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Safety Evaluation for Packaging (Onsite) Disposable Solid Waste Cask

B. D. Flanagan

Rust Federal Services of Hanford Inc., Richland, WA 99352

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Abstract: This safety evaluation for packaging (SEP) evaluates and documents the ability of the Disposable Solid Waste Cask (DSWC) to meet the packaging requirements of HNF-CM-2-14, *Hazardous Material Packaging and Shipping*, for the onsite transfer of special form, highway route controlled quantity, Type B fissile radioactive material. This SEP evaluates five shipments of DSWCs used for the transport and storage of Fast Flux Test Facility unirradiated fuel to the Plutonium Finishing Plant Protected Area.

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Brian Bishop
Release Approval

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LIST OF TERMS

ASTM	American Society for Testing and Materials
CCC	core component container
cm	centimeter
DFA	driver fuel assembly
dpm/cm ²	disintegrations per minute per square centimeter
DSWC	disposable solid waste cask
FFTF	Fast Flux Test Facility
ft	foot
in.	inch
IDS	interim decay storage
ISC	interim storage cask
kg	kilogram
km	kilometer
km/h	kilometers per hour
kPa	kilopascal
lb	pound
lbf/in ²	pound-force per square inch
m	meter
μCi/cm ²	microcuries per square centimeter
mi	mile
mi/h	miles per hour
MPa	megapascal
mrem/h	millirem per hour
mSv/h	millisieverts per hour
ppm	parts per million
SARP	safety analysis report for packaging
SEP	safety evaluation for packaging
std cm ³ /s	standard cubic centimeter per second
Sv	sievert
TCRP	total conditional release probability
W	watt

SAFETY EVALUATION FOR PACKAGING (ONSITE) DISPOSABLE SOLID WASTE CASK

PART A: DESCRIPTION AND OPERATIONS

1.0 GENERAL INFORMATION

1.1 INTRODUCTION

This safety evaluation for packaging (SEP) evaluates and documents the ability of the Disposable Solid Waste Cask (DSWC) to meet the packaging requirements of HNF-CM-2-14, *Hazardous Material Packaging and Shipping*, for the onsite transfer of special form, highway route controlled quantity, Type B fissile radioactive material. Onsite transfer is the transport of hazardous materials on controlled routes confined to established limited areas and to portions of federally owned roadways to which public access is prohibited during transfer.

This SEP evaluates five shipments of DSWCs used for the transport and storage of Fast Flux Test Facility (FFTF) unirradiated fuel to the Plutonium Finishing Plant (PFP) Protected Area. The original packaging system, as described in the DSWC SARP WHC-SD-TP-SARP-003 (WHC 1995), has been changed by eliminating both impact limiters and their associated load binders, eliminating the tiedown frame, utilizing a redesigned tiedown system, and changing the contents to include unirradiated fuel. The impact limiters have been eliminated due to height restrictions en route. The current height of the package on the trailer (without impact limiters) is approximately 5.18 m (17 ft). The original use of the DSWC was for onsite transfer and burial of FFTF nonfuel irradiated core components or solid wastes from the 400 Area.

Part A of this SEP provides information on the packaging, contents, operational features, and any other controls associated with the use of the DSWC packaging system for unirradiated fuel. Part B contains packaging evaluations and related analyses.

This SEP expires one year from the date of release.

1.2 SYSTEM DESCRIPTION

The DSWC packaging system consists of a DSWC cask, lifting and tiedown equipment, and a dedicated transporter trailer. The transport trailer will incorporate a General 30-ton jeep during transport to aid in distributing weight on the Hanford site roads. No impact limiters will be used. The system will be used to provide packaging for onsite transfer and storage of unirradiated driver fuel assemblies (DFAs) placed within a core component container (CCC). All supporting equipment associated with the DSWC cask is reusable. The DSWC cask is considered nonreusable due to the welded closure plate.

A complete description of the DSWC packaging system and its operational features is provided in WHC-SD-TP-SARP-003, *Safety Analysis Report for Packaging (Onsite) Disposable Solid Waste Cask Packaging System* (WHC 1995).

2.0 PACKAGING SYSTEM

A complete description of the packaging system is provided in WHC-SD-TP-SARP-003 (WHC 1995). Note that impact limiters, associated binders, and tiedown frame will not be used and that the tiedown system has been changed to accommodate the cask without impact limiters.

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3.0 PACKAGE CONTENTS

3.1 GENERAL DESCRIPTION

The authorized contents for the DSWC under this SEP is seven (or fewer) unirradiated DFAs located in the CCC. The CCC is a bundle of six closed storage tube assemblies around a central tube and welded into one unit for receipt of seven DFAs. The fuel is removed from the FFTF located in the 400 Area.

Table A3-1 gives a complete description of the fuel composition for one of seven DFAs.

Table A3-1. Driver Fuel Assembly (DFA) Payload Summary (Fueled).

Type	Fuel description	Array description	Pin dimensions
217-pin DFA, 7 DFAs per core component container	29.3% PuO ₂ , remaining UO ₂ (natural Uranium)	Hexagonal array at 0.7214 cm (0.286 in.) pin lattice pitch	0.23-in. dia., 36-in. active fuel length

3.2 CONTENT RESTRICTIONS

The DSWC can contain seven unirradiated DFAs (the center DFA would have a 15 in. length of the inlet nozzle removed) in a CCC. The total decay heat load of the cask shall not exceed 400 W when uniformly distributed over the entire cavity of the DSWC. Maximum weight of the payload, including the weight of the CCC, is 2,268 kg (5,000 lb).

No material shall be allowed in the DSWC packaging system that would be likely to react with the contents or packaging components.

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4.0 TRANSPORT SYSTEM

4.1 TRANSPORTER

The transporter will be the DSWC transporter, drawing number H-4-65152, *DSWC Transporter Assembly* (HEDL 1984). The main frame is 11.58 m (38 ft) long and has a center loading platform, which is 3.66 m (12 ft) wide, 4.27 m (14 ft) long, and 66 cm (26 in.) above the ground. Three axles with 12 wheels are located behind the loading platform, and a gooseneck for connecting to a tractor is located in front of the loading platform. Equipment storage is provided on top of the gooseneck and on top of the rear frame. The transporter will be connected to a General 30 ton jeep during transport to aid in distributing weight on the Hanford site roads.

The overall height of the package on the trailer is approximately 5.18 m (17 ft). The gross weight of the package is 43,553 kg (96,017 lb).

4.2 TIEDOWN SYSTEM

The package will be restrained using the engineered tiedown system evaluated in Part B, Section 10.0. The tiedown system consists of a top and bottom support tiedown assembly. Chains are used to attach the top tiedown assembly to the trailer bed, and a specially designed kick plate is used to support the DSWC in the lower assembly.

The tiedown system is designed to meet 49 CFR 393.102, "Securement Systems." The aggregate working load limit of the tiedown assemblies used to secure an article against movement in any direction must be at least 0.5 times the weight of the article.

4.3 SPECIAL TRANSFER REQUIREMENTS

4.3.1 Routing and Access Control

All roads used by the transporter south of the Wye Barricade to the FFTF shall be closed until the transport vehicle reaches the Wye Barricade.

Maximum mileage per shipment shall be 80.5 km (50 mi).

Oversize permits are required for transport. Contact Road Maintenance and Services for specific requirements. The route shall be evaluated for height restrictions.

4.3.2 Radiological Limitations

Transportation exclusive use dose rate limitations are: the accessible surface of the package must be below 200 mrem/h (2 mSv/h), less than 10 mrem/h (0.1 mSv/h) at 2 m (78.74 in.) from the package, and less than 2 mrem/h (0.02 mSv/h) in any normally occupied space (49 CFR 173.441).

External contamination limits are as shown in Table A4-1 for the exterior of the cask.

Table A4-1. External Cask Contamination Limits.

Contaminant	Maximum permissible limits	
	$\mu\text{Ci}/\text{cm}^2$	dpm/cm^2
Beta-gamma-emitting radionuclides; all radionuclides with half-lives less than ten days; natural uranium; natural thorium; uranium-235; uranium-238; thorium-232; thorium-228 and thorium-230 when contained in ores or physical concentrates	10^{-5}	22
All other alpha-emitting radionuclides	10^{-6}	2.2

Source: 49 CFR 173.443, 1996, "Shippers--General Requirements for Shipments and Packagings," Code of Federal Regulations, as amended.

4.3.3 Speed Limitations

The transport vehicle shall drive a maximum of 16.1 km/h (10 mi/h) on straight roadways and 8.05 km/h (5 mi/h) on curves or dirt roads (WHC 1995).

4.3.4 Environmental Conditions

If extreme fog, ice, or adverse snow conditions exist, the package shall not be transported.

4.3.5 Escort and Emergency Response

Since the DSWC contains a highway route controlled quantity of radioactive material, a specified route shall be followed from the 400 Area to the Plutonium Finishing Plant in the 200 Area. The route shall be determined prior to shipment in accordance with HNF-CM-2-14.

The shipper shall have an approved emergency plan in place, and those involved in executing the plan must have attended a prejob meeting and discussed the plan and route before transporting the DSWC.

Due to the nature of the payload, escorts shall be used for the entire route.

5.0 ACCEPTANCE OF PACKAGING FOR USE

The DSWC shall have passed all acceptance tests and requirements provided in WHC-SD-TP-SARP-003 (WHC 1995) prior to use. Any degradation of the cask will be repaired prior to use. The DSWC cask is considered nonreusable due to the welded closure plate.

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6.0 OPERATING REQUIREMENTS

6.1 GENERAL REQUIREMENTS

The following are general requirements for the use of the DSWC. B&W Hanford Company shall prepare operating procedures based on the following requirements; the FFTF fuel characteristics; and Fluor Daniel Hanford, Inc. safety requirements. Prior to use, the specific operating procedures with appropriate Quality Assurance/Quality Control hold points shall be written by the user and approved in accordance with HNF-CM-2-14.

For loading and unloading operations, follow the operational controls provided in WHC-SD-TP-SARP-003 (WHC 1995). The CCC operational requirements are stated in WHC-SD-TP-SARP-010 (WHC 1996). Operational requirements are also provided in detailed FFTF operating procedures.

6.2 TIEDOWN SYSTEM

The tiedown system consists of an upper and lower tiedown assembly with chain and ratchet binders securing the DSWC to the trailer. A detailed description of the tiedown assemblies is provided in Part B, Section 10.0.

The DSWC cask shall be loaded onto the trailer in such a way that the lifting eyes on the cask closure plate do not interfere with the top tiedown assembly. The lifting eyes should be positioned either parallel or perpendicular to the trailer fore-aft centerline as shown in Figure A6-1.

Figure A6-1. Alignment of Disposable Solid Waste Cask onto Trailer.

6.3 STORAGE RECEIPT OF PACKAGE

The DSWC casks will be used for storage of the unirradiated fuel until disposition is determined. Therefore, the unloading procedures for the DSWC consist only of removing the cask from the transporter. The cask is placed into its assigned storage location. The contents are not removed from the package.

6.3.1 Loading the Trailer

Detailed loading procedures shall be provided by FFTF Engineering. The procedures shall include securing the cask on the transporter using the tiedown system described in Part B, Section 10.0.

6.3.2 Off-Loading the Trailer

Detailed off-loading procedures shall be provided to the PFP by FFTF Engineering. The procedures shall include the safe loosening and proper storage of the tiedown equipment.

7.0 QUALITY ASSURANCE REQUIREMENTS

7.1 INTRODUCTION

This section describes the QA requirements for the fabrication, operation, and maintenance of the DSWC Transport System. The design and fabrication of the DSWC cask was performed by Nuclear Packaging, Inc and meets the requirements as described in WHC-SD-TP-SARP-003 (WHC 1995). The CCC QA requirements are described in WHC-SD-TP-SARP-010 (WHC 1996). The design and fabrication of the tiedown system was performed by Rust Federal Services of Hanford and Numatec respectively. The format and requirements for procurement, fabrication, operation, and maintenance are taken from HNF-CM-4-2; WHC-IP-0705 (WHC 1995); and HNF-CM-2-14.

7.2 GENERAL REQUIREMENTS

The tiedown system used for the DSWC is not required to meet the requirements for safety class and safety significant items. The tiedown system has been designed, procured, and fabricated to meet 49 CFR 393.102 and standard commercial practices.

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8.0 MAINTENANCE

Follow the maintenance requirements of WHC-SD-TP-SARP-003 (WHC 1995).

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9.0 REFERENCES

- 49 CFR 173, 1996, "Shippers--General Requirements for Shipments and Packagings," *Code of Federal Regulations*, as amended.
- 49 CFR 393, 1996, "Parts and Accessories for Safe Operation," *Code of Federal Regulations*, as amended.
- HEDL, 1984, *DSWC Transporter Assembly*, drawing H-4-65152, Sheet 1, Rev. 0, Nuclear Packaging, Inc., Hanford Engineering Development Laboratory, Richland, Washington.
- HNF-CM-2-14, *Hazardous Material Packaging and Shipping*, Fluor Daniel Hanford, Inc., Richland, Washington.
- HNF-CM-4-2, *Quality Assurance Manual*, Fluor Daniel Hanford, Inc., Richland, Washington.
- WHC, 1995, *Safety Analysis Report for Packaging (Onsite) Disposable Solid Waste Cask Packaging System*, WHC-SD-TP-SARP-003, Rev. 0-B, Westinghouse Hanford Company, Richland, Washington.
- WHC, 1996, *Safety Analysis Report for Packaging (Onsite) Interim Storage Cask*, WHC-SD-TP-SARP-010, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

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10.0 APPENDIX: DRAWINGS

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GENERAL NOTES UNLESS OTHERWISE SPECIFIED

1. REMOVE ALL BURRS AND SHARP EDGES.
2. TOLERANCES: ALL DIMENSIONS ARE IN INCHES.
FRACTIONS: $\pm 1/16$
ANGLES: ± 2
3. MARK PER HS-B5-0015, TYPE 2 (DIE STAMPING) WITH DRAWING NUMBER, REVISION NUMBER, AND PART NUMBER WHERE INDICATED USING 3/8 HIGH CHARACTERS.
4. ALL WELDING PROCEDURES AND PERSONNEL SHALL BE QUALIFIED IN ACCORDANCE WITH AWS D1.1. WELDING PROCEDURES SHALL BE AVAILABLE FOR AUDIT OR REVIEW.

