NEW DEVELOPMENTS IN AUGER PRESSURE GROUTED (APG) PILES

Presented by:

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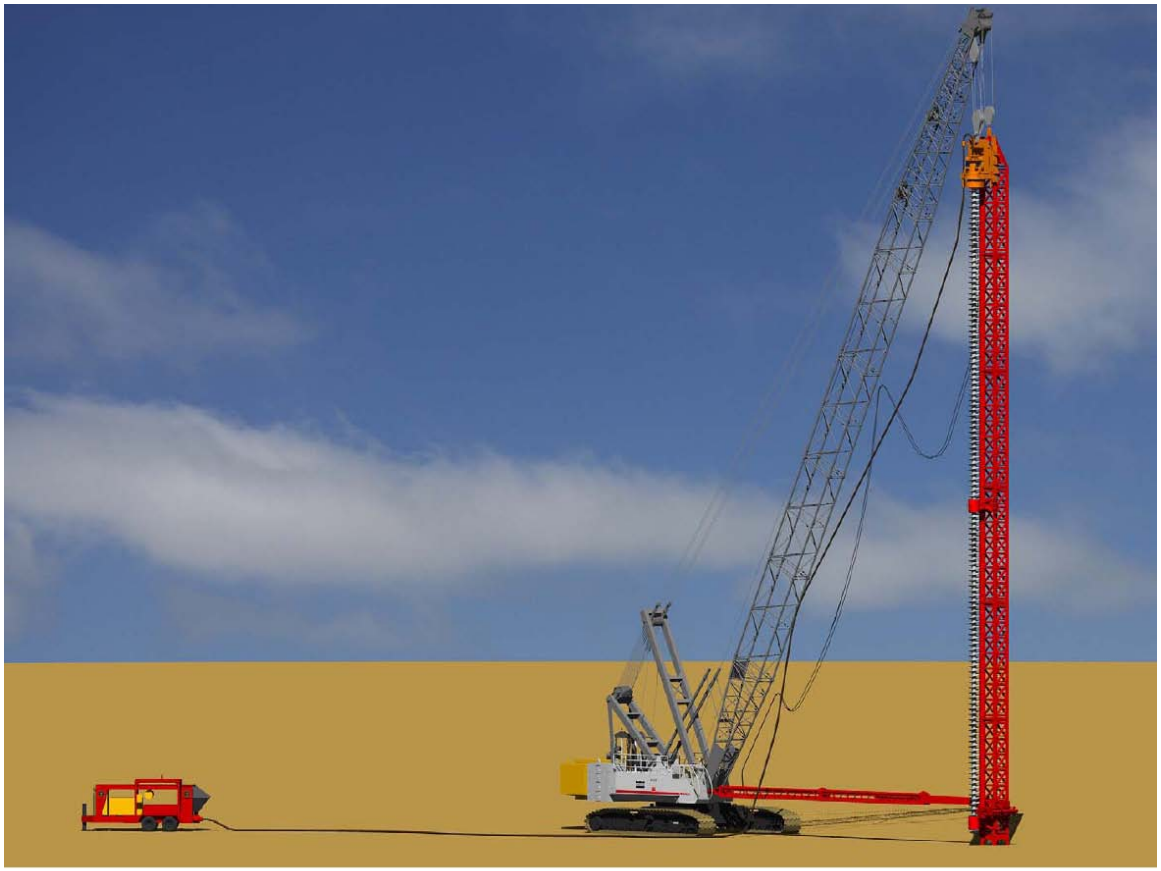
Berkel & Company Contractors, Inc.

Advantages of APG Piles

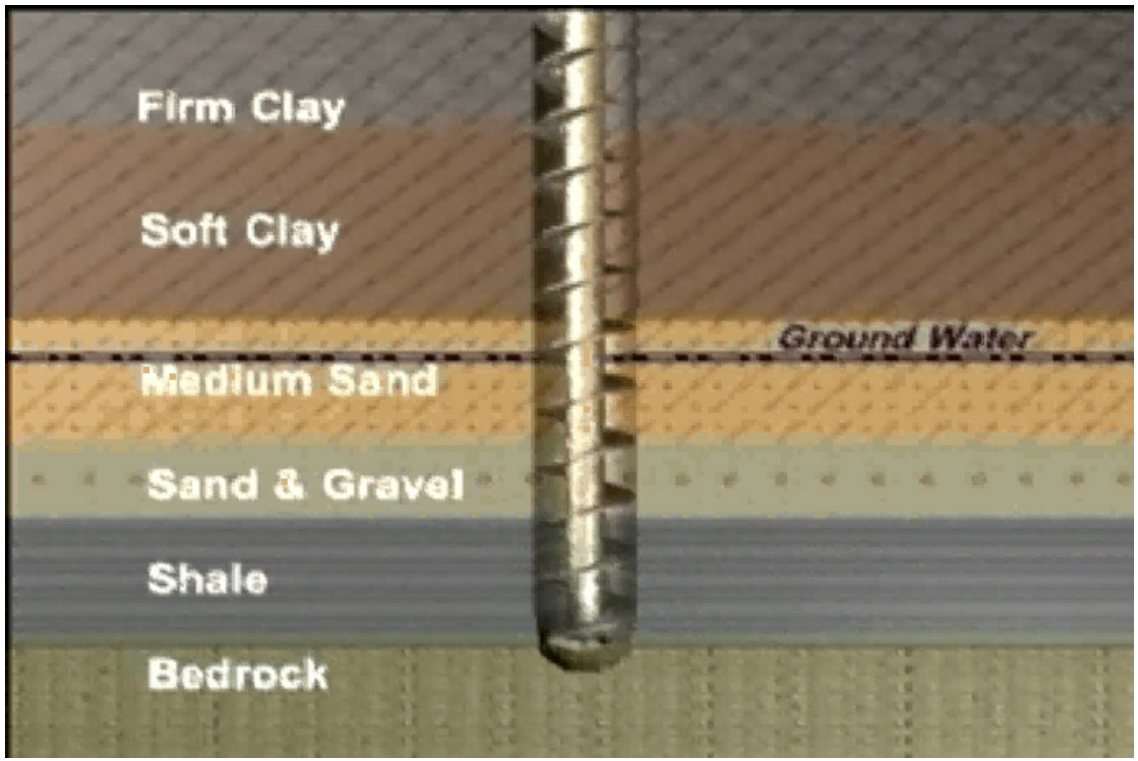
- Speed of Installation
- High Capacity
- Economic
- Adaptable to Limited Access Areas
- Minimal Vibrations from Installation
- Installation Independent from Soil Conditions

What are APG and APGD piles?



APG Piling Rig

Berkel & Company



APG PILE INSTALLATION

APG Piling Rig

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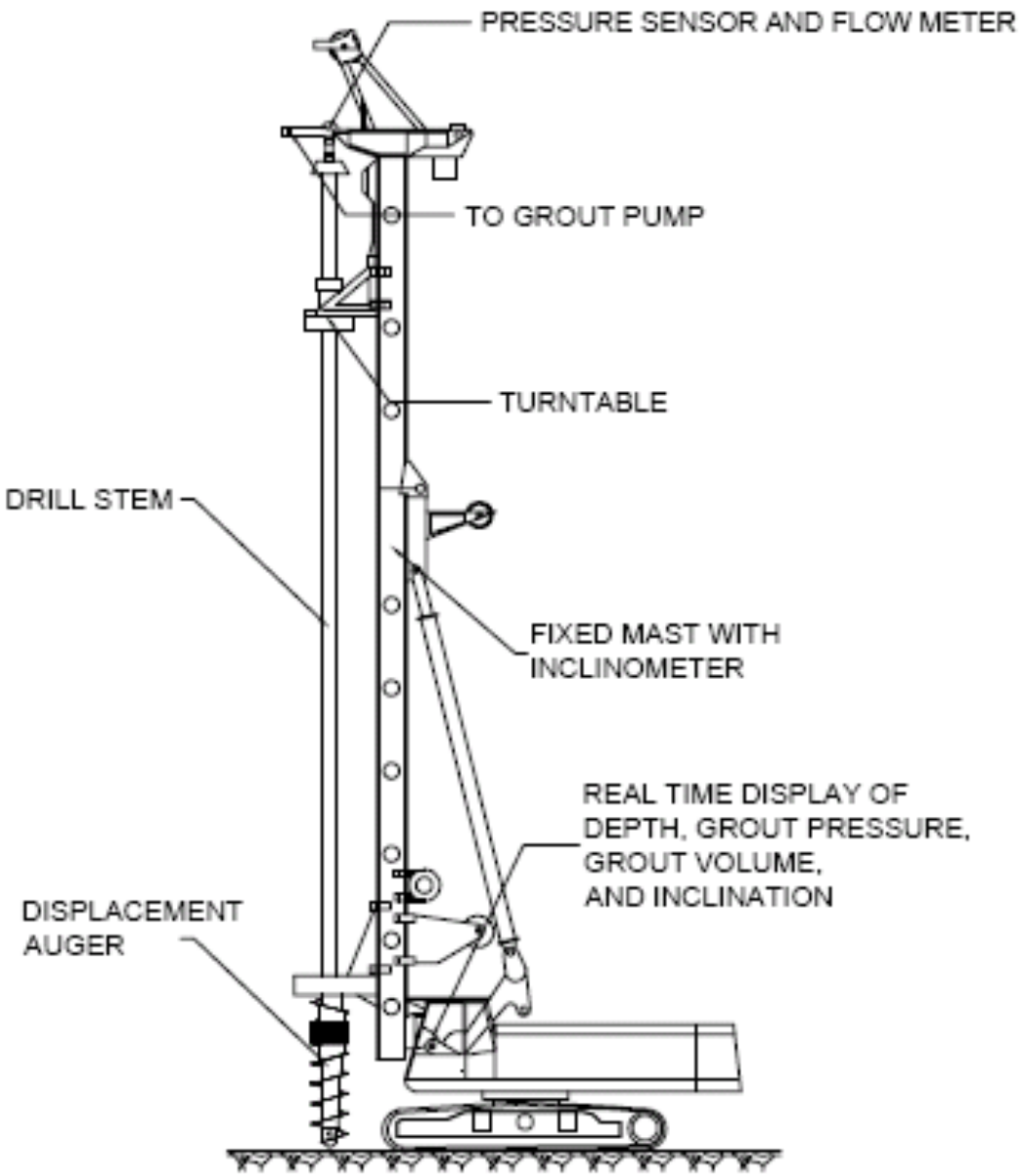
Crane Pile Installation

