REINHOLD ENVIRONMENTAL ®

2024 Reinhold/PCUG Round Table Presentation

Hosted by LG&E/KU and Co-hosted by Southern Co. and TVA

in The Marriott Resort Lexington Griffin Gate Hotel, Lexington, KY on June 24-25, 2024

Flue Gas Desulfurization Scrubber Basics 101

Presented by

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June 24, 2024

Reinhold PCUG Conference
Lexington, KY

Safety Starter

Before beginning work activity:

- Situation
- Task
- Action
- Result

Otherwise we never get Around Tuit!

Providing Clean Air since 1977

- Allied Chemical Pilot Plant 1977-1981
  Demonstration Plant attached to Dean H. Mitchell Station – NIPSCO

- NIPSCO 1981 -2007
  D. H. Mitchell Station
  Michigan City Generating Station
  R. M. Schahfer Station FGD Units 17 & 18
- Ameren 2007 – 2024 Hitachi FGD Systems
  Duck Creek Power Plant
  Coffeen Power Plant
  Newton Power Plant
  Sioux Energy Center
- Engaged in Environmentally Proactive Employment for my career

Entered workforce June 1973 - 1977 at Metal &Thermite Chemicals

Recycling Tin Stannates from soda cans, etc. to make chrome auto bumpers, auto trim, magnetic audiotape (8 track, cassette), etc.

Why Scrubbers?

- Clean Air Act of 1970
  Revisions made in 1977 and 1990
- Six Common Pollutants

  -Particulate Matter, Ozone, Sulfur Dioxide,

  Nitrogen Dioxide, Carbon Monoxide, Lead
- States required to adopt enforceable plans to achieve standard and control emissions drift across state lines and downwind states

Process Overview

- Three Basic Components
  - Reagent Preparation System
  - Absorber System
  - Waste Disposal System

Absorber Vessels

Vertical Spray Towers

Horizontal Spray Towers

Suspension versus solution

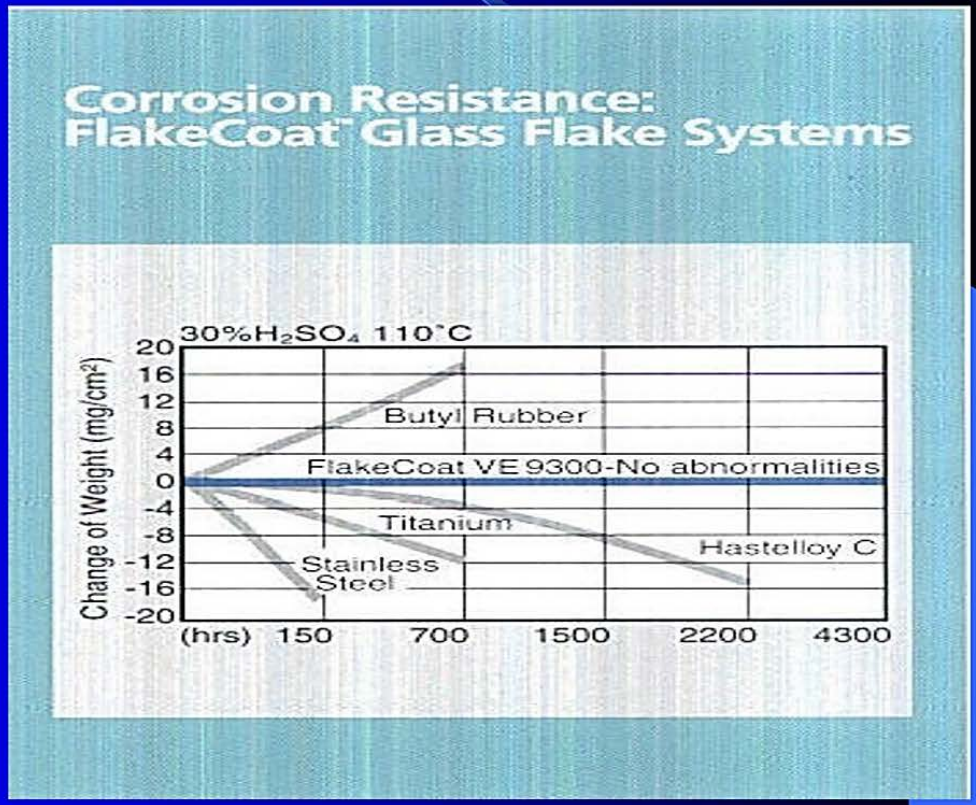
Oxidation Air to support chemical reaction

