U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

PRESENTATION TO
THE NUCLEAR WASTE TECHNICAL REVIEW BOARD

SUBJECT:  REGULATIONS, CODES, AND
STANDARDS FOR CASK DESIGN

PRESENTER:  MARILYN WARRANT

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PROCESS FOR DEVELOPING A SPENT FUEL CASK

- Preliminary Design
- Engineering Tests
- Final Design
- Design Verification Tests
- Certification
- Build Prototype
- Acceptance Tests
- Performance Evaluation Tests
- Operational Tests
- Transportation of Spent Fuel
SAFE TRANSPORTATION REGULATION

INTERNATIONAL ATOMIC ENERGY AGENCY

DEPARTMENT OF TRANSPORTATION

PRIMARY RESPONSIBILITY FOR SAFETY IN TRANSPORTING ALL HAZARDOUS MATERIAL

NUCLEAR REGULATORY COMMISSION

DEPARTMENT OF ENERGY

MODEL REGULATIONS
REGULATORY PHILOSOPHY

• GOAL IS TO MAINTAIN LOW RISK REGARDLESS OF CONTENTS

• PACKAGING PROVIDES PRIMARY PROTECTION

• REGULATIONS SPECIFY PERFORMANCE FOR PACKAGINGS

• ENGINEERING CRITERIA REQUIREMENTS ARE USED TO SIMULATE DAMAGE OF TRANSPORTATION ACCIDENTS

• PACKAGE PERFORMANCE IS DEMONSTRATED BY ANALYSIS OR TESTING
CONTAINMENT

IMPACT LIMITERS

CASK
BODY
CONTAINMENT
BOUNDARY

LID

SPENT
FUEL
ASSEMBLY

SEAL

87TV6000.57
CONTAINMENT

• NO RELEASE OF MATERIAL UNDER NORMAL TRANSPORT CONDITIONS MEASURED TO A SENSITIVITY OF A_2 \times 10^{-6}/HR

• LIMITED RELEASE UNDER HYPOTHETICAL ACCIDENT CONDITIONS (A_2/WEEK)
SHIELDING

NEUTRON SHIELD

GAMMA SHIELD ($\alpha, \beta$ AND $\gamma$)

SPENT FUEL
SHIELDING

- LIMITED EXTERNAL EXPOSURE

- LIMIT FOR NORMAL CONDITIONS OF TRANSPORT
  \[ \leq 200 \text{ MILLIREM/HR AT SURFACE} \]
  \[ \leq 10 \text{ MILLIREM/HR AT 2 METER} \]

- LIMIT FOR ACCIDENT CONDITIONS
  \[ \leq 1 \text{ REM/HR AT 1 METER} \]
PREVENTING A SUSTAINED NUCLEAR CHAIN REACTION

OPTIONS:
- MAINTAIN ACCEPTABLE GEOMETRY WITH BASKET
- USE "POISONS" IN BASKET TO ABSORB NEUTRONS
- EXCLUDE MODERATOR FROM CASK CAVITY
CRITICALITY

CRITICALITY
CASK PERFORMANCE REQUIREMENTS

- CONTAINMENT OF RADIOACTIVE MATERIAL
- CONTROL OF RADIATION EMITTED FROM THE MATERIAL
- DISSIPATION OF ANY HEAT GENERATED BY THE MATERIAL
- MAINTENANCE OF A "SUB-CRITICAL" CONDITION
NORMAL CONDITIONS OF TRANSPORT

(1) HEAT
(2) COLD
(3) REDUCED PRESSURE
(4) INCREASED PRESSURE
(5) VIBRATION
(6) WATER SPRAY
(7) FREE DROP
(8) CORNER DROP
(9) COMPRESSION
(10) PENETRATION
NRC DESIGN PERFORMANCE STANDARDS

10 CFR 71
HYPOTHETICAL ACCIDENT CONDITIONS

IMPACT
PUNCTURE
FIRE (1475°F)
IMMERSION
VARIOUS ORIENTATIONS ARE CONSIDERED FOR THE FREE DROP TEST

END

SIDE

CENTER OF GRAVITY OVER CORNER

SLAP DOWN
TESTS
HYPOTHETICAL ACCIDENT CONDITIONS

- SEQUENTIAL TESTS
  - FREE DROP - 30 FEET onto an unyielding surface
  - PUNCTURE DROP - 40 INCHES onto a 6 INCH DIAMETER, MILD STEEL, PUNCTURE BAR
  - THERMAL - 30 MINUTE EXPOSURE TO 1475°F FULLY ENGULFING THERMAL ENVIRONMENT
  - IMMERSION - 50 FEET below surface for 8 HOURS
QUESTIONS CONCERNING CURRENT REGULATORY PERFORMANCE TESTS

- IS THERE A TECHNICAL CONNECTION TO ACTUAL ACCIDENT CONDITIONS?

