2023

AF&PA
RECOVERY BOILER PROGRAM
ANNUAL CONFERENCE

FEBRUARY 8, 2023
ATLANTA, GEORGIA

American Forest & Paper Association
Recovery Boiler Committee

AF&PA RECOVERY BOILER PROGRAM
2023 ANNUAL CONFERENCE
ATLANTA, GEORGIA

Atlanta Airport Marriott
Grand Ballroom: Salon E

AGENDA

Wednesday, February 8, 2023

7:00 am — Registration & Continental Breakfast (Grand Ballroom: Salon F&G)
- Wayne Grilliot – AF&PA

8:00 am — General Assembly – Review AF&PA Antitrust Policy & Chairman's Report
- Frank Navojosky – International Paper

8:10 am — Operation & Maintenance Subcommittee Report
- Wes Hill – Georgia-Pacific

8:15 am — Research & Development Subcommittee Report
- Greg Burns – Domtar

8:20 am — TAPPI Energy, Recovery, & Recaust Committee Report
- Ryan Henry – Green Bay Packaging

8:35 am — Effects of Lower Furnace Operations on Deposit Formation in Recovery Boilers
- Honghi Tran – University of Toronto

9:15 am — Water Side Tube Damage and Failure Mechanisms in Kraft Recovery Boilers
- Scott Holloway – Solenis
  - Presented by James Meredeth – Solenis

9:45 am — Coffee Break (Grand Ballroom: Salon F&G)

10:00 am — Proper Sootblower System Design, Maintenance, & Operation
- Danny Tandra – Clyde Industries

11:00 am — Proper Sootblower System Design, Maintenance, & Operation
- Simon Youssef & Paul Heim – Diamond Power / Babcock & Wilcox

12:00 noon — Lunch (Grand Ballroom: Salon F&G)

1:00 pm — Autonomous Spout Deck
- Greg Imig – Andritz

1:30 pm — SpoutRunner Automatic Spout Cleaning Device
- Simon Youssef – Babcock & Wilcox

American Forest & Paper Association

Wednesday, February 8, 2023 (Continued)

2:00 pm Valmet Chemical Cleaning & Boiler Tube Deposit Inspections (BTDI)
- Rick Baxter & Dylan Price – Valmet

2:30 pm Multivariate Analysis (MVA) Opportunities in the Recovery Boiler Area
- Andrew Jones – International Paper

3:00 pm Coffee Break (Grand Ballroom - Salon F&G - 1st Floor)

3:15 pm Recovery Boiler Tuning
- Joe Klover – Jansen Combustion and Boiler Technologies

3:45 pm Finnish Recovery Boiler Committee Report
- Emma Kärkkäinen – Finnish Recovery Boiler Committee

4:15 pm Swedish-Norwegian Recovery Boiler Committee Report
- Johan Jansson & Kristian Rosenqvist
  – Swedish-Norwegian Recovery Boiler Committee
  - Presented by Dean Clay - Boiler Services & Inspection (BSI)

4:30 pm BLRBAC Activities Report
- Dean Clay – Boiler Services & Inspection

4:45 pm AF&PA Recovery Boiler Operational Safety Seminar Update
- Dean Clay – Boiler Services & Inspection

4:55 pm Closing Remarks & Questions

5:00 pm Adjourn

* TAPPI Book Sale: Wednesday February 8, 2023 (9:30 am – 3:30 pm) outside Salon E
25% Discount on the Kraft Recovery Boilers, Third Edition Book and other Select TAPPI Books!!! Plus, no Shipping Cost!!!

AF&PA POLICY STATEMENT ON COMPLIANCE WITH ANTITRUST LAWS

Fair and vigorous competition is essential to the maintenance of this country's free enterprise system. In furtherance of this principle, all activities are to be conducted in strict compliance with antitrust laws. Staff, officers, directors, members, and committee members are reminded that they are required to comply with the spirit and requirements of the antitrust laws.

A free exchange of ideas on matters of mutual interest to representatives of AF&PA members is necessary for the success of all meetings. Such an exchange of views is essential to the successful operation of every trade association. It is not the purpose of this policy to discourage the exploration in depth of any matters of legitimate concern to meeting participants. Nevertheless, to ignore certain antitrust ground rules, either through ignorance or otherwise, is to create a hazard business people cannot afford.

The Sherman Antitrust Act, The Clayton Act, the Federal Trade Commission Act, and the Robinson-Patman Act comprise the basic federal antitrust laws, which set forth the broad areas of conduct considered illegal as restraints of trade. In general, agreements or understandings between competitors that operate as an impediment to free and open competition are forbidden. The broad language of these laws suggests the scope of federal antitrust prohibitions by forbidding any "agreement or understanding...to substantially lessen competition or tend to create a monopoly in any line of commerce." In particular, the antitrust laws prohibit:

--discussing the fixing or regulating of prices, markups, or the conditions or terms for the sale.

--discussing the establishment of geographic trading areas, allocation of markets or customers, or classification of certain customers as being entitled to preferential treatment.

--discussing or participating in any plan designed to induce any manufacturer or distributor to sell or refrain from selling, or discriminate in favor of or against any particular customer or class of customers.

--discussing limiting or restricting the quantity of products to be produced.

--discussing or participating in any plan designed to control the means of transportation or channels through which products may be sold.

--discussing or participating in any plan which has the effect of discriminating against or excluding competitors.

This is, at best, only a general outline of some of the areas, which pose antitrust dangers in discussions between competitors and between sellers and their customers. They are provided to guide discussion during meetings, and in connection with social or other gatherings on those occasions. Meeting attendees should be familiar with the "Antitrust Guide for Members and Staff of the American Forest & Paper Association". Copies are available from the committee staff executive or the AF&PA Legal Department.

If any question arises about an item on a meeting agenda, it should be reviewed by legal counsel before the meeting. If the question does not arise until the meeting has begun, or if a questionable topic is about to be discussed in connection with any gathering, whether or not a formal meeting, that discussion should be immediately stopped and not resumed until approved by legal counsel.

Notice and Disclaimer of Liability Concerning AF&PA Recovery Boiler Program Guidelines, Procedures, Best Practices, Checklists, and other AF&PA Recovery Boiler Program Documents

The material presented in the AF&PA Recovery Boiler Program documents is intended to be for information only. They are not complete and are subject to change as more information is developed or becomes available. Therefore, neither the authors nor those individuals or companies that have provided assistance in preparation or distribution of the documents assume any liability for the accuracy or completeness of the material presented, nor shall they be held liable for any direct or consequential loss or damage of any nature whatsoever arising from or in connection with the use of the documents or the information contained therein. It is recognized that procedures for a specific recovery boiler may require substantial modifications from procedures presented in the documents to make them useful and applicable for that boiler. Accordingly, the documents do not set, and should not be construed as setting, standards for acceptable practice, policies, procedures, limits, or goals. Not following the procedures contained therein shall not constitute improper or negligent practice.

WARNING: The material in the AF&PA Recovery Boiler Program documents is not intended to accurately reflect the requirements of any or all federal, state, local, or foreign laws, codes, and regulations. Each user of the AF&PA Recovery Boiler Program documents has the responsibility to review and comply with the legal requirements of these laws, codes, and regulations.

Energy, Recovery, & Recaust Committee Report

American Forest & Paper Association - Recovery Boiler Program

2023 Annual Conference & Meetings

Atlanta, Georgia

TAPPI
Energy, Recovery, & Recaust Committee

- Wei Ren – Committee Chair
- Ryan P Henry – Recovery & Power Boilers
- Ben Bunner – Energy Management
- Fred Call – Water Treatment
- Peter Gorog – Lime Kilns & Reaust

TIPs Recently Published

- **TIP 0416-10:** Stripping of Kraft Pulping Process Condensates: Regulations, Design and Operation
  - WGC: Johnson, Paul L; Lundberg
- **TIP 0416-28:** Sootblower Safety and Upgrade Guidelines
  - WGC: Jameel, Ishaq; Clyde Industries

TIPS Nearing Completion:

TIP 0402-30: Inspection for Cracking of Composite Tubes in Black Liquor Recovery boilers.

- WGC: Singbeil, Doug;
- Currently in final stages of review process

TIP 0416-15: Chloride and Potassium Measurement and Control in the Pulping and Chemical Recovery Cycle

- WGC: Jones, Andy; International Paper
- Last edits now then final review

TIP 0416-20: Recovery Boiler Sootblowers: Practical Guidelines

- WGC: Tandra, Danny; Clyde Industries
- Review 90% Complete; 14-APR-2023 Deadline

Want to help?

TIP 0416-04: Design Engineer Decisions Tree – Paper Mill Boiler Feedwater

- Risk of withdrawal

TIP 0416-06: Keys to Successful Chemical Cleaning of Boilers

- Working Group Chair (WGC) needed

TIP 0416-07: Evaluating Reverse Osmosis for Treating Makeup for Boiler Feedwater

- WGC & WG members needed

Want to help?

TIP 0416-08: Guidelines for replacement of generating bank tubes with expanded joints in two-drum boilers

- Need at least two (2) more reviewers

TIP 0416-13: Water Treatment-related Opportunities for Energy Conservation in a Paper Mill Powerhouse

- WGC & WG members needed

TIP 0416-24: Energy checklist: pulp mill

- Risk of withdrawal

Want to help?

TIP 0416-25: Nitrogen Oxide Emissions Control from Biomass and Kraft Recovery Boilers. WGC: Bunner, Ben.

- WG members needed

TIP 0416-26: Best Practice for Recovery Boiler Inspection (Optimizing Inspection Scope)

- Risk of withdrawal

Abstract submittal deadline is March 17, 2023

Contact Info:

Ryan P Henry

Utilities Manager

Green Bay Packaging – Arkansas Kraft Division

rhenry@gbp.com

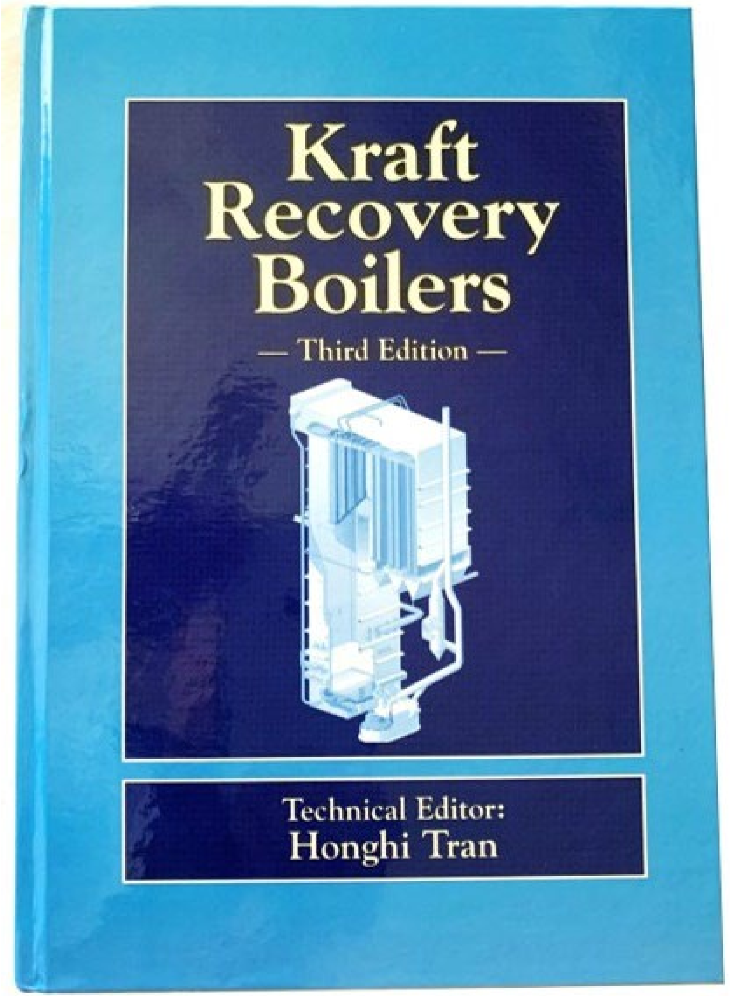
Effects of Lower Furnace Operation on Deposit Formation in Recovery Boilers

PULP&
PAPER
UNIVERSITY OF TORONTO

Honghi Tran
University of Toronto
Toronto, ON, CANADA

AF&PA Recovery Boiler Program Annual Meeting and Conference
Atlanta, GA, February 8-9, 2023

References - “Kraft Recovery Boilers” Book



- Chapter 9 – Deposit Formation & Plugging
- Chapter 4 – Black Liquor Sprays
- Chapter 5 – Black Liquor Burning Processes
- Chapter 6 – Char Bed Processes

Presentation Outline

- Problems with Deposits
- Deposit Types
- Deposit Formation and Properties
- Effects of Lower Furnace Operation
- Summary

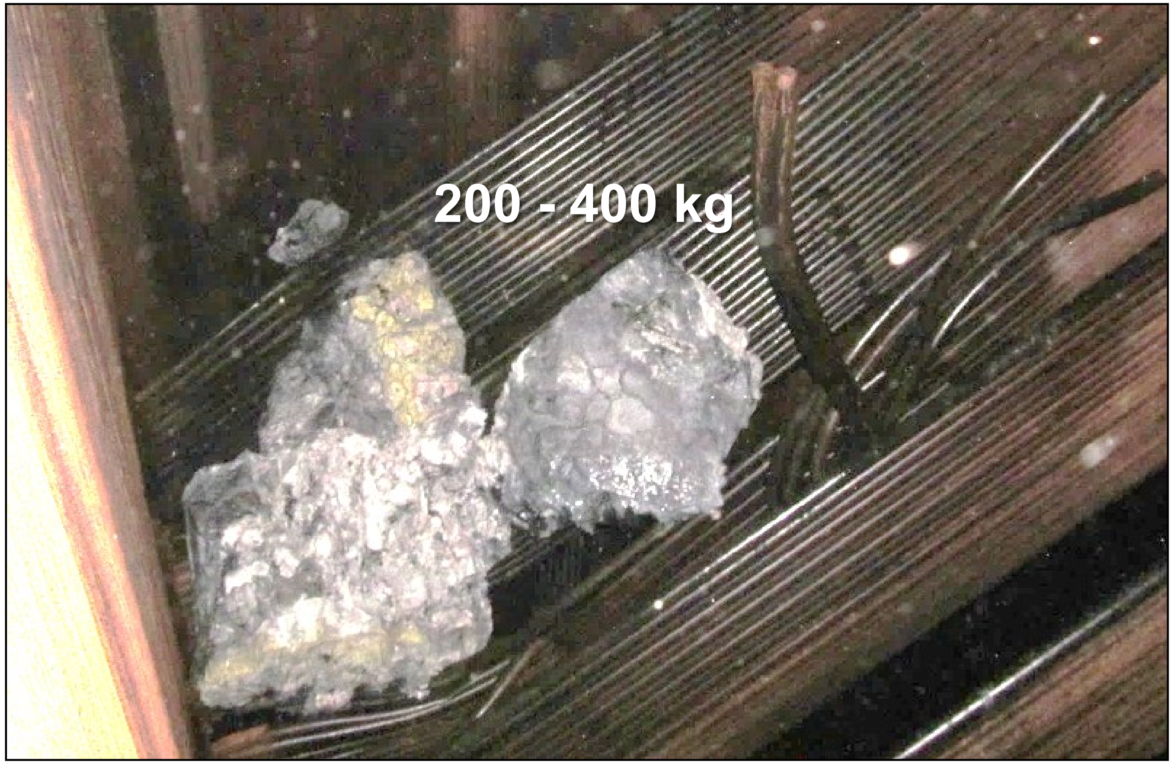
Problems with Deposits

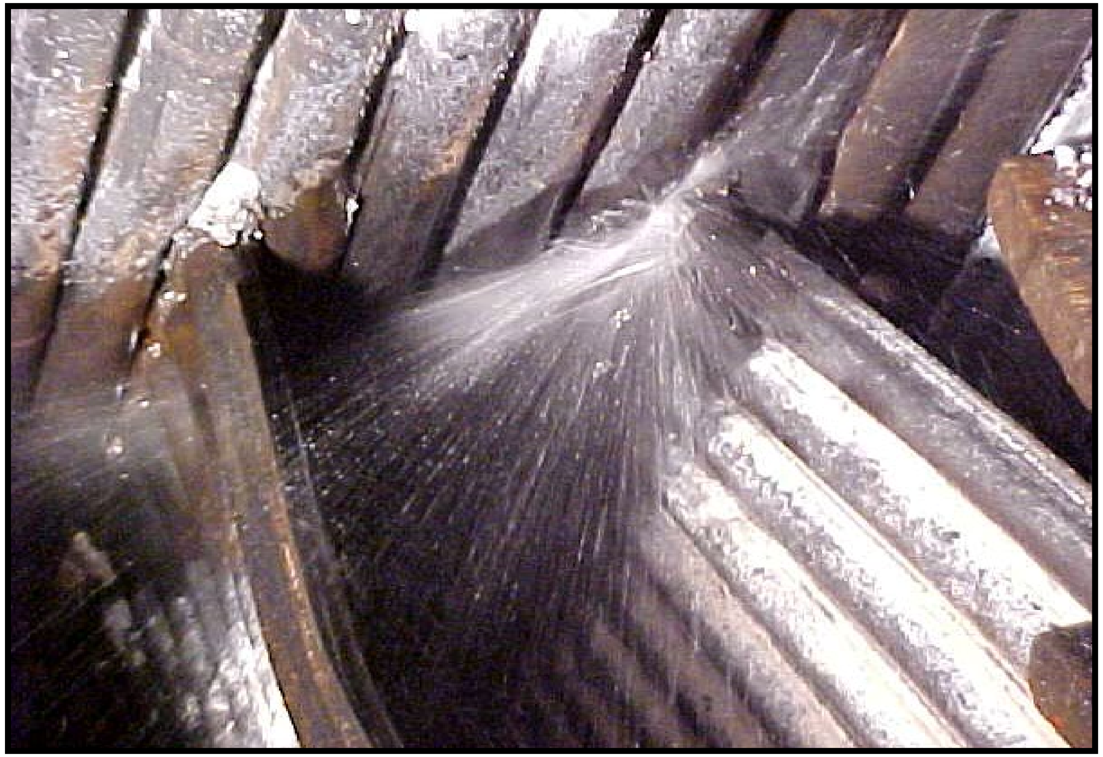
Superheater Fouling

Superheater Corrosion

Boiler Bank Inlet Plugging

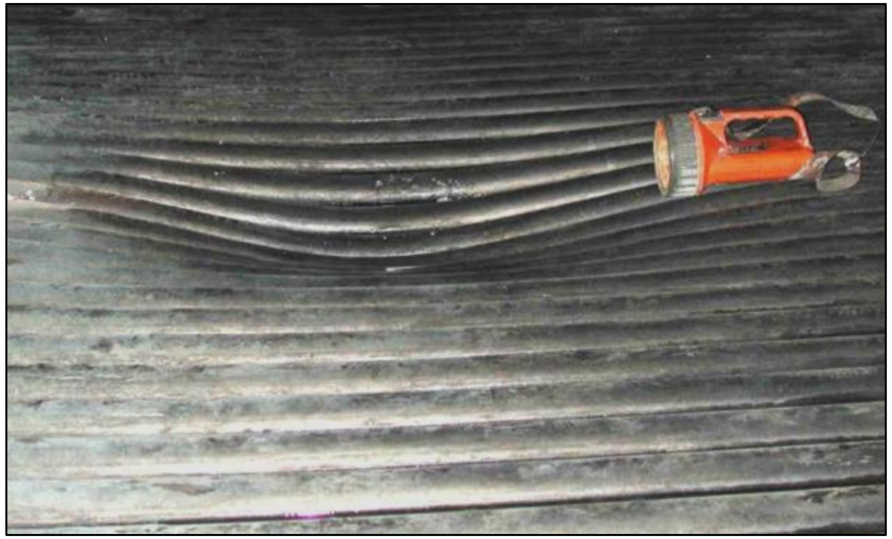
Screen Tube Damaging



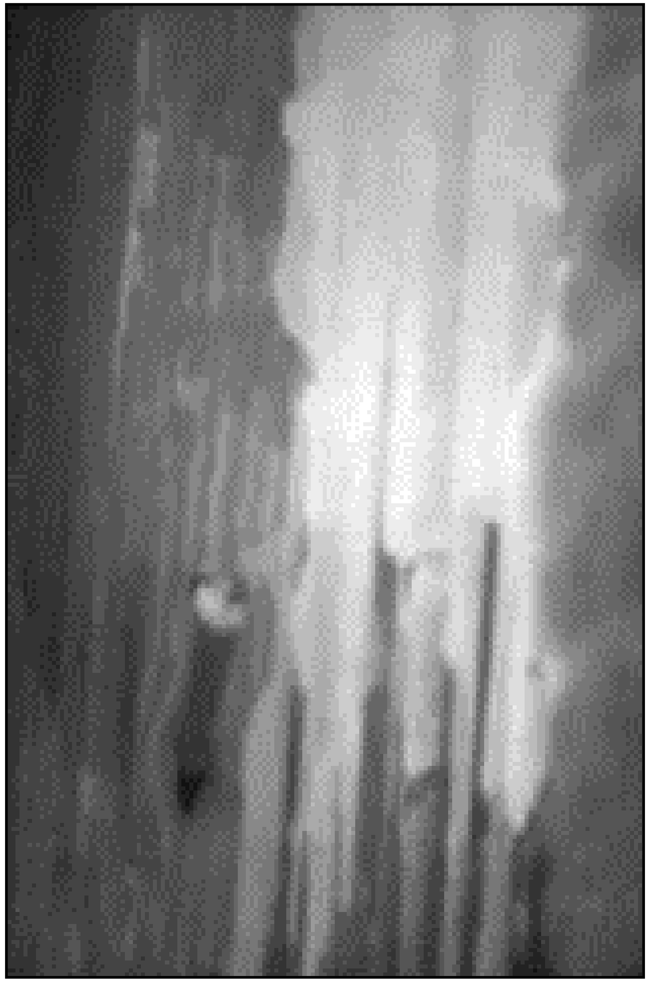


Others

- Sootblower lance tube damaging →
- Floor tube denting



- Promoting jellyroll smelt formation
- Clogging smelt spout openings



(Courtesy: Danny Tandra, Clyde Industries)

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- **Deposit Types**
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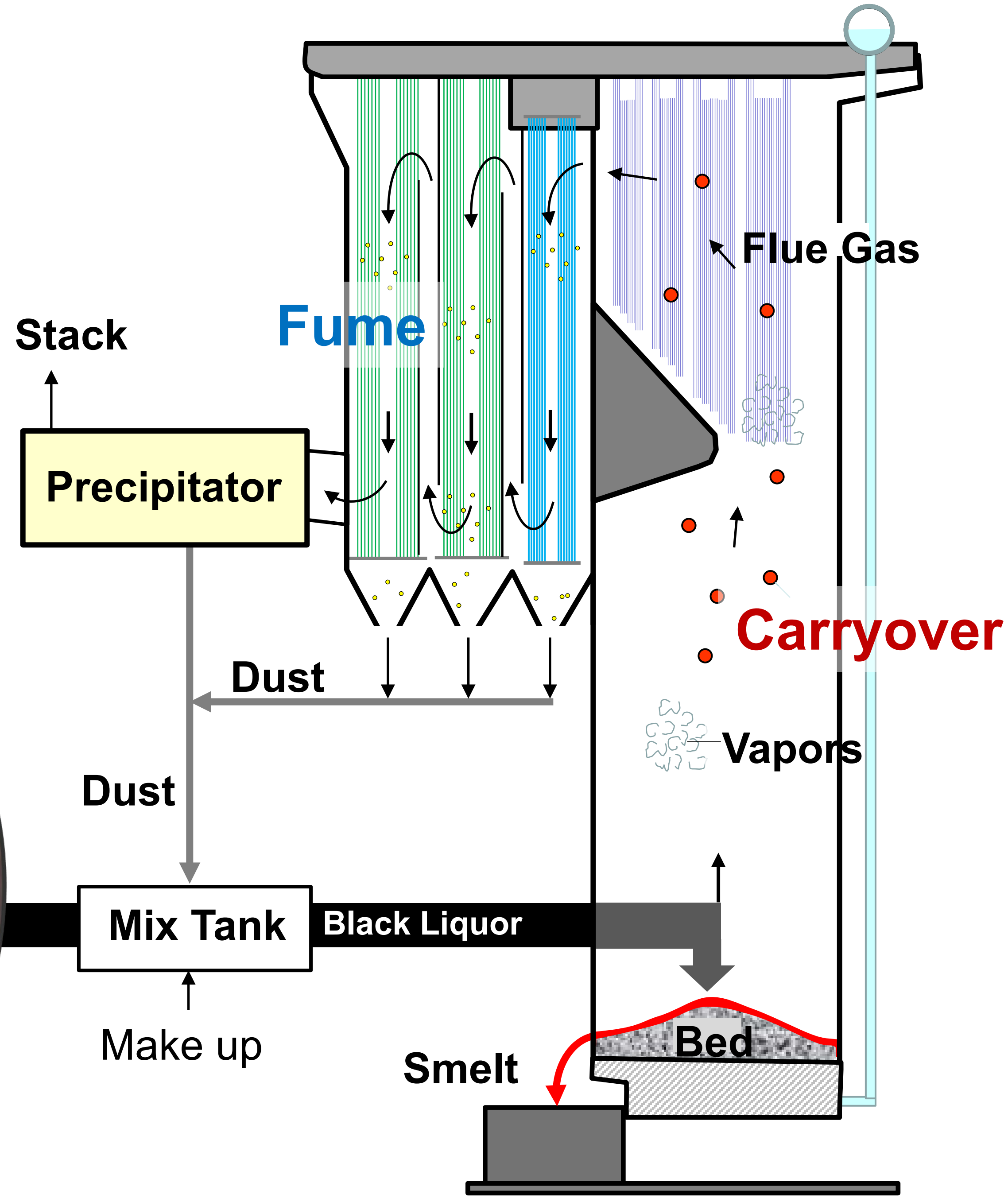
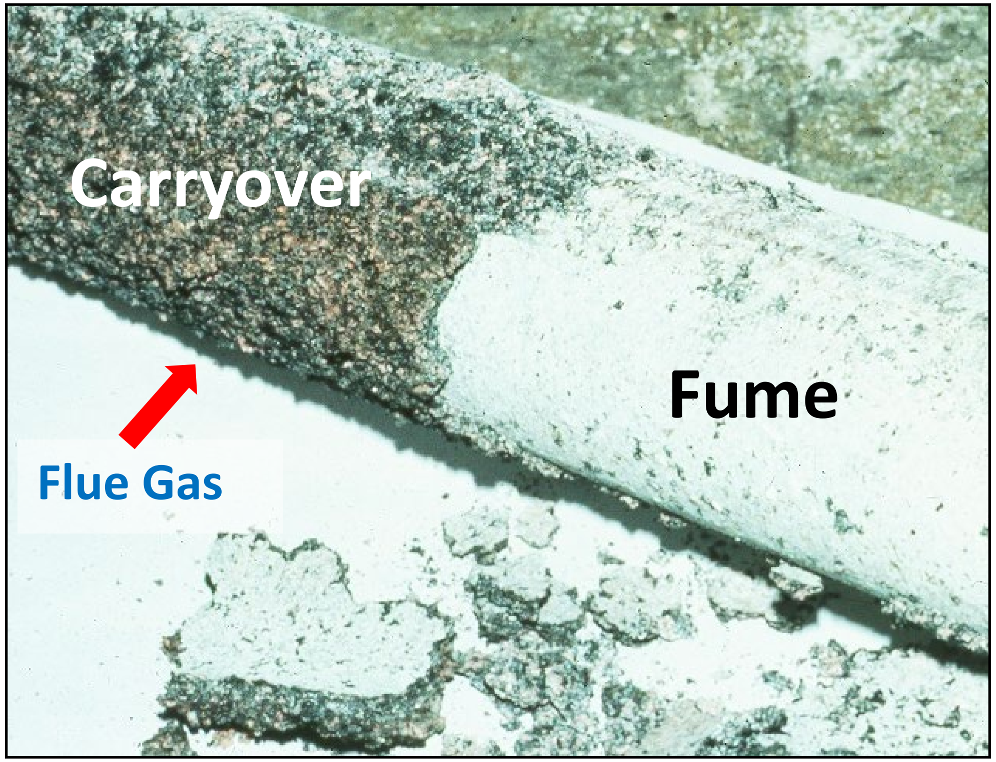
Deposit Types

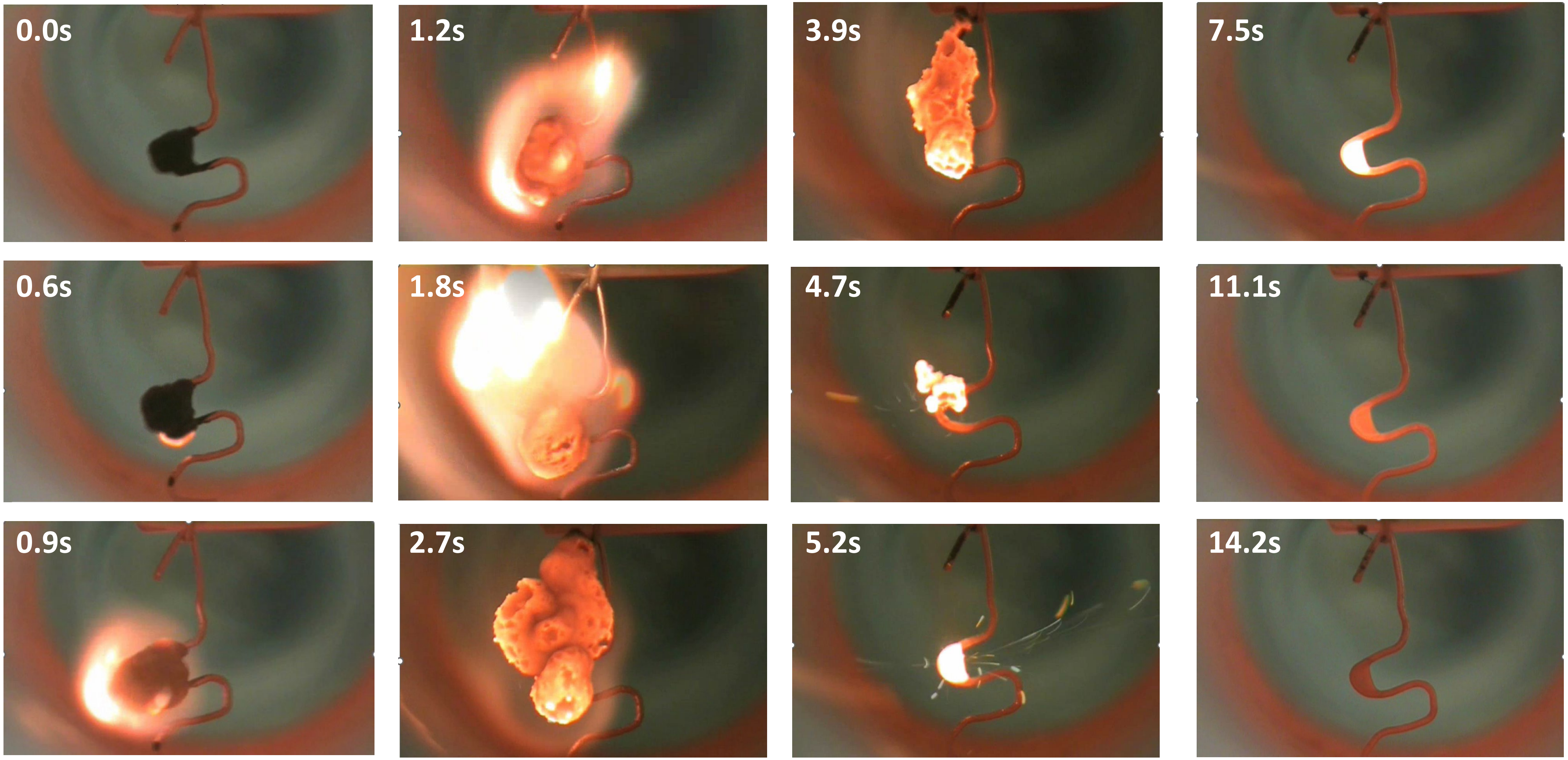


Carryover vs. Fume

- Carryover
  - 0.01 – 3 mm molten/partially molten smelt or partially burned liquor particles
  - Pink, smelt-like and may contain char
  - Formed mainly on the tube front side
- Fume
  - Submicron particles of condensed Na/K salts
  - White and powdery
  - Formed by condensing directly on tube surfaces, or in the flue gas and subsequently driven to tube surfaces by thermophoresis.

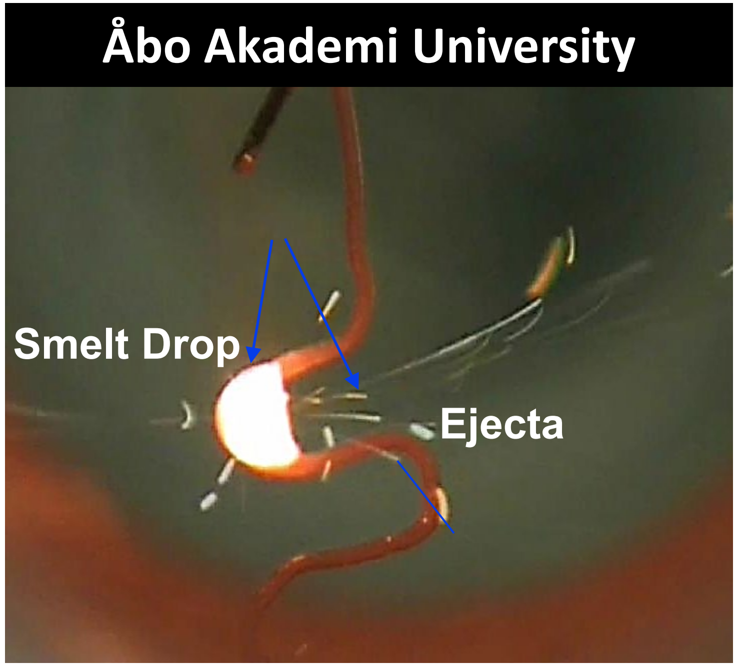


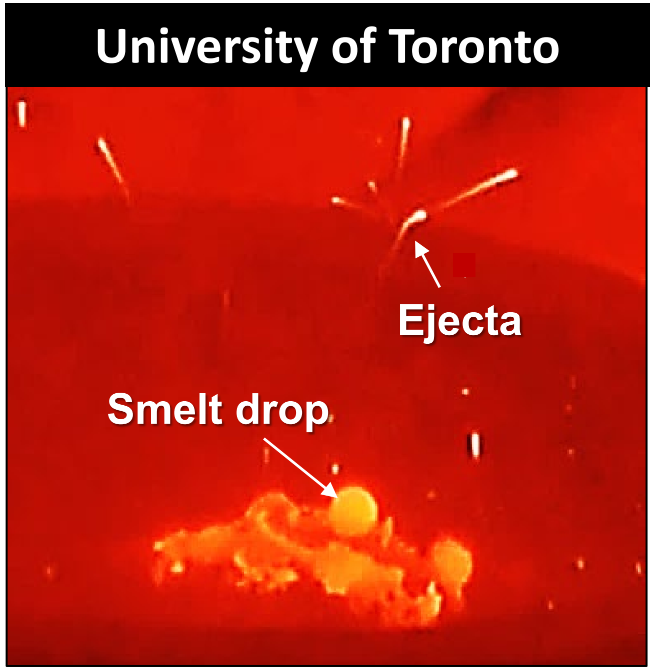
Black Liquor Droplet (800°C, air)

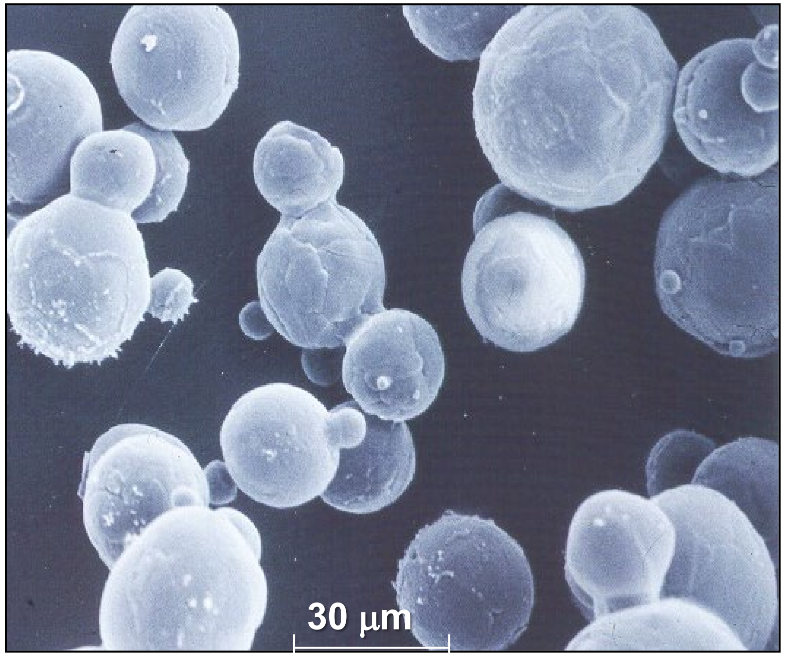


Mikko Hupa, TAPPI Kraft Recovery Operations Course (2023)

Intermediate Sized Particles (ISP)

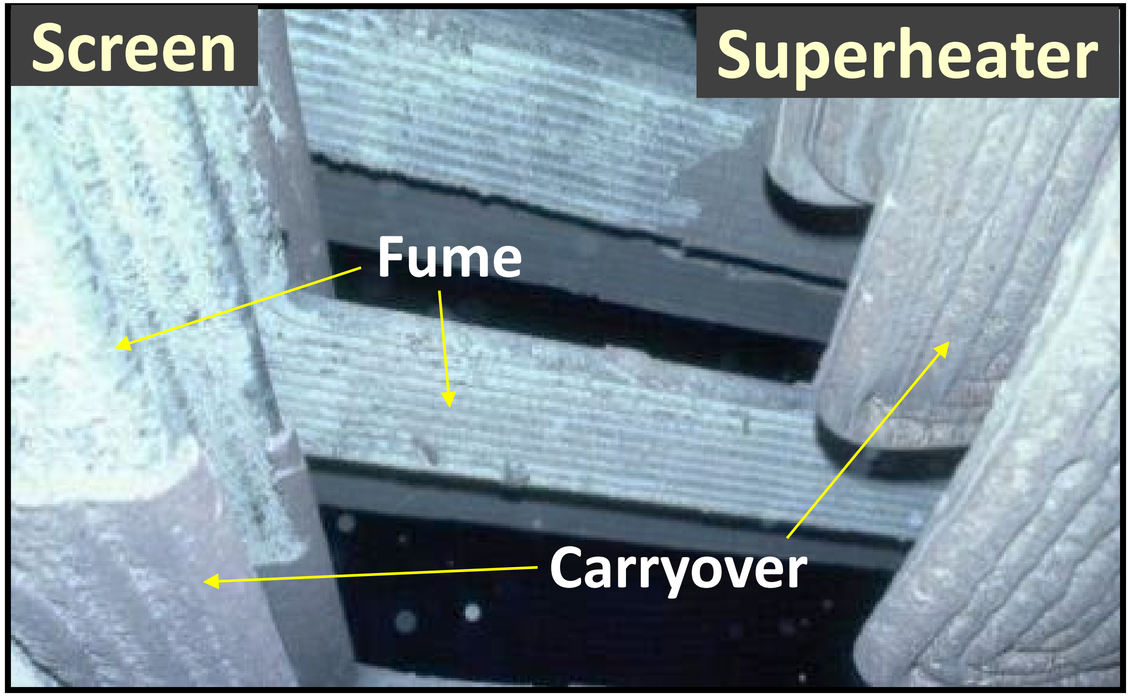


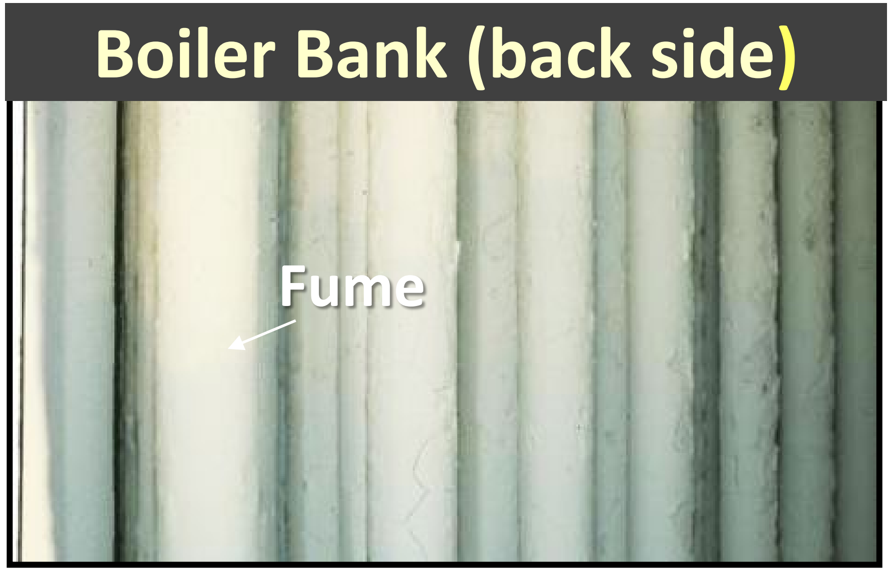


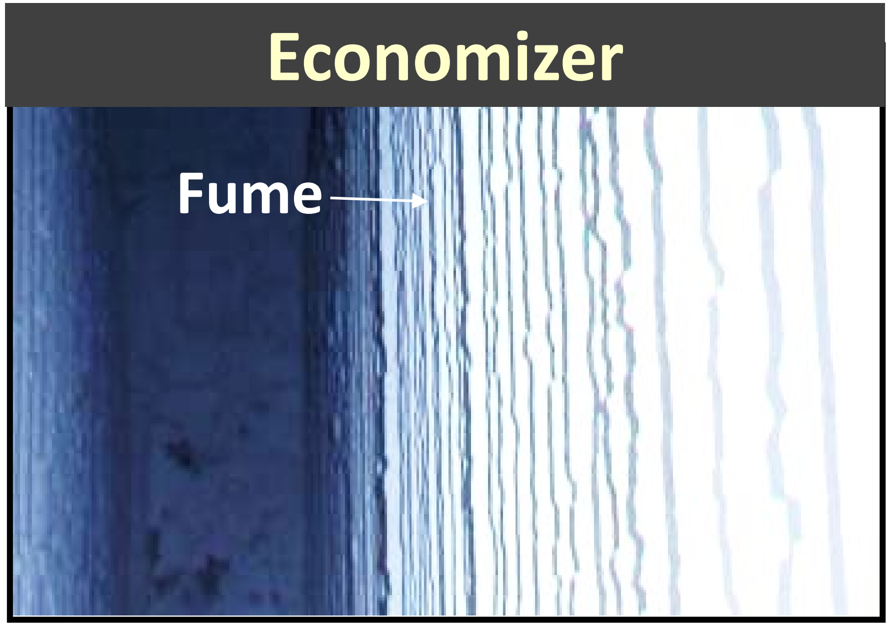


- **Solidified, oxidized smelt beads, ~ 20 μm (1 – 100 μm)**
- **Compared to carryover and fume, the quantity of ISP is TOO SMALL to be significant**

Deposits at Different Locations in a Boiler







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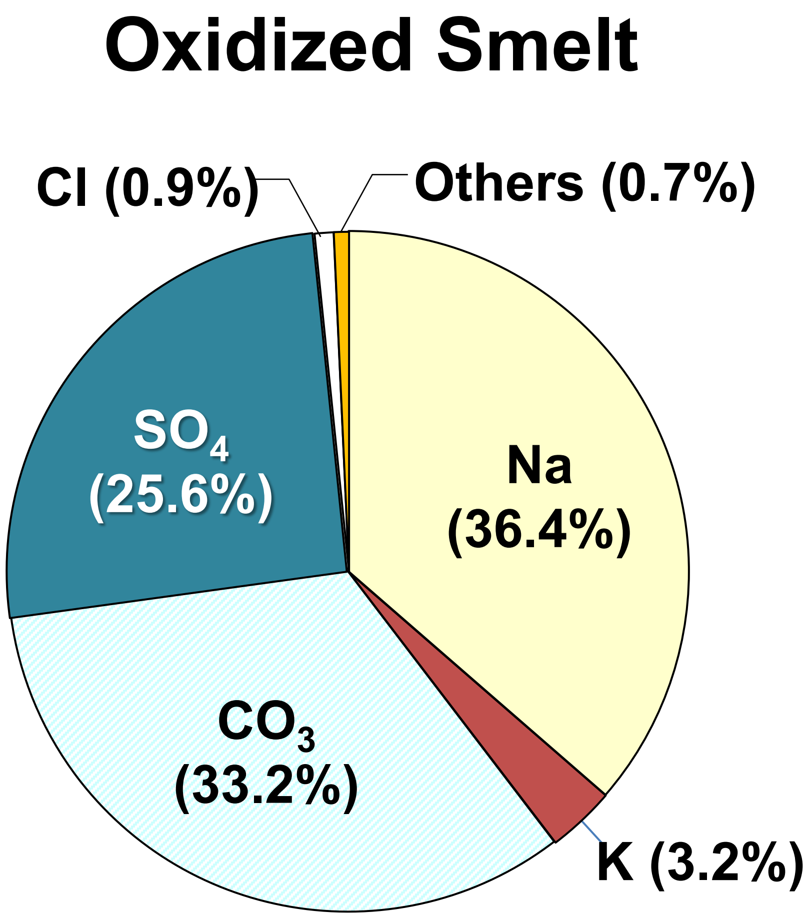
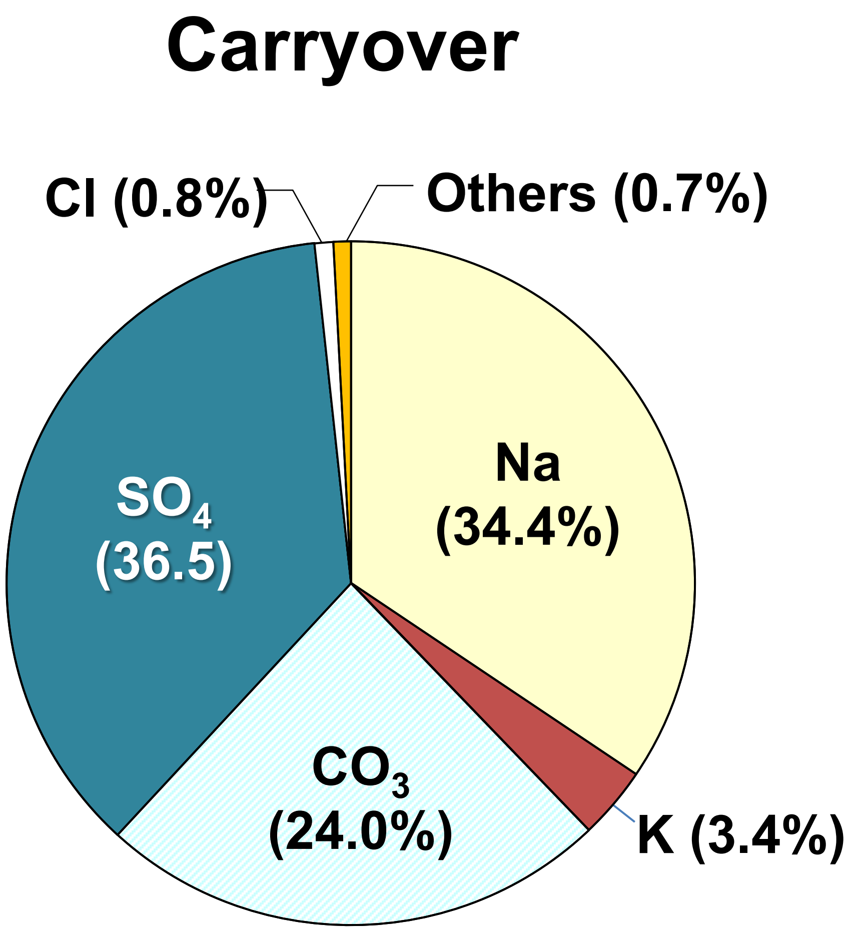
- **Deposit Composition and Properties**
- Effects of Lower Furnace Operation
- Conclusions

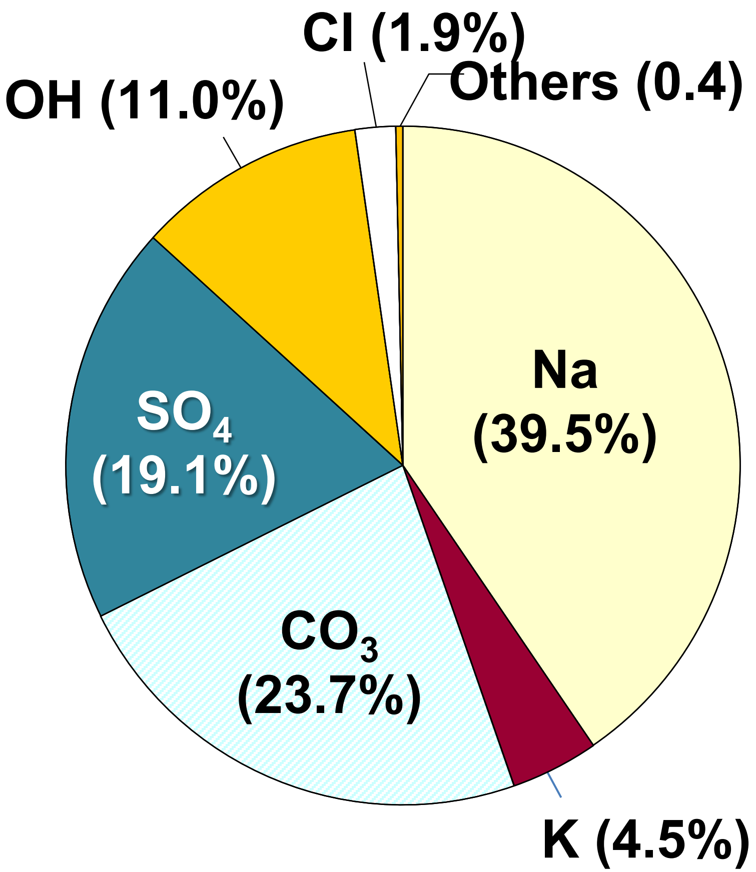
Carryover Composition



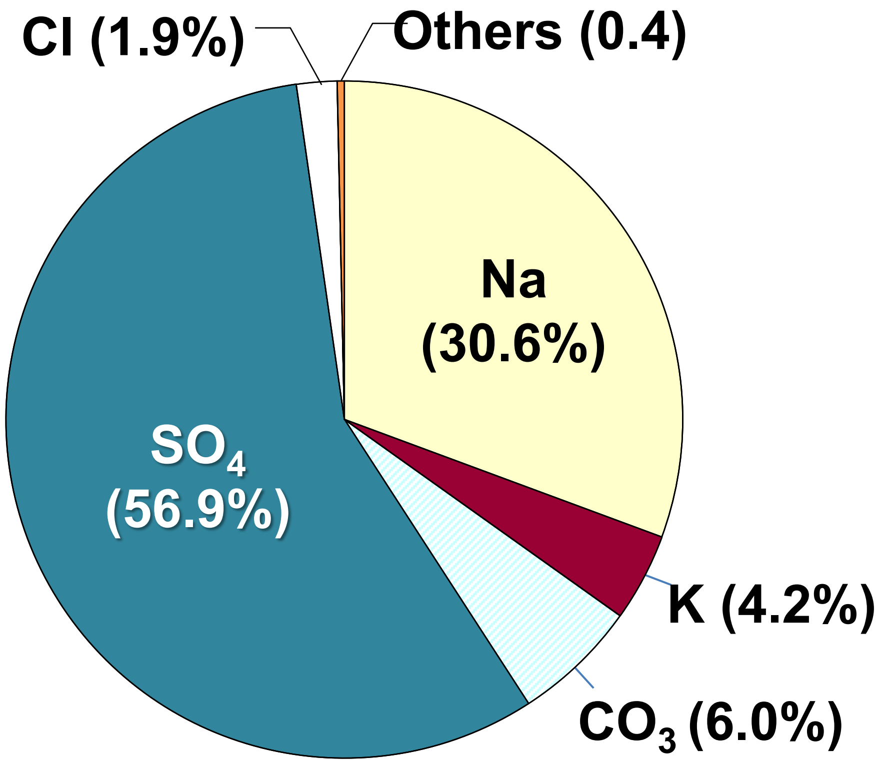


Fume Composition

Near Char Bed

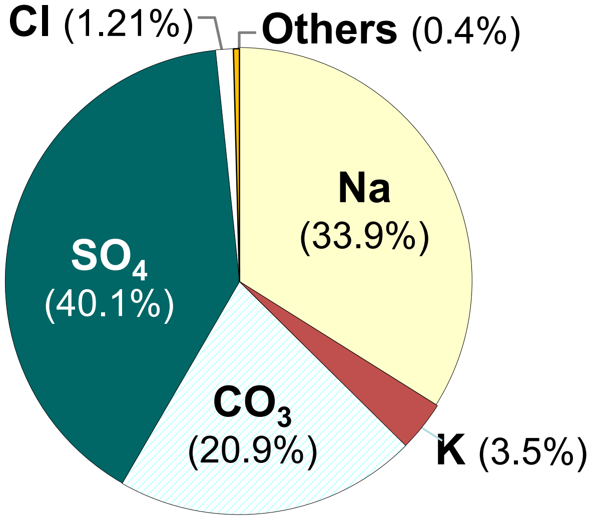


Upper Furnace

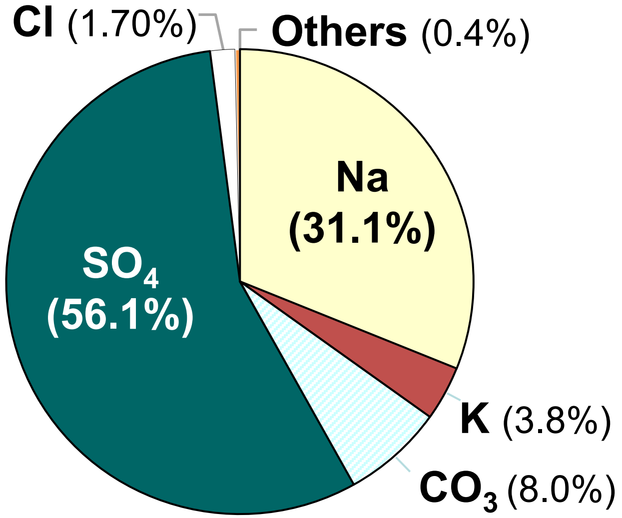


Deposit Composition

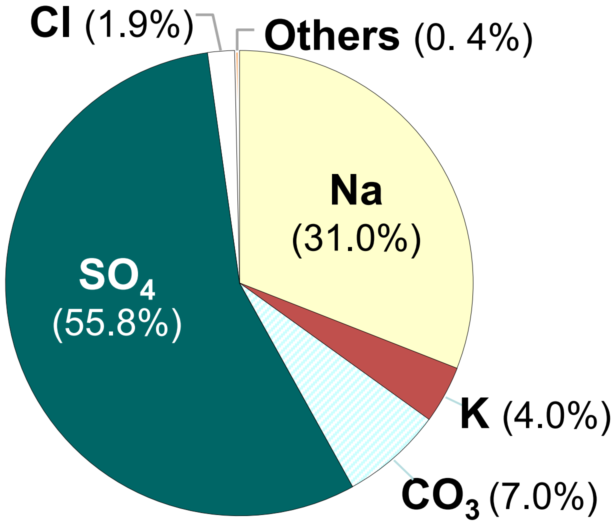
Superheater Deposit



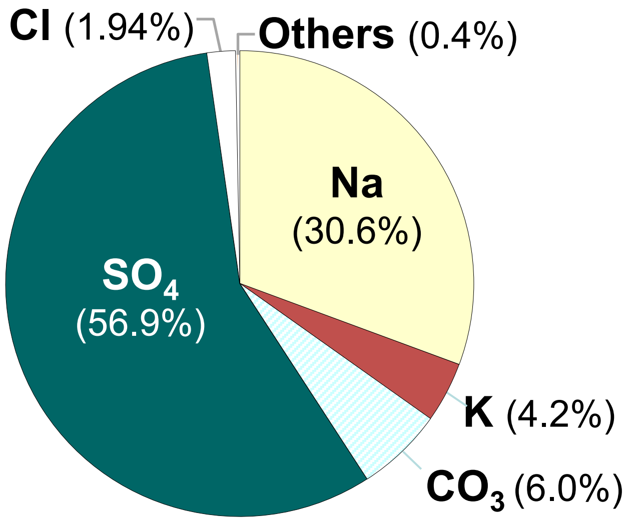
Boiler Bank Deposit



Economizer Deposit

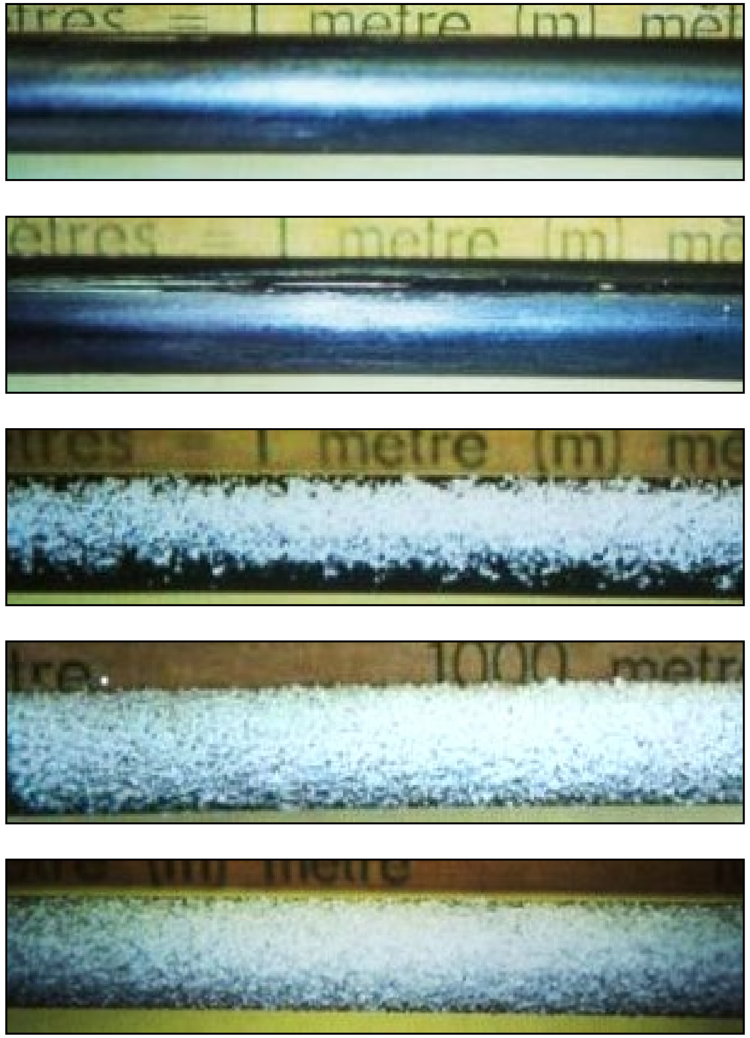


Precipitator Ash



Effect of Carryover Composition on Deposition

(Entrained Flow Reactor, 800°C for 20 minutes)



mole% Cl/(Na+K)

0

1

5

10

20

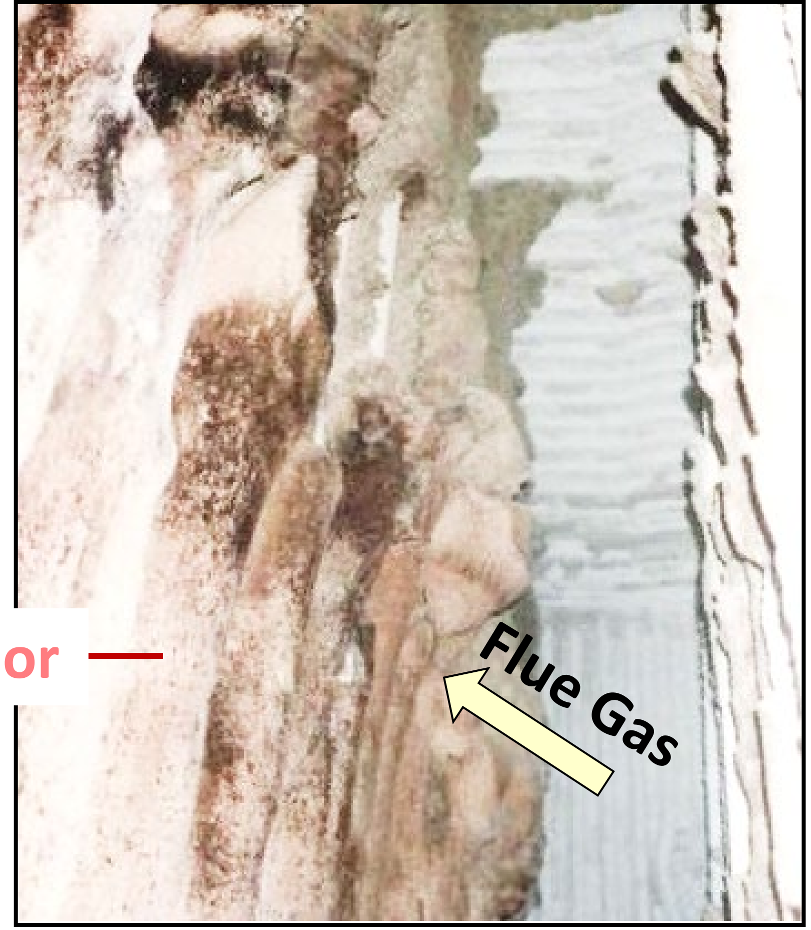
- **Similarly, potassium (K) and sulfide (S^{2-}) also increase the liquid content and lower the sticky temperature of carryover particles**

Shenassa R., Tran, H.N., Kuln D.C.S
Pulp & Paper Canada (1999)

Ability of a Carryover Particle to Deposit

- Increases with its liquid content, which is a function of its composition and temperature
  - Minor components Cl, K and S (sulfide) are important
- Sticky temperature (T_{sticky}) decreases with increasing Cl, K and S contents

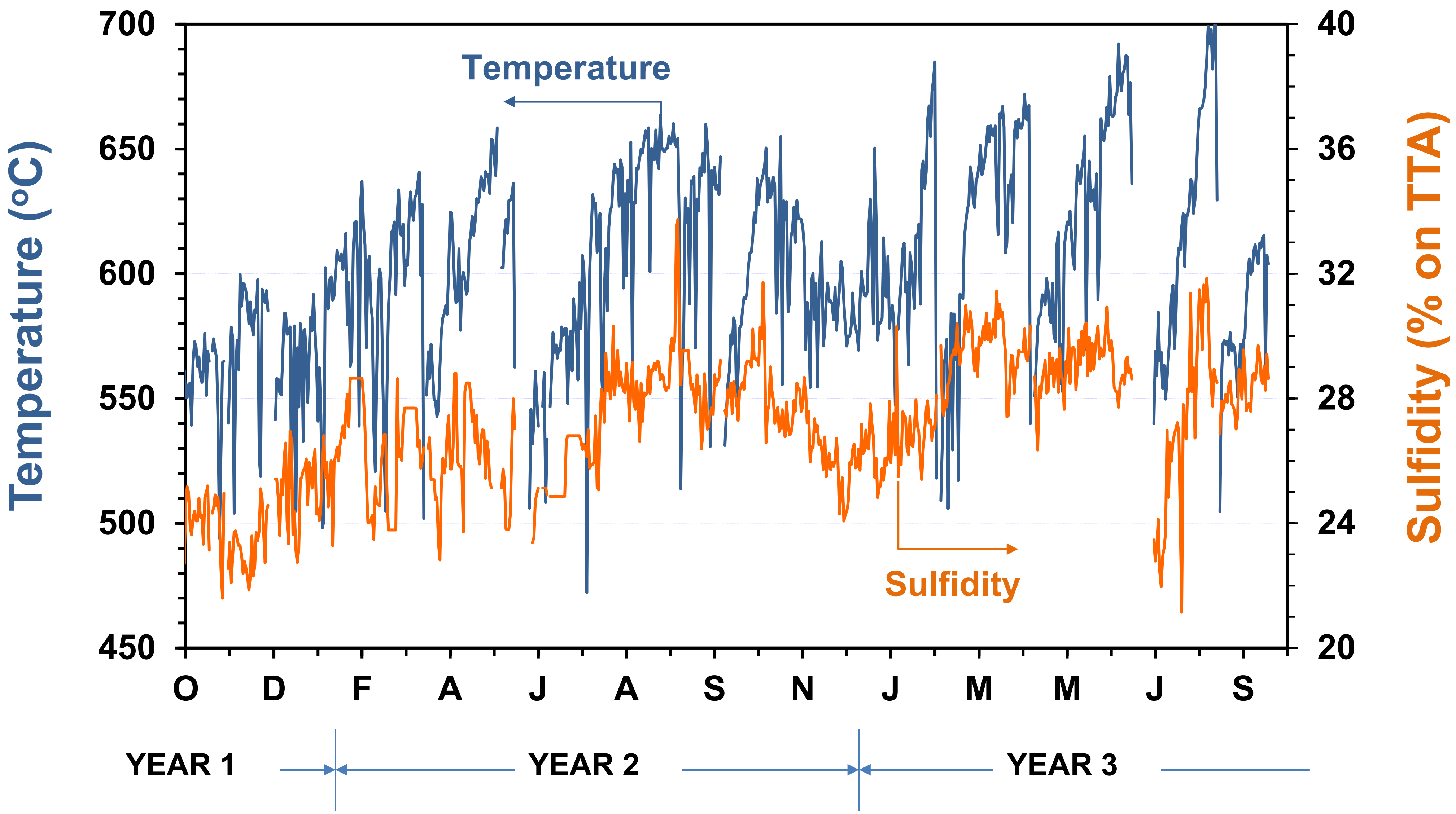
Deposits at SH Entrance



Pink Color

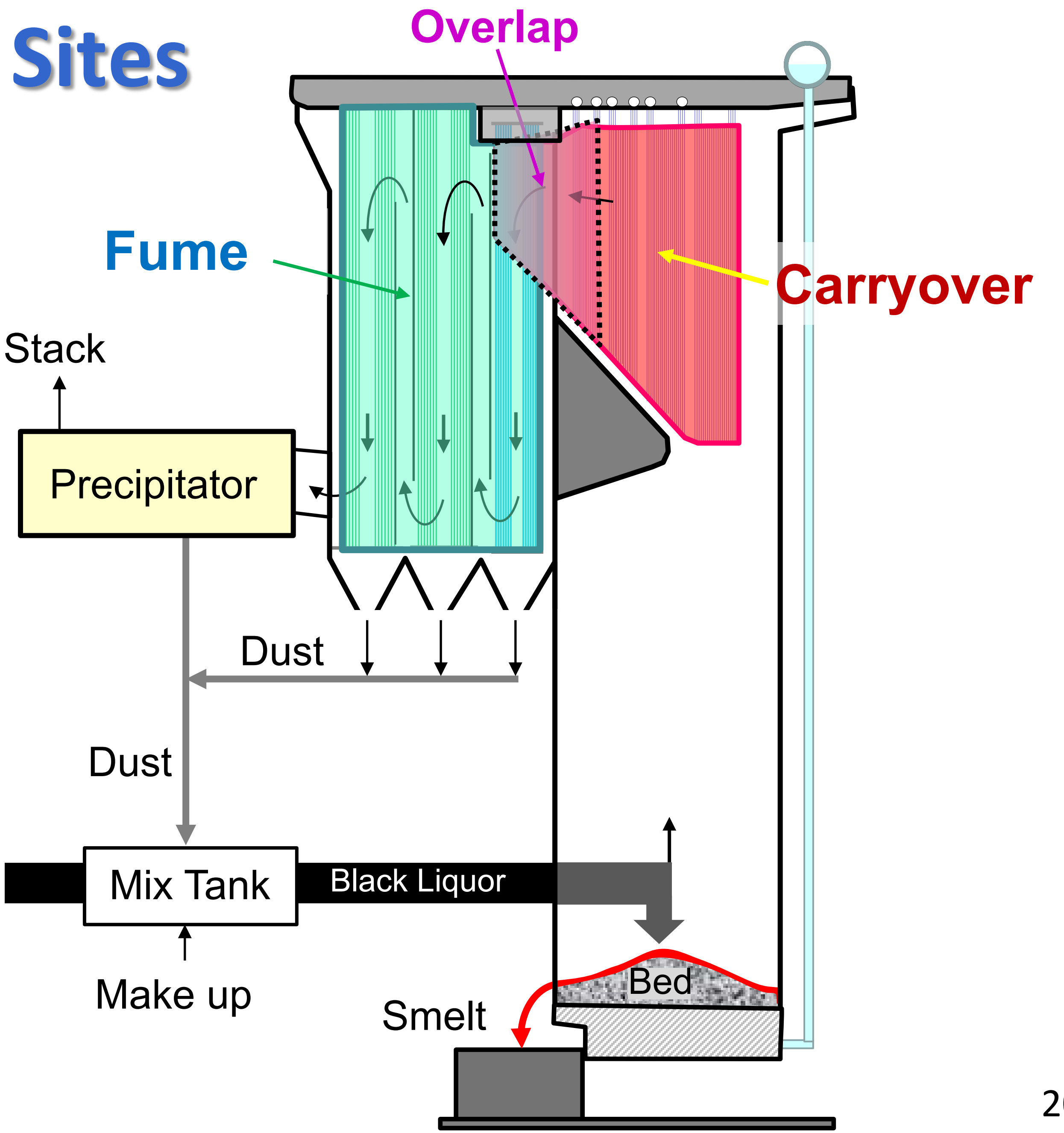
Indicative of sulfide present in deposit

Effect of Sulfidity on GB Outlet Gas Temperature

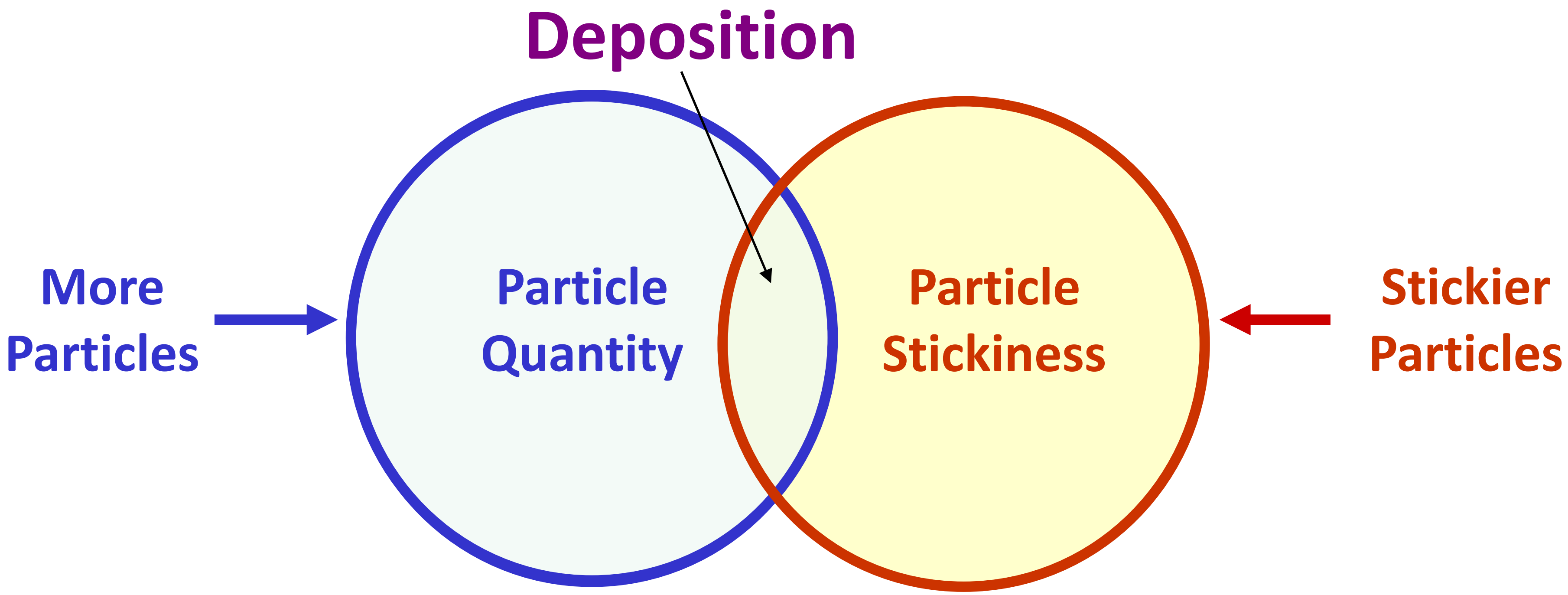


Preferential Deposition Sites

- Carryover
  - Superheater and generating bank inlet
- Fume
  - Upper superheater, generating bank, and economizer
- Overlap
  - From upper superheater to generating bank inlet
- ESP ash consists of mostly fume (95^{+}%)



Deposition Requirements



- More and stickier particles ➔ Larger overlapping area ➔ More severe deposition

Presentation Outline

- Problems with Deposits
- Deposit Types
- Deposit Composition and Properties
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Variables Contributing to Stickier Carryover

Stickier Carryover

Chloride ↑
- Mill location
- Makeup chemicals
- Degree of mill closure
- Liquor sulfidity
- Bed temperature

Potassium ↑
- % hardwood
- Degree of mill closure

Sulfide ↑
- Firing load
- Air flow rate
- Air distribution
- Liquor sulfidity
- Retention time

Temperature ↑
- Firing load
- Air flow rate
- BL heating value
- Flue gas temperature

Affected by Lower Furnace Operation

Variables Contributing to Particle Quantity

More Particles

Firing Load ↑

- Pulp production
- Wood species
- EA to wood ratio
- Liquor inventory
- Process changes
- Process upsets

Gas Velocity ↑

- Firing load
- Air flow rate
- Air distribution
- Air port design
- Air port pressure
- % excess O_2
- ID fan speed

Particle Size & Density ↓

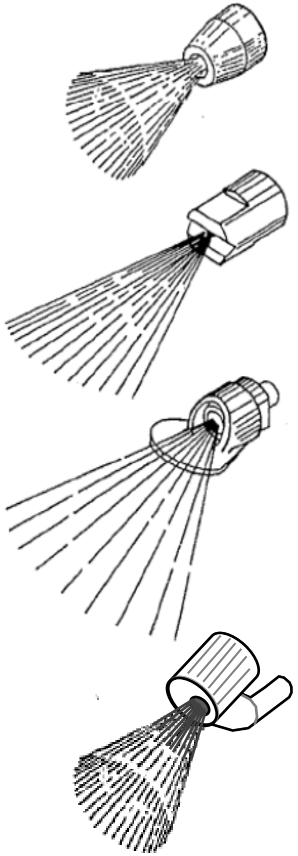
- BL droplet size
- BL solids content
- BL org./inorg. ratio
- BL temperature
- BL pressure
- BL residual EA
- BL swelling properties

Others

- BL nozzle design
- BL gun position
- BL spray angle

Importance of liquor sprays

Lower Furnace Operation vs. Carryover

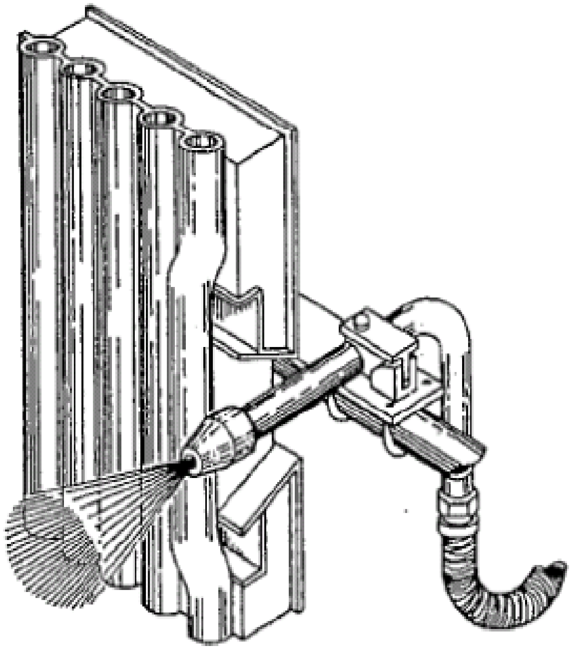


Swirl Cone

V-Type

Splash Plate

Beer Can



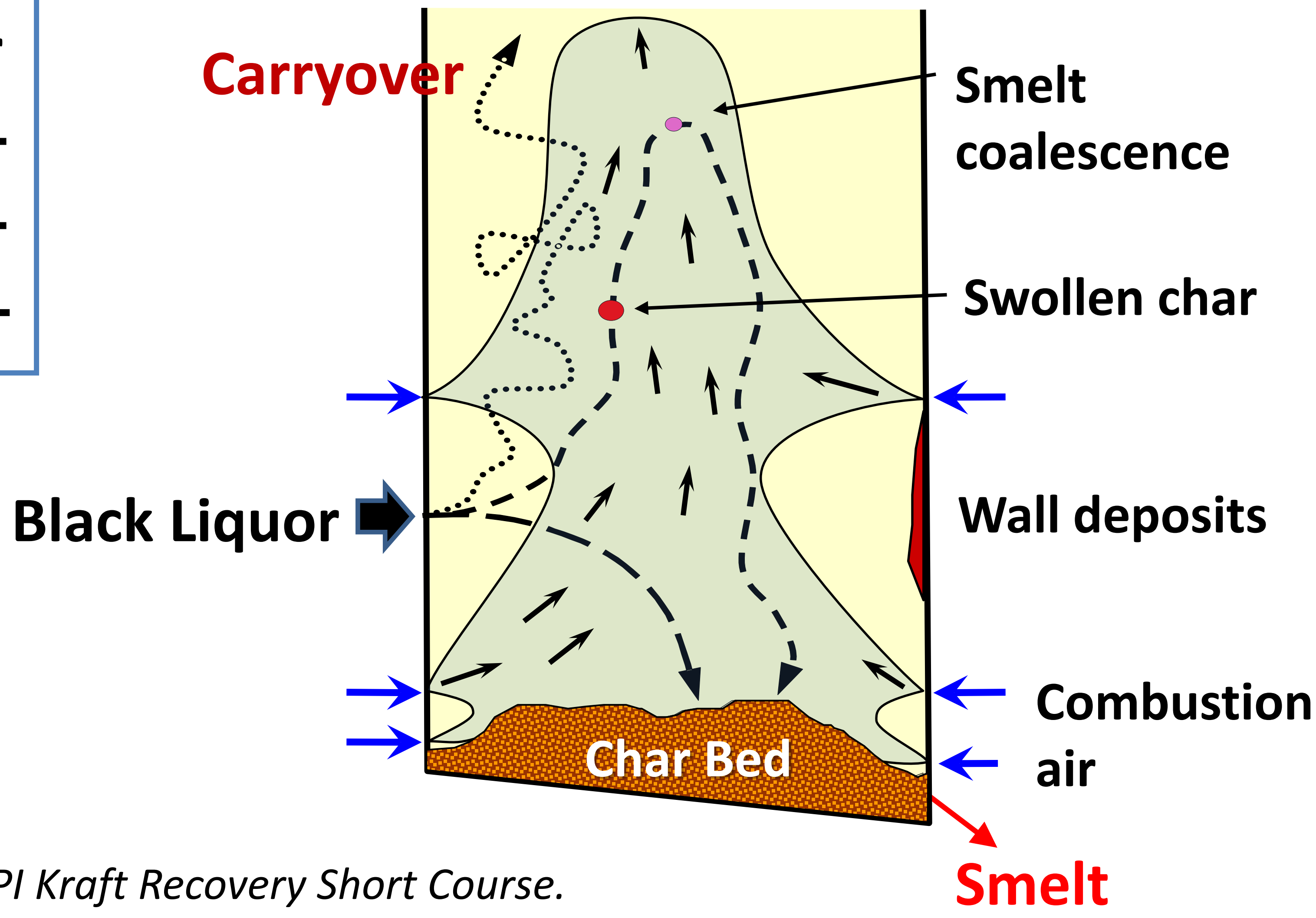
Typical Nozzle Gun Assembly

Splash Plate Nozzle

Adams, T.N., "Kraft Recovery Boilers – 3rd Ed.", Chapter 4 (2019)

Effect of Droplet Size on Trajectory

Initial Droplet Diameter	
Small (< 1mm)	....
Medium (1 to 2 mm)	– – – –
Large (> 2 mm)	—— —— –



Wessel, R. and Adams, T.N., 2006 TAPPI Kraft Recovery Short Course.