5 GUIDE
SCALE: 1/4"

6 GUSSET
SCALE: 1/2

1 ASSEMBLY
SCALE: 1/8

NAME: K. A. WILLIAMS	U.S. DEPARTMENT OF ENERGY
DESIGN:	Research Operations Office
SPR: 200	B & W Hanford Co.
REV: 0	KICK PLATE ASSEMBLY
DATE: 8 D FLANAGAN	DSWC TIE DOWN
REV:	SYSTEM
REV:	
REV:	
REV:	

[illegible]

PART B: PACKAGE EVALUATION**1.0 INTRODUCTION****1.1 SAFETY EVALUATION METHODOLOGY**

The Disposable Solid Waste Cask (DSWC) has been analyzed to meet the requirements of HNF-CM-2-14, *Hazardous Material Packaging and Shipping*, for the onsite transport of Type B fissile material. The onsite normal transport conditions and accident conditions were analyzed or referenced as demonstrated in this part. The Driver Fuel Assemblies (DFA) meet the criteria for those conditions. The DSWC and core component container (CCC) are mentioned in the evaluations as adding a further level of protection but are not relied upon to meet the criteria.

1.2 EVALUATION SUMMARY AND CONCLUSIONS

The DSWC is safe for the onsite transfer of approved loadings of unirradiated DFAs within the CCC, as demonstrated or referenced by this safety evaluation for packaging (SEP). All loading/unloading and acceptance requirements and tests shall be followed and documented, as stated in Part A of this SEP.

1.2.1 Contents

The contents evaluated as acceptable for this SEP are seven (or fewer) unirradiated DFAs in a CCC (Part B, Section 2.0).

1.2.2 Radiological Risk

The radiological risk evaluation performed demonstrates that the system meets the onsite transportation safety requirements (Part B, Section 3.0).

1.2.3 Containment

Containment of the radioactive material is maintained throughout all normal transport conditions as demonstrated by the special form tests and analyses performed for the DFAs (Part B, Section 4.0).

1.2.4 Shielding

The package shielding, analyzed by comparison, meets the shielding requirements of 200 mrem/h at any point on the outside surface and 10 mrem/h at any point 2 m from the surface when transporting seven DFAs (Part B, Section 5.0).

1.2.5 Criticality

Subcriticality of the DSWC is maintained as demonstrated by K_{eff} being less than 0.95 (Part B, Section 6.2). The evaluation addressed the criticality aspect of storing CCCs with unirradiated fuel inside DSWCs, including transportation through the Reactor Service Building and the 400 Area.

1.2.6 Structural

The DSWC structurally meets normal transport conditions, and meets the acceptance criteria for the risk associated with onsite accident conditions (Part B, Section 7.0). As prepared for transport, the contents are protected both thermally and physically by the concrete structure of the cask.

1.2.7 Thermal

The DSWC contents have a maximum decay heat of 350 W in the CCC (50 W per DFA). The maximum allowable heat load for the cask is 400 W. Therefore, the heat removal capability provided by the cask is acceptable.

1.2.8 Gas Generation

Gas generation within the DSWC will not occur during normal transport conditions (Part B, Section 9.0).

1.2.9 Tiedown System

The DSWC tiedown system (Part B, Section 10.0) was designed specifically for the DSWC. The DSWC tiedown system meets all requirements per 49 CFR 173 and 49 CFR 393.

1.3 REFERENCES

- 10 CFR 71, 1996, "Packaging and Transportation of Radioactive Material," *Code of Federal Regulations*, as amended.
- 49 CFR 173, 1996, "Shippers--General Requirements for Shipments and Packagings," *Code of Federal Regulations*, as amended.
- 49 CFR 393, 1996, "Parts and Accessories for Safe Operation," *Code of Federal Regulations*, as amended.
- HNF-CM-2-14, *Hazardous Material Packaging and Shipping*, Fluor Daniel Hanford, Inc., Richland, Washington.

2.0 CONTENTS EVALUATION

2.1 DISCUSSION

The contents authorized for the DSWC packaging, under this SEP are seven (or fewer) Fast Flux Test Facility (FFTF) DFAs distributed in the CCC. The fuel assemblies are unirradiated and "special form" according to 49 CFR 173.469 (Colten 1978). A more detailed evaluation of the unirradiated fuel assemblies is provided in *Safety Analysis Report for Packaging (Onsite) Interim Storage Cask* (Clements 1996).

2.2 REFERENCES

- 49 CFR 173, 1996, "Shippers--General Requirements for Shipments and Packagings," *Code of Federal Regulations*, as amended.
- Colten, L. B., 1978, *FFTF Fuel Assembly Special Form Evaluation*, HEDL-TC-1095, Hanford Engineering Development Laboratory, Richland, Washington.
- Clements, M. D., 1996, *Safety Analysis Report for Packaging (Onsite) Interim Storage Cask*, WHC-SD-TP-SARP-010, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

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3.0 RADIOLOGICAL RISK EVALUATION

3.1 INTRODUCTION

The DSWCs will be used to ship Type B quantities of unirradiated special form nuclear fuel on the Hanford Site from the FFTF to the Plutonium Finishing Plant, which is a distance of approximately 80.5 km (50 mi). The DSWC will contain up to seven unirradiated DFAs. Radiological risks are evaluated to determine compliance with onsite transportation safety requirements per HNF-CM-2-14.

There will be one cask per shipment and a total of five shipments. The maximum distance per shipment will be 80.5 km (50 mi). The fuel assemblies are special form and meet the requirements of 49 CFR 173 for special form materials. The transport system is assumed to weigh 45.36 or more metric tons (50 or more tons).

The containment system is conservatively assumed to consist solely of the fuel assemblies for the purpose of this evaluation. In fact, the CCC provides some containment, and the welded DSWC provides a level of containment.

For accident environments, the package must meet the onsite transportation safety requirements as outlined in HNF-CM-2-14 and Mercado (1994). The requisite safety is determined by a radiological risk evaluation, which uses dose consequences, risk acceptance criteria, failure threshold values, and Hanford Site accident frequencies. For the evaluation, accidents are categorized as impact, crush, puncture, and fire. Risk acceptance criteria are outlined in Section 3.2. The dose consequence analyses results are provided in Section 3.3. Failure thresholds are given in Section 3.4. The analysis of accident release frequencies for associated failure thresholds is given in Section 3.5. The accident frequencies, together with the dose values, provide the necessary input to provide an evaluation of acceptance of the risk related to the shipping campaign as outlined.

3.1.1 Discussion and Results

The DSWC failure thresholds were determined based on the special form tests performed on the DFAs per 49 CFR 173. Given the event where no failure thresholds were directly addressed by those tests, failure was conservatively assumed to occur. The conditional probabilities of release for mechanical and thermal accident scenarios were summed to give a total conditional release probability. The total conditional release probability was then multiplied by the Hanford Site annual accident rate to arrive at an annual accident release frequency. The annual release frequency was compared to the dose consequence results to determine acceptance. For the special form un-irradiated fuel, a comparison of the annual release frequency with the criteria determined from the dose consequence study showed the acceptance criteria are met. Therefore, the DSWC shipments will comply with onsite radiological transportation safety requirements.

3.2 RISK ACCEPTANCE CRITERIA

Graded dose limitations for probable, credible, and incredible accident frequencies ensure safety in radioactive material packaging and transportation (Mercado 1994). The dose limitations to the offsite and onsite individual for probable, credible, and incredible accident frequencies are presented in Table B3-1.

Table B3-1. Risk Acceptance Criteria Limits.

Description	Annual frequency	Onsite dose limit* Sv (rem)	Offsite dose limit* Sv (rem)
Incredible	$< 10^{-7}$	None	None
Incredible	10^{-7} to $< 10^{-6}$	None	.25 (25)
Credible	10^{-6} to 10^{-3}	.05/.15/.5 (5/15/50)	.005/.015/.05 (.5/1.5/5)
Probable	10^{-3} to 1	.002/.006/.02 (.2/.6/2)	.0001/.0003/.001 (.01/.03/.1)

*Effective dose equivalent/lens of eye/all other organs

3.3 DOSE CONSEQUENCE ANALYSIS RESULTS

A dose consequence study of seven irradiated DFA fuel assemblies was made in the Interim Storage Cask Safety Analysis Report for Packaging (SARP [Clements 1996]). The results of the dose consequence analysis showed that the accident release frequency is required to be in the credible range--that is, less than 10^{-3} . The DSWC will ship seven unirradiated fuel assemblies. The unirradiated fuel assemblies contain no fission or activation products and therefore is bounded by the dose consequence analysis for the irradiated assemblies. Therefore, requiring release frequencies in the credible range is conservative for this analysis.

3.4 PACKAGE FAILURE THRESHOLD ANALYSIS

The failure thresholds of the special form fuel are based on the testing requirements in 49 CFR 173.469 for special form radioactive material. No credit is taken for the DSWC or CCC. This is due simply to expedite the evaluation, since the assemblies, by themselves, provide sufficient containment. The failure thresholds are as follows:

- Impact: 48.3-km/h (30-mi/h) velocity change onto a typical Hanford Site surface. This value is taken from the impact test, which requires that special form material be subjected to a 9.14-m (30-ft) drop.

- **Puncture:** The fuel assembly fails a puncture test. (Note that the DSWC would provide puncture protection to a large extent.)
- **Crush:** Fails any crush force. (Again, the DSWC would provide protection for most accident scenarios.)
- **Fire:** Survives a 10-minute, 800 °C heat test (49 CFR 173.469). Fire failure thresholds are usually determined by the amount of time a container survives being engulfed in a fire. For this case, the special form material passes a 10-minute heat test at 800 °C. Because the fuel will be contained in the DSWC, which is constructed with a 76.2-cm (30-in.) wall of concrete, the heat test is being regarded as the failure threshold. Also, the values for the conditional failure probability of a package due to fire are based on the probability of the duration of the fire and not on the extent or type of the fire.

3.5 ACCIDENT FREQUENCY ASSESSMENT

3.5.1 Approach

The accident frequency assessment is based on the assumption that a single failure mode is appropriate for each of the different forces described as impact, puncture, crush, and fire. Package failure frequencies from different scenarios with similar consequences and the same type of force are summed to determine a composite failure mode for analysis. Fire and nonfire cases are summed to give a total conditional release probability.

The frequency (F) of a truck accident is the product of the annual number of trips, the number of miles per trip, and the accident rate per mile.

$$F = \text{number of trips/year} \times \text{miles/trip} \times \text{accidents/mile}$$

Hanford Site truck accidents have been compiled in a report using Site-specific data (Green et al. 1996). The resulting accident rate for trucks is 2.0×10^{-7} accidents per mile. Therefore $F = 5 \times 50 \times 2.0 \times 10^{-7} = 5 \times 10^{-5}$.

The frequency of truck accidents is multiplied by the sum of the conditional release probabilities of the specific failure modes to arrive at an annual accident release frequency.

3.5.2 Accident Release Frequency Analysis

An accident sequence analysis is developed for each failure type (impact, puncture, crush, and fire) and presented in Table B3-2. Information for the probability of occurrence and conditional probabilities of failure was taken from Dennis et al. (1978) and H&R (1995). The conditional probabilities are summed for comparison to the risk criteria. A summary of the evaluation is shown in Table B3-2.

Table B3-2. Accident Scenario Frequency Assessment Summary.

Accident scenario and failure magnitude	Probability of occurrence	Conditional probability of failure	Conditional release probability
Impact failure (48.3 km/h (30 mi/h))	0.80	0.0051	0.0041
Puncture (fails)	0.80	1.0	0.8
Crush failure (fails)	0.89	1.0	0.89
Fire (10 minute)	0.018	0.05	0.00092
Total conditional release probability (TCRP)			1.7
Annual release frequency = $TCRP \times F = 8.5 \times 10^{-5} \text{ y}^{-1}$			

The impact failure threshold is a 48.3-km/h (30-mi/h) change in velocity onto a typical Hanford Site surface. The probability of occurrence of a collision or overturn event is $0.80 \times F$ and the conditional probability of impact failure is 0.0051.

Both puncture and crush are conservatively assumed to produce failure in the fuel. The probability that an accident will involve crush forces is 0.89, and the probability of puncture is 0.80.

A special form radioactive material must withstand a 10-minute, 800 °C fire per 49 CFR 173.469. The probability of fire occurrence in an accident is 0.018, and the conditional probability of failure 0.05 (H&R 1995).

3.6 EVALUATION AND CONCLUSION

Table B3-2 shows the conditional release probabilities calculated for each scenario and sums them to give a total conditional release probability. The summed probability is then multiplied by F , the frequency, to arrive at an annual accident release frequency. The annual accident release frequency for five shipments of special form fuel with no credit taken for the container is 8.5×10^{-5} . This is less than 10^{-3} required to meet onsite safety requirements.

3.7 REFERENCES

49 CFR 173, 1996, "Shippers--General Requirements for Shipments and Packagings," *Code of Federal Regulations*, as amended.

Clements, M. D., 1996, *Safety Analysis Report for Packaging (Onsite) Interim Storage Cask*, WHC-SD-TP-SARP-010, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

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.

Green, J. R., B. D. Flanagan, and H. W. Harris, 1996, *Hanford Site Truck Accident Rate, 1990-1995*, WHC-SD-TP-RPT-021, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

H&R, 1995, *Recommended Onsite Transportation Risk Management Methodology*, H&R522-1, H&R Technical Associates, Inc., Oak Ridge, Tennessee.

HNF-CM-2-14, *Hazardous Material Packaging and Shipping*, Fluor Daniel Hanford, Inc., Richland, Washington.

