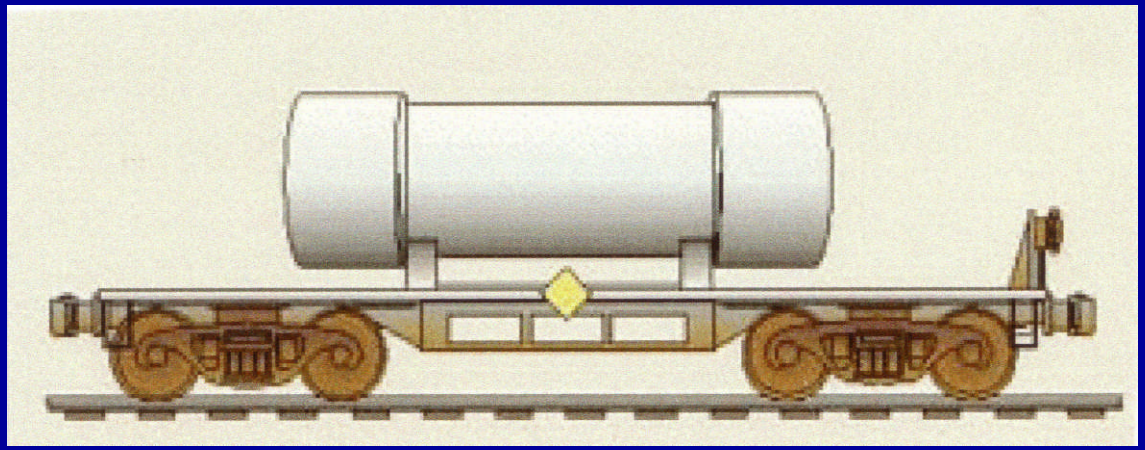
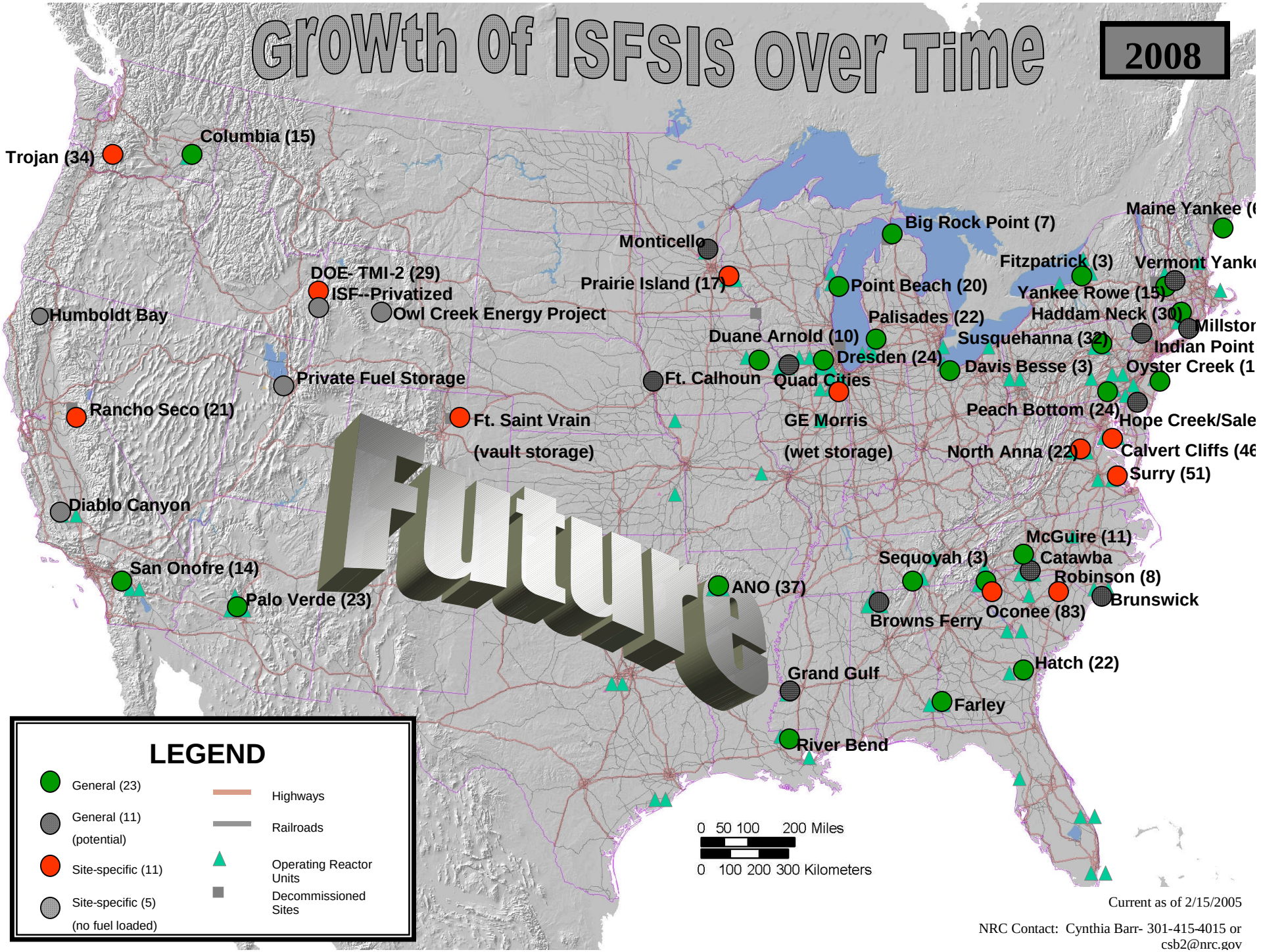
Shipment of Spent Fuel by Rail: Safety by Design



Midwestern Radioactive Materials Transportation Committee
Traverse City, Michigan
May 24, 2005

Earl Easton
Spent Fuel Project Office
U.S. Nuclear Regulatory Commission


GrOWth Of ISFSIs over Time
2008
Trojan (34)
Columbia (15)
Humboldt Bay
DOE- TMI-2 (29)
ISF--Privatized
Owl Creek Energy Project
Private Fuel Storage
Rancho Seco (21)
Ft. Saint Vrain
(vault storage)
Diablo Canyon
San Onofre (14)
Palo Verde (23)
Monticello
Prairie Island (17)
Big Rock Point (7)
Point Beach (20)
Palisades (22)
Duane Arnold (10)
Dresden (24)
Quad Cities
Ft. Calhoun
GE Morris
(wet storage)
Fitzpatrick (3)
Yankee Rowe (15)
Haddam Neck (30)
Susquehanna (32)
Davis Besse (3)
Peach Bottom (24)
North Anna (22)
Maine Yankee (
Vermont Yank
Millstor
Indian Point
Oyster Creek (1
Hope Creek/Sale
Calvert Cliffs (46
Surry (51)
McGuire (11)
Catawba
Robinson (8)
Brunswick
Sequoyah (3)
Oconee (83)
Browns Ferry
ANO (37)
Hatch (22)
Grand Gulf
Farley
River Bend
Future
LEGEND
General (23)
General (11)
(potential)
Site-specific (11)
Site-specific (5)
(no fuel loaded)
Highways
Railroads
Operating Reactor Units
Decommissioned Sites
0 50 100 200 Miles
0 100 200 300 Kilometers
Current as of 2/15/2005
NRC Contact: Cynthia Barr- 301-415-4015 or csb2@nrc.gov

