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November 16, 2009

For Jon Honeycutt
Permission

From: Jon Honeycutt, Staff Professional JC

Reviewed By: Steve Kiser, Principal Professional SK

Subject: **Report of SPT Energy – MACTEC CME 55 Track (RAL)**
Hammer Serial No. MEC-21 Automatic Hammer
WORK INSTRUCTION No. 8 (DCN:NAP-077)
North Anna 3 Project
Louisa County, Virginia
MACTEC Project No. 6468-09-2473

Jonathan Honeycutt, of MACTEC Engineering and Consulting, Inc. (MACTEC), performed energy measurements on the drill rig at the subject site per the referenced Work Instructions. This memorandum summarizes the field testing activities and presents the results of the energy measurements.

SPT Energy Field Measurements

SPT energy measurements were made on September 1, 2009, during drilling of Boring M-30(DH) at the referenced site. The testing was performed by Jonathan Honeycutt from approximately 4:05 PM to 4:45 PM on September 1 under clear skies with a temperature of about 75 degrees Fahrenheit. The boring was drilled by MACTEC personnel using equipment from the MACTEC Raleigh office. The drilling equipment consisted of a CME 55 model track drill rig with an SPT automatic hammer. The drilling tools consisted of AW-J-sized drilling rods and a 2-foot long split-barrel sampler. Mud rotary drilling techniques were used to advance the boring at the time of energy testing. The drill rig operator during sampling was Mr. Thomas Hahn. Energy measurements were recorded during sampling at the depth intervals shown in Table 1.

The energy measurements were performed with a Pile Driving Analyzer (PDA) model PAX (Serial No. 3622L), and calibrated accelerometers (Serial Nos. K983 and K0686) and strain gages (Serial Nos. AW#75/1 and AW#75/2). A steel drill rod, 2 feet long and instrumented with dedicated strain gages, was inserted at the top of the drill rod string immediately below the SPT hammer. The inserted rod was also instrumented with two piezoresistive accelerometers that were bolted to the outside of the rod. The instrumented rod insert had a cross-sectional area of approximately 1.22 square inches and an outside diameter of approximately 1.75 inches at the gage location. The drill rods included in the drill rod string were hollow rods in 5 to 10 foot long sections, with an outside and inside diameter of approximately 1.75 and 1.375 inches, respectively. The recommended operation rate of the hammer is not known. Due to the closed hammer system, the hammer lubrication condition and anvil dimensions could not be observed.

18 Pages Total

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Calibration Records

The calibration records for all the above are filed in DCN NAP-223.

Calculations for EFV

The work was done in accordance with ASTM D 4633-05. The strain and acceleration signals were converted to force and velocity by the PDA. The maximum energy transmitted to the drill rod string (EFV), as measured at the location of the strain gages and accelerometers, was calculated by the PDA using the equation shown below:

$$EFV = \int F(t) * V(t) * dt$$

Where: EFV = Transferred energy (EFV equation), or Energy of FV
F(t) = Calculated force at time t
V(t) = Calculated velocity at time t

As recommended by ASTM D4633-05, the force-velocity method of energy calculation was used. The equation shown above for calculating EFV, integrated over the complete wave event, measures the total energy content of the event using both force and velocity measurements. The EFV values associated with each blow analyzed are tabulated in the attached PDIPLOT tables and are also shown graphically in the PDIPLOT charts.

Calculations for ETR

The ratio of the measured transferred energy (EFV) to the theoretical potential energy of the SPT system (140 lb weight with the specified 30 inch fall) is the ETR. The ETR values (as percent of the theoretical value) are shown in Table 1.

Comparison of ETR to Typical Energy Transfer Ratio Range

Based on a research report published by the Florida Department of Transportation (FDOT) (Report WPI No. 0510859, 1999), the average ETR measured for automatic hammers is 79.6%. The standard deviation was 7.9%; therefore, the range of ETRs within one standard deviation of the average was reported to be 71.7% to 87.5%. This range of ETRs was also consistent with other research that was cited in the FDOT research paper; however, maximum and minimum ETR values of up to 98% and 56%, respectively, were reported in the literature. The ETR values shown in Table 1 are generally within the range of typical values for automatic hammers as reported in the literature.

Discussion

Based on the field testing results, observations from the SPT energy measurements are summarized below:

- The data obtained by the PDA are generally consistent between individual hammer blows and between the sample depths tested. In general, the first and last one (and sometimes two or more) hammer blow records recorded by the PDA produced poor quality data (which is relatively common) and, as such, the record(s) was(were) not

used in the data reduction. This may result in more or less hammer blows evaluated for ETR than what is shown on the boring logs.

- The average energy transferred from the hammer to the drill rods for each individual depth interval using the EFV method ranged from 302 foot-pounds to 317 foot-pounds. These average energy transfers correspond to energy transfer ratios (ETR) of 86.3% to 90.6% of the theoretical energy (350 foot-pounds) of the SPT hammer.

- The average at each depth interval was calculated as the transferred energy for each analyzed blow of the depth intervals divided by the total number of hammer blows analyzed. The overall average energy transfer of the SPT system (for all the depth intervals tested) was 306.1 foot-pounds, with an average ETR of 87.4%.

