# FINAL DATA REPORT Revision 0 GEOTECHNICAL EXPLORATION AND TESTING SUPPLEMENT 2 DOMINION POWER NORTH ANNA NUCLEAR POWER STATION NORTH ANNA 3 PROJECT MINERAL, LOUISA COUNTY, VIRGINIA

**December 16, 2009** 

## VOLUME 1

# APPENDIX B.2 SPT Energy Measurement Reports

**Prepared By:** 

# MACTEC ENGINEERING AND CONSULTING, INC. RALEIGH, NORTH CAROLINA

### **MACTEC PROJECT No. 6468-09-2473**

**Prepared For:** 

# Bechtel Power Corporation Subcontractor No. 25161-500-HC4-CY00-00001

North Anna 3 Project

MACTEC Project: 6468-09-2473

# SPT Energy Report – Vendor A (supplement 2 – 29 borings) Dated Nov 16 and Dec 2 2009



Engineering and constructing a better tomorrow

November 16, 2009

From: Jon Honeycutt, Staff Professional LC.

Reviewed By: Steve Kiser, Principal Professional

Subject:

Report of SPT Energy – MACTEC CME-550x ATV Hammer Serial No. MEC-05 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 2, 2009, during drilling of Boring M-9 at the referenced site. The testing was performed by Jonathan Honeycutt from approximately 8:30 AM to 10:00 AM on September 2 under clear skies with a temperature of about 65 degrees Fahrenheit. The boring was drilled by MACTEC personnel using equipment from the MACTEC Atlanta office. The drilling equipment consisted of a CME-550x model ATV 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. Ruben Landeros. 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 automatic SPT hammer. The inserted rod was also instrumented with two piezoresistive accelerometers that were bolted to the outside of the rod. The instrumented rod was two feet below the hammer impact point and 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 inside diameter of approximately 1.75 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

MACTEC Engineering and Consulting, Inc.

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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 280 foot-pounds to 298 foot-pounds. These average energy transfers correspond to energy transfer ratios (ETR) of 80.0% to 85.1% 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 291.2 foot-pounds, with an average ETR of 83.2%.
- Attachments: Page 4 Table 1 Summary of SPT Energy Measurements 1 Page Pages 5 – 6 Work Instruction No. 8 DCN:NAP 077 – 2 Pages (without attachments) Page 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) <sup>a</sup>	Energy Transfer Ratio (%) <sup>b</sup> (Average ETR)
						15.4 - 16.9	4 - 5 - 4	16	290	82.9%
MEC-05	MACTEC	Ruben			AW-J	17.9 - 19.4	5 - 6 - 6	17	295	84.3%
CME-550x ATV)	Atlanta	Landeros	M-9	9/2/2009		22.9 - 24.4	5 - 6 - 6	19	295	84.3%
	Atlanta	Landeros				27.8 - 29.3	5 - 7 - 7	19	298	85.1%
						32.8 - 34.3	5 - 8 - 8	22	280	80.0%
							Ave	rage for Rig:	291.2	83.2%

<sup>a</sup>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).

<sup>b</sup>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.

Pag D <b>G</b> O	The average EFV and ETR va	The average EFV and ETR values may differ slightly and insignificantly from those in the PDIPLOT tables due to roundoff.										
e5of8	Prepared By: 2	Date: 11-16-09	Checked By: 8UL	Date: 11-16-09								
37 302	For for 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	
Issued By:	D. Steven Copley, P.E.	050 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:

- Geotechnical Work Plan (complete copy of current revision available at Field Office), Section 4.2 and Attachment 2

   Drilling and Sampling Procedures (attached)
- 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)

<u>Specific Instructions</u> (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

**<u>Records</u>**: All records generated shall be considered QA Records.

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

Project Manager:				Date:		
Principal Professional:	D.	Aguer	Coplay		Date:	8-31-09
Site Manager:	8	1. Salah dan kata dan kata dari	. 0	Date:		

No. of Pages: \_\_\_\_15\_\_\_\_

DCN: NAP077

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MACTEC

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# RECORD OF SPT ENERGY MEASUREMENT

	GENERAL INFORMA	TION		DRILL RIG DATA							
PRO IFCT:	North Anna 3 Project	t.	5	MAKE:			CME	CME			
LOCATION:	Virginia			MODEL:			550 X	A+	V		
PROJECT NO.:	6468-09-2473			SERIAL NO	0.:	M	EC-05	-			
DATE:	9/2/2009			HAMMER	TYPE:	V	wto				
WEATHER:	650F 30	NNJ		ROPE CO	NDITION:	N/A					
INSPECTOR:	JNH	1		ROD SIZE: AW-J							
DRILLING COMPANY:	MACTEC -			NO. OF SH	EAVES:	N/A					
			BORING	DATA							
	AL A		BORING	DAIA			<u> </u>				
BORING NUMBER:	141-7 Vori										
DEPTH DRILLED:	0.20 1100 -	1 2 m - 2.0 - 2.04								-9.20000	
TIME DRIVEN:	8.30 HI1-	10:00 MM					•	1997 - State 1997		ana a Adamson	
RIG OPERATOR:											
HAMMER OPERATOR:	362	21									
PDA PAK SERIAL NU.:	177-12										
ACCEL SERIAL NOS	11- 492	1A1- KALSK									
STRAIN SERIAL NOS -	745 4.2 #	: 1/2			1						
DITAIL OF THE HOOT	SAMPLE	SPT		1	-						
	DEPTH	N-VALUE		-							
	(feet)	(lqd)		1	1						
	104-119	4-5-4		1			1				
	13.74/611		1.1	1	1						
	. 1				-						
	17.9-19,4	5-6-6				·					
			· ·								
	22.9-24,4	5-6-6									
	27.8-29.3	6-7-7								•	
74	770 7/13	5.00			_						
	34.8-39.2	5-0-0									
										1	
				-							
			1								
							1			1	
									-		
REMARKS	ASTM D 4633-05	Testing performed in accordance with ASTM D 4633-05				udiscon in discon in EC		Der	REN	0	
	Reviewed by.			فالاسترا اللدي فكارد مراجعه والهد				Page 8	0187Y	at and the second	

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#### MACTEC Engineering and Consulting, Inc. - Case Method Results

Test date: 2-Sep-2009

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MACTEC Engi Case Method I	neering and C Results	onsulting, Inc.				PDIPL	.OT Ver. 2008	P 2 - Printed: 5.	age 1 of 1 -Oct-2009			
NORTH ANNA OP: JNH	3 Project - BC	DRING M9 (15	Rig Serial No	. MEC-05; CN	IE 550 X (R.L. Test date: 2-	anderous) ∙Sep-2009						
AR:         1.22 in^2         SP:         0.           LE:         21.00 ft         EM: 30,         WS: 16,807.9 f/s         JC:         0           JC:         0												
CSX: Max Measured Compr. Stress BPM: Blows per Minute												
TSX: Tension	Stress Maxim	ium					EF2: E	Energy of F^2				
VMX: Maximu	m Velocity						ETR: E	Energy Transf	er Ratio			
FMX: Maximu	m Force						EMX: N	Max Transferr	ed Energy			
FVP: Force/V	elocity proport	ionality										
BL#	CSX	TSX	VMX	FMX	FVP	BPM	EF2	ETR	EMX			
	ksi	ksi	f/s	kips	0	**	k-ft	(%)	k-ft			
2	21.1	8.2	14.7	26	0.8	1.9	0.219	86.2	0.302			
3	21.6	9.2	14.3	26	0.8	55.9	0.199	82.6	0.289			
4	19.8	10.9	14.0	24	0.8	52.9	0.206	87.6	0.307			
5	21.6	9.1	14.3	26	0.8	53.5	0.203	84.8	0.297			
6	18.8	9.6	13.3	23	0.8	54.0	0.204	84.1	0.294			
7	20.1	8.2	14.1	25	0.8	53.4	0.199	81.6	0.286			
8	21.1	9.7	13.7	26	0.9	54.7	0.194	82.0	0.287			
9	18.9	8.3	13.1	23	0.8	53.5	0.196	80.2	0.281			
10	18.8	7.8	13.2	23	0.8	54.2	0.196	78.3	0.274			
11	20.0	7.5	13.9	24	0.8	53.2	0.196	77.3	0.270			
12	18.8	9.0	13.9	23	0.8	52.7	0.200	81.8	0.286			
13	21.3	9.4	14.2	26	0.8	53.1	0.199	81.1	0.284			
14	20.6	8.7	14.2	25	0.8	53.2	0.198	83.2	0.291			
15	19.4	8.8	13.7	24	0.8	53.2	0.198	81.7	0.286			
16	21.2	7.6	14.3	26	0.8	53.1	0.201	86.3	0.302			
17	21.4	7.7	13.8	26	0.9	53.9	0.200	85.6	0.300			
Average	20.3	8.7	13.9	25	0.8	50.4	0.200	82.8	0.290			
				Total nur	mber of blow	vs analyzed: 16						

Time Summary

Drive 42 seconds 8:49:27 AM - 8:50:09 AM (9/2/2009) BN 1 - 17



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#### MACTEC Engineering and Consulting, Inc. - Case Method Results

Test date: 2-Sep-2009

MACTEC Engineering and Consulting, Inc. Case Method Results

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NORT OP: JI	'H ANNA NH	3 Project - BC	ORING M9 (17	'.9' - 19.4' san	nple)		Rig Serial No. I	MEC-425; C	CME 550 X (R.I Test date: 2	anderous) Sep-2009
AR:	1.22 ir	1^2							SP:	0.492 k/ft3
LE:	23.40 ft								EM: 3	80,000 ksi
WS: 1	6,807.9 f/	s							JC:	0.70
CSX:	Max Mea	sured Compr	. Stress					BPM:	Blows per Mir	nute
TSX:	Tension	Stress Maxim	um					EF2:	Energy of F^2	2
VMX:	Maximun	n Velocity						ETR:	Energy Trans	fer Ratio
FMX:	Maximun	n Force						EMX:	Max Transfer	red Energy
FVP:	Force/Ve	locity proport	ionality							
	BL#	CSX	TSX	VMX	FMX	FVP	BPM	EF2	ETR	EMX
		ksi	ksi	f/s	kips	П	**	k-ft	(%)	k-ft
	2	20.0	8.1	14.4	24	0.5	1.9	0.198	83.6	0.293
	3	18.6	7.7	15.3	23	0.7	53.0	0.190	85.4	0.299
	4	16.3	8.5	15.4	20	0.6	53.3	0.189	81.7	0.286
	5	17.7	8.0	15.1	22	0.5	53.4	0.198	86.7	0.304
	6	17.1	8.0	15.4	21	0.5	53.6	0.194	83.0	0.291
	7	16.1	8.2	16.2	20	0.6	53.5	0.190	80.6	0.282
	8	17.6	8.1	15.1	21	0.7	54.1	0.184	81.9	0.286
	9	18.5	6.9	15.3	23	0.5	54.0	0.191	82.8	0.290
	10	17.5	7.5	15.8	21	0.5	53.7	0.187	81.5	0.285
	11	17.6	7.3	15.6	22	0.5	52.8	0.190	83.3	0.292
	12	16.3	8.1	16.3	20	0.6	53.2	0.184	83.1	0.291
	13	18.9	7.2	14.2	23	0.7	53.3	0.191	84.9	0.297
	14	18.6	6.9	15.2	23	0.5	52.6	0.195	88.4	0.310
	15	16.1	7.5	16.4	20	0.5	53.8	0.190	84.9	0.297
	16	18.5	7.1	15.0	23	0.5	53.1	0.193	84.5	0.296
	17	18.5	7.5	15.2	23	0.7	53.3	0.189	88.3	0.309
	18	18.4	6.3	14.9	22	0.5	53.5	0.188	86.9	0.304
Avera	ge	17.8	7.6	15.3	22	0.6	50.4	0.191	84.2	0.295
					Total nur	mber of blow	s analyzed: 17			

Time Summary

Drive 26 seconds 9:04:01 AM - 9:04:27 AM (9/2/2009) BN 1 - 18



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#### MACTEC Engineering and Consulting, Inc. - Case Method Results

Test date: 2-Sep-2009

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NORTH ANNA 3 Project - BORING M9 (22.9' - 24.4' sample) OP: JNH Page 1 of 1 PDIPLOT Ver. 2008.2 - Printed: 5-Oct-2009

Rig Serial No. MEC-05; CME 550 X (R.Landerous) Test date: 2-Sep-2009

					Total nun	nber of blows	analyzed: 19	)		
Avera	ige	17.8	8.7	14.9	22	0.6	50.8	0.207	84.4	0.295
	20	15.9	7.2	15.4	19	0.6	53.8	0.200	83.4	0.292
	19	17.6	7.7	15.1	21	0.5	53.0	0.211	86.7	0.303
	18	17.9	6.7	13.7	22	0.6	53.4	0.205	84.6	0.296
	17	18.1	7.2	14.7	22	0.7	53.1	0.201	85.1	0.298
	16	16.4	7.4	14.8	20	0.6	53.0	0.205	84.1	0.294
	15	17.6	7.7	15.6	21	0.6	53.9	0.199	83.0	0.291
	14	18.2	7.6	14.5	22	0.7	52.9	0.199	84.3	0.295
	13	18.3	8.3	13.5	22	0.6	53.9	0.202	82.3	0.288
	12	17.8	7.9	15.1	22	0.7	53.2	0.199	83.8	0.293
	11	16.8	9.1	14.8	20	0.6	54.3	0.197	77.8	0.272
	10	18.2	8.7	14.2	22	0.6	54.0	0.210	84.8	0.297
	9	16.3	9.9	15.4	20	0.6	52.6	0.214	85.5	0.299
	8	18.5	10.5	15.0	23	0.7	54.0	0.203	82.8	0.290
	7	18.9	10.5	15.2	23	0.7	54.0	0.210	83.8	0.293
	6	17.7	9.4	14.5	22	0.6	53.4	0.215	84.7	0.296
	5	18.1	9.7	15.7	22	0.6	53.5	0.208	86.6	0.303
	4	17.7	8.8	14.6	22	0.6	53.8	0.214	86.4	0.302
	3	18.6	10.5	15.6	23	0.7	53.7	0.214	87.5	0.306
	2	18.8	10.5	14.8	23	0.6	1.9	0.218	86.1	0.301
	DEII	ksi	ksi	f/s	kips	. v.	**	k-ft	(%)	k-ft
	BI #	CSX	TSX	VMX	FMX	F\/P	BPM	FF2	FTR	FMX
FVP:	Force/Velo	city proporti	ionalitv							ou Enorgy
FMX	Maximum F	Force						EMX N	lax Transferre	ed Energy
VMX.	Maximum \	/elocity	um					FTR' F	nergy Transfe	er Ratio
TSX	Tension St	ress Maxim	um					FF2' F	neray of F^2	ato
CSX.	Max Measi	red Compr	Stress					BPM B	lows per Min	ute
WS: 1	6.807.9 f/s								JC:	0.70
LE:	28.40 ft								EM: 30	0.000 ksi
AR:	1.22 in^2	2							SP: (	0.492 k/ft3
01.0									Test date. Z-	000-2005

