Worldwide Pollution Control Association

ESKOM Scrubber Seminar

April 12th – 13th, 2007

Visit our website at www.wpca.info

Duke Carolinas Scrubbers

Scott Williams

Background

North Carolina Clean Air Plan
aka NCCAP

- Enacted 2002

- 150,000 tons SO2/yr. cap by 2009
- 80,000 tons SO2/yr. cap by 2013
- 264,000 tons SO2 emitted 2003

Background

Duke Power FGD Program

Station/Unit	Location	Net Capacity Each (MW)	Expected Startup
Allen 1 & 2	Belmont, NC	165	2009
Allen 3, 4 & 5	Belmont, NC	275	2009
Belews Creek 1 & 2	Walnut Cove, NC	1120	2008
Cliffside 5	Cliffside, NC	560	2010
Marshall 1 & 2	Terrell, NC	385	2007
Marshall 3 & 4	Terrell, NC	660	2007/2006

Background

- Challenges
  - Multiple Base Load Stations Affected
  - Minimal FGD Experience
  - Regulatory Uncertainty
  - Minimal Available Space
  - Fuel Uncertainty
  - Rising Raw Material Costs

- Strategy
  - System Wide Approach
  - Standardize As Much As Reasonable
  - Involve Primary Contractors Upfront
  - Emphasis On Planning Prior To Execution

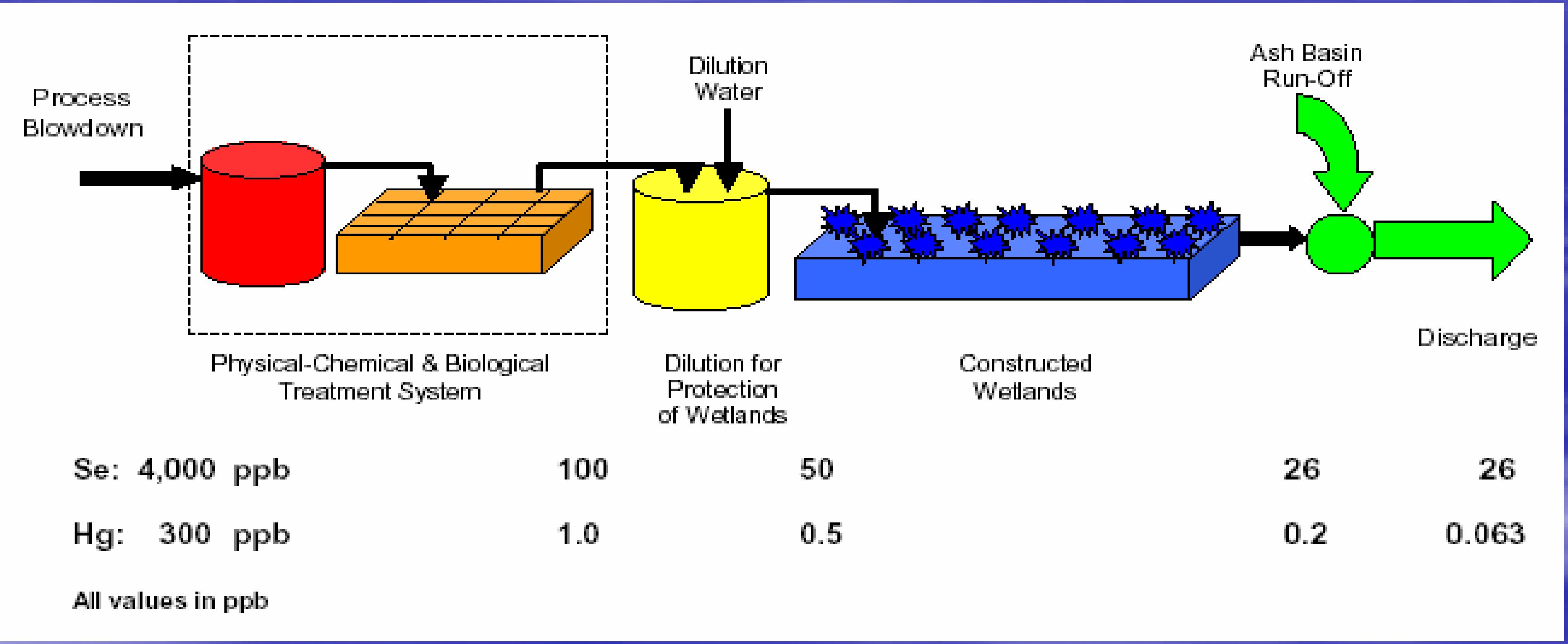
Marshall Progress

Marshall Progress

Belews Creek - Progress

Belews Creek - Progress

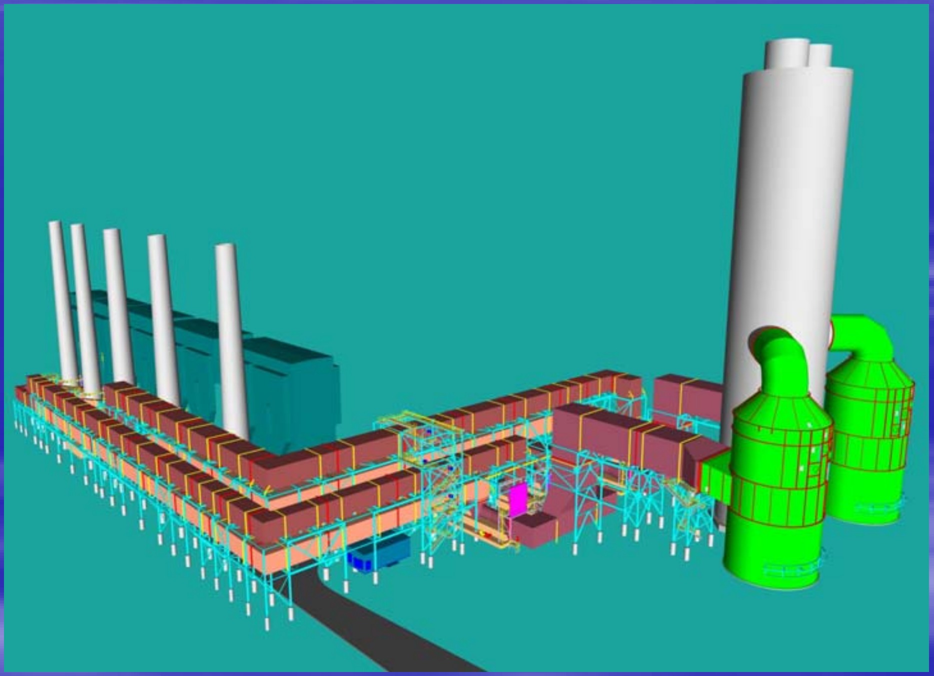
Belews Creek Unique Features – Wastewater Treatment



Allen Unique Features – Flue Gas Handling

Lengthy Duct Runs

- Minimal space requires remote location of absorbers
- Duct runs exceed 700 feet
- Axial booster fans
- Constructability reviews to minimize impact on existing plant operations



