B&W FUEL COMPANY

BW

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May 10, 1993

Charles E. MacDonald, Chief
Transportation Branch
Division of Safeguards
and Transportation, NMSS
United States Nuclear Regulatory
Commission
Washington D.C., 20555

Dear Mr. MacDonald:

REFERENCE: Certificate of Compliance for Model No. 51032-2, Docket 71-9252

B&W Fuel Company (BWFC) submitted an application on October 27, 1992 to become an independent certificate holder of the presently licensed Siemens' 51032-1 fresh fuel shipping container, Docket 71-6581. The application was supplemented on March 9, 1993. Your staff requested further information regarding the application on April 22, 1993. Attachment I and Appendix 1A provides the response to your questions.

The only changes to the text of the SAR resulting from the response are in chapter 1 which includes drawing revisions. We also added Appendix B - "Exhibit P" Application for Licensing of Combustion Engineering, Inc. Shipping Container Model 927A, Appendix C - "Appendix P-1" From The Application for Licensing of Combustion Engineering, Inc. Shipping Container Model 927A, and Appendix D - BWFC Critical Buckling Analysis & Side Drop Analysis to the SAR.

Due to recent changes in design specifications for fuel assemblies, Table 6.1 was also revised. The changes included pellet diameter changes and fuel pellet densities. Attachment II provides justification for these changes.

Six copies of the revised chapter 1, revised drawings, Appendices B, C and D and Table 6.1 are included.

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It is essential to support upcoming BWFC contracts to have these containers fabricated and approved for use in June of 1993. Should you have any questions regarding this application, please feel free to contact me at (804) 522-6202. Thank you for your attention and cooperation to this matter.

Sincerely,

B&W FUEL COMPANY
COMMERCIAL NUCLEAR FUEL PLANT

Kathryn S. Knapp

Kathryn S. Knapp
Manager, Safety & Licensing

cc: C. W. Carr

DRAWINGS

1. The drawings should be revised as follows:

Drawing 12215926 C Rev. 1 --	provide material specifications.
Drawing 12215929 D Rev. 1 --	justify that the gusset in Detail B is only welded on a single edge.
Drawing 12215931 D Rev. 1 --	specify the locations and spacings of the shock mounts, stiffener angles, and forklift channels; specify the size and thickness of plates.
Drawing 12215932 D Rev. 1 --	specify the locations and spacings of the shock mounts, stiffener angles, and forklift channels; specify the size and thickness of plates.
Drawing 12215934 C Rev. 1 --	specify the closure bolt material.
Drawing 12215935 D Rev. 1 --	specify the number and spacing of the separator blocks.

RESPONSE:

Drawing 12215926 C Rev. 1 --	**This drawing provides details of the full clamp assembly, the thrust plate and the shock mount. The material specifications are provided on Drawing 12215935 D. Section 1.3, Associated Drawings has been revised to indicate drawing cross-references.**
Drawing 12215929 D Rev. 1 --	**The weld on the gusset in Detail B is welded on all four sides. This has been clarified by a drawing revision.**
Drawing 12215931 D Rev. 1 --	**Drawing has been revised to include the locations and spacings of the shock mounts, stiffener angles, and forklift channels and the size and thickness of plates.**

Drawing 12215932 D Rev. 1 -- **Drawing has been revised to include the locations and spacings of the stiffener angles and the size and thickness of plates. The locations and spacings of the shock mounts and forklift channels were not included as the drawing depicts the cover assembly and does not contain either.**

Drawing 12215934 C Rev. 1 -- **This drawing provides details of the restraining bar, the half clamp, the closure bolt and the guide pin. The material specifications are provided on Drawing 12215935 D for all but the closure bolt. The material specifications for the closure bolt is provided on Drawing 12215929 D. Section 1.3, Associated Drawings has been revised to indicate drawing cross-references.**

Drawing 12215935 D Rev. 1 -- **Drawing 1215929D has been revised to indicate the quantity and spacing of the separator blocks. Section 1.3, Associated Drawings has been revised to indicate drawing cross-references.**

2. Show that the critical buckling load of the spacer is greater than the critical buckling load of the load-bearing members of a fuel assembly, as stated in Note 2 on Drawing 1216010 D Rev. 1.

RESPONSE:

The following analysis was conducted to verify that the failure load of the shipping container spacer assemblies exceeds the fuel assembly critical buckling load. The analysis has been included as Appendix D to the SAR.

1.0 PURPOSE

The purpose of this analysis is to verify that the failure load of MK-B and MK-BW shipping container spacer assemblies exceeds fuel assembly critical buckling load.

2.0 SUMMARY

An extremely conservative buckling and compression failure analysis was performed on the MK-B spacer. This represents a worst case analysis for both spacers since the MK-B spacer is taller and the MK-B fuel assembly has a higher critical buckling load.

The critical buckling load for the MK-B fuel assembly is 5168 pounds (Ref. Doc. B&W 32-1176304-00). To determine the buckling load of the MK-B spacer, each support was modeled as a column with pinned ends. Each support is actually a composite member. To provide a more conservative analysis, the smallest member of the composite was considered to carry the full load. The critical buckling load for each support is 32,800 pounds. With four supports, this translates to a buckling load in excess of 131,200 pounds.

The compressive failure load was calculated to be 15,000 pounds for each support. This translates to a spacer compressive failure load in excess of 60,000 pounds.