Mercado, J. E., 1994, *Report on Equivalent Safety for Transportation of Radioactive Materials*, WHC-SD-TP-RPT-001, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

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4.0 CONTAINMENT EVALUATION

4.1 INTRODUCTION

The fuel pin cladding is assumed in this evaluation to provide the containment barrier. The CCC and DSWC provide a significant addition to the containment function. Should the DSWC and CCC be penetrated, the pin cladding would provide the necessary containment. There are no valves, penetrations, or other devices that could cause a loss of containment. Structural and thermal evaluations (Part B, Sections 3.0 and 8.0) and special form of the fuel assemblies demonstrate that there are no hazardous conditions for normal conditions of transport given in 10 CFR 71.

4.2 CONTAINMENT SOURCE SPECIFICATION

The authorized contents under this SEP are unirradiated fuel assemblies confined (canned) in a single, cylindrical, stainless-steel CCC. Six tubes are located around a central tube that provides the support for the lower CCC plate and the handling socket for grappling the CCC. The outside diameter of the CCC is 51 cm (20 in.) maximum, and length is 371 cm (146 in.) maximum. Weight of the CCC is estimated at 454 kg (1,100 lb). The CCC will store seven DFA containers, each having a decay heat not exceeding a maximum of 50 W and not exceeding a maximum total of 350 W. The weight of the CCC loaded with seven DFAs is less than the 680-kg (5,000-lb) limit. The CCC is designed to be a sealed (canned) container following the installation of the fuel assemblies. The confinement (canned) criterion for final CCC assembly is a leak rate of the closure seal to 1×10^{-1} std cm³/s. The entire CCC assembly leak rate verified at the manufacturer is 10^{-5} std cm³/s.

The containment boundary used for the evaluation is the driver fuel assemblies. On each DFA, the end caps are welded to the fuel pin cladding to form an encapsulating boundary for enclosed fuel pellets. The CCC and DSWC are shown to provide an additional level of confinement but are not included in the evaluation because the DFAs alone are sufficient.

4.3 NORMAL TRANSFER CONDITIONS

The fuel assemblies meet the special form requirements, and individual fuel pins are leak tested at fabrication. Special form requirements are much more severe than normal transfer conditions and therefore the DFAs are considered to withstand the normal transfer conditions. Confinement is effected by welding a closure plate over the top of the receptacle and shield plug.

4.4 CONTAINMENT EVALUATION

Structural evaluation (Part B, Section 5.0); thermal evaluation (Part B, Section 8.0); and risk evaluation (Part B, Section 3.0) demonstrate that there would be no loss of containment as a result of any credible accident conditions.

4.5 REFERENCES

WHC, 1995, *Safety Analysis Report for Packaging (Onsite) Disposable Solid Waste Cask Packaging System*, WHC-SD-TP-SARP-003, Rev. 0-B, Westinghouse Hanford Company, Richland, Washington.

5.0 SHIELDING EVALUATION

5.1 DISCUSSION

The radial reflector shipping container, which transports four DFAs, is basically a 14-gauge (0.078-in.-thick) cylinder made of carbon steel (WHC 1993). The radial reflector shipping container meets the U.S. Department of Transportation requirements of 200 mrem/h at any point on the outside surface and 10 mrem/h at any point 2 m from the surface. The DSWC, which transports seven DFAs, uses considerably more material for its construction including a 2.54-cm- (1-in.-) thick steel liner and over 50.8 cm (20 in.) of reinforced concrete on the side and 30.5-cm- (12-in.-) thick shield plugs on the ends (WHC 1995). Therefore, by comparison, the DSWC will meet the shielding requirements of 200 mrem/h at any point on the outside surface and 10 mrem/h at any point 2 m from the surface when transporting seven DFAs.

5.2 REFERENCES

- 10 CFR 71, 1994, "Packaging and Transportation of Radioactive Materials," *Code of Federal Regulations*, as amended.
- WHC, 1995, *Safety Analysis Report for Packaging (Onsite) Disposable Solid Waste Cask Packaging System*, WHC-SD-TP-SARP-003, Rev. 0-B, Westinghouse Hanford Company, Richland, Washington.
- WHC, 1993, *Safety Analysis Report for Packaging (Onsite) Radial Reflector Shipping Container*, WHC-SD-FF-SARP-001, Rev. 1, Westinghouse Hanford Company, Richland, Washington.

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6.0 CRITICALITY EVALUATION

6.1 DISCUSSION

The criticality evaluation was performed in *Criticality Safety Evaluation Report for Storage of FFTF Fuel Assemblies in Disposable Solid Waste Casks* (Part B, Section 6.2). This evaluation addresses the criticality aspect of storing CCCs with unirradiated fuel inside DSWCs, including transportation through the Reactor Service Building and the 400 Area. A DSWC containing seven unirradiated FFTF fuel assemblies is safely subcritical. The evaluation is similar to the one performed for the ISC cask (Clements 1996), which also transports seven fuel assemblies in a CCC. No additional administrative controls in this SEP are required by WHC-SD-SQA-CSA-514 (see appendix, Section 6.3).

6.2 REFERENCES

Clements, M. D., 1996, *Safety Analysis Report for Packaging (Onsite) Interim Storage Cask*, WHC-SD-TP-SARP-010, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

6.3 APPENDIX: CRITICALITY SAFETY EVALUATION REPORT

SEP 25 1996 Sta 34 22	ENGINEERING DATA TRANSMITTAL	Page 1 of 1 1. EDT 616573
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2. To: (Receiving Organization) FFTF	3. From: (Originating Organization) Criticality and Shielding	4. Related EDT No.: 616573
5. Proj./Prog./Dept./Div.: FFTF Plant	6. Design Authority/ Design Agent/Cog. Engr.: R. F. Richard	7. Purchase Order No.: NA
8. Originator Remarks: Transmittal of WHC-SD-SQA-CSA-514, Criticality Safety Evaluation Report for Storage of FFTF Fuel Assemblies in Disposable Solid Waste Casks		9. Equip./Component No.: NA
		10. System/Bldg./Facility: FFTF
11. Receiver Remarks:		12. Major Assm. Dwg. No.: NA
11A. Design Baseline Document? ☐ Yes ☒ No 9/25/96		13. Permit/Permit Application No.: NA
		14. Required Response Date: 9/30/96

15. DATA TRANSMITTED					(F)	(G)	(H)	(I)
(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	Approval Designator	Reason for Transmittal	Originator Disposition	Receiver Disposition
1	WHC-SD-SQA-CSA-514		0	Criticality Safety Evaluation Report for Storage of FFTF Fuel Assemblies in Disposable Solid Waste Casks	S,Q	1,2	/	/

16. KEY					
Approval Designator (F)		Reason for Transmittal (G)		Disposition (H) & (I)	
E, S, Q, D or N/A (see WHC-CM-3-5, Sec.12.7)		1. Approval	4. Review	1. Approved	4. Reviewed no/comment
		2. Release	5. Post-Review	2. Approved w/comment	5. Reviewed w/comment
		3. Information	6. Dist. (Receipt Acknow. Required)	3. Disapproved w/comment	6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION (See Approval Designator for required signatures)											
(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN
1	/	Cog. Eng. R. F. Richard	<i>R. F. Richard</i>	9/25/96	NO-35	1		Crit. Sfty Rep. J. E. Baker	<i>J. E. Baker</i>	9/25/96	NO-35
1	/	Cog. Mgr. J. Greenberg	<i>J. Greenberg</i>	9/25/96	NO-35	1	/	Tech. Review T. Chiao	<i>T. Chiao</i>	9/25/96	NO-35
1	/	Cog. J. E. Parker	<i>J. E. Parker</i>	9/25/96	N2-11						
1	/	Safety R. O. Zimmerman	<i>R. O. Zimmerman</i>	9/25/96	N2-10						

18. R. F. Richard Signature of EDT Originator	19. S. W. Miller Authorized Representative Date for Receiving Organization 9/19/96	20. J. Greenberg Design Authority/Cognizant Manager 9/12/96	21. DOE APPROVAL (if required) Ctrl. No. ☐ Approved ☐ Approved w/comments ☐ Disapproved w/comments
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BD-7400-172-2 (05/96) GEDF97

BD-7400-172-1

ref WHC-SD-SQA-CSA-514, Rev. 0

Criticality Safety Evaluation Report for Storage of FFTF Fuel Assemblies in Disposable Solid Waste Casks

R. F. Richard
Westinghouse Hanford Company, Richland, WA 99352
U.S. Department of Energy Contract DE-AC06-87RL10930

EDT/ECN: 616573 UC: 533
Org Code: 8M730 Charge Code: B93AU
B&R Code: EX7003000 Total Pages: 9

Key Words: Disposable Solid Waste Cask, CSWC, Criticality, FFTF

Abstract: This Criticality Safety Evaluation allows unirradiated FFTF fuel assemblies to be stored in Disposable Solid Waste Casks.

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Chris Killough
Release Approval

9-25-96
Date

Release Stamp

Approved for Public Release

A-6400-073 (10/95) GEF321

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CSER 96-016

Title: Criticality Safety Evaluation Report for Storage of FFTF Fuel Assemblies in Disposable Solid Waste Casks

Prepared by: RF Richard Date: 9/12/96
R. F. Richard
Engineer, Criticality & Shielding

Reviewed by: Tung Chiao Date: 9/12/96
T. Chiao
Engineer, Criticality & Shielding

Approved by: J. Greenberg Date: 9/12/96
J. Greenberg
Manager, Criticality & Shielding

gms RO Zimmerman Date: 9-19-96
R. O. Zimmerman
Team Leader, FFTF Safety

1.0 Introduction and Summary

Previous criticality analyses (Richard 1995) have addressed the storage of Core Component Containers (CCC), containing FFTF fuel, inside Interim Storage Casks (ISC). Unirradiated fuel was used for those analyses. An ISC is essentially a concrete annulus designed to accommodate a CCC with up to seven FFTF fuel assemblies or pin containers. The Disposable Solid Waste Cask (DSWC), currently available at FFTF, is also a concrete annulus with dimensions similar to that of an ISC. Using the available DSWCs for storage of CCCs containing unirradiated fuel will result in a cost savings by reducing the number of ISCs needed for interim storage.

This CSER addresses the criticality aspect of storing CCCs with unirradiated fuel inside DSWCs including transportation through the Reactor Service Building (RSB) and the 400 Area. Since a DSWC is nearly identical to an ISC the neutronic behavior of their contents is the same. A DSWC containing seven unirradiated FFTF fuel assemblies is safely subcritical.

2.0 System Description

The DSWC is a concrete annulus with an outer diameter of 84 inches and height of 172 inches. It has an inner carbon steel liner of thickness 0.937

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inch with an inside diameter of 22.13 inches. Sheet metal is wrapped around the outside of the liner to a thickness of 2.85 to 3.32 inches. A 12 inch thick carbon steel shield plug fits into the opening at the cask top. A closure plate is welded into place onto the DSWC above the shield plug.

DSWCs will be used for storage of CCCs containing unirradiated FFTF Driver Fuel Assemblies (DFA). After removal from the Interim Examination and Maintenance Cell a CCC will be loaded into a DSWC at the Cask Loading Station (CLS) by the Solid Waste Cask. The DSWC will then be transported by truck from the CLS through the RSB 550-ft level floor and 400 Area to the Plutonium Finishing Plant for storage.

3.0 Special Requirements and Controls

Since a DSWC lacks the high integrity seals of an ISC, thereby providing a less substantial water barrier, pin containers, which can be more reactive than fuel assemblies when moderated, are not allowed. A cover seal is not required for criticality safety. However, no moderator material is allowed in the DSWC.

4.0 Method of Analysis and Results

A DSWC is very similar to an ISC. They are both concrete casks with an inner carbon steel liner and shield plug. Their dimensions are nearly the same and are presented in Table 1.

Table 1. Cask Dimensions (inches)

Parameter	ISC	DSWC
Inner Diameter	21	22.13
Inner Height	150	147.6
Liner Thickness	1.5	0.937
Shield	3.0	2.85 to 3.32
Outer Diameter	83.75	84
Outer Height	180	172
Plug Thickness	12	12

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There are minor dimensional differences between the two casks. A DSWC has a slightly larger inner diameter than an ISC and a slightly shorter inner height. The liner of an ISC is thicker than that of a DSWC. An ISC has a 3.0 inch carbon steel shield outside of the liner. Rather than a solid shield, a DSWC has a carbon steel sheet metal wrap around the liner. The sheet metal is wrapped to a thickness of 2.85 to 3.32 inches. This wrapping is located along the axial length of the liner surrounding the fuel region of fuel assemblies in a CCC inside the DSWC. The outside diameter of a DSWC is slightly larger and the outside height is slightly shorter than an ISC. None of these differences have a significant effect on the neutronics of fuel stored in a cask.

Since a DSWC and ISC have very similar dimensions, results of the ISC analysis can be directly applied to the DSWC.

The ISC criticality analysis assumed the occurrence of the degradation phenomenon referred to as hot cell rot. Fuel pins that have experienced this phenomenon have been irradiated and stored in a hot sodium environment. Only unirradiated FFTF DFAs will be placed into CCCs that will be stored in DSWCs. Hot cell rot is not an issue for unirradiated fuel assemblies that have been stored in Interim Decay Storage (IDS) (Brehm 1996, Appendix A). Fuel assemblies that have experienced hot cell rot can assume more reactive geometries and therefore bound intact assemblies. Table 2 is a summary of results from the analysis of seven fuel assemblies in an ISC (Richard 1995). The flooded case is more reactive than the dry. Unirradiated fuel was used for all analyses. The unirradiated fuel enrichment used was that of the highest enriched standard DFA with 29.32 wt% plutonium containing 11.88 wt% ^{240}Pu . A ^{240}Pu content of ≥ 10 wt% rather than 11.88 wt% has only a minor affect on reactivity, and doesn't change the conclusions of this report.

Table 2. Summary of Results from ISC Analysis Seven Fuel Assemblies in an ISC		
Condition	k_{eff}	σ
Hot Cell Rot - Flooded	0.8201	0.0028
Intact Assemblies - Flooded	0.7836	0.0026
Intact Assemblies - Dry	0.4660	0.0017
Infinite Array of ISCs	0.8219	0.0028

The results clearly show that seven fuel assemblies stored in an ISC have a k_{eff} less than 0.95 at the 95 % confidence level. Assemblies affected by hot cell rot have a higher k_{eff} than those that remain intact. A DSWC will contain only unirradiated DFAs that have been stored in IDS and therefore they will remain intact. Since an ISC and a DSWC are very similar, the neutronic

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behavior will be no different from one to the other and therefore seven unirradiated fuel assemblies stored in a DSWC, and transported through the 400 Area, will also be safely subcritical. Fuel assemblies other than standard DFAs will require further analysis prior to storage in a DSWC.

