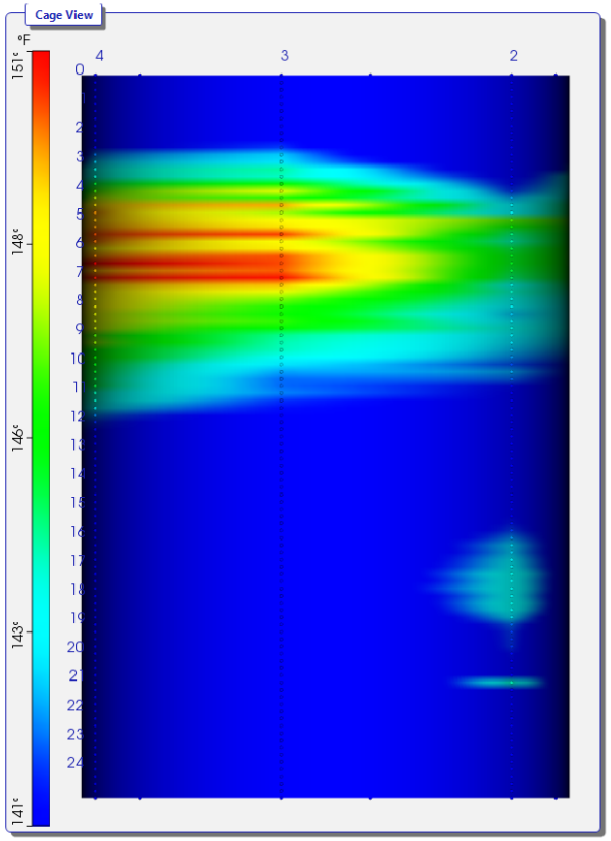
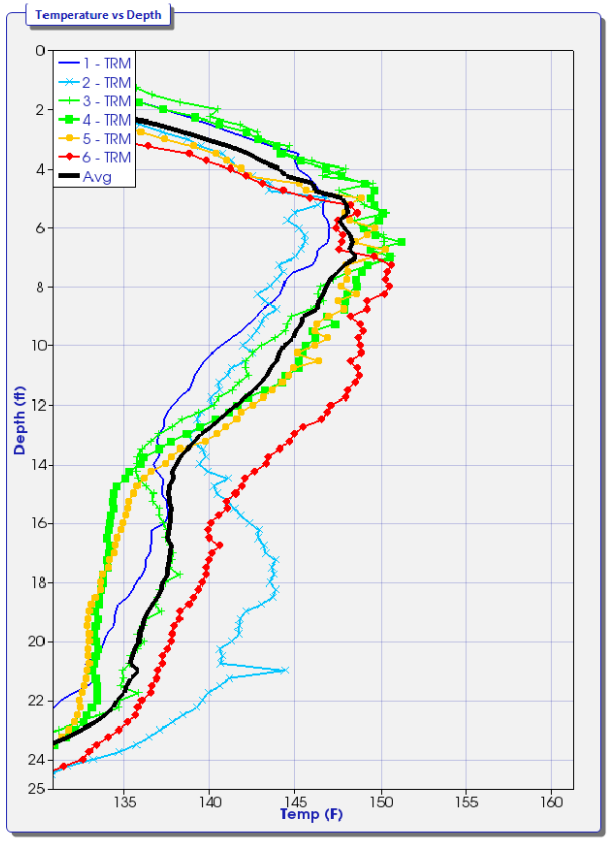
Thermal Integrity Testing of Foundations





Juan F. Castellanos, P.E.,
FDOT State Construction Geotechnical Engineer

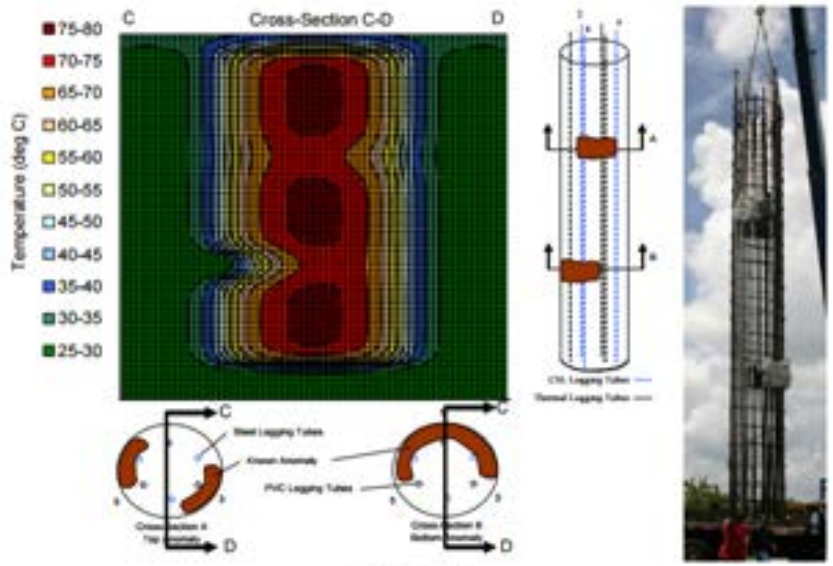
THERMAL INTEGRITY TESTING OF DRILLED SHAFTS - FINAL REPORT

Principal Investigators:
Gray Mullins, Ph.D., P.E. and Stan Kranc, Ph.D., P.E.

Graduate Researchers:
Kevin Johnson, Michael Stokes, and Danny Winters

Prepared for:

© Florida Department of Transportation



MAY 2007
FDOT GRANT #BD544-20

USF UNIVERSITY OF SOUTH FLORIDA
Civil & Environmental Engineering

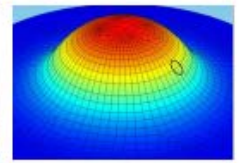
OPTIMIZING THE USE OF THE THERMAL INTEGRITY SYSTEM FOR EVALUATING AUGER-CAST PILES

BDV25 TWO977-09

DRAFT FINAL REPORT

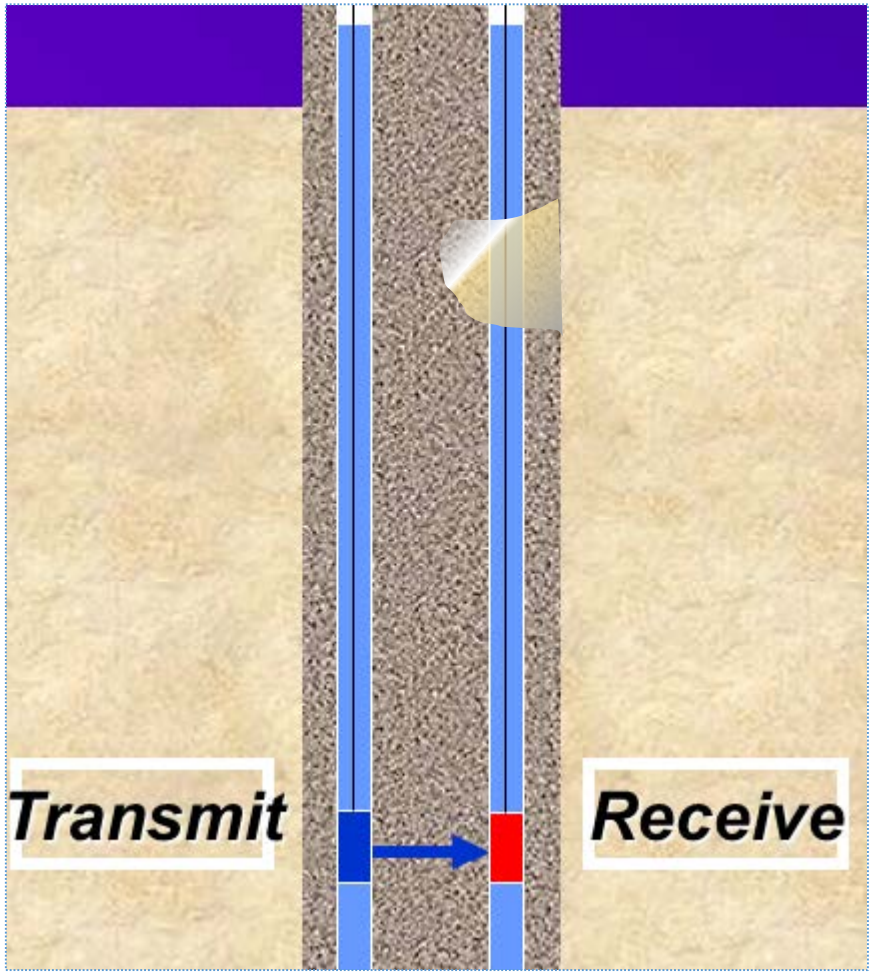
Gray Mullins, Ph.D., P.E.
Principal Investigator
And
Kevin Johnson, MCE, E.I.
Doctoral Candidate

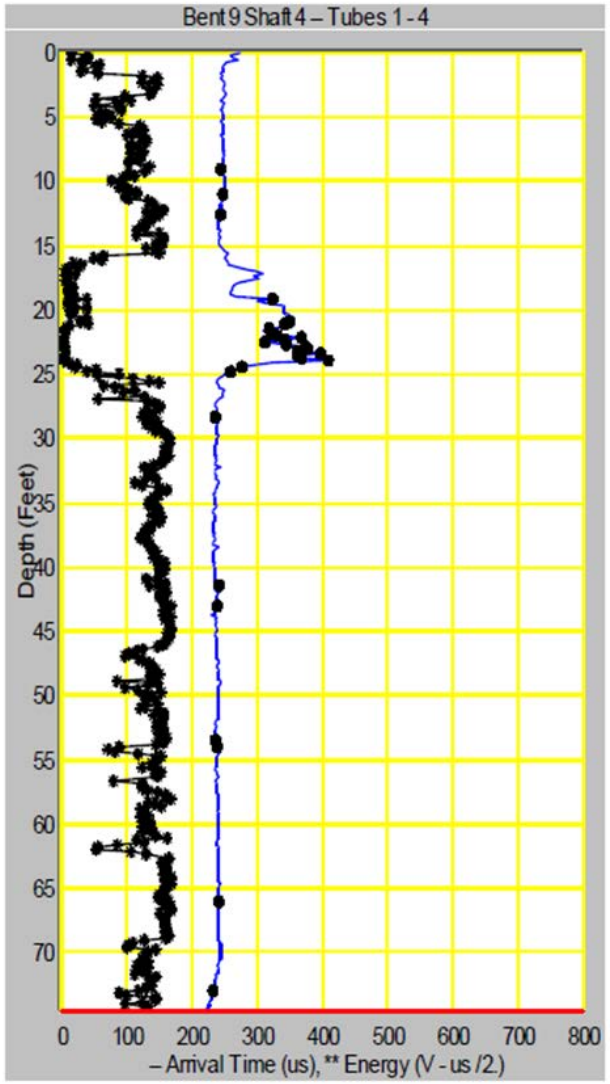
FDOT



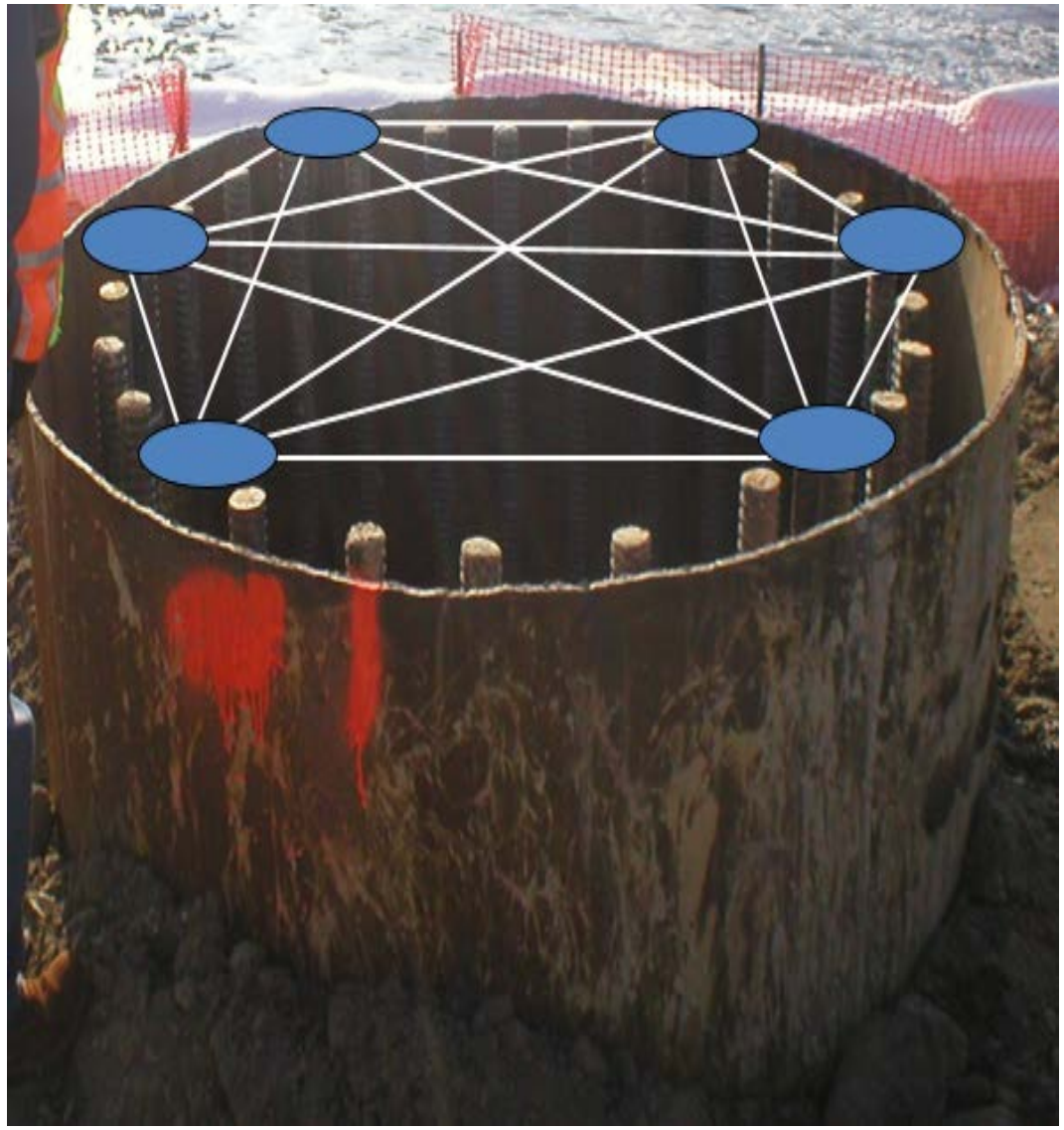
June 2016

Cross Sonic Logging (CSL) testing

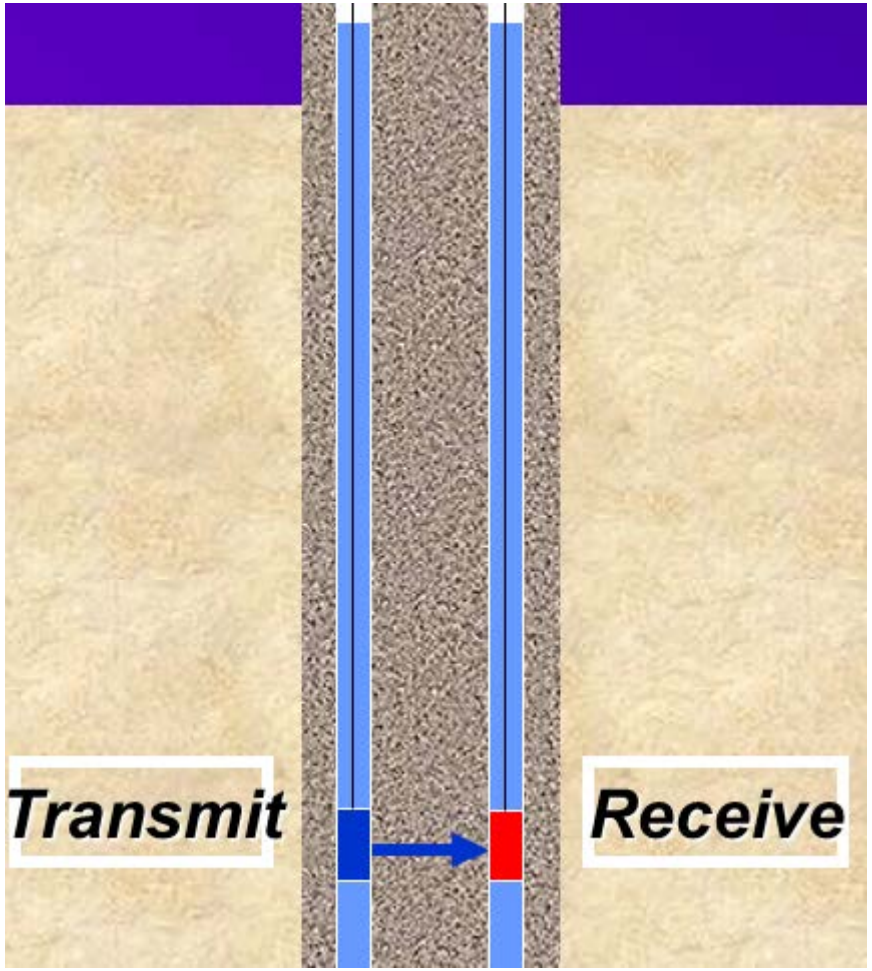




CSL testing

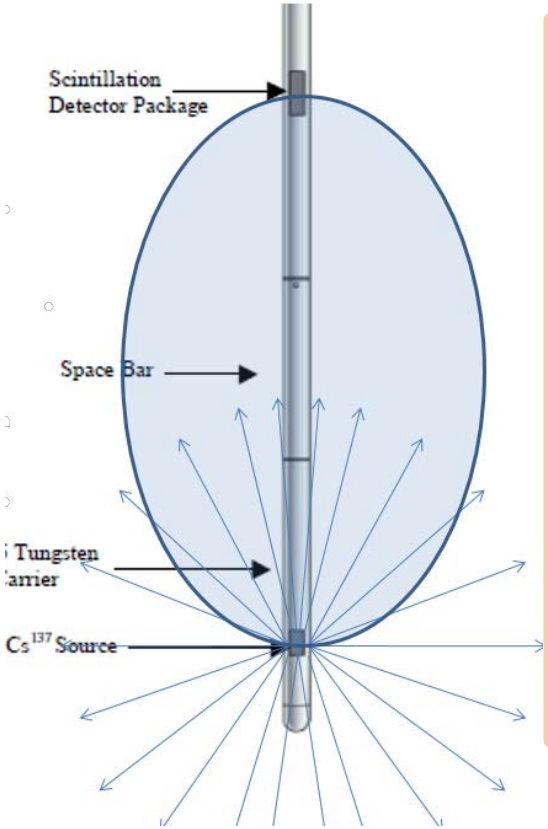


- Information inside tubes perimeter only.
- Debonding and bleeding issues.
- Steel tubes preferred