Goals for Effective Spraying

- Control droplet size (2 to 4 mm)
  - Minimize particle carryover
  - Deliver mostly dry liquor to bed
  - Control height of char bed
- Distribute liquor spray
  - Create a uniform symmetrical bed shape
  - Minimize liquor on furnace walls

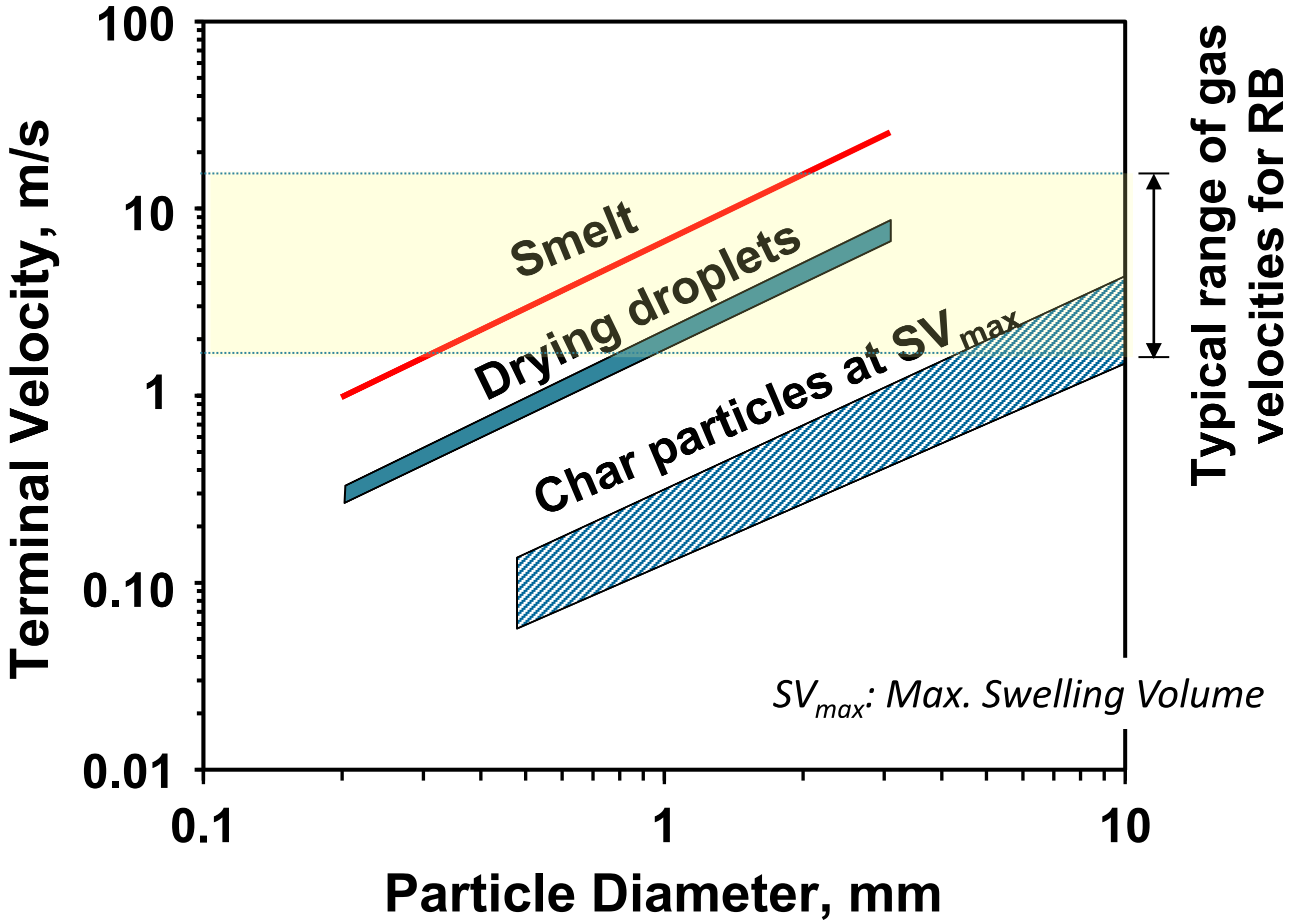
Jones, A.K., TAPPI Kraft Recovery Operations Course (2023)

Effects of Air Flow Rate and Distribution

- High air flow rate increases carryover
- Air distribution
  - Secondary air affects carryover the most
  - Air interlacing helps minimize carryover
  - Tertiary air has little effect on carryover

Terminal Velocity vs. Particle Size

- Carryover may or may not entrained in the flue gas depending on
  - Its size and density (porosity)
  - Flue gas velocity
- Fume is always entrained!



Hupa, M.., "Kraft Recovery Boilers – 3rd Ed.,", Chapter 5, p. 93, (2019)

Fume Properties

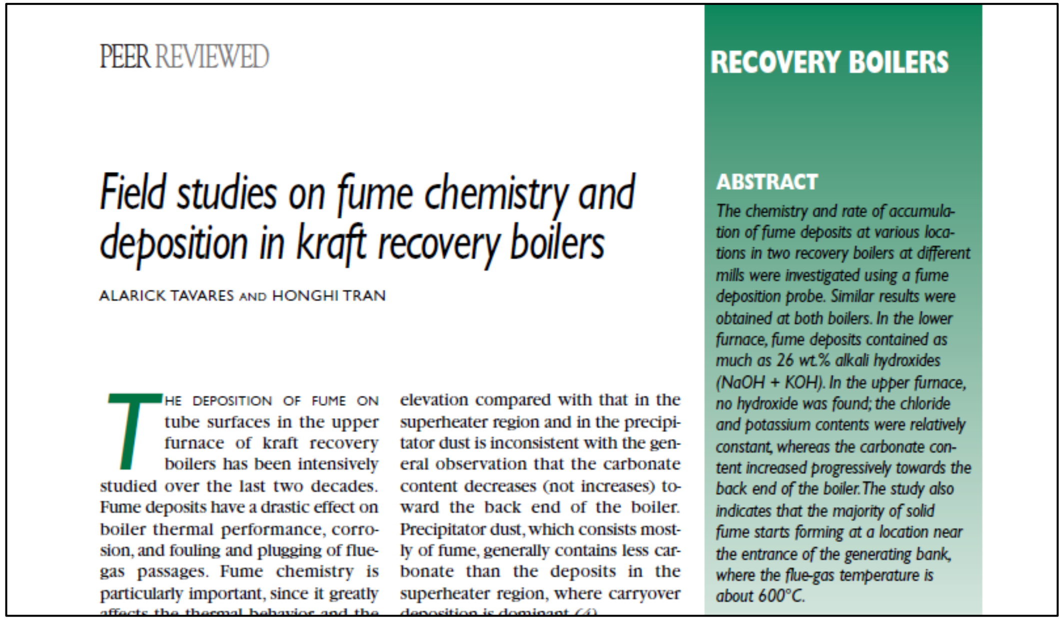
- Fume is not sticky unless it is acidic
  - Low bed temperature produces less fume, but high SO_2
  - High SO_2 in the flue gas may result in acidic sulfate formation, making fume stickier → Fouling/plugging in the generating bank and economizer
- Main problems with fume
  - Fume deposits can sinter and become hard quickly at >500°C (930°F)
  - More fume → High internal recycled dust load and high particulate emissions

Lower Furnace Operation vs. Fume Quantity

- **Fume Quantity**
  - **Directly proportional to the amount of alkali vapors in the gas**
  - **Exponentially increases with increase in bed temperature**
    - Liquor firing load
    - Liquor solids content
    - Air distribution (particularly primary air)
  - **At a given average bed temperature, poorly distributed temperature bed produces more fume**

References – TAPPI Journal

- *Tavares, A. and Tran, H.N., TAPPI Journal, 80 [12] (1997).*
- *Tavares, A., Tran, H.N., and Reid, T., TAPPI Journal, 81 [9], 134-138 (1998).*



PEER REVIEWED

RECOVERY BOILERS

Field studies on fume chemistry and deposition in kraft recovery boilers

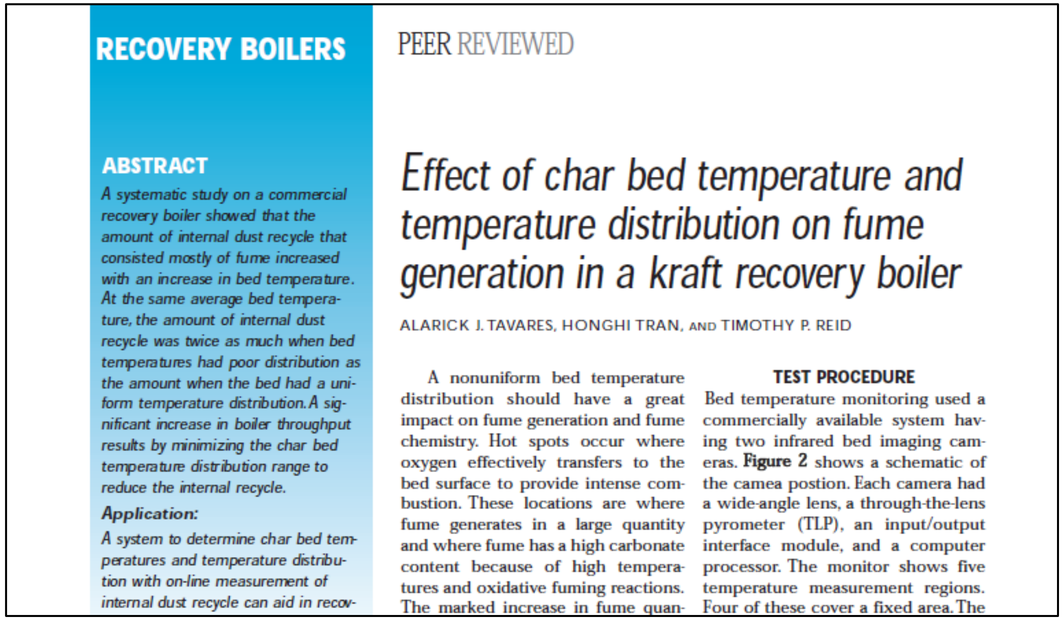
ALARICK TAVARES AND HONGHI TRAN

ABSTRACT

The chemistry and rate of accumulation of fume deposits at various locations in two recovery boilers at different mills were investigated using a fume deposition probe. Similar results were obtained at both boilers. In the lower furnace, fume deposits contained as much as 26 wt.% alkali hydroxides (NaOH + KOH). In the upper furnace, no hydroxide was found; the chloride and potassium contents were relatively constant, whereas the carbonate content increased progressively towards the back end of the boiler. The study also indicates that the majority of solid fume starts forming at a location near the entrance of the generating bank, where the flue-gas temperature is about 600°C.

THE DEPOSITION OF FUME ON tube surfaces in the upper furnace of kraft recovery boilers has been intensively studied over the last two decades. Fume deposits have a drastic effect on boiler thermal performance, corrosion, and fouling and plugging of flue-gas passages. Fume chemistry is particularly important, since it greatly

elevation compared with that in the superheater region and in the precipitator dust is inconsistent with the general observation that the carbonate content decreases (not increases) toward the back end of the boiler. Precipitator dust, which consists mostly of fume, generally contains less carbonate than the deposits in the superheater region, where carryover



RECOVERY BOILERS

PEER REVIEWED

Effect of char bed temperature and temperature distribution on fume generation in a kraft recovery boiler

ALARICK J. TAVARES, HONGHI TRAN, AND TIMOTHY P. REID

ABSTRACT

A systematic study on a commercial recovery boiler showed that the amount of internal dust recycle that consisted mostly of fume increased with an increase in bed temperature. At the same average bed temperature, the amount of internal dust recycle was twice as much when bed temperatures had poor distribution as the amount when the bed had a uniform temperature distribution. A significant increase in boiler throughput results by minimizing the char bed temperature distribution range to reduce the internal recycle.

Application:

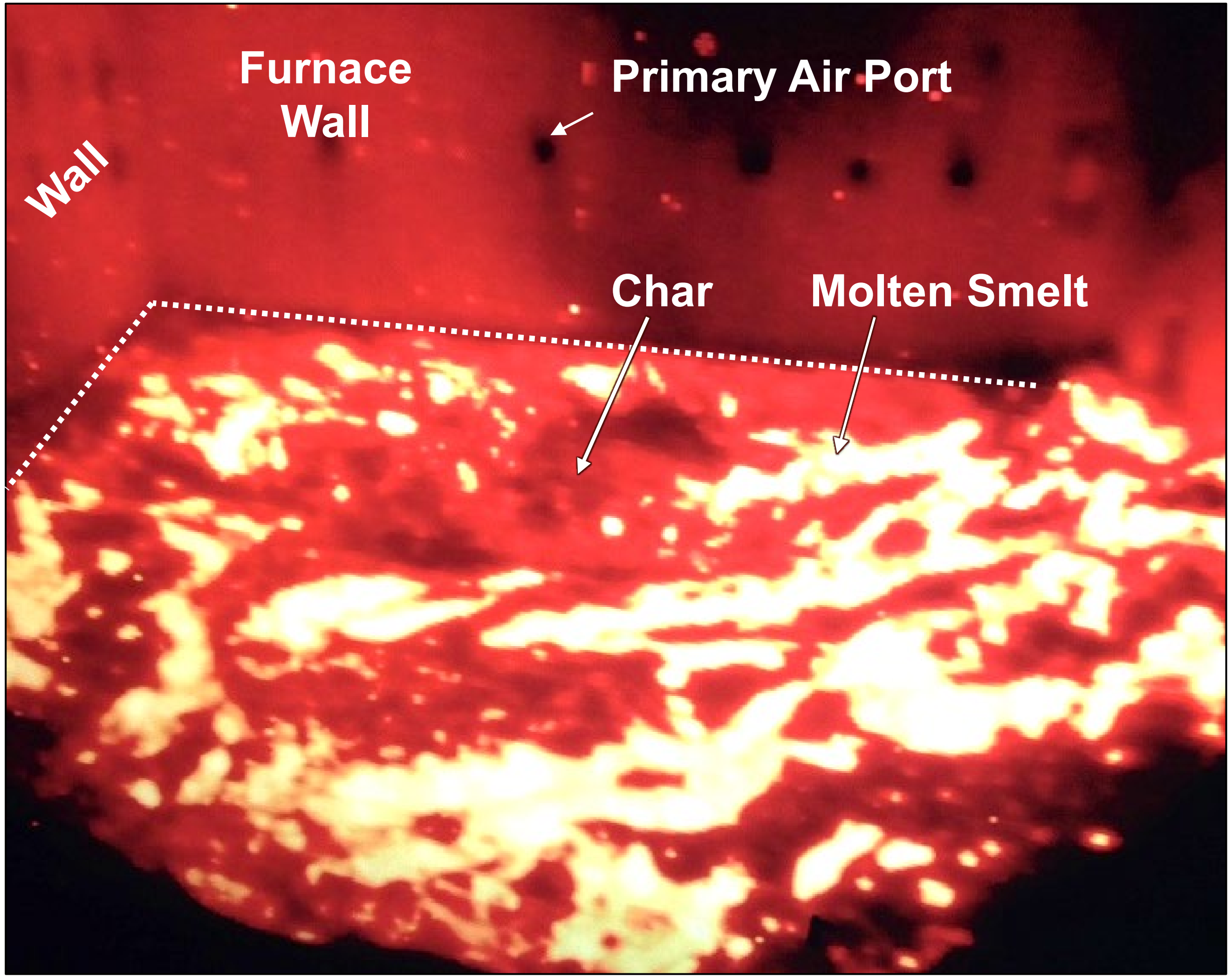
A system to determine char bed temperatures and temperature distribution with on-line measurement of internal dust recycle can aid in recov-

A nonuniform bed temperature distribution should have a great impact on fume generation and fume chemistry. Hot spots occur where oxygen effectively transfers to the bed surface to provide intense combustion. These locations are where fume generates in a large quantity and where fume has a high carbonate content because of high temperatures and oxidative fuming reactions.

TEST PROCEDURE

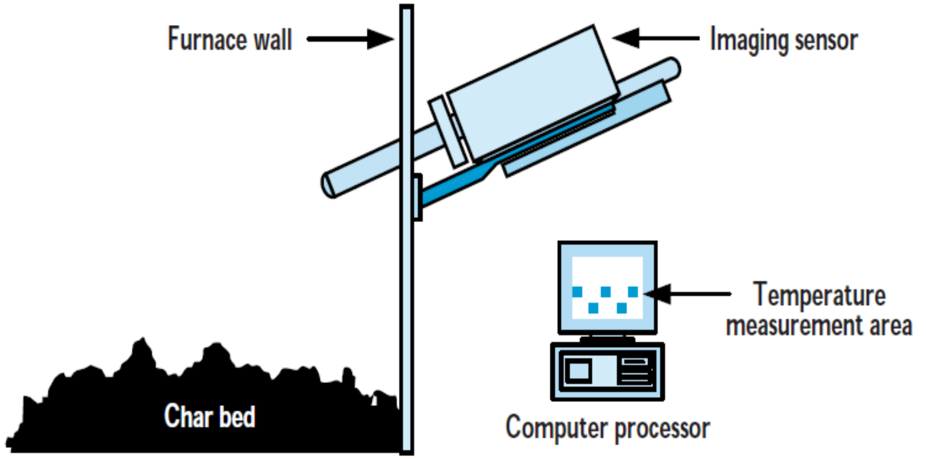
Bed temperature monitoring used a commercially available system having two infrared bed imaging cameras. **Figure 2** shows a schematic of the camea postion. Each camera had a wide-angle lens, a through-the-lens pyrometer (TLP), an input/output interface module, and a computer processor. The monitor shows five temperature measurement regions. Four of these cover a fixed area. The

Char Bed (10 minutes after blackout)

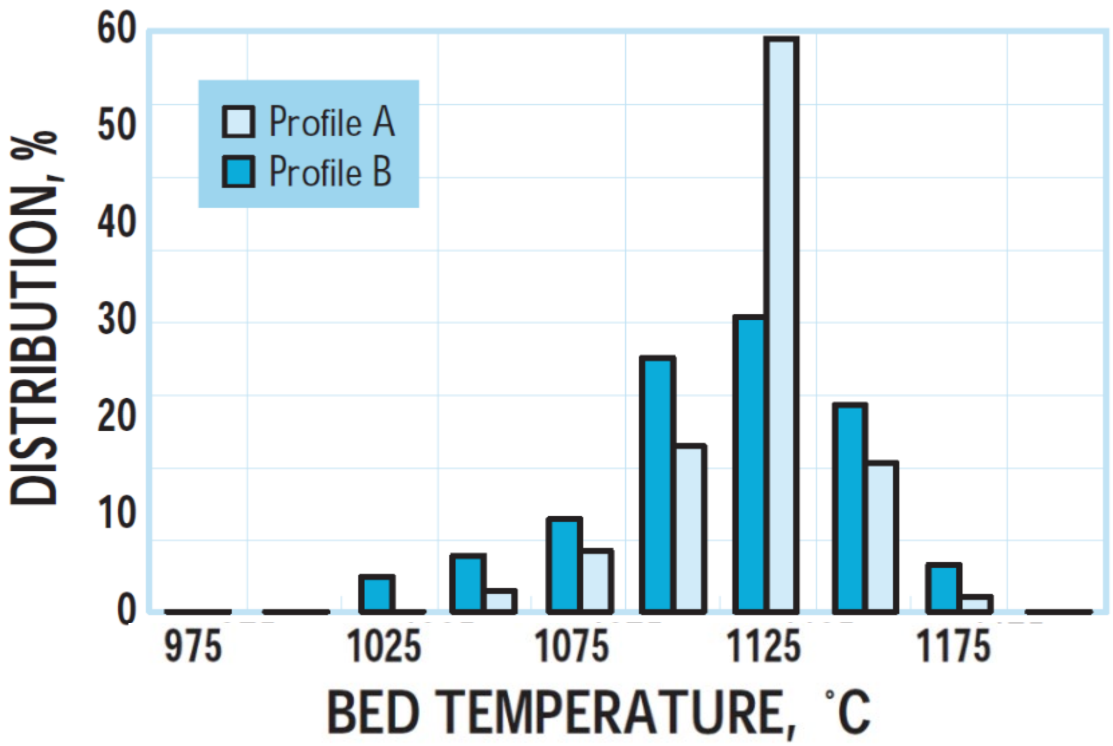


(Courtesy: Wanicley Viana, Susano)

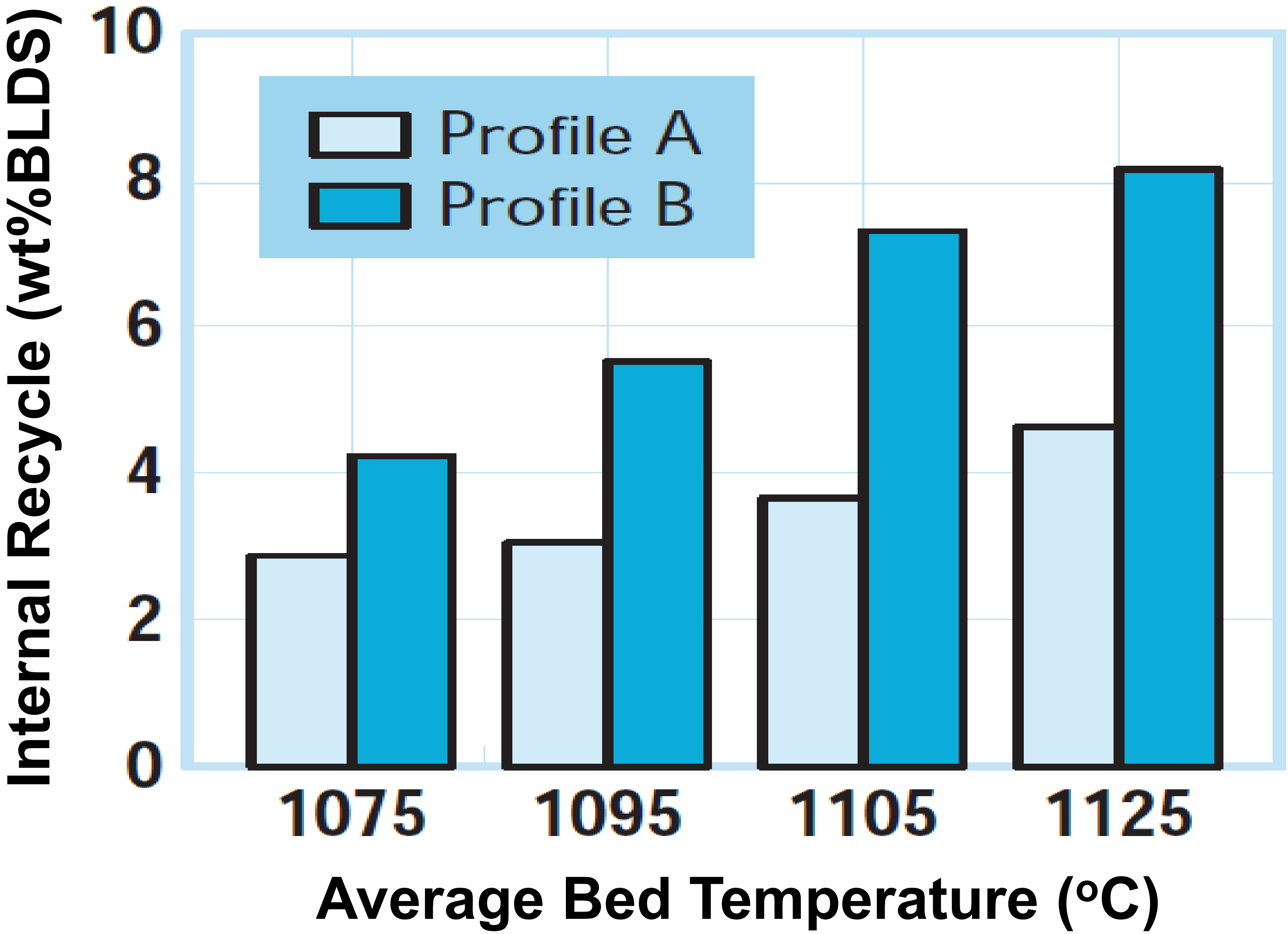
Effects of T_{Bed} Distribution Profiles on Fume Formation



Two Profiles with Same Average T_{Bed}



Effects of T_{Bed} Distribution Profiles on Fume Formation



Summary - 1

- Recovery boiler deposits can cause many problems in boiler operation
- Deposits are formed by carryover and fume
- The amount of carryover depends strongly on liquor firing load, liquor spray, and liquor swelling properties
- The stickiness of carryover is affected mainly by chloride, potassium and sulfide contents

Summary - 2

- The amount of fume increases exponentially with increasing lower furnace temperature
- At a given average bed temperature, bed with a poor temperature distribution profile produces more fume than that with a good temperature distribution profile
- Fume is always entrained in the flue gas
- Fume is not sticky unless it contains acidic sulfates

AF&PA Recovery Boiler Program 2023 Annual Conference

Water Side Tube Damage and Failure Mechanisms In Kraft Recovery Boilers

8 Feb 2023

Atlanta, GA

Introduction

- Discussion restricted to water-side tube failure mechanisms
  - No superheater, cold side, near drum, or turbine scenarios…etc.
- Failure modes / critical factors
- Remedies and mitigating factors
  - Chemical
  - Operational
- Recovery boiler tube failure impacts

Under Deposit Corrosion (UDCC & UDAC)

Critical factors

- Requires porous deposit
- Concentrating mechanism
- Inappropriate and/or poorly controlled internal treatment chemistry
- Local chemistry beneath deposit dramatically different from bulk boiler water…*can be higher or lower pH*
- Wick boiling vs. nucleate boiling

Under Deposit Corrosion (UDCC & UDAC) cont…

Deposits partially trap heat and inhibit water from contacting the tube surface in free flow in order to carry away steam bubbles

Deposits formed in high heat flux areas resulting in chimney affect

Chemistry upsets in deposit-free boilers may have little to no effect, but…

Chemistry upsets in systems where deposition is present (even highly localized) can result in dramatically different outcomes

Caustic gouging is not accompanied by microstructural degradation, which means that final failure is most often ductile and will produce a thin-edged or pin-hole failure.

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Under Deposit Corrosion (UDCC & UDAC) cont…

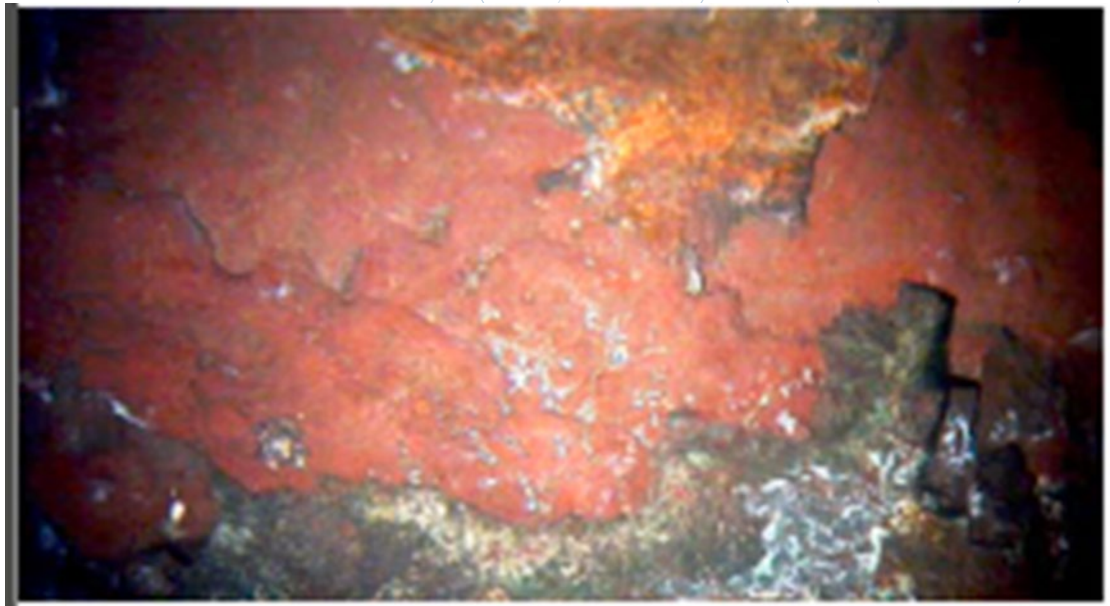
Low sodium-to-phosphate (acidic) ratios in the boiler water, often associated with phosphate hideout

- 2.2:1 sodium to phosphate or less

A concentrating mechanism

- Deposition which concentrates boiler solids
- Departure from nucleate boiling/steam blanketing
- Steam-water separation at horizontal tube runs or poor circulation areas

Identification of acid phosphate attack by metallurgists is required to determine if iron corrosion residue is maracite. Acid phosphate corrosion yields a deposit that contains two or three distinct layers of which the white/gray inner layer is maracite ($NaFePO_4$) speckled with red hematite.

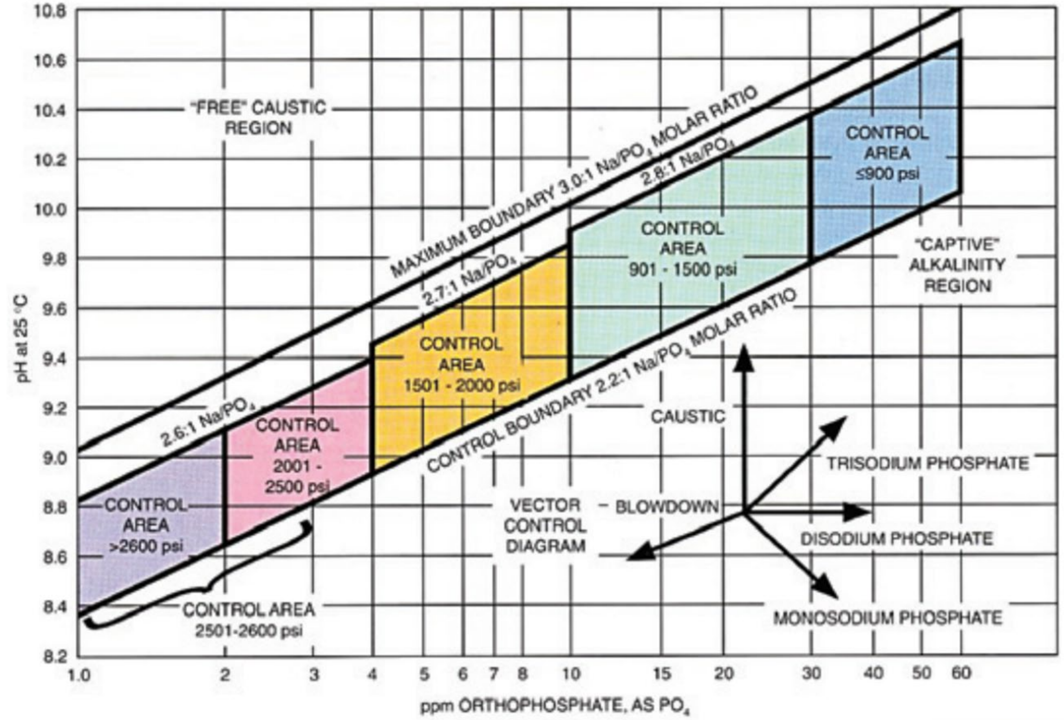


Deposit may be layered, with red hematite iron oxide

Congruent Phosphate : pH

Essential under conditions where makeup is demineralized quality or better and where porous-deposit-forming contamination is likely (iron transport in pulp & paper industry)

Maintaining Na:PO4 ratio within established limits reliably ensures that the chemistry underneath an iron deposit looks relatively close to bulk boiler water chemistry



Steam Blanketing

- Critical factors
  - Heat flux
  - Horizontal or slanted tubes
  - Fluid flow

Conditions that can lead to disruptions in the flow of the steam/water mixture within a given tube can be influenced by the angle of the affected tubes, circulation, and heat input

Velocity is not sufficient to maintain turbulence and proper mixing of steam and water during passage through the tube

Results in stratification from the separation of the steam from the water, within the tube

Most commonly prominent in sloped tubes located away from the radiant heat zone of the boiler.

As the steam/water mixture is separated, deposits consistent with this phenomenon can occur as steam is flashed off and otherwise dissolved solids are left to cycle up locally and then precipitate onto the tube surfaces.

Under deposit corrosion is a concern, as previously discussed, as well as overheat failures

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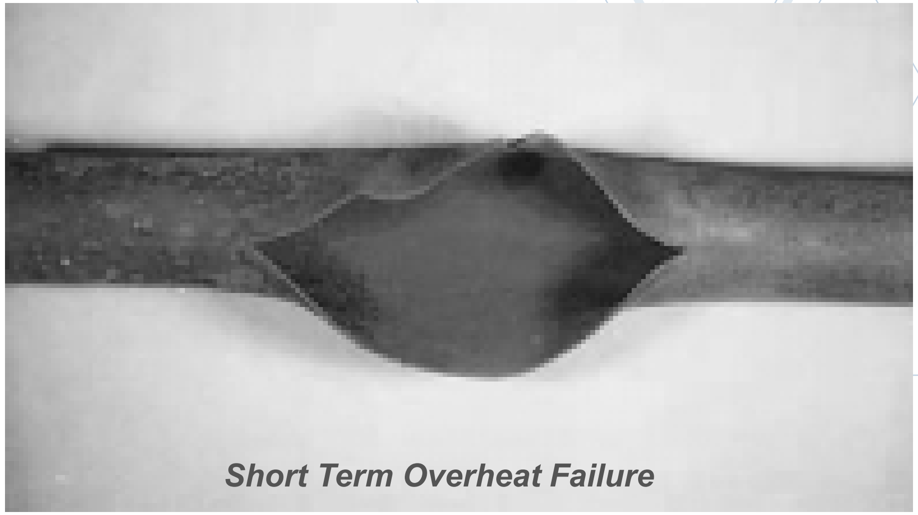
Overheat Failures – Short Term/Long Term

Short Term Critical factors

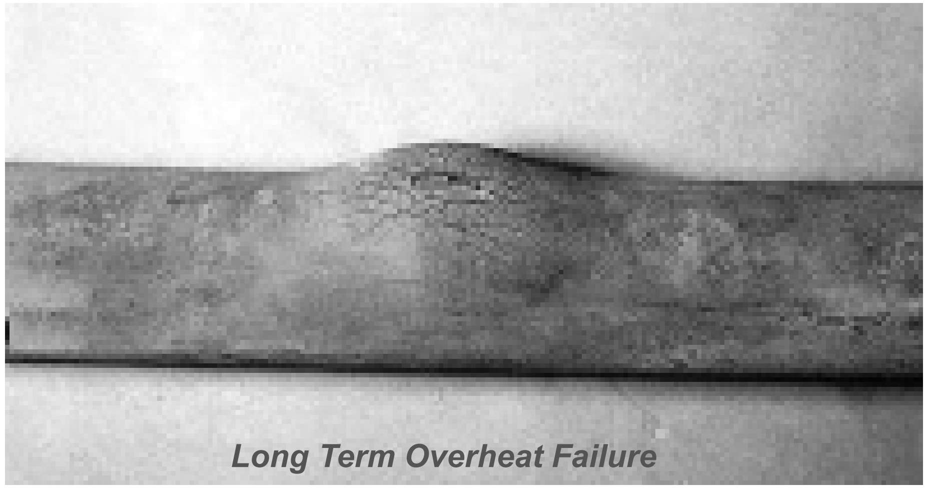
- Low water level
- Partial or complete tube pluggage
- Rapid startups / excessive load swings
- Excessive heat input

Thin-lipped longitudinal rupture

Fish-mouth appearance



Short Term Overheat Failure



Long Term Overheat Failure

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Overheat Failures – Long Term

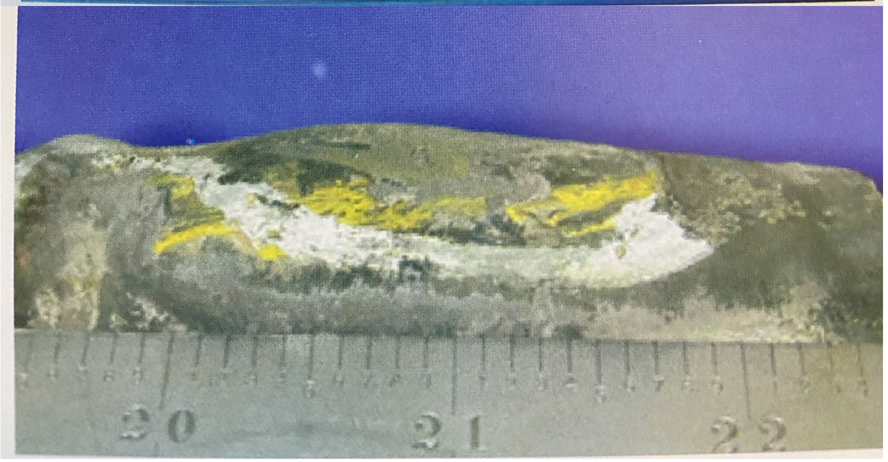
Critical Factors

- Gradual accumulation of deposits or scale
- Partially restricted water flow
- Excessive heat input or flue gas channeling
- Inclined or horizontal tubes subject to steam blanketing

Characterization

- Tube temperature > 850°F
- Blistering / bulging
- Thick-lipped rupture or longitudinal cracking
- Internal and external thermal oxidation

Metallurgical examination of microstructure may be required to confirm long-term overheat failures



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Oxygen Attack

Critical Factors

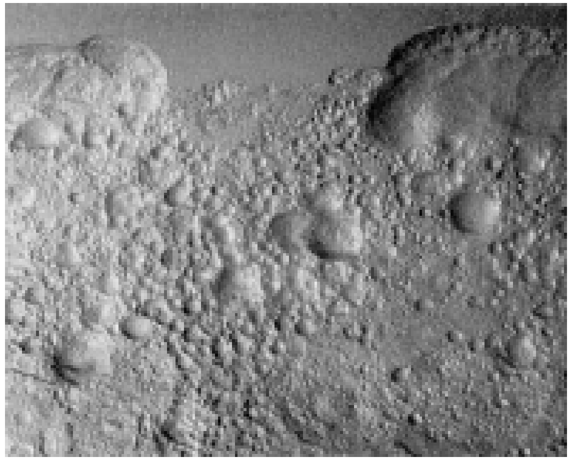
- Deaeration – mechanical problems
- Feedwater – FWP lube/seal water, air inleakage
- Condensate - air or process water inleakage
  - *If condensate not returned to heater section of DA

Primarily manifests in economizer attack, in many cases

- Startup – high DO may decrease cycles and stress required for corrosion fatigue (SCC) to begin by an order of magnitude
- Improper layup – manifests in boiler, proper, attack

TABLE E
Oxygen Distribution in Feedwater and Boiler Water

Pressure (psig)	ppm O_2 in Boiler Water / ppm O_2 in Feedwater
180	1/5,000
600	1/1,570
1,000	1/950
2,000	1/500



Characterization

- Cathode depolarization – oxide/passive layer formation no longer self-limiting
- Hemispherical pitting / corrosion product turbucules

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General

Minimizing Waterside Tube Failures

- Control Fe, Cu, and DO transport into the boiler
- Consistent control of FW & internal boiler water chemistry
- Proper monitoring of key KOI/KPI parameters
  - Employing swift and effective response procedures for deviations
- Chemical cleaning when needed

RB Failure Impacts:

- Production losses
- Maintenance costs
- Safety concerns

References/Acknowledgements

1. Singh P.M.,Pawel, S.J. (DE-FC36-02ID14243) - “Stress-Assisted Corrosion in Boiler Tubes”, pg. 103
2. Beardwood, E.S. – “Keys to Successful Feedwater and Deaeration Within Industrial Steam-Generating Systems”, Steam, 2017, pg. 4
3. DeWitt-Dick, D., McIntyre, S., Hofilena, J. – “Boiler Failure Mechanisms”
4. Noble, C.A. – “Boiler Tube Damage Mechanisms, Preventing Failures in Steam Generating Equipment”
5. Bartholomew, R.D. PE – “Recovery Boiler Water Treatment”

Sootblower
Design, Maintenance, and Operations

AF&PA Meeting – Atlanta, GA, USA
February 8 - 9th, 2023
Clyde Industries (Formerly Known as Clyde Bergemann Pulp & Paper Division)

Sootblower Age

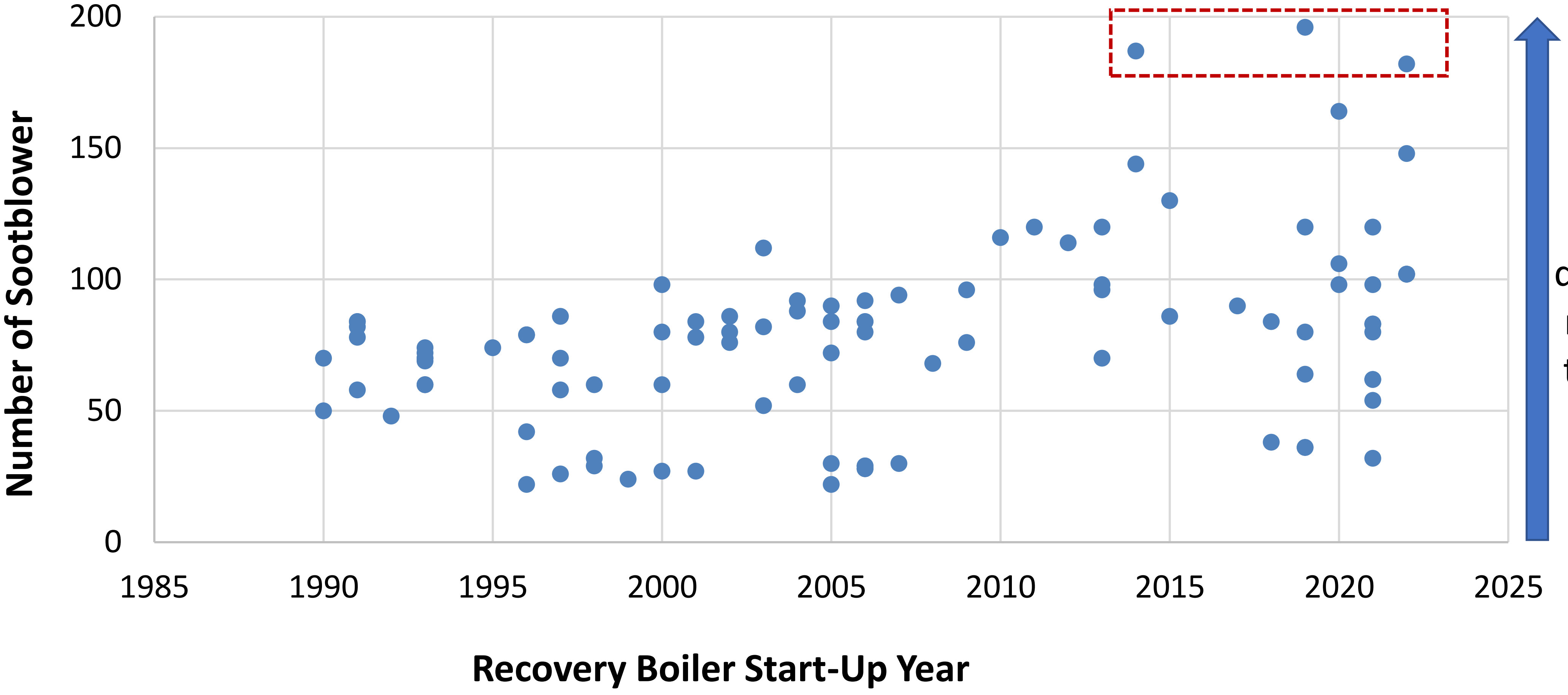
- In Canada & USA, many sootblowers are operated well beyond their normal service life.

Sootblower	Canada	USA	Brazil	Finland	Sweden + Norway
Average Age	41	41	18	28	34
Oldest	71	66	41	59	60

- Although it is possible to extend the sootblower's service life, boiler operators need to have a systematic maintenance approach to ensure safety, reliability, and at the same time, control the maintenance cost.

Number of Sootblower in Recovery Boilers

Three largest RBs in the world have close to 200 sootblowers



The higher the quantity of SB, the more challenging to maintain them

Challenges facing pulp mills

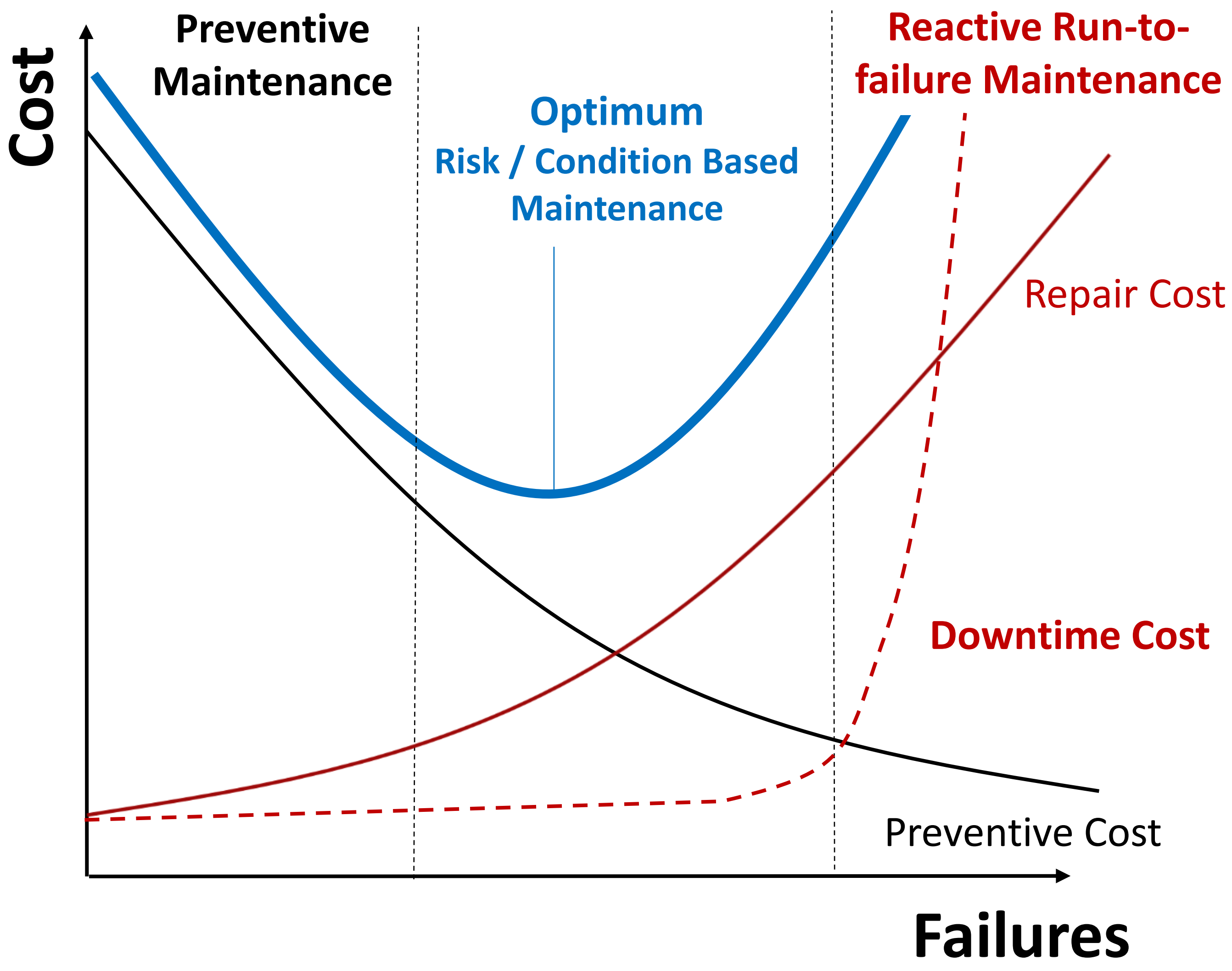
- Aging sootblower equipment
- High quantity of sootblowers, making it harder to maintain them
- Retiring experienced personnel
- Lack of trained maintenance team
- Competing budget & resources

MAINTENANCE APPROACH

Risk and Condition Based Maintenance

Maintenance

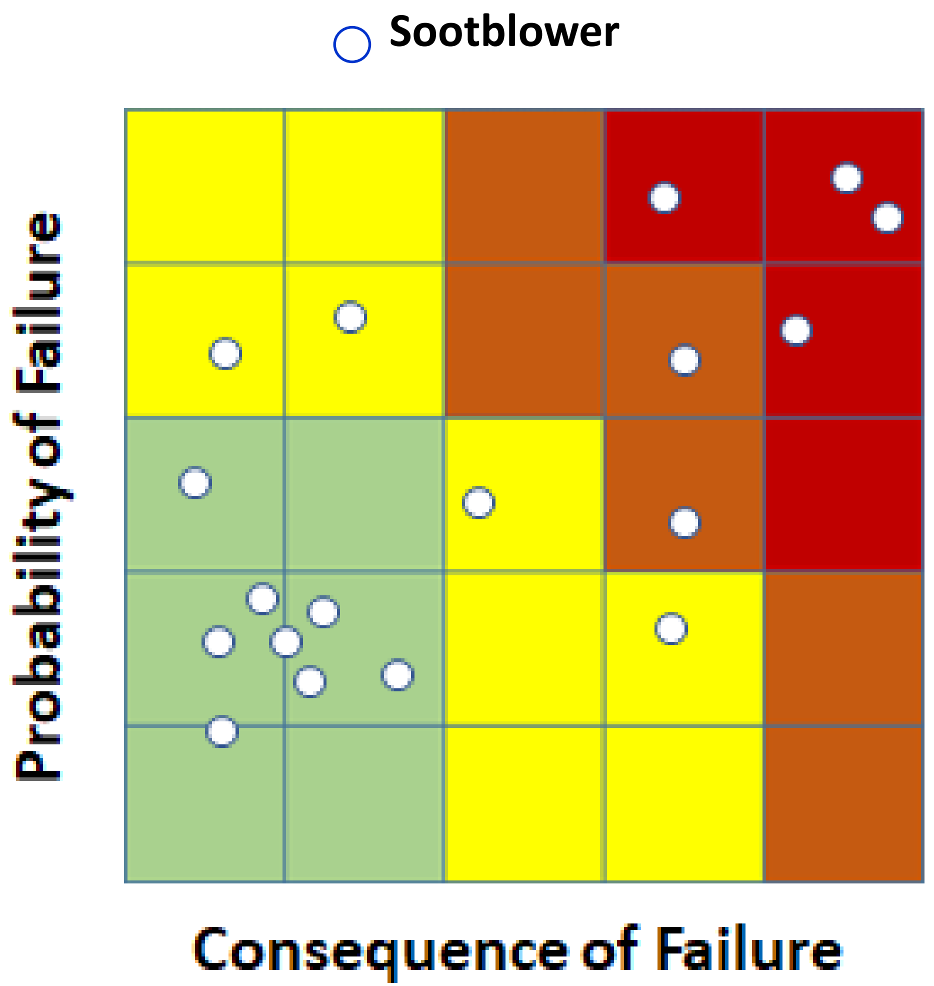
- Sootblower is NOT a "precision equipment" that needs a costly *preventive maintenance.*
- But *reactive run-to-failure maintenance* is also a bad choice – High repair / downtime costs & Unsafe Operations.
- Risk & Condition Based maintenance is the most appropriate approach – It reduces operating costs, downtime, and failures.



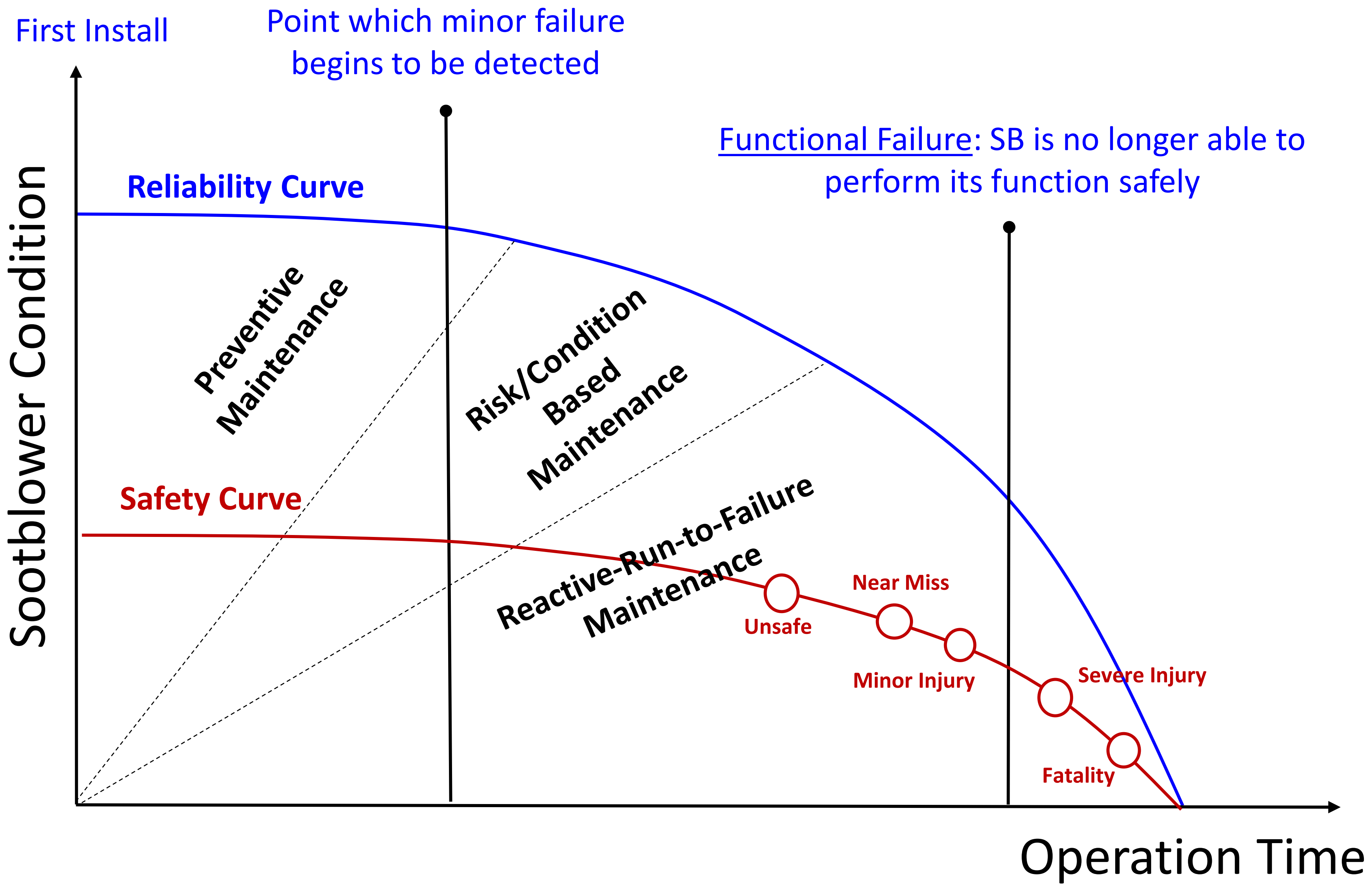
Risk & Condition Based Inspection (RBI)

- RBI assesses the probability of failure (PoF) and the consequence of failure (CoF) associated with each sootblower

- The key success factor to maintain a large quantity of sootblowers under limited maintenance resources is **<u>to know your risk and maintenance priority</u>**!

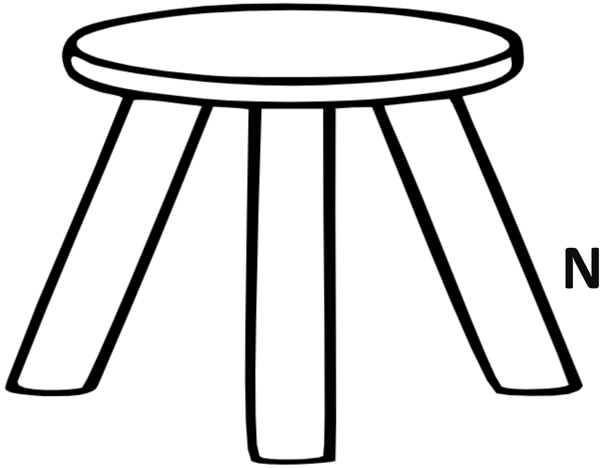


Equipment Reliability



RBI – Three-Legged Stool

Risk-Based Inspection



Walkdown (Visual Inspection)

Non-Destructive Examination (NDE) of tubes

Real-time Monitoring (Sensors)

1. Cycle count & time
2. Motor Current
3. Steam Pressure
4. Steam Temperature
5. Vibration

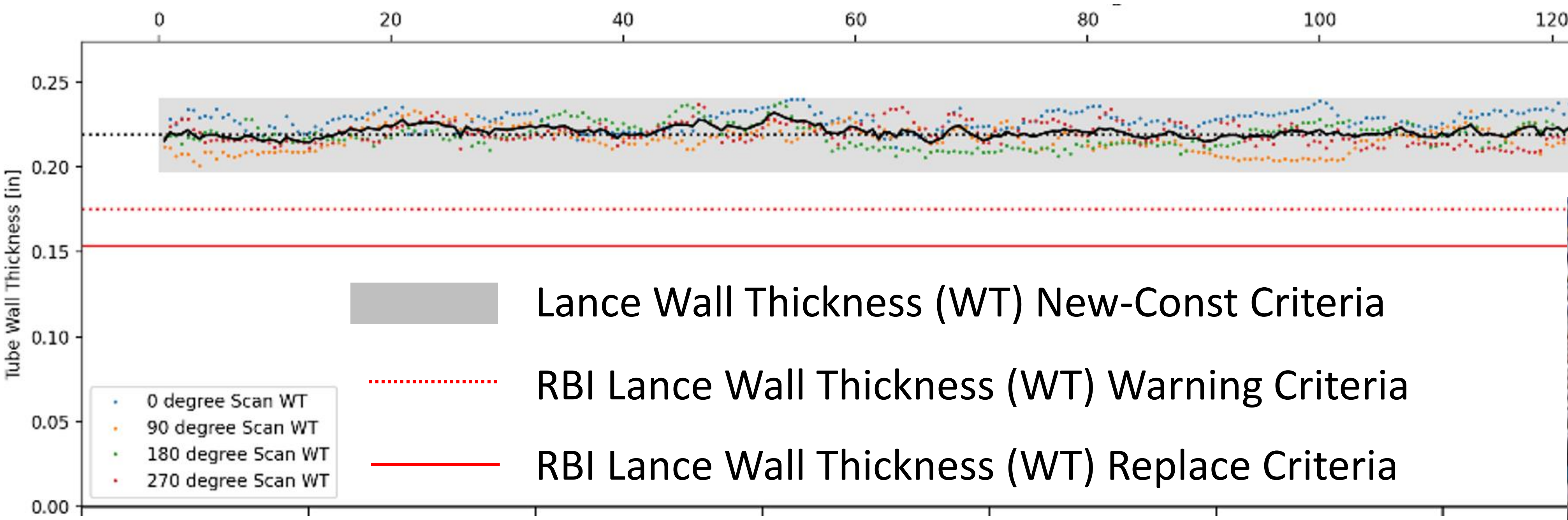
Problem with traditional NDT Strategy

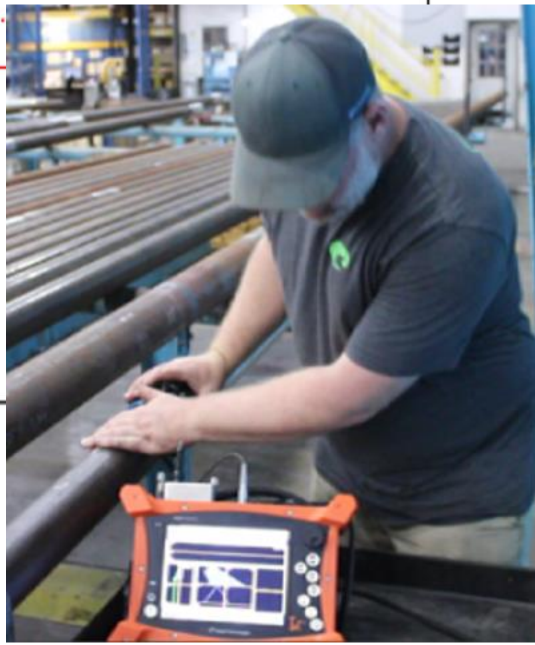
- Many pulp mills choose to pass the responsibility for the scope of lance & feed tube inspection to their NDE contractor
  - Few contractors understand bending stress calculation-based inspection
- Inspection data is evaluated against requirements of codes for new construction (e.g., ASME), and NOT post-construction codes for operating equipment
  - This often leads to inappropriate and expensive repair/replace decisions

NEW-Construction Code Vs POST-Construction Code

- Inspection scope driven by grid- and time-based approach, rather than one based on risk evaluation
  - Costly, time-consuming, and unnecessary yearly NDE inspection for **ALL** tubes

New-Construction vs Post-Construction Criteria





OPERATING ISSUES

Most common causes, Detection and Mitigation

BLRBAC Report – RB Downtime due to sootblower (2001 – 2022)

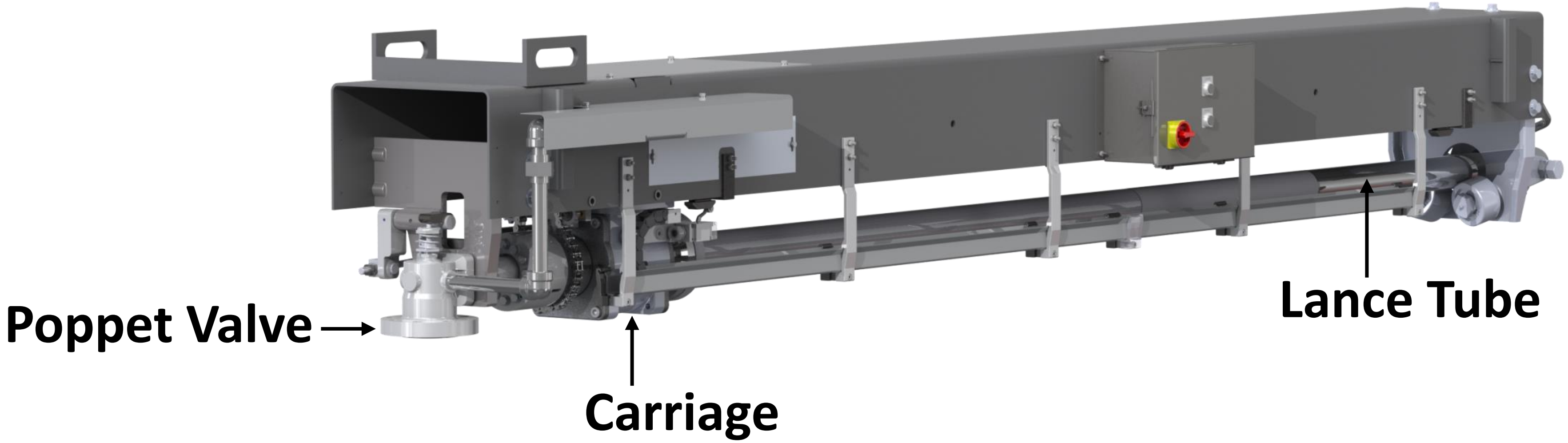
CLYDE INDUSTRIES

No.	RB DOWNTIME due to Sootblower (BLRBAC Report 2001 - 2022)	Downtime (hr)	# of Incident
1	**CARRIAGE**: Failed To Retract (Stuck in the Boiler)	2706	4
2	**LANCE TUBE**: Failure / Propelled Into Boiler	1314	3
3	**STEAM QUALITY**: Erosion due to condensate	1074	14
4	**POPPET VALVE**: Leaking Valve	964	17
5	**CLEANING FREQUENCY**: Overcleaning	838	15
6	**POPPET VALVE**: Incorrect Pressure Setting	527	6
7	**LANCE TUBE**: Hitting Boiler Tubes	375	8
8	**CLEANING FREQUENCY:** Undercleaning / Clinker Formed & Fall	226	2
	Total	8024	69

Most Severe (rows 1–2)

Most Frequent (rows 3–5)

Less Severe (rows 6–8)



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Carriage Fail to Retract

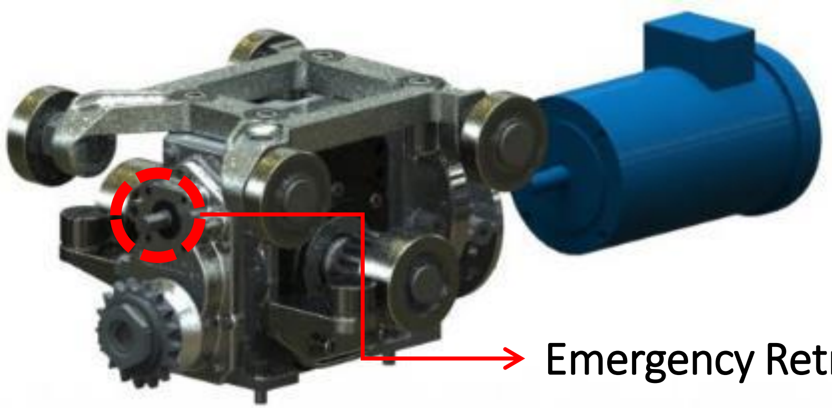
- **Most common causes**
  - Limit switch failure
    (may lead to gearbox failure)
  - Losing power
- **Detection**
  - Insertion & retraction time exceeds normal operation
- **Mitigation**
  - Monitor insert & retract time
  - Have the plan, the necessary tools and trained team to execute an emergency retract.

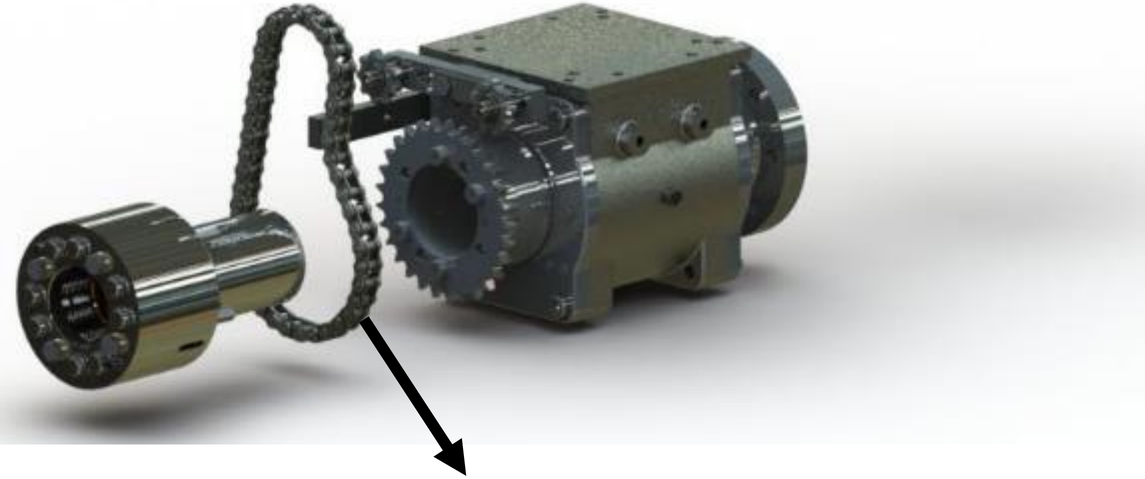
Example of a limit switch failure. Sootblower was "forced" retracted by the PLC

How to emergency retract a stuck sootblower

CLYDE INDUSTRIES

- <u>Reduce the blowing pressure</u> to a minimum allowable while working on stuck sootblower to prevent sootblower-induced-tube erosion





<u>Disconnect the rotation chain</u> BEFORE emergency retracting the blower to prevent lance rotation and bent lance hitting the boiler tubes

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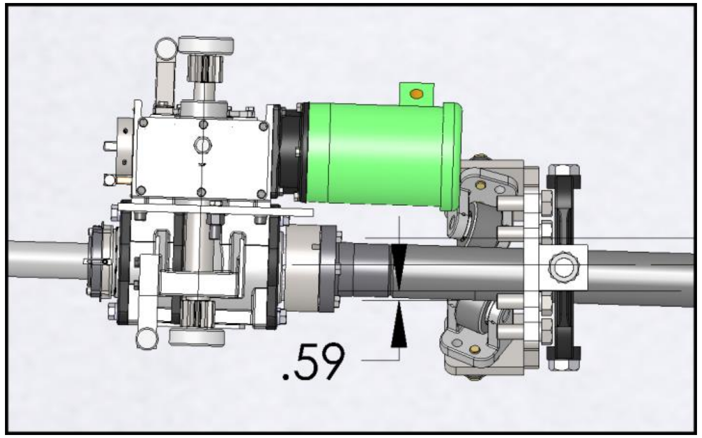
Lance Tube Failure

- A hot topic lately after an incident in Canada in 2017, where a lance tube failed, fell into the furnace, punctured the floor and caused a smelt-water explosion.
- Although there were only 3 occurrences in North America that caused a smelt-water explosion since 2001, there were several near-misses
  - 4 incidents reported in 2017 (Brazil, Poland, Finland, Austria)
  - 3 incidents reported in 2018 (Thailand, USA, Brazil)

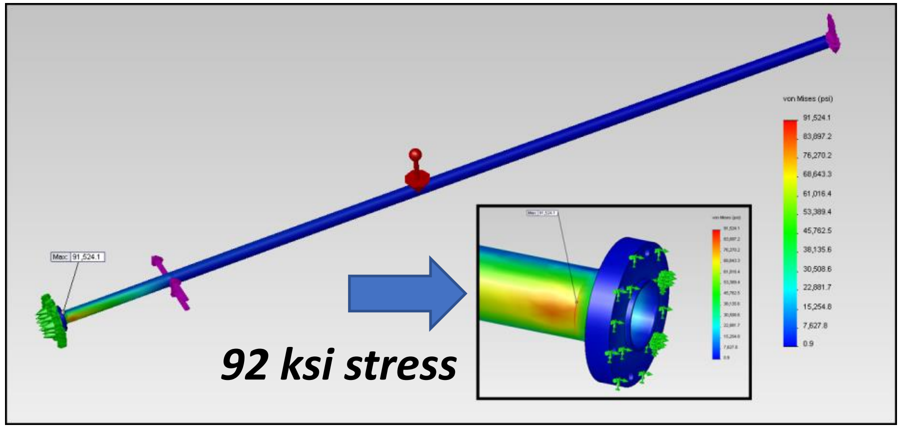
Incident in a Brazilian mill

Lance Tube Failure

- **Most common causes**
  - Sootblower misalignment
    (causing the lance tube to experience abnormal loading)
  - Lance corrosion
  - Poor lance design and manufacturing defect
- **Detection**
  - Abnormal motor amperage
  - Visual inspection
  - Non-Destructive Test (NDT)
    - 100% before lance tube shipment
    - Systematic NDE during scheduled outage
- **Mitigation**
  - Monitor motor amperage
  - Understand what-to-look during visual inspection
  - Scavenging air system
  - Implement systematic RBI NDE plan



Misalignment 0.59" will result in **92 ksi stress** near flange weld (Note that Max Normal Loading is 12 ksi)



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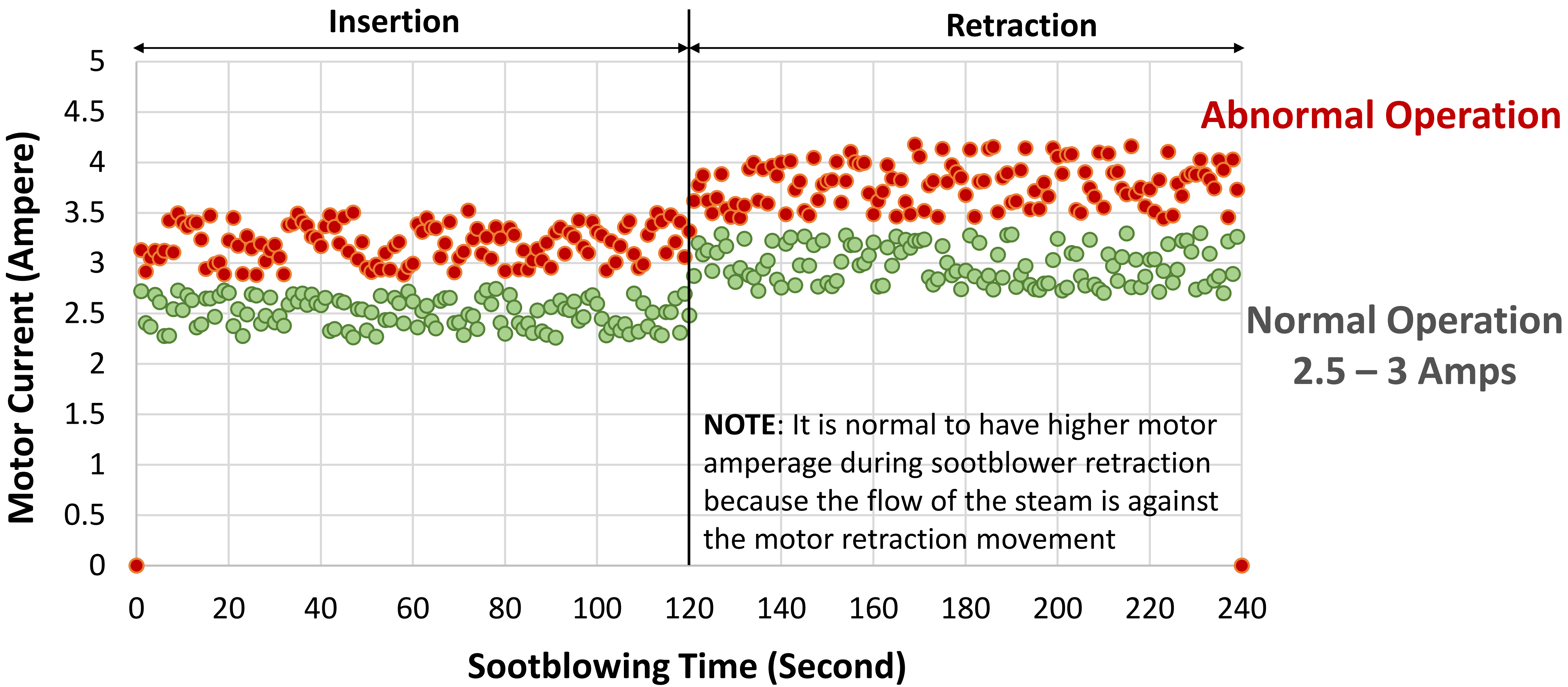
Monitor Sootblower Motor Current



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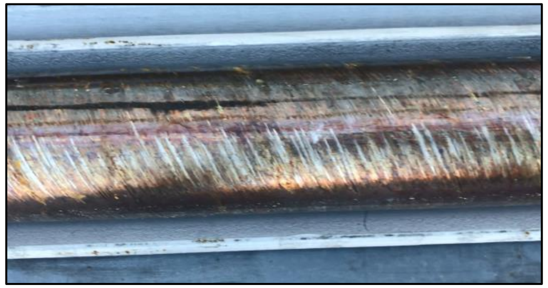
Understand what-to-look during visual inspection

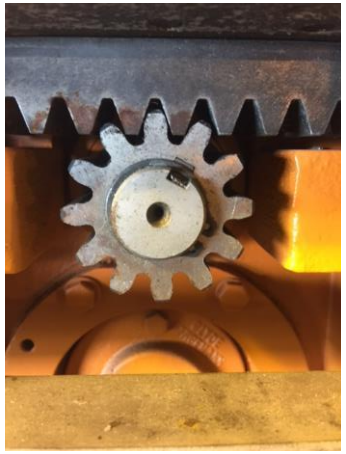
CLYDE INDUSTRIES

- Sign of misalignment
  - Uneven worn gear rack
  - Uneven feed/lance tube scoring
  - Poor gear rack & pinion engagement

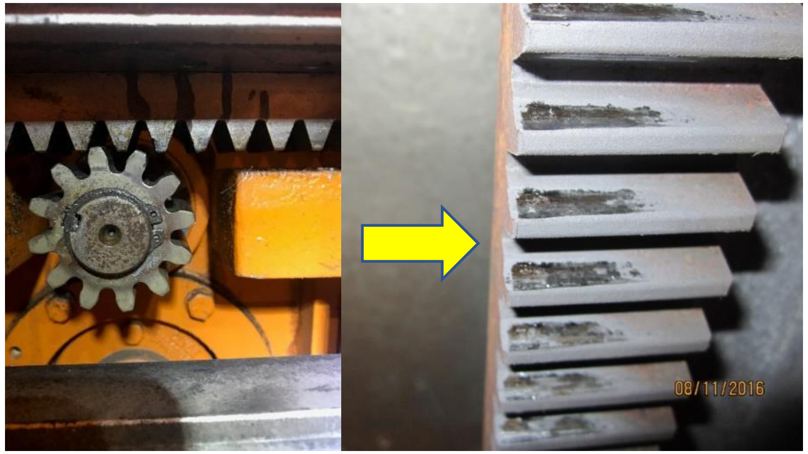


Uneven scoring of the tube

Both sides of the gear rack should wear at the same rate



Proper Engagement



Poor Engagement

- **Warning:** Do not replace the gear rack without first fixing the misalignment issue as this will increase the risk of lance failure

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Lance Tube Corrosion

- When harmful flue gas is allowed to enter the lance through the nozzles

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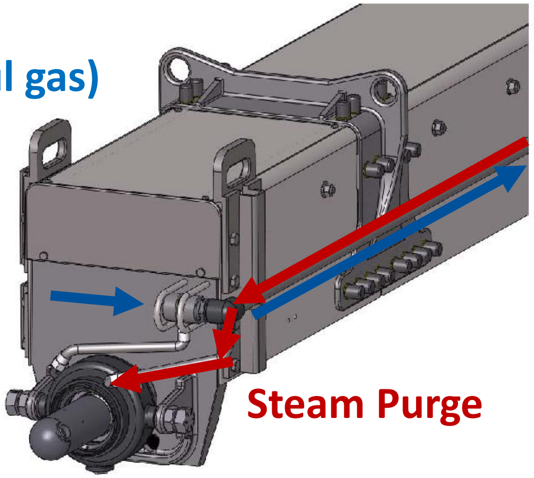
Steam & Air Flows in a Sootblower

Cleaning Steam Flows



Scavenging Air

In operation ONLY when the sootblower is in <u>REST</u> position

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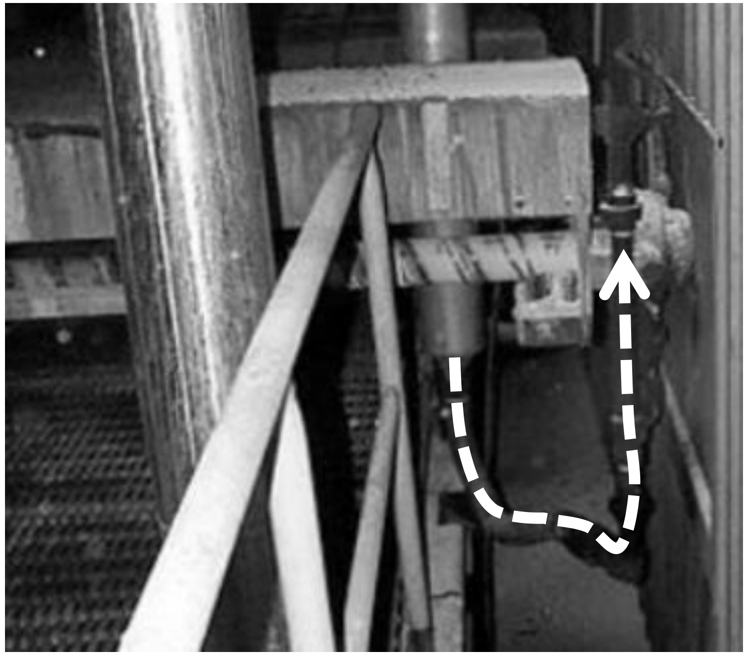
Scavenging Air



WRONG

CORRECT

- Make sure the hose does not form a U shape bend
- The U shape bend may trap condensate, preventing the air to flow and protect the sootblower from corrosive gas

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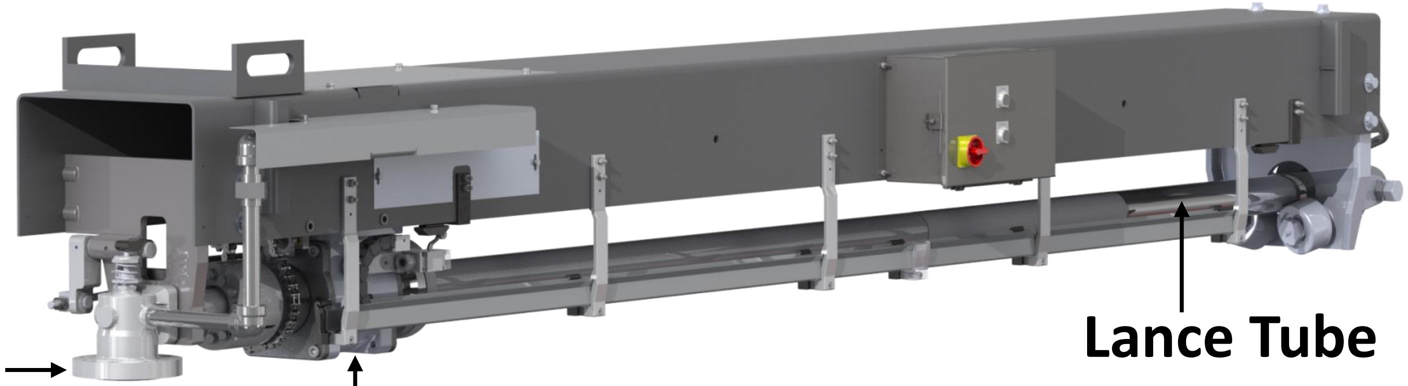
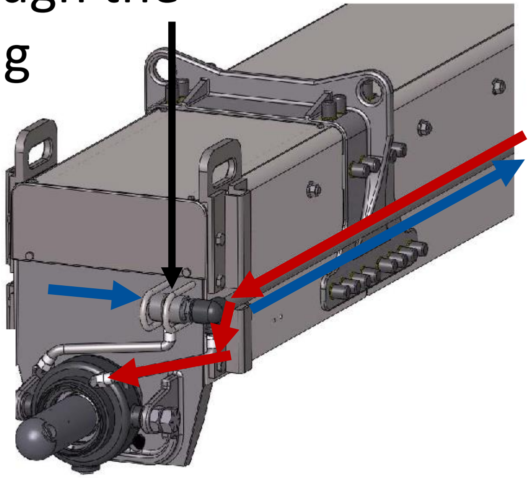


Sootblower-Induced-Tube Erosion (1 of 2)

- **Most common causes**
  - Poor quality of steam source
  - Lack of proper slope in the steam piping
  - Leaking poppet valve & broken check valve

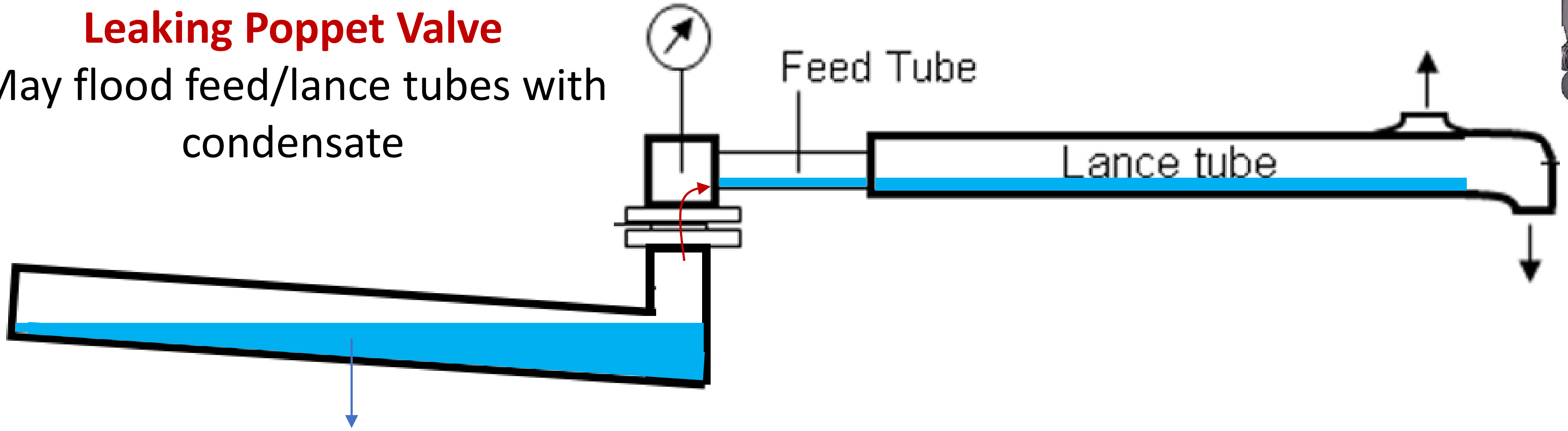
Broken Check Valve

May flood the neighboring SBs with condensate through the supply air piping



Leaking Poppet Valve

May flood feed/lance tubes with condensate



Condensate accumulated from poor piping slope

Sootblower-Induced-Tube Erosion (2 of 2)

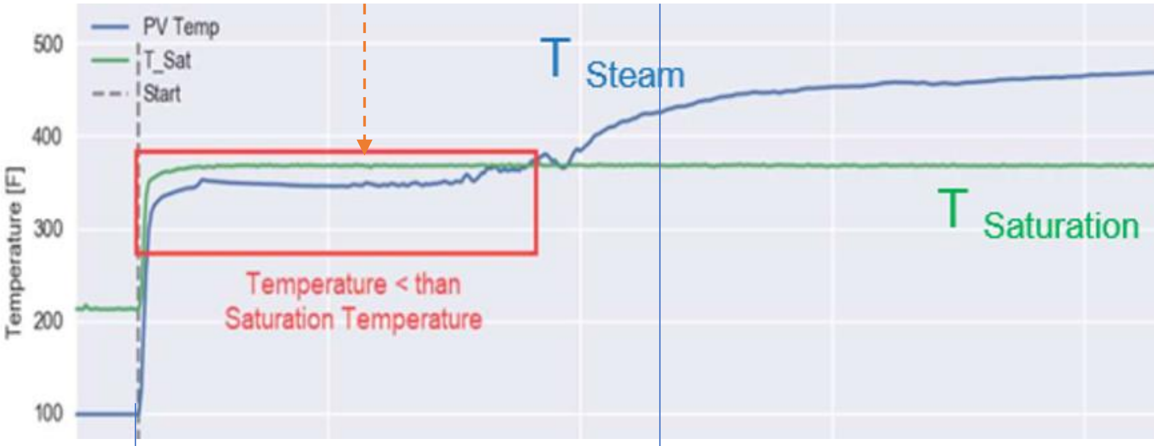
Detection

- Superheat steam degradation at the source
- Sootblowing steam below saturation temp during operation
- Poppet valve, feed tube, or air supply piping are HOT when not in use
- Short service life of feed tube packing

Mitigation

- At least 70 ^{o}F (40 ^{o}C) superheat. Don't use sat steam
- Have a plan to detect & replace leaking poppet valve & broken check valve
- If fixing piping slope is too costly, then implement the plan to systematically purge the condensate from the piping.

