

NRC Presentation

PART 71--PACKAGING AND TRANSPORTATION OF RADIOACTIVE MATERIAL

**By Westinghouse Electric Company LLC
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Purpose and Agenda

Purpose

PART 71--PACKAGING AND TRANSPORTATION OF RADIOACTIVE MATERIAL

Agenda

- Perfumed or Blended U Transport
- MCC License Amendments
- Traveller Licensing
- General Package Licensing

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Perfumed or Blended U Transport

Perfumed Uranium

What we wish to transport

- Contract with a European customer
- Option to order fuel fabricated from uranium that does not conform to the corresponding limits for Enriched Commercial Grade UF6 described in ASTM Specification C 996-96, *Standard Specification for Uranium Hexafluoride Enriched to Less than 5% U-235*.
- It does, however, fall well within the limits for Enriched Reprocessed UF6 found in the same specification.
- “Perfumed” or “Blended” uranium is the term given to unirradiated material that has been processed in a system that has handled irradiated material.

Perfumed Uranium

What we wish to transport

- Additional hazards exist if the UF₆ contains uranium recovered from reprocessing of spent nuclear fuel.
- In this case, the UF₆ is contaminated with artificial uranium isotopes, fission products, and transuranics.
- The artificial uranium isotopes include U-232, U-233, U-236, and U-237.
- The fission products with non-negligible contributions to the value of A₂ are Ru-106 (Ruthenium) and Tc-99 (Technetium).
- Transuranics include Np-237 (neptunium) and Pu-239 (plutonium).

Perfumed Uranium

What we wish to transport

- U-232 is of special concern,
 - Some of its decay products are strong gamma emitters (in particular Th-232).
- While the activity of the fission products slowly decreases with time due to radioactive decay, the activity of the U-232 progeny (and thus its gamma radiation) strongly increases during the first 10 years, until secular equilibrium with U-232 is obtained.

Perfumed Uranium

10CFR and TSR-1 Limits – Unirradiated Uranium

	10CFR	TSR-1
Pu	$2 \cdot 10^3$ Bq/g U235	$2 \cdot 10^3$ Bq/g U235
FP	$9 \cdot 10^6$ Bq/g U235	$9 \cdot 10^6$ Bq/g U235
U236	$5 \cdot 10^{-3}$ g/g U235	$5 \cdot 10^{-3}$ g/g U235
Enriched	> 0.72wt% U235	> 0.711 wt% U235
		Small amount U234 present

Perfumed Uranium ASTM C996-96 Limits

	Enriched Commercial Grade UF ₆		Enriched Reprocessed UF ₆	
²³² U	0.0001 µg/gU	5.5.1; 5.5.2; 5.5.3	0.050 µg/gU	Note 2
²³⁴ U	10.0 X 10 ³ µg/g ²³⁵ U	Note 3	2000 µg/g ²³⁵ U	Note 2
²³⁶ U	250 µg/gU	5.5.3		Note 2
⁹⁹ Tc	0.01 µg/gU	5.5.1; 5.5.2; 5.5.3	5 µg/gU	Note 2
Total Gamma Activity	< 5000 MeV Bq/kg		4.4 X 10 ⁵ MeV Bq/kg	
Alpha Activity Np / Pu	< 0.4 Bq/gU		3300 Bq/gU	

Perfumed Uranium

ASTM C996-96 Notes

- **5.5.1** If the U-236 measurement result is less than 125 $\mu\text{g/gU}$, then measurement of U-232 and Tc-99 is not required unless agreed upon between buyer and seller.
- **5.5.2** If the U-236 measurement result is greater than 125 but less than 250 $\mu\text{g/gU}$, then measurement and reporting of U-232 and Tc-99 are required for routine acceptance of the UF₆.
- **5.5.3** The buyer may consider acceptance of the lot above 250 $\mu\text{g/gU}$ on the basis of the total significance of all the measured levels of radionuclides to determine the suitability for intended use in the fuel fabrication and irradiation. If the U-236 measurement result is greater than 250 but less than 500 $\mu\text{g/gU}$, then measurement of U-232 and Tc-99 and notification of results before shipment are required.

