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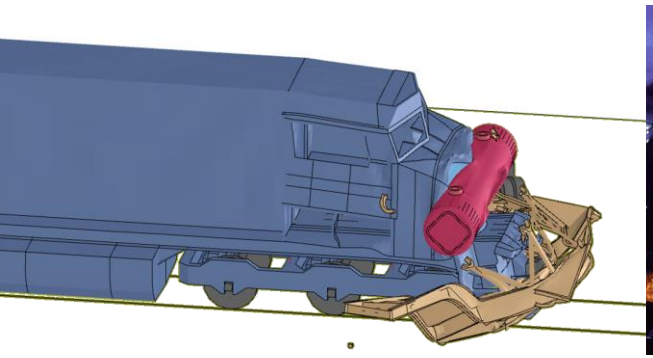

Assuring the Safety of Radioactive Material Transportation

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Outline

- Transportation Regulations
- Regulatory Certification
  - Demonstration by Test
  - Demonstration by Analysis
- Comparison to Real Accidents
- Extra-Regulatory Response
- Risk Communication

Radioactive Material Transportation Regulations

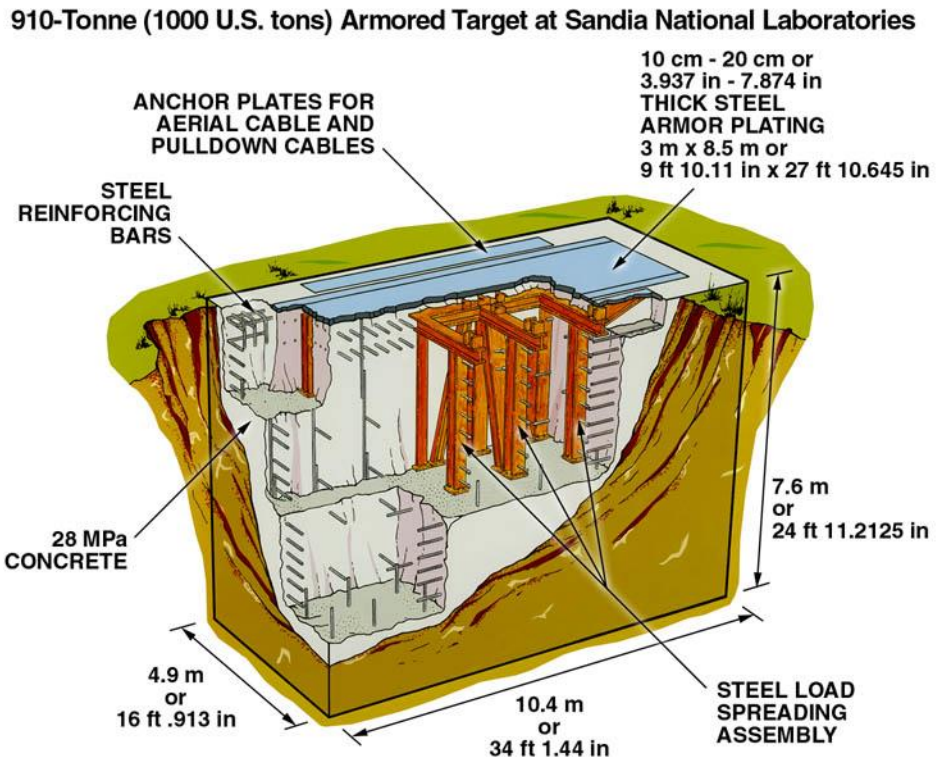
- Transportation of hazardous material is regulated by the Department of Transportation in the Code of Federal Regulations, Title 49, Parts 171-178 (49CFR171-178).
- For radioactive materials, regulations from the Nuclear Regulatory Commission (NRC) in 10CFR71 also apply.
- The regulations provide increasing levels of rigor depending on the form and quantity of material being transported.
- For large quantities (known as Type B), packages must be accident resistant.

Regulatory Hypothetical Accidents

- A free drop from a height of 9 meters onto an essentially rigid target
- Dynamic crush from a 500-kg steel plate dropped from 9 meters with the package resting on a rigid target
- A free drop from a height of 1 meter onto a 15-cm diameter puncture probe
- A 30-minute engulfing hydrocarbon fuel fire
- Immersion under 15 meters of water (200 meters for some packages)

9-Meter Free Drop Test

- Essentially Rigid Target



Drop Test Examples

- TRUPACT-III (full scale)

- ENUN-32P (1/3-scale)

- ATR (full scale)

Dynamic Crush Test

- Only required for packages with a mass less than 500 kg and a density less than that of water
- For light-weight packages the drop test may not represent the most severe loading that could occur during an accident

Puncture Test

- The puncture spike is required to be 15 cm in diameter and of a sufficient length to produce maximum damage, but not less than 20 cm.

- The spike is made from mild steel and attached to the essentially rigid target.