Time Summary

Drive 31 seconds

9:20:31 AM - 9:21:02 AM (9/2/2009) BN 1 - 20



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#### MACTEC Engineering and Consulting, Inc. - Case Method Results

Test date: 2-Sep-2009

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NORTH ANNA 3 Project - BORING M9 (27.8' - 29.3' sample) OP: JNH Page 1 of 1 PDIPLOT Ver. 2008.2 - Printed: 5-Oct-2009

Rig Serial No. MEC-05; CME 550 X (R.Landerous) Test date: 2-Sen-2009

					Total nur	nber of blows	analyzed: 19			
Avera	ige	18.4	10.2	14.9	22	0.6	50.7	0.216	85.2	0.298
	20	17.9	9.4	15.6	22	0.6	52.7	0.214	84.6	0.296
	19	19.3	9.3	14.7	24	0.7	53.2	0.213	88.3	0.309
	18	16.6	9.1	15.5	20	0.6	52.9	0.213	86.8	0.304
	17	16.9	9.7	15.1	21	0.6	53.7	0.212	83.8	0.293
	16	19.0	9.6	14.9	23	0.7	54.1	0.210	84.3	0.295
	15	16.4	8.9	15.4	20	0.6	53.1	0.213	82.6	0.289
	14	16.5	9.6	15.4	20	0.6	53.6	0.212	83.6	0.293
	13	19.3	10.1	14.6	24	0.5	53.4	0.217	88.4	0.309
	12	18.9	10.5	15.3	23	0.7	53.4	0.215	87.9	0.308
	11	19.1	10.7	14.4	23	0.5	54.3	0.218	85.9	0.301
	10	17.5	10.1	15.5	21	0.6	52.3	0.221	86.0	0.301
	9	19.9	9.3	13.8	24	0.8	53.8	0.218	84.4	0.296
	8	19.8	9.9	14.2	24	0.5	52.8	0.223	86.8	0.304
	7	16.2	10.5	15.3	20	0.6	53.4	0.213	89.4	0.313
	6	19.8	10.5	13.5	24	0.8	53.3	0.217	82.3	0.288
	5	17.1	10.5	15.3	21	0.6	54.3	0.209	82.2	0.288
	4	19.7	11.6	14.8	24	0.7	53.1	0.218	83.5	0.292
	3	20.1	11.5	14.6	24	0.8	53.8	0.222	83.9	0.294
	2	18.7	12.4	16.0	23	06	19	0 224	84 7	0 297
	DL#	ksi	ksi	f/s	kips	п	**	k-ft	(%)	k-ft
	BI#	CSX	TSY	VMX	FMX	F\/P	RPM	EE2	FTR	EMX
FVP:	Force/Veloc	city proportio	nalitv					E1077.	Mux Hunslein	cu Energy
FMX.	Maximum F	orce						ETT.	Max Transferr	ed Enerav
VMX-	Maximum V							ETR.	Energy Transf	er Ratio
TON.	Tonsion Str	ese Maximu	511855						Energy of EA2	ule
COX-	Max Moasu	red Compr	Stroce					RDM.	Blows per Min	
WS·1	6 807 9 f/s								JC:	0 70
I F	34 40 ft								EM: 30	) 000 ksi
	1 22 in^2								SP· (	1/02 k/ft3
OP: J	NH								l est date: 2-	Sep-2009

Time Summary

Drive 44 seconds

9:36:26 AM - 9:37:10 AM (9/2/2009) BN 1 - 21



PDIPLOT Ver. 2008.2 - Printed: 5-Oct-2009

#### MACTEC Engineering and Consulting, Inc. - Case Method Results

Test date: 2-Sep-2009

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MACTEC Engineering and Consulting, Inc.	
Case Method Results	

Page 1 of 1 PDIPLOT Ver. 2008.2 - Printed: 5-Oct-2009

NORTH ANNA 3 Project - BORING M9 (32.8' - 34.3' sample)	
OP: JNH	

Rig Serial No. MEC-05; CME 550 X (R.Landerous) Test date: 2-Sep-2009

01.0									Test date. Z-	0cp=2003
AR:	1.22	in^2							SP: (	0.492 k/ft3
LE:	38.30	ft							EM: 30	0,000 ksi
WS: 1	16,807.9 <sup>-</sup>	f/s							JC:	0.70
CSX:	Max Me	asured Compr	r. Stress					BPM: E	Blows per Min	ute
TSX:	Tension	Stress Maxim	num					EF2: E	Energy of F^2	
VMX:	Maximu	m Velocity						ETR: E	Energy Transfe	er Ratio
FMX:	Maximu	m Force						EMX: N	Max Transferre	ed Energy
FVP:	Force/V	elocity proport	ionality							
	BL#	CSX	TSX	VMX	FMX	FVP	BPM	EF2	ETR	EMX
		ksi	ksi	f/s	kips	[]	**	k-ft	(%)	k-ft
	2	18.0	10.9	14.3	22	0.8	1.9	0.222	79.0	0.276
	3	18.3	11.7	14.5	22	0.8	53.0	0.231	79.2	0.277
	4	19.9	11.3	14.3	24	1.0	54.0	0.230	79.6	0.278
	5	20.5	11.6	13.6	25	0.9	52.2	0.238	82.4	0.289
	6	19.9	11.9	13.5	24	0.9	53.2	0.241	82.7	0.289
	7	20.0	11.4	15.5	24	0.9	54.0	0.234	80.1	0.280
	8	18.3	11.3	14.7	22	0.9	53.1	0.240	80.9	0.283
	9	19.8	11.2	15.2	24	0.9	53.6	0.236	81.1	0.284
	10	20.3	10.9	14.0	25	1.0	54.2	0.235	78.2	0.274
	11	17.8	9.9	14.3	22	0.9	54.0	0.231	77.9	0.273
	12	19.9	10.0	14.5	24	1.0	53.0	0.235	80.9	0.283
	13	18.2	10.2	14.5	22	0.8	53.7	0.236	78.6	0.275
	14	19.4	10.6	13.9	24	0.9	53.0	0.231	79.2	0.277
	15	17.9	10.2	13.9	22	0.8	53.5	0.228	79.8	0.279
	16	20.0	10.8	14.2	24	1.0	52.6	0.238	81.7	0.286
	17	18.4	10.5	14.0	22	0.9	52.9	0.235	83.6	0.293
	18	17.7	9.6	13.4	22	0.8	54.3	0.231	78.8	0.276
	19	19.5	10.0	13.0	24	1.0	53.2	0.230	80.0	0.280
	20	18.7	8.9	12.9	23	0.8	53.6	0.229	78.5	0.275
	21	19.4	8.9	12.8	24	1.0	52.9	0.232	79.3	0.278
	22	18.4	9.8	13.0	22	0.8	53.4	0.228	79.2	0.277
	23	19.5	10.3	13.2	24	0.9	52.3	0.232	82.3	0.288
Avera	age	19.1	10.5	14.0	23	0.9	51.0	0.233	80.1	0.280

Time Summary

Drive 36 seconds

Total number of blows analyzed: 22

9:50:03 AM - 9:50:39 AM (9/2/2009) BN 1 - 23

Project: N Pile: BOR Operator: 50 kips — F	DRTH ANNA 3 NG M9(17.9-19.4) - Description: CME 550X(R.LANDEROUS) JNH -23.0 f/s V- 0.0 m/s 204.6 ms	BN 13 9/2/2009 9:04:21 AM LP 0.00 ft CSX 18.9 ksi CSI 19.5 ksi TSX 7.2 ksi EMX 0.3 k-ft STK 4.80 ft FVP 0.75 [] SFR 3 kips RX5 8 kips RMX 6 kips	LE AR EM SP WS UC JC 2L/c FR	23.40 1.22 30,000.0 0.492 16,807.9 16,807.9 0.70 2.78 2.2 5.000	ft in^2 ksi k/ft3 f/s [] ms ksec/ft kHz

MACTEC Engineering and Consulting, Inc.

Engineering and constructing a better tomorrow

ЛАСТЕС

November 16, 2009

Non

From: Jon Honeycutt, Staff Professional <u>2</u>. <u>C</u>\_\_\_\_

Reviewed By: Steve Kiser, Principal Professional

Subject:

Report of SPT Energy – MACTEC CME-45c Track Hammer Serial No. MEC-12 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 2, 2009, during drilling of Boring M-8 at the referenced site. The testing was performed by Jonathan Honeycutt from approximately 11:20 AM to 12:50 PM on September 2 under clear skies with a temperature of about 65 degrees Fahrenheit. The boring was drilled by MACTEC personnel using equipment from the MACTEC Raleigh office. The drilling equipment consisted of a CME 45c 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. Donnie Rhodes. 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 was two feet below the hammer impact point and 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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www.mactec.com

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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 292 foot-pounds to 305 foot-pounds. These average energy transfers correspond to energy transfer ratios (ETR) of 83.4% to 87.1% 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 297.1 foot-pounds, with an average ETR of 84.9%.
- Attachments: Page 4 Table 1 Summary of SPT Energy Measurements 1 Page Pages 5 - 6 Work Instruction No. 8 DCN:NAP 077– 2 Pages (without attachments) Page 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) <sup>a</sup>	Energy Transfer Ratio (%) <sup>b</sup> (Average ETR)
				9/2/2009	AW-J	23.7 - 25.2	19 - 17 - 16	52	293	83.7%
MEC-12	MACTEC	Donnia				28.7 - 30.2	4 - 6 - 11	21	292	83.4%
(CME-45c	Raleigh	Rhodes	M-8			33.7 - 35.2	4 - 7 - 7	18	. 293	83.7%
Track)	Raioigii	Tenodes				38.7 - 40.2	5 - 8 - 11	24	300	85.7%
						43.7 - 45.2	13 - 14 - 15	41	305	87.1%
							Ave	rage for Rig:	297.1	84.9%

<sup>a</sup>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).

<sup>b</sup>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.

Page 23 of 87 DGNHNAAB302 Checked By: Date: 11-16-09 Prepared By: Date: 11-16-09

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

Issued To:	Jonathan Honeycutt, Steve	Kiser	
Issued By:	D. Steven Copley, P.E.	050 8-31-09	Date: <u>August 31, 2009</u>
Valid From:	August 31, 2009		To: <u>August 31, 2010</u>

#### Task Description: Perform SPT Energy Measurements

#### Applicable Technical Procedures or Plans, or other reference:

- Geotechnical Work Plan (complete copy of current revision available at Field Office), Section 4.2 and Attachment 2

   Drilling and Sampling Procedures (attached)
- 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)

<u>Specific Instructions</u> (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.

