REINHOLD ENVIRONMENTAL Ltd.

2019 NOx-Combustion-CCR Round Table Presentation

February 11 & 12, 2019, in Salt Lake City, Utah / Hosted by PacifiCorp

2019 NOx-Combustion-CCR/PCUG Conference

Impact of Air In-Leakage on Combustion, Emissions and Cost of Unit Compliance & Operation

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HTT ISOMEMBRANE

Affordable Clean Energy (ACE) Rule

(EPA's replacement to the Clean Power Plan CPP)


EPA United States Environmental Protection Agency

Proposal: Affordable Clean Energy (ACE) Rule

On August 21, 2018, the U.S. Environmental Protection Agency proposed the Affordable Clean Energy (ACE) rule which would establish emission guidelines for states to develop plans

<u>Proposes to reduce GHG emissions through four main actions</u>:

- ACE defines the "best system of emission reduction" (BSER) for existing power plants as **on-site, heat-rate efficiency improvements**;
  - *Supports lower operating costs, improving competitiveness and dispatchability.*
- ACE updates the **New Source Review (NSR)** permitting program to further encourage efficiency improvements at existing power plants;
  - *Currently NSR is triggered when total annual emissions increases, penalizing efficiency improvements that would increase dispatchability. The update proposes NSR to be triggered when hourly emissions increase.*
- ACE provides states with a list of "candidate technologies" that can be used to establish standards of performance and be incorporated into their state plans;
- ACE aligns regulations under CAA section 111(d) to give states adequate time and flexibility to develop their state plans.

Opportunities to Resolve Air In-Leakage

- Boiler Dead Air Spaces
  - Penthouse penetrations
  - Header vestibules
  - Nose arch
  - Lower slopes
  - Casing
  - etc.
- In-situ Manufactured Expansion Joints
  - Flue Gas Path
  - Primary Air
  - etc.
- HRSG's
  - Penetrations
  - Expansion Joints

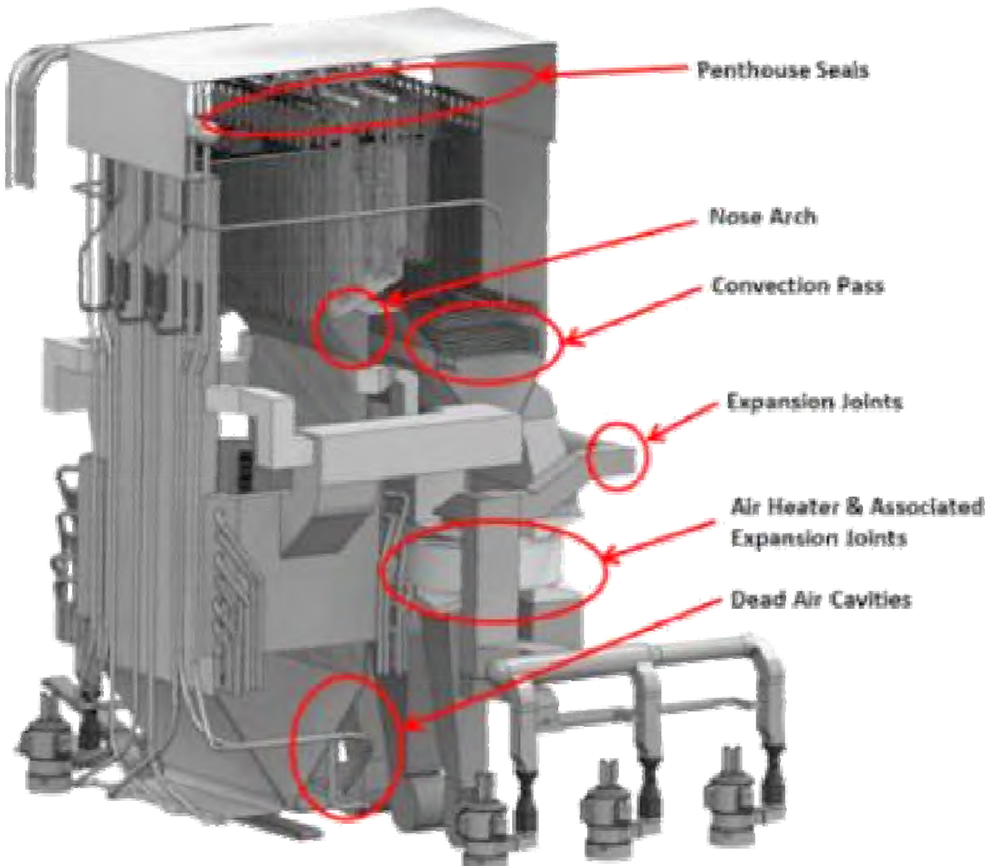


Image Courtesy of STORM ENGINEERING

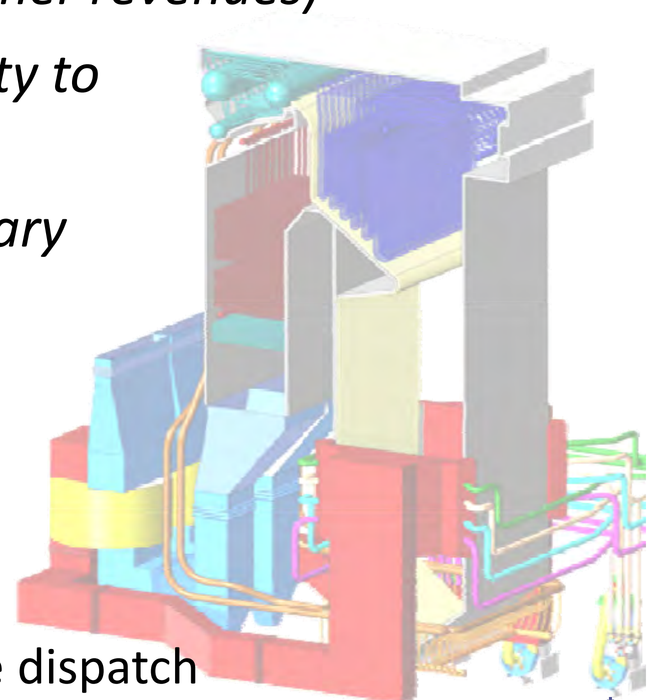
Plant Financial Performance =

<u>CRITICAL: Know the $ value of each heat rate point</u>

- Heat Rate – *(lowest cost per saleable MW)*
- Dispatchability – *(higher capacity factor > higher revenues)*
- Optimize Capacity – *(net generation, reliability to avoid lost opportunity costs)*
- Reduce Production Costs – *(fuel costs, auxiliary power consumption, sorbent costs)*
- Emissions Compliance
- Safety

• **<u>All are Impacted by Air In-Leakage</u>**

  - Made worse by increased cycling & unpredictable dispatch



Drawing Courtesy of STORM ENGINEERING

Impacts of Air In-Leakage

- Heat Rate: (150-300 Btu/kWh effect common)
- Erroneous O_2 readings
- Efficiency: *(=improved profitability)*
  - Excess fuel consumption per Saleable MW
  - High LOI's (~25 Btu/kWh)
  - EGT: every 10°F over = (~25-30 Btu/kWh)
  - Parasitic power consumption
  - Fan limitations > loss of saleable MW, reduced capacity
- Reliability & Maintenance:
  - Increased slagging (~25 Btu/kWh)
  - Tube failure potential: accelerated tube wastage, overheating, clinker damage
  - Increased back-end corrosion
- Emissions:
  - (MATS compliance) Excess PM/per MMBtu
  - Sorbent consumption requirements

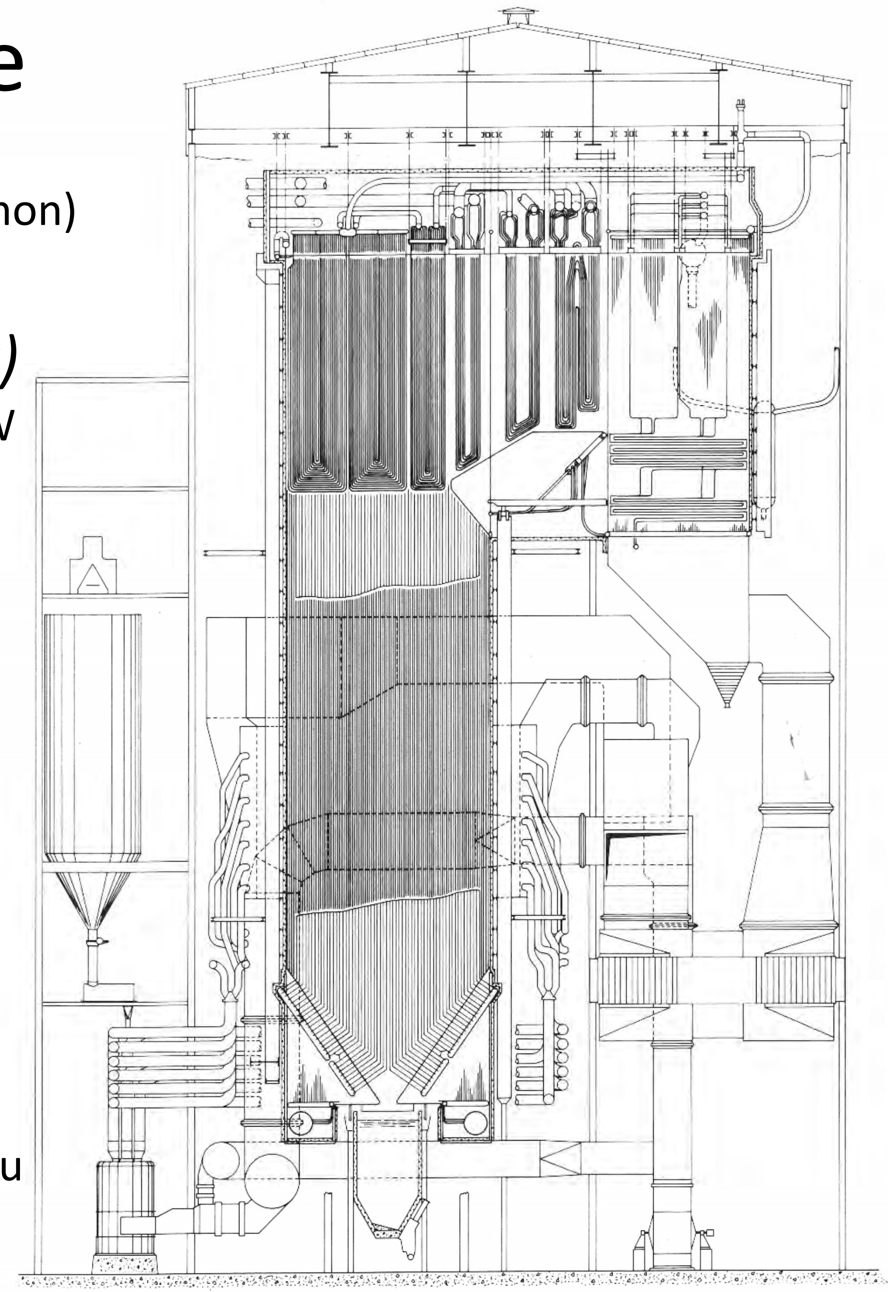


Image Courtesy of Combustion Fossil Power Systems

Environmental Impacts of Air In-Leakage

- Excess Air
  - Excessive NOx emissions
  - Reduced combustion efficiency
- Inaccurate 0_2 Readings
  - Higher fuel consumption = more throughput per BTU
- Increased Gas Volume
  - Can exceed the capacity of the APC equipment
- Increased Gas Velocity
  - Insufficient residence time
  - Poor gas flow distribution
- Decreased Flue Gas Temperatures
  - Reduces sorbent effectiveness
- Increased Moisture
  - Increases ash resistivity
  - Increases wetted particulate

Boiler Thermal Efficiency and Emissions

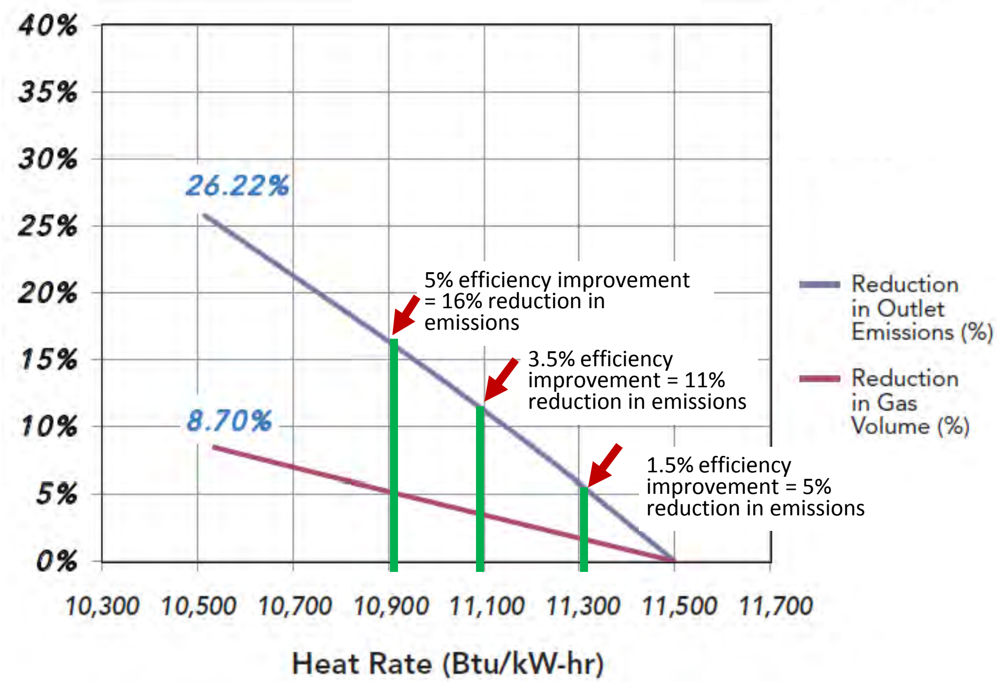
- Improved Efficiency

  = reduced gas volume

  = reduction in outlet emissions

EXAMPLE: Minimizing air in-leakage is critical to improving unit efficiency. An improvement of 8.7% reduces throughput/gas volume (gv) the same, optimizing APC performance, reducing outlet emissions by ~26%.