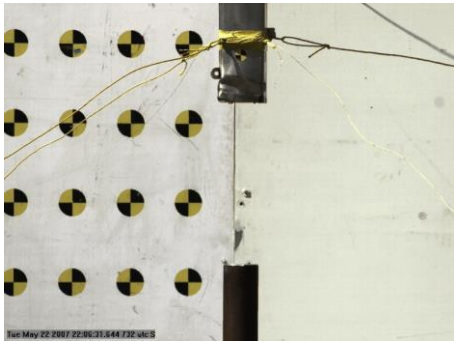
- Corner radius must not be more than 6 mm.

Puncture Test Examples

- MFFP

- TRUPACT-III

- ATR



- ENUN-32P

Engulfing Fire Test

- Fire must extend from 1 meter to 3 meters beyond the edge of the package
- Average flame temperature is at least 800° C
- Fire must last for at least 30 minutes, which requires about 12 cm of jet aircraft fuel
- Fuel is floated on a layer of water to assure uniform depth and to protect the bottom of the pan from the heat

Immersion Test

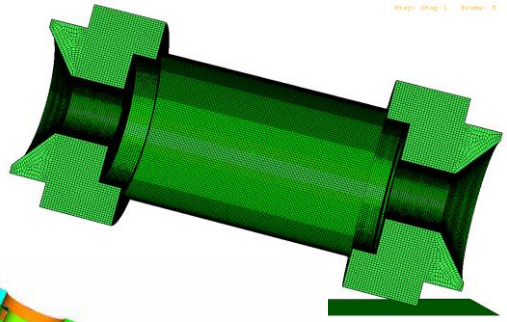
- The preceding tests are all sequential on the same package.
- This test may be performed on an undamaged package (except fissile material packages must be subjected to an additional 0.9-m immersion after the other tests).
- For packages with more than 10,000 A_2, the immersion depth is 200 meters (2 MPa).

Finite Element Analysis of Impacts

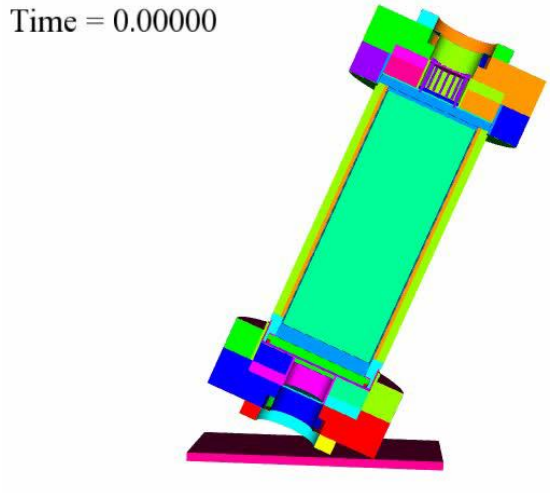
- Most packages are designed based upon the ASME Boiler and Pressure Vessel Code.
- Specifically, Section III, Division 3 is for the design of containments for transportation and storage of spent nuclear fuel and high level radioactive waste.
- Analyses may be stress-based (allowable stress is some portion of yield or ultimate strength) or strain based (allowable strain is some portion of uniform elongation strain or failure strain).
- Demonstration of compliance by analyses gives some indication of margin of safety, where demonstration by test generally does not.

