CONSOLIDATED APPLICATION FOR RENEWAL
OF
CERTIFICATE OF COMPLIANCE
FOR
MODEL NO: RMG-181-I SHIPPING PACKAGE

Certificate No. 5492

Package Identification No.: USA/5492/B()F

Submitted By: Nuclear Fuel Services, Inc.
P. O. Box 218
Erwin, TN 37650

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1.0 GENERAL INFORMATION

1.1 Introduction

This document represents a consolidated application for renewal of Certificate of Compliance No. 5492 for the Model No. RMG-181-I shipping container. The container is used for the shipment of unirradiated Uranium, Uranium compounds or solutions. The containers shipped Fissile Class III are limited to 18 containers per shipment. Fissile Class II containers have H/U-235 ratios not exceeding 3 with a maximum transport index of 1.3.

The applicable portions of the format described in Regulatory Guide 7.9 "Standard Format and Content of Part 71 Application for Approval of Packaging of Type B, Large Quantity, and Fissile Radioactive Material," will be followed in this application.

1.2 Package Description

1.2.1 Packaging

The packaging authorized by this certificate consists of an outer DOT Specification 17H steel drum and sealed inner container of 5-inch Schedule 40 steel pipe. The contents are further contained in polyethylene bottles and/or metal cans. The inner container is centered and supported within the metal drum by 1" x 1" x 1/4" angle iron or by two sets of 1-1/2" x 1-1/2" x 1/4" steel angles. The void space between drum and inner container is filled with vermiculite. Each end of the inner container shall have a minimum 1" thick by 4-3/4" diameter wood block plus 3 inches of vermiculite. A 1/8" asbestos sheet or equivalent material is placed between both ends of the inner container and the outer drum. The package is identified as Model No. RMG-181-I, and is described on Nuclear Fuel Services' drawing number RMG-181-I (see Section 1.3, Appendix A).

1.2.2 Operational Features

The package does not utilize any special operational features.