3.0 CALCULATIONS

The MK-B spacer was modeled as four (4) supports made of 1/2 schedule 40 stainless steel round tubing. The following support properties were used:

Modulus of Elasticity	(E) = 28,000 ksi [1]
Tensile Strength	(S_{ut}) = 60,000 psi [2]
Wall Thickness	(t) = 0.109 inches
Inside Diameter	(d) = 0.622 inches
Outside Diameter	(D) = 0.840 inches
Support Length long)	(L) = 12 inches (conservatively
Area	(A) = 0.250 in^2

Moment of Inertia (I)

$$
\begin{aligned}
I &= \pi \cdot D^4/64 - \pi \cdot d^4/64 \\
&= \pi \cdot 0.840^4/64 - \pi \cdot 0.622^4/64 \\
&= 0.0244 - 0.0073 \\
&= 0.0171\ in^4
\end{aligned}
$$

Each support was modeled as a column with pinned ends. The following equation was used for the critical buckling load:

Critical Buckling Load: $P_{cr} = \pi^2 \cdot E \cdot I / L^2$ [3]
$= 9.870 \cdot 28e6 \cdot 0.0171/144$
$= 32,800$ pounds per support

For the entire spacer the buckling load is in excess of 131,200 pounds.

The compressive failure load was calculated using the same member as analyzed for buckling. The following equation was used:

Critical Compressive Load: $P_{cr} = A \cdot S_{ut}$
$= 0.250 \cdot 60,000$
$= 15,000$ pounds per support

For the entire spacer the critical compressive load is in excess of 60,000 pounds.

4.0 CONCLUSION

It is impossible for the spacer to fail before the fuel assembly buckles. This conclusion can be drawn by visually comparing the fuel assembly to the spacer. The minimum load to cause failure of the MK-B shipping container spacer assembly is in excess of 60,000 pounds. This is well over the 5168 pound critical buckling load of the fuel assembly.

These calculations shall also serve to verify the performance of the MK-BW spacer. This spacer is more heavily constructed than the MK-B spacer and is required to carry less load.

5.0 REFERENCES

(1) Gere & Timoshenko, Mechanics of Materials, PWS, Boston, 1984, page 744.

(2) Gere, p746.

(3) Gere, p557.

STRUCTURAL

1. The application relies on test results of similar, but not identical, packages to justify that the Model No. 51032-2

package meets the requirements of 10 CFR Part 71. The application should provide detailed comparisons of the 51032-2 package to these previously tested packages to show that the differences between them are minor and that the test results will not be changed significantly. The comparison of packages should include the following:

a. Weight and size of package.
b. Weight and size of contents.
c. Material specifications, thickness and sizes of plates or structural shapes, types and sizes of welds, numbers and sizes of bolts.

d. Numbers and spacings of stiffeners, clamps, separators, and shock mounts.
e. Safety components such as spacers and end bearing plates.

Note that modifications which may be considered as an improvement can have an adverse effects on the test results. For instance, upgrading the shock mount bolts to Grade 5 will increase the bolt ultimate strength ten times, from 12,000 psi to 120,000 psi. As a result, the shock mount bolts may not fail in a 30 foot drop, and the fuel clamps may not be able to keep the two fuel assemblies inside the strongback.

RESPONSE:

In a telephone conversation with the approximate time of 1:30 pm on April 26, 1993, Henry Lee, NRC Transportation Branch, agreed with BWFC that since the 51032-1 and the 52013-2 packages were almost identical that a description of how they differ is more appropriate.

An itemized list of the differences between the 51032-2 container and the 51032-1 container upon which the 51032-2 design is based is provided below. This list has been added to Section 1.1.1 of the 51032-2 container SAR.

A. The 51032-2 container employs a spacer for each fuel assembly in the aft (upper) end of the container strongback, see BWFC Drawing 1216010-01. The spacer provides axial adjustment and restraint between a fuel assembly (FA) and the 51032-2 container's End Thrust Bracket (BWFC Dwg. 1215930D-02). The spacer also provides axial adjustment and restraint between a control component assembly (CCA), shipped fully inserted into a fuel assembly, and the End Thrust Bracket. The spacers are used as an option, and their

use is preferred by BWFC's customers for FA/CCA shipments. No credit is taken for CCA neutron absorption in the 51032-2 criticality analysis.

There is no mention of a spacer used for the 51032-1 container operations, nor is there mention of a spacer used for the 927C container (the package upon which the 51032-1 design is based).

B. BWFC performed an analysis to determine the effects on the 51032-2 container in a 30 foot side drop situation, see Appendix A (BWFC Doc. ID 32-1222980-01). The analysis results recommend that a 3/8" rectangular gusset be fillet welded within each separator, perpendicular to the length of the tubing and located lengthwise between the holes/slots. The gussets serve as structural reinforcements, stiffening the separators, minimizing deformation due to impact loads, and most likely eliminating interference of the separators with the other adjacent fuel assembly.

There is no mention of separator gussets used for the 51032-1 or 927C container operations.

C. Also, as a result of the analysis referenced in B., BWFC has upgraded the separator bolts/studs from 5/8" diameter, SAE Grade 2 bolts/studs to 1" diameter, SAE J429 Grade 8 bolts/studs. The heavier bolts/studs serve as additional structural reinforcements, to withstand the shear of a fuel assembly impact force, although testing has shown that the occurrence of the fuel assembly breaking loose and impacting the separators is unlikely.

