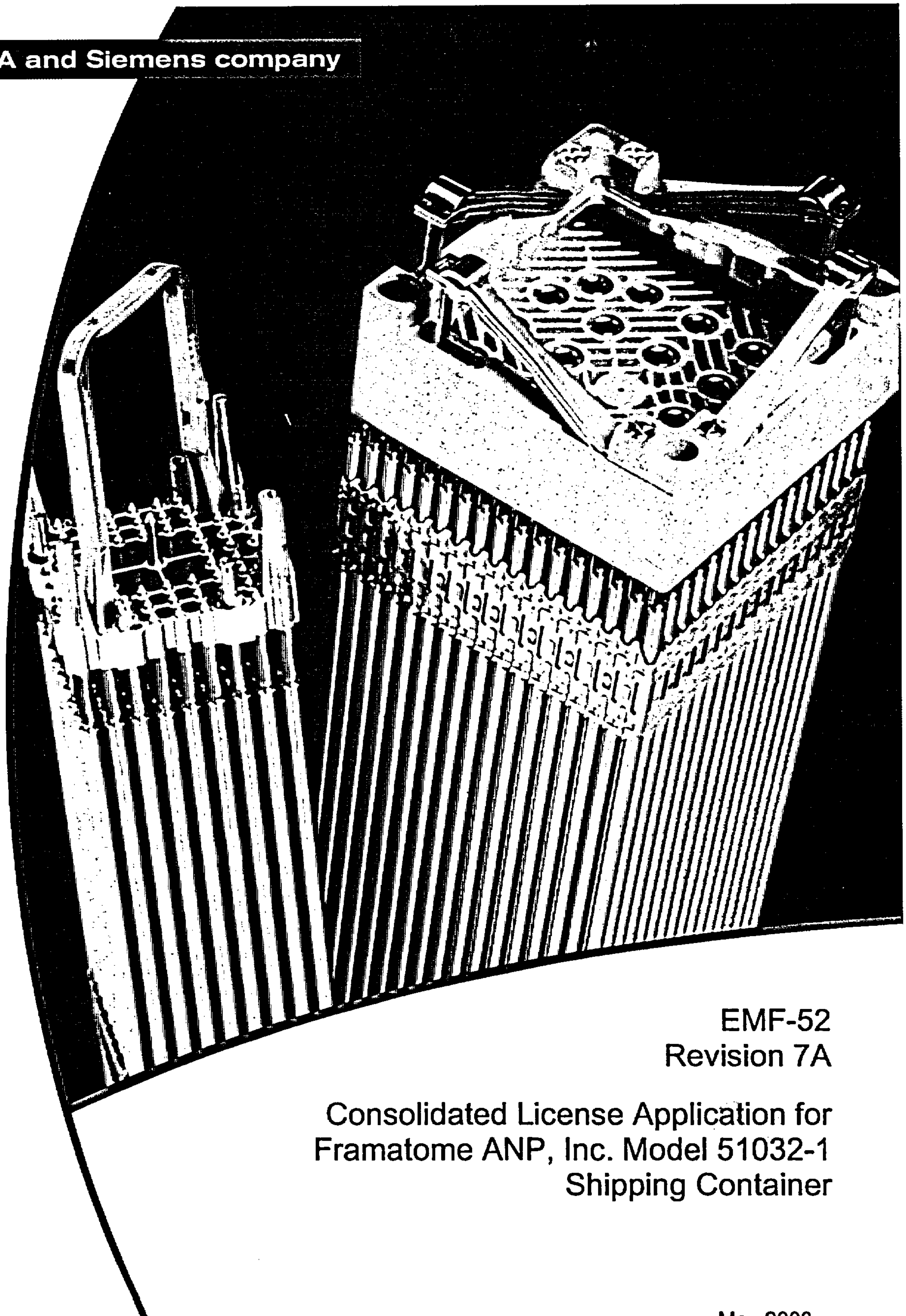
An AREVA and Siemens company



EMF-52
Revision 7A

Consolidated License Application for Framatome ANP, Inc. Model 51032-1 Shipping Container

May 2003

FRAMATOME ANP

CONSOLIDATED LICENSE APPLICATION

FOR

FRAMATOME ANP, INC.

MODEL 51032-1 SHIPPING CONTAINER

Certificate of Compliance No. 6581
Docket No. 71-6581

Prepared by
J. K. Davis

Framatome ANP, Inc.

Consolidated License Application for Framatome ANP, Inc.
Model 51032-1 Shipping Container

Certificate of Compliance No. 6581
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Nature of Changes for Revision 7A

Item	Paragraph or Page(s)	Description and Justification
1.	viii	Added Table 2.6 Allowable Contents to List of Tables <u>Justification</u>: NUREG-1609 recommends that the application provide a description of the package contents, in the same detail as intended for the certificate of compliance, in a single location.
2.	2.1.1	In first paragraph changed reference from Figure 2.11 to Figure 2.2. <u>Justification</u>: Corrected incorrect figure reference.
3.	2.1.1	In the next to the last paragraph on page 2-2 changed reference from Figure 2.7 to Figure 2.2. <u>Justification</u>: Corrected incorrect figure reference.
4.	2.1.1	Last paragraph on page 2-2 changed reference from Figure 2.8 to Figure 2.2. Added the last four sentences to the paragraph to reference the structural assessment of the center thrust plate in Appendix III. <u>Justification</u>: Corrected incorrect figure reference. The center thrust plate has been part of the certificate since it was originally issued. The structural assessment in Appendix III justifies its use.
5.	2.1.2	Changed reference from Figure 2.7 and Figure 2.9 to Figure 2.2. <u>Justification</u>: Corrected incorrect figure references.
6.	2.3	Changed last paragraph to reference new Table 2.6 which summarizes the package's allowable contents. <u>Justification</u>: Table added to comply with NUREG-1609 recommendation that the application provide a description of the contents, in the same detail as intended for the certificate of compliance, in a single location.
7.	Page 2-10	Added Table 2.6, Allowable Contents. The table also lists the maximum allowable weight for each fuel description. <u>Justification</u>: Same as Item 5 above plus the weight is given in the table to show that all allowable fuel descriptions are bounded by the weight of the fuel assemblies previously approved (2 X 1650 lbs).