Agitation to support suspension
Acidic/Corrosive solution 4.5 – 8.0 pH

Absorber Materials of Construction

Comparison to Rubber and Alloy

- Corrosion Resistance

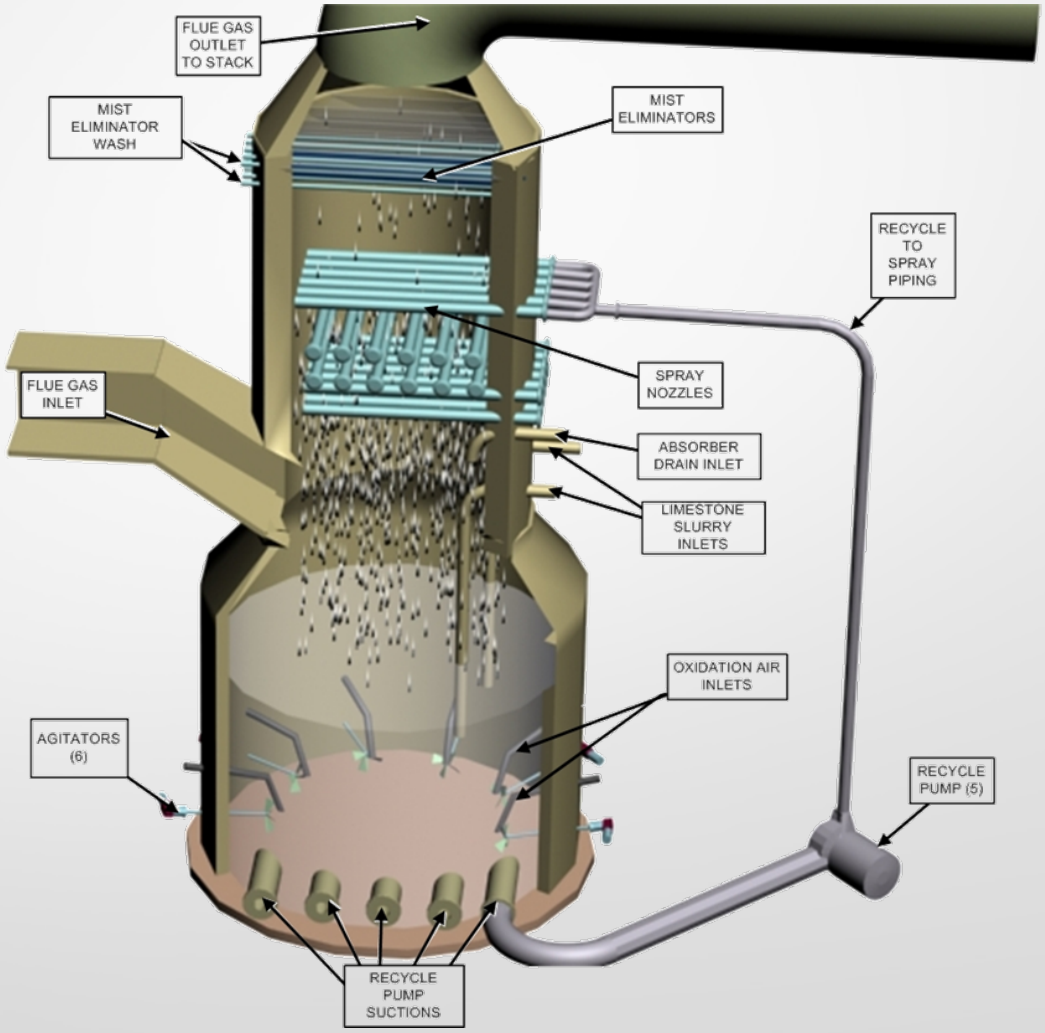


Absorber and Oxidation Systems

- Comprised of the:
  - Absorber Vessel
  - Limestone Slurry Feed System
  - Recycle Pump System
  - Absorber Bleed System
  - Oxidation Air System
  - Mist Eliminators and Inlet Duct Wash System
  - Temporary Slurry Storage System
  - Flush and Drain Systems

