



March 3, 2009

Mr. Ryan Rusk, P.E.  
AECOM / STS Consultants, Inc.  
750 Corporate Woods Parkway  
Vernon Hills, IL 60061

**Re: Standard Penetration Test Energy Measurements**  
Kingston Power Plant  
Harriman, TN  
GRL Job No. 099015

Dear Mr. Rusk,

This report presents results of energy measurements obtained on February 10, 11, and 18, 2009 during Standard Penetration Tests (SPT) sampling for the above referenced project. A total of five automatic hammers and one safety hammer mounted on six different drill rigs were tested. The six drill rigs were as follows; CME 850, Diedrich D-25, Diedrich D-50, Diedrich D-120, Mobile B-57 (DR-35), and a Mobile B-57 (SN-91034). All dynamic tests were performed on NWJ drill rods with the exception of the Diedrich D-25 drill rig which used AWJ rods. GRL Engineers, Inc. obtained the dynamic measurements with instrumented NWJ and AWJ subsections and a Model PAX Pile Driving Analyzer®. This report describes the testing procedures and summarizes the test results. Appendix A describes our measurement and analysis methods, Appendix B is a summary of the field data, and Appendix C shows the calibration certificates of the Model PAX and the sensors employed in this test series.

#### **PURPOSE AND SCOPE OF WORK**

At the request of AECOM/STS Consultants, Inc., GRL has carried out SPT energy measurements at the Kingston Power Plant. GRL performed SPT energy measurements according to ASTM D4633-05. Specifically, we provided SPT energy measurements at a minimum of 5 sample intervals for each drill rig. The depth of the sampling varied for each drill rig but was generally between 10 and 45 feet. The primary concern for this testing was to provide energy measurements where SPT N values were considered to be reasonably high so as to provide a good statistical basis for the energy calibration. Since much of the soils sampled have very low SPT N values it was often difficult to obtain the energy measurements where SPT N values were greater than about 10 blows per foot.

## **EQUIPMENT**

### ***Drilling and SPT Hammer Equipment***

#### **CME 850 SN# 296002 (Auto Hammer)**

SPT energy measurements were made on an automatic hammer mounted on a CME 850 drill rig. The drilling method used to advance the boring was the rotary mud method. SPT energy measurement tests were performed at the continuous sampling penetrations between 36 and 45 feet. In total, 5 energy measurement events were monitored at boring 09-202.

#### **Diedrich D-25 SN# 122 (Safety Hammer)**

SPT energy measurements were provided on a safety hammer (cathead and rope) mounted on a Diedrich D-25 drill rig. Energy measurements, for the above stated drill rig, were collected at borehole location 09-304. SPT energy measurements were performed at continuous sampling penetrations between 12 and 24 feet. In total, 6 energy measurements were monitored at this borehole location. Two split spoon samplers were used for this testing with one of the samplers being an oversized split spoon. Three of the energy tests were performed with the regular sized sampler and three were preformed with the oversized spoon.

#### **Diedrich D-50 SN# 3321870551 (Auto Hammer)**

SPT energy measurements were performed on an automatic hammer mounted on a Diedrich D-50 drill rig. Energy measurements for this drill rig were collected at continuous sampling penetrations between 31 and 41 feet at boring location 09-108. In total, 5 energy measurement events were monitored at this borehole location.

#### **Diedrich D-120 SN# 080 (Auto Hammer)**

SPT energy measurements were performed on an automatic hammer mounted on a Diedrich D-120 drill rig. Energy measurements for the above stated drill rig were collected at continuous sampling intervals between 10 and 22 feet. In total, 5 energy measurement events were monitored at this borehole location.

#### **Mobile B-57 SN# DR-35 (Auto Hammer)**

**AECOM Designation: Mobile B-57 (V.H.)**

SPT energy measurements were performed on an automatic hammer mounted on a Mobile B-57 drill rig. Energy measurements, for the above stated drill rig, were collected at continuous sampling intervals between 24 and 34 feet. In total, 5 energy measurement events were monitored at this borehole location.

**Mobile B-57 SN# 91034 (Auto Hammer)**  
**AECOM Designation: Mobile B-57 (G.B.)**

SPT energy measurements were performed on an automatic hammer mounted on a Mobile B-57 drill rig. Energy measurements for the above stated drill rig were collected at continuous sampling intervals between 14 and 24 feet. In total, 5 energy measurement events were monitored at this borehole location.

***Instrumentation***

A Model PAX Pile Driving Analyzer (PDA) data acquisition system was used to collect and process the dynamic measurements of force and velocity. A two foot long section of NWJ or AWJ rod subsection was instrumented with two full bridge foil resistance strain gages and two piezoresistive accelerometers mounted at the midpoint location of the instrumented rod. Calibration certificates are included in Appendix C.

Analog signals from the strain gages and accelerometers were conditioned, digitized, stored, and processed with the PDA. The sampling frequency used during the SPT testing was 10 kHz. Selected output from the PDA for each recorded impact included the maximum calculated rod top force (FMX), maximum rod top velocity (VMX), maximum energy transfer (EFV), and the hammer operating rate (BPM).

**MEASUREMENTS AND CALCULATIONS**

***FV Method (EFV)***

Energy transfer to the PDA gage location, E<sub>fv</sub>, was computed by the PDA using force, F(t), and velocity, v(t), records as follows:

$$E_{fv} = \int_a^b F(t) \cdot v(t) dt$$

The time "a" corresponds to the start of the record when the energy transfer begins, and "b" is the time at which energy transferred to the rod reaches a maximum value. The FV Method is currently recognized in ASTM D4633-05, and is the theoretically correct result; therefore, no other energy calculation methods are reported.

**Corrected SPT number (N<sub>60</sub>)**

While the primary purpose of SPT energy testing is to calculate the maximum transferred energy of each hammer blow, the overall average value can be used to calculate the corrected SPT number (N<sub>60</sub>). To adjust the SPT N-values for hammer performance, the following correction, as suggested by Seed for N-value adjustment to 60% transfer efficiency (e.g. 210 ft-pounds), was used:

$$N_{60} = \left( \frac{E_m}{210} \right) N_m$$

Where:

$N_{60}$  = Corrected N-value

$E_m$  = overall average measured energy transfer

$N_m$  = number of blows for middle 12 inches of sampler penetration

A general introduction to dynamic SPT testing methods is included in this report as Appendix A.

Any cross-sectional area difference between the GRL rod subsection and the drill rods, any loose connections or changes in area at section joints, or any cross-sectional area differences between the individual drill rod sections will result in stress wave reflections that can influence the energy transfer. The EFV transferred energy calculation method, utilizing both force and velocity records, is theoretically correct and gives energy transfer results that are not adversely affected by cross-sectional area changes or loose connectors. The EFV results are included in Appendix B for all records collected and accepted after checking them for consistency.

## **RESULTS**

Upon return to the office, the records collected by the PDA were checked again for consistency and accuracy. For example, records from very weak startup or final impacts were not included in average results. Appendix B contains representative plots of force and normalized velocity versus time, as well as plots and tables of PDA results for all hammer blows at each dynamically monitored sampling depth. The PDA results include the EFV (transferred energy by the FV method, as recommended by ASTM D4633-05), ETR (energy transfer efficiency for the EFV method), BPM (hammer operating rate), FMX (maximum rod top force), and VMX (maximum rod top velocity). The plots show each calculated PDA result versus split-spoon penetration and blow number, while the tables show statistical summaries for each 6 inch increment and full printouts of every blow. At the end of each table is a statistical evaluation of the results which includes the average and standard deviation of the entire measurement sample.

Tables 1 through 6 summarize the average transferred energy values calculated by the EFV method. The records consist of averaged hammer blows from the second and third 6 inch increment (i.e. N value) at each dynamically monitored sampling depth. The "energy transfer ratio" (ETR) is defined as the ratio of maximum transferred energy EFV divided by the theoretical hammer potential energy of 350 ft-lbs (i.e., computed per the 140 lb SPT hammer and the standard 30 inch drop as specified by ASTM D1586-99). The average hammer operating rate is reported in blows per minute (BPM). A summary

of the dynamic measurements of the energy transfer to the drill rods for each drill rig is provided in the table below.

Borehole and Drill Rig	Avg. EFV (ft-lbs)	Avg ETR (%)	Range of EFV (ft-lbs)	Range of ETR (%)
CME 850 SN #296002	276	79	269 - 280	77 – 80
Diedrich D-25 SN #122	273	78	265 - 282	76 - 80
Diedrich D-50 SN #321870551	196	56	190 - 206	54 - 59
Diedrich D-120 SN #080	271	78	258 - 288	74 – 82
Mobile B-57 SN #DR-35	324	93	311 - 331	89 - 95
Mobile B-57 SN # 91034	308	88	293 - 321	84 - 92

## **CONCLUSIONS**

Based upon the dynamic test data obtained, the following conclusions are presented:

1. Loose connections and cross sectional area changes in the drill string were observed in the force and velocity records. However, energy transfer values calculated using the EFV equation are not adversely affected by the connectors and therefore are considered the best indication of transferred energy.
2. Dynamic measurements of the average transferred energy to the drill rods using the EFV equation ranged from 196 to 324 ft-lbs for all six of the drill rigs. This corresponds to a transfer efficiency ranging from 56 to 93% of the SPT hammer energy of 350 ft-lbs.

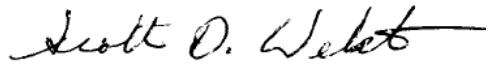
Please review both ASTM D4633-05 and ASTM D1586-99 prior to applying these test results. The energy calibrations reported herein are valid for the same hammer/drill rig, with the same drill operator, same anvil dimensions, and same drilling methods.

March 3, 2009

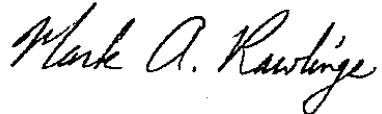
We appreciate the opportunity to be of assistance to you on this project. Please contact our office should you have any questions regarding this submittal, require additional information, or if we may be of further service.

Sincerely,

GRL Engineers, Inc.



Scott D. Webster, P.E.



Mark Rawlings

SDW:MR:dms

**TABLE 1: Summary of SPT Energy Measurements**  
**Kingston Power Plant**  
**CME 850, SN #296002**

Test Date	Split Spoon Sample No.	Reported Sample Depth (feet)	Reported Rod Length (feet)	Reported Blow Count (blows/6")	SPT Field N Value	Avg. Energy Transferred FV Method (ft-lbs)	Energy Transfer Efficiency(1) (%)	Blow per Minute (bpm)	N <sub>60</sub>
2/10/2009	SS-19	36.0 - 38.0	40	3-2-WH-3	2	269	77	36	3
2/10/2009	SS-20	38.0 - 40.0	44	5-8-6-8	14	280	80	47	19
2/10/2009	SS-21	40.0 - 42.0	46	8-17-20-10	37	273	78	45	48
2/10/2009	SS-22	42.0 - 43.0	48	30-70	100	271	77	43	129
2/10/2009	SS-23	43.0 - 43.9	48	72-100/5"	100/5"	280	80	46	133/5"
<b>Average<sup>(2)</sup></b>						<b>276</b>	<b>79</b>	<b>45</b>	
<b>Standard Dev.<sup>(2)</sup></b>						<b>5</b>	<b>2</b>	<b>2</b>	

Notes:

- 1 - Energy transfer efficiency is the energy calculated by the FV method divided by the SPT hammer potential energy of 140 lbs times 2.5 foot drop height or 350 ft-lbs.
- 2 - Average and standard deviation are calculated using averaged data from SPT hammer blows from the last two six inch increments (i.e. N value) from all sampling depths tested.

**TABLE 2: Summary of SPT Energy Measurements**  
**Kingston Power Plant - Boring 09-304**  
**Diedrich D-25, SN #122**

Test Date	Split Spoon Sample No.	Reported Sample Depth (feet)	Reported Rod Length (feet)	Reported Blow Count (blows/6")	SPT Field N Value	Avg. Energy Transferred FV Method (ft-lbs)	Energy Transfer Efficiency <sup>(1)</sup> (%)	Blow per Minute (bpm)	N <sub>60</sub>
2/11/2009	SS-7	12.0 - 14.0	17	12-17-20-21	37	280	80	35	49
2/11/2009	SS-8	14.0 - 16.0	19	12-12-12-12	24	271	77	35	31
2/11/2009	SS-9	16.0 - 18.0	21	3-2-5-5	7	266	76	32	9
2/11/2009	SS-10	18.0 - 20.0	24	7-7-8-8	15	282	80	32	20
2/11/2009	SS-11	20.0 - 22.0	25	4-4-3-3	7	265	76	33	9
2/11/2009	SS-12	22.0 - 24.0	27	3-3-4-4	7	280	80	34	9
<b>Average<sup>(2)</sup></b>						<b>273</b>	<b>78</b>	<b>33</b>	
<b>Standard Dev.<sup>(2)</sup></b>						<b>8</b>	<b>2</b>	<b>1</b>	

Notes:

- 1 - Energy transfer efficiency is the energy calculated by the FV method divided by the SPT hammer potential energy of 140 lbs times 2.5 foot drop height or 350 ft-lbs.
- 2 - Average and standard deviation are calculated using averaged data from SPT hammer blows from the last two six inch increments (i.e. N value) from all sampling depths tested.

**TABLE 3: Summary of SPT Energy Measurements**  
**Kingston Power Plant - Boring 09-108**  
**Diedrich D-50, SN #321870551**

Test Date	Split Spoon Sample No.	Reported Sample Depth (feet)	Reported Rod Length (feet)	Reported Blow Count (blows/6")	SPT Field N Value	Avg. Energy Transferred FV Method (ft-lbs)	Energy Transfer Efficiency <sup>(1)</sup> (%)	Blow per Minute (bpm)	N <sub>60</sub>
2/10/2009	SS-16	31.0 - 33.0	35	4-4-5-5	9	193	55	31	8
2/10/2009	SS-17	33.0 - 35.0	37	4-4-3-4	7	206	59	33	7
2/10/2009	SS-19	37.0 - 39.0	42	2-8-8-6	16	190	54	36	14
2/10/2009	SS-20	39.0 - 41.0	45	2-2-2-3	4	190	54	36	4
2/10/2009	SS-21	41.0 - 43.0	47	3-3-3-2	6	199	57	35	6
<b>Average<sup>(2)</sup></b>						<b>196</b>	<b>56</b>	<b>35</b>	
<b>Standard Dev.<sup>(2)</sup></b>						<b>8</b>	<b>2</b>	<b>1</b>	

Notes:

- 1 - Energy transfer efficiency is the energy calculated by the FV method divided by the SPT hammer potential energy of 140 lbs times 2.5 foot drop height or 350 ft-lbs.
- 2 - Average and standard deviation are calculated using averaged data from SPT hammer blows from the last two six inch increments (i.e. N value) from all sampling depths tested.

**TABLE 4: Summary of SPT Energy Measurements**  
**Kingston Power Plant - Boring 09-403**  
**Diedrich D-120, SN #080**

Test Date	Split Spoon Sample No.	Reported Sample Depth (feet)	Reported Rod Length (feet)	Reported Blow Count (blows/6")	SPT Field N Value	Avg. Energy Transferred FV Method (ft-lbs)	Energy Transfer Efficiency <sup>(1)</sup> (%)	Blow per Minute (bpm)	N <sub>60</sub>
2/11/2009	SS-1	10.0 - 12.0	15	4-5-11-13	16	274	78	39	21
2/11/2009	SS-2	12.5 - 14.5	19	8-25-35-29	60	276	79	40	79
2/11/2009	SS-3	15.0 - 17.0	20	13-11-9-9	20	288	82	39	27
2/11/2009	SS-4	17.5 - 19.5	24	5-5-4-3	9	262	75	40	11
2/11/2009	SS-5	20.0 - 22.0	25	4-3-4-3	7	258	74	38	9
<b>Average<sup>(2)</sup></b>						<b>271</b>	<b>78</b>	<b>39</b>	
<b>Standard Dev.<sup>(2)</sup></b>						<b>14</b>	<b>4</b>	<b>1</b>	

Notes:

1 - Energy transfer efficiency is the energy calculated by the FV method divided by the SPT hammer potential energy of 140 lbs times 2.5 foot drop height or 350 ft-lbs.

2 - Average and standard deviation are calculated using averaged data from SPT hammer blows from the last two six inch increments (i.e. N value) from all sampling depths tested.

**TABLE 5: Summary of SPT Energy Measurements**  
**Kingston Power Plant - Boring 09-414**  
**Mobile B-57, SN #DR-35**

Test Date	Split Spoon Sample No.	Reported Sample Depth (feet)	Reported Rod Length (feet)	Reported Blow Count (blows/6")	SPT Field N Value	Avg. Energy Transferred FV Method (ft-lbs)	Energy Transfer Efficiency <sup>(1)</sup> (%)	Blow per Minute (bpm)	N <sub>60</sub>
2/10/2009	SS-13	24.0 - 26.0	31	3-3-3-4	6	324	93	32	9
2/10/2009	SS-14	26.0 - 28.0	33	2-3-3-4	6	331	95	39	9
2/10/2009	SS-15	28.0 - 30.0	34	2-2-2-4	4	325	93	38	6
2/10/2009	SS-16	30.0 - 32.0	36	1-3-4-4	7	329	94	39	11
2/10/2009	SS-17	32.0 - 34.0	38	2-1-1-3	2	311	89	29	3
<b>Average<sup>(2)</sup></b>						<b>324</b>	<b>93</b>	<b>36</b>	
<b>Standard Dev.<sup>(2)</sup></b>						<b>9</b>	<b>3</b>	<b>5</b>	

Notes:

- 1 - Energy transfer efficiency is the energy calculated by the FV method divided by the SPT hammer potential energy of 140 lbs times 2.5 foot drop height or 350 ft-lbs.
- 2 - Average and standard deviation are calculated using averaged data from SPT hammer blows from the last two six inch increments (i.e. N value) from all sampling depths tested.

**TABLE 6: Summary of SPT Energy Measurements**  
**Kingston Power Plant - Boring 09-211**  
**Mobile B-57, SN #91034**

Test Date	Split Spoon Sample No.	Reported Sample Depth (feet)	Reported Rod Length (feet)	Reported Blow Count (blows/6")	SPT Field N Value	Avg. Energy Transferred FV Method (ft-lbs)	Energy Transfer Efficiency <sup>(1)</sup> (%)	Blow per Minute (bpm)	N <sub>60</sub>
2/18/2009	SS-1	14.0 - 16.0	21	6-6-7-10	13	300	86	25	19
2/18/2009	SS-2	16.0 - 18.0	24	13-14-7-8	21	321	92	42	32
2/18/2009	SS-3	18.0 - 20.0	24	5-8-9-11	17	293	84	29	24
2/18/2009	SS-4	20.0 - 22.0	26	4-5-5-7	10	309	88	33	15
2/18/2009	SS-5	22.0 - 24.0	29	4-5-3-5	8	310	88	33	12
<b>Average<sup>(2)</sup></b>						<b>308</b>	<b>88</b>	<b>34</b>	
<b>Standard Dev.<sup>(2)</sup></b>						<b>12</b>	<b>3</b>	<b>6</b>	

Notes:

1 - Energy transfer efficiency is the energy calculated by the FV method divided by the SPT hammer potential energy of 140 lbs times 2.5 foot drop height or 350 ft-lbs.

2 - Average and standard deviation are calculated using averaged data from SPT hammer blows from the last two six inch increments (i.e. N value) from all sampling depths tested.

## **Appendix A**

***An Introduction into SPT Dynamic Pile Testing***

## APPENDIX A

### AN INTRODUCTION INTO SPT DYNAMIC PILE TESTING

The following has been written by GRL Engineers, Inc. and may only be copied with its written permission.

#### 1. BACKGROUND

The Standard Penetration Test is frequently conducted as an in-situ assessment of soil strength. This test requires that a 140 lb weight is dropped 30 inches onto a drive rod at whose bottom a sampler is usually installed. The sampler is driven for 18 inches; the number of blows required for the last 12 inches of driving is the so-called N-value. The N-value may be used as a strength indicator for foundation design or as a means of assessing the liquefaction potential of soils.

Obviously, the SPT hammer efficiency is an important consideration when using the N-values for design purposes. Measurements have indicated that the energy in the drive rod is sometimes only 30% and may reach 90% of the potential or rated energy of the SPT hammer ( $E_{\text{rated}} = 0.35 \text{ kip-ft}$  or  $0.475 \text{ kJ}$ ). The type of hammer used to drive the rod is the main reason for these variations. On the average, the energy in the drive rod is 60% of the standard rated energy.

Because of the variability of energy, methods based on N-values are considered unreliable. However, measurements during SPT testing using the Case Method can be done on a routine basis and these measurements yield the transferred energy values. With measured energy,  $EM_x$ , known, an adjustment of the measured N-value,  $N_m$ , can be made as follows.

$$N_{60} = N_m [E_m / (0.6E_r)] \quad (1)$$

Thus, if the measured energy value is equal to the normally expected transferred energy of 60% of  $E_{\text{rated}}$  then the adjusted and measured N-values are identical. On the other hand, if the measured energy is only 30% then the adjusted blow count will be reduced by 50%.

#### 2. DYNAMIC TESTING AND ANALYSIS METHODS APPLIED TO SPT

The Case Method of dynamic pile testing, named after the Case Institute of Technology where it was

developed between 1964 and 1975, requires that a substantial ram mass (e.g. a pile driving hammer) impacts the pile top such that the pile undergoes at least a small permanent set. Thus, the method is also referred to as a "High Strain Method". The Case Method requires dynamic measurements on the pile or shaft under the ram impact and then a calculation of various quantities. Conveniently, for SPT applications, the measurements and analyses are done by a single piece of equipment: the SPT Analyzer. The Pile Driving Analyzer® (PDA) is also suitable to perform these measurements and data processing.

A related analysis method is the "Wave Equation Analysis" which calculates a relationship between bearing capacity, pile stresses, transferred energy and field blow count. The GRLWEAP™ program performs this analysis and provides a complete set of helpful information and input data. This program can be used very effectively to simulate the SPT driving process.

#### 3. MEASUREMENTS

GRL uses equipment manufactured by Pile Dynamics, Inc. The system includes either an SPT-Analyzer™ (SPTA) or a Pile Driving Analyzer® (PDA), an instrumented rod section and two accelerometers. SPT energy testing is very closely related to and borrows procedures from dynamic pile testing. Those interested in the basis of the SPT energy testing method may obtain extensive literature on dynamic pile testing from GRL Engineers, Inc.

##### 3.1 SPT Analyzer or Pile Driving Analyzer

The basis for the results calculated by the SPTA or PDA are strain and acceleration measured in an instrumented rod section. These signals are converted to rod top force,  $F(t)$ , and rod top velocity,  $v(t)$ . The SPTA or PDA conditions, calibrates and displays these signals and immediately computes average pile force and velocity thereby eliminating bending effects. The product of these two

measurements is then integrated over time which yields the energy transferred to the instrumented section as a function of time (see Section 4.1).

For convenience and accuracy, strain measurements are usually taken on an instrumented section of SPT drive rod. Ideally, the section properties of the instrumented rod and those of the drive rod are the same, however, using subs, other sections can also be utilized.

For the instrumented section, PDI provides a force calibration in such a way that the output of the instrumented rod is directly calculated without the need for an accurate elastic modulus or cross sectional area of the rod section.

The acceleration measurements are often demanding in the SPT environment, because of high frequency and high acceleration motion components. An experienced measurement engineer, therefore, has to evaluate the quality of this data before final conclusions are drawn from the numerical results calculated by SPTA or PDA.

SPTA or PDA records are taken while the standard N-value is acquired in the conventional manner. This then allows a direct correlation between N-value and average transferred energy.

### **3.2 HPA**

The SPT hammer's ram velocity may be directly obtained using radar technology in the Hammer Performance Analyzer™. The impact velocity results can be automatically processed with a PC or recorded on a strip chart. HPA measurements yield a hammer kinetic energy, but not the energy transferred to the drive rod.

## **4 RECORD EVALUATION BY SPTA OR PDA**

### **4.1 HAMMER PERFORMANCE**

The PDA calculates the energy transferred to the pile top from:

$$E(t) = \int_0^t F(\tau)v(\tau) d\tau \quad (2)$$

The maximum of the  $E(t)$  curve is often called **ENTHRU** or **EMX**; it is the most important quantity for an overall evaluation of the performance of a hammer

and driving system. **EMX** allows for a classification of the hammer's performance when presented as,  $e_T$ , the rated transfer efficiency, also called energy transfer ratio (**ETR**) or global efficiency.

$$e_T = EMX/E_R \quad (3)$$

where  $E_R$  is the hammer manufacturer's rated energy value or 0.35 kip-ft (0.475 kJ) in the case of the SPT hammer.

Often in the SPT literature one finds also reference to the EF2 energy. This evaluation is based on assumed proportionality between force and velocity (see also Section 5):

$$v(t) = F(t) / Z \quad (4)$$

where  $Z = EA/c$  is the pile impedance, E is the elastic modulus, A is the cross sectional area and c is the speed of the stress wave in the pile material..

Combining equations 2 and 4 leads to

$$EF(t) = \int_0^t F(\tau)^2 / Z d\tau \quad (5)$$

The EF2 transferred energy value is the EF-value at the time  $t = 2L/c$ , where L is the drive rod length and c is the stress wave speed in steel (16,800 ft/s or 5,124 m/s). Since the force is easier to measure than both force and velocity, Equation 5 is preferred by some test engineers. However, the EF method is fraught with errors and certain correction factors have to be applied to make it approximately correct. Among the error sources are the following:

- Proportionality is often violated prior to time  $2L/c$ . The proportionality between force and velocity in a downward traveling wave only holds if the wave does not encounter a disturbance prior to reflecting off the pile toe. Such disturbances include a change in cross sectional area, an open or loose splice or joint, or resistance along the shaft.
- Using only one force measurement precludes a data quality check based on the proportionality between force and velocity. Thus, a force measurement that is for some reason in error may not be detectable, which will lead to errors in the EF2 value. Data quality checks will be discussed further in Section 5.

The use of EF2 is therefore not recommended but it is often included in result presentations for the sake of completeness.

#### 4.2 STRESSES

During SPT monitoring, it is also of interest to monitor compressive stresses at both the top of the drive rod and at its bottom.

At the pile top (location of sensors) the maximum compression stress averaged over the rod's cross section, **CSX**, is directly obtained from the measurements. Note that this stress value refers to the instrumented section. If the rod has a different cross sectional area then the stress in the rod will be different from CSX.

The SPTA or PDA can also calculate, in an approximate manner, the force at the rod bottom, **CFB**. To obtain the corresponding stress, this force value should be divided by the appropriate cross sectional area, e.g. by the rod area just above the sampler or by the sampler area itself. Of course, non-uniform stress components as they might occur at the sampler tip due to a sloping rock are not considered in this calculation.

#### 5. DATA QUALITY CHECKS

Quality data is the first and foremost requirement for accurate dynamic testing results. It is therefore important that the measurement engineer performing SPTA or PDA tests has the experience necessary to recognize measurement problems and take appropriate corrective action should problems develop. Fortunately, dynamic pile testing allows for certain data quality checks because two independent measurements are taken that have to conform to the so-called proportionality relationship.

As long as there is only a wave traveling in one direction, as is the case during impact when only a downward traveling wave exists in the rod, force and velocity measured at its top are proportional

$$F = v Z \quad (5)$$

where Z is again the pile impedance,  $Z = EA/c$ . This relationship can also be expressed in terms of stress

$$\sigma = F/A = v (E/c) \quad (6)$$

or strain

$$\epsilon = \sigma/E = v / c \quad (7)$$

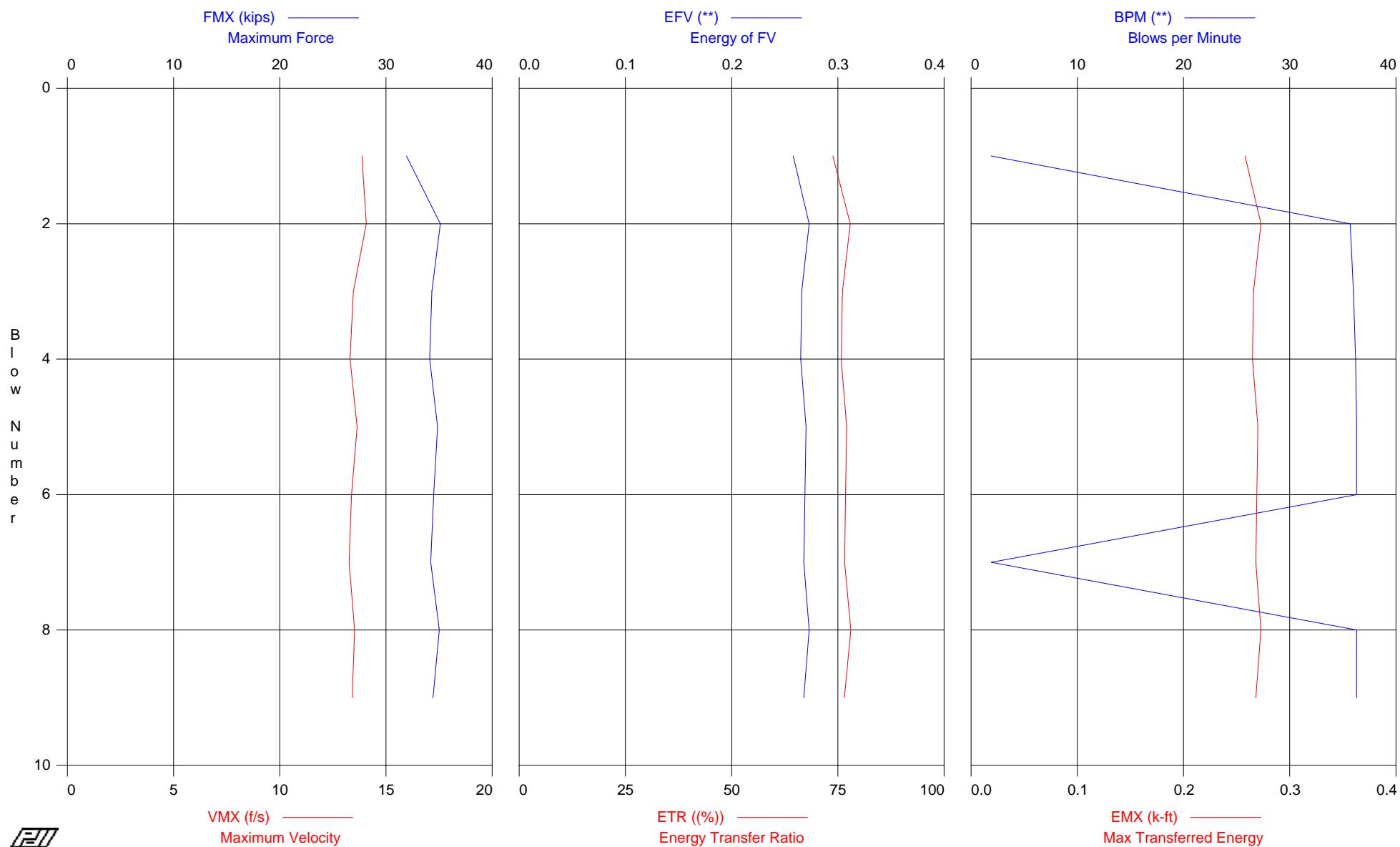
This means that the early portion of strain times wave speed must be equal to the velocity unless the proportionality is affected by high friction near the pile top or by a pile cross sectional change not far below the sensors. Checking the proportionality is an excellent means of assuring meaningful measurements but is only truly meaningful for perfectly uniform rods. Open or loose splices, for example, will lead to a non-proportionality. For SPT rods it is fortunate that usually no soil resistance acts along the shaft and for that reason, proportionality can exist until the stress wave returns from sampler top or rod bottom unless connectors are not sufficiently tightened or have a significant mass.

Velocity data quality can also be checked by looking at the final displacement, DFN, which is calculated from the acceleration by double integration. If the calculated final displacement is much higher or lower than indicated by the N-value, the accelerometer attachment may be loose or the sensor may be faulty. If major drift in the velocity is observed, the EMX value may be in error, even though proportionality from impact to time  $2L/c$  exists. In this case, it may be useful to evaluate the energy transferred to the drill rod at time  $2L/c$ , which is calculated by the PDA or SPTA as the E2E quantity.

## **Appendix B**

## **SPT Results**

## KINGSTON PLANT - B 09-202 SS-19



KINGSTON PLANT - B 09-202 SS-19  
OP: SW

SPT AUTO

Test date: 10-Feb-2009

AR: 1.43 in<sup>2</sup>  
LE: 42.0 ft  
WS: 16,807.9 f/s

SP: 0.492 k/ft<sup>3</sup>  
EM: 30,000 ksi  
JC: 0.70

FMX: Maximum Force  
VMX: Maximum Velocity  
EFV: Energy of FV  
ETR: Energy Transfer Ratio  
BPM: Blows per Minute

EMX: Max Transferred Energy  
EF2: Energy of F<sup>2</sup>  
DFN: Final Displacement  
FVP: Force/Velocity proportionality

BL#	depth	BLC	TYPE	FMX	VMX	EFV	ETR	BPM	EMX	EF2	DFN	FVP	
end	ft	bl/ft		kips	f/s	**	(%)	**	k-ft	k-ft	in	[]	
1	0.50	2	AV1	32	13.9	0.258	74	1.9	0.258	0.280	1.59	0.88	
			MAX	32	13.9	0.258	74	1.9	0.258	0.280	1.59	0.88	
4	1.00	6	AV3	35	13.6	0.268	77	36.0	0.268	0.297	1.46	0.99	
			STD	0	0.3	0.004	1	0.2	0.004	0.005	0.15	0.01	
			MAX	35	14.1	0.273	78	36.2	0.273	0.303	1.63	1.00	
6	1.50	4	AV2	35	13.5	0.270	77	36.3	0.270	0.303	2.02	1.01	
			STD	0	0.1	0.000	0	0.0	0.000	0.001	0.39	0.00	
			MAX	35	13.6	0.270	77	36.3	0.270	0.304	2.40	1.01	
9	2.00	6	AV3	35	13.4	0.270	77	24.8	0.270	0.295	1.67	1.01	
			STD	0	0.1	0.002	1	16.2	0.002	0.006	0.67	0.00	
			MAX	35	13.5	0.273	78	36.3	0.273	0.301	2.41	1.02	
				Average	34	13.5	0.268	77	28.5	0.268	0.296	1.67	0.99
				Std. Dev.	1	0.3	0.004	1	14.2	0.004	0.008	0.48	0.04
				Maximum	35	14.1	0.273	78	36.3	0.273	0.304	2.41	1.02

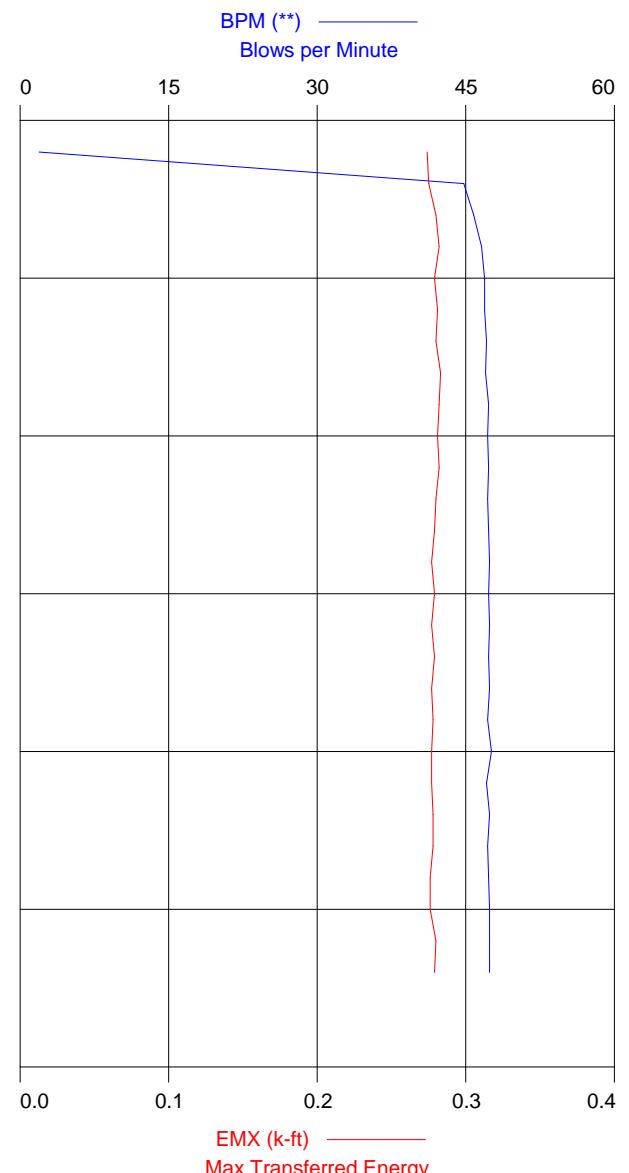
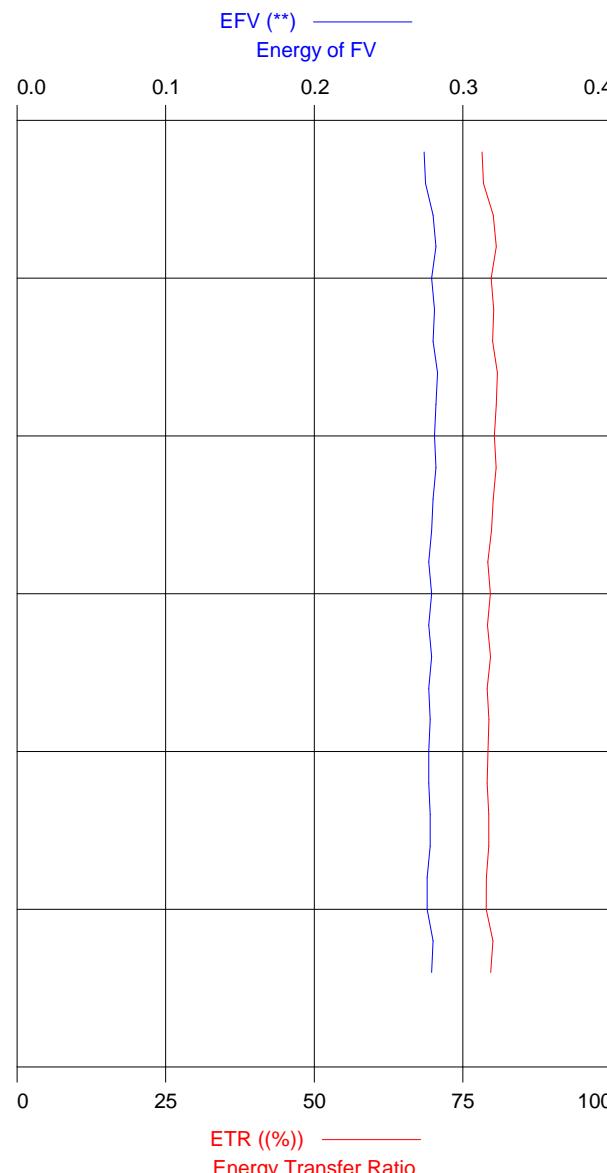
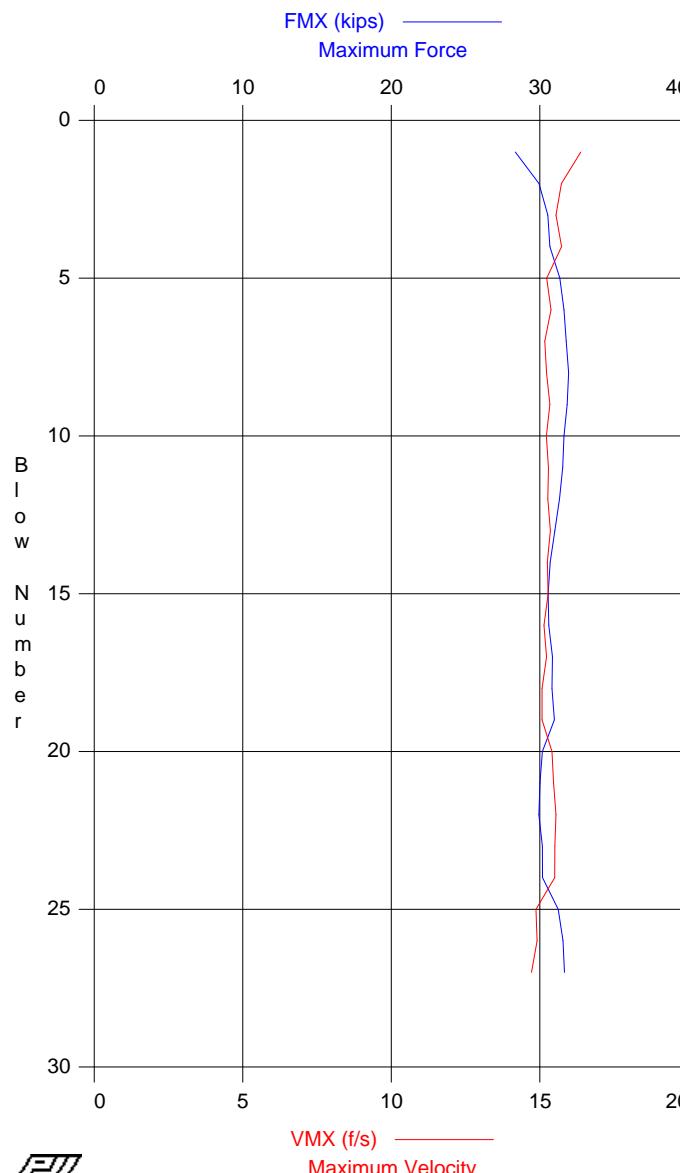
Total number of blows analyzed: 9

