APPENDIX V

PACKAGE COMPONENT EVALUATIONS

APPENDIX V

PACKAGE COMPONENT EVALUATIONS

The Model 51032-1a package includes design changes to assure that the main shock mount bolts yield and dissipate energy in any drop configuration, except for a drop in the normal upright configuration which is the least subject to failure potential. Clearances between the assembled strongback and the containment vessel are about two and one-half inches and may limit the combined distortion of bolts, full-clamps and shock mounts. The static tensile tests result in shock mount bolt failure at about 1.7 inches of bolt distortion, which is sufficient for the desired energy dissipation. When the bolts are loaded transverse to the shock mount, the net distortion at failure, including bolt and mount, is about 3.2 inches in static tests.

To assure that the distortion occurs in the shock mount bolts, other bolts which could fail and relieve the stress on the shock mounts have been strengthened. These have also been tested statically to verify that their strength exceeds that of the shock mount bolts.

Full-clamp assemblies consist of 2-1/2 x 2-1/2 x 1/2 inch angle bars which span the strongback, clamping to its lip, and sliding clamps which bolt to the angle bars and hold the fuel elements in the corners of the strongback (see Figure 2.17). These full-clamps were strengthened, by about a factor of three, relative to the drop-tested package to assure that they retain the fuel elements within the strongback during the time required to distort and fail the shock mount bolts. In the drop-tested package, abrupt failure

of the shock mount bolts protected the full clamps until they impacted the cover. To assure this same failure mode in the Model 51032-1a container, even though dynamic loads could result in shock mount bolt failures before the clamp distortion is excessive even if the clamp were the weak link statically, static tests were made to show that the full clamps are, in fact, stronger than the shock mount bolts.

The separator blocks and their attaching bolts have been strengthened to provide at least 23% more strength than those in the Model 51032-1 packages. This increased strength, when eight separator blocks are employed with Type AA fuel elements, assures that the strength of the separator blocks per unit weight of the contents is equivalent to the Model 51032-1 package. To obtain the increased strength, a gusset plate has been added to the block and the carbon steel bolts have been replaced by grade 8 bolts, which have a shear strength of 90,000 psi as compared to 38,400 psi for the previously used bolts. New washers have also been provided to prevent the bolts from tearing out of the strongback.

Aluminum honeycomb energy absorbing material has been added at the strongback ends to absorb energy in the end-drop configuration. The purchase order specified that the strength shall be between 1200 and 1500 psi. The manufacturer has provided test data on the actual material which gave an average strength of 1310 psi up to 80% compression.

The influence of dynamic loading conditions on component performance is discussed in Section V.6.

V.1 Shock Mount and Bolt Response in End-Drop Configurations

Two different static tests of the shock mount and stainless steel bolt behavior have been conducted for designs

similar to the one selected. The first was with a stock 304 SS 5/8 inch diameter bolt with no undercut. The second was with a 304 SS 3/4 inch diameter bolt undercut to 0.6 inch diameter over a 4 inch length to improve the tensile properties for the cover-drop accident. The loading for both tests was prototypical for an end-drop. The head-end of the bolt was forced to move in a straight line perpendicular to the bolt axis. This shear loading leads to distortion of the shock mount and bending of the bolt. The mid-section tends to be supported by the shock mount and the most severe stresses are at the two ends.

The first test was carried to bolt failure when the head end had been moved 3.255 inches and the loading was 24,000 pounds. Failure occurred at the nut end in a thread root. The second test was taken to the 30,000 pound limit of the testing machine when the deflection was 2.6 inches. There was no indication of approach to failure and it was predicted that the ultimate joint strength would again be determined by the thread-root strength which scales up to 35,000 lb based upon the experience with the 5/8 inch bolt. The expected bolt head movement at failure would have been equal to the 3.25 inches in the first test, or greater if the reduced section were to develop significant elongation.

To provide greater assurance that the shock mount bolt is the weakest link in a cover-drop, the undercut diameter was reduced to 0.43 inches. This reduces the tensile strength to 1/2 the 0.6 inch diameter strength. Since the strength in the transverse loading in end drops was not limited by the undercut to 0.6 inch, the reduction to 0.43 inch will not reduce the strength by as much as a factor of 2. Furthermore, the bolt head movement will be

enhanced since the undercut section must certainly elongate at the reduced strength. It is conservative, therefore, to assume that the load at failure will be at least 16,500 lb, the head movement at failure at least 3.2 inches and the energy absorption at least 1/2 that of the extrapolated energy absorption obtained in the second test.

The force-deflection curve for the second test with the undercut 3/4 inch diameter bolt is shown in Figure V.1, with the extrapolation beyond the test machine limit shown as a dotted line. In this test, the mount was fastened with the four 3/8 inch bolts used to fasten the mount to the shipping container. The test determined, as desired, that these bolts provide a stronger link than the stainless steel shock mount bolts.

V.2 Shock Mount Bolt Response in a Cover Drop

In a cover drop the shock mount bolts are in tension and the shock mount itself is put in compression. In static tests the mount is not expected to provide significant energy dissipation and was not included in the tests. The bolts, however, yield plastically and have been tested in the Tinius-Olsen machine.

A standard Type 304L SS bolt, machined down to 0.6 inch diameter over a four inch length, was tested to failure. The test gave a 42 percent elongation at a failure tensile strength of 27,000 pounds. The average energy dissipation was 25,000 in.-lbs. per inch of deformation of the 0.6 inch diameter portion of the bolt length. This provides 48,000 ft.-lbs. of energy absorption in the set of 14

shock mount bolts. The stress-strain curve for this bolt is given in Figure V.2.

The bolts actually used in the shock mount are undercut to 0.43 inch diameter over a four inch length. The expected elongation at failure is the same as in the test and the energy absorption is 24,000 ft.-lbs.

In a similar test of 5/8 inch low carbon steel bolts used in the Model 51032-1 package, the shock mount bolt energy absorption capability was found to be less than 4,000 ft.-lbs. for all 14 bolts. Thus, the Model 51032-1a package with 14 shock mounts dissipates at least an additional 20,000 ft.-lbs. in bolt distortion.

V.3 Combined Energy Dissipation of the Shock Mount Bolts, Aluminum Honeycomb, Strongback Extension, and Fuel Element Nozzles in End Drops

Tests described in Section V.1 on the shock mounts define the energy dissipation in those assembles. At the strongback ends, aluminum honeycomb has been added which has a compressive strength (1310 psi) and area designed to absorb at minimum of 129,000 ft.-lbs. of energy. As the strongback and its contents move toward the container end, this material compresses and dissipates energy while the shock mount bolts are deformed.

As designed, there is a one-half inch clearance between the honeycomb and the containment vessel. When the container impacts the ground, the end may be pushed in sufficiently to close this gap. In drop tests of the Model 51032-1 package, the end did not appear to be pushed in any more than that. The performance of the

honeycomb is not sensitive to this uncertainty and is described here assuming that the gap is closed only by relative motion between strongback and container.

The two ends of the shipping package differ in honeycomb absorber design because at the fuel element nozzle end the nozzle projects two inches into the honeycomb. The honeycomb is cut back in that area and additionally cut back to facilitate assembly. The design is shown in Figure 2.20. As the strongback and fuel elements move forward, the nozzle impails into the honeycomb and it is assumed that the honeycomb area interior to the nozzle is unavailable for energy dissipation. Crushing of the raised section of honeycomb material begins when the 1/2 inch clearance gap is closed. The area of the raised section is 135 in^2 and begins crushing first. With the exception of the nozzle area, the depressed section begins to compress when the strongback has moved an additional 2.25 inches toward the container end. The depressed area crushed is 77 in^2. The honeycomb thickness is 7.75 inches in the raised area and 5.625 inches in the depressed area.

The manufacturer has provided test data on the production run for the honeycomb which shows that the honeycomb will crush 80% with an average force of 1310 psi. The energy absorption capability is therefore:

$$E = 1310 \times 0.8 \times \{7.75 \times 135 + 5.625 \times 77\} = 1{,}550{,}000 \text{ in-lb}$$

$$E = 120{,}000 \text{ ft-lb}$$

There is a 2.5 inch extension of the sides at the strongback beyond the thrust plate. This will strike the container end 1 inch before the honeycomb is fully compressed. The crushing strength is calculated to be 225,000 lb and it can, therefore, add 19,000 ft-lb of energy dissipation. The fuel element nozzle would strike the end 1/2 inch before the honeycomb is fully compressed, although the energy balance indicates that the strongback would be stopped before that point. If not, the combined crushing strength of the two nozzles is 500,000 pounds of force and could add 20,000 foot pounds of energy dissipation in 1/2 inch of crushing.

The combined stopping force versus relative strongback-container displacement due to shock mount bolts, honeycomb, strongback extension and fuel element nozzles is presented in Figure V.3. In this figure the sloping lines show the increase in stopping force as the bolts and shock mounts yield. The step down at 3.25 inches is due to the failure of the bolts. The first step up at 0.5 inch occurs at gap closure as the raised section of honeycomb begins to crush. The second step up at 2.75 inches occurs as the depressed section of honeycomb begins to crush. The third step up at 5.75 inches is where the strongback extension begins crushing and the final step at 6.25 inches results when the fuel element nozzles begin to crush. The arrow at 6.2 inches, however, indicates that the kinetic energy is dissipated at that point and the last step due to crushing of the nozzles should not occur.

The situation at the other end of the container is much more simple. The full 300 in^2 of the honeycomb area

crushes uniformly and has a restraining force of 400,000 lb. Complete compression from 8.25 inch thickness to 1.65 inch thickness could absorb 220,000 ft-lb of energy. Since the shock mounts provide 30,000 ft-lbs and the total needed is only 159,000 ft-lbs, the honeycomb will only crush 4 inches. The strongback will not reach the container end and will not crush.

V.4 Integrity of the Full Clamps

A lower limit for the strength of the full clamps was determined by loading one in a near prototypical manner on the Tinius-Olsen testing machine. Preliminary tests demonstrated that small design changes would greatly improve the performance and, therefore, part no. 5 of Figure 2.17 was replaced by a similar part 3/4 inch thick and 2 1/2 x 4 inches. This provides 4 inches of bearing length on the lip of the strongback. The bolts for the sliding clamp have been replaced by similar but high-strength grade 8 bolts with 150,000 psi ultimate strength. In the final test the 2 1/2 x 2 1/2 x 1/2 inch angle bar began yielding at 17,000 pounds force and was bent 1 inch at 23,000 pounds force. At that point there was some slippage in the test jig linkage and the bolts, part 10 of Figure 2.17 appeared near to failure. The test was run with a weaker SAE grade 2 bolt rather than the specified grade 8. Because the test had demonstrated sufficient strength the test was terminated prior to failure. The total deflection of the beam resulting from combined beam bending, bolt distortion, clamp distortion, and strong-back lip distortion was 2.3 inches. The distortion at 23,000 lb would have been less and the strength higher with the high-strength bolt.

The test also determined that the sliding clamp is self-locking under the applied loads and will not slip.

There are nine full clamps in the Model 51032-1a shipping package with the Type AA fuel elements. These provide a total restraining force in excess of 207,000 pounds of force (9 x 23,000). This is sufficiently larger than the 180,000 pound strength of the 14 shock-mount bolts and assures that the shock-mount bolts would elongate to failure and prevent failure of the full clamps in a 30 ft drop on the cover.

Tests conducted on the aluminum clamp assemblies shown in Figure 2.18, result in a deflection of 0.267 inch at 10,000 pounds force. For BWR fuel elements this indicates smaller deflections, at equivalent "g" loadings, than were obtained in the drop tested Model 51032-1 package. The force deflection curve is shown in Figure V.4.

V.5 Integrity of the Separator Blocks

The Model 51032-1a package separator blocks have been tested on the Tinius-Olsen compression machine. The test established that buckling strength of the gusset plate was greater than the 30,000 pound limit of the machine. The plate did not buckle and there was no significant block deformation. Without the gusset plate, significant deformation occurs at 16,000 pounds force. The attachment of the separator blocks to the strongback was also strengthened. Notably, Grade 8 bolts with a shear strength of 90,000 psi are used instead of carbon steel bolts with a shear strength of 38,400 psi and 3/8 inch thick washers are added in place of 1/8 inch thick washers to distribute the load over a larger area of the strongback channel.

V.6 The Influence of Dynamic Loading on Component Performance

Steel shows some increase in tensile strength under impact loading*. The ductility under some loading conditions increases and for other conditions decreases. The increases in strength are mainly in the range of ten percent to twenty percent. Davies and Magee studied a wide range of materials, including Types 302 and 310 stainless steel, at room temperature and found "no significant change in tensile ductility over the investigated strain rate range", which included the range of interest for the impact loadings in container drop tests. Type 310 stainless steel showed a small increase in strength with higher strain rate, while for Type 302 the strength was independent of strain rate. At elevated temperatures, Steichen found an increasing trend in ductility in Types 304 and 316 stainless steel towards the upper end of the strain rate range, which did not quite reach the range of interest for this application.

Relative to the performance evaluation of the Model 51032-1a packaging, it is only important that the dynamic effects do not alter the designed bolt deformation mode, (i.e., that the stainless steel shock mount bolts deform while the high-strength carbon steel bolts do not fail). Available data supports this result. With respect to energy dissipation in the stainless steel bolt distortion, the data suggests a small increase in energy dissipation capability under impact loads.

---

* See, for example, R. G. Davies and C. L. Magee, Journal of Eng. Mat. and Tech., April 1975, pages 151-155, and J. M. Steichen, High Strain Rate Mechanical Properties of Types 304 and 316 Stainless Steel, HEDL-TME-71-164, November 1971.

FIGURE V.1

SHOCK MOUNT LOADING CHARACTERISTICS

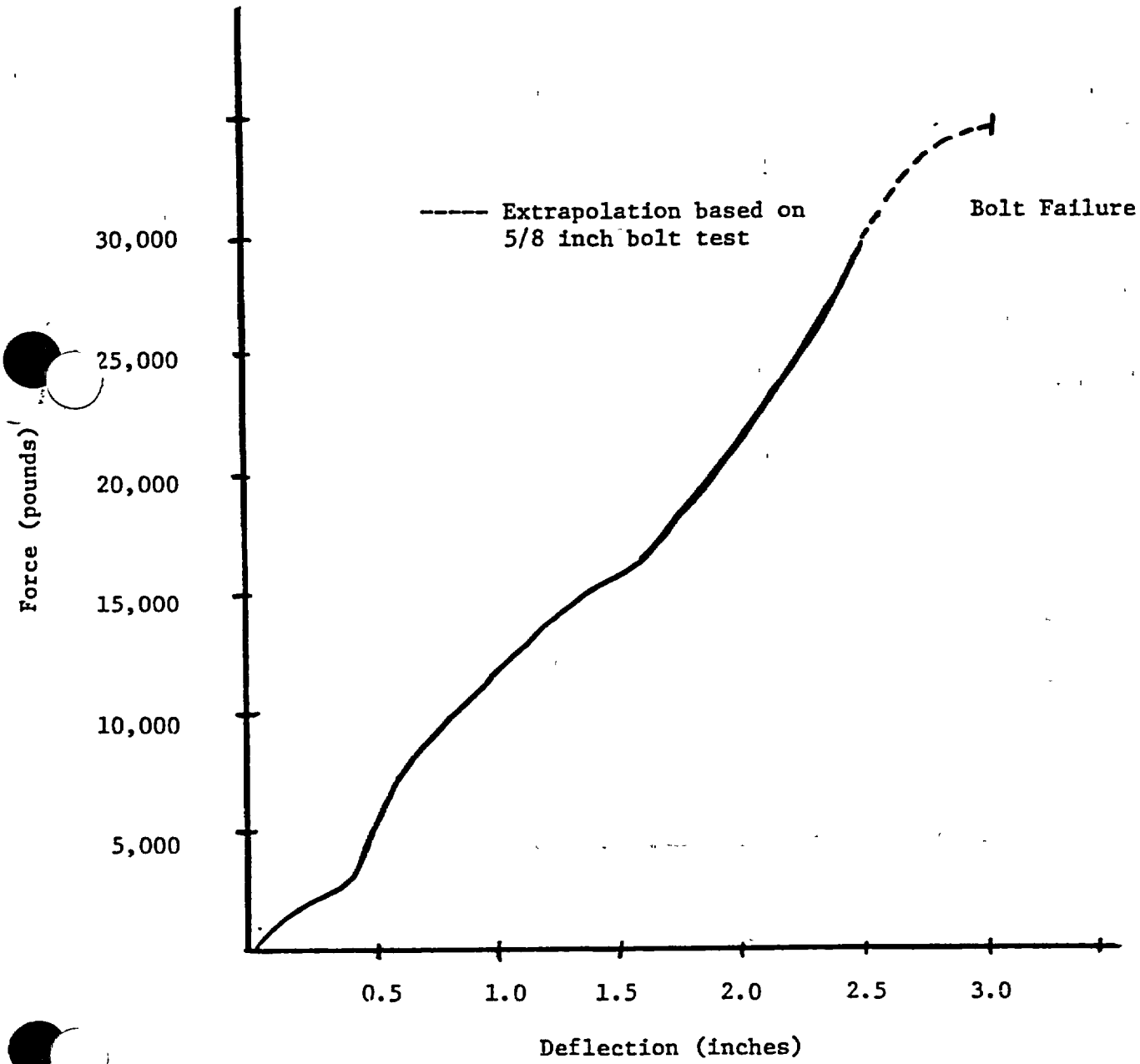


FIGURE V.2

SHOCK MOUNT BOLT TENSILE STRESS-STRAIN CURVE

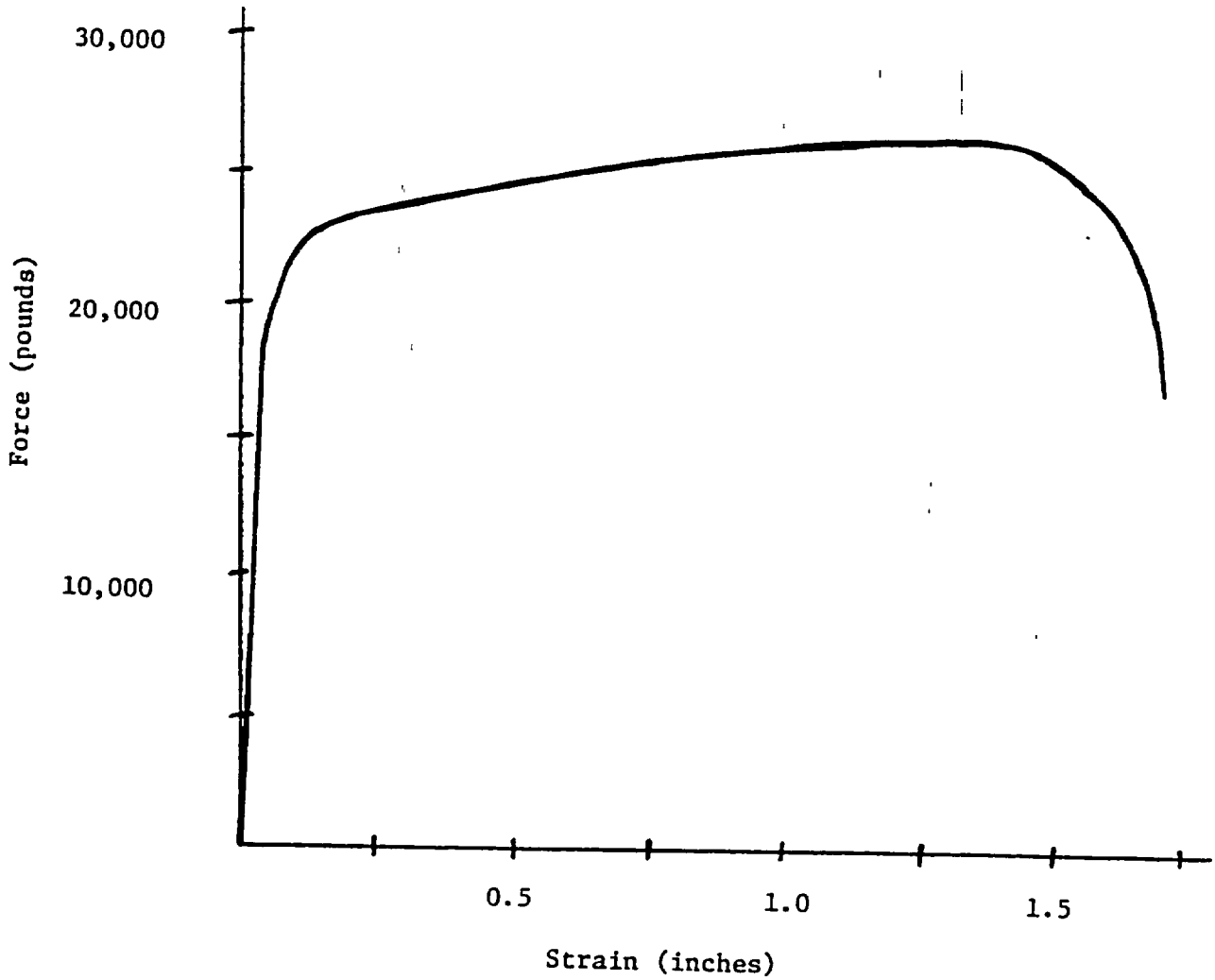
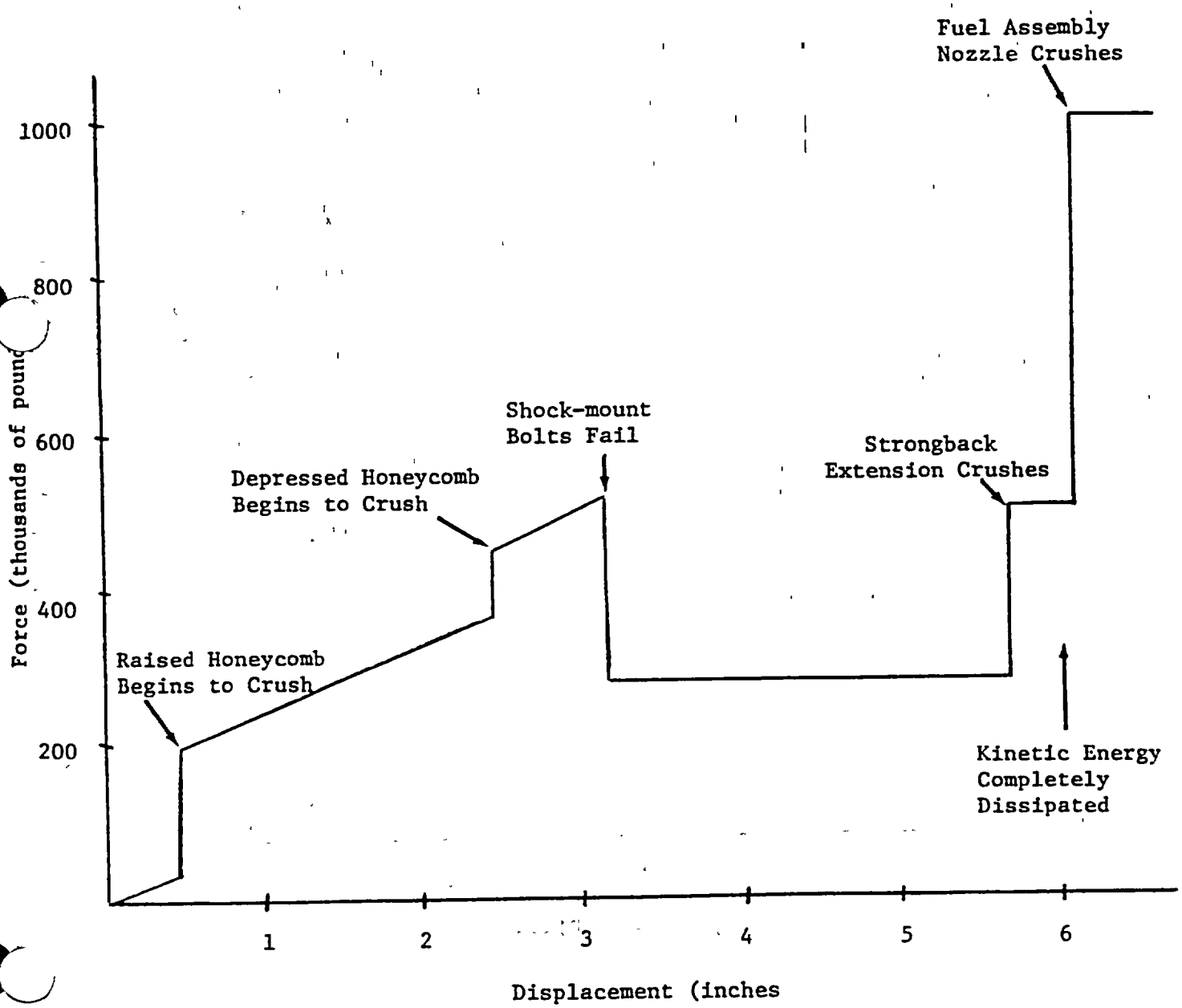


FIGURE V.3

LOADED STRONGBACK STOPPING FORCE IN AN END DROP



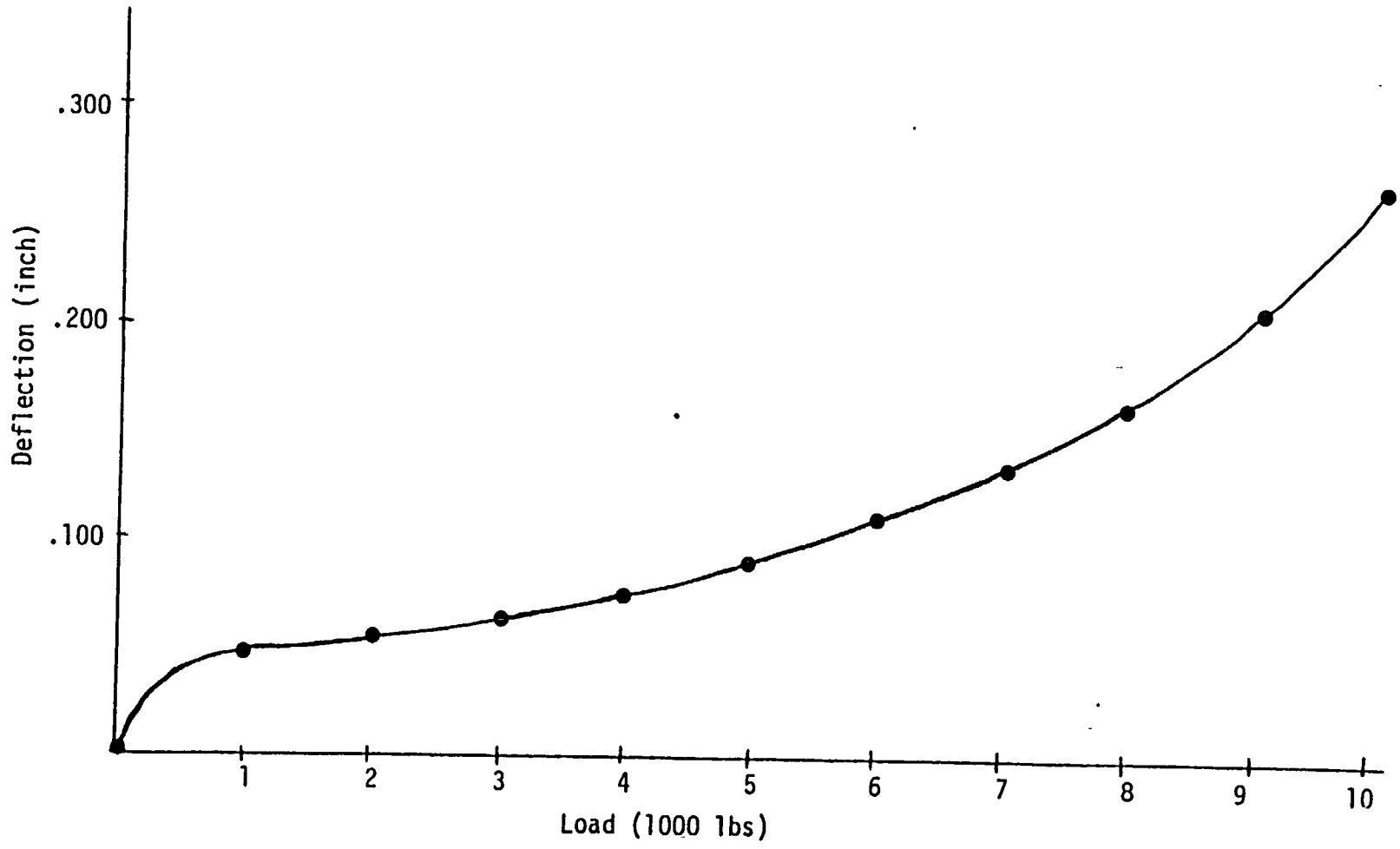


Figure V.4

Force Deflection Curve For
Model 51032-1a Alum[illegible]n Clamp Assembly

APPENDIX VI

FUEL ROD DROP TEST REPORT

FUEL ROD DROP TEST

GENERAL

Of interest to persons involved with the shipment of fuel assemblies is the degree of containment and protection provided by the fuel rods themselves. To get a feel for containment and protection provided it was decided to subject individual fuel rods to the hypothetical accident conditions detailed in Appendix B of 10CFR71.

This test consisted of subjecting three fuel rods to the specified 30 ft. drop test. Test conditions, methods, procedures and results are discussed below.

FUEL ROD DESCRIPTION

The three fuel rods used in this test were earlier fabricated and employed for certain quality control examinations. As such, one rod had been autoclaved, and two of the rods had small holes drilled through the cladding near the plugs; one rod had a single 0.016 inch hole, and the other rod had a 0.125 inch hole. Upon completion of the quality control examinations, these fuel rods were to be scrapped; instead, they were turned over to Nuclear Safety for the subject test. The physical characteristics of the fuel rods are defined below:

Overall Length:	158.148 inches (nominal);
Fuel Length:	144 inch (nominal);
Fuel:	Sintered depleted UO_2 pellets;
Cladding:	36.5 (nominal) mil zircaloy-2;
Tube O.D.:	0.570 inches (nominal).

All three fuel rods had been fabricated in accordance with standard process specifications, and contained the standard internal hardware components, and, as such, were prototypical of rods which will make up typical fuel assemblies.

TEST CONDITIONS

Since the fuel rods contained depleted uranium, each rod was individually encased in a thin polyethylene tube, which as taped to the two end plugs with masking tape. This was done to provide secondary containment in the event of rod rupture as a result of the impact.

The rods were dropped (by hand) from a height of two feet above the parapet of the UO_2 building to the concrete pad (8 inches thick) at the south side of the building, thus constituting a 30 foot drop to an unyielding surface.

METHODS AND PROCEDURES

The three fuel rods (individually encased in thin polyethylene tubing) were held, one at a time, out over the edge of the building such that the lowest part of the rods were 30 feet above the concrete pad -- and released (see photo No. 1).

ROD NO. 1 (45° L Drop)

This fuel rod was not autoclaved and had a 0.016 inch hole drilled in the plenum region (upper end). The rod was held at a 45° angle with the lower end 30 ft. above the concrete pad, and dropped such that the lower end plug (no plenum spring) was the first part of the fuel rod to make contact with the pad.

ROD NO. 2 (Flat Drop)

This fuel rod was not autoclaved and had a 0.125 inch hole drilled in the plenum region (upper end). The rod was held horizontal 30 ft. above the concrete pad and dropped; the fuel rod was in this same position when it made contact with the pad.

ROD NO. 3 (straight drop)

This fuel rod had been autoclaved in accordance with standard process specifications; no holes had been drilled in this rod. This rod was held vertical with the lower end 30 ft. above the concrete pad, and dropped such that the lower end plug (no plenum spring) was the first part of the fuel rod to make contact with the pad.

RESULTS

Each fuel rod, after being subjected to the afore described tests, was inspected for damage and release of radioactive material. In no case was there any release of radioactive material (as determined by surveys with alpha sensitive instruments), nor were there any cracks in either the tubing or the welds detected.

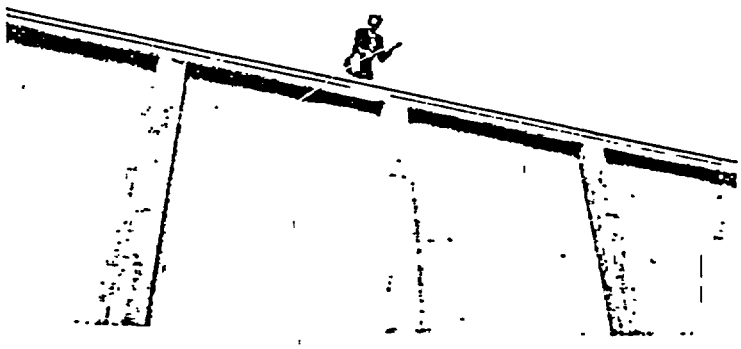
Photographs were taken of the fuel rods subjected to these drop tests; these appear, along with brief discussions, on the following pages.

Witnesses: H. Paul Estey H. Paul Estey

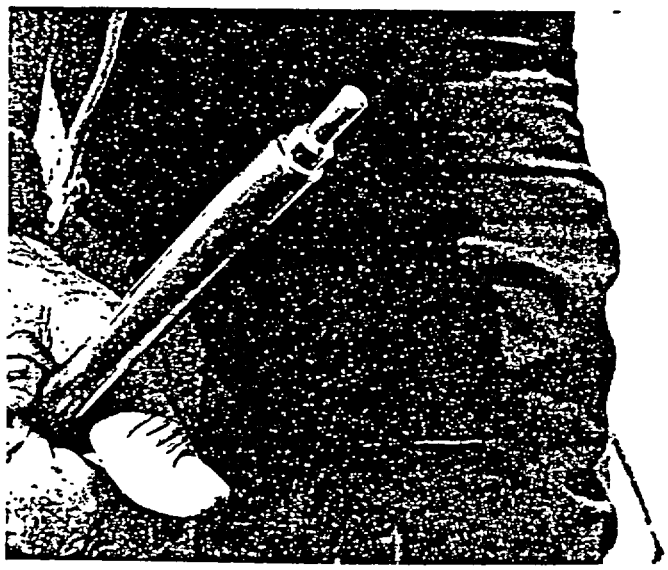
W. S. Nechodom W S Nechodom

R. L. Miles R. L. Miles

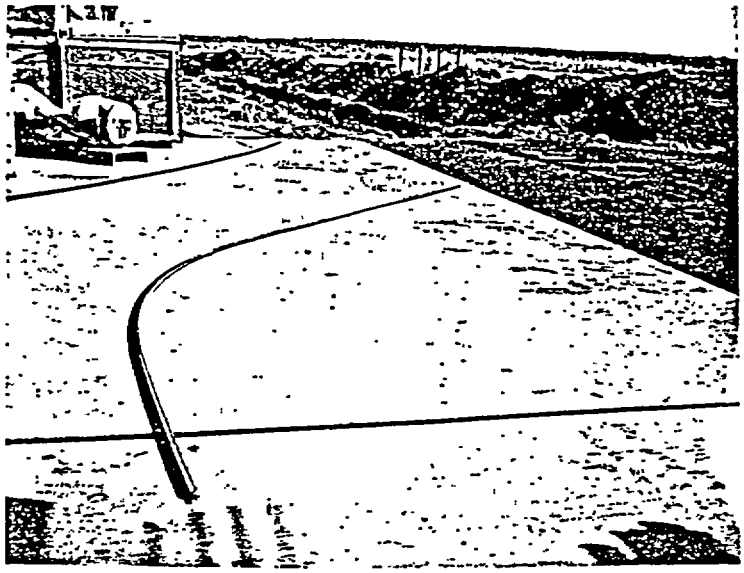
E. L. Foster E. L. Foster



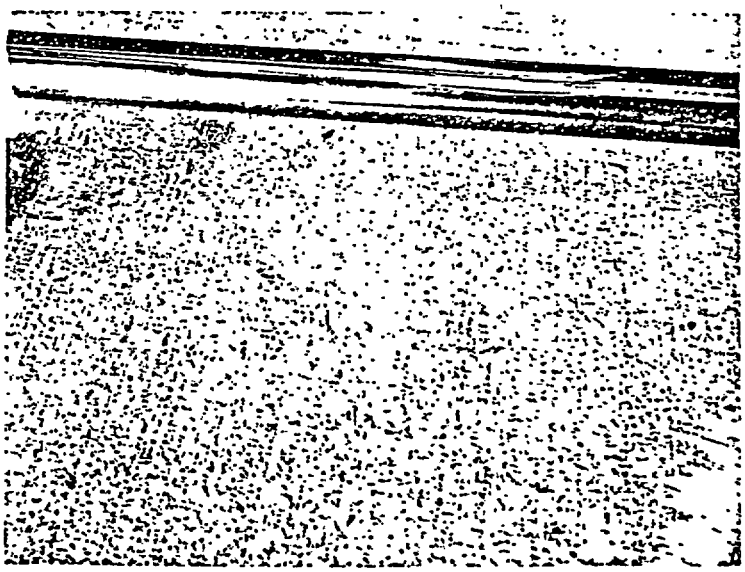
Preparation for dropping fuel rods from the roof of the UO_2 building to the concrete pad at the south end of the building.



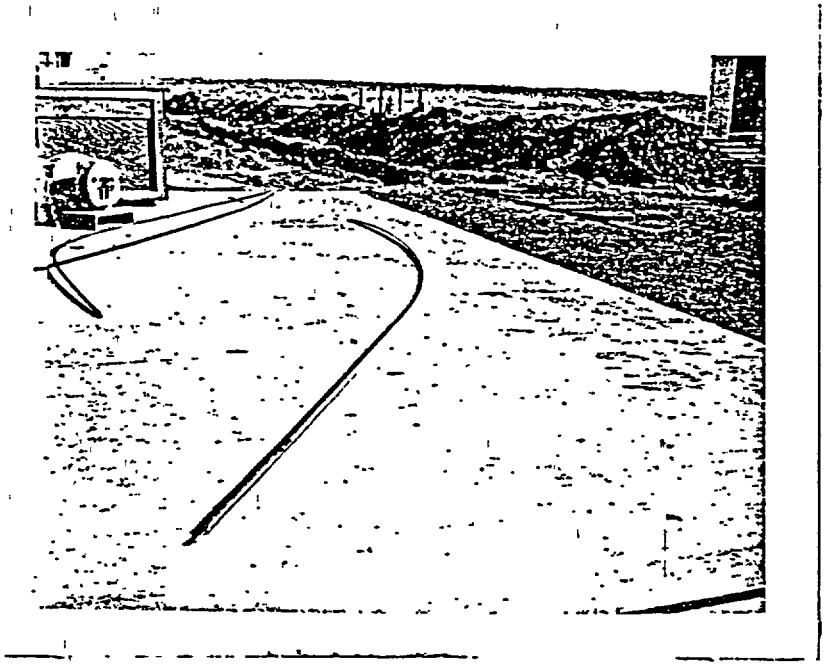
Rod No. 1: This photo shows the lower end plug and weld region of the fuel rod dropped at a 45° angle. The tip of the lower end plug was deformed.



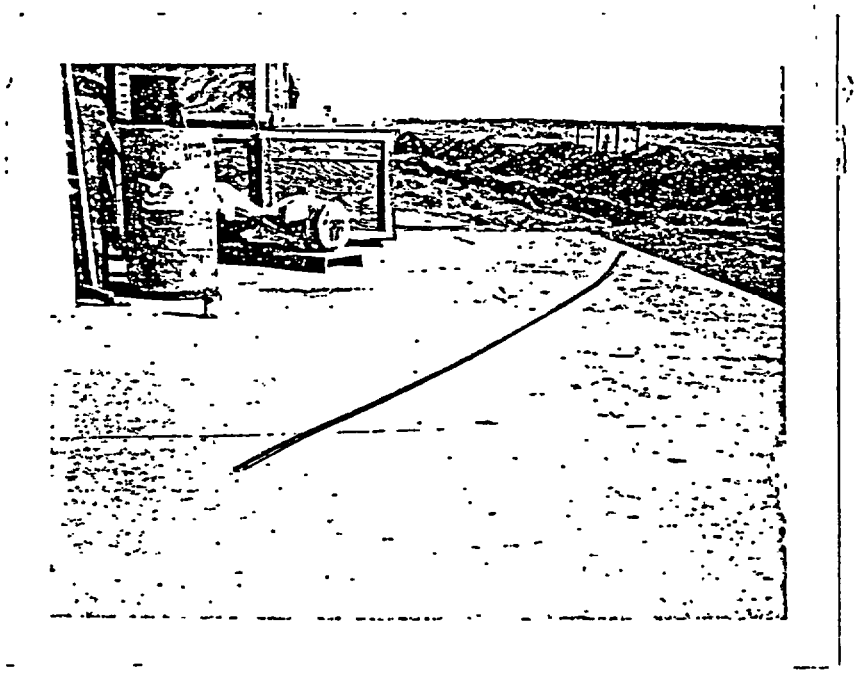
Rod No. 1: This photo shows the warp developed in the fuel rod dropped at a 45° angle.



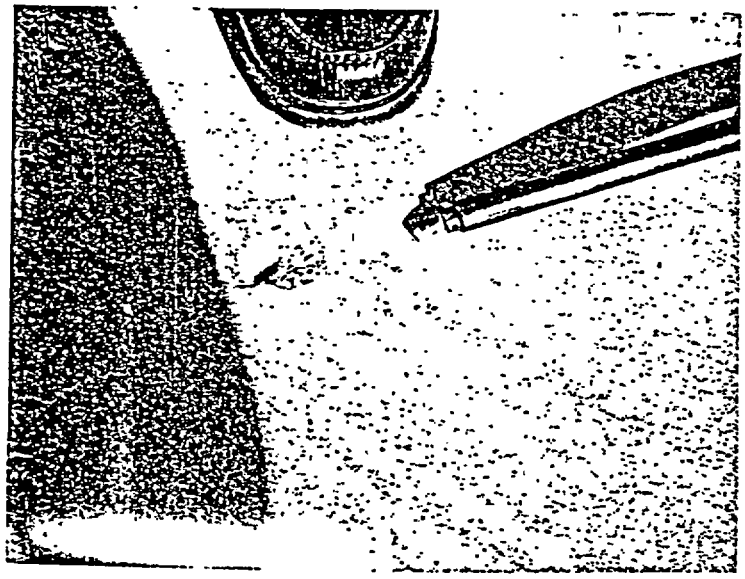
Rod No. 2: This photo shows abrasion of the rod surface of the fuel rod dropped in the horizontal (flat) position.



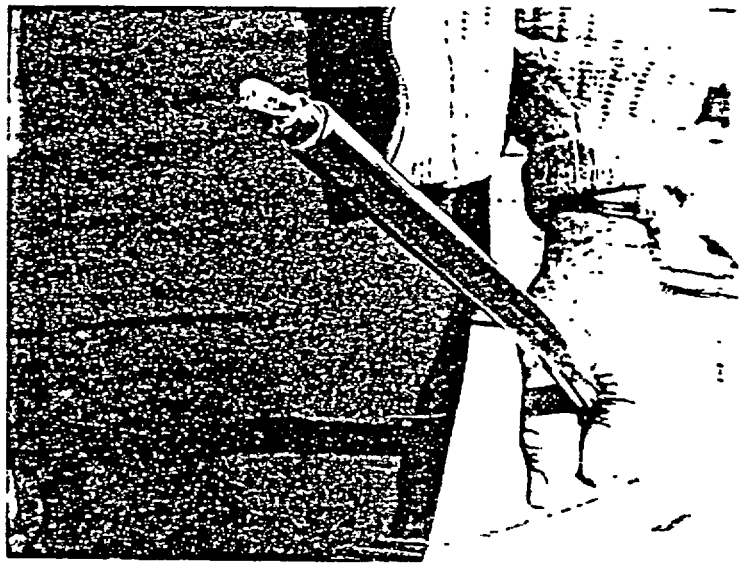
Rod No. 2: This photo shows the warp developed in the fuel rod dropped in the horizontal (flat) position.



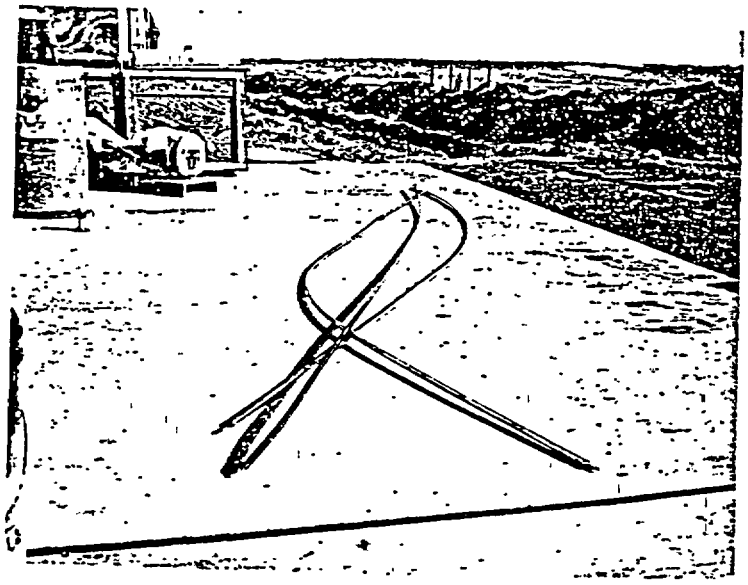
Rod No. 3: This photo shows the warp developed in the fuel rod dropped in the vertical (straight) position.



