Thermal Analysis of HI-STAR 100 and NAC-STC

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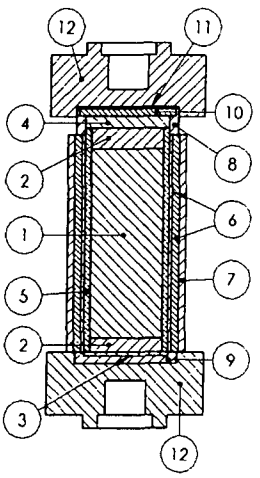
Overview of Work

- Analysis will be performed on:
  - *HI-STAR 100*
  - *NAC-STC*
- Hypothetical Fire Runs:
  - 30-minute Runs with Post Cool Down
    - 800°C (1475°F) P-Thermal Fire – Fire Simulated Using Simplified BCs
    - 1000°C (1832°F) P-Thermal Fire
  - 11-hr Runs with Post Cool Down
    - 1000°C (1832°F) P-Thermal Fire
    - CAFE/P-Thermal Fire – Fire Simulated Using CFD Fire Code
      - Benchmark CAFE
      - Four P-Thermal cool-down analyses @ 1, 2, 3, and 11 hours

HI-STAR 100 Thermal Analysis

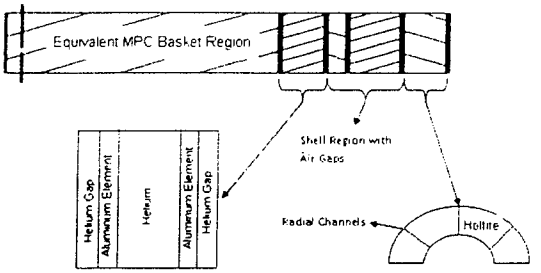
HI-STAR 100 as Modeled

1 Basket Assembly
2 Top/Bottom Basket Assembly
3 MPC Bottom Plate
4 MPC Top Lid
5 MPC Peripheral Region
6 Inner/Gamma Shells
7 Holtite/Radial Channel Neutron Shield
8 Flange
9 Overpack Bottom Plate
10 Overpack Top Lid
11 Buttress Plate
12 Impact Limiters



HI-STAR 100 as Modeled (Cont.)

- Ignored geometric feature less than 1-in thick
  - Use Equivalent Thermal Resistance (from SAR)
  - Orthotropic Thermal Conductivity
    - SAR presented orthotropic properties for the MPC Basket Region only

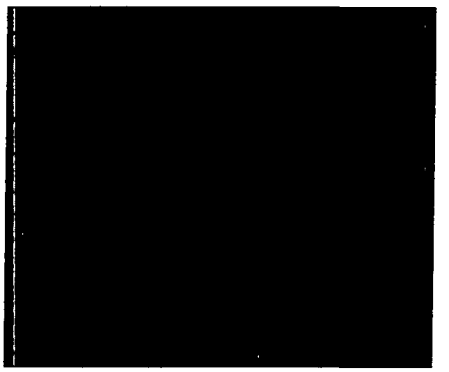


- Added holes at the ends of the Impact Limiters

HI-STAR 100 Materials and Mesh

- Material Properties
  - Use Properties (k, C_p, ρ, ε) found in the SAR
- Components/Materials:
  - MPC Outer Shell: Stainless Steel (Alloy X), Aluminum 1100 and other exotic materials
  - Overpack: Carbon Steel and Holtite Insulation
  - Limiters: Aluminum Alloy (Honeycomb)
- Voids:
  - Between MPC & Overpack: Helium
  - Contact Gaps, Shell Region: Air