Attachments: Page 4 Table 1 - Summary of SPT Energy Measurements – 1 Page
Page 5 - 6 Work Instruction No. 8 DCN:NAP 077– 2 Pages (without attachments)
Pages 7 Record of SPT Energy Measurement – 1 Page
Pages 8 – 17 PDIPLOT Output – 10 Pages
Page 18 Force-Velocity Plot – 1 Page

TABLE 1
SUMMARY OF SPT ENERGY MEASUREMENTS (ASTM D4633-05)
North Anna 3 Project
Louisa County, Virginia
MACTEC Project No. 6468-09-2473

Automatic Hammer Serial Number and Rig Model	Rig Owner	Rig Operator	Boring No. Tested	Date Tested	Drill Rod Size	Sample Depth (feet)	SPT Blow Count (blows per six inches)	No. of Blows Analyzed	Average Measured Energy (Average EFV) (ft-lbs)[a]	Energy Transfer Ratio (%)[b] (Average ETR)
MEC-21 (CME 55 Track)	MACTEC Raleigh	Thomas Hahn	M-30 (DH)	9/1/2009	AW-J	11.1 - 12.6	4 - 6 - 6	16	304	86.9%
						13.7 - 15.2	4 - 7 - 7	19	302	86.3%
						18.7 - 20.2	6 - 7 - 6	19	317	90.6%
						23.7 - 25.2	7 - 8 - 10	25	307	87.7%
						28.7 - 30.2	11 - 14 - 15	40	303	86.6%
								Average for Rig:	**306.1**	**87.4%**

[a]Measured Energy is energy based on the EFV method, as outlined in ASTM D4633-05, for each blow recorded by the PDA. In some cases, the initial and final one to two blows produced poor quality data, and were not used to calculate the Average Measured Energy. This may result in more or less blows evaluated for ETR than what is shown on the boring logs.

EFV = EMX * 1000 lbs/kip, where EMX equals the maximum transferred energy measured by the PDA (see attached PDA data).

[b]Energy Transfer Ratio is the Measured Energy divided by the theoretical SPT energy of 350 foot-pounds (140 pound hammer falling 2.5 feet).

The average EFV and ETR values may differ slightly and insignificantly from those in the PDIPLOT tables due to roundoff.

Prepared By: L C.	Date: 11-16-09		Checked By: [signature]	Date: 11-16-09

For Jon Honeycutt
With Permission

Work Instruction No. 8
North Anna 3 Project
MACTEC Engineering and Consulting, Inc.
Project Number: 6468-09-2473

Issued To: Jonathan Honeycutt, Steve Kiser Rev. No. 0

Issued By: D. Steven Copley, P.E. DSC 8-31-09 Date: August 31, 2009

Valid From: August 31, 2009 To: August 31, 2010

Task Description: Perform SPT Energy Measurements

Applicable Technical Procedures or Plans, or other reference:

1. Geotechnical Work Plan (complete copy of current revision available at Field Office), Section 4.2 and Attachment 2 – Drilling and Sampling Procedures (attached)
2. Engineering Specification for Subsurface Investigation and Laboratory Testing, No. 25161-500-3PS-CY00-Q0001, Rev. 000, Issued for use August 21, 2009, Section 3.3 Drilling Equipment (attached)
3. ASTM D 4633-05 (attached)

Specific Instructions (note attachments where necessary): Perform energy measurements for each drill rig on site in general accordance with ASTM D 4633-05. Consult with Site Manager as to schedule for performing the measurements. Hammer weights have been checked, and records will be available on site. All rigs are using automatic hammer systems. Confirm that automatic hammer system is being operated within manufacturer's recommendations or in a typical operating fashion as observed from watching one or two SPT measurements prior to measuring energy. Check each drill rig using all hammer/rod combinations that it will be using. Depths for measurements should be coordinated with the Site Manager. See Site Manager for current boring logs of holes drilled, if available, and use these to plan most effective field measurement program. Submit copies of calibration records for equipment to Principal Professional for review prior to beginning work on site.

Confirm with Site Manager that approval of equipment calibration records have been received prior to beginning field testing. If unexpected conditions are encountered that affect measurements, contact Site Manager or Principal Professional immediately.

Report Format: Prepare standard report in accordance with ASTM D 4633-05 requirements.

Specific Quality Assurance Procedures Applicable: 10CFR21; NQAP 16-01 Procedure For Conforming To Federal Regulation 10CFR21; QAP 20-1; QAP 25-1; Section 306 of the Energy Reorganization Act of 1974. Current revisions apply; copies available in Field Office.

Hold Points or Witness Points: None

Records: All records generated shall be considered QA Records.

Reviewed and Approved By (Note: Only one signature required for issuance):

Project Manager: _____ Date: _____

Principal Professional: D. Aaron Copley Date: 8-31-09

Site Manager: _____ Date: _____

No. of Pages: 15 DCN: NAP077

QA Form 24-1 Revised 8/12/2009

MACTEC

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RECORD OF SPT ENERGY MEASUREMENT

GENERAL INFORMATION		DRILL RIG DATA	
PROJECT:	North Anna 3 Project	MAKE:	CME
LOCATION:	Virginia	MODEL:	55 Truck
PROJECT NO.:	6468-09-2473	SERIAL NO.:	MEC-21
DATE:	9/1/2009	HAMMER TYPE:	Auto
WEATHER:	Sunny 75°F	ROPE CONDITION:	N/A
INSPECTOR:	JNH	ROD SIZE:	AW-J
DRILLING COMPANY:	MACTEC - Raleigh	NO. OF SHEAVES:	N/A

BORING DATA			
BORING NUMBER:	M-30(BH)		
DEPTH DRILLED:	Various		
TIME DRIVEN:	4:05 pm - 4:45 pm		
RIG OPERATOR:	T. HAHN		
HAMMER OPERATOR:	N/A		
PDA PAK SERIAL NO.:	3622L		
INSTR. ROD AREA:	1.22 in2		
ACCEL. SERIAL NOS.:	A1-K983 : A2-K0686		
STRAIN SERIAL NOS.:	75 AW # 1 / 2		

