Performance of Spent Fuel Transportation Casks in Environments similar to the Baltimore Tunnel Fire

Midwestern Radioactive Materials Transportation Committee
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Purpose of the Tunnel Fire Study

- To determine how three representative spent fuel cask designs certified by the NRC might have responded in an accident such as the Baltimore Tunnel Fire.

Assumptions used to Define the Tunnel Fire Environment

- Seven hour fire – 23 hour cool down.
- Temperature profiles developed by National Institute of Standards and Technology (NIST).
- Maximum flame temperature of 1800^{o}F.
- Casks located one rail car length from fire source.
- Same fire model that was used for the HI-STAR 100 analysis that was previously presented to the Committee by Chris Bajwa.

Spent Fuel Transport Casks Analyzed in Baltimore Tunnel Fire Study

	Typical Transport Mode	Loaded Weight, lbs	Contents	Cask Closure Design Features
HI-STAR 100 (cask on rail car)	Rail	277,300	68 BWR 32 PWR	Bolted Lid with O-rings, Inner Welded Canister
TN-68 (cask on rail car)	Rail	260,400	68 BWR	Bolted Lid with O-rings
NAC-LWT (cask in ISO container on rail car)	Truck	52,000	1 PWR	Bolted Lid with O-rings

HI-STAR – 100 Rail Cask (conceptual image)

Key Results for HI STAR-100 Rail Cask

Inner Canister remains intact

→ No release from cask

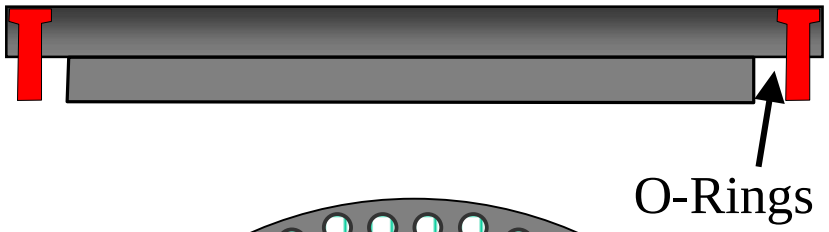
Peak Fuel Cladding Temperature	Cladding Burst Temperature	Temperature Margin
884° F	1382° F	498° F

→ No release from spent fuel rods

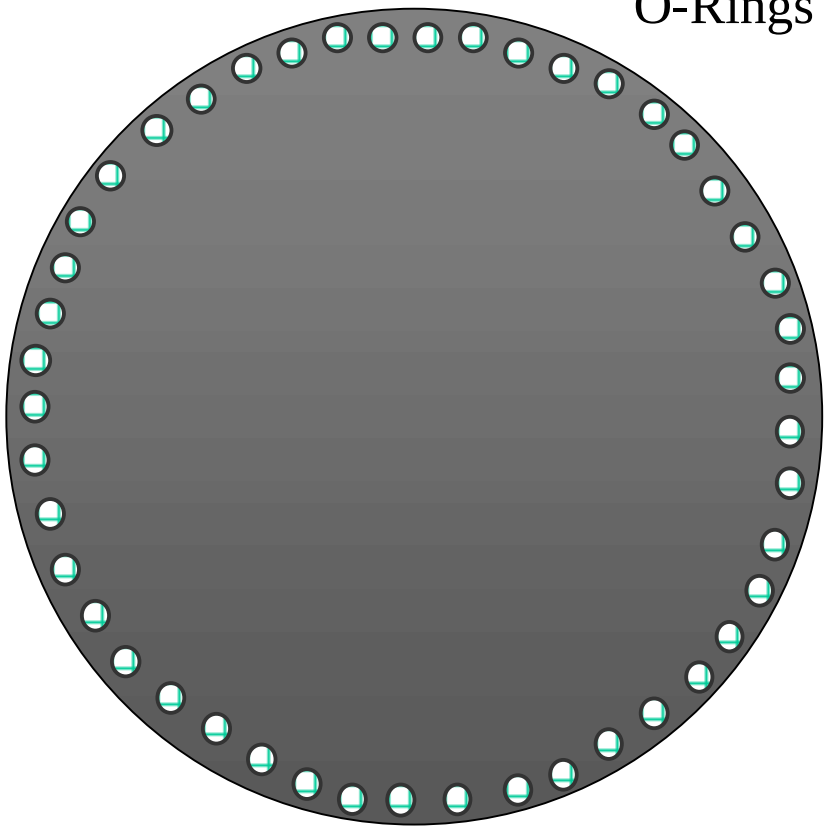
Peak Temperature In Seal Region	Outer Seal Temperature Limit	Inner Seal Temperature Limit
1177° F	1200° F Metallic	1200° F Metallic