<u>Specific Quality Assurance Procedures Applicable</u>: 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

**<u>Records</u>**: All records generated shall be considered QA Records.

Page 1 of 15 DCN NAP077 Page 24 of 87 D6N#NAR302

Volume 1, Revision 0

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

Project Manager:				Date:		
Principal Professional:	D.	Agun	Coplay		Date:	8-31-09
Site Manager:			. (	Date:		

No. of Pages: \_\_\_\_15\_\_\_\_

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DCN: NAP077

QA Form 24-1 Revised 8/12/2009

MACTEC

2801 YORKMONT ROAD, SUITE 100 CHARLOTTE, NC 28208 Telephone: (704) 357-8600 / Facsimile: (704) 357-8638

# RECORD OF SPT ENERGY MEASUREMENT

GENERAL INFORMATION				DRILL RIG DATA						
PROJECT:	North Anna 3 Project	North Anna 3 Project				CA	16			
LOCATION:	Virginia			MODEL:		45C TRACK				
PROJECT NO .:	6468-09-2473			SERIAL NO	).:	ME	C-+3-12	SK	11-11-09	
DATE:	9/2/2009			HAMMER T	YPE:	Av	to			
WEATHER:	SUNNY 6	SOF	an she an	ROPE CON	DITION:	N/A				
INSPECTOR:	INH			ROD SIZE:		AW-J				
DRILLING COMPANY:	MACTEC - Role	ash		NO. OF SH	EAVES:	N/A				
			BORING	DATA						
BORING NUMBER:	1 11- 8		I	DAIA		<u>-</u>				
DEPTH DRILLED.	Vari				·····					
TIME DRIVEN.	11:20 pm -	12:50 0:00								
RIG OPERATOR:	D. RUNT.	carso fire								
HAMMER OPERATOR:	N N	/A								
PDA PAK SERIAL NO :	363	221						·····		
INSTR. ROD AREA:	1.77 in 2									
ACCEL SERIAL NOS :	A1- K983: 47-KALP6									
STRAIN SERIAL NOS .:	754.131	12								
	SAMPLE	SPT	<b></b>		1					
•	DEPTH	N-VALUE					:			
	(feet)	(bpf)								
: "S	12 7 20 7	10 15 11		· · · · ·		1.				
. • 🔅	asi 1-ksia	1-1-1-16	<u> </u>	+						
	28.7-30.2	4-6-11	3							
						*				
	232.200	4-7-2								
	32.7-12.2	1-4-4								
st.1										
	38.7-40.2	5-8-11								
	243 7-457	13-14:00								
	- J. T. 15.0	12 11-13				++				
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		·····								
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		······				++				
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KEMARKS:	l esting performed in	accordance with								
	ASTM D 4633-05									
	Deviewed D							0	2	
	Reviewed By:		L			i		KEV	.0	
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PDIPLOT Ver. 2008.1 - Printed: 16-Nov-2009

#### MACTEC Engineering and Consulting, Inc. - Case Method Results

Test date: 2-Sep-2009

MACTEC Engineering and Consulting, Inc. Case Method Results Page 1 of 1 PDIPLOT Ver. 2008.1 - Printed: 16-Nov-2009

NORTH ANNA 3 Project - BORING M-8 (23.7' - 25.2' sample) OP: JNH Rig Serial No. MEC-12; CME-45c Track (D. RHODES)

OP: J	NH								Test date: 2	-Sep-2009
AR:	1.22 i	n^2							SP:	0.492 k/ft3
LE:	29.20 f	t							EM: 3	0,000 ksi
WS: 1	6,807.9 f	/s							JC:	0.70
CSX:	Max Me	asured Compr	r. Stress					BPM:	Blows per Mir	nute
TSX:	Tension	Stress Maxim	num					EF2:	Energy of F <sup>2</sup>	2
VMX:	Maximu	m Velocity						ETR:	Energy Trans	fer Ratio
FMX:	Maximu	m Force						EMX:	Max Transferr	red Energy
FVP:	Force/V	elocity proport	ionality							0,7
	BL#	CSX	TSX	VMX	FMX	FVP	BPM	EF2	ETR	EMX
		ksi	ksi	f/s	kips	П	**	k-ft	(%)	k-ft
	2	19.2	12.6	14.0	23	0.8	1.9	0.291	94.2	0.330
	3	20.8	12.6	14.0	25	0.8	58.1	0.277	82.2	0.288
	4	19.0	10.1	12.6	23	0.8	56.8	0.273	83.3	0.291
	5	19.6	11.4	14.0	24	0.8	56.7	0.267	81.1	0.284
	6	20.0	11.6	14.3	24	0.8	56.3	0.267	80.8	0.283
	7	20.3	10.5	13.4	25	0.9	56.2	0.272	82.8	0.290
	8	20.0	9.8	13.5	24	0.8	56.3	0.272	83.0	0.290
	9	18.8	8.9	12.6	23	0.8	56.3	0.268	81.5	0.285
	10	19.6	9.3	13.3	24	0.8	56.3	0.270	80.9	0.283
	11	19.6	11.0	14.2	24	0.8	56.2	0.266	82.0	0.287
	12	18.7	10.6	13.6	23	0.8	56.4	0.267	80.9	0.283
	13	19.9	8.7	13.7	24	0.8	56.4	0.266	81.1	0.284
	14	18.2	9.7	13.7	22	0.7	56.4	0.264	82.1	0.287
	15	19.9	8.6	13.7	24	0.8	56.3	0.267	79.8	0.279
	16	20.0	8.6	14.0	24	0.8	56.4	0.270	81.4	0.285
	17	19.8	8.3	14.2	24	0.8	56.3	0.266	86.4	0.302
	18	18.4	8.0	12.5	22	0.8	56.5	0.266	82.4	0.289
	19	17.5	8.3	12.6	21	0.8	56.3	0.270	81.5	0.285
	20	17.9	8.4	12.9	22	0.8	56.4	0.264	82.6	0.289
	21	18.9	8.7	13.9	23	0.8	56.3	0.268	80.5	0.282
	22	19.7	9.0	13.9	24	0.8	56.4	0.265	85.4	0.299
	23	19.9	9.0	14.4	24	0.8	56.5	0.263	83.5	0.292
	24	20.1	9.4	14.6	24	0.8	56.4	0.266	81.7	0.286
	25	19.4	8.6	13.3	24	0.8	56.4	0.269	82.3	0.288
	26	19.4	8.8	14.0	24	0.8	56.5	0.263	80.4	0.281
	27	17.7	8.5	12.8	22	0.8	56.1	0.272	81.5	0.285
	28	19.9	8.4	14.1	24	0.8	56.5	0.268	82.7	0.289
	29	19.8	8.7	14.1	24	0.8	56.2	0.267	83.9	0.294
	30	19.9	8.4	14.4	24	0.8	56.5	0.266	84.6	0.296
	31	20.0	8.2	14.2	24	0.8	56.4	0.270	83.0	0.291
	32	18.3	8.4	13.4	22	0.8	56.5	0.265	83.4	0.292
	33	20.2	8.3	14.7	25	0.8	56.3	0.267	86.5	0.303
	34	19.2	8.1	13.0	23	0.8	56.4	0.268	83.1	0.291
	35	19.5	7.8	13.9	24	0.8	56.3	0.266	87.1	0.305
	36	20.3	8.3	14.7	25	0.8	56.4	0.268	85.8	0.300
	37	19.9	7.6	13.9	24	0.8	56.4	0.272	84.6	0.296
	38	19.9	7.3	14.9	24	0.8	56.3	0.265	86.8	0.304
	39	19.1	8.9	14.1	23	0.8	56.4	0.271	84.0	0.294
	40	19.0	8.0	13.9	23	0.8	56.5	0.268	82.4	0.289
	41	19.4	8.7	14.2	24	0.8	56.2	0.268	85.7	0.300
	42	20.3	8.4	14.7	25	0.8	56.5	0.271	87.2	0.305
	43	20.1	8.2	14.3	25	0.8	56.4	0.274	85.5	0.299
	44	18.0	7.4	13.8	22	0.7	56.4	0.264	85.2	0.298
	45	18.9	7.0	13.4	23	0.8	56.3	0.277	85.5	0.299
	40	19.3	7.1	14.0	24	0.8	56.4	0.272	84.2	0.295
	47	19.0	7.1	13.7	23	0.8	20.2	0.271	84.1	0.294
	48 40	1/.0	0.8 7 0	13.4	21	0.7	50.3	0.268	83.9	0.294
	49 50	19.1	1.2	14.8	23	0.7	50.Z	0.267	80.4	0.302
	5U 51	17.9	0.2	12.8	22	0.8	50.4	0.273	80.8	0.304
	51 52	19.0	0.9	13.5	23	0.8	50.0 56 4	0.273	80.9 00 E	0.304
	52 52	20.0 19.0	1.0	14.0	24	0.0	56.6	0.272	00.0	0.310
A	55	10.2	0.4	13.3		0.0	00.0	0.200	00.2	0.302
Avera	ge	19.3	8.7	13.8	24	0.8	55.4	0.269	83.8	0.293

Time Summary

Drive 1 minute 25 seconds

11:23:35 AM - 11:25:00 AM (9/2/2009) BN 1 - 53

Total number of blows analyzed: 52



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Page 29 of 87 DCN#NAP302 MACTEC Engineering and Consulting, Inc. Case Method Results Page 1 of 1 PDIPLOT Ver. 2008.1 - Printed: 16-Nov-2009

NORTH ANNA 3 Project - BORING M-8 (28.7' - 30.2' sample) OP: JNH Rig Serial No. MEC-12; CME-45c Track (D.Rhodes) Test date: 2-Sen-2009

0F. J									Test uate. 2-	3ep-2009
AR:	1.22 in/	<u>`</u> 2							SP: (	).492 k/ft3
LE:	34.20 ft								EM: 30	),000 ksi
WS: 1	16,807.9 f/s								JC:	0.70
CSX:	Max Meas	sured Comp	r. Stress					BPM:	Blows per Min	ute
TSX:	Tension S	tress Maxin	num					EF2:	Energy of F^2	
VMX:	Maximum	Velocity			ETR:	Energy Transf	er Ratio			
FMX:	Maximum	Force						EMX:	Max Transferre	ed Energy
FVP:	Force/Vel	ocity proport	tionality							
	BL#	CSX	TSX	VMX	FMX	FVP	BPM	EF2	ETR	EMX
		ksi	ksi	f/s	kips	[]	**	k-ft	(%)	k-ft
	2	18.9	16.2	14.3	23	0.8	1.9	0.274	82.9	0.290
	3	18.8	14.3	14.1	23	0.8	56.2	0.273	86.0	0.301
	4	20.1	13.3	15.7	25	0.7	56.6	0.272	84.8	0.297
	5	19.5	14.2	15.7	24	0.7	56.5	0.263	84.2	0.295
	6	17.4	12.3	13.9	21	0.7	56.1	0.263	84.4	0.295
	7	17.1	11.9	13.8	21	0.7	56.5	0.259	85.3	0.299
	8	19.7	13.3	15.2	24	0.7	56.5	0.267	84.3	0.295
	9	19.8	12.7	15.4	24	0.7	56.3	0.268	84.1	0.295
	10	19.3	12.4	15.1	24	0.7	56.4	0.258	82.4	0.288
	11	17.2	11.2	12.9	21	0.8	56.2	0.259	83.4	0.292
	12	17.9	10.7	13.8	22	0.7	56.3	0.261	81.0	0.284
	13	18.3	10.7	13.7	22	0.7	56.2	0.260	80.8	0.283
	14	19.0	8.7	14.7	23	0.7	56.0	0.256	82.2	0.288
	15	18.7	9.8	14.8	23	0.7	56.3	0.258	81.2	0.284
	16	18.9	9.6	13.9	23	0.8	56.2	0.255	83.3	0.292
	17	18.4	9.4	14.3	22	0.7	56.2	0.256	82.5	0.289
	18	17.3	9.1	13.9	21	0.7	56.4	0.254	80.9	0.283
	19	16.6	9.0	13.4	20	0.7	56.4	0.255	82.8	0.290
	20	18.2	9.4	13.6	22	0.8	56.2	0.256	84.4	0.295
	21	17.3	7.7	12.8	21	0.7	56.3	0.259	84.8	0.297
	22	19.2	7.3	15.6	23	0.7	56.1	0.254	82.9	0.290
Avera	age	18.5	11.1	14.3	23	0.7	53.7	0.261	83.3	0.292

Total number of blows analyzed: 21

Time Summary

Drive 35 seconds

11:47:18 AM - 11:47:53 AM (9/2/2009) BN 1 - 22



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Test date: 2-Sep-2009

MACTEC Engineering and Consulting, Inc.	
Case Method Results	

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NORTH ANNA 3 Project - BORING M-8 (33.7' - 35.2' sample) OP: JNH Rig Serial No. MEC-12; CME-45c Track (D.Rhodes) Test date: 2-Sep-2009

	1 00 1-4	2							00. (	100 1/60
AR:	1.22 in^	2							SP: (	J.492 κ/π3
LE:	39.20 ft								EM: 30	J,000 KSI
WS: 1	6,807.9 f/s								JC:	0.70
CSX:	Max Meas	ured Comp		BPM: B	lows per Minu	ute				
TSX:	Tension St	tress Maxin	num		EF2: E	nergy of F^2				
VMX:	Maximum	Velocity						ETR: E	nergy Transfe	er Ratio
FMX:	Maximum	Force						EMX: N	lax Transferre	ed Energy
FVP:	Force/Velc	city propor	tionality							
	BL#	CSX	TSX	VMX	FMX	FVP	BPM	EF2	ETR	EMX
		ksi	ksi	f/s	kips	[]	**	k-ft	(%)	k-ft
	2	20.2	15.8	15.8	25	0.7	1.9	0.262	84.7	0.296
	3	19.8	15.4	14.5	24	0.8	56.2	0.267	83.9	0.294
	4	18.1	14.7	13.7	22	0.8	56.4	0.268	85.2	0.298
	5	19.0	13.2	13.6	23	0.8	56.1	0.266	83.8	0.293
	6	19.2	12.8	14.2	23	0.8	56.2	0.261	82.6	0.289
	7	18.9	12.0	13.5	23	0.8	56.7	0.260	83.2	0.291
	8	19.7	13.1	15.0	24	0.7	56.6	0.262	84.5	0.296
	9	19.6	13.2	15.1	24	0.7	56.2	0.260	83.6	0.293
	10	18.4	11.7	13.6	23	0.8	56.2	0.257	83.9	0.294
	11	19.0	12.9	14.7	23	0.7	56.1	0.260	83.4	0.292
	12	19.2	12.8	14.9	23	0.7	56.3	0.259	83.9	0.294
	13	17.3	12.2	12.9	21	0.7	56.3	0.261	83.2	0.291
	14	18.5	10.6	14.8	23	0.7	56.3	0.256	85.9	0.301
	15	18.3	10.6	13.9	22	0.7	56.0	0.257	83.4	0.292
	16	17.4	10.8	13.7	21	0.7	56.4	0.255	83.0	0.291
	17	18.5	11.2	15.1	23	0.7	56.3	0.252	83.7	0.293
	18	17.9	10.7	14.6	22	0.7	56.0	0.253	82.3	0.288
	19	16.4	11.0	12.7	20	0.7	56.5	0.262	84.3	0.295
Avera	ge	18.6	12.5	14.2	23	0.7	53.3	0.260	83.8	0.293
					Total nur	nber of blows	analyzed: 18	}		