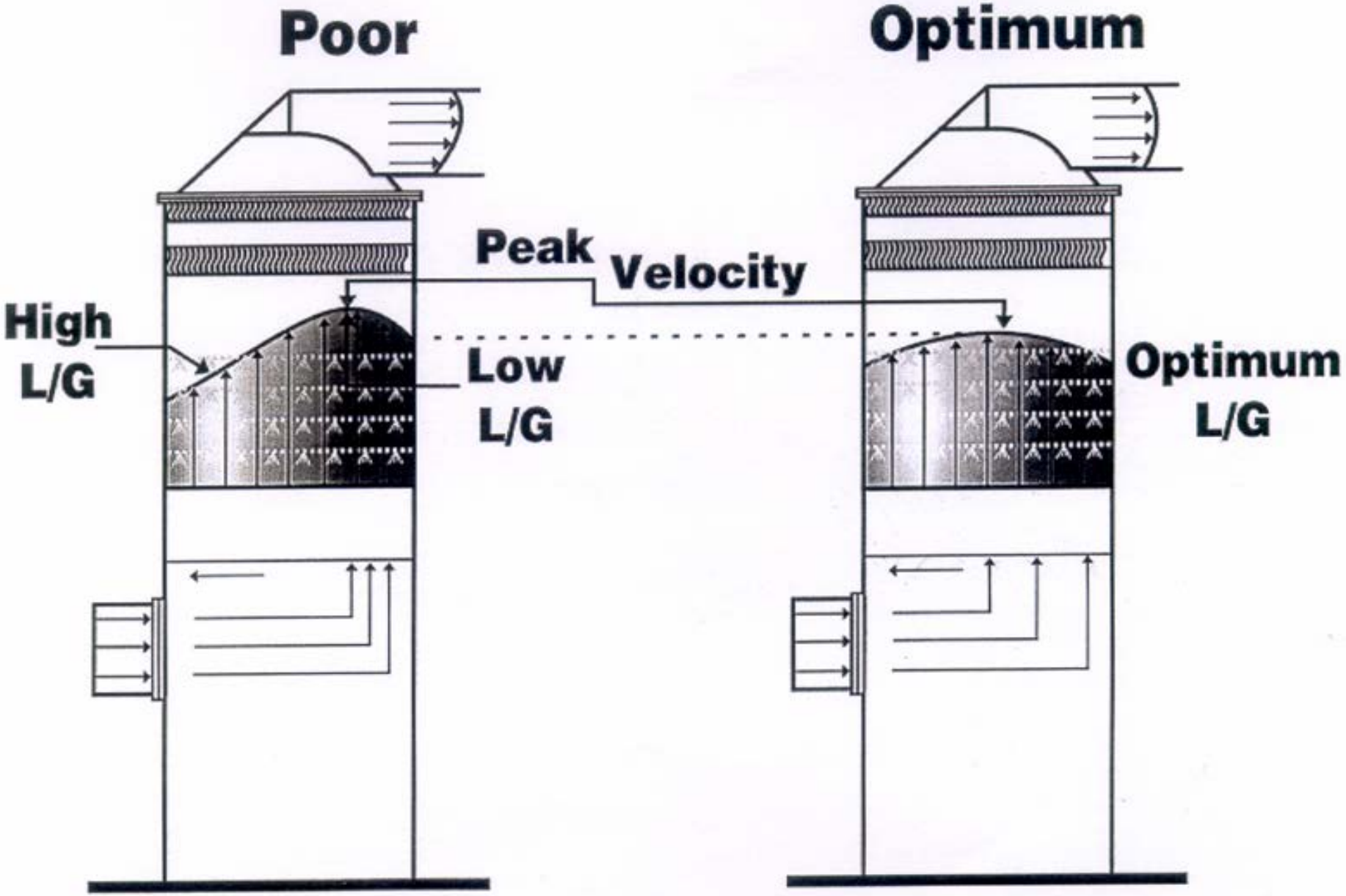
Absorber Vessel

- Heart of the system
  - 0.60 #/mmbtu SO_2 Federal emission limit
  - Typical removal rate of 94% with 2 of 5 Absorber Recylce Pumps in service @ 50,000 gpm flow
- All reactions take place here
- Zones within the vessel:
  - Gas contact zone
  - Reaction Tank
  - Inlet and Outlet Ducts