→ No release from cask

SIDE VIEW

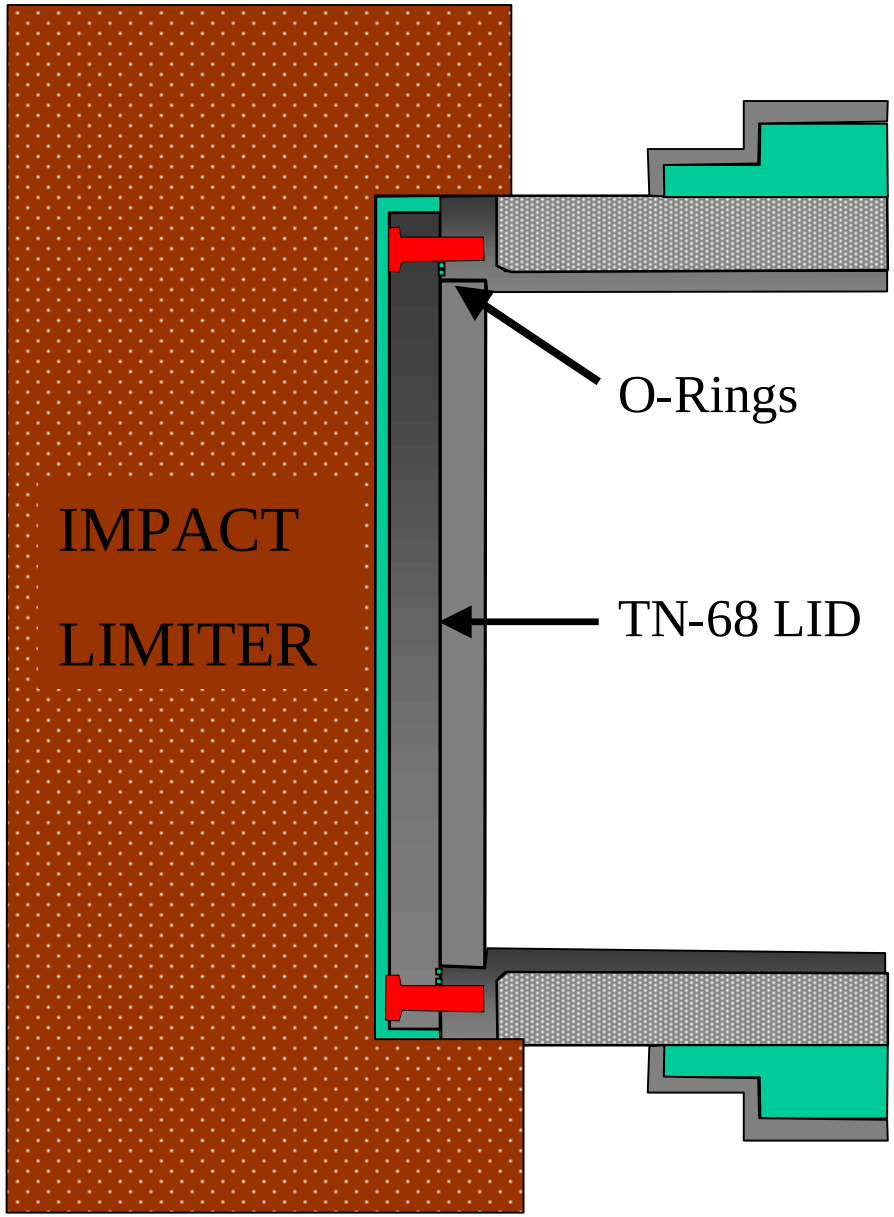


O-Rings



END ON VIEW

TN-68 LID



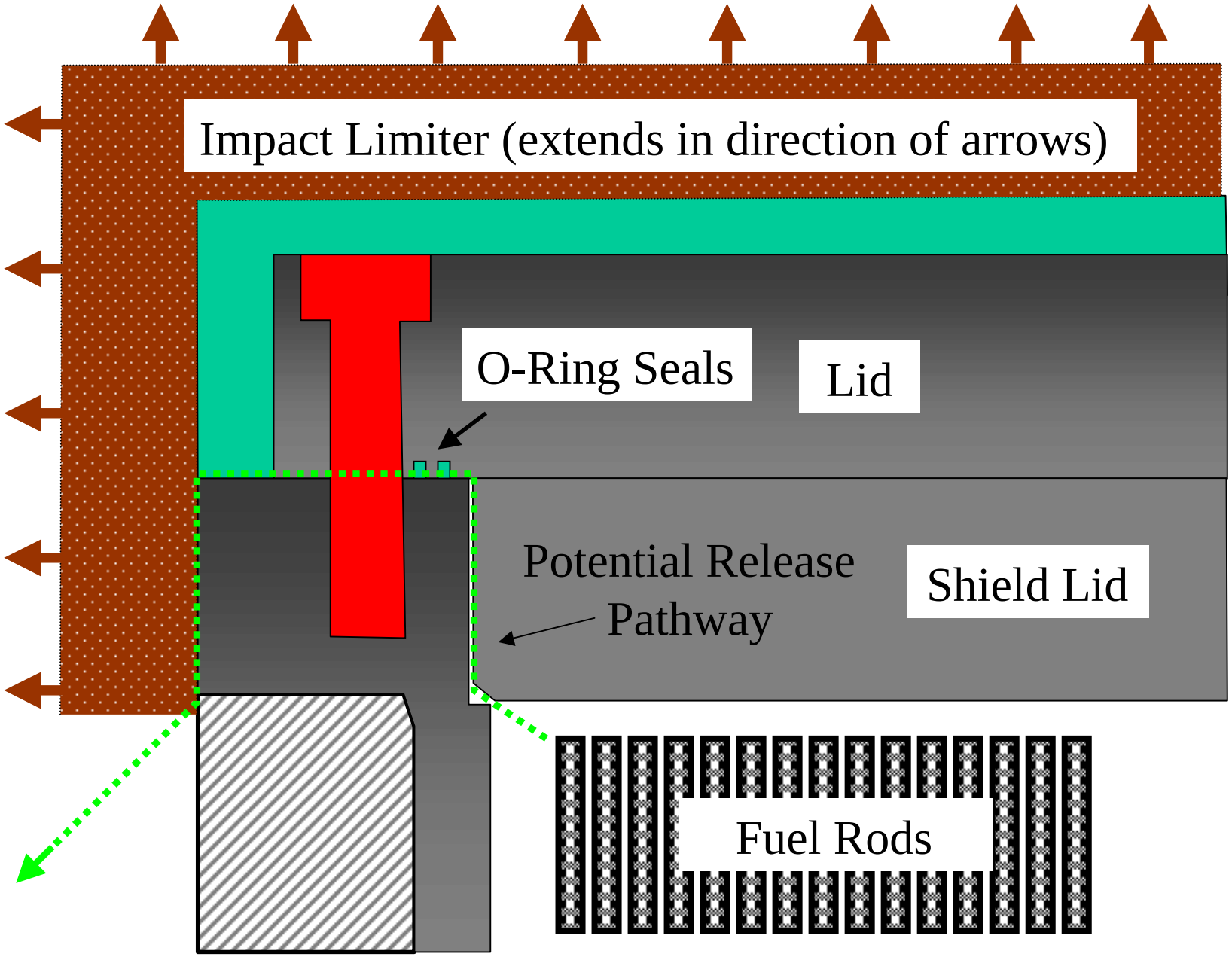
Key Results for TN-68 Rail Cask

Peak Cladding Temperature	Cladding Burst Temperature	Temperature Margin
845° F	1382° F	537° F

