YUCCA
MOUNTAIN
PROJECT

Studies

Thermal Testing Program Update

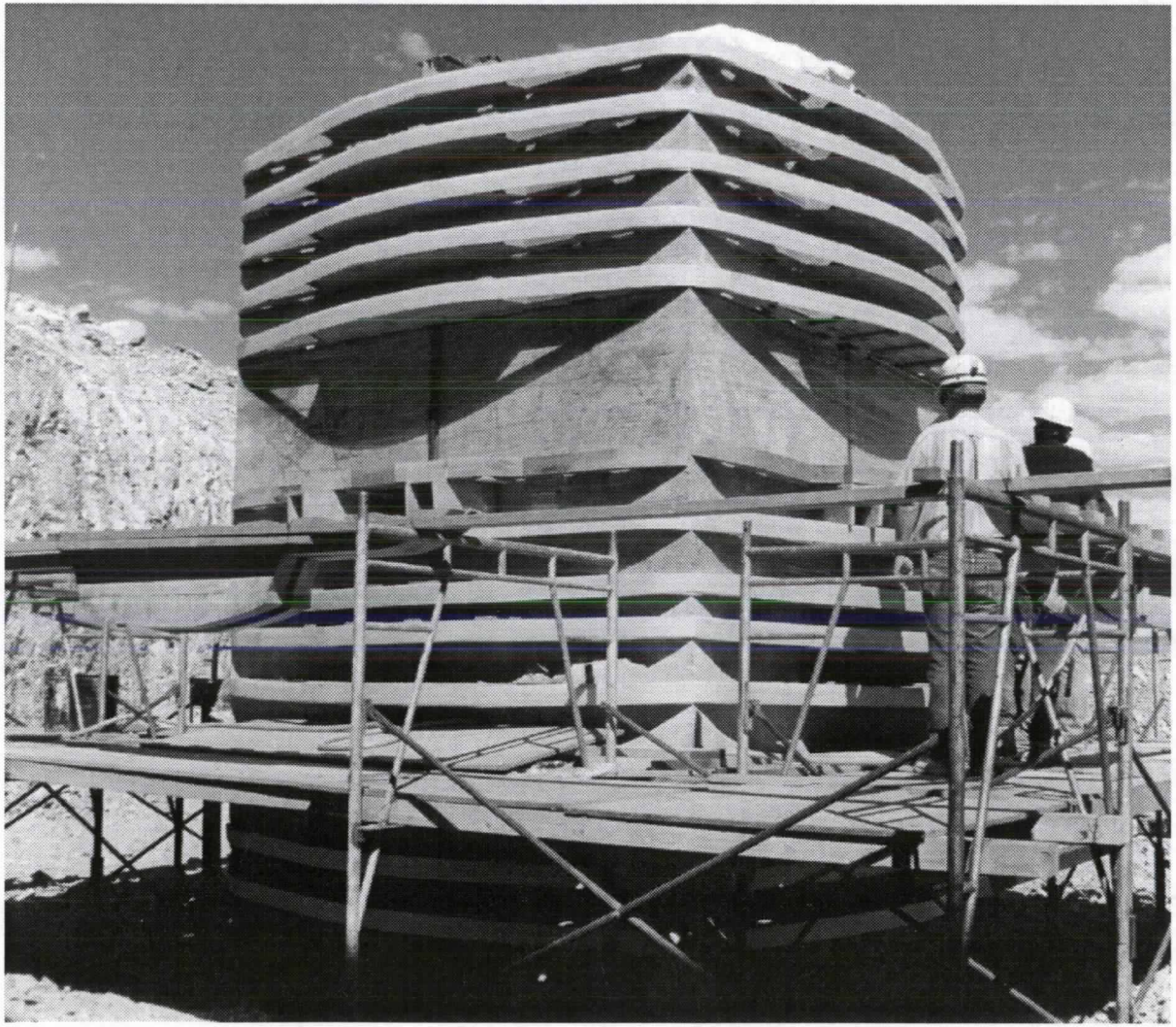
Presented to:
Nuclear Waste Technical Review Board

Presented by:
Robert M. Yasek
Department of Energy
Yucca Mountain Site Characterization Office

January 20-21, 1998

U.S. Department of Energy
Office of Civilian Radioactive
Waste Management

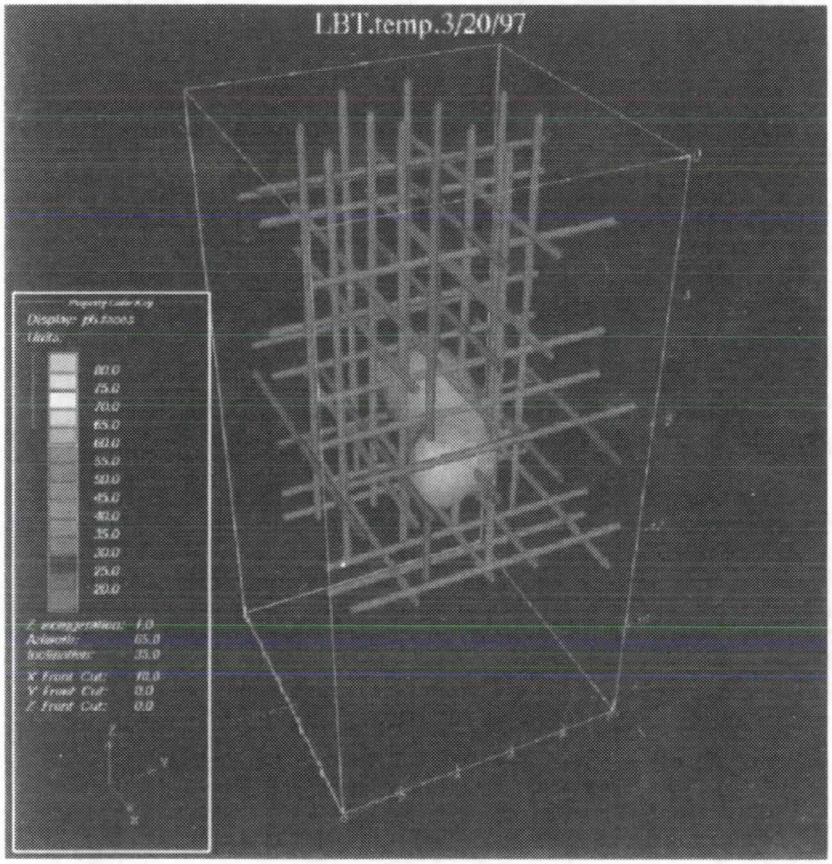
Large Block Test - Objectives and Layout

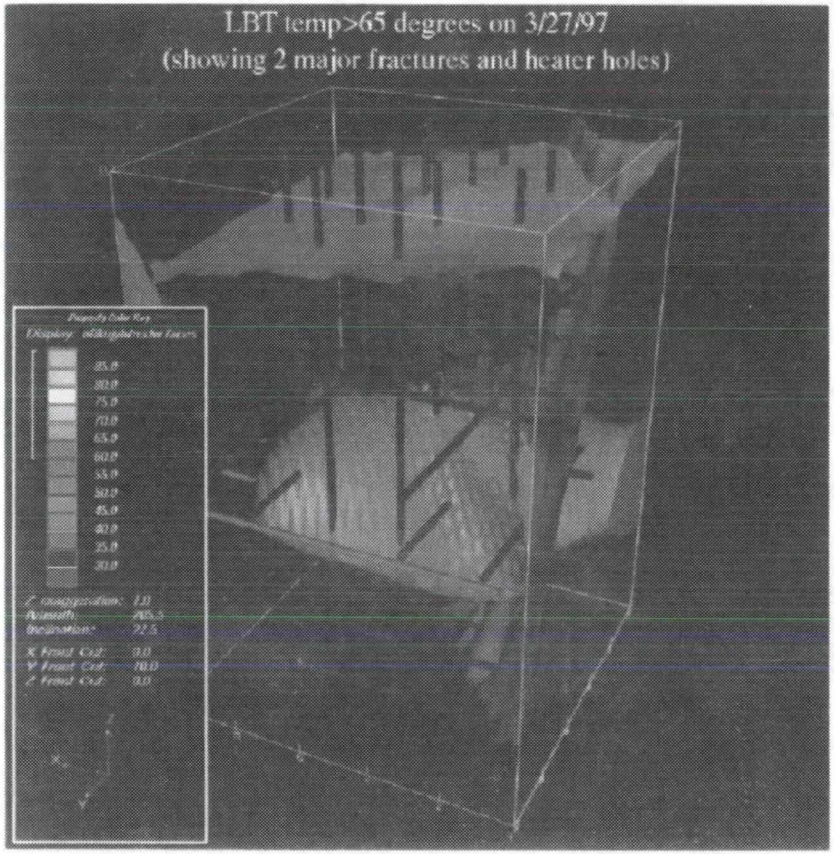


Large Block Test - Schedule

- Cooling phase to continue through FY98
- Post-test characterization program to start in early FY99, with detailed analysis and reporting to be completed by July, 1999