Scrubber Integration

Scott Williams
Duke Energy

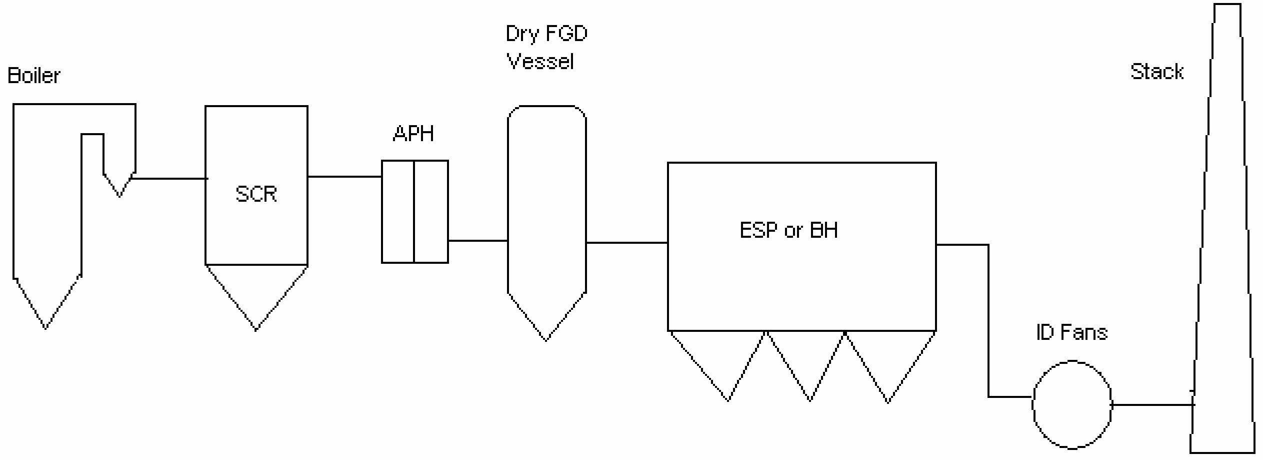
Combustion System Issues

- Dry or Wet Scrubber?
- What fuels will the plant burn?
- Do we Upgrade Existing Fans of Add "booster fans"?
- Boiler/Duct Structural Evaluation ?

- What do we do with the byproduct?
- If the stack is not reheated… what about H2 SO4 emissions- “blue plume”?
- Is a Wet ESP needed for H2SO4 removal?
- What about future emission regulations?
  - Mercury?
  - SO3 ?
  - NOx ?

Dry or Wet FGD-Critical Decision ?

- Dry Attributes
  - – Fewer moving parts
  - – Maintenance cost lower
  - – Lime typically more expensive- may use less
  - – Transportation cost and availability of Lime
  - – More difficult to retrofit into existing plant
  - – Better suited for low sulfur installations
  - – Also removes SO3



Dry FGD Block Diagram

$Ca(OH)_2$+ SO_2 yields $CaSO_3$-1/2 H20+1/2H20

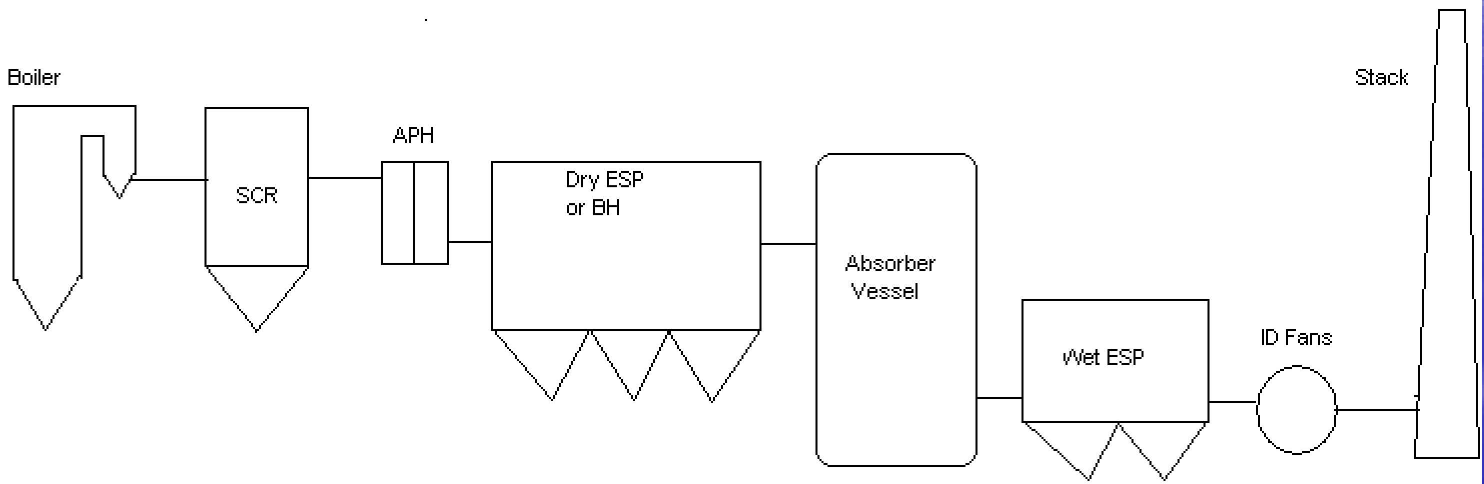
$Ca(OH)_2$ +SO_3 + H_2O yields $CaSO_4$ –$2H_2O$

$CaSO_3$ + 1/$2H_2O$ yields $CaSO_4$

Wet

- More complicated process
- More equipment to maintain
- High Water Usage
- More reagent required- May be lower cost/ton
- Transportation cost of limestone/ availability
- Retrofits into existing unit- Easier to build with plant “on-line”
- Better suited for higher Sulfur Installations

SO_2 + $CaCO_3$ + 1/2H_2O yields $CaSO_3$ - 1/2 H_2O +CO_2
SO_2 + 1/2O_2 +$CACO_3$ +2H_2O yields $CaSO_4$ - 2H_2O +CO_2 [i]



