LIMESTONE INJECTION FOR PROTECTION OF SCR CATALYST

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Introduction & Background

- Gaseous Arsenic Poisoning Predominant Deactivation Mechanism
- CaO Potential Poison at High Percentages
- Gaseous As Controllable with CaO from
  - Naturally in Coal
  - Limestone Addition to Fuel
  - Fuel Blending

Arsenic Control Through Limestone Addition

- Gaseous Arsenic (AsO_3) as Catalyst Poison
- Addition of Limestone ($CaCO_3$) to Coal form solid Non-Poisoning Form ($(Ca_3(AsO_4)_2)$)

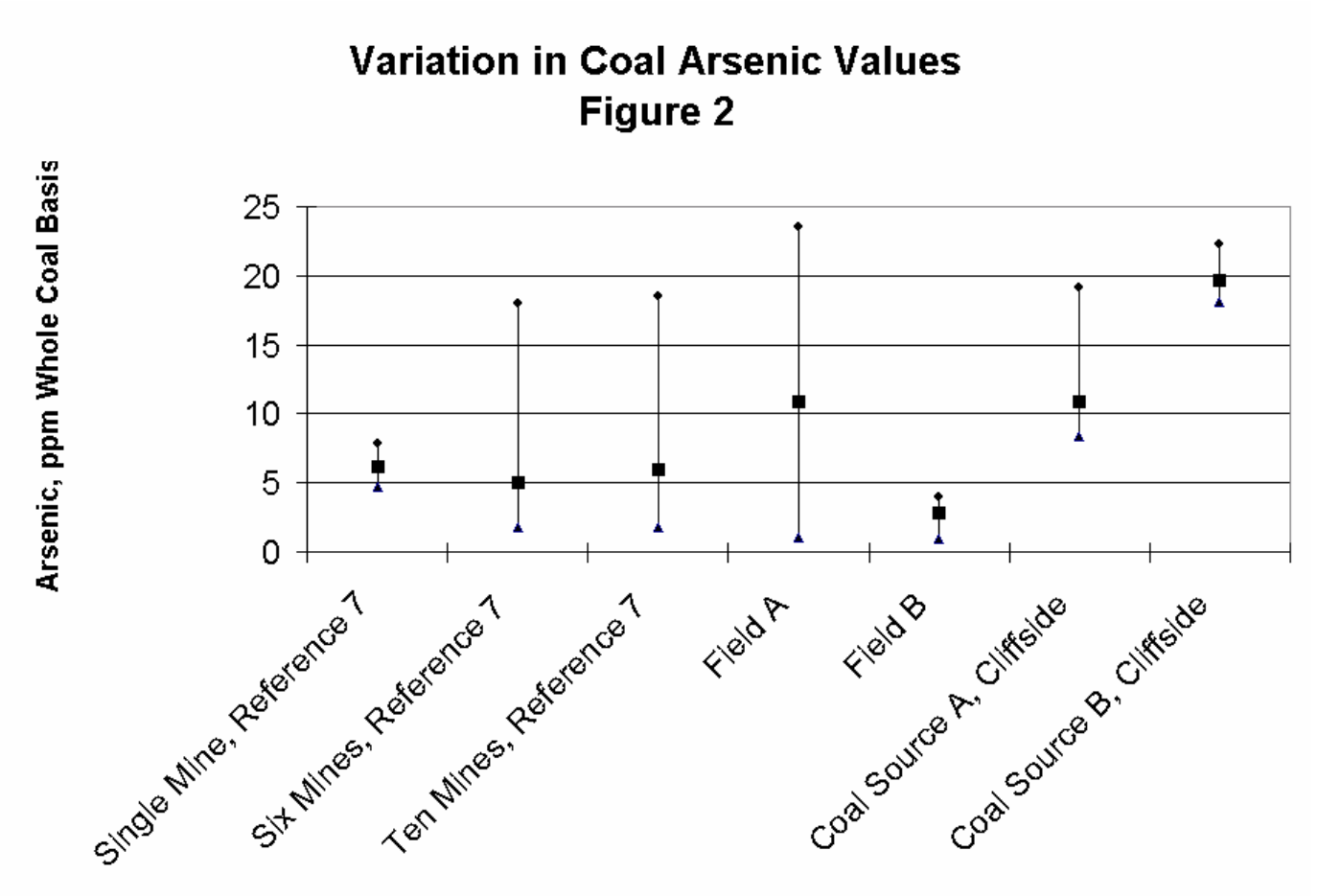
European And Japanese Experience

- Japanese Experience Good, Low As Coals - Dry Bottom Units
- European Experience Good, Low As Coals - Dry Bottom Units
- Bad European Experience, Low As Coals - Wet Bottom Ash Recirculation
- Recirculation Revaporized As to Gaseous Phase

United States Coals

- USGS Coal Database - 22 ppm As Average
- Coal Cleaning Reduces As by 35 to 83%
- Utilities Need for Fuel Flexibility

