REINHOLD ENVIRONMENTAL Ltd.

2015 APC Round Table & Expo Presentation

July 13 & 14, 2015, in Atlanta, GA / Hosted by Southern Company

ENGINEERING
YOUR SPRAY SOLUTION

Successful Operation of Flue Gas Humidification/Cooling Using Spray Nozzles Upstream of DSI

Robert Van Durme, P.E.







Workshop Overview ….

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- What is DSI
- The Challenges of Upstream Cooling
- Fluid Application Engineering
- Comparison of Nozzle Technologies
- Case Study
- Question & Answer

What is DSI….

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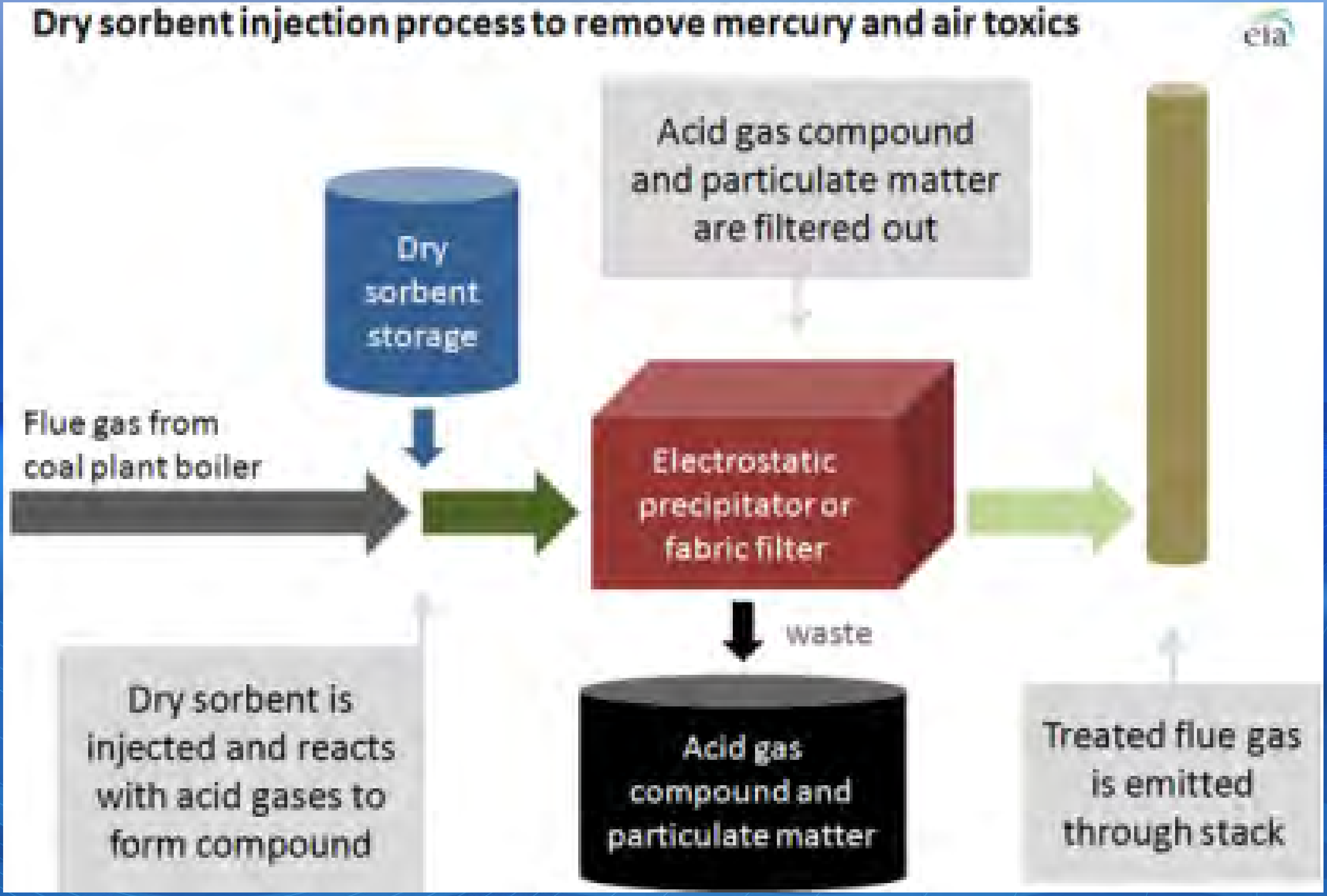
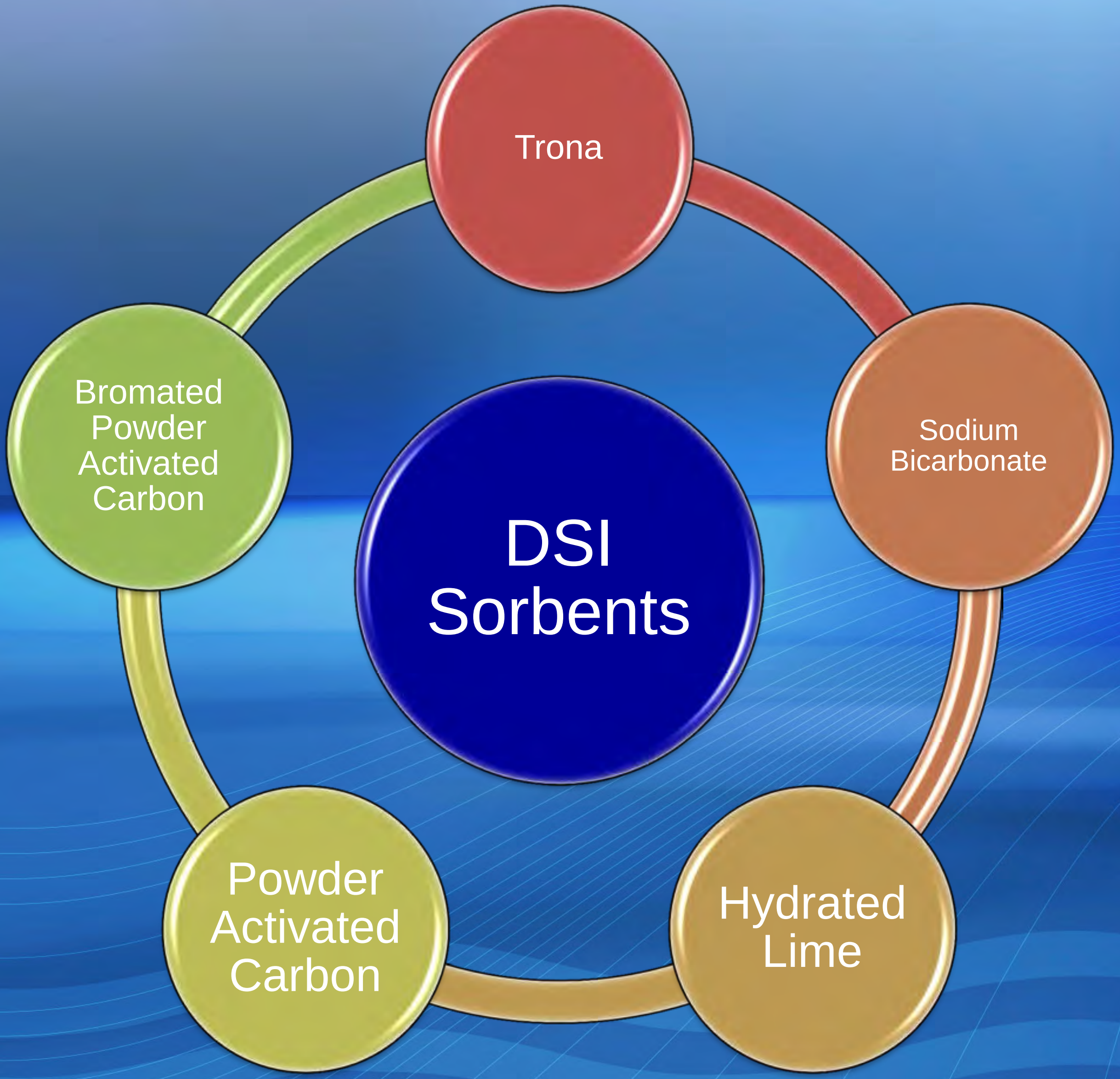


Source: U.S. Energy Information

What is DSI….


Trona
Sodium Bicarbonate
Hydrated Lime
Powder Activated Carbon
Brominated Powder Activated Carbon
DSI Sorbents

What is DSI….

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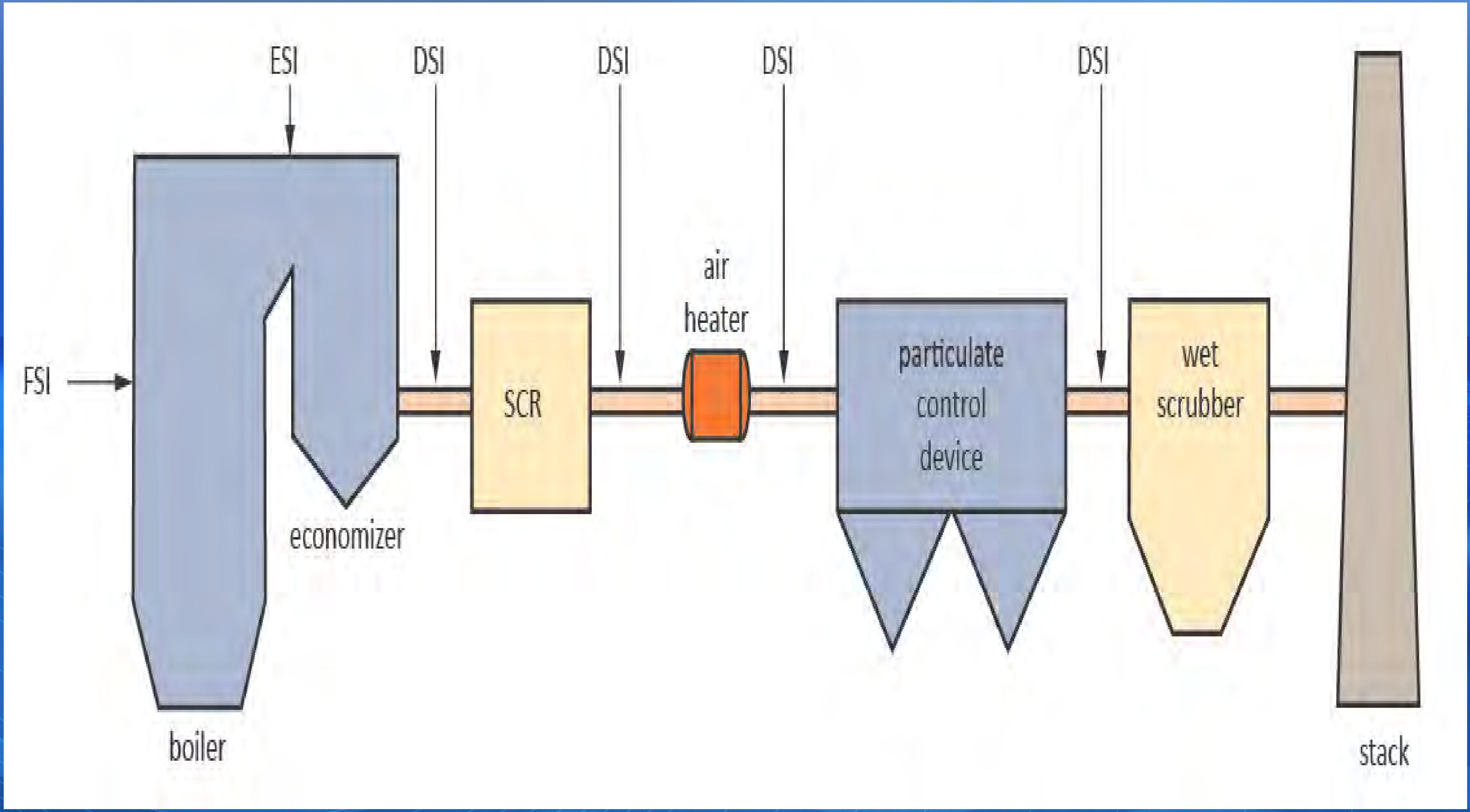

