71-9022

10D

EXXON NUCLEAR COMPANY, INC.

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Process & Equipment Engineering Department

PDR Return to 396SS

July 10, 1985 '85 JUL 15 P3:03

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amendment
7/19/85
Jackson

Mr. Charles E. MacDonald, Chief
Transporation Certification Branch
Division of Fuel Cycle & Material Safety, NMSS
U.S. Nuclear Regulatory Commission
Washington, DC 20555

License No. SNM-1227
Docket No. 70-1257

Dear Mr. MacDonald:

CERTIFICATE OF COMPLIANCE NO. 9022.

We (Exxon Nuclear Co., Inc.) request revisions to the subject Certificate of Compliance:

Section 5(b)(1)

Please change the enrichment limit from 4.1 wt% to 5.0 wt%.

Section 5(b)(2)

Proposed limits: "Net weight of containment vessel not to exceed 170 kgs total and 120 KgU. All uranium to be within the 11-1/2" ID x 57-1/4" long boundary of the containment vessel."

Section 5(c)

Please change minimum transport index to 0.5.

The attached application demonstrates conformance to all requirements of 10 CFR 71 and the 1973 IAEA regulations.

A check for the $150 application fee is enclosed.

We request your timely consideration of this application. We plan to use the revised Certificate of Compliance in obtaining a revised Certificate of Competent authority and transportation licenses in foreign countries before the September 30, 1985 expiration date of the current Certificate of Competent authority.

25572

Adv. Copy to FCTC 07/18/85

If the proposed Certificate of Compliance could be issued by August 15, 1985, then we would not be forced to use Revision 10, which does not meet 1973 IAEA regulations.

I am available to discuss questions that may arise during the review of this application ((509) 375-8656).

Sincerely,

Lonnie D. Gerrald

L. D. (Lonnie) Gerrald
Corporate Licensing

LDG:jrs

Enclosure
As Stated

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DATE OF DOC. 07/10/85

DATE RCVD. 07/15/85

FCUF ______ PDR ✓

FCAF ______ LPDR ______

WM ______ I&E REF. ✓

WMUR ______ SAFEGUARDS ______

FCTC ✓ OTHER ______

DESCRIPTION:

request revision for the Certificate of Compliance

07/26/85 INITIAL CEC

SHIPPING CONTAINER APPLICATION

1.0 GENERAL INFORMATION

1.1 Introduction

This amended application is submitted for approval for delivery to a carrier for transport of Combustion Engineering's CE-250-2 shipping container. The CE-250-2 shipping container will be used for the transport of uranium oxide with an H/U atomic ratio $\leq$ 2.26 and an U-235 enrichment $\leq$ 5 wt%. This shipping container meets the criteria of 10 CFR Part 71.59 for shipping as Fissile Class II, with a maximum of 100 packages per shipment and a transport index of 0.5.

1.2 Package Description

1.2.1 Packaging

The CE-250-2 package consists of a 16-gauge steel inner container 11-5/8" outer diameter by 57-1/4" long, with a bolted and gasketed top flange closure and steel welded bottom plate. The inner container is centered within a 22-1/2" I.D. by 68-3/8" long 16-gauge outer steel drum. The inner container is supported by twelve 1/4" diameter steel springs welded to the inner container at the top flange and the bottom of the container. The void space between the inner and outer container is filled with vermiculite.

The CE-250-2 package design incorporates two containment boundaries. The primary containment consists of the outer 16-gauge steel drum, and the secondary containment consists of the bolted and gasketed inner container.

Closure of the inner container is maintained by a heat resistant gasket and six 1/2" hex head bolts and nuts. These bolts and nuts secure the 1/2" steel inner lid to the package. The outer container is then sealed with a standard 17H 12-gauge bolt ring over the 16-gauge outer lid.

The weight of the package is approximately 575 lbs when loaded, and constructed in accordance with Combustion Engineering's Drawing No. NFM-E-Z2175 Rev. 2, attached as Appendix 1.4.

It should be noted that the CE-250-2 package does not contain any valves, sampling ports or protrusions.

1.2.2 Operational Features

Not Applicable - The CE-250-2 package is a simple design with no operational features.

1.2.3 Contents of Packaging

Each package will be limited to a maximum of 300 pounds (136 kilograms) of uranium oxide (UO_2 or U_3O_8), in either powder or pellet form, enriched to a maximum of five weight percent (wt%) and having $H/U \leq 2.26$. Each powder or pellet container will have a gasketed, tight fitting lid. The containers may be either round powder cans or rectangular pellet boxes. At a maximum of 5 wt% U_{235}, the package would contain a maximum of 6.0 kg of U_{235}. The maximum radioactivity for each package is 0.324 curies, and with 100 packages per shipment, yielding 32.4 curies of radioactivity per Fissile Class II Shipment (Specific Activity from Table A-4, 10 CFR 71).

1.2.4 Other Data

The inner container will be sealed at room temperature and pressure. Since the decay heat from 5 wt% uranium oxide is minimal, no coolants are necessary.

1.3 Quality Assurance

A Quality Assurance program for the CE-250-2 has been approved by the U.S. Nuclear Regulatory Commission.

1.4 Appendix

Dimensional details of the CE-250-2 shipping container are described in CE Drawing NFM-E-Z2175, Rev. 2, attached.

2.0 STRUCTURAL EVALUATION

2.1 Structural Design

2.1.1 Discussion

The secondary containment of the package is the 11-1/2" I.D. x 57-1/4" long 16-gauge steel inner container. The inner container closure is achieved by securing a 1/2" steel lid to the inner flange with six 1/2" hex head bolts and nuts, tack welded to the flange.

The primary containment vessel consists of two 55-gallon drums which have been welded together to the following dimensions: 22-1/2" I.D. x 68-3/8" long. The closure of the outer container is assured by a standard 17H 12-gauge ring with 5/8" bolt and nut. See View B on Drawing NFM-E-Z2175.

2.1.2 Design Criteria

The test results described in Appendix 2.9 support the structural requirements specified in 10 CFR Parts 71.71 and 71.73.

2.2 Weights and Centers of Gravity

The CE-250-2 container weighs approximately 575 lbs when loaded. The containers of uranium oxide weigh about 300 lbs, with the CE-250-2 container weighing about 275 lbs. The container is approximately symmetrical; the center of gravity is at the center of the container. When the cans are loaded inside the inner container, the center of gravity shifts vertically to a slightly lower point because of the spacer used to make up the remaining volume within the inner package.

2.3 Mechanical Properties of Materials

Materials of all structural components used in the manufacture of the container have physical and mechanical properties equivalent to or better than 16-gauge steel.

2.4 General Standards for All Packaging

2.4.1 Chemical and Galvanic Reactions

There are no significant chemical, galvanic or other reactions among the packaging components and the package contents. The CE-250-2 shipping container is fabricated of carbon steel. The contents are: vermiculite for insulation between the outer and inner containers,and steel cans containing uranium oxide in either the powder or pellet form.

2.4.2 Positive Closure

Positive closure of the CE-250-2 containers is assured by: 1) The inner container being gasketed and sealed with six hex head bolts and nuts and 2) the outer container being sealed by a standard 17H 12-gauge bolt locking ring with drop forged lugs, one of which is threaded, having a 5/8-inch diameter bolt and lock nut. Both of these closure systems insure that the container cannot be inadvertently opened. Each package incorporates provisions for a tamper-proof seal.

2.4.3 Lifting Devices

No lifting devices are incorporated as a structural part of this container.

2.4.4 Tie Down Devices

No tie down devices are incorporated as a structural part of this container.

2.5 Normal Conditions of Transport

The CE Model 250-2 package is identical to the Westinghouse BB-250-2 package, except that the overall length is 68-3/8 inches and the inner container length is 57-1/4 inches (compared to 74 and 63-1/2 inches, respectively). These packages both utilize design concepts which are similar to those used in the design of the NUMEC LA-36 and Pu 10-I packages. These packages were tested in accordance with the requirements specified in 10 CFR Part 71.71 for normal conditions of transport, to assure compliance with the standards outlined in Section 71.59. (See Appendix 2.9 for tests performed on the NUMEC Pu 10-I and LA-36 containers.)

2.6 Hypothetical Accident Conditions

This section describes the hypothetical accident conditions as specified in 10 CFR 71.73, and meets the standards in 71.59. The inner container of the CE-250-2, when fully loaded, weighs approximately 340 lbs, over a base area of 106 in^2, resulting in a vertical loading of 3.2 lbs/in^2. The inner container of the NUMEC Pu 10-I package, when fully loaded, including the neutron moderator, weighs 279 lbs over a base area of 78.54 in^2, resulting in a vertical loading of 3.55 lbs/in^2. Thus, the tests performed on the latter container are valid for the CE-250-2 package.

As a result, it is concluded that:

1) The integrity of the package is not affected by the test. Separation of the lid from the drum does not occur. In this connection, test experience with the BB-250-1 shows that, as a result of a top corner drop, the lid and the body are folded together into a tighter closure.

2) The incorporation of five inches of vermiculite is equal to that provided in the NUMEC package, and is sufficient to assure that after the drop and thermal tests, the temperature of the inner container of the CE-250-2 package would not exceed the observed maximum of 500°F. Since the gasket is service-rated to 800°F, the closure of the inner container is not compromised.

3) The test series does not result in the addition of moderation to the contained fissile material.

4) The dimensions of a damaged package are conservatively taken to be 20 inches O.D. x 64-3/8 inches long. This assumes a reduction of 2-1/2 inches in diameter as the result of a drop test with the package in a horizontal position, plus a reduction of 4 inches in height as a result of a drop test with the package in a vertical position. No deformations in excess of these values were experienced during the testing of the Pu 10-I package. See Appendix 2.9 for BB-250-2 and Pu 10-I test results.

2.7 Special Form

N/A; all radioactive material in the packages is in normal form.

2.8 Fuel Rods

N/A; the CE-250-2 package is not used for the shipment of fuel rods.

2.9 Appendix

1) BB-250-2 Test Results - Westinghouse SNM-338.

2) NUMEC Pu 10-I Test Results SNM-414.

3) NUMEC IA-36 Test Results SNM-145.

3.0 THERMAL EVALUATION

Materials of all structural components used in the manufacture of the container have physical and mechanical properties equivalent to or better than mild steel throughout a temperature range of $-40^{o}F$ to $1500^{o}F$.