#### Time Summary

Drive 25 seconds

1:10:08 PM - 1:10:33 PM (2/10/2009) BN 1 - 9

## KINGSTON PLANT - B 09-202 SS-20



KINGSTON PLANT - B 09-202 SS-20  
OP: SW

SPT AUTO  
Test date: 10-Feb-2009

AR: 1.43 in<sup>2</sup>  
LE: 44.0 ft  
WS: 16,807.9 f/s

SP: 0.492 k/ft<sup>3</sup>  
EM: 30,000 ksi  
JC: 0.70

FMX: Maximum Force  
VMX: Maximum Velocity  
EFV: Energy of FV  
ETR: Energy Transfer Ratio  
BPM: Blows per Minute

EMX: Max Transferred Energy  
EF2: Energy of F<sup>2</sup>  
DFN: Final Displacement  
FVP: Force/Velocity proportionality

BL#	depth	BLC	TYPE	FMX	VMX	EFV	ETR	BPM	EMX	EF2	DFN	FVP			
end	ft	bl/ft		kips	f/s	**	(%)	**	k-ft	k-ft	in	]			
5	0.50	10	AV5	30	15.7	0.278	79	37.2	0.278	0.262	1.10	0.75			
			STD	1	0.4	0.003	1	17.7	0.003	0.003	0.41	0.04			
			MAX	31	16.4	0.282	81	46.9	0.282	0.266	1.73	0.81			
13	1.00	16	AV8	32	15.3	0.281	80	47.2	0.281	0.268	0.66	0.81			
			STD	0	0.1	0.001	0	0.1	0.001	0.002	0.07	0.01			
			MAX	32	15.4	0.283	81	47.3	0.283	0.270	0.74	0.82			
19	1.50	12	AV6	31	15.2	0.278	79	47.3	0.278	0.265	0.81	0.79			
			STD	0	0.1	0.001	0	0.1	0.001	0.001	0.12	0.01			
			MAX	31	15.3	0.279	80	47.4	0.279	0.266	1.00	0.80			
27	2.00	16	AV8	31	15.2	0.278	79	47.3	0.278	0.264	0.77	0.79			
			STD	1	0.3	0.001	0	0.1	0.001	0.003	0.26	0.03			
			MAX	32	15.5	0.280	80	47.6	0.280	0.268	1.27	0.84			
				Average	31	15.3	0.279	80	45.4	0.279	0.265	0.81	0.79		
				Std. Dev.	1	0.3	0.002	1	8.6	0.002	0.003	0.28	0.03		
				Maximum	32	16.4	0.283	81	47.6	0.283	0.270	1.73	0.84		

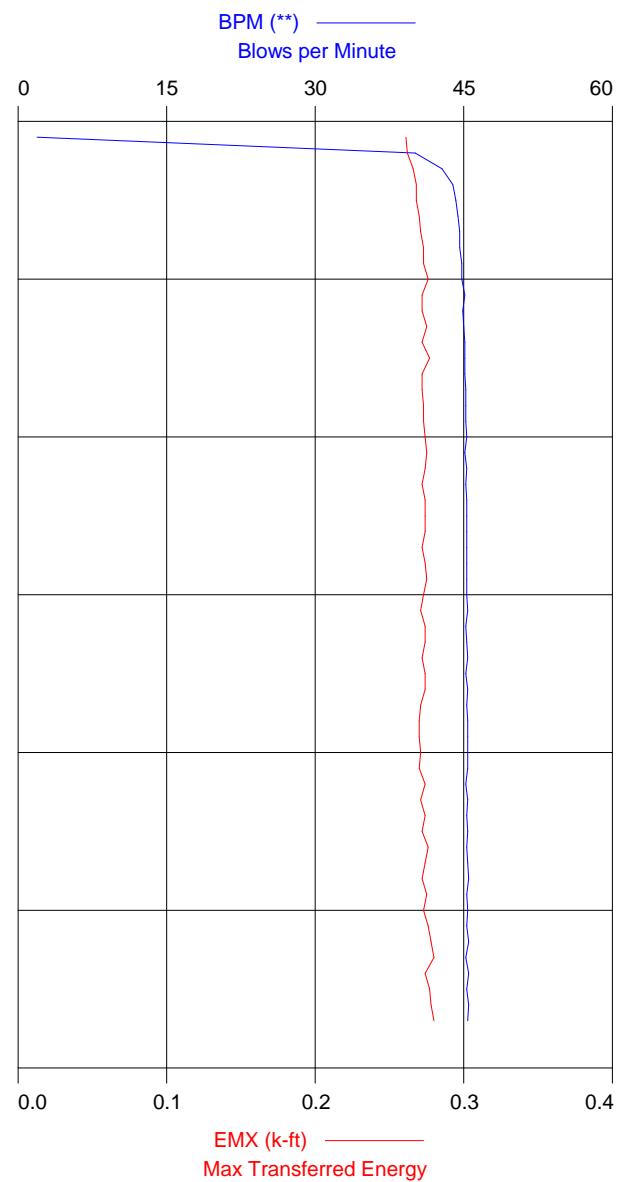
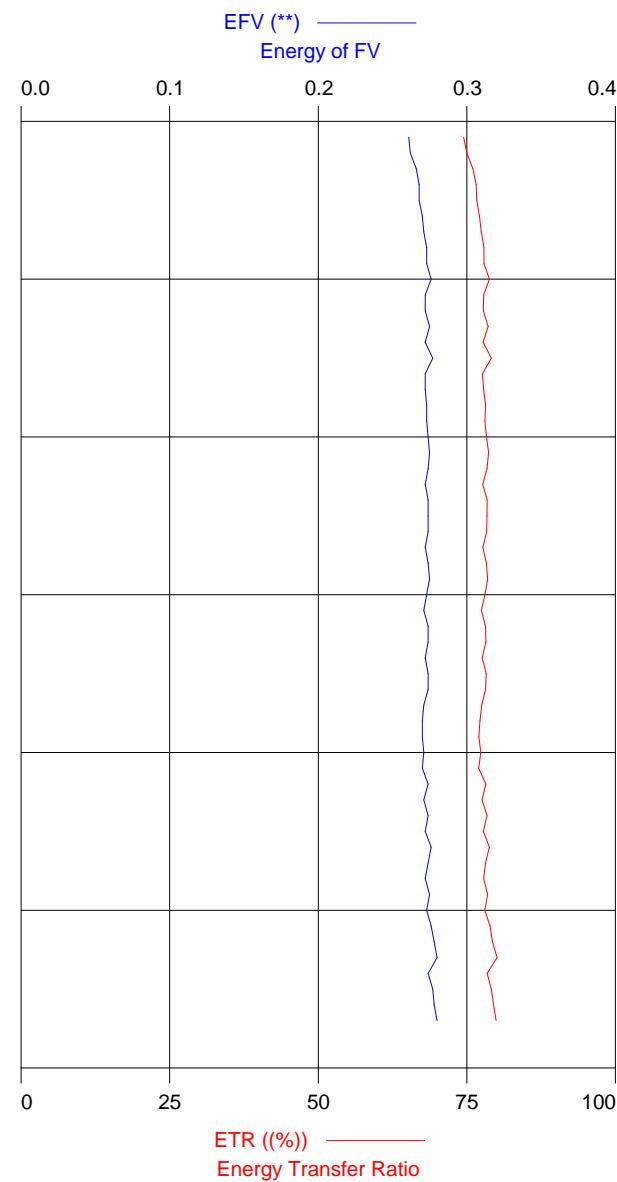
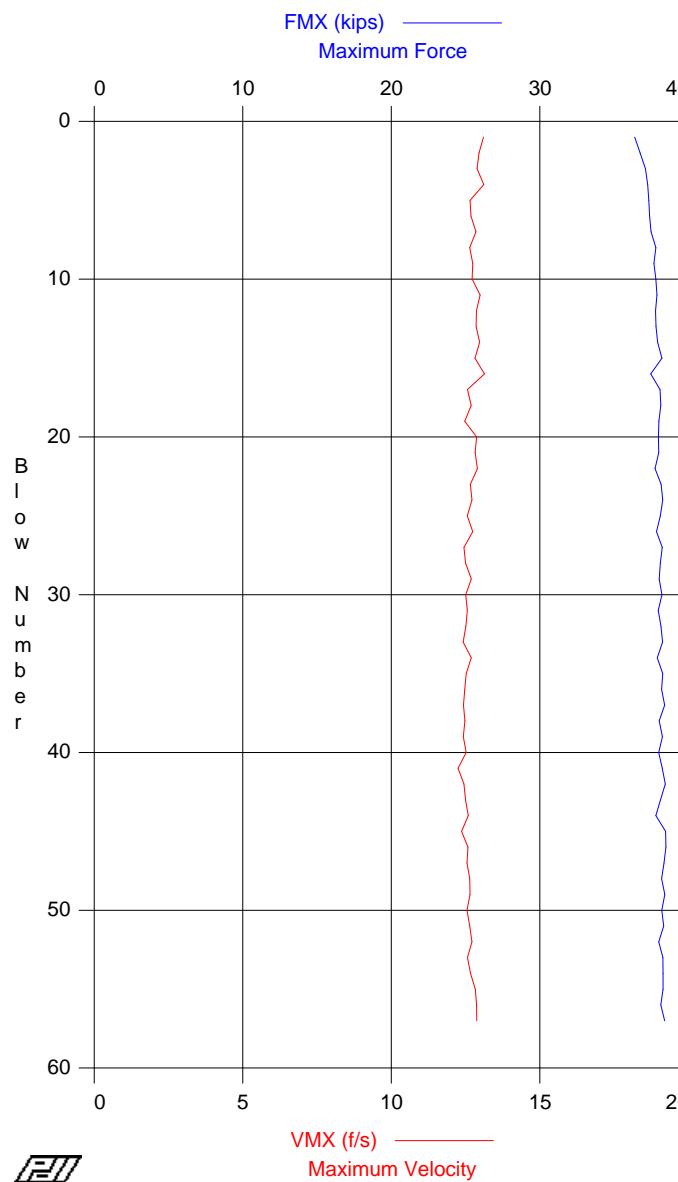
Total number of blows analyzed: 27

#### Time Summary

Drive 33 seconds

1:19:48 PM - 1:20:21 PM (2/10/2009) BN 1 - 27

## KINGSTON PLANT - B 09-202 SS-21



KINGSTON PLANT - B 09-202 SS-21  
OP: SW

SPT AUTO  
Test date: 10-Feb-2009

AR: 1.43 in<sup>2</sup>  
LE: 46.0 ft  
WS: 16,807.9 f/s

SP: 0.492 k/ft<sup>3</sup>  
EM: 30,000 ksi  
JC: 0.70

FMX: Maximum Force  
VMX: Maximum Velocity  
EFV: Energy of FV  
ETR: Energy Transfer Ratio  
BPM: Blows per Minute

EMX: Max Transferred Energy  
EF2: Energy of F<sup>2</sup>  
DFN: Final Displacement  
FVP: Force/Velocity proportionality

BL#	depth end ft	BLC bl/ft	TYPE	FMX kips	VMX f/s	EFV **	ETR (%)	BPM **	EMX k-ft	EF2 k-ft	DFN in	FVP []		
10	0.50	20	AV10	37	12.8	0.269	77	39.6	0.269	0.317	0.93	1.05		
			STD	0	0.2	0.005	1	12.6	0.005	0.006	0.23	0.05		
			MAX	38	13.1	0.276	79	44.8	0.276	0.323	1.49	1.12		
27	1.00	34	AV17	38	12.8	0.273	78	45.2	0.273	0.323	0.43	1.05		
			STD	0	0.2	0.001	0	0.1	0.001	0.003	0.09	0.04		
			MAX	38	13.1	0.277	79	45.3	0.277	0.327	0.58	1.12		
47	1.50	40	AV20	38	12.5	0.273	78	45.3	0.273	0.323	0.46	1.08		
			STD	0	0.1	0.002	1	0.1	0.002	0.003	0.13	0.03		
			MAX	38	12.7	0.276	79	45.4	0.276	0.327	0.74	1.12		
57	2.00	20	AV10	38	12.7	0.276	79	45.4	0.276	0.322	0.44	1.07		
			STD	0	0.1	0.003	1	0.1	0.003	0.002	0.18	0.04		
			MAX	38	12.9	0.280	80	45.5	0.280	0.325	0.72	1.15		
			Average	38	12.7	0.273	78	44.3	0.273	0.322	0.53	1.06		
			Std. Dev.	0	0.2	0.003	1	5.7	0.003	0.004	0.24	0.04		
			Maximum	38	13.1	0.280	80	45.5	0.280	0.327	1.49	1.15		

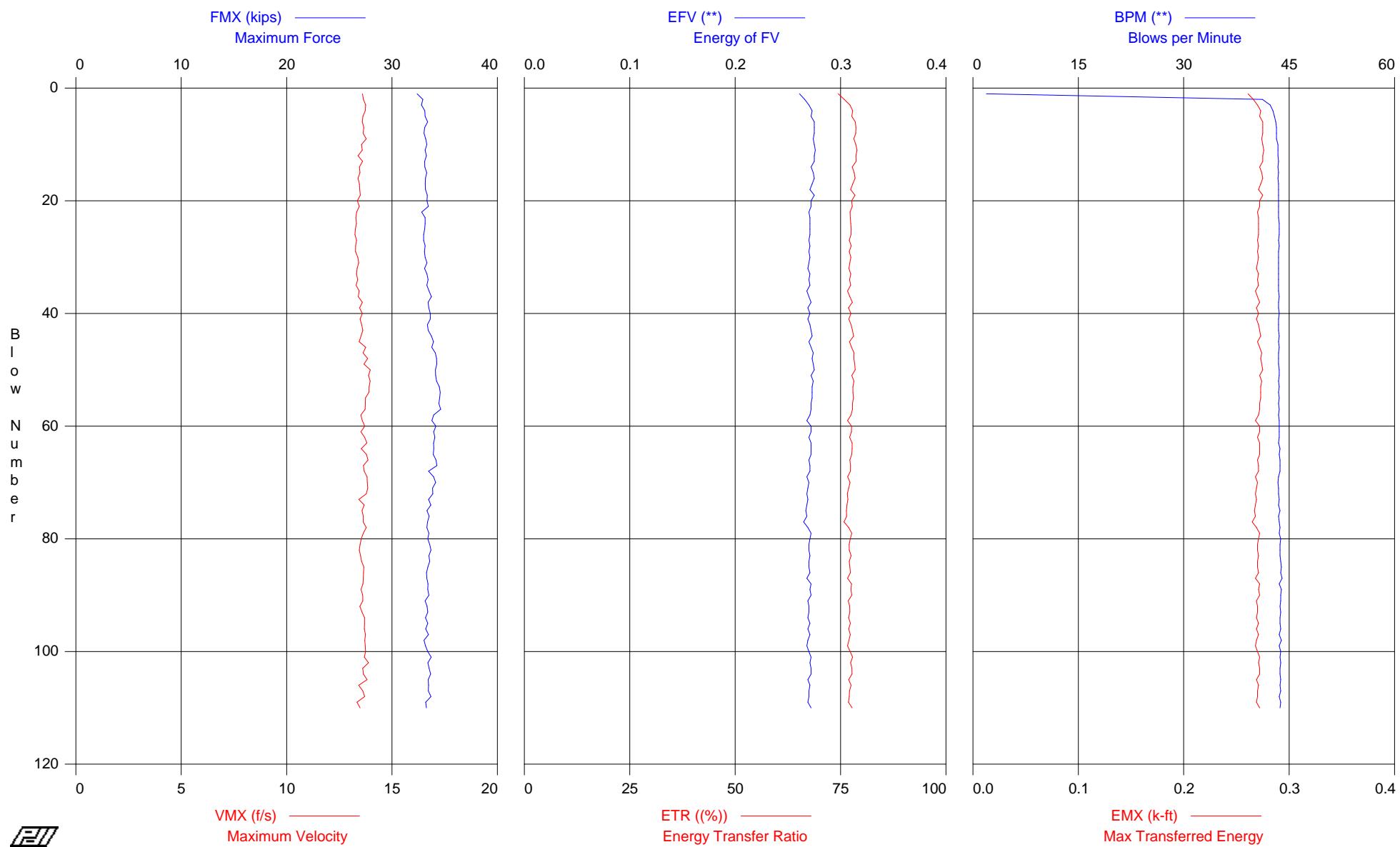
Total number of blows analyzed: 57

#### Time Summary

Drive 1 minute 15 seconds

1:30:39 PM - 1:31:54 PM (2/10/2009) BN 1 - 57

## KINGSTON PLANT - B 09-202 SS-22



KINGSTON PLANT - B 09-202 SS-22  
OP: SW

SPT AUTO  
Test date: 10-Feb-2009

AR: 1.43 in<sup>2</sup>  
LE: 48.0 ft  
WS: 16,807.9 f/s

SP: 0.492 k/ft<sup>3</sup>  
EM: 30,000 ksi  
JC: 0.70

FMX: Maximum Force  
VMX: Maximum Velocity  
EFV: Energy of FV  
ETR: Energy Transfer Ratio  
BPM: Blows per Minute

EMX: Max Transferred Energy  
EF2: Energy of F<sup>2</sup>  
DFN: Final Displacement  
FVP: Force/Velocity proportionality

BL# end	depth ft	BLC bl/ft	TYPE	FMX kips	VMX f/s	EFV **	ETR (%)	BPM **	EMX k-ft	EF2 k-ft	DFN in	FVP []			
40	0.50	80	AV40	33	13.5	0.272	78	42.3	0.272	0.288	0.33	0.96			
			STD	0	0.1	0.003	1	6.5	0.003	0.003	0.10	0.01			
			MAX	34	13.8	0.276	79	43.6	0.276	0.296	0.65	0.99			
110	1.00	140	AV70	34	13.7	0.271	77	43.6	0.271	0.310	0.12	0.96			
			STD	0	0.1	0.002	1	0.1	0.002	0.036	0.10	0.01			
			MAX	35	14.0	0.275	78	44.0	0.275	0.422	0.35	0.99			
				Average	34	13.6	0.271	77	43.2	0.271	0.302	0.20	0.96		
				Std. Dev.	0	0.2	0.002	1	4.0	0.002	0.031	0.14	0.01		
				Maximum	35	14.0	0.276	79	44.0	0.276	0.422	0.65	0.99		

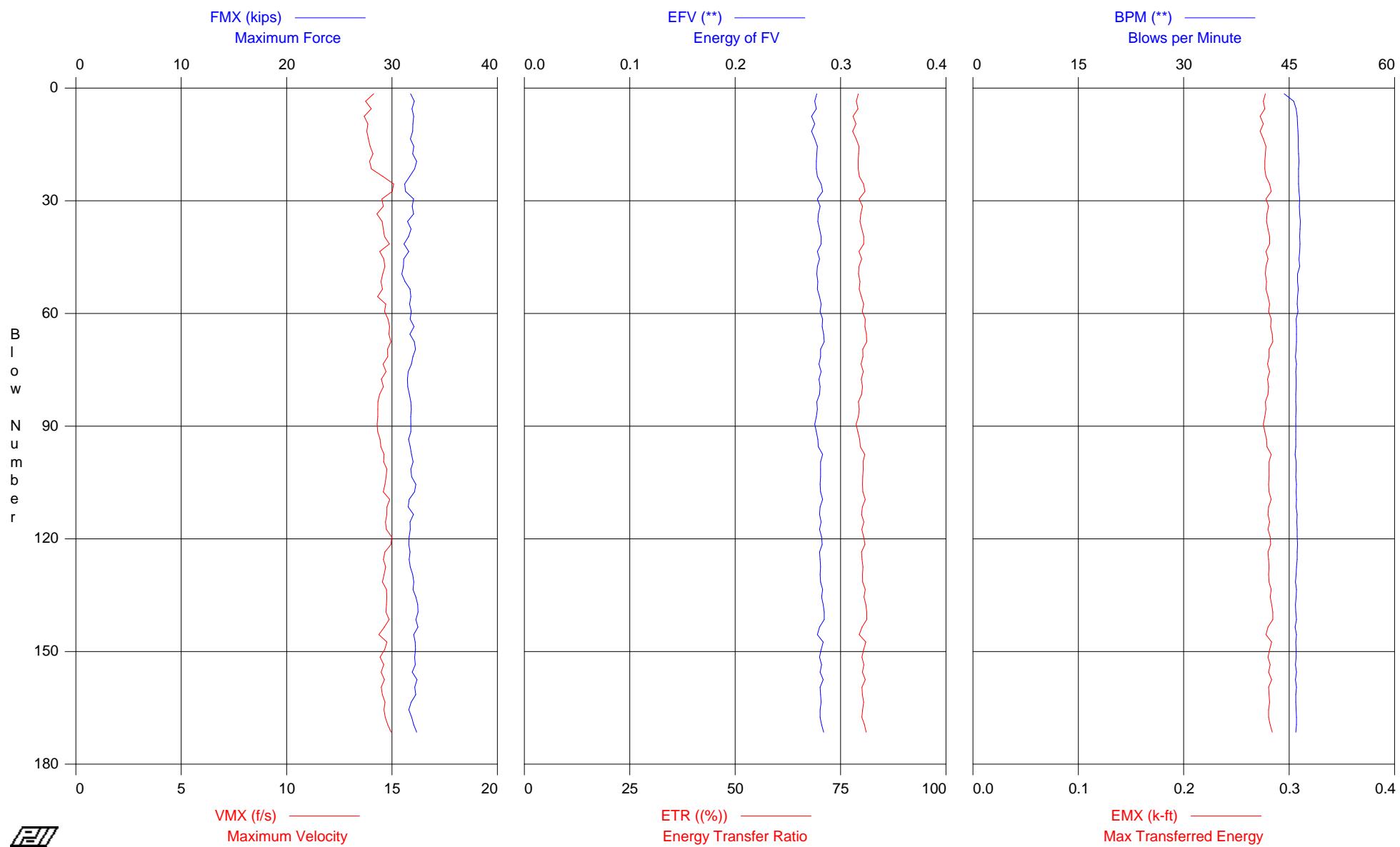
Total number of blows analyzed: 110

#### Time Summary

Drive 2 minutes 30 seconds

1:45:17 PM - 1:47:47 PM (2/10/2009) BN 1 - 110

## KINGSTON PLANT - B 09-202 SS-23



KINGSTON PLANT - B 09-202 SS-23  
OP: SW

SPT AUTO  
Test date: 10-Feb-2009

AR: 1.43 in<sup>2</sup>  
LE: 48.0 ft  
WS: 16,807.9 f/s

SP: 0.492 k/ft<sup>3</sup>  
EM: 30,000 ksi  
JC: 0.70

FMX: Maximum Force  
VMX: Maximum Velocity  
EFV: Energy of FV  
ETR: Energy Transfer Ratio  
BPM: Blows per Minute

EMX: Max Transferred Energy  
EF2: Energy of F<sup>2</sup>  
DFN: Final Displacement  
FVP: Force/Velocity proportionality

BL#	depth	BLC	TYPE	FMX	VMX	EFV	ETR	BPM	EMX	EF2	DFN	FVP				
end	ft	bl/ft		kips	f/s	**	(%)	**	k-ft	k-ft	in	[]				
72	0.50	144	AV72	32	14.4	0.279	80	46.2	0.279	0.273	0.20	0.85				
				STD	0	0.4	0.003	1	0.4	0.003	0.002	0.08	0.04			
				MAX	33	15.2	0.286	82	46.6	0.286	0.279	0.53	0.93			
172	0.90	250	AV100	32	14.6	0.281	80	46.0	0.281	0.275	0.21	0.84				
				STD	0	0.2	0.003	1	0.1	0.003	0.018	0.09	0.01			
				MAX	33	15.2	0.286	82	46.3	0.286	0.412	0.39	0.87			
				Average	32	14.5	0.280	80	46.1	0.280	0.275	0.20	0.84			
				Std. Dev.	0	0.3	0.003	1	0.3	0.003	0.014	0.09	0.03			
				Maximum	33	15.2	0.286	82	46.6	0.286	0.412	0.53	0.93			

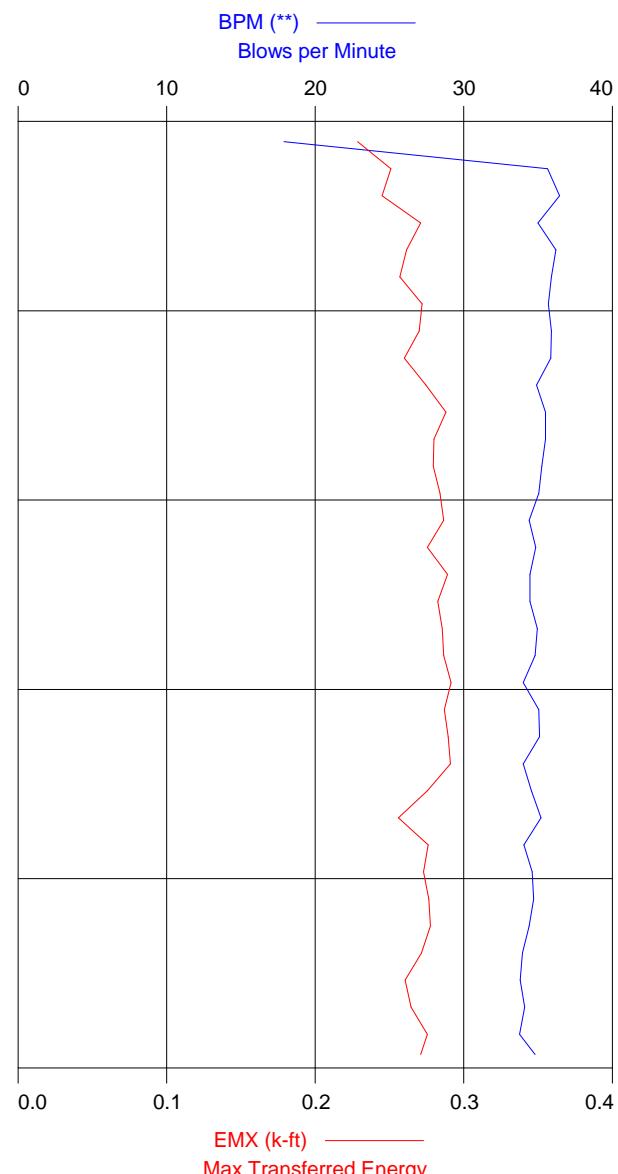
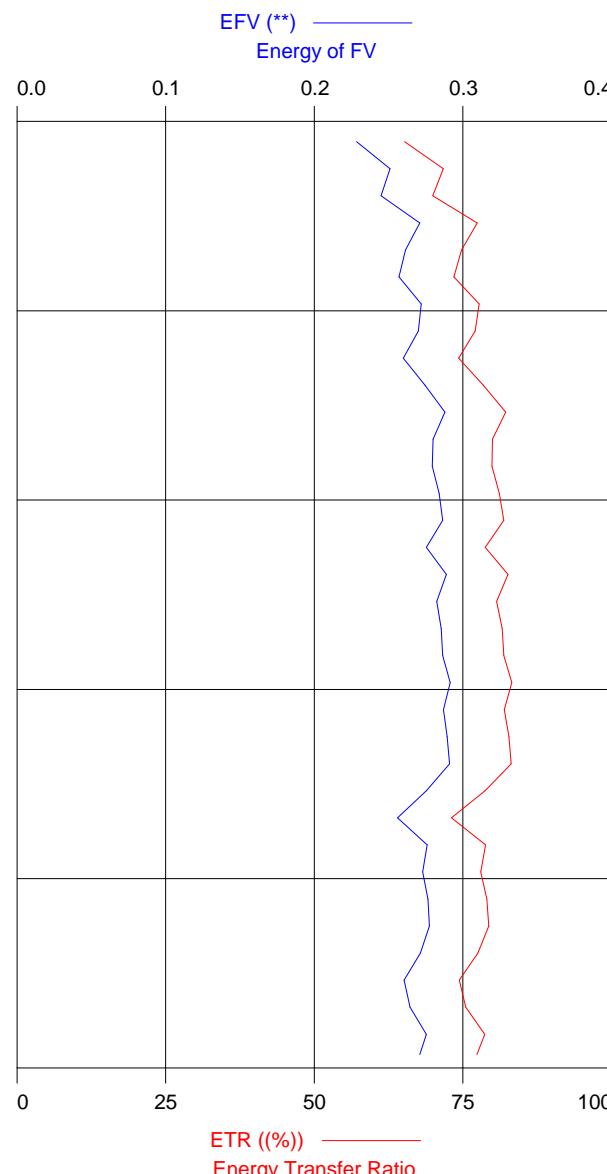
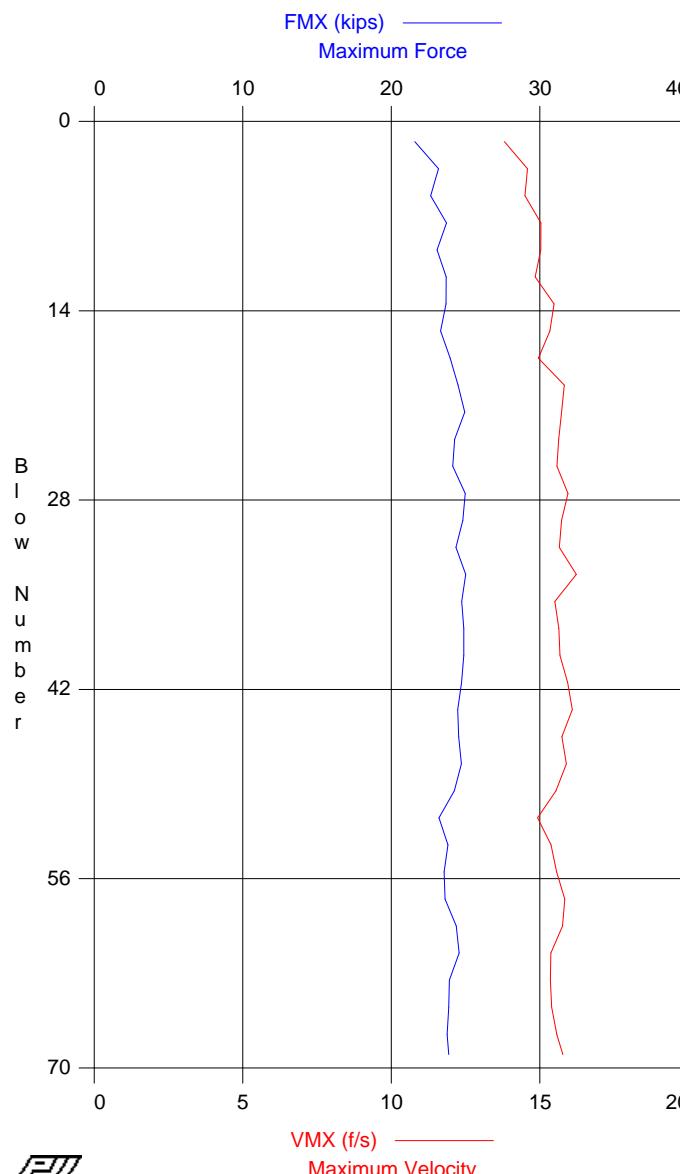
Total number of blows analyzed: 172

#### Time Summary

Drive 3 minutes 42 seconds

2:01:27 PM - 2:05:09 PM (2/10/2009) BN 1 - 172

## KINGSTON PLANT - B 09-304 SS-7



**VMX (f/s) ————— Maximum Velocity**

**ETR ((%)) ————— Energy Transfer Ratio**

**EMX (k-ft) ————— Max Transferred Energy**

KINGSTON PLANT - B 09-304 SS-7  
OP: SW

SPT AUTO  
Test date: 11-Feb-2009

AR: 1.16 in<sup>2</sup>  
LE: 17.0 ft  
WS: 16,807.9 f/s

SP: 0.492 k/ft<sup>3</sup>  
EM: 30,000 ksi  
JC: 0.70

FMX: Maximum Force  
VMX: Maximum Velocity  
EFV: Energy of FV  
ETR: Energy Transfer Ratio  
BPM: Blows per Minute

EMX: Max Transferred Energy  
EF2: Energy of F<sup>2</sup>  
DFN: Final Displacement  
FVP: Force/Velocity proportionality

BL#	depth	BLC	TYPE	FMX	VMX	EFV	ETR	BPM	EMX	EF2	DFN	FVP				
end	ft	bl/ft		kips	f/s	**	(%)	**	k-ft	k-ft	in	lbf				
11	0.50	22	AV11	23	14.6	0.253	72	32.5	0.253	0.199	0.71	0.72				
				STD	1	0.6	0.017	5	9.7	0.017	0.014	0.15	0.03			
				MAX	24	15.5	0.285	81	37.0	0.285	0.222	0.96	0.77			
28	1.00	34	AV17	24	15.5	0.274	78	35.5	0.274	0.216	0.54	0.71				
				STD	1	0.5	0.013	4	0.7	0.013	0.010	0.12	0.02			
				MAX	25	16.3	0.296	85	37.0	0.296	0.228	0.81	0.76			
48	1.50	40	AV20	25	15.8	0.286	82	34.6	0.286	0.223	0.53	0.72				
				STD	0	0.3	0.006	2	0.5	0.006	0.005	0.07	0.02			
				MAX	25	16.6	0.296	85	35.6	0.296	0.229	0.66	0.75			
69	2.00	42	AV21	24	15.5	0.271	77	34.3	0.271	0.212	0.47	0.71				
				STD	1	0.3	0.009	3	0.6	0.009	0.008	0.08	0.01			
				MAX	25	16.0	0.288	82	35.9	0.288	0.223	0.66	0.75			
				Average	24	15.4	0.273	78	34.4	0.273	0.214	0.54	0.72			
				Std. Dev.	1	0.6	0.016	4	4.0	0.016	0.012	0.13	0.02			
				Maximum	25	16.6	0.296	85	37.0	0.296	0.229	0.96	0.77			

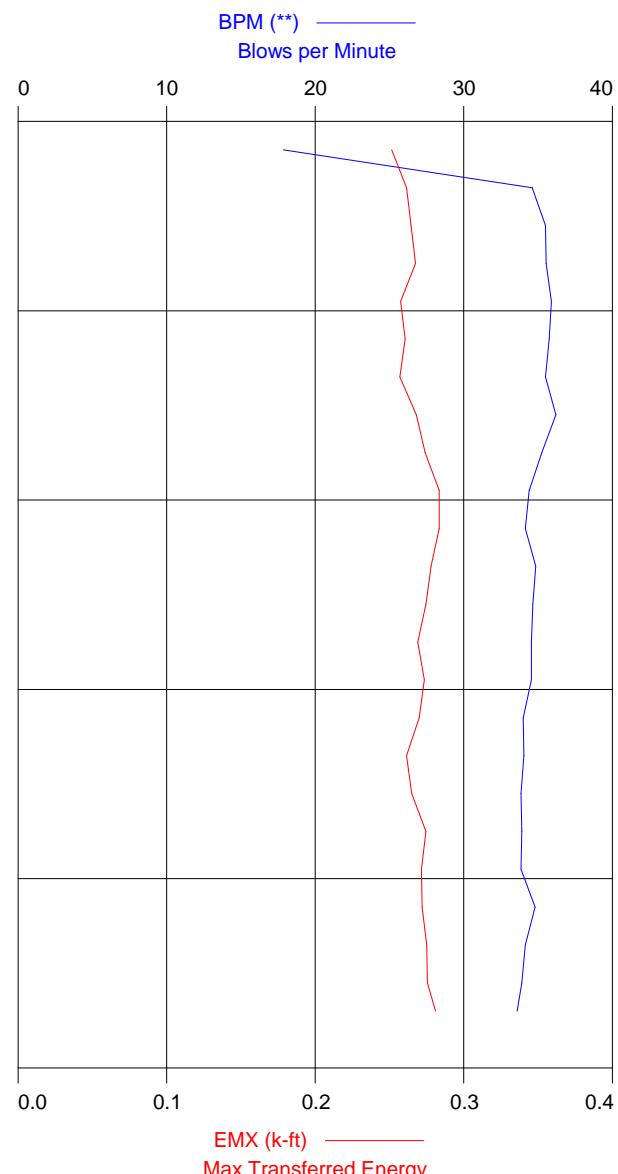
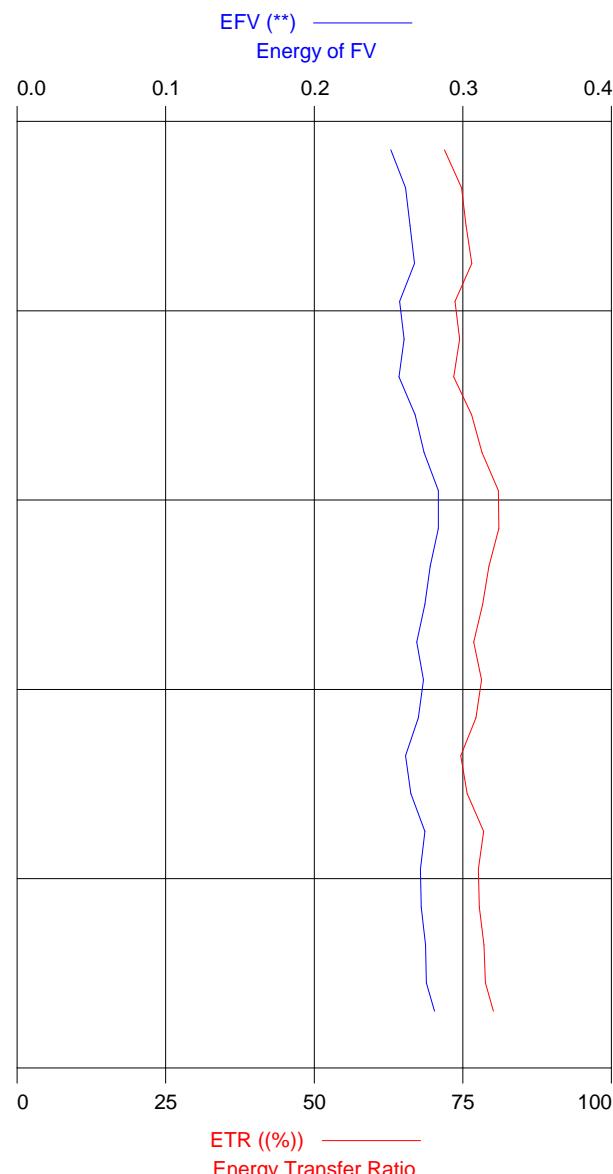
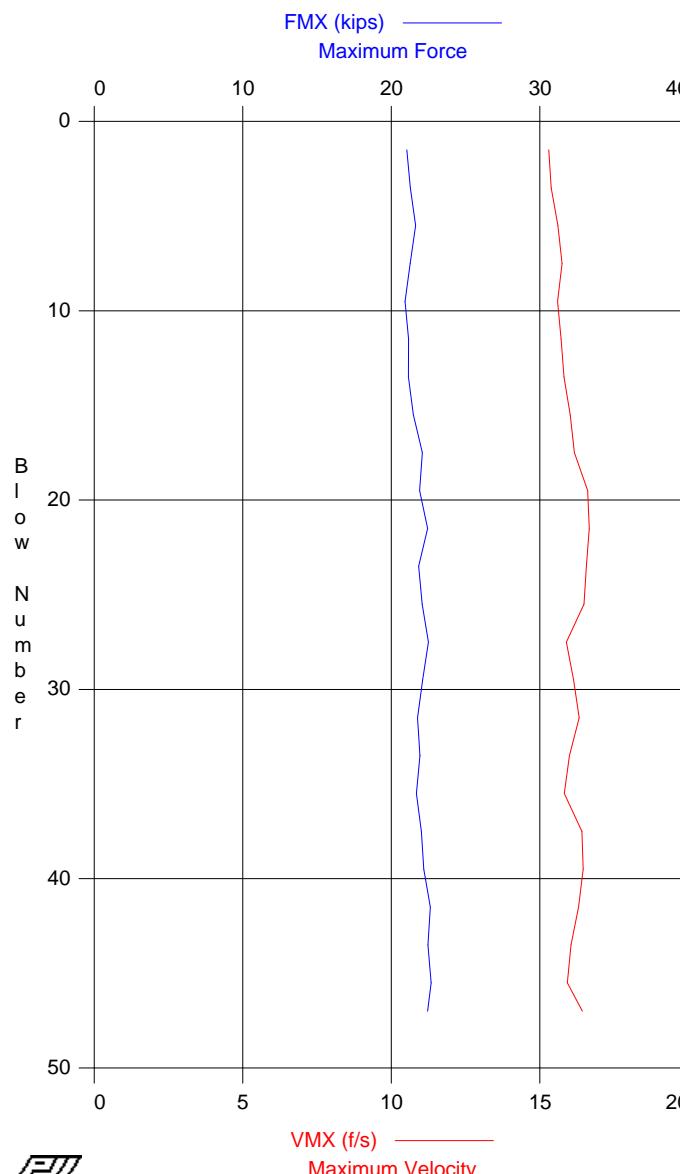
Total number of blows analyzed: 69