SAMPLE DEPTH (feet)	SPT N-VALUE (bpf)
11.1 - 12.6	4-6-6
13.7 - 15.2	4-7-7
18.7 - 20.2	6-7-6
23.7 - 25.2	7-8-10
28.7 - 30.2	11-14-15

REMARKS: Testing performed in accordance with ASTM D 4633-05

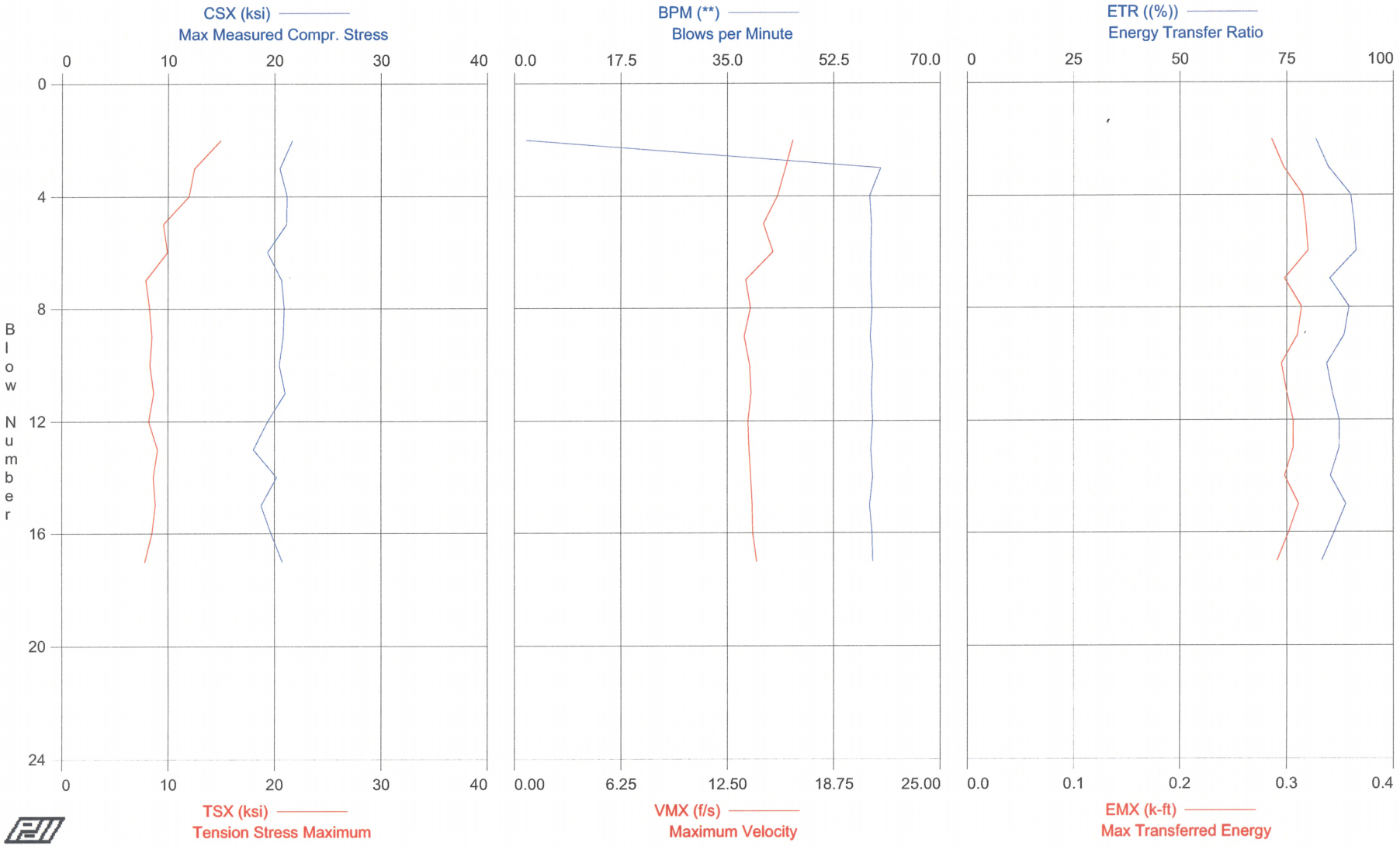
Reviewed By:

MACTEC Engineering and Consulting, Inc. - Case Method Results

PDIPLOT Ver. 2008.1 - Printed: 16-Nov-2009

Test date: 1-Sep-2009

NORTH ANNA 3 Project - BORING M-30(DH) (11.1' - 12.6' sample)



NORTH ANNA 3 Project - BORING M-30(DH) (11.1' - 12.6' sample)
OP: JNH

Rig Serial No. MEC-21; CME 55 (T.Hahn)
Test date: 1-Sep-2009

AR: 1.22 in^2
LE: 16.60 ft
WS: 16,807.9 f/s

SP: 0.492 k/ft3
EM: 30,000 ksi
JC: 0.70

CSX: Max Measured Compr. Stress
TSX: Tension Stress Maximum
VMX: Maximum Velocity
FMX: Maximum Force
FVP: Force/Velocity proportionality

BPM: Blows per Minute
EF2: Energy of F^2
ETR: Energy Transfer Ratio
EMX: Max Transferred Energy