- ➔ 5% gv reduction = 16% emissions reduction
- ➔ 3.5% gv reduction = 11% emissions reduction
- ➔ 1.5% gv reduction = 5% emissions reduction



Graph Courtesy of Neundorfer Inc. Particulate Knowledge

Data & Graph provided by Neundorfer, Inc.
"Boiler MACT Compliance: You Might be Closer Than You Think"

Flue Gas Temperature and Emissions

- Reduced Flue Gas Temperature

= reduction in outlet emissions

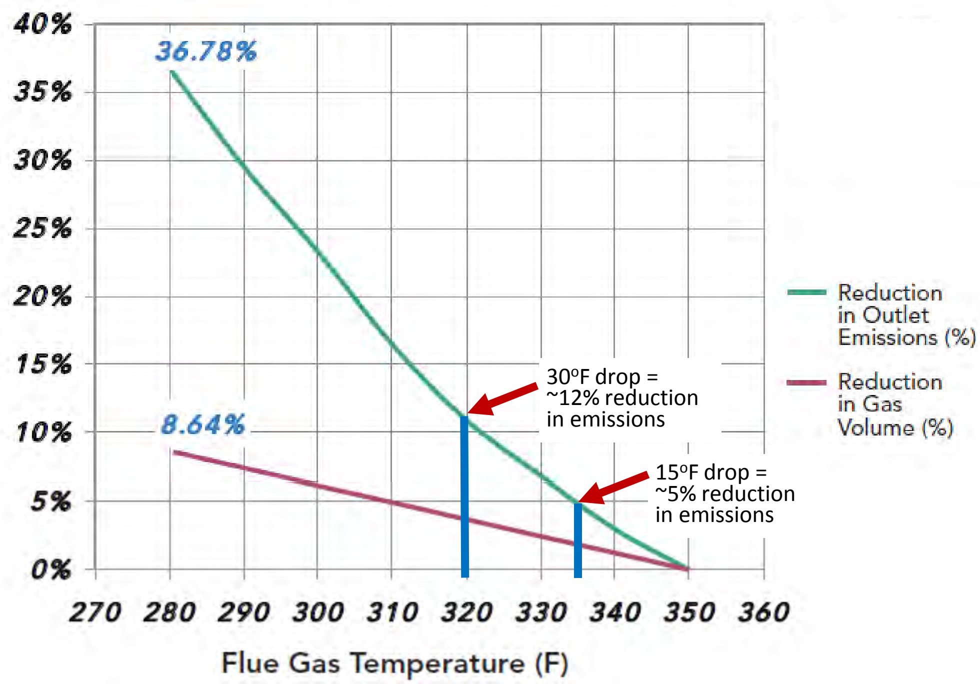
EXAMPLE: As flue gas temperature is reduced from 350˚ to 280˚, the gas volume is reduced by about 8.6%.

Ash resistivity and ESP performance are very sensitive to flue gas temperature.

By controlling flue gas temperature, outlet emissions were reduced by over 36%.

➔ 30ºF reduction = 12% emissions reduction

➔ 15ºF reduction = 5% emissions reduction



Graph Courtesy of Neundorfer Inc. Particulate Knowledge

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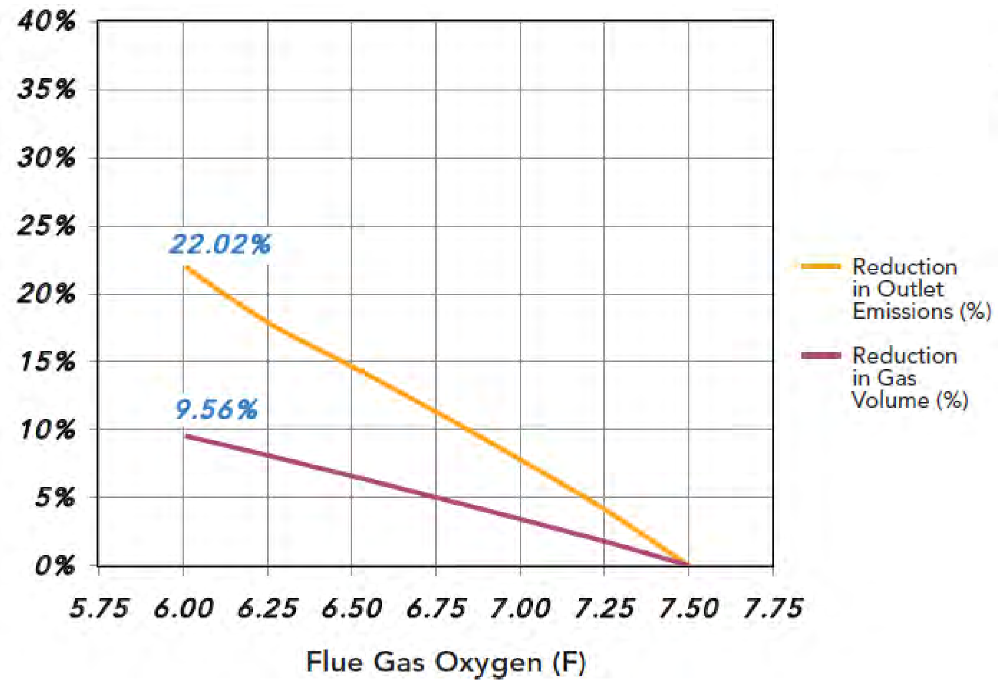
Flue Gas Oxygen and Emissions

- Reduced air in-leakage/tramp air

  = reduced stack O_2 concentration

  = reduction in outlet emissions



Graph Courtesy of Neundorfer Inc. Particulate Knowledge.

EXAMPLE: Reducing the stack O_2 concentration from 7.5% to 6% reduced the treated gas volume by ~9.5%, resulting in a ~22% reduction in outlet emissions.

Data & Graph provided by Neundorfer, Inc.
"Boiler MACT Compliance: You Might be Closer Than You Think"

Cycling, Fractures, Corrosion = Air In-Leakage

- Average age of coal-fired is 40+ years old – Designed for baseload
- Mechanical damage
  - stress fractures
  - weld cracking
  - refractory failure
  - corrosion
  - Erosion

Traditional Options: Weld Repairs

- *Tend to re-crack at the heat affected zone of the weld repair, requiring repetitive repairs*





Traditional Options: Refractory

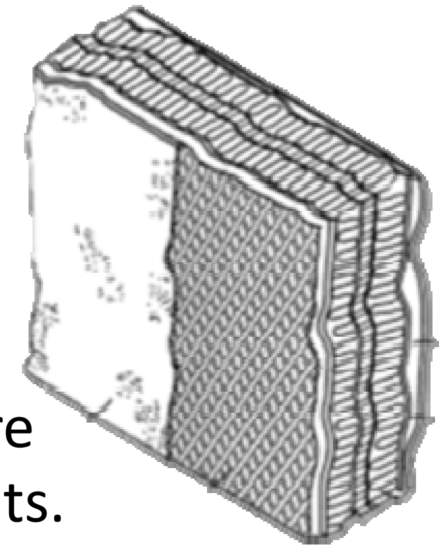
- *Lack of reliability can cause sudden spikes in excess air that can jeopardize unit performance and efficiency.*




NEEDED: Sealing Method that's Compatible with Boiler Operation and Cycling

- High temperature threshold
- Malleable: Resilient in multi-plane movement, cycling environments
- Reliable: Maintenance-free, long-term sealing capability to reduce repetitive repairs and damage control
- Adaptable & rapid in-situ fabrication

Development of a Flexible, High Temperature Sealing System



- ISOMEMBRANE: Designed to remain flexible, handling multi-plane movement in high-temperature (1,800°F), cycling and variable pressure environments.
  - Boiler Dead Air Dead Spaces
  - Expansion Joints

(12) United States Patent
Gelorme et al.

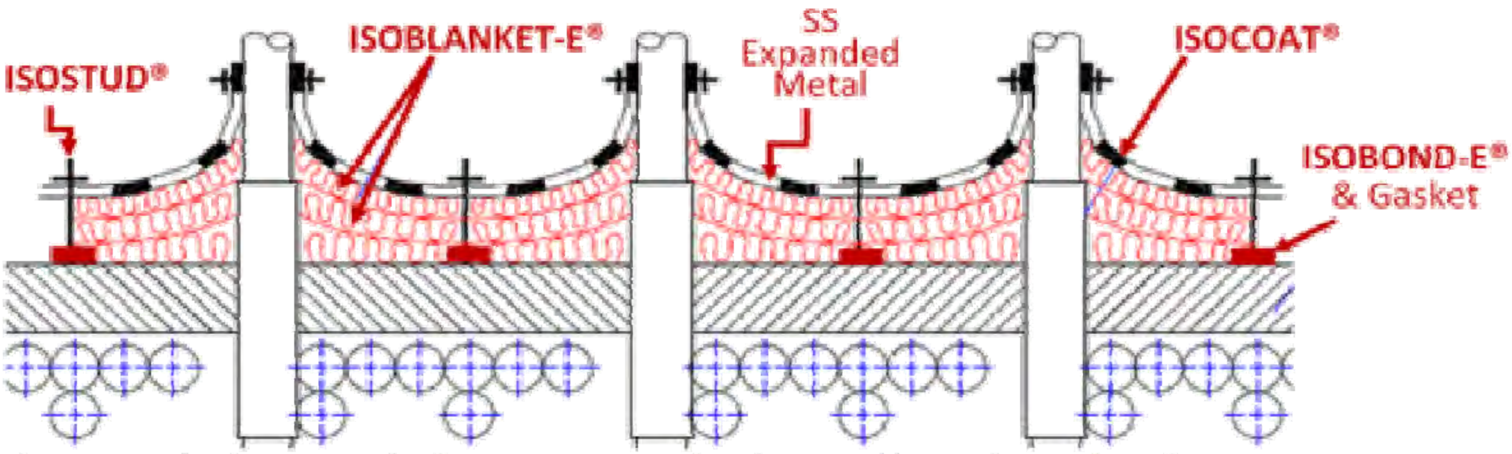
(10) Patent No.: US 8,590,904 B2
(45) Date of Patent: Nov. 26, 2013

(54) HIGH TEMPERATURE SEAL

(58) Field of Classification Search

- 1982: Developed in Denmark for boiler dead air space
- 1993: HTT introduced ISOMEMBRANE® to North America
  - 4 proprietary components (w/13-15 stages in the installation process)
  - 2 patents for seal construction
- 1995: Developed in-situ manufactured expansion joint encapsulations
- 2019: Over 2,500 North American installations since 1993

ISOMEMBRANE® Sealing System



Multi-layered system of several proprietary developed components:

- ISOBOND-E®: high strength, high temperature adhesive
- ISOBLANKET-E®: high tensile strength, high temperature blanket
- ISOCOAT®: protective topcoat sealing layer
- ISOSTUD®: stud design that increases seal attachment uniformity to ~99%, & reduces installation time ~10%

- These components work in unison to optimize sealing by merging flexibility, impermeability and robustness

ISOMEMBRANE® as a Tool

Boiler Dead Air Space Applications

- A maintenance-free alternative to refractory and weld repairs
- Provides reliable crack & penetration sealing service-life that typically lasts the life of the tubes

Boiler Installation Overview

example:

Header Vestibule Installation

www.isomembrane.com

Case Study: 770MW CE Boiler – 1972

Air In-Leakage Reduction Project: December 2017

Penthouse: comprehensive sealing over the furnace
Flue Gas Path: 5 in-situ manufactured expansion joints

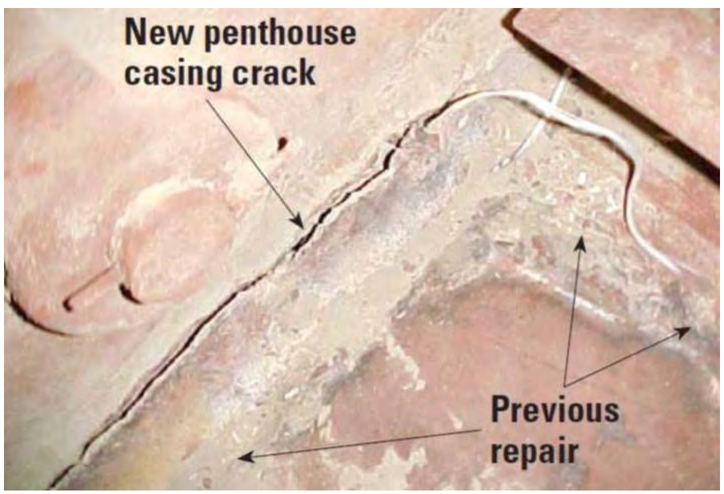
<u>Snapshot Results</u>:

- Heat Rate improved
- Fully dispatched
- Excess O_2: dropped ~0.6%
- 2 de-slagging outages avoided
- FEGT Reduced 8.5°F
- Reduced aux power consumption
- Plus, other improvements

First year savings: $3,180,671 - ROI 2.8 months

Case Study: Background

1999 ISOMEMBRANE Installation-PH over the Backpass



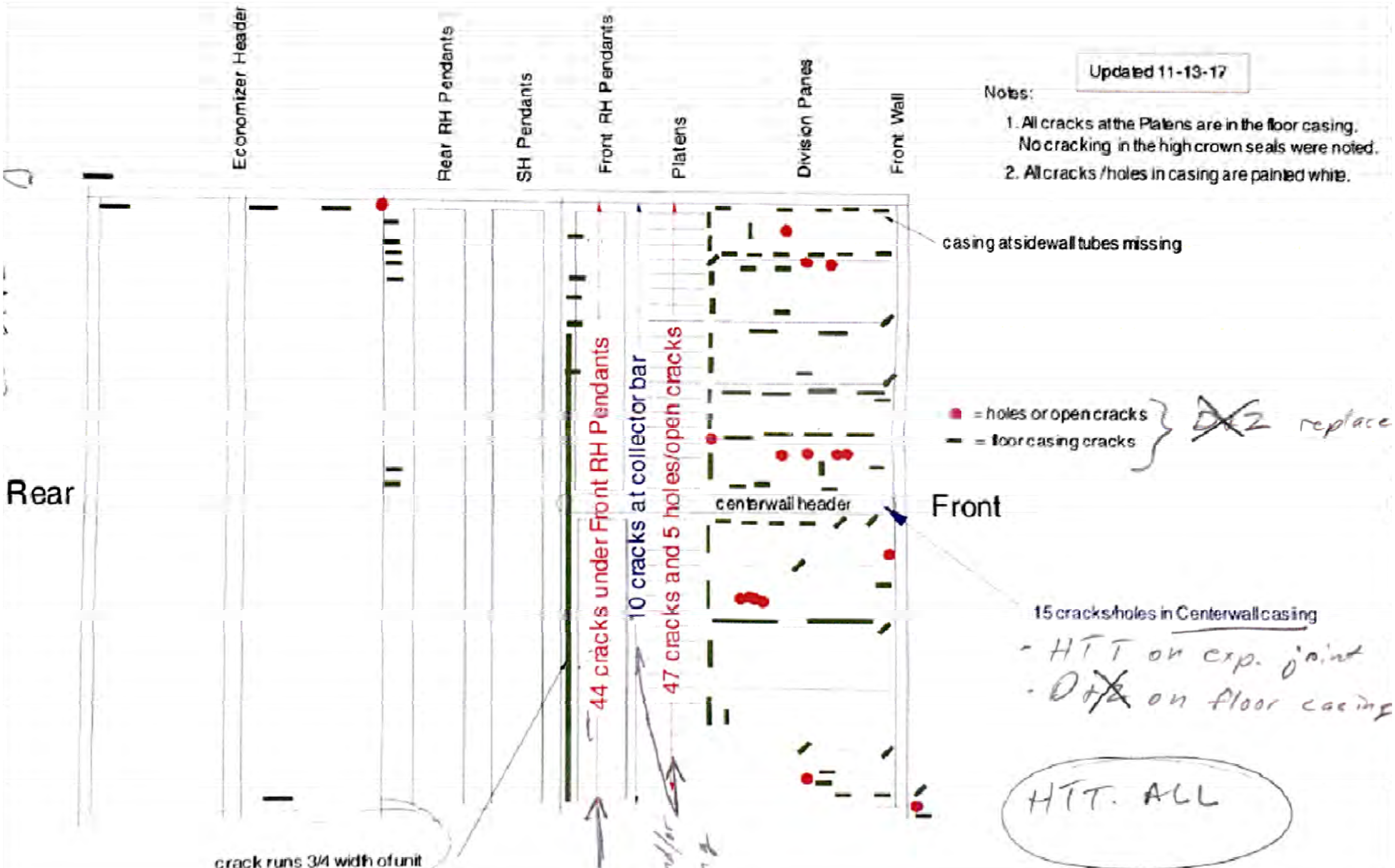
Images Courtesy of POWER Magazine & Innovative Combustion Technologies, Inc.

Case Study: ISOMEMBRANE® Reliability

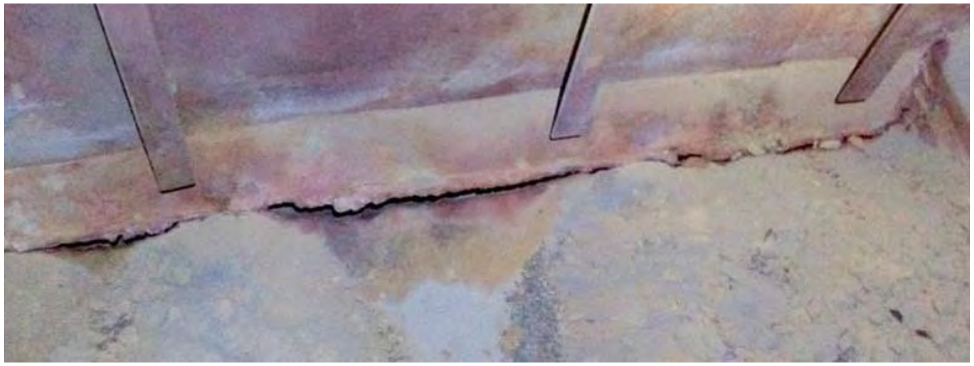
*2017 - after **18 years in-service –***

Still sealing, no maintenance required

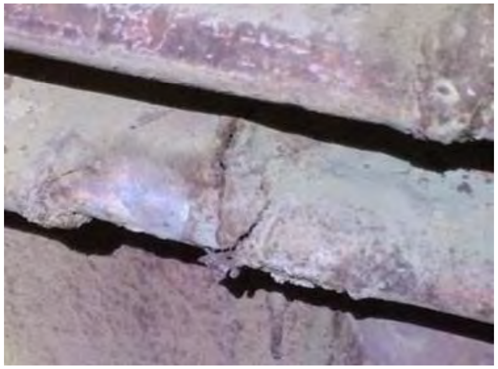
Case Study: Inspection Map



Case Study: Penthouse Inspection



Case Study: Penthouse Inspection



Case Study: Penthouse Inspection

Case Study: ISOMEMBRANE® Scope Penthouse - Over the Furnace

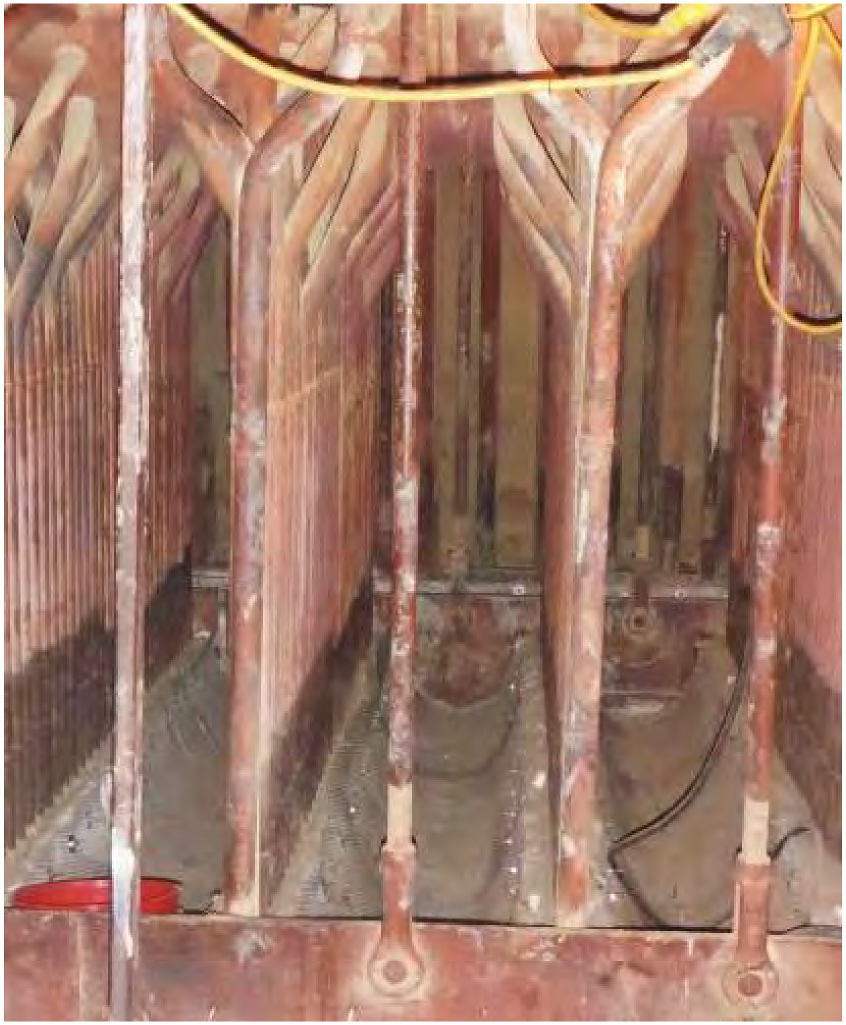
Case Study: Boiler Sealing Project Timeline