Perfumed Uranium

ASTM C996-96 Notes (cont'd)

Notes

- **Note 2:** Enrichment of Reprocessed UF₆ feed material at the limit of Specification C787 could be expected to reach these limits. Defining these limits does not imply that any fuel fabrication plant designed for Enriched Commercial grade UF₆ could handle Enriched Reprocessed UF₆ without dilution with Enriched Commercial Grade UF₆ and other special precautions. With respect to the variability of Reprocessed UF₆ from various fuel histories and the demands that would be placed on the fuel fabricators and users, it could be necessary for the seller and buyer to agree on lower limits after enrichment than implied by Specification C787 feed limits.
- **Note 3:** Meeting the limit of $10 \times 10^3 \mu\text{g}^{234}\text{U}/\text{g}^{235}\text{U}$ may impose restrictions on the allowable combination of concentrations of ²³⁴U in the feed material and ²³⁵U in the enriched uranium and tails material. If the ²³⁴U level is expected to be greater than 10×10^3 but less than $11 \times 10^3 \mu\text{g}^{234}\text{U}/\text{g}^{235}\text{U}$, then the parties may reach agreement in advance to accept the material.

Perfumed Uranium Limits Converted to $\mu\text{g/gU}$ @ 5wt%

Isotope ($\mu\text{g/gU}$)	ASTM C996-96 Enriched Commercial Grade	ASTM C996-96 Enriched Reprocessed UF6	Proposed "Perfumed" Material Limits	Proposed "Perfumed" License Limits
U-232	0.0001	0.05	0.0001437	0.0002
U-234	500	2000	518.35	550
U-235			50000	50000
U-236	250	250*	691.95	1000
Tc	0.01	5	0.01	0.01

Perfumed Uranium

Unlimited A2 Value

- RAM transport regulations require the use of packaging types that correspond to contents. The quantity of radioactive material in a package shall not exceed the relevant limits specified in the regulations.
- Enriched commercial grade uranium may be transported in either a Type A or Type IP-2 that also must meet requirements for packages containing fissile material. (e.g., either “AF” or “IF”)
- The contents in a Type A package shall not contain an activity greater than one A2 for an individual nuclide or the sum of A2 fractions shall not be greater than 1 for mixtures of radionuclides.
- **Unirradiated uranium enriched to 20% or less has an unlimited A2 value.**
- **Therefore, any quantity of unirradiated uranium may be transported in a Type A package.**
- Unirradiated uranium by definition may include a small mass fraction of uranium-236.

Perfumed Uranium

Unlimited A2 Value (cont'd)

- The unlimited A2 values for unirradiated uranium, natural uranium, depleted uranium, and ^{238}U are based on the application of the LSA criterion limit $10^{-4} \times \text{Qc/g}$ used in the Q system (TS-G-1.1 I.68).
- The ^{236}U in the “perfumed” material is $2.8 \times 10^{-1} / \text{g}^{235}\text{U}$ and exceeds the limit for ^{236}U in the definition of unirradiated uranium.
- In addition, the definition of unirradiated uranium makes no provision for contamination with ^{232}U .
- It may include a small mass fraction of ^{236}U .

Perfumed Uranium

Unlimited A2 Value (cont'd)

- Even though the composition exceeds the definition for unirradiated uranium, international regulations allow for the determination of A2 values for radionuclides that are not listed in TSR-1 Section IV, Table 2.
- **TSR-1 §403. For individual radionuclides which are not listed in Table 2, the determination of the basic radionuclide values referred to in §402 shall require multilateral approval.**
- It is permissible to use an A2 value calculated using a dose coefficient for the appropriate lung absorption type, as recommended by the International Commission on Radiological Protection, if the chemical forms of each radionuclide under both normal and accident conditions of transport are taken into consideration.

Perfumed Uranium

LSA – U.S. Definitions

10CFR71.3 Definitions

- *Low Specific Activity (LSA) material* means radioactive material with limited specific activity which is nonfissile or is excepted under §71.15, and which satisfies the descriptions and limits set forth below.

49CFR173.403 Definitions

- Low Specific Activity (LSA) material means Class 7 (radioactive) material with limited specific activity which satisfies the descriptions and limits set forth below. Shielding material surrounding the LSA material may not be considered in determining the estimated average specific activity of the package contents.

Perfumed Uranium

LSA – TSR-1 Definitions

A Type IP-2 package may contain low specific activity material

- 226. Low specific activity (LSA) material shall mean radioactive material which by its nature has a limited specific activity, or radioactive material for which limits of estimated average specific activity apply. External shielding materials surrounding the LSA material shall not be considered in determining the estimated average specific activity.
- Enriched commercial grade uranium may be classified as LSA-II because the activity is distributed throughout the uranium hexafluoride (UF₆) or uranium oxide (UO₂) and the average specific activity does not exceed 10⁻⁴ A2/g (TS-R-1 2009 Edition, para. 409 (b) (ii)).