#### Time Summary

Drive 1 minute 57 seconds

10:38:24 AM - 10:40:21 AM (2/11/2009) BN 1 - 69

## KINGSTON PLANT - B 09-304 SS-8



KINGSTON PLANT - B 09-304 SS-8  
OP: SW

SPT AUTO  
Test date: 11-Feb-2009

AR: 1.16 in<sup>2</sup>  
LE: 19.0 ft  
WS: 16,807.9 f/s

SP: 0.492 k/ft<sup>3</sup>  
EM: 30,000 ksi  
JC: 0.70

FMX: Maximum Force  
VMX: Maximum Velocity  
EFV: Energy of FV  
ETR: Energy Transfer Ratio  
BPM: Blows per Minute

EMX: Max Transferred Energy  
EF2: Energy of F<sup>2</sup>  
DFN: Final Displacement  
FVP: Force/Velocity proportionality

BL#	depth	BLC	TYPE	FMX	VMX	EFV	ETR	BPM	EMX	EF2	DFN	FVP				
end	ft	bl/ft		kips	f/s	**	(%)	**	k-ft	k-ft	in	[]				
11	0.50	22	AV11	21	15.6	0.261	75	32.2	0.261	0.216	0.84	0.66				
				STD	0	0.3	0.008	2	9.6	0.008	0.007	0.11	0.01			
				MAX	22	16.0	0.270	77	36.6	0.270	0.223	1.00	0.67			
23	1.00	24	AV12	22	16.2	0.272	78	35.2	0.272	0.228	0.78	0.64				
				STD	1	0.4	0.012	3	0.9	0.012	0.010	0.10	0.01			
				MAX	23	16.8	0.284	81	36.4	0.284	0.240	0.98	0.67			
35	1.50	24	AV12	22	16.2	0.270	77	34.4	0.270	0.229	0.71	0.66				
				STD	0	0.3	0.006	2	0.4	0.006	0.005	0.10	0.02			
				MAX	23	16.5	0.278	79	35.1	0.278	0.234	0.90	0.69			
47	2.00	24	AV12	22	16.2	0.274	78	34.0	0.274	0.234	0.71	0.67				
				STD	0	0.3	0.007	2	0.5	0.007	0.006	0.10	0.02			
				MAX	23	16.6	0.290	83	34.8	0.290	0.246	0.91	0.69			
				Average	22	16.1	0.269	77	34.0	0.269	0.227	0.76	0.66			
				Std. Dev.	1	0.4	0.010	3	4.8	0.010	0.010	0.12	0.02			
				Maximum	23	16.8	0.290	83	36.6	0.290	0.246	1.00	0.69			

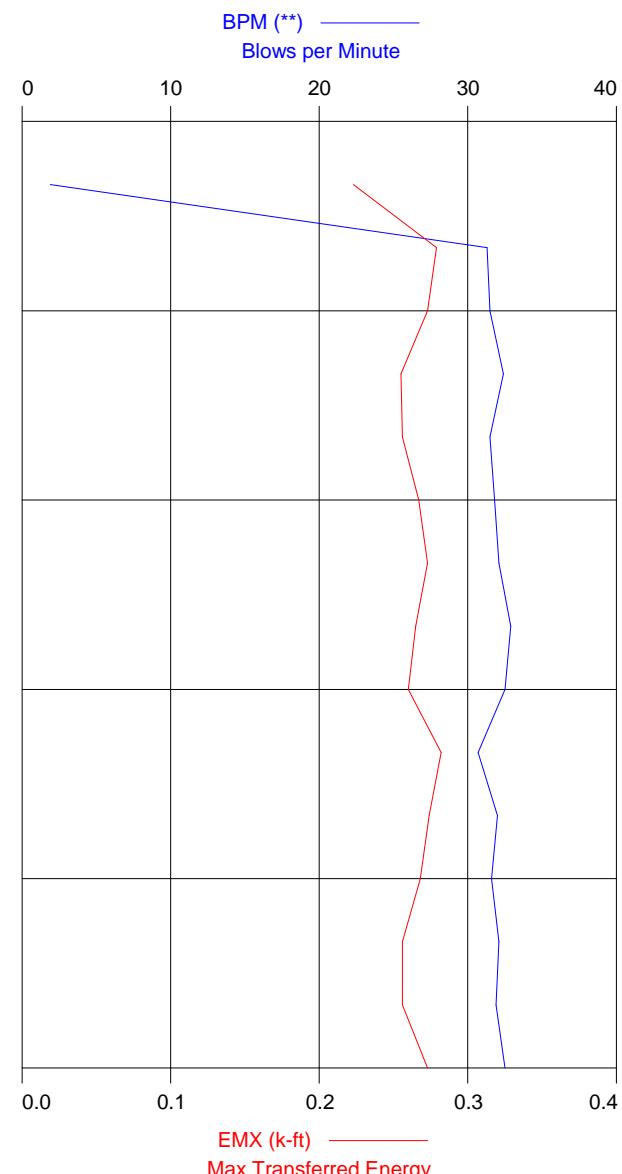
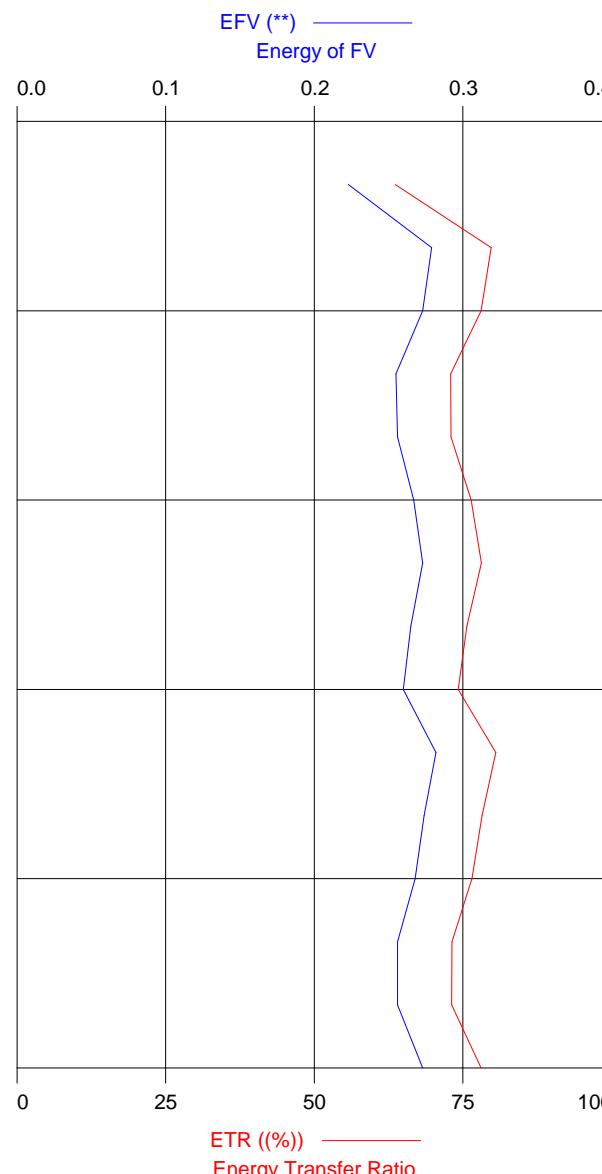
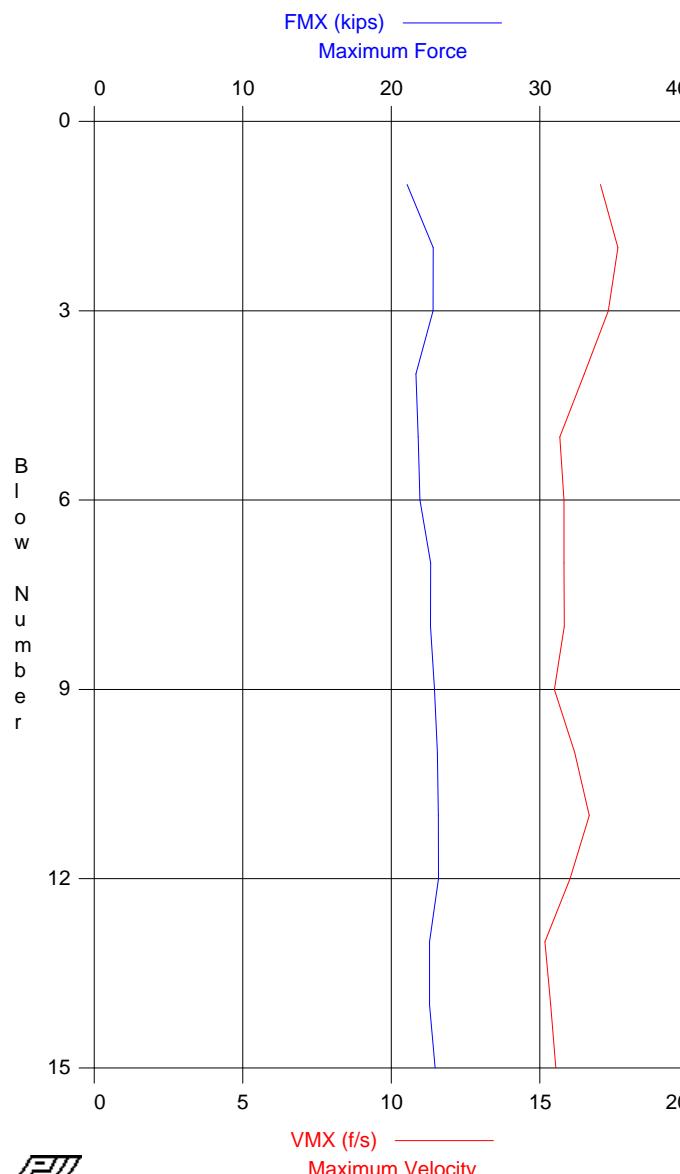
Total number of blows analyzed: 47

#### Time Summary

Drive 1 minute 20 seconds

10:48:20 AM - 10:49:40 AM (2/11/2009) BN 1 - 47

## KINGSTON PLANT - B 09-304 SS-9



KINGSTON PLANT - B 09-304 SS-9  
OP: SW

SPT AUTO  
Test date: 11-Feb-2009

AR: 1.16 in<sup>2</sup>  
LE: 21.0 ft  
WS: 16,807.9 f/s

SP: 0.492 k/ft<sup>3</sup>  
EM: 30,000 ksi  
JC: 0.70

FMX: Maximum Force  
VMX: Maximum Velocity  
EFV: Energy of FV  
ETR: Energy Transfer Ratio  
BPM: Blows per Minute

EMX: Max Transferred Energy  
EF2: Energy of F<sup>2</sup>  
DFN: Final Displacement  
FVP: Force/Velocity proportionality

BL#	depth	BLC	TYPE	FMX	VMX	EFV	ETR	BPM	EMX	EF2	DFN	FVP		
end	ft	bl/ft		kips	f/s	**	(%)	**	k-ft	k-ft	in	]		
2	0.50	4	AV2	22	17.3	0.251	72	16.6	0.251	0.202	2.31	0.69		
			STD	1	0.3	0.028	8	14.7	0.028	0.015	0.35	0.02		
			MAX	23	17.6	0.279	80	31.3	0.279	0.217	2.66	0.70		
5	1.00	6	AV3	22	16.5	0.261	75	31.8	0.261	0.207	2.75	0.69		
			STD	1	0.7	0.008	2	0.4	0.008	0.008	1.02	0.02		
			MAX	23	17.3	0.273	78	32.4	0.273	0.219	3.64	0.71		
10	1.50	10	AV5	23	15.8	0.269	77	32.0	0.269	0.215	1.25	0.68		
			STD	0	0.2	0.008	2	0.7	0.008	0.006	0.13	0.02		
			MAX	23	16.2	0.282	81	32.9	0.282	0.224	1.39	0.71		
15	2.00	10	AV5	23	15.8	0.265	76	32.0	0.265	0.215	1.20	0.68		
			STD	0	0.5	0.008	2	0.3	0.008	0.006	0.04	0.03		
			MAX	23	16.7	0.274	78	32.5	0.274	0.223	1.24	0.72		
			Average	23	16.1	0.264	75	29.9	0.264	0.212	1.67	0.68		
			Std. Dev.	1	0.7	0.014	4	7.5	0.014	0.010	0.81	0.02		
			Maximum	23	17.6	0.282	81	32.9	0.282	0.224	3.64	0.72		

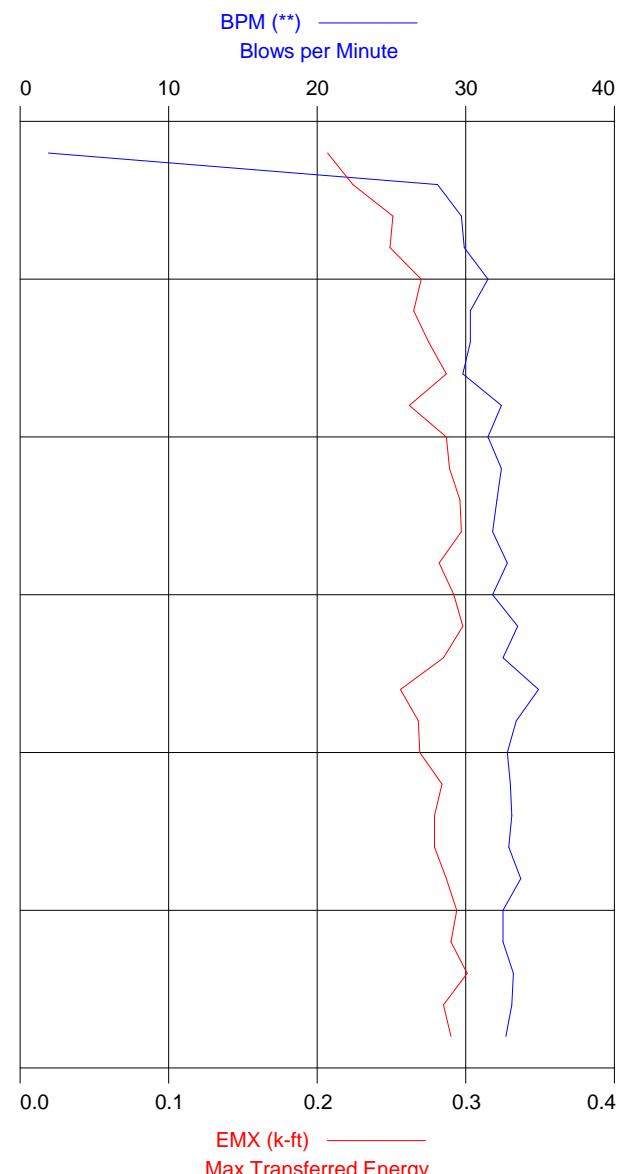
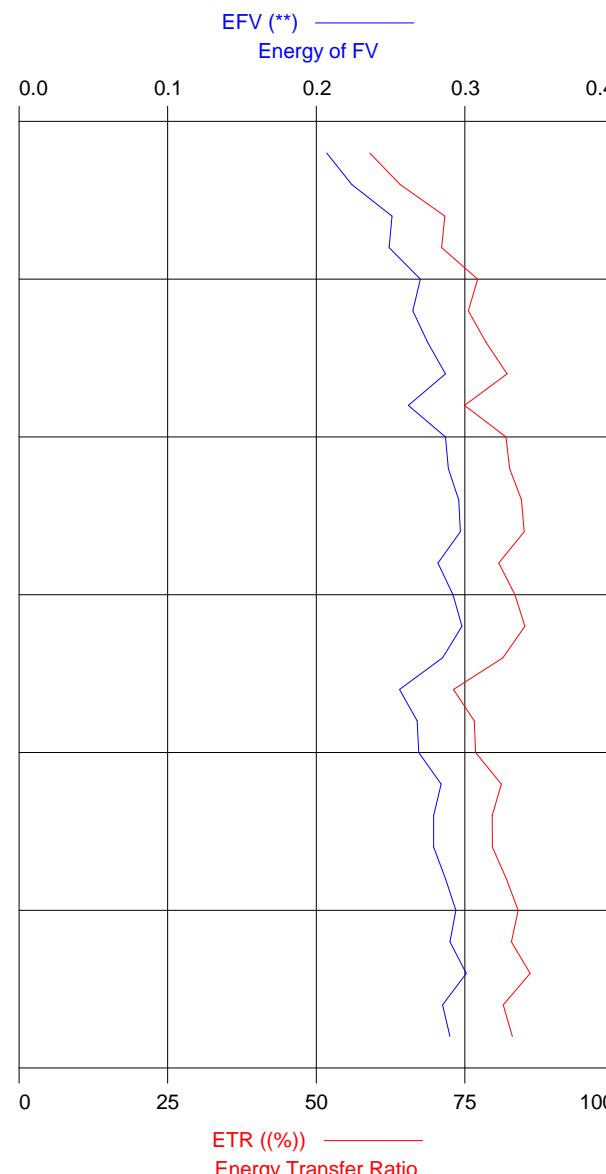
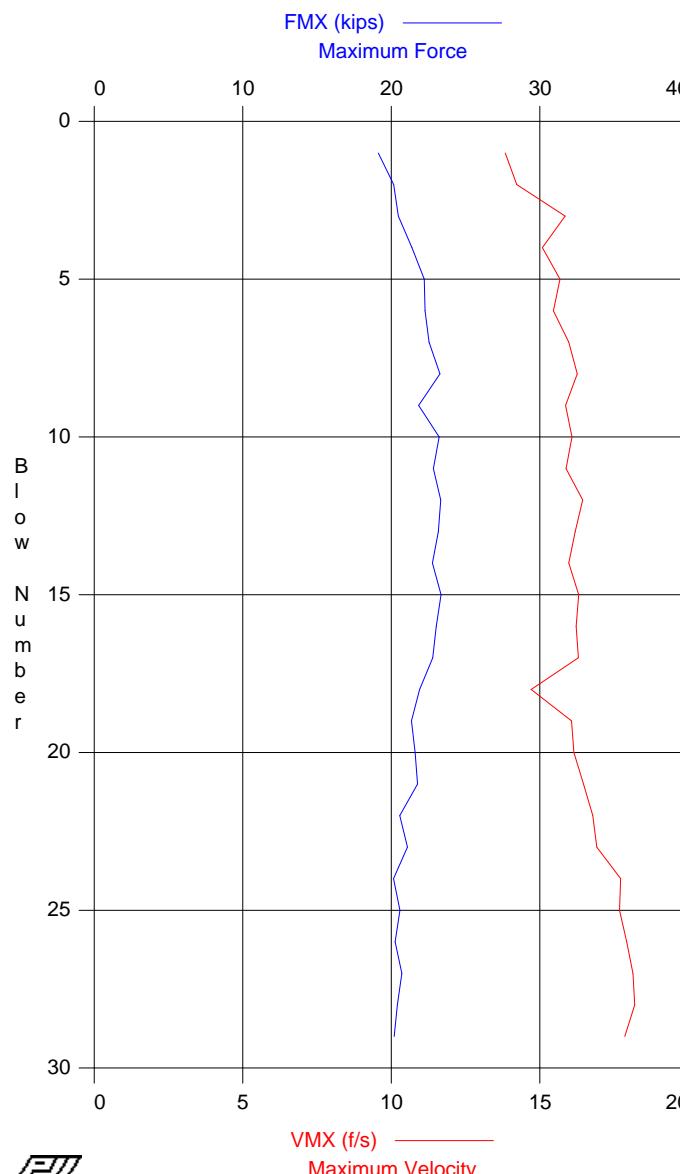
Total number of blows analyzed: 15

#### Time Summary

Drive 26 seconds

10:57:37 AM - 10:58:03 AM (2/11/2009) BN 1 - 15

## KINGSTON PLANT - B 09-304 SS-10



KINGSTON PLANT - B 09-304 SS-10  
OP: SW

SPT AUTO  
Test date: 11-Feb-2009

AR: 1.16 in<sup>2</sup>  
LE: 24.0 ft  
WS: 16,807.9 f/s

SP: 0.492 k/ft<sup>3</sup>  
EM: 30,000 ksi  
JC: 0.70

FMX: Maximum Force  
VMX: Maximum Velocity  
EFV: Energy of FV  
ETR: Energy Transfer Ratio  
BPM: Blows per Minute

EMX: Max Transferred Energy  
EF2: Energy of F<sup>2</sup>  
DFN: Final Displacement  
FVP: Force/Velocity proportionality

BL# end	depth ft	BLC bl/ft	TYPE	FMX kips	VMX f/s	EFV **	ETR (%)	BPM **	EMX k-ft	EF2 k-ft	DFN in	FVP		
6	0.50	12	AV6	21	15.0	0.244	70	25.2	0.244	0.206	1.07	0.67		
			STD	1	0.7	0.022	6	10.5	0.022	0.019	0.22	0.03		
			MAX	22	15.9	0.270	77	31.5	0.270	0.228	1.54	0.70		
13	1.00	14	AV7	23	16.1	0.285	81	31.5	0.285	0.239	1.04	0.69		
			STD	0	0.2	0.011	3	1.0	0.011	0.008	0.12	0.01		
			MAX	23	16.4	0.297	85	32.4	0.297	0.248	1.22	0.70		
21	1.50	16	AV8	22	16.0	0.279	80	33.1	0.279	0.233	0.98	0.67		
			STD	1	0.5	0.013	4	0.8	0.013	0.011	0.13	0.03		
			MAX	23	16.5	0.298	85	34.9	0.298	0.247	1.19	0.72		
29	2.00	16	AV8	20	17.7	0.288	82	33.0	0.288	0.228	1.06	0.53		
			STD	0	0.5	0.007	2	0.4	0.007	0.003	0.08	0.04		
			MAX	21	18.2	0.301	86	33.7	0.301	0.234	1.14	0.60		
			Average	22	16.3	0.276	79	31.0	0.276	0.227	1.03	0.64		
			Std. Dev.	1	1.1	0.022	6	5.7	0.022	0.016	0.15	0.07		
			Maximum	23	18.2	0.301	86	34.9	0.301	0.248	1.54	0.72		

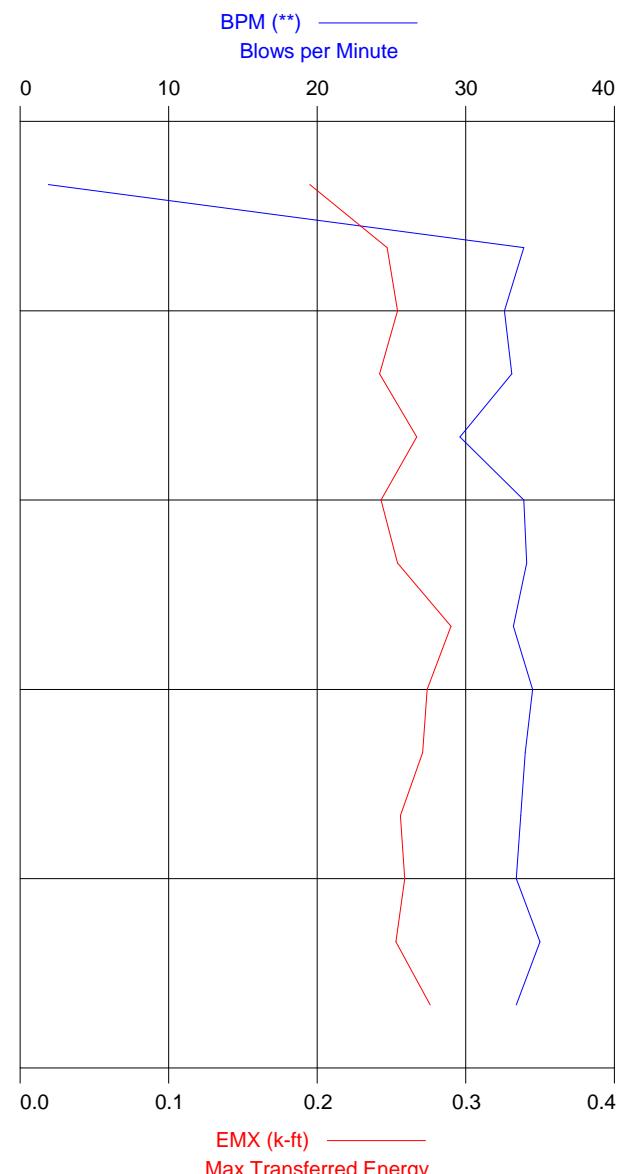
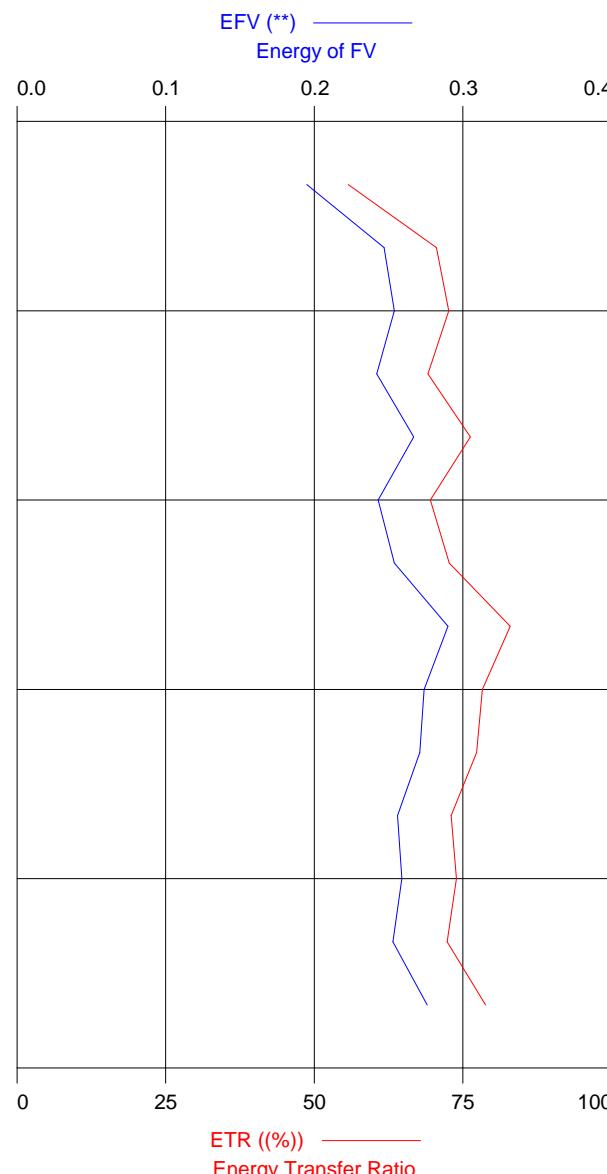
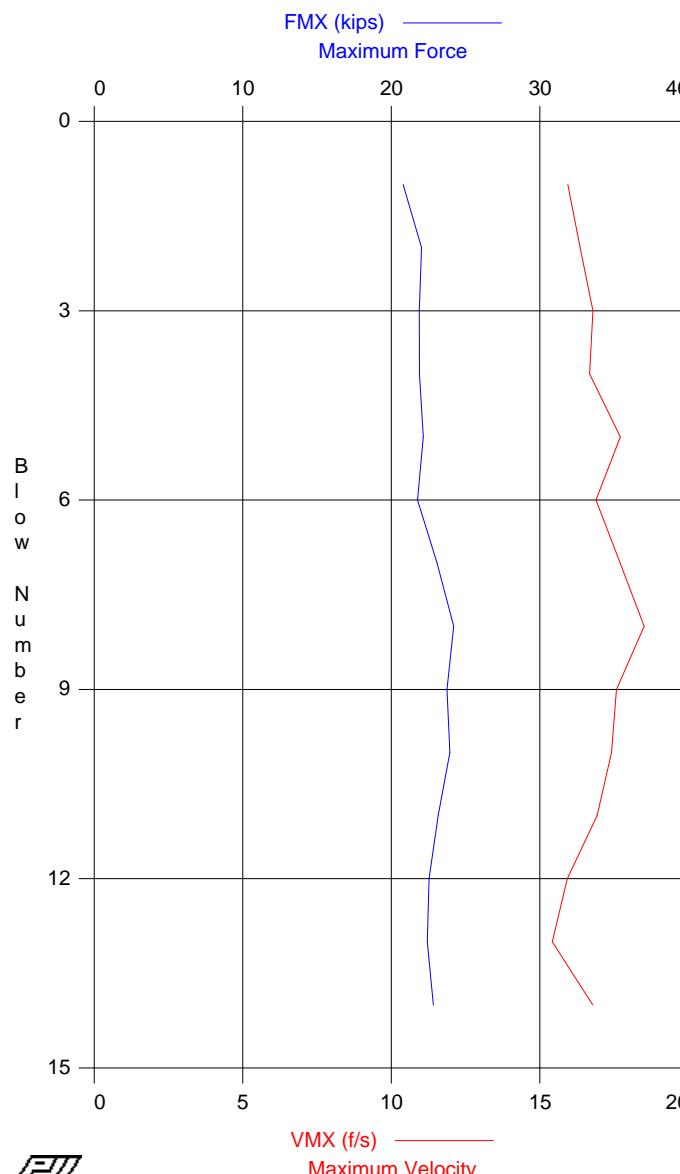
Total number of blows analyzed: 29

#### Time Summary

Drive 52 seconds

11:05:49 AM - 11:06:41 AM (2/11/2009) BN 1 - 29

## KINGSTON PLANT - B 09-304 SS-11



KINGSTON PLANT - B 09-304 SS-11  
OP: SW

SPT AUTO  
Test date: 11-Feb-2009

AR: 1.16 in<sup>2</sup>  
LE: 25.0 ft  
WS: 16,807.9 f/s

SP: 0.492 k/ft<sup>3</sup>  
EM: 30,000 ksi  
JC: 0.70

FMX: Maximum Force  
VMX: Maximum Velocity  
EFV: Energy of FV  
ETR: Energy Transfer Ratio  
BPM: Blows per Minute

EMX: Max Transferred Energy  
EF2: Energy of F<sup>2</sup>  
DFN: Final Displacement  
FVP: Force/Velocity proportionality

BL#	depth	BLC	TYPE	FMX	VMX	EFV	ETR	BPM	EMX	EF2	DFN	FVP		
end	ft	bl/ft		kips	f/s	**	(%)	**	k-ft	k-ft	in	■		
4	0.50	8	AV4	22	16.4	0.234	67	25.4	0.234	0.187	1.84	0.72		
			STD	1	0.3	0.023	7	13.6	0.023	0.010	0.23	0.02		
			MAX	22	16.8	0.254	73	33.9	0.254	0.195	2.21	0.75		
8	1.00	8	AV4	23	17.7	0.264	75	32.7	0.264	0.211	2.02	0.69		
			STD	1	0.6	0.017	5	1.8	0.017	0.011	0.12	0.04		
			MAX	24	18.5	0.290	83	34.1	0.290	0.228	2.20	0.74		
11	1.50	6	AV3	24	17.3	0.267	76	34.1	0.267	0.213	2.06	0.78		
			STD	0	0.3	0.008	2	0.3	0.008	0.006	0.16	0.02		
			MAX	24	17.6	0.274	78	34.5	0.274	0.219	2.24	0.79		
14	2.00	6	AV3	23	16.0	0.263	75	33.9	0.263	0.206	1.83	0.69		
			STD	0	0.6	0.010	3	0.8	0.010	0.006	0.08	0.01		
			MAX	23	16.8	0.276	79	35.0	0.276	0.215	1.90	0.71		
			Average	23	16.9	0.256	73	31.2	0.256	0.204	1.94	0.72		
			Std. Dev.	1	0.8	0.021	6	8.2	0.021	0.014	0.19	0.04		
			Maximum	24	18.5	0.290	83	35.0	0.290	0.228	2.24	0.79		

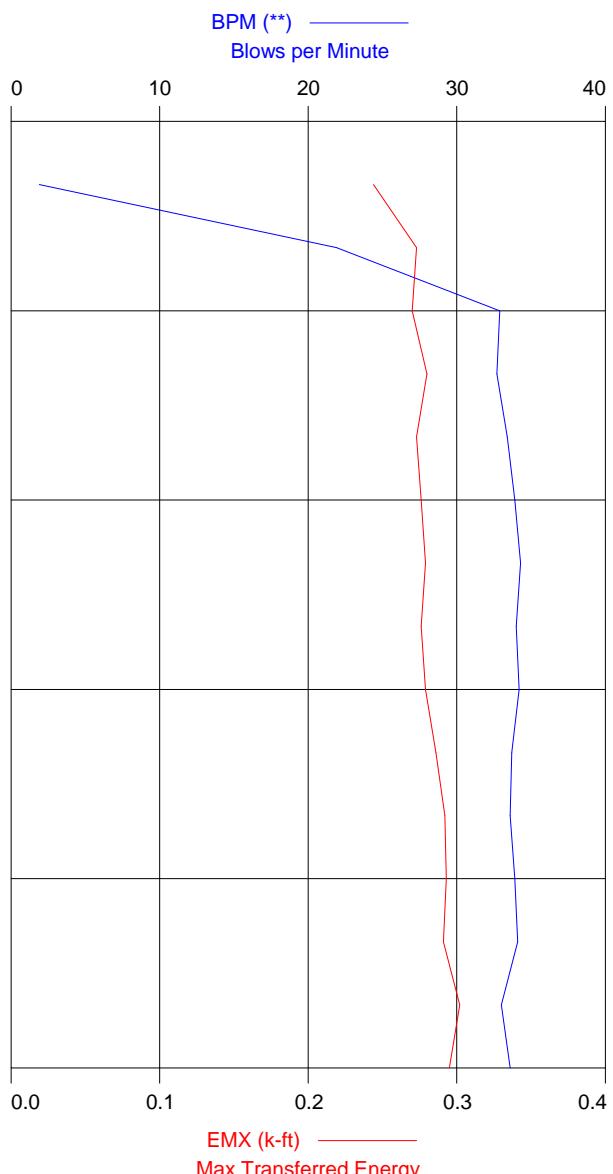
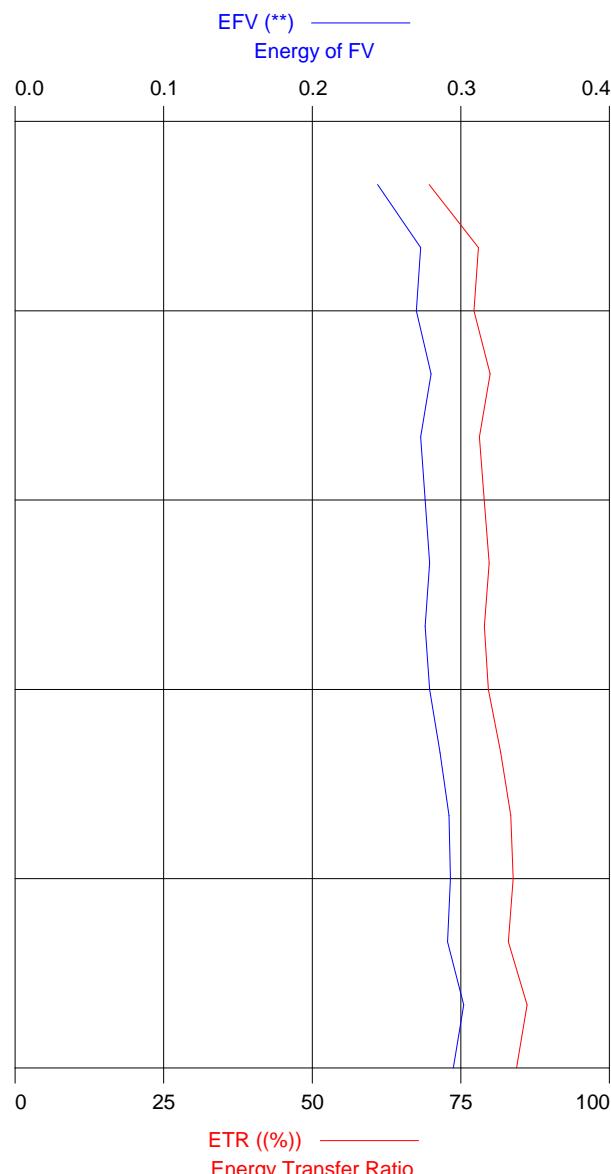
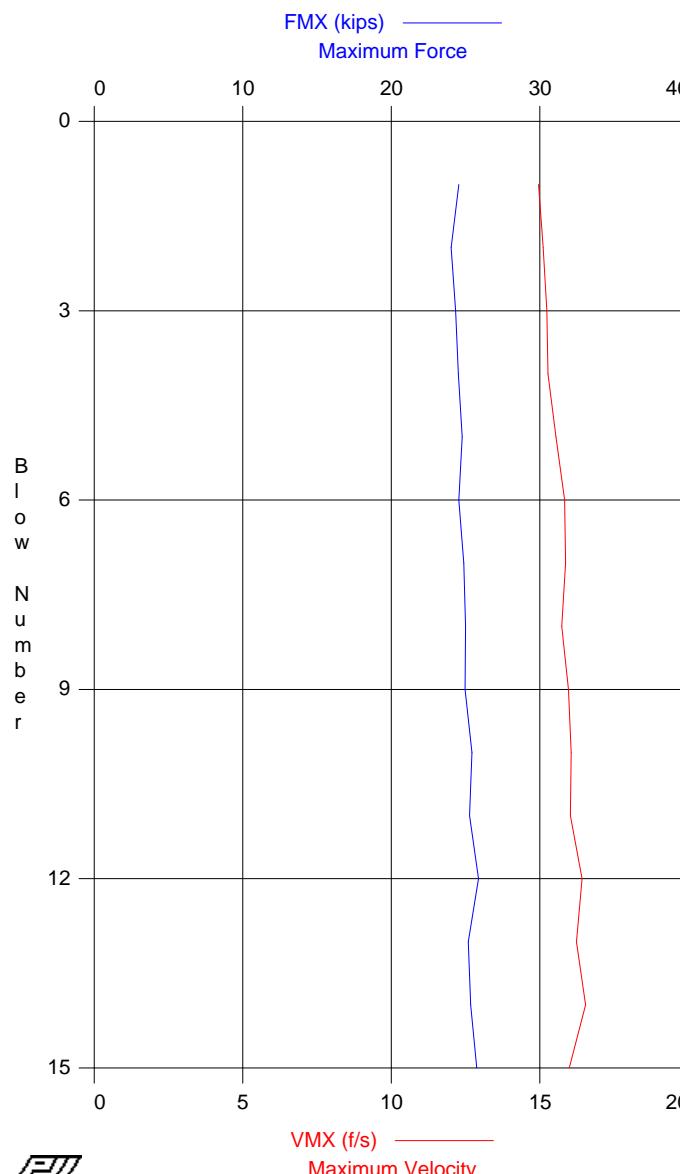
Total number of blows analyzed: 14