BL#	CSX ksi	TSX ksi	VMX f/s	FMX kips	FVP []	BPM **	EF2 k-ft	ETR (%)	EMX k-ft
2	21.6	14.9	16.3	26	0.8	1.9	0.251	81.8	0.286
3	20.5	12.4	15.9	25	0.8	60.2	0.246	84.7	0.297
4	21.2	11.9	15.4	26	0.9	58.4	0.243	90.0	0.315
5	21.1	9.5	14.6	26	0.9	58.7	0.244	90.8	0.318
6	19.3	9.9	15.2	24	0.8	58.6	0.242	91.3	0.320
7	20.6	7.9	13.6	25	0.9	58.6	0.236	85.1	0.298
8	20.9	8.2	13.9	25	0.9	58.8	0.235	89.6	0.314
9	20.8	8.5	13.5	25	0.9	58.5	0.234	88.5	0.310
10	20.4	8.3	13.8	25	0.8	58.9	0.233	84.4	0.295
11	21.0	8.6	13.9	26	0.8	58.7	0.234	85.7	0.300
12	19.3	8.2	13.7	24	0.8	58.9	0.235	87.3	0.306
13	18.0	9.0	13.8	22	0.8	58.6	0.235	87.3	0.306
14	20.2	8.6	13.9	25	0.8	58.9	0.228	85.3	0.298
15	18.7	8.8	14.0	23	0.8	58.4	0.235	88.9	0.311
16	19.7	8.5	14.0	24	0.8	58.8	0.231	86.2	0.302
17	20.7	7.8	14.2	25	0.8	58.9	0.230	83.2	0.291
Average	20.3	9.5	14.4	25	0.8	55.2	0.237	86.9	0.304

Total number of blows analyzed: 16

Time Summary

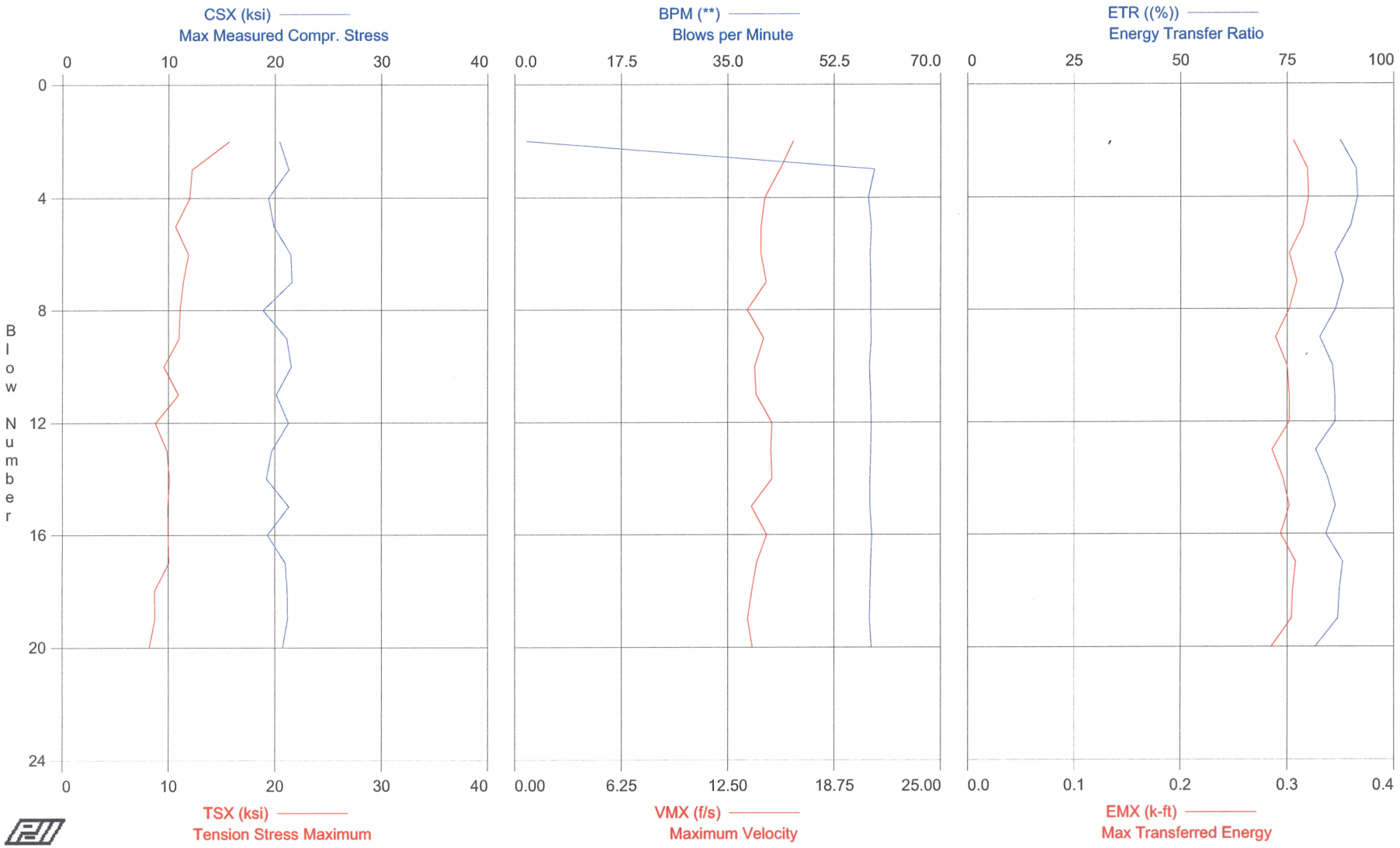
Drive 1 minute 44 seconds 3:54:35 PM - 3:56:19 PM (9/1/2009) BN 1 - 18

