YUCCA MOUNTAIN PROJECT

Studies

Engineering Barrier Segment/Waste Package

Presented to:
Nuclear Waste Technical Review Board
Full Board Meeting

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Office of Civilian Radioactive
Waste Management

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Contents

- Current Design
- Waste Package Cost
- History of Design
- What Has Been Tried and What Remains to Be Tried
- Thermal Analyses
- Structural Analyses

Waste Forms

- Commercial Spent Nuclear Fuel
  - PWR
  - BWR
- Classified Waste
  - SRS
  - West Valley
  - Hanford
- Other DOE Spent Nuclear Fuel
  - 200 plus waste forms compiled into categories
- Navy Fuel

Waste Package Designs

- Uncanistered Spent Nuclear Fuel
- Canistered Spent Nuclear Fuel
- Defense High Level Waste
- DOE-owned Spent Nuclear Fuel
- Canistered Navy Fuel

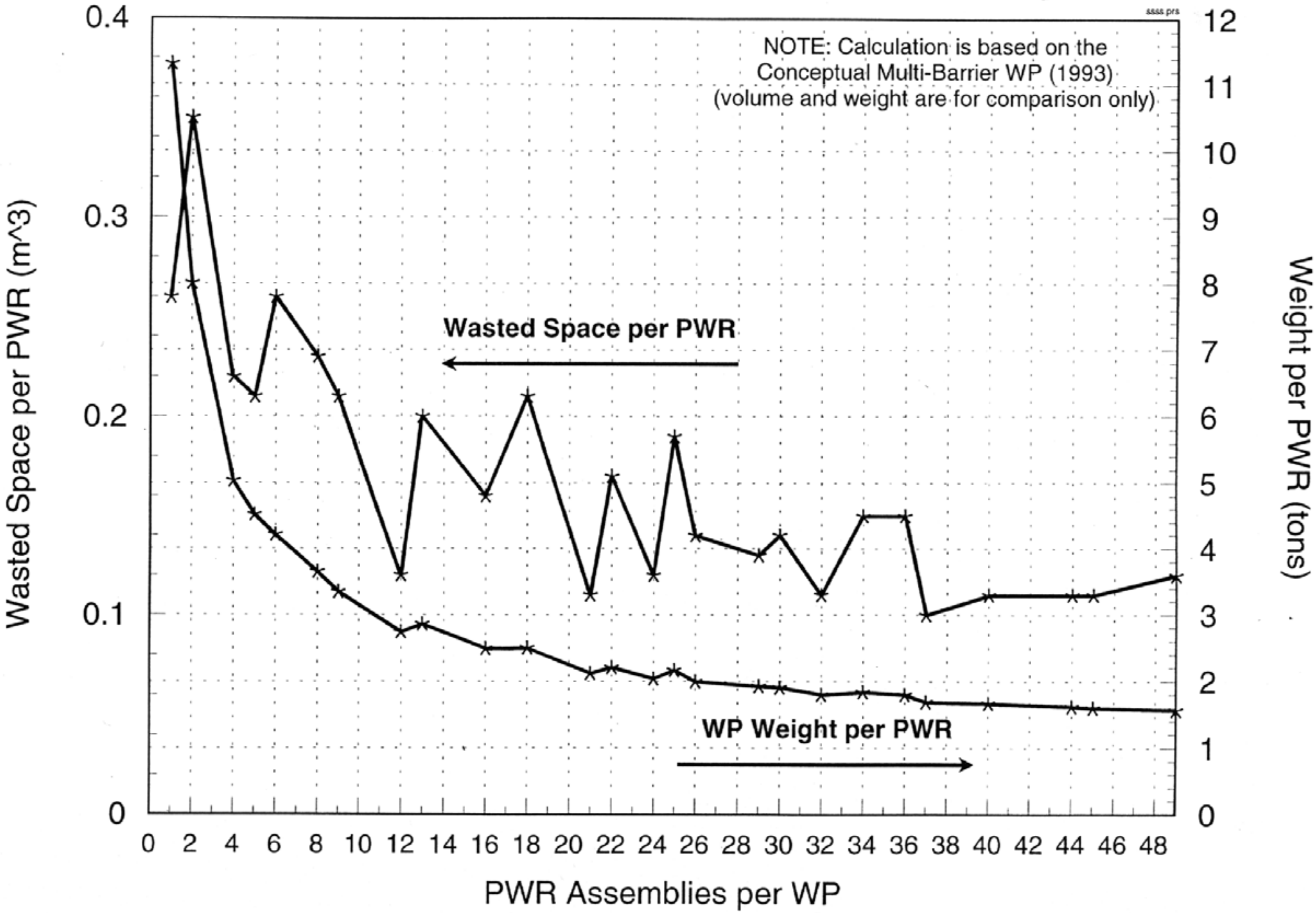
Licensing Considerations

- **Waste package design(s) must have the intended contents specifically defined, similar to cask storage**
  - **SNF size, type, enrichment, burnup, cooling time, etc.**
  - **Bounding SNF defined by the Design Basis Fuel**
- **Each different segment of the waste stream must have a license, regardless if the same physical WP design was used**
- **Different segments of the waste stream have unique requirements to be addressed by the waste package designs**

Waste Stream Considerations

- **Commercial SNF waste stream projections indicate a wide distribution in characteristics**
  - **For example, the heat output the 90th percentile can be more than twice the average heat output**
  - **The word “nominal” cannot be used to describe the average**
- **Projected SNF was sorted by assembly characteristics important to design**
  - **Physical size and weight of assembly**
  - **Heat output at time of emplacement**
  - **Criticality potential (k-infinity)**

