Reinhold Environmental Ltd.

2007 APC Round Table & Expo Presentation

July 8-10, 2007
Chattanooga, TN
Hosted by TVA

Membrane WESP

- A Lower Cost Technology to Reduce PM2.5, SO_3 & Hg^{+2} Emissions

John Caine
General Manager
SOUTHERN*environmental*,INC.
6690 West Nine Mile Road
Pensacola, Florida 32526
850-941-3001
jcaine@sei-group.com

SOUTHERN environmental INC.

Overview

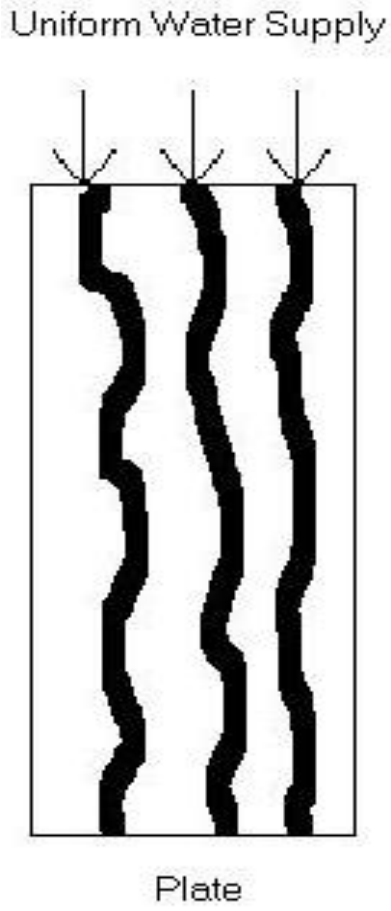
- Discussion of SO_3 Problem
- Compare metal plates with Membrane
- Brief overview of evolution of membrane WESP technology
- NSP Membrane ‘build-up” test results
- 1st Commercial unit - SSCC Stevenson, AL
- Condensing wet ESP details/advantages
- Cost comparison-Metal plate vs. Membrane WESP

SOUTHERN environmental INC.

Introduction

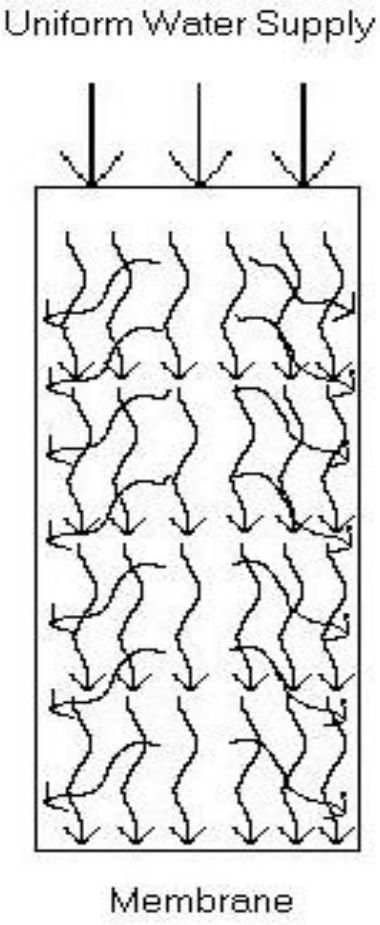
- More new Wet FGD Systems installed
- Increased SO_3 emissions after SCR's
- WESP - Best control for SO_3 emissions
- WESP - Excellent control for PM2.5 & Hg^{+2}
- Membrane WESP - Lower cost for SO_3 & PM2.5 control after FGD wet scrubber

Problems of Conventional Wet ESP



- Channeling and dry spots
- Wet-dry interface
- **Intermittent** collect/clean
- Metal Plates build-up
- Corrosion
- High Cost of Materials

Advantages of Wet Membrane Precipitation



- Water distribution
- Gravity assisted capillary action
- Uniform wetting of Membrane
- **Continuous** collect/clean
- No build-up on Membranes
- Low weight
- Low cost