Item	Paragraph or Page(s)	Description and Justification
8.	Pages 2-11 to 2-18	Added new Figure 2.1 and renumbered old Figures 2.1 through 2.6 to Figures 2.2 through 2.7 respectively. The sizes of the new Figures 2.2 through 2.7 were changed to 11" X 17". Justification: New Figure 2.1 was inadvertently left out of Revision 7 of EMF-52. With the addition of Figure 2.1, the Figures now match the list of Figures in Table 2.1. The figure sizes were increased to make them more legible.
9.	10.1.4.1	In the last paragraph on page 10-3, corrected the combined minimum mass to 5974 pounds (4100 pounds + 1874 pounds) and corrected the percent of maximum mass to 20.3% (((7500-5974)/7500) X 100%). Justification: An earlier revision of EMF-52 (6A) had corrected the maximum mass but had failed to correct the combined minimum mass and the percent of the maximum mass.
10.	11.1	In first paragraph changed Fissile Class I to fissile. Justification: Fissile Classes are no longer used in the regulations.
11.	Page 12-1	Corrected title of Reference 4 to "Application for the Use of the 51032-2 Shipping Container for Transport of Radioactive Materials". Justification: The model number in the title had been incorrect.
12.	Distribution	Updated Distribution

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2 Package Description

As specified in 10 CFR 71.33, the Model 51032-1 shipping container and its contents are described herein. For ready reference, a listing of the safety and licensing related drawings is provided in Table 2.1.

The Model 51032-1 container is very similar to several containers which have been tested, licensed, and previously used (ref. JN-52, October 1971). These similar containers are listed below:

- Model UNC-2800, License No. SNM-777, Special Permit No. 5419 (see Ref. 1)
- Model 927A, 927B, 927C, License No. SNM-1067, Special Permit No. 6078 (see Refs. 2 and 3)

The design of the Model 51032-1 container is based on the Model 927C container. Throughout the application the Model 51032-1 container is compared to the Models UNC-2800, 927A, 927B, and 927C to demonstrate compliance with 10CFR71 requirements. Where necessary, additional engineering evaluations, including drop test data, are provided.

2.1 Model 51032-1 Container

The empty weight of the Model 51032-1 packaging is 4050 ± 150 pounds. Specific materials of construction, weights, dimensions, and fabrication methods of the packaging components are described below.

2.1.1 Container Description

The containment vessel, including stiffening rings, is a 43-inch diameter (nominal dimension) right cylinder 216 inches long, fabricated of 11-gauge (0.1196 inch) steel (see Figures 2.1 and 2.2). The containment vessel is fabricated in two sections: base and cover assemblies (see Figures 2.3 and 2.4). Continuous closure flanges are welded to the base and cover assemblies, and an "0" ring gasket is fitted between the mating flanges. Using 10 steel alignment pins permanently fixed to the closure flange of the base assembly, the two halves of the containment vessel are mated and sealed together with 58 closure bolts. Steel washers are inserted between the mating flanges to prevent excessive distortion of the "0" ring gasket as nuts are tightly seated complete the closure.

Seven steel stiffening rings (five rollover angles and two end rings) are welded to each of the base and cover assemblies to strengthen the containment vessel shell. Rollover rings are fabricated of 2½ x 2½ x 5/16 inch angles, and end rings are fabricated of 3½ x 2½ x 3/8 inch angles.

Four steel skids are welded to the base assembly. These skids support the package and are designed to permit bolting the stacking brackets when packages are stacked for storage or transport. Stacked packages, however, are not normally bolted together during transport.

Four sets (two per set) of stacking brackets are welded to the cover assembly.

Welded to each set of stacking brackets is a steel lifting lug. These lugs may be used to support the loaded package. Use has been shown not to generate stress in any material of the packaging in excess of its yield strength with a minimum safety factor of 3.4.

Two forklift pickup channels are welded to the base assembly to facilitate package handling.

Fourteen (seven per side) shock-mount support brackets are welded to the interior side of the base assembly shell. The weight of the fuel elements and the related support mechanism is transferred to these brackets through up to 14 shock mounts. (The actual number of shock mounts included in each package is dependent upon the weight of the fuel elements being transported.)

The minimum number of shock mounts as a function of the total package content weight is given in Section 2.1.2.

The shock-mounted strongback supports and protects the fuel elements. The standard strongback (see Figure 2.5) is designed to securely hold two long (or four short, see Figure 2.6) fuel elements in place with a minimum spacing of six inches between the two fuel element cavities formed by the strongback components. The main strongback member is a single "U"-shaped channel formed of ¼-inch steel. The standard strongback channel is about 196 inches long, 25-3/8 inches wide, and 12½ inches high.

Side and bottom steel angle supports are welded to the exterior of the strongback channel in seven locations on the standard strongbacks and five on the short strongbacks to provide rigidity and additional strength.

Separator blocks are bolted to the strongback channel such that the centerline of the spacer blocks corresponds to the centerline of the strongback channel. The number of blocks used in each package is dependent upon the weight of the fuel element to be transported. The minimum number required as a function of fuel element weight in pounds is specified in Section 2.1.2.

Fourteen steel angles are welded to the exterior sides (seven per side) of the strongback channel. During shipping, these angles secure the strongback to support tubes by a steel bolt, nut, and lock washer system (one each per lock-down angle).

Seven strongback support tubes provide support and hold the strongback assembly in place during shipping and storage. The support tubes are attached to the interior of the containment vessel through shock mounts (two per support tube), to the shock mount support brackets. The shock mounts minimize vibrational effects on the fuel elements during transport and handling. In the event of a fire severe enough to destroy the natural rubber portion of the shock mounts, the fuel elements remain in essentially the same position within the package as the result of the steel bolts, washers, and nuts incorporated into the shock mount assemblies (see Figure 2.2).

Steel end thrust brackets (see Figure 2.2) are bolted to the strongback at both ends of the fuel elements to prevent longitudinal movement. When shipping four fuel elements, a steel center thrust bracket (see Figure 2.6) is bolted into the strongback between fuel elements in each cavity. A handle is attached to the center thrust bracket to facilitate its removal from the strongback during unpacking operations. The structural assessment of the center thrust bracket is given in Appendix III, Pages III-3 and III-8. This bracket was not in place during the drop testing of the package. The center thrust bracket adds to the overall strength of the package. Not having the center thrust bracket in place during the drop test made for a more conservative test.

There are no materials specifically used as non-fissile neutron absorbers or moderators in this packaging.

2.1.2 Fuel Element Clamps, Shock Mounts, and Separator Blocks

Fuel elements are clamped in-place within the strongback and restrained from lateral or vertical movement (see Figure 2.6). These clamping devices hold the fuel elements against the bottom and sides of the strongback channel such that the maximum fuel element separation distance is achieved. The adjustable clamps are mounted on steel angle brackets that extend laterally across the top of the strongback channel. These brackets are clamped to the top of the strongback channel. There are two types of clamps: one designed to clamp on the spacers of PWR fuel elements (see Figure 2.2), and the other designed to clamp between the spacers of BWR fuel elements (see Figure 2.2). BWR fuel element clamps are either steel or aluminum.

Fuel elements may not contain polyethylene shims between adjacent rows of fuel rods within the fuel elements.