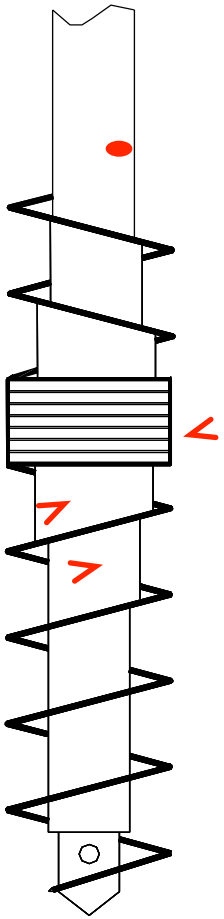


APGD Piling Rig

Berkel Displacement Pile Tool

Reverse flighting

Stem becomes progressively larger, terminating in the displacing element

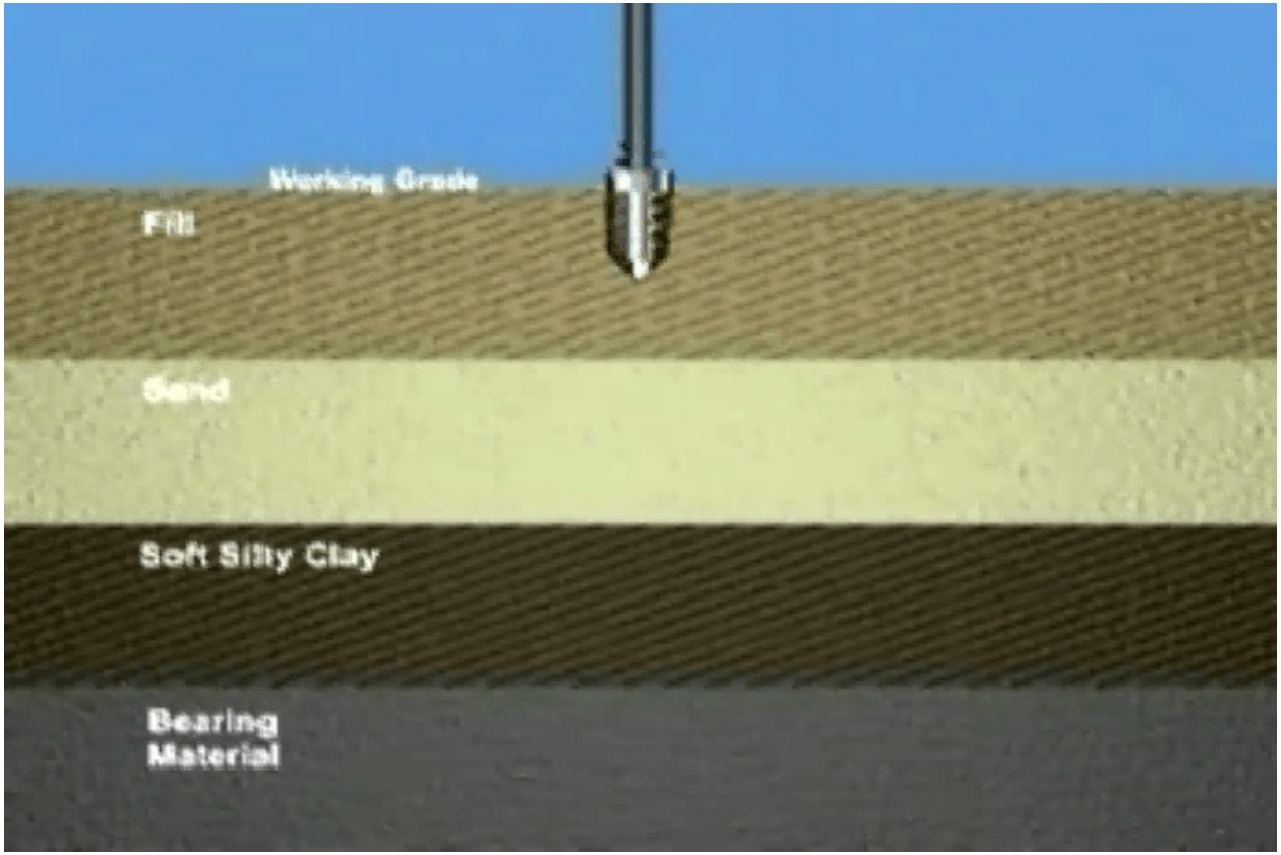


Stem, smaller than flighting

Displacing element. Same diameter as the flighting below

+- 3 feet, regular flighting,

12” to 18” diameter



APGD PILE INSTALLATION

APGD Piling Rig

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PILE LOAD TESTING

Pile Load Test in Static Compression

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High Strain Dynamic Test

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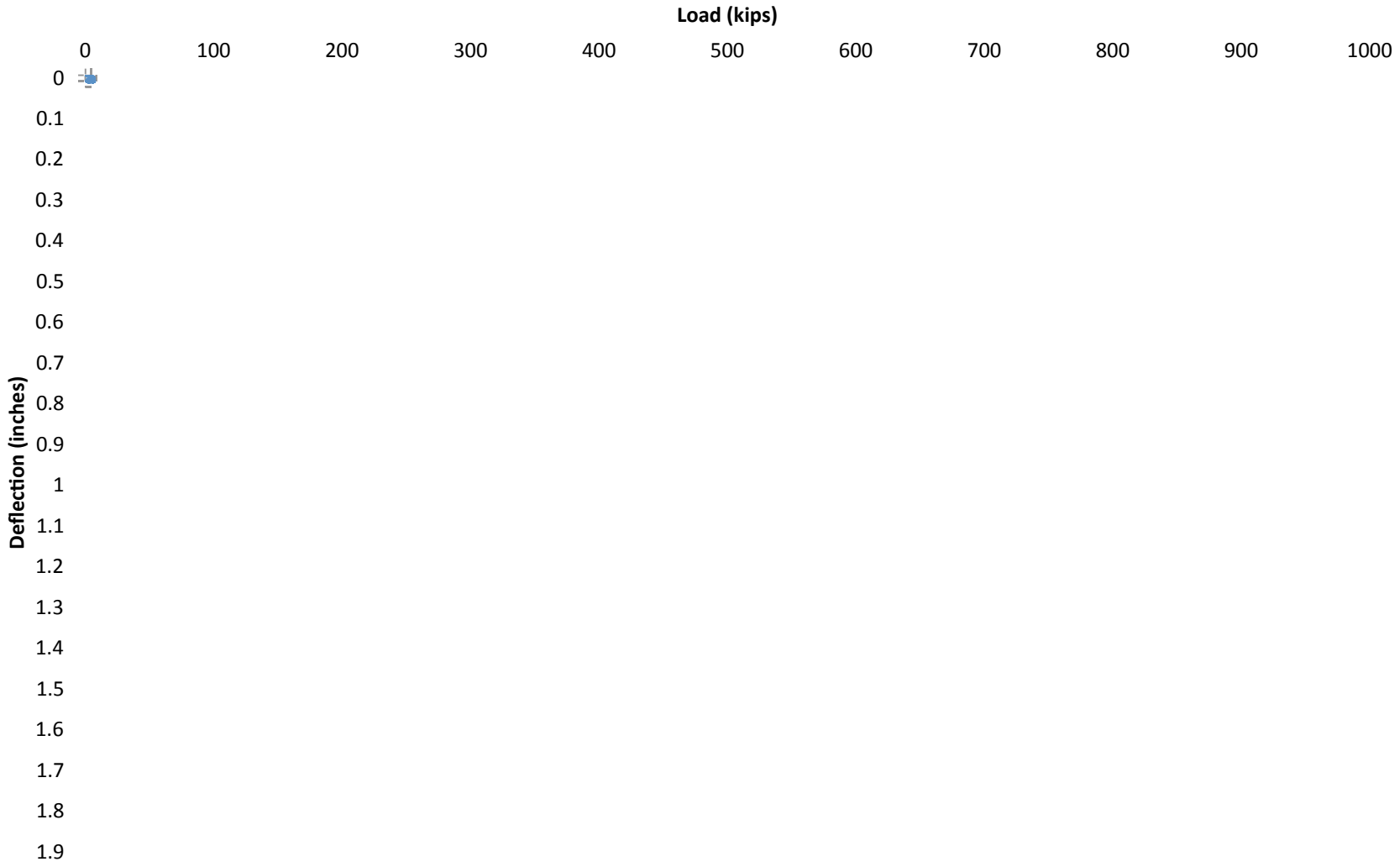

Load vs. Deflection Plot

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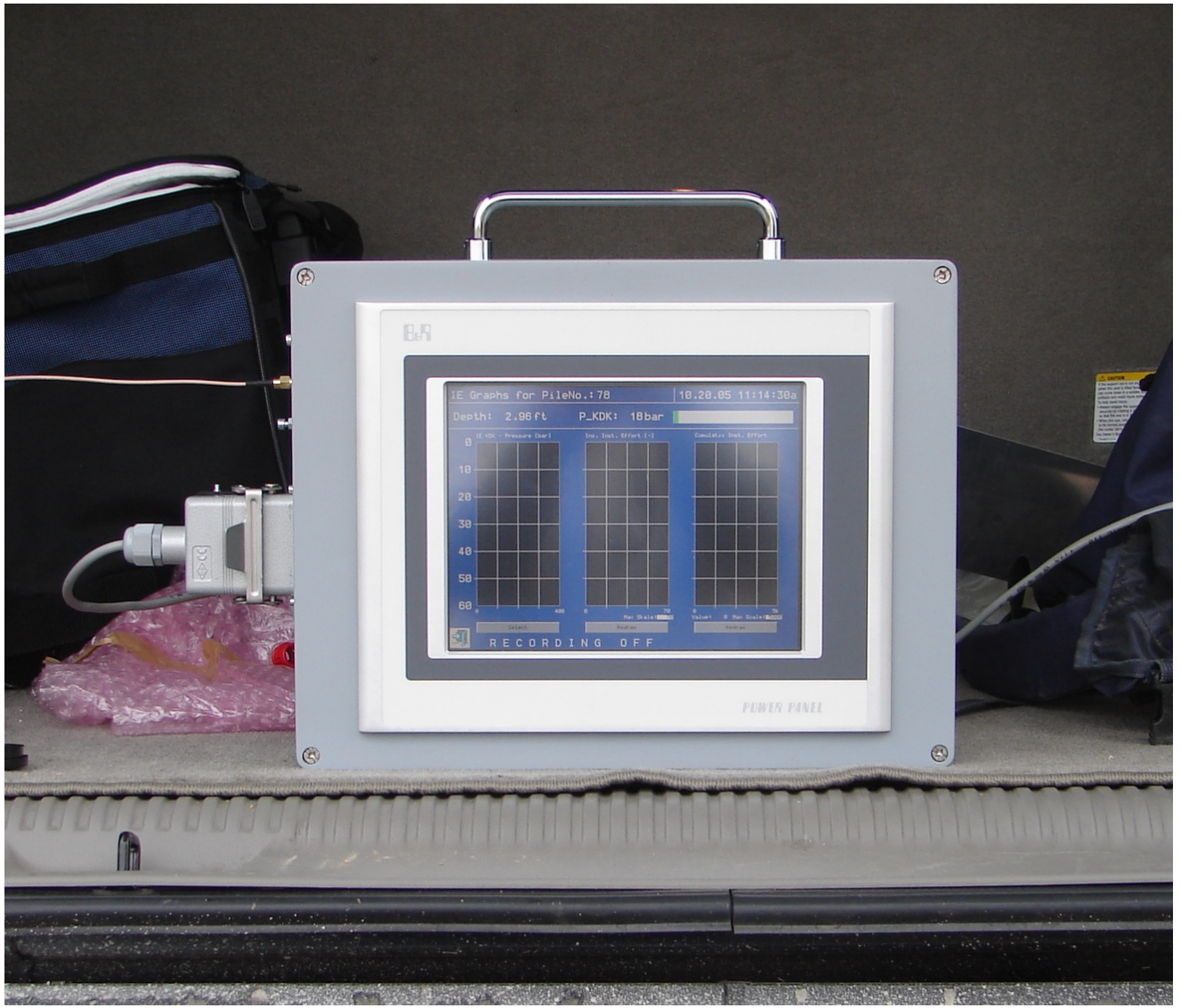
Automated Monitoring Equipment (AME)


Stem Rotation Proximity Sensor
Grout Pressure Transducer
Overview of Drilling Platform and Sensors
Main Wench Proximity Sensor (Depth)
Inclinometer
Hydraulic Fluid (turntable) Pressure Sensor