Evolution of membrane WESP

- 1st Pilot - Fly Ash in Air Test
- 2nd Pilot - Lime Kiln–GP, Cedar Springs, GA
- 3rd Pilot - Bruce Mansfield SO_3, PM & Hg
- 4th Pilot – Knauf Insulation – Phenol Formaldehyde Resin

Pilot Unit 1-Fly Ash Air Test

Location: SEI Jobsite, Pensacola, FL

Pilot Unit 1-Fly Ash Air Test

Location: SEI Jobsite, Pensacola, FL

Power Off

Power On

Pilot Unit 2-Lime Kiln

Location: Georgia Pacific, Cedar Springs, GA

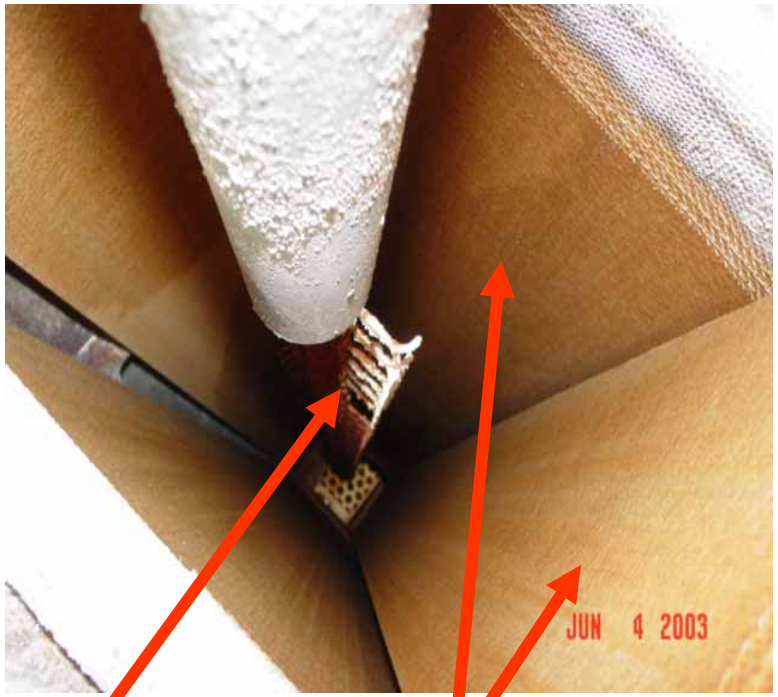
Pilot Unit

Pilot Unit 2-Lime Kiln – After 6 Months

Location: Georgia Pacific, Cedar Springs, GA

Looking from the side-No build-up

Looking down through one tube: No build-up

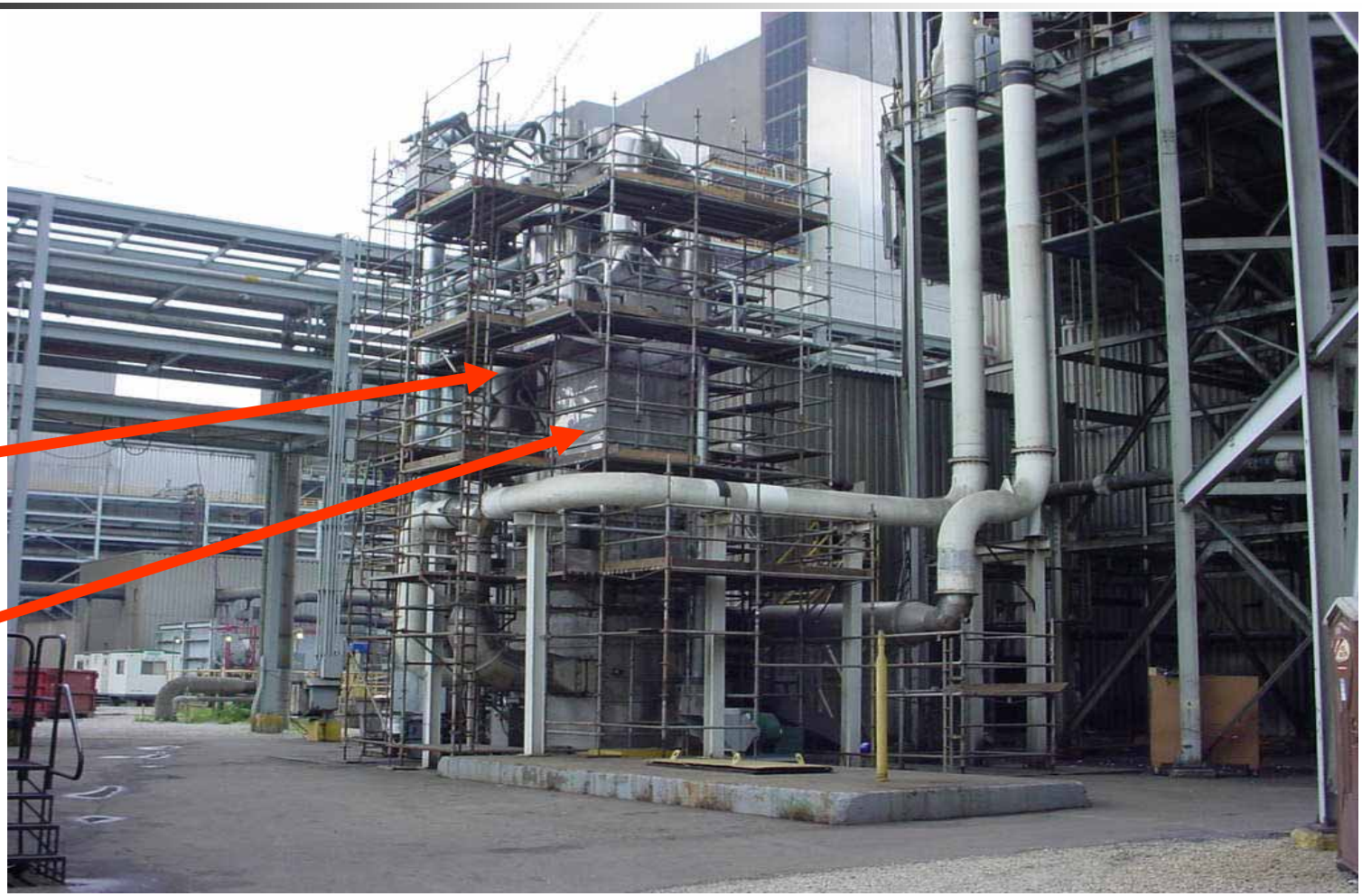


Discharge Electrode

Membranes

Pilot Unit 3-DOE Utility Pilot Unit

Location: First Energy's Bruce Mansfield Plant, Shippingport, PA



Background-Metal Plate WESP

