AF&PA RECOVERY BOILER PROGRAM
2025 ANNUAL CONFERENCE & COMMITTEE MEETINGS

CONFERENCE SCHEDULE

Tuesday, February 4, 2025 – Atlanta Airport Marriott; 4711 Best Road; Atlanta, Georgia 30337

7:00 am - 9:00 am	Continental Breakfast (B+PDR Restaurant – 1st Floor, near Lobby)
7:00 am - 10:00 am	Registration (Southern Ballroom - Florida/Tennessee Room – 1st Floor)
8:30 am - 3:30 pm	Operation & Maintenance Subcommittee Meeting (Southern Ballroom - Florida/Tennessee Room – 1st Floor)
9:45 am - 10:00 am	Coffee Break (Florida/Tennessee & Alabama/Georgia Room – 1st Floor)
10:00 am - 3:30 pm	Research & Development Subcommittee Meeting (Southern Ballroom - Alabama/Georgia Room – 1st Floor)
12:00 n - 1:00 pm	Lunch (B+PDR Restaurant – 1st Floor, near Lobby)
2:30 pm - 2:45 pm	Coffee Break (Florida/Tennessee & Alabama/Georgia Room – 1st Floor)
4:00 pm - 5:15 pm	Steering Committee Meeting (Closed Meeting) (Southern Ballroom – Alabama/Georgia Room – 1st Floor)
6:00 pm - 7:00 pm	Reception (B+PDR Restaurant – 1st Floor, near Lobby)
7:00 pm - 9:00 pm	Dinner (B+PDR Restaurant – 1st Floor, near Lobby)

Wednesday, February 5, 2025, Recovery Boiler Conference – Florida/Tennessee/Alabama Room

7:00 am Continental Breakfast (B+PDR Restaurant – 1st Floor, near Lobby)

7:00 am Registration (Southern Ballroom - Florida/Tennessee/Alabama Room – 1st Floor)

8:00 am General Assembly – Review AF&PA Antitrust Policy & Chairman's Report
- Wes Hill – Georgia-Pacific

8:10 am Operation & Maintenance Subcommittee Report
- Stephen Cox – International Paper

8:15 am Research & Development Subcommittee Report
- Jeff Wagoner – International Paper

8:20 am TAPPI Energy, Recovery, & Recaust Committee Report
- Daniel Franco - Recovery Specialist

8:35 am Shock Pulse Generator (SPG) Online Recovery Boiler Cleaning
- Sarah Henke - Valmet

9:05 am Model-Based Recovery Boiler Intelligent Sootblowing Optimization
- Simon Youssef & Jeremy Brown - Babcock & Wilcox

9:35 am Coffee Break (Florida/Tennessee/Alabama Room – 1st Floor)

9:50 am Dissolving Tank TTA/Density Correlation
- Honghi Tran - University of Toronto

10:30 am Impacts of Auxiliary Fuel Co-Firing with Black Liquor on Recovery Boiler Maintenance and Reliability
- Mark LeBel - ANDRITZ

Wednesday, February 5, 2025, Recovery Boiler Conference - (Continued)

11:00 am In-Situ Device for Green and Black Liquor Analysis
- Richard Salliss - Keit Industrial Analytics

11:30 am Mill Impacts of Lignin Recovery Including the Effects on the Recovery Boiler
- Shadan Mostafavi - Noram Engineering

12:00 noon Lunch (B+PDR Restaurant – 1st Floor, near Lobby)

1:00 pm Advanced Tools for Bed Monitoring, Smelt Reduction, Smelt Flow, Automated Shatter Jets, and Carryover
- Sam Miller - ANDRITZ

1:30 pm OnGuard iController with Leak Alert System
- Jeff Armstrong - Solenis

2:00 pm Mitigating High Intermediate Superheater Steam Temperatures
- Steve Campbell - Jansen Combustion and Boiler Technologies

2:30 pm Non-Destructive Testing on Suspected SAC Locations
- James Saxon III & Thomas Kapperman - Applied Technical Services, Inc. (ATS)

3:00 pm Coffee Break (Florida/Tennessee/Alabama Room – 1st Floor)

3:15 pm 2025 International Chemical Recovery Conference - September 24-26, 2025, in Toronto!
- Niko De Martini – University of Toronto

3:17 pm Minimizing Unplanned Outages and Recovery Boiler Maintenance Costs Utilizing On-line Pulsed Detonation IMPULSE Cleaning
- Vince Barreto - PowerPlus Cleaning Systems

3:45 pm Finnish Recovery Boiler Committee Report
- Iiris Honkavaara - Finnish Recovery Boiler Committee

4:15 pm A More Integrated Approach to Optimizing Recovery Boiler Operation
- Andy Jones - Integrated Test & Measurement (ITM)

4:45 pm BLRBAC Activities Report
- Dean Clay - Boiler Services & Inspection, LLC (BSI)
  - BLRBAC ESP Subcommittee Secretary

5:00 pm Closing Remarks, Questions, & Adjourn

- 2024 BLRBAC Incident Summary - ESP Subcommittee presented by Dean Clay in the Tuesday, February 4, 2025, O&M Subcommittee Meeting.

- The AF&PA Recovery Boiler Program Status Report presented by Wayne Grilliot in the Tuesday, February 4, 2025, Subcommittee Meetings.

- **TAPPI Book Sale:** Wednesday February 5, 2025 **(9:30 am – 3:30 pm)** outside the Florida Room
  25% Discount on the Kraft Recovery Boilers, Third Edition Book and other Select TAPPI Books!!! Plus, no Shipping Cost!!!

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.

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.

ESP Subcommittee

2024 BLRBAC INCIDENT SUMMARY

Combining John Andrews Spring & Frank Navojosky Fall 2024 Presentations

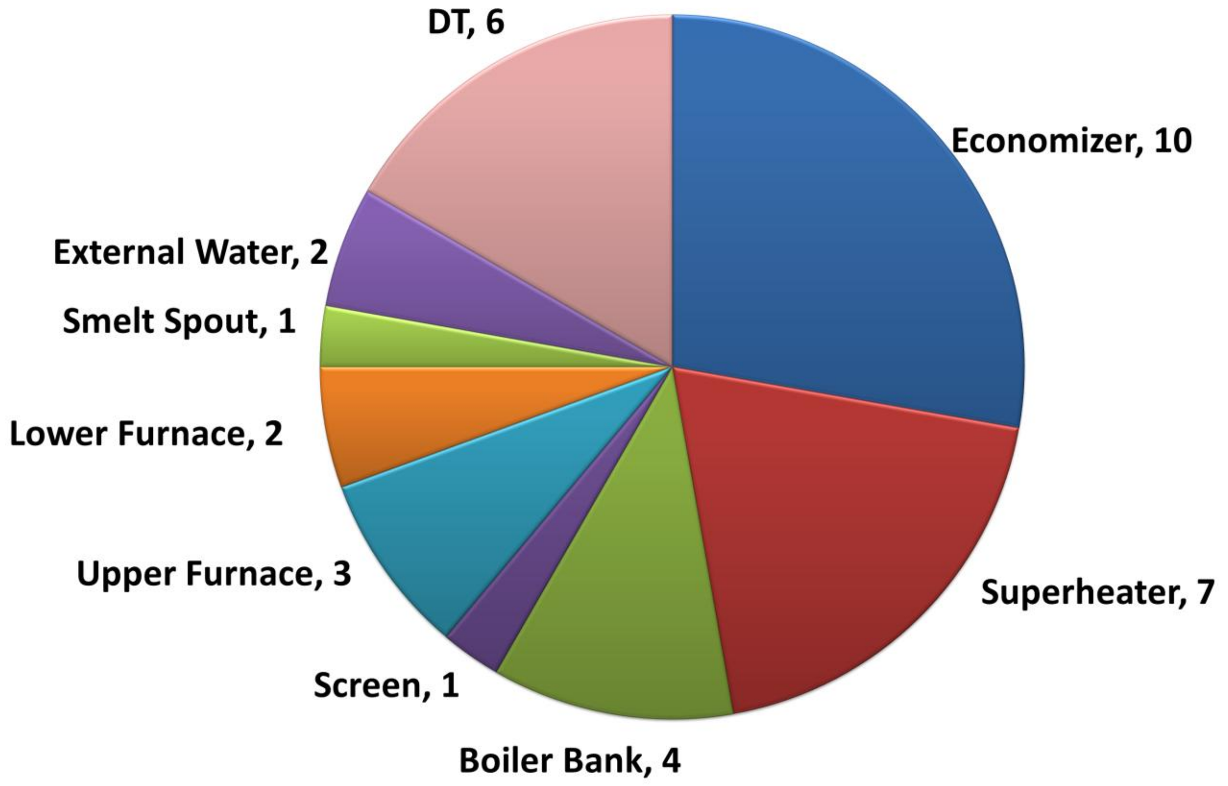
Incident Questionnaire Review

- 36 US and Canadian incidents
  - 0 Smelt Water Explosions
  - 6 Critical
  - 24 Non-critical
  - 5 Dissolving Tank Explosions
  - 1 DT Incident

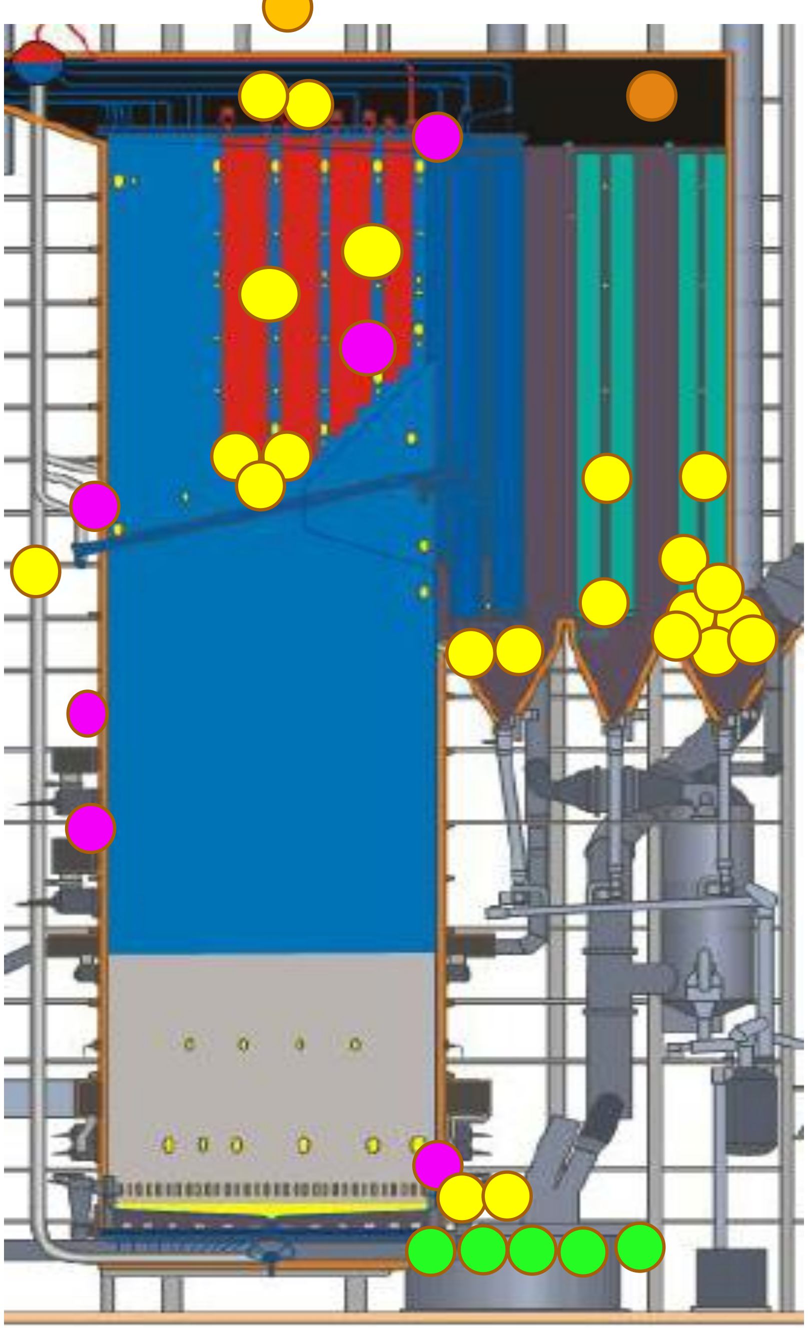
- 6 ESP'd (including 2 Superheater leaks)
- 4 Critical incidents
  - 1 Critical in operation with a bed and no ESP
  - 3 Critical in operation with a bed & ESP'd
  - 75% of Critical ESP'd that Should ESP

- 3 International Incidents Submitted

Incident Locations



2024 Incident Locations



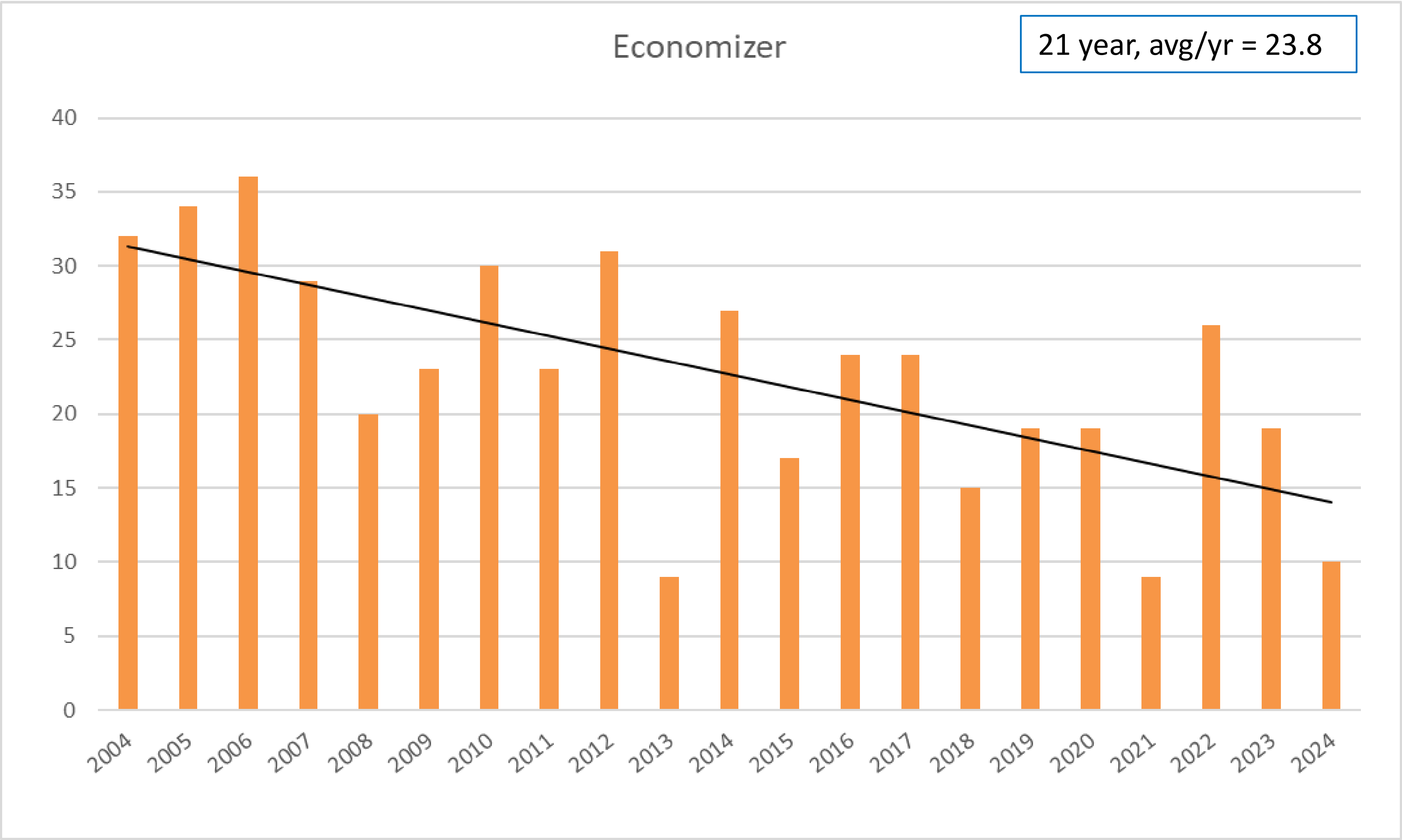
- ESP/No Leak
- Non-Critical
- Critical
- DT Incident
- External