Steam below saturation temp



SB Start

Retract

26

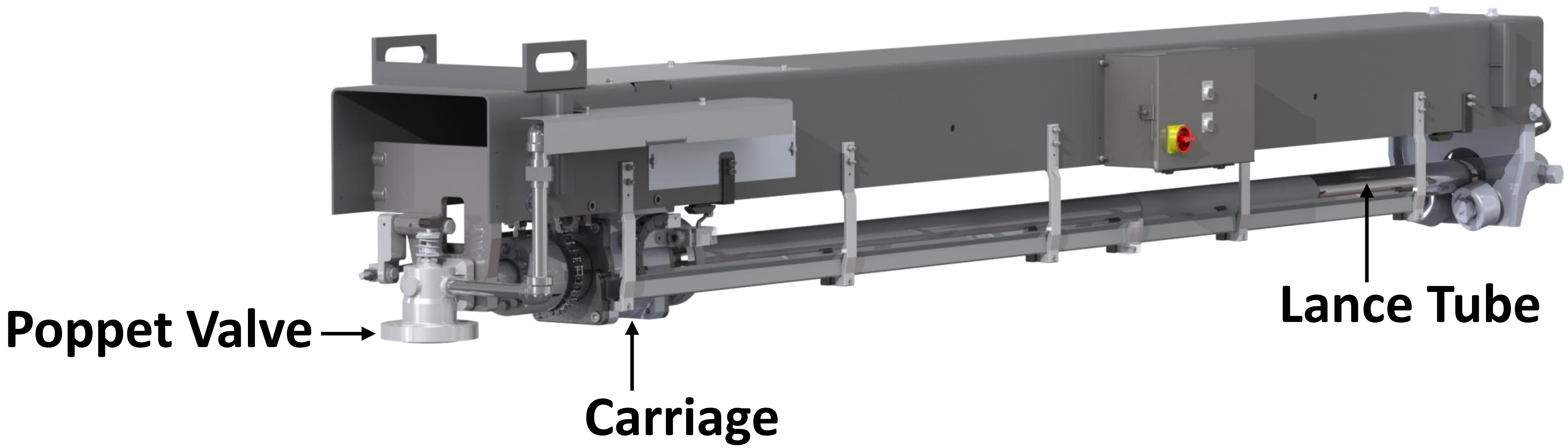
BLRBAC Report - Downtime due to sootblower (2001 – 2022)

No.	RB DOWNTIME due to Sootblower (BLRBAC Report 2001 - 2022)	Downtime (hr)	# of Incident
1	**CARRIAGE**: Failed To Retract (Stuck in the Boiler)	2706	4
2	**LANCE TUBE**: Failure / Propelled Into Boiler	1314	3
3	**STEAM QUALITY**: Erosion due to condensate	1074	14
4	**POPPET VALVE**: Leaking Valve	964	17
5	**CLEANING FREQUENCY**: Overcleaning	838	15
6	**POPPET VALVE**: Incorrect Pressure Setting	527	6
7	**LANCE TUBE**: Hitting Boiler Tubes	375	8
8	**CLEANING FREQUENCY:** Undercleaning / Clinker Formed & Fall	226	2
	Total	**8024**	**69**

Most Severe (rows 1–2)

Most Frequent (rows 3–5)

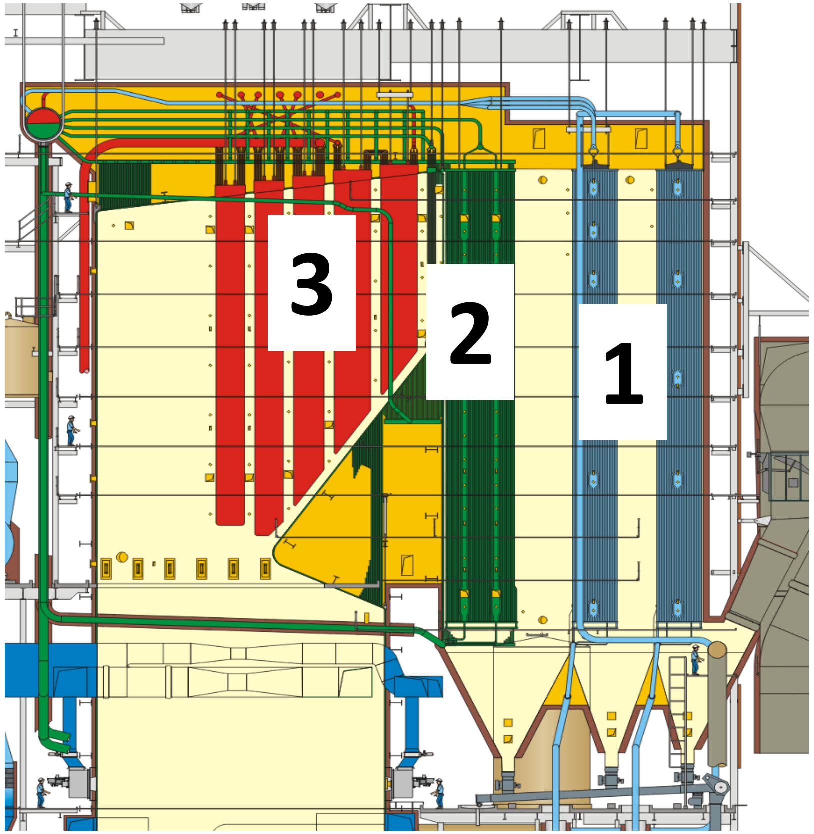
Less Severe (rows 6–8)



27

Over & Under Cleaning

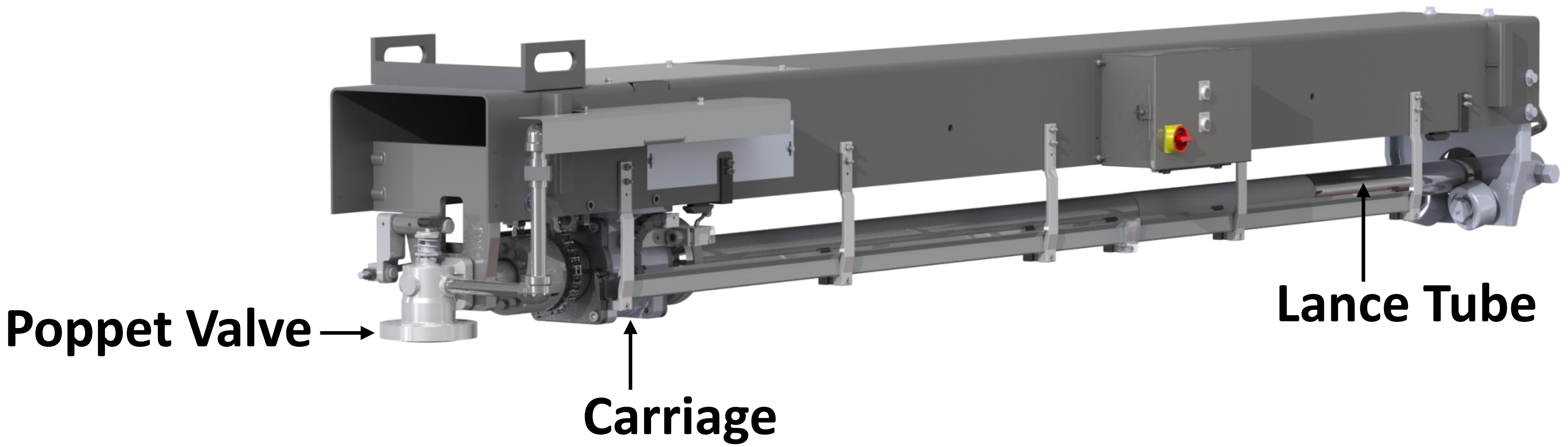
- **Most common causes**
  - Lack of understanding on the rate of deposit accumulation in the boiler areas
- **Detection**
  - Too low or too high of sootblower steam consumption (>15% or <1% of total boiler steam production)
- **Mitigation**
  - Gain insight into the rate of deposit accumulation in the boiler *(a fouling detection sensor such as strain gauge can give us this insight)*
  - Use 3-2-1 rule of thumb (if appropriate)
    - Superheater : Genbank : Econ = 3 : 2 : 1



28

BLRBAC Report - Downtime due to sootblower (2001 – 2022)

No.	RB DOWNTIME due to Sootblower (BLRBAC Report 2001 - 2022)	Downtime (hr)	# of Incident	
1	**CARRIAGE**: Failed To Retract (Stuck in the Boiler)	2706	4	Most Severe
2	**LANCE TUBE**: Failure / Propelled Into Boiler	1314	3	
3	**STEAM QUALITY**: Erosion due to condensate	1074	14	Most Frequent
4	**POPPET VALVE**: Leaking Valve	964	17	
5	**CLEANING FREQUENCY**: Overcleaning	838	15	
6	**POPPET VALVE**: Incorrect Pressure Setting	527	6	Less Severe
7	**LANCE TUBE**: Hitting Boiler Tubes	375	8	
8	**CLEANING FREQUENCY:** Undercleaning / Clinker Formed & Fall	226	2	
	Total	8024	69	



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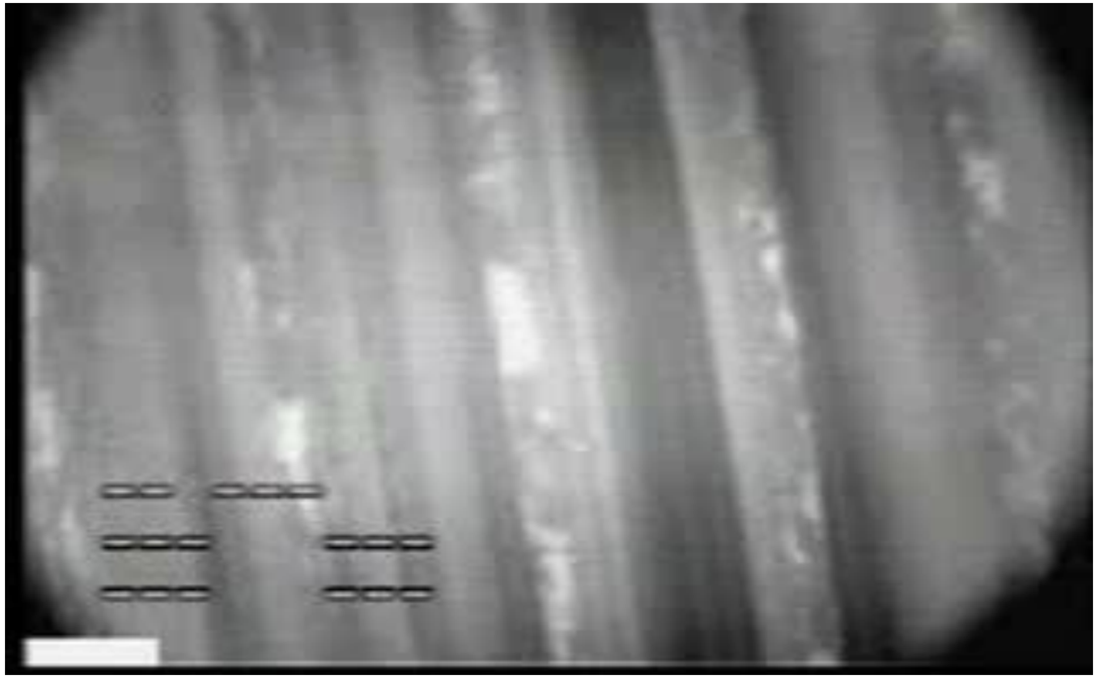
Incorrect Poppet Valve Pressure Setting

- **Most common causes**
  - Lack of understanding the appropriate set pressure for different areas of the boiler
  - Pressure setting is not being monitored or checked regularly.
- **Detection**
  - Excessive platen movement during sootblowing.
  - Excessive steam flow during operation (>30 KPPH or 13.6 tph or 3.8 kg/s)
- **Mitigation**
  - Understand the appropriate pressure setting for each sootblower.
  - Implement the plan to detect & correct poppet valve pressure setting.
  - If high efficiency nozzle is used, avoid setting the pressure to above 350 psig (24 bar g)



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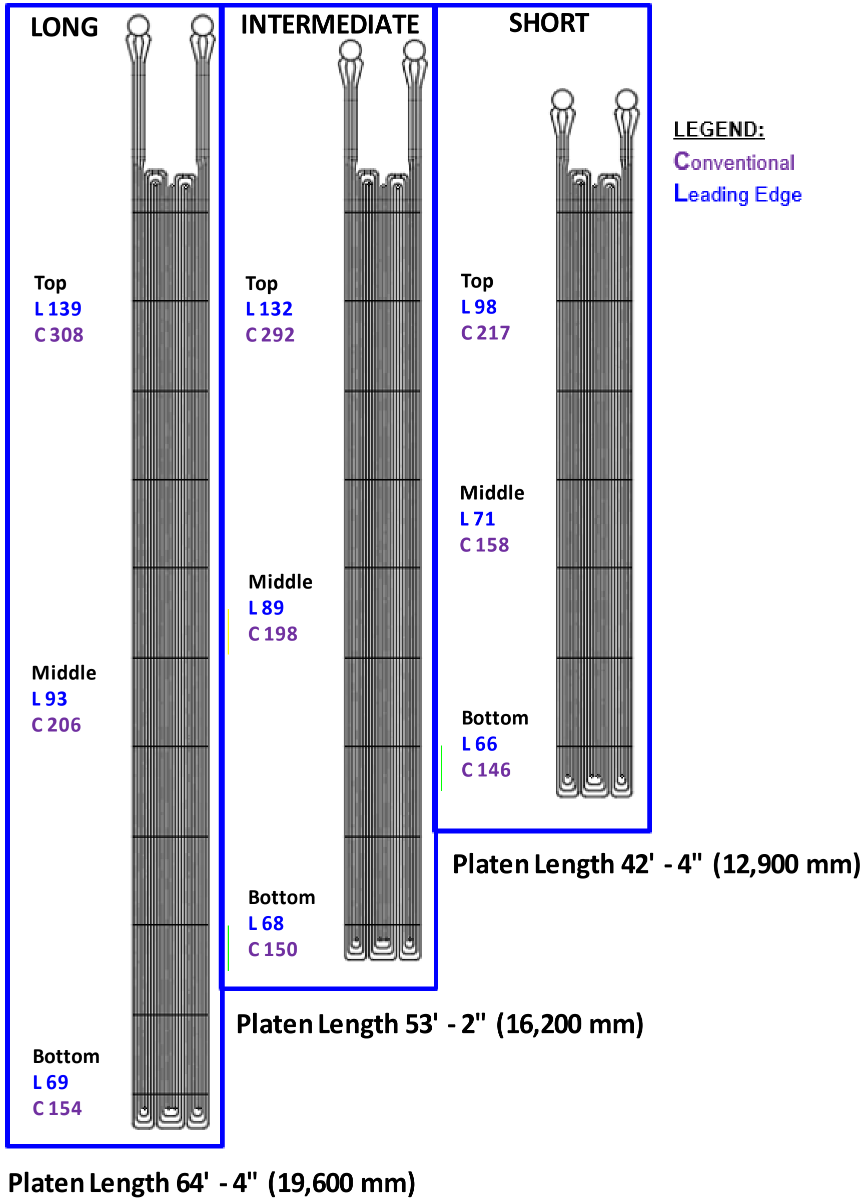
GUIDELINE



NOTE:
L 98 = The maximum P_{Nozzle} for leading edge nozzle is 98 psig
C 217 = The maximum P_{Nozzle} for conventional nozzle is 217 psig

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Pulp & Paper Centre

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	Total	**8024**	**69**

Most Severe (rows 1–2)

Most Frequent (rows 3–5)

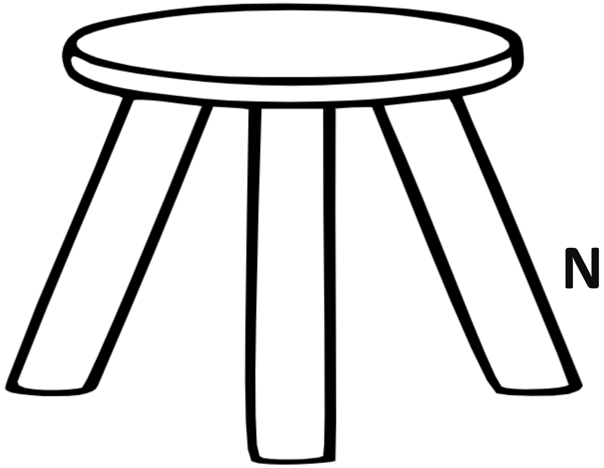
Less Severe (rows 6–8)

Lance hitting the boiler tubes

- **Most common causes**
  - Imbalanced nozzle
  - Bend lance tube

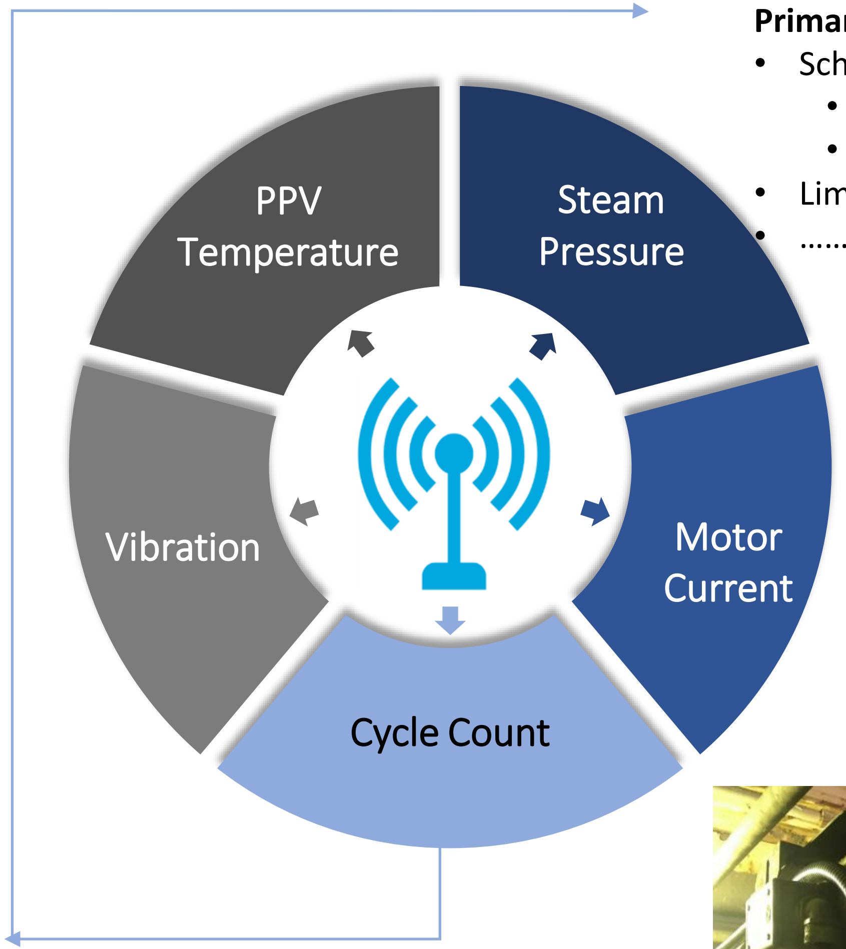
    overheating or impact from falling deposit
- **Detection**
  - Abnormal vibration of sootblower housing and noise during operation
- **Mitigation**
  - Replace (don’t repair) the nozzles, especially if the mill does not have the proper tools to repair.
  - Implement the plan to detect abnormal vibration of the sootblower

RBI – Three-Legged Stool



1. Cycle count & time
2. Motor Current
3. Steam Pressure
4. Steam Temperature
5. Vibration

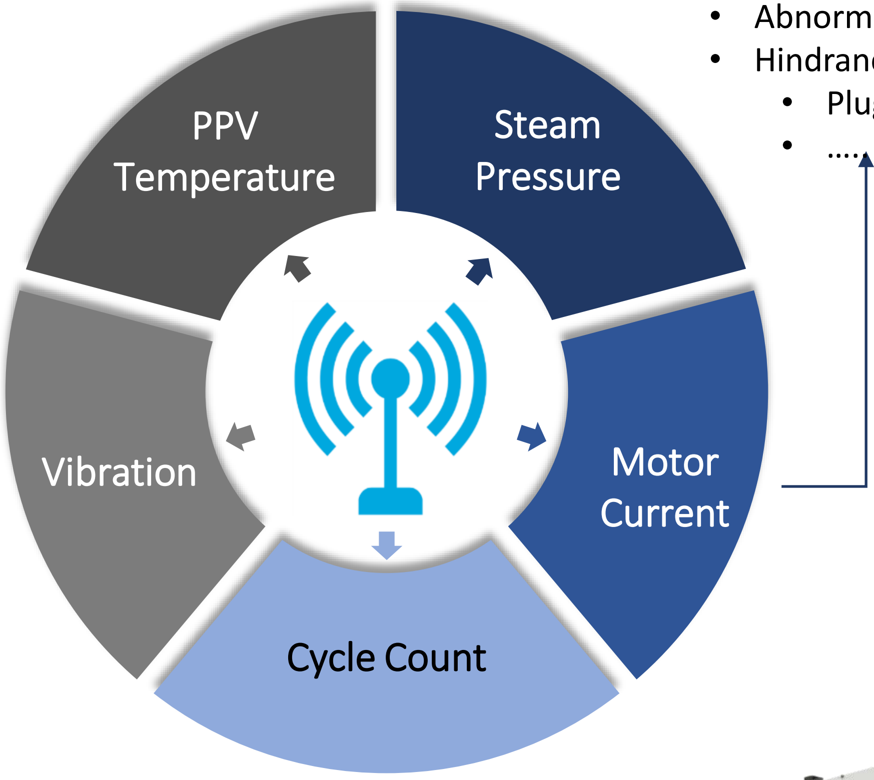
CI Sensors



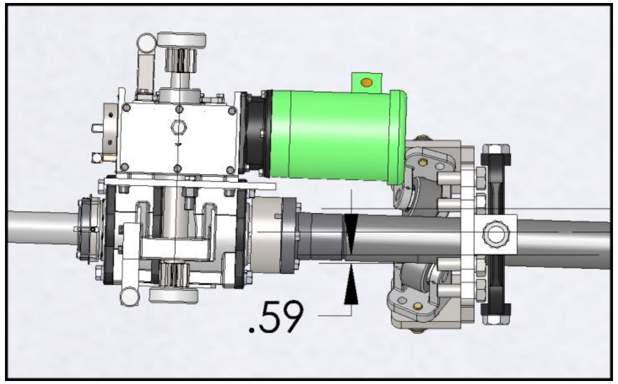
Primary Detection

- Scheduled basic maintenance
  - Lubrication
  - Feed tube rotation
- Limit switch malfunction
- ……

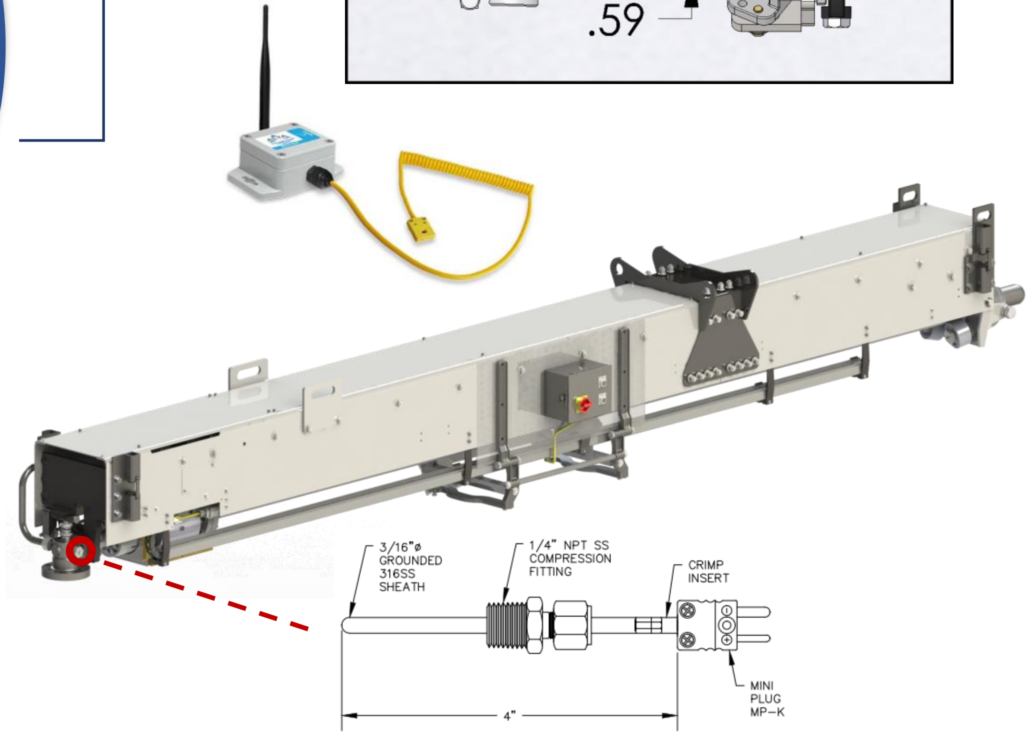
CI Sensors



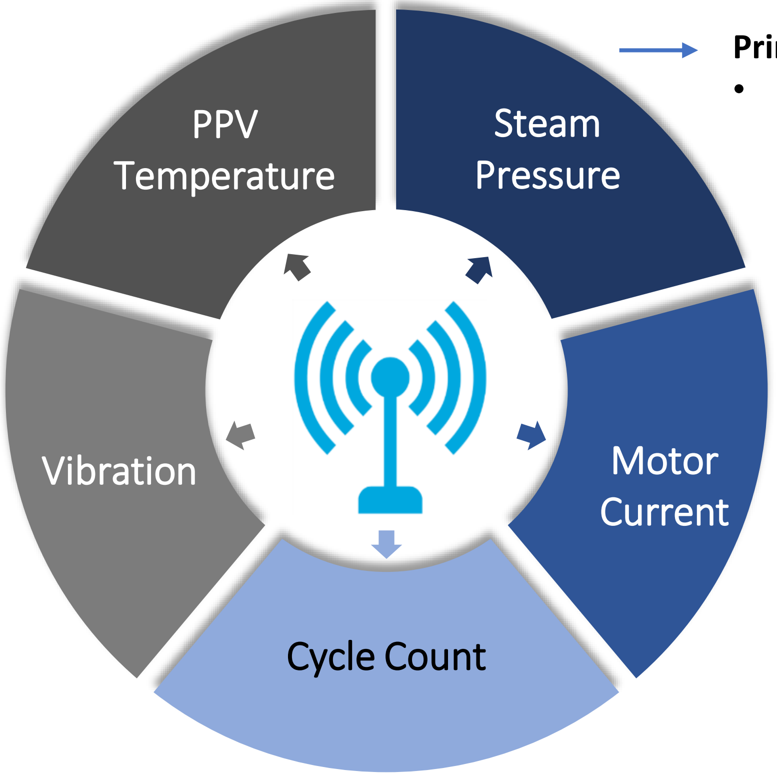
Primary Detection
- Abnormal Stress
- Hindrance
  - Plugged wallbox
  - ….



- Normal Loading is Max 83MPa (12ksi)
- Misalignment 15 mm, the stress went up to **634 Mpa** (**92 ksi) stress** near flange weld

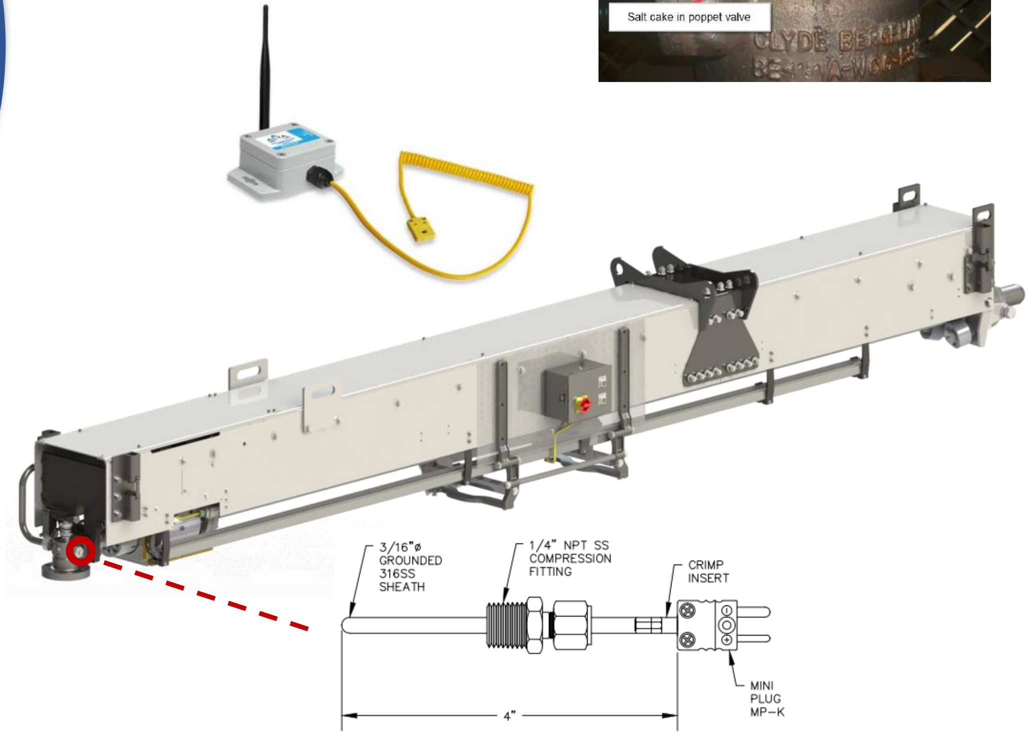


CI Sensors



Primary Detection

- Steam flow anomaly
  - Insufficient cooling / cleaning
  - Nozzle tip blown off
  - Poppet valve plugging
  - …



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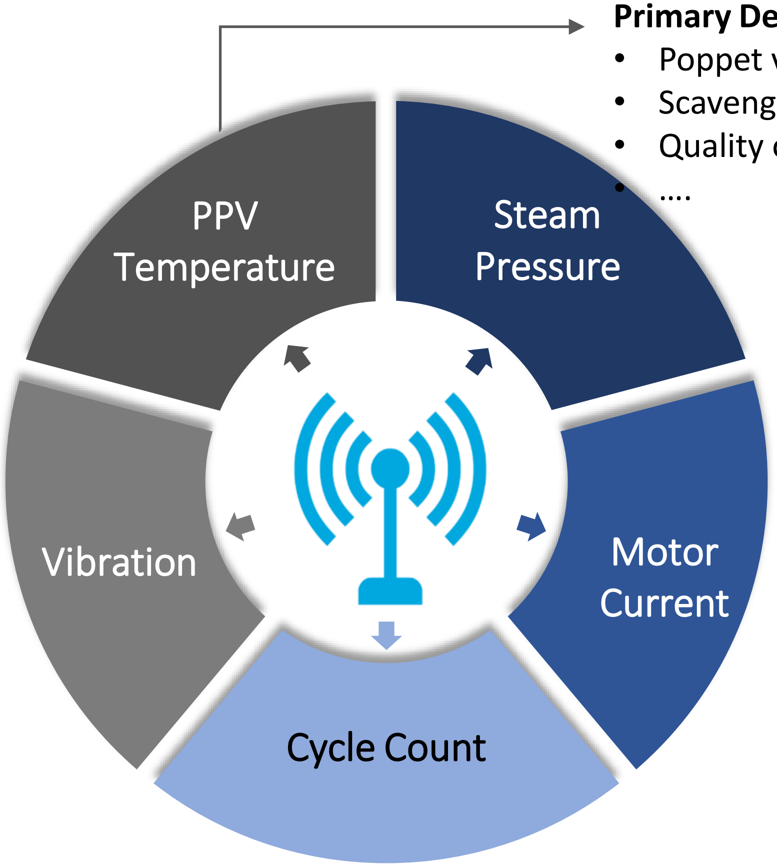
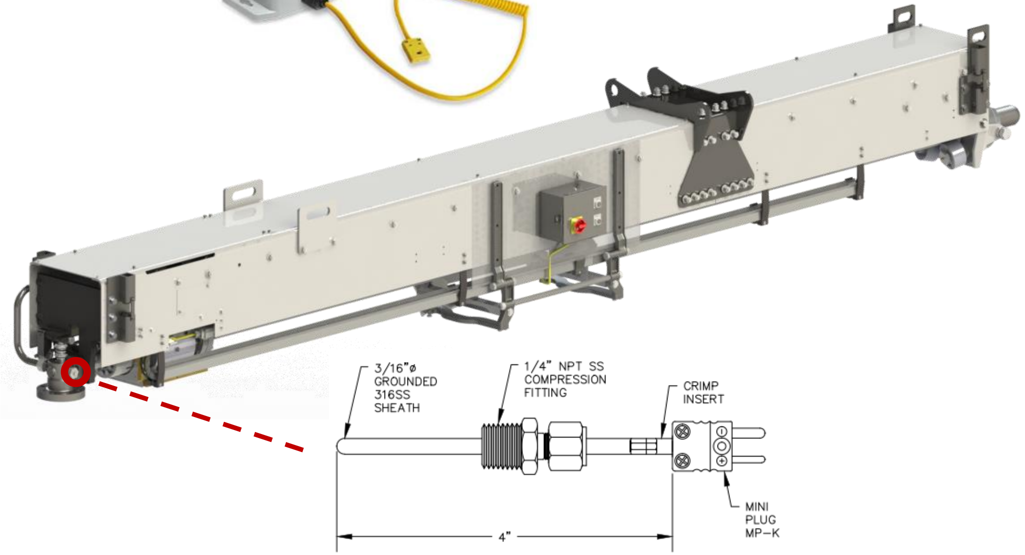


Primary Detection
- Poppet valve leak
- Scavenging air malfunction
- Quality of steam
- ….



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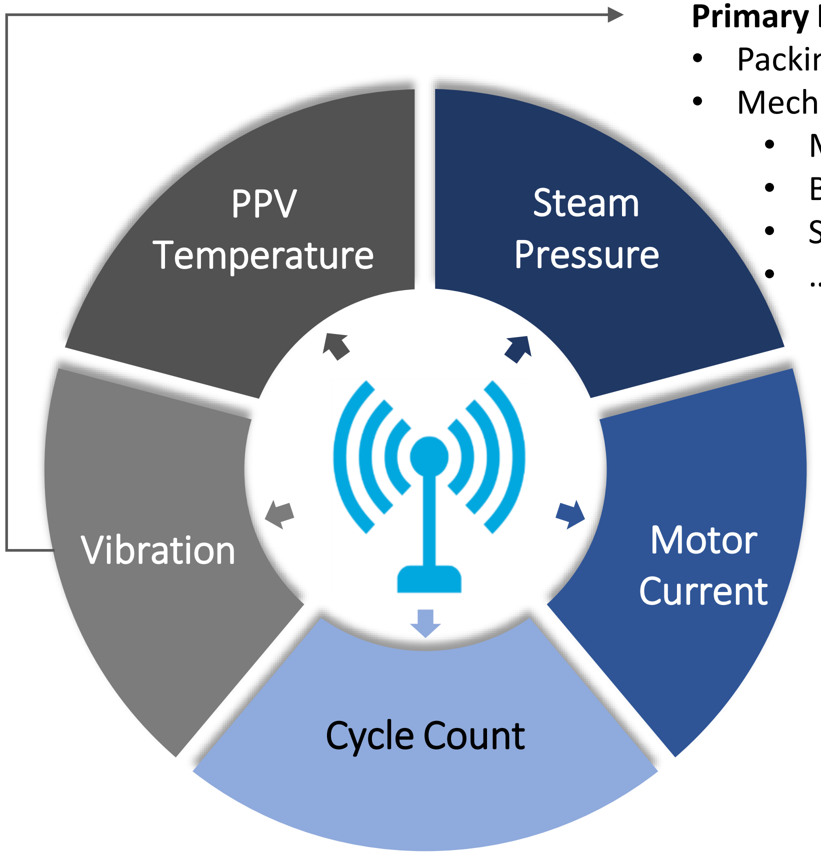
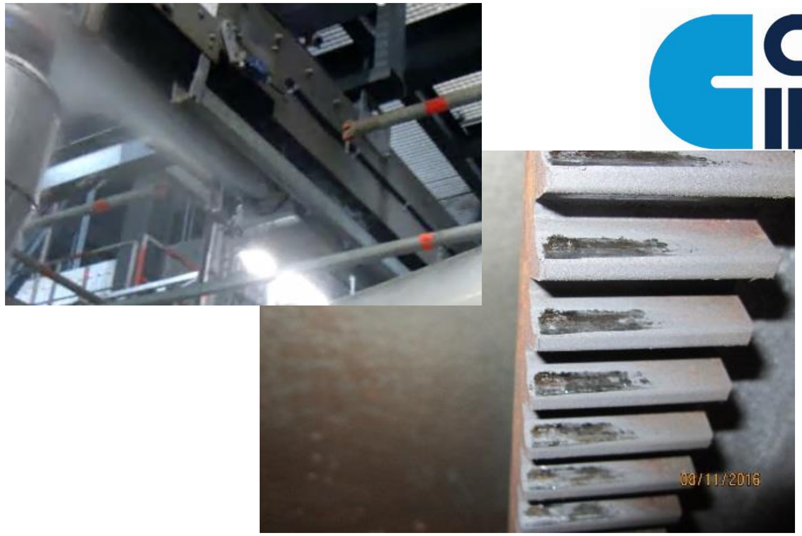
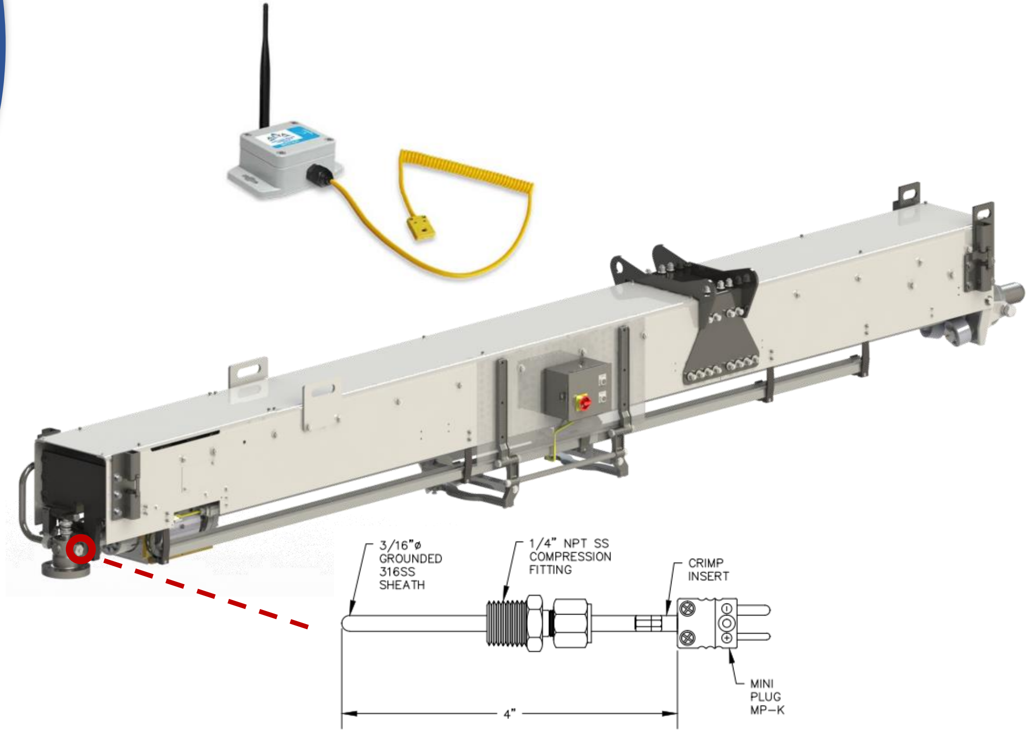


Primary Detection

- Packing leak
- Mechanical issues
  - Misalignment
  - Bent lance tube
  - Scored feed tubes
  - …..





Three Key Takeaways

1. The key success factor to maintain a large quantity of sootblowers under limited maintenance resources is ***to know your risk and maintenance priority***!

2. Consider implementing ***Risk & Condition Based Maintenance*** to reduce operating costs, downtime, and failure

3. Learn ***what to look*** during regular boiler walkdown to deal with sootblower issues early and prevent safety issue and costly repairs

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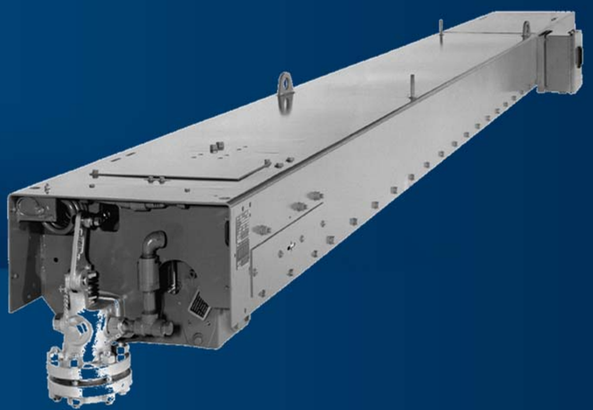
AF&PA Recovery Boiler Program

Proper Sootblower System Design, Maintenance, & Operation



Prepared by Simon Youssef & Paul Heim

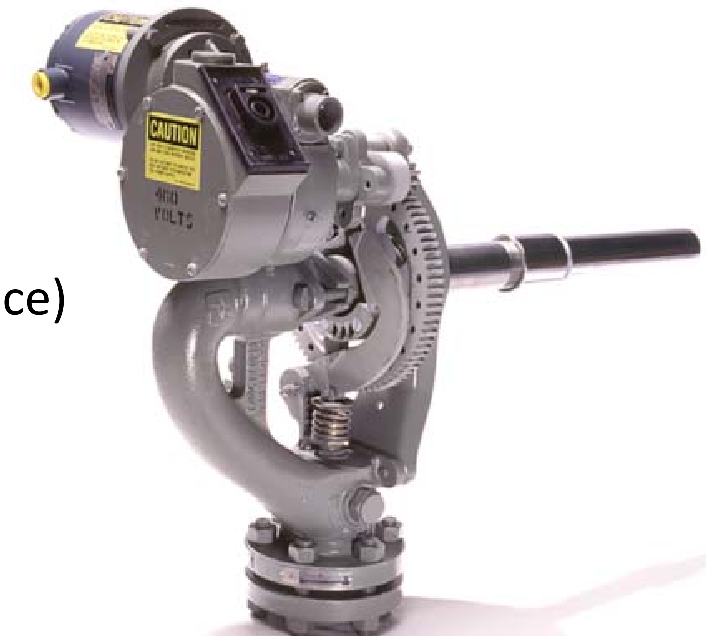
B&W Pulp & Paper Product Support

Agenda

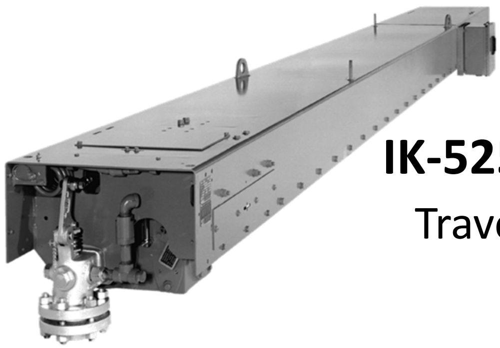
- Types of Boiler Cleaning Equipment
- IK Sootblower Components
- Poppet Valve Types & Maintenance
- Nozzle Development History
- Peak Impact Pressure Measurement
- Indexing Sootblowers
- Proper Lance Manufacturing & Maintenance
- Feed Tubes & Packing
- IK Carriages & Front Rollers Alignment
- IK Control & Power Supply Assemblies
- Sootblower Condensate Issues & Mitigation Methods

G9B Rotary Sootblower

- Options
  - EMD
  - AMD
  - MANUAL
  - Lane Blowing (18” - 24” cavity clearance)
  - Mass Blowing (4” cavity clearance)
  - Steam or Air
  - Element Materials:
    - Carbon Steel
    - 310 SST
    - Dialoy
    - RA330



Diamond Power® Retractable Sootblower Evolution



IK-525/R (1968)
Travel ≤ 32’-6”

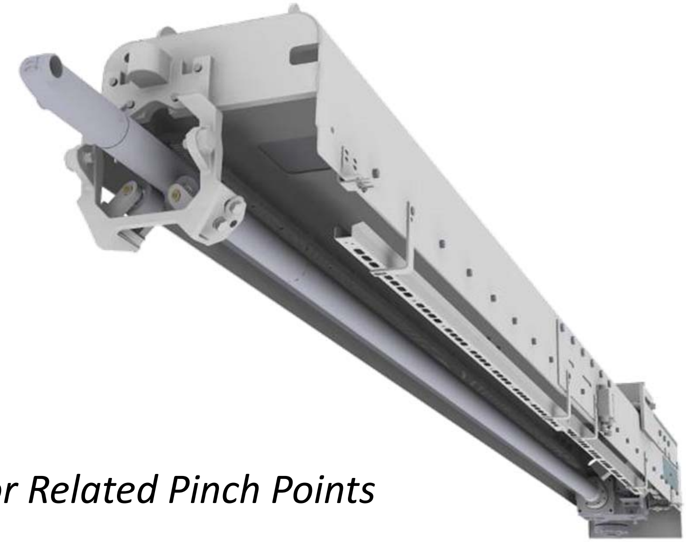
IK-SD (1983)
Travel ≤ 32’-6”

IK-600 (1993)
Travel ≤ 22’-0”

IK-600MX (2001)
Travel ≤ 32’-6”

IK-700/R (2007)
Travel ≤ 45’-6”

IK-700 Design Criteria & Benefits



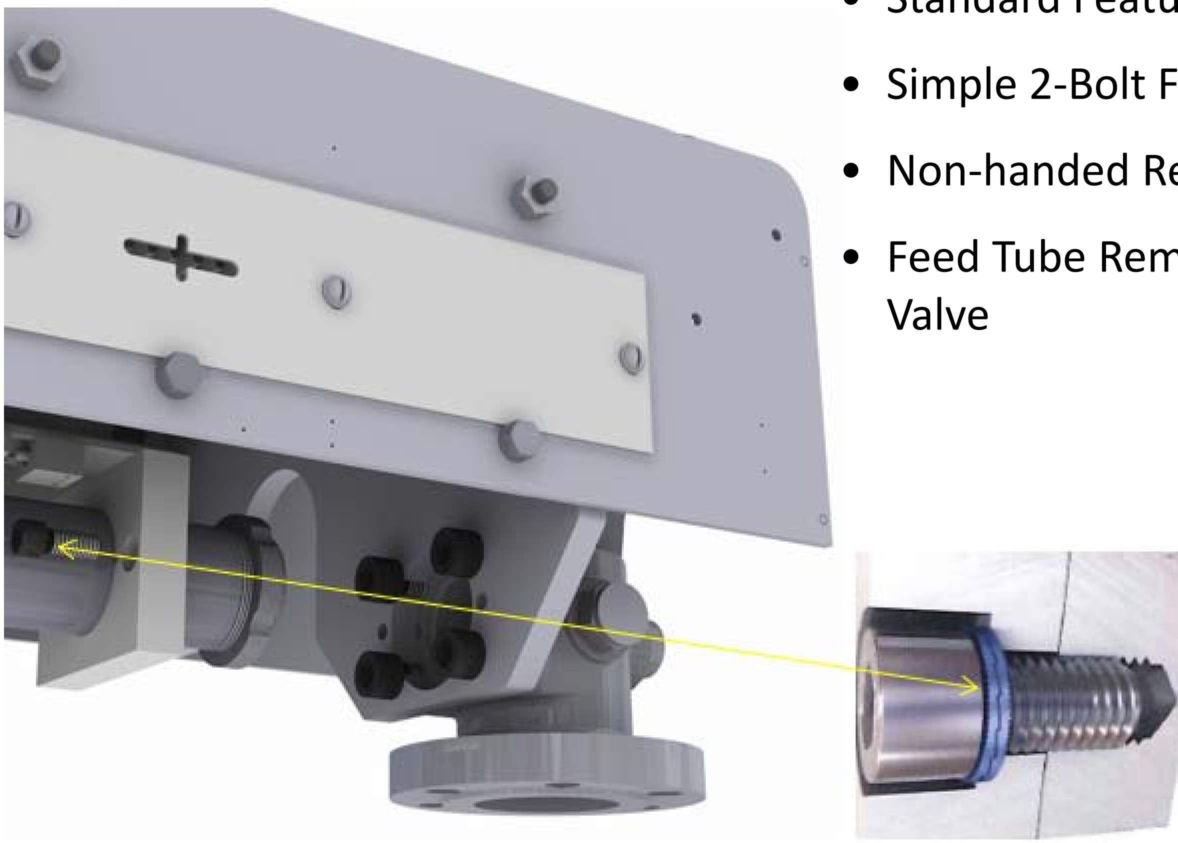
- Best Cleaning Technology
- Reliable Low Maintenance Design
- Minimal Lubrication Points
- Safety Standards
  - *No External Moving Parts, Chains or Related Pinch Points*
- Parts Migration Path and Interchangeability from IK-500/600 Models
- Proven to Have the Industry's Best ROI and Longest Service Life

Optional Top Access Panel

IK-700® Top Access Panel

- Top Carriage Removal
- Full Access without Sacrificing Stability

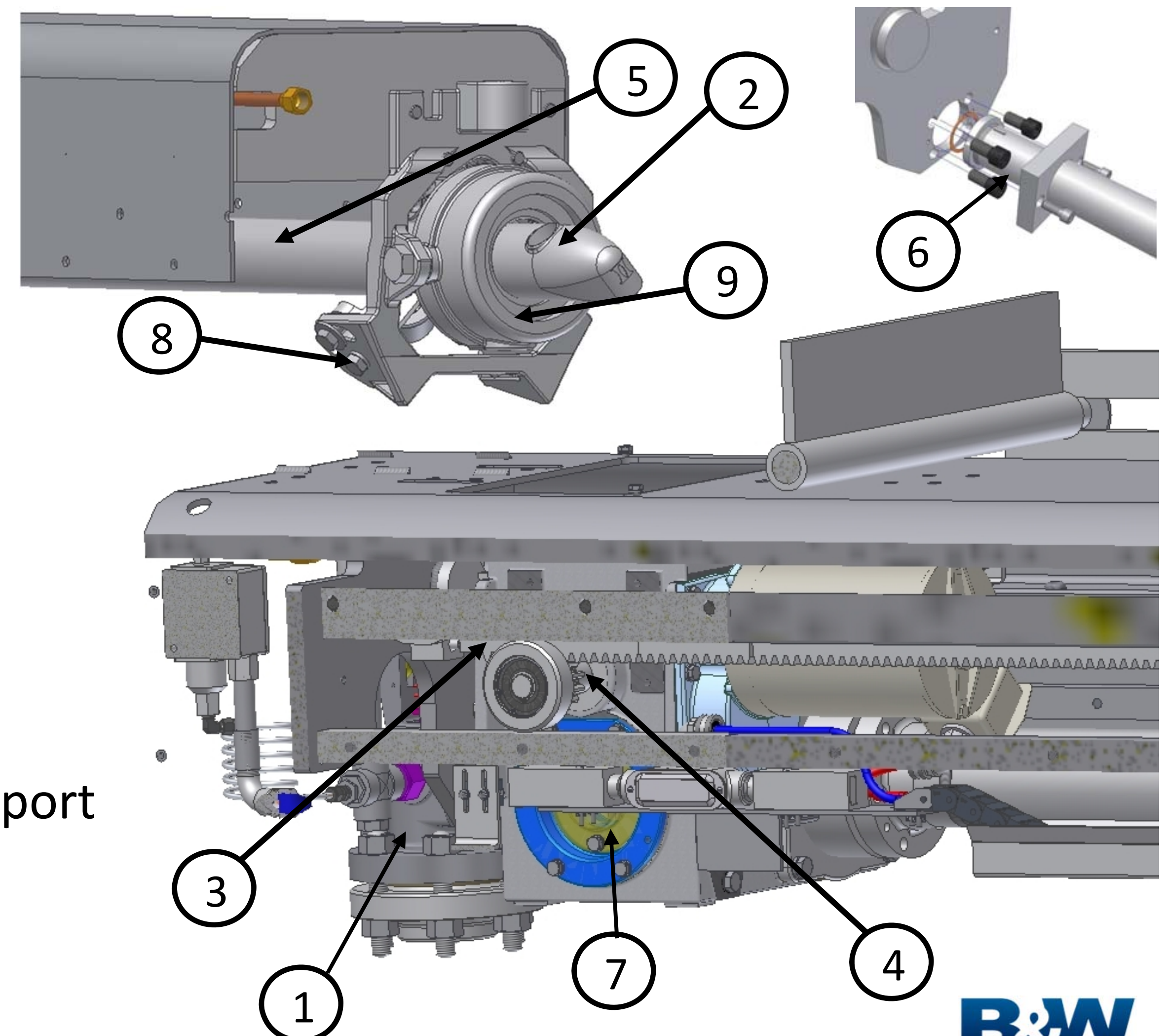
Solid Mount Poppet Valve



- Completely Redesigned Mounting Mechanism
- Standard Feature on All IK-700® Models
- Simple 2-Bolt Feed tube retainer
- Non-handed Rear Bulkhead
- Feed Tube Removal Without Removing Poppet Valve

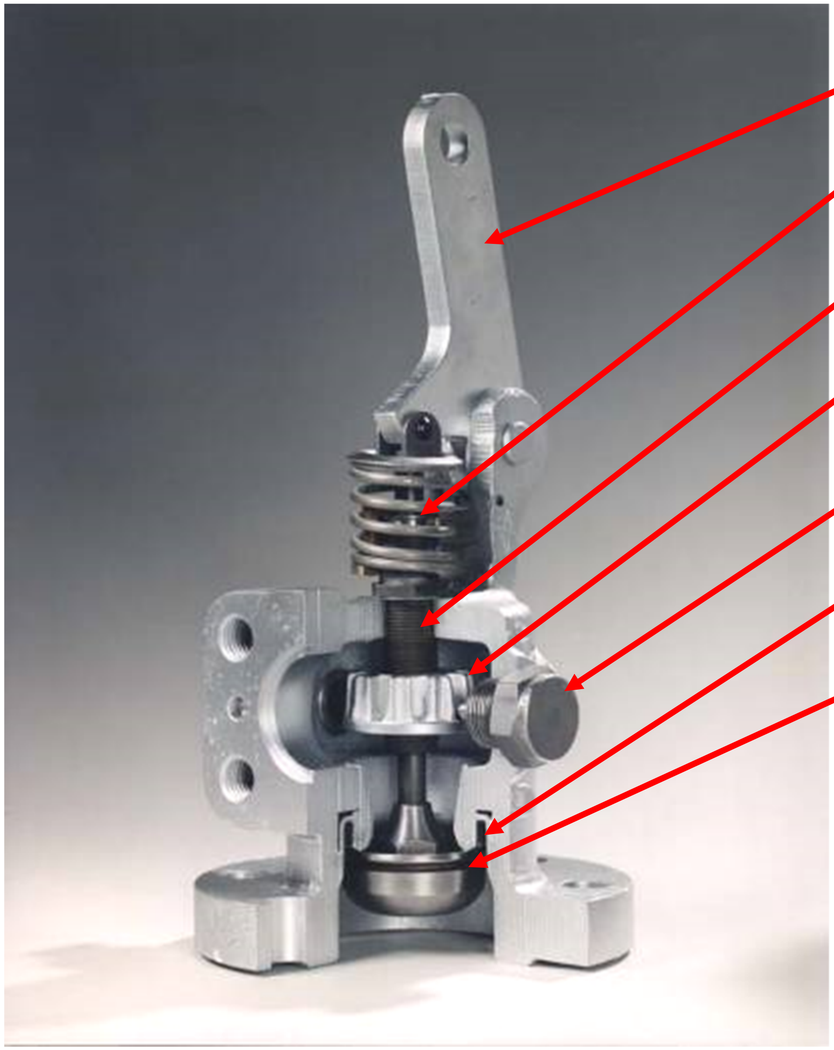
IK Sootblower Components

- 1 - Poppet Valve
- 2 - Nozzle
- 3 - Indexing PHM
- 4 - Rack & Pinion
- 5 - Lance Tube
- 6 - Feed Tube
- 7 - Carriage
- 8 - Front Roller Support
- 9 - Wall Box



Poppet Valve Components

Internally Adjustable Poppet Valve



Trigger

Valve Stem, Spring, Packing

Valve Stem Guide

Pressure Control Disc

Lock Pin Plug

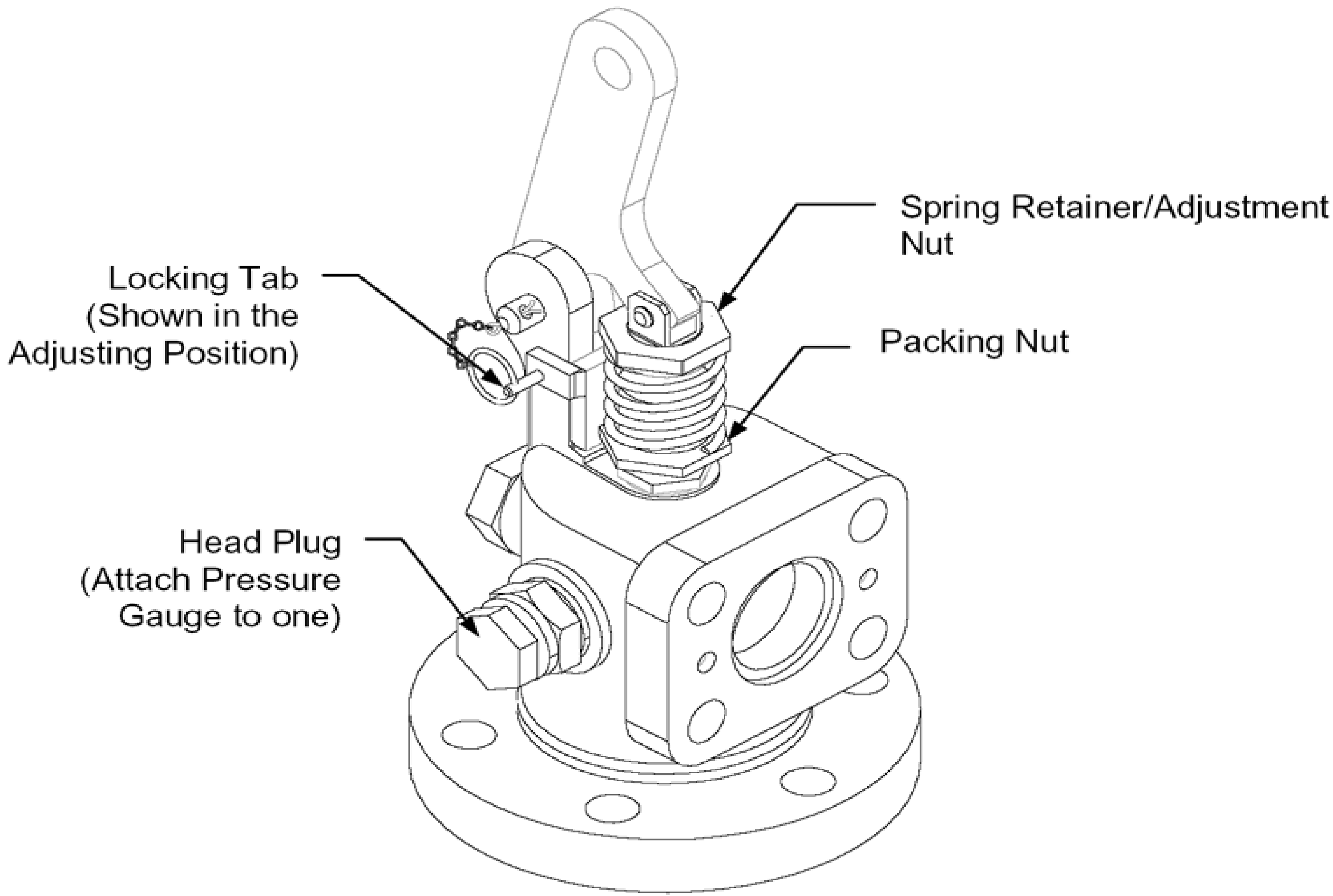
Stellite Hard-Faced Valve Seat

Floating Valve Disc

- Hydrostatically Tested to 1.5X rated pressure

Poppet Valve Components

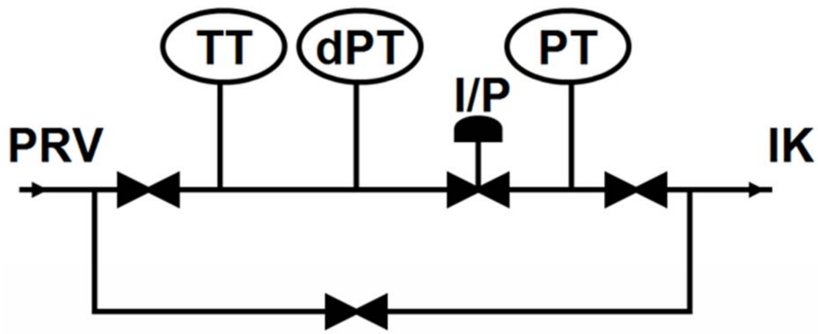
Externally Adjustable Poppet Valve (EAPC)

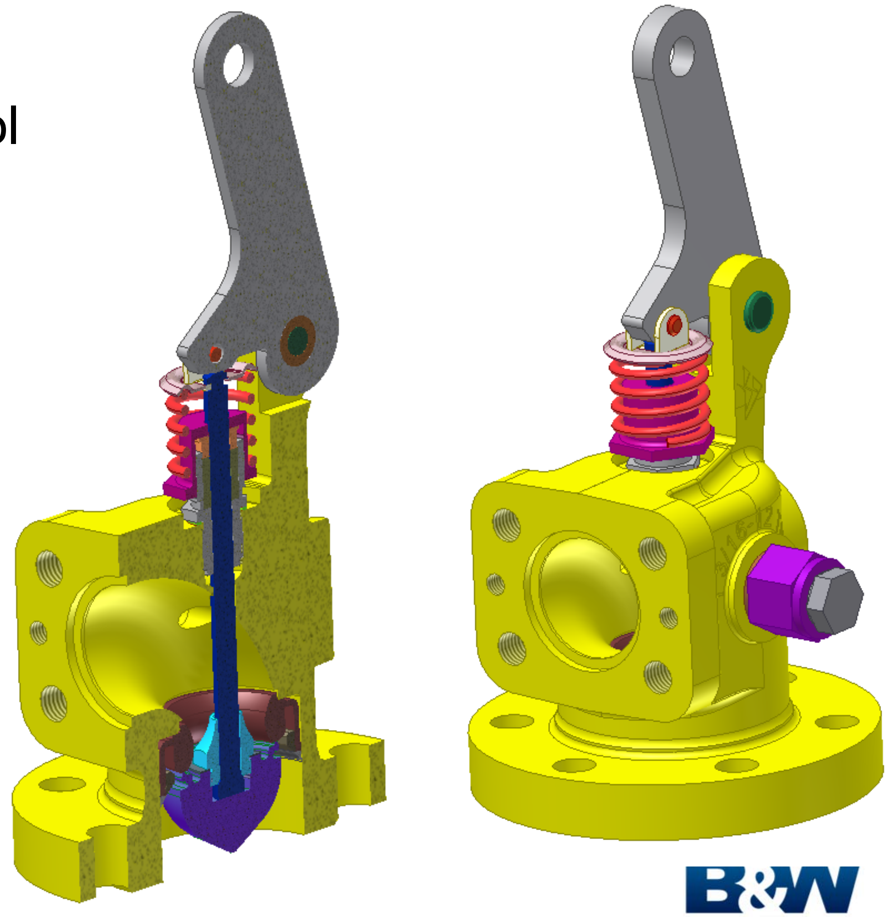


M600 – Low Loss Poppet Valve

Non- Adjustable Poppet Valve

- Smooth Transition path for Cleaning Media
- No Pressure Control Disc
- Drop in Replacement
- Used with Variable Flow Control Header



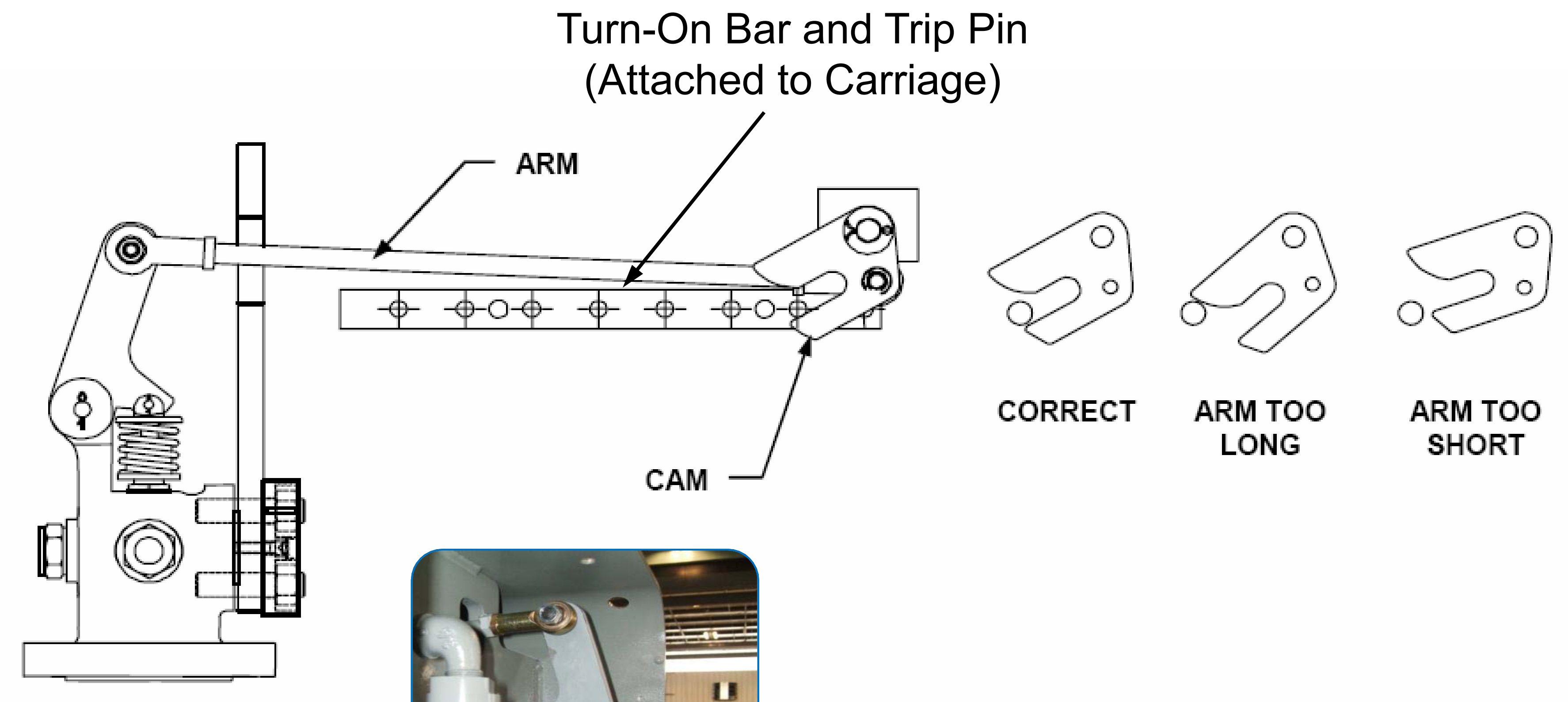


Poppet Valve Inspection

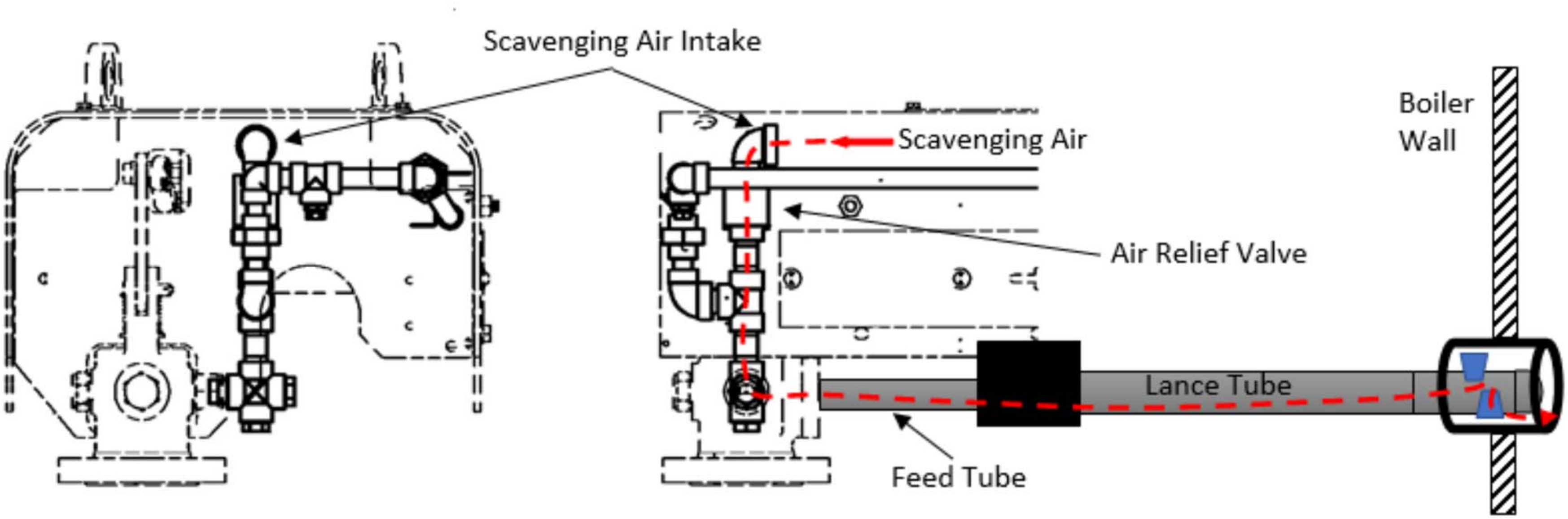
Inspect every 3 to 6 months

1. Is flange gasket leaking?
2. Can you hear a valve leak? Is the lance tube or feed tube hot? Use Infrared Temp Gun to check?
3. Observe while operating
4. Check for leaks at stem and feed tube
5. Does lever move freely?
6. Is valve stem sticking?
7. Tighten or change stem packing as needed0

Steam Turn-On Assembly
Poppet Valve Linkage

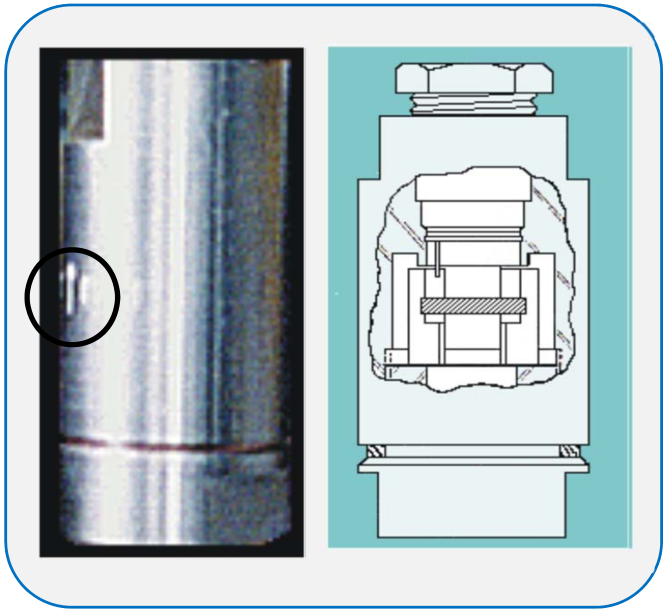


Scavenging Air – Air Relief Valve

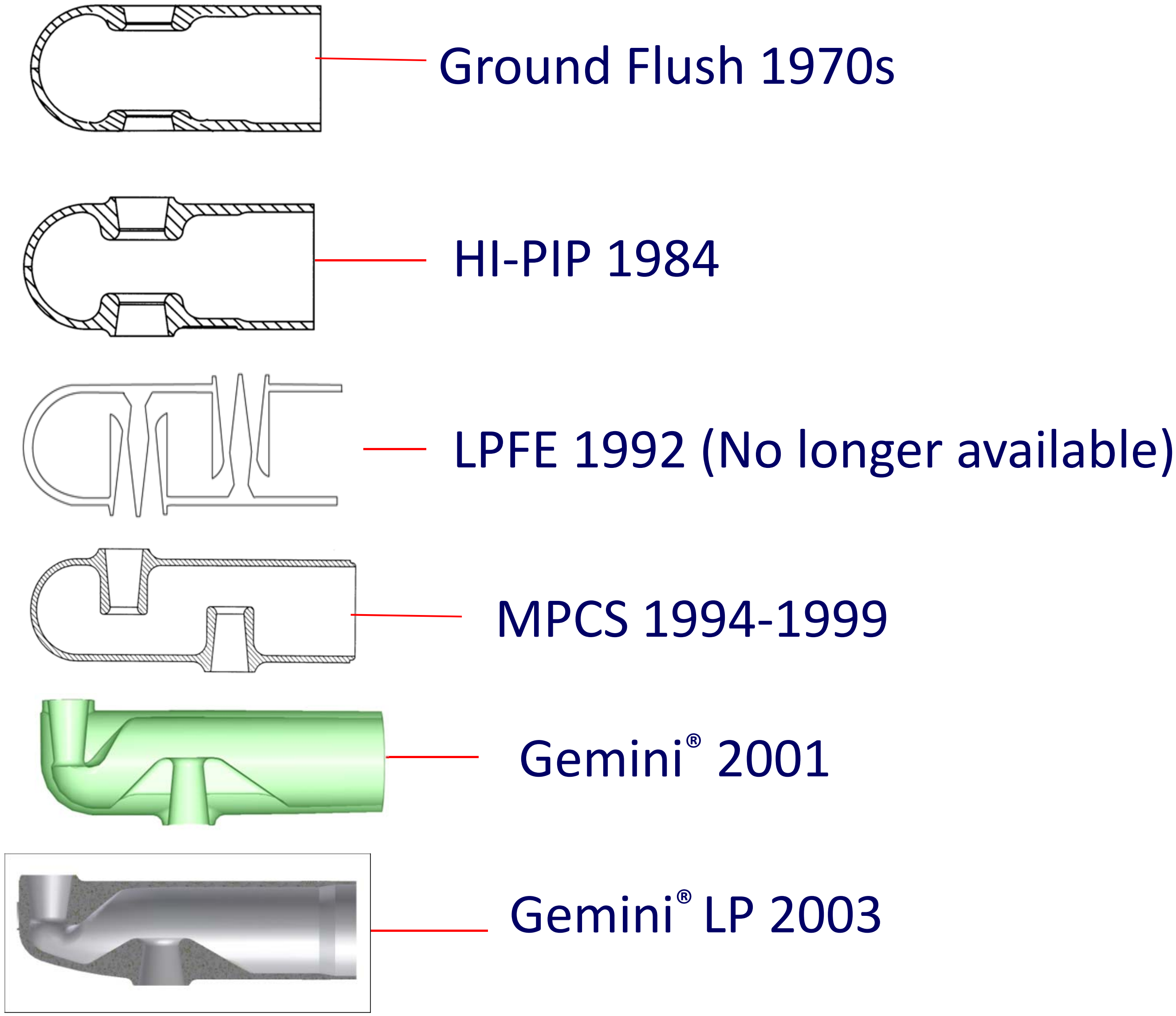


Air Relief Valve Maintenance

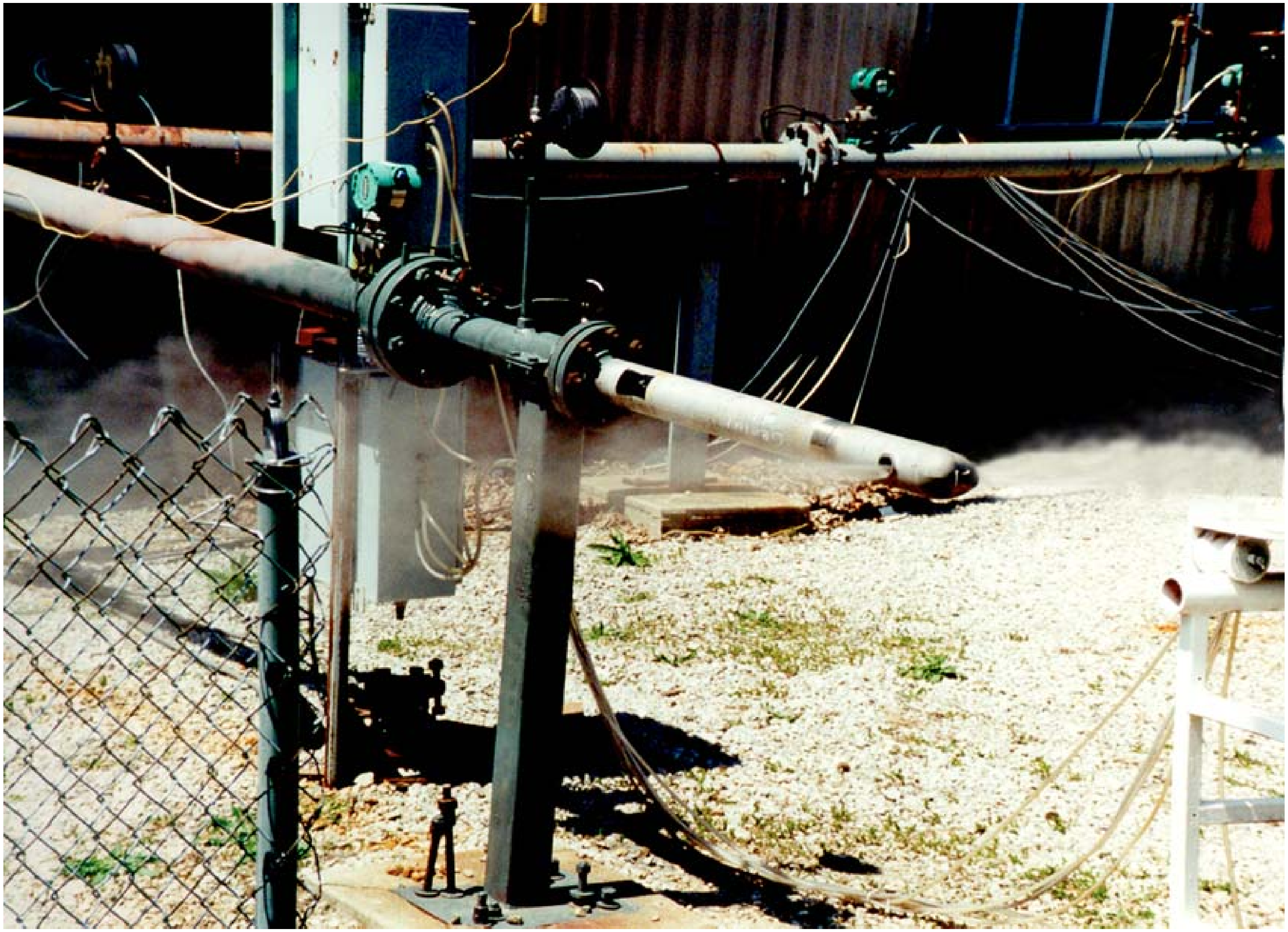
1. Inspect every 3 to 6 months. Does it pull a draft?
2. Replace if steam blows out when sootblower operates (or if someone has plugged it!)
3. Reinstall with arrow, pointing up.
4. Must be installed vertically.
5. <u>Install with street elbow facing boiler to prevent hazard if valve fails!</u>



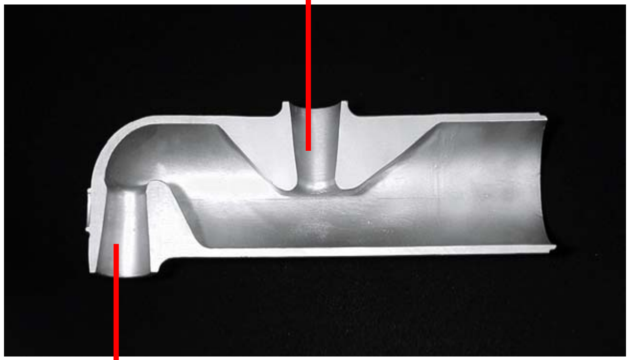
Nozzle Development History



Nozzle Test Facility

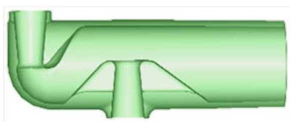
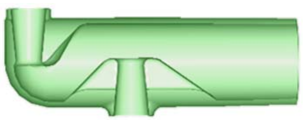
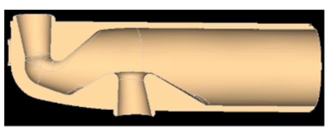


Gemini® Nozzle



- Patented, Investment Cast Design
- Greater Cleaning Effectiveness
- Innovative Internal Flow Path to Two High-Performance Nozzle Jets
- Provides Equal Cleaning Distribution to Reduce Potential for Sootblower-Induced Boiler Tube Erosion

Gemini® Types & Features

	Lance Size	Jet Size	Jet Orientation	Features
	3-1/2	7/8	90°- 90°	Mostly used for steam cleaning to minimize steam consumption.
	3-1/2	1	90°- 90°	High cleaning efficiency with economical steam consumption. More effective in lane cleaning.
	3-1/2	1-1/4	90°- 90°	High cleaning efficiency with high steam flow. Suited for SH zones where high steam flow is required along with improved cleaning potential. Better cleaning depth.
	3-1/2	1	°85 - 95°	High cleaning efficiency with ability to reach within platens and pendants.