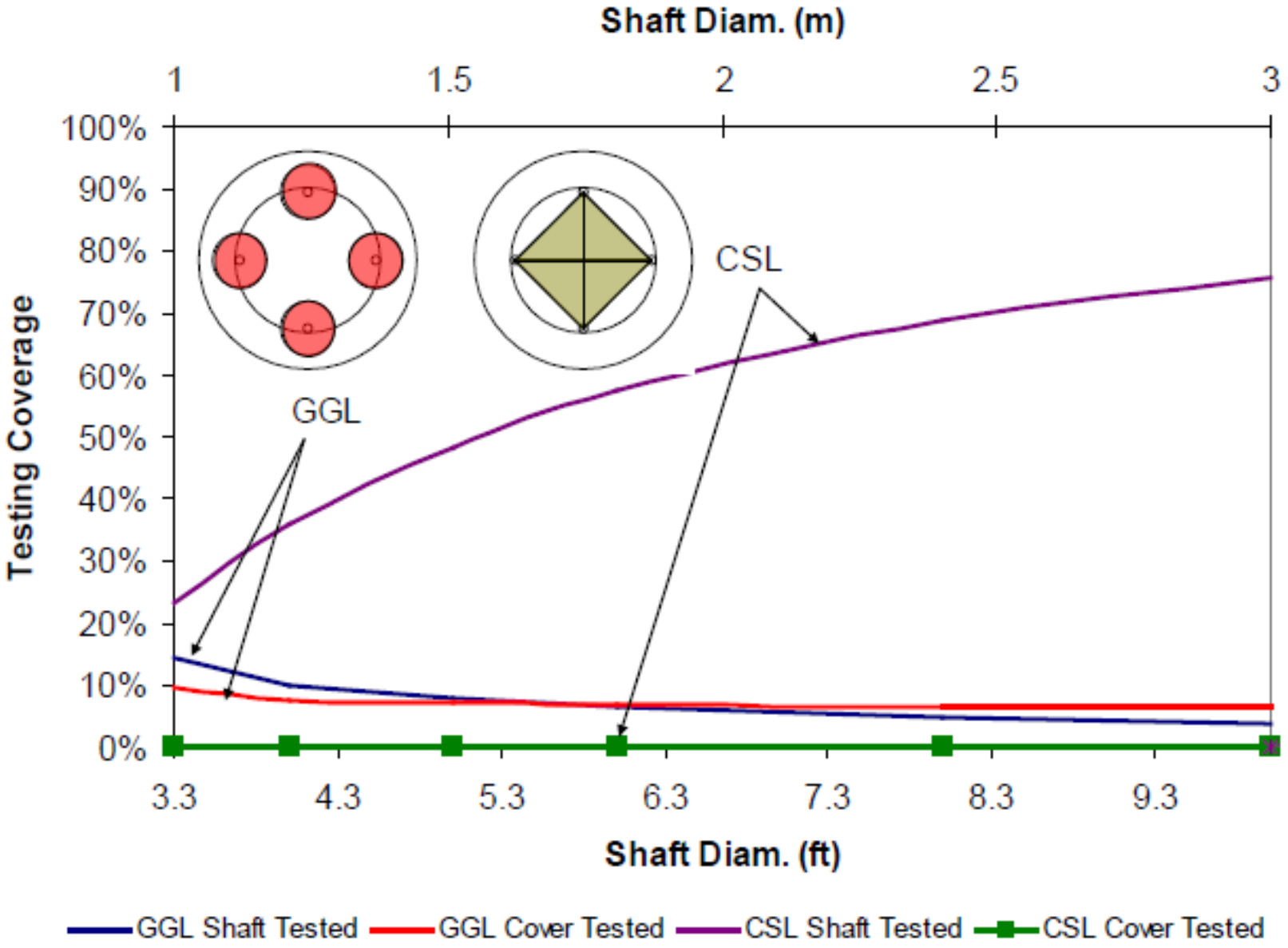


Gamma- Gamma Logging

- Needs PVC access tubes (100 mm range)
- Local cover information
- Uses radioactive materials (Cessium 137)
- Probe must be retrieved
- Long probe vs. bent PVC tubes



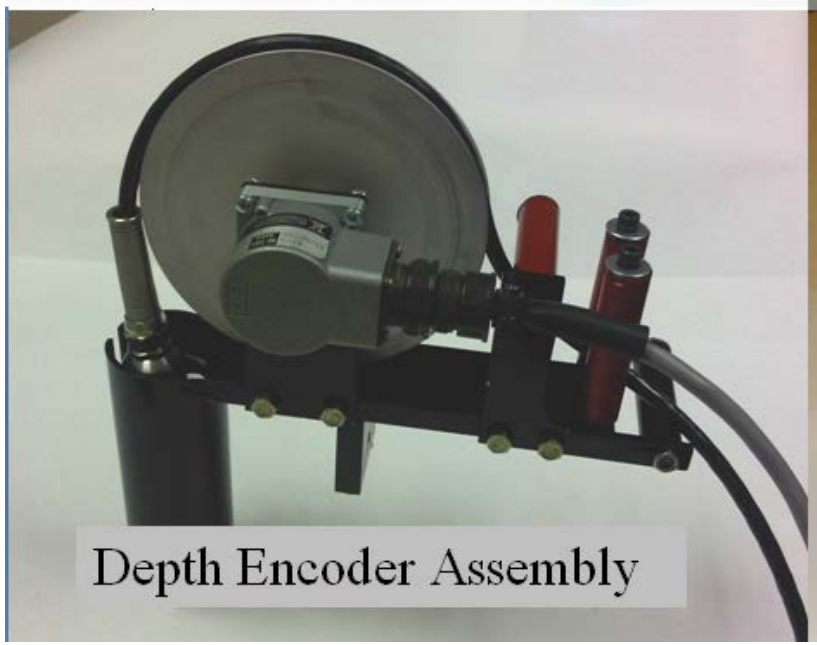
Coverage by GGL and CSL

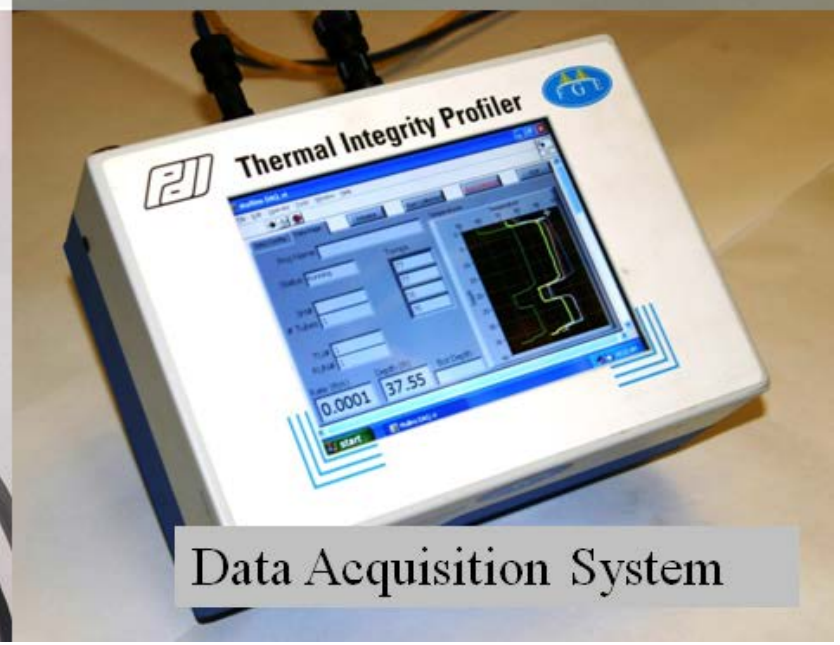


What does Thermal Integrity Testing show:

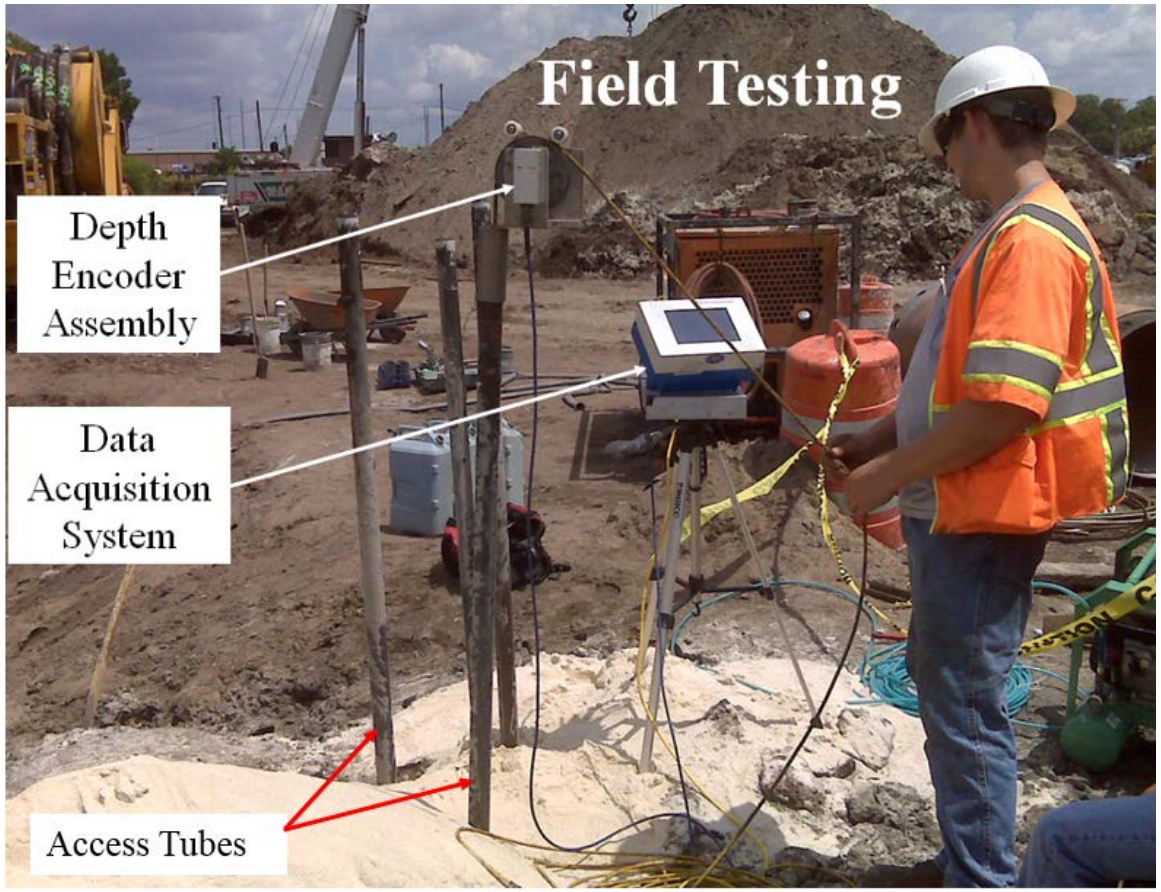
- Tests the entire volume of concrete (100%)
- Cage alignment
- Radius vs. Depth-Estimated shaft shape
- Necks, bulges, or inclusions
- Concrete cover
- Quality of concrete

Thermal Integrity Testing



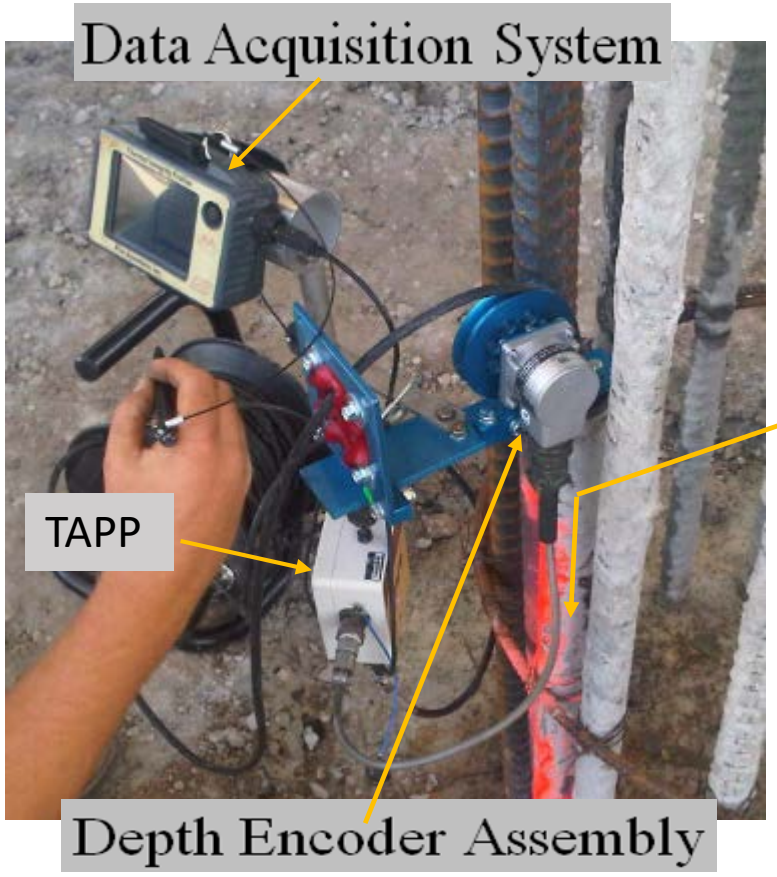


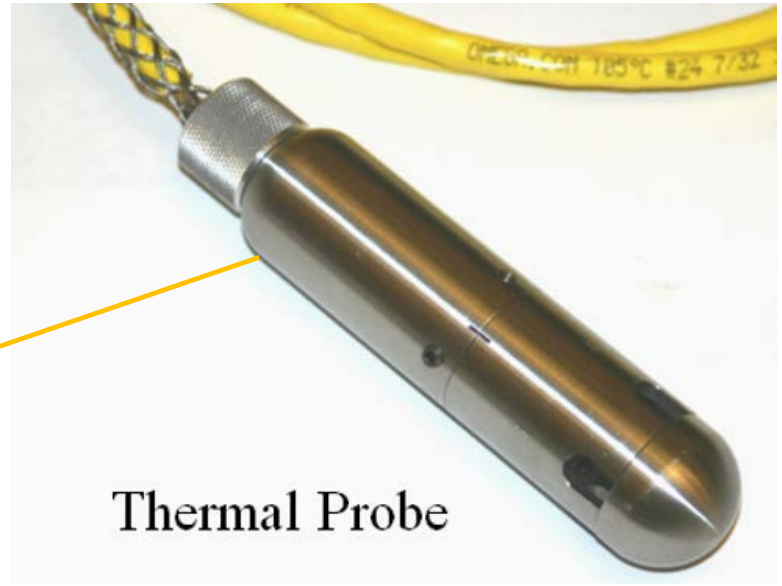
Thermal Integrity Testing



ASTM D7949 - 14

Standard Test Methods for Thermal Integrity Profiling of Concrete Deep Foundations

