

# Reinhold Environmental Ltd.



## 2010 NO<sub>x</sub>-Combustion Round Table & Expo Presentation

***February 8 & 9, 2010***

***Chattanooga, TN***

All presentations posted on this website are copyrighted by Reinhold Environmental, Ltd (RE). Any unauthorized downloading, attempts to modify or to incorporate into other presentations, link to other websites, or obtain copies for any other uses than the training of attendees to RE's Conferences is expressly prohibited, unless approved in writing by RE or the original presenter. RE does not assume any liability for the accuracy or contents of any materials contained in this library which were presented and/or created by persons who were not employees of RE.

**DTE Energy<sup>®</sup>**



## **Controlling NO<sub>x</sub> via. On-Line Coal Analysis**

WPCA Conference  
Chattanooga, TN  
9 February 2010

Tony Widenman  
Fuel SME & Technological Specialist-Fuel  
widenmana@dteenergy.com

Can you really control NO<sub>x</sub> by  
on-line as-fired coal analysis?

That depends



# Types of NO<sub>x</sub>

- Three types of NO<sub>x</sub>
  - **Thermal NO<sub>x</sub>** from the combustion air
    - ♦ Fixation of atmospheric N<sub>2</sub> @ ▲T
    - ♦ *f*(combustion T (>2,370°F), air/fuel)
    - ♦ ▼NO<sub>x</sub>(T) by ▼T, ▼t, ▼[N<sub>2</sub>], ▼[O<sub>2</sub>]
  - **Fuel NO<sub>x</sub>** from the coal
    - ♦ Oxidation of coal N compounds
    - ♦ NO<sub>x</sub>(F) ~75-95% of total NO
    - ♦ T <2,650°F
    - ♦ NO<sub>x</sub>(F) more readily produced than NO<sub>x</sub>(T)
    - ♦ Unlike NO<sub>x</sub>(T):
      - ♦NO<sub>x</sub>(F) ▼ sensitivity to T over the range in coal flames
      - ♦NO<sub>x</sub>(F) ▲ sensitivity to air/fuel
  - **Prompt NO<sub>x</sub>** from thermal decomposition
    - ♦ [H-C] in flame zone + N<sub>2</sub> ► N ► NO
    - ♦ Fixation of atmospheric N<sub>2</sub> by H-C fragments in the reducing atmosphere of the flame zone
    - ♦ Total NO<sub>x</sub>(P) ▼▼ compared to NO<sub>x</sub>(T) & NO<sub>x</sub>(F)



# Fuel NO<sub>x</sub>

- Only Fuel NO<sub>x</sub> is available by on-line coal analysis
  - PGNAA will measure C, H, N
    - NO<sub>x</sub>(F) is calculated
  - XRF cannot measure C, H, N
    - NO<sub>x</sub>(F) is inferred by calibration and fuel quality knowledge
- If you know Fuel NO<sub>x</sub>, what can you do about it?
  - NO<sub>x</sub> is recorded by the analyzer before the bunkers/silos, so the delay would be hours, yet the operator can still be proactive by:
    - changing blend (if applicable)
    - changing fuel type (if possible)
    - changing reclaim location (if stockpile location known)
  - But is controlling NO<sub>x</sub> by fuel the primary objective?
- Better to improve combustion efficiency
  - Improves NO<sub>x</sub>, SO<sub>2</sub>, CO, CO<sub>2</sub>, heat rate, dispatch cost, O&M
- Remember, boilers burn Btus, not tons
  - Therefore, increasing coal calorific value reduces tons
    - This also reduces NO<sub>x</sub>, SO<sub>2</sub>, CO, CO<sub>2</sub>, heat rate, dispatch cost, O&M



## On-line Coal Analysis — Own It!

- Don't do it unless you are ready to own it!
- Champion must be accountable
- Support is mandatory from top down
- Cannot accept anything but total buy-in
- Thinking must change so the analyzer is the first source of coal related information
- On-line coal analysis must be a routine operating tool
- On the other hand, challenge the results; just like any other instrument reading, results are challenged when suspicious values occur
  - This increases knowledge and acceptance
  - Provide inputs to make the tool more useful



## Instrumentation

- **PGNAA** (Prompt Gamma Neutron Activation Analysis)
  - Radioactive source(s)
  - NRC license
  - Radioactive shielding required
  - Annual cost for sources & license
- **PFTNA** (Pulsed Fast Thermal Neutron Analysis)
- **XRF** (X-ray Fluorescence)
  - State registration
- **Microwave** (“loose” moisture)
- **XRF/PGNAA**
  - Same as above
- **NMR w/LIBS** (Laser Induced Breakdown Spectroscopy)



## Instrumentation

- **They all work**
  - Type depends on the application
  - What needs to be monitored
- Real-time results vs. 2+ weeks
- Does NOT replace the ASTM laboratory (today)
- Process instruments (change monitors)
- Annual expense varies w/license, consumables, etc.
- System cost varies
  - \$200k-1,000k
  - Add sampler cost if applicable (\$350k-1,000k)

