71-9246

UNITED STATES DEPARTMENT OF COMMERCE
National Institute of Standards and Technology
Gaithersburg, Maryland 20899

October 17, 2011

ATTN: Document Control Desk
Vonna Ordaz, Director
Division of Spent Fuel Storage and Transportation
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Subject: Renewal of Certificate of Compliance No. 9246, Docket No. 71-9246

The National Institute of Standards and Technology respectfully requests renewal of the subject Certificate of Compliance for the Model No. ST package, identification number USA/9246/AF.

There are several certificate changes being requested as part of the certificate renewal. Justification for each change is discussed in the attached document. All original analyses for the currently approved package that were previously submitted are still valid.

This submittal includes the original licensing analyses reformatted as prescribed by Regulatory Guide 7.9. This is intended to reduce the burden on both the NRC and NCNR staffs by placing the information in an easy-to-read format and consolidating the original licensing analyses into one document. Consolidation of licensing documentation is consistent with the regulation in paragraph 71.38(c) in Title 10 of the *Code of Federal Regulations*.

If you have any questions, please contact Mr. William Schuster at (301) 975-2380 (phone) or william.schuster@nist.gov (email).

Sincerely,

Sean O'Kelly, Chief
Reactor Operations and Engineering
NIST Center for Neutron Research

Attachments:
1. Additional Information in Support of Renewing Certificate of Compliance No. 9246
2. Safety Analysis Report for Packaging, "ST" Package, Certificate of Compliance Number 9246

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**Additional Information in Support of Renewing
Certificate of Compliance No. 9246**

The National Institute of Standards and Technology (NIST) Center for Neutron Research (NCNR) is requesting renewal of the Certificate of Compliance (COC) No. 9246 for the ST package. All analyses previously submitted remain the same and are still valid.

The following pages of this document further discuss the request and any changes that are necessary to COC No. 9246.

Additional Information in Support of Renewing
Certificate of Compliance No. 9246

Document: Certificate of Compliance No. 9246, Revision 6

The following changes, identified in COC condition five (5) that describes the ST package, are requested for clarification purposes.

Current text, 5(a)(2), "Description":

> A closed steel pipe for the transport of an unirradiated research reactor fuel element. The pipe is a 5-1/2-inch OD carbon steel pipe, approximately 71 inches in length, with a closed bottom end and flanged top end. The top end is closed by a cover plate, which is 1/4-inch thick, and 6-1/2 inches in diameter, and a gasket. The cover plate is secured to the pipe flange by 8 cap screws. A wooden nozzle support and top support position the fuel assembly within the pipe. The package weighs approximately 75 pounds, including the fuel element.

Proposed text, 5(a)(2), "Description":

> A closed steel pipe for the transport of an unirradiated research reactor fuel element. The pipe is a 5-1/2-inch OD carbon steel pipe, approximately 71 inches in length, with a closed bottom end and flanged top end. The top end is closed by a cover plate, which is 1/4-inch thick, and 6-1/2 inches in diameter, and a gasket. The cover plate is secured to the pipe flange by 8 cap screws. A wooden nozzle support, bottom support, and top support position the fuel element within the pipe. The package weighs approximately 75 pounds, including the fuel element.

Discussion:

The proposed addition of "bottom support" reflects another support that is part of the original design of the ST package and used to position the fuel element inside the ST package (Reference: NIST Drawing No. D-04-048, Sheet 1, Rev. 4).

The proposed change of "assembly" to "element" is for clarity and consistency and does not reflect an actual change in the contents of the package (Reference: NIST Drawing No. D-04-048, Sheet 1, Rev. 4).

Additional Information in Support of Renewing
Certificate of Compliance No. 9246

Document: Certificate of Compliance No. 9246, Revision 6

The following changes, identified in COC condition six (6) that discuss operating procedures for the ST package, are requested considering the information provided in Chapter 7 of the "Safety Analysis Report for Packaging, "ST" Package, Certificate of Compliance Number 9246".

Current text:

> In addition to the requirements of Subpart G of 10 CFR Part 71, the package shall be prepared for shipment, operated, and maintained in accordance with the loading, unloading, and quality assurance procedures in the application. Prior to each shipment, the shipper shall make the determinations specified in the NIST "ST" Series Shipping Container Shipper's Checklist in the application.

Proposed text:

> In addition to the requirements of Subpart G of 10 CFR Part 71, the package shall be prepared for shipment, operated, and maintained by written procedures prepared to meet the requirements and make the determinations specified in Chapter 7 of the package application.

Discussion:

The proposed change to the text is requested considering the inclusion of the essential elements required for package operations in Chapter 7 of the "Safety Analysis Report for Packaging, "ST" Package, Certificate of Compliance Number 9246".

The change would also permit NIST and package users the flexibility to make changes to procedural steps that are not needed to ensure the proper preparation of the package for shipment and therefore should not require NRC approval. This appears to be consistent with the NRC staff's position presented SFST-ISG-20, "Transportation Package Design Changes Authorized Under 10 CFR Part 71 Without Prior NRC Approval".

Safety Analysis Report for Packaging "ST" Package

Certificate of Compliance Number 9246

National Institute of Standards and Technology
U.S. Department of Commerce

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Safety Analysis Report for Packaging "ST" Package

Certificate of Compliance Number 9246

October 2011

U.S. Department of Commerce
Rebecca M. Blank, Acting Secretary

National Institute of Standards and Technology
Patrick D. Gallagher, Under Secretary for Standards and Technology and Director

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1 General Information

1.1 Introduction

The NIST Center for Neutron Research (NCNR) is a reactor-laboratory complex providing the National Institute of Standards and Technology (NIST) and the nation with a world-class facility for the performance of neutron-based research. The heart of this facility is the National Bureau of Standards Reactor (NBSR). The NBSR is operated 24 hours a day, seven days a week with routine shutdowns every five-and-one-half weeks for partial refueling and as needed for maintenance. The ST package, used for transporting a single unirradiated NBSR fuel element, directly supports the routine refueling requirement and the research mission of the NCNR.

NIST originally submitted an application requesting approval of the ST package on February 7, 1992. The U.S. Nuclear Regulatory Commission (NRC) reviewed the application and issued Certificate of Compliance (COC) Number 9246 for the Model Number ST Package on February 26, 1992. The package is currently approved and authorized for use as a Type A Fissile package with a Criticality Safety Index (CSI) of 50 under COC Number 9246, Revision 6.

This report contains the results of the analyses provided by the original package application into the format prescribed by NRC Regulatory Guide (RG) 7.9, "Standard Format and Content of Part 71 Applications for Approval of Packages for Radioactive Material." It should be noted that not all sections prescribed by RG 7.9 are applicable. Additionally, not all sections prescribed by RG 7.9 were discussed or presented in the original package application.

NIST maintains an NRC-approved quality assurance program for activities conducted regarding transportation packages, as required by Subpart H of Title 10 of the *Code of Federal Regulations*. This program is currently approved and effective under Approval Number 0390, Revision 9.

1.2 Package Description

1.2.1 Packaging

Package Overall Dimensions[1]

The ST package consists of a 0.9525-cm (0.375-in) carbon steel plate, a 0.3175-cm (0.125-in) thick, 13.335-cm (5.25-in) inside diameter carbon steel welded tube, a 0.635-cm (0.5-in) carbon steel flange, and a 0.635-cm (0.25-in) carbon steel cover plate. The overall length of the package is 177.8 cm (70 in). The approximate gross weight (package and contents, as defined, per 49 CFR) of the loaded package is 34 kg (75 lbs). Engineering drawings of the package are provided in Figures 1.2.1.1 and 1.2.1.2.

Package Containment Features

The package opening consists of a flange and cover plate. The flange is tapped with eight (8) 1/4-20 holes used to attach the cover plate with screws. A 0.3175-cm (0.125-in) thick neoprene gasket with the same hole pattern forms a seal between the flange and cover plate. The cover screws protrude through the flange and have a 0.15875-cm (0.0625-in) diameter hole used for attaching a tamper seal. When a fuel element is inserted with the support pieces attached, the cover and gasket are applied, bolted, properly torqued, and sealed.

Package Shielding and Barrier Features

There are no safety-related shielding features or personnel barriers incorporated into the original package design.

Package Criticality Control Features

There are no safety-related features intended for criticality control (e.g. neutron poisons, moderators, or spacers) incorporated into the original package design.

Package Structural Features

There are no safety-related structural features incorporated into the original package design; however, there are features intended to orient, support, and restrict movement of the package contents during normal conditions of transport.

Support pieces are assembled on a NBSR fuel element when inserting it into the package. The outside diameter of the support pieces is slightly smaller than the inside diameter of the package. This permits insertion of the fuel element and supports into the package and restricts movement during normal conditions of transport.

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[1] In accordance with various Federal Acts, the Code of Federal Regulations, and Executive Order 12770 (see Preface), it is NIST policy that the International System of Units shall be used in all NIST publications. However, it should be noted that the package design is based in United States Customary System units. All values in SI units provided are converted, not measured, were not used in design or fabrication of the package, and should be considered "for reference only".

Package Heat Transfer Features

There are no features intended for heat transfer incorporated into the original package design.

Package Markings

The package will be marked as required by 49 CFR and 10 CFR Part 71.

Summary of Key Design Parameters

A summary of key design parameters are provided in Table 1.2.1.1.

1.2.2 Contents

Identification and Quantity of Fissile Material

The maximum quantity of material per package is one NBSR MTR-type fuel element containing not more than 360 g of ^{235}U.

Physical Form

The permitted type and form of material per package is one NBSR MTR-type fuel element composed of enriched uranium and aluminum.

Location and Configuration of Contents

Support pieces are assembled on a NBSR fuel element when inserting it into the package to restrict movement.

Each NBSR fuel element is wrapped and sealed in a plastic bag (or equivalent) that is resistant to moisture and dust. The plastic bag assists in maintaining cleanliness of the fuel element and is not considered to be part of the packaging.

1.2.3 Special Requirements for Plutonium

The package is not authorized to ship plutonium. Therefore, this section is not applicable.

1.2.4 Operational Features

The package design is not considered to be complex as it does not have multiples valves, connections, piping, openings, seals, or boundaries. Therefore, this section is not applicable.