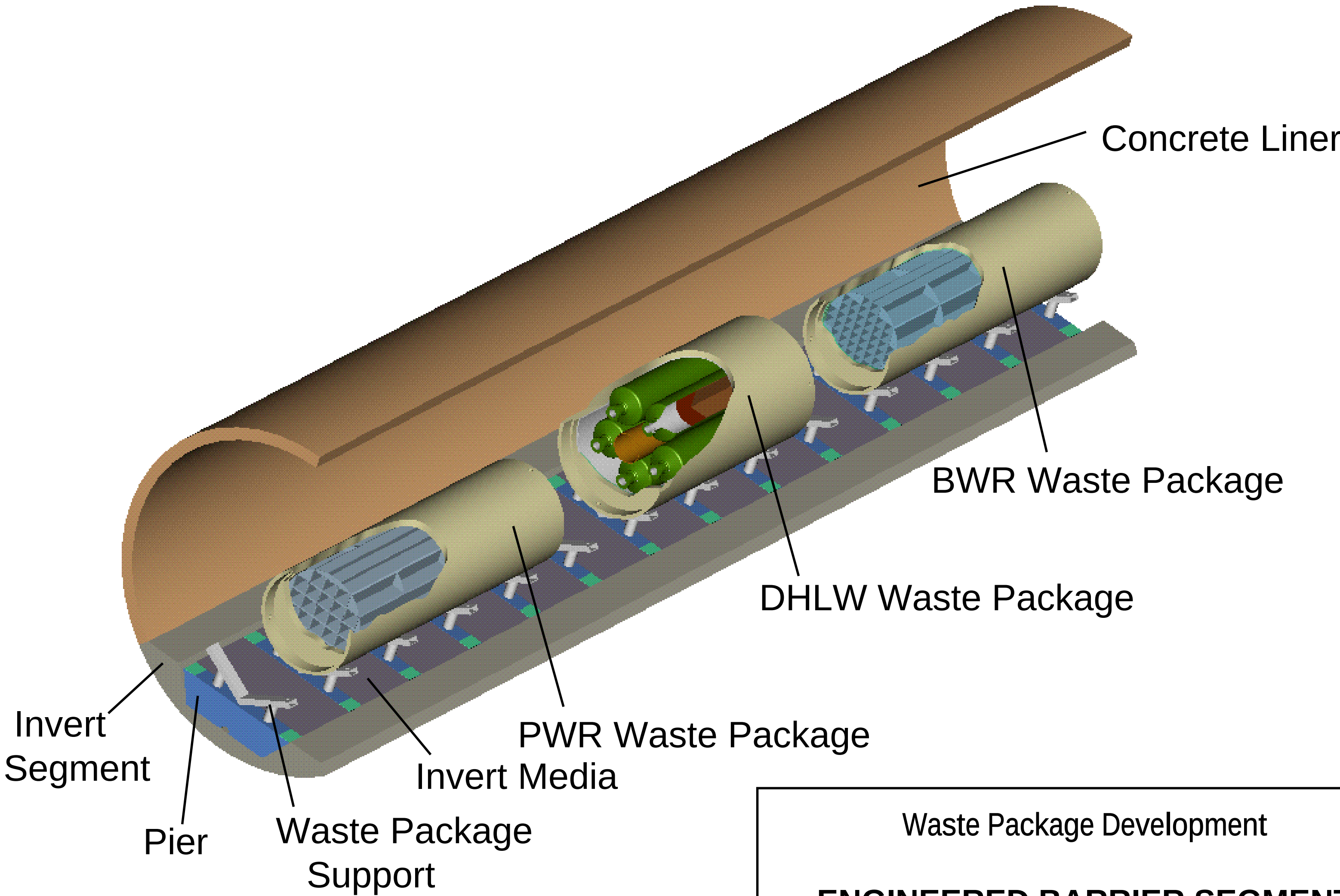
WP Basket Configuration Efficiency



List of Waste Package Designs

Concept	Waste Package	Outer Diam. (m)	Outer Length (m)	Tare Mass w/o top lids (kg)	Loaded Mass (kg)	Number WP's	Unit Cost in 97$	Total Cost Millions
1(a)	21-PWR - No Absorber	1.664	5.335	33,000	51,000	1454	$321,000	$467
1(b)	21-PWR - Absorber Plates	1.664	5.335	33,000	51,000	2653	$402,000	$1,067
1(c)	21-PWR - Absorber Rods, No Absorber Plates	1.664	5.335	33,000	51,000	132	$427,000	$56
2	12-PWR - No Absorber	1.320	5.335	24,000	34,000	398	$222,000	$95
3	12-PWR - Long, Absorber Plates	1.35	5.87	27,000	39,000	155	$286,000	$44
4(a)	44-BWR - No Absorber	1.604	5.335	31,000	47,000	707	$326,000	$230
4(b)	44-BWR - Absorber Plates	1.604	5.335	31,000	47,000	2119	$434,000	$920
5	24-BWR - Thick Absorber Plates	1.27	5.335	23,000	32,000	49	$360,000	$18
6	Commercial Canistered Fuel (Westinghouse 44 BWR Design)	1.95	5.66	33,000	69,000			
7	5-HLW/DOE Spent Fuel	1.970	3.790	24,000	38,000	1249	$281,000	$351
8	5-HLW/DOE Spent Fuel, Long	2.00	5.37	34,000	58,000	414	$308,000	$128
9(a)	Navy Fuel - Canistered Long	1.896	6.24	35,000	79,000	90	$380,000	$34
9(b)	Navy Fuel - Canistered Short	1.896	5.53	31,000	73,000	210	$350,000	$74
10	DOE SNF - Low Enriched	TBD	TBD	TBD	TBD	598	$350,000	$209