Rod No. 3: This photo shows the damage done to the concrete pad, and the lower end plug, caused by the fuel rod dropped in the vertical (straight) position.



Rod No. 3: This photo shows the lower end plug and weld region of the fuel rod dropped in the vertical (straight) position.



Rod Nos. 1, 2 & 3: This photo shows all three fuel rods together -- depicting the relative warps developed as the results of the individual drop tests.

SECOND FUEL ROD DROP TEST

GENERAL

Additional information was desired on the degree of containment of radioactive materials and environmental protection afforded by the fuel rods themselves during the transport of nuclear fuel assemblies. The object of this test was to determine the upper range of probable damage that could be expected as a result of impact with an internal component of the packaging.

This test consisted of dropping (individually) three loaded fuel rods 30 feet onto a 4" x 4" x 3/8" steel angle positioned on a concrete pad. Test conditions, methods, procedures and results are discussed below.

FUEL ROD DESCRIPTION

The test rods are those described in the Fuel Rod Description in JN-55. These same rods were previously subjected to various 30 foot drop tests as described in JN-55.

TEST CONDITIONS

As stated above, the test rods had been used in previous tests, and, as such, exhibited bends and warps prior to being subjected to the following tests. However, none of the rods exhibited any cracks or other enclosure failure (as described in the Results section of JN-55).

Since the fuel rods contain depleted uranium, each rod was individually encased in a thin polyethylene tube, which was taped to the two end plugs with masking tape. This was done to provide secondary containment in the event of rod rupture as a result of the impact.

The rods were hand-dropped (see Photo No. 1 of JN-55) from a height of two feet above the parapet of the UO_2 building onto a 4" x 4" x 3/8" steel angle set on a concrete pad 30 feet below at ground level.

METHODS AND PROCEDURES

The three loaded fuel rods (individually encased in thin polyethylene tubing) were held, one at a time, out over the edge of the building and allowed to drop (in the horizontal position) across a 4" x 4" x 3/8" steel angle set on a concrete pad 30 feet below.

RESULTS

Following the completion of the drops, the three rods were positioned upon the steel angle (Photo No. 1) to show how they struck the angle and the pad, and to show the deformations inflicted. The deformations inflicted

by these drops are not truly depicted in Photo No. 1 as all of the rods exhibited deformations as the results of previous drop tests (reference JN-55).

Photo No. 2 shows the points (arrows) of impact of each of the fuel rods upon the steel angle.

Photo No. 3 shows the overall warping and bending of the fuel rods resulting from the combined tests. The arrows locate the points of impact with the steel angle in the most recent tests.

Each fuel rod, after being subjected to the above described tests, was inspected for damage and surveyed for release of radioactive material. In no case was there any release of radioactive material (as determined by surveys with alpha sensitive instruments), nor were there any cracks detected in either the tubing or the welds.

Witnesses: H. Paul Estey H. Paul Estey

J. D. Cudmore James D. Cudmore

R. L. Miles R. L. Miles

R. E. Daling Roger E. Daling

PHOTO NO. 1

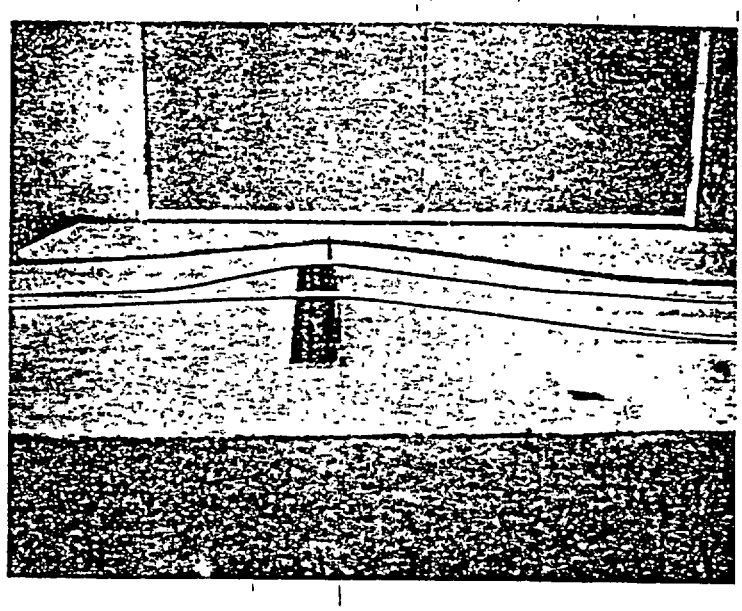


PHOTO NO. 2

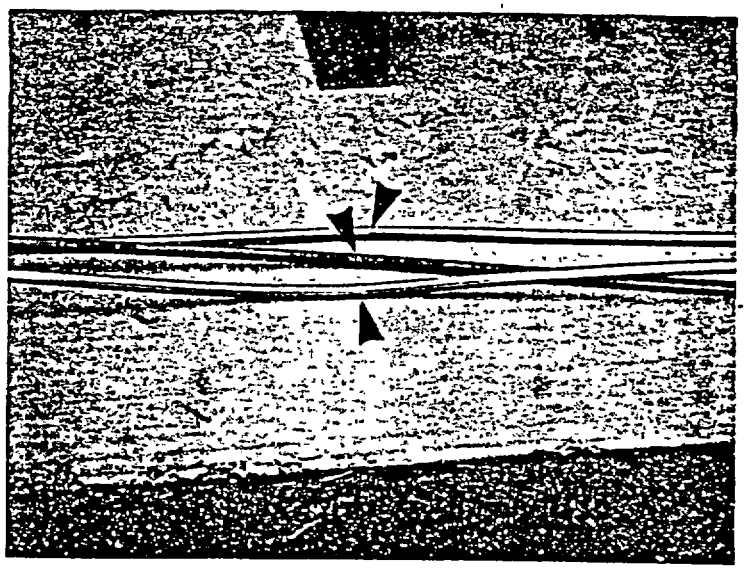
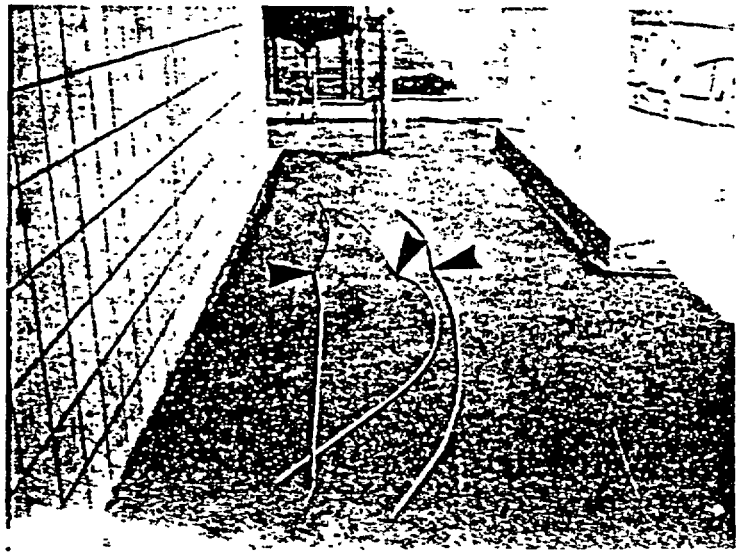


PHOTO NO. 3



APPENDIX VII

CRITICALITY SAFETY ANALYSIS OF T15X15 FUEL

TABLE OF CONTENTS

Section Page

1. INTRODUCTION 1
   1.1 Summary 1

2. ANALYSIS METHODOLOGY 3
   2.1 Nuclear Analysis Methodology 3
   2.2 Computer Codes and Databases Used 3
   2.3 Cross Section Preparation 3
   2.4 Benchmarking 3

3. COMPONENT DESCRIPTION AND ANALYSIS 6
   3.1 Standard T15X15 Fuel Assembly 7
      3.1.1 Computer Model Description 9
      3.1.2 Analysis of Single Container with Standard T15X15 Fuel Assembly 10
      3.1.3 Analysis of Array of Undamaged Containers (Normal Conditions) with Standard Trino Fuel Assembly 16
      3.1.4 Analysis of Array of Damaged Containers (Accident Conditions) with Standard Trino Fuel Assembly 22
   3.2 T15X15 Cruciform Assembly 30

4. QA REVIEW DESCRIPTION 33

5. REFERENCES 34

LIST OF TABLES

Table VII-1 Summary Table of Criticality Evaluation for the Model 51032-1 Shipping Container 2

Table VII-2 Benchmark Data Used for Determination of Calculation Bias for the Model 51032-1 Shipping Container Analysis 5

Table VII-3 Model 51032-1 Major Components and Comparison of Actual vs. Modeled Conditions 6

Table VII-4 Comparison of Actual vs. Modeled Conditions for Standard T15X15 Fuel Assembly 7

Table VII-5 Drop Test Results vs. Damaged Conditions Modeled 10

Table VII-6 Single Model 51032-1 Shipping Container, Interspersed Moderator Sensitivity Study, 15x15 Array of Rods in Bundles, Large Diameter (0.350") Pellets 12

Table VII-7 Single Model 51032-1 Shipping Container, Interspersed Moderator Sensitivity Study, 15x15 Array of Rods in Bundles, Small Diameter (0.332") Pellets 13

Table VII-8 Single Model 51032-1 Shipping Container, Interspersed Moderator Sensitivity Study, Standard Trino Assembly, Large Diameter (0.350") Pellets 14

Table VII-9 Single Model 51032-1 Shipping Container, Interspersed Moderator Sensitivity Study, Standard Trino Assembly, Small Diameter (0.332") Pellets 15

Table VII-10 Infinite Array of Model 51032-1 Shipping Containers, Undamaged Conditions, Interspersed Moderator Sensitivity Study, 15x15 Array of Rods in Bundles, Large Diameter (0.350") Pellets 17

Table VII-11 Infinite Array of Model 51032-1 Shipping Containers, Undamaged Conditions, Interspersed Moderator Sensitivity Study, 15x15 Array of Rods in Bundles, Small Diameter (0.332") Pellets 18

Table VII-12 13x13x3 (507 Total) Array of Model 51032-1 Shipping Containers, Undamaged Conditions, Interspersed Moderator Sensitivity Study, 15x15 Array of Rods in Bundles, Large Diameter (0.350") Pellets 19

Table VII-13 13x13x3 (507 Total) Array of Model 51032-1 Shipping Containers, Undamaged Conditions, Interspersed Moderator Sensitivity Study, 15x15 Array of Rods in Bundles, Small Diameter (0.332") Pellets 20

Table VII-14 15x15x3 (675 Total) Array of Model 51032-1 Shipping Containers, Undamaged Conditions, 7 vol% Interspersed Moderator Between Containers, Polyethylene Sensitivity Study, 15x15 Array of Rods in Bundles, Large Diameter (0.350") Pellets 21

Table VII-15 10x10x2 (200 Total) Array of Model 51032-1 Shipping Containers, Damaged Conditions, Bundles and Strongbacks Centered in Containers, Interspersed Moderator Sensitivity Study, 15x15 Array of Rods in Bundles, Large Diameter (0.350") Pellets 25

Table VII-16 10x10x2 (200 Total) Array of Model 51032-1 Shipping Containers, Damaged Conditions, Bundles and Strongbacks Shifted in Containers, Interspersed Moderator Sensitivity Study, 15x15 Array of Rods in Bundles, Large Diameter (0.350") Pellets 26

Table VII-17 10x10x2 (200 Total) Array of Model 51032-1 Shipping Containers, Damaged Conditions, Bundles and Strongbacks Centered in Containers, Interspersed Moderator Sensitivity Study, 15x15 Array of Rods in Bundles, Small Diameter (0.332") Pellets 27

Table VII-18 10x10x2 (200 Total) Array of Model 51032-1 Shipping Containers, Damaged Conditions, Bundles and Strongbacks Shifted in Containers, Interspersed Moderator Sensitivity Study, 15x15 Array of Rods in Bundles, Small Diameter (0.332") Pellets 28

Table VII-19 12x12x2 (288 Total) Array of Model 51032-1 Shipping Containers, Damaged Conditions, Bundles and Strongbacks Shifted in Containers, Fully Flooded Interspersed Moderator, Polyethylene Sensitivity Study, 15x15 Array of Rods in Bundles, Small Diameter (0.332") Pellets 29

Table VII-20 Component Dimensions for Trino Cruciform Assembly 32

LIST OF FIGURES

Figure VII-1 Standard T15X15 Assembly Layout 8

Figure VII-2 Bundles and Strongbacks Shifted within Containers under Damaged Conditions 24

Figure VII-3 T15X15 Cruciform Assembly Layout 31

1. INTRODUCTION

This supplemental Criticality Safety Evaluation (CSE) provides the criticality safety basis for adding a fifth category of fuel (T15X15) to the allowed payloads in the model 51032-1 shipping container. It also provides justification for changing the clad and gap requirements for the existing four fuel categories based on the need to include cruciform assemblies to be shipped with the T15X15 payload. The four fuel categories allowed by the current Certificate of Compliance (COC; Reference 5) were analyzed for criticality safety in Reference 6.

Section 2 of this CSE details the methodologies used for the criticality analysis. Component description and analysis are provided in Section 3. Section 4 contains the Quality Assurance (QA) review and comment resolution. Section 5 documents the references. Sample computer inputs are provided in Appendix VII-A.

1.1 *Summary*

This CSE shows that sufficient margin to safety exists to add the following fuel category to the allowed payloads for the model 51032-1 shipping container:

- Unirradiated fuel assemblies consisting of uranium dioxide fuel pellets clad in zircalloy or stainless steel tubes. Uranium is enriched to a maximum of 5.0 w/o in the U-235 isotope. The pellets must have a nominal OD not less than 0.332 inch and not greater than 0.350 inch. The sum of the cladding wall thickness and the pellet-clad radial gap must not be less than 0.016 inch. The maximum length of the active fuel region is 196 inches. Fuel assemblies consist of 208 fuel rods in a 15x15 array with a nominal fuel rod pitch of 0.527 inch and a maximum assembly cross section of 7.91 inches square. The rod arrangement is shown in Figure VII-1. The transport index for this category is 0.4.

This CSE also justifies the following change to the clad and pellet-clad gap requirement for the existing four fuel categories in the current COC:

- The sum of the cladding wall thickness and the pellet-clad radial gap must not be less than 0.023 inch.

A summary of the results in this CSE is provided in.

Table VII-1 Summary Table of Criticality Evaluation for the Model 51032-1 Shipping Container

Description of Most Reactive Case	k_{eff}	σ	bias	$k_{eff} + 2\sigma + bias$
Standard Trino Fuel Assembly				
Single Package with standard T15X15 fuel assembly	0.9044	0.0037	NA	0.9117
15x15x3 Array of Undamaged Packages (675 Containers) with standard T15X15 fuel assembly	0.8601	0.0030	NA	0.8661
12x12x2 Array of Damaged Packages (288 Containers) with standard T15X15 fuel assembly	0 9073	0.0033	NA	0.9139

2. ANALYSIS METHODOLOGY

2.1 *Nuclear Analysis Methodology*

Monte Carlo techniques were used in this analysis. The sensitivities of pellet diameter, interspersed moderation, number of rods in a bundle, and placement of low density polyethylene inside the containers were evaluated.

2.2 *Computer Codes and Databases Used*

The following codes and cross section libraries are part of the SCALE 4.2 system of codes (Reference 1) placed on the SPC HP workstation SSL01.

```
791176    Jun 22 1994 11:36:41 o0o001.a (XSDRN)
545416    Feb 21 1994 10:25:06 o0o002.a (NITAWL)
516744    Feb 21 1994 10:14:38 o0o008.a (BONAMI)
1094280   Jun 22 1994 11:46:27 o0o009.a (KENO.Va)
112000    Feb 23 1994 15:16:47 albdata.bin
4256216   Feb 23 1994 14:40:21 pxs123.bin (123 group master cross section library)
362140    Feb 25 1994 16:54:21 pxs16.bin (16 group master cross section library)
9020996   Feb 23 1994 14:53:45 pxs218.bin (218 group master cross section library)
824404    Feb 23 1994 14:38:03 pxs27.bin (27 group master cross section library)
94400     Feb 23 1994 15:12:03 stdcomp.bin (standard comp. library)
44812     Feb 23 1994 15:14:40 wtdata.bin
287       Jul  7 1994 09:35:35 csas25
2295      Jul  7 1994 17:07:41 drva
```

2.3 *Cross Section Preparation*

BONAMI and NITAWL adjust the cross section data for the specific problem (e.g., perform resonance self-shielding corrections). The Hansen-Roach 16-energy group cross sections available in SCALE were used for all calculations.

2.4 *Benchmarking*

The bias and its standard deviation are calculated using the methods described in Reference 4. These methods use standard analysis of variance principles.

k_c is the value of k_{eff} that results from the calculation of benchmark experiments using a particular calculation method. This value represents a combination of theoretical techniques and numerical data. The value for k_c is the weighted average (grand average) of the average k_{eff} values for a series of benchmark cases that are applicable to the system being modeled. Each individual benchmark case is weighted by the inverse of the k_{eff} variance (square of standard deviation).

The average value of the variance is taken as the "within class" variance. The variance of the average k_{eff} data, weighted as for the grand average, is taken as the "between class" variance. Since the true value for all benchmark cases is assumed to be 1.0 (critical), the class effect (the change in average k_{eff} from case to case) is also the bias and the variance of the class effect is the variance of the bias.

The calculation bias, Δk_b, is therefore calculated as $1-\Delta k_c$. A negative bias indicates conservative calculation results.

The SCALE 4.2 system of codes was developed for use by the USNRC and its licensees. SPC benchmarking of SCALE 4.2 on HP Workstations includes critical experiments of 4.31% enriched assemblies from NUREG/CR-0073 (Reference 2) which were modeled using the same methodology used in these calculations.

A bias estimate based on 23 pooled cases was calculated from the 16-group data in Table 12 of Reference 3 and is -0.00321 ± 0.00261. Again, negative bias indicates conservative results. The benchmark data used to calculate this bias is provided in Table VII-2

Table VII-2 Benchmark Data Used for Determination of Calculation Bias for the Model 51032-1 Shipping Container Analysis

CaseID	Average k_{eff}	σ
a-c001x	1.00355	0.00249
a-c002x	1.00905	0.00257
a-c003x	1.00845	0.00252
a-c004	1.00435	0.00265
a-c005a	1.00244	0.00265
a-c005b	1.00198	0.00252
a-c006a	1.00188	0.00236
a-c006b	0.99954	0.00237
a-c007a	1.00425	0.00247
a-c007x	1.00788	0.00253
a-c008a	1.00148	0.00231
a-c008x	1.00109	0.00242
a-c009a	1.00062	0.00233
a-c010a	1.00481	0.00239
a-c011a	1.00356	0.00275
a-c012a	1.00063	0.00244
a-c013a	1.00142	0.00240
a-c013x	1.01149	0.00227
a-c014a	0.99991	0.00241
a-c014x	1.00732	0.00259
a-c029a	0.99956	0.00242
a-c030a	1.00278	0.00257
a-c031a	0.99736	0.00239

3. COMPONENT DESCRIPTION AND ANALYSIS

The model 51032-1 shipping container major components and their actual and modeled dimensions are provided in Table VII-3. Except for some rubber gaskets, the entire container is constructed of carbon steel. Therefore, only the results of the drop tests need to be considered for decreased dimensions during damaged conditions, i.e., there is no wood or plastic to burn away, which could decrease spacing between fuel bundles and/or containers.

This section provides an analysis for shipping T15X15 fuel bundles in model 51032-1 shipping containers. Descriptions of the payloads and modeled conditions are provided in subsections below.

Table VII-3 Model 51032-1 Major Components and Comparison of Actual vs. Modeled Conditions

Parameter	Actual	Modeled	Reference for Actual Conditions
SEPARATOR BLOCKS			
Outer Width	6" min	6"	DWG EMF-309,813 R-0
Outer Height	8 ± 1/2"	7.5"	"
Length	9 ± 1/2"	8.5"	"
Steel Thickness	3/8 ± 1/16"	0.3125"	"
Number in Container	5 min	5	EMF-52, Rev. 6, p. 2-6
STRONGBACK ASSEMBLY			
Width	24-7/8 ± 5/16"	24.5625"	DWG EMF-303,898 R-4
Height	12-1/2 ± 3/4"	11.5625"	"
Length	196 ± 1"	197"	"
Steel Thickness	1/4 ± 1/16"	0.1875"	"
CONTAINER STEEL SHELL			
Inner Radius	19-7/8 ± 3/8"	19.5"	DWG EMF-303,360 R-5
Outer Length	216-1/4 ± 1-5/16	197"	"
Steel Thickness	11 ga	0.09568" (80% of nominal 11 ga)	"
Container C-C Spacing	> 42-1/8 ± 3/8"	41.75" (undam) 40.75" (dam)	DWG EMF-309,813 R-0

3.1 *Standard T15X15 Fuel Assembly*

The layout of a standard T15X15 fuel assembly is shown in Figure VII-1. The reference for this assembly layout is provided in Appendix VII-B. A comparison of actual and modeled dimensions for the standard T15X15 fuel assembly are provided in Table VII-4.

Table VII-4 Comparison of Actual vs. Modeled Conditions for Standard T15X15 Fuel Assembly

Parameter	Actual	Modeled	Reference for Actual Conditions
STANDARD ROD			
Pellet Diameter	0.350"	0.350"	See Appendix VII-B
Theoretical Density	95%	95% 98% in some cases	
Diametral Gap	0.005"	0.016" (clad + gap thickness; modeled as void)	
Clad Thickness	0.0151" ± 5%		
Rod OD	0.385"	0.382"	
THICK CLAD ROD			
Pellet Diameter	0.332"	0.332"	See Appendix VII-B
Theoretical Density	95%	95% 98% in some cases	
Diametral Gap	0.005"	0.016" (clad + gap thickness; modeled as void)	
Clad Thickness	0.024" ± 5%		
Rod OD	0.385"	0.364"	
ASSEMBLY			
Enrichment	4.47 wt% ^{235}U	5 wt% ^{235}U	See Appendix VII-B
Assembly Cross Section	7.909" x 7.909" max	7.909"	PECO DWG 302951D, Rev. 0101
Rod Array Size	15x15	15x15	See Appendix VII-B
Nominal Rod Pitch	0.52727"	0.52727"	Calculated from Assembly Cross Section and Rod Array Size
Active Fuel Length	< 108.039"	197"	See Appendix VII-B

	T												T
T													
												T	T
							X					T	
						T	T					T	
T						T							

	Standard Rod	T	Thick Clad Rod	X	Empty Location

Figure VII-1 Standard T15X15 Assembly Layout

3.1.1 Computer Model Description

The model 51032-1 shipping container was modeled with the dimensions shown in Table VII-3. Except for the length of the strongback assembly, all components were modeled at minimum dimensions. This was done to minimize the amount of steel in the model and to provide a minimum credible spacing between containers. Maximizing the length of the strongback assembly increases the amount of fissile material on the strongback, but concurrently increases the amount of steel (a poison) in the container. Using the maximum strongback length vs. the minimum length adds 2.31 kg carbon steel to the model. However, modeling the strongback thickness at the minimum value over the entire length (highly conservative), removes over 74 kg of carbon steel from the model. This alone more than makes up for the added steel due to the increased length. In addition, all other steel components (separator blocks, clamps, exterior bracing) are either modeled at minimum dimensions or are completely ignored. The KENO model uses approximately 597 kg of carbon steel in a single model 51032-1 container. A single model 51032-1 shipping container prepped for bundle loading actually weighs at least 4100 lbs (1860 kg). Note that a very small amount of this actual weight is due to rubber gasket material. This shows that the amount of steel used in the model is less than that actually contained in the model 51032-1 shipping containers (conservative).

Appendix IV of Reference 6 provides the results of the 30-foot drop tests. A summary of the worst case results, along with the modeled damaged conditions, is provided in Table VII-5.

Table VII-5 Drop Test Results vs. Damaged Conditions Modeled

Parameter	Horizontal (x) Drop Test Result	Vertical (z) Drop Test Result	Modeled in Damaged Conditions
Horizontal (x) Offset of Strongback	0.875"	1.25"	1.5"
Vertical (y) Offset of Strongback	2.75"	0.5"	3.0"
C-C Container Spacing Affected by Damage to Outer Container	No significant change	No significant change	1" reduction in C-C spacing

The standard T15X15 assemblies were modeled with the dimensions shown in Table VII-4. Each of the pellet diameters was used (in separate sets of calculations). Instead of explicitly modeling the pellet-clad gap and the clad, a bounding minimum (conservative) clad+gap thickness of 0.016" was used in the model. This 0.016" thick region was modeled as void. Modeling the clad and gap in this manner results in a smaller outer rod diameter than actually exists. However, the amount of moderator within the assembly is thereby maximized.

Full water reflection is used around the container in the single container calculations and around the array in the array calculations. No pathway for preferential flooding has been identified. Fuel bundles are held in place with clamps. If polyethylene sheathing is used, the current COC requires that it be open on each end.

3.1.2 Analysis of Single Container with Standard T15X15 Fuel Assembly

Calculations were performed for a single model 51032-1 shipping container. The following sets of cases were analyzed, each varying interspersed moderation from dry to fully flooded:

- Bundles in container consist of 15x15 array of rods. The rods contain the large diameter pellets.
- Bundles in container consist of 15x15 array of rods. The rods contain the small diameter pellets.
- Bundles in container consist of the standard T15X15 assembly (15x15 array of rods with several empty locations; see Figure VII-1). The rods contain the large diameter pellets.

- Bundles in container consist of the standard T15X15 assembly (15x15 array of rods with several empty locations; see Figure VII-1). The rods contain the small diameter pellets.

The results of these calculations are provided in

Table VII-6 through Table VII-9. As shown in these tables, the maximum $k_{eff}+2\sigma$ is 0.91041, well below 0.95. The peak reactivity occurs with the small pellet diameter and at fully flooded conditions. The results also show that the bundles with a 15x15 array of rods are more reactive than the standard T15X15 assemblies. Therefore, the 15x15 bundles are used in the subsequent damaged and undamaged calculations.

Calculations were also performed to show that modeling the combination of clad+gap as void yields either identical or conservative results relative to explicitly modeling the clad and gap. The most reactive case from

Table VII-6 through Table VII-9 (case 15x15s.100.1) was used. This case was modified to explicitly model the clad as zircalloy and stainless steel, in separate cases. The results are summarized below and show that modeling the combination of clad+gap as void does indeed yield either identical or conservative results, i.e., the zircalloy clad model yields statistically identical results and the stainless steel clad model yields a slightly lower reactivity, as expected.

```
246075 Jul 29 06:43:21 1999 droa-15x15s.100.1Z    .90251   .00349   .90834   .90949
255555 Jul 29 09:25:20 1999 droa-15x15s.100.1S    .89976   .00350   .90561   .90676
```

Table VII-6 Single Model 51032-1 Shipping Container, Interspersed Moderator Sensitivity Study, 15x15 Array of Rods in Bundles, Large Diameter (0.350") Pellets

Filename (droa-?)	Vol% IM	k_{eff}	σ	$k_{eff} + 2\sigma$
15x15l.000.1	0	0.32410	0.00243	0.32896
15x15l.001.1	1	0.31857	0.00282	0.32421
15x15l.003.1	3	0.31822	0.00219	0.32260
15x15l.005.1	5	0.32985	0.00294	0.33573
15x15l.007.1	7	0.34569	0.00230	0.35029
15x15l.010.1	10	0.37629	0.00256	0.38141
15x15l.020.1	20	0.49832	0.00310	0.50452
15x15l.030.1	30	0.57982	0.00254	0.58490
15x15l.040.1	40	0.63519	0.00303	0.64125
15x15l.050.1	50	0.68659	0.00297	0.69253
15x15l.060.1	60	0.72974	0.00330	0.73634
15x15l.070.1	70	0.77600	0.00278	0.78156
15x15l.080.1	80	0.81175	0.00364	0.81903
15x15l.090.1	90	0.84854	0.00332	0.85518
15x15l.100.1	***100***	***0.89236***	***0.00372***	***0.89980***

Table VII-7 Single Model 51032-1 Shipping Container, Interspersed Moderator Sensitivity Study, 15x15 Array of Rods in Bundles, Small Diameter (0.332") Pellets

Filename (droa-?)	Vol% IM	k_{eff}	σ	$k_{eff} + 2\sigma$
15x15s.000.1	0	0.31945	0.00255	0.32455
15x15s.001.1	1	0.31211	0.00267	0.31745
15x15s.003.1	3	0.30852	0.00234	0.31320
15x15s.005.1	5	0.31767	0.00232	0.32231
15x15s.007.1	7	0.33161	0.00221	0.33603
15x15s.010.1	10	0.36639	0.00279	0.37197
15x15s.020.1	20	0.48974	0.00314	0.49602
15x15s.030.1	30	0.57853	0.00318	0.58489
15x15s.040.1	40	0.63714	0.00293	0.64300
15x15s.050.1	50	0.68970	0.00304	0.69578
15x15s.060.1	60	0.73319	0.00369	0.74057
15x15s.070.1	70	0.78160	0.00350	0.78860
15x15s.080.1	80	0.82792	0.00330	0.83452
15x15s.090.1	90	0.86715	0.00292	0.87299
15x15s.100.1	***100***	***0.90341***	***0.00350***	***0.91041***

Table VII-8 Single Model 51032-1 Shipping Container, Interspersed Moderator Sensitivity Study, Standard T15X15 Assembly, Large Diameter (0.350") Pellets

Filename (droa-?)	Vol% IM	k_{eff}	σ	$k_{eff} + 2\sigma$
trinol.000.1	0	0.31937	0.00276	0.32489
trinol.001.1	1	0.31224	0.00262	0.31748
trinol.003.1	3	0.31010	0.00235	0.31480
trinol.005.1	5	0.32153	0.00264	0.32681
trinol.007.1	7	0.33321	0.00248	0.33817
trinol.010.1	10	0.36554	0.00244	0.37042
trinol.020.1	20	0.48252	0.00287	0.48826
trinol.030.1	30	0.56310	0.00335	0.56980
trinol.040.1	40	0.61863	0.00302	0.62467
trinol.050.1	50	0.67204	0.00378	0.67960
trinol.060.1	60	0.71480	0.00322	0.72124
trinol.070.1	70	0.75696	0.00313	0.76322
trinol.080.1	80	0.79774	0.00299	0.80372
trinol.090.1	90	0.83706	0.00309	0.84324
trinol.100.1	***100***	***0.88372***	***0.00394***	***0.89160***

Table VII-9 Single Model 51032-1 Shipping Container, Interspersed Moderator Sensitivity Study, Standard T15X15 Assembly, Small Diameter (0.332") Pellets

Filename (droa-?)	Vol% IM	k_{eff}	σ	$k_{eff} + 2\sigma$
trinos.000.1	0	0.30480	0.00238	0.30956
trinos.001.1	1	0.30186	0.00245	0.30676
trinos.003.1	3	0.30061	0.00231	0.30523
trinos.005.1	5	0.30351	0.00222	0.30795
trinos.007.1	7	0.32660	0.00224	0.33108
trinos.010.1	10	0.36083	0.00245	0.36573
trinos.020.1	20	0.47831	0.00283	0.48397
trinos.030.1	30	0.55705	0.00282	0.56269
trinos.040.1	40	0.62657	0.00332	0.63321
trinos.050.1	50	0.67334	0.00303	0.67940
trinos.060.1	60	0.72378	0.00331	0.73040
trinos.070.1	70	0.76653	0.00319	0.77291
trinos.080.1	80	0.81178	0.00330	0.81838
trinos.090.1	90	0.85472	0.00337	0.86146
trinos.100.1	***100***	***0.88574***	***0.00322***	***0.89218***

3.1.3 Analysis of Array of Undamaged Containers (Normal Conditions) with Standard T15x15 Fuel Assembly

Calculations were performed for an array of model 51032-1 shipping containers under normal or undamaged conditions. Bundles of 15x15 rods were placed in the containers, since Section 3.1.2 shows that bundles with a 15x15 array of rods are more reactive than the standard T15X15 assemblies. Page 45 of Reference 6 states that the water spray test demonstrated that water would not leak into the package. Therefore, in the undamaged calculations of this subsection, the insides of the containers remain dry. The following sets of cases were analyzed, each varying interspersed moderation (between containers) from dry to fully flooded:

- Infinite array of containers. The rods contain the large diameter pellets.
- Infinite array of containers. The rods contain the small diameter pellets.
- 13x13x3 (507 total) array of containers. The rods contain the large diameter pellets.
- 13x13x3 (507 total) array of containers. The rods contain the small diameter pellets.

The results of these calculations are provided in Table VII-10 through Table VII-13. As shown in these tables, k_{eff} for an infinite number of model 51032-1 shipping containers exceeds 0.95. However, for an array of 507 containers, the maximum $k_{eff}+2\sigma$ is 0.84254, well below 0.95. The peak reactivity occurs with the large pellet diameter and at 7 vol% interspersed moderator. This peak case (15lu.007.507) was modified to include 675 containers in a 15x15x3 array. The results are summarized below. The resulting k_{eff} $+2\sigma$ is 0.86233.

```
269428 Aug  2 11:49:08 1999 droa-15lu.007.675    .85681    .00276    .86142    .86233
```

Except for some rubber gaskets and a polyethylene bundle sheath in some cases, no hydrogenous shipping components are use in the model 51032-1 shipping container. In order to show that this small amount of hydrogenous material does not have an adverse impact on reactivity, the most reactive case above (15lu.007.675) was modified to include low density polyethylene inside the container, but outside of the bundles. The amount of polyethylene inside the container was varied from 1 to 10 vol%. The results are summarized in Table VII-14. As expected, since the peak interspersed moderator was already identified and used, addition of polyethylene to the inside of the container results in lower reactivities.

In summary, since five times the allowed number of containers must be analyzed at undamaged conditions, the analysis in this subsection supports shipments of 675/5 = 135 containers.

Table VII-10 Infinite Array of Model 51032-1 Shipping Containers, Undamaged Conditions, Interspersed Moderator Sensitivity Study, 15x15 Array of Rods in Bundles, Large Diameter (0.350") Pellets

Filename (droa-?)	Vol% IM	k_{eff}	σ	$k_{eff} + 2\sigma$
15lu.000.inf	0	0.80197	0.00135	0.80467
15lu.001.inf	1	0.93633	0.00186	0.94005
15lu.003.inf	3	1.00207	0.00209	1.00625
15lu.005.inf	***5***	***1.00326***	***0.00265***	***1.00856***
15lu.007.inf	7	0.97210	0.00289	0.97788
15lu.010.inf	10	0.92199	0.00279	0.92757
15lu.020.inf	20	0.74999	0.00264	0.75527
15lu.030.inf	30	0.63820	0.00271	0.64362
15lu.040.inf	40	0.57510	0.00255	0.58020
15lu.050.inf	50	0.53667	0.00276	0.54219
15lu.060.inf	60	0.50816	0.00258	0.51332
15lu.070.inf	70	0.47937	0.00230	0.48397
15lu.080.inf	80	0.46285	0.00248	0.46781
15lu.090.inf	90	0.44185	0.00260	0.44705
15lu.100.inf	100	0.43037	0.00242	0.43521

Table VII-11 Infinite Array of Model 51032-1 Shipping Containers, Undamaged Conditions, Interspersed Moderator Sensitivity Study, 15x15 Array of Rods in Bundles, Small Diameter (0.332") Pellets

Filename (droa-?)	Vol% IM	k_{eff}	σ	$k_{eff} + 2\sigma$
15su.000.inf	0	0.79631	0.00141	0.79913
15su.001.inf	1	0.93265	0.00192	0.93649
15su.003.inf	***3***	***0.99946***	***0.00230***	***1.00406***
15su.005.inf	5	0.99464	0.00233	0.99930
15su.007.inf	7	0.97278	0.00273	0.97824
15su.010.inf	10	0.91791	0.00260	0.92311
15su.020.inf	20	0.74003	0.00295	0.74593
15su.030.inf	30	0.63108	0.00256	0.63620
15su.040.inf	40	0.56530	0.00255	0.57040
15su.050.inf	50	0.52139	0.00270	0.52679
15su.060.inf	60	0.49433	0.00254	0.49941
15su.070.inf	70	0.46973	0.00235	0.47443
15su.080.inf	80	0.44838	0.00258	0.45354
15su.090.inf	90	0.43712	0.00253	0.44218
15su.100.inf	100	0.41831	0.00229	0.42289

Table VII-12 13x13x3 (507 Total) Array of Model 51032-1 Shipping Containers, Undamaged Conditions, Interspersed Moderator Sensitivity Study, 15x15 Array of Rods in Bundles, Large Diameter (0.350") Pellets

Filename (droa-?)	Vol% IM	k_{eff}	σ	$k_{eff} + 2\sigma$
15lu.000.507	0	0.54721	0.00270	0.55261
15lu.001.507	1	0.63285	0.00299	0.63883
15lu.003.507	3	0.76561	0.00291	0.77143
15lu.005.507	5	0.82168	0.00277	0.82722
15lu.007.507	***7***	***0.83634***	***0.00310***	***0.84254***
15lu.010.507	10	0.81878	0.00263	0.82404
15lu.020.507	20	0.70422	0.00235	0.70892
15lu.030.507	30	0.61148	0.00316	0.61780
15lu.040.507	40	0.55491	0.00261	0.56013
15lu.050.507	50	0.51802	0.00273	0.52348
15lu.060.507	60	0.49483	0.00234	0.49951
15lu.070.507	70	0.46929	0.00261	0.47451
15lu.080.507	80	0.45013	0.00219	0.45451
15lu.090.507	90	0.43556	0.00273	0.44102
15lu.100.507	100	0.42392	0.00247	0.42886

Table VII-13 13x13x3 (507 Total) Array of Model 51032-1 Shipping Containers, Undamaged Conditions, Interspersed Moderator Sensitivity Study, 15x15 Array of Rods in Bundles, Small Diameter (0.332") Pellets

Filename (droa-?)	Vol% IM	k_{eff}	σ	$k_{eff} + 2\sigma$
15su.000.507	0	0.52762	0.00261	0.53284
15su.001.507	1	0.61376	0.00259	0.61894
15su.003.507	3	0.75358	0.00276	0.75910
15su.005.507	5	0.80694	0.00273	0.81240
15su.007.507	***7***	***0.82675***	***0.00323***	***0.83321***
15su.010.507	10	0.80830	0.00281	0.81392
15su.020.507	20	0.69301	0.00325	0.69951
15su.030.507	30	0.60301	0.00306	0.60913
15su.040.507	40	0.53919	0.00267	0.54453
15su.050.507	50	0.50740	0.00245	0.51230
15su.060.507	60	0.48313	0.00264	0.48841
15su.070.507	70	0.45833	0.00274	0.46381
15su.080.507	80	0.44044	0.00268	0.44580
15su.090.507	90	0.42963	0.00234	0.43431
15su.100.507	100	0.41446	0.00258	0.41962

Table VII-14 15x15x3 (675 Total) Array of Model 51032-1 Shipping Containers, Undamaged Conditions, 7 vol% Interspersed Moderator Between Containers, Polyethylene Sensitivity Study, 15x15 Array of Rods in Bundles, Large Diameter (0.350") Pellets

Filename (droa-?)	Vol% PE	k_{eff}	σ	$k_{eff} + 2\sigma$
15lu.007.675	***0***	***0.85681***	***0.00276***	***0.86233***
15lupe001.007.675	1	0.83370	0.00249	0.83868
15lupe003.007.675	3	0.77004	0.00288	0.77580
15lupe005.007.675	5	0.70645	0.00282	0.71209
15lupe007.007.675	7	0.65059	0.00274	0.65607
15lupe010.007.675	10	0.57932	0.00272	0.58476

3.1.4 Analysis of Array of Damaged Containers (Accident Conditions) with Standard T15x15 Fuel Assembly

Calculations were performed for an array of model 51032-1 shipping containers under accident or damaged conditions. Bundles of 15x15 rods were placed in the containers, since Section 3.1.2 shows that bundles with a 15x15 array of rods are more reactive than the standard Trino assemblies. As previously stated, no pathway has been identified for preferential flooding of the container. The following sets of cases were analyzed, each varying interspersed moderation (both inside and between containers) from dry to fully flooded:

- 10x10x2 (200 total) array of containers. The rods contain the large diameter pellets. Bundles and strongbacks are centered in container.
- 10x10x2 (200 total) array of containers. The rods contain the large diameter pellets. Bundles and strongbacks are shifted in container.
- 10x10x2 (200 total) array of containers. The rods contain the small diameter pellets. Bundles and strongbacks are centered in container.
- 10x10x2 (200 total) array of containers. The rods contain the small diameter pellets. Bundles and strongbacks are shifted in container.

Cases with the bundles and strongbacks shifted in the containers have the strongbacks shifted by the amount listed in Table VII-5. The bundles are then shifted in the same horizontal direction, so that they are against the inside of the strongback. These shifts are performed so that the spacing between bundles in four adjacent containers is minimized. Figure VII-2 shows this configuration. Grid lines were placed through the centers of the containers in Figure VII-2 to better show the direction in which bundles and strongbacks were shifted.

The results of these calculations are provided in Table VII-15 through Table VII-18. As shown in these tables, the maximum $k_{eff}+2\sigma$ is 0.91036, well below 0.95. The peak reactivity occurs with the small pellet diameter, bundles and strongbacks shifted, and fully flooded conditions. The peak cases (15sds.100.200 and 15sdc.100.200) were modified to include 288 containers in a 12x12x2 array. The results are summarized below. The maximum resulting $k_{eff}+2\sigma$ is 0.91194.

```
282464 Jul 29 11:59:29 1999 droa-15sds.100.288    .90504   .00345   .91080   .91194
264805 Jul 30 04:57:12 1999 droa-15sdc.100.288    .90254   .00391   .90907   .91036
```

As discussed in Section 3.1.3, except for some rubber gaskets and a polyethylene bundle sheath in some cases, no hydrogenous shipping components are use in the model 51032-1 shipping container. In order to show that this small amount of hydrogenous material does not have an

adverse impact on reactivity, the most reactive case above (15sds.007.288) was modified to include low density polyethylene inside the container, but outside of the bundles. The amount of polyethylene inside the container was varied from 1 to 10 vol%. Since the container is fully flooded, as the polyethylene volume fraction increases, the water volume fraction must decrease, so that the sum of the two volume fractions equals unity. The results are summarized in Table VII-19. The maximum k_{eff} +2σ for these cases is 0.91194 and occurs with 0 vol% polyethylene.

In summary, since two times the allowed number of containers must be analyzed at damaged conditions, the analysis in this subsection supports shipments of 288/2 = 144 containers.