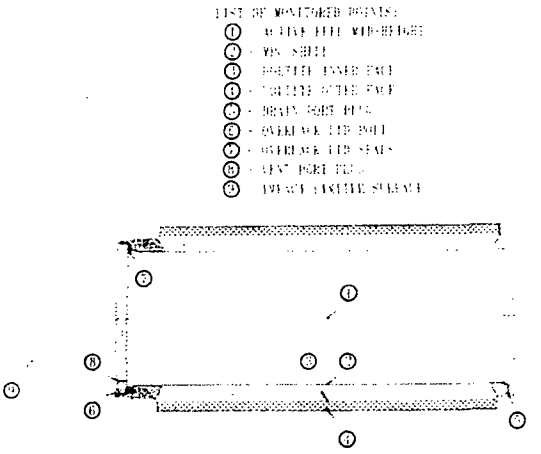
- Total Number of Elements: 192,390



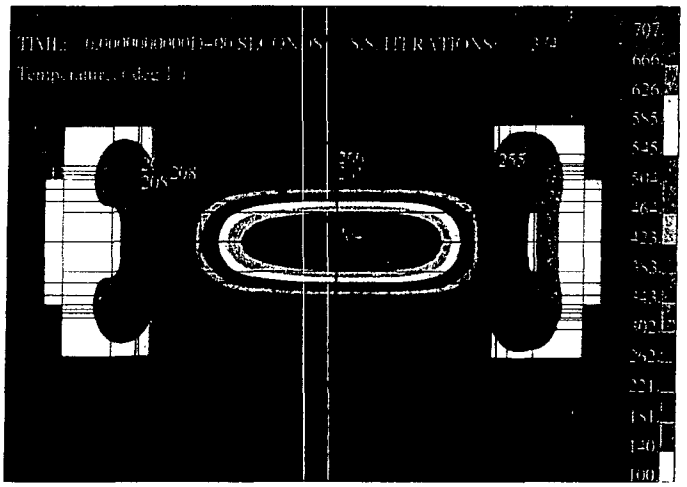
Normal Conditions using P-Thermal

- Boundary Conditions
  - Ambient Conditions
    - 38°C (100°F) Ambient Temperature
    - Insolation as prescribed in 10CFR71:
      - Non-horizontal Flat Surfaces and Curved Surfaces
    - Radiation (e=0.85) and Convection (0.9 Btu/ft^2-hr-F or 5 W/m^2-C)
- No Credit for Holtite
- Impact Limiter Volume assumed to be Air

Control Points Monitored in HI-STAR 100 SAR: Basis for Comparison



Normal Conditions Results
(Temperatures @ Control Points Highlighted)



March 30, 2001
Hi-Star 100 SAR

Comparison with SAR

No.	Location	SAR*	Current Analysis	Difference (%)
1	Center MPC Basket	708	704	-0.5
2	MPC Shell/Overpack Boundary	309	281	-8.7
3	Holtite Inner Face	259	266	3.0
4	Package Outer Surface	223	222	~0.0
5	Drain Port Plug	259	255	-1.1
6	Overpack Lid Bolt	159	207	**29.5**
7	Overpack Lid Seals	160	208	29.3
8	Vent Port Plug	160	208	**30.6**
9	Impact Limiter Surface	127	133	5.1

*SAR values are used as based values

Hypothetical Accident Conditions

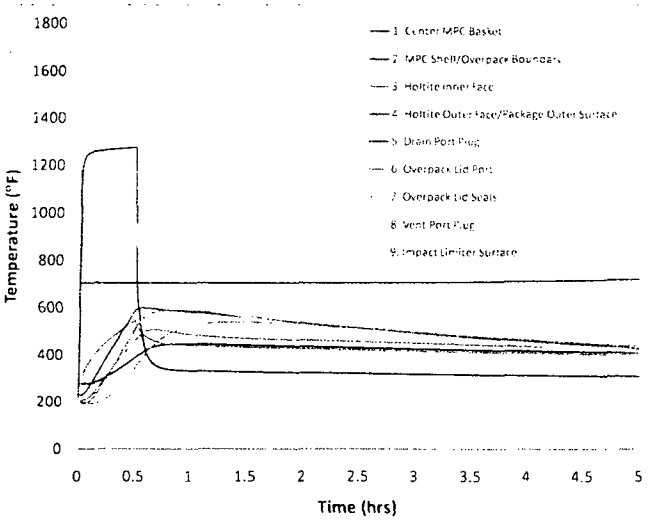
- All Runs (P-Thermal and CAFE/P-Thermal)
  - Credit for Holtite
  - Crushed Aluminum for Impact Limiters
    - Properties for Uncrushed Dimensions
- P-Thermal Runs
  - Fire Simulated Using
    - 800°C (1475°F) or 1000°C (1832°F) Fire Temperature
    - Radiation (e=0.9) and Convection at 15 Btu/ft^2-hr-F (85W/m^2-C)
- CAFE/P-Thermal Runs
  - Fire Simulated with CAFE CFD Code: Two Way Couple