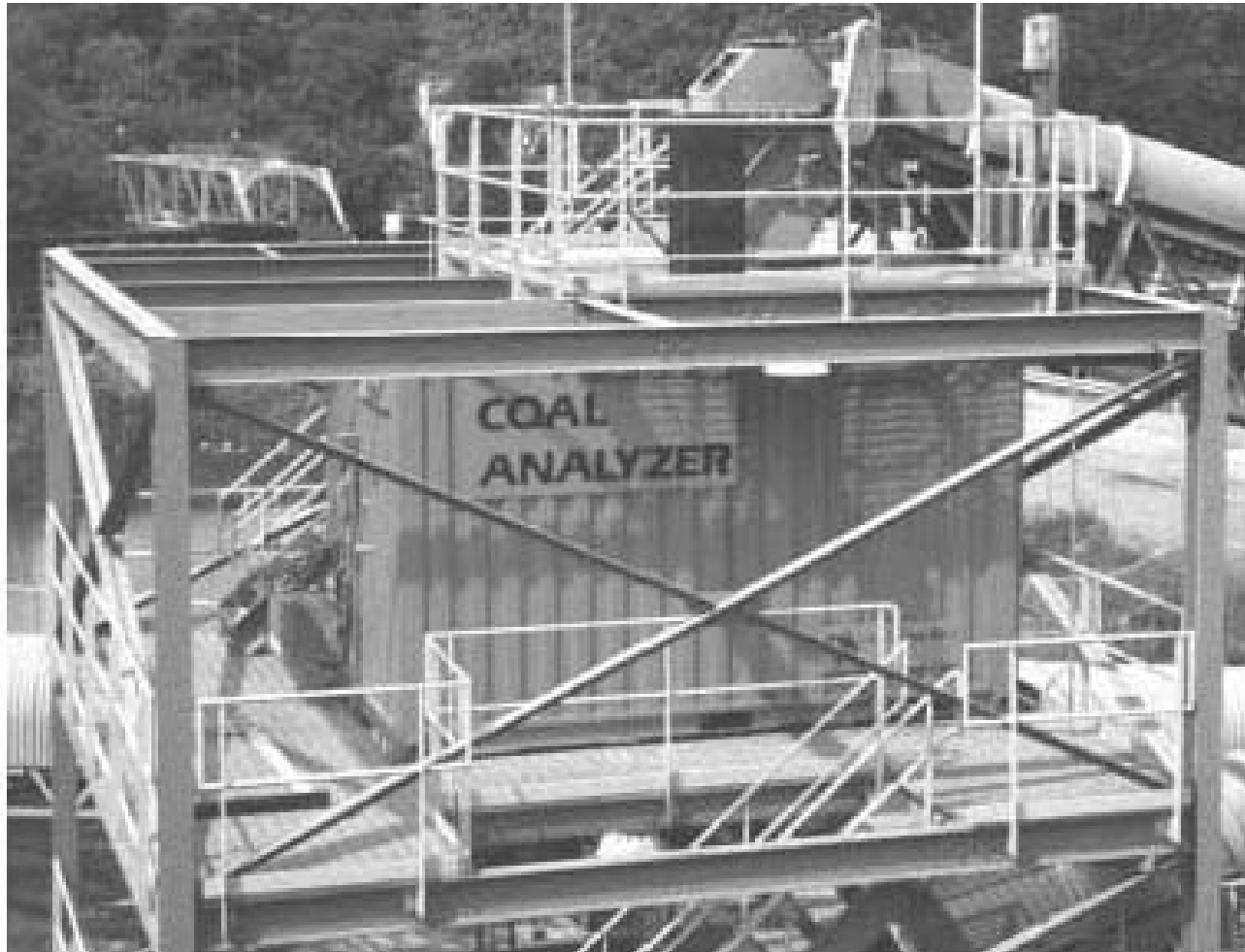


# XRF vs. PGNAA

Measurement	PGNAA	XRF
<i>Short Proximate Analysis</i>		
Moisture	✓ + microwave	✓ + microwave
Ash	calculated	calculated
Sulfur	✓	✓
Btu/lb	calculated	calculated
Lbs SO <sub>2</sub> /MBtu	calculated	calculated
<i>Elemental Analysis</i>		
Hydrogen	✓	
Carbon	✓	
Nitrogen	✓	
Sodium	✓ -%?	✓
Magnesium	✓ -%?	✓
Aluminum	✓	✓
Silica	✓	✓
Sulfur	✓	✓
Chlorine	✓ (over sensitive)	✓
Potassium	✓	✓
Calcium	✓	✓
Titanium	✓	✓
Iron	✓	✓



