DISTRIBUTION SHEET

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Distribution	Packaging Engineering	Date 1/31/95
Project Title/Work Order		EDT No.
Radiological Transportation Risk Assessment of the Shipment of Sodium-Bonded Fuel from the Fast Flux Facility to the Idaho National Engineering Laboratory (WHC-SD-TP-RPT-013)		ECN No. 614558

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
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ENGINEERING CHANGE NOTICE

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1. ECN 614558

Proj. ECN

2. ECN Category (mark one)	3. Originator's Name, Organization, MSIN, and Telephone No.	3a. USQ Required?	4. Date
Supplemental [] Direct Revision [X] Change ECN [] Temporary [] Standby [] Supersedure [] Cancel/Void []	JR Green/84100/G2-02/376-0610	[] Yes [X] No	1/31/95
	5. Project Title/No./Work Order No.	6. Bldg./Sys./Fac. No.	7. Approval Designator
	Sodium-Bonded Fuel Pins/B171G	MO-404	ESQ
	8. Document Numbers Changed by this ECN (includes sheet no. and rev.)	9. Related ECN No(s).	10. Related PO No.
	WHC-SD-TP-RPT-013, Rev. 0	NA	NA

11a. Modification Work	11b. Work Package No.	11c. Modification Work Complete	11d. Restored to Original Condition (Temp. or Standby ECN only)
[] Yes (fill out Blk. 11b) [X] No (NA Blks. 11b, 11c, 11d)	NA	NA Cog. Engineer Signature & Date	NA Cog. Engineer Signature & Date

12. Description of Change

Additional analyses were completed for 169 fuel pin assembly shipments and were incorporated into the document.

DISCLAIMER

13a. Justification (mark one)

Criteria Change	[X]	Design Improvement	[]	Environmental	[]	Facility Deactivation	[]
As-Found	[]	Facilitate Const	[]	Const. Error/Omission	[]	Design Error/Omission	[]

13b. Justification Details

169 fuel pin shipment was identified as a possible activity.

14. Distribution (include name, MSIN, and no. of copies)

See attached Distribution Sheet.

RELEASE STAMP

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15. Design Verification Required	16. Cost Impact				17. Schedule Impact (days)	
	ENGINEERING		CONSTRUCTION			
[] Yes	Additional	[NA] $	Additional	[NA] $	Improvement	[NA]
[X] No	Savings	[NA] $	Savings	[NA] $	Delay	[NA]

18. Change Impact Review: Indicate the related documents (other than the engineering documents identified on Side 1) that will be affected by the change described in Block 12. Enter the affected document number in Block 19.

SDD/DD	[]	Seismic/Stress Analysis	[]	Tank Calibration Manual	[]
Functional Design Criteria	[]	Stress/Design Report	[]	Health Physics Procedure	[]
Operating Specification	[]	Interface Control Drawing	[]	Spares Multiple Unit Listing	[]
Criticality Specification	[]	Calibration Procedure	[]	Test Procedures/Specification	[]
Conceptual Design Report	[]	Installation Procedure	[]	Component Index	[]
Equipment Spec.	[]	Maintenance Procedure	[]	ASME Coded Item	[]
Const. Spec.	[]	Engineering Procedure	[]	Human Factor Consideration	[]
Procurement Spec.	[]	Operating Instruction	[]	Computer Software	[]
Vendor Information	[]	Operating Procedure	[]	Electric Circuit Schedule	[]
OM Manual	[]	Operational Safety Requirement	[]	ICRS Procedure	[]
FSAR/SAR	[]	IEFD Drawing	[]	Process Control Manual/Plan	[]
Safety Equipment List	[]	Cell Arrangement Drawing	[]	Process Flow Chart	[]
Radiation Work Permit	[]	Essential Material Specification	[]	Purchase Requisition	[]
Environmental Impact Statement	[]	Fac. Proc. Samp. Schedule	[]	Tickler File	[]
Environmental Report	[]	Inspection Plan	[]		[]
Environmental Permit	[]	Inventory Adjustment Request	[]		[]

19. Other Affected Documents: (NOTE: Documents listed below will not be revised by this ECN.) Signatures below indicate that the signing organization has been notified of other affected documents listed below.

Document Number/Revision	Document Number/Revision	Document Number Revision

20. Approvals

Signature	Date	Signature	Date
OPERATIONS AND ENGINEERING		ARCHITECT-ENGINEER	
Cog. Eng. JR Green	2/1/95	PE	
Cog. Mgr. JG Field	2/6/95	QA	
QA SB Dutta	2/1/95	Safety	
Safety DW McNally	2-1-95	Design	
Environ. DJ Carrell	2-1-95	Environ.	
Other		Other	
Tech Rev. PM Daling	2-2-95		
DC Johnston	2-3-95		
		DEPARTMENT OF ENERGY	
		Signature or a Control Number that tracks the Approval Signature	
		ADDITIONAL	

RELEASE AUTHORIZATION

Document Number:	WHC-SD-TP-RPT-013, Rev. 1
Document Title:	Radiological Transportation Risk Assessment of the Shipment of Sodium-Bonded Fuel from the Fast Flux Test Facility to the Idaho National Engineering Laboratory
Release Date:	02/03/95

This document was reviewed following the procedures described in WHC-CM-3-4 and is:

APPROVED FOR PUBLIC RELEASE

WHC Information Release Administration Specialist:

V. L. Birkland — 2/3/95

V.L. Birkland

SUPPORTING DOCUMENT

1. Total Pages 74

2. Title	3. Number	4. Rev No.
Radiological Transportation Risk Assessment of the Shipment of Sodium-Bonded Fuel from the Fast Flux Test Facility to the Idaho National Engineering Laboratory	WHC-SD-TP-RPT-013	1

5. Key Words	6. Author
Risk assessment, transportation risk, sodium-bonded metal alloy fuel, uranium-plutonium carbide fuel, RADTRAN 4 analysis, release fractions, FFTF shutdown environmental assessment, T-3, spent fuel, irradiated fuel	Name: J. R. Green Signature J R Green Organization/Charge Code 84100/B171G

7. Abstract

This document was written in support of *Environmental Assessment: Shutdown of the Fast Flux Test Facility (FFTF), Hanford Site, Richland, Washington.* It analyzes the potential radiological risks associated with the transportation of sodium-bonded metal alloy and mixed carbide fuel from the FFTF on the Hanford Site in Washington State to the Idaho Engineering Laboratory in Idaho in the T-3 Cask. RADTRAN 4 is used for the analysis which addresses potential risks from normal transportation and hypothetical accident scenarios.

8. RELEASE STAMP

RECORD OF REVISION	(1) Document Number WHC-SD-TP-RPT-013	Page 1

(2) Title

Radiological Transportation Risk Assessment of the Shipment of Sodium-Bonded Fuel from the Fast Flux Test Facility to the Idaho National Engineering Laboratory

CHANGE CONTROL RECORD

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1 RS	Additional analyses completed for 169 fuel pin assembly shipments. Replace all pages. Per ECN 614558.	JR Green JRGreen 2/1/95	JG Field 2/1/95

RADIOLOGICAL TRANSPORTATION RISK ASSESSMENT OF THE SHIPMENT OF SODIUM-BONDED FUEL FROM THE FAST FLUX TEST FACILITY TO THE IDAHO NATIONAL ENGINEERING LABORATORY

Packaging Engineering

January 1995

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LIST OF TERMS

ALI	Annual Limit on Intake
CFR	Code of Federal Regulations
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
FFTF	Fast Flux Test Facility
HEDL	Hanford Engineering Development Laboratory
ICRP	International Commission on Radiological Protection
INEL	Idaho National Engineering Laboratory
NRC	U.S. Nuclear Regulatory Commission
SAR	Safety Analysis Report
SNL	Sandia National Laboratories
TI	Transportation Index
WHC	Westinghouse Hanford Company

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1.0 INTRODUCTION

The Fast Flux Test Facility (FFTF) is a sodium-cooled research reactor located on the Hanford Site near Richland, Washington. The shutdown of the FFTF was initiated by a memorandum from the U.S. Department of Energy (DOE) on December 15, 1993. An Environmental Assessment of the FFTF shutdown addresses the issue of the potential for significant individual and cumulative environmental impacts due to the shutdown. This document supports the Environmental Assessment by providing the necessary information to assess the impacts of the transportation of a portion of the FFTF irradiated fuel.

The shutdown effort of the FFTF includes the redisposition of the FFTF fuel and test assemblies. As part of the redisposition, the sodium-bonded metal alloy and mixed (uranium-plutonium) carbide irradiated and non-irradiated fuel will be transported by truck in licensed casks from the FFTF to the Idaho National Engineering Laboratory (INEL) near Idaho Falls, Idaho, to be stored with other fuels of the same type. This document addresses the radiological risks involved in the transportation of the sodium-bonded metal alloy and carbide fuel. Impacts from both incident-free transportation, that is normal transportation without incident, and potential accidents are presented. The computer code RADTRAN 4 (Neuhauser and Kanipe 1992) was used for the analyses. Included in this report is a discussion of the shipping campaign, the RADTRAN 4 computer code, the input variables used in the code, the computer code results, and possible population health effects.

2.0 SHIPPING CHARACTERISTICS

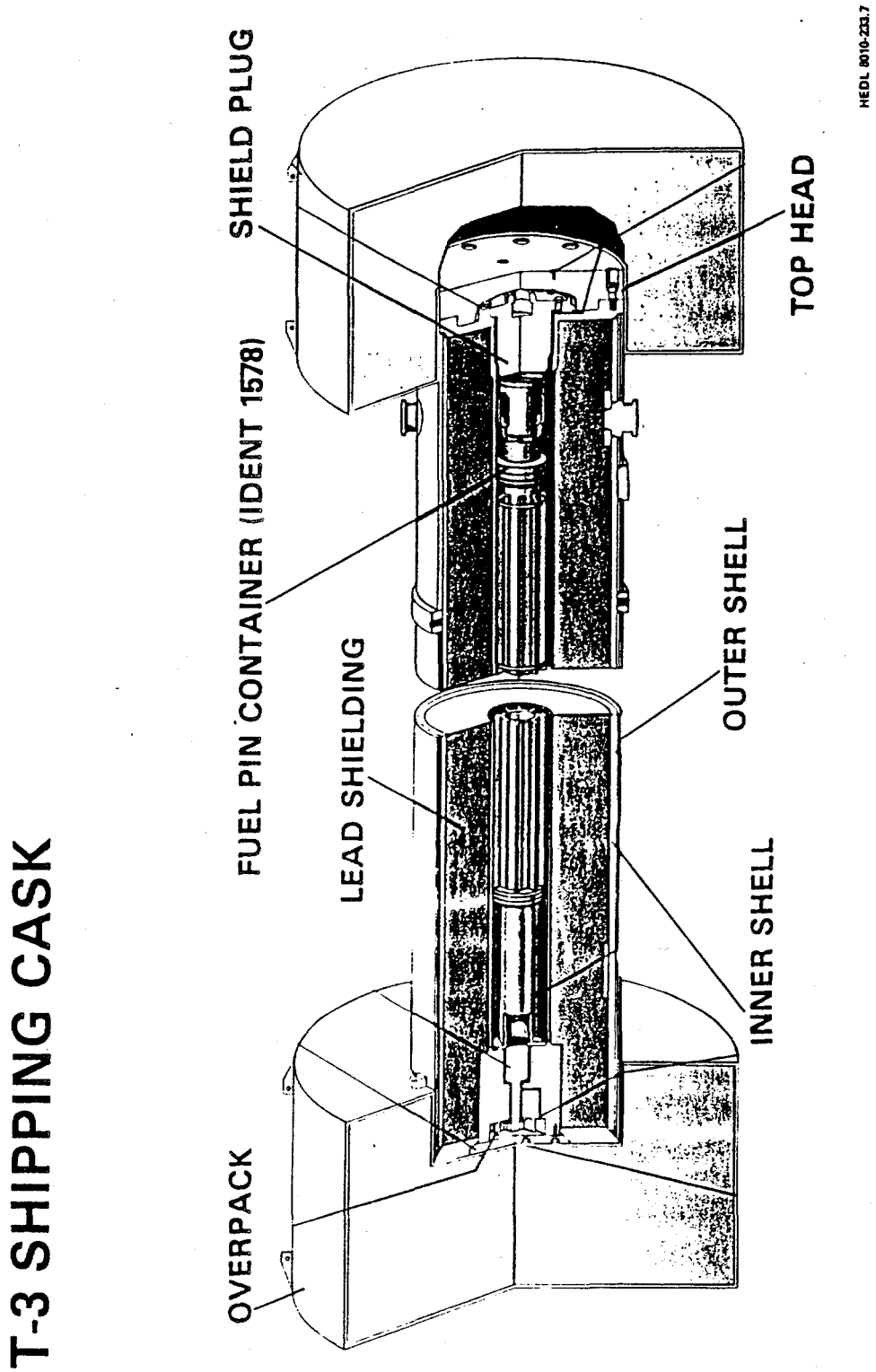
The irradiated fuel will be transported in licensed casks by trailer trucks travelling under highway route controlled procedures. The trailer trucks will follow specific routes giving prior notification to states and tribes. Shipping will be by exclusive use as defined in Title 49, *Code of Federal Regulations*, Part 173 Subsection 403(i) (49 CFR 173.403(i)). Satellite tracking and consideration of weather conditions will help to ensure the safe transport of the irradiated fuel.

2.1 SHIPPING CASK

The sodium-bonded metal alloy fuel may be shipped as a complete assembly including the fuel pins, duct, nozzle, and handling socket or the fuel pins may be removed, washed, and placed inside an approved pin container which fits inside the T-3 Spent Fuel Shipping Cask containment vessel. The carbide fuel pins will be shipped without additional hardware in an approved pin container inside the T-3 cask. The T-3 cask is a certified spent fuel shipping cask; U.S. Nuclear Regulatory Commission (NRC) and DOE Certificate of Compliances (CoCs) (USA/9132/B(M)F) are issued (NRC 1991) (DOE 1994b). Currently only the sodium-bonded metal alloy fuel pins are covered under the CoCs for the T-3 cask. An amendment to the CoCs will be required before the sodium-bonded carbide fuel can be shipped.

The cask conforms with all the U.S. Department of Transportation (DOT) regulations for spent fuel packaging in 49 CFR 173. The T-3 cask also complies with the specifications of Title 10, *Code of Federal Regulations*, Part 71 (10 CFR 71). The cask is designed, fabricated, and maintained to

Figure 1. T-3 Certified Shipping Cask.



protect the health and safety of the public during the transportation of irradiated fuel. The cask meets the criteria of 10 CFR 71 which requires that the payload be adequately shielded and contained, and that criticality be prevented under normal conditions of transport, and hypothetical accident conditions.

The T-3 cask design and fabrication specifications were made in English units. Therefore, to remain consistent with the T-3 Safety Analysis Report (SAR) (WHC 1990), references only to the T-3 cask itself are made in inches and feet. The T-3 cask, as illustrated in Figure 1, is essentially two cylindrical stainless steel shells separated by 8 radial in. of lead shielding and surrounded by a sun shield and impact limiters (WHC 1990). The inner shell is denoted as the primary containment vessel. It is constructed from 304L stainless steel and has an outside diameter of 8.625 in. with a nominal wall thickness of 0.322 in. The bottom end cap of the inner shell is sealed with a 12.374 in. thick stainless steel plug. The top of the inner shell is closed by an 11.625 in. stainless steel plug bolted in place with 16 flange screws. Both top and bottom plugs are closed with a dual seal design.

The biological shielding of the T-3 cask is supplied by the 8 annular in. of lead which separates the inner containment vessel and the outer shell. The outer shell consists of 1 in. of stainless steel surrounded by a 0.08 in. diameter wire wrap overlaid with a ten gauge stainless steel cover. Both ends of the casks are closed with bolted end plates. The outer diameter of the outer shell is 26.44 in. and it is 177.2 in. long. In addition, the cask ends are covered by impact limiters constructed of steel shells filled with rigid structural polyurethane foam.

The T-3 cask has been shown to withstand 10 CFR 71 hypothetical accident conditions (WHC 1990). These include a 9 m (30 ft) drop of the cask onto an unyielding surface, followed by a puncture test consisting of a 1 m (40 in.) drop of the cask onto a 15 cm (6 in.) diameter vertical cylindrical bar, followed by a thermal loading (fire) of 30 minute duration at 800 °C (1475 °F). Two separate immersion tests also include the consideration of water leakage for criticality analysis and the cask response to an external pressure loading of 147 kPa (21 psi) which simulates water pressure at a depth of 15 m (50 ft).

The T-3 cask is secured to the transport vehicle with an engineered tiedown system which meets all applicable regulatory requirements. Cask loading, securing, and unloading procedures are documented in the T-3 Cask User's Guide (WHC 1986).

2.2 CASK CONTENTS

The metal alloy fuel pins being shipped to INEL from the FFTF contain a small amount of sodium (up to 9 g) between the cladding and the fuel, to facilitate heat transfer during reactor use, and are therefore referred to as sodium-bonded. The sodium-bonded carbide pins contain no more than 16 g of sodium per pin. Both irradiated and non-irradiated sodium-bonded metal alloy fuel is being shipped, but the shipments from FFTF to INEL will be bounded by the consideration of a maximum of 1,200 irradiated sodium-bonded metal alloy pins and 18 irradiated sodium-bonded mixed carbide pins. The fuel cladding is austenitic, martensitic, or other high-strength stainless steel alloys. All

pins will be inspected for cladding rupture prior to loading and any fractured or cracked fuel pins will be shipped in sealed fuel pin tubes constructed of 300 series stainless steel. The fuel assembly containing the metal alloy fuel pins consists of the fuel, cladding, duct, nozzle, and handling socket.

Fuel pins removed from the assembly hardware will be washed and placed in an approved stainless steel T-3 cask pin container. Pin containers have spacers which offer the irradiated fuel pins physical support within the T-3 cask. They are bolted shut, and although they are not qualified as "containment", they do add an additional barrier to exterior elements. Containers vary in the number of pins they can physically contain. The Ident 69 container holds over 100 pins, whereas, the Ident 1578 container holds 42 pins. The T-3 cask holds one container.

2.3 SHIPPING ROUTE

The truck carrying the T-3 cask will leave the FFTF on the Hanford Site in Washington and proceed to INEL near Idaho Falls, Idaho, via interstate and state highway systems. The truck will begin travel on Washington State Route 240 and proceed on Washington I-82, Oregon I-82, Oregon I-84, Idaho I-84, Idaho I-86, Idaho I-15, and Idaho U.S. 26. The computer code Highway 3.1 (Johnson et al. 1993) was utilized to generate population density and mileage data for the analyses. The total one-way distance traveled was determined to be 864 kilometers (537 miles) with 90.4% in rural areas (4.0 people/square kilometer), 8.2% in suburban areas (361.1 people/square kilometer) and 1.4% in urban areas (2042.6 people/square kilometer). The majority of travel (67%) will occur on limited access multilane highways and the remainder will be on multilane divided highways or principal highways.

2.4 SODIUM CONSIDERATIONS

The T-3 cask has been proven to be leak tight under both normal and accident conditions as defined by the NRC. The T-3 SAR concludes that infiltration of water into the cask from immersion or storage in a moist environment is quite implausible (WHC 1990). The only possible scenario that could result in an immersion accident condition greater than that defined by the NRC would be an accident on Interstate 82 crossing the Columbia River. No other significant bodies of water are located between the FFTF and INEL. However, the I-82 bridge across the Columbia is a straight section of divided multilane highway and an immersion accident is not credible.

Regulations limit the quantity of "free" sodium within a cask to 200 g. Water reacting with free sodium causes the release of heat and can cause an increase in pressure in sealed vessels. The T-3 SAR analyzes a physically improbable leakage scenario and concludes that the combined effects of the heat and pressure build-up from a reaction of 200 g of sodium with water would not cause a breach in the T-3 cask. The T-3 cask would maintain containment. The sodium within the fuel pins is bound between the cladding and the fuel. It is not "free" within the cask to react with moisture and so is not considered to add an additional burden on the cask.

3.0 RISK ASSESSMENT METHODOLOGY

The RADTRAN 4 computer code (Neuhauser and Kanipe 1992) was used to perform the analyses of the FFTF shipments to INEL. RADTRAN was developed by Sandia National Laboratories (SNL) to calculate the risks associated with the transportation of radioactive materials. The original code was written by SNL in 1977 in association with the preparation of NUREG-0170, *Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes* (NRC 1977). The code has since been refined and expanded and is currently maintained by SNL under contract from DOE.

The RADTRAN 4 computer code is organized into seven models (Neuhauser and Kanipe 1994). They are:

- material model
- transportation model
- population distribution model
- health effects model
- accident severity and package release model
- meteorological dispersion model
- economic model

The code uses the first three models to calculate the potential population dose due to normal, incident-free transportation and the first six models to calculate the risk to the population from user-defined accident scenarios. The economic model is not used in this study.

3.1 MATERIAL MODEL

The material model defines the source as either a point source or as a line source. For distances less than twice the package dimension, the source is conservatively assumed to be a line source. For all other cases, the source is modeled as a point source which emits radiation equally in all directions.

The material model also contains a library of 59 isotopes each of which has 11 defining parameters which are used in the calculation of dose. The user can add isotopes not in the RADTRAN library by creating a data table in the input file consisting of eleven parameters.

3.2 TRANSPORTATION MODEL

The transportation model allows the user to input descriptions of the transportation route. A transportation route may be divided into links or segments of the journey with information for each link on population density, mode of travel (e.g., trailer truck, ship, etc.), accident rate, vehicle speed, road type, vehicle density, and link length. Alternatively, the transportation route can also be described by aggregate route data for rural, urban, and suburban areas with user input for the fraction of route spent in each area. For the T-3 shipments, the aggregate route method was used.

3.3 HEALTH EFFECTS MODEL

The health effects model in RADTRAN 4 is outdated and is replaced by hand calculations. The health effects are determined by multiplying the population dose (person-rem) supplied by RADTRAN 4 by a conversion factor. The conversion factors relate population dose to latent cancer fatalities and total detriment from cancer fatalities, cancer incidents, and genetic effects. They are taken from the International Commission on Radiological Protection (ICRP) Publication 60 (ICRP 1991) and are listed in Table 1.

Table 1. Health Effect Conversion Factors (ICRP 1991).

	Worker	Public
Latent Cancer Fatality (per person-rem)	4.0 E-04	5.0 E-04
Total Detriment (per person-rem)	5.6 E-04	7.3 E-03

3.4 ACCIDENT SEVERITY AND PACKAGE RELEASE MODEL

Accident analysis in RADTRAN 4 is performed using the accident severity and package release model. The user can define up to 20 severity categories for three population densities (urban, suburban and rural), each increasing in magnitude. NUREG-0170 (NRC 1977) defines eight severity categories for spent fuel containers that are related to fire, puncture, crush, and immersion environments. Various other studies have also been performed for small (Clarke et al. 1976) and large (Dennis et al. 1978) packages which can also be used to generate severity categories. The accident scenarios are further defined by allowing the user to input release fractions, and aerosol and respirable fractions for each severity category. These fractions are also a function of the physical-chemical properties of the materials being transported.

3.5 METEOROLOGICAL DISPERSION MODEL

RADTRAN 4 allows the user the choice of two different methods for the modeling of the atmospheric transport of radionuclides after a potential accident. The user can either input Pasquill atmospheric stability category data or averaged time-integrated concentrations. In the T-3 cask analyses, the dispersion of radionuclides after a potential accident is modeled by the use of time-integrated concentration values in downwind areas compiled from national averages by SNL.

3.6 INCIDENT-FREE TRANSPORT

The models described above are used by RADTRAN 4 to determine dose from incident-free transportation or risk from potential accidents. The public and worker doses calculated by RADTRAN 4 for incident-free transportation are dependent upon the type of material being transported and the Transportation Index (TI) of the package or packages. The TI is defined in 49 CFR 173.403(bb) as the highest package dose rate in millirem per hour at a distance of 1 m from the external surface of the package. Dose consequences

are also dependent upon the size of the package, which as described in the material model description, will determine whether the package is modeled as a point source or line source for close-proximity exposures.