When transporting fuel elements weighing in excess of 800 pounds, restraint bars are included in the package. Restraint bars consist of steel angle brackets that extend across the top of the strongback channel and are clamped to the strongback flanges in the same manner as are the full clamps. The restraint bars are provided for additional restraint in the event of an accident.

Strongback components required for each package vary with the size and weight of the fuel elements shipped. The limiting criteria are as follows:

1. The weight of the strongback and contained fuel per shock mount shall not exceed that of the drop tested package.
2. Full clamp assemblies used to retain fuel elements within the strongback shall not fail at forces required for failure of the shock mounts.
3. The weight of contained fuel per separator block shall not exceed that of the drop tested and analyzed package.

Equations for calculating the required number of shock mounts, full clamp assemblies, and separator blocks were derived from drop test results and component tests which assure compliance with the above noted criteria. The relationships and their bases are discussed in Section 10.1.2, and the number of various components calculated to be required for various package content weights are given in Tables 2.2 through 2.5.

The number of restraining bars employed for transporting fuel elements weighing in excess of 800 pounds shall be one fewer than the number of full clamps (i.e., N_c-1). In addition, half clamps are normally applied at the end of each fuel element but are not taken into account in this calculation. These half clamps provide some degree of conservatism. When four short fuel elements are transported in one container, W shall be the combined weight of the two fuel elements.

2.2 Containment Vessel Penetrations

There are no sampling ports or tie-down devices.

There are two valves on the containment vessel: one allows pressurization (with dry air or nitrogen) of the containment vessel, and the other is used for relieving the pressure prior to opening the vessel. As such, both valves are located in one end of the containment vessel.

These valves are not of safety significance. The containment vessel is not normally pressurized except for leak testing on an annual basis.

There are no structural or mechanical means provided or required for the transfer or dissipation of heat and there are no coolants utilized in the packages. (Decay heat for the unirradiated fuels to be transported is negligible, <20W).

2.3 Package Contents

Each fuel element is enclosed in an unsealed polyethylene sheath, the ends of which are neither taped nor folded in any manner that would prevent the flow of liquids into or out of the ends of sheathed fuel elements.

The maximum contents weight for the Model 51032-1 package is 3400 pounds.

The allowable contents are given in Table 2.6. Fuel types L1, L2 and L4 are new to the list. Appendix VIII (Section 11.1) provides a supplemental criticality safety analysis in support of these three new fuel types.

TABLE 2.5
MODEL 51032-1 PACKAGE
BWR (ALUMINUM) FUEL ELEMENT
CLAMP ASSEMBLY REQUIREMENTS

Number of Shock Mounts	Required Number of Full Clamp Assemblies (minimum)	Fuel Element[a] Weight (lbs.)
14	10	887 ≥ W ≥ 640
14	9	639 ≥ W ≥ 474
14	8	473 ≥ W ≥ 356
14	7	355 ≥ W ≥ 267
14	6	266 ≥ W ≥
12	10	1363 ≥ W ≥ 1066
12	9	1065 ≥ W ≥ 711
12	8	710 ≥ W ≥ 498
12	7	497 ≥ W ≥ 356
12	6	355 ≥ W ≥ 254
12	5	253 ≥ W
10	8	1077 ≥ W ≥ 829
10	7	828 ≥ W ≥ 533
10	6	532 ≥ W ≥ 356
10	5	355 ≥ W ≥ 237
10	4	236 ≥ W
8	6	790 ≥ W ≥ 592
8	5	591 ≥ W ≥ 356
8	4	355 ≥ W ≥ 214
8	3	213 ≥ W
6	4	504 ≥ W ≥ 356
6	3	355 ≥ W

[a] **When two fuel elements are shipped in the container, W is the weight of each. If four short fuel elements are shipped, W is the combined weight of two fuel elements.**

TABLE 2.6 ALLOWABLE CONTENTS

Fuel Type	W15	W17	GEN1	Rods	T 15x15	T 15X15 Cruc	L1	L2	L4
Max Enrichment., % U-235	5.0	5.0	5.0	5.0	5.0	2.8	5.05	5.05	5.05
Maximum No. of Fuel Rods	204	264	Any	Any	208	28	208	208	264
Minimum No. Non-fuel Rods	21	25	0	0	0	0	17	17	25
Nom Max Clad OD, inch	0.430	0.380	0.500	0.500	0.400	0.500	0.430	0.430	0.374
Nom Min Clad OD, inch	0.410	0.355	0.260	0.260	0.364	0.260	0.428	0.428	0.372
Max Pellet OD, inch	0.384	0.334	0.454	0.454	0.35	0.454	0.3707	0.3742	0.3232
Nom Max Theoretical Pellet Density*	95	95	95	95	95	95	97.5	97.5	97.5
Array Size	15X15	17X17	Any	Ind. Rods	15X15	14X14 cruc.	15X15	15X15	17X17
Max. Fuel Length, inch	196	196	196	196	196	116	196	196	196
Max Cross Section, inch	8.445	8.432	8.25	5**	7.91	8.25	8.520	8.520	8.432
Nom Max Rod Pitch, inch	0.563	0.496	Any	Any	0.527	0.556	0.568	0.568	0.496
***	0.023	0.023	0.023	0.023	0.016	0.023	0.023	0.023	0.023
Max Weight (of two****), lbs.	≤3300	≤3300	≤3300	≤3300	≤3300	≤3300	≤3300	≤3300	≤3300
CSI	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4

* Assumes pellet is a right circular cylinder with no end dish.

** Rod container consists of a schedule 40 steel pipe with a maximum nominal diameter of 5 inches.

*** Min Sum Clad Thickness & Pellet-Clad gap ((Min Clad OD - Max Pellet OD)/2), inch

**** Two bundles or two rod tubes with rods.

FIGURE 2.1 Model 51032-1 Vessel (Isometric View)