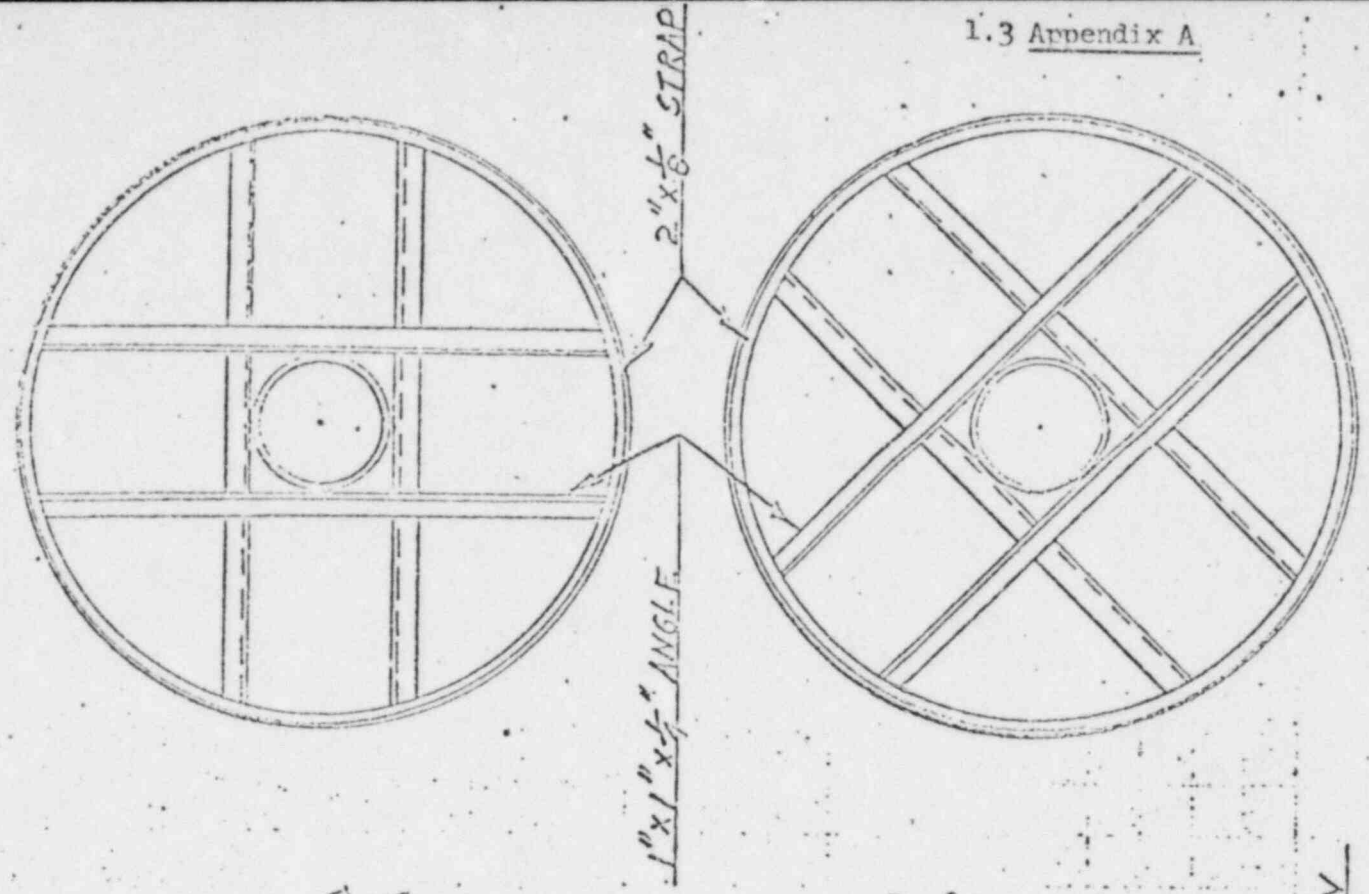
1.2.3 Contents of Packaging

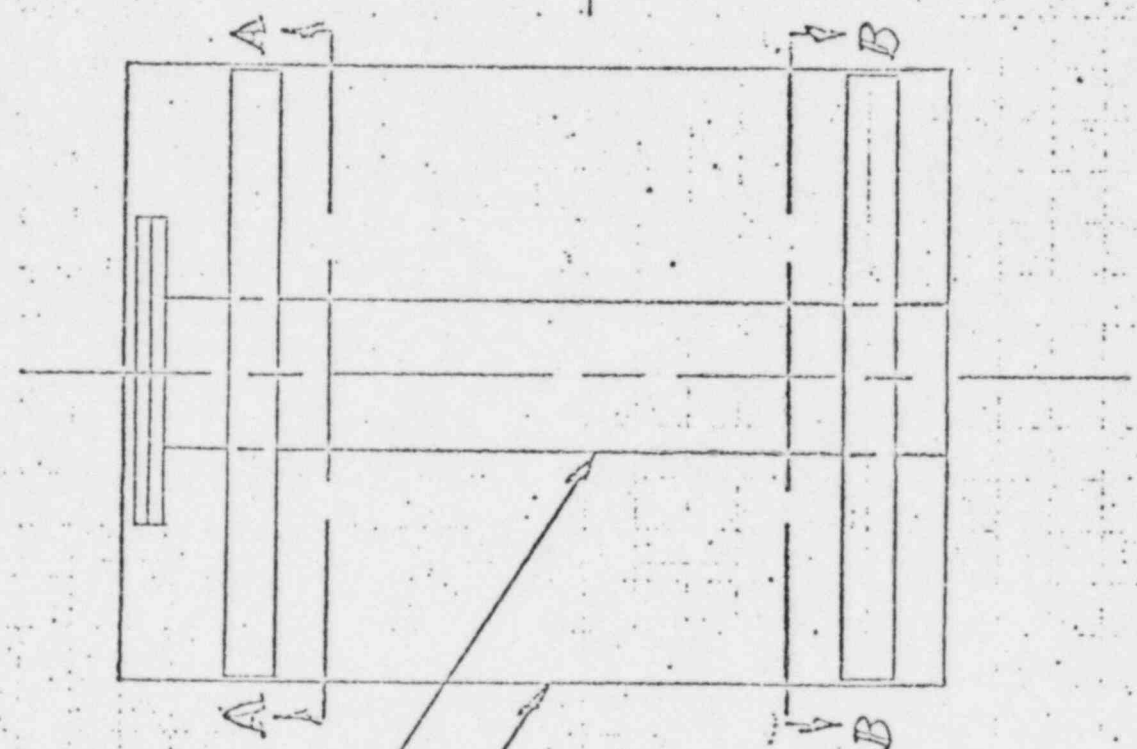
The authorized contents consist of large quantities of fissile radioactive material as:

a. Uranium or any Uranium compound or solution, of any enrichment, with no more than 10 kilograms of U-235 contained in not more than 100 pounds of material. Shipment authorized as Fissile Class III with not more than 18 packages per transport vehicle or stowage area.

b. U-235 as metal, compounds or alloys having an H/U-235 ratio of not more than 3 considering all sources of hydrogen in the inner container, and not more than 14 kilograms of

U-235 contained in a maximum of 100 pounds of material. Shipment authorized as Fissile Class II with a minimum transport index of 1.3 assigned to each package.





