1   0.01524  0.0      0.92710  0.0      3.18389   0.0
unit  299
cuboid    10 1  22.35835  0.0      0.92710  0.0      3.18389   0.0
unit  300
cuboid   500 1   0.50165  0.0      0.92710  0.0      3.18389   0.0
unit  301
cuboid   500 1   1.79197  0.0      0.92710  0.0      3.18389   0.0
unit  302
cuboid     5 1   0.01524  0.0      0.92710  0.0      3.18389   0.0
unit  303
cuboid     3 1   0.15240  0.0      0.92710  0.0      3.18389   0.0
unit  304
cuboid     3 1   1.11125  0.0      0.92710  0.0      3.18389   0.0
unit  305
cuboid     3 1   1.11125  0.0      0.22860  0.0      3.18389   0.0
unit  306
cuboid     3 1   0.15240  0.0      0.22860  0.0      3.18389   0.0
unit  307
cuboid     3 1   0.01524  0.0      0.22860  0.0      3.18389   0.0
unit  308
cuboid     3 1  22.35835  0.0      0.22860  0.0      3.18389   0.0
unit  309
cuboid   500 1   0.50165  0.0      0.22860  0.0      3.18389   0.0
unit  310
cuboid   500 1   1.79197  0.0      0.22860  0.0      3.18389   0.0
unit  311
cuboid     5 1   0.01524  0.0      0.22860  0.0      3.18389   0.0
unit  312
cuboid     3 1   0.15240  0.0      0.22860  0.0      3.18389   0.0
unit  313
cuboid     3 1   1.11125  0.0      0.22860  0.0      3.18389   0.0
unit  314
cuboid     3 1   1.11125  0.0      0.01524  0.0      3.18389   0.0
unit  315
cuboid     3 1   0.15240  0.0      0.01524  0.0      3.18389   0.0
unit  316
cuboid     5 1   0.01524  0.0      0.01524  0.0      3.18389   0.0
unit  317
cuboid     5 1  22.35835  0.0      0.01524  0.0      3.18389   0.0
unit  318
cuboid   500 1   0.50165  0.0      0.01524  0.0      3.18389   0.0
unit  319
cuboid   500 1   1.79197  0.0      0.01524  0.0      3.18389   0.0
unit  320
cuboid     5 1   0.01524  0.0      0.01524  0.0      3.18389   0.0
unit  321
cuboid     3 1   0.15240  0.0      0.01524  0.0      3.18389   0.0
unit  322
cuboid     3 1   1.11125  0.0      0.01524  0.0      3.18389   0.0
unit  323
cuboid     3 1   1.11125  0.0      5.2308633  0.0      3.18389   0.0
unit  324
cuboid     3 1   0.15240  0.0      5.2308633  0.0      3.18389   0.0
unit  325
cuboid     5 1   0.01524  0.0      5.2308633  0.0      3.18389   0.0
```

```
unit  326
cuboid  500 1  22.35835  0.0      5.2308633  0.0     3.18389   0.0
unit  327
cuboid  500 1   0.50165  0.0      5.2308633  0.0     3.18389   0.0
unit  328
cuboid  500 1   1.79197  0.0      5.2308633  0.0     3.18389   0.0
unit  329
cuboid    5 1   0.01524  0.0      5.2308633  0.0     3.18389   0.0
unit  330
cuboid    3 1   0.15240  0.0      5.2308633  0.0     3.18389   0.0
unit  331
cuboid    3 1   1.11125  0.0      5.2308633  0.0     3.18389   0.0
unit  332
cuboid    3 1   1.11125  0.0      0.4691634  0.0     3.18389   0.0
unit  333
cuboid    3 1   0.15240  0.0      0.4691634  0.0     3.18389   0.0
unit  334
cuboid    5 1   0.01524  0.0      0.4691634  0.0     3.18389   0.0
unit  335
cuboid    5 1  22.35835  0.0      0.4691634  0.0     3.18389   0.0
unit  336
cuboid  500 1   0.50165  0.0      0.4691634  0.0     3.18389   0.0
unit  337
cuboid  500 1   1.79197  0.0      0.4691634  0.0     3.18389   0.0
unit  338
cuboid    5 1   0.01524  0.0      0.4691634  0.0     3.18389   0.0
unit  339
cuboid    3 1   0.15240  0.0      0.4691634  0.0     3.18389   0.0
unit  340
cuboid    3 1   1.11125  0.0      0.4691634  0.0     3.18389   0.0
unit  341
cuboid    3 1   1.11125  0.0      5.2308633  0.0     3.18389   0.0
unit  342
cuboid    3 1   0.15240  0.0      5.2308633  0.0     3.18389   0.0
unit  343
cuboid    5 1   0.01524  0.0      5.2308633  0.0     3.18389   0.0
unit  344
cuboid  500 1  22.35835  0.0      5.2308633  0.0     3.18389   0.0
unit  345
cuboid  500 1   0.50165  0.0      5.2308633  0.0     3.18389   0.0
unit  346
cuboid  500 1   1.79197  0.0      5.2308633  0.0     3.18389   0.0
unit  347
cuboid    5 1   0.01524  0.0      5.2308633  0.0     3.18389   0.0
unit  348
cuboid    3 1   0.15240  0.0      5.2308633  0.0     3.18389   0.0
unit  349
cuboid    3 1   1.11125  0.0      5.2308633  0.0     3.18389   0.0
unit  350
cuboid  500 1   1.11125  0.0      0.95631  0.0     3.18389   0.0
unit  351
cuboid  500 1   0.15240  0.0      0.95631  0.0     3.18389   0.0
unit  352
cuboid  500 1   0.01524  0.0      0.95631  0.0     3.18389   0.0
unit  353
