Irradiated Hardware Characterization and Packaging During Decommissioning of the Ford Nuclear Reactor at University of Michigan

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ABSTRACT

Characterization of all irradiated hardware during decommissioning of experimental and research reactors always presents a host of challenges not normally associated with characterization of irradiated hardware from commercial nuclear reactors. The campaign to characterize all of the irradiated hardware from the Ford Nuclear Reactor at the University of Michigan was no exception. The Ford Nuclear Reactor was an MTR pool style reactor that was in continual use up to the point of decommissioning.

Some of the unique challenges involved with experimental pool reactors are the lack of symmetry around the core for neutron activation analysis calculations, the large inventory of activated components, the high degree of variability within that inventory, and the packaging of the entire inventory into the most efficient liner combinations. The entire high activity inventory was successfully packaged into two (2) steel fuel pool liners and shipped in two (2) cask shipments.

INTRODUCTION

The Reactor Pool cleanup project performed in 2006 by WMG, Inc at the University of Michigan (U of Mich) Ford Nuclear Reactor (FNR) facility involved the characterization, packaging, classification, and shipment of irradiated hardware and miscellaneous material. The purpose of the reactor pool cleanup was to remove all of the highly activated components from the pool as part of the decontamination and decommissioning (D & D) of the FNR facility. For the purpose of this paper, highly activated components are those components that require a cask shipment to meet Department of Transportation (DOT) limits.

The FNR facility was in operation from 1957 through 2004 under Atomic Energy Commission / Nuclear Regulatory Commission (NRC) License No. R-28 in support of a wide variety of education and research programs. The project inventory consisted of an equally wide variety of irradiated components as listed in Table I below.

WMG developed the waste management plan, characterization plan, survey plan, and shipping procedures. WMG also characterized the hardware, prepared packaging plans, assisted U of Mich personnel in developing the cask handling procedures, helped to load the liners and shipping casks and prepared the shipment documentation for the project. The characterization plan, survey plan and shipping procedures were developed and transmitted to the appropriate U of Mich personnel during the early stages of the project. This document summarizes the characterization, classification, component processing and packaging work, and shipment documentation performed by WMG leading to one 8-120B cask shipment and one 1-13G cask Shipment.

The on-site work started in January, 2006 and is ongoing. The two (2) cask shipments were made to the Barnwell disposal site in October of 2006 for burial as low-level radioactive waste.

NOMENCLATURE

The following lists the terms and acronyms used throughout this paper:

DOT – United States Department of Transportation

NRC – United States Nuclear Regulatory Commission

CFR – United States Code of Federal Regulations

D&D – Decommissioning and Dismantlement

WAC – Waste Acceptance Criteria

RQ – Reportable Quantity

U of Mich – University of Michigan

FNR – Ford Nuclear Reactor

IAW – in accordance with

HARDWARE CHARACTERIZATION

This section summarizes the hardware inventory and characterization methods employed to characterize all 177 components in the inventory. Characterization is the basis for classifying radioactive material for transport and disposal. Waste characterization and classification was calculated in accordance with (IAW) 10CFR61 [1] and the transportation classification IAW 49CFR173 [2]. The two sources of radioactivity that must be accounted for are the surface contamination (i.e., from all surfaces in contact with the FNR pool water) and the activation products from exposure to a neutron flux (i.e., the segmented components from the FNR experimental hardware).

All items were individually characterized and classified for transport and disposal in accordance with (IAW) the Barnwell Waste Management Facility Site Disposal Criteria [3], the "Low-Level Waste Licensing Branch Technical Position on Radioactive Waste Classification" [4], and the "Branch Technical Position on Concentration Averaging and Encapsulation" [5] issued by the USNRC. All work was performed under WMG's 10 CFR Part 50 Appendix B and NQA-1 Quality Assurance program.

Dose profiles were taken on the 177 different components. Most of these components had unique physical geometries and chemical compositions that required unique dose-to-curie conversion factors. The characterization approach utilized measured dose rates and dose-to-curie conversion to account for the easily detectable gamma emitting nuclides along with calculated scaling factors to account for the hard to detect nuclides. For proper characterization of all components, the establishment of proper scaling factors was critical.