**Time Summary** 

Drive 4 minutes 56 seconds

11:55:59 AM - 12:00:55 PM (9/2/2009) BN 1 - 20



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#### MACTEC Engineering and Consulting, Inc. - Case Method Results

Test date: 2-Sep-2009

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MACTEC Engineering and Consulting, Inc. Case Method Results Page 1 of 1 PDIPLOT Ver. 2008.1 - Printed: 16-Nov-2009

NORTH ANNA 3 Project - BORING M-8 (38.7' - 40.2' sample) OP: JNH Rig Serial No. MEC-12; CME-45c Track (D. Rhodes)

Avera	ige	17.2	10.3	15.7	∠ I Total pur	U.0 nber of blows	04.1 analyzed: 24	0.200	0.00	0.300
A.v.o.75	20	17.0	0.1 10.2	10.0	19	0.5	50.3	0.247	07.2	0.305
	24	18.1	4.9	15.5	22	0.6	56.3	0.247	84.1	0.294
	23	16.5	5.6	16.5	20	0.5	56.4	0.248	87.7	0.307
	22	18.0	6.8	14.3	22	0.5	56.3	0.250	86.7	0.303
	21	17.8	7.8	14.9	22	0.7	56.4	0.250	85.9	0.301
	20	17.8	7.4	15.7	22	0.6	56.4	0.247	84.9	0.297
	19	15.7	9.9	16.2	19	0.5	56.3	0.250	83.9	0.294
	18	17.1	9.8	15.5	21	0.5	56.3	0.253	84.5	0.296
	17	17.9	10.2	14.2	22	0.5	56.4	0.252	85.4	0.299
	16	17.8	9.6	15.7	22	0.6	56.3	0.248	84.7	0.296
	15	15.6	9.2	16.9	19	0.5	56.3	0.251	84.9	0.297
	14	17.3	10.0	15.4	21	0.5	56.4	0.257	85.7	0.300
	13	17.7	10.3	14.9	22	0.7	56.2	0.253	86.5	0.303
	12	18.1	10.1	14.8	22	0.7	56.3	0.257	85.5	0.299
	11	16.7	10.8	16.7	20	0.6	56.6	0.253	86.5	0.303
	10	15.8	11.0	16.7	19	0.5	56.3	0.257	85.5	0.299
	9	15.7	11.8	16.7	19	0.5	56.5	0.253	84.4	0.295
	8	18.0	13.3	16.1	22	0.6	56.3	0.258	85.7	0.300
	7	17.1	11.5	16.0	21	0.5	56.4	0.255	87.2	0.305
	6	18.6	14.1	15.0	23	0.7	56.7	0.260	84.6	0.296
	5	17.2	13.1	16.7	21	0.6	56.5	0.258	84.7	0.297
	4	18.1	14.7	15.2	22	0.5	56.7	0.269	88.4	0.309
	3	18.3	14.8	15.3	22	0.5	56.1	0.274	88.2	0.309
	2	17.6	14.6	15.9	22	0.6	1.9	0.274	86.6	0.303
		ksi	ksi	f/s	kips	П	**	k-ft	(%)	k-ft
	BL#	CSX	TSX	VMX	FMX	FVP	BPM	EF2	ETR	EMX
FVP:	Force/Ve	elocity proport	ionality							5,
FMX:	Maximur	n Force						EMX: N	lax Transferr	ed Enerav
VMX:	Maximur	n Velocity						ETR: E	nergy Transf	er Ratio
TSX:	Tension	Stress Maxim	um					EF2: E	neray of F^2	
CSX:	Max Me	asured Compr	r. Stress					BPM: B	lows per Min	ute
WS: 1	16,807.9 f	/s							JC:	0.70
LE:	44.20 f	t							EM: 30	0.000 ksi
AR:	1.22 i	n^2							SP: (	0.492 k/ft3
OP: J	NH								Test date: 2-	Sep-2009

Time Summary

Drive 4 minutes 22 seconds

12:10:11 PM - 12:14:33 PM (9/2/2009) BN 1 - 26



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#### MACTEC Engineering and Consulting, Inc. - Case Method Results

Test date: 2-Sep-2009

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MACTEC Engineering and Consulting, Inc. Case Method Results Page 1 of 1 PDIPLOT Ver. 2008.1 - Printed: 16-Nov-2009

NORTH ANNA 3 Project - BORING M-8 (43.7' - 45.2' sample) OP: JNH Rig Serial No. MEC-12; CME-45c Track (D. Rhodes)

OP: JNH								Test date: 2-	Sep-2009
AR: 1.22	in^2							SP: (	0.492 k/ft3
LE: 49.20	ft							EM: 30	0,000 ksi
WS: 16,807.9	f/s							JC:	0.70
CSX: Max Me	easured Comp	r. Stress					BPM: E	Blows per Min	ute
TSX: Tension	n Stress Maxim	num					EF2: E	Eneray of F^2	
VMX: Maximu	m Velocity						ETR: E	Energy Transf	er Ratio
FMX: Maximu	Im Force						EMX: 1	Max Transferr	ed Enerav
FVP: Force/V	elocity proport	tionality							5,
BI #	CSX	TSX	VMX	FMX	FVP	BPM	FF2	FTR	FMX
	ksi	ksi	f/s	kips	П	**	k-ft	(%)	k-ft
2	19.1	15.5	16.3	23	0.7	1.9	0.254	85.2	0.298
3	18.3	12.9	14.7	22	0.7	56.4	0.268	87.9	0.308
4	19.1	11.7	15.4	23	0.7	56.5	0.261	86.4	0.302
5	17.9	14.1	13.5	22	0.8	56.5	0.260	86.0	0.301
6	19.2	11.5	15.8	23	0.7	56.3	0.261	85.9	0.301
7	18.5	11.1	14.4	23	0.7	56.6	0.262	85.2	0.298
8	17.8	12.6	13.2	22	0.7	56.3	0.261	86.4	0.302
9	18.6	10.9	15.1	23	0.7	56.3	0.259	87.0	0.305
10	17.0	12.6	13.3	21	0.7	56.7	0.258	86.3	0.302
11	19.1	11.9	15.7	23	0.7	56.3	0.258	84.8	0.297
12	19.1	11.9	15.9	23	0.7	56.6	0.259	84.6	0.296
13	18.1	12.3	13.5	22	0.7	56.2	0.261	86.1	0.301
14	19.0	10.2	15.7	23	0.7	56.6	0.261	85.9	0.301
15	18.7	12.2	14.6	23	0.7	56.6	0.256	84.7	0.296
16	17.5	12.0	13.4	21	0.7	56.4	0.261	88.3	0.309
17	17.8	11.0	13.8	22	0.7	56.6	0.264	85.9	0.301
18	18.0	11.9	13.5	22	0.7	56.7	0.264	85.8	0.300
19	19.4	10.2	16.1	24	0.7	56.6	0.264	86.8	0.304
20	18.6	11.7	14.2	23	0.7	56.5	0.266	85.9	0.301
21	18.8	11.8	14.4	23	0.7	56.5	0.263	86.0	0.301
22	19.4	10.3	16.4	24	0.7	56.7	0.265	87.8	0.307
23	19.2	11.6	15.4	23	0.7	56.5	0.261	85.8	0.300
24	18.8	11.4	14.7	23	0.7	56.5	0.260	88.7	0.310
25	18.2	10.5	15.0	22	0.7	56.7	0.262	89.1	0.312
26	19.1	11.0	15.6	23	0.7	56.4	0.262	86.7	0.304
27	19.6	10.6	16.6	24	0.7	56.7	0.265	88.6	0.310
28	19.4	10.9	16.0	24	0.7	56.7	0.258	87.0	0.305
29	19.6	10.5	16.3	24	0.7	56.4	0.265	86.8	0.304
30	18.9	10.3	15.1	23	0.7	56.7	0.269	88.8	0.311
31	19.2	9.1	15.8	23	0.7	56.5	0.261	87.8	0.307
32	19.2	9.0	15.8	23	0.7	56.7	0.262	85.9	0.301
33	19.1	9.1	15.3	23	0.7	56.6	0.263	88.6	0.310
34	19.2	9.6	15.5	23	0.7	56.6	0.264	90.4	0.317
35	19.8	8.8	15.8	24	0.7	56.4	0.260	87.0	0.305
30	10.3	0.5	14.5	22	0.7	50./	0.261	ōð.4	0.309
31	19.7	9.4	10.3	24	0.7	50.5 56.9	0.265	90.8	0.318
30	19.0	0.1 0.7	10.7	24	0.7	00.0 56.1	0.203	90.1	0.315
39	20.1	Ö./	10.3	20	0.7	56 9	0.202	00.0 97.2	0.310
40	19.4	0.9	10.0	24 22	0.7	00.0 56 5	0.203	01.2	0.305
41	10.9	/.4 6 0	14.1	∠3 22	0.0 0.2	56.0	0.209	00.4 88 2	0.310
42	10.7	10.7	15.5	20	0.0	50.2	0.200	00.0	0.009
Average	18.9	10.7	10.1	_23	0.7	05.Z	0.262	07.1	0.305

Time Summary

Drive 1 minute 47 seconds

Total number of blows analyzed: 41

12:24:49 PM - 12:26:36 PM (9/2/2009) BN 1 - 42



MACTEC Engineering and Consulting, Inc.



Engineering and constructing a better tomorrow

November 16, 2009

From: Jon Honeycutt, Staff Professional J. C

Reviewed By: Steve Kiser, Principal Professional

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 2foot 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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www.mactec.com

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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

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

TABLE 1

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) <sup>a</sup>	Energy Transfer Ratio (%) <sup>b</sup> (Average ETR)
						11.1 - 12.6	4 - 6 - 6	16	304	86.9%
MEC-21	MACTEC	Thomas Hahn	M-30 (DH)		AW-J	13.7 - 15.2	4 - 7 - 7	19	302	86.3%
(CME 55	Raleigh			9/1/2009		18.7 - 20.2	6 - 7 - 6	19	317	90.6%
Track)	i taroign					23.7 - 25.2	7 - 8 - 10	25	307	87.7%
						28.7 - 30.2	11 - 14 - 15	40	303	86.6%
							Ave	rage for Rig:	306.1	87.4%

<sup>a</sup>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).

<sup>b</sup>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.

Page 41 DらN4N	The average EFV and ETR val	ues may differ slightly and insignifican	atly from those in the PDIPLOT tables due	to roundoff.	
Ang of	Prepared By: J. C.	Date: 11-16-09	Checked By: 70-1	Date: 11-16-09	
90, 87 90, 87 F(	or <u>Am Annoycu</u> With Permission	<u>L</u>	Ϋ́.		

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

Issued To:	Jonathan Honeycutt, Steve	Kiser	
Issued By:	D. Steven Copley, P.E.	050 8-31-09	Date: <u>August 31, 2009</u>
Valid From:	August 31, 2009		To: <u>August 31, 2010</u>

#### Task Description: Perform SPT Energy Measurements

#### Applicable Technical Procedures or Plans, or other reference:

- Geotechnical Work Plan (complete copy of current revision available at Field Office), Section 4.2 and Attachment 2

   Drilling and Sampling Procedures (attached)
- 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)

<u>Specific Instructions</u> (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

**<u>Records</u>**: All records generated shall be considered QA Records.

Page 1 of 15 DCN NAP077 Page 42 of 87 D6N#NAR302

Volume 1, Revision 0

Page 229 of 542

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

Project Manager:				Date:		
Principal Professional:	D.	Anon	Coplay		Date:	8-31-09
Site Manager:			. 0	Date:		

No. of Pages: \_\_\_\_15\_\_\_\_

DCN: NAP077

QA Form 24-1 Revised 8/12/2009

MACTEC

2801 YORKMONT ROAD, SUITE 100 D CHARLOTTE, NC 28208 Telephone: (704) 357-8600 / Facsimile: (704) 357-8638

# RECORD OF SPT ENERGY MEASUREMENT

•	GENERAL INFORMA	ATION		DRILL RIG DATA				• •	
PROJECT:	North Anna 3 Project			MAKE:		CN	IE		
LOCATION:	Virginia	<i>1</i> .		MODEL:		55	Risel		
PROJECT NO .:	6468-09-2473	:		SERIAL N	0.:	ME	(-21		
DATE:	9/1/200	0.9		HAMMER	TYPE:	1Ard	40		
WEATHER:	SUNNY	JSOF		ROPE CO	NDITION:	N/A			
INSPECTOR:	JUH	, ,		ROD SIZE	:	AW-J			
DRILLING COMPANY:	MACTEC - Rule:	<ĥ	i de la composición d Casa de la composición	NO. OF SH	HEAVES:	N/A			
			BOBING	DATA					
	1 14. 20/19		BURING	DATA		T			
BORING NUMBER:	N-30(9)								
DEPTH DRILLED:	Van	ous .							-
TIME DRIVEN:	7.05 pm -	4,75 pm							
RIG OPERATOR:	MAHN	· ·							
HAMMER OPERATOR:	. N/								
PDA PAK SERIAL NO.:	362	(2L		5 9 5			·		
INSTR. ROD AREA:	1.22ind	10 14101							
ACCEL. SERIAL NOS .:	HI-K983	42-40686.						2 A A	
STRAIN SERIAL NOS .:	75 AW #	112	· · · ·	T	1				
	SAMPLE	SPT	S						
1	DEPTH	N-VALUE	1.					÷	
÷	(feet)	(bpf)							
•.	11,1-12.6	4-6-6	1					6	
· ·									
	127 100	4-2 -7						• • •	· · · · · ·
	1301-18.2	<u></u>							
÷ .									1.1
	13.7-20.2	6-7-6		C	1				
	177-7-7	-> > 10			1	++			
	125.7 - 25.0	1-8-10							
*									
	28.7-30.2	11-14-15							
						1.0			
	·								
					-				
1.00									
		1							
DEMAN	Teeller			I		1			
REMARKS:	l esting performed in	accordance with				1.1			
	ASTN D 4633-05								1
	Deviewed by						P	age 44 of 8	7
Valuma 1 1	Paulician C		Dogo 22	1  of  542			n	6N#NAP30	12