ALL WELDED CONSTRUCTION

NUCLEAR FUEL SERVICES, INC.
A SUBSIDIARY OF W. R. GRACE & CO.
ERWIN, TENNESSEE

55 GAL. DRUM BIRDCAGE WITH 5" DIA SLEEVE

DATE 11/10/65 BY [illegible] DWG. NO RMG-181-I

2.0 STRUCTURAL EVALUATION

2.1 Structural Design

2.1.1 Discussion

The containment vessel is a 5-inch Schedule 40 steel pipe with ASA standard threaded pipe cap closure and contains sealed polyethylene bottles and/or sealed metal cans. The containment vessel is supported in a DOT Specification 17H steel drum by two supports, either 1" x 1" x 1/4" angle iron framework as shown in drawing number RMG-181-I, (see Section 1.3 Appendix A), or two sets of 1-1/2" x 1-1/2" x 1-1/4" steel bearing band. Vermiculite is used to fill the entire void between the containment vessel and outer container; 1/8" asbestos sheet or equivalent material is placed between both ends of the containment vessel and outer container; 3 inches of vermiculite and a 1" thick wood block are located in bottom and top of containment vessel.

2.1.2 Design Criteria

The container meets or exceeds the design criteria for DOT Specification 17H (Title 49 CFR 178.118) steel drums. The 5-inch I.D. Schedule 40 steel pipe supported by angle iron framework or spokes in hoops further strengthens the package. Also, see Section 2.5 for additional design criteria.

2.2 Weights and Centers of Gravity

Package Constituents	Weight (lbs.)
55-gallon drum	52
Uranium-bearing Material	100 (Maximum)
Vermiculite	59
Supporting Structure	4
Pipe	18
RMG-181-I Total	233

The center of gravity is located 16" from the bottom of the drum along the vertical axis of symmetry in the center of the package.

2.3 Mechanical Properties of Materials

The outer containment 55-gallon drum meets DOT 17H specifications. The containment vessel is a 5-inch Schedule 40 steel pipe centered inside the drum.

2.4 General Standards for all Packages

2.4.1 Chemical and Galvanic Reactions

Uranium metal, compounds, or solutions are contained within polyethylene bottles and/or metal cans. Packaging in this manner inhibits any chemical or galvanic reactions.

2.4.2 Positive Closure

The polyethylene bottles and metal cans have affixed to them a tamper proof wire lock and seal. The polyethylene bottles and/or metal cans are then contained within a 5" I.D. pipe sleeve. The pipe has a welded bottom and ASA standard threaded pipe cap closure. The 55-gallon drum closure utilizes a 12-gauge bolted ring with drop forged lugs, one of which is threaded, having a 5/8" bolt. The 55-gallon drum closure meets Title 49 CFR 178.118-8 requirements.

2.4.3 Lifting Devices

The RMG-181-I package does not utilize any lifting devices.

2.4.4 Tiedown Devices

The RMG-181-I package does not utilize any tiedown devices.

2.5 Standards for Type B and Large Quantity Packaging

This package, when properly constructed and assembled, meets the standards prescribed in DOT Regulations Section 173.395(c)(2), 173.396(c)(3), and 173.398(c), thereby qualifying the package as a Type B and Large Quantity Package.

The package consists of a metal drum-type birdcage which conforms to a 55-gallon size DOT Specification 6L, except for the following modifications:

a. A 3-inch thickness of vermiculite must be placed at each end of the inner containment vessel.

b. A 1/8" asbestos sheet or equivalent material must be placed between each end of the inner containment vessel and the outer drum.

c. In lieu of the centering mechanism as prescribed in 178.103-3(c), an angle iron framework, 1" x 1" by 1/4" is utilized.

d. A minimum 1" thick x 4-3/4" diameter wood disc must be inserted at each end of the inner containment vessel so that the contents are between these blocks. The specified thickness of vermiculite at each end may be reduced by an amount equal to the thickness of each wood block.