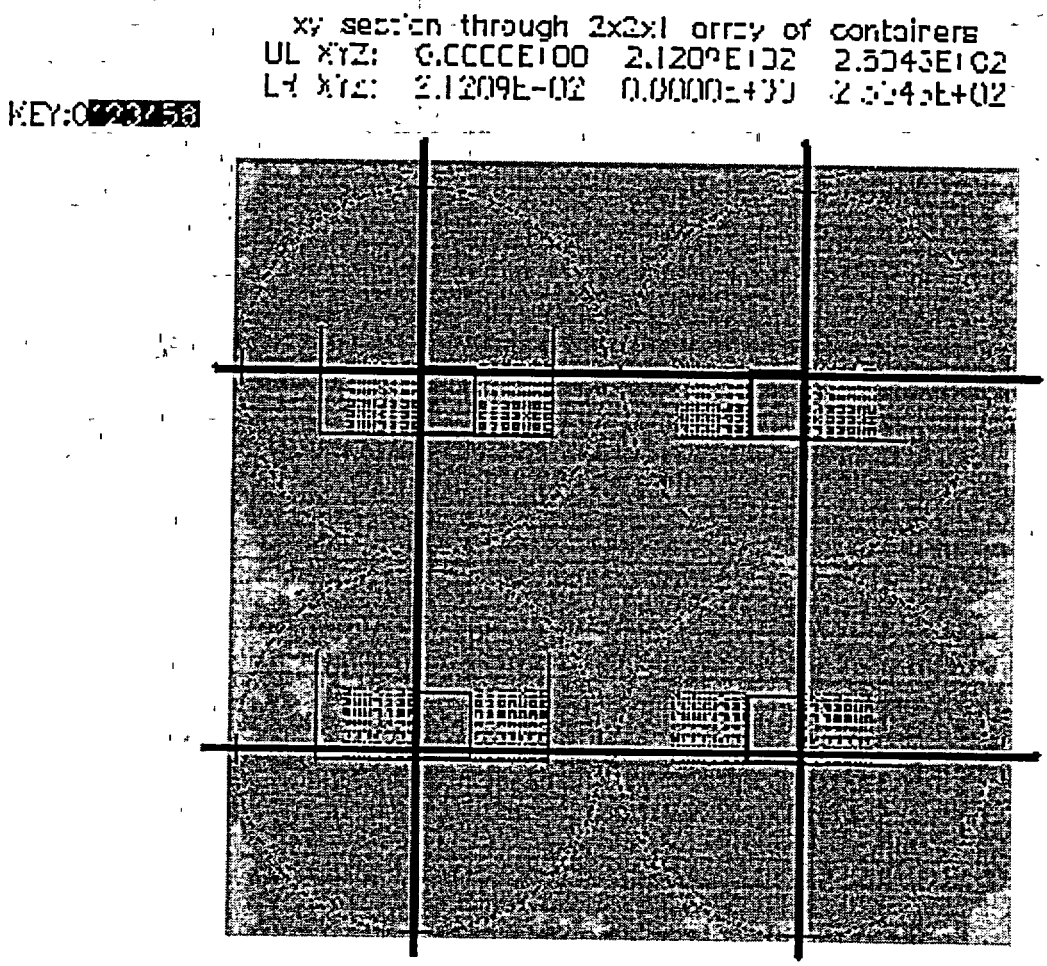


Figure VII-2 Bundles and Strongbacks Shifted within Containers under Damaged Conditions

Table VII-15 10x10x2 (200 Total) Array of Model 51032-1 Shipping Containers, Damaged Conditions, Bundles and Strongbacks Centered in Containers, Interspersed Moderator Sensitivity Study, 15x15 Array of Rods in Bundles, Large Diameter (0.350") Pellets

Filename (droa-?)	Vol% IM	k_{eff}	σ	$k_{eff} + 2\sigma$
15ldc.000.200	0	0.51327	0.00268	0.51863
15ldc.001.200	1	0.67802	0.00268	0.68338
15ldc.003.200	3	0.77884	0.00273	0.78430
15ldc.005.200	5	0.74186	0.00307	0.74800
15ldc.007.200	7	0.67622	0.00269	0.68160
15ldc.010.200	10	0.59904	0.00299	0.60502
15ldc.020.200	20	0.55333	0.00280	0.55893
15ldc.030.200	30	0.59212	0.00299	0.59810
15ldc.040.200	40	0.63881	0.00273	0.64427
15ldc.050.200	50	0.69035	0.00328	0.69691
15ldc.060.200	60	0.72985	0.00321	0.73627
15ldc.070.200	70	0.76828	0.00368	0.77564
15ldc.080.200	80	0.81889	0.00392	0.82673
15ldc.090.200	90	0.85159	0.00327	0.85813
15ldc.100.200	***100***	***0.89490***	***0.00387***	***0.90264***

Table VII-16 10x10x2 (200 Total) Array of Model 51032-1 Shipping Containers, Damaged Conditions, Bundles and Strongbacks Shifted in Containers, Interspersed Moderator Sensitivity Study, 15x15 Array of Rods in Bundles, Large Diameter (0.350") Pellets

Filename (droa-?)	Vol% IM	k_{eff}	σ	$k_{eff} + 2\sigma$
15lds.000.200	0	0.51248	0.00241	0.51730
15lds.001.200	1	0.68291	0.00313	0.68917
15lds.003.200	3	0.77440	0.00264	0.77968
15lds.005.200	5	0.73512	0.00295	0.74102
15lds.007.200	7	0.67678	0.00301	0.68280
15lds.010.200	10	0.61109	0.00259	0.61627
15lds.020.200	20	0.56055	0.00329	0.56713
15lds.030.200	30	0.59591	0.00322	0.60235
15lds.040.200	40	0.64050	0.00311	0.64672
15lds.050.200	50	0.68806	0.00345	0.69496
15lds.060.200	60	0.72777	0.00335	0.73447
15lds.070.200	70	0.77527	0.00352	0.78231
15lds.080.200	80	0.81395	0.00332	0.82059
15lds.090.200	90	0.85567	0.00279	0.86125
15lds.100.200	***100***	***0.88527***	***0.00329***	***0.89185***

Table VII-17 10x10x2 (200 Total) Array of Model 51032-1 Shipping Containers, Damaged Conditions, Bundles and Strongbacks Centered in Containers, Interspersed Moderator Sensitivity Study, 15x15 Array of Rods in Bundles, Small Diameter (0.332") Pellets

Filename (droa-?)	Vol% IM	k_{eff}	σ	$k_{eff} + 2\sigma$
15sdc.000.200	0	0.49548	0.00243	0.50034
15sdc.001.200	1	0.66916	0.00277	0.67470
15sdc.003.200	3	0.77035	0.00279	0.77593
15sdc.005.200	5	0.72518	0.00298	0.73114
15sdc.007.200	7	0.67075	0.00322	0.67719
15sdc.010.200	10	0.59396	0.00274	0.59944
15sdc.020.200	20	0.54132	0.00254	0.54640
15sdc.030.200	30	0.58711	0.00298	0.59307
15sdc.040.200	40	0.63927	0.00323	0.64573
15sdc.050.200	50	0.69411	0.00343	0.70097
15sdc.060.200	60	0.72893	0.00338	0.73569
15sdc.070.200	70	0.78935	0.00347	0.79629
15sdc.080.200	80	0.81957	0.00340	0.82637
15sdc.090.200	90	0.86626	0.00309	0.87244
15sdc.100.200	***100***	***0.90207***	***0.00338***	***0.90883***

Table VII-18 10x10x2 (200 Total) Array of Model 51032-1 Shipping Containers, Damaged Conditions, Bundles and Strongbacks Shifted in Containers, Interspersed Moderator Sensitivity Study, 15x15 Array of Rods in Bundles, Small Diameter (0.332") Pellets

Filename (droa-?)	Vol% IM	k_{eff}	σ	$k_{eff} + 2\sigma$
15sds.000.200	0	0.49710	0.00276	0.50262
15sds.001.200	1	0.66112	0.00286	0.66684
15sds.003.200	3	0.76510	0.00307	0.77124
15sds.005.200	5	0.72197	0.00292	0.72781
15sds.007.200	7	0.66943	0.00320	0.67583
15sds.010.200	10	0.60277	0.00296	0.60869
15sds.020.200	20	0.55516	0.00315	0.56146
15sds.030.200	30	0.59657	0.00318	0.60293
15sds.040.200	40	0.64554	0.00257	0.65068
15sds.050.200	50	0.69272	0.00314	0.69900
15sds.060.200	60	0.74084	0.00342	0.74768
15sds.070.200	70	0.77851	0.00267	0.78385
15sds.080.200	80	0.82522	0.00322	0.83166
15sds.090.200	90	0.86162	0.00357	0.86876
15sds.100.200	***100***	***0.90392***	***0.00322***	***0.91036***

Table VII-19 12x12x2 (288 Total) Array of Model 51032-1 Shipping Containers, Damaged Conditions, Bundles and Strongbacks Shifted in Containers, Fully Flooded Interspersed Moderator, Polyethylene Sensitivity Study, 15x15 Array of Rods in Bundles, Small Diameter (0.332") Pellets

Filename (droa-?)	Vol% PE	k_{eff}	σ	$k_{eff} + 2\sigma$
15sds.100.288	***0***	***0.90504***	***0.00345***	***0.91194***
15sdspe001.100.288	1	0.89459	0.00359	0.90177
15sdspe003.100.288	3	0.90270	0.00390	0.91050
15sdspe005.100.288	5	0.90120	0.00330	0.90780
15sdspe007.100.288	7	0.89997	0.00329	0.90655
15sdspe010.100.288	10	0.89937	0.00321	0.90579

3.2 *T15X15 Cruciform Assembly*

The layout of a T15X15 cruciform assembly is shown in Figure VII-3. The reference for this assembly layout is provided in Appendix VII-B. The component dimensions for the T15X15 cruciform assembly are provided in Table VII-20.

With only one exception, the T15X15 cruciform assemblies meet the requirements for category 3 fuel in the current COC for the model 51032-1 shipping containers (Reference 5). The exception is that the current COC requires:

> "Cladding must have a minimum wall thickness of 0.02 inch and a minimum nominal pellet-clad radial gap of 0.003 inch."

The T15X15 cruciform assemblies meet the 0.02 inch minimum clad wall thickness, but the pellet-clad radial gap is only approximately 0.0025 inch. Calculations in Section 3.1.2 show that modeling the clad and gap as void, instead of explicitly modeling the gap as void and the clad as zircalloy or stainless steel, results in either identical or conservative results. These calculations support a change in the COC wording for categories 1 through 4 to:

> "The sum of the cladding wall thickness and the pellet-clad radial gap must not be less than 0.023 inch."[1]

Since the minimum cladding wall thickness of the T15X15 cruciform assemblies is 0.0266 inch, the cladding alone (without the gap) meets this requirement. This change in wording to the current COC will bring the T15X15 cruciform assemblies into compliance with the requirements of category 3 fuel.

1.
[1] As identified in section 11.2 of EMF-52.

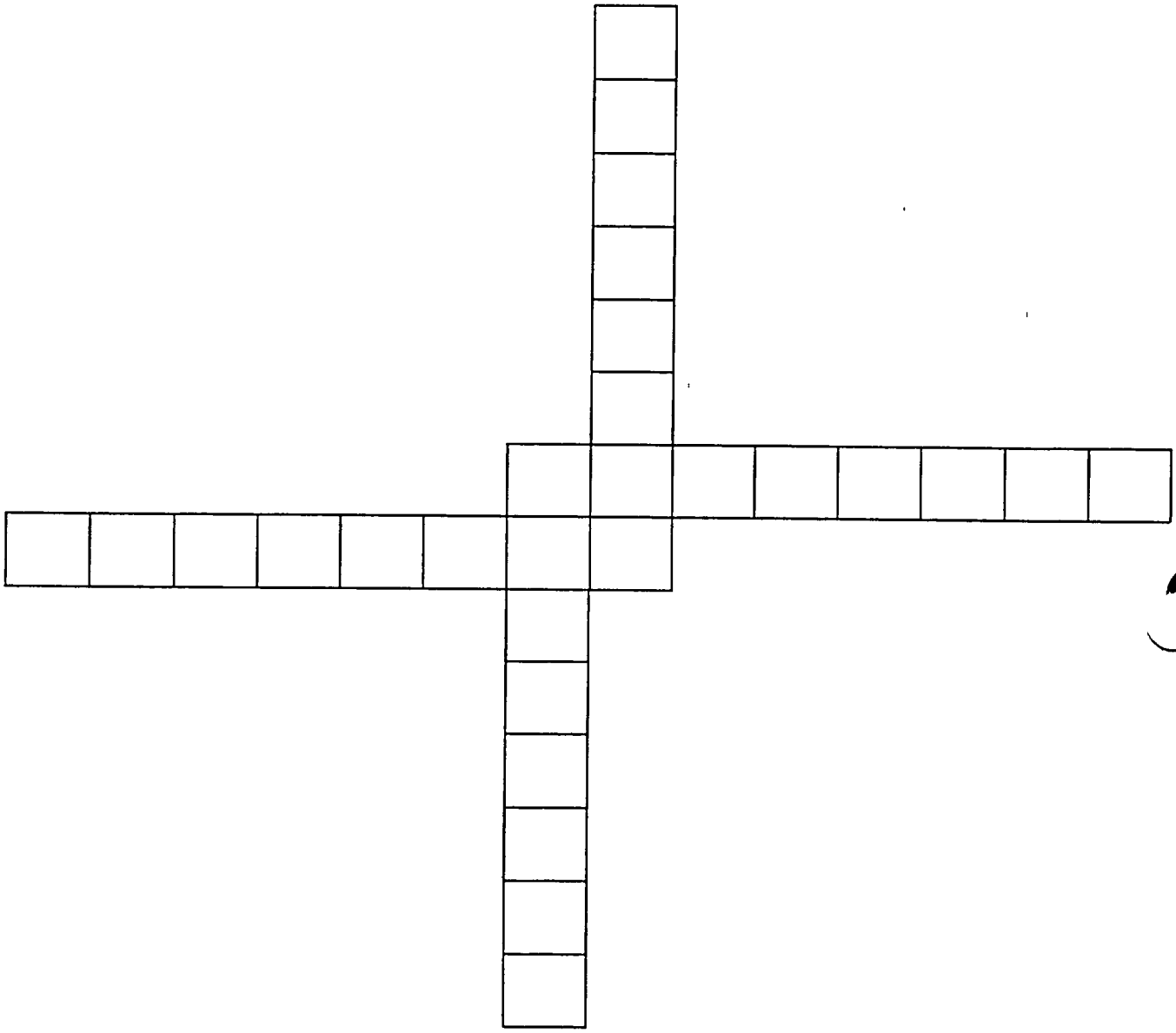


Figure VII-3 T15X15 Cruciform Assembly Layout

Table VII-20 Component Dimensions for T15X15 Cruciform Assembly

Parameter	Actual	Reference for Actual Conditions
Clad Thickness	0.0288" ± 5%	See Appendix VII-B
Rod OD	0.430"	
Enrichment	2.73 wt% ^{235}U	
Assembly Cross Section	7.574" x 7.574"	
Rod Array Size	14x14	
Rod Pitch	0.556" (center 4 rods) 0.547" (remaining rods)	
Active Fuel Length	< 115.838"	

4. QA REVIEW DESCRIPTION

1) Methodology used in this CSE is clearly defined and was verified to be applicable. Agreement is indicated by a check mark in the CSE text. The calculation methods including details on cross section preparation, atom densities assumed, and geometry models were reviewed and determined to be adequate. Each of these items was verified to be conservative.

2) Assumptions were reviewed for reasonableness and applicability to this analysis. Agreement is indicated by a check mark in the CSE text.

3) Modeling was reviewed and determined to conservatively model the actual system. A listing of one or more of the most reactive cases is included in the CSE.

4) Referenced sources were reviewed for applicability to this CSE.

5) Input information was checked against referenced sources.

6) Input for computer calculations were checked for agreement with values in the CSE text.

7) Hand calculations were independently checked.

8) K_{eff} for worst case accident conditions is specifically stated in the text.

9) Comments are provided below and are referenced in the CSE text as QA-N, where N is the corresponding comment number.

5. REFERENCES

1) SCALE Standardized Computer Analyses for Licensing Evaluation, NUREG/CR-2000 ORNL/NUREG/CSD-2, Volumes 1, 2, and 3.

2) Critical Separation Between Subcritical Clusters of 4.31 wt% Enriched UO_2 Rods in Water with Fixed Neutron Poisons, NUREG/CR-0073.

3) EMF-94-175, "Validation and Verification of KENO.Va" by R. E. Coen, Siemens Power Corporation - Nuclear Division, 2101 Horn Rapids Road, Richland, WA 99352.

4) UCRL-53369, Nuclear Criticality Safety Experiments, Calculations, and Analyses - 1958 to 1982: Compilation of Papers from the Transactions of the American Nuclear Society, Volume 2: Summaries, Lawrence Livermore National Laboratory, W. Marshall, et al, "Criticality Safety Criteria," pp.687-688.

5) Certificate USA/6581/AF, Revision 27, Model 51032-1 Certificate.

6) ANF-52, Revision 5, Consolidated License Application for Siemens Nuclear Power Corporation Model 51032-1 Shipping Container.

APPENDIX VII-A SAMPLE COMPUTER INPUTS

1) **Case "drda-single.98"**: Single model 51032-1 shipping container, fully flooded, 15x15 array of rods in bundles, small diameter (0.332") pellets, UO_2 at 98% TD.

```
=csas25
51032 category 5 (trino fuel)
hans  infhom

' mixture 1
'  uo2 pellets, interior to assy
uo2 1 0.98 293.0 92235 5.000' 92238 95.000  end

' mixture 2
'  uo2 pellets, edge, not facing adj assy
uo2 2 0.98 293.0 92235 5.000  92238 95.000  end

' mixture 3
'  uo2 pellets, edge, facing adj assy
uo2 3 0.98 293.0 92235 5.000  92238 95.000  end

' mixture 4
'  carbon steel in container
carbonsteel 4 1.0 293.0 end

' mixture 5
'  interspersed moderator
h2o 5 den=1.0 1.00 293.0 end

' mixture 6
'  reflector water
h2o  6 den=1.0 1.00 293 end

end comp
more data
 res=  1 cyli  4.1893E-01 dan(  1)= 2.7649E-01
 res=  2 cyli  4.3752E-01 dan(  2)= 1.7928E-01
 res=  3 cyli  4.3530E-01 dan(  3)= 1.9903E-01
end more
51032 category 5 (trino fuel)

read parameters
   tme=90 gen=103 npg=500 nsk=3
   flx=yes fdn=yes xsl=yes nub=yes pwt=yes
   run=yes plt=yes
end parameters

read geom

unit 1
com='standard rod - larger pellet - interior'
' for std rod, pellet diam = 0.350 in.
cyli 1 1 0.44450 2p250.19
' use min clad + gap thickness = 0.016 in.
cyli 0 1 0.48514 2p250.19
' use max nom rod pitch = 0.52727 in.
cubo 5 1 4p0.66963 2p250.19

unit 2
com='standard rod - larger pellet - edge, not facing adj assy'
' for std rod, pellet diam = 0.350 in.
cyli 2 1 0.44450 2p250.19
' use min clad + gap thickness = 0.016 in.
cyli 0 1 0.48514 2p250.19
' use max nom rod pitch = 0.52727 in.
cubo 5 1 4p0.66963 2p250.19
```

```
unit 3
com='standard rod - larger pellet - edge, facing adj assy'
' for std rod, pellet diam = 0.350 in.
cyli 3 1 0.44450 2p250.19
' use min clad + gap thickness = 0.016 in.
cyli 0 1 0.48514 2p250.19
' use max nom rod pitch = 0.52727 in.
cubo 5 1 4p0.66963 2p250.19

unit 4
com='thick rod - smaller pellet - interior'
' for thick rod, pellet diam = 0.332 in.
cyli 1 1 0.42164 2p250.19
' use min clad + gap thickness = 0.016 in.
cyli 0 1 0.46228 2p250.19
' use max nom rod pitch = 0.52727 in.
cubo 5 1 4p0.66963 2p250.19

unit 5
com='thick rod - smaller pellet - edge, not facing adj assy'
' for thick rod, pellet diam = 0.332 in.
cyli 2 1 0.42164 2p250.19
' use min clad + gap thickness = 0.016 in.
cyli 0 1 0.46228 2p250.19
' use max nom rod pitch = 0.52727 in.
cubo 5 1 4p0.66963 2p250.19

unit 6
com='thick rod - smaller pellet - edge, facing adj assy'
' for thick rod, pellet diam = 0.332 in.
cyli 3 1 0.42164 2p250.19
' use min clad + gap thickness = 0.016 in.
cyli 0 1 0.46228 2p250.19
' use max nom rod pitch = 0.52727 in.
cubo 5 1 4p0.66963 2p250.19

unit 7
com='location in assy with no rod'
' use max nom rod pitch = 0.52727 in.
cubo 5 1 4p0.66963 2p250.19

unit 101
com='15x15 array on +x side of container'
array 1 -10.04445 -10.04445 -250.19

unit 102
com='15x15 array on -x side of container'
array 2 -10.04445 -10.04445 -250.19

unit 103
com='trino assy on +x side of container'
array 3 -10.04445 -10.04445 -250.19
cubo 5 1 4p10.04445 2p250.19

unit 104
com='trino assy on -x side of container'
array 4 -10.04445 -10.04445 -250.19
cubo 5 1 4p10.04445 2p250.19

unit 501
com='separator block'
' min dims per emf-309,813 rev. 0
'  6 in. w x 7.5 in. h x 8.5 in. l x 0.3125 in. thk
cubo 5 1 2p6.82625 2p8.73125 2p10.795
cubo 4 1 2p7.62    2p9.525   2p10.795
' place on 39.4 in. centers
cubo 5 1 2p7.62    2p9.525   2p50.038

unit 502
com='1x1x5 array of separator blocks'
```

```
' min of 5 blocks required in 51032
' y-coord matches 1/2 of bundle height
array 5 -7.62 -10.04445 -250.19
' match the bundle height
cubo 5 1 2p7.62 2p10.04445 2p250.19

global
unit 601
com='single container'
' center fuel in container
array 6 -27.70890 -10.04445 -250.19
' match strongback width and height
cubo 5 1 2p31.19437 19.32430 -10.04445 2p250.19
' add strongback steel
repl 4 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' undamaged spacing between containers 41.75 in.
' cubo 5 1 4p53.0225 2p250.43303
'  add 30 cm water reflector
repl 6 2 3r3.0 10

end geom

read array

ara=1 nux=15 nuy=15 nuz=1
fill 6 5 5 5 5 5 5 5 5 5 5 5 5 5 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 end fill

ara=2 nux=15 nuy=15 nuz=1
fill 5 5 5 5 5 5 5 5 5 5 5 5 5 5 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 5 5 5 5 5 5 5 5 5 5 5 5 5 6 end fill

ara=3 nux=15 nuy=15 nuz=1
fill 6 5 5 5 5 5 5 7 7 7 7 7 7 7 7
     6 4 4 4 4 4 4 5 5 5 5 5 5 5 7
     6 4 4 4 4 4 4 4 4 4 4 4 4 5 7
     6 4 4 4 4 4 4 4 4 4 4 4 4 5 7
     6 4 4 4 4 4 4 4 4 4 4 4 4 5 7
     6 4 4 4 4 4 4 4 4 4 4 4 4 5 7
     6 4 4 4 4 4 4 4 4 4 4 4 4 5 7
```

```
     6 4 4 4 4 4 4 7 4 4 4 4 4 5 7
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     7 5 5 5 5 5 5 5 5 5 5 5 5 5 5 end fill

ara=4 nux=15 nuy=15 nuz=1
fill 7 7 7 7 7 7 7 7 5 5 5 5 5 5 6
     7 5 5 5 5 5 5 5 4 4 4 4 4 4 6
     7 5 4 4 4 4 4 4 4 4 4 4 4 4 6
     7 5 4 4 4 4 4 4 4 4 4 4 4 4 6
     7 5 4 4 4 4 4 4 4 4 4 4 4 4 6
     7 5 4 4 4 4 4 4 4 4 4 4 4 4 6
     7 5 4 4 4 4 4 4 4 4 4 4 4 4 6
     7 5 4 4 4 4 4 7 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 5 5 5 5 5 5 5 5 5 5 5 5 5 7 end fill

ara=5 nux=1 nuy=1 nuz=5
fill f501 end fill

ara=6 nux=3 nuy=1 nuz=1
fill 102 502 101 end fill

end array

read start
   nst=1
end start

read bounds
   all=vacuum
end bounds

read bias
   id=500 2 11
end bias

read plot

' ************************************************************
'  use this block for plotting single container calcs        *
'                                                            *
ttl=' xy section through strongback '
xul=-32          yul=16          zul=0
xlr=32           ylr=-16         zlr=0
uax=1.0          vdn=-1.0        nax=150   lpi=10   end
'
ttl=' xy section through one container '
xul=-82          yul=82          zul=0
xlr=82           ylr=-82         zlr=0
uax=1.0          vdn=-1.0        nax=150   lpi=10   end
'
ttl=' xz section through one container '
xul=-82          yul=0           zul=-283
xlr=82           ylr=0           zlr=283
wax=1.0          udn=1.0         nax=150   lpi=10   end
'                                                            *
' ************************************************************

end plot
```

```
end data
end
```

2) **Case "drda-undam.98"**: 15x15x3 (675 total) array of model 51032-1 shipping containers, undamaged conditions, 7 vol% interspersed moderator between containers, 15x15 array of rods in bundles, large diameter (0.350") pellets, UO_2 at 98% TD.

```
=csas25
51032 category 5 (trino fuel)
hans  infhom

' mixture 1
'  uo2 pellets, interior to assy
uo2 1 0.98 293.0 92235 5.000  92238 95.000  end

' mixture 2
'  uo2 pellets, edge, not facing adj assy
uo2 2 0.98 293.0 92235 5.000  92238 95.000  end

' mixture 3
'  uo2 pellets, edge, facing adj assy
uo2 3 0.98 293.0 92235 5.000  92238 95.000  end

' mixture 4
'  carbon steel in container
carbonsteel 4 1.0 293.0 end

' mixture 5
'  interspersed moderator
h2o 5 den=1.0 0.07 293.0 end

' mixture 6
'  reflector water
h2o  6 den=1.0 1.00 293 end

end comp
more data
 res=  1 cyli  1.0428E-01 dan(  1)= 9.7805E-01
 res=  2 cyli  7.0576E-01 dan(  2)= 5.9434E-01
 res=  3 cyli  6.7335E-01 dan(  3)= 6.8717E-01
end more
51032 category 5 (trino fuel)

read parameters
   tme=90 gen=103 npg=500 nsk=3
   flx=yes fdn=yes xsl=yes nub=yes pwt=yes
   run=yes plt=yes
end parameters

read geom

unit 1
com='standard rod - larger pellet - interior'
' for std rod, pellet diam = 0.350 in.
cyli 1 1 0.44450 2p250.19
' use min clad + gap thickness = 0.016 in.
cyli 0 1 0.48514 2p250.19
' use max nom rod pitch = 0.52727 in.
cubo 0 1 4p0.66963 2p250.19

unit 2
com='standard rod - larger pellet - edge, not facing adj assy'
' for std rod, pellet diam = 0.350 in.
cyli 2 1 0.44450 2p250.19
' use min clad + gap thickness = 0.016 in.
cyli 0 1 0.48514 2p250.19
```

```
' use max nom rod pitch = 0.52727 in.
cubo 0 1 4p0.66963 2p250.19

unit 3
com='standard rod - larger pellet - edge, facing adj assy'
' for std rod, pellet diam = 0.350 in.
cyli 3 1 0.44450 2p250.19
' use min clad + gap thickness = 0.016 in.
cyli 0 1 0.48514 2p250.19
' use max nom rod pitch = 0.52727 in.
cubo 0 1 4p0.66963 2p250.19

unit 4
com='thick rod - smaller pellet - interior'
' for thick rod, pellet diam = 0.332 in.
cyli 1 1 0.42164 2p250.19
' use min clad + gap thickness = 0.016 in.
cyli 0 1 0.46228 2p250.19
' use max nom rod pitch = 0.52727 in.
cubo 0 1 4p0.66963 2p250.19

unit 5
com='thick rod - smaller pellet - edge, not facing adj assy'
' for thick rod, pellet diam = 0.332 in.
cyli 2 1 0.42164 2p250.19
' use min clad + gap thickness = 0.016 in.
cyli 0 1 0.46228 2p250.19
' use max nom rod pitch = 0.52727 in.
cubo 0 1 4p0.66963 2p250.19

unit 6
com='thick rod - smaller pellet - edge, facing adj assy'
' for thick rod, pellet diam = 0.332 in.
cyli 3 1 0.42164 2p250.19
' use min clad + gap thickness = 0.016 in.
cyli 0 1 0.46228 2p250.19
' use max nom rod pitch = 0.52727 in.
cubo 0 1 4p0.66963 2p250.19

unit 7
com='location in assy with no rod'
' use max nom rod pitch = 0.52727 in.
cubo 0 1 4p0.66963 2p250.19

unit 101
com='15x15 array on +x side of container'
array 1 -10.04445 -10.04445 -250.19

unit 102
com='15x15 array on -x side of container'
array 2 -10.04445 -10.04445 -250.19

unit 103
com='trino assy on +x side of container'
array 3 -10.04445 -10.04445 -250.19
cubo 0 1 4p10.04445 2p250.19

unit 104
com='trino assy on -x side of container'
array 4 -10.04445 -10.04445 -250.19
cubo 0 1 4p10.04445 2p250.19

unit 501
com='separator block'
' min dims per emf-309,813 rev. 0
'  6 in. w x 7.5 in. h x 8.5 in. l x 0.3125 in. thk
cubo 0 1 2p6.82625 2p8.73125 2p10.795
cubo 4 1 2p7.62    2p9.525   2p10.795
' place on 39.4 in. centers
cubo 0 1 2p7.62    2p9.525   2p50.038
```

```
unit 502
com='1x1x5 array of separator blocks'
' min of 5 blocks required in 51032
' y-coord matches 1/2 of bundle height
array 5 -7.62 -10.04445 -250.19
' match the bundle height
cubo 0 1 2p7.62 2p10.04445 2p250.19

unit 601
com='single undamaged container'
' center fuel in container
array 6 -27.70890 -10.04445 -250.19
' match strongback width and height
cubo 0 1 2p31.19437 19.32430 -10.04445 2p250.19
' add strongback steel
repl 4 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 0 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' undamaged spacing between containers 41.75 in.
cubo 5 1 4p53.0225 2p250.43303
'  add 30 cm water reflector
'  repl 6 2 3r3.0 10

unit 701
com='single damaged container - strongback centered'
' center fuel in container
array 6 -27.70890 -10.04445 -250.19
' match strongback width and height
cubo 5 1 2p31.19437 19.32430 -10.04445 2p250.19
' add strongback steel
repl 4 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303
'  add 30 cm water reflector
'  repl 6 2 3r3.0 10

unit 702
com='single damaged container - strongback shifted +x, +y'
' shift fuel 1.5 in. +x and 3.0 in. +y in container
array 6 -20.41345 -2.42445 -250.19
' match strongback width and height
cubo 5 1 35.00437 -27.38437 26.94430 -2.42445 2p250.19
' add strongback steel
repl 4 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303
'  add 30 cm water reflector
'  repl 6 2 3r3.0 10

unit 703
com='single damaged container - strongback shifted -x, +y'
' shift fuel 1.5 in. -x and 3.0 in. +y in container
array 6 -35.00435 -2.42445 -250.19
' match strongback width and height
cubo 5 1 27.38437 -35.00437 26.94430 -2.42445 2p250.19
' add strongback steel
repl 4 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
```

```
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303
'  add 30 cm water reflector
'  repl 6 2 3r3.0 10

unit 704
com='single damaged container - strongback shifted +x, -y'
' shift fuel 1.5 in. +x and 3.0 in. -y in container
array 6 -20.41345 -17.66445 -250.19
' match strongback width and height
cubo 5 1 35.00437 -27.38437 11.70430 -17.66445 2p250.19
' add strongback steel
repl 4 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303
'  add 30 cm water reflector
'  repl 6 2 3r3.0 10

unit 705
com='single damaged container - strongback shifted -x, -y'
' shift fuel 1.5 in. -x and 3.0 in. -y in container
array 6 -35.00435 -17.66445 -250.19
' match strongback width and height
cubo 5 1 27.38437 -35.00437 11.70430 -17.66445 2p250.19
' add strongback steel
repl 4 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303
'  add 30 cm water reflector
'  repl 6 2 3r3.0 10

global
unit 901
com='15x15x3 array of undamaged containers'
array 7 0.0 0.0 0.0
'  add 30 cm water reflector
repl 6 2 6r3.0 10

unit 902
com='10x10x2 array of damaged containers - centered'
array 8 0.0 0.0 0.0
'  add 30 cm water reflector
repl 6 2 6r3.0 10

unit 903
com='10x10x2 array of damaged containers - shifted'
array 9 0.0 0.0 0.0
'  add 30 cm water reflector
repl 6 2 6r3.0 10

end geom

read array

ara=1 nux=15 nuy=15 nuz=1
fill 3 2 2 2 2 2 2 2 2 2 2 2 2 2 2
     3 1 1 1 1 1 1 1 1 1 1 1 1 1 2
     3 1 1 1 1 1 1 1 1 1 1 1 1 1 2
     3 1 1 1 1 1 1 1 1 1 1 1 1 1 2
     3 1 1 1 1 1 1 1 1 1 1 1 1 1 2
```

```
     3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
     3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
     3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
     3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
     3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
     3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
     3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
     3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
     3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
     3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 end fill

ara=2 nux=15 nuy=15 nuz=1
fill 2 2 2 2 2 2 2 2 2 2 2 2 2 2 3
     2 1 1 1 1 1 1 1 1 1 1 1 1 1 3
     2 1 1 1 1 1 1 1 1 1 1 1 1 1 3
     2 1 1 1 1 1 1 1 1 1 1 1 1 1 3
     2 1 1 1 1 1 1 1 1 1 1 1 1 1 3
     2 1 1 1 1 1 1 1 1 1 1 1 1 1 3
     2 1 1 1 1 1 1 1 1 1 1 1 1 1 3
     2 1 1 1 1 1 1 1 1 1 1 1 1 1 3
     2 1 1 1 1 1 1 1 1 1 1 1 1 1 3
     2 1 1 1 1 1 1 1 1 1 1 1 1 1 3
     2 1 1 1 1 1 1 1 1 1 1 1 1 1 3
     2 1 1 1 1 1 1 1 1 1 1 1 1 1 3
     2 1 1 1 1 1 1 1 1 1 1 1 1 1 3
     2 1 1 1 1 1 1 1 1 1 1 1 1 1 3
     2 2 2 2 2 2 2 2 2 2 2 2 2 2 3 end fill

ara=3 nux=15 nuy=15 nuz=1
fill 3 2 2 2 2 2 2 7 7 7 7 7 7 7 7
     3 1 1 1 1 1 1 1 2 2 2 2 2 2 2 7
     3 1 1 1 1 1 1 1 1 1 1 1 1 1 2 7
     3 1 1 1 1 1 1 1 1 1 1 1 1 1 2 7
     3 1 1 1 1 1 1 1 1 1 1 1 1 1 2 7
     3 1 1 1 1 1 1 1 1 1 1 1 1 1 2 7
     3 1 1 1 1 1 1 1 1 1 1 1 1 1 2 7
     3 1 1 1 1 1 1 7 1 1 1 1 1 1 2 7
     3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
     3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
     3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
     3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
     3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
     3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
     7 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 end fill

ara=4 nux=15 nuy=15 nuz=1
fill 7 7 7 7 7 7 7 7 7 2 2 2 2 2 2 3
     7 2 2 2 2 2 2 2 2 1 1 1 1 1 1 3
     7 2 1 1 1 1 1 1 1 1 1 1 1 1 1 3
     7 2 1 1 1 1 1 1 1 1 1 1 1 1 1 3
     7 2 1 1 1 1 1 1 1 1 1 1 1 1 1 3
     7 2 1 1 1 1 1 1 1 1 1 1 1 1 1 3
     7 2 1 1 1 1 1 1 1 1 1 1 1 1 1 3
     7 2 1 1 1 1 1 7 1 1 1 1 1 1 1 3
     2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 3
     2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 3
     2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 3
     2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 3
     2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 3
     2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 3
     2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 7 end fill

ara=5 nux=1 nuy=1 nuz=5
fill f501 end fill

ara=6 nux=3 nuy=1 nuz=1
fill 102 502 101 end fill

ara=7 nux=15 nuy=15 nuz=3
fill f601 end fill
```

```
ara=8 nux=10 nuy=10 nuz=2
fill f701 end fill

ara=9 nux=10 nuy=10 nuz=2
fill 702 703 4q2
     704 705 4q2
     702 703 4q2
     704 705 4q2
     702 703 4q2
     704 705 4q2
     702 703 4q2
     704 705 4q2
     702 703 4q2
     704 705 4q2
       702 703 4q2
       704 705 4q2
       702 703 4q2
       704 705 4q2
       702 703 4q2
       704 705 4q2
       702 703 4q2
       704 705 4q2
       702 703 4q2
       704 705 4q2 end fill

end array

read start
   nst=1
end start

read bounds
   all=vacuum
end bounds

read bias
   id=500 2 11
end bias

read plot

' ************************************************************
'  use this block for plotting container array calcs         *
'                                                            *
ttl=' xy section through one strongback '
xul=16          yul=81          zul=250.43303
xlr=88          ylr=32          zlr=250.43303
uax=1.0         vdn=-1.0        nax=150   lpi=10   end
'
ttl=' xy section through one container '
xul=0           yul=106.045     zul=250.43303
xlr=106.045     ylr=0           zlr=250.43303
uax=1.0         vdn=-1.0        nax=150   lpi=10   end

ttl=' xy section through 2x2x1 array of containers '
xul=0           yul=212.090     zul=250.43303
xlr=212.090     ylr=0           zlr=250.43303
uax=1.0         vdn=-1.0        nax=150   lpi=10   end

ttl=' xy section through array '
xul=-32         yul=1622.675    zul=250.43303
xlr=1622.675    ylr=-32         zlr=250.43303
uax=1.0         vdn=-1.0        nax=150   lpi=10   end

ttl=' xz section through one container '
xul=0           yul=51.7525     zul=0
xlr=106.045     ylr=51.7525     zlr=500.86606
wax=1.0         udn=1.0         nax=150   lpi=10   end
```

```
ttl=' xz section through array '
xul=-32          yul=51.7525      zul=-32
xlr=1622.675     ylr=51.7525      zlr=1534.59818
wax=1.0          udn=1.0          nax=150   lpi=10   end
'
' ************************************************************
end plot

end data
end
```

3) **Case "drda-dam.98"**: 12x12x2 (288 total) array of model 51032-1 shipping containers, damaged conditions, bundles and strongbacks shifted in containers, fully flooded, 15x15 array of rods in bundles, small diameter (0.332") pellets, UO_2 at 98% TD.

```
=csas25
51032 category 5 (trino fuel)
hans  infhom

' mixture 1
'  uo2 pellets, interior to assy
uo2 1 0.98 293.0 92235 5.000  92238 95.000  end

' mixture 2
'  uo2 pellets, edge, not facing adj assy
uo2 2 0.98 293.0 92235 5.000  92238 95.000  end

' mixture 3
'  uo2 pellets, edge, facing adj assy
uo2 3 0.98 293.0 92235 5.000  92238 95.000  end

' mixture 4
'  carbon steel in container
carbonsteel 4 1.0 293.0 end

' mixture 5
'  interspersed moderator
h2o 5 den=1.0 1.00 293.0 end

' mixture 6
'  reflector water
h2o  6 den=1.0 1.00 293 end

end comp
more data
 res=  1 cyli  4.1044E-01 dan(  1)= 2.7818E-01
 res=  2 cyli  4.4739E-01 dan(  2)= 1.7862E-01
 res=  3 cyli  4.3145E-01 dan(  3)= 1.6896E-01
end more
51032 category 5 (trino fuel)

read parameters
   tme=90 gen=103 npg=500 nsk=3
   flx=yes fdn=yes xs1=yes nub=yes pwt=yes
   run=yes plt=yes
end parameters

read geom

unit 1
com='standard rod - larger pellet - interior'
' for std rod, pellet diam = 0.350 in.
cyli 1 1 0.44450 2p250.19
' use min clad + gap thickness = 0.016 in.
cyli 0 1 0.48514 2p250.19
' use max nom rod pitch = 0.52727 in.
```

```
cubo 5 1 4p0.66963 2p250.19

unit 2
com='standard rod - larger pellet - edge, not facing adj assy'
' for std rod, pellet diam = 0.350 in.
cyli 2 1 0.44450 2p250.19
' use min clad + gap thickness = 0.016 in.
cyli 0 1 0.48514 2p250.19
' use max nom rod pitch = 0.52727 in.
cubo 5 1 4p0.66963 2p250.19

unit 3
com='standard rod - larger pellet - edge, facing adj assy'
' for std rod, pellet diam = 0.350 in.
cyli 3 1 0.44450 2p250.19
' use min clad + gap thickness = 0.016 in.
cyli 0 1 0.48514 2p250.19
' use max nom rod pitch = 0.52727 in.
cubo 5 1 4p0.66963 2p250.19

unit 4
com='thick rod - smaller pellet - interior'
' for thick rod, pellet diam = 0.332 in.
cyli 1 1 0.42164 2p250.19
' use min clad + gap thickness = 0.016 in.
cyli 0 1 0.46228 2p250.19
' use max nom rod pitch = 0.52727 in.
cubo 5 1 4p0.66963 2p250.19

unit 5
com='thick rod - smaller pellet - edge, not facing adj assy'
' for thick rod, pellet diam = 0.332 in.
cyli 2 1 0.42164 2p250.19
' use min clad + gap thickness = 0.016 in.
cyli 0 1 0.46228 2p250.19
' use max nom rod pitch = 0.52727 in.
cubo 5 1 4p0.66963 2p250.19

unit 6
com='thick rod - smaller pellet - edge, facing adj assy'
' for thick rod, pellet diam = 0.332 in.
cyli 3 1 0.42164 2p250.19
' use min clad + gap thickness = 0.016 in.
cyli 0 1 0.46228 2p250.19
' use max nom rod pitch = 0.52727 in.
cubo 5 1 4p0.66963 2p250.19

unit 7
com='location in assy with no rod'
' use max nom rod pitch = 0.52727 in.
cubo 5 1 4p0.66963 2p250.19

unit 101
com='15x15 array on +x side of container'
array 1 -10.04445 -10.04445 -250.19

unit 102
com='15x15 array on -x side of container'
array 2 -10.04445 -10.04445 -250.19

unit 103
com='trino assy on +x side of container'
array 3 -10.04445 -10.04445 -250.19
cubo 5 1 4p10.04445 2p250.19

unit 104
com='trino assy on -x side of container'
array 4 -10.04445 -10.04445 -250.19
cubo 5 1 4p10.04445 2p250.19
```

```
unit 501
com='separator block'
' min dims per emf-309,813 rev. 0
'  6 in. w x 7.5 in. h x 8.5 in. l x 0.3125 in. thk
cubo 5 1 2p6.82625 2p8.73125 2p10.795
cubo 4 1 2p7.62    2p9.525   2p10.795
' place on 39.4 in. centers
cubo 5 1 2p7.62    2p9.525   2p50.038

unit 502
com='1x1x5 array of separator blocks'
' min of 5 blocks required in 51032
' y-coord matches 1/2 of bundle height
array 5 -7.62 -10.04445 -250.19
' match the bundle height
cubo 5 1 2p7.62 2p10.04445 2p250.19

unit 601
com='single undamaged container'
' center fuel in container
array 6 -27.70890 -10.04445 -250.19
' match strongback width and height
cubo 5 1 2p31.19437 19.32430 -10.04445 2p250.19
' add strongback steel
repl 4 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' undamaged spacing between containers 41.75 in.
cubo 5 1 4p53.0225 2p250.43303
'  add 30 cm water reflector
'  repl 6 2 3r3.0 10

unit 701
com='single damaged container - strongback centered'
' center fuel in container
array 6 -27.70890 -10.04445 -250.19
' match strongback width and height
cubo 5 1 2p31.19437 19.32430 -10.04445 2p250.19
' add strongback steel
repl 4 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303
'  add 30 cm water reflector
'  repl 6 2 3r3.0 10

unit 702
com='single damaged container - strongback shifted +x, +y'
' shift fuel 1.5 in. +x and 3.0 in. +y in container
array 6 -20.41345 -2.42445 -250.19
' match strongback width and height
cubo 5 1 35.00437 -27.38437 26.94430 -2.42445 2p250.19
' add strongback steel
repl 4 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303
'  add 30 cm water reflector
'  repl 6 2 3r3.0 10

unit 703
com='single damaged container - strongback shifted -x, +y'
```

```
' shift fuel 1.5 in. -x and 3.0 in. +y in container
array 6 -35.00435 -2.42445 -250.19
' match strongback width and height
cubo 5 1 27.38437 -35.00437 26.94430 -2.42445 2p250.19
' add strongback steel
repl 4 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303
'  add 30 cm water reflector
'  repl 6 2 3r3.0 10

unit 704
com='single damaged container - strongback shifted +x, -y'
' shift fuel 1.5 in. +x and 3.0 in. -y in container
array 6 -20.41345 -17.66445 -250.19
' match strongback width and height
cubo 5 1 35.00437 -27.38437 11.70430 -17.66445 2p250.19
' add strongback steel
repl 4 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303
'  add 30 cm water reflector
'  repl 6 2 3r3.0 10

unit 705
com='single damaged container - strongback shifted -x, -y'
' shift fuel 1.5 in. -x and 3.0 in. -y in container
array 6 -35.00435 -17.66445 -250.19
' match strongback width and height
cubo 5 1 27.38437 -35.00437 11.70430 -17.66445 2p250.19
' add strongback steel
repl 4 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303
'  add 30 cm water reflector
'  repl 6 2 3r3.0 10

unit 901
com='10x10x2 array of undamaged containers'
array 7 0.0 0.0 0.0
'  add 30 cm water reflector
repl 6 2 6r3.0 10

unit 902
com='10x10x2 array of damaged containers - centered'
array 8 0.0 0.0 0.0
'  add 30 cm water reflector
repl 6 2 6r3.0 10

global
unit 903
com='12x12x2 array of damaged containers - shifted'
array 9 0.0 0.0 0.0
'  add 30 cm water reflector
repl 6 2 6r3.0 10

end geom
```

```
read array

ara=1 nux=15 nuy=15 nuz=1
fill 6 5 5 5 5 5 5 5 5 5 5 5 5 5 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 end fill

ara=2 nux=15 nuy=15 nuz=1
fill 5 5 5 5 5 5 5 5 5 5 5 5 5 5 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 5 5 5 5 5 5 5 5 5 5 5 5 5 6 end fill

ara=3 nux=15 nuy=15 nuz=1
fill 6 5 5 5 5 5 5 7 7 7 7 7 7 7 7
     6 4 4 4 4 4 4 5 5 5 5 5 5 5 7
     6 4 4 4 4 4 4 4 4 4 4 4 4 5 7
     6 4 4 4 4 4 4 4 4 4 4 4 4 5 7
     6 4 4 4 4 4 4 4 4 4 4 4 4 5 7
     6 4 4 4 4 4 4 4 4 4 4 4 4 5 7
     6 4 4 4 4 4 4 4 4 4 4 4 4 5 7
     6 4 4 4 4 4 4 7 4 4 4 4 4 5 7
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     6 4 4 4 4 4 4 4 4 4 4 4 4 4 5
     7 5 5 5 5 5 5 5 5 5 5 5 5 5 5 end fill

ara=4 nux=15 nuy=15 nuz=1
fill 7 7 7 7 7 7 7 7 5 5 5 5 5 5 6
     7 5 5 5 5 5 5 5 4 4 4 4 4 4 6
     7 5 4 4 4 4 4 4 4 4 4 4 4 4 6
     7 5 4 4 4 4 4 4 4 4 4 4 4 4 6
     7 5 4 4 4 4 4 4 4 4 4 4 4 4 6
     7 5 4 4 4 4 4 4 4 4 4 4 4 4 6
     7 5 4 4 4 4 4 4 4 4 4 4 4 4 6
     7 5 4 4 4 4 4 7 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 4 4 4 4 4 4 4 4 4 4 4 4 4 6
     5 5 5 5 5 5 5 5 5 5 5 5 5 5 7 end fill
```

```
ara=5 nux=1 nuy=1 nuz=5
fill f501 end fill

ara=6 nux=3 nuy=1 nuz=1
fill 102 502 101 end fill

ara=7 nux=10 nuy=10 nuz=2
fill f601 end fill

ara=8 nux=10 nuy=10 nuz=2
fill f701 end fill

ara=9 nux=12 nuy=12 nuz=2
fill 702 703 5q2
     704 705 5q2
     702 703 5q2
     704 705 5q2
     702 703 5q2
     704 705 5q2
     702 703 5q2
     704 705 5q2
     702 703 5q2
     704 705 5q2
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       702 703 5q2
       704 705 5q2
       702 703 5q2
       704 705 5q2
       702 703 5q2
       704 705 5q2
       702 703 5q2
       704 705 5q2
       702 703 5q2
       704 705 5q2 end fill

end array

read start
   nst=1
end start

read bounds
   all=vacuum
end bounds

read bias
   id=500 2 11
end bias

read plot

' ************************************************************
'  use this block for plotting container array calcs         *
'                                                            *
ttl=' xy section through one strongback '
xul=16          yul=81          zul=250.43303
xlr=88          ylr=32          zlr=250.43303
uax=1.0         vdn=-1.0        nax=150   lpi=10   end
'
ttl=' xy section through one container '
xul=0           yul=106.045     zul=250.43303
xlr=106.045     ylr=0           zlr=250.43303
uax=1.0         vdn=-1.0        nax=150   lpi=10   end

ttl=' xy section through 2x2x1 array of containers '
xul=0           yul=212.090     zul=250.43303
xlr=212.090     ylr=0           zlr=250.43303
```

```
uax=1.0          vdn=-1.0         nax=150   lpi=10   end

ttl=' xy section through array '
xul=-32          yul=1304.54      zul=250.43303
xlr=1304.54      ylr=-32          zlr=250.43303
uax=1.0          vdn=-1.0         nax=150   lpi=10   end

ttl=' xz section through one container '
xul=0            yul=51.7525      zul=0
xlr=106.045      ylr=51.7525      zlr=500.86606
wax=1.0          udn=1.0          nax=150   lpi=10   end

ttl=' xz section through array '
xul=-32          yul=51.7525      zul=-32
xlr=1304.54      ylr=51.7525      zlr=1033.73212
wax=1.0          udn=1.0          nax=150   lpi=10   end
'
' ************************************************************
end plot

end data
end
```

APPENDIX VII-B MISCELLANEOUS REFERENCES

The following pages provide miscellaneous reference data for the T15X15 fuel assemblies.