# PGNAA as Part of Sampling System





# PGNAA Over-the-Belt Analyzer





# Over-the-Belt PGNAA



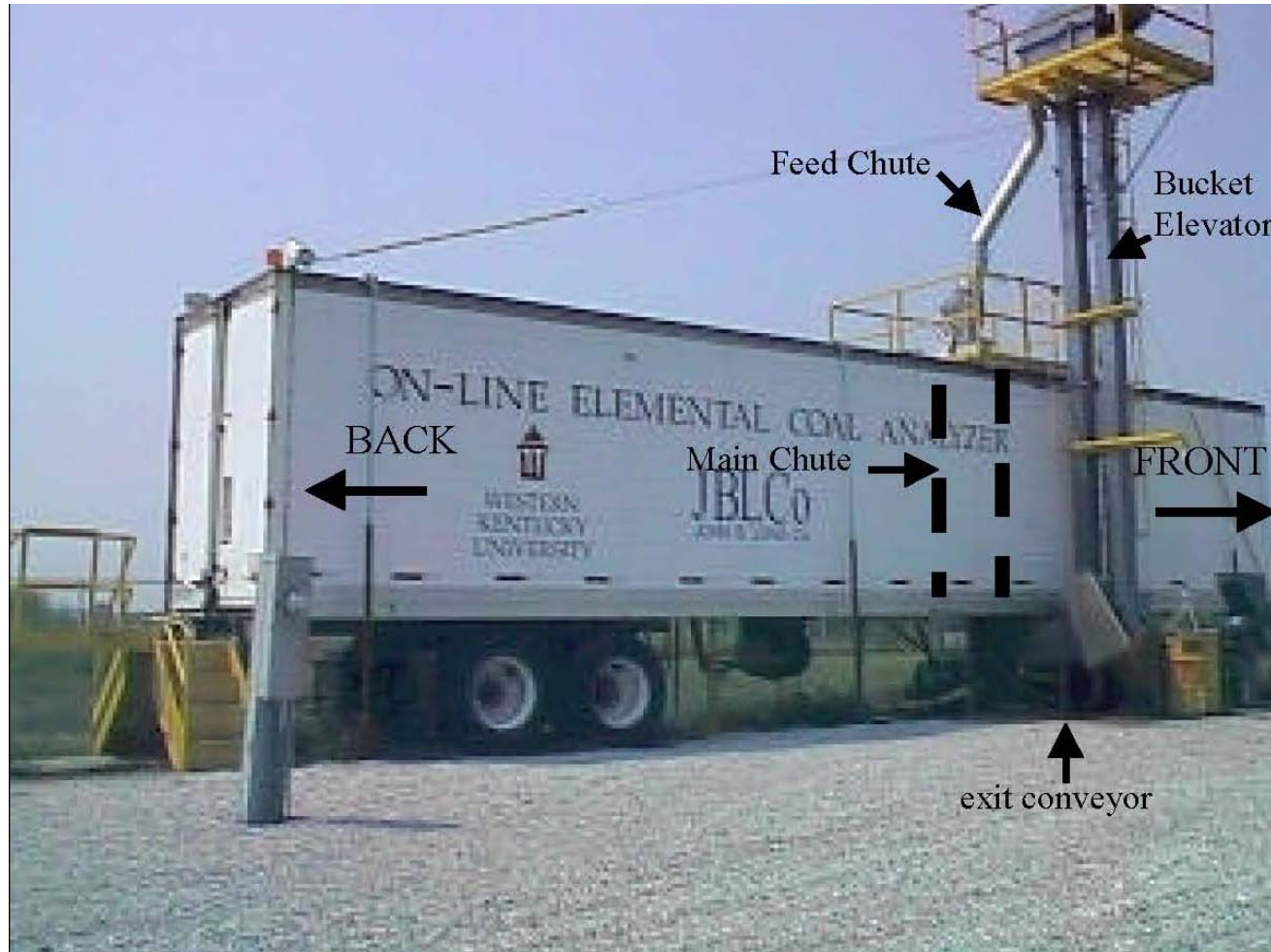


# Over-the-Belt PGNAA



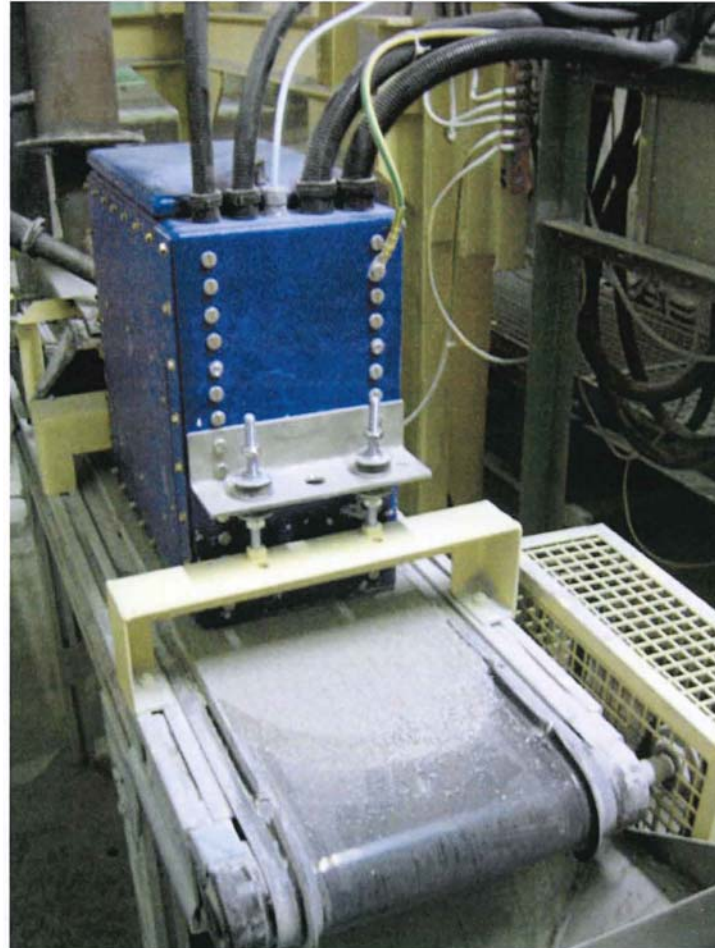


# PFTNA Prototype Coal Analyzer



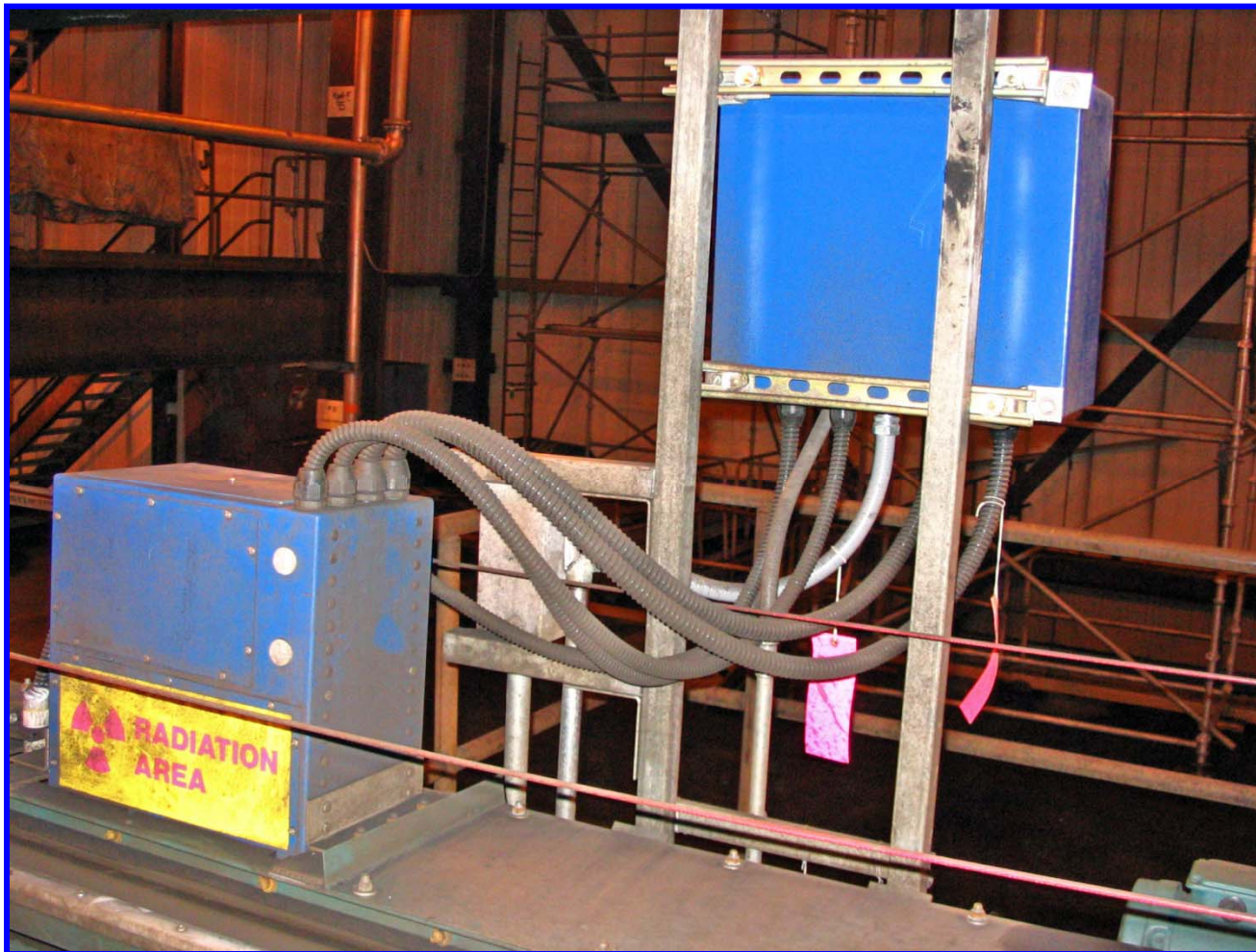