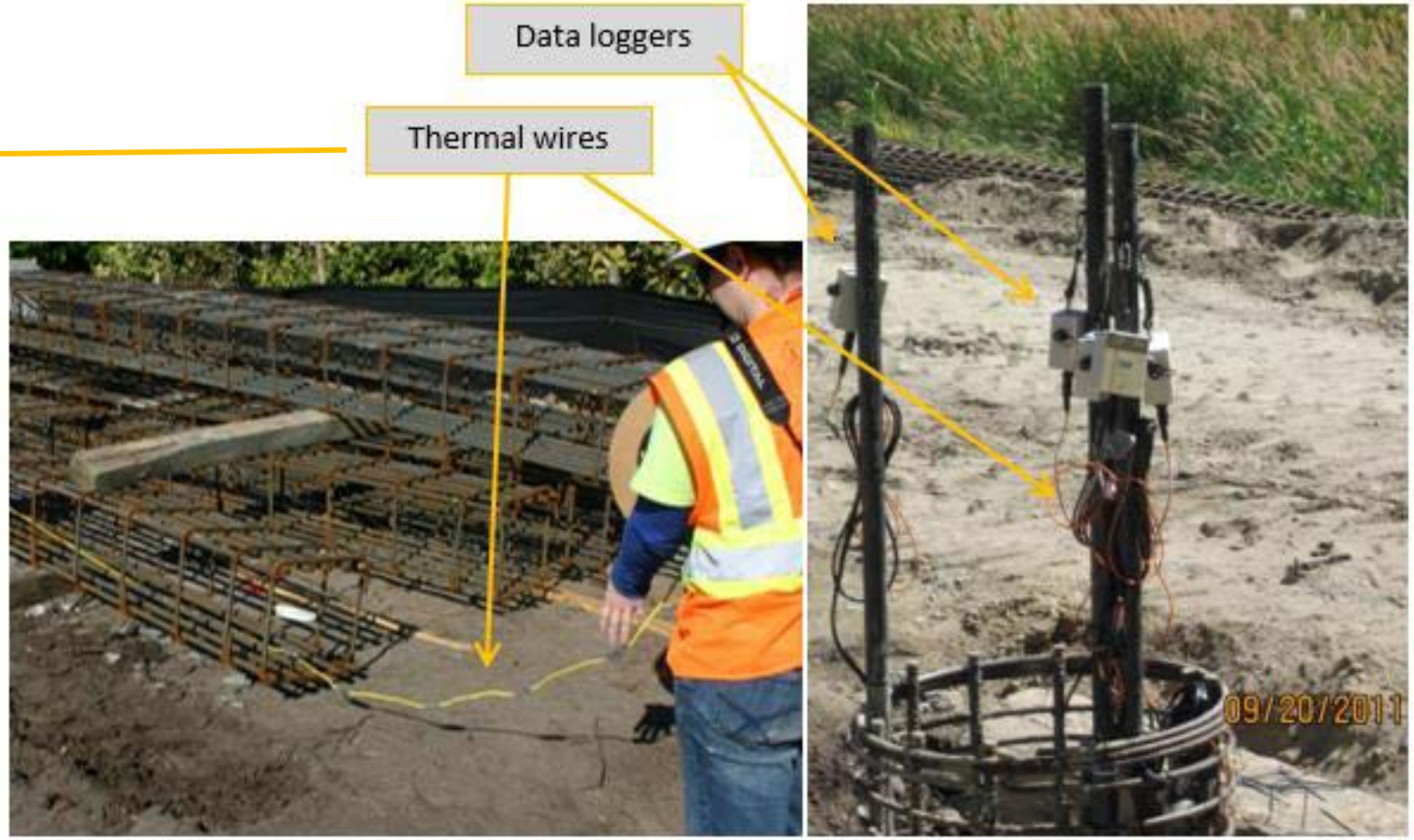




Method A - Uses Probes through Access Tubes

ASTM D7949 - 14

Standard Test Methods for Thermal Integrity Profiling of Concrete Deep Foundations



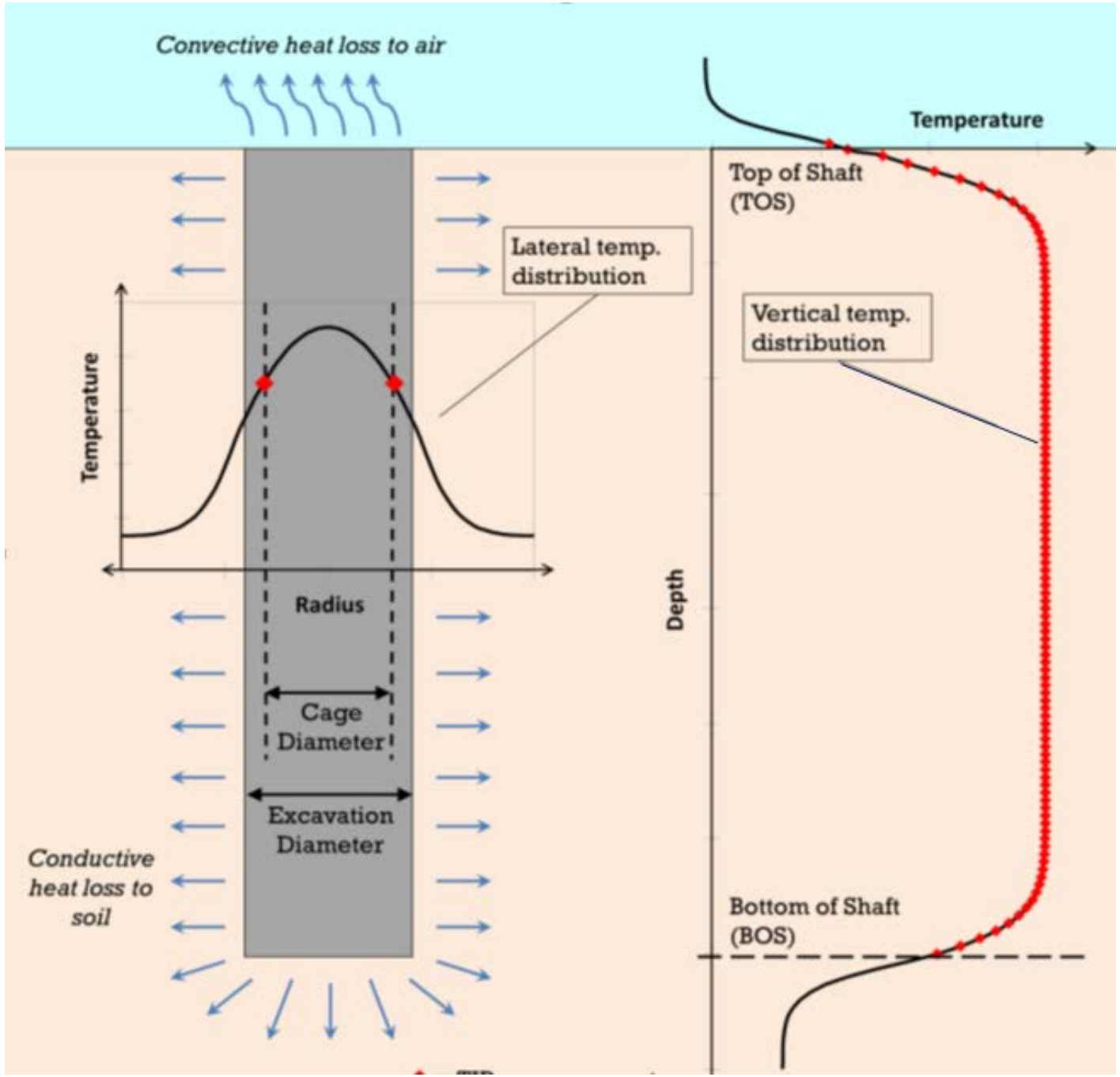
Method B - Uses Embedded wires attached to reinforcement cage

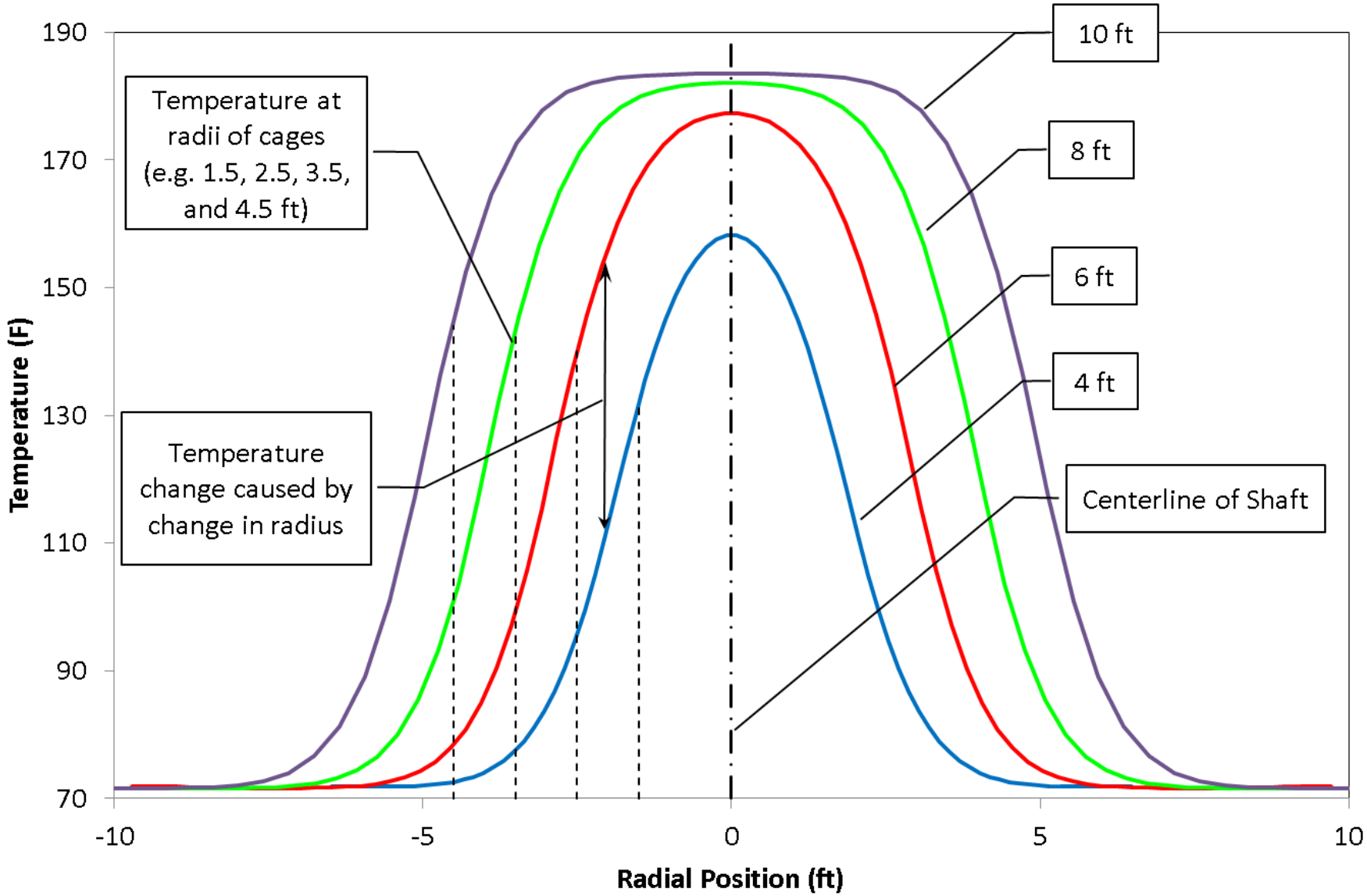
Thermal Integrity Testing

- It may be used on both Drilled Shafts and Auger Cast Piles
- Does not have debonding or bleeding issues (as CSL)
  - No false alarms
- It could work in PVC and steel tubes and in embedded wires in concrete
  - Access tubes not necessary

Limitation: Test window limited to few days.