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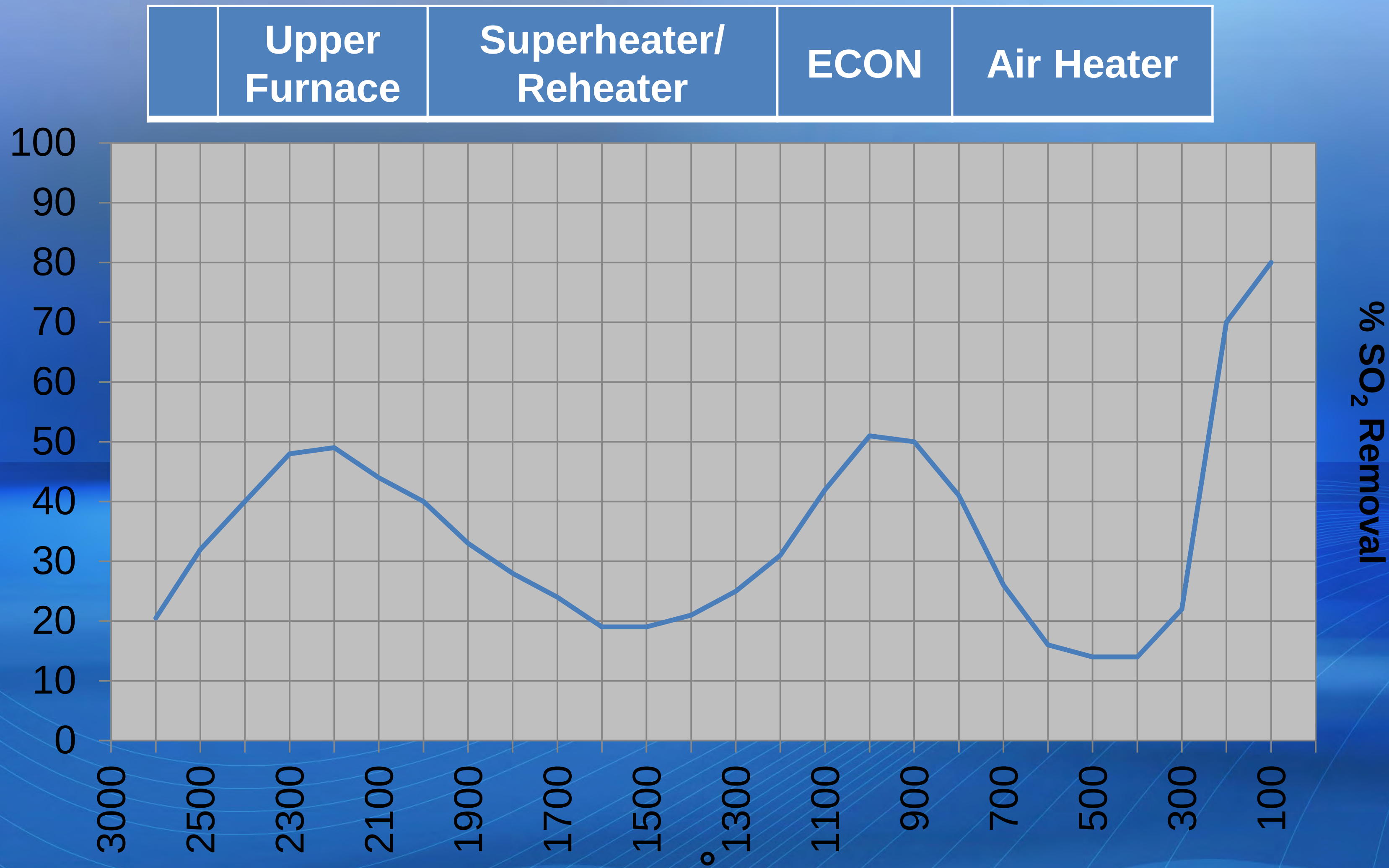

Figure 1 - SO_2 Removal As A Function of Flue Gas Temperature at Ca/S of 2.0 - Dry Sorbent FGD – Calcium Based Reagents (1)

“Results of Dry Sorbent Injection Testing to Reduce HCL”, Carl Laird, Kevin Smith, Carmeuse Lime & Stone; Brandon Looney, Southern Company

Challenges of Upstream Cooling

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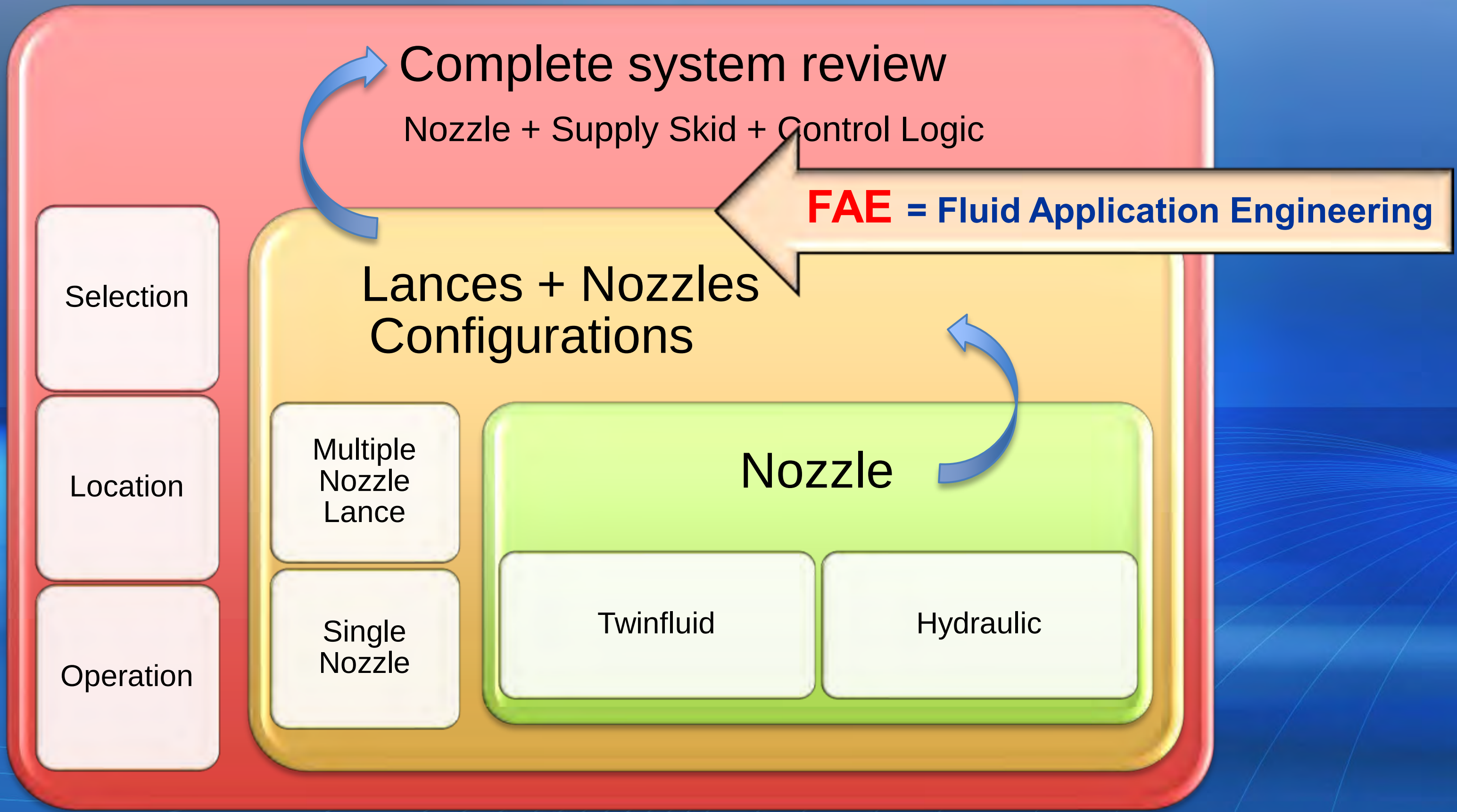
Anyone can do it!

Due diligence needs to be performed…



From components to systems – from small to big

The complete system must be matched to perform

Selection

- Droplet Size
- Twinfluid/Hydraulic
- Operating Pressure
- Spray Angle
- Turndown
- Material
- Turndown Ratio
- Free passage

Location

- Evaporation Distance
- Coverage
- Orientation
- Gas Distribution
- Temperature
- Duct Geometry
- Accessibility

Operation

- Steady-state
- Process Fluctuations
- Control Logic
- Redundancy
- Fail-safe
- Maintenance
- Nozzle Wear
- Durability

Comparison of Nozzle Technologies

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Twinfluid

Twinfluid with Ring Gap Technology

Hydraulic

Spillback

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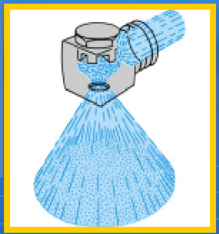
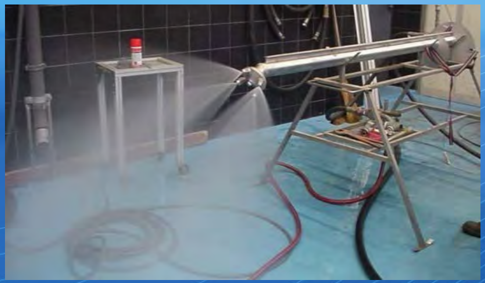
Spray Nozzle Types

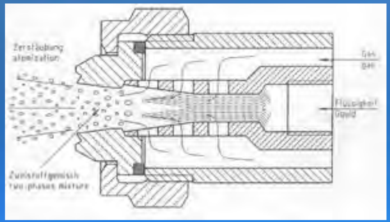
Air Atomizing – shearing liquid into droplets with a high velocity air stream using compressed air

Hydraulic Atomizing – shearing a high velocity sheet of liquid into droplets by the relative velocity of the adjacent, relatively stationary, air.