3.7 POTENTIAL ACCIDENT ANALYSIS

The potential accident analysis performed in RADTRAN 4 calculates population doses for each accident severity category using six exposure pathway models. They include inhalation, resuspension, groundshine, cloudshine, ingestion, and direct exposure. However, RADTRAN 4 assumes that any contaminated area is either mitigated or public access controlled so the ingestion pathway is assumed to be zero. The consequences calculated for each severity category are multiplied by the appropriate probabilities for each category and summed to give a total radiological accident risk.

4.0 RADTRAN 4 INPUT PARAMETERS

RADTRAN 4 computer code input files divide easily into parameters associated with the source term, parameters which are used for incident-free transportation, and data that are associated with potential accidents. Input file listings for each of the three cases run can be found in the Appendix. This section provides the technical basis for the input parameters used in the three RADTRAN cases.

4.1 SOURCE TERM PARAMETERS

The shipments from FFTF to INEL involve two types of fuel pins. Sodium-bonded metal alloy fuel pins and sodium-bonded mixed carbide fuel pins. The T-3 SAR analyzes sodium-bonded metal alloy fuel and helium-bonded carbide fuel. In a WHC Supporting Document, (WHC-SD-FF-DA-021), included in the SAR, two sodium-bonded metal alloy fuel payloads and one helium-bonded carbide fuel payload were characterized. The radionuclide inventories of the metal alloy fuel payloads were shown to bound the proposed pin shipments. The sodium-bonded mixed carbide pins are approximately the same weight and size as the helium-bonded pins analyzed in the SAR. In addition, the helium-bonded carbide pins were characterized to bound all carbide pins within the scope of the SAR and contained 23 weight percent plutonium, much more than the sodium-bonded carbide pins to be shipped. The Detailed Radiation Plan contained in a data library at the Hanford Site lists the sodium-bonded carbide pins as containing 14.86 weight percent plutonium. Therefore, the carbide pin analysis within the SAR is considered to bound the sodium-bonded carbide pins to be shipped to INEL.

ORIGEN2 (Croff 1980) runs were made to calculate curie inventories for all three potential payloads. The power histories used in the ORIGEN2 runs were typical of fast reactor environments and considered to be worst case. Two of the three payloads described in the T-3 SAR have had additional ORIGEN2 runs made on them (see section 7.0 Appendix). The two runs consisted of the worst case metal alloy fuel payload and the carbide fuel payload. For these two runs, the original ORIGEN2 input files for the T-3 SAR were modified to extend the decay times of the pins to up to 1,095 days after shutdown. The FFTF was shutdown in March 1992; accordingly, the source term for the T-3 cask shipment uses the curie values listed in the ORIGEN2 output for an

after-shutdown decay time of 850 days. Most of the fuel assemblies were removed from the reactor before March 1994 and will have additional decay time before shipment, so the 850 day decay time is a conservative value.

The determination of the source term for the two types of shipments also included the consideration of the activation of sodium. The FFTF uses liquid sodium as a coolant. Therefore, although the fuel pin assembly will be washed before insertion into the approved pin containers, 200 g of free sodium per shipment is conservatively assumed to be present. Additionally, the pins themselves contain some sodium encased between the cladding and the fuel. The maximum quantity contained within the metal alloy pins is assumed to be 9 g, one gram more than the T-3 SAR limit. The maximum quantity within the sodium-bonded carbide pins is 15.52 g, a number taken from historical data.

ORIGEN2 (see section 7.0 Appendix) runs were made to determine the activation of sodium within the pins during reactor operation. The number of curies of ^{22}Na per gram of sodium bonding after 850 days of shutdown time was found to be 2×10^{-3} Ci/g. The power history used for this analysis assumed a worst case flux and reactor location.

The ^{22}Na present in the FFTF sodium coolant was determined by decaying laboratory analysis results conducted in February 1993 (see section 7.0 Appendix). The ^{22}Na activity per gram of coolant 850 days after shutdown was found to be 3.6×10^{-7} Ci.

The source term for the sodium-bonded metal alloy fuel duct, nozzle, and handling socket was generated following procedures outlined in section 7.0 Appendix. The values found for the additional assembly hardware were added to the 169 fuel pin inventory.

Table 1 in the Appendix contains the total sodium-bonded metal alloy curie quantity generated from the ORIGEN2 runs. Table 4 contains the total curie quantity for the carbide pins. These total source terms were refined using precedence set by SNL as discussed in the RADTRAN 4 User's Manual (Neuhauser and Kanipe 1992). SNL suggests disregarding radionuclides that contribute a small percentage to the hazard of a package. Sensitivity studies conducted by SNL have shown that radionuclides that are a small percentage of the hazard contribute a correspondingly small percentage of the dose or risk. The hazard of a radionuclide in this instance is measured by the percentage contribution of the particular radionuclide to the total A_2 quantities within the package. A_2 values are assigned to each radionuclide by the International Atomic Energy Agency and adopted by the DOT in 49 CFR 173. They are determined for each radionuclide by consideration of a series of exposure routes and are a measure of the toxicity of the radionuclide. Radionuclides with high A_2 values are relatively less toxic than radionuclides with low A_2 values.

Of the 61 radionuclides identified as part of the metal alloy total source term, 20 of these were eliminated using two criteria. The hazards were normalized to 1.0. Radionuclides were then eliminated until the normalized sum reached a value of 0.99. This indicates that 99% of the hazard of the package is included. The second criterion used was the Annual Limit on Intake (ALI), as defined in the ICRP Publication 30 (ICRP 1979-1982). The ALI is that activity of a radionuclide which when taken by one individual gives the

limit set by the ICRP for a year of occupational exposure. Radionuclides that were eliminated from the source term by the first criterion were replaced on the list if their quantity was greater than ten times the ALI, even if their hazard indicator was extremely low. Isotopes with quantities lower than ten times their respective ALI values that also contribute less than 1% to the total hazard of the shipment will not change the RADTRAN 4 results which are reported to three significant figures. See the example below.

Example: The three radionuclides, ^{137}Cs, ^{225}Ac, and ^{239}Np, listed below with their quantities and A_2 values, are from a hypothetical mixture awaiting shipment.

Column	A	B	C	D	
Radionuclide	Quantity (Ci)	A_2 (Ci)	Number of A_2s (A/B)	Normalized (C/Sum)	10 x ALI (Ci)
^{137}Cs	120	10	12	0.996	2.0 E-03
^{225}Ac	1.0 E-04	0.002	0.05	0.00415	3.0 E-06
^{239}Np	2.0 E-04	25	0.000008	6.64 E-07	2.0 E-02
SUM	----	----	12.050008	1.0	----

Column A represents the quantity of the radionuclide present. Column B is the corresponding A_2 value for that radionuclide. Column C is the quantity of the radionuclide in Column A divided by the A_2 value for that radionuclide. Column D is then found by normalizing the Column C results. The normalized results can be used as a hazard indicator. For instance, in this mixture, ^{137}Cs contains 99.6% of the hazard. So, ^{225}Ac and ^{239}Np may be omitted from the list for transportation analysis purposes. However, when the quantities of ^{225}Ac and ^{239}Np are compared to their ALI values, the quantity of ^{225}Ac is greater than ten times the ALI value so it is left on the list.

Tables 1 and 4 in the Appendix were generated on an Excel 5.0 (Microsoft Corporation 1993) spreadsheet and give the A_2 values, number of A_2s, and ALI values for each isotope, as well as the normalized hazard and final hazard for the refined source term. As can be seen, using this methodology, 20 radionuclides were omitted from the sodium-bonded metal alloy source term leaving 41 radionuclides in the final source term, and 31 radionuclides were eliminated from the carbide fuel source term (including ^{22}Na) leaving 55 radionuclides in the final source term. Tables 1 and 4 show that the hazard remaining in the final source terms after refinement are 99.998% and 99.999998% respectively.

Table 2 gives the final source term for the 100 pin and 18 sodium-bonded pin metal alloy shipments and Table 4 gives the final source term for the 18 pin carbide fuel shipment. These source terms represent conservative values. They were generated using worst-case metal alloy and carbide fuel pin payloads. The source terms are decayed to 850 days after shutdown, when in fact many of them will have aged for much longer time periods before shipment. Furthermore, the sodium-bonded metal alloy fuel source terms also include a worst-case fuel pin sodium bonding content of 9 g per pin and the inclusion of

200 g of free sodium within each shipment even though washing will remove most of the free sodium.

RADTRAN 4 has a radionuclide library which contains data for 59 isotopes. Of the 41 radionuclides in the sodium-bonded metal alloy source term, six of them were not contained within the RADTRAN 4 library. Of the 55 radionuclides in the carbide fuel source term, 19 of them were not contained in the RADTRAN 4 library. Accordingly, the information needed for each of the radionuclides not in the library had to be gathered. To maintain consistency with RADTRAN 4, the original references were used whenever possible for the sources of this information even when more current data were available. The eleven values needed for each radionuclide and the reference for the data follow.

1. Half-life (ICRP 1983)
2. Photon energy (ICRP 1983)
3. Cloudshine dose factor, external immersion (DOE 1988a) (Eckerman et al. 1988)
4. Committed effective dose equivalent for inhalation (DOE 1988b) (Eckerman et al. 1988)
5. Committed effective dose equivalent for ingestion (DOE 1988b) (Dunning 1983) (Eckerman et al. 1988)
6. Food transfer factor - set to zero since any contamination from accidents will be mitigated
7. Soil transfer factor - also set to zero
8. Deposition velocity of aerosol particles (Neuhauser and Kanipe 1992)
9. Lung type - determined by radiation characteristics
10. One-year lung dose for inhalation (Dunning 1983)
11. One-year marrow dose for inhalation (Dunning 1983)

The Appendix contains the two data sets generated for the radionuclides not contained in the RADTRAN 4 library. Table 3 lists the data for the sodium-bonded metal alloy fuel and Table 6 lists the data for the carbide fuel. As discussed in Section 3, these eleven parameters are used in RADTRAN 4 to calculate population dose from potential accidents.

Two additional parameters are associated with the source term. These parameters will later determine the release of the radionuclides given an accident of a certain magnitude. The parameters define the physical-chemical properties of the radionuclides being shipped. They are the physical-chemical group and the dispersibility category of the radionuclide. For spent fuel, five physical-chemical groups were defined. These were: Noble gases (Kr), Halogens (I) and Tritium, Volatile solids (Cs and Na), Spent fuel particles (mixed fission products, actinides and immobile solids), and Ruthenium. The dispersibility category default values were taken from the RADTRAN User's Manual.

4.2 INCIDENT-FREE TRANSPORTATION INPUT PARAMETERS

The metal alloy fuel pin shipments are represented by three cases. These cases are meant to bound the T-3 cask shipments that may be required. The first case is the shipment of the 169 fuel pin assembly. No more than 6 such shipments will occur. The next case contains 100 fuel pins and requires

12 shipments. The last case requires 70 shipments consisting of 18 fuel pins. The 18 carbide fuel pins will be transported to INEL in one T-3 cask shipment (after an amendment to the CoCs has been completed).

Table 2 is a list of input parameters that are used by RADTRAN 4 in the calculation of population dose for incident-free transport. The first three lines of the table show differences between the sodium-bonded metal alloy fuel pin cases and the carbide fuel pin case. The rest of the values in the table are common to all shipments.

RADTRAN 4 uses the dose rate at 1 m in calculating dose to the public and worker. In the absence of historical data, for shipments containing 169 or 100 pins of the sodium-bonded metal alloy fuel, a dose rate at 1 m of 14 mrem/hr was selected. This will cause RADTRAN 4 to conservatively use the regulatory limits for the vehicle. For the 18 pin shipments, historical dose readings from the T-3 cask were used.

The historical dose readings (see section 7.0 Appendix) reviewed were from a random sampling of records for shipments to Idaho in the T-3 cask. Measurements were taken at 1 m when the cask was loaded with a variety of payloads. The majority of the values reviewed for payloads consisting of irradiated fuel (mixed fission products, and plutonium and uranium isotopes) were less than 0.5 mrem/hr, but a figure of 0.7 mrem/hr was recorded for a shipment containing 30,000 curies. The value used in this analysis for the 18 pin shipments was 2 mrem/hr, more than twice the 0.7 mrem/hr value.

The computer code Highway 3.1 (Johnson, et al. 1993) was used to generate the travel fractions and mileage input values shown in Table 2. RADTRAN 4 default values, based on national averages, were used where case-specific values were unknown.

4.3 POTENTIAL ACCIDENT INPUT PARAMETERS

The risk associated with accidents which may take place during the transportation of nuclear materials is calculated by multiplying the probability of a certain event times the consequence of the event. The probability of an event resulting in a specific release is determined by multiplying the accident rate times the conditional probability of an accident of a certain severity. Release quantities are used to calculate the consequences of a release and are determined by multiplying the cask inventory times the fractional release of the radionuclides associated with the severity category. Aerosolized and respirable fractions of the released material are used to calculate the amount of released material that can become airborne and that can be inhaled, respectively. The conditional probabilities calculated in RADTRAN 4 are then multiplied by the shipping distance, accident rate, and dose consequence of the release and summed for a total risk. Five of the parameters used in these calculations are listed in the following subsection along with the reference material for the particular parameters used in this study.

Table 2. Input Parameters for Incident Free Transport.[a]

Parameter	169 Metal Alloy Pin Assembly	100 Metal Alloy Pins	18 Metal Alloy Pins	Carbide
Number of Shipments	6	12	70	1
Pins per Shipment	169	100	18	18
Duct, Nozzle, and Handling Socket	Yes	No	No	
Dose rate 1 m from Vehicle/Package (mrem/hr)	14.0	14.0	2.0	2.0
Length of Package (m)			4.5	
Distance traveled (km)[b]			864.0	
Exclusive Use			Yes	
Fraction of Travel in Rural Population Zone[b]			0.904	
Fraction of Travel in Suburban Population Zone[b]			0.082	
Fraction of Travel in Urban Population Zone[b]			0.014	
Velocity in Rural Population Zone (km/hr)[c]			88.6	
Velocity in Suburban Population Zone (km/hr)[c]			40.3	
Velocity in Urban Population Zone (km/hr)[c]			24.2	
Number of Crewmen			2	
Distance from Source to Crew (m)			10.0	
Stop Time per km (hr/km)[c]			0.011	
Persons Exposed While Stopped[c]			50	
Average Exposure Distance While Stopped (m)[c]			20.0	
Number of People per Vehicle on Link[c]			2	
Fraction of Rural-Suburban Travel on Freeways[b]			0.66	
Traffic Count Passing a Specific Point-Rural Zone, One-Way[c]			470	
Traffic Count Passing a Specific Point-Suburban Zone, One-Way[c]			780	
Traffic Count Passing a Specific Point-Urban Zone, One-Way[c]			2,800	
Population Density in Rural Zone (people/km^2)[b]			4.0	
Population Density in Suburban Zone (people/km^2)[b]			361.1	
Population Density in Urban Zone (people/km^2)[b]			2,042.6	

(a) Values shown are shipment specific unless otherwise noted.
(b) Values generated with the HIGHWAY 3.1 computer code (Johnson et al. 1993).
(c) Default values from RADTRAN 4 (Neuhauser and Kanipe 1992)*

4.3.1 Accident Rate

Expressed as accidents per mile, the accident rate is taken from national averages (Neuhauser and Reardon 1986). Each population density zone (rural, suburban and urban) has a baseline accident rate. In accidents/km these are:

	Accidents/km
Rural	1.4 E-07
Suburban	3.0 E-06
Urban	1.6 E-05

4.3.2 Accident Severity Category

Conditional probabilities relate the fractions of all accidents that occur of a given severity level. For this analysis, 6 severity categories were defined. The conditional probabilities of accidents in each severity category are a function of the population density of the area. Each severity category represents the conditional probability that an accident with mechanical and thermal forces of certain magnitudes (from crush, impact, puncture and fire) will occur. Different types of accidents resulting in the same magnitude of force on the spent fuel cask are thus represented by the same severity category. In this manner, accidents with little or no impact on the cask but with a high probability of occurrence and accidents with severe cask impact but a very low probability of occurrence are represented. The sum of the conditional probabilities must add to 1.0. The severity fractions for this study, as shown in Table 3, were taken from median values developed by SNL for spent fuel casks (Neuhauser and Reardon 1986). They are based on a study funded by the NRC known as the Modal Study (Fischer et al. 1986).

Table 3. Accident Severity Fractions (Neuhauser and Reardon 1986).

Severity Category	Rural	Suburban	Urban
Severity 1	6.03 E-01	6.02 E-01	6.04 E-01
Severity 2	3.94 E-01	3.94 E-01	3.95 E-01
Severity 3	3.0 E-03	4.0 E-03	3.8 E-04
Severity 4	3.0 E-06	4.0 E-06	3.8 E-07
Severity 5	5.0 E-06	3.0 E-06	2.5 E-07
Severity 6	7.0 E-06	2.0 E-06	1.3 E-07

4.3.3 Release Fraction

The release fraction is defined as the fraction of material that could be released from a cask as a result of accidents of a given severity. Release fractions are needed for each severity category and physical-chemical group. Release fraction data from various sources are compiled in Table 4.

Table 4 shows the results of a variety of release fraction studies. The NUREG-0170 values shown were compiled in 1977 and are highly conservative. Casks are assumed to release their entire contents to the environment for accidents above severity category 4 (in an 8 severity category system). The results of two Wilmot studies conducted on commercial and Savannah River Plant spent fuel are also shown in Table 4. These values are included in the table for comparison purposes. They are not as conservative as the NUREG-0170 release fractions and are intended to be used for light water reactor spent fuel. The numbers found in the "Offsite Transportation of Spent Nuclear Fuel" (DOE 1994a) for metallic spent fuel were developed from laboratory measurements and the NRC Modal Study. The laboratory measurements were made of the release of fission products from irradiated aluminum clad aluminum alloy fuels at high temperatures (Shibata et al., 1984). Mishima (Mishima 1994) has gathered information on release fractions for DOE non-reactor nuclear facilities. This document does not address the issue of cladding rupture, but does set a bounding value for a release fraction due to the oxidation of metals in an upflow of air as shown under the delta phase plutonium metal entry in the tables. The compilation of release fractions found in the HEDL document represents conservative values used in 1981 for liquid metal fast breeder reactor fuel.

Release fractions are governed by thermal stresses. For the two types of fuels identified for shipment to INEL in the T-3 cask, the release fractions used are those developed from laboratory measurements in a study performed by Shibata of the behavior of aluminide fuel subjected to thermal stress. The release fractions for the aluminide fuel are directly dependent upon the low melting point of the aluminum cladding (less than 600°C) and the eutectic temperature of the aluminum alloy fuel (640 °C) (Shibata et al. 1984). These release fractions will be bounding values for the two types of fuels to be shipped if these fuels have higher thermal integrities than the aluminide fuel.

The maximum steady state and transient temperature limit for the sodium-bonded metal alloy fuel has been established in the T-3 SAR to be 647°C. This temperature limit is higher than the melting point of the aluminum cladding and the eutectic temperature of the aluminum alloy fuel. The aluminide release fractions, therefore, will bound the metal alloy fuel case.

The sodium-bonded carbide fuel is not covered in the T-3 SAR, however the helium-bonded carbide fuel thermal integrity limit is listed in the SAR as 816°C. Both the helium-bonded and sodium-bonded carbide fuels are clad with either 20% cold worked 316 stainless steel or 20% cold worked D-9 stainless steel cladding. D-9 is a titanium-stabilized variant of the 316 stainless steel. The melting point of these stainless steel alloys is listed as being in the range of 1370°C to 1425°C. In addition, the fuel and clad materials

Table 4. Release Fraction Data.

Description		Severity Category 1	2	3	4	5	6	7	8	Source
Type B Plutonium	Pu	0	0	0	0	0	0	.01	.1	NUREG-0170 (NRC 1977)
Shipping Containers	Cask	0	0	.01	.1	1.0	1.0	1.0	1.0	
Savannah River Plant Spent Fuel	Co60	0	0	0.012	0.012	0.012	0.012	---	---	SNL Cost and Risk Report (Wilmot, et al. 1983)
	Kr	0	0	0	0.01	0.1	0.11	---	---	
	Cs	0	0	0	1.0E-08	2.0E-04	2.8E-04	---	---	
	Eu, Sr, Pu	0	0	0	1.0E-08	5.0E-08	5.0E-08	---	---	
	Ru	0	0	0	1.0E-08	1.0E-06	4.2E-05	---	---	
Metallic Spent Fuel	Inert Gas	0.0	9.9E-03	3.3E-02	3.9E-01	3.3E-01	6.3E-01	---	---	"Appendix I Offsite Transportation of Spent Nuclear Fuel" (DOE 1994)
	Iodine	0.0	1.1E-07	3.5E-07	6.0E-06	3.5E-06	6.0E-05	---	---	
	Cs	0.0	3.0E-08	1.0E-07	1.0E-06	1.0E-06	1.0E-05	---	---	
	Ru	0.0	4.1E-09	1.4E-08	2.4E-07	1.4E-07	2.4E-06	---	---	
	Particulates	0.0	3.0E-10	1.0E-09	1.0E-08	1.0E-08	1.0E-07	---	---	

Description	Severity Category 1	2	3	4	5	6	7	8	Source
Commercial Spent Fuel Co60	1E-01	1E-01	1E-01	1E-01	1E-02	---	---	---	"Transportation Accident Scenario for Commercial Spent Fuel" (Wilmot 1981)
Noble Gases	---	3E-05	1E-01	1E-01	1E-01	---	---	---	
Cs134	---	8E-06	2E-04	3E-04	1E-03	---	---	---	
Cs137	---	8E-06	2E-04	3E-04	1E-03	---	---	---	
I129	---	9E-06	6E-04	4E-04	4E-03	---	---	---	
Sr90	---	5E-07	2E-06	4E-06	9E-07	---	---	---	
Ru106	---	---	1E-06	1E-06	4E-05	---	---	---	
Actinides	---	5E-07	2E-06	3E-06	9E-07	---	---	---	
Delta phase Plutonium Metal:	Airborne release of particulates formed by oxidation at elevated temperatures less than ignition: 3E-05								DOE Release Fraction Study (Mishima 1993)
Uranium (bounding value for actinides):	Heating in an upflow of air and allowing resulting oxides to slough away during oxidation process: 1E-03								

Liquid Metal Fast Breeder Reactor Fuel						Safety Analysis Guide (HEDL-MG-153) (Lucas 1981)
Radioactive Material	Gap Release	Heated Fuel	Molten Fuel	Fire	Explosion	
Noble Gases	1.00	1.00	1.00	1.00	1.00	
Halogens	0.10	0.50	0.50	1.00	1.00	
Volatile Solids	0.05	0.05	0.50	0.01	0.01	
Nonvolatile Solids	0.01	0.01	0.01	0.01	0.01	

have been specifically developed for use in fast reactors and have been extensively tested in environments which resulted in cladding temperatures greater than 600°C. The only essential difference between the two carbide fuels is the sodium between the cladding and the fuel. Carbide fuels in general have shown a high degree of performance within high temperature sodium-cooled fast reactors and show excellent material characteristics in a sodium environment. Both sodium-bonded and helium-bonded carbide pins have been irradiated for over 400 days in the FFTF and neither type of fuel showed evidence of phase change in the cladding. There is no indication whatsoever that the sodium between the fuel and clad will cause a 700°C reduction in the melting point of the clad material or will influence the behavior of the fuel to an extent that the conservative release fractions determined in the aluminide fuel study are not applicable. Therefore, the release fractions determined in the Shibata study for aluminide fuel are considered bounding for the T-3 cask fuel types. A list of the release fractions by physical-chemical group that were used in this analysis can be found in Table 5.

Table 5. Release Fractions, Aerosolized Fractions, and Respirable Fractions.

Severity Category		1	2	3	4	5	6
Group 1 - Noble Gases		0	9.9 E-03	3.3 E-02	3.9 E-01	3.3 E-01	6.3 E-01
Group 2 - Halogens and Tritium		0	1.1 E-07	3.5 E-07	6.0 E-06	3.5 E-06	6.0 E-05
Group 3 - Volatile Solids		0	3.0 E-08	1.0 E-07	1.0 E-06	1.0 E-06	1.0 E-05
Group 4 - Spent Fuel Particles		0	3.0 E-10	1.0 E-09	1.0 E-08	1.0 E-08	1.0 E-07
Group 5 - Ruthenium		0	4.1 E-09	1.4 E-08	2.4 E-07	1.4 E-07	2.4 E-06
Aerosolized Fraction	Gas	0	1	1	1	1	1
	Volatile Solids	0	1	1	1	1	1
	Spent Fuel Particles	0	1	1	1	1	1
Respirable Fraction	Gas	0	1	1	1	1	1
	Volatile Solids	0	0.05	0.05	0.05	1	1
	Spent Fuel Particles	0	0.05	0.05	0.05	0.05	0.05

4.3.4 Aerosolized Fractions and Respirable Fractions

The aerosolized and respirable fractions are dependent upon the physical-chemical form of the radionuclides. The fractions are taken from Wilmot's study of risk associated with the transport of nuclear materials (Wilmot 1983) and from the RADTRAN User's Manual and are shown in Table 5.