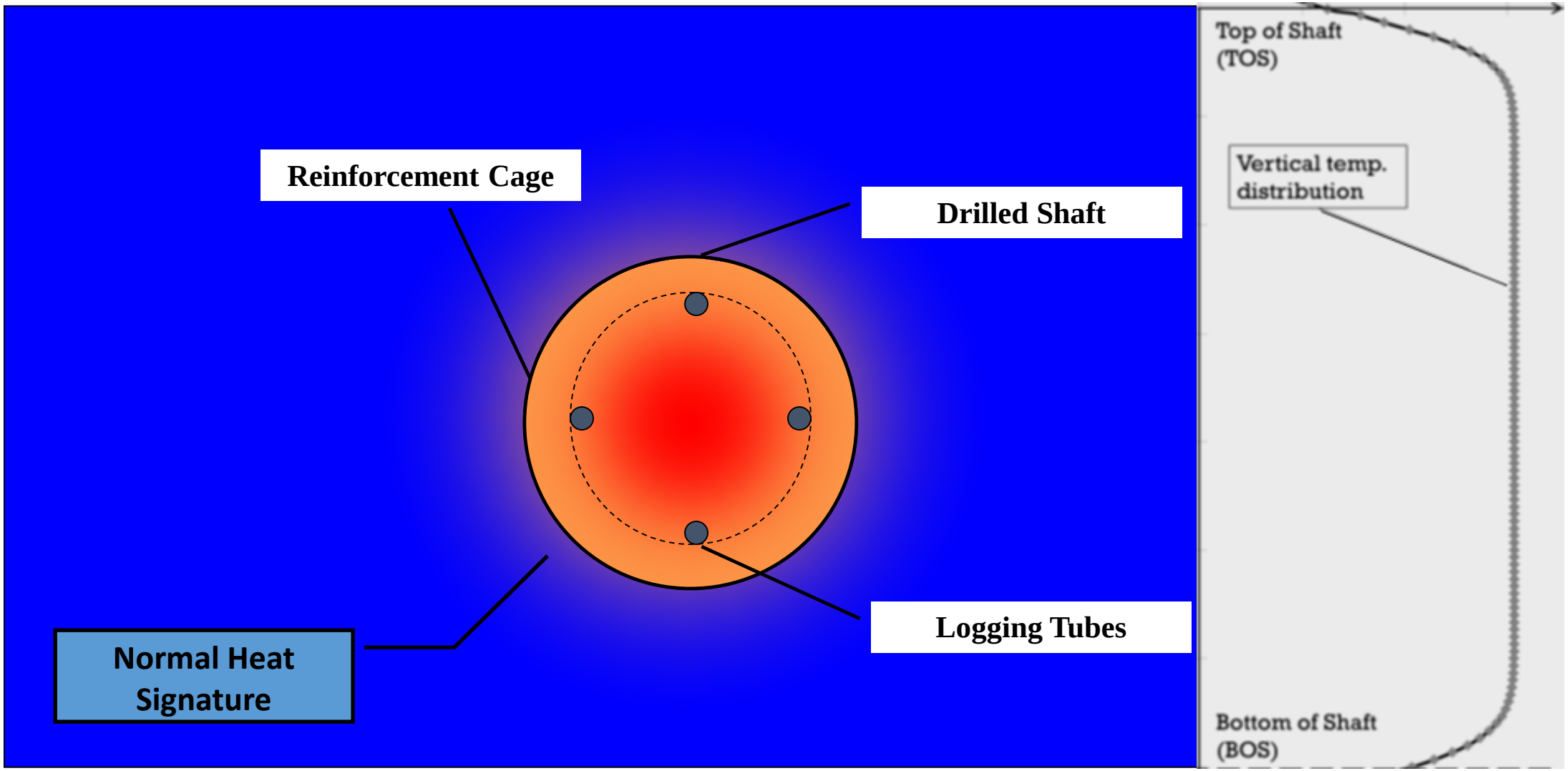
Concepts used by Thermal Testing



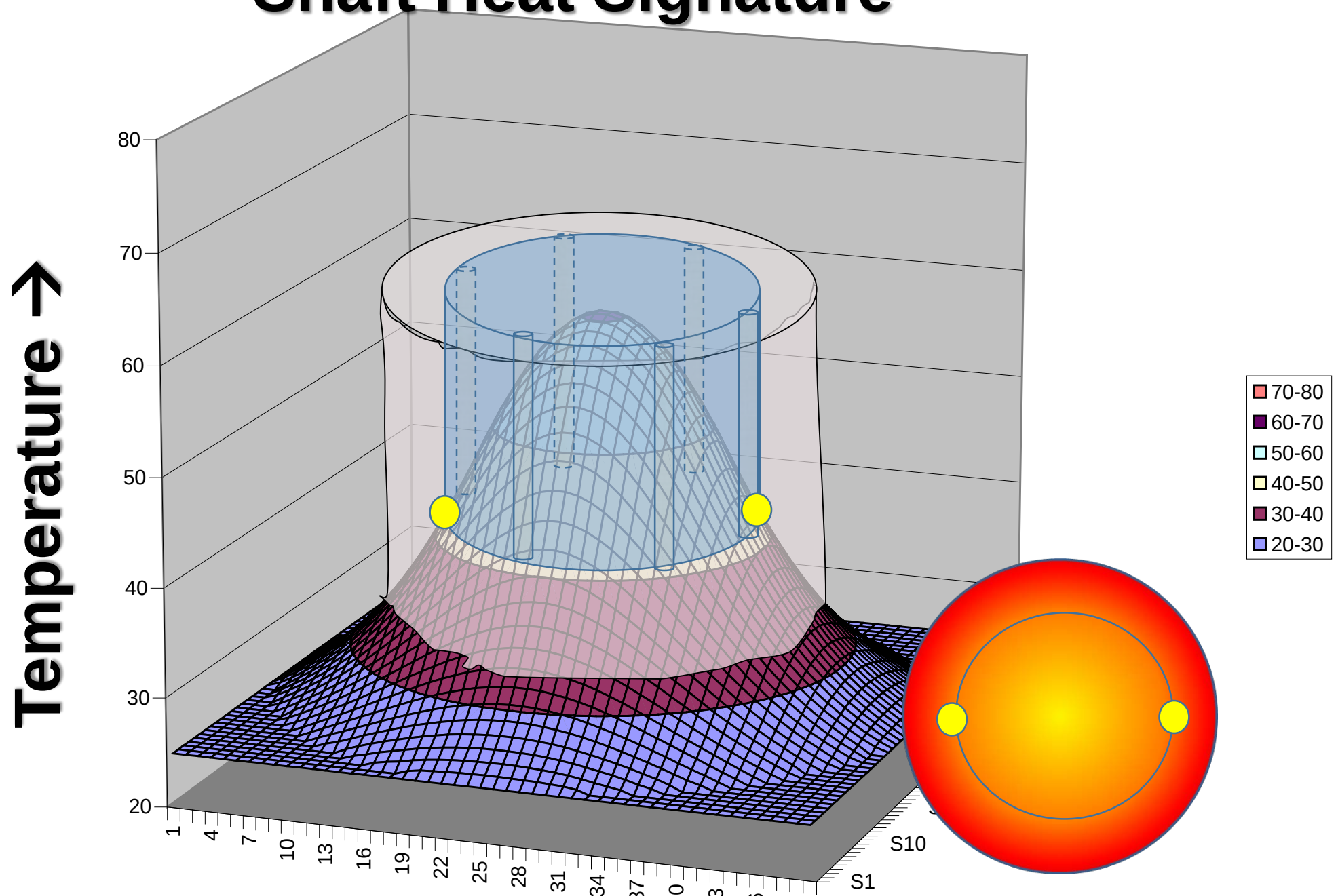


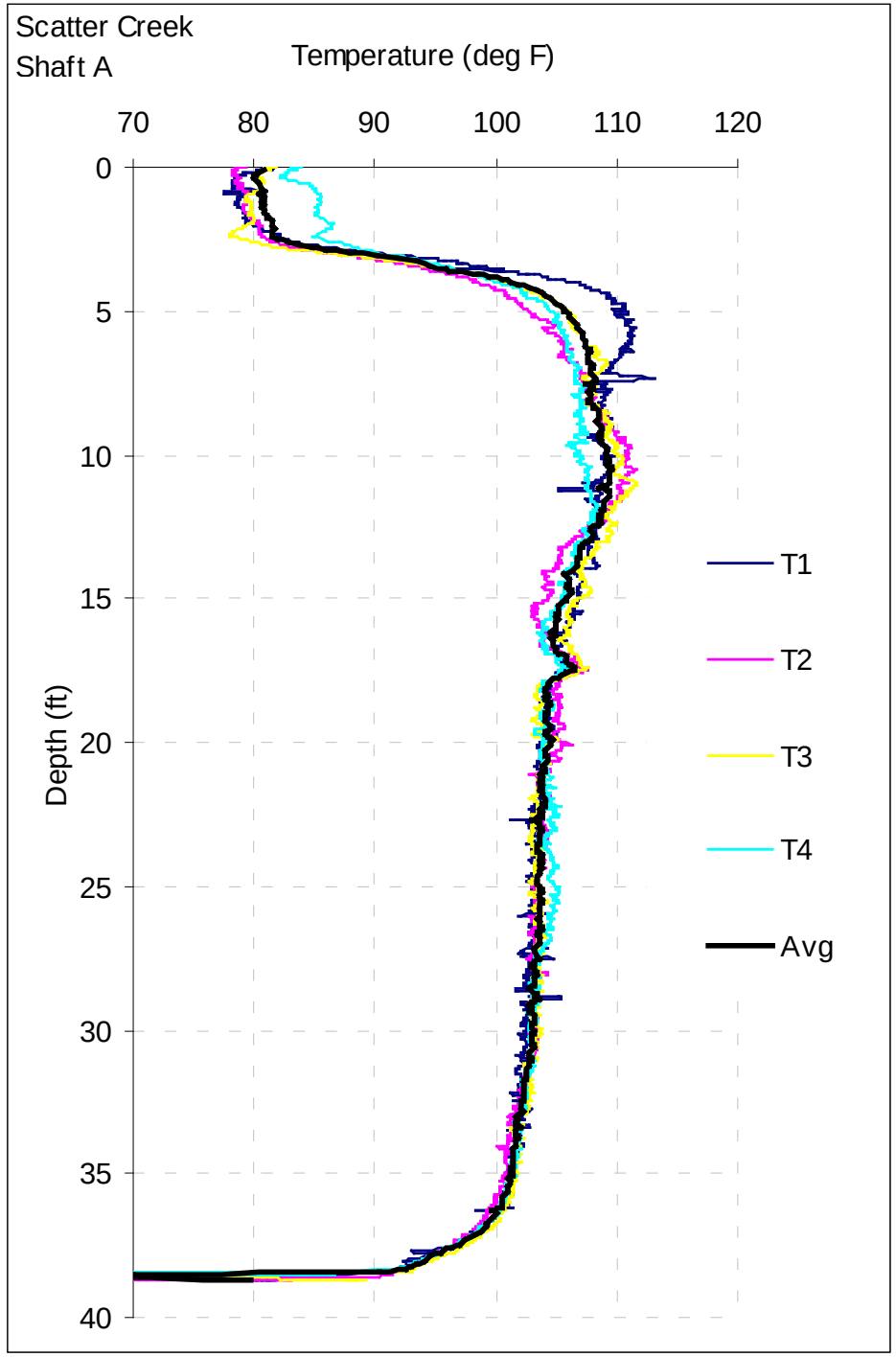
Temperature radial distribution for several sizes

Thermal Integrity Testing



Shaft Heat Signature

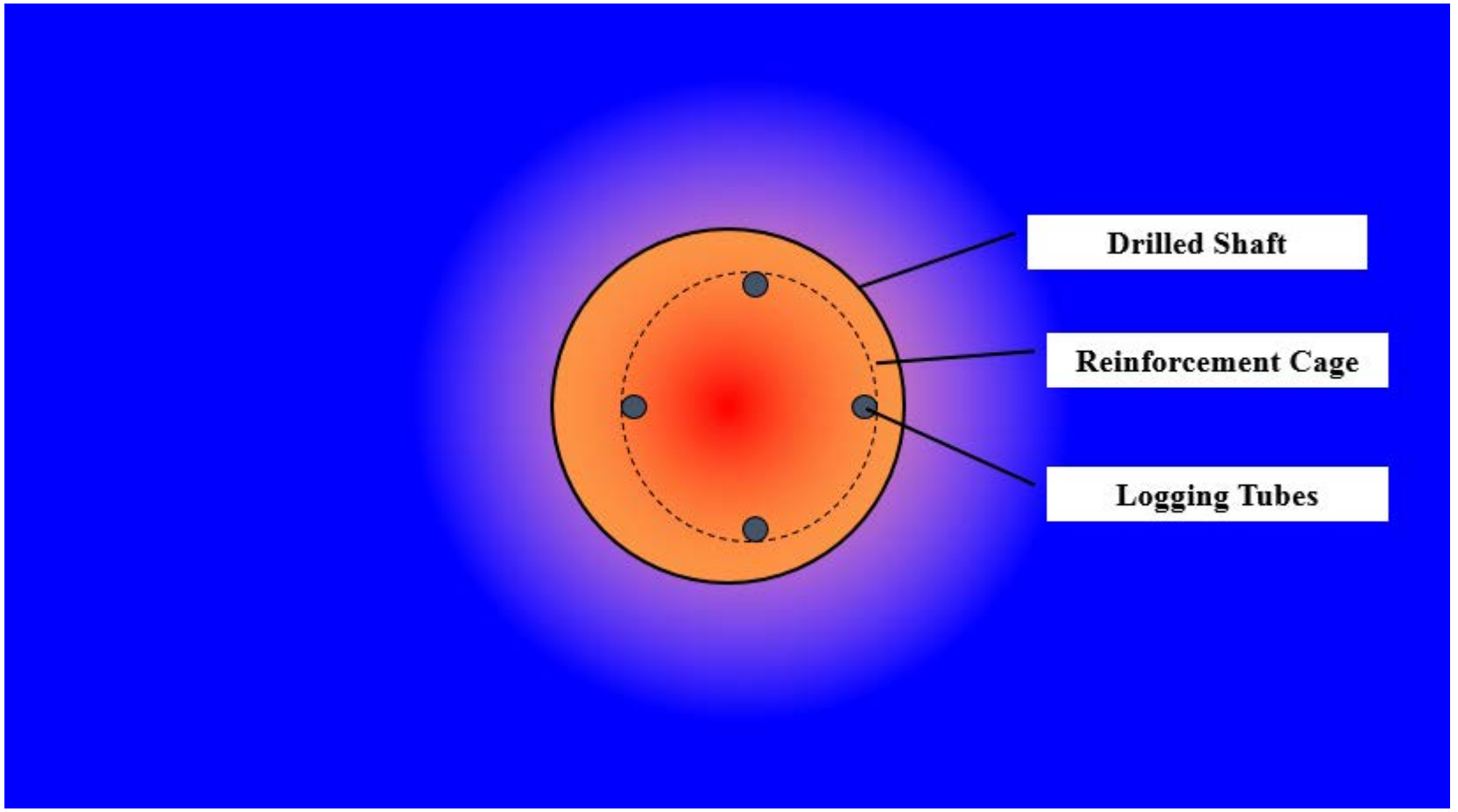


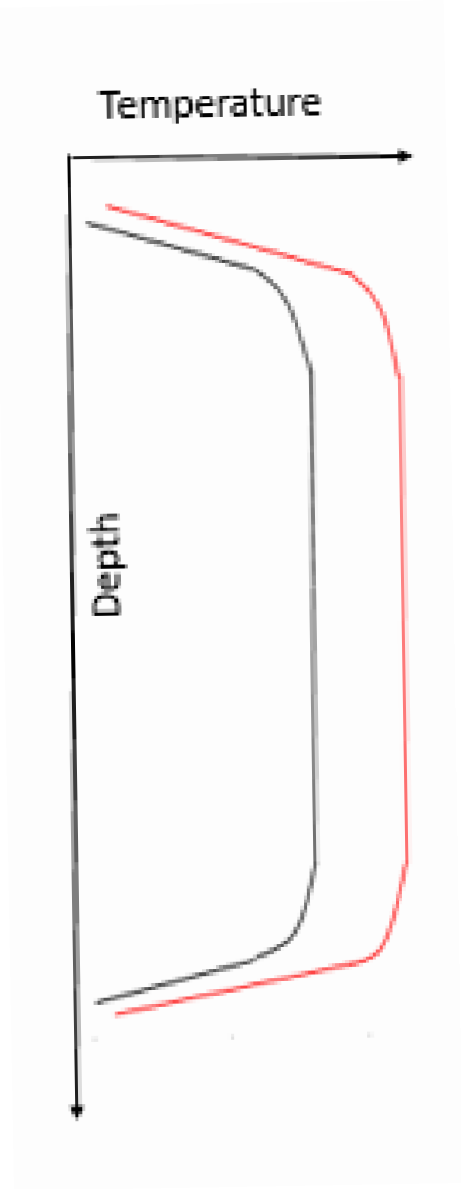


Field Observations

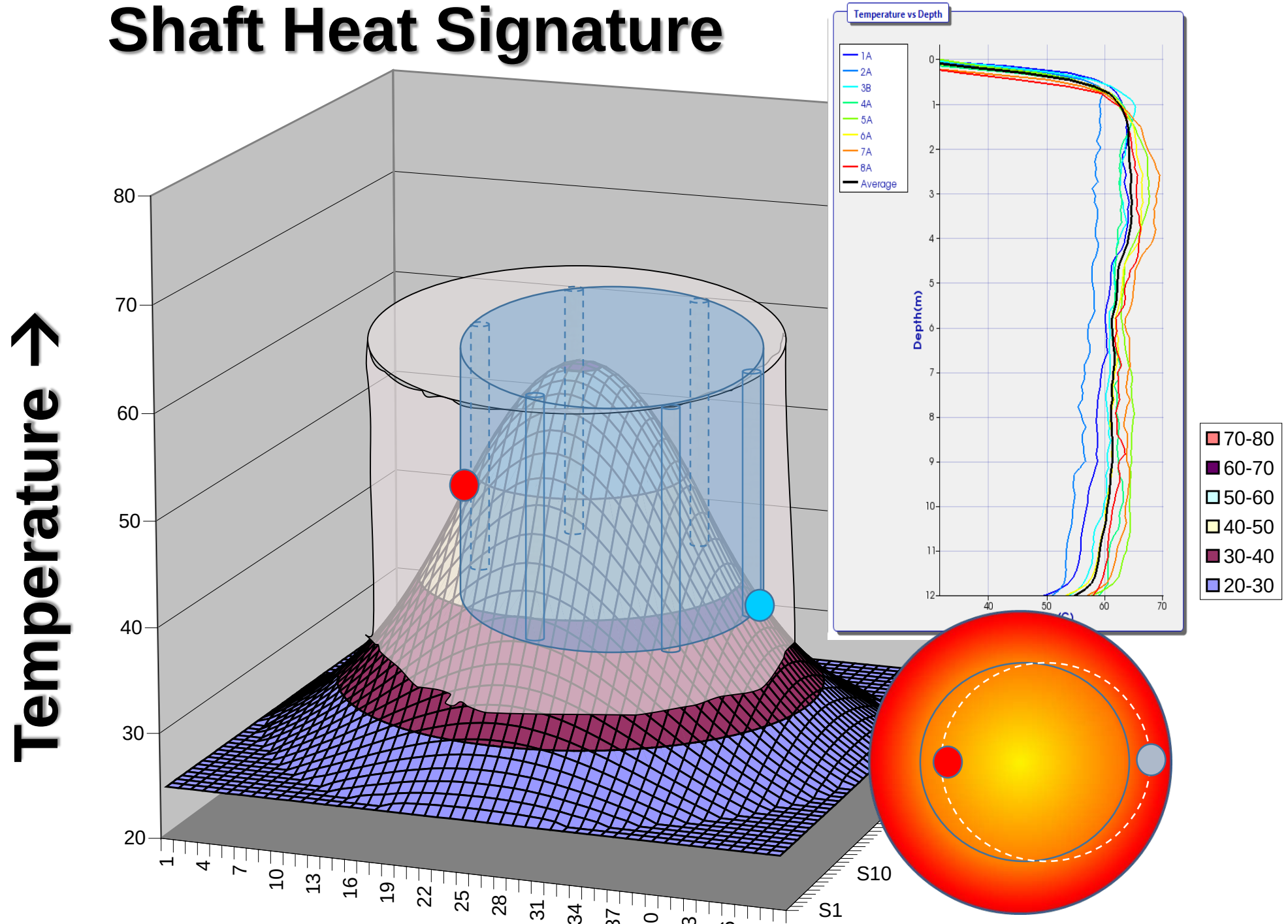
- Little to no cage eccentricity *(all tubes same temp throughout)*
- Clean top and toe signature *(approximate 1 diameter temperature roll-off top and bottom)*
- Good Shaft

