71-9251

Docket 71-9251
Model BW-2901

FRAMATOME ANP

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

April 17, 2003

Subject: Additional information for the for the model BW-2901 Shipping Package Certificate of Compliance No. 9251

Reference: (1) NRC Request for Additional Information "CERTIFICATE OF COMPLIANCE NO. 9251 FOR THE MODEL NO. BW-2901 PACKAGE" Dated February 3, 2003.

(2) Submittal of Consolidated Application for Renewal of Certificate of Compliance No. 9251 for the BW-2901 Shipping Package, reference EHSL-02-020

Enclosure (I) Response to Request for Additional Information
Enclosure (II) List of effected pages
Attachment (I) Change pages for the Consolidated application for renewal of BW-2901

Dear Mr. Monninger,

This submittal provides a response to the NRC Request for Additional Information stated in reference 1. As stated in reference 1 this application was submitted to address the NRC CAL for packages of this type. During the conversion of this document to electronic format several typographical errors propagated for which change pages are being submitted.

Six copies of the change pages are provided as Attachment I. These pages should be used to replace the corresponding pages from the application as described in Enclosure (II).

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

Sincerely,

Robert W Sharkey
Manager, Environmental, Health,
Safety and Licensing

FRAMATOME ANP, INC.
1724 Mount Athos Road, P.O. Box 11646, Lynchburg, VA 24506-1646
Tel.: 434-832-5000 Fax: 434-832-0622 www.us.framatome-anp.com
An AREVA and Siemens Company

EHSL03-35

NMSS01

Enclosure I

Response to NRC Request For Additional Information
Docket 71-9251
Model BW-2901 Package

Section 2-1

Request: Revise the application to describe the testing that was performed to demonstrate the effectiveness of the lid clamps.

Response: Section 2.3.2.1 "Thirty Foot Drop Test" and 2.3.2.2 "Piston Drop Test" of the application have been revised to describe the testing performed to demonstrate the effectiveness of the lid clamps. Pages 2-4, 2-5, 2-6, 2-7, and 2-8 have been revised and are included as replacement pages to the October 8 submittal.

Section 6-1

Request: Submit improved quality copies of the following figures from Chapter 6: Figures 6-4, 6-5, and 6-6 (which should be in color). The figures were not legible.

Response: Chapter 6, Figures 6-4, 6-5, and 6-6 have been revised for clarity.

Section 6-2

Request: The following editorial errors are noted:

a. "KENO" is incorrectly spelled 'RENO" in a number of places, including the titles of Tables 6.5.2.1-1 and 6.5.2.1-2.
b. "K-effective" is incorrectly spelled "R-effective' in the title of Table 6.5.2.3-1.

Response: The editorials errors noted above have been corrected and revised pages 6-41, 6-42, 6-43 and 6-46 are attached.

Section 7-1:

Request: Revise the operating procedures to address use of the lid clamps.

Response: Sections 7.1 and 7.2 have been revised to incorporate procedures for using lid clamps. Container operating procedures have also been prepared to address the new configuration and implementation is pending amendment approval.

Section 7-2

Request: Revise the operating procedures to be consistent with the authorized content loadings described in the Certificate of Compliance. The operating procedures (Section 7.1.2) address shipments that are loaded without the borated aluminum plates. However, Chapter 6 of the application addresses criticality safety of the package, and does not include analyses for loadings that do not include the borated plates.

Response: The operating procedures (Section 7.1.2) that address shipments that are loaded without the borated aluminum plates have been deleted from the application. Shipment will be made in accordance with the approved contents of the Certificate of Compliance.

Section 7-3

Request: Revise the justification for eliminating the annual gasket replacement to address the confinement of fissile material (in powder and pellet form) under normal conditions of transport and hypothetical accident conditions.