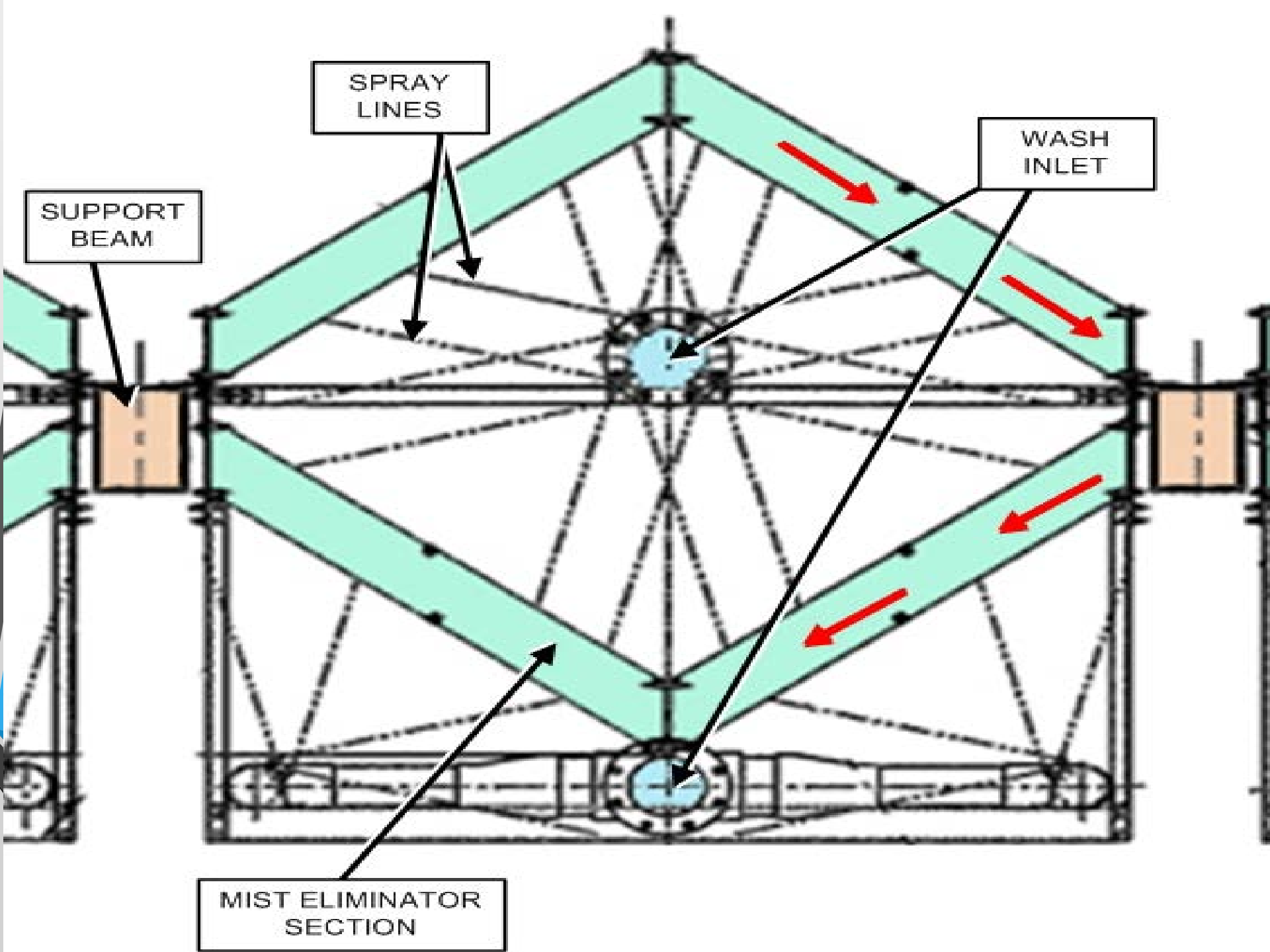
Absorber Spray Headers 50K gpm

Importance of Gas Flow Distribution



Mist Eliminators and Wash

- As the flue gas flows through the slurry it entrains or carries over some of the slurry out of the absorber vessel
- Removed from the flue gas stream by the Mist Eliminators
- Can remove 98 % of the entrained slurry mixture from the flue gas prior to its exiting to the stack


SPRAY LINES
WASH INLET
SUPPORT BEAM
MIST ELIMINATOR SECTION

Mist Eliminator Configurations

Mist Eliminator Build Up

MW TIME: 05/28/2024 9:35:47 AM

UNIT 1 ABSORBER

ME PMPS ON

A

ME WASH PUMPS

1-86202

1-86632

310.55 DEG F

1-86633 >160 DEG F

109.48 DEG F

OA BLWR A

14213.50 CFM 1-86630

14.65 PSIG 1-86631

1-86636

>30

OA BLWR B

OX AGITATOR SEQ CONTROL

STEP

RESET

Man Bypass OFF

OX AGITATOR STARTUP SEQ: TOTAL TIME REMAINING	260 SEC	TIME ELAPSED

COMPLETE	CURRENT STEP 0	STEP TIME REMAINING 0 SEC

STEP	STATUS	DESCRIPTION
1	COMPLETE Time Elapsed	Place all Agitators to Auto
2	COMPLETE Time Elapsed	Starts Agitator A
3	COMPLETE Time Elapsed	Starts Agitator B
4	COMPLETE Time Elapsed	Starts Agitator C
5	COMPLETE Time Elapsed	Starts Agitator D
6	COMPLETE Time Elapsed	Starts Agitator E

A LOCAL FLUSH 1-88208A 1OA5501SAA A

A LOCAL FLUSH 1-88208B 1OA5501SAB A

A LOCAL FLUSH 1-88208C 1OA5501SAC A

A LOCAL FLUSH 1-88208D 1OA5501SAD A

A LOCAL FLUSH 1-88208E 1OA5501SAE A

83 62.25 41 20.75 0

0011-360-610-4012

MEGAWATTS 411 MW | THROTTLE PRS 3510 PSI | FURNACE PRESS -0.25 "WC | FDWTR FLOW 2774 KLB | SX-1 | SH TEMP 1011 °F | RH TEMP 1010 °F | Condensor Vac -27.9 "Hg | Fuel Flow 90.3 %