Atomizing Method / Turn-down / Droplet Size

Air Atomizing / < 40:1 / as small as 20 micron SMD , 80 -100 psi



Simple Hydraulic / < 3:1 / as small as 30 micron SMD , 2500 psi, <1gpm

Spillback (Return Flow) Hydraulic / 10:1 / as small as 100 micron SMD rated capacity dependent at full flow

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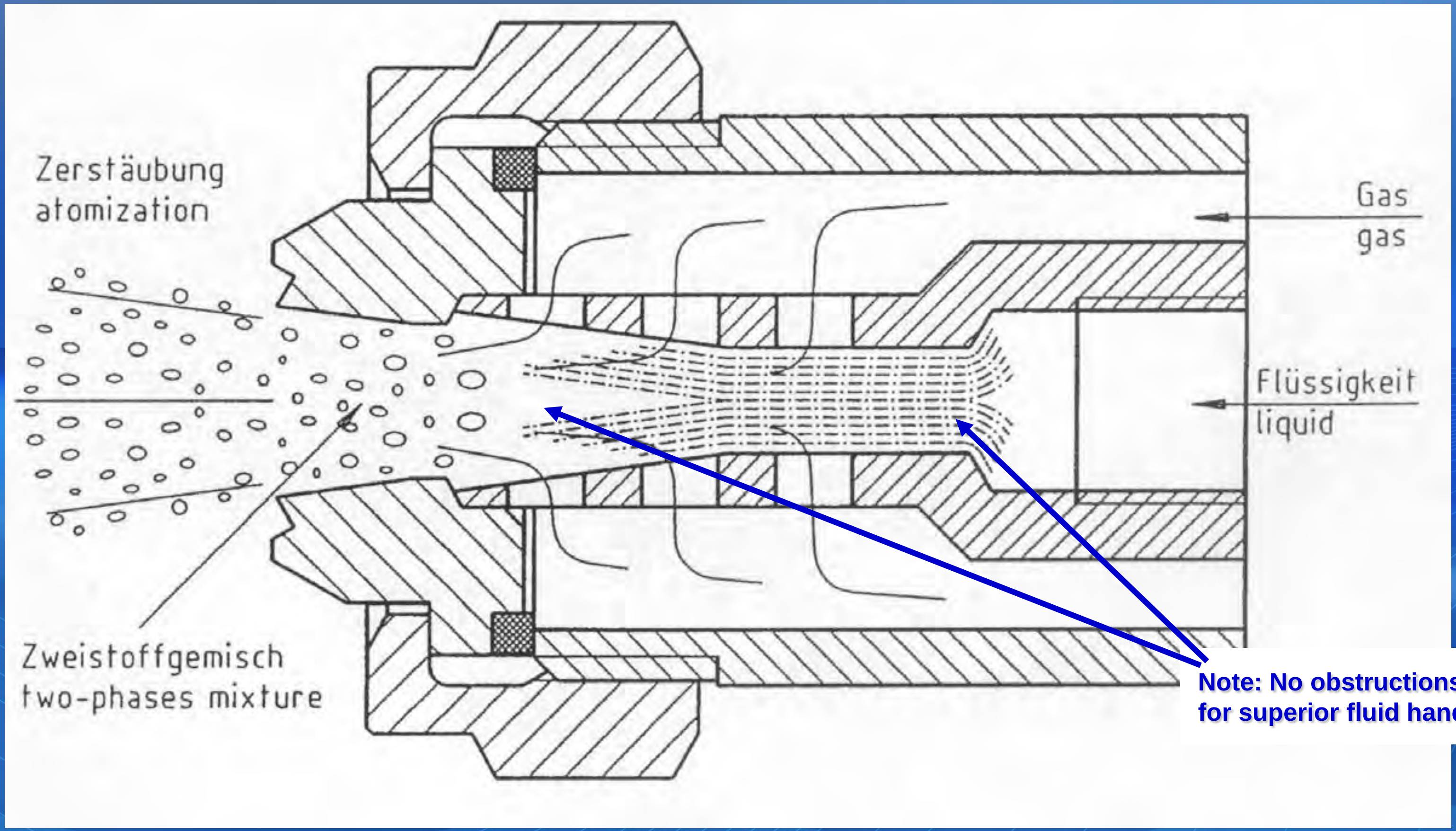
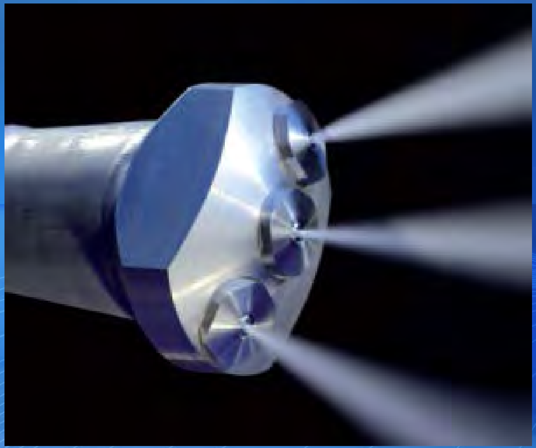
Lechler Nozzle: Twin Fluid - Laval-Type (internal mixing)



Note: No obstructions in fluid path for superior fluid handling.

Lances and systems for humidification/cooling can be single point or multiple nozzle configuration to ensure proper spray coverage



A barrier air pipe can cover entire lance and provide low pressure (~ .5 psig) air supply to keep nozzle orifice clean from buildup

Parameters which Influence Droplet Size – Air atomizing

Higher Air/Liquid mass ratio provides smaller droplets
Higher air pressure can provide a narrow droplet spectrum
For a given flow rate and droplet size, choose the smallest capacity nozzle operated at the highest air pressure to use the lowest amount of air

Standard Twinfluid

Standard Twinfluid with Ring Gap

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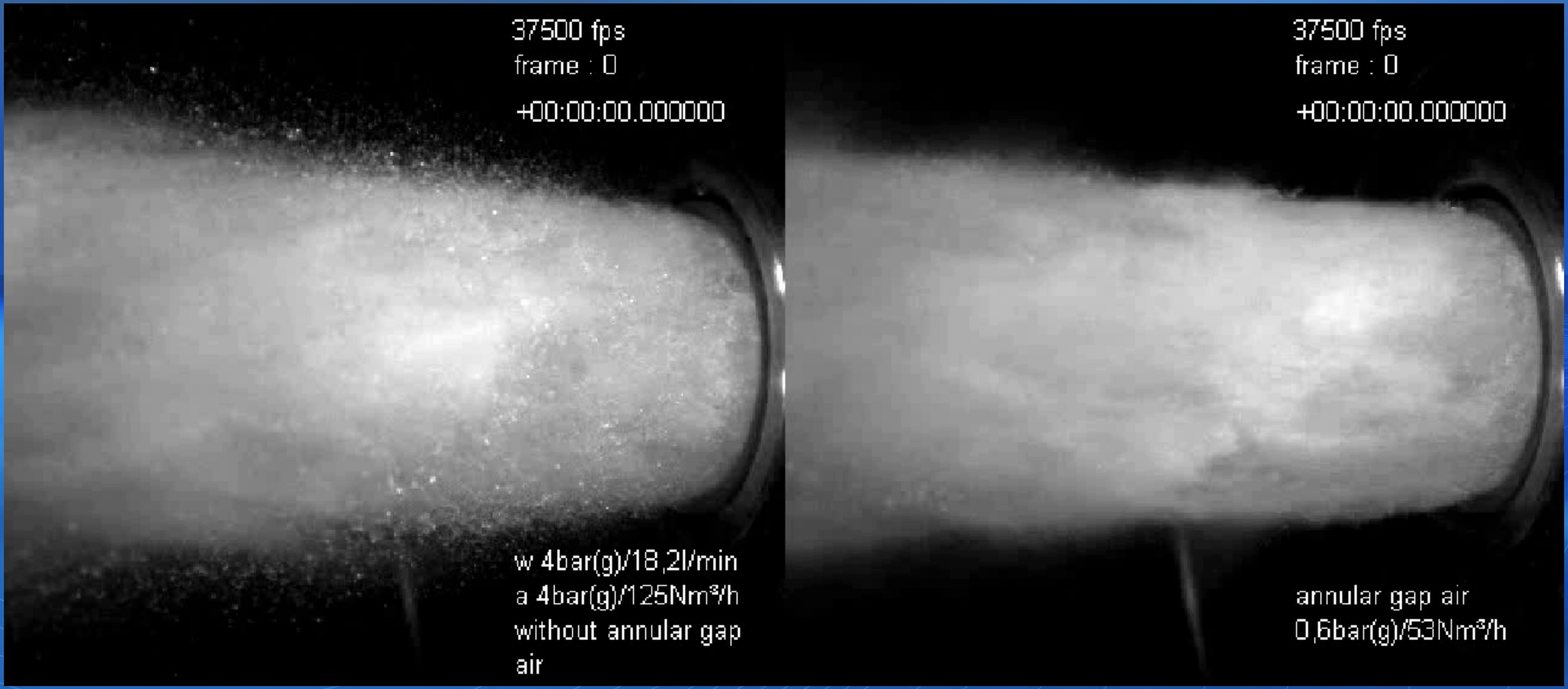
Ring Gap Technology



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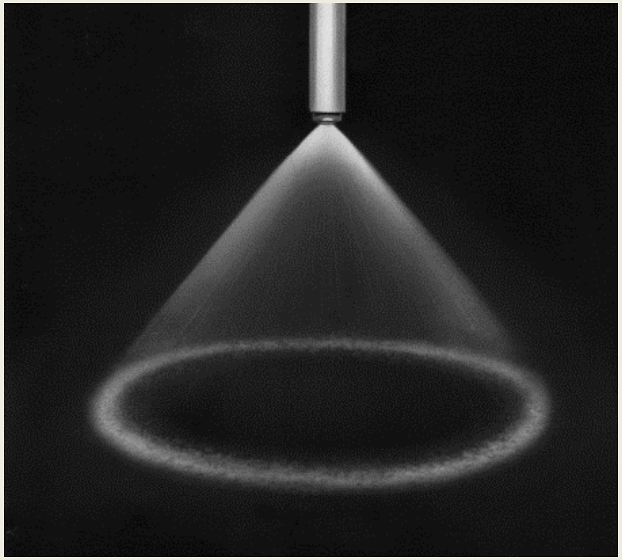
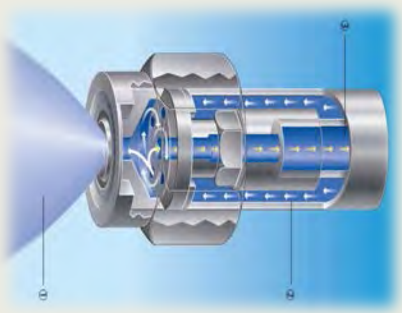
Hydraulic Nozzle



- Finely atomized hollow cone spray is produced by pump pressure orifice.
- The droplet size is proportional to the supply pressure
- Dmax can be several times greater than twinfluid or Spillback technology
- Regulation of the spray volume is achieved by adjusting supply pressure.