Examples of Impact Analyses

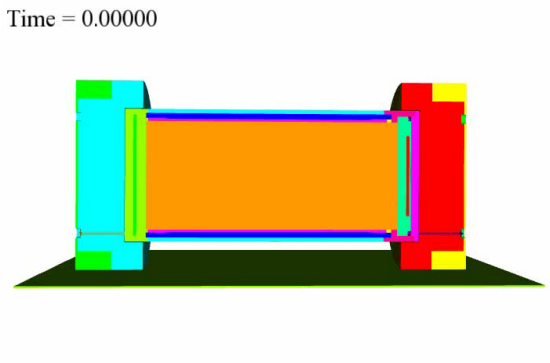
- ENSA Impact Limiter



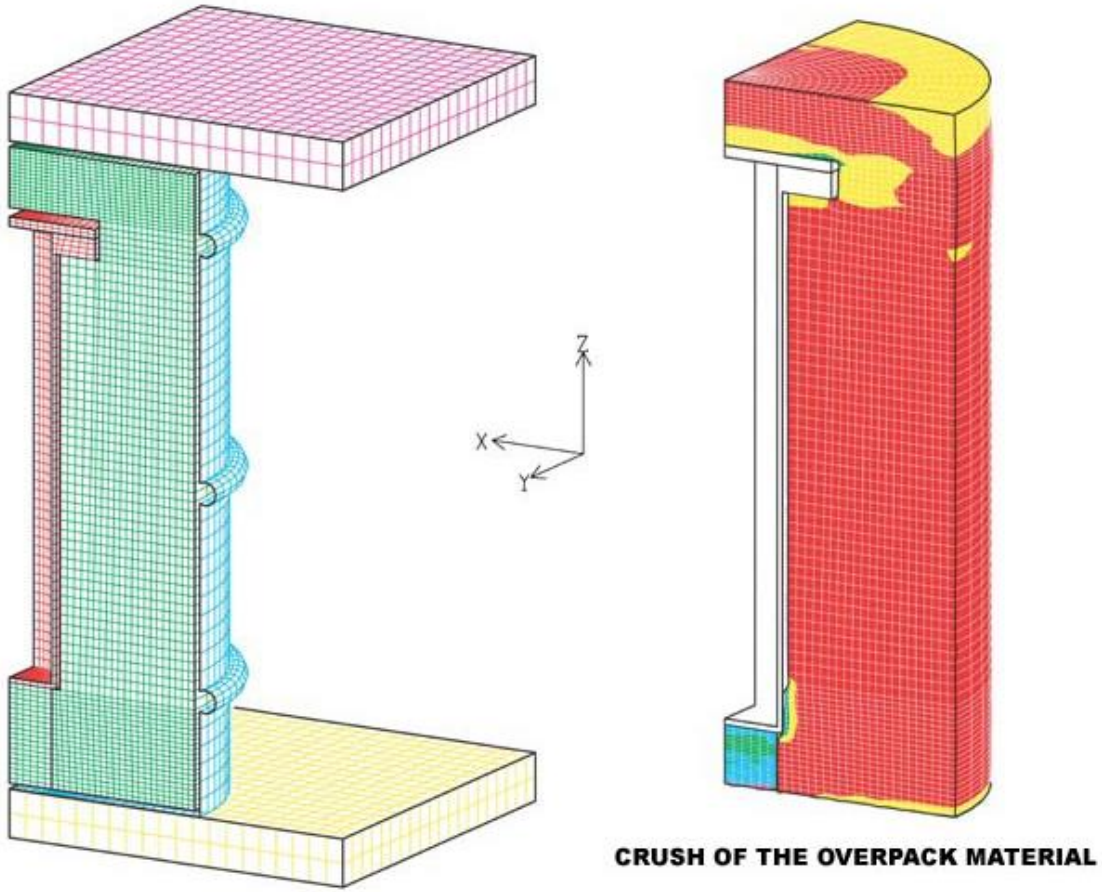
- HI-STAR100



- NAC-STC

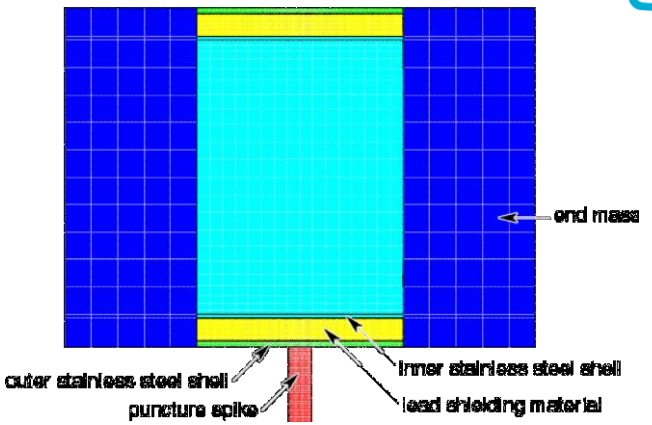


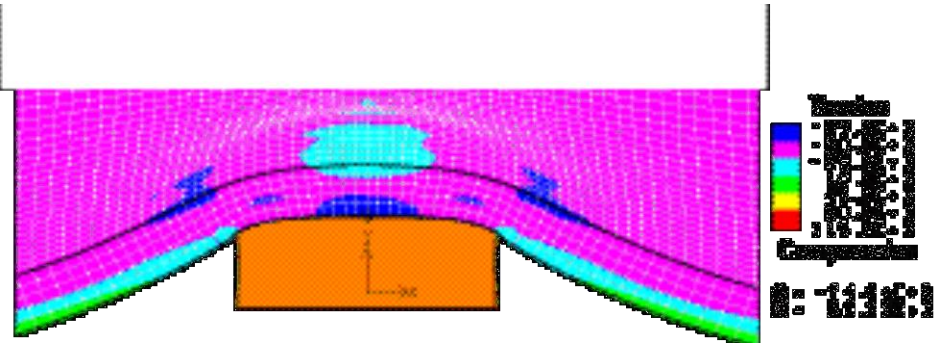
Analyses of Dynamic Crush

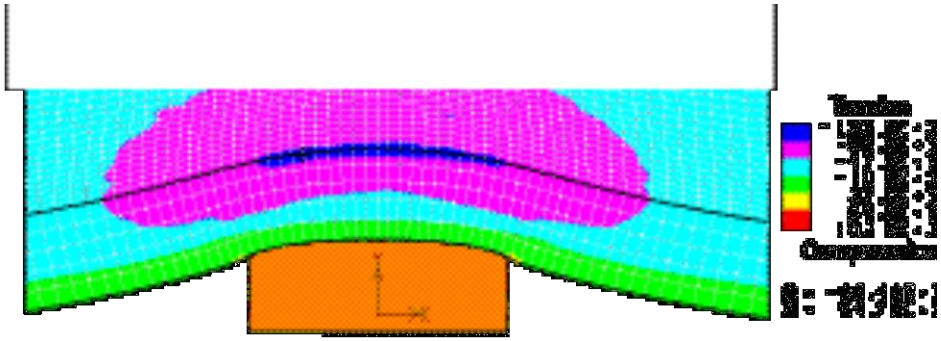


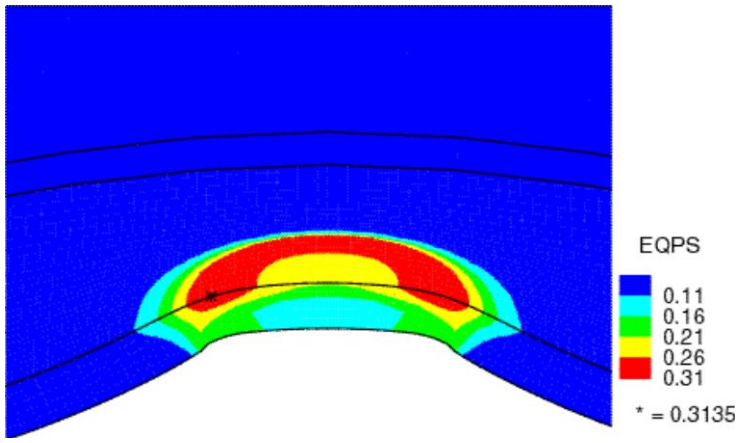
CRUSH OF THE OVERPACK MATERIAL

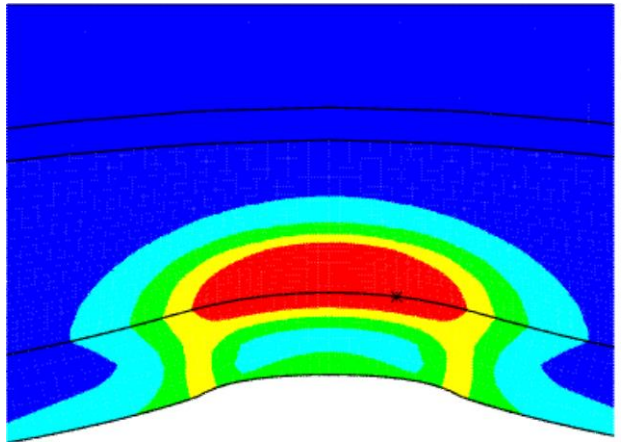
Analyses of Puncture











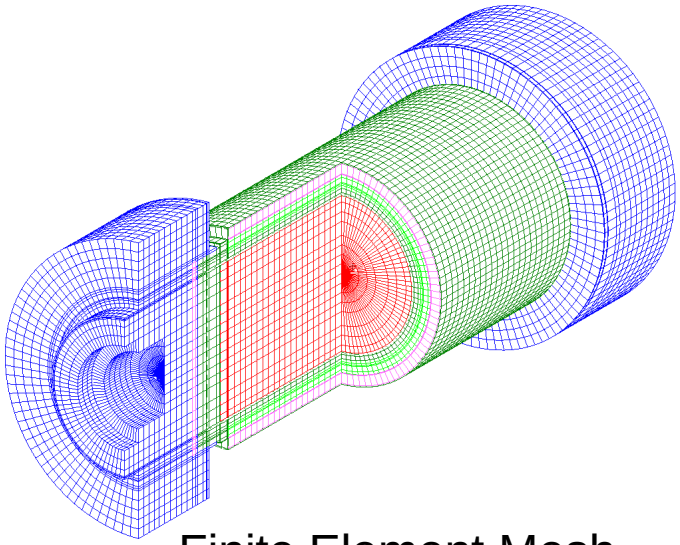
Failure ≈ 1.1

Analysis of Fires

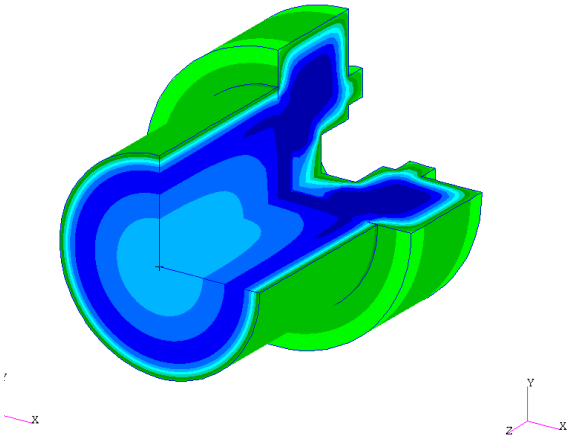
- Regulations allow analyses to be performed using a uniform thermal boundary condition with a temperature of 800° C, a flame emissivity of 0.9, a surface absorptivity of at least 0.8, and a convective coefficient appropriate to the engulfing fire environment.

- For comparison to test results, the actual fire environment must be simulated, which requires a coupled analysis—one calculation of the combustion/fluid dynamics/radiation and one of the heat transfer within the package.