Spent Slurry Disposal System

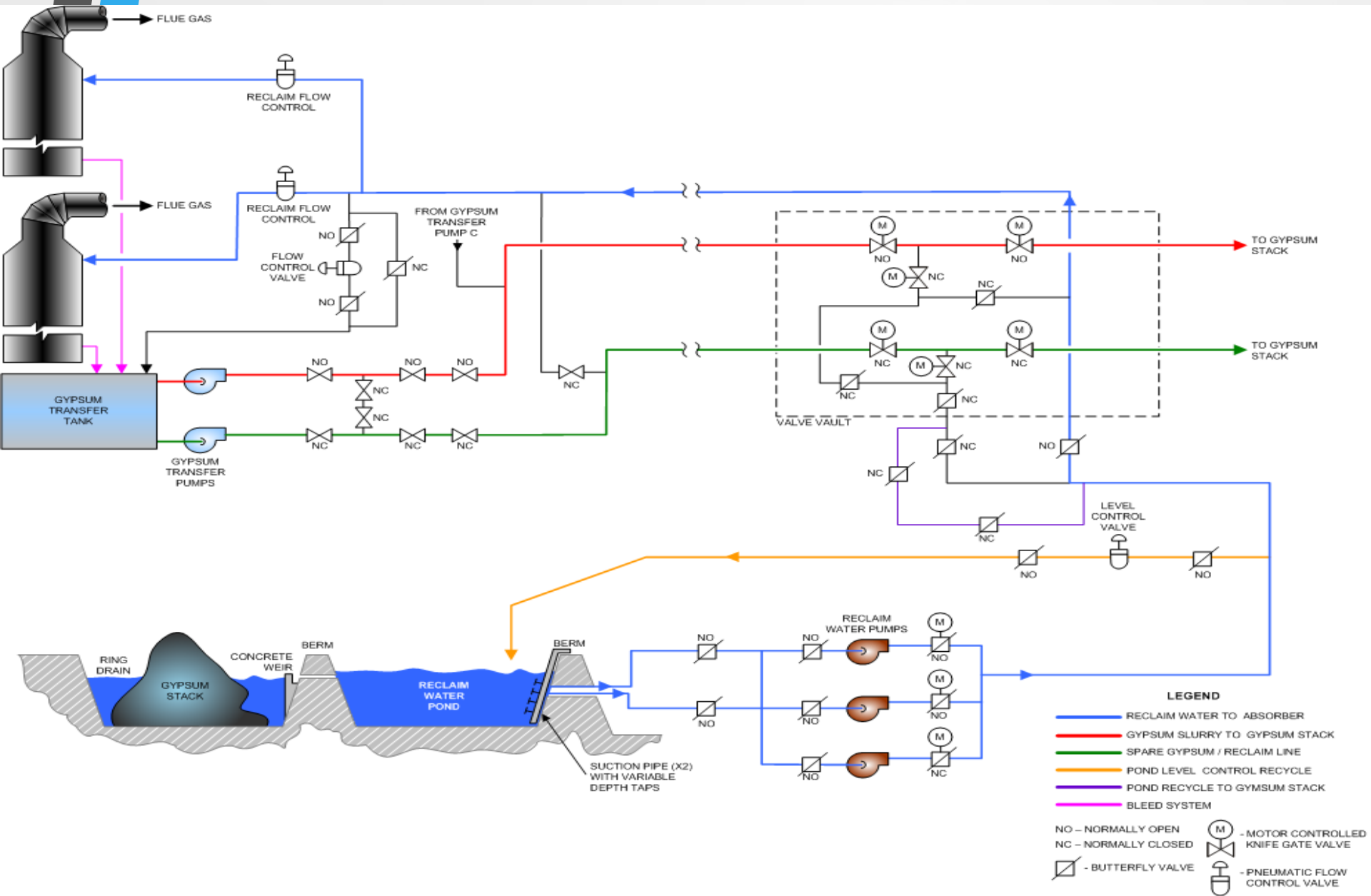
- Gypsum Bleed System
  - Bleed Pumps from Absorber to Gypsum Transfer Tank
  - Gypsum Transfer Tank Pumps to Gypsum Pond @ 750 gpm
- Gypsum Pond (Wet Stack)

  Gypsum Settles – Water overflows to Reclaim Pond

  Reclaim Pumps return water to Absorber to maintain appropriate liquid

Some FGD systems are affiliated with downstream gypsum processors who convert to drywall or gypsum soil amendment for farmers