Although a DSWC and ISC are similar there are seal differences that should be noted. An ISC has two high integrity mechanical seals blocking water access. A DSWC has a neoprene seal associated with the shield plug and the closure plate is welded in place. Even though the neoprene seal and the welded closure plate of the DSWC lack the integrity of the ISC seals, water leakage is not likely. Even if water were to enter the DSWC, the CCC inside has a high integrity seal to block water access. In addition, when flooded, a DSWC (like an ISC) with seven fuel assemblies will be safely subcritical even if hot cell rot is assumed. But since hot cell rot is not an issue, a flooded DSWC with seven unirradiated fuel assemblies will be even more subcritical.

As with an ISC, the contents of a DSWC will be neutronically isolated from its surroundings. They both have similar concrete thickness which provides the isolation and prevents interaction with any other casks. An infinite array of ISCs has a k_{eff} similar to that of a single ISC. A loaded DSWC is neutronically indistinguishable from a loaded ISC, therefore an infinite array of DSWCs would have the same k_{eff} as an infinite array of ISCs. Also, mixing DSWCs and ISCs in the array would have no effect on k_{eff} .

Since an infinite array of flooded DSWCs is subcritical, a Criticality Alarm System is not required. There are no fire fighting restrictions, therefore, the fire fighting category should be A.

There are five DSWCs available for storage of CCCs with seven fuel assemblies each. An additional calculation was done of five adjacent internally dry CCCs surrounded by 12 inches of concrete reflection. The k_{eff} is 0.5917 ± 0.0019 . The MONK6B Monte Carlo code was used. The input file for this calculation is CCC5DRY.

5.0 Contingency Analysis

From the above discussion it is clear that criticality is impossible when seven unirradiated DFAs are stored within a CCC inside a DSWC. There are no contingencies that would lead to a criticality. Even with the complete flooding of a DSWC criticality would not occur. An ISC containing an internally moderated CCC with six pin containers is safely subcritical, therefore, if a CCC containing 6 pin containers were loaded into a DSWC in error, the cask would remain subcritical even under flooded conditions. The concrete of the DSWC isolates the DFAs inside so that there is no neutronic interaction with its surroundings. A DSWC and its contents or an array of DSWCs will always remain far below a k_{eff} of 0.95 allowing for biases and a 2 σ confidence level.

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If a DSWC were to tip over due to an accident or seismic event and assume an end-to-end arrangement with another DSWC, there would be no affect on criticality safety. The contents of a DSWC are neutronically isolated from its surroundings and would not interact with the contents of another DSWC.

6.0 References

6.1 Documents

Richard, R. F., 1995, *Criticality Safety Evaluation for Long Term Storage of FFTF Fuel in Interim Storage Casks*, WHC-SD-FF-CSER-004, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Internal memo, WF Brehm to SW Hiller, "Hot Cell Rot Not an Issue for Safe Storage of Green Fuel in DSWC", July 15, 1996.

6.2 Drawings

H-4-302135, *ISC Assembly*, Westinghouse Hanford Company, Richland, Washington.

H-4-65155, *Steel Liner Weldment Details DSWC*, Westinghouse Hanford Company, Richland, Washington.

H-4-65157, *Disposable Solid Waste Cask Concrete Assembly*, Westinghouse Hanford Company, Richland, Washington.

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Appendix A
Hot Cell Rot Memo

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**Westinghouse
Hanford Company**

**Internal
Memo**

From: MECHANICAL ENGINEERING AND INSERVICE INSPECTION 96-051
Phone: 376-9779
Date: July 15, 1996
Subject: HOT CELL ROT NOT AN ISSUE FOR SAFE STORAGE OF UNIRRADIATED FFTF FUEL IN DSWC

To: SW Hiller

cc: JE Baker	N2-57	SL Mischke	N2-11
SA Chastain	H0-40	DL Nielsen	N2-53
JG Field	G1-11	JN Paglieri	N2-10
S Guttenberg	N2-53	PR Prevo	N2-10
JA Lamendola	N2-02	RF Richard	H0-35
CG McCargar	N2-56	WFB/File/Lb	

Several instances of post-irradiation brittle failure of LMR fuel pin cladding have been reported. The failures were generally observed during post-irradiation examination, and involved cracking and zero-ductility rupture of the stainless steel fuel cladding. These pins had been exposed to high temperatures and, usually, high neutron fluences as a result of their irradiation histories. Most, if not all, cases involved storage of the fuel pins in conditions where air and water vapor had access to the fuel pin for at least part of the storage period. The phenomenon has been labeled "hot cell rot".

Hot cell rot is thought to be a form of caustic stress-corrosion cracking, involving residual sodium hydroxide on surfaces of fuel pins; possible interaction of stainless steel with cesium and other fission products on the inner surface of the fuel pin diameter, and aggravated by high stresses resulting from long-time irradiation. In the more general case of caustic stress-corrosion cracking, the presence of moisture is definitely required.

For FFTF fuel pins associated with driver fuel assemblies and experiments, we essentially eliminate the hot cell rot issue by loading the washed fuel assemblies into a Core Component Container (CCC) in the IEM Cell argon atmosphere, and then placing the CCC in an Interim Storage Cask (ISC) containing high purity helium, and sealed with a confirmed leak rate of less than $1.0E-7$ (ten to the minus seven) cc/sec..

It is planned to wash the "green" or unirradiated FFTF fuel assemblies, that had been stored in the Interim Decay Storage sodium pool, in the IEM Cell, then load the assemblies into a CCC, and load the CCC's into a Disposable Solid Waste Cask (DSWC) for dry storage. The DSWC will not be inerted, but will be welded closed after loading. The issue of hot cell rot has been raised regarding storage of washed green fuel in a DSWC.

rot
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Discussion pertaining to hot cell rot and green fuel is presented below:

Hot cell rot has been seen only in irradiated fuel pin cladding that has experienced high temperature and high internal pressure from fission gas buildup during irradiation. Even after completion of irradiation, such fuel cladding will have considerable residual stress present. The green fuel has not experienced any fluence, high temperatures, severe thermal gradients, or high internal fission gas pressure. Therefore any residual stresses in the green fuel pins will be much lower than in irradiated fuel pins.

Hot cell rot is suspected to be associated with residual sodium or caustic fission products. Since the green fuel has not been irradiated, there will be no fission products. The moist argon-water rinse sodium removal process used in the IEM Cell for driver fuel assemblies has removed essentially all the sodium from fuel pin surfaces, based on examination of driver fuel assemblies after washing. The same process will be used for green fuel assemblies which are identical in geometry to the irradiated assemblies. Therefore, the presence of significant sodium on the green fuel pins after washing is extremely unlikely.

The CCC will be sealed in the IEM Cell. We have previously established that the IEM Cell atmosphere is a satisfactory environment for driver fuel assemblies. The leak rate in a sealed CCC is typically less than $1.0E-3$ cc/sec. The volume of a CCC is about $3.4E5$ cc. Therefore, it would take over ten years for air to leak in and replace the atmosphere in an inerted CCC. That number is itself very conservative, since the leak rate assumes one atmosphere differential pressure, and the inside and outside of the CCC would be at essentially equal pressure. The DSWC will be welded closed, retarding the potential for significant air leakage into the CCC even further.

With the three factors above considered together, the potential for the combination of stress, caustic, and moisture that could cause hot cell rot on green fuel pins washed in the IEM Cell and stored in a DSWC, is extremely small. Therefore, there should be no unacceptable risk storing washed green fuel in a DSWC, and the criticality analysis for green fuel storage need not account for fuel cladding degradation from "hot cell rot".

W F Brehm

W. F. Brehm, Fellow Engineer
FFTF Engineering

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CHECKLIST FOR INDEPENDENT TECHNICAL REVIEW

DOCUMENT REVIEWED

NUMBER: WHC-SD-SQA-CSA-514, Rev. 0TITLE: Criticality Safety Evaluation Report for Storage of FFTF Fuel Assemblies in Disposable Waste CasksReviewer(s) T. Chiao

I. Method(s) of Review

- ☐ 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)

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

III. Comments:

Comments have been incorporated in the text

IV. REVIEWER:

Tang Chiao

DATE:

7/7/96

7.0 STRUCTURAL EVALUATION

7.1 INTRODUCTION

The purpose of this section is to provide a structural evaluation for the DSWC packaging system, while transporting seven DFAs, against applicable Hanford Site-specific requirements. This evaluation relies on previous evaluations performed for the DFAs and DSWC. The DFAs have been evaluated to the special form requirements in *FTR Fuel Assembly, Special Form Evaluation* (Colton 1978). Evaluations for the DSWC can be found in WHC-SD-TP-SARP-003 (WHC 1995) and the original DSWC design analysis report (NuPac 1982).

7.2 STRUCTURAL EVALUATION OF PACKAGE

The DFAs meet the "special form" requirements of 49 CFR 173.469. Included in the special form tests is an impact test 9.1-m (30-ft drop), percussion test, bending test, and heat test (800 °C [1,472 °F] fire for 10 minutes). No chemical or galvanic reactions will occur between the packaging materials and contents.

The DFAs were stored in the interim decay storage (IDS) pool for a period of several years at temperatures up to approximately 204 °C (400 °F). The sodium flow was very low, and the IDS sodium purity is maintained and monitored at a very low (about 1 ppm) oxygen in sodium. Under such conditions, sodium is essentially an inert environment. The washing process involves reaction of the small amount of sodium adherent to the DFA after its removal from IDS in a moist argon environment for approximately one hour, followed by rinsing with high-purity 93 °C (200 °F) water. The rinse water conductivity is monitored; the rinse process is complete when the conductivity of the rinse water is reduced to 20 micromhos/cm. The DFA is then dried to a very low dew point and removed to the interim examination and maintenance cell, which has a moisture content of about 100 ppm. No residual sodium, sodium hydroxide, or moisture is left on the DFA after the washing and drying process. In conclusion, the sodium storage and washing process for the unirradiated DFAs does nothing to adversely affect the mechanical properties of the material, and the Special Form Evaluation is still valid.

No physical change to the DSWC has occurred other than no impact limiters will be used during transport. The original lifting equipment designed for the DSWC will be used. No tiedown devices exist that are a structural part of the package.

7.2.1 Brittle Fracture

In accordance with the guidance provided in Regulatory Guide 7.11 (NRC 1991), brittle fracture criteria are only imposed on the containment boundary of a package. The containment boundary (DFA) is made of 316 austenitic stainless steel. The American Society of Mechanical Engineers code exempts austenitic stainless steel and bolting material 2.54 cm (1 in.) and less in diameter from low-temperature testing for brittle fracture (ASME 1989).

7.2.2 Weights and Center of Gravity

The total weight (fully loaded) of the DSWC is 43,553 kg (96,017 lb). The maximum payload weight is 2,268 kg (5,000 lb). A summary of the component weights is provided in WHC-SD-TP-SARP-003 (WHC 1995). The payload, one CCC 499 kg (1,100 lb) and seven DFAs (7 @ 176.9 = 1,238.3 kg [7 @ 390 = 2,730 lb]), is 1,737.3 kg (3,830 lb), which is below the maximum payload weight of 2,268 kg (5,000 lb).

The DSWC is completely axisymmetric and very nearly symmetric about its central cross section normal to the longitudinal axis. The center of gravity is taken as the point on the centerline halfway up the cask.

7.2.3 Positive Closure

The end caps are welded to the fuel pin cladding to form an encapsulating boundary for enclosed fuel pellets. Positive DSWC closure confinement is achieved by welding a permanent closure plate to the receptacle. The welded closure plate also acts as the tamperproof feature.

7.3 NORMAL TRANSFER CONDITIONS

7.3.1 Conditions To Be Evaluated

The following conditions or events are intended to envelop the effects of Hanford Site normal transport conditions.

- Free drop from a height of 30.48 cm (1 ft) onto an unyielding surface in the worst loading orientation
- Vibration normally incident to transportation
- Penetration of a 5.91-kg (13-lb), 3.175-cm- (1.25-in.-) diameter steel rod dropped from a height of 1 m (39.37 in.)
- Application of water spray that simulates rainfall of approximately 5.08 cm (2 in.).

7.3.2 Discussion

Individual fuel assemblies meet special form requirements, which are more severe than the four normal transport conditions listed above. The cask is not shown to retain the contents if dropped upside down, because the contents may impact the closure plate and cause failure. The cask is operationally controlled to preclude an upside down drop.

Experience has shown that vibration and vibration resonance have had no adverse effects on the package during use, and they have also demonstrated no adverse effects during test runs. Transfer speed limit is 16.1 km/h (10 mi/h).

Drum packages with sheet metal thicknesses of 14-gauge steel, less than that of the DSWC containment, routinely pass the penetration bar test. By analogy, the DSWC will pass the penetration bar test.

The DSWC is constructed of concrete and carbon steel, which are painted with an epoxy coating. The DSWC is positively sealed by welding; wetting the packaging will have no adverse effects.

7.4 ACCIDENT CONDITIONS

A risk assessment was performed in Part B, Section 3.0, to evaluate the driver fuel assemblies under credible accident conditions. The evaluation concludes that risk associated with the onsite transfer of seven DFAs from the FFTF to the Plutonium Finishing Plant is acceptable.

The failure thresholds used in the risk analysis for the special form fuel are based on the testing requirements in 49 CFR 173.469 for special form radioactive material. Conservatively, no credit was taken for the DSWC and CCC.

7.5 REFERENCES

49 CFR 173, 1996, "Shippers--General Requirements for Shipments and Packagings," *Code of Federal Regulations*, as amended.

ASME, 1989, *American Society of Mechanical Engineers Boiler and Pressure Vessel Code*, Section III, Subsection NC, American Society of Mechanical Engineers, New York, New York.