Large Block Test - Layout



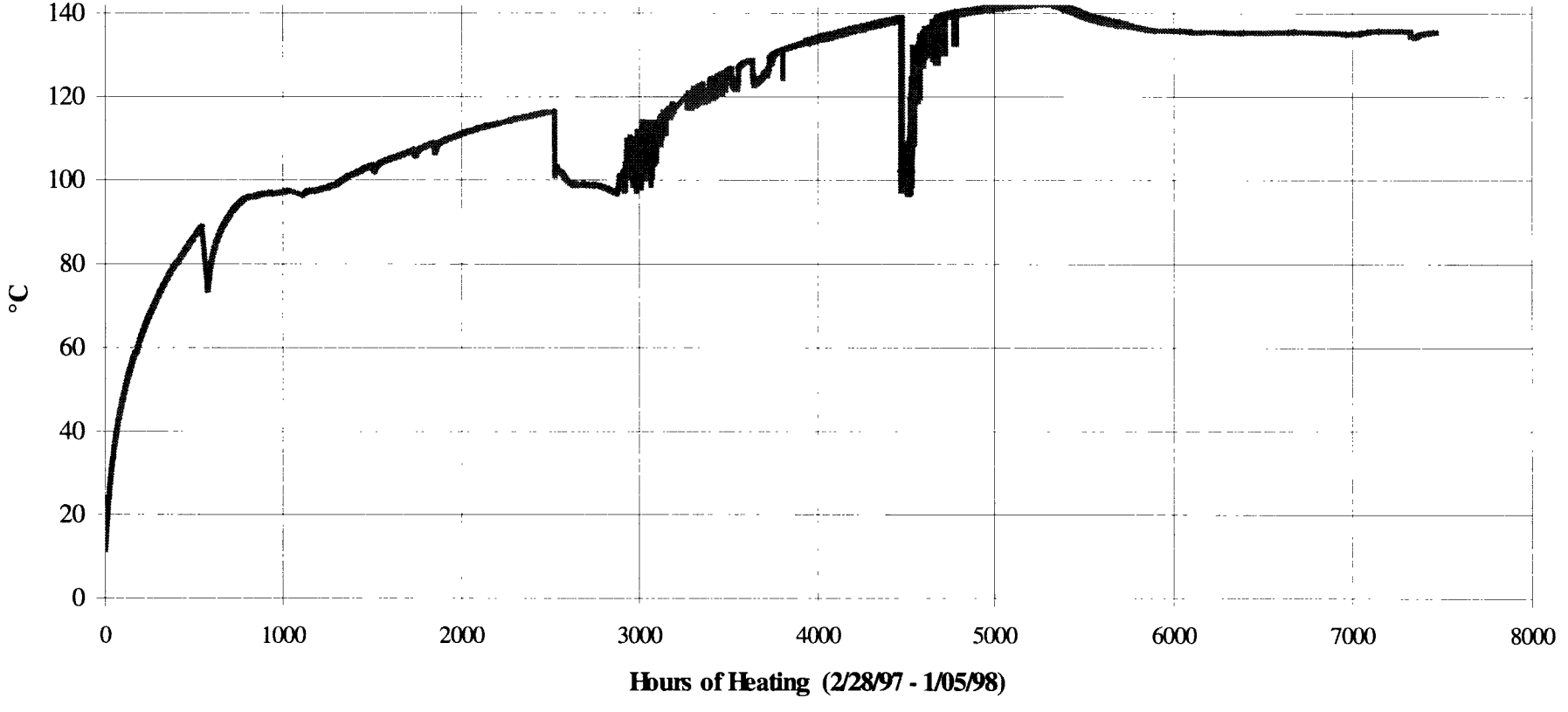


Temperature distributions in the block after 20 and 27 days of heating

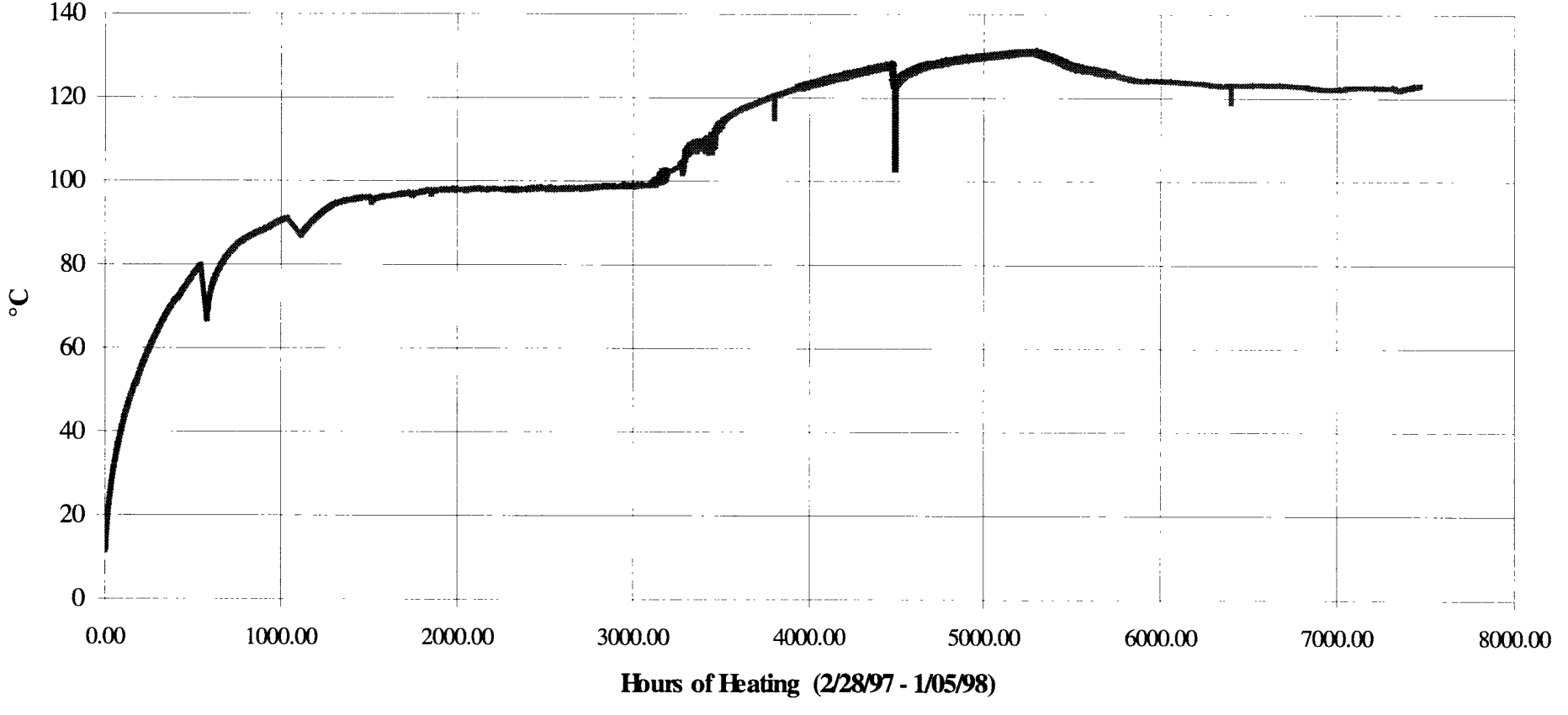
Large Block Test - Thermal

- Maximum temperature in block maintained at 135°C to 140°C, as seen in data from TT1 and TT2 (two vertical boreholes)
- Some cooling in the power ramp-down period, as seen in data from NT3 (horizontal borehole 0.46m below the heater plane), but temperatures now relatively constant
- Significant temperature fluctuations observed in many locations are likely due to thermal-hydrologic phenomena