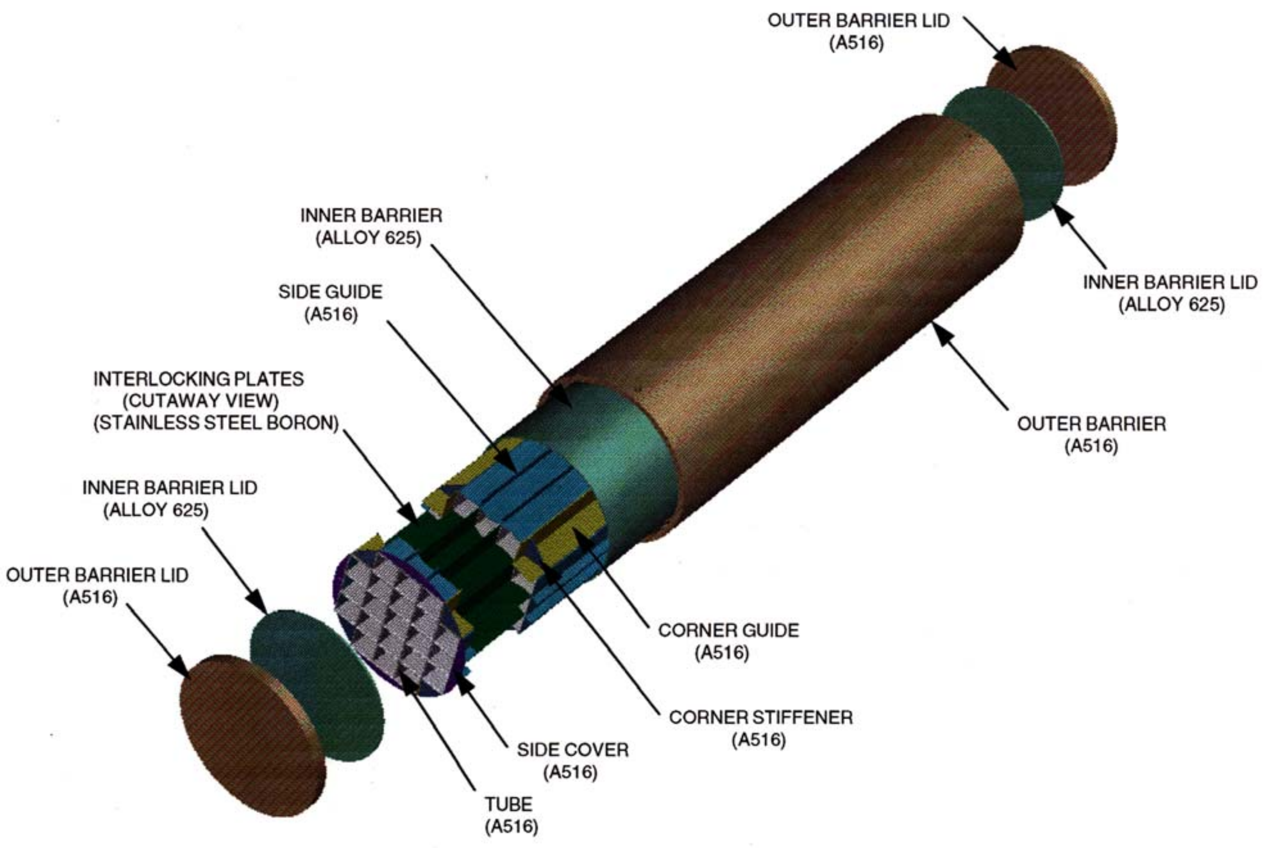
Waste Quantity, Mix and Throughput Study Report, B00000000-01717-5705-00059 REV 00.



Waste Package Development

ENGINEERED BARRIER SEGMENT

21 PWR UCF Waste Package Assembly



21-PWR UCF
WASTE PACKAGE ASSEMBLY

Design Basis Waste Package Environment

- **High average thermal loading (80 to 100 MTU/Acre)**
  - **Waste container surface temperatures above boiling for thousands of years**
  - **Relative humidity low initially but will increase as repository cools**
  - **Some potential for drips getting water on containers**
  - **Repository edge and fault avoidance effects will cause localized low thermal loading**
- **Water in vicinity of waste packages**
  - **Bicarbonate water with pH 4.5 to 10.5**

Waste Package Materials

- **Dual barrier design provides two independent failure mechanisms**
  - **Corrosion-Allowance Barrier**
    - » **Subject to general corrosion**
    - » **Permits performance prediction; thickness governs time to failure**
    - » **Galvanic protection of corrosion-resistant material**
    - » **Relatively low cost**
    - » **Current design 100 mm A516 carbon steel**
  - **Corrosion-Resistant Barrier**
    - » **Subject to localized corrosion**
    - » **Initiation of corrosion and failure random**
    - » **Not thickness dependent**
    - » **Current design 20 mm alloy 625 high-nickel steel**

Waste Package Basket Design/Materials

- **Defense-in-depth**
  - – **Basket structure, carbon steel tubes**
    - » **Load bearing**
    - » **Heat removal**
    - » **Long term performance, as it degrades,**
      - **Moderator displacement (reduces probability of criticality)**
      - **Retards radionuclides**
  - – **Performance based neutron absorbing material**
    - » **Corrosion resistant, Stainless steel-boron**
    - » **Non-structural, in compliance with NRC guidance**
  - – **Thermal shunt, ensures cladding temperature is met**

History of Design

- 1988: Thin-Walled, Bore hole design
- 1992: Definition of advanced conceptual design options
- 1992: Robust/Multi-Barrier, Drift emplaced
- 1993: Multi-Purpose Canister/ Robust/Multi-Barrier
- 1996: Advanced conceptual design finished
- 1996 through 1999: Viability assessment design

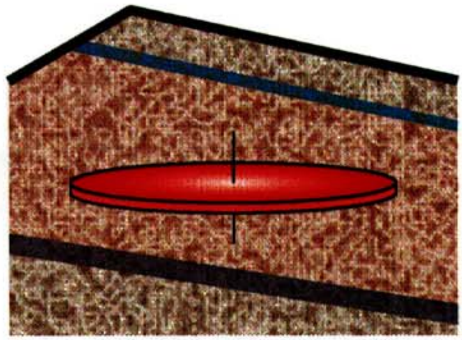
What Remains to Be Tried

- Extend life: Drip shields or ceramic coatings
- Protect drip shield: Backfill at closure, thermal leveling (blending/lag storage, ventilation)
- Preclosure: Totally shielded waste packages
- Extend life: Continuous line loading of waste packages in drifts (blending/lag storage, ventilation)
- Extend life: Barrier material reevaluation
- Release: Cladding failure model, Performance Assessment
- Criticality:
  – Neutron absorbers and configurations
  – Depleted Uranium for highly enriched waste forms