- **Reliability by Design:**
  - **309 or 330 Stainless Steel Composition withstands harsh environments.**
  - **Cast Body resistant to fatigue failure and cracking.**

Typical Blowing Pressure Settings

Recovery Boiler:
Based on 1” Gemini GF Nozzle, 2-3/4” FT NI, 600 # Poppet Valve

	Typical, Blowing Pressure (psig)	Recommended Limit (psig)
Super Heater	250	300
Boiler Bank	230	270
Economizer	200	230

Note:

- Sootblower OEM will provide a data chart on the sootblower location drawing that includes the blower tagging, blower type, nozzle jet size & quantity and recommended poppet valve head pressure.
- Bank penetration - up to 6 feet depending upon blowing pressure, tube spacing, nozzle type, gas stream temperature, and flow.

Nozzle Damage

Overheating Caused By One Or More of The Following

- **Inadequate Cooling Flow**
- **Pressure At Poppet Valve Set Too Low**
- **System PRV Not Controlling Pressure**

Nozzle Damage

Thermal Fatigue Cracking Caused By

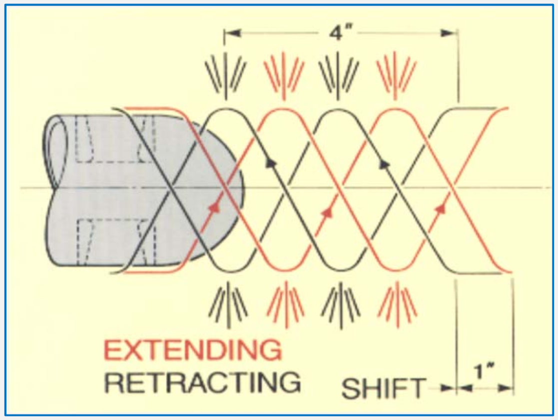
- **Lance not fully retracted and/or improper lance tube length**
- **Continuous wetting of hot surface of nozzle by condensate at a considerably lower temperature**

Note: Sootblower nozzle tip should be at least 1.5" behind the centerline of the boiler tube opening

Internal Carriage Indexing

90 degree backlash built in to hub gear:

- To verify the lance hub is indexing:
  - Start IK and watch when it reverses
  - There should be a small lag between when the carriage moves in reverse and when the lance rotation reverses



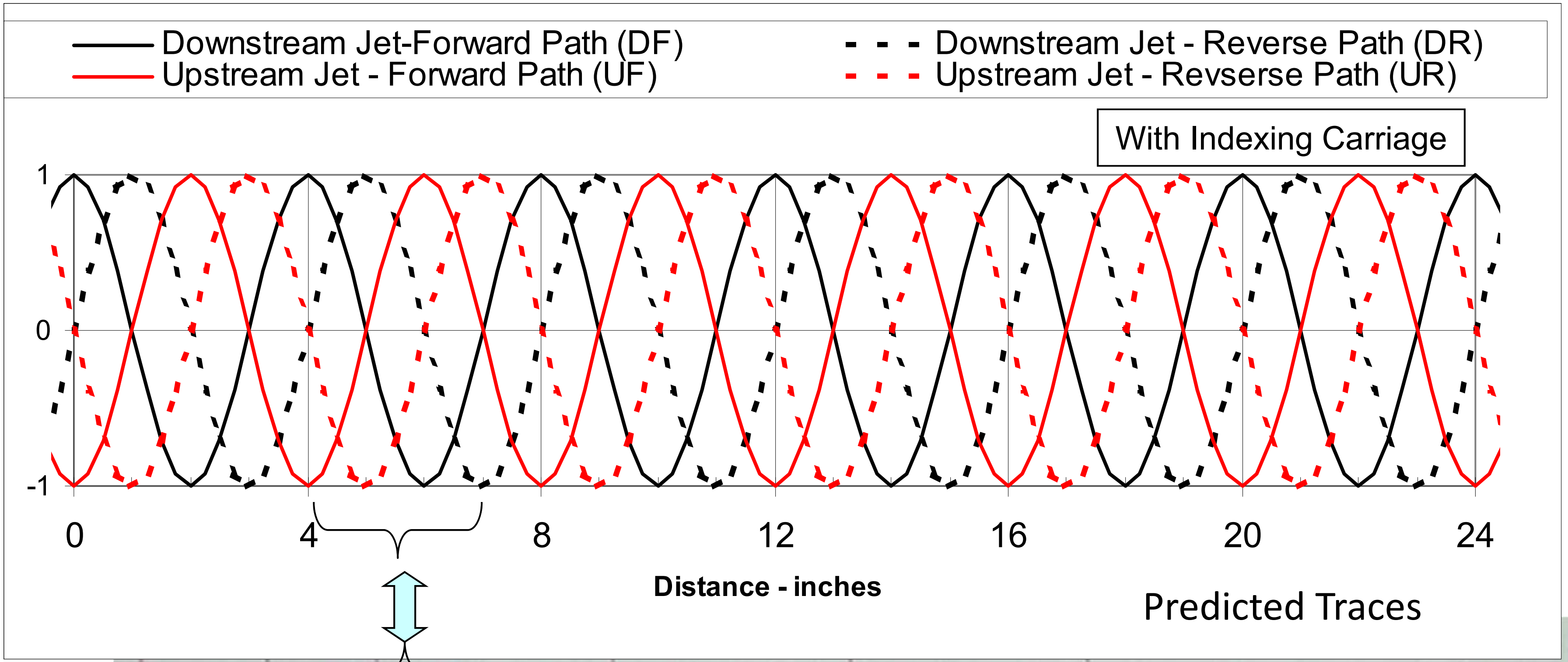
Internal Carriage Indexing

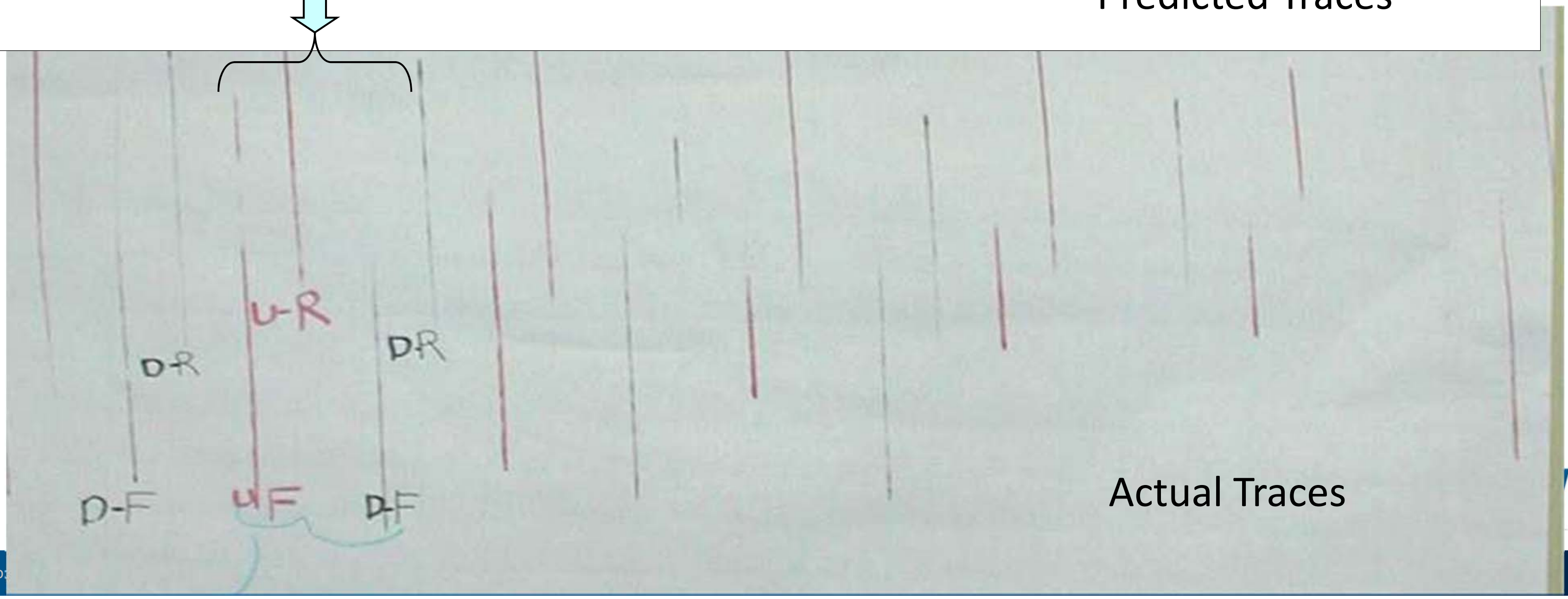
- The only no load lance nozzle indexing in the industry.
- Lance rotation pauses momentarily at reversal point reducing motor and gear box load

Blower W/Internal Carriage Indexing

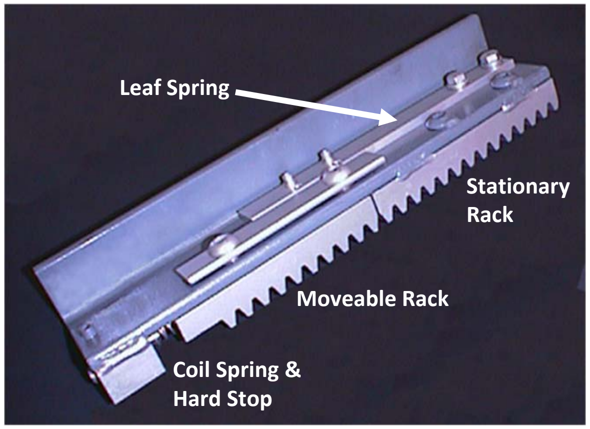
90° Notch for Indexing bevel gear

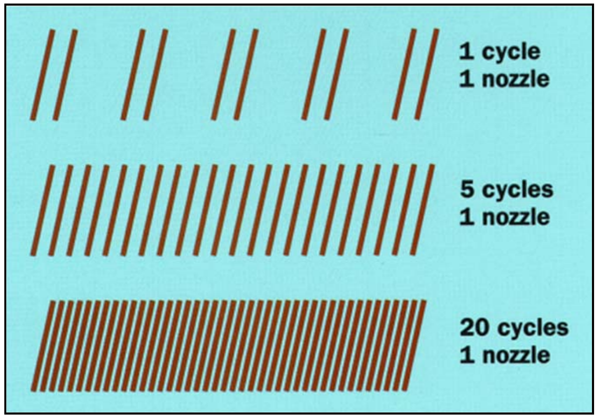
Gemini Cleaning Patterns - 4” Nozzle Spacing & 4” Carriage Helix





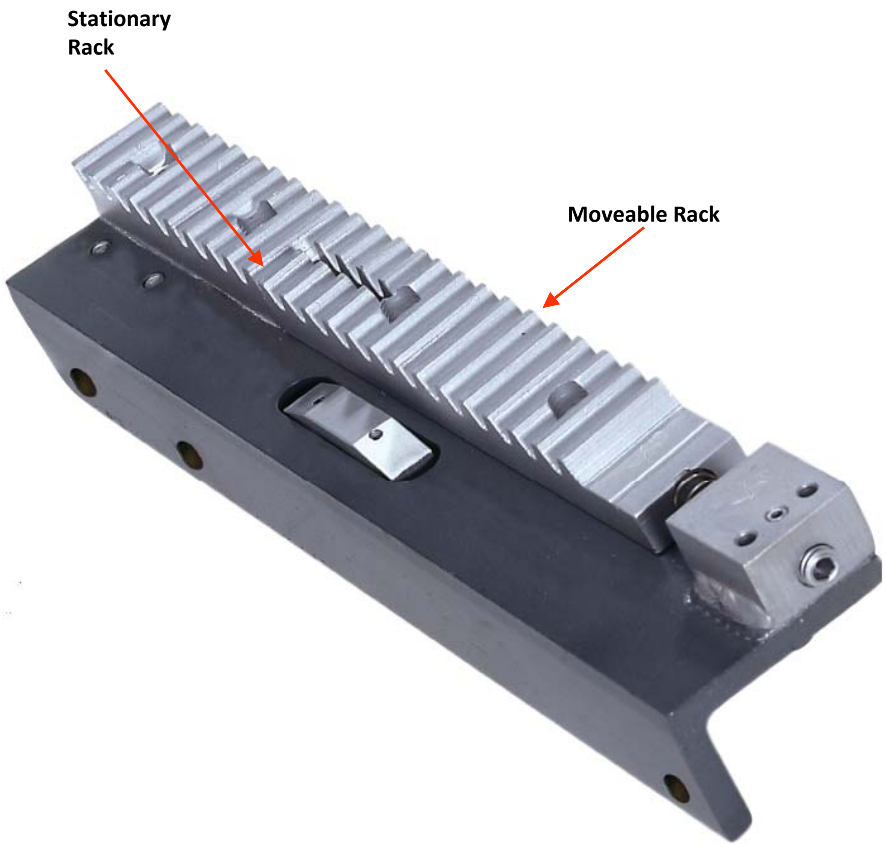
Progressive Helix Mechanism (PHM)

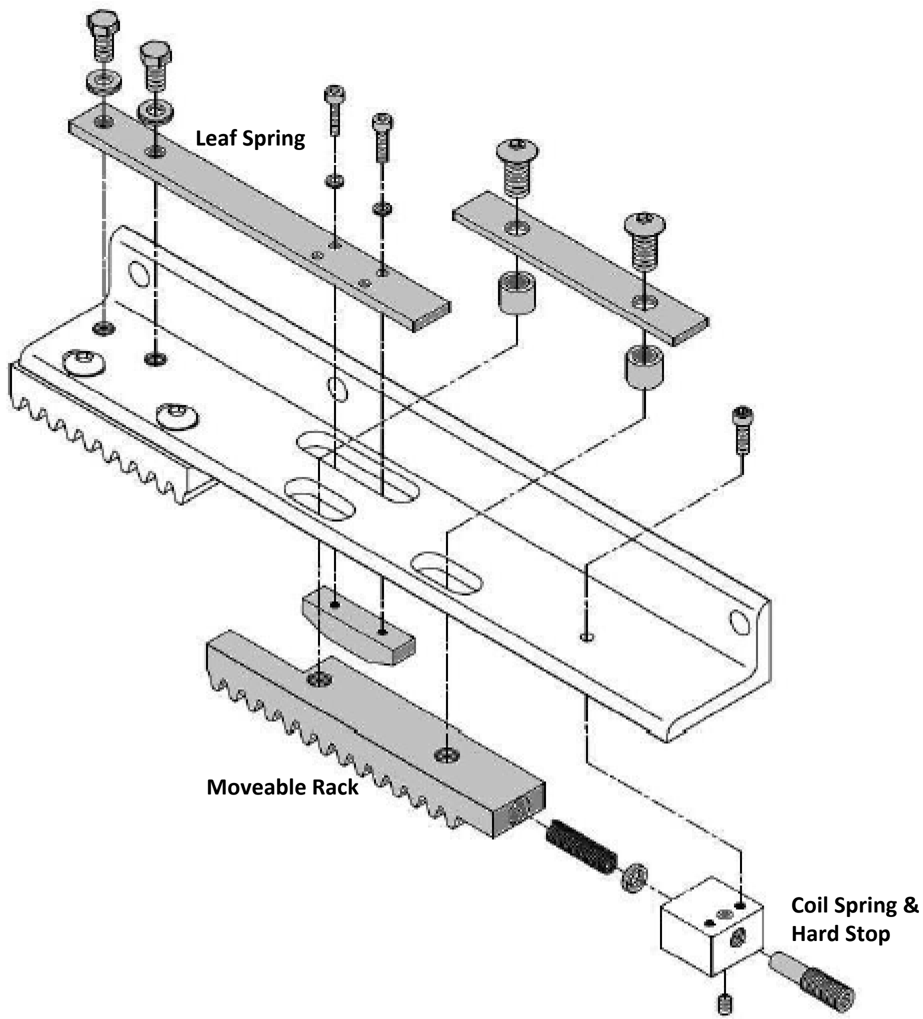




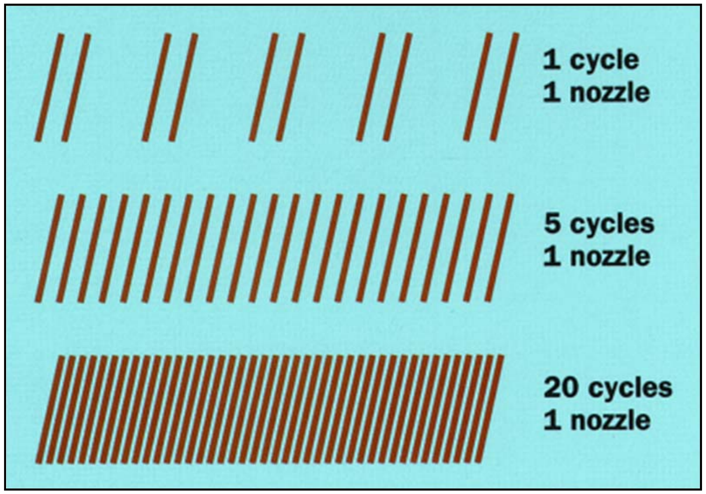
- The carriage advances one gear rack tooth per cycle resulting in rotating the nozzle 47.4 degrees for every cleaning cycle.
- Improved cleaning coverage, reduced boiler tube erosion
- Combats lance tube heat set and lance OD ash build-up
- Inhibits localized internal lance tube corrosion
- 448 operating cycles before the nozzle repeats the same cleaning path.

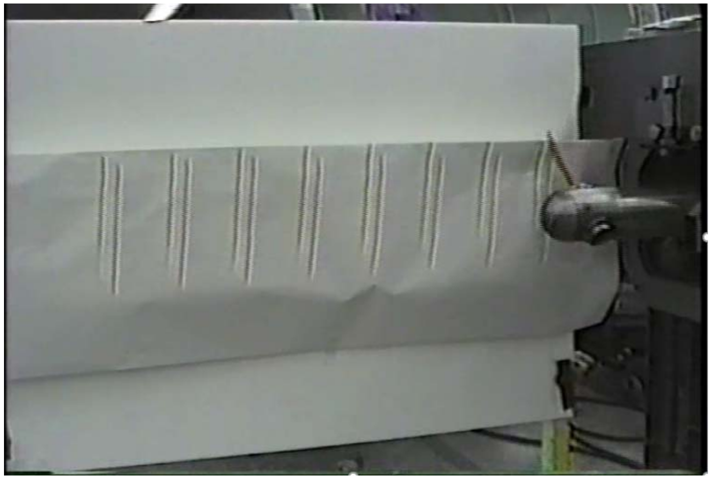
Progressive Helix Mechanism (PHM)



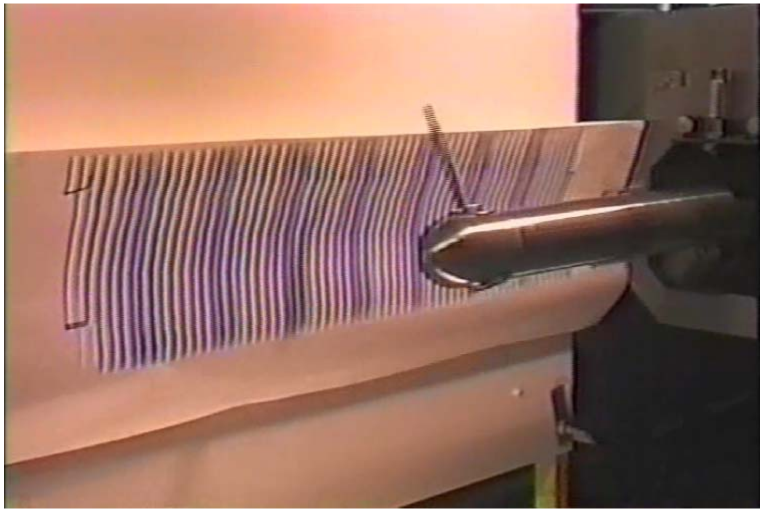


Progressive Helix Mechanism (PHM)





1 Cycle 1 Nozzle

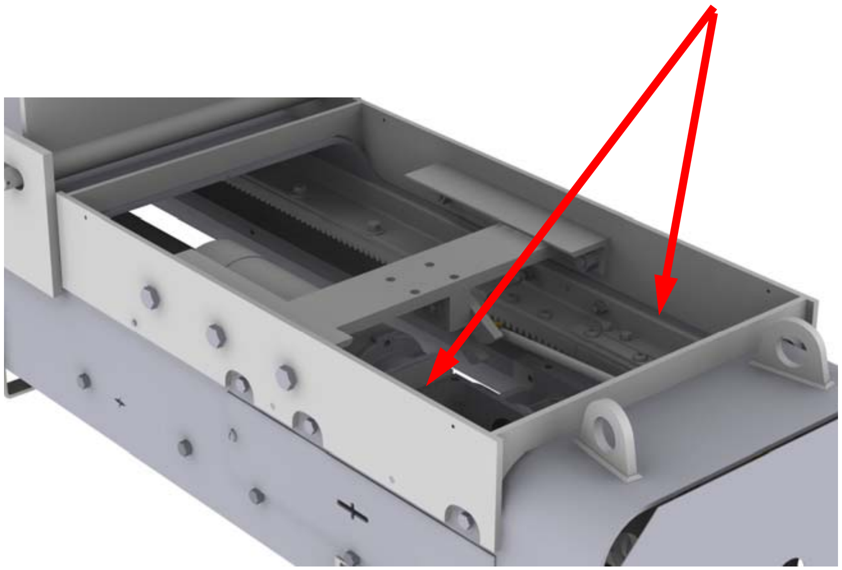


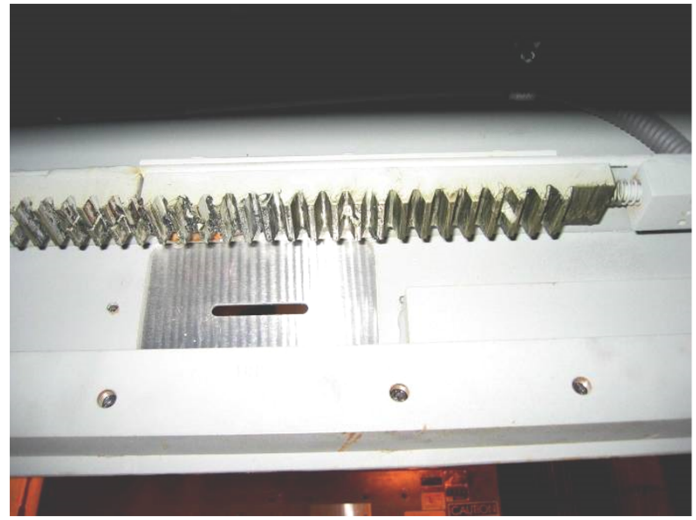
18 Cycles 1 Nozzle

Blower W/PHM

PHM integrated into gear rack on both sides near the rear bulkhead

Progressive Helix Mechanism (PHM)

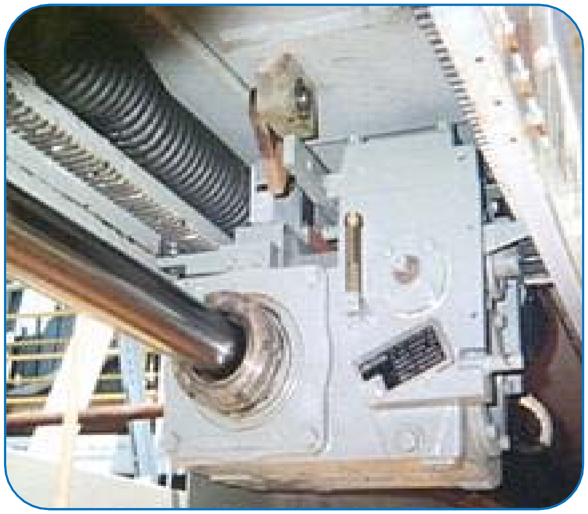


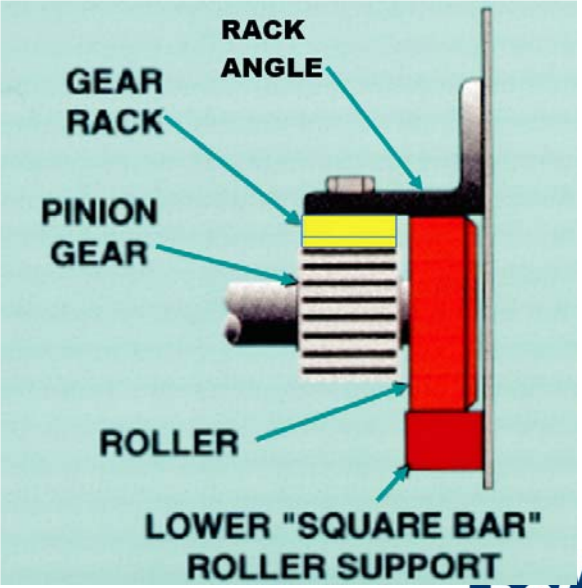


Blower W/PHM

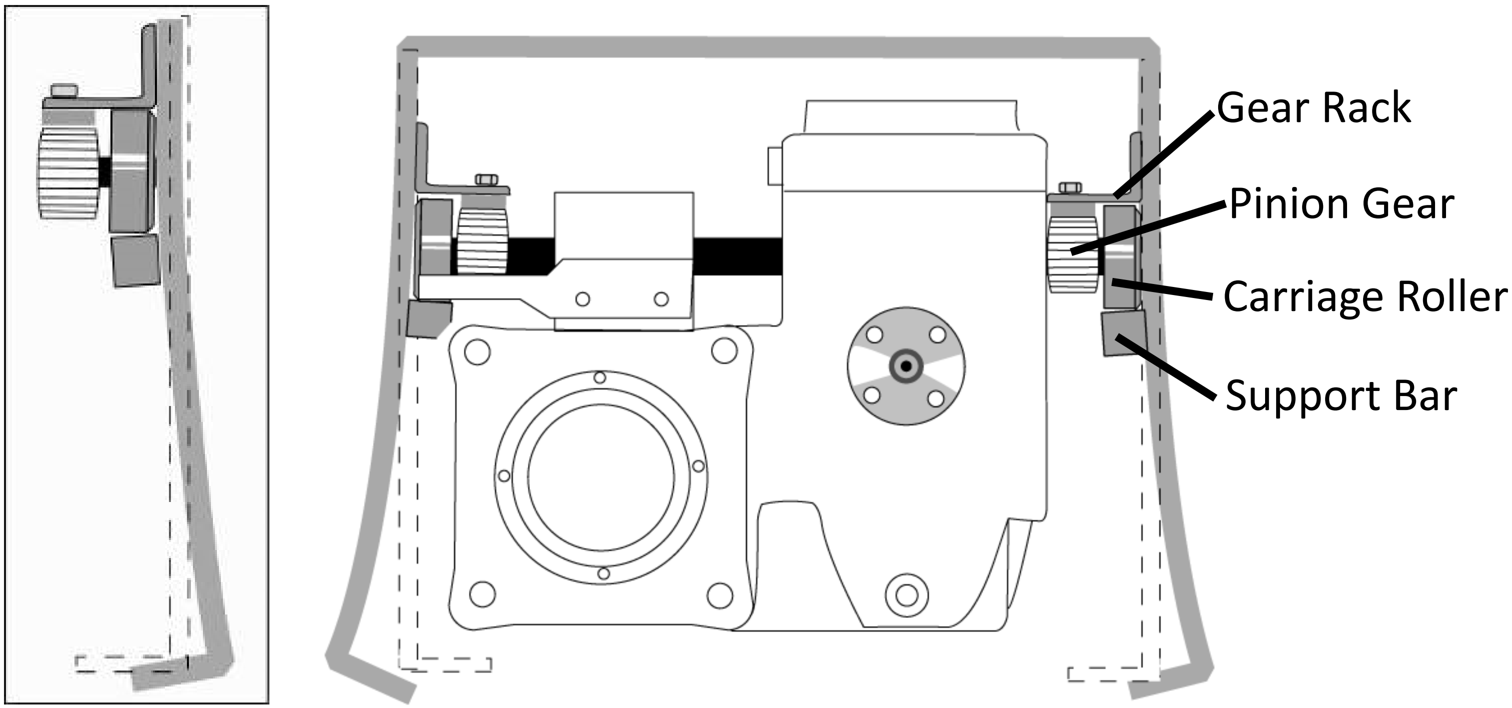
IK Rack And Pinion Drive

- Lance mounted to one side for minimum clearance
- The gear rack angle and lower bar are designed to resist gear separating forces between the drive pinion and the gear rack to maintain correct pinion contact with gear rack
- Lubricate six months interval with a synthetic moly-lithium grease





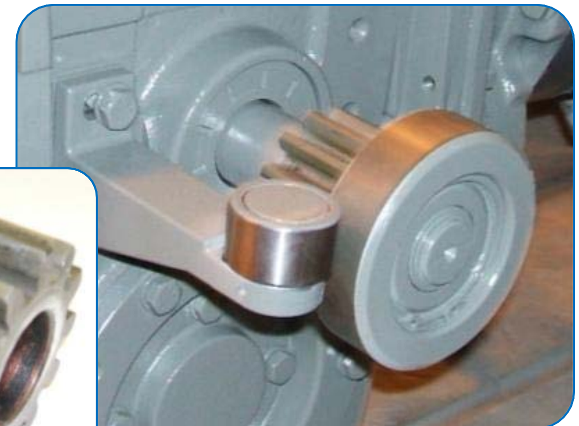
Sootblower Beam Side Wall Bending

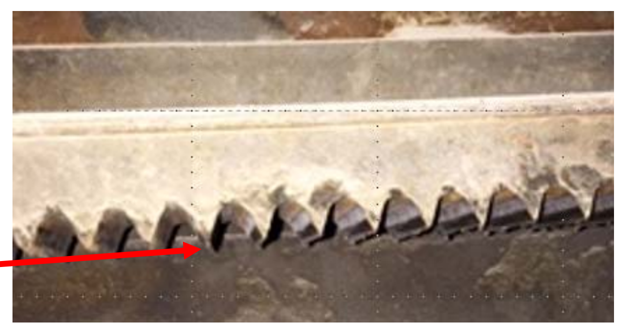


Gear separation forces tend to spread the side walls apart

Pinion Gears and Rollers

- Inspect pinion gears for signs of wear and notice full width contact
- Inspect rollers for free rotation and full contact
- If pinion wear is severe, expect the gear rack to also be damaged
- Rollers and gear rack may eventually get a "knife edge" on gears, if this happens, replace

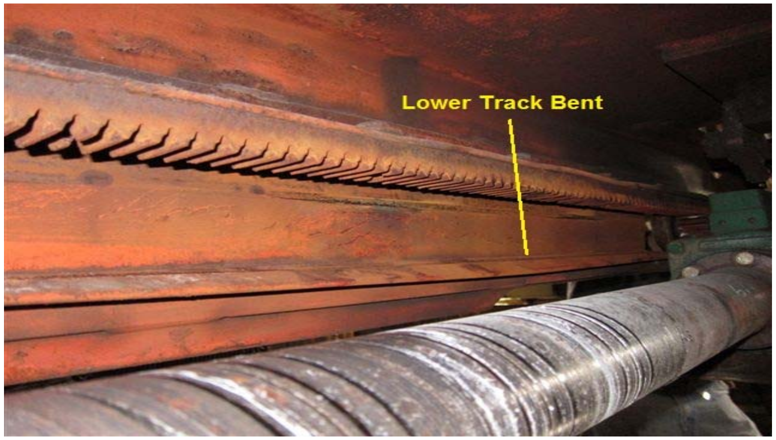




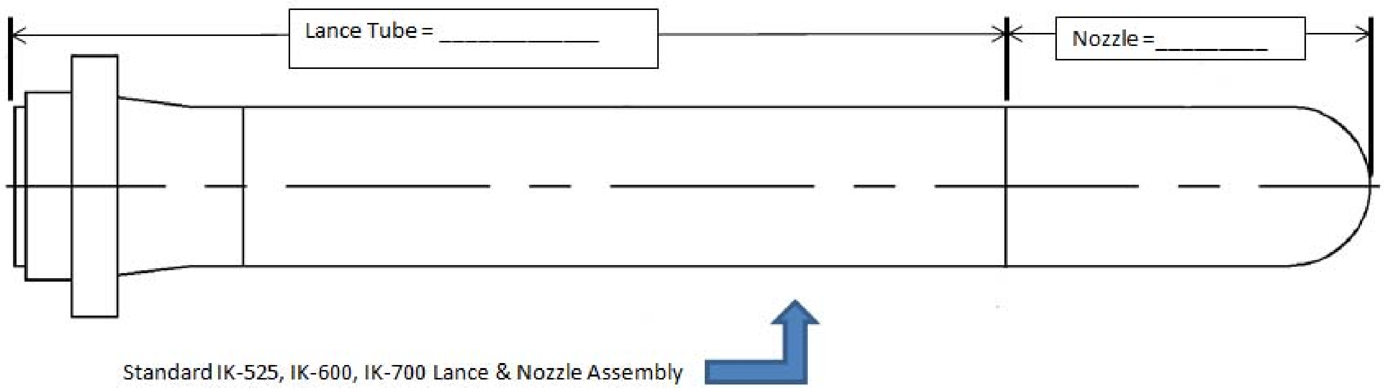
"Knife edged"

Beam Failures & Replacements

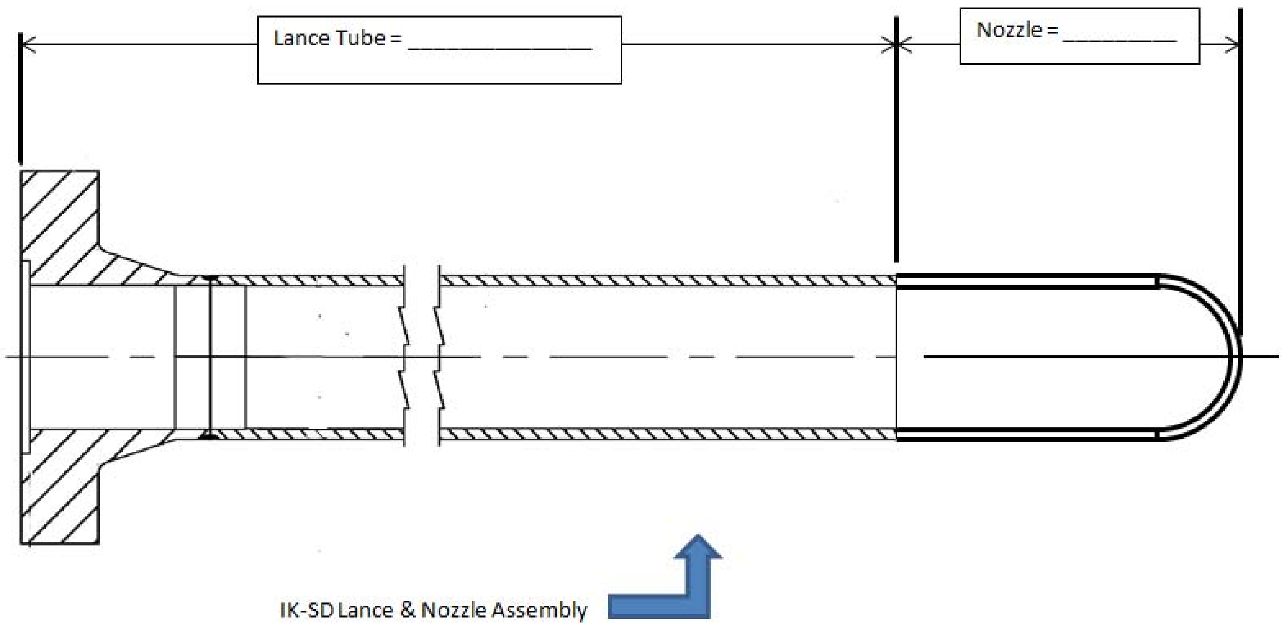
New Replacement
Beam



IK Lance Tubes

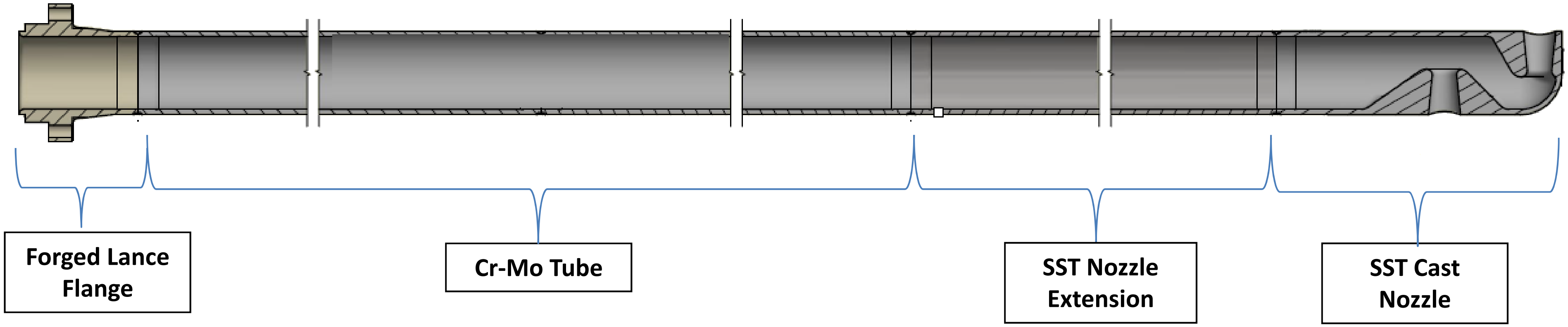


Standard IK-525, IK-600, IK-700 Lance & Nozzle Assembly



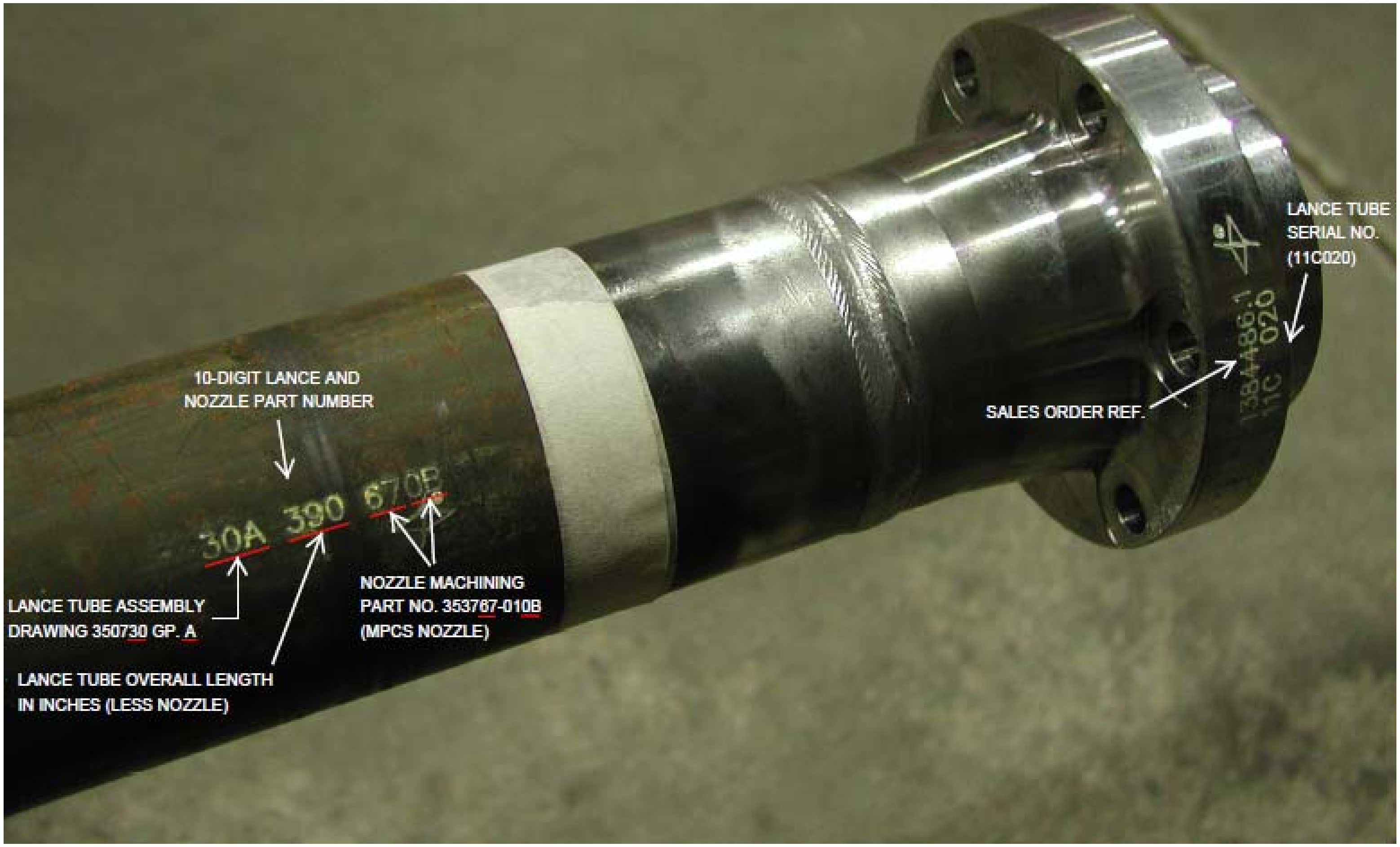
IK-SD Lance & Nozzle Assembly

Common IK Lance Tubes Recovery



- **Lance Tube Materials**
  - **Croloy 1-1/4:** Most commonly used lance tube material 3.5" OD.
  - **B&W 6330:** High Strength version of Croloy. Used for slag fall bend resistance and for most 4.00" and 5.00" OD lance tube installations.

Diamond Power Lance Tube Markings



Diamond Power Lance Manufacturing

- Highly controlled raw material sourcing
- Automated welds that are qualified to ASME Section IX
- Exceeds ASME B31.1 Radiographic Testing (RT) acceptance criteria
- Nondestructive evaluation (NDE) via RT for all forged flange, front-to-rear, splice, and lance-to-nozzle welds
- Unique X-ray serial number stamped on flange for weld testing traceability (Since mid-2005, the first two characters of the serial number indicate the year of manufacture)
- X-ray images are stored as permanent records and are available for lance tubes manufactured from 2009 to present

"IK" LANCE TUBE FAILURES

- Bent Lance Tubes
  Prime reasons for bent Lance Tube:
  - Lance tube overheat from lack of cooling per boiler location
  - A slag fall from upper furnace while sootblower fully extended
  - Improper sootblower sequence – blowing bottom to top in a lane

- Failed welds that were not produced correctly per OEM specifications

- Lance tube breaking apart due to ID corrosion
  Prime reasons for ID corrosion:
  - Condensate inside the lance tube mixing with boiler gases
  - Improper sootblower drain angle
  - Improper air purge through the lance tube to keep boiler gases out
  - Leaky poppet valves leading to condensate formation
  - Non-indexing lance tube

"IK" LANCE TUBES PM

- Periodically walk down sootblowers in operation & verify proper lance roller engagement
- Verify PHM installed & operational
- Verify proper blowing pressures per OEM standards
- Periodic non destructive testing of all lance tube welds in recovery boilers
- Periodic UT inspection of lance tube wall thickness per OEM recommendations
- Phased array or shear wave methods can be used to check welds; this requires a properly trained technician equipped with calibrated equipment.

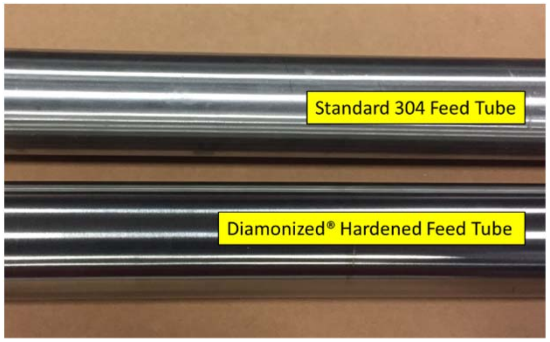
- Replace immediately lance tubes that are:
  - Bent
  - Bulged
  - Surface heavily scored, gouged
  - Faulty welds
  - Cast nozzle tip blown off or cracked
  - Pinholes leaking steam from the lance
  - Does not meet minimum wall ID thickness per OEM recommendations

Feed Tube General Information

- Feed tubes are available in two sizes for Diamond Power products 2.375” & 2.75”
- End connections available are threaded end, retaining ring, and split ring
- Threaded ends are the standard for any newly supplied IK-700 sootblower
- Surface finishes available are polished and Diamonized®
- Discrete 10-digit part numbers are used to define a feed tube in a clear and easy way

Diamonized® Feed Tube

Diamonized is 20% harder than chrome with virtually no surface cracking or delaminating

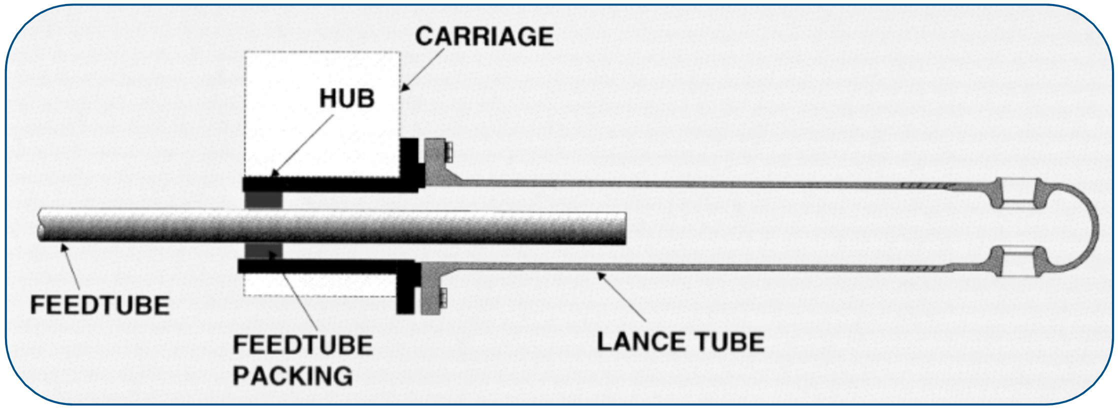


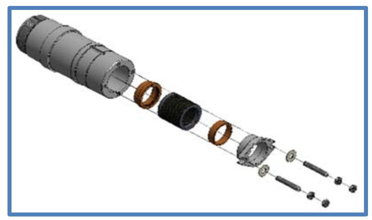
Hardness:	304SS:	26 Rc
	Chrome Plating:	56 Rc
	Flame Spray Coating:	55 Rc
	Diamonized:	66 Rc

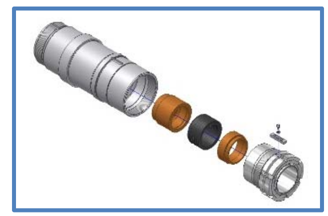
- Exceptionally dense hard surface for a superior sealing surface and excellent wear resistance.
- Diamonizing process hardens the base material
- Not a weld overlay, flame spray or plating process
- Patented Process

Feed Tube Packing and Glands

- Packing is contained in the carriage hub, compressed between two brass bushings to seal between the lance tube and feed tube



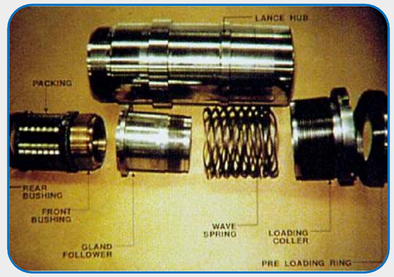


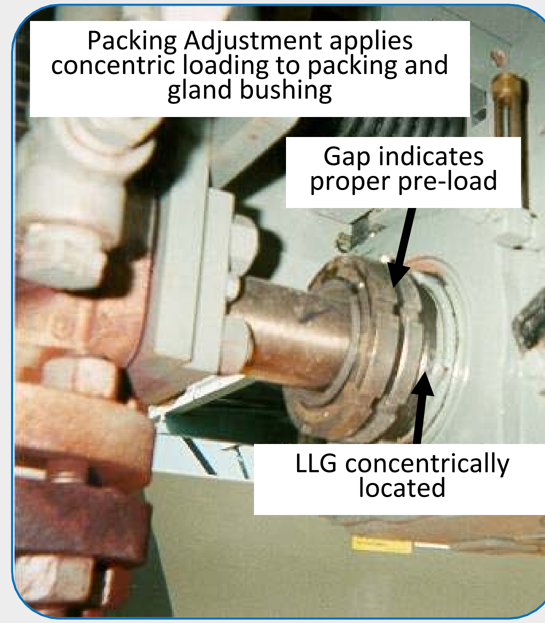


New Feed Tube	Worn Feed Tube
• Solid ring graphite foil (graphoil) packing • Live loaded gland **Benefits:** • Reduced maintenance • About 5,000 cycles without steam and condensate leakage	• Split ring graphite fiber (woven) packing **Benefits:** • Fiber lasts longer than foil on scratched tube • Less labor to install, but has to be re-tightened regularly

Live Loaded Feed Tube Packing Advantage

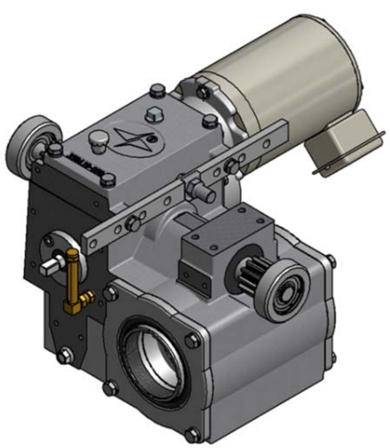
- Constant concentric packing load
- Visual indicator adjust approximately three times before packing change
- Packing change cycle up to 5,000 Operations dependent upon condition of feed tube
- Corrosion inhibitor graphoil packing design





Carriage Models

- **Series One** - Full-Oil Bath Carriage
- **Series One-G** - Carriage with separate greases in both chambers
- **PowerTrain®** - Maintenance Free, Dry Hub Carriage

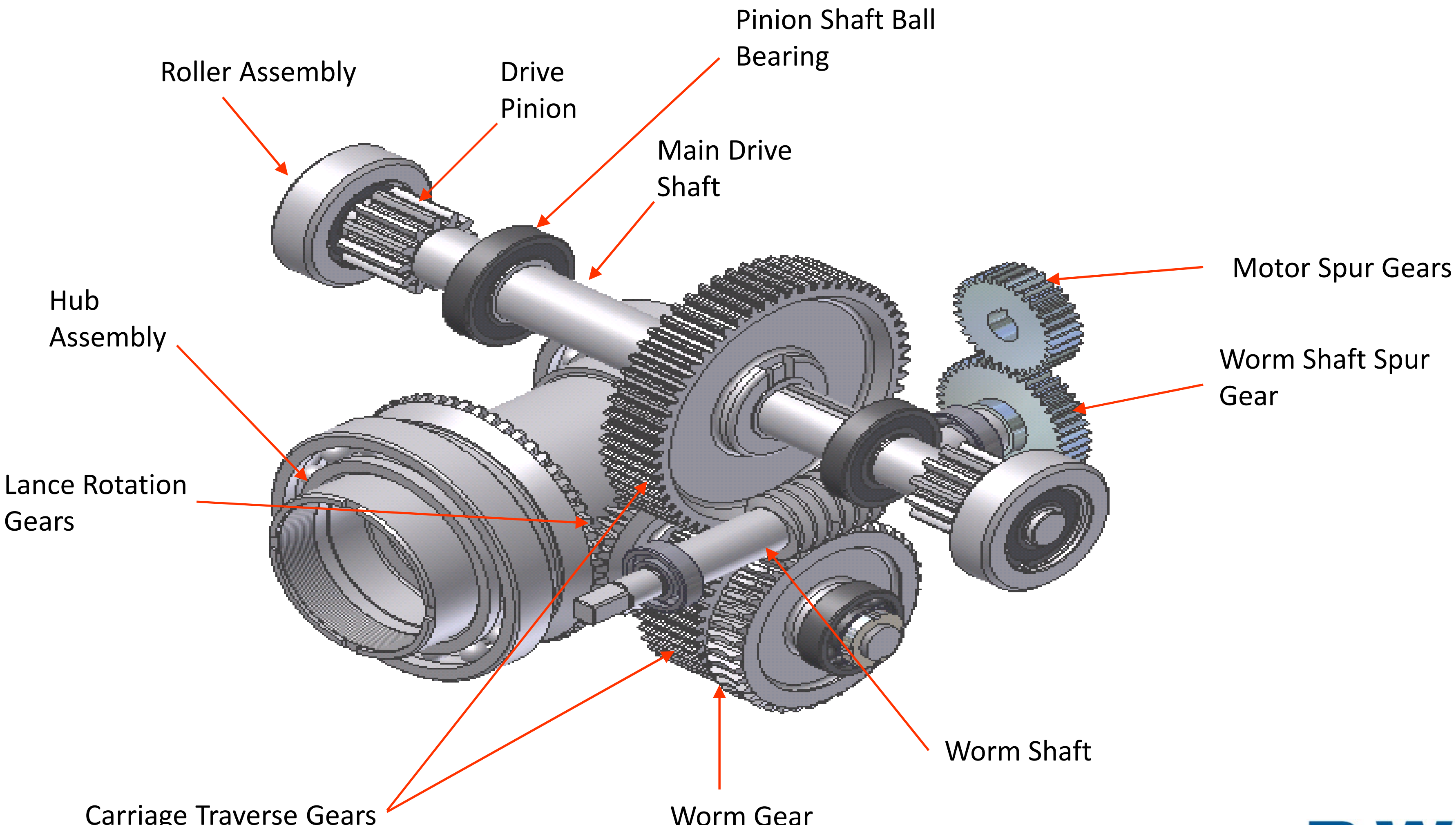


Series One Carriage

Series One-G Carriage

PowerTrain®

Series-One Carriage



PowerTrain® Carriage

Features

No oil level to check,
no oil to change

Lubricated-for-life gearbox

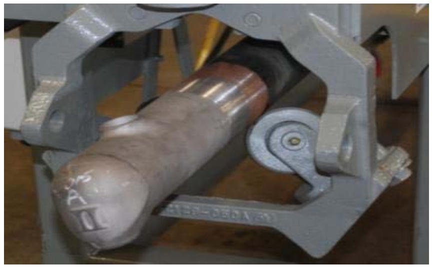
Self-lubricated bearings that withstand steam temperatures above 900 ^{o}F without the need of oil or grease

Isolated hub chamber with advanced dry-film lubrication on hub gear set

IK Front Support Rollers

- Keep lance tube in correct position
- Must be aligned with lance travel helix
- May require periodic lubrication
- When bearings fail or are misaligned, lance surface is damaged

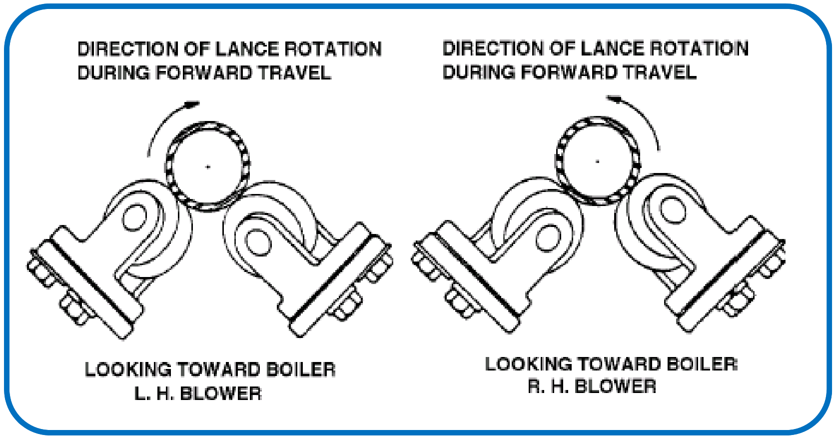
Note: On Diamond Sootblowers, front rollers should never require shims under the base plate. Lifting off of rollers is a symptom of the wallbox sagging or lance dragging on boiler tubes!



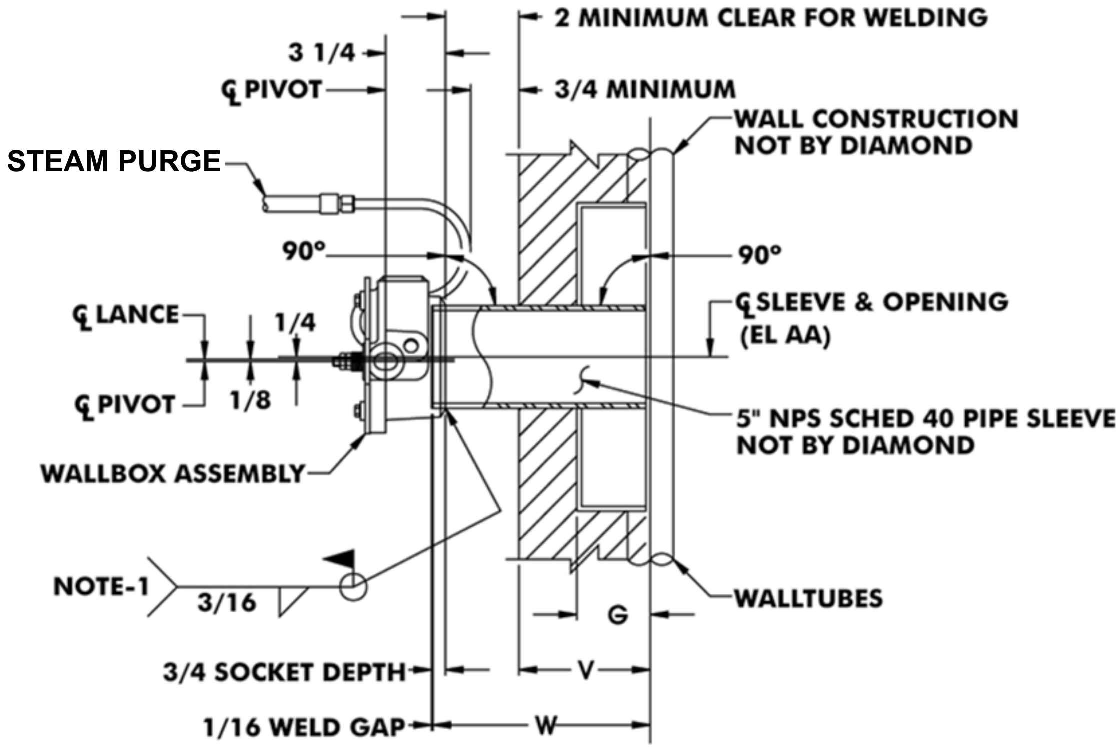
IK Front Support Rollers

Series One, Series One-G, PowerTrain, and Full-Oil Bath Conversion Carriages.

- Slotted adjustment feature
- Rollers align with helix marks on lance tube
- Manual or grease cup lube fittings on older models
- Lube if needed at 3 to 6 months intervals
- Use synthetic moly-lithium grease

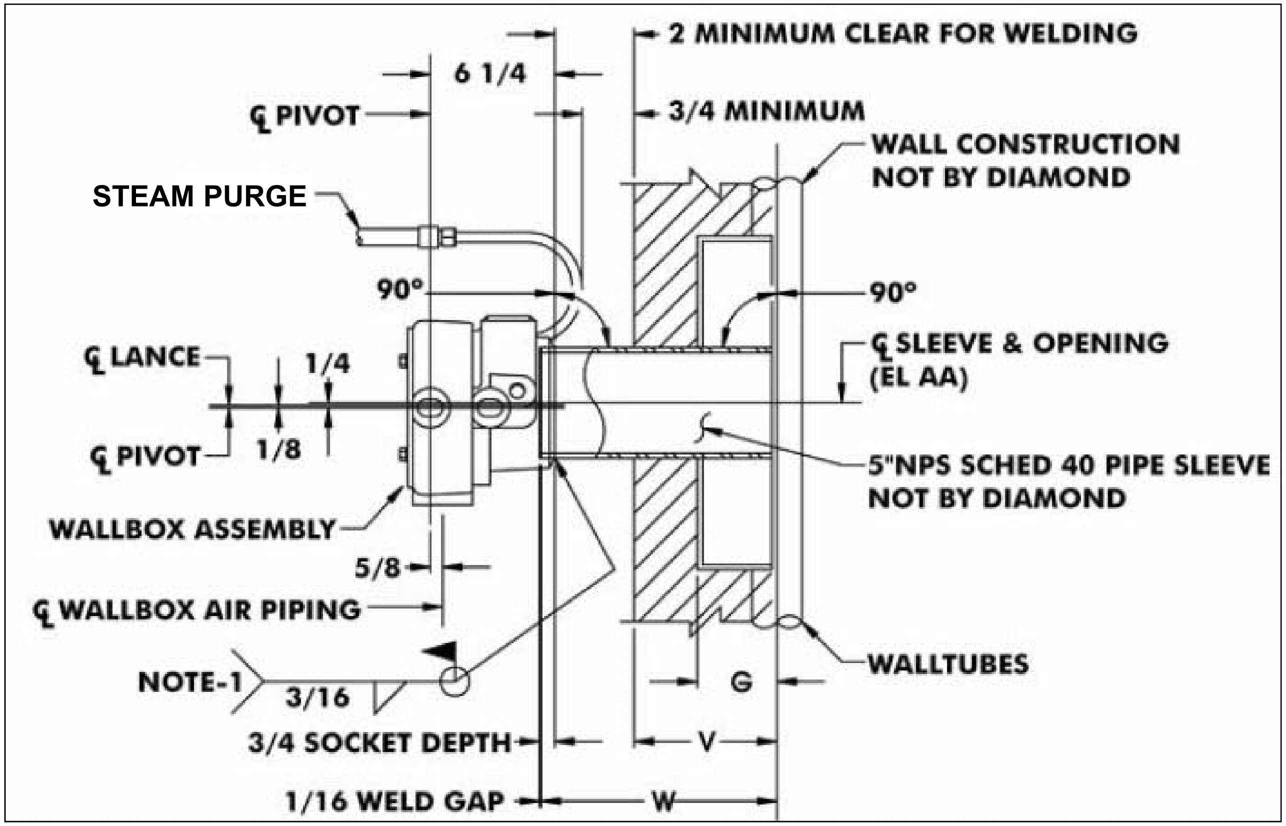


IK Recovery Negative Pressure Wallbox



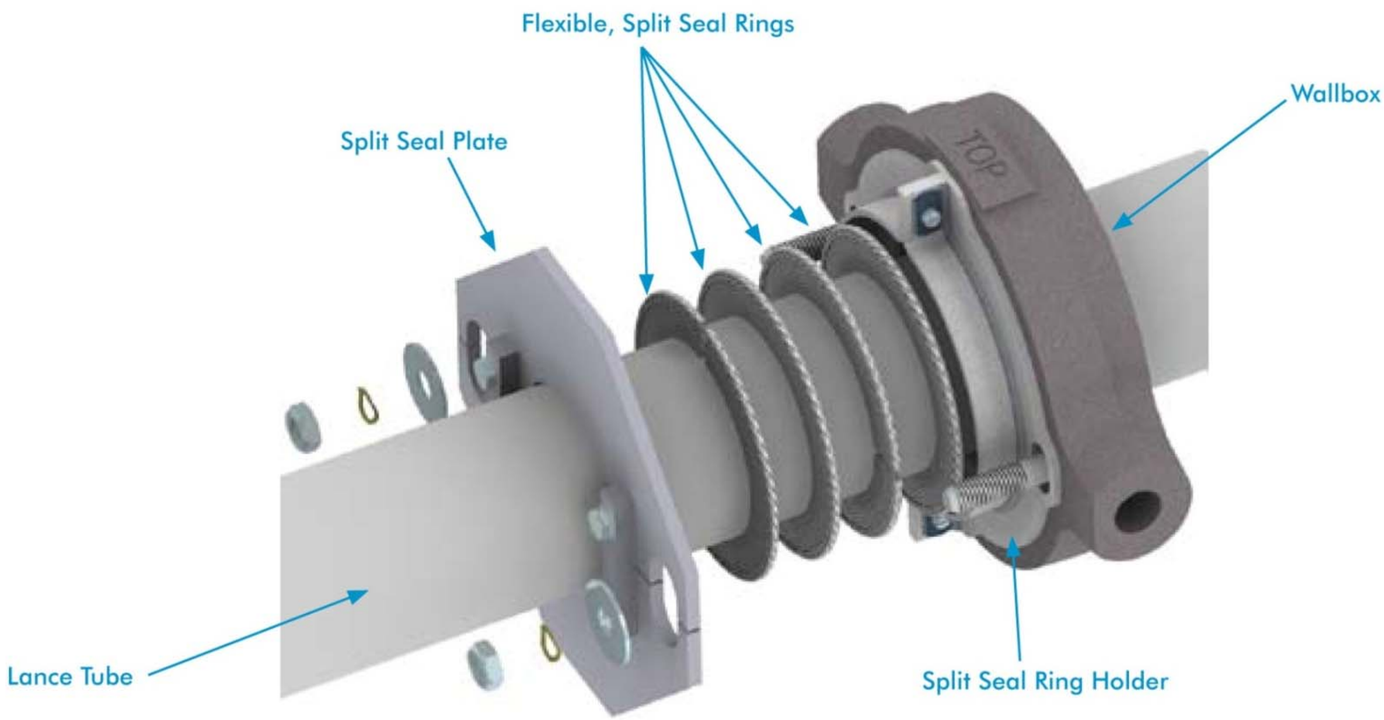
Negative Pressure, Steam Purge Recovery Wallbox Configuration

IK Recovery Plus Pressure Wallbox



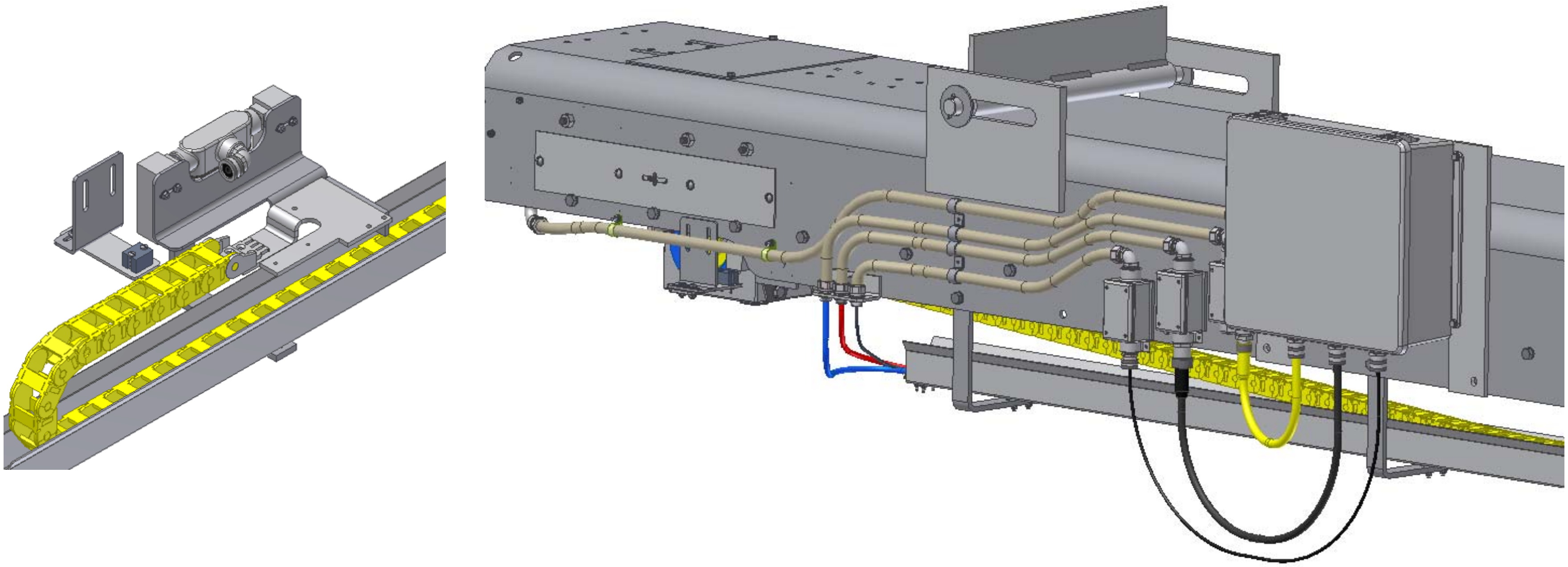
Mechanical Wallbox Seal Kit

1. A seal holder is attached permanently to wallbox face
2. Seal holder is then filled with four sealing rings
3. Then the unit is capped-off by our current wallbox seal plate.



IK-700 Control & Power Supply

Energy Chain – Blower at Rest Position



- Energy chain Snap-open, hinged to left or right, along outer radius
- Chain push pull capacity 90 lb/foot
- Chain rated temperature -40/+266 F
- Travelling limit switches
- Arc Flash Compliant control box
- Customized control box location

IK-700 Control & Power Supply

Expanda Cable – Externally Mounted

Steam/Condensate Issues

Condensate in sootblowing steam causes:

- Boiler tube erosion, leading to expensive repairs and possibly unscheduled outages.
- Reduced feed tube packing life
- Potential personnel hazards when packing fails

Condensate cannot be completely eliminated, but reducing the amount of condensate minimizes damage.

Steam/Condensate Issues

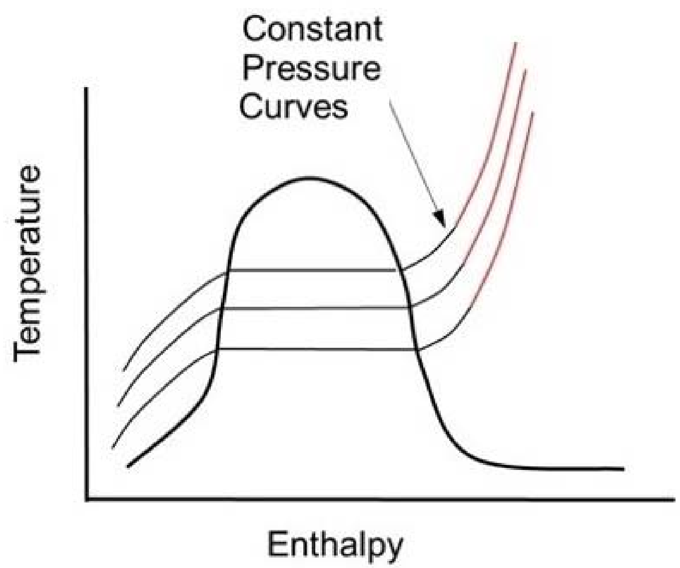
Contributors to increased condensate at Sootblowers:

- Poor Steam Supply - Saturated Source or Minimal Superheat

Steam/Condensate Issues

Preferred Steam Source Conditions

General Recommendation:
Minimum 100°F Superheat
h = 1300 Btu/Lb or greater



Steam/Condensate Issues

More superheat is always better for condensate reduction:

- Less condensate is created in the header
- Branch lines warm up faster when the sootblowers start
- Sootblower poppet, feed tube, and lance warm up faster

Increasing steam temperature is seldom feasible:

- High temperature sources may not exist
- Existing carbon steel supply pipe may not be rated for the upgraded source temperature
- Higher quality steam is valuable for other uses

Steam/Condensate Issues

Contributors to increased condensate at Sootblowers:

- Poor Steam Supply - Saturated Source or Minimal Superheat
- Deteriorated or Missing Pipe Insulation

Steam/Condensate Issues

Equation for Overall Heat Transfer Coefficient:

$$U_{Overall} := \frac{2\cdot\pi}{\underbrace{\frac{1}{r_{inside}\cdot h_{inside}}}_{0.920} + \underbrace{\frac{\ln\left(\frac{r_{outside}}{r_{inside}}\right)}{k_{pipe}}}_{0.006} + \underbrace{\frac{\ln\left(\frac{r_{insulation}}{r_{outside}}\right)}{k_{insulation}}}_{28.058} + \underbrace{\frac{1}{r_{outside}\cdot h_{outside}}}_{0.511}}$$

→ 0.920 0.006 28.058 0.511

Note the fact that insulation far outweighs all other factors.

Steam/Condensate Issues

Maintaining the pipe insulation is necessary and not excessively costly when compared to other measures for condensate reduction. Without adequate insulation, other corrective measures less effective.