Table 1.2.1.1: ST Package Key Design Parameters

Designer	NIST	
Package Model	"ST" Series	
Package Type	Type A Fissile	
Package Identification Number	USA/9246/AF	
Quantity	4 packages	
Dimensions		
Overall Length	177.8 cm	70 in
Outside Diameter	13.97 cm	5.5 in
Inside Diameter	13.335 cm	5.25 in
Wall Thickness	0.3175 cm	0.125 in
Weight - Gross, or Loaded	34 kg	75 lbs
Weight - Unloaded	24.95 kg	55 lbs
Materials of Construction		
Package Body	Carbon steel	

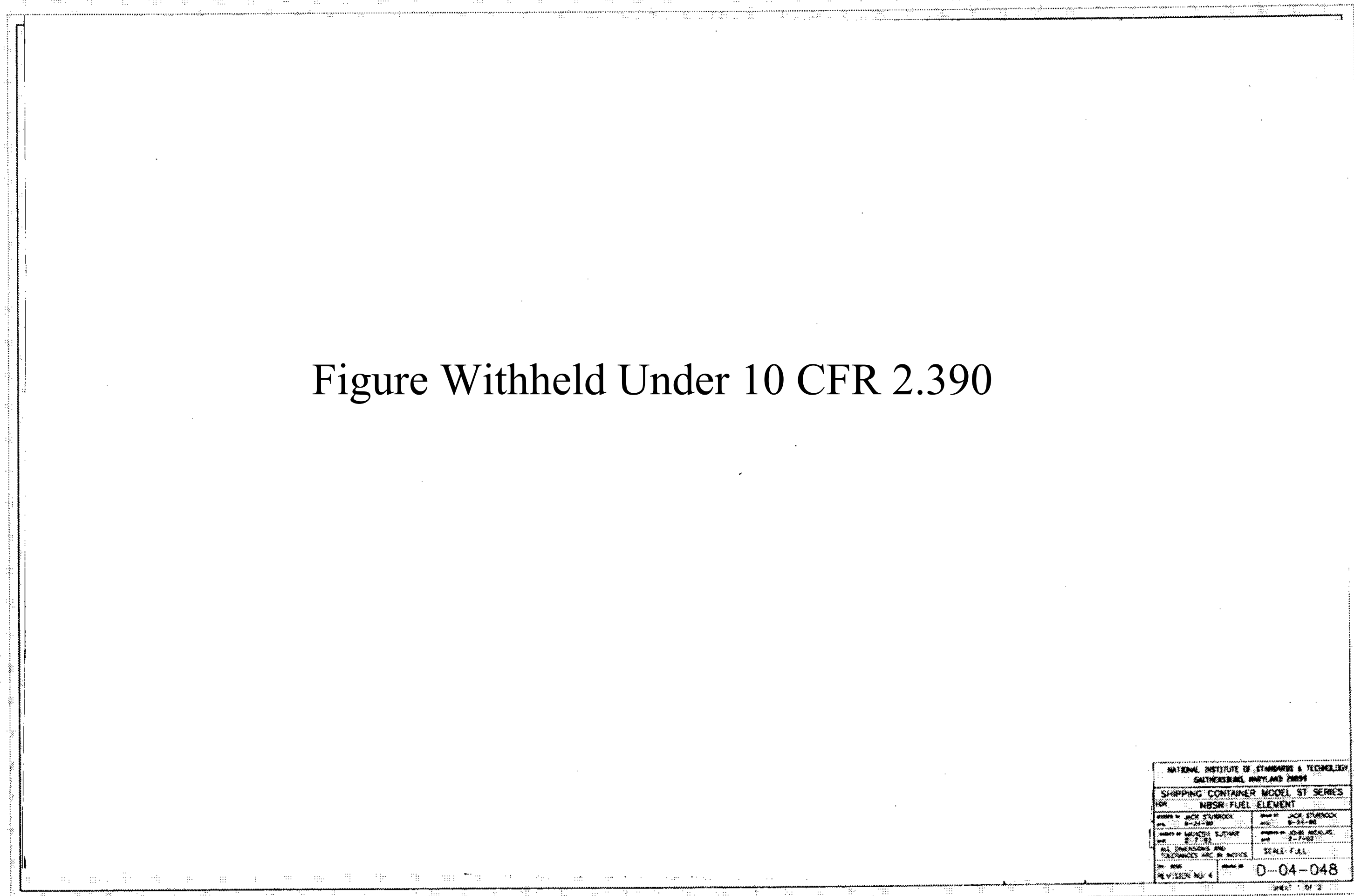

Figure 1.2.1.1 Shipping Container Model ST Series (D-04-048, Sh. 1)

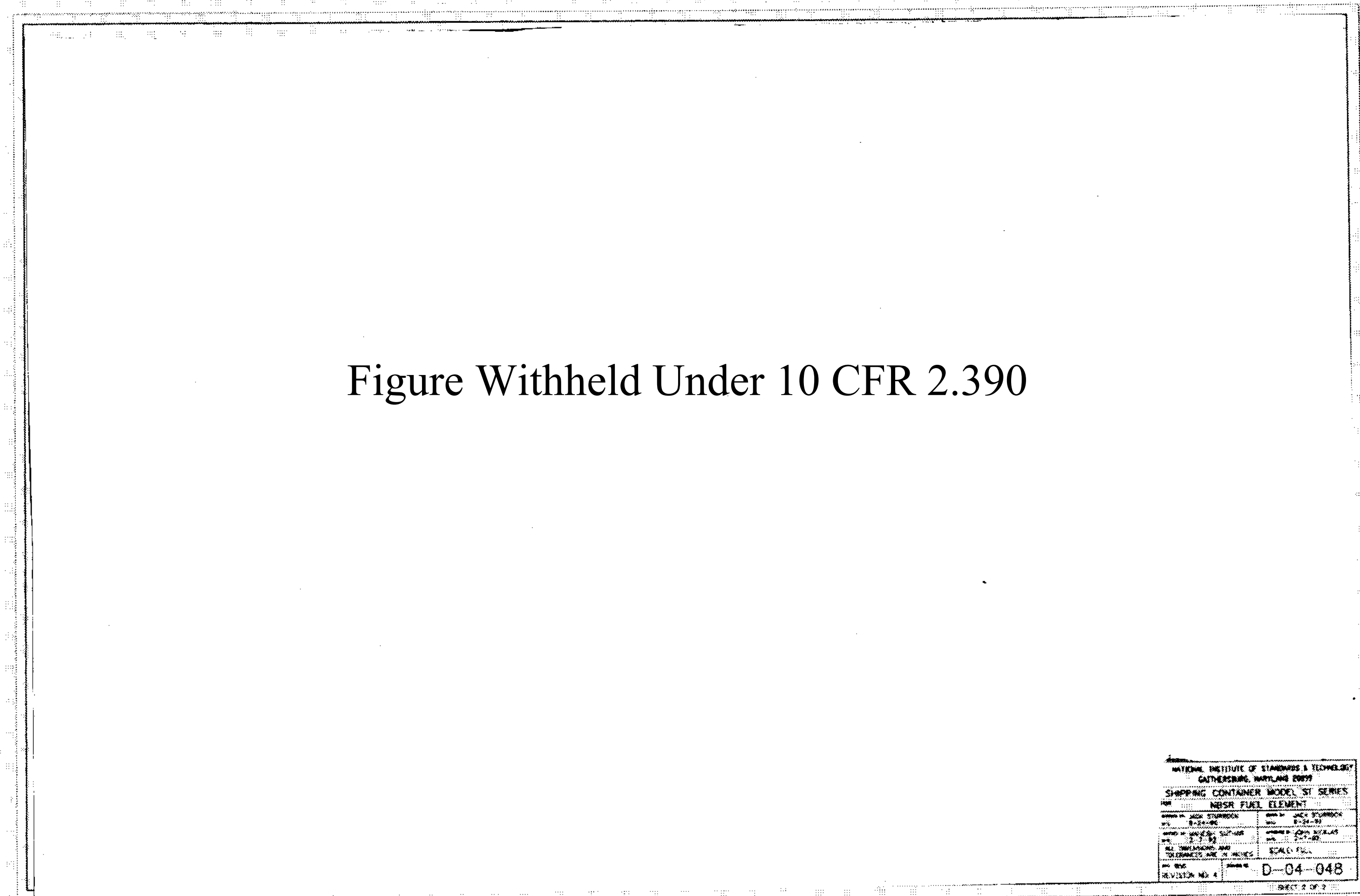

Figure 1.2.1.2 Shipping Container Model ST Series (D-04-048, Sh. 2)

2 Structural Evaluation

2.1 Description of Structural Design

2.1.1 Discussion

The package is limited to a Type A quantity of radioactive material. In addition, the quantity of fissile material (two packages with one unirradiated fuel element each) is limited to less than the critical mass of ^{235}U. The criticality safety of the fissile material does not depend on the packaging to maintain geometry. Therefore, there are no structural members or systems that received credit or were identified as performing any specific safety functions in the original package application.

2.1.2 Design Criteria

There were no design criteria identified in the original package application.

2.1.3 Weights and Centers of Gravity

2.1.3.1 Weights

The gross weight of the loaded package is approximately 34 kg (75 lbs). The weight of the unloaded package is approximately 24.95 kg (55 lbs). The weight of the NBSR MTR-type fuel element being transported is 8.26 kg (18.2 lbs).

2.1.3.2 Centers of Gravity

The centers of gravity of the package were not discussed in the original package application.

2.1.4 Identification of Codes and Standards for Package Design

The package was designed, fabricated, assembled, and tested by NIST according to commercially accepted engineering standards. No specific codes or standards were identified in the original package application.

2.2 Materials

2.2.1 Material Properties and Specifications

There were no material mechanical properties specifically identified for structural evaluation in the original package application.

2.2.2 Chemical, Galvanic, or Other Reactions

There were no chemical, galvanic, or other reactions between package materials identified in the original package application.

2.2.3 Effects of Radiation on Materials

There were no presumed effects of radiation on the package materials identified in the original package application.