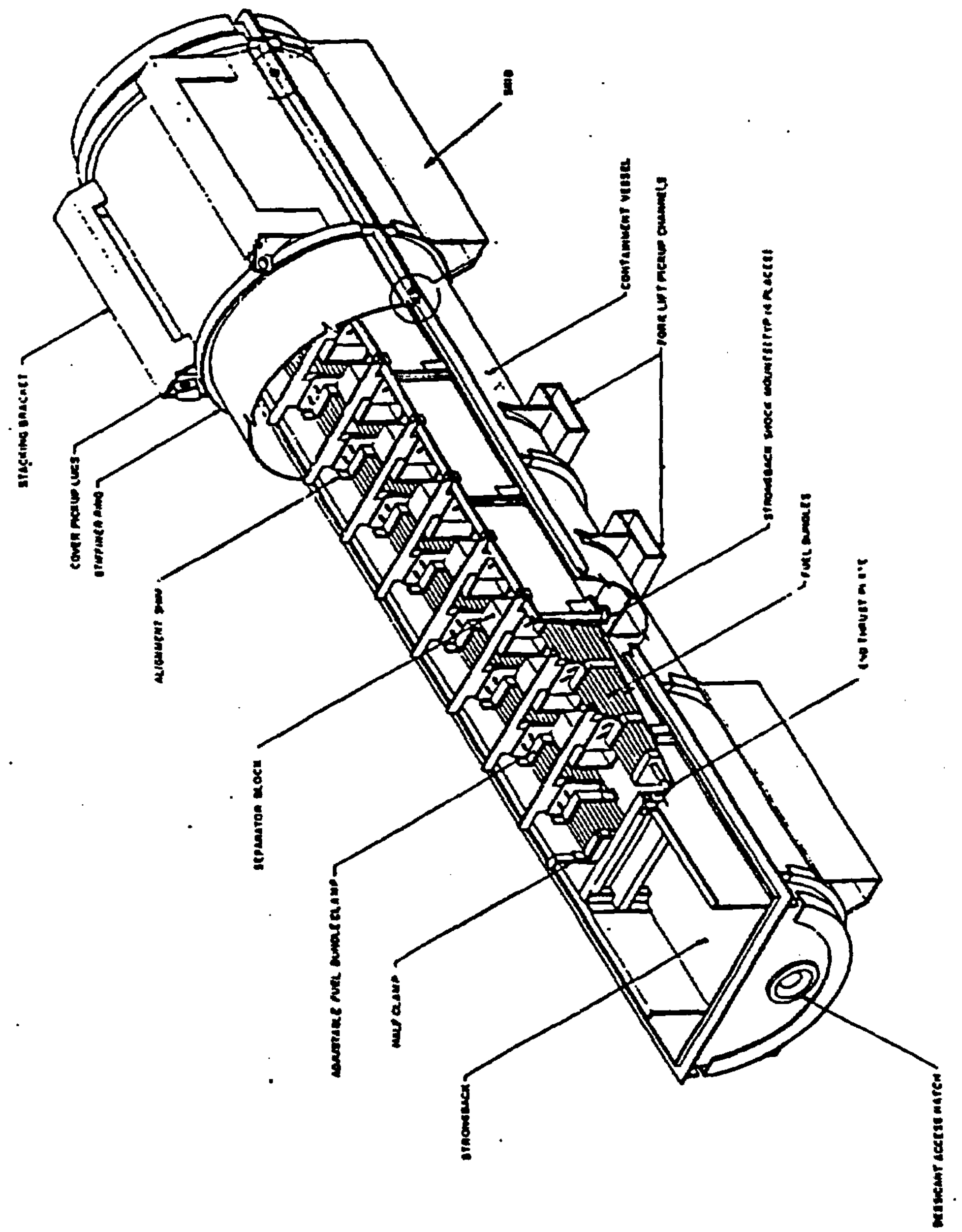

FIGURE WITHHELD UNDER 10 CFR 2.390

Siemens Power Corporation

SCALE: 1" = 1'

Figure 2.2

	DATE	NAME
DRAWN BY	03-16-99	WDB
[illegible]	06-22-99	RLF
APPROVED	06-15-99	RLF
APPROVED	06-24-99	JRT
APPROVED	06-24-99	TMH

TITLE: SHIPPING CONTAINER MODEL 51032-1 ASSEMBLY

DRAWING NO. EMF-309,813 R-2

SH NO. 1

SHEETS 2

FIGURE WITHHELD UNDER 10 CFR 2.390

Siemens Power Corporation		
SCALE: 1" = 1'	Figure 2.2 (cont.)	
DRAWN BY 06-29-00 RLF	TITLE SHIPPING CONTAINER MODEL 51032-1 ASSEMBLY	
	DRAWING NO. EMF-309,813 R-2	SH NO. 2 / SHEETS 2

14 15 16

FIGURE WITHHELD UNDER 10 CFR 2.390

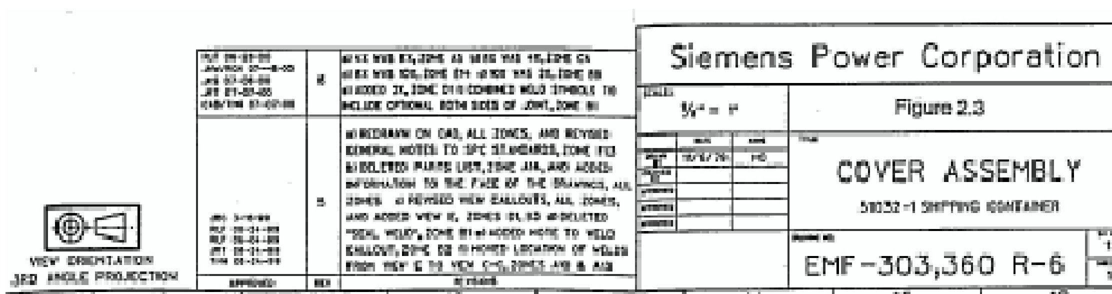

FIGURE WITHHELD UNDER 10 CFR 2.390

Siemens Power Corporation

SCALE: 1/8" = 1"

Figure 2.4

BASE ASSEMBLY

51032-1 SHIPPING CONTAINER

VIEW ORIENTATION
3RD ANGLE PROJECTION

APPROVED	REV	REVISIONS
	7	
	6	

EMF-303,359 R-7

FIGURE WITHHELD UNDER 10 CFR 2.390

APPROVED	REV	REVISIONS
RLF 08-29-00 RGN 02-09-00 JMS 07-26-00 JRT 07-07-00 CAB/THH 07-07-00	5	a) ADDED OPTION 2, ZONES G8 & A12 b) ADDED "OPTION 1 ONLY" AND "OPTION 1", ZONES H3 & A13 c) 12X WAS 14X, ZONE D15 d) TOLERANCE +/- 1/2 WAS +/- 1/4, ZONE A8
JHG [illegible] RLF 09-17-99 RLF 09-14-99 JRT 09-14-99 THH 09-14-99	4	a) REDRAWN ON CAD, ALL ZONES, AND REVISED GENERAL NOTES TO SPC STANDARDS, ZONE F15 b) SECTION A-A WAS C-C AND DELETED REMAINING VIEWS. c) DELETED VIEWS AND DIMENSIONS RELATED TO THE LIFTING STRUTS AND PIVOT, ALL ZONES d) DELETED CALLOUTS FOR 1 5/8 MAX DIA HOLES, ZONE D3, 3/4 DIA HOLES, ZONE B3, AND 7 15/16 DIMENSION, ZONE E4 e) ADDED 3/8 TO FILLET WELD SYMBOL, ZONE B14

Siemens Power Corporation

SCALE: 1" = 1'