The 51032-1 container still uses 5/8" diameter, SAE Grade 2 bolts/studs.

D. Due to the addition of spacers, used for shipping CCA's inside FA's (See Item A above), separator gussets, which provide extra lateral support inside the separators (See Item B above), and larger separator fasteners (See item C above), the 51032-2 empty container weight is approximately 100 pounds heavier than an empty 51032-1 container. The extra weight only includes the added weight of structural reinforcements as described in A. and B above. The maximum fuel weight drop tested in the 51032-1 container (3306 lbs.) is the maximum allowable FA + CCA weight to be shipped in the 51032-2 container.

E. As noted in the NRC's comments and questions on the 51032-2 container package, the shock mount bolts used during the actual drop testing were 5/8" diameter, SAE Grade 2 bolts. These shock mount bolts are the bolts which attach through the center of the shock mounts to the strongback support tubes, of which there are seven. Since there are fourteen shock mounts in the 51032-2 container base, there are fourteen shock mount bolts present.

In the last licensing submittal (03/09/93) of the 51032-2 container package 71-9252, it was determined that Grade 5 bolts would be used instead of Grade 2 bolts. Because the shock mount bolts were designed to fail, and did so during the 30' drop testing, the 51032-2 shock mount bolt strength was re-evaluated. BWFC has determined that SAE Grade 2 bolts will be used at the shock mount locations, just as originally designed for the 51032-1 container.

F. BWFC has determined that the 51032-2 will use SAE J429, Grade 5 bolts at the following significant locations:

1) The full clamp assembly bolts, which attach the clamps to the strongback channel flanges (2 per full clamp assembly).
2) The full clamp assembly bolts, which attach the fuel assembly grid clamps to the clamp angles (4 per full clamp assembly).
3) The restraining bar assembly bolts, which attach the restraining bars to the strongback channel flanges (2 per restr. bar assy.).
4) The bolts which attach the strongback to the strongback support tubes (7 tubes total, 2 bolts per tube).
5) The bolts which attach the shock mounts to the container base (4 per shock mount, 56 total).

As previously stated in item E, the mode of failure during all drop tests was the shock mount bolts, which will remain as SAE Grade 2 bolts. This is consistent with the shock mount bolts present during drop testing as they were SAE Grade 2 bolts. Therefore, it can be concluded that the bolt material upgrade to SAE J429, Grade 5 at the five locations itemized above is a structural improvement, and because the 51032-2 container will utilize SAE Grade 2 shock mount bolts, the drop test results from the 51032-1 and the 927C will continue to be valid test results for the 51032-2

container.

G. The 51032-2 container utilizes 3/8" thick separators (tubes), made from ASTM A500, Grade B steel, reinforced with a 3/8" thick ASTM A36 structural steel gusset fillet welded inside to separate the two fuel assemblies within the strongback channel (See item B. on prev. pages, see BWFC Dwg. 1215929D, Rev. 2, Detail B).

The 927C container, upon which the 51032-1 design is based (and ultimately the 51032-2 design), utilizes 3/16" thick tubes as separators, without any reinforcing gussets whatsoever.

H. Unlike the 51032-1 and the 927C containers, the 51032-2 container will use full clamp assemblies at all fuel assembly spacer grid and end fitting locations during fuel assembly shipments. Half clamp assemblies will be used to maintain the spacers in the strongback (See item A.) or will be shipped so that they make no contact with the fuel assemblies.

As described in previous submittals of 71-9252, the half clamp assemblies are used as operational features for loading and unloading the fuel assemblies into and from the 51032-2 containers.

The 51032-1 and 927C containers use half clamp assemblies at grid and or end fitting locations (two locations each fuel assembly) where the 51032-2 container uses the sturdier full clamp assemblies. Therefore, the 51032-2 container provides a degree of extra structural support for the fuel assemblies in the strongback.

I. The last major difference between the 51032-2 container and either the 51032-1 or the 927C container is the container appearance, which will be different in color and ID labeling. The 51032-2 container will be legibly marked with its own Doc. ID number, according to Part 71.

2. The side drop analysis shown in Appendix 1A should be revised to consider the following:

   a. The clear distance between separator blocks required to maintain a six inch minimum separation between fuel assemblies appears to be calculated non-conservatively. The factor L/29 should not be used to reduce the rotational angle.

b. The impact force (82,680 lbs) is too large for the 1/4-inch thick strongback or the 3/8" thick separator block to bear.

RESPONSE:

2a. The clear distance required to maintain a six inch minimum separation between fuel assemblies within the 51032-2 container strongback has been recalculated and is documented in Appendix 1A to this letter. The analysis has also been included as Appendix D to the SAR.

2b. The impact force of 82,680 lbs. was conservatively estimated for purposes of examining the strength of the separator bolts, only. A more realistic separator loading analysis was performed and is shown in section 5.3 of Appendix 1A. This is also included in Appendix D to the SAR.

CRITICALITY

Verify that the structural considerations in the side drop analysis, above, do not affect the criticality model for accident conditions (see Item 2 under STRUCTURAL)

RESPONSE:

It can be concluded from Appendix 1A that the structure and configuration of the 51032-2 container will maintain a six inch separation between fuel assemblies in the event of a thirty foot side drop, and since nothing was changed on the 51032-2 container, except the bolts (previously discussed in Structural section above), the criticality model previously submitted in 71-9252, Rev. 1 is still valid.