2.3 Fabrication and Examination

2.3.1 Fabrication

The package was fabricated by NIST according to commercially accepted engineering standards. No specific codes or standards were identified in the original package application.

2.3.2 Examination

The package was examined by NIST according to commercially accepted engineering standards. No specific codes or standards were identified in the original package application.

2.4 General Requirements for All Packages

2.4.1 Minimum Package Size

The smallest overall dimension of this package is 13.97 cm (5.5 in). This is greater than 10 cm (4 in); therefore, the requirement of 10 CFR 71.43(a) is satisfied.

2.4.2 Tamper-Indicating Feature

The tamper-indicating feature is also discussed in Section 1.2.1, "Packaging", under "Package Containment Features". In summary, the tamper-indicating device for the package is provided by a tamper seal that passes through a hole in each of the eight (8) 1/4-20 screws that are used to attach the cover plate and gasket.

To tamper with contents of the package, it is necessary to remove the screws and cover plate; thus, a severed seal will indicate purposeful tampering. With the tamper seal intact, it is impossible to gain access to the contents of the package undetected, satisfying the requirement of 10 CFR 71.43(b).

2.4.3 Positive Closure

The positive closure device is also discussed in Section 1.2.1, "Packaging", under "Package Containment Features". In summary, the positive closure device for the package is provided by the eight (8) 1/4-20 screws that are used to attach the cover plate and gasket. The attaching screws protrude through the flange and have a 0.15875-cm (0.0625-in) diameter hole used for attaching a tamper seal.

By procedure, when a fuel element is inserted with the support pieces attached, the cover and gasket are applied, bolted, properly torqued, and sealed. It is necessary to deliberately loosen the screws with an Allen wrench to facilitate opening. With the screws torqued and tamper seal intact, it is impossible to gain access to the contents of the package unintentionally, satisfying the requirement of 10 CFR 71.43(c).

2.5 Lifting and Tie-Down Standards for All Packages

2.5.1 Lifting Devices

There are no lifting devices incorporated into the approved package design.

2.5.2 Tie-Down Devices

There are no tie-down devices incorporated into the approved package design.

2.6 Normal Conditions of Transport

In normal conditions of transport, two (2) packages with one unirradiated fuel element each may be transported at the same time in an exclusive use vehicle.

The package was submitted to a series of tests (NIST, 1990c) in accordance with 49 CFR Part 173 (Type A packaging tests) and 10 CFR Part 71.

Prior to the test, the package was loaded with a dummy element. A dummy element is a sample of a NBSR fuel element that is identical to a NBSR fuel element in materials and dimensions except the fuel plates are replaced with plates made from aluminum stock.

Upon completion of the tests, the package was examined for any damage that could affect its integrity. The package was then opened. The dummy element was removed and examined for any damage that would indicate a possible failure of the package containment effectiveness. Finally, the interior of the package was examined for any damage that could affect its integrity.

An inspection of the package revealed no damage, internally or externally, that would affect its integrity. The package exterior did show some cosmetic damage (e.g. areas of chipped paint) that was determined to be acceptable. An inspection of the dummy element also showed no damage from the testing.

The test parameters, inspections, and results were documented (NIST, 1990d) and summarized in a report (NIST, 1990c).

2.6.1 Heat

The original package application did not discuss subjecting the package to a heat test.

As discussed in Section 3, the package design and contents do not require a certain thermal performance in order to be transported safely. Considering the limitations placed on the contents and method of transport, exposure to an ambient temperature of 38 °C (100 °F) in still air and in the shade should not have an adverse effect on the packaging or its contents and surface temperature of the package will not exceed the limitations in 10 CFR 71.43(g).

2.6.2 Cold

The original package application did not discuss subjecting the package to a cold test.

As discussed in Section 3, the package design and contents do not require a certain thermal performance in order to be transported safely. Considering the limitations placed on the contents and method of transport, exposure to a cold ambient temperature of -40 °C (-40 °F) in still air and in the shade is not expected or likely.

2.6.3 Reduced External Pressure

The original package application did not discuss subjecting the package to a reduced external pressure test.

Considering the limitations placed on the contents and method of transport, exposure to a reduced external pressure of 25 kPa (3.5 lbf/in^2) absolute is not expected or likely. However, exposure to a reduced external pressure should not have an adverse effect on the packaging or its contents.

2.6.4 Increased External Pressure

The original package application did not discuss subjecting the package to an increased external pressure test.

Considering the limitations placed on the contents and method of transport, exposure to an increased external pressure of 140 kPa (20 lbf/in^2) absolute is not expected or likely. However, exposure to an increased external pressure should not have an adverse effect on the packaging or its contents.

2.6.5 Vibration

The original package application did not discuss subjecting the package to a vibration test.

Considering the low weight of the package, limitations placed on the contents, and method of transport, exposure to a vibration incident to normal methods of transportation should not have an adverse effect on the packaging or its contents.

2.6.6 Water Spray

The package was subjected to a water spray test that simulated exposure to rainfall of approximately 5 cm/h (2 in/h) for at least 1 hour (NIST, 1990c). Sprinklers were arranged so that all sides of the package were wetted. Measurement of the simulated rainfall exceeded the 5 cm/h (2 in/h) requirement (NIST, 1990d).

Following the test, the package was examined for any deterioration or evidence of water entering the container. No water entered the container. No deterioration or other affects from the test were observed or otherwise noted.

2.6.7 Free Drop

The package was subjected to a free drop test from a height of 1.2 m (4 ft) after the conclusion of the water spray test (NIST, 1990c). The package was dropped from a height of 1.2 m (4 ft) onto a poured concrete pad. Due to the geometry of this package, this test was repeated such that: (1) the first drop was on the closed, welded end; (2) the second drop was on the end with the removable plate; and, (3) the third drop was with the package horizontal. As discussed in Section 2.6.8, "Corner Drop", the package was also subjected to a corner drop test prior to the free drop test.

The package was examined for any damage that could affect its integrity. No damage or other affects from the test were observed or otherwise noted.

2.6.8 Corner Drop

Due to the geometry of the package, a corner drop test was required to be conducted prior to the free drop test (NIST, 1990c). The package was dropped from a height of 0.3 m (1 ft) on each corner of each end (four drops per end). There was a total of eight drops for this test.

The package was examined for any damage that could affect its integrity. No damage or other affects from the test were observed or otherwise noted.

2.6.9 Compression

The package was subjected to a compression test of 325 kg (715 lbs) for 24 hours (NIST, 1990c). This test requires a compressive load applied uniformly to the top and bottom of package in the position the package would normally be transported. Therefore, the package was placed with the longitudinal axis of the package horizontal and each end resting on an unyielding surface.

In accordance with 10 CFR 71.71(c)(9), the compressive load must be the greater of five times the weight of the package or the equivalent of 13 kPa (2 lbf/in^2) multiplied by the vertically projected area of the package. The unloaded weight of the package is 24.95 kg (55 lbs). The projected area of the package (13.97 cm (5.5 in) diameter, 177.8 cm (70 in) length) is 2500 cm^2. The compressive load was calculated as follows:

$$(1)\ 5\ \times 24.95\ kg\ (55\ lbs.) = 124.75\ kg\ (275\ lbs.)$$
$$(2)\ 1300\ \frac{kg}{m^2}\ \times\ 0.25\ m^2 = 325\ kg\ (715\ lbs.)$$

Therefore, a compressive load of at least 325 kg (715 lbs) was required to be placed along the length of the package. This was accomplished by placing layers of lead bricks on top of the package. Thirty (30) bricks, each weighing 11.95 kg (26.35 lbs)., were placed on top using three layers of eight bricks and a final layer of six bricks (NIST, 1990d). The 357 kg (787.1 lb) load remained in place for 24 hours. This provided the uniform compression loading on two sides as required by 10 CFR 71.71(c)(9).

The package was examined for any damage that could affect its integrity. No damage or other affects from the test were observed or otherwise noted.

2.6.10 Penetration

The package was subjected to a penetration test by dropping a 3.2-cm (1.26-in) diameter bar, weighing 6 kg (13.23 lbs), from a height of 1 m (3.28 ft) (NIST, 1990c). The package was resting on an unyielding surface, positioned horizontally as it would be during a shipment. The bar impacted the center of the curved portion of the package. The axis of the bar remained perpendicular to the surface of the package throughout the test. The bar did not strike the surface obliquely.

The test bar was examined for any deformity at the impact point; none was found. The package was examined for any damage that could affect its integrity. No damage or other affects from the test were observed or otherwise noted.

2.7 Hypothetical Accident Conditions

The package is limited to a Type A quantity of radioactive material. In addition, the quantity of fissile material (two packages with one element each) is limited to less than the critical mass of ^{235}U. The package was not evaluated for accident conditions since the criticality safety of the fissile material does not depend on the packaging to maintain geometry.

2.7.1 Free Drop

The original package application did not discuss subjecting the package to tests based on hypothetical accident conditions.

2.7.2 Crush

The original package application did not discuss subjecting the package to tests based on hypothetical accident conditions.

2.7.3 Puncture

The original package application did not discuss subjecting the package to tests based on hypothetical accident conditions.

2.7.4 Thermal

The original package application did not discuss subjecting the package to tests based on hypothetical accident conditions.

2.7.5 Immersion – Fissile Material

The original package application did not discuss subjecting the package to tests based on hypothetical accident conditions.

However, it should be noted that the criticality analysis discussed in Section 6 assumes full moderation and reflection of fuel elements on all sides.

2.7.6 Immersion – All Packages

The original package application did not discuss subjecting the package to tests based on hypothetical accident conditions.

2.7.7 Deep Water Immersion Test

The original package application did not discuss subjecting the package to tests based on hypothetical accident conditions.

2.7.8 Summary of Damage

The original package application did not discuss subjecting the package to tests based on hypothetical accident conditions.

2.8 Accident Conditions for Air Transport of Plutonium

The package is not authorized for air transport of plutonium. Therefore, this section is not applicable.

2.9 Accident Conditions for Fissile Material Packages for Air Transport

The package is not authorized for air transport of fissile material. Therefore, this section is not applicable.

2.10 Special Form

The package is not designed or authorized to transport special form radioactive material. Therefore, this section is not applicable.