BLRBAC Reported Leaks (US + Canada) 2004 thru 2024

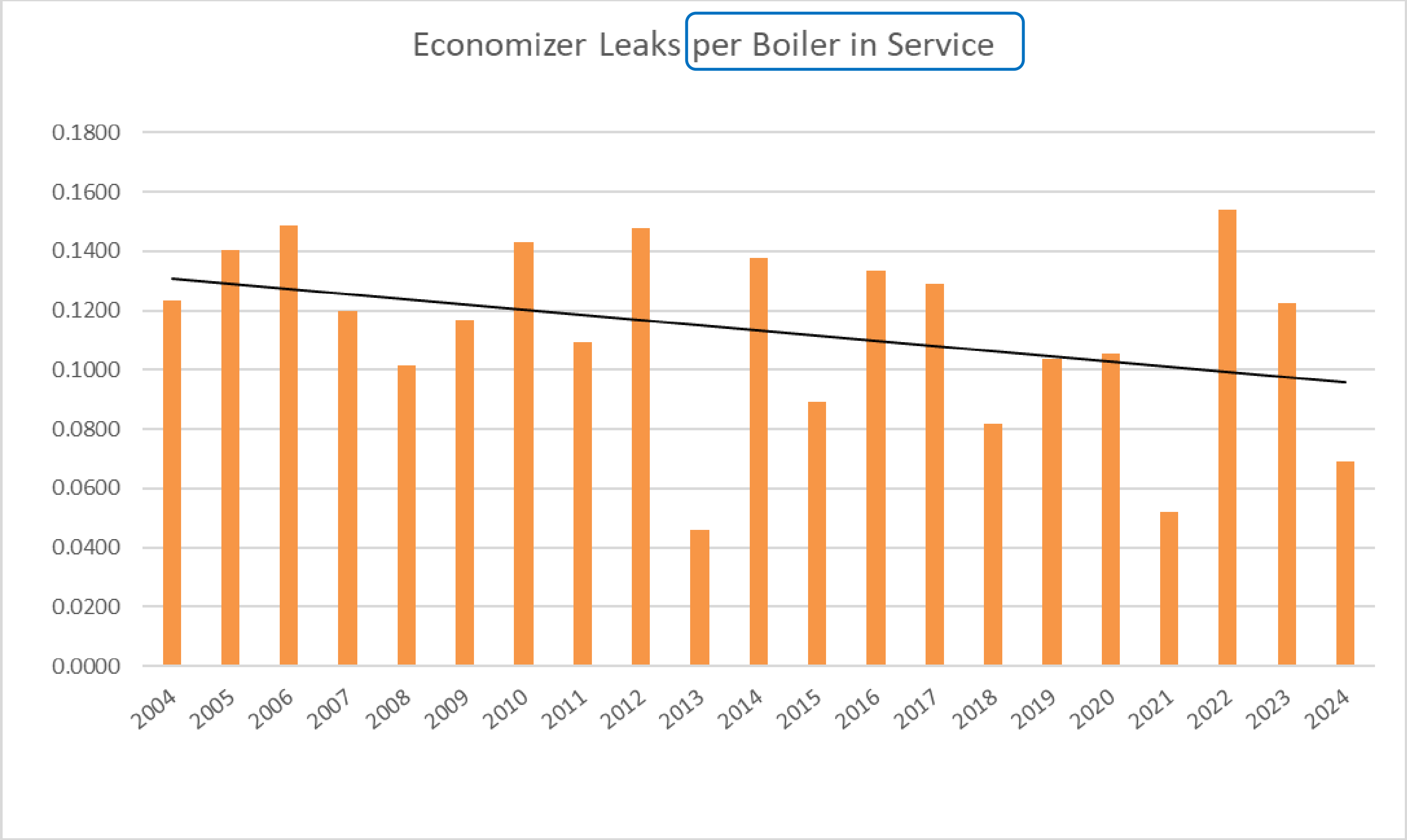
Location	21 Year Total	Average/Year
Economizer	477	23.8
Superheater	150	7.5
Upper furnace	143	7.1
Boiler Bank*	112	5.6
Lower Furnace*	106	5.3
Screen*	43	2.2
Smelt Spout	32	1.6

*Four Smelt-Water Explosions Recorded 2004 thru 2023,
One from Boiler Bank Leak, Two Screen Tube Leaks, One Floor Leak