Project Inventory

The project inventory was divided into 21 groups of similar component types. In general, the physical characteristics of the components were defined from information supplied by the U of Mich. Detailed drawings were available for some of the components, and whenever possible, these drawings were used to calculate the exact physical characteristics of the component. Most components were weighed underwater and a buoyancy correction factor was applied to determine the waste weight of the component. The waste volume was then calculated for each component based on the waste weight and density of the material. Whenever drawings were not available, the physical characteristics of each component were gathered from other U of Mich supplied sources, assumed upon input from the U of Mich personnel or assumed based on experience from similar decommissioning projects.

The waste volume of each component is also provided in Table I. The waste volume is the most important physical parameter for characterization purposes because there were no transuranics associated with the surface contamination for any components in the inventory. The general survey approach for all components was specified before any surveys were taken. Figure 1 shows a picture prior to decommissioning showing several components residing in the reactor pool. Figures 2 and 3 below show the loaded CNS 1-13G and 8-120 liners.

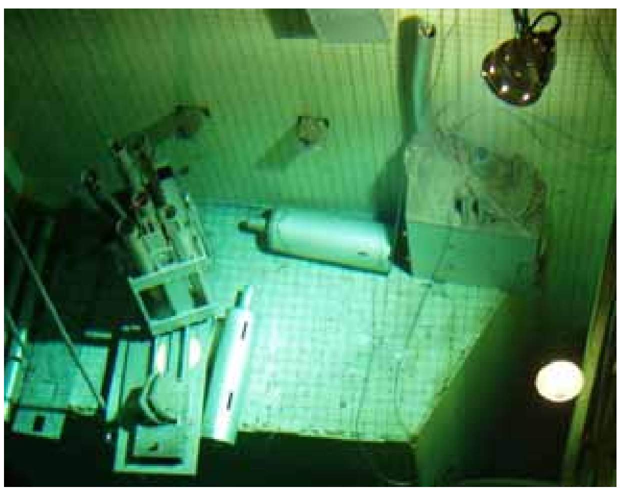

Fig. 1. Typical components in FNR pool.

Table I. University of Michigan 2006 Project Disposal Inventory

Component Type	Number of Units	Volume (ft^3)
Control Rod	1	0.043
Shim Rods	10	0.372
HSSI Facility	7	1.338
UCSB Facility	2	1.214
Old Heavy Water Tank	12	0.752
New Heavy Water Tank	20	0.701
IAR Dummies	2	0.551
IAR Assemblies	2	0.767
IAR Footers and Baskets	4	0.079
Reactor Core Grid Plate	1	1.527
Reactor Core Components	11	0.678
East Experiment Grid	2	1.657
South Experiment Grid	3	2.325
IST Trolley	4	0.979
Collimators	6	3.329
Beam-Port Extensions	12	0.910
Soldier Rods	24	0.501
Neutron Detectors	3	0.111
Europium Experiment Assembly	1	0.293
Experiment Holders	26	1.115
Miscellaneous Components	24	0.861
Inventory Totals	**177**	**20.1**

Characterization Methodology

Each of the items was characterized with a WMG computer code using input data furnished by the U of Mich. This data includes the FNR operation history, component irradiation histories and component design information.

The codes used for component characterization were as follows:

- Characterization: RADCOR™ and RADMAN™
- Dose-to-Curie Calculations: MegaShield™ and QAD-CGGP-A

These codes have been used for characterization and classification of hundreds of commercial waste shipments to the Barnwell disposal site. The design report for RADCOR™ is on file with the CNS Regulatory Affairs Group and the RADCOR™ methodology is described in NUREG/CR-4968.

The U of Mich power cycle history is presented below in Table II. The irradiation and decay history associated with each characterized item was based upon the FNR operating history given in Table II.