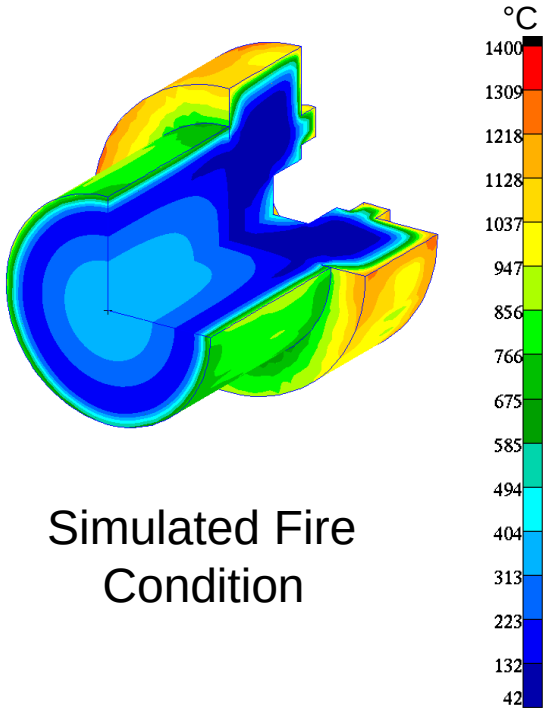
Example Fire Analyses



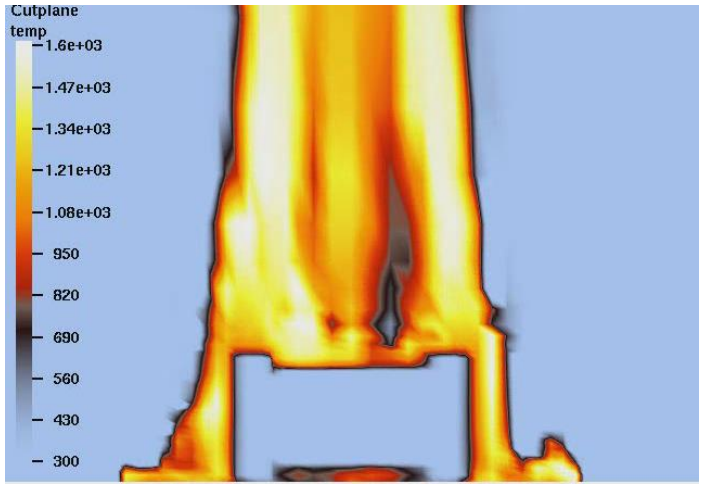
Finite Element Mesh



Uniform Boundary Condition



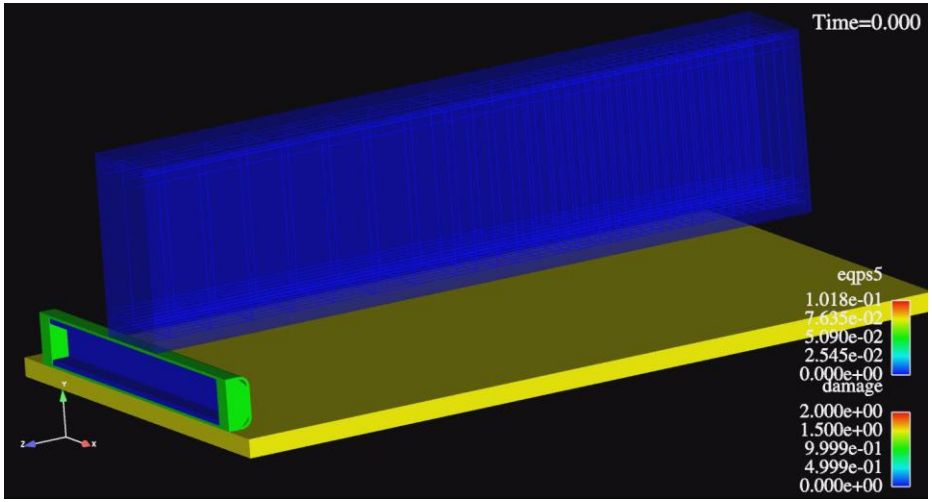
Simulated Fire Condition

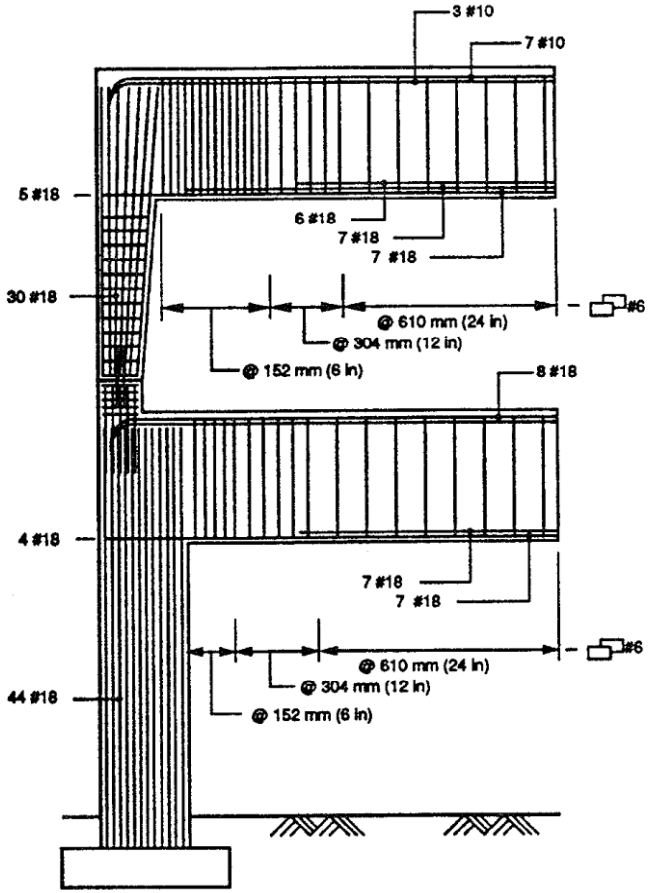


Real Accidents

- The regulatory 9-meter drop test results in an impact velocity of 30 mph. Many accidents have initial speeds greater than this number, so there is concern that the regulatory impact does not envelop the severity of possible accidents.