cuboid  500 1  22.35835  0.0      0.95631  0.0     3.18389   0.0
unit  354
cuboid  500 1   0.50165  0.0      0.95631  0.0     3.18389   0.0
unit  355
cuboid  500 1   1.79197  0.0      0.95631  0.0     3.18389   0.0
unit  356
cuboid  500 1   0.01524  0.0      0.95631  0.0     3.18389   0.0
```

```
unit  357
cuboid  500 1   0.15240  0.0     0.95631  0.0     3.18389   0.0
unit  358
cuboid  500 1   1.11125  0.0     0.95631  0.0     3.18389   0.0
unit  359
cuboid  500 1   1.11125  0.0     0.01524  0.0     3.18389   0.0
unit  360
cuboid  500 1   0.15240  0.0     0.01524  0.0     3.18389   0.0
unit  361
cuboid  500 1   0.01524  0.0     0.01524  0.0     3.18389   0.0
unit  362
cuboid  500 1  22.35835  0.0     0.01524  0.0     3.18389   0.0
unit  363
cuboid  500 1   0.50165  0.0     0.01524  0.0     3.18389   0.0
unit  364
cuboid  500 1   1.79197  0.0     0.01524  0.0     3.18389   0.0
unit  365
cuboid  500 1   0.01524  0.0     0.01524  0.0     3.18389   0.0
unit  366
cuboid  500 1   0.15240  0.0     0.01524  0.0     3.18389   0.0
unit  367
cuboid  500 1   1.11125  0.0     0.01524  0.0     3.18389   0.0
unit  368
cuboid  500 1   1.11125  0.0     0.22860  0.0     3.18389   0.0
unit  369
cuboid  500 1   0.15240  0.0     0.22860  0.0     3.18389   0.0
unit  370
cuboid  500 1   0.01524  0.0     0.22860  0.0     3.18389   0.0
unit  371
cuboid  500 1  22.35835  0.0     0.22860  0.0     3.18389   0.0
unit  372
cuboid  500 1   0.50165  0.0     0.22860  0.0     3.18389   0.0
unit  373
cuboid  500 1   1.79197  0.0     0.22860  0.0     3.18389   0.0
unit  374
cuboid  500 1   0.01524  0.0     0.22860  0.0     3.18389   0.0
unit  375
cuboid  500 1   0.15240  0.0     0.22860  0.0     3.18389   0.0
unit  376
cuboid  500 1   1.11125  0.0     0.22860  0.0     3.18389   0.0
unit  377
cuboid  500 1   1.11125  0.0     0.92710  0.0     3.18389   0.0
unit  378
cuboid  500 1   0.15240  0.0     0.92710  0.0     3.18389   0.0
unit  379
cuboid  500 1   0.01524  0.0     0.92710  0.0     3.18389   0.0
unit  380
cuboid  500 1  22.35835  0.0     0.92710  0.0     3.18389   0.0
unit  381
cuboid  500 1   0.50165  0.0     0.92710  0.0     3.18389   0.0
unit  382
cuboid  500 1   1.79197  0.0     0.92710  0.0     3.18389   0.0
unit  383
cuboid  500 1   0.01524  0.0     0.92710  0.0     3.18389   0.0
unit  384
cuboid  500 1   0.15240  0.0     0.92710  0.0     3.18389   0.0
unit  385
cuboid  500 1   1.11125  0.0     0.92710  0.0     3.18389   0.0
unit  386
cuboid    3 1   1.11125  0.0     1.74625  0.0     3.18389   0.0
unit  387
cuboid   10 1   1.11125  0.0     0.92710  0.0     3.18389   0.0
```

```
unit  388
cuboid     3 1    1.11125   0.0      0.22860  0.0      3.18389   0.0
unit  389
cuboid     5 1    1.11125   0.0      0.01524  0.0      3.18389   0.0
unit  390
cuboid   500 1    1.11125   0.0      5.2308633  0.0      3.18389   0.0
unit  391
cuboid     5 1    1.11125   0.0      0.4691634  0.0      3.18389   0.0
unit  392
cuboid   500 1    1.11125   0.0      5.2308633  0.0      3.18389   0.0
unit  393
cuboid     5 1    1.11125   0.0      0.01524  0.0      3.18389   0.0
unit  394
cuboid     3 1    1.11125   0.0      0.22860  0.0      3.18389   0.0
unit  395
cuboid    10 1    1.11125   0.0      0.92710  0.0      3.18389   0.0
unit  396
cuboid     3 1    1.11125   0.0      0.22860  0.0      3.18389   0.0
unit  397
cuboid     5 1    1.11125   0.0      0.01524  0.0      3.18389   0.0
unit  398
cuboid   500 1    1.11125   0.0      5.2308633  0.0      3.18389   0.0
unit  399
cuboid     5 1    1.11125   0.0      0.4691634  0.0      3.18389   0.0
unit  400
cuboid   500 1    1.11125   0.0      5.2308633  0.0      3.18389   0.0
unit  401
cuboid   500 1    1.11125   0.0      0.95631    0.0      3.18389   0.0
unit  402
cuboid   500 1    1.11125   0.0      0.01524  0.0      3.18389   0.0
unit  403
cuboid   500 1    1.11125   0.0      0.22860  0.0      3.18389   0.0
unit  404
cuboid   500 1    1.11125   0.0      0.92710  0.0      3.18389   0.0
unit  405
cuboid     3 1    1.11125   0.0      1.74625  0.0      0.03302   0.0
unit  406
cuboid     3 1    0.15240   0.0      1.74625  0.0      0.03302   0.0
unit  407
cuboid     3 1    0.01524   0.0      1.74625  0.0      0.03302   0.0
unit  408
cuboid     3 1   23.97125   0.0      1.74625  0.0      0.03302   0.0