	DATE	NAME
DRAWN BY	10-12-79	HD
CHECKED BY		
APPROVED	10-15-79	KC
APPROVED	10-18-79	PS
APPROVED		

Figure 2.5

TITLE
STRONGBACK ASSEMBLY
51032-1 SHIPPING CONTAINER

DRAWING NO. EMF-303,898 R-5

REV. NO. 1

SHEET 1

FIGURE WITHHELD UNDER 10 CFR 2.390

1b HALF CLAMP DETAIL

FIGURE 2.6

3	ADDED TOLERANCE, ZONE A4	TMH 3-20-98 JRT 3-20-98 RLF 3-20-98 JNW 3-20-98 BGN 3-20-98
2	a) EMF WAS XN, ZONE G10 b) REVISED HALF CLAMP, ZONE E9 c) ADDED OPTIONAL, ZONE G2 d) REVISED NOTE, ZONE B5	BGN 3-12-98 WDG 03-14-98 RLF 03-16-98 JRT 03-16-98 TMH 03-16-98
1	REDRAWN & PICTORIAL CHANGE	[illegible]

REVISIONS

RESPONSIBLE ENGR	APPROVED	APPROVED	APPROVED
DRAWN BY B FLORA DATE 10-6-71	CHECKED BY	SCALE NONE	Q A AUDIT

Siemens Power Corporation – ND

FUEL PACKAGING MODEL

Nº 51032-1 ISOMETRIC

DWG. NO.	SH NO.	SHTS	REV
2a EMF-300,607	1	1	3

10 Standards for Hypothetical Accident Conditions

The integrity of Model 51032-1 packaging when subjected to hypothetical accident conditions has been established through conservative design analyses and testing programs. Drop tests, as described below, were conducted with Model 51032-1 packages loaded with two simulated fuel elements weighing 1650 pounds each. The adequacy of Model 51032-1 packaging is thereby demonstrated for all FANP fuel elements weighing no more than 1650 pounds.

In addition to the package test data supplied in this application, test data on similar packages can be found in the references listed below.

1. Model UNC-2800; USNRC Certificate of Compliance No. 5419 (see Reference 1).
2. Models 927A, 927B and 927C; USNRC Certificate of Compliance No. 6078 (see References 2 and 3).

The Model 51032-1 container design is based on the Model 927C packaging. Changes were made where necessary to meet FANP specifications. In all structural and containment respects, however, the Model 51032-1 package equals or exceeds the capabilities of packages upon which the design is based.

Experience in use of the container has led to some desired minor design changes in internal components. The integrity of the components which have been changed is established by component tests as described.

Section 10.1 below establishes the integrity of the Model 51032-1 container for fuel elements weighing up to 1650 pounds.

10.1 Model 51032-1 Package

The Model 51032-1 package has been designed, constructed, and the contents so limited (as described in Section 2.0) that the performance requirements specified in 10 CFR 71.55(e) are met if the package is subjected to the hypothetical accident conditions specified in 10 CFR 71.73. The ability of the Model 51032-1 package to satisfactorily withstand the hypothetical accident conditions has been assessed as described below.

Free drop tests were performed with similar packages (Model 927A, see References 2 and 3, Model UNC-2800, see Reference 1, and Appendix III of this document), as well as with the Model 51032-1 package. A description of the drop tests on the Model 51032-1 package is provided in Appendix IV, and a summary of those tests is given below.

10.1.1 Model 51032-1 Container - Horizontal Cover Drop Evaluation

A Model 51032-1 package was loaded with two simulated full length fuel elements weighing 1653 pounds each. The gross weight of the dropped package was 7486 pounds. The package was turned over onto its cover, elevated so that the lowest point of the package (in a horizontal position) was 30 feet above the target surface and dropped onto its cover. This drop test was designed to determine the capability of the full clamps to hold the fuel elements in the strongback.

Upon impact, the base of the outer shell was drawn in about three inches at the center before the strongback shock mount system failed in tension. Although the full clamp cross members were deformed, they did not fail, and only one came loose from its clamped position at the strongback flange. The simulated fuel elements were retained in the strongback and the minimum 6-inch separation between the fuel elements was retained. The steel stiffener rings on the containment vessel cover were slightly deformed and the half clamps punctured the containment vessel when the strongback assembly broke loose from the base and impacted on the cover. The cover and base assemblies remained secured together around the flange connection. In its damaged condition, and as the package lay immediately following impact, the minimum distance between the top of the fuel elements and the outer edge of the deformed stiffener rings was 5 inches (3 inches between top of the fuel elements and the inner edge of the stiffener rings). See Appendix IV for further details.

10.1.2 Model 51032-1 Container - End Drop Evaluation

Another Model 51032-1 package was loaded as in Drop No. 1 except that the eight restraining bars were omitted as irrelevant for this drop orientation (gross weight equaled 7406 pounds). The package was set on its forward end, elevated so that the lowest point of the package (in a vertical position) was 30 feet above the target point and dropped onto its forward end. This drop test was designed to determine the capability of the end thrust plate to retain fuel elements in the strongback, and to obtain a maximum "g" value ("g" values obtained for each drop test are contained in the Test Report, Appendix IV).

Upon impact, the strongback shock mount bolts failed in shear and the forward end of the strongback impacted against the forward end of the containment vessel. The package remained vertical, free standing on its forward end. The only visible damage to the containment vessel was deformation of the flange connection on the forward end (three closure bolts sheared off), minor puncturing of the forward end of the containment vessel by the strongback, and the forward end of the strongback was crumpled back to the leading edges of the end thrust plate side plates (the end thrust plate is secured to the sides of the strongback by means of five ¾-inch bolts through each side plant and the sides of the strongback). Neither the thrust plate bolts nor the end thrust plate side plates, nor the end thrust plate exhibited any visible damage as the result of the drop test. The simulated fuel elements remained secured within the strongback, and the cover and base assemblies remained secured together around the flange connection except for the three closure bolts on the forward (impact) end.

10.1.3 Model 51032-1 Container - 75° Cover Corner Drop Evaluation

The package used in Drop No. 2 was rendered usable for an additional drop test by replacing the 14 shock mount bolts and straightening the closure flanges on the forward end. The package contents for Drop No. 3 was the same as for Drop No. 2 (gross weight = 7406 pounds). The package was set on its aft end and rigged such that it would land with its long axis at a 75° ± 1° angle with the horizontal and the cover toward the ground. The package was then elevated so that the lowest point of the package was 30 feet above the target surface and dropped only the aft cover corner at a 75° ± 1° angle. This drop test was designed to determine the capability of the flange closure bolts to withstand the maximum shearing force, and to demonstrate that the base and cover assemblies will remain secured together. Upon impact, the aft end of the cover crumpled, as did the leading corner of the strongback. Following initial impact, the package fell over onto its cover. The base and cover assemblies remained secured together;

only one closure bolt failed. Upon opening the package, it was observed that the strongback had broken free from the base assembly. The aft end thrust plate remained secured to the strongback, and the simulated fuel elements were retained within the strongback.