Automated Monitoring Equipment

Berkel & Company



Inspector's Remote Monitor

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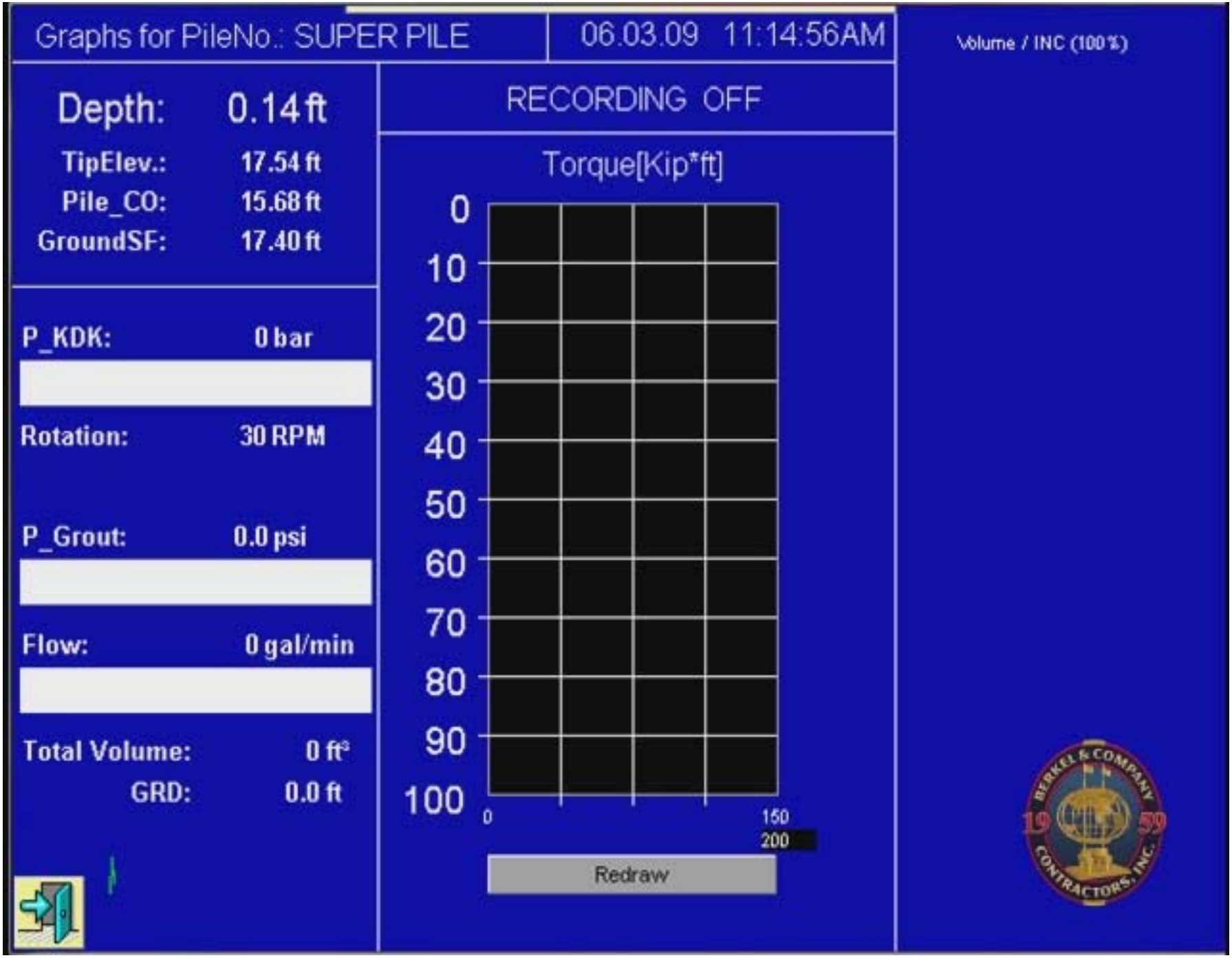
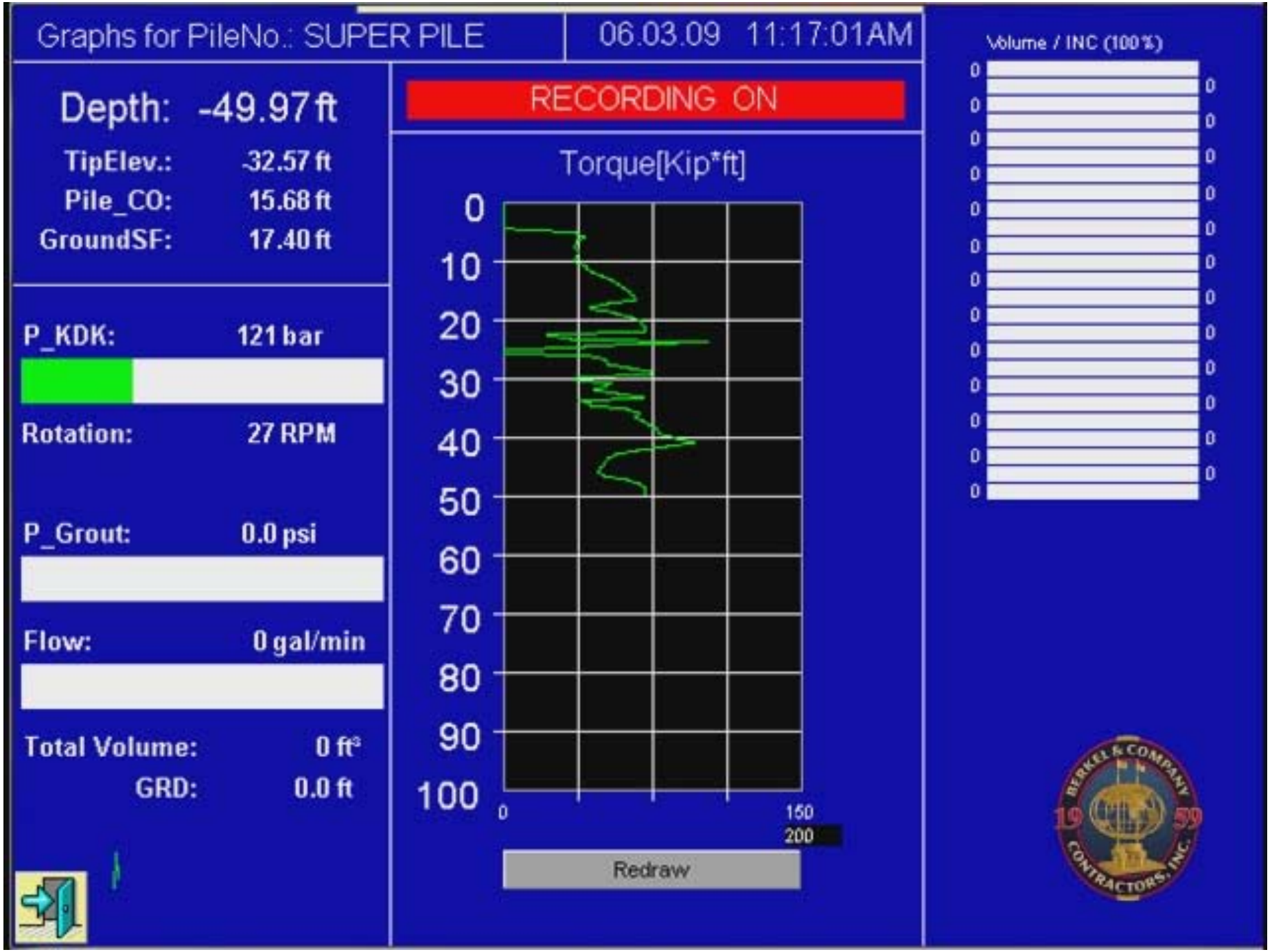
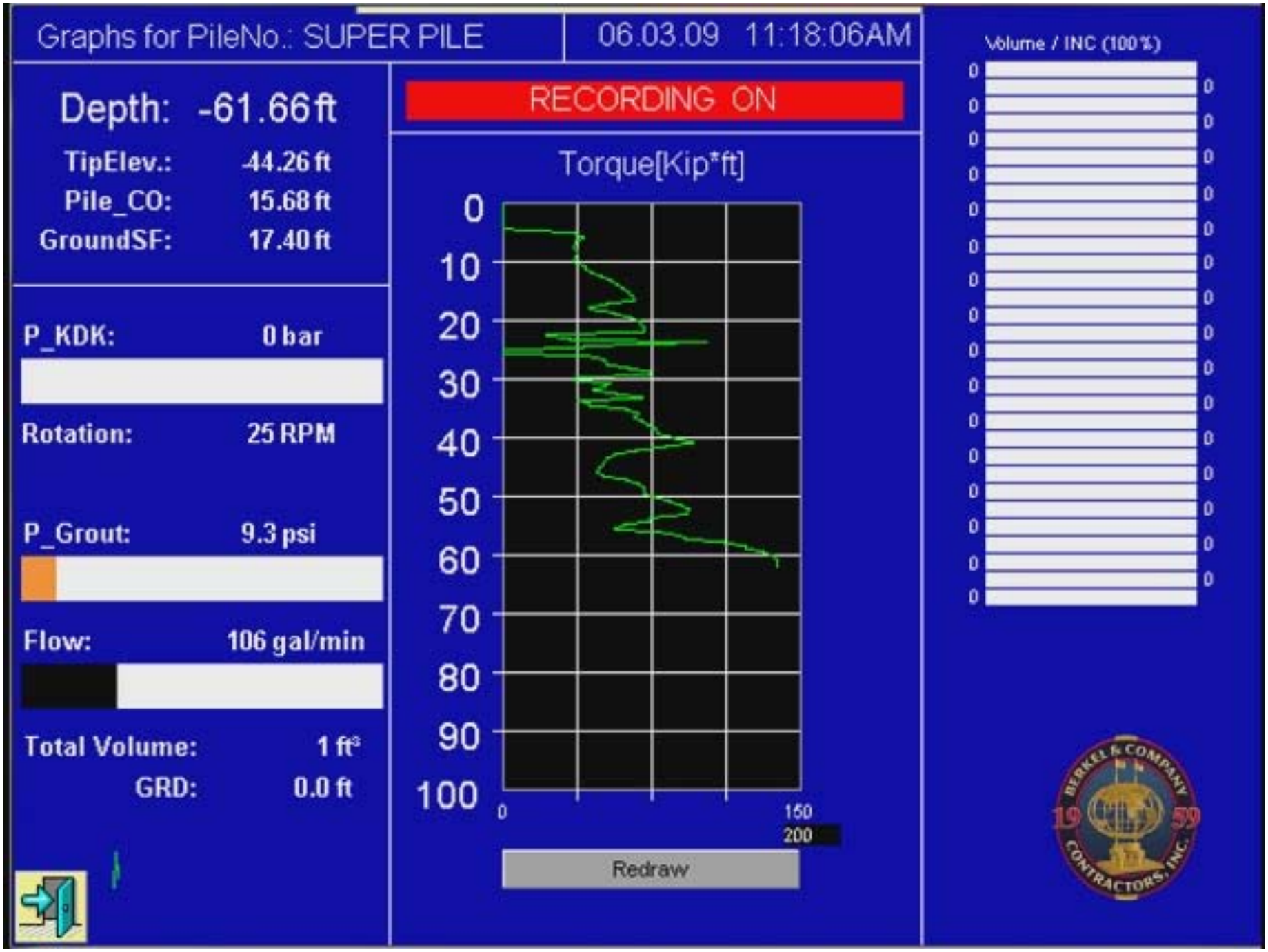
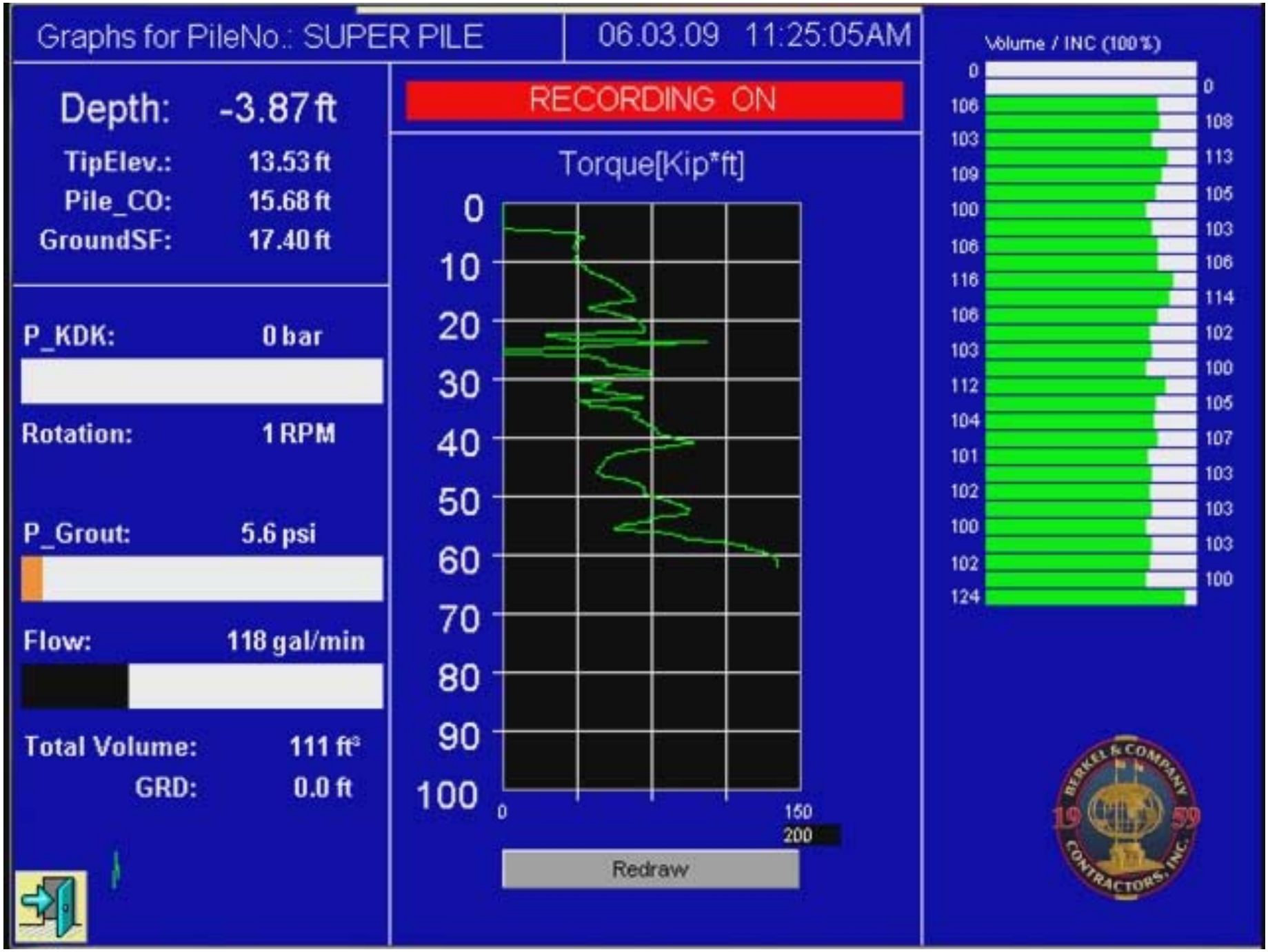

Graphs for PileNo.: SUPER PILE
06.03.09 11:14:56AM
Volume / INC (100%)
Depth: 0.14 ft
TipElev.: 17.54 ft
Pile_CO: 15.68 ft
GroundSF: 17.40 ft
RECORDING OFF
Torque[Kip*ft]
0
10
20
30
40
50
60
70
80
90
100
0
150
200
P_KDK: 0 bar
Rotation: 30 RPM
P_Grout: 0.0 psi
Flow: 0 gal/min
Total Volume: 0 ft³
GRD: 0.0 ft
Redraw
BERKEL & COMPANY
19
59
CONTRACTORS, INC.