Foreground-Membrane WESP

SOUTHERN environmental INC.

Pilot Unit Performances

UNIT	LIME KILN MEMBRANE WESP	DOE METAL PLATE WESP		DOE MEMBRANE WESP	
Application	Lime Dust	SO3, PM		SO3, PM	
Description	1 Fld Upflow Membrane	2 Fld Upflow Metal		2 Fld Upflow Membrane	
Downstream of:	Rod Deck Scrubber	Wet FGD		Wet FGD	
Gas Vol. ACFM	7,000	8,000	15,000	8,000	15,000
Gas Temp. ^{o}F	130^{0} F	125^{0} F	125^{0}F	125^{0} F	125^{0}F
SCA – 1st Fld. 2nd Fld.	65	35	19	35 35	18 21
Gas Velocity thru WESP, fps	***11***	***9***	***16.7***	***9***	***16.7***
Outlet Opacity, %	<5	<2	<5	<2	<5
Inlet Loading, Gr/ACF	0.04	0.054	0.05	0.046	.05
Outlet Loading Gr/ACF	0.0027	0.004	0.015	0.0017	0.01
PM Efficiency %	***93***	***93***	***70***	***96***	***80***
SO3 Efficiency %	***N/A***	***88***	***65***	***93***	***71***
Hg^{+2} Efficiency %	***N/A***	***76***	***50***	***82***	***61***