5.0 TRANSPORTATION IMPACTS

5.1 INCIDENT-FREE IMPACTS

Table 6 presents the results of the incident-free transportation of the three sodium-bonded metal alloy fuel pin shipments. The carbide fuel pin shipment (one shipment of 18 pins) is also represented. The population doses are the values given by the RADTRAN 4 computer code. These were multiplied by the ICRP-60 health effects conversion factors given in Table 1.

The results indicate that the incident-free population dose from shipping 12 shipments of 100 pins is slightly higher than that found from 70 shipments of 18 pins. This is due to the use of the regulatory limit of 200 mrem/hr dose rate at the cask surface for the 100 pin shipments. The 6 shipments of the 169 fuel pin assembly fall in between the other two metal alloy shipments. The population dose from 6 shipments of the 169 pin assembly is 0.186 person-rem to the worker, 5.27 person-rem to the public, and a total of 5.46 person-rem. The population dose from 12 shipments is 0.371 person-rem to the worker, 10.5 person-rem to the public, and a total of 10.9 person-rem. Alternately, the population dose from 70 shipments would be 0.309 person-rem to the worker, 9.34 person-rem to the public and 9.65 person-rem total. The single sodium-bonded carbide shipment population dose is 4.42×10^{-3} person-rem to the worker, 0.134 person-rem to the public with a total of 0.138 person-rem.

There are no excess latent cancer fatalities or excess total detriments resulting from the normal transportation of the sodium-bonded metal alloy fuel pins or from the carbide fuel pins. The results show a total of 2.71×10^{-3} latent cancer fatalities for 6 shipments of the 169 pin assembly, 5.26×10^{-3} latent cancer fatalities from 12 shipments of 100 sodium-bonded metal alloy fuel pins, 4.79×10^{-3} latent cancer fatalities from 70 shipments containing 18 pins of sodium-bonded metal alloy fuel, and 1.84×10^{-3} latent cancer fatalities from the single carbide pin shipment. Total detriments for the shipments are 3.86×10^{-2}, 7.69×10^{-2}, 6.84×10^{-2} and 9.81×10^{-4} for the 6 shipments, 12 shipments, 70 shipments, and single shipment respectively.

5.2 POTENTIAL ACCIDENT RISKS

Table 7 presents the total risks from potential accidents of the different types of shipments. The ICRP-60 health effects conversion factors were again used to calculate latent cancer fatalities and total detriment from RADTRAN 4 results. Table 7 shows population risks of 2.51×10^{-4} person-rem for 6 shipments of the 169 pin assembly, 2.96×10^{-4} person-rem for 12 shipments of 100 sodium-bonded metal alloy fuel pins, 3.11×10^{-4} person-rem for 70 shipments of 18 sodium-bonded metal alloy fuel pins, and 3.07×10^{-6} person-rem for the single shipment of sodium-bonded carbide fuel. Latent cancer fatalities are found to be 1.26×10^{-7}, 1.48×10^{-7}, 1.56×10^{-7} and 1.54×10^{-9}. Total detriments are 2.24×10^{-8}, 2.16×10^{-6}, 2.27×10^{-6}, and 2.24×10^{-8}. These results show no excess latent cancer fatalities or total detriment resulting from potential accidents related to the shipment of the FFTF fuel.

Table 6. Risks from Incident-Free Transportation.

	Metal Alloy Fuel Pins			Carbide Fuel Pins
	6 Shipments	12 Shipments	70 Shipments	1 Shipment
Pins per Shipment	169	100	18	18
Population Dose (person-rem)				
Worker	0.186	0.371	0.309	0.00442
Public	5.27	10.5	9.34	0.134
Total	5.46	10.9	9.65	0.138
Latent Cancer Fatalities				
Worker	7.44E-05	1.48E-04	1.24E-04	1.77E-06
Public	2.64E-03	5.25E-03	4.67E-03	6.70E-05
Total	2.71E-03	5.40E-03	4.79E-03	6.88E-05
Total Detriment				
Worker	1.04E-04	2.08E-04	1.73E-04	2.48E-06
Public	3.85E-02	7.67E-02	6.82E-02	9.78E-04
Total	3.86E-02	7.69E-02	6.84E-02	9.81E-04

Table 7. Risks from Potential Accidents.

	Metal Alloy Fuel Pins			Carbide Fuel Pins
	6 Shipments	12 Shipments	70 Shipments	1 Shipment
Pins per Shipment	169	100	18	18
Population Risk (person-rem)	2.51E-04	2.96E-04	3.11E-04	3.07E-06
Latent Cancer Fatalities	1.26E-07	1.48E-07	1.56E-07	1.54E-09
Total Detriment	1.83E-06	2.16E-06	2.27E-06	2.24E-08

5.3 CONCLUSIONS

Transportation impacts relating to normal, incident-free transportation and potential accident scenarios were considered for the shipment of irradiated sodium-bonded metal alloy and carbide fuel from the FFTF to INEL in support of the Environmental Assessment of the FFTF shutdown. RADTRAN 4 was used to analyze the incident-free and accident transportation risks. Input parameters used were conservative. Potential population dose and population risk were low for both types of analysis performed. No excess latent cancer fatalities or total detriments were found to result from the proposed shipments.

6.0 REFERENCES

10 CFR 71, 1993, "Packaging and Transportation of Radioactive Material," *Code of Federal Regulations*, as amended.

49 CFR 173, 1993, "Transportation," *Code of Federal Regulations*, as amended.

Clarke, R. K., J. T. Foley, W. F. Hartman, and D. W. Larson, 1976, *Severities of Transportation Accidents, Volume 1 - Summary*, SLA-74-001, Sandia National Laboratories, Albuquerque, New Mexico.

Croff, A. G., 1980, *A User's Manual for the ORIGEN2 Computer Code*, ORNL/TM-7175, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Dennis, A. W., J. T. Foley, W. F. Hartman, and D. W. Larson, 1978, *Severities of Transportation Accidents Involving Large Packages*, SAND77-0001, Sandia National Laboratories, Albuquerque, New Mexico.

Dobbin, K., 1994, *Sodium-22, Radioactivity for FFTF Sodium-Bonded Assemblies*, Draft Internal Memo, Westinghouse Hanford Company, Richland, Washington.

DOE, 1987, *Final Environment Impact Statement: Disposal of Hanford Defense High-level, Transuranic and Tank Wastes*, DOE/EIS 0113, U.S. Department of Energy, Washington, D.C.

DOE, 1988a, *External Dose Rate Conversion Factors for Calculation of Dose to the Public*, DOE/EH-0070, U.S. Department of Energy, Washington, D.C.

DOE, 1988b, *Internal Dose Conversion Factors for Calculation of Dose to the Public*, DOE/EH-0071, U.S. Department of Energy, Washington, D.C.

DOE, 1994a, *Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Draft Environmental Impact Statement*, Volume 1, Appendix I, DOE/EIS-0203-D, Richland, Washington.

DOE, 1994b, *Revision 5 of DOE Certificate 9132 for T-3 Cask*, USA/9132/B(M)F (DOE), U.S. Department of Energy, Washington, D.C.

Dunning, D. D., 1983, *Estimates of Internal Dose Equivalent from Inhalation and Ingestion of Selected Radionuclides*, WIPP/DOE-176, U.S. Department of Energy, Washington, D.C.

Eckerman, K. F., A. B. Wolbarst, and A. C. B. Richardson, 1988, *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors For Inhalation, Submersion, and Ingestion*, Federal Guidance Report No. 11., Office of Radiation Programs, U.S. Environmental Protection Agency, Washington, D.C.

Fischer, L. E., et al., 1986, *Shipping Container Response to Severe Highway and Railway Accident Conditions*, NUREG/CR-4829, Volume 1, Lawrence Livermore National Laboratory, Livermore, California.

ICRP, 1979-1982, *Limits for Intakes of Radionuclides by Workers*, ICRP Publication 30, Pergammon Press, Oxford.

ICRP, 1983, *Radionuclide Transformation, Energy, and Intensity of Emissions*, ICRP Publication 38, Pergammon Press, Oxford.

ICRP, 1991, *1990 Recommendations of the International Commission on Radiological Protection*, ICRP Publication 60, Pergammon Press, Oxford.

Johnson P. E., D. S. Joy, D. B. Clarke, and J. M. Jacobi, 1993, *HIGHWAY 3.1 - An Enhanced Highway Routing Model: Program Description, Methodology, and Revised User's Manual*, ORNL/TM-12124, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Lucas, D. E., 1981, *Safety Analysis Guide for Nonreactor Nuclear Facilities*, HEDL-MG-153, Westinghouse Hanford Company, Richland, Washington.

Microsoft Corporation, 1993, *Microsoft Excel User's Guide*, Redmond, Washington.

Mishima, J., 1993, *Recommended Values and Technical Bases for Airborne Release Fractions (ARFs), Airborne Release Rates (ARRs), and Respirable Fractions (RFs) for Materials from Accidents in DOE Fuel Cycle, Ex-Reactor Facilities Revision 2*, Draft DOE-HDBK-0013-93, July 1993, U.S. Department of Energy, Washington, D.C.

Neuhauser, K. S., and F. L. Kanipe, 1992, *RADTRAN 4: Volume 4 -- User Guide*, SAND89-2370, Sandia National Laboratories, Albuquerque, New Mexico.

Neuhauser, K. S., and F. L. Kanipe, 1994, *RADTRAN 4: Volume 2 -- Technical Manual*, SAND89-2370, Sandia National Laboratories, Albuquerque, New Mexico.

Neuhauser, K. S., and P. C. Reardon, 1986, *A Demonstration Sensitivity Analysis for RADTRAN III*, SAND85-1001, Sandia National Laboratories, Albuquerque, New Mexico.

Nielsen, D., 1994, *Historical Dose Readings From T-3 Fuel Shipments to Idaho*, Westinghouse Internal Memo Number 18310-DLN-012.

NRC, 1977, *Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes. Vol. 1*, NUREG-0170, U.S. Nuclear Regulatory Commission, Washington, D.C.

NRC, 1991, *Revision 12 of NRC Certificate of Compliance for T-3 Cask*, USA/9132/B(M)F (NRC), U.S. Nuclear Regulatory Commission, Washington, D.C.

Schwarz, R. A., 1994, *ORIGEN2 Calculations for FFTF Metal and Carbide Fuel*, 8D530-RAS-94-009, Westinghouse Hanford Company, Richland, Washington.

Shibata, T., T. Tamai, M. Hayashi, J. C. Posey, and J. L. Snelgrove, 1984, *Release of Fission Products from Irradiated Aluminide Fuel at High Temperatures*, Nuclear Science and Engineering.....

WHC, 1986, *T-3 Cask Users' Manual*, HEDL-7035, Revision 1, Westinghouse Hanford Company, Richland, Washington.

WHC, 1990, *Consolidated Safety Analysis Report for the T-3 Spent Fuel Shipping Cask*, Revision 6, Westinghouse Hanford Company, Richland, Washington.

Wilmot, E. L., 1981, *Transportation Accident Scenarios for Commercial Spent Fuel*, SAND80-2124, Sandia National Laboratories, Albuquerque, New Mexico.

Wilmot, E. L., M. M. Madsen, J. W. Cashwell, and D. S. Joy, 1983, *A Preliminary Analysis of the Cost and Risk of Transporting Nuclear Waste to Potential Candidate Commercial Repository Sites*, SAND83-0867, Sandia National Laboratories, Albuquerque, New Mexico.

7.0 APPENDIX

7.1 INPUT FILES

7.1.1 RADTRAN 4 Input File for 6 Shipments, 169 Sodium-Bonded Metal Alloy Pin Assembly

```
&& Edited Mon Jan  9 12:57:06 1995
&& _FFTF_169_Pins Plus Assembly_6_Shipments_
&& _fftf169a.in4_
TITLE RADTRAN 4.0 INPUT
FORM UNIT
DIMEN 39 6 4 10 18
PARM 1 3 2 1 0
POPDEN     4.000    361.100   2042.600
PACKAGE
   LABGRP
       GRP1       GRP3       GRP4       GRP5
SHIPMENT
   LABISO
       NA22       MN54       FE55       CO58       CO60       KR85
       SR89       SR90        Y90        Y91       ZR95       NB95
      RU106      SB125     TE125M      TE127      CS134      CS137
      CE144     PR144M      PM147     TE127M      NI63       RU103
     PM148M      SM151      EU154      EU155      TA182       U235
       U236      NP237      PU236      PU238      PU239      PU240
      PU241      AM241      CM242
NORMAL
   NMODE=1
       9.040E-01  8.200E-02  1.400E-02  8.856E+01  4.032E+01  2.416E+01
       2.000E+00  1.000E+01  0.000E+00  1.100E-02  5.300E+01  0.000E+00
       0.000E+00  5.000E+01  2.000E+01  0.000E+00  1.000E+02  1.000E+02
       2.000E+00  0.000E+00  0.000E+00  6.600E-01  4.700E+02  7.800E+02
       2.800E+03
ACCIDENT
   ARATMZ
       NMODE=1   1.400E-07    3.000E-06    1.600E-05
   SEVFRC
     NPOP=1
       NMODE=1
       6.03E-01  3.94E-01  3.00E-03  3.00E-06  5.00E-06  7.00E-06
     NPOP=2
       NMODE=1
       6.02E-01  3.94E-01  4.00E-03  4.00E-06  3.00E-06  2.00E-06
     NPOP=3
       NMODE=1
       6.04E-01  3.95E-01  3.80E-04  3.80E-07  2.50E-07  1.30E-07
RELEASE
   RFRAC
     GROUP=1
       0.00E+00  9.90E-03  3.30E-02  3.90E-01  3.30E-01  6.30E-01
     GROUP=2
       0.00E+00  3.00E-08  1.00E-07  1.00E-06  1.00E-06  1.00E-05
     GROUP=3
       0.00E+00  3.00E-10  1.00E-09  1.00E-08  1.00E-08  1.00E-07
     GROUP=4
       0.00E+00  4.10E-09  1.40E-08  2.40E-07  1.40E-07  2.40E-06
   AERSOL
     DISP=6
       0.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00
     DISP=7
       0.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00
     DISP=10
       0.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00
   RESP
     DISP=6
       0.00E+00  5.00E-02  5.00E-02  5.00E-02  5.00E-02  5.00E-02
     DISP=7
       0.00E+00  5.00E-02  5.00E-02  5.00E-02  1.00E+00  1.00E+00
     DISP=10
       0.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00
```

```
EFINE   NA22
      9.50E+02  2.19E+00  3.55E-01  8.00E+03  1.20E+04  0.00E+00
      0.00E+00  1.00E-02  2.00E+00  1.10E+04  1.10E+04
DEFINE  NI63
      3.66E+04  0.00E+00  0.00E+00  3.00E+03  5.40E+02  0.00E+00
      0.00E+00  1.00E-02  2.00E+00  2.50E+04  2.50E+02
DEFINE    Y90
      2.67E+00  1.69E-06  0.00E+00  8.20E+03  1.00E+04  0.00E+00
      0.00E+00  1.00E-02  1.00E+00  6.10E+04  7.40E+02
DEFINE PR144M
      5.00E-03  1.27E-02  8.46E-04  4.20E+02  1.10E+02  0.00E+00
      0.00E+00  1.00E-02  1.00E+00  2.70E+02  6.70E-02
DEFINE PM148M
      4.13E+01  1.99E+00  3.23E-01  1.70E+04  7.00E+03  0.00E+00
      0.00E+00  1.00E-02  1.00E+00  1.30E+05  1.10E+04
DEFINE  TA182
      1.15E+02  1.29E+00  2.12E-01  3.70E+04  6.00E+03  0.00E+00
      0.00E+00  1.00E-02  1.00E+00  1.30E+02  1.10E+03
DEFINE   U236
      8.54E+09  1.57E-03  1.92E-05  6.70E+06  2.50E+05  0.00E+00
      0.00E+00  1.00E-02  3.00E+00  7.70E+07  6.10E+04
DEFINE  CM242
      1.63E+02  1.83E-03  1.55E-05  1.70E+07  1.10E+05  0.00E+00
      0.00E+00  1.00E-02  1.00E+00  2.30E+07  6.90E+06
EOF
ISOTOPES  -1   6      1.00    14.000   1.00    0.00  SPFUEL
         NA22  3.05E-02       GRP3   7
         MN54  2.34E+00       GRP4   6
         FE55  2.41E+00       GRP4   6
         CO58  6.27E-01       GRP4   6
         CO60  7.51E+00       GRP4   6
         NI63  1.56E+00       GRP4   6
         KR85  2.58E+03       GRP1  10
         SR89  2.08E+00       GRP4   6
         SR90  2.11E+04       GRP4   6
          Y90  2.12E+04       GRP4   6
          Y91  1.30E+01       GRP4   6
         ZR95  3.69E+01       GRP4   6
         NB95  8.28E+01       GRP4   6
        RU103  8.14E-02       GRP5   6
        RU106  1.28E+04       GRP5   6
        SB125  3.18E+03       GRP4   6
       TE125M  7.75E+02       GRP4   6
        TE127  1.73E+01       GRP4   6
       TE127M  1.77E+01       GRP4   6
        CS134  1.14E+04       GRP3   7
        CS137  2.45E+04       GRP3   7
        CE144  3.59E+04       GRP4   6
       PR144M  4.30E+02       GRP4   6
        PM147  3.14E+04       GRP4   6
       PM148M  2.55E-02       GRP4   6
        SM151  5.57E+02       GRP4   6
        EU154  6.50E+02       GRP4   6
        EU155  1.13E+03       GRP4   6
        TA182  3.05E-02       GRP4   6
         U235  1.45E-02       GRP4   6
         U236  1.15E-01       GRP4   6
        NP237  1.19E-01       GRP4   6
        PU236  1.18E+00       GRP4   6
        PU238  4.27E+02       GRP4   6
        PU239  1.14E+02       GRP4   6
        PU240  3.18E+01       GRP4   6
        PU241  6.14E+02       GRP4   6
        AM241  3.13E+00       GRP4   6
        CM242  8.94E-01       GRP4   6
DISTKM
        NMODE=1  864.20
PKGSIZ
        SPFUEL     4.50
EOF
EOI
```

7.1.2 RADTRAN 4 Input File for 12 Shipments, 100 Sodium-Bonded Metal Alloy Pins

```
&& Edited Wed Jan 11 13:57:39 1995
&& _FFTF_100_Pins_12_Shipments_
&& _fftf100d.in4_
TITLE RADTRAN 4.0 INPUT
FORM UNIT
DIMEN 39 6 4 10 18
PARM 1 3 2 1 0
POPDEN     4.000    361.100   2042.600
PACKAGE
   LABGRP
       GRP1       GRP3       GRP4       GRP5
SHIPMENT
   LABISO
       NA22       MN54       FE55       CO58       CO60       KR85
       SR89       SR90        Y90        Y91       ZR95       NB95
      RU106       SB125     TE125M      TE127      CS134      CS137
      CE144      PR144M      PM147     TE127M       NI63      RU103
     PM148M       SM151      EU154      EU155      TA182       U235
       U236       NP237      PU236      PU238      PU239      PU240
      PU241       AM241      CM242
NORMAL
   NMODE=1
       9.040E-01  8.200E-02  1.400E-02  8.856E+01  4.032E+01  2.416E+01
       2.000E+00  1.000E+01  0.000E+00  1.100E-02  5.300E+01  0.000E+00
       0.000E+00  5.000E+01  2.000E+01  0.000E+00  1.000E+02  1.000E+02
       2.000E+00  0.000E+00  0.000E+00  6.600E-01  4.700E+02  7.800E+02
       2.800E+03
ACCIDENT
   ARATMZ
       NMODE=1   1.400E-07    3.000E-06    1.600E-05
   SEVFRC
     NPOP=1
       NMODE=1
       6.03E-01  3.94E-01  3.00E-03  3.00E-06  5.00E-06  7.00E-06
     NPOP=2
       NMODE=1
       6.02E-01  3.94E-01  4.00E-03  4.00E-06  3.00E-06  2.00E-06
     NPOP=3
       NMODE=1
       6.04E-01  3.95E-01  3.80E-04  3.80E-07  2.50E-07  1.30E-07
RELEASE
   RFRAC
     GROUP=1
       0.00E+00  9.90E-03  3.30E-02  3.90E-01  3.30E-01  6.30E-01
     GROUP=2
       0.00E+00  3.00E-08  1.00E-07  1.00E-06  1.00E-06  1.00E-05
     GROUP=3
       0.00E+00  3.00E-10  1.00E-09  1.00E-08  1.00E-08  1.00E-07
     GROUP=4
       0.00E+00  4.10E-09  1.40E-08  2.40E-07  1.40E-07  2.40E-06
   AERSOL
     DISP=6
       0.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00
     DISP=7
       0.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00
     DISP=10
       0.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00
   RESP
     DISP=6
       0.00E+00  5.00E-02  5.00E-02  5.00E-02  5.00E-02  5.00E-02
     DISP=7
       0.00E+00  5.00E-02  5.00E-02  5.00E-02  1.00E+00  1.00E+00
     DISP=10
       0.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00
DEFINE   NA22
       9.50E+02  2.19E+00  3.55E-01  8.00E+03  1.20E+04  0.00E+00
       0.00E+00  1.00E-02  2.00E+00  1.10E+04  1.10E+04
DEFINE   NI63
       3.66E+04  0.00E+00  0.00E+00  3.00E+03  5.40E+02  0.00E+00
       0.00E+00  1.00E-02  2.00E+00  2.50E+04  2.50E+04
```

```
DEFINE    Y90
       2.67E+00  1.69E-06  0.00E+00  8.20E+03  1.00E+04  0.00E+00
       0.00E+00  1.00E-02  1.00E+00  6.10E+04  7.40E+02
DEFINE PR144M
       5.00E-03  1.27E-02  8.46E-04  4.20E+02  1.10E+02  0.00E+00
       0.00E+00  1.00E-02  1.00E+00  2.70E+02  6.70E-02
DEFINE PM148M
       4.13E+01  1.99E+00  3.23E-01  1.70E+04  7.00E+03  0.00E+00
       0.00E+00  1.00E-02  1.00E+00  1.30E+05  1.10E+04
DEFINE  TA182
       1.15E+02  1.29E+00  2.12E-01  3.70E+04  6.00E+03  0.00E+00
       0.00E+00  1.00E-02  1.00E+00  1.30E+02  1.10E+03
DEFINE   U236
       8.54E+09  1.57E-03  1.92E-05  6.70E+06  2.50E+05  0.00E+00
       0.00E+00  1.00E-02  3.00E+00  7.70E+07  6.10E+04
DEFINE  CM242
       1.63E+02  1.83E-03  1.55E-05  1.70E+07  1.10E+05  0.00E+00
       0.00E+00  1.00E-02  1.00E+00  2.30E+07  6.90E+06
EOF
ISOTOPES  -1   12     1.00    14.000   1.00   0.00  SPFUEL
         NA22  1.81E-02       GRP3   7
         MN54  5.63E-01       GRP4   6
         FE55  5.77E-01       GRP4   6
         CO58  1.99E-01       GRP4   6
         CO60  2.38E+00       GRP4   6
         NI63  4.96E-01       GRP4   6
         KR85  1.53E+03       GRP1  10
         SR89  1.23E+00       GRP4   6
         SR90  1.25E+04       GRP4   6
          Y90  1.25E+04       GRP4   6
          Y91  7.68E+00       GRP4   6
         ZR95  2.18E+01       GRP4   6
         NB95  4.90E+01       GRP4   6
        RU103  4.82E-02       GRP5   6
        RU106  7.57E+03       GRP5   6
        SB125  1.88E+03       GRP4   6
       TE125M  4.58E+02       GRP4   6
        TE127  1.02E+01       GRP4   6
       TE127M  1.05E+01       GRP4   6
        CS134  6.72E+03       GRP3   7
        CS137  1.45E+04       GRP3   7
        CE144  2.12E+04       GRP4   6
       PR144M  2.55E+02       GRP4   6
        PM147  1.86E+04       GRP4   6
       PM148M  1.51E-02       GRP4   6
        SM151  3.30E+02       GRP4   6
        EU154  3.84E+02       GRP4   6
        EU155  6.66E+02       GRP4   6
        TA182  7.35E-03       GRP4   6
         U235  8.58E-03       GRP4   6
         U236  6.82E-02       GRP4   6
        NP237  7.02E-02       GRP4   6
        PU236  6.97E-01       GRP4   6
        PU238  2.53E+02       GRP4   6
        PU239  6.72E+01       GRP4   6
        PU240  1.88E+01       GRP4   6
        PU241  3.63E+02       GRP4   6
        AM241  1.85E+00       GRP4   6
        CM242  5.29E-01       GRP4   6
DISTKM
        NMODE=1  864.20
PKGSIZ
        SPFUEL     4.50
EOF
EOI
```