Thermal Integrity Testing

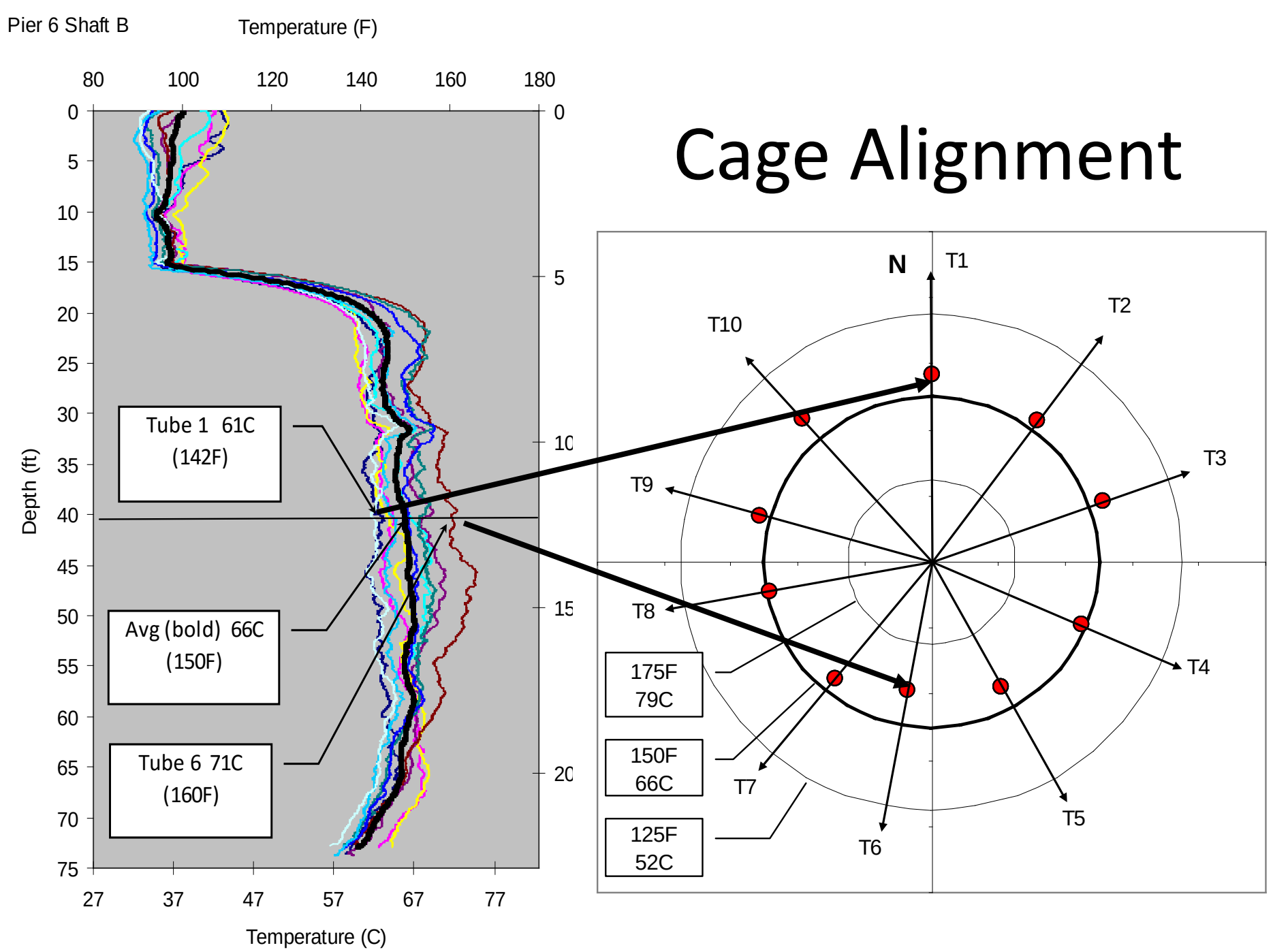




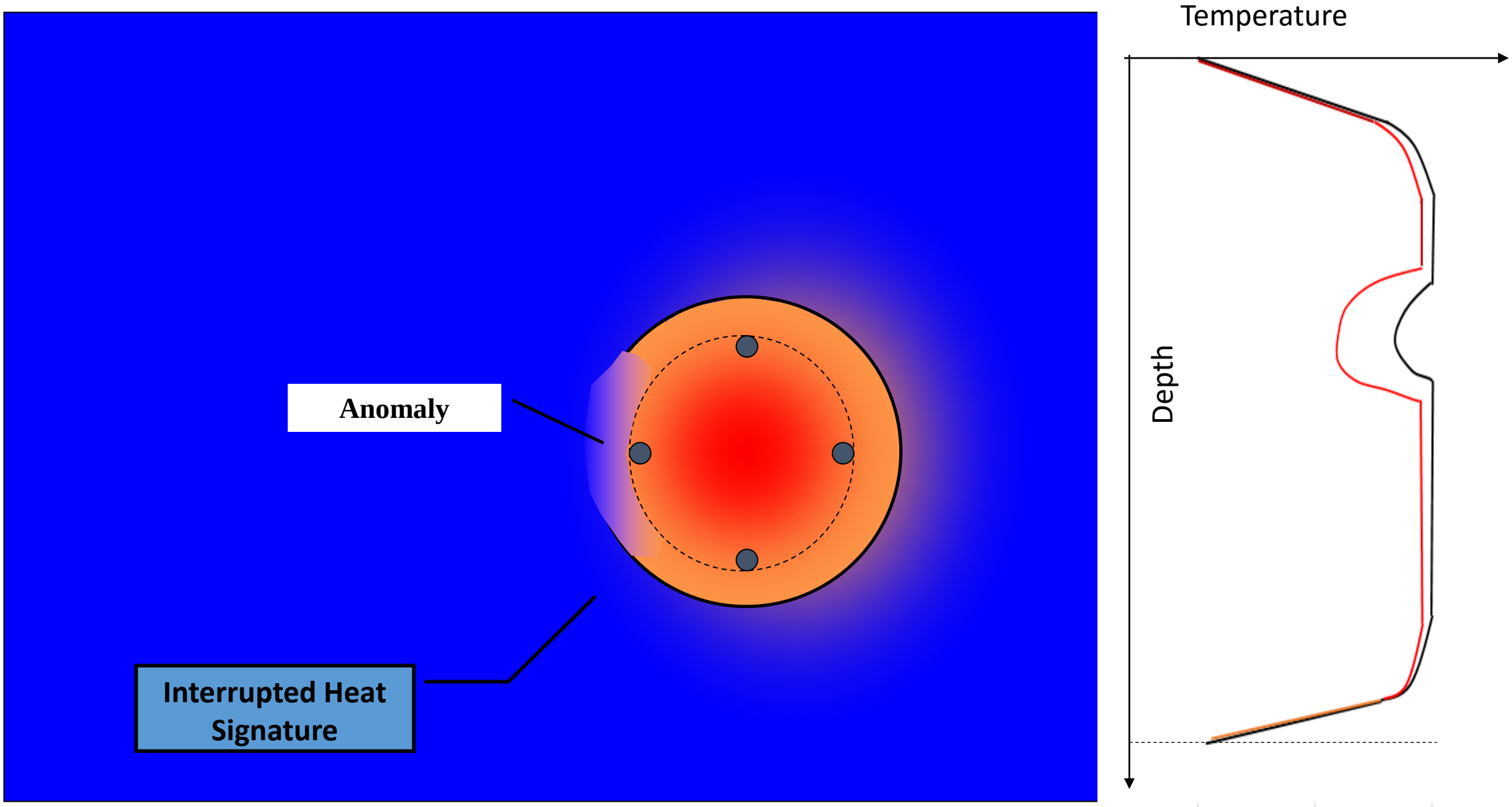
Shaft Heat Signature



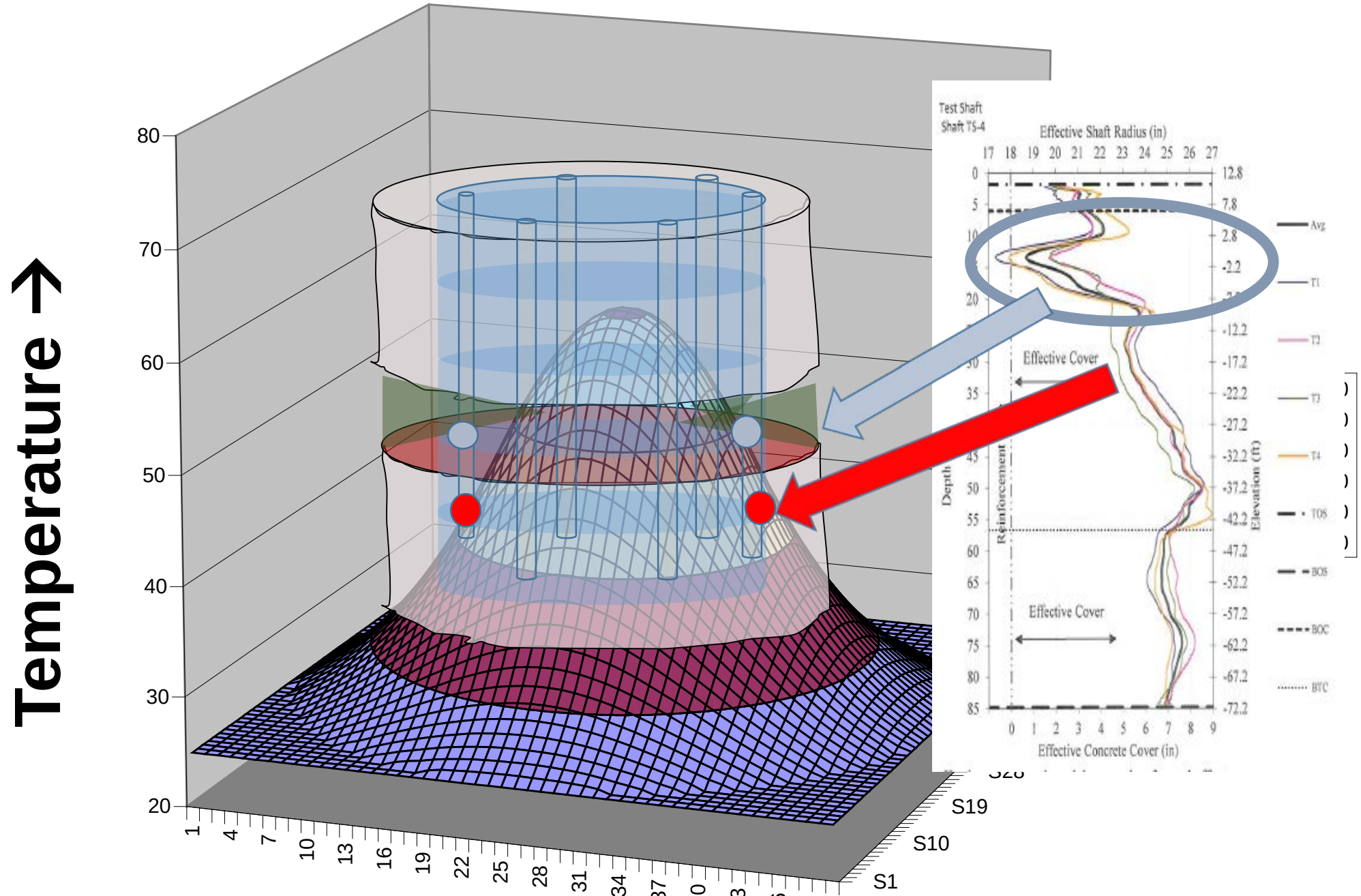
Cage Alignment

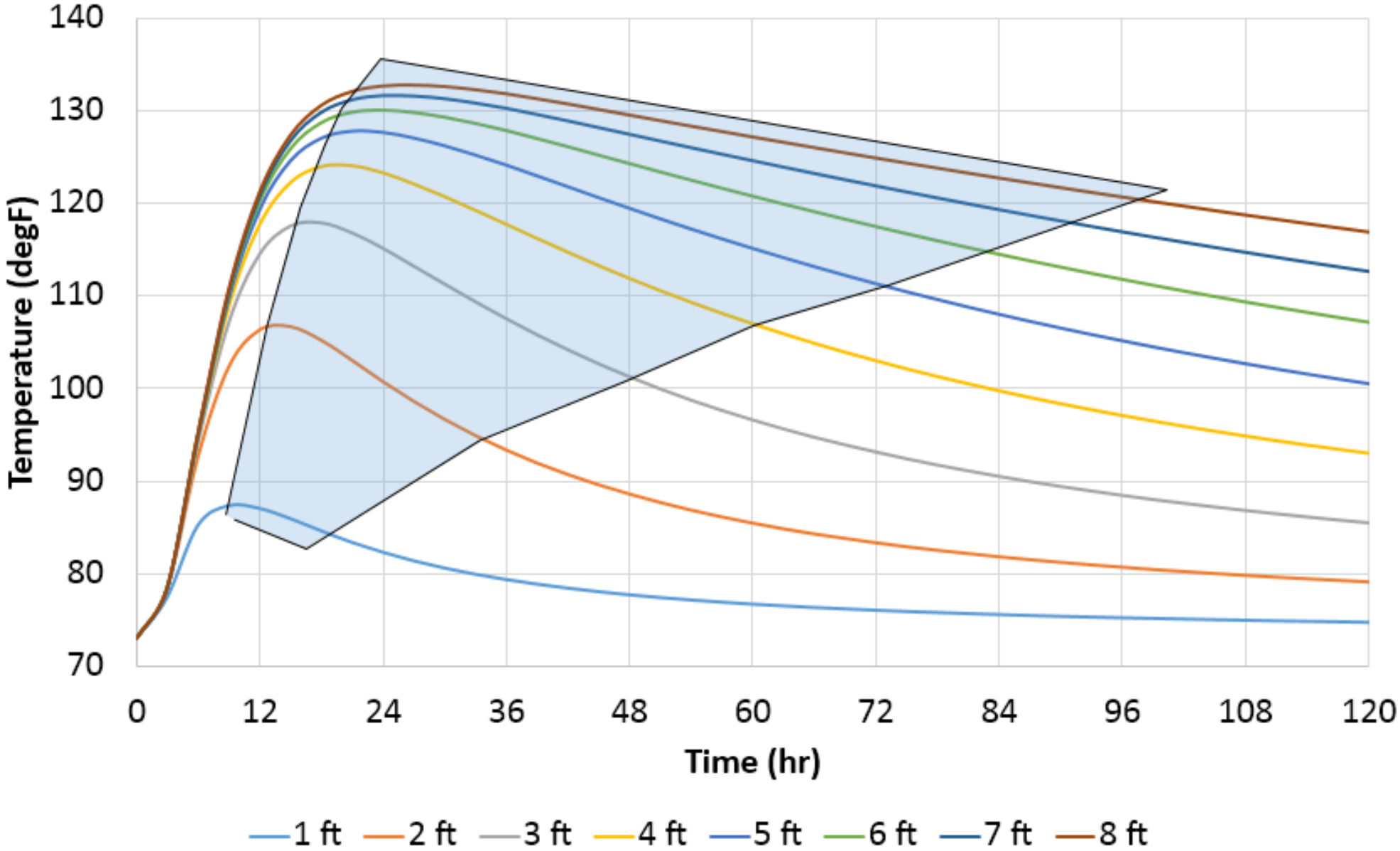


Thermal Integrity Testing

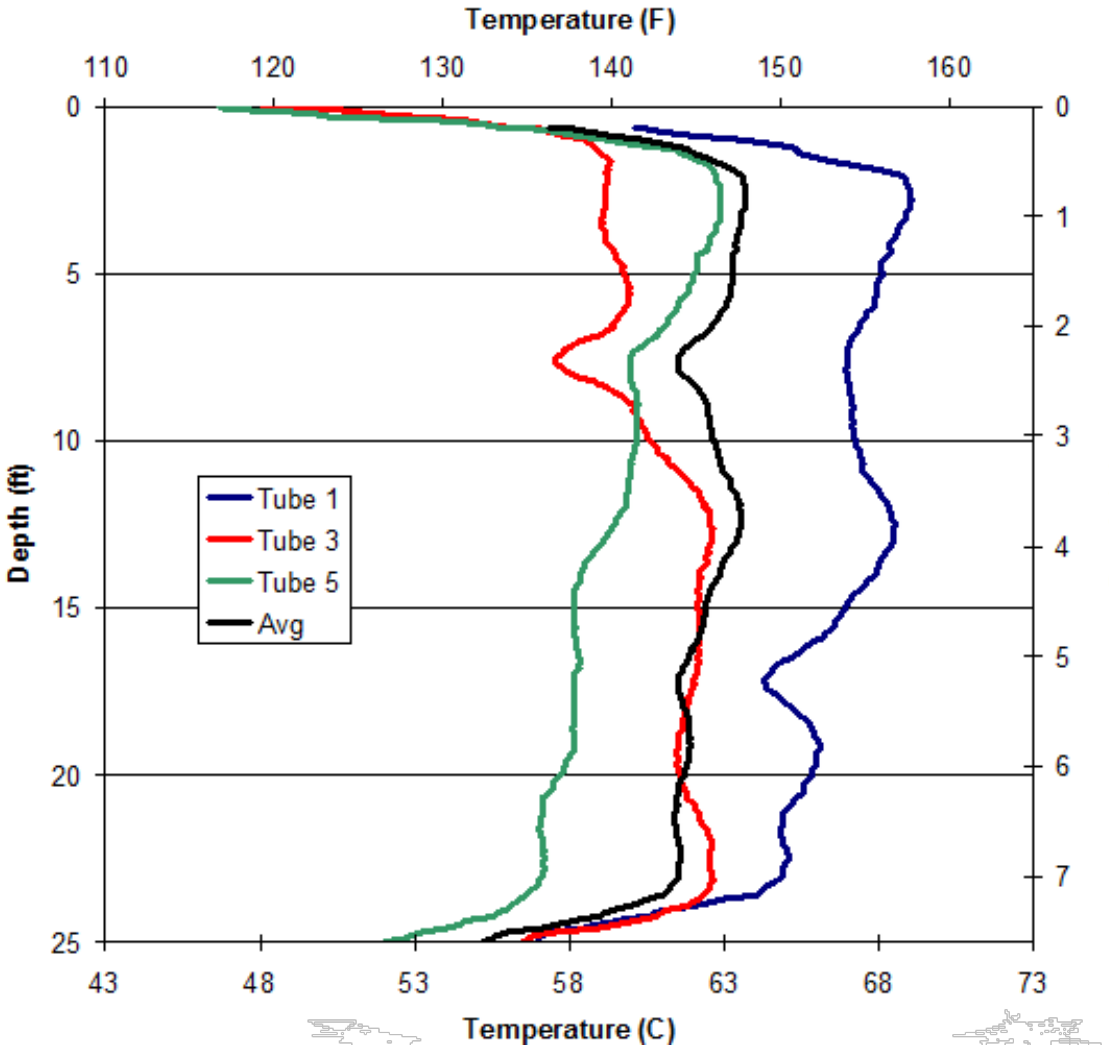


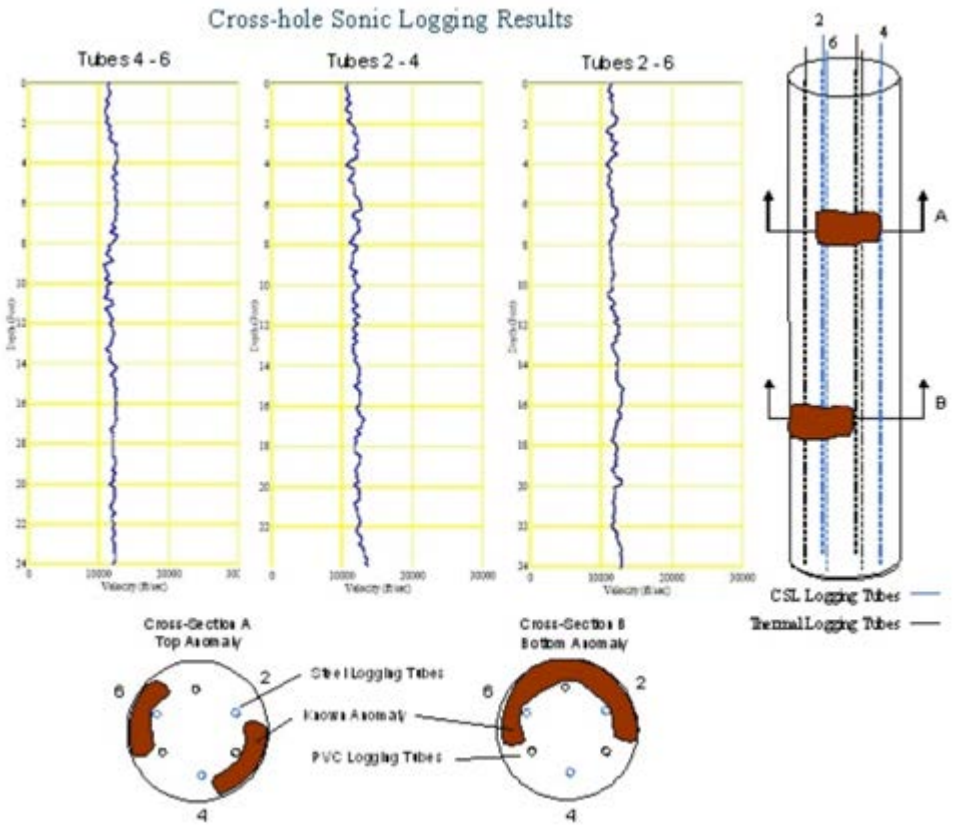
Shaft Heat Signature



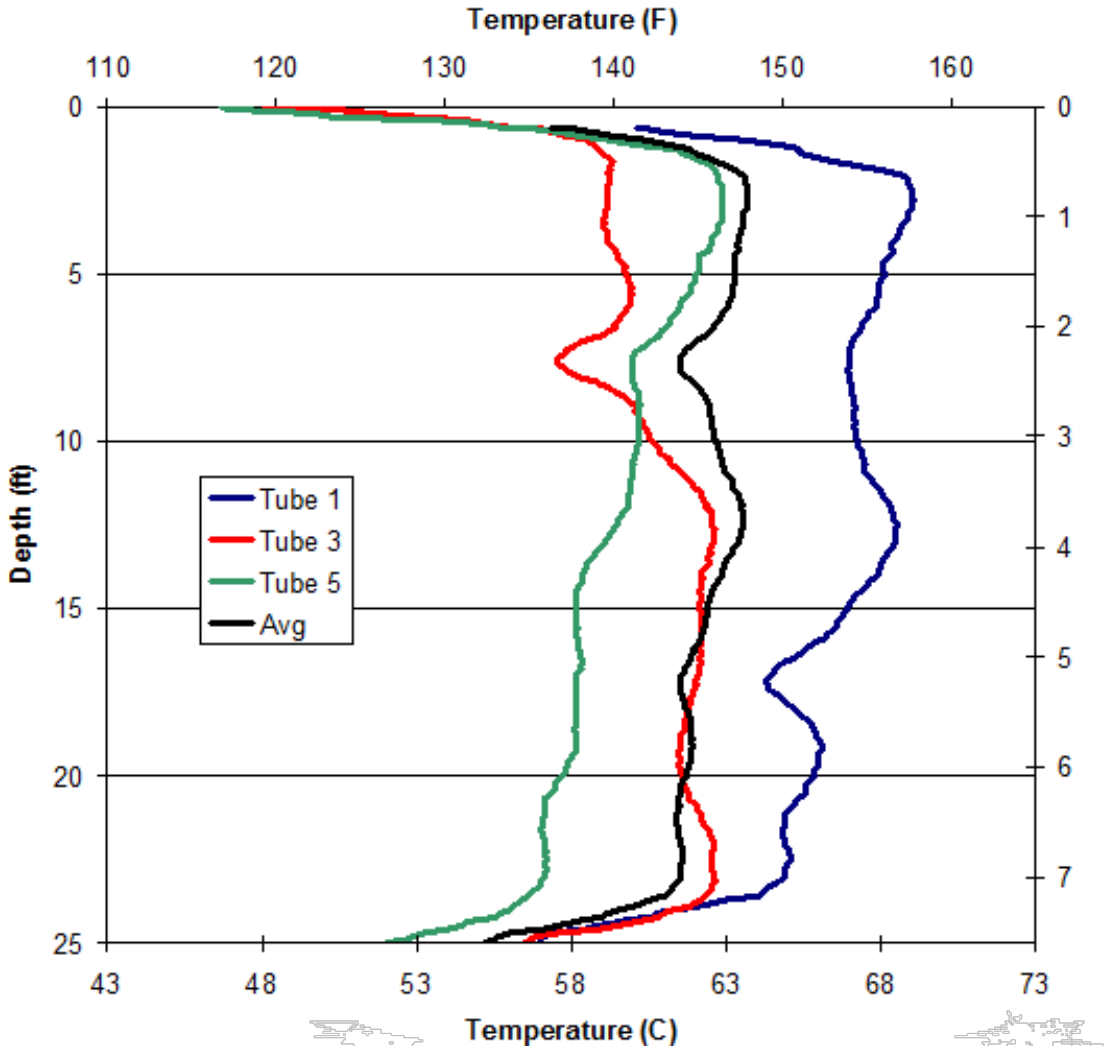


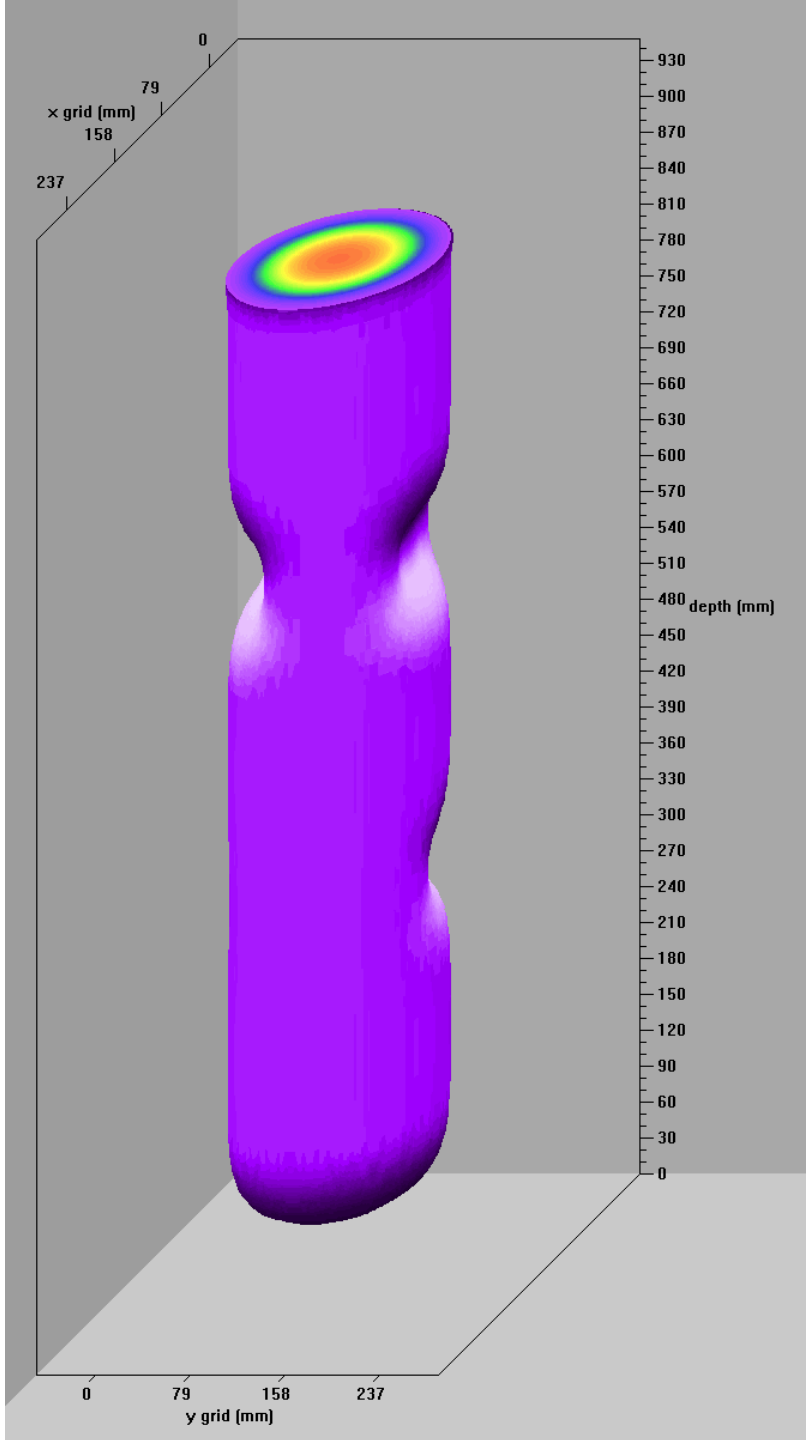
Optimum testing time for different size shafts


Temperature (F)
110
120
130
140
150
160
0
5
10
15
20
25
Depth (ft)
Tube 1
Tube 3
Tube 5
Avg
43
48
53
58
63
68
73
Temperature (C)
0
1
2
3
4
5
6
7
Depth (m)


Cross-hole Sonic Logging Results