→ No release from spent fuel rods

Peak Temperature In Seal Region	Outer Seal Temperature Limit	Inner Seal Temperature Limit
811° F	644° F Metallic	644° F Metallic

→ Minor release of CRUD possible


Impact Limiter (extends in direction of arrows)
O-Ring Seals
Lid
Potential Release
Pathway
Shield Lid
Fuel Rods

Staff Estimation of Possible CRUD Release from the TN-68 Rail Cask in a Baltimore Tunnel Fire Type Accident

- Staff calculation based on methodology used in NUREG/CR-6672 and Security Assessments.
- Amount released less than 3.4 Curies of Co^{60}
- Estimate consistent with release estimate in Modal Study (1987) for Livingston Fire Analysis.

Realistic Conservatism in Release Estimates

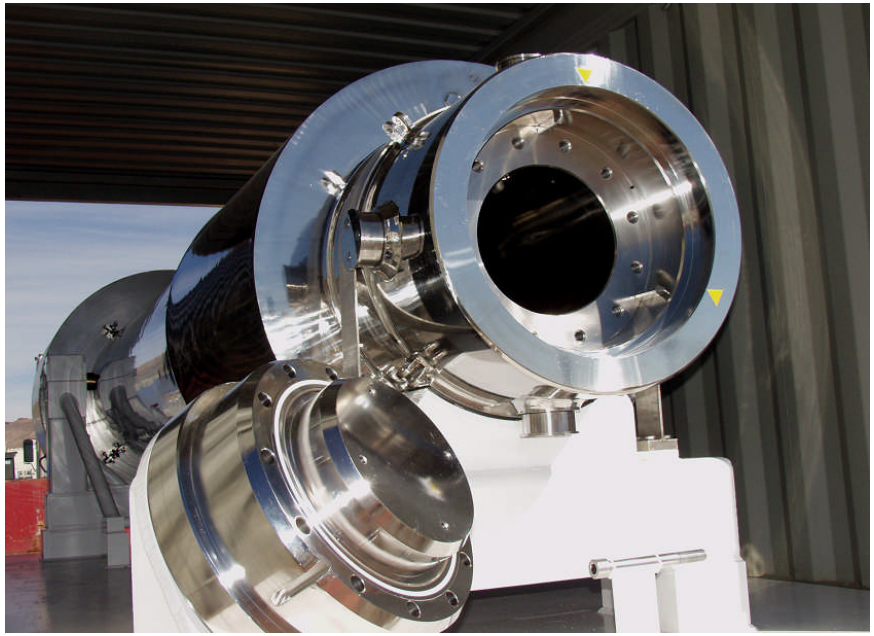
- Realistic Assumptions
  - Based on realistic values for CRUD on BWR rods, not highest values.
- Conservatisms
  - Does not consider plugging of release pathways.
  - No credit for metal to metal contact between lid and cask.
  - No credit given for seals in regions where the seals remain below their rated service temperature, i.e., total area of seals were considered to be at the peak seal temperature.

NAC-LWT Truck Cask

Below:
NAC-LWT with personnel barrier

Above:
NAC-LWT in ISO container

Right:
NAC-LWT rail shipment
in ISO containers, configuration
that is analyzed in study.



Left:
NAC-LWT with lid removed. Note stepped configuration of Lid. Impact limiter affixed to bottom end.

Right:
NAC-LWT inside ISO Container. Lid bolted in place. Impact limiters not in place.