Pile No.: SUPER PILE
Berkel&Co.
0
03.06.09 11:16:26AM
Depth: -34.05ft
Tipelev.: -16.65ft
Rec Time: 01 : 24
Max Depth: -34.05 ft
Penetration:
22 ft/min
Rotation:
29 RPM
P-Grout:
0.0 psi
P-KDK:
69 bar
Torque:
58 Kip*ft
F: 6
No Errors Mode: Flowmeter
Sensors are ok


Graphs for PileNo.: SUPER PILE
06.03.09 11:17:01AM
Depth: -49.97 ft
TipElev.: 32.57 ft
Pile_CO: 15.68 ft
GroundSF: 17.40 ft
RECORDING ON
Torque[Kip*ft]
0
10
20
30
40
50
60
70
80
90
100
0
150
200
Redraw
P_KDK: 121 bar
Rotation: 27 RPM
P_Grout: 0.0 psi
Flow: 0 gal/min
Total Volume: 0 ft³
GRD: 0.0 ft
Volume / INC (100%)
BERKEL & COMPANY
CONTRACTORS, INC.
19 59


Graphs for PileNo.: SUPER PILE
06.03.09 11:18:06AM
Depth: -61.66 ft
TipElev.: -44.26 ft
Pile_CO: 15.68 ft
GroundSF: 17.40 ft
RECORDING ON
Torque[Kip*ft]
0
10
20
30
40
50
60
70
80
90
100
0
150
200
Redraw
P_KDK: 0 bar
Rotation: 25 RPM
P_Grout: 9.3 psi
Flow: 106 gal/min
Total Volume: 1 ft³
GRD: 0.0 ft
Volume / INC (100%)
BERKEL & COMPANY CONTRACTORS, INC.
19 59


Pile No.: SUPER PILE
Berkel&Co.
0
03.06.09 11:18:09AM
Depth: -61.21 ft
Tipelev.: -43.81 ft
Rec Time: 03 : 07
Max Depth: -62.19 ft
Penetration: 8 ft/min
Rotation: 25 RPM
P-Grout: 22.4 psi
P-KDK: 0 bar
Flow: 106 gal/min
GRD: 0.0 ft
LastInc: 0
Remdepth
Volume:
Step 31 from 31
RD: 0.02 ft
Need: 1.8 ft³
Act.: 2.1 ft³
Perc.: 119 %
Volume: 2 ft³
Perc.: 2 %
F: 6
No Errors Mode: Flowmeter
Sensors are ok


Graphs for PileNo.: SUPER PILE
06.03.09 11:25:05AM
Depth: -3.87 ft
TipElev.: 13.53 ft
Pile_CO: 15.68 ft
GroundSF: 17.40 ft
RECORDING ON
Torque[Kip*ft]
0
10
20
30
40
50
60
70
80
90
100
0
150
200
Redraw
P_KDK: 0 bar
Rotation: 1 RPM
P_Grout: 5.6 psi
Flow: 118 gal/min
Total Volume: 111 ft³
GRD: 0.0 ft
Volume / INC (100%)
0 106 103 109 100 106 116 106 103 112 104 101 102 100 102 124
0 108 113 105 103 106 114 102 100 105 107 103 103 103 100
BERKEL & COMPANY CONTRACTORS, INC. 19 59

Berkel & Company
APGD Pile Installation Record
Drill Simulation

Job Site Data:

Project name: Super Pile '09
Project #: 06-2009
Contractor: San Francisco
City: DFI
State: CA
Machine#: 913

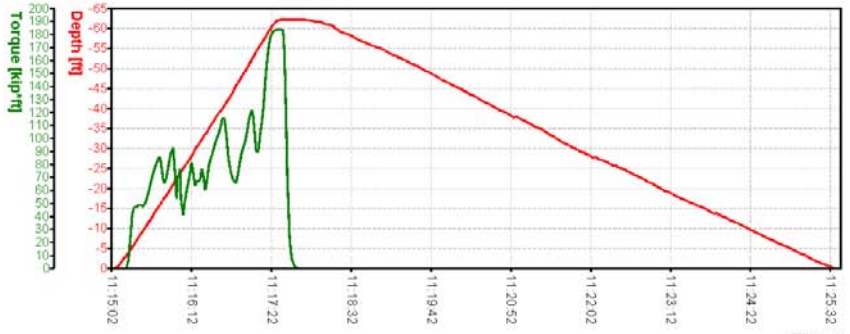
Pile Data for Pile No: SUPERPILE '09

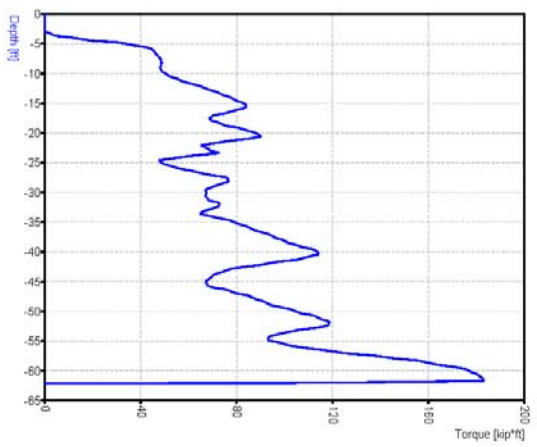
Date: 6/3/2009
Start Time: 11:15:02 AM
End Time: 11:25:41 AM
Total Time: 00:10:39

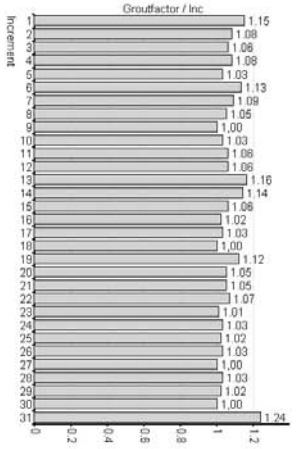
Max Drill Depth: 62.19 ft
Finished Pile Length: 60.47 ft
Pile Tip Elevation: -44.79 ft
Ground Surface Elevation: 17.40 ft
Pile Cut Off Elevation: 15.68 ft

Elapsed Drilling Time: 00:02:26
Elapsed Grouting Time: 00:07:43
Total Pause Time: 00:00:00

Theoretical Pile Volume: 106.90 ft³
Total Grout Volume: 113.06 ft³
Total Grout Factor: 1.06







INC 31 = 1 ft INC 30 = 1.47 ft
INC 29 - 1 = 2 ft

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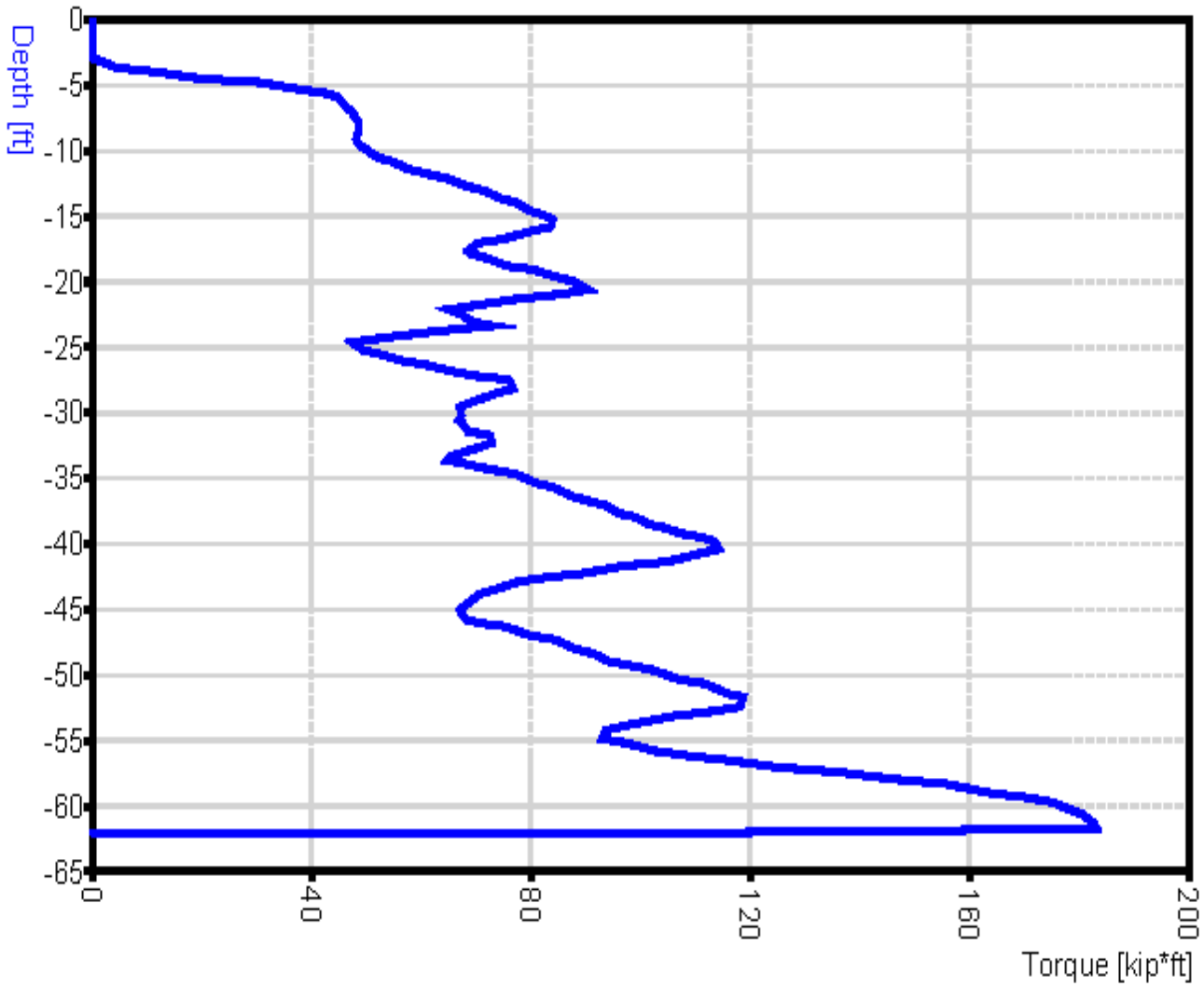
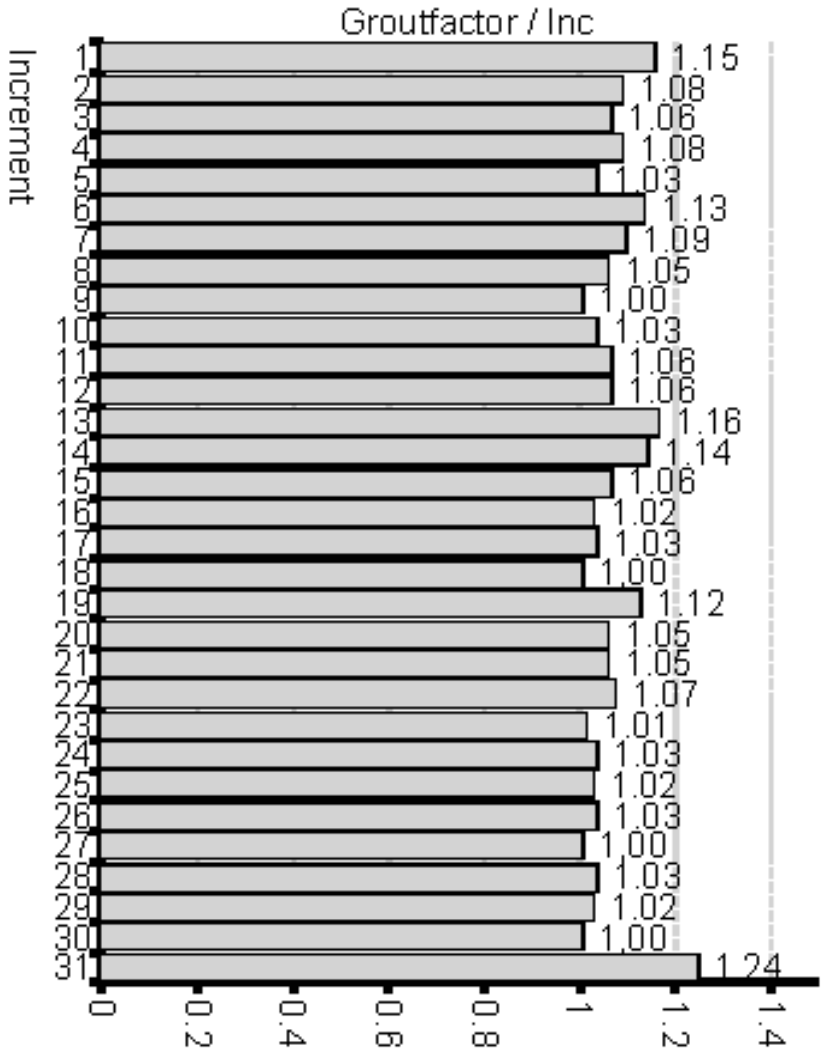


Auger Torque vs. Depth



INC 31 = 1 ft INC 30 = 1.47 ft
INC 29 - 1 = 2 ft

Incremental Grout Factors

Pile Data for Pile No: SUPERPILE '09

Date:	6/3/2009	Max Drill Depth:	62.19 ft
Start Time:	11:15:02 AM	Finished Pile Length:	60.47 ft
End Time:	11:25:41 AM	Pile Tip Elevation:	-44.79 ft
Total Time:	00:10:39	Ground Surface Elevation:	17.40 ft
		Pile Cut Off Elevation:	15.68 ft
Elapsed Drilling Time:	00:02:26	Theoretical Pile Volume:	106.90 ft^3
Elapsed Grouting Time:	00:07:43	Total Grout Volume:	113.06 ft^3
Total Pause Time:	00:00:00	Total Grout Factor:	1.06