APPENDIX 1A

MODEL 51032-2 SHIPPING CONTAINER
SIDE DROP ANALYSIS

1.0 PURPOSE

The purpose of this analysis is to determine if the required separation between fuel assemblies in the Shipping Container Model No. 51032-2(Ref. 1) is maintained following a 30 foot drop of the container on its side. The analysis method found in Appendix P-1 of References 2 and 3 will be followed.

2.0 SUMMARY

This conservative analysis indicates that for a 30 foot drop of the shipping container on its side, the top fuel assembly could fracture the positioning brackets and impact onto the separating blocks, assuming no impact energy is absorbed by the brackets or the fuel assembly itself. The maximum "clear" distance between separation blocks required to maintain a 6 inch minimum separation between fuel assemblies is 11.4 inches.

3.0 IMPACT VELOCITY AND ENERGY

For a 30 foot drop, the Impact Velocity is,

$$v = (2gh)^{1/2} = ((2)(386\ in/sec^2)(30\ ft)(12\ in/ft))^{1/2}$$

$$v = 527\ in/sec$$

Fuel Assembly Weight(maximum for licensing) ≈ 1650 lbs. (Ref.2)

Impact Energy = $\frac{1}{2} mv^2 = \frac{1}{2}(1650/386)(527)^2$ = 593,592 in-lbs.

4.0 ENERGY ABSORBED BY BRACKET AND FUEL

It was found, in the corresponding section of the analysis in Appendix P-1 of Reference 2, that the amount of available energy absorbed by the brackets and the fuel assembly during the fracture of the bracket bolts is **negligible**. Therefore, for conservatism, it will be assumed, in the calculation of the maximum separator block spacing, that the energy absorbed by the bracket and fuel is **zero**.

5.0 IMPACT OF FUEL ASSEMBLY ON SEPARATOR BLOCKS

5.1 Separator Block Spacing

In accordance with the assumption in section 4.0, the fuel assembly would impact the 6"x8"x9"long separator blocks with a large amount of kinetic energy. Since the separator blocks are relatively rigid, this energy will be absorbed in the fuel assembly primarily by "plastic strain." The impact velocity would be the maximum velocity calculated in Section 3(i.e. 527

in/sec).

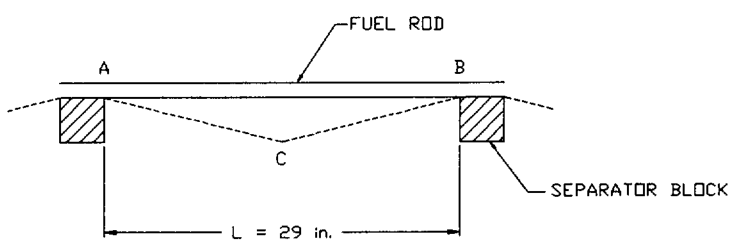
For impact at this velocity, it is unlikely that the spacer grids will provide significant lateral shear resistance. Therefore, it will be assumed that the fuel rods act individually, instead of as a composite structure. It will also be assumed in this section that the separator blocks are rigid and do not deflect upon impact.

The MK-B9 Fuel Rod weight-per-inch (Ref. 4) is approximately 6.94/151 ≈ 0.046 lbs/in. Thus, for a span of length "L", the impact energy that must be absorbed by a single fuel rod is,

$E_f = \frac{1}{2} mv^2 = \frac{1}{2}(0.046 \text{ lbs/in})(L)(527 \text{ in/sec})^2/(386 \text{ in/sec}^2)$

$E_f \approx (16.55)(L)$ in-lbs.

Assuming plastic hinges form at locations A, B, and C on the impacting fuel rod, the internal work is derived by the following,



Work = $\frac{1}{2}P\delta$ where $P = 16M_p/L$ (case 2d, p.225, Ref. 6)

(Ref. 5) M_p = the fully plastic moment at each hinge of the deformed fuel rod.

$\delta = (L/2)(\theta)$

Substitution gives,

Work = $4M_p\theta$

For the fuel rod cross section (Ref. 7),

$M_p = \sigma_y \cdot 4/3 \cdot (R^3 - R_i^3)$ where σ_y = yield stress
$2R$ = O.D. of cladding = 0.430"
$2R_i$ = I.D. of cladding = 0.377"

Although the previous expression is actually only applicable for perfectly plastic materials, and Zircaloy-4 exhibits strain hardening, it is considered valid in this case due to the "approximate" nature of the calculation. To somewhat compensate for the strain hardening effect, σ_y will be taken as the average of the yield and ultimate strength of the Zirc-4 fuel rod. The yield strength and ultimate strength of cold-worked Zirc-4 cladding at 70°F are 81,000 psi and 112,000 psi, respectively (Ref. 8).

$\therefore \sigma_y \approx (81{,}000 + 112{,}000)/2 = 96{,}500$ psi.
$\therefore M_p = (96{,}500)(4)((0.430/2)^3 - (0.377/2)^3)/3 = 417$ in-lbs.

It should be noted that this neglects the possible increase in strength under dynamic loading.

