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THE GENERAL ELECTRIC MODEL BU-7 URANIUM SHIPPING CONTAINER -- CRITICALITY SAFETY ANALYSIS

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ABSTRACT

The General Electric Model BU-7 Shipping Container has been shown to meet the specific criticality standards for a Fissile Class I Package as required in Title 10, Part 71 of the U.S. Atomic Energy Commission's Code of Federal Regulations (10CFR71). Each BU-7 container is restricted by the results of the analysis to contain limited quantities of dry, unirradiated uranium compounds enriched up to four percent in the U-235 isotope.

The KENO Monte Carlo criticality code was used with a modified Hansen and Roach 16-Group set of cross sections in the analysis.

INTRODUCTION

General Electric now uses the Model BU-5 shipping container for the transportation of low-enriched, unirradiated, uranium oxides. The GE Model BU-5 contains a solid insulating medium called VPAC, an acronym for vermiculite, plyamine and powdered ammonium chloride catalyst.

In order to lighten the net weight of the container and thus effect savings in the cost of transporting the fuel, a phenolic resin has been proposed as a substitute insulating medium. The phenolic resin has a density of approximately 8 pounds per cubic foot.

The GE Model BU-7 shipping container is thus identical to the GE Model BU-5, except that a lighter phenolic resin insulation is used instead of the VPAC insulation.

ANALYSIS SCOPE

To demonstrate that the GE Model BU-7 package meets the specific criticality safety standards for a Fissile Class I package as required by Part 71, Title 10, of the U.S. Atomic Energy Commission's Code of Federal Regulations.

SUMMARY AND CONDITIONS

The results demonstrate that the GE Model BU-7 shipping container meets the specific standards of the U.S. Atomic Energy Commission's Title 10 Part 71 for a Fissile Class I package when used for the transportation of dry, unirradiated, low-enriched, uranium compounds.

The GE Model BU-7 and the insulating mixture are to be as described in the *Package Description* section of this report. The insulating mixture shall have a density of 8 ± 1 pounds/cubic foot.

The fuel content of *each package* (BU-7) is to be restricted as follows:

Enrichment:	Uranium enriched up to a maximum of 4% in the U-235 isotope.
Moderation:	Dry uranium compounds. A maximum hydrogen-to-uranium ratio of 0.45, considering all sources of hydrogenous moderators in the inner containment.
Physical Form:	Uranium compounds in the form of powder, pellets or powder-pellet mixtures.

Contents: Not to exceed the lesser of:

(1) Two safe batches (90% of a minimum critical mass of UO$_2$ as a function of the maximum enrichment and physical composition[a] (powder or pellets) of the uranium in the container, or

(2) 89 kilograms of total contents.[b]

[a] The more limiting value of pellets shall be used when a combination of powder and pellets is present.
[b] The 89 kilograms of UO$_2$ is not a criticality limit but a value chosen as the load stop-limit.

PACKAGE DESCRIPTION

The BU-7 inner containment is a nominal 10-gallon Department of Transportation (DOT) Specification 17H drum constructed of 18-gauge steel, modified by the welded attachment of a closure flange to accept a 3/10-inch thick steel lid which is gasketed for resistance to high temperature and is attached by twelve 5/16-inch steel bolts. The inside dimensions of the inner containment drum are 10.75 inches in diameter by 27 inches high. The outer containment is a nominal 55-gallon, DOT Specification 17H, 18-gauge steel drum, 22.62 inches outer diameter and 35.5 inches high.

The space between the concentric inner and outer containers is completely filled with a solid insulating medium—phenolic resin. The phenolic resin is the same as that used in the FL-10-1 package, and the 5A and 30AB overpacks. The resin has a density of 8 ± 1 pounds/cubic foot. Its chemical composition is shown in Table 1.

Table 1
CHEMICAL COMPOSITION OF THE PHENOLIC RESIN INSULATION

Elemental Weight Percent*		Organic Compounds – Weight Percent	
Carbon	41.0%	Union Carbide Phenolic Resin BRL2760	65.8%
Hydrogen	4.5%	Silicone Surfactant LS30	2.0%
Boron	3.2%	Boric Anhydride B-203	8.2%
Silicon	2.2%	Anhydride Oxalic Acid	8.2%
Calcine	0.5%	Freon 113	6.6%
Nitrogen	~0	Fiberglass Roving	9.6%
Fluorine	~0		
Oxygen	48.6%		

*Density = 8 ± 1 pounds/cubic foot

The uranium is contained in two nominal 5-gallon pails, or two or more nominal 2.5-gallon pails, fabricated of minimum 24-gauge steel. The pails have an inside diameter of 11.25 inches and are vertically stacked in the inner containment of each BU-7.

TECHNICAL CONSIDERATIONS

The KENO[1] Monte Carlo criticality code was used for the computations with a Knight-modified[2] Hansen and Roach[3] set of cross sections obtained from Oak Ridge National Laboratory.