Steam/Condensate Issues

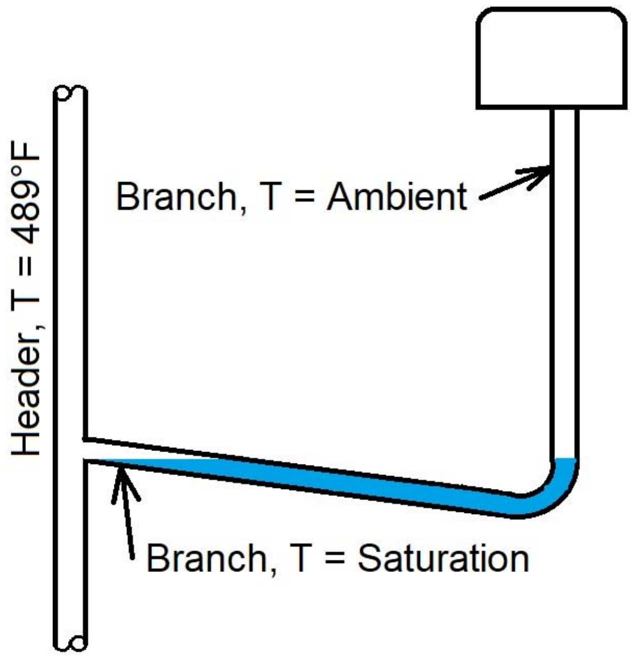
Contributors to increased condensate at Sootblowers:

- Poor Steam Supply - Saturated Source or Minimal Superheat
- Deteriorated or Missing Pipe Insulation
- Pipe Arrangement – Slope and Looped Connections

Steam/Condensate Issues

Incorrect slope creates a low point:

A low spot not only collects condensate between operating cycles but also allows cooling of the pipe downstream, requiring more heat and making more condensate when the sootblower starts. **All pipe should slope at ½" per foot minimum toward the drain.**

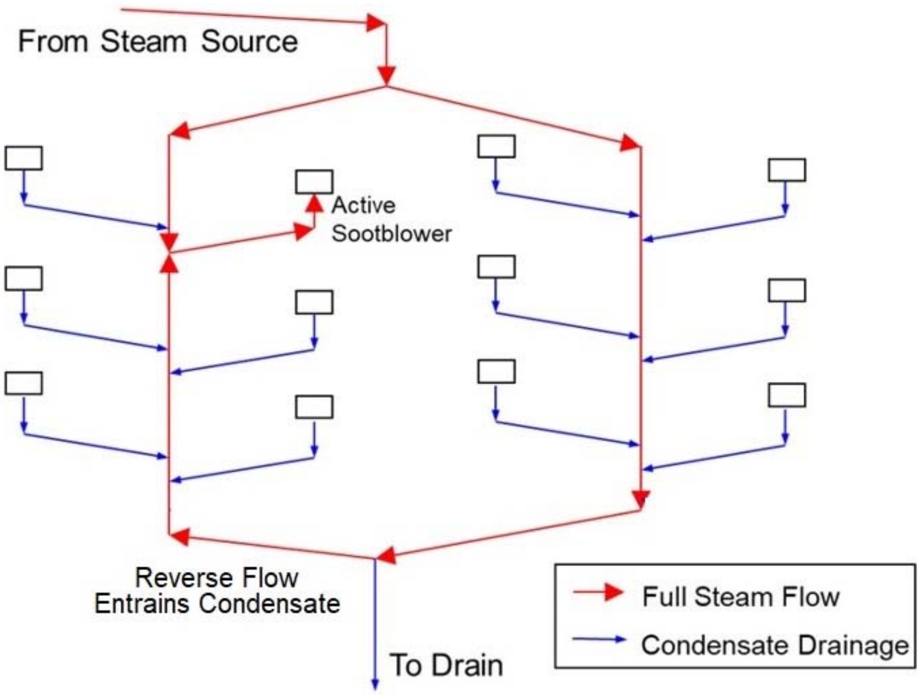


Steam/Condensate Issues

Headers connected at drain, creating a loop:

When multiple headers share a common drain, reverse flow occurs, entraining condensate that should have gone to the drain. Each header should have its own drain to prevent this.

Check valves can be used to prevent reverse flow but are a poor substitute, as they can malfunction without being detected.

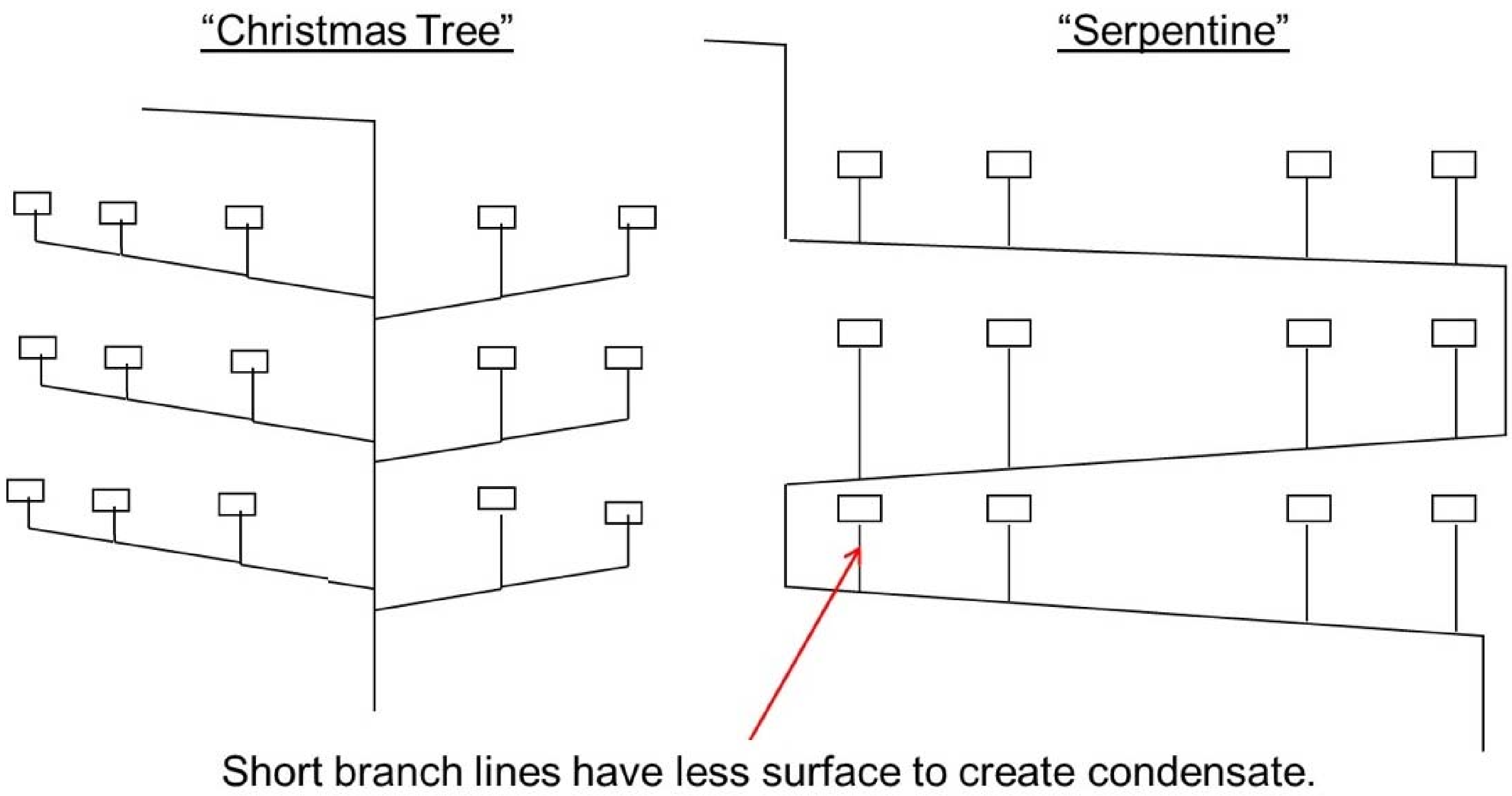


Steam/Condensate Issues

Contributors to increased condensate at Sootblowers:

- Poor Steam Supply - Saturated Source or Minimal Superheat
- Deteriorated or Missing Pipe Insulation
- Pipe Arrangement – Slope and Looped Connections
- Pipe Arrangement - Branch Line Length

Steam/Condensate Issues



Steam/Condensate Issues

Contributors to increased condensate at Sootblowers:

- Poor Steam Supply - Saturated Source or Minimal Superheat
- Deteriorated or Missing Pipe Insulation
- Pipe Arrangement – Slope and Looped Connections
- Pipe Arrangement - Branch Line Length
- Sootblower Drain Angle

Steam/Condensate Issues

Sootblower slope in the hot position must be set to drain toward the boiler. An inventory of condensate in the lance tube blasts boiler tubes at start-up and contributes to accelerated internal corrosion of the lance tube while idle, leading to lance failures.


Correct


Incorrect

Steam/Condensate Issues

Contributors to increased condensate at Sootblowers:

- Poor Steam Supply - Saturated Source or Minimal Superheat
- Deteriorated or Missing Pipe Insulation
- Pipe Arrangement – Slope and Looped Connections
- Pipe Arrangement - Branch Line Length
- Sootblower Drain Angle
- Drain System

Steam/Condensate Issues

Steam Traps vs. Thermal Drains

- Steam Trap Example:
  - 2” Schedule 40 Pipe (upstream of steam trap)
  - 600 psig Condensate @ 480°F, Density = 50 lbm/ft^3
  - 600 psig Saturated Steam @ 489°F, Density = 1.33 lbm/ft^3
  - Trap Flow Capacity = 5000 lbm/hr (sub-cooled liquid near saturation temperature)
  - Condensate Velocity in 2” Pipe = 1.2 ft/s
  - Saturated steam upstream of condensate flows at the same velocity.
  - Saturated Steam Flow Rate in 2” Pipe = 133 lbm/hr

Steam/Condensate Issues

Steam Traps vs. Thermal Drains

- Thermal Drain Example:
  - 2” Schedule 40 Pipe (upstream of drain station)
  - 600 psig Saturated Steam @ 489°F, Density = 1.33 lbm/ft^3
  - Thermal Drain Capacity = 1800 lbm/hr (saturated steam)
  - Steam Velocity in 2” Pipe = 16.1 ft/s
  - High velocity scrubs condensate from the header
  - With superheated steam, the header can be maintained above saturation temperature when properly controlled

Steam/Condensate Issues

Steam Traps vs. Thermal Drains

Steam Flow in 2" Schedule 40 Header		
	Mass Flow (Lbm/Hr)	Velocity (Ft/Sec)
Thermal Drain	1800	16.1
Steam Trap	133	1.2

Piping/Drain System Analysis

- Collect operating data
- Perform a detailed system walkdown inspection
- Take Steam and/or Pipe Surface Temperature Measurements
- If needed, perform a Thermal-Hydraulic Analysis including:
  - Pressure drop calculations
  - Heat loss calculations
  - Moisture generation rates
  - Drain system analysis (capacities & benefits vs. costs)

Results of the analysis determine which corrective measures apply.

Summary of Corrective Measures

Correct problems with the existing system:

- Maintain pipe insulation and lagging
- Establish correct pipe slope where needed
- Set sootblower slopes to the recommended drain angles
- Maintain steam traps in good working order

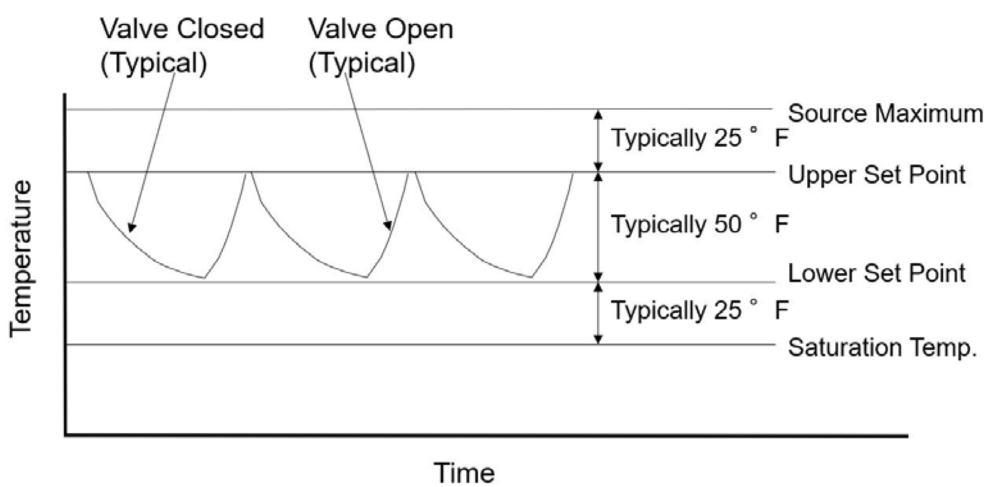
Summary of Corrective Measures

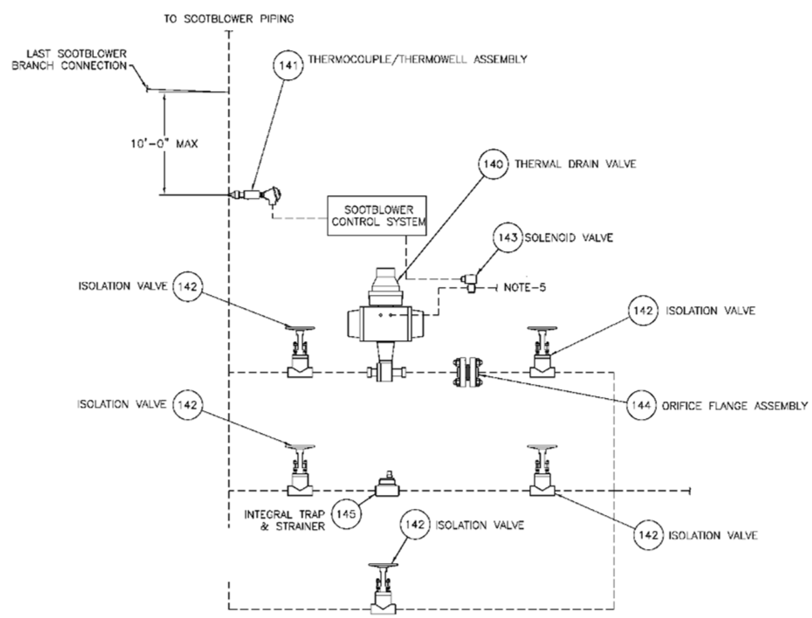
Consider upgrades:

- Provide a separate drain for each header
- Replace traps with thermal drains
- Connect to a better steam source if possible

Thermal Drain System

- Metal-seated Full Port Ball Valve
- Downstream Orifice to prevent cavitation
- Thermocouple and Controller to maintain header temperature





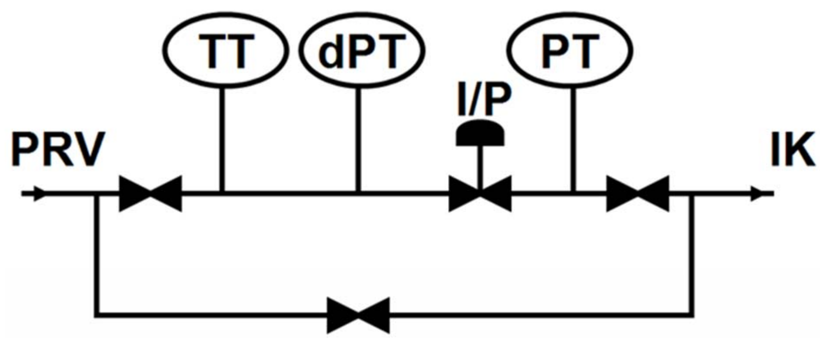
Summary of Corrective Measures

If condensate remains excessive due to causes that can't be eliminated, change sootblower operation to reduce damage:

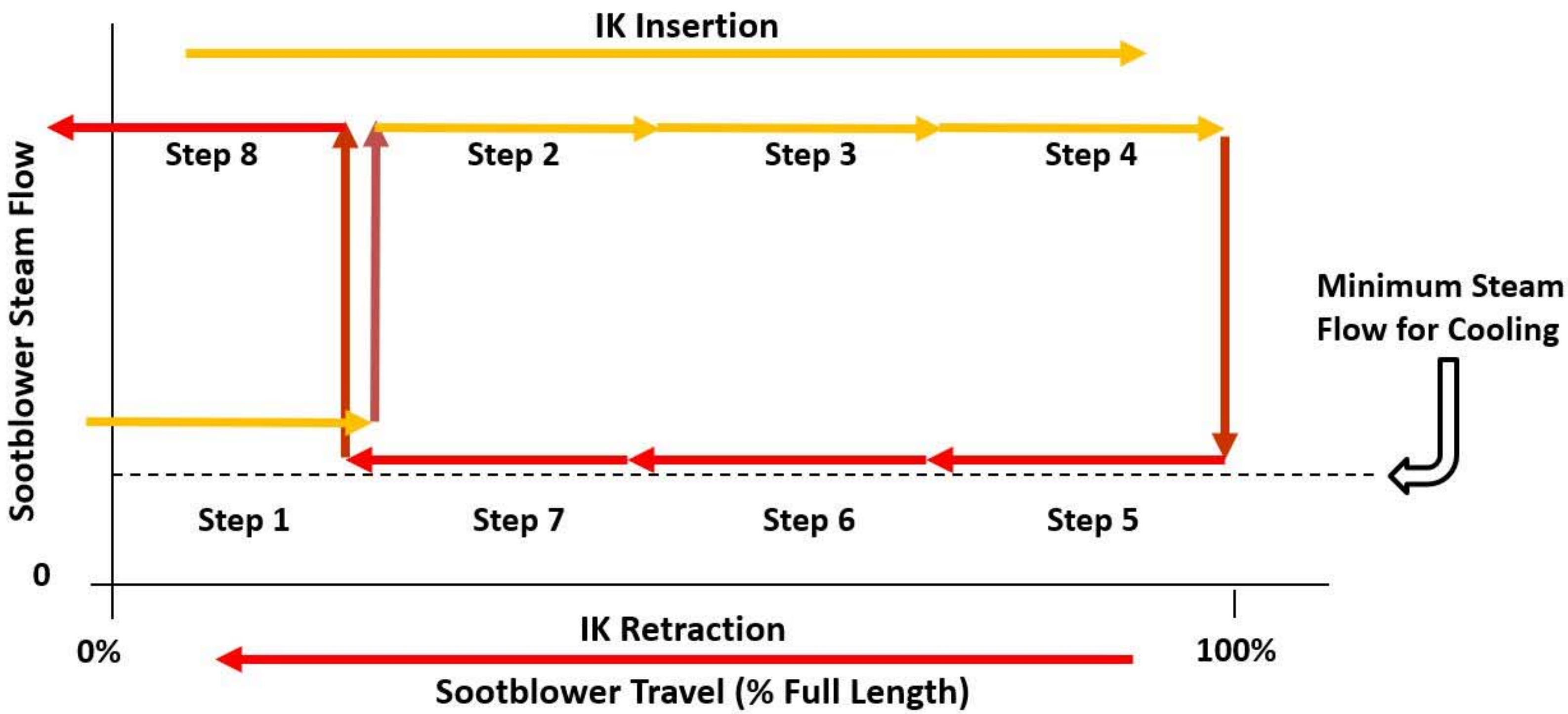
- Operate at reduced pressure/flow at the start of the blowing cycle to purge condensate from the system and warm the branch line before operating at full pressure.
    - Variable Flow Control
    - One-Way Blowing

Variable Flow Control System

- Flow Control Valve
- PLC/DCS controls flow versus time
- Poppet valves are set wide open

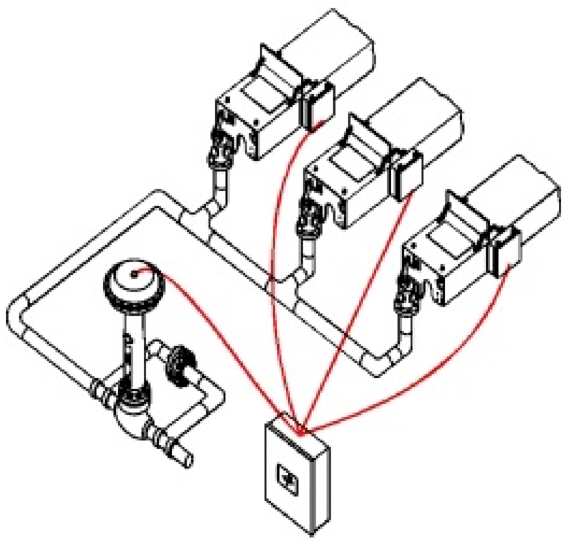


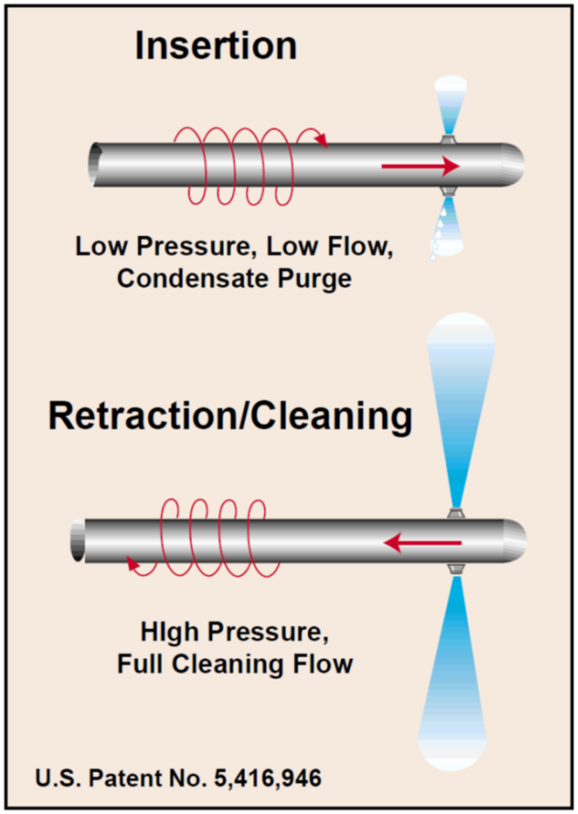
Variable Flow Control System



One-Way Blowing System

- On-Off Valve
- Orifice installed parallel to valve
- Poppet valves are set normally
- Reduced flow during insert travel
- Full flow during retract travel





Conclusion

- Many potential contributors that can cause condensate problems
- Several methods are available for identifying root cause(s)
- Options are available to minimize condensate occurrence and alleviate tube erosion
- We hope this information has been helpful in providing you with a “Roadmap” to help troubleshoot and resolve similar condensate problems.

Questions ?

ANDRITZ GROUP

OPERATOR FREE SPOUT DECK SOLUTIONS

AF&PA

FEBRUARY 8, 2023

ANDRITZ

ENGINEERED SUCCESS

1

CHAPTER OVERVIEW

2

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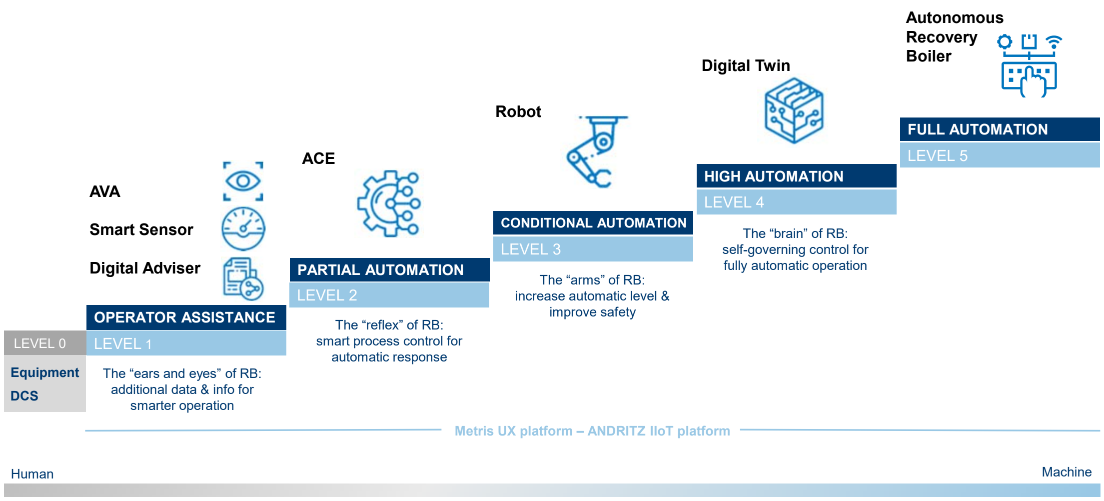
A SELF-GOVERNING RECOVERY BOILER



CHAPTER 2
SMELT SPOUT CLEANING ROBOT

SPOUT DECK – HIGH RISK AREA

Operators must enter for regular tasks:

- Spout cleaning
- Smelt sampling
- Spout plugging / clearing
- Shatter jet adjusting

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ANDRITZ SMELT SPOUT ROBOT COMPONENTS

Automated smelt spout cleaning

Delivered with protective suit to cover against smelt splashes

Accurate and stabile tool movement

Spout location tracking with laser sensors

High availability

Strong support construction

Durable cleaning tool

Reduction sampling as an option

Collision free operation

Smart cleaning

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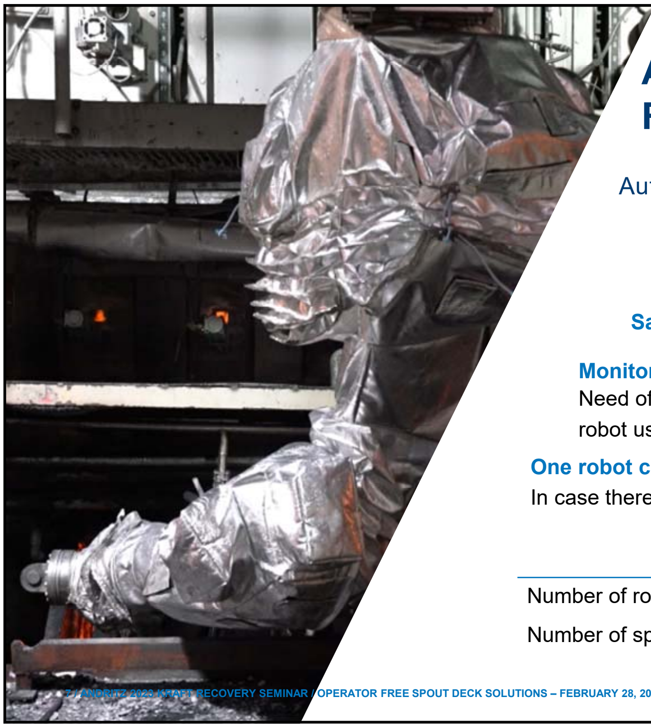

ANDRITZ SPOUT ROBOT CONTROL

Automated smelt spout cleaning

Tool optimization is based on smelt behavior.

Safe and easy tool change by bolted connection.

Monitored tool wear change
Need of tool change is indicated by the robot user interface.

One robot can clean up to three spouts.
In case there are more spouts, more robots are used.

Number of robots

Number of robots	1	2	3	4	5
Number of spouts	1-3	4-6	7-9	10-12	13-15

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INSTALLED SYSTEM

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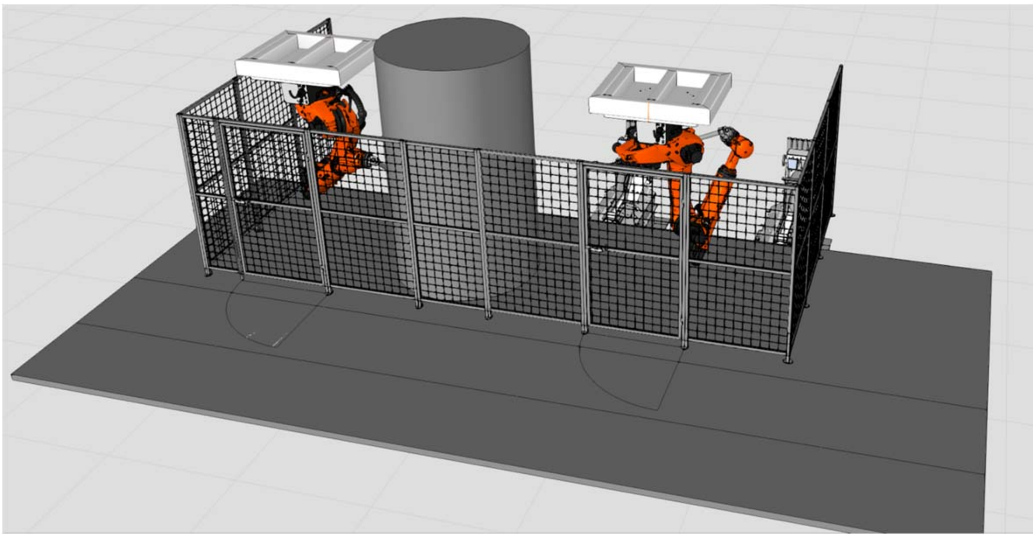
ANDRITZ SMELT SPOUT ROBOT SAFETY FENCE



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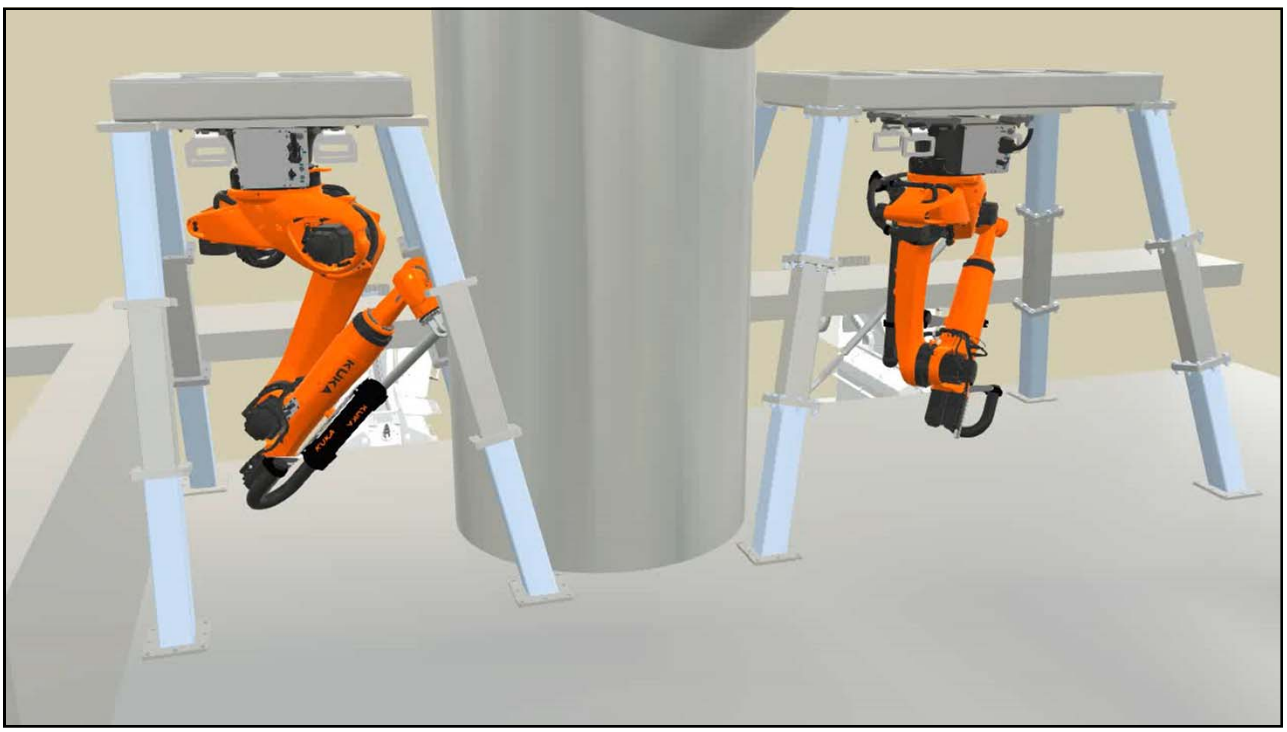

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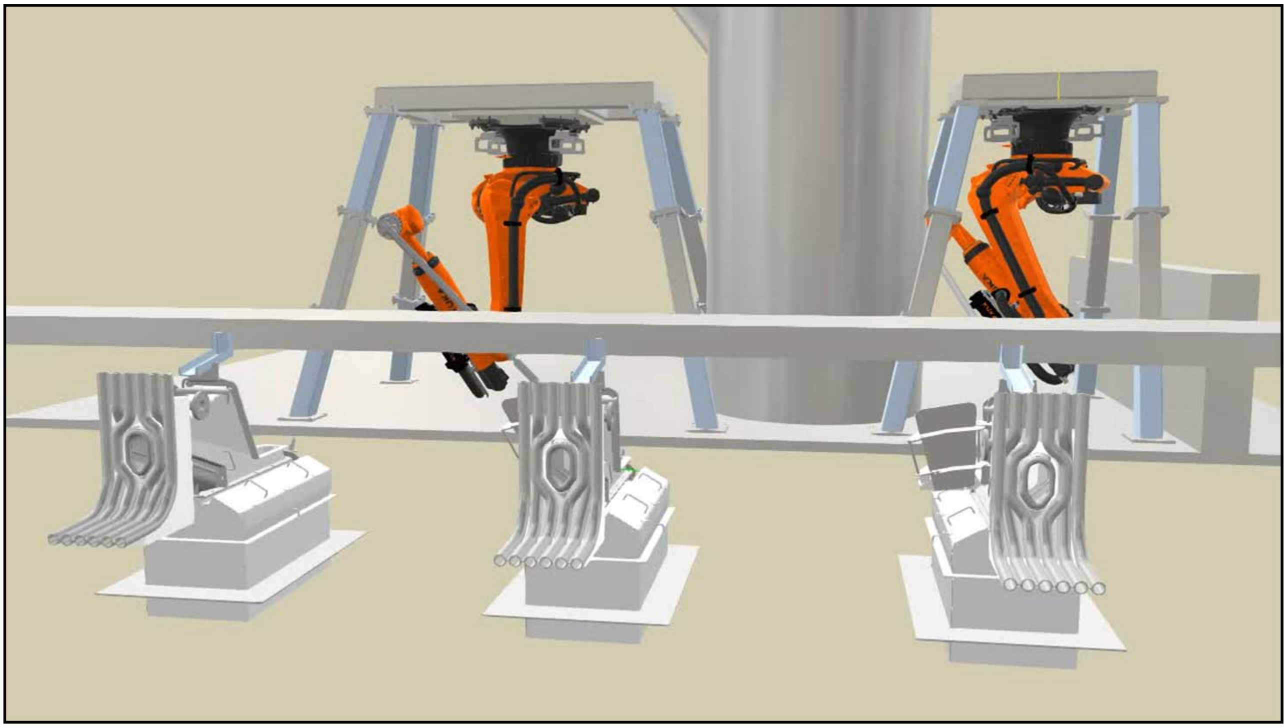

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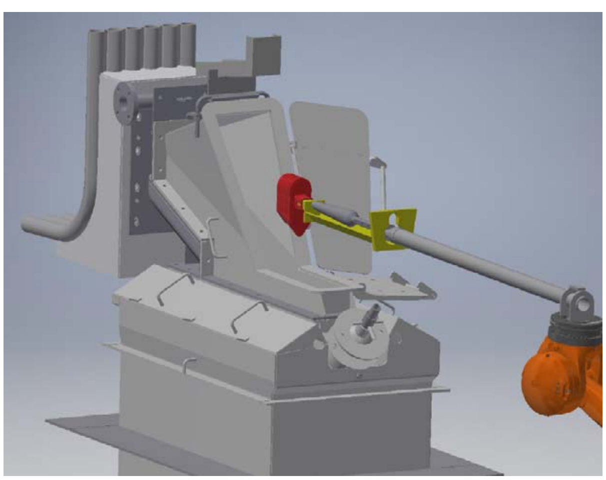
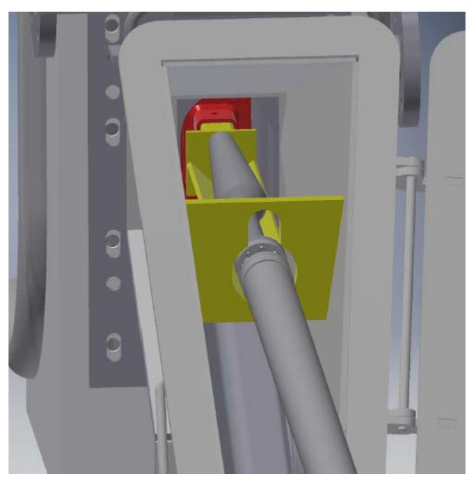
ROBOT PLUG INSTALLATION

Metris
ANDRITZ Digital Solutions





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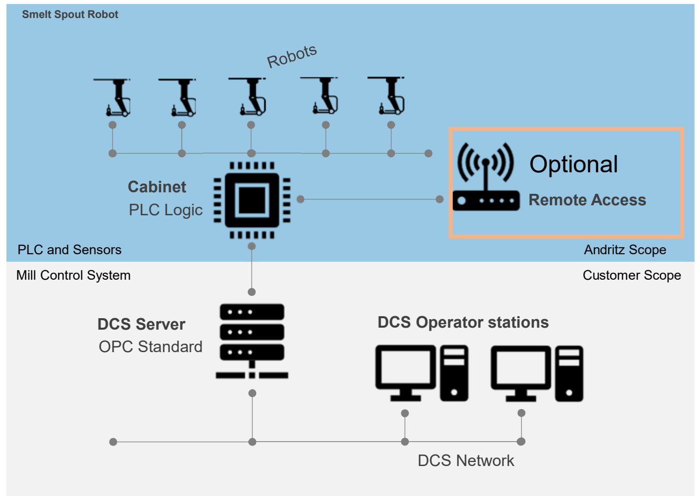
ROBOT CONTROL TOPOGRAPHY

Automated smelt spout cleaning and sampling technology

The robot can be controlled locally or remotely

- The robot has a local PLC which handles communication between the DCS and PLC as well as between the PLC and the robotic system.
- The control unit provides a possibility to access robot's working area by using local touch panel
- **Option**: The process cameras in the control room ensures that some malfunctions can be reset remotely



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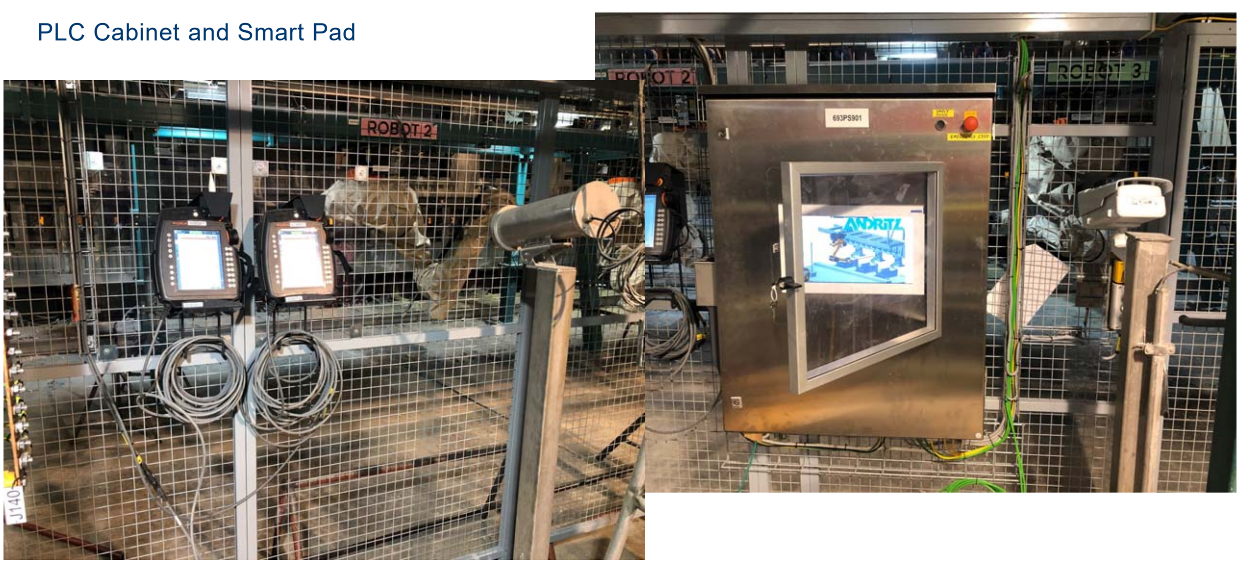
INSTALLATION PICTURES

PLC Cabinet and Smart Pad



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AUTOMATIC TOOL CLEANING STATION

Metris
ANDRITZ Digital Solutions

- Cleans the robot's spout cleaning tool automatically
- Optimizes cleaning tool lifecycle
- Less heat stress for tool tip
- Keeps measuring environment stabile

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CHAPTER 3
AUTOMATED SHATTER JET POSITIONER

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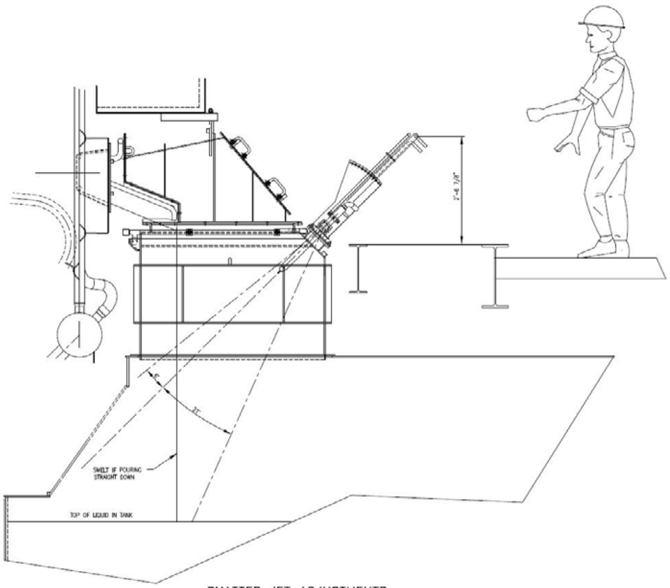
SHATTER JET POSITIONER MOUNTED ON HOOD



SHATTER JET ADJUSTMENTS

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AUTOMATED SHATTER JET

Visual analysis tool maps dispersion field

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CHAPTER 4
AUTOMATED MEASUREMENT OF REDUCTION EFFICIENCY

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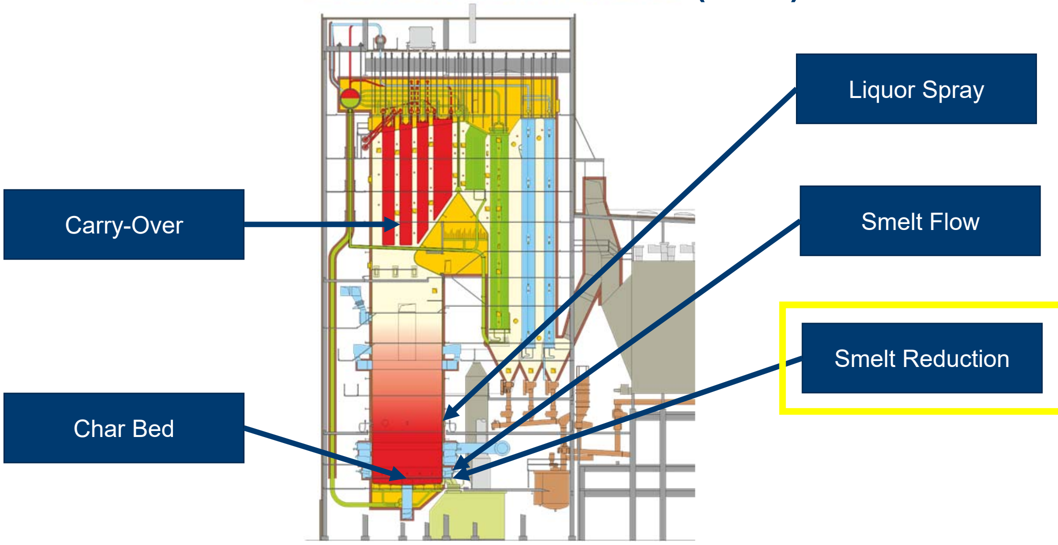
ANDRITZ SMART PRODUCTS
ANDRITZ VISUALIZATION ANALYSIS (AVA)



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SMELT REDUCTION ONLINE ANALYSIS

Automated tool cleaning

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SMELT REDUCTION ONLINE ANALYSIS

Automated smelt sampling

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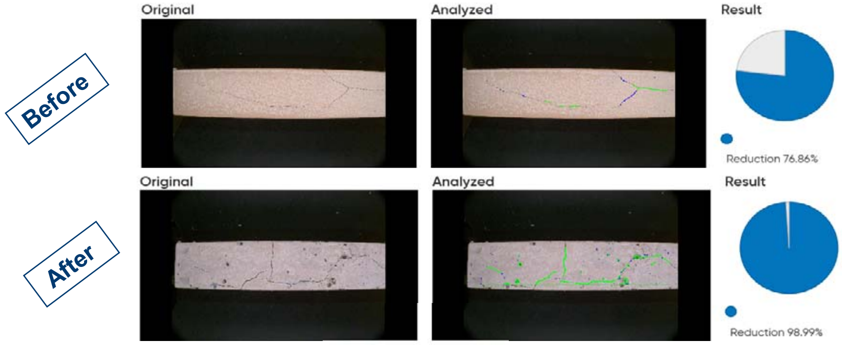
SMELT REDUCTION



AVA DATA

- Reduction %
- Reduction boiler average
- Reduction per spout

CONTROL

- Fuel supply
- Char bed control
- Air distribution
- Green liquor quality

SAVINGS AND BENEFITS

- Improved chemical recovery
- Real-time analysis
- Less laboratory analyses
- Reduced carry-over

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SMELT REDUCTION

AVA Recovery Boiler Toolbox

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PRELIMINARY SCHEDULE

- Critical path components have been both PLC and Robot
- Schedule volatility
- Generally allocate 12-15 months until ready to install

Questions?

Reach out to:

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Greg Imig, Product Manager
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greg.imig@andritz.com

LEGAL DISCLAIMER

SpoutRunner™ Spout Cleaner

Prepared by Simon Youssef
Pulp & Paper Product Support

SpoutRunner™
Automatic Spout Cleaning – Patent Pending

Customer Requested Design Criteria

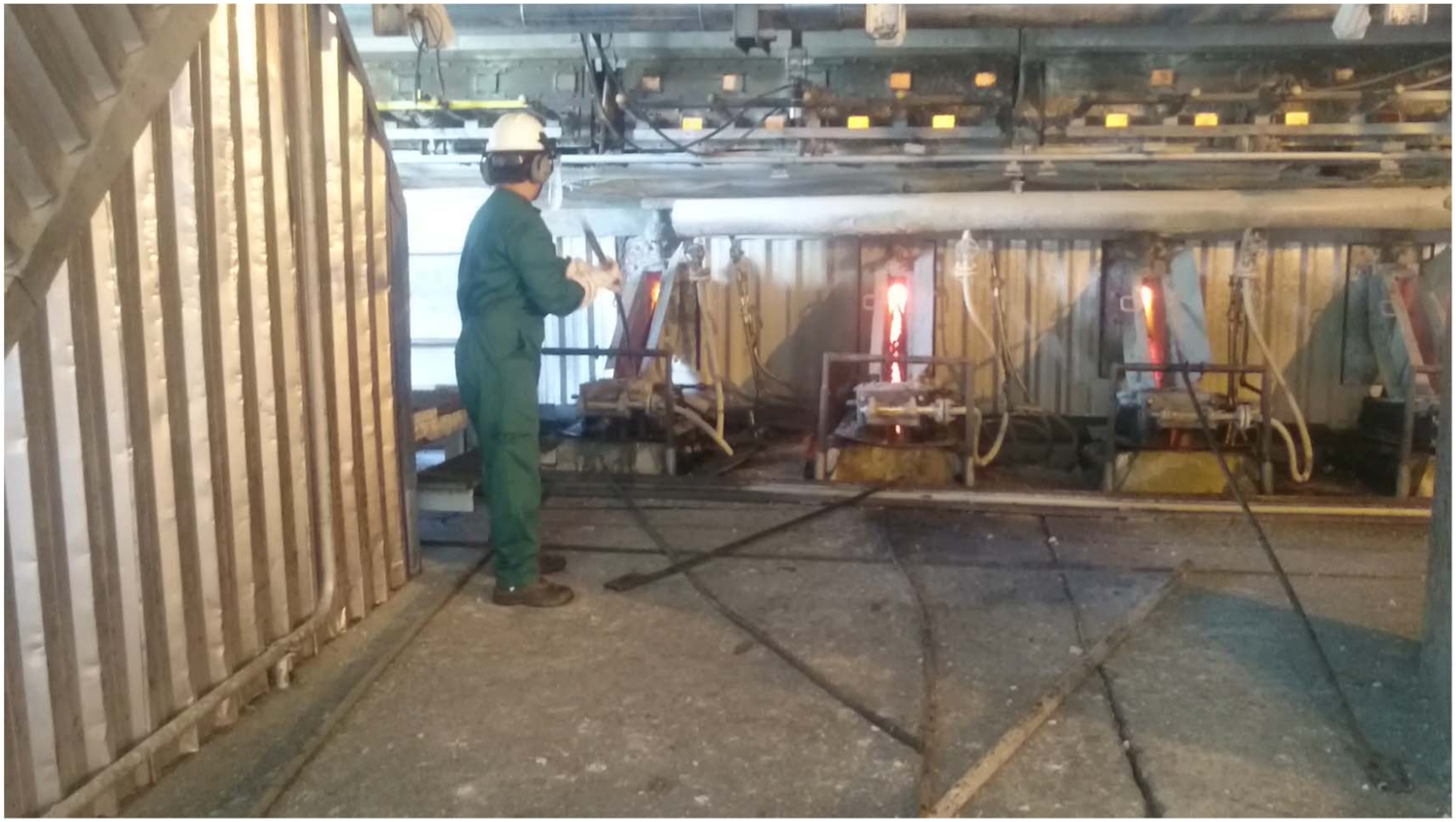
- Minimize the operators time on the spout deck.
- Maintain the ability to manually clean the spout and hood.
- Leave the spout deck open and freely accessible.
- Automatically clean the spout trough and opening.

SpoutRunner™
Automatic Spout Cleaning

Benefits:

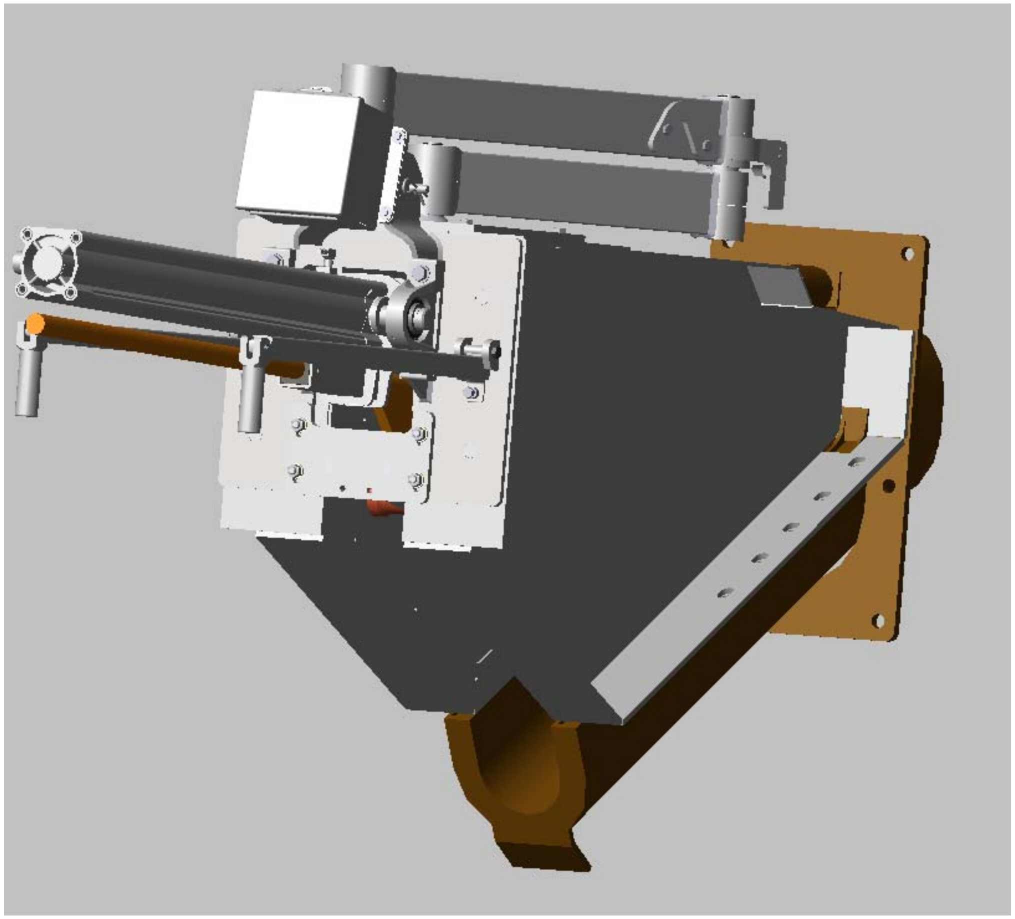
- A safer environment
- Steady and consistent smelt flow through the spout
- Full visibility of the spout & smelt opening, with the integrated Camera (Option)
- Reduction of thermal cycling of the spout

Traditional Spout Cleaning



SpoutRunner™ Description

- Consists of a hinged pneumatic drive, when activated, uses gravity and pneumatic force to deploy a cleaning head into spout



SpoutRunner™ Description

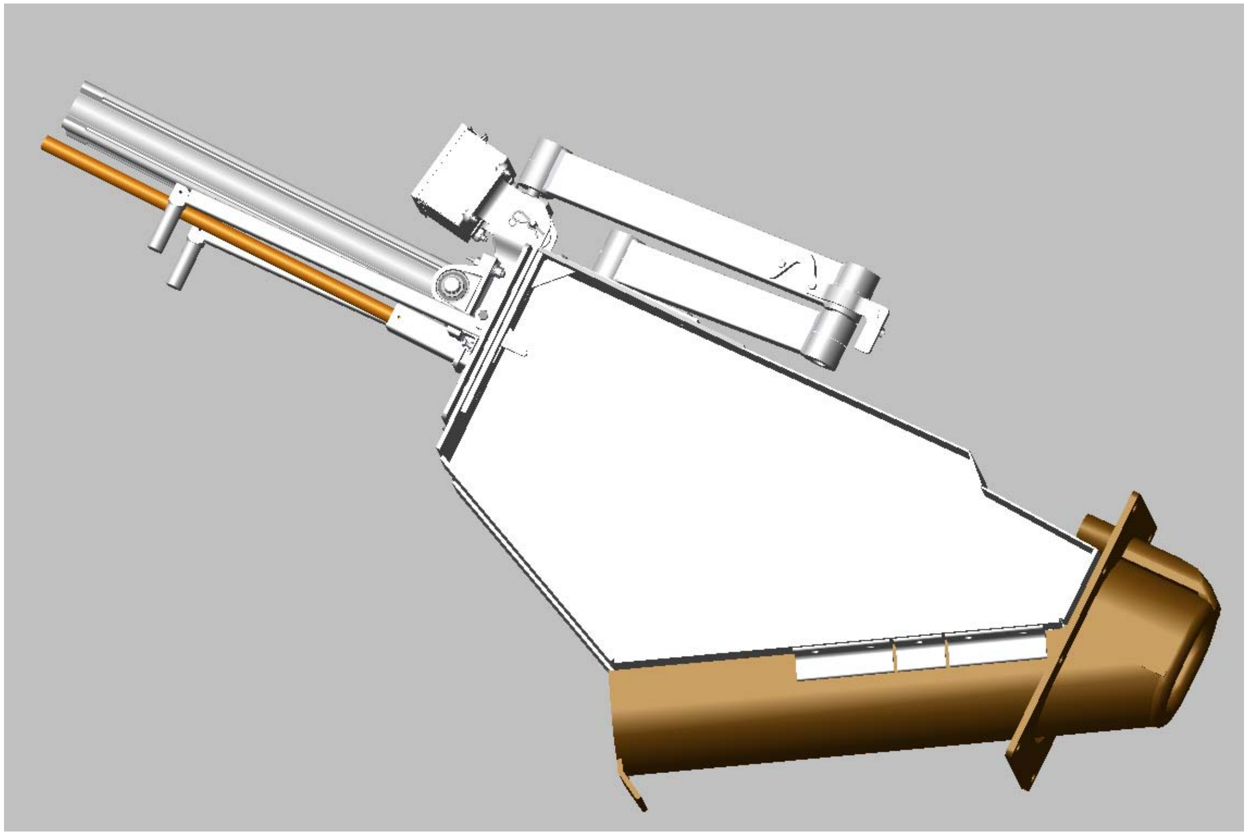
- Engagement of the head blades with the spout wall and the traversing action helps dislodging hardened Smelt deposits

SpoutRunner™ Description

- Cylinder fully retracts after a cleaning cycle placing the cleaning head at a safe distance away from spout

SpoutRunner™ Description

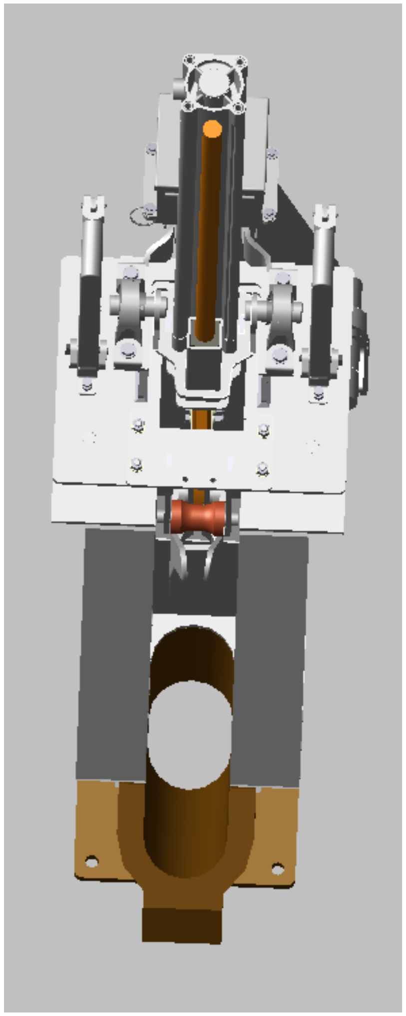
- SpoutRunner™ system bolts directly to existing spout or hood



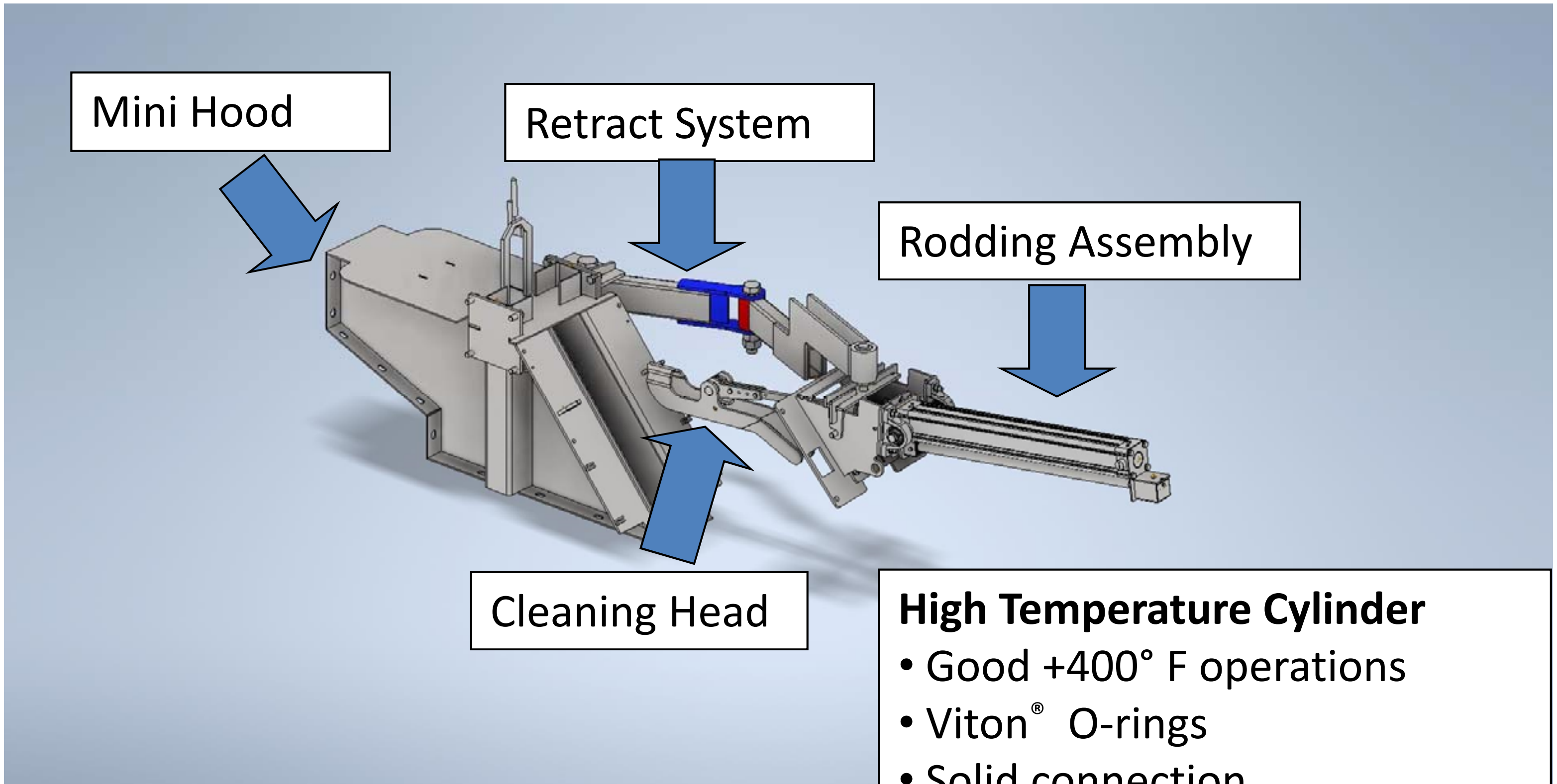
Automatic Spout Cleaning

SpoutRunner™ Description

- Open cleaning head design allows open view of spout

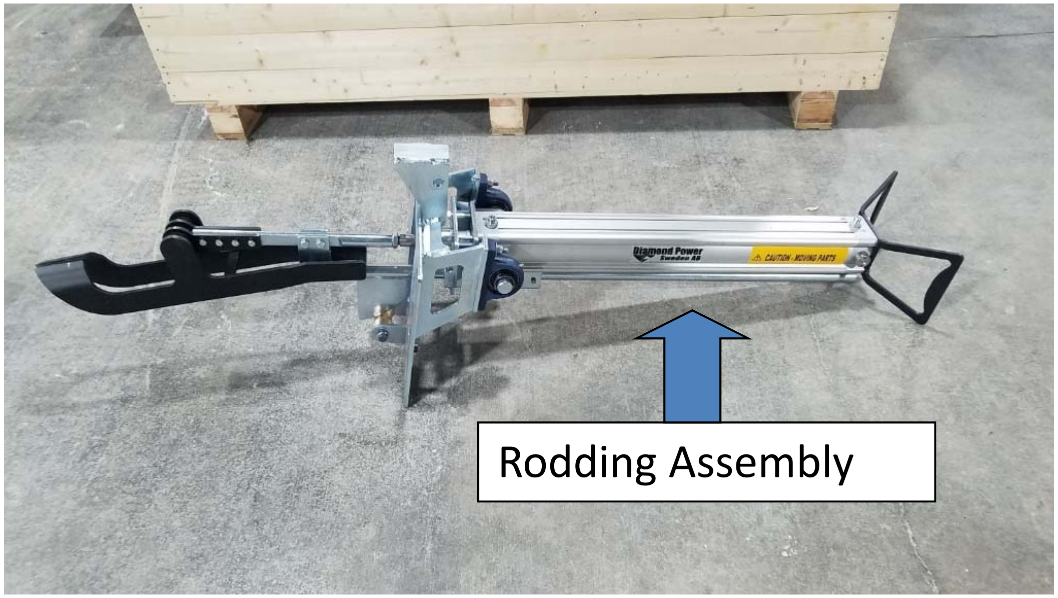


SpoutRunner™ Components



High Temperature Cylinder
- Good +400° F operations
- Viton® O-rings
- Solid connection

SpoutRunner™ Components



Guide Bushing

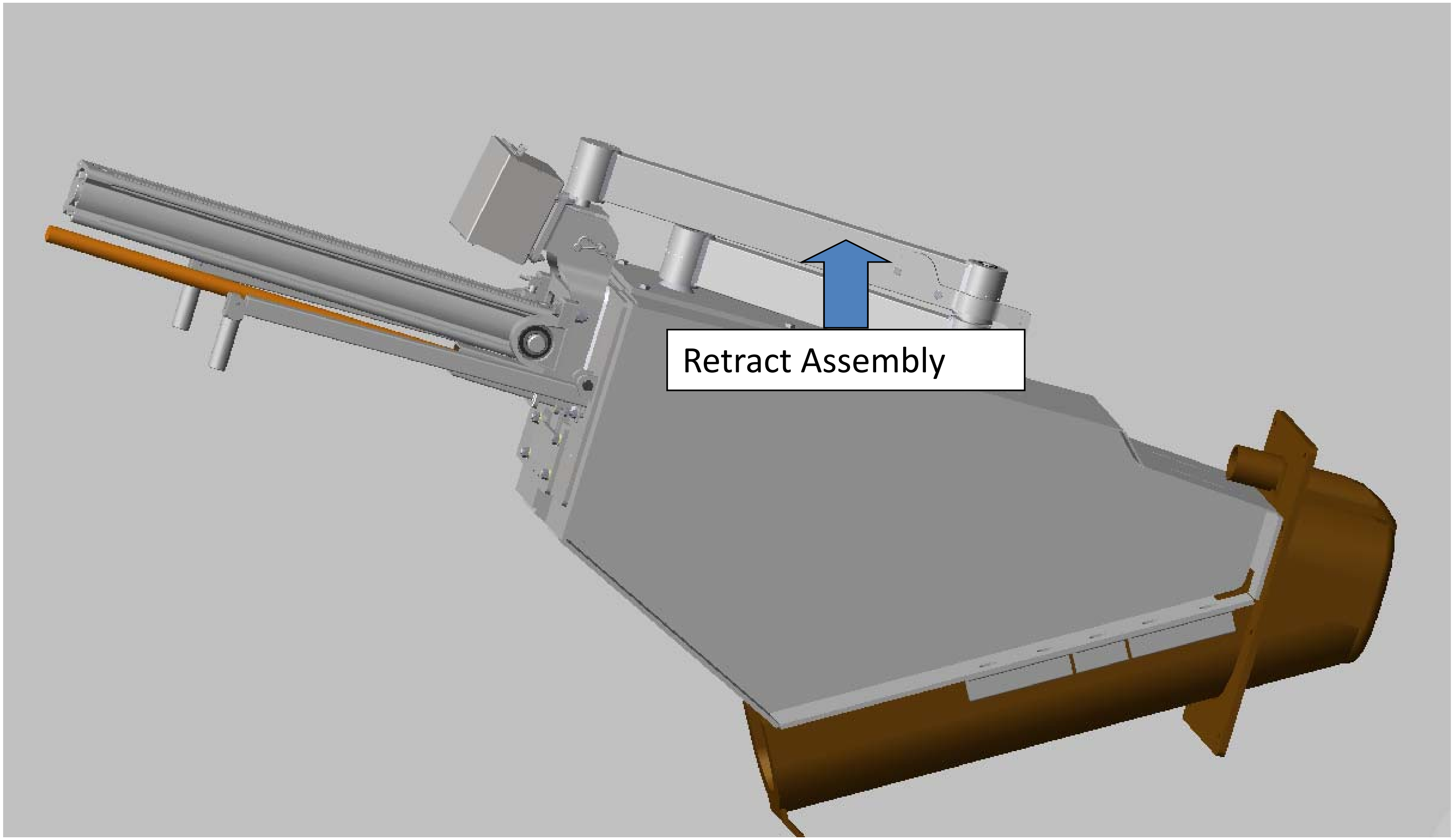
- Cleaning head is made from durable boron-alloyed hardened steel
- Double-acting cylinder 80 or 100 mm diameter, (3.5” or 4”)
- Cylinder stroke can vary depending on the design
- Air cylinder is constructed with high temperature Viton seals
- Zinc-coated structural steel
- PTFE bushing with stainless steel power embedded

  Allows for smooth operation

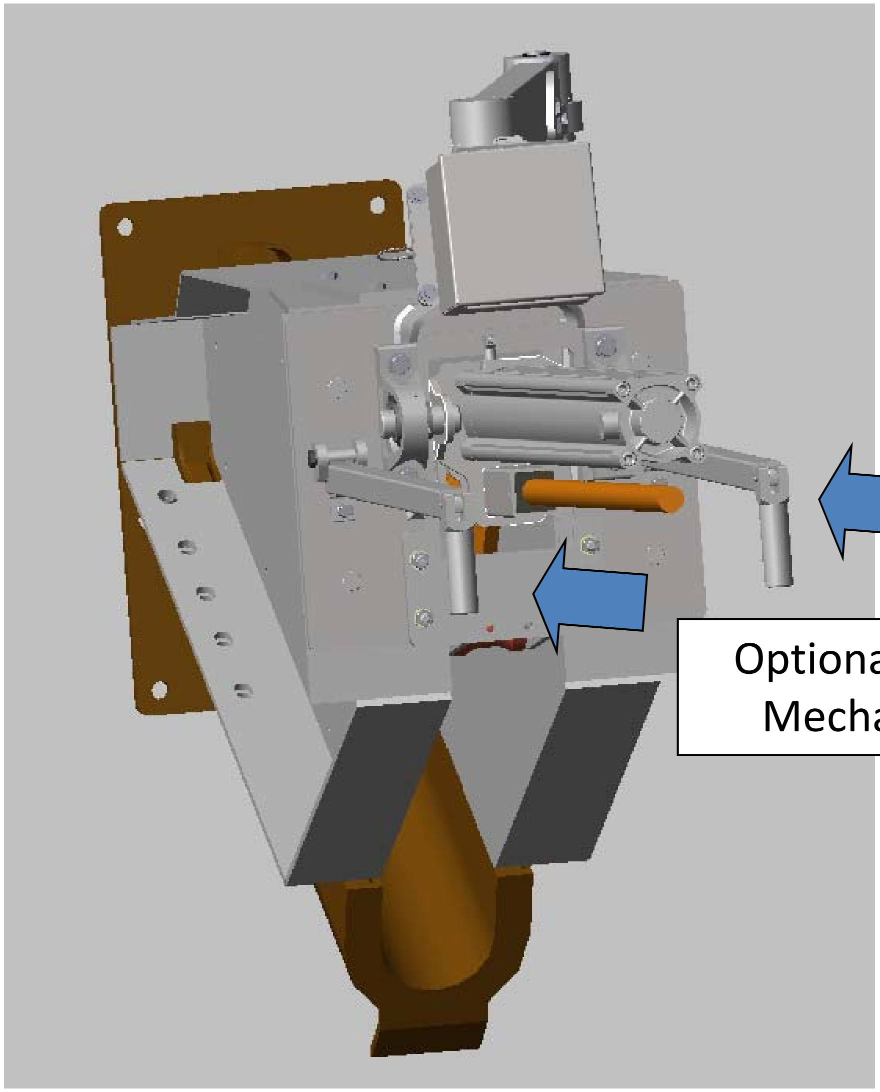
  Allows for long service of the bushing

  Shorter bushing reduces chance of binding

SpoutRunner™ Components



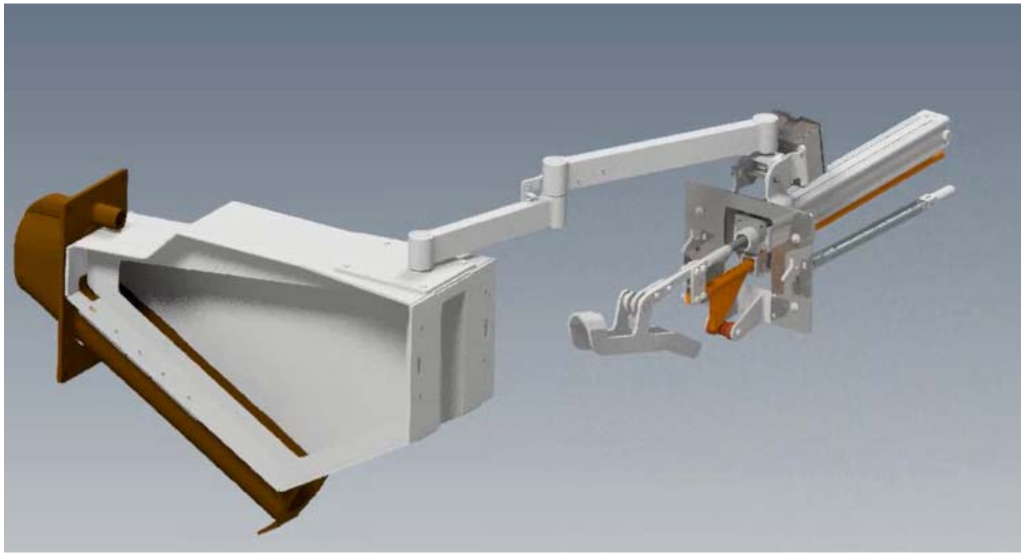
SpoutRunner™ Components



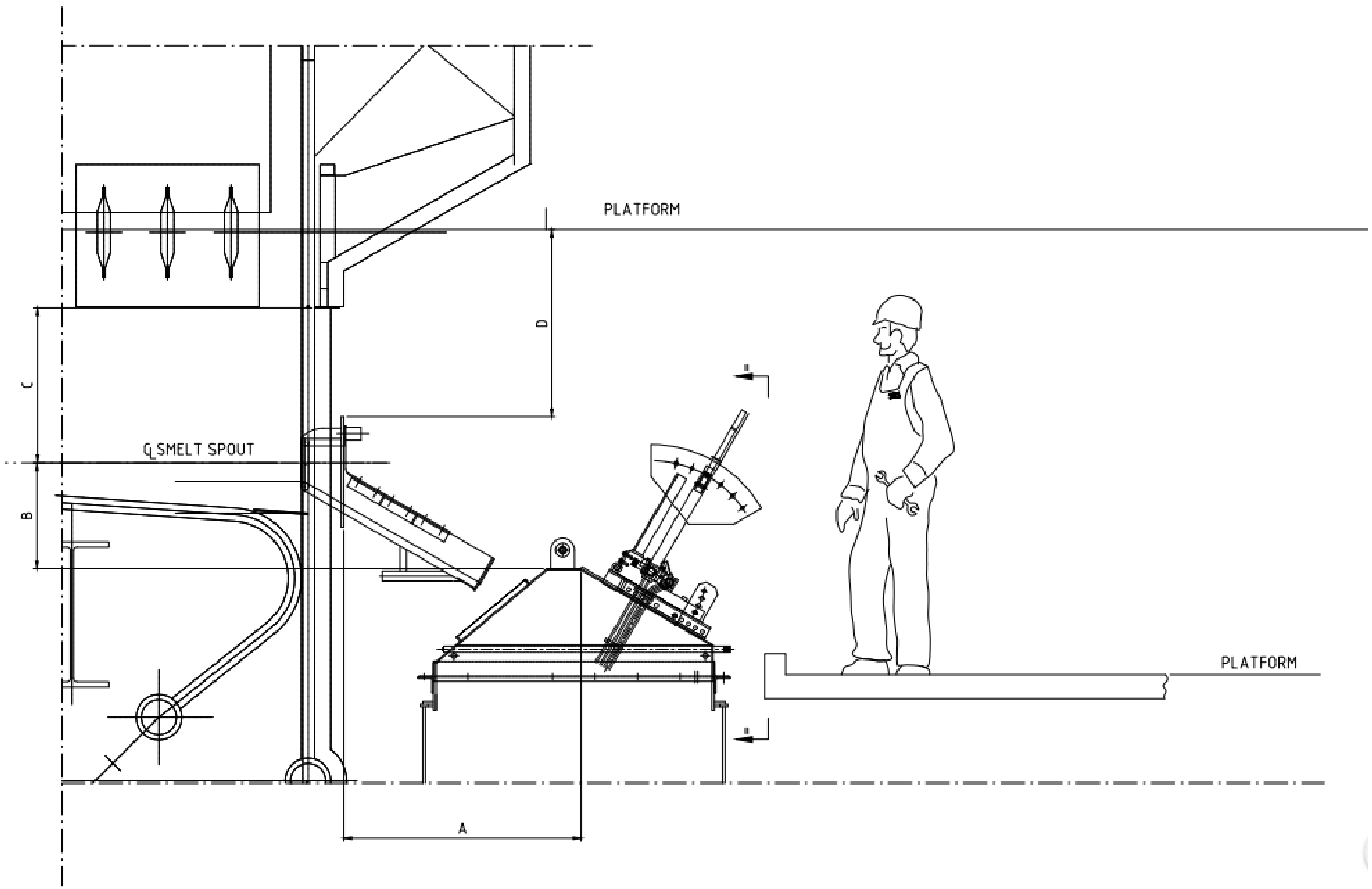
Optional Latch Mechanism

Steps to Retract the Rodding Assembly

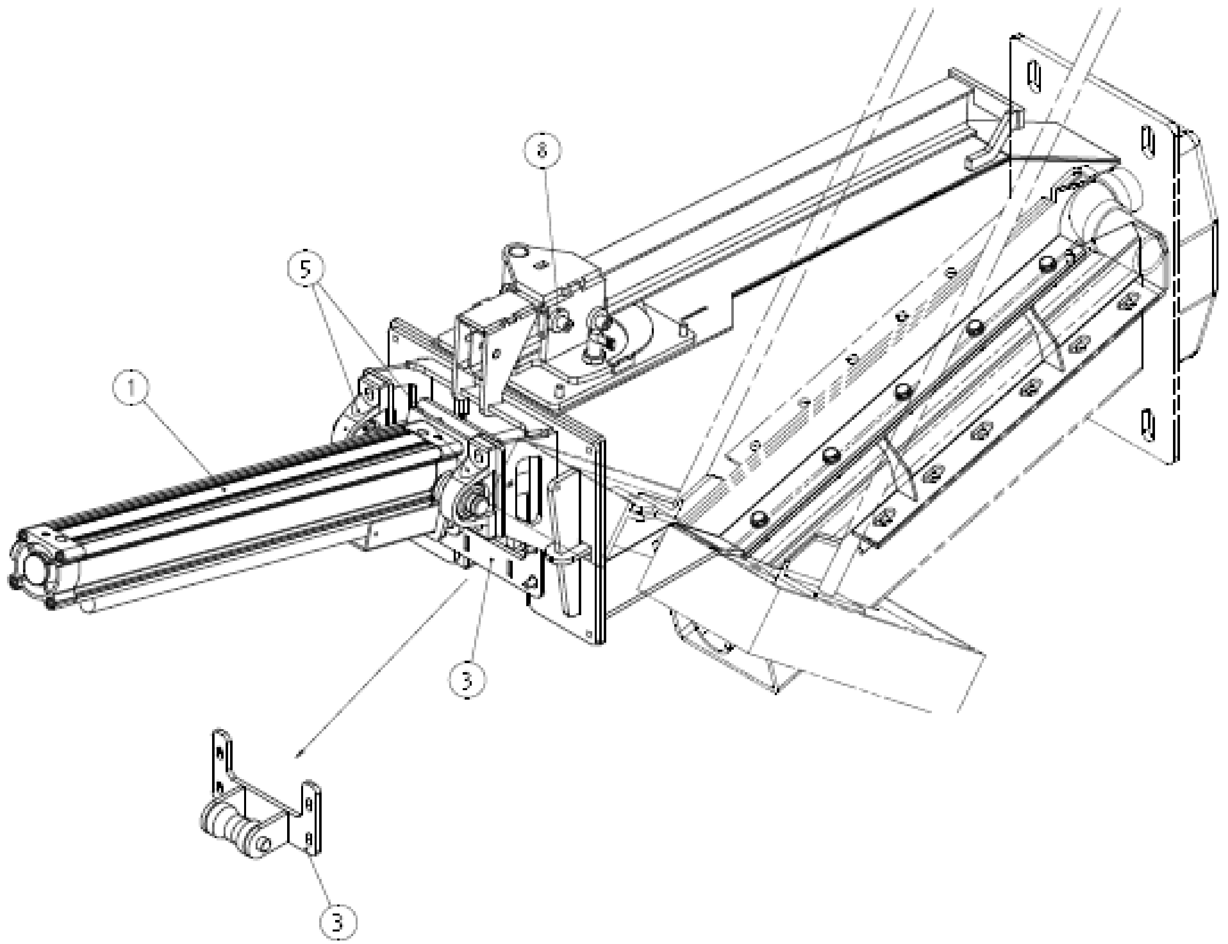
- Remove latches holding rodding assembly to the hood
- Push back the rodding assembly with brackets attached to the rear of cylinder
- Once the rodding assembly is totally retracted swivel the assembly to the left or right