2.11 Fuel Rods

The original package application did not specifically discuss the cladding in the context of containment during normal or accident conditions.

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3 Thermal Evaluation

3.1 Description of Thermal Design

3.1.1 Design Features

There are no design features that received credit or were identified as important to thermal performance in the original package application.

3.1.2 Content's Decay Heat

The contents of the package are limited to unirradiated enriched uranium, which has negligible decay heat. Therefore, the package does not require certain thermal design features in order to transport the contents safely.

3.1.3 Summary Tables of Temperatures

There was no discussion of temperatures that could affect the package under normal or hypothetical conditions in the original package application.

3.1.4 Summary Tables of Pressures

There was no discussion of pressures that could affect the package under normal or hypothetical conditions in the original package application.

3.2 Material Properties and Component Specifications

3.2.1 Material Properties

There are no thermal properties for materials that received credit or were identified as important to heat transfer in the original package application.

3.2.2 Component Specifications

There are no material specifications that received credit or were identified as important to thermal performance of the package in the original package application.

3.3 Thermal Evaluation under Normal Conditions of Transport

3.3.1 Heat and Cold

There was no thermal evaluation of the package in the original package application.

3.3.2 Maximum Normal Operating Pressure

There was no thermal evaluation of the package in the original package application.

3.4 Thermal Evaluation under Hypothetical Accident Conditions

3.4.1 Initial Conditions

There was no thermal evaluation of the package in the original package application.

3.4.2 Fire Test Conditions

There was no thermal evaluation of the package in the original package application.

3.4.3 Maximum Temperatures and Pressure

There was no thermal evaluation of the package in the original package application.

3.4.4 Maximum Thermal Stresses

There was no thermal evaluation of the package in the original package application.

3.4.5 Accident Conditions for Fissile Material Packages for Air Transport

The package is not authorized for air transport of fissile material. Therefore, this section is not applicable.

4 Containment

4.1 Description of the Containment System

As stated in the original package specification (NIST, 1990b), the containment system consists of a bolted closure. The bolted closure is synonymous with the package opening, as described in Section 1.2.1, "Packaging", under "Package Containment Features".

The package opening consists of a flange and cover plate. The flange is tapped with eight (8) 1/4-20 holes used to attach the cover plate with screws. A 0.3175-cm (0.125-in) thick neoprene gasket with the same hole pattern forms a seal between the flange and cover plate. The attaching screws protrude through the flange and have a 0.15875-cm (0.0625-in) diameter hole used for attaching a tamper seal. When a fuel element is inserted with the support pieces attached, the cover and gasket are applied, bolted, properly torqued, and sealed.

4.2 Containment under Normal Conditions of Transport

As discussed in Section 2.6, the package prevents the loss or dispersal of radioactive material under normal conditions of transport as demonstrated by physical testing.

4.3 Containment under Hypothetical Accident Conditions

There was no evaluation of the containment system under hypothetical accident conditions in the original package application for the reasons discussed in Section 2.7.

4.4 Leakage Rate Tests for Type B Packages

This package is a Type A Fissile package. Therefore, this section is not applicable.

5 Shielding Evaluation

5.1 Description of Shielding Design

5.1.1 Design Features

There are no shielding design features for this package. The contents are limited to unirradiated enriched uranium; therefore, external radiation levels are low and shielding is not necessary.

5.1.2 Summary Table of Maximum Radiation Levels

There was no maximum radiation level table provided in the original package application.

5.2 Source Specification

5.2.1 Gamma Source

There was no gamma source discussion provided in the original package application.

5.2.2 Neutron Source

There was no neutron source discussion provided in the original package application.

5.3 Shielding Model

5.3.1 Configuration of Source and Shielding

There are no shielding design features for this package. Therefore, this section is not applicable.

5.3.2 Material Properties

There are no shielding design features for this package. Therefore, this section is not applicable.

5.4 Shielding Evaluation

5.4.1 Methods

There are no shielding design features for this package. Therefore, this section is not applicable.

5.4.2 Input and Output Data

There are no shielding design features for this package. Therefore, this section is not applicable.

5.4.3 Flux-to-Dose-Rate Conversion

There are no shielding design features for this package. Therefore, this section is not applicable.

5.4.4 External Radiation Levels

The contents are limited to unirradiated enriched uranium; therefore, external radiation levels are low. Operating procedures and routine determinations require that radiation surveys be made prior to each shipment.

There were no external radiation levels discussed in the original package application.

6 Criticality Evaluation

6.1 Description of Criticality Design

6.1.1 Design Features

There are no design features that received credit or were identified as important to criticality control in the original package application.

6.1.2 Summary Tables of Criticality Evaluation

The original analyses, performed by Babcock & Wilcox (B&W) (Koudelka, 1991a and 1991b), assumed a number of fuel elements would be fully flooded and arranged to achieve optimal moderation and reflection geometry. No credit was given to highlight the negative reactivity (poison) effect of the steel in the package and the spacing between the packages in transport.

Summary tables from these criticality analyses are provided in Table 6.1.2.1 and Table 6.1.2.2.

6.1.3 Criticality Safety Index

The original package application was before the changes to 10 CFR 71.59 in 1996 and therefore did not discuss Criticality Safety Index (CSI) for the package. However, when the NRC and DOT adopted the new regulations, the NRC modified COC 9246 (Revision 2) and included the new CSI provision based on the original criticality analyses.

CSI is based on the number of packages evaluated in the array for the criticality model. The CSI for the package was determined using this equation:

$$CSI = \frac{50}{N}$$

where

N = the number of packages used in the array for the criticality model

Based on the original criticality analyses, one (1) package was used for N (the array) in the criticality model; therefore, the package CSI was set at 50.

6.2 Fissile Material Contents

According to Koudelka (1991a), each standard NBSR fuel element was modeled explicitly to contain 17 fuel plates in the top and bottom fueled region, making a total of 34 plates. The fuel portion of each plate, measuring 6.19 cm by 28.88 cm by 0.05 cm (2.436 in by 11.37 in by 0.020 in), is uniformly loaded with a matrix of 93% enriched UO_2 and Al to give a total plate loading of 10.294 g ^{235}U. Clad thickness is 0.039 cm (0.01525 in) and water gap spacing is 0.295 cm (0.116 in). A 15.24-cm (6.0-in) long water-filled center section separates the top and bottom fueled regions of the element. The total ^{235}U loading for the element is 350 g.

6.3 General Considerations

6.3.1 Model Configuration

The model configuration was not discussed in the original package application.

6.3.2 Material Properties

No additional material properties important to the criticality design were identified or discussed in the original package application.

6.3.3 Computer Codes and Cross-Section Libraries

To conduct the criticality analyses (Koudelka, 1991a), a model of the fuel element was developed for computer simulations using Standardized Computer Analyses for Licensing Evaluation (Scale) computer software system, KENO V.a three-dimensional (3-D) Monte Carlo criticality computer code, and the Scale 3 16-group Master Library. This was accomplished through CSAS25, a Scale 3 control model.

According to the Oak Ridge National Laboratory (ORNL) website (ORNL, 2011), Scale is a comprehensive modeling and simulation suite for nuclear safety analysis and design developed and maintained by ORNL under contract with NRC and US Department of Energy (DOE) to perform reactor physics, criticality safety, radiation shielding, and spent fuel characterization for nuclear facilities and transportation/storage package designs. According to the KENO primer (Busch and Bowman, 2003), KENO V.a three-dimensional (3-D) Monte Carlo criticality computer code is the primary criticality safety analysis tool in SCALE.

6.3.4 Demonstration of Maximum Reactivity

As shown in Table 6.1.2.1, the upper limit of K_{eff} for four elements arranged two-by-two on a uniform square pitch does not exceed 0.734.

As shown in Table 6.1.2.2, additional analyses were conducted to show that the upper limit of K_{eff} for seven elements in their most reactive configuration does not exceed 0.881 (Koudelka, 1991b).

6.4 Single Package Evaluation

6.4.1 Configuration

Evaluation of a single package was not presented in the original package application.

6.4.2 Results

Evaluation of a single package was not presented in the original package application.

6.5 Evaluation of Package Arrays under Normal Conditions of Transport

6.5.1 Configuration

The analyses used to evaluate the package arrays were based on 10 CFR 71.61, previously titled "Fissile Class III". The regulations have been updated several times since the original submission and these specific requirements are no longer in existence:

§ 71.61 Specific standards for a Fissile Class III shipment.

a) Twice this number of undamaged packages would be subcritical if stacked together in any arrangement, assuming close reflection on all sides of the stack by water; and

The assumptions used for the calculations assumed that the given number fuel elements would be fully flooded and arranged to achieve optimal moderation and reflection geometry. No credit was given to highlight the negative reactivity (poison) effect of the steel in the package and the spacing between the packages in transport.

6.5.2 Results

This analysis assumed the four (4) fuel elements would be fully flooded and arranged to achieve optimal moderation and reflection geometry with no credit given to the package or spacing. The results are summarized in Table 6.1.2.1

6.6 Package Arrays under Hypothetical Accident Conditions

6.6.1 Configuration

The analyses used to evaluate the package arrays were based on 10 CFR 71.61, previously titled "Fissile Class III". The regulations have been updated several times since the original submission and these specific requirements are no longer in existence:

§ 71.61 Specific standards for a Fissile Class III shipment.

b) This number of packages would be subcritical if stacked together in any arrangement, closely reflected on all sides of the stack by water, and with optimum interspersed hydrogenous moderation. Except as permitted under § 71.41, each package must be considered to have been subjected to the tests specified in § 71.73 (Hypothetical Accident Conditions).

The assumptions used for the calculations assumed that the given number fuel elements would be fully flooded and arranged to achieve optimal moderation and reflection geometry. No credit was given to highlight the negative reactivity (poison) effect of the steel in the package and the spacing between the packages in transport.

6.6.2 Results

Two (2) packages contain no more than 720 g ^{235}U. Criticality cannot be achieved under any condition since this is less than the smallest mass of ^{235}U required to achieve criticality (NIST, 1992e).

6.7 Fissile Material Packages for Air Transport

6.7.1 Configuration

The package is not authorized for air transport of fissile material. Therefore, this section is not applicable.