See Appendix 2.9, Page VI-7, of NUMEC Pu 10-I tests "No damage was suffered by any of the components or materials of construction due to exposure to the thermal test".

4.0 CONTAINMENT

4.1 Containment Boundary

The primary containment of the CE-250-2 package is the outer 16-gauge 55-gallon drums which have been welded together (22-1/2 inches I.D. x 68-3/8 inches long). The secondary containment boundary is the 16-gauge steel inner container, 11-5/8 inches outer diameter x 57-1/4 inches long. As a result of the tests performed on the Westinghouse BB-250-2 and the NUMEC Pu 10-I containers, it was determined that the integrity of the CE-250-2 package would not be affected by the test conditions.

4.1.1 Containment Vessel

The outer shell of the CE-250-2 package is composed of two 55-gallon drums made of 16-gauge steel welded together.

4.1.2 Containment Penetrations

There are no penetrations into the primary containment.

4.1.3 Seals and Welds

All seals and welds are specified in Drawing NFM-E-Z2175, Rev. 2.

4.1.4 Closure

Closure of the outer container is achieved by using a standard 17 H 12-gauge nut and bolt ring securing the 16-gauge outer lid. The closure of the inner container is maintained by a gasket and six hex head bolts (1/2 inch 13 UNC-2A x 1-3/4 inches long) and nuts (1/2 inch 13 UNC-2B). These two closure devices provide positive sealing of the container.

4.2 Requirements for Normal Conditions of Transport

It is concluded that under normal conditions of transport, as specified in 10 CFR Part 71.71, the test results described in Section 2.6 of this application indicate the following:

1) There will be no release of radioactive material from the containment vessel;

2) The effectiveness of the packaging will not be reduced;

3) There will be no mixture of gases or vapors in the container which could, through any credible increase of pressure or an explosion, significantly reduce the effectiveness of the package; and

4) The package is so designed and constructed, and its contents so limited, that under the normal conditions of transport specified in 10 CFR Part 71.71:

   (a) The package will be subcritical;

   (b) The geometric form of the package contents will not be substantially altered; and

   (c) There will be no substantial reduction in the effectiveness of the packaging, including:

      (i) Reduction by more than 5 percent in the total effective volume of the packaging on which nuclear safety is assessed;

      (ii) Reduction by more than 5 percent in the effective spacing on which nuclear safety is assessed, between the center of the containment vessel and the outer surface of the packaging; or

      (iii) Occurrence of any aperture in the outer surface of the packaging large enough to permit the entry of a 4-inch cube.

4.3 Containment Requirements for the Hypothetical Accident Conditions

The effect on the loaded CE-250-2 container of conditions hypothesized to occur in an accident was assessed during the testing of a loaded NUMEC Pu 10-I container. Two 30-foot free drop tests and puncture tests, as specified in 10 CFR Part 71.73, were conducted.

These tests demonstrated that no radioactive material would be released.

The thermal tests performed on the NUMEC Pu 10-I container demonstrated that no damage was suffered by any of the components or materials of construction during the thermal test.

Examination of the containers, subsequent to their removal from 24 hours of immersion under three feet of water, revealed that no water leaked into the containment vessel.

It was evident from the above tests that the package would remain subcritical because the material remains confined to a subcritical geometry and the geometric form of the contained material is not altered.

5.0 SHIELDING EVALUATION

N/A; the packages are used for the shipment of uranium oxide in pellet or powder form in steel cans, which are then placed in the container.

The dose rate at one meter from the CE-250-2 containing low-enriched uranium is estimated to be equal to or less than that for a transport index of 0.5 due to the Fissile II classification. Thus, shielding is not a part of the construction of the package.

6.0 CRITICALITY SAFETY EVALUATION

6.1 Introduction

This criticality safety analysis demonstrates conformance to the requirements of 10 CFR 71.59 for Fissile Class II shipments. The proposed transport index is 0.5 which corresponds to 100 (max) containers per shipment.

6.2 Analysis Criteria

6.2.1 Assumed Array Size

The models analysed for normal and accident conditions were arrays of 500 (minimum) and 200 (minimum) containers, respectively.

The containers were stacked edge-to-edge in all directions in all models. Containers are normally shipped on wooden pallets which provide about 8" edge-to-edge spacing between tiers of containers. This spacing and the wood of the pallet were conservatively neglected.

The containers (500 or 200 minimum) were stacked in three dimensions in the optimum arrangement, taken here as that cuboidal arrangement with the minimum geometric buckling for the given number of containers. (In this optimum arrangement, the overall array shape would be cubical.) The cylindrical container has a length-to-diameter ratio of about 3/1 at both normal and accident conditions. Assuming that N containers are placed end-to-end (end faces of cylinders touching), the optimum stacking pattern would be 3N by 3N by N. Therefore, the product 3Nx3NxN must be at least 500 (normal) or 200 (accident). The normal condition array is 12x12x4 or 576 containers. The accident condition array is 9x9x3 or 243 containers. Thus, the 500 and 200 minimum requirements are conservatively met.

6.2.2 Reflection

All models employed full water reflection (12" thick, 1.0 gm/cc density) at all faces of the array.

6.2.3 Moderation

6.2.3.1 Internal Moderation

The moderation inside the inner vessel was fixed at an H/U ratio of 2.26 for all cases analysed. For the UO_2 powder cases, this was modeled at 7% water in the UO_2-Water mixture. For the UO_2 pellet cases, this was modeled as a cell-weighted mixture (homogeneous cross sections) representing 0.5" diameter x 57.25" long pellets (95% TD) on a 1.2228" square pitch with water (0.1185 gm/cc) between the pellets.

In practice, the H/U ratio determination for a shipment will include all materials within the inner vessel.

The sealed (gasketed) inner vessel provides resistance to water (or other hydrogenous material) entry for all credible accident conditions. Additional resistance to increasing the H/U of the U oxide is provided by the required sealed steel container within the inner vessel.

If water entered the gasketed inner vessel, but not the U oxide container, the H/U of the inner vessel would be increased although the resulting effect on the k-eff would be similar to that of increasing the density of the interspersed moderator; a safe condition.

Therefore, internal moderation control is provided at maximum credible accident conditions and the fissile material need not be analysed at optimum moderation.

6.2.3.2 External Moderation

The optimum moderation conditions were determined for each array. The moderator was water uniformly interspersed between containers and in the container annulus. The annulus normally contains vermiculite. Cases with vermiculite in the annulus and water between containers were also analysed.

All tabulated results referring to a variable water density or moderator density refer to this external moderator rather than the internal moderation.

6.2.4 Neutron Absorbers

The models did include some of the steel of the containers.

The steel of the inner vessel was explicitly modeled as carbon steel. This includes a 16-gauge wall, a 0.125" thick bottom, and a 0.5" thick lid.

All surfaces of the outer container (drum) were explicitly modeled as 16-gauge carbon steel.

The actual container has considerably more steel than in the model. Therefore, the model is conservative.

6.2.5 Fissile Materials

The proposed constraints on fissile materials in the container are:

1) Maximum Enrichment - 5.0 wt% U-235.

2) Maximum Mass - 300 pounds uranium oxide.

3) H/U (atom ratio) - 2.26 (maximum).

4) Geometry Restrictions (within inner vessel) - None.

5) U-235 Mass Restrictions - No explicit limit. Implicit limit is 6 kg U-235 based on 120 kg uranium at 5 wt% U-235.

6) Form - Uranium oxide as powder or pellets.

For comparison, the constraints of the current Certificate of Compliance are:

1) Maximum Enrichment - 4.1 wt% U-235.

2) Maximum Mass - 300 pounds total.

3) H/U (atom ratio) - 2.26 (maximum).

4) Geometry Restrictions - 73.2 in^2 (max.) fissile cross sectional area.

5) U-235 Mass Restrictions - 4.5 kg (max.).

6) Form - Uranium oxide as powder or pellets.

The models employed to justify the proposed constraints had the following characteristics:

1) Enrichment - 5 wt% U-235.

2) Fissile Mass - 120 kg uranium (about 300 pounds UO_2).

3) H/U - 2.26 (represented as 22.6 lbs water in about 323 lbs UO_2-water).

4) Geometry - The most reactive geometry for the 323 lbs of UO_2-water in the inner vessel is to fill this vessel with UO_2-water with a density near 1.2 gm U/cc. Higher uranium densities are less reactive because the fissile volume must be reduced to maintain the fixed mass (323 lbs UO_2-water). Lower uranium densities would result in less than 120 kgU and lower array k-effectives. Evidence supporting these statements is presented in this analysis.

5) U-235 Mass - The U-235 mass is controlled by the total fissile mass and the enrichment specifications. A separate specification is not needed.

6) Form - UO_2 was employed in all models. UO_2 is more reactive than other forms such as U_3O_8 or UO_3.

Cases with powder and pellets were analysed to assure acceptability of both homogeneous (powder) and heterogenous (pellets) uranium oxides.

6.3 Analysis Methods

k_{eff} for the arrays were calculated using KENO-IV and the Hansen-Roach cross section library. The KENO code was obtained from the Radiation Shielding Information Center (RSIC) as part of the SCALE-2 system. All code revisions

provided by the RSIC newsletter and by personal communications with code experts at ORNL have been implemented. Evidence of validation of these methods will be presented in a later section of this analysis.

6.3.1 Geometry Models

Typical KENO input listings are attached for reference.

The basic unit is composed of five regions:

1) UO_2-water in inner vessel.

2) Carbon steel wall, bottom and lid for this vessel.

3) Annulus between inner vessel and outer container (drum).

4) Carbon steel wall, bottom and lid for the drum.

5) Interspersed moderator in the volume between the drum and a cuboid tangent to the drum surfaces and to the drum end faces.

The basic unit (Box Type 1) is stacked into the array being analysed (12x12x4 or 9x9x3) and then full water reflection is applied at the six faces of the array.

A differential albedo (#1012 in the KENO library - 30.48 cm water) was used to simulate the reflector. This albedo was validated at Exxon Nuclear Company using critical experiment data (Section 6.5.2).

6.3.2 Cross Sections

The Hansen-Roach library contains several cross section sets for U-235 and U-238. The 16-group sets differ from each other in the cross section data for groups 8-12 (resonance region). The appropriate sets were selected by matching the sigma-m (effective) (hereafter, sig-m) of the fissile material being analysed to the sigma-p (sig-p) identity of the cross section set. If the desired sig-p was between that of two available sets, a weighted average of the two sets was typically used to simulate the needed nuclide.