unit  409
cuboid   500 1    1.79197   0.0      1.74625  0.0      0.03302   0.0
unit  410
cuboid     5 1    0.01524   0.0      1.74625  0.0      0.03302   0.0
unit  411
cuboid     3 1    0.15240   0.0      1.74625  0.0      0.03302   0.0
unit  412
cuboid     3 1    1.11125   0.0      1.74625  0.0      0.03302   0.0
unit  413
cuboid     3 1    1.11125   0.0      0.22860  0.0      0.03302   0.0
unit  414
cuboid     3 1    0.15240   0.0      0.22860  0.0      0.03302   0.0
unit  415
cuboid     3 1    0.01524   0.0      0.22860  0.0      0.03302   0.0
unit  416
cuboid     3 1   23.97125   0.0      0.22860  0.0      0.03302   0.0
unit  417
cuboid   500 1    1.79197   0.0      0.22860  0.0      0.03302   0.0
unit  418
cuboid     5 1    0.01524   0.0      0.22860  0.0      0.03302   0.0
```

```
unit  419
cuboid     3 1   0.15240  0.0    0.22860  0.0    0.03302  0.0
unit  420
cuboid     3 1   1.11125  0.0    0.22860  0.0    0.03302  0.0
unit  421
cuboid     3 1   1.11125  0.0    0.01524  0.0    0.03302  0.0
unit  422
cuboid     3 1   0.15240  0.0    0.01524  0.0    0.03302  0.0
unit  423
cuboid     5 1   0.01524  0.0    0.01524  0.0    0.03302  0.0
unit  424
cuboid     5 1  23.97125  0.0    0.01524  0.0    0.03302  0.0
unit  425
cuboid   500 1   1.79197  0.0    0.01524  0.0    0.03302  0.0
unit  426
cuboid     5 1   0.01524  0.0    0.01524  0.0    0.03302  0.0
unit  427
cuboid     3 1   0.15240  0.0    0.01524  0.0    0.03302  0.0
unit  428
cuboid     3 1   1.11125  0.0    0.01524  0.0    0.03302  0.0
unit  429
cuboid     3 1   1.11125  0.0   23.74646  0.0    0.03302  0.0
unit  430
cuboid     3 1   0.15240  0.0   23.74646  0.0    0.03302  0.0
unit  431
cuboid     5 1   0.01524  0.0   23.74646  0.0    0.03302  0.0
unit  432
cuboid     5 1  23.97125  0.0   23.74646  0.0    0.03302  0.0
unit  433
cuboid   500 1   1.79197  0.0   23.74646  0.0    0.03302  0.0
unit  434
cuboid     5 1   0.01524  0.0   23.74646  0.0    0.03302  0.0
unit  435
cuboid     3 1   0.15240  0.0   23.74646  0.0    0.03302  0.0
unit  436
cuboid     3 1   1.11125  0.0   23.74646  0.0    0.03302  0.0
unit  437
cuboid   500 1   1.11125  0.0    2.58445  0.0    0.03302  0.0
unit  438
cuboid   500 1   0.15240  0.0    2.58445  0.0    0.03302  0.0
unit  439
cuboid   500 1   0.01524  0.0    2.58445  0.0    0.03302  0.0
unit  440
cuboid   500 1  23.97125  0.0    2.58445  0.0    0.03302  0.0
unit  441
cuboid   500 1   1.79197  0.0    2.58445  0.0    0.03302  0.0
unit  442
cuboid   500 1   0.01524  0.0    2.58445  0.0    0.03302  0.0
unit  443
cuboid   500 1   0.15240  0.0    2.58445  0.0    0.03302  0.0
unit  444
cuboid   500 1   1.11125  0.0    2.58445  0.0    0.03302  0.0
unit  445
cuboid   500 1   1.11125  0.0    1.74625  0.0    1.58750  0.0
unit  446
cuboid   500 1  24.13889  0.0    1.74625  0.0    1.58750  0.0
unit  447
cuboid   500 1   1.95961  0.0    1.74625  0.0    1.58750  0.0
unit  448
cuboid   500 1   1.11125  0.0    1.74625  0.0    1.58750  0.0
unit  449
cuboid   500 1   1.11125  0.0   24.44750  0.0    1.58750  0.0
```

```
unit  450
cuboid  500 1  24.13889  0.0     24.44750  0.0     1.58750   0.0
unit  451
cuboid  500 1   1.95961  0.0     24.44750  0.0     1.58750   0.0
unit  452
cuboid  500 1   1.11125  0.0     24.44750  0.0     1.58750   0.0
unit  453
cuboid  500 1   1.11125  0.0     2.12725  0.0     1.58750   0.0
unit  454
cuboid  500 1  24.13889  0.0     2.12725  0.0     1.58750   0.0
unit  455
cuboid  500 1   1.95961  0.0     2.12725  0.0     1.58750   0.0
unit  456
cuboid  500 1   1.11125  0.0     2.12725  0.0     1.58750   0.0
unit  457
cuboid    3 1   1.11125  0.0     1.74625  0.0     0.01524   0.0
unit  458
cuboid    3 1  24.13889  0.0     1.74625  0.0     0.01524   0.0
unit  459
cuboid  500 1   1.95961  0.0     1.74625  0.0     0.01524   0.0
unit  460
cuboid    3 1   1.11125  0.0     1.74625  0.0     0.01524   0.0
unit  461
cuboid    3 1   1.11125  0.0     24.44750  0.0     0.01524   0.0
unit  462
cuboid    5 1  24.13889  0.0     24.44750  0.0     0.01524   0.0
unit  463
cuboid  500 1   1.95961  0.0     24.44750  0.0     0.01524   0.0
unit  464
cuboid    3 1   1.11125  0.0     24.44750  0.0     0.01524   0.0
unit  465
cuboid  500 1   1.11125  0.0     2.12725  0.0     0.01524   0.0
unit  466