- 4,291 sq/ft - Completed in 13 shifts

	A	B	C	D	E	F	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
1	Gorgas Steam Plant - December Outage - ISOMEMBRANE® Installation								Actual Start			In-Progress			Actual Completion									
2				HIGH TEMPERATURE TECHNOLOGIES, Inc. - 704-375-2111			10%: S=Stud		25%: G=Gasket			40%: B=ISOBlanket1			60%: BB=ISOBlanket2				80%: X=HexMetal			90%: SC=Secured		
3				Project Schedule			MON	TUES	WED	THUR	FRI	SAT	SUN	MON	TUES	WED	THUR	FRI	SAT	SUN	MON	TUES	WED	THUR
4	Line/Area			DESCRIPTION	Sq/Ft	Lin/Ft	11/27	11/28	11/29	11/30	12/1	12/2	12/3	12/4	12/5	12/6	12/7	12/8	12/9	12/10	12/11	12/12	12/13	12/14
5	PENTHOUSE			DAYS TO FINISH BOILER:			17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	
6	7/A	X	OFFLINE	Penthouse Center Wall Header Expansion Joint (2 sides, 33 lf ea.)	132	66									50%									
7	7/B	X	OFFLINE	Penthouse Center Wall Casing at Floor (2 sides, 31.5 lf ea.)	189	63									50%									
8	7/C1	X	OFFLINE	Doghouse 1 Penthouse North Furnace "A" Division Panel	88	44																		
9	7/C2	X	OFFLINE	Doghouse 2 Penthouse North Furnace "A" Division Panel	88	44																		
10	7/C3	X	OFFLINE	Doghouse 3 Penthouse North Furnace "A" Division Panel	88	44																		
11	7/C4	X	OFFLINE	Doghouse 4 Penthouse North Furnace "A" Division Panel	88	44																		
12	7/D1	X	OFFLINE	Doghouse 1 Penthouse South Furnace "B" Division Panel	88	44																		
13	7/D2	X	OFFLINE	Doghouse 2 Penthouse South Furnace "B" Division Panel	88	44																		
14	7/D3	X	OFFLINE	Doghouse 3 Penthouse South Furnace "B" Division Panel	88	44																		
15	7/D4	X	OFFLINE	Doghouse 4 Penthouse South Furnace "B" Division Panel	88	44																		
16	7/E	X	OFFLINE	Penthouse North Furnace "A": Support Hanger Division Panel Side	74	32																		
17	7/E	X	OFFLINE	Penthouse South Furnace "B": Support Hanger Division Panel Side	74	32																		
18	7/F	X	OFFLINE	Penthouse North Furnace "A": Side Wall Header Casing (2 sides, 31 lf ea.)	93	62																		
19	/H (no "G	X	OFFLINE	Penthouse South Furnace "B": Side Wall Header Casing (2 sides, 31 lf ea.)	93	62																		
20	7/I	X	OFFLINE	Penthouse Front Water Wall Header (2 sides, 74 lf ea.)	222	148																		
21	7/J	X	OFFLINE	Penthouse Furnace Penthouse Floor Expansion Joint	110	74																		
22	7/K	X	OFFLINE	Penthouse Superheater Penetrations Inlet & Outlet Platens (40 bays)	1200	na																		
23	7/L	X	OFFLINE	Penthouse Reheat Penetrations Inlet & Outlet Platens (100 bays)	1400	na																		
24				Total Boiler Square Footage	4291																			

- The plant estimated repairing the same boiler scope with weld repairs and refractory would have required 52 shifts.

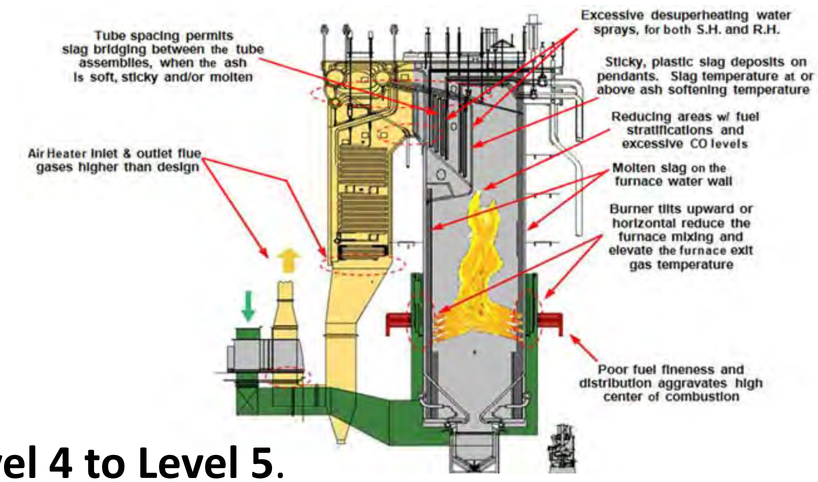
Case Study: Installation
Penthouse – Over the Furnace

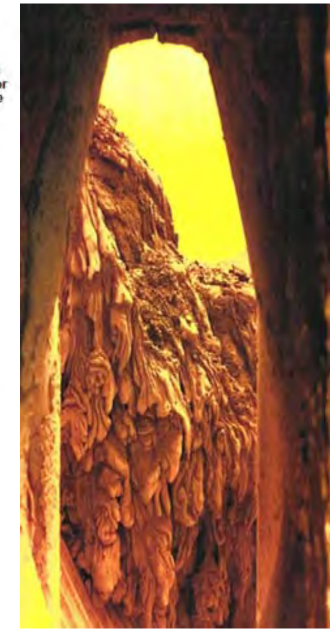


Case Study: Installation
Penthouse – Over the Furnace

Case Study: Installation Penthouse – Over the Furnace

CASE RESULTS:
OPERATIONAL ROI





1. **Improved Heat Rate**: From a **Level 4 to Level 5**.
   Best Heat Rate of the utility's coal-fired units
   - *(In addition to ISOMEMBRANE® sealing the boiler and joints, the plant did some **condenser**, boiler trough, tube membrane and fan blade repairs.)*
2. **Fully dispatched**: Previously load-following.
3. **De-slagging outages have been reduced 50%** since returning to service. Previously this unit typically required 3-5 de-slagging outages per year, with each outage having a duration of 42-48 hours each.
4. **Boiler air control is vastly improved**: **Excess O_2 reduced 0.6%**
   Before sealing: Excess O_2 = 3.8-4.0%, After sealing: Excess O_2 = 3.2-3.4%.
   - Operators had to "*reteach themselves how to run the unit*"
   - No longer have to "fudge" O_2 settings
   - Before sealing, boiler air in-leakage was measured at 17%. Currently ~3%.
5. **Excess fan capacity**: Parasitic power consumption reduced.
6. **Reduction in LOI**: Estimated, 1% reduction.
7. **Opacity Reduction**: 27%

CASE RESULTS: BOILER ROI Calculator

The Boiler ROI calculator was created for HTT by **INNOVATIVE COMBUSTION TECHNOLOGIES** (ICT). ICT specializes in addressing combustion side parameters to identify & explore opportunities for improved unit heat rate, performance, availability, capacity and operability.

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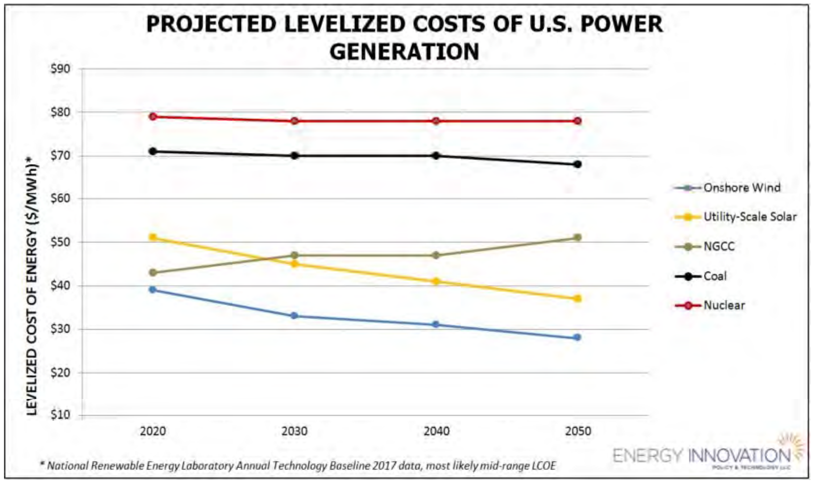
Yellow Boxes are for manual data entry. *Other fields self compute.*

For a copy of this BOILER ROI Calculator (in Excel format), email *patrick@isomembrane.com*, and I'll send you a copy.

	A	B	C	D	E–F	G–H	I	J
7	**ROI Calculator - Air In-Leakage Control**							
8	Unit Net Load (Mw)	770			Hours/yr	6570		
9	Availability	75%			Capacity Factor	75%		
10	Number of ID Fans	4			Fan HP	6,000		
11	Heat Rate (Btu/Kwhr)	8,691	2017 - 9,820		Heat Rate (Btu/Mwhr)	8,691,000		
12	Fuel Cost ($/ton)	$51			Fuel Heating Value (HHV) Btu/lb	12,000		
14	**Calculations:**							
15	**MW's/year** - MW's/year= Unit Net Load (Mw) * Cap Factor (%) * 365 (days/yr) * 24 (hrs/day)		3,794,175	Total MW's				
16	**Fuel Cost**							
17	$/MMBtu = Fuel Cost ($/ton) *1,000,000 / (HHV (Btu/lb) * 2000 (lb/ton))		$ 2.13	$/MMBtu				
18	$/MwHr = (Heat Rate (Btu/MwHr) * Fuel Cost ($/ton)) / (Heating Value (Btu/lb) * 2000 lb/ton)		$ 18.47	$/MwHr	Estimated Annual Saving from Reduced Sorbent Consumption, ESP Power, Fuel Efficiency, etc.:		$ 250,000	
20	***Parameter***		***Quantity or % Change in Heat Rate***		***Sale Price or Penalty***	***Total Cost Savings (per year)***	***Savings LOW***	***Savings HIGH***
21	**FLYASH LOSS ON IGNITION (LOI)** *(alternative way of looking at fuel savings)*		1 % Reduction in LOI		8.69 Btu/KwHr	$ 70,072	$ 70,072	
22	(Assume 0.1% Heat Rate per 1% LOI)		2 % Reduction in LOI		17.38 Btu/KwHr	$ 140,144		$ 140,144
24	**LOST GENERATION**	Occurrences/yr	Hours/occ		$/Mwhr			
25	**Lost Generation (54Mw de-rate to shed furnace slag)**	0	8		$25	$ -	$ -	
26	Lost Generation (54Mw de-rate to shed furnace slag)	0	8		$25	$ -		$ -
27	**Lost Generation (Unit off-line due to slagging incident, (x) 3-day incidents/yr)**	2	42		$25	$ 1,617,000	$ 1,617,000	
28	Lost Generation (Unit off-line due to slagging incident, (x) 3-day incidents/yr)	3	42		$25	$ 2,425,500		$ 2,425,500
29	**Plus fuel oil for restarts**	2	41,000	$4.15	gallon		$ 340,300	
31	**REDUCED AUXILIARY HORSEPOWER FOR ID FANS**							
32	(Repair resulted in decrease in mass flow of ~4%) yielding ~ reduction in ID hP of 10%	600.00	# ID Fans*Capacity factor*HP Reduction*.7455 Kw*Yearly Hours		$0.045 KwHr/Bus Bar cost	$ 396,733	$ 396,733	
33	(Repair resulted in decrease in mass flow of ~8%) yielding ~ reduction in ID hP of 20%	1200.00	# ID Fans * Capacity factor * HP Reduction * .7455 Kw * Yearly Hours		$0.045 KwHr/Bus Bar cost	$ 793,465		$ 793,465
35	**DE-SUPERHEATING SPRAY FLOWS (SH)** Assume 0.025% Heat rate for 1% of MSF	1	1 % MSF Sprays Reduced		2.17 Btu/KwHr	$ 17,518	$ 17,518	
36	De-superheating Spray Flows (SH) Assume 0.025% Heat rate for 1% of MSF	2	2 % MSF Sprays Reduced		4.35 Btu/KwHr	$ 35,036		$ 35,036
38	**DE-SUPERHEATING SPRAY FLOWS (RH)** Assume 0.2% Heat rate for 1% of MSF	1	1 % MSF Sprays Reduced		17.38 Btu/KwHr	$ 140,144	$ 140,144	
39	De-superheating Spray Flows (RH) Assume 0.2% Heat rate for 1% of MSF	2	2 % MSF Sprays Reduced		34.76 Btu/KwHr	$ 280,289		$ 280,289
40	*MSF (Main Steam Flow)							
42	**REDUCED BOILER EXIT GAS TEMPERATURE** (.25% change in heat rate per 10°F)		8.5 °F Reduction		18.47 Btu/KwHr	$ 148,904	$ 148,904	
43	**AH A Gas Out: 335F** (2017) **to 324F** (2018) **/ AH B Gas Out: 319F** (2017) **to 313F** (2018)		20 °F Reduction		43.46 Btu/KwHr	$ 350,361		$ 350,361
44	**COST OF FUTURE MAINTENANCE ACTIVITIES AVOIDED**	Low	High					
45	Penthouse Vacuuming	$ 15,000	$ 20,000				$ 15,000	$ 20,000
46	Refractory Redo/Repairs	$ 25,000	$ 40,000				$ 25,000	$ 40,000
47	Penthouse casing/penetration weld repairs	$ 60,000	$ 120,000				$ 60,000	$ 120,000
48							$ 100,000	$ 180,000
50	Cost: Unit 10 ISOMEMBRANE® Applications : PH over furnace, ESP Inlet XJ's, AH Inlet XJ's & FGD Duct XJ		$ 733,725	ROI (Months): 2.8		**Annual Potential Savings Total**	$ 2,930,671	$ 4,384,796
52	**CONFIDENTIAL: This document and calculator are for internal use only.**							
53							$ 3,180,671	

CASE RESULTS:
FINANCIAL ROI

$3,180,671 annual savings
Project ROI 2.8 months



1. **Avoided 2 de-slagging outages** *(average 42 hours each)*: In the 9 months following the installation, zero de-slagging outages had been required. **Current Savings: $1,617,000** Annual savings: $2,482,200 - $3,309,600/year
2. **Start-up Fuel Oil Reduction**: 41,000 gallons at $4.15/gal = $170,150 x 2 = **$340,300**
3. **Reduced Fan Auxiliary Power Consumption**: **$396,733**
4. **Reduced de-superheating (RH & SH) spray flows**: **$157,662**
5. **Reduction in dry gas loss and FEGT**: **$148,904**
6. **Reduction in LOI**: 1% reduction = **$70,072**
7. **Repetitive maintenance avoided**: Estimated, **$100,000-$180,000**
8. **Other financial improvements**: Additional savings from reduced sorbent consumption, corrosion, ESP power consumption, & improved fuel efficiency. Estimated, **$250,000-$350,000**

(Based on results data provided by the plant or estimated based on experience with hundreds of boilers by HTT, Innovative Combustion Technologies and Storm Engineering.)