6.7.2 Results

The package is not authorized for air transport of fissile material. Therefore, this section is not applicable.

6.8 Benchmark Evaluations

6.8.1 Applicability of Benchmark Experiments

According to Koudelka (1991a), the CSAS25 control module has been benchmarked against numerous known-critical systems by B&W and other organizations.

6.8.2 Bias Determination

According to Koudelka (1991a), B&W benchmark and validation work shows that the CSAS25 control module does not underestimate the actual K_{eff} value of a system by more than 2%. Therefore, a bias value of 0.02 plus two-sigma (2σ) was added to the calculated values of K_{eff} shown in Tables 6.1.2.1 and 6.1.2.2.

Table 6.1.2.1 – Four NBS Elements on Square Pitch in an Infinite Sea of Water

Run ID	Element Separation	Upper Limit of K_{eff}
NBSG	0.0 cm	0.708
NBSH	0.5 cm	0.734
NBSI	1.0 cm	0.726
NBSJ	3.0 cm	0.590
NBSK	30.0 cm	0.412

Table 6.1.2.2 – Seven NBS Elements on Square Pitch in an Infinite Sea of Water

Run ID	Element Separation	Upper Limit of K_{eff}
NBSB	0.0 cm	0.849
NBSC	0.5 cm	0.876
NBSD	1.0 cm	0.881
NBSEE	1.5 cm	0.874
NBSFF	2.0 cm	0.859

Figure Withheld Under 10 CFR 2.390

Figure 6.2.1.1 NBSR MTR-type Fuel Element

Figure Withheld Under 10 CFR 2.390

Figure 6.2.1.2 Typical Top and Bottom Flat Fuel Plate

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7 Package Operations

The required determinations and steps presented here were previously outlined in the "NIST "ST" Series Shipping Container Loading, Unloading, and Quality Assurance Procedure" and "NIST "ST" Series Shipping Container Shipper's Checklist" in the original package application. Some changes were required to determinations or steps used for package operations for clarity, consistency with other documents (e.g. certificate of compliance and engineering drawing), and to update steps that reference outdated regulatory requirements.

7.1 Package Loading

Local procedures, checklists, or other appropriate documents shall be written and utilized during shipping activities. The following routine determinations (from 10 CFR 71.87) are presented with guidance that can be used to develop steps or inspection points. Any documented results from these local procedures, checklists, or other appropriate documents at the time of each shipment should be retained in accordance with regulatory requirements, as appropriate.

Previously, the determinations in Section 7.1.1 and Section 7.1.2 were outlined in the "Loading, Unloading, and Quality Assurance Procedure" as presented in the original package application and required by Condition 6 in the Certificate of Compliance.

7.1.1 Preparation for Loading

Before each shipment of licensed material, the users of the package shall make the routine determinations listed in 10 CFR 71.87, as applicable.

Routine determination, 10 CFR 71.87(a):

The package is proper for the contents to be shipped.

Amplifying guidance:

The package is designed and approved for transportation of one NBSR unirradiated MTR-type fuel element.

Routine determination, 10 CFR 71.87(b):

The package is in unimpaired physical condition except for superficial defects such as marks or dents.

Amplifying guidance:

Inspect the package for any damage that could affect its integrity, e.g. cracks, weld failures, major deformations.

Routine determination, 10 CFR 71.87(i):

The level of non-fixed (removable) radioactive contamination on the external surfaces of each package offered for shipment is as low as reasonably achievable, and within the limits specified in DOT regulations in 49 CFR 173.443.

Amplifying guidance:

Contaminations surveys should be conducted on the package in accordance with local written instructions, as appropriate, to ensure the shipment is within the limits. This may require surveys to be conducted during preparations for loading, loading of contents, or preparation for transport.

Routine determination, 10 CFR 71.87(j):

External radiation levels around the package and around the vehicle, if applicable, will not exceed the limits specified in 10 CFR 71.47 at any time during transportation.

Amplifying guidance:

Radiation surveys should be conducted on the package in accordance with local written instructions, as appropriate, to ensure the shipment is within the limits. This may require surveys to be conducted during preparations for loading, loading of contents, or preparation for transport.

7.1.2 Loading of Contents

Before each shipment of licensed material, the users of the package shall make the routine determinations listed in 10 CFR 71.87, as applicable. Non-applicable determinations are included and discussed for completeness.

Routine determination, 10 CFR 71.87(c):

Each closure device of the packaging, including any required gasket, is properly installed and secured and free of defects.

Amplifying guidance:

Inspect all bolts, threads, and gasket for condition and damage. Appropriate inspection points that may be considered:

- Bolts –Any evidence of binding or galling during operation of the bolt? Any evidence of damage or rounding out to the bolt head?
- Threads – Any evidence of thread damage during operation or upon inspection?
- Gasket – Are there any portions of the gasket that are torn, ripped, fraying, or appear to interfere with the operation of the threaded fasteners?

Close the package using the cover and gasket. Assure that the cover is snug against the top support on the fuel element.

Tighten and torque all cover bolts to between 7 ft.lbs and 10 ft.lbs.

- The cover bolts are a commercial-off-the-shelf part and are not intended to be torqued in excess of 10 ft.lbs.

Using the hole in the threaded end of the bolt, attach a wire-type tamper seal.

- As discussed in Section 2.4.2, installation of a tamper-indicating feature is required to satisfy the general package requirement of 10 CFR 71.43(b).

Routine determination, 10 CFR 71.87(d):

Any system for containing liquid is adequately sealed and has adequate space or other specified provision for expansion of the liquid.

Amplifying guidance:

Considering the package design and contents, there is no system for containing liquid; therefore, this routine determination is not applicable.

Routine determination, 10 CFR 71.87(e):

Any pressure relief device is operable and set in accordance with written procedures.

Amplifying guidance:

Considering the package design and contents, there is no pressure relief device; therefore, this routine determination is not applicable.

Routine determination, 10 CFR 71.87(f):

The package has been loaded and closed in accordance with written procedures.

Amplifying guidance:

As discussed, the determinations and guidance in Section 7.1 shall be incorporated into written procedures, checklists, or other appropriate documents that will be utilized during shipping activities. Therefore, this routine determination should assure that those procedures are followed accordingly.

Routine determination, 10 CFR 71.87(g):

For fissile material, any moderator or neutron absorber, if required, is present and in proper condition.

Amplifying guidance:

Considering the package design and contents, there are no required moderators or neutron absorbers; therefore, this routine determination is not applicable.

Routine determination, 10 CFR 71.87(i):

The level of non-fixed (removable) radioactive contamination on the external surfaces of each package offered for shipment is as low as reasonably achievable, and within the limits specified in DOT regulations in 49 CFR 173.443.

Amplifying guidance:

Contaminations surveys should be conducted on the package in accordance with local written instructions, as appropriate, to ensure the shipment is within the limits. This may require surveys to be conducted during preparations for loading, loading of contents, or preparation for transport.

Routine determination, 10 CFR 71.87(j):

External radiation levels around the package and around the vehicle, if applicable, will not exceed the limits specified in 10 CFR 71.47 at any time during transportation.

Amplifying guidance:

Radiation surveys should be conducted on the package in accordance with local written instructions, as appropriate, to ensure the shipment is within the limits. This may require surveys to be conducted during preparations for loading, loading of contents, or preparation for transport.

Aside from these routine determinations, loading the contents of the package requires assembly or installation of supports to the fuel element to limit movement during normal conditions of transport. The following guidance is a suggested outline for assembly or installation of the support while inserting the fuel element into the package.

- Assemble nozzle support to fuel element.
- Insert fuel element into the package, nozzle end first. Assure that the fuel element is in contact with the bottom support and the rear of the package.
- Place top support in the end of the fuel element.
- Close the package using the cover and gasket. Assure that the cover is snug against the top support on the fuel element.

7.1.3 Preparation for Transport

Before each shipment of licensed material, the users of the package shall make the routine determinations listed in 10 CFR 71.87, as applicable. Non-applicable determinations are included and discussed for completeness.

Routine determination, 10 CFR 71.87(c):

Each closure device of the packaging, including any required gasket, is properly installed and secured and free of defects.

Amplifying guidance:

Verify the tamper seal is installed on the package. As discussed in Section 2.4.2, installation of a tamper-indicating feature is required to satisfy the general package requirement of 10 CFR 71.43(b).

Routine determination, 10 CFR 71.87(h):

Any structural part of the package that could be used to lift or tie down the package during transport is rendered inoperable for that purpose, unless it satisfies the design requirements of 10 CFR 71.45.

Amplifying guidance:

Considering the package design and contents, there are no structural parts of the package that could be used to lift or tie down the package during transport; therefore, this routine determination is not applicable.

Routine determination, 10 CFR 71.87(i):

The level of non-fixed (removable) radioactive contamination on the external surfaces of each package offered for shipment is as low as reasonably achievable, and within the limits specified in DOT regulations in 49 CFR 173.443.

Amplifying guidance:

Contaminations surveys should be conducted on the package in accordance with local written instructions, as appropriate, to ensure the shipment is within the limits. This may require surveys to be conducted during preparations for loading, loading of contents, or preparation for transport.

Routine determination, 10 CFR 71.87(j):

External radiation levels around the package and around the vehicle, if applicable, will not exceed the limits specified in 10 CFR 71.47 at any time during transportation.

Amplifying guidance:

Radiation surveys should be conducted on the package in accordance with local written instructions, as appropriate, to ensure the shipment is within the limits. This may require surveys to be conducted during preparations for loading, loading of contents, or preparation for transport.

Aside from these routine determinations, preparation for transport requires the following additional checks. These checks were previously outlined in the "NIST "ST" Series Shipping Container Shipper's Checklist" as presented in the original package application and required by Condition 6 in the Certificate of Compliance. The following language is suggested for inclusion in local procedures, checklists, or other appropriate documentation used for preparation for transport.