Scrubber/Membrane WESP - Mercury Removal @ DOE Pilot Unit

Species	%	Scrubber Inlet (µg/ m^3)	WESP Inlet/Scrubber Outlet (µg/ m^3)	Scrubber Eff. % wt.	WESP Outlet (µg/ m^3)	WESP Eff. % wt.
Ash Hg	33	4.5	0.8	82%	0.2	72%
Hg^{+2}	44	5.8	1.8	69%	0.4	78%
Hg^{0}	23	3	3	0%	2.7	10%
Combined		13.3	5.6	58%	3.3	41%

Scrubber+WESP Efficiency: (Ash Hg + Hg^{+2}) = 94%

NSP Membrane Buildup Test

Design/Operating Parameters for Test on One Module

Gas Volume to WESP Module	245,000 ACFM
Gas Temperature	135 °F
Coal Type	***PRB w/high Ca Ash***
Coal Sulfur Content	<1% Wt.
No. & Dimension of tubes	400 tubes ea. 9” x 12”
Length of tubes	4 Ft.
Gas Flow in Module	Upflow at 9 fps
No. of Tubes tested	18
Inlet loading to WESP	0.03 Gr./ACF
Time of Continuous Operation	6 Months

SOUTHERN environmental INC.

NSP Membrane Test after 6 Months

First Commercial Membrane WESP

Location: Smurfit-Stone Container Corp. Stevenson, Alabama

Design Parameters for New Installation

2 Boilers - WESP downstream of Na Scrubber

Total Boilers Max. Firing Rate, MMBtu/hr	445
Gas Volume to WESP, ACFM	125,000
Gas Temperature, ^{o}F	135
Fuel Type, Oil	#6 Bunker C
Fuel Sulfur Content Max.	4% wt.
Inlet loading to WESP, lb./MMBtu	0.13
Inlet loading, lb./hr	60
H_2SO_4 inlet concentration, ppmv	***20 approx.***
Outlet Emission Rate, lb./MMBtu	0.05
Outlet Emission Rate, lb./hr	22
Outlet Emission, Gr/ACF	0.02
Removal Efficiency (PM & H_2SO_4)	62%

First Commercial Membrane WESP

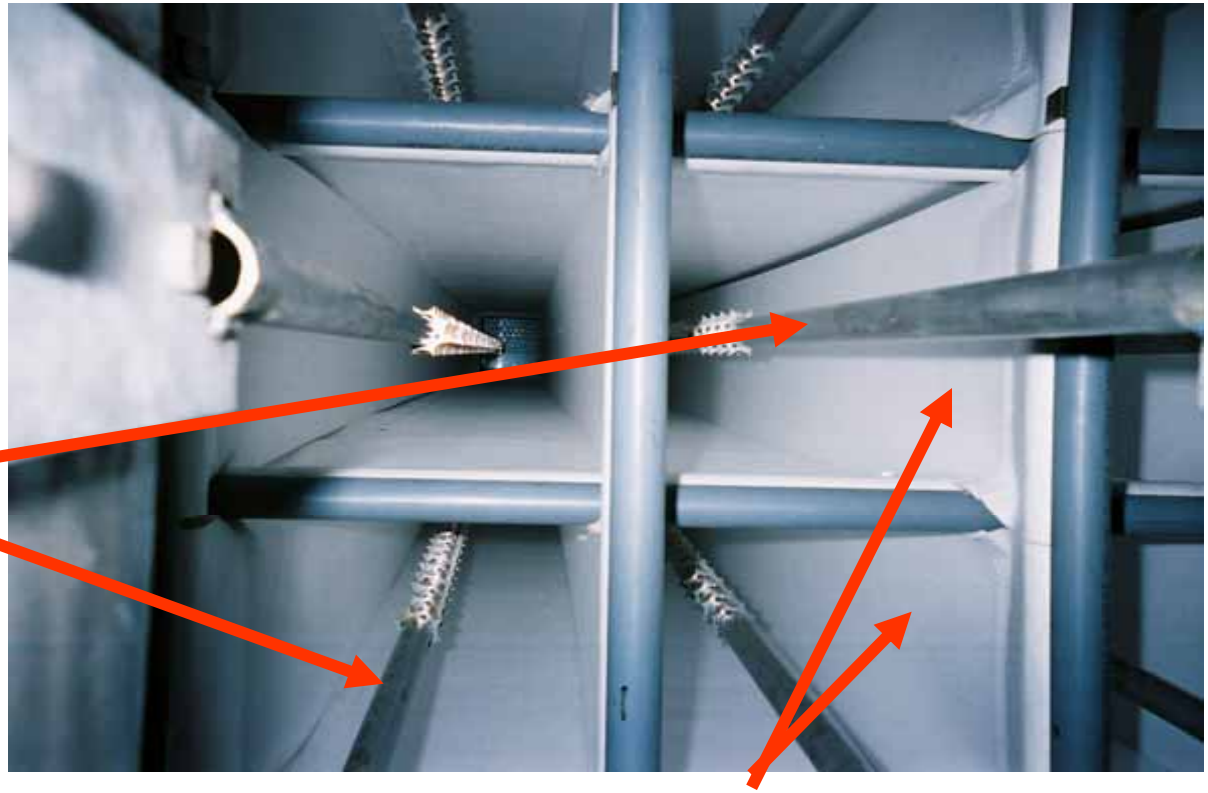
Location: Smurfit-Stone Container Corp. Stevenson, Alabama