Tests[4] performed by the General Electric Company demonstrate that the capacity of a 5-gallon can is [illegible] kilograms of randomly stacked pellets, indicating a void fraction of approximately 62%. We have, therefore, very conservatively assumed for computational purposes that each 5-gallon can is full of about 85 kilograms of 4%-enriched UO_2 pellets [illegible] the maximum amount of 4%-enriched pellets to be allowed in any 5-gallon can is [illegible] kilograms on a safe basis.

Since the pellets, which come from a dry environment, are loaded into the essentially dry inner containers of the BU-7, there is practically no hydrogenous moderation present between the fuel lumps. Therefore, pellets in the 5-gallon cans are considered to be a homogeneous mixture, with a density of 4.2 grams UO_2/cc [(theoretical UO_2 × (1-void fraction)]. This homogeneous mixture density used [illegible] conservative, since the density of UO_2 pellets will not exceed 4.2 grams UO_2/cc. The fuel mixture number densities corresponding to 4% enriched UO_2 at an H-to-U ratio of 0.45 are given in Table 2.

Table 2
NUMBER DENSITIES OF FUEL MIXTURE

Element	Number Density, Atoms/Barn-cm
U-235	0.0003796
U-238	0.008[illegible]8
O (in fuel)	0.01[illegible]7
H	0.0042165
O (in water)	0.002100

Since the H/U ratio is constant, the value of σ_p (barns per absorber atom) is also constant. A σ_p of 29.5 barns per U-238 atom was computed. A conservative value of 12 barns per U-238 atom was used in the calculations. This low value will underestimate the resonance absorptions in U-238 and yield larger values of the multiplication constant.

The BU-7 was represented in the KENO computer program by the same geometric model used in the analysis of the BU-5 package.[5]

RESULTS

- **Normal Conditions of Transport**

  The reactivity of an infinite array of undamaged BU-7's loaded with approximately 171 kilograms of dry, 4%-enriched UO_2 (number densities as given in Table 2), was shown to be subcritical under two sets of conditions:

  1. Interspersing moisture with a density of [illegible] per cubic foot

2. Insulating mixture with a density of 7 pounds/cubic foot –

k_∞ = 0.67669 ± 0.00107 (1σ)

The nuclear densities of the insulating mixtures used in the analysis are given in Table 3.

b. Accidental Conditions

An array of 256 (8 x 8 x 4) BU-7's, loaded as above and fully water-reflected, was shown to be subcritical under conditions of optimum inter-unit moderation.

For the analysis of the accident conditions, no credit was taken at all for the insulating mixture, and the spaces in between inner containments, not occupied by steel, were assumed to contain water of various densities.

The reactivity of the fully water-reflected array is given in Table 4 as a function of inter-unit water density. It can be seen from this table that the maximum reactivity for the array occurs at an inter-unit water density of 0.125 grams/cc, and is less than 0.81.

Table 3
NUMBER DENSITIES OF THE INSULATING MIXTURE

Density = 8 lb/ft³ of Insulation		Density = 7 lb/ft³ of Insulation	
Element	Number Density Atoms/Barn-cm	Element	Number Density Atoms/Barn-cm
Carbon	2.034×10^{-3}	Carbon	2.305×10^{-3}
Hydrogen	3.445×10^{-3}	Hydrogen	3.014×10^{-3}
Boron	2.292×10^{-4}	Boron	1.997×10^{-4}
Silicon	6.044×10^{-5}	Silicon	5.289×10^{-5}
Chlorine	1.088×10^{-5}	Chlorine	9.520×10^{-6}
Oxygen	2.344×10^{-3}	Oxygen	2.051×10^{-3}

Table 4
Keff OF FULLY WATER REFLECTED ARRAY OF
256 (8 x 8 x 4) BU-7'S

Inter-Unit H_2O Density, gm/cc	99% Confidence Interval
0.25	0.67616 to 0.72590
0.125	0.77043 to 0.80985
0.06	0.71041 to 0.77316
0.03	0.64875 to 0.69431

REFERENCES

1. G. E. Whitesides and N. F. Cross, "KENO - A Multigroup Monte Carlo Criticality Program," CTC-5, Oak Ridge Computing Technology Center (1969).

2. G. E. Whitesides, KENO Cross Section Library.

3. G. E. Hansen and W. H. Roach, "Six and Sixteen Group Cross Sections for Fast and Intermediate Critical Assemblies," LAMS-2543, Los Alamos Scientific Laboratory.

4. Internal Document, General Electric Company, San Jose, California (1967).

5. License No. SNM-54 (Docket #70-1007), Appendix D, Modification 18, April 14, 1972, Table V (p. 1-55) and Figure 1.6.3 (p. 1-60).

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SUMMARY

GE Model BU-7 Shipping Container meets criticality standards of 10CFR71. Report states the calculational methods used in testing the container.

By cutting out this rectangle and folding on the center line, the above information can be fitted into a standard card file.

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