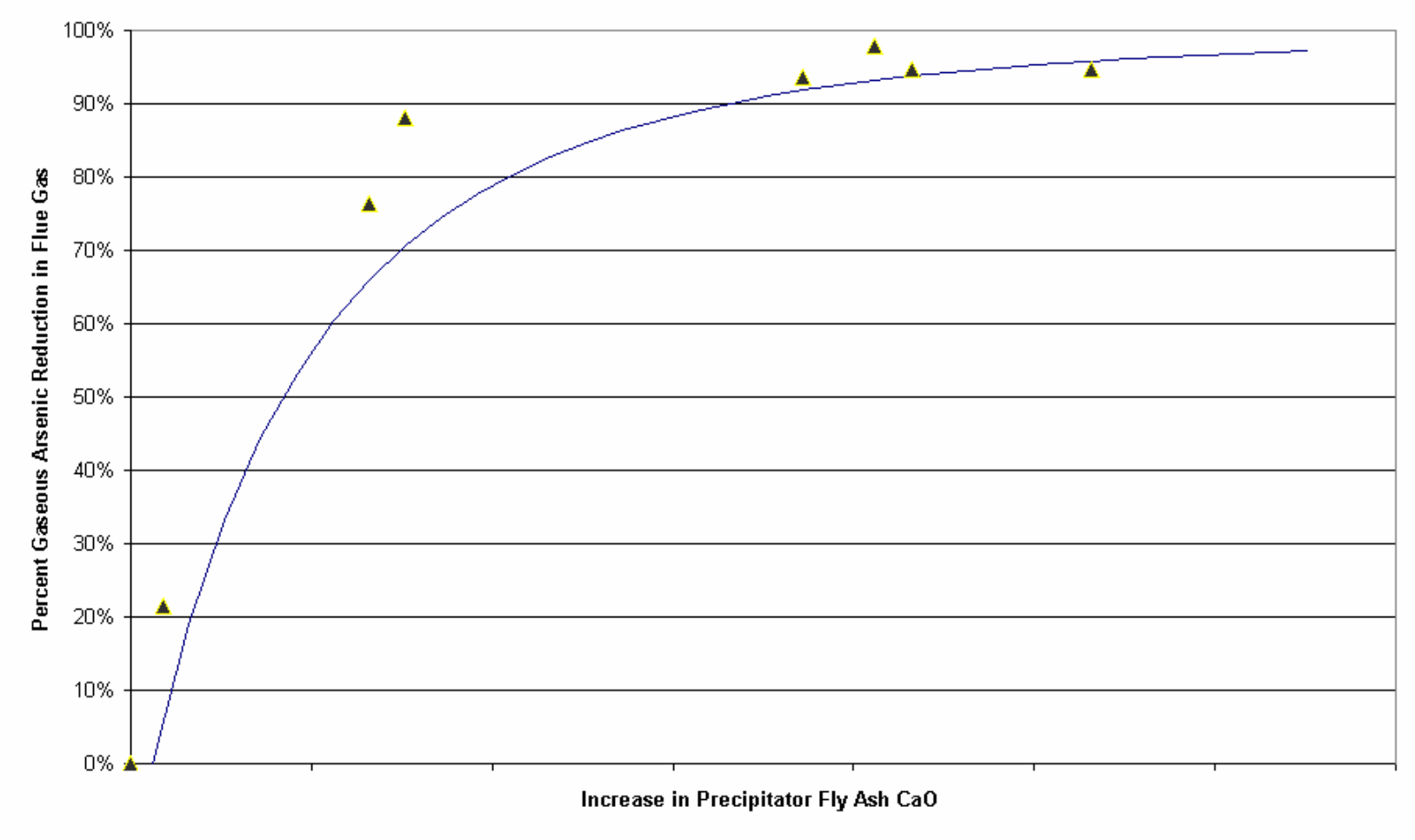
Arsenic Variation in Coals



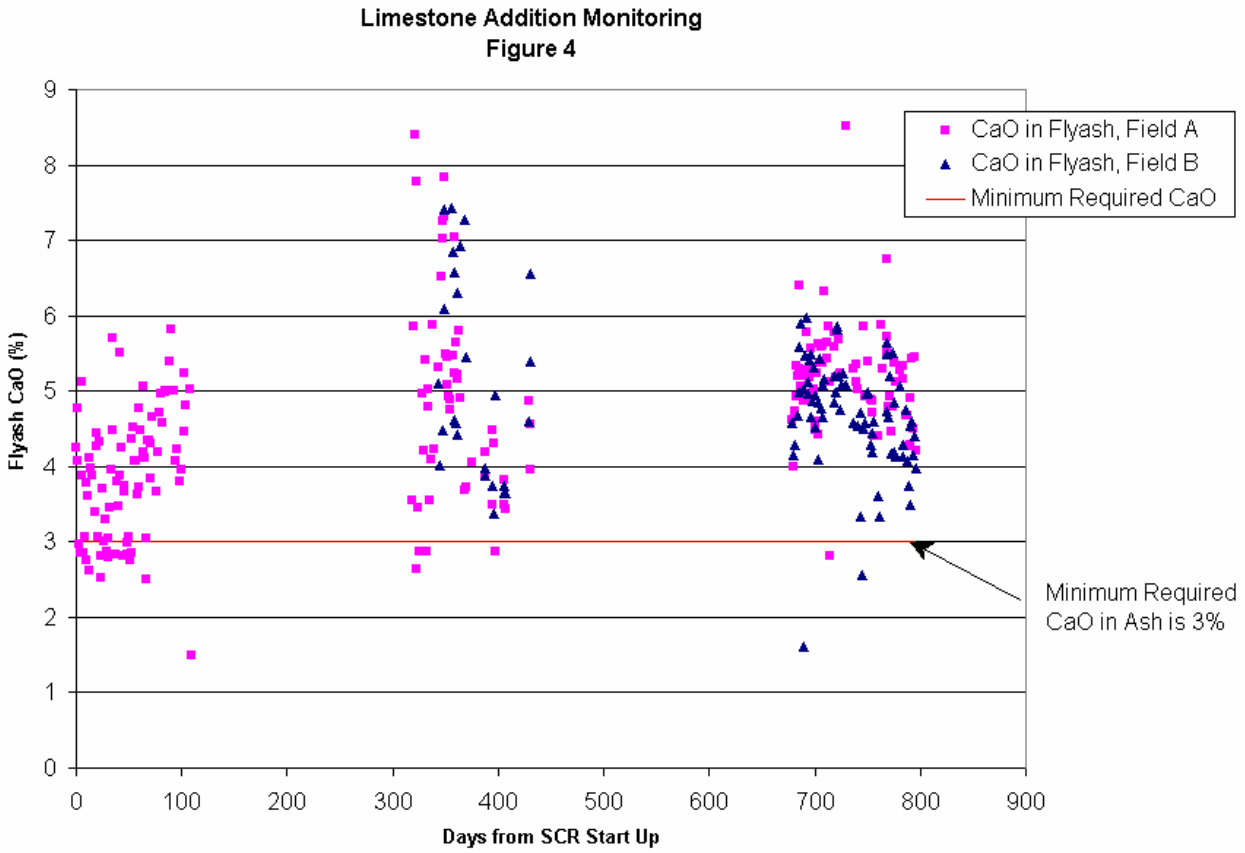
First US Limestone Addition

- Large Variation in As Concentration with Low CaO
- Arsenic Levels as High as 24 ppm
- Unit Had Past History of Slagging
- Approach
  - Temporary Limestone Feed System
  - Measure Gaseous Arsenic (AsO_3)
  - Observe Boiler Performance

