APPLICATION FOR USE OF THE 51032-2 SHIPPING CONTAINER FOR TRANSPORT OF RADIOACTIVE MATERIALS

B&W FUEL COMPANY

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Approvals:

T S Wilkerson TS WILKERSON 7-12-93
Manager, Manufacturing Engineering Date

J T Ford 7-12-93
Manager, Manufacturing Date

R. L. Gardner 7-12-93
Manager, Quality Assurance Date

Kathryn S Knapp Kathryn S. Knapp 7-7-93
Manager, Safety and Licensing Date

AR Shumaker AR SHUMAKER 7-12-93
Project Engineer Date

TABLE OF CONTENTS

Page

1.0 GENERAL INFORMATION 1-1

1.1 Introduction 1-1
1.2 Package Description 1-3
1.2.1 Packaging 1-3
1.2.2 Operational Features 1-7
1.2.3 Contents of Packaging 1-7
1.3 Associated Drawings 1-7

2.0 STRUCTURAL EVALUATION 6

2.1 Structural Design 6
2.2 Weights and Centers of Gravity 6
2.3 Mechanical Properties of Materials 7
2.4 General Standards for All Packages 7
2.4.1 Minimum Package Size 7
2.4.2 Tamperproof Feature 7
2.4.3 Positive Closure 7
2.4.4 Chemical and Galvanic Reactions 7
2.5 Lifting and Tiedown Standards for all Packages 7
2.5.1 Lifting Devices 7
2.5.2 Tiedown Devices 8
2.6 Normal Conditions of Transport 8
2.6.1 Heat 8
2.6.2 Cold 8
2.6.3 Reduced External Pressure 9
2.6.4 Increased External Pressure 9
2.6.5 Vibration 9
2.6.6 Water Spray 9
2.6.7 Free Drop 9
2.6.8 Corner Drop 9
2.6.9 Compression 9
2.6.10 Penetration 10
2.7 Hypothetical Accident Conditions 10
2.7.1 Free Drop 10
2.7.2 Puncture 12
2.7.3 Thermal 13
2.7.4 Immersion - Fissile Material 13
2.7.5 Immersion - All Packages 14A
2.7.6 Summary of Damage 14A
2.8 Special Form 14A
2.9 Fuel Rods 14A
2.10 30 Foot Side Drop Analysis 14A
2.11 BWFC Buckling Load Analysis 14C

3.0 THERMAL EVALUATION 15

4.0 CONTAINMENT.. 16

4.1 Containment Boundary.. 16
4.1.1 Containment Vessel.. 16

TABLE OF CONTENTS (Con't)

Page

4.1.2 Containment Penetrations.................... 16
4.1.3 Seals and Welds............................ 16
4.1.4 Closure.................................... 16
4.2 Requirements for Normal Conditions of Transport.... 16
4.3 Containment Requirements for the Hypothetical Accident Conditions 16
4.4 Special Requirements 17

5.0 SHIELDING EVALUATION.. 18

6.0 CRITICALITY EVALUATION 19

6.1 Discussion and Results 19
6.2 Package Fuel Loading 19
6.3 Model Specifications 20
6.3.1 Description of Calculational Model 20
6.3.2 Normal Array Calculational Model 21
6.3.3 Damaged Array Calculational Model 21
6.4 Criticality Calculation 22
6.4.1 Geometry Descriptions 22
6.4.2 Fuel Loading or Other Contents Loading Optimization 22
6.4.3 Criticality Results 23
6.5 Critical Benchmark Experiments 25
6.5.1 Benchmark Experiments and Applicability 25
6.5.2 Details of Benchmark Calculations 26
6.5.3 Results of Benchmark Calculations 26
6.6 Appendix - KENO-IV Input Listings 56

7.0 OPERATING PROCEDURES.. 72

7.1 Procedures for Loading Package 72
7.2 Generalized Unloading Procedures 74
7.3 Preparation of Empty Package for Transport 76
7.4 Transport Controls 76