Perfumed Uranium LSA Mat'l in AF-96 Packages

- Approval of the perfumed uranium contents for the Type AF package would require calculations using the hypothetical model for LSA to show that the effective dose associated with the intake of 10 mg of the mixture of nuclides is less than the dose criterion of 50 mSv.
- Likewise, if the mixture of nuclides is less than $10^{-4} \times \text{QC/g}$, the Q value for the perfumed uranium mixture is 'unlimited'.
- The regulations require that A2 value calculated using a dose coefficient for the appropriate lung absorption type.

Perfumed Uranium LSA Mat'l in AF-96 Packages

Low specific activity materials with 'unlimited' A1 or A2 values

- I.68. The 1973 Edition of the Transport Regulations recognized a category of materials whose specific activities are so low that it is inconceivable that an intake could occur which would give rise to a significant radiation hazard, namely LSA material. These were defined in terms of a model where it was assumed that it is most unlikely that a person would remain in a dusty atmosphere long enough to inhale more than 10 mg of material.

Perfumed Uranium LSA Mat'l in AF-96 Packages

I-68 (cont'd)

- Under these conditions, if the specific activity of the material is such that the mass intake is equivalent to the activity intake assumed to occur for a person involved in an accident with a Type A package, namely 10^{-6} A2, then this material should not present a greater hazard during transport than the quantities of radioactive material transported in Type A packages.
- This hypothetical model is retained within the Q system and leads to an LSA criterion limit of $10^{-4} \times \text{QC/g}$; thus, the Q values for those radionuclides whose specific activity is below this level are listed as 'unlimited'.

Perfumed Uranium LSA Mat'l in AF-96 Packages

I-68 (cont'd)

- In the cases where this criterion is satisfied the effective dose associated with an intake of 10 mg of the nuclide is less than the dose criterion of 50 mSv.
- Natural uranium and thorium, depleted uranium and other materials such as U-238, Th-232 and U-235 satisfy the above LSA criterion.
- Calculations using the latest dose coefficients listed in the BSS [I.10] and by the ICRP [I.9] indicate that unirradiated uranium enriched to <20% also satisfies the same criterion, on the basis of the isotopic mixtures given in ASTM C996-90 [I.34].
- A1 and A2 values for irradiated reprocessed uranium should be calculated on the basis of the mixtures equation, taking into account uranium radionuclides and fission products.

Perfumed Uranium

No “IF-96” for LSA Mat’l in U.S. Regulations

- The U.S.A. competent authority, U.S. Department of Transportation (DOT), hazardous material regulations do not allow the use of an industrial package for the transport of fissile material. The type code for industrial package design for fissile material, IF, is not recognized by the DOT.
- Use of either the Type AF or Type IF package requires multilateral approval.
- In both cases the applicant must demonstrate that the material does not present a greater hazard during transport than the quantities of radioactive material transported in Type A packages.
- Justification for use of the Type AF package is based on a calculated the A2 value for the perfumed uranium using the hypothetical Q model for LSA material.
- The use of a Type IF package is allowed based on a contents that meets the requirements for LSA-II, specific activity less than 10^{-4} A2/gram.

Perfumed Uranium “IF-96” or “AF-96”?

- Westinghouse has had discussions with several European Competent Authorities regarding the transport of this material in “IF” or “AF” packagings.
- CA responses include:
 - Validate US “AF-96” approval as an “IF-96”
 - Transport using a new calculation for unlimited A2 value for U enriched to 20% or less with the “AF-96” designation.
 - Needs further consideration. Cannot issue “IF-96” validation for an “AF—96” approval, but may issue Special Arrangement while under review.