- 21



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

#### MACTEC Engineering and Consulting, Inc. - Case Method Results

Test date: 1-Sep-2009

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MACTEC Engineering and Consulting, Inc.     Page       Case Method Results     PDIPLOT Ver. 2008.1 - Printed: 16-Nov-									age 1 of 1 Nov-2009	
NORT <u>OP: JI</u>	'H ANNA 3 NH	Project -	BORING M-30(D	H) (11.1' - 1	2.6' sample)		Rig	Serial No. M	EC-21; CME 55 Test date: 1-	(T.Hahn) Sep-2009
AR: LE:	1.22 in <sup>4</sup> 16.60 ft	2							SP: 0 EM: 30	).492 k/ft3 ),000 ksi
<u>VV5: 1</u>	0,807.9 I/S		na Chasa					DDM	JU:	0.70
CSX:	Max Meas	trees May	ipr. Stress					BPIMI:	Blows per Mini	lte
VMX	Maximum	Velocity	Imum						Energy Transf	ar Ratio
FMX.	Maximum	Force						ETT.	Max Transferre	ed Energy
FVP:	Force/Velo	city prop	ortionality					2003		ou Enorgy
	BL#	CSX	TSX	VMX	FMX	FVP	BPM	EF2	ETR	EMX
		ksi	ksi	f/s	kips	П	**	k-ft	(%)	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
Avera	ge	20.3	9.5	14.4	25	0.8	55.2	0.237	86.9	0.304
	-				Total num	ber of blows	analyzed: 16			

Time Summary

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

Drive 1 minute 44 seconds



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

#### MACTEC Engineering and Consulting, Inc. - Case Method Results

Test date: 1-Sep-2009

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Page 47 of 87 DCN#NAP302 MACTEC Engineering and Consulting, Inc. Case Method Results

NORTH ANNA 3 Project - BORING M-30(DH) (13.7' - 15.2' sample) OP: JNH Page 1 of 1 PDIPLOT Ver. 2008.1 - Printed: 16-Nov-2009

Rig Serial No. MEC-21; CME 55 (T.Hahn) Test date: 1-Sep-2009 SP: 0.492 k/ft3

AR:	1.22 in^2	2							SP: (	0.492 k/ft3
LE:	19.20 ft								EM: 30	0,000 ksi
WS: 1	6,807.9 f/s								JC:	0.70
CSX:	Max Measu	ured Comp	or. Stress					BPM:	Blows per Min	ute
TSX:	X: Tension Stress Maximum								Energy of F <sup>2</sup>	
VMX:	MX: Maximum Velocity								Energy Transf	er Ratio
FMX:	Maximum I	Force						EMX:	Max Transferr	ed Energy
FVP:	Force/Velo	city propor	tionality							
	BL#	CSX	TSX	VMX	FMX	FVP	BPM	EF2	ETR	EMX
		ksi	ksi	f/s	kips	[]	**	k-ft	(%)	k-ft
	2	20.4	15.7	16.4	25	0.8	1.9	0.273	87.4	0.306
	3	21.3	12.2	15.6	26	0.8	59.1	0.257	91.2	0.319
	4	19.4	12.0	14.7	24	0.8	58.1	0.265	91.5	0.320
	5	19.9	10.7	14.5	24	0.8	58.6	0.264	89.9	0.315
	6	21.5	11.9	14.5	26	0.9	58.4	0.261	86.3	0.302
	7	21.6	11.4	14.8	26	0.9	58.5	0.260	88.2	0.309
	8	18.9	11.1	13.6	23	0.8	58.5	0.257	86.3	0.302
	9	21.1	11.0	14.6	26	0.9	58.6	0.251	82.6	0.289
	10	21.5	9.6	14.1	26	1.0	58.3	0.261	85.7	0.300
	11	20.1	10.9	14.2	25	0.8	58.5	0.260	86.2	0.302
	12	21.3	8.8	15.1	26	0.9	58.6	0.252	86.3	0.302
	13	19.7	9.9	15.0	24	0.9	58.5	0.247	81.7	0.286
	14	19.2	10.1	15.1	23	0.8	58.4	0.250	84.5	0.296
	15	21.3	9.9	13.9	26	1.0	58.4	0.253	86.4	0.302
	16	19.3	10.0	14.8	24	0.8	58.7	0.253	84.1	0.294
	17	21.0	10.1	14.2	26	0.8	58.5	0.255	88.0	0.308
	18	21.2	8.7	13.9	26	0.9	58.4	0.250	87.2	0.305
	19	21.2	8.7	13.7	26	0.9	58.3	0.253	86.9	0.304
	20	20.7	8.2	14.0	25	0.8	58.6	0.253	81.5	0.285
Avera	ige	20.5	10.6	14.5	25	0.9	55.5	0.257	86.4	0.302
					Total nur	nber of blows	analyzed: 19	)		

Time Summary

Drive 34 seconds

4:05:23 PM - 4:05:57 PM (9/1/2009) BN 1 - 20



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

#### MACTEC Engineering and Consulting, Inc. - Case Method Results

Test date: 1-Sep-2009

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MACTEC Engineering and Consulting, Inc.	
Case Method Results	

Page 1 of 1 PDIPLOT Ver. 2008.1 - Printed: 16-Nov-2009

 OP:
 JNH

 AR:
 1.22 in^2

Rig Serial No. MEC-21; CME 55 (T.Hahn) Test date: 1-Sep-2009 SP: 0.492 k/ft3

AR: 1.22	In^∠ ft							5P: 0 EM: 30	1.492 K/113
WS 16 807 9	f/s							JC.	0.70
CSX: Max Me	asured Comp	r Stress					RPM · F	lows per Min	
TSX: Tension	Stress Mavim	num					EF2: E	nergy of EA2	uto
VMX Maximu	m Velocity			nergy 011 2	er Ratio				
FMX: Maximu	m Force						EMX: N	lay Transferr	ed Energy
FVP: Force/V	elocity proport	tionality							ou Enorgy
BL#	CSX	TSX	VMX	FMX	FVP	BPM	EF2	ETR	EMX
	ksi	ksi	f/s	kips	П	**	k-ft	(%)	k-ft
2	20.3	10.2	14.8	25	0.5	1.9	0.239	90.1	0.315
3	18.2	9.4	16.3	22	0.6	58.6	0.234	91.6	0.320
4	20.4	9.7	14.6	25	0.8	59.1	0.237	92.0	0.322
5	20.0	10.5	15.3	24	0.5	58.5	0.241	90.4	0.316
6	19.6	10.4	15.6	24	0.7	58.6	0.234	94.2	0.330
7	16.5	9.9	16.0	20	0.6	58.8	0.235	91.2	0.319
8	17.3	8.0	16.3	21	0.6	58.5	0.230	92.5	0.324
9	19.7	8.1	15.3	24	0.7	58.6	0.234	90.8	0.318
10	19.9	8.5	14.9	24	0.5	58.6	0.233	91.3	0.319
11	18.9	7.8	15.7	23	0.5	58.7	0.233	90.4	0.317
12	17.4	9.5	16.1	21	0.6	58.6	0.234	91.7	0.321
13	19.4	9.6	15.4	24	0.5	58.6	0.237	91.8	0.321
14	19.7	8.4	15.2	24	0.7	58.6	0.230	93.0	0.326
15	18.4	9.2	16.0	22	0.6	58.6	0.232	92.6	0.324
16	20.4	9.6	14.3	25	0.5	58.7	0.235	90.9	0.318
17	18.6	7.7	15.7	23	0.7	58.6	0.228	86.8	0.304
18	16.9	9.4	15.8	21	0.6	58.6	0.231	89.7	0.314
19	20.0	8.5	13.5	24	0.8	58.5	0.227	87.3	0.305
20	20.2	8.5	13.7	25	0.8	58.5	0.228	80.6	0.282
Average	19.1	9.1	15.3	23	0.6	55.6	0.233	90.5	0.317
				Total nur	nber of blows	analyzed: 19	)		

Time Summary

Drive 31 seconds

4:15:08 PM - 4:15:39 PM (9/1/2009) BN 1 - 20



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

#### MACTEC Engineering and Consulting, Inc. - Case Method Results

Test date: 1-Sep-2009

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Case Method I	Results					PDIPLC	71 ver. 2008.	I - Printed: 16-	1007-2009
NORTH ANNA OP: JNH	A 3 Project - B0	DRING M-30(I	DH) (23.7' - 2	5.2' sample)		Rig	Serial No. ME	C-21; CME 55 Test date: 1-	(T.Hahn) Sep-2009
AR: 1.22	in^2							SP: (	).492 k/ft3
LE: 29.20	ft							EM: 30	),000 ksi
WS: 16,807.9	f/s							JC:	0.70
CSX: Max Me	easured Compi	r. Stress					BPM:	Blows per Min	ute
TSX: Tension	n Stress Maxim	num					EF2:	Energy of F^2	
VMX: Maximu	Im Velocity						ETR:	Energy Transfe	er Ratio
FMX: Maximu	Im Force						EMX:	Max Transferre	ed Energy
FVP: Force/V	elocity proport	tionality							
BL#	CSX	TSX	VMX	FMX	FVP	BPM	EF2	ETR	EMX
	ksi	ksi	f/s	kips	0	**	k-ft	(%)	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

MACTEC Engineering and Consulting, Inc. С

Page 1 of 1 2008 1 - Printed /-2009

0.307

87.7

Time Summary

Average

Drive 50 seconds

20.5

10.1

13.2

25 0.9 56.3 Total number of blows analyzed: 25 0.255

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



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

#### MACTEC Engineering and Consulting, Inc. - Case Method Results

Test date: 1-Sep-2009

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MACTEC Engineering an	d Consulting, Inc.
Case Method Results	

NORTH ANNA 3 Project - BORING M-30(DH) (28.7' - 30.2' sample) OP: JNH Page 1 of 1 PDIPLOT Ver. 2008.1 - Printed: 16-Nov-2009

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

OP: JNH								Test date: 1-	Sep-2009
AR: 1.22	in^2							SP: (	).492 k/ft3
LE: 34.20	ft							EM: 30	),000 ksi
WS: 16,807.9	f/s							JC:	0.70
CSX: Max Me	asured Comp	r. Stress					BPM: E	Blows per Min	ute
TSX: Tension	Stress Maxim	num					EF2: E	Energy of F^2	
VMX: Maximu	m Velocity						ETR: E	Energy Transf	er Ratio
FMX: Maximu	m Force						EMX: I	Max Transferre	ed Energy
FVP: Force/V	elocity proport	tionality							
BL#	CSX	TSX	VMX	FMX	FVP	BPM	EF2	ETR	EMX
	ksi	ksi	f/s	kips	П	**	k-ft	(%)	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	12.0	25	0.7	58.5	0.208	84.0	0.290
20	21.0	0.0	11.7	20	0.7	50.0	0.270	03.0	0.293
20	20.6	7.0	12.0	22	0.0	59.0	0.209	04.0 92.5	0.290
21	20.0	0.7	12.2	20	0.9	59.0	0.202	00.0	0.292
20	20.0	6.2	12.7	25	0.0	58.6	0.275	84.6	0.303
20	10.7	6.6	12.6	20	0.0	58.6	0.200	85.6	0.230
31	20.3	6.4	12.0	24	1.0	58.7	0.200	85.1	0.300
32	10.2	7.0	13.7	23	0.8	58.4	0.200	80.1	0.200
33	19.2	6.2	12.9	23	0.0	58.7	0.200	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	12.0	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	83	12 7	25	0.8	57.2	0 270	86.6	0 303
		0.0		Total nur	nber of blows	analyzed: 40	)	00.0	0.000

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

50 kips F

0.0 n s

	BN 19									
N)	9/1/20	9/1/2009 4:15:38 PM								
,	LP	0.00	ft	LE	24.20	ft				
	CSX	20.0	ksi	AR	1.22	in^2				
23.0	CSI	20.4	ksi	EM	30,000.0	ksi				
f/s	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	Π	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				
204.6 ms										

MACTEC Engineering and Consulting, Inc.



Engineering and constructing a better tomorrow

December 2, 2009

From: Jon Honeycutt, Staff Professional JNH 12/2/07 Reviewed By: Steve Kiser, Principal Professional

Subject:

Report of SPT Energy – MACTEC CME-55 Trailer (RAL) Hammer Serial No. MEC-425 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 2, 2009, during drilling of Boring M-11 at the referenced site. The testing was performed by Jonathan Honeycutt from approximately 10:05 AM to 11:15 AM on September 2 under clear skies with a temperature of about 65 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 trailer-mounted 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. Phil Pitts. 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 was two feet below the hammer impact point and 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.

14 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 blows evaluated for ETR than what is shown on the boring logs. The test results collected at depths of 23.9 and 28.9 feet were not used in the determination of the ETR due to inconsistency in transferred energy between successive hammer blows.

- The average energy transferred from the hammer to the drill rods for each individual depth interval using the EFV method ranged from 278 foot-pounds to 310 foot-pounds. These average energy transfers correspond to energy transfer ratios (ETR) of 79.4% to 88.6% 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 298.6 foot-pounds, with an average ETR of 85.3%.