cuboid  500 1  24.13889  0.0     2.12725  0.0     0.01524   0.0
unit  467
cuboid  500 1   1.95961  0.0     2.12725  0.0     0.01524   0.0
unit  468
cuboid  500 1   1.11125  0.0     2.12725  0.0     0.01524   0.0
unit  469
cuboid    3 1   1.11125  0.0     1.74625  0.0     0.15240   0.0
unit  470
cuboid    3 1  24.13889  0.0     1.74625  0.0     0.15240   0.0
unit  471
cuboid  500 1   1.95961  0.0     1.74625  0.0     0.15240   0.0
unit  472
cuboid    3 1   1.11125  0.0     1.74625  0.0     0.15240   0.0
unit  473
cuboid    3 1   1.11125  0.0     24.44750  0.0     0.15240   0.0
unit  474
cuboid    3 1  24.13889  0.0     24.44750  0.0     0.15240   0.0
unit  475
cuboid  500 1   1.95961  0.0     24.44750  0.0     0.15240   0.0
unit  476
cuboid    3 1   1.11125  0.0     24.44750  0.0     0.15240   0.0
unit  477
cuboid  500 1   1.11125  0.0     2.12725  0.0     0.15240   0.0
unit  478
cuboid  500 1  24.13889  0.0     2.12725  0.0     0.15240   0.0
unit  479
cuboid  500 1   1.95961  0.0     2.12725  0.0     0.15240   0.0
unit  480
cuboid  500 1   1.11125  0.0     2.12725  0.0     0.15240   0.0
```

```
unit  481
cuboid    3 1   1.11125  0.0      1.74625  0.0     1.74625   0.0
unit  482
cuboid    3 1  24.13889  0.0      1.74625  0.0     1.74625   0.0
unit  483
cuboid  500 1   1.95961  0.0      1.74625  0.0     1.74625   0.0
unit  484
cuboid    3 1   1.11125  0.0      1.74625  0.0     1.74625   0.0
unit  485
cuboid    3 1   1.11125  0.0      24.44750  0.0     1.74625   0.0
unit  486
cuboid    3 1  24.13889  0.0      24.44750  0.0     1.74625   0.0
unit  487
cuboid  500 1   1.95961  0.0      24.44750  0.0     1.74625   0.0
unit  488
cuboid    3 1   1.11125  0.0      24.44750  0.0     1.74625   0.0
unit  489
cuboid  500 1   1.11125  0.0      2.12725  0.0     1.74625   0.0
unit  490
cuboid  500 1  24.13889  0.0      2.12725  0.0     1.74625   0.0
unit  491
cuboid  500 1   1.95961  0.0      2.12725  0.0     1.74625   0.0
unit  492
cuboid  500 1   1.11125  0.0      2.12725  0.0     1.74625   0.0
unit  493
cuboid    3 1  28.32100  0.0     28.32100  0.0     1.74625   0.0
unit  494
cuboid    8 1  28.32100  0.0     28.32100  0.0     0.63500   0.0
unit  495
cuboid    3 1  28.32100  0.0     28.32100  0.0     2.38125   0.0
unit  496
array 1 3*0
unit  497
array 2 3*0
unit  498
array 3 3*0
unit  499
array 4 3*0
unit  500
array 5 3*0
unit  501
array 6 3*0
unit  502
array 7 3*0
unit  503
array 8 3*0
unit  504
array 9 3*0
unit  505
array 10 3*0
unit  506
array 11 3*0
unit  507
array 12 3*0
unit  508
array 13 3*0
unit  509
cuboid   0 1  14.1605  -14.1605   14.1605  -14.1605  37.465 -37.465
hole       508     -14.1605    -14.1605   -37.465
cuboid   7 1  14.35024 -14.35024  14.35024 -14.35024 38.735 -37.65474
cylinder     0    1     26.79200 41.40276   -39.24224
cylinder     3    1     26.79200 44.57776   -41.78224
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cylinder     7   1     26.91341 44.72965  -41.90365
unit  510
cylinder     0   1     188.39395  44.72965  -41.90365
hole        509   0.0             0.0                0.0
hole        509   0.0           -53.82684            0.0
hole        509   0.0          -107.65368            0.0
hole        509   0.0          -161.48052            0.0
hole        509   0.0            53.82684            0.0
hole        509   0.0           107.65368            0.0
hole        509   0.0           161.48052            0.0
hole        509   46.61541      -26.91342            0.0
hole        509   46.61541      -80.74026            0.0
hole        509   46.61541     -134.56710            0.0
hole        509   46.61541       26.91342            0.0
hole        509   46.61541       80.74026            0.0
hole        509   46.61541      134.56710            0.0
hole        509  -46.61541      -26.91342            0.0
hole        509  -46.61541      -80.74026            0.0
hole        509  -46.61541     -134.56710            0.0
hole        509  -46.61541       26.91342            0.0
hole        509  -46.61541       80.74026            0.0
hole        509  -46.61541      134.56710            0.0
hole        509   93.23082        0.0                0.0
hole        509   93.23082      -53.82684            0.0
hole        509   93.23082     -107.65368            0.0