Response: The BW-2901 family of packages has been in use for several decades and Framatome has significant experience with this package. With the benefit of this experience we know that the gasket integrity does not degrade over the short period of one year. Additionally the material is shielded from the weather and sun by its configuration. Framatome recognizes the importance of the gasket and does not propose to eliminate its use or reduce its effectiveness. The procedure section 7.2 has been revised to add additional detail regarding the inspection performed on the gasket to assure its effectiveness. 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. Three (3) lid clamps are installed approximately 120 degrees apart. Each clamp is tightened until the clamp halves make contact in the bolt area. Finally, the shipping container is appropriately labeled and a tamper-proof seal is applied. The shipping container is then ready for shipment.

Section 8-0

Request: Revise the application to provide a maintenance program for the package.

Response: Section 8-2 of the application has been revised to provide more detail regarding the maintenance program for the package.

Enclosure II
List of effected change pages

Page Number	Change
Page 1-3	Remove and replace with new page 1-3. Made editorial change to 1.2.3.1 for w/o ^{235}U.
Page 2-4 through 2-8	Remove and replace pages 2-4, 2-5, 2-6, 2-7 and 2 -8 with the pages numbered the same. These change pages describe the drop test and results of the tests.
Page 6-2	Remove and replace pages 6-2 with page numbered the same. Text errors corrected for B10, U235 and UO2,
Page 6-3	Remove and replace pages 6-3 with page numbered the same. Text errors corrected for inches in section 7 following 0.365.
Page 6-6	Remove and replace pages 6-6 with page numbered the same. Text errors corrected for B10, spelling of NITAWL, BONAMI and extraneous 6 removed.
Page 6-12	Remove and replace pages 6-12 with page numbered the same. Text errors corrected: Section I changed Z to 2. Section J. changed volt to vol. %. Section K. changed B1° to B10.
Page 6-14	Remove and replace pages 6-12 with page numbered the same. Table 6.3.1.2-1 changed Den to Density, and footnote A from 102' to 10^{24}
Page 6-15	Remove and replace pages 6-15 with page numbered the same. Changed section 6.4.2 model Ri toR1.
Page 6-17	Remove and replace pages 6-17 with page numbered the same. Changed tests^3 to tests.
Page 6-18	Remove and replace pages 6-18 with page numbered the same. Table 6.4.2.1-1 added sigma sign in column 4 and added inches symbol after 0.37.
Pages 6-19 and 6-20	Remove and replace pages 6-19 and 6-20 with page numbered the same. Replaced Uo2 with UO2 and UOZ with UO2.
Page 6-22	Remove and replace pages 6-22 with page numbered the same. Replaced volt with vol. %.
Page 6-24	Remove and replace pages 6-14 with page numbered the same. Replaced volt with

Enclosure II
List of effected change pages

	vol. %.
Page 6-26	Remove and replace pages 6-26 with page numbered the same. Changed Grams Polv to Grams Poly.
Page 6-28	Remove and replace pages 6-28 with page numbered the same. Replaced volt with vol. % and iwt with1wt.
Page 6-29	Remove and replace pages 6-29 with page numbered the same. Replaced volt with vol. %.
Page 6-31	Remove and replace pages 6-31 with page numbered the same. Corrected U235.
Page 6-33	Remove and replace pages 6-33 with page numbered the same. Replaced a with σ.
Page 6-35	Remove and replace pages 6-35 with page numbered the same. Changed UOZ to UO2.
Page 6-39	Remove and replace pages 6-39 with page numbered the same. Changed LRS to LRC and added +/- sign.
Page 6-41, 6-42, 6-43 and 6-46	Remove and replace pages 6-41, 6-42, 6-43 and 6-46 with pages numbered the same. Fix editorials RENO to KENO and R-effectives to K-effectives.
Page 6-82, 6-83, 6-84, and 6-85	Remove and replace pages 6-82, 6-83, 6-84, and 6-85. This change replaces figures 6-4, 6-4a, 6-5 and 6-6 with more vivid figures and color where applicable.
Page 7-1, 7-2 and 7-3	Replace page 7-1 and 7-2 with new page 7-1, 7-2 and 7-3. Changes UOZ to UO_2 and adds procedural step for removing lid clamp in paragraph 7.1. Instructions for adding the ring clamp have been incorporated into this section. Operational testing of the lid clamps has demonstrated that torque requirements are not needed to confirm that the clamps are properly positioned and engaged. To assure proper use the operators are instructed to tighten the lid clamps until the surfaces meet. Additional detail has been added to the gasket inspection procedure.
Page 8-2	Replace page 8-2 with page numbered the same. A new paragraph has been added to provide additional detail regarding the maintenance program for the package.