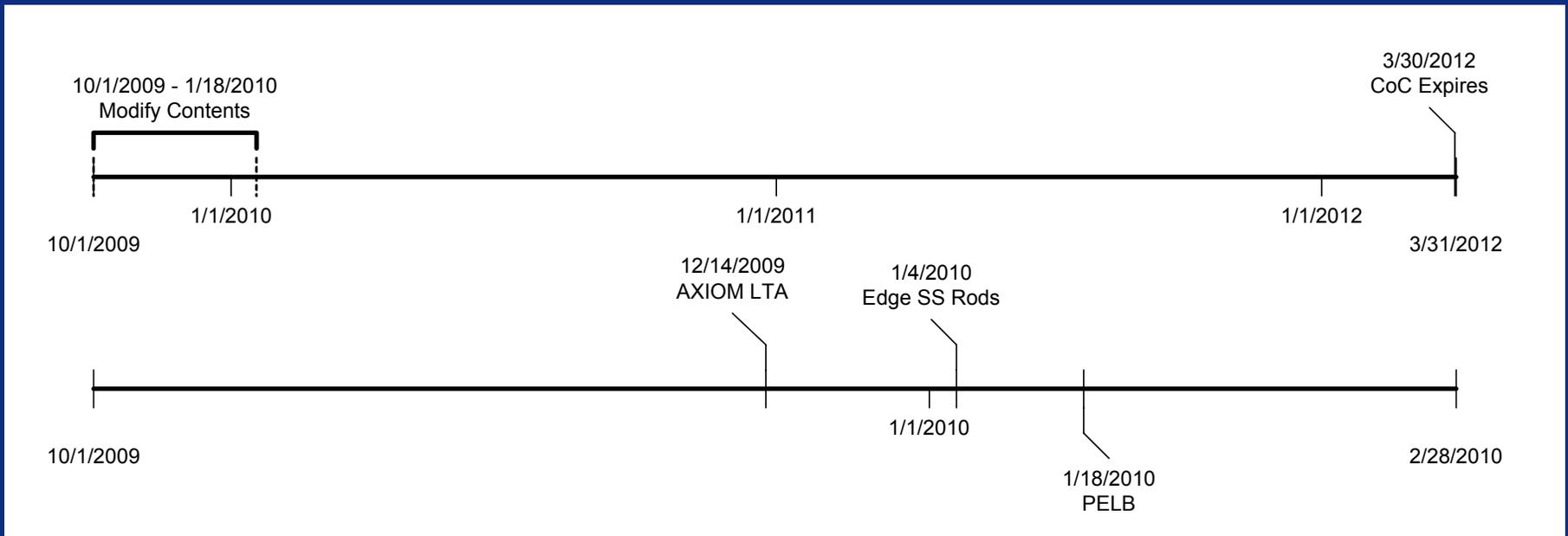
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USA/9239/AF
MCC License Amendments

MCC USA/9239/AF

- MCC continued use as AF package beyond 2012 or until the renewal is not allowed.
- MCC used to transport Westinghouse fuel in US, Europe and Asia, and VVER in Europe (South Ukraine and Czech Republic)
- Modification to fuel designs will continue to require request to amend contents type and form