10.1.4 Package Component Tests and Evaluations

Performance criteria for package components were given in Section 2.1.2 which assure the safety of the container under hypothetical accident conditions. Drop tests clearly show the adequacy of the package configuration for a particular payload (fuel element) weight. These results can be extrapolated to other configurations to assure continued adequacy at lower fuel content weights with fewer separator blocks, clamp assemblies, and shock mounts. A discussion of each extrapolation is provided herein.

10.1.4.1 Model 51032-1 Separator Block Integrity

Separator blocks were not tested in the Model 51032-1 drop tests. The separator blocks and attachment method used in the Model 51032-1 shipping package are identical to those employed in the Applied Design shipping package 927C (Appendix III compares these shipping containers). The 927C package separator block arrangement was previously evaluated (see Reference 3). Since the maximum content weight for the 51032-1 container exceeds that of the 927C package, the total number of separator blocks that can be used is increased (see Appendix III). The maximum fuel element weight per separator block is, therefore, limited to that which was previously demonstrated to be adequate. In particular, the number of separator blocks (N_b) used is at least:

$$N_b \geq \frac{W}{187.5}$$

where W is the weight of one fuel element expressed in pounds, or if four fuel elements are contained, the combined weight of two fuel elements.

In the drop tests (see Appendix IV) the 51032-1 container was loaded with two simulated fuel elements 1650 lbs. each and eight separator blocks were used in the container. Therefore, assuming the load is uniformly distributed, each of the eight separators supported 206.25 lbs., which is greater than the 187.5 lbs.

The drop tests of the 51032-1 container clearly show the adequacy of the package configuration for a particular payload (fuel element) weight. The drop test results have been used to extrapolate to other configurations to assure continued adequacy at lower fuel content weights with fewer package components. Equations for calculating the required number of separator blocks were derived from the drop test results to assure compliance with the following performance criterion (see Section 2.1.2, pages 2-3 and 2-4):

> "The weight of contained fuel per separator block shall not exceed that of the drop tested and analyzed package."

The maximum overall mass of a loaded fuel container is 7500 lbs. Payload can be as small as 1874 lbs. for a combined minimum mass of 5974 lbs. - a change of 20.3% of the maximum mass.

It is assumed that the resulting accelerations in a 30 foot drop test will not change as consequence of the reduction in mass. This is a reasonable and conservative assumption as the mass variation is relatively small. Therefore, extrapolation of the required number of separators and other components is appropriate.

10.1.4.2 Fuel Element Clamps and Shock Mounts

The drop tested Model 51032-1 container was loaded with a total content (simulated fuel elements) weight 3300 pounds. The U-shaped strongback channel weighs approximately 700 pounds with the thrust plates, clamps, separator blocks, etc., in place the total weight supported by the shock mounts (fuel and packaging components) was approximately 4500 pounds.

The total weight associated with each of the 14 shock mounts, therefore, is 321.43 pounds. To comply with criterion #1 of Section 2.1.2, which assures proportional energy dissipation by the shock mounts at reduced content weights, the required relationship to be satisfied is as follows:

$$N_S \geq \frac{nW_{FE} + W_S}{321.43}$$

where: N_S = the number of shock mounts
n = the number of contained fuel elements
W_{FE} = the weight in pounds of each fuel element
W_S = the weight in pounds of the strongback and attached components[3]

The drop test results clearly show the adequacy of the package configuration. The shock mounts are designed to be the weakest link (i.e., the most likely to fail) in the components securing the fuel element in the package.

Through the deformation process leading to eventual failure, the shock mounts absorb energy. The energy of the package is proportional to payload mass. The energy absorption capability of the shock mounts provided in the tested container was adequate to meet with required criterion. It is reasonable to assume that if the payload mass is increased or decreased, the energy absorption capability of the shock mounts needs to be changed proportionally in order to provide equivalent (same percentage) energy absorption capabilities.

In the cover drop test of the Model 51032-1 package, the shock mount bolts failed in tension. Tests of the 5/8-inch Grade 2 shock mount bolts indicate an ultimate strength in the range of 11,000 to 12,000 pounds. Hence, clamp loading/deformation is limited by tensile failure of the shock mount bolts. The maximum restraining force exerted by the shock mounts in the drop tested package was 168,000 pounds (14 x 12,000 pounds). Since the nine full clamp assemblies to retain the 3300 pound contents in the package did not fail in the cover drop test (the most severe test of the clamps and shock mounts), it can be stated that each clamp assembly is capable of restraining a load of at least 15,360 pounds. The required number of PWR (steel) full clamp assemblies at various content weights, therefore, can be determined from the relationship:

[3] Note that it is conservative to assume a fixed maximum weight for the strongback when computing shock mount requirements for lower fuel content weights. W_s was, therefore, assumed to be 1200 pounds for computing the required number of shock mounts for various fuel element weights given in Table 2.3.

$$N_C^{PWR} \geq \left(\frac{12}{15.36}\right)\left(\frac{N_S}{1+\frac{W_S}{nW_{FE}}}\right)$$

where: N_C^{PWR} = the number of PWR (steel) full clamp assemblies
N_S = the number of attached shock mount bolts
n = the number of fuel elements
W_{FE} = the weight in pounds of each fuel element
W_S = the weight of the strongback and attached components[4]

Due to the excessive weight of steel fuel clamps for packaging BWR fuel elements, FANP has designed the aluminum clamps shown in Figure 2.9. Tests on the aluminum clamps have shown that they will not fail and have only marginally larger deformation than the steel clamps used in the drop tests at forces of up to 6000 pounds per clamp (12,000 pounds per clamp assembly). (See Figure 10.1 for the comparison of the force deflection curves for the steel and aluminum clamps at applied forces of up to 6000 pounds. The tests were conducted with the force applied vertically against the clamp assembly as would occur in a cover drop accident.)