hole        509   93.23082       53.82684            0.0
hole        509   93.23082      107.65368            0.0
hole        509  -93.23082        0.0                0.0
hole        509  -93.23082      -53.82684            0.0
hole        509  -93.23082     -107.65368            0.0
hole        509  -93.23082       53.82684            0.0
hole        509  -93.23082      107.65368            0.0
hole        509  139.84623      -26.91342            0.0
hole        509  139.84623      -80.74026            0.0
hole        509  139.84623       26.91342            0.0
hole        509  139.84623       80.74026            0.0
hole        509 -139.84623      -26.91342            0.0
hole        509 -139.84623      -80.74026            0.0
hole        509 -139.84623       26.91342            0.0
hole        509 -139.84623       80.74026            0.0
cylinder    8 1 218.87395    44.72965   -41.90365
cuboid      0 1 4p218.87396 44.72965   -41.90365
global
unit 511
array   14  3*0
replicate   8  1  4*0  2*30.48  1
end geom
read array
ara=1  nux=2   nuy=3  nuz=1  fill  1  2  3  4  5  6 end fill
ara=2  nux=2   nuy=3  nuz=1  fill  7  8  9 10 11 12 end fill
ara=3  nux=2   nuy=3  nuz=1  fill 13 14 15 16 17 18 end fill
ara=4  nux=2   nuy=3  nuz=1  fill 19 20 21 22 23 24 end fill
ara=5  nux=10  nuy=19 nuz=1  fill 25 26 27 28 196 29 30 31 32 33
34 35 36 37 197 38 39 40 41 42
43 44 45 46 198 47 48 49 50 51
52 53 54 55 199 56 57 58 59 60
61 62 63 64 200 65 66 67 68 69
70 71 72 73 201 74 75 76 77 78
79 80 81 82 202 83 84 85 86 87
88 89 90 91 203 92 93 94 95 96
97 98 99 100 204 101 102 103 104 105
106 107 108 109 205 110 111 112 113 114
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115 116 117 118 206 119 120 121 122 123
124 125 126 127 207 128 129 130 131 132
133 134 135 136 208 137 138 139 140 141
142 143 144 145 209 146 147 148 149 150
151 152 153 154 210 155 156 157 158 159
160 161 162 163 211 164 165 166 167 168
169 170 171 172 212 173 174 175 176 177
178 179 180 181 213 182 183 184 185 186
187 188 189 190 214 191 192 193 194 195 end fill
ara=6  nux=10  nuy=19 nuz=1  fill 215 216 217 218 386
219 220 221 222 223
224 225 226 227 387 228 229 230 231 232
233 234 235 236 388 237 238 239 240 241
242 243 244 245 389 246 247 248 249 250
251 252 253 254 390 255 256 257 258 259
260 261 262 263 391 264 265 266 267 268
269 270 271 272 392 273 274 275 276 277
278 279 280 281 393 282 283 284 285 286
287 288 289 290 394 291 292 293 294 295
296 297 298 299 395 300 301 302 303 304
305 306 307 308 396 309 310 311 312 313
314 315 316 317 397 318 319 320 321 322
323 324 325 326 398 327 328 329 330 331
332 333 334 335 399 336 337 338 339 340
341 342 343 344 400 345 346 347 348 349
350 351 352 353 401 354 355 356 357 358
359 360 361 362 402 363 364 365 366 367
368 369 370 371 403 372 373 374 375 376
377 378 379 380 404 381 382 383 384 385 end fill
ara=7  nux=8  nuy=5  nuz=1  fill 405 406 407 408 409 410 411 412
413 414 415 416 417 418 419 420
421 422 423 424 425 426 427 428
429 430 431 432 433 434 435 436
437 438 439 440 441 442 443 444 end fill
ara=8  nux=4  nuy=3  nuz=1  fill 445 446 447 448 449 450 451 452
453 454 455 456 end fill
ara=9  nux=4  nuy=3  nuz=1  fill 457 458 459 460 461 462 463 464
465 466 467 468 end fill
ara=10 nux=4  nuy=3  nuz=1  fill 469 470 471 472 473 474 475 476
477 478 479 480 end fill
ara=11 nux=4  nuy=3  nuz=1  fill 481 482 483 484 485 486 487 488
489 490 491 492 end fill
ara=12 nux=1  nuy=1  nuz=3  fill 495 494 493 end fill
ara=13 nux=1  nuy=1  nuz=12 fill 507 506 505 504 503 502 501 500
499 498 497 496 end fill
ara=14 nux=1  nuy=1  nuz=4  fill f510 end fill
end array
read bnds +xb=vac -xb=vac +yb=vac -yb=vac +zb=vac
 -zb=vac  end bnds
end data
end
```

6.6 REFERENCES

1) Title 10 Code of Federal Regulations Part 71 (10CFR71)

2) Certificate of Compliance 6294, Rev. 13 for Package USA/6294/AF

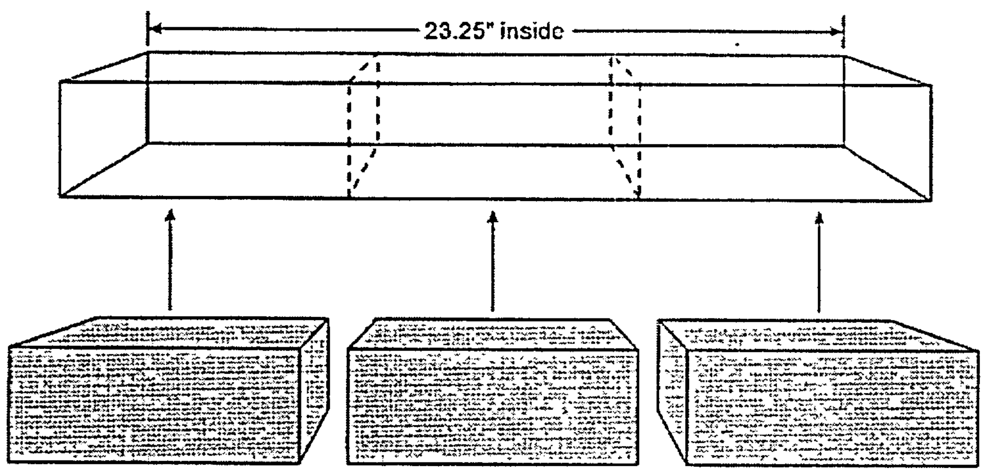
3) "Design and Structural Evaluation of a Low Enriched U02 Pellet and Powder Shipping Package - Model UNC 2901," W. L. Hoffman, United Nuclear Corp.; April 1979

3) Deleted

5) "SCALE 4.2 - Modular Code System for Performing Standardized Computer Analyses For Licensing Evaluation," ORNL CCC-545, Oak Ridge National Laboratory, Oak Ridge, Tenn., 1993.