Colten, L. B., 1978, *FFTF Fuel Assembly Special Form Evaluation*, HEDL-TC-1095, Hanford Engineering Development Laboratory, Richland, Washington.

NRC, 1991, *Fracture Toughness Criteria of Base Material for Ferritic Steel Shipping Cask Containment Vessels with a Maximum Wall Thickness of Four Inches*, Regulatory Guide 7.11, Rev. 0, U.S. Nuclear Regulatory Commission, Washington, D.C.

NuPac, 1982, *Design Analysis Report for the FFTF Disposable Solid Waste Cask*, D-1, Rev. 3, Nuclear Packaging Inc., Federal Way, Washington (released by EDT 118712, July 27, 1990).

WHC, 1995, *Safety Analysis Report for Packaging (Onsite) Disposable Solid Waste Cask Packaging System*, WHC-SD-TP-SARP-003, Rev. 0-B, Westinghouse Hanford Company, Richland, Washington.

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8.0 THERMAL EVALUATION

8.1 DISCUSSION

The thermal evaluation provided in the original DSWC SARP, WHC-SD-TP-SARP-003 (WHC 1995), shows that the DSWC meets the applicable standards for onsite transfer when restricted to a maximum of 400-W payloads. The DFAs have a maximum heat generation of less than 50 W each according to WHC-SD-FF-SARP-001 (WHC 1993). Therefore, the total heat load provided by seven DFAs would be less than 350 W, which is below the 400-W maximum.

8.2 REFERENCES

- WHC, 1995, *Safety Analysis Report for Packaging (Onsite) Disposable Solid Waste Cask Packaging System*, WHC-SD-TP-SARP-003, Rev. 0-B, Westinghouse Hanford Company, Richland, Washington.
- WHC, 1993, *Safety Analysis Report for Packaging (Onsite) Radial Reflector Shipping Container*, WHC-SD-FF-SARP-001, Rev. 1, Westinghouse Hanford Company, Richland, Washington.

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9.0 PRESSURE AND GAS EVALUATION

9.1 GAS GENERATION

Gas generation within the DSWC cavity will not occur during normal transport conditions. The mixed oxide fuel is clad in stainless steel, confined in the fuel assemblies, and contained within the CCC. The gas generated from the decaying fuel can be considered negligible and will have little effect even if released from the fuel assemblies.

9.2 PACKAGE PRESSURE

The CCC within the DSWC can realize an increase in its ambient pressure by way of the temperature differential between the purge gas temperature and the temperature of the cask internals. Expansion occurs in the heating of the dry inert atmosphere from normal or accident conditions. The CCC has a Helicoflex¹ metallic o-ring for sealing purposes with a leak rate of 10^{-3} cm³/s corrected to 1 atmosphere differential pressure.

The maximum internal pressure of the DSWC, loaded with a 600-W heat load, is 20.68 kPa (3.0 lbf/in²) and is below the allowable as evaluated in WHC-SD-TP-SARP-003 (WHC 1995). WHC (1995) provides the pressure evaluation for the DSWC cask.

9.3 REFERENCES

WHC, 1995, *Safety Analysis Report for Packaging (Onsite) Disposable Solid Waste Cask Packaging System*, WHC-SD-TP-SARP-003, Rev. 0-B, Westinghouse Hanford Company, Richland, Washington.

¹ Helicoflex is a trademark of Helicoflex Corporation.

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10.0 TIEDOWN SYSTEM EVALUATION

The DSWC tiedown system described here is designed for use with the DSWC without impact limiters and utilizes the original DSWC trailer. The tiedown system is designed to meet the requirements of 49 CFR 393.102 and standard commercial practice. The system is composed of two primary components, an upper section and a lower section, which restrain the DSWC from movement on the trailer. At the top of the DSWC, the tiedown structure is installed to secure the cask from vertical movement and prevent tip-over. Underneath the DSWC is a kick plate mounting structure, which acts as blocks restraining both lateral and longitudinal movement of the DSWC. The tiedown is fastened to the trailer using chain and ratchet binders. The system uses the currently installed interim storage cask (ISC) tiedown points on the trailer as they are more than adequate for this use. Using the existing DSWC bolt pattern, the kick plate is fastened to the existing lowboy trailer.

10.1 SYSTEM DESIGN

The modified DSWC tiedown system is analyzed and evaluated in Part B, Section 10.5.

The primary components of the DSWC tiedown system are the kick plate, top tiedown structure, trailer tiedown brackets, chain, and ratchet binders. The tiedown system is designed not to be a structural part of the DSWC and subsequently is not subject to the 10-5-2g loading requirements of 10 CFR 71.

The tiedown structure (see drawing on page B10-5) located at the top of the DSWC is a C-channel, C 8 x 18.75, made of American Society for Testing and Materials (ASTM) A-36 carbon steel bent in a ring 215.9 cm (85 in.) in diameter. The ring has an X-frame consisting of a 10.16-cm- (4-in.-) wide by 1.27-cm- (0.5-in.-) thick plate and a 2.54-cm x 10.16-cm (1-in. x 4-in.) bar across the top for support. A 1.91-cm (0.75-in.) plate is welded in four places to the C-channel for the tiedown point to the chain and shackles.

The DSWC must be placed on the trailer and the top tiedown structure installed on the DSWC as shown in Figure A6-1. This is required to ensure that there is no interference of the tiedown system with the DSWC closure plate lifting eyes.

The tiedown trailer brackets are borrowed from the ISC tiedown system (drawing H-4-302136). These brackets are two ASTM A-36 carbon steel plates welded to form a "T" section. The 6.35-cm (2.5-in.) web section is offset from vertical by 5.3° to facilitate fit-up with the ISC ratchet binders. Each of the four units are secured to the trailer by four 1.5-in.-diameter bolts, which are bolted through the 5.72-cm (2.25-in.) base plate to the underside of the trailer deck.

The kick plate structure (see drawing on page B10-6) is fundamentally a 266.7-cm- (105-in.-) round, 2.54-cm- (1.0-in.-) thick plate constructed of ASTM A-36 carbon steel fitted with kick plate brackets. At each quadrant of the main plate, a kick plate bracket is welded. The kick plate bracket is essentially a curved section of 2.54-cm (1.0-in.) plate with a 215.9-cm

(85-in.) radius, 55.88 cm (22.0 in.) in length, welded to the main plate and fitted with three 2.54-cm (1.0-in.) gusset plates. In the center of the main plate is an 81.28-cm (32-in.) circular cutout and six equally spaced threaded bolt holes on a 96.52-cm- (38-in.-) diameter bolt circle. These bolt holes are used to fix the kick plate structure to the trailer bed with six 1.5-in. bolts threaded from underneath the trailer.

The worst-case loading of the tiedown system is the U.S. Department of Transportation regulatory requirement, 49 CFR 393.102, that the aggregate working load limit of the tiedown assemblies used to secure an article against movement in any direction must be at least 0.5 times the weight of the article.

10.2 TIEDOWN EVALUATION

The tiedown evaluation is based on loads applied by the governing securement loading case, which is a lateral loading of 0.5g applied at the center of gravity of the DSWC. The 0.5g load is derived from 49 CFR 393.102 that states that the aggregate working load limit of the tiedown assemblies used to secure an article against movement in any direction must be at least 0.5 times the weight of the article. Therefore, depending on the tiedown component, the applied load may be less than 0.5g. The aggregate working load limit shall not be less than $43,545 \text{ kg} \times 0.5 = 21,772 \text{ kg}$ ($96,000 \text{ lb} \times 0.5 = 48,000 \text{ lb}$). For the purpose of providing conservatism, a working load limit of 22,680 kg (50,000 lb) is used throughout the evaluation.

10.2.1 Tiedown Trailer Bracket

The analysis of the tiedown trailer bracket is provided in Part B, Section 10.5. Based on the working load limit of the tiedown chains, the load applied to the brackets was 5,783 kg (12,750 lb). The analysis checked the welds and bolts on the bracket for the new loading direction since these brackets were originally designed for use with the ISC. The margin of safety for the welds is 3.6, and the margin of safety for the bolts is determined to be large.

10.2.2 Kick Plate Bracket

The analysis of the kick plate bracket is provided in Part B, Section 10.5. The load applied to the kick plate bracket was 22,680 kg (50,000 lb) in a perpendicular direction to the bracket face. The weakest part of the design is the welds. All lateral load is transferred to the gusset and its weld. The analysis checked the welds of the plate. A conservative analysis of the weld shows a margin of safety of 0.16.

10.2.3 Top Tiedown Assembly

The analysis of the top tiedown assembly is provided in Part B, Section 10.5. The loads applied to the top tiedown assembly are 5,783 kg (12,750 lb) at each of the four chain tiedown points and the reaction applied

to the cross member support. The weld between the plate and C-channel of the tiedown point was analyzed and found to be adequate. The bending stress of the x-frame was also found to be acceptable.

10.3 ATTACHMENTS AND RATINGS

Information related to the chain, shackles, and ratchet type load binder used between the top tiedown assembly and tiedown trailer bracket is shown in Table B10-1. The minimum working load limit must be 5,897 kg (13,000 lb). Two shackles previously obtained for the top tiedown assembly are also being used in the tiedown system. The working load limit for the shackles already obtained are 8,618 kg (19,000 lb) and 5,896 kg (13,000 lb).

Table B10-1. Information on Tiedown Assemblies.

Attachment	Crosby stock No.	Working load limit kg (lb)
Screw pin shackle	NA	8,618 kg (19,000)
Screw pin shackle	NA	5,896 kg (13,000)
¾-in. chain (Grade 8)	273563	8,210 kg (18,100)
Ratchet load binder (L-140)	1048440	5,897 kg (13,000)
Clevis chain hook with latch (S-314A)	1225162	8,210 kg (18,100)
1-in. master link (A-342)	1014324	11,050 kg (24,360)
1½-in. screw pin shackle (S-210)	1019427	22,680 kg (50,000)

10.4 REFERENCES

10 CFR 71, 1996, "Packaging and Transportation of Radioactive Material," *Code of Federal Regulations*, as amended.

49 CFR 393, 1996, "Parts and Accessories for Safe Operation," *Code of Federal Regulations*, as amended.

Crosby, 1994, *General Catalog*, The Crosby Group, Inc., Tulsa, Oklahoma.

10.5 APPENDIX: TIEDOWN SYSTEM ANALYTICAL CALCULATIONS

ANALYTICAL CALCULATIONS

Page 1 of 13

Subject DSWC Tiedown System
 Originator Bryan Flanagan B. Eng Date 10/10/96
 Checker Tom Tomatjowski Date 11-22-96

Kickplate Bracket Weld

$$F_a = .4 \times \text{base yield} \\ = .4 \times 36,000 \\ F_a = 14,400$$

Determine size of fillet weld required for the support fixture. Assume no weld on curved 22" long plate. Assume fixture is infinitely stiff.

$$f_1 = \frac{V}{A_w} \quad f_2 = \frac{M}{S_w} \quad A_w = 6.8 = 48.1 \text{ in}^2 \\ S_w = \frac{(6.8)^{3/2}}{6} = 6.8 = 64.1 \text{ in}^3$$

$$f_1 = \frac{50k}{48} = 1041.67 \text{ lb/in}$$

$$f_2 = \frac{4' \cdot 50k}{24} = 3125 \text{ lb/in}$$

$$F = \sqrt{f_1^2 + f_2^2} = \sqrt{1041.67^2 + 3125^2} = 3294$$

$$W_r = \frac{F}{(1.33)(F_a)} = \frac{3294}{(1.33)(14400)} = 0.324 \text{ in} \quad M.S. = \frac{.375}{.324} - 1$$

Therefore use $\frac{3}{8}$ " weld $M.S. = 0.16$

ANALYTICAL CALCULATIONS

Page 3 of 13Subject DSWC Tie-down SystemOriginator Brian Flanagan B. FlanaganDate 10/31/96Checker Tom TomaszewskiDate 11-22-96

Calculating Torque for Bolts and Screws

Tension preload caused by torquing
(Standard Handbook of Fastening and Joining)

$$T = KDP$$

T = installation Torque in-lb.

K = Torque coefficient

D = nominal bolt diameter in.

P = clamp load objective lb.

Using - Hex Head Bolt $1\frac{1}{2}$ - 6 UNC - 2A ASTM A-325

Allowable load on bolt - 77,700 lb. (AISC)

Clamp load objective is .39 - .44 of allowable

$$P = .39(77,700) = 30303 \text{ lb} \quad P = .44(77,700) = 34188 \text{ lb}$$

$$D = 1.5 \text{ in}$$

$$K = 0.20 \text{ (Dry, unlubricated)}$$

$$T_{.39} = (0.2)(1.5)(30303) = 9091 \text{ in-lb} \cdot \frac{1}{12} \frac{\text{ft-lb}}{\text{in-lb}}$$

$$= 758 \text{ ft-lb}$$

$$T_{.44} = (0.2)(1.5)(34188) = 10256 \text{ in-lb}$$

$$= 855 \text{ ft-lb}$$

Therefore, use torque value of 750 - 850 ft-lb.

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 4 of 13
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject DSWC Tie-down System
 (8) Originator R.S. Marlowe Date 12/17/96
 (9) Checker Harold E. Adkins, Jr. Date 12/17/96

(10)

Determine the minimum thread engagement for bolts and screws used in the tie-down system. The minimum length is controlled by the shear stress in the internal threads in the A-36 plate which take the 1½-6UNC-2A ASTM A-325 bolts. The maximum load in these bolts is 34,188 lbf. The internal thread shear area, A_n , is given

$$A_n = \pi n L_e D_{min} \left[\frac{1}{2n} + 0.57735 (D_{min} - E_{max}) \right]$$

where L_e is the engagement length, n is the number of threads per inch, D_{min} is the minimum major diameter of the external thread, and E_{max} is the maximum pitch diameter of the internal thread (Oberg 1978). These values may be found in Oberg 1978. The shear area is:

$$A_n = \pi 6 L_e 1.4794 \left[\frac{1}{12} + 0.57735 (1.4794 - 1.4022) \right] = 3.5668 L_e$$

where A_n is in units of in² and L_e is in units of inches. The allowable shear in the A-36 plate is taken to be 14,400 lbf/in², a standard value according to the American Institute of Steel Construction. The length of engagement is given by

$$L_e = \frac{34,188}{(14,400)(3.5668)} = 0.7 \text{ in.}$$

Use a thread length of 0.875 in.