Tubes 4 - 6
Tubes 2 - 4
Tubes 2 - 6
2
6
4
A
B
CSL Logging Tubes
Thermal Logging Tubes
Cross-Section A
Top Anomaly
Cross-Section B
Bottom Anomaly
Steel Logging Tubes
Known Anomaly
PVC Logging Tubes
6
2
4

3-D image of a shaft with loss of concrete cover



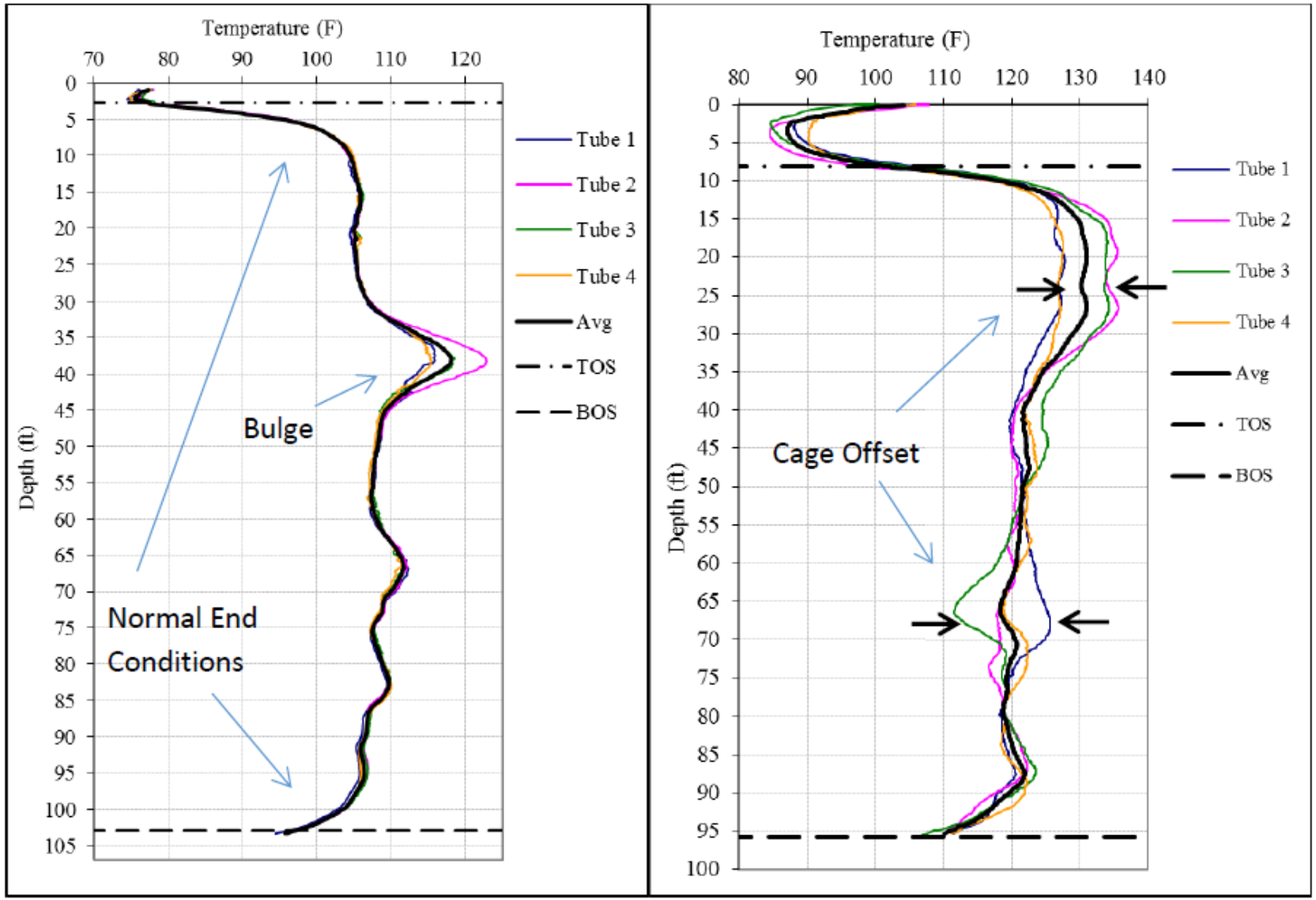


Analysis

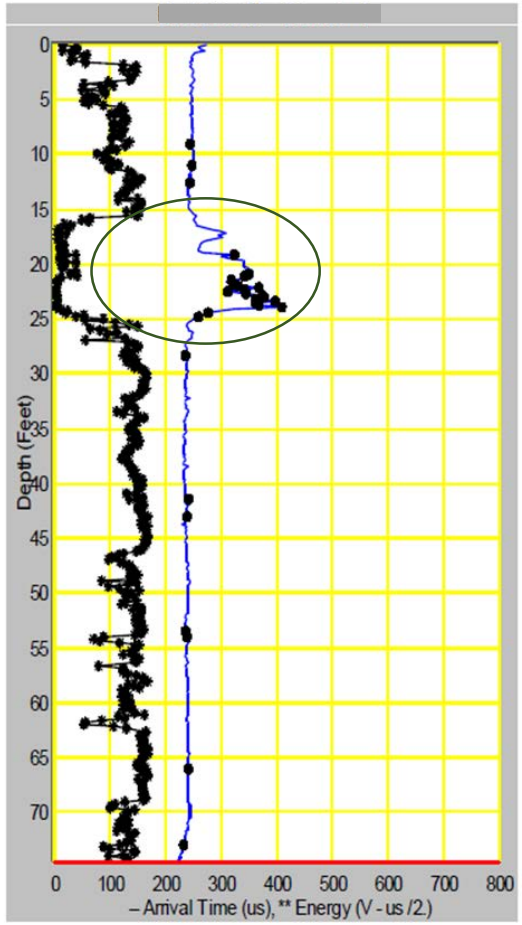
There are 4 levels of analysis:

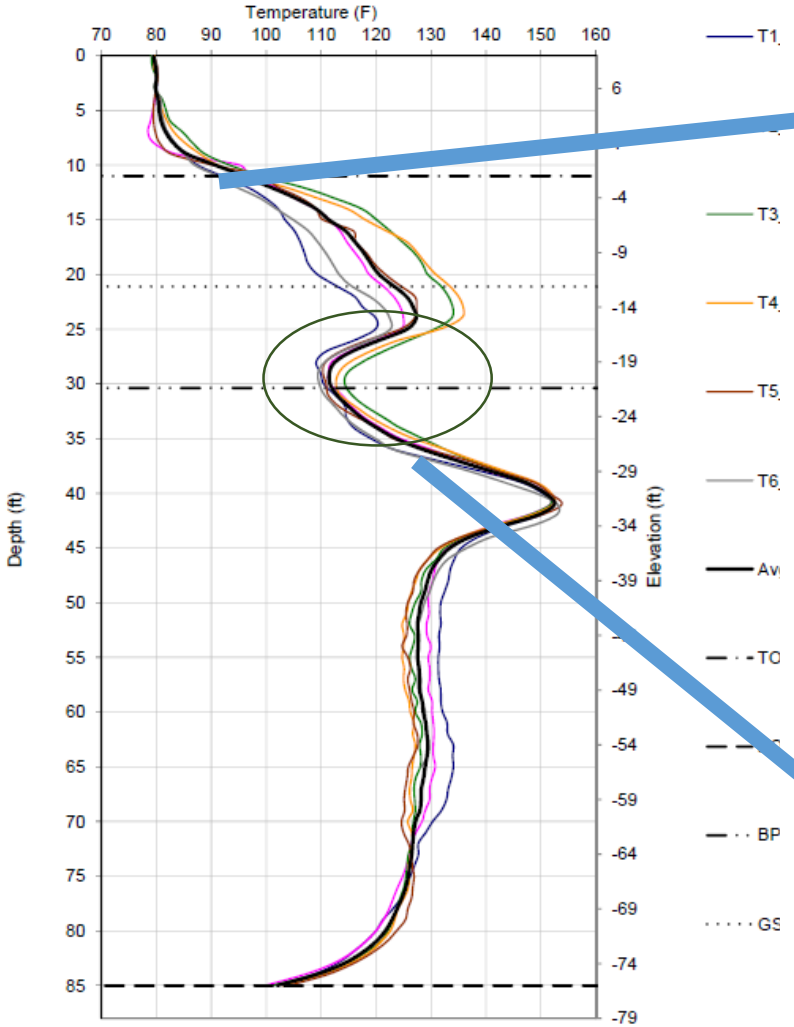
- Level 1: Direct Observation of Temperature Profiles
- Level 2: Superimposed construction logs and concrete yield data. Radius determination.
- Level 3: Three dimensional thermal modeling
- Level 4: Signal matching numerical models to field data.