#### Time Summary

Drive 23 seconds

11:13:51 AM - 11:14:14 AM (2/11/2009) BN 1 - 14

## KINGSTON PLANT - B 09-304 SS-12



KINGSTON PLANT - B 09-304 SS-12  
OP: SW

SPT AUTO  
Test date: 11-Feb-2009

AR: 1.16 in<sup>2</sup>  
LE: 27.0 ft  
WS: 16,807.9 f/s

SP: 0.492 k/ft<sup>3</sup>  
EM: 30,000 ksi  
JC: 0.70

FMX: Maximum Force  
VMX: Maximum Velocity  
EFV: Energy of FV  
ETR: Energy Transfer Ratio  
BPM: Blows per Minute

EMX: Max Transferred Energy  
EF2: Energy of F<sup>2</sup>  
DFN: Final Displacement  
FVP: Force/Velocity proportionality

BL#	depth	BLC	TYPE	FMX	VMX	EFV	ETR	BPM	EMX	EF2	DFN	FVP		
end	ft	bl/ft		kips	f/s	**	(%)	**	k-ft	k-ft	in	□		
4	0.50	8	AV4	24	15.1	0.267	76	22.4	0.267	0.240	2.11	0.74		
			STD	0	0.1	0.014	4	12.6	0.014	0.002	0.08	0.01		
			MAX	25	15.3	0.280	80	32.9	0.280	0.243	2.23	0.75		
7	1.00	6	AV3	25	15.7	0.276	79	33.9	0.276	0.248	1.93	0.73		
			STD	0	0.1	0.002	1	0.4	0.002	0.004	0.04	0.01		
			MAX	25	15.9	0.279	80	34.3	0.279	0.253	1.96	0.74		
11	1.50	8	AV4	25	15.9	0.283	81	33.9	0.283	0.258	1.76	0.72		
			STD	0	0.1	0.006	2	0.2	0.006	0.006	0.04	0.00		
			MAX	25	16.1	0.292	83	34.2	0.292	0.265	1.80	0.73		
15	2.00	8	AV4	26	16.3	0.295	84	33.7	0.295	0.266	1.67	0.71		
			STD	0	0.2	0.004	1	0.4	0.004	0.001	0.08	0.01		
			MAX	26	16.5	0.302	86	34.1	0.302	0.268	1.80	0.73		
			Average	25	15.8	0.281	80	30.7	0.281	0.253	1.86	0.72		
			Std. Dev.	1	0.5	0.013	4	8.3	0.013	0.011	0.18	0.01		
			Maximum	26	16.5	0.302	86	34.3	0.302	0.268	2.23	0.75		

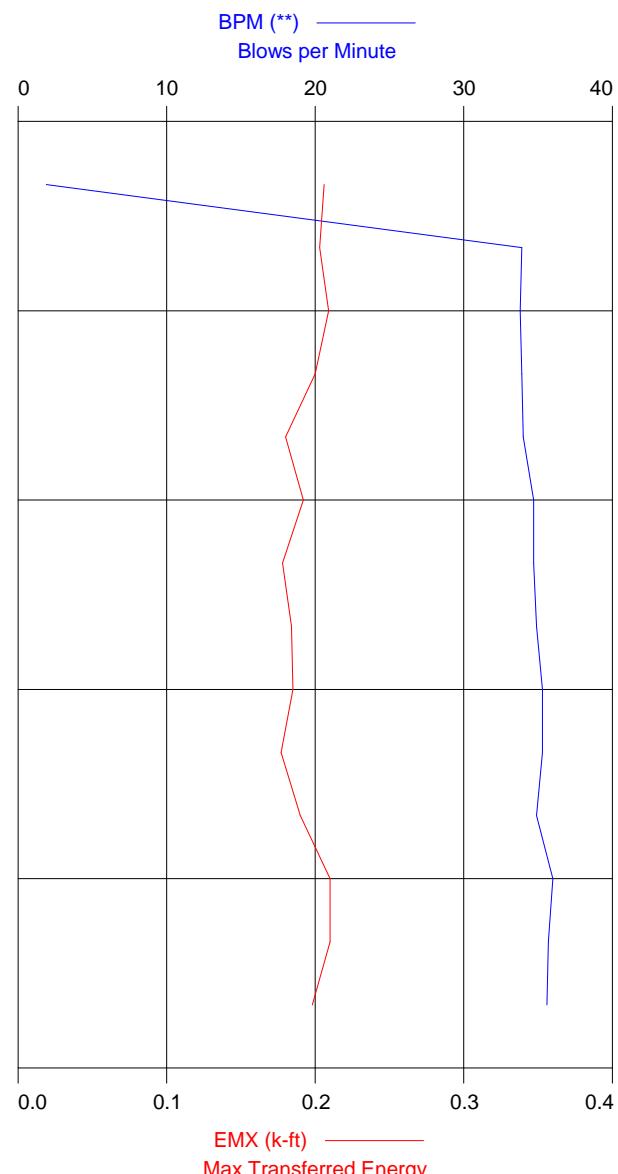
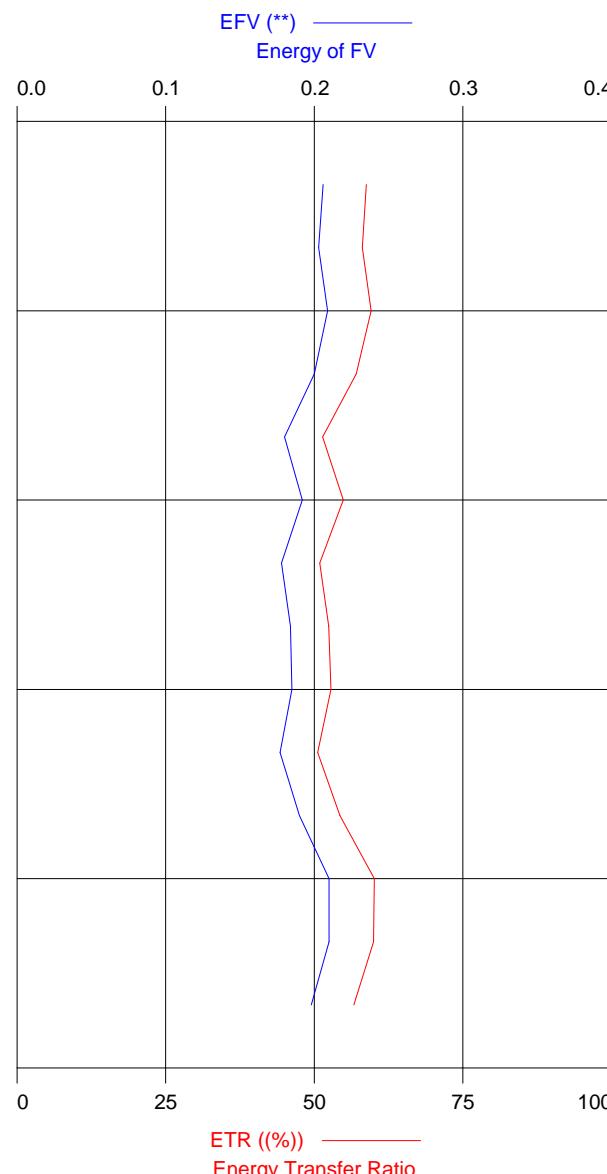
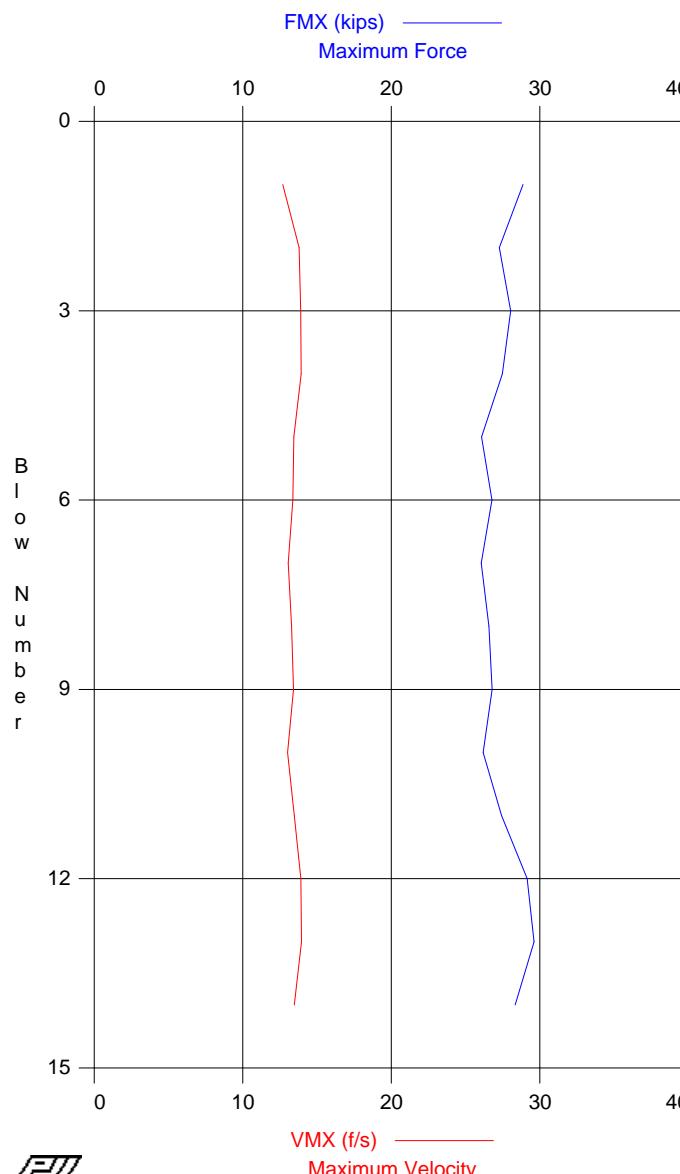
Total number of blows analyzed: 15

#### Time Summary

Drive 26 seconds

11:21:40 AM - 11:22:06 AM (2/11/2009) BN 1 - 15

## KINGSTON PLANT - B 09-108 SS-16



KINGSTON PLANT - B 09-108 SS-16  
OP: SW

SPT AUTO  
Test date: 10-Feb-2009

AR: 1.43 in<sup>2</sup>  
LE: 35.0 ft  
WS: 16,807.9 f/s

SP: 0.492 k/ft<sup>3</sup>  
EM: 30,000 ksi  
JC: 0.70

FMX: Maximum Force  
VMX: Maximum Velocity  
EFV: Energy of FV  
ETR: Energy Transfer Ratio  
BPM: Blows per Minute

EMX: Max Transferred Energy  
EF2: Energy of F<sup>2</sup>  
DFN: Final Displacement  
FVP: Force/Velocity proportionality

BL#	depth	BLC	TYPE	FMX	VMX	EFV	ETR	BPM	EMX	EF2	DFN	FVP	
end	ft	bl/ft		kips	f/s	**	(%)	**	k-ft	k-ft	in	[]	
4	0.50	8	AV4	27.9	13.6	0.204	58.4	25.9	0.204	0.196	1.39	0.80	
			MAX	28.9	13.9	0.209	59.6	33.9	0.209	0.205	1.50	0.88	
9	1.00	10	AV5	26.5	13.3	0.184	52.5	34.7	0.184	0.172	1.28	0.78	
			MAX	26.8	13.4	0.192	54.9	35.3	0.192	0.179	1.43	0.79	
14	1.50	10	AV5	28.1	13.6	0.197	56.3	35.5	0.197	0.188	1.37	0.81	
			MAX	29.6	14.0	0.210	60.1	36.0	0.210	0.203	1.47	0.83	
				Average	27.5	13.5	0.194	55.5	32.5	0.194	0.185	1.35	0.80
				Maximum	29.6	14.0	0.210	60.1	36.0	0.210	0.205	1.50	0.88

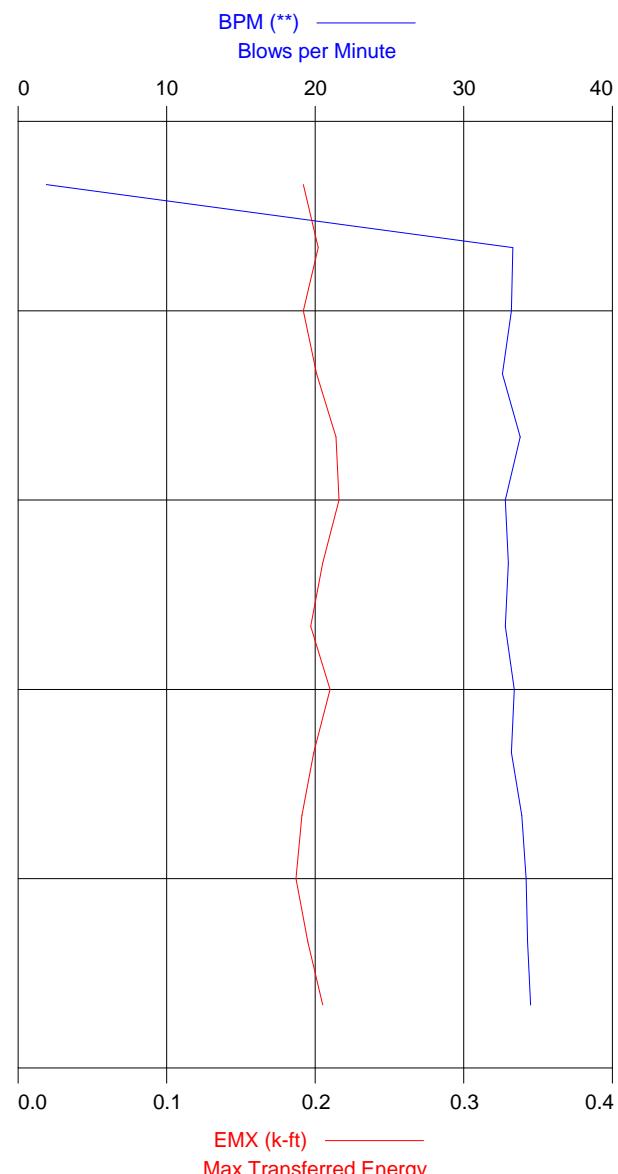
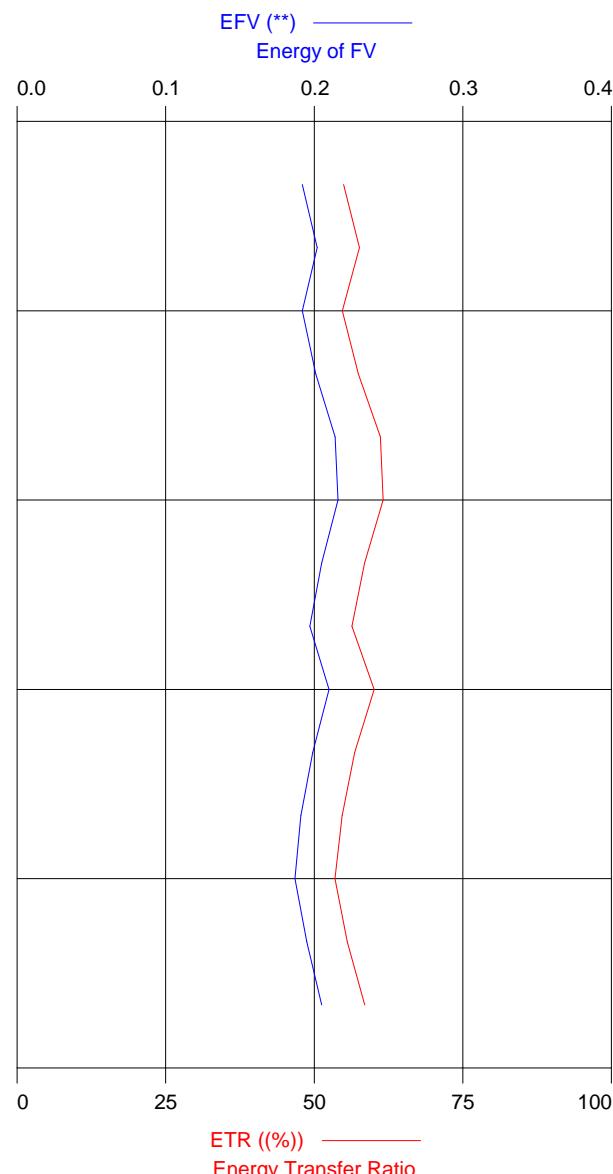
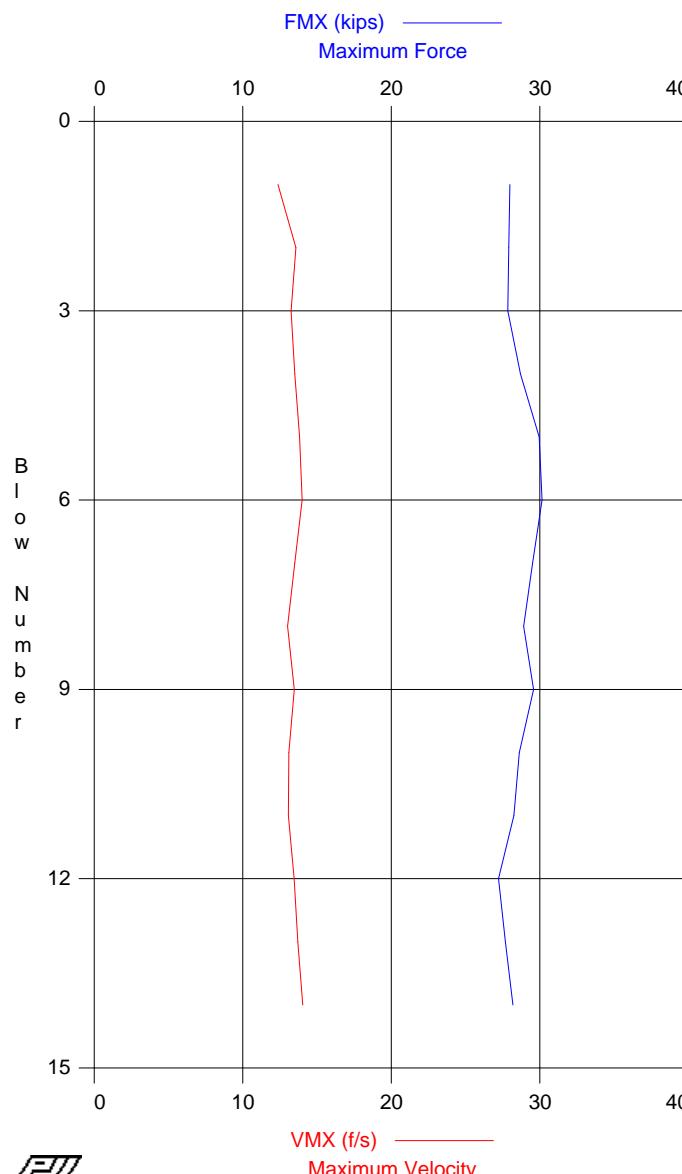
Total number of blows analyzed: 14

#### Time Summary

Drive 23 seconds

10:14:23 AM - 10:14:46 AM (2/10/2009) BN 1 - 14

## KINGSTON PLANT - B 09-108 SS-17



KINGSTON PLANT - B 09-108 SS-17  
OP: SW

SPT AUTO  
Test date: 10-Feb-2009

AR: 1.43 in<sup>2</sup>  
LE: 37.0 ft  
WS: 16,807.9 f/s

SP: 0.492 k/ft<sup>3</sup>  
EM: 30,000 ksi  
JC: 0.70

FMX: Maximum Force  
VMX: Maximum Velocity  
EFV: Energy of FV  
ETR: Energy Transfer Ratio  
BPM: Blows per Minute

EMX: Max Transferred Energy  
EF2: Energy of F<sup>2</sup>  
DFN: Final Displacement  
FVP: Force/Velocity proportionality

BL# end	depth ft	BLC bl/ft	TYPE	FMX kips	VMX f/s	EFV **	ETR (%)	BPM **	EMX k-ft	EF2 k-ft	DFN in	FVP	
3	0.50	6	AV3	27.9	13.1	0.195	55.8	22.8	0.195	0.199	1.42	0.83	
			MAX	28.0	13.6	0.202	57.6	33.3	0.202	0.204	2.21	0.89	
7	1.00	8	AV4	29.6	13.7	0.209	59.6	33.0	0.209	0.208	1.28	0.84	
			MAX	30.1	14.0	0.216	61.6	33.8	0.216	0.218	1.54	0.85	
10	1.50	6	AV3	29.0	13.2	0.202	57.7	33.1	0.202	0.201	1.19	0.85	
			MAX	29.6	13.5	0.210	60.1	33.4	0.210	0.209	1.31	0.86	
14	2.00	8	AV4	27.8	13.6	0.194	55.6	34.2	0.194	0.190	1.20	0.78	
			MAX	28.3	14.0	0.205	58.5	34.5	0.205	0.199	1.63	0.82	
				Average	28.6	13.4	0.200	57.2	31.2	0.200	0.199	1.27	0.82
				Maximum	30.1	14.0	0.216	61.6	34.5	0.216	0.218	2.21	0.89

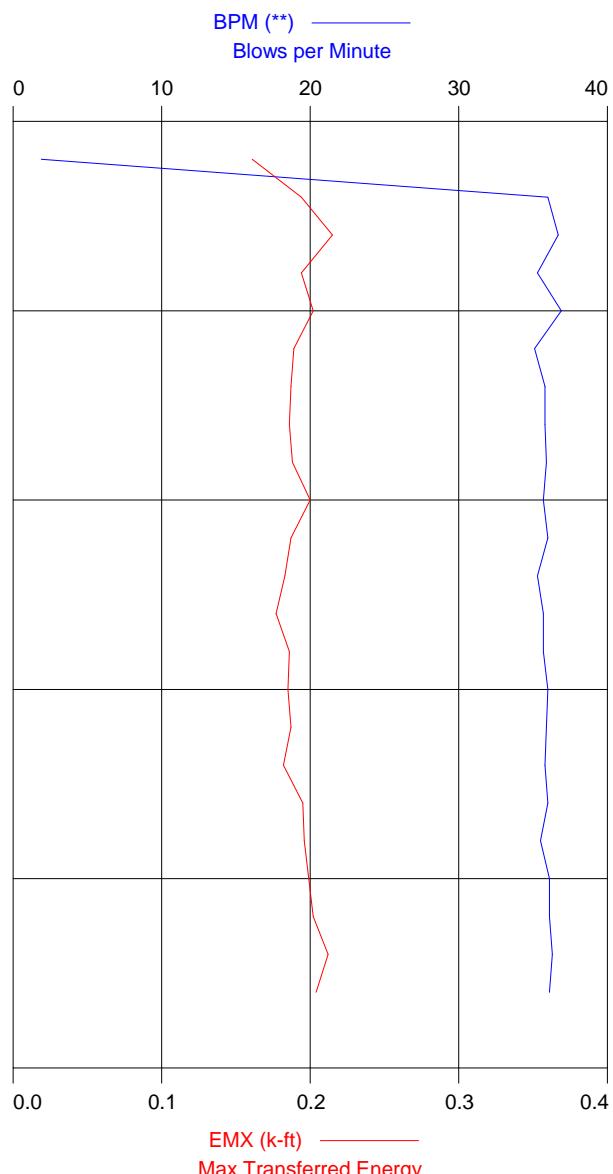
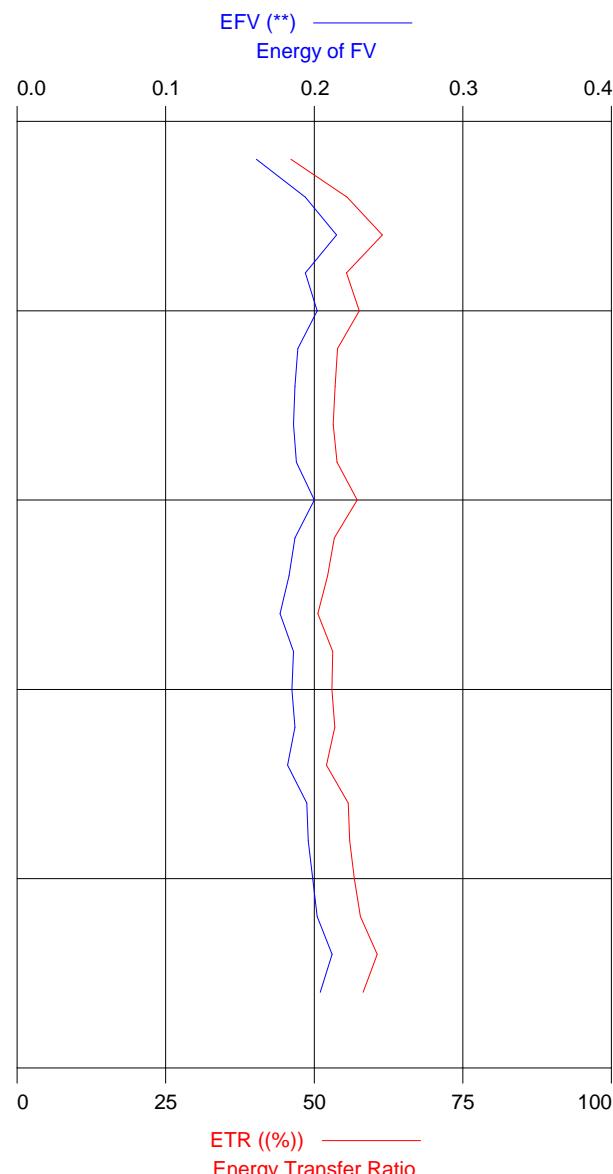
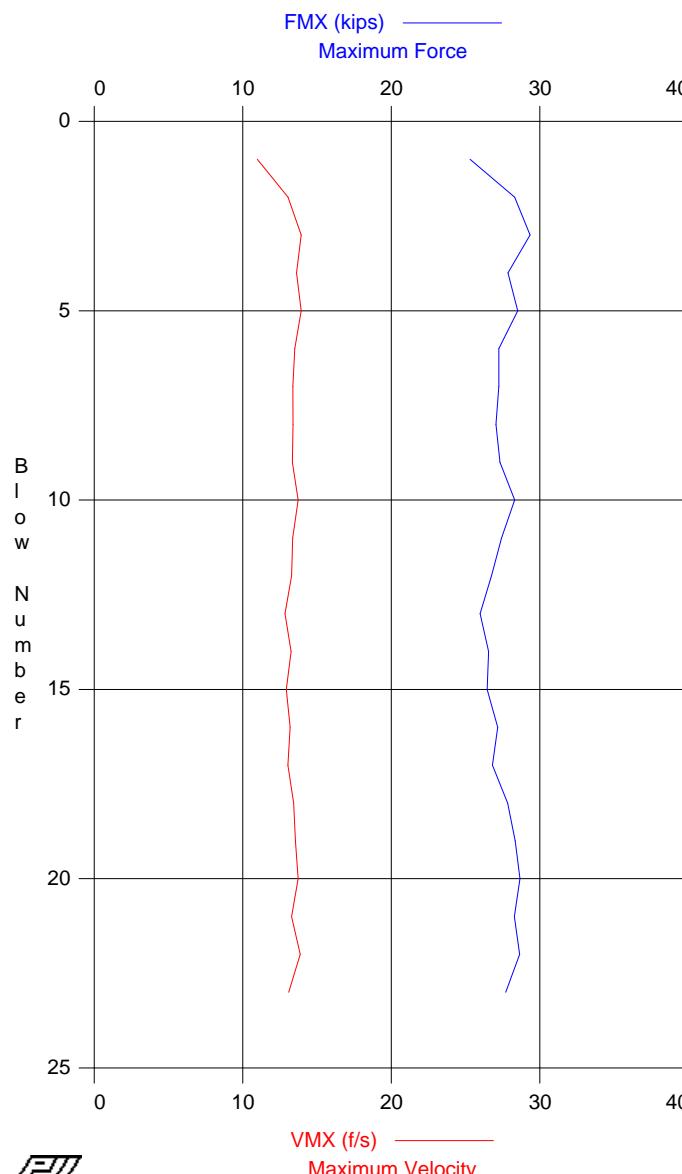
Total number of blows analyzed: 14

#### Time Summary

Drive 23 seconds

10:27:38 AM - 10:28:01 AM (2/10/2009) BN 1 - 14

## KINGSTON PLANT - B 09-108 SS-19



KINGSTON PLANT - B 09-108 SS-19  
OP: SW

SPT AUTO  
Test date: 10-Feb-2009

AR: 1.43 in<sup>2</sup>  
LE: 42.0 ft  
WS: 16,807.9 f/s

SP: 0.492 k/ft<sup>3</sup>  
EM: 30,000 ksi  
JC: 0.70

FMX: Maximum Force  
VMX: Maximum Velocity  
EFV: Energy of FV  
ETR: Energy Transfer Ratio  
BPM: Blows per Minute

EMX: Max Transferred Energy  
EF2: Energy of F<sup>2</sup>  
DFN: Final Displacement  
FVP: Force/Velocity proportionality

BL#	depth end ft	BLC bl/ft	TYPE	FMX kips	VMX f/s	EFV **	ETR (%)	BPM **	EMX k-ft	EF2 k-ft	DFN in	FVP []	
1	0.50	4	AV1	25.3	11.0	0.161	46.1	1.9	0.161	0.158	1.15	0.85	
			MAX	25.3	11.0	0.161	46.1	1.9	0.161	0.158	1.15	0.85	
9	1.00	16	AV8	27.9	13.5	0.194	55.6	35.9	0.194	0.183	0.97	0.81	
			MAX	29.3	13.9	0.215	61.5	36.9	0.215	0.207	2.26	0.85	
17	1.50	16	AV8	26.9	13.2	0.186	53.1	35.8	0.186	0.176	0.88	0.79	
			MAX	28.3	13.7	0.200	57.2	36.0	0.200	0.187	1.16	0.81	
23	2.00	12	AV6	28.2	13.5	0.201	57.5	36.0	0.201	0.191	1.11	0.81	
			MAX	28.7	13.9	0.212	60.6	36.3	0.212	0.201	1.34	0.83	
				Average	27.5	13.3	0.192	54.8	34.4	0.192	0.182	0.98	0.80
				Maximum	29.3	13.9	0.215	61.5	36.9	0.215	0.207	2.26	0.85

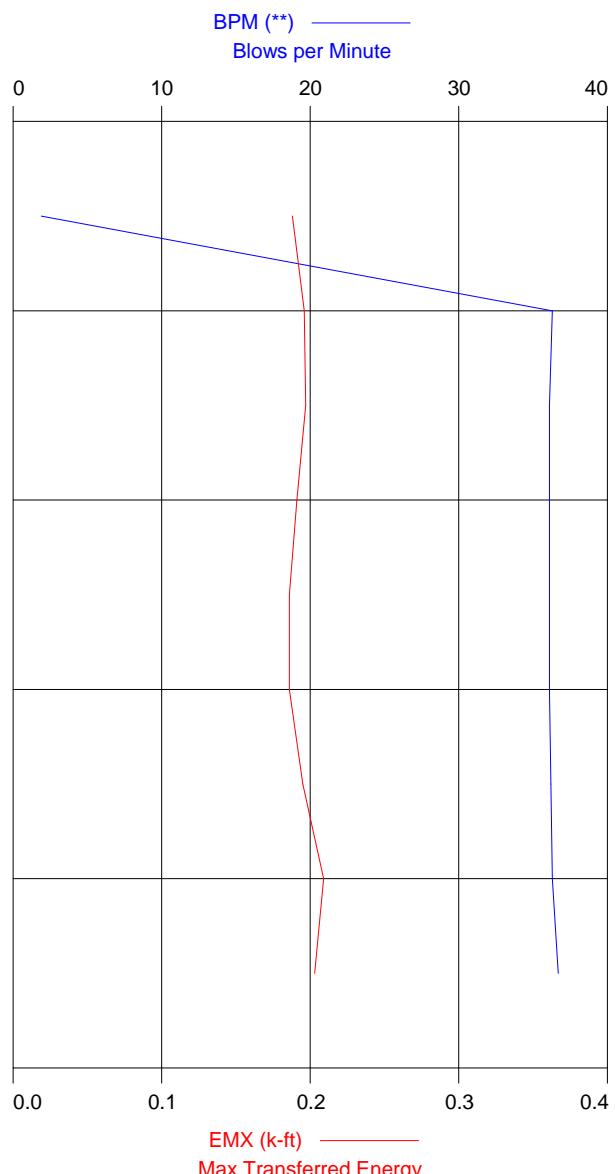
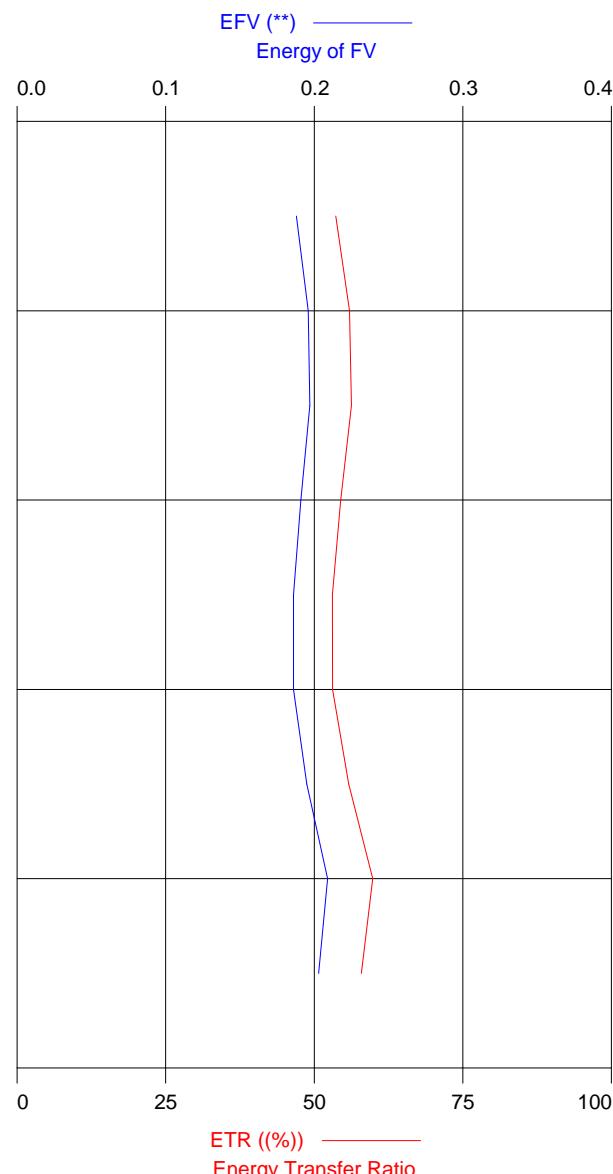
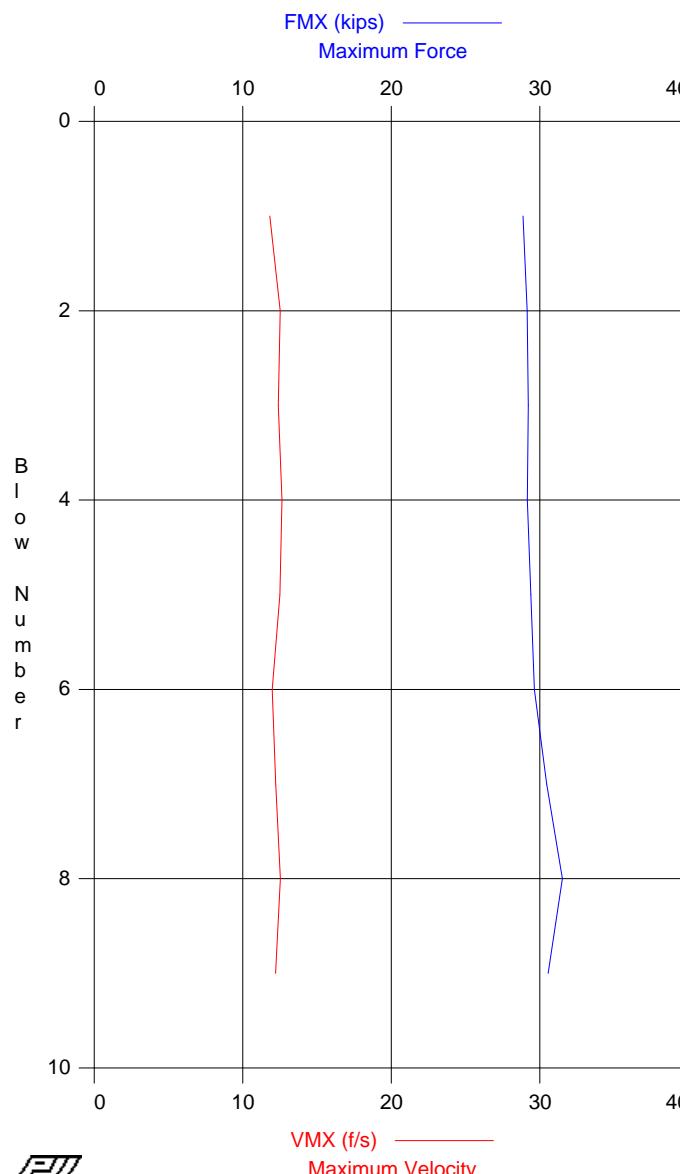
Total number of blows analyzed: 23

#### Time Summary

Drive 37 seconds

10:53:41 AM - 10:54:18 AM (2/10/2009) BN 1 - 23

## KINGSTON PLANT - B 09-108 SS-20



KINGSTON PLANT - B 09-108 SS-20  
OP: SW

SPT AUTO  
Test date: 10-Feb-2009

AR: 1.43 in<sup>2</sup>  
LE: 45.0 ft  
WS: 16,807.9 f/s

SP: 0.492 k/ft<sup>3</sup>  
EM: 30,000 ksi  
JC: 0.70

FMX: Maximum Force  
VMX: Maximum Velocity  
EFV: Energy of FV  
ETR: Energy Transfer Ratio  
BPM: Blows per Minute