Spillback Nozzle



- Finely atomized hollow cone spray is produced by balancing the flow through the nozzle orifice and the return line.
- The high pressure liquid feed flow produces a uniform spray angle and Dmax < 300 um over the entire range of flow.
- Regulation of the spray volume is achieved by adjusting a control valve on the return line.

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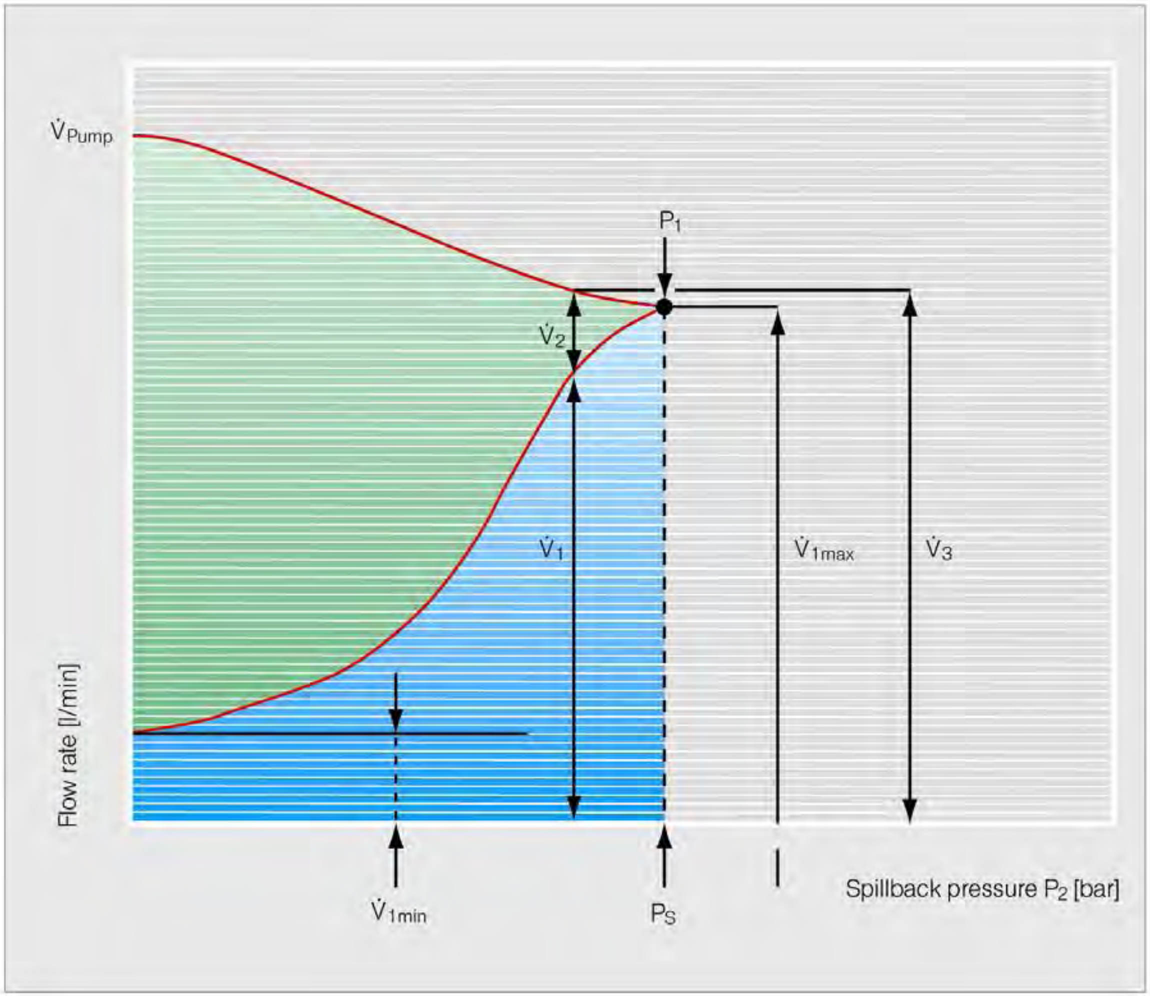
Spillback Nozzle



$\dot{V}_1$ = Sprayed volume

$\dot{V}_{1max.}$ = Max. sprayed volume (return line closed)

$\dot{V}_{1\,min.}$ = Min. sprayed volume (return line com-pletely open)

$\dot{V}_2$ = Spillback flow rate

$\dot{V}_3$ = Pump delivery

$\dot{V}_{Pump}$ = Pump delivery per nozzle

P_1 = Constant feed pressure

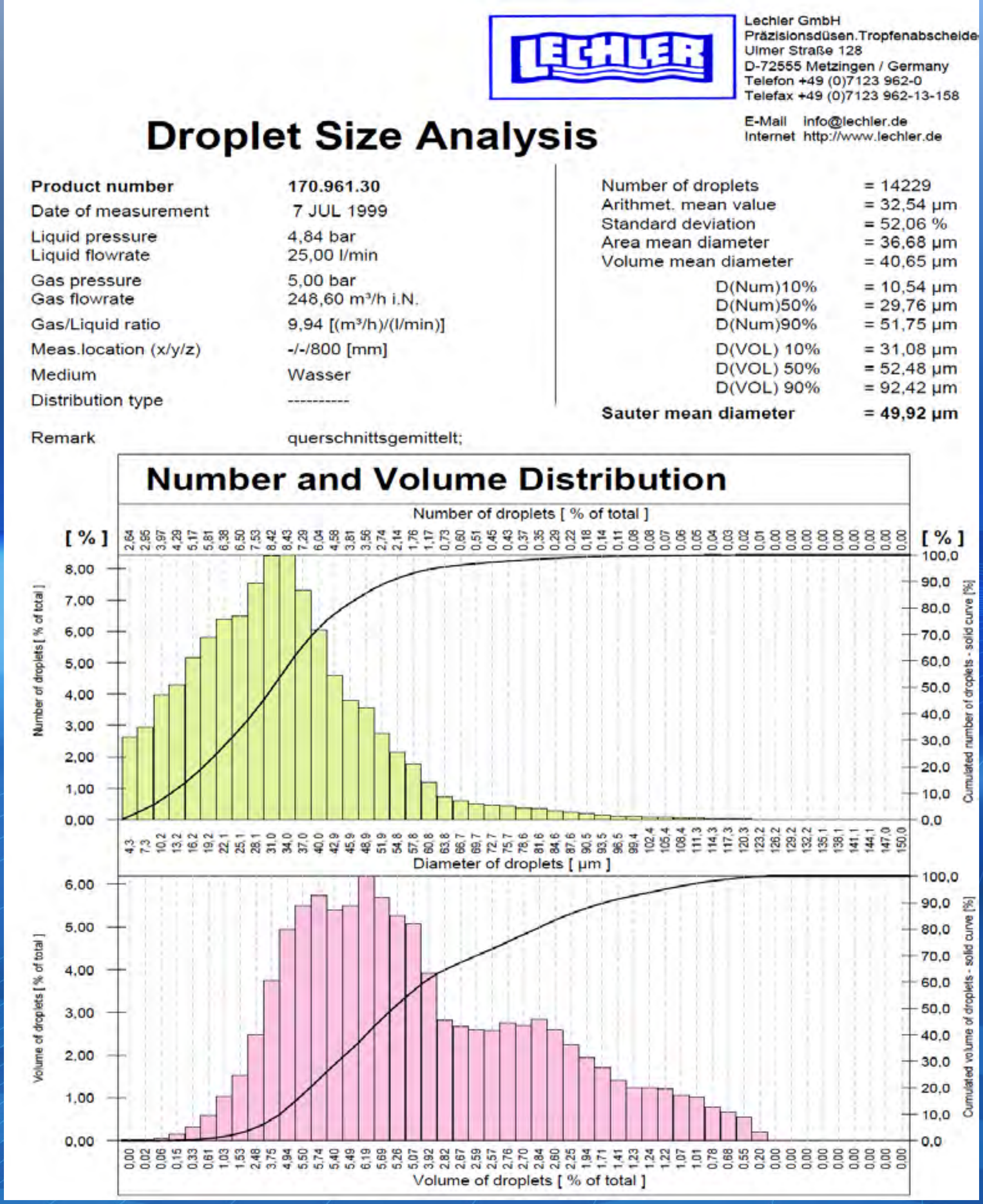
P_2 = Spillback pressure

P_S = Spillback pressure at $\dot{V}_{1max.}$ (P_{max} for control valve)

Turn down ratio = $\dot{V}_{1max.} / \dot{V}_{1min.}$

Droplet Size

Characterization



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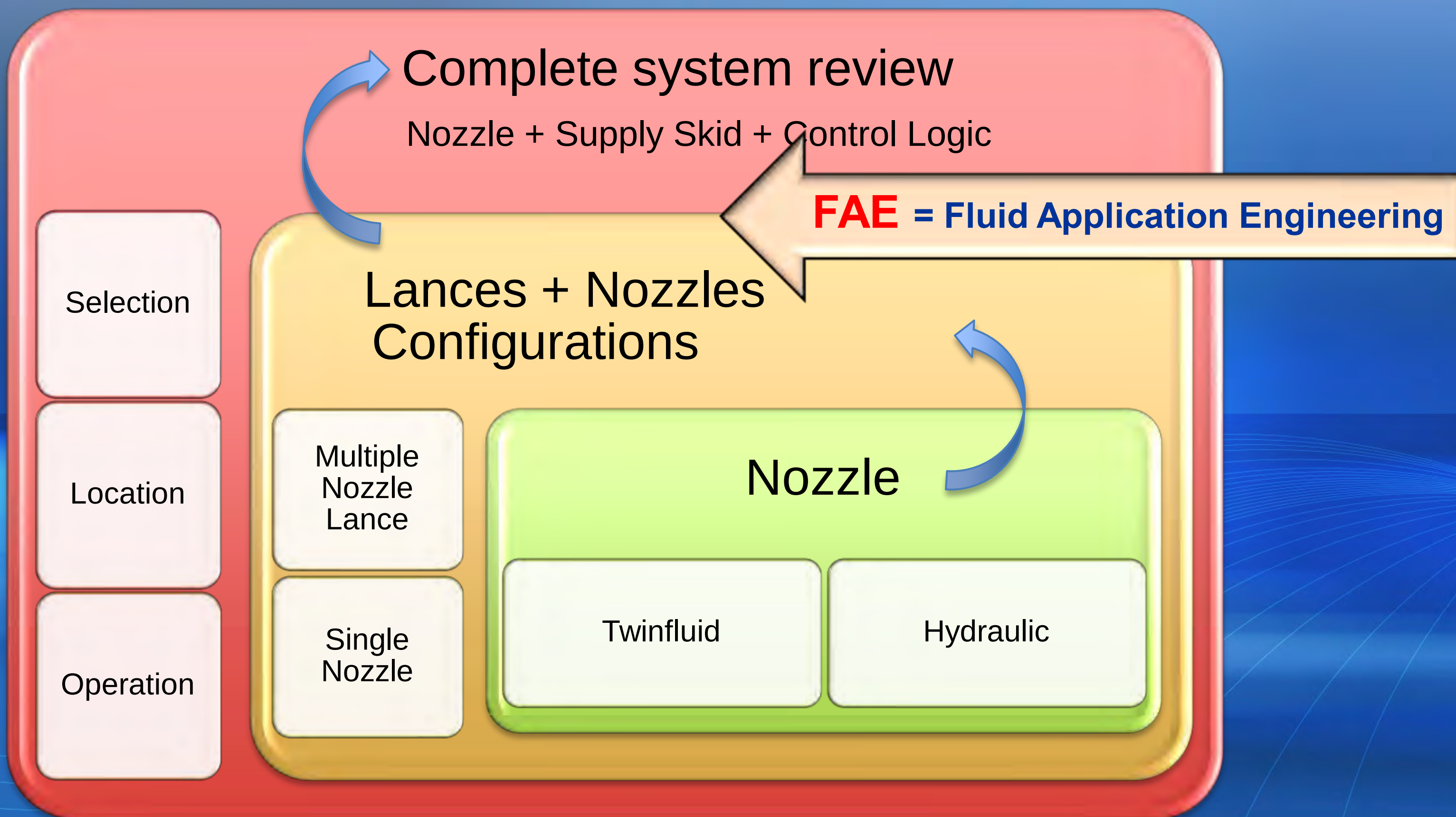
Due diligence needs to be performed…



