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Technical Challenges Related To Spent Nuclear Fuel Dry Cask Storage / Transportation Analysis and Design

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THE FUTURE VISION

- Long-term vision with respect to technical challenges related to analysis/design
- Designs are introducing new approaches for tackling technical and other issues, for example:
  - – above-ground storage to below-ground storage,
  - – transportation aging and disposal (TAD) casks

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TECHNICAL CHALLENGES:

1) Use of exotic and un-conventional non-code approved materials;
2) Increased mass and fissile material loads;
3) Increased number of fuel assemblies for both, BWR and PWR fuels;
4) Burn-up credit;
5) Fracture mechanics analytical approach;
6) Loading high burn-up fuels; and
7) Analysis vs. testing.

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CURRENT STATUS OF ISFSI IN US & TECHNICAL CHALLENGES

- There are 51 independent spent fuel storage installations (ISFSIs) across 33 States
- Over 1,100 loaded storage casks
- More optimized designs with reduced engineering and safety margins required more detailed technical review

THEN AND NOW

- Ten years ago, a large-capacity cask was designed to hold 24 PWR assemblies
- Presently, a large-capacity cask is designed to hold 32 – 37 PWR assemblies (a 50% capacity increase with no increase in size)
- Ten years ago, casks held thermal load of up to about 20 KW
- Presently, casks hold approximately 40 KW thermal loading (a 100% increase in thermal loading, with passive cooling)

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THEN AND NOW CONTD…

- Ten years ago, high burn up fuel was limited to a maximum 45 MW days / MTU
- Presently, high burn up fuel of up to 70 MW days/MTU is considered (a 50% increase in burn up)
- Little research on higher burn up fuel and cladding behavior during long term storage and under the 10 CFR Part 71 transport hypothetical-accident-conditions

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INCREASING TECHNICAL COMPLEXITY

- The higher-capacity casks, higher heat loads, increased fissile-material contents, and increased source terms challenge engineering design margins
- Industry and NRC use of advanced computer-assisted tools: structural, thermal, shielding, and criticality analyses
- Requires more exacting design and more detailed NRC technical review

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MODELLING TECHNOLOGIES

- "State of the art" modelling technologies require increased NRC information technology equipment and computational modelling software needs;
- Enhanced training and skill of the regulator in use and interpretation of the new modelling technology, tools and results

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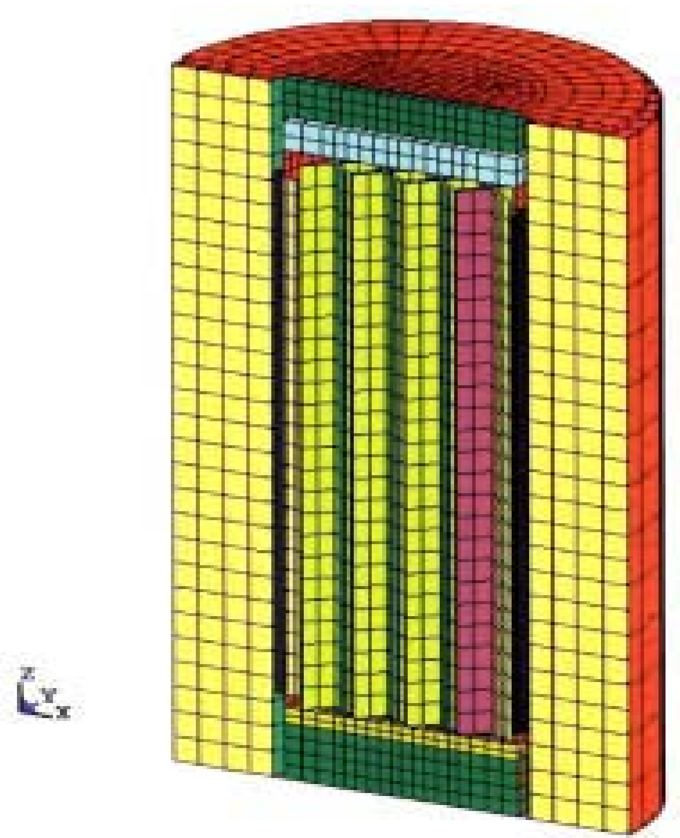
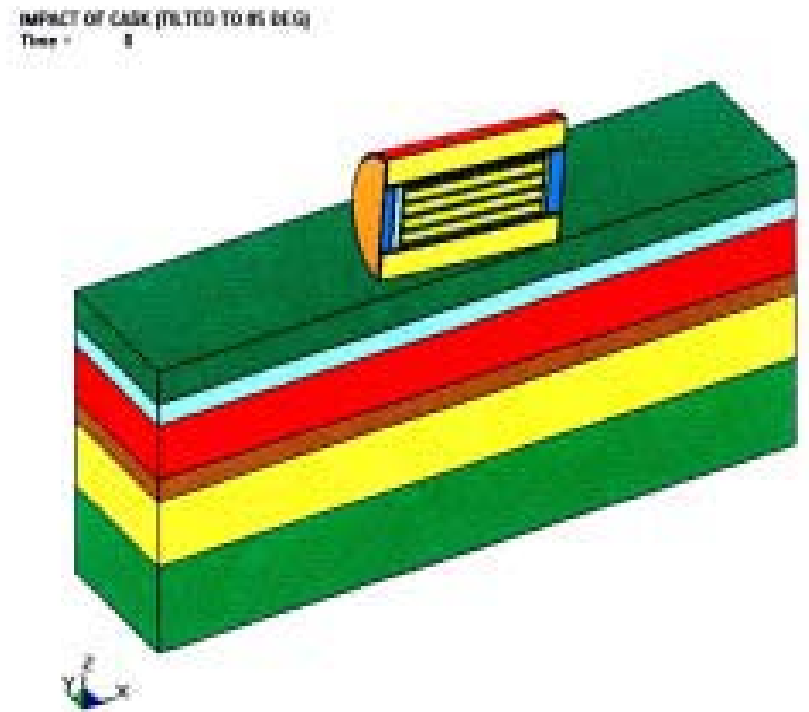
MODELLING TECHNIQUE