Status of Ongoing Activities

- NAS Storage Study
- NAS Transportation Study
- NRC Security Assessments
- Package Performance Study
- Baltimore Tunnel Fire Study
- Highway Tunnel Fire Study

Status of TRUPACT-III Application

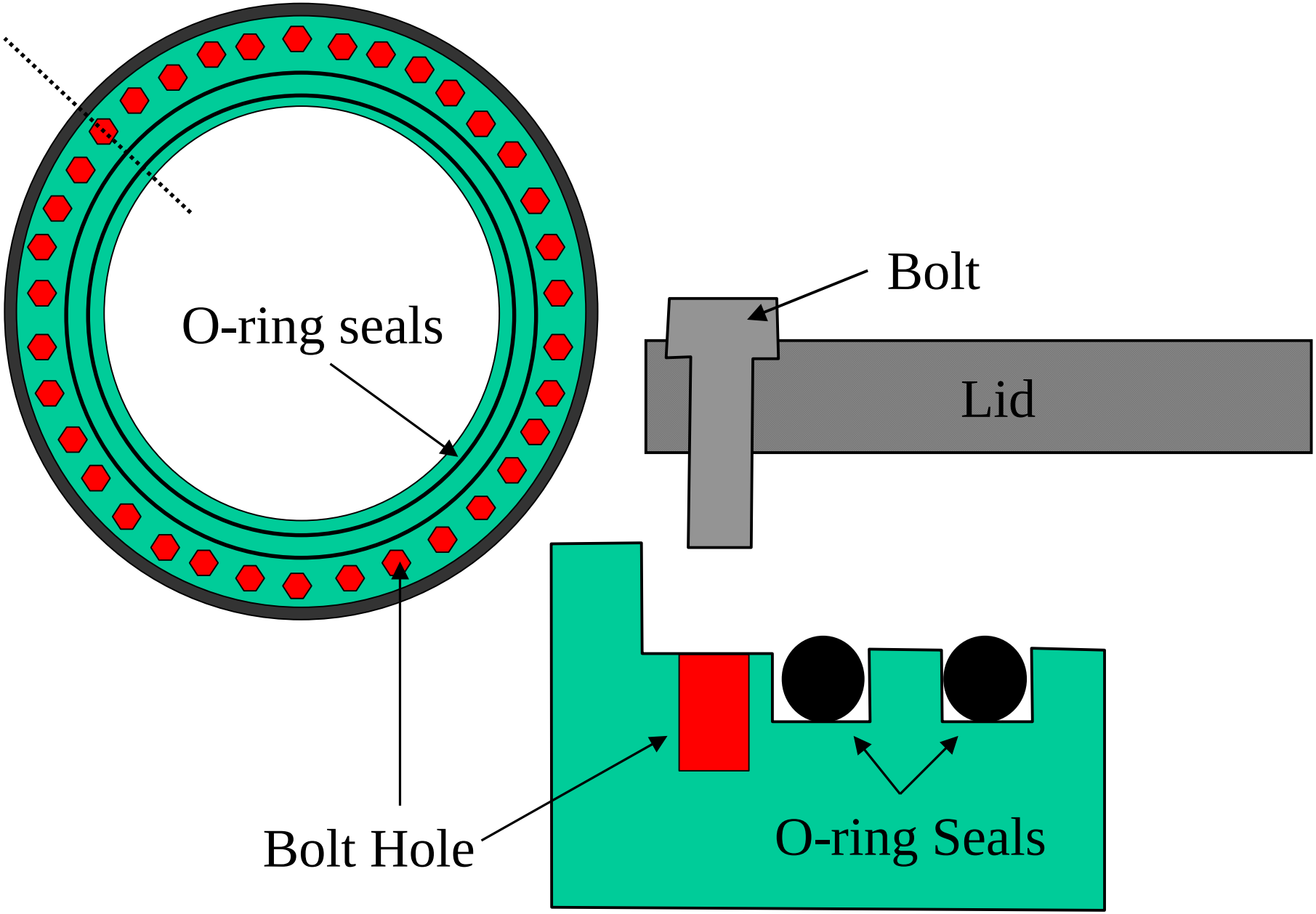
- **Application submitted March 12, 2004.**
- **Package evaluation based on computer analysis and half-scale model testing.**
- **Initial NRC review identified several structural and thermal issues.**
- **Structural and thermal issues discussed at public meeting in July 2004 .**