Equating internal work to impact energy gives the following,

$4M_p\theta = \frac{1}{2}mv^2$
$\therefore \theta = (E_f)/4M_p) = ((16.55\ (L)\ )/(\ (4)\ (417)) = (0.0099)\ (L)$ rad

Therefore, the maximum plastic deflection of the fuel rod is,

$\delta = \theta \cdot L/2 = (\ (0.0099)\ (L)\ )\ (L/2) = (0.00496)\ (L^2) = \delta_{max}$

Fuel assembly-to-separator block spacing (See Figure 1), prior to drop, assuming the fuel assembly outer envelope is 8.54 in. for MK-B, can be calculated as follows,

$(24.375 - (2)(8.54) - 6)/2 = 0.648$ in.

Therefore, $\delta_{max} \approx 0.648$ in., to maintain a 6 inch minimum fuel assembly spacing.

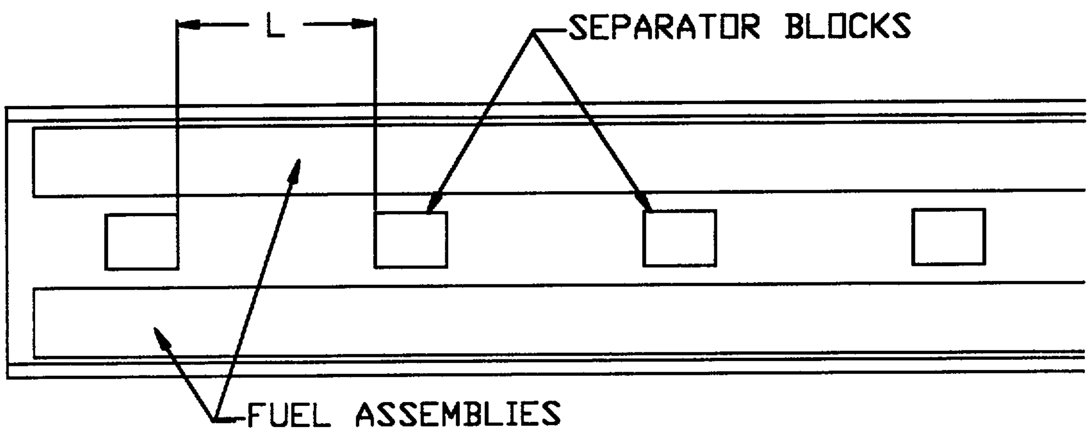
Substitution gives the following expression,

$$(\ (0.00496)\ (L^2)\ ) = 0.648$$

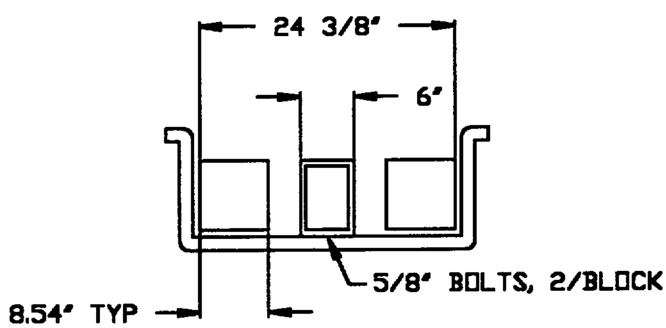
It is concluded that the maximum "clear" distance between separator blocks required to maintain a 6 inch minimum separation between fuel assemblies is,

$\therefore L = (0.648/0.00496)^{1/2} \approx$ <u>11.4 in.</u>

Figure 1 - Strongback Channel



- TOP VIEW -



- END VIEW -

5.2 Separator Block Bolts

The impact force of the fuel assembly on the separator block following a 30 foot drop of the container on its side will be estimated. It will be assumed that this force will be transferred to the separator block bolts in the form of a direct shear force through their cross sectional area. The designed bolts are made from 5/8" diameter Grade 8 High Strength Steel(Ref. 9).

A finite element model of the separator block using "shell" elements (STIF 63) was made on ANSYS 4.4A (Ref. 10) to estimate the block stiffness. Loads ranging from 2,000 to 100,000 pounds were applied at the center of one side of the block (nodes 105 & 106), while two points in the approximate location of the bolts were constrained in 6 degrees-of-freedom and the nodes along bottom edge of the block were constrained in the Z-direction to simulate the constraint of the strongback that the block is bolted to (See Figure 2).

The results can be seen in Figure 3 in terms of an apparent linear "Load vs. Deflection", from which the approximate stiffness of the separator block, in its actual orientation, is determined. It should be noted that in this section it is assumed that the strongback and F/A are rigid and do not deflect or absorb energy upon impact. All energy is thus absorbed by the separator block and bolts, where the stiffness of the block is the limiting case. This is also conservative. The calculated stiffness of the block is 52,000 lbs/in. An unrestrained deflection, "x", is then determined for the above stiffness by equating kinetic energy and "elastic" potential energy as follows,

$\frac{1}{2}mv^2 = \frac{1}{2}kx^2$ where m = 1650 lbs./9 blocks = 183 lbs.

v = 527 in/sec (Section 3.0)
k = 52,000 lbs./in. (Figure 3)

$x = ((183)(527)^2/(386)(52,000))^{1/2} = 1.59$ in.