The sig-m for each mixture being analysed was calculated using a subroutine added to the standard KENO code. Neutron collision data are stored in KENO subroutine BEGIN and then processed in the added subroutine to calculate the sig-escape, sig-p and sig-m for each fissile mixture using the collision data, the macroscopic cross sections for the mixture, and the atom density for the nuclide. These data are weighted averages for groups 8-12. The output from each KENO run includes these data in addition to standard KENO output data.

Thus, each KENO run provides feedback on the accuracy of the parameters used to select cross sections. The KENO-derived parameters should be more accurate because the actual system model is used rather than the cruder approximations often employed. These methods have been extensively checked for validity.

As stated above, the calculated sig-m's are compared to the sig-p's of the input nuclides for each KENO run. If the calculated sig-m is greater than the sig-p of the set used, the calculated k-eff will tend to be biased high (conservative) and the run is not repeated with a more appropriate set (sig-p) unless a more accurate k-eff is needed. If the calculated sig-m is lower than the sig-p of the set used, the k-eff will be biased low (non-conservative) and the run will be repeated with the appropriate cross section sets, unless the sig-m:sig-p difference is small or a course search yields an obviously poor result.

The sig-p of the cross section sets used and the KENO-calculated sig-m data are provided for reference.

The Hansen-Roach library (Knight-modified) was used because:

1) The cross sections yield amazingly good results. For most cases analysed with 16 group and 123 group cross sections, the resulting k-eff's are not significantly different.

2) If reasonable care is taken in accounting for resonance effects, the k-eff results tend to be conservative.

3) Group data from KENO such as flux, leakage, and absorptions are easier to check for anomalies and to interpret with 16 groups compared to (for example) 123 groups).

6.4 KENO Results

6.4.1 Normal Conditions

Undamaged containers were stacked into a 12x12x4 array. The array faces were reflected by 12" of full density water.

The optimum moderation search results are in Table 1. All of these cases had the tabulated interspersed moderator between containers. Unless otherwise noted, this moderator was also assumed in the annulus between the inner vessel and the drum.

The Table 1 data indicate that:

1) The peak k-eff is 0.922 $\pm$ 0.007.

2) Although the above k-eff occurred in a vermiculite-in-annulus case, the water-in-annulus peak k-eff is not significantly different.

3) The array is subcritical by a considerable margin even if a reasonable allowance is made for the possibility of a higher k-eff at a moderator density between two tabulated values.

4) The optimum interspersed water density is about 0.04-0.08 gm/cc.

5) There is no evidence that pellets are more reactive than powders given the limits on geometry, mass and internal moderation.

The Table 1 search data were generated using 83 generations of 100 neutrons each. All of the results appear reasonably converged; there was no significant trend as generations were omitted from the final average.

To verify the adequacy of these approximate 8,000 neutron results, a case was run again with 83 generations of 250 neutrons. The third case in Table 1 (6% interspersed water, powder, no vermiculite) was selected. The second run result was 0.911 ± 0.004 for approximately 20,000 neutron histories. This result is slightly lower than the approximate 8,000 neutron results (0.918 ± 0.007) but the difference is not significant.

Since all results are considerably subcritical and given the replication results with more histories, these data are adequate to demonstrate subcriticality.

Table 2 contains additional data for cases of UO_2-water powder mixtures at 3.0 gm U/cc instead of the 1.2 gm U/cc density of Table 1. Although the inner vessel did contain 323 lbs of UO_2-water, the fissile volume was reduced from 100 liters to 40 liters.

The effect of decreased diameter of vessel at constant length and decreased length at constant diameter were examined. In each case, the fissile volume was placed symmetrically within the inner vessel. In each case, the 60 liters not occupied by fissile material was void.

The Table 2 data indicate that the full inner container at a lower powder bulk density is more reactive than higher powder densities with reduced volumes. All results, except those of Table 2, used the full container model.

6.4.2 Accident Conditions

The contents and the dimensions of the inner vessel are not changed in the accident case. The diameter of the drum is decreased from 22.5 inches to 20 inches and the drum length is reduced from about 69 inches to about 65 inches. The only other change from normal conditions is the array size: 9x9x3 here versus 12x12x4 at normal conditions.

The calculated results are in Table 3. The peak k-eff is 0.918 ± 0.007.

Interspersed moderator densities greater than 0.10 gm/cc, the maximum tabulated value, will result in decreased interaction among the containers in the array and a corresponding lower value for k-eff. For example, k-inf for damaged containers (infinite array) with 0.12 gm/cc interspersed water is 0.994 ± 0.005. Thus, any number of containers would be subcritical at moderator densities greater than 0.12 gm/cc.

6.5 Methods Verification

The KENO-IV code, the Hansen-Roach cross sections, and all modeling methods have been extensively benchmarked by many investigators (including Exxon Nuclear) against data from many critical experiments.

Additional verifications were performed by us for this analysis:

1) Critical experiments on U_3O_8 powders with a H/U = 2.03 were analysed.

2) A critical experiment with flooded and reflected fuel assemblies was analysed using the same differential albedo employed in the CE-250 cases.

6.5.1 Benchmarks With H/U = 2.03

These critical experiments are documented in NUREG/CR-2500 (RFP-3277). Some details of the experiments and the models are given below.

The experiments employed 15 cm cubes of damp U_3O_8 in aluminum cans. The cans were stacked into arrays on a split table. Plastic sheets served as the moderator between the cans and as the reflector.

Only two experiments are available with the subject H/U. Others at lower H/U's are available but were not analysed for this verification. The two cases used here are denoted "F" and "G".

Two types of plastic were used in the reflector: one with fire-retardant additive and one without this additive. The "Tris" additive composition included two nuclides not in the Hansen-Roach (or AMPX) library: bromine and phosporous. The fire-retardant plastic was modeled without these two nuclides; there were no substitutions. The two types were placed into the reflector as recommended in the source report. All in-core (between cans) plastic was without additive.

The thickness of the plastic sheets between cans in the core was 0.93 cm (exp. "F") and 2.43 cm (exp. "G"). The core of experiment "F" was under-moderated and the experiment "G" core was near optimum moderation.

The experiments were explicitly modeled using the documented average dimensions and compositions.

Calculated results:

Experiment "F"

k-eff - 1.009 ± 0.005

Sig-p for input U-235/U-238 - 1600/78

Sig-m(eff) calculated - 1659 ± 4.4 / 78.9 ± 0.21

Experiment "G"

k-eff - 1.012 ± 0.005

Sig-p for input U-235/U-238 - 1700/82.0

Sig-m(eff) calculated - 1721/81.9

The calculated k-eff's are conservative by about 1.2% relative to the assumed actual k-eff of 1.000.

6.5.2 Differential Albedo Validation

The critical experiments of the previous section employed a plastic reflector. The CE-250 array models were water reflected. A critical experiment documented in BAW-1487-7 was analysed to verify the differential albedo employed in the CE-250 calculations. Several of the experiments in this reference have been previously analysed for methods verification. The single experiment selected for the albedo overcheck was Case #2321. For comparison, the case was also analysed using the water weighting function for 10 reflector regions of 3 cm each. The albedo and the weighting function are part of the standard KENO system.

Albedo Results

k-eff - 1.012 ± 0.004

Sig-p for input U-235/U-238 - 2460/62.5

Sig-m(eff) calculated - 2540 ± 70 / 64.9 ± 1.8

Weighted Reflector Results

k-eff - 1.006 ± 0.005

Sig-p for input U-235/U-238 - 2460/62.5

Sig-m(eff) calculated - 2587 ± 85 / 66.0 ± 2.2

Both results are conservative relative to the observed k-eff of 1.003. Although the albedo result is higher than the weighted value, the difference is not significant.

Table 1

12x12x4 Array of Undamaged Containers
Inner Vessel Full of 5% Enriched UO_2-Water (7 wt% water)
Bulk Density of Homogeneous UO_2-Water - 1.2 gm U/cc

Interspersed Water Density gm/cc	Micro Sig-p (input) U-235/U-238 (barns)	Micro Sig-m (calculated) U-235/U-238 (barns)	k-eff
0.02	1600/87	1622/88.4	0.859 ± 0.008 WW
0.04	1600/87	1640/89.5	0.900 ± 0.009 WW
0.06	1600/87	1653/90.3	0.918 ± 0.007 WW
0.08	1600/87	1642/89.6	0.881 ± 0.009 WW
0.02	1600/87	1626/86.7	0.866 ± 0.008 VW
0.04	1600/87	1625/86.6	0.901 ± 0.007 VW
0.06	1600/87	1626/86.7	0.913 ± 0.006 VW
0.08	1600/87	1640/87.4	0.922 ± 0.007 VW
0.10	1600/87	1635/87.1	0.915 ± 0.008 VW
0			0.782 ± 0.008 PWW
0.02			0.882 ± 0.008 PWW
0.04			0.902 ± 0.008 PWW
0.06			0.896 ± 0.007 PWW

Notes:

WW - Powder case, water in annulus, water between containers.
VW - Powder case, vermiculite in annulus, water between containers.
PWW - Pellet case, water in annulus, water between containers.

Table 2

12x12x4 Array of Undamaged Containers
Inner Vessel With 323 Pounds of 5% Enriched UO_2-Water (7 wt% water)
Bulk Density of Homogeneous UO_2-Water - 3.0 gm U/cc

Interspersed Water Density gm/cc	Micro Sig-p (input) U-235/U-238 (barns)	Micro Sig-m (calculated) U-235/U-238 (barns)	k-eff
0.04	1500/80	1517/80.9	0.837 ± 0.007 L
0.06	1500/80	1521/81.1	0.842 ± 0.008 L
0.08	1500/80	1520/81.0	0.813 ± 0.008 L
0.02	1500/80	1461/77.9	0.819 ± 0.007 D
0.04	1500/80	1472/78.5	0.793 ± 0.007 D
0.06	1500/80	1463/78.0	0.748 ± 0.011 D

Notes:

L denotes cases with reduced diameter and full length.

D denotes cases with reduced length and full diameter..