MACTEC Engineering and Consulting, Inc. - Case Method Results

PDIPLOT Ver. 2008.1 - Printed: 16-Nov-2009

Test date: 1-Sep-2009

NORTH ANNA 3 Project - BORING M-30(DH) (13.7' - 15.2' sample)

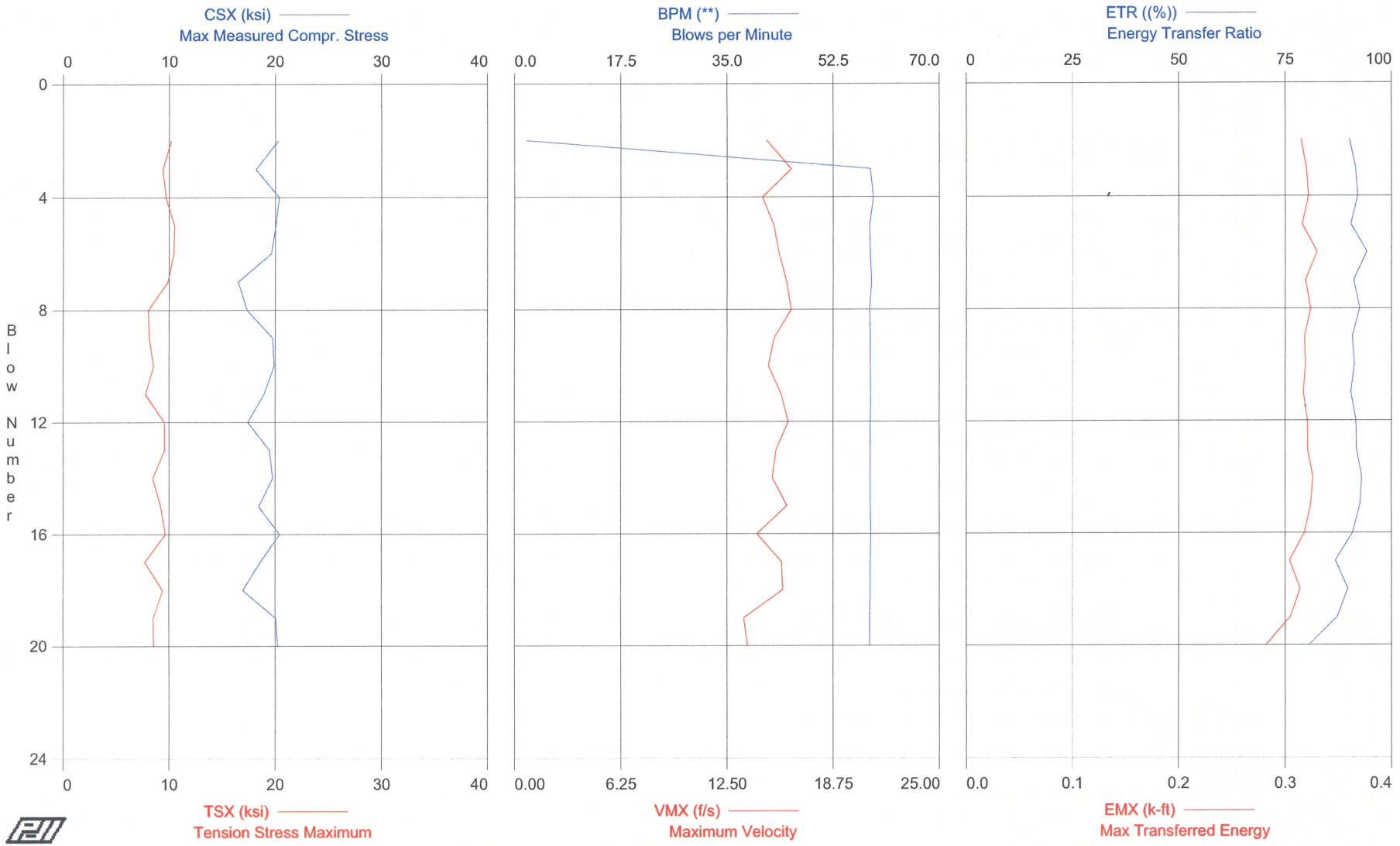


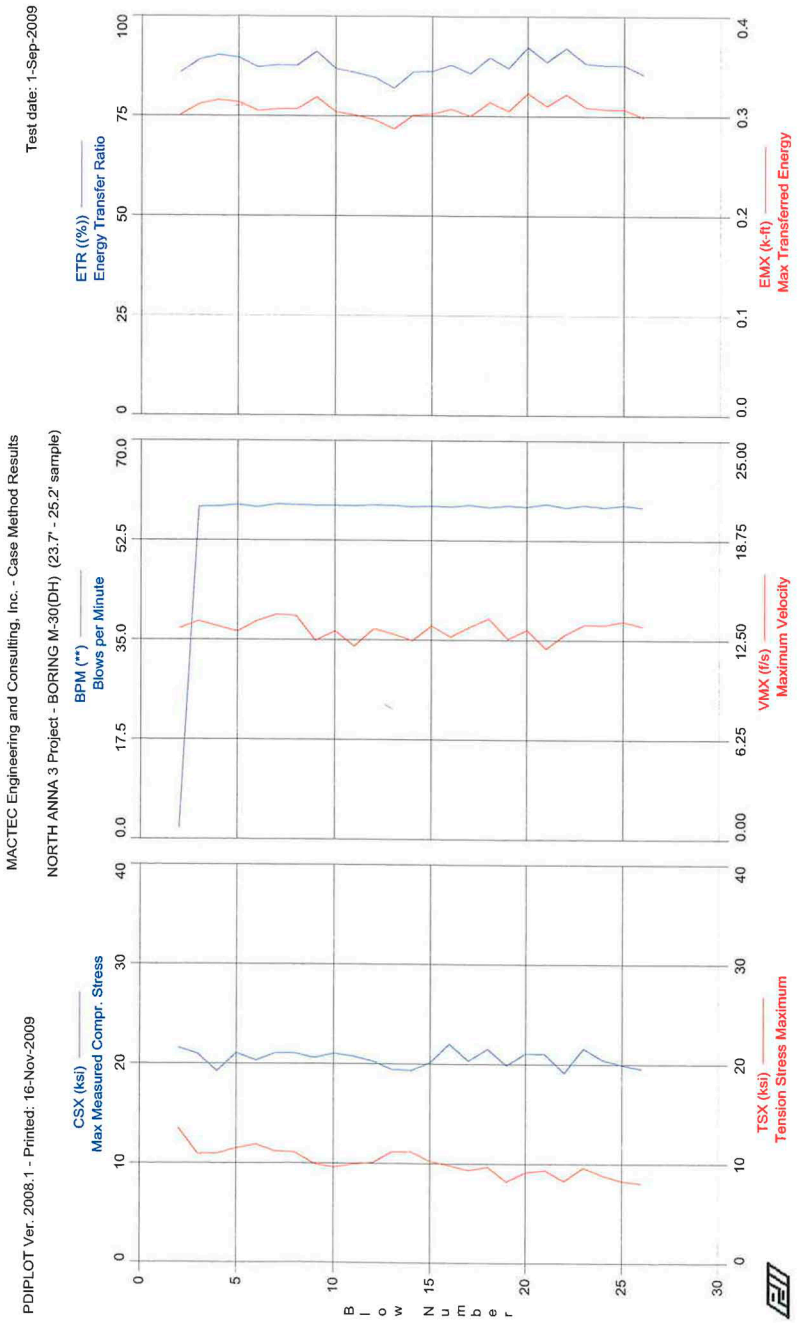
MACTEC Engineering and Consulting, Inc. - Case Method Results

PDIPLOT Ver. 2008.1 - Printed: 16-Nov-2009

Test date: 1-Sep-2009

NORTH ANNA 3 Project - BORING M-30(DH) (18.7' - 20.2' sample)





MACTEC Engineering and Consulting, Inc.
Case Method Results

PDIPLOT Ver. 2008.1 - Printed: 16-Nov-2009

NORTH ANNA 3 Project - BORING M-30(DH) (23.7' - 25.2' sample)
Rig Serial No. MEC-21; CME 55 (T.Hahn)
OP: JNH
Test date: 1-Sep-2009

AR: 1.22 in^2
LE: 29.20 ft
WS: 16,807.9 f/s
SP: 0.492 k/ft3
EM: 30,000 ksi
JC: 0.70

CSX: Max Measured Compr. Stress
TSX: Tension Stress Maximum
VMX: Maximum Velocity
FMX: Maximum Force
FVP: Force/Velocity proportionality
BPM: Blows per Minute
EF2: Energy of F^2
ETR: Energy Transfer Ratio
EMX: Max Transferred Energy

BL#	CSX ksi	TSX ksi	VMX f/s	FMX kips	FVP []	BPM **	EF2 k-ft	ETR (%)	EMX k-ft
2	21.6	13.5	13.2	26	0.9	1.9	0.249	85.9	0.301