2.6 Normal Conditions of Transport

The package design has proven to withstand hypothetical accident conditions in prototype testing; see Section 2.7. Referring to these tests, external temperatures would have negligible effects, if any, on the internal pressures, chemical composition, or the geometric or material buckling of the package under normal transport conditions. The 55-gallon drum (17H container) also must pass the testing specified in Title 49 CFR 178.118-12 and 13.

2.7 Hypothetical Accident Conditions

A prototype package was prepared as stated in Section 1.2.1, with 100 lbs. of material, and then tested.

2.7.1 Free Drop

First, the package was dropped 30 feet onto solid concrete. The package shown in Section 1.3 deformed to a minimum diameter of 22-1/2" with the sleeve displaced off-center by 1/2". The package with two hoops each spaced by 6 spokes deformed less than 1/2" and still had a minimum diameter larger than 23".

2.7.2 Puncture

The package was then dropped 3-1/2 feet onto a 6" diameter ram. The outer drum was only slightly deformed and the inner pipe was not damaged by such tests.

2.7.3 Thermal

The package was tested in a fuel oil fire for 30 minutes. The temperature of the fire read 2000 to 2100°F by optical pyrometer; readings were taken at ten minute intervals.

2.7.4 Water Immersion

After the fire test, the drum was immersed for 24 hours in water. The depth at the drum lid was four feet.

2.7.5 Summary of Damage

The inner containers showed no signs of excessive heat. No water leaked into the pipe sleeve and no water leaked out of the containers with water sealed inside (see Section 3.5). The bottle with no water in it remained dry inside and out.

2.8 Special Form

The package does not claim to be used for Special Form Material.

3.0 THERMAL EVALUATION

3.1 Discussion

Vermiculite is utilized as an insulating material for this container. The vermiculite is poured 3" deep into the sleeve and surrounds the 5" sleeve filling the remaining volume of the 55-gallon drum. No subsystems are necessary because no internal heat is generated from the unirradiated Uranium.

The inner polyethylene containers showed no signs of excessive heat resulting from fire testing at temperatures of 2000 to 2100°F.

3.2 Summary of Thermal Properties of Materials

Thermal conductivity of vermiculite.

$$k_v = 0.0317 \frac{BTU}{ft.hr.^oF}$$

Reference: Properties and Uses
Zonolite Brand Vermiculite
W. R. Grace Co.
Bulletin G-231
Copyright 1964
Revised 1976, Page 6

3.3 Technical Specifications of Components

The RMG-181-I shipping container is specified in Section 1.2 and shown in Section 1.3, Appendix A.

3.4 Thermal Evaluation for Normal Conditions of Transport

Referring to prototype testing under Hypothetical Accident Conditions, external temperatures resulting from normal transport conditions would have negligible effects, if any, on the internal pressures, chemical composition or the geometric and material buckling of the package.

3.5 Hypothetical Accident Thermal Evaluation

3.5.1 Test Model

Soluble Uranium compounds and solutions in sealed metal cans or polyethylene bottles are packaged in a 55-gallon drum birdcage prepared exactly as described below. Pyrophoric materials are sealed in the inner containers under inert gas and/or under oil and are packaged like soluble compounds.

(1) A drum was fitted with a 5" I.D. pipe sleeve with a welded bottom and a pipe cap top. A 1/8" sheet of asbestos was placed under the sleeve and the drum was filled with vermiculite. Vermiculite was also poured 3" deep in the sleeve.

(2) Three inner containers were added to the sleeve: a 2-liter polyethylene bottle with 100 g water sealed inside, a No. 3 can with 100 g water sealed inside, and a 2-liter polyethylene bottle sealed empty.

(3) Pipe dope was applied to the pipe cap threads, and the pipe cap was tightened with a 36" pipe wrench. The lid was then put on the drum.

(4) The drum was tested in a fuel oil fire for 30 minutes. The temperature of the fire read 2000 to 2100°F by optical pyrometer; readings were taken at ten minute intervals.

3.5.2 Package Conditions and Environment

Although this drum had not been dropped just prior to the fire and immersion tests previous drop tests have shown that neither the pipe sleeve nor the inner containers are damaged; see Sections 2.7.1 and 2.7.2.

3.5.3 Package Temperatures

The temperature of the fire that completely enveloped the drum read 2000 to 2100°F by optical pyrometer; readings were taken at ten minute intervals.