# XRF on Secondary Sample Conveyor





# XRF Over Sampler Reject Conveyor

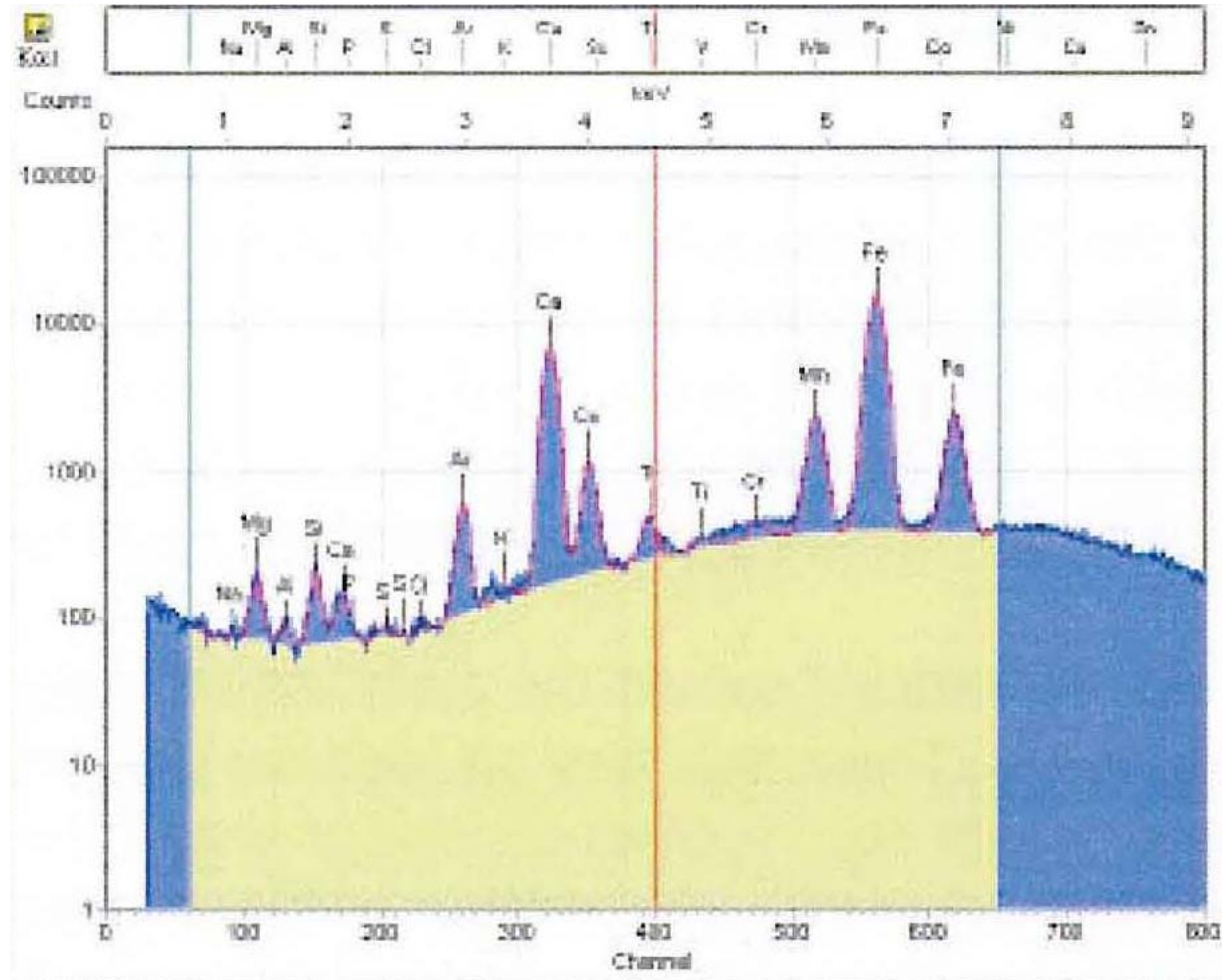
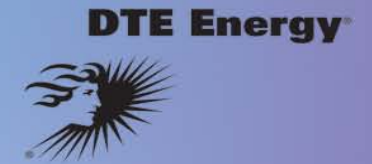




## What To Do With the Results

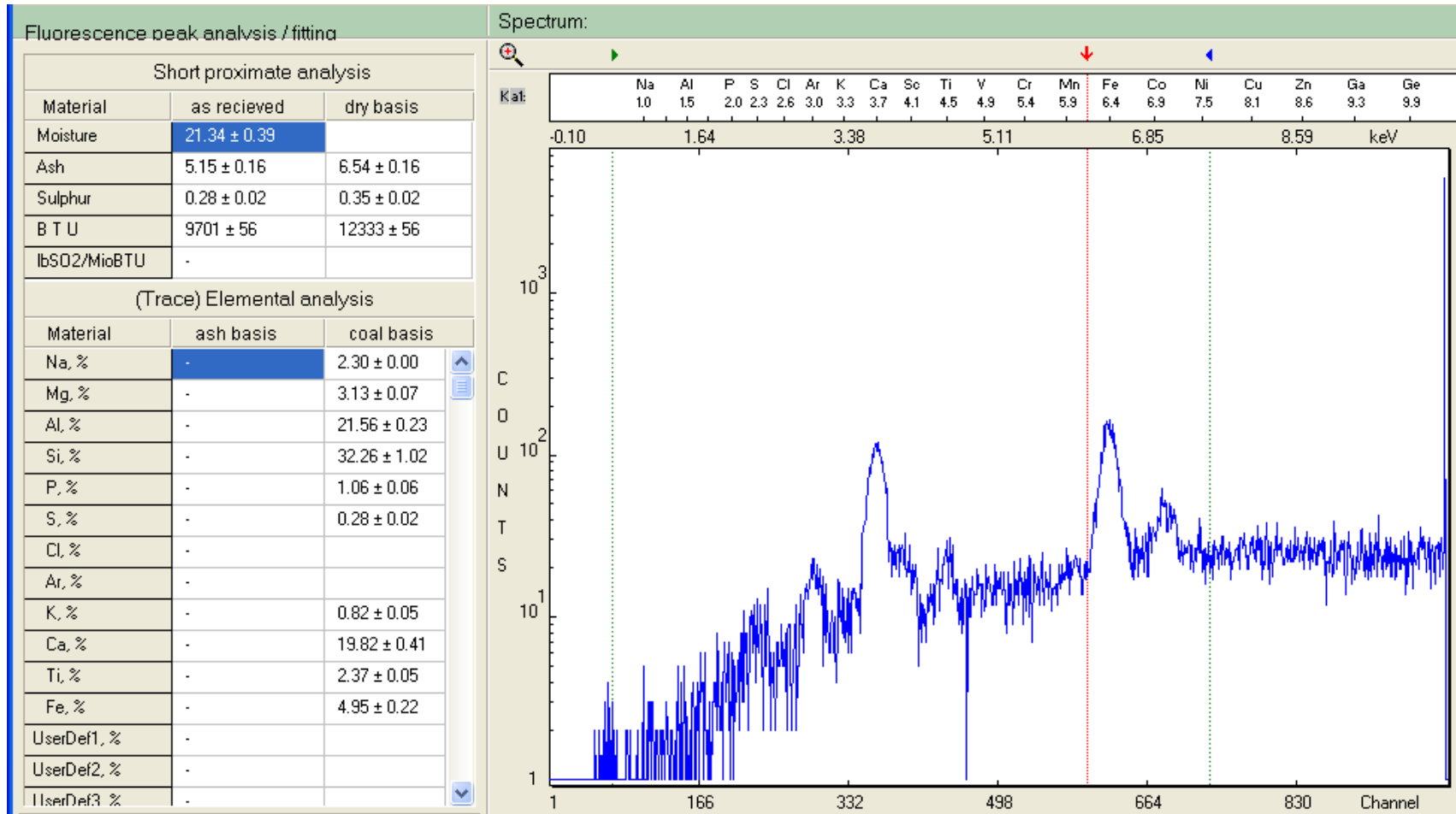
- Elemental spectra
- Elemental values
- Calculated values
- Input to PI
- Graph PI outputs
- Follow trends of elemental & calculated values
- Follow coal quality from on-line analyzer to:
  - Stockpile
  - Bunker/silo
  - Pulverizer/Feeder