Measurements Needed for Engineering



Typical Contract Drawing



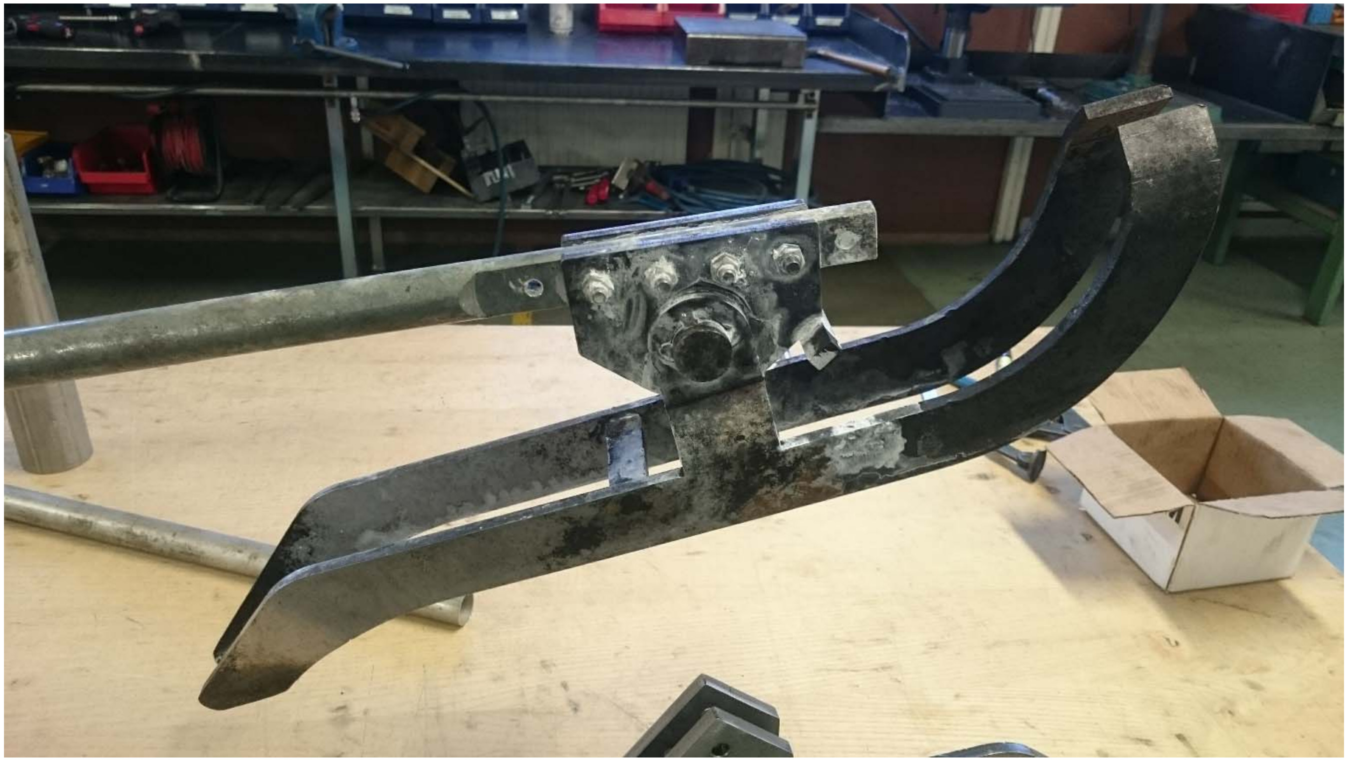
SpoutRunner™ Components
US Mill – In Operation Since Dec 2019

SpoutRunner™ Cleaning Heads

SpoutRunner™ Cleaning Heads

SpoutRunner™ Cleaning Heads

SpoutRunner™ Cleaning Heads



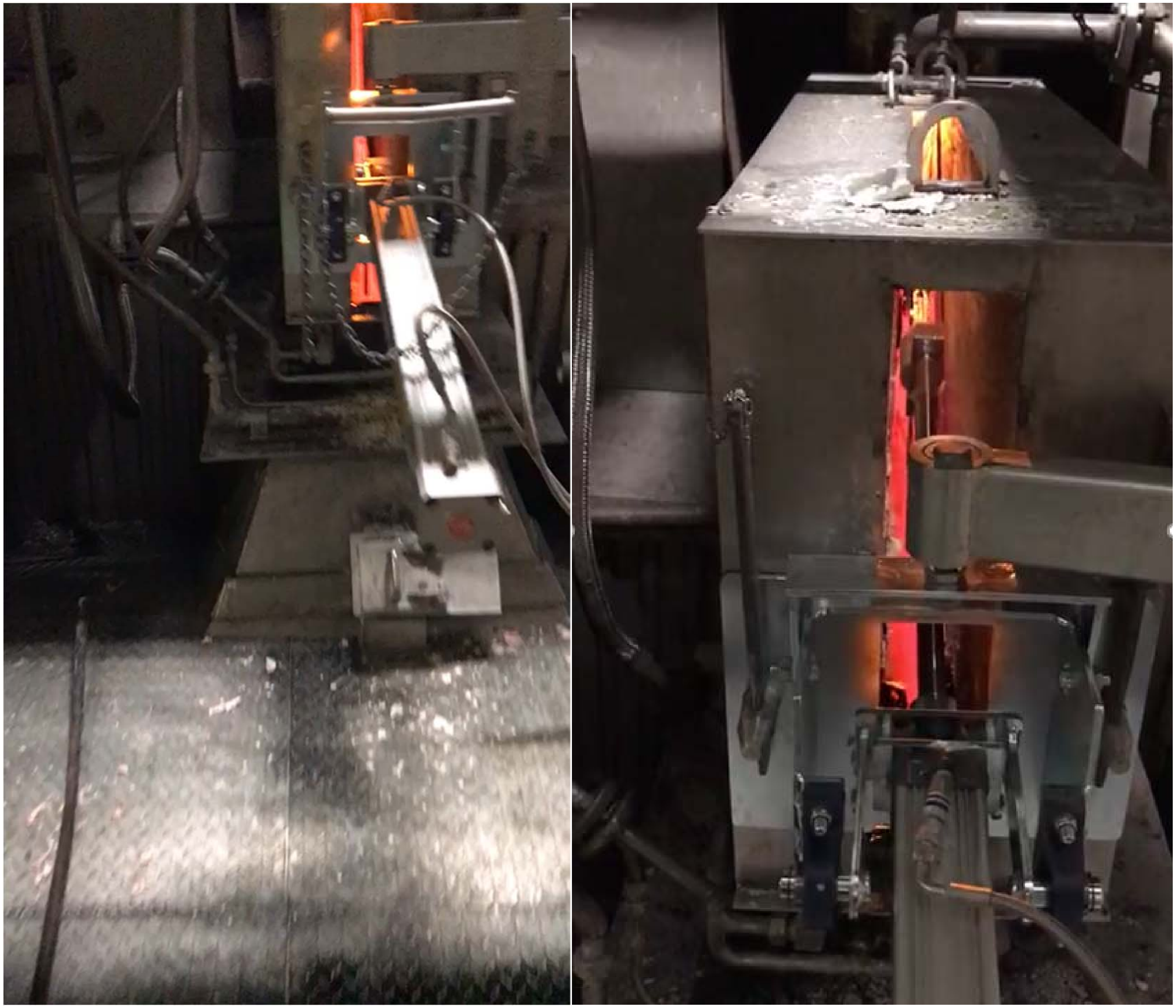
Cutting head after 6 weeks in operation
(cleaning every 9 minutes 24/7)

Spout Cleaning

Spout Cleaning

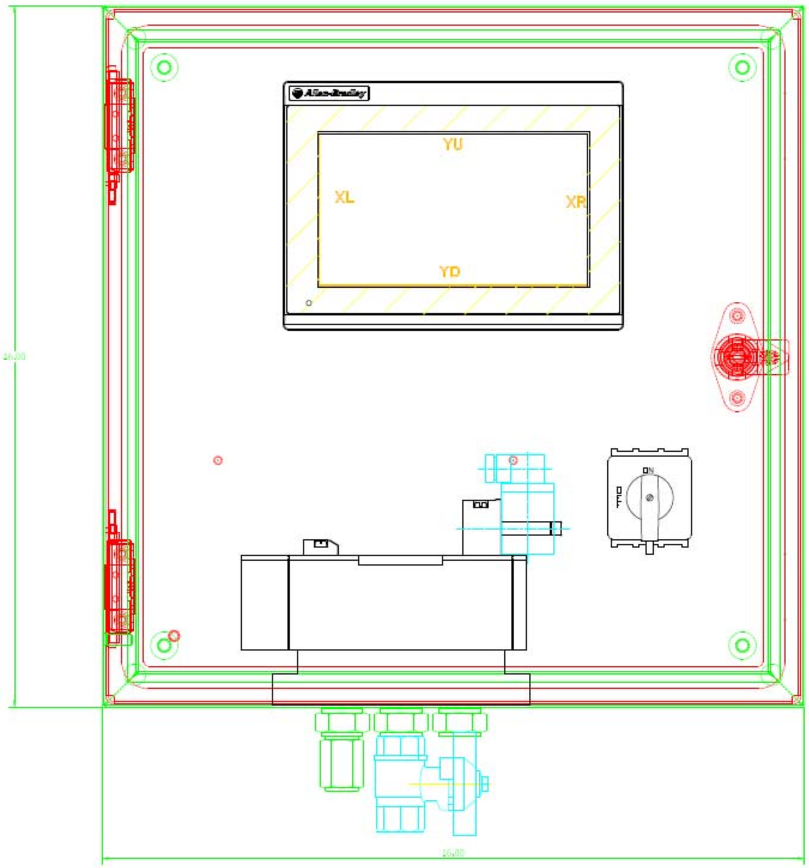
Spout Cleaning

Spout Cleaning

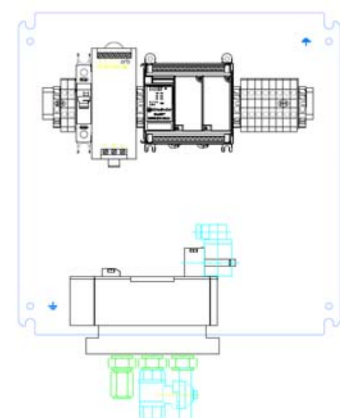


Retract Side Mounted

Control Box

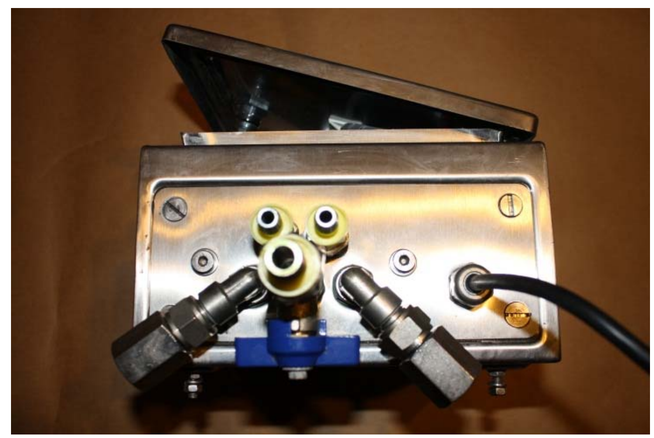


- Control box SS NEMA 4X
- Manual push button
- Lockable
- Remote/Local/Off Switch
- Local HMI
- Encloses and protects:
    - PLC & I/O
    - Electrical connections
    - Solenoid valve

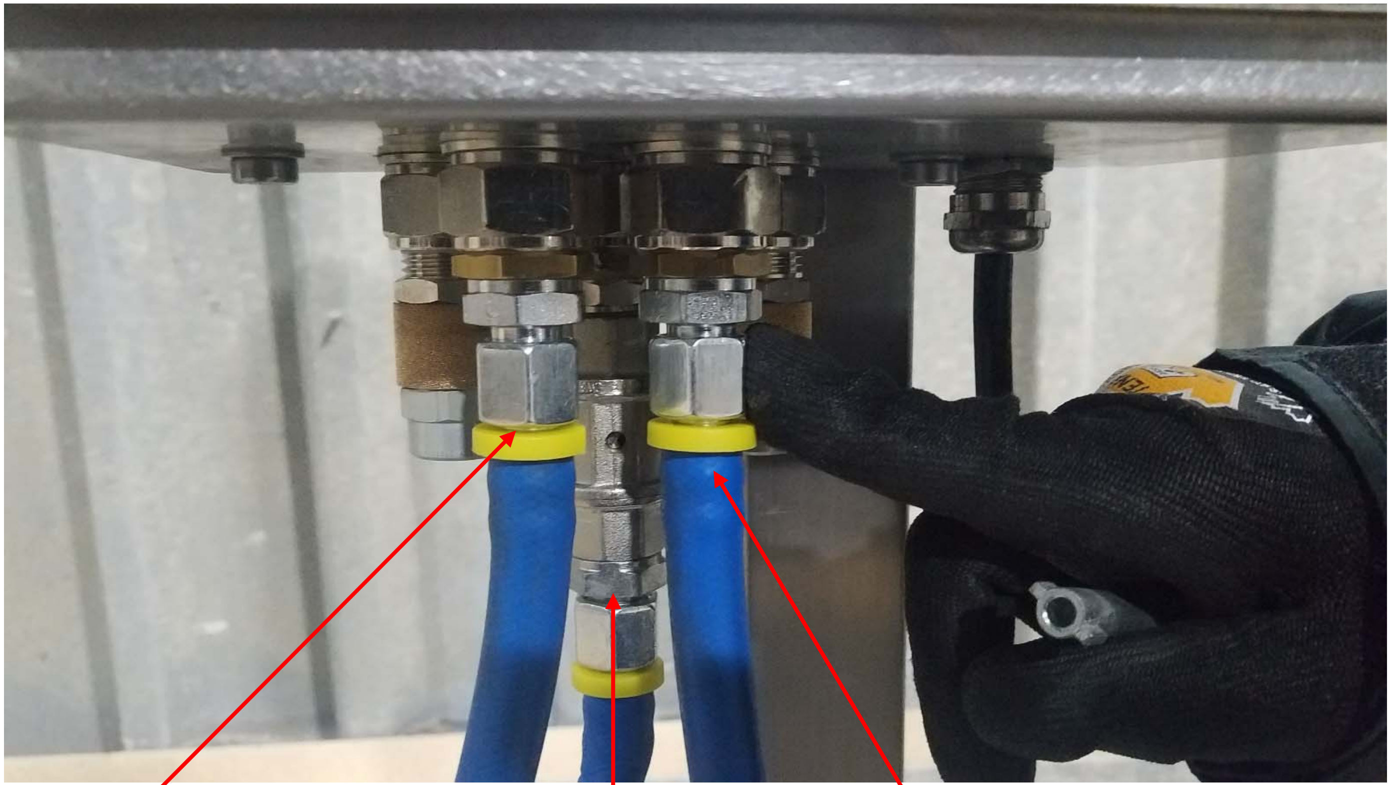


Control Box

- Control box SS NEMA 4X
- 4-way control valve that provides air flow control to the cylinder
- Isolation ball valve on each control box that is self bleeding
- Air exhaust silencers
- Local push button



Control Box

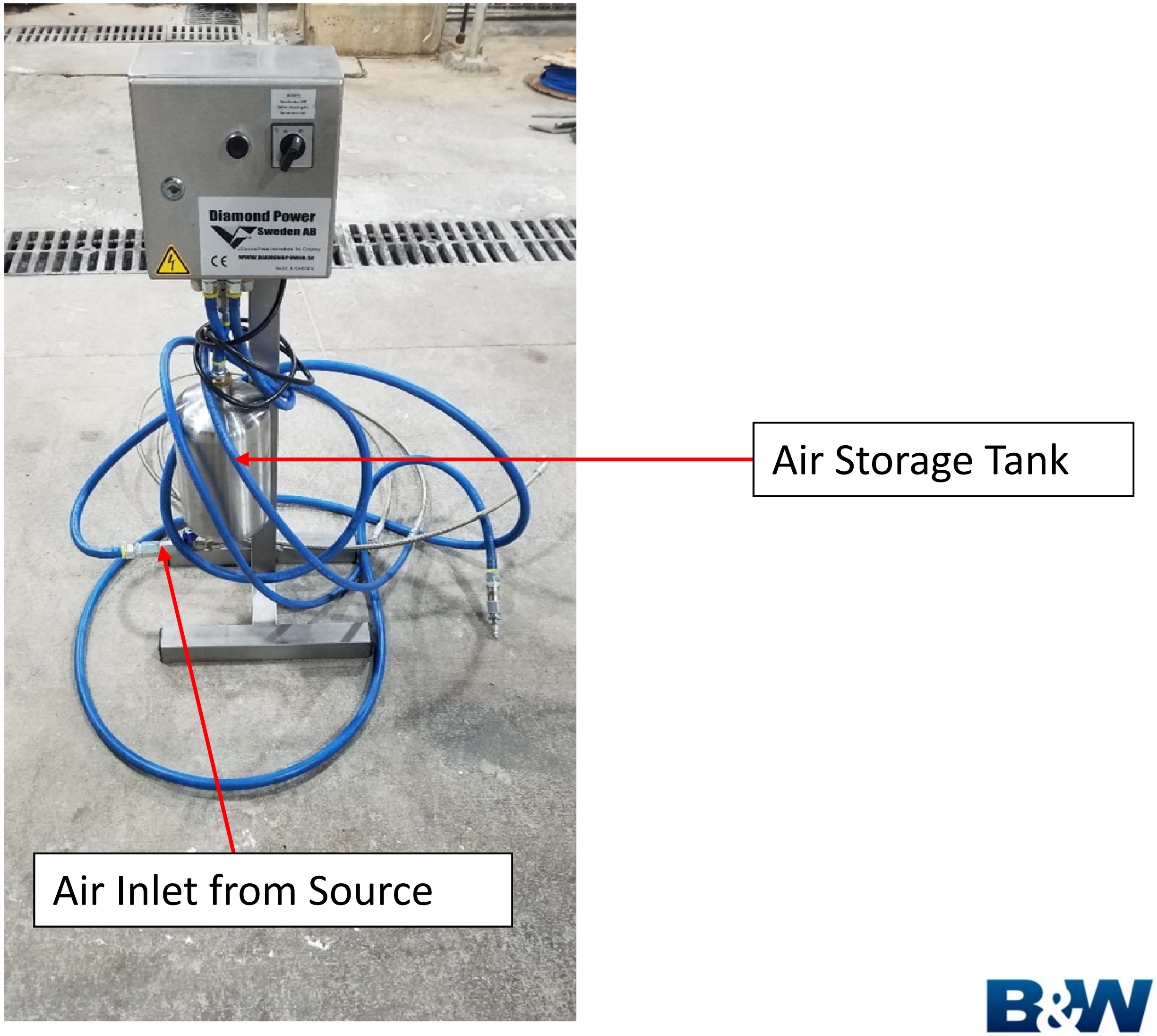


Air Outlet to Front of Cylinder

Air Inlet from Storage Tank

Air Outlet to Rear of Cylinder

Control Box


Diamond Power
Sweden AB
Air Storage Tank
Air Inlet from Source

Installations Kraft Recovery Boilers

- Kotkamills, Finland
- Sca Obbola, Sweden
- Stora Enso Imatra, Finland
- Suzano, tres lagoas, Brazil
- Paper Excellence Skookumchuck, BC Canada
- GP Big Island (Soda Process)

Spout Installation - Finland

Manual Spout Cleaning

Automatic Spout Cleaning

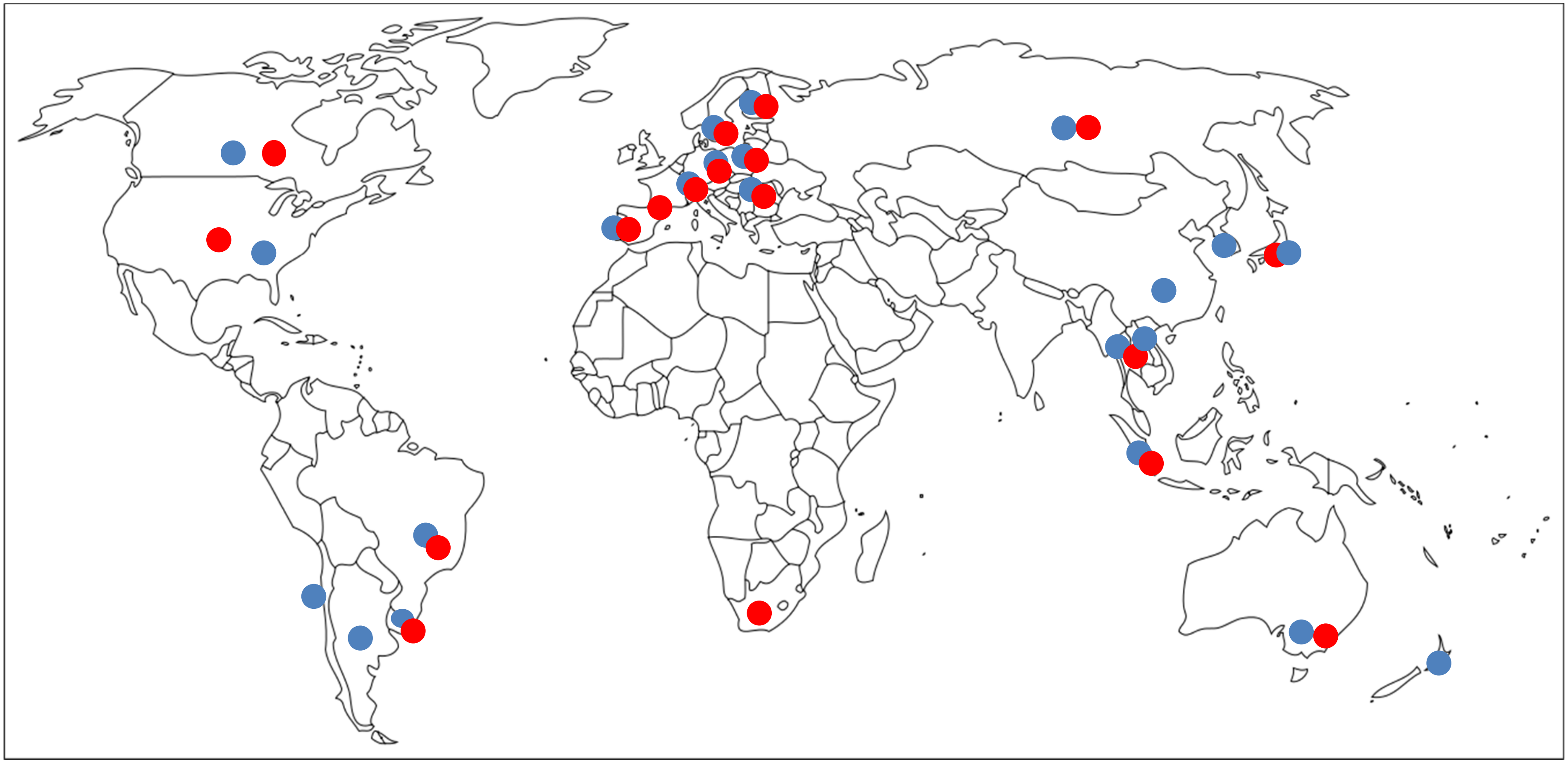
Spout Condition

Manual vs. Auto Cleaning - Finland

Spout after one Year of Manual Spout Cleaning

Spout after one year of Automatic Spout Cleaning

References



- ~15,000 rodders in 27 countries
- +250 char bed cameras in 20 countries

Questions

The Winning Formula – Valmet Chemical Cleaning & Boiler Tube Deposit Inspections

Rick Baxter – Service Manager, Cleaning Business
Dylan Price – Service Engineer, Chemical Cleaning

Valmet

The Winning Formula – Valmet Chemical Cleaning & Boiler Tube Deposit Inspections

Today's agenda

- Chemical Cleaning
- Cleaning Preparations and Program
- Chemical Cleaning & BTDI
- Boiler Tube Deposit Inspections (BTDI)
- References / Case Studies
- Key Takeaways

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Why Chemically Clean a Boiler?

Having a boiler with excessive deposits on the internal tube surfaces can result in:

- Major tube failures (potential for smelt water reaction)
- Reduced boiler efficiency
- Higher fuel costs

When Is Chemical Cleaning Necessary?

- When the deposit weight density is:
  - Below 1000 psi – 20 to 40 g/ft^2
  - 1000 to 2000 psi – 12 to 20 g/ft^2
- Immediately after a feed water quality excursion
- When localized heavy deposits are discovered
- After tube failure due to overheating

Valmet

Will Chemical Cleaning Corrode My Boiler?

When performed by qualified field service advisors, the answer is no.

Exceptions:

- Excessive circulation rates of acid solvents may result in unacceptable metal loss.
- When the dissolved iron concentration reaches 12,000 ppm, the corrosion rate may increase significantly therefore the boiler must be immediately drained to sewer.

Any leaks that occur in a system during a properly managed chemical cleaning are the result of:

- Dissolution of deposit plugging a pin hole or crack
- Cleaning a corroded weld

Basic Chemical Cleaning Program

1. Mechanical preparation
2. Preheat boiler with hot water
3. Solvent stage(s) with monitoring
4. Rinsing with demin water
5. Neutralization + passivation
6. Final rinse with hydrotest
7. Inspection
8. Tube and header hand flushing (If required)
9. Reinstatement
10. Final hydrotest
11. Suspended solids removal and final passivation

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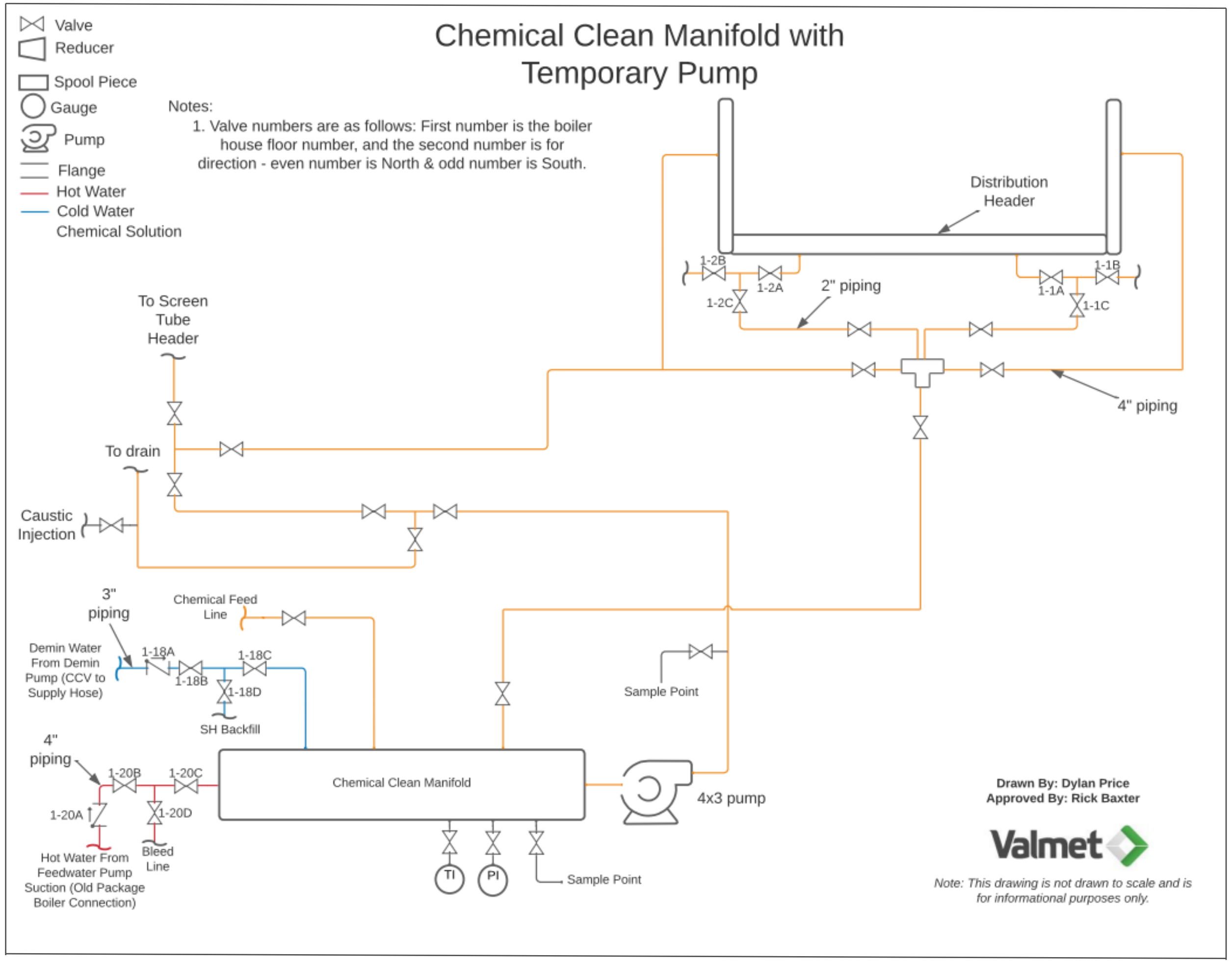
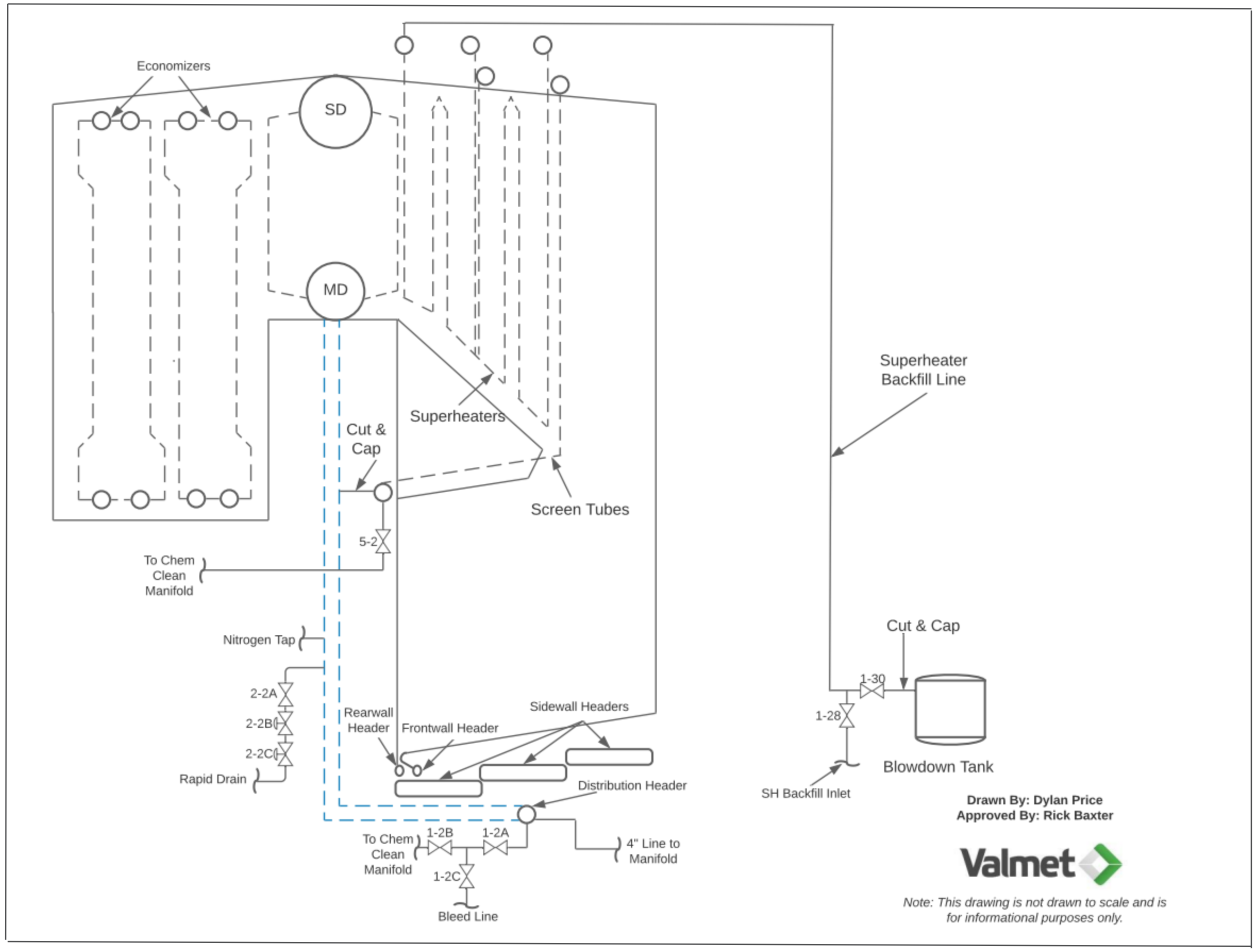
Major Phases of Boiler Chemical Cleaning

1. Planning
2. Procurement
3. On-Site preparations
4. Cleaning execution
5. Inspection and reinstatement
6. Startup



Planning

1. Boiler chemical cleaning planning should take place concurrently with overall outage planning
2. Customer provided with detailed drawings
3. Valves are labeled
4. Procedures are customized for successful chemical cleaning of individual boilers



Procurement

1. Chemical cleaning service company
2. Mechanical contractor
3. Hand flushing services (if needed)
4. Rental items

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On-Site Preparations

1. All contract personnel safety trained
2. Valmet Project Manager on-site minimum of 3-4 days prior to the start of cleaning
3. Valmet Service Engineer on-site 2 days prior to the start of cleaning
   - Assist Chemical Cleaning Vendor onto Site
   - Derive Valve Positioning List
4. Mill operators assigned and briefed (2 on 24 hour per day basis)

Valmet

Cleaning Execution

1. A Collaborative effort between Advisor/Project Manager, Mill Operations, and the Chemical Cleaning Service Company
2. Cleaning procedure executed
3. Flows, temperatures, and levels routinely monitored and recorded by operators, advisors, and chemical cleaning vendor
4. Boiler walked routinely for leak detection
5. Chemical cleaning vendor operates temporary equipment, handles chemicals, and routinely analyzes solvent for concentrations and pH.
6. Advisor/Project Manager/Service Engineer interprets results of solvent analyses to determine solvent progress and initiation of next stage

Inspection

1. Inspection nozzles/handhole Caps removed
2. Headers and drums inspected
3. Sludge removed from tubes and headers

Lower waterwall header post manual flushing

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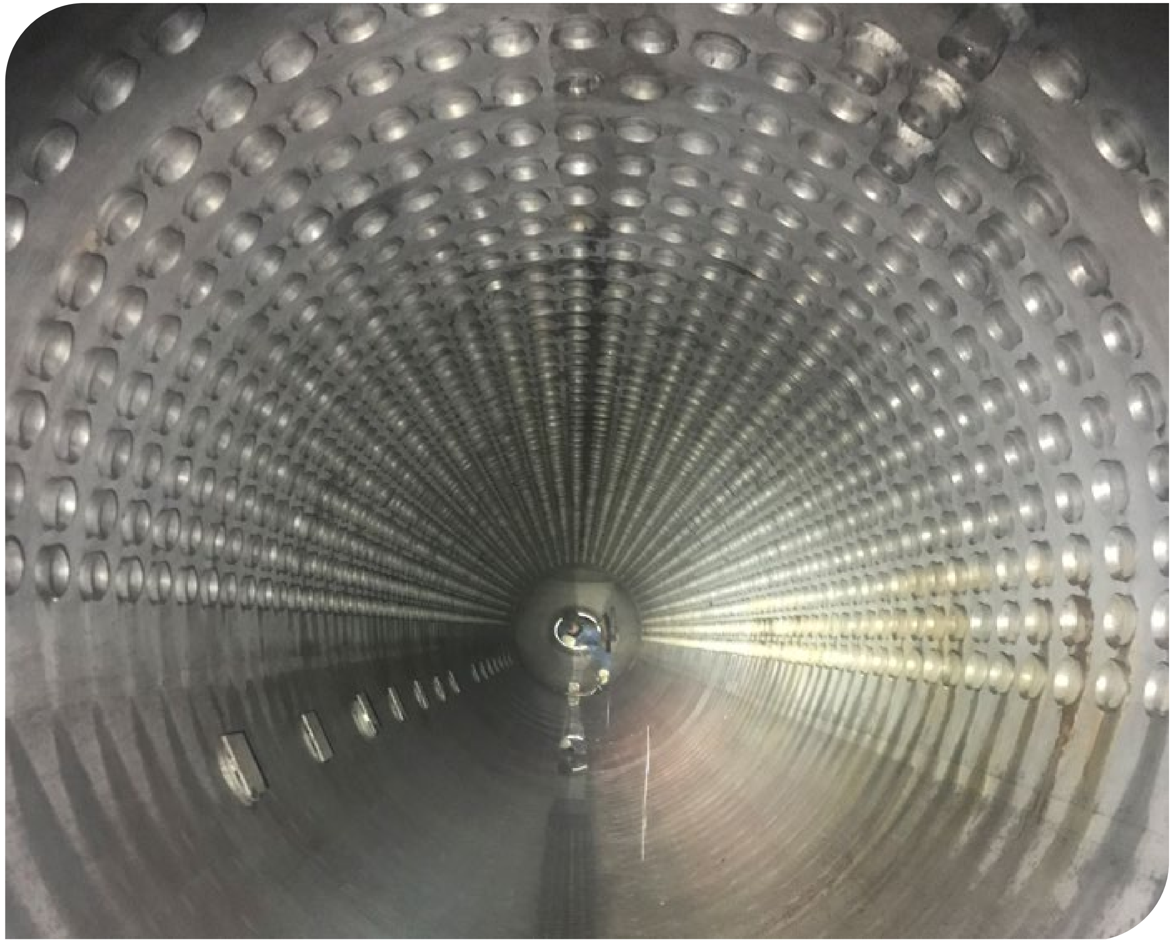
Steam drum prior to hand flushing

Mud drum prior to hand flushing



Startup

Final Passivation and Suspended Iron Reduction

- Add chemicals at Steam Drum
- Fire boiler to desired PSI
- Reduce suspended iron in boiler to 1 ppm or less using blowdown procedure

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Valmet Boiler Tube Deposit Inspection

What is Boiler Tube Deposit Inspection (BTDI)?

How can it help my boiler operate more efficiently?

BTDI is a process that measures scales on the internal surface of boiler tubes using an advanced, proprietary ultrasonic technique. It allows for the:

1. **Early detection of scale accumulation**
   - Continued operation with low quality water and poor water chemistry will lead to thick scales demanding early acid cleaning
2. **Assessment of acid cleaning needs**
   - Tube samples may not be representative, as they are sometimes not taken in the most critical parts of the boiler
3. **Assessment of acid cleaning results**
   - Can be used to verify baseline deposit readings after a chemical cleaning project has been completed

Boiler Tube Deposit Inspections Video

Improving boiler performance and safety

Valmet

The Method

Deposit scale on internal surfaces is measured using an advanced ultrasound technique

Scale thickness can be measured reliably even in relatively clean tubes

Thicker scales requiring removal by chemical cleaning can also be detected

Typically, 150 – 250 points are measured in one twelve-hour shift

The results include internal scale thickness measured in mils which can be converted into DWD results in g/ft^2

Did you know?

Valmet is the ONLY company that does Boiler Tube Deposit Inspections!

Valmet

Recovery Field Services Delivers Accuracy, Reliability

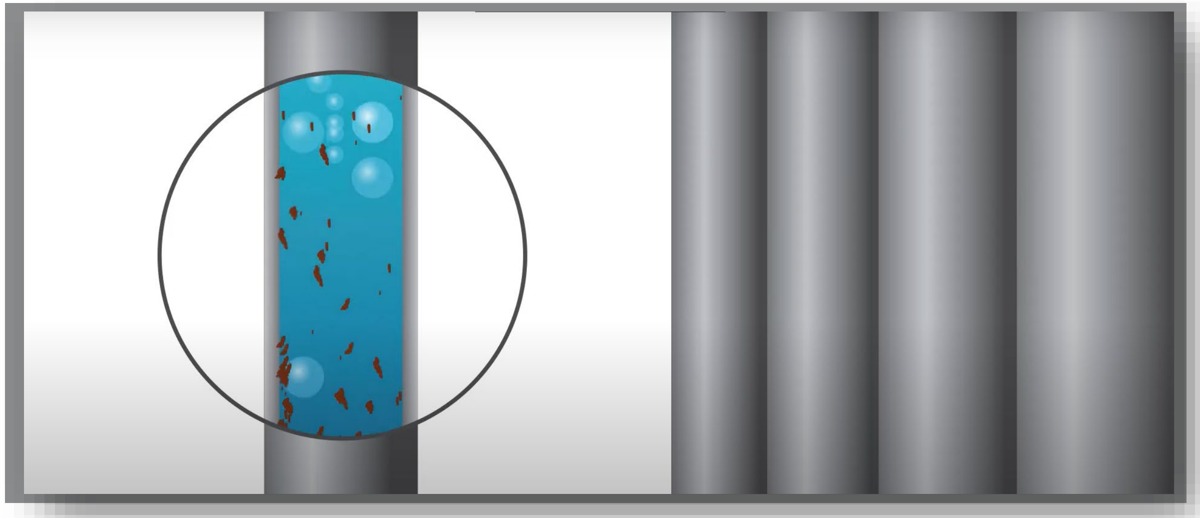
Successful boiler tube inspection at Graphic Packaging – West Monroe Mill

"Valmet is providing a quality service with their tube deposit scanning. Very accurate results compared to laboratory deposit weight densities. We were very impressed. Also, the technicians were on the spot and very punctual with getting the data and reporting out."

Engineering Services Manager | West Monroe, LA
Graphic Packaging International

Mill needed a way to measure the deposit thickness of the harmful scale inside the boiler tubes of Recovery Boilers #4 and #5.

Valmet's Recovery Field Services team conducted a Boiler Tube Deposit Inspection complete with full report, analysis and recommendations.



Results

- Delivered results with high-level accuracy
- Exceeded customer expectations
- Mill personnel impressed with reliability of Recovery Field Service technicians

References

North America:

- MWV, Covington, VA, PB9, 2015
- Clearwater, McGehee, AR, RB, 2021
- Domtar Ashdown, AR, RB2, 2021
- Domtar, Bennettsville, SC, 2016
- Domtar, Kingsport, TN, 2016
- Domtar, Windsor, Quebec, RB1, 2016, 2019, 2021
- WR, Phenix City, AL, 2016, 2017, 2018, 2019, 2020, 2021, 2022
- WR, Covington, WV, 2022
- Domtar, Johnsonburg, PA 2017
- Domtar Hawesville, KY, RB3 & RB4, 2020, 2021
- RFP, St Felicien, Quebec, 2017
- RFP Calhoun, TN, RB3, 2019, 2020
- GRU DeerHaven BFB, Gainesville, FL 2018
- Sappi Somerset, ME RB1, HFB1 & HFB2, 2018
- WR, Longview, WA, 2018
- GP, Toledo, OR, RB1, 2022
- Port Townsend Paper, WA, RB1 2019
- Irving Pulp & Paper, Saint John, NB, RB 2019
- IP Grande Prairie, Alberta, 2017, 2019
- IP Savannah, RB15, 2019
- IP Ticonderoga, NY, RB, 2019
- IP Columbus, MS, RB1, 2019
- IP Pensacola, FL, RB1, 2019, 2022
- IP Springfield, OR, RB4, 2020, 2021, 2022
- IP Bogalusa, LA, RB20 & 21, 2020, 2021
- IP Prattville, AL, RB1, 2020, 2021, 2022
- IP Mansfield, LA, RB1, 2020, 2021, 2022
- IP Mansfield, LA, RB2, 2022
- IP New Bern, NC, RB1, 2020
- IP Port Wentworth, RB3, 2022
- IP Flint River, Oglethorpe, GA, 2022
- GPI West Monroe, LA, RB4 & RB5, 2021
- GPI Texarkana, AR, 2022
- Woodland Pulp, ME, RB3, 2018, 2019, 2020, 2021, 2022

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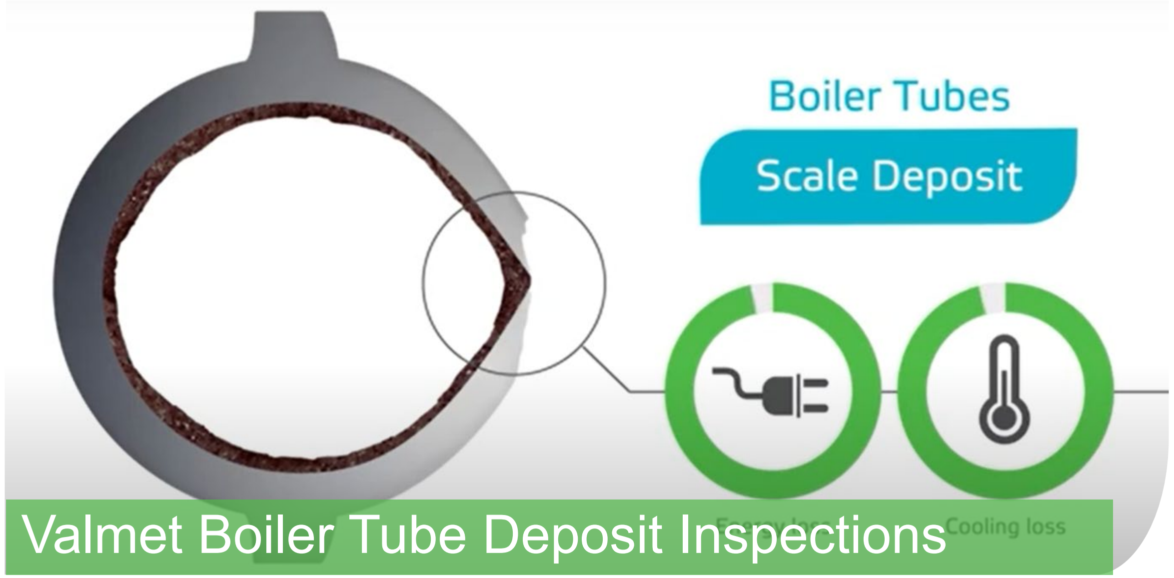
Key presentation takeaways


Chemical Cleaning & BTDI – A Power Couple

- Bundled services allow for cost savings and customized chemical cleaning program
- Valmet offers both equipment and services
- Chemical cleaning + BTDI = Outage time savings



Valmet Boiler Tube Deposit Inspections

- Non-destructive ultrasound technology
- Valmet is the ONLY company who can perform Boiler Tube Deposit Inspections

Valmet

Additional information

Boiler Tube Deposit Inspection

- BTDI website
- BTDI video
- BTDI case study

Chemical Cleaning

- Chemical cleaning website
- Chemical cleaning for recovery & power boilers
- Chemical cleaning case study #1
- Chemical cleaning case study #2

The Winning Formula – Valmet Chemical Cleaning & Boiler Tube Deposit Inspections

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Valmet FORWARD

Using Machine Learning to Identify Root Causes of Recovery Boiler Fouling Rates

Andrew Jones & Jerry Ng

International Paper

Summary

- Machine learning tools can extract actionable information on recovery boiler operating parameters from the rate of change in strain gage weights
- Care must be taken in how data is prepared in order to maximize the value of the information generated
- Predicting fouling rates is possible but requires different techniques than those used to determine the effect of boiler operating parameters
    - The value of these predictions need to be explored further

Method Used

- Data downloaded either directly from OSI PI or from the 1 hour aggregated Braincube database for the recovery boiler
  - Braincube allows for filtering and averaging of the data and lagging if data from upstream of the recovery boiler is used (i.e. evaporator parameters such as boiling point rise)
- Data set consists of two primary groups of variables
  - Process variables that can be manipulated by the operators of recovery boilers – 1 hour averages
  - “Deltas” of the strain gage weights
    - Most typically we use the change in total superheater weight over the aggregation period of the Braincube database usually 1 hour.
  - Originally we used a moving average of these weights in an attempt to reduce the impact of sootblowers, this was not a good idea from a numerical standpoint as it caused complications in validating the strength of the model by inducing auto-correlation

Method Used

- Data is typically filtered so that only "full-load" of the recovery boiler is used as this is normally the operating condition where fouling is a concern.
    - Full load is normally 80-100% of the normal operating range of the recovery boiler as measured by steam flow
    - Co-firing of auxiliary fuel is included as these can often be high fouling conditions
- Machine learning method that has been most successful is the use of Gradient-Boosted Trees (more on this coming up…)
- All models are validated with data not used to train the models
- Typically 3 to 6 months of hourly data is used to build the models with a large number of potential features (process variables that may explain the rate of fouling)
- Relationships between the features and the label (Fouling Rate) are developed using Accumulated Local Effects (ALE) plots that are generated from the solution Gradient Boosted Trees.

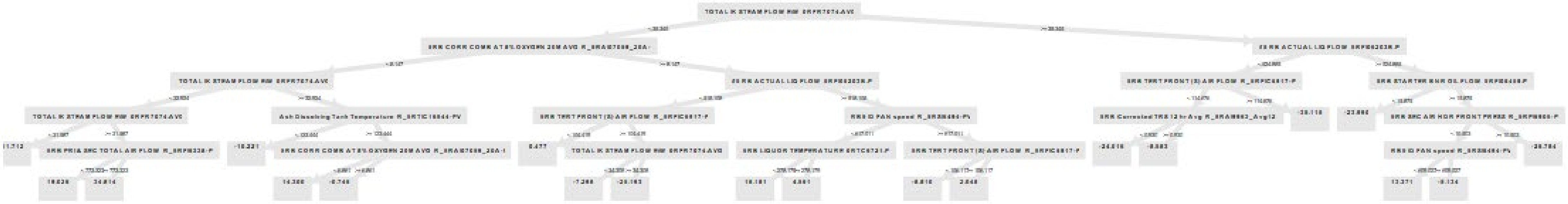
Gradient Boosted Trees

- One of the most powerful methods to develop predictive machine learning models
- A decision tree is built (shown on next page) that identifies the feature that best segments the label into different ranges
  - For example if excess air is less than 4.0% then the fouling rate is in the range is less than 100 lbs/hr, if it is greater than 4.0% then the fouling rate is greater than 100 lbs/hr
  - This “split” does not necessarily separate all of the data, but it is the “BEST” split to separate the data available at that point of the analysis.
  - The tree then branches downward in a way that continues to split the data in the most significant way from a statistical standpoint
  - The number of splits, the depth of the tree and certain criteria on how the variables are chosen for the splits are parameters that are controlled in the modelling process.

Gradient Boosted Trees

- A second decision tree is then built to predict the difference between the label and the prediction generated by the first tree
- This is continued iteratively until the best fit is obtained, this may take a large number of trees (typical 50-200)
- Overfitting is controlled by cross validation versus a portion of the data not used to build the model, tree building stopped when it does not better predict the “held-out” data – “cross-validation”
- Many techniques can be used to best build a “family” of trees best suited to model a particular process
- A final check on the strength of the model is done with data that has been held out from the entire process to see how well the target variable can be predicted.

Decision Tree – This is the First Tree of the ensemble built using the Gradient Boosted Tree Machine Learning Tool – the model used actually has 106 of these trees as the "best" model



You can see how it is very challenging to view and present these trees!!

Model Performance and VIPs

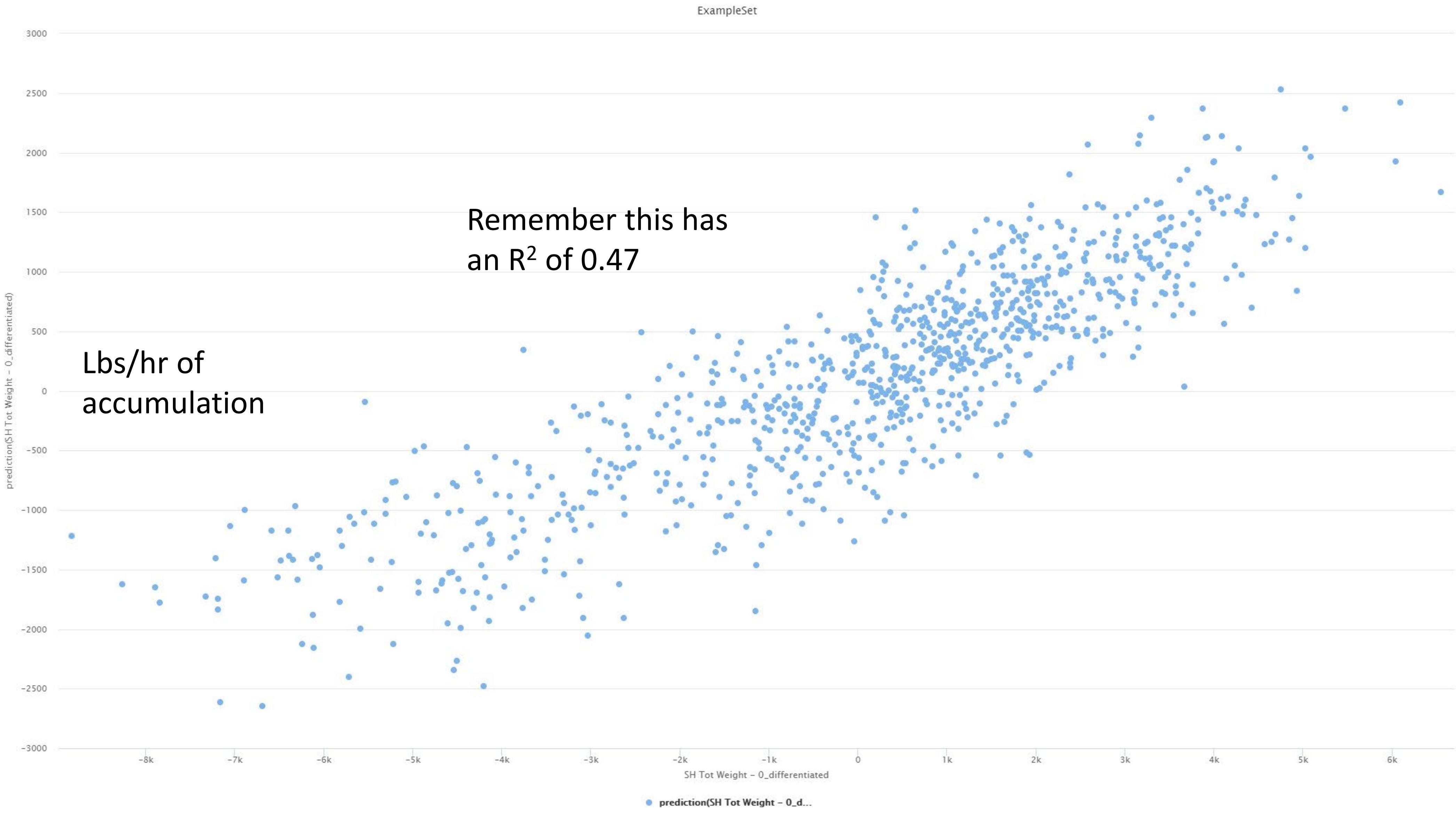
```
Model Metrics Type: Regression
 Description: N/A
 model id: rm-h2o-model-production_model-2906
 frame id: rm-h2o-frame-production_model-2906
 MSE: 3639368.2
 RMSE: 1907.7128
 R^2: 0.472368
 mean residual deviance: 3639368.2
 mean absolute error: 1472.3959
 root mean squared log error: NaN
Variable Importances:
```

Variable	Relative Importance	Scaled Importance	Percentage
TOTAL IK STEAM FLOW E/W 0RFR7074.AVG	24759455744.000000	1.000000	0.163494
5RB SEC AIR HDR FRONT PRESS R_5RPI6905-PV	14672083968.000000	0.592585	0.096884
#5 RB ACTUAL LIQ FLOW 5RFI06203B.PV	12801754112.000000	0.517045	0.084534
RB5 ID FAN speed R_5RSI6494-PV	12563651584.000000	0.507428	0.082962
5RB CORR COMB AT 8% OXYGEN 20M AVG R_5RAI07059_20A-PV	11582675968.000000	0.467808	0.076484
5RB TERT AIR HDR FRONT PRESS R_5RPI6907-PV	11037844480.000000	0.445803	0.072886
5RB TERT AIR DUCT PRESS R_5RPIC6373-PV	9920230400.000000	0.400664	0.065506
Ash Dissolving Tank Temperature R_5RTIC16544-PV	8702906368.000000	0.351498	0.057468
5RB PRI & SEC TOTAL AIR FLOW R_5RFI6338-PV	8571506176.000000	0.346191	0.056600
5RB TERT FRONT (S) AIR FLOW R_5RFIC6917-PV	6824795648.000000	0.275644	0.045066
Percent Tertiary Air	5578608640.000000	0.225312	0.036837
5RB PRI FRONT (S) AIR FLOW R_5RFIC6915-PV	5240470016.000000	0.211655	0.034604
5RB Corrected TRS 12 hr Avg R_5RAI9963_Avg12h	4988245504.000000	0.201468	0.032939
5RB STARTER BNR OIL FLOW 5RFI06459.PV	4502010880.000000	0.181830	0.029728
5RB LIQUOR TEMPERATURE 0RTC6721.PV	3845398784.000000	0.155310	0.025392
Ash rotary feeder current R_5RII06334-PV	3318419968.000000	0.134026	0.021913
5RB LOAD BURNER OIL FLOW 5RFI06460.PV	2076007040.000000	0.083847	0.013708
5RB LOAD BNR OIL PRESS R_5RPIC6458-PV	453404864.000000	0.018312	0.002994
5RB TERT AIR DUCT PRESS R_5RPIC6373-SP	0.000000	0.000000	0.000000

The R^2 here is the indication of how well the model was "trained"

The amount of sootblowing steam used is the most important variable, not that surprising but wait…

Actual Versus Predicted Fouling Rate



Foul

Clean

Lbs/hr of accumulation

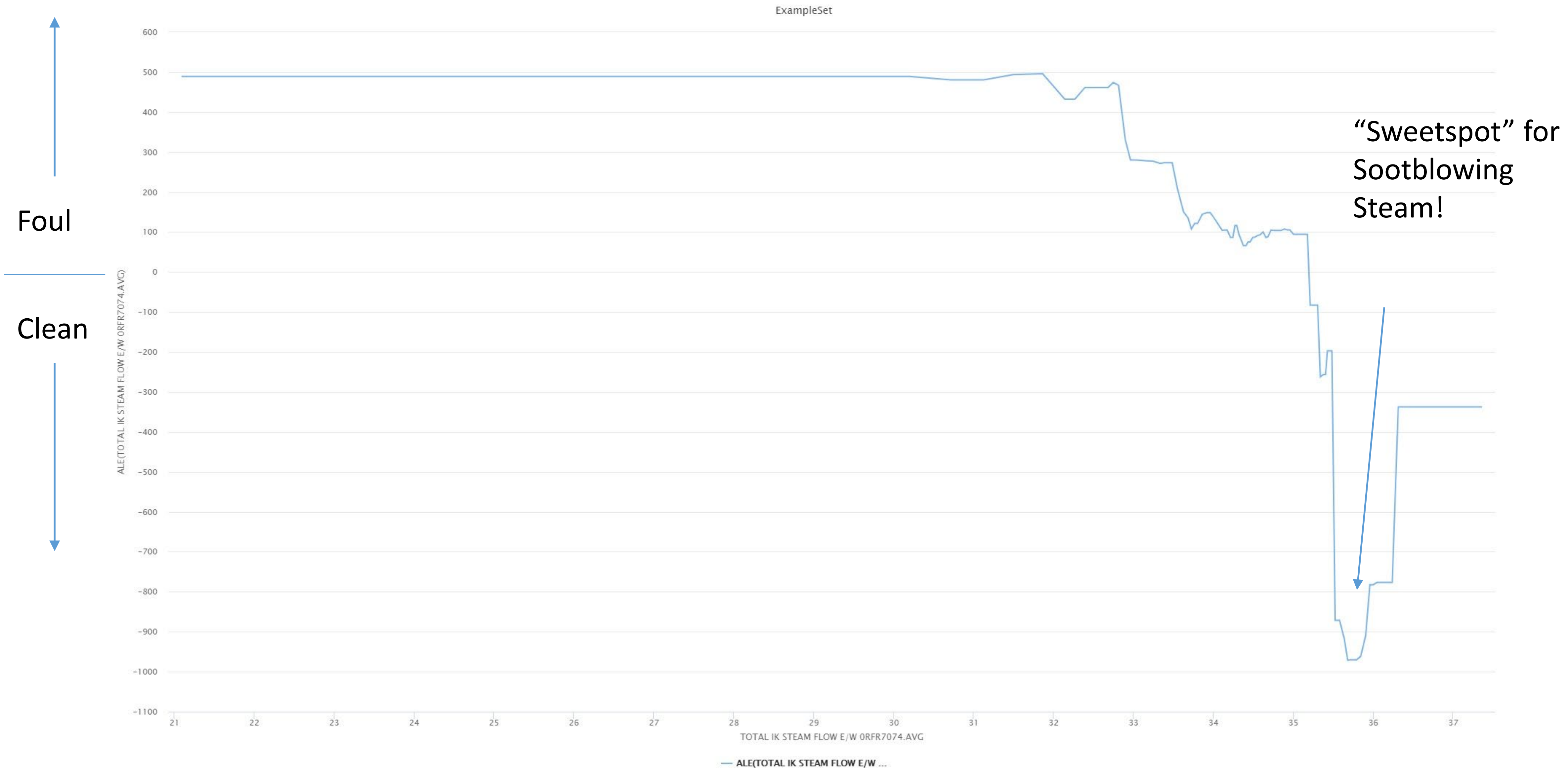
Remember this has an R^2 of 0.47

Attribute weights – What is most important in the model?

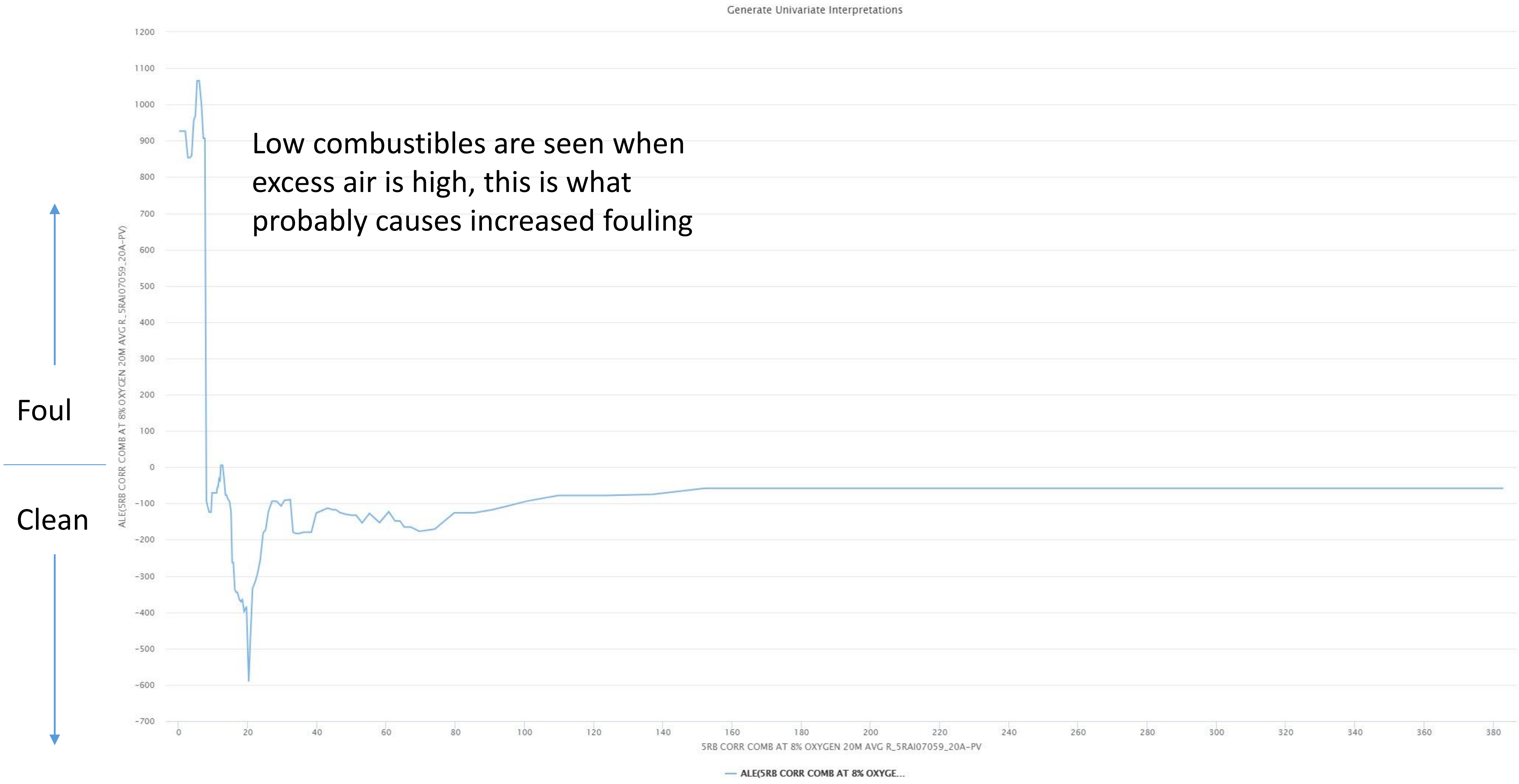
attribute	weight
TOTAL IK STEAM FLOW E/W 0RFR7074.AVG	2399077...
5RB TERT AIR DUCT PRESS R_5RPIC6373-PV	1465303...
5RB SECONDARY AIR FLOW R_5RFIC6350-PV	1448032...
5RB LIQUOR GUN PRESSURE 0RPR6204.PV	1427048...
#5 RB ACTUAL LIQ FLOW 5RFI06203B.PV	1387350...
Ash Dissolving Tank Temperature R_5RTIC16544-PV	1330563...
RB5 ID FAN speed R_5RSI6494-PV	9584192...
5RB FEEDWATER FLOW 20 MIN AVG R_5R_FEEDWTR_AVG	7740953...
5RB O2 FROM 5RB STACK 5RAR09964.PV	6947406...
5RB Corrected TRS 12 hr Avg R_5RAI9963_Avg12h	6500730...
5RB CORR COMB AT 8% OXYGEN 20M AVG R_5RAI07059_20A-PV	6392997...
5RB PRI AIR HDR FRONT PRESS R_5RPI6903-PV	6293765...
5RB LIQUOR TEMPERATURE 0RTC6721.PV	6242058...
Ash rotary feeder speed R_5RSI6334-PV	5927867...
5RB PRI FRONT (S) AIR FLOW R_5RFIC6915-PV	5443376...
5RB BL DENSITY A 5RDR06207A.PV	5044140...
5RB CORRECTED TRS 5RAR09963A.PV	4151534...
Ash rotary feeder current R_5RII06334-PV	3600620...
5RB QUAT (N) AIR FLOW R_5RFIC18279-PV	3471248...
5RB LOAD BNR OIL PRESS R_5RPIC6458-PV	2384347...
5RB 850# Steam Flow 5RFI6275A.PV	0
5RB TERT AIR DUCT PRESS R_5RPIC6373-SP	0

Accumulated Local Effects Plots (ALE)

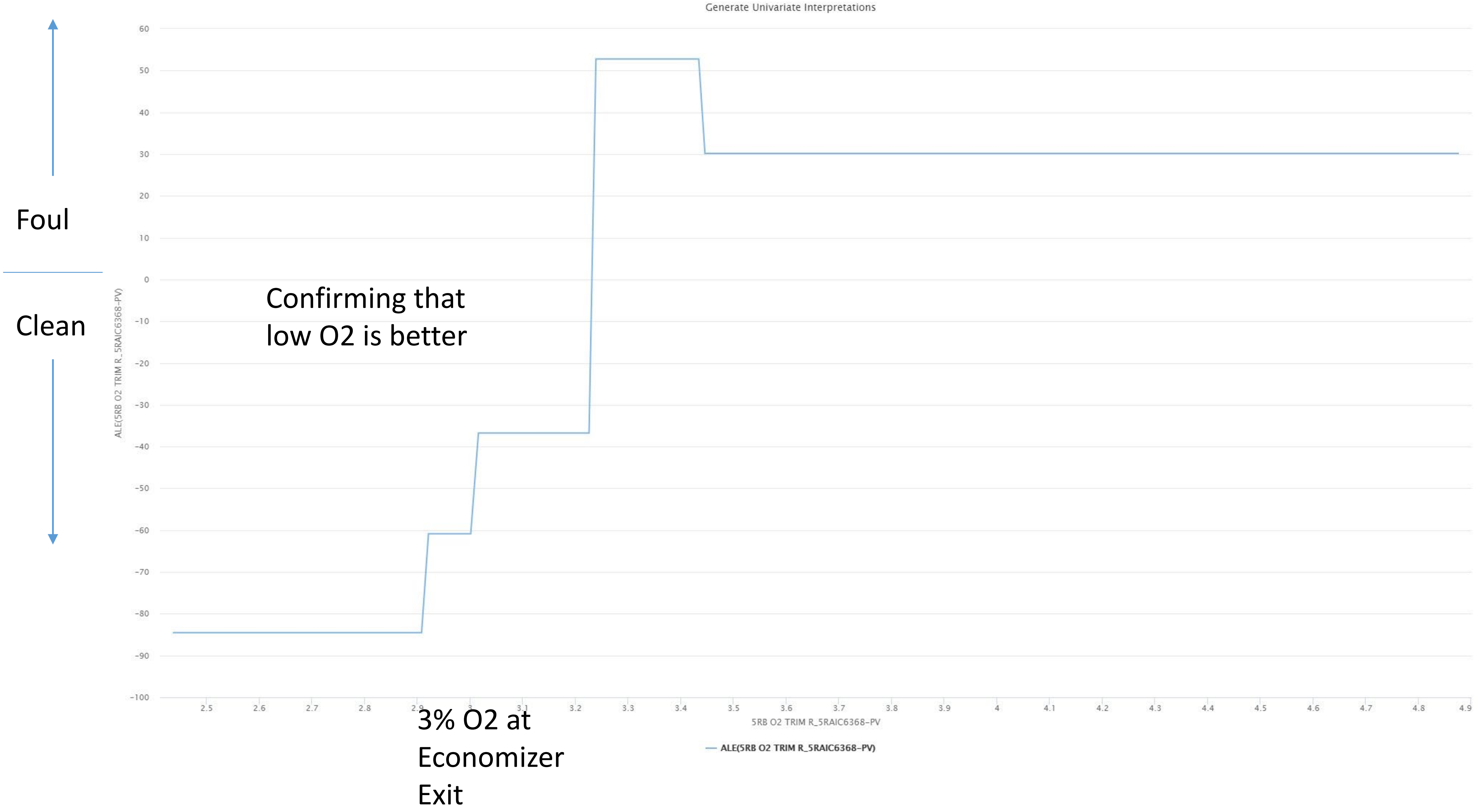
- One of the biggest challenges of using Gradient Boosted Trees for modeling is interpretation of the results
- You obtain tens to hundreds of trees from the modeling effort, it is not possible to interpret this information from simply studying the trees that are built
  - The most important variables can be identified and this is useful but only to a limited extent
- This is where ALE plots can be used!
- An ALE plot is developed by using a technique that identifies the relationship between a "feature" and the target variable independent of the effects of other features
  - For example it can determine the effect of the "Sootblowing Steam Flow" on the rate of fouling
  - This is an excellent reference on this topic https://christophm.github.io/interpretable-ml-book/ale.html

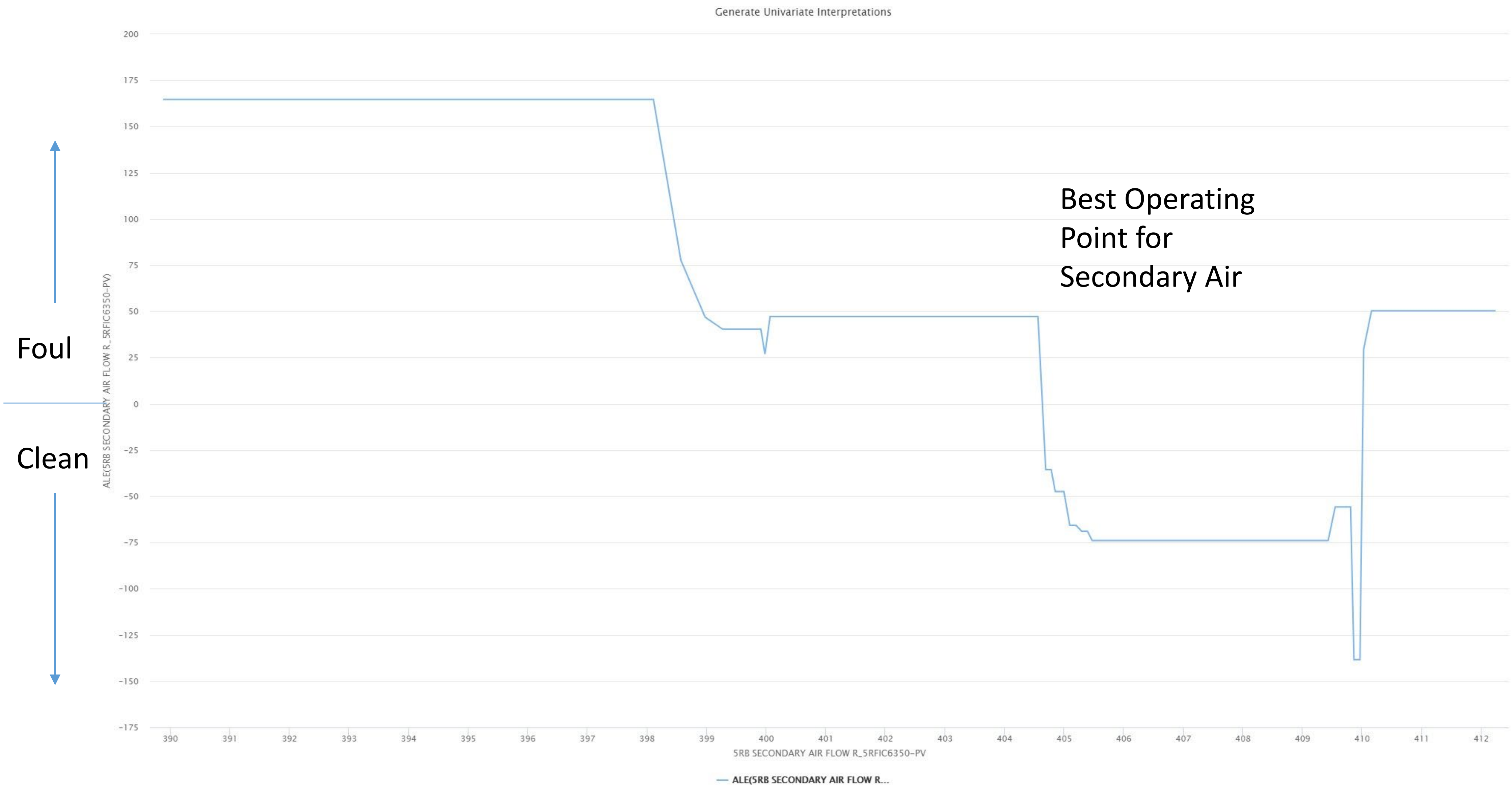


ExampleSet
Foul
Clean
"Sweetspot" for Sootblowing Steam!
ALE(TOTAL IK STEAM FLOW E/W 0RFR7074.AVG)
TOTAL IK STEAM FLOW E/W 0RFR7074.AVG
ALE(TOTAL IK STEAM FLOW E/W ...



Generate Univariate Interpretations
Low combustibles are seen when excess air is high, this is what probably causes increased fouling
Foul
Clean
ALE(5RB CORR COMB AT 8% OXYGEN 20M AVG R_5RAI07059_20A-PV)
5RB CORR COMB AT 8% OXYGEN 20M AVG R_5RAI07059_20A-PV
ALE(5RB CORR COMB AT 8% OXYGE...


Generate Univariate Interpretations
ALE(5RB O2 TRIM R_5RAIC6368-PV)
5RB O2 TRIM R_5RAIC6368-PV
ALE(5RB O2 TRIM R_5RAIC6368-PV)
Foul
Clean
Confirming that low O2 is better
3% O2 at Economizer Exit


Generate Univariate Interpretations
Best Operating
Point for
Secondary Air
Foul
Clean
ALE(5RB SECONDARY AIR FLOW R_5RFIC6350-PV)
5RB SECONDARY AIR FLOW R_5RFIC6350-PV
ALE(5RB SECONDARY AIR FLOW R...
200
175
150
125
100
75
50
25
0
-25
-50
-75
-100
-125
-150
-175
390
391
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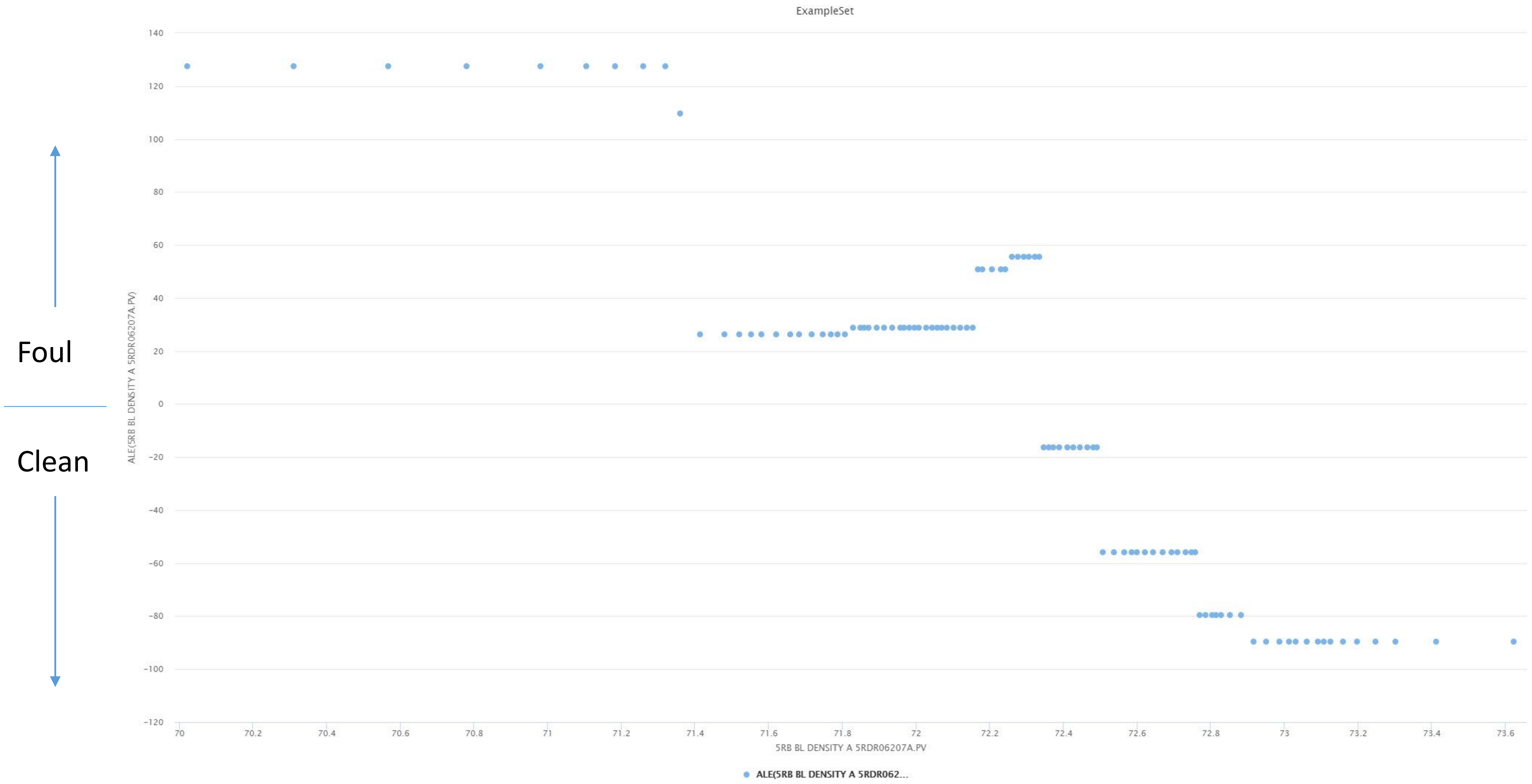
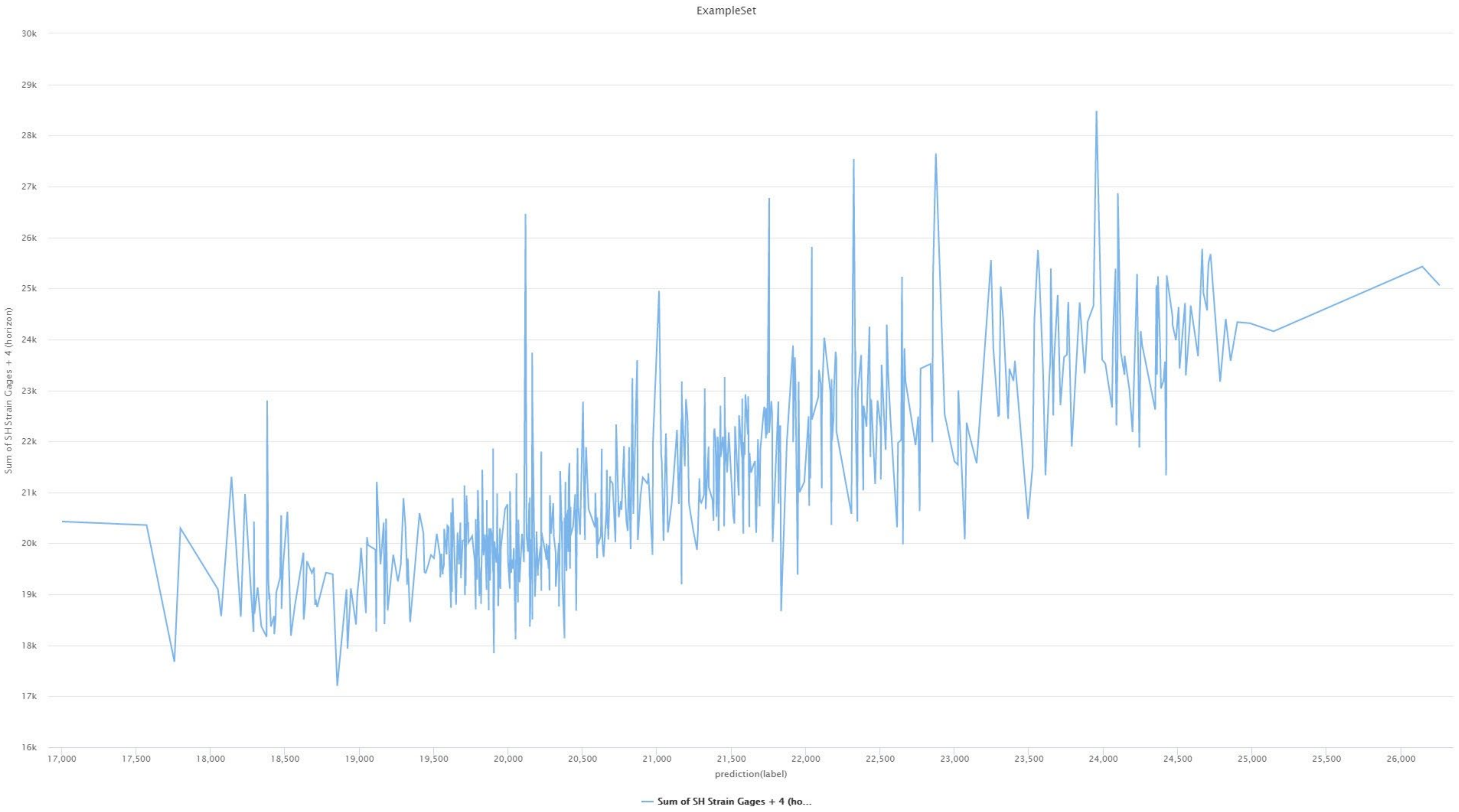


Foul
Clean
ExampleSet
ALE(5RB BL DENSITY A 5RDR06207A.PV)
5RB BL DENSITY A 5RDR06207A.PV
ALE(5RB BL DENSITY A 5RDR062...