From components to systems – from small to big

The complete system must be matched to perform

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Successful operation of flue gas humidification/cooling using spray nozzles upstream of Dry Sorbent Injection (DSI)

Robert Van Durme, P.E. – Lechler Inc., Key Account Manager
Leon Lenertz, P.E. – Xcel Energy – Red Wing Station, Operations Manager
Ashwin Patni – Lechler Inc., Key Account Manager

Xcel Energy Red Wing Station Unit 1 & 2

Plant Data

Plant Issues and Opportunities for Improvement

Modeling

Results & Findings

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Xcel Energy Red Wing Station Unit 1 & 2

Design Data

–Each Unit Size: 12MW

–Original built as coal-fired generation plant

–Currently burns RDF (Refuse-Derived Fuel)

In-Duct Scrubber

–Flue gas design flowrate: 110,000 ACFM

–Total water feed flowrate at design 24 gpm/unit

–Total compressed air: ~ 1,500 SCFM

–~ 425° Preheater Outlet

–~ 285° Baghouse Inlet

–Approximate lime usage: 4,500 tons/year

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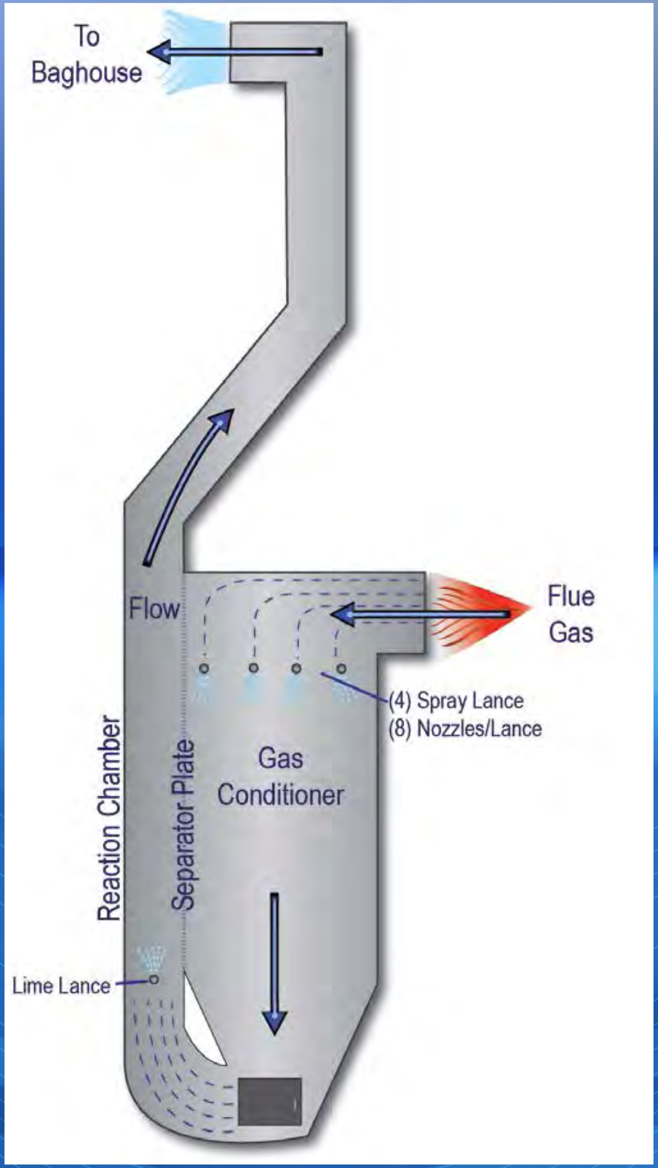
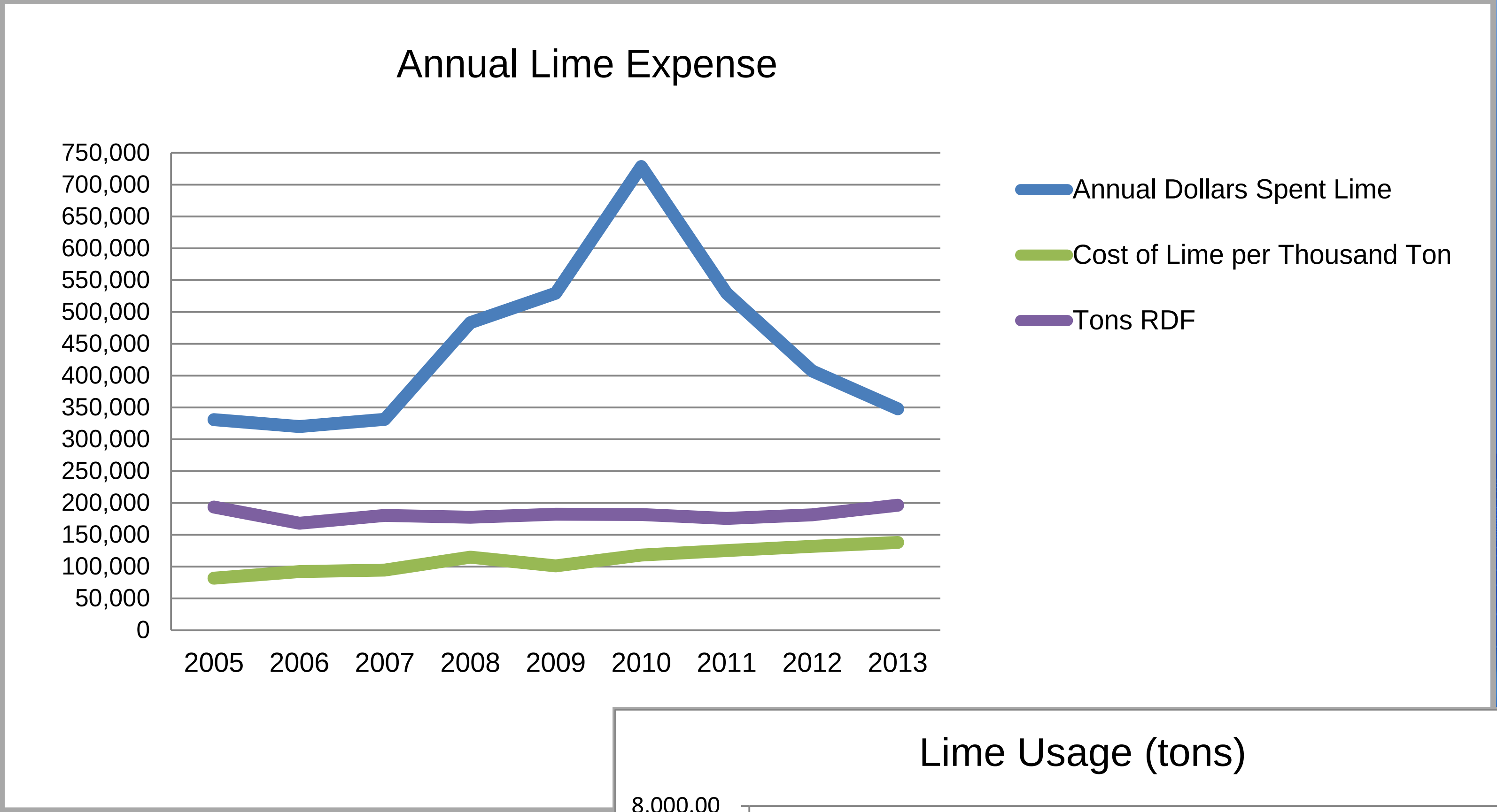
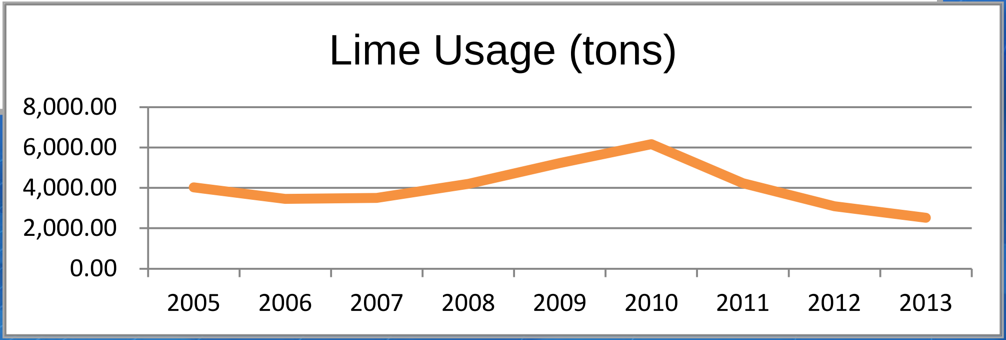
Red Wing Plant Data (cont'd)