Attachment 1 Change Pages

1.2.3.1 **Pellets or Rejected Pellets**

Maximum Enrichment 5.05 w/o ^{235}U

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

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 9/5/2002 - 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. Testing was performed with two distinct, but related designs of the package, the BW-2901, and the ABB-2901.

The packages were suspended from a crane with a quick release mechanism and a pull string. Each package was measured to be a few inches higher than the 30 foot requirement prior to release. The packages were dropped onto a reinforced concrete pad with the direct impact onto an embedded steel plate.

Two specimens for the BW-2901 design were tested. Test specimen # 139 was 672 lbs gross weight, loaded with 409 lbs of solid dunnage blocks. The package was oriented 17.5 degrees from horizontal with the initial impact on the lid. The closure bolt was positioned 180 degrees from impact as determined by the testing performed at LLNL. Following the placement of the standard closure ring and tightening of the closure bolt, three retention clamps were added to the package lid to provide additional strength to the closure setup. The clamps were positioned approximately at the 2, 6, and 10 O'Clock positions for the BW-2901 specimen. The bolts on the clamps were tightened with a small (6") open face wrench until the two pieces of the clamp were engaged. No significant torque was applied.

Test specimen #140 was 667 lbs gross weight with 404 lbs internal payload. The 30 foot drop test at 17.5 degrees relative to horizontal was performed with a single retention clamp in addition to the standard closure ring, located 90 degrees (3 O'Clock) from the closure bolt which was directly opposite the point of

impact. The 90 degree location was determined to be the location at which the single clamp would provide the least amount of benefit.

Additional tests were performed with the ABB-2901 package. Slight variations existed in the placement of the 3 clamps for this package relative to the placement on the BW-2901 package. The ABB-2901 package gross weight was 660 lbs.

The test conditions were mild, with an ambient temperature of approximately 85 degrees Fahrenheit, and negligible winds.

Results - In both cases the BW-2901 and ABB-2901 specimens with the three retention clamps impacted the test pad in the desired location. The three retention clamps performed as expected and showed no signs of wear or damage. The clamp located at the point of impact cut into the side of the packages and crimped the closure ring and lid together. There was no breach or opening of the container lid or separation of the closure ring from the package rim.

The test with specimen #140 and the single retention clamp resulted in a partial lid separation of approximately 1" between the 10 and 2 O'Clock positions. Since extensive preliminary testing was successfully performed on the BW-2901 design prior to the above mentioned confirmatory tests, without retention clamps, it appeared that the single retention clamp contributed to the lid separation by providing a pinch point at one location preventing the closure ring from uniform distortion.

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.

Supplemental Tests Conditions 9/5/2002- Following the 30 foot drop test, package specimen # 139 was puncture tested three consecutive times. The package was oriented at 55 degrees from horizontal with the impact point directly on the closure ring. The height was measured to conservatively be greater than 40 inches from the point of impact. The first puncture test was performed directly onto the closure bolt in an attempt to break the bolt loose, or peel the lid off. The second puncture sequence involved a direct hit onto the closure ring at the point where the ring was least engaged following the drop test. The third and final test was performed directly onto the retention clamp in order to attempt to break the seal at that point.

A single puncture test was performed with the ABB-2901 specimen, with impact directly on the closure bolt.