7.1.3 RADTRAN 4 Input File for 70 shipments, 18 Sodium-Bonded Metal Alloy Pins

```
&& Edited Wed Jan 11 14:04:32 1995
&& _FFTF_18_Pins_70_Shipments_
&& _fftf18d.in4_
TITLE RADTRAN 4.0 INPUT
FORM UNIT
DIMEN 39 6 4 10 18
PARM 1 3 2 1 0
POPDEN     4.000    361.100   2042.600
PACKAGE
   LABGRP
       GRP1       GRP3       GRP4       GRP5
SHIPMENT
   LABISO
       NA22       MN54       FE55       CO58       CO60       KR85
       SR89       SR90        Y90        Y91       ZR95       NB95
      RU106      SB125     TE125M      TE127      CS134      CS137
      CE144     PR144M      PM147     TE127M       NI63      RU103
     PM148M      SM151      EU154      EU155      TA182       U235
       U236      NP237      PU236      PU238      PU239      PU240
      PU241      AM241      CM242
NORMAL
   NMODE=1
       9.040E-01  8.200E-02  1.400E-02  8.856E+01  4.032E+01  2.416E+01
       2.000E+00  1.000E+01  0.000E+00  1.100E-02  5.300E+01  0.000E+00
       0.000E+00  5.000E+01  2.000E+01  0.000E+00  1.000E+02  1.000E+02
       2.000E+00  0.000E+00  0.000E+00  6.600E-01  4.700E+02  7.800E+02
       2.800E+03
ACCIDENT
   ARATMZ
       NMODE=1   1.400E-07    3.000E-06    1.600E-05
   SEVFRC
     NPOP=1
       NMODE=1
       6.03E-01  3.94E-01  3.00E-03  3.00E-06  5.00E-06  7.00E-06
     NPOP=2
       NMODE=1
       6.02E-01  3.94E-01  4.00E-03  4.00E-06  3.00E-06  2.00E-06
     NPOP=3
       NMODE=1
       6.04E-01  3.95E-01  3.80E-04  3.80E-07  2.50E-07  1.30E-07
RELEASE
   RFRAC
     GROUP=1
       0.00E+00  9.90E-03  3.30E-02  3.90E-01  3.30E-01  6.30E-01
     GROUP=2
       0.00E+00  3.00E-08  1.00E-07  1.00E-06  1.00E-06  1.00E-05
     GROUP=3
       0.00E+00  3.00E-10  1.00E-09  1.00E-08  1.00E-08  1.00E-07
     GROUP=4
       0.00E+00  4.10E-09  1.40E-08  2.40E-07  1.40E-07  2.40E-06
   AERSOL
     DISP=6
       0.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00
     DISP=7
       0.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00
     DISP=10
       0.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00
   RESP
     DISP=6
       0.00E+00  5.00E-02  5.00E-02  5.00E-02  5.00E-02  5.00E-02
     DISP=7
       0.00E+00  5.00E-02  5.00E-02  5.00E-02  1.00E+00  1.00E+00
     DISP=10
       0.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00
DEFINE   NA22
       9.50E+02  2.19E+00  3.55E-01  8.00E+03  1.20E+04  0.00E+00
       0.00E+00  1.00E-02  2.00E+00  1.10E+04  1.10E+04
DEFINE   NI63
       3.66E+04  0.00E+00  0.00E+00  3.00E+03  5.40E+02  0.00E+00
       0.00E+00  1.00E-02  2.00E+00  2.50E+04  2.50E+04
DEFINE    Y90
       2.67E+00  1.69E-06  0.00E+00  8.20E+03  1.00E+04  0.00E+00
       0.00E+00  1.00E-02  1.00E+00  6.10E+04  7.40E+02
```

```
DEFINE PR144M
      5.00E-03  1.27E-02  8.46E-04  4.20E+02  1.10E+02  0.00E+00
      0.00E+00  1.00E-02  1.00E+00  2.70E+02  6.70E-02
DEFINE PM148M
      4.13E+01  1.99E+00  3.23E-01  1.70E+04  7.00E+03  0.00E+00
      0.00E+00  1.00E-02  1.00E+00  1.30E+05  1.10E+04
DEFINE  TA182
      1.15E+02  1.29E+00  2.12E-01  3.70E+04  6.00E+03  0.00E+00
      0.00E+00  1.00E-02  1.00E+00  1.30E+02  1.10E+03
DEFINE   U236
      8.54E+09  1.57E-03  1.92E-05  6.70E+06  2.50E+05  0.00E+00
      0.00E+00  1.00E-02  3.00E+00  7.70E+07  6.10E+04
DEFINE  CM242
      1.63E+02  1.83E-03  1.55E-05  1.70E+07  1.10E+05  0.00E+00
      0.00E+00  1.00E-02  1.00E+00  2.30E+07  6.90E+06
EOF
ISOTOPES  -1   70     1.00    2.000   1.00   0.00  SPFUEL
         NA22  3.31E-03       GRP3   7
         MN54  1.01E-01       GRP4   6
         FE55  1.04E-01       GRP4   6
         CO58  3.58E-02       GRP4   6
         CO60  4.29E-01       GRP4   6
         NI63  8.93E-02       GRP4   6
         KR85  2.75E+02       GRP1  10
         SR89  2.22E-01       GRP4   6
         SR90  2.25E+03       GRP4   6
          Y90  2.25E+03       GRP4   6
          Y91  1.38E+00       GRP4   6
         ZR95  3.93E+00       GRP4   6
         NB95  8.82E+00       GRP4   6
        RU103  8.67E-03       GRP5   6
        RU106  1.36E+03       GRP5   6
        SB125  3.38E+02       GRP4   6
       TE125M  8.25E+01       GRP4   6
        TE127  1.84E+00       GRP4   6
       TE127M  1.89E+00       GRP4   6
        CS134  1.21E+03       GRP3   7
        CS137  2.61E+03       GRP3   7
        CE144  3.82E+03       GRP4   6
       PR144M  4.58E+01       GRP4   6
        PM147  3.34E+03       GRP4   6
       PM148M  2.71E-03       GRP4   6
        SM151  5.94E+01       GRP4   6
        EU154  6.92E+01       GRP4   6
        EU155  1.20E+02       GRP4   6
        TA182  1.32E-03       GRP4   6
         U235  1.54E-03       GRP4   6
         U236  1.23E-02       GRP4   6
        NP237  1.26E-02       GRP4   6
        PU236  1.25E-01       GRP4   6
        PU238  4.55E+01       GRP4   6
        PU239  1.21E+01       GRP4   6
        PU240  3.38E+00       GRP4   6
        PU241  6.54E+01       GRP4   6
        AM241  3.34E-01       GRP4   6
        CM242  9.52E-02       GRP4   6
DISTKM
        NMODE=1  864.20
PKGSIZ
        SPFUEL     4.50
EOF
EOI
```

7.1.4 RADTRAN Input File for Single Shipment, Sodium-Bonded Carbide Pins

```
&& Edited Sun Aug  7 13:28:03 1994
&& _FFTF_18_Carbide Pins_1 Shipments_
&& _fftfcba.in4_
TITLE RADTRAN 4.0 INPUT
FORM UNIT
DIMEN 52 6 5 10 18
PARM 1 3 2 1 0
POPDEN     4.000    361.100   2042.600
PACKAGE
   LABGRP
      GRP1       GRP2       GRP3       GRP4       GRP5
SHIPMENT
   LABISO
      H3GAS      MN54       FE55       CO58       CO60       NI63
       KR85      SR89       SR90        Y90        Y91       ZR95
      NB95M      TC99      RU103      RU106      AG110     AG110M
     CD113M     SN119M     SN123      SB124      SB125      TE125M
      TE127     TE127M     CS134      CS137      CE144      PR144M
      PM146      PM147      SM151      EU152      EU154      EU155
      TB160       U237      NP238      NP239      PU238      PU239
      PU240      PU241      AM241     AM242M      AM242      AM243
      CM242      CM243      CM244       NB95
NORMAL
   NMODE=1
       9.040E-01  8.200E-02  1.400E-02  8.856E+01  4.032E+01  2.416E+01
       2.000E+00  1.000E+01  0.000E+00  1.100E-02  5.300E+01  0.000E+00
       0.000E+00  5.000E+01  2.000E+01  0.000E+00  1.000E+02  1.000E+02
       2.000E+00  0.000E+00  0.000E+00  6.600E-01  4.700E+02  7.800E+02
       2.800E+03
ACCIDENT
   ARATMZ
       NMODE=1   1.400E-07    3.000E-06    1.600E-05
   SEVFRC
     NPOP=1
       NMODE=1
       6.03E-01  3.94E-01  3.00E-03  3.00E-06  5.00E-06  7.00E-06
     NPOP=2
       NMODE=1
       6.02E-01  3.94E-01  4.00E-03  4.00E-06  3.00E-06  2.00E-06
     NPOP=3
       NMODE=1
       6.04E-01  3.95E-01  3.80E-04  3.80E-07  2.50E-07  1.30E-07
RELEASE
   RFRAC
     GROUP=1
       0.00E+00  9.90E-03  3.30E-02  3.90E-01  3.30E-01  6.30E-01
     GROUP=2
       0.00E+00  1.10E-07  3.50E-07  6.00E-06  3.50E-06  6.00E-05
     GROUP=3
       0.00E+00  3.00E-08  1.00E-07  1.00E-06  1.00E-06  1.00E-05
     GROUP=4
       0.00E+00  3.00E-10  1.00E-09  1.00E-08  1.00E-08  1.00E-07
     GROUP=5
       0.00E+00  4.10E-09  1.40E-08  2.40E-07  1.40E-07  2.40E-06
   AERSOL
     DISP=6
       0.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00
     DISP=7
       0.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00
     DISP=10
       0.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00
   RESP
     DISP=6
       0.00E+00  5.00E-02  5.00E-02  5.00E-02  5.00E-02  5.00E-02
     DISP=7
       0.00E+00  5.00E-02  5.00E-02  5.00E-02  1.00E+00  1.00E+00
     DISP=10
       0.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00
DEFINE   NI63
       3.66E+04  0.00E+00  0.00E+00  3.00E+03  5.40E+02  0.00E+00
       0.00E+00  1.00E-02  2.00E+00  2.50E+04  2.50E+04
```

```
DEFINE    Y90
       2.67E+00  1.69E-06  0.00E+00  8.20E+03  1.00E+04  0.00E+00
       0.00E+00  1.00E-02  1.00E+00  6.10E+04  7.40E+02
DEFINE  NB95M
       3.61E+00  6.83E-02  9.64E-03  2.20E+03  1.00E+04  0.00E+00
       0.00E+00  1.00E-02  1.00E+00  2.00E+04  5.10E+02
DEFINE  AG110
       2.85E-04  3.06E-02  4.98E-03  5.30E+04  1.10E+04  0.00E+00
       0.00E+00  1.00E-02  1.00E+00  4.42E+05  9.17E+04
DEFINE AG110M
       2.50E+02  2.74E+00  4.50E-01  5.30E+04  1.10E+04  0.00E+00
       0.00E+00  1.00E-02  1.00E+00  4.42E+05  9.17E+04
DEFINE CD113M
       4.96E+03  1.85E-01  0.00E+00  4.20E+05  1.50E+05  0.00E+00
       0.00E+00  1.00E-02  2.00E+00  3.50E+06  1.25E+06
DEFINE SN119M
       2.93E+02  1.15E-02  3.46E-04  5.30E+03  1.20E+03  0.00E+00
       0.00E+00  1.00E-02  1.00E+00  4.42E+04  1.00E+04
DEFINE  SN123
       1.29E+02  6.88E-03  1.14E-03  7.90E+03  7.70E+03  0.00E+00
       0.00E+00  1.00E-02  1.00E+00  6.58E+04  6.42E+04
DEFINE  SB124
       6.02E+01  1.80E+00  3.15E-01  5.50E+03  9.30E+03  0.00E+00
       0.00E+00  1.00E-02  1.00E+00  4.58E+04  7.75E+04
DEFINE PR144M
       5.00E-03  1.27E-02  8.46E-04  4.20E+02  1.10E+02  0.00E+00
       0.00E+00  1.00E-02  1.00E+00  2.70E+02  6.70E-02
DEFINE  PM146
       2.02E+03  7.53E-01  1.20E-01  1.10E+05  3.20E+03  0.00E+00
       0.00E+00  1.00E-02  2.00E+00  9.17E+05  2.67E+04
DEFINE  TB160
       7.23E+01  1.12E+00  1.78E-01  2.20E+04  6.40E+03  0.00E+00
       0.00E+00  1.00E-02  1.00E+00  1.83E+05  5.33E+04
DEFINE   U237
       6.75E+00  1.42E-01  2.13E-02  3.30E+03  2.70E+03  0.00E+00
       0.00E+00  1.00E-02  1.00E+00  9.60E+03  6.50E+02
DEFINE  NP238
       2.12E+00  5.50E-01  9.16E-02  3.10E+04  3.40E+03  0.00E+00
       0.00E+00  1.00E-02  1.00E+00  9.60E+03  1.30E+03
DEFINE  NP239
       2.36E+00  1.72E-01  2.66E-02  2.20E+03  2.90E+03  0.00E+00
       0.00E+00  1.00E-02  1.00E+00  1.50E+04  2.80E+02
DEFINE AM242M
       5.56E+05  5.11E-03  7.54E-05  5.10E+08  4.20E+06  0.00E+00
       0.00E+00  1.00E-02  3.00E+00  2.50E+07  4.40E+06
DEFINE  AM242
       6.68E-01  1.83E-03  2.19E-03  6.10E+04  1.10E+05  0.00E+00
       0.00E+00  1.00E-02  1.00E+00  3.30E+05  2.00E+04
DEFINE  CM242
       1.63E+02  1.83E-03  1.55E-05  1.70E+07  1.10E+05  0.00E+00
       0.00E+00  1.00E-02  1.00E+00  9.80E+07  5.90E+06
DEFINE  CM243
       1.04E+04  1.34E-01  2.02E-02  3.50E+04  2.90E+06  0.00E+00
       0.00E+00  1.00E-02  3.00E+00  1.20E+08  1.10E+07
EOF
ISOTOPES  -1     1      1.00     2.000    1.00    0.00  SPFUEL
         H3GAS  1.23E+01       GRP2  10
          MN54  3.53E+01       GRP4   6
          FE55  8.24E+00       GRP4   6
          CO58  2.84E-01       GRP4   6
          CO60  1.55E+00       GRP4   6
          NI63  3.69E-01       GRP4   6
          KR85  1.08E+02       GRP1  10
          SR89  1.70E-01       GRP4   6
          SR90  7.23E+02       GRP4   6
           Y90  7.24E+02       GRP4   6
           Y91  1.15E+00       GRP4   6
          ZR95  4.88E+00       GRP4   6
          NB95  1.10E+01       GRP4   6
         NB95M  3.62E-02       GRP4   6
          TC99  2.65E-01       GRP4   6
         RU103  2.07E-02       GRP5   6
         RU106  5.35E+03       GRP5   6
         AG110  1.48E-01       GRP4   6
        AG110M  1.12E+01       GRP4   6
        CD113M  1.80E+00       GRP4   6
```

```
          SN119M  1.01E+00      GRP4   6
           SN123  2.41E+00      GRP4   6
           SB124  2.06E-03      GRP4   6
           SB125  3.66E+02      GRP4   6
          TE125M  8.94E+01      GRP4   6
          TE127M  3.52E+00      GRP4   6
           TE127  3.45E+00      GRP4   6
           CS134  4.63E+02      GRP3   7
           CS137  1.91E+03      GRP3   7
           CE144  3.93E+03      GRP4   6
          PR144M  4.07E+01      GRP4   6
           PM146  2.86E-01      GRP4   6
           PM147  3.07E+03      GRP4   6
           SM151  7.71E+01      GRP4   6
           EU152  3.27E-01      GRP4   6
           EU154  4.94E+01      GRP4   6
           EU155  2.37E+02      GRP4   6
           TB160  1.51E-02      GRP4   6
            U237  7.40E-02      GRP4   6
           NP238  1.69E-03      GRP4   6
           NP239  6.68E-02      GRP4   6
           PU238  9.71E+00      GRP4   6
           PU239  9.69E+01      GRP4   6
           PU240  7.23E+01      GRP4   6
           PU241  3.02E+03      GRP4   6
           AM241  1.76E+01      GRP4   6
          AM242M  3.38E-01      GRP4   6
           AM242  3.37E-01      GRP4   6
           AM243  6.67E-02      GRP4   6
           CM242  7.31E+00      GRP4   6
           CM243  5.57E-02      GRP4   6
           CM244  1.65E+00      GRP4   6
DISTKM
        NMODE=1   864.20
PKGSIZ
          SPFUEL      4.50
EOF
EOI
```

7.2 TABLES FOR SODIUM-BONDED METAL ALLOY AND CARBIDE FUEL PINS

TABLE 1. SODIUM-BONDED METAL ALLOY FUEL PIN SOURCE TERM AND HAZARD INDICATOR.

Summary Table for Sodium-Bonded Metal Alloy Fuel Pins after 850 Days Decay (FFTF Metal Fuel Assembly).

		169 Pins Quantity (Ci)	169 Pins Plus Assembly Quantity (Ci)	A2 (Ci)	Qty/A2	Normalized Hazard	ALI Ci	10xALI	Less Than 10xALI	Final Hazard
	NA 22		1.81E-02	8.00E+00	2.26E-03	7.41E-09	6.00E-04	6.00E-03		1.25E-08
	CR 51	6.50E-07	1.60E-06	6.00E+02	2.67E-09	8.74E-15	2.00E-02	2.00E-01	x	
	MN 54	9.52E-01	2.34E+00	2.00E+01	1.17E-01	1.56E-07	9.00E-04	9.00E-03		1.56E-07
	FE 55	9.75E-01	2.41E+00	1.00E+03	2.41E-03	3.20E-09	4.00E-03	4.00E-02		3.20E-09
	CO 58	3.36E-01	6.27E-01	2.00E+01	3.14E-02	5.51E-08	1.00E-03	1.00E-02		5.51E-08
	CO 60	4.03E+00	7.51E+00	7.00E+00	1.07E+00	1.89E-06	2.00E-04	2.00E-03		1.89E-06
	NI 63	8.38E-01	1.56E+00	1.00E+02	1.56E-02	2.75E-08	3.00E-03	3.00E-02		2.75E-08
	NB 92	5.15E-21	1.27E-20	3.00E+00	4.22E-21	1.38E-26	*2.0E-05	2.00E-04	x	
	MO 93	6.62E-03	1.63E-02	1.90E+02	8.58E-05	2.81E-10	5.00E-03	5.00E-02	x	
	KR 85	2.58E+03	2.58E+03	1.00E+03	2.58E+00	8.46E-06	NA			8.46E-06
	SR 89	2.08E+00	2.08E+00	1.00E+01	2.08E-01	6.82E-07	8.00E-04	8.00E-03		6.82E-07
	SR 90	2.11E+04	2.11E+04	4.00E-01	5.29E+04	1.73E-01	2.00E-05	2.00E-04		1.73E-01
	Y 90	2.12E+04	2.12E+04	1.00E+01	2.12E+03	6.94E-03	7.00E-04	7.00E-03		6.94E-03
	Y 91	1.30E+01	1.30E+01	3.00E+01	4.33E-01	1.42E-06	2.00E-04	2.00E-03		1.42E-06
	ZR 95	3.69E+01	3.69E+01	2.00E+01	1.84E+00	6.05E-06	4.00E-04	4.00E-03		6.05E-06
	NB 95	8.28E+01	8.28E+01	2.00E+01	4.14E+00	1.36E-05	1.00E-03	1.00E-02		1.36E-05
	RU103	8.14E-02	8.14E-02	2.50E+01	3.26E-03	1.07E-08	2.00E-03	2.00E-02		1.07E-08
**	RH103M	7.34E-02	7.34E-02	1.00E+03	7.34E-05	2.41E-10	1.00E+00	1.00E+01	x	
	RU106	1.28E+04	1.28E+04	7.00E+00	1.83E+03	6.00E-03	9.00E-05	9.00E-04		6.00E-03
**	RH106	1.28E+04	1.28E+04	3.00E+00	4.27E+03	1.40E-02	4.00E-02*	4.00E-01		1.40E-02
	SB125	3.18E+03	3.18E+03	2.50E+01	1.27E+02	4.17E-04	2.00E-03	2.00E-02		4.17E-04
	TE125M	7.75E+02	7.75E+02	1.00E+02	7.75E+00	2.54E-05	7.00E-04	7.00E-03		2.54E-05
	TE127	1.73E+01	1.73E+01	2.00E+01	8.65E-01	2.83E-06	2.00E-02	2.00E-01		2.83E-06
	TE127M	1.77E+01	1.77E+01	2.00E+01	8.83E-01	2.89E-06	3.00E-04	3.00E-03		2.89E-06
	TE129	1.65E-04	1.65E-04	2.00E+01	8.24E-06	2.70E-11	7.00E-02	7.00E-01	x	
	TE129M	2.53E-04	2.53E-04	1.00E+01	2.53E-05	8.30E-11	6.00E-04	6.00E-03	x	
	I131	9.94E-23	9.94E-23	1.00E+01	9.94E-24	3.26E-29	5.00E-05	5.00E-04	x	
	CS134	1.14E+04	1.14E+04	1.00E+01	1.14E+03	3.72E-03	1.00E-04	1.00E-03		3.72E-03
	CS137	2.45E+04	2.45E+04	1.00E+01	2.45E+03	8.04E-03	2.00E-04	2.00E-03		8.04E-03
	BA140	3.46E-15	3.46E-15	2.00E+01	1.73E-16	5.67E-22	1.00E-03	1.00E-02	x	
	LA140	3.98E-15	3.98E-15	3.00E+01	1.33E-16	4.35E-22	1.00E-03	1.00E-02	x	
	CE141	4.81E-03	4.81E-03	2.50E+01	1.92E-04	6.31E-10	7.00E-04	7.00E-03	x	
	PR143	4.88E-14	4.88E-14	2.00E+01	2.44E-15	8.00E-21	8.00E-04	8.00E-03	x	
	CE144	3.59E+04	3.59E+04	7.00E+00	5.12E+03	1.68E-02	3.00E-05	3.00E-04		1.68E-02
**	PR144	3.59E+04	3.59E+04	3.00E+00	1.20E+04	3.92E-02	1.00E-01	1.00E+00		3.92E-02
	PR144M	4.30E+02	4.30E+02	3.00E+00	1.43E+02	4.70E-04		0.00E+00		4.70E-04
	ND147	8.18E-19	8.18E-19	2.00E+01	4.09E-20	1.34E-25	9.00E-04	9.00E-03	x	
	PM147	3.14E+04	3.14E+04	2.50E+01	1.25E+03	4.11E-03	1.00E-04	1.00E-03		4.11E-03
	PM148M	2.55E-02	2.55E-02	3.00E+00	8.50E-03	2.79E-08	3.00E-04	3.00E-03		2.79E-08
	SM151	5.57E+02	5.57E+02	9.00E+01	6.19E+00	2.03E-05	1.00E-04	1.00E-03		2.03E-05
	EU154	6.50E+02	6.50E+02	1.00E+01	6.50E+01	2.13E-04	2.00E-05	2.00E-04		2.13E-04
	EU155	1.13E+03	1.13E+03	4.00E+02	2.82E+00	9.23E-06	9.00E-05	9.00E-04		9.23E-06
	TA182	1.24E-02	3.05E-02	2.00E+01	1.53E-03	2.04E-09	3.00E-04	3.00E-03		2.04E-09
	W181	8.01E-02	8.01E-02	1.00E+02	8.01E-04	2.62E-09	3.00E-02	3.00E-01	x	
	W185	8.04E-02	8.04E-02	2.50E+01	3.22E-03	1.05E-08	7.00E-03	7.00E-02	x	
	W188	2.22E-03	2.22E-03	5.40E+00	4.11E-04	1.35E-09	1.00E-03	1.00E-02	x	
	RE188	2.24E-03	2.24E-03	1.00E+01	2.24E-04	7.35E-10	3.00E-03	3.00E-02	x	
	U235	1.45E-02	1.45E-02	1.00E+03	1.45E-05	4.75E-11	1.00E-06	1.00E-05		4.75E-11
	U238	1.15E-01	1.15E-01	2.70E-02	4.27E+00	1.40E-05	1.00E-06	1.00E-05		1.40E-05
	U237	1.51E-02	1.51E-02	2.00E-03	7.54E+00	2.47E-05	3.00E-03	3.00E-02	x	
	NP237	1.19E-01	1.19E-01	5.40E-03	2.20E+01	7.20E-05	4.00E-09	4.00E-08		7.20E-05
	NP238	2.00E-04	2.00E-04	2.00E-03	1.00E-01	3.28E-07	6.00E-05	6.00E-04	x	
	NP239	1.48E-03	1.48E-03	2.50E+01	5.91E-05	1.94E-10	2.00E-03	2.00E-02	x	
	PU236	1.18E+00	1.18E+00	1.90E-02	6.20E+01	2.03E-04	4.00E-08	4.00E-07		2.03E-04
	PU237	1.62E-05	1.62E-05	5.40E+02	2.99E-08	9.81E-14	3.00E-03	3.00E-02	x	
	PU238	4.27E+02	4.27E+02	3.00E-03	1.42E+05	4.67E-01	2.00E-08	2.00E-07		4.67E-01

TABLE 1. SODIUM-BONDED METAL ALLOY FUEL PIN SOURCE TERM AND HAZARD INDICATOR.

