National Spent Nuclear Fuel Program Overview and Mtg. Objectives

by

Mark Arenaz

DOE-ID

NRC Transportation Meeting
June 1, 2006

Providing for safe, efficient transportation of DOE spent nuclear fuel

Objectives of Today's Meeting

- *Provide background on Office of Environmental Management's (DOE-EM) National Spent Nuclear Fuel Program (NSNFP)*
- *Discuss the role of the Standardized Canister during transportation of DOE-EM managed spent nuclear fuel (SNF)*
- *Provide an overview of the Standardized Canister design and testing*
- *Discuss moderator exclusion under 10 CFR 71.55 and ISG-19*
- *Discuss plans for topical report preparation and submittal*

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Enclosure 2

NSNFP Role

- *The Idaho National Laboratory was designated as the DOE SNF lead laboratory to ....*

  "Direct the research, development and testing of treatment, shipment, and disposal technologies for all DOE SNF, and all such DOE activities shall be coordinated and integrated under the direction of the Manager, DOE-ID." (Idaho Settlement Agreement)

- *Established the NSNFP in October 1995 to conduct these activities*

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Meeting Agenda

9:00 a.m.	Introductions
9:10 a.m.	Meeting Objectives and NSNFP Role
9:20 a.m.	DOE-EM SNF Packaging and Transportation
9:40 a.m.	DOE-EM Standardized Canister Design and Test Program
10:15 a.m.	Criticality Approach
10:45 a.m.	Topical Report Contents
11:00 a.m.	Summary & NRC Feedback
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11:30 a.m.	Adjourn

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Packaging DOE-owned SNF for Storage & Transportation

National Spent Nuclear Fuel Program

by
Thomas Hill
Idaho National Laboratory

NRC Transportation Meeting
June 1, 2006

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Standardized Canister Not a Cask

- *Standardized Canister is <u>not</u> a self-contained transportation package*
- *Standardized Canister is <u>not</u> a Transportation, Aging, and Disposal (TAD) canister*
- *Standardized Canister is a subpart of the transportation cask*
- *Standardized Canister provides robust containment*

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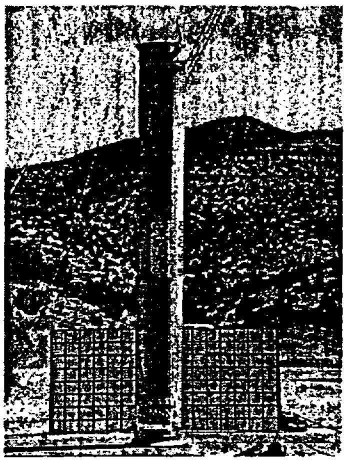
Standardized Canister Approach



Drop Testing at Sandia National Laboratories

- Developed to be used for DOE-EM SNF packaging
- Robust performance
- Maintains containment under accident conditions
- Full scale testing and validation of analytical models
- Compatible with storage, transportation and disposal plans without being reopened

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DOE Standardized Canister Deployment

- Standardized Canister included in contract for Idaho Spent Fuel Facility. NRC license granted in November 30, 2004 to Foster Wheeler for dry storage facility incorporating the Standardized Canister.

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Standardized Canister Approach

- Preliminary meetings have been held with a cask vendor
- The Standardized Canister will fit in existing commercial rail cask designs
- Certificates of Compliance (C of C) will need to be amended for the intended DOE fuel types and canister loads
- Standardized Canister topical report provides basis for transportation package C of C development

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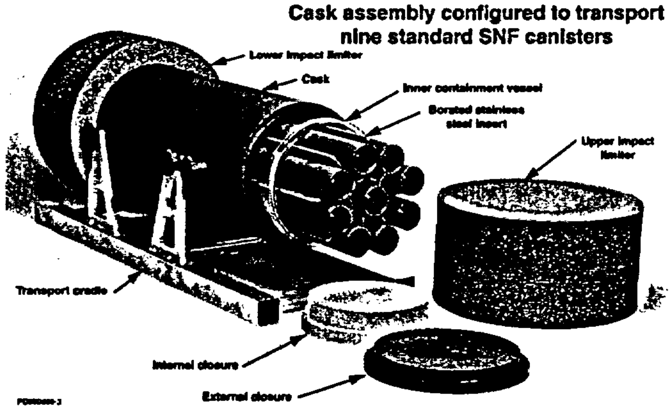
Potential Cask Configuration