Pressure and stress calculations were neglected because actual test conditions properly simulated the conditions that would cause pressure build-up, (see Regulatory Guide 7.9 Section 3.5.4).

3.5.4 Evaluation of Package Performance for the Hypothetical Accident Thermal Conditions

The inner containers showed no signs of excessive heat. No water leaked into the pipe sleeve, and no water leaked out of the sealed containers inside. The bottle with no water in it remained dry inside and out.

4.0 CONTAINMENT

4.1 Containment Boundary

The RMG-181-I shipping package has three levels of containment:

a. inner containment - sealed polyethylene bottles and/or sealed metal cans.

b. containment vessel - 5-inch I.D. steel pipe.

c. outer containment - 55-gallon drum.

4.1.1 Containment Vessel

The containment vessel is a 5-inch I.D. Schedule 40 steel pipe, with an ASA standard threaded pipe closure. The outer containment meets the requirements specified for a DOT 17H container as stated in Title 49 CFR 178.118.

4.1.2 Containment Penetrations

To gain access to the contained material within a closed RMG-181-I package, one must go through the following in sequence;

a. Head of a 55-gallon drum, closed by the means of a 12-gauge bolted ring with drop forged lugs, one of which is threaded,

b. vermiculite inside the top portion of the outer containment,

c. 1/8" asbestos sheet or equivalent material in between the containment vessel and the outer containment,

d. an ASA standard threaded pipe closure over a 5-inch Schedule 40 steel pipe,

e. three inches of vermiculite and 1" thick wood block in the top of containment vessel, and

f. a sealed polyethylene bottle or sealed metal can.

4.1.3 Seals and Welds

All body seams on the 55-gallon drum are welded. An 1/8" asbestos gasket or equivalent material is placed between the containment vessel and the 55-gallon drum. The containment vessel has pipe dope applied to pipe cap threads, then the pipe cap is tightened with a 36" pipe wrench.

4.1.4 Closure

The 55-gallon drum utilizes a 12-gauge bolted ring with drop forged lugs, one of which is threaded, having a 5/8" bolt, for closure as specified in Title 49 CFR 178.118-8. The 5" pipe sleeve has an ASA standard threaded pipe cap closure. The polyethylene bottles and/or metal cans are affixed with a tamper proof lock wire and seal, adequate to prevent inadvertent opening of the container.

4.2 Requirements for Normal and Hypothetical Conditions of Transport

Through prototype testing, the package has proven not to release contained materials or solutions when exceeding the conditions specified in Appendix B, Title 10 CFR Part 71; see Section 2.7.

5.0 SHIELDING EVALUATION

Since the contents of the container are limited to unirradiated Uranium, the pipe sleeve and 55-gallon drum offer sufficient shielding.

6.0 CRITICALITY EVALUATION

6.1 Discussion and Results

The RMG-181-I package may contain Uranium metal, alloys, solutions or Uranium compounds of any enrichment of U-235. The 5" I.D. sleeves are critically safe for U-235 at Uranium densities up to 3.2 g/cc at optimum moderation and fully reflected (TID-7016, Rev. 1).

6.2 Package Loading

The package is loaded in the following manner:

a. Uranium or any Uranium compound or solution, of any enrichment, with no more than 10 kilograms of U-235 contained in not more than 100 pounds of material.

   Shipment authorized as Fissile Class III with not more than 18 packages per transport vehicle or stowage area.

b. U-235 as metal, compounds or alloys having an H/U-235 ratio of not more than 3 considering all sources of hydrogen in the inner container, and not more than 14 kilograms of U-235 contained in a maximum of 100 pounds of material.

   Shipment authorized as Fissile Class II with a minimum transport index of 1.3 assigned to each package.

6.3 Model Specification

6.3.1 Description of Calculation Model

The model determines the k_{eff} for a 100% enriched system in a 5-inch I.D. cylinder. The solid angle corresponding to this k_{eff} determines the number of packages permitted per transport vehicle or stowage area. The packaging array is assumed to be close packed and analyzed for normal and accident conditions (see Section 6.5, Appendix B and Appendix C).

6.3.2 Package Regional Densities

Assumed H/U-235 = 100
critical mass = 1.8 kg
critical volume = 7-liter

critical concentration = 0.27 g/cc

Reference:

TID-7028
fig. 8 and fig. 9

The above concentration is used to find a corresponding k_∞ and migration area taken from ARH 600, Vol. II, Fig. III.B.11.93-1.