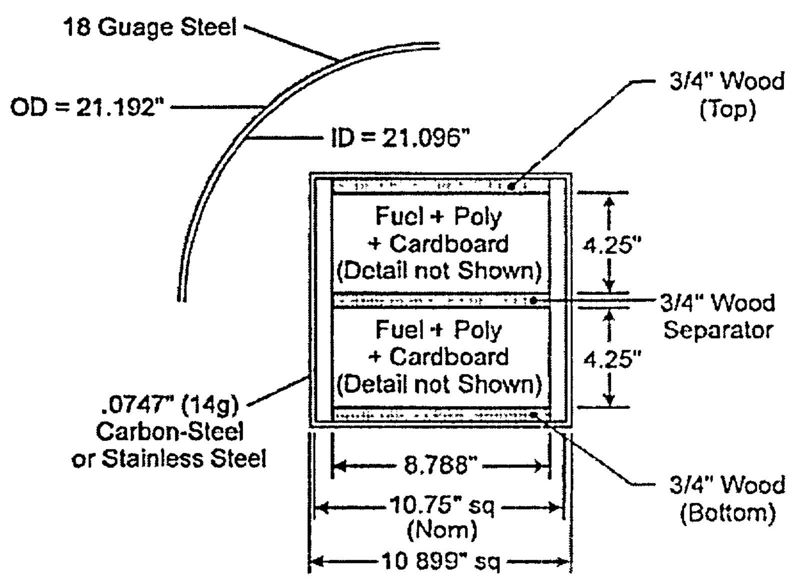
6) FRAMATOME ANP Document No. 38-1210275-00, "Application For Use Of Shipping Container Model No. UNC-2901 For The Transport of Special Nuclear Material," Certificate Of Compliance No. 6294, Combustion Engineering, Inc., NRC Docket No. 71-6294.

Figure 6-2
Fuel Column Model



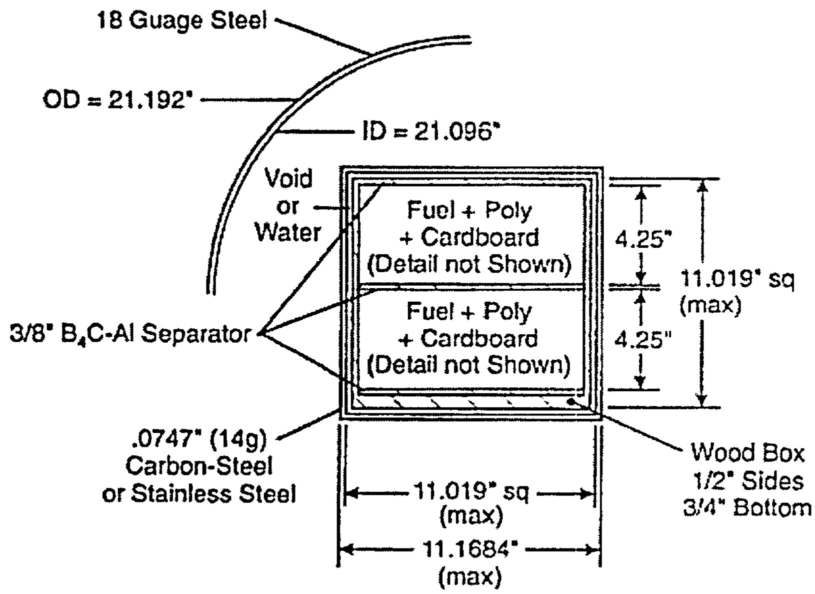
Model box (top) is created from three real boxes without cardboard or polyethylene between box ends
Inside length determined by length of three steel trays - 3 X 7.75" = 23.25"

Figure 6-3
Original Pellet Tray Model



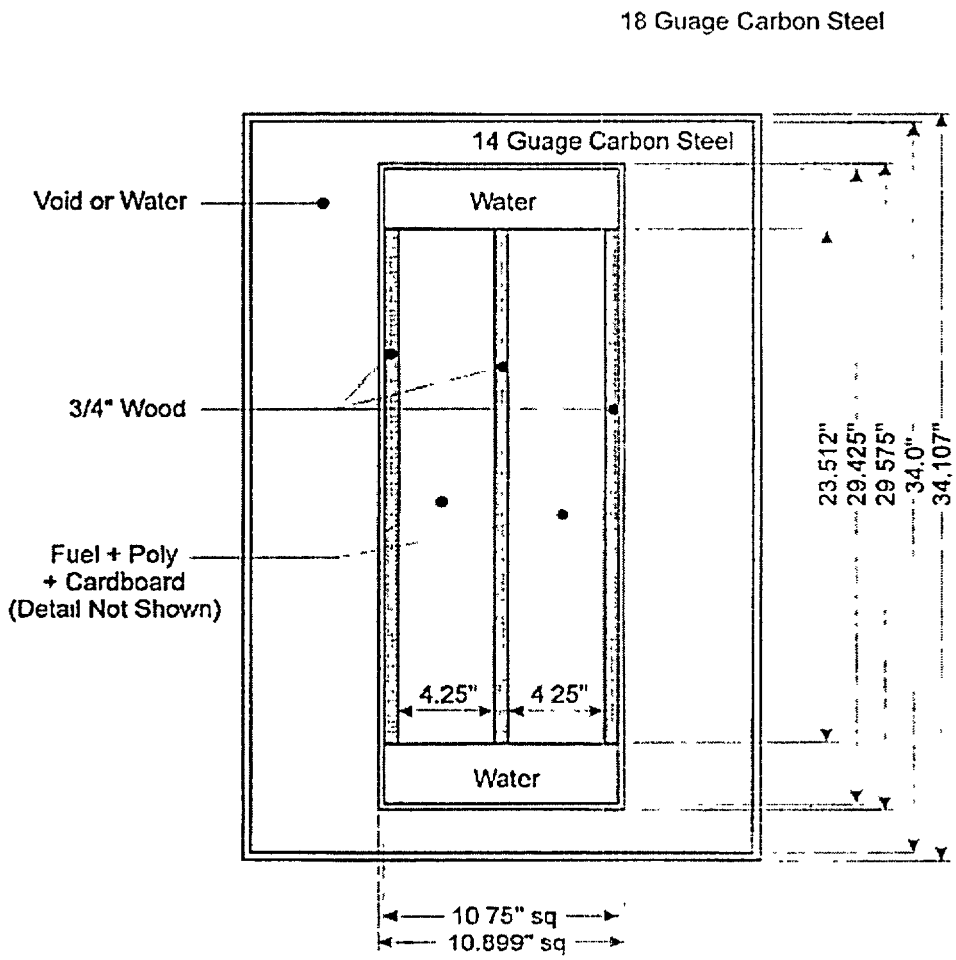
BW 2901 Top View

Figure 6-3A
Typical Container Model



BW 2901 Top View

Figure 6-4
Original Pellet Tray Model



BW 2901 Side View

B&W FUEL COMPANY
APPLICATION FOR THE USE OF THE BW-2901 SHIPPING CONTAINER REV: **5**

Figure 6-4A
Typical Container Modet

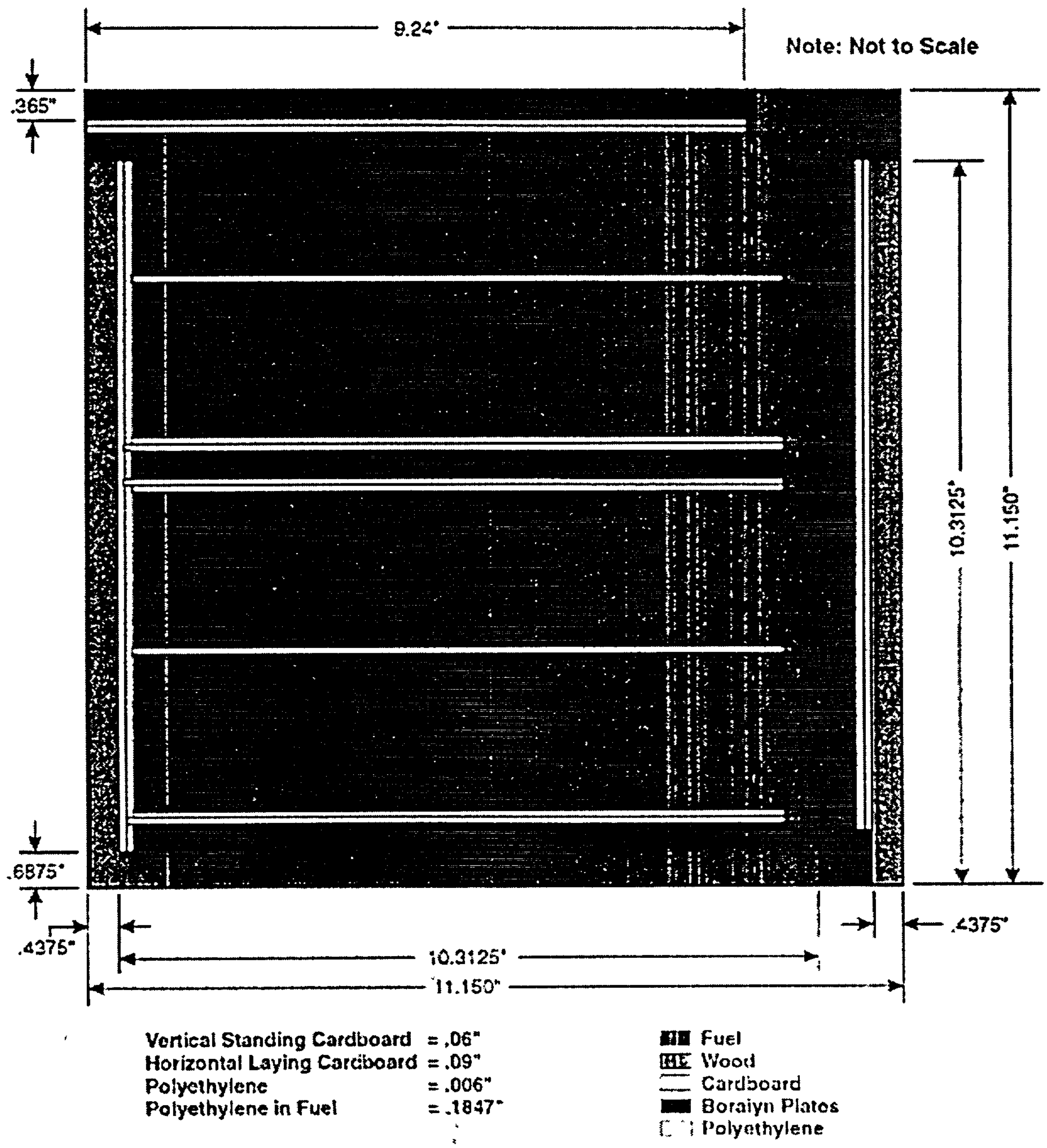
FIGURE WITHHELD UNDER 10 CFR 2.390

B&W FUEL COM'PAN1Y
APPLICATION FOR THE USE OF THE BW-2901 SHIPPING CONTAINER REV: 5

Figure 6-5
Scrap Container Accident Model
(Model-Ri)

FIGURE WITHHELD UNDER 10 CFR 2.390

Figure 6-6
Final Exact Scrap Model
(Model-R2)



7.0 OPERATING PROCEDURES

Loading and unloading of the package is a relatively simple, straight forward operation, however, to ensure proper and safe packaging, detailed procedures are employed. New fuel pellets, reject pellets and/or hard scrap are shipped in the BW-2901 shipping container. The following generalized description provides a brief overview of the detailed procedures for loading and unloading the containers. Typically, fuel pellets and UOZ powder are manufactured at the selected pellet vendor's manufacturing facility (currently Framatome ANP, Inc. in Richland, WA) and fuel pellets are shipped to the FRAMATOME ANP, Lynchburg, Virginia facility for fabrication into completed fuel assemblies. Shipments from Lynchburg to the pellet vendor are usually of excess material or scrap generated during handling. In general, the information provided below for loading and unloading pellets also applies, except for the point of origin as noted above, to reject pellets and/or hard scrap.

7.1 PROCEDURES FOR LOADING THE CONTAINER

The following loading steps apply to all shipping configurations and pellet contents. Pellet trays are filled and packaged within cardboard boxes. Next, the boxes are transferred to a scale area where they are weighed and verified to be within the loading limits established by the criticality analyses (see Section 6). From the scale area the pellet boxes are brought to the BW-2901 loading area or they are placed in storage to await shipment.