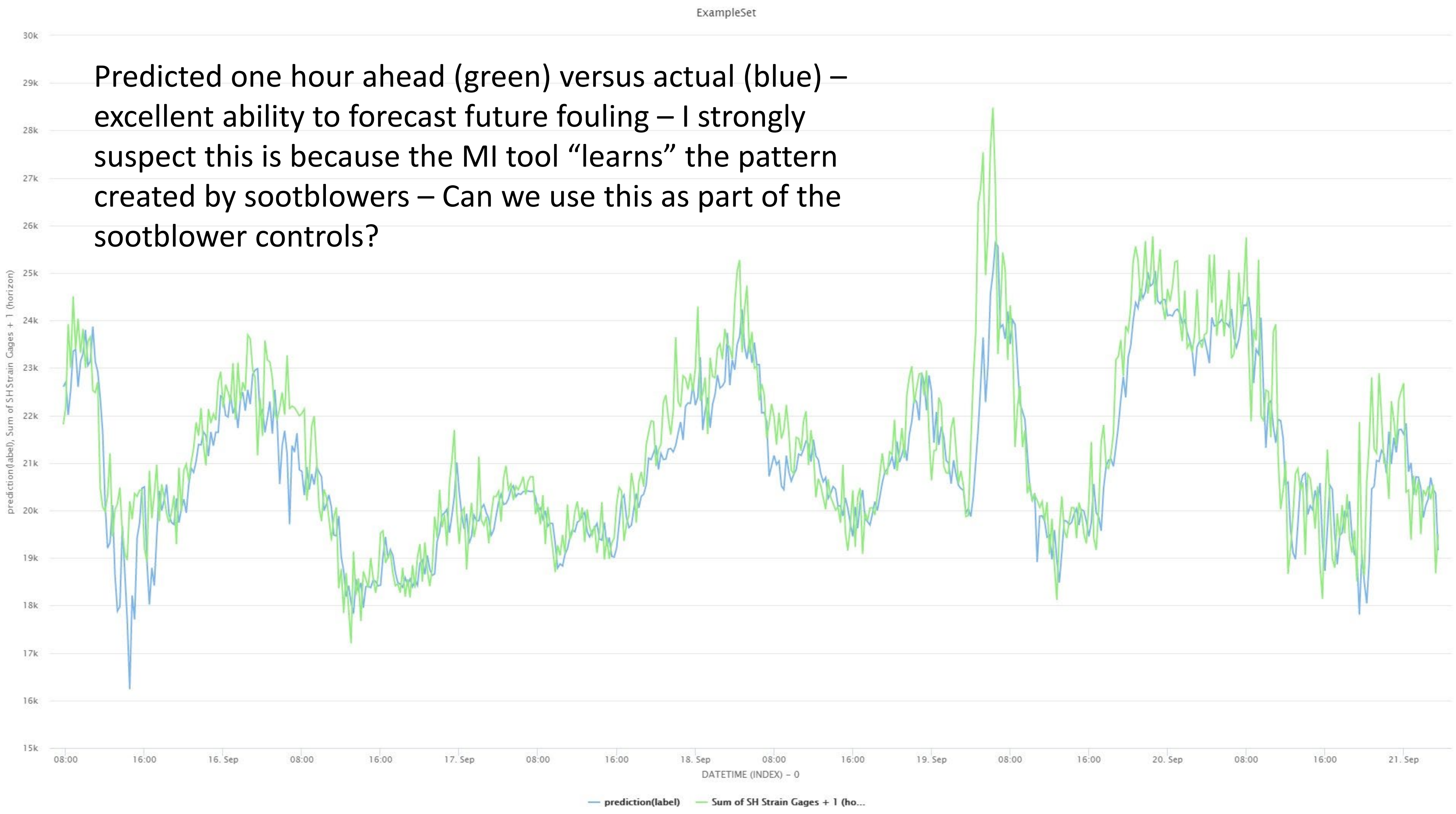
Predicting Future Fouling

- This is another machine learning technique that uses a Sliding Range validation method, rather than holding out parts of the data set for validation
- It tries to build a predictive model that uses past values of your target variable to predict future values
- Still trying to figure out if this is useful in a production setting, but good forecasts of the fouling rate over the next hour were obtained.
- What is probably happening is that the machine learning tool is learning the impact of the sootblowers on the deposit weight based on the frequency and location of the sootblowing
- Possibly this may be useful in better selecting the best sootblowers to operate

Actual versus Prediction Fouling 1 hour ahead



Predicted one hour ahead (green) versus actual (blue) – excellent ability to forecast future fouling – I strongly suspect this is because the MI tool “learns” the pattern created by sootblowers – Can we use this as part of the sootblower controls?



Conclusions

- Models with relatively low predictive power (R^2 0.4-0.6 and Q^2 0.2-0.3) can be built between recovery boiler operating parameters and the rate of fouling.
  - This models are probably not suitable for prediction of the rate of fouling as this is driven primarily by the sootblowers, but they are useful for identifying operating parameter ranges that are associated with lower fouling rates
- Prediction of the future total superheater strain gage weight can be built using “forecasting” type time series modeling
  - These models are probably using the pattern of removal of the sootblowers and the short term fouling rate to extrapolate the total weight in the next hour
  - The application of this type of information needs further thought as to whether it can be used to reduce the rate of fouling of recovery boilers.

Recovery Boiler Tuning

Jansen Combustion and Boiler Technologies, Inc.

Kirkland, Washington, USA

JANSEN
Combustion & Boiler Technologies, Inc.

JANSEN's Background

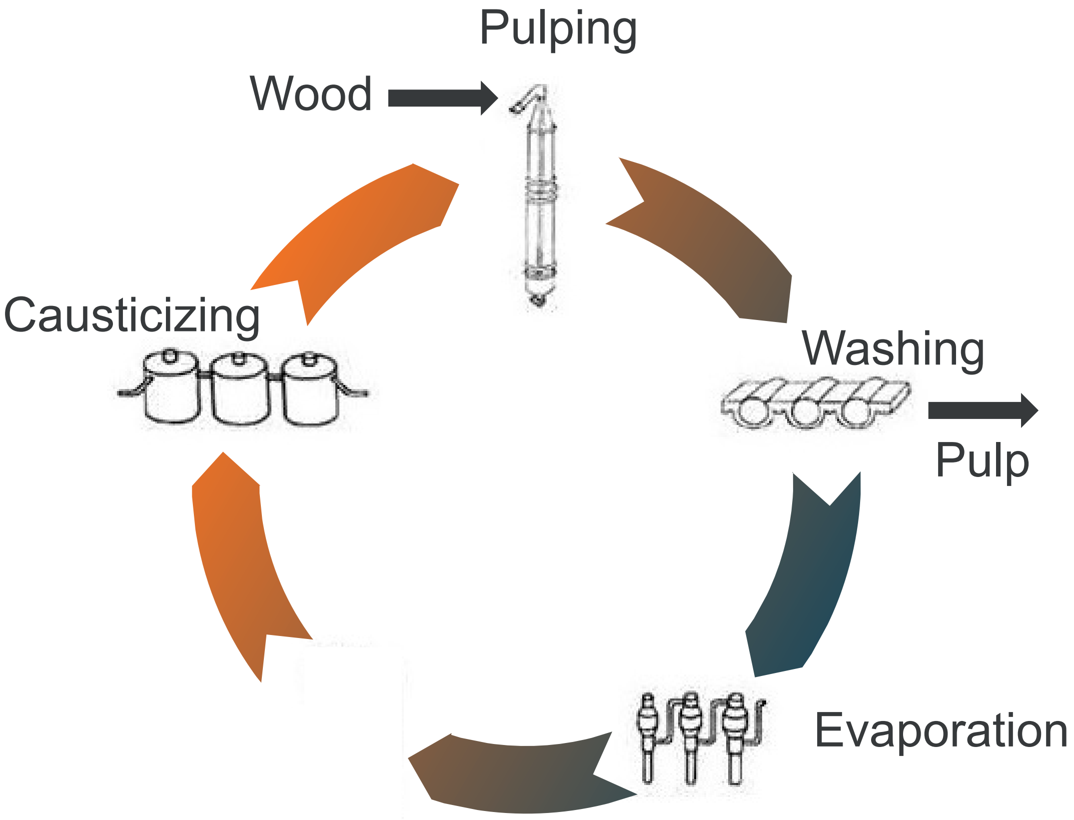
Experience

- Over 46 years of boiler experience
- Biomass/sludge/RDF/MSW/Chemical Recovery boilers
- Tested/evaluated over 350 boilers, worldwide
- Over 100 advanced air systems on biomass fueled power and recovery boilers

Why Tune a Recovery Boiler

Critical to mill operations

- Peak operation is essential
  - Optimal efficiency → pulping rate
  - “Clean” boiler → availability
  - Good combustion → compliance
- Combination of any impact operations
- Deficiencies are costly



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Begin with a Survey

Confirm instrumentation

- Instrument accuracy can drift over time
- Instrumentation may not be in a reliable location
- Spot check combustion air and flue gas pressure and temperatures
- Confirm boiler O_2 instruments with field measurements
- Identify imbalances in temperature, O_2, and CO
- Check accuracy of air flow metering based on liquor firing rate
- Observe physical conditions in the boiler

Begin with a Survey

Verify Damper Operation

- Note the positions
- Visually confirm automatic dampers response
- Manually stroke hand dampers
- Restore functionality if possible
- Close areas that are sources of tramp air

Begin with a Survey

Interview operators

- Most first-hand experience with Boiler
- Good source of collective knowledge
- Develop relationships
- Establish trust in the process

Focus Areas

Liquor Delivery/Bed

- Foundational element of process
- Primarily impacted by delivery
    - Pressure, temperature, and solids
    - Gun size, angle, type, number
    - External considerations
- Secondary influence may be combustion air

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Focus Areas

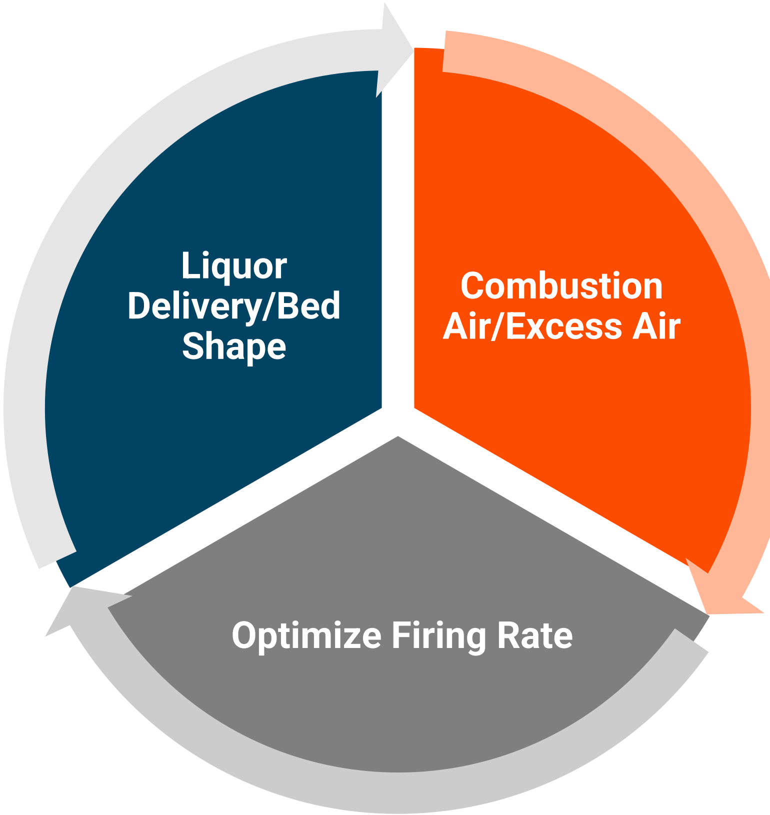
Combustion Air/Excess Air

- Primary
  - Shaping perimeter
  - Minimize solids runoff (sloped floor)
- Secondary
  - Height
  - Burning/heat
- Tertiary/Quaternary
  - Finish combustion
  - Deep staging for NO_x control

Tuning Process

Tuning Sequence

- Results from the survey direct the process
- Sequential progression
- Each step dependent on previous step(s)
- Multiple iterations are necessary
- Continually monitor process variables that naturally vary over time.



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Tuning Process

Liquor Delivery and Bed Condition

- Maintain proper liquor delivery pressures
- Remain safely away from boiling transition temperature
- Change number or size of liquor guns
- Balance delivery around boiler perimeter
- Vary delivery angle to delivery spray onto the center of the floor
- Changes are small and measured
  - Make one change at a time and track response
- Be patient

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Tuning Process

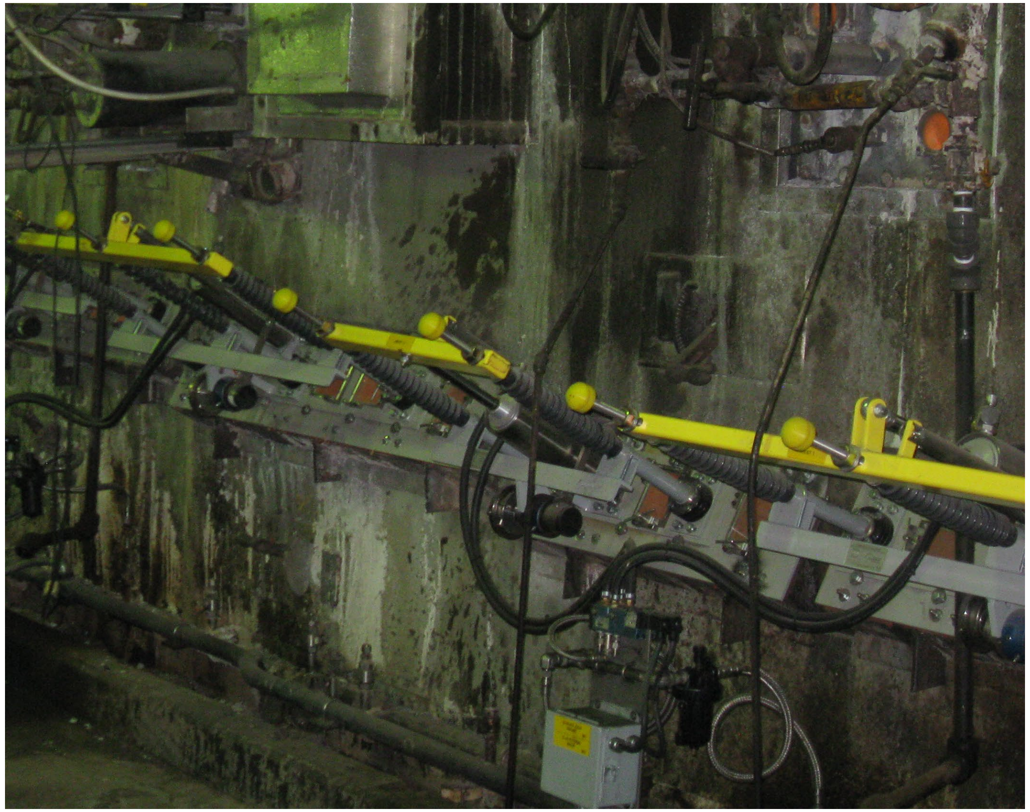
Combustion Air Changes

- Final step is to manipulate air flow settings
- Verify total air flow per liquor firing
- Target typical splits for each level
- Excess air level/Boiler O_2 at acceptable range

Tuning Process

Tuning Primary Combustion Air

- Negative impacts
  - Undercut bed
  - Lowered reduction efficiencies
  - Can increase excess air
- Tuning Activities
  - Balance delivery arrangement
  - Set windbox dampers similarly around perimeter
  - Target appropriate windbox pressure
  - Ensure backpressure
  - Target the appropriate flow



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Tuning Process

Tuning Secondary Combustion Air

- Negative impacts
  - Out of control bed size
  - Problematic furnace temperatures
  - Can increase excess air
  - Carryover
- Tuning Activities
  - Balance around perimeter/side walls
  - Target appropriate pressures
  - Set hand dampers in SA ports/nozzles for best penetration
  - Minimize tramp air through burners
  - Establish appropriate flow set point

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Tuning Process

Tuning Tertiary/Quaternary Combustion Air

- Negative impacts
  - Elevated CO and TRS
  - Increased NO_x
- Tuning activities
  - Balance arrangement
  - Target appropriate pressures
  - Ensure proper air flow quantity

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Tuning Process

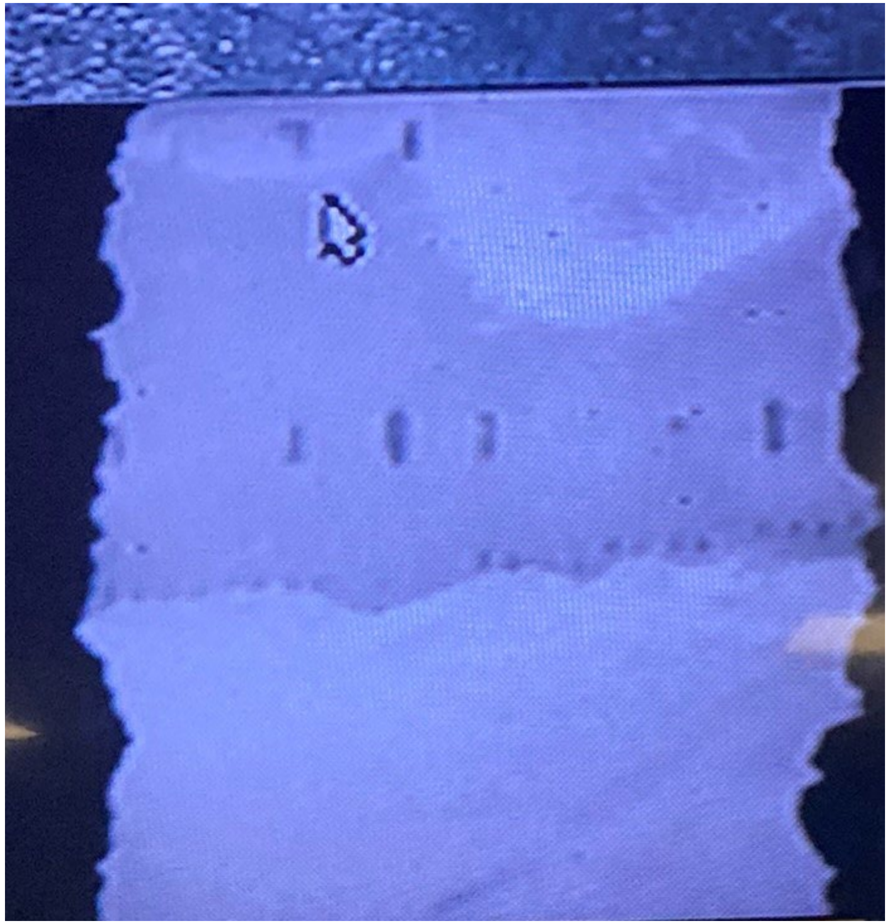
Optimize Firing Rate

- Done incrementally
- Maintain good bed conditions
- Confirm air settings
- Maintain splits

Boiler Examples

Poor Primary Air Arrangement

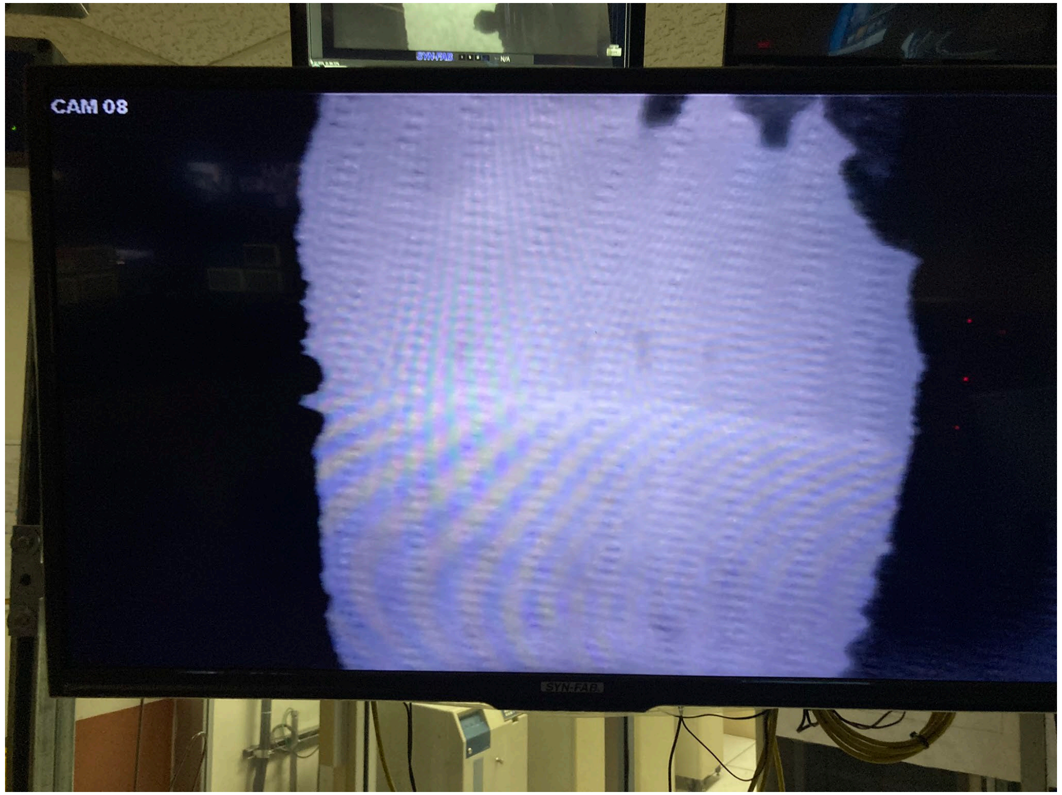
- Dampers settings randomly set
- Inconsistent pressures
- Scalloping of surface
- Bed is thin
- Some wall burning



Boiler Examples

Balanced Air Arrangement

- Set all PA dampers to same position
- Reduced PA flow
- Balanced SA delivery from side-to-side
- Evened SA pressures
- Decreased SA flow
- Furnace O_2 decreased from 3.6% (vol., wet) to 2.9% (vol., wet)
- CO went from 150 ppm to 0 ppm
- Carryover reduced by 20%



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Boiler Examples

Poor Liquor delivery and Air arrangement

- Liquor delivery too fine
- Imbalanced delivery – off center bed
- Secondary air system is inoperable
- Current work in progress

Thank you

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SUOMEN SOODAKATTILAYHDISTYS
FINNISH RECOVERY BOILER COMMITTEE

Finnish Recovery Boiler Committee Report

AF&PA Recovery Boiler Conference 2023
February 8th, 2023

Emma Kärkkäinen

Content

- Overview of the FRBC
- Overview of recovery boilers in Finland
- Incident statistics 2002 - 2022
- Committee activities

Overview of the FRBC

Introduction

- The Finnish Recovery Boiler Committee (FRBC) has promoted **safe**, **economic** and **environmentally friendly** operation of recovery boilers and closely related processes since 1964.

- The FRBC…
  - collects information about incidents involving recovery boilers and provides details of these to its members
  - publishes guidelines, recommends practices, and arranges conferences and meetings
  - conducts and supports research projects related to safe operation and improved economy of recovery boilers

FRBC Members

- The members of the Committee include pulp mills, recovery boiler manufacturers, a number of insurance, engineering and inspection companies and research organisations in Finland.

- Total 30 members, including 14 pulp mills
  - 25 voting members, 5 universities
  - An annual member fee is collected from the Committee members

FRBC Organisation

Annual Meeting
25 voting members

Board
Chairman*: Kari Saari, UPM
12 members + secretary

*Chairman term is 2 years

Secretariat
Sakari Vuorinen
Emma Kärkkäinen
Päivi Lampinen

Durability sub-committee
16 members + secretary
(Sakari Vuorinen)

Environmental sub-committee
7 members + secretary
(Emma Kärkkäinen)

Automation sub-committee
8 members + secretary
(Emma Kärkkäinen)

Black Liquor sub-committee
12 members + secretary
(Sakari Vuorinen)

Program sub-committee
5 members + secretariat
(Päivi Lampinen)

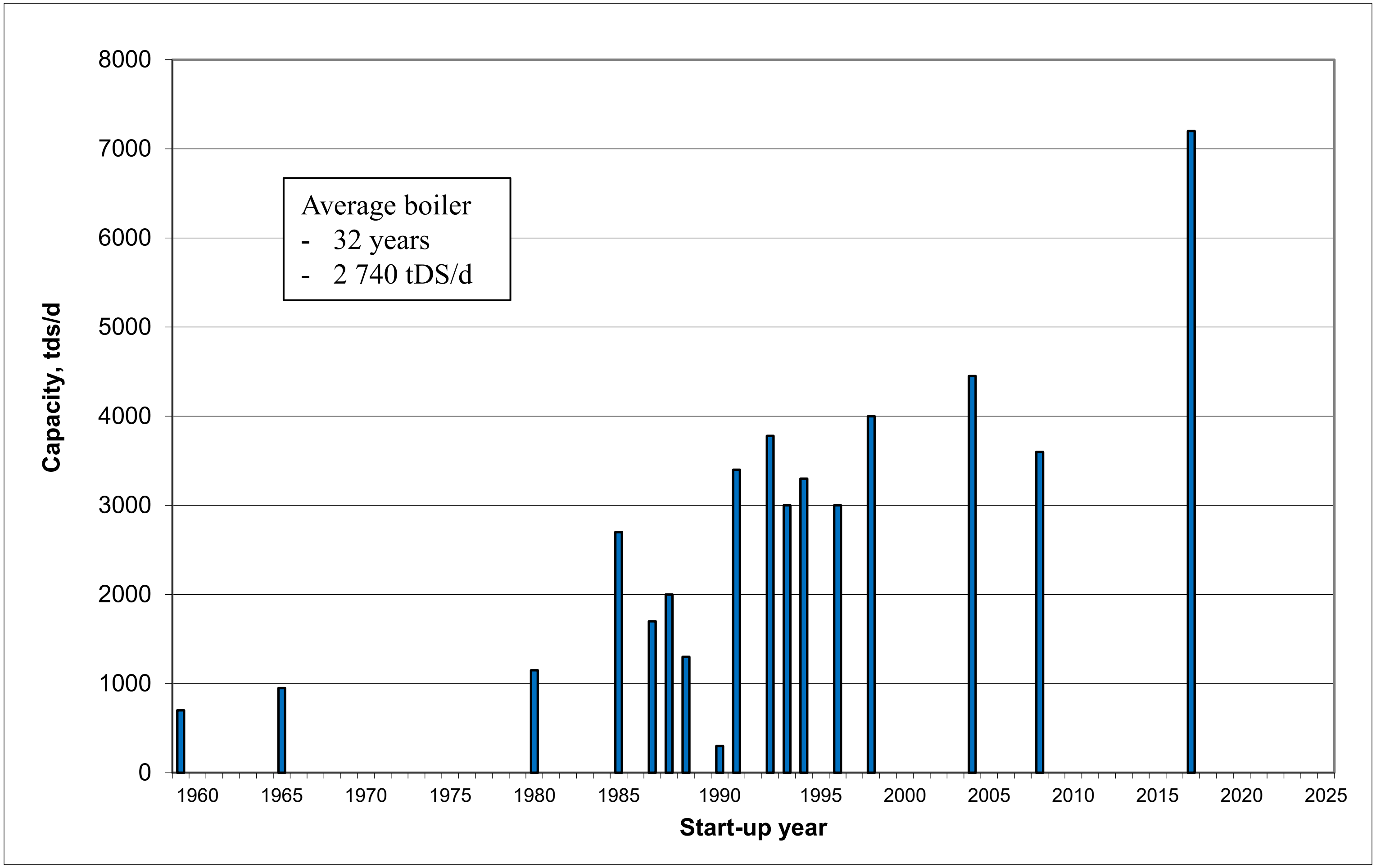
SUOMEN SOODAKATTILAYHDISTYS
FINNISH RECOVERY BOILER COMMITTEE

Overview of Recovery Boilers in Finland

Finnish Recovery Boilers

- Number of recovery boilers 17
  - The oldest started-up in 1959, MM Kotkamills
  - The newest started-up in 2017, Metsä Fibre Äänekoski mill
  - The largest 7200 tDS/d, Valmet boiler
  - The smallest 300 tDS/d Stora Enso Heinola mill, Tampella boiler
- Number of mills 14
- Average boiler age 32 yrs (1990)
- Average boiler capacity 2740 tDS/d
- Combined capacity 46 530 tDS/d

Finnish Recovery Boilers



Recovery Boiler Incident Statistics 2002 - 2022

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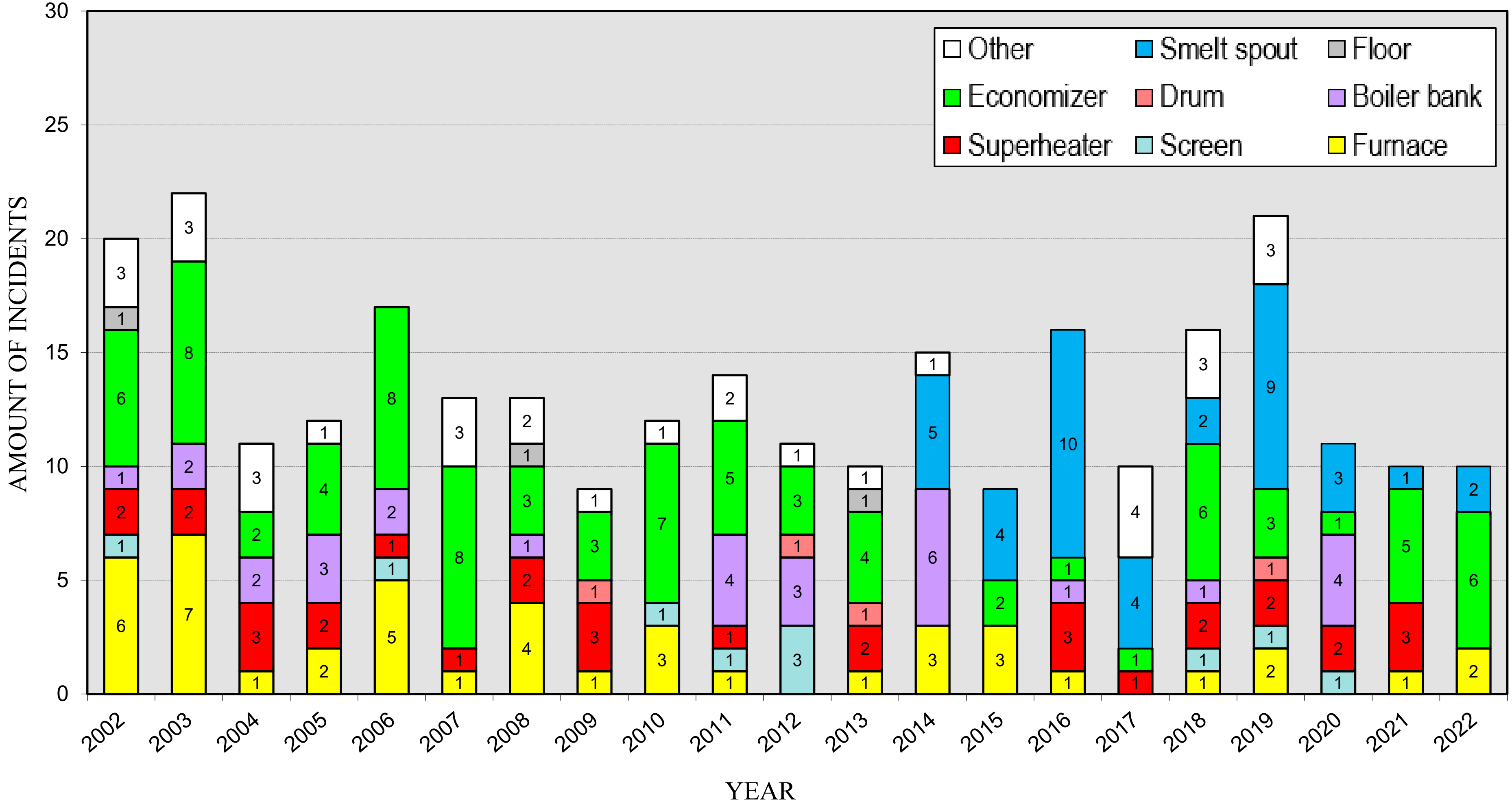
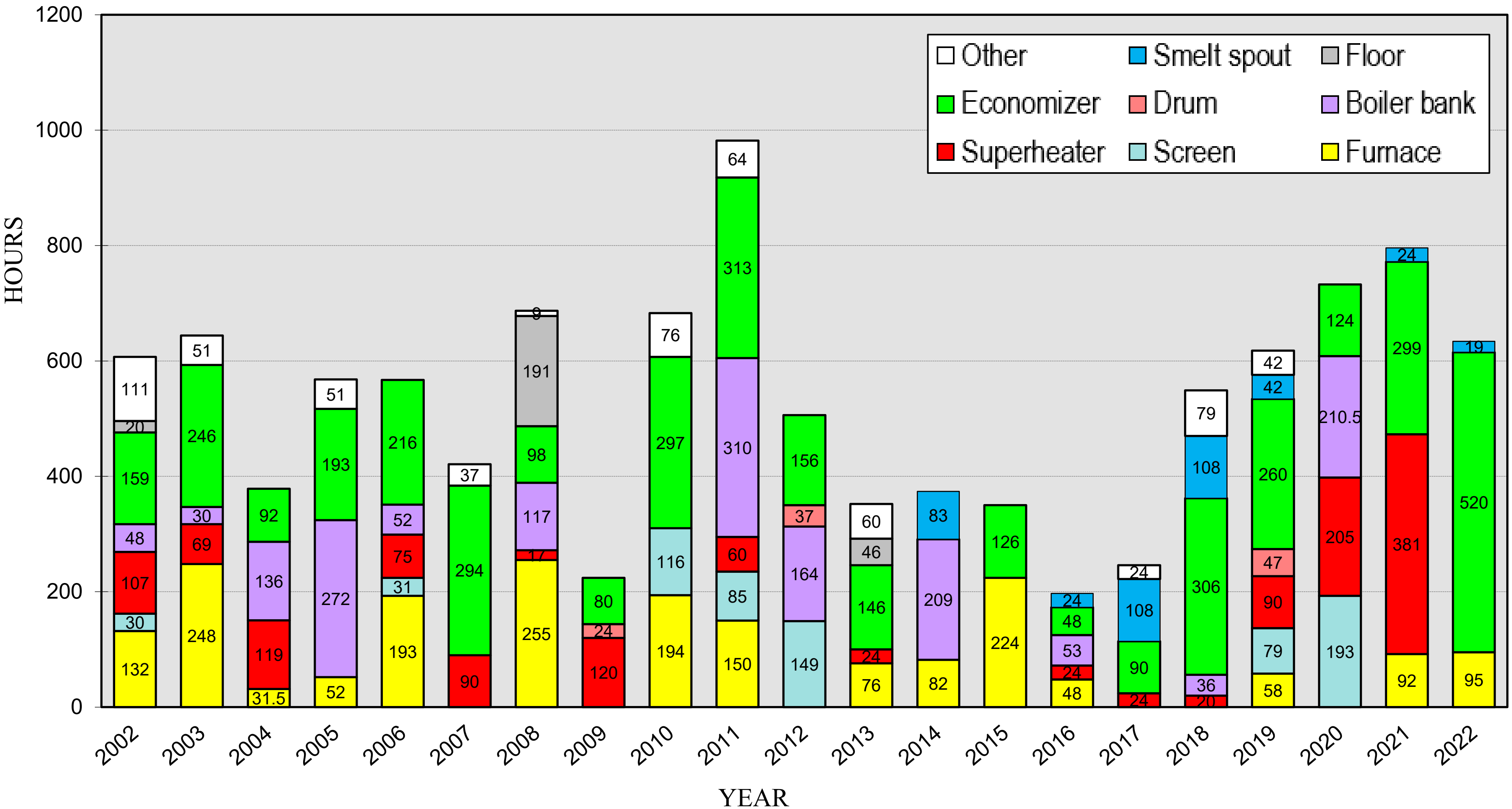
FINNISH RECOVERY BOILER COMMITTEE

REPORTED INCIDENTS 2002-2022



SUOMEN SOODAKATTILAYHDISTYS
FINNISH RECOVERY BOILER COMMITTEE

DOWNTIME 2002-2022



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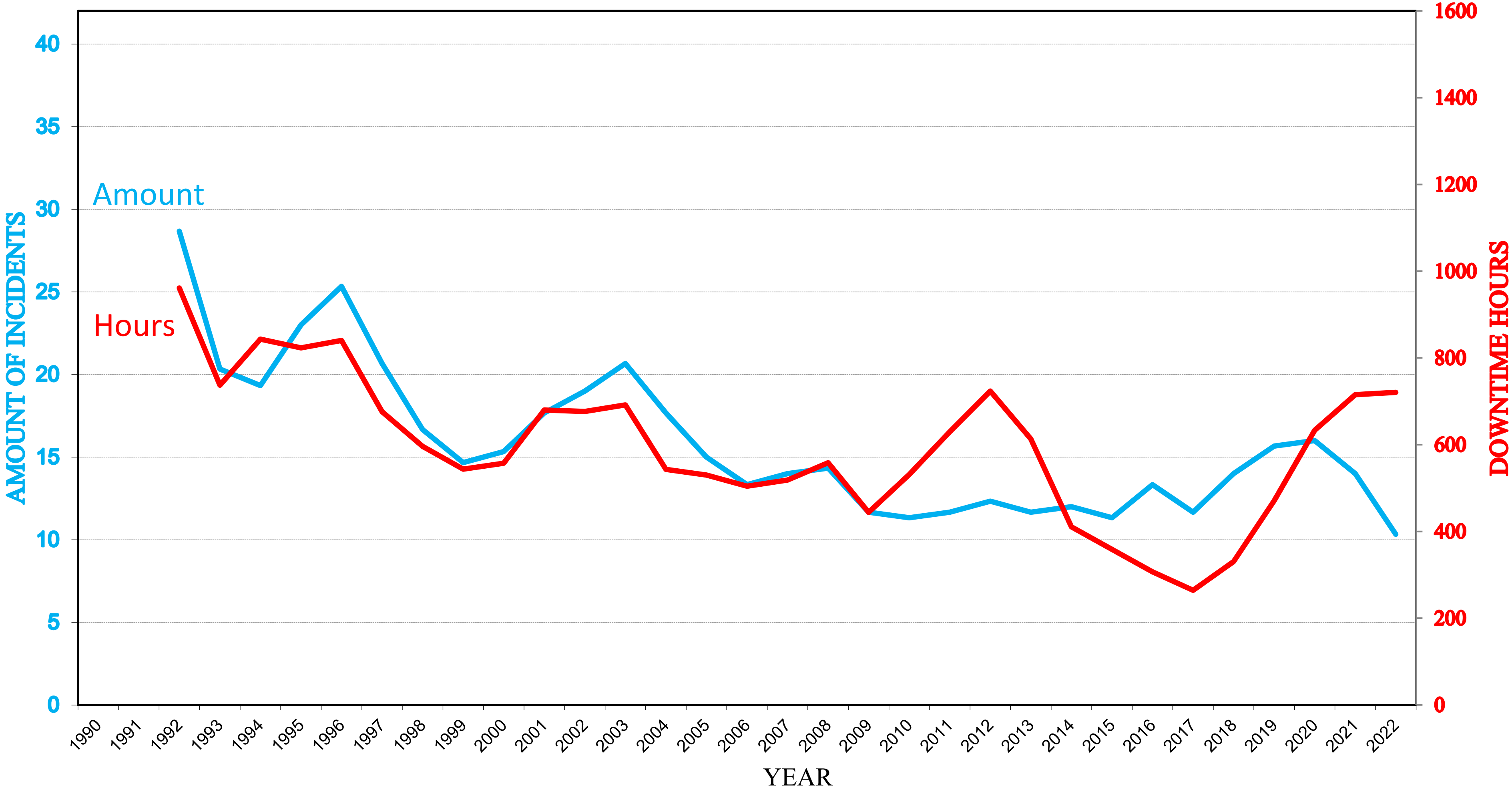
FINNISH RECOVERY BOILER COMMITTEE

INCIDENTS and DOWNTIME trends
3-year running average



Committee Activities

Activities

- Events
  - "Recovery boiler day" seminar was arranged on October 27th in Tampere
  - "Chief Engineer Day" seminar will be arranged on February 9th, 2023 in Kotka (mill visit to MM Kotkamills)
  - "Operators' day" seminar will be arranged in March 2023
  - FRBC 60th Anniversary Seminar will be arranged in June 2024

Projects 2021-2023

Durability sub-committee

- Update of material recommendation: Pipe peeling and S0-piping alignment, 2021-2022
- Development of the recovery boiler operator safety clothing, 2021-2022
- Review of recovery boiler ceramic structures, 2021-2022
- Ion exchange in recovery boiler make-up water preparation – monitoring, control and actions, 2021
- Impact of amount of melt at T0 on corrosion, 2020-2021

Black liquor sub-committee

- Superheater surface max. temperature change in relation to boiler size, 2022-
- Pulp mill deposit formation and aging – Phase 2, 2021

Projects 2021-2023

Environment sub-committee

- POP compounds in green liquor dregs, 2023-
- List of Finnish thesis works related to recovery boilers, 2023-
- CCUS (Carbon Capture, Utilization and Storage) in pulp mills, 2022-2023
- Lime kiln emissions with alternative fuels, 2021
- Update of NCG handling recommendations, 2020-2021

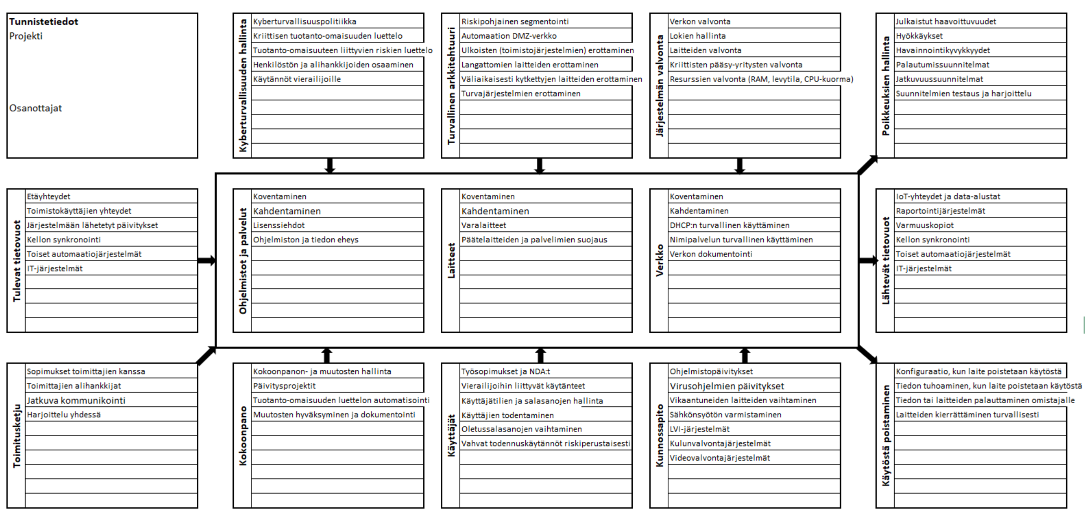
Automation sub-committee

- Electrical safety systems of boilers (update), 2023
- Cybersecurity in pulp mills and recovery boilers, 2022
- Recommendation on safety instrumented systems, 2021

Basics of cybersecurity at pulp mills

Insta Advance Oy

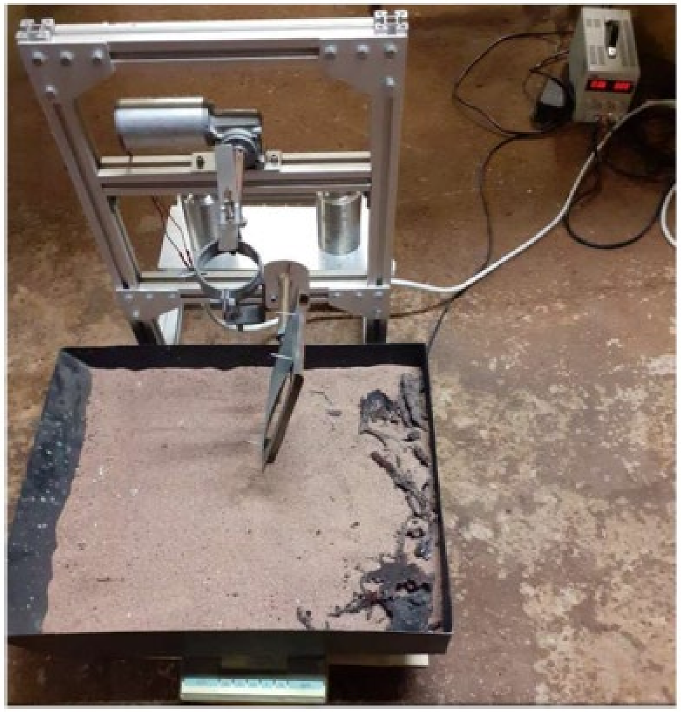
- An introductory guide to assessing and identifying cybersecurity risks at pulp mills and recovery boilers
- Target audience: mill personnel with no background in cybersecurity issues
- Appendices included a risk assessment matrix and a check list for relevant cybersecurity aspects



Development of the recovery boiler operator safety clothing

Finnish Institute of Occupational Health

- Project phases
  1. Mapping the needs of the pulp mills
  2. Setting requirements for protective clothing
  3. Mapping suitable material
     - Smelt tests with 7 different material
  4. Updating recommendations
- Three-layered material combination gave protection against smelt, but it would be too heavy to use
- Breakthrough material was not found



Project: Susanna Mäki, TTL
Pic: Heidi Soili, SGS Fimko Oy

SUOMEN SOODAKATTILAYHDISTYS
FINNISH RECOVERY BOILER COMMITTEE

Additional info on the committee website (in Finnish)

www.soodakattilayhdistys.fi

Questions:
emma.karkkainen@afry.com
sakari.vuorinen@afry.com
paivi.lampinen@afry.com

Sodahuskommittén

Report from the Swedish-Norwegian Recovery Boiler Committee

2022

Johan Jansson and Kristian Rosenqvist, AFRY

Secretary of the Swedish-Norwegian Recovery Boiler Committee (SNRBC)

Förbättrar personsäkerheten och driftsäkerheten för sodahusprocessen

Topics

- Members and organization
- Recovery Boilers in Sweden and Norway
- Reported incidents
- Standardization
- Recommendations and standardization
- Certification of operators
- Experience sharing day
- Recovery Boiler meeting
- Prioritized projects

Members

- All mills producing kraft pulp and Domsjö in Sweden (22 mills), and Borregaard in Norway
- Recovery boiler manufacturers (Andritz and Valmet)
- 3rd party (Dekra and Kiwa)
- Swedish Paper Industry Workers' Union

Organization

The Board of the SNRBC
Chairman: Anders Fransson, Valmet
Secretary: Johan Jansson, Kristian Rosenqvist AFRY
18 members (11 voting)

- **Recommendations Subcommittee**
  Secretary: Lars Andersson, AFRY
  Additional 4 members
- **Incidents Subcommittee**
  Secretary: David Good, Dekra
  Additional 13 members
- **Education Subcommittee**
  Secretary: Björn Lundgren, Kiwa
  Additional 5 members
- **EIA Subcommittee**
  (Electricity, Instrumentation, Automation)
  Secretary: Kristian Rosenqvist, AFRY
  Additional 8 members

Recovery Boilers in Sweden and Norway

Fall 2022
- New recovery boiler at Metsä board Husum starting up

Spring 2019
- Increased capacity Smurfit Kappa Piteå

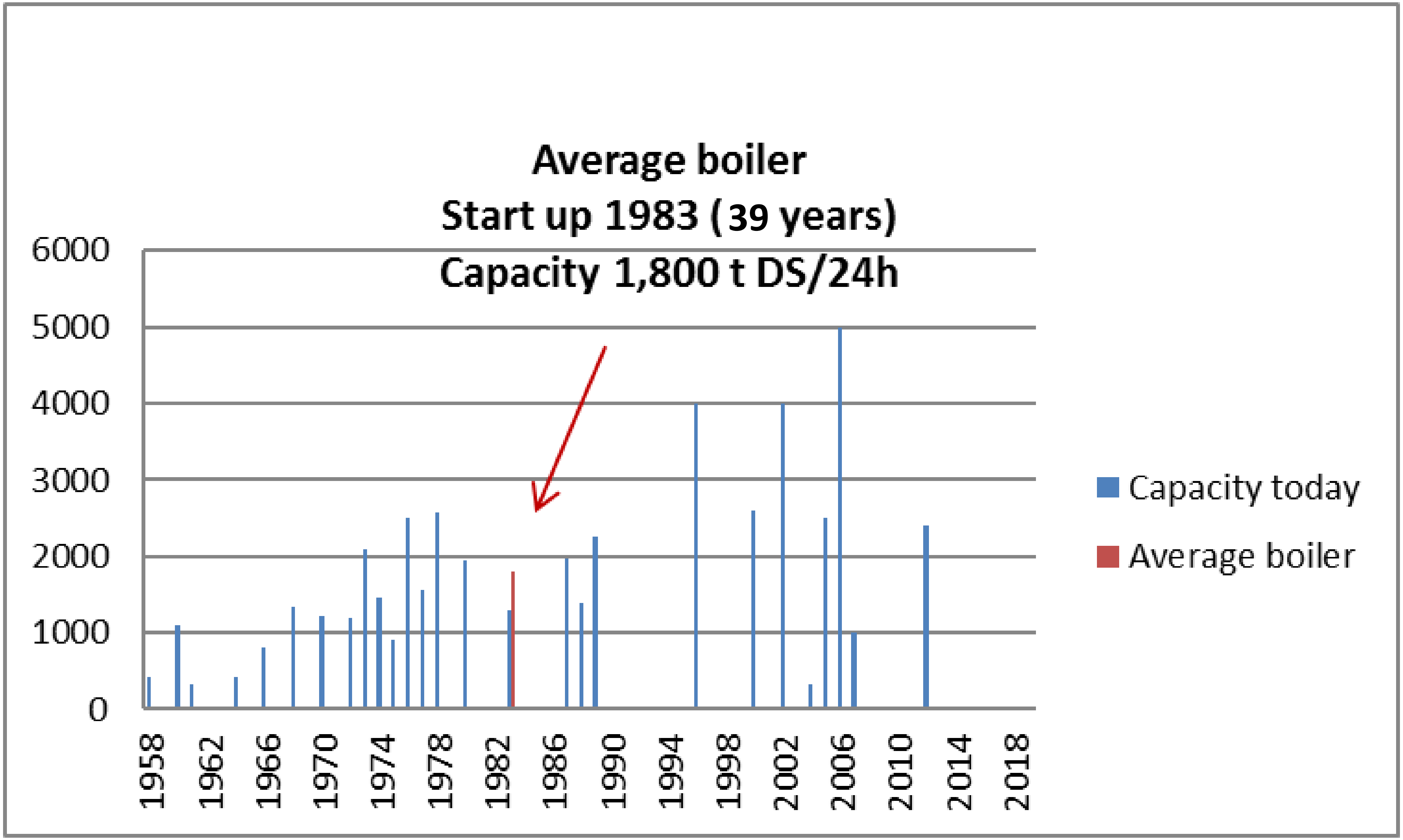
Autumn 2018
- Increased capacity recovery boiler SCA Östrand

Autumn 2016
- Increased capacity recovery boiler Södra Cell Värö

Autumn 2013
- The boiler in SCA Munksund was converted to single drum
- New evaporator line in BillerudKorsnäs Skärblacka

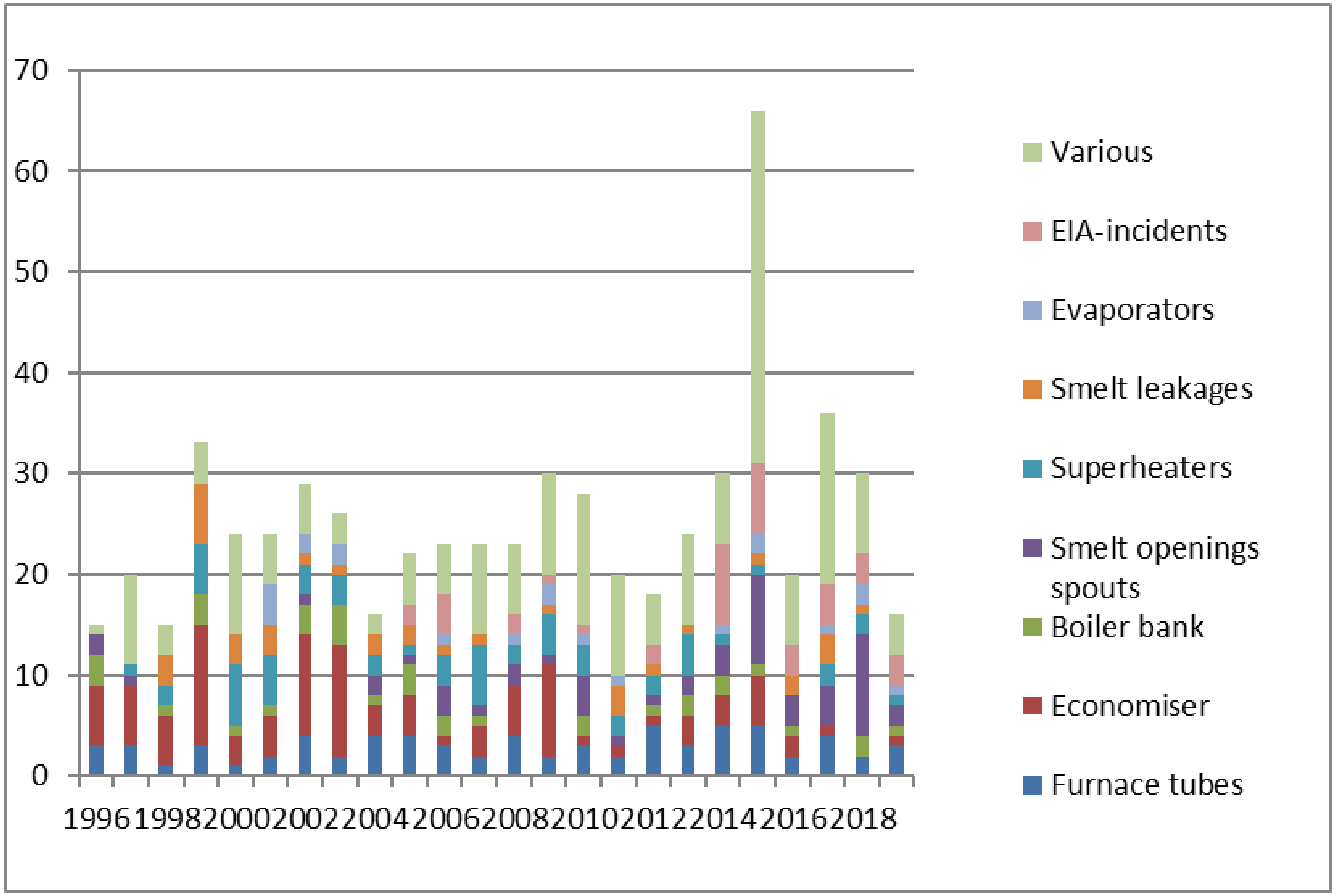
Summer 2012
- Closure of Södra Cell Tofte, Norway

Recovery Boilers in Sweden and Norway

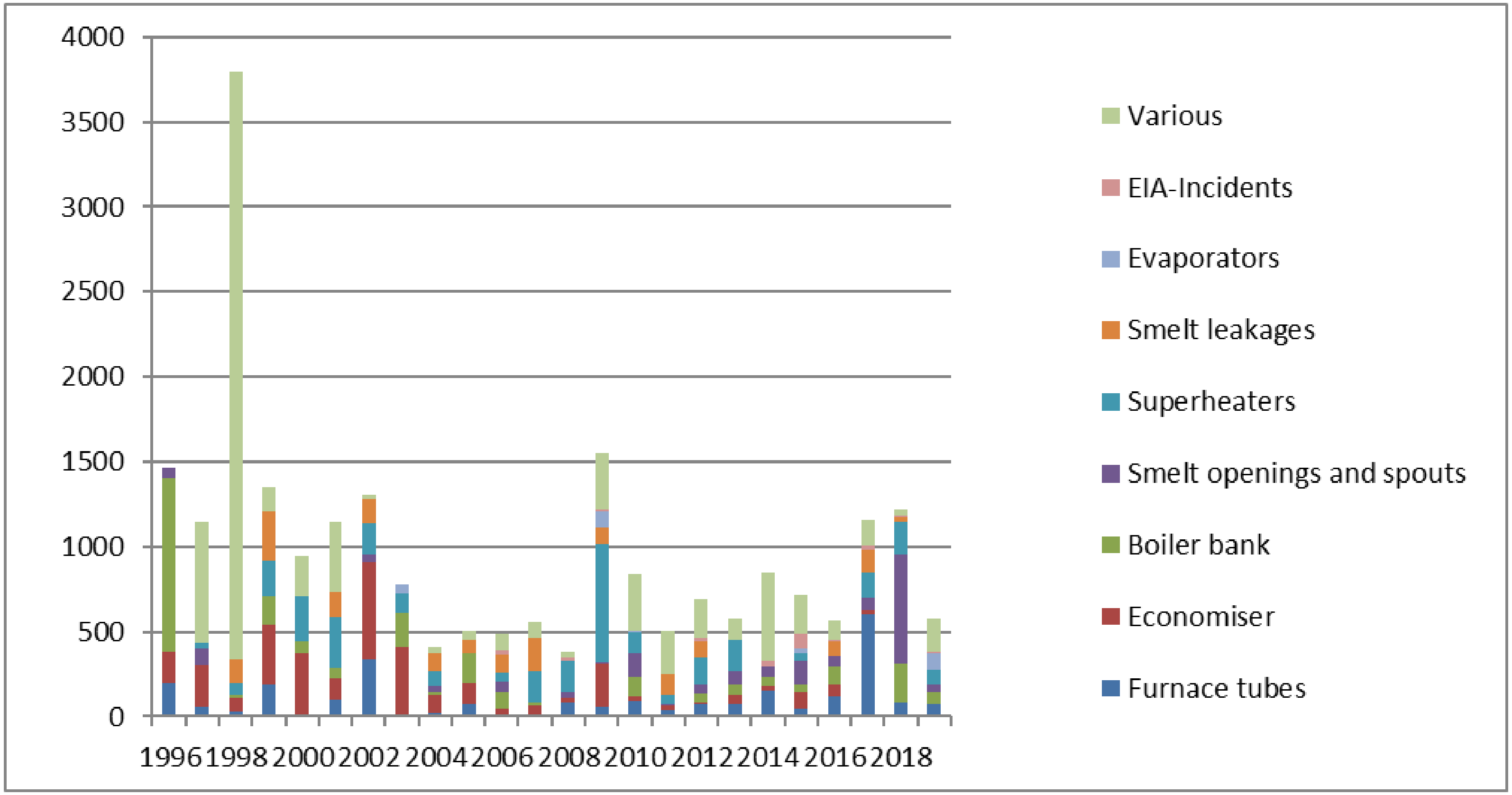


Reported incidents

- Amount of incidents (until October 2020)



Reported incidents
- Down time [h] (until October 2020)



Standardization

- We are members in the Swedish Standardization, SIS

- We are represented in the Swedish Working Group TK285, Boilers

- We take part in the CEN Standardization work for the boiler standard: EN 12952, "Water tube boilers"

SWEDISH STANDARDS INSTITUTE

SVENSK STANDARD
SS-EN 12952-1

Fastställd 2002-01-11
Utgåva 1

Vattenrörspannor och hjälpinstallationer –
Del 1: Allmänt

Water-tube boilers and auxiliary installations –
Part 1: General

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 12952-1

December 2001

ICS 27.040

English version

Water-tube boilers and auxiliary installations - Part 1: General

Chaudières à tubes d'eau et installations auxiliaires - Partie 1: Généralités

Wasserrohrkessel und Anlagenkomponenten - Teil 1: Allgemeines

This European Standard was approved by CEN on 10 March 2000.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: rue de Stassart, 36 B-1050 Brussels

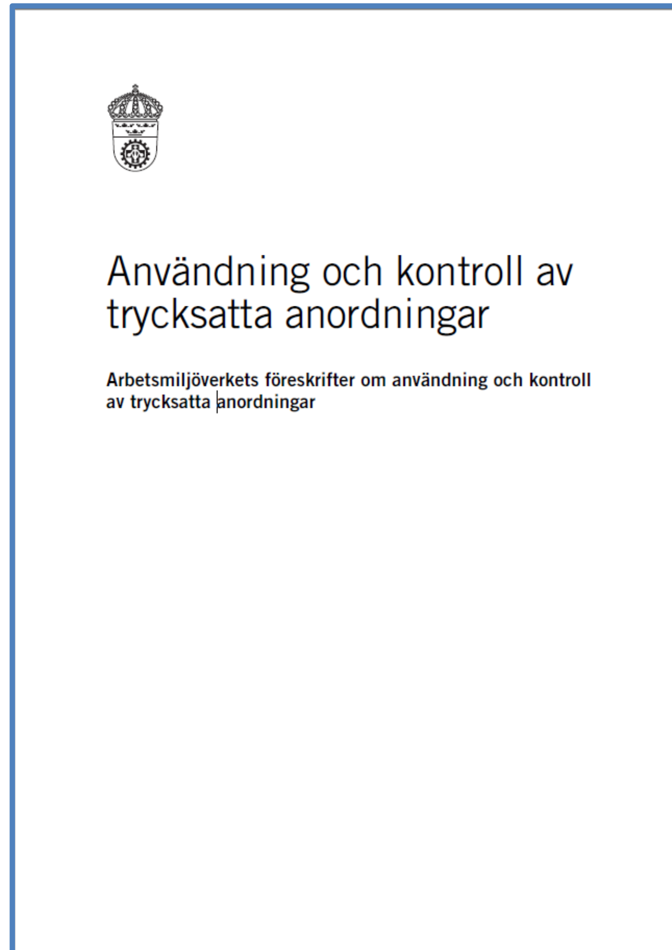
Ref. No. EN 12952-1:2001 E

Standardization

Since november 2017 Sweden has a new regulation för pressurized devices (AFS 2017:3)

Important changes, relevant to recovery boilers are:

- Inspection of boilers
- Assessment of remaining lifetime, routines, journal keeping
- Certification of boiler operators


Användning och kontroll av trycksatta anordningar

Arbetsmiljöverkets föreskrifter om användning och kontroll av trycksatta anordningar

Recommendations

The SNRBC has 40 recommendations, divided in areas like:

B: Construction and equipment
C: Operation and operational disturbances

B: Konstruktion och utrustning

Nr.	Titel
B1	Sodapannors konstruktion och utrustning
B2	Säkerhet i sodahusbyggnader

C: Drift och driftstörningar

Nr.	Titel
C1	Information om kritiska tillstånd och händelser i sodahuset.
C2	Information om sodapannedrift samt förebyggande och åtgärdande av driftstörningar.

Rekommendation från
Sodahuskommittén
Allmänna villkor för användande av Sodahuskommitténs rekommendationer framgår av rekommendation A 3

Nr B 1
Utgåva 3, september 2013

Sodapannans konstruktion och utrustning

Föreliggande rekommendation B 1, bygger på och kompletterar i vissa delar den harmoniserade standarden SS-EN 12952. Rekommendation B 1 behandlar konstruktions- och utrustningsdetaljer som i praktiken visat sig främja personsäkerhet och driftsäkerhet. Rekommendationerna är främst avsedda att tillämpas vid projektering av nya sodapannor, men kan även tjäna som riktlinjer vid ombyggnad av äldre sodapannor.

Även de rekommendationer beträffande luteldning i sodapannor som tidigare publicerats i rekommendation B 17 och B 19 har reviderats varvid vissa delar av innehållet i B 17 och B 19 har överförts till denna rekommendation B 1.

Rekommenderade utrustningar, samt de exempel på utförande som ges i denna rekommendation, anses av Sodahuskommittén kunna ge godtagbar säkerhet.

Hänvisningar

Föreskrifter
Europaparlamentets och Rådets direktiv 97/23/EG, Pressure Equipment Directive (PED)
AFS 1999:4, "Tryckbärande anordningar".
AFS 1990:12, "Ställningar"
AFS 1995:10, "Manhål på vissa behållare"
BKR, Boverkets konstruktionsregler

Standard
Europastandardserien EN 12952 (svensk standard med beteckning SS-EN 12952).

Rekommendationer
Sodahusets utrustning finns kortfattat beskriven även i rekommendation A 1.
Sodapannans tryckdelar är namngivna och beskrivna i rekommendation A 2.
Sodahuskommitténs rekommendationer angående konstruktion och utrustning av sodapannans viktigaste hjälpsystem, samt rekommendationer angående säkerhetssystem återfinns under ämnesområde B och F på Sodahuskommitténs hemsida.

Sodahuskommittén, 169 99 Stockholm

Updating of the recommendations every third year

Recommendations approved 2021-2022

B4 Construction and design of dissolving tank (2022)
B22 Recovery boiler air systems
B17 Evaporation black liquor systems (2022)
B5 Safety equipment around recovery boilers (2022)
D4 Repair and maintenance welding of recovery boilers (2022)
B2 Safety in boiler houses (2021)
B8 Emergency shutdown and rapid drainage of recovery boiler (2021)
C4 Quality of makeup water, condensate, feed water, boiler water and steam (2021)
C12 Chemical cleaning of water-side scaling (2021)
B13 Combustion of oil and gas in recovery boilers - equipment and safety systems (2020)

Certification of recovery boiler operators

The minimum accepted recovery boiler experience until examination and certification is 2 years

All certificates need to be updated/renewed each 7th year

The “re-examination test” is web-based and divided into three main parts:

- Recovery boiler design
- Combustion optimization
- Safety

Education adopted to also suit the knowledge requirements for boiler operators in the renewed Swedish regulation of pressurized devices

Certification of recovery boiler operators

Knowledge requirements in the renewed Swedish regulation of pressurized devices (AFS 2017:3):

- Knowledge of the regulation for pressurized devices
- Boiler principles: thermodynamics, superheated steam, phase transitions
- Boiler construction
- Risks during start and stop of boiler
- Monitoring and safety system of boiler
- Emergency situations and how the operator should act
- Properties of steam, water and oil at temperatures exceeding 110C
- Special risks in boilers where heat can be accumulated and how to prevent these risks
- Boiler control system
- Boiler alarms related to safety and critical to safety

	Kategori			
Färdighet eller kunskap	1	2	3	4
Ha kunskaper om kraven för pannor i dessa föreskrifter: – Fortlöpande tillsyn – Pannans livslängd – Kontroll – Övervakning	X	X	X	X
Känna till de grundläggande principerna bakom pannor: termodynamik, överhettning och fasomvandling.	X	X	X	X
Kunna ISO-standardenheter för temperatur, tryck, massa, densitet och energi.	X	X	X	X
Kunna beskriva hur pannan och de huvudkomponenter som är förbundna med pannan fungerar.	X	X	X	X
Ha grundläggande kunskaper om de risker som finns vid start och stopp av en panna.	X	X	X	X
Ha grundläggande kunskaper om de risker som finns med eldning av olika bränslen.	X	X	X	X
Kunna beskriva och förstå en pannas övervaknings- och säkerhetsutrustning, varför de finns, hur de fungerar och vilka åtgärder som ska vidtas när de aktiveras.	X	X	X	X
Ha kunskaper om de nödsituationer som kan uppkomma vid användning av pannor och hur en [pannoperatör] ska agera vid dessa nödsituationer.	X	X	X	X
Känna till krav vid ständig och periodisk övervakning.	X	X	X	X
Ha kunskaper om egenskaper hos ånga samt vatten och olja som hanteras över 110°C.	X		X	
Veta vilka särskilda risker som finns vid eldning av pannor där restvärme kan ackumuleras i farlig mängd och hur dessa risker förebyggs.	X	X		
Veta hur de styr- och reglersystem som säkerställer att pannan hålls inom tillåtna värden fungerar.	X	X		
Känna till vad som skiljer säkerhetsrelaterade och säkerhetskritiska larm från övriga larm.	X	X		

Certification of recovery boiler operators

Phase 1, 4 days	Phase 2, 4 days	Phase 3, 4 days	Phase 4, 4 days
Introduction	Process control, phase 1	Process control, phase 2	Process control, phase 3
Introduction to pulp production and chemical recovery	Energy technology	Regulations	Critical conditions
Environmental technologies	Feed- and boiler water	Safety systems	Operation and operational disturbances
Process- and production economy	Boiler circulation and steam formation	Fuel, hot water and hot oil boilers	Safety aspects of operation, case study
Project	Combustion technology	Material and damages	Final presentation of project
Homework	Presentation of project, part	Site visit	
		Presentation of project, part	

Experience sharing day

Operators and other persons from member companies meet and discuss important topics.

2019 the topic was

” Experience of weak gases, strong gases, dissolving tank gases and methanol in the recovery boiler”

- How does it look in our home mills
  - Recent situations, routines, instructions
- Regulations, norms, recommendations
- Discussions

Next Experience sharing day, April 2022 on topic:

”**Incidence handling and emergency shut-downs**”

Prioritized projects 2023

Risk Analysis Recovery Boiler (continuation) – SIL classification
Guidelines on risk analysis of recovery boiler incl

- Required safety functions in a recovery boiler
- By SNRBC recommended SIL-level (Safety Integrity Level) for each safety function
- Added chapters on what should be included in boiler testing

Smelt run-offs
- Bench marking study based on data from many swedish mills, to analyze the effects of different mill-parameters on the smelt run-off phoenomena

Risk Analysis Phase 3

Risk Analysis Phase 3 is a study that will form the basis for an update of the *SNRCs Recommendation B18 Recovery boilers Safety system,* as well as *Recommendation F4 Risk analyses for Recovery boiler*

Requirements for safety functions on a Recovery boiler:

- Formal recuirements (PED, SS-EN-standards, AFS)
- Other requirements
    - SNRCs recommendations
    - Facility specific requirements that emerge in connection with risk analyses

The objective with the study is to prepare a document where:

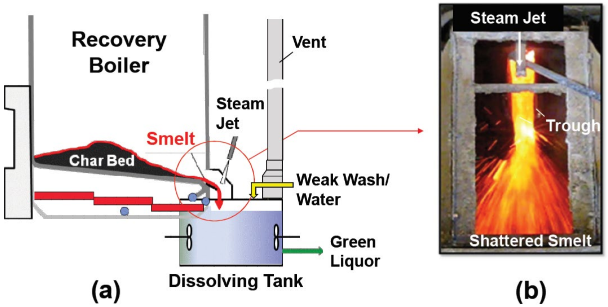
- All requirements for safety functions are listed
- For each safety function it is indicated where the requirement originates from
- For each safety function the critical event it is supposed to protect against is described
- For each safety function a minimum SIL-recuirement recommended by SNRC is specified

Content of the final report

- Compilation of current regulations
- Working methods for risk analysis for new SIS
- Calibration of Risk graph
- Safety functions divided into:
  - Liquor and Steam (Firing liquor & The boiler's pressure vessel)
  - Furnace
  - Weak gas & Smelt dissolving tank vent gas
  - Start burners
  - Strong gas & Methanol/Turpentine

- Block division of end elements when SIF is triggered
- Breakdown of SIF and the old concept of ”Emergency shutdown”

Smelt run-off study



- In this study, process variables, as well as mill- specific parameters are studied to establish clear patterns that could be linked to smelt run-off incidents. An extensive number of variables are looked at, including things such as black-and white liquor properties, air system configuration, washing sequence in the evaporation area, boiler dimensions etc.

- The project is divided into two phases, where the first step is to collect plant information from the mills involved in the study. The purpose is to get a broader picture of how mill-specific conditions relates to the presence of smelt rushes and try to identify links. The working group will determine what type of information is relevant to investigate, how to practically do it and what type of samling is appropriate to provide a better picture of the causes of the issue.

- Based on the collected data, an assessment is made as to whether further sampling could be interesting for increased insight - and how this should be done practically.

- In phase two, there will be an analysis of process data for specific facilities, with results and conclusions from phase 1 guiding the work

Thank You!