Two-Module WESP-Elevation View

First Commercial Membrane WESP

Location: Smurfit-Stone Container Corp. Stevenson, Alabama

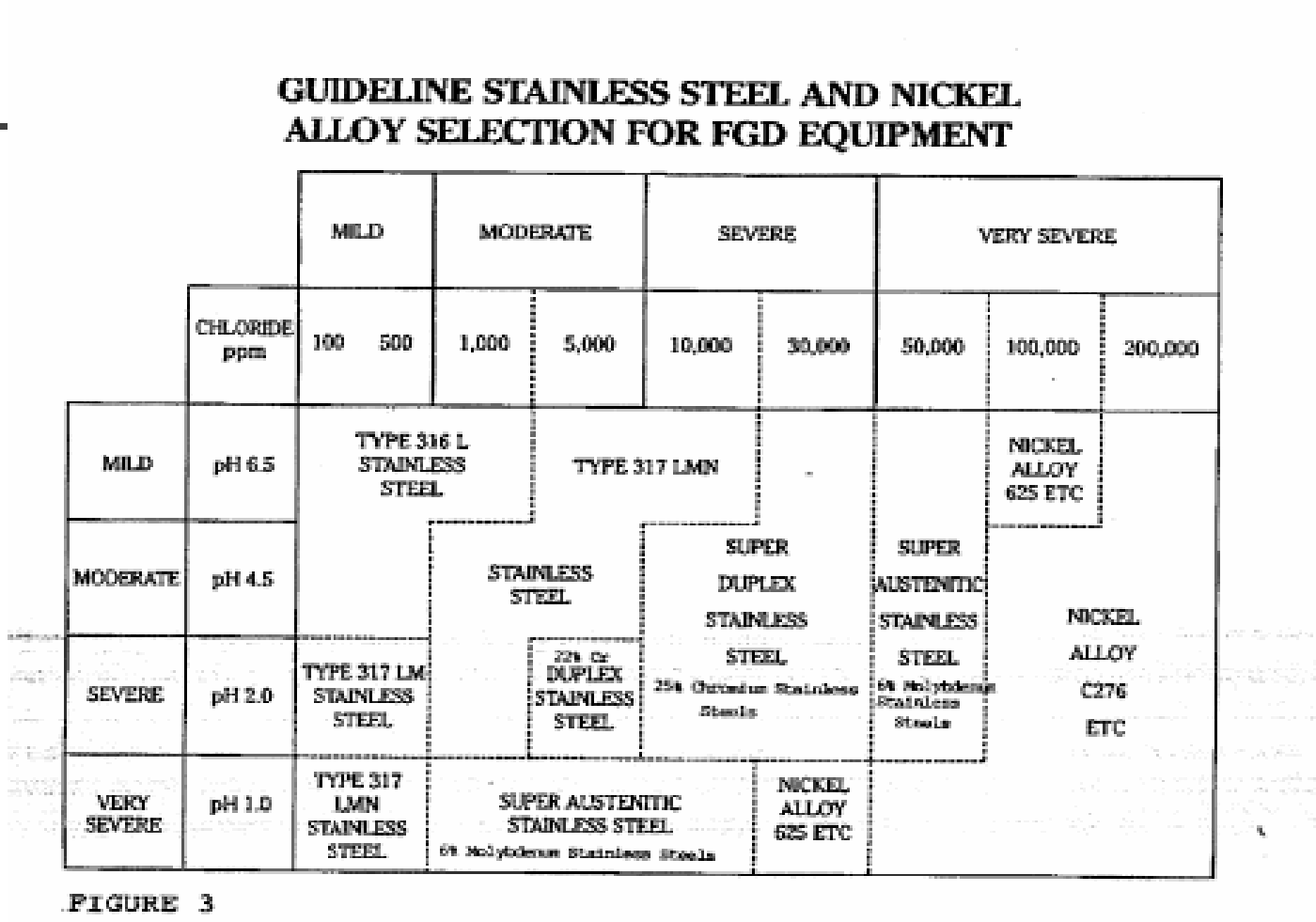
View of top of Membrane Tubes w/RDE's



Material of Construction for WESP

- Selection depends on chlorides and sulfuric acid in the system
- Chlorides
  - Very low (<5ppm) in the flue gas after WFGD
  - Low to very high chlorides in the WESP make-up water
- Sulfuric acid
  - Typical sulfuric acid conc. After WFGD ~30ppmv (high sulfur bituminous coal)

Guidelines for Material Selection



Source: “Selection of alloys for air pollution control equipment” by William L. Mathay

Theoretically 316L SS should be adequate for the system that has <500 ppm chlorides and >4.5pH