Although the aluminum BWR clamps may be adequate at forces of up to those assumed as the capability of PWR steel clamps (15,360 pounds), the test data support the use of assumed loadings of up to 12,000 pounds per clamp assembly. Again, assuming that the shock mounts exert a maximum restraining force of 168,000 pounds, the number of full clamp assemblies (aluminum clamps) required to limit the load on each to ≤ 12,000 pounds is as follows:

$$N_C^{BWR} \geq \frac{N_S}{1+\frac{W_S}{nW_{FE}}}$$

where: N_C^{BWR} = the number of BWR (aluminum) full clamp assemblies
N_S = the number of attached shock mount bolts
n = the number of fuel elements
W_{FE} = the weight in pounds of each fuel element
W_S = the weight of the strongback and attached components[5]

In summary, the cover drop test was designed to determine the capability of the full clamps to hold the fuel elements in the strongback (the most severe test of the clamps and shock mounts). The shock mounts failed in tension (as designed) and the full clamps were deformed, but did not fail. The fuel elements were retained in the strongback and the minimum six inch separation

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[4] Note that it is conservative to assume a fixed minimum weight for the strongback when computing the required number of full clamp assemblies for various fuel content weights. W_S was, therefore, assumed to be the weight of strongback channel without attachments (i.e., 700 pounds) for computing the number of full clamps required to meet the criteria given in Section 2.1.2 for specific numbers of shock mounts at the various fuel element weights given in Table 2.4.

[5] Note that it is conservative to assume a fixed minimum weight for the strongback when computing the required number of full clamp assemblies for various fuel content weights. W_S was, therefore, assumed to be the weight of the strongback channel without attachments (i.e., 700 pounds) for computing the number of full clamps required to meet the criteria given in Section 2.1.2 for specified numbers of shock mounts at the various fuel element weights as given in Table 2.5.

between the fuel elements was retained. This proved that the number of clamps and the numbers of shock mounts in the tested container were adequate.

Drop test results have been used to extrapolate to other configurations to assure continued adequacy at lower content weights with fewer package components.

In order to maintain the same relative strength between the different container components and to assure that the shock mounts absorb energy through the deformation process while the payload is secured, the number of full clamps needs to be adjusted as the number of shock mounts changes.

Equations for calculating the required number of full clamps were derived from drop test results to assure compliance with the following performance criterion (see Section 2.1.2):

> "Full clamps used to retain fuel elements within the strongback shall not fail at forces required for failure of the shock mounts."

10.2 Fuel Rod Drop Tests

To supplement information obtained from the package drop tests and assess the capability of fuel rods to withstand dynamic loads similar to those experienced under hypothetical accident conditions, drop tests were also performed with individual fuel rods. Details relative to those tests are presented in Appendix VI. Although the tests resulted in significant warping and bending of the individual fuel rods, in no case were any cracks or other breaches of the cladding detected. Each fuel rod was surveyed (using alpha sensitive detectors) after being tested and in no case was there any release of radioactive material.

10.3 Thermal Accident Test Considerations

Under thermal accident conditions (exposure to a thermal radiation environment of 1475°F for 30 minutes), with the exception of the BWR (aluminum) clamps, the integrity of all packaging materials significant to the continued safety of the container would be maintained. If BWR clamps were utilized and exposed to the specified thermal environment, it is possible that the clamps would melt. Should that occur, the fuel elements could be released and move into contact with the steel separator blocks and/or the steel clamp brackets which span the strongback (see Figure 2.2). Assuming that either or both of the above should occur, the minimum spacings between adjacent fuel elements assumed in related criticality safety evaluations (see Section 11) would be maintained. Hence, the safety of the package would be assured in the event of a thermal accident involving the Model 51032-1 package described herein.

10.4 Summary

The Model 51032-1 packaging, with a gross weight ranging from 7406-7486 pounds, satisfactorily passed a series of three "most damaging" 30 foot drop tests. These test results, coupled with the satisfactory results of 30-foot drop tests and other "hypothetical accident condition" tests and analyses performed on, or for, packaging Models UNC-2800, 927A, 927B and 927C and static tests on components of the package clearly demonstrate that the Model 51032-1 packaging meets the requirements for fissile material packages.

As a result of the above assessment, it is concluded that should the Model 51032-1 package be subjected to the hypothetical accident conditions:

1. A reduction of shielding is not applicable since shielding is neither required nor a design criteria; and
2. No radioactive material would be released from the package.

Also, as a result of the assessment described above, it is concluded that if subjected to the hypothetical accident conditions, the Model 51032-1 package would be subcritical assuming:

1. The fissile material is in the most reactive credible configuration consistent with the damaged condition of the packaging and the chemical and physical form of the contents.
2. Maximum credible water moderation of the contents consistent with the damaged conditions of the contents.
3. Full water reflection of the contents consistent with the damaged condition of the contents.

Refer to Section 11 for criticality safety criteria, assumptions, methods of analysis, and results.