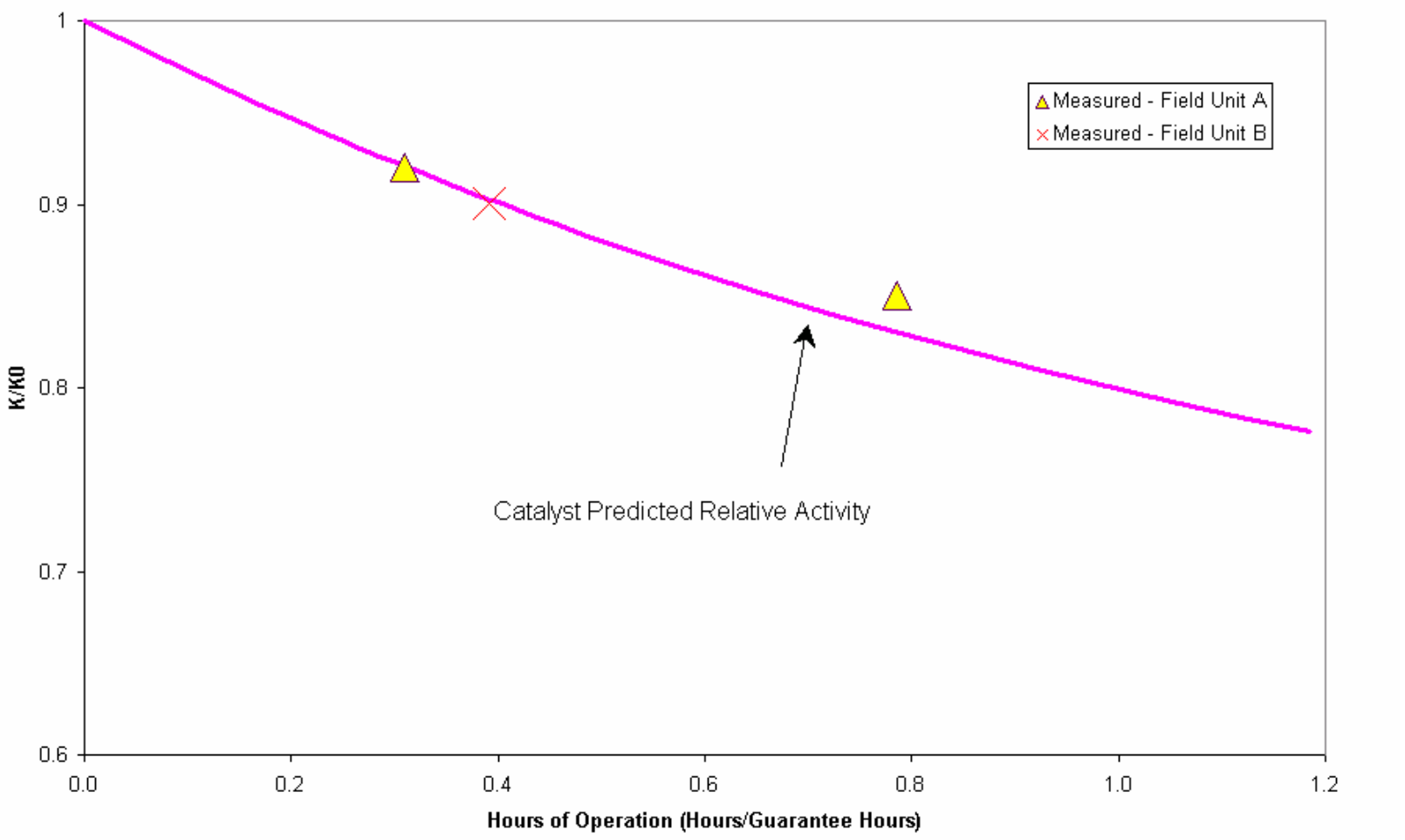
Effect of Limestone Addition



Limestone Addition Experience



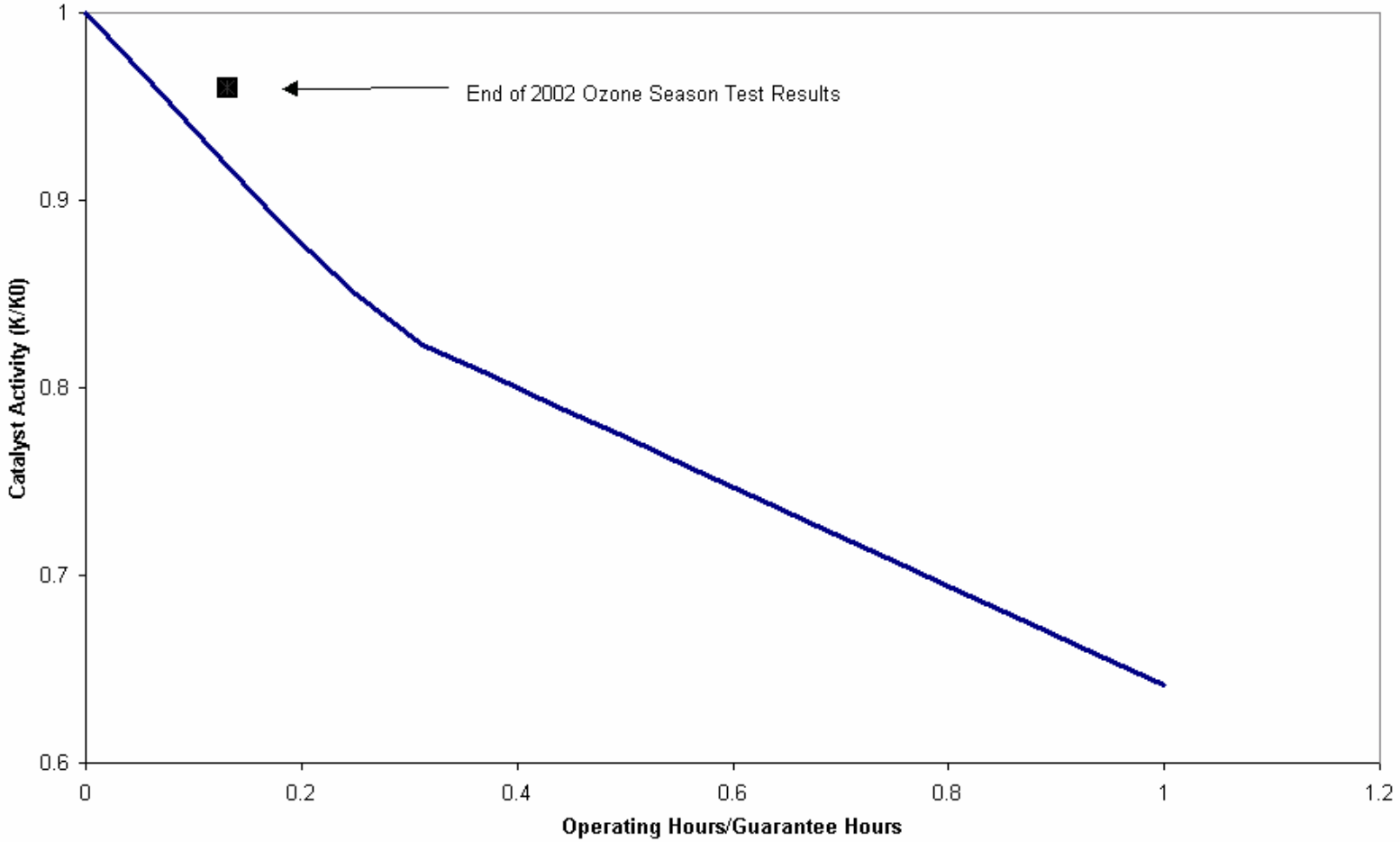
Limestone Addition Experience



Duke Energy Cliffside Unit 5

- 50% of Fuels Did Not Require Limestone
- Two Fuels Cannot Achieve Continuous Operation With Limestone Addition
- Using Limestone Addition System and Fuel Knowledge Two Initial Catalyst Layers
- Cormetech FIELD Guide Developed for Fuel Range

Duke Energy Cliffside Unit 5



Mark Barger

Project Manager – Cliffside 5

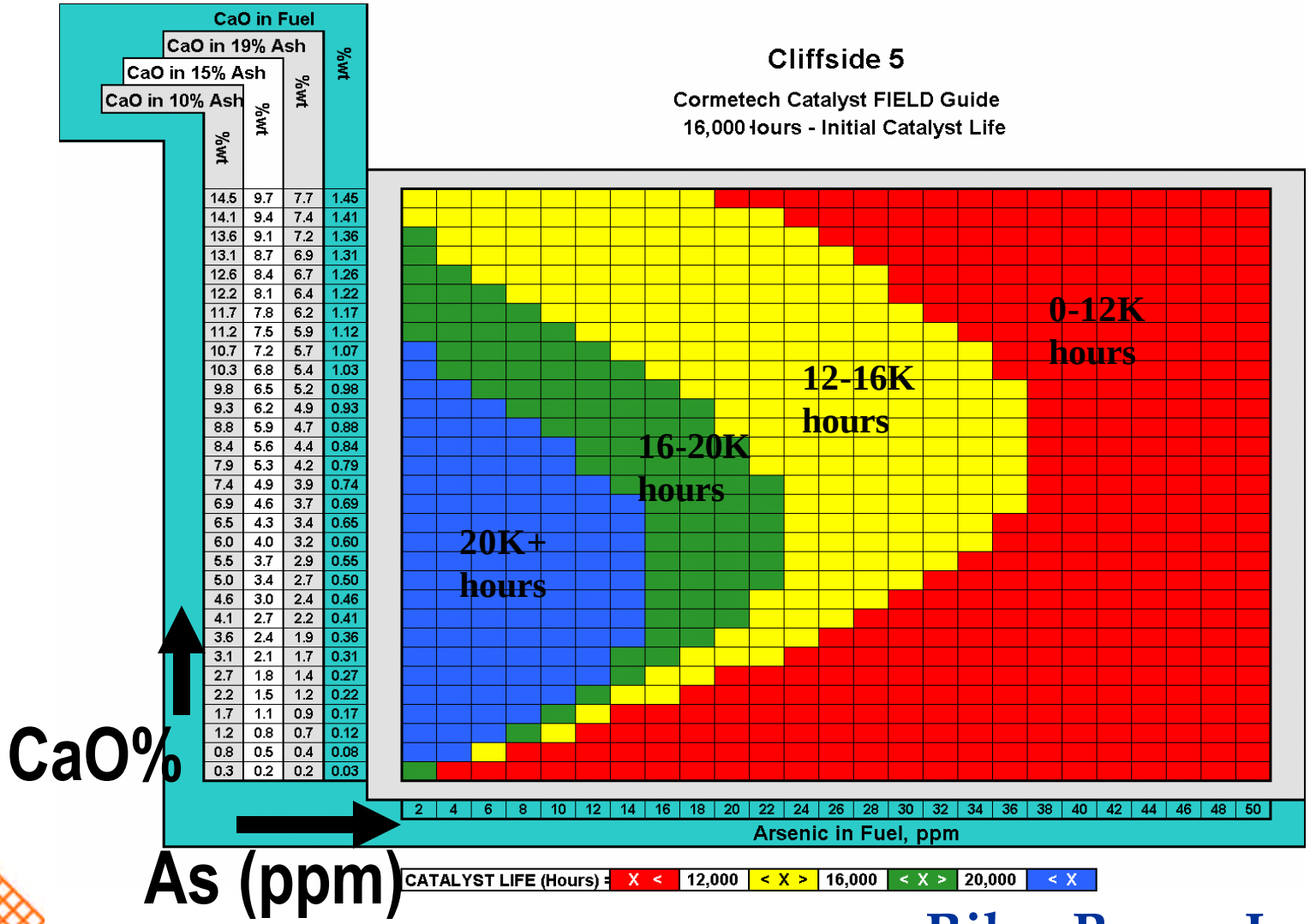
CORMETECH

SCR Catalyst Supplier for Cliffside 5 Project

FIELD Guide

- **F**uel **I**mpact and **E**valuation of **L**ife **D**etermination
- Unit Design Specific
- Assumes Constant Fuel Sulfur Level
- For Arsenic poisoning SCR applications