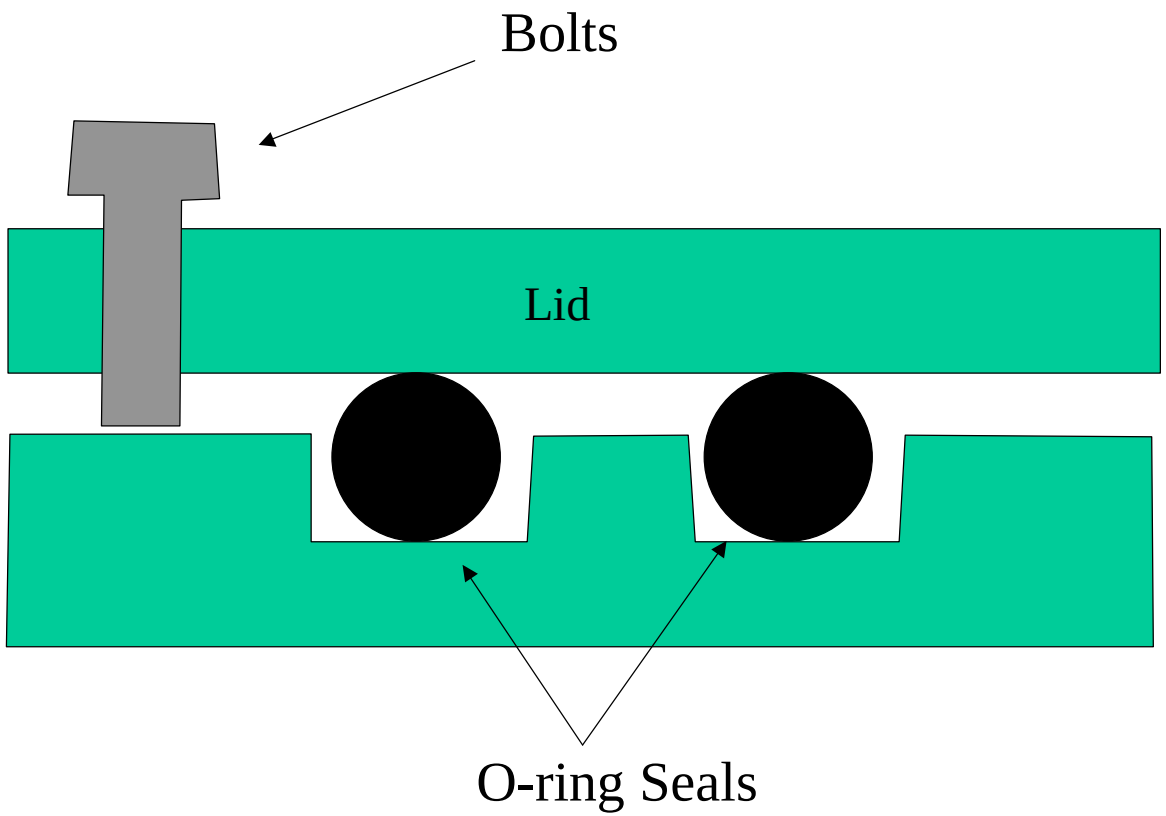
Status of TRUPACT-III Application

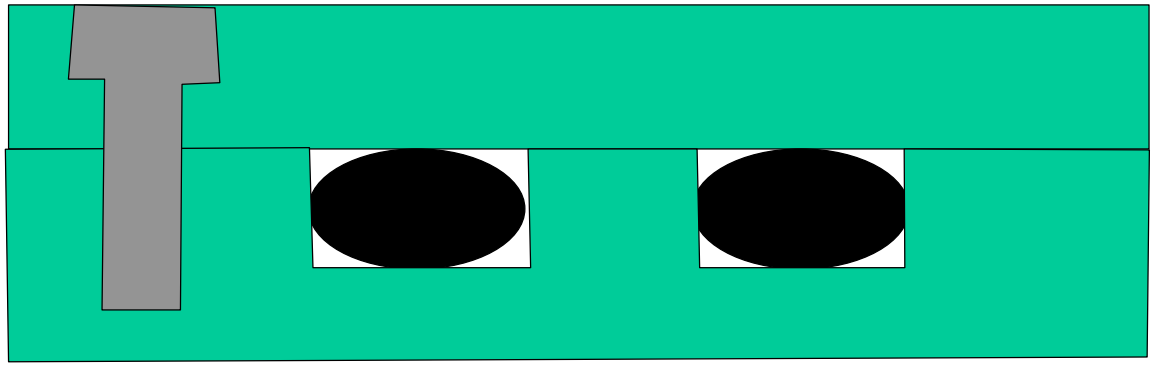
- **Applicant requests withdrawal of application in August 2004.**
- **NRC accepts withdrawal of application documenting additional information needed for resubmitting - September 2004.**
- **Public meeting held on the redesign of TRUPACT-III in April 2005.**

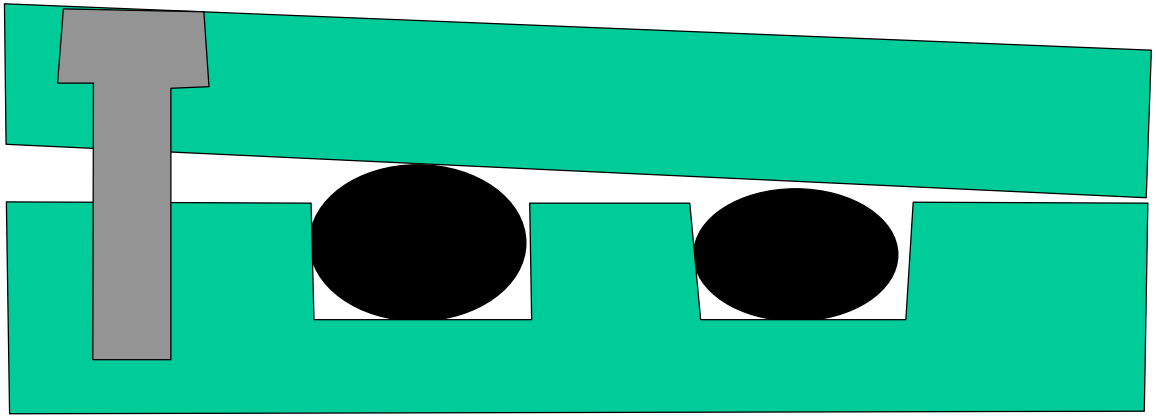
Structural and Thermal Concerns with Original Application

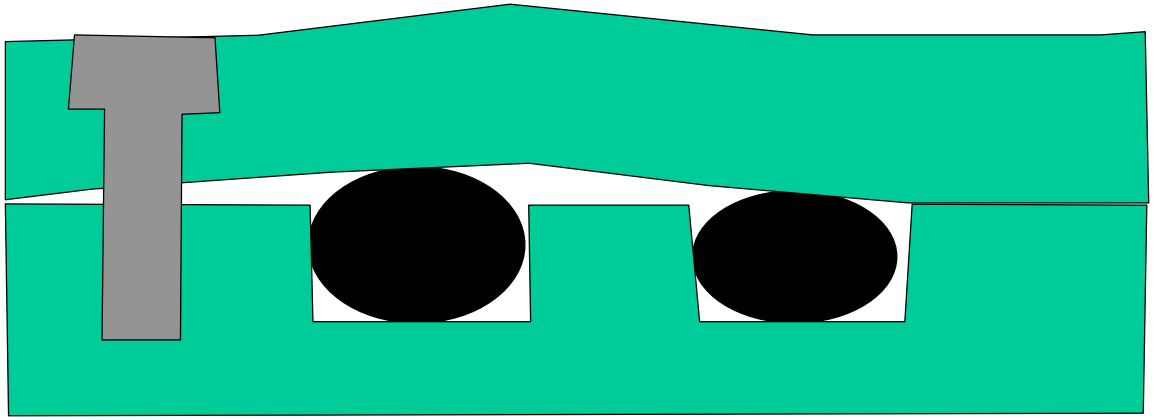
1. **Non-linear analysis showed yielding in the seal region.**
2. **Code margins were too small given variability of impact limit strength.**
3. **Puncture tests were not performed on revised overpack.**
4. **Temperature limits were exceeded for materials used in the containment structural assembly.**