Summary Table for Sodium-Bonded Metal Alloy Fuel Pins after 850 Days Decay (FFTF Metal Fuel Assembly).

			169 Pins							
		169 Pins	Plus Assembly							
		Quantity	Quantity	A2	Qty/A2	Normalized	ALI	10xALI	Less Than	Final
		(Ci)	(Ci)	(Ci)		Hazard	Ci		10xALI	Hazard
	PU239	1.14E+02	1.14E+02	2.00E-03	5.68E+04	1.86E-01	2.00E-08	2.00E-07		1.86E-01
	PU240	3.18E+01	3.18E+01	2.00E-03	1.59E+04	5.21E-02	2.00E-08	2.00E-07		5.21E-02
	PU241	6.14E+02	6.14E+02	1.00E-01	6.14E+03	2.01E-02	6.00E-07	6.00E-06		2.01E-02
	AM241	3.13E+00	3.13E+00	8.00E-03	3.92E+02	1.28E-03	6.00E-09	6.00E-08		1.28E-03
	CM242	8.94E-01	8.94E-01	2.00E-01	4.47E+00	1.47E-05	3.00E-07	3.00E-06		1.47E-05
	Totals	2.18E+05	2.18E+05		3.05E+05	1.00E+00				1.00E+00
* Based on best available data					Total A2s=	3.05E+05				
** Included in RADTRAN Parent Isotope					Total Ci (100 Pins) =		2.18E+05			

TABLE 2. FINAL SODIUM-BONDED METAL ALLOY FUEL PIN SOURCE TERM.

Summary Table for Sodium-Bonded Metal Alloy Fuel Pins.

		169 Fuel Pins Plus Assembly Quantity (Ci)	100 Fuel Pins Quantity (Ci)	18 Fuel Pins Quantity (Ci)
*/***	NA 22	3.05E-02	1.81E-02	3.31E-03
	MN 54	2.34E+00	5.63E-01	1.01E-01
	FE 55	2.41E+00	5.77E-01	1.04E-01
	CO 58	6.27E-01	1.99E-01	3.58E-02
	CO 60	7.51E+00	2.38E+00	4.29E-01
*	Ni 63	1.56E+00	4.96E-01	8.93E-02
	KR 85	2.58E+03	1.53E+03	2.75E+02
	SR 89	2.08E+00	1.23E+00	2.22E-01
	SR 90	2.11E+04	1.25E+04	2.25E+03
*	Y 90	2.12E+04	1.25E+04	2.25E+03
	Y 91	1.30E+01	7.68E+00	1.38E+00
	ZR 95	3.69E+01	2.18E+01	3.93E+00
	NB 95	8.28E+01	4.90E+01	8.82E+00
	RU 103	8.14E-02	4.82E-02	8.67E-03
**	RH103M	4.34E-02	4.34E-02	7.82E-03
	RU106	1.28E+04	7.57E+03	1.36E+03
**	RH106	1.28E+04	7.57E+03	1.36E+03
	SB125	3.18E+03	1.88E+03	3.38E+02
	TE125M	7.75E+02	4.58E+02	8.25E+01
	TE127	1.73E+01	1.02E+01	1.84E+00
	TE 127M	1.77E+01	1.05E+01	1.89E+00
	CS134	1.14E+04	6.72E+03	1.21E+03
	CS137	2.45E+04	1.45E+04	2.61E+03
	CE144	3.59E+04	2.12E+04	3.82E+03
**	PR144	3.59E+04	2.12E+04	3.82E+03
*	PR144M	4.30E+02	2.55E+02	4.58E+01
	PM147	3.14E+04	1.86E+04	3.34E+03
*	PM148M	2.55E-02	1.51E-02	2.71E-03
	SM151	5.57E+02	3.30E+02	5.94E+01
	EU154	6.50E+02	3.84E+02	6.92E+01
	EU155	1.13E+03	6.66E+02	1.20E+02
*	TA182	3.05E-02	7.35E-03	1.32E-03
	U235	1.45E-02	8.58E-03	1.54E-03
*	U236	1.15E-01	6.82E-02	1.23E-02
	NP237	1.19E-01	7.02E-02	1.26E-02
	PU236	1.18E+00	6.97E-01	1.25E-01
	PU238	4.27E+02	2.53E+02	4.55E+01
	PU239	1.14E+02	6.72E+01	1.21E+01
	PU240	3.18E+01	1.88E+01	3.38E+00
	PU241	6.14E+02	3.63E+02	6.54E+01
	AM241	3.13E+00	1.85E+00	3.34E-01
	CM242	8.94E-01	5.29E-01	9.52E-02
	Totals	2.18E+05	1.29E+05	2.32E+04
*	Not in RADTRAN Library			
**	Included in RADTRAN Parent Isotope			
***	Includes Pin Amount + 200 g			
	Maximum Per Container			

TABLE 3. ISOTOPE DATA FOR SODIUM-BONDED METAL ALLOY FUEL PINS (AUGMENTATION OF RADTRAN 4 LIBRARY).

Update of RADTRAN Library Data for Sodium-Bonded Metal Alloy Pins.

A	B	C	D	E	F	G	H	I	J	K	L
	HALF-LIFE	PHOTON E	CLOUDSHINE	CEDE	CEDE	FOOD TR.	SOIL TR.	DEP. VEL	LUNG	1 YR LUNG	1 YR MARROW
	(DAYS)	(MEV/DIS)	DOSE FACTOR	INHAL.	ING.	FACTOR	FACTOR	(M/SEC)	TYPE	DOSE - INH	DOSE
			(REM-M^3/CI-SEC)	(REM/CI)	(REM/CI)					(REM/CI)	(REM/CI)
NA22	9.50E+02	2.19E+00	3.55E-01	8.0E+03	1.2E+04	0	0	0.01	2	1.1E+04	1.1E+04
NI63	3.66E+04	0.00E+00	0.00E+00	3.0E+03	5.4E+02	0	0	0.01	2	**2.50E+04	**2.50E+04
Y 90	2.67E+00	1.69E-06	0.00E+00	8.2E+03	1.0E+04	0	0	0.01	1	6.1E+04	7.4E+02
PR144M	5.00E-03	1.27E-02	8.46E-04	*4.2E+02	*1.1E+02	0	0	0.01	1	2.7E+02	6.7E-02
PM148M	4.13E+01	1.99E+00	3.23E-01	1.7E+04	7.0E+03	0	0	0.01	1	**1.3E+05	**1.1E+04
TA182	1.15E+02	1.29E+00	2.12E-01	3.7E+04	6.0E+03	0	0	0.01	1	**1.3E+02	**1.1E+03
U236	8.54E+09	1.57E-03	1.92E-05	6.7E+06	2.5E+05	0	0	0.01	3	7.7E+07	6.1E+04
CM242	1.63E+02	1.83E-03	1.55E-05	1.7E+07	1.1E+05	0	0	0.01	1	9.8E+07	5.9E+06
SOURCES:											
B - ICRP 38			I - RADTRAN User's Manual						1 - T1/2 Less Than 1 year		
C - ICRP 38			J - Emission Type						2 - Gamma and Beta		
D - DOE 1988a			K - Dunning 1983						3 - Alpha		
E - DOE 1988b			L - Dunning 1983								
F - DOE 1988b			* Best Available Data								
G - RADTRAN User's Manual			** CEDE/Weighting Factor								
H - RADTRAN User's Manual											

TABLE 4. CARBIDE FUEL PIN SOURCE TERM AND HAZARD INDICATOR.

Summary Table for Carbide Fuel Pins after 850 Days Decay (FFTF Metal Fuel Assembly).

	91 Pins (Ci)	18 Pins (Ci)	A2 (Ci)	Qty/A2	Normalized Hazard	ALI (Ci)	10xALI	Less Than 10xALI	Final Hazard
H3	6.20E+01	1.23E+01	1000	0.01227	9.61E-08	8.00E-02	8.00E-01		9.6126E-08
NA22		5.49E-03	8	0.00069	5.38E-09	6.00E-04	6.00E-03	x	
MN54	1.79E+02	3.53E+01	20	1.76637	1.38E-05	8.00E-04	8.00E-03		1.3836E-05
FE55	4.17E+01	8.24E+00	1000	0.00824	6.46E-08	4.00E-03	4.00E-02		6.4565E-08
CO58	1.44E+00	2.84E-01	20	0.01419	1.11E-07	7.00E-04	7.00E-03		1.1117E-07
CO60	7.85E+00	1.55E+00	7	0.22171	1.74E-06	3.00E-05	3.00E-04		1.7367E-06
NI63	1.87E+00	3.69E-01	100	0.00369	2.89E-08	8.00E-04	8.00E-03		2.8943E-08
KR85	5.47E+02	1.08E+02	1000	0.10824	8.48E-07	NA			8.4785E-07
SR89	8.61E-01	1.70E-01	10	0.01703	1.33E-07	1.00E-04	1.00E-03		1.3341E-07
SR90	3.66E+03	7.23E+02	0.4	1807.91	0.014162	4.00E-06	4.00E-05		0.01416175
Y90	3.66E+03	7.24E+02	10	72.3758	0.000567	6.00E-04	6.00E-03		0.00056693
Y91	5.80E+00	1.15E+00	30	0.03824	3E-07	1.00E-04	1.00E-03		2.995E-07
ZR95	2.47E+01	4.88E+00	20	0.24379	1.91E-06	1.00E-04	1.00E-03		1.9097E-06
NB95	5.54E+01	1.10E+01	20	0.54762	4.29E-06	1.00E-03	1.00E-02		4.2896E-06
NB95M	1.83E-01	3.62E-02	3	0.01206	9.45E-08	2.00E-03	2.00E-02		9.4463E-08
TC99	1.34E+00	2.65E-01	25	0.01059	8.29E-08	7.00E-04	7.00E-03		8.2925E-08
RU103	1.04E-01	2.07E-02	25	0.00083	6.47E-09	6.00E-04	6.00E-03		6.4704E-09
RU106	2.71E+04	5.35E+03	10	535.451	0.004194	1.00E-05	1.00E-04		0.00419429
AG110	7.51E-01	1.48E-01	3	0.0495	3.88E-07	8.00E-03*	8.00E-02		3.8772E-07
AG110M	5.65E+01	1.12E+01	7	1.59513	1.25E-05	9.00E-05	9.00E-04		1.2495E-05
CD113M	9.09E+00	1.80E+00	50	0.03596	2.82E-07	2.00E-06	2.00E-05		2.8165E-07
SN119M	5.08E+00	1.01E+00	100	0.01005	7.87E-08	1.00E-03	1.00E-02		7.8742E-08
SN123	1.22E+01	2.41E+00	3	0.80308	6.29E-06	2.00E-04	2.00E-03		6.2907E-06
SB124	1.04E-02	2.06E-03	5	0.00041	3.22E-09	2.00E-04	2.00E-03		3.2228E-09
SB125	1.85E+03	3.66E+02	25	14.6532	0.000115	5.00E-04	5.00E-03		0.00011478
TE125M	4.52E+02	8.94E+01	100	0.89387	7E-06	4.00E-04	4.00E-03		7.0019E-06
TE127	1.74E+01	3.45E+00	20	0.17229	1.35E-06	2.00E-02	2.00E-01		1.3495E-06
TE127M	1.78E+01	3.52E+00	20	0.17595	1.38E-06	3.00E-04	3.00E-03		1.3782E-06
CS134	2.34E+03	4.63E+02	10	46.2659	0.000362	1.00E-04	1.00E-03		0.00036241
CS137	9.65E+03	1.91E+03	10	190.78	0.001494	2.00E-04	2.00E-03		0.00149442
CE144	1.72E+04	3.39E+03	7	484.898	0.003798	1.00E-05	1.00E-04		0.00379831
PR144M	2.06E+02	4.07E+01	3	13.5758	0.000106	1.00E-01*	1.00E+00		0.00010634
PM146	1.45E+00	2.86E-01	3	0.09547	7.48E-07	4.00E-05	4.00E-04		7.4786E-07
PM147	1.55E+04	3.07E+03	25	122.875	0.000963	1.00E-04	1.00E-03		0.0009625
SM151	3.90E+02	7.71E+01	90	0.85648	6.71E-06	1.00E-04	1.00E-03		6.709E-06
EU152	1.65E+00	3.27E-01	10	0.03272	2.56E-07	2.00E-05	2.00E-04		2.5627E-07
EU154	2.50E+02	4.94E+01	5	9.88615	7.74E-05	2.00E-05	2.00E-04		7.744E-05
EU155	1.20E+03	2.37E+02	60	3.95604	3.1E-05	9.00E-05	9.00E-04		3.0989E-05
TB160	7.63E-02	1.51E-02	10	0.00151	1.18E-08	2.00E-04	2.00E-03		1.1817E-08
U237	3.74E-01	7.40E-02	0.002	36.9989	0.00029	2.00E-03	2.00E-02		0.00028982
NP238	8.56E-03	1.69E-03	0.002	0.8463	6.63E-06	6.00E-05	6.00E-04		6.6292E-06
NP239	3.38E-01	6.68E-02	25	0.00267	2.09E-08	2.00E-03	2.00E-02		2.0917E-08
PU238	4.91E+01	9.71E+00	0.003	3237.36	0.025359	7.00E-09	7.00E-08		0.02535893
PU239	4.90E+02	9.69E+01	0.002	48471.4	0.379687	6.00E-09	6.00E-08		0.3796867
PU240	3.66E+02	7.23E+01	0.002	36168.1	0.283312	6.00E-09	6.00E-08		0.28331244
PU241	1.53E+04	3.02E+03	0.1	30164.8	0.236287	3.00E-07	3.00E-06		0.23628737
AM241	8.90E+01	1.76E+01	0.008	2199.81	0.017232	6.00E-09	6.00E-08		0.01723155
AM242M	1.71E+00	3.38E-01	0.002	169.22	0.001326	6.00E-09	6.00E-08		0.00132553
AM242	1.70E+00	3.37E-01	0.002	168.429	0.001319	8.00E-05	8.00E-04		0.00131934
AM243	3.37E-01	6.67E-02	0.008	8.34231	6.53E-05	6.00E-09	6.00E-08		6.5347E-05
CM242	3.70E+01	7.31E+00	0.2	36.5637	0.000286	3.00E-07	3.00E-06		0.00028641
CM243	2.82E-01	5.57E-02	0.009	6.18901	4.85E-05	9.00E-09	9.00E-08		4.848E-05

TABLE 4. CARBIDE FUEL PIN SOURCE TERM AND HAZARD INDICATOR.

Summary Table for Carbide Fuel Pins after 850 Days Decay (FFTF Metal Fuel Assembly).

	91 Pins (Ci)	18 Pins (Ci)	A2 (Ci)	Qty/A2	Normalized Hazard	ALI (Ci)	10xALI	Less Than 10xALI	Final Hazard
CM244	8.36E+00	1.65E+00	0.01	165.284	0.001295	1.00E-08	1.00E-07		0.0012947
NI59	1.33E-02	2.63E-03	900	2.9E-06	2.29E-11	2.00E-03	2.00E-02	x	
CD115M	1.04E-03	2.05E-04	30	6.8E-06	5.36E-11	5.00E-05	5.00E-04	x	
SB126	2.07E-02	4.08E-03	3	0.00136	1.07E-08	5.00E-04	5.00E-03	x	
CE141	3.78E-03	7.48E-04	25	3E-05	2.34E-10	6.00E-04	6.00E-03	x	
PM148M	1.03E-02	2.03E-03	3	0.00068	5.29E-09	3.00E-04	3.00E-03	x	
CR51	1.86E-07	3.69E-08	600	6.1E-11	4.81E-16	2.00E-02	2.00E-01	x	
FE59	2.80E-05	5.54E-06	10	5.5E-07	4.34E-12	3.00E-04	3.00E-03	x	
PU237	7.31E-06	1.45E-06	0.002	0.00072	5.66E-09	3.00E-03	3.00E-02	x	
PU243	2.92E-11	5.77E-12	0.002	2.9E-09	2.26E-14	4.00E-02	4.00E-01	x	
RB86	1.60E-11	3.16E-12	30	1.1E-13	8.26E-19	8.00E-04	8.00E-03	x	
NB92	1.80E-21	3.55E-22	3	1.2E-22	9.28E-28	2.00E-04*	2.00E-03	x	
RH103M	9.42E-02	1.86E-02	1000	1.9E-05	1.46E-10	1.00E+00	1.00E+01	x	
RH106	2.71E+04	5.35E+03	3	1784.84	0.013981	***			0.01398098
AG109M	3.50E-03	6.93E-04	3	0.00023	1.81E-09	8.00E-03*	8.00E-02	x	
AG111	6.48E-26	1.28E-26	20	6.4E-28	5.02E-33	9.00E-04	9.00E-03	x	
IN115M	7.30E-08	1.44E-08	20	7.2E-10	5.65E-15	4.00E-02	4.00E-01	x	
SN125	5.92E-20	1.17E-20	10	1.2E-21	9.17E-27	4.00E-04	4.00E-03	x	
TE129	1.67E-04	3.31E-05	20	1.7E-06	1.3E-11	6.00E-02	6.00E-01	x	
TE129M	2.57E-04	5.08E-05	10	5.1E-06	3.98E-11	2.00E-04	2.00E-03	x	
I131	9.60E-23	1.90E-23	10	1.9E-24	1.49E-29	5.00E-05	5.00E-04	x	
XE131M	1.81E-18	3.59E-19	10	3.6E-20	2.81E-25	**		x	
CS136	2.91E-16	5.76E-17	7	8.2E-18	6.45E-23	7.00E-04	7.00E-03	x	
BA136M	4.80E-17	9.49E-18	3	3.2E-18	2.48E-23	1.00E-01*	1.00E+00	x	
BA137M	9.12E+03	1.80E+03	3	601.582	0.004712	***			0.00471232
BA140	2.66E-15	5.27E-16	20	2.6E-17	2.06E-22	1.00E-03	1.00E-02	x	
LA140	3.07E-15	6.06E-16	30	2E-17	1.58E-22	1.00E-03	1.00E-02	x	
PR143	3.41E-14	6.75E-15	20	3.4E-16	2.64E-21	7.00E-04	7.00E-03	x	
PR144	1.72E+04	3.39E+03	3	1131.43	0.008863	***			0.00886271
ND147	1.70E-18	3.35E-19	20	1.7E-20	1.31E-25	8.00E-04	8.00E-03	x	
PM148	5.77E-04	1.14E-04	3	3.8E-05	2.98E-10	5.00E-04	5.00E-03	x	
EU156	1.41E-13	2.79E-14	3	9.3E-15	7.3E-20	5.00E-04	5.00E-03	x	
TB161	8.90E-30	1.76E-30	3	5.9E-31	4.6E-36	2.00E-03	2.00E-02	x	
NP240M	1.81E-09	3.59E-10	0.002	1.8E-07	1.4E-12	3.00E-03*	3.00E-02	x	
Totals		3.05E+04		127662	1				0.999999973

*Best available data

**DAC = 4.0E-10 Ci/cm^3

*** Included in RADTRAN Parent Calculations

TABLE 5. FINAL CARBIDE FUEL PIN SOURCE TERM.

Carbide Pin Summary Table.

		18 Pins
	H3	1.23E+01
	MN54	3.53E+01
	FE55	8.24E+00
	CO58	2.84E-01
	CO60	1.55E+00
*	NI63	3.69E-01
	KR85	1.08E+02
	SR89	1.70E-01
	SR90	7.23E+02
*	Y90	7.24E+02
	Y91	1.15E+00
	ZR95	4.88E+00
	NB95	1.10E+01
*	NB95M	3.62E-02
	TC99	2.65E-01
	RU103	2.07E-02
	RU106	5.35E+03
*	AG110	1.48E-01
*	AG110M	1.12E+01
*	CD113M	1.80E+00
*	SN119M	1.01E+00
*	SN123	2.41E+00
*	SB124	2.06E-03
	SB125	3.66E+02
	TE125M	8.94E+01
	TE127	3.45E+00
	TE127M	3.52E+00
	CS134	4.63E+02
	CS137	1.91E+03
	CE144	3.39E+03
*	PR144M	4.07E+01
*	PM146	2.86E-01
	PM147	3.07E+03
	SM151	7.71E+01
	EU152	3.27E-01
	EU154	4.94E+01
	EU155	2.37E+02
*	TB160	1.51E-02
*	U237	7.40E-02
*	NP238	1.69E-03
*	NP239	6.68E-02
	PU238	9.71E+00
	PU239	9.69E+01
	PU240	7.23E+01
	PU241	3.02E+03
	AM241	1.76E+01
*	AM242M	3.38E-01
*	AM242	3.37E-01
	AM243	6.67E-02
*	CM242	7.31E+00

TABLE 5. FINAL CARBIDE FUEL PIN SOURCE TERM.

Carbide Pin Summary Table.

		18 Pins
*	CM243	5.57E-02
	CM244	1.65E+00
***	RH106	5.35E+03
***	BA127M	1.80E+03
***	PR144	3.39E+03
*	Not included in RADTRAN	
	Library	
***	Included in RADTRAN	
	Parent Isotope Calculation	

TABLE 6. ISOTOPE DATA FOR CARBIDE FUEL PINS (AUGMENTATION OF RADTRAN 4 LIBRARY).

Update of RADTRAN Library Data for Carbide Pins.