MCC USA/9239/AF

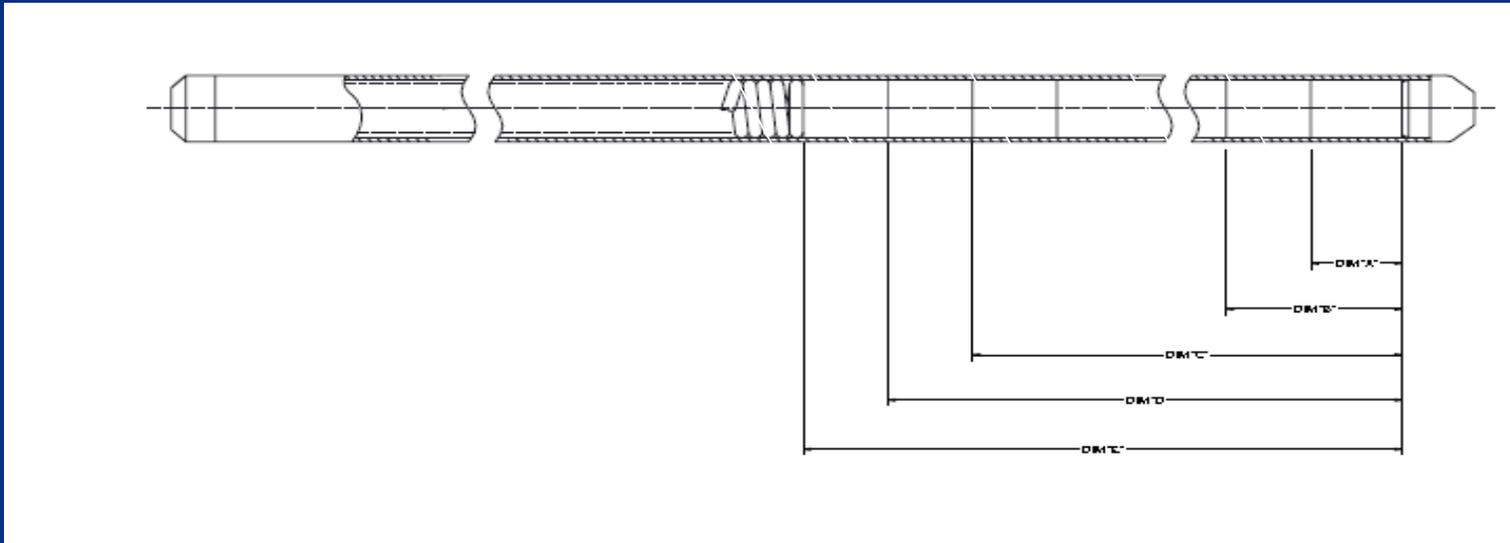


MCC Amendment Requests

- Special center fuel assembly fabricated in support of AXIOM LTA project. Special center fuel assembly will be shipped one time on December 14, 2009
- Special fuel assembly with stainless steel rods replacing fuel rods on edge. Ongoing commitment to customer to supply this type of fuel assembly with next shipment 01/04/10
- Fuel assembly parameters are specified in 5.(b)(1) of the CoC No. 9329 by reference to Appendix 1-5 of the application. Fuel assembly parameters are summarized for each fuel design (14X14, 15X15, 16X16, 17X17, and VVER-1000) in Appendix 1-5 and include the length of annular fuel pellet zones at the bottom and top of the pellet stack in the fuel rods. This condition is specified as an optional annular pellet zone with a nominal length at the top and bottom of fuel rod. The annular pellet stack length is increasing with new fuel designs that utilize higher burnable absorber loading for extended burn up. As a result, Westinghouse realizes a need to justify extending the length of the annular pellet zone allowed by the CoC. SSD 01/18/2009

MCC USA/9239/AF

Fuel Rod Pellet Stack



PELB – Annular Pellet (6 – 8 inches)

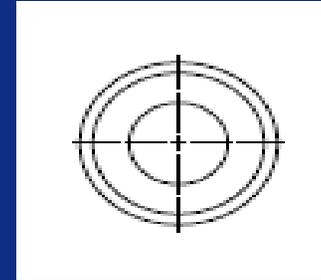
PELE – Solid Pellet

PELI – Burnable Absorber Pellet (IFBA)

MCC USA/9239/AF

Annular Pellet Lattice Physics

Thermal utilization f is defined as the ratio of the rate of thermal neutron absorption in the fuel to the total rate of thermal neutron absorption in all materials. Moderating the central region of the annular pellets or moderating the fuel rod diametric gap is expected to increase the moderator volume. As V_M / V_F increases the thermal utilization decreases.



The effective resonance integral can be written in the form where A_F is the surface area of the fuel pellet and M_F is its mass. As A_F / M_F decreases the resonance integral decreases. The A_F / M_F for annular pellets is approximately 1.5 to 1.6 times the A_F / M_F for the solid pellets. As A_F / M_F increases the resonance integral increases, therefore, replacing solid pellets with annular pellets is expected to decrease k_{eff} .

$$f = \frac{\sum_a^F \bar{\phi}_F}{\sum_a^F \bar{\phi}_F + \sum_a^M (V_M / V_F) \bar{\phi}_M}$$