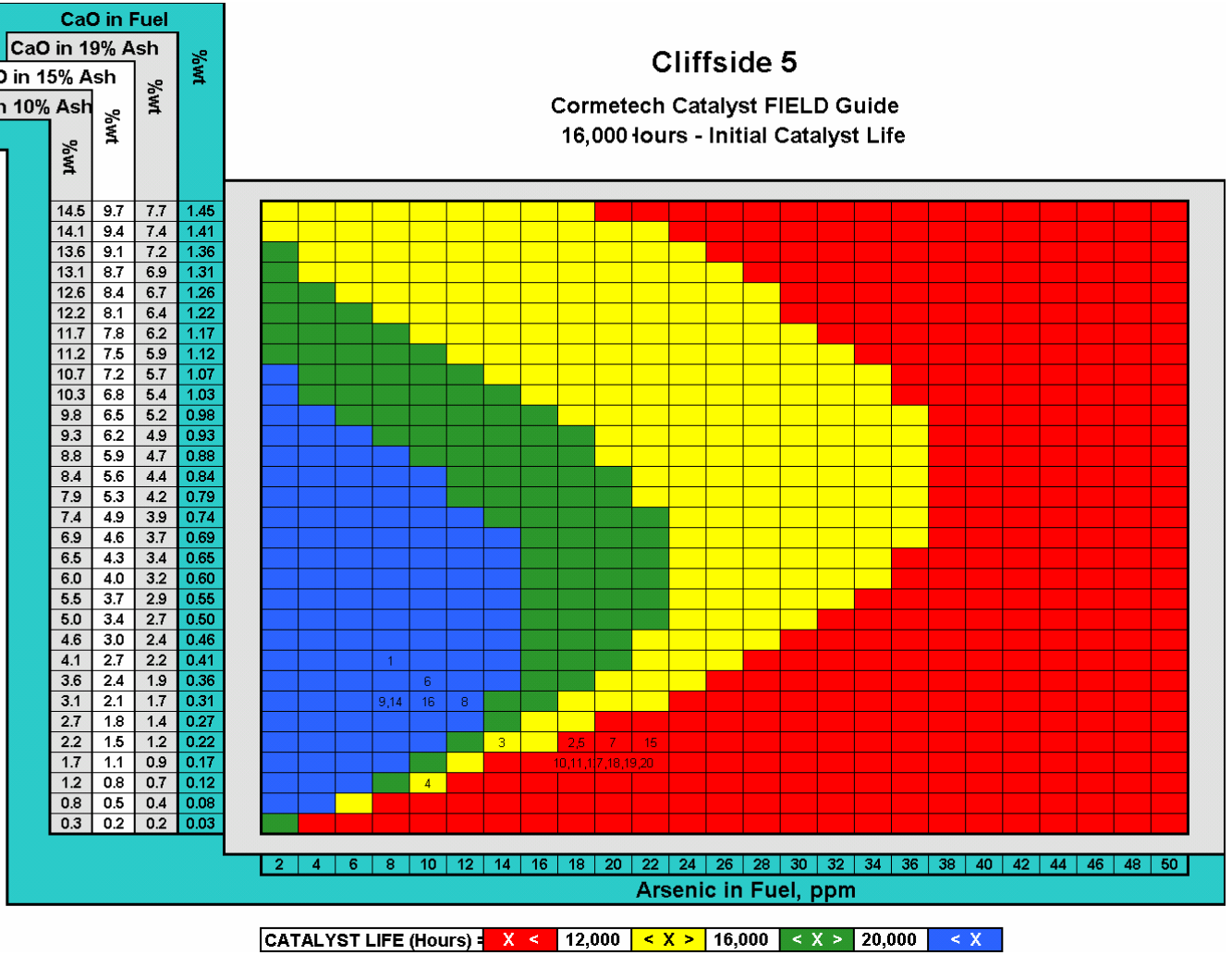
FIELD Guide



CORMETECH

Cliffside 5 with 2002 fuels plotted

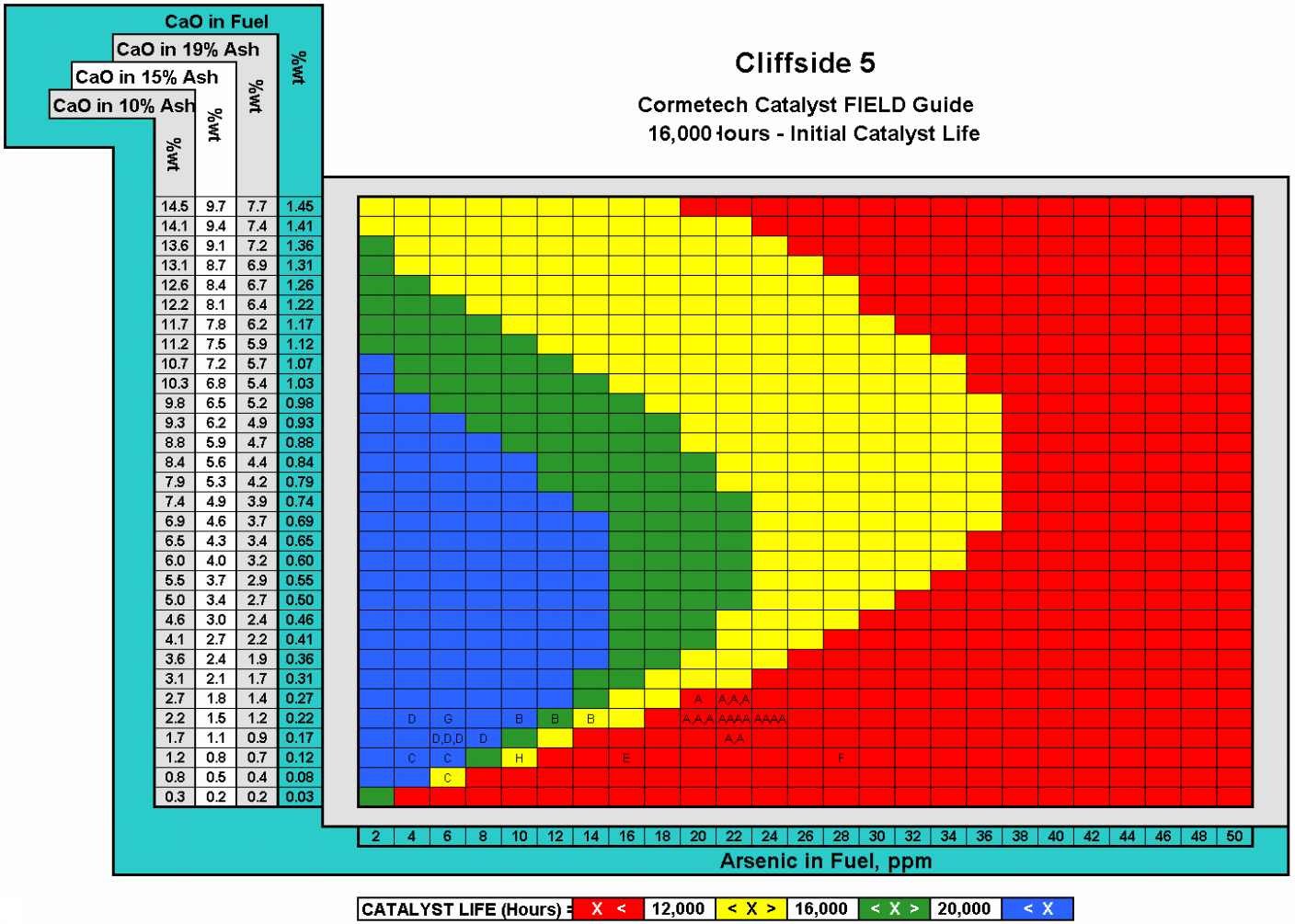
CaO in 10% Ash %wt	CaO in 15% Ash %wt	CaO in 19% Ash %wt	CaO in Fuel %wt
14.5	9.7	7.7	1.45
14.1	9.4	7.4	1.41
13.6	9.1	7.2	1.36
13.1	8.7	6.9	1.31
12.6	8.4	6.7	1.26
12.2	8.1	6.4	1.22
11.7	7.8	6.2	1.17
11.2	7.5	5.9	1.12
10.7	7.2	5.7	1.07
10.3	6.8	5.4	1.03
9.8	6.5	5.2	0.98
9.3	6.2	4.9	0.93
8.8	5.9	4.7	0.88
8.4	5.6	4.4	0.84
7.9	5.3	4.2	0.79
7.4	4.9	3.9	0.74
6.9	4.6	3.7	0.69
6.5	4.3	3.4	0.65
6.0	4.0	3.2	0.60
5.5	3.7	2.9	0.55
5.0	3.4	2.7	0.50
4.6	3.0	2.4	0.46
4.1	2.7	2.2	0.41
3.6	2.4	1.9	0.36
3.1	2.1	1.7	0.31
2.7	1.8	1.4	0.27
2.2	1.5	1.2	0.22
1.7	1.1	0.9	0.17
1.2	0.8	0.7	0.12
0.8	0.5	0.4	0.08
0.3	0.2	0.2	0.03



CORMETECH

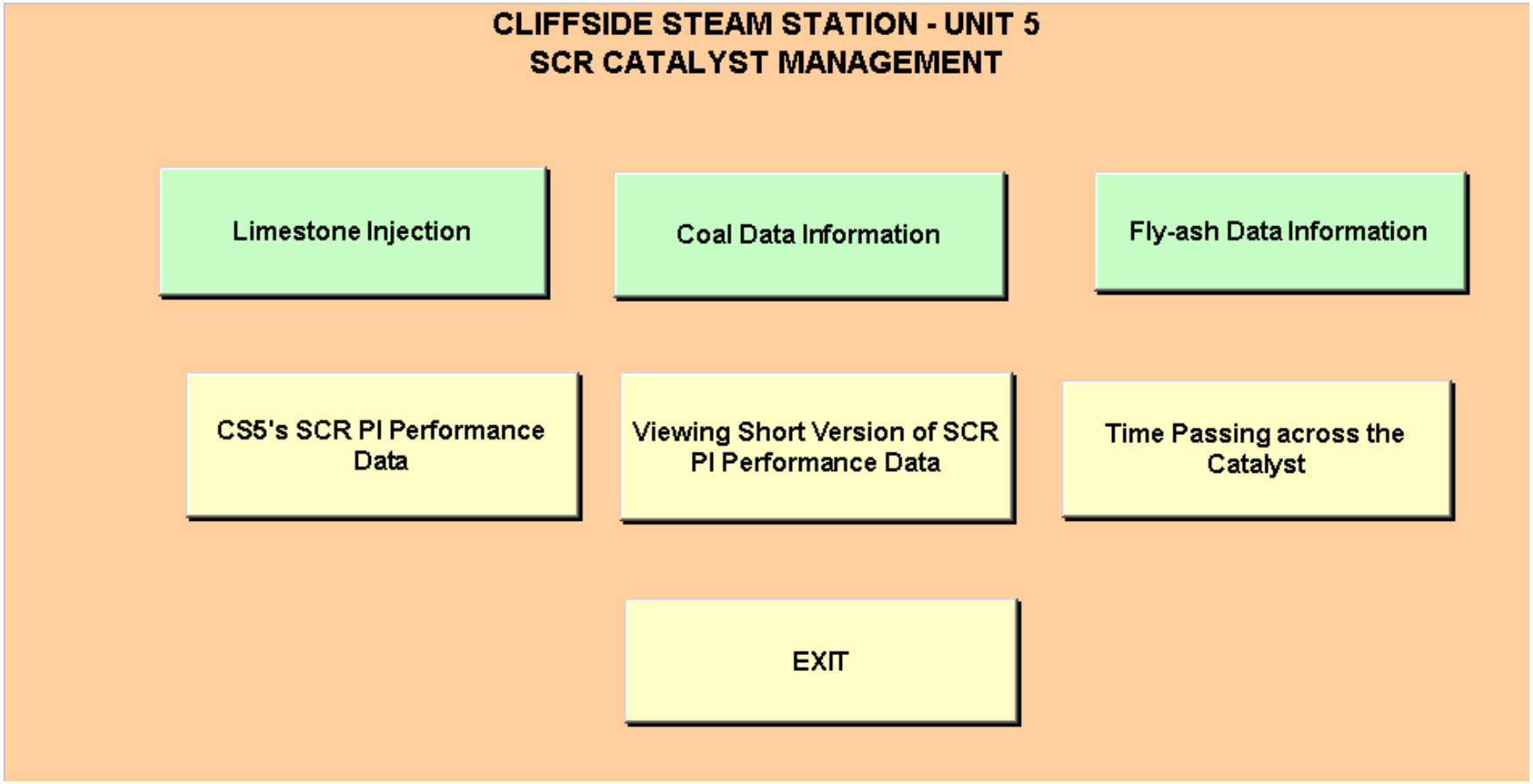
Riley Power Inc.