CASE RESULTS: MAINTENANCE ROI

1. **ISOMEMBRANE®** was **less than half the cost than traditional repair methods, and 3x faster to install**.
2. **Reduction or elimination of repetitive weld & refractory repairs, and vacuuming**.
   - Reduced annual repairs equals reduced welder & boiler-maker requirements, freeing up quality welders/workers to focus on more critical applications
3. **Reduced safety risks:** fewer workers on-site, less hot work, fewer vacuum hoses, etc.

CASE RESULTS:
RELIABILITY/EFOR ROI

1. **Reduced potential for boiler tube wastage and forced outages**.
   - Air in-leakage allows for sub-stoichiometric conditions. As plants are experimenting with different fuels (especially Illinois Basin), it's common to see wastage rates increase to 80 mpy.
   - The average lost opportunity cost of each tube leak for this plant is ~$950,000 - ~$1,450,000. (If ash has accumulated, delays to access to repair can occur.)
2. **Reduced propensity for slagging and/or clinker falls**.
3. **Reduced propensity for secondary combustion.**

Case Study: Duke Marshall Penthouse

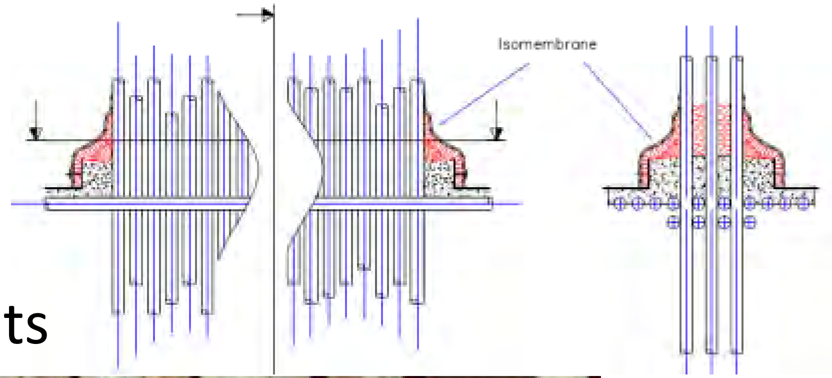
- Unit 4: 700 MW Supercritical Unit
- 3-5 feet of ash accumulation
  - approximately 100 tons
- Ingress of flyash caused typical problems
  - Safety
  - Reliability
  - Efficiency
  - Housekeeping

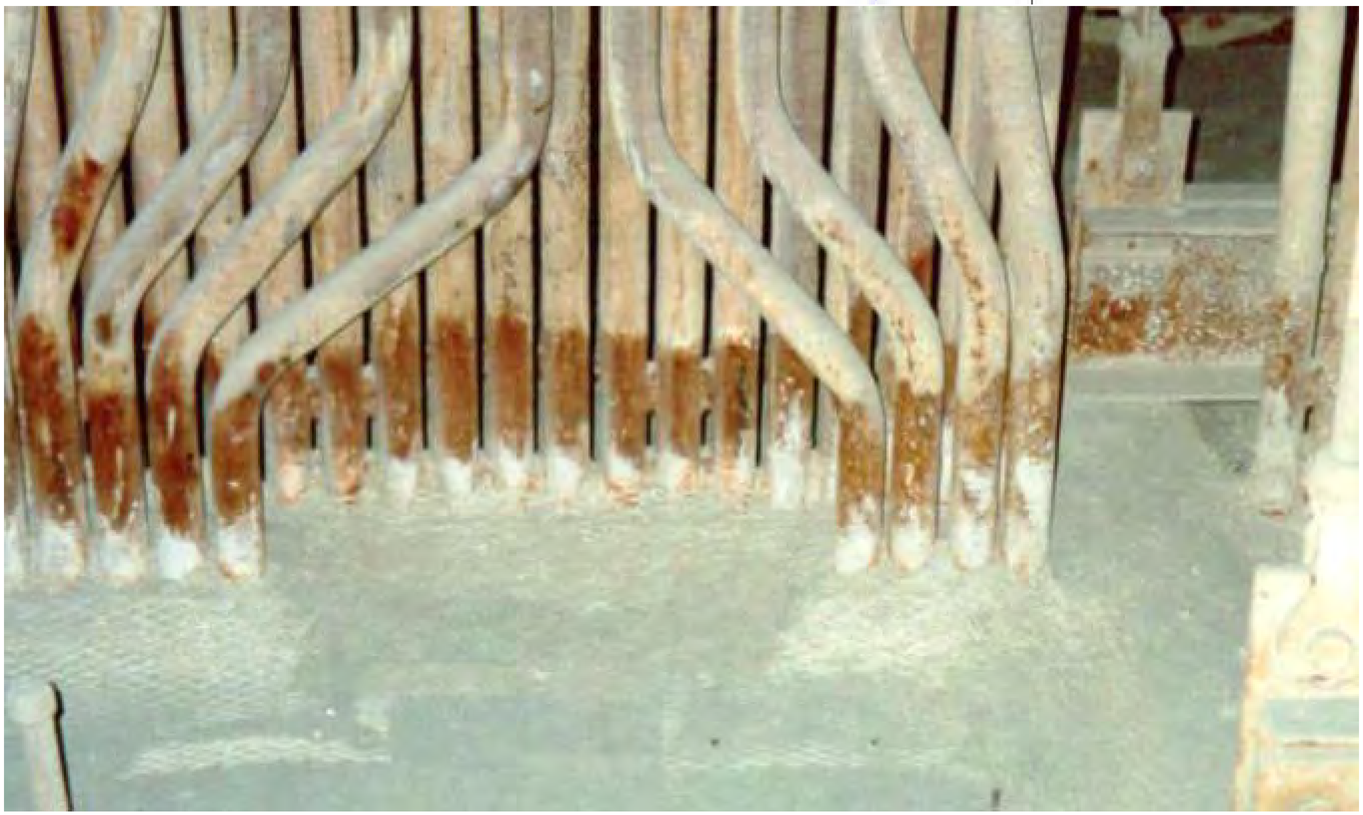
Prior to installation of ISOMEMBRANE® in 1994

Case Study: Duke Marshall Penthouse

After 1 Year in Service

- No vacuuming required
- Reduced outage requirements
- Reduced costs and labor requirements

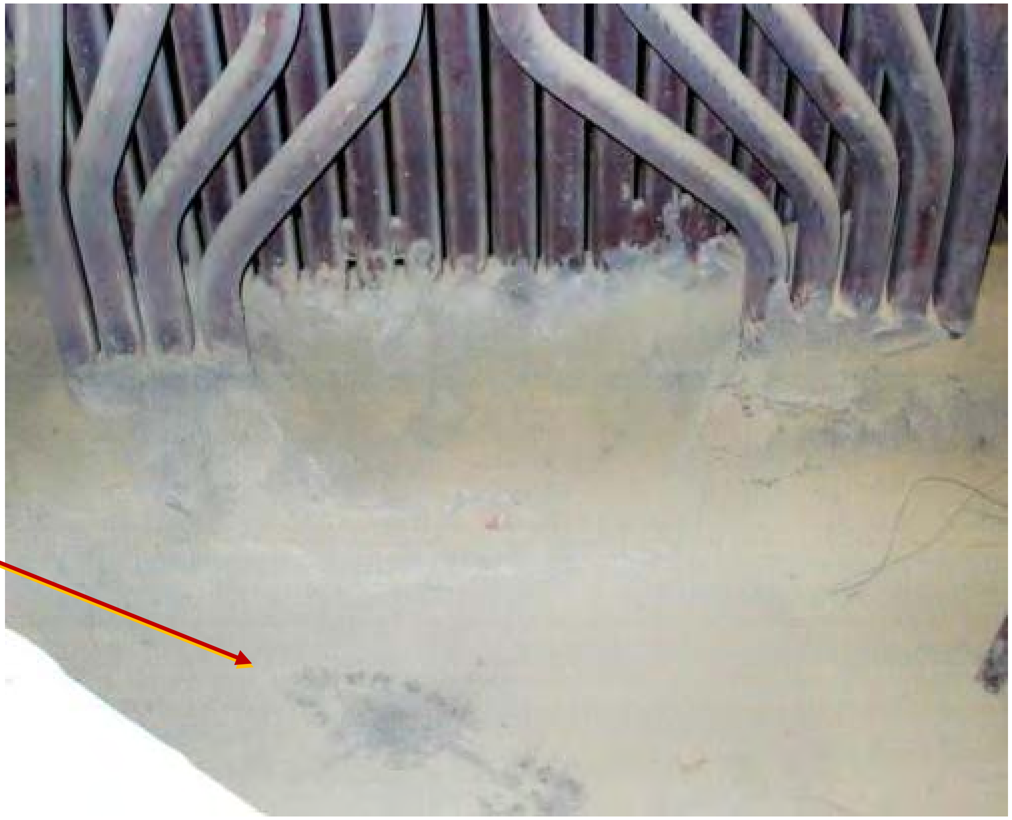




Case Study: Duke Marshall Penthouse
After 10 Years in Service

- Still no vacuuming required, only minor ash dusting exhibited
- Improved outage costs, budget flexibility, labor and safety
- Significant payback in reduced vacuuming & inspection costs alone

Minor ash dusting
(note foot print)



Case Study: Duke Marshall Penthouse
After 16 Years

- No ISOMEMBRANE® maintenance required
- Improved outage effectiveness, safety, and time & budgetary savings

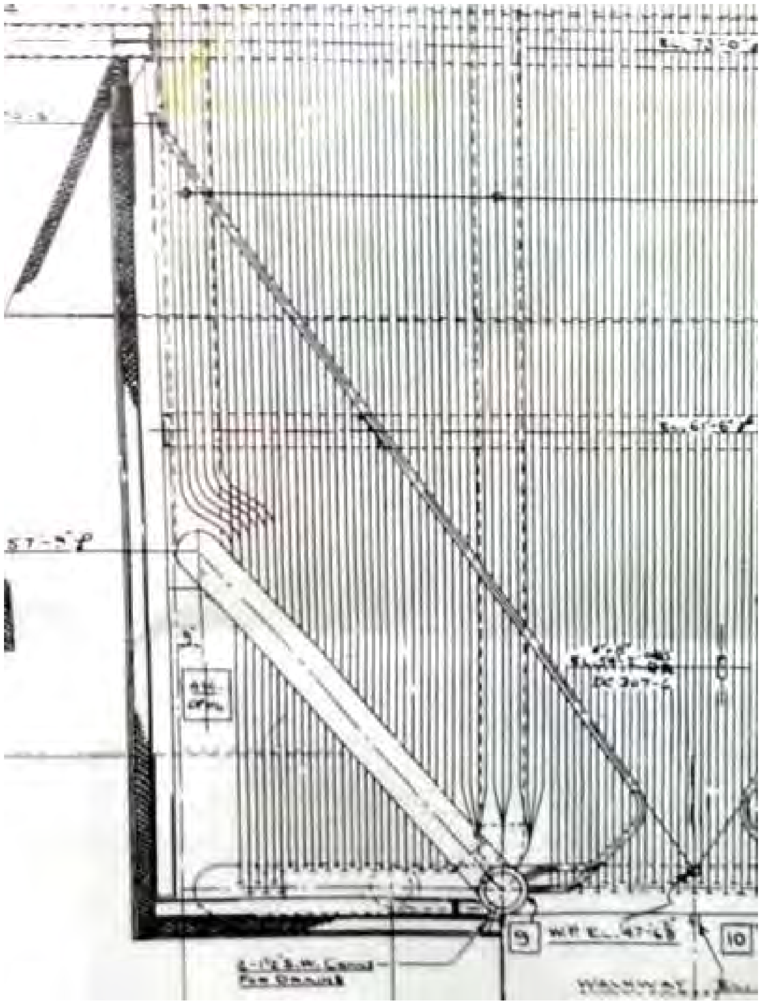
Original ISOMEMBRANE® Installation in 1994