$$I = C_1 + C_2 \frac{A_F}{M_F}$$

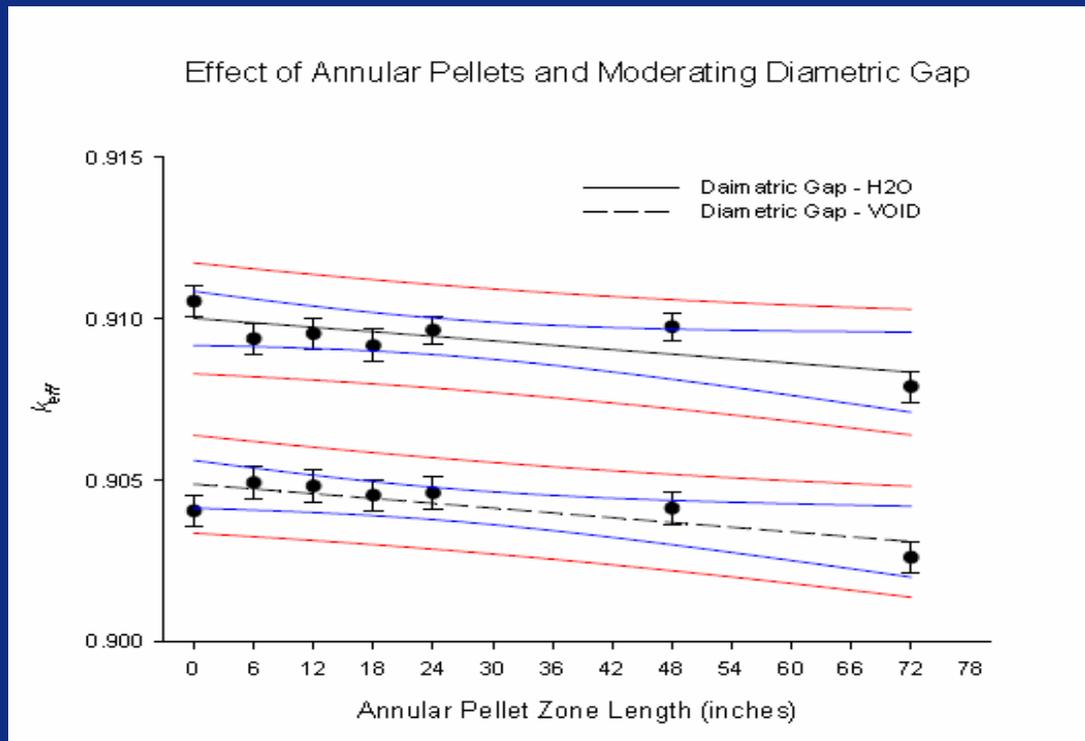
MCC USA/9239/AF

Annular Pellet Lattice Physics.

Separate the effect of increased moderation from annular pellet zone.

The dominant effect on neutron multiplication in fuel rod lattices is contained in the behavior of thermal utilization f and the resonance escape probability p .

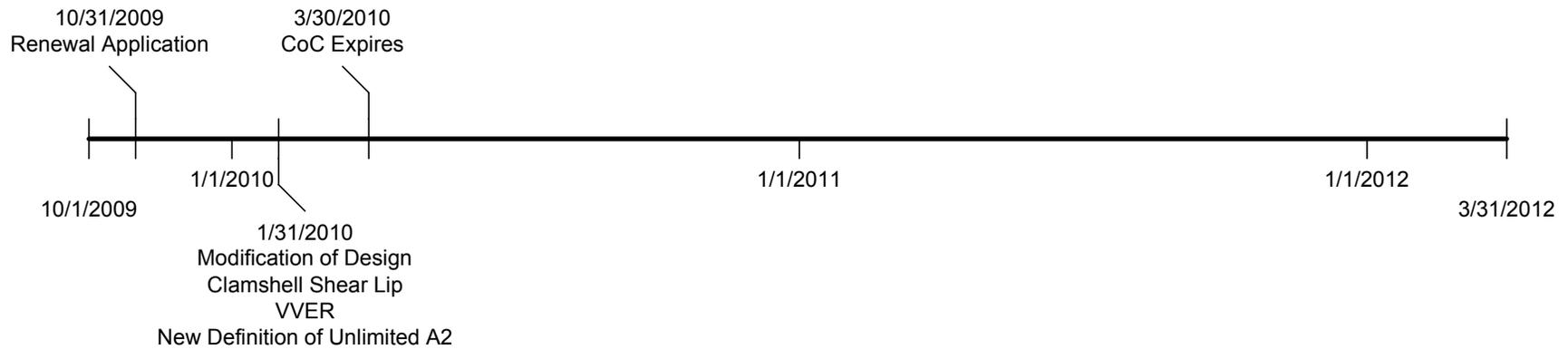
Increased moderation from water in the diametric gap increases the $keff$, but the effect of the annular pellet is to decrease $keff$. Evaluating both effects simultaneously confounded the individual effects. The effect of increased moderation was offset by replacing the solid pellets with annular pellets, and the combined effects result in a small increase in $keff$ relative to the condition of void in the diametric gap and solid pellets.



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USA/9297/AF-96 Traveller License Amendments

TRAVELLER USA/9297/AF-96



USA/9297/AF-96

Traveller - Contents

5.(b)(1) Fuel Assembly (Continued)

- (ii) Non-fissile base-plate mounted core components and spider-body core components are permitted.
- (iii) Neutron sources or other radioactive material are not permitted.
- (iv) Materials with moderating effectiveness greater than full density water are not permitted.
- (v) There is no restriction on the length of top and bottom annular blankets.