Cliffside 5 with 2003 fuels plotted



Linton Hutcheson

Cliffside Unit 5 SCR Management



Limestone Injection

CLIFFSIDE STEAM STATION, UNIT 5

SCR CAT Management

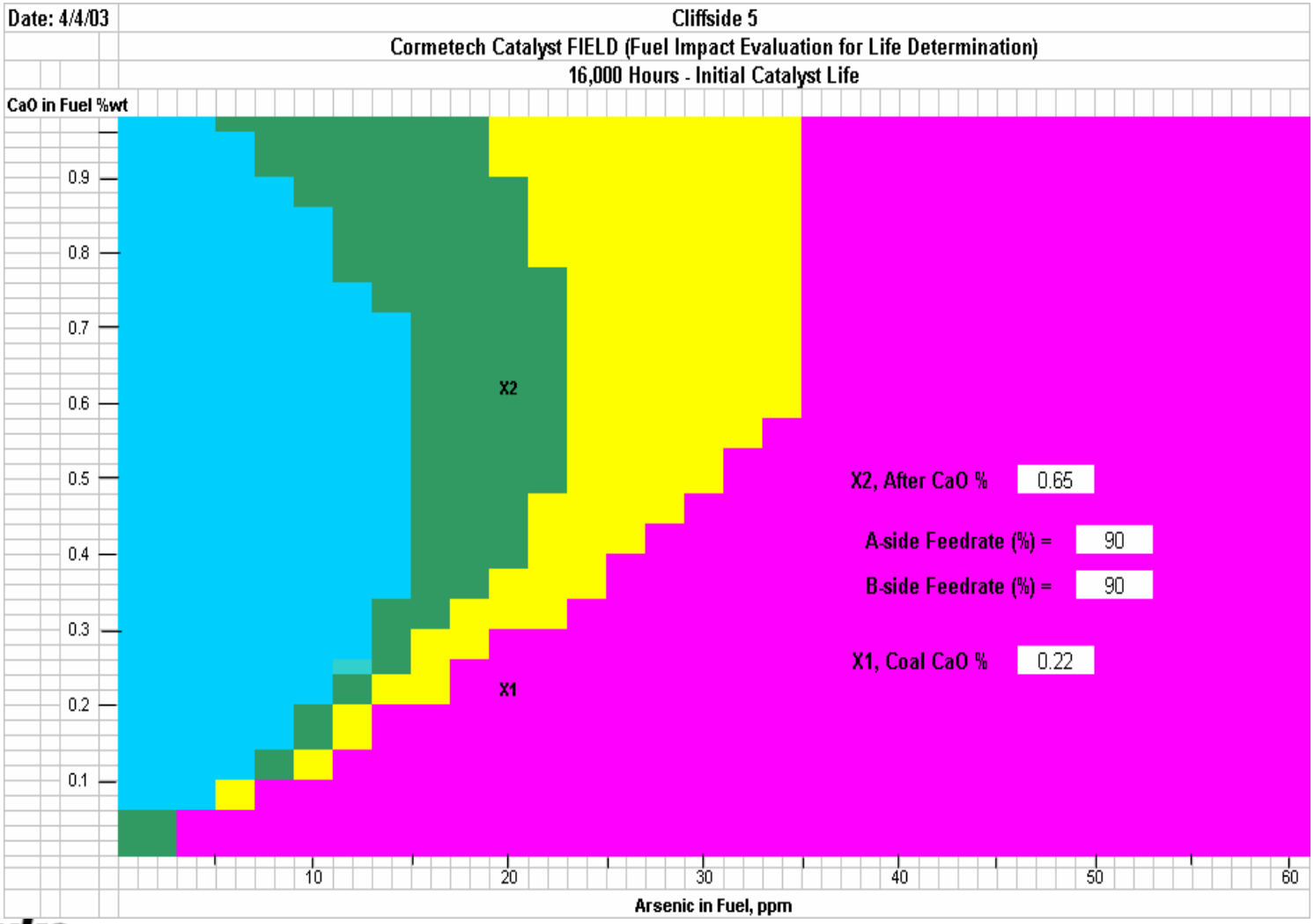
LIMESTONE FEEDRATE

Please select coal supplier, select guarantee Btu and specify CaCO3 (% in coal)

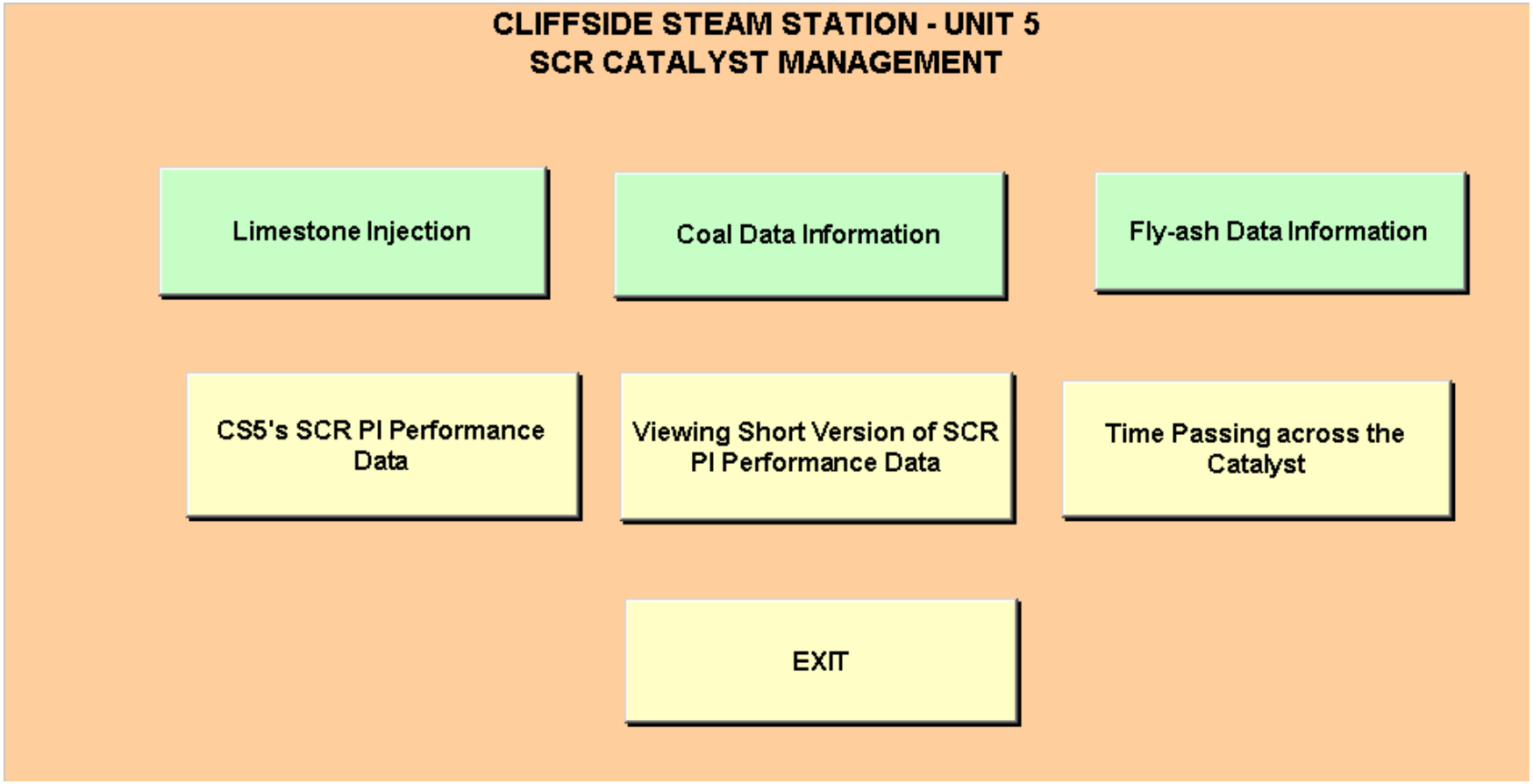
Date:	4/4/2003			
Over-writing CaCO3 (% in Coal):				
Coal Supplier:	Coal "A"			
Guarantee Btu:	12,500			
% Blend (25, 50, 75 or 100):	100			

Calculate CaCO3 Feedrate

FIELD GUIDE


Date: 4/4/03
Cliffside 5
Cormetech Catalyst FIELD (Fuel Impact Evaluation for Life Determination)
16,000 Hours - Initial Catalyst Life
CaO in Fuel %wt
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
X2
X1
X2, After CaO % 0.65
A-side Feedrate (%) = 90
B-side Feedrate (%) = 90
X1, Coal CaO % 0.22
10
20
30
40
50
60
Arsenic in Fuel, ppm