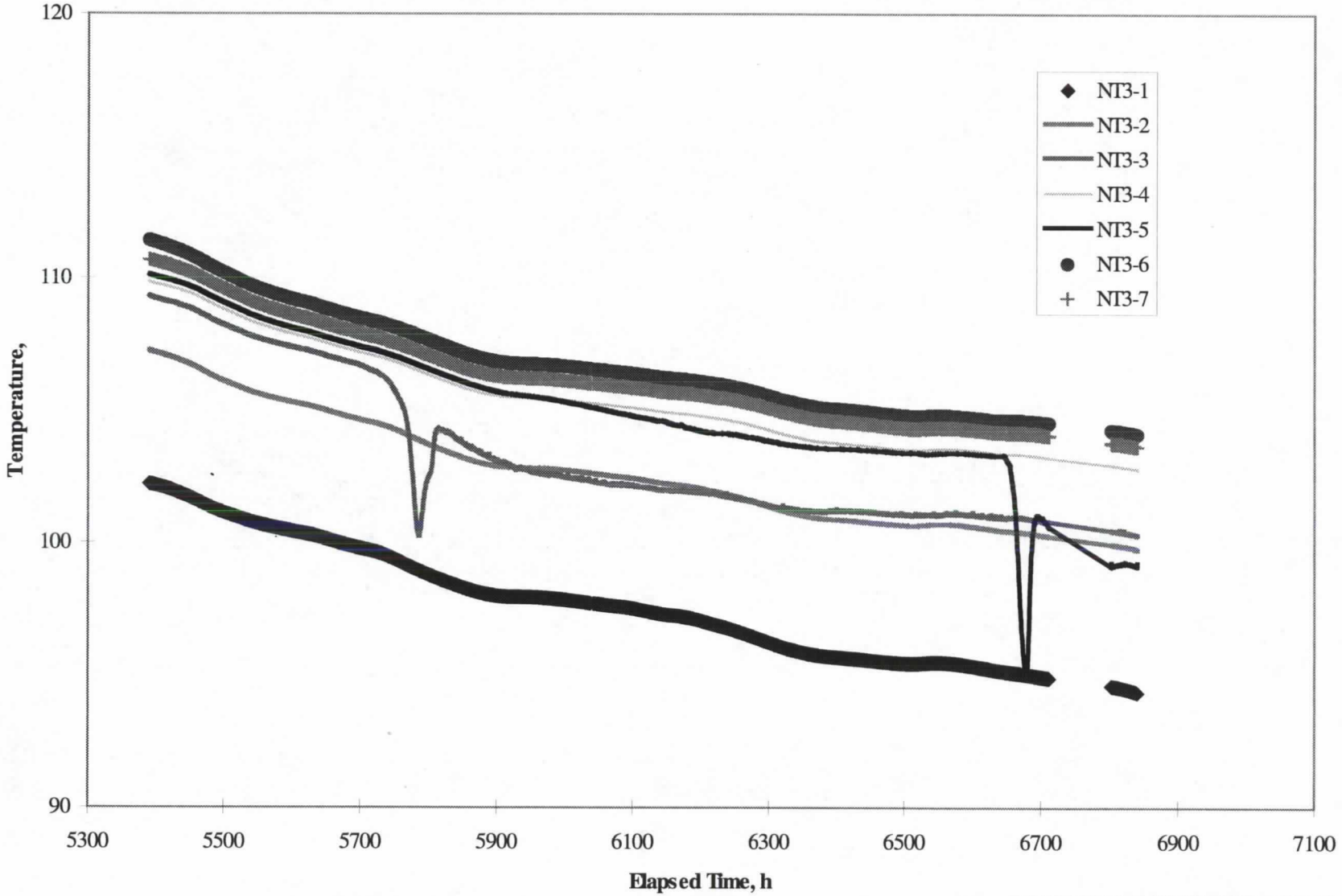
Temperature of RTD at TT1-14

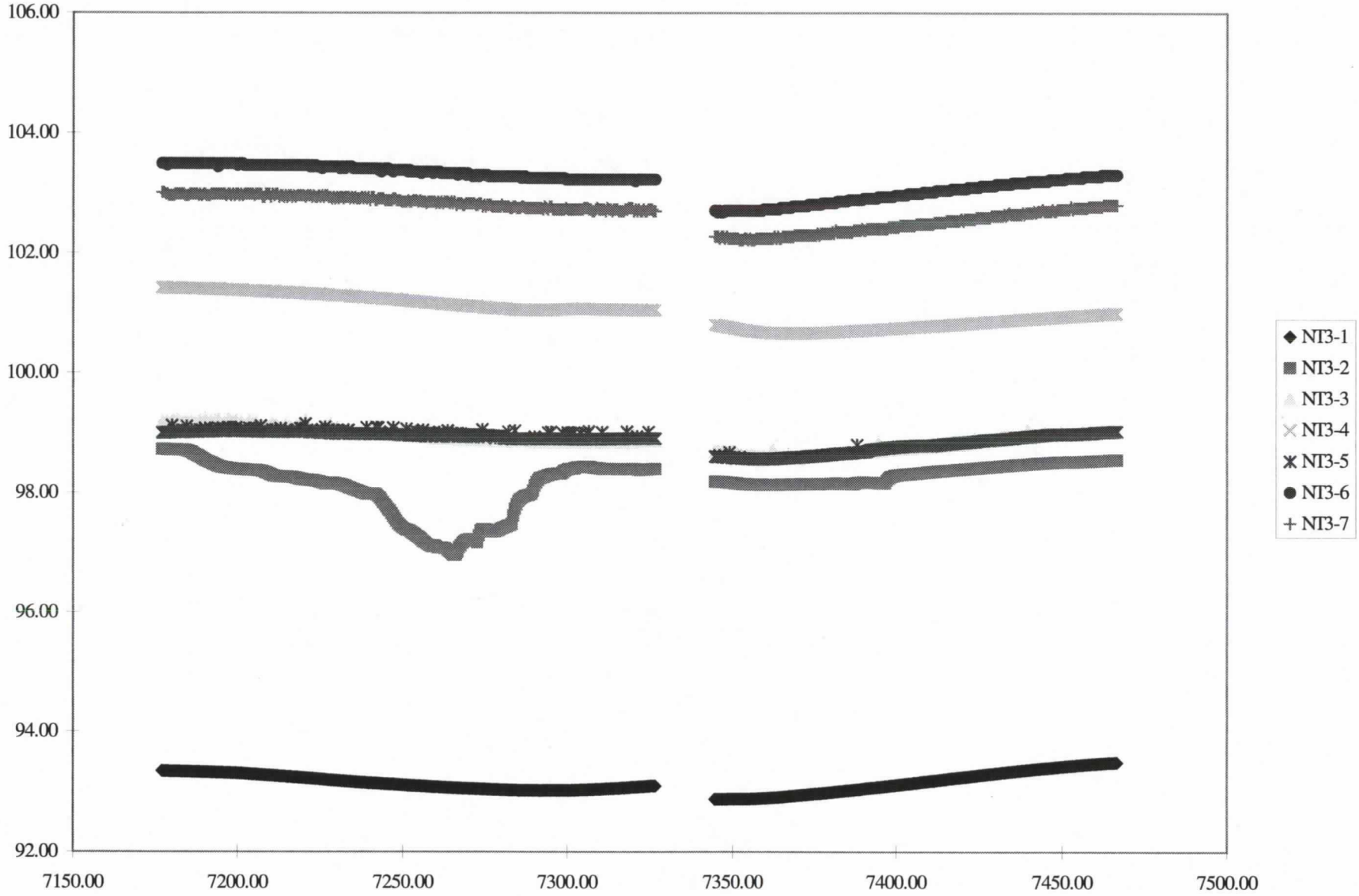


Temperature of RTD at TT2-14



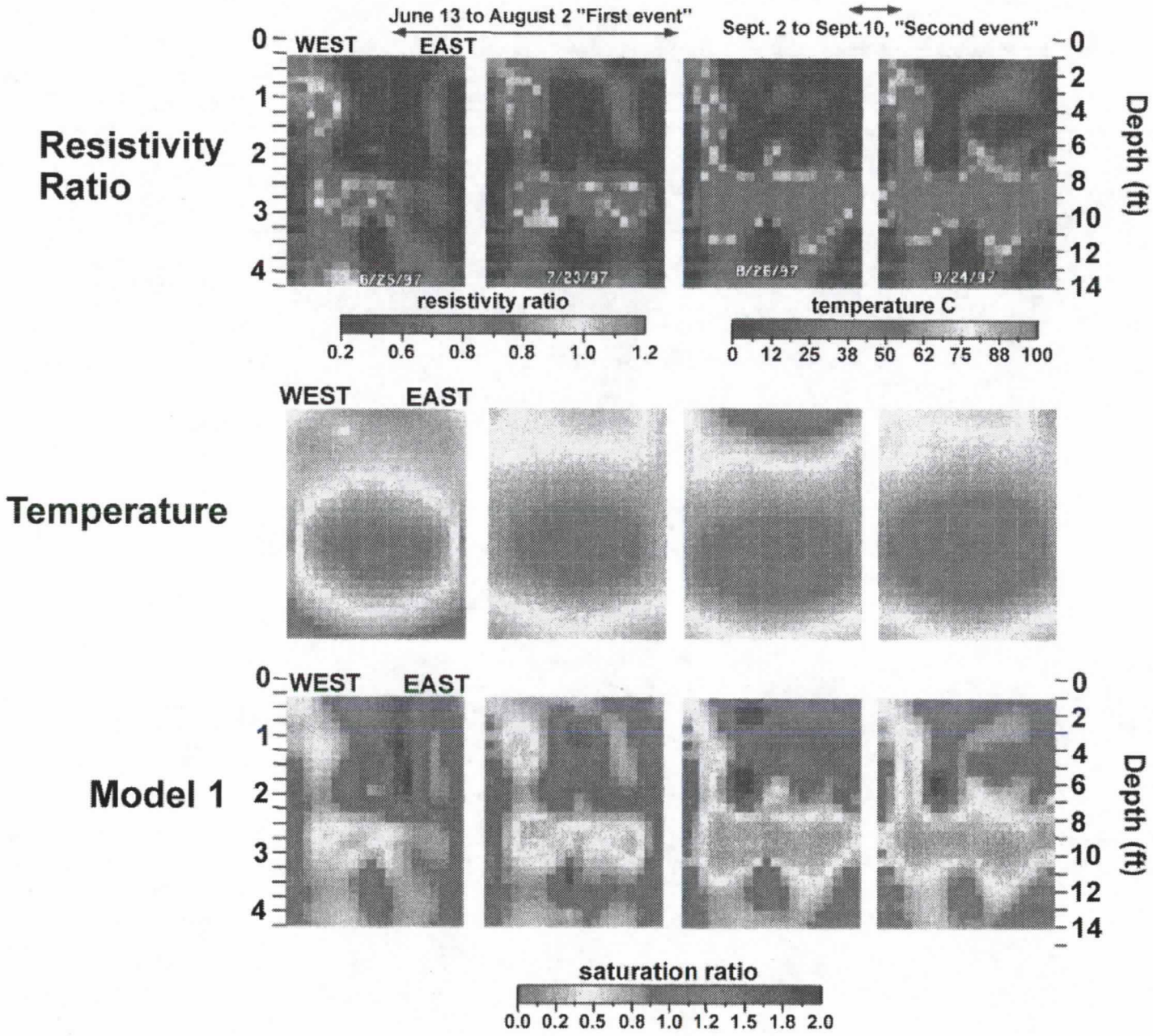
Temperatures in NT3 from 10/11/97 to 12/10/97



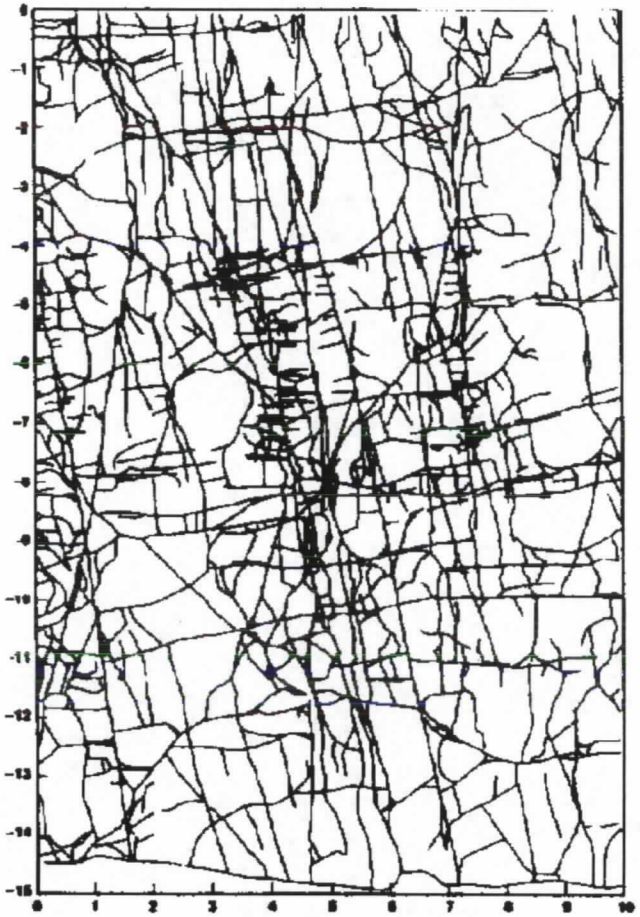

106.00
104.00
102.00
100.00
98.00
96.00
94.00
92.00
7150.00
7200.00
7250.00
7300.00
7350.00
7400.00
7450.00
7500.00
NT3-1
NT3-2
NT3-3
NT3-4
NT3-5
NT3-6
NT3-7

Large Block Test - Hydrology

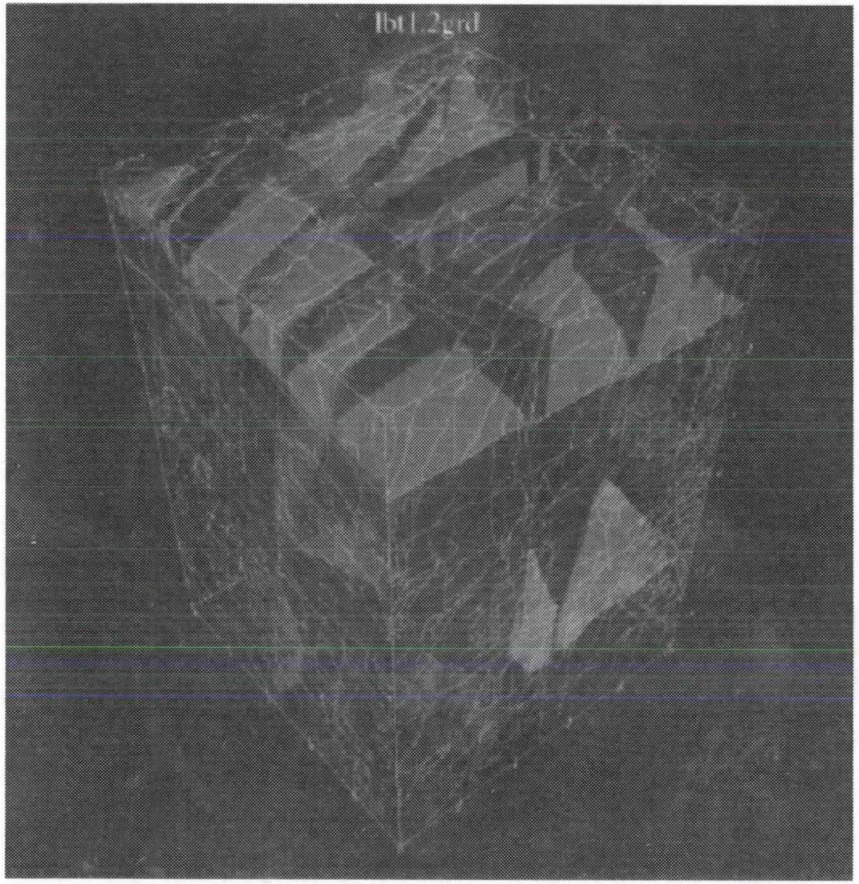
- Saturation tomographs suggest a region of dry rock has formed around the heater
  - As much as 80% of the original water lost
- Saturation has increased locally along vertical, linear features
  - Some of these increases became more pronounced during times of significant temperature variability


June 13 to August 2 "First event"
Sept. 2 to Sept.10, "Second event"
Resistivity Ratio
WEST
EAST
6/25/97
7/23/97
8/26/97
9/24/97
Depth (ft)
resistivity ratio
0.2 0.6 0.8 0.8 1.0 1.2
temperature C
0 12 25 38 50 62 75 88 100
Temperature
Model 1
saturation ratio
0.0 0.2 0.5 0.8 1.0 1.2 1.5 1.8 2.0

Large Block Test - Mechanical



Fractures on north face of block (distance in feet)



3D physical model of fractures within the block

Large Block Test - Mechanical
(continued)

- All instrumented fractures have opened since the start of heating
- Sub-horizontal fracture about 50cm from the top of the block shows significant top-to-the-east movement
- N-S trending, sub-vertical fracture also shows significant movement (eastern sub-block up with respect to western sub-block)

Large Block Test - Mechanical
(continued)

- Thermal perturbations at ~2500 hours were preceded by an acceleration of fracture opening and sliding
- This deformation known to increase fracture permeability, suggesting that mechanical response may have contributed to the thermal-hydrologic behavior

Single Heater Test - Objectives

- Assess the thermomechanical response of TSw2 to a linear heat source
- Enhance our understanding of T-M-H-C processes in an intermediate-scale field test
- Shakedown of instrument performance for the larger, more complex Drift Scale Test