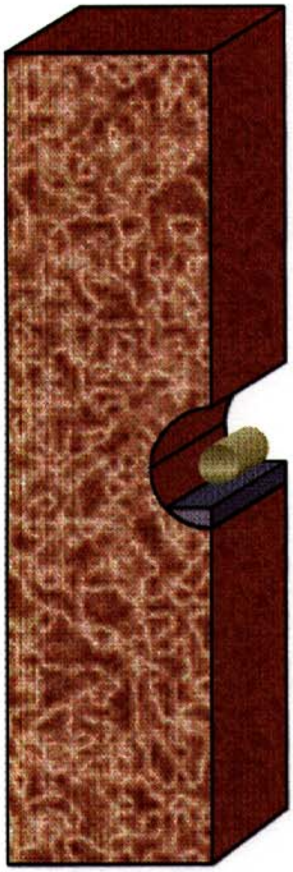
Waste Package Thermal Restraints

- Thermal restraints are governed by temperature limits for:
  - Cladding
  - Drift wall
  - Zeolites
- Repository thermal loading 80-100 metric tons uranium per acre
- Waste Package maximum thermal output limit is 18kW

Four Model Thermal Analysis Approach



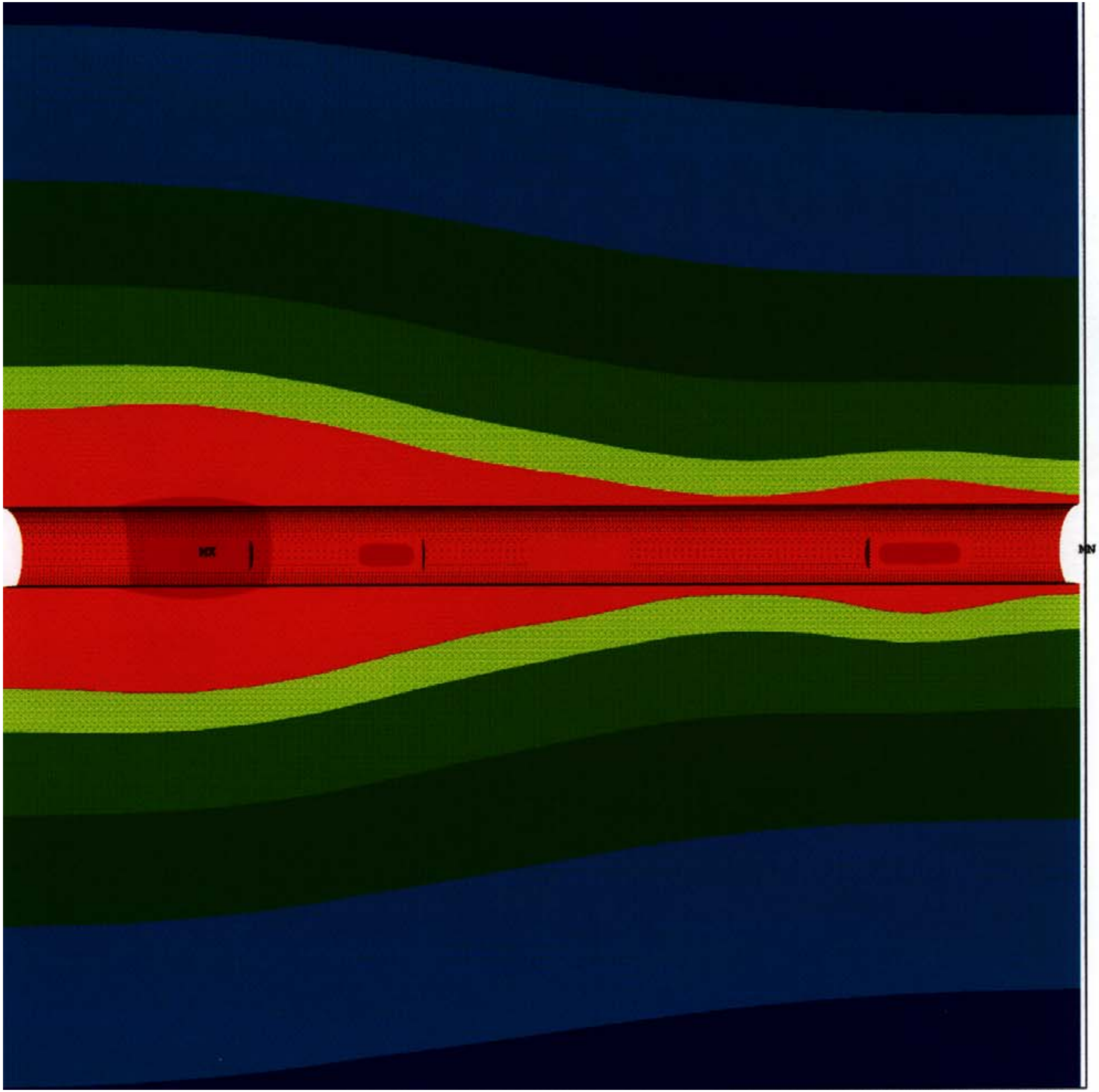
Repository Disk
Long-Term Response
Due to Thermal Loading



Drift Emplacement
Provide Time-Dependent
Boundary Conditions
for Near-Field

Waste Package
Incorporate Specific Materials
and Design Configuration

1/4 SNF Assembly
Peak Cladding Temperatures
(Effective Conductivity)



