WASTE CLASSIFICATION OF A SPENT FUEL ASSEMBLY CAGE

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ABSTRACT

Many nuclear plants will exhaust their current spent fuel storage capacities before the DOE will be ready to start accepting spent fuel for disposal. NSP is in that predicament with its Prairie Island plant PI will exhaust its spent fuel storage capacity by the mid-1990's. To meet PI's storage needs, NSP is evaluating the feasibility of full scale implementation of fuel consolidation. The goal of fuel consolidation is to store more fuel in a given space. To achieve this, not only must the fuel rods be reconfigured and repackaged, but it is also necessary to process the cages so that they are not using potential fuel storage space. In this paper, the term "cage" refers to the structure of the fuel assembly minus all the fuel rods. Although the assembly handling and rod configuring aspects of consolidation have received most attention, cage processing is also a major concern. In addition to concerns about methods of in-pool volume reduction of cages, cost concerns are important. The cost of processing and disposal or storage of cages is critical to overall economic viability of fuel consolidation.

INTRODUCTION

In fall of 1987, NSP initiated a Consolidation Demonstration Program at Prairie Island, during which a total of 36 fuel assemblies were consolidated. The program will be completed this spring with the processing of the fuel assembly cages. We intend to immediately dispose of all waste material that meets burial criteria. Therefore, it will be necessary to perform waste classification on the cages. Waste classification of a material involves determining the activity concentrations of certain nuclides and comparing those concentrations to the 10CFR Part 61 limits for shallow land burial.

In order to help us better plan the cage processing part of our Consolidation Program, we decided to perform waste classification on a cage that was left over from a total assembly reconstitution project. This work was performed in late summer of 1987 by WasteChem and SAIC. This paper describes the waste classification methodology used, which is based on material sampling, and the results. The results indicate that at least 70% of the cage is buriable.

CAGE DESCRIPTION

The cage which was analyzed was from an Exxon TOPROD-type 14 x 14 PWR fuel assembly. This cage was left over from a complete fuel assembly reconstitution. The fuel assembly had been in-core for two cycles and achieved a burnup of about 24 GWD/MTU.

Figure 1 shows a fuel assembly and identifies the cage components and component material for the Exxon cage. The end fittings (nozzles) are SS-304. Guide tubes and instrument tubes are Zirc-4. Spacer bands are also Zirc-4. Spacer springs and grids are Inc-718. Holddown springs on the top nozzle are Inc-718.

The active fuel region begins about 8 inches below the top nozzle and ends about 1 inch above the bottom nozzle.

WASTE CLASSIFICATION

The waste classification method used by SAIC is based on radiochemical analysis of material samples. The concentrations of activation products in a cage component depend on the elements present in the material and on the neutron irradiation history of the component. Some of these elements are contaminants. Their concentrations are not always accurately known and the history of exposure to neutrons is often difficult to determine. A small amount of sampling and analysis eliminates much of this uncertainty and can lead to more accurate results. Performing detailed measurements and classification of a representative component yields certain factors to use in performing waste classification of similar components, that is, a scaling factor, a dose partitioning factor, and a dose-to-Curie conversion. These factors are based on Cobalt-60 activity because Cobalt-60 is an easily analyzed nuclide with a relatively long half-life. Once these factors are obtained, it is easy to classify other similar components because the only data required for the similar components are measured dose rate profiles.