Cask assembly configured to transport nine standard SNF canisters



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Standardized Canister Design

- *Robust*
  - *Thirty foot any orientation drop*
  - *Forty inch drop onto six inch pin*
- *Designed per American Society of Mechanical Engineers Boiler & Pressure Vessel Code Section III*
- *Material compatible with SNF contents and waste package*
  - *Corrosion resistance materials*
  - *>40 year design life*
- *Seal welded*
  - *Leak test to less than 1 x 10^{-4} std•cm^3/s*

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Standardized Canister Details

- Four unique geometries
  - 18-inch and 24-inch nominal diameters
  - 10-foot and 15-foot nominal lengths
- Multiple basket designs can be accommodated
- Internal impact plates shaped to match the inside head profile
  - 2 inches thick
  - In both top and bottom heads

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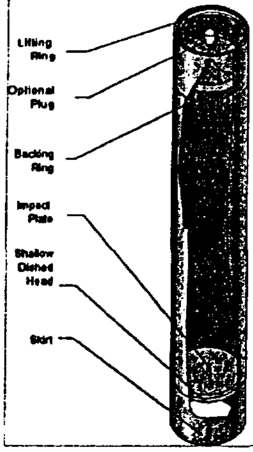
Standardized DOE Spent Nuclear Fuel Canister



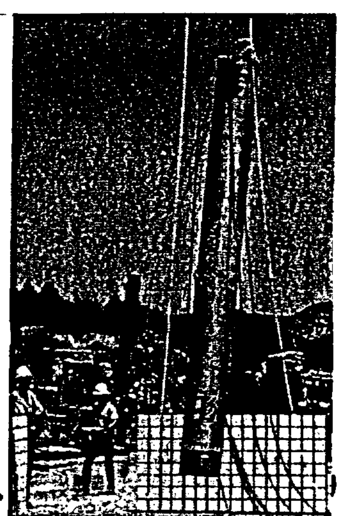
Nominal Outside Diameters:
18 in. and 24 in.

Wall Thickness:
3/8 in. for 18 in. canister
1/2 in. for 24 in. canister

Maximum Weight with Fuel:
5,000 to 10,000 lbs.

External Lengths:
Short Canister: 118.11 in.
Long Canister: 179.92 in.

Material:
Canister Body: SS316 L



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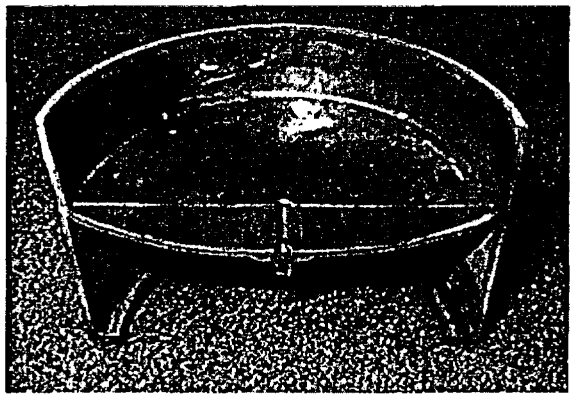
Standardized Canister Cross Section



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Standardized Canister Test Program

- Modeled Standardized Canisters using finite element structural analysis computer program ABAQUS/Explicit
- Applied plastic material behavior with 20% increase in the stress-strain curve to account for dynamic strengthening of the material (permitted per American Society of Mechanical Engineers Code)
- Drop testing included helium leak testing
- Compared deformation to model predictions

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Why Conduct Drop Test?