Figure 2 -
Separator Block ANSYS Model

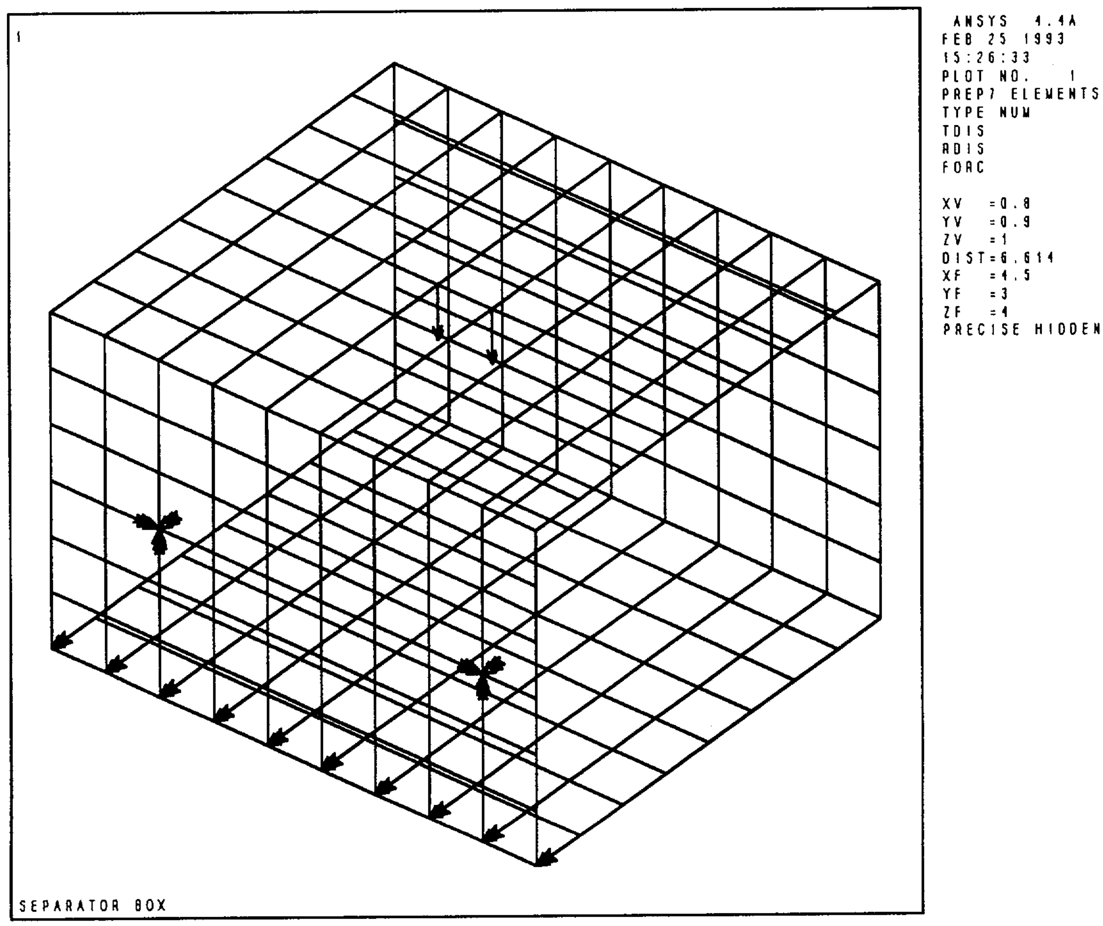
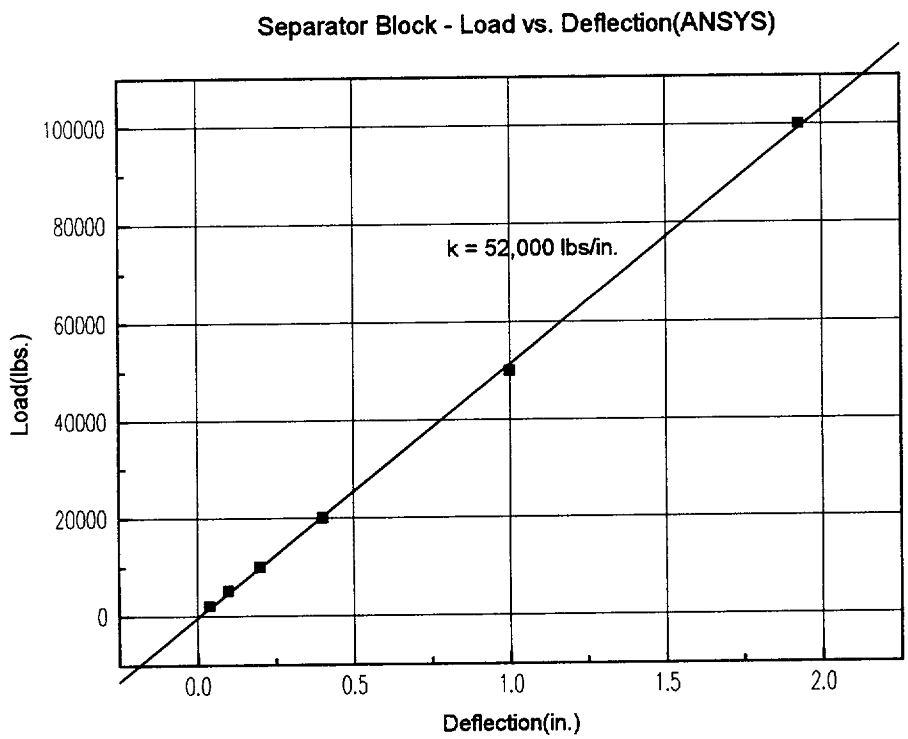