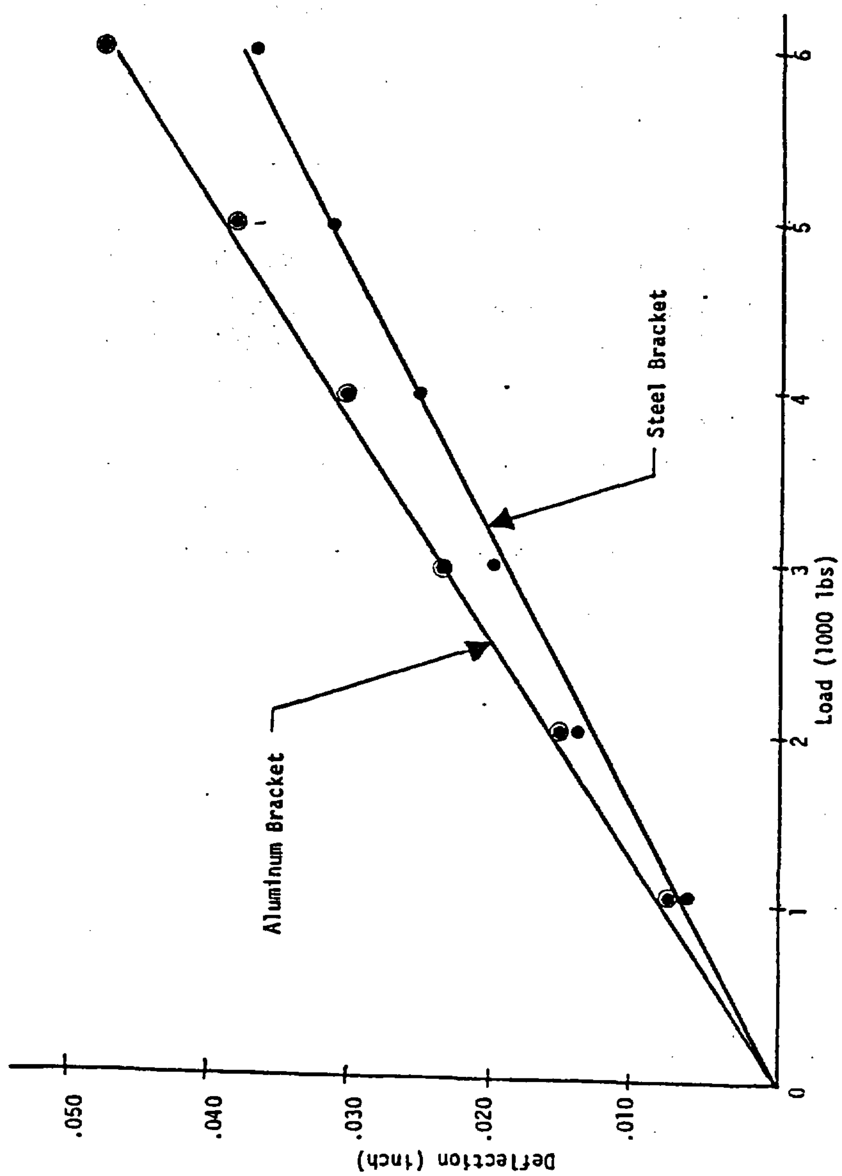

FIGURE 10.1 Steel and Aluminum Clamp Assembly Force Deflection Curve Comparison

11 Criticality Safety Analysis

11.1 Introduction and Summary

The Model 51032-1 package has been used for shipping finished fuel assemblies since the early 1970's. This package meets all criticality safety criteria for fissile shipments when loaded with the allowable assembly types or consolidated rods.

The allowable fuel types include one generic category with an assembly size up to 8.25 inches square and two other categories with an assembly size up to 8.45 inches square. In addition, a Schedule 40 steel pipe with a nominal OD of 5 inches may be used to hold any number of 5% (max.) enriched rods. One or two such pipes up to 196 inches long may be transported in each Model 51032-1 container.

Appendix VII provides a supplemental criticality safety analysis in support of a fifth fuel type, T15X15. This appendix also revises the concept of separate minimums for cladding wall thickness and pellet-clad gap to a minimum sum of those two dimensions for the four currently identified fuel types.

Appendix VIII provides a supplemental criticality safety analysis in support of three new fuel types, three 15x15 designs (L1 and L2) and one 17x17 design (L4).

All calculated k-eff data are less than 0.95. Because the parameters of the rod container fall well within those of the allowable fuel assembly types, it is obvious that any k-eff for shipping containers carrying pipe containers will be well below that of containers carrying fuel assemblies. Consequently, rod containers are not analyzed in this application.

11.2 Allowable Contents

Assemblies of UO_2 fuel rods with zircaloy or stainless steel cladding of nominal thickness and with nominal pellet-clad gap (radial) summed to not less than 0.023 inch. Rods containing gadolinia or other neutron absorbers are allowable but not required. The maximum length of the enriched zone is 196 inches and the maximum allowable bundle-average enrichment at any transverse section along the fuel length is 5.0%. Rod containers with rods as described are also allowed. Other limits and controls for these assemblies are listed in Table 11.1.

11.3 Description of Calculation Models

Details of the models are provided in the KENO-Va input listings and geometry plots in Section 11.6.

11.3.1 Normal Array Calculation Model

The packages were modeled with the strongback in the normal position and with the two assemblies in the normal position. An infinite array in a 42.24 inch square-pitch arrangement was modeled with dry conditions within the packages and optimum interspersed moderation between packages.

11.3.2 Damaged Array Calculation Model

The packages were modeled with the strongbacks shifted to produce the minimum possible bundle-bundle separations between adjacent packages. This occurs with the strongback shifted to the left or right by nearly three inches from center to where steel parts of the strongback (support brackets at bottom, upper edge of strongback at top) are contacting the steel shell. The bundle-bundle separations within packages were modeled at the minimum credible value; i.e., the bundles were both touching the separator blocks and they were shifted to the left or right edge of the strongback in the same direction as the strongback was shifted in the package to allow maximum possible interaction with bundles in adjacent packages. For this model the minimum horizontal edge-to-edge spacing between assemblies in adjacent packages is 6.5 inches. Arrays were modeled in a 39.24 inch square-pitch arrangement and in a 39.24 inch triangular-pitch arrangement; the reactivities of the two arrangements were not significantly different. The 39.24 inch pitch is very conservative considering the very slight deformation observed during 30-foot drop testing. The arrays modeled contained more than 250 packages; e.g., 11x12x2 arrays (264 units) with full water reflection or infinite arrays. Various degrees of moderation within and between packages were modeled to determine the peak reactivity condition.

11.4 Calculation Results

KENO-Va and CASMO-3G calculation results are used to demonstrate compliance with 10 CFR Part 71. CASMO was used primarily for sensitivity studies to determine the most reactive set of parameters and then KENO was used to replicate certain cases, including the peak reactivity. CASMO results do not have a Monte Carlo uncertainty which greatly facilitates sensitivity analyses. All calculations were based on fuel rods with a 196 inch long stack of pure UO_2 with an average density of 10.412 g/cc (95% TD) and with an enrichment of 5.0 wt.% U-235[6]. All fuel rods were clad with 0.020 inch thick Zircaloy. All packages modeled contained two fuel assemblies spaced six inches edge-to-edge by the minimum allowable number (5) of separator blocks. The 27-group cross section library from SCALE, as processed by NITAWL, was used in all KENO calculations. KENO calculations typically employed 80 generations of 400 neutrons to give a well-converged solution with a relatively small Monte Carlo uncertainty. Calculation results for the allowable contents are grouped together first for damaged conditions and then later for undamaged conditions.

11.4.1 Damaged Array Calculation Results

Finite arrays (11x12x2, 264 packages) were modeled for cases with low density water within and between packages. Infinite arrays were modeled for cases with full density water within packages. Since the neutron leakage from large flooded arrays is expected to be very small, the k-eff from finite arrays would be very close to the k-inf value. However, with low density water within and between packages, leakage effects may be significant. Several combinations of pellet and clad dimensions were modeled to demonstrate compliance.

[6] The use of 196 in. fuel length as the length of the container is conservative because it allows more end-to-end neutron interaction between fuel assemblies in adjacent containers than 196 in. of fuel in a 216 in. container. Likewise, the use of 5 wt% enriched UO_2 for the entire fuel column length is conservative in that natural ends are not modeled. In effect 5 wt% is the maximum pellet enrichment.

12 References

1. CONF-710801 (Volume 2) Health and Safety (TID-4500), "Proceedings, Third International symposium, Packaging, and Transportation of Radioactive Materials," August 1971, pp. 873-885.

2. Exhibit P, "Application for Licensing of Combustion Engineering, Inc., Shipping Container Model 927A," July 3, 1969, License SNM-1067, Docket No. 70-1100.

3. Exhibit P (including Appendix P-1), "Application for Licensing of Combustion Engineering, Inc., Shipping Containers Models 927B and 927C," February 23, 1971, License SNM-1067, Docket No. 70-1100.

4. "Application for the Use of the 51032-2 Shipping Container for Transport of Radioactive Materials", August 6, 1998, Docket No. 71-9252.

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