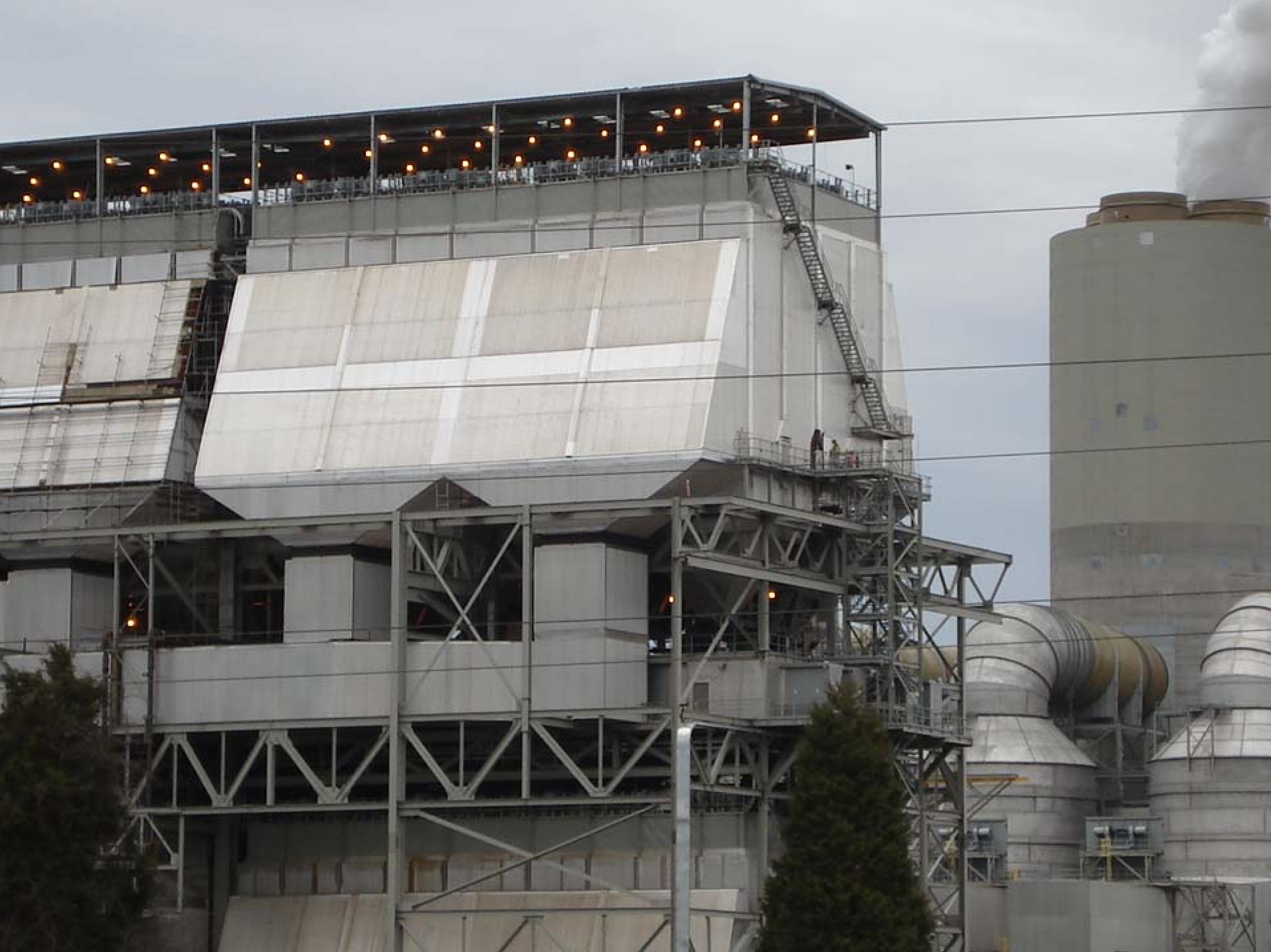
WET FGD Block Diagram

What Fuel will the Plant Burn-Critical Decision?

- The addition of a scrubber will allow expanding fuel supplies to higher SO2 fuel if engineered to do so.
- Part of this decision making process is to determine what the impacts of a fuel change will be on the “balance of plant”.
- A thorough analysis is required.

Particulate Control

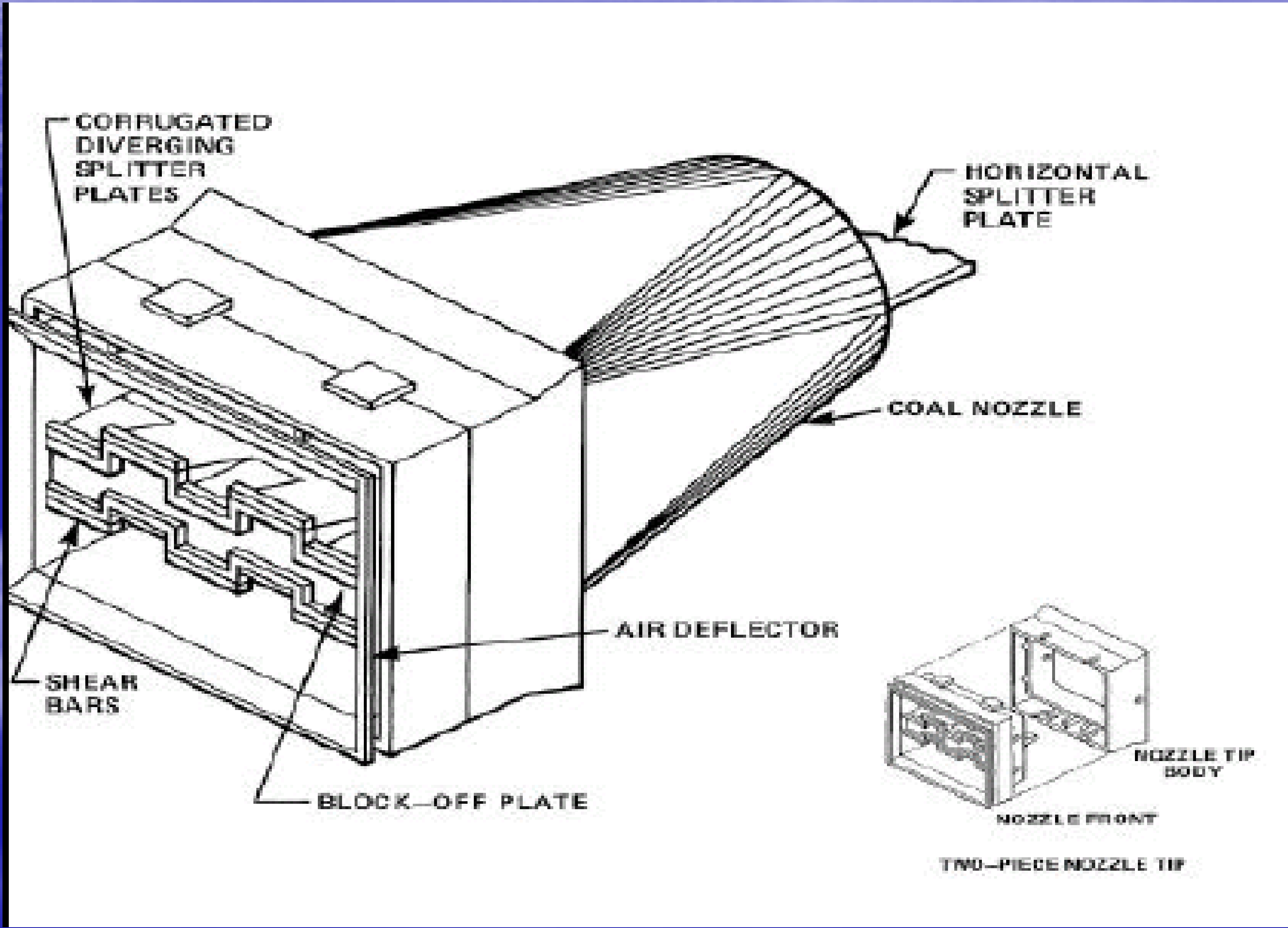
- Is the ESP/BH sized appropriately?
- The function of the Particulate Control changes somewhat to include being a filter for the scrubber.
- Typically, if sale quality gypsum is required a maximum particulate is required into the WFGD- In the Duke Energy case- 86 mg/SM3.



NOX Equipment

- Low NOx burners increase unburned carbon in the ash, which if not properly regulated, cause collection issues with particulate control equipment. Also tends to be smoldering coal carryover downstream.
- Typically, dynamic or static classifies are required, with additional mill calibration attention.
- In our case, LOI is up to 20% on several units with Low NOx burners.