  - Essentially rigid target (all the accident energy is absorbed by the package)
  - Impact velocity is perpendicular to the rigid target
  - Impact is in the worst orientation
  - Neglect the transport conveyance
- The regulatory fire burns for 30 minutes. Many accidents have fire durations longer than this, so there is concern that the regulatory impact does not envelop the severity of possible accidents.
  - Fully engulfing
  - No intervening structures

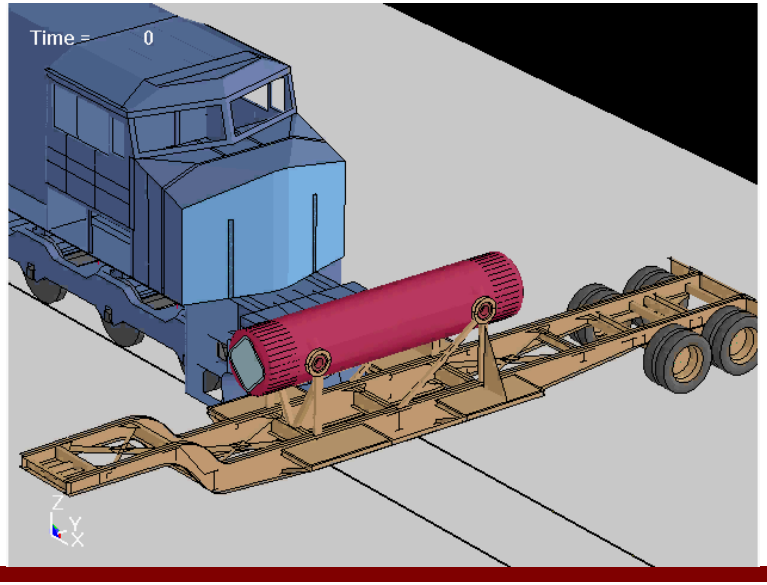
Viaduct Collapse during the Loma Prieta Earthquake