Following is an explanation of how the data was gathered on the cage that was characterized, a definition for

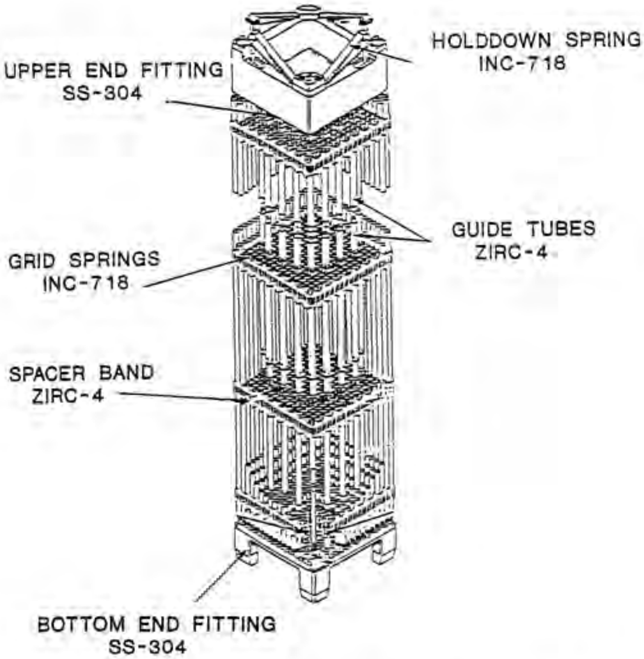

Fig. 1. Prairie Island Exxon Toprod Assembly Cage.

each of the factors just mentioned and how each was determined, and an illustration of how these factors are combined with a measured dose rate to yield a nuclide activity concentration.

Last summer, Wastechem and SAIC technicians came to PI to collect data on the cage components. The activities consisted of component dose-rate profiling and sampling of surface and bulk component material.

The SAIC Fuel Pool Sampler was used to remotely acquire bulk material samples of cage components and a sample of surface contamination. The sampler head is fitted with either a grinding tool or a rotating wire brush, depending on whether a volume or a surface sample is needed. Table I shows which components of the cage were sampled.

The spacer bands were not sampled because they are Zirc-4, the same as the guide tubes. Also, the Inc-718 spacer springs were not sampled because their inaccessibility made it unlikely we could get a reliable material sample or dose measurement.

PI personnel measured the dose-rate profile of the cage using an Eberline model RO-7 instrument. Table I shows the contact dose rates measured for the various components.

The activated metal samples were analyzed for gamma-emitting nuclides and ^{14}C, ^{55}Fe, ^{63}Ni and ^{94}Nb. The radiochemical analysis data provide scaling factors for these nuclides. A scaling factor is defined as:

TABLE I

Prairie Island Exxon Toprod Cage-Dose Rates of Sampled Components

Component	Material	Contact Dose R/hr
Upper End Fitting	SS-304	400
Holddown Spring	Inc-718	-
Guide Tube	Zirc-4	22.5
Spacer	Zirc-4 (band) and Inc-718 (springs)	180

*No material sample taken

Scaling factor for nuclide

$$X = \frac{\text{Curies of nuclide X in sample}}{\text{Curies of Cobalt-60 in sample}}$$

The radiochemical analysis also yields the data necessary to determine what fraction of the measured dose rate is due to Cobalt-60. This partitioning is based on the relative abundance of the gamma-emitting nuclides measured in the sample and on the calculated relative worth of each nuclide to the total dose.

The last thing needed in order to calculate nuclide activity concentrations was a dose-to-Curie conversion coefficient for Cobalt-60. Usually, SAIC would determine this coefficient using a device called a Quantiscan. This device measures the gamma-spectrum of a component at a specific point and yields the exact activity concentration of Cobalt-60. When the Cobalt-60 activity concentration is combined with the Cobalt-60 dose, a conversion coefficient is obtained:

Cobalt-60 dose-to-Curie

$$\text{conversion} = \frac{\text{Ci/m3 of Cobalt-60}}{\text{R/hr from Cobalt-60}}$$

The Quantiscan was not used on the Exxon cage, but it will be used for waste classification of the 36 cages from the Westinghouse fuel assemblies which were consolidated. For the Exxon cage, dose-to-Curie coefficients were estimated by referring to similar components in the SAIC database.

Figure 2 shows a sample of how the activity concentration of Nickel-63 in the holddown spring was determined using the technique just explained.