# XRF Spectrum





# Elemental Spectra & Values





# Measured & Calculated Values

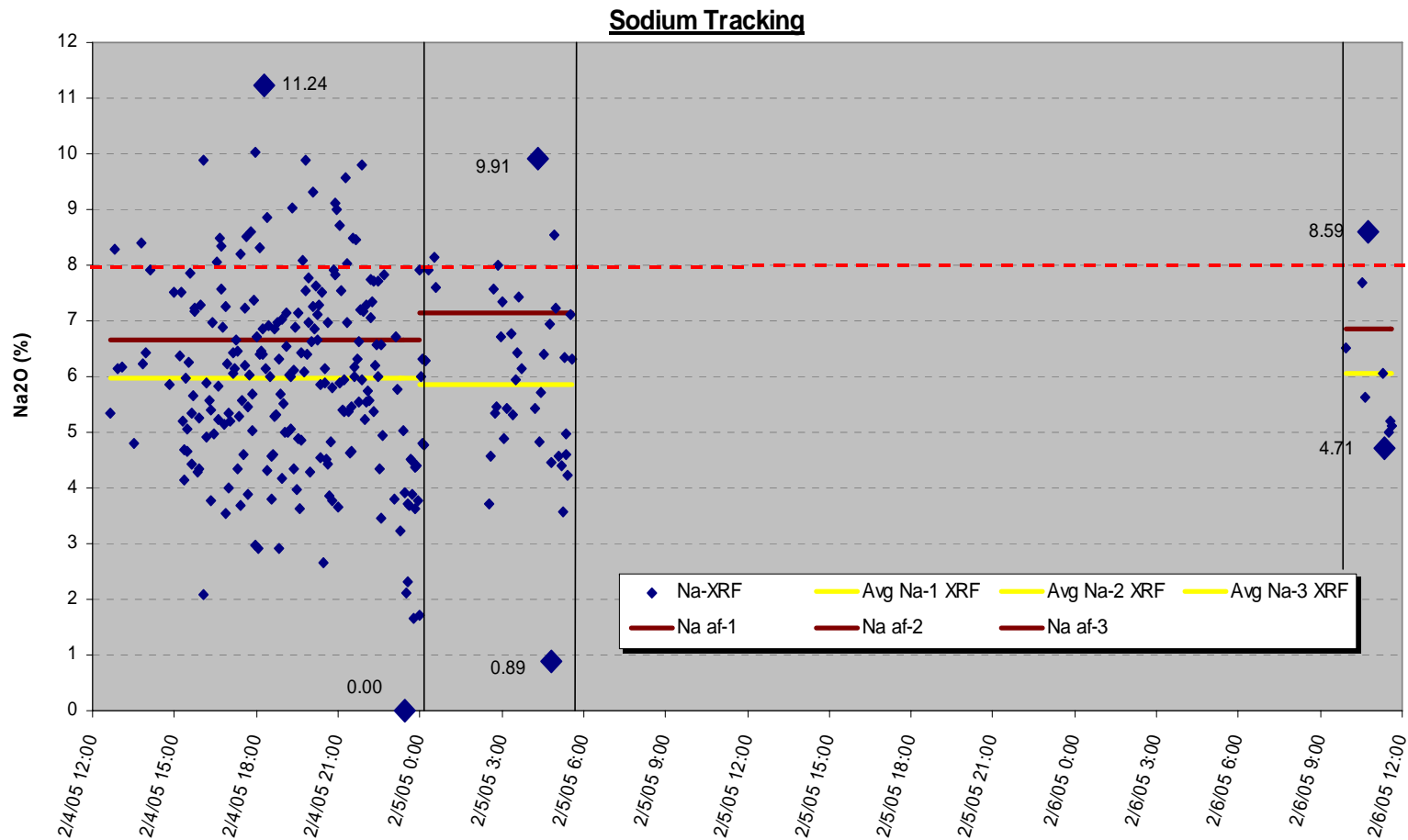
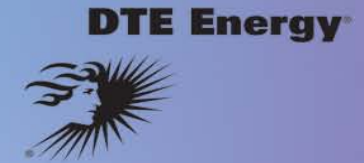
<i>Monroe Online Coal Analyzer Detail</i>	Units	Last Sample	Back 1	Back 2	Back 3	Back 4	Back 5	Back 6	Back 7	Back 8
		6/14/05 9:25 AM	6/14/05 9:24 AM	6/14/05 9:22 AM	6/14/05 9:20 AM	6/14/05 9:17 AM	6/14/05 9:15 AM	6/14/05 9:13 AM	6/14/05 9:12 AM	6/14/05 9:10 AM
<b>Silo Model Variables</b>										
Blend 1	%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Blend 2	%	60.2	61.2	58.3	58.3	61.6	56.8	62.0	61.4	58.9
Blend 3	%	39.8	38.8	41.7	41.7	38.4	43.2	38.0	38.6	41.1
Heating Value A/R	Btu/lb	10167	10289	10284	10397	10106	10109	10095	10119	10145
Cost	\$/MBtu	1.47	1.46	1.48	1.48	1.46	1.49	1.49	1.46	1.47
SO2 Rate	lb/MBtu	0.96	1.17	1.06	1.26	1.05	1.00	0.98	1.19	0.86
Ash Loading	lb/MBtu	6.45	6.25	6.51	6.23	6.43	6.44	6.47	6.37	6.41
Base/Acid Ratio		0.35	0.34	0.34	0.33	0.36	0.36	0.36	0.36	0.36
Moisture	%	19.24	18.67	18.69	18.22	19.54	19.29	19.37	19.28	19.21
Iron	%	8.35	8.04	8.33	8.14	7.98	8.16	8.18	7.97	8.14
Calcium	%	8.42	8.73	8.29	8.43	9.27	8.99	8.91	9.26	8.95
Silica + Alumina	%	60.18	62.55	61.31	62.97	59.82	59.17	59.27	60.21	59.60
Slagging Alkalinity		11.04	11.31	10.88	10.96	11.78	11.57	11.50	11.79	11.52
Volatility Ratio		0.76	0.76	0.76	0.78	0.77	0.78	0.76	0.82	0.75
<b>Other Variables</b>										
Aluminum	%	19.87	21.02	20.41	21.22	19.85	19.50	19.50	20.04	19.69
Ash Dry Basis	%	8.12	7.90	8.24	7.92	8.08	8.07	8.10	7.99	8.05
Ash A/R	%	6.56	6.43	6.70	6.47	6.50	6.51	6.53	6.45	6.50
Ash Type		1.27	1.37	1.25	1.30	1.44	1.37	1.36	1.45	1.37
Fixed Carbon	%	39.68	39.46	39.24	39.17	38.47	38.31	39.16	37.66	38.76
Heating Value MAF	Btu/lb	13701	13735	13783	13807	13663	13624	13623	13623	13656
Manganese	%	0.03	0.03	0.03	0.04	0.03	0.02	0.02	0.03	0.03
Magnesium	%	2.22	2.27	2.12	2.18	2.22	2.20	2.23	2.32	2.22
Phosphorous	%	0.89	0.93	0.88	0.89	0.93	0.93	0.93	0.94	0.93
Potassium	%	1.73	1.64	1.73	1.68	1.62	1.68	1.67	1.64	1.66
PRB		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Silica	%	40.31	41.53	40.89	41.75	39.97	39.67	39.77	40.17	39.91
Sodium	%	0.89	0.94	0.86	0.85	0.88	0.90	0.92	0.89	0.91
Sulfur	%	0.54	0.66	0.60	0.71	0.58	0.55	0.54	0.66	0.47
Sulfur Dry Basis	%	0.66	0.81	0.73	0.87	0.72	0.68	0.67	0.81	0.59