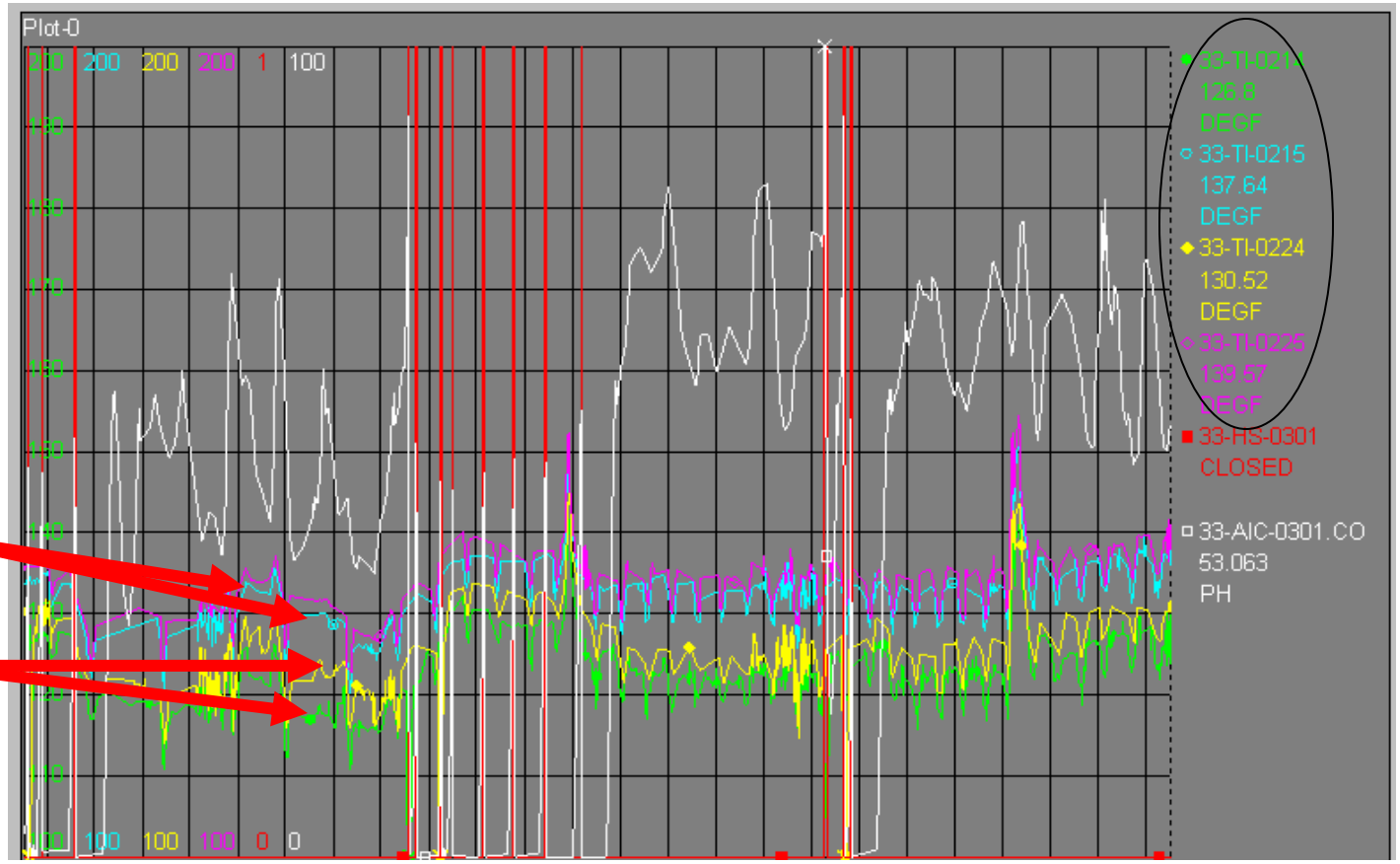
Condensing WESP Concept

- Saturated gas flows inside the tube formed by collecting electrodes
- The cooling medium flows outside of this tube
- Due to temperature difference, condensation occurs on the tube surface
- Condensation reduces the rate of corrosion allowing the use of low alloy steel for the “tube”