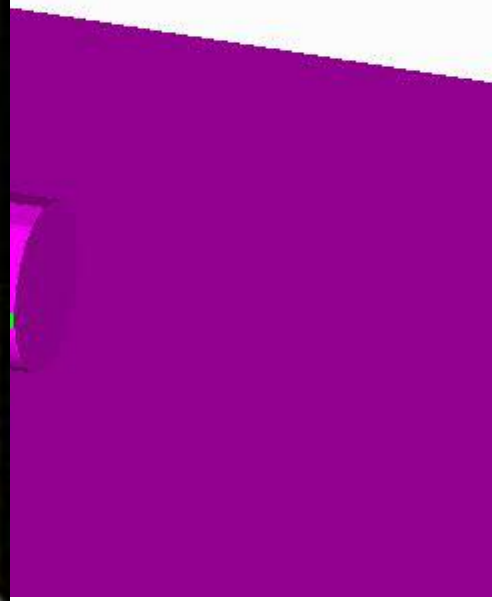


Result:
No release of radioactive material

Impact by a Locomotive



Propane Tank Explosion



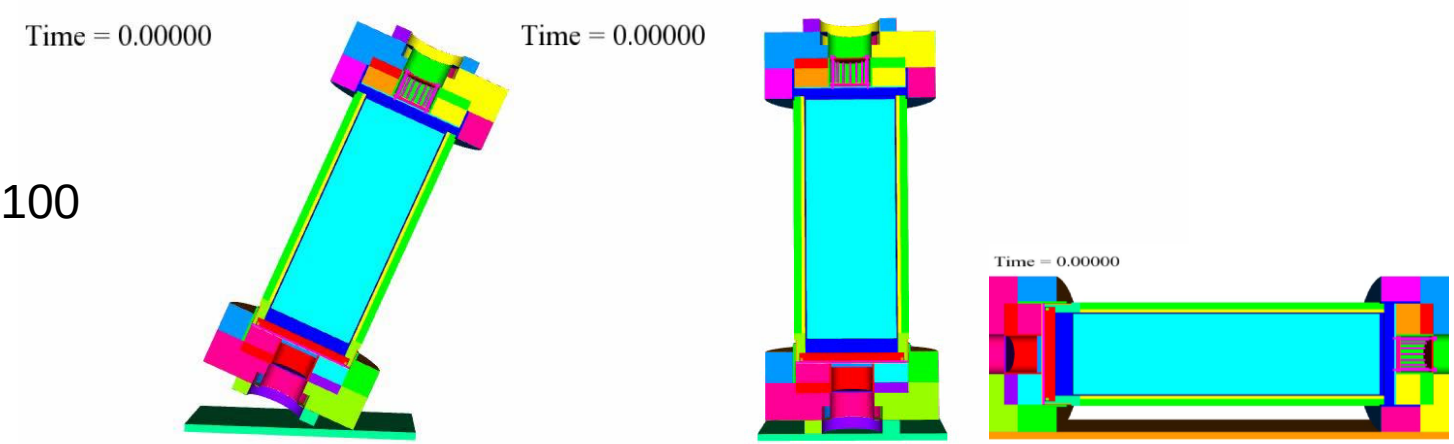
Truck Impact into a Rigid Wall

Response to Extra-Regulatory Events

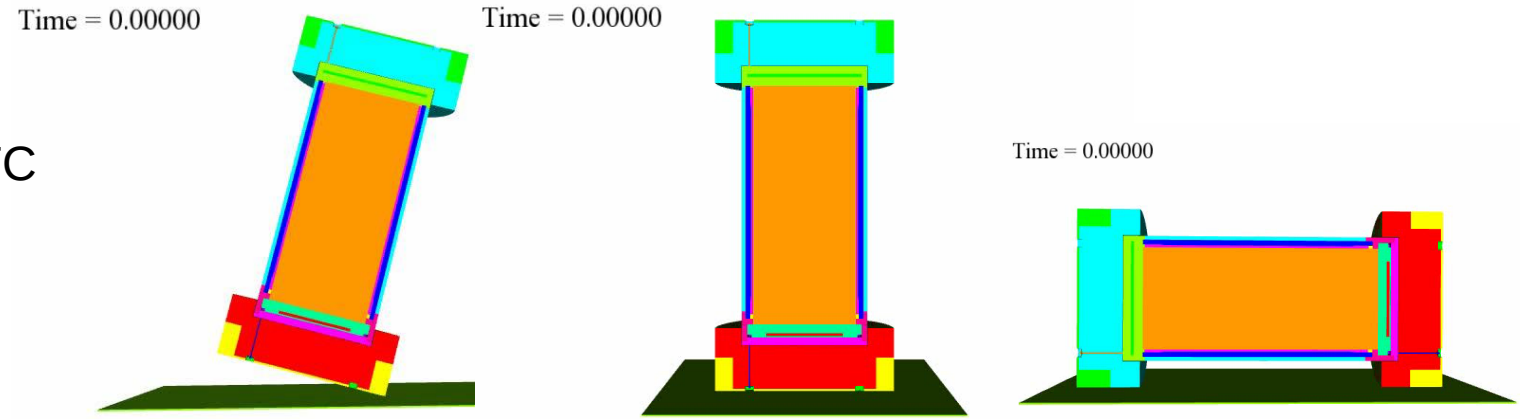
- Transportation risk assessments consider what would happen in the extremely unlikely event that the package was involved in an accident more severe the regulatory hypothetical accidents.
- Impacts onto rigid targets at speeds greater than 30 mph have been analyzed.
- Engulfing fires with higher temperature and longer duration have also been analyzed.