- *Clearly demonstrate Standardized Canister's robust design*
  - *ASME Code, Section III, code allowable stress limits are exceeded for 30 foot accidental drop (elastic-plastic deformations)*
  - *Demonstrate that the Standardized Canister will not rupture or leak after an accidental drop*
  - *Validate the analytical model used for analysis through deformation comparisons*

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Demonstration of Robustness of Standardized Canisters

- *Preliminary drop tests performed in 1998 proved design concept*
- *Full-scale testing of nine 18-inch Standardized Canisters in 1999 at Sandia drop test facility*
  - *Completed eight drop tests*
    - *Drop heights per 10 CFR 71.73(c)*
    - *30-foot drop onto an essentially unyielding horizontal surface*
    - *40-in drop onto a 6-in diameter bar*
  - *One test to simulate a drop onto a waste package (or transportation cask) during the loading sequence*
  - *Helium leak testing demonstrated leak-tight containment after drops (four of most heavily damaged)*
  - *Computer pre-test and post-test predictions matched actual results*

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Demonstration of Robustness of Standardized Canisters (Cont'd)

- *All Standardized Canisters passed a pressure test, holding 50 psig air steady for one hour*
- *Observed no changes in initial weld seam flaws when comparing pre- and post-drop radiographs*
- *Full-scale testing of two 24-inch Standardized Canisters in 2004 at Sandia drop test facility*
  - *Completed two drop tests of 24-inch standardized canister*
    - *Drop heights per 10 CFR 71.73(c)*
    - *30-foot drop onto an essentially unyielding horizontal surface*
  - *Helium leak testing demonstrated containment after drops*
  - *Computer pretest predictions matched actual results*

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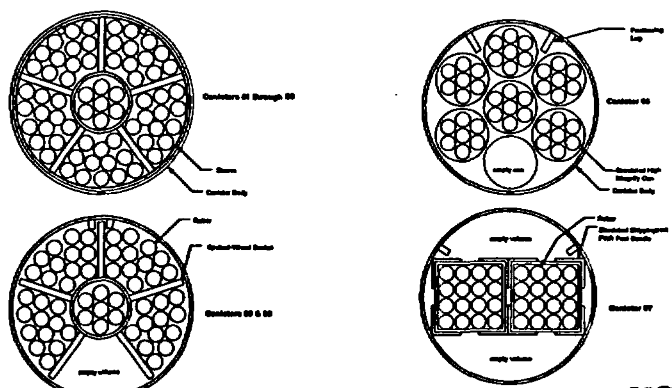
Test Canister Internals



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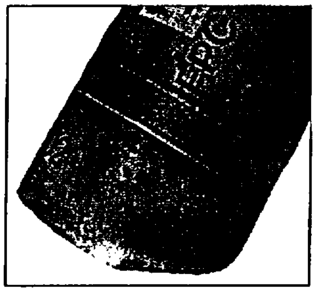
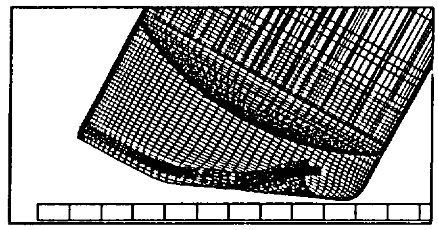
Actual drop test match with ABAQUS Explicit model

18 inch canister results

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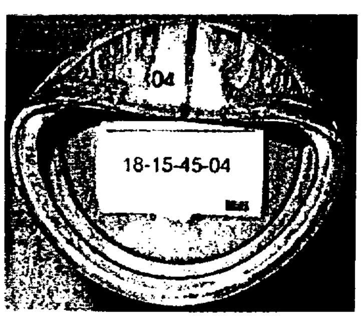
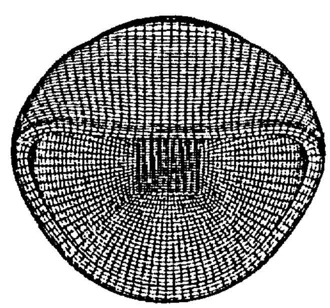
Actual drop test match with ABAQUS Explicit model – 18-in.





- *Impact angle of 45 degrees*

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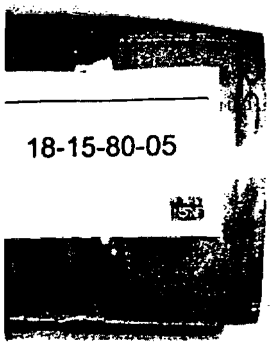
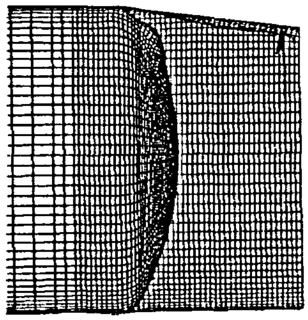
Actual drop test match with ABAQUS Explicit model – 18-in.