A	B	C	D	E	F	G	H	I	J	K	L
	HALF-LIFE	PHOTON E	CLOUDSHINE	CEDE	CEDE	FOOD TR.	SOIL TR.	DEP. VEL	LUNG	1 YR LUNG	1 YR MARROW
	(DAYS)	(MEV/DIS)	DOSE FACTOR	INHAL.	ING.	FACTOR	FACTOR	(M/SEC)	TYPE	DOSE - INH	DOSE
			(REM-M^3/CI-SEC)	(REM/CI)	(REM/CI)					(REM/CI)	(REM/CI)
NI63	3.66E+04	0	0.00E+00	3.0E+03	5.4E+02	0	0	0.01	2	**2.50E+04	**2.50E+04
Y90	2.67E+00	1.69E-06	0.00E+00	8.2E+03	1.0E+04	0	0	0.01	1	6.10E+04	7.40E+02
NB95M	3.61E+00	6.83E-02	9.64E-03	2.2E+03	1.0E+04	0	0	0.01	1	2.00E+04	5.10E+02
AG110	2.85E-04	3.06E-02	4.98E-03	5.3E+04	1.1E+04	0	0	0.01	1	**4.42E+05	**9.17E+04
AG110M	2.50E+02	2.74E+00	4.50E-01	5.3E+04	1.1E+04	0	0	0.01	1	**4.42E+05	**9.17E+04
CD113M	4.96E+03	1.85E-01	0.00E+00	4.2E+05	1.5E+05	0	0	0.01	2	**3.50E+06	**1.25E+06
SN119M	2.93E+02	1.15E-02	3.46E-04	5.3E+03	1.2E+03	0	0	0.01	1	**4.42E+04	**1.00E+04
SN123	1.29E+02	6.88E-03	1.14E-03	7.9E+03	7.7E+03	0	0	0.01	1	**6.58E+04	**6.42E+04
SB124	6.02E+01	1.80E+00	3.15E-01	5.5E+03	9.3E+03	0	0	0.01	1	**4.58E+04	**7.75E+04
PR144M	5.00E-03	1.27E-02	8.46E-04	*4.2E+02	*1.1E+02	0	0	0.01	1	2.70E+02	6.70E-02
PM146	2.02E+03	7.53E-01	1.20E-01	1.1E+05	3.2E+03	0	0	0.01	2	**9.17E+05	**2.67E+04
TB160	7.23E+01	1.12E+00	1.78E-01	2.2E+04	6.4E+03	0	0	0.01	1	**1.83E+05	**5.33E+04
U237	6.75E+00	1.42E-01	2.13E-02	3.3E+03	2.7E+03	0	0	0.01	1	9.60E+03	6.50E+02
NP238	2.12E+00	5.50E-01	9.16E-02	3.1E+04	3.4E+03	0	0	0.01	1	9.60E+03	1.30E+03
NP239	2.36E+00	1.72E-01	2.66E-02	2.2E+03	2.9E+03	0	0	0.01	1	1.50E+04	2.80E+02
AM242M	5.56E+05	5.11E-03	7.54E-05	5.1E+08	4.2E+06	0	0	0.01	3	2.50E+07	4.40E+06
AM242	6.68E-01	1.83E-02	2.19E-03	6.1E+04	1.2E+03	0	0	0.01	1	3.30E+05	2.00E+04
CM242	1.63E+02	1.83E-03	1.55E-05	1.7E+07	1.1E+05	0	0	0.01	1	9.80E+07	5.90E+06
CM243	1.04E+04	1.34E-01	2.02E-02	3.5E+04	2.9E+06	0	0	0.01	3	1.20E+08	1.10E+07
SOURCES:											
B - ICRP 38			I - RADTRAN User's Manual						1 - T1/2 Less than 1 year		
C - ICRP 38			J - Emission Type						2 - Gamma and Beta		
D - DOE 1988a			K - Dunning 1983						3 - Alpha		
E - DOE 1988b			L - Dunning 1983								
F - DOE 1988b			* Best Available Data								
G - RADTRAN User's Manual			** CEDE/Weighting Factor								
H - RADTRAN User's Manual											

7.3 TABLE REFERENCES

DOE, 1988a, *External Dose Rate Conversion Factors for Calculation of Dose to the Public*, DOE/EH-0070, U.S. Department of Energy, Washington, D.C.

DOE, 1988b, *Internal Dose Conversion Factors for Calculation of Dose to the Public*, ODE/EH-0071, U.S. Department of Energy, Washington, D.C.

Dunning, D. D., 1983, *Estimates of Internal Dose Equivalent from Inhalation and Ingestion of Selected Radionuclides*, WIPP/DOE-176, U.S. Department of Energy, Washington, D.C.

ICRP, 1983, *Radionuclide Transformation, Energy, and Intensity of Emissions*, ICRP Publication 38, Pergammon Press, Oxford.

Neuhauser, K. S., and F. L. Kanipe, 1992, *RADTRAN 4: Volume 4 -- User Guide*, SAND89-2370, Sandia National Laboratories, Albuquerque, New Mexico.

7.4 INTERNAL MEMOS

7.4.1 Sodium-22 Radioactivity for FFTF Sodium-Bonded Assemblies

Westinghouse Hanford Company — **Internal Memo**

From: Criticality and Radiological Analyses — KDD-8D150-94-003
Phone: 376-9415 N2-32
Date: August 10, 1994
Subject: SODIUM-22 RADIOACTIVITY FOR FFTF SODIUM-BONDED ASSEMBLIES

To: J. R. Green G2-02

cc:

R. A. Burk	N2-01	T. M. Burke	N2-01
J. W. Daughtry	H4-64	J. G. Field	G2-02
J. Geenborg	HO-35	R. K. Hulvey	N2-33
D. C. Johnston	N2-02	S. F. Kessler	N2-32
E. F. Loika	N2-51	J. C. Midgett	N2-51
J. V. Nelson	H4-64	R. F. Richard	H4-64
R. A. Schwarz	HO-35	J. R. Vincent	N2-33
J. B. Waldo	N2-57	W. V. Witherspoon	N2-33
KDD File/LB			

Reference: ORIGEN2 Isotope Generation and Depletion Code, CCC-371, Oak Ridge National Laboratory, Oak Ridge, TN, December 1985.

In response to your request, I am providing you the activity of sodium-22 for both sodium inside the pins and coolant that may cling to the outside of sodium-bonded FFTF test assemblies, MFF-1, MFF-1A, MFF-2, MFF-3, MFF-4, MFF-5, MFF-6, IFR-1, and ACN-1. Activation and decay of sodium-22 in the bond were calculated with the ORIGEN2 nuclide transmutation computer program (Reference). A sodium bond was placed inside these test assemblies to provide good heat transfer from the fuel to the cladding. Activity for the coolant sodium that may cling to the exterior of the pins was estimated by decaying the February 1993 FFTF coolant sodium laboratory test results. The activities of the sodium bond and coolant are different because the coolant spends only a fraction of the time during reactor operation in a significant neutron flux region.

A conservative set of assumptions was selected for the purpose of analyzing the safety of shipment of pins from these assemblies. It was assumed that the sodium in the pins was located at the midplane of the core, even though much of the sodium bond is displaced away from core center during fuel restructuring. It was assumed that these pins were located in the highest total neutron flux in the reactor (5.5×10^{15} neutrons per square centimeter per second) for 291 MW reactor operation and exposed for 853 equivalent full power days (EFPD). Test assembly, ACN-1 was irradiated at 400 MW reactor power but discharged in June of 1985. Its subsequent decay drops its sodium-22 level below that of the other tests irradiated at a later date. It was assumed that the exposure was continuous and ended on the last day of FFTF operation, March 19, 1992. Neutron cross sections were selected from those labeled "FFTF Pu/U" in Table 4.4 of the Reference. The resultant activity was decayed for 850 days to be consistent with other nuclide activities you are using for your safety analysis.

Given the above assumptions, the resultant sodium-22 activity of 2×10^{-5} Curies per gram of sodium bond was computed. For the coolant sodium, 300 Area Radiochemistry Laboratory analysis (Laboratory Serial Number 93-04987, attached) measured a sodium-22 activity of 5.2×10^{-7} Curies per gram of coolant sodium in February of 1993. When decayed with a half life of 2.6 years to July, 1994 (850 days after FFTF shutdown), this activity drops to 3.6×10^{-7} Curies per gram of sodium coolant.

K D Dobbin

K. D. Dobbin
Senior Principal Engineer

Reviewed by:
S. F. Kessler
Senior Engineer

siw

Concurrence:
J. W. Daughtry, Manager
Criticality and Radiological Analyses

Attachment

SAMPLE IDENTIFICATION	Number C-PR1-64	ALKALI METAL ANALYSIS	Lab Serial No. 93-04987
	Source FFTF		
	Time		Date Received 2/93
	Date 2/93		

Sample Submitter	MSIN	Phone		Work Order
Tom Thoelke	N2-04	6-4776	Na ☒ NaK ☐ Li ☐	

Special Instructions: PRIMARY Sodium

	ANALYSIS	RESULT*
☐	Oxygen	
☐	Hydrogen	
☐	Carbon	
☐	Nitrogen	
☐	Sodium	
☒	Plutonium	Included with total Alpha
☐	Particulates	
☒	Aluminum	0.2
☐	Barium	<.02
☐	Bismuth	<.2
☐	Boron	<.04
☐	Cadmium	<.01
☒	Calcium	0.3
☐	Cesium	—
☐	Chlorine	~~<.02~~ RFK
☒	Chromium	0.4
☐	Cobalt	<.02
☒	Copper	0.03
☐	Fluorine	—
☐	Gold	—
☒	Iron	2.9

	ANALYSIS	RESULT*
☒	Lead	0.06
☐	Lithium	0.1
☒	Magnesium	0.7
☒	Manganese	0.4
☐	Molybdenum	<.04
☒	Nickel	0.25
☐	Phosphorus	—
☐	Potassium	—
☐	Rubidium	—
☒	Silicon	0.1
☐	Silver	<.02
☐	Strontium	<.01
☐	Sulfur	—
☐	Tin	5.
☐	Titanium	0.04
☐	Uranium	< 2.
☐	Vanadium	<.02
☐	Zinc	—
☒	Tritium	1.6×10^{-7} Ci/gm
☐	Gamma Spectrometry	Na-22 = 5.2×10^{-7} Ci/gm
☐		Cs-137 = $<1 \times 10^{-10}$ Ci/gm
☐		
☒	total Alpha	1.2×10^{-12} Ci/gm

Analyst's Remarks: Pu too Low to isolate from other possible alpha emitters

No other Gamma Emitters Detected

Sample Cups were only ~ 60% filled.

...ported By		Date Completed
R. Keough	SJ Bos 3/25/93	3/23/93

*Unless otherwise indicated, all results are expressed in P PM.

Distribution: White - Final Report
Canary - Laboratory Logbook
Pink - Originator

BC-7340-032 (01/93)

7.4.2 Historical Dose Readings from T-3 Fuel Shipments to Idaho

Westinghouse Hanford Company | **Internal Memo**

From: FFTF Shutdown Project Office 18310-DLN-012
Phone: 376-9809 N2-53
Date: August 9, 1994
Subject: HISTORICAL DOSE READINGS FROM T-3 FUEL SHIPMENTS TO IDAHO

To: J. R. Green G2-02

cc: J. G. Field G2-02
S. Guttenberg N2-53
M. T. Jansky H6-26
D. C. Johnston N2-02
D. H. Jones N2-53
DLN File/LB

Attached are a random sampling of shipping records from fuel shipments to Idaho in the T-3 casks to support the RADTRAN analysis you are conducting for the FFTF Shutdown Environmental Assessment. If you need further assistance, please call me.

D. L. Nielsen
Senior Engineer

ejt

Attachment 1

00706

SHIPPING INST.

Company: [illegible] National Lab.
Address: PO Box 2528
City, State, Zip: Idaho Falls ID. 83403-2528
Attention: D.R. Garcia (208) 533-7726

– EXTERIOR INSPECTION PERMITTED –

Contractor: ☐ PNL ☐ KEH ☒ WHC
Site Caller: [illegible]
PR No. 647832 Veh No. [illegible]

Ship: ☒ Prepaid ☐ Collect Via:
☒ Motor-Rail ☐ Air Psgr.
☒ Excl. Use ☐ Air Cargo
☐ DOE Veh. ☐ Mail
☐ UPS Sur. ☐

SHIPMENT DESCRIPTION

Proper Shipping Name Radioactive Material,		UN Number
1. Empty Packages	☐	UN 2908
2. Low Specific Activity, n.o.s	☐	UN 2912
3. Limited quantity, n.o.s.	☐	UN 2910
4. N.O.S.	☐	UN 2982
5. Fissile n.o.s. RQ	☒	UN 2918
6. Special Form, n.o.s.	☐	UN 2974
7. Instruments & Articles	☐	UN 2911
8. Dangerous When wet	☐	

Material Form: ☐ Special (A1) ☒ Normal (A2)

Labels Applied: ☐ Empty ☐ Radioactive LSA ☐ White I ☐ Yellow II ☒ Yellow III ☐ None ☐ Danger (Air Cargo) ☒ Secondary [illegible]

Material Category: ☐ Empty ☐ Low Specific Act (LSA) ☐ Limited Quantity ☐ Type A Quantity ☐ Type B Quantity ☒ Highway Route ☒ Controlled Quantity

For Normal Form: Physical Form: ☒ Solid ☐ Liquid ☐ Gas; Chemical Form: ☐ Metal ☒ Oxide ☐ Elemental ☐ Nitrate; Other ______

TYPE PACKAGE	CONSTRUCTION
☐ Strong Tight	☐ Box, FB
☐ Type A	☐ Wood
☐ Type B	☒ Steel
☐ Type B (U)	☐ Drum
☒ Type B (M)	☒ Cask
	☐ Other ______

FISSILE CLASS: ☐ Non Fissile ☐ Fissile Exempt ☐ Fissile I ☐ Fissile II ☒ Fissile III; Grams Fissile 1189

SNM: ☐ No ☒ Yes; ☐ Category I ☐ Category II ☐ Category III ☐ Category IV ☒ Category IV

ACCOUNTABILITY/SECURITY CONTROL: ☐ Classified ☒ Unclassified
Consignee authorized to receive this qty ☒ NA ☐
Sig. Security Svc Reqd. ☒
Pu, EU > 1 g ☒ NU, DU > 1 Kg ☐
Security Escorts Req. ☐ Not. Req. ☒
External Cask Temperature N/A ☐ (Max. 122° F (1980° F ES. Use) ______ °F

Packaging conforms to appropriate packaging procedure ☐ N/A ☒ Yes
Complies with D.O.T. packaging and labeling requirements ☐ N/A ☒ Yes
Container acceptability documented (incl. 7A cert.) ☐ N/A ☒ Yes
Container examined. No evidence of deterioration or damage ☒ Yes
QA Inspection Current ☒ Yes ☐ N/A Seals required ☐ No ☒ Yes
Shipping Doc. [illegible] Authorization No. 174-709-4-1 HBB-[illegible]

No. Pkgs.	Model Package	COC/Spec. No.	Serial No.	Seal No.	Isotopes	Curies/Pkg	Watts	Gross Weight
1	Type B	USA/9132/B(M)	# 2	WHC 52[illegible]	[illegible] 239	8,550	50	43,000#
	T-3 cask	F (DOE)		WHC 5[illegible]	[illegible] Mn 54			

☒ WARNING – FISSILE CLASS III SHIPMENT PERSONNEL HANDLING AND STOWING THIS SHIPMENT MUST BE ADVISED TO NOT LOAD MORE THAN 1 PACKAGE PER VEHICLE. IN ANY LOADING OR STOWAGE AREA THIS SHIPMENT MUST BE SEGREGATED BY AT LEAST 20 FEET FROM OTHER PACKAGES BEARING RADIOACTIVE LABELS.

(Packager may describe package in detail on plain unlined lines above) TOTAL 8,550 | 50 | 43,000#

Originator's Signature [signature] Date [illegible] Organization [illegible] Complete Cost Code (Inc. end function) 18510 174-709-4-1

AREA RADIATION MONITORING

Surface Dose Rate of Package ☐ <0.5 or 6 mrem/hr (N + B γ)
Dose Rate at 1 Meter from Surface of Package ☒ <0.5 or ___ mrem/hr (N + B γ)
Smears of Outer Container ☒ <220 or ____ dpm B γ/cm² ☒ <22 or ____ dpm B γ/cm²
TRUCK LOAD OR EXCLUSIVE USE: Surface: ☐ < 200 or ___ mrem/hr (N + B γ); @ 6 feet: ☐ < 10 or ___ mrem/hr (N + B γ); @ Cab or Sleeper ☐ < 2.0 or ___ mrem/hr (N + B γ)
Additional Data and Instructions (Inc. Readings on Internal Packaging) NONE
Signature Radiation Monitoring [signature] Bldg. 4717 4621 [illegible] Survey No. X-R-005 Date 11-16-92

AUTHORIZATION FOR SHIPMENT AND CERTIFICATION

AIR TRANSPORT CERTIFICATION: Cargo Only ☐ Danger Labels Applied; Passenger ☐ 1. Ltd. Qty. ☐ 2. < 3 T.I. ☐ 3. Research or Medical Diagnosis ☐ 4. Human Medical Research; Pkg. Dimensions

This is to certify that the above named materials are properly classified, described, packaged, marked and labeled, and are in proper condition for transportation according to the applicable federal, state, local and international regulations for the transportation of hazardous materials.

Authorized Signature [signature] Printed Name James H. Eide Date 11/15/92

APPROVED FOR OFFSITE SHIPMENT

B.L. No. | Date Shipped | E.T.A. | Routing ☐ N/A | Placards ☒ Yes ☐ No
Surveyed By | Date | Approved for Shipment Westinghouse Hanford Company | Date | Route Plan ☒ Yes ☐ No

GPO 1988-594-677 54-6000-172 (04/88)

POOR COPY RECEIVED DOCUMENT PROCESSING

OFFSITE RADIOACTIVE SHIPMENT RECORD

EXTERIOR INSPECTION PERMITTED

11260

SHIPPING INST.

Ship To:
Company: Argonne National Lab
Address: PO Box 2528
City, State/Zip: Idaho Falls, ID 83403-2528
Attention: DR Garcia 208-533-7226

Contractor: ☐ PNL ☐ KEH ☒ WHC
Site Carrier: [illegible]
PR No. [illegible] Veh. No. [illegible]

Ship: ☒ Prepaid ☐ Collect Via:
☒ Motor Rail ☐ Air Frgt.
☒ Excl. Use ☐ Air Cargo
☐ DOE Veh. ☐ Mail
☐ UPS Sur. ☐

SHIPMENT DESCRIPTION AND CERTIFICATION

Proper Shipping Name — UN Number
Radioactive Material,
1. Empty Packages ☐ UN 2908
2. Low Specific Activity, n.o.s. ☐ UN 2912
3. Limited quantity, n.o.s. ☐ UN 2910
4. N.O.S. RQ ☒ UN 2982
5. Fissile n.o.s. ☐ UN 2918
6. Special Form, n.o.s. ☐ UN 2974
7. Instruments & Articles ☐ UN 2911
8. ☐

Material Form: ☐ Special (A1) ☒ Normal (A2)

Labels Applied: ☐ Empty ☐ Radioactive LSA ☐ White I ☒ Yellow II ☐ Yellow III ☐ None ☐ Danger (Air Cargo) ☐ Secondary

Material Category: ☐ Empty ☐ Low Specific Act (LSA) ☐ Limited Quantity ☐ Type A Quantity ☒ Type B Quantity ☐ Highway Route Controlled Quantity

For Normal Form Identity:
Physical Form: ☒ Solid ☐ Liquid ☐ Gas
Chemical Form: ☐ Metal ☐ Oxide ☒ Elemental ☐ Nitrate ☐ Other

TYPE PACKAGE: ☐ Strong Tight ☐ Type A ☐ Type B ☐ Type B (U) ☒ Type B (M)

CONSTRUCTION: ☐ Box, FB ☐ Wood ☒ Steel ☐ Drum ☒ Cask ☐ Other

FISSILE CLASS: ☒ Non Fissile ☐ Fissile Exempt ☐ Fissile I ☐ Fissile II ☐ Fissile III
Grams Fissile

SNM: ☒ No ☐ Yes ☐ <1 gr ☐ Category I ☐ Category II ☐ Category III

ACCOUNTABILITY/SECURITY CONTROL: ☐ Classified ☒ Unclassified
Consignee authorized to receive this qty ☒
Sig. Security Svc. Req. ☐ NA ☒
[illegible] N/A ☐
Security Escorts Req. ☐ Not Req. ☒
External Cask Temperature N/A ☒
(Max. 122° F LTL, 180° F Ex. Use) < 180 °F

Packaging conforms to appropriate packaging procedure: ☐ N/A ☒ Yes
Complies with D.O.T. packaging marking and labeling requirements: ☐ N/A ☒ Yes
Container acceptability documented (incl. 7A cert): ☐ N/A ☒ Yes

Container examined: No evidence of deterioration or damage ☒ Yes
QA Inspection Current ☒ Yes ☐ N/A Seals required ☐ No ☒ Yes
Shipping Doc. 49 CFR Authorization No. N/A

No. Pkgs.	Model Package	COC/Spec. No.	Serial No.	Seal No.	Isotopes	Curies/Pkg.	T.I.	Gr. Wt.
1	TYPE B	USA/9132/B(M)F	001	52151/52152	Mn54 Ta182 Cr51 Co60 Co58 Fe59	3,675	0.1	43,000

(Shipper may describe package in detail on one of unused lines above) TOTAL: 3,675 0.1 43,000

This is to certify that the above named materials are properly classified, described, packaged, marked and labeled, and are in proper condition for transportation, according to the applicable federal, state, local and international regulations for the transportation of hazardous materials.

Certifier's Signature [signature] Date 9-24-92 Organization [illegible] Complete Cost Code (inc. end function) E04581

AREA MONITOR

Surface Dose Rate of Package: ☐ ≤0.5 or 1.0 mrem/hr (N + βγ)
Dose Rate at 1 Meter from Surface of Package: ☒ ≤0.5 or ___ mrem/hr (N + βγ)
Smears of Outer Container: ☒ ≤22 dpm βγ/cm² ☒ ≤2.2 dpm α/cm²
TRUCK LOAD OR EXCLUSIVE USE: Surface: ☒ ≤ 200 mrem/hr (N + βγ); @ 6 feet: ☒ ≤ 10 mrem/hr (N + βγ); @ Cab: ☒ ≤ 2.0 mrem/hr (N + βγ) of Sleeper

Additional Data and Instructions (Inc. Readings on Internal Packaging): NONE

Signature - Radiation Monitoring [signature] Bldg. FFTF Survey No. X-R-005 Date 9-24-92

AUTHORIZATION FOR SHIPMENT

APPROVAL

AIR TRANSPORT CERTIFICATION | Cargo Only: ☐ Danger Labels Applied | Passenger: ☐ 1. Ltd. Qty. ☐ 3. Research or Medical Diagnosis ☐ 2. ≤3 T.I. ☐ 4. Human Medical Research | Pkg. Dimensions

Traffic has inspected and verified preshipment compliance to DOT regulations.
Authorized Signature [signature] Printed Name Greg O'Bones Date 9/29/92

APPROVED FOR OFFSITE SHIPMENT

TRAFFIC

B.L. No. | Date Shipped | E.T.A. | Routing ☐ N/A | Placards ☐ Yes ☒ No
Surveyed By | Date | Approved for Shipment Westinghouse Hanford Company | Date | Route Plan ☐ Yes ☒ No

*U.S. GPO: 1991-691-114/40068 — 54-6000-088 (10/88)

EMERGENCY Contact #(509) 373-38[illegible]

OFFSITE RADIOACTIVE SHIPMENT RECORD
– EXTERIOR INSPECTION PERMITTED –

12223

SHIPPING INST.