Multiple WP Model
at 10 years

83 MTU/acre
(ACD WP Spacings)
(22.5 m Drift Spacing)

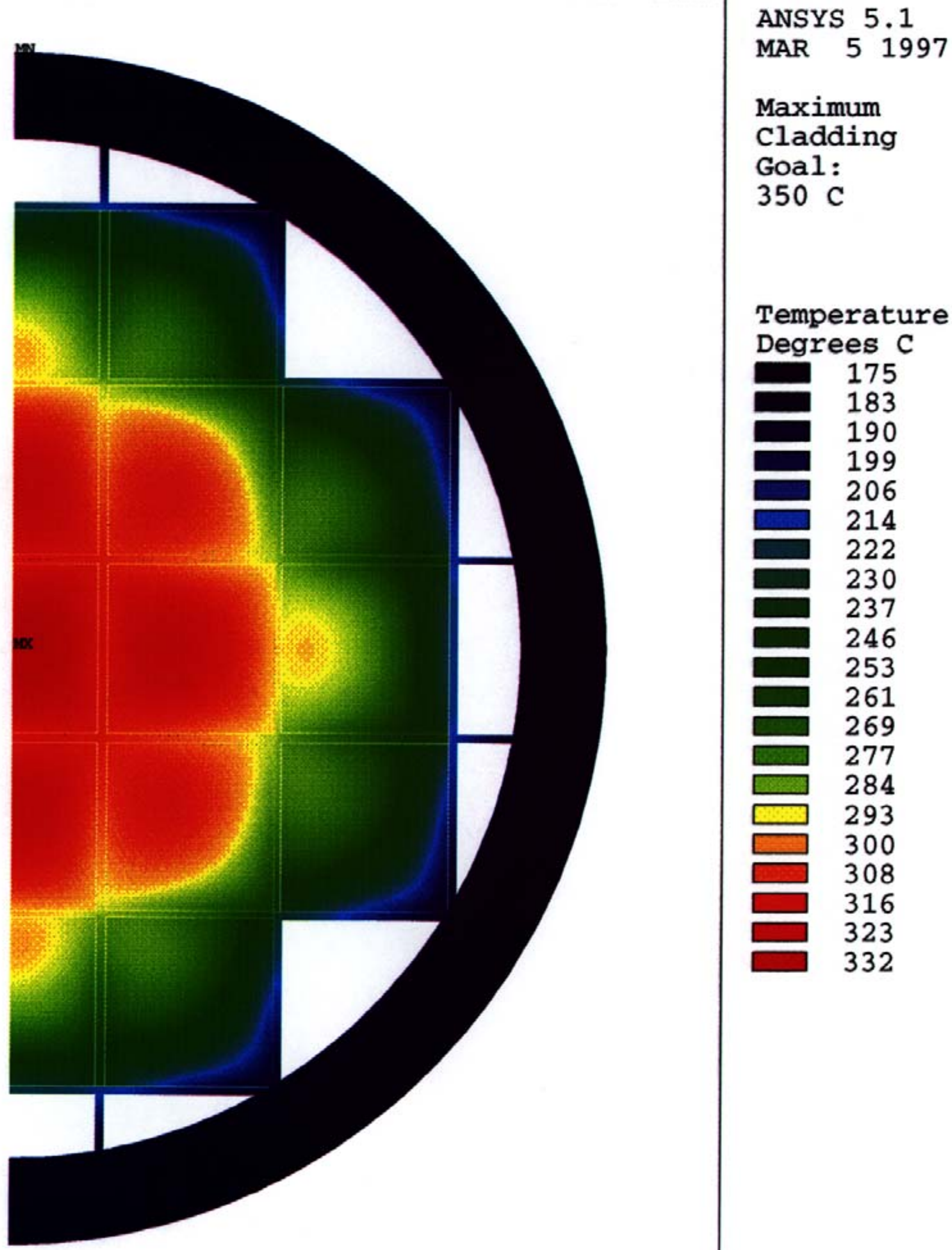
Left to Right:

[21 PWR WP with
Design Basis SNF

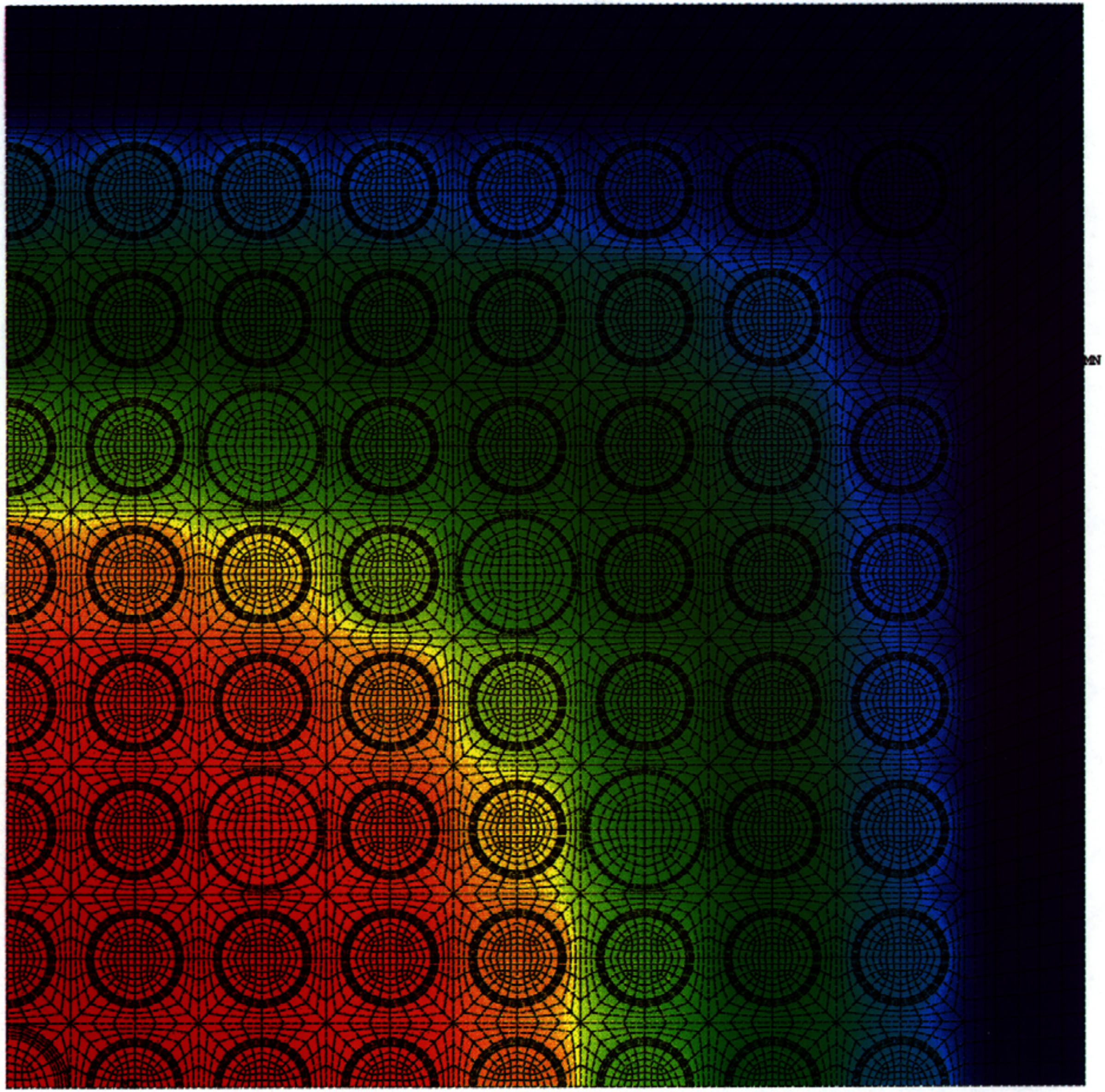
[4 DHLW WP
Savannah River

[21 PWR WP with
Below Average SNF

[44 BWR WP
Average SNF



21 PWR UCF/WP at Time of Peak Temp. (2 years)



ANSYS 5.0 A
FEB 3 1995

Temperature
Min =300
Max =316

300
301
302
302
303
304
305
305
306
307
308
309
309
310
311
312
312
313
314
315
316

Degrees C

SNF Temperatures
750 watts/assembly
300°C Basket Wall

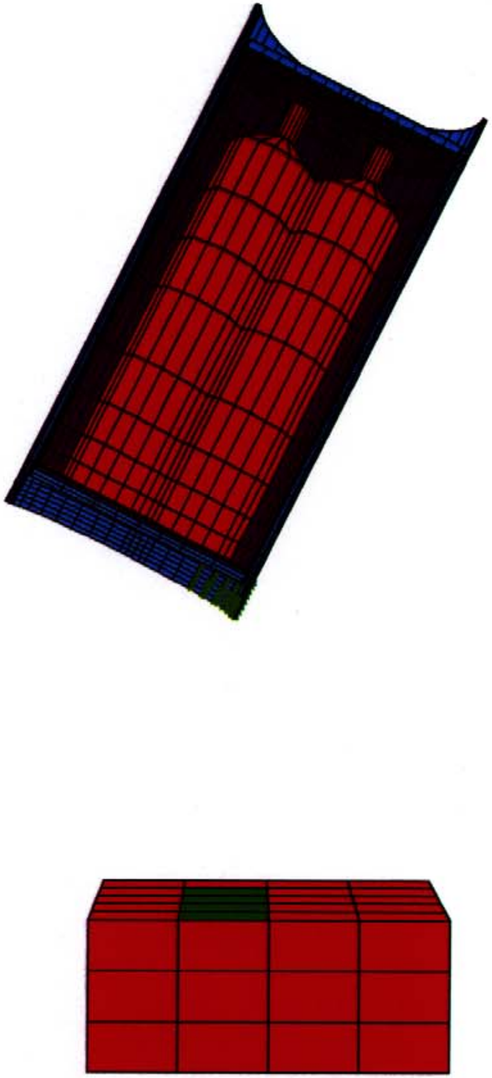
Effective Conductivity
Determination Analysis

Structural Analysis

- Requirements/Criteria
  - Maintain waste containment during transportation, emplacement, and retrieval [EBDRD 3.7.1.E]
  - Dispersal of radioactive waste materials should be limited during accidents or other dynamic effects [EBDRD 3.7.1.H, EBDRD 3.7.1.2.A]
  - Withstand a 2-m drop onto flat unyielding surface without breaching [CDA Assumption EBDRD 3.7.1.1.F]
  - Contain waste for at least 3000 years [CDA Assumption EBDRD 3.7.1.I]

