U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

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Office of Nuclear Material Safety and Safeguards

Spent Fuel Transportation Fire Studies

(NMSS/DSFM)

This poster depicts NRC's studies of truck and rail transport accidents involving fires in regard to regulatory requirements for shipment of spent nuclear fuel (SNF). The agency initiated these studies in response to a 2006 National Academy of Sciences review of procedures and regulations. Although accidents involving SNF have not occurred by rail or roadway, the analyses of fire accident scenarios were based on severe historical railway and roadway fires (of non-nuclear materials) in terms of their potential impact on SNF containers.

The combined summary of this work on fire accidents demonstrates that current NRC regulations and packaging standards provide a high degree of protection to public health and safety against releases of radioactive material in real-world transportation accidents, if such events were to involve SNF containers.

NRC conducted fire studies to understand:

- Fuel types/quantities in actual fires
- Temperatures in realistic/idealized fires
- Fire durations in real accidents
- Effect on package size/mass
- Behavior of Important-to-Safety components
- Actions, if any, that may be needed for real-world fire accidents

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Analytical Codes

COBRA-SFS (PNNL) and ANSYS

Predict transient thermal response of packages during fire/extended post-fire cooldown

Fire Dynamics Simulator (NIST)

Predict fire conditions in accident scenarios, used as BCs for COBRA-SFS and ANSYS thermal models of SNF packages

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Baltimore Tunnel Fire

- Train carrying HAZMAT (not SNF) derailed; tank car carrying liquid tripropylene
- Ignition of spilled tripropylene led to severe fire lasting ~3 hours (NTSB)
- Conservative modeling of fire predicted that if fully oxygenated, fire duration of ~7 hours with peak gas temperatures of 1140°C in flame region and 1070°C at 20 meters away

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Consequences

- HAC design basis assumes neutron shield is lost; dose within regulatory limits
- No fuel rod cladding failure predicted (no release of SNF particulate/fission gases)
- For packages with failed seals, potential release of $<A_2$ quantity CRUD detaching from fuel rods
- No loss of gamma shielding for TN-68 or HI-STAR100
- Localized lead melting in NAC-LWT, provides gamma shielding with no dose consequence

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Caldecott Tunnel Fire

- Tanker truck and trailer overturned/caught fire in tunnel
- Tank trailer cargo: 8,800 gallons gasoline
- Fire duration (NTSB):
  - Overall duration: 2.7 hours
  - Intense for 40 minutes

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Consequences for NAC LWT

Fire duration 40 minutes; 1074°C peak gas temperature

- **Neutron shield**
  - HAC design basis assumption (neutron shield lost and dose within regulatory limits)
- **Gamma shield**
  - Lead reaches melting point ~23 minutes after start of 40-minute fire
  - Localized melting, still provides shielding
- **Metallic lid seal**
  - Seal temperatures (391/423°C with and w/o ISO container) are below 427°C continuous-use limit
- **Cladding**
  - PCT (284°C/279°C with and w/o ISO container) below limits
- **Vent/Drain port polymeric O-rings**
  - Peak temperatures in seal region (557/698°C with and w/o ISO container) exceed continuous-use limit of TFE (301°C) and Viton (288°C) seals, conservatively assumed to have failed
- **Potential release through failed seals**
  - CRUD particles from cladding exterior: 0.01 Curies
  - 0.001 A_2 quantity $<A_2$/week regulatory limit

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MacArthur Maze Fire

- Tanker truck and trailer overturned/caught fire
- Tank trailer cargo: 8,600 gallons gasoline
- I-580 roadway located above the fire
- Intense fire weakened steel girders, collapsing two spans onto tanker

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Consequences for GA-4

Pre-collapse fire: 1100°C for 37 minutes; Post-collapse fire: 900°C for 71 minutes

- **Gamma shield**
  - Peak temperature 804°C < 1132°C depleted uranium melting temperature
- **O-rings**
  - Based on ANSYS results, peak temperatures of cask lid O-ring (627°C), drain valve seal (832°C), and gas sample port seal (810°C) exceed the continuous-use limit of EPDM seals (150°C)
  - Analyses assumed seal failure
- **Fuel cladding**
  - Predicted PCT ~760°C during post-fire cooldown, exceeding short-term and estimated burst-temperature limits
- **Estimate of potential release**
  - Model based on pressure in package and leakage between lid and flange for lid clamping force
  - Potential release
    - Fission products and SNF particles
    - CRUD particles spalled from cladding surface
  - Total release calculated: 0.24 A_2 quantity $<A_2$/week regulatory limit
    - Conservatively neglects particulate settling
    - Conservatively assumes no restriction on particle size that can pass through small gap

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Newhall Pass Fire

- Chain-reaction collision of 33 tractor-trailer trucks; 24 trucks destroyed
  - Fire started near tunnel exit; spread full length of tunnel
- Combustible material: diesel (in truck fuel tanks), tires, wood, fruit/vegetables, etc.
- Fire duration
  - Estimated 3~5 hours; local fires on individual vehicles estimated 0.5~1.0 hours

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Consequences for GA-4

Peak fire temperatures (854°C – 1088°C), local fire durations of ~26 to 60 minutes

Neutron shield
- HAC design basis assumption (neutron shield lost and dose within regulatory limits)

Gamma shield
- 649°C peak temperature < depleted uranium melting point (1132°C)

O-rings
- ANSYS results: peak temperatures of lid O-ring (353°C), drain valve seal (359°C), and gas sample port seal (294°C) exceed continuous-use limit of EPDM seals (150°C)
- Seal failure assumed for potential release of CRUD in cladding exterior

Fuel cladding
- FRAPCON predicted no fuel failure
- FRAPTRAN predicted no fuel failure based on COBRA-SFS results, potential fuel failure in three of ten cases based on ANSYS results

MacArthur Maze conditions bounded Newhall Pass tunnel conditions

Conservatively assume MacArthur Maze scenario consequences

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