Single Heater Test - Schedule

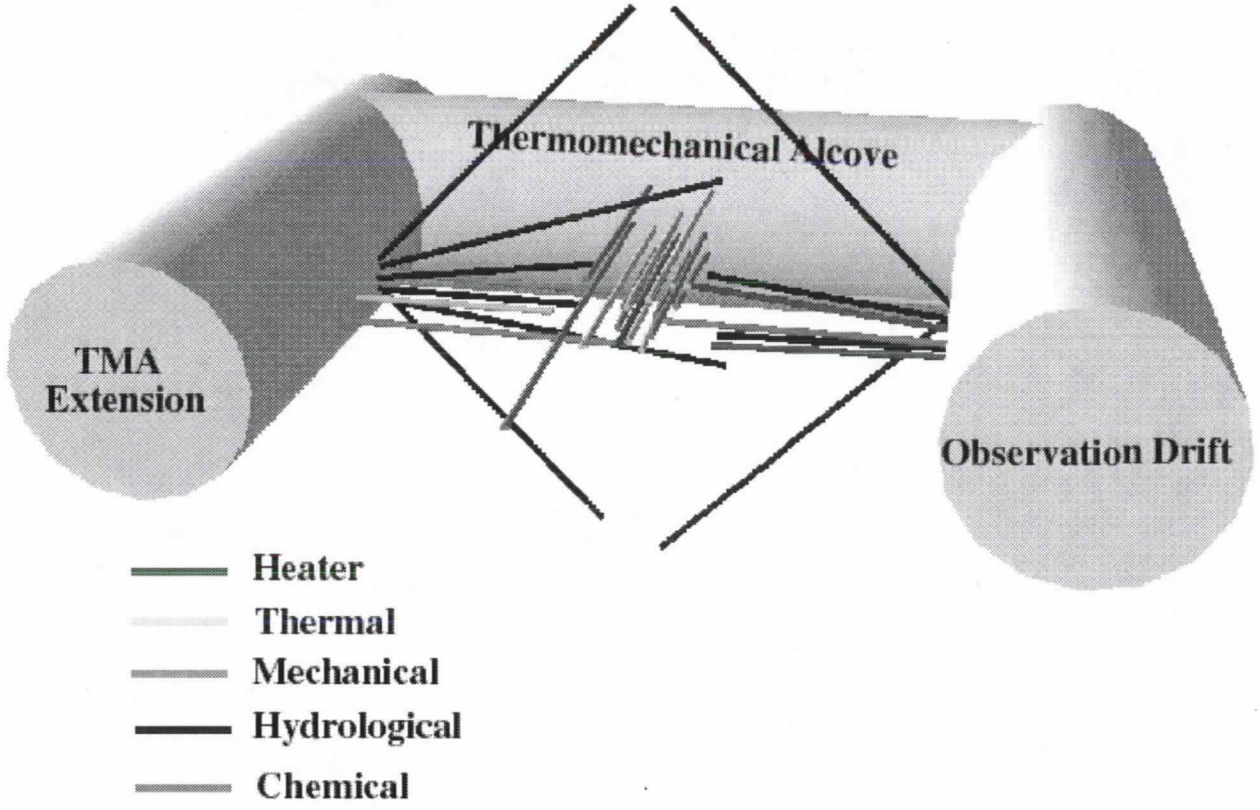
- Cooling phase has ended, though data acquisition system still operating
- Post-test characterization to include:
  - Dry overcoring and additional dry-drilled boreholes - targeting heater borehole and hydrology borehole 16 (water sampling)
  - Air injection and gas tracer testing
  - Goodman Jack testing
  - Rock bolt pull tests

Single Heater Test - Schedule
(continued)

- Post-test characterization to include (cont.):
  - Mineralogy-petrology analyses
  - Laboratory hydrologic properties
  - Evaluation of heater and instrument performance
  - Laboratory thermal-mechanical properties
- Detailed analysis and reporting to be complete by January, 1999

Single Heater Test - Layout

Borehole Perspective

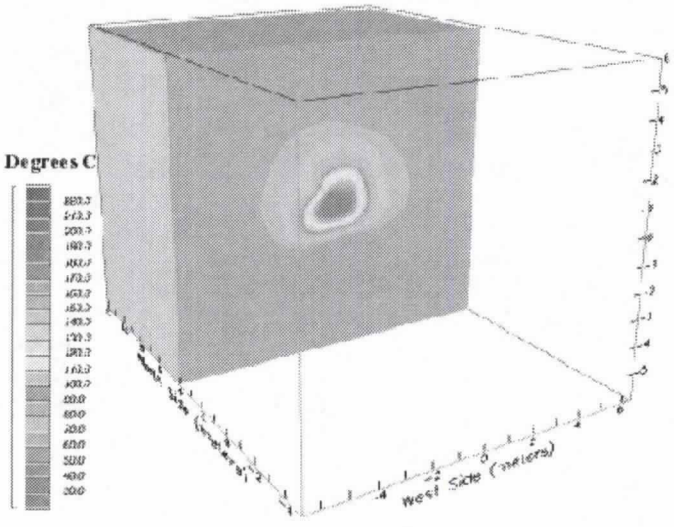


Single Heater Test - Predictions vs. Measurements

- Thermal and mechanical measurements compare well with predictions
- Heat transfer dominated by conduction, but important to incorporate hydrology into model predictions and analyses

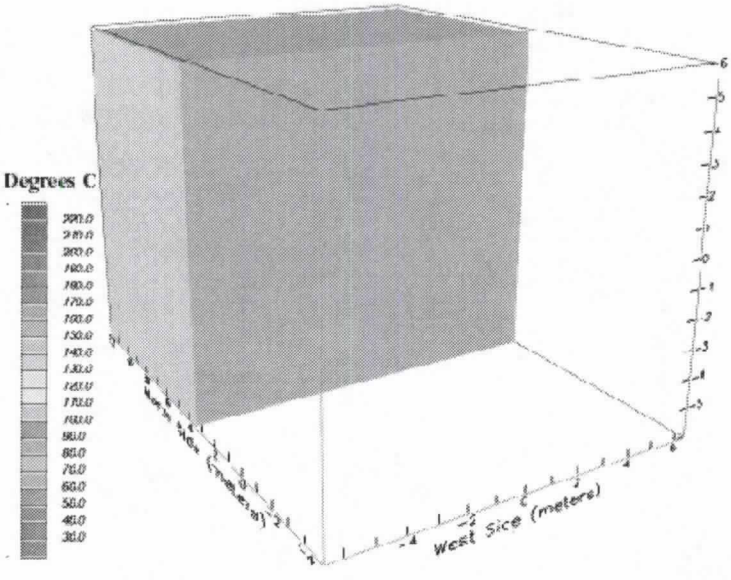
Single Heater Test: Predictions

Perspective Isotherms
Vertical Slice at Heater Midlength



Last Day of Heating (May 28, 1997)

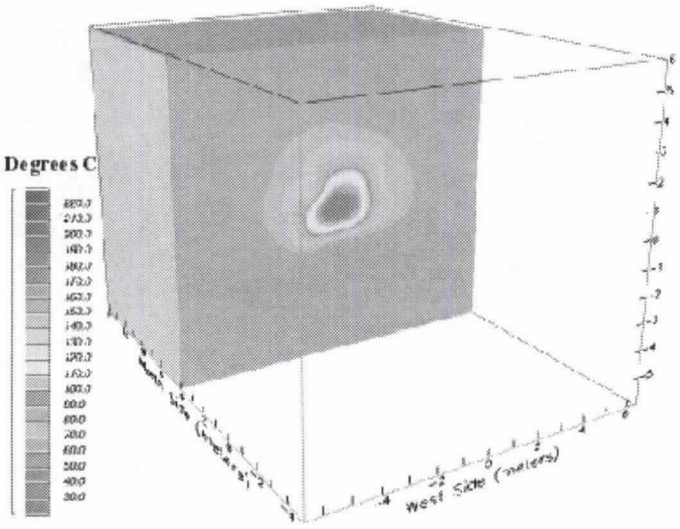
171th Day of Cooling (Nov. 15, 1997)



DRAFT

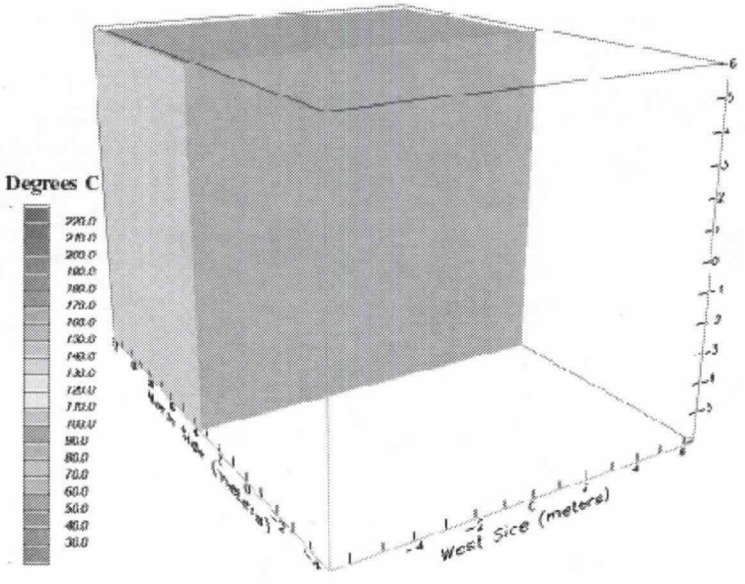
Single Heater Test: Measurements

Perspective Isotherms
Vertical Slice at Heater Midlength



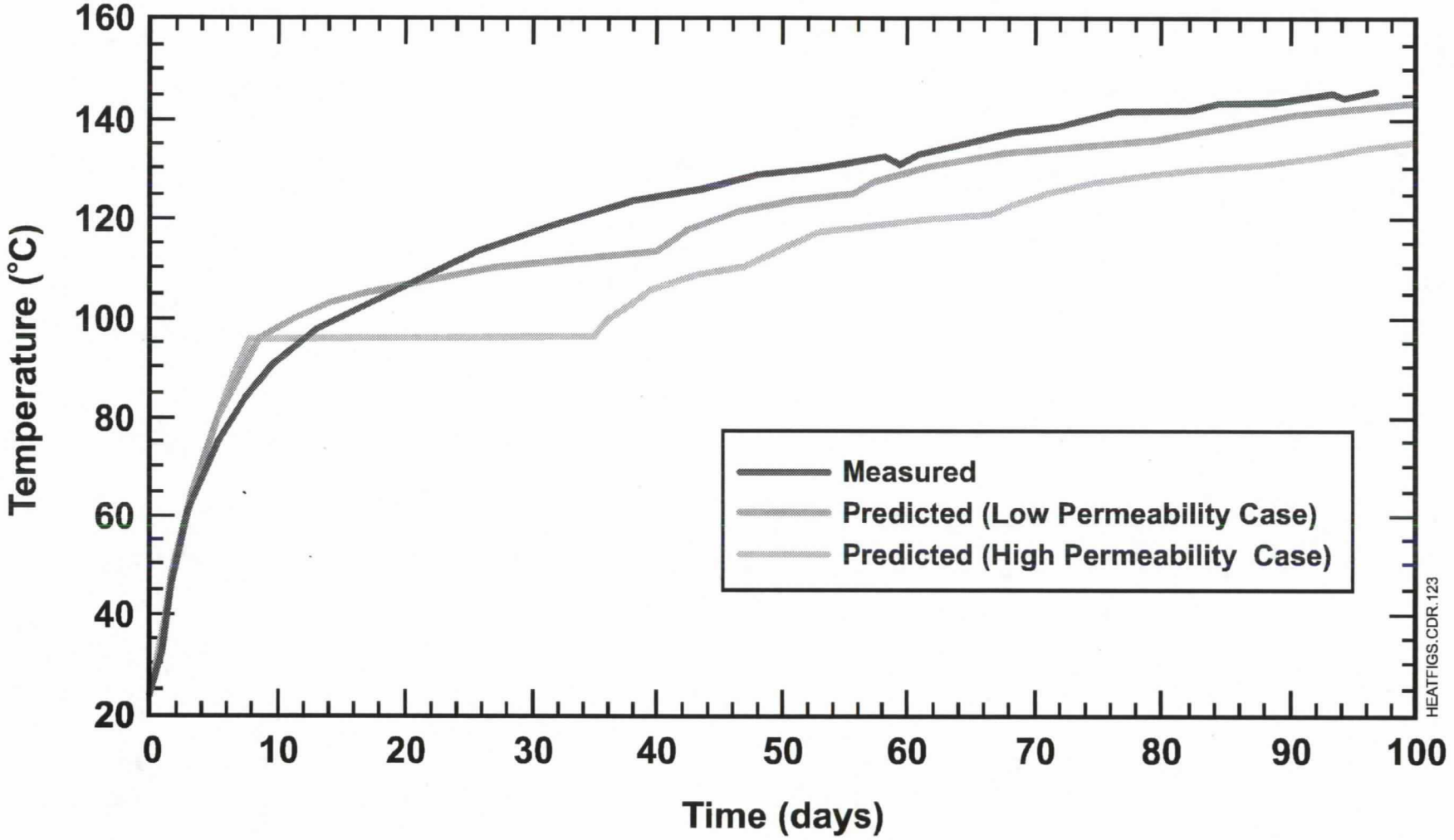
Last Day of Heating (May 28, 1997)