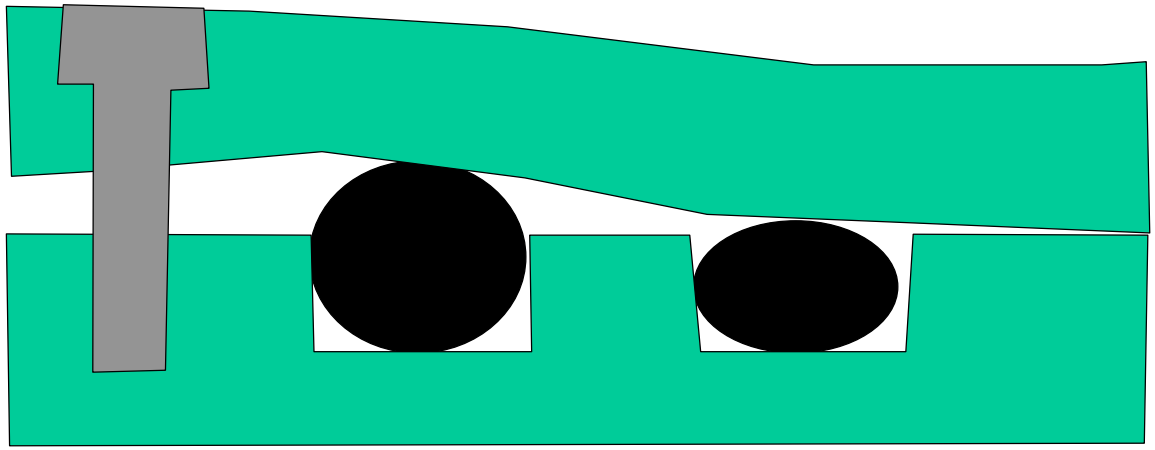

O-ring seals
Bolt
Lid
Bolt Hole
O-ring Seals


Bolts
Lid
O-ring Seals

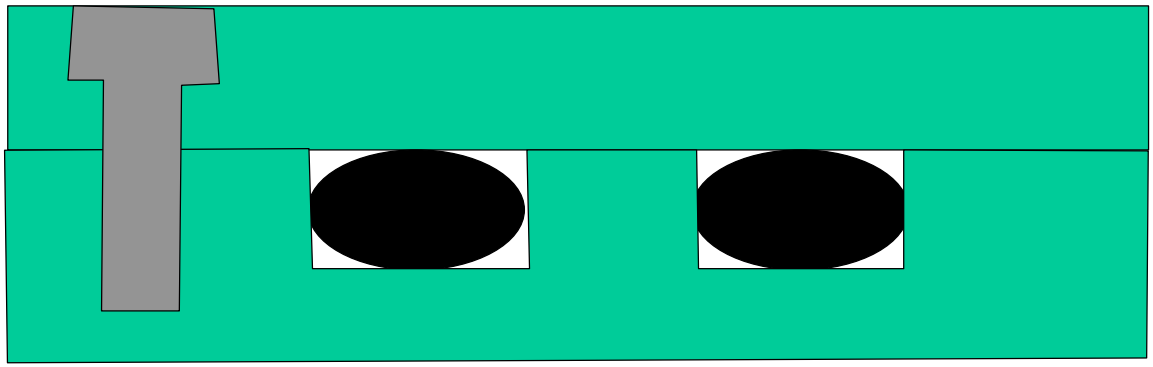








Approvals based on analysis



After accident conditions:

- No yielding of bolts
- No deformation of sealing surfaces
- Code margins applied

Introduction

- Rail is a safe way to transport hazardous materials. Over 99.99% of hazmat carloads arrive without release. There has never been a release involving the rail shipment of spent nuclear fuel.

- Significant improvements in tank car design were instituted by FRA after 1996 that should continue to make rail transport of hazardous materials even safer in the future.

Introduction

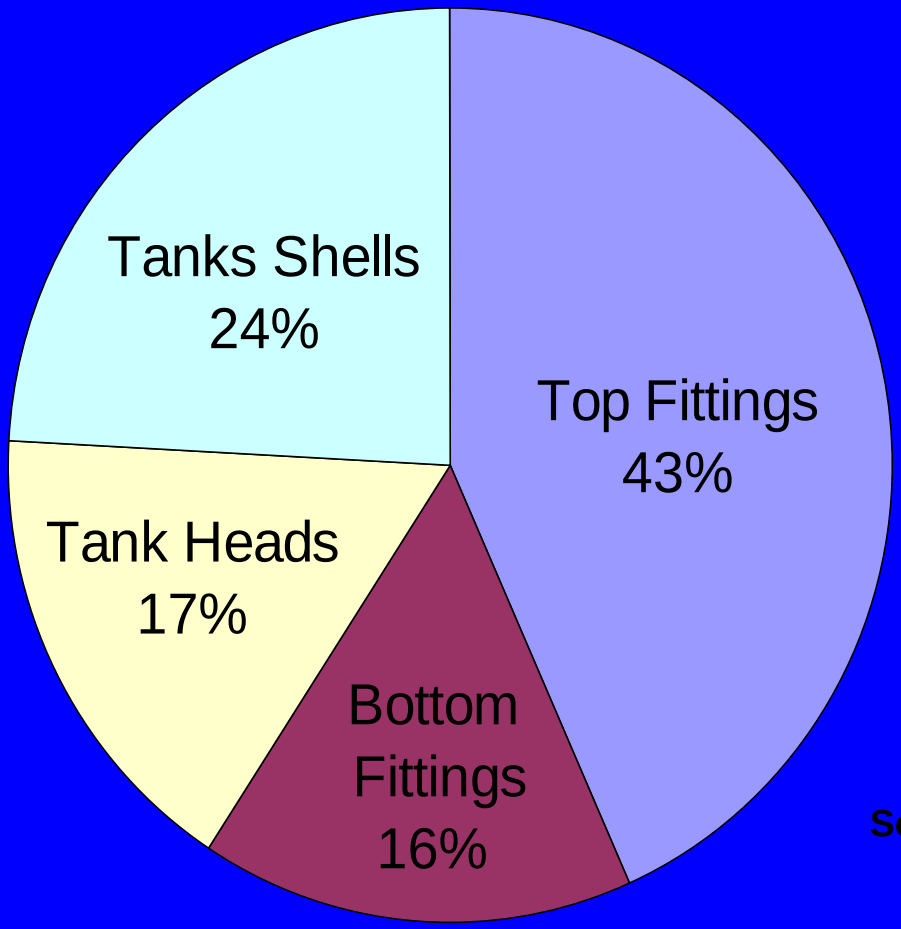
- Historically, most releases of hazardous materials in rail accidents have resulted from the failure of rail tank cars.

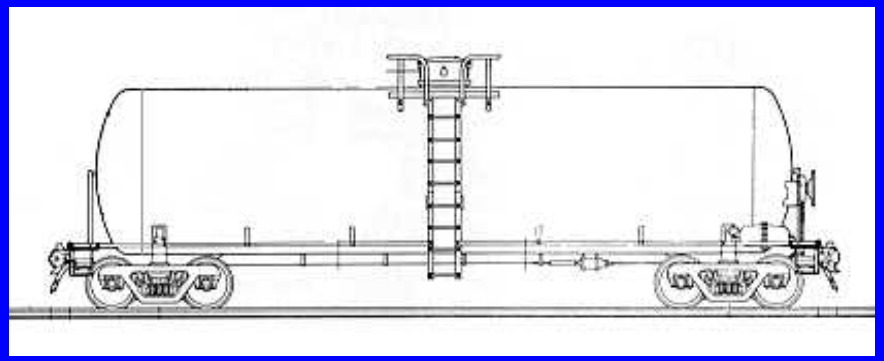
- The design characteristics of spent fuel rail casks provide a large margin of safety against the types of events that have caused releases from tank cars, and from the environments (fires, explosions) resulting from accidents involving tank cars.