Post-Fire Cool-Down Conditions

- Only P-Thermal is used in this step
- No Credit for Holtite
- 10% Reduction in Effective Conductivity of Neutron Shield Region
- Boundary Conditions
  - 38°C (100°F) Ambient Temperature
  - Radiation (e=0.66) and Convection (0.9 Btu/ft^2-hr-F or 5W/m^2-C)

Hypothetical Accident Conditions

30-minutes P-Thermal Fire, 1475°F Results



Comparison with SAR (1475°F Results) @30 Minutes

No.	Location	SAR	Current Analysis	Difference (%)
1	Center MPC Basket	708	704	-0.5
2	MPC Shell/Overpack Boundary	313	390	**24.6**
3	Holtite Inner Face	604	551	-8.7
4	Package Outer Surface	1348	1278	-5.1
5	Drain Port Plug	645	587	-8.8
6	Overpack Lid Bolt	415	511	**23.1**
7	Overpack Lid Seals	392	461	**17.6**
8	Vent Port Plug	283	343	**21.5**
9	Impact Limiter Surface	983	958	-2.4

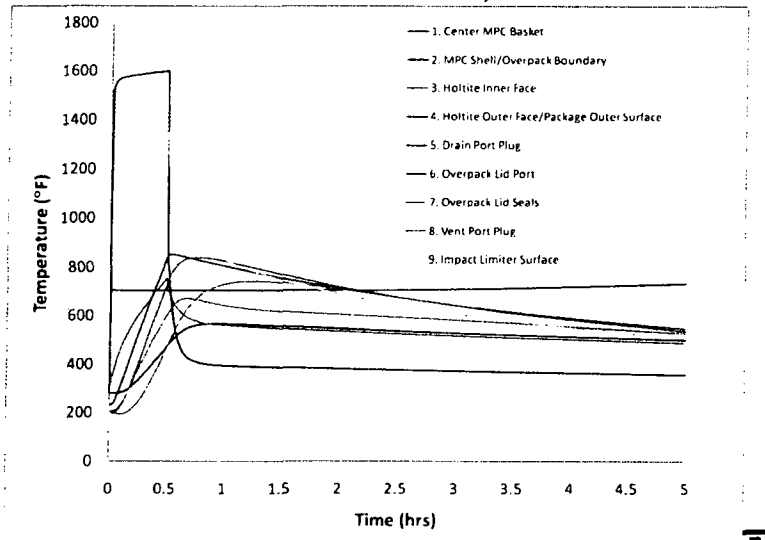
Comparison with SAR (1475°F Results) Max. Temperatures During Cool-Down

- SAR vs. P-Thermal: Peak Temperatures at most ±6 minutes apart

No.	Location	SAR	Current Analysis	Difference (%)
2	MPC Shell/Overpack Boundary	419	450	7.3
3	Holtite Inner Face	604	551	-8.7
4	Package Outer Surface	1348	1278	-5.1
5	Drain Port Plug	662	601	-9.2
6	Overpack Lid Bolt	514	594	**15.5**
7	Overpack Lid Seals	490	509	3.8
8	Vent Port Plug	443	541	**22.1**
9	Impact Limiter Surface	983	958	-2.4

Hypothetical Fire Accident Conditions

30-minutes P-Thermal Fire, **1832°F** Results



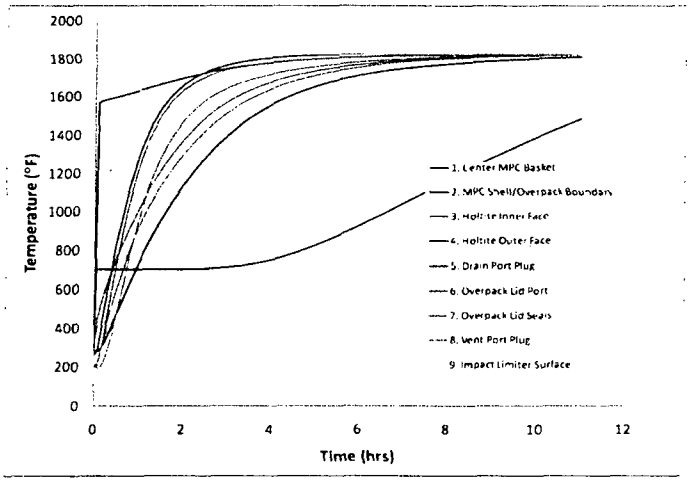
Temperatures at Control Points (1832°F Results)