- *Impact angle of 80 degrees*

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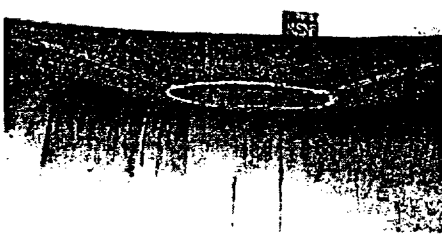
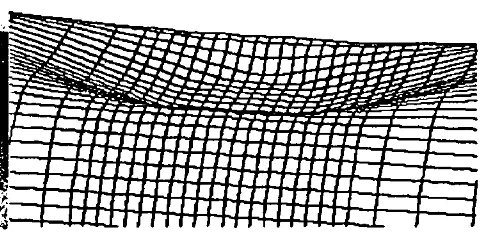
Actual drop test match with ABAQUS Explicit model – 18-in.





- *Six-inch puncture bar test from 40-in.*

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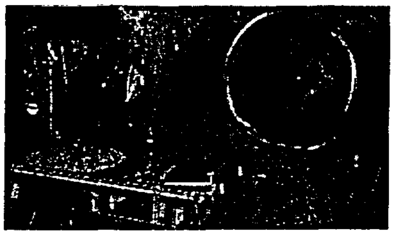
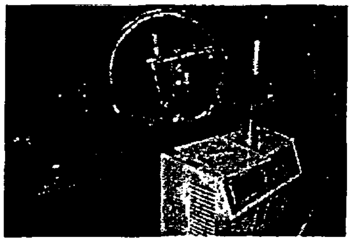
Pressure Testing – Post Drop

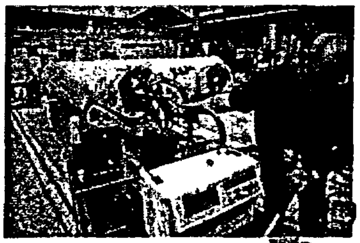
- Test canisters post drop pressure test
  - Held greater than 50 psig air steady for 1 hour



Helium Leak Testing – Post Drop

- Test canisters post drop leak testing
  - Helium leak tested less than $1x10^{-7}$ std cc/sec (leaktight)



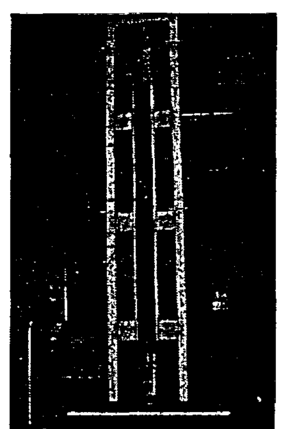


Standardized Canister Material Test Program

- Loads associated with accidental drop events are typically design governing for canisters
- The better the elastic-plastic material definition is, the better the analytical predictions
- Material test program validates the material properties under dynamic loading

Approach

- The approach is to use the INL developed Impact Testing Machine or ITM
- It is a drop weight device with weights as large as 1600 pounds and drop heights up to 13 feet
- A true impact is achieved instead of a hydraulic-based system that imposes strain rates only



Material Dynamic Testing Goals

- *Quantify the increase (over that obtained from quasi-static tensile testing) of the canister material (316L stainless steel) true stress-strain curves with respect to varying strain rates*
- *Validate the analytical 20% increase in the stress-strain curve to account for dynamic strengthening of the material*
- *Examine if cracking or tearing is initiated*

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Dynamic Testing Effort:

- *Addresses adequate range of strain rates*
- *Incorporates temperature effects*
- *Gain weld and base metal response insights*
- *Investigates bending and shear responses*

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Standardized Canister Fabrication Considerations

- Base metal flaws are considered bounded by weld flaws
- For final closure welds as confinement boundaries on stainless steel canisters, ISG-18 states that reasonable assurance of no leakage is achieved by using welding and examination techniques described by ISG-15
- Standardized Canister weld design, specifications, and tests are consistent with ISG-15
- According to ISG-15, the minimum detectable flaw size must be demonstrated to be less than the critical flaw size