Key Results for NAC-LWT Truck Cask shipped by Rail in an ISO Container

Peak Cladding Temperature	Cladding Burst Temperature	Temperature Margin
1099° F	1382° F	283° F

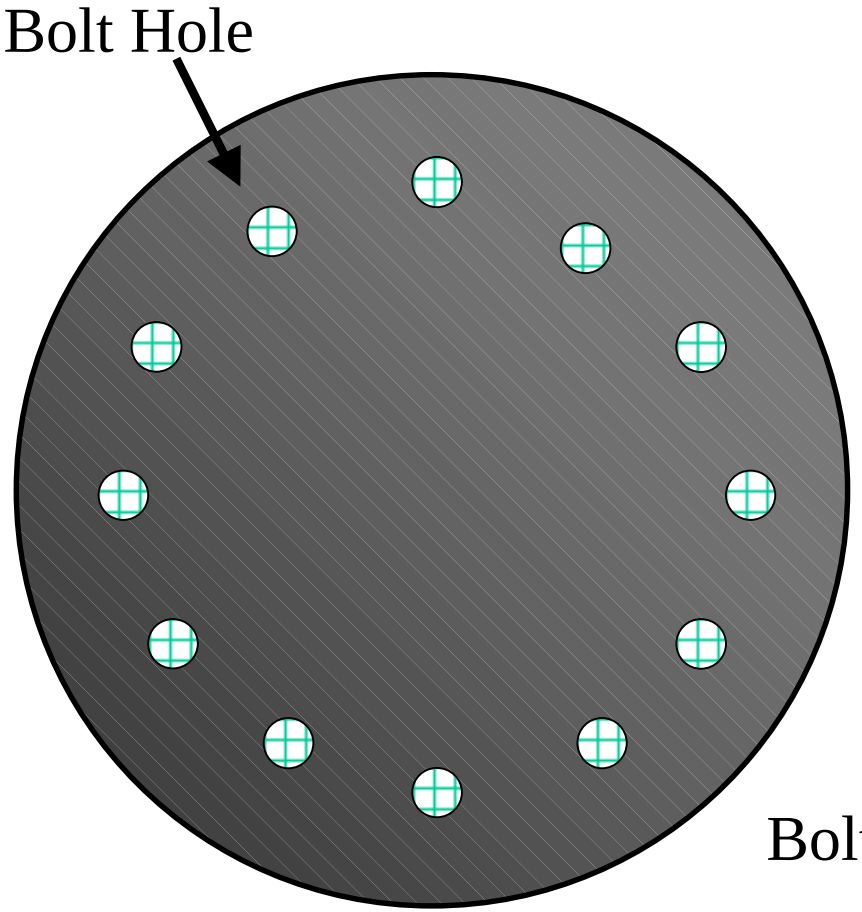
→ No release from spent fuel rods

Peak Temperature In Seal Region	Outer Seal Temperature Limit	Inner Seal Temperature Limit
1350° F	735° F Teflon	800° F Metallic