CLASSE III

TABLE 1.1.3

FUEL PELLET AND FUEL ROD SPECIFICATIONS

Region	Initial U-235 w/o (nominal)	Theoretical Density (% nominal)	Pellet Diameter (cm)	Cold Fuel Length (cm)
10	4.47	95.0	.8890*	265.6
11	4.47	95.0	.8890*	265.6
12	4.47	95.0	.8890*	265.6
13	4.47	95.0	.8890*	265.6

Fuel Rod Outer Diameter	= 0.385 in (0.978 cm)
Clad Material	= SS-304
Clad Thickness **	= 0.0151 in (0.0384 cm)
Gas Fill	= Air
Fuel Rod Diametral Gap	= 0.005 in (0.0127 cm)

(*) Thick clad rod pellet diameter = 0.3320 in (0.8433 cm)
(**) Thick clad thickness = 0.024 in (0.061 cm)

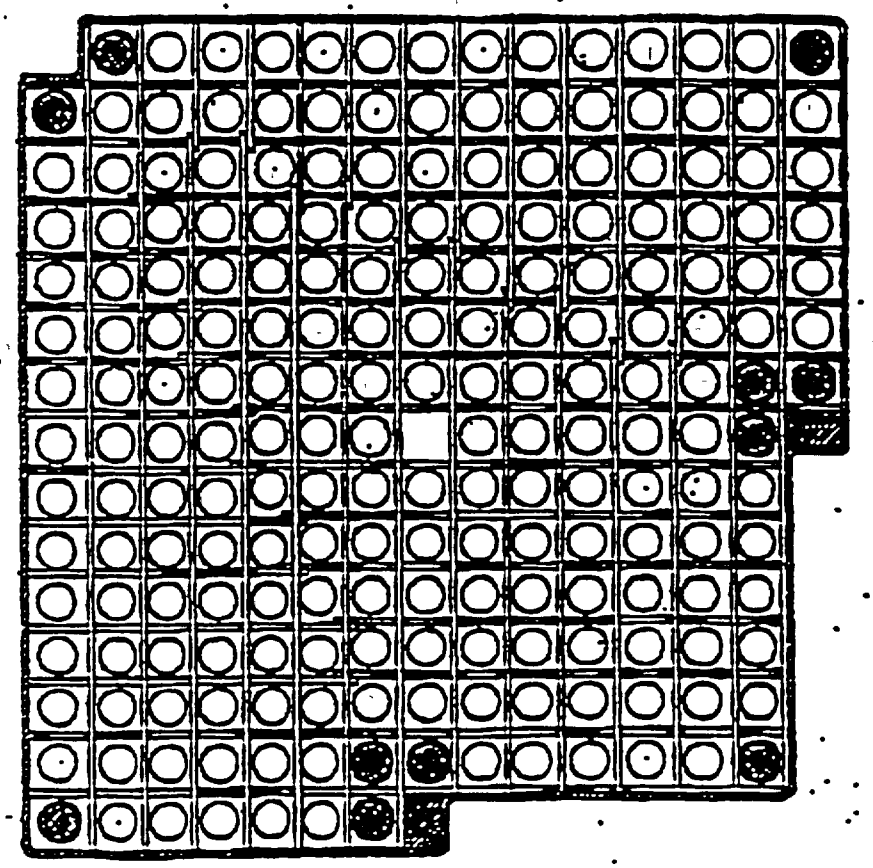
Centrale NEL TRINO R.F.S. Doc: DAR.0001.IIIFV.0031

Elettronucleare "E. Fermi" TRINO

SEZIONE D - CAPITOLO D-3
PROGETTO NUCLEARE DEL NOCCIOLO

Rev. 2 del 15/12/85

ATTACHMENT 3



15.1 mil cladding thickness
Incamiciatura standard (197 barrette) STANDARD ROD

Incamiciatura a spessore maggiorato (11 barrette) THICK ROD
24 mil cladding thickness

Enel

NUCLEAR PLANT MANAGEMENT (SGN)

VIA TORINO, N° 6 - 00184 ROMA
PHONE (+39 6) 85091 TELEFAX (+39 6) 85095861

TO: SIEMENS POWER CORPORATION- NUCLEAR DIVISION ATT. MR LARRY O'MALLEY	FAX N°: 001.425.453 -4446
FROM: PAPA ANGELO	

OUR REF.: 98 -

SUBJECT: ENEL SALE OF 295 CAORSO AND TRINO FUEL ELEMENTS

With reference to your request of information about the tolerance on the thickness of 15 mil thick Trino cladding you will find in attachment the drawing related to the 15 and 28.8 mil thick Trino claddings: we do not have the same drawing for the thick rod cladding. For both the above-mentioned thicknesses the tolerance is 5 %.

We will send to you our opinion on the approach on the third bullet in section 2 of Item B (meeting minutes) after the next two meeting in Caorso and Trino the 6th and the 7th of July.

Best regards.

XC: WC DEY
SF KUICK

FDG/

TRANSMISSION DATE:	NUMBER OF SHEETS:	SIGNATURE:
05/07/99	1 + 4	

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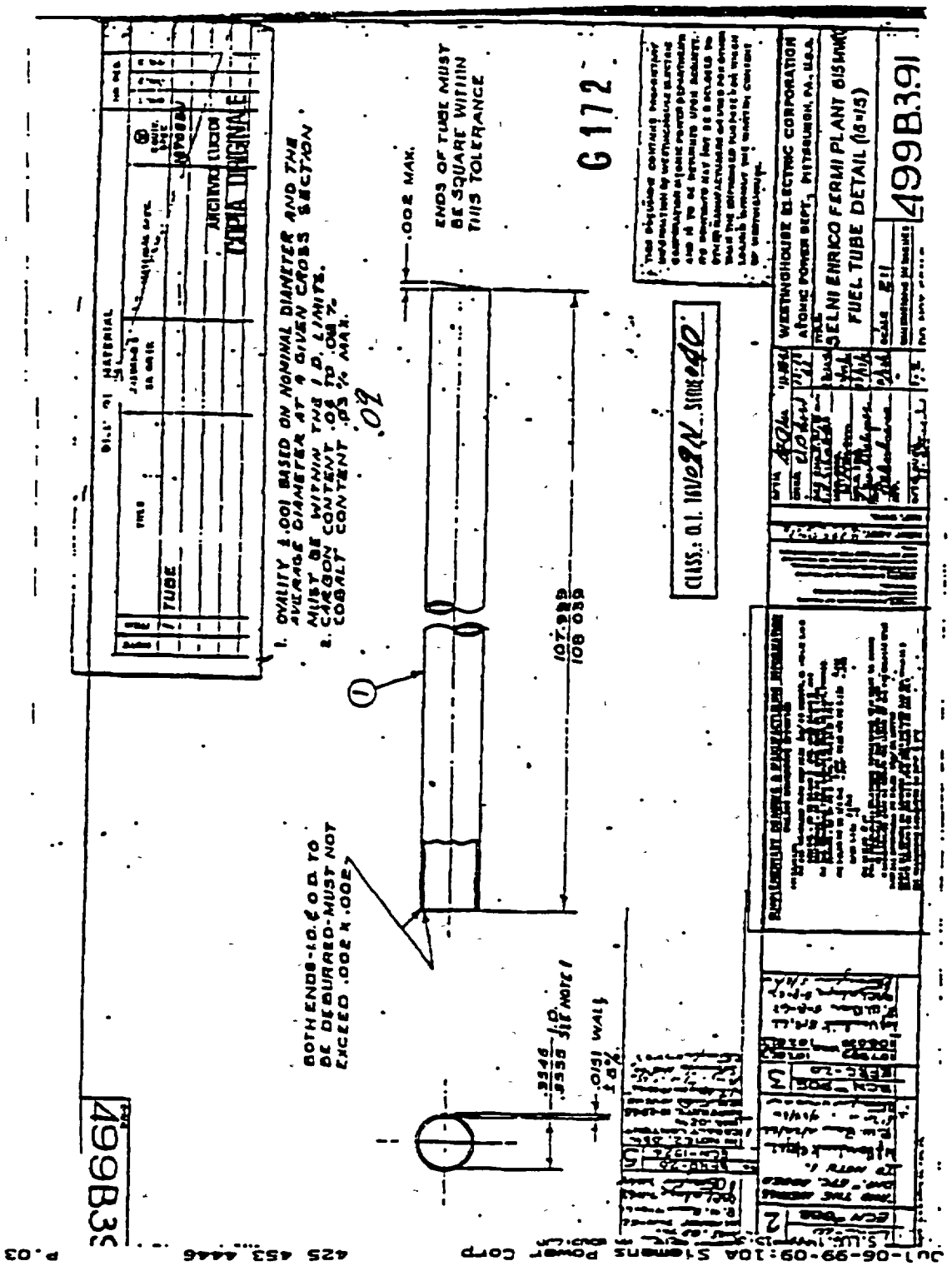

TUBE
1. OVALITY ±.001 BASED ON NOMINAL DIAMETER AND THE AVERAGE DIAMETER AT A GIVEN CROSS SECTION.
MUST BE WITHIN THE I.D. LIMITS.
2. CARBON CONTENT .08 TO .08 %
COBALT CONTENT .05 % MAX.
COPIA ORIGINALE
.002 MAX.
ENDS OF TUBE MUST BE SQUARE WITHIN THIS TOLERANCE
G172
107.989
108.035
BOTH ENDS-I.D. & O.D. TO BE DEBURRED-MUST NOT EXCEED .002 X .002
.0191 WALL
WESTINGHOUSE ELECTRIC CORPORATION
Atomic Power Dept., Pittsburgh, Pa., U.S.A.
SELNI ENRICO FERMI PLANT
FUEL TUBE DETAIL
499B391
499B3

The minimum of 0.2% yield strength obtained from actual tensile tests on tube specimens at 725°F is above 80,000 psi. The maximum stress in the fuel cladding at maximum steady state pressure (2,030 psig), worst tolerance combination and full power average core temperature conditions (625°F average clad temperature) is a compressive stress of 34,900 psi.

From the bursting test results it was extrapolated that at 725°F bursting of the clad would occur at a pressure of 7,200 psi. The internal pressure buildup due to gaseous fission products does not represent a limiting factor on the design of fuel tube.

To detect any defect in the material and insure integrity, all fuel tubes are ultrasonically and hydrostatically tested and many are eddy current tested. In addition, on a statistical basis, the inside surface is visually inspected with a boroscope and the outside surface is fluid penetrant inspected. Rejection standards on the eddy current test are based on defects in excess of 10% of the wall thickness. No linear indications are accepted by the fluid penetrant test.

The fuel rod ends are hermetically sealed with end plugs arc welded to the fuel tube under an inert gas atmosphere. The technique for end plug welds was extensively evaluated by radiographic inspection, helium leak testing, and destructive tests including mechanical (bursting) and metallographic examination.

D-I.B.3 Cruciform Fuel Assembly

In the reactor core the cruciform fuel assembly may be either inserted in the core or attached to a control rod absorber assembly.

Though the cruciform fuel assemblies fixed and movable are absolutely identical in all respects, it is sometimes convenient to use a different term when referring to the latter type. Therefore the movable cruciform fuel assembly (attached to a control rod absorber assembly) bears also the name of Fuel Follower.

The cruciform fuel assembly reduces the neutron flux peaking due to the formation of a moderator slot after the control rod absorber withdrawal, contributes to the power generation beeing made out of fuel, acts as a guide to the absorber, and serves to prevent excessive bypass coolant flow through the control rod channel.

a) Description

The cruciform fuel assembly, shown on Fig. 4:D-1, can be attached to an adapter or to the bottom of the control rod absorber assembly and it is shaped to fit the control rod slot.

D-1: 8
March 1964

All structural parts of a cruciform assembly are made of AISI 304 stainless steel. The overall length is 115.838 in. and the total weight is approximately 160 lbs.

A cruciform assembly is essentially composed of three main sections welded together: (1) the interlock with the control rod absorber assembly; (2) the central section containing the fuel bearing rods; (3) the end assembly.

The interlock is a stainless steel cutaway inverted T which provides a close fit for the bottom absorber end and also the engagement surfaces for the Universal Handling Tool used on the square fuel assemblies. The opposite surface to the engagement has 25 holes to accept the fuel rod end plugs of the central section of the assembly.

The central section consists essentially of two separate panels formed by a total of 28 rods which, as shown in Figure 4:D-1, are allowed to move relative to one another for most of their length. Relative motion is not possible at the extreme ends where the rods are welded to the rigid end adapters.

This design yields a lower spring rate in lateral deflection, thereby allowing the cruciform fuel assembly to conform more easily to the control rod channel envelope. This reduces rod clad wear to a negligible level and provides added insurance against jamming or binding due to thermal bowing.

All rods, with the exception of two, contain UO_2 pellets. Each rod is made up of eight compartments with seven stainless steel separator plugs welded to the cladding at alternate intervals of 13.847 in. or 12.773 in. in the same fashion that end plugs are normally welded to the cladding of square fuel assembly rods. Each compartment separator plug has a small hole drilled through its length to equalize the fission gas pressure throughout the length of the fuel rod. The separator plugs are laterally machined to form a plane on which a tie strap is welded. Tie straps 0.030 in. thick keep together the plugs, and therefore, the fuel tubes of each panel.

The arrangement of the central four rods is evident from Figure 4:D-1. The fuel is removed from two diagonally opposite rods out of the above four rods to prevent formation of possible hot spots when the clearance between rods in opposite panels is reduced by movement of either panel.

The rod walls have a thickness of 23.3 mils and are made of AISI stainless steel 10% cold worked. The rods have an outer diameter of 0.430 in. and a pitch of 0.547 in. except for the four central rods which have a pitch of 0.566 in.

The cruciform assemblies contain the 5.15% of the total fuel weight contained in the core. The enrichment of this fuel is 2.73%, that is, equal to that of the first core region having the lower enrichment. Power in the cruciform fuel assembly rods is maintained below the level of the surrounding core by the low enrichment and by the

D-1: 9
March 1984

higher cladding thickness. The worst power peak in the followers is expected to be only 80% of the core peak, so that fuel temperature in the pellet center will be well below the normal accepted value.

The end assembly is simply an offset cruciform stainless steel section with holes bored to accept the terminal plugs of the 28 rods of the follower central section.

The cruciform fuel assemblies which are maintained fixed in the reactor core bear an adapter, shown on Fig. 5:D-1, which reproduces the offset cruciform shape. A 0.319 in. thick stop is riveted on each of the four blades. When the cruciform fuel assembly is inserted in the core, the stops rest on the edges of the adjacent square fuel assembly end plates and prevent the cruciform assembly from falling into the shroud tube below. The stops, as shown on Fig. 5:D-1, are arranged in such a way to rest on the edges of two diagonally opposed fuel assembly end plates in order to allow removal of the other two adjacent square fuel assemblies while the cruciform assembly is in place. The upper portion of the adapter has the characteristic shape of an inverted T to permit engagement with the Universal Handling Tool.

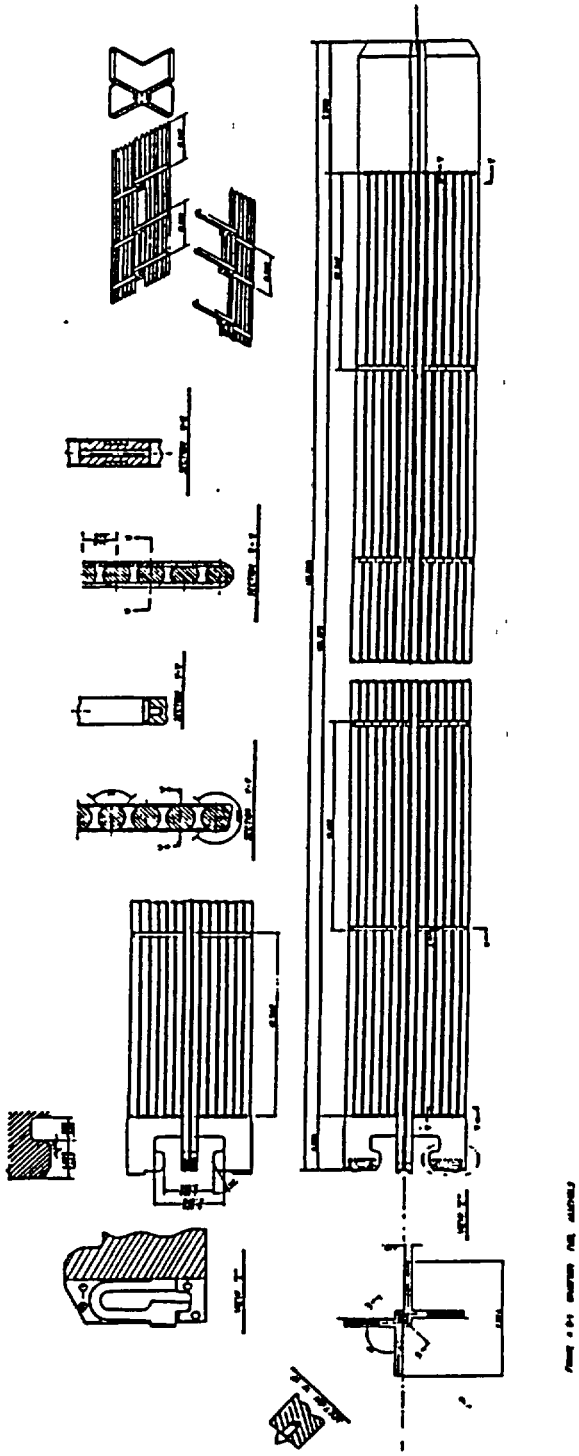
b) Design Considerations

A quite conservative approach was used to establish the cruciform fuel assembly design to account for the motion to which fuel followers unlike the square assemblies may be subjected.

Clad thickness is increased from the nominal requirement of 15 mils for stationary fuel rods to 20 mils. This increase minimizes the stress due to control rod motion and provides a wear allowance.

Fuel rods are divided into short compartments to minimize the accumulated weight of fuel bearing upon the bottom pellet of each stack. As in the square fuel assemblies, pellets have dished centers to ensure that this load is carried on the outer circumference of each pellet where temperature is low.

Dashpots are designed to dissipate the scram energy without applying more than 3.0 g's to the control rod assembly. The acceleration during a control rod drive mechanism normal step is 3.6 g's. Fuel follower pellets thus experience less force on scramming than they do during normal rod motion. It may be noted that the fuel follower exposed to 3.6 g's acceleration imposes about the same load on the bottom fuel pellet in a 12 in. compartment as a square fuel assembly element of 43 in. compartment length.



NUCLEAR CRITICALITY SAFETY ANALYSIS

MODEL 51032-1 SHIPPING CONTAINER SUPPLEMENTAL EVALUATION (L1, L2, AND L4 ASSEMBLY DESIGNS)

EMF-52 APPENDIX VIII

REVISION 7

JANUARY 2003

TABLE OF CONTENTS

1.0 EXECUTIVE SUMMARY ... 1
1.1 Allowed Contents ... 1
1.2 Criticality Safety Index (CSI) ... 1
1.3 Reactivity Summary ... 1

2.0 INTRODUCTION ... 5

3.0 ANALYSIS METHODOLOGY ... 6
3.1 Nuclear Analysis Methodology ... 6
3 2 Computer Codes and Databases Used ... 6
3 3 Benchmarking ... 6
3.3.1 Benchmarking Methodology ... 6
3.3 2 Benchmarking Results ... 7

4.0 COMPONENT DESCRIPTION AND ANALYSIS ... 14
4 1 L1 Fuel Assembly Design ... 15
4.1.1 Computer Model Description ... 15
4.1.2 Analysis of Single Container with L1 Fuel Assemblies ... 16
4.1.3 Analysis of Array of Undamaged Containers (Normal Conditions) with L1 Fuel Assemblies ... 18
4.1.4 Analysis of Array of Damaged Containers (Accident Conditions) with L1 Fuel Assemblies ... 20
4.1.5 Calculation of CSI with L1 Fuel Assemblies ... 23
4.2 L2 Fuel Assembly Design ... 24
4.2.1 Computer Model Description ... 24
4.2 2 Analysis of Single Container with L2 Fuel Assemblies ... 24
4.2.3 Analysis of Array of Undamaged Containers (Normal Conditions) with L2 Fuel Assemblies ... 25
4.2.4 Analysis of Array of Damaged Containers (Accident Conditions) with L2 Fuel Assemblies ... 27
4.2.5 Calculation of CSI with L2 Fuel Assemblies ... 29
4.3 L4 Fuel Assembly Design ... 30
4 3.1 Computer Model Description ... 30
4.3.2 Analysis of Single Container with L4 Fuel Assemblies ... 30
4.3.3 Analysis of Array of Undamaged Containers (Normal Conditions) with L4 Fuel Assemblies ... 31
4.3 4 Analysis of Array of Damaged Containers (Accident Conditions) with L4 Fuel Assemblies ... 33
4.3 5 Calculation of CSI with L4 Fuel Assemblies ... 35

5.0 REVISION HISTORY ... 36
5.1 Revision 0 ... 36

6.0 REFERENCES ... 37

APPENDIX A - TECHNICAL REVIEW.....A1

APPENDIX B - CALCULATION DATA.....B1

APPENDIX C - CALCULATION INPUTS.....C1

APPENDIX D - COPIES OF REFERENCES.....D1

INDEX OF TABLES

Table 1 List of Acronyms and Abbreviations vi

Table 2 Fuel Specification Summary 1

Table 3 Summary of Reactivity Results for the Model 51032-1 Shipping Container with Assembly Types L1, L2, and L4 4

Table 4 Benchmark Data from Reference 4 for 238-Group Cross Section Library and Heterogeneous UO_x without Gd_2O_3 9

Table 5 Model 51032-1 Major Components and Comparison of Actual vs Modeled Conditions 14

Table 6 Comparison of Actual vs Modeled Conditions for L1 Fuel Assembly 15

Table 7 Drop Test Results vs. Damaged Conditions Modeled 16

Table 8 Comparison of Actual vs. Modeled Conditions for L2 Fuel Assembly 24

Table 9 Comparison of Actual vs Modeled Conditions for L4 Fuel Assembly 30

Table 10 Single 51032-1 Container Loaded with L1 Fuel Assemblies, IM (Inside and Outside Container) Varied from Dry to Fully Flooded B1

Table 11 Infinite Array of Undamaged 51032-1 Containers Loaded with L1 Fuel Assemblies, Inside of Containers Remain Dry, IM (Between Containers) Varied from Dry to Fully Flooded B1

Table 12 15x15x3 Array of Undamaged 51032-1 Containers Loaded with L1 Fuel Assemblies, Inside of Containers Remain Dry, IM (Between Containers) Varied from Dry to Fully Flooded B2

Table 13 15x15x3 Array of Undamaged 51032-1 Containers Loaded with L1 Fuel Assemblies, 7 vol% IM (Between Containers), PE Inside Containers but Outside Assemblies Varied from 0 to 10 vol% B2

Table 14 12x12x2 Array of Damaged 51032-1 Containers Loaded with L1 Fuel Assemblies, Strongbacks and Assemblies Centered Inside Containers, IM (Inside and Between Containers) Varied from Dry to Fully Flooded B3

Table 15 12x12x2 Array of Damaged 51032-1 Containers Loaded with L1 Fuel Assemblies, Strongbacks and Assemblies Shifted Inside Containers, IM (Inside and Between Containers) Varied from Dry to Fully Flooded B3

Table 16 12x12x2 Array of Damaged 51032-1 Containers Loaded with L1 Fuel Assemblies, Strongbacks and Assemblies Shifted Inside Containers, Fully Flooded Conditions, PE Inside Containers but Outside Assemblies Varied from 0 to 10 vol% B4

Table 17 Single 51032-1 Container Loaded with L2 Fuel Assemblies, IM (Inside and Outside Container) Varied from Dry to Fully Flooded B4

Table 18 Infinite Array of Undamaged 51032-1 Containers Loaded with L2 Fuel Assemblies, Inside of Containers Remain Dry, IM (Between Containers) Varied from Dry to Fully Flooded B5

Table 19 15x15x3 Array of Undamaged 51032-1 Containers Loaded with L2 Fuel Assemblies, Inside of Containers Remain Dry, IM (Between Containers) Varied from Dry to Fully Flooded B5

Table 20 15x15x3 Array of Undamaged 51032-1 Containers Loaded with L2 Fuel Assemblies, 7 vol% IM (Between Containers), PE Inside Containers but Outside Assemblies Varied from 0 to 10 vol% B6

Table 21 12x12x2 Array of Damaged 51032-1 Containers Loaded with L2 Fuel Assemblies, Strongbacks and Assemblies Centered Inside Containers, IM (Inside and Between Containers) Varied from Dry to Fully Flooded B6

Table 22 12x12x2 Array of Damaged 51032-1 Containers Loaded with L2 Fuel Assemblies, Strongbacks and Assemblies Shifted Inside Containers, IM (Inside and Between Containers) Varied from Dry to Fully Flooded B7

Table 23 12x12x2 Array of Damaged 51032-1 Containers Loaded with L2 Fuel Assemblies, Strongbacks and Assemblies Shifted Inside Containers, Fully Flooded Conditions, PE Inside Containers but Outside Assemblies Varied from 0 to 10 vol% B7

Table 24 Single 51032-1 Container Loaded with L4 Fuel Assemblies, IM (Inside and Outside Container) Varied from Dry to Fully Flooded B8

Table 25 Infinite Array of Undamaged 51032-1 Containers Loaded with L4 Fuel Assemblies, Inside of Containers Remain Dry, IM (Between Containers) Varied from Dry to Fully Flooded B8

Table 26 15x15x3 Array of Undamaged 51032-1 Containers Loaded with L4 Fuel Assemblies, Inside of Containers Remain Dry, IM (Between Containers) Varied from Dry to Fully Flooded B9

Table 27 15x15x3 Array of Undamaged 51032-1 Containers Loaded with L4 Fuel Assemblies, 7 vol% IM (Between Containers), PE Inside Containers but Outside Assemblies Varied from 0 to 10 vol% B9

Table 28 12x12x2 Array of Damaged 51032-1 Containers Loaded with L4 Fuel Assemblies, Strongbacks and Assemblies Centered Inside Containers, IM (Inside and Between Containers) Varied from Dry to Fully Flooded B10

Table 29 12x12x2 Array of Damaged 51032-1 Containers Loaded with L4 Fuel Assemblies, Strongbacks and Assemblies Shifted Inside Containers, IM (Inside and Between Containers) Varied from Dry to Fully Flooded B10

Table 30 12x12x2 Array of Damaged 51032-1 Containers Loaded with L4 Fuel Assemblies, Strongbacks and Assemblies Centered Inside Containers, Fully Flooded Conditions, PE Inside Containers but Outside Assemblies Varied from 0 to 10 vol% B11

INDEX OF FIGURES

Figure 1 L1 and L2 Fuel Assembly Layout 2
Figure 2 L4 Fuel Assembly Layout 3
Figure 3 Analyse-it® Plots for Normality Test 12
Figure 4 Standardized Residual Plots from Analyse-it® 13
Figure 5 Cutaway View of a 51032-1 Containing L1 Fuel Assemblies 17
Figure 6 Single 51032-1 Container Loaded with L1 Fuel Assemblies 18
Figure 7 Arrays of Undamaged 51032-1 Containers Loaded with L1 Fuel Assemblies 19
Figure 8 15x15x3 Array of Undamaged 51032-1 Containers Loaded with L1 Fuel Assemblies, Low Density PE Inside Container 20
Figure 9 Cutaway View of Strongbacks and Assemblies Centered Inside 51032-1 Containers 21
Figure 10 Cutaway View of Strongbacks and Assemblies Shifted Inside 51032-1 Containers 21
Figure 11 12x12x2 Array of Damaged 51032-1 Containers Loaded with L1 Fuel Assemblies 22
Figure 12 12x12x2 Array of Damaged 51032-1 Containers Loaded with L1 Fuel Assemblies, Fully Flooded Conditions, Low Density PE in Container but Outside of Assemblies 23
Figure 13 Single 51032-1 Container Loaded with L2 Fuel Assemblies 25
Figure 14 Arrays of Undamaged 51032-1 Containers Loaded with L2 Fuel Assemblies 26
Figure 15 15x15x3 Array of Undamaged 51032-1 Containers Loaded with L2 Fuel Assemblies, Low Density PE Inside Container 27
Figure 16 12x12x2 Array of Damaged 51032-1 Containers Loaded with L2 Fuel Assemblies 28
Figure 17 12x12x2 Array of Damaged 51032-1 Containers Loaded with L2 Fuel Assemblies, Fully Flooded Conditions, Low Density PE in Container but Outside of Assemblies 29
Figure 18 Single 51032-1 Container Loaded with L4 Fuel Assemblies 31
Figure 19 Arrays of Undamaged 51032-1 Containers Loaded with L4 Fuel Assemblies 32
Figure 20 15x15x3 Array of Undamaged 51032-1 Containers Loaded with L4 Fuel Assemblies, Low Density PE Inside Container 33
Figure 21 12x12x2 Array of Damaged 51032-1 Containers Loaded with L4 Fuel Assemblies 34
Figure 22 12x12x2 Array of Damaged 51032-1 Containers Loaded with L4 Fuel Assemblies, Fully Flooded Conditions, Low Density PE in Container but Outside of Assemblies 35
Figure 23 W Test Percentage Points when Number of Cases, n, Exceeds 50 ..... D1

Table 1 List of Acronyms and Abbreviations

Acronym	Definition
COC	Certificate of Compliance
CSI	Criticality Safety Index
FANP	Framatome ANP, Inc
IM	Interspersed Moderator
MAX	Maximum
MIN	Minimum
NCS	Nuclear Criticality Safety
NCSA	Nuclear Criticality Safety Analysis
OD	Outside Diameter
PE	Polyethylene
SCALE	Standardized Computer Analyses for Licensing Evaluation

1.0 EXECUTIVE SUMMARY

This Nuclear Criticality Safety Analysis (NCSA) shows that sufficient margin to safety exists to add fuel categories L1, L2, and L4 (described in Section 1.1) to the allowed payloads for the model 51032-1 shipping container.

1.1 *Allowed Contents*

The allowed contents are unirradiated, sintered UO_2 pellets in fuel rods assembled into fuel assemblies The fuel assembly specifications are in accordance with Table 2. The locations of the guide tubes and instrument tubes are in accordance with Figure 1 and Figure 2

Table 2 Fuel Specification Summary

Assembly Type	L1	L2	L4
Rod Array Size	15X15	15X15	17X17
# Fuel Rods	208	208	264
# Non-Fuel Locations	17	17	25
Fuel Rod Pitch	0.568"	0.568"	0.496"
MAX Pellet OD	0 3707"	0.3742"	0 3232"
MIN Clad OD	0.428"	0 428"	0.372"
MAX Active Fuel Length	196"	196"	196"
MAX Enrichment ^{235}U	5.05	5.05	5.05
MAX UO_2 Theoretical Density	97.5%	97.5%	97.5%

1.2 *Criticality Safety Index (CSI)*

The CSI for fuel categories L1, L2, and L4 is 0.4. With this CSI, 50/0.4 or 125 packages may be shipped together.

1.3 *Reactivity Summary*

A summary of the reactivity results is provided in Table 3.

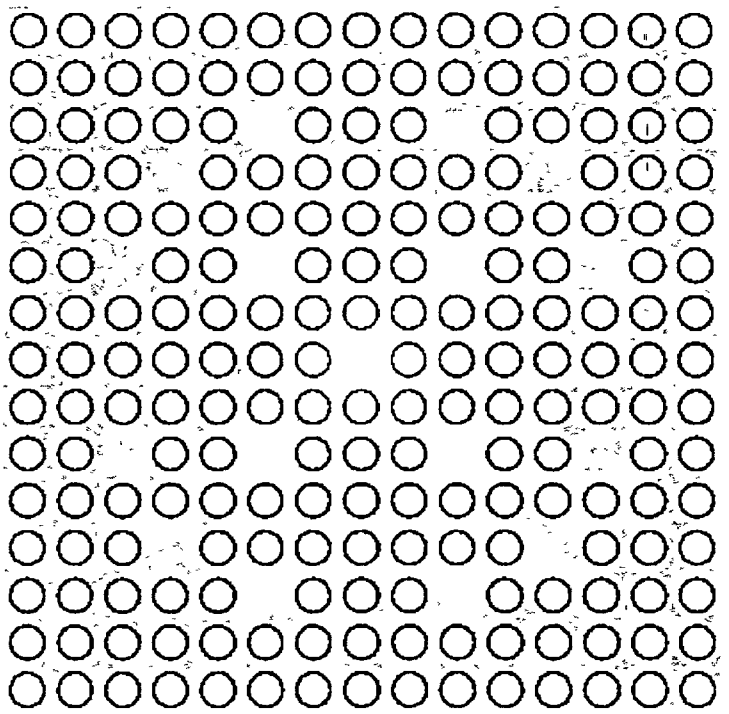


Figure 1 L1 and L2 Fuel Assembly Layout

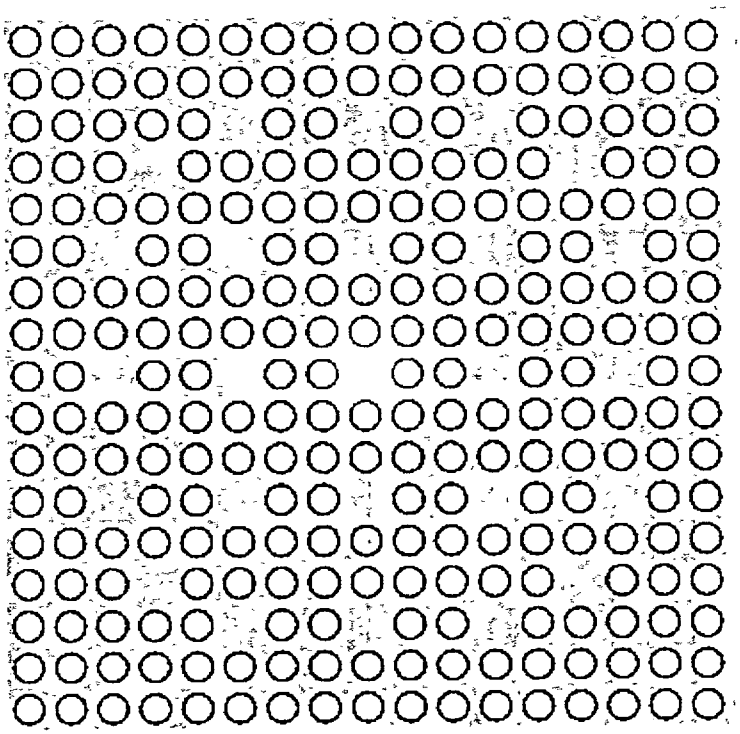


Figure 2 L4 Fuel Assembly Layout

Table 3 Summary of Reactivity Results for the Model 51032-1 Shipping Container with Assembly Types L1, L2, and L4

Description of Most Reactive Case	k_{eff}	σ	Bias	Biased k_{eff}
L1 Fuel Assembly (5.05 wt% ^{235}U)				
Single Package	0.9283	0.0007	0.0168	0.9451
15x15x3 Array of Undamaged Packages (675 Containers)	0.9093	0.0006	0.0168	0.9261
12x12x2 Array of Damaged Packages (288 Containers)	0.9306	0.0008	0.0168	0.9474
L2 Fuel Assembly (5.05 wt% ^{235}U)				
Single Package	0.9290	0.0008	0.0168	0.9458
15x15x3 Array of Undamaged Packages (675 Containers)	0.9109	0.0007	0.0168	0.9277
12x12x2 Array of Damaged Packages (288 Containers)	0.9313	0.0007	0.0168	0.9481
L4 Fuel Assembly (5.05 wt% ^{235}U)				
Single Package	0.9271	0.0007	0.0168	0.9439
15x15x3 Array of Undamaged Packages (675 Containers)	0.9041	0.0006	0.0168	0.9209
12x12x2 Array of Damaged Packages (288 Containers)	0.9298	0.0007	0.0168	0.9466

2.0 INTRODUCTION

This NCSA provides the nuclear criticality safety (NCS) basis for adding three additional categories (L1, L2, and L4) to the allowed payloads in the model 51032-1 shipping container. The fuel categories allowed by the current Certificate of Compliance (COC; Reference 1) were analyzed for NCS in Reference 2.

Section 3.0 of this NCSA details the methodologies used for the criticality analysis. Component description and analysis are provided in Section 4.0. Section 5.0 provides the revision history. Section 6.0 documents the references. The technical review is documented in Appendix A Appendix B provides a summary of all SCALE calculation results. Sample computer inputs are provided in Appendix C. Copies of selected references may be provided in Appendix D.

3.0 ANALYSIS METHODOLOGY

3.1 *Nuclear Analysis Methodology*

Monte Carlo techniques were used in this analysis. Sensitivities to pellet diameter, clad diameter, rod pitch, bundle size, interspersed moderator (IM), and placement of low density polyethylene (PE) inside the containers were evaluated

3.2 *Computer Codes and Databases Used*

This NCSA employed the SCALE-4 4a (PC version) code system (Reference 3) using the CSAS25 module, KENO-V.a, and the ENDF/B-V 238-group cross section library to calculate the neutron multiplication factor, k_{eff}. Within the SCALE package, BONAMI and NITAWL adjust the cross section data for the specific problem (e.g., perform resonance self-shielding corrections)

3.3 *Benchmarking*

3.3.1 Benchmarking Methodology

SCALE 4.4a-PC and associated modules using ENDF/B-V 238-group cross sections were validated for use at FANP in Reference 4. The bias and its standard deviation are calculated using the methods described in Reference 4. These methods use standard analysis of variance principles, consistent with NUREG/CR-6698 (Reference 6). For the reviewer's use, the calculational bias evaluation methodology described in Reference 4 is repeated in this subsection.

The approach employed for determining the 95/95 upper limit ($K_{95/95}$) for calculated k_{eff} of the SCALE 4.4a version of KENO-V.a is based on the following equation:

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

where K_{KENO} is the KENO multiplication factor of interest,

ΔK_B is the mean calculational method bias,

$M_{95/95}$ is the 95/95 multiplier appropriate to the degrees of freedom for the number of validation analyses,

σ_m^2 is the mean calculational method variance deduced from the validation analyses, and

σ^2_{KENO} is the standard deviation appropriate to the KENO multiplication factor of interest.

For a given KENO-V.a eigenvalue and uncertainty, the magnitude of $K_{95/95}$ is computed by the above equation. These results provide a 95 percent confidence that in 95 percent of similar analyses the validated calculational model will not yield a multiplication factor greater than $K_{95/95}$

The equation for the mean calculational method bias (ΔK_B) is the difference between the weighted mean k-value for the validation experiments and unity.

$$\Delta K_B = K^{ave} - 1$$

K^{ave} is given by the following equation (equation 6 from Reference 6):

$$K^{ave} = \sum_1^n K_i(\sigma_i)^{-2} \Big/ \sum_1^n (\sigma_i)^{-2}$$

The pooled method analysis variance, σ_m^2 is the sum of the variance about the mean and the average total uncertainty. This value is determined as follows (equations 4 and 5 from Reference 6):

$$\sigma_m^2 = \frac{\left(\frac{1}{n-1}\right)\sum_i \frac{1}{\sigma_i^2}\left(k_{eff,i} - \overline{k_{eff}}\right)^2}{\frac{1}{n}\sum_i \frac{1}{\sigma_i^2}} + \frac{n}{\sum \frac{1}{\sigma_i^2}}$$

$M_{95/95}$ is obtained from the one side tolerance statistical tables and is valid for data that has a distribution consistent with the assumptions associated with the tables in Reference 7.

The plots of statistical data that are included in this section were created using Analyse-it®, a commercially available statistical software add-in for Microsoft Excel.

The bias, square root of pooled method analysis variance, weighted mean, and 95/95 multipliers were obtained by using the FANP computer code USLS prepared by L.A. Hassler. The code description and verification is documented in Reference 8.

The determination for normality was made by using the Shapiro-Wilk coefficient produced by Analyse-it® and comparing this value with W test percentage points associated with the number of benchmarks being evaluated. When n, the number of cases being evaluated, exceeds 50, the W test percentage points were obtained from Appendix D. When $n \leq 50$, the W test percentage points can be obtained from any standard statistics table containing Shapiro-Wilk data.