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Critical Flaw Size Testing

- Flaws 150% of the detection limit (i.e., 1.5 mm flaw) did not result in through-wall cracking
- Flaws up to a single weld pass (about 2.5 mm) did not result in through-wall cracking
- All but the closure welds are to be made and inspected at the fabrication facility to ASME Code requirements and independently reviewed by an authorized inspector
- Closure welds for the standardized canister are not located near the highest strain

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Conclusions for As-Designed Condition

- Standardized Canisters are designed, fabricated, and N-stamped to ASME Code requirements
- Analyses show a significant margin of safety
- Drop tests validate the analytical model and demonstrate containment integrity

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Reliance upon Standardized Canister Integrity for Moderator Exclusion will ....

- Provide cask vendors a means to effectively address the wide variety of DOE-EM SNFs that may be transported
- Avoid the risk of reopening Standardized Canisters to meet transportation requirements
- Avoid the risks, radiological wastes and personnel exposure associated with obtaining additional fuel-specific data
- Avoid destructive tests and associated disruption of the fuel and cladding
- Simplify analyses and resulting controls

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Summary

- *Standardized Canisters provide the ability to safely handle DOE-EM SNF and provide containment under handling and transportation accident conditions*
  - *Designed to ASME Section III*
  - *Analysis*
  - *Proof testing*

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Criticality Analysis for DOE Standardized Canisters

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National Spent Nuclear Fuel Program

Philip Wheatley
Idaho National Laboratory

NRC Transportation Meeting
June 1, 2006

Providing for safe, efficient transportation of DOE spent nuclear fuel

Outline

- Overview
- Aluminum fuel description
- Basket and Standardized Canister
- Analyses assumptions
- Analyses
- Summary

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Overview

- Aluminum plate spent nuclear fuel provides largest variety of fuel types and a significant number of Standardized Canisters (~800)
- Standardized Canister provides moderator exclusion for criticality analysis
- Single Standardized Canister analyses have been performed
  - Degraded fuel in basket (horizontal)
  - Degraded fuel in sphere (vertical)
  - Degraded fuel in cylinder (vertical)
- Preliminary analyses of a close-packed array of four Standardized Canisters

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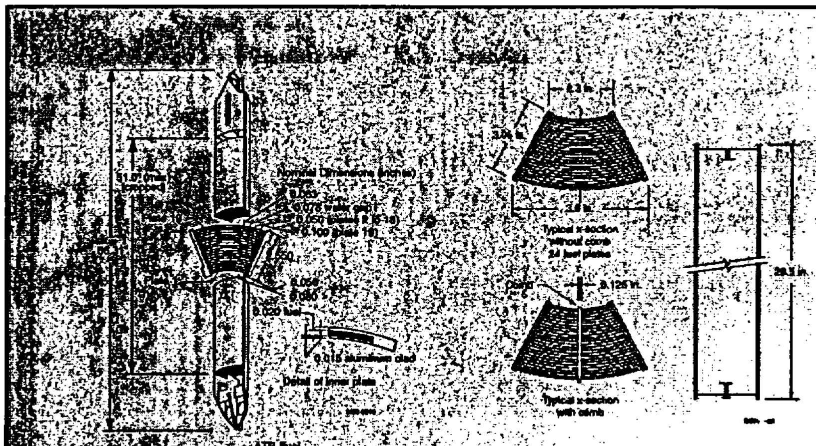

ATR Fuel Assembly

1085 g U^{235} / assembly (BOL)

Loading in canister:

- 7.86 kg U^{235} / meter (linear)
- 32.65 kg U^{235} (total; 15-ft canister)

MURR Fuel Assembly

783 g U^{235} / assembly (BOL)

Loading in canister:

- 8.05 kg U^{235} / meter (linear)
- 23.21 kg U235 (total; 10-ft canister)

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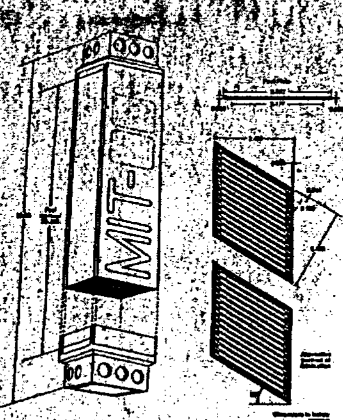