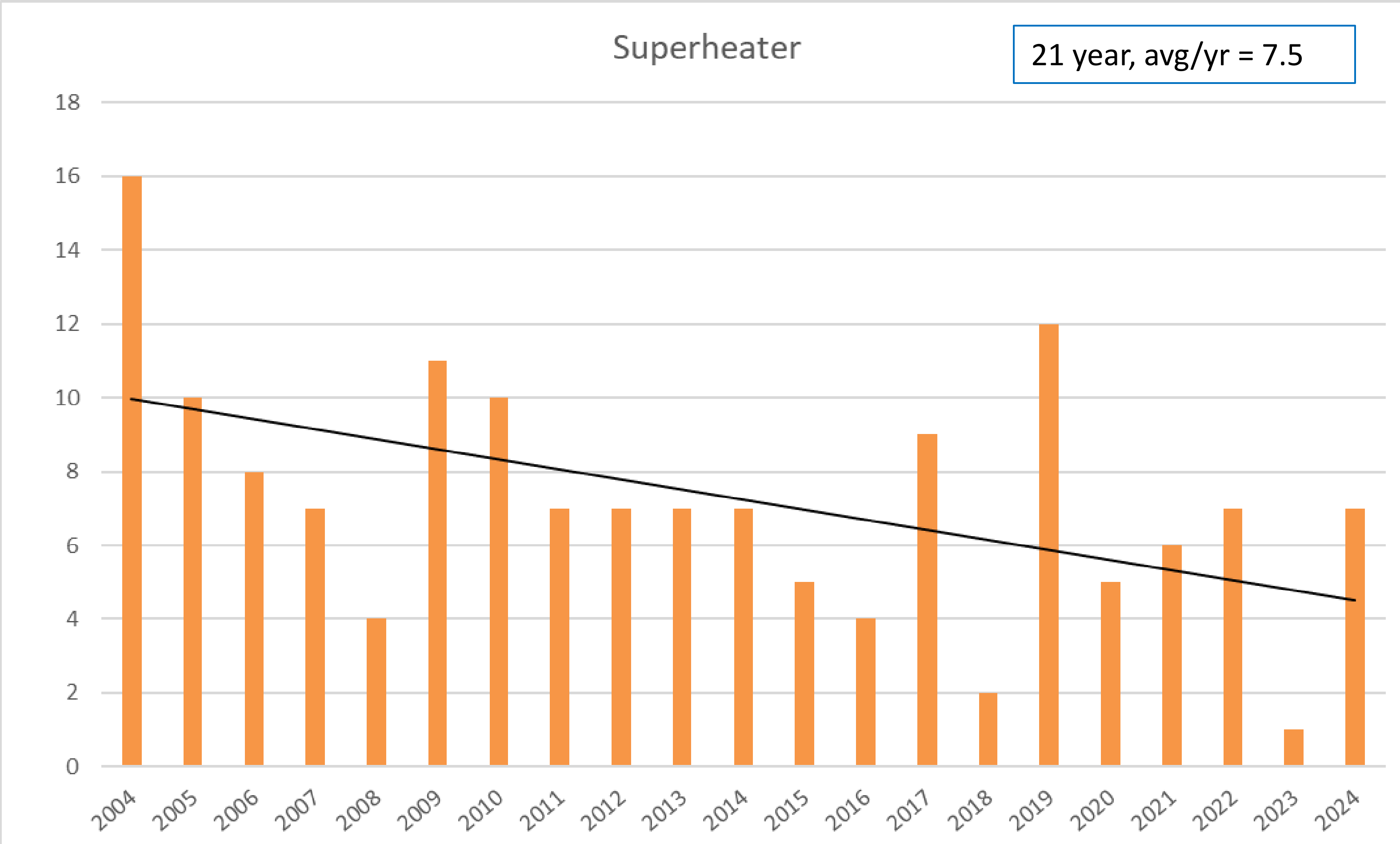
Boiler Component Leak trends



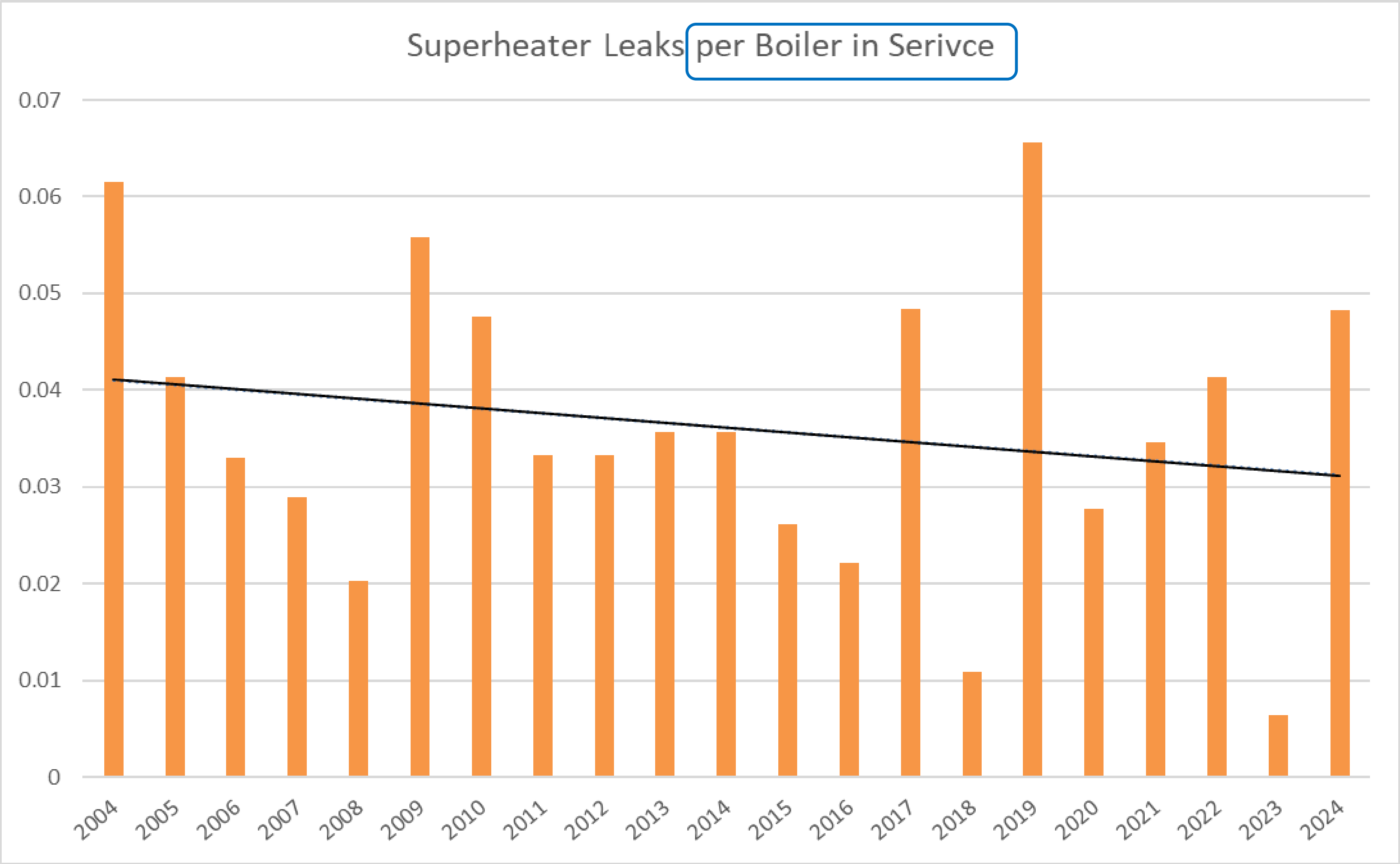
Boiler Component Leak trends



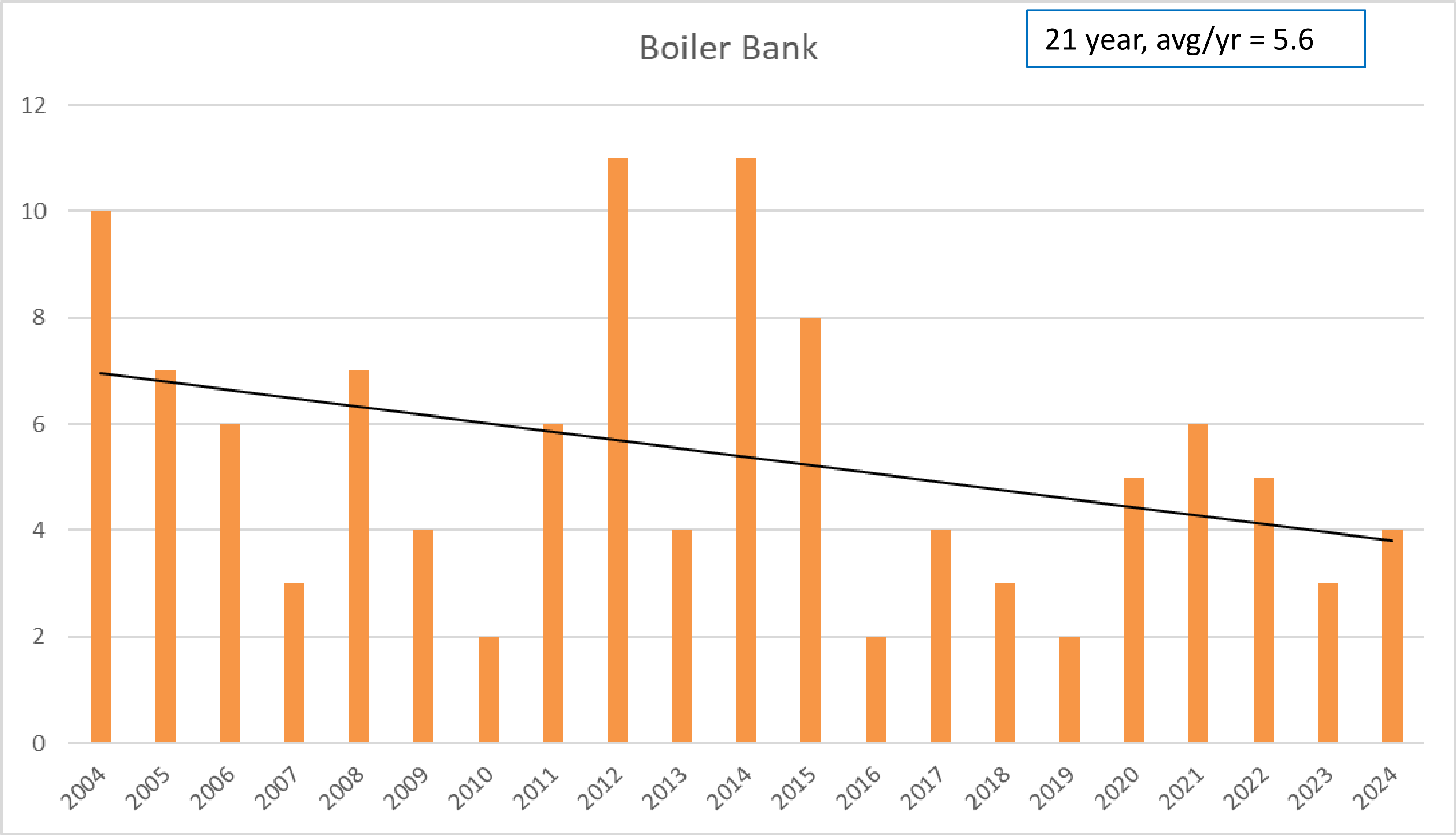
Boiler Component Leak trends



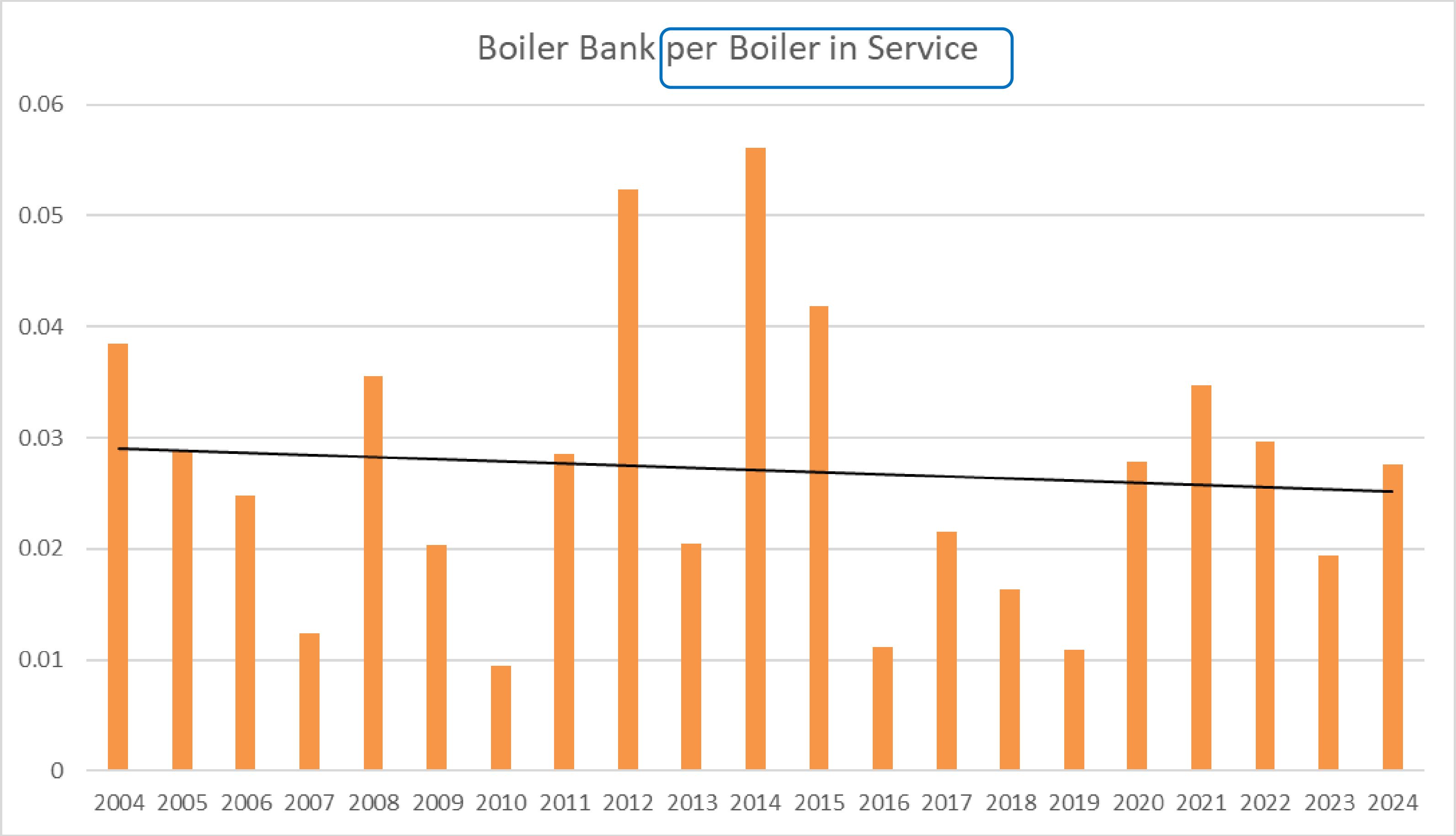
Boiler Component Leak trends



Boiler Component Leak trends

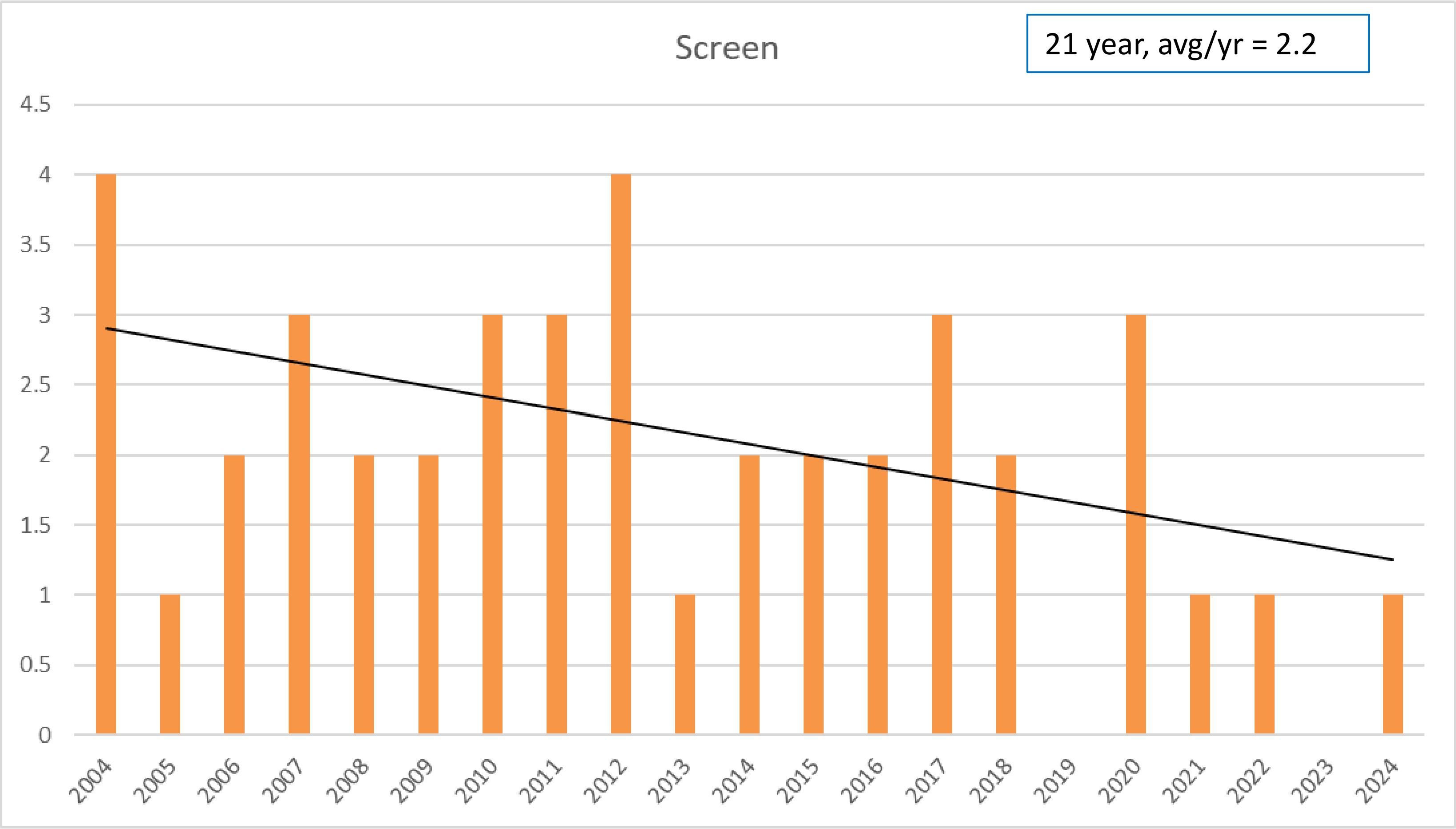


Boiler Component Leak trends

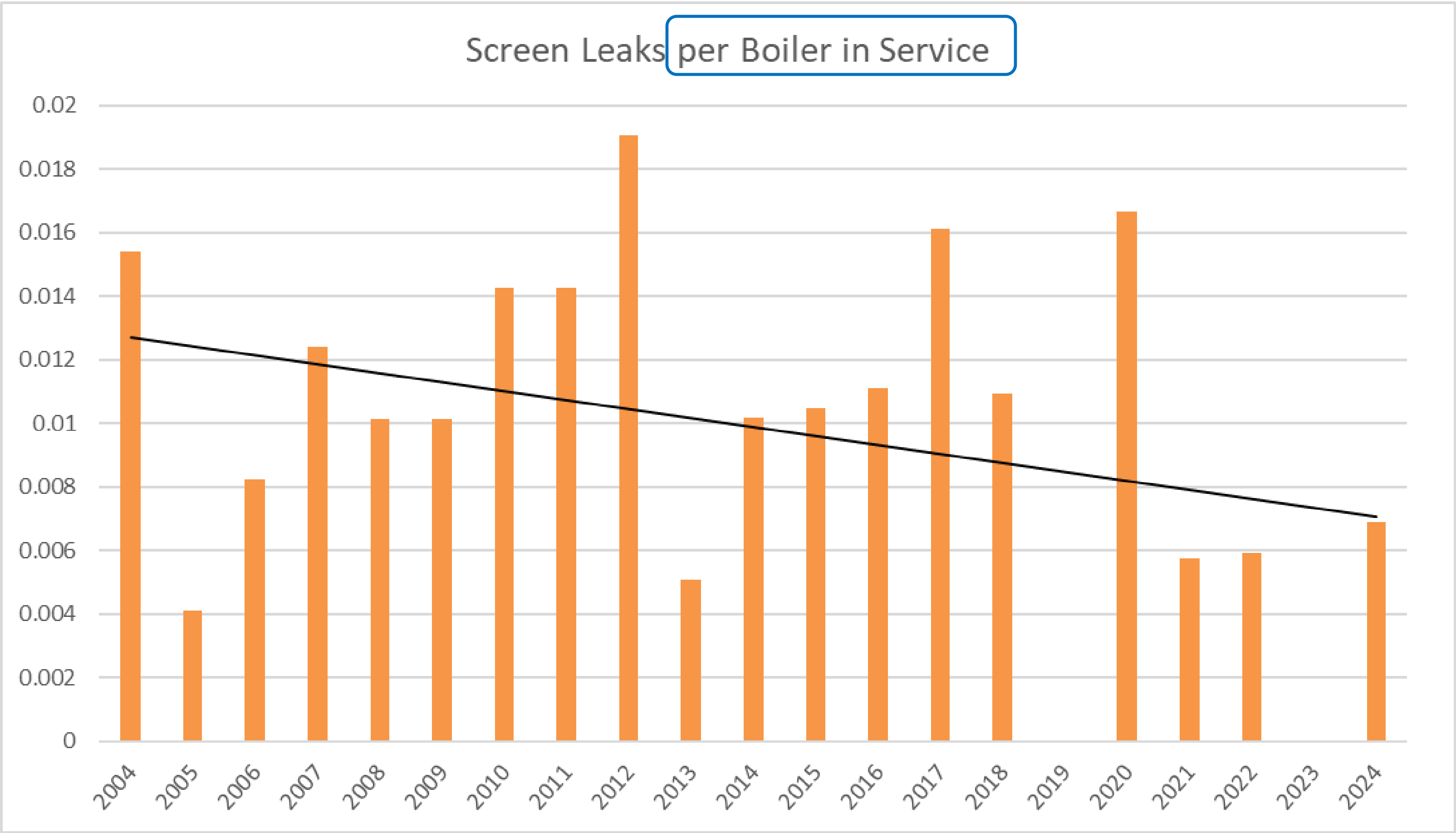


Note, this is the flattest line, showing the least improvement, it maybe telling us to increase our focus on preventing boiler bank tube leaks