- No SAR Data to Compare

No.	Location	@30 min	Peak During Fire
1	Center MPC Basket	704	-
2	MPC Shell/Overpack Boundary	469	567
3	Holtite Inner Face	755	755
4	Package Outer Surface	1601	1601
5	Drain Port Plug	833	851
6	Overpack Lid Bolt	722	839
7	Overpack Lid Seals	598	673
8	Vent Port Plug	461	742
9	Impact Limiter Surface	1363	1363

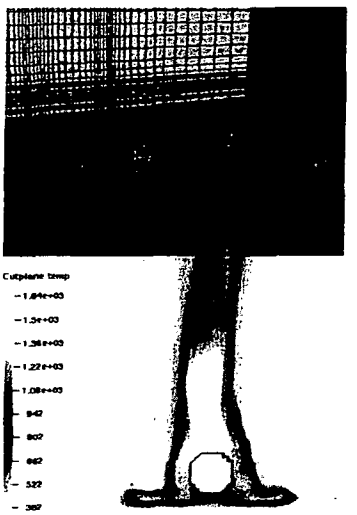
Hypothetical Fire Accident Conditions

11hr P-Thermal Fire, 1832°F Results



CAFE/P-Thermal Fire Runs

CFD-FEA Fire Simulation



CAFE
Calculate External Fire Environment

P-Thermal
Calculate Fire Effects on Ca

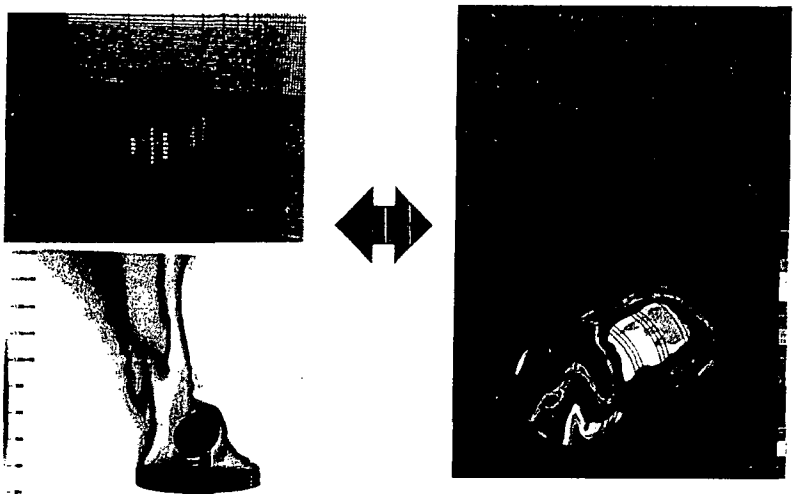
Benchmark CAFE

- Benchmark CAFE to Large Calorimeter Tests
- Three Test Conducted at Sandia's Lurance Burn Site
  - 15ft long, 8ft Diameter Calorimeter
  - 26 ft Diameter JP-8 Fuel Pool
  - Low Wind Conditions (< 3m/s)
    - 35-45 minute Burns
    - Test 1: Steady 1m/s Wind
- Test met requirements stated in 10CFR71.73(c)(4) for objects the size of the test unit and larger

Benchmark CAFE (Cont.)

- Test Data Available
  - Wind data collected at four locations around the pool (at three heights in each location)
  - Pool Recession Rate
  - Temperatures Inside and Outside the Calorimeter
  - Heat Flux Measured at Six locations adjacent to the Calorimeter
- Use Temperatures Inside Calorimeter to Benchmark CAFE
  - Temperature is a direct measurement
    - Uncertainty of Measurements are well understood
  - Heat Fluxes can be used but have larger uncertainty bounds
    - Obtained from indirect heat flux methods: Uncertainties Amplified

Benchmark Models



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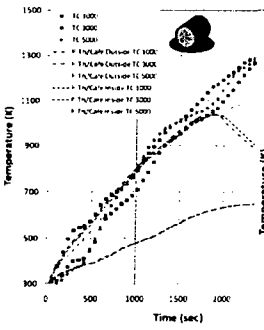
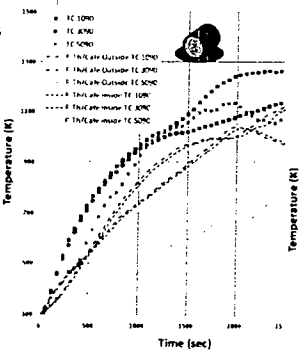
Benchmark Results