Causes of Rail Accidents releasing non-radioactive Hazardous Materials prior to 1996

- Major Mechanisms
  - Container breach from puncture or impact.
  - Failure of top or bottom fittings on tank cars.
  - Hydraulic rupture
  - Explosions due to fire.
- Notes on data
  - Data refers to shipment in tank cars.
  - Requirements for tank cars upgraded after 1996.

Distribution of Accident Caused Releases by Source - Rail Tank Cars with Shelf Couplers only





Source: Ensuring Tank Car Safety
Proceedings from a Public Information Meeting
Federal Railroad Administration
Washington, D.C.
December 18, 1996

Based on pre-1996 data

Top and Bottom Fittings

- Tank cars require top and bottom fittings for loading, unloading, and maintenance.
- Prior to 1996, accidents involving top and bottom fittings, accounted for about 60% of accident releasing hazardous materials.

Spent fuel casks do not have top or bottom fittings.

Top and Bottom Fittings

Above: Examples of top fittings on rail tank cars

Right: Top fitting sheared off in an accident

Puncture of Tank Heads

- Account for 17% of accidents releasing hazardous materials.
- Often caused by rail coupler.
- Characterized by low puncture velocities.

Rail Coupler

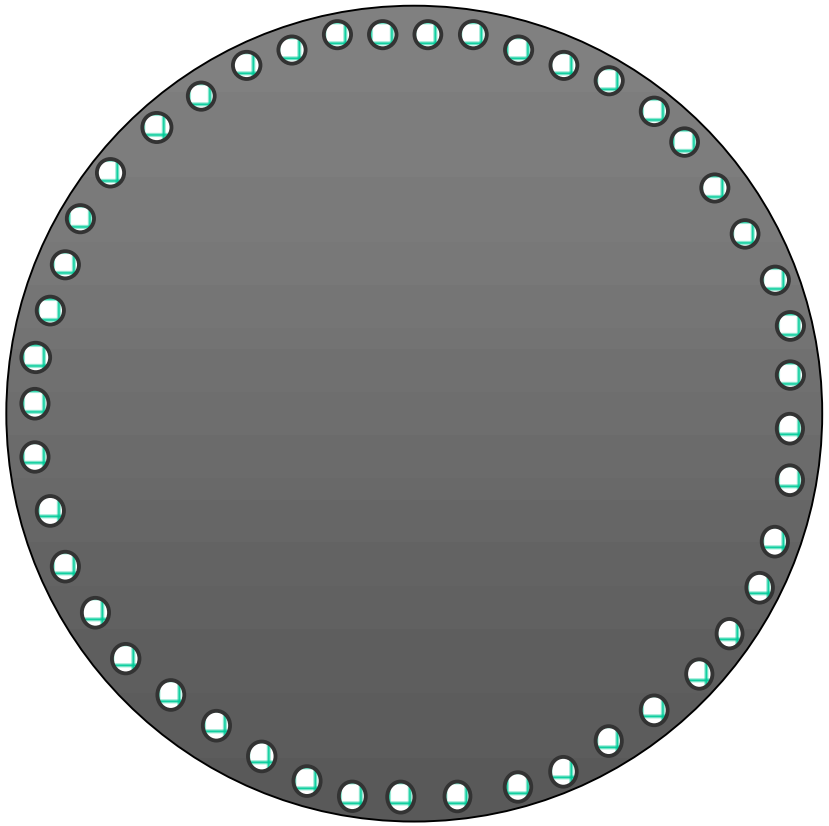
Rail Spent Fuel Casks

- Greater wall thickness at ends (impact limiter)
- Rail coupler at greater distance from cask.
- Shipped in rail cars approved to AAR Standards
- Analysis shows coupler will not penetrate cask ends or walls. (NUREG-6672)