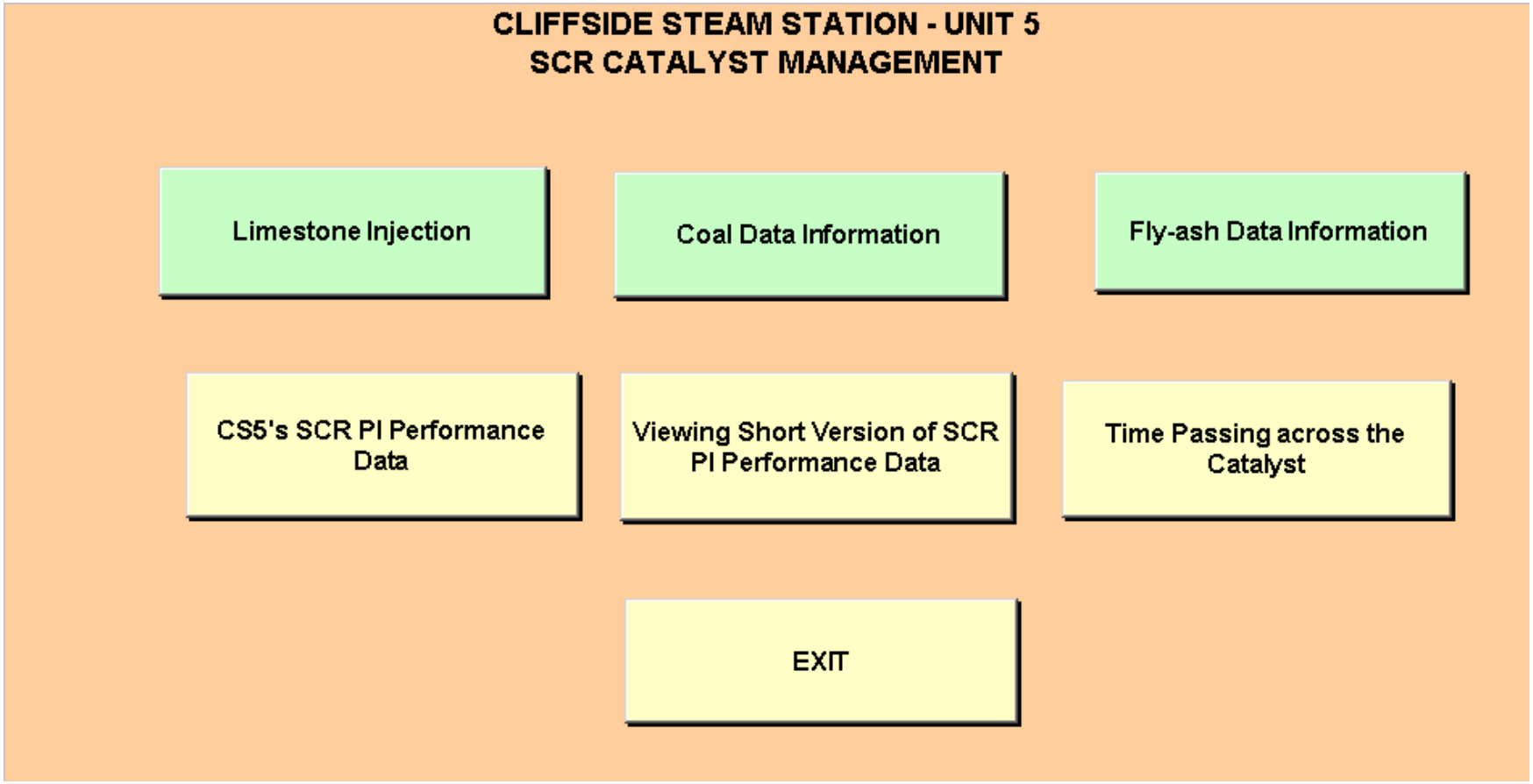
Cliffside Unit 5 SCR Management



Coal Data Information

Catalyst Management Coal Analytical Reports	
Notes: New reports are highlighted in the "Train Arrival Date" row.	
Coal Identification	Coal "A"
Proximate Analysis (As_Received)	
HHV (Btu/lb)	13125
Moisture (%)	5.34
Ash (%)	7.42
Sulfur (%)	1.14
Vltlt_Matter (%)	35.15
Ultimate Analysis (Dry)	
Carbon (%)	75.5
Hydrogen (%)	4.98
Nitrogen (%)	1.74
Ash Elemental Oxide	
Silica (%)	46.79
Alumina (%)	26.28
Titania (%)	1.42
Iron (%)	11.39
Calcium (%)	2.81
Magnesum (%)	1.04
Sodium (%)	0.47
Potassium (%)	2.54
Phosphorous (%)	1.19
Sulf_Trioxide (%)	1.19
Strontium (%)	0.3
Barium (%)	0.2
Manganese (%)	0.03
Trace Metals - dry whole coal basis	
Arsenic_Ppm	19.5
Barium_Ppm	131
Chromium_Ppm	13
Cobalt_Ppm	7.1
Copper_Ppm	24
Iodine_Ppm	3.5
Chlor_Ppm	423
Fluorine_Ppm	100
Cadmium_Ppm	0.09
Mercury_Ppm	0.1
Manganese_Ppm	15
Lead_Ppm	7
Molybdenum_Ppm	2.1
Vanadium_Ppm	32
Nickel_Ppm	15
Selenium_Ppm	2.7
Bromine_Ppm	3.5
Beryllium_Ppm	1.7
Zinc_Ppm	20
Calcium_Ppm	
Thallium_Ppm	0.7
Antimony_Ppm	1.11
Silver_Ppm	0.16

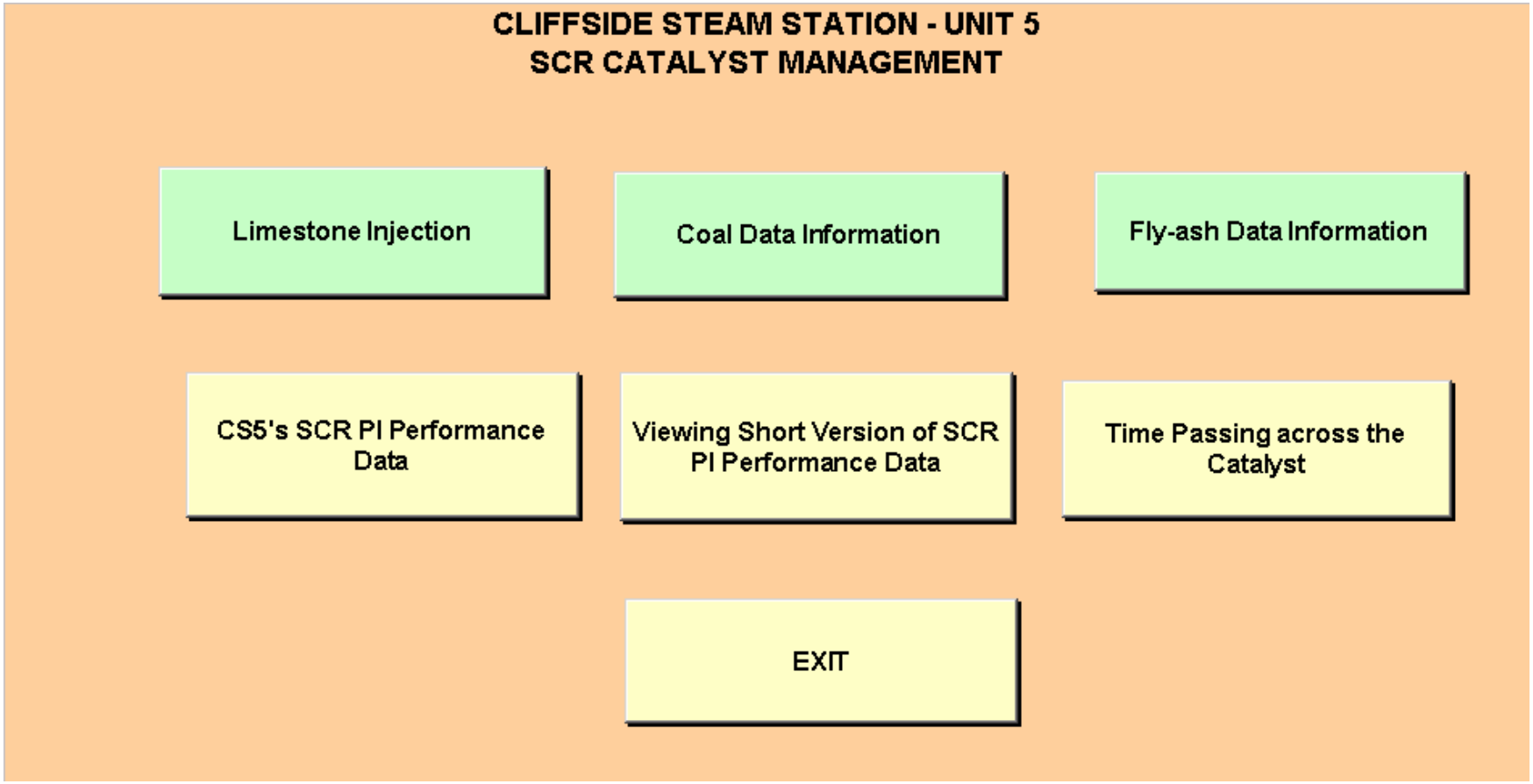
Cliffside Unit 5 SCR Management



Fly-ash Data Information

Analytical Reports		
Flyash Samples form Economizer Outlet and ESP Inlets for Summer 02'		
ID No.	22038666	22038761
Collection Side	A	B
Test No. (Note below)	CAT 1	CAT 1
Lime Inj On?	No	No
Approx Inj Rate %	0	0
Collected Date	8/2/2002	8/2/2002
Laboratory	CT&E	CT&E
Free CaO, %	<0.10	<0.10
Cl, %	0.02	0.06
Hg, PPM	0.05	0.06
SiO2, %	53.44	52.56
Al3O2, %	29.2	30.42
TiO2, %	1.45	1.45
Fe2O3, %	7.68	7.74
CaO, %	1.95	1.98
MgO, %	0.92	0.91
K2O, %	2.62	2.49
Na2O, %	0.28	0.29
SO3, %	0.04	0.05
P2O5, %	0.31	0.37