Low NOx Burners

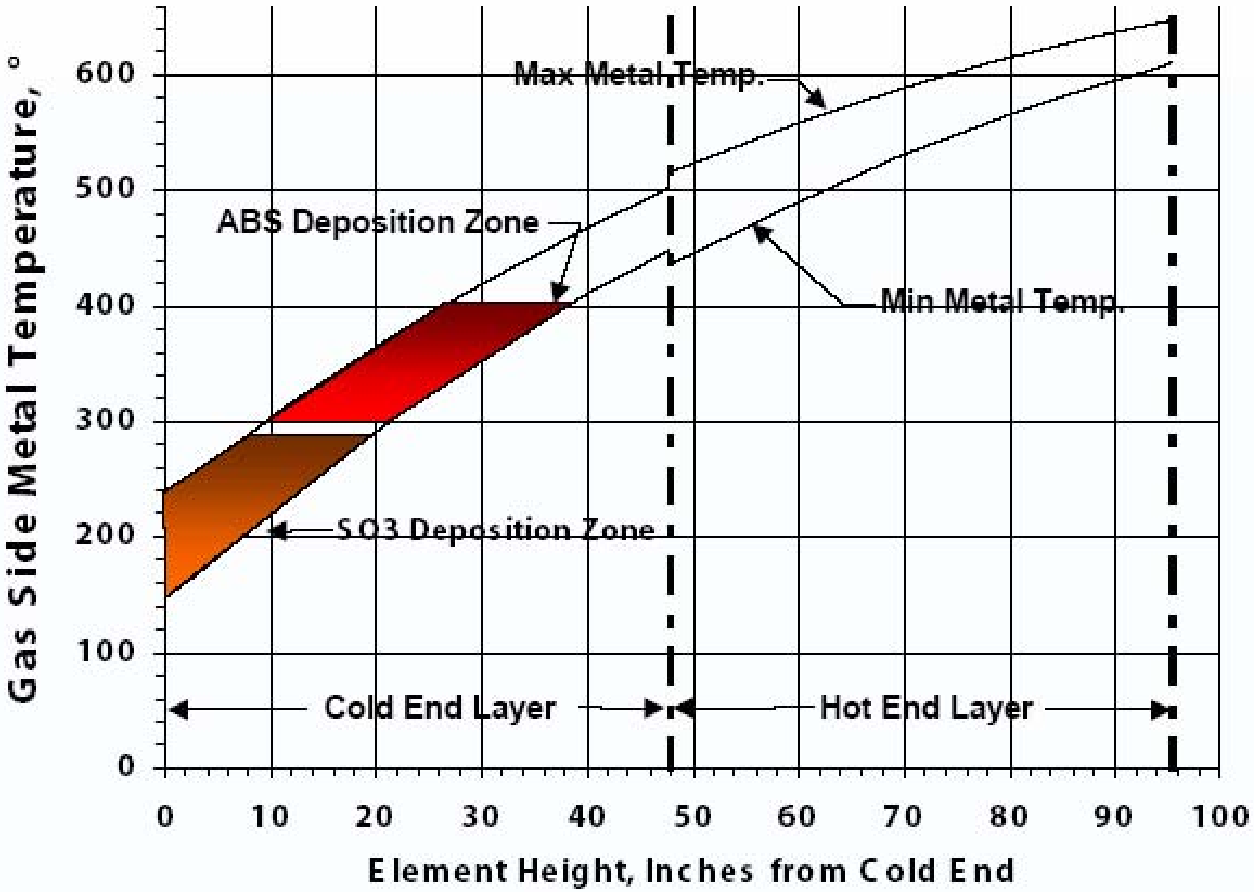


Preheater/Selected Catalytic Reduction Issues

ABS & Fouling Concerns

- SCR equipment adds the potential for fouling the air preheater cold end baskets with not only ammonium bisulfate (ABS) deposits but also SO_3 .
- ABS deposits form in a temperature range of 300^{o}F (148 C) to 400^{o}F (205 C).
- SO_3 deposition occurs from 275^{o}F (135 C) and below.
- The planned use of higher sulfur fuels further increases SO_3 levels which tends to expand the ABS deposition zone to the upper temperature limit, & it will increase SO_3 fouling rates at the cold end.

Cliffside
Unit 5
ABS & SO3 Deposition Zone, DU/DUe



Selected Catalytic Reactor Issues (SCR)

- Levels of Calcium Oxide and Arsenic in the ash are the major concern.
- The SO2 to SO3 conversion rate of the catalyst is a major issue.- This increases the SO3 in the flue gas stream- “blue plume”
- Unit does not have as much “turn-down” due to temperature restrictions on Catalyst.
- Limestone injection may be required is high Arsenic in coal.