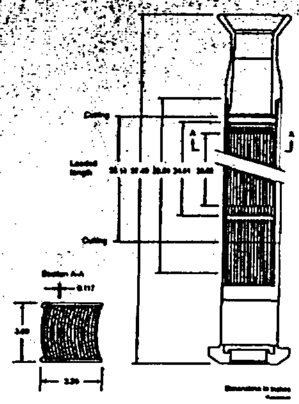

MIT Fuel Assembly

525 g U^{235} / assembly (BOL)

Loading in canister:
- 6.12 kg U^{235} / meter (linear)
- 15.75 kg U235 (total; 10-ft canister)

ORR Fuel Assembly

300 g U^{235} / assembly (BOL)

Loading in canister:
- 3.6 kg U^{235} / meter (linear)
- 10.41 kg U^{235} (total; 10-ft canister)

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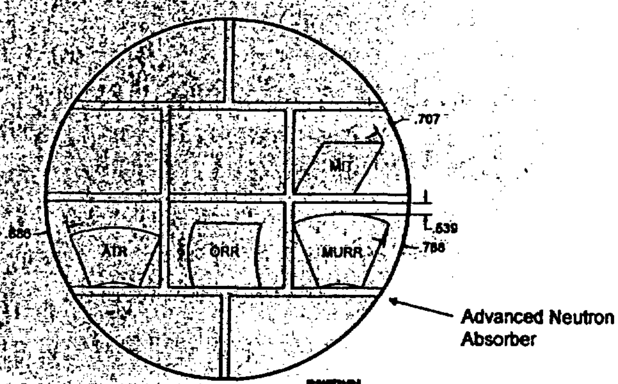
Type 1a 18-inch Diameter Basket



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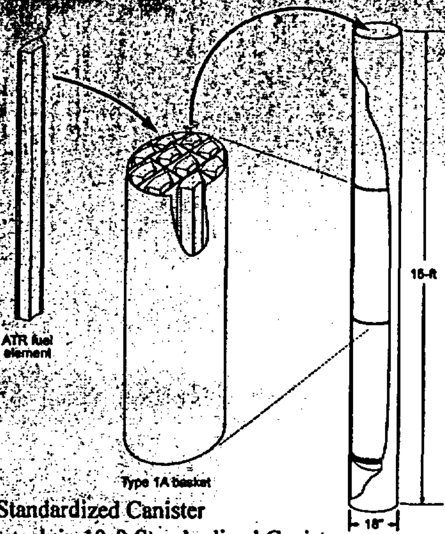
Standardized Canister and Basket Loading



ATR – 3-stack in 15-ft Standardized Canister
MURR, ORR, MIT – 3-stack in 10-ft Standardized Canister

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ISG-19 Applicability

- NRC guidance allows moderator exclusion for commercial SNF that could fracture under impact loads associated with hypothetical accident conditions (ISG-19)
- Reliance on Standardized Canister rather than fuel properties increases safety and surety

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Assumptions for Aluminum SNF

- Each loaded Standardized Canister is treated as a closed system
  - Beginning-of-life fissile content
  - Fixed canister volume
- In a loaded Standardized Canister:
  - ATR fuel represents maximum total fissile mass
  - MURR fuel represents maximum linear loading
- Analyses assume 11 vol % water saturation of the fuel matrix in plate fuel; allowable void volume in the sintered metal fuel matrix at production

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Assumptions for Aluminum SNF (continued)

- Loss of geometry
  - All fuel rubblized and retained within the Standardized Canister
  - Vertical Standardized Canister orientation represents most reactive system due to axial reconfiguration
- Effects of neutron poisons minimized

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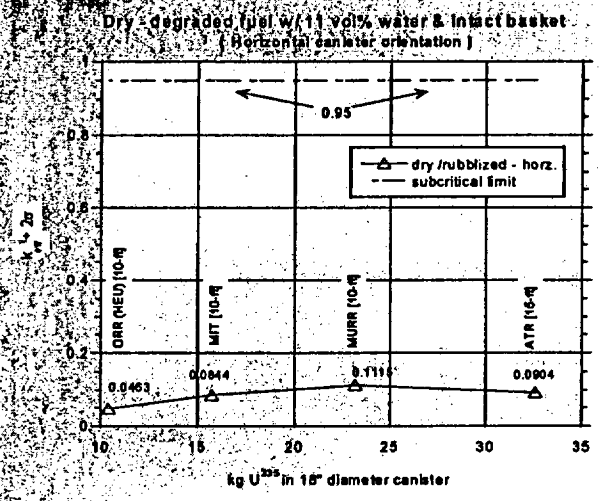