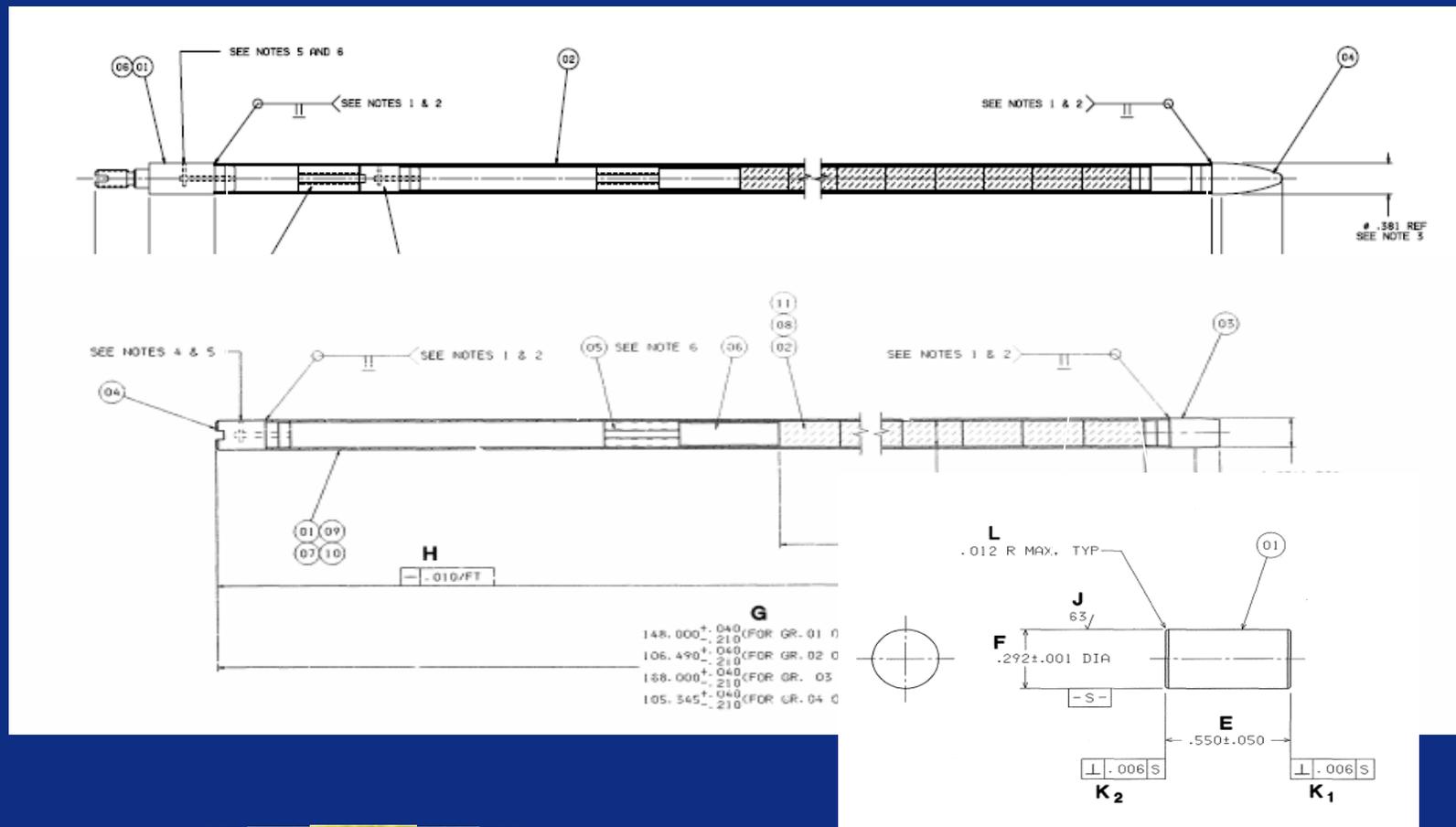
USA/9297/AF-96

Secondary Source Rod Assembly

The function of the secondary source rod assembly is to maintain the secondary source material in an appropriate configuration to give an acceptable neutron count for the detectors and to prevent secondary source material erosion by the primary coolant system. These assemblies are used as a source of neutrons after initial startup and during reactor operation. Neutrons are primarily required as an "above background" source for verification that the neutron detectors are functioning correctly.

USA/9297/AF-96

Secondary Source Rod Assembly



USA/9297/AF-96

Secondary Source Rod Assembly

Pellets shall be manufactured from a homogeneous mixture of antimony and beryllium powders.

Density 3.5 g/cc

Be + Sb (including Be as BeO) 99.0 %

Be 20.3-23.3%

BeO 3 %

170-350 grams of material per rod

USA/9297/AF-96

Sb-Be Photo-Neutron Source

The material in the encapsulated SSA rod is Sb-Be (Antimony-Beryllium).

Sb-Be is not a radioactive material until it becomes irradiated.

Antimony undergoes a neutron activation reaction $\text{Sb}(n,\gamma)$ in the reactor core.

Gamma radiation from the Antimony-124 source is used to excite photo-neutron emission from the beryllium.



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General Package Licensing

- Amendments, Revisions, Renewals
- Application Format
- Approved Contents
- AF-96 Applications

General Package Licensing Amendments, Revisions, Renewals

§71.31 Contents of application.