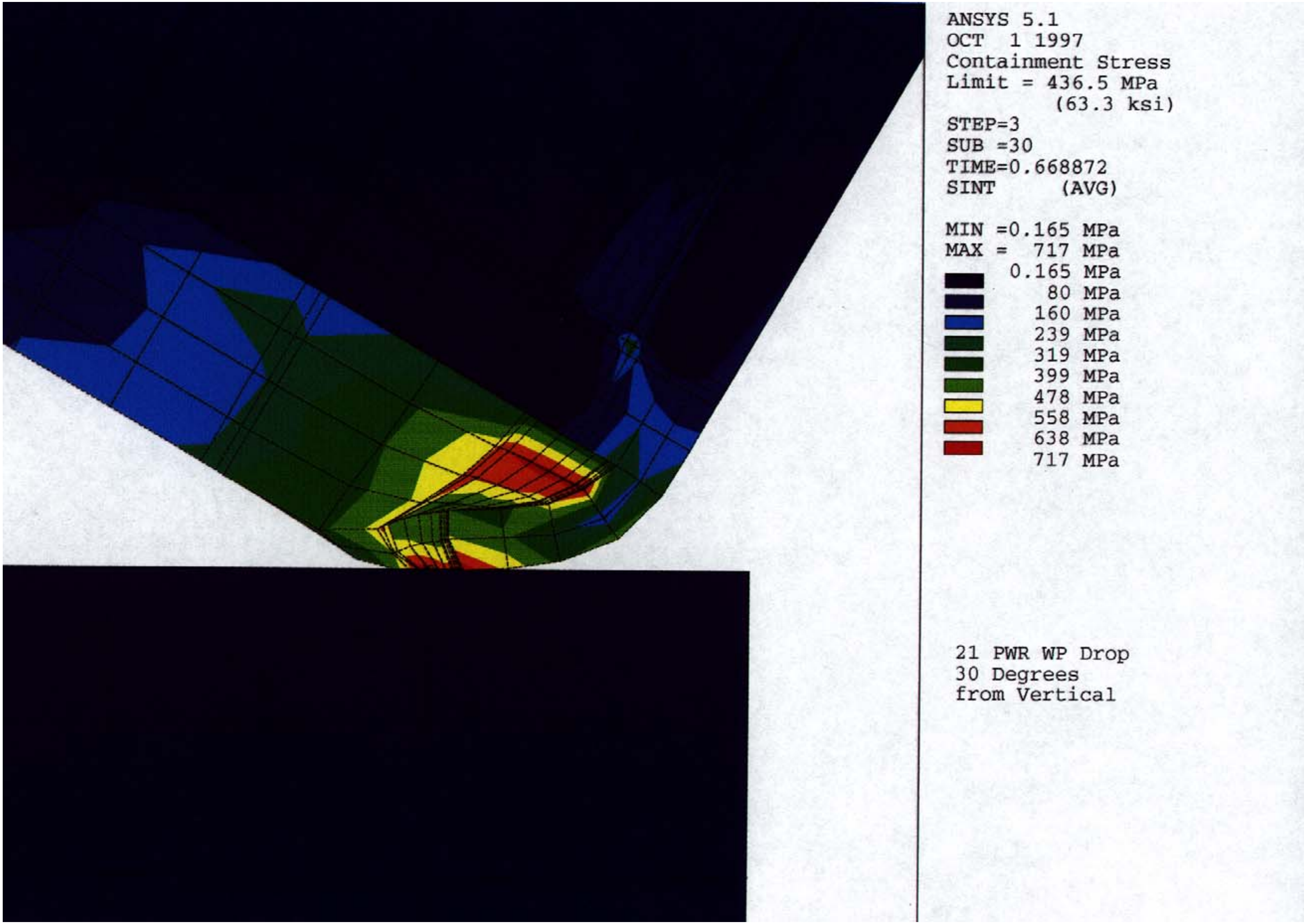
Structural Analysis
(Continued)

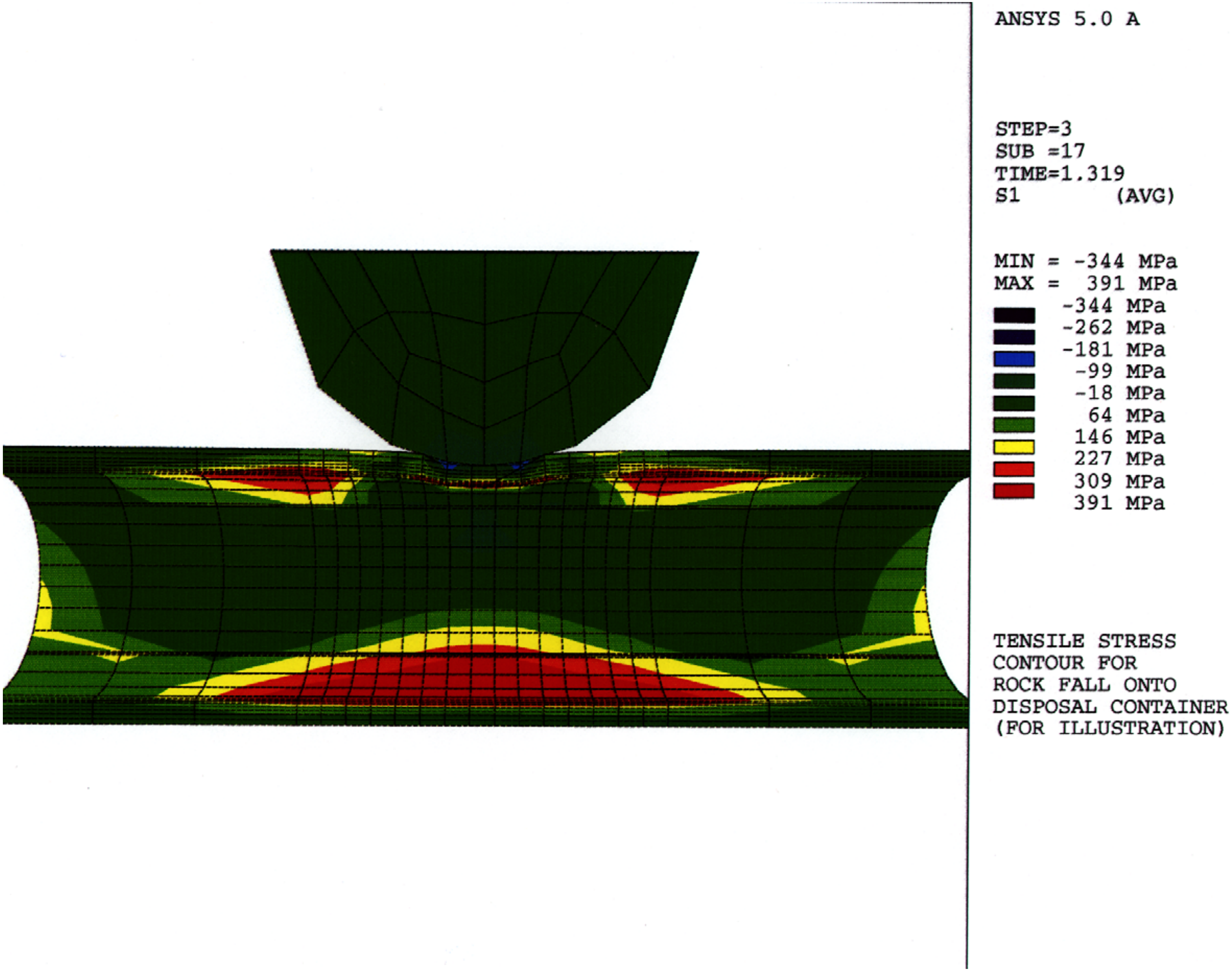
- **Preclosure Analyses**
  - **Handling Load**
    - » **SNF loading and container closure**
    - » **Waste container lifting and moving**
    - » **Emplacement/Retrieval**
  - **Design Basis Events**
    - » **Drops (vertical, horizontal, oblique)**
    - » **Tip-over**
    - » **Impacts (missile from failure of pressurized component, rock fall, etc.)**
- **Postclosure Analyses**
  - **Drift Liner Collapse/Rock Fall**
  - **Seismic Event**