Case Study: Lower Slope Clinker Damage

- 18’ x 4’ square clinker impact
- Emergency outage
- ISOMEMBRANE® installed in 3 shifts



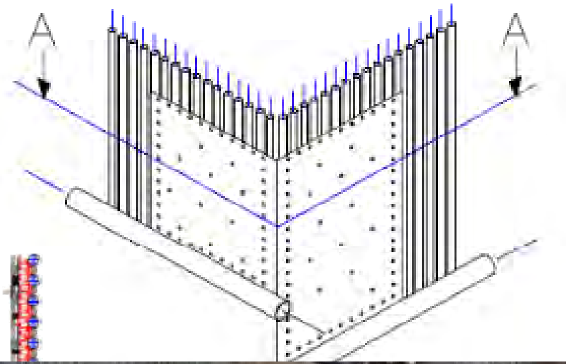
Case Study: Lower Dead Air Space



Case Study: Lower Dead Air Space

Installation prior to the ISOCOAT® layer

Case Study: Stoker Furnace Corner Casing Seal



Case Study: Stoker Boiler Chill Tube Casing Irregular Surface Installation Flexibility

Before

After

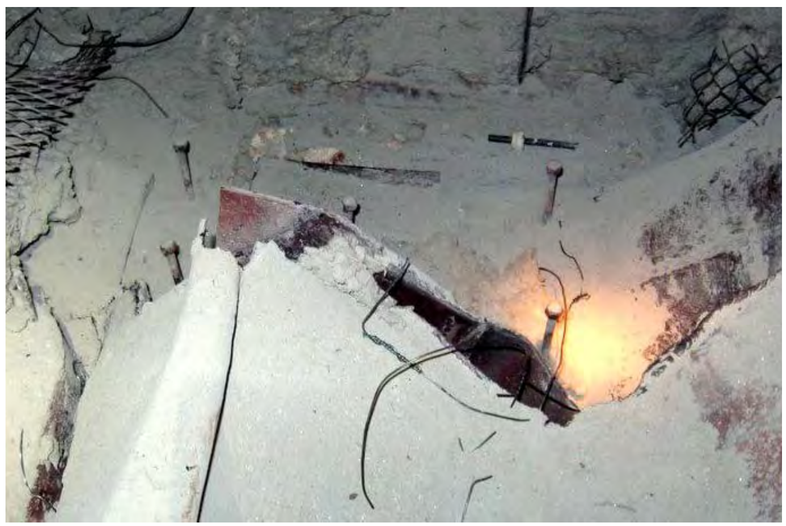
Case Study: Center Waterwall Header

Before

ISOMEMBRANE® in the
4th & 5th stages of installation

Installation Considerations

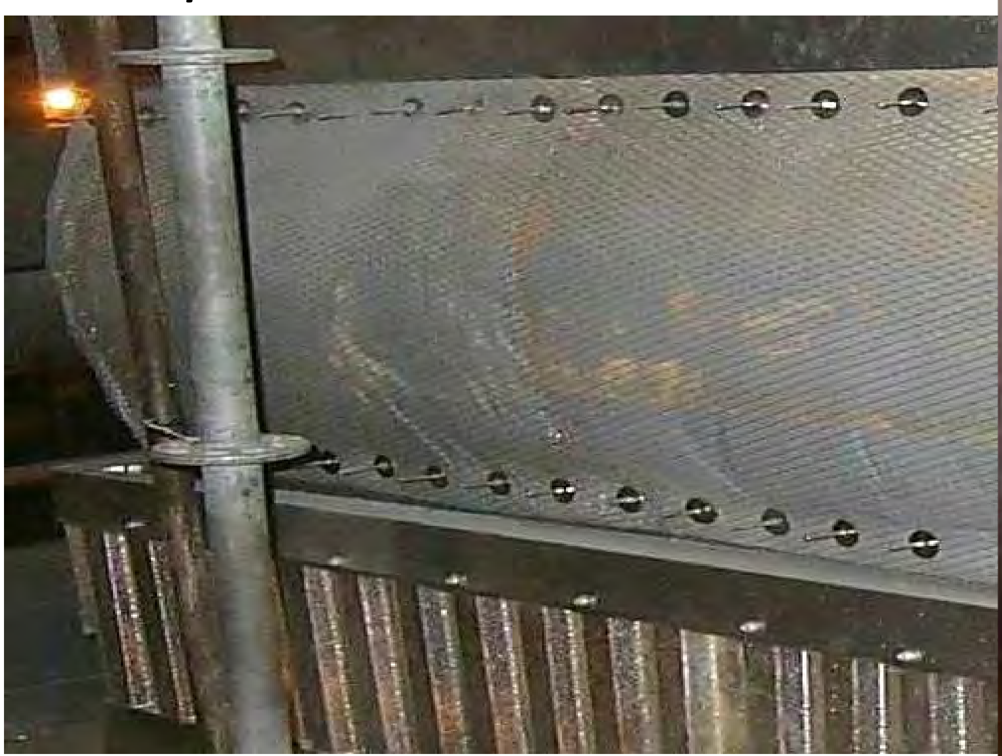
- Substrate Conditions
- Understanding of Movement
- Proper Installations



ISOMEMBRANE® as a Tool

In-situ Manufactured Expansion Joints

Aging and failing expansion joints are one of the most immediate risks to power plant compliance, availability, net output and emissions.



The Real Costs of Flue Gas Path Leakage

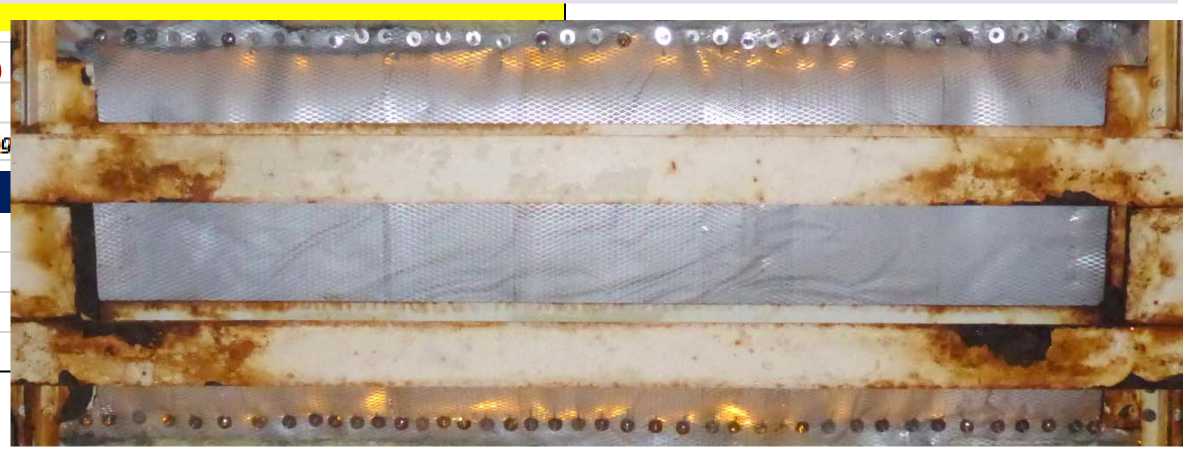
*Fan ROI Calculator by Howden Fan**

7	**FAN MOTOR ENERGY SAVINGS CALCULATOR**		
13	**Power Consumption Savings**		
14	Horsepower	700	HP
15	Voltage	4160	Volts
16	Fan Power Factor	0.85	(0.85 for 3
17	Current Before	64	Amps
18	Current After	54	Amps
19	Amp Draw Improvement	16%	Improvem
20	Energy cost	8	cents/KWh
22	Power Before	391.97	KW
23	Power After	330.72	KW
24	Power Δ	61.25	KW
26	Energy (24 hrs)	1,469.89	KWh
27	Plant Availability Factor	90%	
28	Energy (8760 hrs)	482,858.08	KWh
29	Annualized Savings	$ 38,628.65	Savings
31	Project Cost	$ 25,021.00	
32	ROI	236	days
33	*Note: This ROI calculation reflects only the direct energy saving*		
35	**Pressure Improvement**		
36	Pressure Before	16	"WC
37	Pressure After	12	"WC
38	Recovered Pressure	4	"WC
39	Improvement	25%	Improvement

A copy of this ROI Calculator in Excel format is available from HTT

CASE: 53MW Pennsylvania waste-to-energy plant.

- In-situ manufactured expansion joint encapsulation of failed joint & corroded ductwork upstream of the baghouse inlet
- ***Completed in 2 shifts, while unit online***
- **Immediate Plant Reported Results:**
  - **Decrease in Fan Pressure**: 16"WC to 12"WC *(25% improvement)*
  - **Decrease in Amp Draw**: 64 amps to 54 amps *(16% improvement)*
  - **Capacity Recovered: 1 MW**
- Value of Recovered Capacity: **$275,520** (wholesale PJM for 2017)
- Annual savings from reduced parasitic power consumption: **$38,625**
- **ROI: 29 days**



Case Study: ISOMEMBRANE® In-situ Manufactured Expansion Joint Encapsulations

- Unit 10: A&B APH Secondary Air Joints (2) *(Internal)*
- Unit 10: Scrubber/ID Fan Duct Joint *(Internal)*
- Unit 10: Precipitator Outlet Joints (2) *(Online)*

Case Study: A/B APH Secondary Air Joints

(Internal Installation)

- External access limitations avoided
- Avoid demolition and refabricating the duct and flange
- In-situ manufactured joint installed in 2-2.5 shifts

Existing Corroded Metal Bellows Joint.
Expensive & time-consuming to replace.
With in-situ manufactured joint encapsulations, demolition, flange/metal repair & fabrication are not required. Nor are detailed measurements.

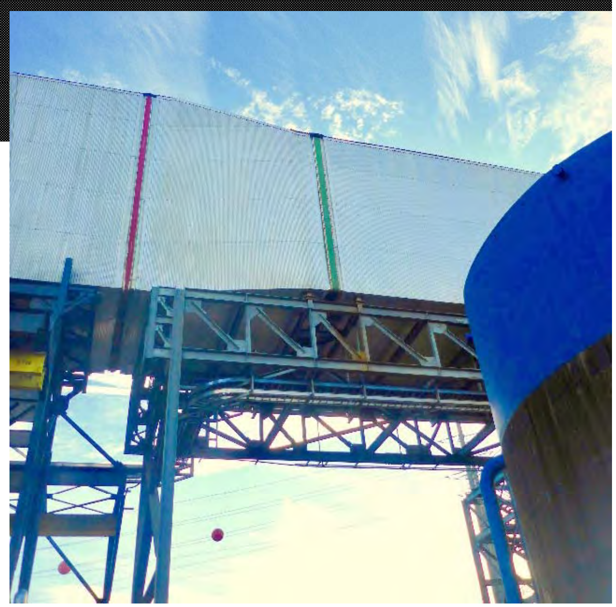
- *ISOMEMBRANE® bridges beyond corroded flanges & ductwork to good metal.*
- *120 linear feet per joint*
- *Both joints completed in 5 shifts*

Case Study: Scrubber/ID Fan Duct Joint
(Internal Installation)

- Minimizes scaffolding requirements & costs
- Improves job-site safety

ISOMEMBRANE® INTERNAL in-situ manufactured expansion joint encapsulation over existing fabric type joint,