Figure 3 -
Separator Block - Load vs. Deflection(ANSYS)



The impact force can then be estimated as follows,

$$F = kx = (52{,}000)(1.59) = 82{,}680 \text{ lbs.}$$

The allowable shear stress is as follows (Ref. 11),

$$\tau_{allow} = (0.6)(\sigma_y) = (0.6)(130{,}000) = 78{,}000 \text{ psi.}$$

The shear stress in the bolts is then,

$$\tau = F/A_{bolts} \qquad \text{where } A_{bolts} = (2)((\pi)(5/8)^2/4)$$

$$\tau = 82{,}680/0.614 = 134{,}747 \text{ psi.} >> 78{,}000 \text{ psi.}$$

Assuming 2 bolts are used per separator block, the required bolt diameter can be determined as follows,

$$\tau_{allow} = (F)/((2)(\pi)(d)^2/4)$$

$$d_{min} = ((2)(82{,}680)/(\pi)(78{,}000))^{1/2} = 0.821 \text{ in.} \rightarrow 7/8''$$

5.3 Realistic Separator Block Loading

In the previous section, a conservative impact load was estimated for purposes of examining the strength of the separator bolts only. A more realistic maximum impact load can be estimated from the drop testing results of references 12 and 13. Since the drop height, container material, geometry, and strongback supporting structure of the 51032 container and the 927 container are essentially the same, the dynamic loading applications upon impact would be approximately the same.

The 30 foot side drop test results showed that the fuel assemblies remained in the hold-down brackets and the brackets remained in place across the strongback. This shows that a significant amount of energy was absorbed prior to loading the brackets. It is therefore concluded that the loading required to shear the 3/8 inch SAE J429 Grade 5 bolts of the 51032-2 ("limiting"), would not be reached in the bracket assemblies during impact. This loading, however, will be calculated and used as an estimate of the maximum loading that the separator block could see if the bolts were to break in a 30 foot side drop.

From Reference 9, the yield strength of Grade 5 bolts is 92,000 psi. Therefore, the shear strength of the bolts is,

τ_y = (0.6) (92,000 psi) = 55,200 psi

The cross-sectional area of the bolts (per bracket assy) is,

A_{bolts} = (2 bolts) (π) (0.375 in.)^2/4 = 0.221 in^2

The maximum impact load would then be,

F_{max} = (55,200 psi) (0.221 in^2) (10 bracket assy's) = 121,933 lbs.

The corresponding maximum "g" factor is then,

"g" factor = 121,933 lbs./1,650 lbs. = 74 g's

Assuming, conservatively, that the "dynamic" yield strength of the 1/4 inch strongback equals the "static" yield strength, or 36,000 psi., and that the one inch separator block bolts are used, the maximum bearing load that the strongback can take is calculated as follows,

$P_{max} = 2td\sigma_y$ (Ref. 14) where t = 1/4 inch
d = 1 inch

P_{max} = (2) (0.25 in.) (1 in.) (36,000 psi.) (9 separator Blocks)
= 162,000 lbs.

"g" factor = 162,000 lbs./1,650 lbs. = 98 g's

$$M.S. = \frac{98 - 74}{74} \times 100\% = 32\%$$

6.0 CONCLUSIONS AND RECOMMENDATIONS

It has been shown by the present analysis that the maximum "clear" spacing between separator blocks, to maintain a 6 inch minimum fuel assembly separation, following a 30 foot drop of the shipping container on its side, is 11.4 inches. It has also been shown conservatively that, as a minimum, 7/8" diameter bolts should be used to withstand the shear of the impact force. It is recommended that 1" bolts be used. It is also recommended that a 3/8" inch rectangular gusset be fillet welded within each separator block, perpendicular to the length of the square tubing and located lengthwise between bolt holes. This will stiffen the separator block, minimize deformation due to such high impact loads, and most likely eliminate interference of the separator block with the other adjacent fuel assembly.

It should be noted that the 121,933 pound impact force calculated corresponds in section 5.3 corresponds to about 13,548 pounds per each of the nine separator blocks. In references 2 and 3 it was stated that the separator block, with gusset plate, could take a compressive load of greater than 30,000 pounds without significantly deflecting; and without a gusset plate at about 16,000 pounds.

7.0 REFERENCES

1. A) 02-1215929D-01, MODEL 51032-2 VESSEL(ISOMETRIC VIEW).
   B) 02-1085158D-01, SHIPPING CONTAINER FOR JERSEY NUCLEAR CO. FUEL ASSEMBLIES(51032-1)
   C) 02-1085281A-00, TUBE(SEPARATOR BLOCK).
   D) 02-1085191B-00, SEPARATOR ASSEMBLY.

2. 38-1210302-00, CONSOLIDATED LICENSE APPLICATION FOR ANF FOR MODEL NO. 51032-1 SHIPPING CONTAINER.

3. 43-10188A-00, APPLICATION FOR USE OF MODEL NO. 51032-1 SHIPPING CONTAINER FOR TRANSPORT.

4. 32-1202241-00, MK-B9 FUEL ROD VOLUME & WEIGHT, O. PACHECO.