Example 1 - Level 1



Example 2 - Level 1





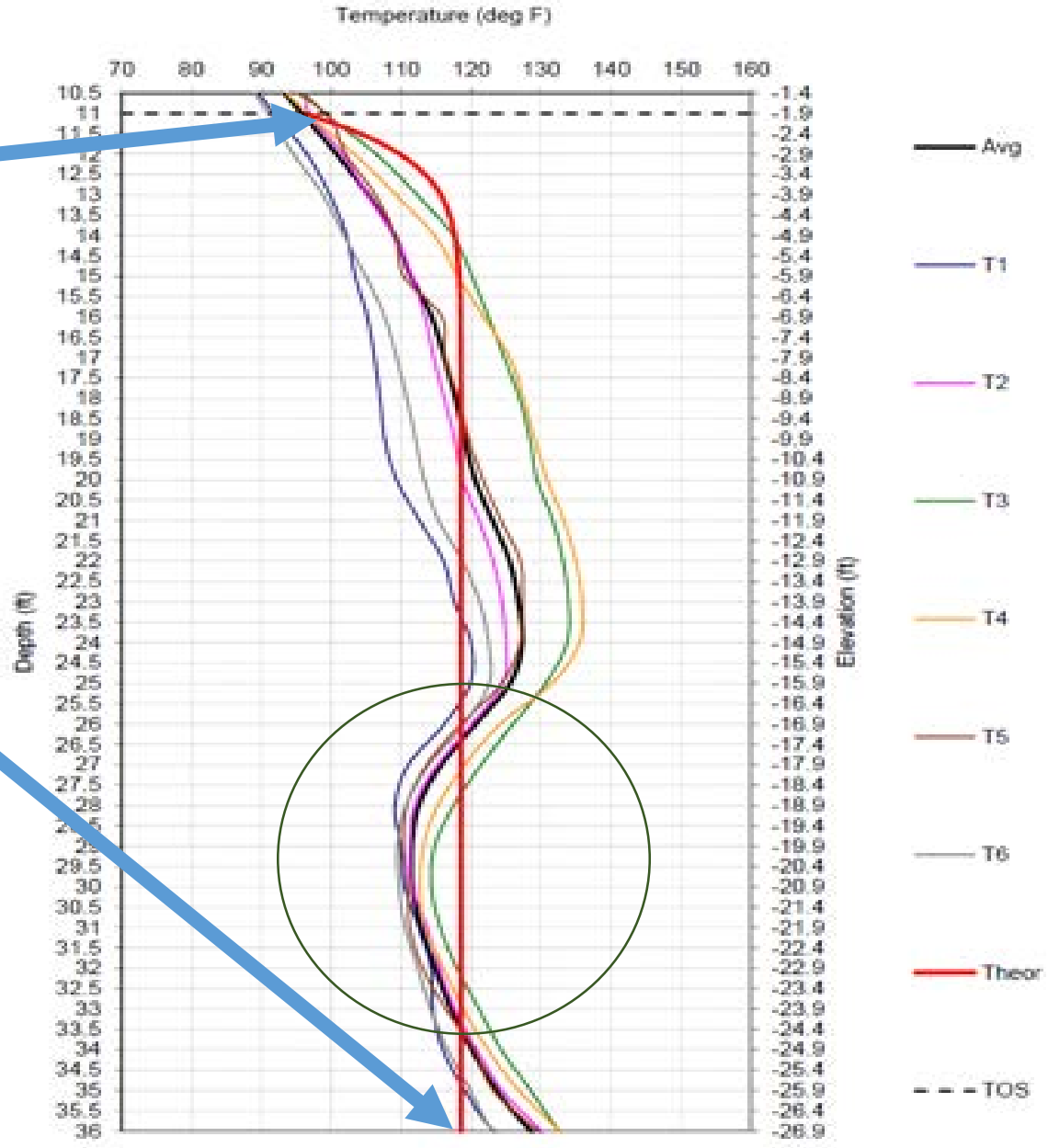
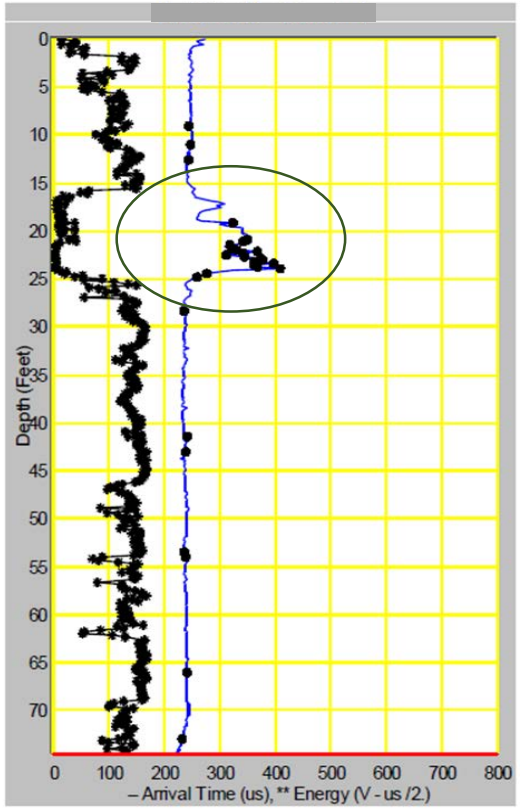
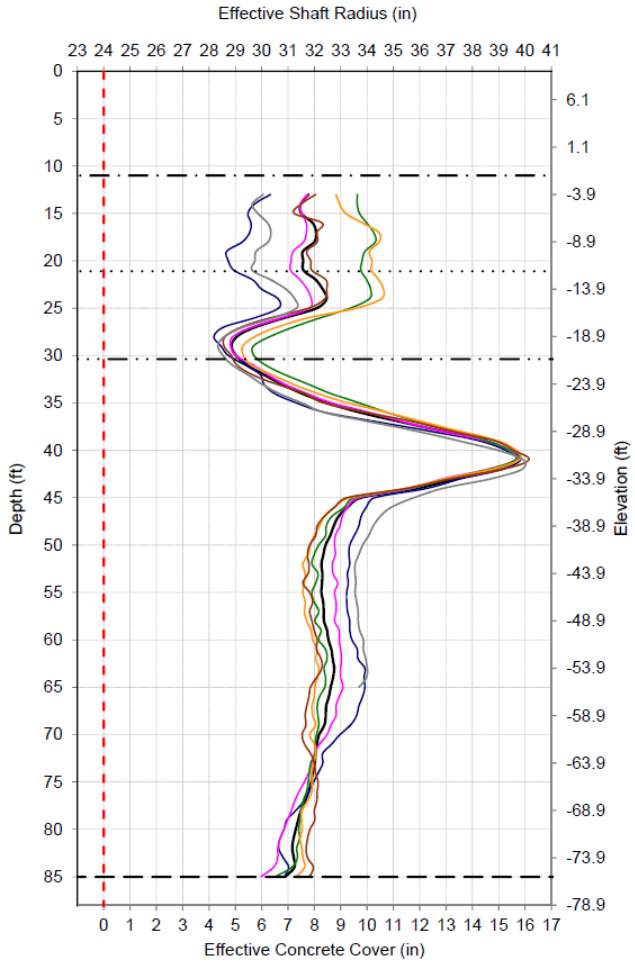
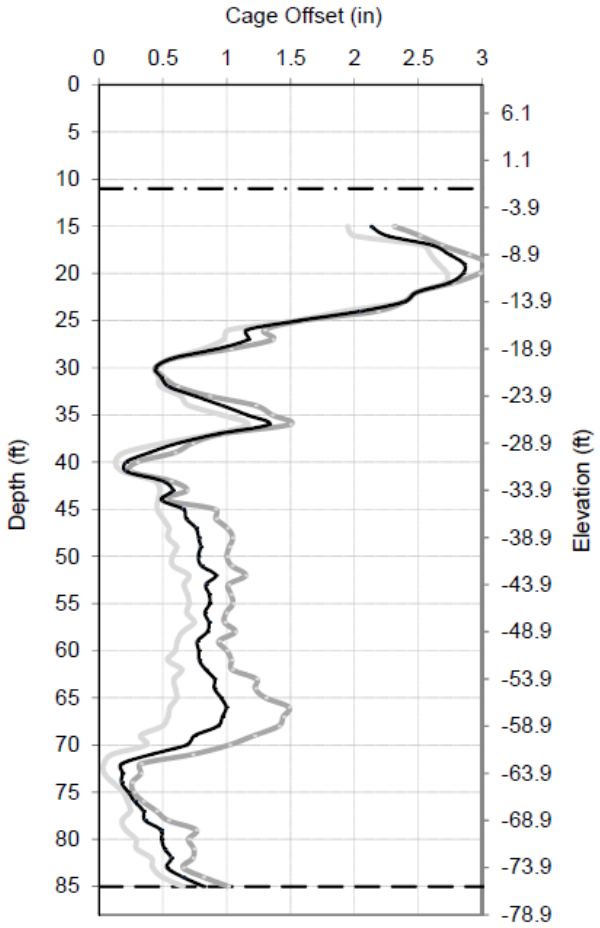