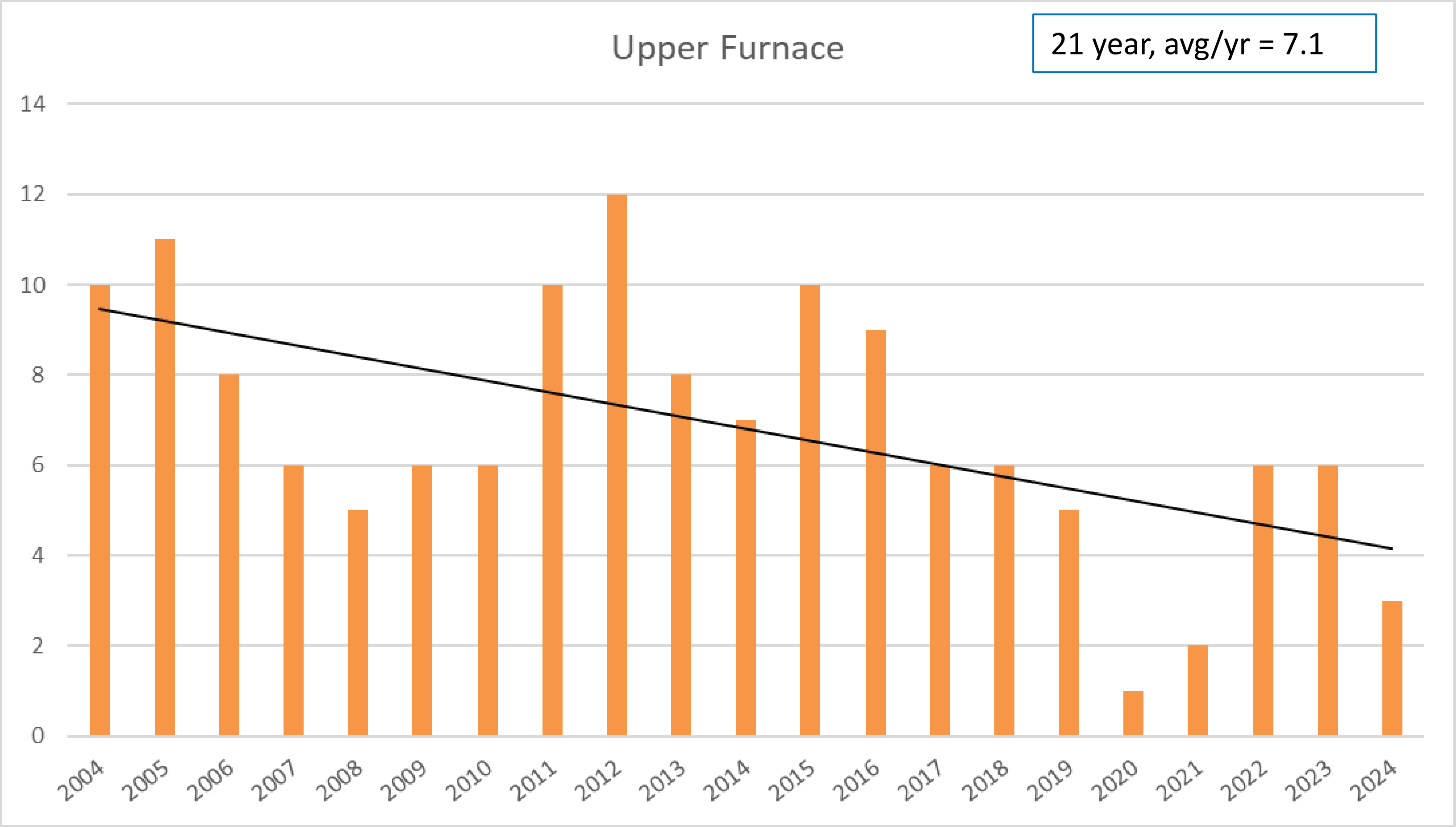
Boiler Component Leak trends



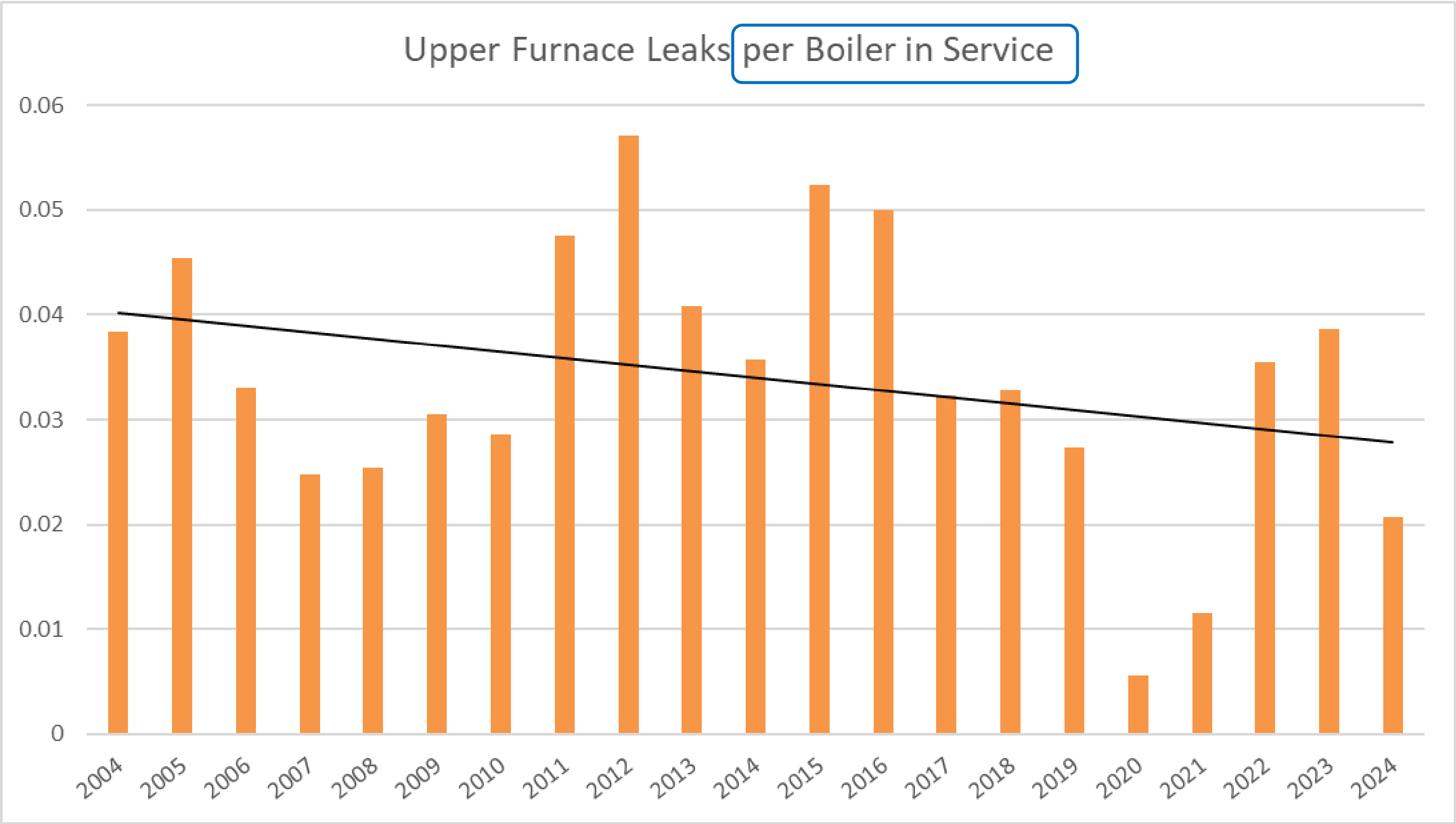
Boiler Component Leak trends



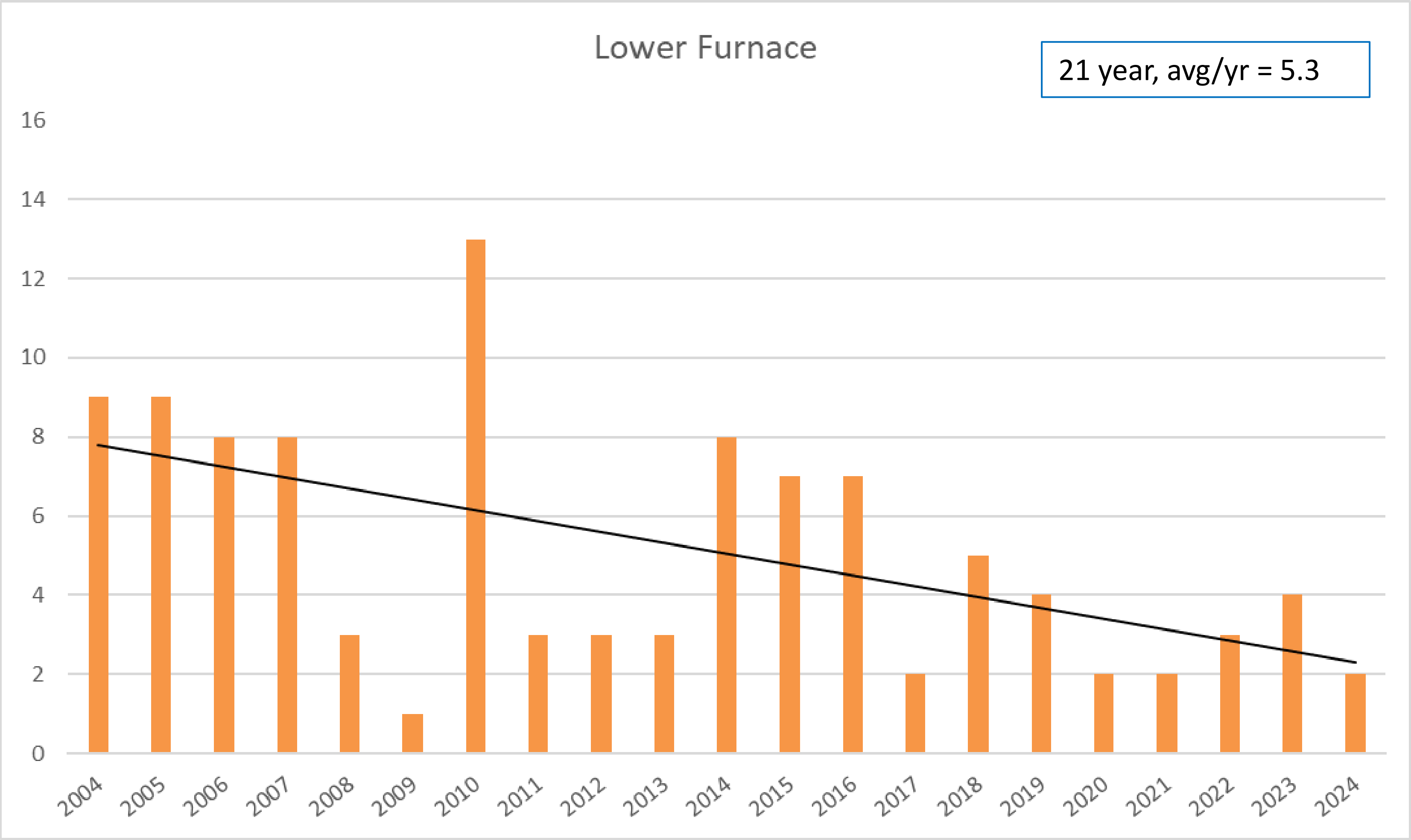
Boiler Component Leak trends



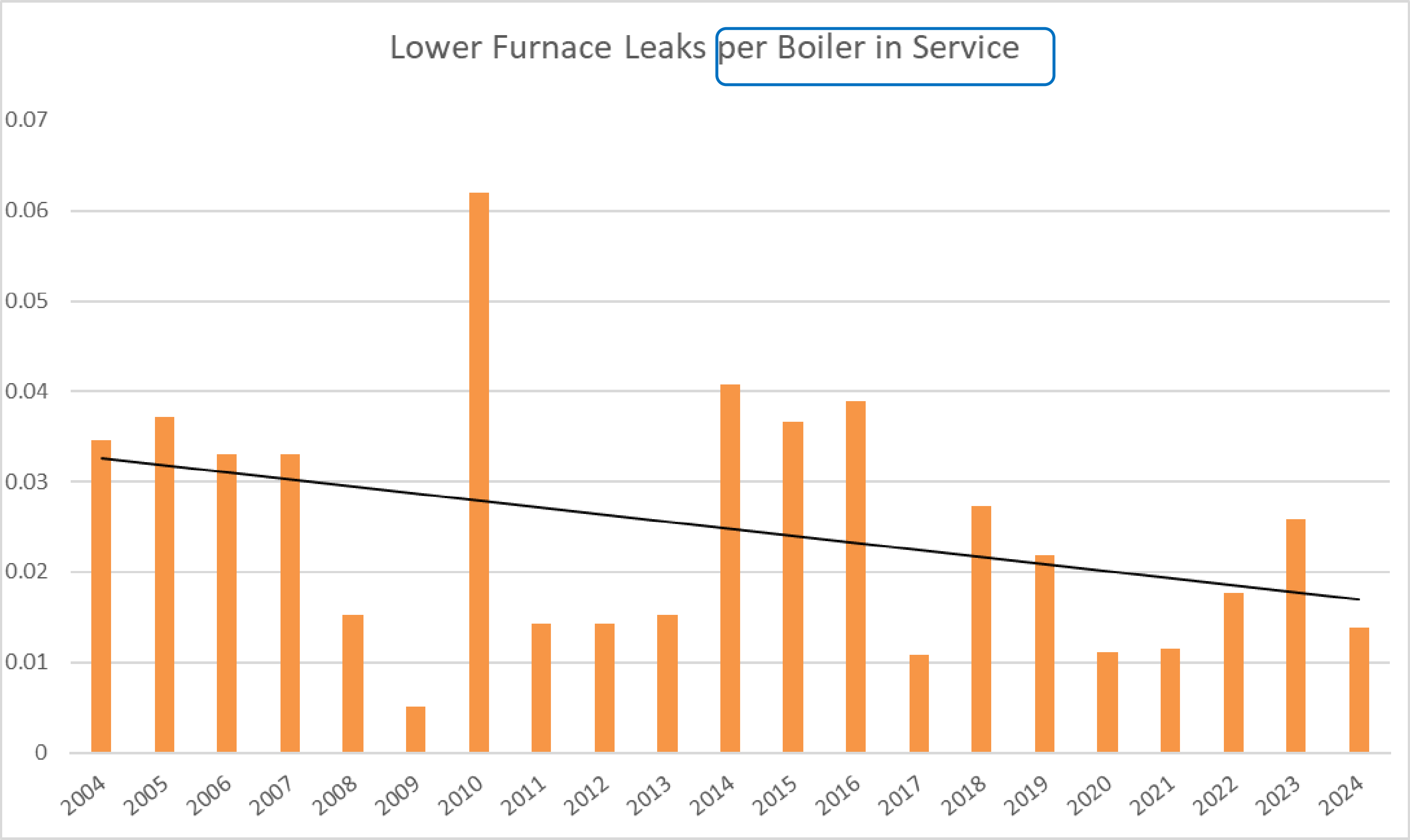
Boiler Component Leak trends



Boiler Component Leak trends

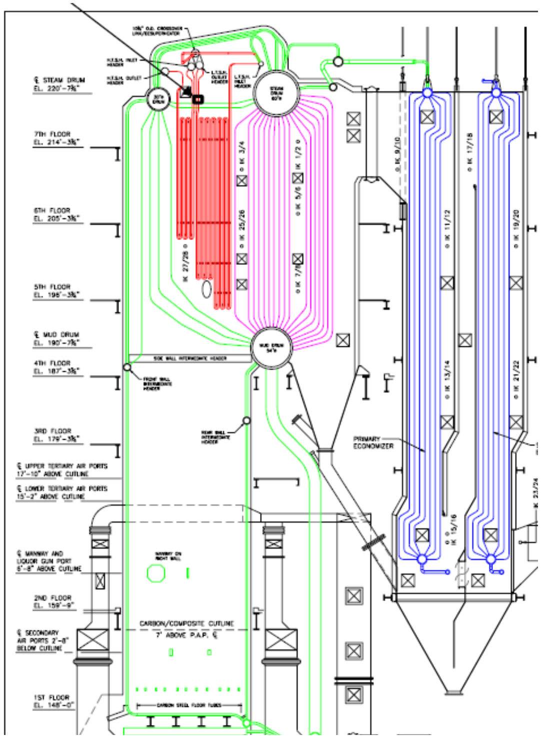


Boiler Component Leak trends



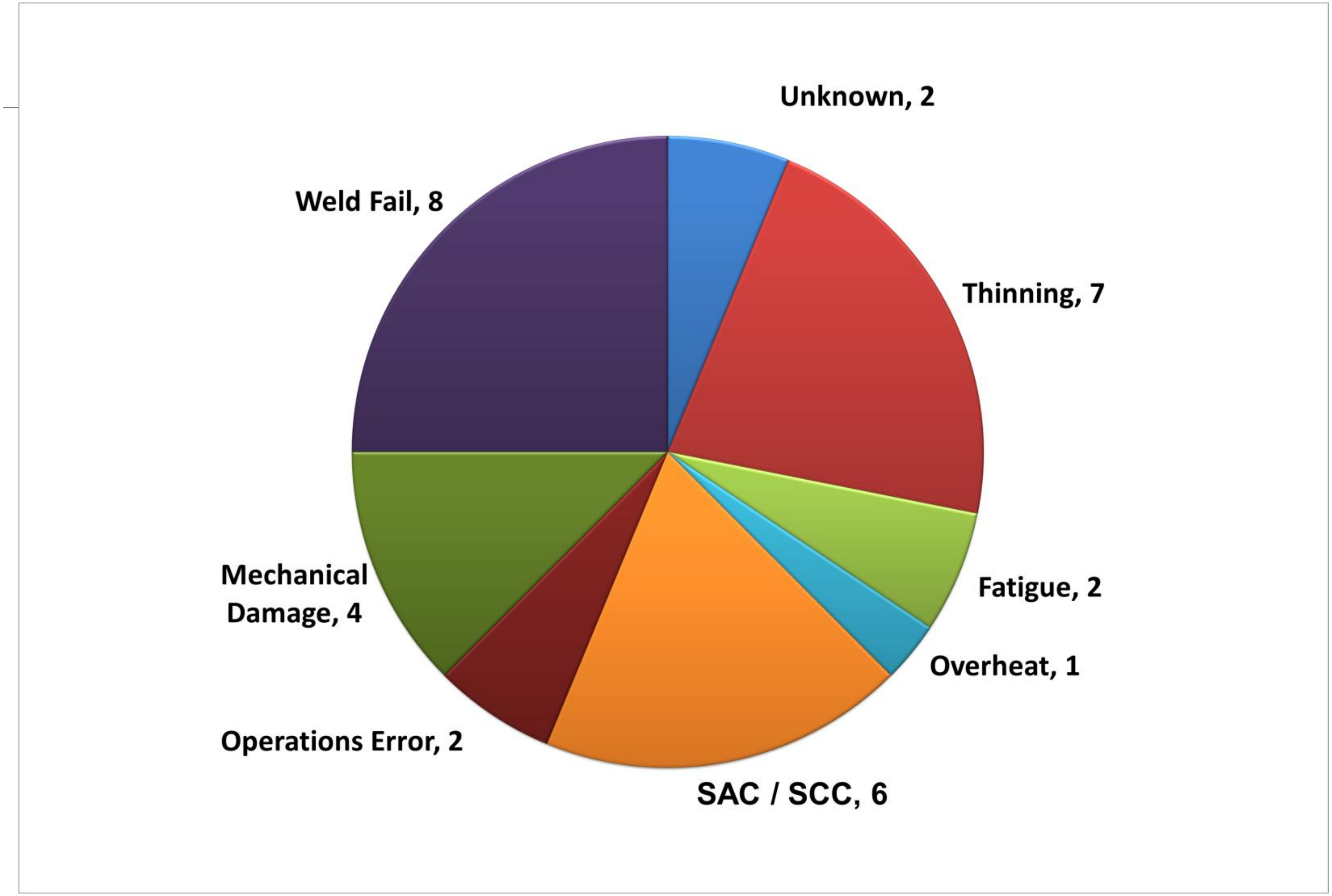
Incidents by Boiler Type

- Drums
  - 1 - 13
  - 2 - 21
  - 3 - 2
- Back End
  - Large Economizer - 29
  - Cascade - 6
  - Cyclone - 1