3	21.0	10.9	13.7	26	0.9	58.3	0.251	89.1	0.312
4	19.2	10.9	13.3	23	0.8	58.4	0.256	90.3	0.316
5	21.0	11.5	13.0	26	0.9	58.7	0.255	89.6	0.314
6	20.3	11.9	13.7	25	0.8	58.3	0.254	87.2	0.305
7	21.0	11.2	14.1	26	0.8	58.8	0.251	87.7	0.307
8	21.1	11.1	14.0	26	0.8	58.7	0.255	87.7	0.307
9	20.6	9.9	12.5	25	0.9	58.6	0.254	91.2	0.319
10	21.0	9.6	13.1	26	0.9	58.6	0.253	86.8	0.304
11	20.7	9.9	12.1	25	1.0	58.5	0.252	85.9	0.301
12	20.2	10.0	13.2	25	0.9	58.7	0.249	84.7	0.296
13	19.4	11.1	12.9	24	0.8	58.6	0.255	82.0	0.287
14	19.3	11.2	12.5	24	0.8	58.4	0.252	86.0	0.301
15	20.1	10.2	13.4	25	0.8	58.5	0.257	86.2	0.302
16	22.0	9.8	12.7	27	1.0	58.4	0.257	87.8	0.307
17	20.3	9.3	13.3	25	0.9	58.7	0.252	85.7	0.300
18	21.5	9.7	13.9	26	0.9	58.3	0.258	89.7	0.314
19	19.9	8.2	12.6	24	0.8	58.6	0.261	87.0	0.305
20	21.1	9.1	13.1	26	0.9	58.4	0.251	92.3	0.323
21	21.0	9.4	12.0	26	0.8	58.9	0.255	88.6	0.310
22	19.1	8.3	12.9	23	0.8	58.3	0.257	92.0	0.322
23	21.6	9.6	13.5	26	0.9	58.7	0.254	88.2	0.309
24	20.4	8.8	13.5	25	0.8	58.3	0.260	87.7	0.307
25	19.9	8.3	13.7	24	0.8	58.7	0.257	87.8	0.307
26	19.5	8.0	13.4	24	0.8	58.3	0.259	85.5	0.299
Average	20.5	10.1	13.2	25	0.9	56.3	0.255	87.7	0.307