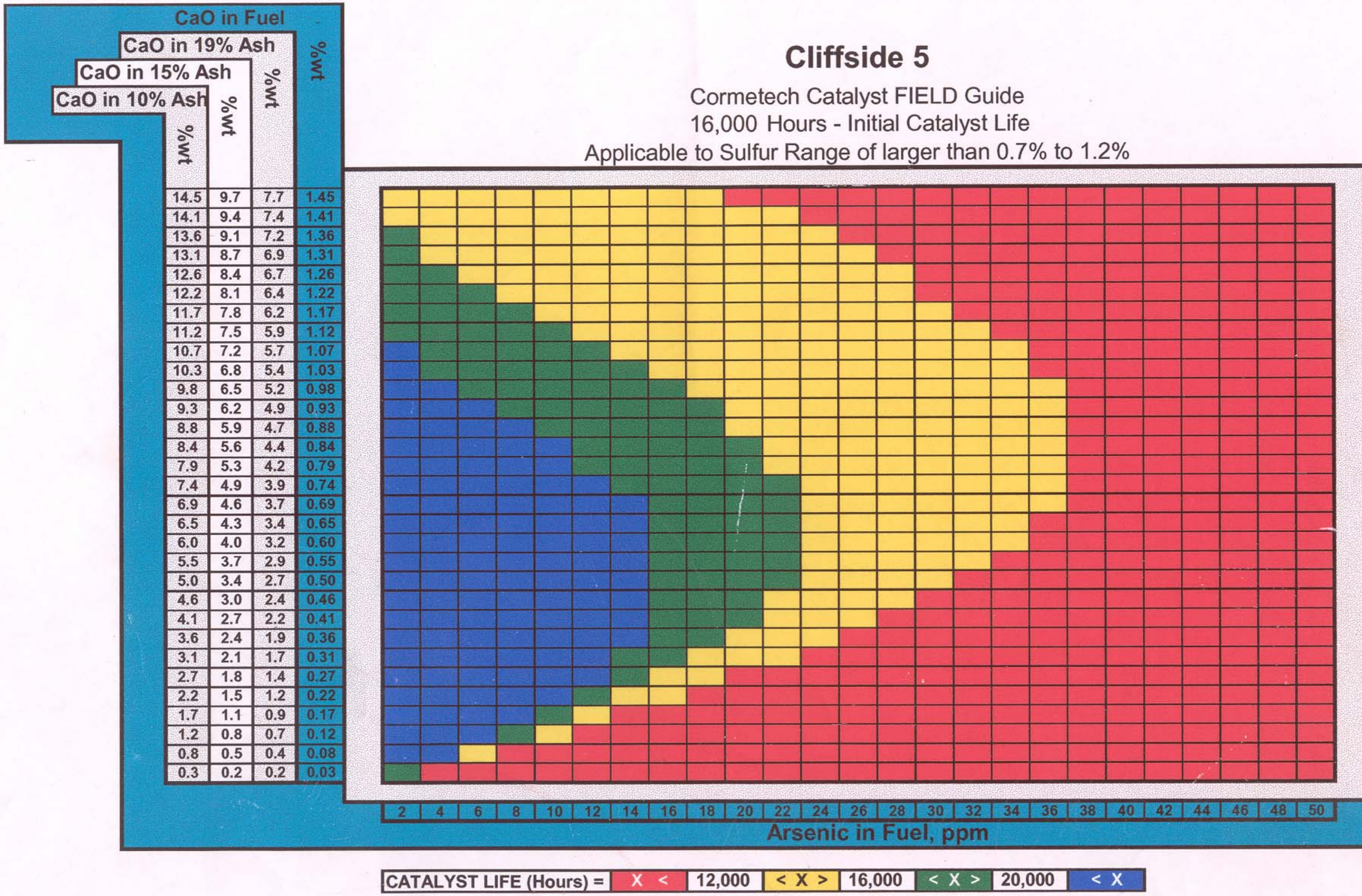

12 8:26AM

Cliffside 5

Cormetech Catalyst FIELD Guide

16,000 Hours - Initial Catalyst Life

Applicable to Sulfur Range of larger than 0.7% to 1.2%

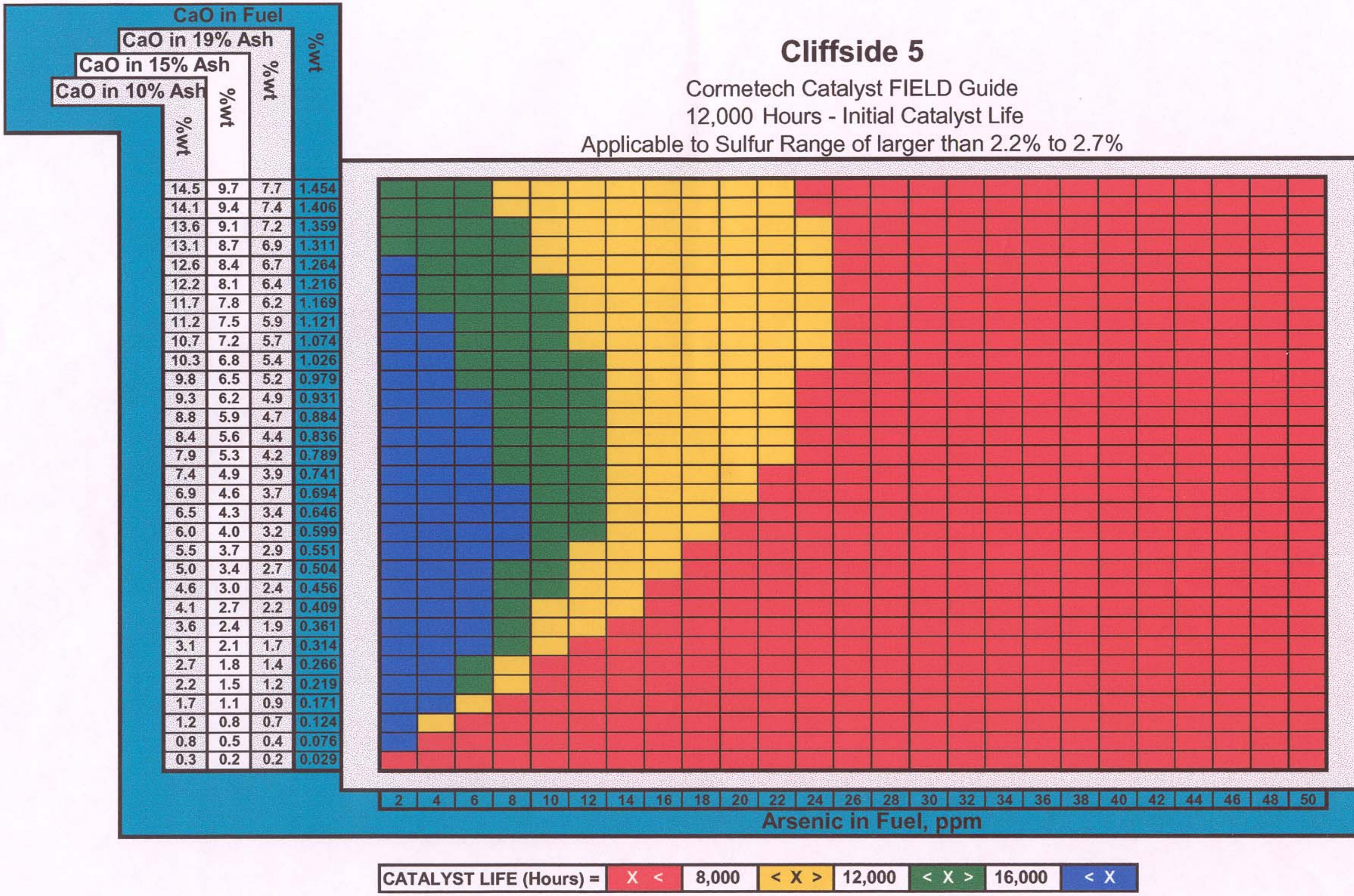


Cliffside 5

Cormetech Catalyst FIELD Guide

12,000 Hours - Initial Catalyst Life

Applicable to Sulfur Range of larger than 2.2% to 2.7%



Ash Removal System

- Typically the removal capability of the ash system is known. For example, the system may be designed to remove 20% ash coals.
- However, certain coals do not convey well with wet ash systems. Conversion to burn high calcium fuels may require a conversion to a “dry ash” system.

Boiler and Pulverizer Evaluation

- It will be necessary to evaluation the Following:
  - – Total Fuel Flow
  - – Ash Flow
  - – Flue Gas Velocity
  - – Boiler Slagging- Furnace
  - – Boiler Fouling- Backpass