Company: Argonne Nat'l Lab.
Address: PO Box 2528
City, State, Zip: Idaho Falls, ID 83403-2528
Attention: W P Kenney

Contractor: ☐ PNL ☐ KEH ☒ WHC
Site Carrier: W.L. VANDERBURG
PR No. 95159 Veh. No. 4394

Ship: ☒ Prepaid ☐ Collect Via:
☒ Motor/Rail ☐ Air Ptgr.
☒ Excl. Use ☐ Air Cargo
☐ DOE Veh. ☐ Mail
☐ UPS Sur. ☐ _____

SHIPMENT DESCRIPTION AND CERTIFICATION

Proper Shipping Name — UN Number
Radioactive Material,

1. Empty Packages	☐	UN 2908
2. Low Specific Activity, n.o.s	☒	UN 2912
3. Limited quantity, n.o.s.	☐	UN 2910
4. N.O.S. RQ	☒	UN 2982
5. Fissile n.o.s.	☐	UN 2918
6. Special Form, n.o.s.	☐	UN 2974
7. Instruments & Articles	☐	UN 2911
8. _____	☐	_____

Material Form: ☐ Special (A1) ☒ Normal (A2)

Labels Applied: ☐ Empty ☐ Radioactive LSA ☐ White I ☐ Yellow II ☒ Yellow III ☐ None ☐ Danger (Air Cargo) ☐ Secondary _____

Material Category: ☐ Empty ☐ Low Specific Act. (LSA) ☐ Limited Quantity ☐ Type A Quantity ☒ Type B Quantity ☐ Highway Route Controlled Quantity

For Normal Form Identify:
Physical Form: ☒ Solid ☐ Liquid ☐ Gas
Chemical Form: ☐ Metal ☐ Oxide ☒ Elemental ☐ Nitrate
Other _____

TYPE PACKAGE: ☐ Strong Tight ☐ Type A ☐ Type B ☐ Type B (U) ☒ Type B (M)

CONSTRUCTION: ☐ Box, FB ☐ Wood ☒ Steel ☐ Drum ☒ Cask ☐ Other _____

FISSILE CLASS: ☒ Non Fissile ☐ Fissile Exempt ☐ Fissile I ☐ Fissile II ☐ Fissile III
Grams Fissile _____

SNM: ☒ No ☐ Yes ☐ < 1 gr ☐ Category I ☐ Category II ☐ Category III

ACCOUNTABILITY/SECURITY CONTROL: ☐ Classified ☒ Unclassified
Consignee authorized to receive this qty ☒
Sig. Security Svc. Req. ☐ NA ☒
Pu, EU > 1 g ☐ NA NU, DU > 1 Kg ☐
Security Escorts Req. ☐ Not. Req. ☒
External Cask Temperature N/A ☐
(Max. 122°F LTL, 180°F Ex. Use) < 110 °F

Packaging conforms to appropriate packaging procedure ☐ N/A ☒ Yes
Complies with D. O. T. packaging marking and labeling requirements ☐ N/A ☒ Yes
Container acceptability documented (Incl. 7A cert.) ☐ N/A ☒ Yes

Container examined: No evidence of deterioration or damage ☒ Yes
QA Inspection Current ☒ Yes ☐ N/A Seals required ☐ No ☒ Yes
Shipping Doc. 49CFR Authorization No. _____

No. Pkgs.	Model Package	COC/Spec. No.	Serial No.	Seal No.	Isotopes	Curies/Pkg	T. I.	Gr. Wt.
1	T-3	USA/9122/B(M)F	#2	49786	Co60, Al, SS, Zn, W	18,636	1.2	43000
				49787				
(Shipper may describe package in detail on one of unused lines above)					TOTAL	18,636	1.2	43000

This is to certify that the above named materials are properly classified, described, packaged, marked and labeled, and are in proper condition for transportation, according to the applicable federal, state, local and international regulations for the transportation of hazardous materials.

Certifier's Signature	Date	Organization	Complete Cost Code (Inc. and function)
[signature]	8-5-91	FFTF Refueling	B311 – 18510

AREA MONITOR

Surface Dose Rate of Package: ☐ ≤0.5 or 15 mrem/hr (N + βγ)
Dose Rate at 1 Meter from Surface of Package: ☐ ≤0.5 or ___ mrem/hr (N + βγ)
Smears of Outer Container: ☒ ≤22 dpm βγ/cm² ☒ ≤2.2 dpm α/cm²
TRUCK LOAD OR EXCLUSIVE USE: Surface: ☒ ≤ 200 mrem/hr (N + βγ); @ 6 feet: ☒ ≤ 10 mrem/hr (N + βγ); @ Cab or Sleeper ☐ ≤ 2.0 mrem/hr (N + βγ)

Additional Data and Instructions (Inc. Readings on Internal Packaging)

Signature - Radiation Monitoring		Bldg.	Survey No.	Date
[signature]		FFTF	34101	8-5-91

APPROVAL

AUTHORIZATION FOR SHIPMENT

AIR TRANSPORT CERTIFICATION ▸ | Cargo Only: ☐ Danger Labels Applied | Passenger: ☐ 1. Ltd. Qty. ☐ 3. Research or Medical Diagnosis ☐ 2. ≤ 3 T. I. ☐ 4. Human Medical Research | Pkg. Dimensions

Traffic has inspected and verified preshipment compliance to DOT regulations.

Authorized Signature ▸ [signature] Printed Name ▸ Greg O Brown Date ▸ 8-5-91

APPROVED FOR OFFSITE SHIPMENT

TRAFFIC

B. L. No.	Date Shipped	E. T. A.	Routing	☐ N/A	Placards
	8/5/91		TRI state		☒ Yes ☐ No
Surveyed By	Date	Approved for Shipment Westinghouse Hanford Company		Date	Route Plan ☐ Yes ☒ No

Emergency Contact # 911

A.U.S. GOVERNMENT PRINTING OFFICE: 1991—592-378/40007

54-6000-008 (10/88)

SHIPPING INST.

Company [illegible]
Address P.O. Box 2528
City, State, Zip Idaho Falls ID 83403-2528
Attention G.R. Garcia

EXTERIOR INSPECTION PERMITTED 00689

Contractor: ☐ PNL ☐ KEH ☒ WHC

Shipping: ☒ Prepaid ☐ Collect
☒ Motor-Rail ☐ Air Frgt.
☒ Excl. Use ☐ All Cargo
☒ DOE Van ☐ Mail
☐ UPS

Site Carrier
PR No. Veh. No.

SHIPMENT DESCRIPTION

Proper Shipping Name — Radioactive Material, | UN Number
1. Empty Packages ☐ UN 2908
2. Low Specific Activity, n.o.s. ☐ UN 2912
3. Limited quantity, n.o.s. ☐ UN 2910
4. N.O.S. ☐ UN 2982
5. Fissile n.o.s. RQ ☒ UN 2918
6. Special Form, n.o.s. ☐ UN 2974
7. Instruments & Articles ☐ UN 2911
8. ☐

Material Form: ☐ Special (A1) ☒ Normal (A2)

Labels Applied: ☐ Empty ☐ Radioactive LSA ☐ White I ☐ Yellow II ☒ Yellow III ☐ None ☐ Danger (Air Cargo) ☐ Secondary

Material Category: ☐ Empty ☐ Low Specific Act. (LSA) ☐ Limited Quantity ☐ Type A Quantity ☐ Type B Quantity ☒ Highway Route Controlled Quantity

Physical Form: ☒ Solid ☐ Liquid ☐ Gas
Chemical Form: ☐ Metal ☒ Oxide ☐ Element ☐ Nitrate
Other

TYPE PACKAGE: ☐ Strong Tight ☐ Type A ☐ Type B ☐ Type B (U) ☒ Type B (M)

CONSTRUCTION: ☐ Box, FB ☐ Wood ☒ Steel ☐ Drum ☒ Cask ☐ Other

FISSILE CLASS: ☐ Non Fissile ☐ Fissile Exempt ☐ Fissile I ☐ Fissile II ☒ Fissile III
Grams Fissile 726.75

SNM: ☐ No ☒ Yes ☐ < 1 g ☐ Category I ☐ Category II ☐ Category III ☒ Category IV

ACCOUNTABILITY/SECURITY CONTROL: ☐ Classified ☒ Unclassified
Consignee authorized to receive this qty. ☒
Sig. Security Rec. Req. ☒ NA ☐
Pu, EU > 1 g ☒ Nu, DU > 1 kg ☐
Security Escorts Req. ☐ Not. Req. ☒
External Cask Temperature N/A ☐
(Max 122°F (Max 180°F ES Use)) < 180 °F

Packaging conforms to appropriate packaging procedure ☐ N/A ☒ Yes
Complies with D.O.T. packaging and labelling requirements ☐ N/A ☒ Yes
Container acceptability documented (incl. 7A cert.) ☐ N/A ☒ Yes

Container examined. No evidence of deterioration or damage ☒ Yes
QA Inspection Current ☒ Yes ☐ N/A Seals required ☐ No ☒ Yes
Shipping Doc. 49 CFR Authorization No. WHC-C2C-21

No. Pkg.	Model Package	COC/Spec. No.	Serial No.	Seal No.	Isotopes	Curies/Pkg.	TI	Gross Weight
1	TYPE B	USA/9132/B(M)F	#2	50766	Mixed Oxide 237	30696	50	43000
	7-3			788	Pu/U 235			
	"WARNING — FISSILE CLASS III SHIPMENT. DO NOT LOAD MORE THAN (1) PACKAGES PER VEHICLE."				238 Am 54			
(Packager may describe package in detail on one of unused lines above)					TOTAL	30696	50	43,000

Originator Signature | Date | Organization | Complete Cost Code (inc. and function) 185101 E 04581

AREA RADIATION MONITORING

Surface Dose Rate of Package ☐ < 0.5 or 5 mrem/hr (N + β) | Dose Rate at 1 Meter from Surface of Package ☐ < 0.5 or 17 mrem/hr (N + β) | Smears of outer Container ☐ < 22 or dpm β γ/cm² ☐ < 22 α or dpm α/cm²

TRUCK LOAD OR EXCLUSIVE USE: Surface ☒ ≤ 200 or mrem/hr (N + β γ)
@ 6 feet ☒ ≤ 10 or mrem/hr (N + β γ)
@ Cab ☐ ≤ 2.0 or mrem/hr (N + β γ) of Sleeper

Additional Data and Instructions (Incl. Readings on Internal Packaging) N/A

Signature of Radiation Monitor | Bldg. | Survey No. | Date 8/24/92

AUTHORIZATION FOR SHIPMENT AND CERTIFICATION

Air Transport Certification | Cargo Only ☐ Danger Labels Applied | Passenger ☐ 1. Ltd. Qty. ☐ 2. < 3.7 ☐ 3. Research or Medical Diagnosis ☐ 4. Human Medical Research | Pkg. Dimensions

This is to certify that the above named materials are properly classified, described, packaged, marked and labelled, and are in proper condition for transportation according to the applicable federal, state, local and international regulations for the transportation of hazardous materials.

Authorized Signature | Printed Name Greg O. Bones | Date 8/24/92

APPROVED FOR OFFSITE SHIPMENT

B/L No. RNW 7836 | Date Shipped | E.T.A. | Routing ☐ N/A | Placards ☒ Yes ☐ No
Surveyed By | Date | Approved for Shipment Westinghouse Hanford Company | Date | Route Plan ☒ Yes ☐ No

GPO 1988-594-677 54-6000-172 (04/88)

OFFSITE RADIOACTIVE SHIPMENT RECORD — EXTERIOR INSPECTION PERMITTED — 00945

SHIPPING INST.

Company: Argonne Natl. Lab.
Address: PO Box 2528
City, State, Zip: Idaho Falls, ID 83403
Attention: W.P. Kenney

Contractor: ☐ PNL ☐ KEH ☒ WHC
Site Carrier: J.L. Butts
PR No. 62998 Veh. No. 110-6...

Ship: ☒ Prepaid ☐ Collect Via: ☒ Motor-Rail ☐ Air Frgt. ☒ Excl. Use ☐ Air Cargo ☐ DOE Veh. ☐ Mail ☒ UPS Sur. ☐

SHIPMENT DESCRIPTION

Proper Shipping Name — UN Number
Radioactive Material,
1. Empty Packages ☐ UN 2908
2. Low Specific Activity, n.o.s. ☐ UN 2912
3. Limited quantity, n.o.s. ☐ UN 2910
4. N.O.S. ☐ UN 2982
5. Fissile n.o.s. RG ☒ UN 2918
6. Special Form, n.o.s. ☐ UN 2974
7. Instruments & Articles ☐ UN 2911
8. ☐

Material Form: ☐ Special (A1) ☒ Normal (A2)

Labels Applied: ☐ Empty ☐ Radioactive LSA ☐ White I ☐ Yellow II ☒ Yellow III ☐ None ☐ Danger (Air Cargo) ☐ Secondary

Material Category: ☐ Empty ☐ Low Specific Act. (LSA) ☐ Limited Quantity ☐ Type A Quantity ☐ Type B Quantity ☒ Highway Route ☒ Controlled Quantity

For Normal Form: Physical Form: ☒ Solid ☐ Liquid ☐ Gas; Chemical Form: ☐ Metal ☒ Oxide ☐ Element ☐ Nitrate; Other

TYPE PACKAGE: ☐ Strong Tight ☐ Type A ☐ Type B ☐ Type B (U) ☒ Type B (M)

CONSTRUCTION: ☐ Box, FB ☐ Wood ☒ Steel ☐ Drum ☒ Cask ☐ Other

FISSILE CLASS: ☐ Non Fissile ☐ Fissile Exempt ☐ Fissile I ☐ Fissile II ☒ Fissile III; Grams Fissile 869

SNM: ☒ Category III

ACCOUNTABILITY/SECURITY CONTROL: ☐ Classified ☒ Unclassified; Consignee authorized to receive this qty ☒; Sig. Security Svc. Req. NA ☒; Pu, EU > 1 g ☒; NU, DU > 1 Kg ☐; Security Escorts Req. ☐ Not Req. ☒; External Cask Temperature N/A ☐ (Max 122°F; 180° F ES Use) < 180 °F

Packaging conforms to appropriate packaging procedure ☐ N/A ☒ Yes
Complies with D.O.T. packaging and labeling requirements ☐ N/A ☒ Yes
Container acceptability documented (incl. 7A cert.) ☐ N/A ☒ Yes
Container examined; No evidence of deterioration or damage ☒ Yes
QA Inspection Current ☒ Yes ☐ N/A; Seals required ☐ No ☒ Yes
Shipping Doc. HUC-C2C-1? Authorization No. WR-F103

No. Pkgs.	Model Package	COC/Spec. No.	Serial No.	Seal No.	Isotopes	Curies/Pkg	T.I.	Gross Weight
1	T-3	USA/9132 B(M)F	S/N 001	499847 / 499183	MFP Pu 239, Pu 240, U235, U238, Co 60	10.524	50	40000
(Packager may describe package in detail on the unused lines above)					TOTAL	10.524	50	40,000

Originator's Signature: S. N. Miller Date: 7-18-91 Organization: FFTF Refueling
Complete Cost Code (inc. end function): 47501-IM-114

AREA RADIATION MONITORING

Surface Dose Rate of Package ☒ ≤0.5 or ___ mrem/hr (N + BY)
Dose Rate at 1 Meter from Surface of Package ☒ <0.5 or ___ mrem/hr (N + BY)
Smears of Outer Container ☒ <22 or ___ dpm BY/cm² ☒ <22 α or ___ dpm α/cm²
Air, TRUCK LOAD OR EXCLUSIVE USE: Surface ☒ < 200 or ___ mrem/hr (N + BY); @ 6 feet ☒ < 10 or ___ mrem/hr (N + BY); @ Cab ☒ < 2.0 or ___ mrem/hr (N + BY) or Sleeper
Additional Data and Instructions (inc. Readings on Internal Packaging)
Signature Radiation Monitoring: [signature] Bldg.: FFTF Survey No.: 99070 Date: 7-18-91

AUTHORIZATION FOR SHIPMENT AND CERTIFICATION

Air Transport Certification: Cargo Only ☐ Danger Label Applied; Passenger ☐ 1. Ltd. Qty. ☐ 3. Research or Medical Diagnosis ☐ 2. <3 T.I. ☐ 4. Human Medical Research; Pkg. Dimensions

This is to certify that the above named materials are properly classified, described, packaged, marked and labeled, and are in proper condition for transportation according to the applicable federal, state, local, and international regulations for the transportation of hazardous materials.

Authorized Signature: Greg O. Boness Printed Name: Greg O. Boness Date: 7-18-91

APPROVED FOR OFFSITE SHIPMENT

B. L. No. Date Shipped Routing: TRI State ☐ N/A Placards ☒ Yes ☐ No
Surveyed By Date Approved for Shipment Westinghouse Hanford Company Date Route Plan ☒ Yes ☐ No

☆ GPO 1988-594-677 Reg. guide 63 attached 54-6000-172 (04/88)

POOR COPY RECEIVED DOCUMENT PROCESSING

OFFSITE RADIOACTIVE SHIPMENT RECORD
– EXTERIOR INSPECTION PERMITTED –

12116

G INST.

Company: Argonne Nat. Lab.
Address: PO Box 2528
State, Zip: Idaho Falls ID 83403-2528
Attention: W.P. Kennedy

Contractor: ☐ PNL ☐ KEH ☒ WHC
Site Carrier: Jimmy Butts
PR No. 62998 Veh. No. 6YE4362

Ship: ☒ Prepaid ☐ Collect Via:
☒ Motor-Rail ☐ Air Psgr.
☒ Excl. Use ☐ Air Cargo
☐ DOE Veh. ☐ Mail
☐ UPS Sur. ☐ _____

DESCRIPTION AND CERTIFICATION

Proper Shipping Name / Radioactive Material,	UN Number
1. Empty Packages	☐ UN 2908
2. Low Specific Activity, n.o.s	☐ UN 2912
3. Limited quantity, n.o.s.	☐ UN 2910
4. N.O.S. RQ	☒ UN 2982
5. Fissile n.o.s.	☐ UN 2918
6. Special Form, n.o.s.	☐ UN 2974
7. Instruments & Articles	☐ UN 2911
8. _____	☐ _____

Material Form: ☐ Special (A1) ☒ Normal (A2)

Labels Applied: ☐ Empty ☐ Radioactive LSA ☐ White I ☐ Yellow II ☒ Yellow III ☐ None ☐ Danger (Air Cargo) ☐ Secondary _____

Material Category: ☐ Empty ☐ Low Specific Act. (LSA) ☐ Limited Quantity ☐ Type A Quantity ☒ Type B Quantity ☐ Highway Route Controlled Quantity

For Normal Form Identify:
Physical Form: ☒ Solid ☐ Liquid ☐ Gas
Chemical Form: ☐ Metal ☐ Oxide ☒ Elemental ☐ Nitrate
Other _____

TYPE PACKAGE: ☐ Strong Tight ☐ Type A ☐ Type B ☒ Type B (M)

CONSTRUCTION: ☐ Box, FB ☐ Wood ☒ Steel ☐ Drum ☒ Cask ☐ Other _____

FISSILE CLASS: ☒ Non Fissile ☐ Fissile Exempt ☐ Fissile I ☐ Fissile II ☐ Fissile III
Grams Fissile _____

SNM: ☒ No ☐ Yes ☐ < 1 gr ☐ Category I ☐ Category II ☐ Category III

ACCOUNTABILITY/SECURITY CONTROL: ☐ Classified ☒ Unclassified
Consignee authorized to receive this qty ☒
Sig. Security Svc. Req. ☐ NA ☒
Pu, EU > Lg ☐ N/A NU, DU > Lkg ☐
Security Escorts Req. ☐ Not. Req. ☒
External Cask Temperature N/A ☐
(Max. 122°F LTL, 180°F Ex. Use) < 180 °F

Packaging conforms to appropriate packaging procedure ☐ N/A ☒ Yes
Complies with D. O. T. packaging marking and labeling requirements ☐ N/A ☒ Yes
Container acceptability documented (incl 7A cert.) ☐ N/A ☒ Yes

Container examined: No evidence of deterioration or damage ☒ Yes
QA Inspection Current ☒ Yes ☐ N/A Seals required ☐ No ☒ Yes
Shipping Doc. N/A Authorization No. N/A

SHIP

Pkgs.	Model Package	COC/Spec. No.	Serial No.	Seal No.	Isotopes	Curies/Pkg	T.I.	Gr. Wt.
1	T-3	USA/4132/B(M)	2072	119982	Co60, Mn54, Ta182	522	2.5	113,000
			T3-2	119983				

(Shipper may describe package in detail on one of unused lines above) TOTAL 522 2.5 113000

This is to certify that the above named materials are properly classified, described, packaged, marked and labeled, and are in proper condition for transportation, according to the applicable federal, state, local and international regulations for the transportation of hazardous materials.

Certifier's Signature: _____ Date: 7-1-91 Organization: FFTF Refueling Complete Cost Code (inc. and function): B311

AREA MONITOR

Surface Dose Rate of Package: ☐ ≤0.5 or 10 mrem/hr (N + βγ)
Dose Rate at 1 Meter from Surface of Package: ☐ ≤0.5 or 1.5 mrem/hr (N + βγ)
Smears of Outer Container: ☒ ≤22 dpm βγ/cm² ☒ ≤2.2 dpm α/cm²
TRUCK LOAD OR EXCLUSIVE USE: Surface: ☒ ≤ 200 mrem/hr (N + βγ); @ 6 feet: ☒ ≤ 10 mrem/hr (N + βγ); @ Cab or Sleeper ☒ ≤ 2.0 mrem/hr (N + βγ)

Additional Data and Instructions (Int. Readings on Internal Packaging)

Signature, Radiation Monitoring: _____ Bldg. 4717 Survey No. 8504 Date 7-1-91

APPROVAL

AUTHORIZATION FOR SHIPMENT

AIR TRANSPORT CERTIFICATION ▸ Cargo Only: ☐ Danger Labels Applied
Passenger: ☐ 1. Ltd. Qty. ☐ 2. ≤3 T.I. ☐ 3. Research or Medical Diagnosis ☐ 4. Human Medical Research
Pkg. Dimensions

Traffic has inspected and verified preshipment compliance to DOT regulations.

Authorized Signature ▸ Greg O. Boness Printed Name ▸ Greg O. Boness Date ▸ 7-1-91

APPROVED FOR OFFSITE SHIPMENT

TRAFFIC

B. L. No.	Date Shipped	E. T. A.	Routing: TRI state ☐ N/A	Placards ☒ Yes ☐ No
Surveyed By	Date	Approved for Shipment: Westinghouse Hanford Company	Date	Route Plan ☐ Yes ☒ No

U.S. GOVERNMENT PRINTING OFFICE: 1991—592-378/40007

54-6000-080 (10/88)

OFFSITE RADIOACTIVE SHIPMENT RECORD — EXTERIOR INSPECTION PERMITTED — No. 00945

Company: Argonne Nat. Lab.
Address: PO Box 2528
City, State, Zip: Idaho Falls, ID
Attention:

Contractor: ☐ PNL ☐ KEH ☒ WHC
Site Carrier:
PR No.: Veh. No.

Ship: ☒ Prepaid ☐ Collect Via: ☒ Motor-Rail ☐ Air Psgr. ☒ Excl. Use ☐ Air Cargo ☐ DOE Veh. ☐ Mail ☐ UPS Surf. ☐

Proper Shipping Name Radioactive Material,	UN Number
1. Empty Packages	☐ UN 2908
2. Low Specific Activity, n.o.s	☐ UN 2912
3. Limited quantity, n.o.s.	☐ UN 2910
4. N.O.S.	☐ UN 2982
5. Fissile n.o.s.	☒ UN 2918
6. Special Form, n.o.s.	☐ UN 2974
7. Instruments & Articles	☐ UN 2911
8.	☐

Material Form: ☐ Special (A1) ☒ Normal (A2)

Label Applied: ☐ Empty ☐ Radioactive LSA ☐ White I ☐ Yellow II ☒ Yellow III ☐ None ☐ Danger (Aircraft) ☐ Secondary

Material Category: ☐ Empty ☐ Low Specific Act. (LSA) ☐ Limited Quantity ☐ Type A Quantity ☐ Type B Quantity ☒ Highway Route ☒ Controlled Quantity

For Normal Form: Identity; Physical Form: ☒ Solid ☐ Liquid ☐ Gas; Chemical Form: ☐ Metal ☒ Oxide ☐ Element ☐ Nitrate; Other:

TYPE PACKAGE: ☐ Strong Tight ☐ Type A ☐ Type B ☐ Type B (U) ☒ Type B (M)

CONSTRUCTION: ☐ Box, FB ☐ Wood ☒ Steel ☐ Drum ☒ Cask ☐ Other

FISSILE CLASS: ☐ Non Fissile ☐ Fissile Exempt ☐ Fissile I ☐ Fissile II ☒ Fissile III ☐ Grams Fissile

SNM: ☐ No ☒ Yes; ☐ Category I ☐ Category II ☐ Category III ☒ Category IV

ACCOUNTABILITY SECURITY CONTROL: ☐ Classified ☒ Unclassified; Consignee authorized to receive this qty ☒; Sig. Security Escort Req. NA ☒; Pu, EU > 1 g ☒; U, DU > 1 Kg ☐; Security Escort Req. ☐ Not. Req. ☒; External Cask Temperature (Max 122°F, Ltd. 1900°F ES Use) N/A ☒ °F

Packaging conforms to appropriate packaging procedure ☐ N/A ☒ Yes
Complies with D.O.T. packaging and labeling requirements ☐ N/A ☒ Yes
Container acceptability documented (incl. 7A cert.) ☐ N/A ☒ Yes

Container examined: No evidence of deterioration or damage ☒ Yes
QA Inspection Current ☒ Yes ☐ N/A Seals required ☐ No ☒ Yes
Shipping Doc. WHC-CRC-17 Authorization No. WR-E103

No. Pkgs.	Model Package	COC/Spec No.	Serial No.		Isotopes	Curies/Pkg	T.I.	Gross Weight
1	T-3	USA/9132/B(U)F		WHC 4954419567		10,524	50	43,000
(Packager may describe package in detail on one of unused lines above)						10,524	50	43,000

Originator's Signature: [signature] Date: 3-26-91 Organization: FFTF Refueling Ops. Complete Cost Code (inc. end function): 88011 3915

AREA RADIATION MONITORING

Surface Dose Rate of Package: ☐ <0.5 or 25 mrem/hr (N + B γ)
Dose Rate at 1 Meter from Surface of Package: ☐ <0.5 or 15 mrem/hr (N + B γ)
Smears of Outer Container: ☒ <22 or ___ dpm α/cm²; ☒ <22 or ___ dpm B γ/cm²

TRUCK LOAD OR EXCLUSIVE USE: Surface: ☒ <200 or ___ mrem/hr (N + B γ); @ 6 feet: ☒ <10 or ___ mrem/hr (N + B γ); @ Cab ☒ <2.0 or ___ mrem/hr (N + B γ) or Sleeper

Additional Data and Instructions (inc. Readings on Internal Packaging):

Signature (Radiation Monitoring): [signature] Bldg.: 4717 Survey No.: 30702 Date: 3-26-91

AUTHORIZATION FOR SHIPMENT AND CERTIFICATION

AIR TRANSPORT CERTIFICATION: Cargo Only ☐ Label Applied; Passenger ☐ 1. Ltd. Qty. ☐ 2. <3.1 ☐ 3. Research or Medical Diagnosis ☐ 4. Human Medical Research; Pkg. Dimensions

This is to certify that the above named materials are properly classified, described, packaged, marked and labeled, and are in proper condition for transportation according to the applicable federal, state, local and international regulations for the transportation of hazardous materials.