Total number of blows analyzed: 25

Time Summary

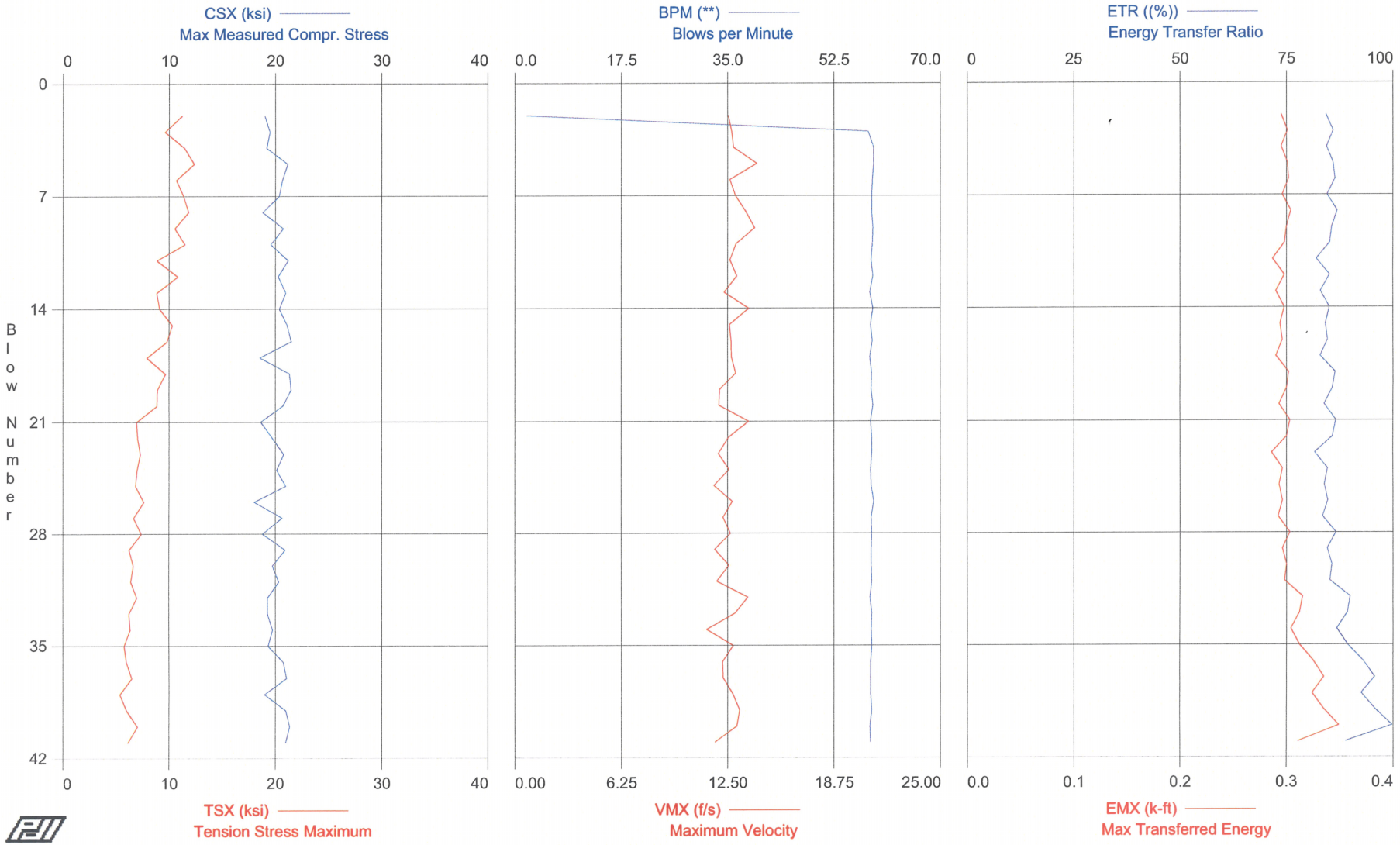
Drive 50 seconds 4:23:26 PM - 4:24:16 PM (9/1/2009) BN 1 - 27

MACTEC Engineering and Consulting, Inc. - Case Method Results

PDIPLOT Ver. 2008.1 - Printed: 16-Nov-2009

Test date: 1-Sep-2009

NORTH ANNA 3 Project - BORING M-30(DH) (28.7' - 30.2' sample)



NORTH ANNA 3 Project - BORING M-30(DH) (28.7' - 30.2' sample)
OP: JNH

Rig Serial No. MEC-21; CME 55 (T.Hahn)
Test date: 1-Sep-2009

AR: 1.22 in^2
LE: 34.20 ft
WS: 16,807.9 f/s

SP: 0.492 k/ft3
EM: 30,000 ksi
JC: 0.70

CSX: Max Measured Compr. Stress
TSX: Tension Stress Maximum
VMX: Maximum Velocity
FMX: Maximum Force
FVP: Force/Velocity proportionality

BPM: Blows per Minute
EF2: Energy of F^2
ETR: Energy Transfer Ratio
EMX: Max Transferred Energy