- Verify all required and any local quality assurance procedures are completed prior to shipment.
- Verify the package is labeled in accordance with regulatory requirements.
- As appropriate, verify that the shipment is in accordance with the Certificate of Compliance and meets any additional regulatory requirements or commitments. Examples of these requirements may include, but are not limited to: Exclusive use vehicle, Escorted (driver has companion), No more than two packages per vehicle.
- Verify that the shipping papers are filled out in accordance with regulatory requirements.
- As appropriate, verify all required shipping documentation is complete and provided to the driver.
- As appropriate, verify written instructions required for exclusive use shipments have been provided to the driver.

7.2 Package Unloading

In addition to local procedures, checklists, or other appropriate documents, the package shall be received and opened in accordance with the following applicable steps of 10 CFR 20.1906, "Procedure for receiving and opening packages".

Procedure for receiving and opening packages, 10 CFR 20.1906(b)(1):

Monitor the external surfaces of a package labeled with a Radioactive White I, Yellow II, or Yellow III label (as specified in U.S. Department of Transportation regulations) for radioactive contamination unless the package contains only radioactive material in the form of a gas or in special form as defined in 10 CFR 71.4.

Amplifying guidance:

The package does not contain radioactive material in the form of a gas or in a special form; therefore, contaminations surveys should be conducted on the package in accordance with local written instructions, as appropriate.

Procedure for receiving and opening packages, 10 CFR 20.1906(b)(2):

Monitor the external surfaces of a package labeled with a Radioactive White I, Yellow II, or Yellow III label (as specified in U.S. Department of Transportation regulations) for radiation levels unless the package contains quantities of radioactive material that are less than or equal to the Type A quantity, as defined in Sec. 71.4 and appendix A to part 71 of this chapter.

Amplifying guidance:

The package contains, but may not exceed, a Type A quantity of material; therefore, radiation surveys should be conducted on the package in accordance with local written instructions, as appropriate.

Procedure for receiving and opening packages, 10 CFR 20.1906(b)(3):

Monitor all packages known to contain radioactive material for radioactive contamination and radiation levels if there is evidence of degradation of package integrity, such as packages that are crushed, wet, or damaged.

Amplifying guidance:

Inspect the package for any damage that might indicate there could be damage to the fuel element inside the package. Suggested inspection points are upon receipt, while opening, and after unloading.

Procedure for receiving and opening packages, 10 CFR 20.1906(c):

Perform the monitoring required 10 CFR 20.1906(b) as soon as practical after receipt of the package, but not later than 3 hours after the package is received if it is received during normal working hours, or not later than 3 hours from the beginning of the next working day if it is received after working hours.

Amplifying guidance:

No further amplifying guidance is available.

Procedure for receiving and opening packages, 10 CFR 20.1906(d):

Immediately notify the final delivery carrier and the NRC Operations Center (301-816-5100), by telephone, when: (1) Removable radioactive surface contamination exceeds the limits of 10 CFR 71.87(i); or (2) External radiation levels exceed the limits of 10 CFR 71.47.

Amplifying guidance:

No further amplifying guidance is available.

Procedure for receiving and opening packages, 10 CFR 20.1906(e):

Establish, maintain, and retain written procedures for safely opening packages in which radioactive material is received; and ensure that the procedures are followed and that due consideration is given to special instructions for the type of package being opened.

Amplifying guidance:

Local procedures, checklists, or other appropriate documents shall be written specific to the package and utilized during package unloading.

Aside from the steps required by 10 CFR 20.1906, package unloading requires the following additional steps. These steps were outlined in the "Loading, Unloading, and Quality Assurance Procedure" as presented in the original package application and required by Condition 6 in the Certificate of Compliance. The following language is suggested for inclusion in local procedures, checklists, or other appropriate documentation used for package unloading.

- Verify the tamper seal is in place and intact. Verify the serial number on the seal is the same as indicated on the shipping papers. *(Note: installation of a tamper-indicating feature was required to satisfy the general package requirement of 10 CFR 71.43(b))*
- Remove the tamper seal, cover bolts, cover, and gasket.
- Remove the fuel element.
- Perform an initial inspection of the fuel element for any observable damage.
- Remove the top support and nozzle support.

7.3 Preparation of Empty Package for Transport

A separate procedure for preparing an empty package for transport was not provided in the original package application.

However, local procedures, checklists, or other appropriate documents shall be written and utilized to ensure the empty package is prepared for transport in accordance with the appropriate regulations and requirements.

7.4 Other Operations

There were no procedures for other operations identified in the original package application.

8 Acceptance Tests and Maintenance Program

8.1 Acceptance Tests

There are no specific first-use acceptance tests that were identified in the original package application. Additionally, there are currently no plans to construct any new ST packages that would require implementing acceptance tests.

8.1.1 Visual Inspection and Measurements

There are no specific first-use visual inspection and measurement tests that were identified in the original package application.

8.1.2 Weld Examinations

There are no specific first-use weld examinations that were identified in the original package application.

8.1.3 Structural and Pressure Tests

There are no specific first-use structural and pressure tests that were identified in the original package application.

8.1.4 Leakage Tests

There are no specific first-use leakage tests that were identified in the original package application.

8.1.5 Component and Material Tests

There are no specific first-use component and material tests that were identified in the original package application.

8.1.6 Shielding Tests

There are no specific first-use acceptance tests that were identified in the original package application.

8.1.7 Thermal Tests

There are no specific first-use thermal tests that were identified in the original package application.

8.1.8 Miscellaneous Tests

There are no specific first-use miscellaneous tests that were identified in the original package application.

8.2 Maintenance Program

8.2.1 Structural and Pressure Tests

There are no systems or components that necessitate periodic structural or pressure tests to ensure continued performance of the package.

8.2.2 Leakage Tests

There are no systems or components that necessitate periodic leakage tests to ensure continued performance of the package.

8.2.3 Component and Material Tests

There is no periodic test or replacement schedule for package components or materials.

Routine use of the package may cause fatigue or damage to the off-the-shelf components. This damage would most likely occur to the socket head cap screws or gasket. The socket head cap screws are used with the cover and gasket to close the package. The screws, which are tightened and torqued, will occasionally round-out or have thread galling issues and require replacement. The gasket material will occasionally tear from contact with one of the screws used to close the package and require replacement. Damage to these components will likely be identified during receipt, loading, and unloading.

8.2.4 Thermal Tests

There are no systems or components which would necessitate a periodic thermal test to ensure continued performance of the package.

8.2.5 Miscellaneous Tests

There are no periodic miscellaneous tests currently identified for the package or components.

9 References

Busch, R. D., Bowman, S. M. "The KENO V.a Primer," in proc. American Nuclear Society 2003 Annual Meeting "The Nuclear Technology Expansion: Unlimited Opportunities", June 1–5, 2003, San Diego, California.

Koudelka, A.J., to Baldwin, M.N. 1991a. Four NBSR Elements in Infinite Sea of Water. Memorandum. Babcock & Wilcox.

Koudelka, A.J., to Baldwin, M.N. 1991b. Seven NBSR Elements in Infinite Sea of Water. Memorandum. Babcock & Wilcox.

NIST. 1990a. Description of the N.I.S.T. Shipping Cask.

NIST. 1990b. NIST "ST" Series Shipping Container Specification.

NIST. 1990c. NIST "ST" Series Shipping Container – Testing for Normal Conditions of Transport. 2 pages.

NIST. 1990d. Package Type 7A Test Protocol.

NIST. 1990e. NIST "ST" Series Shipping Container Subcritical Analysis (10 CFR 71.61).

"SCALE - A Comprehensive Modeling and Simulation Suite for Nuclear Safety Analysis and Design," Oak Ridge National Laboratory, accessed September 23, 2011, http://scale.ornl.gov/index.shtml.

Slaback, Les. 1990a. "Certificate of Compliance". Memorandum. NIST.

Slaback, Les. 1990b. "DOT Type 7A Test of NIST "ST" Series Package". Memorandum. NIST. 2 pages.

Sturrock, Jack. 1990a. "Shipping Container Model ST Series" [Engineering Drawing]; Drawing D-04-048, Sheets 1 and 2, Revision 4. NIST, Gaithersburg, MD.

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10 Appendix

Scanned copies of select documents used in the original package application are provided in the following pages.

NIST
UNITED STATES DEPARTMENT OF COMMERCE
National Institute of Standards and Technology
Gaithersburg, Maryland 20899

(301) 975-6210
FTS 879-6210
FAX (301) 921-9847

February 7, 1992

Mr. Charles E. MacDonald
Chief, Transportation Branch
Division of Safeguards and Transportation
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. MacDonald:

The National Institute of Standards and Technology requests approval of its shipping container designated "ST" with the condition that two containers, each containing a single unirradiated NBSR fuel element, may be transported at one time in an exclusive vehicle. Enclosed are a description of the container and supporting documents.

Sincerely,

J. Michael Rowe
Chief, Reactor Radiation Division

Enclosure

DESCRIPTION OF N.I.S.T. SHIPPING CASK

(DOT TYPE 7A PACKAGE "ST" SERIES)

The N.I.S.T. Shipping Cask consists of a carbon steel welded tube, 5 1/2" outside diameter x 1/8" wall x 70" long, welded closed on one end with a 3/8" thick carbon steel plate and a 1/2" thick carbon steel flange welded to the other. This flange is tapped with eight 1/4-20 holes to receive a cover plate and 1/8" thick neoprene gasket with the same hole pattern. The attaching screws protrude through the flange and have a 1/16" diameter hole for attaching a seal. The fuel element has wooden attachments at each end that are assembled to it outside the cask. The wooden attachments are almost the same diameter as the inside diameter of the tube to restrict movement. A 3/16" sponge tape is also applied on the flange end as a cushion backup. The fuel element assembly is inserted and the cover and gasket applied and bolted then properly torqued and sealed. The loaded cask weighs approximately 55 pounds. At approximately 1/2" from each end is a 6 1/2" x 1/4" thick square plate with four 3/4" diameter holes for attachment of carrying handles. These holes are also to be used for securing the cask during shipment.

The design of this shipping cask complies with the requirements of 49CFR173.411 and 173.412. Specifically 49CFR173.412(b) is met by the holes for a seal, 173.412(f) is met by the bolted closure and the non-volatile nature of the contents, 173.412(i) is met by the designed limited area opening (22 in^2) and eight securing bolts, 173.412(l) is met by the design detail that the tie down flange is not an integral part of the containment portion of the package.