Table 3

9x9x3 Array of Damaged Containers
Inner Vessel Full of 5% Enriched UO_2-Water (7 wt% water)
Bulk Density of Homogeneous UO_2-Water - 1.2 gm U/cc

Interspersed Water Density gm/cc	Micro Sig-p (input) U-235/U-238 (barns)	Micro Sig-m (calculated) U-235/U-238 (barns)	k-eff
0.02	1600/87	1605/87.4	0.827 ± 0.007
0.04	1600/87	1639/87.3	0.886 ± 0.009
0.06	1600/87	1642/89.6	0.918 ± 0.007
0.08	1600/87	1642/89.7	0.909 ± 0.008
0.10	1600/87	1663/90.9	0.894 ± 0.008

6.6.0 Typical KENO Input/Output Listings

```
TYPICAL KENO INPUT LISTING, NORMAL CONDITIONS
 CE-250, NORMAL SIZE, FULL INNER, 6% WATER, 12X12X4 ARRAY
25.0
83 100 3 16 6 7 3 8 5 1 12 12 4
7 2 0 2010 00 1 0 0 0 0 0 00 0 0
6*1012
NOTE UDEN,WT.FRACT WATER=  1.2000E 00  7.0000E-02
NOTE UDEN,U235,U238,OX,WVOL=
NOTE   1.2000E 00  1.5375E-04  2.8844E-03  6.0762E-03  1.0247E-01
NOTE  SIG-P: 1600/87
1  -92508  6.15E-05
1  92509  9.225E-05
1  92816  1.7306E-03
1  92817  1.1538E-03
1 8100  6.0762E-03
1 502  1.0247E-01
2 100 1.0
3 502 0.06
BOX  1
NOTE  NOMINAL INSIDE DIMS OF INNER VESSEL: 11.5" DIAM X 57.125" LONG
NOTE  INNER VESSEL MODEL:  11.625" ID X 57.25" LONG
NOTE  FILLED WITH UO2-WATER (7 WT.% WATER)
CYLI  1 14.76375 72.7075 -72.7075
NOTE  CARBON STEEL WALL
NOTE    & 0.5" LID & 0.125" BOTTOM
CYLI  2 14.91564 73.9775 -73.025
NOTE  ANNULUS (NORMALLY VERMICULITE, MIST HERE)
NOTE NORMAL DRUM SIZE: 22.5"D X 68.6875"L (INSIDE)
NOTE  VESSEL-DRUM END SPACE: BOTTOM:4.4375", TOP: 6.375"
CYLI  3 28.575 90.17 -84.29625
NOTE  DRUM WALL, LID, BOTTOM: 16 GAGE = 0.0598" THICK
CYLI  2 28.7269 90.3219 -84.4481
NOTE  FILL OUT BOX WITH INTERSPERSED MODERATOR
CUBO  3 28.7269 -28.7269 28.7269 -28.7269 90.3219 -84.4481
END KENO
```

TYPICAL KENO INPUT LISTING, ACCIDENT CONDITION

```
 CE-250, ACCIDENT SIZE, K-EFF, FULL INNER, 6% WATER, 9X9X3 ARRAY
25.0
83 100 3 16 6 7 3 8 5 1 9 9 3
7 2 0 2010 00 1 0 0 0 0 0 00 0 0
6*1012
NOTE UDEN,WT.FRACT WATER=  1.2000E 00  7.0000E-02
NOTE UDEN,U235,U238,OX,WVOL=
NOTE    1.2000E 00  1.5375E-04  2.8844E-03  6.0762E-03  1.0247E-01
NOTE  SIG-P: 1600/87
1  -92508  6.15E-05
1  92509  9.225E-05
1  92816  1.7306E-03
1  92817  1.1538E-03
1 8100  6.0762E-03
1 502  1.0247E-01
2 100 1.0
3 502 0.06
BOX  1
NOTE  NOMINAL INSIDE DIMS OF INNER VESSEL: 11.5" DIAM X 57.125" LONG
NOTE  INNER VESSEL MODEL:  11.625" ID X 57.25" LONG
NOTE  FILLED WITH UO2-WATER (7 WT.% WATER)
CYLI  1 14.76375 72.7075 -72.7075
NOTE  CARBON STEEL WALL
NOTE    & 0.5" LID & 0.125" BOTTOM
CYLI  2 14.91564 73.9775 -73.025
NOTE  ANNULUS (NORMALLY VERMICULITE, MIST HERE)
NOTE  ACCIDENT CONDITIONS: REDUCE DIAM.BY 2.5", LEN BY 4.0"
NOTE  DRUM IS NOW 20.0" ID X 64.6875" LONG
NOTE  VESSEL-DRUM END SPACE: BOTTOM:2.4375", TOP: 4.375"
CYLI  3 25.4 85.09 -79.21625
NOTE  DRUM WALL, LID, BOTTOM: 16 GAGE = 0.0598" THICK
CYLI  2 25.5519 85.2419 -79.3681
NOTE  FILL OUT BOX WITH INTERSPERSED MODERATOR
CUBO  3 25.5519 -25.5519 25.5519 -25.5519 85.2419 -79.3681
END KENO
```

```
TYPICAL KENO INPUT LISTING, VERMICULITE-IN-ANNULUS
CE-250, NORMAL SIZE, FULL INNER, 6% WATER, 12X12X4 ARRAY
25.0
83 100 3 16 6 13 4 15 5 1 12 12 4
13 2 0 1010 00 1 0 0 0 0 0 00 0 0
6*1012
NOTE UDEN,WT.FRACT WATER=  1.2000E 00  7.0000E-02
NOTE UDEN,U235,U238,OX,WVOL=
NOTE   1.2000E 00  1.5375E-04  2.8844E-03  6.0762E-03  1.0247E-01
 NOTE  SIG-P:  1600/87
1  -92508  6.15E-05
1  92509  9.225E-05
1  92816  1.7306E-03
1  92817  1.1538E-03
1 8100  6.0762E-03
1 502  1.0247E-01
2 100 1.0
3 502 0.06
NOTE  VERMICULITE PER ARH-600
4 13100 2.3E-4
4 26100 9.0E-5
4 1102 8.1E-4
4 19100 1.2E-4
4 12100 4.2E-4
4 8100 2.42E-3
4 14100 5.2E-4
BOX  1
NOTE  NOMINAL INSIDE DIMS OF INNER VESSEL: 11.5" DIAM X 57.125" LONG
NOTE  INNER VESSEL MODEL:  11.625" ID X 57.25" LONG
NOTE  FILLED WITH UO2-WATER (7 WT.% WATER)
CYLI  1 14.76375 72.7075 -72.7075
NOTE  CARBON STEEL WALL
NOTE & 0.5" LID & 0.125" BOTTOM
CYLI  2 14.91564 73.9775 -73.025
NOTE  ANNULUS FILLED WITH VERMICULITE
NOTE NORMAL DRUM SIZE: 22.5"D X 68.6875"L (INSIDE)
NOTE  VESSEL-DRUM END SPACE: BOTTOM:4.4375", TOP: 6.375"
CYLI  4 28.575 90.17 -84.29625
NOTE  DRUM WALL, LID, BOTTOM: 16 GAGE = 0.0598" THICK
CYLI  2 28.7269 90.3219 -84.4481
NOTE  FILL OUT BOX WITH INTERSPERSED MODERATOR
CUBO  3 28.7269 -28.7269 28.7269 -28.7269 90.3219 -84.4481
END KENO
```

TYPICAL KENO OUTPUT, K-EFF EDIT TABLE
CE-250, NORMAL SIZE, FULL INNER, 6% WATER, 12X12X4 ARRAY

GENS. SKIPPED	K-EFF	95% CONFIDENCE LIMITS	TOTAL HISTORIES
3	0.91603 +/- 0.00749	0.90106 TO 0.93100	8000
4	0.91559 +/- 0.00757	0.90046 TO 0.93073	7900
5	0.91585 +/- 0.00766	0.90052 TO 0.93117	7800
6	0.91439 +/- 0.00762	0.89915 TO 0.92964	7700
7	0.91681 +/- 0.00732	0.90216 TO 0.93146	7600
8	0.91751 +/- 0.00739	0.90273 TO 0.93228	7500
9	0.91759 +/- 0.00749	0.90261 TO 0.93256	7400
10	0.91879 +/- 0.00749	0.90380 TO 0.93378	7300
11	0.91869 +/- 0.00760	0.90350 TO 0.93389	7200
12	0.91667 +/- 0.00743	0.90182 TO 0.93152	7100
13	0.91555 +/- 0.00745	0.90065 TO 0.93044	7000
14	0.91546 +/- 0.00755	0.90035 TO 0.93057	6900
15	0.91659 +/- 0.00758	0.90143 TO 0.93175	6800
16	0.91627 +/- 0.00769	0.90090 TO 0.93165	6700
17	0.91715 +/- 0.00775	0.90164 TO 0.93265	6600
18	0.91622 +/- 0.00782	0.90058 TO 0.93185	6500
19	0.91539 +/- 0.00790	0.89960 TO 0.93118	6400
20	0.91698 +/- 0.00786	0.90127 TO 0.93269	6300
21	0.91684 +/- 0.00798	0.90088 TO 0.93281	6200
22	0.91496 +/- 0.00788	0.89919 TO 0.93073	6100
24	0.91841 +/- 0.00768	0.90305 TO 0.93377	5900
26	0.91987 +/- 0.00772	0.90442 TO 0.93532	5700
28	0.91876 +/- 0.00796	0.90283 TO 0.93469	5500
30	0.91847 +/- 0.00824	0.90199 TO 0.93496	5300
32	0.91986 +/- 0.00820	0.90346 TO 0.93626	5100
34	0.92231 +/- 0.00835	0.90562 TO 0.93901	4900
36	0.92284 +/- 0.00870	0.90544 TO 0.94023	4700
38	0.92581 +/- 0.00875	0.90831 TO 0.94330	4500
40	0.92564 +/- 0.00915	0.90734 TO 0.94393	4300
42	0.92703 +/- 0.00945	0.90814 TO 0.94592	4100
44	0.92653 +/- 0.00992	0.90668 TO 0.94638	3900
46	0.92771 +/- 0.01015	0.90740 TO 0.94802	3700
48	0.93024 +/- 0.01057	0.90910 TO 0.95137	3500
50	0.93041 +/- 0.01104	0.90832 TO 0.95250	3300

NOTE: Reported k-eff: 0.918 +/- 0.009

7.0 OPERATING PROCEDURES

7.1 Procedures for Loading the Package

A specific operating procedure for loading the CE-250-2 is used by Logistics Personnel. This procedure outlines personal and criticality safety, loading methods, installation of a seal, and application of DOT radioactive labels.