Red Wing Plant Data (Cont'd)
Annual Lime Usage and Expense





Case Study

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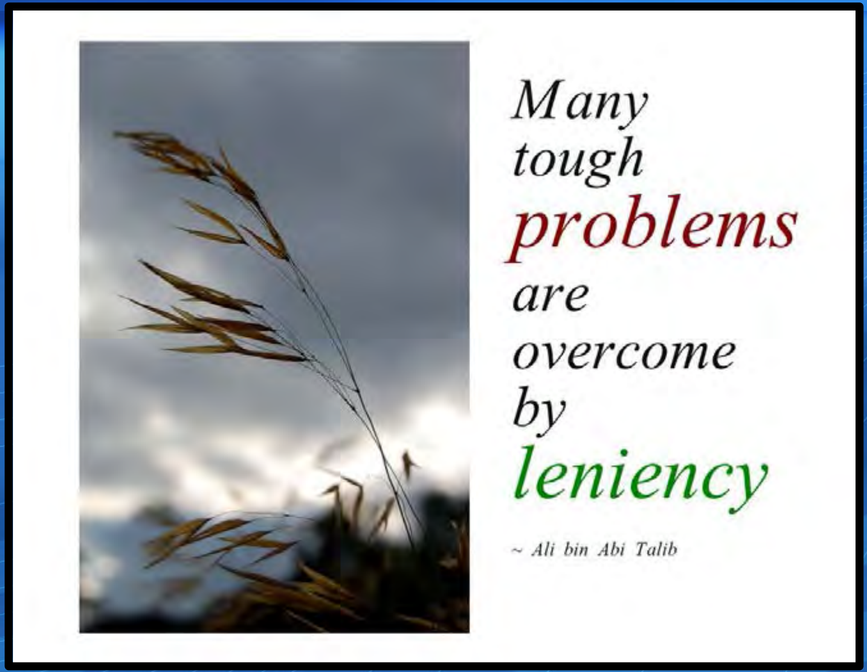
- **High energy costs for compressed air usage: 1,500 SCFM (750 SCFM/unit)**
- **Maintenance costs for air compressor: $ 25,000+ annually**
- **Increasing lime usage/costs: $ 700,000 annually**
- **Nozzles: High maintenance and man-hours for servicing**
- **Reaching bag temperature limit**



Case Study - Plant Issues (cont’d)

High Compressed Air Usage

Nozzle design issue

High Maintenance Costs

Air compressor required

Frequent maintenance

Premature Nozzle Wear

316SS nozzle material construction, not suitable for process conditions

Acid gas condensation on metal surfaces

Duct Wetting

Incorrect nozzle/lance layout inside ductwork

Why duct humidification/cooling prior to DSI?

- **Improve reactivity rates with reduced gas temperature**
- **Reduce fan power usage**
- **Lower operating costs via lower temperature bags**
- **Reduce sorbent usage/type**
- **Reduce ESP loading**

What's the catch….hasn't this been tried before?

- Duct wetting
- Duct corrosion
- Buildup and pluggage
- Reliability issues

Case Study - Timeline

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2010

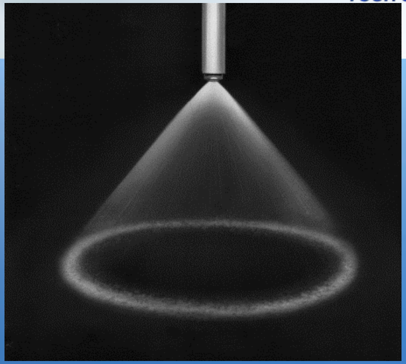
- Droplet size modeling

2011

- Installed test nozzles
- Installed 2 complete set of nozzle twinfluid lances

2012-2013

- Converted to hydraulic-only lance design

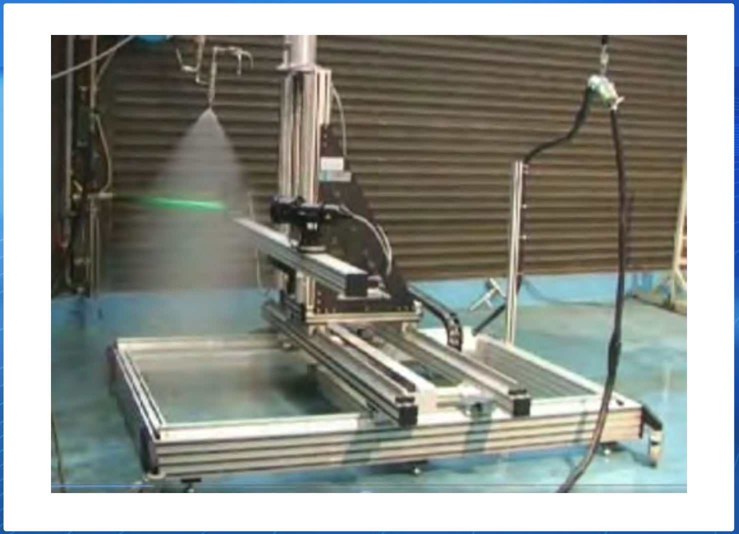


Original Lances

- Aggressive corrosion of base material

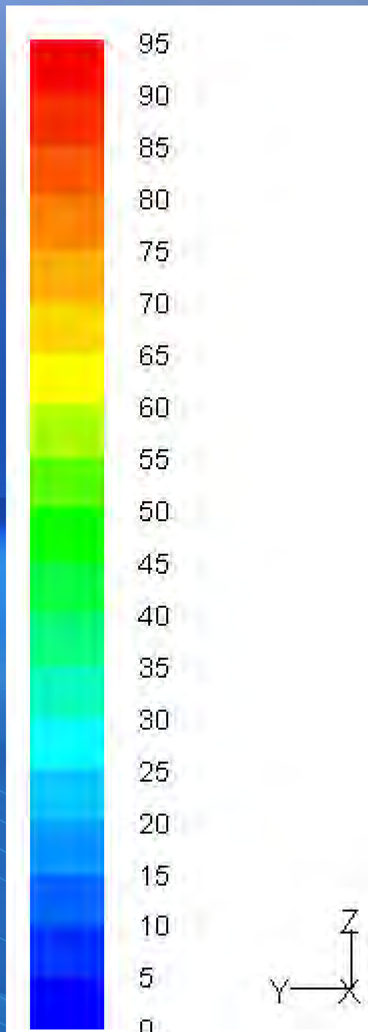
PDPA

- Phase Doppler Particle Analyzer

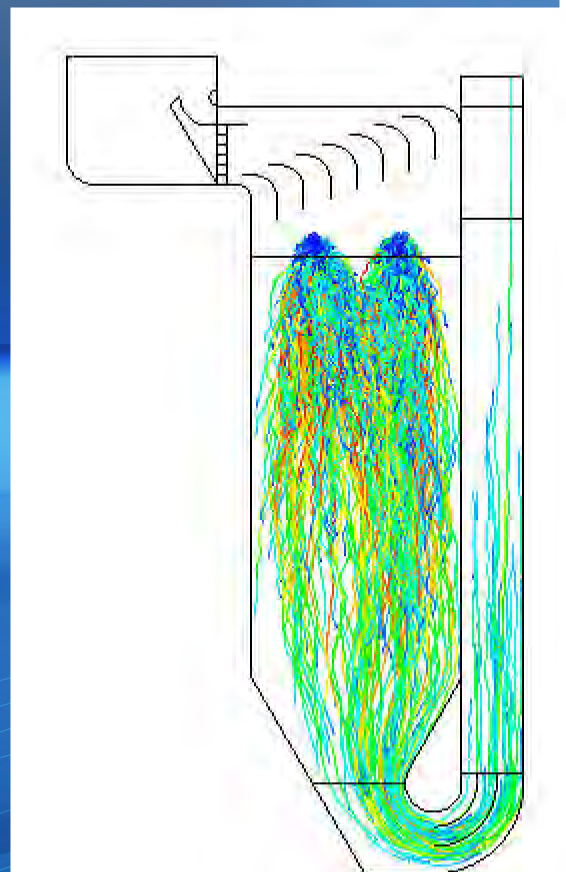


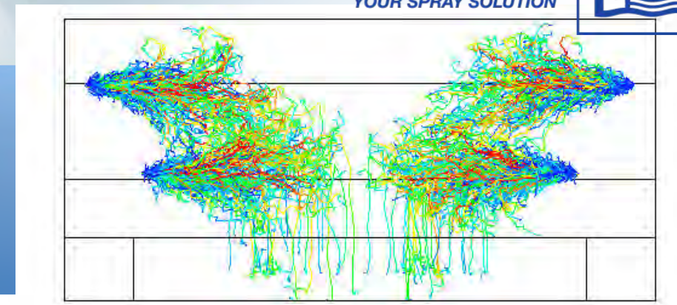
Case Study - Modeling

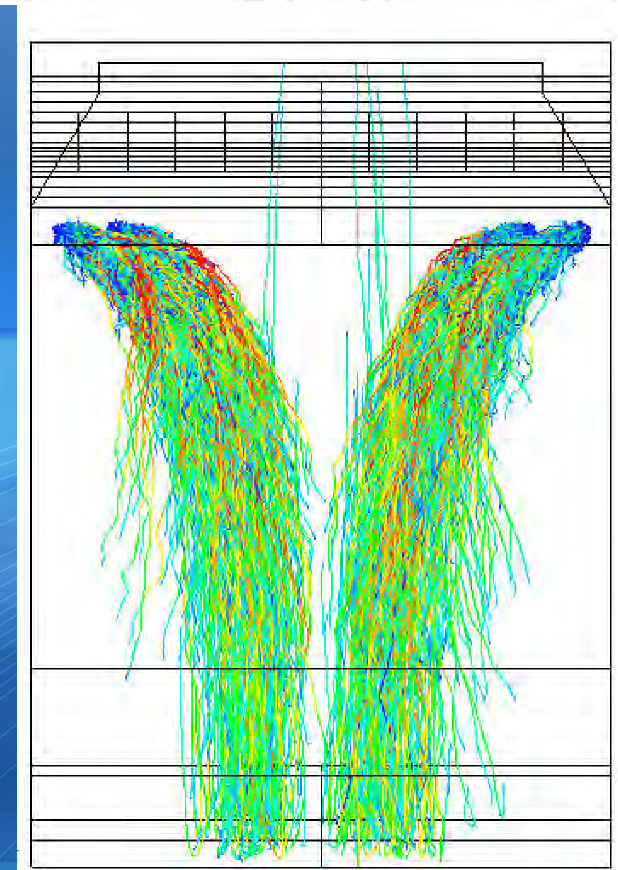
Droplet Diameter (microns)