Results - All three of the puncture tests on #139 were unsuccessful in removing or breaching the lid or closure ring containment. Test specimen #140 was not puncture tested, due to the results of the 30 foot drop test.

The results of the ABB-2901 puncture test was a slight separation of the lid (~1 inch) between the clamps.

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.

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 B10 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 UO2 with the U-235 content not to exceed 7.47 kg U235

2) The enrichment limit will be 5.05 wt%

3) The maximum allowed pellet density is 97.6% of the UO2 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.

6.2.1 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 % B10 in natural Boron. The minimum B10 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. 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 BONAMI, NITAWL (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, NITAWLII (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.

I. The wood support ribs in the drum were modeled only at both ends of the drum. The 2 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 vol.% B4C (23.702 wt% B4C -areal density of 83.823 mg/sq. cm.).

K. A 25% reduction in the B10 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.

Table 6.3.1.2-1 Material Number Densities

Material/Density	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 10^{24} atoms/gaw.

6.4 Criticality Calculation

6.4.1 Calculational Method

The revised criticality analysis was performed with the KENOVa Monte-Carlo code [5]. 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

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. 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 Sigma	%IM Inner Container	%IM Outer Container	K-eff + 2σ
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 0.37" or 0.32" 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 UO2) or twelve trays of smaller pellets (144 kgs UO2, 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

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 vol. % 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 K-effective 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 6.4.2.6-2
Scrap Container Volume Fraction Results With Borated Plates At 20 Vol.% 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

Table 6.4.2.8-1

Effect of Polyethylene on Scrap Pellet Shipments

Run	Pckg. Frac.	Grams Poly	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

Table 6.4.2.8-2
Scrap Container Criticality Results With 2000 Additional Grams Polyethylene and 20 Vol.% 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 vol.% 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).

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% U235 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

The maximum K-effective for the system is 0.94803 with a 0.02 bias and 2σ 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.

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 K-effective 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 BW-2901 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 UO2 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 UO2 theoretical density (10.96%).

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 SCALE 4.2 library with KENOVa is conservative relative to other available KENO versions at FRAMATOME ANP.

6.5.2.1 LRC 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

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

Spacing **Between Arrays** (in.)	Core **Number**	KENOIV 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
KENO-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)