EMX: Max Transferred Energy  
EF2: Energy of F<sup>2</sup>  
DFN: Final Displacement  
FVP: Force/Velocity proportionality

BL#	depth	BLC	TYPE	FMX	VMX	EFV	ETR	BPM	EMX	EF2	DFN	FVP	
end	ft	bl/ft		kips	f/s	**	(%)	**	k-ft	k-ft	in	[]	
2	0.50	4	AV2	29.0	12.2	0.192	54.8	19.1	0.192	0.196	1.79	0.92	
			MAX	29.1	12.5	0.196	56.0	36.3	0.196	0.197	2.14	0.93	
4	1.00	4	AV2	29.2	12.5	0.194	55.4	36.1	0.194	0.192	2.26	0.91	
			MAX	29.2	12.6	0.197	56.3	36.1	0.197	0.197	2.41	0.92	
6	1.50	4	AV2	29.5	12.2	0.186	53.1	36.1	0.186	0.187	1.82	0.93	
			MAX	29.6	12.5	0.186	53.1	36.1	0.186	0.189	2.73	0.95	
9	2.00	6	AV3	30.8	12.3	0.202	57.9	36.4	0.202	0.206	1.14	0.98	
			MAX	31.5	12.5	0.209	59.8	36.7	0.209	0.213	1.94	0.99	
				Average	29.8	12.3	0.195	55.5	32.4	0.195	0.196	1.69	0.94
				Maximum	31.5	12.6	0.209	59.8	36.7	0.209	0.213	2.73	0.99

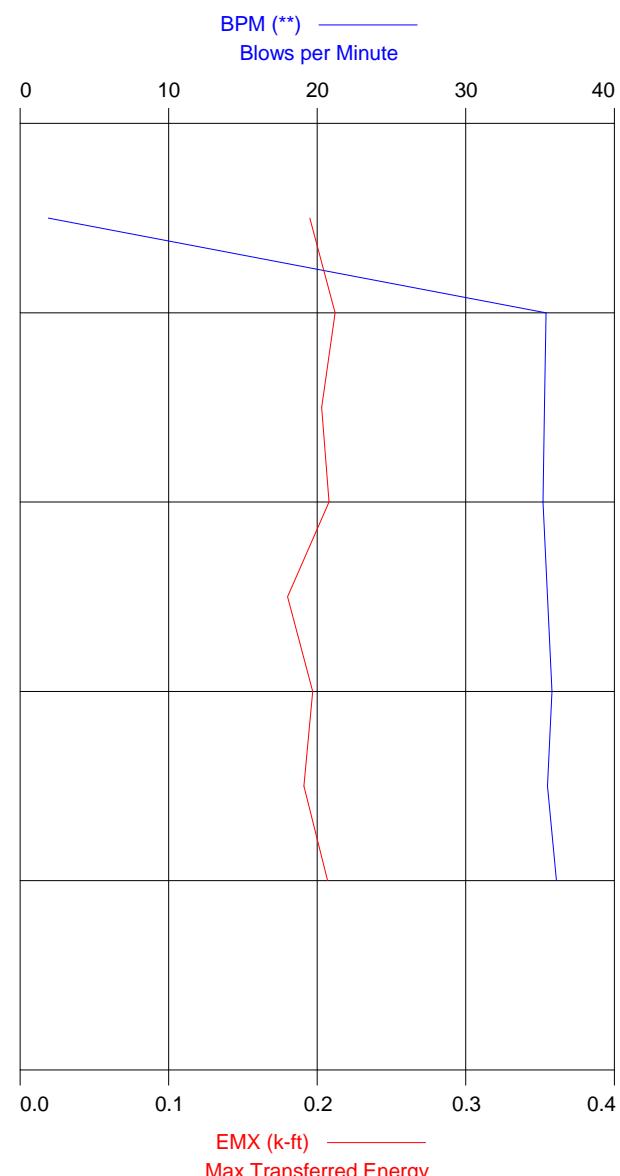
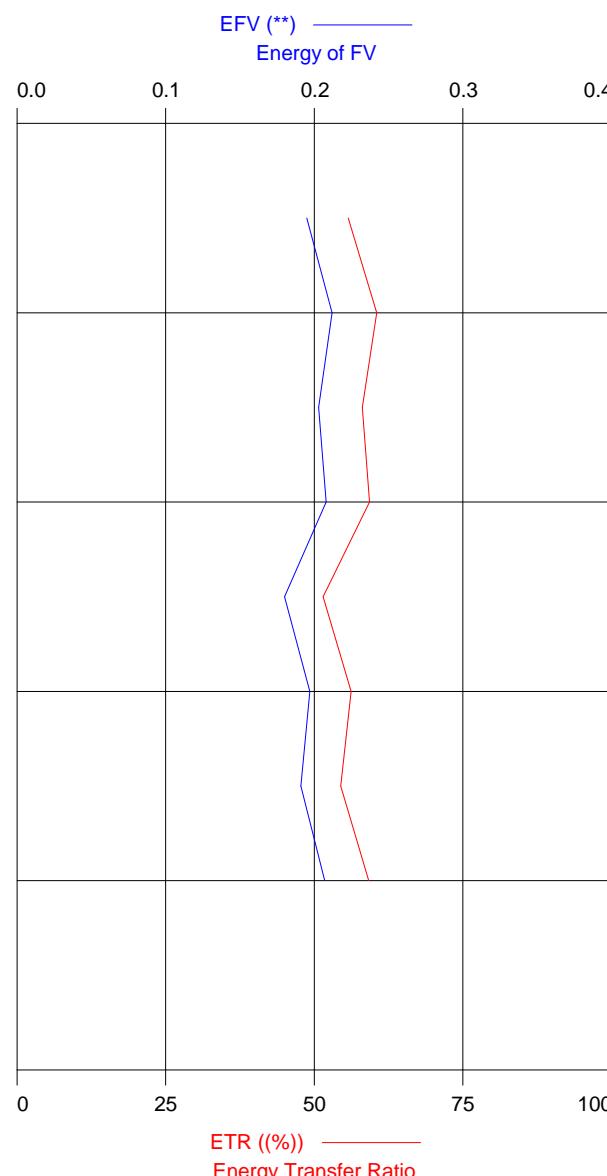
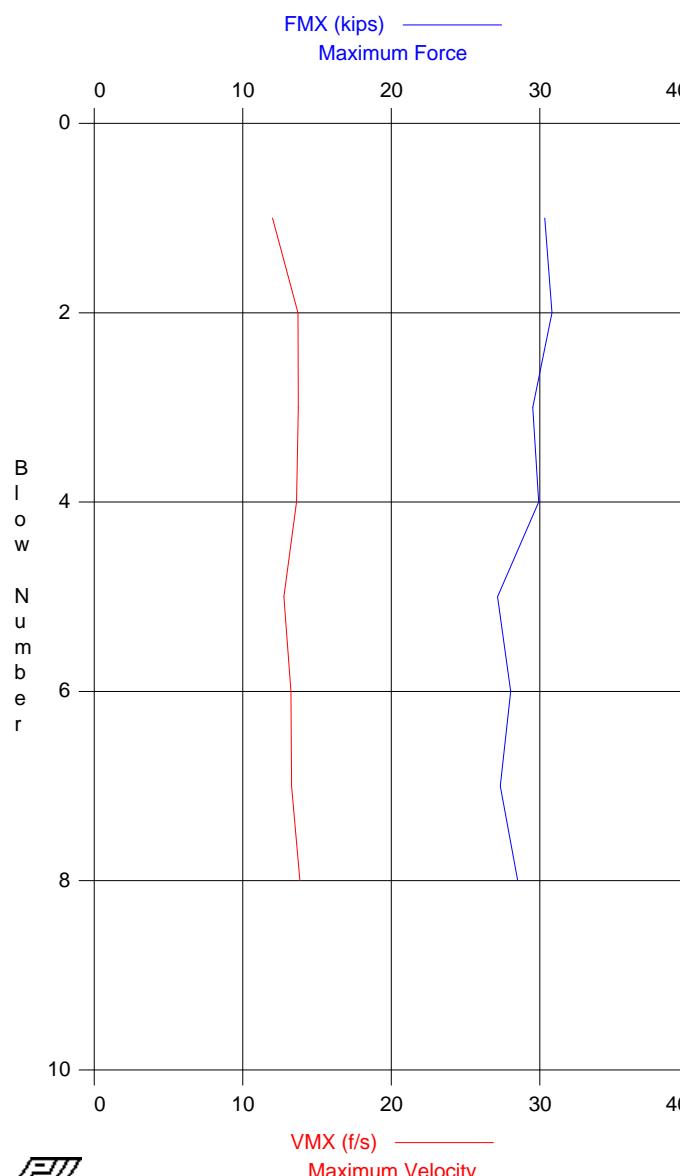
Total number of blows analyzed: 9

#### Time Summary

Drive 14 seconds

11:04:39 AM - 11:04:53 AM (2/10/2009) BN 1 - 9

## KINGSTON PLANT - B 09-108 SS-21



KINGSTON PLANT - B 09-108 SS-21  
OP: SW

SPT AUTO  
Test date: 10-Feb-2009

AR: 1.43 in<sup>2</sup>  
LE: 47.0 ft  
WS: 16,807.9 f/s

SP: 0.492 k/ft<sup>3</sup>  
EM: 30,000 ksi  
JC: 0.70

FMX: Maximum Force  
VMX: Maximum Velocity  
EFV: Energy of FV  
ETR: Energy Transfer Ratio  
BPM: Blows per Minute

EMX: Max Transferred Energy  
EF2: Energy of F<sup>2</sup>  
DFN: Final Displacement  
FVP: Force/Velocity proportionality

BL#	depth	BLC	TYPE	FMX	VMX	EFV	ETR	BPM	EMX	EF2	DFN	FVP	
end	ft	bl/ft		kips	f/s	**	(%)	**	k-ft	k-ft	in	[]	
3	0.50	6	AV3	30.2	13.2	0.203	58.1	24.2	0.203	0.206	0.93	0.90	
			MAX	30.8	13.7	0.212	60.5	35.4	0.212	0.214	1.15	0.99	
6	1.00	6	AV3	28.4	13.2	0.195	55.7	35.5	0.195	0.190	1.93	0.83	
			MAX	29.9	13.6	0.208	59.3	35.8	0.208	0.204	1.97	0.85	
8	1.50	4	AV2	27.9	13.6	0.199	56.8	35.8	0.199	0.193	1.94	0.77	
			MAX	28.5	13.9	0.207	59.2	36.1	0.207	0.201	2.05	0.78	
				Average	29.0	13.3	0.199	56.9	31.3	0.199	0.197	1.56	0.84
				Maximum	30.8	13.9	0.212	60.5	36.1	0.212	0.214	2.05	0.99

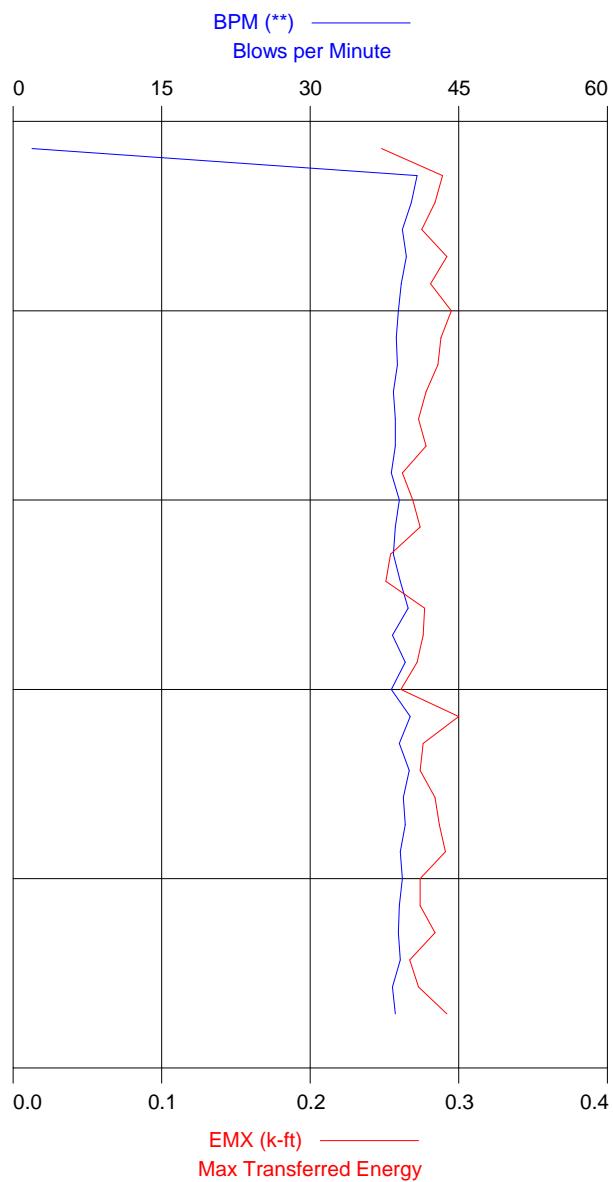
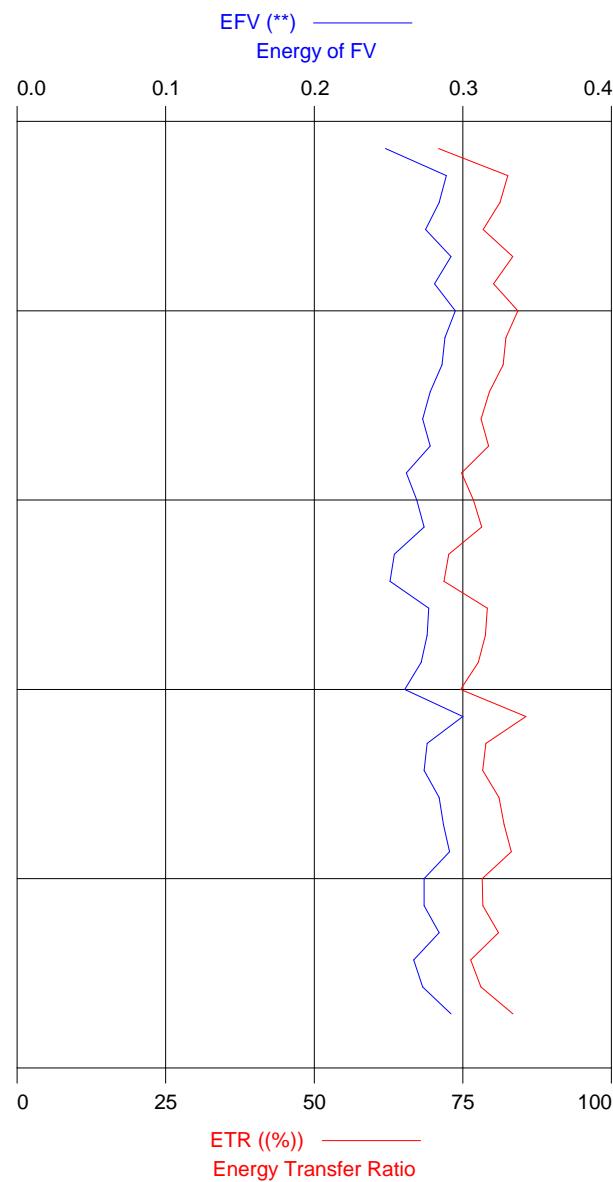
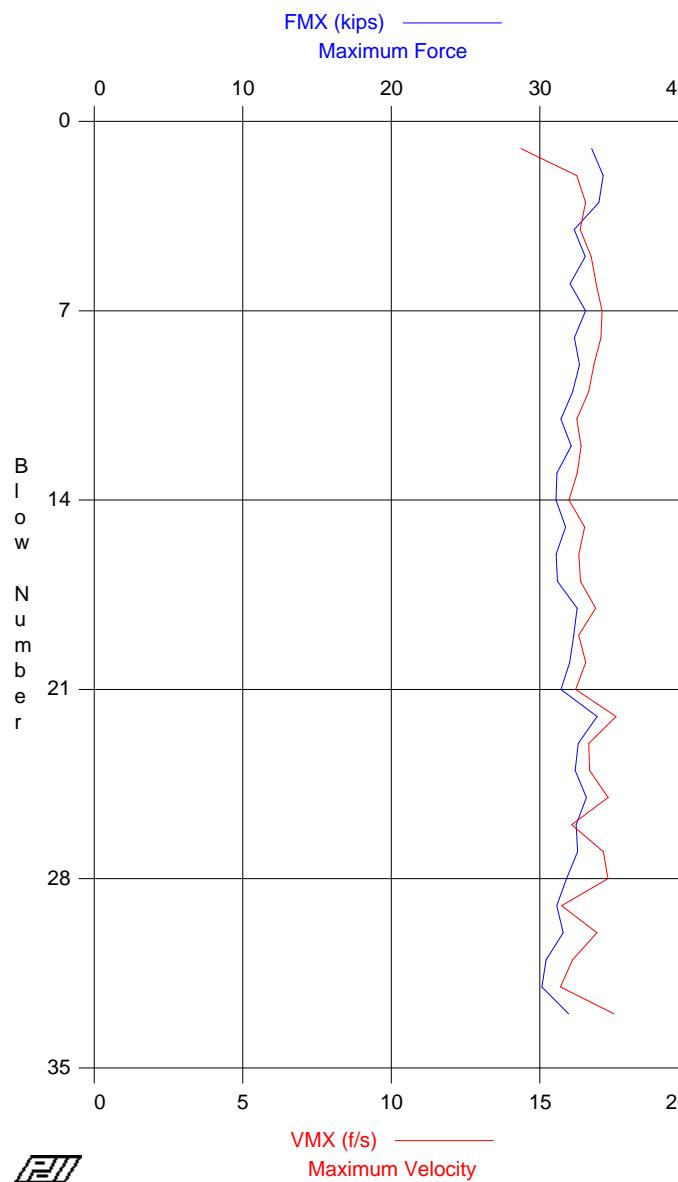
Total number of blows analyzed: 8

#### Time Summary

Drive 12 seconds

11:18:19 AM - 11:18:31 AM (2/10/2009) BN 1 - 8

## KINGSTON PLANT - B09-403 SS-1



**VMX (f/s) ————— Maximum Velocity**

**ETR ((%)) ————— Energy Transfer Ratio**

**EMX (k-ft) ————— Max Transferred Energy**

KINGSTON PLANT - B09-403 SS-1  
OP: SW

SPT AUTO  
Test date: 11-Feb-2009

AR: 1.43 in<sup>2</sup>  
LE: 15.0 ft  
WS: 16,807.9 f/s

SP: 0.492 k/ft<sup>3</sup>  
EM: 30,000 ksi  
JC: 0.70

FMX: Maximum Force  
VMX: Maximum Velocity  
EFV: Energy of FV  
ETR: Energy Transfer Ratio  
BPM: Blows per Minute

EMX: Max Transferred Energy  
EF2: Energy of F<sup>2</sup>  
DFN: Final Displacement  
FVP: Force/Velocity proportionality

BL# end	depth ft	BLC bl/ft	TYPE	FMX kips	VMX f/s	EFV **	ETR (%)	BPM **	EMX k-ft	EF2 k-ft	DFN in	FVP []			
5	0.50	10	AV5	33	16.0	0.278	79	32.4	0.278	0.238	1.75	0.81			
			STD	1	0.9	0.016	5	15.2	0.016	0.007	0.05	0.05			
			MAX	34	16.7	0.292	83	40.8	0.292	0.247	1.83	0.91			
10	1.00	10	AV5	32	16.9	0.286	82	38.8	0.286	0.238	1.20	0.75			
			STD	0	0.2	0.006	2	0.3	0.006	0.005	0.24	0.01			
			MAX	33	17.1	0.295	84	39.2	0.295	0.244	1.51	0.76			
21	1.50	22	AV11	32	16.4	0.268	77	38.8	0.268	0.227	0.63	0.75			
			STD	0	0.2	0.009	3	0.5	0.009	0.008	0.15	0.01			
			MAX	33	16.9	0.278	79	39.9	0.278	0.237	0.91	0.78			
33	1.96	26	AV12	32	16.7	0.281	80	39.2	0.281	0.240	0.60	0.74			
			STD	1	0.6	0.009	3	0.5	0.009	0.008	0.09	0.02			
			MAX	34	17.6	0.300	86	40.1	0.300	0.256	0.76	0.79			
				Average	32	16.5	0.277	79	38.0	0.277	0.235	0.87	0.76		
				Std. Dev.	1	0.6	0.012	3	6.4	0.012	0.009	0.45	0.04		
				Maximum	34	17.6	0.300	86	40.8	0.300	0.256	1.83	0.91		

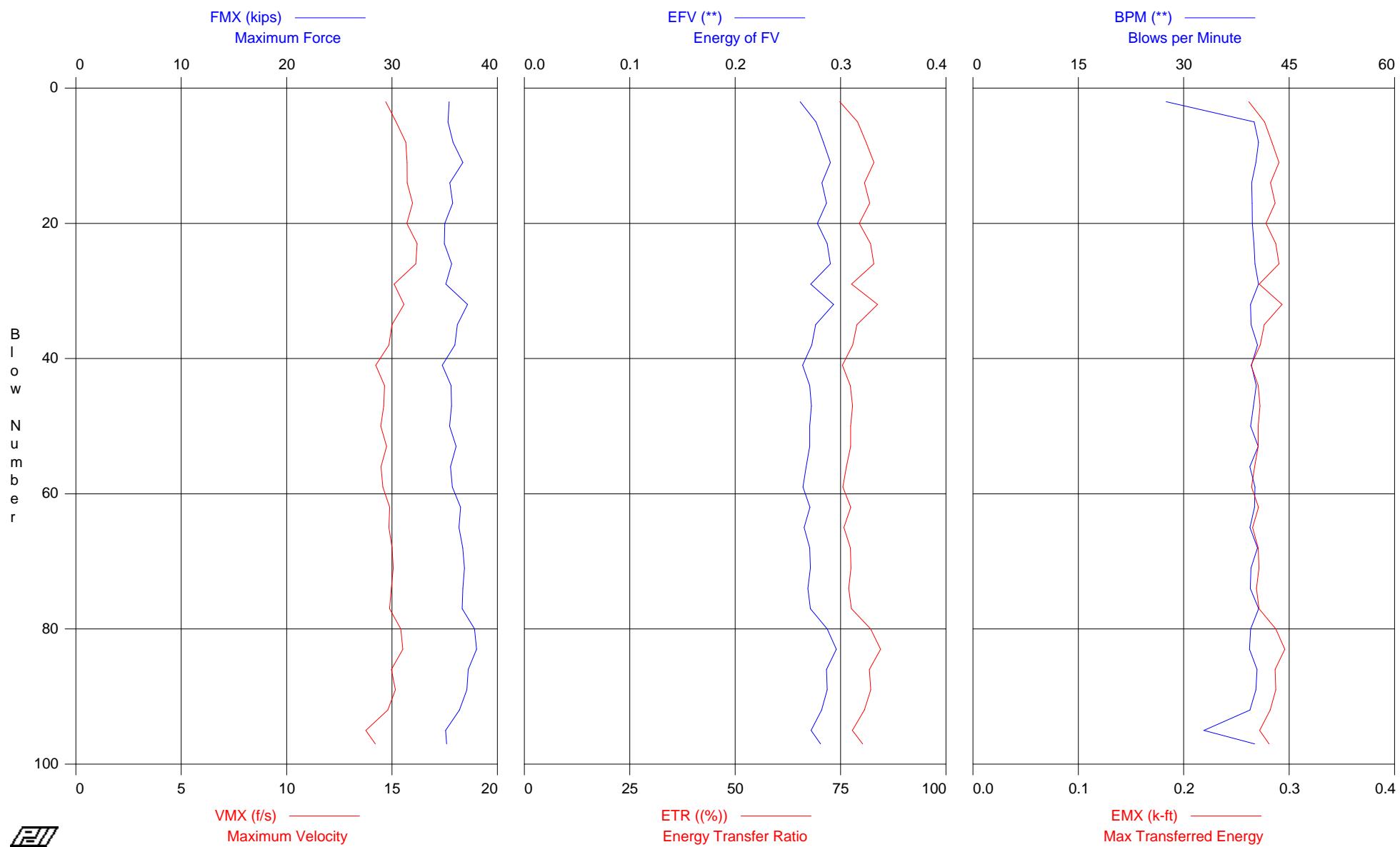
Total number of blows analyzed: 33

#### Time Summary

Drive 49 seconds

8:55:22 AM - 8:56:11 AM (2/11/2009) BN 1 - 33

## KINGSTON PLANT - B 09-403 SS-2



KINGSTON PLANT - B 09-403 SS-2  
OP: SW

SPT AUTO  
Test date: 11-Feb-2009

AR: 1.43 in<sup>2</sup>  
LE: 19.0 ft  
WS: 16,807.9 f/s

SP: 0.492 k/ft<sup>3</sup>  
EM: 30,000 ksi  
JC: 0.70

FMX: Maximum Force  
VMX: Maximum Velocity  
EFV: Energy of FV  
ETR: Energy Transfer Ratio  
BPM: Blows per Minute

EMX: Max Transferred Energy  
EF2: Energy of F<sup>2</sup>  
DFN: Final Displacement  
FVP: Force/Velocity proportionality

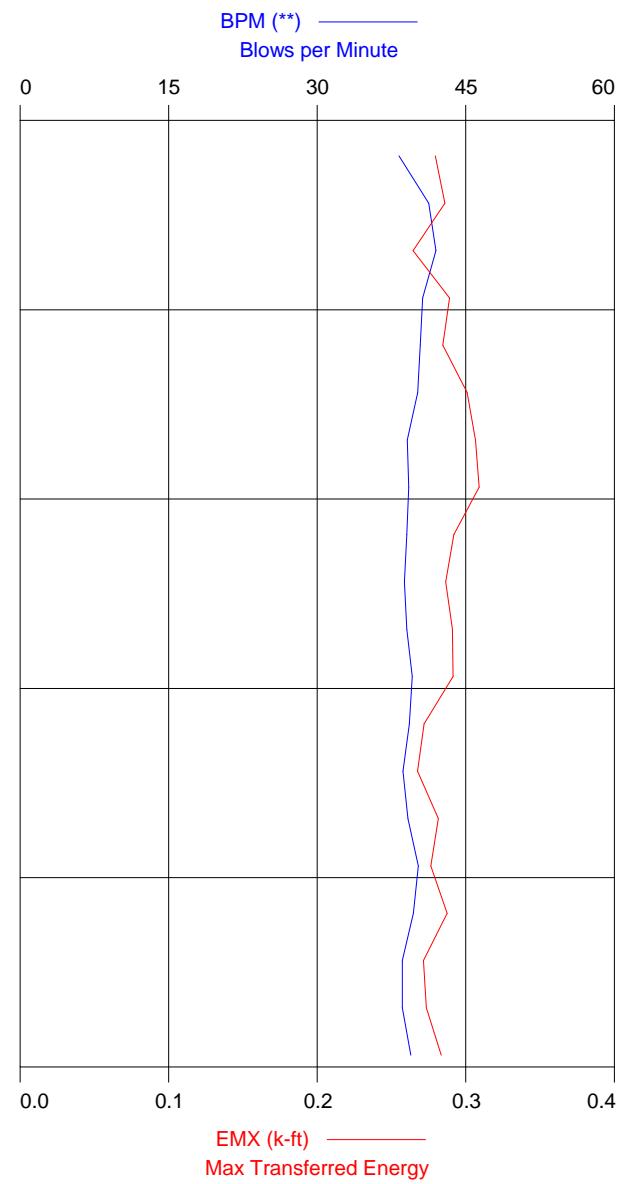
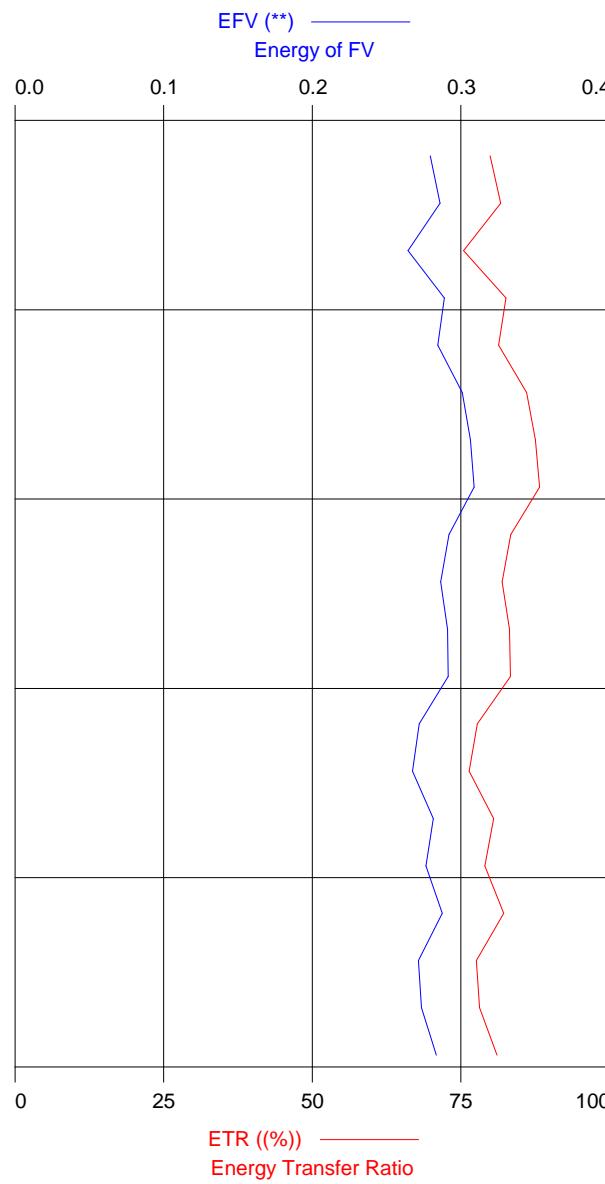
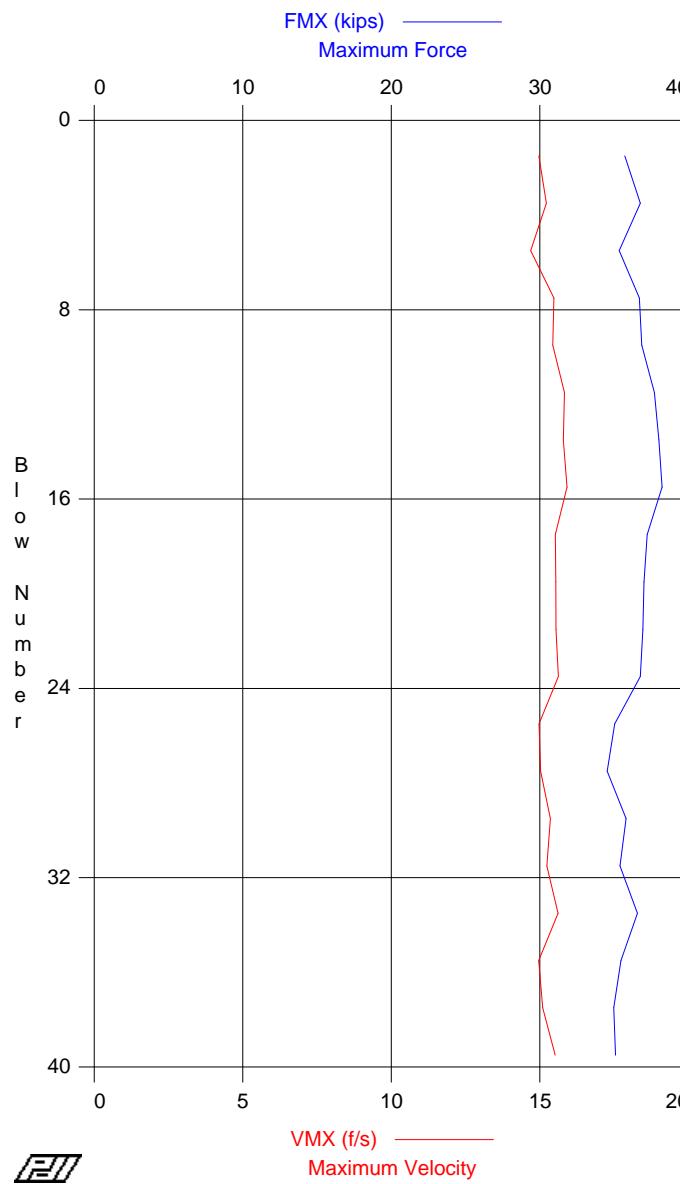
BL#	depth	BLC	TYPE	FMX	VMX	EFV	ETR	BPM	EMX	EF2	DFN	FVP				
end	ft	bl/ft		kips	f/s	**	(%)	**	k-ft	k-ft	in	lbf				
8	0.50	16	AV8	35	15.1	0.273	78	35.5	0.273	0.254	0.95	0.92				
				STD	0	0.4	0.010	3	12.7	0.010	0.005	0.24	0.03			
				MAX	36	15.9	0.285	81	41.1	0.285	0.264	1.35	0.95			
33	1.00	50	AV25	36	15.8	0.285	81	40.0	0.285	0.255	0.41	0.88				
				STD	1	0.5	0.015	4	0.4	0.015	0.015	0.09	0.04			
				MAX	37	16.8	0.299	85	41.0	0.299	0.270	0.55	0.94			
68	1.50	70	AV35	36	14.7	0.270	77	39.9	0.270	0.250	0.27	0.96				
				STD	1	0.3	0.010	3	0.6	0.010	0.009	0.02	0.01			
				MAX	37	15.3	0.290	83	40.9	0.290	0.264	0.32	0.97			
97	2.00	58	AV29	37	14.9	0.280	80	39.2	0.280	0.264	0.31	0.97				
				STD	1	0.6	0.011	3	3.7	0.011	0.008	0.05	0.02			
				MAX	38	15.7	0.302	86	41.1	0.302	0.281	0.42	1.01			
				Average	36	15.1	0.277	79	39.4	0.277	0.256	0.37	0.94			
				Std. Dev.	1	0.6	0.013	4	4.4	0.013	0.012	0.20	0.04			
				Maximum	38	16.8	0.302	86	41.1	0.302	0.281	1.35	1.01			

Total number of blows analyzed: 97

#### Time Summary

Drive      2 minutes 25 seconds      9:07:56 AM - 9:10:21 AM (2/11/2009) BN 1 - 97

## KINGSTON PLANT - B 09-403 SS-3



KINGSTON PLANT - B 09-403 SS-3  
OP: SW

SPT AUTO  
Test date: 11-Feb-2009

AR: 1.43 in<sup>2</sup>  
LE: 20.0 ft  
WS: 16,807.9 f/s

SP: 0.492 k/ft<sup>3</sup>  
EM: 30,000 ksi  
JC: 0.70

FMX: Maximum Force  
VMX: Maximum Velocity  
EFV: Energy of FV  
ETR: Energy Transfer Ratio  
BPM: Blows per Minute

EMX: Max Transferred Energy  
EF2: Energy of F<sup>2</sup>  
DFN: Final Displacement  
FVP: Force/Velocity proportionality

BL#	depth	BLC	TYPE	FMX	VMX	EFV	ETR	BPM	EMX	EF2	DFN	FVP			
end	ft	bl/ft		kips	f/s	**	(%)	**	k-ft	k-ft	in	[]			
11	0.50	22	AV11	36	15.2	0.283	81	40.5	0.283	0.290	0.65	0.94			
				STD	1	0.6	0.019	6	1.5	0.019	0.019	0.09			
				MAX	38	15.9	0.305	87	42.2	0.305	0.311	0.75			
22	1.00	22	AV11	37	15.7	0.297	85	39.1	0.297	0.304	0.80	0.94			
				STD	1	0.2	0.011	3	0.3	0.011	0.009	0.08			
				MAX	38	15.9	0.312	89	39.6	0.312	0.316	0.99			
31	1.50	18	AV9	35	15.2	0.277	79	39.4	0.277	0.282	0.81	0.90			
				STD	1	0.3	0.010	3	0.9	0.010	0.011	0.04			
				MAX	37	15.7	0.295	84	41.6	0.295	0.301	0.86			
40	2.00	18	AV9	36	15.3	0.280	80	39.1	0.280	0.285	0.89	0.90			
				STD	1	0.4	0.008	2	0.6	0.008	0.008	0.03			
				MAX	37	16.1	0.291	83	39.9	0.291	0.296	0.94			
				Average	36	15.4	0.285	81	39.6	0.285	0.291	0.78			
				Std. Dev.	1	0.4	0.015	4	1.1	0.015	0.015	0.11			
				Maximum	38	16.1	0.312	89	42.2	0.312	0.316	0.99			