# What is the Application?

- **Moisture**
  - Control moisture; indirect Btu input measure
- **Ash**
  - Blending to ash load or ash percent limit
- **Coal quality**
  - Knowledge for problem solving
  - Proactive boiler operation, fuel change, blend change, etc.
  - Is it really bad coal?
- **Ash characteristics**
  - Slagging, fouling, resistivity, ESP index
- **Reduce emissions**
  - NO<sub>x</sub>, SO<sub>2</sub>, CO, CO<sub>2</sub>
- **Optimize blending**
  - Maximize use of least expensive coal while minimizing boiler & other O&M issues
- **Reduce fuel cost**
  - Maximize use of cheapest coal
- **Reduce kWh cost relative to market**
  - Maximize use of cheapest coal, yet change coal blend to meet demand

# On-Line Analyzer vs. Mechanical Sampler Quality Comparison



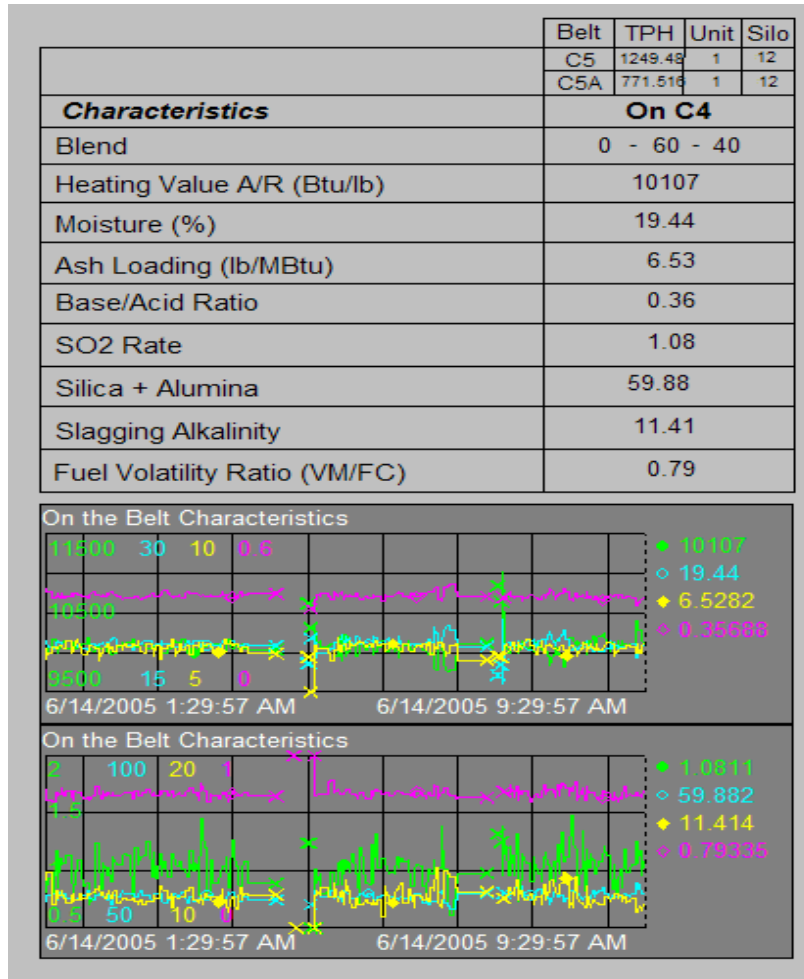


# Measure & Calculated Fuel Characteristics

- On-line fuel analysis will report:
  - **Proximate**  
(moisture<sub>[c]</sub>, ash<sub>[c]</sub>, volatile<sub>[c]</sub>, fixed carbon<sub>[c]</sub>, sulfur<sub>[m]</sub>, Btu<sub>[c]</sub>, **MAF Btu<sub>[c]</sub>**)
  - **Ultimate**  
(C<sub>[m/c]</sub>, H<sub>[m/c]</sub>, N<sub>[m/c]</sub>, O<sub>[c]</sub>)
  - **Ash Mineral<sub>[m]</sub>**  
(oxides of **Si, Al, Ti, Fe, Ca, Mg<sub>[m/x%]</sub>, K, Na<sub>[m/x%]</sub>**.)
  - **Slagging & fouling relationships<sub>[c]</sub>**
  - **Trace Elements<sub>[m]</sub>**  
(Sb, As, Be, Be, Cd, Cr, Co, Pb, Mn, Hg<sub>[m/x%]</sub>, Mo, Ni, Se, Tl, V, Zn)
  - **Ash Fusion<sub>[c]</sub>**
  - **Heat Rate<sub>[c]</sub>**
  - Depending on the analysis technique, non-elemental values are inferred by calibration & applicable algorithm
  - Report any other characteristics that are calculable from measured and calculated fuel values plus what is available from external data sources such as PI