3.3.2 Benchmarking Results

As previously stated, SCALE 4.4a-PC and associated modules using ENDF/B-V 238-group cross sections were validated for use at FANP in Reference 4. The calculations in this NCSA are bounded by the Reference 4 validation report.

As stated in Reference 4, $K_{95/95}$ (called "biased k_{eff}" later in this NCSA) can be obtained by adding the calculated total uncertainty to the average k_{eff} produced by KENO-V.a.

All calculations in this NCSA utilize the 238-group cross section library and heterogeneous UO_x without Gd_2O_3. Reference 4 uses a pool of 82 critical experiments to calculate the total uncertainty for heterogeneous UO_x without Gd_2O_3 The benchmark data used to calculate the total uncertainty for the 238-group cross section library and heterogeneous UO_x without Gd_2O_3 is provided in Table 4.

Figure 3 provides the Analyse-it® plots for normality and shows that the 82 points are normally distributed about the mean with a Shapiro-Wilk coefficient of 0 9869. According to the W test percentage points obtained from Appendix D, 82 points are normally distributed about the mean if the Shapiro-Wilk coefficient is greater than 0.971.

Figure 4 shows the standardized residuals from the value obtained by dividing the predicted k_{eff} by experimental (measured) values of k_{eff} plotted against EALF. Figure 4 illustrates that any potential trends in the data are statistically insignificant. The 82 benchmark cases used for this validation included cases with various amounts of IM. As evidenced by the standardized residual versus EALF plot in Figure 4, there is no significant trend for IM.

Using the 82 data points in Table 4 and the FANP computer code USLS (Reference 8), the resulting bias, pooled uncertainty, and 95/95 multiplier are

Bias = -1.019699E-02

Square Root of Pooled Variance = 3.194255E-03

95/95 One-Sided Tolerance Limit Multiplier = 1.961

Provided the KENO-V.a calculated k_{eff} has a standard deviation less than or equal to 0.001, $K_{95/95}$ (biased k_{eff}) is calculated as follows (see section 3.3.1 for equations):

$$K_{95/95} = K_{KENO} + 1.019699E\text{-}02 + 1.961*[(3.194255E\text{-}03)^2 + (0.001)^2]^{1/2}$$

$$\mathbf{K_{95/95} = K_{KENO} + 0.0168}$$

Therefore, in this NCSA, the biased k_{eff} is obtained by adding 0.0168 to the k_{eff} produced by KENO-V.a, while ensuring that the KENO-V.a calculated k_{eff} has a standard deviation (σ) less than or equal to 0.001. The biased k_{eff} is then compared to the 0 95 limit.

Table 4 Benchmark Data from Reference 4 for 238-Group Cross Section Library and Heterogeneous UO_x without Gd_2O_3

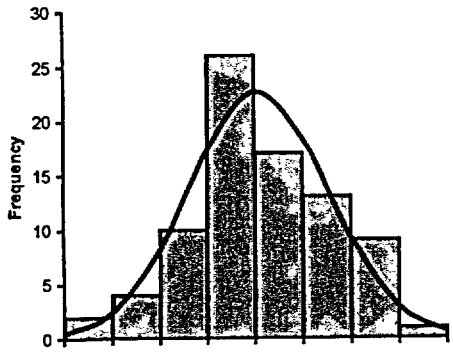
File Name	k-mean	σ
c004.out	0.9930	0.0010
c005b.out	0.9931	0 0008
c006b.out	0.9941	0.0009
c007a out	0.9944	0.0008
c008b.out	0.9931	0.0007
c009b.out	0.9928	0.0008
c010b.out	0.9952	0.0009
c011b.out	0.9964	0.0008
c012b.out	0.9938	0.0009
c013b out	0.9953	0.0008
c014b.out	0.9942	0.0009
c029b.out	0.9942	0.0008
c030b.out	0.9946	0.0008
c031b.out	0.9951	0.0008
core01.out	0.9952	0.0007
core12a.out	0 9950	0.0006
core18.out	0.9950	0.0007
aclp1.out	0.9889	0.0009
aclp2.out	0.9939	0 0008
aclp3.out	0.9934	0.0007
aclp4.out	0.9875	0.0008
aclp5.out	0.9873	0.0008
aclp7.out	0.9867	0.0008
aclp9.out	0.9879	0.0007
aclp10.out	0.9883	0 0008
acp11a.out	0.9919	0 0006
acp11b out	0.9916	0.0009
acp11c.out	0.9915	0.0008
acp11d out	0.9920	0.0009
acp11e.out	0.9918	0.0006
acp11f.out	0.9916	0.0006

Table 4 Benchmark Data from Reference 4 for 238-Group Cross Section Library and Heterogeneous UO_x without Gd_2O_3

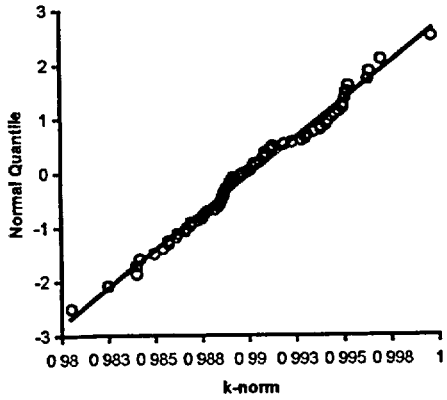
File Name	k-mean	σ
acp11g.out	0.9908	0.0007
aclp12.out	0 9889	0.0008
aclp13.out	0.9906	0.0009
acp13a.out	0.9884	0.0007
aclp14.out	0.9891	0.0009
aclp15.out	0.9823	0.0007
aclp16.out	0.9841	0.0007
aclp17.out	0.9874	0.0007
aclp18.out	0.9859	0.0008
aclp19.out	0.9888	0.0006
aclp20.out	0.9869	0.0008
aclp21.out	0.9854	0.0007
rcon01.out	0 9910	0.0007
rcon02.out	0.9909	0.0008
rcon03.out	0.9882	0.0007
rcon04.out	0 9899	0.0007
rcon05.out	0.9899	0.0008
rcon06.out	0.9906	0.0008
rcon07.out	0.9904	0.0008
rcon09.out	0.9884	0.0006
rcon10.out	0.9909	0.0008
rcon11.out	0.9876	0.0007
rcon12.out	0 9897	0.0007
rcon13.out	0.9894	0.0007
rcon14.out	0 9915	0.0007
rcon15.out	0.9892	0.0007
rcon16.out	0.9894	0.0006
rcon17.out	0 9909	0.0007
rcon18 out	0 9897	0.0007
rcon19.out	0.9915	0.0007
rcon20.out	0.9903	0.0007
rcon21.out	0.9915	0.0008
rcon28.out	0 9894	0.0007

Table 4 Benchmark Data from Reference 4 for 238-Group Cross Section Library and Heterogeneous UO_x without Gd_2O_3

File Name	k-mean	σ
mdis01.out	0.9885	0.0010
mdis02.out	0.9862	0.0008
mdis03.out	0.9805	0.0008
mdis04 out	0.9884	0.0008
mdis05.out	0 9891	0.0009
mdis06.out	0.9963	0.0008
mdis07.out	0.9886	0.0008
mdis08.out	0.9840	0.0009
mdis09.out	0.9861	0.0009
mdis10.out	0.9912	0.0008
mdis11.out	0.9997	0.0008
mdis13 out	0.9878	0 0008
mdis14.out	0 9854	0.0009
mdis15.out	0.9842	0.0008
mdis16.out	0.9970	0.0009
mdis17.out	0.9951	0.0009
mdis18.out	0.9923	0.0009
mdis19.out	0 9888	0.0008



n	82
Mean	0.990167
95% CI	0 989373 to 0.990960
Variance	0 0000130
SD	0 0036119
SE	0 0003989
CV	0%



	Coefficient	p
Shapiro-Wilk	0 9869	0 5779
Skewness	0 0498	0 8459
Kurtosis	-0 0324	0 8961

Figure 3 Analyse-it® Plots for Normality Test

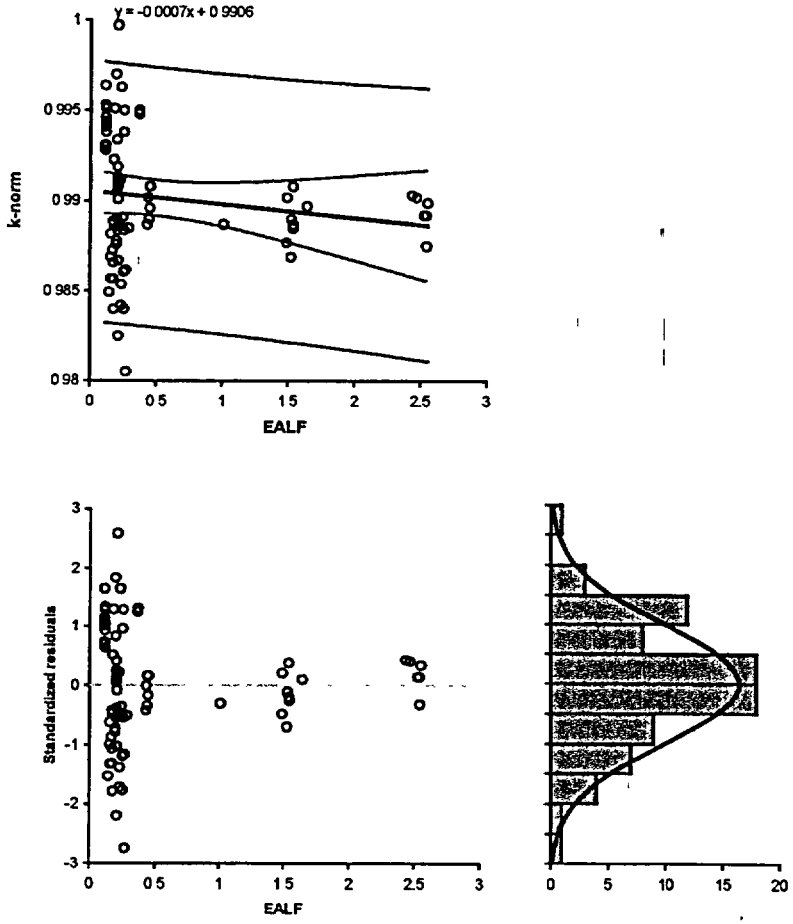


Figure 4 Standardized Residual Plots from Analyse-it®

4.0 COMPONENT DESCRIPTION AND ANALYSIS

This section provides analyses for three additional categories (L1, L2, and L4) to the allowed payloads in the model 51032-1 shipping container. Descriptions of the payloads and modeled conditions are provided in subsections that follow.

For container modeling and sensitivity studies, the reader is referred to References 2 and 5 The container and assembly modeling and sensitivity studies performed in this analysis are identical to those performed for existing payload types in these references.

The model 51032-1 shipping container major components and their actual and modeled dimensions are provided in Table 5 Except for some rubber gaskets, the entire container is constructed of carbon steel. Therefore, only the results of the drop tests need to be considered for decreased dimensions during damaged conditions, i e., there is no wood or plastic to burn away, which could decrease spacing between fuel assemblies and/or containers.

Table 5 Model 51032-1 Major Components and Comparison of Actual vs. Modeled Conditions

Parameter	Actual	Modeled	Reference for Actual Conditions
SEPARATOR BLOCKS			
Outer Width	6" MIN	6"	Drawing EMF-309,813 R-2
Outer Height	8 ± 1/2"	7.5"	"
Length	9 ± 1/2"	8.5"	"
Steel Thickness	3/8 ± 1/16"	0.3125"	"
Number in Container	5 MIN	5	Reference 2, p 2-6
STRONGBACK ASSEMBLY			
Width	24-7/8 ± 5/16"	24 5625"	Drawing EMF-303,898 R-5
Height	12-1/2 ± 3/4"	11.5625"	"
Length	196 ± 1"	197"	"
Steel Thickness	1/4 ± 1/16"	0.1875"	"
CONTAINER STEEL SHELL			
Inner Radius	19-7/8 ± 3/8"	19.5"	Drawing EMF-303,360 R-6
Outer Length	216-1/4 ± 1-5/16"	197"	"
Steel Thickness	11 ga	0.09568" (80% of nominal 11 ga)	"
Container C-C Spacing	> 42-1/8 ± 3/8"	41.75" (undam) 40.75" (dam)	DWG EMF-309,813 R-2

4.1 *L1 Fuel Assembly Design*

The L1 fuel assembly is a 15x15 design. The layout of the L1 fuel assembly is shown in Figure 1. Only the fuel rod locations are explicitly shown in Figure 1. The "empty" locations in Figure 1 are guide and instrument tube (non-fueled) locations. A comparison of actual and modeled dimensions for the L1 fuel assembly is provided in Table 6

Table 6 Comparison of Actual vs. Modeled Conditions for L1 Fuel Assembly

Parameter	Actual	Modeled	Reference for Actual Conditions
FUEL ROD			
MAX Pellet Diameter	0.3707"	0.3707"	Pending Certificate of Compliance
Theoretical Density	97.5%	98%	
MIN Clad OD	0.428"	0.428"	
ASSEMBLY			
MAX Enrichment	5.05 wt% ^{235}U	5.05 wt% ^{235}U	Pending Certificate of Compliance
Assembly Cross Section	8 520" x 8.520" MAX	8.520" x 8 520"	
Rod Array Size	15x15	15x15	
Number of Non-Fueled Grid Locations	17 (see Figure 1)	17	
Nominal Rod Pitch	0.568"	0.568"	
Active Fuel Length	144"	197"	

4.1.1 Computer Model Description

The model 51032-1 shipping container was modeled with the dimensions shown in Table 5, exactly as it was modeled in Reference 5, which supported the most recently added fuel categories (Trino fuel).

Except for the length of the strongback assembly, all components were modeled at minimum dimensions This was done to minimize the amount of steel in the model and to provide a minimum credible spacing between containers. Maximizing the length of the strongback assembly increases the amount of fissile material on the strongback, but concurrently increases the amount of steel (a poison) in the container. Using the maximum strongback length, compared to the minimum length, adds 2.31 kg carbon steel to the model. However, modeling the strongback thickness at the minimum value over the entire length (highly conservative), removes over 74 kg of carbon steel from the model. This alone, more than compensates for the steel added due to the increased length. In addition, all other steel components (separator blocks, clamps, exterior bracing) are either modeled at minimum dimensions or are completely ignored. The KENO model uses approximately 597 kg of carbon steel in a single model 51032-1 container. Via a telecon on 8/9/99, Bob Summerville (FANP) reported that a single model 51032-1 shipping container prepped for assembly loading weighs at least 4100 lbs (1860 kg). Note that a very small amount of this actual weight is due to rubber gasket material. This shows that the amount of steel used in the model is significantly less than that actually contained in the model 51032-1 shipping containers (conservative).

Appendix IV of Reference 2 provides the results of the 30-foot drop tests. A summary of the worst case results, along with the modeled damaged conditions, is provided in Table 7.

Table 7 Drop Test Results vs. Damaged Conditions Modeled

Parameter	Horizontal (x) Drop Test Result	Vertical (z) Drop Test Result	Modeled in Damaged Conditions
Horizontal (x) Offset of Strongback	0.875"	1.25"	1.5"
Vertical (y) Offset of Strongback	2 75"	0.5"	3 0"
C-C Container Spacing Affected by Damage to Outer Container	No significant change	No significant change	1" reduction in C-C spacing

The L1 assemblies were modeled with the dimensions shown in Table 6. By modeling the maximum pellet diameter and the minimum clad OD, both fuel and moderator within the assembly are maximized. In order to minimize any neutron absorption in the clad material, the clad was modeled as void

Full water reflection was used around the container in the single container calculations and around the array in the array calculations. No pathway for preferential flooding has been identified. Fuel assemblies are held in place with clamps. If PE sheathing is used, the current COC requires that it be open on each end

4.1.2 Analysis of Single Container with L1 Fuel Assemblies

Calculations were performed for a single model 51032-1 shipping container loaded with the L1 fuel design. The shipping container and L1 assemblies were modeled as described in Table 5 and Table 6. IM (inside the shipping container and assemblies) was varied from dry to fully flooded. Figure 5 presents a cutaway view of a 51032-1 containing L1 fuel assemblies

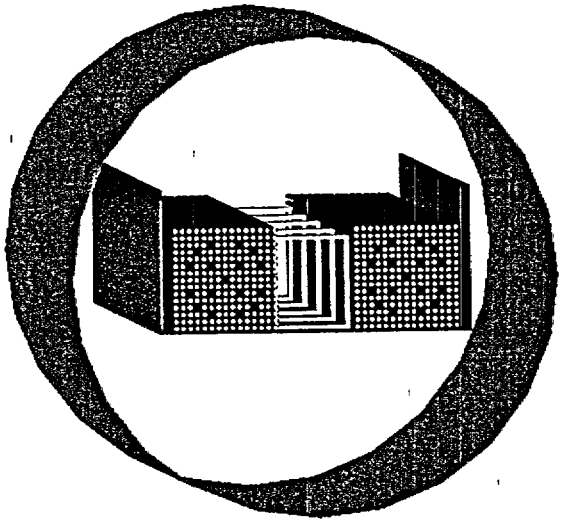


Figure 5 Cutaway View of a 51032-1 Containing L1 Fuel Assemblies

The results of the calculations for a single container loaded with L1 fuel assemblies are presented graphically and in tabular form in Figure 6 and Table 10, respectively. The maximum biased k_{eff} occurs at fully flooded conditions and is 0.9451, below 0.95.

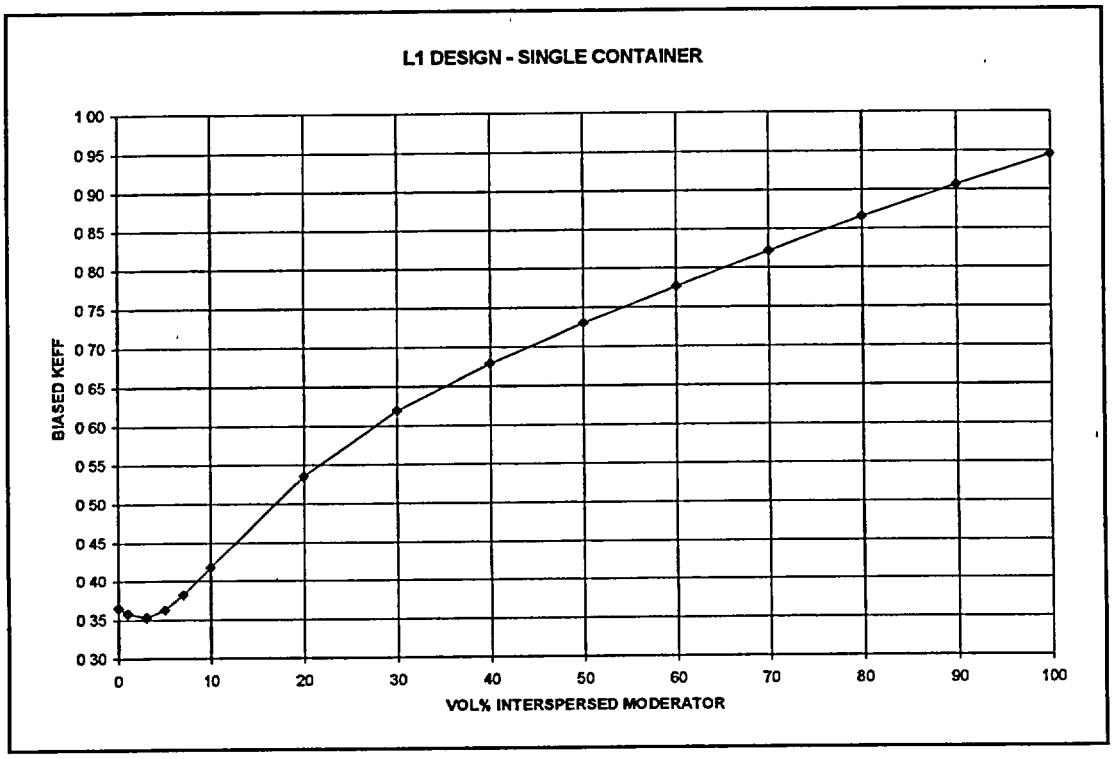


Figure 6 Single 51032-1 Container Loaded with L1 Fuel Assemblies

4.1.3 Analysis of Array of Undamaged Containers (Normal Conditions) with L1 Fuel Assemblies

Calculations were performed for an array of model 51032-1 shipping containers under normal or undamaged conditions. L1 fuel assemblies were placed in the containers. Page 9-1 of Reference 2 states that the water spray test demonstrated that water would not leak into the package. Therefore, in the undamaged calculations of this subsection, the insides of the containers remain dry. The following sets of cases were analyzed, each varying IM (between containers) from dry to fully flooded.

- Infinite array of containers
- 15x15x3 (675 total) array of containers

A 15x15x3 array was chosen so that the array would contain enough containers to justify a CSI of 0 4, while also maintaining a nearly cubic shaped array in order to maximize the reactivity. The dimensions of a 15x15x3 array of undamaged 51032-1 containers are approximately 1591 cm x 1591 cm x 1503 cm.

The results of the calculations for an infinite and 15x15x3 array of undamaged 51032-1 containers loaded with L1 fuel assemblies are presented graphically in Figure 7. This data is presented in tabular form in Table 11 and Table 12, respectively. For an infinite array, the maximum biased k_{eff} occurs at 5 vol% IM and is 1.0685. For a 15x15x3 array, the maximum biased k_{eff} occurs at 7 vol% IM and is 0.9261, below 0.95.

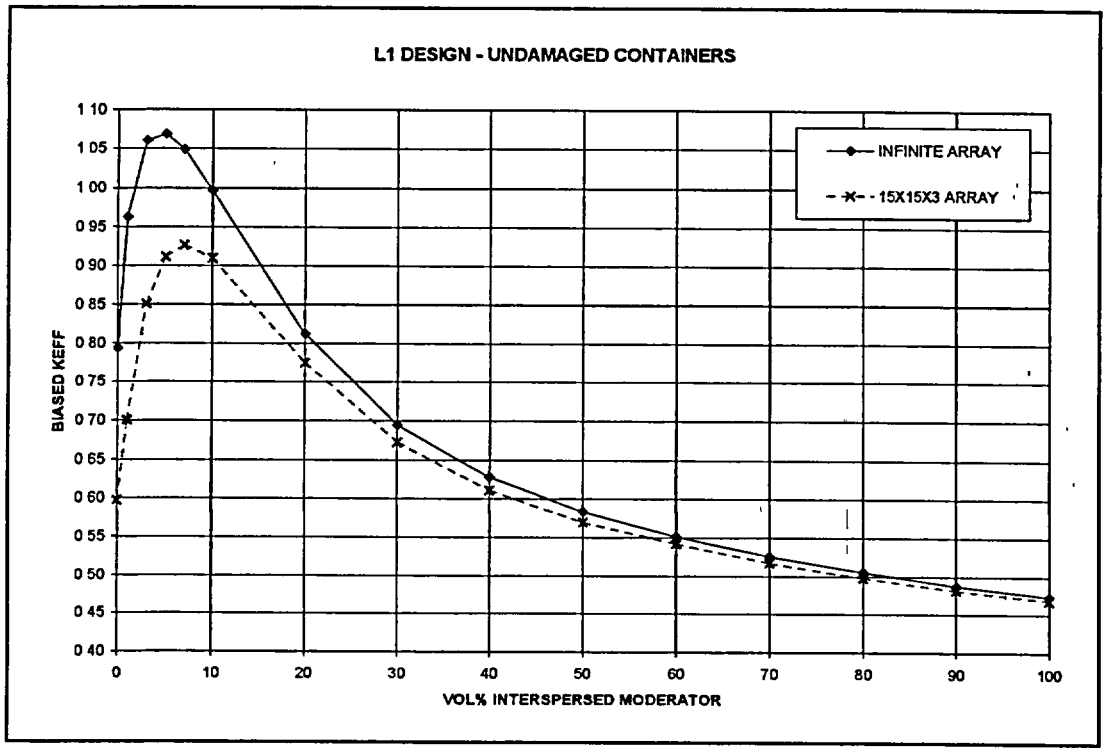


Figure 7 Arrays of Undamaged 51032-1 Containers Loaded with L1 Fuel Assemblies

As discussed previously, except for some rubber gaskets and a PE assembly sheath in some cases, no hydrogenous shipping components are used in the model 51032-1 shipping container. In order to show that this small amount of hydrogenous material does not have an adverse impact on reactivity, the most reactive case for a 15x15x3 array of undamaged containers (case U675C007 with 7 vol% IM) was modified to include low density PE inside the container, but outside of the bundles. The amount of PE inside the container was varied from 1 to 10 vol%. The amount of IM between containers was maintained at 7 vol%. The results are summarized graphically and in tabular form in Figure 8 and Table 13, respectively. As expected, since the peak IM was already identified and used, addition of PE to the inside of the container results in lower reactivities.

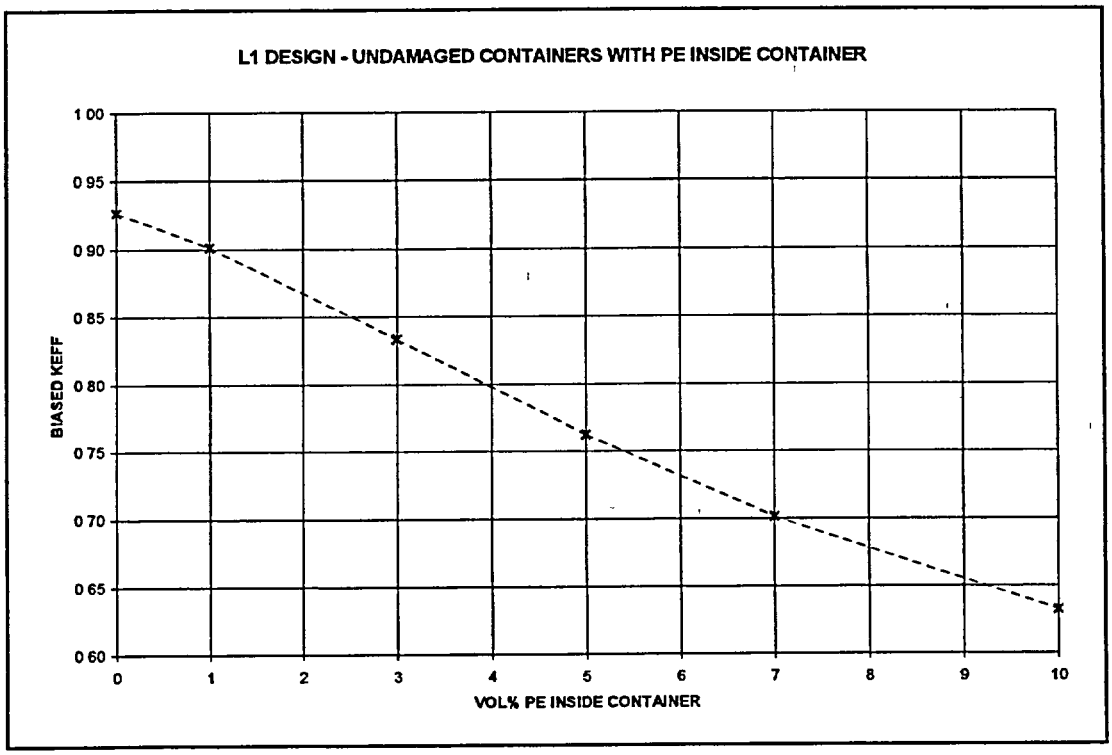


Figure 8 15x15x3 Array of Undamaged 51032-1 Containers Loaded with L1 Fuel Assemblies, Low Density PE Inside Container

4.1.4 Analysis of Array of Damaged Containers (Accident Conditions) with L1 Fuel Assemblies

Calculations were performed for an array of model 51032-1 shipping containers under accident or damaged conditions. L1 fuel assemblies were placed in the containers. As previously stated, no pathway has been identified for preferential flooding of the container. The following sets of cases were analyzed, each varying IM (both inside and between containers) from dry to fully flooded:

- 12x12x2 (288 total) array of containers. Bundles and strongbacks are centered in container.
- 12x12x2 (288 total) array of containers. Bundles and strongbacks are shifted in container.

A 12x12x2 array was chosen so that the array would contain enough containers to justify a CSI of 0.4, while also maintaining a nearly cubic shaped array in order to maximize the reactivity. The dimensions of a 12x12x2 array of damaged 51032-1 containers are approximately 1242 cm x 1242 cm x 1002 cm

Cases with the bundles and strongbacks shifted in the containers have the strongbacks shifted by the amount listed in Table 7. The bundles are then shifted in the same horizontal direction, so that they are against the inside of the strongback These shifts are performed so that the spacing between bundles in four adjacent containers is minimized. Figure 9 and Figure 10 show cutaway views of four adjacent 51032-1 containers with the strongbacks and assemblies centered and shifted, respectively.

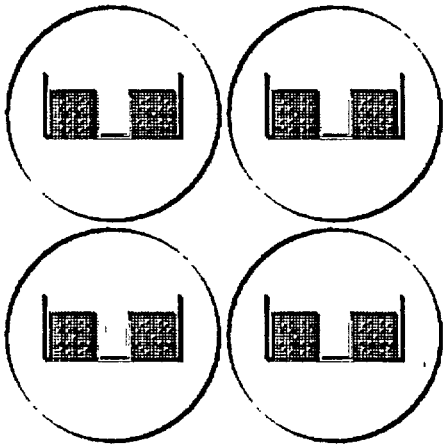


Figure 9 Cutaway View of Strongbacks and Assemblies Centered Inside 51032-1 Containers

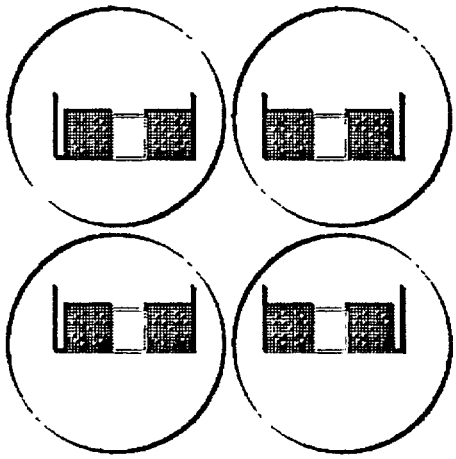


Figure 10 Cutaway View of Strongbacks and Assemblies Shifted Inside 51032-1 Containers

The results of the calculations for a 12x12x2 array of damaged 51032-1 containers loaded with L1 fuel assemblies are presented graphically in Figure 11. This data is presented in tabular form in Table 14 and Table 15 Whether the strongbacks and assemblies are centered or shifted in the containers, the maximum biased k_{eff} occurs at fully flooded conditions. The maximum biased k_{eff} for the centered and shifted cases is 0.9446 and 0.9458, respectively, both below 0.95.

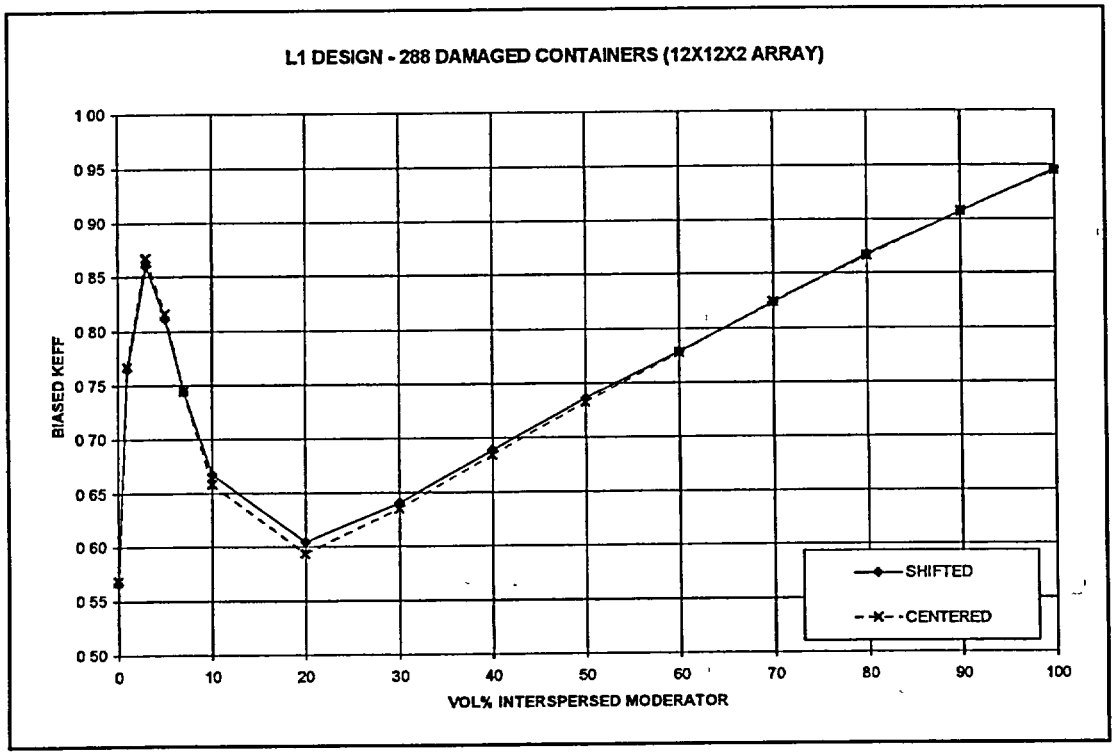


Figure 11 12x12x2 Array of Damaged 51032-1 Containers Loaded with L1 Fuel Assemblies

As discussed previously, except for some rubber gaskets and a PE assembly sheath in some cases, no hydrogenous shipping components are used in the model 51032-1 shipping container. In order to show that this small amount of hydrogenous material does not have an adverse impact on reactivity, the most reactive case for a 12x12x2 array of damaged containers (case D288S100 with fully flooded conditions) was modified to include low density PE inside the container, but outside of the bundles. The amount of PE inside the container was varied from 1 to 10 vol% Since the container is fully flooded, as the PE volume fraction increases, the water volume fraction in the same region must decrease, so that the sum of the two volume fractions equals unity. PE volume percents greater than 10% were not used in these calculations. At 10 vol% PE, each 51032-1 would contain over 300 kg PE. As stated earlier, the only hydrogenous components used are some rubber gaskets and a PE assembly sheath for some cases, well below 300 kg The results are summarized graphically and in tabular form in Figure 12 and Table 16, respectively. As expected, since the peak IM condition was fully flooded and the added PE displaces water, the addition of low density PE does not significantly impact reactivity. The maximum biased k_{eff} occurs at 3 vol% PE is 0.9474, below 0.95.

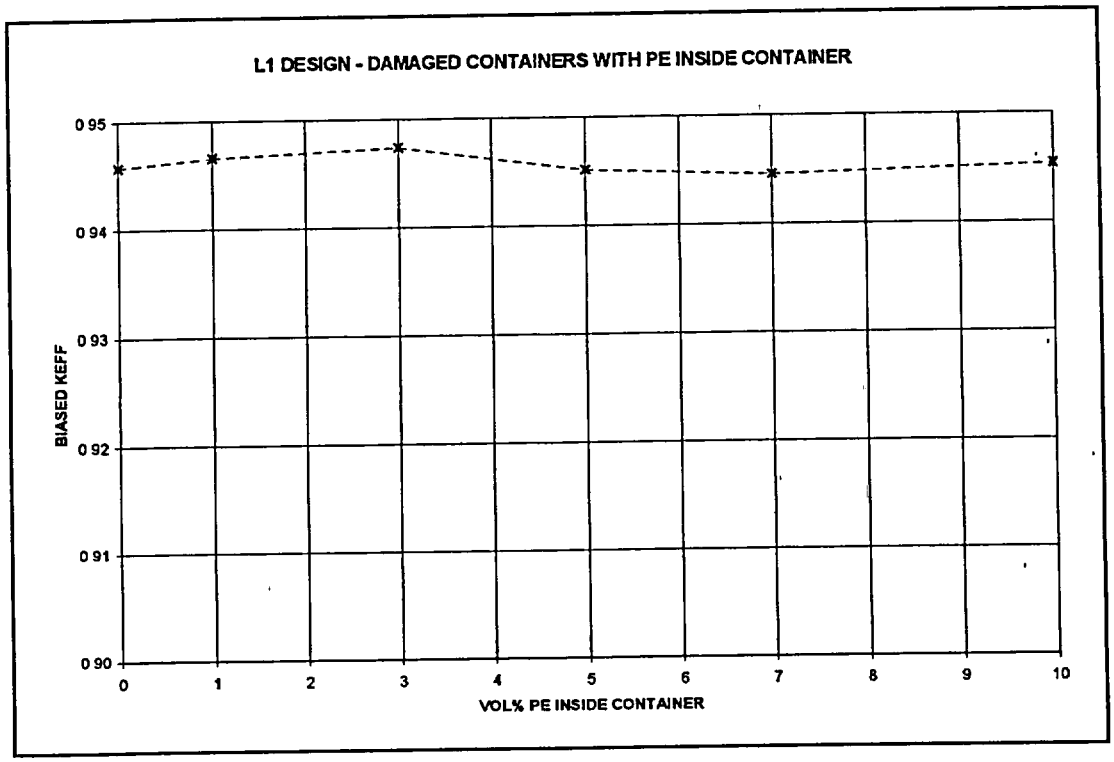


Figure 12 12x12x2 Array of Damaged 51032-1 Containers Loaded with L1 Fuel Assemblies, Fully Flooded Conditions, Low Density PE in Container but Outside of Assemblies

4.1.5 Calculation of CSI with L1 Fuel Assemblies

The CSI is set such that five times the allowed number of packages at undamaged conditions and two times the allowed number of packages at damaged conditions must have a k_{eff} less than 0.95. The CSI is calculated as 50/N, where N is the number of allowed packages. The CSI is rounded to the highest tenth.

Section 4.1.3 shows that an array of 675 undamaged 51032-1 containers loaded with L1 fuel assemblies has a maximum k_{eff} of 0.9261. This supports shipments of 675/5 or 135 containers loaded with L1 fuel assemblies. This results in a CSI of 0.4. Section 4.1.4 shows that an array of 288 damaged 51032-1 containers loaded with L1 fuel assemblies has a maximum k_{eff} of 0.9474. This supports shipments of 288/2 or 144 containers loaded with L1 fuel assemblies. This results in a CSI of 0.4.

Therefore, the calculations of this section support a CSI of 0.4 for 51032-1 containers loaded with L1 fuel assemblies.

4.2 *L2 Fuel Assembly Design*

The L2 fuel assembly is a 15x15 design. The layout of the L2 fuel assembly is shown in Figure 1. Only the fuel rod locations are explicitly shown in Figure 1. The "empty" locations in Figure 1 are guide and instrument tube (non-fueled) locations. A comparison of actual and modeled dimensions for the L2 fuel assembly is provided in Table 8.

Table 8 Comparison of Actual vs. Modeled Conditions for L2 Fuel Assembly

Parameter	Actual	Modeled	Reference for Actual Conditions
FUEL ROD			
MAX Pellet Diameter	0 3742"	0.3742"	Pending Certificate of Compliance
Theoretical Density	97.5%	98%	
MIN Clad OD	0.428"	0.428"	
ASSEMBLY			
MAX Enrichment	5 05 wt% ^{235}U	5.05 wt% ^{235}U	Pending Certificate of Compliance
Assembly Cross Section	8 520" x 8.520" MAX	8.520" x 8 520"	
Rod Array Size	15x15	15x15	
Number of Non-Fueled Grid Locations	17 (see Figure 1)	17	
Nominal Rod Pitch	0.568"	0 568"	
Active Fuel Length	144"	197"	

4.2.1 Computer Model Description

The model 51032-1 shipping container was modeled with the dimensions shown in Table 5, exactly as it was modeled in Section 4.1 for the L1 fuel assembly analysis and in Reference 5, which supported the most recently added fuel categories (Trino fuel).

The L2 assemblies were modeled with the dimensions shown in Table 8. By modeling the maximum pellet diameter and the minimum clad OD, both fuel and moderator within the assembly are maximized In order to minimize any neutron absorption in the clad material, the clad was modeled as void.

Full water reflection was used around the container in the single container calculations and around the array in the array calculations. No pathway for preferential flooding has been identified Fuel assemblies are held in place with clamps. If PE sheathing is used, the current COC requires that it be open on each end

4.2.2 Analysis of Single Container with L2 Fuel Assemblies

Calculations were performed for a single model 51032-1 shipping container loaded with the L2 fuel design. The shipping container and L2 assemblies were modeled as described in Table 5 and Table 8. IM (inside the shipping container and assemblies) was varied from dry to fully flooded. Figure 5 shows a

cutaway view of a 51032-1 containing L1 fuel assemblies Loading of L2 assemblies in the 51032-1 is identical to that of L1 assemblies.

The results of the calculations for a single container loaded with L2 fuel assemblies are presented graphically and in tabular form in Figure 13 and Table 17, respectively. The maximum biased k_{eff} occurs at fully flooded conditions and is 0 9458, below 0.95.

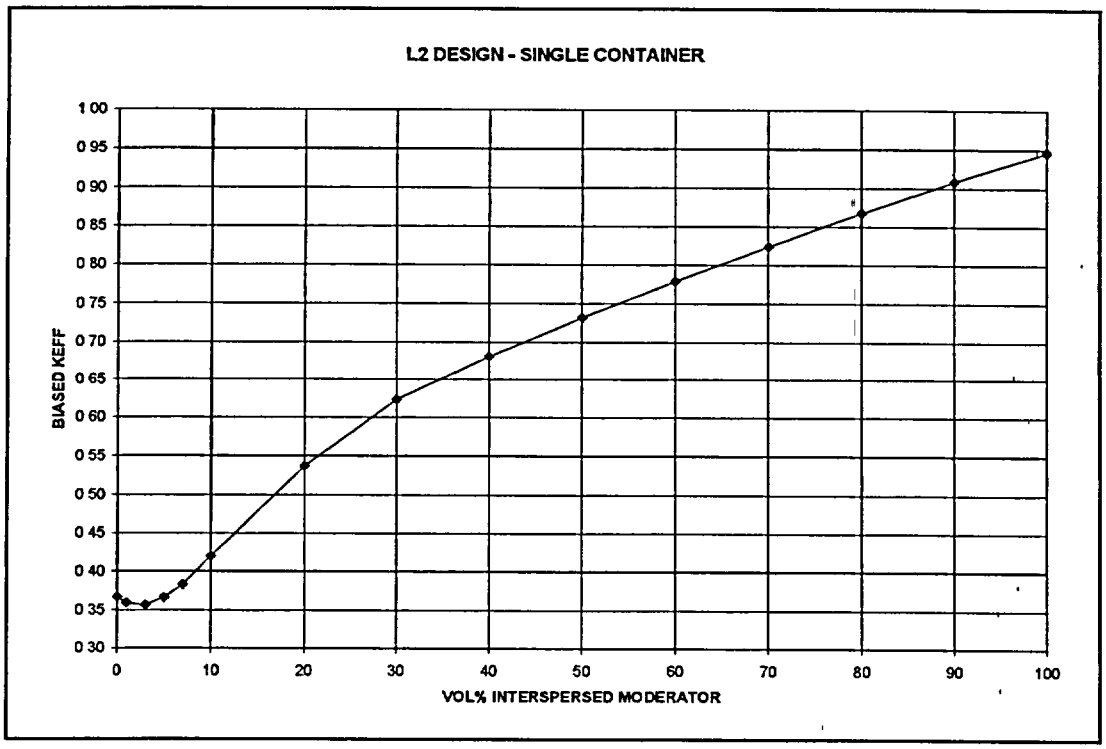


Figure 13 Single 51032-1 Container Loaded with L2 Fuel Assemblies

4.2.3 Analysis of Array of Undamaged Containers (Normal Conditions) with L2 Fuel Assemblies

Calculations were performed for an array of model 51032-1 shipping containers under normal or undamaged conditions. L2 fuel assemblies were placed in the containers. Page 9-1 of Reference 2 states that the water spray test demonstrated that water would not leak into the package. Therefore, in the undamaged calculations of this subsection, the insides of the containers remain dry. The following sets of cases were analyzed, each varying IM (between containers) from dry to fully flooded:

- Infinite array of containers
- 15x15x3 (675 total) array of containers

A 15x15x3 array was chosen so that the array would contain enough containers to justify a CSI of 0 4, while also maintaining a nearly cubic shaped array in order to maximize the reactivity. The dimensions of a 15x15x3 array of undamaged 51032-1 containers are approximately 1591 cm x 1591 cm x 1503 cm

The results of the calculations for an infinite and 15x15x3 array of undamaged 51032-1 containers loaded with L2 fuel assemblies are presented graphically in Figure 14. This data is presented in tabular form in Table 18 and Table 19, respectively. For an infinite array, the maximum biased k_{eff} occurs at 5 vol% IM and is 1 0693. For a 15x15x3 array, the maximum biased k_{eff} occurs at 7 vol% IM and is 0.9277, below 0 95.