Cliffside Unit 5 SCR Management

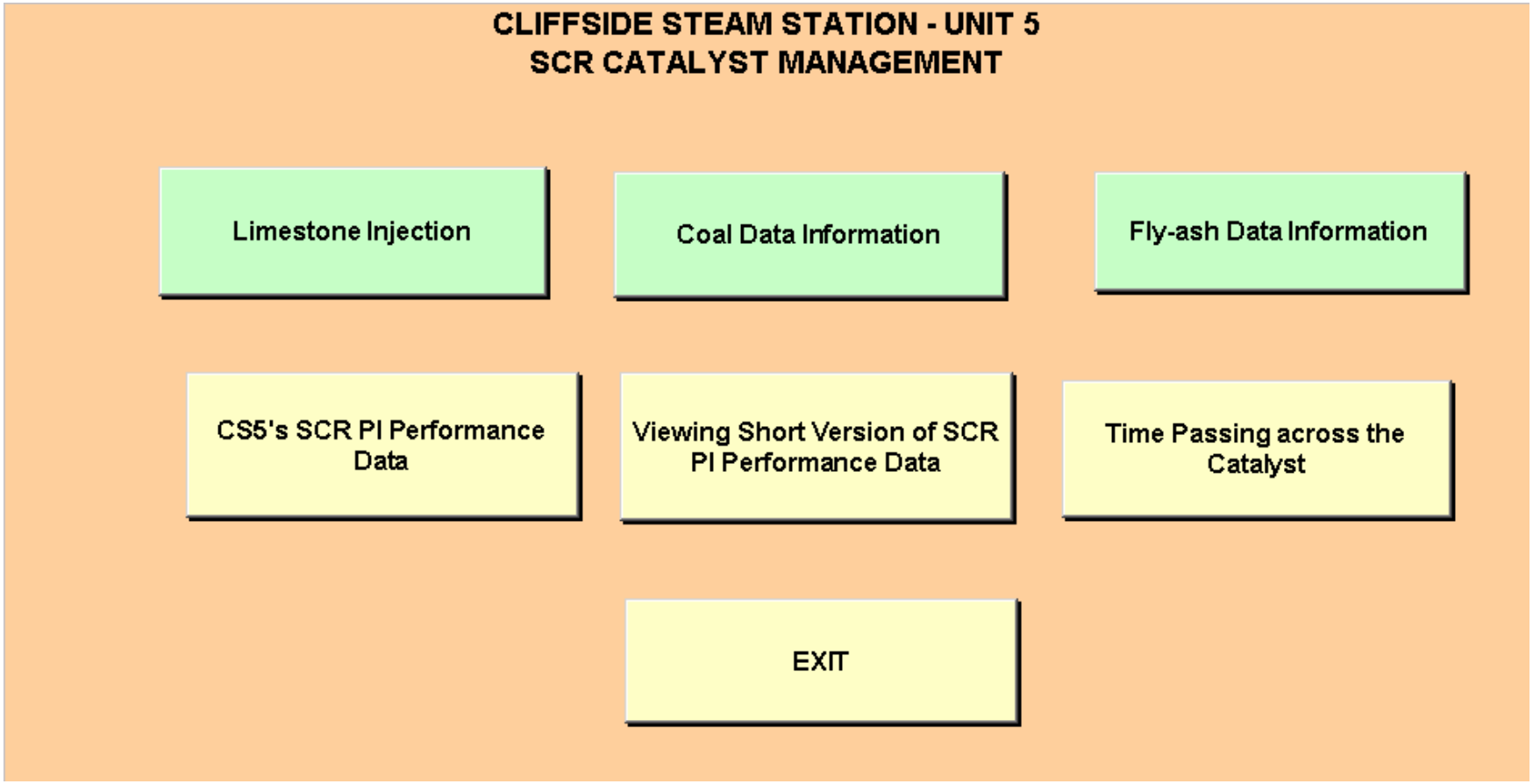


CS5's SCR PI Performance Data

CLIFFSIDE STEAM STATION, UNIT 5			NOx TESTING DATA	
Summary of 24 Hours to Midnight on:	4/1/2003 0:00			
Total hours flue-gas passed over catalyst @ load > 0 MW	0 Hours			
Bypassed the Catalyst for the entire period				
Hours flue-gas passed over catalyst @ load ≥ 425 MW:	0 Hours			
Bypassed the Catalyst for the entire period	(Hourly averages are shown starting from column "H")			
Hours flue-gas passed over catalyst @ load ≥ 580 MW:	0 Hours			
Bypassed the Catalyst for the entire period	(Average, Maximum and Minimum values are shown in c			
PI Performance Data				
Description	*PI UNITS*	Average	Maximum	Minimum
GENERAL UNIT INFORMATION				
UNIT GROSS LOAD	MW	583.95	598.16	494.42
NET UNIT LOAD	MW	560.38	573.64	470.38
AUXILIARY LOAD	MW	23.59	25.45	22.67
EXPECTED HEAT RATE	BTUKWH	9353.55	9381.37	9265.64
REAL TIME HEAT RATE	BTUKWH	9403.35	9567.23	9274.11
TOTAL Q FIRED	MBTU/HR	5165.16	5281.32	4381.65
FLUE GAS TEMPERATURES				
AVG AH GAS INLET A	DEG F	666.20	676.38	638.30
AVG AH GAS INLET B	DEG F	579.82	588.55	556.24
AVG AH GAS OUTLET A	DEG F	281.65	292.07	269.99
AVG AH GAS OUTLET B	DEG F	273.06	280.87	261.11
Econ A Outlet O2	PCT	1.81	2.59	1.41
Econ B Outlet O2	PCT	3.23	3.72	2.87
O2 at Econ Outlet - Avg	PCT	2.52	3.09	2.24
Exp O2 at Econ Outlet	PCT	3.43	3.43	3.43
O2 at APH Outlet	PCT	4.98	5.65	4.69
O2 at APH A Outlet	PCT	4.47	5.37	4.04
O2 at APH B Outlet	PCT	5.50	6.09	5.11
AIR AND FLUE GAS DRAFTS				