7.2 Procedures for Unloading the Package

A specific operating procedure for unloading the CE-250-2 package outlines the proper order and methods to be used, including a radiation survey by Health Physics.

7.3 Procedure for Inspection

A specific inspection of the CE-250-2 is performed prior to the loading of the package. This inspection looks for package damage, gasket condition, paint, bolt and nut condition, and stenciling.

8.0 MAINTENANCE TESTS AND MAINTENANCE PROGRAM

8.1 Acceptance Tests

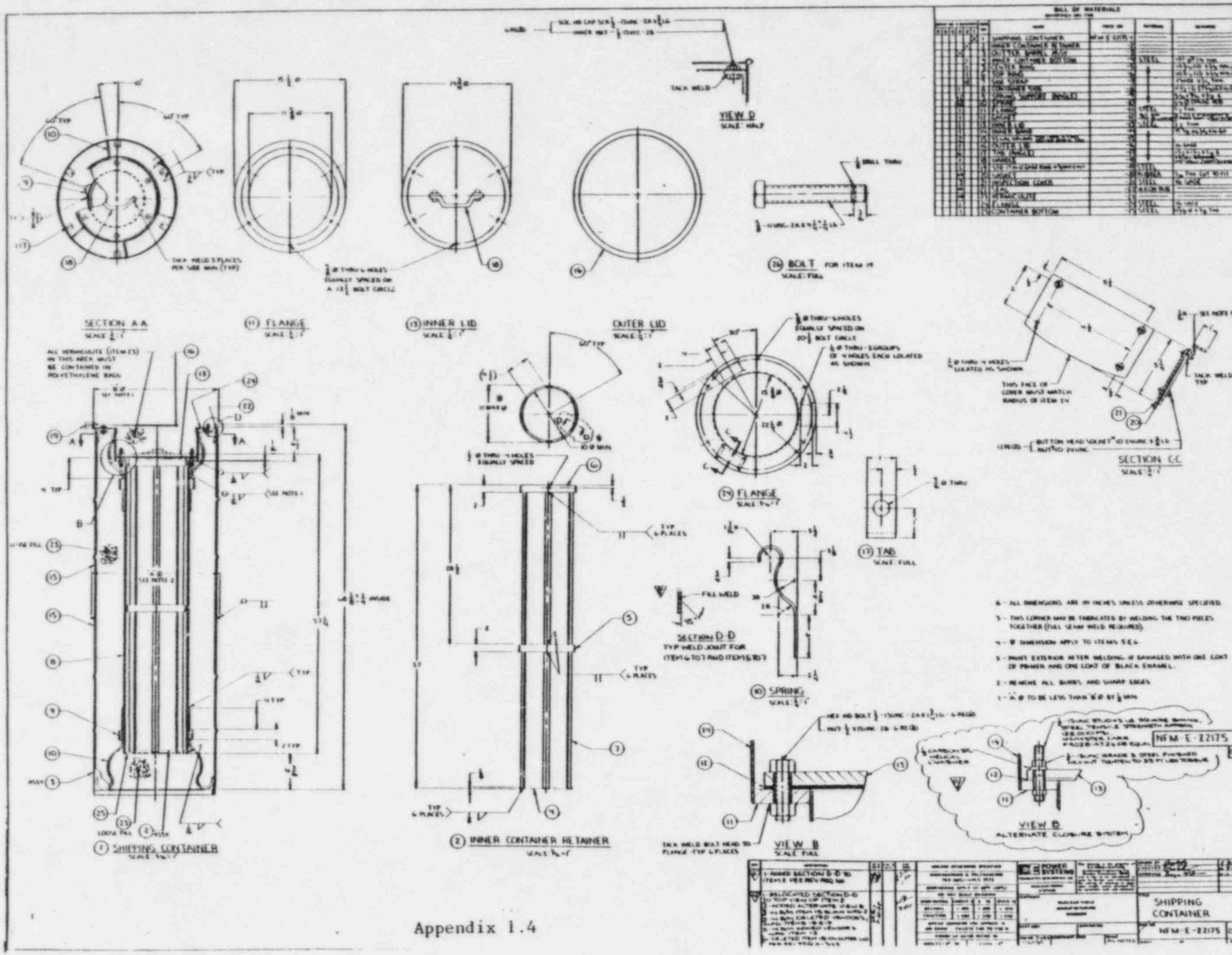
All containers to be fabricated will be constructed in accordance with CE Drawing NFM-E-Z2175, Rev. 2, and shall be inspected prior to placing the containers in use. Changes to the design of the container, which fall outside of the safety envelope specified in this application, will be submitted to NRC for approval. This may include re-testing of the container if analytical results are not capable of demonstrating tnat the test sequence previously performed would be applicable to the changes made.

8.2 Maintenance Program

Logistics personnel determine during pre-loading inspections when any repair or replacement of material is required.

8.3 Quality Assurance

The fabrication of new containers or maintenance cf old containers is accomplished under the purview of the Quality Assurance Program.



SECTION A-A
FLANGE
INNER LID
OUTER LID
VIEW D
BOLT FOR ITEM 19
FLANGE
TAB
SPRING
SECTION D-D
SECTION CC
SHIPPING CONTAINER
INNER CONTAINER RETAINER
VIEW B
ALTERNATE CLOSURE SYSTEM
NFM-E-22175
SHIPPING
CONTAINER

Appendix 1.4

APPENDIX 2.9

NUMEC LICENSE SNM-414

Pu 10-I TEST RESULTS

VI.1 NUMEC Pu-10-I Container

VI.1.1 Container Description

a. Gross Weight - 400 lbs. (max.)

b. Model Number - Pu-10-I

c. Materials of construction, weights, dimensions, and methods of fabrication.

Outside drum: 19" or 24" diameter
Pressure vessel: Solid stainless steel, with flanged, gasketed, bolted closure
Pressure vessel gasket: 1/8" target or blue asbestos compressed asbestos sheet
Moderator: Polyethylene granules with polyester resin filling interstices
Primary container: 11 liter polyethylene bottle contained in two sealed polyvinyl bags

More detailed design information is provided in the enclosed drawings, and in the following sections.

d. Identification and maximum radioactivity of radioactive constituents

1. Pu-239 - 154 Curies (Transport Group I)
2. U-233 - 1.71 Curies (Transport Group II)
3. U-235 - 5.24×10^{-3} (Transport Group III)

e. Classification of material to be shipped:

Large source and fissile material

f. Identification, chemical and physical form, and maximum quantities of fissile constituents:

1. Uranyl nitrate solutions having a concentration of U-235 not to exceed 350 grams per liter, provided that (a) the combined U-233 and plutonium content is not more than 1% of the U-235 content, and (b) the minimum free acid is 2 molar.

2. Uranyl nitrate solutions having a concentration of U-233 and U-235 not to exceed 250 grams per liter, provided that (a) the U-233 content is not greater than 10% of the combined U-233 and U-235 content, and (b) the plutonium content is not more than 1% of the combined U-233 and U-235 content, and (c) the minimum free acid is 2 molar.

3. Plutonium nitrate solutions having a concentration not to exceed 250 grams Pu-239 per liter, provided that (a) the Pu-240 content is at least 3% of the total plutonium, and (b) the minimum free acid is 2 molar.

4. Maximum quantity of material per package: Ten (10) liters of solution, containing not more than 2.5 kilograms of fissile isotope.

g. Extent of reflection, amount and identity of non-fissile neutron absorbers in the fissile constituents, and the atomic ratio of moderation to fissile constituents.

The fissile material is contained in a polyethylene bottle (0.16" wall thickness) which is contained in a cadmium wrapped 3/16" thick stainless steel pressure vessel. A 2 inch thick polyethylene-polyester resin composite surrounds the cadmium wrapped pressure vessel. Items f1, 2, 3, and 4 above specifies the atomic ratios of moderation to fissile constituents.

h. Maximum weight of contents: 42 pounds including the polyethylene bottle.

DELETE - i. Maximum amount of decay heat: For plutonium containing less than 1 w/o Pu-238, we estimate a 30°F temperature differential between the solution and the outside of the container, yielding an internal temperature of 160°F under condition 1 of Appendix A, 10 CFR 71.

VI.1.2 Container Evaluation

VI.1.2.1 General Standards

a. Internal Reactions

All fissile material is contained within a polyethylene bottle (0.16" wall thickness) which is double bagged in 0.012 inch PVC, and contained in a pressure vessel fabricated from stainless steel, precluding the possibility of internal chemical reactions with the packaging material.

b. Closure

Closure of drums consists of a 12 gauge bolted ring with drop forged lugs, one of which is threaded, using a 5/8" bolt.

c. Lifting Devices

No lifting devices are incorporated as a structural part of the container or its lid.

d. Tie-down Devices

No tie-down devices are incorporated as a structural part of this container.

e. Structural Standards for Large Quantity Packaging

Because the package may contain in excess of 20 curies of transport Group I materials, as defined in 10 CFR 71.4(f), it is evaluated as a large quantity package as well as a fissile material package.

1. Load Resistance

Calculations demonstrate that the yield strength of the packaging material is not exceeded under the conditions set forth in 10 CFR 71.32(a).

2. External Pressure

The containment vessel is equivalent to an ICC 2R container, and is therefore capable of withstanding an external pressure of 25 psig.

VI.1.2.2 Criticality Hazards for Fissile Material Packages

DELETE REFERENCE TO Pu.

a. Optimum Water Moderation is a Normal Condition of Shipment.

Under this condition, 2.5 kg U-235 is subcritical in a 5.625" I.D. cylinder with full water reflection (Figure K-1.2(a), Y-1272), and up to 250 gm Pu/liter is subcritical in an infinite 5.625" I.D. water reflected infinite cylinder (Figure J-2.7, Y-1272).

DELETE VENTED CAP.

b. All fissile material is contained within a polyethylene which is provided with a vented cap which has been tested to open at 8 ounces to 16 ounces internal pressure. The bottle is enclosed in two 12-mil polyvinal seamless bags, each of which has been sealed to prevent leakage of liquid. The enclosed bottle is placed within the containment vessel which is provided with a gasketed flanged closure.