Reclaim Water System



Gypsum Transfer System Overview

- System Operation:
  - Gypsum transfer tank also receives fluids from:
    - System flushes
    - Absorber slurry drawdown
    - The following sumps:
      - Absorber building
      - Reactant Prep Building

System Overview

- System Operation:
  - The gypsum transfer pumps increase pressure to overcome the substantial head developed by the slurry in the piping.
  - Two pumps that take suction off the gypsum transfer tank
    - Pumps A or B
  - The pumps can also take suction off the Temporary Slurry storage tank (Million gallon capacity = 1 Absorber volume)
    - Can pump back to gypsum transfer tank
  - Each pump can discharge to either of the two piping runs that lead to the gypsum stack
    - Main gypsum transfer line
    - Spare gypsum transfer/reclaim line

Gypsum Transfer Piping
Nearly half mile routing underground from Storage Tank to Settling Pond

FGD Scrubber Chemistry Overview

- Flue Gas Desulfurization (FGD) Scrubbers
  - Remove SO_2 from flue gas before entering stack
  - Ensure plants meet environmental regulation on flue gas
  - First and foremost a chemical plant
    - Constant and dynamic system
    - Requires active and daily attention to ensure proper operation

The FGD Process

- Wet Scrubbers Use Limestone ($CaSO_4$)
  - Byproduct is gypsum; sometimes used as drywall; Georgia Pacific and others
- Spray Dry Scrubbers use Lime ($Ca(OH)_2$)
  - Byproduct is Quicklime, Bakedlime, OxoCalcium
- Some small scale Scrubbers use Caustic Soda

The FGD Process

- FGD Scrubbers use limestone ($CaCO_3$) to remove SO_2 from gas

  $$CaCO_3 + SO_2 + 2H_2O + ½O_2 \rightarrow CaSO_4 \cdot 2H_2O + CO_2$$

  - Byproduct is gypsum ($CaSO_4 \cdot 2H_2O$)
- Several factors can and need to be monitored to control and maintain performance

pH Control

- pH is the measure of acidity of a solution
- Standard operating pH range 4.5 – 5.5
- Maintaining this level of slight acidity ensures
  - Higher rate of limestone dissolution and consumption
  - Optimum rate of SO_2 dissolution
  - Low level of corrosiveness to protect piping, vessels and other equipment

pH Control

- Monitored by pH probes in Absorber slurry
- FGD Scrubber Absorber slurry will tend to acidify as more SO_2 is absorbed
  - Limestone slurry is slightly alkaline
  - Absorber slurry pH is kept at optimum level through addition of limestone slurry to maintain 4.5 – 5.5 pH at Ameren
    - Limestone slurry feed is also controlled by SO_2 inlet levels/MW algorithm

Direct Analytical Methods

- Gravimetric Weight Percent Solids
  - Standard EPRI testing with direct results
  - Involves vacuum filtration of sample and weighing of dried solids

Direct Analytical Methods

Gravimetric Weight Percent Solids

- Standard EPRI testing with direct results
- Involves vacuum filtration of sample and weighing of dried solids
- Estimated time: 1 hour
- Recommended Tests per Week: 1
- Confirm indirect methods of density/percent solids testing

Online Density Monitoring

- Meters allow density of slurry to be monitored constantly
- These readings should be checked once per shift

Nuclear Density Meters in use at Ameren

pH

- Standard operating range: 4.5 – 5.5
- Maintaining this level of slight acidity ensures:
  - Higher rate of limestone dissolution and consumption
  - Optimum rate of SO_2 absorption
  - Low level of corrosiveness to protect piping, storage/transfer tanks, and other equipment

Particle Size

- Direct indicator of Ball mill performance
  - Test shows small enough particle size is being achieved
    - Particle size greatly affects limestone dissolution, slurry density, and scrubber power consumption
  - Slurry should have 90% solids passage through 325 standard mesh sieve
  - Test run on limestone slurry
- Method – Particle Size Sieve Test
  - Method involves running slurry solids through sieve to collect larger particles than will pass
  - Estimated Time: 1.5 hours
  - Recommended Tests per Week: 1

Chemistry

Oxidation & Agitation

Chemical Consumption/Disposition

- Wet FGD - Lime/Limestone Usage
- Significant O&M Expense
  - On site grinding /delivery from off site source, slaking
  - Chemical additives; Dibasic Acid (DBA), Activated Carbon (ACI) etc.
  - Gypsum Storage/Disposal

  - Duck Creek (441 MW – Single Unit) 2009 44,665 Tons Limestone Usage
  - Gypsum Production 74,903 Tons (Estimated)