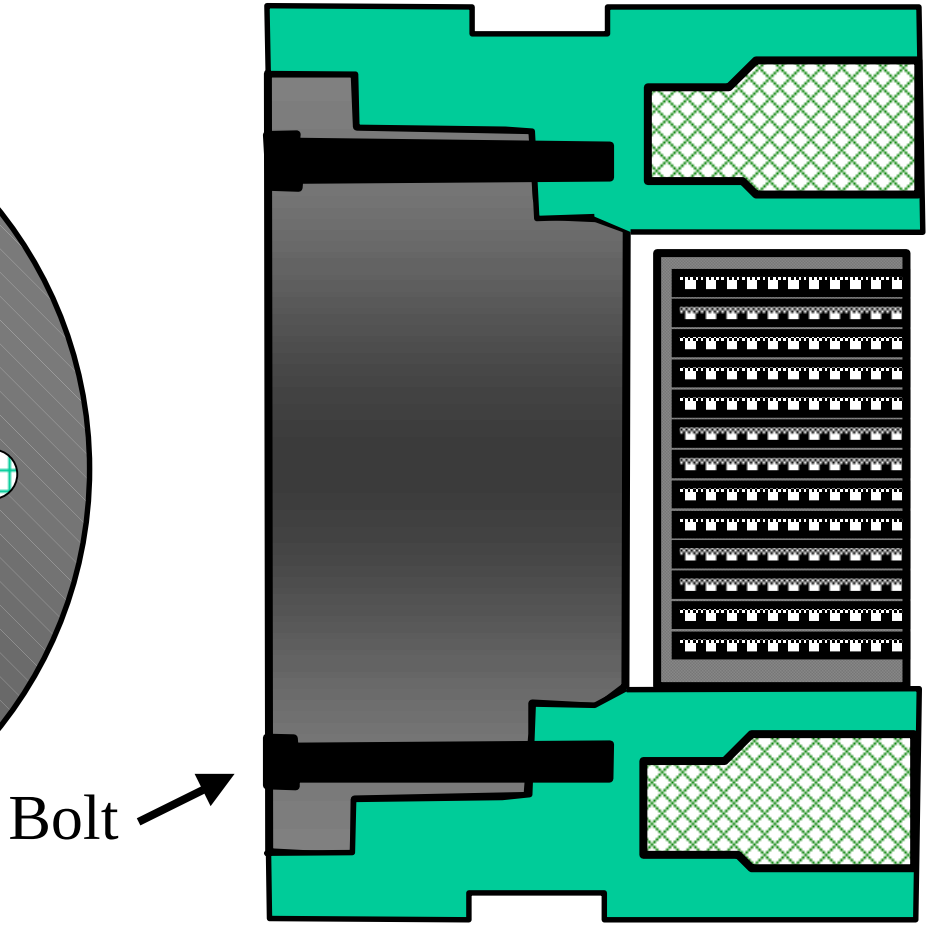
→ Minor release of CRUD possible

CRUD is a thin layer of corrosion that sometimes forms on a fuel rod when the surface oxidizes.