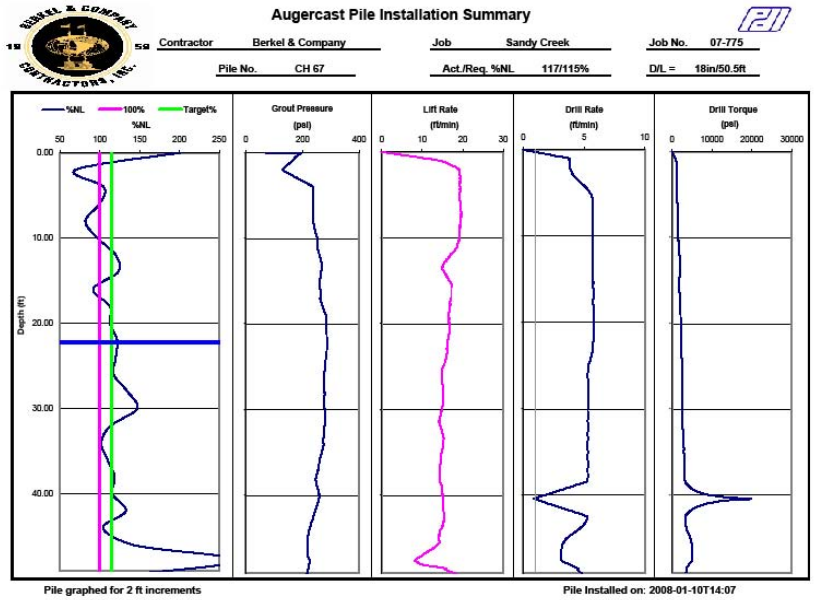
Summary Data

PIR-A Components

Control Unit

Magnetic Flowmeter

PIR-A Data



Production Summary Sheet

Contractor: BERKEL & COMPANY
Job: SANDY CREEK

Pile Name	Date / Time Installed	Drill Footage (ft)	Pile Volume (yrds)	Drill Time (h:mm:ss)	Bottom Time (h:mm:ss)	Grout Time (h:mm:ss)	Install Time (h:mm:ss)
	Total			Average			
	86 Piles	4336 ft	314 yrds	0:12:11	0:01:21	0:05:03	0:18:35
CH 07	1/7/08 1:19 PM	50.0	3.68	0:09:57	0:00:36	0:03:01	0:13:34
CH 01	1/14/08 11:11 AM	50.6	3.58	0:16:19	0:00:27	0:17:22	0:34:08
CH 02	1/11/08 12:38 PM	50.5	3.72	0:14:25	0:00:32	0:03:50	0:18:47
CH 03	1/9/08 1:08 PM	50.5	3.46	0:16:03	0:00:33	0:03:53	0:20:29
CH 04	1/8/08 12:21 PM	50.5	3.66	0:09:55	0:00:11	0:03:59	0:14:05
CH 05	1/7/08 4:35 PM	50.6	3.86	0:12:09	0:00:05	0:03:45	0:15:59
CH 06	1/8/08 11:57 AM	50.5	3.51	0:11:29	0:00:09	0:03:24	0:15:02
CH 08	1/14/08 10:15 AM	50.5	3.86	0:10:26	0:00:41	0:03:44	0:14:51
CH 09	1/11/08 12:19 PM	50.5	3.87	0:12:51	0:00:18	0:03:51	0:17:00
CH 10	1/14/08 9:37 AM	50.5	3.89	0:15:14	0:00:33	0:03:43	0:19:30
CH 11	1/11/08 8:52 AM	50.5	3.72	0:11:09	0:00:19	0:03:41	0:15:09
CH 12	1/14/08 8:47 AM	50.5	3.73	0:12:34	0:00:23	0:03:43	0:16:40
CH 13	1/9/08 12:29 PM	50.5	3.56	0:12:59	0:00:20	0:03:47	0:17:06
CH 14	1/11/08 8:27 AM	50.5	3.61	0:10:45	0:00:17	0:04:05	0:15:07
CH 15	1/9/08 12:04 PM	50.5	3.57	0:14:24	0:00:36	0:03:46	0:18:46
CH 16	1/8/08 11:35 AM	50.5	3.47	0:11:51	0:00:11	0:03:19	0:15:21
CH 17	1/14/08 10:48 AM	50.5	3.81	0:13:28	0:00:15	0:03:46	0:17:29
CH 18	1/11/08 10:54 AM	50.5	3.68	0:10:50	0:00:15	0:03:20	0:14:25
CH 19	1/14/08 11:48 AM	50.5	4.31	0:16:01	0:00:16	0:04:02	0:20:19
CH 20	1/11/08 11:18 AM	50.5	3.67	0:12:02	0:00:44	0:42:18	0:55:04
CH 21	1/9/08 3:31 PM	50.5	3.45	0:12:39	0:00:21	0:03:36	0:16:36
CH 22	1/8/08 4:06 PM	50.5	3.72	0:30:39	0:00:19	0:05:41	0:36:39
CH 24	1/8/08 3:36 PM	50.5	3.86	0:09:56	0:00:16	0:04:07	0:14:19
CH 25	1/11/08 7:31 AM	50.5	3.78	0:15:07	0:31:44	0:03:20	0:50:11
CH 26	1/10/08 3:20 PM	50.5	3.65	0:13:10	0:00:17	0:03:34	0:17:01
CH 27	1/7/08 12:57 PM	50.0	3.53	0:08:41	0:00:38	0:02:45	0:12:04
CH 28	1/10/08 4:11 PM	50.5	3.51	0:12:35	0:00:18	0:03:23	0:16:16
CH 29	1/14/08 9:12 AM	50.5	3.58	0:10:45	0:00:35	0:10:09	0:21:29
CH 30	1/11/08 10:25 AM	50.5	3.59	0:13:30	0:00:29	0:03:08	0:17:07
CH 31	1/14/08 8:15 AM	50.5	3.87	0:10:19	0:00:35	0:18:37	0:29:31
CH 32	1/9/08 3:04 PM	50.5	3.40	0:12:42	0:00:21	0:03:30	0:16:33
CH 34	1/9/08 11:37 AM	50.5	3.68	0:13:32	0:00:30	0:03:44	0:17:46
CH 35	1/8/08 11:16 AM	50.5	3.67	0:11:08	0:00:13	0:03:23	0:14:44
CH 36	1/14/08 7:48 AM	50.5	3.75	0:17:20	0:00:28	0:03:44	0:21:32
CH 37	1/11/08 10:04 AM	50.5	3.65	0:11:50	0:00:26	0:03:33	0:15:49
CH 38	1/10/08 3:51 PM	50.5	3.70	0:12:07	0:00:21	0:03:35	0:16:03
CH 39	1/10/08 2:59 PM	50.5	3.44	0:12:56	0:00:17	0:03:30	0:16:43
CH 40	1/8/08 3:13 PM	50.5	3.74	0:10:55	0:00:33	0:03:38	0:15:06
CH 41	1/7/08 12:42 PM	50.1	3.62	0:07:53	0:00:04	0:03:33	0:11:30
CH 42	1/8/08 7:51 AM	50.5	3.73	0:11:43	0:00:12	0:03:41	0:15:36
CH 43	1/9/08 7:55 AM	50.5	3.71	0:13:15	0:38:48	0:03:32	0:55:35
CH 44	1/11/08 9:32 AM	50.5	3.79	0:09:28	0:07:01	0:10:51	0:27:20
CH 46	1/9/08 11:12 AM	50.5	3.65	0:14:01	0:00:24	0:03:22	0:17:47
CH 47	1/8/08 10:50 AM	50.5	3.48	0:13:07	0:00:15	0:03:33	0:16:55
CH 48	1/7/08 1:54 PM	50.0	3.60	0:09:04	0:00:05	0:03:47	0:12:56
CH 49	1/8/08 1:40 PM	50.5	3.55	0:12:00	0:00:10	0:03:49	0:15:59

Nondestructive Testing (NDT)

NDT Controversy

- Many methods and versions available
- Experiences with NDT have ranged from very good to complete failure
- Reliability of methods have been questioned
- NDT practitioners are unwilling (or unable) to make quantitative judgements
- NDT creates more questions than answers

APG Piles Unique Properties

- Large length to diameter ratio (>30)
- High component of capacity in skin friction
- Pumping grout under pressure through layered soils produces multiple changes in cross-sectional area (bulges)
- These properties limit the applicability of certain types of NDT methods

Integrity Testing Methods

- Impulse echo methods - testing from the pile top with a hammer impact
- Limited to an L/D ratio <30
- Cannot detect small (< 1 ft long) defects
- Difficult to distinguish bulges and necking
- Use should be limited to providing additional information - not as a sole pass/fail indicator

Impulse Echo (PIT or PET)

Impulse Echo (PIT)

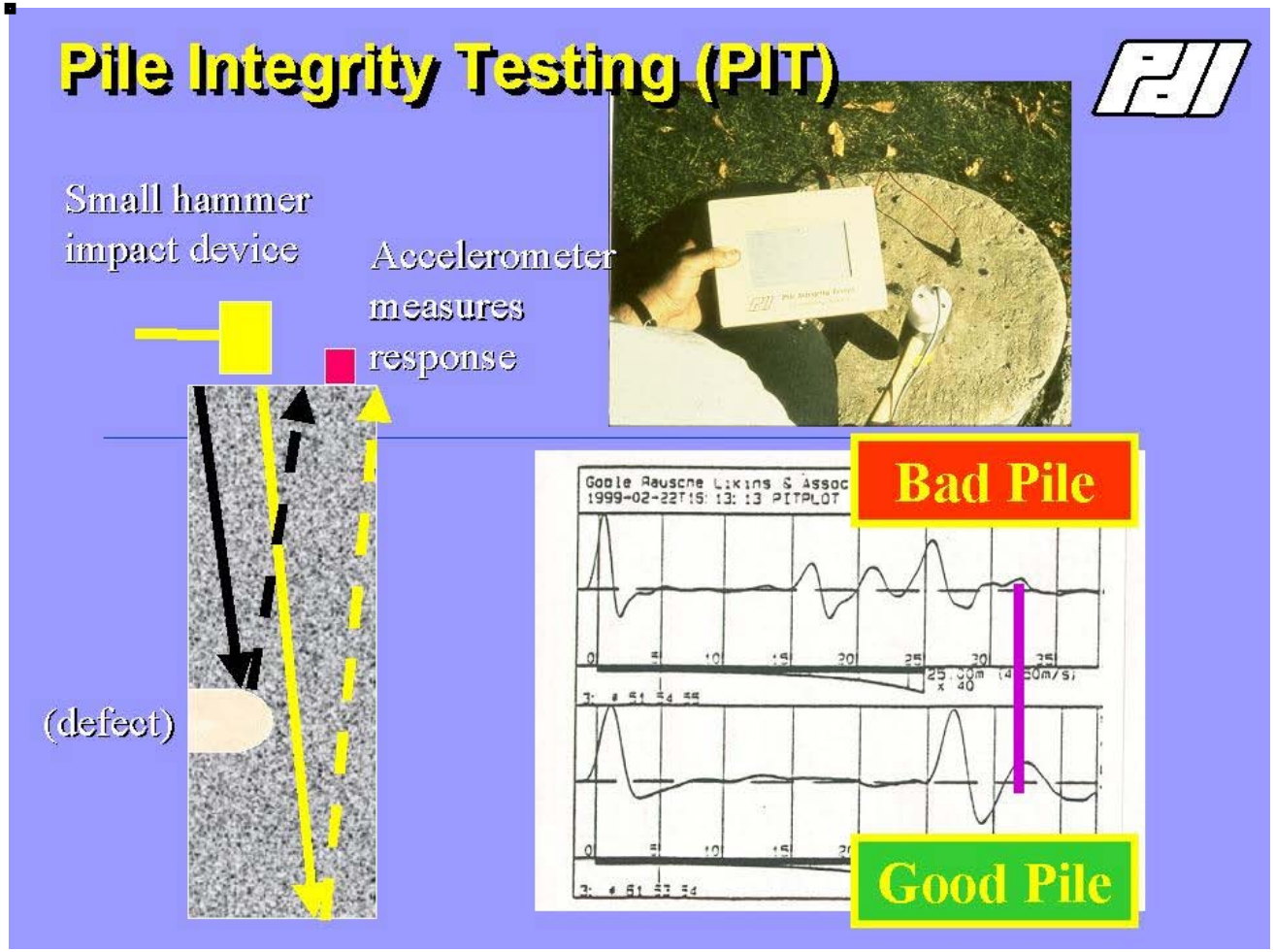
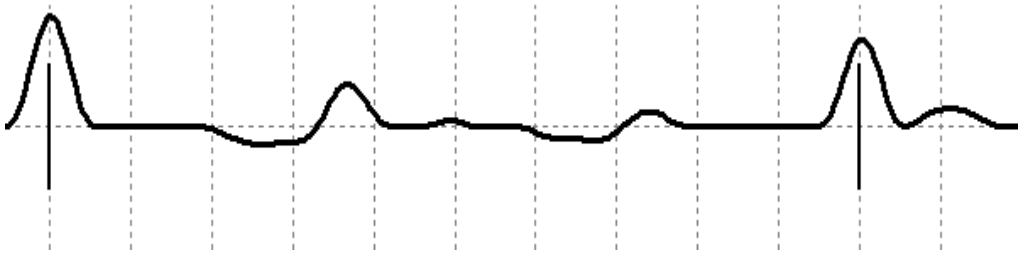