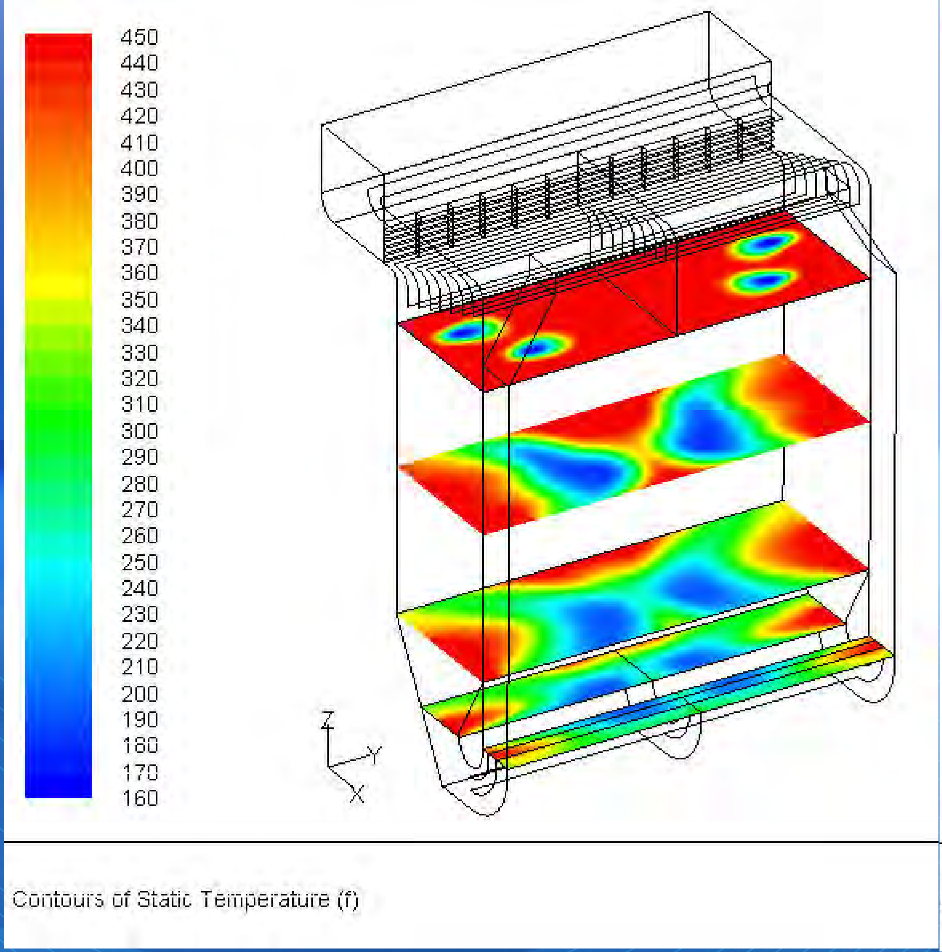


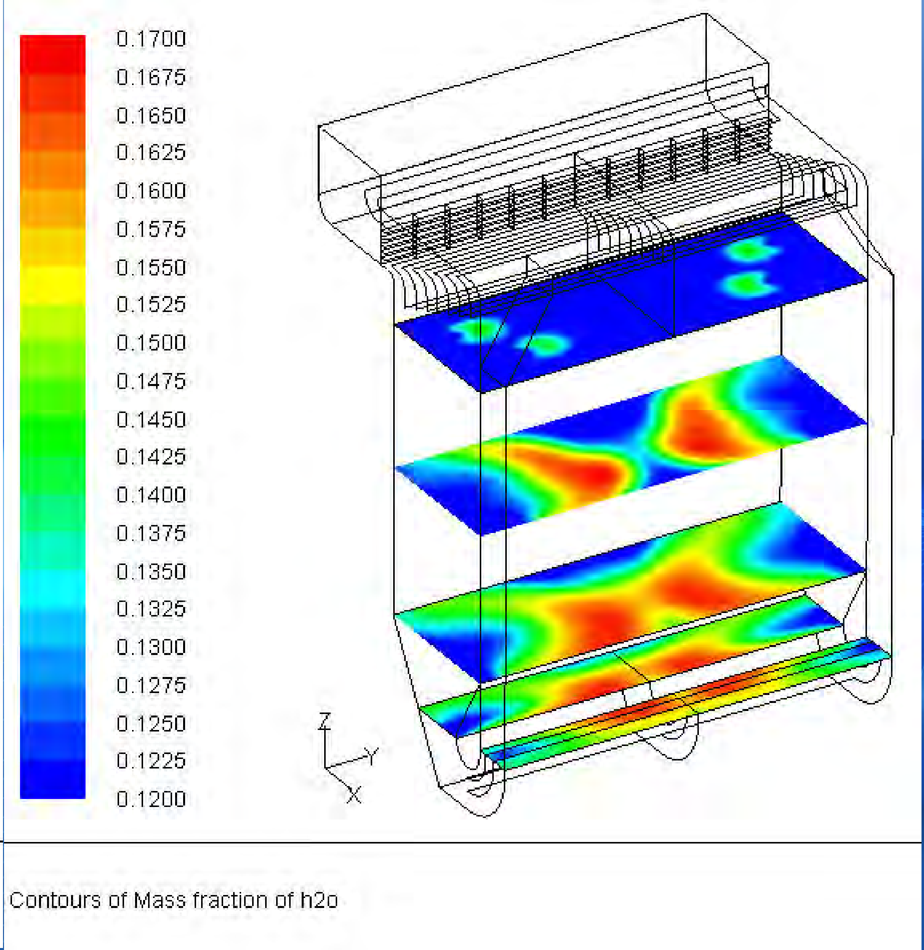
With 3,200 droplets tracked, only a few carry-over into the reaction chamber.











CFD Analysis (4 Nozzle Configuration)

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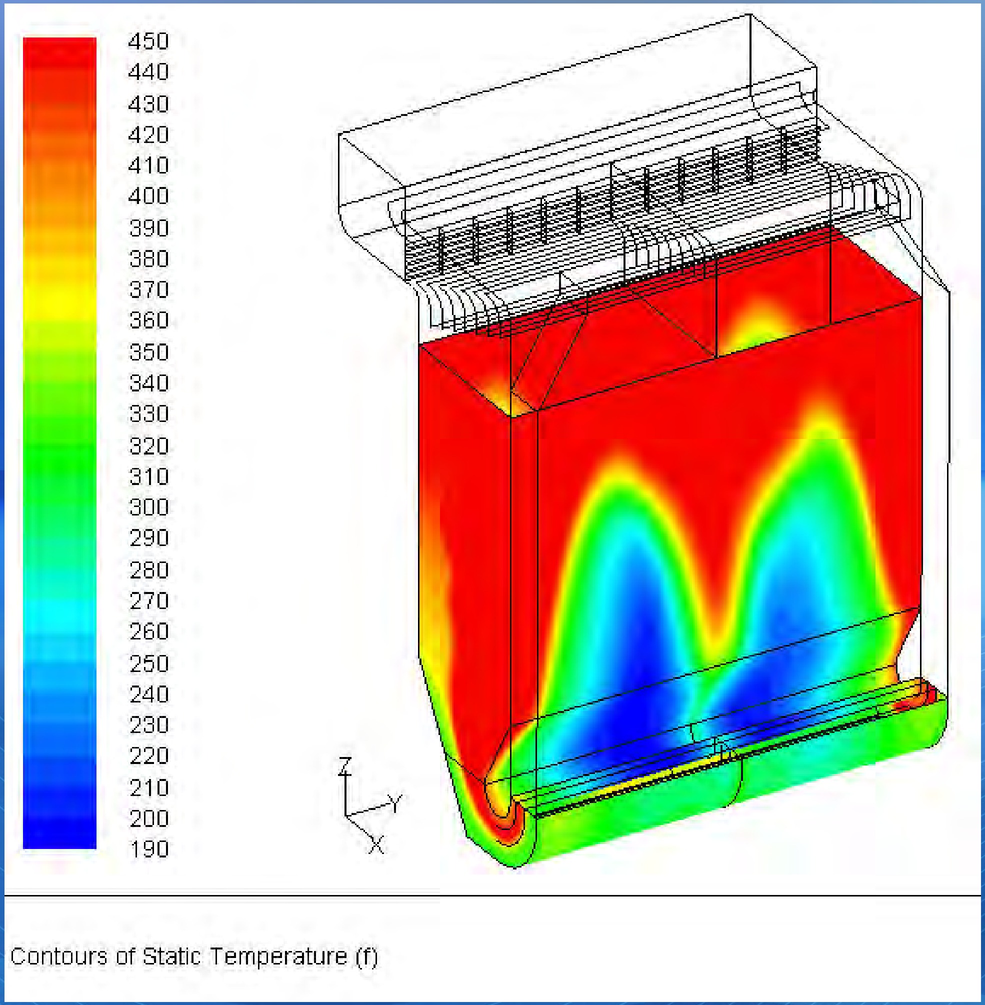

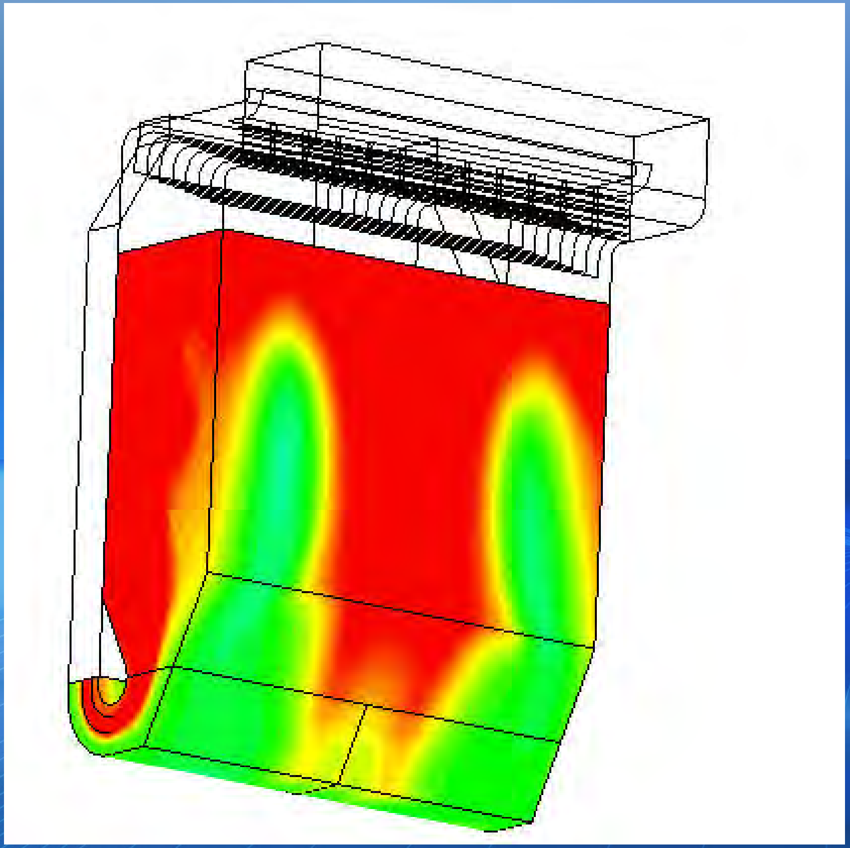

CFD Analysis (8 Nozzle Configuration)