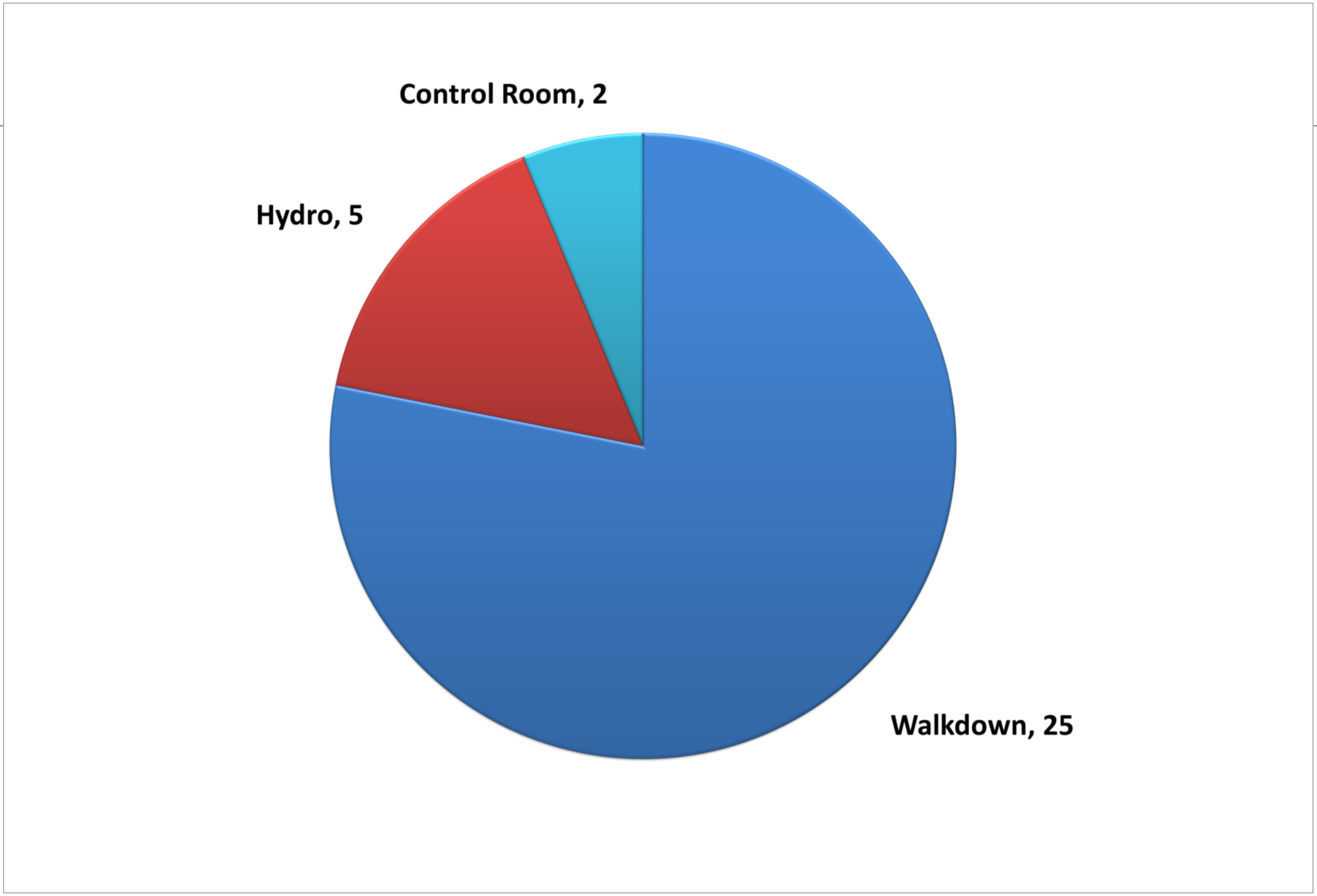
3-drum example

Leak Cause



Unknown, 2
Weld Fail, 8
Thinning, 7
Mechanical Damage, 4
Fatigue, 2
Overheat, 1
Operations Error, 2
SAC / SCC, 6

How Discovered



Leak Detection Systems

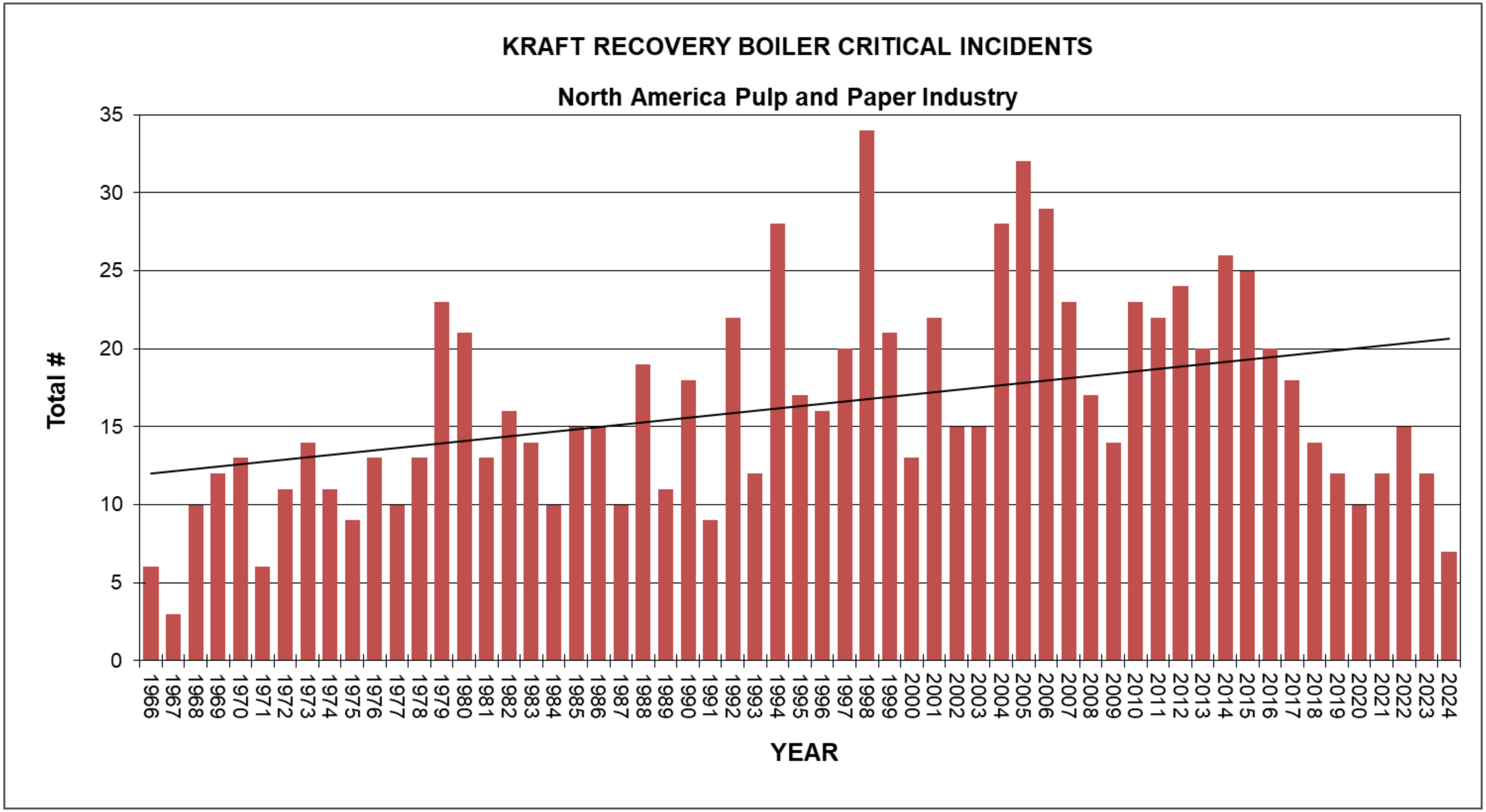
- Leak Detection Systems installed – 20 (56%)
  - Identified leak – 0
  - Confirmed leak - 0