More than 100 Additional SCR Data Points Stored

Cliffside Unit 5 SCR Management



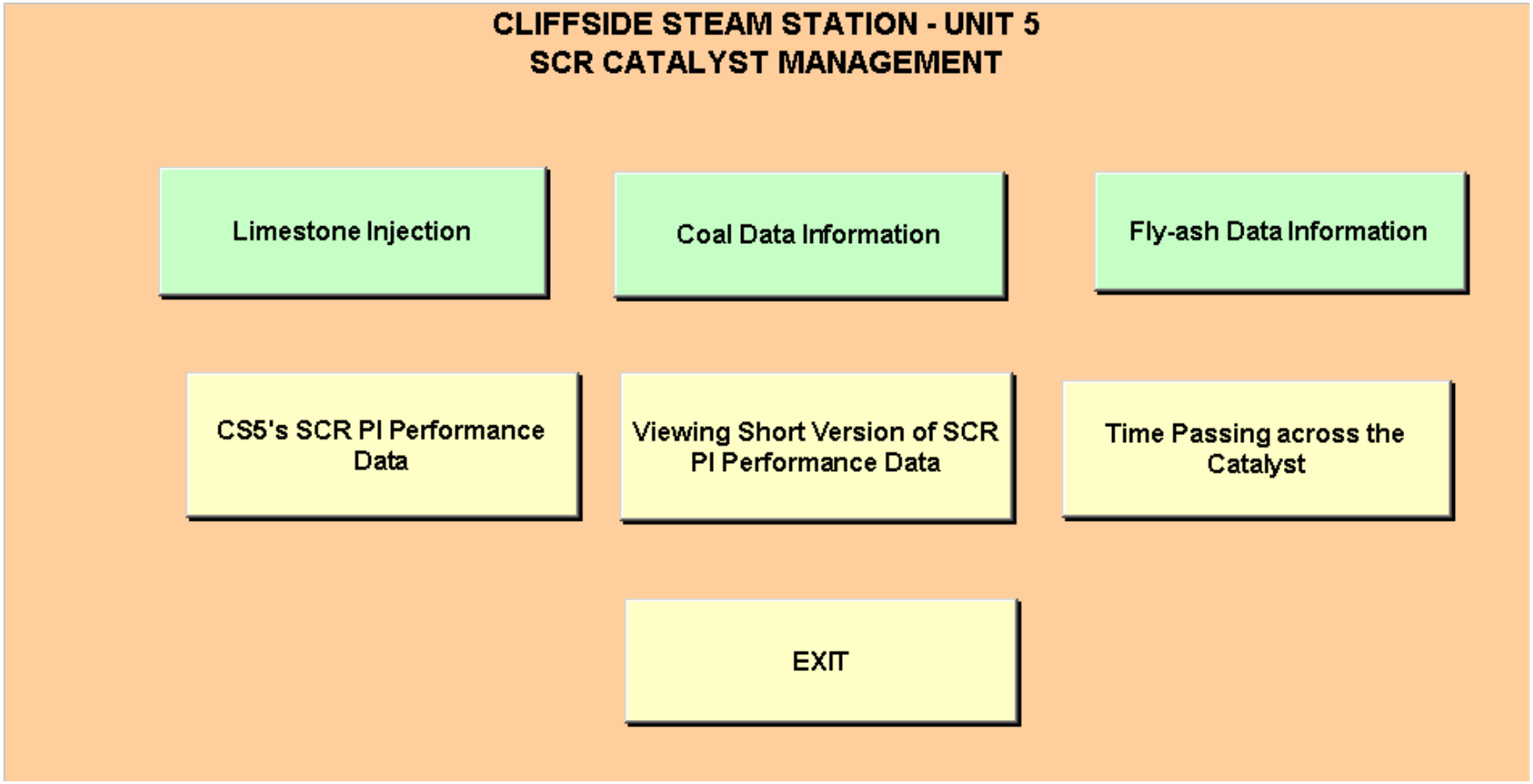
Viewing Short Version of PI Data

CLIFFSIDE STEAM STATION, UNIT 5			NOx TESTING DATA			
Summary of 24 Hours to Midnight on:	4/4/2003 0:00					
Total hours flue-gas passed over catalyst @ load > 0 MW	18 Hours					
Between 00:00 hour and 01:00 hour.						
Hours flue-gas passed over catalyst @ load ≥ 425 MW:	18 Hours					
Between 00:00 hour and 01:00 hour.	**(Hourly averages are shown starting from column "H")**					
Hours flue-gas passed over catalyst @ load ≥ 580 MW:	**16 Hours**					
Between 00:00 hour and 01:00 hour.	**(Average, Maximum and Minimum values are shown in columns "E", "F" and "G" respectively)**					
PI Performance Data						
Description	***PI Descriptor***	***PI Tag***	***PI UNITS***	**Average**	**Maximum**	**Minimum**
GENERAL UNIT INFORMATION						
UNIT GROSS LOAD	5 Gross Load	5LOAD	MW	564.36	593.24	397.36
NET UNIT LOAD	5 Net Unit Load	5loadnet	MW	540.59	569.21	375.66
AUXILIARY LOAD	5 Total Aux	5aux	MW	23.71	25.32	20.88
EXPECTED HEAT RATE	5 Exp Net Unit Heat Rate	5hrx	BTUKWH	9272.34	9301.94	9204.73
REAL TIME HEAT RATE	5 Realtime Unit Heat Rate	5HRR	BTUKWH	9387.43	9528.85	9244.75
TOTAL Q FIRED	5 Fuel Consumption Rate	5BTURATE	MBTUHR	4993.27	5242.39	3569.10
WATER & STEAM TOTAL FLOW						
FEEDWATER TO ECONOMIZER	5 Selected FW Flow-KBH	AC5CF00B	KBH	3833.09	4101.84	2576.38
CONTINUOUS BLOWDOWN FLOW	5 Continuous Blowdown Flow	AL5BB60A	KBH	6.43	6.56	6.35
MAIN STEAM	5 Selected Stm Flow-KBH	AC5SM64C	KBH	3641.85	3886.91	2406.80
SH SPRAY FLOW	Superheater Spray Flow	5WSHS	KBH	2.18	70.21	0.00
REHEAT SPRAY FLOW	Reheat Spray Flow	5WRHS	KBH	22.33	22.98	20.05
WATER AND STEAM TEMPERATURE						
MAIN STEAM PATH						
FINAL FEEDWATER OUT TEMP	5A FWH Cnds Outlet Temp	TE5CF01B	DEG F	480.70	486.14	444.94
MAIN STEAM TEMP	5 Main Steam Temp	5TMS	DEG F	985.38	1017.18	951.08
EXPECTED MAIN STEAM TEMP	5 Exp Main Steam Temp	5TMSX	DEG F	1000.00	1000.00	999.98
REHEAT STEAM PATH						
RH OUTLET A	5 Selected RH Stm Temp A	AL5SS62S	DEG F	970.85	995.35	913.47
RH OUTLET B	5 Selected RH Stm Temp B	AL5SS63T	DEG F	958.63	980.15	890.08

Viewing Short Version of PI Data

CLIFFSIDE STEAM STATION, UNIT 5				NOx TESTING DATA		
Summary of 24 Hours to Midnight on:	4/4/2003 0:00					
Total hours flue-gas passed over catalyst @ load > 0 MW	18 Hours					
Between 00:00 hour and 01:00 hour.						
Hours flue-gas passed over catalyst @ load ≥ 425 MW:	18 Hours					
Between 00:00 hour and 01:00 hour.	**(Hourly averages are shown starting from column "H")**					
Hours flue-gas passed over catalyst @ load ≥ 580 MW:	**16 Hours**					
Between 00:00 hour and 01:00 hour.	**(Average, Maximum and Minimum values are shown in columns "E", "F" and "G" respectively)**					
PI Performance Data						
Description	***PI Descriptor***	***PI Tag***	***PI UNITS***	**Average**	**Maximum**	**Minimum**
NH3 Injection Skid						
INJ HDR LIQ NH3 SUB CL TEM	INJ HDR LIQ NH3 SUB CL TEM	AL5CR300	DEG F	334.55	380.65	308.02
SCR A NH3 INJ HEADER FLOW	SCR A NH3 INJ HEADER FLOW	FT5CR41A	PPH	1.02	1.35	0.09
SCR B NH3 INJ HEADER FLOW	SCR B NH3 INJ HEADER FLOW	FT5CR42A	PPH	-2.22	-2.02	-2.42
SCR A NH3 INJ FLOW VLV A D	SCR A NH3 INJ FLOW VLV A D	FZ5CR41A	PCT	0.00	0.00	0.00
SCR A NH3 INJ FLOW VLV B D	SCR A NH3 INJ FLOW VLV B D	FZ5CR41E	PCT	0.00	0.00	0.00
SCR B NH3 INJ FLOW VLV A D	SCR B NH3 INJ FLOW VLV A D	FZ5CR42A	PCT	0.00	0.00	0.00
SCR B NH3 INJ FLOW VLV B D	SCR B NH3 INJ FLOW VLV B D	FZ5CR42E	PCT	0.00	0.00	0.00
SCR NH3 SUPPLY PRESS	SCR NH3 SUPPLY PRESS	PT5CR40A	PSIG	123.74	147.03	91.37
SCR NH3 SUPPLY TEMP	SCR NH3 SUPPLY TEMP	TE5CR40A	DEG F	73.23	81.53	63.42
SCR NH3 INJ HEADER A TEMP	SCR NH3 INJ HEADER A TEMP	TE5CR41A	DEG F	300.13	304.15	291.50
SCR NH3 INJ HEADER A DIL A	SCR NH3 INJ HEADER A DIL A	TE5CR41E	DEG F	305.97	311.01	295.94
SCR NH3 INJ HEADER B TEMP	SCR NH3 INJ HEADER B TEMP	TE5CR42A	DEG F	306.23	311.31	296.67
SCR NH3 INJ HEADER B DIL A	SCR NH3 INJ HEADER B DIL A	TE5CR42E	DEG F	312.36	318.09	301.54
SCR NH3 INJ FLOW VLV A1 PO	SCR NH3 INJ FLOW VLV A1 PO	ZT5CR41A	PCT			
SCR NH3 INJ FLOW VLV A2 PO	SCR NH3 INJ FLOW VLV A2 PO	ZT5CR41B	PCT	-0.90	-0.87	-0.92
SCR NH3 INJ FLOW VLV B1 PO	SCR NH3 INJ FLOW VLV B1 PO	ZT5CR42A	PCT	-0.40	-0.34	-0.43
SCR NH3 INJ FLOW VLV B2 PO	SCR NH3 INJ FLOW VLV B2 PO	ZT5CR42B	PCT			
Dilution Air Skid						
SCR A DIL AIR FLOW	SCR A DIL AIR FLOW	FT5CR41E	PPH	0.38	0.42	0.34
SCR B DIL AIR FLOW	SCR B DIL AIR FLOW	FT5CR42E	PPH	0.47	0.51	0.44
SCR DIL AIR FAN A DISCH TE	SCR DIL AIR FAN A DISCH TE	TE5CR46A	DEG F	73.03	85.30	51.52
SCR DIL AIR FAN B DISCH TE	SCR DIL AIR FAN B DISCH TE	TE5CR46E	DEG F	67.03	77.10	48.95
SCR DIL AIR STM COIL A OUT	SCR DIL AIR STM COIL A OUT	TE5CR47A	DEG F	318.82	323.78	308.23
SCR DIL AIR STM COIL B OUT	SCR DIL AIR STM COIL B OUT	TE5CR48A	DEG F	185.66	193.54	179.53
SCR DIL AIR FAN DISCH PRES	SCR DIL AIR FAN DISCH PRES	PT5CR46A	INWC	5.42	7.13	3.81
DILUTION AIR HTR STM PRESS	DILUTION AIR HTR STM PRESS	PT5CR616	PSIG			
DILUTION AIR HTR STM PR	DILUTION AIR HTR STM PR	PV5CR618	PCT			
SCR DIL AIR STM COIL A STM	SCR DIL AIR STM COIL A STM	ZT5CR47A	PCT	74.86	99.76	43.16
SCR DIL AIR STM COIL B STM	SCR DIL AIR STM COIL B STM	ZT5CR48A	PCT	0.88	0.97	0.82

Cliffside Unit 5 SCR Management



Time Passing Across the Catalyst

SCR Management			
CLIFFSIDE STEAM STATION, UNIT 5			
Hour of Flue-Gas Passing Over the Catalyst			
Summary	Total-to-date		
	4/4/2003	2003	2002
Total hours flue-gas passed over catalyst @ load > 0 MW:	2,123	18	2,105
Hours flue-gas passed over catalyst @ load ≥ 425 MW:	1,641	18	1,623
Hours flue-gas passed over catalyst @ load ≥ 580 MW:	1,154	16	1,138

Conclusions

- Optimum Catalyst Designs are Achievable With Current and Future Fuel Knowledge
- Limestone Addition Reduces Gaseous As
- Limestone Addition Protects
- Limestone Adds to Fuel Flexibility
- Limestone System is Part of an Integrated SCR Reactor Design, Fuel Purchase, Catalyst Management, and Plant Operation Approach