NIST "ST" SERIES SHIPPING CONTAINER
CONTAINER SPECIFICATION

Model:

ST series

Container Description

Each container consists of a 5.5" outside diameter carbon steel tube, 70" long, with flanges welded to each end, opening at one end only via a bolted cover plate. See attached drawing for detailed engineering specifications.

Classification: fissile material packaging.

Gross weight: approximately 75 lbs, with element

Containment system: Bolted closure

Construction materials: see attached drawing for size and material specifications, internal element support structure, and tie down fixtures. There are no valves, vents, or coolants in this system.

Content: one unirradiated NBSR MTR-type fuel element, nominally 350 grams of ^{235}U, not to exceed 360 grams of ^{235}U (see attached drawing)

Package Evaluation

The design specification and construction controls for this package are as specified in 49CFR173.24, 173.411, 173.412, 173.461, 173.462, and 173.465. Usage and package maintenance procedures are enclosed.

Shipping Configuration

Quantity: two packages per shipment, not to exceed a total quantity of 720 grams of ^{235}U. This amount is less than the least amount of ^{235}U that can be made critical under optimum conditions of moderation, reflection, shape, and purity.

Marking, labeling, placarding, shipping papers: as required by 49CFR.

Vehicle: Transport will be via an exclusive use vehicle.

Package tie-down: Each container shall be secured to the interior structure of the transport vehicle.

NIST
UNITED STATES DEPARTMENT OF COMMERCE
National Institute of Standards and Technology
Gaithersburg, Maryland 20899

(301) 975-6210
FTS 879-6210
FAX (301) 921-9847

February 14, 1992

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

Reference: Docket Number 71-9246

Dear Mr. MacDonald:

Enclosed please find the additional requested information pertaining to criticality (10CFR71.61), and package integrity 10CFR71.55. Revised drawings of the container (Revision 2) are attached. This reflects the removal of the lifting and tie-down eyelets from the package design. There are no tie-down or lifting devices which are a structural part of the package in this final design.

Sincerely,

J. Michael Rowe
Chief, Reactor Radiation Division

Enclosure

UNITED STATES DEPARTMENT OF COMMERCE
National Institute of Standards and Technology
(formerly National Bureau of Standards)
Gaithersburg, Maryland 20899

October 9, 1990

MEMORANDUM FOR Record

From: Les Slaback JS for LAS

Subject: **Certificate of Compliance**

Package: "ST" Series Container for NBSR Fuel Element

Specification: USDoT Type 7A

Date Tested: October 4-9, 1990

We herewith warrant and certify that the referenced containers have been manufactured and tested in accordance with:

10 CFR 71
49 CFR 173.411
49 CFR 173.412
49 CFR 173.415
49 CFR 173.417
49 CFR 173.461
49 CFR 173.465

Copies of relevant documentation are attached.

UNITED STATES DEPARTMENT OF COMMERCE
National Institute of Standards and Technology
(formerly National Bureau of Standards)
Gaithersburg, Maryland 20899

October 9, 1990

MEMORANDUM FOR Record

From: Les Slaback JS for LAS

Subject: DoT Type 7A Test of NIST "ST" Series Package

The "ST" series DoT Type 7A Radioactive Material Package is described in Enclosure 1. This package is designed to transport a single NBSR fuel element in compliance with 49CFR173 and 10CFR71.

The tested package is identical to those that will be used for transport, and in fact is itself expected to be used for transport. Prior to the sequence of tests, the package will be loaded with a dummy element as per the loading procedure (Enclosure 2). All tests required by 49CFR 173.465 are shown in Enclosure 3. These will be performed in sequence and the results recorded on Enclosure 3. Photographs will be taken of each test to document the physical conditions of the test.

Water Test: The sprinklers will be arranged so that all sides of the package are wetted. The simulated rainfall via sprinklers shall be measured and will exceed 2" per hour. A post test time delay to allow "soak in" is not required since this is a metal container. Following the test, the package will be examined for any deterioration or evidence of water entering the container.

Free Drop Test: The package will be dropped from a height of 4 foot onto a poured concrete pad. Because of the geometry of this package this test will be repeated such that

(1) the first drop is on the closed, welded end,
(2) the second drop is on the end with the removable plate, and
(3) the third drop is with the package horizontal.

Prior to the 4' free drop test the package will be dropped from a height of one foot on each corner of each end (four drops per end), as per 49CFR 173.365(c)(3). The package will be examined for any damage that could affect its integrity.

Penetration Test: A 6kg, 3.2cm diamater bar will be dropped so as to impact the center of the package from a height of 1 meter. The package shall be resting on an unyielding surface, positioned horizontally as it would be during a shipment. Because the bar must impact a curved surface of the package, care must be taken that the impact is not glancing. If the bar does not substantially recoil (bounce) vertically the test will be repeated.

The test bar will be examined for any deformity at the impact point (none permitted). The package will be examined for any damage that could affect its integrity.

Compression Test: This test will be applied in the geometry in which the package normally is positioned during shipment, that is with the longitudinal axis of the package horizontal and each end resting on an unyielding surface (concrete). The projected area of the package (5-1/2" diameter pipe, 70" long) is $2500cm^2$. This requires the greater of (1) 1300 kg/m^2 x 0.25 m^2 = 325 kg (715 lbs.), or (2) 5 x 55lbs. = 275 lbs. Hence 325kg will be placed along the length of the package by placing three layers of lead bricks, each layer consisting of eight bricks (11.9 kg/brick), plus four additional bricks for a total of 28 bricks (333kg) on top of the package. This will provide the uniform compresion loading on two sides as required by 49CFR 173.365(d). The load shall remain in place for 24 hours.

Upon completion of this test, the package will be examined for any damage that could affect its integrity.

Upon completion of the test sequence, the package will be opened. The dummy element will be examined for any damage that would indicate a possible failure of the package containment effectiveness. The interior of the package will be examined for any damage that could affect its integrity. Any observed damage will be documented on the testing results form.

Enclosure 3

PACKAGE TYPE 7A TEST PROTOCOL

Package Tested: Shipping Container for Single NBSR Fuel Element

Date of Test: 10/4/90

Package ID: PROTOTYPE

	PASS	FAIL
1. Pretest inspection (complies with drawings, no construction defects, no corrosion, no distortions)	✓	
2. Water spray test (Start time: 13:40) (The water spray test shall simulate exposure to rainfall of approximately 5 cm (2 inches) per hour for one hour. Time elapsed 1:05 hrs. Depth of water collected >3" inches.)	✓	
	Observation: NO Evidence of Deterioration	
3. Free drop test (Time: 15:05) (Free fall drop of 1.2 meters (4 feet) onto a flat, horizontal, unyielding surface.)	✓	
	Observation: Chipped paint but no Damage to structural integrity	
4. Penetration test (Time: 15:15) (One meter (3.3 feet) vertical drop of penetration test bar onto the center of the weakest part of packaging specimen.)	✓	
	Observation: Chipped paint and small (less than 1mm) Scratch in surface	
5. Compression test (Start time: 09:00) 10/5/90 Stopped 9:40 Am 10/9/90 (Compression test shall last for at least 24 hours and consist of 325 kg. of lead bricks placed along the length of the container, with the container in a horizontal position.)	✓	
	Observation:	

The test was started at 16:15 10/4/90 but the bricks fell during the night and was restarted using 30 bricks totalling 357 kg

Remarks: Note that it was raining moderately during the water spray test.

This package **has/~~has not~~** passed all DoT Type 7A tests (49CFR 173.365).

Tests Conducted By: Timothy F. Mengers
Print Name

Tim F. Mengers
Signature

Tests Observed By: JOHN SHUBIAK
Print Name

John Shubiak
Signature

NIST "ST" SERIES SHIPPING CONTAINER
TESTING FOR NORMAL CONDITIONS OF TRANSPORT

The "ST" series Fissile Material Package is designed to transport a single NBSR fuel element in compliance with 49CFR173 and 10CFR71. This package was tested to demonstrate its integrity for normal conditions of transport.

The tested package is identical to those that will be used for transport. Prior to the sequence of tests, the package was loaded with a dummy element. The dummy element is identical to a fueled element except for the absence of the fueled portion of the internal plates. All tests required by 10CFR71.71 were performed in sequence as outlined below. Photographs were taken to document the physical conditions of the test.

Water Test: The sprinklers were arranged so that all sides of the package are wetted. The simulated rainfall via sprinklers was measured and exceeded 2" per hour. A post test time delay to allow "soak in" was not required since this is a metal container. Following the test, the package was examined for any deterioration or evidence of water entering the container. No water entered the container.

Free Drop Test: The package was dropped from a height of 4 feet onto a poured concrete pad. Because of the geometry of this package this test was repeated such that

(1) the first drop was on the closed, welded end,
(2) the second drop was on the end with the removable plate, and
(3) the third drop was with the package horizontal.

Prior to the 4' free drop test the package was dropped from a height of one foot on each corner of each end (four drops per end). The package was examined for any damage that could affect its integrity. No damage was found.

Penetration Test: A 6kg, 3.2cm diameter bar was dropped so as to impact the center of the package from a height of 1 meter. The package was resting on an unyielding surface, positioned horizontally as it would be during a shipment. Because the bar must impact a curved surface of the package, care was taken that the impact was not glancing.

The test bar was examined for any deformity at the impact point; none was found. The package was examined for any damage that could affect its integrity. No damage was observed.

Compression Test: This test was applied in the geometry in which the package normally is positioned during shipment, that is with the longitudinal axis of the package horizontal and each end resting on an unyielding surface (concrete). The projected area of the package (5-1/2" diameter pipe, 70" long) is 2500cm^2. This requires the greater of (1) 1300 kg/m^2 x 0.25 m^2 = 325 kg (715 lbs.), or (2) 5 x 55lbs. = 275 lbs. Hence 325kg was placed along the length of the package by placing three layers of lead bricks, each layer consisting of eight bricks (11.9 kg/brick), plus four additional bricks for a total of 28 bricks (333kg) on top of the package. This provided the uniform compression loading on two sides as required by 10CFR71.71. The load remained in place for 24 hours.