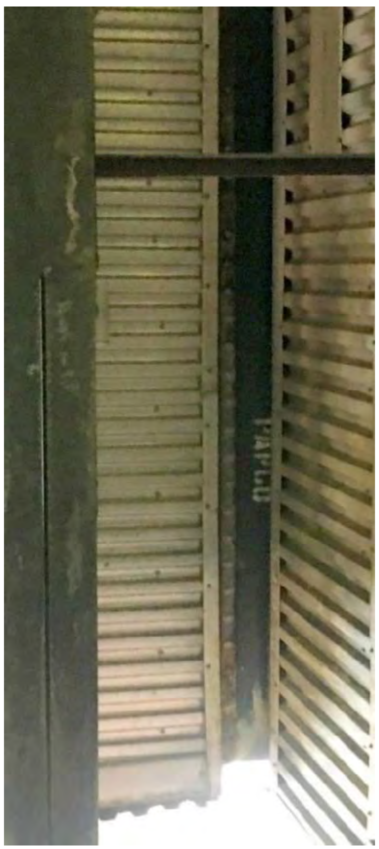
- *Internal install avoided the need for expensive exterior, ground-up scaffolding*
- *Joint Size: 28’4” x 28’4”*
- *Completed in 2 shifts*



Case Study: Precipitator Outlet Joints (2)

External, Online Installation

- Completed outside the outage window



ISOMEMBRANE® expansion joint encapsulation over existing joint

- *Each Joint: 113’ x 48’*
- *322 linear feet per joint -744 total LF*
- *2 joints completed in 7 shifts*

Case Study: Online Installations

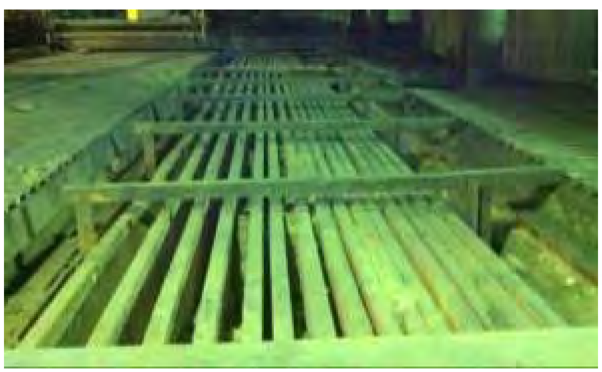
Safety dependent, typically negative draft / <350^{o}F

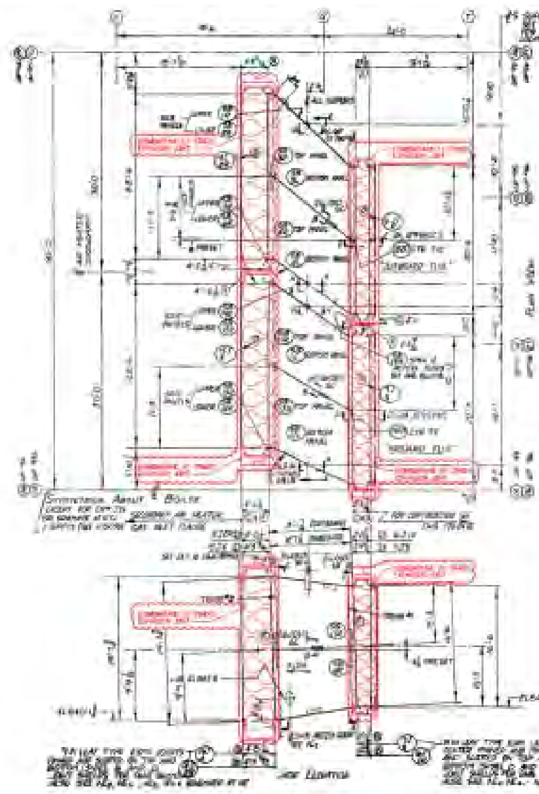
- Emergency Response: *(Can typically deploy within 12 -24 hours)*
- Allows work to be completed without loss of production, minimizing job-site traffic & projects to oversee.

Case Study: Economizer Outlet Joints

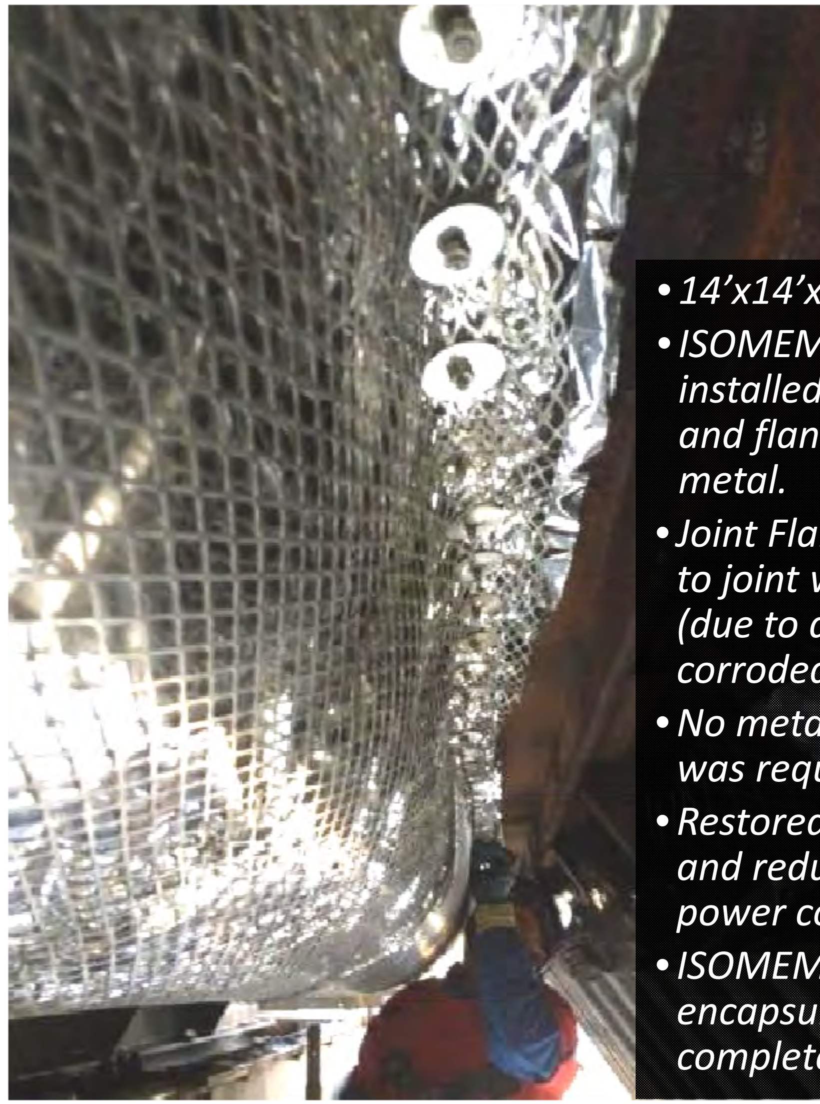
- **1170MW Supercritical Unit**
- **8 Economizer Outlet Joints Per Unit**
- Operating parameters
  - Temperature: <1,200ºF
  - Pressure: -15” WC
- Two sizes
  - 22’ x 20’ x 4.5’ seal breach
  - 22’ x 12’ x 4.5’ seal breach

NOTE: On 1/7/2014, on start-up, this unit tripped. The boiler had a 25” excursion, going from -15” to +10” in about a minute. The plant found no issues or disturbances with the ISOMEMBRANE® expansion joint.



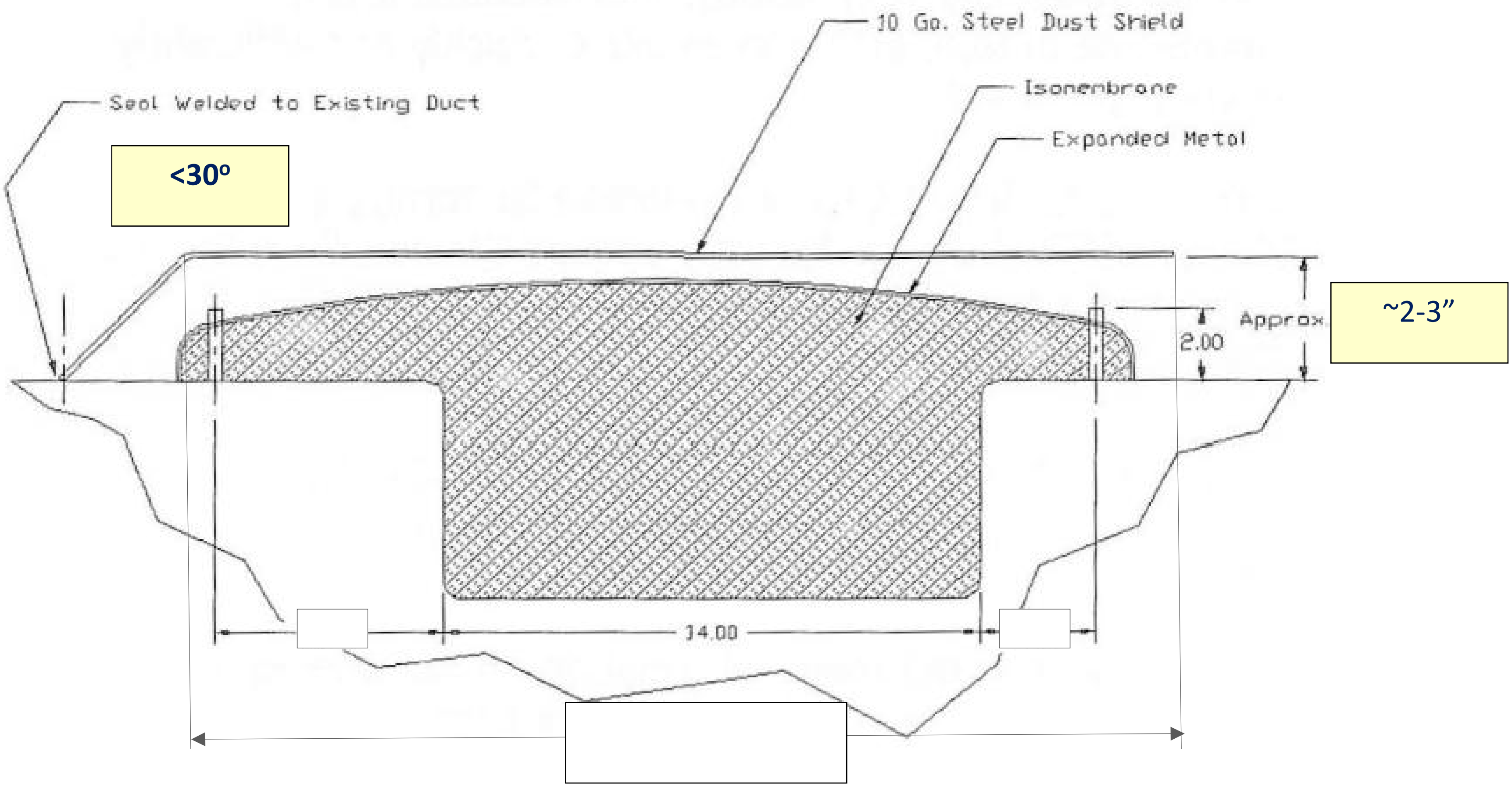


Case Study: Precipitator Outlet Joint & Flange



- 14’x14’x30” joint
- ISOMEMBRANE® installed over the joint and flange to good metal.
- Joint Flanges adjacent to joint were cracked (due to ash loading) & corroded.
- No metal fabrication was required.
- Restored fan capacity and reduced parasitic power consumption.
- ISOMEMBRANE® encapsulation was completed in 3 shifts.

Expansion Joint Shielding
High Temperature Internal Encapsulation



Case Study: Internal Encapsulation

Before

After

- with flow shield

RFQ Requirements

No Detailed Pre-engineering Required

Approximate *joint dimensions, temperature & pressure*

Part/Location/Unit:		
Quantity:		**Per Unit**
Length:		**ft/in**
Width:		**ft/in**
Breach (flange to flange):	/	**in./** if adjacent ductwork is corroded, approx distance to good metal beyond the flange
Movement:		**inches** ☐**Expands** or ☐**Contracts** at operating temperature
Temperature:		**ºF** (approx.)
Pressure+/-:		**"H_2O** (approx.) ☐**Negative** or ☐**Positive**
Install Location Preference:		☐External ☐Internal ☐Undetermined
Target Install Date?		
Level of Urgency		*"1" being Very High, "5" being Very Low*
Drawings/Photos Available?		