REFERENCE:

Oberg, Erik, 1978, et al, *Machinery's Handbook*, Twentieth Edition, Industrial Press, New York, New York.

ANALYTICAL CALCULATIONS

Page 15 of 13

Subject DSWC Tiedown System
 Originator Randall S. Marlow Date 12/19/96
 Checker Harold E. Atkins, Jr. Date 12/19/96

$\hat{n}$ = unit vector in direction of cable

$$\hat{n} = \frac{(63-32)\hat{i} + (-42+32)\hat{j} + (6-169.5)\hat{k}}{[31^2 + 10^2 + 163.5^2]^{1/2}}$$

$$\hat{n} = 0.1859\hat{i} - 0.0600\hat{j} - 0.9807\hat{k}$$

ANALYTICAL CALCULATIONS

Page 6 of 13Subject DSWC Tiedown SystemOriginator Randall S. MarlowDate 12/19/96Checker Harold E. Atkins, Jr.Date 12/19/96Tension in Cable (Chain) $T \equiv$ cable tension force

$$I = T [0.1859 \underline{\underline{L}} - 0.0600 \underline{\underline{x}} - 0.9807 \underline{\underline{L}}]$$

where T is the cable tension. The tension developed by 0.5g upward acceleration is given by

$$T = \frac{50,000}{4(0.9807)} \approx 12,750 \text{ lbf}$$

To prevent tipping from a side load, a tension must develop in 2 cables:

The overturning moment is

$$50,000 (86.375) - 100,000 \left(\frac{84}{2} \right) = 118,750 \text{ in-lbf}$$

about the y-axis. The moment caused by the cable tension is

$$2 \underline{\underline{x}} \cdot T \begin{vmatrix} \underline{\underline{L}} & \underline{\underline{x}} & \underline{\underline{L}} \\ 74 & -32 & 164.5 \\ 0.1859 & -0.06 & -0.9807 \end{vmatrix} = 208 T$$

ANALYTICAL CALCULATIONS

Page 7 of 13Subject DSWC Tiedown SystemOriginator Randall S. Marlowe, EITDate 12/19/96Checker Harold E. Atkins, Jr. EITDate 12/19/96

To prevent tipping, the tension T required is

$$T = \frac{118,750}{208} = 571.16\text{ lb}$$

which is minimal. Use tension of 12,750 lb.

Bolt Shear

The shear in a bolt which attaches the plate to the trailer is

$$T = \frac{50,000}{6(1405)}$$

$$\tau = 5,930.16\text{ lb/in}^2$$

which is below the AISC allowable.

Tension Components

The downward force is 12,500 lb. The axial lug force is $T_L \cdot (0.7L - 0.7x) = 2,220\text{ lb}$. The force normal to the lug in horizontal plane is $T_L \cdot (0.7L + 0.7x) = 1,135\text{ lb}$.

ANALYTICAL CALCULATIONS

Page 8 of 13

Subject PSWC Tiedown System
 Originator Kentall S. Martin
 Date 12/19/96
 Checker Kim E. Alving, Jr.
 Date 12/19/96

Vertical component = 12,500 lbf
 Force in x-dir = 2,370 lbf
 Force in y-dir = 765 lbf

Weld:

$$M_x = 765 (6) = 4,590 \text{ in-lbf}$$

$$S_w = b d = 8 (2.5) = 20 \text{ in}^2$$

$$F_x = \frac{M_x}{S_w} + \frac{A_s}{V} = \frac{4590}{20} + \frac{16}{765}$$

$$= 280 \text{ lbf/in}$$

$$M_y = 2370 (6) = 14,220 \text{ in-lbf}$$

$$S_w = d^2/3 = 8^2/3 = 21.3 \text{ in}^2$$

$$F_y = \frac{14,220}{21.3} + \frac{16}{2370} = 820 \text{ lbf/in}$$

$$F_z = 12,500/6 = 780 \text{ lbf/in}$$

$$F = [280^2 + 820^2 + 780^2]^{1/2} = 1,170 \text{ lbf/in}$$

$$w = \frac{1170}{(0.7)(14,400)} = 0.12$$

$$M.S. = \frac{.12}{.5} = .24 - 1 = 3.2 \text{ weld is OK}$$

ANALYTICAL CALCULATIONS

Page 9 of 13

Subject DSAC Tiedown System
Originator Randall S. Markin 12/19/96 Date CSM
Checker Harold E. Ankles, Jr. MEH Jr. Date 12/19/96

Bolts

The load from the tiedown system produces negligible stress in the 4 1 1/2 - 6UNC - 2A ASTM A-325 bolts which anchor the attachment point.

ANALYTICAL CALCULATIONS

Page 10 of 13Subject DSWC Tiedown SystemOriginator Randall S. MarlowDate 12/19/96Checker Harold E. Atkins, Jr.Date 12/19/96Top Ring Tiedown Point

The force on the weld is computed elsewhere (see p. B10-30) using the finite-element method. The force on one leg of the fillet weld was found to be 2,160 lbf/in. The required weld size is

$$w = \frac{2,160}{.7(14,400)} = 0.21.$$

The actual weld is 0.25. The margin of safety is

$$M.S. = \frac{.25}{.21} - 1 \approx 0.2$$

ANALYTICAL CALCULATIONS

Page 11 of 15Subject DSWC Tiedown SystemOriginator Bryan Flanagan E. J.Date 11/6/96Checker Tom TomaszewskiDate 11-22-96Top Tiedown Assembly - Bending of Cross Support Find I for section

$$A_1 = 2 \text{ in}^2 \quad A_2 = 4 \text{ in}^2$$

New C.G. (NEUTRAL AXIS, NA)

$$G C_1 = (4)(1.5)(1.25) + (1)(4)(2.5)$$

$$C_1 = 1.75 \quad d_1 = C_1 - \frac{1}{2}(1.5) = 1.5$$

$$C_2 = 2.75 \quad d_2 = C_2 - \frac{1}{2}(4) = 0.75$$

$$I_1 = \frac{b h^3}{12} = \frac{4(1.5)^3}{12} = 0.042 \text{ in}^4$$

$$I_2 = \frac{b h^3}{12} = \frac{1(4)^3}{12} = 5.33 \text{ in}^4$$

$$I_{TOT} = I_{cg} + A d^2$$

$$I_{TOT} = [0.042 + 2(1.5)^2] + [5.33 + 4(0.75)^2]$$

$$= 4.542 + 7.58$$

$$I_{TOT} = \underline{\underline{12.12 \text{ in}^4}}$$

ANALYTICAL CALCULATIONS

Page 12 of 13Subject PSWC Tiedown SystemOriginator Randall S. MarlowDate 12/19/96Checker Harold E. Adkins, Jr.Date 12/19/96

Assume simple beam connection:

$$\text{Maximum Moment} = 12,500(6) = 75,000 \text{ in. lb}$$

$$\sigma_T = \text{bending stress} = \frac{Mc}{I} = \frac{75,000(2.75)}{12.12} = 17,000 \text{ lb/in}^2$$

$$\tau = \frac{12,500}{(1)(12.12)} \int_{y_0}^{2.75} y(1) dy \quad -1.25 \leq y_0 \leq 2.75$$

$$\tau_{\max} = \frac{12,500}{2(12.12)} (2.75^2 - 0) = 3,900 \text{ lb/in}^2$$

at the neutral axis.

At the extreme fiber, $\tau = 0$.

$$\begin{aligned} \text{Bending stress allowable} &= 0.6(36,000) \\ &= 21,600 \text{ lb/in}^2 \end{aligned}$$

Shear is negligible.

$$M.S. = \frac{21,600}{17,000} - 1 = 0.27$$

ANALYTICAL CALCULATIONS

Page 15 of 13Subject OSWC Tiedown SystemOriginator Randall S. Marlow CSMDate 12/12/96Checker Harold E. Atkins, Jr. MPEDate 12/14/96Stitch Weld

The shear stress at the weld joint is

$$\tau = \frac{12,500}{2(12.12)} (2.75^2 - 1.25^2)$$

$$= 3,094 \text{ lbf/in}^2$$

The force/length on the weld is :

$$f = \frac{3,094(1)}{2} = 1,550 \text{ lbf/in}$$

Required weld size is

$$w = \frac{1,550}{(0.7)(14,400)} = 0.15 \text{ in.}$$

Since weld is 3 in. long with 6 in. between centers, increase weld size by a factor of 2.

$$\text{Required } w = 2 \times 0.15 = 0.3 \text{ in}$$

use $3/8"$ weld

$$MS = \frac{.375}{.3} - 1 = 0.25$$

CHECKLIST FOR CHECKING OF ANALYSIS/CALCULATIONSDocument Checked DSWC Tiedown Ring AnalysisAuthor R.S. Marlow Report No. _____ EDT No. _____

Yes No N/A

☒	☐	☐	Problem adequately defined.
☒	☐	☐	Necessary assumptions stated and supported.
☒	☐	☐	Computer codes and data files documented.
☒	☐	☐	Data used in calculations stated in document.
☒	☐	☐	Data checked for consistency with original source information as applicable.
☒	☐	☐	Mathematical derivations checked including dimensional consistency of results.
☒	☐	☐	Models appropriate and used within range of validity or use outside range of established validity justified.
☒	☐	☐	Hand calculations checked for errors.
☒	☐	☐	Computer code run streams correct and consistent with analysis documentation.
☒	☐	☐	Computer code output consistent with input and with results reported in analysis documentation.
☒	☐	☐	Acceptability limits on analytical results applicable and supported. Limits checked against sources.
☒	☐	☐	Safety margins consistent with good engineering practices.
☒	☐	☐	Conclusions consistent with analytical results and applicable limits.
☒	☐	☐	Results and conclusions address all points required in the problem statement.

I have checked the analysis/calculation and its complete and accurate to the best of my knowledge.

<u>12/12/96</u>
Checker	Date
<u>12/19/96</u>

DSWC Tie-Down Ring Analysis

Randall S. Marlow
12/11/96

1.0 Introduction

This document describes the analysis of the critical welds in the re-design of the DSWC tie-down ring (Williams 1996). The critical welds are the 1/4" fillet welds between the webs of the criss-crossing T-beams and the top flange of the channel which forms the ring. The criss-crossing webs were added to the design to limit the deformation of the tie-down ring under the tie-down loads.

2.0 Analysis**2.1 Modeling**

Figure 2.1-1 shows the ABAQUS/Standard (HKS 1995) finite-element model which was constructed to determine the forces on the critical welds. The finite-element mesh is made of 4-noded shell of the type called S4R in the ABAQUS vernacular. The material model is linear-elastic with a modulus of 29,000,000 lbf/in² and a Poisson's ratio of 0.3.

A downward vertical load of 12,500 lbf is applied to each one of the tie-down tags to model the loading of the ring by the tie-down cables. Loads in the horizontal plane are neglected. The mesh is constrained in the displacement degrees-of-freedom at the four nodes which are at the locations in the model which correspond to the locations where the tie-down ring is in contact with the DSWC.

The two gussets which prevent warping of the webs of the T-beams are not included in the model. In the model, a 1-in. thick gusset has been added between the end of one T-beam and the nearby tag to investigate the effect of a proposed design change. The gusset is shown in Figure 2.1-2.

The ABAQUS/Standard input file for the analysis is contained in Attachment A. Note that lengthy node and element definitions are not included.

2.2 Results

The direct tensile force/length in the T-beam web normal to the critical weld is contoured in Figure 2.2-1. The maximum force/length is 15,800 lbf/in. The force/length in the T-beam web parallel to the weld is contoured in Figure 2.2-2. The maximum is 5,100 lbf/in. The maximum force/length is the square-root of the sum of the squares of the tensile and shear forces, or 16,600 lbf/in. The stressed area of a 1-in. long segment of a 1/4" fillet weld is approximately 0.25 in². The weld stress is therefore $16,600/(2)(0.18) = 46,100$ lbf/in². The allowable weld stress is assumed to be 14,400 lbf/in². The weld alone is clearly unacceptable.

The addition of the gusset removes the unacceptable weld stress. Figure 2.2-3 is a contour of the direct tensile force/length in the T-beam web and gusset normal to the critical weld. The maximum force/length is 2,510 lbf/in. Figure 2.2-4 is a contour of the force/length parallel to the weld. The maximum force/length is 620 lbf/in. If the gusset is welded to the tag with two ¼" fillet welds along the length of the top of the tag, then the stress in this weld (which in this case is greater than the stress in the so-called critical weld) is only 7,200 lbf/in², which is far below the allowable.

The deformed shape of the tie-down ring is shown in Figure 2.2-5. The displacements are magnified by a factor of 100 to display the distortion. The maximum deflection in the center is 0.056 in.

2.3 Recommendation

Add a gusset between the end of each T-beam and the top of each tie-down ear.

3.0 References

HKS, 1995, ABAQUS /Standard User's Manual, Hibbit, Karlsson & Sorenson, Inc., Pawtucket, Rhode Island.

Williams, K.A., 1996, Upper Assembly DSWC Tie Down System, Drawing H-4-302543, B&W Hanford Co., Richland, Washington.