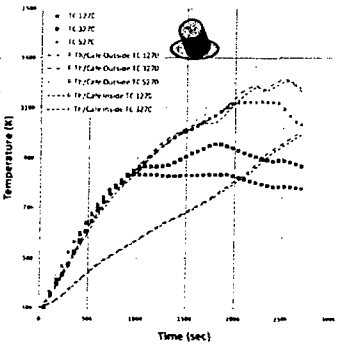
Side of Calorimeter



Top of Calorimeter



Bottom of Calorimeter



Comments

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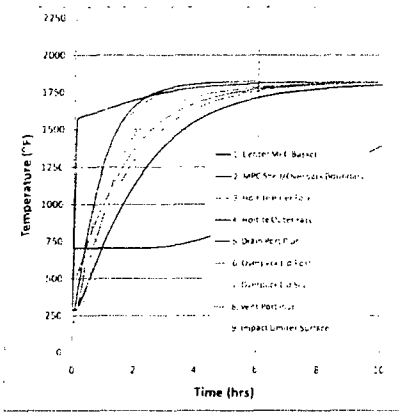
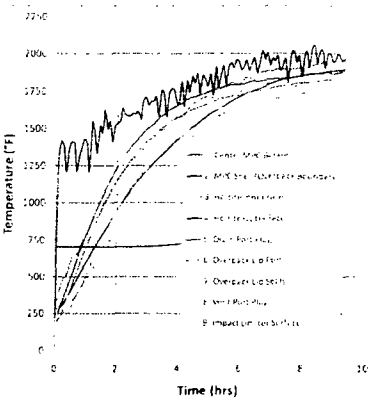
Current HI-STAR Results

11 hr, 1832°F P-Thermal Fire



11 hr, CAFE/P-Thermal Fire



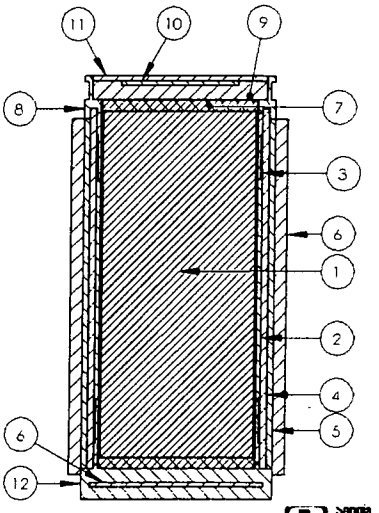
HI-STAR 100: Current Status

- Analyses already performed for HI-STAR 100:
  - NCT
  - Hypothetical Fire Simulations
    - 30-minute, 1475°F (800°C) P-Thermal Fire
    - 30-minute, 1832°F (1000°C) P-Thermal Fire
    - 11 hrs, 1832°F P-Thermal Fire
    - 11 hr CAFE/P-Thermal Fire (need cool-down)

Status of NAC-STC Thermal Analysis

NAC-STC as Modeled

1	Basket Assembly
2	Inner Shell
3	Inner Shell Ring (2)
4	Gamma Shield
5	Outer Shell
6	Neutron Shield (Side and Bottom)
7	Canister
8	Top Forging
9	Inner Lid
10	Inner Lid Ring
11	Outer Lid
12	Bottom Plate
13	Limiters (Not Shown)



NAC-STC Materials and Mesh (Model under construction)

- Material Properties
  - Use Properties (k, C_p, ρ, ε) found in the SAR
- Components/Materials:
  - Fuel Basket: Effective Properties
    - No Canister
  - Overpack:
    - Various Stainless Steel Alloys
    - Gamma Shield and Neutron Shield
  - Limiters: Balsa, Redwood
- Total Number of Elements: 146,347

NAC-STC: Current Status

- Currently determining how to model the fuel and basket region
- Runs to be performed – same as the HI-STAR
  - NCT
  - Hypothetical Fire Runs:
    - 30-minute Runs with Post Cool Down
      - 800°C (1475°F) P-Thermal Fire – Fire Simulated Using Simplified BCs
      - 1000°C (1832°F) P-Thermal Fire
    - 11-hr Runs with Post Cool Down
      - 1000°C (1832°F) P-Thermal Fire
      - CAFE/P-Thermal Fire – Fire Simulated Using CFD Fire Code
        - » Four P-Thermal cool-down analyses @ 1, 2, 3, and 11 hours