Because this system provides double containment of the fissile material in a subcritical geometry, and precludes the leakage of liquids into an unsafe geometry in spite of any single packaging error, the fissile content of any single packaging exceeds the minimum critical mass under conditions of optimum configuration (sphere) and reflection.

Administrative procedures detailed in VI.1.2.5 below are used to verify the leak tightness of each containment vessel.

VI.1.2.3 <u>Evaluation of a Single Package</u>

a. Normal Conditions of Transport

1. Exposure to direct sunlight at an ambient temperature of 130°F in still air.

The external container is a steel drum inside of which is a vermiculite insulated steel structure containing a moderator, a stainless steel pressure vessel, and the product solution. All are exposed without damage to more severe thermal conditions during the required thermal test with no damage. As previously indicated, the solution may achieve a temperature of 160°F, which is within the allowable limits for the ultra-ethylux bottle.

2. Exposure to an ambient temperature of -40°F.

Loss of properties of the steel and insulating material at that temperature will not occur, and possible crystallization of the moderator will not change its moderating properties. The polyethylene bottle is composed of "ultra-ethylux-28" as produced by Westlake Plastics Company, or equal, and does not embrittle until the temperature is reduced to -55°F. To allow for expansion of the solution on thawing, at least 10% free space is provided in the bottle.

3. Exposure to atmospheric pressure of 0.5 times standard atmospheric pressure.

The drum lids have no gaskets, allowing the equilization of pressure.

4. Vibration

Each package is vibrated for 5 minutes as a part of the fabrication procedure in order to promote settling of the vermiculite insulation.

5. Water Spray

Experience with packages using similar drum designs (LA-36, HA-10, Ref: SNM-145) demonstrate that exposure to heavy rain for extended periods of time does not result in water inleakage.

6. Free Drop

This test was not performed because the Pu-10-I container does not depend on spacing for nuclear safety.

7. Corner Drop

Because the package is fabricated from steel, this test does not apply.

8. Penetration

The drums are fabricated from 16 Ga. steel, and are similar to those used for the NUMEC LA-36 containers. Therefore, the test results reported in Section X of SNM-145 apply.

9. Compression

A 2,000 pound load was placed on top of a sample package for a period of 24 hours with no measurable deflection of the drum.

Based on the above, we conclude that requirements set forth in 10 CFR 71.35(a) (1), (2), (3); (b) (1) and (4) 111 are satisfied. 10 CFR 71.35(a) (4) and (5) do not apply as there are no coolants in this package. 10 CFR 71.35(b) 1 and 3 are discussed in VI.1.2.2 above, and 10 CFR 71.35(b) (4), (i) and (II) does not apply as the spacing provided by the package does not effect nuclear safety.

With regard to 10 CFR 71.35(c), the vent valve is closed prior to all shipments.

b. Accident Test Conditions

Five sample containers identified in Drawings ASK-1058-D-1, 2, and 3 were subjected to the accident test conditions required by 10 CFR 71. These drawings show direction of impact for each container, and indicate maximum internal temperatures recorded.

Drop tests were conducted in a manner to assure that the lowest point of the container was at least 30 feet above the point of impact on an unyielding surface at the time of release. Thermal tests were performed in a furnace which provided the required conditions. However, containers numbered 1 and 2 were exposed to high temperatures for 36 minutes to compensate for a temperature

drop in the furnace observed immediately subsequent to the insertion of the containers. The other containers were exposed for the required period. Here, the temperature drop was minimized by additional pre heating of the furnace to 1600°F. An 11 liter polyethylene bottle containing sand for ballast was placed within each container.

Container number 5 suffered impact on the top corner causing the drum lid to spring open and release some vermiculite. Resulting from this failure, further testing was held in abeyance pending evaluation of the damage, and the determination of corrective measures. As finally determined, these measures consisted of the use of drum lids with a sufficient lip to completely enclose the upper half of the rolled lip on the drum body, and the omission of the lid gasket to assure better seating.

That these measures were sufficient to assure closure under accident conditions was demonstrated by container number 3 which was also corner dropped. The lid remained properly seated on the drum, and no vermiculite was lost.

Container number 4 was impacted on both its top and bottom surface. The impact onto its top surface caused a seam in the upper drum body to separate slightly, yielding an opening measuring about 1/8" x 1". No measurable amount of vermiculite was lost through this opening, and subsequent to the above tests, the drum was impacted from a height of 40 inches onto a 6 inch diameter by 8 inch long bar, as specified by 10 CFR 71. Impact occurred on the welded seam joining the drums. Although a 1-1/2" to 2" deep depression resulted, the integrity of the drum and weld was not violated.

As previously indicated, other tests were performed as illustrated in Figures 1, 2 and 3 of this application.

Examination of the containers subsequent to their removal from 24 hours of immersion under three feet of water revealed three principal facts; (1) no water leaked into the containment vessel, (2) no moderator was lost, and (3) the maximum temperature experienced within the containment vessel was in excess of 100°F, but less than 150°F. Additionally, the cadmium wrapping of the containment vessel was in no way effected by the test sequence. From these findings, we conclude that:

1. No radioactive material will be released from the package under the stated accident conditions.

2. The package will remain subcritical as the material remains confined to a subcritical geometry, and the geometric form of the contained material is not altered (10 CFR 71.35 (b)(2).

3. Double containment is maintained in that the internal temperatures noted during the tests are insufficient to compromise the integrity of

   a. the polyethylene bottle
   b. the PVC bagging
   c. the pressure vessel

   It is recognized, however, the pressure buildup within the polyethylene bottle may displace gram quantities of solution from the bottle. However, such material remains doubly contained within the double PVC bag and the pressure vessel.

4. No damage was suffered by any of the components or materials of construction due to exposure to the thermal test.

VI.1.2.4 Evaluation of an array of Pu-10-I containers

In view of the fact that the test conditions did not effect the containment or moderation of the material within the container, we evaluate an array of Pu-10-I containers in both the damaged and undamaged condition on the basis of the following conditions:

Solution Diameter	- 5.56"
H/X Ratio	- 44
Cadmium Thickness	- 0.016"
Moderator Thickness	- 2.0"
Equivalent Water Thickness	- 1.91"

Two methods are considered herein to demonstrate that the cadmium wrapped 5.625" diameter cylinders are isolated when surrounded by the equivalent of 1.9 inches of water.

We consider first an analysis based on neutron penetration data, and correlated to interacting subcrits, as reported in K-1478.

By this method, a just critical array is described when

$$K = 1.0 - \frac{kc}{1-V}$$

where

kc = reactivity of subcrit
$V = \Omega F\,(1 - UF)(ab)\,p$
ΩF = fractional solid angle
$(1-UF)$ = fast leakage probability
$(ab)p$ = neutron penetration. The weighting factor p is set equal to 1.0.

To obtain values of geometric buckling Bg^2, an appropriate value of δ is required. Using the critical height of a cadmium wrapped water

APPENDIX 2.9

WESTINGHOUSE LICENSE SNM-338

BB-250-2 TEST RESULTS

16.4 Limits and Controls

The Fissile Class II limit, Fissile Class III limit, and the Procedural Controls presented in Sections 4.4, 4.5, and 4.6, respectively, will apply directly to this package, if "Equipment Specification E-676498" is substituted for "Equipment Specification E-676200".

17. NUMEC LA-36 Shipping Package

The construction, limits on contents, and loading procedures will be in strict compliance with those given in Amendment 71-1 of License SNM-145, Docket 70-135.

18. BB 250-2 Shipping Package

18.1 Packaging Description

Designation - BB 250-2

Gross Weight - 575 pounds, maximum

Fabrication - The design and fabrication details for this container are given in Westinghouse sketch #SKA-252 which is attached as Appendix L to this application.

Coolants - Not applicable

18.2 Contents Description

Radioactivity - Not applicable

Identification and enrichment of SNM - The SNM will be unirradiated uranium enriched to a maximum of 4 w/o in the isotope U-235.

18.2 (continued - BB 250-2)

Form of SNM - The SNM will be in the form of bulk uranium oxide (UO_2 or U_3O_8) with a density $\leq$ 2 grams/cubic centimeter. The moisture content of the SNM will not exceed 0.5 w/o and the total H/U ratio, including all packaging materials, will not exceed 1.13.

Neutron Absorbers, etc. - None

Maximum Weight of Fissile Content - 4.0 kilograms U-235

Maximum Net Weight of Contents - 250 pounds of oxides enriched $\leq$ 4 w/o contained in 9.5 inch diameter Fiberpak drums or other containers having equivalent strength. These are contained in an 11.5 inch diameter (maximum) cylindrical inner container.

Maximum Decay Heat - Not applicable

18.3 <u>Compliance with Subpart C of 10 CFR 71</u>

General Standards - The materials which have been specified for this package will not result in significant chemical or galvanic reactions. There will be no specific lifting or tie down devices.

General Criticality Standards - Tests demonstrate that immersion in water, alone, is not sufficient to affect the structural integrity of the 9.5 inch diameter Fiberpak drums. Calculations using LEOPARD procedures show that a fully reflected, 11 5 inch diameter, infinitely long cylinder is nuclearly safe for homogeneous uranium enriched $\leq$ 4 w/o in U-235 under any conditions of moderation.

18.3 (continued - BB 250-2)

Normal and Accident Conditions Evaluation - This package utilizes design concepts which are similar to those used in the design of the NUMEC LA-36 and Pu-10-1 packages, described in SNM-145 and SNM-414, respectively. The outer shell consists of two 16 ga, 22.5" diameter (nominal) steel drums welded end-to-end to form a package approximately 74" long. The inner container is an 11.5" diameter (maximum), 16 gauge (nominal) steel cylinder with a flanged closure consisting of a 1/2 inch thick (minimum) bolted flange and flange cover. A minimum of six 1/2"-13 NC bolts are used to seat a 1/8 inch thick Anchor Packing Company "Target" or "425" gasket which is provided to assure a leak-tight closure. Six tightly closed Fiberpak drums contain the uranium oxide. These drums have a nominal 9.5 inch diameter. Vermiculite is used to provide thermal and mechanical insulation for the gasketed inner container which is positioned with a minimum of 12 steel spring spacers, as shown in the sketch #SKA-252. The top insulation plug may be fabricated of unibestos. At least 5 inches of vermiculite insulates the inner container from the drum, except at the bottom where its thickness may be 4 inches.