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

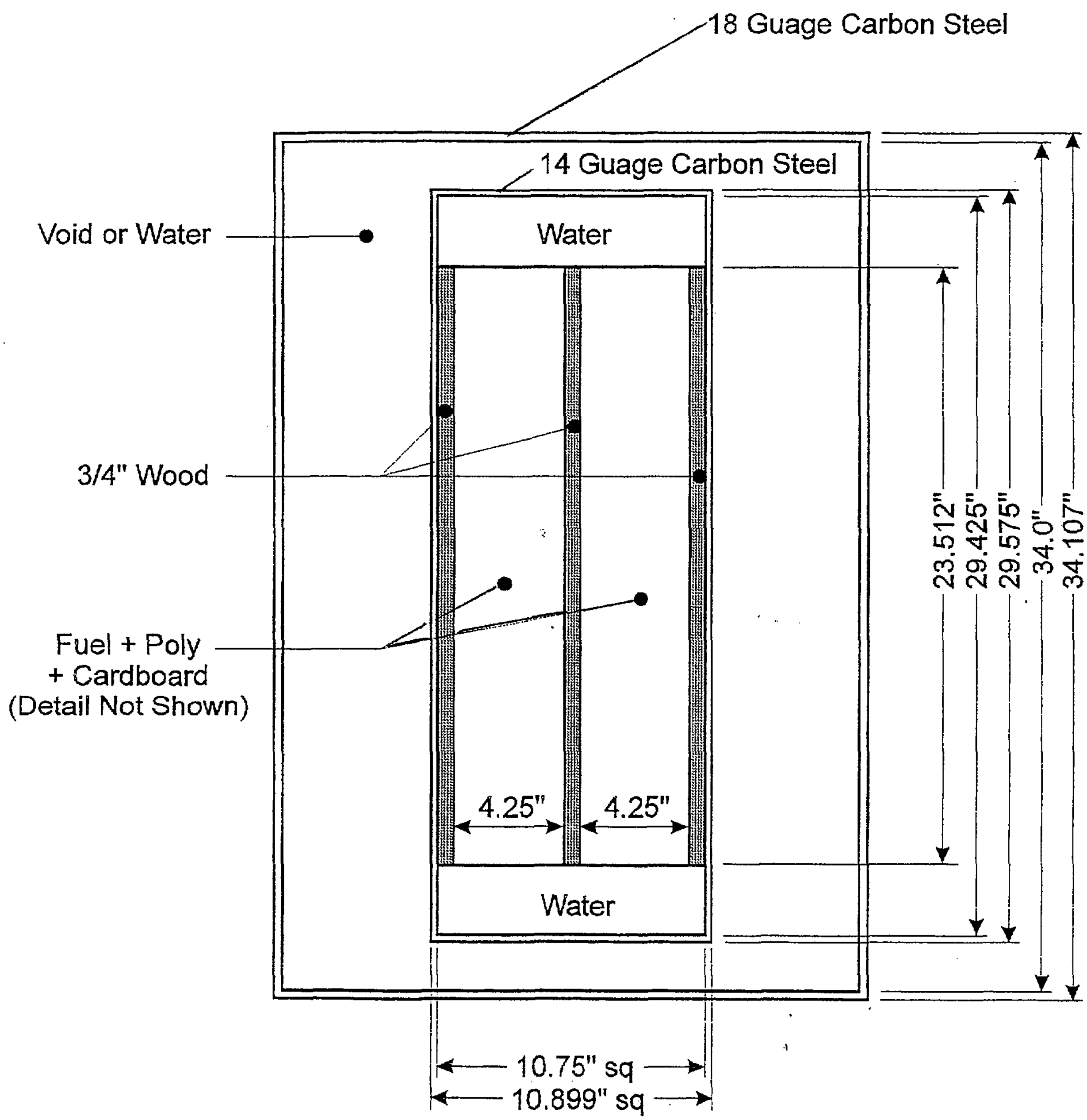
Enrich./ Microfiche	Base K-eff.	2σ Unc.	Max. K-eff.	Description
5.1 wt%/ Reference Base Case	0.912	±0.007	0.939	Reference - Base case
5.1 wt%/ b11825	0.91131	±0.00120	0.93251	27 gp Base case w/KENOVa
5.1 wt %/ b11850	0.91173	±0.00118	0.93291	123 gp Base case w/KENOVa

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.