  Coffeen Energy Center Information (915 MW from 2 Units)
  - Fuels projects 95% Limestone Utilization
  - 1.68 pounds of Gypsum created per ton of Limestone used

Typical Limestone Storage Dome

30 Day Rolling Average Detail

Plant: SIOUX ENERGY CENTER
Operating Day Criteria = 1 hours
Report Period: 03/24/2024 Through 04/23/2024

Source: SXU01 **Standard Limit:** 1.249
Parameter: HGLB/T_M

Date	Daily			30 - Day		
	Operating Hours	Valid Hours	Average	Valid Days	Valid Hours	Average
03/24/24	24	24	0.095952593	30	679	0.301063191
03/25/24	24	24	0.100011729	30	679	0.292088335
03/26/24	0	0	F	30	679	0.292088335 F
03/27/24	0	0	F	30	679	0.292088335 F
03/28/24	0	0	F	30	679	0.292088335 F
03/29/24	0	0	F	30	679	0.292088335 F
03/30/24	0	0	F	30	679	0.292088335 F
03/31/24	0	0	F	30	679	0.292088335 F
04/01/24	0	0	F	30	679	0.292088335 F
04/02/24	0	0	F	30	679	0.292088335 F
04/03/24	0	0	F	30	679	0.292088335 F
04/04/24	0	0	F	30	679	0.292088335 F
04/05/24	0	0	F	30	679	0.292088335 F
04/06/24	24	24	0.152375351	30	680	0.288433854
04/07/24	24	24	0.097465002	30	680	0.283075699
04/08/24	24	24	0.128344908	30	680	0.278970677
04/09/24	24	24	0.091974946	30	680	0.273310352
04/10/24	24	24	0.090387773	30	680	0.267548149
04/11/24	24	24	0.194533583	30	680	0.265880907
04/12/24	0	0	F	30	680	0.265880907 F
04/13/24	0	0	F	30	680	0.265880907 F
04/14/24	24	24	0.325221487	30	680	0.268817516
04/15/24	24	24	0.229198813	30	680	0.265163633
04/16/24	24	24	0.225551562	30	680	0.258752803
04/17/24	24	24	0.234722786	30	680	0.252869137
04/18/24	24	24	0.190137313	30	680	0.245170455
04/19/24	24	24	0.182862669	30	680	0.237232882
04/20/24	0	0	F	30	680	0.237232882 F
04/21/24	0	0	F	30	680	0.237232882 F
04/22/24	0	0	F	30	680	0.237232882 F
04/23/24	0	0	F	30	680	0.237232882 F

ACI INJECTION LOG

MONTH	August						YEAR 2023
DATE	U1 # Added	POE/UOE	U2 # Added	POE/UOE	Silo Start Level	Silo End Level	Total Usage #	COMMENTS
1	No Addition		No Addition					
2	60	R. Ferguson	60	R. Ferguson				
3	60	R. Ferguson		R. Fergu				
4	60	R. Ferguson		R. Fergu				
5	60	R. Ferguson		R. Fergu				
6	60	R. Ferguson		R. Fergu				
7	60	R. Ferguson		R. Fergu				
8	60	R. Ferguson		R. Fergu				
9	60	R. Ferguson		R. Fergu				
10	60	R. Ferguson		R. Fergu				
11	60	R. Ferguson		R. Fergu				
12	Unit Off	R. Ferguson		R. Fergu				
13	Unit Off	R. Ferguson		R. Fergu				
14	Unit Off	R. Ferguson		R. Fergu				
15	Unit Off	R. Ferguson		R. Fergu				
16	Unit Off	R. Ferguson		R. Fergu				
17	Unit Off	R. Ferguson		R. Fergu				
18	Unit Off	R. Ferguson		R. Fergu				
19	60	R. Ferguson		R. Fergu				
20	60	R. Ferguson		R. Fergu				
21	60	R. Ferguson		R. Fergu				
22	60	R. Ferguson		R. Fergu				
23	60	R. Ferguson		R. Fergu				
24	60	R. Ferguson		R. Fergu				
25	60	R. Ferguson		R. Fergu				
26	60	R. Ferguson		R. Fergu				
27	60	R. Ferguson		R. Fergu				
28	60	R. Menge	60	R. Ferguson				
29	60	R. Menge	60	B. Wieschhaus				
30	60	K. Mathenia	60	J. Manse				Bag Inventory: 7 Bags
31	60	PI Trend	60	PI Trend				Silo Level: 25'
	1380		1800					
Truck Unloading Date:				Bill Of Lading Net Weight:				Monthly Total: 3180

Preventive Maintenance Musings

- Key requirement to overall successful plant operation
- Often is deferred to perform breakdown maintenance
- Generally completed when we "get around to it"
- Preventive Maintenance ===> Improved Availability and Reliability