Figure courtesy of Pile Dynamics Inc

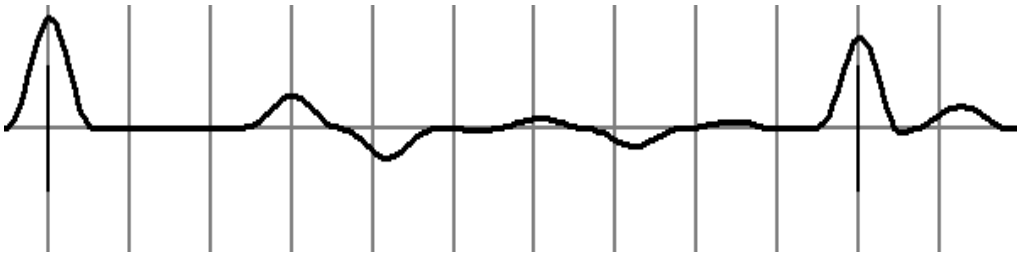
Records Can Be Difficult to Distinguish

A

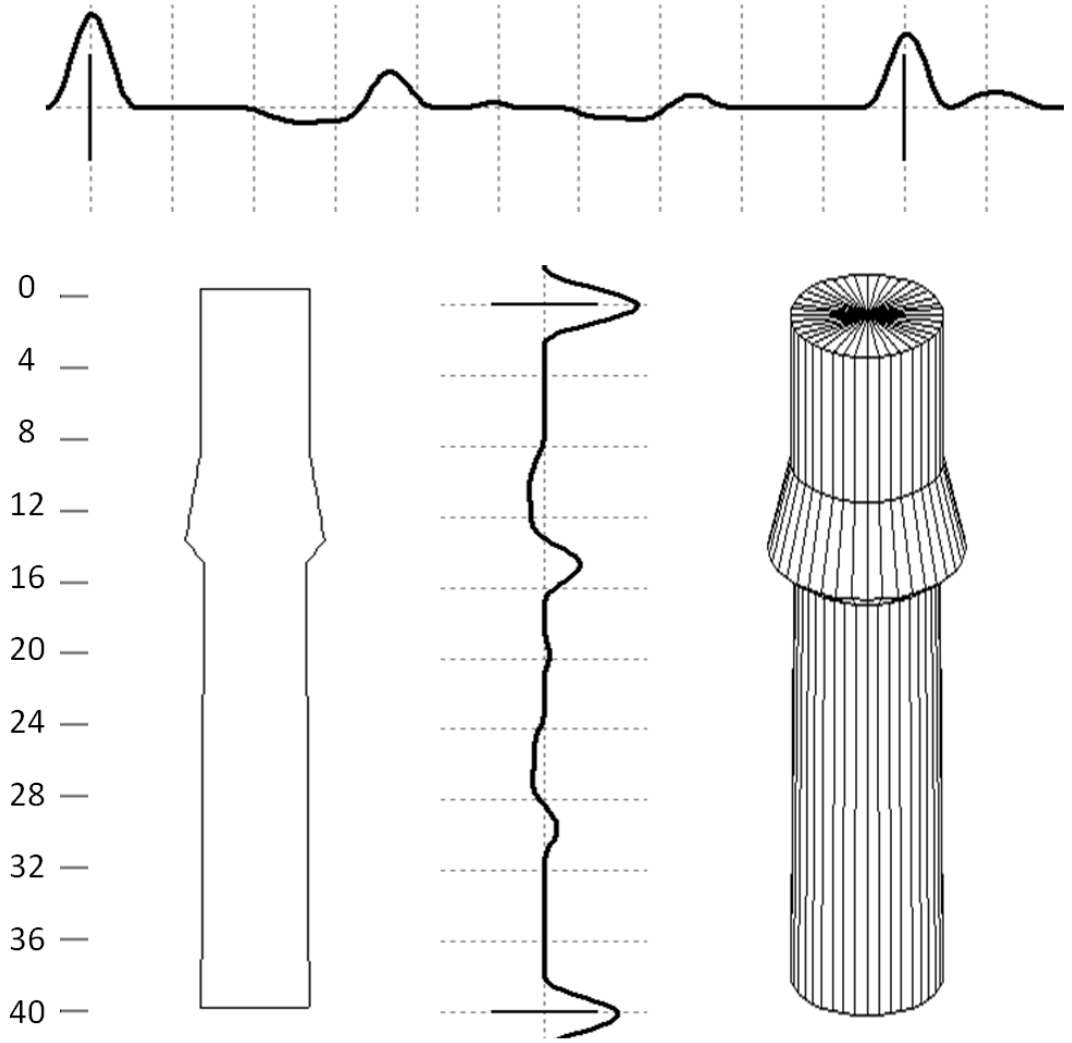


B

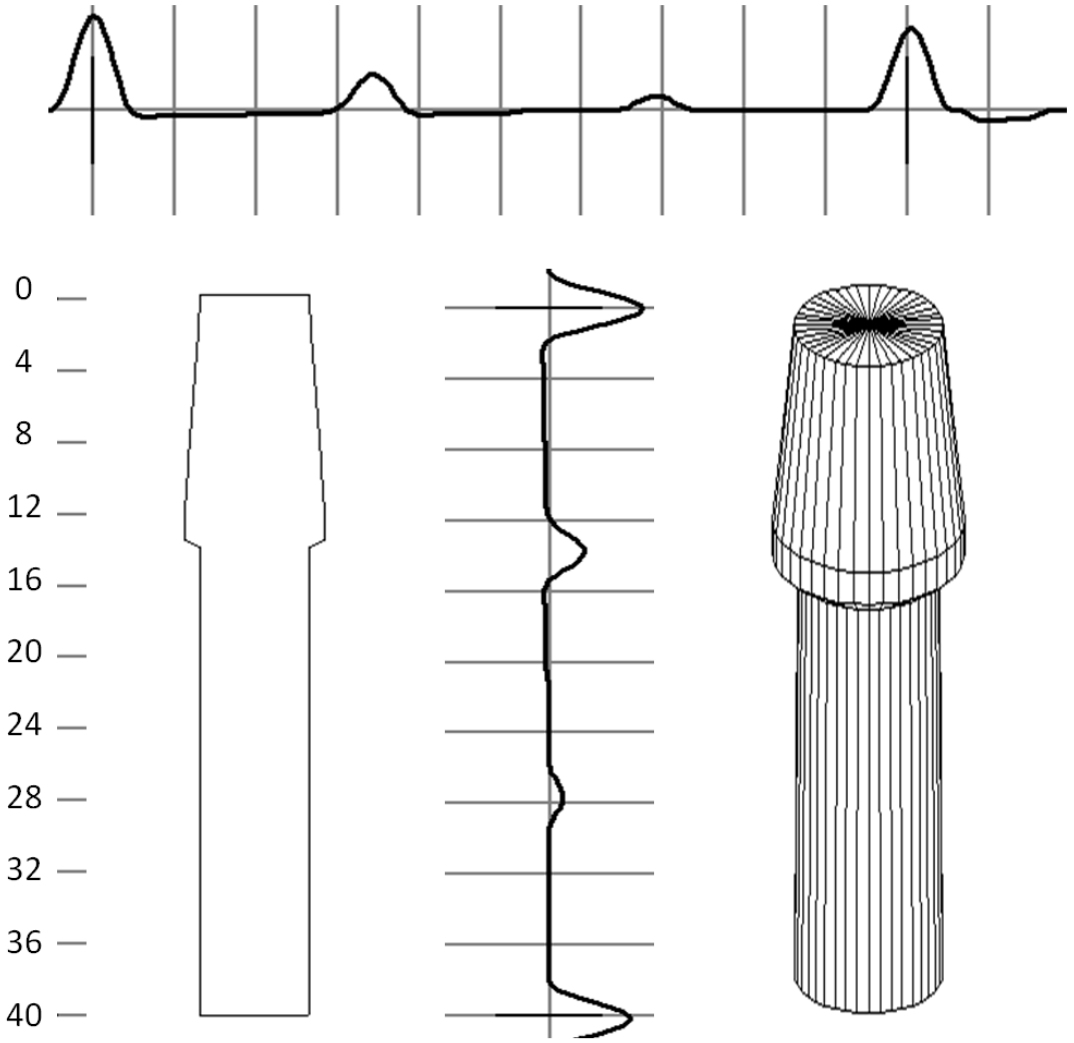
C



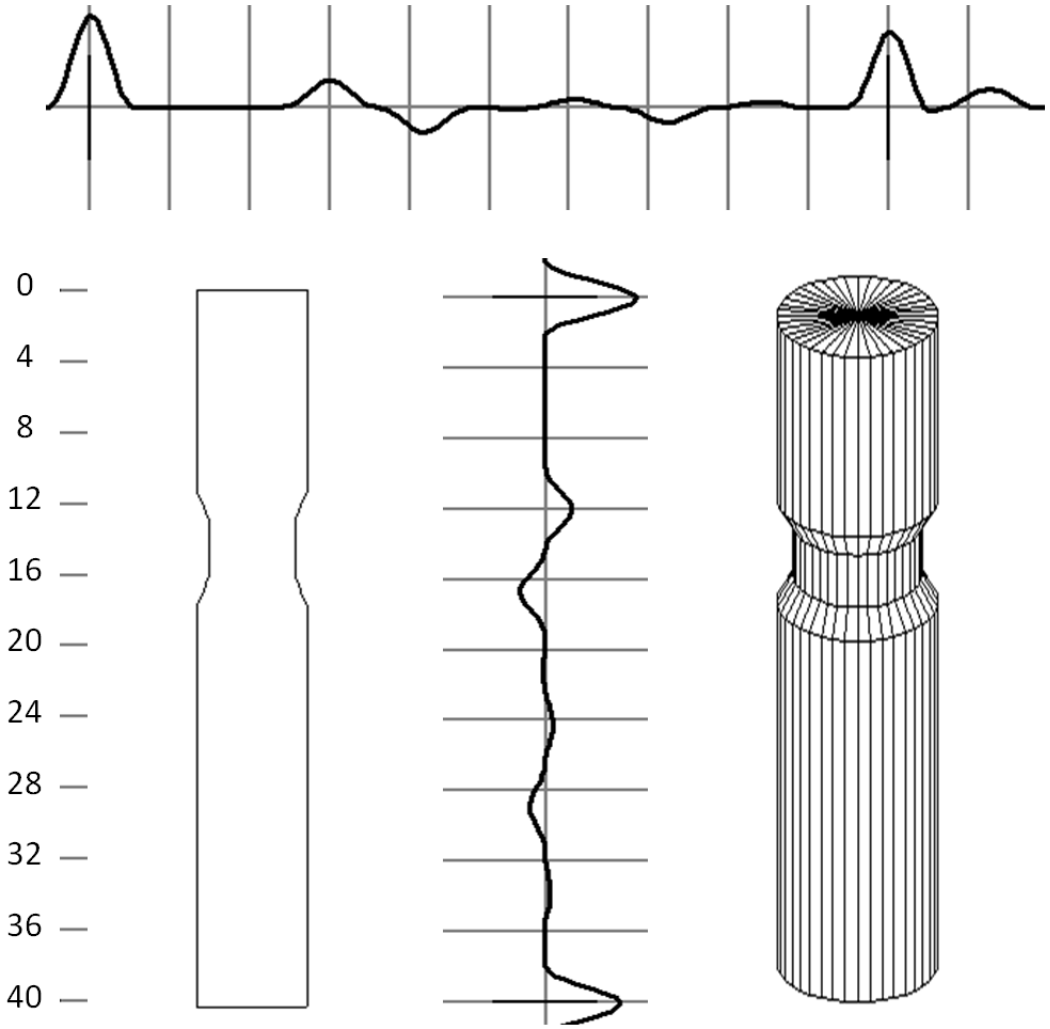
Simulated Response - Bulge



Simulated Response - Bulge



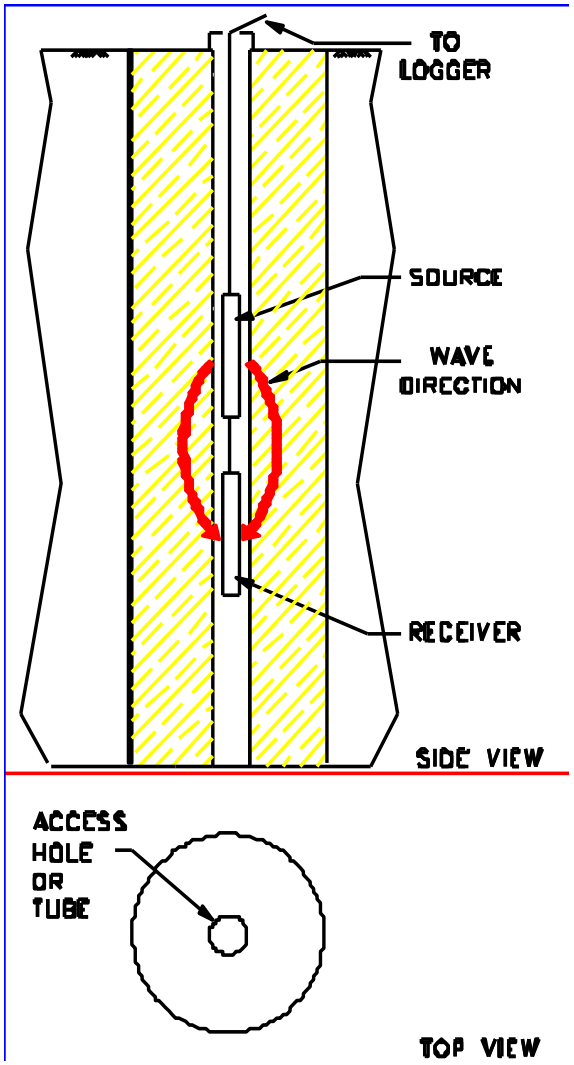
Simulated Response - Neck

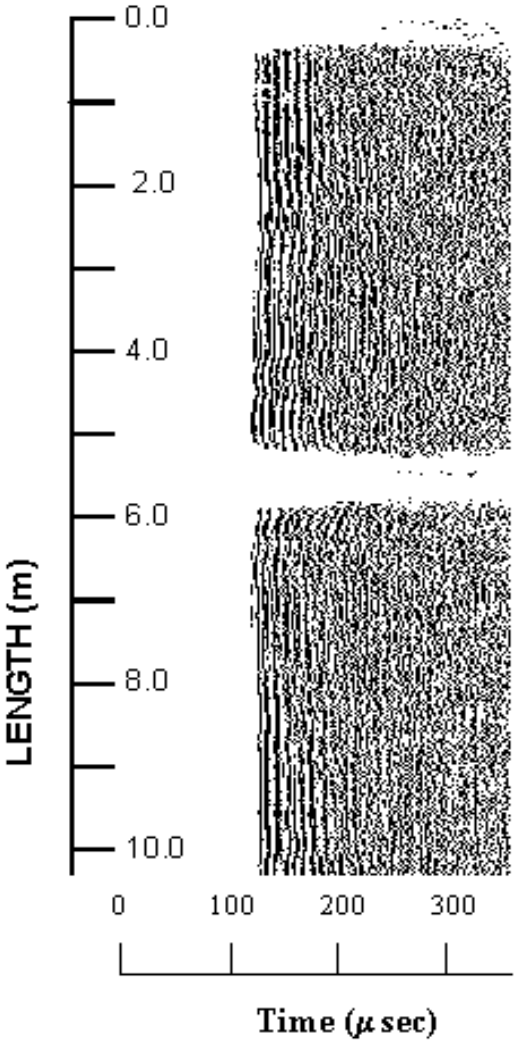


Sonic Logging

- Crosshole for large piles and singlehole for small (<24 inch) piles
- Developed to overcome sonic echo limitations
- Access tubes must be installed in piles
- Potential for debonding between PVC and grout is a problem
- Typical testing rate is 1 to 10%