171th Day of Cooling (Nov. 15, 1997)

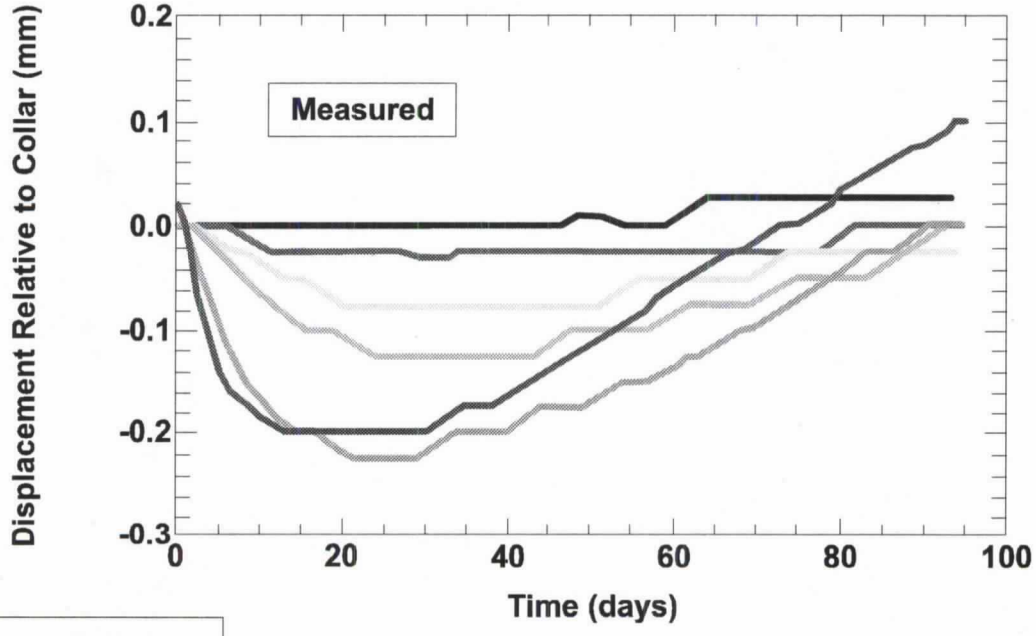


DRAFT

Single Heater Test
Measured and Predicted Temperatures
(TMA-TC-1A-7)

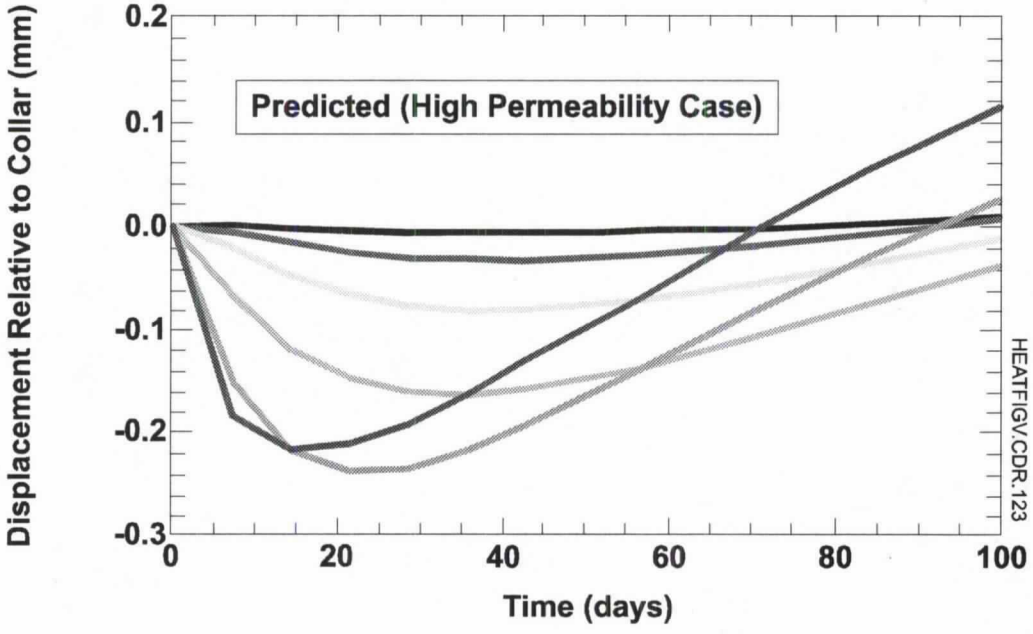


Single Heater Test
Measured and Predicted Displacements
(TMA-MPBX-4)



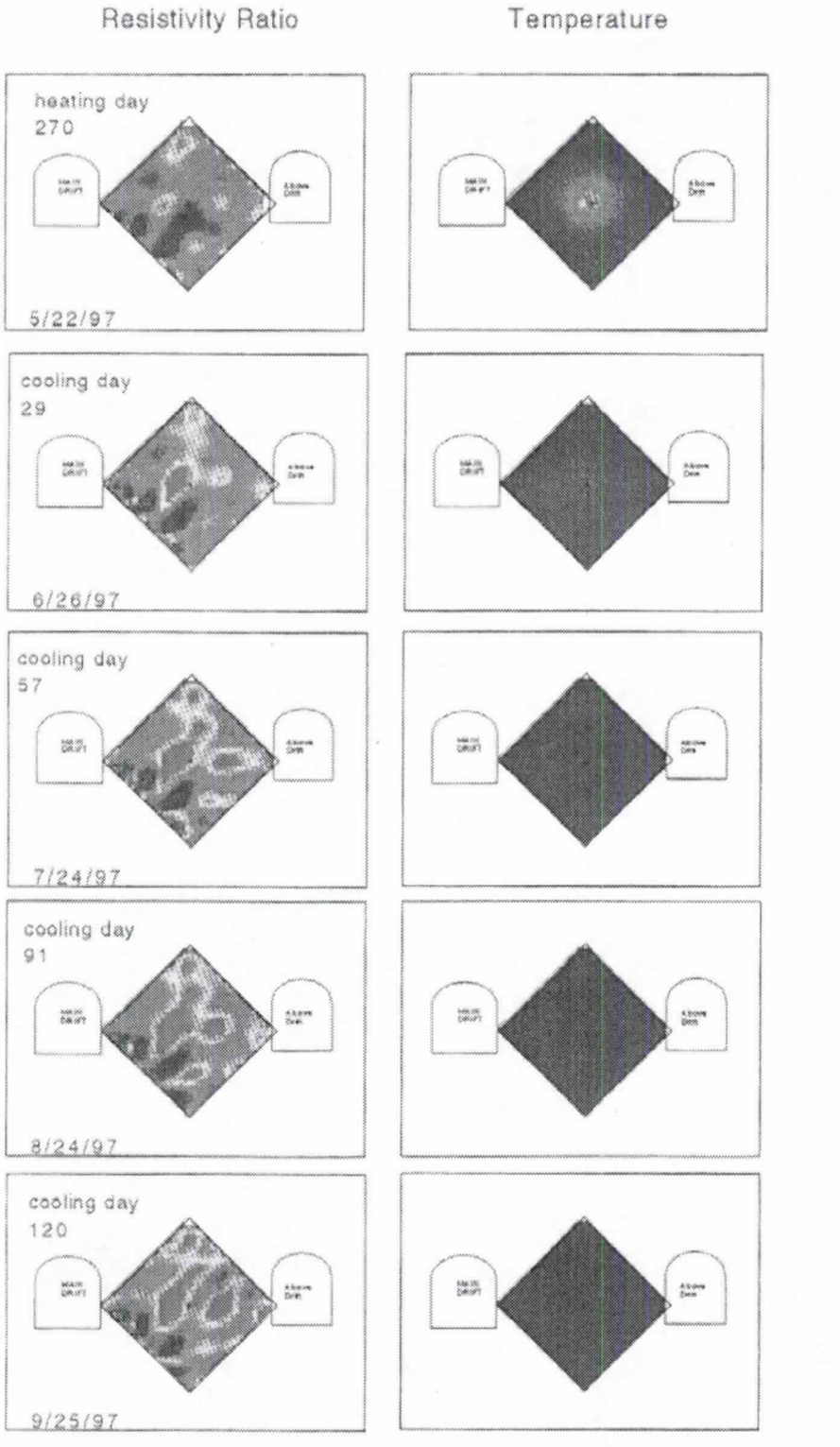
TMA-BX-4-1
TMA-BX-4-2
TMA-BX-4-3
TMA-BX-4-4
TMA-BX-4-5
TMA-BX-4-6