Upon completion of this test, the package was examined for any damage that could affect its integrity. No damage was observed.

Upon completion of the test sequence, the package was opened. The dummy element was examined for any damage that would indicate a possible failure of the package containment effectiveness. The interior of the package was examined for any damage that could affect its integrity. Other than chipped paint on the exterior of the package no effects of the testing were observed on the package. The dummy fuel element also showed no effects from the testing. It was not distorted or marred in any way. The package clearly met all the performance requirements of 10CFR71.57(d).

NIST "ST" SERIES SHIPPING CONTAINER
SUBCRITICAL ANALYSIS (10CFR71.61)

Criteria: Twice this number of packages would be subcritical.

The attached report of a criticality analysis by the fabricator of the NBSR fuel, Babcock and Wilcox, demonstrates that up to seven undamaged NBSR fuel elements, arranged in any undamaged configuration, would be subcritical for any moderation and reflection geometry. No credit is taken for the poison effect of the steel in the package, nor for the spacing between packages.

Criteria: This number of packages would be subcritical if stacked together in any arrangement with optimal reflection and moderation.

Two (2) packages contain no more than 720 grams. Criticality cannot be achieved under any condition since this is less than the smallest mass of ^{235}U required to achieve criticality.

Babcock & Wilcox
a McDermott company

Naval Nuclear Fuel Division

To	A. J. Koudelka - NNFD-15A		
From	M. N. Baldwin - NNFD-15A	File No. or Ref.	MNB91-04
Subj.	FOUR NBSR ELEMENTS IN INFINITE SEA OF WATER	Date	1/31/91

REFERENCE 1: MEMO FROM J. W. HARWELL TO B. O. KIDD TITLED "NUCLEAR CRITICALITY SAFETY EVALUATION OF RIFLE RACKS IN THE RTRFE AREA TO INCLUDE ADDITIONAL ELEMENT TYPES," MARCH 28, 1989.

As you requested in response to a request from the National Institute of Standards and Technology, I have determined the upper limit of K-eff for four fully flooded NBSR fuel elements arranged 2x2 on a uniform square pitch in an infinite sea of water. The evaluation shows that the maximum K-eff value does not exceed 0.734.

For this evaluation, the basic NBSR element employed in Reference 1, and modeled in KENO Va was used. Each standard NBSR element was modeled explicitly to contain 17 fuel plates in the top and bottom fueled region, making a total of 34 fuel plates. The 2.436-Inch by 11.37-Inch by 0.020- Inch fueled portion of each plate is uniformly loaded with a matrix of 93% enriched UO2 and aluminum to give a total plate loading of 10.294 Grams U-235. Clad thickness is 0.01525 Inches and water gap spacing is 0.116 Inches. A 6.00 Inch long water-filled center section separates the top and bottom fueled regions of the element. Total U-235 loading for the element is 350 grams.

The computer code KENO Va and the 16-group Master Library from Scale-3 processed thru BONAMI were used for the calculations. This was accomplished through the use of the Scale-3 control module CSAS25. Scale-3 is a modular code system for performing standardized computer analyses for licensing evaluations. It was prepared for the U. S. Nuclear Regulatory Commission by Oak Ridge National Laboratory. The CSAS25 control module has been benchmarked against numerous known-critical systems by Babcock & Wilcox Company (B&W) in addition to many other organizations. Since B&W benchmark and validation work shows that this control module (with various option restrictions which B&W imposes on criticality safety calculations) never underestimates the actual K-eff value of a system by more than 2%, and since a statistical uncertainty is always associated with a KENO Va calculation, a bias value of 0.02 plus two-sigma is always added to the calculated value when criticality safety is the consideration.

Five calculations, representing variations in the element spacing were made. The results presented in Table 1 include the two-sigma uncertainty and the 0.02 bias. K-eff is at a maximum when the element separation is about 0.5 Cm.

Although this evaluation uses the same calculational techniques, codes, bias value and cross-section library as would an internal criticality safety evaluation, and although the writer is confident that the K-eff quoted is conservative for safety considerations, and although it has been independently reviewed by another criticality safety engineer who has included his QA statement; this memo does not address many items that would be required by our evaluation procedures (such as review of required procedures, double contingency evaluation, posting requirements, etc.). This memo is not intended to constitute a criticality safety evaluation as defined by our procedures, and must not be subject to audit as a criticality safety evaluation. It is rather, what our customer requested: a determination of the upper limit of K-eff for four fully flooded NBSR fuel elements arranged 2x2 on a uniform square pitch in an infinite sea of water.

M. N. Baldwin

M. N. Baldwin

QA Statement:

I have reviewed these calculations and concur with the model, the codes used, the calculational techniques, the cross-section library, the results and conclusions. I further concur that this evaluation is not and is not intended to be a criticality safety evaluation as defined by NNFD procedures.

J. W. Harwell

J. W. Harwell

cc: FM Alcorn, NNFD-15A
JJ Bazley, NNFD-15A
AB Croft, NNFD-15A
RL Dunham, NNFD-15A
JW Harwell, NNFD-15A
BO Kidd, NNFD-15A
TD Lee, NNFD-35
RB Park, NNFD-15A
LL Wetzel, NNFD-15A

**TABLE 1 - RESULTS OF CSAS25 RUNS -
FOUR NBS ELEMENTS ON SQUARE PITCH
IN AN INFINITE SEA OF WATER**

RUN ID	ELEMENT SEPARATION	UPPER LIMIT* OF K-EFF
NBSG	0.0 CM.	0.708
NBSH	0.5 CM.	0.734
NBSI	1.0 CM.	0.726
NBSJ	3.0 CM.	0.590
NBSK	30.0 CM.	0.412

* calc. K-eff + two-sigma + 0.02

Babcock & Wilcox
a McDermott company

Naval Nuclear
Fuel Division

To	A. J. Koudelka, NNFD-46
From	M. N. Baldwin, NNFD-46
File No. or Ref.	MNB91-08
Subj.	SEVEN NBSR ELEMENTS IN INFINITE SEA OF WATER
Date	APRIL 26, 1991

Reference 1: MEMO FROM M N BALDWIN TO A J KOUDELKA TITLED "FOUR NBSR ELEMENTS IN INFINITE SEA OF WATER", JANUARY 31, 1991.

Reference 2: MEMO FROM J W HARWELL TO B O KIDD TITLED "NUCLEAR CRITICALITY SAFETY EVALUATION OF RIFLE RACKS IN THE RTRFE AREA TO INCLUDE ADDITIONAL ELEMENT TYPES", MARCH 28, 1989.

In response to a request to you from the National Institute of Standards and Technology, I determined and reported in Reference 1, the upper limit of K-eff for four fully flooded NBSR fuel elements arranged in their most reactive configuration in an infinite sea of water. The evaluation showed that the maximum K-eff value for four elements does not exceed 0.734.

Recently, a second request was received from the National Institute of Standards and Technology for the upper limit on K-eff for seven fully flooded and reflected elements. This second evaluation shows that the maximum K-eff value for seven elements does not exceed 0.881.

The methods used are basically the same as previously reported, but descriptions are repeated herein for the convience of the reader.

For this evaluation, the basic NBSR element employed in Reference 2, and modeled in KENO Va was used. Each standard NBSR element was modeled explicitly to contain 17 fuel plates in the top and bottom fueled region, making a total of 34 fuel plates. The 2.436-inch by 11.37-inch by 0.020-inch fueled portion of each plate is uniformly loaded with a matrix of 93% enriched UO2 and aluminum to give a total plate loading of 10.294 Gm U-235. Clad thickness is 0.01525 inches and water gap spacing is 0.116 inches. A 6.00 inch long water-filled center section separates the top and bottom fueled regions of the element. Total U-235 loading for the element is 350 grams.

UNCLASSIFIED
Arne J. Olsen 5/7/91
Classifier Date

The computer code KENO Va and the 16-group Master Library from Scale-3 processed through BONAMI were used for the calculations. This was accomplished through the use of the Scale-3 control module CSAS25. Scale-3 is a modular code system for performing standardized computer analyses for licensing evaluations. It was prepared for the U. S. Nuclear Regulatory Commission by Oak Ridge National Laboratory. The CSAS25 control module has been benchmarked against numerous known-critical systems by Babcock & Wilcox Company (B&W) in addition to many other organizations. Since B&W benchmark and validation work shows that this control module (with various option restrictions which B&W imposes on criticality safety calculations) never underestimates the actual K-eff value of a system by more than 2%, and since a statistical uncertainty is always associated with a KENO Va calculation, a bias value of 0.02 plus two-sigma is always added to the calculated value when criticality safety is the consideration.

Five calculations, representing variations in the element spacing were made. The results presented in Table 1 include the two-sigma uncertainty and the 0.02 bias.

Although this evaluation uses the same calculational techniques, codes, bias value and cross-section library as would an internal criticality safety evaluation, and although the writer is confident that the K-eff quoted is conservative for safety considerations, and although it has been independently reviewed by another criticality safety engineer who has included his QA statement; this memo does not address many items that would be required by our evaluation procedures (such as review of required procedures, double contingency evaluation, posting requirements, etc.). This memo is not intended to constitute a criticality safety evaluation as defined by our procedures, and must not be subject to audit as a criticality safety evaluation. It is rather, what our customer requested: a determination of the upper limit of k-eff for seven fully flooded NBSR fuel elements in an infinite sea of water.

M. N. Baldwin

M. N. BALDWIN

QA statement:

I have reviewed these calculations and concur with the model, the codes used, the calculational techniques, the cross-section library, the results and conclusions. I further concur that this evaluation is not and is not intended to be a criticality safety evaluation as defined by NNFD procedures.

J W Harwell

J. W. Harwell

TABLE 1 - RESULTS OF CSAS25 RUNS -
SEVEN NBS ELEMENTS IN AN INFINITE SEA OF WATER

RUN ID	ELEMENT SEPARATION	UPPER LIMIT OF K-EFF *
NBSB	0.0 CM.	0.849
NBSC	0.5 CM.	0.876
NBSD	1.0 CM.	0.881
NBSEE	1.5 CM	0.874
NBSFF	2.0 CM	0.859

* calc. K-eff + two-sigma + 0.02

TOTAL P.05

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