LS-DYNA - Cask Model



Finite-Element Model for Analysis

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NEW DESIGNS AND MATERIALS

- Underground storage designs have presented new structural, civil, and thermal modelling issues
- Lighter-weight transfer cask designs to facilitate cask movements for sites with limited crane capacities, raise new shielding, thermal, and structural modelling issues
- Cask designs relying on mechanical rather than welded connections challenge structural reviews
- Exotic materials (e.g. METAMIC) require extensive review of performance under structural, thermal and radioactivity challenges, and how they meet regulatory requirements

HIGH BURN UP FUEL, MORE FUEL ASSEMBLIES & LOADS

- As the decay heat-load capacities increase and cooling time for the spent fuel assemblies decrease, thermal margins for the fuel clad and other cask components including seals, are decreasing
- Because of uncertainties associated with materials, specifically with the properties of high burn up fuel, the NRC generally encourages a degree of conservatism in the modelling approach
- This degree of conservatism will become more challenging to include in the analysis and design, as the capacities and heat-loads of cask designs increase

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BURN UP CREDIT & CRITICALITY FOR TRANSPORTATION PACKAGES

- Burn up: the amount of energy released from a fuel assembly in a reactor in terms of (MWD/MTU), which results in an overall reduction of fuel assembly reactivity
- Assumption: Conservatively assumed that fuel is unburned
- 10 CFR Part 71 applicants have increasingly sought credit for the reduction in reactivity that occurs with spent fuel burn up, or burn up credit, in their criticality safety analyses
- Goals: 1) higher capacity dry storage and transportation casks, and 2) ability to transport entire inventory of commercial spent fuel

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STRUCTURAL ANALYSIS VS. TESTING ISSUES

- Small-scale model drop testing is:
    - an essential part of mechanical safety assessment and
    - requires a lot of pre- and post-test calculations
- Dedicated test positions/sequences must have:
    - small-scale model, component, and material tests
    - calculations
    - cover all worst-case conditions
- Full-scale and small-scale drop testing needs material and component testing to verify the package response and its structural analysis
- Full-scale package drop testing is more effective for design and safety demonstration
- For large casks (>100 tons) it is difficult to complete drop-test program with one specimen

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REGULATORY DROP TESTING

9-Meter Vertical Drop Cask

9-Meter Oblique Drop Cask

1-Meter Horizontal Drop - Cask

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STRUCTURAL ANALYSIS VS. TESTING ISSUES CONTD…

- The state-of-the art performance of reduced-scale and full-scale model drop testing needs:
  - extensive pre-test analysis,
  - a complete test program,
  - with sophisticated measurement techniques and
  - complex analysis to verify the original package design
- A complete safety assessment needs:
  - a complex combination of all test methods such as: small-scale, full-scale package testing,
  - component tests,
  - materials tests, and
  - calculations and reasoned arguments to comply with all regulatory and design conditions

NRC PACKAGE PERFORMANCE STUDY

- Validate the NRC and industry practices,
- Enhance public confidence in the use of computer modelling and scale model tests,
- Complete full scale and scale model casks drop test analyses, and compare with BAM test data results and analyses,
- Report results to the NRC Commission,
- Compare the response of the casks during a regulatory drop test and a realistic severe train accident scenario,
- Apply results from the German and Japanese analyses to the TAD casks,

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NRC PACKAGE PERFORMANCE STUDY CONTD..

- Perform independent drop test analyses on two certified TAD casks,
- Perform computer simulation of a train-locomotive impact on the German and Japanese casks,
- Visually demonstrate the cask performance in a realistically severe accident,
- Demonstrate NRC’s ability to predict cask performance by computer modelling:
  - 9 meter (30 feet) drop test,
  - train-locomotive crash demonstration test, and
  - fire test on the on the selected TAD cask.

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CONCLUSION

We discussed Technical challenges that NRC is facing due to:

- Use of the un-conventional non-code materials for the storage and transportation casks,
- Analysis vs. testing for normal, and accident conditions regulatory drop analysis,
- Effects of scale-model vs. full-scale cask for drop analysis,
- High burn up fuel and transportation problems

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SUMMARY

<u>We will need to</u>:

- Prioritize the issues and challenges
- Uphold the fundamental principle of safety
- Extend review durations
- Facilitate dialogue in an open and public forum to discuss new proprietary designs. Interaction is our key to success
- As resource demands increase, utilize them as efficiently as possible
- Resolve current issues,
- Accurately envision issues that we may face in future

ANY QUESTIONS?