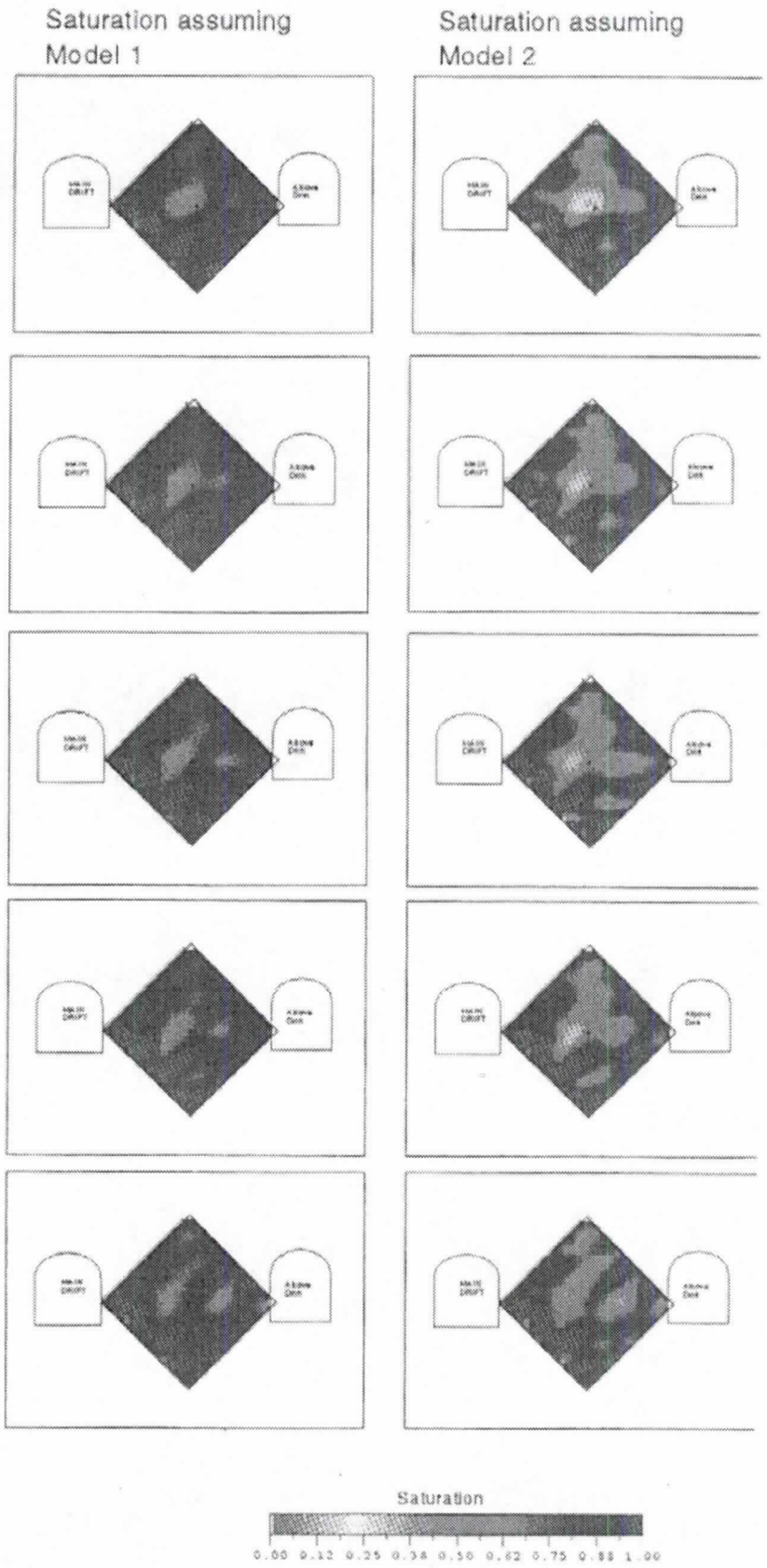
Note: Compression is negative



Single Heater Test - Hydrology

- Significant dryout around heater during heating phase
- Rewetting continues to progress, as seen in Electrical Resistivity Tomography

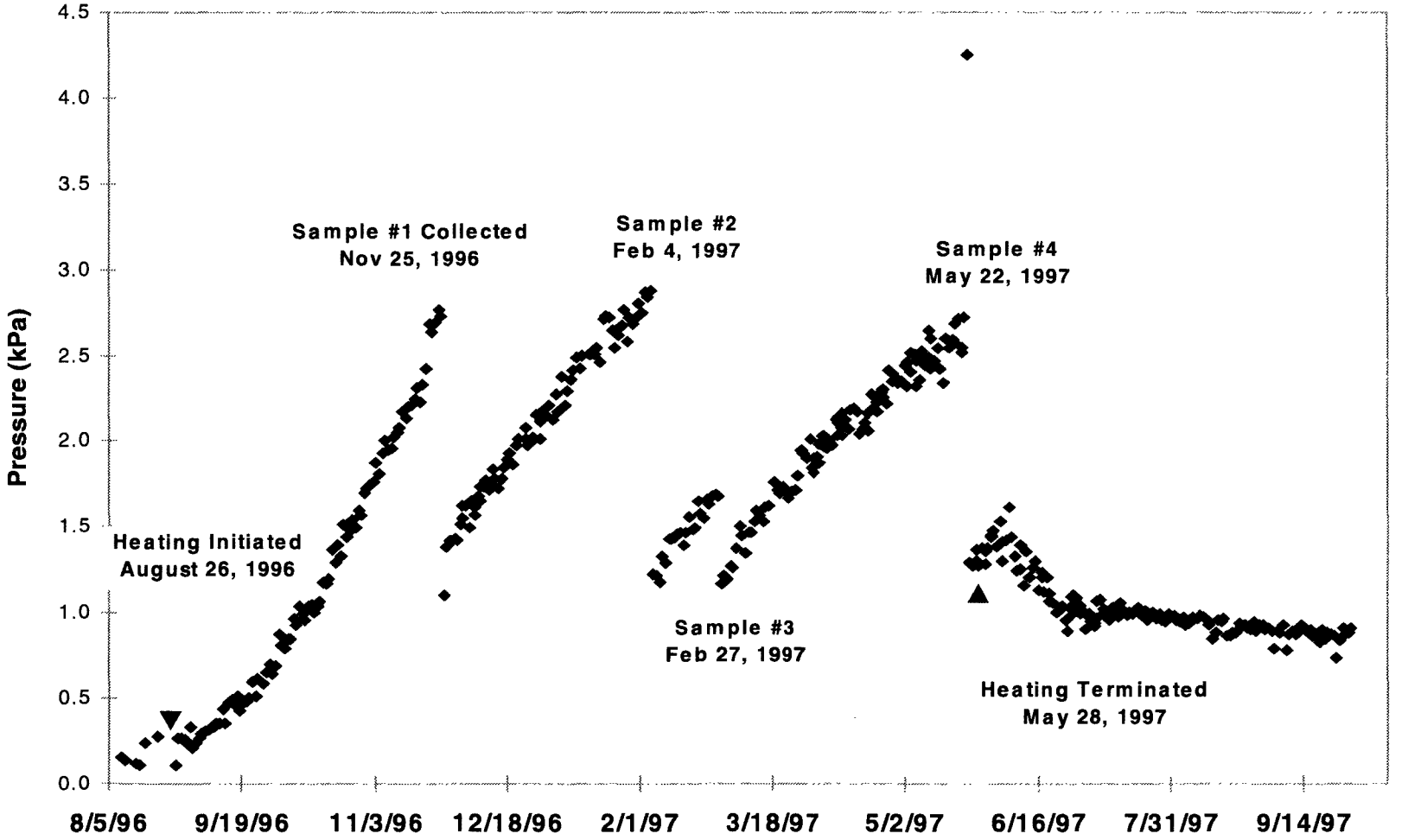

Resistivity Ratio
Temperature
heating day
270
5/22/97
cooling day
29
6/26/97
cooling day
57
7/24/97
cooling day
91
8/24/97
cooling day
120
9/25/97
resistivity ratio
0.2
0.4
0.6
0.8
1.0
1.2
ratios relative to survey prior to heating
Temperature (C)
0
25
50
75
100
125
150
175
200


Saturation assuming
Model 1
Saturation assuming
Model 2
Saturation
0.00 0.12 0.25 0.38 0.50 0.62 0.75 0.88 1.00

Single Heater Test - Hydrology and Geochemistry

- Four water samples collected from Hydrology Borehole 16
- No significant water accumulation after termination of heating phase
- *Insert 16-4 pressure data*
- Water chemistry consistent with condensate origin and interaction with fracture-lining minerals along the flow path. Length-scale of flow path order meters based on reactive transport modeling.

SHT TMA-PRES-16-4



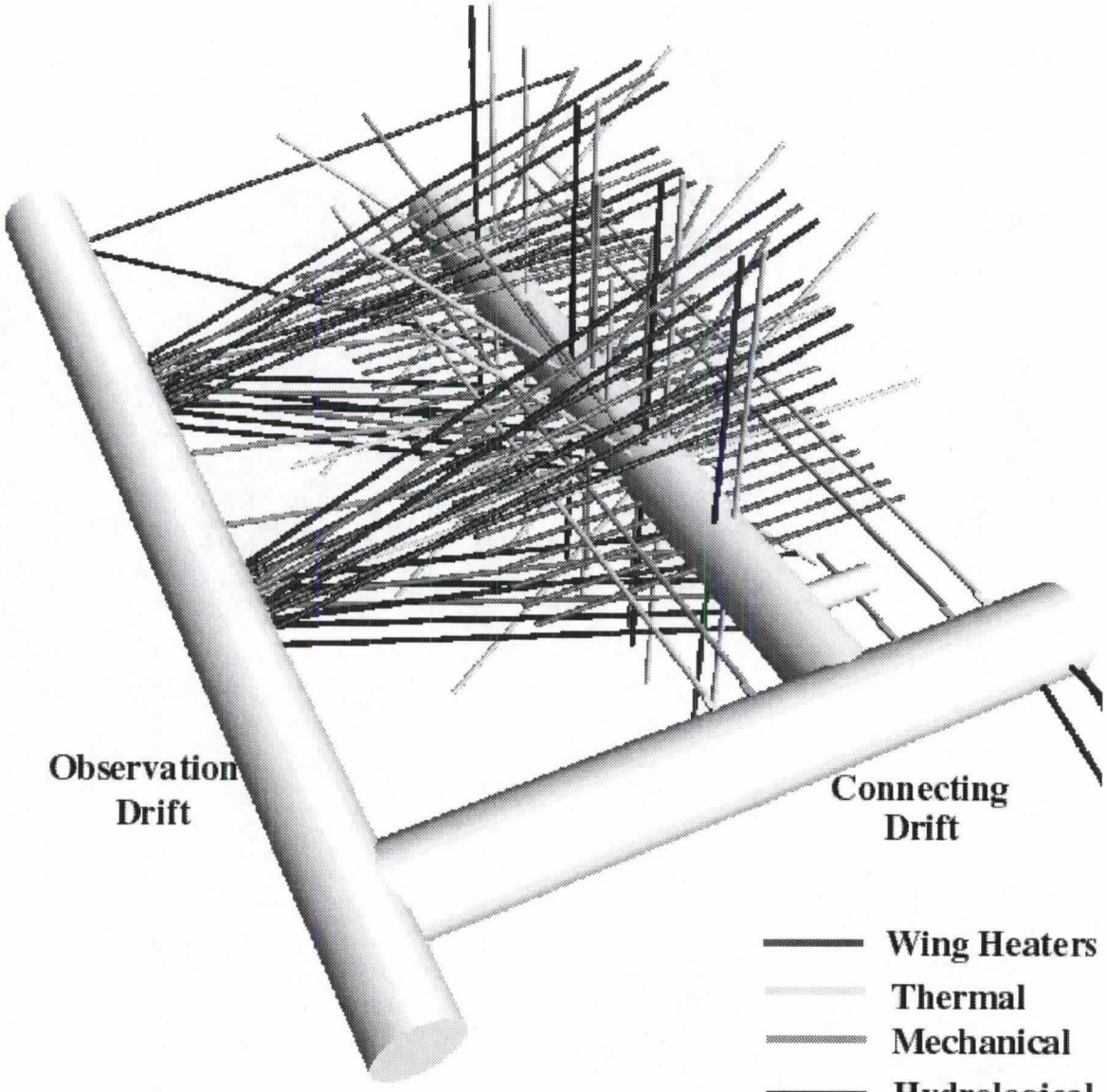
Drift Scale Test - Objectives

- **Predict and measure coupled T-M-H-C processes at the scale of an emplacement drift**
  - **Temperature distribution and heat transfer modes**
  - **Propagation of the drying and re-wetting regions**
  - **Changes in water chemistry and mineralogy**
  - **Thermal expansion and deformation modulus**