ABAQUS

Figure 2.1-1

ABAQUS

Figure 2.1-2

ABAQUS

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ABAQUS VERSION: 5.5-1 DATE: 18-DEC-76 TIME: 10:18:48
STEP 1 INCREMENT 2

Figure 2.2-1

UNREPRODUCIBLE COPY

ABAQUS

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 ABAQUS VERSION: 5.8.1 DATE: 18-10-96 TIME: 10:18:48
 STEP 1 INCREMENT 1

Figure 2.2-2

FILE COPY

ABAQUS

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 ABAQUS VERSION: 5.5.1 DATE: 10-10-88 TIME: 10.10.18
 STEP 1 INTERMEDIATE

Figure 2.2-3

REPRODUCIBLE COPY

ABAQUS

2
3
TIME COMPLETED THIS STEP 1.00 TOTAL ACCUMULATED TIME 1.13
ANALYSIS TERMINATED 1.1.1.1 DURATION 16.48E-06 TIME 16.48E-06
STEP 1 INCREMENT

Figure 2.2-4

NOT REPRODUCIBLE COPY

ABAQUS

Figure 2.2-5

Attachment A. ABAQUS/Standard Input File

Note: An ellipsis denotes the omission of lengthy node or element definitions.

```
*node
1,0.00000E+00,7.0625,0.00000E+00
...
3935,4.4035,7.5972,0.00000E+00
*element,type=s4r,elset=set1
77,1,79,107,3
...
1820,1958,7,2,1943
*element,type=s4r,elset=set2
1,1,3,21,20
...
2032,2168,2132,2127,2138
*element,type=s4r,elset=set3
61,12,18,89,86
...
1852,1982,11,8,1973
*element,type=s4r,elset=set4
2033,2169,1578,1938,2171
...
2832,3064,2900,2197,2200
*element,type=s4r,elset=set5
2897,3114,3115,3129,3126
...
3688,3911,3517,3516,3896
*element,type=s4r,elset=set6
2833,2205,2230,3072,2445
...
2896,3113,2328,2325,2970
*element,type=s4r,elset=set8
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3715,3935,3920,39,40
*material,name=steel
*elastic
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*plastic
36000.,0.0
*shellsection,material=steel,elset=set1
0.5
*shellsection,material=steel,elset=set2
0.75
```

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*shellsection,material=steel,elset=set3
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*shellsection,material=steel,elset=set4
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*shellsection,material=steel,elset=set5
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*shellsection,material=steel,elset=set6
0.5
*shellsection,material=steel,elset=set8
1.0
*boundary
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2188,1,3
2179,1,3
2197,1,3
*restart,write
*step
*static
0.5,1.
*cload
60,2,-12500.0
2155,2,-12500.0
2012,2,-12500.0
2089,2,-12500.0
*elprint,freq=0
*nodeprint,freq=0
*end step
```

CHECKLIST FOR CHECKING OF ANALYSIS/CALCULATIONSDocument Checked DSWC Tie-Down Weld AnalysisAuthor R.S. Marlow Report No. _____ EDT No. _____

Yes No N/A

- ☒ ☐ ☐ Problem adequately defined.
- ☒ ☐ ☐ Necessary assumptions stated and supported.
- ☒ ☐ ☐ Computer codes and data files documented.
- ☒ ☐ ☐ Data used in calculations stated in document.
- ☒ ☐ ☐ Data checked for consistency with original source information as applicable.
- ☒ ☐ ☐ Mathematical derivations checked including dimensional consistency of results.
- ☒ ☐ ☐ Models appropriate and used within range of validity or use outside range of established validity justified.
- ☒ ☐ ☐ Hand calculations checked for errors.
- ☒ ☐ ☐ Computer code run streams correct and consistent with analysis documentation.
- ☒ ☐ ☐ Computer code output consistent with input and with results reported in analysis documentation.
- ☒ ☐ ☐ Acceptability limits on analytical results applicable and supported. Limits checked against sources.
- ☒ ☐ ☐ Safety margins consistent with good engineering practices.
- ☒ ☐ ☐ Conclusions consistent with analytical results and applicable limits.
- ☒ ☐ ☐ Results and conclusions address all points required in the problem statement.

I have checked the analysis/calculation and its complete and accurate to the best of my knowledge.

 Checker _____ Date 12/16/86
12/19/86

DSWC Tie-Down Weld Analysis

Randall S. Marlow

12/19/96

1.0 Introduction

This document describes the structural analysis of the welds between the tie-down lugs, the tie-down ring, and gussets of the DSWC upper tie-down assembly (Williams 1996). Weld #1 is defined as the combination bevel and fillet welds between the top of a tie-down lug and the gusset between the lug and the cross-member. Weld #2 is defined as the weld between the gusset and the cross-member. Weld #3 is defined as the weld between a lug and the ring. The allowable weld stress is assumed to be 14,400 lbf/in².

2.0 Analysis

2.1 Modeling

The forces on the weld were calculated using the ABAQUS/Standard (HKS 1996) finite-element code. The finite-element mesh is shown in Figure 2.1-1. The mesh is constructed of 4-noded S4R shell elements. The mesh is constrained along the left edge of the lug and gusset. The material model is linear-elastic with a modulus of 29,000,000 lbf/in² and a Poisson's ratio of 0.3. A concentrated force is applied to a node at the edge of the hole in the lower right-hand quadrant. The force is comprised of a 12,500 lbf component directed downwards, a horizontal component of 2,220 lbf directed outwards parallel to the top of the lug, and a horizontal out-of-plane component of 1,135 lbf. The input file for the analysis is in Attachment A.

2.2 Results

The loadings on the weld are taken from the forces and moments in the shell elements which are directly adjacent to the locations of the welds. The maximum loadings are summarized in Table 2.2-1. If f_1 , f_2 , and f_3 are the forces per length (in units of lbf/in) for Weld #1, Weld #2 and Weld #3 respectively, then

$$f_1 = \left[\left(\frac{820}{0.75} + 3660 \right)^2 + 290^2 + 1290^2 \right]^{\frac{1}{2}} \approx 4930,$$

$$f_2 = \left[\left(\frac{860}{1.0} + 960 \right)^2 + 350^2 + 2100^2 \right]^{\frac{1}{2}} \approx 2800,$$

$$f_3 = \left[\left(\frac{1140}{0.75} + 2510 \right)^2 + 300^2 + 1540^2 \right]^{\frac{1}{2}} \approx 4320.$$

The required weld sizes are found by dividing the above values by the allowable weld stress multiplied by 0.7×2 to account for the throat and the fact that each weld has two beads.

Therefore, the size of Weld #1 should be at least 0.24 in., the size of Weld #2 should be at least 0.14 in., and the size of Weld #3 should be at least 0.21 in. According to Williams 1996, the weld size is in excess of the minimum required value for each weld. Therefore, the welds are adequate.

Table 2.2-1 Maximum Weld Forces and Moments

	Weld #1	Weld #2	Weld #3
Axial Force (lbf/in)	3660	960	2510
Shear (lbf/in)	1290	2100	1540
Transverse Shear (lbf/in)	290	350	300
Bending ¹ (in-lbf/in)	410	430	570

1) The bending is the moment/length around an axis directed along the weld.

3.0 References

HKS, 1996, *ABAQUS/Standard User's Manual, Version 5.5*, Hibbit, Karlsson, and Sorensen, Inc., Pawtucket, Rhode Island.

Williams, K.A., 1996, Upper Assembly DSWC Tie-Down System, Drawing H-4-302544, B&W Hanford Co., Richland, Washington.

ABAQUS

Figure 2.1-1. Finite-Element Mesh

Attachment A. ABAQUS/Standard Input File

```

*node
1,0.00000E+00,7.0000,0.00000E+00      65,0.75666,4.4262,0.00000E+00
2,0.00000E+00,3.5000,0.00000E+00      66,0.90800,4.3490,0.00000E+00
3,0.00000E+00,6.5625,0.00000E+00      67,1.0593,4.2717,0.00000E+00
4,0.00000E+00,6.1250,0.00000E+00      68,0.13689,4.3254,0.00000E+00
5,0.00000E+00,5.6875,0.00000E+00      69,0.27379,4.2758,0.00000E+00
6,0.00000E+00,5.2500,0.00000E+00      70,0.41068,4.2263,0.00000E+00
7,0.00000E+00,4.8125,0.00000E+00      71,0.54758,4.1767,0.00000E+00
8,0.00000E+00,4.3750,0.00000E+00      72,0.68447,4.1271,0.00000E+00
9,0.00000E+00,3.9375,0.00000E+00      73,0.82136,4.0775,0.00000E+00
10,1.0000,3.5000,0.00000E+00           74,0.95826,4.0279,0.00000E+00
11,0.12500,3.5000,0.00000E+00         75,0.12800,3.9133,0.00000E+00
12,0.25000,3.5000,0.00000E+00         76,0.25600,3.8891,0.00000E+00
13,0.37500,3.5000,0.00000E+00         77,0.38401,3.8649,0.00000E+00
14,0.50000,3.5000,0.00000E+00         78,0.51201,3.8407,0.00000E+00
15,0.62500,3.5000,0.00000E+00         79,0.64001,3.8165,0.00000E+00
16,0.75000,3.5000,0.00000E+00         80,0.76801,3.7923,0.00000E+00
17,0.87500,3.5000,0.00000E+00         81,0.89602,3.7681,0.00000E+00
18,2.2500,4.7500,0.00000E+00          82,0.00000E+00,0.00000E+00,0.00000E+00
19,2.0061,4.7260,0.00000E+00          83,0.00000E+00,0.43750,0.00000E+00
20,1.7716,4.6548,0.00000E+00          84,0.00000E+00,0.87500,0.00000E+00
21,1.5555,4.5393,0.00000E+00          85,0.00000E+00,1.3125,0.00000E+00
22,1.3661,4.3839,0.00000E+00          86,0.00000E+00,1.7500,0.00000E+00
23,1.2107,4.1945,0.00000E+00          87,0.00000E+00,2.1875,0.00000E+00
24,1.0952,3.9784,0.00000E+00          88,0.00000E+00,2.6250,0.00000E+00
25,1.0240,3.7439,0.00000E+00          89,0.00000E+00,3.0625,0.00000E+00
26,0.28125,6.7188,0.00000E+00         90,2.2500,2.2500,0.00000E+00
27,0.56250,6.4375,0.00000E+00         91,1.0240,3.2561,0.00000E+00
28,0.84375,6.1562,0.00000E+00         92,1.0952,3.0216,0.00000E+00
29,1.1250,5.8750,0.00000E+00         93,1.2107,2.8055,0.00000E+00
30,1.4062,5.5938,0.00000E+00         94,1.3661,2.6161,0.00000E+00
31,1.6875,5.3125,0.00000E+00         95,1.5555,2.4607,0.00000E+00
32,1.9688,5.0312,0.00000E+00         96,1.7716,2.3452,0.00000E+00
33,0.25077,6.3329,0.00000E+00         97,2.0061,2.2740,0.00000E+00
34,0.50153,6.1034,0.00000E+00         98,0.28125,0.28125,0.00000E+00
35,0.75230,5.8738,0.00000E+00         99,0.56250,0.56250,0.00000E+00
36,1.0031,5.6442,0.00000E+00          100,0.84375,0.84375,0.00000E+00
37,1.2538,5.4147,0.00000E+00          101,1.1250,1.1250,0.00000E+00
38,1.5046,5.1851,0.00000E+00          102,1.4062,1.4062,0.00000E+00
39,1.7554,4.9555,0.00000E+00          103,1.6875,1.6875,0.00000E+00
40,0.22146,5.9412,0.00000E+00         104,1.9688,1.9688,0.00000E+00
41,0.44291,5.7575,0.00000E+00         105,0.25077,0.66706,0.00000E+00
42,0.66437,5.5737,0.00000E+00         106,0.50153,0.89663,0.00000E+00
43,0.88582,5.3899,0.00000E+00         107,0.75230,1.1262,0.00000E+00
44,1.1073,5.2062,0.00000E+00         108,1.0031,1.3558,0.00000E+00
45,1.3287,5.0224,0.00000E+00         109,1.2538,1.5853,0.00000E+00
46,1.5502,4.8386,0.00000E+00         110,1.5046,1.8149,0.00000E+00
47,0.19444,5.5440,0.00000E+00         111,1.7554,2.0445,0.00000E+00
48,0.38888,5.4005,0.00000E+00         112,0.22146,1.0588,0.00000E+00
49,0.58333,5.2569,0.00000E+00         113,0.44291,1.2425,0.00000E+00
50,0.77777,5.1134,0.00000E+00         114,0.66437,1.4263,0.00000E+00
51,0.97221,4.9699,0.00000E+00         115,0.88582,1.6101,0.00000E+00
52,1.1667,4.8264,0.00000E+00         116,1.1073,1.7938,0.00000E+00
53,1.3611,4.6829,0.00000E+00         117,1.3287,1.9776,0.00000E+00
54,0.17076,5.1417,0.00000E+00         118,1.5502,2.1614,0.00000E+00
55,0.34153,5.0335,0.00000E+00         119,0.19444,1.4560,0.00000E+00
56,0.51229,4.9252,0.00000E+00         120,0.38888,1.5995,0.00000E+00
57,0.68306,4.8169,0.00000E+00         121,0.58333,1.7431,0.00000E+00
58,0.85382,4.7087,0.00000E+00         122,0.77777,1.8866,0.00000E+00
59,1.0246,4.6004,0.00000E+00         123,0.97221,2.0301,0.00000E+00
60,1.1954,4.4921,0.00000E+00         124,1.1667,2.1736,0.00000E+00
61,0.15133,4.7352,0.00000E+00         125,1.3611,2.3171,0.00000E+00
62,0.30267,4.6580,0.00000E+00         126,0.17076,1.8583,0.00000E+00
63,0.45400,4.5807,0.00000E+00         127,0.34153,1.9665,0.00000E+00
64,0.60533,4.5035,0.00000E+00         128,0.51229,2.0748,0.00000E+00
                                         129,0.68306,2.1831,0.00000E+00