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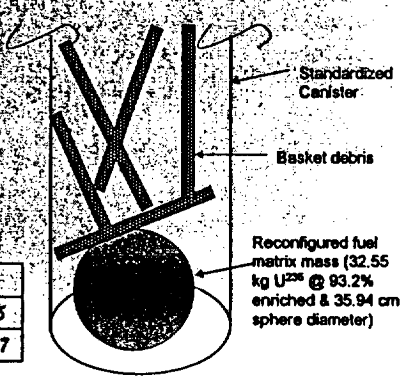
Fuel Rubblization Forming a Sphere

- 30 ATR fuel assemblies rubblized
- Standardized Canister is fully water reflected

Configuration	$k_{eff} + 2\sigma$
sphere w/ no H_2O	*0.4060 + 2*0.0005*
sphere w/ 11% H_2O	*0.5466 + 2*0.0007*



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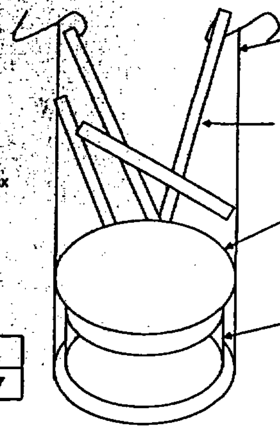
Fuel Rubblization Forming a Cylinder

- 30 ATR fuel assemblies rubblized
- Standardized Canister is fully water reflected
- 11 vol% water saturation of fuel matrix



Configuration	$k_{eff} + 2\sigma$
cylinder w/ 11% H_2O	0.6235 + 2*0.0007

(This configuration analyzed in subsequent 4-pack inside a transport cask)

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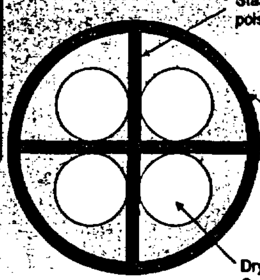
Array Considerations

Configuration	$k_{eff} + 2\sigma$
Void in cask, Standardized Canisters closest	0.8222 + 2*0.0009
Same as above; 10% density water in cask	0.8128 + 2*0.0009
Same as above; flooded cask	0.7697 + 2*0.0008

- Increasing degree of water reflection improves neutronic decoupling of Standardized Canisters inside transport cask



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Summary

- Criticality safety analyses done to date demonstrate significant safety margins given moderator exclusion credit for the Standardized Canister
- Additional analyses are planned with both single Standardized Canisters and arrays to support DOE-EM SNF transportation

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National Spent Nuclear Fuel Program

Topical Report Outline

by
Brett Carlsen
Idaho National Laboratory

NRC Transportation Meeting
June 1, 2006

Providing for safe, efficient transportation of DOE spent nuclear fuel

Proposed Topical Report

- *Provide documentation and basis for concluding that Standardized Canister boundary is sufficient to maintain moderator exclusion.*
- *Provide information and safety bases needed by transportation cask vendors seeking a C of C.*
- *Will follow the format prescribed by Regulatory Guide 7.9.*

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Tentative Outline

1. General Information
2. Structural Evaluation
3. Thermal Evaluation
4. Containment
5. Shielding Evaluation
6. Criticality Evaluation
7. Package Operations
8. Acceptance Tests and Maintenance Program

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Proposed Plan and Schedule

- *Establish robustness of Standardized Canister*
  - *Initial report will address aluminum fuels in type 1A basket.*
  - *The report may be supplemented with analyses to support the inclusion of other fuel types.*
- *Proposed Schedule*
  - *Internal draft report - October 2006*
  - *Submittal to NRC - January 2007*
- *Path forward for NRC interaction and submittal......*
  - *Meetings on structural analysis, criticality, and draft report*
  - *NRC feedback on technical issues and content of Topical Report*

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