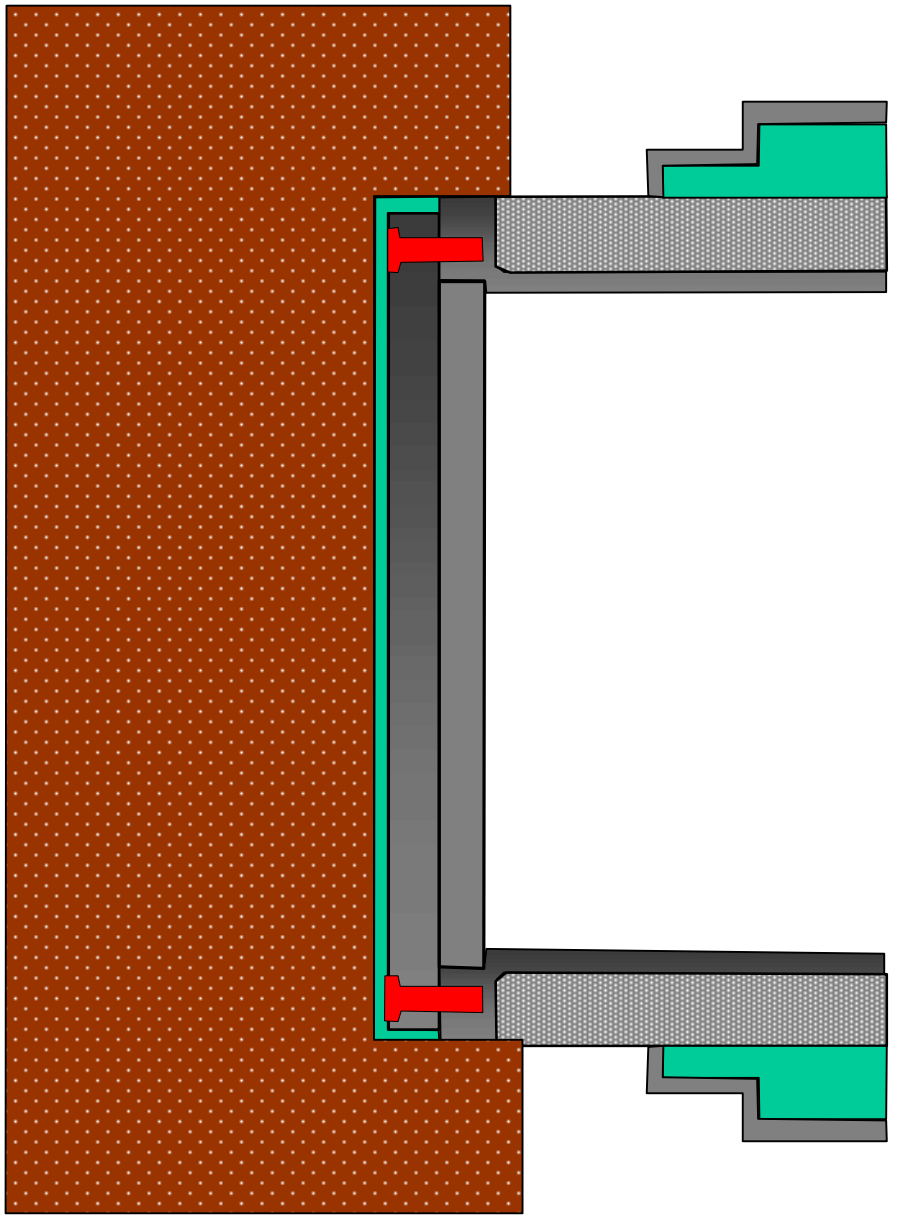
Puncture of Tank Heads

Note location of tank car/cask from nearest coupler

SIDE VIEW

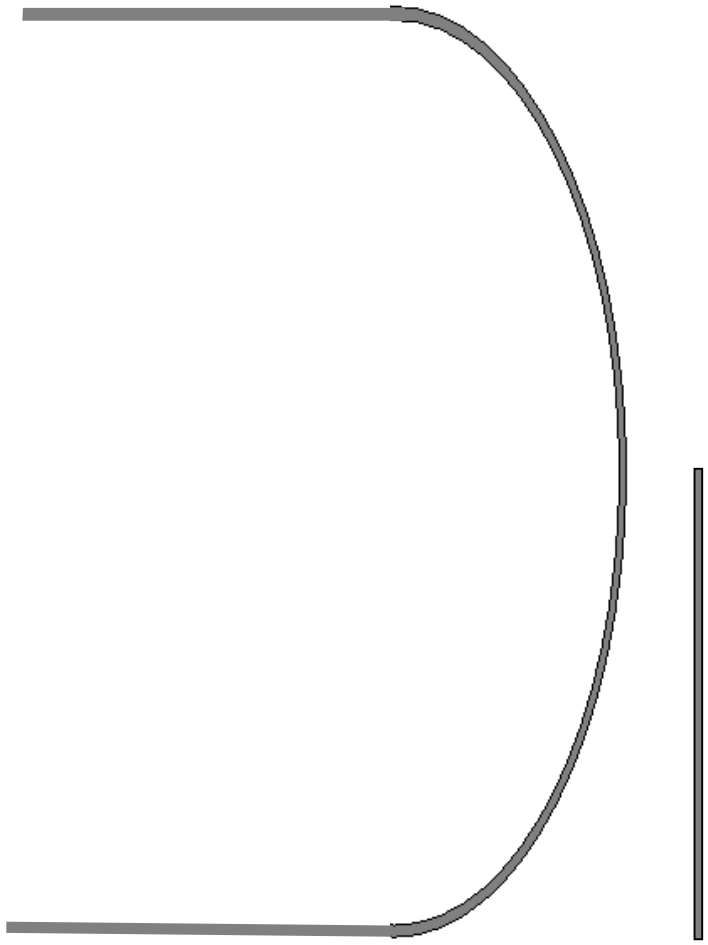


END ON VIEW

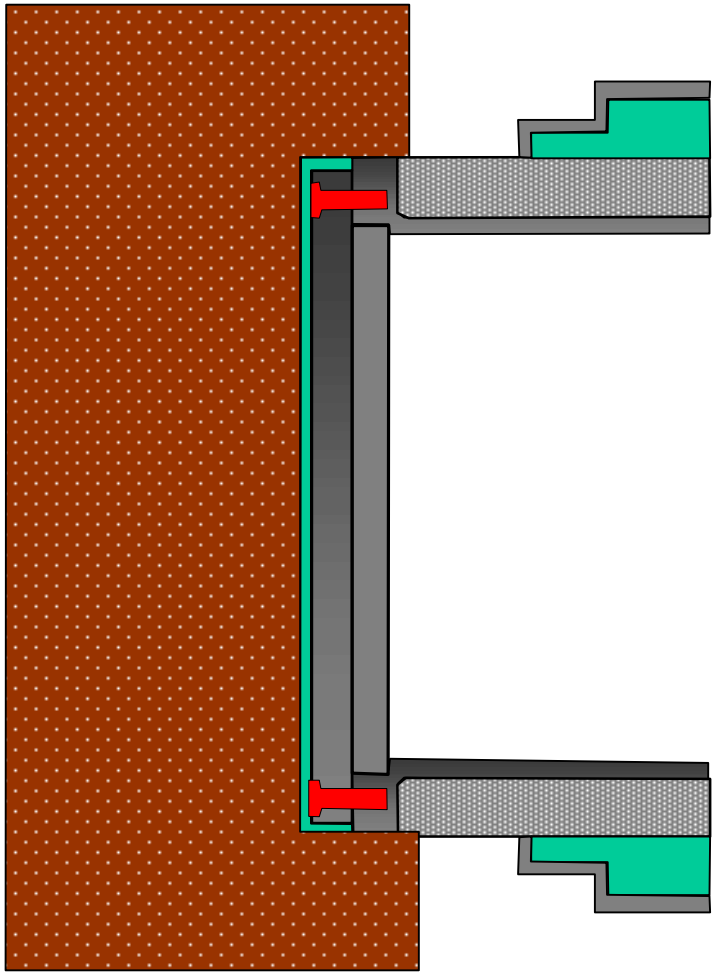


TN-68 LID

Head to Head



Typical Rail Tank Car

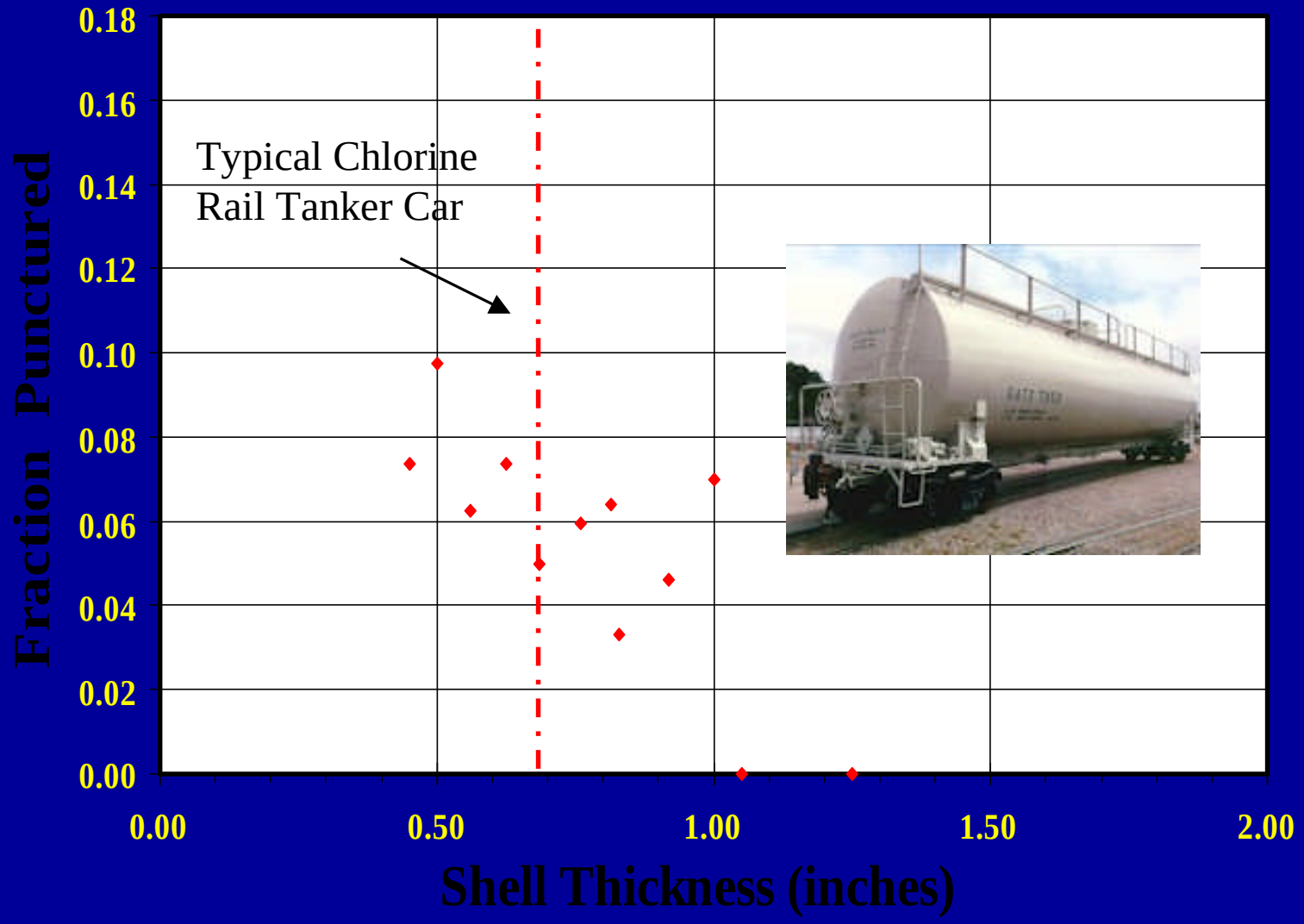


TN-68 Rail Cask

Tank Shell Breach