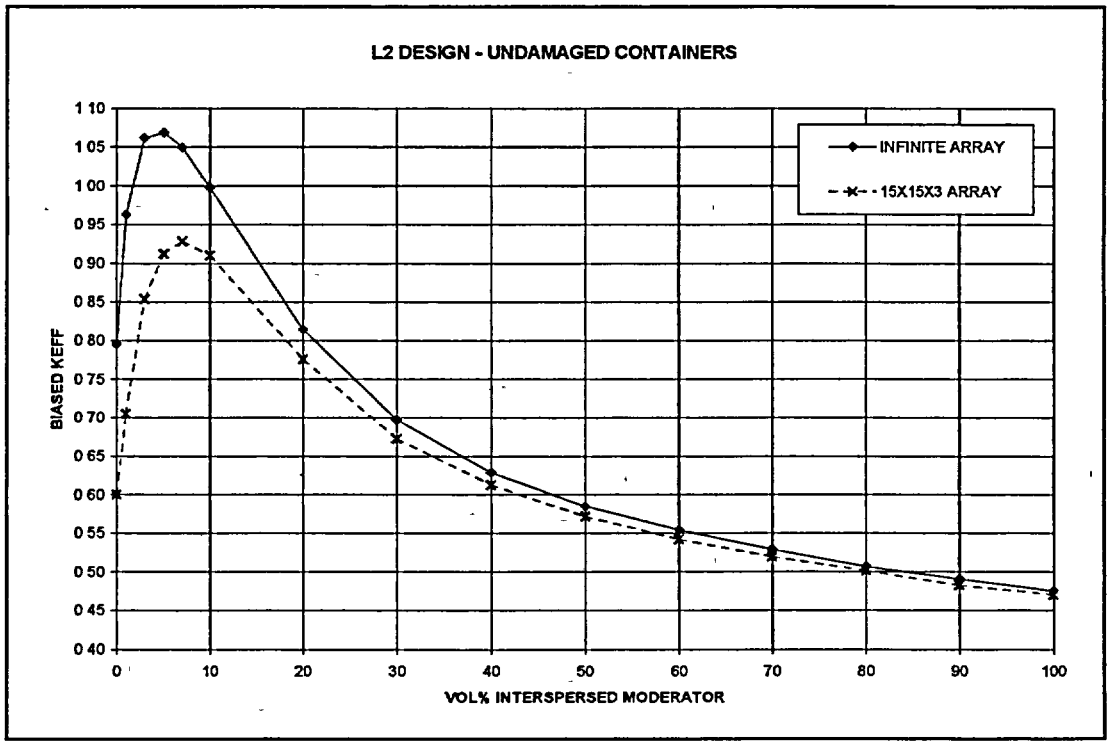


Figure 14 Arrays of Undamaged 51032-1 Containers Loaded with L2 Fuel Assemblies

As discussed previously, except for some rubber gaskets and a PE assembly sheath in some cases, no hydrogenous shipping components are used in the model 51032-1 shipping container. In order to show that this small amount of hydrogenous material does not have an adverse impact on reactivity, the most reactive case for a 15x15x3 array of undamaged containers (case U675C007 with 7 vol% IM) was modified to include low density PE inside the container, but outside of the bundles. The amount of PE inside the container was varied from 1 to 10 vol% The amount of IM between containers was maintained at 7 vol%. The results are summarized graphically and in tabular form in Figure 15 and Table 20, respectively. As expected, since the peak IM was already identified and used, addition of PE to the inside of the container results in lower reactivities.

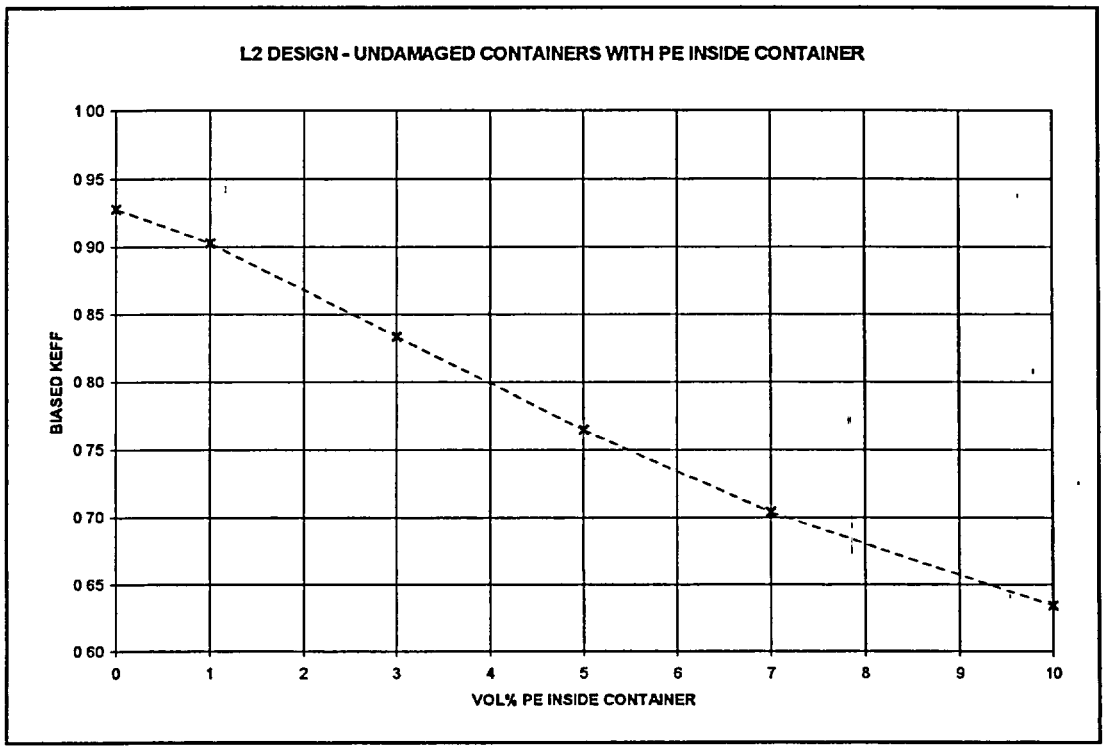


Figure 15 15x15x3 Array of Undamaged 51032-1 Containers Loaded with L2 Fuel Assemblies, Low Density PE Inside Container

4.2.4 Analysis of Array of Damaged Containers (Accident Conditions) with L2 Fuel Assemblies

Calculations were performed for an array of model 51032-1 shipping containers under accident or damaged conditions. L2 fuel assemblies were placed in the containers. As previously stated, no pathway has been identified for preferential flooding of the container. The following sets of cases were analyzed, each varying IM (both inside and between containers) from dry to fully flooded:

- 12x12x2 (288 total) array of containers. Bundles and strongbacks are centered in container.
- 12x12x2 (288 total) array of containers. Bundles and strongbacks are shifted in container.

A 12x12x2 array was chosen so that the array would contain enough containers to justify a CSI of 0.4, while also maintaining a nearly cubic shaped array in order to maximize the reactivity. The dimensions of a 12x12x2 array of damaged 51032-1 containers are approximately 1242 cm x 1242 cm x 1002 cm.

Cases with the bundles and strongbacks shifted in the containers have the strongbacks shifted by the amount listed in Table 7. The bundles are then shifted in the same horizontal direction, so that they are against the inside of the strongback. These shifts are performed so that the spacing between bundles in four adjacent containers is minimized. Figure 9 and Figure 10 show cutaway views of four adjacent 51032-1 containers with the strongbacks and assemblies centered and shifted, respectively.

The results of the calculations for a 12x12x2 array of damaged 51032-1 containers loaded with L2 fuel assemblies are presented graphically in Figure 16. This data is presented in tabular form in Table 21 and Table 22. Whether the strongbacks and assemblies are centered or shifted in the containers, the maximum biased k_{eff} occurs at fully flooded conditions. The maximum biased k_{eff} for the centered and shifted cases is 0.9461 and 0.9478, respectively, both below 0.95.

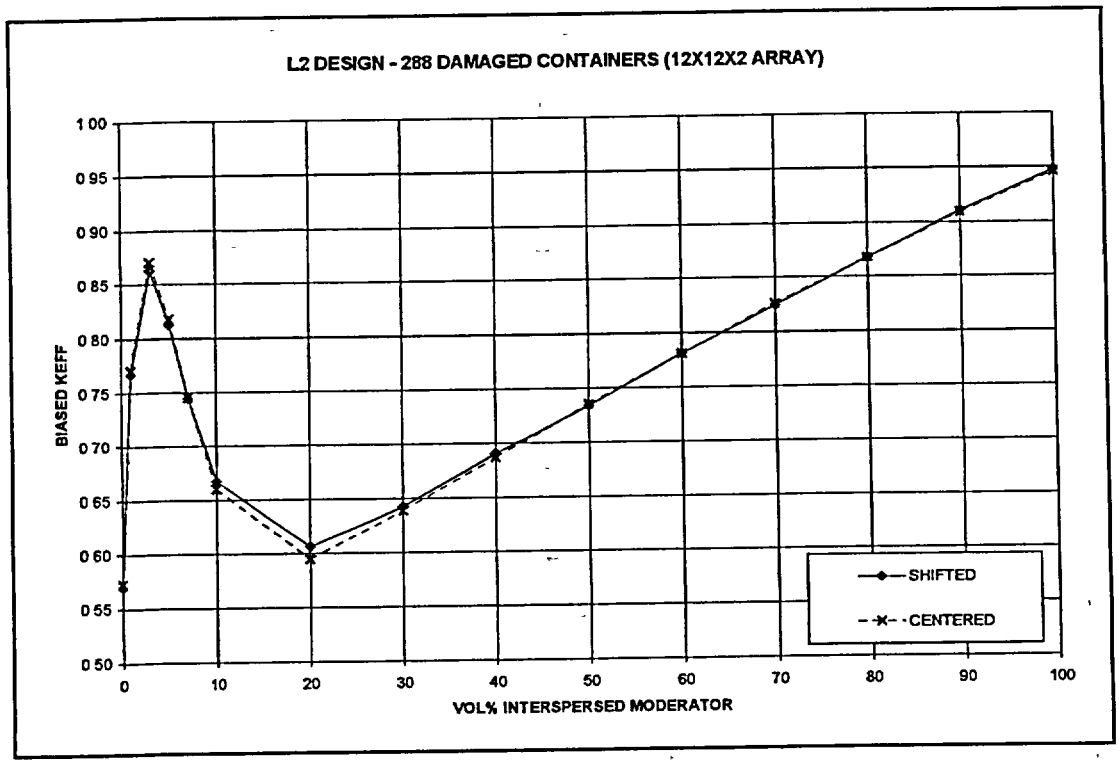


Figure 16 12x12x2 Array of Damaged 51032-1 Containers Loaded with L2 Fuel Assemblies

As discussed previously, except for some rubber gaskets and a PE assembly sheath in some cases, no hydrogenous shipping components are used in the model 51032-1 shipping container. In order to show that this small amount of hydrogenous material does not have an adverse impact on reactivity, the most reactive case for a 12x12x2 array of damaged containers (case D288S100 with fully flooded conditions) was modified to include low density PE inside the container, but outside of the bundles. The amount of PE inside the container was varied from 1 to 10 vol%. Since the container is fully flooded, as the PE volume fraction increases, the water volume fraction in the same region must decrease, so that the sum of the two volume fractions equals unity. PE volume percents greater than 10% were not used in these calculations. At 10 vol% PE, each 51032-1 would contain over 300 kg PE. As stated earlier, the only hydrogenous components used are some rubber gaskets and a PE assembly sheath for some cases, well below 300 kg. The results are summarized graphically and in tabular form in Figure 17 and Table 23, respectively. As expected, since the peak IM condition was fully flooded and the added PE displaces water, the addition of low density PE does not significantly impact reactivity. The maximum biased k_{eff} occurs at 1 vol% PE is 0.9481, below 0.95.

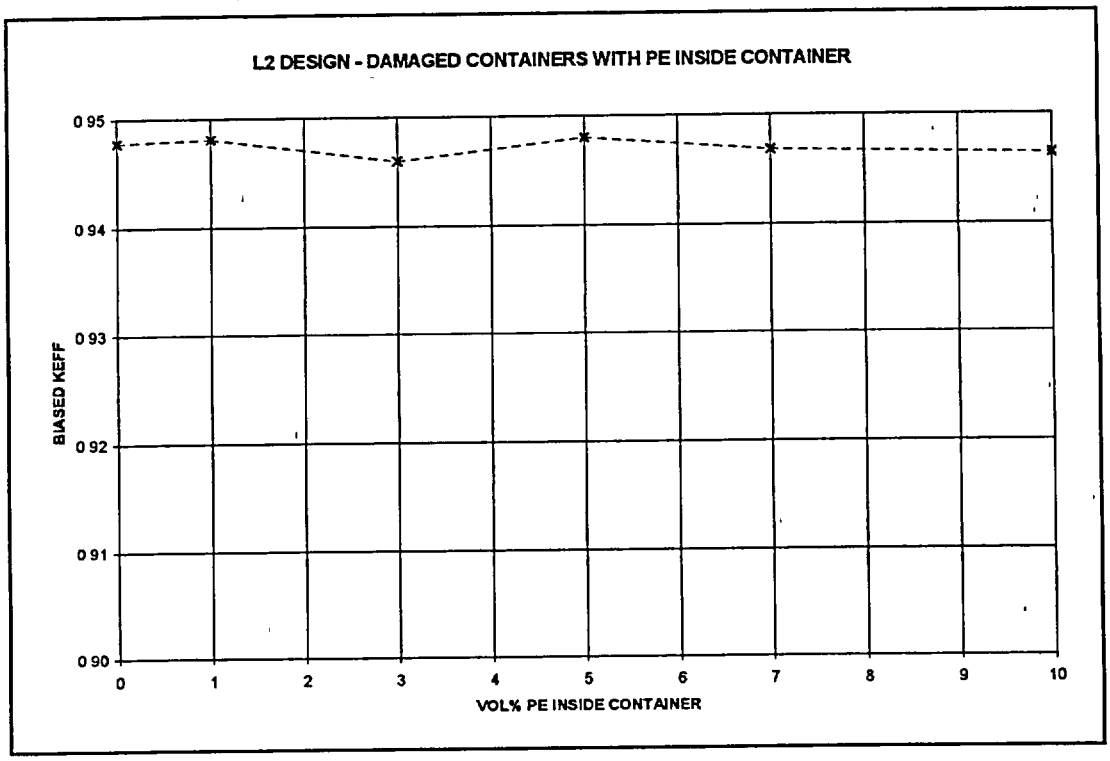


Figure 17 12x12x2 Array of Damaged 51032-1 Containers Loaded with L2 Fuel Assemblies, Fully Flooded Conditions, Low Density PE in Container but Outside of Assemblies

4.2.5 Calculation of CSI with L2 Fuel Assemblies

The CSI is set such that five times the allowed number of packages at undamaged conditions and two times the allowed number of packages at damaged conditions must have a k_{eff} less than 0.95. The CSI is calculated as 50/N, where N is the number of allowed packages. The CSI is rounded to the highest tenth.

Section 4.2.3 shows that an array of 675 undamaged 51032-1 containers loaded with L2 fuel assemblies has a maximum k_{eff} of 0.9277. This supports shipments of 675/5 or 135 containers loaded with L2 fuel assemblies. This results in a CSI of 0.4. Section 4.2.4 shows that an array of 288 damaged 51032-1 containers loaded with L2 fuel assemblies has a maximum k_{eff} of 0.9481. This supports shipments of 288/2 or 144 containers loaded with L2 fuel assemblies. This results in a CSI of 0 4.

Therefore, the calculations of this section support a CSI of 0 4 for 51032-1 containers loaded with L2 fuel assemblies.

4.3 *L4 Fuel Assembly Design*

The L4 fuel assembly is a 17x17 design. The layout of the L4 fuel assembly is shown in Figure 2. Only the fuel rod locations are explicitly shown in Figure 2. The "empty" locations in Figure 2 are guide and instrument tube (non-fueled) locations A comparison of actual and modeled dimensions for the L4 fuel assembly is provided in Table 9.

Table 9 Comparison of Actual vs. Modeled Conditions for L4 Fuel Assembly

Parameter	Actual	Modeled	Reference for Actual Conditions
FUEL ROD			
MAX Pellet Diameter	0.3232"	0 3232"	Pending Certificate of Compliance
Theoretical Density	97.5%	98%	
MIN Clad OD	0 372"	0.372"	
ASSEMBLY			
MAX Enrichment	5.05 wt% ^{235}U	5.05 wt% ^{235}U	Pending Certificate of Compliance
Assembly Cross Section	8.432" x 8.432" MAX	8 432" x 8 432"	
Rod Array Size	17x17	17x17	
Number of Non-Fueled Grid Locations	25 (see Figure 2)	25	
Nominal Rod Pitch	0.496"	0.496"	
Active Fuel Length	145.83"	197"	

4.3.1 Computer Model Description

The model 51032-1 shipping container was modeled with the dimensions shown in Table 5, exactly as it was modeled in Section 4.1 for the L1 fuel assembly analysis and in Reference 5, which supported the most recently added fuel categories (Trino fuel).

The L4 assemblies were modeled with the dimensions shown in Table 9. By modeling the maximum pellet diameter and the minimum clad OD, both fuel and moderator within the assembly are maximized. In order to minimize any neutron absorption in the clad material, the clad was modeled as void.

Full water reflection was used around the container in the single container calculations and around the array in the array calculations. No pathway for preferential flooding has been identified Fuel assemblies are held in place with clamps. If PE sheathing is used, the current COC requires that it be open on each end

4.3.2 Analysis of Single Container with L4 Fuel Assemblies

Calculations were performed for a single model 51032-1 shipping container loaded with the L4 fuel design. The shipping container and L4 assemblies were modeled as described in Table 5 and Table 9. IM (inside the shipping container and assemblies) was varied from dry to fully flooded. Figure 5 shows a

cutaway view of a 51032-1 containing L1 fuel assemblies. Loading of L4 assemblies in the 51032-1 is identical to that of L1 assemblies.

The results of the calculations for a single container loaded with L4 fuel assemblies are presented graphically and in tabular form in Figure 18 and Table 24, respectively. The maximum biased k_{eff} occurs at fully flooded conditions and is 0.9439, below 0.95.

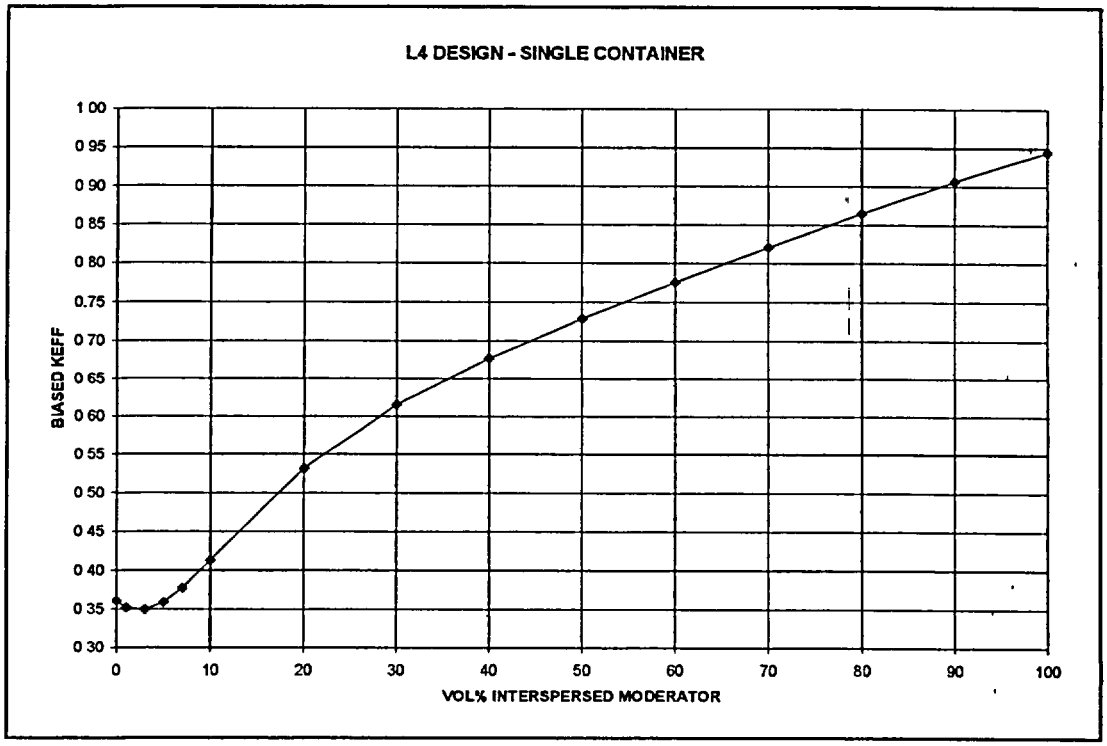


Figure 18 Single 51032-1 Container Loaded with L4 Fuel Assemblies

4.3.3 Analysis of Array of Undamaged Containers (Normal Conditions) with L4 Fuel Assemblies

Calculations were performed for an array of model 51032-1 shipping containers under normal or undamaged conditions. L4 fuel assemblies were placed in the containers. Page 9-1 of Reference 2 states that the water spray test demonstrated that water would not leak into the package. Therefore, in the undamaged calculations of this subsection, the insides of the containers remain dry. The following sets of cases were analyzed, each varying IM (between containers) from dry to fully flooded:

- Infinite array of containers
- 15x15x3 (675 total) array of containers

A 15x15x3 array was chosen so that the array would contain enough containers to justify a CSI of 0.4, while also maintaining a nearly cubic shaped array in order to maximize the reactivity The dimensions of a 15x15x3 array of undamaged 51032-1 containers are approximately 1591 cm x 1591 cm x 1503 cm.

The results of the calculations for an infinite and 15x15x3 array of undamaged 51032-1 containers loaded with L4 fuel assemblies are presented graphically in Figure 19 This data is presented in tabular form in Table 25 and Table 26, respectively. For an infinite array, the maximum biased k_{eff} occurs at 5 vol% IM and is 1 0647. For a 15x15x3 array, the maximum biased k_{eff} occurs at 7 vol% IM and is 0.9209, below 0.95.

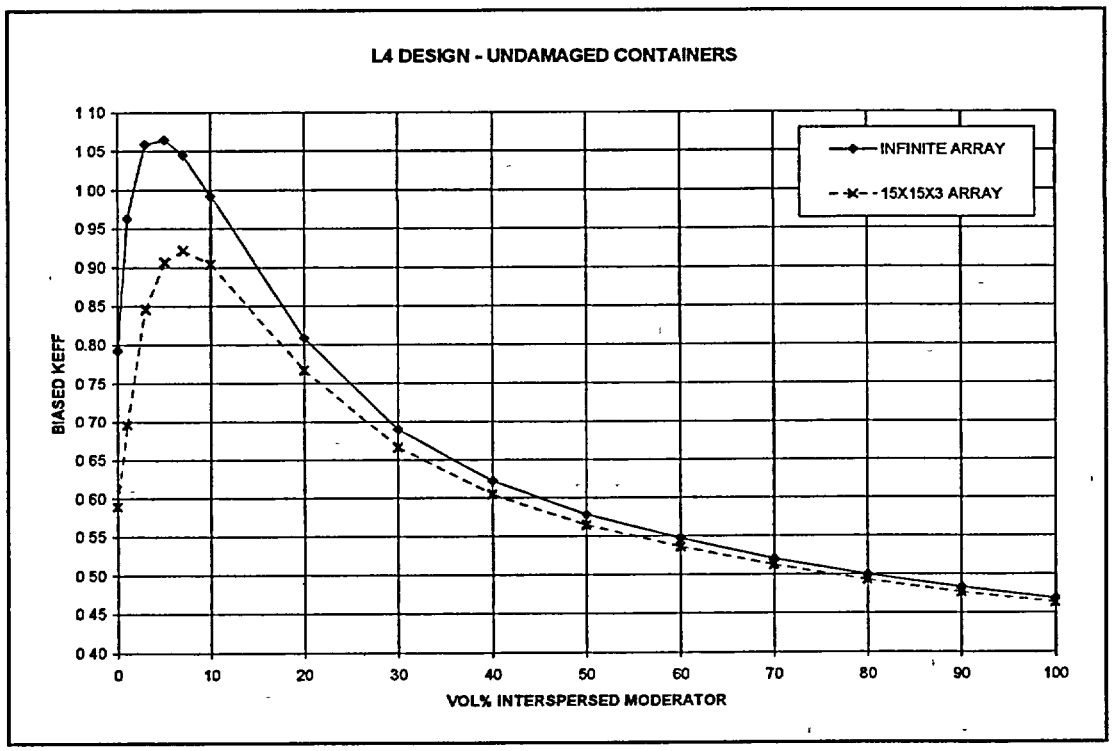


Figure 19 Arrays of Undamaged 51032-1 Containers Loaded with L4 Fuel Assemblies

As discussed previously, except for some rubber gaskets and a PE assembly sheath in some cases, no hydrogenous shipping components are used in the model 51032-1 shipping container. In order to show that this small amount of hydrogenous material does not have an adverse impact on reactivity, the most reactive case for a 15x15x3 array of undamaged containers (case U675C007 with 7 vol% IM) was modified to include low density PE inside the container, but outside of the bundles. The amount of PE inside the container was varied from 1 to 10 vol%. The amount of IM between containers was maintained at 7 vol%. The results are summarized graphically and in tabular form in Figure 20 and Table 27, respectively. As expected, since the peak IM was already identified and used, addition of PE to the inside of the container results in lower reactivities.

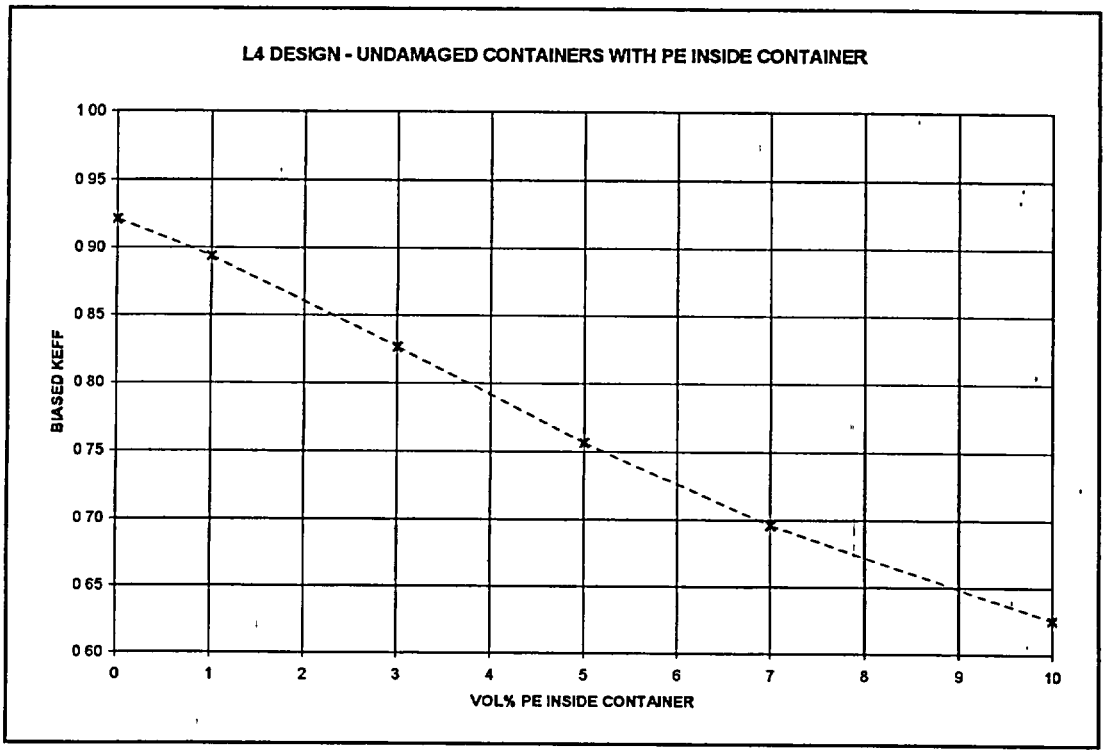


Figure 20 15x15x3 Array of Undamaged 51032-1 Containers Loaded with L4 Fuel Assemblies, Low Density PE Inside Container

4.3.4 Analysis of Array of Damaged Containers (Accident Conditions) with L4 Fuel Assemblies

Calculations were performed for an array of model 51032-1 shipping containers under accident or damaged conditions. L4 fuel assemblies were placed in the containers. As previously stated, no pathway has been identified for preferential flooding of the container. The following sets of cases were analyzed, each varying IM (both inside and between containers) from dry to fully flooded:

- 12x12x2 (288 total) array of containers. Bundles and strongbacks are centered in container.
- 12x12x2 (288 total) array of containers. Bundles and strongbacks are shifted in container.

A 12x12x2 array was chosen so that the array would contain enough containers to justify a CSI of 0.4, while also maintaining a nearly cubic shaped array in order to maximize the reactivity. The dimensions of a 12x12x2 array of damaged 51032-1 containers are approximately 1242 cm x 1242 cm x 1002 cm.

Cases with the bundles and strongbacks shifted in the containers have the strongbacks shifted by the amount listed in Table 7. The bundles are then shifted in the same horizontal direction, so that they are against the inside of the strongback. These shifts are performed so that the spacing between bundles in four adjacent containers is minimized Figure 9 and Figure 10 show cutaway views of four adjacent 51032-1 containers with the strongbacks and assemblies centered and shifted, respectively.

The results of the calculations for a 12x12x2 array of damaged 51032-1 containers loaded with L4 fuel assemblies are presented graphically in Figure 21. This data is presented in tabular form in Table 28 and Table 29. Whether the strongbacks and assemblies are centered or shifted in the containers, the maximum biased k_{eff} occurs at fully flooded conditions. The maximum biased k_{eff} for the centered and shifted cases is 0.9448 and 0 9443, respectively, both below 0.95

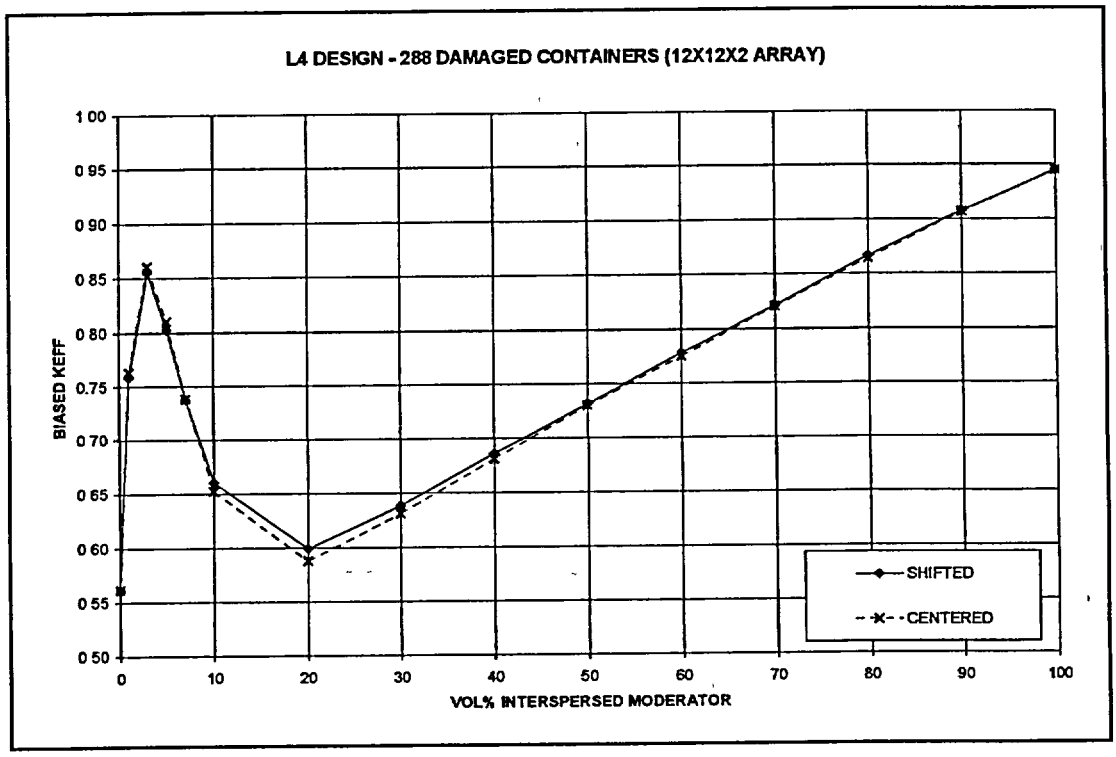


Figure 21 12x12x2 Array of Damaged 51032-1 Containers Loaded with L4 Fuel Assemblies

As discussed previously, except for some rubber gaskets and a PE assembly sheath in some cases, no hydrogenous shipping components are used in the model 51032-1 shipping container. In order to show that this small amount of hydrogenous material does not have an adverse impact on reactivity, the most reactive case for a 12x12x2 array of damaged containers (case D288C100 with fully flooded conditions) was modified to include low density PE inside the container, but outside of the bundles. The amount of PE inside the container was varied from 1 to 10 vol%. Since the container is fully flooded, as the PE volume fraction increases, the water volume fraction in the same region must decrease, so that the sum of the two volume fractions equals unity. PE volume percents greater than 10% were not used in these calculations. At 10 vol% PE, each 51032-1 would contain over 300 kg PE. As stated earlier, the only hydrogenous components used are some rubber gaskets and a PE assembly sheath for some cases, well below 300 kg. The results are summarized graphically and in tabular form in Figure 22 and Table 30, respectively. As expected, since the peak IM condition was fully flooded and the added PE displaces water, the addition of low density PE does not significantly impact reactivity. The maximum biased k_{eff} occurs at 1 vol% PE is 0.9466, below 0.95.

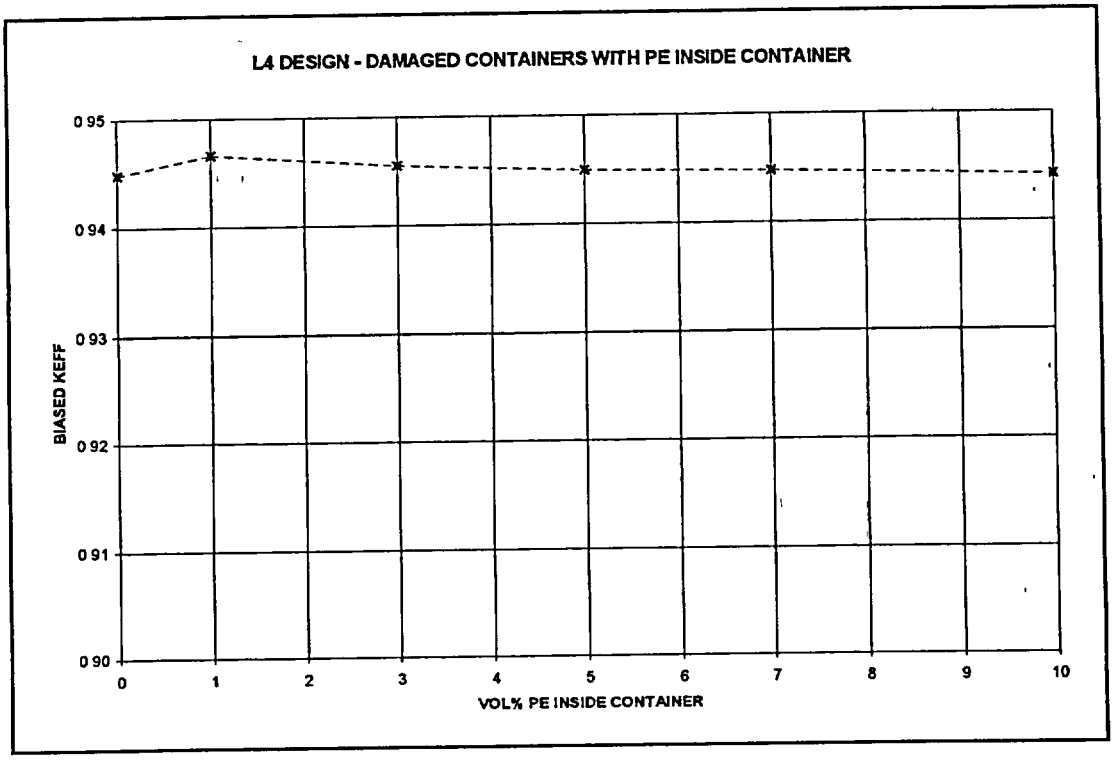


Figure 22 12x12x2 Array of Damaged 51032-1 Containers Loaded with L4 Fuel Assemblies, Fully Flooded Conditions, Low Density PE in Container but Outside of Assemblies

4.3.5 Calculation of CSI with L4 Fuel Assemblies

The CSI is set such that five times the allowed number of packages at undamaged conditions and two times the allowed number of packages at damaged conditions must have a k_{eff} less than 0.95. The CSI is calculated as 50/N, where N is the number of allowed packages. The CSI is rounded to the highest tenth.

Section 4.3.3 shows that an array of 675 undamaged 51032-1 containers loaded with L4 fuel assemblies has a maximum k_{eff} of 0.9209. This supports shipments of 675/5 or 135 containers loaded with L4 fuel assemblies. This results in a CSI of 0.4. Section 4.3.4 shows that an array of 288 damaged 51032-1 containers loaded with L4 fuel assemblies has a maximum k_{eff} of 0.9466. This supports shipments of 288/2 or 144 containers loaded with L4 fuel assemblies. This results in a CSI of 0.4.

Therefore, the calculations of this section support a CSI of 0 4 for 51032-1 containers loaded with L4 fuel assemblies.

5.0 REVISION HISTORY

5.1 *Revision 0*

Revision 0 of this NCSA provided the NCS basis for adding three additional categories (L1, L2, and L4) to the allowed payloads in the model 51032-1 shipping container. The fuel categories allowed by the current (at the time of revision 0) COC (Reference 1) were analyzed for NCS in Reference 2.

6.0 REFERENCES

1) Certificate USA/6581/AF, Revision 31, Model 51032-1 Certificate.

2) EMF-52, Revision 6B, Consolidated License Application for Siemens Power Corporation Model 51032-1 Shipping Container, July 2000.

3) *SCALE (CCC-545): A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation*, NUREG/CR-0200, Rev. 6 (ORNL/NUREG/CSD-2/R6), Volumes I, II, and III, March 2000.

4) EMF-2670, Revision 1, Software Validation Document - PC-SCALE4 4a V&V, 11/26/2002.

5) Criticality Safety Evaluation BFQ-M51032-1.1, Revision 0, M51032-1 Shipping Container Supplemental Criticality Safety Evaluation, 7/27/1999.

6) NUREG/CR-6698, "Guide for Validation of Nuclear Criticality Safety Calculational Methodology" prepared by J.C. Dean and R.W. Tayloe, Jr., January 2001

7) ORDP 20-114, Table 15, pg 45-51.

8) USLS Code Description and Verification, 32-5017356-01 prepared by L A. Hassler, dated 05/19/02.

APPENDIX A - TECHNICAL REVIEW

1) Methodology used in this NCSA is clearly defined and was verified to be applicable. The calculation methods including details on cross section preparation, atom densities assumed, and geometry models were reviewed and determined to be adequate. Each of these items was verified to be conservative.

2) Assumptions were reviewed for reasonableness and applicability to this analysis.

3) Modeling was reviewed and determined to conservatively model the actual system. A listing of one or more of the most reactive cases is included in the NCSA.

4) Referenced sources were reviewed for applicability to this NCSA.

5) Input information was checked against referenced sources.

6) Input for computer calculations was checked for agreement with values in the NCSA text.

7) Hand calculations were independently checked.

8) k_{eff} for worst case accident conditions is specifically stated in the text.

9) Comments and resolutions are provided below.

Technical Review Comments and Resolution

Revision 0:

All comments were editorial in nature and were incorporated into the text.