5. MECHANICS OF MATERIALS, 2ND EDITION, GERE & TIMOSHENKO, PWS, BOSTON, 1984.

6. ROARK'S FORMULAS FOR STRESS AND STRAIN, YOUNG, MCGRAW-HILL, N.Y., 1989.

7. 02-1190498C-03, MK-B FUEL ROD TUBING(AS ORDERED).

8. 32-1173370-00, TENSILE PROPERTIES OF ZIRC-4 F/R CLADDING, S. WILLIAMS.

9. SAE-J429, MECH. AND MATL. REQ. FOR EXTERNALLY THREADED FASTENERS, AUGUST 1983, GLOBAL ENGINEERING DOCUMENTS.

10. BWNT-TM-83, REV. ORIG. 6/92. ANSYS REVISION 4.4A ENGINEERING ANALYSIS SYSTEM USERS MANUAL, VOLUMES 1 & 2.

11. ASME CODE SECTION III, APPENDIX F.

12. TEST REPORT NO. 2312A, QUALIFICATION TEST PROCEDURE FOR THE APPLIED DESIGN COMPANY MODEL 927A METAL SHIPPING AND STORAGE CONTAINER FOR COMBUSTION ENGINEERING, INC. FUEL BUNDLE ASSEMBLY. TEST REPORT NO. 231B ON THE APPLIED DESIGN COMPANY MODEL 927A METAL SHIPPING AND STORAGE CONTAINER FOR COMBUSTION

ENGINEERING, INC. FUEL BUNDLE ASSEMBLY

13. JERSEY NUCLEAR COMPANY, INC. SHIPPING CONTAINER MODEL NUMBER 51032-1, 30 FOOT DROP TEST REPORT.

14. MECHANICAL ENGINEERING DESIGN, 2ND EDITION, SHIGLEY, MCGRAW-HILL BOOK CO., NY, 1972, PP. 327-328.

May 10, 1993

Attachment II

The pellet dimension and density of the Mk B 15x15 fuel assembly has been changed recently to a 0.37" nominal OD and a maximum theoretical density of 0.975 with all tolerances. Since this is outside the tolerance allowed for the Model 51032 shipping container pellet OD and theoretical density, an amendment to the license submittal is required. To preclude future amendments for the remaining fuel assembly types, estimates of the maximum pellet specifications were obtained for these assemblies and an analysis done to determine the reactivity effects of these changes on the K_{MAX} of the container. Table 1 lists the current values under review and the revised values. The change in the U-235 loadings related to these changes is also included. These changes were shown to cause a slight increase in the K_{MAX} of the container as is shown in Table 3.

The CASMO-3 computer program was used to determine the most reactive type assembly is a configuration approximating that of the shipping container. Both the revised pellet and the original pellet were modelled. The delta-k results of these cases are shown in Table 2. The first column shows the difference between the current pellet and the revised pellet. The second shows the delta-k between the Mk BW 15x15 and the other assembly types. The Mk BW 15x15 was chosen as the basis since it was the basis for the licensing calculation. As is seen the Mk C 17x17 assembly is the most reactive by a small margin.

Two KENOIV models were then developed to assess the reactivity effect of the pellet specification change. The first modeled the Mk BW 15x15 assembly in the maximum hypothetical accident condition used for the licensing calculation. The second placed the Mk C 17x17 assembly in the same configuration. The results of these cases are listed in Table 3. The K_{MAX} is obtained from the following equation:

$$K_{MAX} = k_{eff} + 0.005 + \sqrt{(1.763\sigma)^2 + 0.00367^2}$$

where 0.005 ± 0.00376 is the KENO bias associated with the fuel spacing in the container. As is seen from the table there is ample margin to the 0.95 criticality safety limit. The previous K_{MAX} value for the Mk BW 15x15 used for the initial application was 0.93487.

Based upon the analysis described above, the pellet specification has only a minimal effect on the reactivity of the Model 51032 container and there is ample margin to the 0.95 criticality safety criterion.

Table 1. Pellet Specifications

Fuel Type	Current Specification Pellet OD inches (nom)	Current Specification %TD	Revised Specification Pellet OD inches (max)	Revised Specification %TD
Mk B15x15	0.3686	0.963	0.3707	0.975
Mk C17x17	0.324	0.963	0.3252	0.975
Mk BW15x15	0.3625	0.963	0.3671	0.975
Mk BW17x17	0.3195	0.963	0.3232	0.975
CY 15x15	0.361	0.963	0.3672	0.975

Fuel Type	Current Specification U-235 Loading, kg	Revised Specification U-235 Loading, kg
Mk B15x15	24.61	25.20
Mk C17x17	23.34	24.62
Mk BW15x15	24.13	24.24
Mk BW17x17	23.47	24.32
CY 15x15	19.29	20.20

Table 2. CASMO Results For Shipping Container

Assy Type	Δk Revised-Current	Δk Revised vs Mk BW 15x15
Mk B15x15	0.00197	0.00022
Mk C17x17	0.00131	0.00184
Mk BW15x15	0.00331	0.0
Mk BW17x17	0.00296	-0.00231
CY 15x15	0.00411	-0.00058

Table 3. KENOIV Results

Assy Type	$k_{eff} \pm \sigma$	K_{MAX}
Mk BW 15x15	0.92949 ± 0.00099	0.93857
Mk C 17x17	0.92939 ± 0.00100	0.93854