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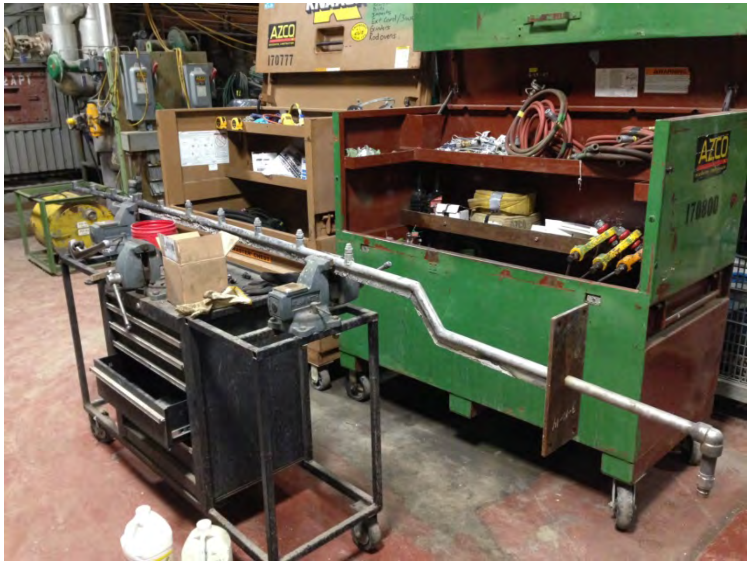
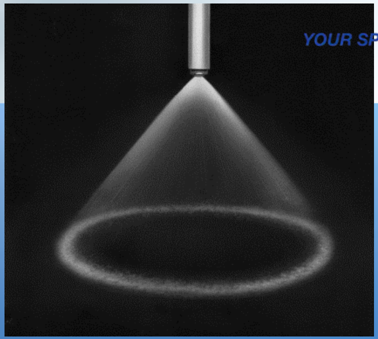


New Lances
- Supplied with high pressure water only
- Angled for structural rigidity

Simplified Pump Skid

Case Study – Equipment Install



Fabricated from Hastelloy to prevent corrosion
Nozzles have been in operation for 3+ years
Operating at ~ 1,300 psig

Case Study – Results & Findings – Comments from Plant

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We shutdown (2-1/2X) 275 HP rotary screw compressors

- Replaced compressor demands with (3X) 30HP Diaphram Pumps (VFD)
  - 3 Total (1 per unit) with 1 on standby

Lime consumption ~ ½ of 2010 timeframe

SO_2 outlets in single digits

SO_2 & HCL removal in mid to high 90(+)% removal efficiencies

Reduced lance/nozzle cleaning on U1 from weekly to every outage (4 months) – (36X) nozzles without screens

Reduced lance/nozzle cleaning on U2 from weekly to every 2 to 3 weeks – (60X) nozzles with screens

Case Study – Results & Findings – Summary

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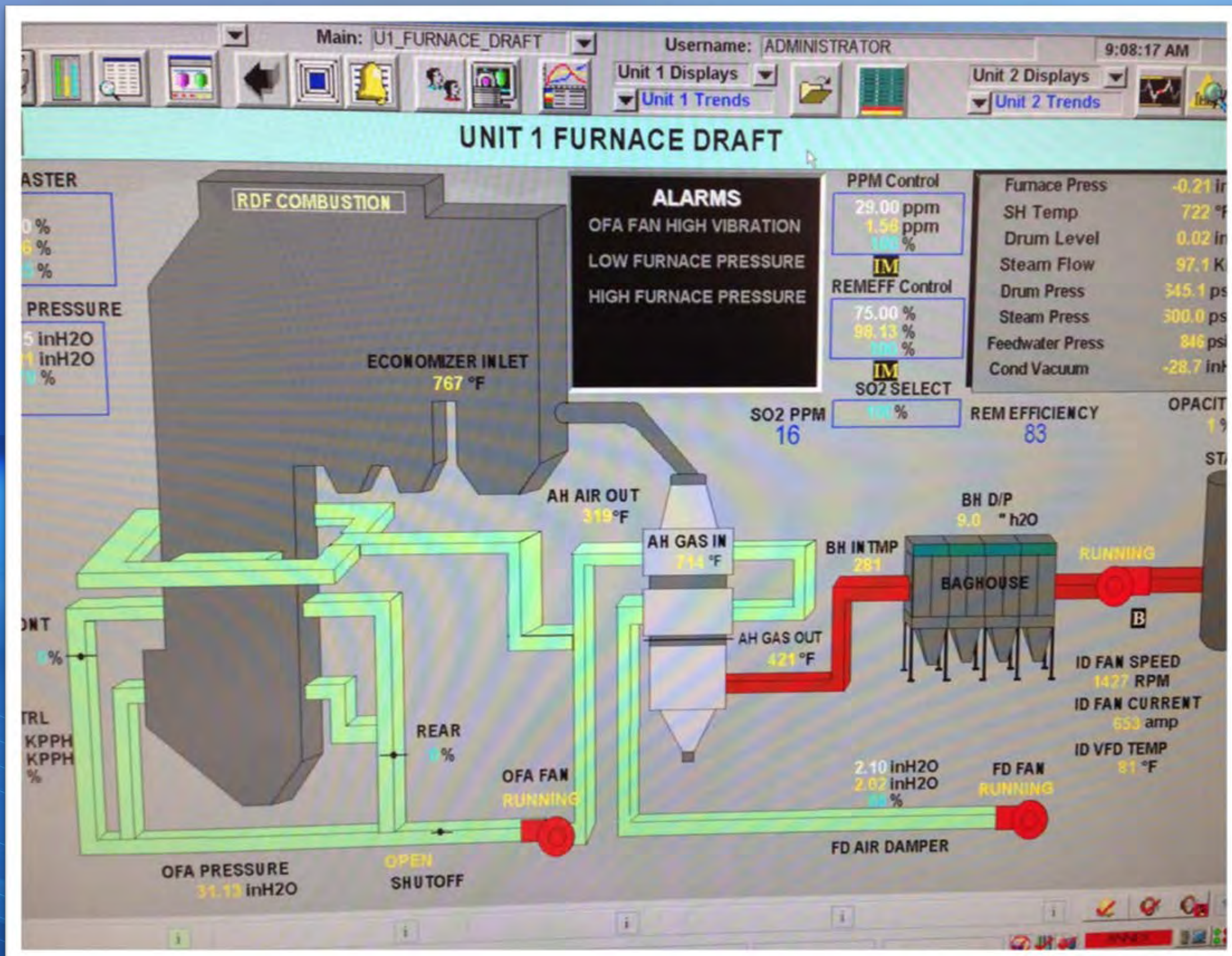
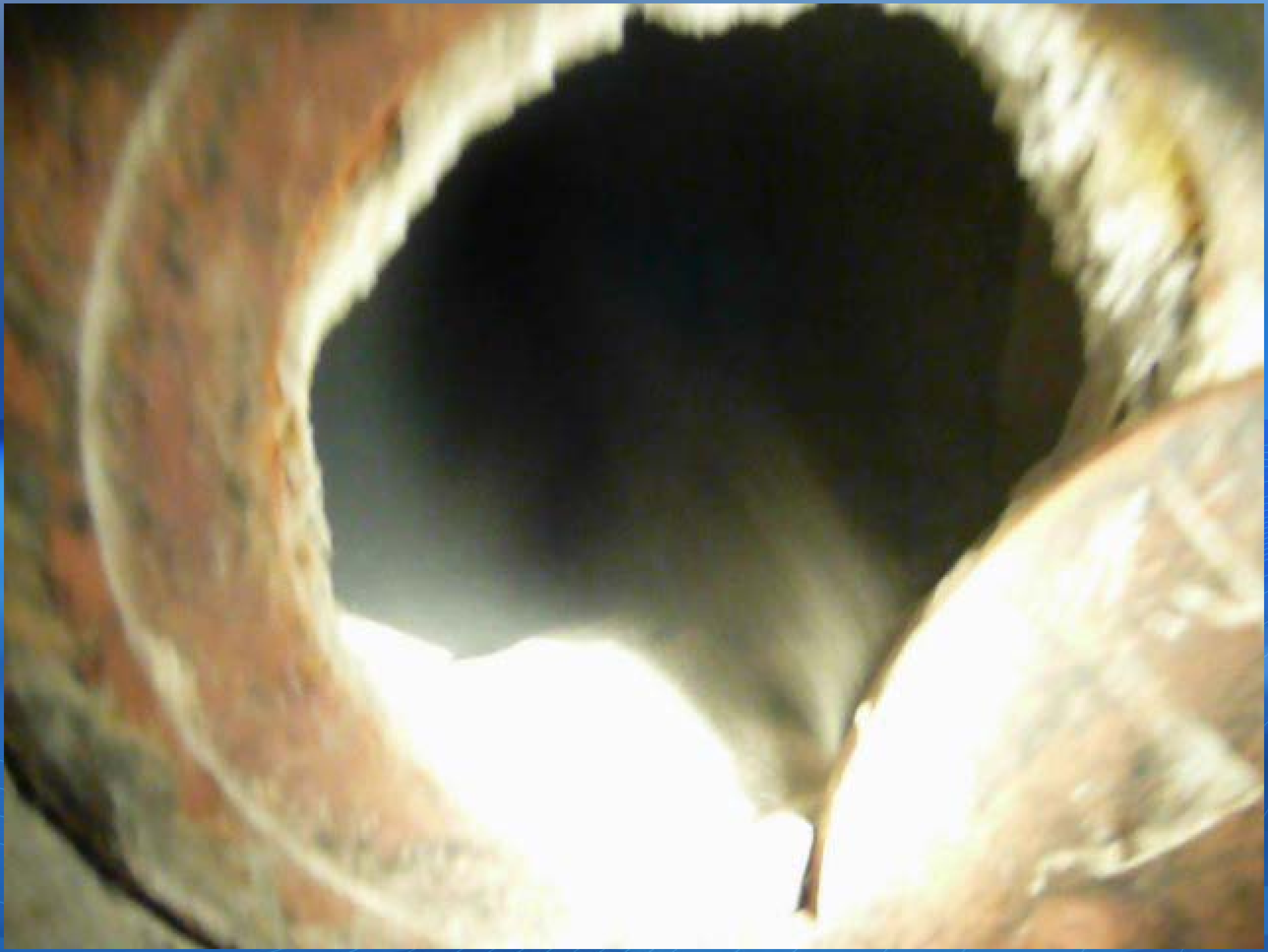
Category	Original Nozzles	New Nozzles
Nozzle cleaning frequency	Once a week	Once every 2-3 Weeks
Required maintenance	Once a week	General inspection
Nozzle Life	6 months	12-18 months
Compressed air	1,500 SCFM	**None**
Water Injection Rate	Up to 16 GPM	**Up to 25 GPM**
Moisture	Wetting of duct	Dry duct
Hopper Plugging Frequency	Frequent	None
Observation by Plant (No firm data)	Unreliable system with high operational costs of compressors	Reliable system with reduced operational and maintenance costs
Annual Maintenance Costs	$ 25,000+	< $ 10,000

Case Study - Control Room Data



Case Study – Nozzle Installation



Upstream Duct Humidification/Cooling before DSI is a viable technology for process improvements

- ✓ Proper Fluid Application Engineering must be performed for successful installation, commissioning, and operation.
- ✓ Each installation is unique.
- ✓ CFD analysis is recommended to ensure proper performance.
- ✓ Downstream effects of lower gas temperature need to be analyzed.
- ✓ Twin-fluid nozzle technology provides the smallest droplet size and highest turndown but may not be most efficient and effective design.

Thank you for your attention!

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For contact details and more information please visit our website.

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