- ARE THE REGULATIONS REPRESENTATIVE OF EXTREMELY SEVERE REAL-WORLD ACCIDENTS?

- DO THE REGULATIONS ADDRESS POTENTIAL HIGH CONSEQUENCE - LOW PROBABILITY TRANSPORTATION ACCIDENT EVENTS?
NRC ASSESSMENTS OF SAFETY PROVIDED BY TRANSPORT REGULATIONS

- 10CFR51.52 -- "ENVIRONMENTAL EFFECTS OF TRANSPORTATION OF SPENT FUEL AND WASTE -- TABLE S-4"

- WASH-1238 -- "ENVIRONMENTAL SURVEY OF TRANSPORTATION OF RADIOACTIVE MATERIALS TO AND FROM NUCLEAR POWER PLANTS" (12/72); SUPPL. 1, NUREG-75/038 (4/75)

- NUREG-0170 -- "FINAL ENVIRONMENTAL STATEMENT ON THE TRANSPORTATION OF RADIOACTIVE MATERIAL BY AIR AND OTHER MODES" (12/77)

- NUREG/CR-4829 -- "SHIPPING CONTAINER RESPONSE TO SEVERE HIGHWAY AND RAILWAY ACCIDENT CONDITIONS" (2/87)
DOE/OCRWM VIEW OF SAFETY PROVIDED BY REGULATIONS

- NRC REGULATIONS ARE GENERALLY CONSISTENT WITH IAEA REGULATIONS

- REGULATIONS ARE INTEGRAL PART OF OCRWM's EFFORTS TO DEVELOP SAFE CASKS

- DOE/OCRWM PERFORMS INDEPENDENT TECHNICAL ASSESSMENTS OF CASK SAFETY
NRC REGULATORY PRACTICE
ESTABLISHED BY

• REGULATIONS
• REGULATORY GUIDES
• NUREG DOCUMENTS
• PRECEDENTS
• STANDARDS (ASTM, ANSI)
• REVIEWS OF ANALYSES AND TESTS
USE OF ANALYSES IN DESIGN

- PRELIMINARY ANALYSES TO DETERMINE CASK PARAMETERS
  - WALL THICKNESS
  - IMPACT LIMITER STRENGTH
  - BOLT SIZE

- DETAILED CONFIRMATORY ANALYSES TO SIMULATE CASK RESPONSE TO NORMAL AND HYPOTHETICAL ACCIDENT CONDITIONS
IMPLEMENTATION OF REGULATIONS IN CASK DESIGN

• USE OF DESIGN GUIDELINES INCORPORATED IN NATIONALLY ACCEPTED REGULATORY GUIDES, DESIGN CODES, AND STANDARDS

• ANALYSIS OF THE DESIGN BY VALIDATED COMPUTER CODES

• VERIFICATION OF DESIGN ANALYSES WITH TEST DATA
**ASTM SPECIFICATIONS**

- PROVIDE ASSURANCE OF A STATED LEVEL OF MATERIAL QUALITY
  - LIST FABRICATION GUIDELINES
  - ESTABLISH MINIMUM PHYSICAL AND MECHANICAL PROPERTY VALUES
  - REQUIRE TESTING TO DEMONSTRATE MINIMUM PROPERTIES ARE MET
ASME BOILER AND PRESSURE VESSEL CODE
SECTION III

- PROVIDES GENERAL DESIGN GUIDELINES FOR CONTAINMENT VESSELS
- SPECIFIES MAXIMUM ALLOWABLE STRESSES FOR MATERIALS ACCORDING TO THEIR USE
- DEFINES QUALIFICATION TESTS OF FABRICATED MATERIALS
ANSI N14 STANDARDS
PACKAGING AND TRANSPORTATION OF RADIOACTIVE MATERIALS

EQUIPMENT
   TIEDOWNS
   TRAILERS
   ANCILLIARY EQUIPMENT

TESTING
   LEAKAGE TESTING

ENVIRONMENT
   SHOCK AND VIBRATION
GEOMETRIC REPRESENTATION OF A MATHEMATICAL MODEL

FINITE ELEMENT MESH FOR CASK CORNER DROP

DEFORMED SHAPE FOR CASK CORNER DROP
CODE VALIDATION (BENCHMARKING)

- CLOSED FORM ANALYTICAL SOLUTIONS
- EXPERIMENTAL DATA
- CONSENSUS OF NUMERICAL SOLUTIONS
- TESTS USER OF CODE ALSO
SAFETY ANALYSIS REPORT FOR PACKAGING CONTENTS

• PACKAGE DESCRIPTION

• ANALYSES AND TEST DATA
  (STRUCTURAL, THERMAL, CONTAINMENT SHIELDING, CRICALITY)

• ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

• QUALITY ASSURANCE