RESULTS

Table II shows the activity concentrations for the 10CFR Part 61 nuclides in the upper end fitting. This component is SS-304, and was in a low flux region. The upper end-fitting meets Class C limits.

TABLE II

Prairie Island Exxon Cage-Holddown Spring-Inc-718

Nuclide	Measured Concentration Ci/M^3	Fraction of Class B Limit	Fraction of Class C Limit
C-14	< 16	< 2	< 0.2
Fe-55	337	-	-
Ni-59	3.2	0.15	0.01
Ni-63	165	0.24	0.02
Nb-94	0.041	2.05	0.21
TRU nCi/g	-	0	0

Table III shows the activity concentrations of the same nuclides in the guide tubes. The guide tube material is Zirc-4. The guide tubes meet Class B limits.

Table IV shows the activity concentrations for the same nuclides in the holddown spring. The spring material is Inc-718. Being located on top of the upper end fitting, the spring was in a low flux region. As the table shows, the spring meets the Class C limits.

TABLE III

Prairie Island Exxon Cage-Upper End Fitting-SS-304.

Nuclide	Measured Concentration Ci/M^3	Fraction of Class B Limit	Fraction of Class C Limit
C-14	0.011	0	0
Fe-55	6906	-	-
Ni-59	11	0.5	0.05
Ni-63	550	0.79	0.08
Nb-94	0.025	1.25	0.13
TRU nCi/g	3.6	0.36	0.04

TABLE IV

Prairie Island Exxon Cage-Guide Tubes-Zirc-4.

Nuclide	Measured Concentration Ci/M^3	Fraction of Class B Limit	Fraction of Class C Limit
C-14	-	0	0
Fe-55	704	-	-
Ni-59	0.62	0.03	0
Ni-63	32	0.05	0
Nb-94	0.011	0.55	0.06
TRU nCi/g	0.2	0.02	0

There are no data for Inc-718 spacers because that material was not sampled. However, based upon data from the Inconel holddown spring, it is expected that Inc-718 from a spacer will exceed Class C limits because spacers are

Component: Holddown Spring
Nuclide: Ni-63

Scaling factor (measured ratio of Ni-63 to Co-60 activities in sample):

$$= \frac{17.1 \text{ Ci Ni-63}}{33.7 \text{ Ci Co-60}} = 0.51$$

Measured dose rate: 50 R/hr

Co-60 dose rate: 50 x 1/1.04 = 48 R/hr
(relative worth of Co-60, Cr-51 and Mn-54)

Co-60 dose-to-Curie factor: $6.7 \frac{\text{Ci/m}^3}{\text{R/hr}}$
(BWR channel clip)

Average activity concentration of Ni-63:

$$48 \text{ R/hr} \times \frac{6.7 \text{ Ci/m}^3}{\text{R/hr}} \times 0.51 = 165 \text{ Ci/m}^3$$

Fig. 2. Example Calculation.

in a high flux region. It may be possible to dispose of some, if not all, of the Inc-718 by averaging it with the rest of the cage components so as to yield a total volume which does meet Class C limits.

CONCLUSION

To complete our Consolidation Demonstration program, we plan the following cage processing effort in conjunction with Wastechem and SAIC.

- Perform waste classification of components from a representative Westinghouse cage
- Volume reduce cages and segregate material according to waste classification results so as to maximize buriable volume - Package buriable material for immediate shipment to a disposal site
- Package remaining material into container suitable for in-pool storage in a rack cell, to remain until DOE will accept for disposal

We expect to achieve a 10 to 1 overall volume reduction on the cages. Based on this assumption, plus our results from waste classification of a cage, we project the following:

1. Approximately 25% of the final waste volume will exceed Class C limits. If we can efficiently segregate this material, it will need just one rack cell for storage.

2. Approximately 75% of the final waste volume will meet disposal criteria.

3. The overall cost of cage processing will amount to about $4000 per cage, assuming disposal of all material that meets burial criteria rather than long term on-site storage.