Boiler Parameters to be Evaluated

- NOx output from Furnace
- Sox output from Furnace
- Unburned Carbon

Marshall 1 and 2 Boiler

350 MWs - MCR

Controlled Circulation

Divided Furnace Design

Main Steam Flow = 2,400,000 Lbs/hr

SHO Steam Temp.= 1050 °F

RHO Steam Temp. = 1000 °F

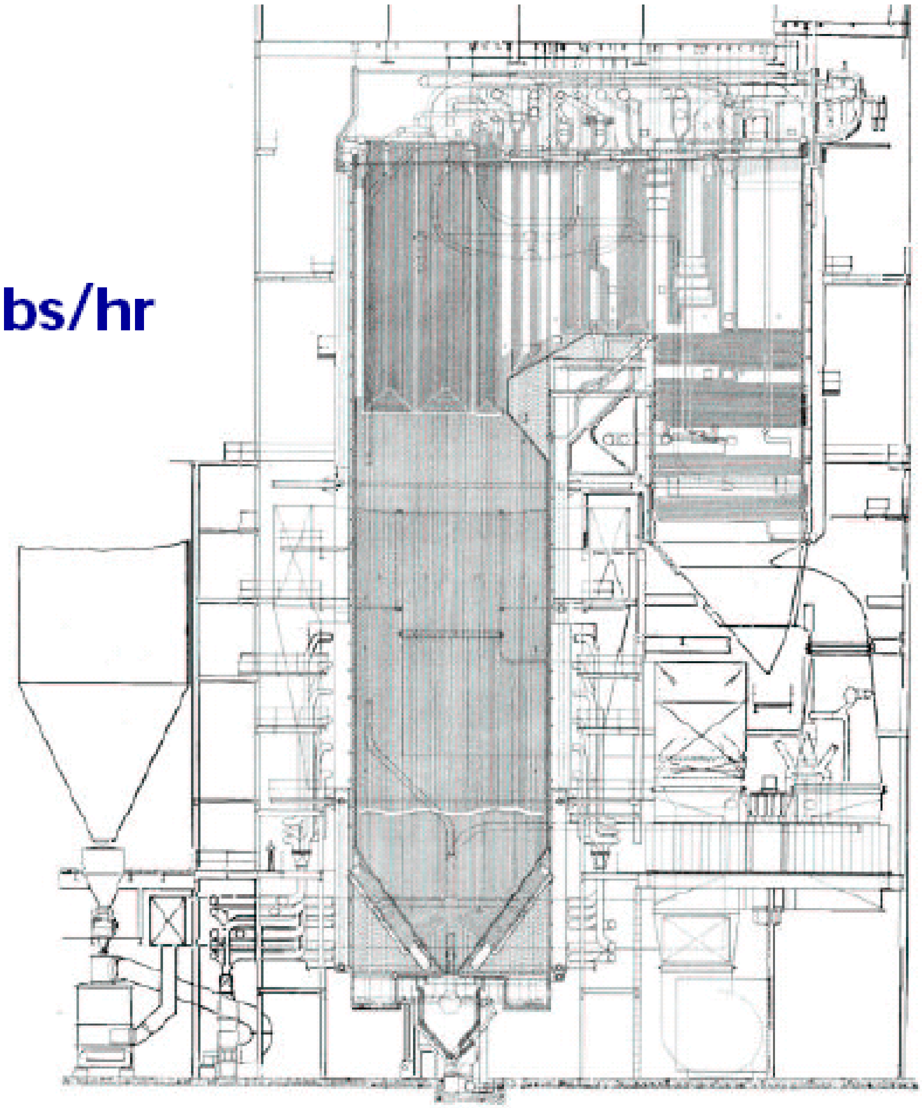
SHO Pressure = 2450 psig

RHO Pressure = 502 psig

FW Temp. = 478 °F

(5) 763 RB Pulverizers/Boiler

NHI/PA = 1.70 MBtu/hr-ft^2



Total Coal for Marshall Station 1 & 2

	Fuel One		Fuel Two		Total Coal	Performance Rating
Blend	Type	%	Type	%	%	
Base	Original Design Coal				Base	
5	NA1	50	CA2-MS	50	6.11	BEST
11	NA2	33	CA2-MS	67	6.45	
2	NA1	33	CA2-MS	67	6.97	
4	NA1	50	CA1-MS	50	8.99	
6	NA1	50	COL	50	10.13	
10	NA2	25	CA1-MS	75	11.45	
9	NA1	67	CA3-MS	33	11.64	
1	NA1	25	CA1-MS	75	11.88	
12	NA2	33	COL	67	11.95	
3	NA1	33	COL	67	12.52	
Reference	CA1-MS	100			15.16	
7	NA1	67	PRB1	33	17.30	
8	NA1	67	PRB2	33	18.80	WORST
13	NA2	33	CA3-MS	67	20.61	

- Less than 10% more than Original Design
- Between 10% and 20% above Original Design
- More than 20% above Original Design

Ash Flow at Marshall Station 1 & 2

	Fuel One		Fuel Two		Ash	Performance Rating
Blend	Type	%	Type	%	%	
Base	Original Design Coal				Base	
7	NA1	67	PRB1	33	-17.77	BEST
6	NA1	50	COL	50	-15.77	
3	NA1	33	COL	67	-15.37	
12	NA2	33	COL	67	-11.82	
8	NA1	67	PRB2	33	-4.79	
5	NA1	50	CA2-MS	50	16.83	
4	NA1	50	CA1-MS	50	19.23	
2	NA1	33	CA2-MS	67	28.65	
11	NA2	33	CA2-MS	67	31.82	
1	NA1	25	CA1-MS	75	38.71	
10	NA2	25	CA1-MS	75	41.18	
Reference	CA1-MS	100			59.59	
9	NA1	67	CA3-MS	33	70.77	WORST
13	NA2	33	CA3-MS	67	179.19	

- Less than 10% more than Original Design

- Between 10% and 20% above Original Design

- More than 20% above Original Design

Recommended Maximum Gas Velocity for Marshall 1 to 2

	Fuel One		Fuel Two		Max Velocity		Performance	Gas Wt. 1 & 2
Blend	Type	%	Type	%	ft/sec	%	Rating	%
Base	Average Current Coal				57	Base		Base
7	NA1	67	PRB1	33	67	17.5		0.72
6	NA1	50	COL	50	63	10.5	BEST	0.76
8	NA1	67	PRB2	33	63	10.5		2.06
3	NA1	33	COL	67	62	8.8		1.10
12	NA2	33	COL	67	62	8.8		0.99
5	NA1	50	CA2-MS	50	61	7.0		-0.32
2	NA1	33	CA2-MS	67	60	5.3		-0.39
11	NA2	33	CA2-MS	67	60	5.3		-0.48
4	NA1	50	CA1-MS	50	59	3.5		0.06
1	NA1	25	CA1-MS	75	58	1.8		0.18
10	NA2	25	CA1-MS	75	57	0.0		0.10
Reference	CA1	100			55	-3.5		1.12
9	NA1	67	CA3-MS	33	54	-5.3	WORST	-0.30
13	NA2	33	CA3-MS	67	48	-15.8		-0.60

- Equal or greater than the Current Average Coal
- Less than the Current Average Coal, but not by more than 10 %
- Less than the Current Average Coal, by more than 10 %

Duke Power - Marshall Station

NOx Ranking of Proposed Coal Blends

MS Blend #	NA Coal	%	Other	%	NOx Performance	Reduction from Current NOx - %
7	NA1	67	PRB1	33		24-28%
8	NA1	67	PRB2	33	BEST	24-28%
12	NA2	33	COL	67	↑	20-24%
3	NA1	33	COL	67		20-24%
6	NA1	50	COL	50		19-23%
4	NA1	50	CA1	50		19-23%
10	NA2	25	CA1	75		19-23%
1	NA1	25	CA1	75		19-23%
11	NA2	33	CA2	67		18-22%
5	NA1	50	CA2	50		18-22%
9	NA1	67	CA3	33	↓	18-22%
2	NA1	33	CA2	67	WORST	17-21%
13	NA2	33	CA3	67		16-20%

Duke Power - Marshall Station

Proposed Coal Blend SOx Ranking

MS Blend #	NA Coal	%	Other	%	Predicted SO_x[1] - lb/MBtu
2	NA1	33	CA2	67	2.1
3	NA1	33	COL	67	2.2
1	NA1	25	CA1	75	2.4
5	NA1	50	CA2	50	2.5
6	NA1	50	COL	50	2.5
11	NA2	33	CA2	67	2.7
12	NA2	33	COL	67	2.8
8	NA1	67	PRB1	33	2.8
4	NA1	50	CA1	50	2.8
8	NA1	67	PRB2	33	2.9
13	NA2	33	CA3	67	2.9
10	NA2	25	CA1	75	2.9
9	NA1	67	CA3	33	2.9

Note 1 - Predicted SOx assumes 100 % conversion of Sulfur to SO2

Pulverizers

Fuel	Coal ID	Original	1	2	3	4	5	6
	Blend		NA1 & CA1-MS	NA1 & CA2-MS	NA1 & COL	NA1 & CA1-MS	NA1 & CA2-MS	NA1 & COL
	%	100	25 : 75	33 : 67	33 : 67	50 : 50	50 : 50	50 : 50
odeled Rank		EBIT	EBIT	EBIT	MWB	EBIT	EBIT	MWB
odeled HGI		55	39	41	45	39	41	45
odeled Moisture		5.0%	7.2%	5.5%	9.5%	5.5%	5.5%	8.5%
00 Mesh Fineness	%	70	70	70	70	70	70	70
aximum Mill Capacity	lbs/hr	106,000	83,443	86,263	91,902	83,443	86,263	91,902
equired Coal Flow - lbs/hr	lbs/hr	86,800	73,912	70,669	74,335	72,004	70,098	72,754
ill in Service		5	6	6	6	6	6	6
Capacity @ MCR	%	82%	89%	82%	81%	86%	81%	79%
vailable Primary Air Temp	°F	594	594	594	594	594	594	594
equired Primary Air Temp	°F	371	391	339	382	344	338	365
rimary Air Mass Flow	lbs/hr	159000	159000	159000	159000	159000	159000	159000
uel Line Velocity	ft/sec	91	90	91	89	91	91	89

Electrical Auxilliaries

- At Marshall Station- 2200 mW total
- An additional 40 mW of power will be used for Auxillaries to power the Wet Scrubber