Extra-Regulatory Impacts

HI-STAR 100

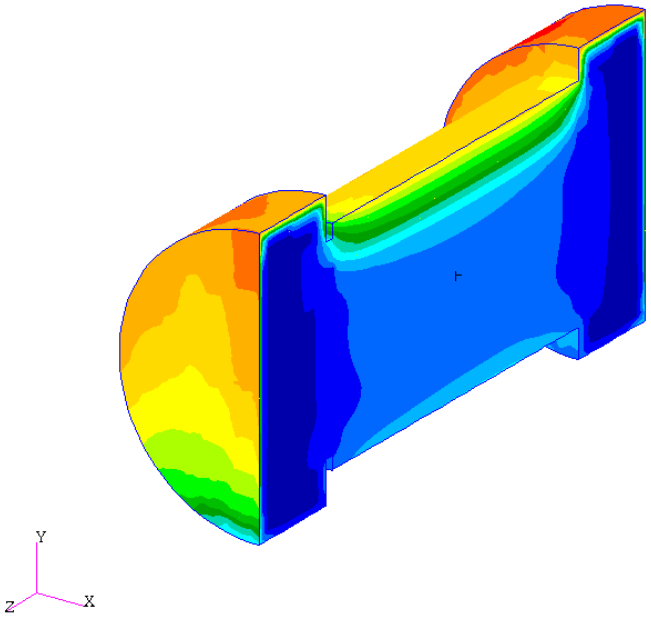


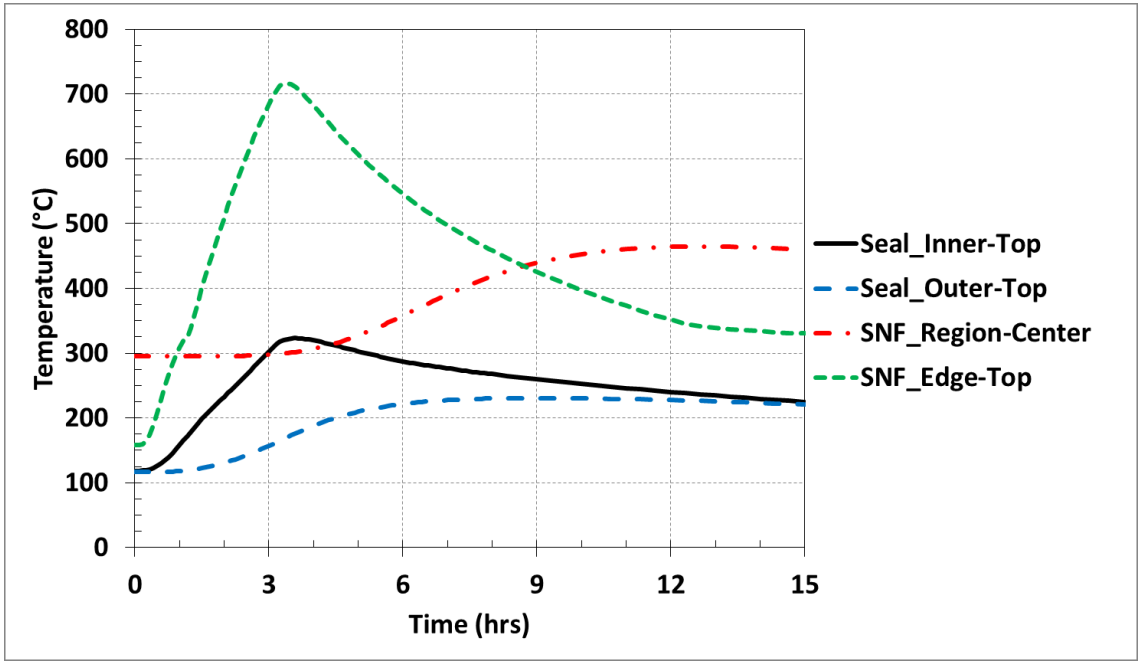
NAC-STC



Extra-Regulatory Fires

NAC-STC after 3-hour Concentric Fire





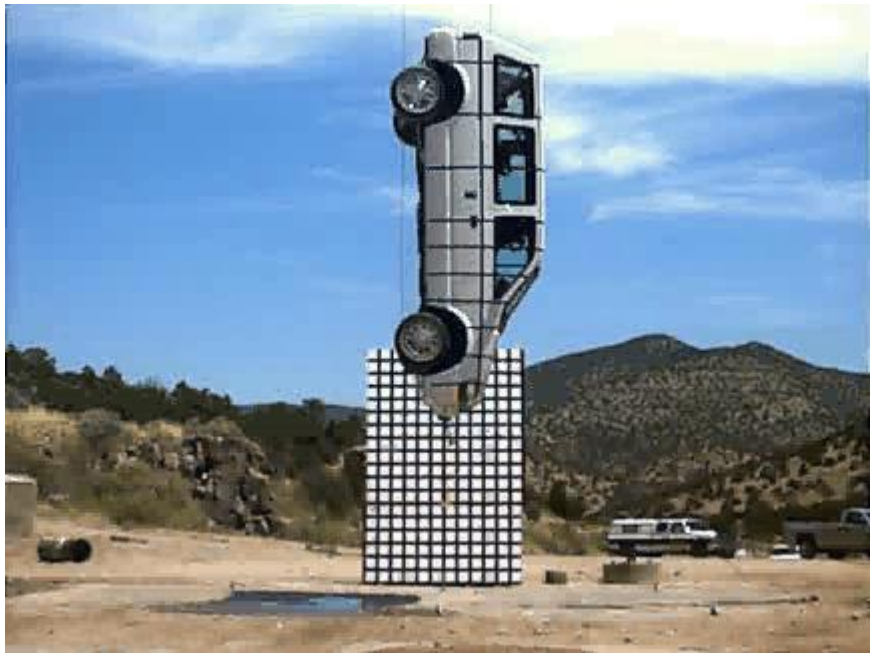
- Seal temperature is below its failure temperature of 350°C.
- Spent fuel temperature is below the rod-burst temperature of 750°C.

Risk Communication

- Hopefully, this presentation has helped you to see why the controls that are placed on the transportation of radioactive material make it a low-risk activity.
- Unfortunately, not all of the stakeholders regarding this type of transportation are in this room.
- One of the most difficult concepts to convince people about is the effect of the essentially rigid target.

Demonstration of Target Hardness

Impact onto an essentially rigid target



Impact onto a concrete target

Demonstration of Target Hardness

Impact onto an essentially rigid target

Impact onto a concrete target

NRC Interactive DVD on Cask Basics

- Sandia produced an interactive DVD for the NRC that provides a background on radioactive material transportation regulations and safety.
- The NRC contact person is Dave Pstrak.

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QUESTIONS?