Authorized Signature: [signature] Printed Name: Greg D. Brocss Date: 3-26-91

APPROVED FOR OFFSITE SHIPMENT

B. L. No.	Date Shipped	ETA	Routing ☐ N/A	Placards ☒ Yes ☐ No
Surveyed By	Date	Approved for Shipment Westinghouse Hanford Company	Date	Route Plan ☒ Yes ☐ No

GPO 1988-594-677 54-6000-172 (04/88)

Company: Advance Nuclear Lab.
Address: P.O. Box 2528
City, State, Zip: Idaho Falls, ID, 83403-2528
Attention: W.P. Kenny

– EXTERIOR INSPECTION PERMITTED –

Contractor: ☐ PNL ☐ KEII ☒ WHC
Site Carrier: R.C. Fraser
PR No. 64232 Veh. No. 45 47

Ship: ☒ Prepaid ☐ Collect Via:
☒ Motor-Rail ☐ Air Psgr.
☒ Excl. Use ☐ Air Cargo
☐ DOE Veh. ☐ Mail
☐ UPS Sur. ☐

Proper Shipping Name / UN Number
Radioactive Material,

1. Empty Packages	☐	UN 2908
2. Low Specific Activity, n.o.s	☐	UN 2912
3. Limited quantity, n.o.s.	☐	UN 2910
4. N.O.S.	☐	UN 2982
5. Fissile n.o.s. KQ	☒	UN 2918
6. Special Form, n.o.s.	☐	UN 2974
7. Instruments & Articles	☐	UN 2911
8. _____	☐	_____

Material Form: ☐ Special (A) ☒ Normal (A2)

Labels Applied
☐ Empty
☐ Radioactive LSA
☐ White I
☐ Yellow II
☒ Yellow III
☐ None
☐ Danger (Air Cargo)
☐ Secondary

Material Category
☐ Empty
☐ Low Specific Activity (LSA)
☐ Limited Quantity
☐ Type A Quantity
☐ Type B Quantity
☒ Highway Route Controlled Quantity

RQ Normal Form Identified
Physical Form: ☒ Solid ☐ Liquid ☐ Gas
Chemical Form: ☐ Metal ☒ Oxide ☐ Elemental ☐ Nitrate
Other _____

TYPE PACKAGE
☐ Strong Tight
☐ Type A
☐ Type B
☒ Type B (U)
☒ Type B (M)

CONSTRUCTION
☐ Box, FB
☐ Wood
☒ Steel
☐ Drum
☒ Cask
☐ Other _____

FISSILE CLASS
☐ Non Fissile
☐ Fissile Exempt
☐ Fissile I
☐ Fissile II
☒ Fissile III
Grams Fissile 1177.4

SNM
☐ No ☒ Yes
☐ < 1 g
☐ Category I
☐ Category II
☒ Category III

CARGO/CARRIER/SECURITY CONTROL
☐ Classified ☒ Unclassified
Consignee Authorized to receive this qty ☒
Sig. Security Area Req. ☐ NA ☒
Pu, EU > 1 g ☒ NU, DU > 1 Kg ☐
Security Escorts Req. ☐ Not. Req. ☒
External Dose Temperature N/A ☒
(Max. 122°F (50°C) 1000 F.E.S. Use) 122°F

Packaging conforms to appropriate packaging procedure ☐ N/A ☒ Yes
Complies with D.O.T. packaging and labeling requirements ☐ N/A ☒ Yes
Container acceptability documented (incl. 7A cert.) ☐ N/A ☒ Yes
Container examined ☒ No evidence of deterioration or damage ☒ Yes
QA Inspection Current ☒ Yes ☐ N/A Seals required ☐ No ☒ Yes
Shipping Doc. WHC-22-12 Authorization No. WK-102

No. Pkgs.	Model Package	COC/Spec. No.	Serial No.	Cask No.	Isotopes	Curies/ Pkg	T.I.	Gross Weight
1	T-2	USA/[illegible]	2	[illegible]	[illegible]	28,000	50	40,000

(Packager may describe package in detail on one of unlisted lines above) TOTAL 28,000 50 40,000

Originator's Signature: [signature] Date: 11-27-90 Organization: WHC ARO
Complete Cost Code (inc. end function): W218UP / 3K81

AREA RADIATION MONITORING

Surface Dose Rate of Package: ☐ <0.5 or ___ mrem/hr (N + Bγ)
Dose Rate at 1 Meter from Surface of Package: ☐ <0.5 or ___ mrem/hr (N + Bγ)
Smears of Outer Container: ☐ <22 or ___ dpm Bγ/cm² ☐ <2.2 or ___ dpm Bγ/cm²

TRUCK LOAD OR EXCLUSIVE USE
Surface: ☐ < 200 or ☒ 1 mrem/hr (N + Bγ)
@ 6 feet: ☐ < 10 or ☒ 1 mrem/hr (N + Bγ)
@ Cab or Sleeper: ☐ <2.0 or ☒ 1 mrem/hr (N + Bγ)

Additional Data and Instructions (inc. Readings on Internal Packaging)

Signature - Radiation Monitoring: [signature] Bldg. _____ Survey No. 30568 Date 11-27-90

AUTHORIZATION FOR SHIPMENT AND CERTIFICATION

AIR TRANSPORT CERTIFICATION: Cargo Only ☐ Cat. Danger Label Applied ☐ Passenger ☐ 1. Ltd. Qty. ☐ 2. T.I. <3 T.I. ☐ 3. Research or Medical Diagnosis ☐ 4. Human Medical Research
Pkg. Dimensions

This is to certify that the above-named materials are properly classified, described, packaged, marked and labeled, and are in proper condition for transportation according to the applicable federal, state, local and international regulations for the transportation of hazardous materials.

Authorized Signature: [signature] Printed Name: W. J. C. Brumley Date: 11-27-90

APPROVED FOR OFFSITE SHIPMENT

B. L. No. _____ Date Shipped _____ F.T.A. _____ Routing _____ ☐ N/A
Placards ☒ Yes ☐ No
Surveyed By _____ Date _____ Approved for Shipment Westinghouse Hanford Company Date _____
Route Plan ☒ Yes ☐ No

GPO 1988-594-677

54-6000-172 (04/88)

POOR COPY RESCANNED
DOCUMENT PROCESSING

OFFSITE RADIOACTIVE SHIPMENT RECORD
– EXTERIOR INSPECTION PERMITTED –

00941

SHIPPING INST.

Company Argonne Natl. Lab
Address PO Box 2528
City, State, Zip Idaho Falls ID 83403-2528
Attention: WP Kinney

Contractor: ☐ PNL ☐ KEH ☒ WHC
Site Carrier
PR No.
Veh. No

Ship: ☒ Prepaid ☐ Collect Via:
☒ Motor-Rail ☐ Air Psgr.
☒ Excl. Use ☐ Air Cargo
☐ DOE Veh. ☐ Mail
☒ UPS Sur. ☐

SHIPMENT DESCRIPTION

Proper Shipping Name Radioactive Material,		UN Number
1. Empty Packages	☐	UN 2908
2. Low Specific Activity, n.o.s.	☐	UN 2912
3. Limited quantity, n.o.s.	☐	UN 2910
4. N.O.S.	☐	UN 2982
5. Fissile n.o.s.	☒	UN 2918
6. Special Form, n.o.s.	☐	UN 2974
7. Instruments & Articles	☐	UN 2911
8.	☐	

Material Form: ☐ Special (A1) ☒ Normal (A2)

Labels Applied: ☐ Empty ☐ Radioactive LSA ☐ White I ☐ Yellow II ☒ Yellow III ☐ None ☐ Danger (Air Cargo) ☐ Secondary

Material Category: ☐ Empty ☐ Low Specific Act. (LSA) ☐ Limited Quantity ☐ Type A Quantity ☐ Type B Quantity ☒ Highway Route ☒ Controlled Quantity

For Normal Form: Physical Form ☒ Solid ☐ Liquid ☐ Gas; Chemical Form ☐ Metal ☒ Oxide ☐ Elemental ☐ Nitrate; Other

TYPE PACKAGE: ☐ Strong Tight ☐ Type A ☐ Type B ☐ Type B (U) ☒ Type B (M)

CONSTRUCTION: ☐ Box, FB ☐ Wood ☐ Steel ☐ Drum ☒ Cask ☐ Other

FISSILE CLASS: ☐ Non Fissile ☐ Fissile Exempt ☐ Fissile I ☐ Fissile II ☒ Fissile III; Grams Fissile

SNM: ☐ No ☒ Yes; ☐ <1 g; ☐ Category I; ☐ Category II; ☐ Category III; ☒ Category IV

ACCOUNTABILITY/SECURITY CONTROL: ☐ Classified ☒ Unclassified; Consignee authorized to receive this qty ☒; Sig. Security Svc. Req. ☒ NA ☐; Pu, EU > 1 g ☒ NU, DU > 1 Kg ☐; Security Escorts Req. ☐ Not. Req. ☒; External Cask Temperature (Max. 122°F) (1980°F ES. Use) N/A ☒ °F

Packaging conforms to appropriate packaging procedure ☒ N/A ☒ Yes
Complies with D.O.T. packaging and labeling requirements ☐ N/A ☒ Yes
Container acceptability documented (Incl. 7A cert.) ☐ N/A ☒ Yes
Container examined: No evidence of deterioration or damage ☒ Yes
QA Inspection Current ☒ Yes ☐ N/A Seals required ☐ No ☒ Yes
Shipping Doc WHC-CZC-II Authorization No. NR-F103

No. Pkgs.	Model Package	COC/Spec. No.	Serial No.	Seal No.	Isotopes	Curies/Pkg	T.I.	Gross Weight
1	T-3	USA/9132/B(M)F	[illegible]	[illegible]	[illegible]	[illegible]	50	[illegible]
						[illegible]		
						[illegible]		
(Packager may describe package in detail on one of unused lines above)					TOTAL	[illegible]	50	[illegible]

Originator's Signature [signature] Date 3-7-91 Organization FFTF Refueling (18510) Complete Cost Code (Inc. end function) 8501139114

AREA RADIATION MONITORING

AREA MONITOR

Surface Dose Rate of Package ☐ <0.5 or ____ mrem/hr (N + β γ)
Dose Rate at 1 Meter from Surface of Package ☐ <0.5 or ____ mrem/hr (N + β γ)
Smears of Outer Container ☐ <22 or ____ dpm β γ/cm² ☐ <2.2 or ____ dpm β γ/cm²

TRUCK LOAD OR EXCLUSIVE USE
Surface: ☒ < 200 or ____ mrem/hr (N + β γ)
@ 6 feet: ☒ < 10 or ____ mrem/hr (N + β γ)
@ Cab or Sleeper ☒ < 2.0 or ____ mrem/hr (N + β γ)

Additional Data and Instructions (Inc. Readings on Internal Packaging)

Signature - Radiation Monitoring | Bldg. | Survey No. | Date ..-91

AUTHORIZATION FOR SHIPMENT AND CERTIFICATION

CERTIFIER

AIR TRANSPORT CERTIFICATION | Cargo Only ☐ Danger Labels Applied | Passenger ☐ 1. Ltd. Qty. ☐ 2. <3 T.I. | ☐ 3. Research or Medical Diagnosis ☐ 4. Human Medical Research | Pkg. Dimensions

This is to certify that the above named materials are properly classified, described, packaged, marked and labeled, and are in proper condition for transportation according to the applicable federal, state, local and international regulations for the transportation of hazardous materials.

Authorized Signature ▸ [signature] Printed Name ▸ Greg C. Bone Date ▸ 3-7-91

APPROVED FOR OFFSITE SHIPMENT

TRAFFIC

B. L. No. | Date Shipped | E.T.A. | Routing ☐ N/A | Placards ☒ Yes ☐ No
Surveyed By | Date | Approved for Shipment Westinghouse Hanford Company | Date | Route Plan ☒ Yes ☐ No

GPO 1988-594-677 54-6000-172 (04/88)

7.4.3 ORIGEN 2 Calculations for FFTF Metal and Carbide Fuel

Westinghouse Hanford Company | **Internal Memo**

From: Radiation Physics and Shielding 8D530-RAS-94-009
Phone: 6-5977 HO-35
Date: August 5, 1994
Subject: ORIGEN 2 CALCULATIONS FOR FFTF METAL AND CARBIDE FUEL

To: J. R. Green G2-02

cc: J. Greenborg HO-35

References: 1. Memo, R. A. Schwarz to J. G. Field, "Shielding Evaluation for Metal and Carbide Fuel Pins," dated January 13, 1990, FRRP:Sc90-001.

Origen 2 Calculations have been made for FFTF metal and carbide fuel assemblies. The input for these calculations was obtained from Reference 1, with the decay times modified to decay the source up to 1095 days. All of the calculations were made on a Sun workstation. The input and output files are stored in cfs in the directory /w97555/t3, which are identical to those delivered on July 28.

R. A. Schwarz
Advanced Scientist

Concurrence:
J. Greenborg, Manager
Radiation Physics and Shielding

Figure 1. Origen 2 Input File for Metal Fuel

```
m
-1
-1
-1
BAS      FFTF METAL FUEL ASSEMBLY
TIT      SOURCE IN THE T 3 CASK FROM METAL ASSEMBLY
RDA      VECTOR -1 = METAL FUEL PIN CONTENT
LIB        0 1 2 3 381 382 383 9 3 0 1 0
PHO             101  102  103  10
LIP        0  0  0
INP      -1  1  -1  -1  1  1
MOV       -1  1  0    169.0
RDA      VECTOR 1 NOW CONTAINS 169 METAL FUEL PINS (1 METAL ASSEMBLY)
RDA      IRRADIATE  FUEL FOR 1133 DAYS AT 7.5MW   (200 MWD/KG)
BUP
IRP       100   7.5    1  2  4  2
IRP       200   7.5    2  3  4  0
IRP       300   7.5    3  4  4  0
IRP       400   7.5    4  5  4  0
IRP       500   7.5    5  6  4  0
IRP       600   7.5    6  7  4  0
IRP       700   7.5    7  8  4  0
IRP       800   7.5    8  9  4  0
IRP       900   7.5    9  10 4  0
IRP      1000   7.5   10  11 4  0
IRP      1100   7.5   11  12 4  0
MOV       12  11  0    1.0
IRP      1143   7.5   11  12 4  0
BUP
OPTL       8 8 8 8 7 8 7 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
OPTA       8 8 8 8 7 8 7 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
OPTF       8 8 8 8 7 8 7 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
OUT       12   1  0  0
MOV       12  1  0  1.0
RDA      BEGIN DECAY
DEC        90.0  1  2  4  4
DEC       120.0  2  3  4  0
DEC       180.0  3  4  4  0
DEC       365.0  4  5  4  0
DEC       730.0  5  6  4  0
DEC       760.0  6  7  4  0
DEC       790.0  7  8  4  0
DEC       820.0  8  9  4  0
DEC       850.0  9 10  4  0
DEC       880.0 10 11  4  0
DEC      1095.0 11 12  4  0
HED      1  DISCHARGE
TIT      DECAY AFTER 769 DAY IRRADIATION
OPTL       8 8 7 8 7 8 7 8 7 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
OPTA       8 8 7 8 7 8 7 8 7 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
OPTF       8 8 7 8 7 8 7 8 7 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
CUT      3  0.001  9  0.001   -1
OUT      12  1  0  0
STP 4
2    922350 101.45   922380 152.17
4    400000  28.18    260000  67.048
4    240000  10.074   420000  0.967   280000  0.6447  230000  0.28207
4    250000  0.56414  740000  0.48355 060000  0.18536 140000 0.2418

END
```

Figure 2. Origen 2 Input File for Carbide Fuel

```
-1
-1
-1
BAS      FFTF CARBIDE FUEL ASSEMBLY
TIT      SOURCE IN THE T3 CASK WITH A MAX OF 23 % PU
RDA      VECTOR -1 = CARBIDE FUEL PIN CONTENT
LIB        0 1 2 3 381 382 383 9 3 0 1 0
PHO              101  102  103  10
LIP        0  0  0
INP      -1  1  -1  -1  1  1
MOV       -1  1  0     1.0
RDA      VECTOR 1 NOW CONTAINS 91 CARBIDE FUEL PINS (1 CARBIDE ASSEMBLY)
RDA      IRRADIATE  FUEL FOR 512 DAYS AT 6.4MW   (70 MWD/KG)
BUP
IRP       100   6.4     1  2  4  2
IRP       200   6.4     2  3  4  0
IRP       300   6.4     3  4  4  0
IRP       400   6.4     4  5  4  0
IRP       500   6.4     5  6  4  0
IRP       512   6.4     6  7  4  0
BUP
OPTL       8 8 8 8 7 8 7 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
OPTA       8 8 8 8 7 8 7 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
OPTF       8 8 8 8 7 8 7 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
OUT       7   1  0  0
MOV       7  1  0  1.0
RDA      BEGIN DECAY
DEC        90.0  1  2  4  4
DEC       120.0  2  3  4  0
DEC       180.0  3  4  4  0
DEC       365.0  4  5  4  0
DEC       730.0  5  6  4  0
DEC       760.0  6  7  4  0
DEC       790.0  7  8  4  0
DEC       820.0  8  9  4  0
DEC       850.0  9 10  4  0
DEC       880.0 10 11  4  0
DEC      1095.0 11 12  4  0
HED      1  DISCHARGE
TIT      DECAY AFTER 512 DAY IRRADIATION
OPTL       8 8 7 8 7 8 7 8 7 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
OPTA       8 8 7 8 7 8 7 8 7 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
OPTF       8 8 7 8 7 8 7 8 7 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
CUT      5  0.00001  7  0.00001   -1
OUT      12  1  0  0
STP 4
2    942420  24.59    922350 259.46   922380  35776.54  942390  9366.24
2    942400  1244.05  942410 129.12   0         0.0     0       0.0
4    280000  509.2    240000 443.5    260000  2175.0    060000  2320.0
4    250000  65.70    140000 24.6     420000  65.75     0       0.0
0
END
```

7.4.4 Fuel Assembly Source Term Calculations

Westinghouse Hanford Company — **Internal Memo**

From: Radiation Physics and Shielding 8D530-SFK-95-001
Phone: 376-9953
Date: January 11, 1995
Subject: ACTIVITY CALCULATION FOR FFTF METAL FUEL DUCT, NOZZLE, AND HANDLING SOCKET

To: J. R. Green G2-02

cc: J. Greenborg H0-35
R. R. Schwarz H0-35
K. D. Dobbin N2-32
D. C. Johnston N2-02
SFK FILE/LB

REFERENCES:
1 Memo, R. A. Schwarz to J. R. Green "Origin 2 Calculation for FFTF Metal and Carbide Fuel" dated August 5, 1994 80530-RAS-94-009.
2 WHC-SD-FF-SWD-046 "Certification of the DKHI-4FRAC Program" dated October 1994.

Reference 1 documented the calculation of fuel pin activities for an FFTF Metal Fuel Assembly. The results of these calculations were used to calculate the activities of the duct, nozzle, and handling socket by using the reaction rate fractions generated by the program DKHI-4FRAC. This program is used to calculate hardware activities for fuel assembly shipments from FFTF to either an examination facility or a disposal facility. A complete description and operating instructions are contained in reference 2. The data in table 1 was calculated by using the results from reference 1 for the isotopes in the fuel pin cladding used to calculate the source term and hazard indicator, and multiplying by the appropriate fraction to get the activity for the duct, nozzle, and handling socket.

S. F. Kessler, Senior Engineer
Radiation Physics and Shielding

Concurrence:
J. Greenborg
Radiation Physics and Shielding

rkj

TABLE 1: HARDWARE ACTIVITIES FOR A METAL FUEL ASSEMBLY

	Cladding	Duct	Nozzle	Handling Socket
Fraction	0.4063	0.44016	0.15315	0.00038
Isotope	(Ci)	(Ci)	(Ci)	(Ci)
Cr^{51}	6.50E-07	7.04E-07	2.45E-07	6.08E-10
Mn^{54}	9.52E-01	1.03E+00	3.59E-01	8.90E-04
Fe^{55}	9.75E-01	1.06E+00	3.68E-01	9.12E-04
Co^{58}	1.99E-01	2.16E-01	7.50E-02	1.86E-04
Co^{60}	2.38E+00	2.58E+00	8.97E-01	2.23E-03
Ni^{63}	4.96E-01	5.37E-01	1.87E-01	4.64E-04
Nb^{92}	5.15E-21	5.58E-21	1.94E-21	4.82E-24
Mo^{93}	6.62E-03	7.17E-03	2.50E-03	6.19E-06
Ta^{182}	1.24E-02	1.34E-02	4.67E-03	1.16E-05

CHECKLIST FOR INDEPENDENT TECHNICAL REVIEW

DOCUMENT REVIEWED
NUMBER: 8D530-SFK-95-001
TITLE: Activity Calculations for FFTF Metal Fuel Duct, Nozzle, and Handling Socket
AUTHOR(s): S. F. Kessler

I. Method(s) of Review

(X) Input data checked for accuracy
( ) Independent calculation performed
  ( ) Hand calculation
  ( ) Alternate computer code:_____
( ) Comparison to experiment or previous results
( ) Alternate method (define)_____

II. Checklist (either check or enter NA if not applied)

(X) Task completely defined
(X) Activity consistent with task specification
(X) Necessary assumptions explicitly stated and supported
(X) Resources properly identified and referenced
(X) Resource documentation appropriate for this application
(X) Input data explicitly stated
(X) Input data verified to be consistent with original source
(NA) Geometric model adequate representation of actual geometry
(NA) Material properties appropriate and reasonable
(NA) Mathematical derivations checked including dimensional consistency
(NA) Hand calculations checked for errors
( ) Assumptions explicitly stated and justified
(X) Computer software appropriate for task and used within range of validity
(NA) Use of resource outside range of established validity is justified
(X) Software runstreams correct and consistent with results
(X) Software output consistent with input
( ) Results consistent with applicable previous experimental or analytical findings
(X) Results and conclusions address all points and are consistent with task requirements and/or established limits or criteria
(X) Conclusions consistent with analytical results and established limits
(NA) Uncertainty assesment appropriate and reasonable
( ) Other (define)_____

III. Comments:_____

IV. REVIEWER: Harvey Goldberg DATE: 16 Januarty 1995

Harvey Goldberg

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