SSL Set-Up and Sonic Log





Sonic Logging

NDT Summary

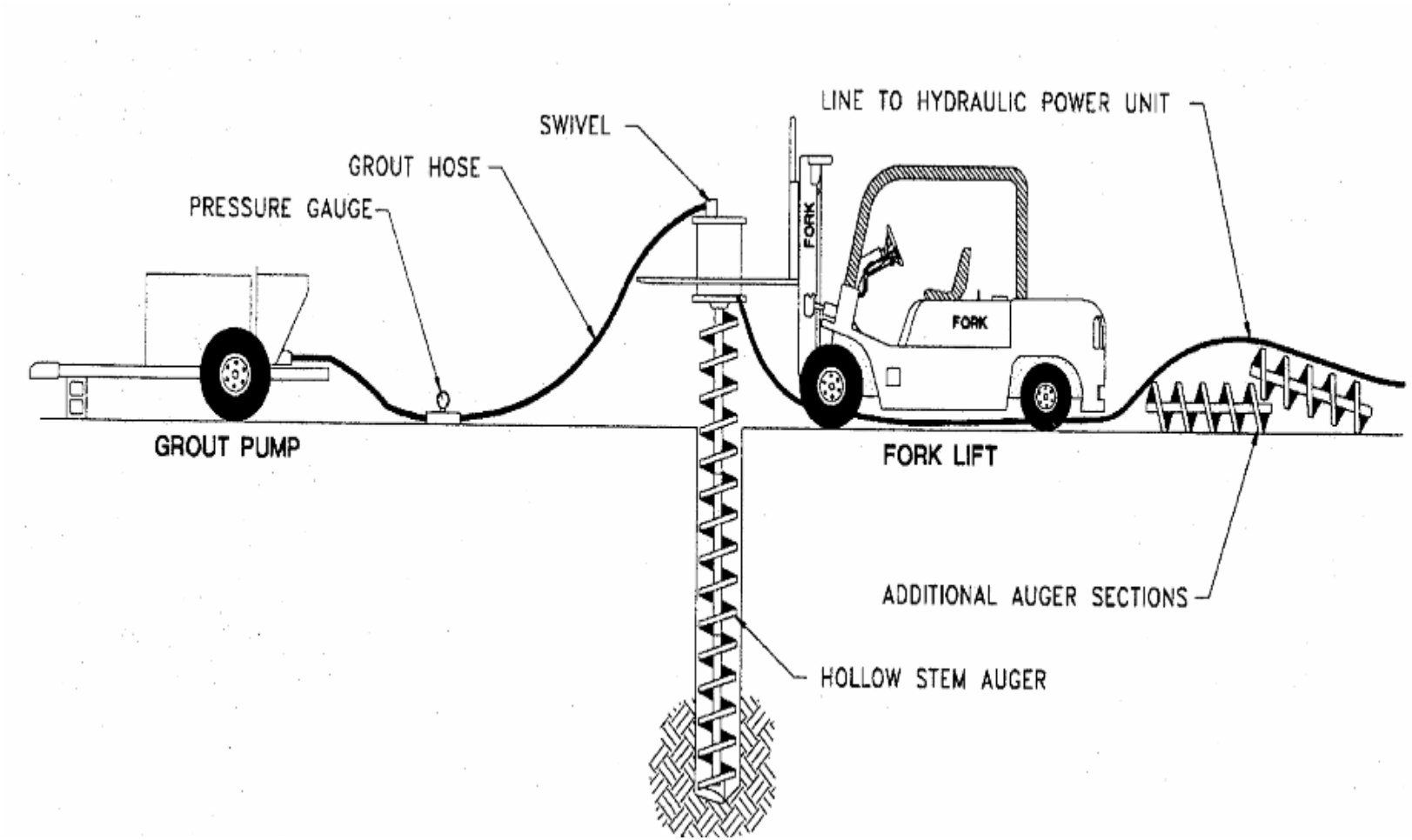
- **Evaluation of NDT records must include three initial steps**
  1. Review the soil conditions
  2. Review the detailed pile installation records
  3. Review the NDT records
- **Use this information to determine if the anomaly is indeed a defect in the pile**
- **A bulge in the pile would not be considered a defect**

Limited Headroom Application

Limited Head Room (LHR) Installation

- Used where overhead clearances are at least 8.5 ft
- Track-mounted or forklift mounted drilling equipment
- Piles are drilled with auger sections typically 3 ft to 10 ft in length
- Installation time much longer than with crane-mounted equipment

Typical Limited Head Room Rig



Track Mounted LHR Rig

Earth Retention

Earth Retention - Temporary

Earth Retention - Permanent

Ground Modification

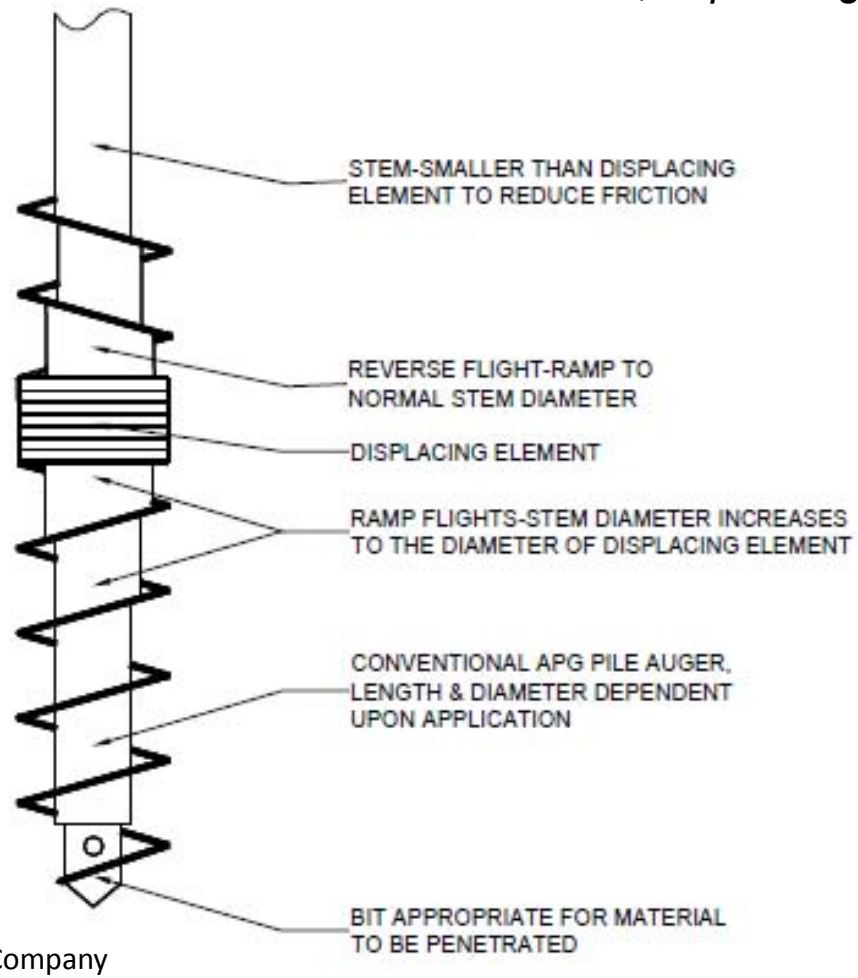
Ground Modification Systems

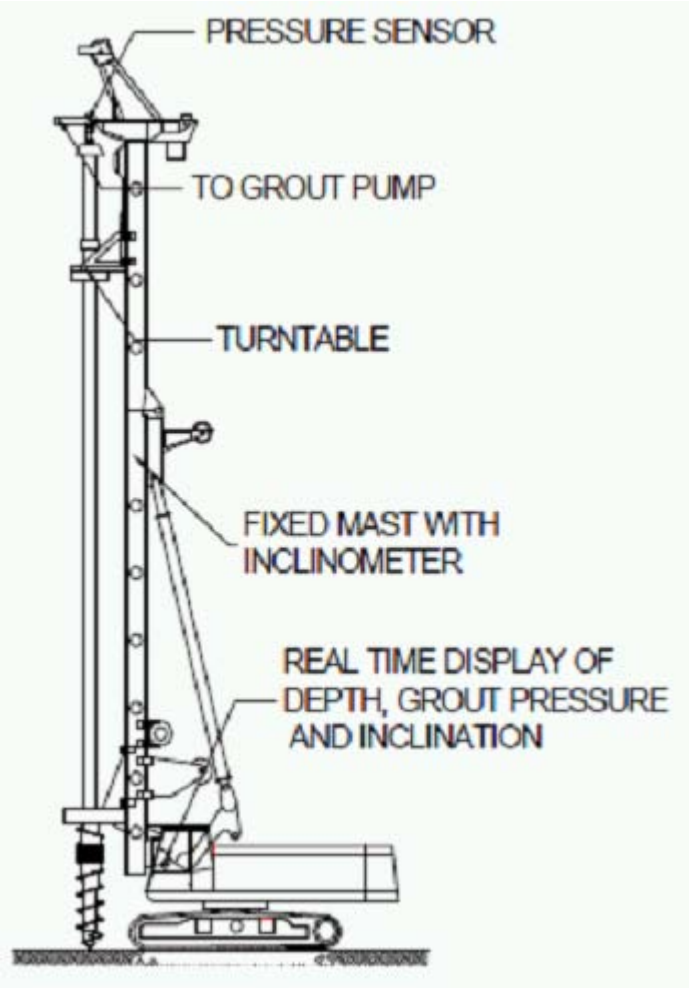
- Installation of displacement piles results in an increase in soil density
- Liquefaction mitigation
- Piled rafts using APGD piles to increase modulus of soil
- Cast-in-place ground improvement elements (CGE)
- Mechanically compacted ground improvement elements (MGE)

Cast-in-Place **G**round Improvement **E**lement**s**
CGE's

Same equipment and processes as auger pressure grouted displacement piles

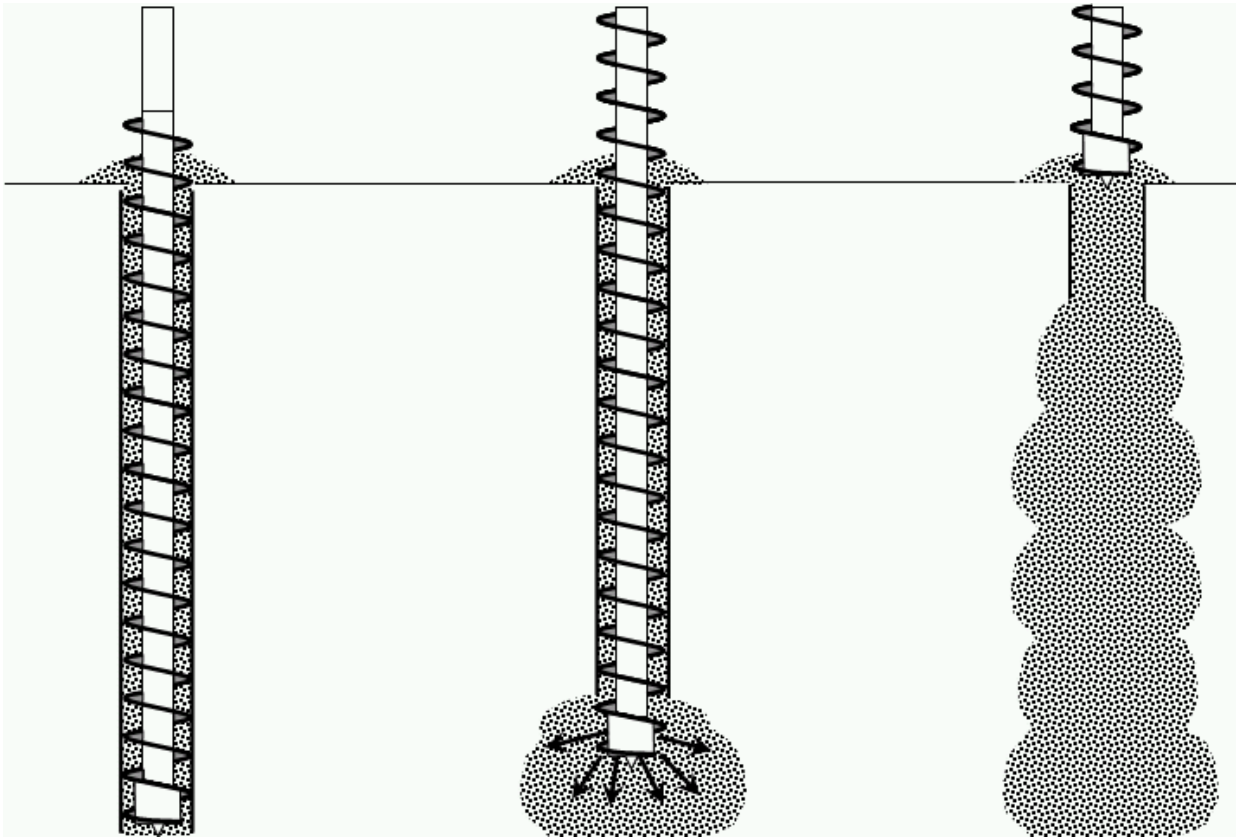
May be cast with normal grout mixes or low strength fillers, depending upon application





Alternative: MGE

Feed granular material via reverse rotation to form a Mechanically compacted Ground improvement Element



1. Tooling rotated in downward transport direction to the target improvement level. Can be rotated in the upward transport direction where necessary to penetrate hard zones.