External versus Internal ISOMEMBRANE® installation:

- ☐*External –External sealing has advantages when the joint is under negative pressure; potentially lower install cost, ability to install ISOMEMBRANE® while the unit is online, and/or avoid the need for internal shielding. On positive pressure joints, this is an option when time and access are limited.)*
- ☐*Internal – Internal sealing has advantages when the joint is under positive pressure; potentially lower install cost, and/or where applicable, avoid/minimize scaffolding requirements.)*

ISOMEMBRANE® for **HRSG's**

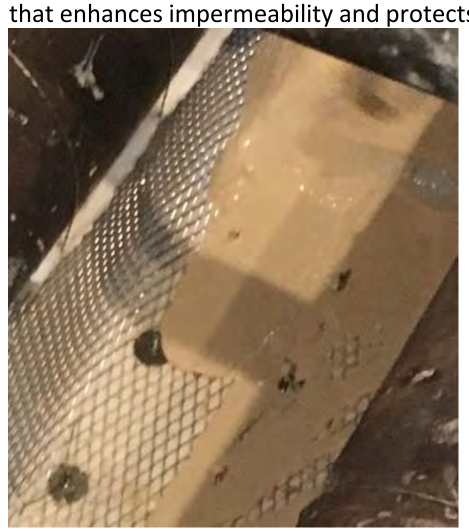
HRSG Superheater Section Penetration Seals

ZURN

BEFORE: This area had been problematic due to chronic cracking causing heat loss, efficiency issues and safety concerns. Standard repair methods were unreliable and required repetitive maintenance.

DURING: ISOSTUD® & ISOBLANKET® Installation.

DURING & AFTER: The final stage, the ISOCOAT® layer, is a thin layer (`1/8") topcoat that enhances impermeability and protects the ISOBLANKET®)



Rooftop Penetration Seals

2017: ISOMEMBRANE®
after 3.25 years in service

DELTAK

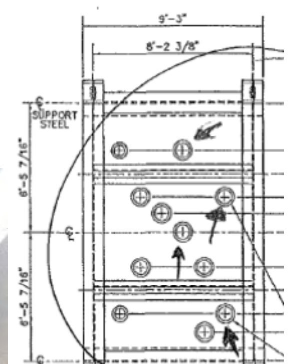




ISOMEMBRANE® Installation June 2014 on a Deltak unit where high heat from leaking roof penetrations damaged controls nearby causing the unit to trip twice.

The ISOMEMBRANE® installation on 8 penetrations was completed in 2 shifts while unit was offline for the weekend.

The plant manager reported the OEM type repairs would have required 7 shifts at almost twice the price.




Rooftop Penetration Seals

Installation Stage 9 of 14 stages

Rooftop Penetration Seals

Installation Stage 9 of 14 stages

Rooftop Penetration Seals

Downcomer Roof Tube Penetrations

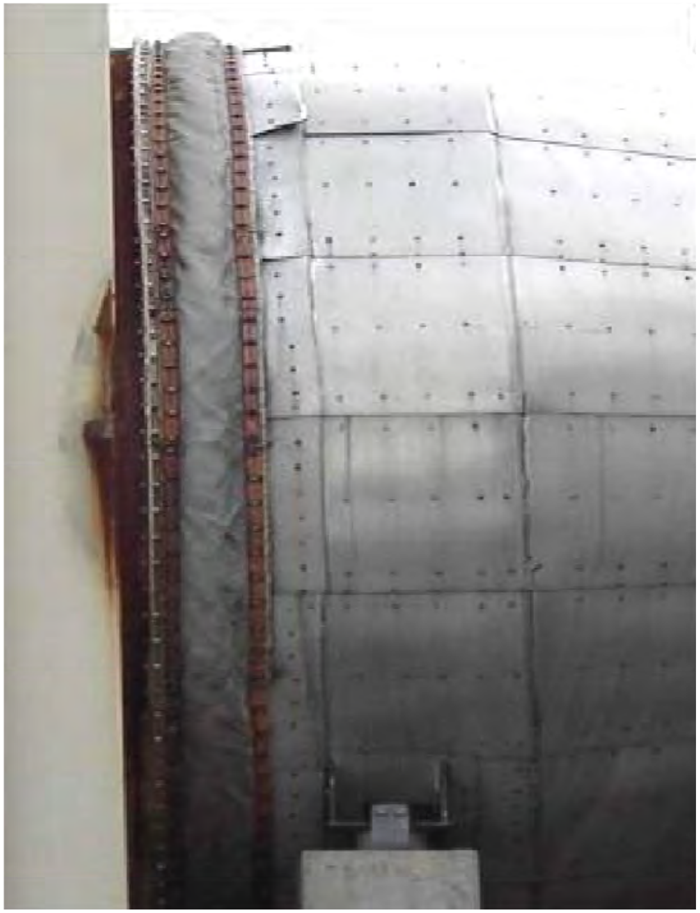
Roof Tube Penetrations

Header Drain Tube Penetrations

Exhaust Expansion Joints

High Temperature – High Pressure

Before



After

Exhaust Expansion Joints

NEM

High Temperature – High Pressure

Before

After

Exhaust Expansion Joints

High Temperature – High Pressure

Before

After

Stack Expansion Joints

ISOMEMBRANE®: Faster to Install, Less Expensive

Fan & Boiler ROI Calculators *(Excel)*

Fan ROI Calculator by Howden

	FAN MOTOR ENERGY SAVINGS CALCULATOR		
7	**FAN MOTOR ENERGY SAVINGS CALCULATOR**		
13	**Power Consumption Savings**		
14	**Horsepower**	**700**	HP
15	**Voltage**	**4160**	Volts
16	**Fan Power Factor**	**0.85**	(0.85 for 3-Phase Electric Motor, 1.
17	**Current Before**	**64**	Amps
18	**Current After**	**54**	Amps
19	**Amp Draw Improvement**	**16%**	**Improvement**
20	**Energy cost**	**8**	**cents/KWh**
22	Power Before	391.97	KW
23	Power After	330.72	KW
24	Power Δ	61.25	KW
26	Energy (24 hrs)	1,469.89	KWh
27	**Plant Availability Factor**	**90%**	
28	Energy (8760 hrs)	482,858.08	KWh
29	**Annualized Savings**	**$ 38,628.65**	**Savings**
31	**Project Cost**	**$ 25,021.00**	
32	**ROI**	**236**	days
33	***Note: This ROI calculation reflects only the direct energy savings for the electric mo***		
35	**Pressure Improvement**		
36	Pressure Before	16	"WC
37	Pressure After	12	"WC
38	**Recovered Pressure**	**4**	"WC
39	**Improvement**	**25%**	Improvement

Boiler ROI Calculator by ICT

The Boiler ROI calculator was created for HTT by INNOVATIVE COMBUSTION TECHNOLOGIES (ICT). ICT specializes in addressing combustion side parameters to identify & explore opportunities for improved unit heat rate, performance, availability, capacity and operability.

HTT

High Temperature Technologies, Inc.
4324 Barringer Drive #107, Charlotte, NC 28217
704.375.2111 *www.isomembrane.com*
Patrick Fitzgerald *cell: 704.621.2465*
patrick@isomembrane.com

Yellow Boxes are for manual data entry. *Other fields self compute*

For a copy of this BOILER ROI Calculator (in Excel format), email me, and I'll send you a copy.
patrick@isomembrane.com

	ROI Calculator - Air In-Leakage Control			
8	Unit Net Load (Mw)	788	Hours/yr	6570
9	Availability	75%	Capacity Factor	55%
10	Number of ID Fans	2	Fan HP	1,800
11	Heat Rate (Btu/Kwhr)	10,500	Heat Rate (Btu/Mwhr)	10,500,000
12	Fuel Cost ($/ton)	50	Fuel Heating Value (HHV) Btu/lb	12,000
14	**Calculations:**			
15	**Mw's/year**	3882870	Total Mw's	
16	Mw's/year= Unit Net Load (Mw) * Cap Factor (%) * 365 (days/yr) * 24 (hrs/day)			
17	**Fuel Cost**			
18	$/MMBtu = Fuel Cost ($/ton) *1,000,000 / (HHV (Btu/lb) * 2000 (lb/ton))	$ 2.08	$/MMBtu	
19	$/MwHr = (Heat Rate (Btu/MwHr) * Fuel Cost ($/ton)) / (Heating Value (Btu/lb) * 2000 lb/ton)	$ 21.88	$/MwHr	

21	*Parameter*		*Quantity or %Change in Heat Rate*		*Cost or Penalty*	*Total Cost Savings (per Year)*	*Savings LOW*	*Savings HIGH*
22	**FLYASH LOSS ON IGNITION (LOI)** *(alternative way of looking at fuel savings)*		1% Reduction in LOI		10.50 Btu/KwHr	$ 84,938	**$ 84,938**	
23	(Assume 0.1% Heat Rate per 1% LOI)		2 % Reduction in LOI		21.00 Btu/KwHr	$ 169,876		**$ 169,876**
25	**LOST GENERATION**	**Occurrences/yr**	**Hours/occ**		**$/Mwhr**			
26	**Lost Generation (54Mw de-rate to shed furnace slag)**	1	8		$35	$ 220,640	$ 220,640	
27	Lost Generation (54Mw de-rate to shed furnace slag)	2	8		$35	$ 441,280		$ 441,280
28	**Lost Generation (Unit off-line due to slagging incident, (x) 3-day incidents/yr)**	1	72		$35	$ 1,985,760	$ 1,985,760	
29	Lost Generation (Unit off-line due to slagging incident, (x) 3-day incidents/yr)	2	72		$35	$ 3,971,520		$ 3,971,520
30	**Plus fuel oil for restarts**							
32	**REDUCED AUXILIARY HORSEPOWER FOR ID FANS**							
33	(Repair resulted in decrease in mass flow of ~4%) yielding ~ reduction in ID hP of 10%	180.00	# ID Fans * Capacity factor * HP Reduction * .7455 Kw * Yearly Hours		$0.045 KwHr/ Bus Bar cost	$ 43,641	**$ 43,641**	
34	(Repair resulted in decrease in mass flow of ~8%) yielding ~ reduction in ID hP of 20%	360.00	# ID Fans * Capacity factor * HP Reduction * .7455 Kw * Yearly Hours		$0.045 KwHr/ Bus Bar cost	$ 87,281		**$ 87,281**
36	**DE-SUPERHEATING SPRAY FLOWS (SH)** Assume 0.025% Heat rate for 1% of MSF	1	1% MSF Sprays Reduced		2.63 Btu/KwHr	$ 21,234	$ 21,234	
37	De-superheating Spray Flows (SH) Assume 0.025% Heat rate for 1% of MSF	2	2 % MSF Sprays Reduced		5.25 Btu/KwHr	$ 42,469		$ 42,469
38								
39	**DE-SUPERHEATING SPRAY FLOWS (RH)** Assume 0.2% Heat rate for 1% of MSF	1	1% MSF Sprays Reduced		21.00 Btu/KwHr	$ 169,876	$ 169,876	
40	De-superheating Spray Flows (RH) Assume 0.2% Heat rate for 1% of MSF	2	2 % MSF Sprays Reduced		42.00 Btu/KwHr	$ 339,751		$ 339,751
41	*MSF (Main Steam Flow)							
43	**REDUCED BOILER EXIT GAS TEMPERATURE** (.25% change in heat rate per 10°F)		10 °F Reduction		26.25 Btu/KwHr	$ 212,344	$ 212,344	
44			20 °F Reduction		52.50 Btu/KwHr	$ 424,689		$ 424,689
45	**COST OF FUTURE MAINTENANCE ACTIVITIES AVOIDED**	**Low**	**High**					
46	Penthouse Vacuuming	$ 20,000	$ 40,000				$ 20,000	$ 40,000
47	Refractory Redo/Repairs	$ 20,000	$ 40,000				$ 20,000	$ 40,000
48	Penthouse casing/penetration weld repairs	$ 20,000	$ 40,000				$ 20,000	$ 40,000
50						**"Fully Loaded" Total**	**$ 2,798,433**	**$ 5,596,866**

Please provide email address for the ROI Calculators & copy of this presentation.

Other Reference Documents:

** **ISOMEMBRANE® Sealing Project Report***
*** **BOILER ROI Calculator** to estimate savings associated with air in-leakage, created by Innovative Combustion Technologies.*
**** **2017 EPRI Heat Rate Conference Paper**, "Impact of Air In-Leakage on Unit Reliability & Operating Costs," by Stephen Storm, Duke Energy's Combustion & Boiler Performance Program Manager, and Patrick Fitzgerald, High Temperature Technologies.*

2019 UDC 24th Annual Users Conference

Controlling Air In-Leakage to Optimize Unit Performance & Reliability, and Reduce Operating Costs

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