Figure 1 Raw Field Measurements for Shaft Pier 9 Shaft 4

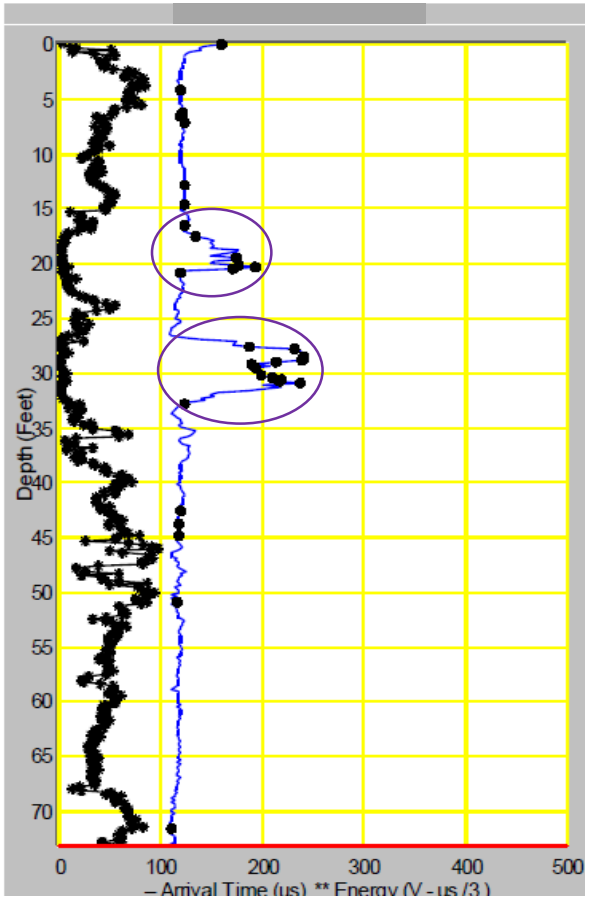
Example 2 - Level 2

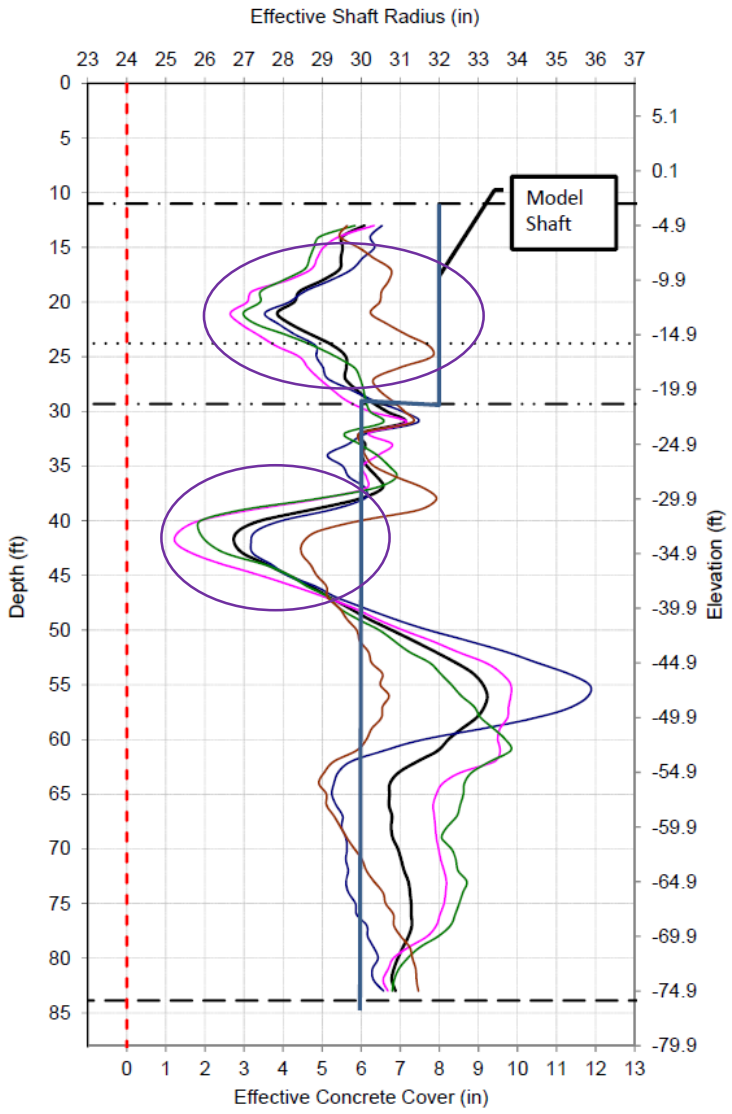


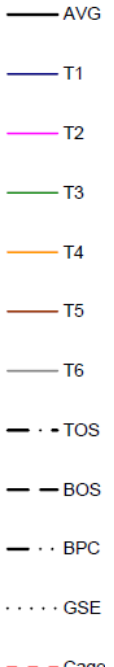


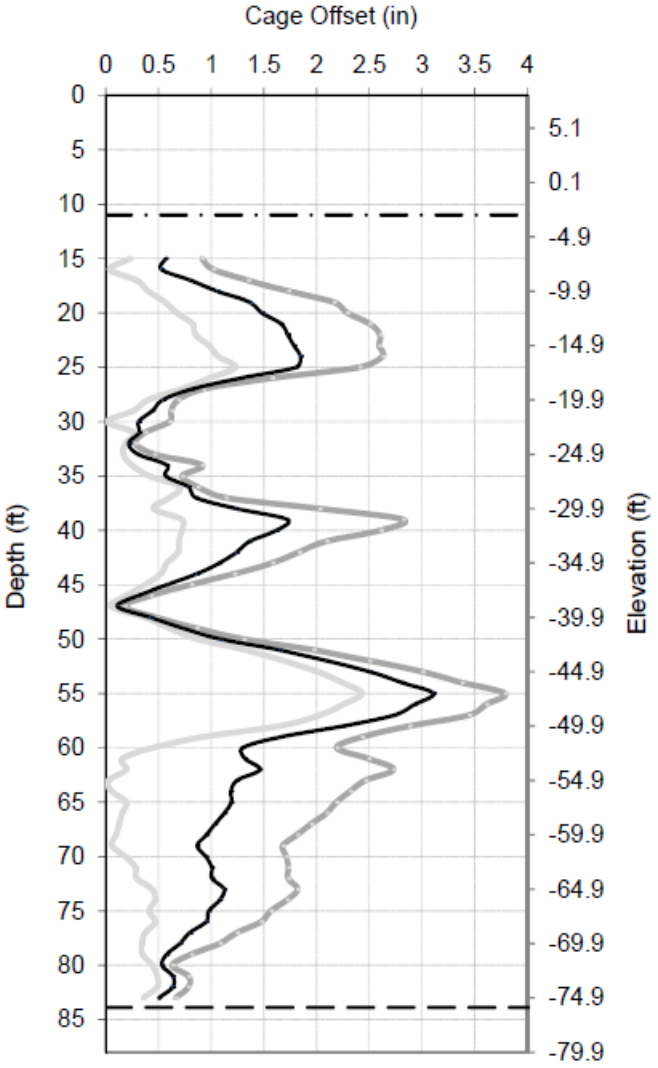


Example 3 - Level 2

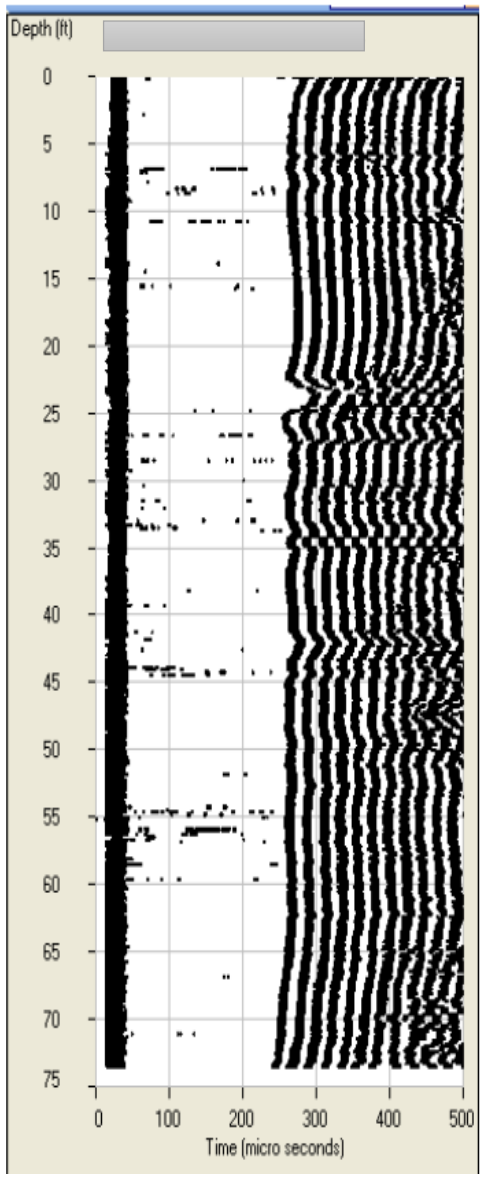


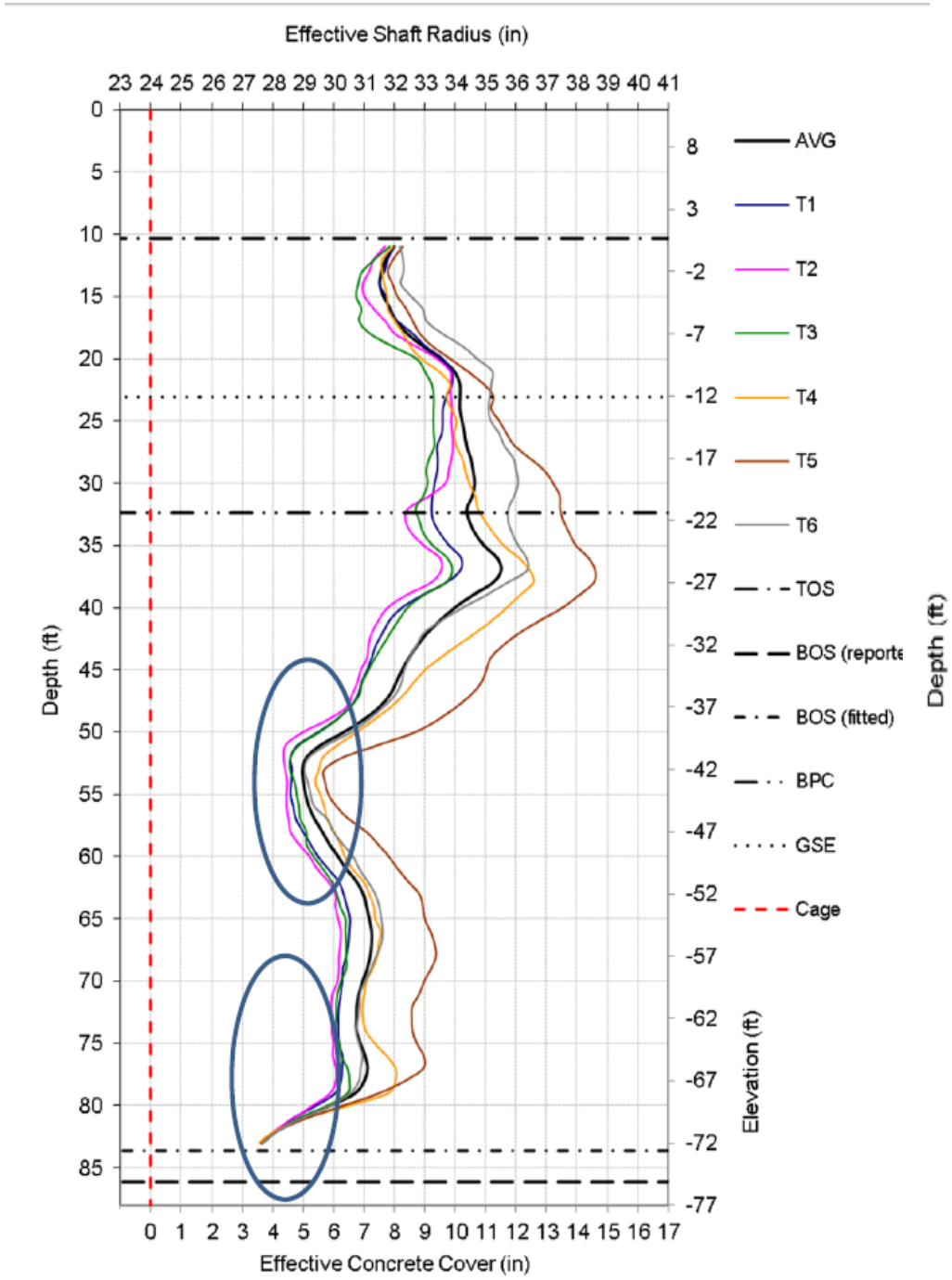


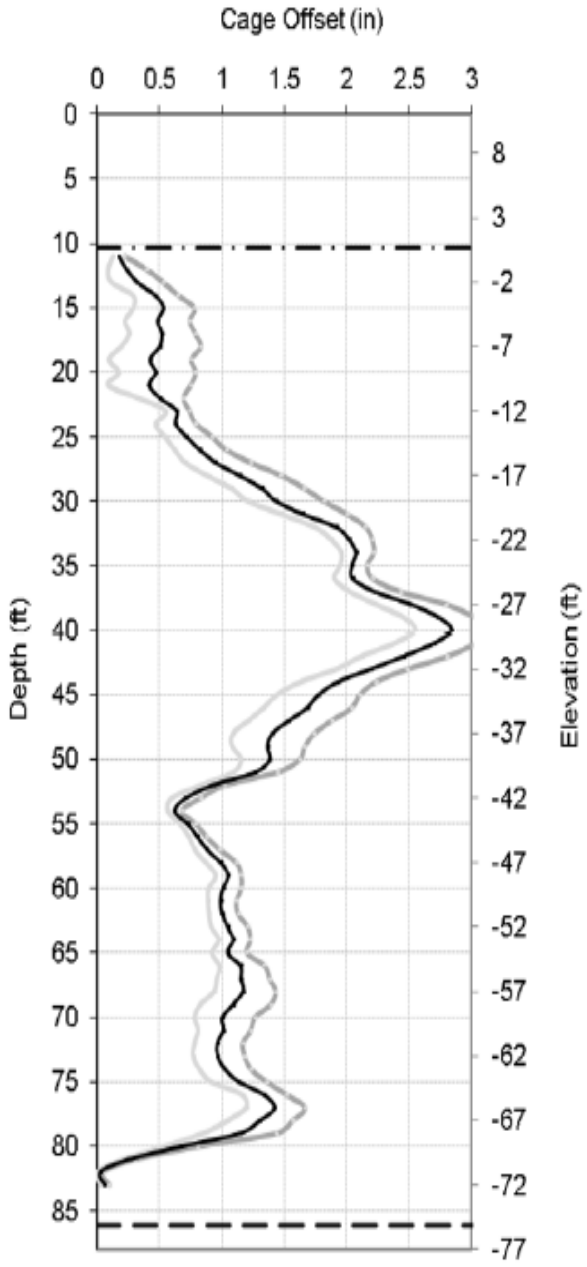




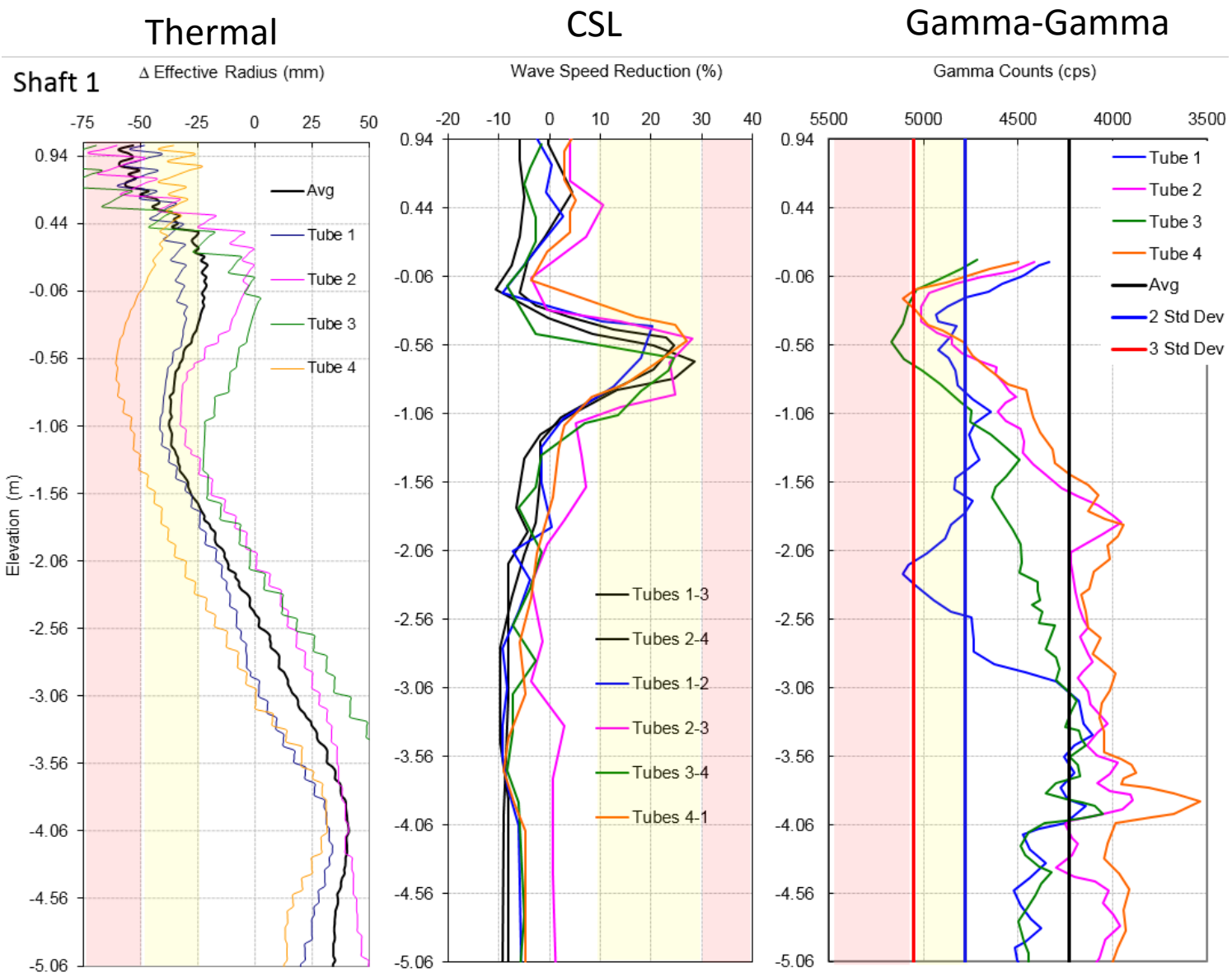
Example 4 - Level 2







Example 5


Thermal
CSL
Gamma-Gamma
Shaft 1
Δ Effective Radius (mm)
Wave Speed Reduction (%)
Gamma Counts (cps)
Elevation (m)
Avg
Tube 1
Tube 2
Tube 3
Tube 4
Tubes 1-3
Tubes 2-4
Tubes 1-2
Tubes 2-3
Tubes 3-4
Tubes 4-1
2 Std Dev
3 Std Dev

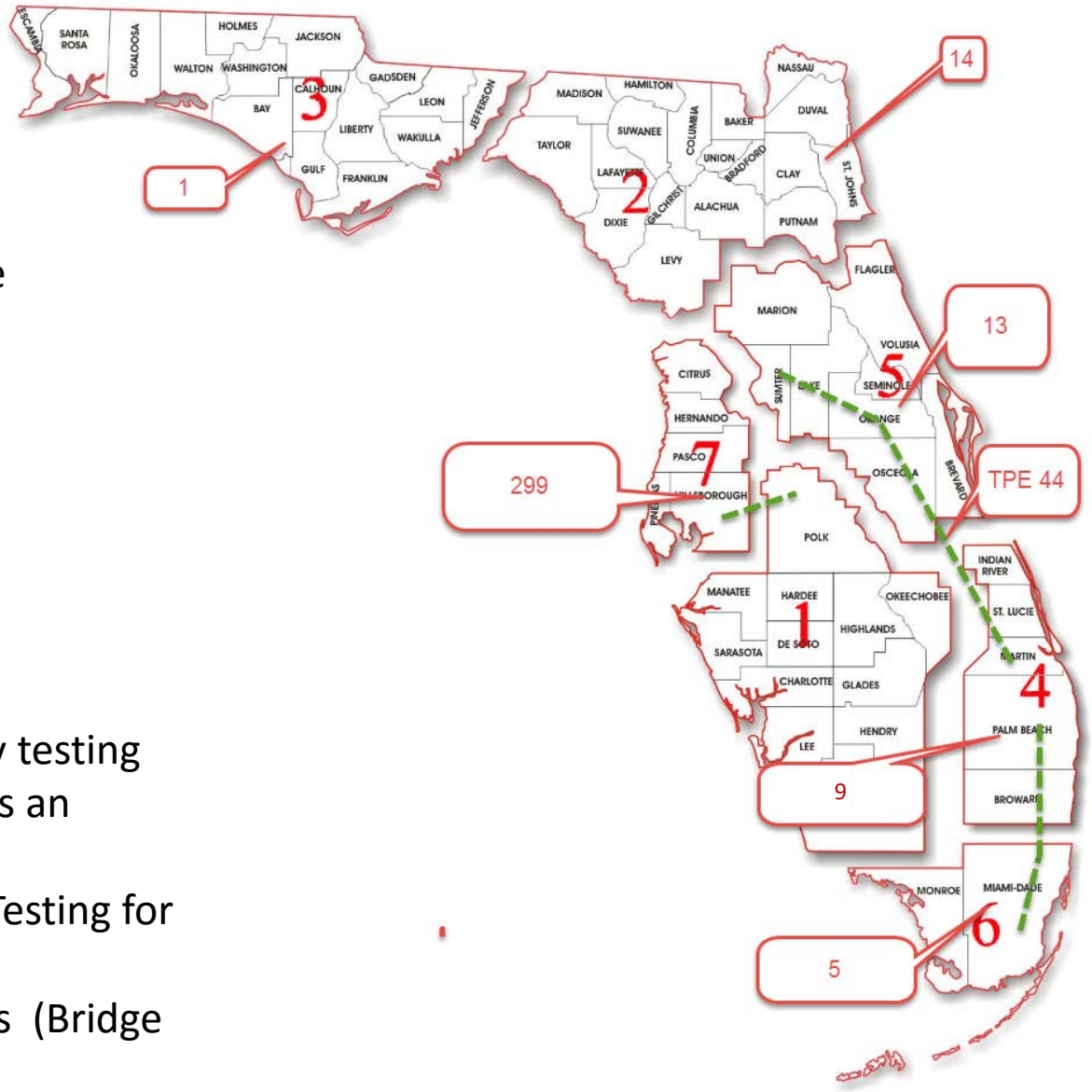
FDOT EXPERIENCE AND PROSPECTIVE

- **EXPERIENCE:**

- As of February 2016, TIP used successfully on 386 drilled shafts statewide (299 in Tampa).
- TIP Test has been accepted by consultants and the industry.
- Currently 4 Consultants in Florida have the capability of performing the test.
- Two FDOT offices own the equipment: State Materials Office and the D4-6 Materials Office.

- **FDOT PROSPECTIVE**

- Specifications still uses CSL as the primary integrity testing
- Thermal Integrity Testing is included in the specs as an option for verification
- Looking forward to use it as the primary Integrity Testing for drilled shafts
- Future inclusion on acceptance for Auger Cast Piles (Bridge applications)



Acknowledgements

- University of South Florida, Civil and Environmental Engineering
- Florida Geotechnical Engineers (FGE)
- Pile Dynamics, PDI
- Drs. Gray Mullins and Danny Winters

QUESTIONS ?

- **COST:**
- ***Consultant fees (FDOT District wide):***

413-Geo Crosshole Sonic Logging (CSL)	Geotechnical Limiting Amount	$1,620.30	Day
421-Geo Dynamic Pile Testing/Pile Driving Analysis	Geotechnical Limiting Amount	$1,845.30	Day
451-Geo Pile Integrity Testing	Geotechnical Limiting Amount	$1,575.30	Day
472-Geo Saximeter Testing	Geotechnical Limiting Amount	$1,275.30	Day
513-Geo Thermal Integrity Tester (TI)	Geotechnical Limiting Amount	$1,620.30	Day
523-Geo Vibration & Noise Monitoring	Geotechnical Limiting Amount	$1,395.30	Day
602-Mobilization - Vibration Monitoring Equipment	Geotechnical Limiting Amount	$ 275.00	Each
615-Mobilization - Pile Driving Analyzer Equipment	Geotechnical Limiting Amount	$ 275.00	Each
616-Mobilization - Pile Integrity Tester Equipment	Geotechnical Limiting Amount	$ 275.00	Each

If you want to do it yourself:

- ***Machine costs $34 K (Includes depth encoder, TAPP, data acquisition system. It does not include TAP for wires)***
- ***Wires with thermometers @ 12": $5/ft***
- ***TAP: $350 each***
- ***Consultant typically charge us $2500 per test (including field collection and report. Same cost as they charge us for CSL testing.***

- **FDOT REPORT REQUIREMENTS:**

- ***T vs Depth graphs*** (measured and theoretical):
  - Indication of unusual temperatures, including cooler local deviations from the average at any depth from the overall average over the entire length.
  - Overall T average temperature and theoretical temperature.
  - Variations in temperature between access tubes which may indicate variations in cage alignment.
- ***Radius*** of the shaft throughout the entire depth.
- ***Alignment*** of the reinforcing cage along the shaft
- ***Calculated concrete cover*** throughout the entire depth.
- ***Conclusion*** stating whether the tested shaft is free from integrity defects and meets the minimum concrete cover and diameter requirements by the specifications.
  - When anomalies are detected, include in the report a three dimensional rendering of the shape of the shaft.