$k_\infty = 1.86$
$M_t^2 = 28.2\ cm^2$

6.4 Criticality Calculations

The k_{eff} was determined in the following manner:

Values for material buckling (0.308) and extrapolation distance (S = 2.1 cm) were taken from ARH 600, Vol. II, Fig. III.B.10.93-1 for a 93% enriched system. A k_{eff} correction factor for a 100% enriched system was calculated by first calculating the critical infinite cylinder radius for the given buckling and extrapolation distance. The calculated radius was 11.6 cm. It was noted from figure 23 of TID-7028 that the minimum critical radius decreases from 6.9 to 6.6 cm in going from 93 to 100% enrichment. An equivalent decrease was assumed for the calculated radius and the effect of this decrease included in the extrapolation distance, S_c:

$$S_c = S + R\left(1 - \frac{6.6}{6.9}\right) = 2.6\ cm$$

The k_∞ and migration area taken from ARH 600, Vol. II, Fig. III.B.11.93-1 were used with the adjusted extrapolation distance to calculate the k_{eff} for a 5-inch I.D. cylinder.

The calculated k_{eff} for a 100% enriched system in a 5-inch I.D. cylinder is 0.603.

$$\Omega = 9\text{-}10k_{eff}$$

The allowed solid angle, Ω = 2.97 steradians.

The close packed array model is shown in Section 6.5 Appendix B. The model tabulation (Section 6.5, Appendix C) shows the number of allowable drums for the given solid angle under normal and accident conditions. Normal conditions assumes a drum spacing from center to center of 24". Accident conditions assume a drum spacing from center to center of 22". The accident drum spacing assumes uniform deformation of the packages.

The resulting number of packages to be demonstrated as subcritical under specific moderation and reflection conditions as per Sections 71.38, 71.39, and 71.40 of Title 10 CFR Part 71 are shown in Section 6.5, Appendix A.

6.5 Appendix A

Uranium or any Uranium compound or solution of any enrichment, with no more than 100 pounds of material are only shipped Fissile Class III.

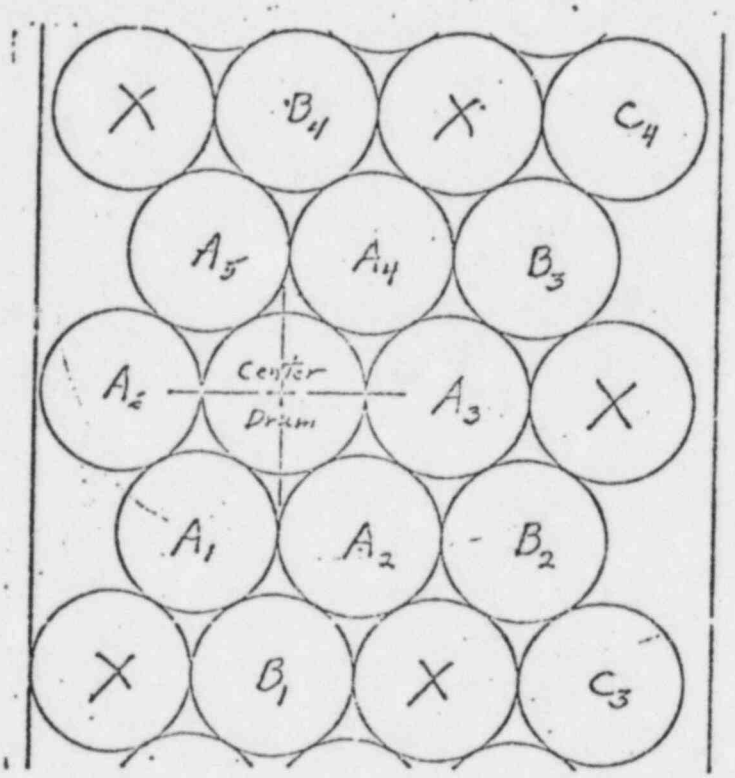
	NORMAL CONDITIONS	ACCIDENT CONDITIONS
No. of Drums.	22	18

Uranium-235 as metal, compounds or alloys having an H/U-235 ratio of not more than 3 considering all sources of hydrogen in the inner container, and not more than 14 kilograms of U-235 contained in a maximum of 100 pounds of material may be shipped Fissile Class II.

Packages of this nature will have a minimum transport index of 1.3 assigned to each package, as specified in Title 49 CFR 173.396(c)(1).