In addition to crafts working in Maintenance Departments, Ameren has practice of maintenance craft training and designations for Operators:

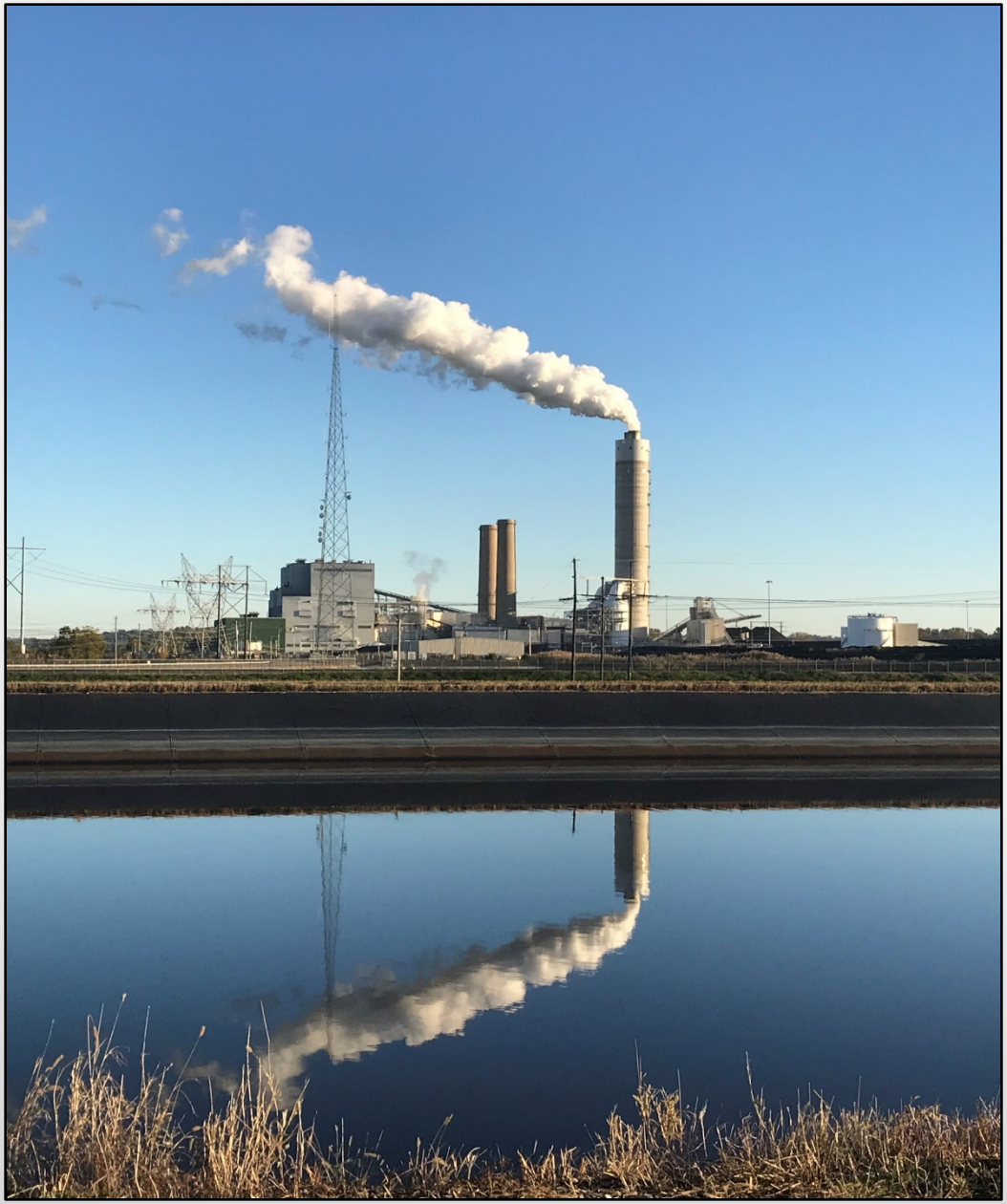
POE - E Electrician

POE - M Mechanical Maintenance (Machinist, rotating equipment repair/replacement etc.)

POE - R Repairman – (Piping repair/tube replacement etc.)

Common Issues

- Abrasion on piping, especially elbows/high velocity flow
- Failure to regularly rotate equipment
- Rotation/training of personnel on Scrubber related equipment
- Philosophy that if it doesn't make Megawatts it doesn't get priority
- Plant generating equipment is off but Scrubber related equipment remains in service to maintain slurry and/or reagent suspension; pumps agitators, etc.



Reflect on your own experiences

Questions ?

What topic can I provide more detail on?

What can you add from your experience?

Whether in the sunrise or sunset of your career – Enjoy the experience !