Time to ESP from Initial Indication

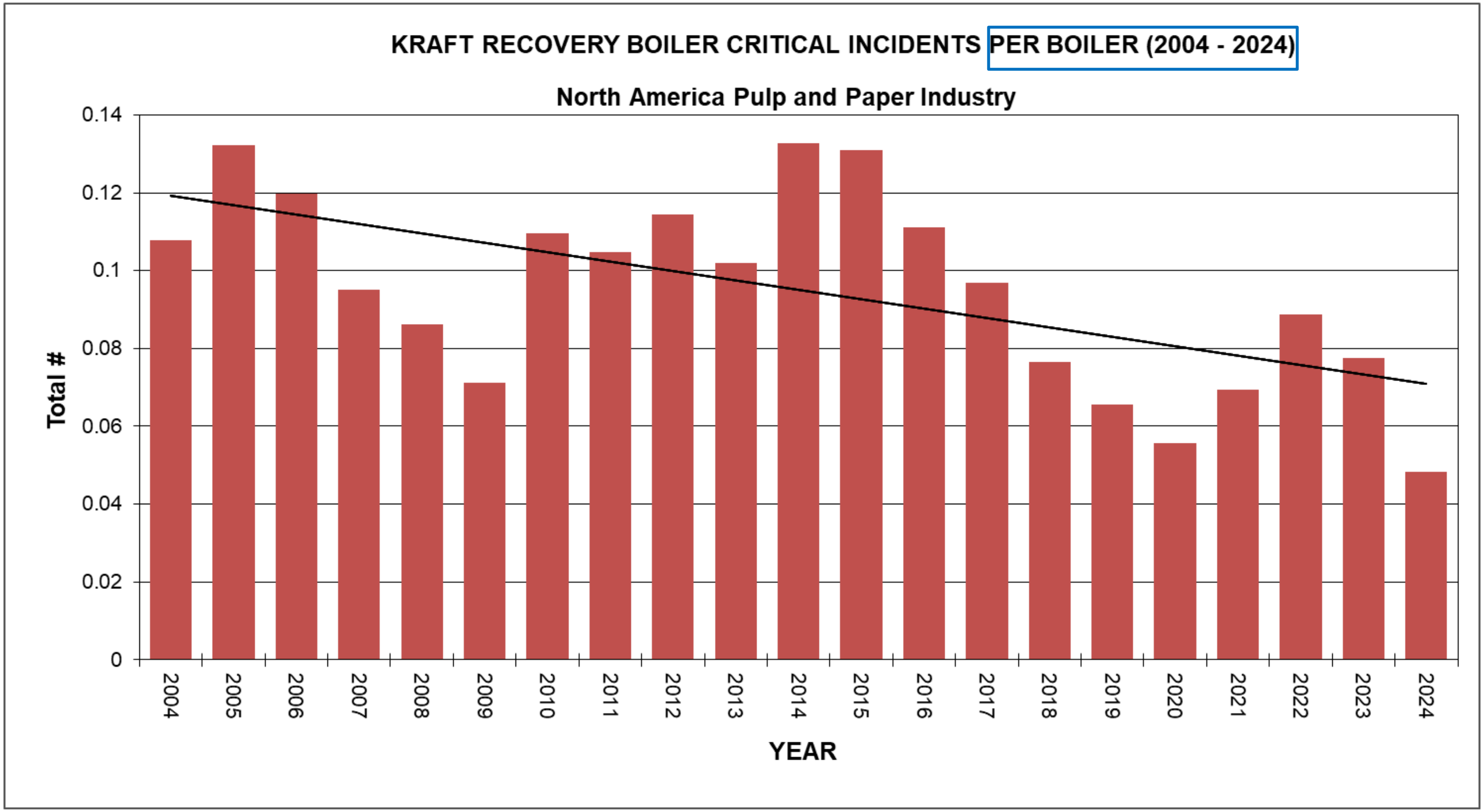
Ranged from 1 minute to 189 minutes

Median time was 56 min

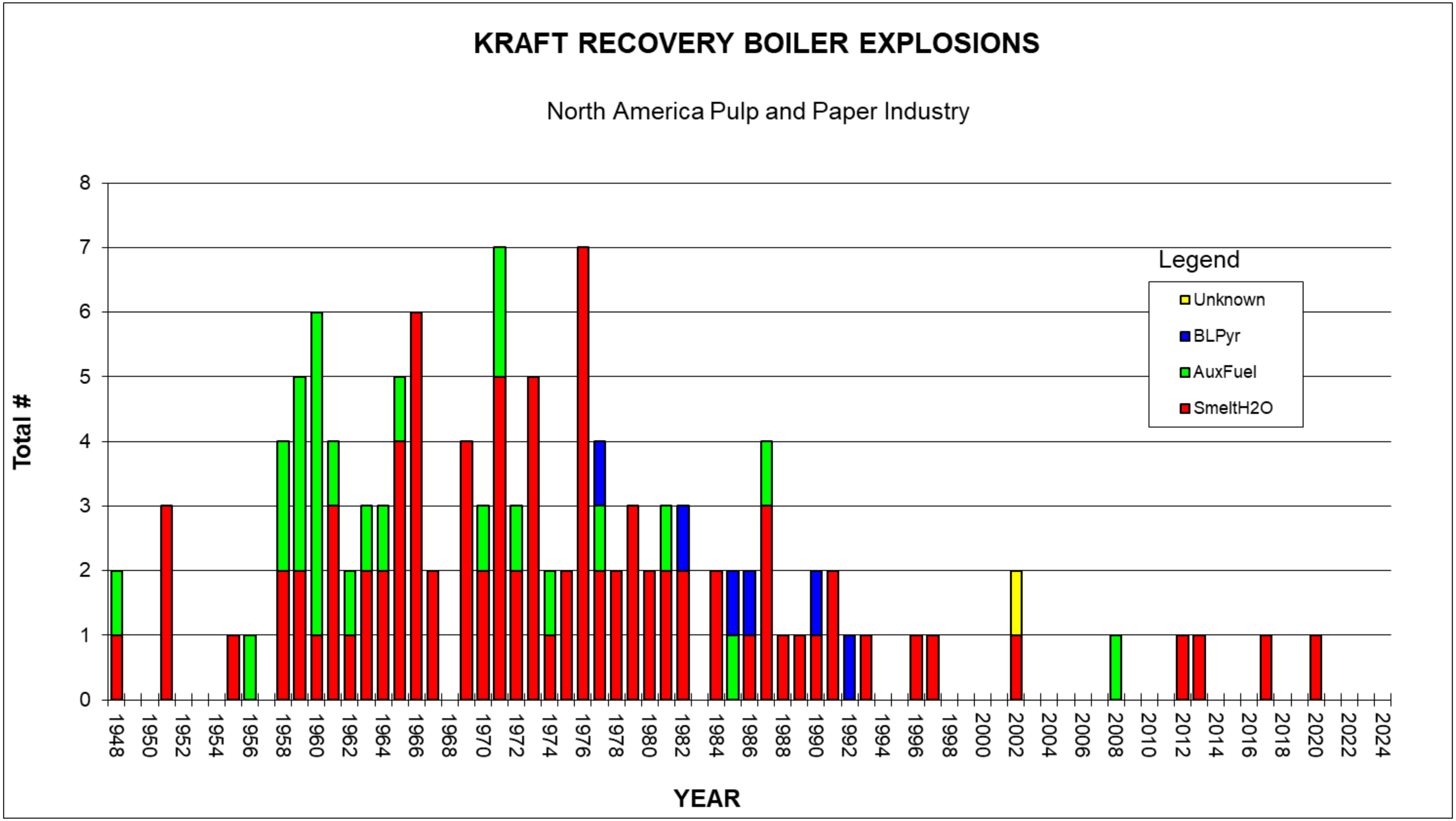
Critical Incidents to Date



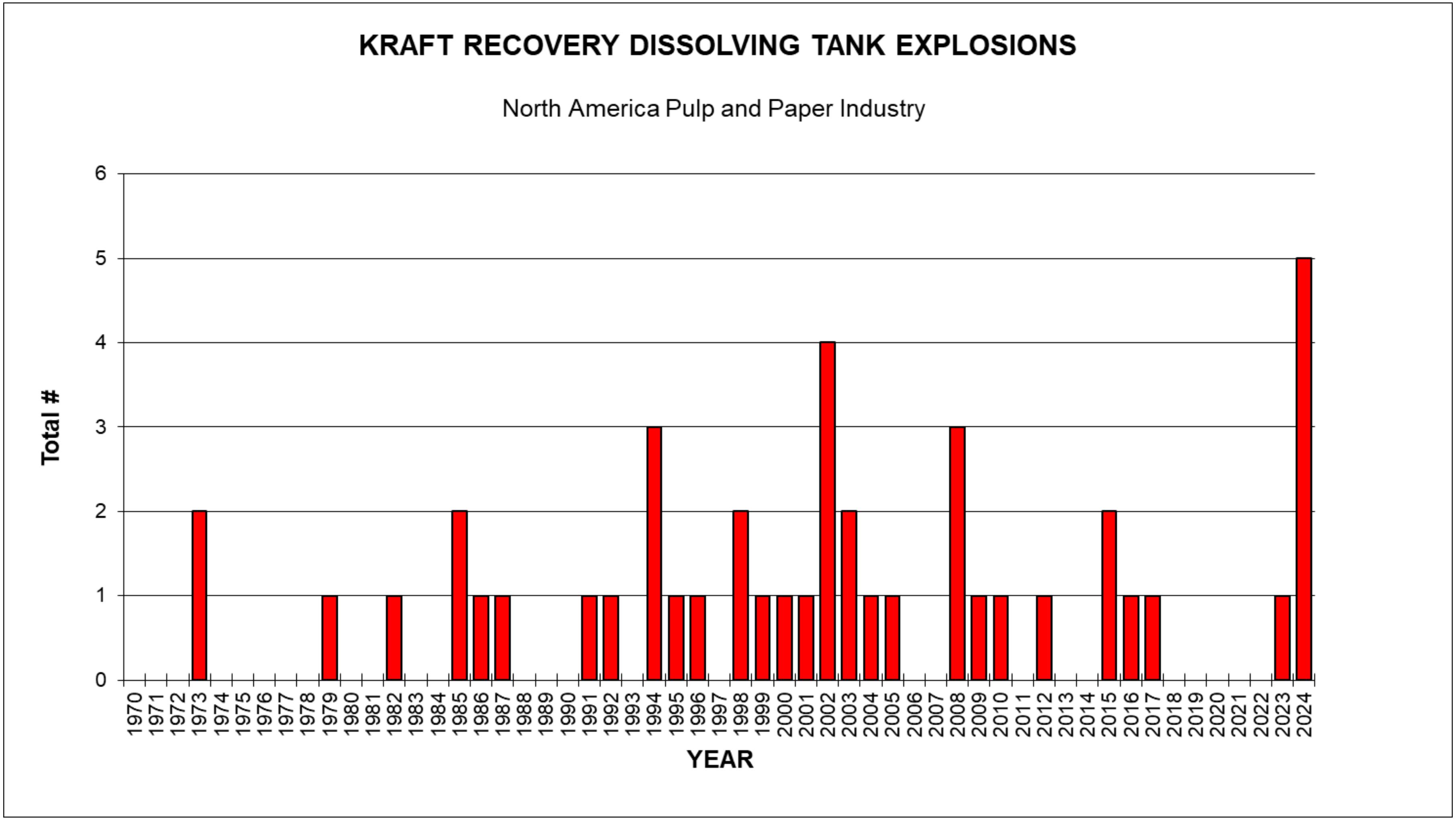
Critical Incidents to Date per Boiler in service



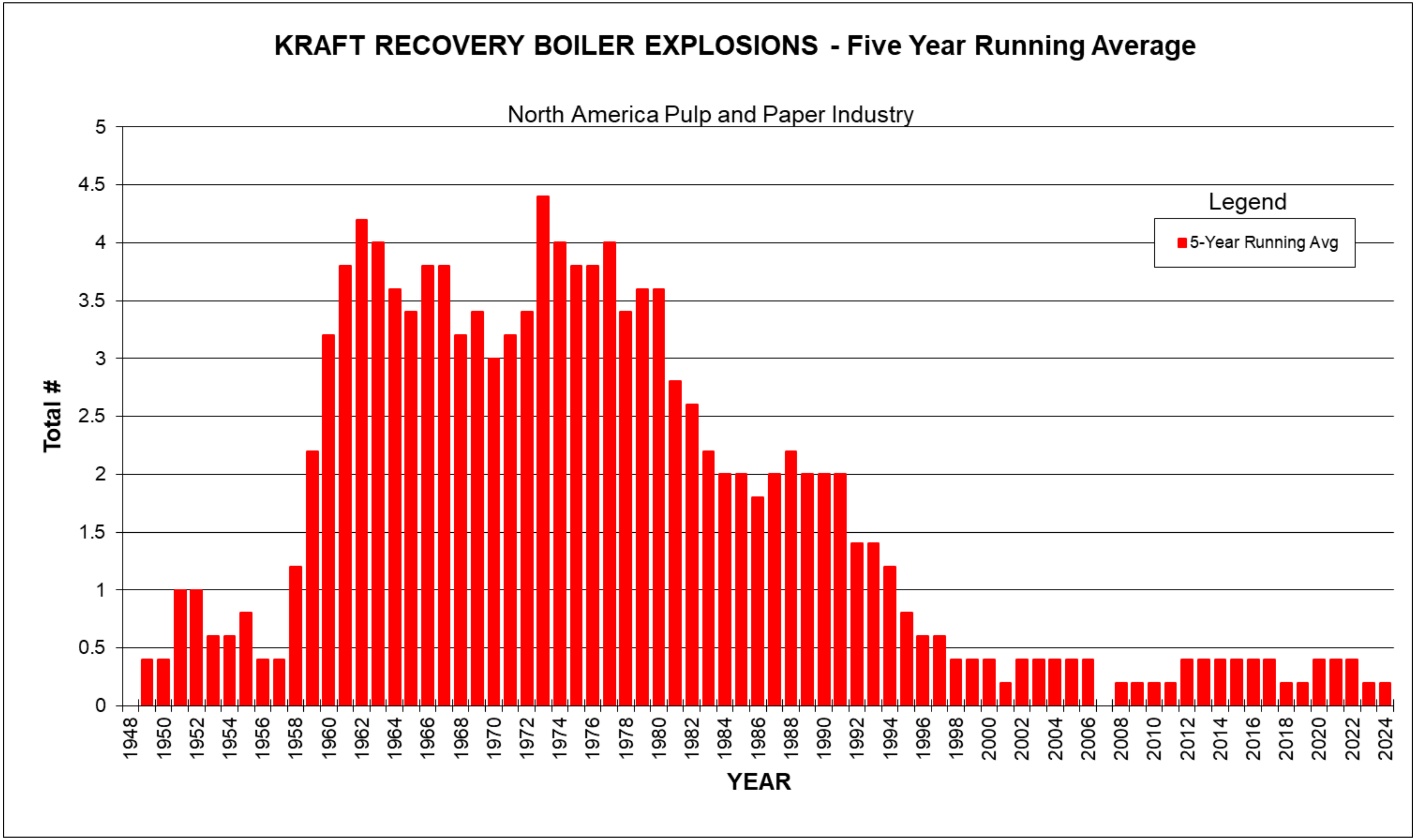
Boiler Explosion History



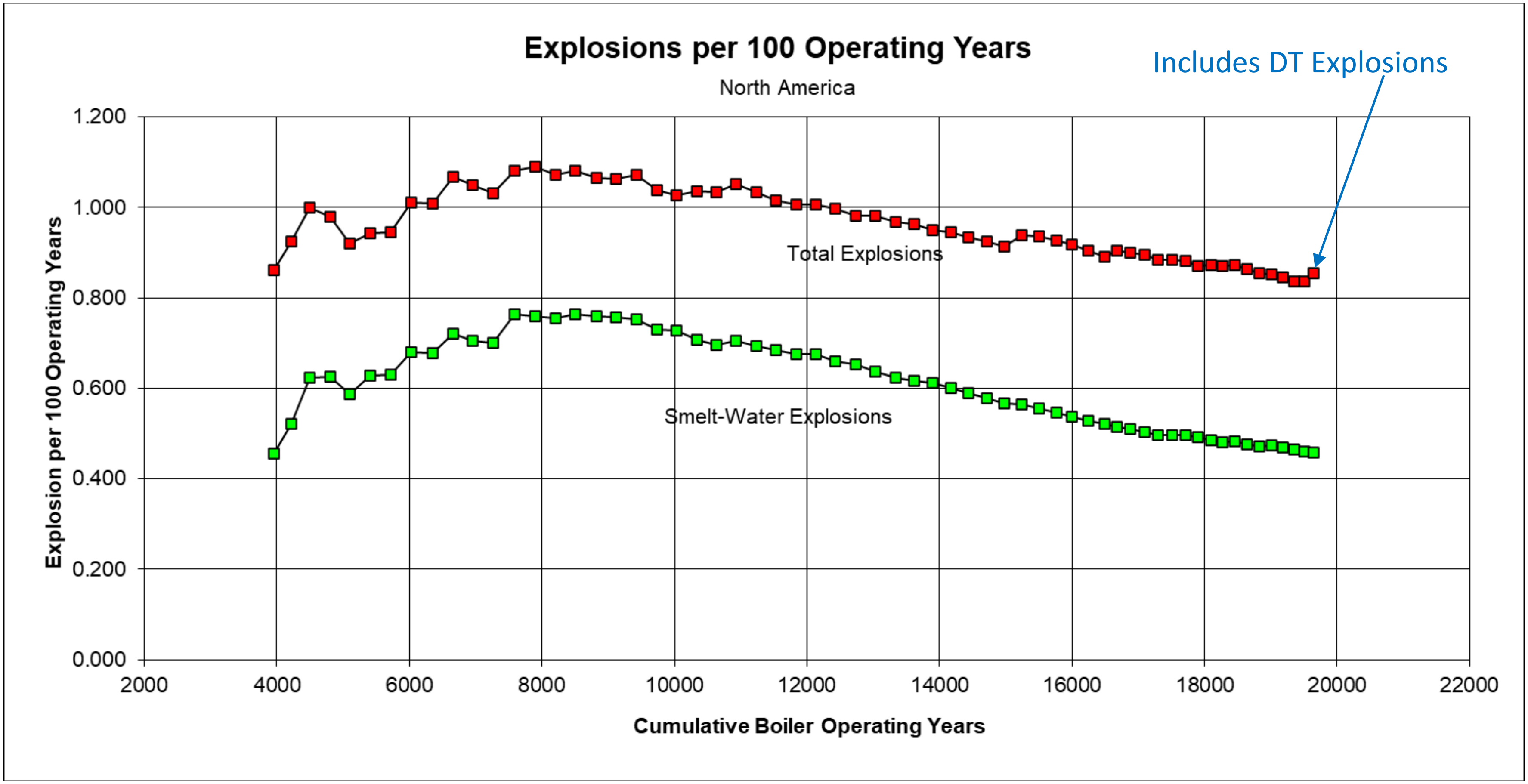
Dissolving Tank Explosions



Explosion History - Five Year Avg



Explosion History per 100 Oper Yr



Boilers in Service

- US and Canadian Total - 145

	US	Canada
Number	118	27
Avg Age	44.3	45.4
Max Age	72	77

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

Learnings

- Spout Deck should be solid surface preferably concrete
- Dissolving tank agitator low amp alarms should be set to alarm if belts burn off or if agitator blades fall off.
- Management of Change procedures should be used when making changes to boiler arrangement.
- Limits on liquor firing rates based on number of spouts open should be emphasized to operators.
- Establish a maximum time limit for firing liquor if there is no smelt flow – even if spouts appear to be open. If liquor is being fired and nothing is coming out, it must be building up somewhere (hopefully not in the superheater)
- Consider redundant DT level indications – especially if DT level is controlled automatically.
- Obtain a copy of AFPA "Recommendations for Dissolving Tank Safety" for training and procedure review.