Solid Angle Calculations

If the 55-gallon drum birdcages were uniformly deformed to 22" diameters and were stacked two deep in a truck, they could be arranged in the following close-packed array:



Stack No.	Center-to-Center
A	22"
B	38.1"
C	38.2"
X	Shielded

Each stack of birdcages would be equivalent to a 5" i.d. x 60" long sleeve spaced 22" center-to-center from its nearest neighbors of 5" i.d. x 60" long sleeves.

6.5 Appendix C

RMG-181-I 100% enriched
K_{eff} = 0.603
Ω allowed = 2.97 steradians

Normal Conditions

Unit	Solid Angle/Unit		Number Units		Total Solid Angle	
	Planar	Stacked	Planar	Stacked	Planar	Stacked
A	0.266	0.378	6	6	1.596	2.268
B	0.092	0.156	6	4	.552	.624
C	0.039	0.072	4		.156	
D	0.021	0.040	4		.084	
Center	-	-	1	1		
Total	-	-	21	22	2.39	2.89
Number Shielded			10	-		
		TOTAL	31	22		

Accident Conditions

Unit	Solid Angle/Unit		Number Units		Total Solid Angle	
	Planar	Stacked	Planar	Stacked	Planar	Stacked
A	0.313	0.430	6	6	1.878	2.580
B	0.109	0.181	6	2	0.654	.362
C	0.047	0.085	4	0	0.188	
D	0.025	0.047	4	0	0.100	
Center			1	1		-
Total	-	-	21	18	2.82	2.94
Number Shielded			10	-		
		TOTAL	31	18		

7.0 OPERATING PROCEDURE

7.1 Procedure for Loading the Package

a. Prior to loading, the package is inspected for any significant damages. The closure of the package and any sealing gaskets are ensured to be present and free from defects.

b. The drum is fitted with a 5" I.D. pipe sleeve with a welded bottom and a pipe cap top. A 1/8" sheet of asbestos or equivalent material is placed under the sleeve and the drum is filled with vermiculite. Vermiculite is also poured 3" deep in the sleeve.

c. Three inner containers, polyethylene bottles or metal cans, are added to the sleeve.

d. Three inches of vermiculite is then added to the sleeve on top of the bottles or cans. Also, a 1" thick wood disc is added to the sleeve.

e. Pipe dope is applied to the pipe cap threads, and the pipe cap is tightened with a 36" pipe wrench. A 1/8" sheet of asbestos or equivalent material is placed on top of the sleeve, and all remaining void spaces are filled with vermiculite. The lid is then put on the drum.

f. The package is physically inspected for leaks. The package and its surface are surveyed.

g. All checks and inspections are documented.

7.2 Procedure for Unloading the Package

a. The package is first inspected for physical damage and leaks. The package and its surface are surveyed.

b. The drum lid is removed.

c. Vermiculite is removed from the top of the package until the pipe cap is accessible. The vermiculite removed from the package is to be contained in a plastic liner until the integrity of the polyethylene bottles and/or metal cans is verified. The 1/8" sheet of insulating material is also removed and bagged.

d. The pipe cap is removed using a 36" pipe wrench.

e. The vermiculite and wood disc are removed from within the pipe.

f. The polyethylene bottles and/or metal cans are now accessible and are examined for physical damage and leaks.

g. All checks and inspections are documented.

7.3 Preparation of an Empty Package for Transport

Empty packages are shipped in accordance with Title 49 CFR 173.29(a) and (e):

a. The external surface must be free of significant removable contamination. The radiation level at the external surface of the package must not exceed 0.5 millirem per hour.

b. All openings, including removable heads, filling, and vent holes, must be tightly closed.

c. A label signifying that the package is empty must be affixed to the package. All other labeling must be removed, obliterated, or completely covered.

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

8.1 Acceptance Test

8.1.1 Visual Inspection

The RMG-181-I shipping container will be visually examined for physical deformation of the structural and containment components. This inspection is to ensure that no damage had occurred during fabrication. Defective containers will be returned to the supplier.

8.1.2 Other Tests

The outer containment of this package must meet DOT 17H shipping package requirements as stated in Title 49 CFR 178.118. These requirements specify testing of randomly selected samples in accordance with Title 49 CFR 178.118-12 and 178.118-13.

8.2 Maintenance Program

The RMG-181-I containers will be stored in an area that protects the container from corrosive and physical damage.