Prior to loading the pellet boxes into the shipping container, the closure ring, outer drum lid, circular insert, inner container cover and cover gasket are removed from the shipping container. The outer shell is inspected to assure that there are no cracks, holes or tears in the drum. The shipping cradle, upon which the shipping containers rest, is also inspected to assure it is in reasonable condition prior to use, i.e., no bent legs, straps in place, etc. Once the shipping container and shipping cradle, are determined to be acceptable for use, the pellet boxes can be loaded.

Whether shipping in the horizontal or vertical position, the same BW-2901 shipping container loading configuration is employed. Pellet boxes are loaded into the inner container, using the separator discussed in Section 7.1.1 or limiting pellet box payload discussed Section 7.1.2.

Before reinstalling the inner container cover and cover gasket, the gasket is inspected for acceptability.

Gaskets shall be replaced at signs of visual degradation. After the gasket and inner container cover are installed over the inner container studs, the nuts are installed and torqued to 35 ± 5 ft - lbs. The circular wooden top spacer is replaced, the outer lid of the drum secured with the ring clamp and the closure ring bolt is torqued to 45 ± 4.5 ft - lbs using a calibrated torque wrench. Finally, the shipping container is appropriately labeled and a tamper-proof seal is applied. The shipping container is then ready for shipment.

7.1.1 Inner Container Loading With Borated Al Plates

Pellet boxes are placed into the inner container in two layers of three boxes each as shown on drawing 1215597D. Three borated aluminum absorber plates, 3/8" thick and having a minimum B10 areal density of 83.823 mg /cm2, are shipped within each BW-2901 container. The absorber plates are located below the bottom layer of pellet boxes, between the two layers of pellet boxes and above the top layer of pellet boxes in each container. All absorber plates have a unique symbol and serial number stamped into at least one end of each plate. Verification of the plate stamp is performed as part of the container loading process. In containers having less than six boxes, solid aluminum or wood spacers are used to occupy the void areas.

7.1.2 Inner Container Loading Without Borated Al Plates

7.1.2.1 Pellets < 4.03 %

When not using borated Aluminum (Al) absorber plates, the maximum number of pellet boxes for fuel _< 4.03$ that can be shipped is four (4) per container with the remaining space being filled by Al or wood spacer blocks in any configuration.

7.1.2.2 Pellets < 4.97 %

When not using borated Aluminum (Al) absorber plates, the maximum number of pellet boxes for fuel _< 4.97% that can be shipped is three (3) per container with the remaining space

being filled by A1 spacer blocks. Pellet boxes and A1 spacer blocks are placed into the inner container in two layers of three, alternating the pellet boxes and the A1 spacer blocks. Each layer should alternate a pellet box and an A1 spacer block. For the bottom layer the loading arrangement should be pellet box, AI spacer, pellet box. For the top layer the loading arrangement should be A1 spacer, pellet box, A1 spacer. All fuel pellet boxes are required to be completely full. For partial loads, the void space may be filled with empty trays. The maximum number of shipping containers per truck when not using the borated aluminum absorber plates is 56.

7.2 PROCEDURES FOR UNLOADING THE CONTAINER

A generalized package unloading discussion is provided below since unloading is, for the most part, just a reverse of the loading process described above in detail. Upon arrival the shipping containers are inspected for potential shipping or handling damage and to verify the integrity of the tamper-proof seals. If the container is found to be damaged and/or the seal has been tampered with, management is informed. If each container is undamaged and each tamper-proof seal is intact, the BW2901 shipping containers are transferred, if necessary, to an unloading area.

Once located in the unloading area appropriate for the shipping configuration (i.e., horizontal or vertical), the closure ring, outer drum lid, circular wooden top spacer, and the inner container nuts, cover and gasket are removed from the shipping container. The pellet boxes are transferred to a temporary storage area, then to a receiving scale station and weighed. After completing receipt inspection, the pellet boxes are transferred to a storage area or into the manufacturing process, as necessary.

Once the inner container has been unloaded, the container is re-loaded, or the packaging materials are replaced, the wooden insert is replaced, then the inner container cover secured. The outer drum lid is secured with the ring clamp and an "EMPTY" label attached to the outside of the container. The empty shipping containers are moved to a transport vehicle or to a storage area to await return to the applicable fuel vendor.

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

8.1 Acceptance Tests

8.1.1 Containers

Containers will be fabricated in accordance with the design drawings referenced in the Certificate of Compliance. The approved Quality Assurance Manual will be used to ensure compliance. Any changes in the drawings shall be submitted to the NRC for approval.

As a minimum, the outer shell of each container shall be conspicuously and durably marked with the owner, package model number, gross weight and package identification number assigned by the NRC.

8.1.2 Boralyn Plates

The Boralyn plates that are to be placed inside the container are a mixture of Aluminum and Boron Carbide. To ensure these poison plates meet the requirements of this package the following inspections/tests will be performed:

1) The length, width, and thickness of the plates will be verified using an inspection plan prior to being placed in service to ensure the validity of the dimensions and tolerances.

2) The minimum B^{10} areal density of 83.823 g/cm^2 for the plates will be verified with neutron attenuation tests on plate and coupon samples using an inspection plan. If the material is so black that the uncertainty of the measurement can not confirm minimum areal density, the minimal B^{10} areal density will be confirmed using the chemical samples described below.

3) Chemical samples will be taken to measure the boron content of the plate material and the amount of B^{10} in the boron to independently verify the minimum B^{10} areal density of 83.823 g/cm^2 using an inspection plan.

8.2 Maintenance Program

Repair and maintenance will also be performed only in accordance with approved drawings and procedures. The shipping containers have no moving parts which require periodic maintenance. Inspections of the container assembly are performed as specified in Section 7. Any unacceptable condition discovered during these inspections is noted and the container appropriately tagged for maintenance.