APPENDIX B - CALCULATION DATA

Table 10 Single 51032-1 Container Loaded with L1 Fuel Assemblies, IM (Inside and Outside Container) Varied from Dry to Fully Flooded

FILE NAME	DATE	TIME	BEST KEFF	SIGMA	BIAS	BIASED KEFF
NOM00000	12/15/2002	07:43p	0 3479	0.0006	0.0168	0.3647
NOM00001	12/15/2002	07:49p	0.3407	0 0005	0.0168	0.3575
NOM00003	12/15/2002	07:56p	0.3360	0.0006	0 0168	0.3528
NOM00005	12/15/2002	08.03p	0.3453	0 0005	0.0168	0.3621
NOM00007	12/15/2002	08:10p	0.3649	0.0005	0.0168	0 3817
NOM00010	12/15/2002	08 17p	0.4004	0.0006	0.0168	0.4172
NOM00020	12/15/2002	08:26p	0.5185	0.0006	0.0168	0 5353
NOM00030	12/15/2002	08:37p	0.6022	0.0007	0.0168	0.6190
NOM00040	12/15/2002	08 48p	0.6619	0.0006	0.0168	0.6787
NOM00050	12/15/2002	08 59p	0.7126	0.0007	0.0168	0.7294
NOM00060	12/15/2002	09.10p	0.7598	0.0008	0.0168	0.7766
NOM00070	12/15/2002	09.21p	0 8053	0.0008	0.0168	0.8221
NOM00080	12/15/2002	09.32p	0 8491	0.0008	0 0168	0.8659
NOM00090	12/15/2002	09:43p	0.8893	0.0008	0 0168	0.9061
NOM00100	12/15/2002	09:55p	0.9283	0.0007	0 0168	0.9451

Table 11 Infinite Array of Undamaged 51032-1 Containers Loaded with L1 Fuel Assemblies, Inside of Containers Remain Dry, IM (Between Containers) Varied from Dry to Fully Flooded

FILE NAME	DATE	TIME	BEST KEFF	SIGMA	BIAS	BIASED KEFF
UINFC000	12/27/2002	12 20p	0.7766	0.0003	0.0168	0.7934
UINFC001	12/27/2002	12.38p	0.9457	0.0004	0.0168	0.9625
UINFC003	12/27/2002	12:49p	1.0436	0.0005	0.0168	1 0604
UINFC005	12/27/2002	12:59p	1.0517	0 0005	0.0168	1 0685
UINFC007	12/27/2002	01:08p	1.0318	0.0005	0.0168	1.0486
UINFC010	12/27/2002	01:17p	0.9794	0 0006	0.0168	0.9962
UINFC020	12/27/2002	01:28p	0.7949	0.0006	0.0168	0.8117
UINFC030	12/27/2002	01:41p	0 6772	0 0006	0.0168	0 6940
UINFC040	12/27/2002	01:55p	0 6105	0.0006	0.0168	0.6273
UINFC050	12/27/2002	02 09p	0.5667	0.0005	0 0168	0.5835
UINFC060	12/27/2002	02.24p	0.5339	0.0005	0.0168	0.5507
UINFC070	12/27/2002	02.39p	0.5091	0.0005	0.0168	0.5259
UINFC080	12/27/2002	02:54p	0.4893	0.0005	0.0168	0.5061
UINFC090	12/27/2002	03:10p	0.4710	0.0005	0 0168	0.4878
UINFC100	12/27/2002	03:26p	0 4566	0.0005	0 0168	0.4734

Table 12 15x15x3 Array of Undamaged 51032-1 Containers Loaded with L1 Fuel Assemblies, Inside of Containers Remain Dry, IM (Between Containers) Varied from Dry to Fully Flooded

FILE NAME	DATE	TIME	BEST KEFF	SIGMA	BIAS	BIASED KEFF
U675C000	12/26/2002	05:08p	0.5803	0.0005	0.0168	0.5971
U675C001	12/26/2002	05 20p	0 6833	0.0006	0.0168	0.7001
U675C003	12/26/2002	05:30p	0.8341	0.0006	0 0168	0.8509
U675C005	12/26/2002	05:39p	0.8942	0.0007	0 0168	0.9110
U675C007	12/26/2002	05:48p	0 9093	0 0006	0.0168	0.9261
U675C010	12/26/2002	05.57p	0 8927	0 0006	0.0168	0.9095
U675C020	12/26/2002	06:11p	0.7577	0.0006	0.0168	0.7745
U675C030	12/26/2002	06:25p	0.6550	0.0006	0.0168	0.6718
U675C040	12/26/2002	06:41p	0.5936	0.0006	0.0168	0.6104
U675C050	12/26/2002	06:55p	0.5526	0 0005	0.0168	0 5694
U675C060	12/26/2002	07:10p	0.5247	0.0005	0.0168	0.5415
U675C070	12/26/2002	07:25p	0.5004	0.0006	0.0168	0.5172
U675C080	12/26/2002	07:41p	0.4811	0.0005	0 0168	0.4979
U675C090	12/26/2002	07:57p	0.4649	0.0005	0 0168	0.4817
U675C100	12/26/2002	08:14p	0.4513	0.0006	0.0168	0.4681

Table 13 15x15x3 Array of Undamaged 51032-1 Containers Loaded with L1 Fuel Assemblies, 7 vol% IM (Between Containers), PE Inside Containers but Outside Assemblies Varied from 0 to 10 vol%

FILE NAME	DATE	TIME	BEST KEFF	SIGMA	BIAS	BIASED KEFF
U675C007	12/26/2002	05:48p	0.9093	0.0006	0.0168	0.9261
U675P001	12/28/2002	10:18a	0.8844	0.0006	0 0168	0 9012
U675P003	12/28/2002	10:29a	0.8169	0.0007	0.0168	0.8337
U675P005	12/28/2002	10:39a	0.7456	0.0007	0.0168	0.7624
U675P007	12/28/2002	10:51a	0.6843	0.0006	0.0168	0.7011
U675P010	12/28/2002	11:03a	0.6156	0.0006	0.0168	0.6324

Table 14 12x12x2 Array of Damaged 51032-1 Containers Loaded with L1 Fuel Assemblies, Strongbacks and Assemblies Centered Inside Containers, IM (Inside and Between Containers) Varied from Dry to Fully Flooded

FILE NAME	DATE	TIME	BEST KEFF	SIGMA	BIAS	BIASED KEFF
D288C000	12/22/2002	05:15p	0.5515	0.0006	0.0168	0.5683
D288C001	12/22/2002	05:25p	0.7503	0.0007	0 0168	0.7671
D288C003	12/22/2002	05:34p	0.8507	0 0007	0.0168	0.8675
D288C005	12/22/2002	05:42p	0.7994	0.0006	0.0168	0.8162
D288C007	12/22/2002	05:51p	0.7277	0 0006	0.0168	0.7445
D288C010	12/22/2002	06.02p	0 6415	0 0006	0.0168	0.6583
D288C020	12/22/2002	06:14p	0.5765	0.0007	0 0168	0.5933
D288C030	12/22/2002	06.26p	0.6183	0 0006	0.0168	0.6351
D288C040	12/22/2002	06:39p	0.6677	0.0007	0.0168	0.6845
D288C050	12/22/2002	06:51p	0.7158	0.0007	0 0168	0.7326
D288C060	12/22/2002	07:04p	0.7608	0 0008	0.0168	0.7776
D288C070	12/22/2002	07:16p	0 8070	0 0007	0.0168	0.8238
D288C080	12/22/2002	07:28p	0.8493	0.0008	0 0168	0.8661
D288C090	12/22/2002	07:40p	0.8904	0 0007	0.0168	0.9072
D288C100	12/22/2002	07:51p	0 9278	0.0008	0 0168	0.9446

Table 15 12x12x2 Array of Damaged 51032-1 Containers Loaded with L1 Fuel Assemblies, Strongbacks and Assemblies Shifted Inside Containers, IM (Inside and Between Containers) Varied from Dry to Fully Flooded

FILE NAME	DATE	TIME	BEST KEFF	SIGMA	BIAS	BIASED KEFF
D288S000	12/22/2002	08:02p	0.5492	0.0006	0 0168	0.5660
D288S001	12/22/2002	08:12p	0.7479	0.0007	0.0168	0.7647
D288S003	12/22/2002	08:21p	0.8436	0.0006	0 0168	0.8604
D288S005	12/22/2002	08:33p	0.7942	0.0007	0 0168	0.8110
D288S007	12/22/2002	08.47p	0.7275	0.0006	0.0168	0.7443
D288S010	12/22/2002	08:58p	0 6507	0.0006	0.0168	0.6675
D288S020	12/22/2002	09:10p	0.5875	0 0006	0.0168	0.6043
D288S030	12/22/2002	09.23p	0.6239	0.0006	0.0168	0.6407
D288S040	12/22/2002	09.37p	0 6722	0 0007	0.0168	0.6890
D288S050	12/22/2002	09.51p	0.7197	0.0006	0.0168	0.7365
D288S060	12/22/2002	10 05p	0.7616	0.0007	0 0168	0.7784
D288S070	12/22/2002	10:17p	0 8067	0.0008	0.0168	0.8235
D288S080	12/22/2002	10.29p	0.8507	0.0007	0.0168	0.8675
D288S090	12/22/2002	10.40p	0.8898	0 0007	0.0168	0.9066
D288S100	12/22/2002	10.50p	0 9290	0.0007	0.0168	0 9458

Table 16 12x12x2 Array of Damaged 51032-1 Containers Loaded with L1 Fuel Assemblies, Strongbacks and Assemblies Shifted Inside Containers, Fully Flooded Conditions, PE Inside Containers but Outside Assemblies Varied from 0 to 10 vol%

FILE NAME	DATE	TIME	BEST KEFF	SIGMA	BIAS	BIASED KEFF
D288S100	12/22/2002	10.50p	0.9290	0 0007	0.0168	0.9458
D288P001	12/28/2002	02:53p	0 9298	0.0008	0 0168	0.9466
D288P003	12/28/2002	03:04p	0.9306	0.0008	0.0168	0.9474
D288P005	12/28/2002	03:15p	0 9284	0 0007	0.0168	0.9452
D288P007	12/28/2002	03:27p	0.9278	0.0009	0 0168	0.9446
D288P010	12/28/2002	03:38p	0 9286	0.0007	0.0168	0.9454

Table 17 Single 51032-1 Container Loaded with L2 Fuel Assemblies, IM (Inside and Outside Container) Varied from Dry to Fully Flooded

FILE NAME	DATE	TIME	BEST KEFF	SIGMA	BIAS	BIASED KEFF
NOM00000	12/15/2002	05:19p	0.3501	0.0006	0 0168	0.3669
NOM00001	12/15/2002	05:25p	0.3421	0.0005	0.0168	0.3589
NOM00003	12/15/2002	05:32p	0 3394	0.0005	0.0168	0.3562
NOM00005	12/15/2002	05:39p	0.3490	0.0005	0.0168	0 3658
NOM00007	12/15/2002	05:47p	0.3662	0.0006	0.0168	0.3830
NOM00010	12/15/2002	05.54p	0.4030	0.0005	0.0168	0.4198
NOM00020	12/15/2002	06:04p	0 5202	0.0006	0.0168	0.5370
NOM00030	12/15/2002	06:15p	0.6061	0.0007	0.0168	0.6229
NOM00040	12/15/2002	06:26p	0 6637	0.0008	0.0168	0.6805
NOM00050	12/15/2002	06:38p	0.7144	0.0007	0.0168	0.7312
NOM00060	12/15/2002	06:50p	0.7621	0.0008	0 0168	0.7789
NOM00070	12/15/2002	07 03p	0 8073	0.0008	0 0168	0.8241
NOM00080	12/15/2002	07:14p	0 8507	0 0008	0.0168	0.8675
NOM00090	12/15/2002	07:24p	0.8918	0 0007	0.0168	0.9086
NOM00100	12/15/2002	07:36p	0 9290	0.0008	0.0168	0 9458

Table 18 Infinite Array of Undamaged 51032-1 Containers Loaded with L2 Fuel Assemblies, Inside of Containers Remain Dry, IM (Between Containers) Varied from Dry to Fully Flooded

FILE NAME	DATE	TIME	BEST KEFF	SIGMA	BIAS	BIASED KEFF
UINFC000	12/27/2002	04:01p	0 7783	0 0003	0.0168	0.7951
UINFC001	12/27/2002	04:18p	0 9456	0 0004	0 0168	0.9624
UINFC003	12/27/2002	04:29p	1 0448	0.0005	0 0168	1.0616
UINFC005	12/27/2002	04:39p	1.0525	0.0006	0.0168	1.0693
UINFC007	12/27/2002	04:48p	1.0325	0.0005	0.0168	1.0493
UINFC010	12/27/2002	04:57p	0.9804	0.0006	0.0168	0.9972
UINFC020	12/27/2002	05:08p	0.7971	0.0006	0 0168	0.8139
UINFC030	12/27/2002	05:20p	0.6800	0.0005	0 0168	0.6968
UINFC040	12/27/2002	05 34p	0 6118	0 0006	0 0168	0 6286
UINFC050	12/27/2002	05:49p	0.5679	0.0006	0.0168	0.5847
UINFC060	12/27/2002	06 04p	0.5373	0 0005	0.0168	0 5541
UINFC070	12/27/2002	06:19p	0.5124	0.0005	0.0168	0.5292
UINFC080	12/27/2002	06.34p	0 4901	0.0005	0.0168	0.5069
UINFC090	12/27/2002	06:50p	0.4738	0.0005	0.0168	0.4906
UINFC100	12/27/2002	07:06p	0.4584	0.0005	0.0168	0.4752

Table 19 15x15x3 Array of Undamaged 51032-1 Containers Loaded with L2 Fuel Assemblies, Inside of Containers Remain Dry, IM (Between Containers) Varied from Dry to Fully Flooded

FILE NAME	DATE	TIME	BEST KEFF	SIGMA	BIAS	BIASED KEFF
U675C000	12/26/2002	08.46p	0 5832	0.0006	0.0168	0.6000
U675C001	12/26/2002	08:59p	0.6879	0 0006	0.0168	0.7047
U675C003	12/26/2002	09.09p	0.8365	0.0006	0.0168	0 8533
U675C005	12/26/2002	09:19p	0 8953	0.0007	0.0168	0.9121
U675C007	12/26/2002	09:28p	0.9109	0.0007	0.0168	0.9277
U675C010	12/26/2002	09:37p	0.8931	0.0006	0.0168	0.9099
U675C020	12/26/2002	09.47p	0.7591	0.0006	0.0168	0.7759
U675C030	12/26/2002	10.00p	0.6553	0 0006	0.0168	0 6721
U675C040	12/26/2002	10.13p	0.5954	0 0006	0.0168	0 6122
U675C050	12/26/2002	10.27p	0 5545	0 0006	0 0168	0.5713
U675C060	12/26/2002	10 41p	0.5251	0.0005	0 0168	0.5419
U675C070	12/26/2002	10 58p	0.5030	0.0006	0.0168	0.5198
U675C080	12/26/2002	11:27p	0.4846	0.0005	0.0168	0.5014
U675C090	12/26/2002	11:44p	0.4660	0 0005	0.0168	0.4828
U675C100	12/27/2002	12:00a	0.4534	0 0005	0.0168	0.4702

Table 20 15x15x3 Array of Undamaged 51032-1 Containers Loaded with L2 Fuel Assemblies, 7 vol% IM (Between Containers), PE Inside Containers but Outside Assemblies Varied from 0 to 10 vol%

FILE NAME	DATE	TIME	BEST KEFF	SIGMA	BIAS	BIASED KEFF
U675C007	12/26/2002	09.28p	0.9109	0.0007	0.0168	0.9277
U675P001	12/28/2002	11:22a	0.8857	0.0007	0.0168	0.9025
U675P003	12/28/2002	11:31a	0 8165	0 0007	0.0168	0.8333
U675P005	12/28/2002	11:41a	0.7478	0.0006	0.0168	0.7646
U675P007	12/28/2002	11:51a	0.6871	0.0007	0 0168	0.7039
U675P010	12/28/2002	12:02p	0.6172	0.0006	0.0168	0.6340

Table 21 12x12x2 Array of Damaged 51032-1 Containers Loaded with L2 Fuel Assemblies, Strongbacks and Assemblies Centered Inside Containers, IM (Inside and Between Containers) Varied from Dry to Fully Flooded

FILE NAME	DATE	TIME	BEST KEFF	SIGMA	BIAS	BIASED KEFF
D288C000	12/22/2002	11:03p	0.5558	0.0006	0.0168	0 5726
D288C001	12/22/2002	11:13p	0.7534	0.0006	0.0168	0 7702
D288C003	12/22/2002	11:22p	0.8535	0.0007	0.0168	0.8703
D288C005	12/22/2002	11:30p	0.8012	0.0006	0.0168	0.8180
D288C007	12/22/2002	11:39p	0.7284	0.0007	0.0168	0.7452
D288C010	12/22/2002	11:49p	0.6437	0 0006	0.0168	0.6605
D288C020	12/23/2002	12:02a	0.5776	0 0006	0.0168	0.5944
D288C030	12/23/2002	12:14a	0.6218	0 0006	0.0168	0 6386
D288C040	12/23/2002	12:27a	0 6702	0.0006	0.0168	0.6870
D288C050	12/23/2002	12:39a	0.7186	0 0007	0.0168	0.7354
D288C060	12/23/2002	12:51a	0.7638	0.0007	0.0168	0.7806
D288C070	12/23/2002	01:02a	0.8089	0.0007	0.0168	0.8257
D288C080	12/23/2002	01:13a	0.8507	0.0008	0.0168	0.8675
D288C090	12/23/2002	01:24a	0.8922	0.0008	0.0168	0.9090
D288C100	12/23/2002	01:35a	0.9293	0.0007	0.0168	0.9461

Table 22 12x12x2 Array of Damaged 51032-1 Containers Loaded with L2 Fuel Assemblies, Strongbacks and Assemblies Shifted Inside Containers, IM (Inside and Between Containers) Varied from Dry to Fully Flooded

FILE NAME	DATE	TIME	BEST KEFF	SIGMA	BIAS	BIASED KEFF
D288S000	12/23/2002	01:46a	0.5528	0 0006	0.0168	0.5696
D288S001	12/23/2002	01:56a	0.7500	0.0007	0.0168	0.7668
D288S003	12/23/2002	02.05a	0.8457	0 0007	0.0168	0.8625
D288S005	12/23/2002	02.13a	0.7955	0 0006	0 0168	0.8123
D288S007	12/23/2002	02.22a	0.7277	0 0006	0.0168	0.7445
D288S010	12/23/2002	02.33a	0.6508	0 0006	0 0168	0 6676
D288S020	12/23/2002	02:45a	0.5892	0.0006	0.0168	0 6060
D288S030	12/23/2002	02.57a	0.6258	0.0007	0.0168	0.6426
D288S040	12/23/2002	03:10a	0.6738	0.0007	0.0168	0.6906
D288S050	12/23/2002	03:22a	0.7172	0.0007	0.0168	0.7340
D288S060	12/23/2002	03:34a	0.7642	0.0007	0.0168	0.7810
D288S070	12/23/2002	03:45a	0.8076	0.0007	0.0168	0.8244
D288S080	12/23/2002	03:56a	0.8510	0.0007	0.0168	0.8678
D288S090	12/23/2002	04:07a	0.8935	0 0008	0.0168	0.9103
D288S100	12/23/2002	04:17a	0.9310	0 0009	0.0168	0.9478

Table 23 12x12x2 Array of Damaged 51032-1 Containers Loaded with L2 Fuel Assemblies, Strongbacks and Assemblies Shifted Inside Containers, Fully Flooded Conditions, PE Inside Containers but Outside Assemblies Varied from 0 to 10 vol%

FILE NAME	DATE	TIME	BEST KEFF	SIGMA	BIAS	BIASED KEFF
D288S100	12/23/2002	04:17a	0.9310	0.0009	0.0168	0.9478
D288P001	12/28/2002	03:49p	0.9313	0 0007	0.0168	0.9481
D288P003	12/28/2002	04:00p	0.9292	0 0009	0.0168	0.9460
D288P005	12/28/2002	04:11p	0.9312	0 0007	0.0168	0.9480
D288P007	12/28/2002	04:22p	0.9300	0 0007	0.0168	0.9468
D288P010	12/28/2002	04:34p	0.9296	0 0008	0.0168	0.9464

Table 24 Single 51032-1 Container Loaded with L4 Fuel Assemblies, IM (Inside and Outside Container) Varied from Dry to Fully Flooded

FILE NAME	DATE	TIME	BEST KEFF	SIGMA	BIAS	BIASED KEFF
NOM00000	12/16/2002	11:02p	0 3435	0.0006	0 0168	0.3603
NOM00001	12/16/2002	11:08p	0.3343	0.0005	0.0168	0.3511
NOM00003	12/16/2002	11:15p	0.3322	0 0005	0 0168	0.3490
NOM00005	12/16/2002	11:22p	0.3417	0 0005	0.0168	0 3585
NOM00007	12/16/2002	11:29p	0.3600	0 0005	0.0168	0.3768
NOM00010	12/16/2002	11:36p	0.3962	0.0005	0.0168	0.4130
NOM00020	12/16/2002	11:46p	0 5146	0.0006	0.0168	0.5314
NOM00030	12/16/2002	11:56p	0 5983	0.0007	0 0168	0.6151
NOM00040	12/17/2002	12:07a	0.6601	0 0007	0.0168	0.6769
NOM00050	12/17/2002	12:19a	0 7113	0 0008	0 0168	0.7281
NOM00060	12/17/2002	12:30a	0.7592	0 0007	0.0168	0.7760
NOM00070	12/17/2002	12:41a	0.8045	0 0007	0.0168	0.8213
NOM00080	12/17/2002	12:52a	0.8474	0.0007	0.0168	0.8642
NOM00090	12/17/2002	01:03a	0.8897	0.0008	0.0168	0.9065
NOM00100	12/17/2002	01:13a	0.9271	0 0007	0.0168	0 9439

Table 25 Infinite Array of Undamaged 51032-1 Containers Loaded with L4 Fuel Assemblies, Inside of Containers Remain Dry, IM (Between Containers) Varied from Dry to Fully Flooded

FILE NAME	DATE	TIME	BEST KEFF	SIGMA	BIAS	BIASED KEFF
UINFC000	12/27/2002	07:43p	0.7757	0.0003	0.0168	0.7925
UINFC001	12/27/2002	08.02p	0.9454	0 0004	0.0168	0.9622
UINFC003	12/27/2002	08:14p	1.0419	0.0004	0.0168	1.0587
UINFC005	12/27/2002	08:24p	1.0479	0.0006	0.0168	1.0647
UINFC007	12/27/2002	08:33p	1.0279	0.0006	0.0168	1.0447
UINFC010	12/27/2002	08:43p	0.9751	0.0006	0.0168	0.9919
UINFC020	12/27/2002	08:54p	0.7915	0.0006	0.0168	0.8083
UINFC030	12/27/2002	09.07p	0.6721	0 0005	0.0168	0.6889
UINFC040	12/27/2002	09:20p	0.6050	0.0006	0 0168	0.6218
UINFC050	12/27/2002	09 35p	0 5614	0.0006	0 0168	0.5782
UINFC060	12/27/2002	09:50p	0.5301	0.0005	0.0168	0.5469
UINFC070	12/27/2002	10:05p	0.5036	0.0006	0.0168	0.5204
UINFC080	12/27/2002	10:21p	0.4827	0.0005	0 0168	0.4995
UINFC090	12/27/2002	10:38p	0.4662	0.0005	0 0168	0 4830
UINFC100	12/27/2002	10:54p	0 4515	0.0005	0.0168	0.4683

Table 26 15x15x3 Array of Undamaged 51032-1 Containers Loaded with L4 Fuel Assemblies, Inside of Containers Remain Dry, IM (Between Containers) Varied from Dry to Fully Flooded

FILE NAME	DATE	TIME	BEST KEFF	SIGMA	BIAS	BIASED KEFF
U675C000	12/27/2002	12:14a	0 5728	0.0005	0.0168	0.5896
U675C001	12/27/2002	12:26a	0.6787	0.0006	0.0168	0 6955
U675C003	12/27/2002	12.36a	0 8288	0.0006	0 0168	0.8456
U675C005	12/27/2002	12 45a	0.8893	0 0006	0.0168	0.9061
U675C007	12/27/2002	12.55a	0.9041	0.0006	0.0168	0.9209
U675C010	12/27/2002	01:04a	0.8870	0.0006	0 0168	0.9038
U675C020	12/27/2002	01:14a	0 7504	0.0007	0 0168	0.7672
U675C030	12/27/2002	01:27a	0 6487	0 0006	0.0168	0.6655
U675C040	12/27/2002	01:40a	0.5874	0.0007	0.0168	0.6042
U675C050	12/27/2002	01:55a	0.5476	0.0005	0.0168	0.5644
U675C060	12/27/2002	02.10a	0.5190	0 0006	0.0168	0.5358
U675C070	12/27/2002	02:25a	0 4958	0 0005	0.0168	0.5126
U675C080	12/27/2002	02:40a	0.4761	0.0005	0.0168	0.4929
U675C090	12/27/2002	02:56a	0.4598	0.0005	0.0168	0.4766
U675C100	12/27/2002	03:12a	0.4466	0 0005	0.0168	0.4634

Table 27 15x15x3 Array of Undamaged 51032-1 Containers Loaded with L4 Fuel Assemblies, 7 vol% IM (Between Containers), PE Inside Containers but Outside Assemblies Varied from 0 to 10 vol%

FILE NAME	DATE	TIME	BEST KEFF	SIGMA	BIAS	BIASED KEFF
U675C007	12/27/2002	12:55a	0.9041	0 0006	0 0168	0.9209
U675P001	12/28/2002	01:50p	0 8772	0 0007	0.0168	0.8940
U675P003	12/28/2002	01:59p	0.8097	0.0007	0.0168	0 8265
U675P005	12/28/2002	02 09p	0.7396	0.0006	0 0168	0.7564
U675P007	12/28/2002	02:19p	0.6789	0 0006	0.0168	0.6957
U675P010	12/28/2002	02:32p	0.6078	0.0006	0.0168	0.6246

Table 28 12x12x2 Array of Damaged 51032-1 Containers Loaded with L4 Fuel Assemblies, Strongbacks and Assemblies Centered Inside Containers, IM (Inside and Between Containers) Varied from Dry to Fully Flooded

FILE NAME	DATE	TIME	BEST KEFF	SIGMA	BIAS	BIASED KEFF
D288C000	12/23/2002	10:08a	0 5448	0 0005	0.0168	0.5616
D288C001	12/23/2002	10:19a	0.7461	0 0006	0.0168	0.7629
D288C003	12/23/2002	10:28a	0.8438	0.0007	0.0168	0.8606
D288C005	12/23/2002	10:37a	0.7932	0.0006	0.0168	0.8100
D288C007	12/23/2002	10:47a	0.7213	0.0006	0.0168	0.7381
D288C010	12/23/2002	10.58a	0.6354	0.0007	0.0168	0.6522
D288C020	12/23/2002	11:10a	0.5708	0.0006	0.0168	0.5876
D288C030	12/23/2002	11.24a	0.6141	0.0008	0.0168	0.6309
D288C040	12/23/2002	11:37a	0.6636	0.0008	0.0168	0 6804
D288C050	12/23/2002	11:51a	0.7131	0.0006	0.0168	0.7299
D288C060	12/23/2002	12:03p	0.7581	0.0007	0 0168	0.7749
D288C070	12/23/2002	12:15p	0 8042	0.0008	0 0168	0.8210
D288C080	12/23/2002	12:26p	0 8476	0.0007	0.0168	0 8644
D288C090	12/23/2002	12:37p	0 8900	0.0008	0.0168	0 9068
D288C100	12/23/2002	12:47p	0.9280	0 0007	0 0168	0 9448

Table 29 12x12x2 Array of Damaged 51032-1 Containers Loaded with L4 Fuel Assemblies, Strongbacks and Assemblies Shifted Inside Containers, IM (Inside and Between Containers) Varied from Dry to Fully Flooded

FILE NAME	DATE	TIME	BEST KEFF	SIGMA	BIAS	BIASED KEFF
D288S000	12/23/2002	01:00p	0.5443	0 0006	0 0168	0.5611
D288S001	12/23/2002	01:10p	0.7415	0.0006	0 0168	0.7583
D288S003	12/23/2002	01:19p	0 8383	0 0007	0.0168	0.8551
D288S005	12/23/2002	01:28p	0.7857	0.0007	0 0168	0.8025
D288S007	12/23/2002	01:37p	0.7206	0 0006	0.0168	0.7374
D288S010	12/23/2002	01:48p	0.6438	0.0006	0.0168	0.6606
D288S020	12/23/2002	02.00p	0.5821	0.0006	0.0168	0.5989
D288S030	12/23/2002	02:13p	0.6216	0.0006	0.0168	0.6384
D288S040	12/23/2002	02:25p	0.6689	0.0007	0.0168	0 6857
D288S050	12/23/2002	02:37p	0.7144	0 0008	0.0168	0 7312
D288S060	12/23/2002	02:49p	0.7614	0.0007	0 0168	0.7782
D288S070	12/23/2002	03:01p	0.8049	0.0008	0.0168	0 8217
D288S080	12/23/2002	03:12p	0.8499	0 0007	0 0168	0 8667
D288S090	12/23/2002	03:23p	0.8905	0 0007	0 0168	0 9073
D288S100	12/23/2002	03:33p	0.9275	0.0008	0 0168	0 9443

Table 30 12x12x2 Array of Damaged 51032-1 Containers Loaded with L4 Fuel Assemblies, Strongbacks and Assemblies Centered Inside Containers, Fully Flooded Conditions, PE Inside Containers but Outside Assemblies Varied from 0 to 10 vol%

FILE NAME	DATE	TIME	BEST KEFF	SIGMA	BIAS	BIASED KEFF
D288C100	12/23/2002	12:47p	0.9280	0.0007	0.0168	0.9448
D288P001	12/28/2002	06:36p	0.9298	0.0007	0.0168	0.9466
D288P003	12/28/2002	06:47p	0.9287	0.0008	0.0168	0.9455
D288P005	12/28/2002	06:58p	0.9281	0.0007	0.0168	0.9449
D288P007	12/28/2002	07:10p	0.9279	0.0008	0.0168	0.9447
D288P010	12/28/2002	07:21p	0.9274	0.0007	0.0168	0.9442

APPENDIX C - CALCULATION INPUTS

The computer input listings for this analysis have been archived on the CSTOR system under the following directory structure:

/critsafety/CSA/SHIPPING/51032-1/51032-1-DATA/51032-1.2/..

Listings of sample cases are provided below.

Due to the similiarity of fuel types L1 and L2, only the L1 sample input files are listed as representative of these fuel types As a reminder to the reader, L1 and L2 are identical, except for the pellet diameter (L2 slightly larger)

L1 Fuel Assembly

Case "NOM00100 IN": Single 51032-1 Container Loaded with L1 Fuel Assemblies, Fully Flooded (see Table 10)

```
=csas25    parm=size=1000000
51032-1
238groupndf5 latticecell

' mixture 1
'  uo2 pellets
uo2 1 0.98 293.0 92235 5.050  92238 94.950  end

' mixture 2
'  carbon steel in strongback
carbonsteel 2 1.0 293.0 end

' mixture 3
'  carbon steel in separator blocks
carbonsteel 3 1.0 293.0 end

' mixture 4
'  carbon steel in container shell
carbonsteel 4 1.0 293.0 end

' mixture 5
'  interspersed moderator
h2o 5 den=1.0 1.00 293.0 end

' mixture 6
'  reflector water
h2o  6 den=1.0 1.00 293 end

end comp
squarepitch 1.44272 0.94158 1 5 1.08712 0 END
51032-1

read param  tme=120 gen=515 npg=2500 nsk=15 nub=yes pwt=yes run=yes
end param

read geom

unit 1
com='fuel rod'
cyli 1 1 0.47079 2p250.19
cyli 0 1 0.54356 2p250.19
cubo 5 1 4p0.72136 2p250.19

unit 2
com='location in assy with no rod'
```

```
cubo 5 1 4p0.72136 2p250.19

unit 101
com='bundle on +x side of container'
array 1 -10.82040 -10.82040 -250.19

unit 102
com='bundle on -x side of container'
array 2 -10.82040 -10.82040 -250.19

unit 501
com='separator block'
' min dims per emf-309,813 rev. 0
'  6 in. w x 7.5 in. h x 8.5 in. l x 0.3125 in. thk
cubo 5 1 2p6.82625 2p8.73125 2p10.795
cubo 3 1 2p7.62    2p9.525   2p10.795
' place on 39.4 in. centers
cubo 5 1 2p7.62    2p9.525   2p50.038

unit 502
com='1x1x5 array of separator blocks'
' min of 5 blocks required in 51032-1
' y-coord matches 1/2 of bundle height
array 5 -7.62 -10.82040 -250.19
' match the bundle height
cubo 5 1 2p7.62 2p10.82040 2p250.19

global
unit 601
com='single container'
' center fuel in container
array 6 -29.26080 -10.82040 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 2p31.19437 18.54835 -10.82040 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
'  add 30 cm water reflector
repl 6 2 3r3.0 10

end geom

read array

ara=1 nux=15 nuy=15 nuz=1
fill 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 2 1 1 1 2 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 2 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 2 1 1 1 2 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 end fill

ara=2 nux=15 nuy=15 nuz=1
fill 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 2 1 1 1 2 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 1 2 1 1 2 1 1
```

```
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 2 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 2 1 1 1 2 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 end fill

ara=5 nux=1 nuy=1 nuz=5
fill f501 end fill

ara=6 nux=3 nuy=1 nuz=1
fill 102 502 101 end fill

end array

read start
   nst=1
end start

read bounds
   all=vacuum
end bounds

read bias
   id=500 2 11
end bias

end data
end
```

Case "U675C007.IN": 15x15x3 Array of Undamaged 51032-1 Containers Loaded with L1 Fuel Assemblies, Inside of Containers Remain Dry, IM (Between Containers) at 7 Vol% (see Table 12)

```
=csas25    parm=size=1000000
51032-1
238groupndf5 latticecell

' mixture 1
'  uo2 pellets
uo2 1 0.98 293.0 92235 5.050  92238 94.950  end

' mixture 2
'  carbon steel in strongback
carbonsteel 2 1.0 293.0 end

' mixture 3
'  carbon steel in separator blocks
carbonsteel 3 1.0 293.0 end

' mixture 4
'  carbon steel in container shell
carbonsteel 4 1.0 293.0 end

' mixture 5
'  interspersed moderator
h2o 5 den=1.0 0.07 293.0 end

' mixture 6
'  reflector water
h2o  6 den=1.0 1.00 293 end

end comp
squarepitch 1.44272 0.94158 1 0 1.08712 0 END
51032-1
```

```
read param  tme=120 gen=515 npg=2500 nsk=15 nub=yes pwt=yes run=yes
end param

read geom

unit 1
com='fuel rod'
cyli 1 1 0.47079 2p250.19
cyli 0 1 0.54356 2p250.19
cubo 0 1 4p0.72136 2p250.19

unit 2
com='location in assy with no rod'
cubo 0 1 4p0.72136 2p250.19

unit 101
com='bundle on +x side of container'
array 1 -10.82040 -10.82040 -250.19

unit 102
com='bundle on -x side of container'
array 2 -10.82040 -10.82040 -250.19

unit 501
com='separator block'
' min dims per emf-309,813 rev. 0
'  6 in. w x 7.5 in. h x 8.5 in. l x 0.3125 in. thk
cubo 0 1 2p6.82625 2p8.73125 2p10.795
cubo 3 1 2p7.62    2p9.525   2p10.795
' place on 39.4 in. centers
cubo 0 1 2p7.62    2p9.525   2p50.038

unit 502
com='1x1x5 array of separator blocks'
' min of 5 blocks required in 51032-1
' y-coord matches 1/2 of bundle height
array 5 -7.62 -10.82040 -250.19
' match the bundle height
cubo 0 1 2p7.62 2p10.82040 2p250.19

unit 601
com='single undamaged container'
' center fuel in container
array 6 -29.26080 -10.82040 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 0 1 2p31.19437 18.54835 -10.82040 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 0 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' undamaged spacing between containers 41.75 in.
cubo 5 1 4p53.0225 2p250.43303

unit 701
com='single damaged container - strongback centered'
' center fuel in container
array 6 -29.26080 -10.82040 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 2p31.19437 18.54835 -10.82040 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303
```

```
unit 702
com='single damaged container - strongback shifted +x, +y'
' shift fuel 1.5 in. +x and 3.0 in. +y in container
array 6 -23.51725 -3.20040 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 35.00437 -27.38437 26.16835 -3.20040 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 703
com='single damaged container - strongback shifted -x, +y'
' shift fuel 1.5 in. -x and 3.0 in. +y in container
array 6 -35.00435 -3.20040 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 27.38437 -35.00437 26.16835 -3.20040 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 704
com='single damaged container - strongback shifted +x, -y'
' shift fuel 1.5 in. +x and 3.0 in. -y in container
array 6 -23.51725 -18.44040 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 35.00437 -27.38437 10.92835 -18.44040 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 705
com='single damaged container - strongback shifted -x, -y'
' shift fuel 1.5 in. -x and 3.0 in. -y in container
array 6 -35.00435 -18.44040 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 27.38437 -35.00437 10.92835 -18.44040 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 801
com='2x2x2 array of damaged containers - centered'
array 8 0.0 0.0 0.0

unit 802
com='2x2x2 array of damaged containers - shifted'
array 9 0.0 0.0 0.0

global
unit 901
com='15x15x3 array of undamaged containers'
```

```
array 7 0.0 0.0 0.0
'  add 30 cm water reflector
repl 6 2 6r3.0 10

unit 902
com='12x12x2 array of damaged containers - centered'
array 10 0.0 0.0 0.0
'  add 30 cm water reflector
repl 6 2 6r3.0 10

unit 903
com='12x12x2 array of damaged containers - shifted'
array 11 0.0 0.0 0.0
'  add 30 cm water reflector
repl 6 2 6r3.0 10

end geom

read array

ara=1 nux=15 nuy=15 nuz=1
fill 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 2 1 1 1 2 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 2 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 2 1 1 1 2 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 end fill

ara=2 nux=15 nuy=15 nuz=1
fill 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 2 1 1 1 2 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 2 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 2 1 1 1 2 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 end fill

ara=5 nux=1 nuy=1 nuz=5
fill f501 end fill

ara=6 nux=3 nuy=1 nuz=1
fill 102 502 101 end fill

ara=7 nux=15 nuy=15 nuz=3
fill f601 end fill

ara=8 nux=2 nuy=2 nuz=2
fill f701 end fill

ara=9 nux=2 nuy=2 nuz=2
fill 702 703
     704 705
       702 703
       704 705 end fill
```

```
ara=10 nux=6 nuy=6 nuz=1
fill f801 end fill

ara=11 nux=6 nuy=6 nuz=1
fill f802 end fill

end array

read start
   nst=1
end start

read bounds
   all=vacuum
end bounds

read bias
   id=500 2 11
end bias

end data
end
```

Case "U675P001.IN": 15x15x3 Array of Undamaged 51032-1 Containers Loaded with L1 Fuel Assemblies, 7 vol% IM (Between Containers), PE Inside Containers but Outside Assemblies at 1 vol% (see Table 13)

```
=csas25    parm=size=1000000
51032-1
238groupndf5 latticecell

' mixture 1
'  uo2 pellets
uo2 1 0.98 293.0 92235 5.050  92238 94.950  end

' mixture 2
'  carbon steel in strongback
carbonsteel 2 1.0 293.0 end

' mixture 3
'  carbon steel in separator blocks
carbonsteel 3 1.0 293.0 end

' mixture 4
'  carbon steel in container shell
carbonsteel 4 1.0 293.0 end

' mixture 5
'  interspersed moderator
h2o 5 den=1.0 0.07 293.0 end

' mixture 6
'  reflector water
h2o  6 den=1.0 1.00 293 end

' mixture 7
'  pe as im inside container
arbmpe 0.92 2 0 1 1 6012 1
                    1001 2 7 0.01 end

end comp
squarepitch 1.44272 0.94158 1 0 1.08712 0 END
51032-1

read param  tme=120 gen=515 npg=2500 nsk=15 nub=yes pwt=yes run=yes
end param
```

```
read geom

unit 1
com='fuel rod'
cyli 1 1 0.47079 2p250.19
cyli 0 1 0.54356 2p250.19
cubo 0 1 4p0.72136 2p250.19

unit 2
com='location in assy with no rod'
cubo 0 1 4p0.72136 2p250.19

unit 101
com='bundle on +x side of container'
array 1 -10.82040 -10.82040 -250.19

unit 102
com='bundle on -x side of container'
array 2 -10.82040 -10.82040 -250.19

unit 501
com='separator block'
' min dims per emf-309,813 rev. 0
'  6 in. w x 7.5 in. h x 8.5 in. l x 0.3125 in. thk
cubo 7 1 2p6.82625 2p8.73125 2p10.795
cubo 3 1 2p7.62    2p9.525   2p10.795
' place on 39.4 in. centers
cubo 7 1 2p7.62    2p9.525   2p50.038

unit 502
com='1x1x5 array of separator blocks'
' min of 5 blocks required in 51032-1
' y-coord matches 1/2 of bundle height
array 5 -7.62 -10.82040 -250.19
' match the bundle height
cubo 7 1 2p7.62 2p10.82040 2p250.19

unit 601
com='single undamaged container'
' center fuel in container
array 6 -29.26080 -10.82040 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 7 1 2p31.19437 18.54835 -10.82040 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 7 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' undamaged spacing between containers 41.75 in.
cubo 5 1 4p53.0225 2p250.43303

unit 701
com='single damaged container - strongback centered'
' center fuel in container
array 6 -29.26080 -10.82040 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 2p31.19437 18.54835 -10.82040 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 702
com='single damaged container - strongback shifted +x, +y'
' shift fuel 1.5 in. +x and 3.0 in. +y in container
array 6 -23.51725 -3.20040 -250.19
```

```
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 35.00437 -27.38437 26.16835 -3.20040 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 703
com='single damaged container - strongback shifted -x, +y'
' shift fuel 1.5 in. -x and 3.0 in. +y in container
array 6 -35.00435 -3.20040 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 27.38437 -35.00437 26.16835 -3.20040 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 704
com='single damaged container - strongback shifted +x, -y'
' shift fuel 1.5 in. +x and 3.0 in. -y in container
array 6 -23.51725 -18.44040 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 35.00437 -27.38437 10.92835 -18.44040 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 705
com='single damaged container - strongback shifted -x, -y'
' shift fuel 1.5 in. -x and 3.0 in. -y in container
array 6 -35.00435 -18.44040 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 27.38437 -35.00437 10.92835 -18.44040 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 801
com='2x2x2 array of damaged containers - centered'
array 8 0.0 0.0 0.0

unit 802
com='2x2x2 array of damaged containers - shifted'
array 9 0.0 0.0 0.0

global
unit 901
com='15x15x3 array of undamaged containers'
array 7 0.0 0.0 0.0
'  add 30 cm water reflector
repl 6 2 6r3.0 10
```

```
unit 902
com='12x12x2 array of damaged containers - centered'
array 10 0.0 0.0 0.0
'  add 30 cm water reflector
repl 6 2 6r3.0 10

unit 903
com='12x12x2 array of damaged containers - shifted'
array 11 0.0 0.0 0.0
'  add 30 cm water reflector
repl 6 2 6r3.0 10

end geom

read array

ara=1 nux=15 nuy=15 nuz=1
fill 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 2 1 1 1 2 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 2 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 2 1 1 1 2 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 end fill

ara=2 nux=15 nuy=15 nuz=1
fill 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 2 1 1 1 2 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 2 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 2 1 1 1 2 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 end fill

ara=5 nux=1 nuy=1 nuz=5
fill f501 end fill

ara=6 nux=3 nuy=1 nuz=1
fill 102 502 101 end fill

ara=7 nux=15 nuy=15 nuz=3
fill f601 end fill

ara=8 nux=2 nuy=2 nuz=2
fill f701 end fill

ara=9 nux=2 nuy=2 nuz=2
fill 702 703
     704 705
       702 703
       704 705 end fill

ara=10 nux=6 nuy=6 nuz=1
fill f801 end fill
```

```
ara=11 nux=6 nuy=6 nuz=1
fill f802 end fill

end array

read start
   nst=1
end start

read bounds
   all=vacuum
end bounds

read bias
   id=500 2 11
end bias

end data
end
```

Case "D288C100 IN": 12x12x2 Array of Damaged 51032-1 Containers Loaded with L1 Fuel Assemblies, Strongbacks and Assemblies Centered Inside Containers, IM (Inside and Between Containers) Fully Flooded (see Table 14)

```
=csas25    parm=size=1000000
51032-1
238groupndf5 latticecell

' mixture 1
'  uo2 pellets
uo2 1 0.98 293.0 92235 5.050  92238 94.950  end

' mixture 2
'  carbon steel in strongback
carbonsteel 2 1.0 293.0 end

' mixture 3
'  carbon steel in separator blocks
carbonsteel 3 1.0 293.0 end

' mixture 4
'  carbon steel in container shell
carbonsteel 4 1.0 293.0 end

' mixture 5
'  interspersed moderator
h2o 5 den=1.0 1.00 293.0 end

' mixture 6
'  reflector water
h2o  6 den=1.0 1.00 293 end

end comp
squarepitch 1.44272 0.94158 1 5 1.08712 0 END
51032-1

read param  tme=120 gen=515 npg=2500 nsk=15 nub=yes pwt=yes run=yes
end param

read geom

unit 1
com='fuel rod'
cyli 1 1 0.47079 2p250.19
cyli 0 1 0.54356 2p250.19
cubo 5 1 4p0.72136 2p250.19

unit 2
```

```
com='location in assy with no rod'
cubo 5 1 4p0.72136 2p250.19

unit 101
com='bundle on +x side of container'
array 1 -10.82040 -10.82040 -250.19

unit 102
com='bundle on -x side of container'
array 2 -10.82040 -10.82040 -250.19

unit 501
com='separator block'
' min dims per emf-309,813 rev. 0
'  6 in. w x 7.5 in. h x 8.5 in. l x 0.3125 in. thk
cubo 5 1 2p6.82625 2p8.73125 2p10.795
cubo 3 1 2p7.62    2p9.525   2p10.795
' place on 39.4 in. centers
cubo 5 1 2p7.62    2p9.525   2p50.038

unit 502
com='1x1x5 array of separator blocks'
' min of 5 blocks required in 51032-1
' y-coord matches 1/2 of bundle height
array 5 -7.62 -10.82040 -250.19
' match the bundle height
cubo 5 1 2p7.62 2p10.82040 2p250.19

unit 601
com='single undamaged container'
' center fuel in container
array 6 -29.26080 -10.82040 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 2p31.19437 18.54835 -10.82040 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' undamaged spacing between containers 41.75 in.
cubo 5 1 4p53.0225 2p250.43303

unit 701
com='single damaged container - strongback centered'
' center fuel in container
array 6 -29.26080 -10.82040 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 2p31.19437 18.54835 -10.82040 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 702
com='single damaged container - strongback shifted +x, +y'
' shift fuel 1.5 in. +x and 3.0 in. +y in container
array 6 -23.51725 -3.20040 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 35.00437 -27.38437 26.16835 -3.20040 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
```

```
cubo 5 1 4p51.7525 2p250.43303

unit 703
com='single damaged container - strongback shifted -x, +y'
' shift fuel 1.5 in. -x and 3.0 in. +y in container
array 6 -35.00435 -3.20040 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 27.38437 -35.00437 26.16835 -3.20040 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 704
com='single damaged container - strongback shifted +x, -y'
' shift fuel 1.5 in. +x and 3.0 in. -y in container
array 6 -23.51725 -18.44040 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 35.00437 -27.38437 10.92835 -18.44040 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 705
com='single damaged container - strongback shifted -x, -y'
' shift fuel 1.5 in. -x and 3.0 in. -y in container
array 6 -35.00435 -18.44040 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 27.38437 -35.00437 10.92835 -18.44040 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 801
com='2x2x2 array of damaged containers - centered'
array 8 0.0 0.0 0.0

unit 802
com='2x2x2 array of damaged containers - shifted'
array 9 0.0 0.0 0.0

unit 901
com='12x12x2 array of undamaged containers'
array 7 0.0 0.0 0.0
'  add 30 cm water reflector
repl 6 2 6r3.0 10

global
unit 902
com='12x12x2 array of damaged containers - centered'
array 10 0.0 0.0 0.0
'  add 30 cm water reflector
repl 6 2 6r3.0 10

unit 903
com='12x12x2 array of damaged containers - shifted'
array 11 0.0 0.0 0.0
```

```
'  add 30 cm water reflector
repl 6 2 6r3.0 10

end geom

read array

ara=1 nux=15 nuy=15 nuz=1
fill 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 2 1 1 1 2 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 2 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 2 1 1 1 2 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 end fill

ara=2 nux=15 nuy=15 nuz=1
fill 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 2 1 1 1 2 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 2 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 2 1 1 1 2 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 end fill

ara=5 nux=1 nuy=1 nuz=5
fill f501 end fill

ara=6 nux=3 nuy=1 nuz=1
fill 102 502 101 end fill

ara=7 nux=12 nuy=12 nuz=2
fill f601 end fill

ara=8 nux=2 nuy=2 nuz=2
fill f701 end fill

ara=9 nux=2 nuy=2 nuz=2
fill 702 703
     704 705
       702 703
       704 705 end fill

ara=10 nux=6 nuy=6 nuz=1
fill f801 end fill

ara=11 nux=6 nuy=6 nuz=1
fill f802 end fill

end array

read start
   nst=1
end start
```

```
read bounds
   all=vacuum
end bounds

read bias
   id=500 2 11
end bias

end data
end
```