Learnings

- If you need to cut off shatter jet steam to look inside the dissolving tank plug the spout first.
- Review high furnace pressure trip settings. They may be set to protect the furnace structure rather than personnel around the unit. Consider a staged trip with an instantaneous trip for furnace protection and a lower trip setting with slight time delay to limit blowout and to trigger the Large Leak Logic.
- For screen tube panels that go to front wall, consider a breaker bar on top tube to provide some protection from large slag falls from the upper furnace. Utilize OEM for proper design and installation.
- Make sure that qualified repair supervision is involved with making leak repairs. Follow the proper weld procedure for those repairs
- Make sure that repair is not an SOFL (Site of Future Leak). Many pinhole leaks may be a result of internal cracking that probably will not be fully removed by welding the pinhole

Learnings

- An inserted spout with the water shut off and smelt flow stopped (Spout plugged) may still be susceptible to the inserted portion overheating due to lack of cooling. This should be considered when determining how long to wait for a repair outage.
- Utilize a "Guard Goose" to observe the bed and smelt pool when there are smelting issues even if spouts appear to be open. Unstable firing conditions such as low sulfidity, jelly rolling smelt, Salt drops, etc. require additional monitoring related to bed condition & spout plugggage/runoffs until the situation is resolved
- Low sulfidity conditions may require additional Auxiliary fuel and reduced liquor burning rates until the condition is resolved.
- Leaks on the FW inlet tubes of an economizer should be inspected for internal oxygen pitting if no other root cause if evident.
- SH tube penetrations at penthouse refractory penetrations may have thinning "Hour-glassing" (especially in some cases if the unit has not been historically dried after water washing). This area should be spot checked

Learnings

- Boilermakers must use care when using a cutting wheel or grinder near boiler tubes to avoid damage and avoid using a torch. May require supervision.
- Areas with vibration bars should be closely visually examined for chaffing
- Understand the construction of your boiler as it relates to water being able to enter the furnace during a tube leak and the decision to ESP or not – Example areas that have the potential for water to enter the furnace when tube leaks are observed to be external are: Loose tube boilers, Sootblower and observation port refractory boxes, Mandoor refractory boxes, Liquor gun refractory boxes, Roof and floor corner seals etc. Operating personnel need to understand the boiler construction and risk for water intrusion into the furnace during a leak
- The refractory crotch area between the Spout wall and floor knuckle tubes should always be closely examined for mechanical damage or hydroblasting “refractory slurry” erosion damage just prior to re-installing new refractory

Reporting RB Incidents to BLRBAC

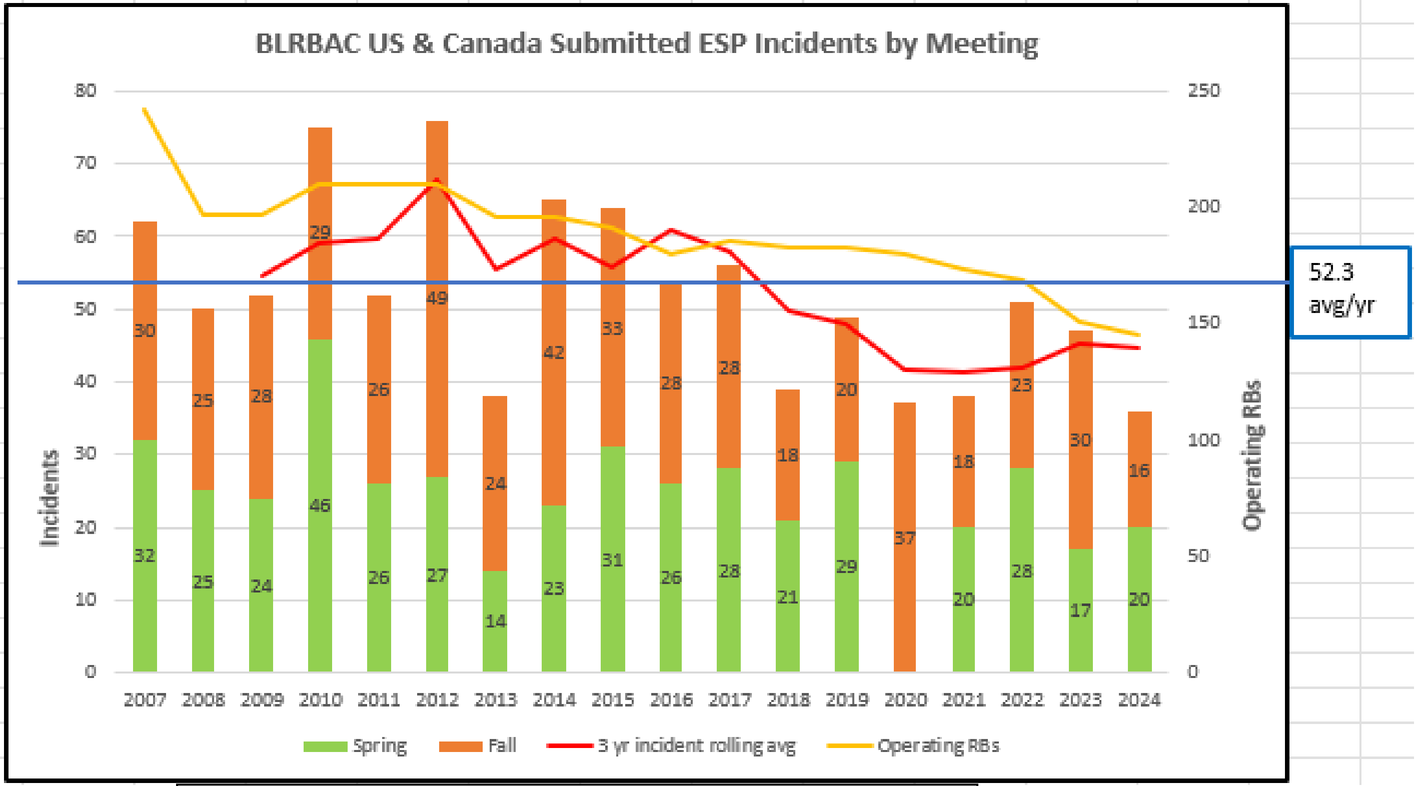
Per BLRBAC "Operating Policies and Procedures" our first primary function is: Analysis, classification and reporting of incidents.

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 would like a separate report for each leak that occurs in different sections of the unit (i.e. critical vs. non-critical areas).

- *We have requested that RB pressure leaks found on a hydro test be reported also*.
- Reporting incidents of smelt rushes and minor damage will be beneficial to prevention of DT explosions. ESP Subcommittee is in the process of revising our incident questionnaire to put more emphasis on DT incidents.



Per the 2024 BLRBAC Operating RB Lists:
Canada 27; US 118; Total 145 operating RBs

FYI, per 2025 RB lists: Canada 25; US 116; 141 total

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

AMERICAN FOREST & PAPER ASSOCIATION RECOVERY BOILER PROGRAM REPORT

BY

WAYNE GRILLIOT

FEBRURAY 4, 2025

2025 AF&PA RECOVERY BOILER ANNUAL CONFERENCE

AF&PA Recovery Boiler Program

The **AF&PA Recovery Boiler Program**

- Established in **1974**
- Help improve the **safety, integrity, and reliability** of Recovery Boiler operations
- Membership is open to all companies & mills that operate Recovery Boilers
- Identify the root cause of Recovery Boiler explosions and critical incidents
- Activities are funded by membership dues

American Forest & Paper Association

AF&PA Recovery Boiler Program

The **Recovery Boiler Program** is directed by a **Steering Committee**

- **Wes Hill** – Georgia-Pacific
- **Jeff Wagoner** – International Paper
- **Gregory Burns** – Domtar
- **Stephen Cox** – International Paper

Program Projects & Initiatives based on Member & Industry Needs

- Member Company Input
- BLRBAC Incidents

AF&PA Recovery Boiler Program

Documents developed by the Program:

- **Reference Manuals**
- **Audit Guidelines**
- **Best Practices**
- **Training Aids**
- **Checklists**
- **Textbooks**
- **Studies**

AF&PA Recovery Boiler Program

- The Program sponsors R&D projects for:
  - **Safety Improvements**
  - **Process Improvements**
- Program Projects and Initiatives focus on:
  - **Safety**
  - **Operations**
  - **Maintenance**
  - **Recovery Boiler Integrity**

AF&PA Recovery Boiler Program

Two Standing Subcommittees

- **Operation & Maintenance Subcommittee**
  - **Wes Hill** – Georgia-Pacific (Co-Chair)
  - **Stephen Cox** – International Paper (Co-Chair)
- **Research & Development Subcommittee**
  - **Gregory Burns** – Domtar (Co-Chair)
  - **Jeff Wagoner** – International Paper (Co-Chair)
- **Subcommittee Membership**
  - Representatives from the Member Companies

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

- **Team Exercises** help operators and supervisors make the important decision: **When to ESP a Recovery Boiler**
  - The Case Studies are based on **actual BLRBAC Recovery Boiler Incidents**
  - **Eight (8) New BLRBAC Case Studies each year for the Team Exercises**!
- Over **4,800** have attended the Seminars since they were started in 1985
- Safety Seminar Monitors
  - **Dean Clay**, BLRBAC ESP Subcommittee Secretary
  - **John Andrews**, Former BLRBAC ESP Subcommittee Chair

Operational Safety Seminars

2024: Four (4) Recovery Boiler Operational Safety Seminars

Two (2) Online Virtual & Two (2) In-Person

- **March 20, 2024** (**Virtual**), Wednesday (7:45 am - 4:30 pm **Eastern Time**)
- **April 10-11, 2024** (**In-Person**), Wednesday afternoon/Thursday morning (**Eastern Time**) After Spring BLRBAC, at the Atlanta Airport Sonesta Hotel
- **May 16, 2024** (**Virtual**), Thursday (7:15 am - 4:00 pm **Pacific Time**)
- **October 9-10, 2024** (**In-Person**), Wednesday afternoon/Thursday morning (**Eastern Time**) After Fall BLRBAC, at the Hilton Atlanta Airport Hotel

Operational Safety Seminars

2025: Five (5) Recovery Boiler Operational Safety Seminars

Three (3) Online Virtual & Two (2) In-Person

- **March 19, 2025** (**Virtual**), Wednesday (7:45 am - 4:30 pm **Eastern Time**)
- **April 9-10, 2025** (**In-Person**), Wednesday afternoon/Thursday morning (**Eastern Time**) After Spring BLRBAC, at the Hilton Atlanta Airport Hotel
- **May 22, 2025** (**Virtual**), Thursday (7:15 am - 4:00 pm **Pacific Time**)
- **September 18, 2025** (**Virtual**), Thursday (7:15 am - 4:00 pm **Pacific Time**)
- **October 8-9, 2025** (**In-Person**), Wednesday afternoon/Thursday morning (**Eastern Time**) After Fall BLRBAC, at the Hilton Atlanta Airport Hotel

Annual Conference & Meetings

2024 AF&PA Recovery Boiler Conference & Committee Meetings

- February 6-7, 2024, at the Atlanta Airport Marriott
- 93 people attended.
- Many of You Here Attended – Thank you.

2025 AF&PA Recovery Boiler Conference & Committee Meetings

- **February 4-5, 2025**, at the **Atlanta Airport Marriott**
- **Great attendance. 99 people registered!!!**
- 1st Tuesday & Wednesday each February
- The Conference is open to everyone interested in Recovery Boilers
- **Thank You for Attending!!!**

Dissolving Tank Studies

- The **O&M and R&D Subcommittees** are both working to develop best practices around Dissolving Tank related issues
- The **R&D Subcommittee** sponsored 4 research projects at the University of Toronto for improved safety and reduced operating risk of Dissolving Tanks
  - The 4 projects focused on:
    - **Dissolving Tank key operating conditions**
    - **Advanced monitoring techniques**
- The 4 projects are complete, and the reports are available to AF&PA Recovery Boiler Program members.
- The R&D Subcommittee is currently considering a **"Dissolving Tank Explosion Relief Venting Guidelines"** project.

Best Practices

- The **O&M Subcommittee** has created the following documents over the last several years:
  - **Recovery Boiler Functional Checks AF&PA Example Document**
  - **Recommendations for Dissolving Tank Safety**
  - **Impact Considerations for Recovery Boiler Extended Run Time**
    - These documents are posted on our website and are available to everyone to download
- Next **O&M Subcommittee** Project
  - **Stress-Assisted Corrosion (SAC)**

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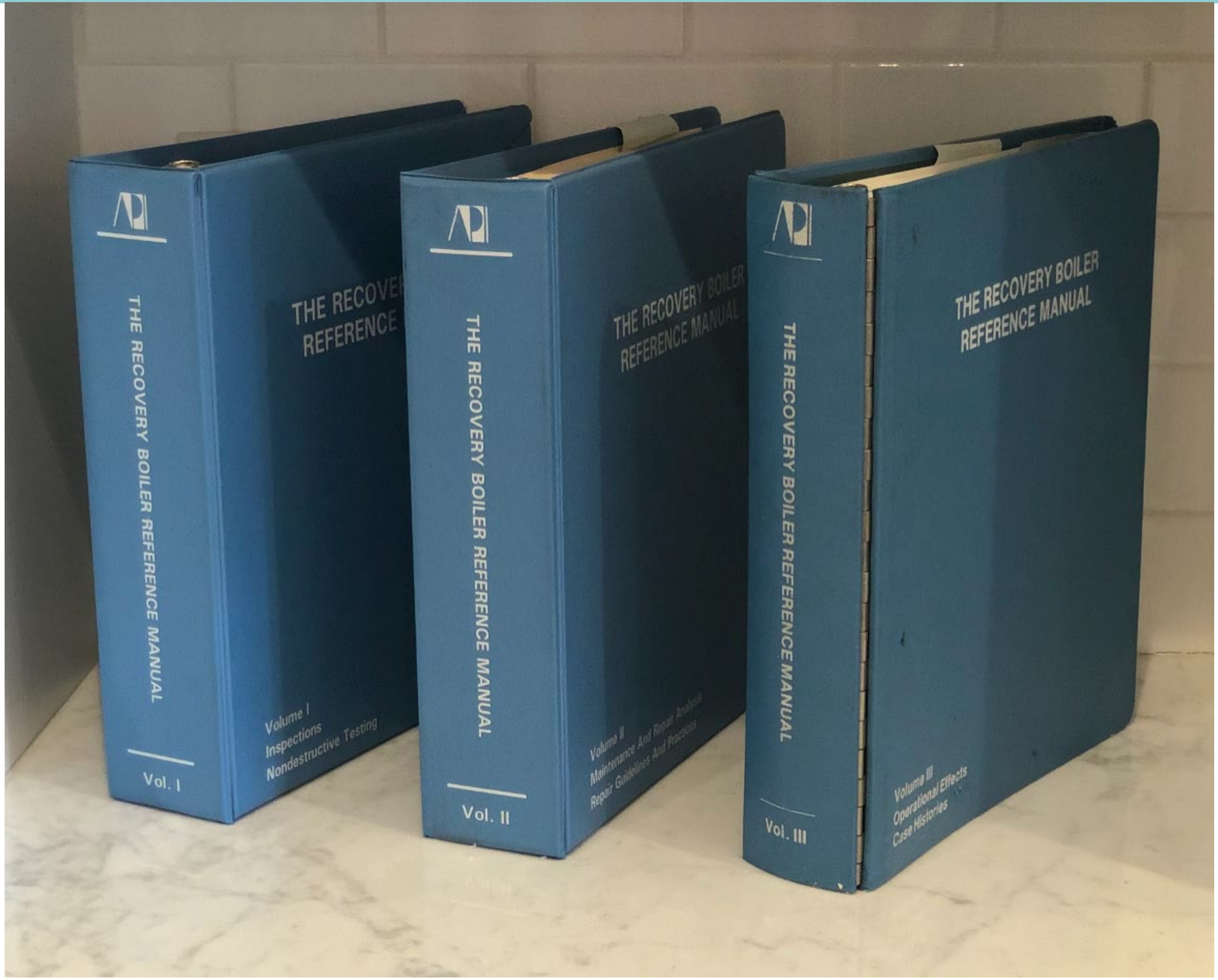
The Recovery Boiler Reference Manual Update



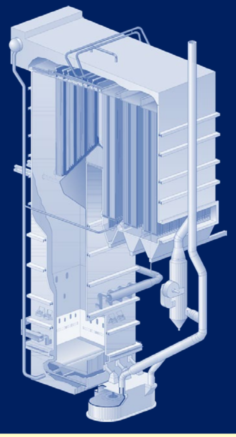
American Forest & Paper Association

The Recovery Boiler Reference Manual Update

- The AF&PA O&M and R&D Subcommittees are working on a join project to update **The Recovery Boiler Reference Manual**
- The Recovery Boiler Reference Manual is a 3-volume (6-chapter) set of hard copy documents that were last updated in the 1990s
- The goal is to have an accurate MS Word version of the manual that can be edited and serve as a basis to make future updates.
- These documents are now on a SharePoint site
- All team members have access and edit rights.
- The plan is to have The Recovery Boiler Reference Manual content updated by February 2026