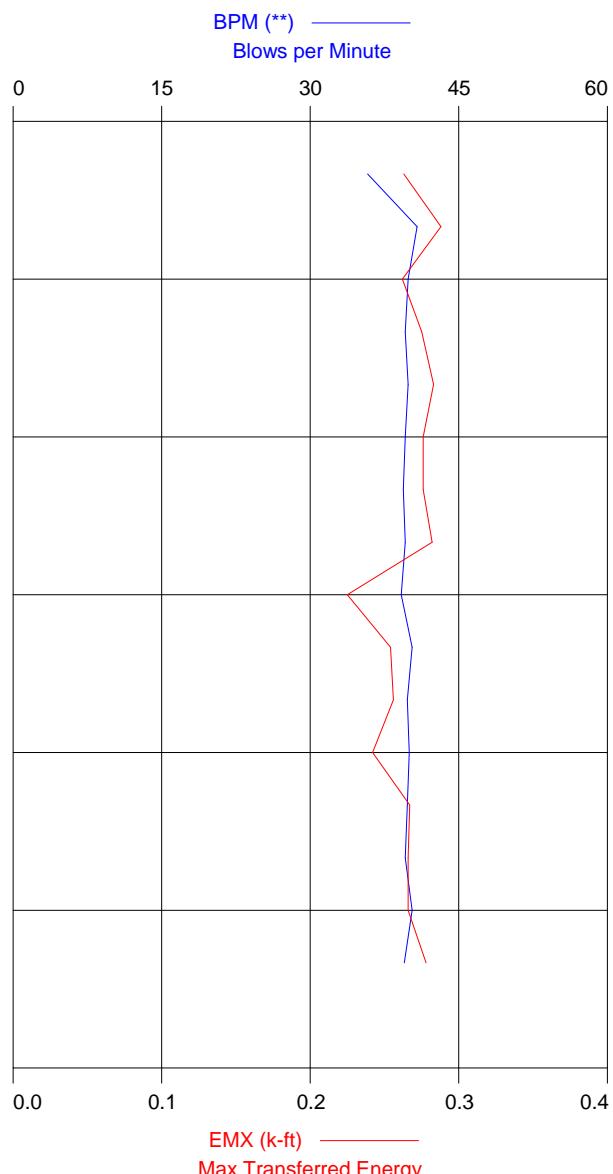
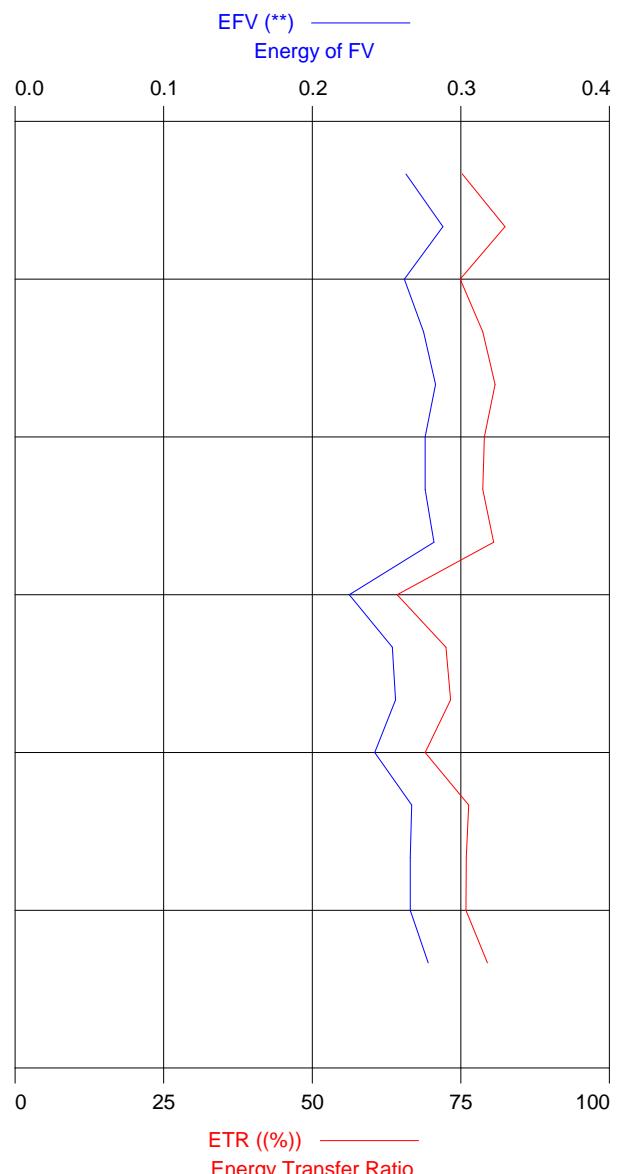
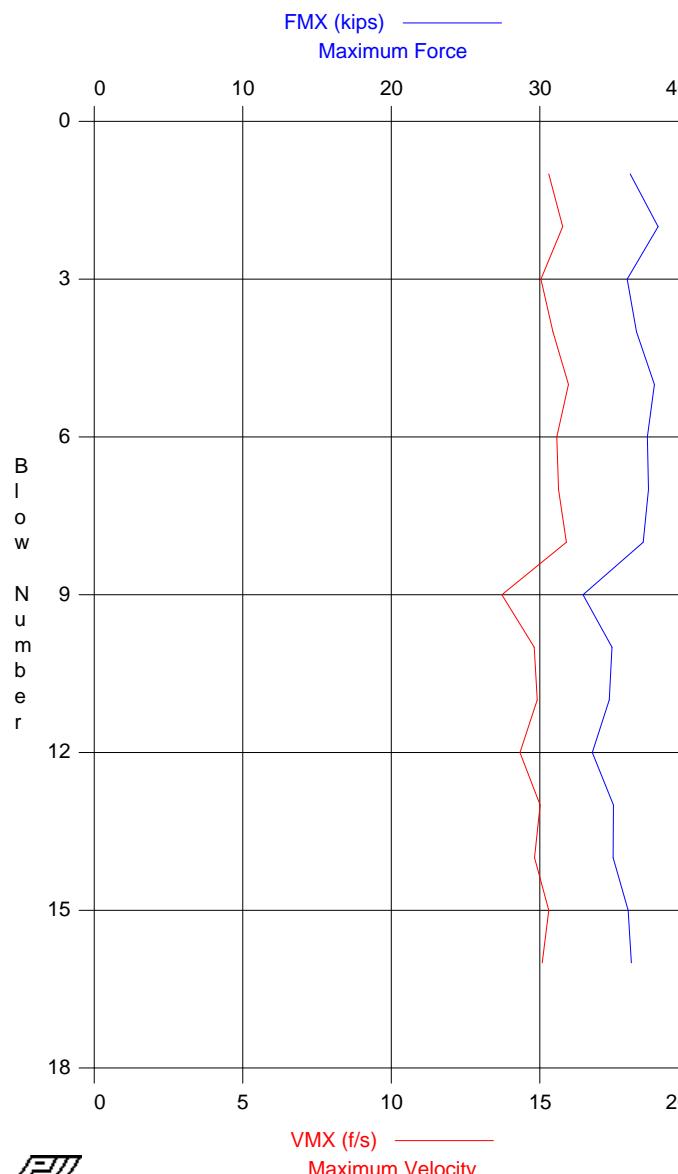
Total number of blows analyzed: 40

#### Time Summary

Drive 59 seconds

9:18:56 AM - 9:19:55 AM (2/11/2009) BN 1 - 40

## KINGSTON PLANT - B 09-403 SS-4\_1



KINGSTON PLANT - B 09-403 SS-4\_1  
OP: SW

SPT AUTO  
Test date: 11-Feb-2009

AR: 1.43 in<sup>2</sup>  
LE: 24.0 ft  
WS: 16,807.9 f/s

SP: 0.492 k/ft<sup>3</sup>  
EM: 30,000 ksi  
JC: 0.70

FMX: Maximum Force  
VMX: Maximum Velocity  
EFV: Energy of FV  
ETR: Energy Transfer Ratio  
BPM: Blows per Minute

EMX: Max Transferred Energy  
EF2: Energy of F<sup>2</sup>  
DFN: Final Displacement  
FVP: Force/Velocity proportionality

BL#	depth	BLC	TYPE	FMX	VMX	EFV	ETR	BPM	EMX	EF2	DFN	FVP		
end	ft	bl/ft		kips	f/s	**	(%)	**	k-ft	k-ft	in	[]		
4	0.50	8	AV4	37	15.4	0.272	78	39.0	0.272	0.269	1.37	0.97		
			STD	1	0.3	0.011	3	1.9	0.011	0.010	0.11	0.00		
			MAX	38	15.8	0.288	82	40.8	0.288	0.284	1.52	0.98		
9	1.00	10	AV5	36	15.4	0.268	77	39.5	0.268	0.265	1.26	0.96		
			STD	2	0.8	0.022	6	0.2	0.022	0.023	0.16	0.01		
			MAX	38	16.0	0.283	81	39.9	0.283	0.283	1.54	0.97		
13	1.50	8	AV4	35	14.8	0.255	73	40.0	0.255	0.244	1.51	0.93		
			STD	1	0.3	0.009	3	0.2	0.009	0.010	0.17	0.01		
			MAX	35	15.0	0.267	76	40.3	0.267	0.253	1.80	0.95		
16	2.00	6	AV3	36	15.1	0.270	77	39.8	0.270	0.265	2.10	0.94		
			STD	1	0.2	0.006	2	0.4	0.006	0.008	0.18	0.01		
			MAX	36	15.3	0.278	79	40.3	0.278	0.275	2.35	0.95		
			Average	36	15.2	0.266	76	39.6	0.266	0.261	1.51	0.95		
			Std. Dev.	1	0.6	0.016	5	1.0	0.016	0.018	0.34	0.02		
			Maximum	38	16.0	0.288	82	40.8	0.288	0.284	2.35	0.98		

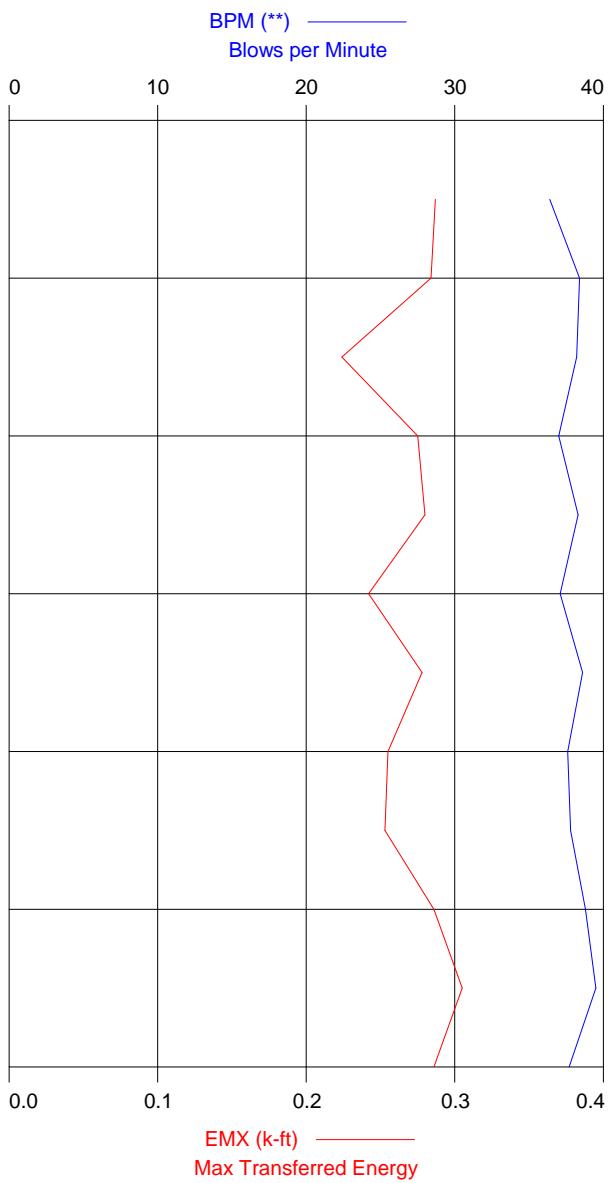
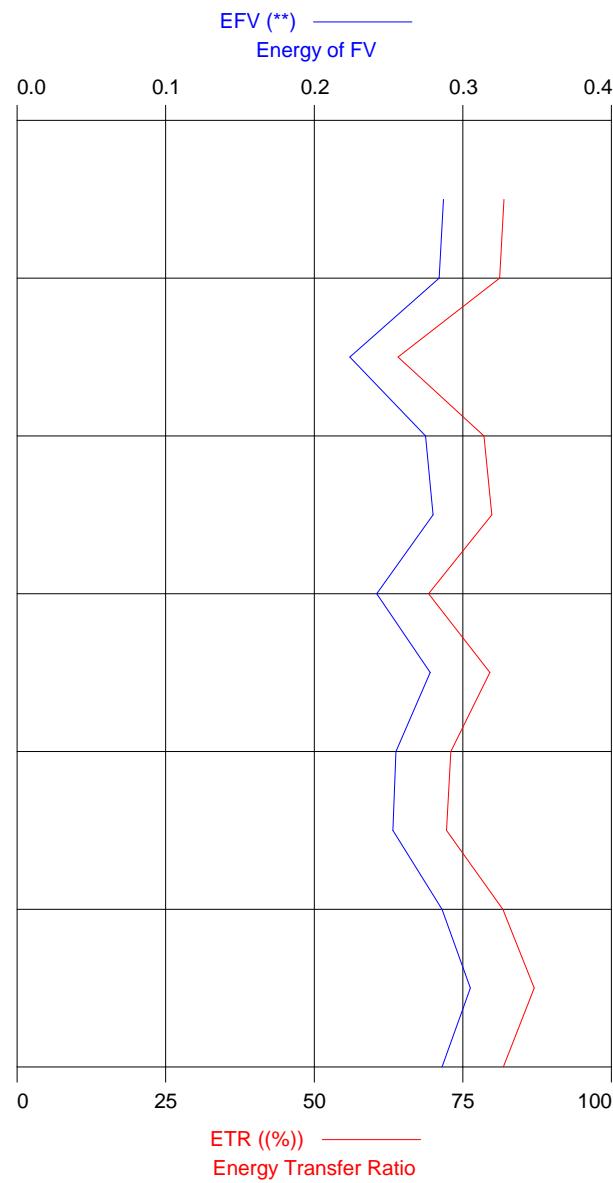
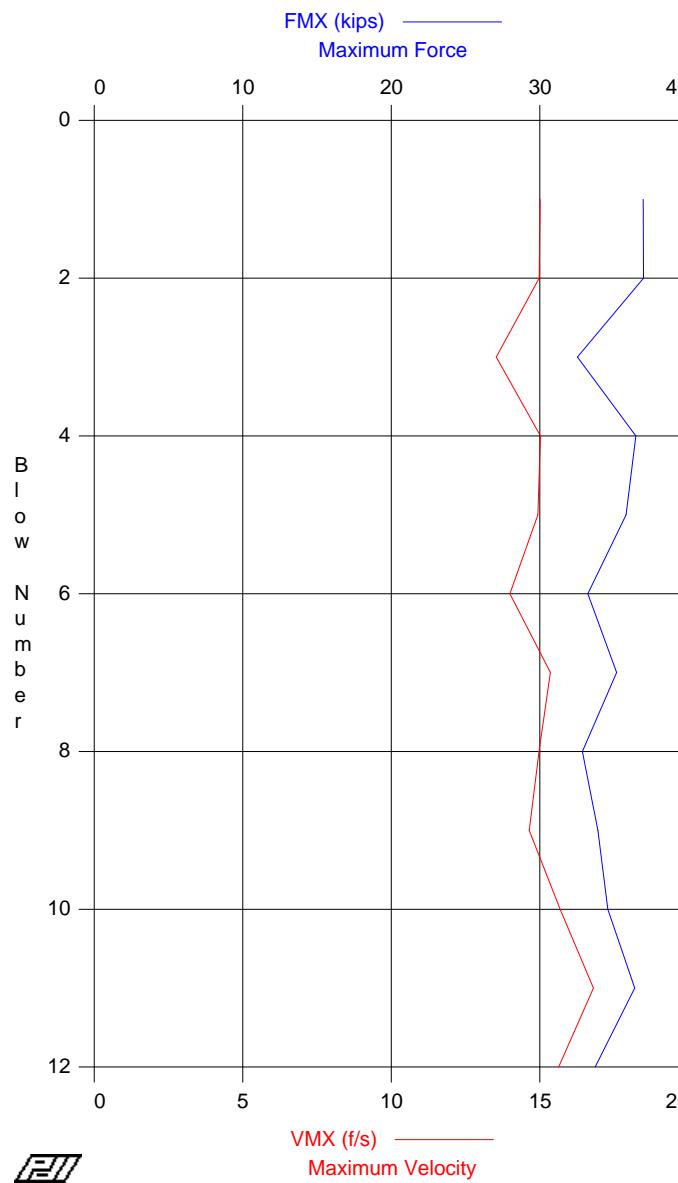
Total number of blows analyzed: 16

#### Time Summary

Drive 23 seconds

9:29:38 AM - 9:30:01 AM (2/11/2009) BN 1 - 16

## KINGSTON PLANT - B 09-403 SS-5\_1



KINGSTON PLANT - B 09-403 SS-5\_1  
OP: SW

SPT AUTO  
Test date: 11-Feb-2009

AR: 1.43 in<sup>2</sup>  
LE: 25.0 ft  
WS: 16,807.9 f/s

SP: 0.492 k/ft<sup>3</sup>  
EM: 30,000 ksi  
JC: 0.70

FMX: Maximum Force  
VMX: Maximum Velocity  
EFV: Energy of FV  
ETR: Energy Transfer Ratio  
BPM: Blows per Minute

EMX: Max Transferred Energy  
EF2: Energy of F<sup>2</sup>  
DFN: Final Displacement  
FVP: Force/Velocity proportionality

BL# end	depth ft	BLC bl/ft	TYPE	FMX kips	VMX f/s	EFV **	ETR (%)	BPM **	EMX k-ft	EF2 k-ft	DFN in	FVP			
2	0.50	4	AV2	37	15.0	0.285	82	37.4	0.285	0.288	2.10	0.97			
			STD	0	0.0	0.002	0	1.0	0.002	0.003	0.14	0.01			
			MAX	37	15.0	0.287	82	38.4	0.287	0.291	2.24	0.98			
5	1.00	6	AV3	35	14.5	0.260	74	37.8	0.260	0.260	2.71	0.94			
			STD	2	0.7	0.025	7	0.6	0.025	0.024	1.13	0.01			
			MAX	36	15.0	0.280	80	38.3	0.280	0.278	4.30	0.95			
9	1.50	8	AV4	34	14.7	0.257	74	37.8	0.257	0.254	1.25	0.90			
			STD	1	0.5	0.013	4	0.5	0.013	0.012	0.28	0.03			
			MAX	35	15.4	0.278	80	38.6	0.278	0.275	1.58	0.93			
12	2.00	6	AV3	35	16.0	0.292	84	38.7	0.292	0.280	2.32	0.83			
			STD	1	0.5	0.009	2	0.7	0.009	0.013	0.13	0.01			
			MAX	36	16.8	0.305	87	39.5	0.305	0.298	2.42	0.84			
				Average	35	15.0	0.271	78	37.9	0.271	0.268	2.02	0.90		
				Std. Dev.	2	0.8	0.022	6	0.8	0.022	0.021	0.83	0.05		
				Maximum	37	16.8	0.305	87	39.5	0.305	0.298	4.30	0.98		

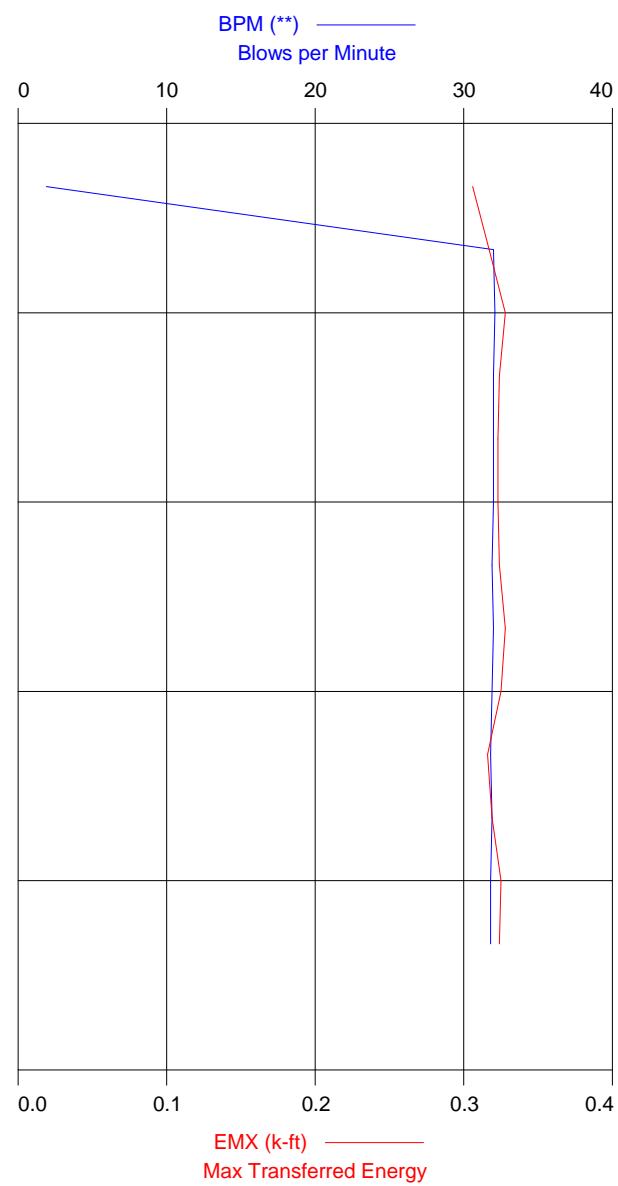
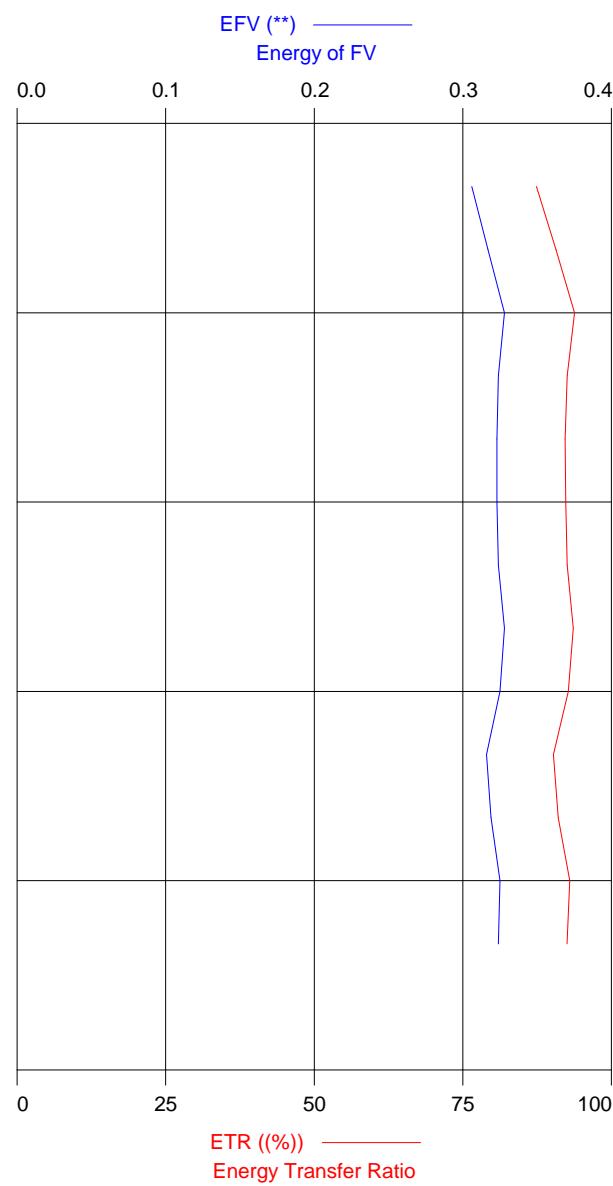
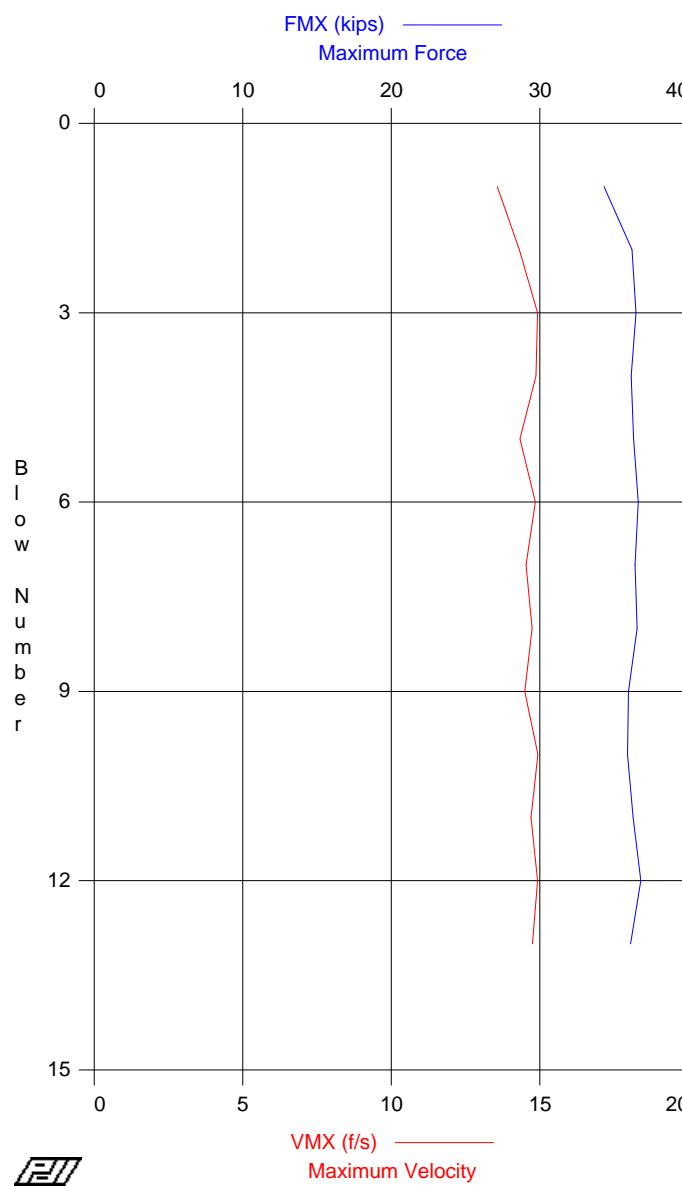
Total number of blows analyzed: 12

#### Time Summary

Drive 17 seconds

9:39:45 AM - 9:40:02 AM (2/11/2009) BN 1 - 12

## KINGSTON PLANT - B 09-414 SS-13



KINGSTON PLANT - B 09-414 SS-13  
OP: SW

SPT AUTO  
Test date: 10-Feb-2009

AR: 1.43 in<sup>2</sup>  
LE: 33.0 ft  
WS: 16,807.9 f/s

SP: 0.492 k/ft<sup>3</sup>  
EM: 30,000 ksi  
JC: 0.70

FMX: Maximum Force  
VMX: Maximum Velocity  
EFV: Energy of FV  
ETR: Energy Transfer Ratio  
BPM: Blows per Minute

EMX: Max Transferred Energy  
EF2: Energy of F<sup>2</sup>  
DFN: Final Displacement  
FVP: Force/Velocity proportionality

BL#	depth	BLC	TYPE	FMX	VMX	EFV	ETR	BPM	EMX	EF2	DFN	FVP			
end	ft	bl/ft		kips	f/s	**	(%)	**	k-ft	k-ft	in	]			
3	0.50	6	AV3	36	14.3	0.317	91	22.0	0.317	0.328	1.90	0.97			
			STD	1	0.6	0.009	3	14.2	0.009	0.008	0.08	0.02			
			MAX	36	14.9	0.328	94	32.1	0.328	0.336	1.97	0.99			
6	1.00	6	AV3	36	14.7	0.323	92	32.0	0.323	0.334	2.00	0.96			
			STD	0	0.3	0.000	0	0.0	0.000	0.002	0.13	0.00			
			MAX	37	14.9	0.324	93	32.0	0.324	0.337	2.18	0.97			
9	1.50	6	AV3	36	14.6	0.326	93	31.9	0.326	0.335	2.32	0.97			
			STD	0	0.1	0.002	0	0.0	0.002	0.000	0.24	0.01			
			MAX	37	14.7	0.328	94	32.0	0.328	0.335	2.59	0.98			
13	2.00	8	AV4	36	14.8	0.321	92	31.8	0.321	0.332	1.60	0.96			
			STD	0	0.1	0.004	1	0.0	0.004	0.004	0.53	0.01			
			MAX	37	14.9	0.325	93	31.9	0.325	0.336	2.27	0.97			
				Average	36	14.6	0.322	92	29.6	0.322	0.332	1.93	0.97		
				Std. Dev.	1	0.4	0.006	2	8.0	0.006	0.005	0.42	0.01		
				Maximum	37	14.9	0.328	94	32.1	0.328	0.337	2.59	0.99		

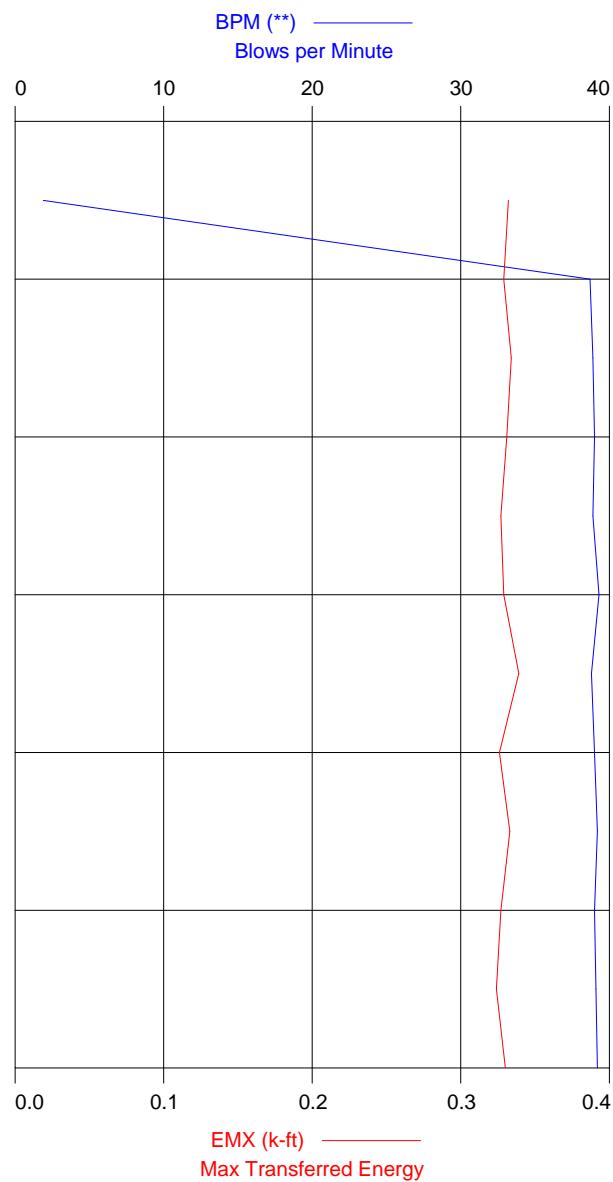
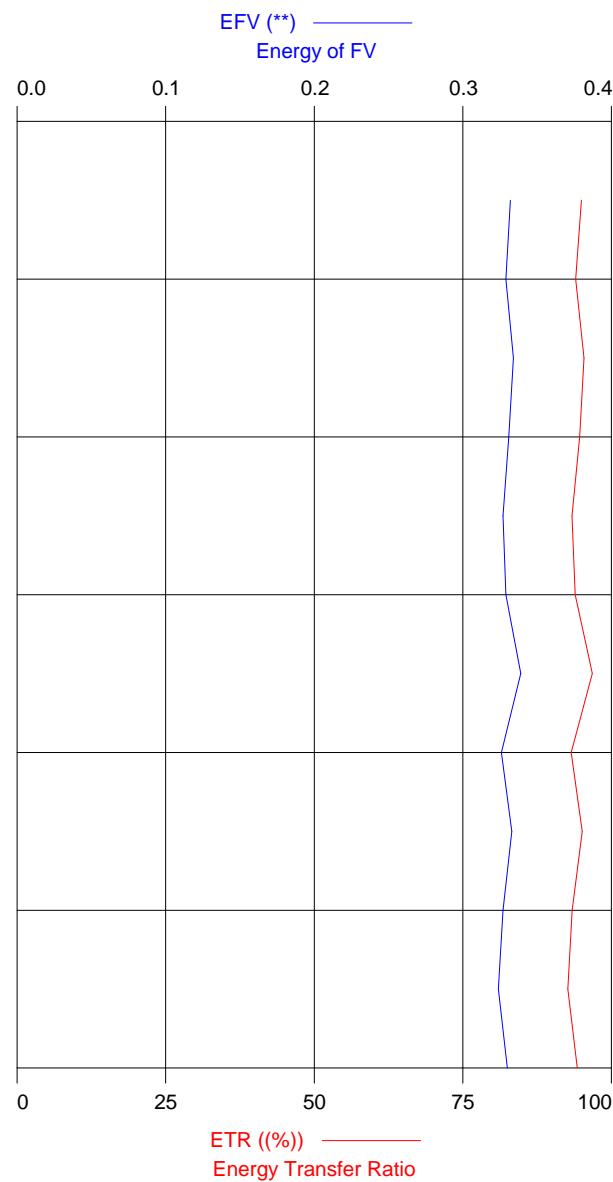
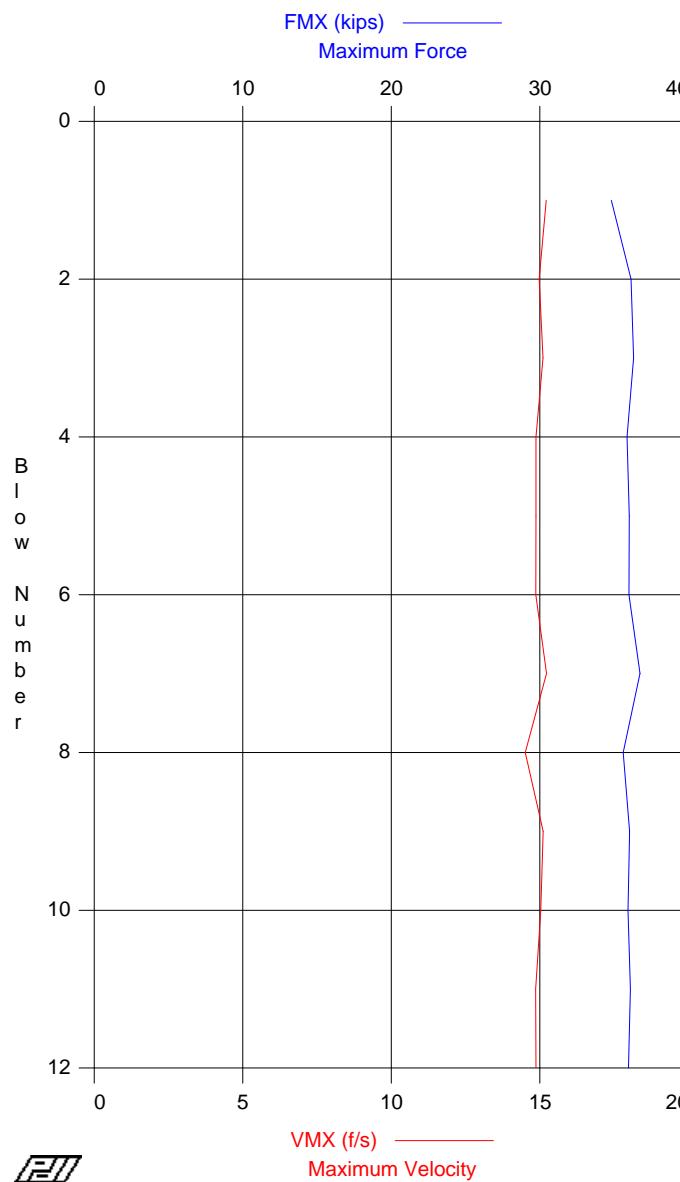
Total number of blows analyzed: 13

#### Time Summary

Drive 22 seconds

11:48:11 AM - 11:48:33 AM (2/10/2009) BN 1 - 13

## KINGSTON PLANT - B 09-414 SS-14



KINGSTON PLANT - B 09-414 SS-14  
OP: SW

SPT AUTO  
Test date: 10-Feb-2009

AR: 1.43 in<sup>2</sup>  
LE: 33.0 ft  
WS: 16,807.9 f/s

SP: 0.492 k/ft<sup>3</sup>  
EM: 30,000 ksi  
JC: 0.70

FMX: Maximum Force  
VMX: Maximum Velocity  
EFV: Energy of FV  
ETR: Energy Transfer Ratio  
BPM: Blows per Minute

EMX: Max Transferred Energy  
EF2: Energy of F<sup>2</sup>  
DFN: Final Displacement  
FVP: Force/Velocity proportionality

BL# end	depth ft	BLC bl/ft	TYPE	FMX kips	VMX f/s	EFV **	ETR (%)	BPM **	EMX k-ft	EF2 k-ft	DFN in	FVP			
2	0.50	4	AV2	35	15.1	0.331	94	20.3	0.331	0.329	2.03	0.92			
			STD	1	0.1	0.001	0	18.4	0.001	0.006	0.01	0.02			
			MAX	36	15.2	0.332	95	38.7	0.332	0.334	2.04	0.95			
5	1.00	6	AV3	36	14.9	0.331	94	38.9	0.331	0.334	1.92	0.95			
			STD	0	0.1	0.003	1	0.0	0.003	0.003	0.11	0.00			
			MAX	36	15.1	0.334	95	39.0	0.334	0.337	2.04	0.95			
8	1.50	6	AV3	36	14.9	0.331	95	39.0	0.331	0.335	2.08	0.95			
			STD	0	0.3	0.006	2	0.2	0.006	0.005	0.04	0.01			
			MAX	37	15.2	0.339	97	39.3	0.339	0.342	2.14	0.97			
12	2.00	8	AV4	36	15.0	0.329	94	39.1	0.329	0.330	1.71	0.95			
			STD	0	0.1	0.003	1	0.1	0.003	0.002	0.22	0.01			
			MAX	36	15.1	0.333	95	39.2	0.333	0.333	2.08	0.95			
				Average	36	15.0	0.330	94	35.9	0.330	0.332	1.91	0.94		
				Std. Dev.	0	0.2	0.004	1	10.3	0.004	0.005	0.20	0.02		
				Maximum	37	15.2	0.339	97	39.3	0.339	0.342	2.14	0.97		

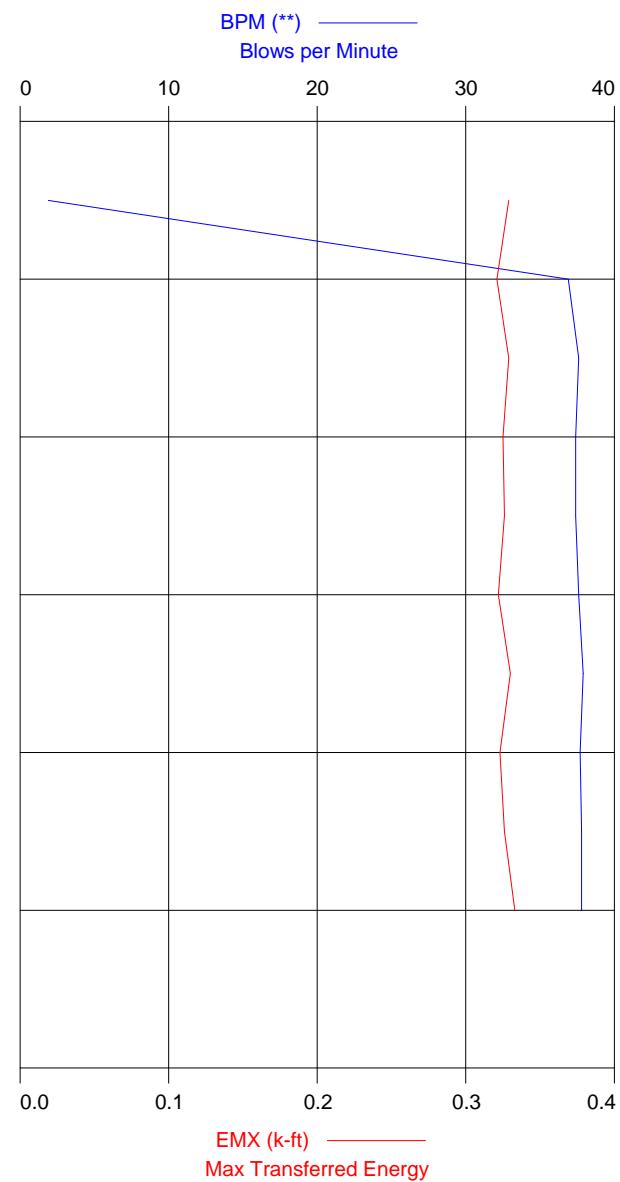
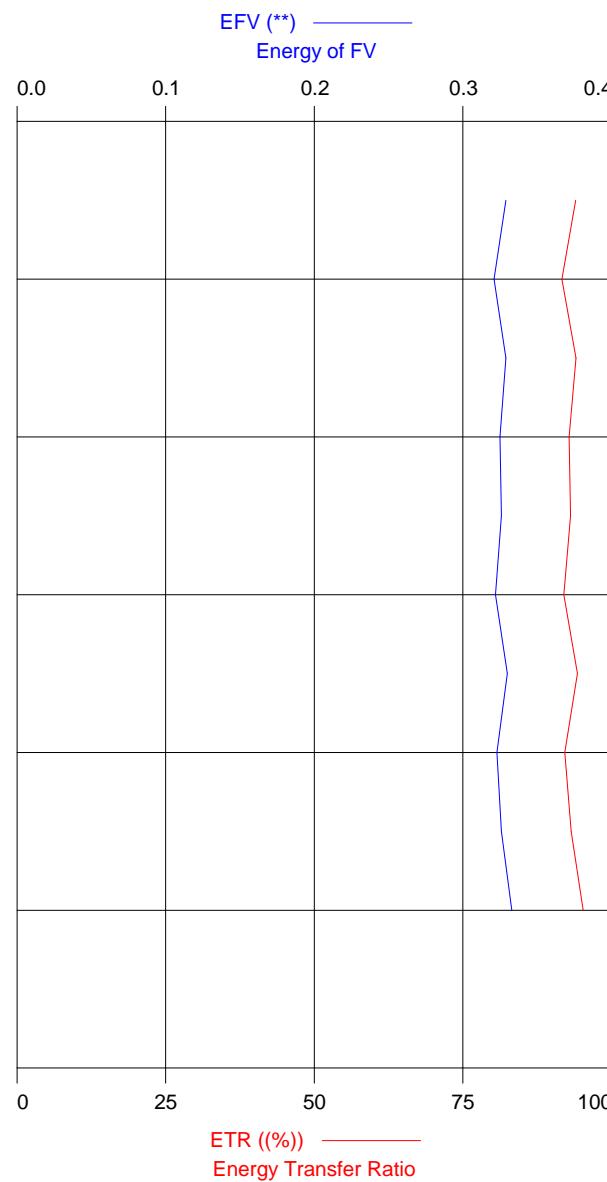
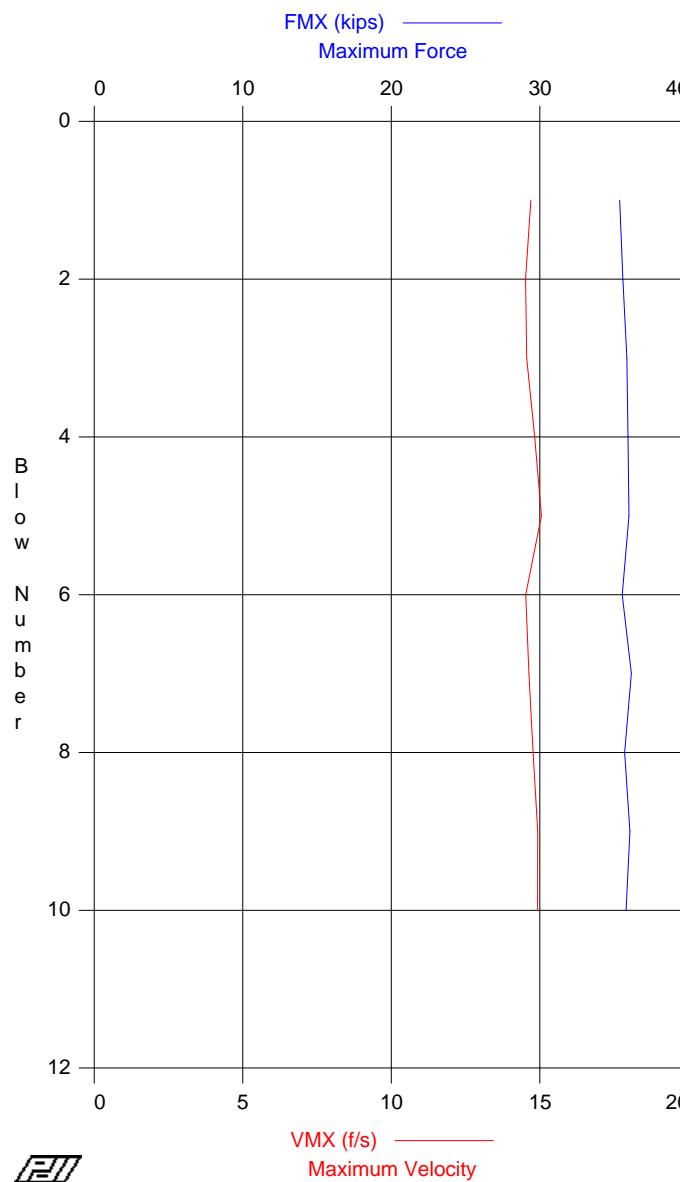
Total number of blows analyzed: 12