Source: Device at wet electrostatic precipitator

Patent No. 5039318 by Harry Johansson

Condensing WESP Operation

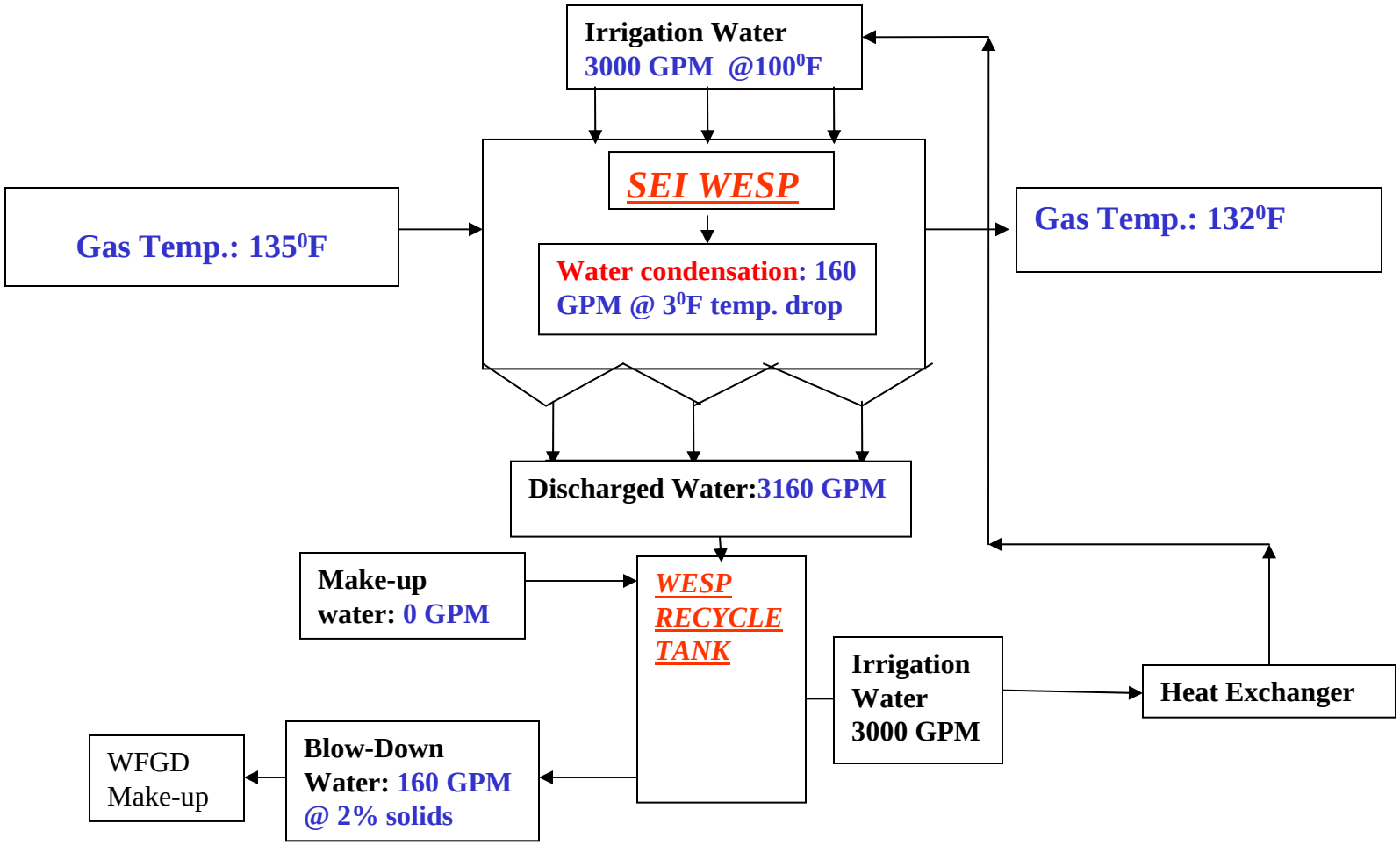


Inlet Gas Temperatures

Outlet Gas Temperatures

Temperature difference: ~10^0F

Condensing WESP Advantage



Condensing WESP Advantages

- Enhances PM collection efficiency
- Needs no make-up water
- No Cl – lower cost materials of construction
- Reduced steam plume

Cost Comparison-Metal Plate vs. Membrane WESP

Vertical flow WESP-located on top of the WFGD (750MW Boiler)

	Membrane WESP ($/kW)	***Metal Plate WESP ($/kW)***
2-field vertical flow- **316L SS**	$20-$25	$30-$35
2-field vertical flow- **254SMO**	$40-$45	$50-$55
2-field vertical flow- **C276**	$75-$80	$85-$90

Assumptions:

1. Installation cost is not included.
2. Outlet ductwork is not included.

Cost Comparison-Metal Plate vs. Membrane WESP

Horizontal flow WESP-located on the grade (750MW Boiler)

	Membrane WESP ($/kW)	***Metal Plate WESP ($/kW)***
3-field horizontal flow-**316L SS**	$30-$35	$40-45
3-field horizontal flow-**254SMO**	$50-55	$60-65
3-field horizontal flow-**C276**	$85-90	$95-100

Assumptions:

1. Installation cost is not included.
2. Inlet/Outlet ductwork is not included.

Picture of Membrane WESP Stack Vs. Metal Plate WESP Stacks

Picture of Membrane WESP Stack Vs. Metal Plate WESP Stacks

Metal Plate WESP Stacks

Membrane WESP Stack

SOUTHERN environmental INC.

Conclusions

- Membranes promote wetting and surface cleaning
- High collection efficiency demonstrated
- No dust build-up after 2+ years operation
- May not need make-up water for operation
- Can use lower cost stainless steels for casing
- Enhances the collection of Hg^{+2} and Hg_p
- Lower cost design

Questions