The effects of the hypothetical accident conditions specified in Appendix C of 10 CFR 71 are considered on the basis of the results described by NUMEC.

18.3 (continued - BB 250-2)

Normal Conditions of Transport - All conditions described in the referenced licenses apply to this package. Because the package array is based on the consideration that each vertical projection of packages is replaced by a continuous cylinder having an identical length, the loss of spacing incurred in a vertical four foot drop test is not of concern. It is considered that the low horizontal loading will result in minimal displacement of the inner container in a horizontal drop test.

Accident Test Conditions - The inner container of the BB 250-2, when fully loaded, weighs 329.4# resulting in a vertical loading of 3.17 lbs/in^2 over a base area of 103.87 in^2. The inner container of the NUMEC Pu-10-1 container, when fully loaded, and including the neutron moderator weighs 279#, resulting in a vertical loading of 3.55 lbs/in^2 over a base area of 78.54 in^2. When placed in a horizontal position, the loadings are 0.456 lb/in^2 for the BB 250-2, and 0.442 lb/in^2 for the NUMEC Pu-10-1 container. Thus the tests performed on the latter container are valid for the BB 250-2 package. As a result, it is concluded that:

1. The integrity of the package is not affected by the tests. Because the lid is bolted in a minimum of six places around the top of the drum body, separation of the lid from the drum body does not occur. In this connec-

18.3 (continued - BB 250-2)

tion, test experience with the BB 250-1 shows that as a result of a top corner drop the lid and the body are folded together into a tighter closure.

2. The incorporation of five inches of vermiculite is equal to that provided in the NUMEC package, and is sufficient to assure that after the drop and fire tests the temperature of the inner container would not exceed the observed maximum of 500°F. Since the gasket is service rated to 800°F, the closure of the inner container is not compromised.

3. The test series does not result in the addition of moderation to the contained fissile material.

4. The dimensions of a damaged package are conservatively taken to be 20" O.D. X 70" Lg. This assumes a reduction of 2 1/2" in diameter as the result of a drop test with the package in a horizontal position, plus a reduction of 4" in height as the result of a drop test with the package in a vertical position. No deformations in excess of these values were experienced during the testing of the Pu-10-1 package.

Single Package Evaluation - The safety considerations which pertain to a single package will assure nuclear safety even assuming that the failure of the inner

23. Pellet Shipping Package

23.1 Packaging Description

[illegible] 2-2 packaging [illegible] described in Part 18.

23.2 Contents Description

Radioactivity - Not applicable

Identification and enrichment of SNM -

The SNM will be unirradiated uranium enriched to a maximum of 5 w/o in the isotope ^{235}U.

Form of SNM -

The SNM will be solid uranium compounds that will not react chemically or decompose at temperatures below 750° F. The material will be enclosed within a container constructed of steel having a 24-gage specified minimum thickness. The container will have a maximum ID of 8.5" and a nominal height of 15.375", and will utilize a gasketed lid with bolted locking ring. The container will be constructed in accordance with US Military Standard MS 24347. As an inner container within the BD-250-2 packaging's inner cylinder, it is considered completely adequate to retain the SNM under the hypothetical accident conditions. A comparison between the structural features of this container and a DOT Spec. 17-H container is shown in Table 23.2.1. A maximum of four of these containers will be inserted in each package. The maximum allowable H/U ratio, considering all sources of hydrogenous material within the inner cylinder of the packaging will not exceed 1.5. A typical arrangement for shipping material in the form of pellets is shown in Westinghouse Drawing C7108D10, which is enclosed as part of Appendix R. Military Standard MS 24347 also is enclosed as part of Appendix R.

Neutron Absorbers, etc. -

None

Maximum Weight of Fissile Content -

5.0 kilograms contained ^{235}U

23.2 Contents Description (continued)

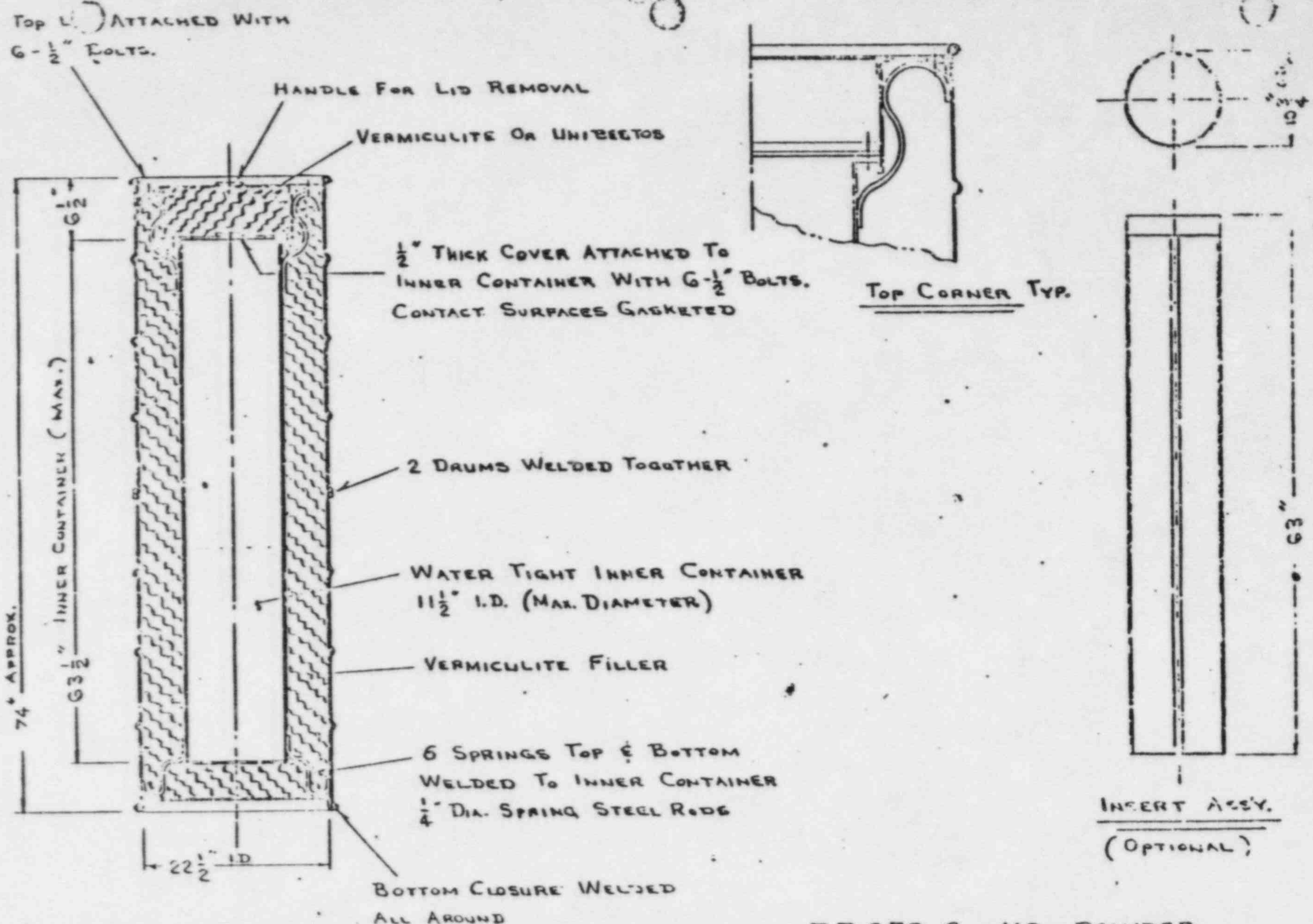
Maximum Net Weight of Contents -

250 pounds of uranium compounds.

Maximum Decay Heat - Not applicable

Table 23.2.1

Structural Feature	MS24347 Container	Spec. 17-H Container
Capacity (gal.)	3.5	5
Type	Straight Side	Straight Side
Diameter (in.)	8.5	11.25
Height (in.)	15.375	12.75
Metal Gauge		
Body	24	24
Cover	24	20
Bottom	24	24
Closure	Bolted Locking Ring	Multiple Lugs
Construction	Welded Seam	Welded Seam



BB250-2 UO_2 POWDER
SHIPPING CONTAINER
2-23-68
D.P. WEISS

SKA-252

APPENDIX 2.9

NUMEC LA-36 TEST RESULTS

DOT 5442

1 NUMEC LA-36 Container

1.1 Package Description

a. Gross Weight: 250#

b. Model Number: LA-36

c. Details of Construction:

This information is provided in the enclosed drawings (10-D-1167, 10-D-1168, 10-A-214 and 10-A-215).

d. Identification and maximum radioactivity of radioactive constituents:

U-234 + U-235 - 11.1 x 10^{-2} curies
U-238 - 1.3 x 10^{-2} curies

e. Classification of material to be shipped:

Fissile material only.

f. Identification, chemical and physical form, and maximum quantities of fissile constituents:

1. Dry non-decomposable forms of uranium having a maximum U-235 assay of 5.0%:

   Maximum Loading: 36 kg of material containing no more than 1.58 kg U-235.
   Maximum Uranium Density: Any
   Maximum Water Content: 0.5 w/o

2. 36 kg of hydrous decomposable compounds containing a maximum of 1.0 kg U-235. The maximum weight of the uranium bearing material shall be 36 kg.

g. Extent of reflection, amount and identity of non-fissile neutron absorbers in the fissile constituents, and the atomic ratio of moderation to fissile constituents:

The fissile bearing material is contained in two sealed 5 gallon ICC-17H pails. The above mass limits assure that no single package contains a critical mass under any credible conditions of moderation and reflection. Non-fissile neutron absorbers, if present, are neglected for the purpose of evaluation. Actual moderation ratios are as follows:

1. Non-decomposable forms of uranium:

   ($\leq$0.5 w/o H_2O)

U-235 Assay	H/X
1-2	14.8
2-3	7.41
3-4	4.95
4-5	3.7

1 NUMEC LA-36 Container

1.1 Package Description

a. Gross Weight: 250#

b. Model Number: LA-36

c. Details of Construction:

This information is provided in the enclosed drawings (10-D-1167, 10-D-1168, 10-A-214 and 10-A-215).

d. Identification and maximum radioactivity of radioactive constituents:

U-234 + U-235 - 11.1 x 10^{-2} curies
U-238 - 1.3 x 10^{-2} curies

e. Classification of material to be shipped:

Fissile material only.

f. Identification, chemical and physical form, and maximum quantities of fissile constituents:

1. Dry non-decomposable forms of uranium having a maximum U-235 assay of 5.0%:

   Maximum Loading: 36 kg of material containing no more than 1.58 kg U-235.
   Maximum Uranium Density: Any
   Maximum Water Content: 0.5 w/o

2. 36 kg of hydrous decomposable compounds containing a maximum of 1.0 kg U-235. The maximum weight of the uranium bearing material shall be 36 kg.

g. Extent of reflection, amount and identity of non-fissile neutron absorbers in the fissile constituents, and the atomic ratio of moderation to fissile constituents:

The fissile bearing material is contained in two sealed 5 gallon ICC-17H pails. The above mass limits assure that no single package contains a critical mass under any credible conditions of moderation and reflection. Non-fissile neutron absorbers, if present, are neglected for the purpose of evaluation. Actual moderation ratios are as follows:

1. Non-decomposable forms of uranium:

   (≤0.5 w/o H_2O)

U-235 Assay	H/X
1-2	14.8
2-3	7.41
3-4	4.95
4-5	3.7

DOT 5446

2. Decomposable forms of uranium:

Optimum hydrogen moderation is assumed.

h. Maximum weight of contents: 36 kg

i. Maximum amount of decay heat: Negligible

1.2 Container Evaluation

1.2.1 General Standards

a. Internal Reactions

1. Non-decomposable forms of uranium:

No internal chemical reactions are considered credible.