#### Time Summary

Drive 16 seconds

11:56:30 AM - 11:56:46 AM (2/10/2009) BN 1 - 12

## KINGSTON PLANT - B 09-414 SS-15



KINGSTON PLANT - B 09-414 SS-15  
OP: SW

SPT AUTO  
Test date: 10-Feb-2009

AR: 1.43 in<sup>2</sup>  
LE: 34.0 ft  
WS: 16,807.9 f/s

SP: 0.492 k/ft<sup>3</sup>  
EM: 30,000 ksi  
JC: 0.70

FMX: Maximum Force  
VMX: Maximum Velocity  
EFV: Energy of FV  
ETR: Energy Transfer Ratio  
BPM: Blows per Minute

EMX: Max Transferred Energy  
EF2: Energy of F<sup>2</sup>  
DFN: Final Displacement  
FVP: Force/Velocity proportionality

BL#	depth	BLC	TYPE	FMX	VMX	EFV	ETR	BPM	EMX	EF2	DFN	FVP		
end	ft	bl/ft		kips	f/s	**	(%)	**	k-ft	k-ft	in	[]		
2	0.50	4	AV2	35	14.6	0.325	93	19.4	0.325	0.313	2.49	0.95		
			STD	0	0.1	0.004	1	17.5	0.004	0.003	0.80	0.01		
			MAX	36	14.7	0.329	94	36.9	0.329	0.315	3.30	0.96		
4	1.00	4	AV2	36	14.7	0.327	93	37.5	0.327	0.314	1.55	0.96		
			STD	0	0.1	0.002	1	0.1	0.002	0.003	0.19	0.01		
			MAX	36	14.8	0.329	94	37.6	0.329	0.317	1.74	0.96		
6	1.50	4	AV2	36	14.8	0.324	93	37.5	0.324	0.310	1.64	0.95		
			STD	0	0.3	0.002	1	0.1	0.002	0.002	0.12	0.01		
			MAX	36	15.1	0.326	93	37.6	0.326	0.312	1.76	0.96		
10	2.00	8	AV4	36	14.8	0.328	94	37.8	0.328	0.314	1.74	0.95		
			STD	0	0.1	0.004	1	0.1	0.004	0.003	0.13	0.01		
			MAX	36	14.9	0.333	95	37.9	0.333	0.318	1.89	0.97		
			Average	36	14.7	0.326	93	34.0	0.326	0.313	1.83	0.95		
			Std. Dev.	0	0.2	0.004	1	10.7	0.004	0.003	0.51	0.01		
			Maximum	36	15.1	0.333	95	37.9	0.333	0.318	3.30	0.97		

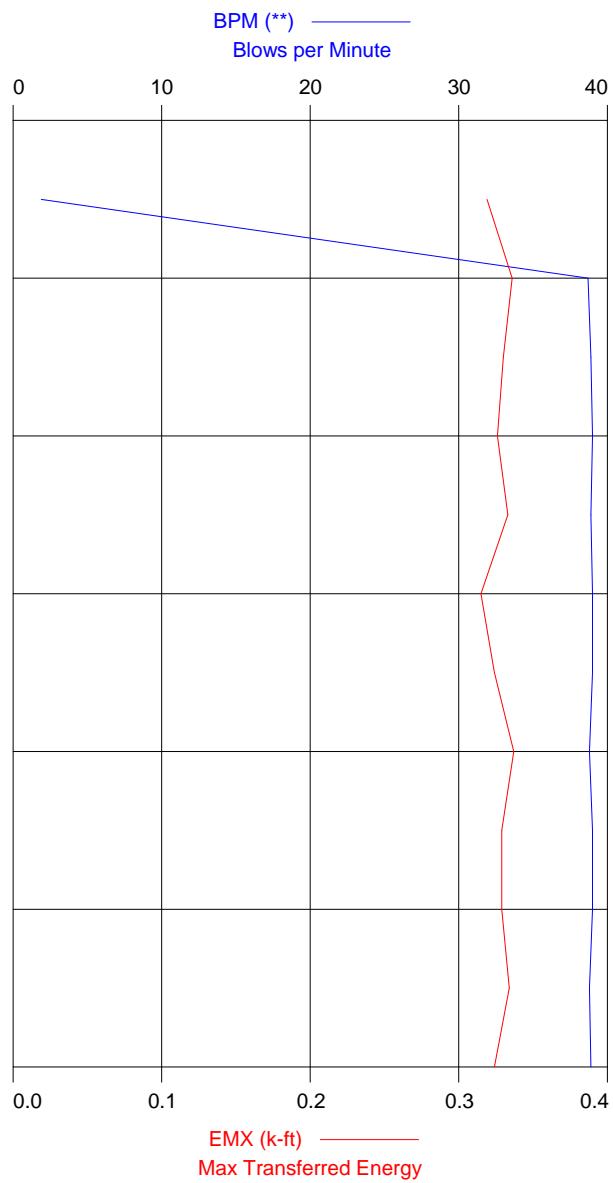
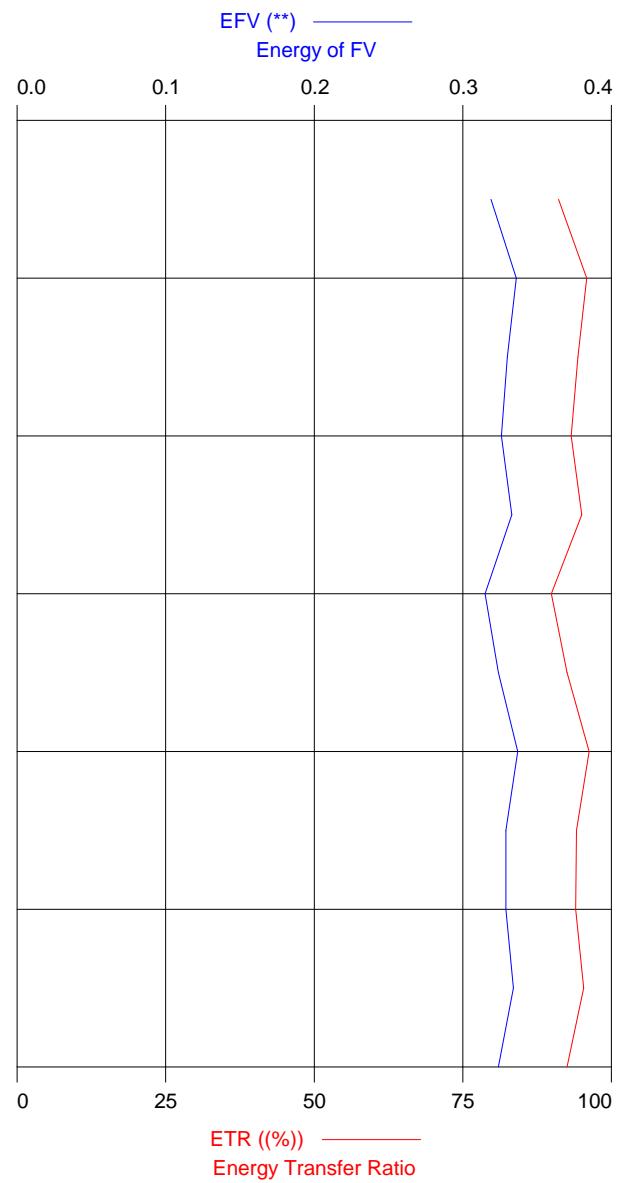
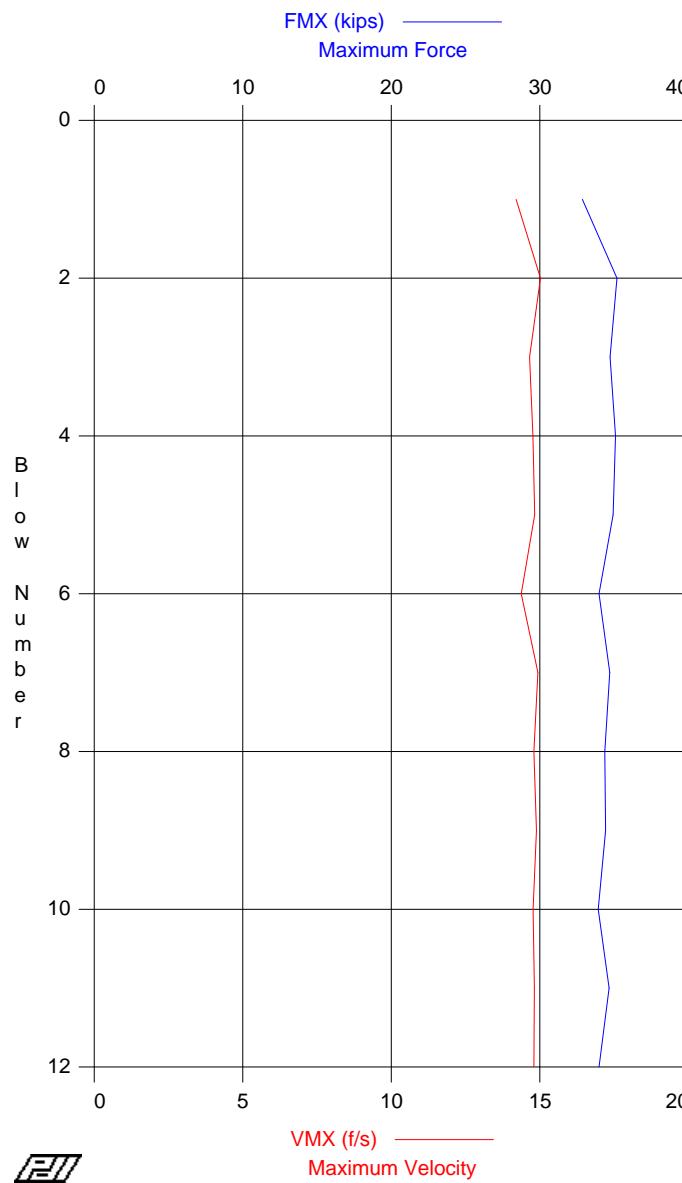
Total number of blows analyzed: 10

#### Time Summary

Drive 14 seconds

12:03:27 PM - 12:03:41 PM (2/10/2009) BN 1 - 10

## KINGSTON PLANT - B 09-414 SS-16



KINGSTON PLANT - B 09-414 SS-16  
OP: SW

SPT AUTO

Test date: 10-Feb-2009

AR: 1.43 in<sup>2</sup>  
LE: 36.0 ft  
WS: 16,807.9 f/s

SP: 0.492 k/ft<sup>3</sup>  
EM: 30,000 ksi  
JC: 0.70

FMX: Maximum Force  
VMX: Maximum Velocity  
EFV: Energy of FV  
ETR: Energy Transfer Ratio  
BPM: Blows per Minute

EMX: Max Transferred Energy  
EF2: Energy of F<sup>2</sup>  
DFN: Final Displacement  
FVP: Force/Velocity proportionality

BL#	depth end ft	BLC bl/ft	TYPE	FMX kips	VMX f/s	EFV ** (%)	ETR (%)	BPM **	EMX k-ft	EF2 k-ft	DFN in	FVP []	
1	0.50	2	AV1	33	14.2	0.319	91	1.9	0.319	0.313	3.02	0.90	
			MAX	33	14.2	0.319	91	1.9	0.319	0.313	3.02	0.90	
4	1.00	6	AV3	35	14.8	0.331	94	38.9	0.331	0.326	1.89	0.92	
			STD	0	0.2	0.004	1	0.1	0.004	0.003	0.61	0.01	
			MAX	35	15.0	0.336	96	39.0	0.336	0.330	2.76	0.93	
8	1.50	8	AV4	35	14.7	0.327	93	38.9	0.327	0.318	1.68	0.92	
			STD	0	0.2	0.008	2	0.1	0.008	0.007	0.14	0.01	
			MAX	35	14.9	0.337	96	39.0	0.337	0.325	1.87	0.92	
12	2.00	8	AV4	34	14.8	0.329	94	38.9	0.329	0.319	1.72	0.90	
			STD	0	0.0	0.004	1	0.1	0.004	0.005	0.22	0.01	
			MAX	35	14.9	0.334	95	39.0	0.334	0.324	1.98	0.92	
				Average	34	14.7	0.328	94	35.8	0.328	0.320	1.86	0.91
				Std. Dev.	1	0.2	0.006	2	10.2	0.006	0.006	0.50	0.01
				Maximum	35	15.0	0.337	96	39.0	0.337	0.330	3.02	0.93

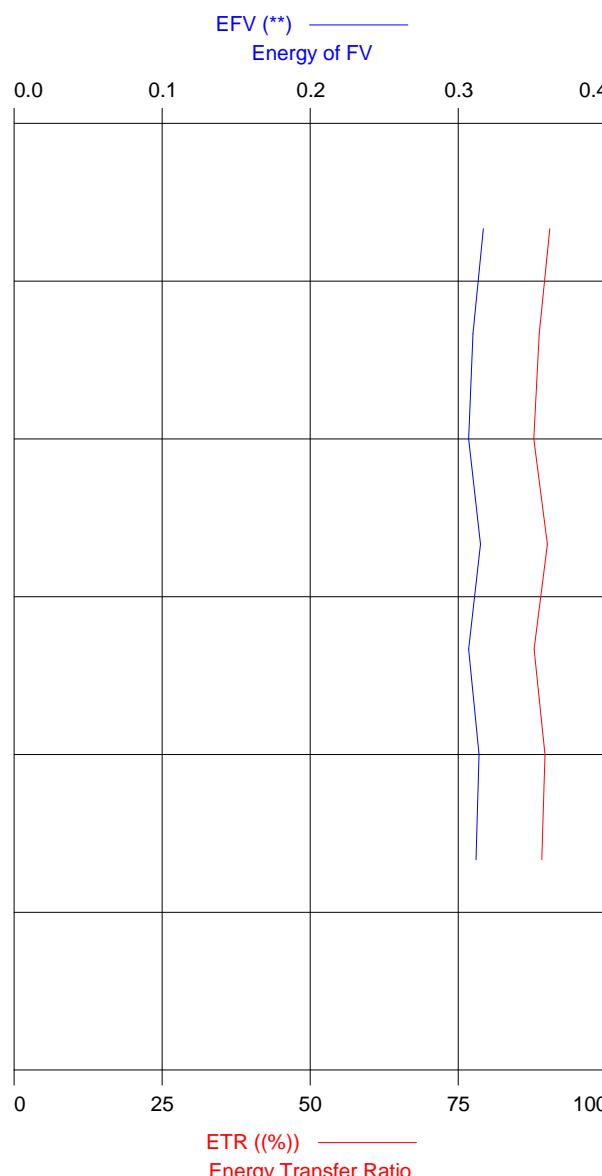
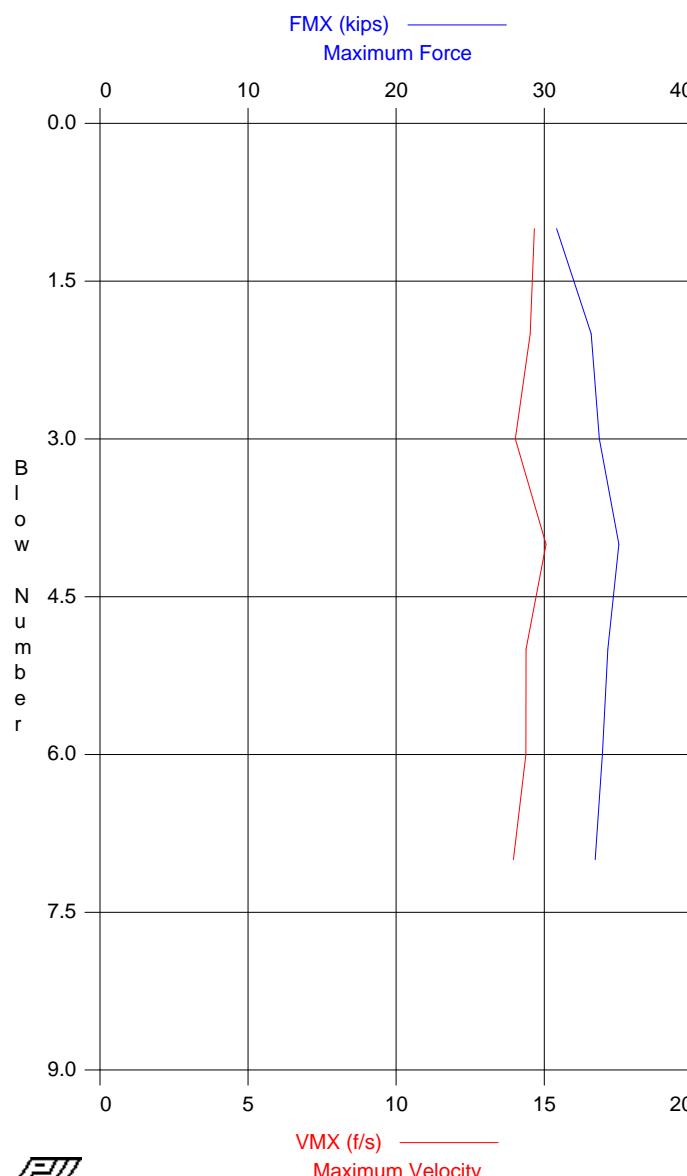
Total number of blows analyzed: 12

#### Time Summary

Drive 17 seconds

12:09:11 PM - 12:09:28 PM (2/10/2009) BN 1 - 12

## KINGSTON PLANT - B 09-414 SS-17



KINGSTON PLANT - B 09-414 SS-17  
OP: SW

SPT AUTO

Test date: 10-Feb-2009

AR: 1.43 in<sup>2</sup>  
LE: 38.0 ft  
WS: 16,807.9 f/s

SP: 0.492 k/ft<sup>3</sup>  
EM: 30,000 ksi  
JC: 0.70

FMX: Maximum Force  
VMX: Maximum Velocity  
EFV: Energy of FV  
ETR: Energy Transfer Ratio  
BPM: Blows per Minute

EMX: Max Transferred Energy  
EF2: Energy of F<sup>2</sup>  
DFN: Final Displacement  
FVP: Force/Velocity proportionality

BL#	depth	BLC	TYPE	FMX	VMX	EFV	ETR	BPM	EMX	EF2	DFN	FVP		
end	ft	bl/ft		kips	f/s	**	(%)	**	k-ft	k-ft	in	[]		
2	0.50	4	AV2	32	14.6	0.313	90	15.4	0.313	0.300	2.13	0.89		
			STD	1	0.1	0.004	1	13.5	0.004	0.005	0.37	0.06		
			MAX	33	14.7	0.317	90	28.9	0.317	0.305	2.50	0.95		
3	1.00	2	AV1	34	14.0	0.307	88	29.2	0.307	0.306	2.06	0.94		
			MAX	34	14.0	0.307	88	29.2	0.307	0.306	2.06	0.94		
4	1.50	2	AV1	35	15.1	0.315	90	29.3	0.315	0.310	3.32	0.93		
			MAX	35	15.1	0.315	90	29.3	0.315	0.310	3.32	0.93		
7	2.00	6	AV3	34	14.2	0.311	89	28.4	0.311	0.304	1.64	0.93		
			STD	0	0.2	0.003	1	1.2	0.003	0.002	0.12	0.01		
			MAX	34	14.4	0.314	90	29.3	0.314	0.306	1.76	0.94		
			Average	33	14.4	0.312	89	24.9	0.312	0.304	2.08	0.92		
			Std. Dev.	1	0.3	0.004	1	9.4	0.004	0.004	0.59	0.04		
			Maximum	35	15.1	0.317	90	29.3	0.317	0.310	3.32	0.95		

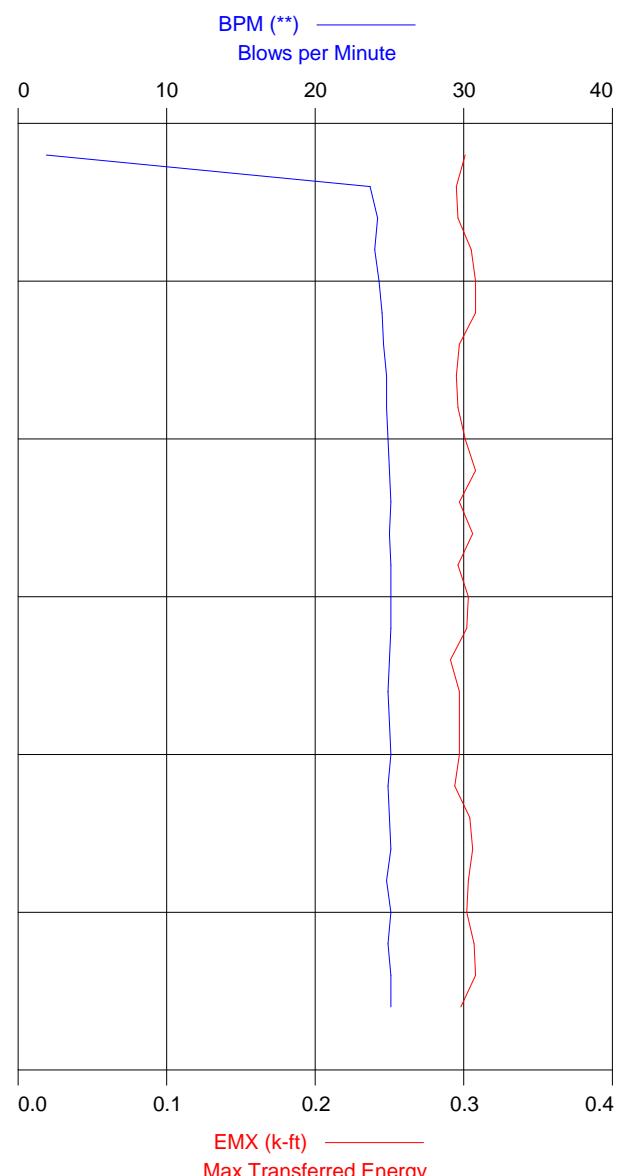
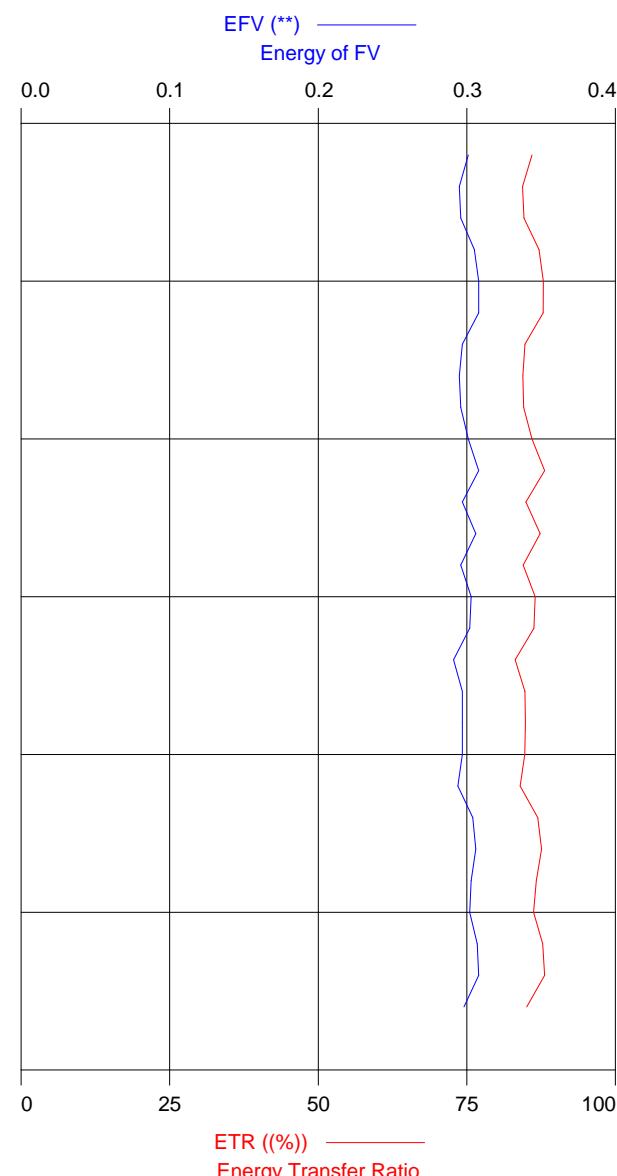
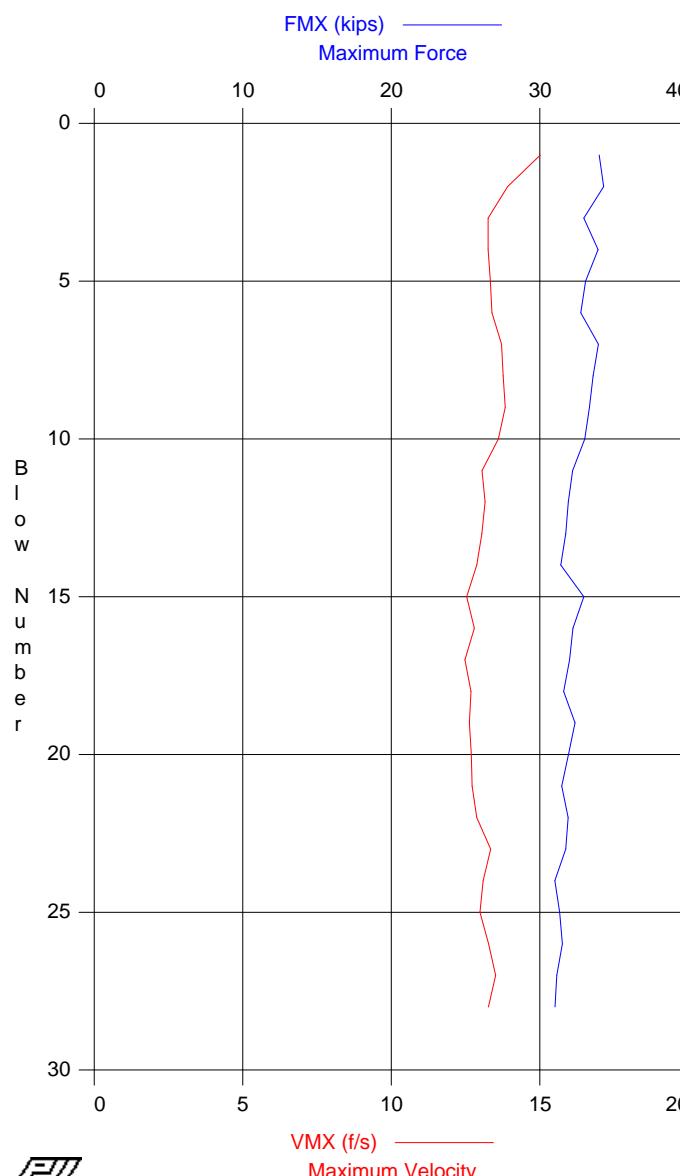
Total number of blows analyzed: 7

#### Time Summary

Drive 12 seconds

12:15:12 PM - 12:15:24 PM (2/10/2009) BN 1 - 7

## KINGSTON PLANT - 09-211 SS-1



KINGSTON PLANT - 09-211 SS-1  
OP: SW

SPT CAL  
Test date: 18-Feb-2009

AR: 1.43 in<sup>2</sup>  
LE: 21.0 ft  
WS: 16,807.9 f/s

SP: 0.492 k/ft<sup>3</sup>  
EM: 30,000 ksi  
JC: 0.70

FMX: Maximum Force  
VMX: Maximum Velocity  
EFV: Energy of FV  
ETR: Energy Transfer Ratio  
BPM: Blows per Minute

EMX: Max Transferred Energy  
EF2: Energy of F<sup>2</sup>  
DFN: Final Displacement  
FVP: Force/Velocity proportionality

BL#	depth	BLC	TYPE	FMX	VMX	EFV	ETR	BPM	EMX	EF2	DFN	FVP			
end	ft	bl/ft		kips	f/s	**	(%)	**	k-ft	k-ft	in	[]			
5	0.50	10	AV5	34	13.8	0.301	86	19.6	0.301	0.307	1.21	0.96			
			STD	1	0.7	0.005	1	8.9	0.005	0.005	0.52	0.03			
			MAX	34	15.0	0.308	88	24.3	0.308	0.312	2.16	1.00			
11	1.00	12	AV6	33	13.6	0.301	86	24.8	0.301	0.301	1.05	0.96			
			STD	1	0.3	0.005	2	0.2	0.005	0.005	0.29	0.03			
			MAX	34	13.8	0.308	88	25.0	0.308	0.307	1.51	1.00			
18	1.50	14	AV7	32	12.8	0.299	85	25.0	0.299	0.286	1.10	0.99			
			STD	0	0.2	0.005	1	0.1	0.005	0.003	0.15	0.03			
			MAX	33	13.2	0.306	87	25.1	0.306	0.291	1.34	1.03			
28	2.00	20	AV10	32	13.0	0.302	86	25.0	0.302	0.285	0.70	0.94			
			STD	0	0.3	0.005	1	0.1	0.005	0.003	0.13	0.04			
			MAX	32	13.5	0.308	88	25.1	0.308	0.290	0.94	1.01			
				Average	32	13.2	0.301	86	24.0	0.301	0.292	0.97	0.96		
				Std. Dev.	1	0.5	0.005	1	4.3	0.005	0.010	0.34	0.03		
				Maximum	34	15.0	0.308	88	25.1	0.308	0.312	2.16	1.03		

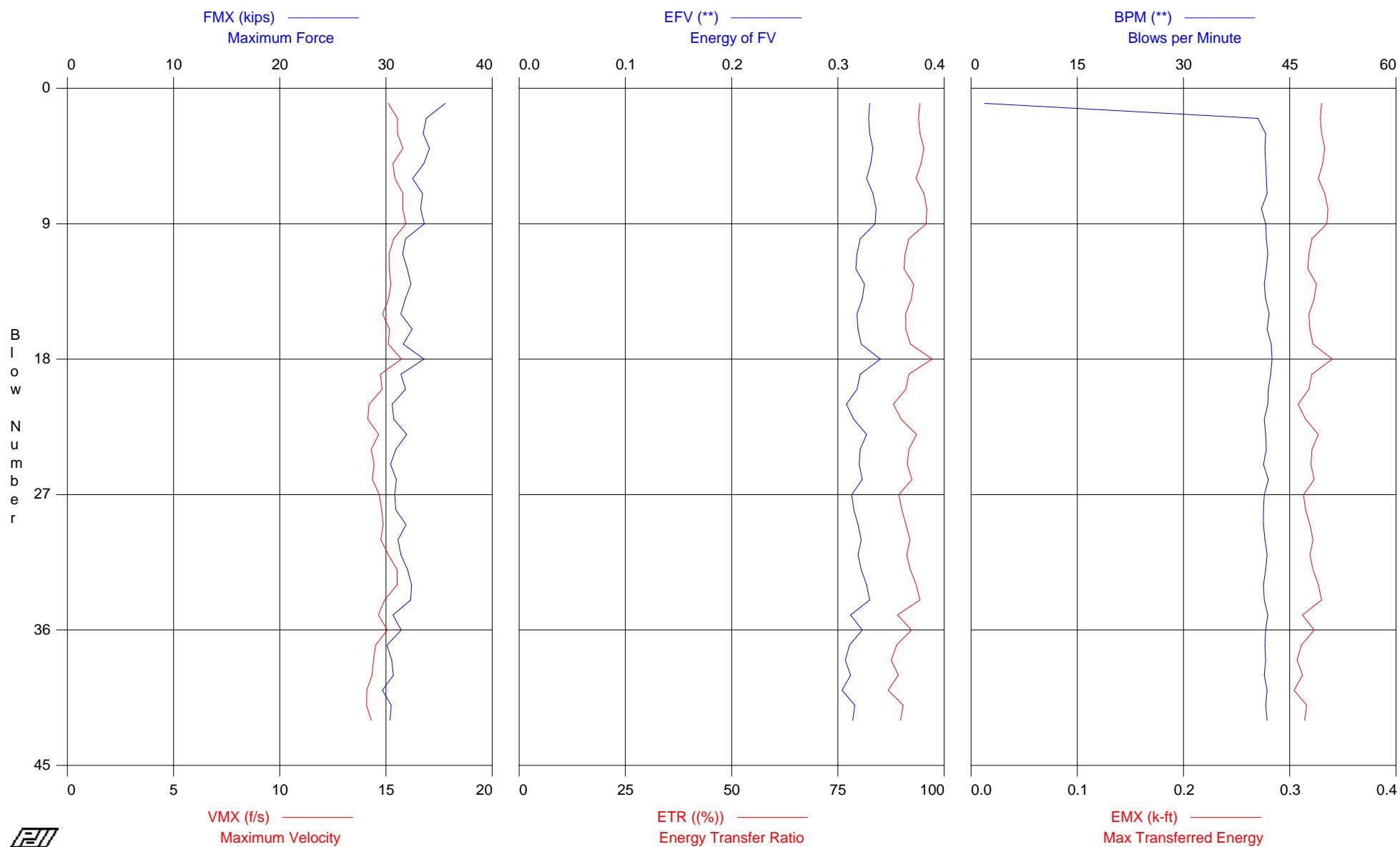
Total number of blows analyzed: 28

#### Time Summary

Drive 1 minute 5 seconds

1:00:16 PM - 1:01:21 PM (2/18/2009) BN 1 - 28

## KINGSTON PLANT - 09-211 SS-2



KINGSTON PLANT - 09-211 SS-2  
OP: SW

SPT CAL  
Test date: 18-Feb-2009

AR: 1.43 in<sup>2</sup>  
LE: 24.0 ft  
WS: 16,807.9 f/s

SP: 0.492 k/ft<sup>3</sup>  
EM: 30,000 ksi  
JC: 0.70

FMX: Maximum Force  
VMX: Maximum Velocity  
EFV: Energy of FV  
ETR: Energy Transfer Ratio  
BPM: Blows per Minute

EMX: Max Transferred Energy  
EF2: Energy of F<sup>2</sup>  
DFN: Final Displacement  
FVP: Force/Velocity proportionality

BL#	depth	BLC	TYPE	FMX	VMX	EFV	ETR	BPM	EMX	EF2	DFN	FVP				
end	ft	bl/ft		kips	f/s	**	(%)	**	k-ft	k-ft	in	■				
13	0.50	26	AV13	33	15.5	0.328	94	38.5	0.328	0.316	0.53	0.82				
				STD	1	0.3	0.006	2	10.6	0.006	0.008	0.15	0.03			
				MAX	36	15.9	0.336	96	41.9	0.336	0.330	0.93	0.89			
27	1.00	28	AV14	31	14.7	0.321	92	41.9	0.321	0.304	0.51	0.81				
				STD	1	0.4	0.007	2	0.4	0.007	0.007	0.12	0.02			
				MAX	34	15.7	0.340	97	42.5	0.340	0.322	0.70	0.86			
34	1.50	14	AV7	32	15.1	0.322	92	41.5	0.322	0.303	0.83	0.79				
				STD	1	0.3	0.005	1	0.2	0.005	0.005	0.11	0.01			
				MAX	32	15.5	0.330	94	41.8	0.330	0.312	0.98	0.82			
42	2.00	16	AV8	30	14.4	0.312	89	41.6	0.312	0.294	0.85	0.80				
				STD	0	0.3	0.005	2	0.2	0.005	0.004	0.11	0.02			
				MAX	31	15.1	0.323	92	41.9	0.323	0.301	1.03	0.82			
				Average	32	15.0	0.322	92	40.7	0.322	0.306	0.63	0.81			
				Std. Dev.	1	0.5	0.008	2	6.1	0.008	0.010	0.20	0.03			
				Maximum	36	15.9	0.340	97	42.5	0.340	0.330	1.03	0.89			