Table II. University of Michigan FNR Operating History

Cycle	Date Startup	Date Shutdown	MW-hr	EFPD
1	1/1/1960	12/31/1970	3960	187.5
2	1/1/1971	12/31/1975	1654	75.0
3	1/1/1976	12/31/1978	1769	61.7
4	1/1/1979	12/31/1980	9036	234.5
5	1/1/1981	12/31/1981	4988	148.7
6	1/1/1982	12/31/1982	5507	126.0
7	1/1/1983	12/31/1983	6079	148.2
8	1/1/1984	12/31/1984	5687	131.9
9	1/1/1985	12/31/1985	927	29.9
10	1/1/1986	12/31/1986	1330	37.1
11	1/1/1987	12/31/1987	1220	33.4
12	1/1/1988	12/31/1988	910	25.9
13	1/1/1989	12/31/1989	1378	36.2
14	1/1/1990	12/31/1990	1837	45.3
15	1/1/1991	12/31/1991	2360	56.9
16	1/1/1992	12/31/1992	2428	60.4
17	1/1/1993	12/31/1993	2663	63.9
18	1/1/1994	12/31/1994	1594	42.3
19	1/1/1995	12/31/1995	1703	45.0
20	1/1/1996	12/31/1996	1741	45.1
21	1/1/1997	12/31/1997	1954	51.3
22	1/1/1998	7/1/1998	686	18.2

Characterization of all irradiated hardware was performed using the dose-to-curie conversion method. Dose-to-curie characterization uses measured dose rates and a dose-to-curie conversion factor developed from WMG's MEGASHIELD™ or the QAD-CGGP-A software to quantify the amount of easy to detect nuclides, such as Co-60. Components with relatively uniform spatial distribution of activity were characterized using dose-to-curie factors calculated with MEGASHIELD™. Components that had significant variation in the spatial distribution of activity, such as the control rod, were characterized using dose-to-curie factors calculated with QAD-CGGP-A.

All surveys ere conducted in an area with a low background count. Due to the geometry of the FNR and nature of experiments conducted with the FNR, most components tended to have a common height of approximately 30-inches or less. Survey guidance was provided to U of Mich personnel for all components. In general, multiple surveys were taken on each component on contact and at 1-foot.

Hard to detect nuclides significant to classification (i.e, Nb-94, Ni-63 etc.) are scaled from the easy to detect nuclides via scaling factors. Scaling factors for activated metal components were developed from WMG's proprietary RADCOR™ software.

Surface contaminant estimation was included with activated components. Surface areas for each component were calculated from information supplied by the U of Mich. A representative surface contamination composite sample was determined based on contamination samples taken from the reactor pool and applied to the surface area of each component.

Liner Packaging

Due to the relatively small size of the components, the majority of the project inventory did not require any special processing (cutting) prior to loading into the disposal liners. Liner loading plans and cut plans were developed prior to commencing hardware packaging. All oversized components were processed IAW the cut plans. As the components were processed, they were sorted and staged for loading into the liners IAW the liner loading plans. Some of the components (i.e., high dose rate components associated with the heavy water tanks) required careful packaging after being loaded into the disposal liners. Any integral lead within the component was removed prior to loading into the disposal liners.

The highest activity components were loaded into the 1-13G liner in order to meet DOT transportation limits. The 1-13G liner was loaded into the 1-13G cask for shipment. The remainder of the components in the inventory were loaded into the 8-120 steel liner, which was loaded into the 8-120B cask for shipment. Note that the project inventory covered by this paper consists, at a minimum, of all of the components that required loading into a shipping cask in order to meet DOT transportation limits. Figure 2 shows the loaded 8-120 liner.