Case "D288S100 IN": 12x12x2 Array of Damaged 51032-1 Containers Loaded with L1 Fuel Assemblies, Strongbacks and Assemblies Shifted Inside Containers, IM (Inside and Between Containers) Fully Flooded (see Table 15)

```
=csas25    parm=size=1000000
51032-1
238groupndf5 latticecell

' mixture 1
'  uo2 pellets
uo2 1 0.98 293.0 92235 5.050  92238 94.950  end

' mixture 2
'  carbon steel in strongback
carbonsteel 2 1.0 293.0 end

' mixture 3
'  carbon steel in separator blocks
carbonsteel 3 1.0 293.0 end

' mixture 4
'  carbon steel in container shell
carbonsteel 4 1.0 293.0 end

' mixture 5
'  interspersed moderator
h2o 5 den=1.0 1.00 293.0 end

' mixture 6
'  reflector water
h2o  6 den=1.0 1.00 293 end

end comp
squarepitch 1.44272 0.94158 1 5 1.08712 0 END
51032-1

read param  tme=120 gen=515 npg=2500 nsk=15 nub=yes pwt=yes run=yes
end param

read geom

unit 1
com='fuel rod'
cyli 1 1 0.47079 2p250.19
cyli 0 1 0.54356 2p250.19
cubo 5 1 4p0.72136 2p250.19

unit 2
com='location in assy with no rod'
cubo 5 1 4p0.72136 2p250.19

unit 101
com='bundle on +x side of container'
array 1 -10.82040 -10.82040 -250.19

unit 102
com='bundle on -x side of container'
```

```
array 2 -10.82040 -10.82040 -250.19

unit 501
com='separator block'
' min dims per emf-309,813 rev. 0
'  6 in. w x 7.5 in. h x 8.5 in. l x 0.3125 in. thk
cubo 5 1 2p6.82625 2p8.73125 2p10.795
cubo 3 1 2p7.62    2p9.525   2p10.795
' place on 39.4 in. centers
cubo 5 1 2p7.62    2p9.525   2p50.038

unit 502
com='1x1x5 array of separator blocks'
' min of 5 blocks required in 51032-1
' y-coord matches 1/2 of bundle height
array 5 -7.62 -10.82040 -250.19
' match the bundle height
cubo 5 1 2p7.62 2p10.82040 2p250.19

unit 601
com='single undamaged container'
' center fuel in container
array 6 -29.26080 -10.82040 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 2p31.19437 18.54835 -10.82040 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' undamaged spacing between containers 41.75 in.
cubo 5 1 4p53.0225 2p250.43303

unit 701
com='single damaged container - strongback centered'
' center fuel in container
array 6 -29.26080 -10.82040 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 2p31.19437 18.54835 -10.82040 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 702
com='single damaged container - strongback shifted +x, +y'
' shift fuel 1.5 in. +x and 3.0 in. +y in container
array 6 -23.51725 -3.20040 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 35.00437 -27.38437 26.16835 -3.20040 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 703
com='single damaged container - strongback shifted -x, +y'
' shift fuel 1.5 in. -x and 3.0 in. +y in container
array 6 -35.00435 -3.20040 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 27.38437 -35.00437 26.16835 -3.20040 2p250.19
' add strongback steel
```

```
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' 1m to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 704
com='single damaged container - strongback shifted +x, -y'
' shift fuel 1.5 in. +x and 3.0 in. -y in container
array 6 -23.51725 -18.44040 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 35.00437 -27.38437 10.92835 -18.44040 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' 1m to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 705
com='single damaged container - strongback shifted -x, -y'
' shift fuel 1.5 in. -x and 3.0 in. -y in container
array 6 -35.00435 -18.44040 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 27.38437 -35.00437 10.92835 -18.44040 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 801
com='2x2x2 array of damaged containers - centered'
array 8 0.0 0.0 0.0

unit 802
com='2x2x2 array of damaged containers - shifted'
array 9 0.0 0.0 0.0

unit 901
com='12x12x2 array of undamaged containers'
array 7 0.0 0.0 0.0
'  add 30 cm water reflector
repl 6 2 6r3.0 10

unit 902
com='12x12x2 array of damaged containers - centered'
array 10 0.0 0.0 0.0
'  add 30 cm water reflector
repl 6 2 6r3.0 10

global
unit 903
com='12x12x2 array of damaged containers - shifted'
array 11 0.0 0.0 0.0
'  add 30 cm water reflector
repl 6 2 6r3.0 10

end geom

read array

ara=1 nux=15 nuy=15 nuz=1
fill 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
```

```
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 2 1 1 1 2 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 2 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 2 1 1 1 2 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 end fill

ara=2 nux=15 nuy=15 nuz=1
fill 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 2 1 1 1 2 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 2 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 2 1 1 1 2 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 end fill

ara=5 nux=1 nuy=1 nuz=5
fill f501 end fill

ara=6 nux=3 nuy=1 nuz=1
fill 102 502 101 end fill

ara=7 nux=12 nuy=12 nuz=2
fill f601 end fill

ara=8 nux=2 nuy=2 nuz=2
fill f701 end fill

ara=9 nux=2 nuy=2 nuz=2
fill 702 703
     704 705
       702 703
       704 705 end fill

ara=10 nux=6 nuy=6 nuz=1
fill f801 end fill

ara=11 nux=6 nuy=6 nuz=1
fill f802 end fill

end array

read start
   nst=1
end start

read bounds
   all=vacuum
end bounds

read bias
   id=500 2 11
end bias

end data
```

```
end
```

Case "D288P003 IN": 12x12x2 Array of Damaged 51032-1 Containers Loaded with L1 Fuel Assemblies, Strongbacks and Assemblies Shifted Inside Containers, Fully Flooded Conditions, PE Inside Containers but Outside Assemblies at 3 vol% (see Table 16)

```
=csas25    parm=size=1000000
51032-1
238groupndf5 latticecell

' mixture 1
'  uo2 pellets
uo2 1 0.98 293.0 92235 5.050  92238 94.950  end

' mixture 2
'  carbon steel in strongback
carbonsteel 2 1.0 293.0 end

' mixture 3
'  carbon steel in separator blocks
carbonsteel 3 1.0 293.0 end

' mixture 4
'  carbon steel in container shell
carbonsteel 4 1.0 293.0 end

' mixture 5
'  interspersed moderator
h2o 5 den=1.0 1.00 293.0 end

' mixture 6
'  reflector water
h2o  6 den=1.0 1.00 293 end

' mixture 7
'  pe + h2o as im inside container
h2o 7 den=1.0 0.97 293.0 end
arbmpe 0.92 2 0 1 1 6012 1
                    1001 2 7 0.03 end

end comp
squarepitch 1.44272 0.94158 1 5 1.08712 0 END
51032-1

read param  tme=120 gen=515 npg=2500 nsk=15 nub=yes pwt=yes run=yes
end param

read geom

unit 1
com='fuel rod'
cyli 1 1 0.47079 2p250.19
cyli 0 1 0.54356 2p250.19
cubo 5 1 4p0.72136 2p250.19

unit 2
com='location in assy with no rod'
cubo 5 1 4p0.72136 2p250.19

unit 101
com='bundle on +x side of container'
array 1 -10.82040 -10.82040 -250.19

unit 102
com='bundle on -x side of container'
array 2 -10.82040 -10.82040 -250.19
```

```
unit 501
com='separator block'
' min dims per emf-309,813 rev. 0
'  6 in. w x 7.5 in. h x 8.5 in. l x 0.3125 in. thk
cubo 7 1 2p6.82625 2p8.73125 2p10.795
cubo 3 1 2p7.62    2p9.525   2p10.795
' place on 39.4 in. centers
cubo 7 1 2p7.62    2p9.525   2p50.038

unit 502
com='1x1x5 array of separator blocks'
' min of 5 blocks required in 51032-1
' y-coord matches 1/2 of bundle height
array 5 -7.62 -10.82040 -250.19
' match the bundle height
cubo 7 1 2p7.62 2p10.82040 2p250.19

unit 601
com='single undamaged container'
' center fuel in container
array 6 -29.26080 -10.82040 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 2p31.19437 18.54835 -10.82040 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' undamaged spacing between containers 41.75 in.
cubo 5 1 4p53.0225 2p250.43303

unit 701
com='single damaged container - strongback centered'
' center fuel in container
array 6 -29.26080 -10.82040 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 7 1 2p31.19437 18.54835 -10.82040 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 7 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 702
com='single damaged container - strongback shifted +x, +y'
' shift fuel 1.5 in. +x and 3.0 in. +y in container
array 6 -23.51725 -3.20040 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 7 1 35.00437 -27.38437 26.16835 -3.20040 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 7 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 703
com='single damaged container - strongback shifted -x, +y'
' shift fuel 1.5 in. -x and 3.0 in. +y in container
array 6 -35.00435 -3.20040 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 7 1 27.38437 -35.00437 26.16835 -3.20040 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
```

```
' im to inside of steel shell
cyli 7 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 704
com='single damaged container - strongback shifted +x, -y'
' shift fuel 1.5 in. +x and 3.0 in. -y in container
array 6 -23.51725 -18.44040 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 7 1 35.00437 -27.38437 10.92835 -18.44040 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 7 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 705
com='single damaged container - strongback shifted -x, -y'
' shift fuel 1.5 in. -x and 3.0 in. -y in container
array 6 -35.00435 -18.44040 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 7 1 27.38437 -35.00437 10.92835 -18.44040 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 7 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 801
com='2x2x2 array of damaged containers - centered'
array 8 0.0 0.0 0.0

unit 802
com='2x2x2 array of damaged containers - shifted'
array 9 0.0 0.0 0.0

unit 901
com='12x12x2 array of undamaged containers'
array 7 0.0 0.0 0.0
'  add 30 cm water reflector
repl 6 2 6r3.0 10

unit 902
com='12x12x2 array of damaged containers - centered'
array 10 0.0 0.0 0.0
'  add 30 cm water reflector
repl 6 2 6r3.0 10

global
unit 903
com='12x12x2 array of damaged containers - shifted'
array 11 0.0 0.0 0.0
'  add 30 cm water reflector
repl 6 2 6r3.0 10

end geom

read array

ara=1 nux=15 nuy=15 nuz=1
fill 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
```

```
     1 1 1 1 1 2 1 1 1 2 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 2 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 2 1 1 1 2 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 end fill

ara=2 nux=15 nuy=15 nuz=1
fill 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 2 1 1 1 2 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 2 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 2 1 1 1 2 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 end fill

ara=5 nux=1 nuy=1 nuz=5
fill f501 end fill

ara=6 nux=3 nuy=1 nuz=1
fill 102 502 101 end fill

ara=7 nux=12 nuy=12 nuz=2
fill f601 end fill

ara=8 nux=2 nuy=2 nuz=2
fill f701 end fill

ara=9 nux=2 nuy=2 nuz=2
fill 702 703
     704 705
       702 703
       704 705 end fill

ara=10 nux=6 nuy=6 nuz=1
fill f801 end fill

ara=11 nux=6 nuy=6 nuz=1
fill f802 end fill

end array

read start
   nst=1
end start

read bounds
   all=vacuum
end bounds

read bias
   id=500 2 11
end bias

end data
end
```

L4 Fuel Assembly

Case "NOM00100 IN": Single 51032-1 Container Loaded with L4 Fuel Assemblies, Fully Flooded (see Table 24)

```
=csas25    parm=size=1000000
51032-1
238groupndf5 latticecell

' mixture 1
'  uo2 pellets
uo2 1 0.98 293.0 92235 5.050  92238 94.950  end

' mixture 2
'  carbon steel in strongback
carbonsteel 2 1.0 293.0 end

' mixture 3
'  carbon steel in separator blocks
carbonsteel 3 1.0 293.0 end

' mixture 4
'  carbon steel in container shell
carbonsteel 4 1.0 293.0 end

' mixture 5
'  interspersed moderator
h2o 5 den=1.0 1.00 293.0 end

' mixture 6
'  reflector water
h2o  6 den=1.0 1.00 293 end

end comp
squarepitch 1.25984 0.82093 1 5 0.94488 0 END
51032-1

read param  tme=120 gen=515 npg=2500 nsk=15 nub=yes pwt=yes run=yes
end param

read geom

unit 1
com='fuel rod'
cyli 1 1 0.41047 2p250.19
cyli 0 1 0.47244 2p250.19
cubo 5 1 4p0.62992 2p250.19

unit 2
com='location in assy with no rod'
cubo 5 1 4p0.62992 2p250.19

unit 101
com='bundle on +x side of container'
array 1 -10.70864 -10.70864 -250.19

unit 102
com='bundle on -x side of container'
array 2 -10.70864 -10.70864 -250.19

unit 501
com='separator block'
' min dims per emf-309,813 rev. 0
'  6 in. w x 7.5 in. h x 8.5 in. l x 0.3125 in. thk
cubo 5 1 2p6.82625 2p8.73125 2p10.795
cubo 3 1 2p7.62    2p9.525   2p10.795
' place on 39.4 in. centers
```

```
cubo 5 1 2p7.62    2p9.525   2p50.038

unit 502
com='1x1x5 array of separator blocks'
' min of 5 blocks required in 51032-1
' y-coord matches 1/2 of bundle height
array 5 -7.62 -10.70864 -250.19
' match the bundle height
cubo 5 1 2p7.62 2p10.70864 2p250.19

global
unit 601
com='single container'
' center fuel in container
array 6 -29.03728 -10.70864 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 2p31.19437 18.66011 -10.70864 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
'  add 30 cm water reflector
repl 6 2 3r3.0 10

end geom

read array

ara=1 nux=17 nuy=17 nuz=1
fill 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 2 1 1 2 1 1 2 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 2 1 1 2 1 1 2 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 end fill

ara=2 nux=17 nuy=17 nuz=1
fill 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 2 1 1 2 1 1 2 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 2 1 1 2 1 1 2 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 end fill

ara=5 nux=1 nuy=1 nuz=5
fill f501 end fill
```

```
ara=6 nux=3 nuy=1 nuz=1
fill 102 502 101 end fill

end array

read start
   nst=1
end start

read bounds
   all=vacuum
end bounds

read bias
   id=500 2 11
end bias

end data
end
```

Case "U675C007.IN": 15x15x3 Array of Undamaged 51032-1 Containers Loaded with L4 Fuel Assemblies, Inside of Containers Remain Dry, IM (Between Containers) at 7 Vol% (see Table 26)

```
=csas25    parm=size=1000000
51032-1
238groupndf5 latticecell

' mixture 1
'  uo2 pellets
uo2 1 0.98 293.0 92235 5.050  92238 94.950  end

' mixture 2
'  carbon steel in strongback
carbonsteel 2 1.0 293.0 end

' mixture 3
'  carbon steel in separator blocks
carbonsteel 3 1.0 293.0 end

' mixture 4
'  carbon steel in container shell
carbonsteel 4 1.0 293.0 end

' mixture 5
'  interspersed moderator
h2o 5 den=1.0 0.07 293.0 end

' mixture 6
'  reflector water
h2o  6 den=1.0 1.00 293 end

end comp
squarepitch 1.25984 0.82093 1 0 0.94488 0 END
51032-1

read param  tme=120 gen=515 npg=2500 nsk=15 nub=yes pwt=yes run=yes
end param

read geom

unit 1
com='fuel rod'
cyli 1 1 0.41047 2p250.19
cyli 0 1 0.47244 2p250.19
cubo 0 1 4p0.62992 2p250.19

unit 2
```

```
com='location in assy with no rod'
cubo 0 1 4p0.62992 2p250.19

unit 101
com='bundle on +x side of container'
array 1 -10.70864 -10.70864 -250.19

unit 102
com='bundle on -x side of container'
array 2 -10.70864 -10.70864 -250.19

unit 501
com='separator block'
' min dims per emf-309,813 rev. 0
'  6 in. w x 7.5 in. h x 8.5 in. l x 0.3125 in. thk
cubo 0 1 2p6.82625 2p8.73125 2p10.795
cubo 3 1 2p7.62    2p9.525   2p10.795
' place on 39.4 in. centers
cubo 0 1 2p7.62    2p9.525   2p50.038

unit 502
com='1x1x5 array of separator blocks'
' min of 5 blocks required in 51032-1
' y-coord matches 1/2 of bundle height
array 5 -7.62 -10.70864 -250.19
' match the bundle height
cubo 0 1 2p7.62 2p10.70864 2p250.19

unit 601
com='single undamaged container'
' center fuel in container
array 6 -29.03728 -10.70864 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 0 1 2p31.19437 18.66011 -10.70864 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 0 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' undamaged spacing between containers 41.75 in.
cubo 5 1 4p53.0225 2p250.43303

unit 701
com='single damaged container - strongback centered'
' center fuel in container
array 6 -29.03728 -10.70864 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 2p31.19437 18.66011 -10.70864 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 702
com='single damaged container - strongback shifted +x, +y'
' shift fuel 1.5 in. +x and 3.0 in. +y in container
array 6 -23.07021 -3.08864 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 35.00437 -27.38437 26.28011 -3.08864 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
```

```
cubo 5 1 4p51.7525 2p250.43303

unit 703
com='single damaged container - strongback shifted -x, +y'
' shift fuel 1.5 in. -x and 3.0 in. +y in container
array 6 -35.00435 -3.08864 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 27.38437 -35.00437 26.28011 -3.08864 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 704
com='single damaged container - strongback shifted +x, -y'
' shift fuel 1.5 in. +x and 3.0 in. -y in container
array 6 -23.07021 -18.32864 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 35.00437 -27.38437 11.04011 -18.32864 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 705
com='single damaged container - strongback shifted -x, -y'
' shift fuel 1.5 in. -x and 3.0 in. -y in container
array 6 -35.00435 -18.32864 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 27.38437 -35.00437 11.04011 -18.32864 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 801
com='2x2x2 array of damaged containers - centered'
array 8 0.0 0.0 0.0

unit 802
com='2x2x2 array of damaged containers - shifted'
array 9 0.0 0.0 0.0

global
unit 901
com='15x15x3 array of undamaged containers'
array 7 0.0 0.0 0.0
'  add 30 cm water reflector
repl 6 2 6r3.0 10

unit 902
com='12x12x2 array of damaged containers - centered'
array 10 0.0 0.0 0.0
'  add 30 cm water reflector
repl 6 2 6r3.0 10

unit 903
com='12x12x2 array of damaged containers - shifted'
array 11 0.0 0.0 0.0
```

```
'  add 30 cm water reflector
repl 6 2 6r3.0 10

end geom

read array

ara=1 nux=17 nuy=17 nuz=1
fill 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 2 1 1 2 1 1 2 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 2 1 1 2 1 1 2 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 end fill

ara=2 nux=17 nuy=17 nuz=1
fill 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 2 1 1 2 1 1 2 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 2 1 1 2 1 1 2 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 end fill

ara=5 nux=1 nuy=1 nuz=5
fill f501 end fill

ara=6 nux=3 nuy=1 nuz=1
fill 102 502 101 end fill

ara=7 nux=15 nuy=15 nuz=3
fill f601 end fill

ara=8 nux=2 nuy=2 nuz=2
fill f701 end fill

ara=9 nux=2 nuy=2 nuz=2
fill 702 703
     704 705
       702 703
       704 705 end fill

ara=10 nux=6 nuy=6 nuz=1
fill f801 end fill

ara=11 nux=6 nuy=6 nuz=1
fill f802 end fill

end array
```

```
read start
   nst=1
end start

read bounds
   all=vacuum
end bounds

read bias
   id=500 2 11
end bias

end data
end
```

Case "U675P001.IN": 15x15x3 Array of Undamaged 51032-1 Containers Loaded with L4 Fuel Assemblies, 7 vol% IM (Between Containers), PE Inside Containers but Outside Assemblies at 1 vol% (see Table 27)

```
=csas25    parm=size=1000000
51032-1
238groupndf5 latticecell

' mixture 1
'  uo2 pellets
uo2 1 0.98 293.0 92235 5.050  92238 94.950  end

' mixture 2
'  carbon steel in strongback
carbonsteel 2 1.0 293.0 end

' mixture 3
'  carbon steel in separator blocks
carbonsteel 3 1.0 293.0 end

' mixture 4
'  carbon steel in container shell
carbonsteel 4 1.0 293.0 end

' mixture 5
'  interspersed moderator
h2o 5 den=1.0 0.07 293.0 end

' mixture 6
'  reflector water
h2o  6 den=1.0 1.00 293 end

' mixture 7
'  pe as im inside container
arbmpe 0.92 2 0 1 1 6012 1
                    1001 2 7 0.01 end

end comp
squarepitch 1.25984 0.82093 1 0 0.94488 0 END
51032-1

read param  tme=120 gen=515 npg=2500 nsk=15 nub=yes pwt=yes run=yes
end param

read geom

unit 1
com='fuel rod'
cyli 1 1 0.41047 2p250.19
cyli 0 1 0.47244 2p250.19
cubo 0 1 4p0.62992 2p250.19

unit 2
```

```
com='location in assy with no rod'
cubo 0 1 4p0.62992 2p250.19

unit 101
com='bundle on +x side of container'
array 1 -10.70864 -10.70864 -250.19

unit 102
com='bundle on -x side of container'
array 2 -10.70864 -10.70864 -250.19

unit 501
com='separator block'
' min dims per emf-309,813 rev. 0
'  6 in. w x 7.5 in. h x 8.5 in. l x 0.3125 in. thk
cubo 7 1 2p6.82625 2p8.73125 2p10.795
cubo 3 1 2p7.62    2p9.525   2p10.795
' place on 39.4 in. centers
cubo 7 1 2p7.62    2p9.525   2p50.038

unit 502
com='1x1x5 array of separator blocks'
' min of 5 blocks required in 51032-1
' y-coord matches 1/2 of bundle height
array 5 -7.62 -10.70864 -250.19
' match the bundle height
cubo 7 1 2p7.62 2p10.70864 2p250.19

unit 601
com='single undamaged container'
' center fuel in container
array 6 -29.03728 -10.70864 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 7 1 2p31.19437 18.66011 -10.70864 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 7 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' undamaged spacing between containers 41.75 in.
cubo 5 1 4p53.0225 2p250.43303

unit 701
com='single damaged container - strongback centered'
' center fuel in container
array 6 -29.03728 -10.70864 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 2p31.19437 18.66011 -10.70864 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 702
com='single damaged container - strongback shifted +x, +y'
' shift fuel 1.5 in. +x and 3.0 in. +y in container
array 6 -23.07021 -3.08864 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 35.00437 -27.38437 26.28011 -3.08864 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
```

```
cubo 5 1 4p51.7525 2p250.43303

unit 703
com='single damaged container - strongback shifted -x, +y'
' shift fuel 1.5 in. -x and 3.0 in. +y in container
array 6 -35.00435 -3.08864 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 27.38437 -35.00437 26.28011 -3.08864 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 704
com='single damaged container - strongback shifted +x, -y'
' shift fuel 1.5 in. +x and 3.0 in. -y in container
array 6 -23.07021 -18.32864 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 35.00437 -27.38437 11.04011 -18.32864 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 705
com='single damaged container - strongback shifted -x, -y'
' shift fuel 1.5 in. -x and 3.0 in. -y in container
array 6 -35.00435 -18.32864 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 27.38437 -35.00437 11.04011 -18.32864 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 801
com='2x2x2 array of damaged containers - centered'
array 8 0.0 0.0 0.0

unit 802
com='2x2x2 array of damaged containers - shifted'
array 9 0.0 0.0 0.0

global
unit 901
com='15x15x3 array of undamaged containers'
array 7 0.0 0.0 0.0
'  add 30 cm water reflector
repl 6 2 6r3.0 10

unit 902
com='12x12x2 array of damaged containers - centered'
array 10 0.0 0.0 0.0
'  add 30 cm water reflector
repl 6 2 6r3.0 10

unit 903
com='12x12x2 array of damaged containers - shifted'
array 11 0.0 0.0 0.0
```

```
'  add 30 cm water reflector
repl 6 2 6r3.0 10

end geom

read array

ara=1 nux=17 nuy=17 nuz=1
fill 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 2 1 1 2 1 1 2 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 2 1 1 2 1 1 2 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 end fill

ara=2 nux=17 nuy=17 nuz=1
fill 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 2 1 1 2 1 1 2 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 2 1 1 2 1 1 2 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 end fill

ara=5 nux=1 nuy=1 nuz=5
fill f501 end fill

ara=6 nux=3 nuy=1 nuz=1
fill 102 502 101 end fill

ara=7 nux=15 nuy=15 nuz=3
fill f601 end fill

ara=8 nux=2 nuy=2 nuz=2
fill f701 end fill

ara=9 nux=2 nuy=2 nuz=2
fill 702 703
     704 705
       702 703
       704 705 end fill

ara=10 nux=6 nuy=6 nuz=1
fill f801 end fill

ara=11 nux=6 nuy=6 nuz=1
fill f802 end fill

end array
```

```
read start
   nst=1
end start

read bounds
   all=vacuum
end bounds

read bias
   id=500 2 11
end bias

end data
end
```

Case "D288C100 IN": 12x12x2 Array of Damaged 51032-1 Containers Loaded with L4 Fuel Assemblies, Strongbacks and Assemblies Centered Inside Containers, IM (Inside and Between Containers) Fully Flooded (see Table 28)

```
=csas25    parm=size=1000000
51032-1
238groupndf5 latticecell

' mixture 1
'  uo2 pellets
uo2 1 0.98 293.0 92235 5.050  92238 94.950  end

' mixture 2
'  carbon steel in strongback
carbonsteel 2 1.0 293.0 end

' mixture 3
'  carbon steel in separator blocks
carbonsteel 3 1.0 293.0 end

' mixture 4
'  carbon steel in container shell
carbonsteel 4 1.0 293.0 end

' mixture 5
'  interspersed moderator
h2o 5 den=1.0 1.00 293.0 end

' mixture 6
'  reflector water
h2o  6 den=1.0 1.00 293 end

end comp
squarepitch 1.25984 0.82093 1 5 0.94488 0 END
51032-1

read param  tme=120 gen=515 npg=2500 nsk=15 nub=yes pwt=yes run=yes
end param

read geom

unit 1
com='fuel rod'
cyli 1 1 0.41047 2p250.19
cyli 0 1 0.47244 2p250.19
cubo 5 1 4p0.62992 2p250.19

unit 2
com='location in assy with no rod'
cubo 5 1 4p0.62992 2p250.19

unit 101
com='bundle on +x side of container'
```

```
array 1 -10.70864 -10.70864 -250.19

unit 102
com='bundle on -x side of container'
array 2 -10.70864 -10.70864 -250.19

unit 501
com='separator block'
' min dims per emf-309,813 rev. 0
'  6 in. w x 7.5 in. h x 8.5 in. l x 0.3125 in. thk
cubo 5 1 2p6.82625 2p8.73125 2p10.795
cubo 3 1 2p7.62    2p9.525   2p10.795
' place on 39.4 in. centers
cubo 5 1 2p7.62    2p9.525   2p50.038

unit 502
com='1x1x5 array of separator blocks'
' min of 5 blocks required in 51032-1
' y-coord matches 1/2 of bundle height
array 5 -7.62 -10.70864 -250.19
' match the bundle height
cubo 5 1 2p7.62 2p10.70864 2p250.19

unit 601
com='single undamaged container'
' center fuel in container
array 6 -29.03728 -10.70864 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 2p31.19437 18.66011 -10.70864 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' undamaged spacing between containers 41.75 in.
cubo 5 1 4p53.0225 2p250.43303

unit 701
com='single damaged container - strongback centered'
' center fuel in container
array 6 -29.03728 -10.70864 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 2p31.19437 18.66011 -10.70864 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 702
com='single damaged container - strongback shifted +x, +y'
' shift fuel 1.5 in. +x and 3.0 in. +y in container
array 6 -23.07021 -3.08864 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 35.00437 -27.38437 26.28011 -3.08864 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 703
com='single damaged container - strongback shifted -x, +y'
' shift fuel 1.5 in. -x and 3.0 in. +y in container
```

```
array 6 -35.00435 -3.08864 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 27.38437 -35.00437 26.28011 -3.08864 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 704
com='single damaged container - strongback shifted +x, -y'
' shift fuel 1.5 in. +x and 3.0 in. -y in container
array 6 -23.07021 -18.32864 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 35.00437 -27.38437 11.04011 -18.32864 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 705
com='single damaged container - strongback shifted -x, -y'
' shift fuel 1.5 in. -x and 3.0 in. -y in container
array 6 -35.00435 -18.32864 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 27.38437 -35.00437 11.04011 -18.32864 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 801
com='2x2x2 array of damaged containers - centered'
array 8 0.0 0.0 0.0

unit 802
com='2x2x2 array of damaged containers - shifted'
array 9 0.0 0.0 0.0

unit 901
com='12x12x2 array of undamaged containers'
array 7 0.0 0.0 0.0
'  add 30 cm water reflector
repl 6 2 6r3.0 10

global
unit 902
com='12x12x2 array of damaged containers - centered'
array 10 0.0 0.0 0.0
'  add 30 cm water reflector
repl 6 2 6r3.0 10

unit 903
com='12x12x2 array of damaged containers - shifted'
array 11 0.0 0.0 0.0
'  add 30 cm water reflector
repl 6 2 6r3.0 10

end geom
```

```
read array

ara=1 nux=17 nuy=17 nuz=1
fill 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 2 1 1 2 1 1 2 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 2 1 1 2 1 1 2 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 end fill

ara=2 nux=17 nuy=17 nuz=1
fill 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 2 1 1 2 1 1 2 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 2 1 1 2 1 1 2 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 end fill

ara=5 nux=1 nuy=1 nuz=5
fill f501 end fill

ara=6 nux=3 nuy=1 nuz=1
fill 102 502 101 end fill

ara=7 nux=12 nuy=12 nuz=2
fill f601 end fill

ara=8 nux=2 nuy=2 nuz=2
fill f701 end fill

ara=9 nux=2 nuy=2 nuz=2
fill 702 703
     704 705
       702 703
       704 705 end fill

ara=10 nux=6 nuy=6 nuz=1
fill f801 end fill

ara=11 nux=6 nuy=6 nuz=1
fill f802 end fill

end array

read start
   nst=1
end start

read bounds
```

```
   all=vacuum
end bounds

read bias
   id=500 2 11
end bias

end data
end
```

Case "D288S100 IN": 12x12x2 Array of Damaged 51032-1 Containers Loaded with L4 Fuel Assemblies, Strongbacks and Assemblies Shifted Inside Containers, IM (Inside and Between Containers) Fully Flooded (see Table 29)

```
=csas25    parm=size=1000000
51032-1
238groupndf5 latticecell

' mixture 1
'  uo2 pellets
uo2 1 0.98 293.0 92235 5.050  92238 94.950  end

' mixture 2
'  carbon steel in strongback
carbonsteel 2 1.0 293.0 end

' mixture 3
'  carbon steel in separator blocks
carbonsteel 3 1.0 293.0 end

' mixture 4
'  carbon steel in container shell
carbonsteel 4 1.0 293.0 end

' mixture 5
'  interspersed moderator
h2o 5 den=1.0 1.00 293.0 end

' mixture 6
'  reflector water
h2o  6 den=1.0 1.00 293 end

end comp
squarepitch 1.25984 0.82093 1 5 0.94488 0 END
51032-1

read param  tme=120 gen=515 npg=2500 nsk=15 nub=yes pwt=yes run=yes
end param

read geom

unit 1
com='fuel rod'
cyli 1 1 0.41047 2p250.19
cyli 0 1 0.47244 2p250.19
cubo 5 1 4p0.62992 2p250.19

unit 2
com='location in assy with no rod'
cubo 5 1 4p0.62992 2p250.19

unit 101
com='bundle on +x side of container'
array 1 -10.70864 -10.70864 -250.19

unit 102
com='bundle on -x side of container'
array 2 -10.70864 -10.70864 -250.19
```

```
unit 501
com='separator block'
' min dims per emf-309,813 rev. 0
'  6 in. w x 7.5 in. h x 8.5 in. l x 0.3125 in. thk
cubo 5 1 2p6.82625 2p8.73125 2p10.795
cubo 3 1 2p7.62    2p9.525   2p10.795
' place on 39.4 in. centers
cubo 5 1 2p7.62    2p9.525   2p50.038

unit 502
com='1x1x5 array of separator blocks'
' min of 5 blocks required in 51032-1
' y-coord matches 1/2 of bundle height
array 5 -7.62 -10.70864 -250.19
' match the bundle height
cubo 5 1 2p7.62 2p10.70864 2p250.19

unit 601
com='single undamaged container'
' center fuel in container
array 6 -29.03728 -10.70864 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 2p31.19437 18.66011 -10.70864 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' undamaged spacing between containers 41.75 in.
cubo 5 1 4p53.0225 2p250.43303

unit 701
com='single damaged container - strongback centered'
' center fuel in container
array 6 -29.03728 -10.70864 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 2p31.19437 18.66011 -10.70864 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 702
com='single damaged container - strongback shifted +x, +y'
' shift fuel 1.5 in. +x and 3.0 in. +y in container
array 6 -23.07021 -3.08864 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 35.00437 -27.38437 26.28011 -3.08864 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 703
com='single damaged container - strongback shifted -x, +y'
' shift fuel 1.5 in. -x and 3.0 in. +y in container
array 6 -35.00435 -3.08864 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 27.38437 -35.00437 26.28011 -3.08864 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
```

```
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 704
com='single damaged container - strongback shifted +x, -y'
' shift fuel 1.5 in. +x and 3.0 in. -y in container
array 6 -23.07021 -18.32864 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 35.00437 -27.38437 11.04011 -18.32864 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 705
com='single damaged container - strongback shifted -x, -y'
' shift fuel 1.5 in. -x and 3.0 in. -y in container
array 6 -35.00435 -18.32864 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 27.38437 -35.00437 11.04011 -18.32864 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 801
com='2x2x2 array of damaged containers - centered'
array 8 0.0 0.0 0.0

unit 802
com='2x2x2 array of damaged containers - shifted'
array 9 0.0 0.0 0.0

unit 901
com='12x12x2 array of undamaged containers'
array 7 0.0 0.0 0.0
'  add 30 cm water reflector
repl 6 2 6r3.0 10

unit 902
com='12x12x2 array of damaged containers - centered'
array 10 0.0 0.0 0.0
'  add 30 cm water reflector
repl 6 2 6r3.0 10

global
unit 903
com='12x12x2 array of damaged containers - shifted'
array 11 0.0 0.0 0.0
'  add 30 cm water reflector
repl 6 2 6r3.0 10

end geom

read array

ara=1 nux=17 nuy=17 nuz=1
fill 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
```

```
     1 1 1 1 1 2 1 1 2 1 1 2 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 2 1 1 2 1 1 2 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 end fill

ara=2 nux=17 nuy=17 nuz=1
fill 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 2 1 1 2 1 1 2 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 2 1 1 2 1 1 2 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 end fill

ara=5 nux=1 nuy=1 nuz=5
fill f501 end fill

ara=6 nux=3 nuy=1 nuz=1
fill 102 502 101 end fill

ara=7 nux=12 nuy=12 nuz=2
fill f601 end fill

ara=8 nux=2 nuy=2 nuz=2
fill f701 end fill

ara=9 nux=2 nuy=2 nuz=2
fill 702 703
     704 705
       702 703
       704 705 end fill

ara=10 nux=6 nuy=6 nuz=1
fill f801 end fill

ara=11 nux=6 nuy=6 nuz=1
fill f802 end fill

end array

read start
   nst=1
end start

read bounds
   all=vacuum
end bounds

read bias
   id=500 2 11
```

```
end bias

end data
end
```

Case "D288P001.IN": 12x12x2 Array of Damaged 51032-1 Containers Loaded with L4 Fuel Assemblies, Strongbacks and Assemblies Centered Inside Containers, Fully Flooded Conditions, PE Inside Containers but Outside Assemblies at 1 vol% (see Table 30)

```
=csas25    parm=size=1000000
51032-1
238groupndf5 latticecell

' mixture 1
'  uo2 pellets
uo2 1 0.98 293.0 92235 5.050  92238 94.950  end

' mixture 2
'  carbon steel in strongback
carbonsteel 2 1.0 293.0 end

' mixture 3
'  carbon steel in separator blocks
carbonsteel 3 1.0 293.0 end

' mixture 4
'  carbon steel in container shell
carbonsteel 4 1.0 293.0 end

' mixture 5
'  interspersed moderator
h2o 5 den=1.0 1.00 293.0 end

' mixture 6
'  reflector water
h2o  6 den=1.0 1.00 293 end

' mixture 7
'  pe + h2o as im inside container
h2o 7 den=1.0 0.99 293.0 end
arbmpe 0.92 2 0 1 1 6012 1
                    1001 2 7 0.01 end

end comp
squarepitch 1.25984 0.82093 1 5 0.94488 0 END
51032-1

read param  tme=120 gen=515 npg=2500 nsk=15 nub=yes pwt=yes run=yes
end param

read geom

unit 1
com='fuel rod'
cyli 1 1 0.41047 2p250.19
cyli 0 1 0.47244 2p250.19
cubo 5 1 4p0.62992 2p250.19

unit 2
com='location in assy with no rod'
cubo 5 1 4p0.62992 2p250.19

unit 101
com='bundle on +x side of container'
array 1 -10.70864 -10.70864 -250.19
```

```
unit 102
com='bundle on -x side of container'
array 2 -10.70864 -10.70864 -250.19

unit 501
com='separator block'
' min dims per emf-309,813 rev. 0
'  6 in. w x 7.5 in. h x 8.5 in. l x 0.3125 in. thk
cubo 7 1 2p6.82625 2p8.73125 2p10.795
cubo 3 1 2p7.62    2p9.525   2p10.795
' place on 39.4 in. centers
cubo 7 1 2p7.62    2p9.525   2p50.038

unit 502
com='1x1x5 array of separator blocks'
' min of 5 blocks required in 51032-1
' y-coord matches 1/2 of bundle height
array 5 -7.62 -10.70864 -250.19
' match the bundle height
cubo 7 1 2p7.62 2p10.70864 2p250.19

unit 601
com='single undamaged container'
' center fuel in container
array 6 -29.03728 -10.70864 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 5 1 2p31.19437 18.66011 -10.70864 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 5 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' undamaged spacing between containers 41.75 in.
cubo 5 1 4p53.0225 2p250.43303

unit 701
com='single damaged container - strongback centered'
' center fuel in container
array 6 -29.03728 -10.70864 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 7 1 2p31.19437 18.66011 -10.70864 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 7 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 702
com='single damaged container - strongback shifted +x, +y'
' shift fuel 1.5 in. +x and 3.0 in. +y in container
array 6 -23.07021 -3.08864 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 7 1 35.00437 -27.38437 26.28011 -3.08864 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 7 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 703
com='single damaged container - strongback shifted -x, +y'
' shift fuel 1.5 in. -x and 3.0 in. +y in container
array 6 -35.00435 -3.08864 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
```

```
cubo 7 1 27.38437 -35.00437 26.28011 -3.08864 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 7 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 704
com='single damaged container - strongback shifted +x, -y'
' shift fuel 1.5 in. +x and 3.0 in. -y in container
array 6 -23.07021 -18.32864 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 7 1 35.00437 -27.38437 11.04011 -18.32864 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 7 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 705
com='single damaged container - strongback shifted -x, -y'
' shift fuel 1.5 in. -x and 3.0 in. -y in container
array 6 -35.00435 -18.32864 -250.19
' match strongback width=24.5625 in. and height=11.5625 in.
cubo 7 1 27.38437 -35.00437 11.04011 -18.32864 2p250.19
' add strongback steel
repl 2 1 2r0.47625 0.0 0.47625 2r0.0 1
' im to inside of steel shell
cyli 7 1 49.53 2p250.19
' steel shell
cyli 4 1 49.77303 2p250.43303
' damaged spacing between containers 41.75 - 1 = 40.75 in.
cubo 5 1 4p51.7525 2p250.43303

unit 801
com='2x2x2 array of damaged containers - centered'
array 8 0.0 0.0 0.0

unit 802
com='2x2x2 array of damaged containers - shifted'
array 9 0.0 0.0 0.0

unit 901
com='12x12x2 array of undamaged containers'
array 7 0.0 0.0 0.0
'  add 30 cm water reflector
repl 6 2 6r3.0 10

global
unit 902
com='12x12x2 array of damaged containers - centered'
array 10 0.0 0.0 0.0
'  add 30 cm water reflector
repl 6 2 6r3.0 10

unit 903
com='12x12x2 array of damaged containers - shifted'
array 11 0.0 0.0 0.0
'  add 30 cm water reflector
repl 6 2 6r3.0 10

end geom

read array
```

```
ara=1 nux=17 nuy=17 nuz=1
fill 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 2 1 1 2 1 1 2 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 2 1 1 2 1 1 2 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 end fill

ara=2 nux=17 nuy=17 nuz=1
fill 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 2 1 1 2 1 1 2 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 2 1 1 1 1 1 1 1 1 1 2 1 1 1
     1 1 1 1 1 2 1 1 2 1 1 2 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 end fill

ara=5 nux=1 nuy=1 nuz=5
fill f501 end fill

ara=6 nux=3 nuy=1 nuz=1
fill 102 502 101 end fill

ara=7 nux=12 nuy=12 nuz=2
fill f601 end fill

ara=8 nux=2 nuy=2 nuz=2
fill f701 end fill

ara=9 nux=2 nuy=2 nuz=2
fill 702 703
     704 705
       702 703
       704 705 end fill

ara=10 nux=6 nuy=6 nuz=1
fill f801 end fill

ara=11 nux=6 nuy=6 nuz=1
fill f802 end fill

end array

read start
   nst=1
end start

read bounds
   all=vacuum
end bounds
```

```
read bias
   id=500 2 11
end bias

end data
end
```

APPENDIX D - COPIES OF REFERENCES

This appendix may include electronically scanned copies of any non-standard references, e.g letters, unissued drawings, etc.

Table 5. Empirical Percentage Points of the Approximate W' Test.

n	p										
	.01	.05	.10	.15	.20	.50	.80	.85	.90	.95	.99
35	0.918	0.943	0.952	0.956	0.964	0.976	0.982	0.985	0.987	0.989	0.992
50	.935	.953	.963	.968	.971	.981	.987	.988	.990	.991	.994
51	0.935	0.954	0.964	0.968	0.971	0.981	0.988	0.989	0.990	0.992	0.994
53	.938	.957	.964	.969	.972	.982	.988	.989	.990	.992	.994
55	.940	.958	.965	.971	.973	.983	.988	.990	.991	.992	.994
57	.944	.961	.966	.971	.974	.983	.989	.990	.991	.992	.994
59	.945	.962	.967	.972	.975	.983	.989	.990	.991	.992	.994
61	0.947	0.963	0.968	0.973	0.975	0.984	0.990	0.990	0.991	0.992	0.994
63	.947	.964	.970	.973	.976	.984	.990	.991	.992	.993	.994
65	.948	.965	.971	.974	.976	.985	.990	.991	.992	.993	.995
67	.950	.966	.971	.974	.977	.985	.990	.991	.992	.993	.995
69	.951	.966	.972	.976	.978	.986	.990	.991	.992	.993	.995
71	0.953	0.967	0.972	0.976	0.978	0.986	0.990	0.991	0.992	0.994	0.995
73	.956	.968	.973	.976	.979	.986	.991	.992	.993	.994	.995
75	.956	.969	.973	.976	.979	.986	.991	.992	.993	.994	.995
77	.957	.969	.974	.977	.980	.987	.991	.992	.993	.994	.996
79	.957	.970	.975	.978	.980	.987	.991	.992	.993	.994	.996
81	0.958	0.970	0.975	0.979	0.981	0.987	0.992	0.992	0.993	0.994	0.996
83	.960	.971	.976	.979	.981	.988	.992	.992	.993	.994	.996
85	.961	.972	.977	.980	.981	.988	.992	.992	.993	.994	.996
87	.961	.972	.977	.980	.982	.988	.992	.993	.994	.994	.996
89	.961	.972	.977	.981	.982	.988	.992	.993	.994	.995	.996
91	0.962	0.973	0.978	0.981	0.983	0.989	0.992	0.993	0.994	0.995	0.996
93	.963	.973	.979	.981	.983	.989	.992	.993	.994	.995	.996
95	.965	.974	.979	.981	.983	.989	.993	.993	.994	.995	.996
97	.965	.975	.979	.982	.984	.989	.993	.993	.994	.995	.996
99	.967	.976	.980	.982	.984	.989	.993	.994	.994	.995	.996

SOURCE: Shapiro and Francia [1972]. Reprinted from the *Journal of the American Statistical Association*, Vol. 67, with the permission of the ASA.

Figure 23 W Test Percentage Points when Number of Cases, n, Exceeds 50