2. Feed granular material via reverse rotation. Use increase in torque or crowd to determine when to move up to next increment.

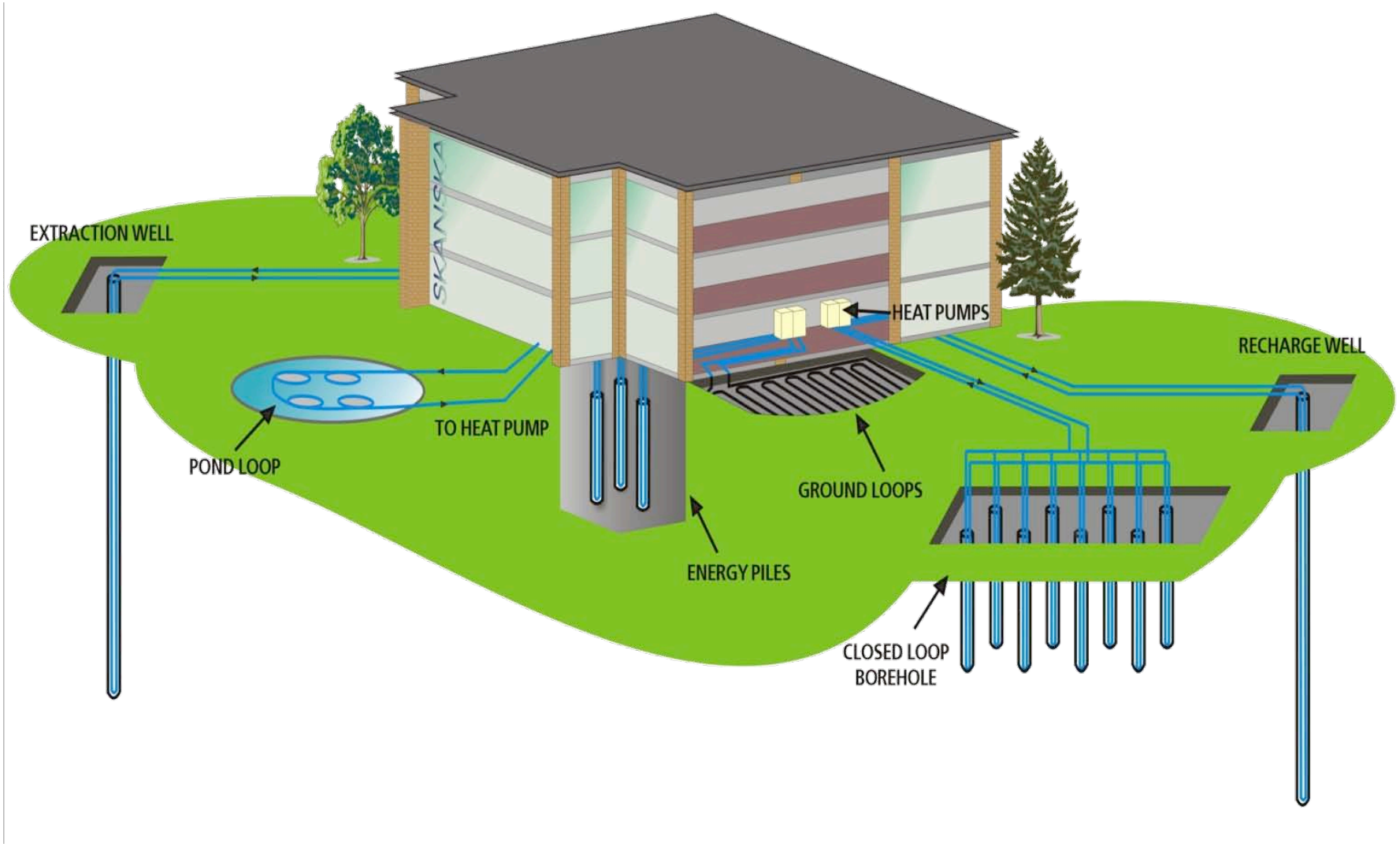
3. Continue until ground heave is noted at the surface.

Auger Pressure Grouted Energy (APGE) Piles®

Geothermal Technology

- Geothermal heat pumps, or ground source heat pumps, replaces/supplements traditional air conditioning and furnace systems
- The heat pumps simply “move” the heat from one place to another absorbing heat from the ground during heating and extracting heat from the building during cooling
- Geothermal systems deliver up to 4 times more energy than they consume resulting in both cost savings and carbon reduction (up to 50%)

Geothermal Solutions



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Benefits of using APGE Piles®

- Low extra over cost for geothermal installation
- Minimal impact on piling program
- Uses building piles as thermal mass
- Heat recovery between seasons
- Makes excellent Value Engineering sense
- Provides a Stable & Sustainable energy source

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Thermal Conductivity Testing

Thermal Conductivity

- **Conductivity is one of the key components used in both the design and operation of geothermal systems**
- **The ability to measure the thermal conductivity of an energy pile is key to proving the pile is acceptable, similar to running a pile load test to prove capacity**

Thermal Conductivity Values
(SI Units - W/m*K)

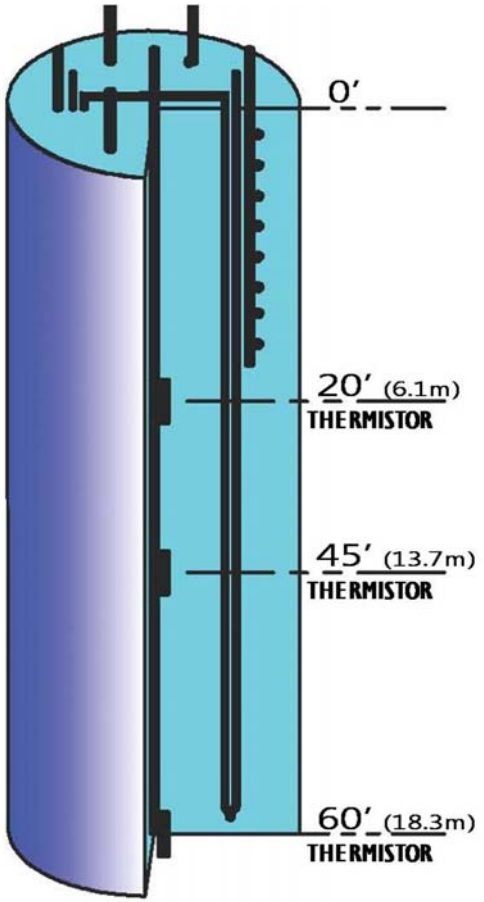
- Air: 0.024
- HDPE: 0.45 (PVC: 0.23)
- Water: 0.6
- Glass: 1.0
- Thermally Enhanced Borehole Grout: 1.35
- Normal Concrete/Structural Grout: 1.35
- Ice: 2.0
- Saturated Clay: 2.0-2.5
- Saturated Sand: 3.0-4.0
- Limestone: 1.5-3.0
- Shale: 1.5-3.5
- Granite: 3.0-4.0
- Copper: 390
- Diamond: 545

Test Procedures

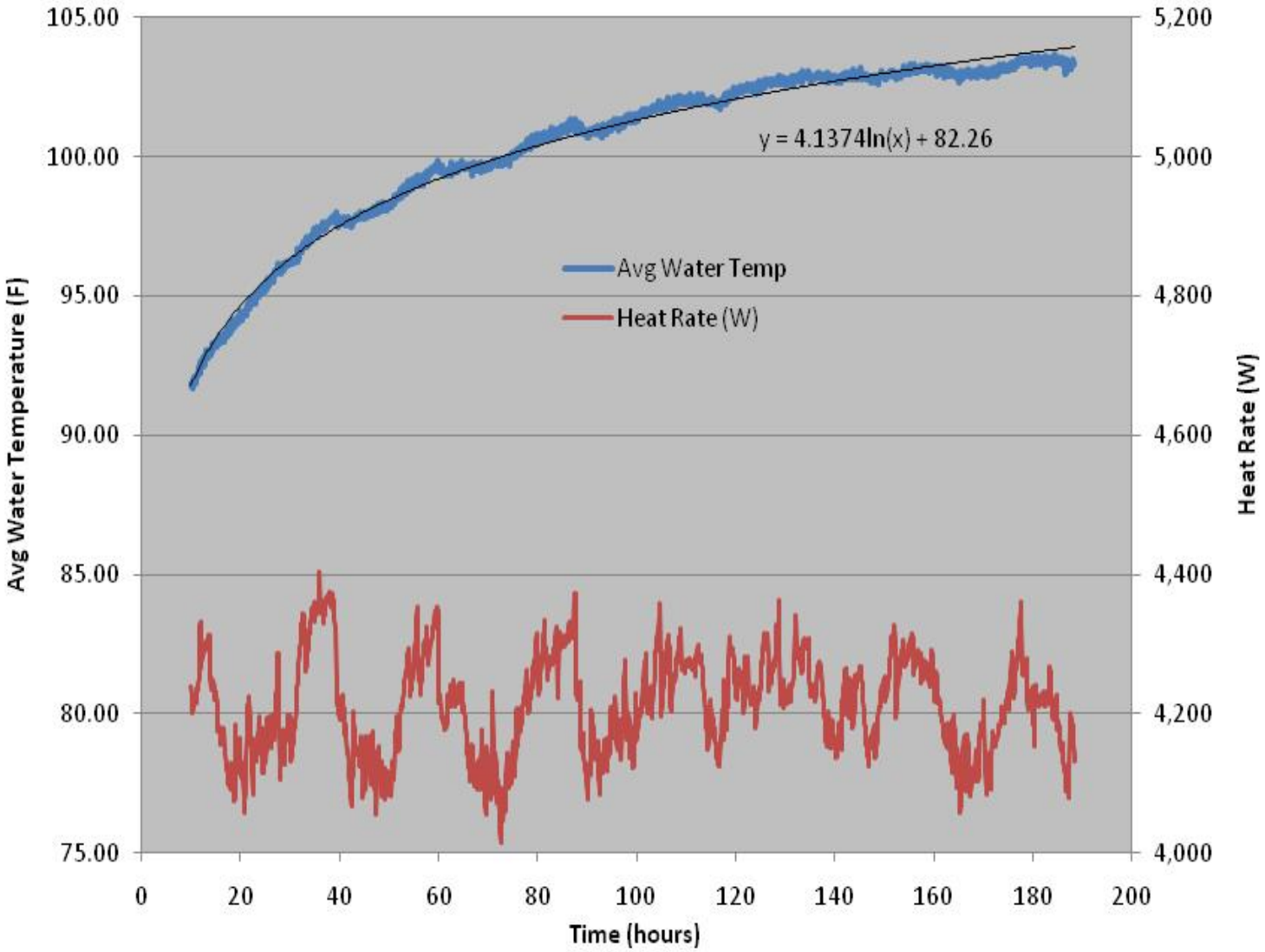
- ASHRAE published recommended procedures for formation thermal conductivity tests (2007)
- Test duration is 36 hours minimum but 48 hours is preferable
- Data should be analyzed using the line source method
- Power variation should be less than 10%
- Heat rate should be between 15 W to 25 W per foot of depth

Thermal Conductivity Test Unit

APGE Pile® and Pipe Loops



Group Test Results



Conclusions

- APG piles have many advantages that will result in continued use and market growth
- New APGD (displacement) piles can now be better utilized in soft soil conditions and for ground improvement
- Pile load testing, automated monitoring, integrity testing can be used for better quality control
- Piles can be used for low headroom, earth retention and ground improvement applications
- Energy piles can be used for cost effective and energy efficient heating and cooling applications

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