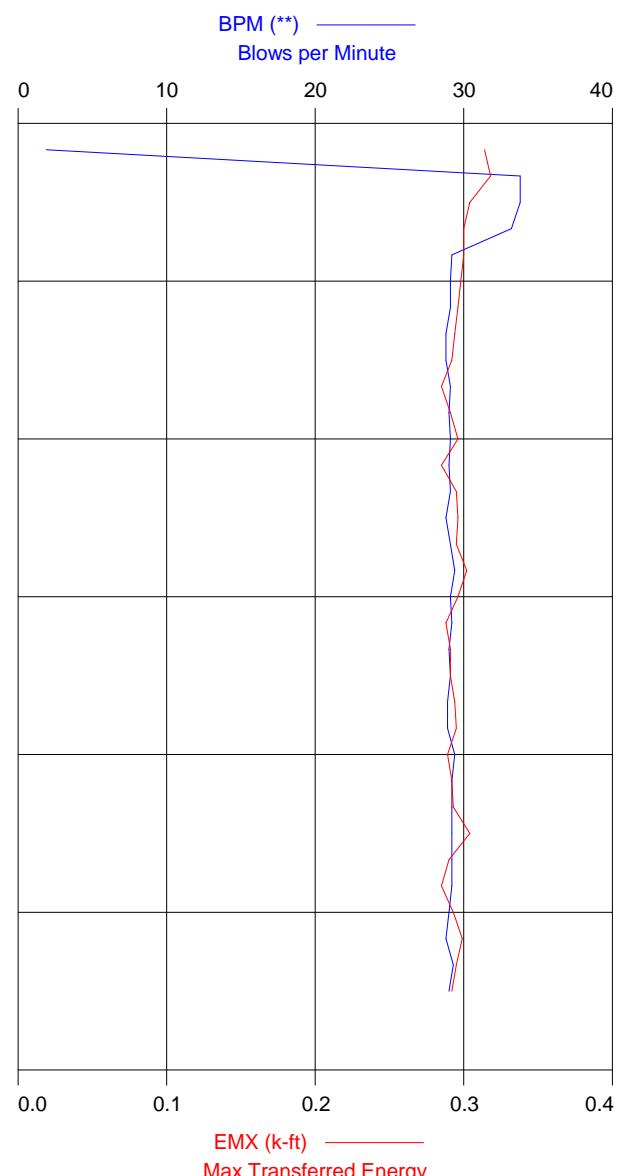
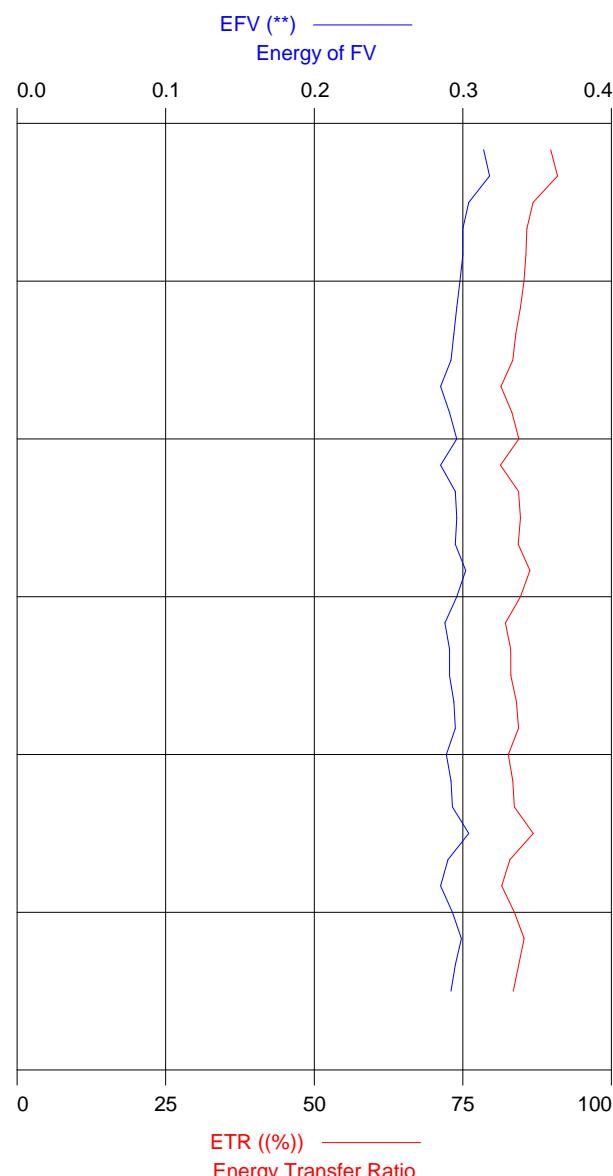
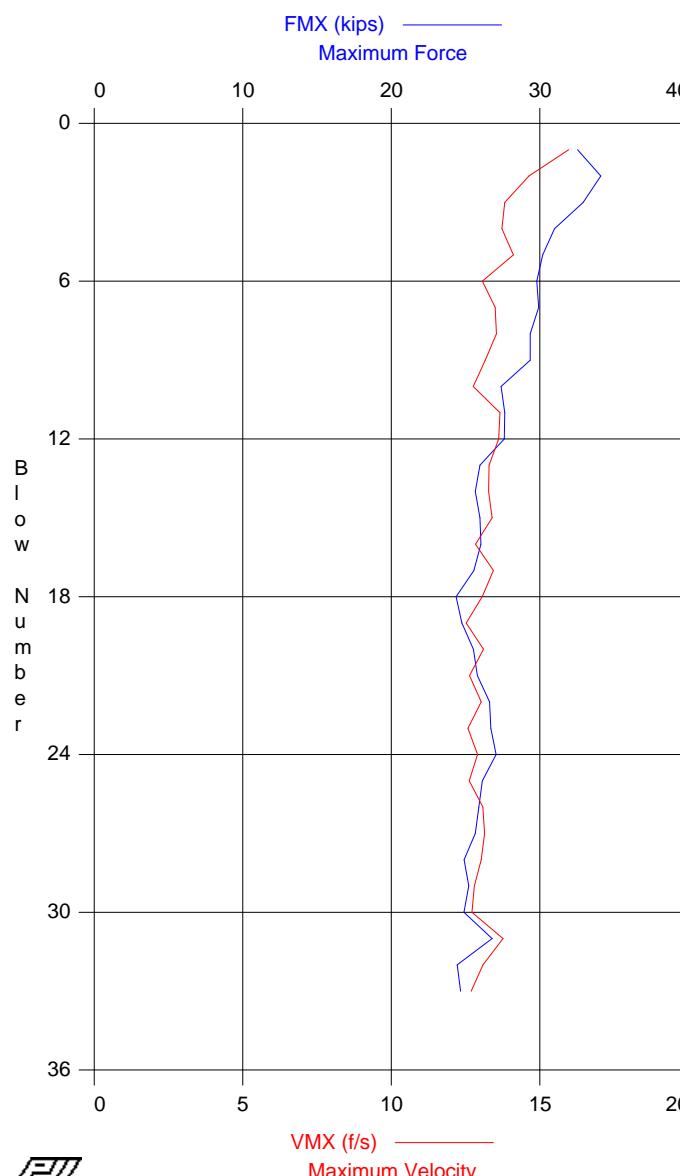
Total number of blows analyzed: 42

#### Time Summary

Drive 59 seconds

1:09:59 PM - 1:10:58 PM (2/18/2009) BN 1 - 42

## KINGSTON PLANT - 09-211 SS-3



KINGSTON PLANT - 09-211 SS-3  
OP: SW

SPT CAL  
Test date: 18-Feb-2009

AR: 1.43 in<sup>2</sup>  
LE: 24.0 ft  
WS: 16,807.9 f/s

SP: 0.492 k/ft<sup>3</sup>  
EM: 30,000 ksi  
JC: 0.70

FMX: Maximum Force  
VMX: Maximum Velocity  
EFV: Energy of FV  
ETR: Energy Transfer Ratio  
BPM: Blows per Minute

EMX: Max Transferred Energy  
EF2: Energy of F<sup>2</sup>  
DFN: Final Displacement  
FVP: Force/Velocity proportionality

BL#	depth	BLC	TYPE	FMX	VMX	EFV	ETR	BPM	EMX	EF2	DFN	FVP			
end	ft	bl/ft		kips	f/s	**	(%)	**	k-ft	k-ft	in	■			
5	0.50	10	AV5	32	14.5	0.307	88	26.4	0.307	0.307	1.11	0.92			
			STD	1	0.8	0.007	2	12.4	0.007	0.009	0.24	0.05			
			MAX	34	16.0	0.318	91	33.8	0.318	0.319	1.49	0.97			
13	1.00	16	AV8	28	13.3	0.292	83	29.0	0.292	0.286	0.98	0.83			
			STD	1	0.3	0.005	1	0.1	0.005	0.007	0.10	0.05			
			MAX	30	13.7	0.298	85	29.1	0.298	0.294	1.20	0.89			
22	1.50	18	AV9	26	13.0	0.294	84	29.1	0.294	0.277	0.75	0.75			
			STD	1	0.3	0.004	1	0.2	0.004	0.004	0.13	0.03			
			MAX	27	13.4	0.302	86	29.4	0.302	0.286	1.01	0.80			
33	2.00	22	AV11	26	12.9	0.293	84	29.1	0.293	0.274	0.70	0.74			
			STD	1	0.3	0.005	1	0.2	0.005	0.004	0.12	0.05			
			MAX	27	13.8	0.304	87	29.4	0.304	0.281	0.92	0.83			
				Average	27	13.3	0.295	84	28.7	0.295	0.283	0.84	0.79		
				Std. Dev.	3	0.7	0.007	2	4.9	0.007	0.013	0.21	0.08		
				Maximum	34	16.0	0.318	91	33.8	0.318	0.319	1.49	0.97		

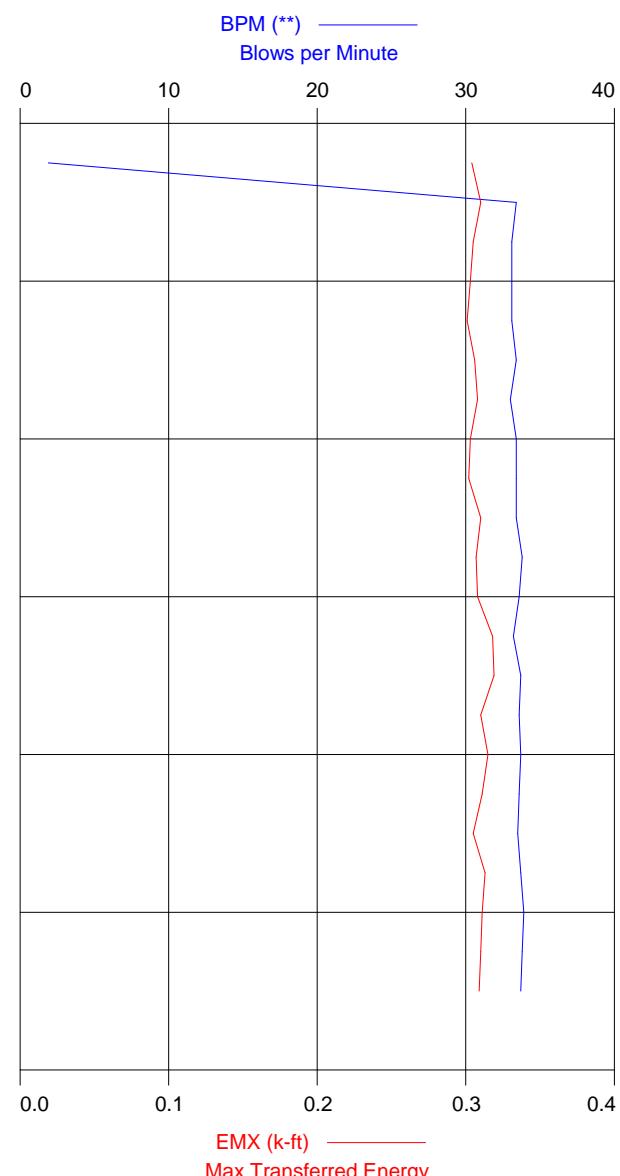
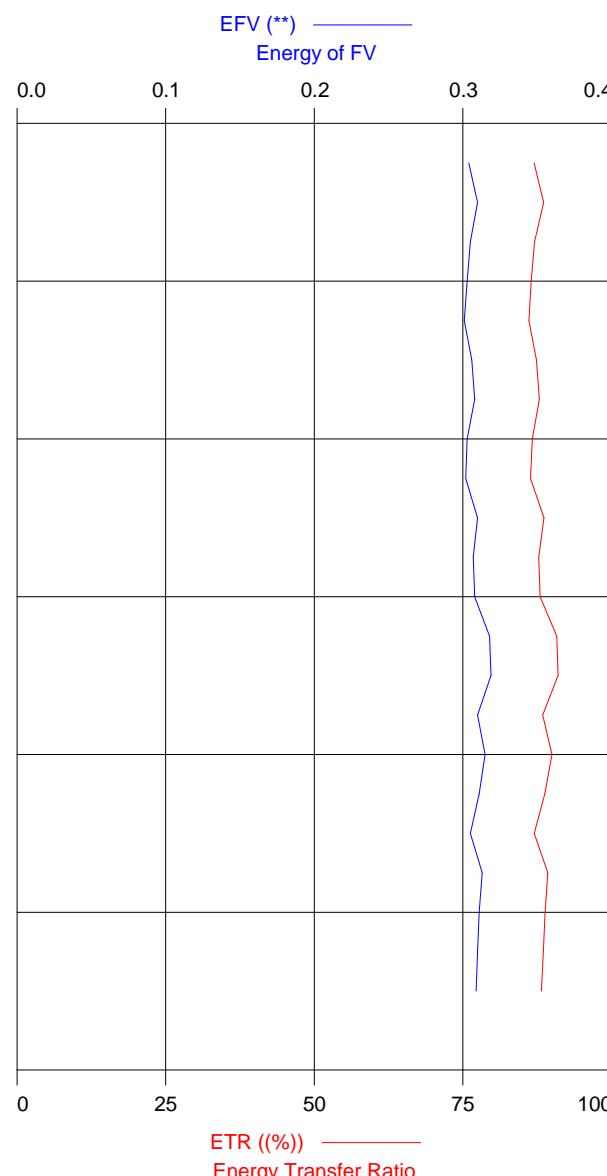
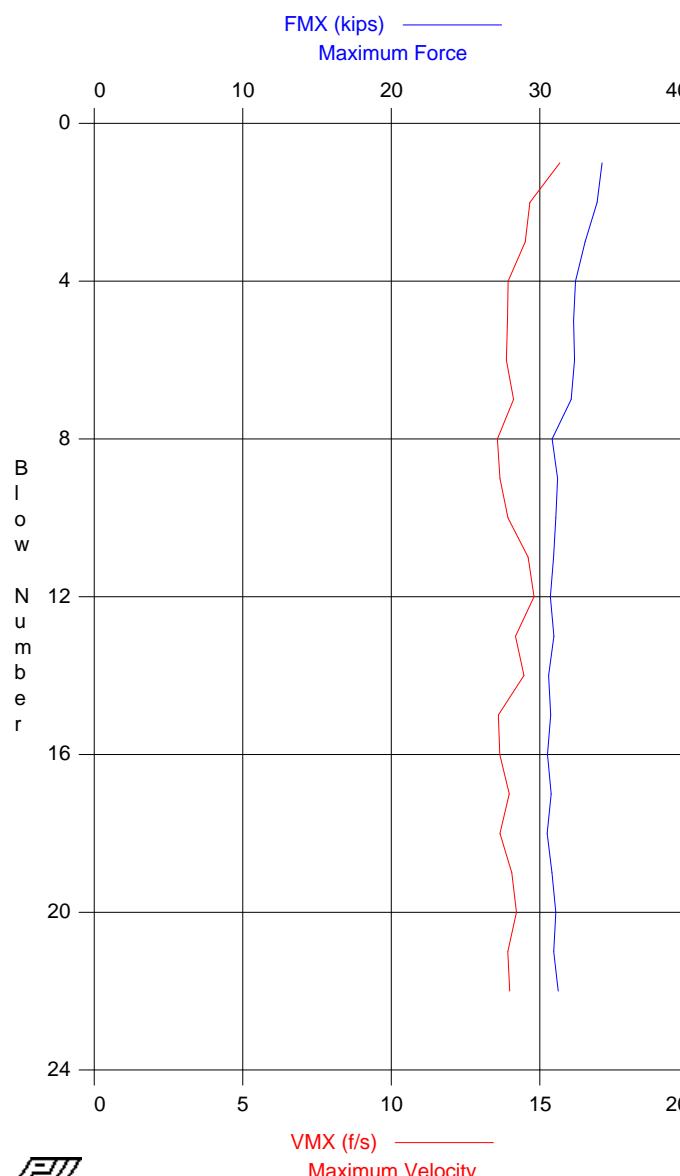
Total number of blows analyzed: 33

#### Time Summary

Drive 1 minute 5 seconds

1:17:19 PM - 1:18:24 PM (2/18/2009) BN 1 - 33

## KINGSTON PLANT - 09-211 SS-4



KINGSTON PLANT - 09-211 SS-4  
OP: SW

SPT CAL  
Test date: 18-Feb-2009

AR: 1.43 in<sup>2</sup>  
LE: 26.0 ft  
WS: 16,807.9 f/s

SP: 0.492 k/ft<sup>3</sup>  
EM: 30,000 ksi  
JC: 0.70

FMX: Maximum Force  
VMX: Maximum Velocity  
EFV: Energy of FV  
ETR: Energy Transfer Ratio  
BPM: Blows per Minute

EMX: Max Transferred Energy  
EF2: Energy of F<sup>2</sup>  
DFN: Final Displacement  
FVP: Force/Velocity proportionality

BL#	depth	BLC	TYPE	FMX	VMX	EFV	ETR	BPM	EMX	EF2	DFN	FVP			
end	ft	bl/ft		kips	f/s	**	(%)	**	k-ft	k-ft	in	■			
5	0.50	10	AV5	33	14.5	0.305	87	26.9	0.305	0.311	1.39	0.93			
			STD	1	0.6	0.003	1	12.5	0.003	0.002	0.31	0.01			
			MAX	34	15.7	0.310	89	33.4	0.310	0.313	1.81	0.96			
10	1.00	10	AV5	32	13.8	0.306	87	33.3	0.306	0.306	1.08	0.89			
			STD	1	0.2	0.003	1	0.2	0.003	0.004	0.34	0.02			
			MAX	32	14.1	0.310	89	33.4	0.310	0.313	1.32	0.91			
15	1.50	10	AV5	31	14.3	0.312	89	33.6	0.312	0.302	1.31	0.86			
			STD	0	0.4	0.005	1	0.2	0.005	0.003	0.15	0.02			
			MAX	31	14.8	0.319	91	33.8	0.319	0.307	1.51	0.89			
22	2.00	14	AV7	31	13.9	0.311	89	33.7	0.311	0.302	0.91	0.85			
			STD	0	0.2	0.003	1	0.1	0.003	0.003	0.06	0.01			
			MAX	31	14.2	0.315	90	33.9	0.315	0.306	0.99	0.87			
				Average	32	14.1	0.309	88	32.0	0.309	0.305	1.15	0.88		
				Std. Dev.	1	0.5	0.005	1	6.6	0.005	0.005	0.31	0.04		
				Maximum	34	15.7	0.319	91	33.9	0.319	0.313	1.81	0.96		

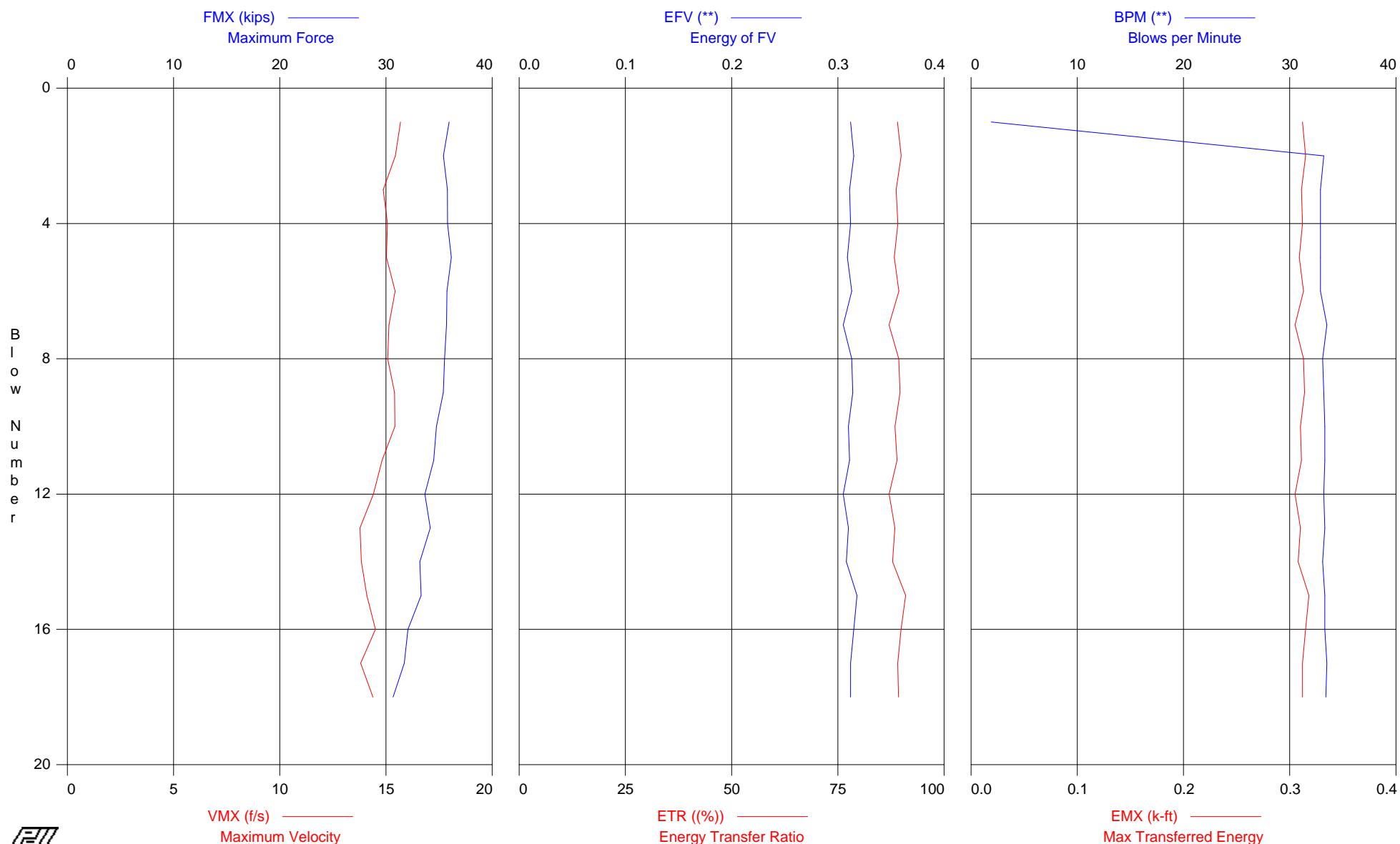
Total number of blows analyzed: 22

#### Time Summary

Drive 37 seconds

1:26:05 PM - 1:26:42 PM (2/18/2009) BN 1 - 22

## KINGSTON PLANT - 09-211 SS-5



KINGSTON PLANT - 09-211 SS-5  
OP: SW

SPT CAL  
Test date: 18-Feb-2009

AR: 1.43 in<sup>2</sup>  
LE: 29.0 ft  
WS: 16,807.9 f/s

SP: 0.492 k/ft<sup>3</sup>  
EM: 30,000 ksi  
JC: 0.70

FMX: Maximum Force  
VMX: Maximum Velocity  
EFV: Energy of FV  
ETR: Energy Transfer Ratio  
BPM: Blows per Minute

EMX: Max Transferred Energy  
EF2: Energy of F<sup>2</sup>  
DFN: Final Displacement  
FVP: Force/Velocity proportionality

BL#	depth	BLC	TYPE	FMX	VMX	EFV	ETR	BPM	EMX	EF2	DFN	FVP			
end	ft	bl/ft		kips	f/s	**	(%)	**	k-ft	k-ft	in	[]			
5	0.50	10	AV5	36	15.2	0.312	89	26.8	0.312	0.323	1.39	1.05			
			STD	0	0.3	0.002	1	12.4	0.002	0.003	0.24	0.02			
			MAX	36	15.7	0.315	90	33.2	0.315	0.327	1.78	1.08			
10	1.00	10	AV5	35	15.3	0.311	89	33.2	0.311	0.319	1.43	1.05			
			STD	0	0.2	0.003	1	0.2	0.003	0.004	0.37	0.02			
			MAX	36	15.4	0.314	90	33.5	0.314	0.322	2.02	1.07			
13	1.50	6	AV3	34	14.3	0.309	88	33.3	0.309	0.305	1.22	0.98			
			STD	0	0.4	0.003	1	0.0	0.003	0.002	0.34	0.02			
			MAX	34	14.8	0.311	89	33.3	0.311	0.308	1.70	1.01			
18	2.00	10	AV5	32	14.1	0.313	89	33.3	0.313	0.300	1.14	0.89			
			STD	1	0.3	0.003	1	0.1	0.003	0.004	0.36	0.04			
			MAX	33	14.5	0.318	91	33.5	0.318	0.306	1.47	0.95			
				Average	34	14.8	0.311	89	31.5	0.311	0.312	1.30	1.00		
				Std. Dev.	2	0.6	0.003	1	7.2	0.003	0.011	0.35	0.07		
				Maximum	36	15.7	0.318	91	33.5	0.318	0.327	2.02	1.08		

Total number of blows analyzed: 18

#### Time Summary

Drive 31 seconds

1:33:08 PM - 1:33:39 PM (2/18/2009) BN 1 - 18

## **Appendix C**

### *Calibration Certificates*

## Calibration Data Sheet for SPT rod #:231 NWJ

Calibrated: 19-Jan-09

Page 1 of 2

## Cycle No. 1

Sample No.	lbs	ME	Bridge 1 Volts	Bridge 2 Volts
1	-1.45	.00	.00	.00
2	1096.01	23.88	.12	.12
3	2165.90	48.79	.23	.23
4	3082.53	70.39	.33	.33
5	4114.69	94.30	.44	.44
6	5295.45	122.17	.57	.57
7	6353.73	146.81	.69	.68
8	7371.95	170.59	.80	.79
9	8399.76	194.65	.91	.91
10	9001.46	208.85	.97	.97
11	10125.33	235.36	1.10	1.09

Bridge 1	Force Cal	Strain Cal	Bridge 2	Force Cal	Strain Cal
Cal Factor	9235.61 lbs/V	215.40 ME/V		9270.15 lbs/V	216.21 ME/V
Offset	7.27	-1.08		.00	-1.25
Corr Coe	.999999	.999985		.999998	.999981
Force Strain Calibration					
EA Factor	42874.89 Kips				
Offset	53.75				
Corr Coe	.999979				

## Cycle No. 2

Sample No.	lbs	ME	Bridge 1 Volts	Bridge 2 Volts
1	6.39	.00	.00	.00
2	1034.79	24.11	.11	.11
3	2033.86	47.36	.22	.22
4	3020.45	70.55	.33	.32
5	4225.37	99.08	.46	.45
6	5202.09	121.74	.56	.56
7	6183.45	144.64	.67	.66
8	7208.08	168.64	.78	.77
9	8016.68	188.18	.87	.86
10	9114.18	213.16	.98	.98
11	10076.96	235.43	1.09	1.08

Bridge 1	Force Cal	Strain Cal	Bridge 2	Force Cal	Strain Cal
Cal Factor	9255.44 lbs/V	216.68 ME/V		9304.83 lbs/V	217.84 ME/V
Offset	4.25	.01		6.96	.07
Corr Coe	.999997	.999988		.999999	.999995
Force Strain Calibration					
EA Factor	42713.91 Kips				
Offset	3.98				
Corr Coe	.999995				

## Calibration Data Sheet for SPT rod #:231 NWJ

Calibrated: 19-Jan-09

Page 2 of 2

Cycle No. 3			Bridge 1 Volts	Bridge 2 Volts
Sample No.	lbs	ME		
1	7.26	.01	.00	.00
2	1105.72	22.01	.12	.12
3	2070.65	44.37	.22	.22
4	3041.97	66.75	.33	.33
5	4002.25	89.07	.43	.43
6	5036.56	113.18	.54	.54
7	6179.73	139.92	.67	.66
8	7251.49	165.07	.78	.78
9	8000.73	182.58	.86	.86
10	9317.50	213.39	1.01	1.00
11	10274.59	236.23	1.11	1.10

Bridge 1	Force Cal	Strain Cal	Bridge 2	Force Cal	Strain Cal
Cal Factor	9251.72 lbs/V	214.42 ME/V		9302.65 lbs/V	215.59 ME/V
Offset	18.19	-2.48		2.44	-2.85
Corr Coe	.999997	.999916		.999996	.999909
Force Strain Calibration					
EA Factor	43140.98 Kips				
Offset	126.13				
Corr Coe	.999906				

Bridge Excitation: 6.4 Volts

A 60.4K Ohm shunt resistor produces 5.0 Volts output.

	Bridge 1	Bridge 2
Calibration Factor:	215.50 ME/V	216.55 ME/V
EA Factor	: 42909.93 Kips	

Calibrated by:



Pile Dynamics, Inc.  
 Calibrated on: 19-Jan-09  
 Traceable to N.I.S.T.

## Calibration Data Sheet for SPT rod #:100AWJ

Calibrated: 11-12-07

Page 1 of 2

## Cycle No. 1

Sample No.	lbs	ME	Bridge 1 Volts	Bridge 2 Volts
1	-1.45	.00	.00	.00
2	1246.54	33.56	.17	.17
3	2016.34	55.52	.27	.27
4	3108.80	86.90	.41	.41
5	4088.10	114.29	.54	.54
6	5250.20	147.18	.70	.70
7	6052.50	169.68	.81	.81
8	7154.53	201.55	.95	.95
9	8052.00	227.61	1.08	1.07
10	9022.89	254.95	1.21	1.20
11	10071.82	283.05	1.35	1.34

## Bridge 1

## Force Cal

## Strain Cal

## Bridge 2

## Force Cal

## Strain Cal

Cal Factor	7472.80	lbs/V	211.40	ME/V	7492.38	lbs/V	211.96	ME/V
Offset	5.71		-.90		14.58		-.65	
Corr Coe	.999992		.999964		.999997		.999972	
Force Strain Calibration								
EA Factor 35346.89 Kips								
Offset	37.82							
Corr Coe	.999975							

## Cycle No. 2

## Sample No.

## lbs

## ME

## Bridge 1

## Bridge 2

Sample No.	lbs	ME	Bridge 1 Volts	Bridge 2 Volts
1	-2.90	.03	.00	.00
2	1005.76	29.17	.13	.13
3	2051.24	59.53	.27	.27
4	3007.73	86.97	.40	.40
5	4090.30	118.57	.54	.54
6	5189.97	149.96	.69	.69
7	6283.56	181.62	.83	.83
8	7031.65	203.12	.93	.93
9	8070.45	233.23	1.07	1.07
10	9177.08	265.32	1.22	1.22
11	10093.29	291.61	1.33	1.34

## Bridge 1

## Force Cal

## Strain Cal

## Bridge 2

## Force Cal

## Strain Cal

Cal Factor	7559.75	lbs/V	218.32	ME/V	7557.82	lbs/V	218.26	ME/V
Offset	-5.40		.02		2.56		.25	
Corr Coe	.999998		.999999		.999998		.999999	
Force Strain Calibration								
EA Factor 34627.54 Kips								
Offset	-6.18							
Corr Coe	.999999							

## Calibration Data Sheet for SPT rod #:100AWJ

Calibrated: 11-12-07

Page 2 of 2

Cycle No. 3			Bridge 1 Volts	Bridge 2 Volts
Sample No.	lbs	ME		
1	-5.22	.00	.00	.00
2	1062.53	30.93	.14	.14
3	2024.06	58.61	.27	.27
4	3057.27	88.56	.40	.40
5	4061.75	117.71	.54	.54
6	5031.12	145.47	.66	.66
7	6093.35	176.47	.81	.80
8	7132.95	206.46	.94	.94
9	8071.55	233.45	1.07	1.07
10	9175.87	265.25	1.21	1.21
11	10002.74	288.99	1.32	1.32

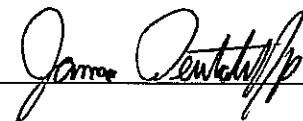
Bridge 1	Force Cal	Strain Cal	Bridge 2	Force Cal	Strain Cal
Cal Factor	7547.45 lbs/v	218.03 ME/V		7582.64 lbs/v	219.04 ME/V
Offset	12.48	.60		-1.75	.19
Corr Coe	.999998	.999997		.999999	.999997
Force Strain Calibration					
EA Factor	34616.74 Kips				
Offset	-8.28				
Corr Coe	.999999				

Bridge Excitation: 6.4 Volts

A 60.4K Ohm shunt resistor produces 5.0 Volts output.

	Bridge 1	Bridge 2
Calibration Factor:	215.92 ME/V	216.42 ME/V
EA Factor	: 34863.73 Kips	

Calibrated by:



Pile Dynamics, Inc.

Calibrated on: 11-12-07

Traceable to N.I.S.T.

QBTA: ON [ALT-F1/BB=601]

Pile Dynamics, Inc.

TG	F2	DPF
A	4	-- US
F	2	3.3

Pile Dynamics  
06-Nov-08 13:32FS — BN 100  
10 SL 2752/ 3440/ 99PJ: sn  
PN: HOPBARLE 39.6 ft  
AR 1.7 in<sup>2</sup>  
EM 30000 ksi  
SP 0.492 K/ft<sup>3</sup>  
WS 16810 ft/s  
WC 16862 ft/sJC 0.40  
FM 1.00  
VM 1.00EA/C 30.3 Ks/ft  
UN KIPSS×0.1  
FR 20000 MB 30DL -33  
UT -1  
PK 1 TM-PEAKF1/2 500/ 213  
F3/4 213/ 213  
A1/2 999/ 999  
A3/4 999/ 305TS 12  
TB 8.0E B PD: k954  
T1 9.5 2L/C 4.7

VA 1000 VE 1022

LP 0.00 LI 1.0

ft

ACCEPT SQ-OFF FL-OFF PR-OFF



contact Pile Dynamics USA  
with your questions  
tel USA - 216 - 831- 6131  
fax USA - 216 - 831- 0916

VMX= 4.0 FMX= 62 AMX= 159  
EMX= 0.2 MEX= 121 FVP= 1.00

ACCELEROMETER CALIBRATION

N.I.S.T. Traceable

SERIAL NUMBER: K954

CALIBRATION FACTOR: .061mv/g

PAK (\*5000): 305 DATE: 06-Nov-08

PDA OPERATOR:

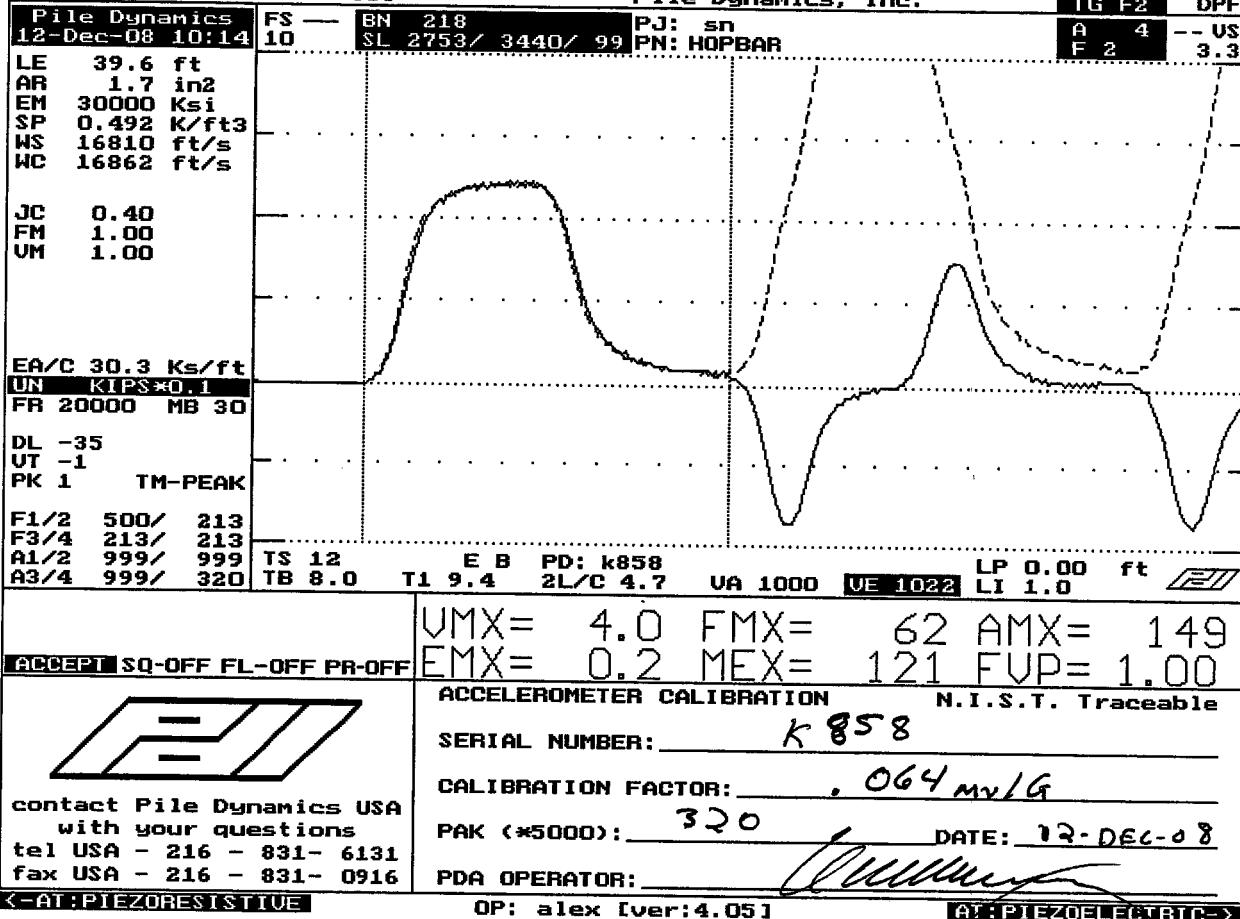
&lt;-AT:PIEZORESISTIVE

OP: alex [ver:4.05]

AT:PIEZOELECTRIC-&gt;

OBTA: ON [ALT-F1/BB=60]

## Pile Dynamics, Inc.



QBTA: ON [ALT-F1/BB=60]

Pile Dynamics, Inc.

TG	F2	DPF
A	4	-- US
F	2	3.3

Pile Dynamics	FS	BN 213	PJ: sn
12-Dec-08 10:12	10	SL 2753/ 3440/ 99	PN: HOPBAR

LE 39.6 ft  
 AR 1.7 in<sup>2</sup>  
 EM 30000 ksi  
 SP 0.492 K/ft<sup>3</sup>  
 WS 16810 ft/s  
 WC 16862 ft/s

JC 0.40  
 FM 1.00  
 UM 1.00

EA/C 30.3 Ks/ft  
 UN KIPS×0.1  
 FR 20000 MB 30

DL -29  
 UT -1  
 PK 1 TM-PEAK

F1/2 500/ 213  
 F3/4 213/ 213  
 A1/2 999/ 999  
 A3/4 999/ 320

TS 12  
 TB 8.0

E B PD: k860  
 2L/C 4.7

VA 1000 UE 1022

LP 0.00 ft LI 1.0

ACCEPT SQ-OFF FL-OFF PR-OFF



contact Pile Dynamics USA  
 with your questions  
 tel USA - 216 - 831- 6131  
 fax USA - 216 - 831- 0916

UMX= 3.9 FMX= 60 AMX= 139  
 EMX= 0.2 MEX= 117 FVP= 0.99

ACCELEROMETER CALIBRATION N.I.S.T. Traceable

SERIAL NUMBER: K 860CALIBRATION FACTOR: .064 mv/GPAK (>5000): 320 DATE: 12-DEC-08PDA OPERATOR: alex

&lt;-AT:PIEZORESISTIVE

DP: alex [ver:4.05]

AT:PIEZOELECTRIC-&gt;