Drift Scale Test - Schedule

- Heating phase initiated on December 3, 1997
- Current plan calls for 4-year heating phase
- Data collection and analysis ongoing with reporting on an annual basis starting in September, 1998

Drift Scale Test
Borehole Perspective



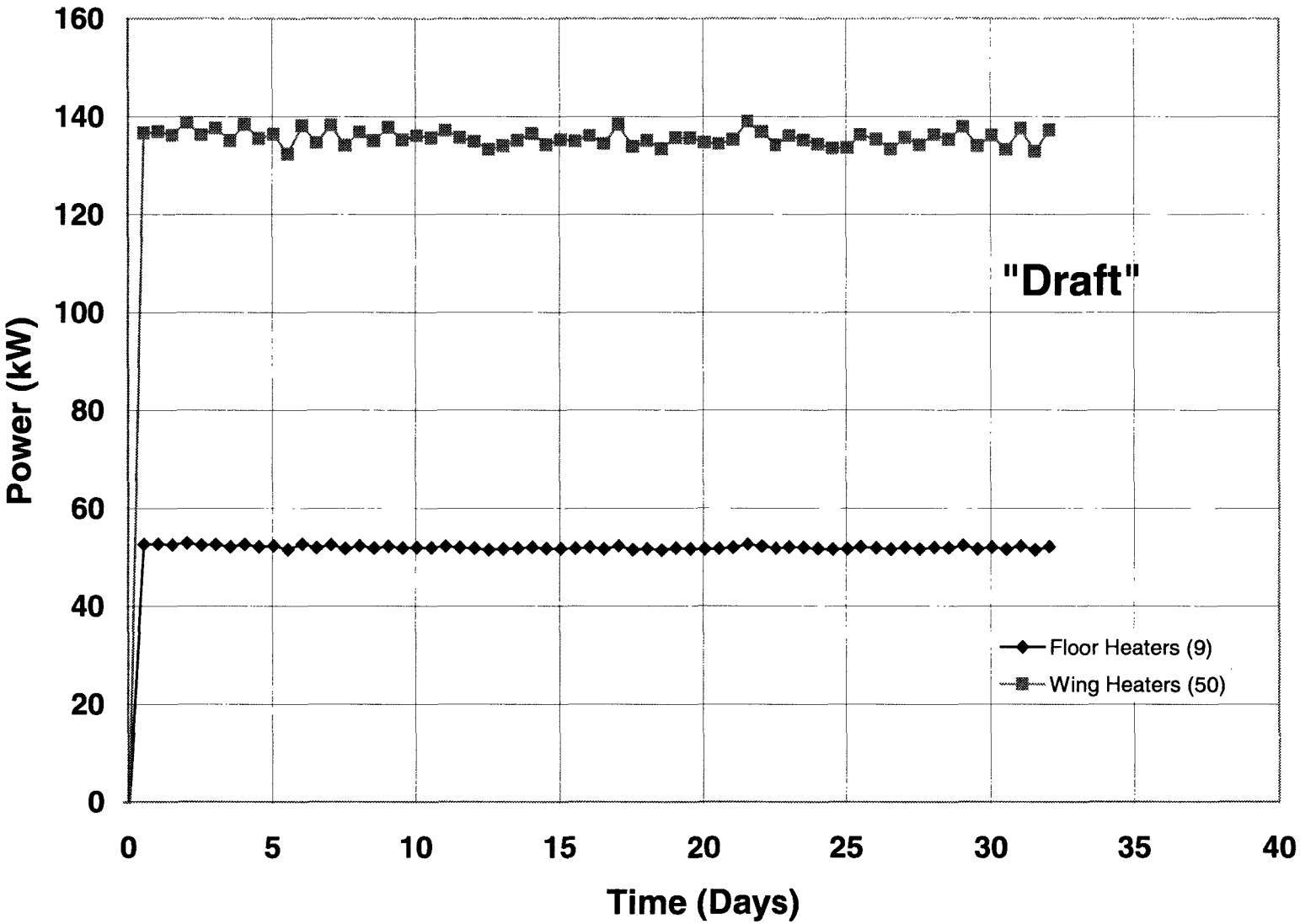
Drift Scale Test - Early Observations

- Pre-heating baseline and initial heating phase measurements have been recorded properly and indicate anticipated behavior
- Heaters, instruments, and Data Collection System operating as expected
- Thermal perturbation of test bed is well within the spatial distribution of the sensors

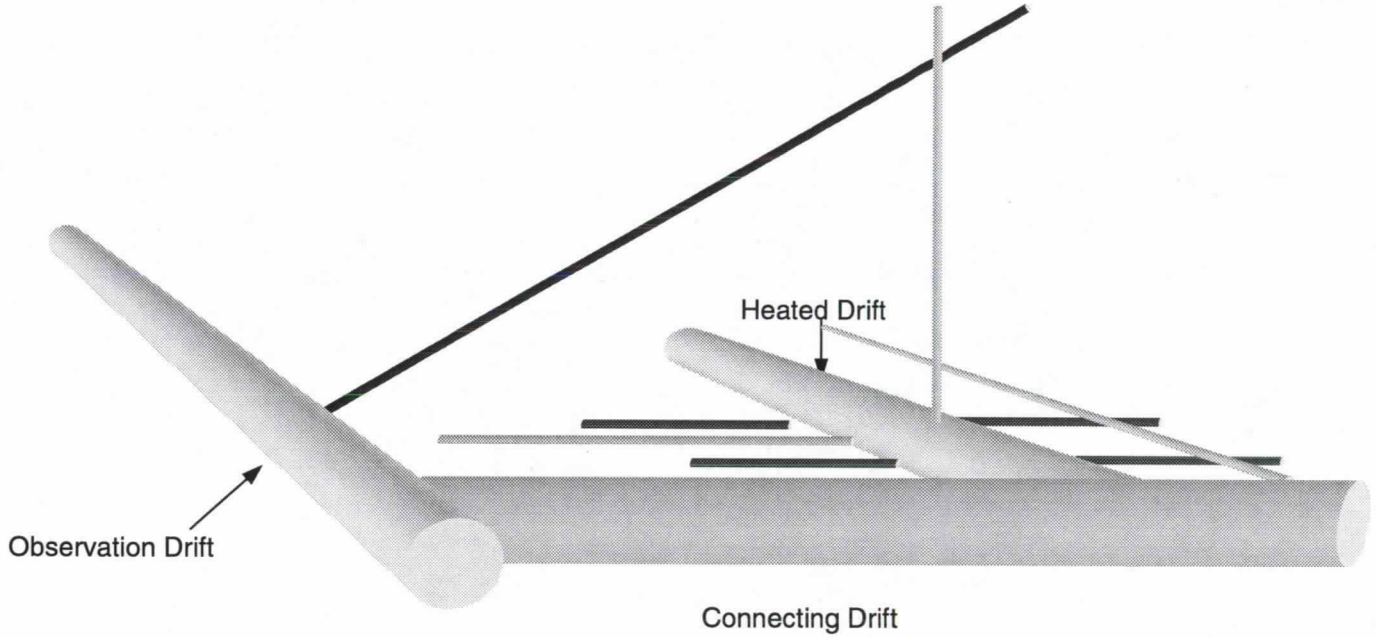
Drift Scale Test - Early Observations
(continued)

- Temperatures range from ambient to 75°C and 82°C in the surface and air of the Heated Drift, respectively
- No water accumulation apparent in the packed-off zones of the hydrology boreholes

Drift Scale Test - Power



Drift Scale Test - Detailed Layout

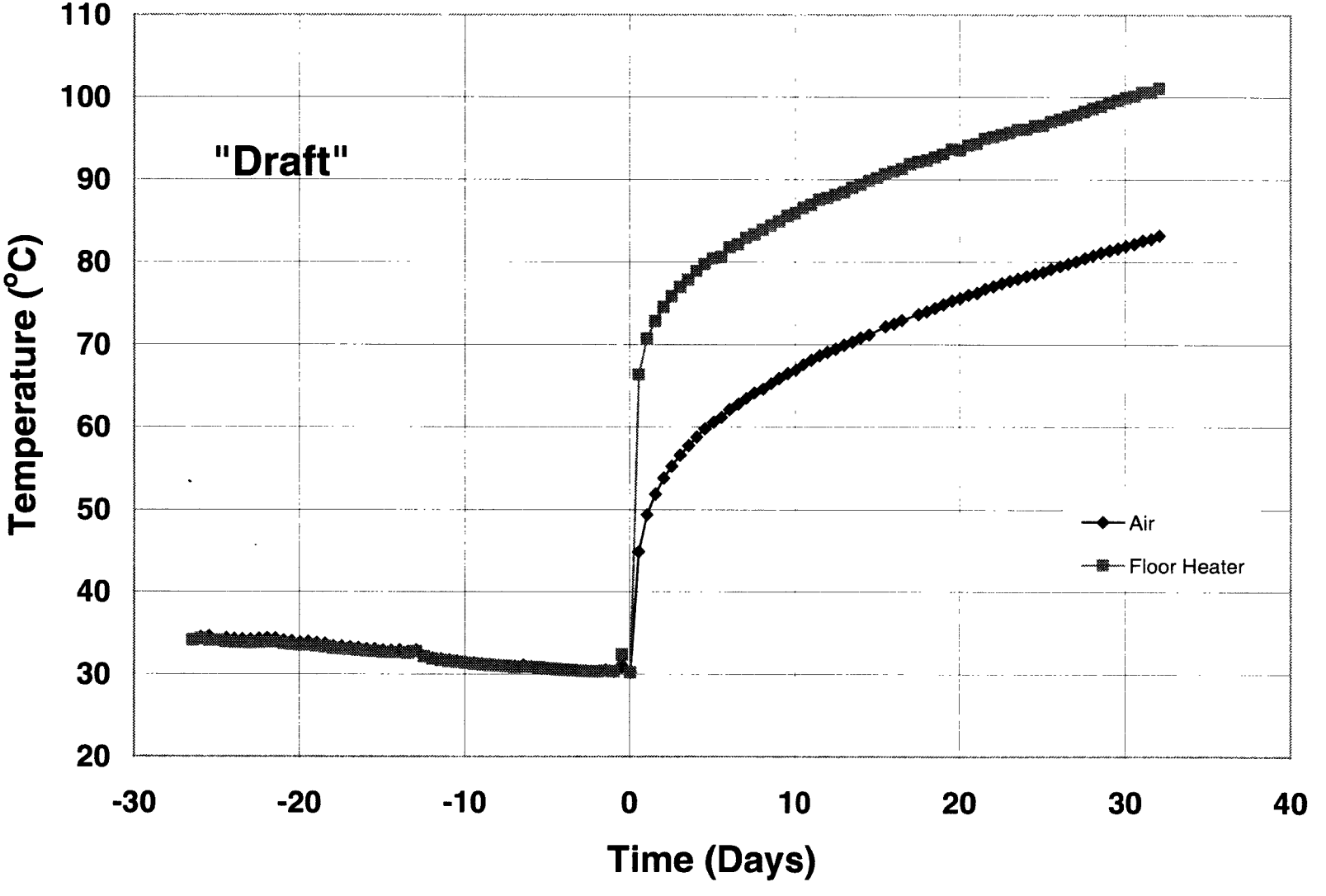


Legend:

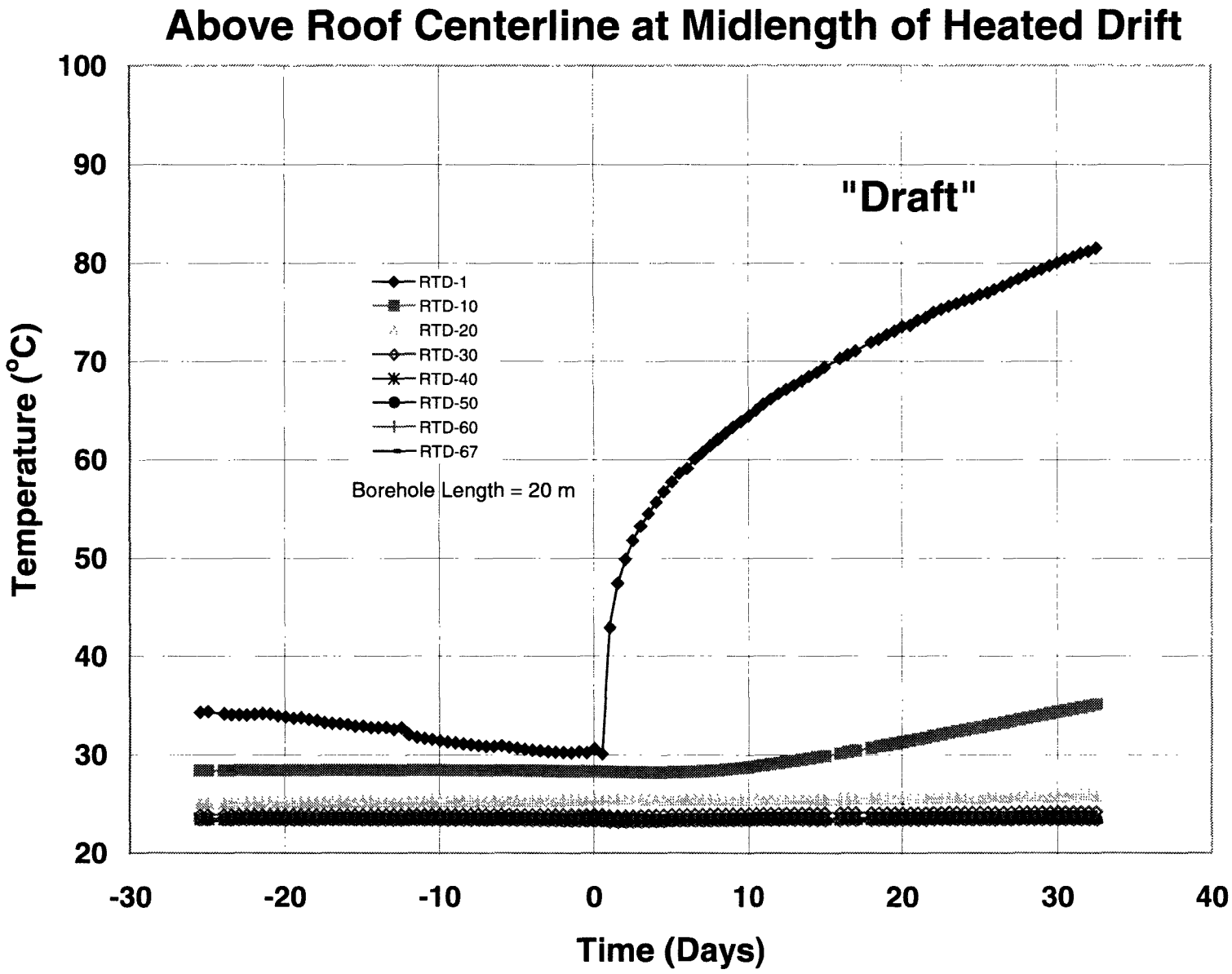
- Wing Heater
- Thermal
- Hydrological

Drift Scale Test - Thermal

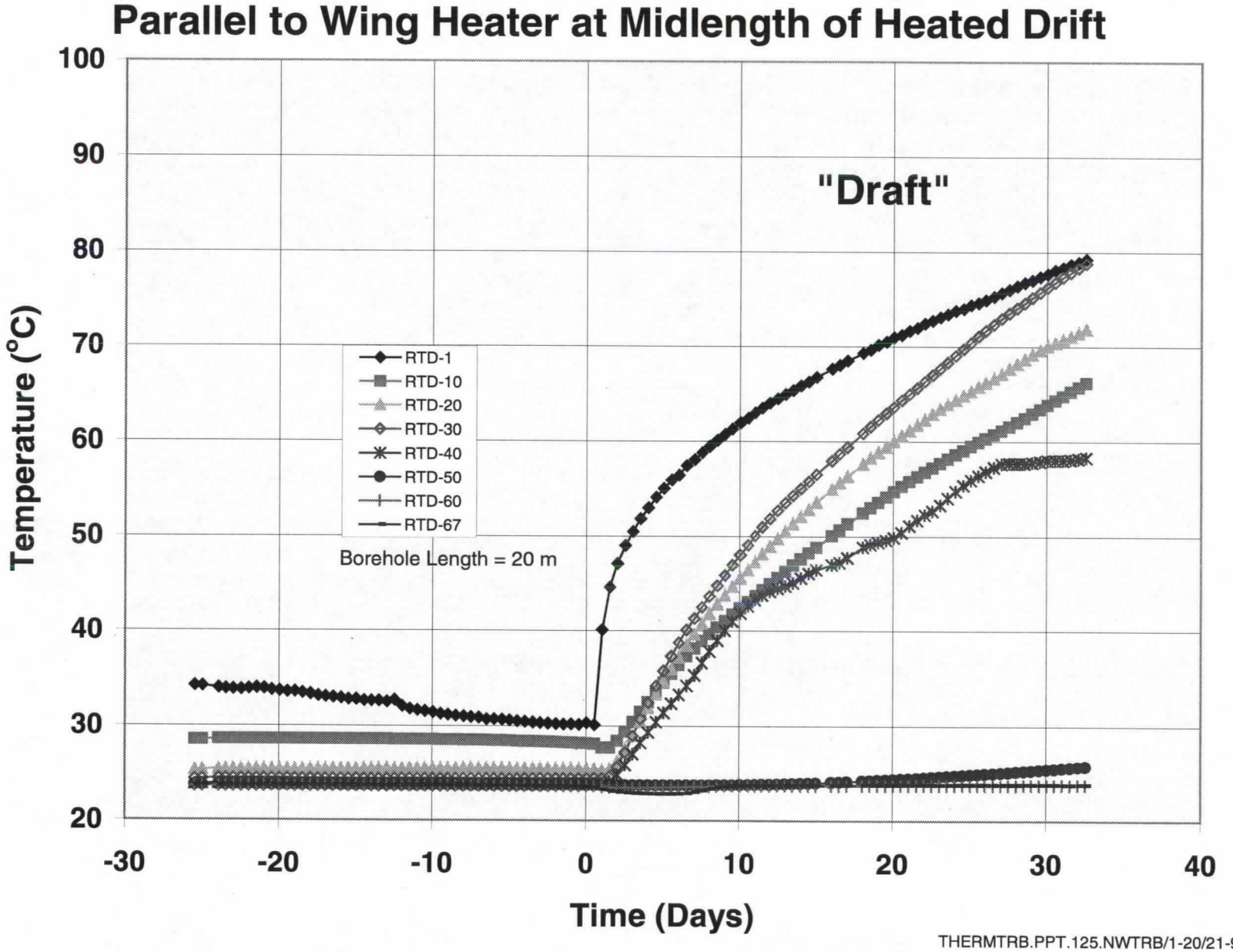
Representative Temperatures for Floor Heaters and Air



Drift Scale Test - Thermal

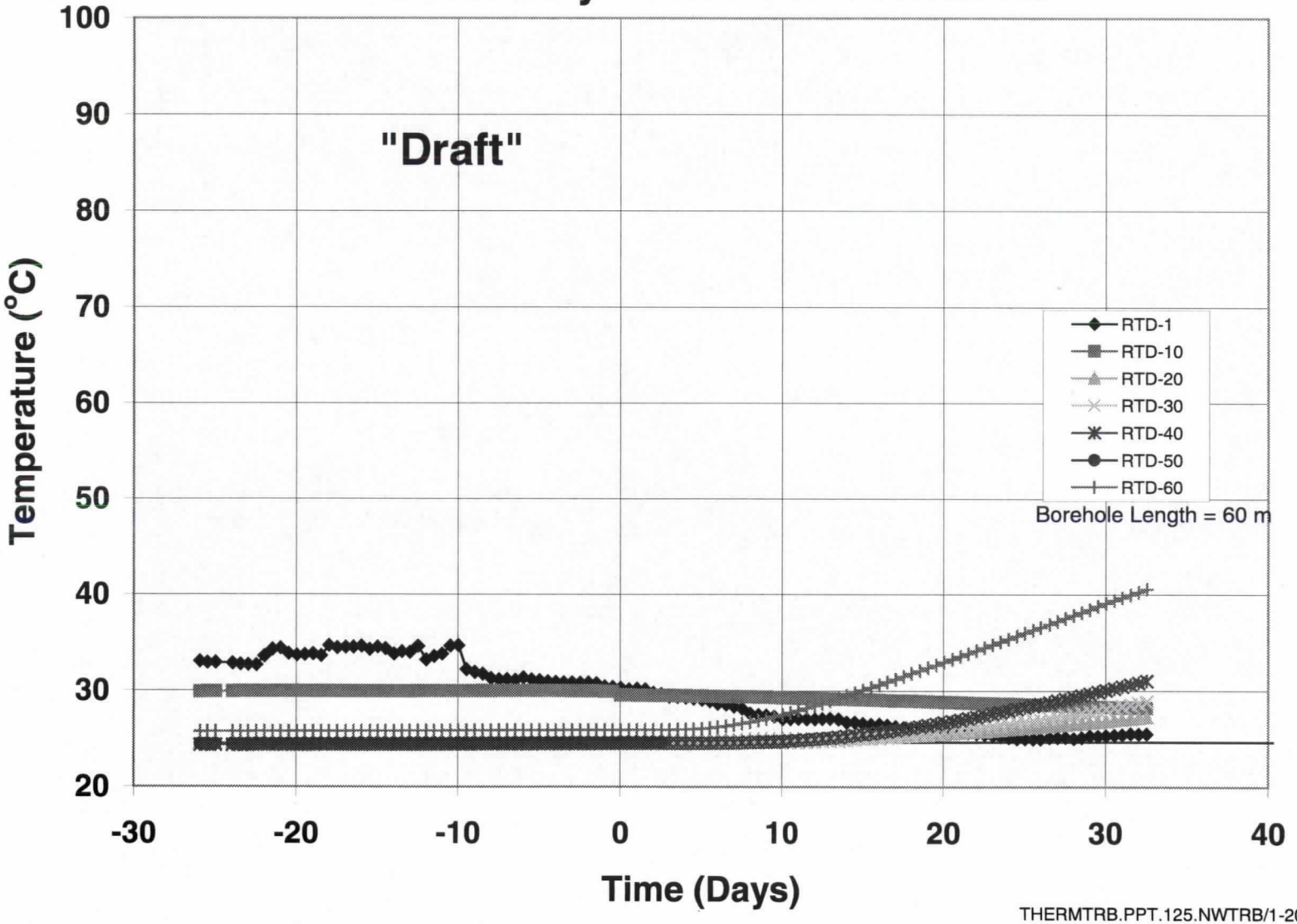


Drift Scale Test - Thermal



Drift Scale Test - Thermal

Longitudinal Axis of Heated Drift Approximately 10 m Horizontally from Roof Centerline



Drift Scale Test - Thermal