ESP Subcommittee

SUBCOMMITTEE REPORT FOR 2022

COMBINED SPRING AND FALL REPORTS

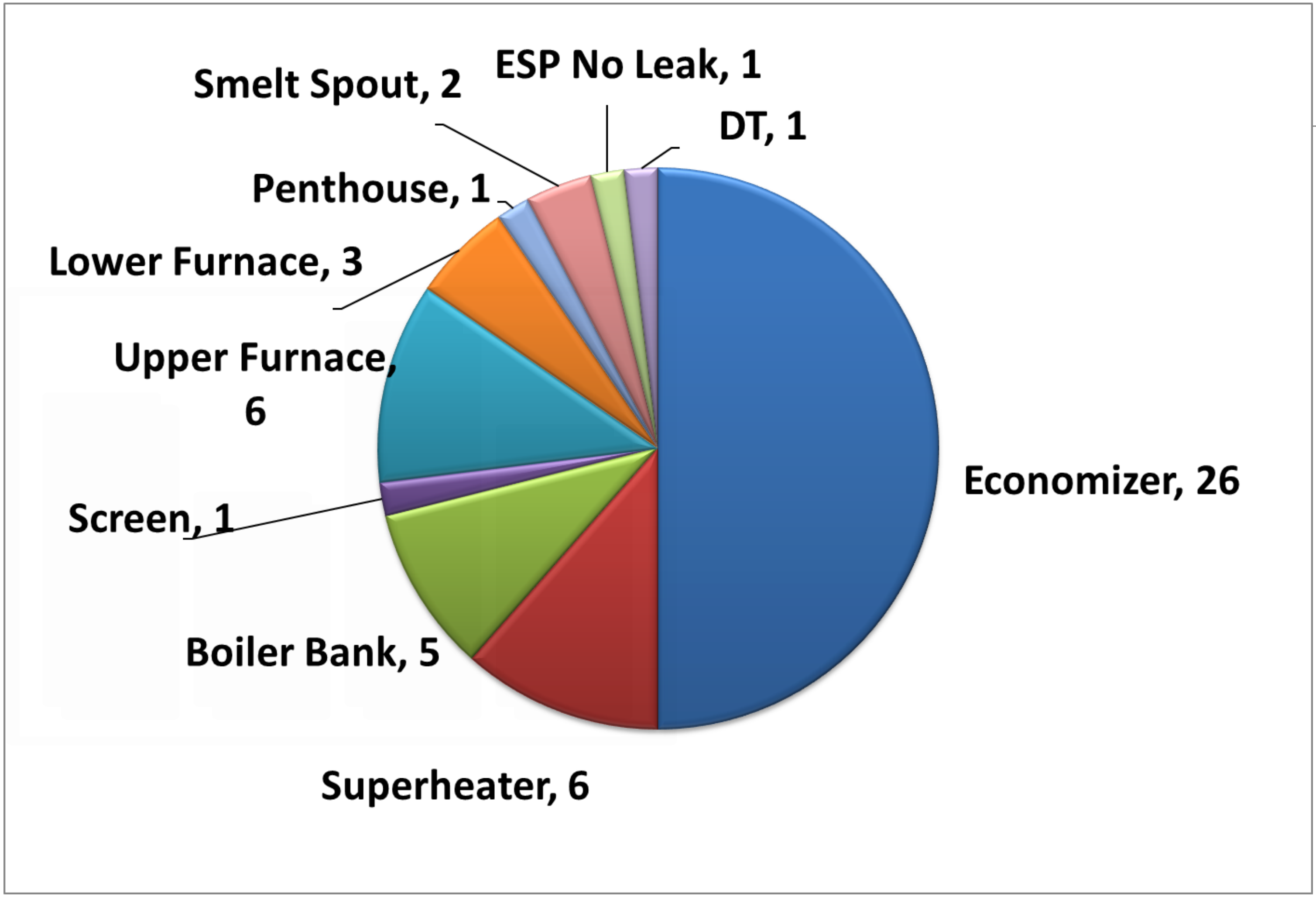
Incident Questionnaire Review

- 51 US & Canada Incidents
  - 0 Smelt Water Explosion
  - 15 Critical
  - 33 Non-critical
  - 2 Spout Cooling Water Leaks
  - 1 ESP No Leak

- 8 ESP'd
  - 6 Critical
  - 60% of Critical that Should ESP

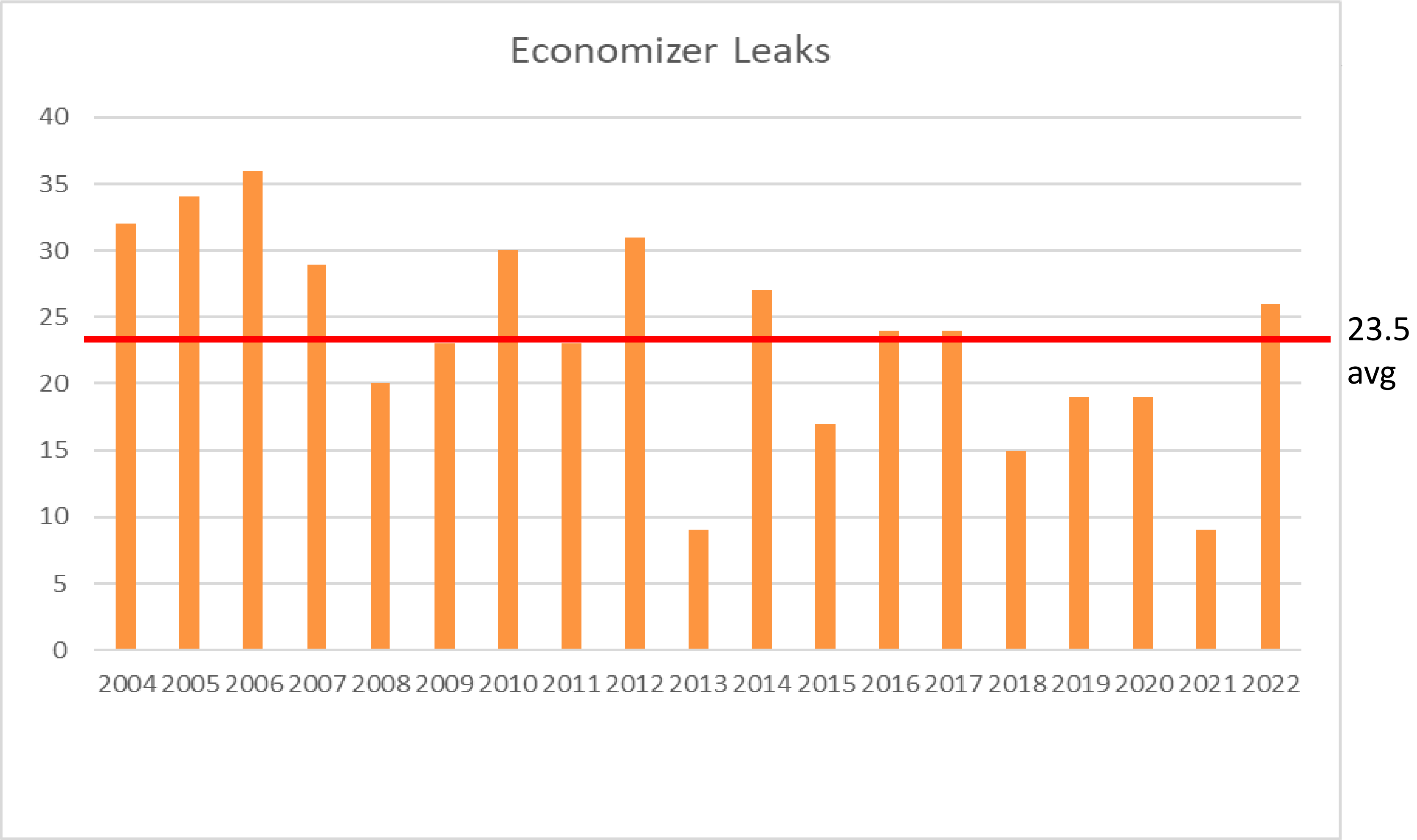
- 1 International Incident Submitted

Incident Locations

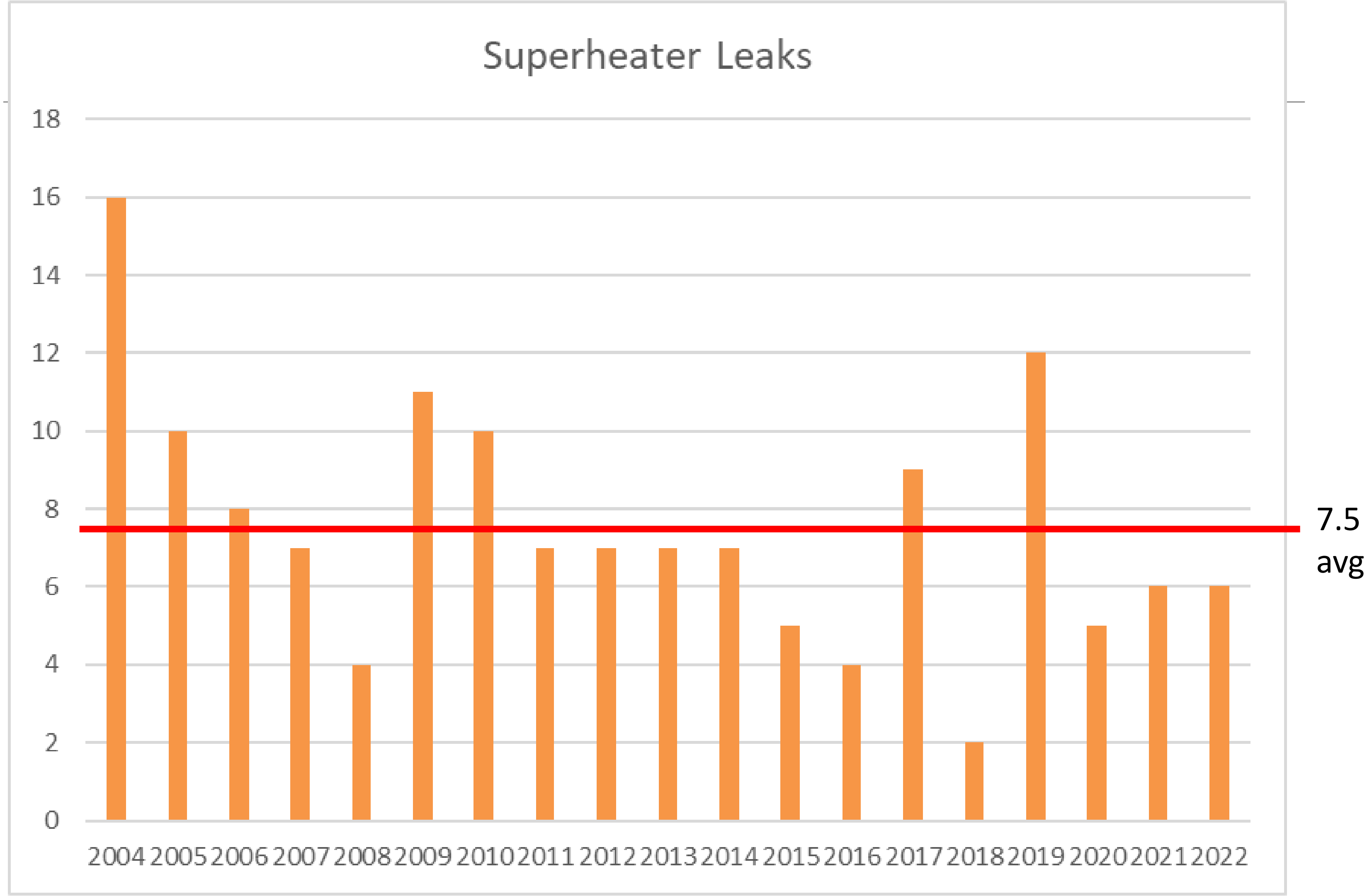


Boiler Component Leak Trends

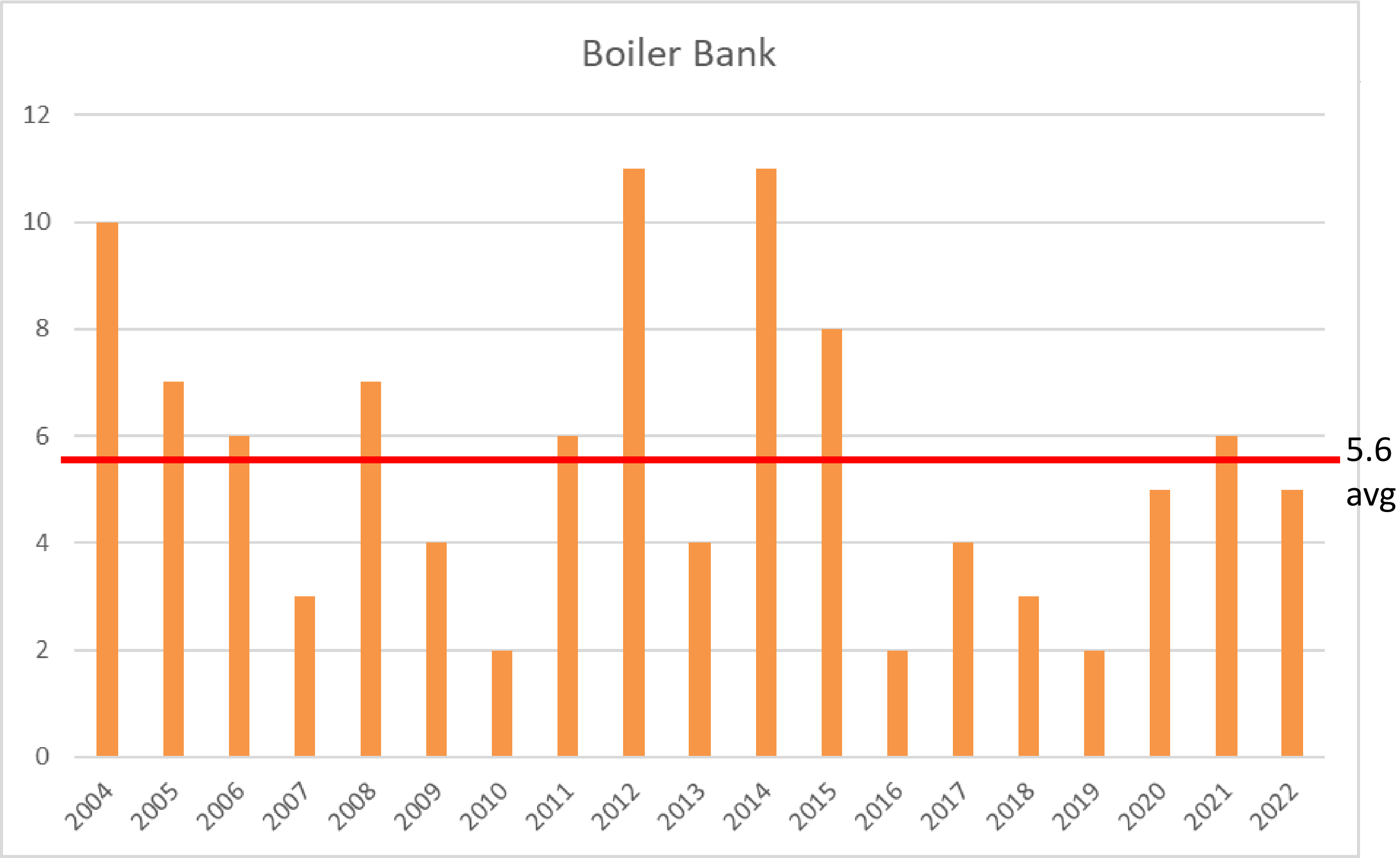
19 Years



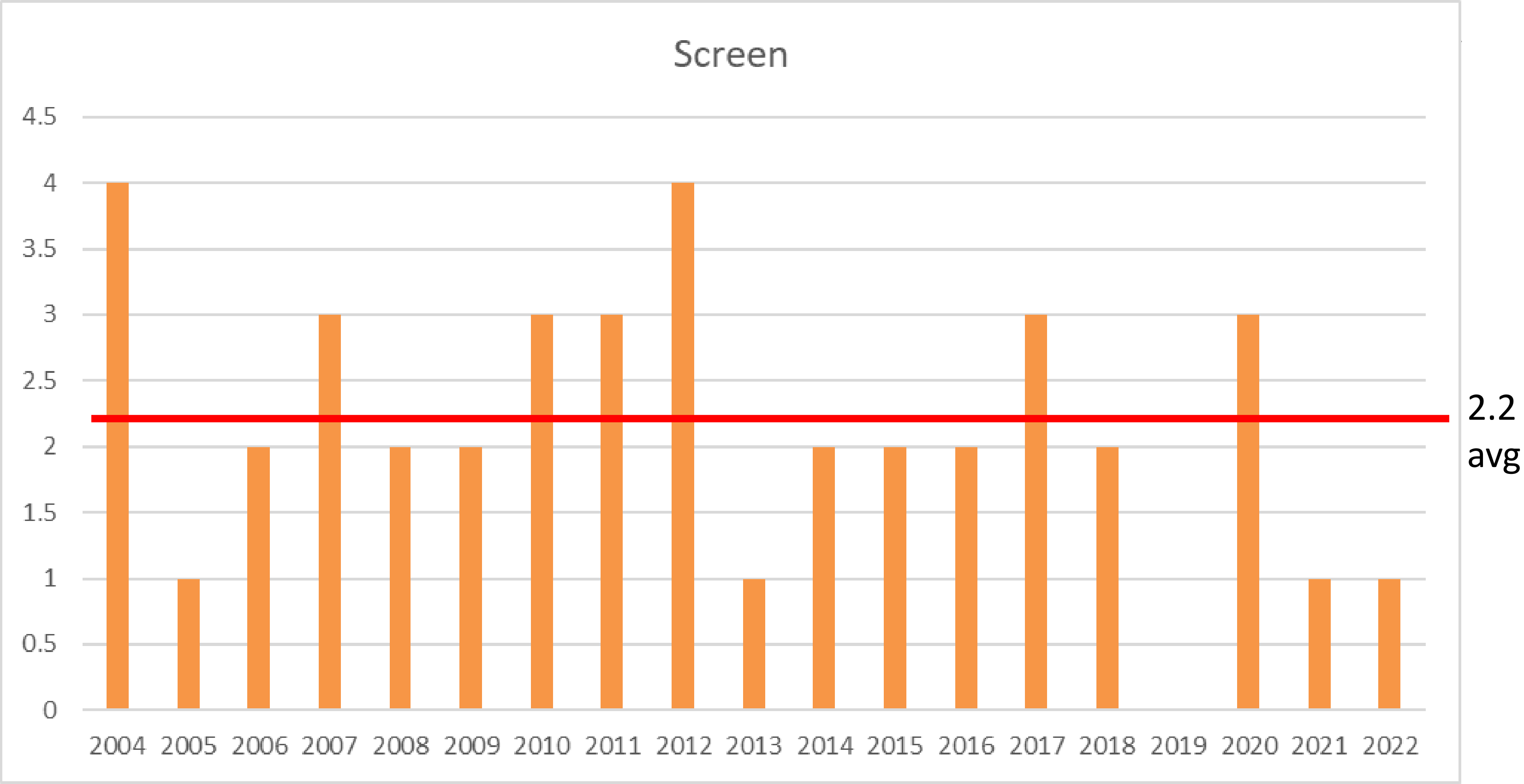
Boiler Component Leak trends



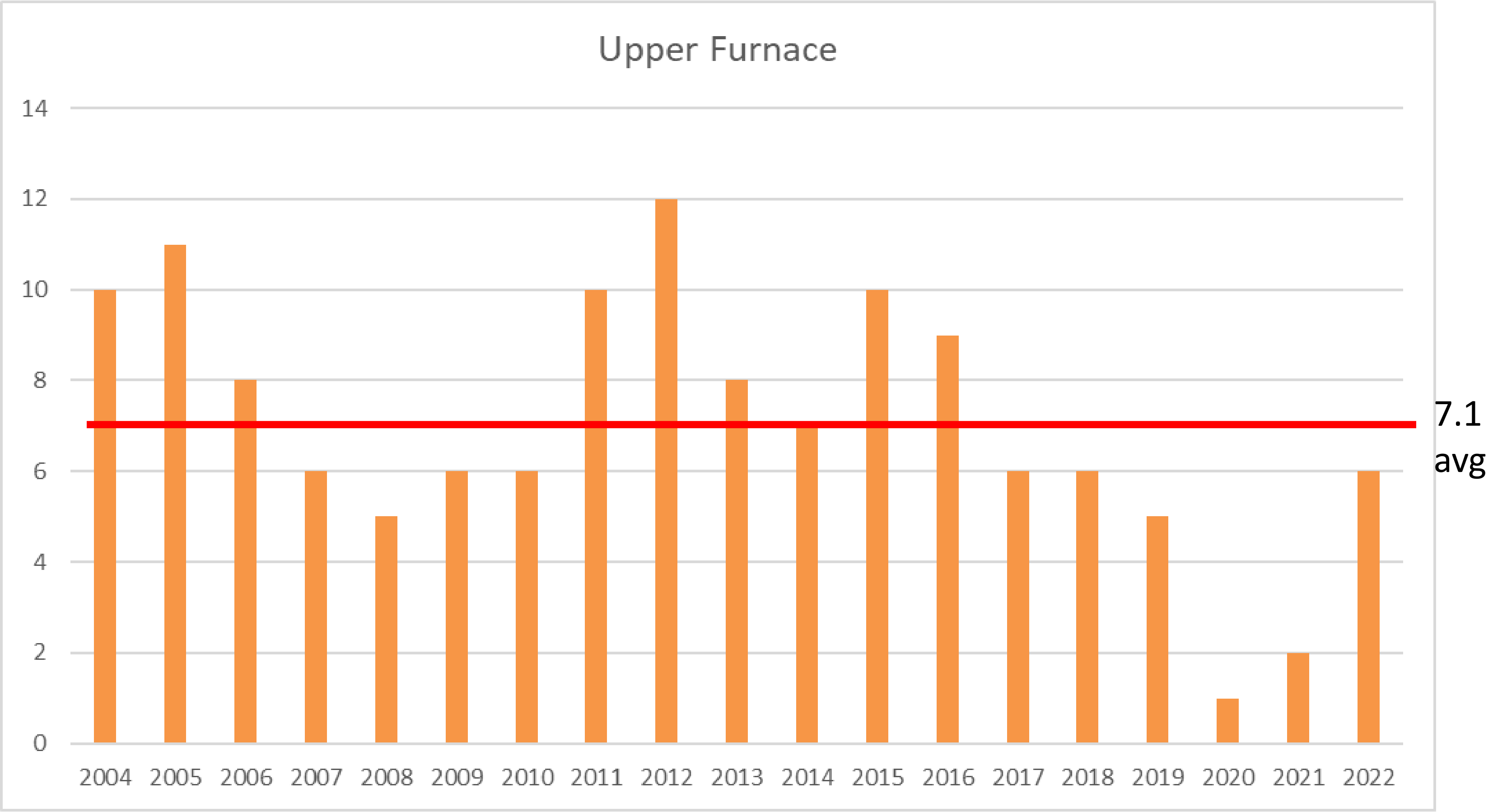
Boiler Component Leak trends



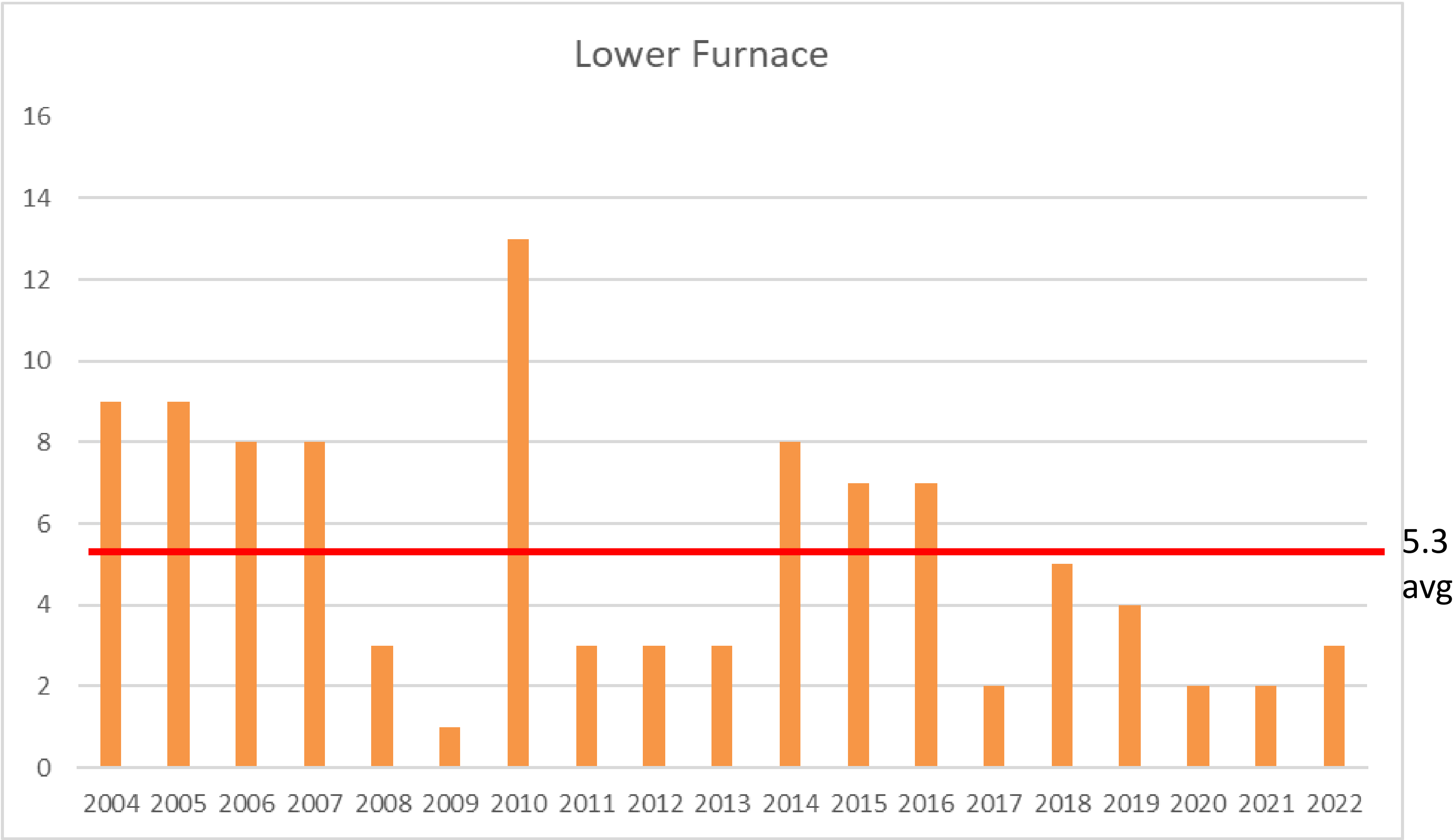
Boiler Component Leak trends



Boiler Component Leak trends



Boiler Component Leak trends



BLRBAC Reported Leaks (US + Canada)
2004 thru 2022

Location	19 Year Total	Average/Year
Economizer	447	23.5
Upper Furnace	134	7.1
Superheater	143	7.5
Lower Furnace*	100	5.3
Boiler Bank*	106	5.6
Screen*	41	2.2
Smelt Spout	31	1.6

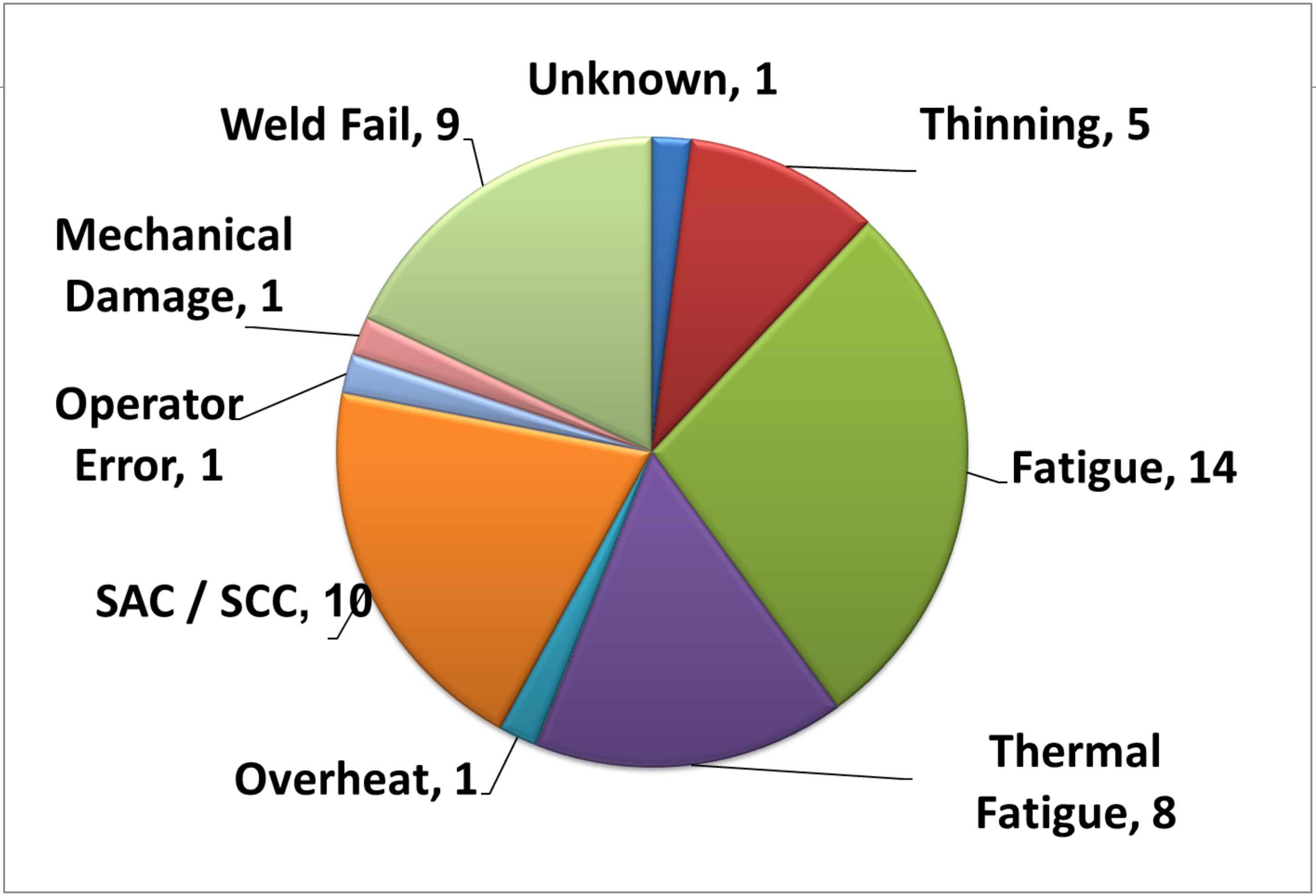
*Four Smelt-Water Explosions Recorded 2004 thru 2022,
One from Boiler Bank Leak, Two Screen Tube Leaks, One Floor Leak

ESP Subcommittee BLRBAC 2022 10

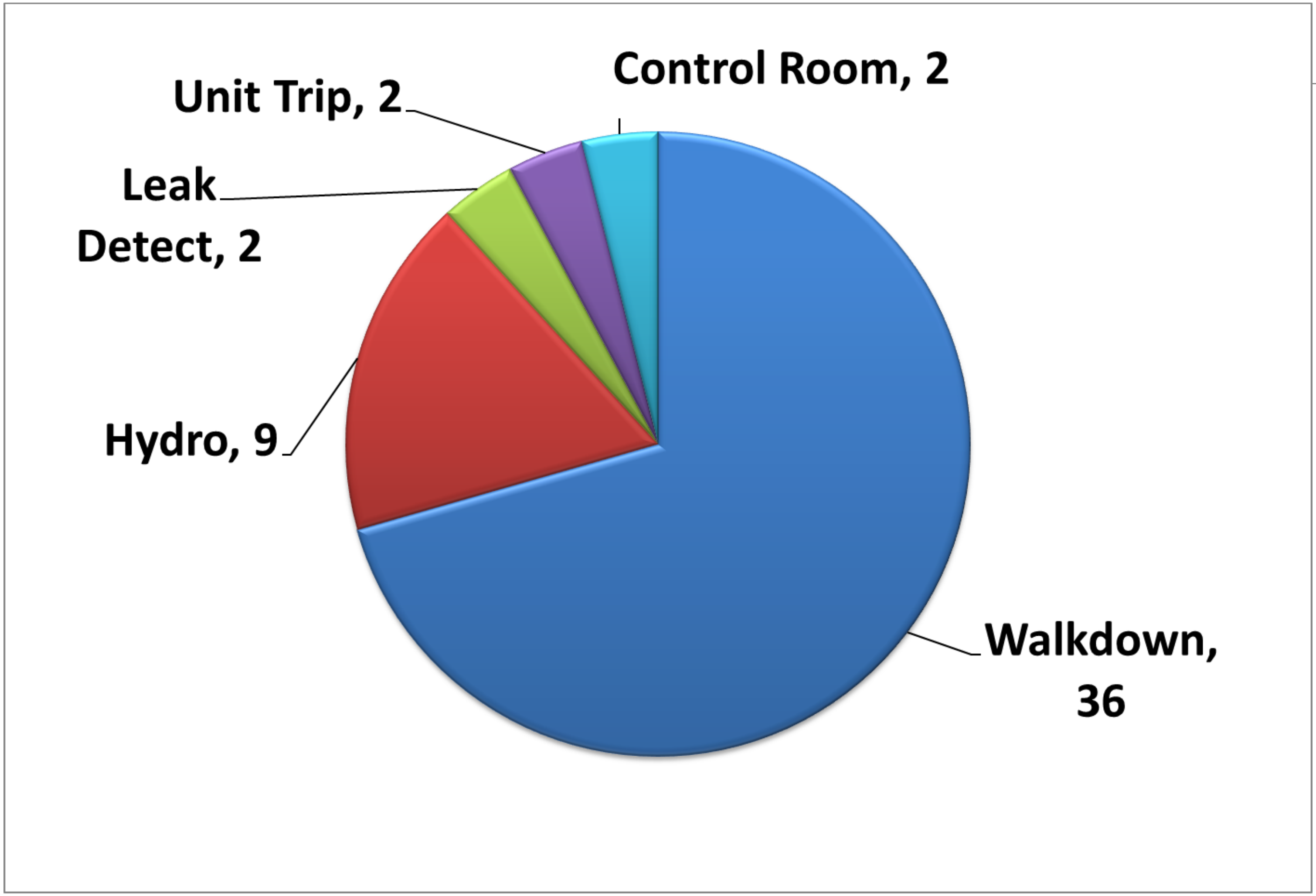
Incidents by Boiler Type

- Drums
  - 1 - 22
  - 2 - 29
  - 3 - 0
- Back End
  - Large Economizer - 47
  - Cascade - 4
  - Cyclone - 0

Leak Cause


Unknown, 1
Thinning, 5
Weld Fail, 9
Mechanical Damage, 1
Operator Error, 1
Fatigue, 14
SAC / SCC, 10
Overheat, 1
Thermal Fatigue, 8

How Discovered



Leak Detection Systems

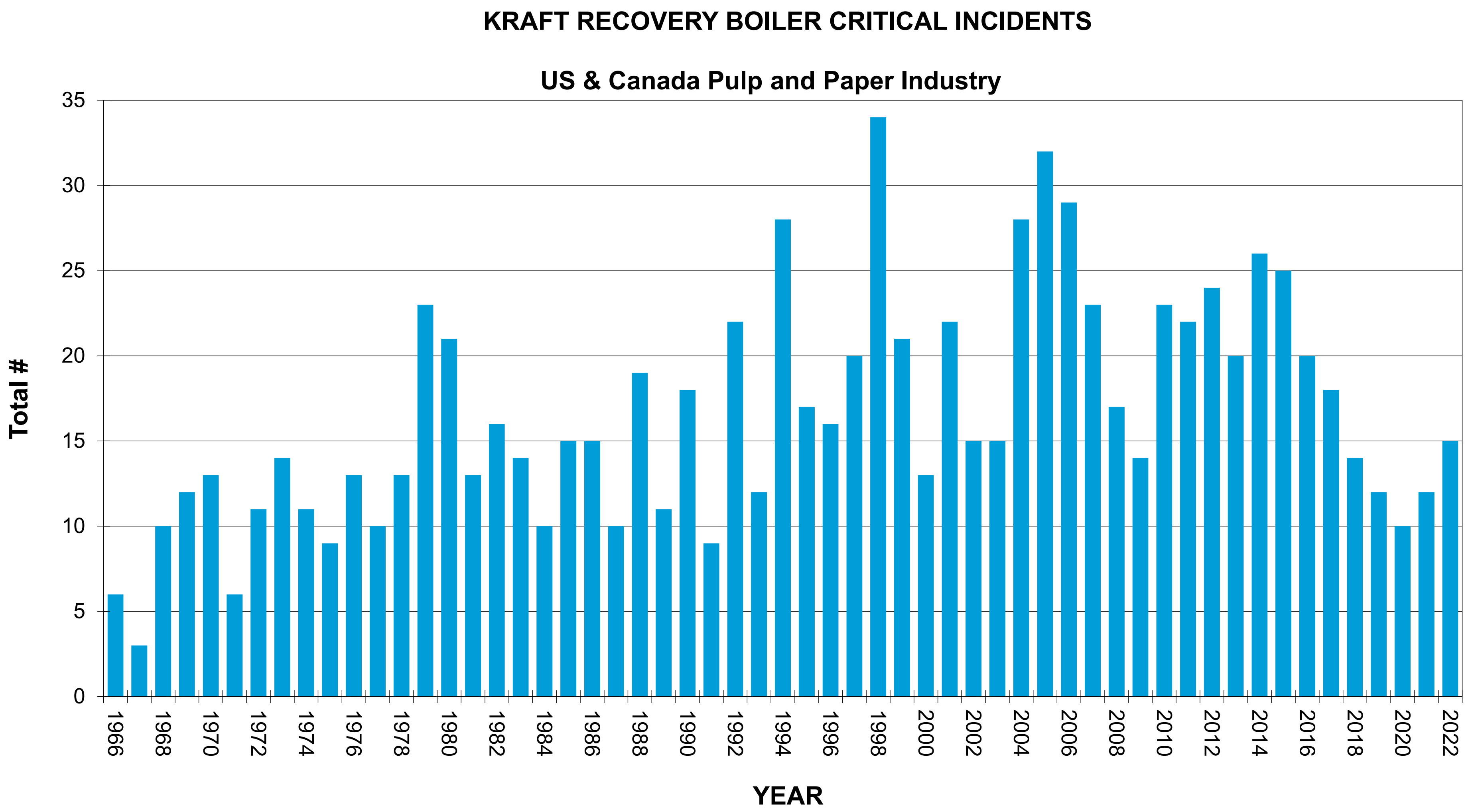
- Leak Detection Systems installed – 20 (39%)
  - Identified leak – 2
  - Confirmed leak - 1

Time to ESP from Initial Indication

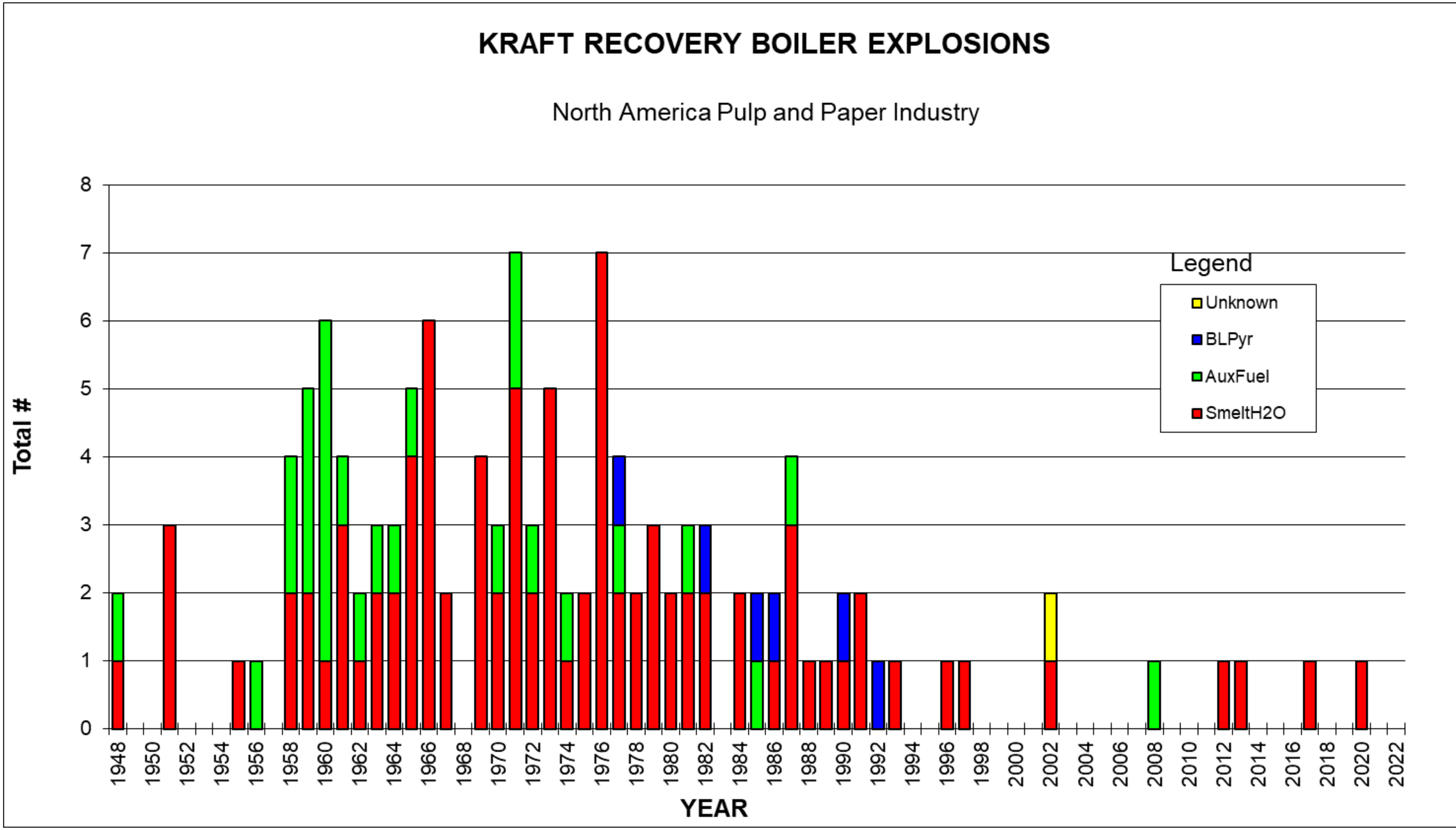
Ranged from 0 minutes to 113 minutes

Median time was 13.3 min

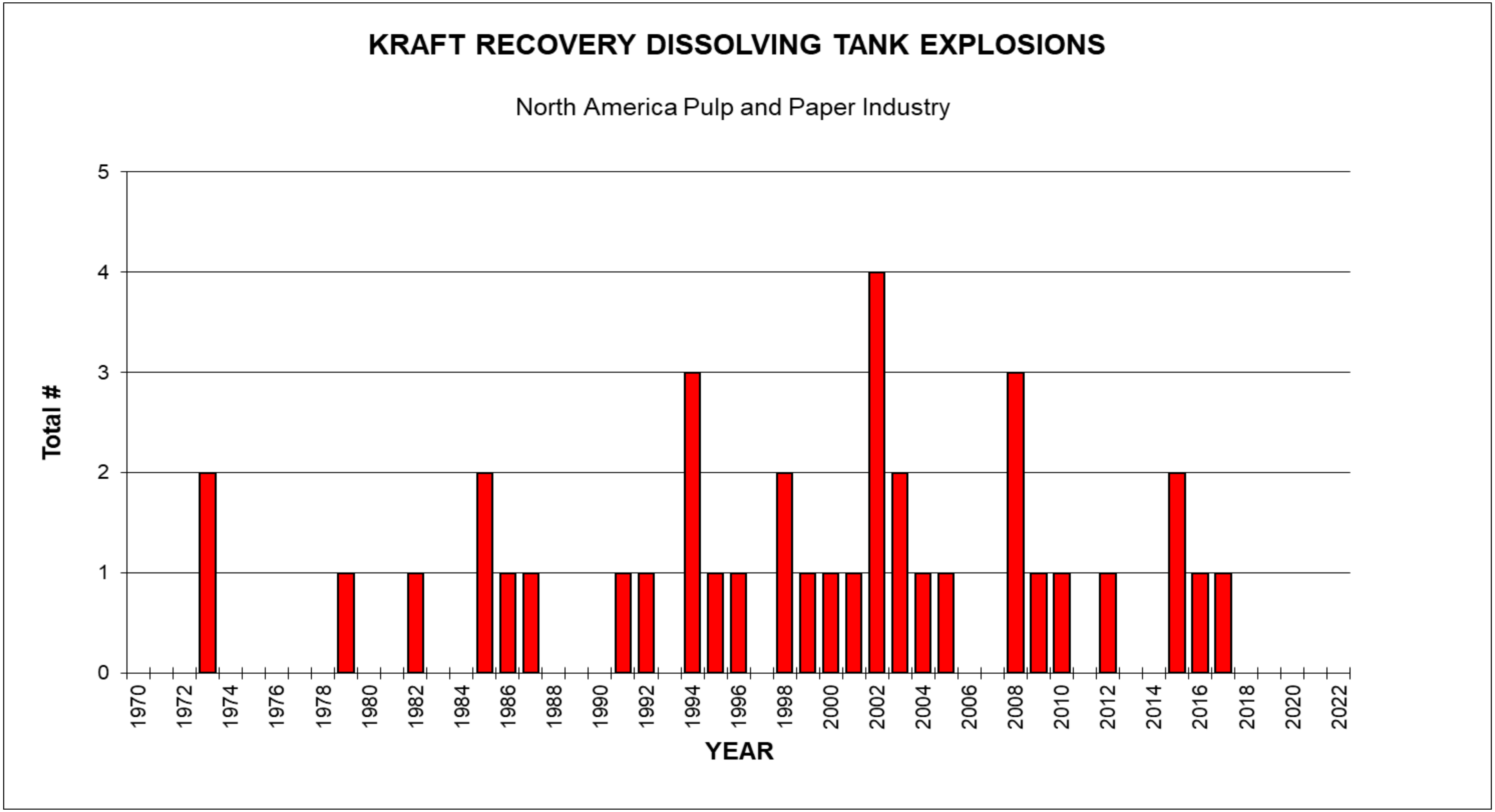
Critical Incidents to Date



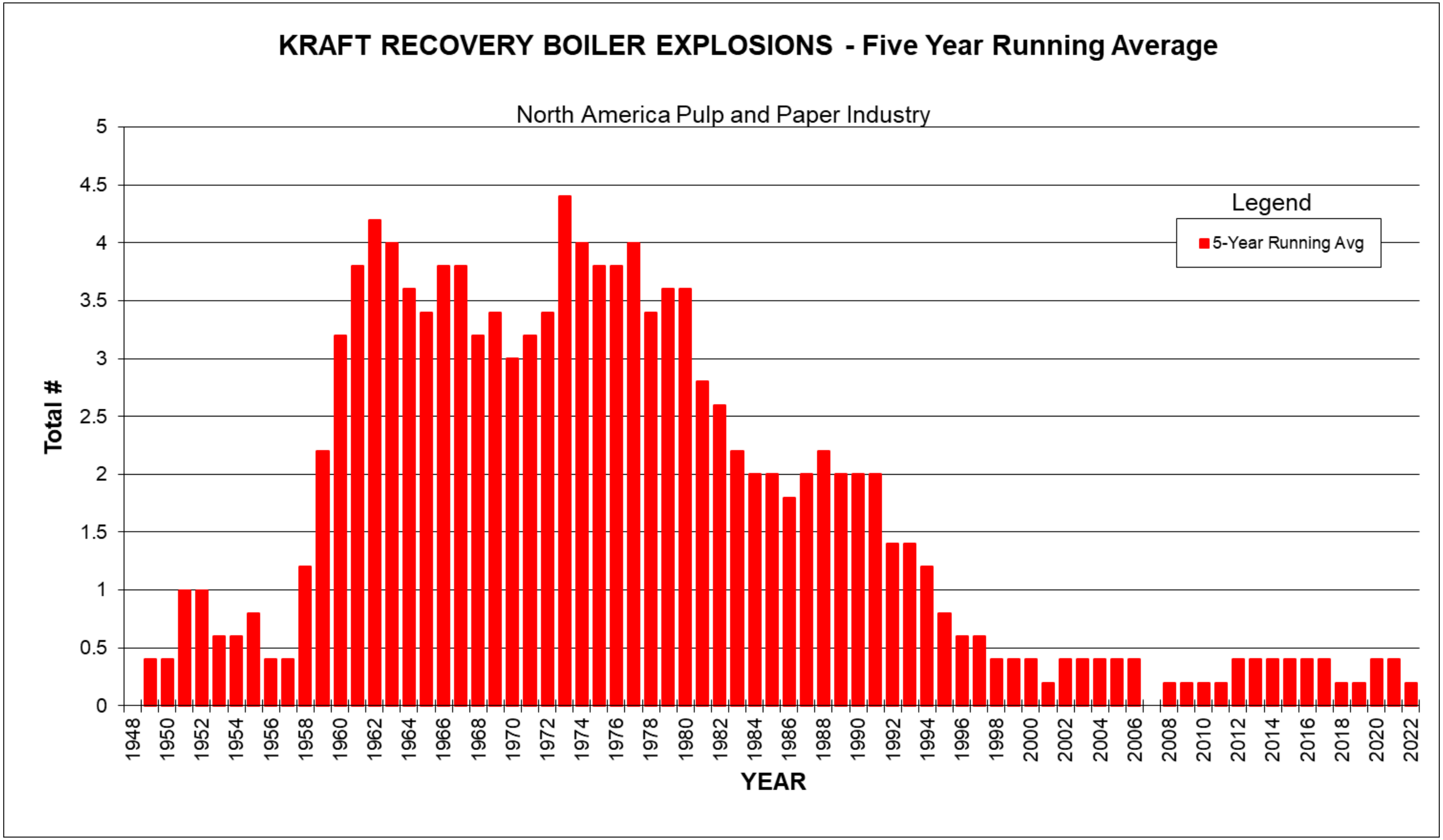
Boiler Explosion History



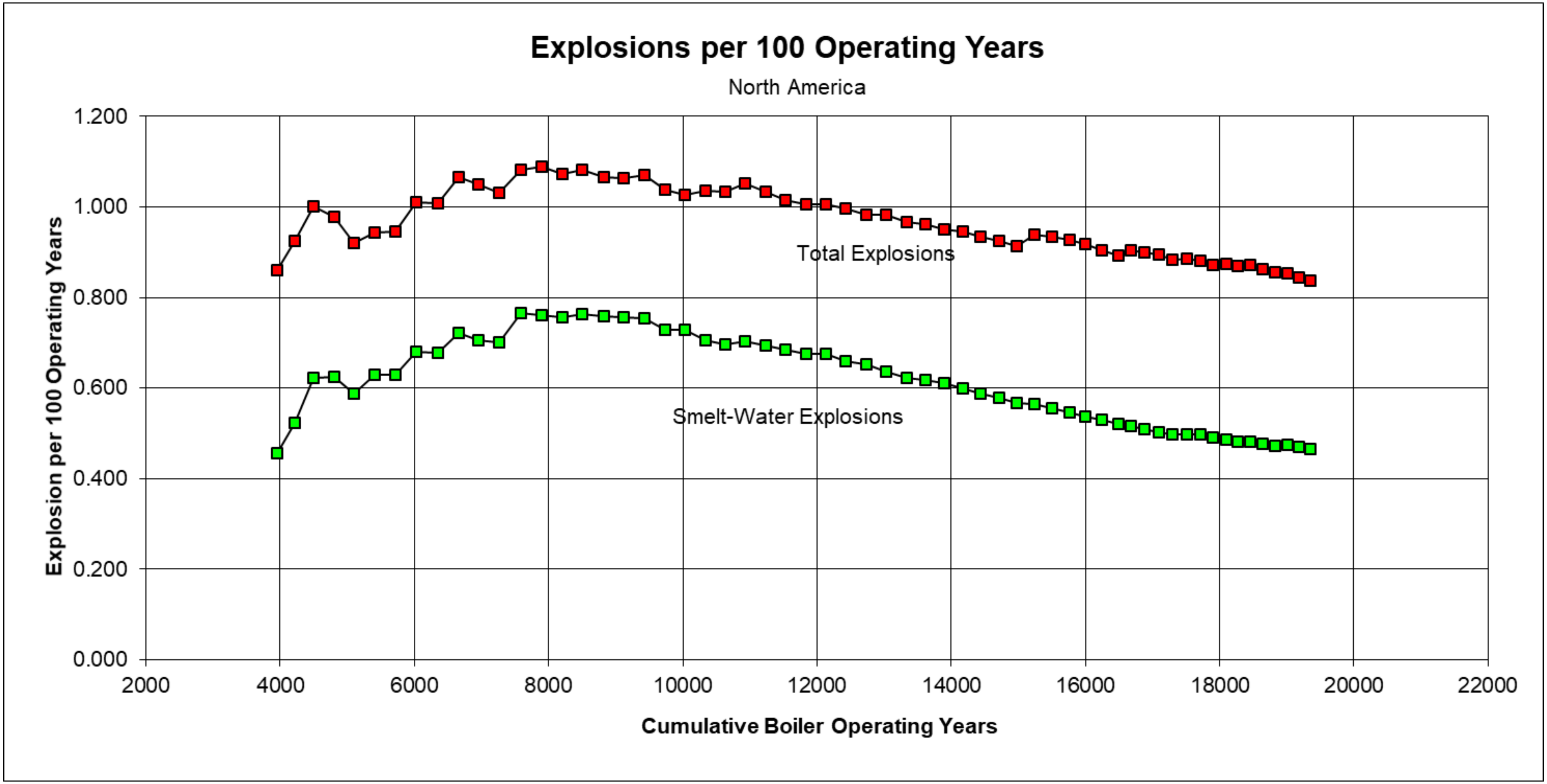
Dissolving Tank Explosions



Explosion History - Five Year Avg



Explosion History per 100 Oper Yr



Boilers in Service

- North American Total - 169

	US	Canada
Number	131	38
Avg Age	43	45.6
Max Age	70	75

- Oldest
  - Kruger Three Rivers, PQ
  - 1947 Alstom
- Contact Dean Clay with any Corrections or Updates

Reporting RB Incidents to BLRBAC

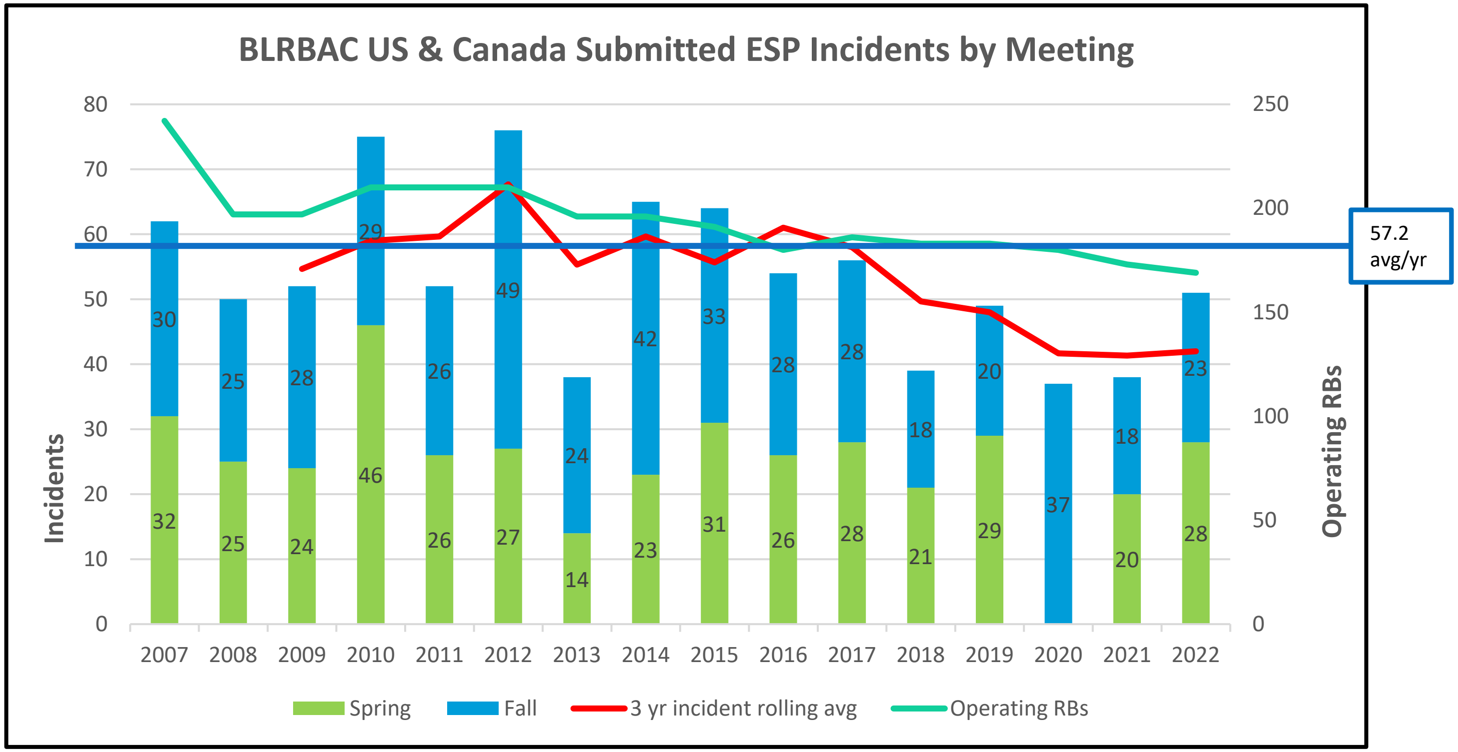
Per BLRBAC "Operating Policies and Procedures" our primary function is: Analysis, classification and reporting of incidents.

As listed in our incident questionnaire Instructions:

The purpose of the Incident Questionnaire is to provide prompt reliable information to aid in preventing explosions through improved awareness, practices and emergency shutdown procedures.

This Questionnaire should be completed for **each** recovery boiler explosion, pressure parts failure or leak, ESP, potentially explosive incident, water entry into furnace, smelt spout leak, or smelt dissolving tank explosion.

- *We have requested that RB pressure leaks found on a hydro test be reported also*.



BLRBAC US & Canada Submitted ESP Incidents by Meeting
Incidents
Operating RBs
80
70
60
50
40
30
20
10
0
250
200
150
100
50
0
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
30
32
25
25
28
24
29
46
26
26
49
27
24
14
42
23
33
31
28
26
28
28
18
21
20
29
37
18
20
23
28
57.2 avg/yr
Spring
Fall
3 yr incident rolling avg
Operating RBs

Learnings

- Minimize welding on tube bends and have spare tube bends on hand.
- Using tube shields long term can cause corrosion behind the tube shield.
- Where failures occur at attachment welds, SAC is highly suspected as the cause. X-raying for SAC prior to repair is prudent. Welding over SAC or defects will cause cracking to spread and cause future failures. Limit the size of pad welds.
- Evaluate the frequency of acid cleanings. Waterside deposits become more tenacious over time and harder to remove. Deposits raise the tube metal surface temperature thereby accelerating corrosion rate.
- Ensure waterside deposits are tested for composition so that acid cleaning steps are appropriate for removing the type of deposit existing on the tube.

Learnings

- Ensure economizer fins are angled and not square and that welds wrap around the fin. Consider stress relieving 2’ beyond the end of the fin.

- Ensure vibration and anti sway restraints exist where needed in Superheaters, Economizers and Generating sections.

- Consider Nipples and Caps for handhole caps in lieu of traditional plug type caps

- Do not assume the sound of a leak in the SH section is a SH leak. Steam/FW differential can help determine the source as well as boiler chemical possible loss. (Is the differential caused by FW flow rise or Steam flow drop?) “If you can’t see it – ESP it!”

- Leading edge Sootblower nozzles will aggravate boiler tube sway and fatigue failures.

Learnings

- When plugging a spout, Consider the dry solids loading on the remaining spouts. (1MM – 1.2MM max. typical)

- Consider increasing Spout cooling water flow to 40-45 gpm if spouts are suffering with Thermal cycle fatigue.
- Ensure all spouts are level (Laser level) to ensure equal smelt flow and acceptable cooling per spout.
- Ensure SB steam is dry steam not saturated. Check header slopes and insulation.
- SB steam traps are one of the most critical steam traps in the mill to maintain. Consider orifices in parallel with traps and cracking drains open ahead of traps.
- Ensure tube material installed is appropriate for the section of the unit. Have a boiler diagram showing material required and verify tube material certs from suppliers

Learnings

- Salt sheds from the SH and or Screen can add enough material to the floor area that it can flow to the DT and cause violence. It is typically Sulfate rich, highly viscous and will tend to dam and jelly roll. This material must be watched for accumulation and must be controlled and be considered bed material.

- The senior most knowledgeable management personnel must be involved in overseeing the situation when spouts are having plugging issues.

- Ensure Leak detection systems/Alarm are being checked on a regular basis, Some were reported to be in alarm for an extended period and not reacted to, some reported to not have active alarms.

- Consider testing the sensitivity of your leak detection system by cracking a drain and simulating a leak. Do not desensitize your system to avoid nuisance alarms such that an actual leak would not be detected. Utilize an MOC process to approve adjustment to any critical alarm settings.

Learnings

- Do not leave hoses around a RB unattended where they may spray into a RB or confuse operations as to the source of the water.

- If multiple past leaks have been occurring on a unit in a certain section, do not become complacent and assume the present leak is in the same area. A leak may have occurred in a different area that may be critical, such as the upper section of an economizer exposed to the rear section of a 2 drum generating section or the top section of a Single drum boiler generation section.

- Do not run with an economizer leak unless you know for certain (and can see) the leak is in a non-critical area. It may be in a critical area. It may be in the economizer area exposed to the furnace with no baffles in between.

- Do not assume sound in a boiler SH section is a non critical SH leak. Even if it is, it can be impinging on a Critical wall tube, roof tube or screen tube. "If you can't see it ESP it". "When in doubt, punch it out". Assume the worst situation is happening and then convince yourself it is not vs. assuming you are dealing with a non-critical situation only to find out it is critical

Learnings

- Consider replacement of pad welded tubes on future outages. Especially if the tube had indication of possible SAC (stress assisted corrosion), which is almost always waterside initiated, and may have produced other waterside cracks that have not reached the OD surface yet.

- Large leak logic states if Furnace trips on High furnace pressure and the drum level gets to the trip point within 45 seconds, the BLRBAC large leak logic will activate. This will shut the FW valve and put it in manual and trigger a "Possible large leak" alarm. This logic is under revision as 45 seconds has been found to be too short ~~long~~. FW systems may be able to supply high flow out of the leak and also recover drum level.

- The longer a boiler goes without acid cleaning, the more tenacious and hard to remove the deposits will become.

- Ensure low drum level trip points do not allow exposure of upper level generating section and phase separation

Learnings

- The number of smelt spouts requiring to be open for liquor firing must be established and adhered to.

- An ESP has not been found by BLRBAC to cause a defect or damage a boiler. An ESP may cause a previously existing defect to propagate to failure. The defect is there prior to ESP and the root cause of the defect should be determined and similar areas examined for similar defects.

- Smelt bed temperatures must be determined through probing the bed through the surface crust with a rod and thermocouples. Surface temperature measurements are not sufficient.

New Documents on blrbac.net

- ESP Subcommittee Learnings, Spring 2005 thru Fall 2022
- How to Participate in a BLRBAC Meeting.
- Both cam be downloaded from the Home page.

Incident Questionnaires

- Obtain Up to Date Questionnaire with Fill In Form from BLRBAC.net
- Submit to Dean Clay at dclayesp@gmail.com
  - Please use Word .docx files, not .pdf
  - Please use .jpg illustrations
- Look for confirmation of receipt from Dean

BLRBAC

Black Liquor Recovery Boiler Advisory Committee

For New (or almost new) Attendees, How to Prepare to Participate in a Meeting, Take Advantage of the Opportunity

How to Participate in a BLRBAC Meeting

- Go to website: www.blrbac.net
- Meetings are typically held twice a year, in early April and early October
- Meetings are currently held at the Sonesta Atlanta Airport North Hotel
- Website will have future meeting dates
- Go to "Meetings", download Meeting Notice and Agenda, usually available 6 weeks ahead of meeting.
- To preregister, follow the link for online registration.
- BLRBAC Meeting starts Monday morning and ends Wednesday around Noon.

How to Participate in a BLRBAC Meeting

- Monday has the subcommittee meetings, morning and afternoon.
- Tuesday morning has the open ESP Subcommittee meeting, where the submitted incidents are reviewed.
- Tuesday afternoon has the Operating Problems Session.
- Wednesday morning has the Main Committee Meeting, followed by technical presentations.

Participating in BLRBAC – cont'd

- Sunday and Monday nights have supplier sponsored Hospitality events, go and meet people.
  - These events will generally have supplier equipment on display and information regarding products and processes offered, as well as information on new technologies and methods. This is a good time to look at this equipment and information and discuss it with the many supplier reps present.
- Tuesday is a single, jointly sponsored, Activity Night, go and meet.

Monday, How to Participate in a BLRBAC Meeting

- Check the agenda for Open Subcommittee meetings, on Monday
  - Closed meetings are for subcommittee members only, to allow members to focus on assigned tasks.
  - Open meetings can be found in both the morning and afternoon.
    - Note, multiple open subcommittee meetings are at the same time, so pick carefully.
- Attend an open meeting that interests you and would benefit your mill; to get the most out of a subcommittee meeting:
  - Review the posted subcommittee agendas (available in the meeting schedule in the advance registration materials), and review the subcommittee minutes from the previous meeting, posted on the website, to see what they plan to cover and what has been covered in past meetings.
  - Review the subcommittee posted Guidelines, on website under "Documents".
  - Check to see if the subcommittee has any documents posted for Review and Comments, under "Documents".

Monday, How to Participate in a BLRBAC Meeting

Example from the Spring 2020 Meeting Registration Materials, Monday Meeting Schedule

- **8:00 am – Noon, Personnel Safety Subcommittee - (OPEN)**
- Welcome: Introduction by chair, Anti-trust Statement
- Update member information
- Introduction of members and visitors
- Read the 2019 October Meeting Minutes
- Discussions:
- "Recovery Area SIF (Serious Injury or Fatality) prevention" - open discussion.
- Open discussion, miscellaneous topics as requested by attendees

Monday, How to Participate in a BLRBAC Meeting

- Subcommittee Meeting
  - Usually they will accept visitor questions/comments during the meeting, on their guidelines, or related topics.
  - You can always send questions ahead of time to the subcommittee Chairman, to allow them to prepare.
  - If you have comments on documents posted for Review and Comment, it is important to send comments prior.
  - Remember, generally the subcommittee will not have a "presentation" to provide you with information, if you do not ask questions, it might be a short meeting.
  - Consider joining the subcommittee, if possible and interested, and you would have the time to attend most future meetings.

BLRBAC Subcommittees (10)

- ESP (Emergency Shutdown Procedure), Frank Navojosky, Chairman
- Safe Firing of Black Liquor, Vernon Blackard, Chairman
- Safe Firing of Auxiliary Fuel, Bruce Knowlen, Chairman
- Personnel Safety, John Fredrickson, Chairman
- Instrumentation, Dave Avery, Chairman
- Waste Streams, Paul Seefeld, Chairman
- Fire Protection in Direct Contact Evaporator, Stephen Cox, Chairman
- Materials & Welding, Mike Blair, Chairman
- Water Treatment, Tom Przybylski, Chairman
- Publicity & News, Matt Paine, Chairman

Current Posted Subcommittee Guidelines (2018 last revs.)

- Recommended Good Practice For Design, Operation, and Testing of the Emergency Shutdown System for Black Liquor Recovery Boilers (Dated: October 2018)
- Safe Firing of Black Liquor in Black Liquor Recovery Boilers (Dated: April 2016)
- Materials & Welding Guidelines (Dated: April 2013)
- Safe Firing of Auxiliary Fuel in Black Liquor Recovery Boilers (Dated: February 2012)
- Fire Protection in Direct Contact Evaporators and Associated Equipment (Dated: February 2016)
- Personnel Safety & Training (Dated: April 2018)
- Application of Rotork Actuators on Black Liquor Recovery Boilers (Dated: October 2005)
- Boiler Water Management Guidelines for Black Liquor Recovery Boiler (Dated: April 2016)
- Instrumentation Checklist and Classification Guide for Instruments and Control Systems Used in the Operation of Black Liquor Recovery Boilers (Dated: April 2014)
- Thermal Oxidation of Waste Streams in Black Liquor Recovery Boilers (Dated: April 2017)

BLRBAC Internet Site, Documents for Review and Comments, Examples

- Recommended Good Practice For Design Operation and Testing of the Emergency Shutdown System For Black Liquor Recovery Boilers - April 2019 Draft
- Safe Firing of Black Liquor in Black Liquor Recovery Boilers - April 2019 Draft
- Boiler Water Management Guidelines for Black Liquor Recovery Boilers - Section 31. 5.1 Revisions - 2018 Draft
- Copper Induced Cracking in Boiler Tubes – May 2019 Draft
- Fire-Protection-for-DCE-2021-Draft

Tuesday, How to Participate in a BLRBAC Meeting

- Open ESP Subcommittee, morning
  - Review the incident summary document that was in your registration packet; individual writeup for each incident.
  - Sit near the front screen so you can clearly see the boiler drawings and photos that will be presented.
  - Take notes on the incidents that you want to share with others in your mill on your return.
    - How did operators make their decisions? Would your operators recognize the trends and signs on a critical leak to ESP?
    - Was the leak mechanism something that could happen to your boiler, Was it somewhere in the unit you haven't been looking on outages?
    - Lessons learned for review back at your facility.

Tuesday, How to Participate in a BLRBAC Meeting

- Operating Problem Session, Afternoon
  - You can submit questions ahead of time, concerns at your mill, or successes at your mill.
  - Moderator will work through the questions, soliciting input from the many knowledgeable people present.
  - Feel free to stand and ask questions.
  - Take notes on items that you want to share with your mill.

Wednesday, How to Participate in a BLRBAC Meeting

- Main Committee Meeting
  - Reports from the Executive Committee on BLRBAC business and issues.
  - Reports from each subcommittee, what they covered in their meetings and what they are going to be working on.
  - Reports from other organizations, as available, AFPA, TAPPI, etc.
- Technical Presentations, usually 2 or 3
  - Topics of interest to our audience, focused on recovery boilers.

BLRBAC Basics

- Objective - promote improved safety of recovery boilers through the interchange of knowledge, experience and data.
- Meetings in April and October in Atlanta
  - **Check www.blrbac.net for the date of the next meeting, and for future meetings.**
  - The website will include a meeting agenda and a link to register online; usually available 6 weeks prior.
  - Meetings are currently held at the Sonesta Atlanta Airport North
- Members are from recovery boiler: operating, manufacturing and insuring companies.
  - Only Members can vote
  - Also have associate members with direct interest

BLRBAC Internet Site

- blrbac.net (old site blrbac.org is no longer active)
- Guidelines and questionnaires
  - Latest versions
  - Draft revisions for review
    - Interested persons are urged to review and provide comments, before the revisions are voted on for approval.
- Articles of Association & Operating Procedures
- Meeting registration forms and information
- Meeting minutes, current and past (to 2001)
- RBs in Service, U.S., Canada
  - Help keep the lists up to date, name changes, closures

BLRBAC Updated Guideline Example

Recommended Good Practice For Design, Operation, and Testing of the Emergency Shutdown System for Black Liquor Recovery Boilers (Dated: October 2018)

CHANGES are listed at the end of the document

October 2018

Recommended Emergency Shutdown Procedure (ESP) & Procedure for Testing ESP System for Black Liquor Recovery Boilers was combined into a single document with Guidelines for Post-ESP Procedures for Black Liquor Recovery Boilers, titled Recommended Good Practice for Design, Operation, and Testing of the Emergency Shutdown System for Black Liquor Recovery Boilers

- Chapter 2 – Clarified that all motorized valves in ESP system should be wired to bypass any local selector switches and any change be functionally tested
- Chapter 2 – The torque limits, and any other device designed to protect the motor or valve, should not be included in the motor control open circuit for the rapid drain valves
- Chapter 2 – Valves used for final pressure reduction that may be used for other functions must function in the event of an ESP
- Chapter 3 – A DCS page showing ESP functions and their status is suggested
- Chapter 3 – A leak located below the ESP rapid drain valve level (8’) is added to conditions for consideration of floor inspection after and ESP

BLRBAC Executive Committee

Revised after Fall 2022 Meeting Election

- **Chairman – David von Oepen, WestRock**
- **Vice Chairman – Frank Navojosky, International Paper**
- **Operator Rep. – Gregory Burns, Domtar**
- **Insurance Rep. – Jimmy Onstead, FM Global**
- **Boiler Mfg. Rep. – John Phillips, Andritz**
- **Treasurer – Len Olavessen, LENRO, Inc.**
  - **To change to Brad Osborne, Electron Machine Corp.**
- **Secretary – Everett Hume, FM Global**

AF&PA

RECOVERY BOILER OPERATIONAL SAFETY SEMINAR

American Forest & Paper Association

Operational Safety Seminars

- The **O&M Subcommittee** sponsors the **Recovery Boiler Operational Safety Seminars**
  - Objective: **Safe Operation of Recovery Boilers**
- Operators, Supervisors, Superintendents, Maintenance Professionals, Engineers, Steam Chiefs, and Managers attend
- **Training continues to increase in importance,** as more senior operators and supervisors retire
- Companies are finding these Safety Seminars to be an important part of their **Safety & Training Programs**

Operational Safety Seminars

- The dialogue among the attendees and monitors of the Safety Seminars provide attendees with valuable information and insight

- **Team Exercises** help operators and supervisors make the important decision: **When to ESP a Recovery Boiler**
  - The Case Studies are based on recent **actual BLRBAC Recovery Boiler Incidents**
  - **Six (6) new Case Studies** for each Safety Seminar Series has been the norm
  - **Increased to Eight (8) new Case Studies** for the 2022 Fall Safety Seminars!

- Over **4,200** people have attended the seminars since they were started in 1985

- We continue to recommend that all companies and mills seriously consider sending people to these valuable seminars

Operational Safety Seminars

2022: Four (4) Virtual Online Recovery Boiler Operational Safety Seminars; 2021 seminars (5) were also virtual.

- April 20, 2022 - (7:45 am – 4:30 pm) Eastern Time – **99 Attended**
- May 18, 2022 - (7:15 am – 4:00 pm) Pacific Time – **77 Attended**
- September 21, 2022 - (7:45 am – 4:30 pm) Eastern Time – **78 Attended**
- October 13, 2022 - (7:15 am – 4:00 pm) Pacific Time – **93 Attended**
- More people can attend due to the lower registration fee (50%)
- **+** No travel time or cost, and less time off the job!

Operational Safety Seminars

2023 Plans: Five (5) Recovery Boiler Operational Safety Seminars

Four (4) Virtual Online & One (1) In-Person

- March 22, 2023 – (7:45 am – 4:30 pm) Eastern Time **(Virtual)**
- April 20, 2023 - (7:15 am – 4:00 pm) Pacific Time **(Virtual)**
- May 23-24, 2023 – (**In-Person**) Atlanta Airport Marriott (2 Half-Days)
- September TBD, 2023 - (7:45 am – 4:30 pm) Eastern Time **(Virtual)**
- October TBD, 2023 - (7:15 am – 4:00 pm) Pacific Time **(Virtual)**

People

- Wayne Grilliot, Consultant, AF&PA Recovery Program Administrator
- John Andrews, past BLRBAC ESP Subcommittee Chairman,
  - Boiler Services & Inspection, LLC
  - Monitor
- Dean Clay, BLRBAC ESP Subcommittee Secretary,
  - Boiler Services & Inspection, LLC
  - Monitor

Introduction

- Seminar format: a mix of presentations related to RB safety and case studies worked on by attendees in their assigned teams.
- All attendees get an electronic booklet containing presentation slides and 8 actual RB incidents reported to BLRBAC in recent years. The cases focus on a broad range of incidents from hearth to economizer.
- The incident mill locations are not identified.
- Each person is assigned 2 cases for their virtual Team to discuss the incidents, to share insights and remedies for each situation.
- There are 4 cases in the morning, and 4 cases in the afternoon.

Introduction

- Attendees are asked to share their relevant personal experiences from their mill.
- Each Team chooses a primary speaker to review the case; others can add comments.
- "Considerations" listed are just to provide food for thought, not to be rigidly answered.
- The monitors are available to answer questions they might have on cases during their review, including explaining some of the "terms" used, if unfamiliar to them.

BLRBAC Previous Year Incident Summary Review John Andrews

Interlocks and Interlock Bypassing
(BLRBAC Instrumentation Subcommittee Guidelines)

Dean Clay

Review Of ESP Subcommittee Learnings
John Andrews

2022
Case 1 - 4

Dean & John

Recovery Boiler Explosion History Review

Comments on Prevention of Explosions

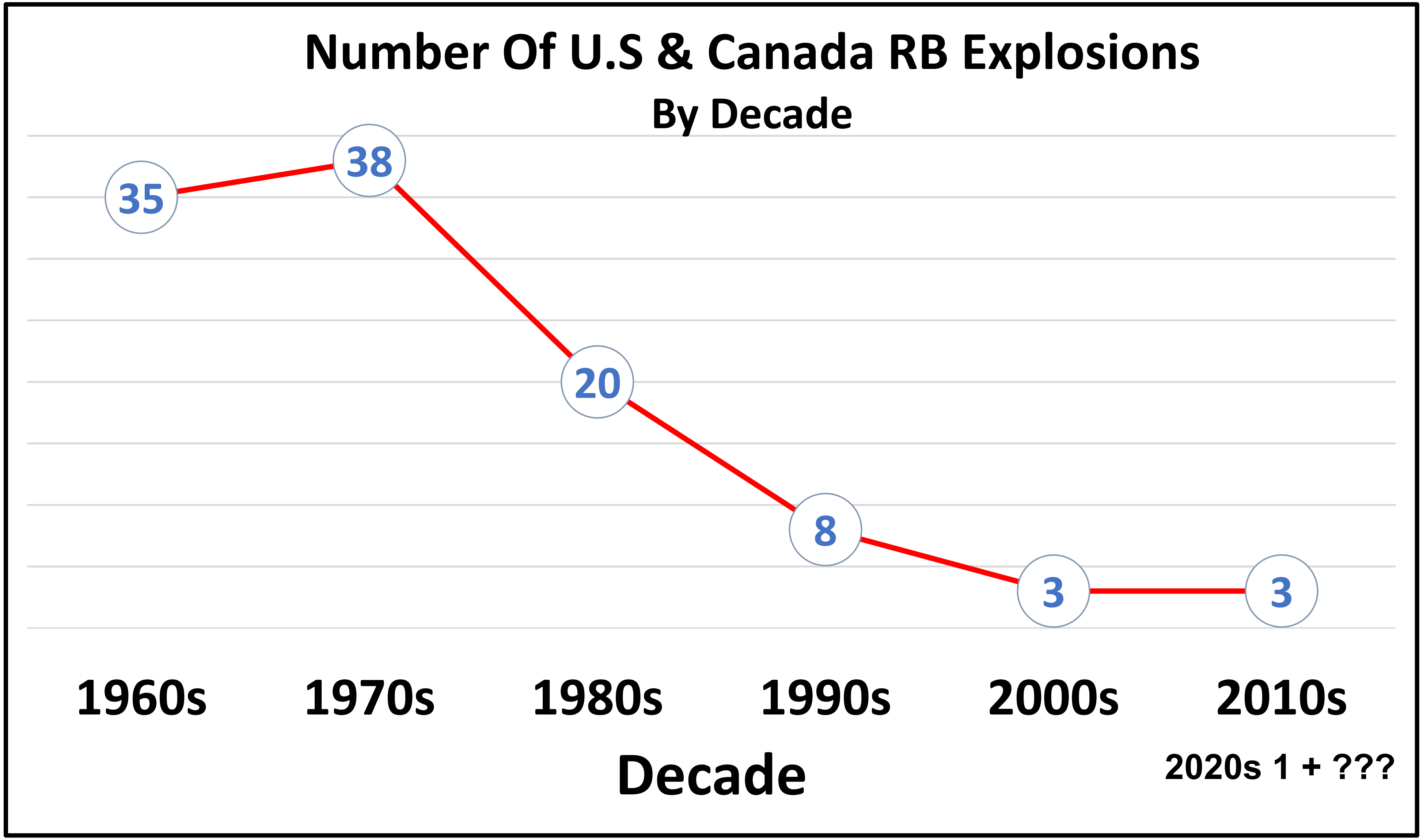
Dean Clay, BSI, BLRBAC ESP Subcommittee Secretary

AF&PA RB Operational Safety Seminars 2022

Based on U.S. BLRBAC Data for RBs in U.S. and Canada, for explosions with damage, 1948 - 2020

Potential Catastrophe

- A major recovery boiler explosion is a catastrophic event at a kraft pulp mill
- Risk of injury or death
  - Fatalities in ≈ 6% of explosions
  - Serious injuries in another ≈ 5%
- Cost of repair
  - Depends on explosion magnitude
  - Potential for permanent shutdown of recovery boiler, or mill closure
- Lost production


Number Of U.S & Canada RB Explosions
By Decade
35
38
20
8
3
3
1960s
1970s
1980s
1990s
2000s
2010s
Decade
2020s 1 + ???

Progress on Explosion Control

- Nearly 4 explosions <u>per year </u>in 1960s and 1970s

- Running 0.3 per year in last two decades
  - Have had a number of near misses

- RB explosions also occur in other countries
  - Information generally not shared

External Resources

- Black Liquor Recovery Boiler Advisory Committee (BLRBAC)
  - Started in 1961
  - Operating mills, boiler manufacturers, insurers
  - Sharing knowledge, generating and maintaining guidelines to help facilitate the safe, reliable operation of Black Liquor Recovery Boilers.

- AF&PA Recovery Boiler Committee
  - Started in mid-1970s, member companies from US, Canada and South America
  - Carries out various projects focused on improving RB safety
  - Cooperates with BLRBAC

Prevention of Recovery Boiler Explosions

- Well-trained operators
- Management commitment from top down
- Boiler integrity management program
- Effective inspection and maintenance program
- Shutdown planning and follow up
- Regular Recovery Boiler Safety Audits

Analysis of Dissolving Tank Explosions
John Andrews

Based on report by Dr. Thomas M. Grace

2022 Fall
Case 7

Description of Events

The Assistant Shift Engineer was contacted and checked this; he then contacted the Shift Engineer. The shift engineer then went with the Assistant Shift Engineer and saw the water.

Upon viewing the water, the shift engineer immediately advised the Assistant Shift Engineer that this was not going to get better and ordered an ESP of the boiler. The operators pulled the liquor guns from the boiler and at 10:30pm the ESP was initiated. Time from initial discovery to ESP was about 5 minutes in total because of the 2 steps of checking and pulling the liquor guns. The shift engineer ordered the ESP within seconds of seeing the water.

2022 Fall
Case 7

Inspection and Repair

Leak was in the hot side of the tube, at the beginning of an upper bend of the primary air port tube.
Root cause is thermal fatigue cracks on adjacent crotch plate for tucked tube running into tube.
Heavy Scale inside tube contributed to the failure by causing elevated tube metal temperatures. The adjacent primary air port was also observed to be blinded over and may have contributed to thermal cycling.

Tube was “pupped” (replaced tube section) and the hydrostatic test was good.

2022 Fall
Case 7

Root Cause

Thermal fatigue.

Additional Notes

SAC in several wall and floor tubes. Some iron/copper deposits being investigated further.

Considerations

- Who had authority to order the ESP?
- Would you remove BL guns prior to initiating the ESP?
- What could have helped identify the leak earlier?
- What other training may help?


138
139
REAR

Waterside Deposits

Figure 7 Failure location after cleaning. Significant SAC is present near failure location.

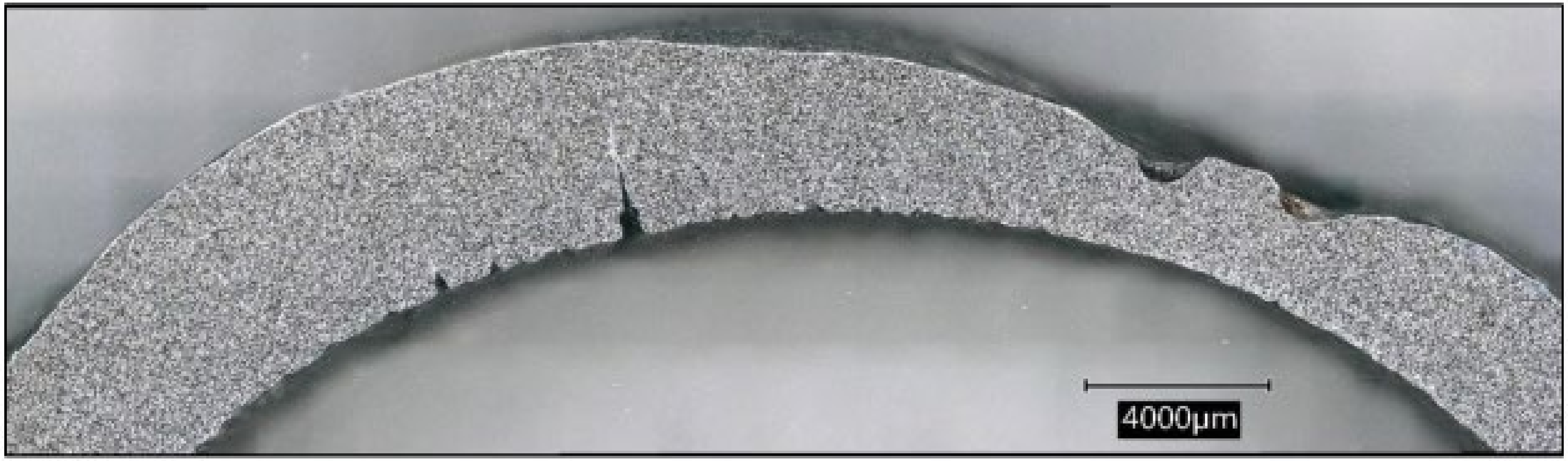


Figure 11 Cross section shows the SAC from the internal side adjacent to the external thinning.

Tube Leak Detection Systems

The goal of a leak detection system is to reliably detect as small a tube leak as possible, as soon as possible, while minimizing false alarms. Operators must be trained on the system, understanding that it may produce false alarms, and be trained on how to determine if the alarm is false.
A second goal is to also alarm large, sudden, leaks.

2020
Opportunities to Improve Recovery Operations

John Andrews