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM................. 78

8.1 Acceptance Tests.................................... 78
8.2 Maintenance Program................................. 79

APPENDIX A
Test Report from Consolidated License Application for Advanced Nuclear Fuels Corporation Model 51032-1 Shipping Container, Docket 71-6581

APPENDIX B
"Exhibit P" Application for Licensing Combustion Engineering, Inc. Shipping Container Model 927A

APPENDIX C
"Exhibit P-1" From the Application for Licensing Combustion Engineering, Inc. Shipping Container Model 927A

1.0 GENERAL INFORMATION

1.1 Introduction

This application is for a Certificate of Compliance for shipping container Model 51032-2. The 51032-2 container is similar to the 51032-1 container presently licensed by Siemens, Docket Number 71-6581. Slight variations are present in the separator block design and the 51032-2 shall be licensed to transport BWFC type fuel assemblies that differ in design than those licensed for the 51032-1 packaging. The differences are addressed in Section 1.1.1.

The Model 51032-2 shipping container is to be used for transporting unirradiated fuel assemblies. The maximum enrichment for any fuel assembly type is 5.0 wt% U-235 and all shipments may be made as Fissile Class I.

1.1.1 Differences Between the 51032-1 and the 51032-2

Essentially, the 51032-2 shipping container is identical to the 51032-1 container (Docket 71-6581) which was based on the 927A shipping container (Docket 71-6078). The differences are discussed in this section below.

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.

B. BWFC has determined 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.

extend across the top of the strongback channel and are clamped to the strongback flanges in the same manner as are the full clamps (see BWFC Drawing 1215934D). The restraining bars are provided for additional restraint in the event of an accident.

Strongback components required for each package vary with the size of the fuel elements shipped.

1. The number of full clamps to be used is dependent upon the number of spacers in the fuel assembly. One full clamp is to be used for each spacer and end fitting The maximum weight supported by each full clamp assembly under hypothetical accident conditions is depicted in the table below.

MODEL 51032-2 PACKAGE
FUEL ASSEMBLY CLAMP REQUIREMENTS

FA Type	FA + CCA Max. Wt. (2 each)	No. Full Clamps Reqd.	Maximum Weight Supported by Each Full Clamp Assy. (lbs)
MK-B	3300 lbs	10	3300 / (3300 + 710) = 82.29% (168,000 / 10) (82.29%) = **13,825**
MK-BW	3016 lbs	10	3016 / (3016 + 710) = 80.94% (168,000 / 10) (82.29%) = **13,599**
C-Y	2510 lbs	9	2510 / (2510 + 710) = 77.95% (168,000 / 9) (77.95%) = **14,551**

2. The number of separator blocks to be utilized is nine (9).

3. The number of restraining bars employed for transporting fuel elements shall be one fewer than the number of fuel element spacers (one between each spacer full clamp).

1.2.1.3 <u>CONTAINMENT VESSEL PENETRATIONS</u>

There are no sampling ports.

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

2.7.5 Immersion - All Packages

Not Applicable. The container is assumed to fill with water for the criticality analysis. Also, water will not affect the materials of construction of either the package or the fuel.

2.7.6 Summary of Damage

After completion of all testing, the Model 51032 Container had provided satisfactory containment of radioactive materials in accordance with 10 CFR 71.

2.8 Special Form

Not Applicable

2.9 Fuel Rods

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 of Appendix A. Although the tests resulted in significant warping and bending of the individual 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.

2.10 30 Foot Side Drop Analysis

The Shipping Container Model 51032-1 was 30 foot drop-tested (Appendix A, B, and C) for a horizontal cover drop and a vertical end drop. Each drop test showed that the fuel assemblies remained intact in their brackets and that the required spacing was maintained. During a 30 foot drop of the container on its side, it is possible, however unlikely, that one of the fuel assemblies could break free from its holding brackets and impact the separator blocks. To assure that the fuel assemblies would maintain a 6 inch minimum spacing, the separator blocks and bolts must be able to withstand the impact force of the fuel assembly such that failure of either would not occur and that the separator block would remain attached to the strongback.