Figure 6-4
Original Pellet Tray Model

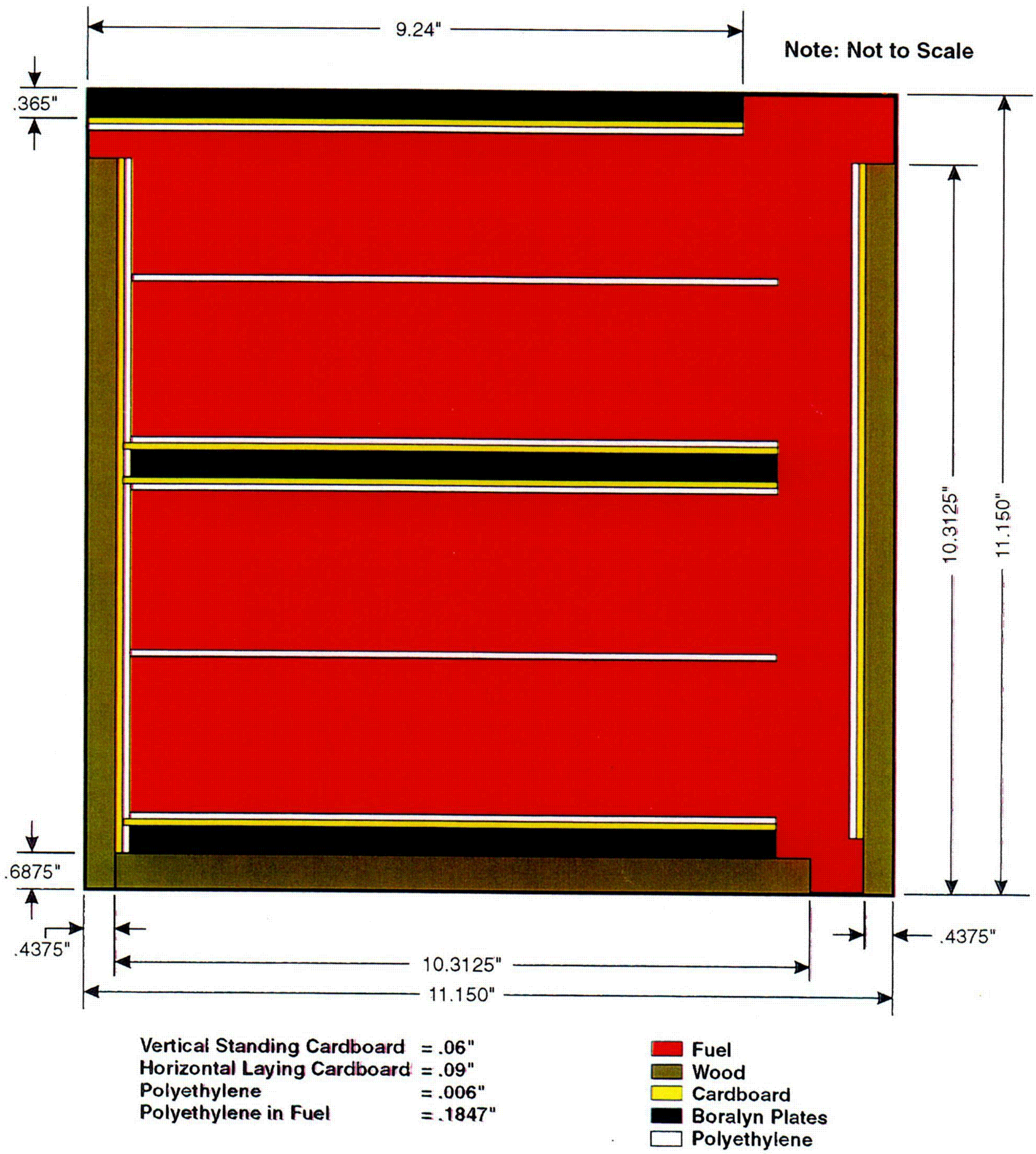


BW 2901 Side View

FIGURE WITHHELD UNDER 10 CFR 2.390

FIGURE WITHHELD UNDER 10 CFR 2.390

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



C01

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 UO_2 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 lid clamp, 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. Three (3) lid clamps are installed approximately 120 degrees apart. Each clamp is tightened until the clamp halves make contact in the bolt area. 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 A1 Plates -DELETED

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), lid clamps, 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, lid clamps are attached 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.

8.2 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 and include the inspection of the outer shell to assure that there are no cracks, holes or tears in the drum. The hardware including the lid clamps, ring clamps are also inspected at this time. Any unacceptable condition discovered during these inspections is noted and the container appropriately tagged for maintenance.

In addition to the inspections described in Chapter 7, Framatome has a maintenance program for periodic inspections of the container internals. A sample of packages will be selected, typically based on age. These packages will be opened and inspected. Items that will be inspected and the acceptance criteria are determined and documented prior to initiating the maintenance inspection. The inspection will look at insulating material, internal welds, key dimensions, spacers and the hardboard rings. Based on the results of the inspection determinations will be made regarding the need to inspect additional packages and or if repairs, maintenance or refurbishment is required. Non conforming packages will be removed from service until reworked.