2. Decomposable forms of uranium:

All decomposable forms of uranium are packaged within an inert material, such as polyethylene in the form of sheet or a bottle in order to preclude chemical reactions between the material, and the 5 gallon pails which provide primary containment.

b. Closure

Closure of the drums consists of a 12 gauge bolted ring with drop forged lugs, one of which is threaded, using a 5/8" bolt.

c. Lifting Devices

No lifting devices are incorporated as a structural part of the package or its lid.

d. Tie Down Devices

No tie down devices are incorporated as a structural part of the package.

e. Structural Standards for Large Quantity Packaging

Not applicable

1.2.2 Criticality Standards for Fissile Material Packages

a. Each container is limited to assure that its contents would remain subcritical under any condition of water moderation and reflection.

b. Each container is further limited to assure that its contents would remain subcritical in an optimum configuration, with optimum water moderation and reflection.

2. Decomposable forms of uranium:

Optimum hydrogen moderation is assumed.

h. Maximum weight of contents: 36 kg

i. Maximum amount of decay heat: Negligible

1.2 Container Evaluation

1.2.1 General Standards

a. Internal Reactions

1. Non-decomposable forms of uranium:

No internal chemical reactions are considered credible.

2. Decomposable forms of uranium:

All decomposable forms of uranium are packaged within an inert material, such as polyethylene in the form of sheet or a bottle in order to preclude chemical reactions between the material, and the 5 gallon pails which provide primary containment.

b. Closure

Closure of the drums consists of a 12 gauge bolted ring with drop forged lugs, one of which is threaded, using a 5/8" bolt.

c. Lifting Devices

No lifting devices are incorporated as a structural part of the package or its lid.

d. Tie Down Devices

No tie down devices are incorporated as a structural part of the package.

e. Structural Standards for Large Quantity Packaging

Not applicable

1.2.2 Criticality Standards for Fissile Material Packages

a. Each container is limited to assure that its contents would remain subcritical under any condition of water moderation and reflection.

b. Each container is further limited to assure that its contents would remain subcritical in an optimum configuration, with optimum water moderation and reflection.

1.2.3 Evaluation of a Single Package

a. Normal Condition of Transport

1. Exposure to direct sunlight at an ambient temperature of 130°F in still air.

   The external container is a steel drum inside of which is a vermiculite insulated steel sleeve which contains two ICC-17H pails. All are exposed without damage to more severe thermal conditions during the required thermal test.

2. Exposure to an ambient temperature of -40°F

   Exposure to -40°F will not affect the structural materials, which are steel, or the insulating material, which is vermiculite.

3. Exposure to atmospheric pressure of 0.5 times standard atmospheric pressure.

   The drum lids have no gasket, allowing equilization of pressure.

4. Vibration

   Each package is vibrated for 5 minutes as a part of the fabrication procedure in order to promote settling of the vermiculite insulation.

5. Water Spray

   A number of containers have been exposed to heavy rain storms for extended periods of time, with no water inleakage. Such exposure exceeds the requirements of the water spray test.

6. Free Drop

   Two sample packages were dropped from a height of 4 feet onto an unyielding surface. One package was dropped bottom end down, and experienced a less than 5% loss of spacing and reduction of volume. The other was dropped in a horizontal position, and also experienced a less than 5% loss of spacing and reduction of volume.

7. Penetration

   Both sample packages were subjected to a penetration test as specified in Appendix A of 10 CFR 71. The resulting dents did not exceed a depth of 3/16 inch.

8. Compression

   A 1275 pound load was placed on top of a sample package for a period of 24 hours with no measurable deflection of the drum.

Based on the above, we conclude that the requirements set forth in 10 CFR 71.35 are satisfied to the extent that they are pertinent.

b. Accident Test Conditions

Two sample packages, each containing at least 36 kg of dry brick mortar, and designated as Drums #1 and #2, were subjected to the accident test conditions, as set forth in Appendix A, 10 CFR 71.

1. Impact

Drum number 1 was dropped at a 45° angle from a height of 30 feet on its cover. The drum caved inward several inches at the point of impact. The ring and cover were not dislodged. Drum number 2 was dropped from a height of 30 feet so as to strike flat on its side. Impact occurred approximately half way between the spacer rods. This drum was then dropped 30 feet in a vertical position, suffering impact on its bottom surface.

2. Puncture

Drum number 1 was dropped through a distance of 40 inches onto a 6 inch diameter cylindrical target. A dent approximately 1-1/8 inches deep resulted.

3. Thermal

Both drums were placed within a furnace heated in excess of 1500°F prior to insertion of the drums, and maintained at 1475°F for 1/2 hour subsequent to the insertion of the drums.

4. Immersion

Both drums were immersed under three feet of water for a period of 24 hours.

5. Container Dismantling and Inspection

The two sample drums were dismantled, inspected and measured to determine the loss of spacing suffered during the impact tests, and the extent of water inleakage into the 5 gallon pails.

5.1 Weight Checks

All pails were weighed before the tests commenced, and again, on the same scale, on completion of the tests. These weights are tabulated below, and demonstrate that no measurable inleakage of water into the pails had occurred.

WEIGHTS OF PAILS

	NUMEC (before tests)	ORGDP (before tests)	ORGDP (after tests)
Number 1			
Top Pail	22,470	22,470	22,470
Bottom Pail	20,470	20,440	20,440
Number 2			
Top Pail	20,510	20,490	20,490
Bottom Pail	20,450	20,440	20,440

5.2 Inspection Checks

5.2.1 Drum number 1 experienced a maximum temperature of 500°F on the cover plate. Removal of the cover and the pails revealed that water had entered, but only half filled the inner container. The inner container had shifted approximately 1/4 inch as a result of the impact.

Both pails experienced maximum temperatures of from 200 to 300°F, and appeared to have suffered little damage. When opened, dryness of the contents was confirmed.

5.2.2 Drum number 2 also experienced a maximum temperature of 500°F on the cover plate. As with drum number 1, water had entered, but only half filled the inner container. The inner container had shifted approximately 7/8 inch as a result of the impact. In addition, the drum had caved in at the point of impact, yielding a total loss of 2-1/2 inches spacing between the center of the inner container, and the nearest point on the outer container.

The upper pail experienced a maximum temperature of 325°F. Pieces of the gasket pulled loose when the lid was removed as a result of the adherence to the side of the pail.

The bottom pail experienced deformation on its rolling hoop, suffering a loss of 1 to 1-1/2 inches in overall height. However, the gasket had not deteriorated appreciably, and maintained its seal. A strip of seemingly caked powder 3/8 inches wide by 3/4 inches long by 1/64 inch thick was found near the top of the pail. No other indications of caked material was noted. Attempts to brush this material from the pail with light pressure were unsuccessful, but similar attempts with finger nail pressure indicated that it may not have been completely reacted. No other attempt had been made to identify the nature of this caking. However, in view of the general tendency of hygroscopic powdered material to form localized adhesions on many apparently dry surfaces, the nature of the milligram quantities of caked powder observed cannot be ascertained with any degree of certainty. It is, therefore, on the basis of recorded weight measurements that moderation control is claimed.

11/22/66

A series of additional tests has been carried out wherein pairs of pails have been dropped together without benefit of the surrounding drum structure, exposed to temperatures typical of those recorded above, and immersed under three feet of water for 24 hours. The results confirm those reported above. Included in these tests were pails which were equipped with lids identical to the standard 17-H lids, except that the closure device is a lever-lock ring formed of .032 steel sheet, in place of the standard lid closure lugs. The lids are identical in all other respects.

Based on the above tests, we conclude that:

1. The individual package remains subcritical under all conditions by virtue of the mass limit.

2. The ability to exclude water from the material being shipped provides the basis for evaluating an array of packages on the basis of dryness of the material.

1.2.4 Evaluation of an Array of LA-36 Containers

1.2.4.1 Dry Compounds

In view of the proven ability to exclude water moderation, we consider that all material being shipped contains a maximum of 0.5 w/o water.

a. Undamaged

Because this material is essentially unmoderated ($H/U \leq 0.5$), criticality cannot be achieved with any finite mass. Accordingly, an infinite number of containers is safe.

b. Damaged

The minimum volume occupied by the LA-36 container in a close packed hexagonal array is $3.46\ R^2H = 3.46\ (.835)^2\ (3.16) = 7.6\ ft^3$.

Mcb = Critical mass of an unreflected sphere of UO_2 (93% U-235)

Because the moderation ratio may be as high as 14.8 for 1.0% enriched uranium, we determine the value of Mcb from Figure 10 of LA-3366. While the value of Mcb thus obtained represents a carbon-water-uranium system, it yields slightly conservative results, as seen in Figure 9 of LA-3366. Thus,

McB = 25 kg U-235. The density ρ_o = 1.7 gm/cc.

The average uranium density ρ for the system is

$$\rho = \frac{1.58\ kg\ U\text{-}235}{215\ liter} = 0074\ gm/cc$$