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130,0.85382,2.2913,0.00000E+00	198,3.5676,0.23511,0.00000E+00
131,1.0246,2.3996,0.00000E+00	199,4.1120,0.25781,0.00000E+00
132,1.1954,2.5079,0.00000E+00	200,2.9170,0.43250,0.00000E+00
133,0.15133,2.2648,0.00000E+00	201,3.3829,0.46948,0.00000E+00
134,0.30267,2.3420,0.00000E+00	202,3.8478,0.51526,0.00000E+00
135,0.45400,2.4193,0.00000E+00	203,2.8001,0.63867,0.00000E+00
136,0.60533,2.4965,0.00000E+00	204,3.1840,0.69946,0.00000E+00
137,0.75666,2.5738,0.00000E+00	205,3.5765,0.77051,0.00000E+00
138,0.90800,2.6510,0.00000E+00	206,3.5000,3.5000,0.00000E+00
139,1.0593,2.7283,0.00000E+00	207,6.0000,1.0000,0.00000E+00
140,0.13689,2.6746,0.00000E+00	208,3.8125,3.1875,0.00000E+00
141,0.27379,2.7242,0.00000E+00	209,4.1250,2.8750,0.00000E+00
142,0.41068,2.7737,0.00000E+00	210,4.4375,2.5625,0.00000E+00
143,0.54758,2.8233,0.00000E+00	211,4.7500,2.2500,0.00000E+00
144,0.68447,2.8729,0.00000E+00	212,5.0625,1.9375,0.00000E+00
145,0.82136,2.9225,0.00000E+00	213,5.3750,1.6250,0.00000E+00
146,0.95826,2.9721,0.00000E+00	214,5.6875,1.3125,0.00000E+00
147,0.12800,3.0867,0.00000E+00	215,5.1250,0.12500,0.00000E+00
148,0.25600,3.1109,0.00000E+00	216,5.2500,0.25000,0.00000E+00
149,0.38401,3.1351,0.00000E+00	217,5.3750,0.37500,0.00000E+00
150,0.51201,3.1593,0.00000E+00	218,5.5000,0.50000,0.00000E+00
151,0.64001,3.1835,0.00000E+00	219,5.6250,0.62500,0.00000E+00
152,0.76801,3.2077,0.00000E+00	220,5.7500,0.75000,0.00000E+00
153,0.89602,3.2319,0.00000E+00	221,5.8750,0.87500,0.00000E+00
154,5.0000,0.00000E+00,0.00000E+00	222,2.4939,2.2740,0.00000E+00
155,2.5938,1.9688,0.00000E+00	223,2.7284,2.3452,0.00000E+00
156,2.9375,1.6875,0.00000E+00	224,2.9445,2.4607,0.00000E+00
157,3.2812,1.4062,0.00000E+00	225,3.1339,2.6161,0.00000E+00
158,3.6250,1.1250,0.00000E+00	226,3.2893,2.8055,0.00000E+00
159,3.9688,0.84375,0.00000E+00	227,3.4048,3.0216,0.00000E+00
160,4.3125,0.56250,0.00000E+00	228,3.4760,3.2561,0.00000E+00
161,4.6563,0.28125,0.00000E+00	229,3.7759,2.9585,0.00000E+00
162,0.62500,0.00000E+00,0.00000E+00	230,3.6980,2.7377,0.00000E+00
163,1.2500,0.00000E+00,0.00000E+00	231,3.5813,2.5330,0.00000E+00
164,1.8750,0.00000E+00,0.00000E+00	232,3.4296,2.3516,0.00000E+00
165,2.5000,0.00000E+00,0.00000E+00	233,3.2483,2.2000,0.00000E+00
166,3.1250,0.00000E+00,0.00000E+00	234,3.0436,2.0833,0.00000E+00
167,3.7500,0.00000E+00,0.00000E+00	235,2.8228,2.0054,0.00000E+00
168,4.3750,0.00000E+00,0.00000E+00	236,4.0757,2.6609,0.00000E+00
169,2.4167,0.75000,0.00000E+00	237,3.9911,2.4537,0.00000E+00
170,1.4858,1.0203,0.00000E+00	238,3.8733,2.2604,0.00000E+00
171,1.8415,0.91699,0.00000E+00	239,3.7254,2.0871,0.00000E+00
172,2.1732,0.82068,0.00000E+00	240,3.5521,1.9392,0.00000E+00
173,2.2875,1.0203,0.00000E+00	241,3.3588,1.8214,0.00000E+00
174,2.9548,0.91699,0.00000E+00	242,3.1516,1.7368,0.00000E+00
175,2.6444,0.82068,0.00000E+00	243,4.3756,2.3632,0.00000E+00
176,2.4767,0.20947,0.00000E+00	244,4.2843,2.1698,0.00000E+00
177,2.4538,0.41602,0.00000E+00	245,4.1652,1.9878,0.00000E+00
178,2.4324,0.60864,0.00000E+00	246,4.0212,1.8226,0.00000E+00
179,1.2523,0.77051,0.00000E+00	247,3.8559,1.6785,0.00000E+00
180,1.0377,0.51526,0.00000E+00	248,3.6740,1.5595,0.00000E+00
181,0.83073,0.25781,0.00000E+00	249,3.4805,1.4681,0.00000E+00
182,1.6606,0.69946,0.00000E+00	250,4.6755,2.0656,0.00000E+00
183,1.5128,0.46948,0.00000E+00	251,4.5774,1.8858,0.00000E+00
184,1.3801,0.23511,0.00000E+00	252,4.4572,1.7153,0.00000E+00
185,2.0579,0.63867,0.00000E+00	253,4.3169,1.5581,0.00000E+00
186,1.9869,0.43250,0.00000E+00	254,4.1597,1.4178,0.00000E+00
187,1.9290,0.21680,0.00000E+00	255,3.9892,1.2976,0.00000E+00
188,2.9749,1.2627,0.00000E+00	256,3.8094,1.1995,0.00000E+00
189,2.6447,1.4996,0.00000E+00	257,4.9754,1.7679,0.00000E+00
190,2.3073,1.7344,0.00000E+00	258,4.8706,1.6019,0.00000E+00
191,2.6724,1.1180,0.00000E+00	259,4.7491,1.4427,0.00000E+00
192,2.3543,1.3110,0.00000E+00	260,4.6127,1.2935,0.00000E+00
193,2.0221,1.4996,0.00000E+00	261,4.4635,1.1571,0.00000E+00
194,2.3919,0.97266,0.00000E+00	262,4.3044,1.0357,0.00000E+00
195,2.0791,1.1180,0.00000E+00	263,4.1383,0.93088,0.00000E+00
196,1.7445,1.2627,0.00000E+00	264,5.2752,1.4703,0.00000E+00
197,3.0228,0.21680,0.00000E+00	265,5.1637,1.3179,0.00000E+00

266,5.0411,1.1701,0.00000E+00	334,3.4150,7.0000,0.00000E+00
267,4.9085,1.0290,0.00000E+00	335,3.0713,7.0000,0.00000E+00
268,4.7674,0.89642,0.00000E+00	336,2.7275,7.0000,0.00000E+00
269,4.6196,0.77379,0.00000E+00	337,2.3838,7.0000,0.00000E+00
270,4.4672,0.66225,0.00000E+00	338,2.5675,5.0312,0.00000E+00
271,5.5751,1.1726,0.00000E+00	339,2.8850,5.3125,0.00000E+00
272,5.4569,1.0340,0.00000E+00	340,3.2025,5.5938,0.00000E+00
273,5.3330,0.89757,0.00000E+00	341,3.5200,5.8750,0.00000E+00
274,5.2042,0.76451,0.00000E+00	342,3.8375,6.1562,0.00000E+00
275,5.0712,0.63571,0.00000E+00	343,4.1550,6.4375,0.00000E+00
276,4.9348,0.51189,0.00000E+00	344,4.4725,6.7188,0.00000E+00
277,4.7961,0.39363,0.00000E+00	345,3.0267,6.2500,0.00000E+00
278,2.0400,7.0000,0.00000E+00	346,3.3065,6.7905,0.00000E+00
279,2.0663,6.7188,0.00000E+00	347,3.1996,6.5840,0.00000E+00
280,2.0925,6.4375,0.00000E+00	348,3.0999,6.3914,0.00000E+00
281,2.1187,6.1562,0.00000E+00	349,2.3912,5.9797,0.00000E+00
282,2.1450,5.8750,0.00000E+00	350,2.6340,6.0830,0.00000E+00
283,2.1713,5.5938,0.00000E+00	351,2.8605,6.1793,0.00000E+00
284,2.1975,5.3125,0.00000E+00	352,3.3822,5.9797,0.00000E+00
285,2.2237,5.0312,0.00000E+00	353,3.2464,6.0830,0.00000E+00
286,1.7850,7.0000,0.00000E+00	354,3.1196,6.1793,0.00000E+00
287,1.5300,7.0000,0.00000E+00	355,3.6035,6.7832,0.00000E+00
288,1.2750,7.0000,0.00000E+00	356,3.8948,6.7649,0.00000E+00
289,1.0200,7.0000,0.00000E+00	357,4.1839,6.7422,0.00000E+00
290,0.76500,7.0000,0.00000E+00	358,3.4469,6.5675,0.00000E+00
291,0.51000,7.0000,0.00000E+00	359,3.6862,6.5305,0.00000E+00
292,0.25500,7.0000,0.00000E+00	360,3.9210,6.4847,0.00000E+00
293,1.4300,6.2500,0.00000E+00	361,3.2884,6.3613,0.00000E+00
294,1.2102,5.9797,0.00000E+00	362,3.4718,6.3005,0.00000E+00
295,1.2942,6.0830,0.00000E+00	363,3.6552,6.2295,0.00000E+00
296,1.3725,6.1793,0.00000E+00	364,2.3769,6.2295,0.00000E+00
297,1.9453,5.9797,0.00000E+00	365,2.3754,6.4847,0.00000E+00
298,1.7484,6.0830,0.00000E+00	366,2.3792,6.7422,0.00000E+00
299,1.5648,6.1793,0.00000E+00	367,2.6339,6.3005,0.00000E+00
300,1.1345,6.7905,0.00000E+00	368,2.6576,6.5305,0.00000E+00
301,1.2474,6.5840,0.00000E+00	369,2.6917,6.7649,0.00000E+00
302,1.3527,6.3914,0.00000E+00	370,2.8802,6.3613,0.00000E+00
303,0.96707,6.2295,0.00000E+00	371,2.9353,6.5675,0.00000E+00
304,0.72842,6.4847,0.00000E+00	372,3.0020,6.7832,0.00000E+00
305,0.49156,6.7422,0.00000E+00	373,3.0996,5.7373,0.00000E+00
306,1.0916,6.3005,0.00000E+00	374,2.8097,5.5004,0.00000E+00
307,0.89515,6.5305,0.00000E+00	375,2.5170,5.2656,0.00000E+00
308,0.70228,6.7649,0.00000E+00	376,2.9992,5.8820,0.00000E+00
309,1.2177,6.3613,0.00000E+00	377,2.7362,5.6890,0.00000E+00
310,1.0667,6.5675,0.00000E+00	378,2.4673,5.5004,0.00000E+00
311,0.91539,6.7832,0.00000E+00	379,2.9114,6.0273,0.00000E+00
312,1.9613,5.7373,0.00000E+00	380,2.6730,5.8820,0.00000E+00
313,1.9668,5.5004,0.00000E+00	381,2.4228,5.7373,0.00000E+00
314,1.9681,5.2656,0.00000E+00	382,6.0000,6.0000,0.00000E+00
315,1.7522,5.8820,0.00000E+00	383,3.8125,3.8125,0.00000E+00
316,1.7367,5.6890,0.00000E+00	384,4.1250,4.1250,0.00000E+00
317,1.7128,5.5004,0.00000E+00	385,4.4375,4.4375,0.00000E+00
318,1.5517,6.0273,0.00000E+00	386,4.7500,4.7500,0.00000E+00
319,1.5102,5.8820,0.00000E+00	387,5.0625,5.0625,0.00000E+00
320,1.4593,5.7373,0.00000E+00	388,5.3750,5.3750,0.00000E+00
321,1.3616,6.7832,0.00000E+00	389,5.6875,5.6875,0.00000E+00
322,1.5948,6.7649,0.00000E+00	390,6.0000,1.6250,0.00000E+00
323,1.8303,6.7422,0.00000E+00	391,6.0000,2.2500,0.00000E+00
324,1.4462,6.5675,0.00000E+00	392,6.0000,2.8750,0.00000E+00
325,1.6582,6.5305,0.00000E+00	393,6.0000,3.5000,0.00000E+00
326,1.8749,6.4847,0.00000E+00	394,6.0000,4.1250,0.00000E+00
327,1.5205,6.3613,0.00000E+00	395,6.0000,4.7500,0.00000E+00
328,1.7132,6.3005,0.00000E+00	396,6.0000,5.3750,0.00000E+00
329,1.9154,6.2295,0.00000E+00	397,5.1667,3.5000,0.00000E+00
330,4.7900,7.0000,0.00000E+00	398,4.8664,4.4009,0.00000E+00
331,4.4463,7.0000,0.00000E+00	399,4.9811,4.0566,0.00000E+00
332,4.1025,7.0000,0.00000E+00	400,5.0881,3.7356,0.00000E+00
333,3.7588,7.0000,0.00000E+00	401,5.7673,3.5000,0.00000E+00

402,5.5378,3.5000,0.00000E+00	470,3.5564,5.2220,0.00000E+00
403,5.3237,3.5000,0.00000E+00	471,4.0315,5.6360,0.00000E+00
404,4.8664,2.5991,0.00000E+00	472,4.2672,6.0297,0.00000E+00
405,4.9811,2.9434,0.00000E+00	473,4.6872,6.6100,0.00000E+00
406,5.0881,3.2644,0.00000E+00	474,4.9768,6.5751,0.00000E+00
407,4.5970,4.1152,0.00000E+00	475,4.9875,6.2125,0.00000E+00
408,4.3337,3.8113,0.00000E+00	476,5.2794,6.2518,0.00000E+00
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DISTRIBUTION SHEET

To	From	Page 1 of 1				
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Project Title/Work Order		EDT No. 618189				
Safety Evaluation for Packaging (Onsite) Disposable Solid Waste Cask (HNF-SD-TP-SEP-054)		ECN No. N/A				
Name	MSIN	Text With All Attach.	Text Only	Attach./Appendix Only	EDT/ECN Only	
D. W. Claussen	S7-55	X				
R. L. Clawson	G1-13	X				
B. D. Flanagan	G1-11	X				
J. G. Field	G1-11	X				
S. W. Hiller	N2-02	X				
C. R. Hoover	G1-11	X				
J. A. Lamendola	N2-02	X				
D. W. McNally	G1-11	X				
J. E. Mercado	G1-11	X				
A. L. Ramble	T5-54	X				
Central Files	A3-88	X				
Document Processing Center	A3-94	X				
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