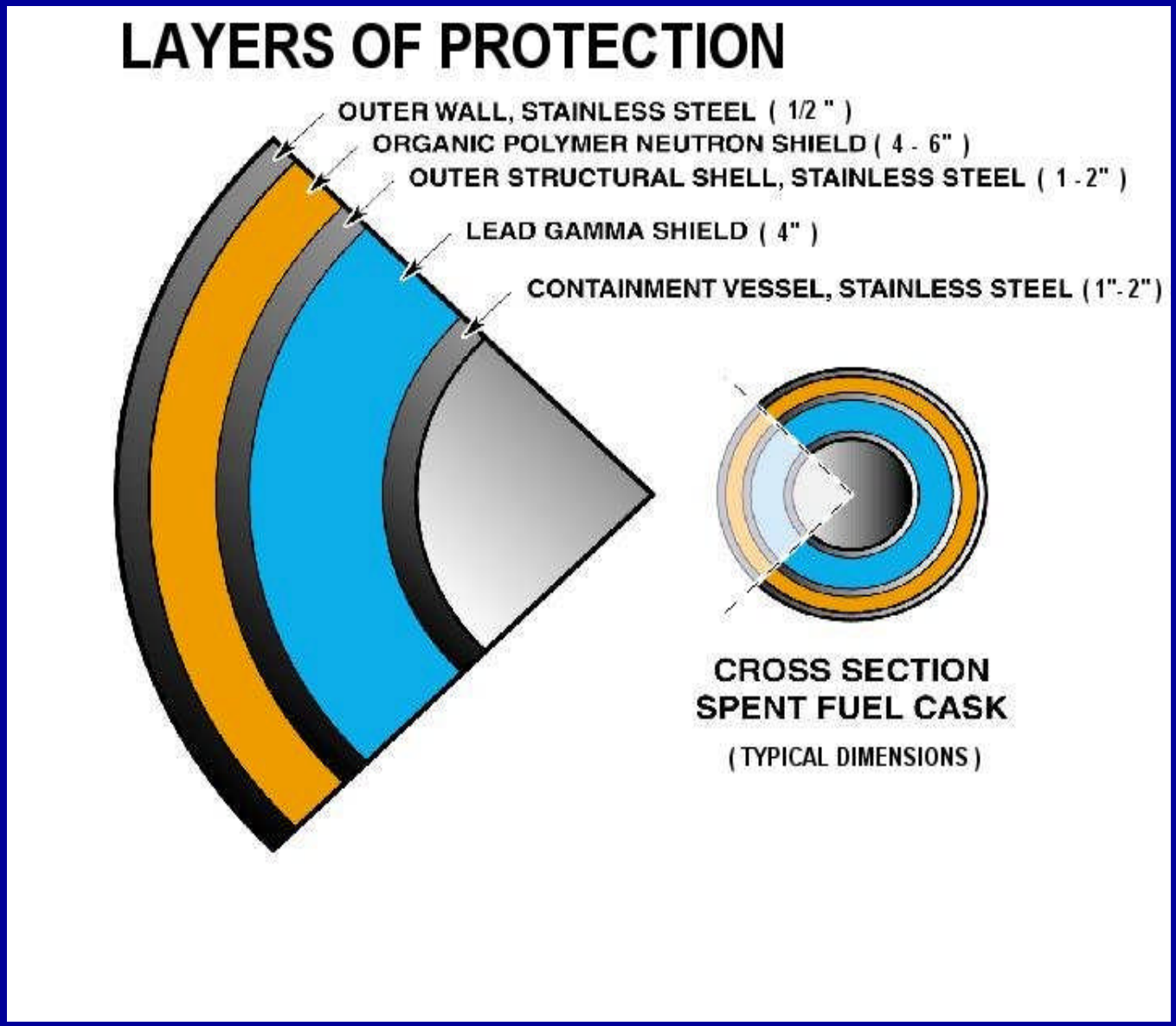
- Accounts for approximately 25% of accidents releasing non-radioactive hazardous material.
- Caused by
  - Puncture
  - Over pressurization (hydraulic rupture) or,
  - Explosion of contents.
- There has never been a breach or release from a spent fuel cask.

Fraction of railroad tank cars involved in puncture-type accidents that failed due to puncture