2.10.1 Separator Block Integrity

Assumptions:

1) The overall stiffness of the loaded container impacting in the horizontal-side orientation would be approximately the same as impacting in the horizontal-cover orientation.

2) The maximum "clear" spacing between separator blocks is 11.4 inches and the blocks are spaced "regularly" along the length of the fuel assemblies.

3) The impact load of the fuel assembly is divided equally among the nine (9) separator blocks.

To estimate the impact load that 1650 pound fuel assembly (maximum weight for licensing) could have on the nine (9) separator blocks of the Shipping Container Model 51032-2, the results of the Model 51032-1 drop tests are used.

Accelerometers attached to the strongback recorded the acceleration versus time for the 30 foot drop tests of the 51032-1 container. It is postulated, per Assumption 1 above, that the maximum acceleration determined for this plot can be used to estimate the impact load that the separator blocks could see if the fuel assembly were to break free from the brackets. The maximum acceleration read from the acceleration vs. time plot for the strongback, in the Jersey Nuclear Co. 30 foot horizontal cover drop test, it approximately 125 g's. The maximum impact load onto each separator block is then calculated as follows:

$$F = (125\ g)(1650\ lbs)/(9\ blocks) \approx 23,000\ lbs.$$

From Section V.5 of Appendix A, single separator blocks (with gusset plates) were compression tested using a Tinius-Olsen compression machine. It was found that at the 30,000 pound limit of the machine, the plate had not buckled and there was no significant block deformation, therefore the buckling strength is greater than 30,000 lbs.

$$\text{Margin of Safety, M.S.} = \frac{30,000 - 23,000}{23,000} \times 100\% = \mathbf{30\%}$$

The shear stress in the bolts is calculated as follows:

$\tau_{bolts} = F_{shear}/A_{bolts}$ where F_{shear} = 23,000 lbs. (Section 2.10.1)
$A_{bolts} = (2) \cdot [(\pi)(1)^2/(4)] = 1.57\ in^2$

τ_{bolts} = 23,000/1.57 = 14,650 psi.

τ_{allow} = (0.6)(130,000 psi.) = 78,000 psi.

$$M.S. = \frac{78,000 - 14,650}{14,650} \times 100\% = 432\%$$

2.10.3 Conclusions

This analysis shows that for a 30 foot drop of the shipping container on its side, the structural integrity of the separator block and separator block bolts would be maintained. Two inch (O.D.) lockwashers are placed under the bolt heads and nuts of the separator block bolted connections to distribute the load over a larger area of the strongback and to prevent the bolts from tearing out of the strongback. It is concluded that the separator blocks would remain attached to the strongback and thus a 6 inch spacing between fuel assemblies would be maintained following a 30 foot side drop.

2.11 BWFC Buckling Load Analysis

An analysis was conducted to verify that the failure load of the shipping container spacer assemblies exceeds the fuel assembly critical buckling load. The references used to perform this analysis are listed below:

(1) Gere & Timoshenko, Mechanics of Materials, PWS, Boston, 1984, page 744.
(2) Gere, p746.
(3) Gere, p557.

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 3584 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.

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	$(L) = 12$ inches (conservatively long)	
Area	$(A) = 0.250\ in^2$	
Moment of Inertia	$(I) = \pi \cdot D^4/64 - \pi \cdot d^4/64$	

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

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

Critical Buckling Load:

$$
\begin{aligned}
P_{cr} &= \pi^2 \cdot E \cdot I/L^2 \quad ^{(3)} \\
&= 9.870 \cdot 28e6 \cdot 0.0171/144 \\
&= 32{,}800 \text{ pounds per support}
\end{aligned}
$$

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:

$$
\begin{aligned}
P_{cr} &= A \cdot S_{ut} \\
&= 0.250 \cdot 60{,}000 \\
&= 15{,}000 \text{ pounds per support}
\end{aligned}
$$

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

2.11.1 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 3584 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.