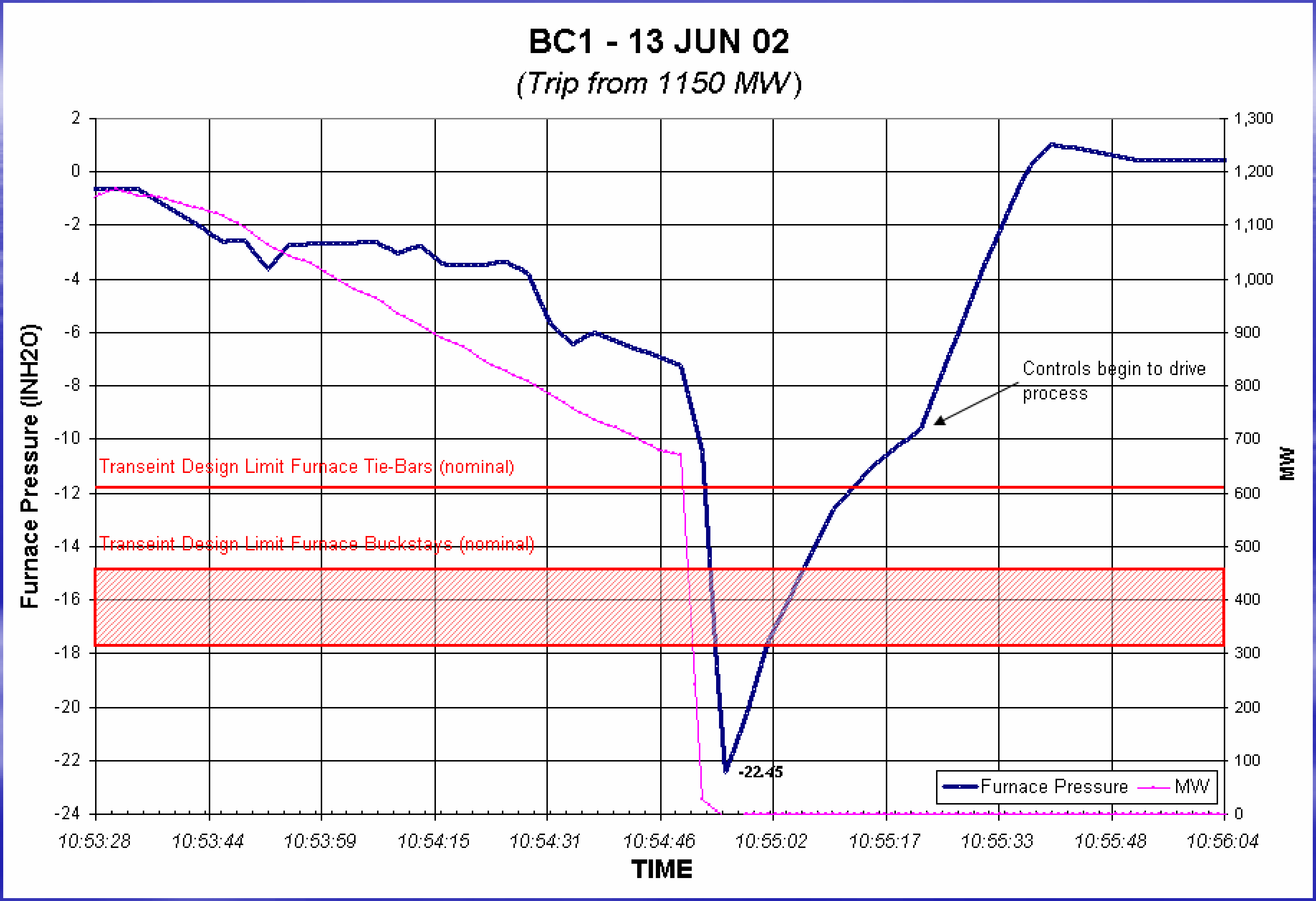
Reinforce the Exiting Combustion System or Open Bypass-Critical Decision

- With the addition of a Wet or Dry FGD (scrubber) fans will need to be upgraded or booster fans added to account for the additional pressure drop in the duct and absorber vessel. These fans will pull more vacuum/pressure on the combustion system.
- This fan upgrade will require a complete structural review of the “combustion system” including the boiler, ductwork, and Particulate Control Devices.

- This Structural Evaluation should include both operating and transcient conditions.
- Transcient Conditions include Master Fuel Trips, Fan “run out”

NFPA 85 (8502)

- *Standard for the Prevention of Furnace Implosions in Multiple Burner Boiler-Furnaces*
  - "The furnace shall be capable of withstanding a transient design pressure without permanent deformation due to yield or buckling of any support member.
  - The transient design pressure shall be at least, but shall not be required to be greater than, -35 IN H2O


BC1 - 13 JUN 02
(Trip from 1150 MW)
Furnace Pressure (INH2O)
MW
TIME
Transeint Design Limit Furnace Tie-Bars (nominal)
Transeint Design Limit Furnace Buckstays (nominal)
Controls begin to drive process
-22.45
Furnace Pressure
MW
2
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
1,300
1,200
1,100
1,000
900
800
700
600
500
400
300
200
100
0
10:53:28
10:53:44
10:53:59
10:54:15
10:54:31
10:54:46
10:55:02
10:55:17
10:55:33
10:55:48
10:56:04

Engineering Design of Boiler Stiffening

- Based on the results of the engineering study, the decision was made to proceed with the detailed engineering design based on complete stiffening of the B&W 1,200 MW Boiler.
- The final result of the engineering required 200 tons of steel – for a total of 22,766 pieces – placed on a 15-story boiler, with a total of 300,000 welds.

Front of Boiler Scaffolding

Buckstay Cover Plate Reinforcement

Open Stack Bypass

- Another option to deal with the boiler/duct implosion design is to leave the existing dry stack open, and design the fans for additional gas flow.
- The old dry stack acts as a “relief valve” for the combustion system.
- Transient analysis can be performed to determine the effects.


5/1/2006 Duke Marshall Steam

Where do we Put the Lime/Limestone and Byproduct ?- Critical Decision

- With the installation of a Wet Scrubber there will be two new piles of substances on the plant site
- For 2200 mW station, 1.6% sulfur coal, and 95% removal the gypsum production rate is expected to be 625,000 tons/year, which is about ½ the amount of ash that comes out of the plant (12% ash in coal).

Possibilities for Gypsum

- Landfill
- Sell or use to produce wallboard for construction
- Agricultural Supplement

Selling Gypsum

- There are a number of requirements to sell gypsum
- For example, emissions from the ESP or Baghouse will be limited in order to keep the “inerts” to 3-4% of the gypsum. This may cause a particulate control upgrade?

Heated or Unheated Stack?- Critical Decision

SO_3 Generation

- SO_3 is generated during the combustion process
- SO_2 is eliminated by the scrubber
- SO_3 is NOT eliminated by the wet scrubber
- When the flue gas temperature is reduced below the acid dew point H_2SO_4 (sulfuric acid) is formed

BLUE PLUME

- H_2SO_4 particles scatter the light more and increase opacity.
- This is called “blue plume”
- 10 ppm of SO_3 out of the scrubber stack produces .03 #/mmBTU of particulate emissions


2 11:24AM

It's a beautiful day in Mt. Carmel, IL.

Unheated Stacks-American Style

- With coal with sulfur percentage greater then 1.5% a “blue plume” may occur
- All unheated stacks have steam plumes
- A “blue plume lingers”, sometimes for kilometers, while the steam plume usually dissipates in a few hundred meters.
- Stack height is also an issue- The closer the top of the stack is to the ground the more likely a plume “touchdown” occurs.