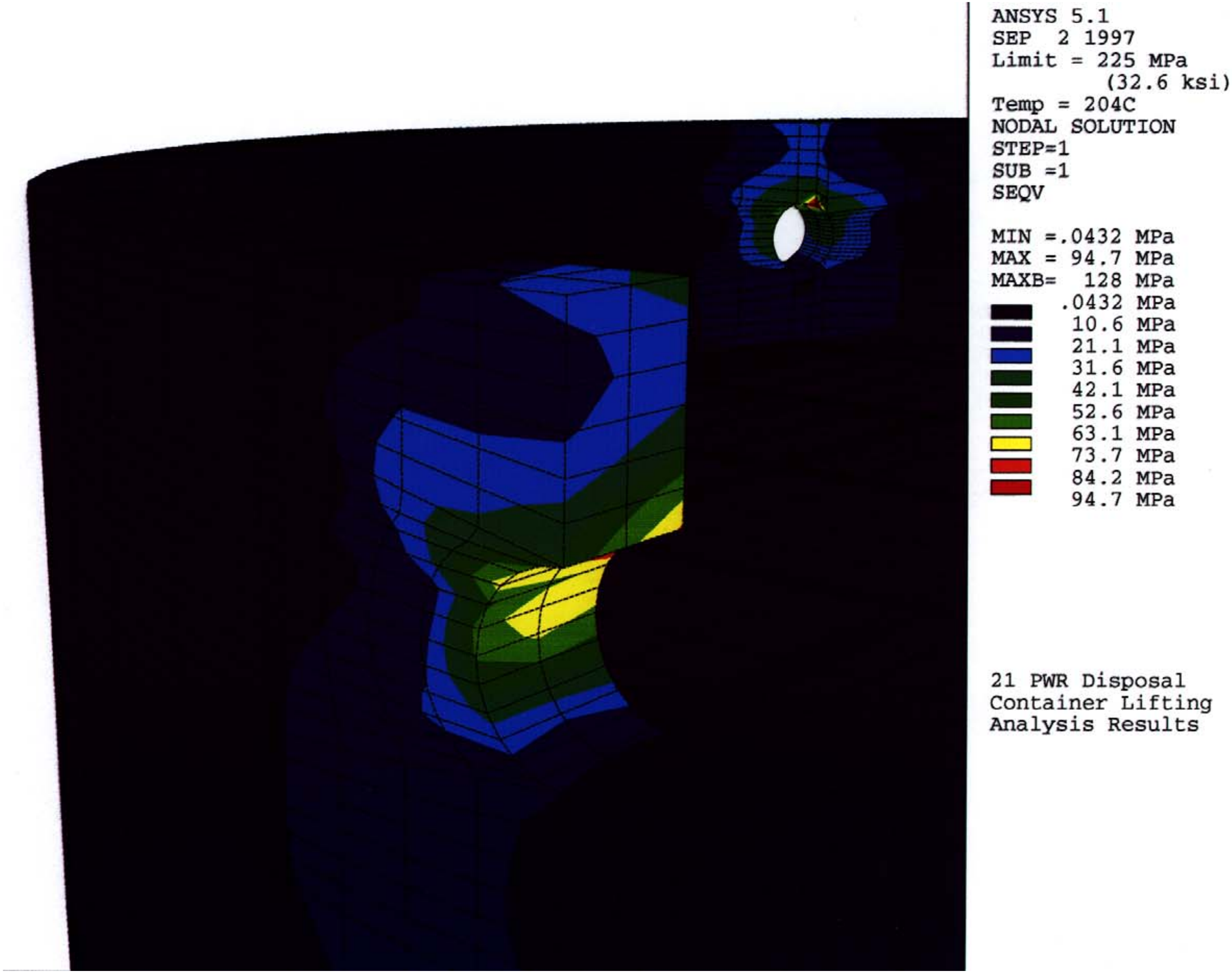


ANSYS 5.0 A

Defense High-Level
Waste Package
2-Meter Drop Model
Initial Position


ANSYS 5.1
OCT 1 1997
Containment Stress
Limit = 436.5 MPa
(63.3 ksi)
STEP=3
SUB =30
TIME=0.668872
SINT (AVG)
MIN =0.165 MPa
MAX = 717 MPa
0.165 MPa
80 MPa
160 MPa
239 MPa
319 MPa
399 MPa
478 MPa
558 MPa
638 MPa
717 MPa
21 PWR WP Drop
30 Degrees
from Vertical


ANSYS 5.0 A
STEP=3
SUB =17
TIME=1.319
S1 (AVG)
MIN = -344 MPa
MAX = 391 MPa
-344 MPa
-262 MPa
-181 MPa
-99 MPa
-18 MPa
64 MPa
146 MPa
227 MPa
309 MPa
391 MPa
TENSILE STRESS
CONTOUR FOR
ROCK FALL ONTO
DISPOSAL CONTAINER
(FOR ILLUSTRATION)


ANSYS 5.1
SEP 2 1997
Limit = 225 MPa
(32.6 ksi)
Temp = 204C
NODAL SOLUTION
STEP=1
SUB =1
SEQV
MIN =.0432 MPa
MAX = 94.7 MPa
MAXB= 128 MPa
.0432 MPa
10.6 MPa
21.1 MPa
31.6 MPa
42.1 MPa
52.6 MPa
63.1 MPa
73.7 MPa
84.2 MPa
94.7 MPa
21 PWR Disposal
Container Lifting
Analysis Results

Analytical Processes Developed

- Spent Nuclear Fuel Effective Thermal Conductivity Methodology
- Burnup Credit Methodology and Probabilistic Configuration Generator
- Elastic-Plastic Structural Methodology