Attachments: Page 4 Table 1 - Summary of SPT Energy Measurements – 1 Page Pages 5-6 Work Instruction No. 8 – DCN:NAP-077 – 2 Pages (without attachments) Page 7 Record of SPT Energy Measurement – 1 Page Pages 8 – 13 PDIPLOT Output – 6 Pages Page 14 Force-Velocity Plot – 1 Page

1	SUMMARI	North A	na 3 Project	IS (ASTIN D403	5-05)	
		Louisa Co MACTEC Proje	unty, Virginia ct No. 6468-09-24	173		
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TABLE 1	
SUMMARY OF SPT ENERGY MEASUREMENTS	(ASTM D4633-05)

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) <sup>a</sup>	Energy Transfer Ratio (%) <sup>b</sup> (Average ETR)
MEC-425	MACTEC					33.9 - 35.4	5 - 6 - 6	17	278	79.4%
(CME 55	Paleigh	Phil Pitts	M-11	9/2/2009	AW-J	38.9 - 40.4	4 - 7 - 8	20	304	86.9%
Trailer)	Kaleigh			-		43.9 - 45.4	6 - 7 - 8	21	310	88.6%
		nices, inc.					Ave	rage for Rig:	298.6	85.3%

<sup>a</sup>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).

<sup>b</sup>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.

Date: (2-2-0%) Checked By: Prepared By: -Date: 12

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

Issued To:	Jonathan Honeycutt, Steve		
Issued By:	D. Steven Copley, P.E.	050 8-31-09	Date: <u>August 31, 2009</u>
Valid From:	August 31, 2009		To: <u>August 31, 2010</u>

#### Task Description: Perform SPT Energy Measurements

#### Applicable Technical Procedures or Plans, or other reference:

- Geotechnical Work Plan (complete copy of current revision available at Field Office), Section 4.2 and Attachment 2

   Drilling and Sampling Procedures (attached)
- 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)

<u>Specific Instructions</u> (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.

<u>Specific Quality Assurance Procedures Applicable</u>: 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

**<u>Records</u>**: All records generated shall be considered QA Records.

Page 1 of 15 DCN NAP077 Page 60 of 87 D6N#NAR302

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

Project Manager:				Date:		
Principal Professional:	D.	Aguer	Coplay		Date:	8-31-09
Site Manager:	8	1. Salah da kata da kata	. 0	Date:		

No. of Pages: \_\_\_\_15\_\_\_\_\_

DCN: NAP077

QA Form 24-1 Revised 8/12/2009

2801 YORKMONT ROAD, SUITE 100 D CHARLOTTE, NC 28208 Telephone: (704) 357-8600 / Facsimile: (704) 357-8638

ACTEC

# RECORD OF SPT ENERGY MEASUREMENT

PROJECT:         North Anna 3 Project         MAKE:         CME           LOCATON:         Virginia         MODEL:         5.5 - 77a. Jun. Mounded           PROJECT NO:         6466-09-2473         SERIAL NO:         MEC. 42.5           DATE:         9/2/2009         HAMMER TYPE:         Auto           WEATHER:         Summy 6500 FF         ROPE CONTION:         N/A           DRTE:         9/2/2009         ROPE CONTION:         N/A           DRTE:         9/2/2009         ROPE CONTION:         N/A           DRTE:         STAMA         ROD SIZE:         AVV-J           DRUING COMPANY:         MACTEC - If a let :         N/A         ROPE CONTION:         N/A           BORING DATA         BORING DATA         BORING DATA         BORING DATA         BORING DATA           BORING PERTOR:         N/A         ID:0.5 (AWA - 1/2)'S 12 m         ID:0.5 (AWA - 1/2)'S 12 m         ID:0.5 (AWA - 1/2)'S 12 m           TIME DRIVEN:         10:0.5 (AWA - 1/2)'S 12 m         ID:0.5 (AWA - 1/2)'S 12 m         ID:0.5 (AWA - 1/2)'S 12 m           INSTER ROD AREA:         1.022:w 2         ID:0.5 (AWA - 1/2)'S 12 m         ID:0.5 (AWA - 1/2)'S 12 m           STAN SERIAL NOS:         SAMPLE         SPT         ID:0.5 (AWA - 1/2)'S 12 m         ID:0.5 (AWA - 1/2)'S 12 m
LOCATION:         Virginia         MODEL:         S.S TTA: LP.         Mounded           PROJECT NO:         B468-09-2473         BERIAL NO:         MER. 142.5         Mounded           PROJECT NO:         B468-09-2473         BERIAL NO:         MER. 142.5         Mounded           WATHER:         Summer (5.°)         Robe Conduction:         N/A         Mounded         Mounded           INSPECTOR:         TANA         ROD SIZE:         AW-J         Mounded         Mounded           BORING RUMBER:         M-11         BORING DATA         MOA         Mounded         Mounded           BORING RUMBER:         M-11         BORING DATA         MACTEC - Role: 10/05 Mann         MACTEC - Role: 10/05 Mann         Mounded
LOOMON       ME       425         DATE:       4/2/200       HAMMER TYPE: $Huto:$ MERTHER:       SUMMAR 65°F       Robe construction:       N/A         MARTHER:       SUMMAR 65°F       Robe construction:       N/A         MARTHER:       SUMMAR 65°F       Robe construction:       N/A         MARTHER:       SUMMAR 65°F       Robe construction:       N/A         DRUING COMPANY:       MACTEC - Rate: down       N/A       N/A         DRUING COMPANY:       MACTEC - Rate: down       N/A       N/A         BORING NUMBER:       MATHER:       N/A       N/A         DEPTH ORILLED:       Various       DIATA       N/A         DATE:       10:05 fawa - 1/:15 fam       N/A       N/A         POAPAR SERIAL NO:       36221       N/A       N/A         NAMER OPERATOR:       N/A       SERIAL NO:       36221         INSTE ROD AREA:       1/22/a/2       STAA       SAMPLE       SET         SAMPLE       SPT       SAMPLE       STAA       SAMPLE       SET         JST RAIN SERIAL NOS:       73:9,4 5-6-6       SET       SET       SET       SET         JST - 3:5,4       6-7-8       SET       SET
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JUNATER:       JUNA       Rob Size:       AW-J         INSPECTOR:       INA       No. or sheAves:       NVA         BORING COMPANY:       MACTEC- $\Re A Erght       No. or sheAves:       NVA         BORING DATA       BORING DATA       BORING DATA         BORING DATA       ID: D 5 FA PA - 1/1 2 1 5 PA PA       NA         IMB DRIVEN:       1D: D 5 FA PA - 1/1 2 1 5 PA PA       ID: D 5 FA PA - 1/1 2 1 5 PA PA         IMB DRIVEN:       1D: D 5 FA PA - 1/1 2 1 5 PA PA       ID: D 5 FA PA - 1/1 2 1 5 PA PA         IMB DRIVEN:       1D: D 5 FA PA - 1/1 2 1 5 PA PA       ID: D 5 FA PA - 1/1 2 1 5 PA PA         IMB DRIVEN:       1D: D 5 FA PA - 1/1 2 1 5 PA PA       ID: D 5 FA PA - 1/1 2 PA PA         IMMER OPERATOR:       ID: D 2 PA PA SERIAL NO:       3622L       ID: D 5 FA PA - 1/1 2 PA         INSTR. ROD AREA:       1/22 PA PA       SPT       ID: D FT PA $
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BORING NUMBER: $M - 11$ DEPTH DRILLED: Various TIME DRIVEN: $10:05 \text{ Amn} - 11:15 \text{ Izm}$ RIG OPERATOR: $D: D: D: 5 \text{ Amn} - 11:21 \text{ S Izm}$ RIG OPERATOR: $D: D: D: 5 \text{ Amn} - 11:21 \text{ m}$ RIG OPERATOR: $D: D: D: D: S \text{ Amn} - 11:21 \text{ m}$ NIA POA PAK SERIAL NO: $3622L$ DEPTH $N=XLUE$ Cocel. SERIAL NOS: $75 \text{ H} \text{ m} \text{ M} \text{ L}$ DEPTH $N=XLUE$ (fee) (bef) 23.9 - 25.4 ( $6 - 8 - 838.4 - 40.4$ ( $4 - 7 - 843.9 - 45.4$ ( $6 - 7 - 8712 + 5 - 4$ ( $6 - 7 - 8712 + 5 - 4$ ( $6 - 7 - 8712 + 5 - 4$ ( $6 - 7 - 8$
$\begin{array}{c c c c c c c c c c c c c c c c c c c $
TIME DRVEN: $10:25:4xx - 11:15:4xx$ RIG OPERATOR:       P: PH S         HAMMER OPERATOR:       NA         DA PAK SERIAL NO:       3622L         INSTR. ROD AREA: $1:22ix^2$ ACCEL SERIAL NOS:       H) - K 98.3 - H2 - K0686         STRAIN SERIAL NOS:       TJ H $ix 42$ SAMPLE       SPT         DEPTH       N-VALUE         (feet)       (bpf)         Z3: 9 - 35: 4 5 - 6 - 6       2         Z8: 9 - 30: 4 6 - 11 - 1.2       2         Z8: 9 - 30: 4 6 - 11 - 1.2       2         Z8: 9 - 30: 4 6 - 11 - 1.2       2         Z8: 9 - 30: 4 5 - 6 - 6       2         Z8: 9 - 30: 4 5 - 6 - 6       2         Z8: 9 - 30: 4 5 - 6 - 6       2         Z8: 9 - 30: 4 5 - 6 - 6       2         Z8: 9 - 30: 4 5 - 6 - 6       2         Z8: 9 - 30: 4 5 - 6 - 7 - 8       2         Z8: 9 - 10 - 1       2         Z8: 9 - 30: 4 5 - 7 - 8       2         Z8: 9 - 10 - 1       2
RIG OPERATOR:       P2 P3HS         HAMMER OPERATOR:       N/A         PDA PAK SERIAL NO::       3622L         INSTR. ROD ARRA: $1.22: \sqrt{2}$ ACCEL SERIAL NOS::       M) - K983 : A2 - K0b36         STR AIN SERIAL NOS::       M) - K983 : A2 - K0b36         STRAIN SERIAL NOS::       M) - K983 : A2 - K0b36         STRAIN SERIAL NOS::       M) - K983 : A2 - K0b36         STARIN SERIAL NOS::       M) - K983 : A2 - K0b36         SAMPLE       SPT         DEPTH       N-VALUE         (body)       Q3.9 - 25:4       G - 8 - 8         Q8.9 - 30:4       G - 11 - 1 Q         Q8.9 - 30:4       G - 11 - 1 Q         Q8.9 - 30:4       G - 11 - 1 Q         Q8.9 - 30:4       G - 11 - 1 Q         Q8.9 - 30:4       G - 11 - 1 Q         Q8.9 - 30:4       G - 11 - 1 Q         Q8.9 - 30:4       G - 7 - 8         Q9       Q12       Q12       Q12
HAMMER OPERATOR: N/A PDA PAK SERIAL NO: 3622 INSTR. ROD AREA: $1.22:n^2$ ACCEL SERIAL NOS: 75.4.0.492 / 2 SAMPLE SPT DEPTH N-VALUE (bpf) 23.9-25.4.6-8-8 33.9-35.4.5-6-6 33.9-35.4.5-6-6 33.9-35.4.5-6-6
PDA PAK SERIAL NO::       3622L         INSTR. ROD AREA: $1.22:n^2$ ACCEL SERIAL NOS: $7J + 4.0 + 9/2$ SAMPLE       SPT         DEPTH       N-VALUE         (feet)       (bpf) $23.9 - 35.4$ $5 - 6 - 6$ $38.9^{-9}$ $38.4 - 40.4$ $4 - 7 - 8$ $38.9^{-9}$ $38.4 - 40.4$ $4 - 7 - 8$ $73.9 - 45.4$ $6 - 7 - 8$ $6 - 7 - 8$ $73.9 - 45.4$ $6 - 7 - 8$ $6 - 7 - 8$
$\frac{\text{NSTR. ROD AREA:} 1.22 : n^{2}}{\text{ACCEL SERIAL NOS:} 1/2 : k(983 : 42 - k(0.636))}$ $\frac{\text{STRAIN SERIAL NOS:} 7.5 : 4 : 1.2 : 1.$
ACCEL SERIAL NOS: $P_1 - K985 - P_1 - K0036$ STRAIN SERIAL NOS: $75 + 4 + 97 + 72$ SAMPLE       SPT         DEPTH       N-VALUE         (freet)       (bpf) $23.9 - 75.4$ $6 - 8 - 8$ $28.9 - 30.4$ $6 - 11 - 12$ $38.9 - 35.4$ $5 - 6 - 6$ $38.9 - 35.4$ $5 - 6 - 6$ $38.9 - 35.4$ $5 - 6 - 6$ $38.9 - 35.4$ $6 - 7 - 8$ $71/2$ $6 - 7 - 8$ $71/2$ $71/2$
$\frac{5 \text{TRAIN SERIAL NOS:}}{3 \text{SAMPLE}} = \frac{75 \text{ H} \text{WP} 1/2}{\text{SAMPLE}}$ $\frac{5 \text{SAMPLE}}{\text{DEPTH}} = \frac{\text{SPT}}{\text{N-VALUE}}$ $\frac{1}{(\text{feet})} = \frac{1}{(\text{bpf})}$ $\frac{23.9 - 25.4}{6 - 8 - 8}$ $\frac{28.9 - 30.9}{6 - 11 - 12}$ $\frac{33.9 - 35.4}{5 - 6 - 6}$ $\frac{38.4 - 40.4}{4 - 7 - 8}$ $\frac{43.9 - 45.4}{6 - 7 - 8}$
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REMARKS: Lesting performed in accordance with
ASTM U 4633-05
Reviewed Pur
Reviewed by: Page 62 of 87

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PDIPLOT Ver. 2008.1 - Printed: 2-Dec-2009

#### MACTEC Engineering and Consulting, Inc. - Case Method Results

Test date: 2-Sep-2009

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Page 63 of 87 DCN#NAP302 MACTEC Engineering and Consulting, Inc. Case Method Results Page 1 of 1 PDIPLOT Ver. 2008.1 - Printed: 2-Dec-2009