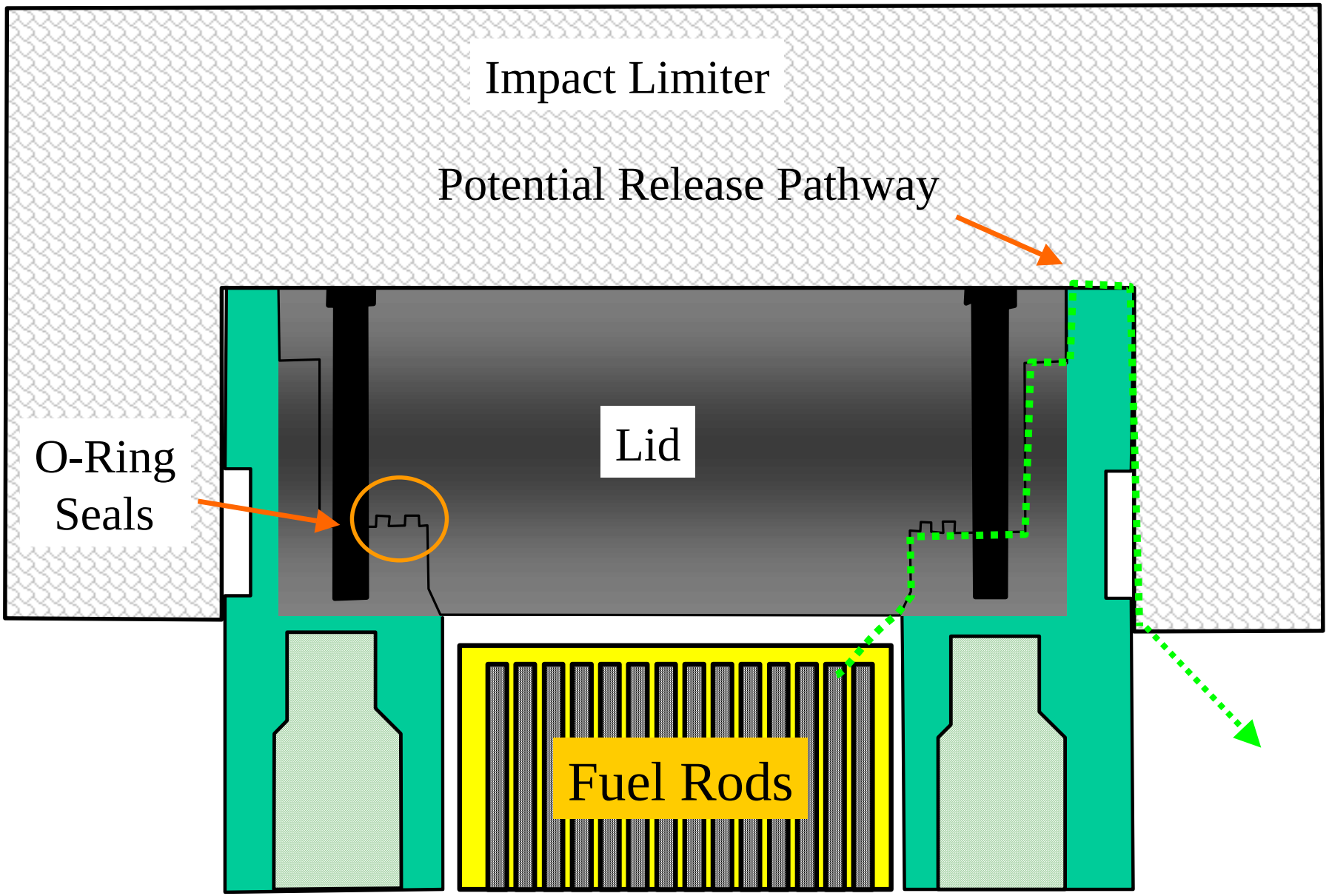
NAC-LWT Truck Cask



LID



LID CLOSURE REGION
(shown without Impact Limiter)



NAC-LWT LID CLOSURE REGION

Staff Estimation of Possible CRUD Release from the NAC-LWT Truck Cask in a Baltimore Tunnel Fire Type Accident

- Staff calculation based on methodology used in NUREG/CR-6672 and Security Assessments.
- Amount released less than 0.02 Curies of Co^{60}

Realistic Conservatism in Release Estimates

- Realistic Assumptions
  - Based on realistic values for CRUD on PWR rods, not highest values.
- Conservatisms
  - Does not consider plugging of release pathways.
  - No credit for metal to metal contact between lid and cask.
  - No credit given for seals in regions where the seals remain below their rated service temperature, i.e., total area of seals were considered to be at the peak seal temperature.

Summary of Key Results

	Potential Releases (calculated)	Comments	Number of A_2's released[1]
HI-STAR 100	None.	Releases prevented by Inner Canister	0
TN-68	3.4 Ci of Co^{60}	Release due to Crud. Cladding remains intact.	0.3
NAC-LWT	0.02 Ci of Co^{60}	Release due to Crud. Cladding remains intact.	.002

[1] The potential releases of radioactive material from all three casks are well below the internationally accepted safety standard of an A_2 quantity per week. The A_2 quantity per week is based on limiting potential exposures to first responders and the public following a severe transportation accident to no more than the occupational dose of 100 mrem . This limit represents approximately 25 percent of the normal background dose of 400 mrem/yr.

Risk Perspective

- NUREG/CR – 6672 predicts that severe fire accidents, including an accident like BTF, will occur once every 4.8×10^{12} miles.
  - The frequency stated is for a class of accidents that would include BTF; however, BTF is extreme (duration) within that class – probability of cask in BTF-type accident is significantly less than that stated (for the entire class of severe fire accidents)
  - Operational considerations further limit frequency; e.g., spent fuel rail shipments not permitted in BT; use of dedicated trains.
- By comparison, a rough estimate of the total rail shipment miles for a proposed repository campaign is about 6.4×10^{6} miles (3200 rail shipments at an average distance of 2000 miles).

Risk Perspective (continued)

- Frequency (F) of a BTF type event:

$$F = F_{mile} M_{campaign} R$$

where, F_{mile} = frequency of severe fire accidents per mile

$M_{campaign}$ = miles per shipping campaign

R = factor based on operational restrictions

- $F = 1.3 \times 10^{-6} R$ events/shipping campaign or one event every 750,000 shipping campaigns.

Conclusions

- The response of three different cask designs indicate that spent fuel would not be released in a Baltimore Tunnel Fire-type accident.
- Any release of radioactive material, such as CRUD, would be extremely small and pose no significant danger to the public or first responders.

Conclusions

- Although the Baltimore Tunnel Fire was a real world event, the chance that a spent fuel cask would be involved in this type of accident is extremely low.