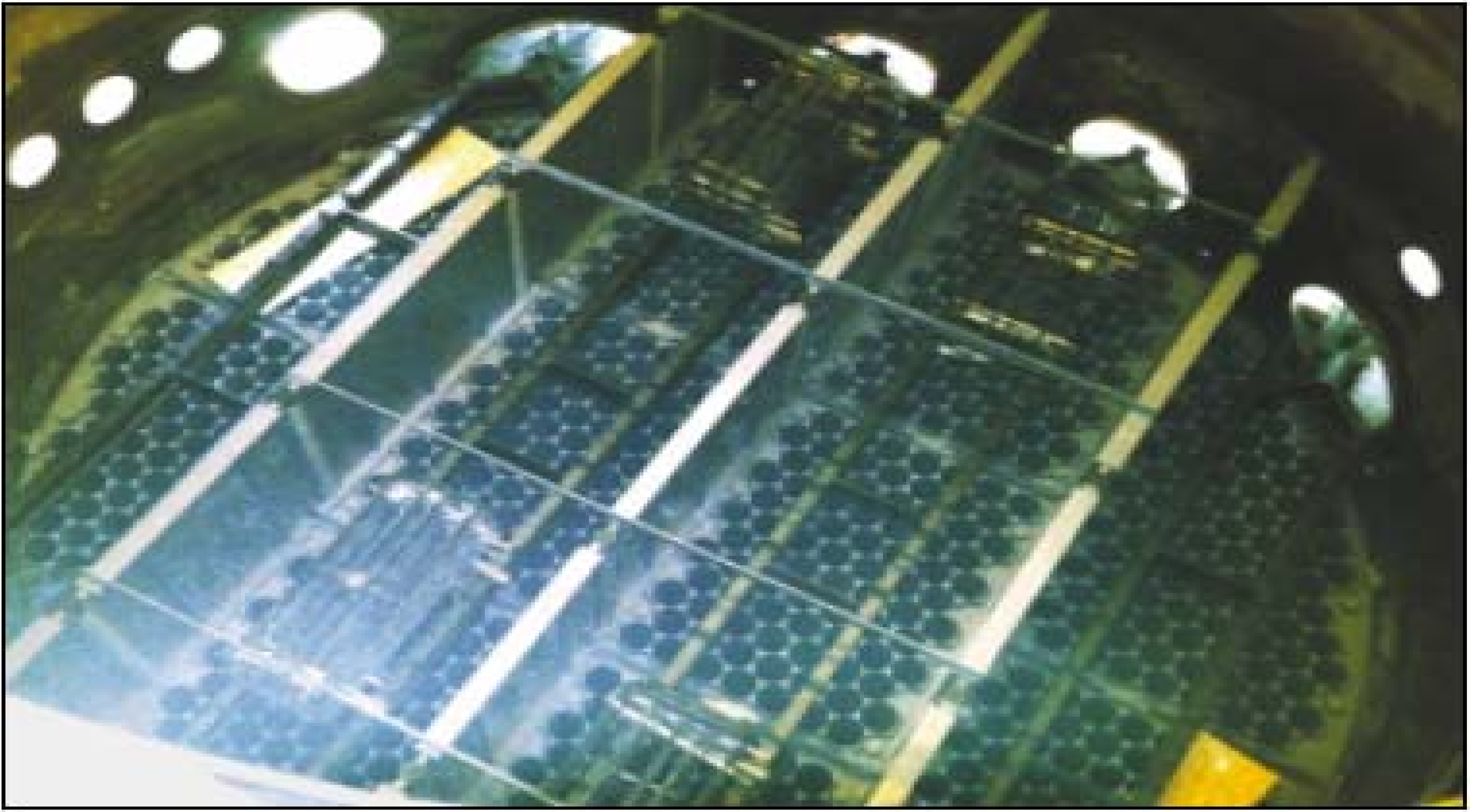
Heated Stack- European Style

- Gets rid of the visibility issue
- Negative impact on Heat rate
- Additional Cost

Is a Wet Precipitator Needed?

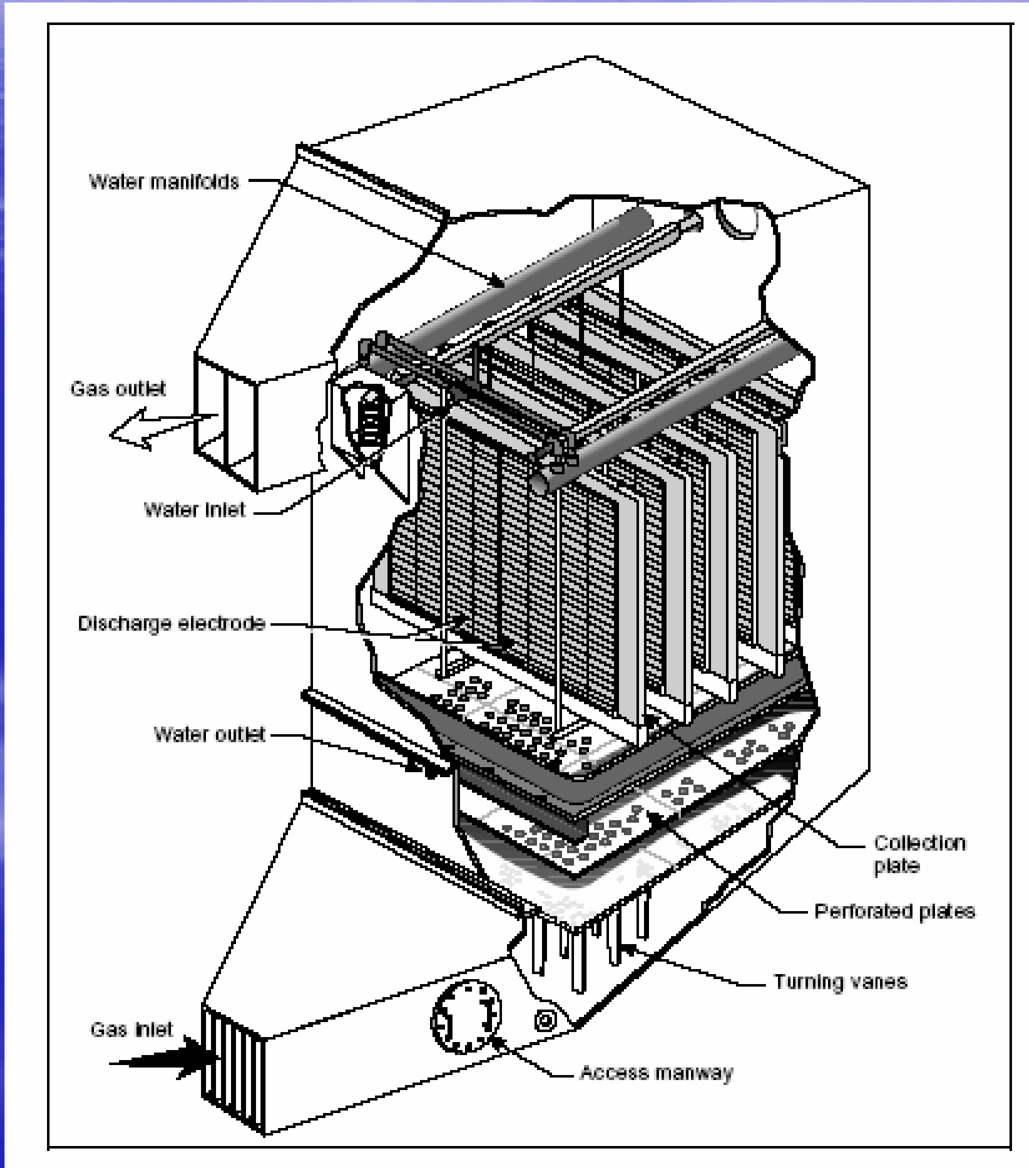
- Removes H2SO4 from the gas stream efficiently
- Will also remove other trace elements
- Intended to for “polishing” removal only
- Increased maintenance cost

Tubular Style Horizontal Flow WESP



Vertical Flow WESP- Cleans with Water- No rappers

Vertical Flow WESP



New Plant Limits

Pollutant	Permit Application (lb/MMBtu)	Proposed Approx. mg/Sm3
NOx	.08	115
SO2	.20	288
TSP	.015	21
PM10	.024	35
CO	.15	216
VOC	.004	6
H2SO4	.006	9
Fluorides	.0015	2
HCl	.0083	12
Lead	.000022	.03

That's All