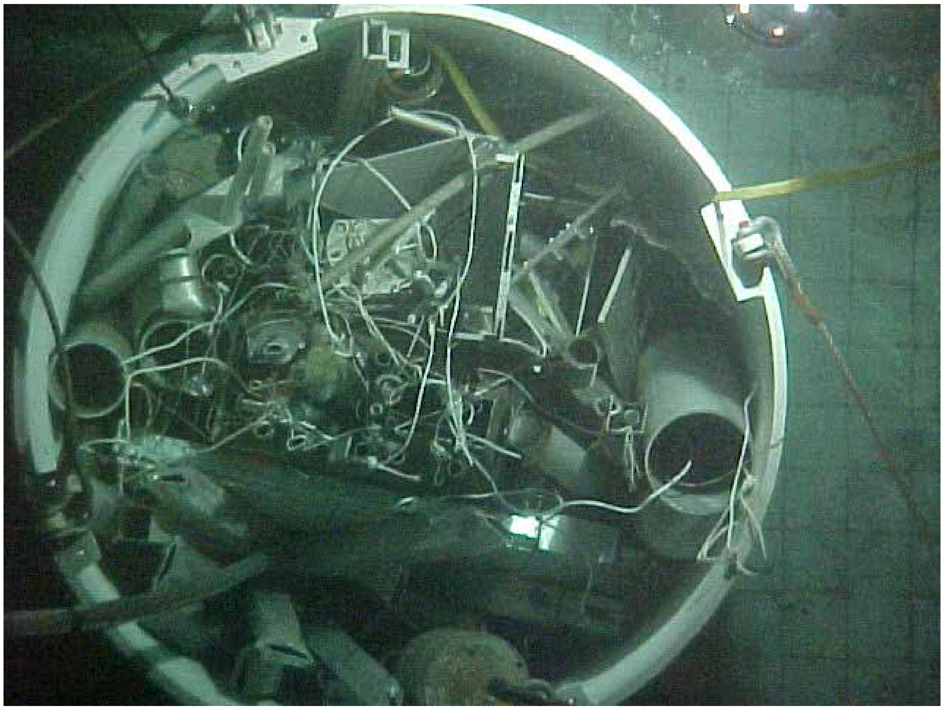

Figure 2. Loaded 8-120 liner.

Packaging plans were developed throughout the project as surveys became available and the inventory became more clearly defined. The packaging plans were carefully developed to maximize both cask shielding ability and liner packaging efficiency. The packaging efficiency in the 1-13 liner and 8-120 liners was approximately 30% and 17% respectively. For the purpose of this paper, packaging efficiency is defined as the percentage of the liner's maximum internal volume that is occupied by the packaged waste. Note that these packaging efficiencies exceed those normally achieved in similar liners loaded with highly activated components. The final packaging plans were used to govern the physical loading of the liners and resulted directly in the final Irradiated Hardware Liner Inventory Logs and corresponding Concentration Averaging Summary and Loaded Liner Summary. Figure 3 shows both loaded liners in the FNR pool prior to shipment for disposal.

Figure 3. Loaded liners.

The 8-120 liner was carefully packaged such that the known hot spots would not affect transportation dose rates. An example of a known hot spot occurred on the top of the core grid plate where stainless steel fasteners with high concentrations of Co-60. The 8-120 packaging plan was developed to ensure that these components were centralized in the liner and that other components were tightly packed around them to provide shielding and prevent movement while in transport..

A number of components had to be segmented prior to loading into the disposal liners for various reasons. Some components, such as the Europium Experiment Assembly and IAR assemblies, were too large to be directly loaded into the disposal liners. Other components, such as the Heavy Water Tanks, had to be segmented in order to maximize liner packaging efficiency. Component processing involved the use of underwater shearing and cutting equipment, to segment the components. Some of the larger components that had low dose areas that would meet NRC Class A requirements were segmented to reduce the volume of material that would be required to be disposed of at Barnwell. Some examples of this material are: the reactor frames, collimators, and beam-port extensions. Materials that were both low activity and NRC Class A waste were removed from the pool as waste to be disposed at the EnergySolutions Clive Disposal Facility. Once all of the major components were segmented per the cut plan, they were loaded into the liners IAW with the developed load plans. Further segmentation of some of the items was done at this time, to allow for more efficient liner loading. The loading of the liners was very successful in maintaining ALARA when loading of the cask occurred.

The liners were loaded into the CNS 8-120B and 1-13G casks and shipped offsite in October of 2006. The 1-13G liner was loaded into the cask underwater in the FNR pool. The 8-120 liner was removed from the FNR pool and loaded into the cask, which was staged next to the FNR pool. The loaded CNS 8-120 B cask departing the U of Mich is shown in Figure 4.

Figure 4. Loaded CNS 8-120B Departing the U of Mich.

REFERENCES

1. 10CFR61, Licensing Requirements for Land Disposal of Radioactive Waste.
2. 49CFR173, Subpart I, Class 7 (Radioactive) Materials, Revised October 1, 1998.
3. Barnwell Waste Management Facility Site Disposal Criteria Chem-Nuclear Systems Barnwell Office. S20-AD-010 revision 22. 11/8/2006.
4. Low-Level Waste Licensing Branch Technical Position on Radioactive Waste Classification. May 1983.
5. Branch Technical Position on Concentration Averaging and Encapsulation. January 1995.