NORTH ANNA 3 Project - BORING M-11 (33.9' - 35.4' sample)) OP: JNH

Rig Serial No. MEC-425; CME 55 TRAILER (RAL) (P.Pitts) Test date: 2-Sep-2009

AR: LE:	1.22 in^ 39.40 ft	2							SP: ( EM: 30	0.492 k/ft3 0,000 ksi
CSX: TSX: VMX: FMX: FVP	Max Meas Tension Si Maximum Maximum	ured Comp tress Maxim Velocity Force	r. Stress num					BPM: E EF2: E ETR: E EMX: M	Blows per Min Energy of F^2 Energy Transf Max Transferre	ute er Ratio ed Energy
	BL#	CSX	TSX	VMX	FMX	FVP	BPM	EF2	ETR	EMX
		ksi	ksi	f/s	kips	0	**	k-ft	(%)	k-ft
	2	20.5	11.6	15.2	25	0.9	1.9	0.217	76.1	0.266
	3	18.4	11.0	14.1	22	0.8	44.0	0.221	77.2	0.270
	4	18.8	11.5	14.5	23	0.8	46.0	0.217	76.8	0.269
	5	19.6	11.0	13.7	24	0.8	46.0	0.221	76.5	0.268
	6	19.3	10.8	14.1	24	0.8	46.2	0.224	78.4	0.274
	7	19.9	10.6	14.5	24	0.8	47.4	0.219	80.2	0.281
	8	20.0	11.0	14.1	24	0.8	46.6	0.219	79.1	0.277
	9	21.0	10.4	13.6	26	0.9	46.6	0.221	79.3	0.277
	10	20.5	10.6	14.1	25	0.8	46.0	0.220	79.4	0.278
	11	19.9	11.1	14.9	24	0.7	47.2	0.221	81.2	0.284
	12	20.5	9.4	13.5	25	0.9	46.1	0.220	81.2	0.284
	13	20.5	9.6	13.3	25	0.9	46.9	0.222	82.4	0.289
	14	18.8	9.7	14.5	23	0.7	46.3	0.224	81.4	0.285
	15	19.3	9.5	14.0	24	0.8	47.0	0.224	80.5	0.282
	16	19.1	8.9	14.0	23	0.7	47.5	0.228	81.3	0.284
	17	20.3	8.9	13.2	25	0.7	47.7	0.224	82.0	0.287
	18	20.8	9.0	13.2	25	0.9	47.8	0.222	79.5	0.278
Avera	ige	19.8	10.3	14.0	24 Total nur	0.8 nber of blows	44.0 analyzed: 17	0.221	79.6	0.278

Time Summary

Drive 27 seconds

10:44:52 AM - 10:45:19 AM (9/2/2009) BN 1 - 18



PDIPLOT Ver. 2008.1 - Printed: 2-Dec-2009

#### MACTEC Engineering and Consulting, Inc. - Case Method Results

Test date: 2-Sep-2009

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NORTH ANNA 3 Project - BORING M-11 (38.9' - 40.4' sample) OP: JNH

Rig Serial No. MEC-425; CME 55 TRAILER (RAL) (P.Pitts) Test date: 2-Sep-2009

AR: 1.22	? in^2							SP: ( EM: 3	0.492 k/ft3
WS: 16.807.9	) f/s							JC:	0.70
CSX: Max M	easured Comp	r. Stress					BPM: E	Blows per Min	ute
TSX: Tensio	n Stress Maxim	num					EF2: E	Energy of F^2	
VMX: Maxim	um Velocity						ETR: E	Energy Transf	er Ratio
FMX: Maxim	um Force						EMX: N	lax Transferr	ed Energy
FVP: Force/	Velocity proport	tionality							
BL#	CSX	TSX	VMX	FMX	FVP	BPM	EF2	ETR	EMX
	ksi	ksi	f/s	kips	[]	**	k-ft	(%)	k-ft
3	16.6	11.9	16.3	20	0.6	4.3	0.202	80.4	0.281
4	18.2	10.3	16.5	22	0.6	40.9	0.203	82.8	0.290
5	18.1	9.7	16.0	22	0.6	44.1	0.207	82.7	0.290
6	20.8	10.2	16.2	25	0.4	49.8	0.233	92.4	0.323
7	19.7	10.4	16.5	24	0.7	52.7	0.227	91.8	0.321
8	17.7	9.5	16.9	22	0.6	57.1	0.212	85.9	0.301
9	20.9	10.2	17.3	25	0.4	50.6	0.231	94.9	0.332
10	20.3	9.1	18.0	25	0.5	53.1	0.230	94.1	0.329
11	20.5	9.2	17.1	25	0.4	53.1	0.228	91.3	0.319
12	20.3	7.9	16.8	25	0.5	52.4	0.229	89.7	0.314
13	17.8	8.5	14.6	22	0.7	52.5	0.226	87.9	0.308
14	17.8	7.9	13.4	22	0.4	52.8	0.227	88.2	0.309
15	20.9	7.5	14.0	25	0.5	52.7	0.229	86.3	0.302
16	19.0	7.5	14.6	23	0.4	53.1	0.222	88.5	0.310
17	19.1	7.3	15.0	23	0.4	53.2	0.220	89.3	0.313
18	18.8	8.2	12.1	23	0.5	52.1	0.224	85.0	0.297
19	20.4	9.1	11.6	25	0.6	52.4	0.227	84.6	0.296
20	20.9	8.7	11.1	26	0.6	52.6	0.229	84.2	0.295
21	18.5	8.1	10.3	23	0.5	53.0	0.217	79.2	0.277
22	20.4	5.3	10.0	25	0.7	52.8	0.212	80.2	0.281
Average	19.3	8.8	14.7	24	0.5	49.3	0.222	87.0	0.304
				Total nur	mber of blows	analyzed: 20	)		

Time Summary

Drive 1 minute 24 seconds

10:54:32 AM - 10:55:56 AM (9/2/2009) BN 1 - 22



PDIPLOT Ver. 2008.1 - Printed: 2-Dec-2009

#### MACTEC Engineering and Consulting, Inc. - Case Method Results

Test date: 2-Sep-2009

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NORTH ANNA 3 Project - BORING M-11 (43.9' - 45.4' sample) OP: JNH

Rig Serial No. MEC-425; CME 55 TRAILER (RAL) (P.Pitts) Test date: 2-Sep-2009

AR:	1.22 in^2							SP:	0.492 k/ft3
LE: 4	9.40 Tt							EIVI:	30,000 KSI
CSX· Ma	av Massurad (	omor Stress					BPM	· Blows per M	
	neion Stress N	lavimum					EF2	Energy of F	^2
VMX · Ma	aximum Veloci	v					ETR'	Energy Tran	sfer Ratio
FMX Ma	aximum Force	.y					EMX	· Max Transfe	erred Energy
FVP: Fo	prce/Velocity pr	oportionality					Emr		Siriou Enorgy
BL	# CS>	C TSX	VMX	FMX	FVP	BPM	EF2	ETR	EMX
	ks	i ksi	f/s	kips	П	**	k-ft	(%)	k-ft
;	3 19.6	6 12.7	15.5	24	0.8	1.9	0.237	84.1	0.294
	4 20.4	12.8	14.3	25	0.8	44.0	0.235	84.6	0.296
:	5 19.5	5 12.7	15.4	24	0.8	48.0	0.259	91.4	0.320
	6 21.7	7 15.5	16.3	26	0.9	51.1	0.245	89.2	0.312
	7 18.9	9 12.0	13.7	23	0.8	55.2	0.234	82.5	0.289
	8 20.8	3 12.9	14.5	25	0.8	52.2	0.255	89.4	0.313
1	9 21.3	3 12.5	14.9	26	0.8	53.6	0.252	88.3	0.309
1	0 22.9	9 12.1	14.5	28	0.9	54.1	0.259	90.6	0.317
1	1 21.9	9 12.1	14.2	27	0.9	54.4	0.259	90.3	0.316
1:	2 22.7	7 12.1	14.4	28	0.9	54.2	0.259	91.9	0.322
1	3 21.6	5 12.2	14.8	26	0.8	54.9	0.244	84.4	0.295
14	4 22.3	3 11.8	14.8	27	0.8	59.1	0.255	88.5	0.310
1	5 22.4	13.1	14.7	27	0.9	53.1	0.242	85.9	0.301
10	6 20.8	3 11.8	14.9	25	0.8	59.6	0.241	85.7	0.300
1	7 22.2	2 10.9	13.1	27	1.0	52.3	0.257	90.1	0.315
18	8 21.2	2 10.0	13.3	26	0.8	55.3	0.256	90.8	0.318
19	9 20.5	5 11.3	14.7	25	0.8	56.0	0.257	90.7	0.317
2	0 19.7	7 11.3	14.2	24	0.8	54.6	0.251	90.1	0.315
2	1 21.4	11.1	15.2	26	0.8	54.9	0.249	90.5	0.317
2	2 20.4	11.1	14.8	25	0.8	55.0	0.257	91.6	0.320
2	3 22.7	9.5	15.1	28	0.8	54.6	0.259	90.3	0.316
Average	21.2	2 12.0	14.6	26	0.8	51.3	0.251	88.6	0.310

Total number of blows analyzed: 21

Time Summary

Drive 1 minute 7 seconds

11:05:53 AM - 11:07:00 AM (9/2/2009) BN 1 - 23

Project: NORTH ANNA 3							BN 11					
Pile: BORING M-11 (43.9-45.4) - Description: CME 55 TRAILER(P.PITTS)						9/2/2009 11:06:47 AM						
Operator: JNH						LP	0.00	ft	LE	49.40	ft	
							CSX	21.9	ksi	AR	1.22	in^2
50	++					23.0	CSI	22.6	ksi	EM	30,000.0	ksi
kips						f/s	TSX	12.1	ksi	SP	0.492	k/ft3
— F	4						EMX	0.316	k-ft	WS	16,807.9	f/s
	1						STK	4.59	ft	WC	16,807.9	f/s
	1						FVP	0.94	[]	JC	0.70	[]
		Δ.					SFR	1	kips	2L/c	5.88	ms
		MM					RX5	6	kips	EA/c	2.2	ksec/ft
		11	how there		Hallow		RMX	4	kips	FR	5.000	kHz
	0.0	n s 🕨				204.6 ms						

MACTEC Engineering and Consulting, Inc.



Engineering and constructing a better tomorrow

December 2, 2009

From: Jon Honeycutt, Staff Professional \_\_\_\_\_ 12/2/09 Reviewed By: Steve Kiser, Principal Professional 2 (2) 12-2-09

Subject:

Report of SPT Energy – MACTEC CME 55-LC Track (RAL) Hammer Serial No. MEC-02 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-10(DH) at the referenced site. The testing was performed by Jonathan Honeycutt from approximately 2:30 PM to 4:00 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-LC model track drill rig with an SPT automatic hammer. The drilling tools consisted of AW-J-sized drilling rods and a 2foot 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. David White. 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 was two feet below the hammer impact point and 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 275 foot-pounds to 302 foot-pounds. These average energy transfers correspond to energy transfer ratios (ETR) of 78.6% to 86.3% 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 283.6 foot-pounds, with an average ETR of 81.0%.
- 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) <sup>a</sup>	Energy Transfer Ratio (%) <sup>b</sup> (Average ETR)
						11.7 - 13.2	3 - 4 - 5	9	302	86.3%
MEC-02	MACTEC	David White	M-10	9/1/2009	AW-J	14.3 - 15.8	4 - 3 - 5	12	280	80.0%
(CME 55-LC	Raleigh		(DH)			19.2 - 20.7	4 - 4 - 5	13	275	78.6%
Track)	Ituroign					24.2 - 25.7	2 - 3 - 4	9	280	80.0%
						29.2 - 30.7	2 - 3 - 5	10	286	81.7%
							Ave	rage for Rig:	283.6	81.0%

<sup>a</sup>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).

<sup>b</sup>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.

100 Prepared By: Checked By: Date: 12-2-09 Date: 12

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

Issued To:	Jonathan Honeycutt, Steve	Kiser	
Issued By:	D. Steven Copley, P.E.	050 8-31-09	Date: <u>August 31, 2009</u>
Valid From:	August 31, 2009		To: <u>August 31, 2010</u>

#### Task Description: Perform SPT Energy Measurements

#### Applicable Technical Procedures or Plans, or other reference:

- Geotechnical Work Plan (complete copy of current revision available at Field Office), Section 4.2 and Attachment 2

   Drilling and Sampling Procedures (attached)
- 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)

<u>Specific Instructions</u> (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.