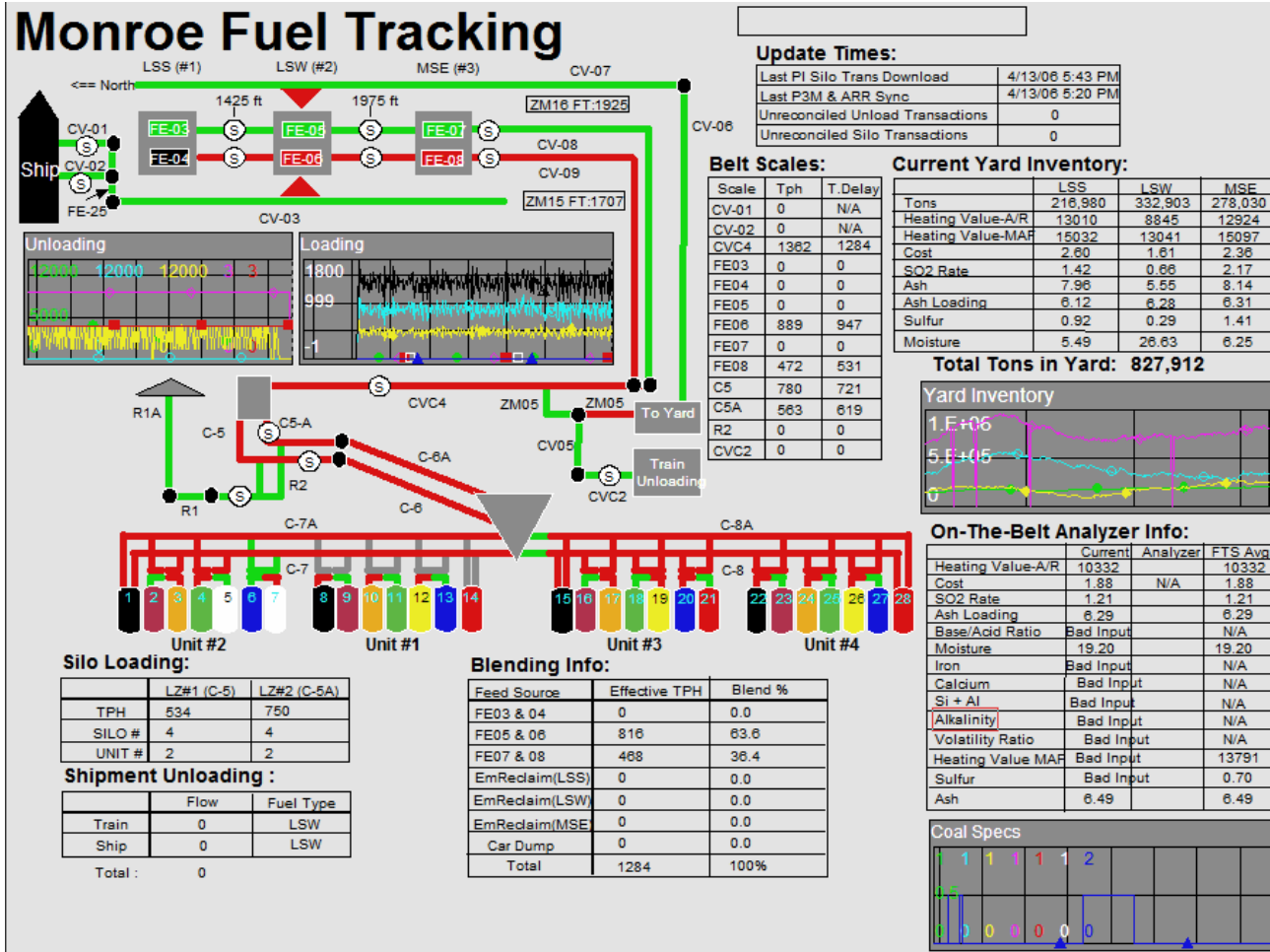


# PI & Calculated Values

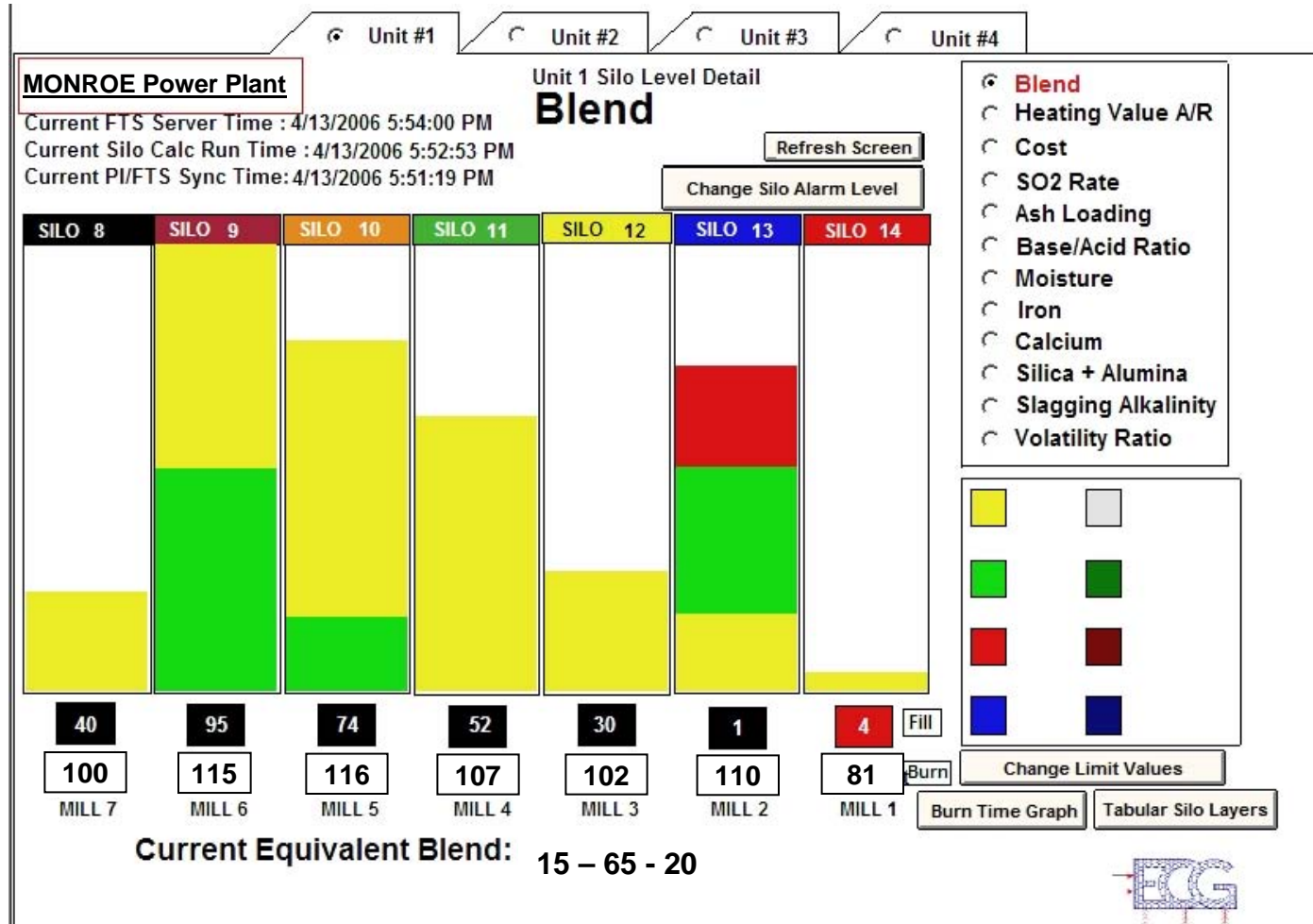
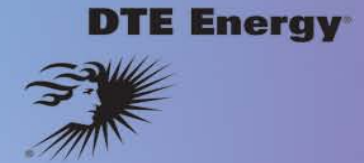




# Digital Fuel Tracking by ECG



# Digital Fuel Tracking by ECG (Blend % by silo)





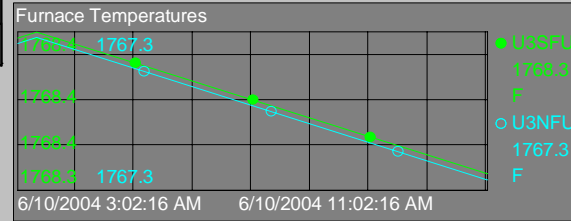
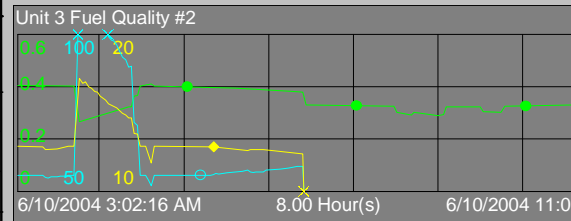
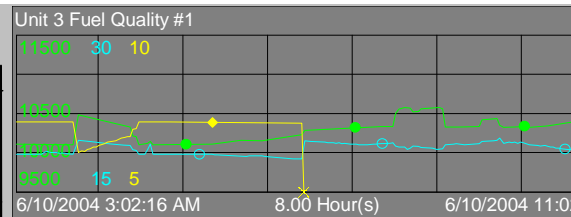
# Operator's Fuel Quality Screen

## Unit 3 Fuel Quality Screen

Characteristics	Firing				On C4
	NOW	1 hrs	2 Hrs	4 Hrs	
	20-56-25	20-56-25	20-57-23	20-55-25	
Blend	20-56-25	20-56-25	20-57-23	20-55-25	29-57-15
Heating Value A/R (Btu/lb)	10508	10445	10436	10311	10454
Moisture (%)	19.18	19.21	19.43	21.32	17.87
Ash Loading (lb/MBtu)	5.17	5.13	6.83	6.57	6.87
Base/Acid Ratio	0.19	0.19	0.20	0.30	0.37
SO2 Rate	1.10	1.10	1.10	1.04	1.11
Silica + Alumina	43.94	43.51	65.42	81.55	66.31
Slagging Alkalinity	9.33	9.22	15.63	18.50	13.96
Fuel Volatility Ratio (VM/FC)	0.56	0.53	0.54	0.52	0.55
North Furnace Temperature	1767				
South Furnace Temperature	1768				

Belt	TPH	Unit	Silo
C5	0	4	28
C5A	1264	4	28

Unit 1      Unit 2      Unit 4



### Operator Guidance

1. If Heating Value A/R is below 10,200 Btu/lb, then unit efficiency will deteriorate and mills will be stressed harder. Watch Furnace Temperature at full load.
2. If Moisture is above 20 percent, then unit efficiency will deteriorate and mills will be stressed harder. Watch Furnace Temperature at full load.
3. If Ash Loading is more than 7 lb/MBtu, then opacity excursions are expected at full load.
4. If Base/Acid Ratio is less than 0.2, then opacity excursions are expected at full load.
5. If Base/Acid Ratio is between 0.2 and 0.25, then there is a potential for opacity problems at full load.
6. If Base/Acid Ratio is more than 0.5, then slagging can be expected at full load.
7. If Base/Acid Ratio is between 0.4 and 0.5, then slagging can be caused by the fuel at full load.
8. If Fuel Volatility Ratio is below 0.25, then combustion will occur in upper furnace, watch Furnace temperature.



**Own It!**

ARE YOU READY TO OWN IT?

TELL ME A BETTER TOOL?

GO FOR IT!