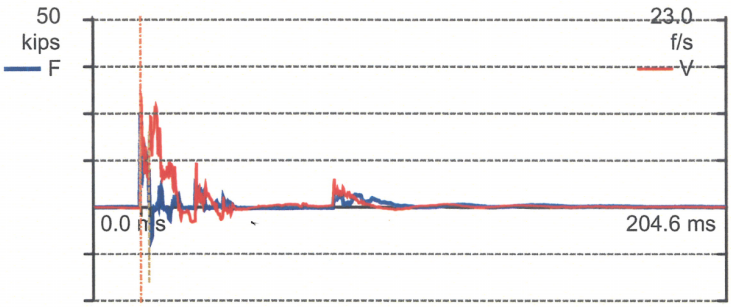
BL#	CSX ksi	TSX ksi	VMX f/s	FMX kips	FVP []	BPM **	EF2 k-ft	ETR (%)	EMX k-ft
2	19.0	11.2	12.5	23	0.8	1.9	0.273	84.2	0.295
3	19.5	9.6	12.7	24	0.8	58.1	0.285	85.9	0.301
4	19.2	11.4	12.8	23	0.8	59.0	0.285	84.4	0.295
5	21.1	12.4	14.2	26	0.8	59.0	0.273	85.9	0.301
6	20.6	10.7	12.6	25	0.8	58.8	0.279	86.4	0.302
7	20.3	11.4	13.0	25	0.9	58.7	0.275	84.5	0.296
8	18.8	11.8	13.6	23	0.8	58.7	0.277	86.9	0.304
9	20.7	10.5	14.1	25	0.8	58.9	0.272	85.6	0.300
10	19.6	11.5	13.0	24	0.8	58.8	0.276	85.1	0.298
11	21.2	8.9	12.6	26	0.9	58.6	0.271	82.0	0.287
12	20.3	10.8	13.0	25	0.8	58.9	0.273	85.1	0.298
13	21.0	8.8	12.3	26	1.0	58.4	0.274	82.9	0.290
14	20.4	9.1	13.7	25	0.8	58.9	0.267	85.1	0.298
15	21.1	10.3	12.6	26	0.9	58.5	0.269	84.1	0.294
16	21.5	9.8	12.7	26	0.9	58.8	0.273	84.6	0.296
17	18.5	7.9	12.7	23	0.8	58.4	0.277	82.9	0.290
18	21.3	9.7	13.0	26	0.9	58.7	0.270	86.4	0.302
19	21.5	8.9	12.0	26	0.8	58.6	0.272	85.7	0.300
20	20.7	8.9	12.0	25	1.0	58.9	0.266	83.8	0.293
21	18.6	6.9	13.7	23	0.8	58.5	0.270	86.5	0.303
22	19.7	7.0	12.5	24	0.8	58.7	0.270	85.8	0.300
23	20.8	7.3	11.9	25	0.8	58.7	0.272	81.6	0.286
24	20.1	7.0	12.6	25	0.7	58.5	0.268	84.6	0.296
25	21.0	6.8	11.7	26	0.7	58.6	0.270	83.8	0.293
26	18.0	7.6	12.8	22	0.8	59.0	0.269	84.6	0.296
27	20.6	6.7	12.2	25	0.9	58.6	0.262	83.5	0.292
28	18.8	7.4	12.7	23	0.8	58.7	0.273	86.6	0.303
29	20.9	6.2	11.7	25	1.0	58.6	0.266	84.6	0.296
30	19.7	6.6	12.6	24	0.9	58.6	0.266	85.6	0.300
31	20.3	6.4	11.9	25	1.0	58.7	0.263	85.1	0.298
32	19.2	7.0	13.7	23	0.8	58.4	0.269	89.9	0.315
33	19.2	6.2	12.9	23	0.8	58.7	0.270	89.2	0.312
34	19.7	6.3	11.3	24	1.0	58.6	0.263	86.7	0.304
35	19.3	5.8	12.8	24	0.8	58.7	0.266	89.3	0.312
36	20.7	6.0	12.2	25	0.7	58.5	0.262	93.0	0.325
37	21.0	6.5	12.2	26	0.7	58.5	0.264	95.7	0.335
38	19.0	5.4	12.8	23	0.8	58.5	0.266	92.5	0.324
39	21.0	6.0	13.2	26	0.7	58.7	0.264	95.8	0.335
40	21.3	7.0	13.0	26	0.7	58.4	0.270	99.7	0.349
41	21.0	6.1	11.8	26	0.8	58.5	0.269	88.8	0.311
Average	20.2	8.3	12.7	25	0.8	57.2	0.270	86.6	0.303

Total number of blows analyzed: 40

Time Summary

Drive 2 minutes 41 seconds 4:32:18 PM - 4:34:59 PM (9/1/2009) BN 1 - 41

Project: NORTH ANNA 3
Pile: BORING M30-DH(18.7-20.2) - Description: CME 55 (T.HAHN)
Operator: JNH



BN 19
9/1/2009 4:15:38 PM

LP	0.00	ft	LE	24.20	ft
CSX	20.0	ksi	AR	1.22	in^2
CSI	20.4	ksi	EM	30,000.0	ksi
TSX	8.5	ksi	SP	0.492	k/ft3
EMX	0.3	k-ft	WS	16,807.9	f/s
STK	3.93	ft	WC	16,807.9	f/s
FVP	0.83	[]	JC	0.70	[]
SFR	1	kips	2L/c	2.88	ms
RX5	5	kips	EA/c	2.2	ksec/ft
RMX	5	kips	FR	5.000	kHz