<u>Specific Quality Assurance Procedures Applicable</u>: 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

**<u>Records</u>**: All records generated shall be considered QA Records.

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

Project Manager:				Date:		
Principal Professional:	D.	Anon	Coplay		Date:	8-31-09
Site Manager:			. 0	Date:		

No. of Pages: \_\_\_\_15\_\_\_\_

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DCN: NAP077

QA Form 24-1 Revised 8/12/2009

2801 YORKMONT ROAD, SUITE 100 D CHARLOTTE, NC 28208 Telephone: (704) 357-8600 / Facsimile: (704) 357-8638

"

EC

## RECORD OF SPT ENERGY MEASUREMENT

	GENERAL INFORMATION					DRILL RIG DATA						
PROJECT:	North Anna 3 Project		MAKE:	CME	E							
LOCATION:	Virginia	•		MODEL: 5			55LC TRACK					
PROJECT NO.:	6468-09-2473			SERIAL NO .:		me	Mec-02					
DATE	911 120	9		HAMMER TYP	E:	An	Auto					
WEATHER	5	-0A		ROPE CONDI	TION:	N/A						
INSPECTOR.	- SNIH			ROD SIZE:		AW-J	2-14-15 A.S. M					
DRILLING COMPANY:	MACTEC - RAI	Fish		NO. OF SHEA	VES:	N/A		a state of the second sec	an an ann an			
	1.61 (		POPINC									
	AA IB Fact	1	BURING	DAIA								
BORING NUMBER:	M-10 (Det	)										
DEPTH DRILLED:	vari	ous.		·					<u>, ( ) ) ) ) ) ) ) ) ) ) ) ) ) ) ) ) ) ) </u>			
TIME DRIVEN:	a. soom -	100 pm							- 100 - 000-			
RIG OPERATOR:	D. WHE +1											
HAMMER OPERATOR:	N/	/A			-							
PDA PAK SERIAL NO.:	362	2		· · · · ·								
INSTR. ROD AREA:	lich IN	1 1 1 1 1 1 1 1						·				
ACCEL. SERIAL NOS .:	141- 4983	3 4X-K0636	·									
STRAIN SERIAL NOS .:	15 AW #	1/2.	+	<del></del>				· ·		· · · · · ·		
	SAMPLE	SPT	ŀ									
* ·	DEPTH	N-VALUE	5 A									
	(feet)	(bpf)	·									
÷.	17-13.2	3-4-5										
	-											
45 - 13 - 14 - 14 - 14 - 14 - 14 - 14 - 14	111 7 . 1- 2	4.25										
	19,3-15.0	7-0-3			-							
		- / .										
•	19.2-20.7	4-4-5				•						
	1947 157	7. 7-4										
	x Til - 15,7	2-0-F										
	29.2.30,7	-2-3-5										
								-				
x.					0.50							
2.												
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DEMARKS-	Testing performed in	accordance with	1				· · · ·	1				
REWARNS.	ASTMD 4622 05	accordance with										
	AG TW D 4035-03			1								
	Reviewed By:							Page	76 of 87	,		
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#### MACTEC Engineering and Consulting, Inc. - Case Method Results

Test date: 1-Sep-2009

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MACTEC Engineering and Consulting, Inc. Page 1 of 1 Case Method Results PDIPLOT Ver. 2008.1 - Printed: 2-Dec-2009 NORTH ANNA 3 Project - Boring M-10(DH) (11.7' - 13.2' sample) Rig Serial No. MEC-02; CME 55LC (RAL) (D.White) OP: JNH Test date: 1-Sep-2009 AR: 1.22 in^2 SP: 0.492 k/ft3 EM: 30,000 ksi LE: 17.50 ft WS: 16,807.9 f/s JC: 0.70 CSX: Max Measured Compr. Stress BPM: Blows per Minute TSX: Tension Stress Maximum EF2: Energy of F^2 VMX: Maximum Velocity ETR: Energy Transfer Ratio FMX: Maximum Force EMX: Max Transferred Energy FVP: Force/Velocity proportionality BPM EMX CSX FMX FVP BL# TSX VMX EF2 ETR k-ft (%) ksi ksi f/s kips [] k-ft 2 3 19.6 10.8 15.4 24 0.8 1.9 0.226 86.4 0.302 19.8 10.3 15.3 24 0.7 51.4 0.219 77.1 0.270 4 5 23 18.8 9.6 152 0.7 52.0 0.224 84 6 0.296 23 52.0 0.224 87.0 0.304 19.2 8.9 15.0 0.7 6 19.4 7.6 15.3 24 0.7 51.7 0.220 88.2 0.309 7 18.7 7.1 13.7 23 0.7 52.2 0.213 88.3 0.309 8 17.9 7.1 13.7 22 0.7 51.7 0.210 86.6 0.303 0.308 9 22 0.208 87.9 6.9 0.7 52.0 18.1 13.6 23 10 8.6 15.5 0.7 51.8 0.215 90.7 18.6 Average 18.9 8.6 14.7 23 0.7 46.3 0.218 86.3 0.302

Time Summary

Drive 56 seconds

2:38:44 PM - 2:39:40 PM (9/1/2009) BN 1 - 10

Total number of blows analyzed: 9



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#### MACTEC Engineering and Consulting, Inc. - Case Method Results

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MACT Case I	EC Engineer Vethod Resu	ing and Cons Its	ulting, Inc.				Page 1 o PDIPLOT Ver. 2008.1 - Printed: 2-Dec-20				
NORT OP: JN	H ANNA 3 Pi NH	roject - Boring	M-10(DH) (	14.3' - 15.8' sa	mple)	Rig Serial No. MEC-02; CME 55LC (RAL) (D.Whi Test date: 1-Sep-20					
AR: LE: WS: 10	1.22 in^2 19.50 ft 6,807.9 f/s								SP: 0. EM: 30, JC: 0	492 k/ft3 000 ksi ).70	
CSX: TSX: VMX: FMX: FVP:	Max Measur Tension Stre Maximum Ve Maximum Fo Force/Veloci	ed Compr. St ess Maximum elocity orce ty proportiona	ress					BPM: EF2: ETR: EMX:	Blows per Minut Energy of F <sup>2</sup> Energy Transfer Max Transferred	e Ratio d Energy	
	BL#	CSX	TSX	VMX	FMX	FVP	BPM	EF2	ETR	EMX	
		ksi	ksi	f/s	kips	[]	**	k-ft	(%)	k-ft	
	2	20.1	16.0	16.4	25	0.8	1.9	0.234	74.4	0.260	
	3	20.0	14.2	16.5	24	0.9	51.9	0.244	77.8	0.272	
	4	19.9	10.7	15.3	24	0.7	52.1	0.239	80.0	0.280	
	5	19.9	11.9	13.8	24	0.8	52.4	0.240	78.8	0.276	
	6	20.0	11.3	14.4	24	0.8	51.8	0.238	81.8	0.286	
	7	18.6	12.2	14.0	23	0.7	52.0	0.237	80.0	0.280	
	8	19.6	10.0	15.2	24	0.7	51.7	0.239	81.1	0.284	
	9	18.3	9.0	15.2	22	0.7	51.9	0.239	82.9	0.290	
	10	18.5	9.2	14.9	23	0.7	51.5	0.232	81.5	0.285	
	11	17.4	10.3	14.6	21	0.7	52.3	0.222	78.3	0.274	
	12	19.2	11.3	14.0	23	0.7	51.7	0.238	83.6	0.293	
	13	18.5	9.6	14.8	23	0.7	51.9	0.224	79.2	0.277	
Averag	ge	19.2	11.3	14.9	23	0.7	47.8	0.235	80.0	0.280	
					Total number	r of blows ar	alyzed: 12				

Time Summary

Drive 36 seconds

2:52:26 PM - 2:53:02 PM (9/1/2009) BN 1 - 13

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MACT Case	EC Engine	ering and C sults	Consulting, Inc.			Page 1 o PDIPLOT Ver. 2008.1 - Printed: 2-Dec-20					
NORTH ANNA 3 Project - Boring M-10(DH) (19.2' - 20.7' sample) OP: JNH							Rig Serial No.	MEC-02; CN	ME 55LC (RAL) Test date: 1-	(D.White) Sep-2009	
AR: LE: WS: 1	1.22 in^ 24.70 ft 6,807.9 f/s	2							SP: 0 EM: 30 JC:	0.492 k/ft3 0,000 ksi 0.70	
CSX:	Max Meas	ured Comp	r. Stress					BPM:	Blows per Min	ute	
TSX:	Tension S	tress Maxin	num					EF2:	Energy of F^2		
VMX:	Maximum	Velocity						ETR:	Energy Transfe	er Ratio	
FMX:	Maximum	Force						EMX:	Max Transferre	ed Energy	
FVP:	Force/Velo	ocity propor	tionality								
	BL#	CSX	TSX	VMX	FMX	FVP	BPM	EF2	ETR	EMX	
		ksi	ksi	f/s	kips	0	**	k-ft	(%)	k-ft	
	2	19.3	13.1	14.2	24	0.8	1.9	0.261	78.4	0.274	
	3	21.0	12.6	14.9	26	0.8	52.0	0.263	80.1	0.280	
	4	21.1	11.2	13.7	26	0.9	52.3	0.259	79.8	0.279	
	5	20.7	11.6	13.9	25	0.8	51.9	0.254	78.5	0.275	
	6	19.6	12.0	13.8	24	0.8	52.2	0.264	77.9	0.273	
	7	19.0	11.8	14.0	23	0.8	52.3	0.268	79.8	0.279	
	8	19.3	11.3	14.1	24	0.8	51.9	0.261	78.9	0.276	
	9	20.9	12.1	13.9	26	0.9	52.0	0.273	80.1	0.280	
	10	20.6	10.8	13.3	25	0.9	52.3	0.257	75.9	0.266	
	11	20.0	9.9	13.6	24	0.8	52.0	0.253	77.6	0.272	
	12	19.0	10.2	13.2	23	0.8	52.5	0.257	79.3	0.277	
	13	20.1	11.3	13.2	25	0.9	51.8	0.256	76.5	0.268	
	14	19.0	10.4	13.0	23	0.8	52.1	0.258	77.9	0.273	
Avera	ge	20.0	11.4	13.8	24 Total pup	0.8	48.2 vs.apalyzed: 13	0.260	78.5	0.275	

Time Summary

Drive 20 seconds

Total number of blows analyzed: 13

3:08:11 PM - 3:08:31 PM (9/1/2009) BN 1 - 14



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NORTH ANNA 3 Project - Boring M-10(DH) (24.2' - 25.7' sample) OP: JNH

Rig Serial No. MEC-02; CME 55LC (RAL) (D.White) Test date: 1-Sep-2009

AR: 1.22	2 in^2							SP: (	0.492 k/ft3
LE: 29.70	) ft							EM: 30	0,000 ksi
WS: 16,807.9	) f/s							JC:	0.70
CSX: Max M	leasured Comp	r. Stress					BPM: E	Blows per Min	ute
TSX: Tensic	on Stress Maxim	num					EF2: E	Energy of F^2	
VMX: Maxim	um Velocity						ETR: E	Energy Transf	er Ratio
FMX: Maxim	um Force						EMX: N	lax Transferr	ed Energy
FVP: Force/	Velocity proport	tionality							
BL#	CSX	TSX	VMX	FMX	FVP	BPM	EF2	ETR	EMX
	ksi	ksi	f/s	kips	0	**	k-ft	(%)	k-ft
2	20.6	16.6	15.7	25	0.8	1.9	0.261	80.5	0.282
3	19.8	14.3	15.4	24	0.8	52.0	0.257	81.4	0.285
4	20.0	11.2	14.0	24	0.8	52.9	0.257	80.3	0.281
5	19.8	12.4	13.8	24	0.8	51.6	0.267	79.7	0.279
6	19.0	11.9	14.0	23	0.8	52.4	0.257	80.4	0.282
7	18.0	12.1	13.8	22	0.8	52.2	0.263	80.2	0.281
8	18.2	12.2	13.8	22	0.8	51.9	0.260	79.9	0.280
9	18.3	11.3	13.8	22	0.8	52.5	0.256	79.4	0.278
10	18.9	10.0	13.2	23	0.8	52.1	0.250	77.3	0.271
Average	19.2	12.4	14.2	23	0.8	46.6	0.259	79.9	0.280
				Total nu	mber of blows	analyzed: 9			

Time Summary

Drive 24 seconds

3:19:54 PM - 3:20:18 PM (9/1/2009) BN 1 - 10



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Test date: 1-Sep-2009

MAC1 Case	FEC Engine Method Re	eering and C esults	onsulting, Inc.				Page 1 PDIPLOT Ver. 2008.1 - Printed: 2-Dec-2					
NORT	ΓΗ ANNA 3 NH	3 Project - Bo	pring M-10(DH	) (29.2' - 30.7	'' sample)		Rig Serial No. MEC-02; CME 55LC (RAL) (D.V Test date: 1-Sep-					
AR: LE: WS: 1	1.22 in 34.70 ft 6,807.9 f/s	^2 S							SP: EM: JC:	0.492 k/ft3 30,000 ksi 0.70		
CSX: TSX: VMX: FMX: FVP:	Max Mea Tension S Maximum Maximum Force/Vel	sured Comp Stress Maxim Velocity Force locity proport	r. Stress num tionality					BPM: EF2: ETR: EMX:	Blows per Mi Energy of F^ Energy Trans Max Transfe	nute 2 sfer Ratio rred Energy		
	BL#	CSX	TSX	VMX	FMX	FVP	BPM	EF2	ETR	EMX		
	_	KSI	KSI	t/s	kips	IJ	**	k-ft	(%)	K-ft		
	2	20.3	16.3	15.4	25	0.8	1.9	0.262	82.1	0.287		
	3	19.8	14.9	15.9	24	0.8	52.0	0.265	84.0	0.294		
	4	18.1	13.8	14.4	22	0.8	52.0	0.263	82.1	0.287		
	5	18.5	12.1	13.9	23	0.7	52.0	0.248	79.2	0.277		
	6	19.1	12.4	13.8	23	0.8	52.5	0.255	81.8	0.286		
	7	18.4	11.3	13.8	22	0.7	51.9	0.247	78.5	0.275		
	8	19.3	12.7	14.0	24	0.8	52.5	0.263	83.1	0.291		
	9	18.9	12.0	13.3	23	0.8	52.0	0.257	77.6	0.272		
	10	18.6	12.6	14.2	23	0.7	52.4	0.258	85.7	0.300		
	11	17.7	11.0	13.5	22	0.7	51.9	0.261	82.5	0.289		
Avera	ige	18.9	12.9	14.2	23	0.8	47.1	0.258	81.7	0.286		
					Total nur	nber of blov	vs analyzed: 10					

Time Summary

Drive 1 minute 25 seconds

3:29:07 PM - 3:30:32 PM (9/1/2009) BN 1 - 11



MACTEC Engineering and Consulting, Inc.