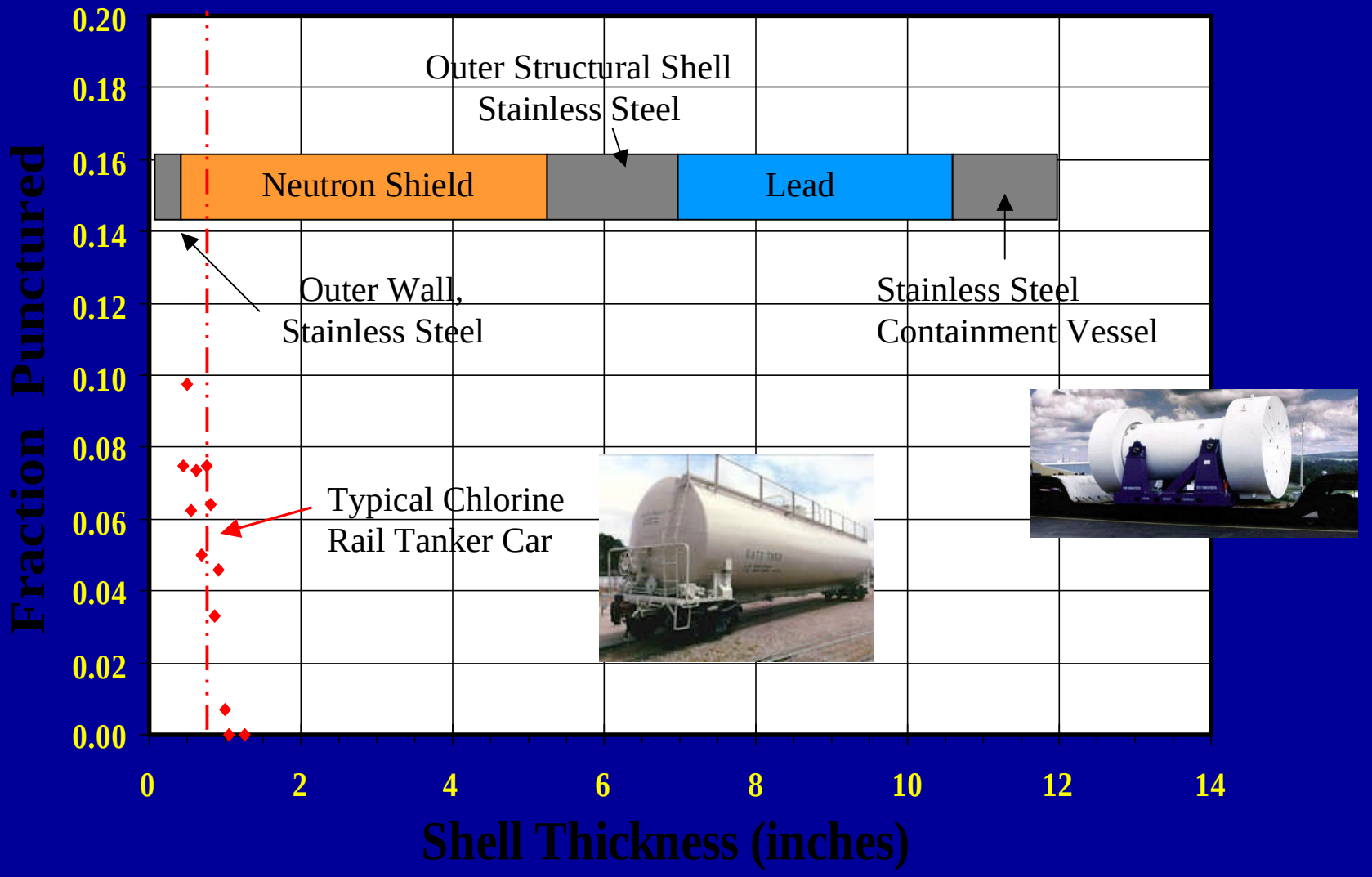


Source: NUREG-6672

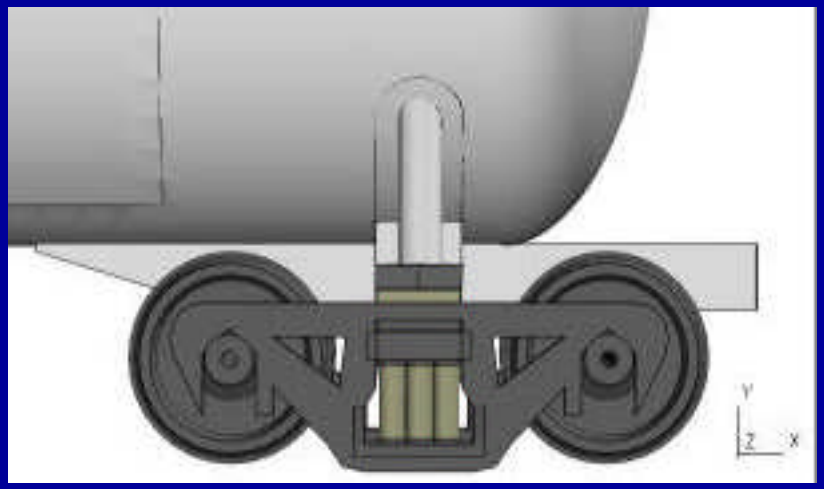
Typical Cross Section of a Spent Fuel Cask

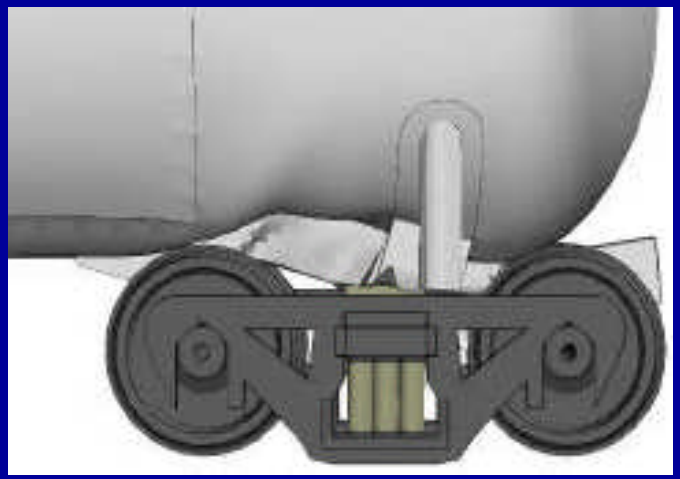


Fraction of railroad tank cars involved in puncture-type accidents that failed due to puncture



Tank Shell Breach





Accident scenario resulting in puncture of tank car wall.

Same scenario is not possible for a rail spent fuel cask. Spent fuel cask and rail car are separate entities.

Tank Shell Breach

Rail Accident near Minot, ND, in January 2002.

Right: Failure of anhydrous ammonia (liquefied compressed gas) tank car. Note wall thickness.

Spent fuel casks do not contain flammable or explosive liquids or gases, or highly pressurized contents.

Improvements in Tank Car Design instituted after 1996

- Since 1996, the Federal Rail Administration has adopted standards that would:
  - Improve puncture protection for tank heads.
  - Require greater use of shelf couplers.
  - Require insulation for pressurized tank cars.
  - Improve the material properties of steels used to build tank cars.
- While these measures are not applicable to spent fuel casks, they should reduce the severity of rail accidents.

Spent Fuel Casks in Accidents involving Fires and Explosions

- Fires
  - Cask approval standards bound severe fires.
  - Duration of “train fires” is not always indicative of cask exposure.
  - Study of Baltimore Tunnel Fire.
- Explosions
  - BAM Propane explosion.
  - Early security work.
  - On-going security assessments.

BAM Test Simulating the effects of a Propane Tank Car
on a CASTOR Transport/Storage Cask

Concluding Thoughts

- Type B accident condition tests provide a high degree of protection against real life rail accidents.
- NRC periodically re-assesses the effectiveness of Type B standards to reflect changes in package design and accident statistics.
- There has never been a release from a spent fuel cask in a rail (or highway) accident.