(a) An application for an approval under this part must include, for each proposed packaging design, the following information:

(1) A package description as required by §71.33;

(2) A package evaluation as required by §71.35; and

(3) A quality assurance program description, as required by §71.37, or a reference to a previously approved quality assurance program.

(b) Except as provided in §71.13, an application for modification of a package design, whether for modification of the packaging or authorized contents, must include sufficient information to demonstrate that the proposed design satisfies the package standards in effect at the time the application is filed.

(c) The applicant shall identify any established codes and standards proposed for use in package design, fabrication, assembly, testing, maintenance, and use. In the absence of any codes and standards, the applicant shall describe and justify the basis and rationale used to formulate the package quality assurance program.

General Package Licensing Amendments, Revisions, Renewals

§71.38 Renewal of a certificate of compliance or quality assurance program approval.

- (a) Except as provided in paragraph (b) of this section, each Certificate of Compliance or Quality Assurance Program Approval expires at the end of the day, in the month and year stated in the approval.
- (b) In any case in which a person, not less than 30 days before the expiration of an existing Certificate of Compliance or Quality Assurance Program Approval issued pursuant to the part, has filed an application in proper form for renewal of either of those approvals, the existing Certificate of Compliance or Quality Assurance Program Approval for which the renewal application was filed shall not be deemed to have expired until final action on the application for renewal has been taken by the Commission.
- (c) In applying for renewal of an existing Certificate of Compliance or Quality Assurance Program Approval, an applicant may be required to submit a **consolidated application** that incorporates all changes to its program that, are incorporated by reference in the existing approval or certificate, into as few referenceable documents as reasonably achievable.

General Package Licensing Amendments, Revisions, Renewals

- What criteria should the applicant use in deciding whether to request a CoC letter amendment instead of CoC revision?
- Is a CoC amended by letter considered a change approved by reference for the purpose of consolidating the application for renewal?

Reason:

CoC amended by letter allows the applicant to defer revalidate the CoC in other countries until such time as the renewal is required.

General Package Licensing Amendments, Revisions, Renewals

- Can changes incorporated by reference be made without revising the application?

RG 7.9 B. STANDARD FORMAT, REVISIONS

Special care should be taken to ensure that the main sections of the application are revised to reflect any design changes reported in supplemental information (i.e., responses to NRC staff requests for information or responses to regulatory positions).

Reason:

In instances where the conditions of the CoC are by reference to the a section of the application, the applicant may want to defer revising the application until such time as the renewal is required.

General Package Licensing Amendments, Revisions, Renewals

- Can the application be submitted for renewal with as the current revision?

Reason:

Either there are no changes (no references), the applicant does not need to consolidate changes made by reference, or the application was revised at the time of the request to modify the package design.

General Package Licensing Application Format

RG 7.9

Purpose of Standard Format

The purpose of this regulatory guide, “Standard Format and Content of Part 71 Applications for Approval of Packaging for Radioactive Material” (hereinafter called “Standard Format”), is to indicate the information to be provided in the application and to establish a uniform format for presenting the information. Use of this format will help ensure the completeness of the information provided, will assist the NRC staff and others in locating the information, and will aid in shortening the time needed for the review process. The application is the principal document in which the applicant provides the information and bases for the NRC staff to determine whether or not the package meets the requirements of 10 CFR Part 71.

Reason:

Some applications seem follow a format using the headers for information contained in NUREG-1609, Standard Review Plan for Transportation Packages for Radioactive Material.

General Package Licensing

Application Format -References used in application

Can a condition in the CoC reference a section in the application?

Reason:

For some contents, in particular fuel assemblies for reactors, it is necessary to specify dimensions and patterns that are more clearly described by a figure or diagram.

Can a non-proprietary application reference documents that are proprietary?

Reasons:

Detailed evaluations are often contained in proprietary documents (specifications, calculation notes, drawings), and summarized in a non-proprietary application. A record of the proprietary document in the references of each section of the application would provide traceability for the information contained in the application.

General Package Licensing Approved Contents

Do conditions of the CoC implicitly exclude components that may be shipped as part of the contents, for example, fuel assemblies may be shipped with core components (*i.e., absorber, burnable absorber, water displacer, secondary source rod assemblies, clad and unclad power suppressor rod assemblies, and damper rod assemblies*) if not explicitly permitted in the approved contents?

Reason:

Engineering judgment can be used to conclude that fuel assemblies shipped with core components are less reactive than the contents configuration assumed for the demonstration of maximum reactivity in the application.

General Package Licensing

AF-96 Application – Criteria for review of previously approved package

Package Tests

- Technical Reviews (Thermal, Shielding, Containment, Criticality Safety)
- Application format revised to current guidance