Kraft Recovery Boilers

- Third Edition -



Technical Editor:
Honghi Tran

Kraft Recovery Boilers

- Third Edition -

by

Terry N. Adams
W. James Frederick
Thomas M. Grace
Mikko Hupa
Andrew K. Jones
W.B.A. Sharp
Douglas Singbeil
Honghi Tran

Technical Editor
Honghi Tran

American Forest & Paper Association

TAPPI PRESS

Kraft Recovery Boilers “Blue Book”

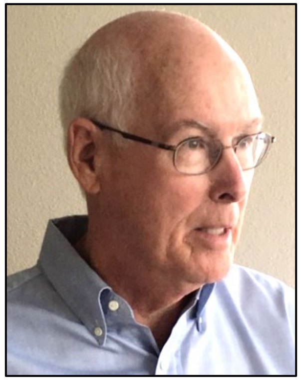
- **The AF&PA R&D Subcommittee** sponsored the publication of the new **Kraft Recovery Boilers, Third Edition** textbook
- **Dr. Honghi Tran** of the University of Toronto led the effort to author the new book
- Dr. Tran and 7 other world-renowned Recovery Boiler experts completed the 16 chapters of the new book
- Book sales have been very strong, with over **1,100 copies sold!!!**
- **In its 6th Printing already!!!**
- Available through **TAPPI Press.**
- The book is also part of the **TAPPI Kraft Recovery Operations Course**
- **TAPPI will be here Tomorrow, Offering the Book at a 25% Discount**

American Forest & Paper Association

Technical Editor & Chapter Author

HONGHI TRAN obtained his B.Sc. and M.Eng. from Shizuoka University in Japan, and his PhD from the University of Toronto in 1982. Honghi is Frank Dottori Professor of Pulp and Paper Engineering and Director of the Pulp & Paper Centre in the Department of Chemical Engineering and Applied Chemistry. He helped establish and direct consecutively 12 large industrial research consortia, focusing on issues related to energy and chemical recovery in kraft pulp mills. Honghi has authored or co-authored over 300 refereed papers and has 8 patents. Honghi has chaired the TAPPI Kraft Recovery Course since 2006. He was named a TAPPI fellow in 2000, PAPTAC fellow in 2015, and Canadian Academy of Engineering Fellow in 2016. Honghi received numerous prestigious awards including the 2013 PAPTAC's John S. Bates Gold Medal and the 2017 TAPPI Gunnar Nicholson Gold Medal. He was inducted to the Paper Industry International Hall of Fame in 2017.

Chapter Authors



TERRY ADAMS was an independent technical consultant to the pulp and paper industry in the area of chemical recovery until he retired in 2017. He obtained a B.Sc. from the University of California at Santa Barbara, a M.Sc. from the University of Michigan, and a Ph.D. from Drexel University with a specialty in combustion. Terry has worked as a Professor at the University of British Columbia, a Combustion Scientist at Weyerhaeuser Co., and since 1986 an independent consultant with a client base of over a hundred mills. He co-authored Kraft Recovery Boiler Physical and Chemical Processes, TAPPI Press, published in 1988 with Dr. Jim Frederick, and is the editor and co-author of Kraft Recovery Boilers, TAPPI Press, published in 1997.

Chapter Authors

THOMAS M. GRACE obtained a B.S. in chemical engineering at the University of Wisconsin and a Ph.D. from the University of Minnesota. He was a faculty at the Institute of Paper Chemistry (now IPST at Georgia Tech) for 22 years, and an adjunct professor at the University of Toronto for 15 years. He formed T. M. Grace Company in 1988, consulting on recovery boilers and chemical recovery. Tom has a long involvement with BLRBAC and the AF&PA Recovery Boiler Committee, investigating recovery boiler explosions for 25 years. He authored many papers and book chapters on chemical recovery. Tom was awarded the TAPPI Gunnar Nicholson Gold Medal in 2001 and inducted to the Paper Industry International Hall of Fame in 2003.

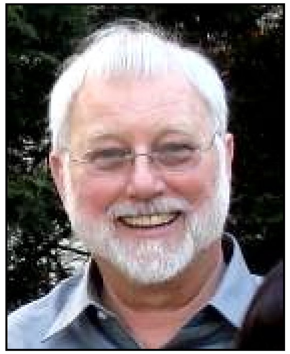
ANDREW K. JONES is a Senior Engineering Fellow at International Paper (IP) where he fosters the implementation on new process innovations. Previously he was the recovery boiler SME. He has been with IP since 1997. Previously he worked for ABB/Combustion Engineering leading an R&D group. He received his PhD from the Institute of Paper Chemistry in 1989. Andy is active in TAPPI, having led the Engineering Division, and was conference chair for the TAPPI PEERS conference. He won the TAPPI Engineering Leadership and Service Award in 2004. He was the conference chair for the ICRC (International Chemical Recovery Conference). Andy was named a TAPPI Fellow in 2016 and he received the Engineering Division Technical Award and Beloit Prize in 2018.

Chapter Authors

MIKKO HUPA is a Chemical Engineering Professor at the Åbo Akademi University (ÅAU) in Turku, Finland. Mikko has supervised more than 40 PhD Theses and authored or co-authored more than 350 journal papers in the areas of high temperature chemistry, biomass and black liquor combustion and gasification, and fluidized bed combustion. Mikko has wide experience as an industrial consultant on issues of chemical aspects of combustion and energy processes. He has served as President of the International Flame Research Foundation, an international organization on industrial combustion with 250 member organizations in nearly twenty countries around the world. Mikko was named a TAPPI Fellow in 2005. Since 2015 he has worked as the President of his university ÅAU.

WILLIAM J. (JIM) FREDERICK, Jr. received his BS, MS, and PhD degrees in Chemical Engineering from the University of Maine. Jim has been active in kraft chemical recovery since 1975, both in industry, research, and consulting. Jim has been active with both TAPPI and the AIChE Forest Products Division throughout his career. He received the AIChE Forest Products Division's award in 1998, and he was named a TAPPI Fellow in 2007. He co-authored the book Kraft Recovery Boiler Physical and Chemical Processes (American Paper Institute, 1988), was a contributing author to Kraft Recovery Boilers (TAPPI Press, Atlanta, 1997). He is the lead author on a new book, Black Liquor Evaporation, to be published by TAPPI in 2019.

Chapter Authors



W.B.A. (SANDY) SHARP is a consultant specializing in solving corrosion and materials problems in pulp and paper mills and chemical plants. He has master's degrees in Metallurgy and in Corrosion from Cambridge and London Universities in the U.K. and a Ph.D. in Chemistry from the University of Ottawa. Sandy's materials engineering experience includes 28 years leading corrosion control efforts within Westvaco (now WestRock). He has published 62 technical papers in refereed journals. He developed TAPPI's short course on solving corrosion problems and has won TAPPI's Joachim Leadership and Service Award and Engineering Division Award. Sandy is a TAPPI Fellow, a Materials Technology Institute Fellow, and the first NACE (Corrosion Engineers' Association) Fellow from the pulp and paper industry.

DOUGLAS SINGBEIL holds a BSc in Chemistry and an MSc in Metallurgy from the University of British Columbia. He began his career with FPInnovations (formerly Paprican) in 1982 as a research scientist. He has since served in numerous roles, including Corrosion Group Leader, Research Leader for Bioenergy & Corrosion, Research Manager for Process Engineering, and is currently Industrial Sector Leader for BioProducts. Over his career, Doug has addressed corrosion in recovery and biomass boilers, digesters and other process equipment. He has authored/co-authored more than 60 papers. He received awards for several of these, including the 1998 and 2004 ISCPPI Walter Mueller Awards and 2005 PAPTAC Weldon Medal. He was appointed a Fellow of NACE International in 2009.

Recovery Boiler Program Information

- AF&PA Recovery Boiler Program Website:

  https://www.afandpa.org/get-involved/industry-programs#RecoveryBoiler

- Recovery Boiler Program General Information

- Information on Available Documents
  - Publications
  - Studies
  - Training Aids
  - Standards

Contact Information

- AF&PA Website:

  http://www.afandpa.org

- AF&PA Recovery Boiler Program Website:

  https://www.afandpa.org/get-involved/industry-programs#RecoveryBoiler

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Questions?

Thank You!

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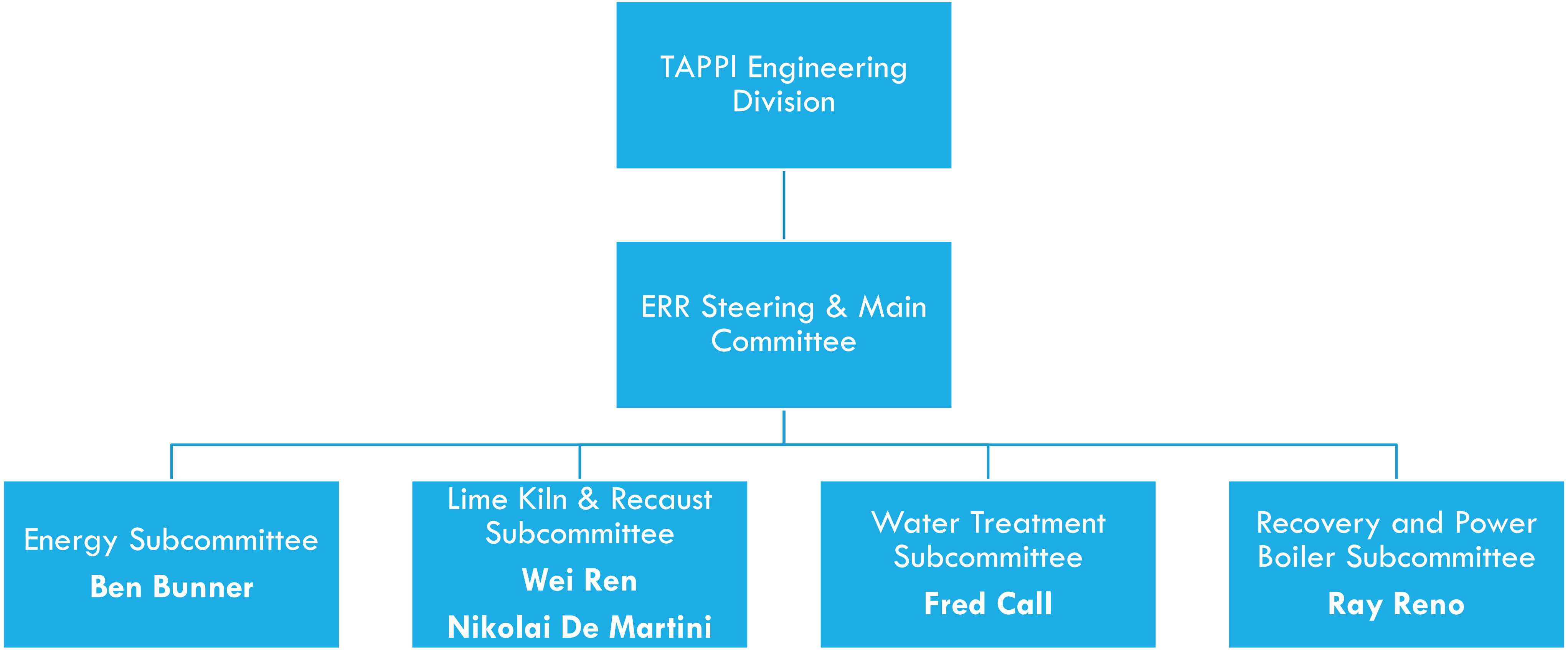
BETTER PRACTICES
BETTER PLANET 2030
SUSTAINABLE PRODUCTS FOR A SUSTAINABLE FUTURE

AFPA – TAPPI ENERGY, RECOVERY, RECAUST (ERR) COMMITTEE UPDATE

Daniel Franco
ERR Committee Vice Chair
2025 – 02 – 05

TAPPI STRUCTURE



ERR STEERING & MAIN COMMITTEE

Chair: **Wei Ren**, FPInnovations

Vice Chair: **Daniel Franco**, Smurfit Kappa

Technical Program Chair: **Alexander Moline**, Domtar

TIP Coordinator: **Ben Bunner**, Andritz

This committee provides a forum to collect information and disseminate the information as a guideline for energy management, sharing ideas on conserving energy, and increasing efficiency. We publish Technical Information Papers (TIPs). We focus on pulp and paper mills and power plants in areas of energy management and energy consumption, including electrical, steam, condensate and efficient heat exchange.

RECOVERY AND POWER BOILER SUBCOMMITTEE

Chair: **Ray Reno**, Volodyne LLC

The objective of this subcommittee is to develop and disseminate information and provide best practice guidelines related to the design and operation of recovery boilers, liquor evaporators, non-condensable gas systems, and related equipment. As well as to develop and disseminate information relating to steam generation from fossil or refusable fuels, either purchased or from on-site sources.

WATER TREATMENT SUBCOMMITTEE

Chair: **Fred Call**, Buckman

The subcommittee aims to develop and disseminate information relating to the management of water quality throughout the power plant cycle. This includes the management of water supplies, boiler feedwater, condensate, cooling water, and industrial cleaning.

ENERGY SUBCOMMITTEE

Chair: **Ben Bunner**, Andritz

The objective of the subcommittee is to develop and disseminate information relating to design, application, and operations in areas of power generation drive equipment' energy policies affecting price and availability; power plant conceptual thermal cycle; and economical and effective energy management technology.

LIME KILN & CAUSTICIZING SUBCOMMITTEE

Chair: **Wei Ren**, FPInnovations

Chair: **Nikolai De Martini**, University of Toronto

The committee will focus on the design and operation of kilns and causticizing equipment in the pulp and paper industry. The goal will be to identify critical needs and develop pathways to increase understanding in key areas to help the industry to meet its goals in manufacturing efficiency and productivity. The committee will promote ongoing collaboration and alignment of industry owners and operators, equipment suppliers, and research organizations.

TAPPICON 2025

- Minneapolis, MN | May 4 – May 7, 2025

- New Program Format - Topics
  - Equipment, Processes & Operations
  - Emerging Technologies & Methodologies
  - Corporate Citizenship, Sustainability & Environmental Impact
  - Innovative Technology for Products & Processes
  - Talent Development, Safety & Best Practices
  - Pulp & Fiber Innovations, Alternative Materials and Applications

ERRC MEETINGS – TWICE ANNUALLY

- Schedule to be determined due to changes to TAPPI conference schedule
- 2025 Spring Meeting to be hosted at TAPPICON
- 2025 Fall Meeting to be hosted after BLRBAC (TBD)

TECHNICAL INFORMATION PAPERS (TIPS)

TIPs contain specialized information (e.g., data, software, calculations) used in the manufacture, evaluation and description of pulp, paper, and related products.

TIPs may contain testing procedures or methods used to evaluate equipment but do not contain pulp and paper testing procedures or methods.

TIP EXAMPLES

- Recovery boiler sootblowers: practical guidelines
- Key to successful chemical cleaning of boilers
- Evaluating reverse osmosis for treating makeup to the boiler feedwater in a pulp and paper mill
- Guidelines for replacement of generating bank tubes with expanded joints in two-drum boilers
- Water treatment-related opportunities for energy conservation in a paper mill powerhouse
- Energy checklist: pulp mill
- Nitrogen oxide emissions control from biomass and kraft recovery boilers in the pulp and paper industry
- Best practice for recovery boiler inspection (optimizing inspection scope)
- Explanation of recovery boiler leak indications

HOPE YOU CAN MAKE IT TO TAPPICON IN MINNEAPOLIS

THANK YOU

Shock Pulse Generators- Valmet

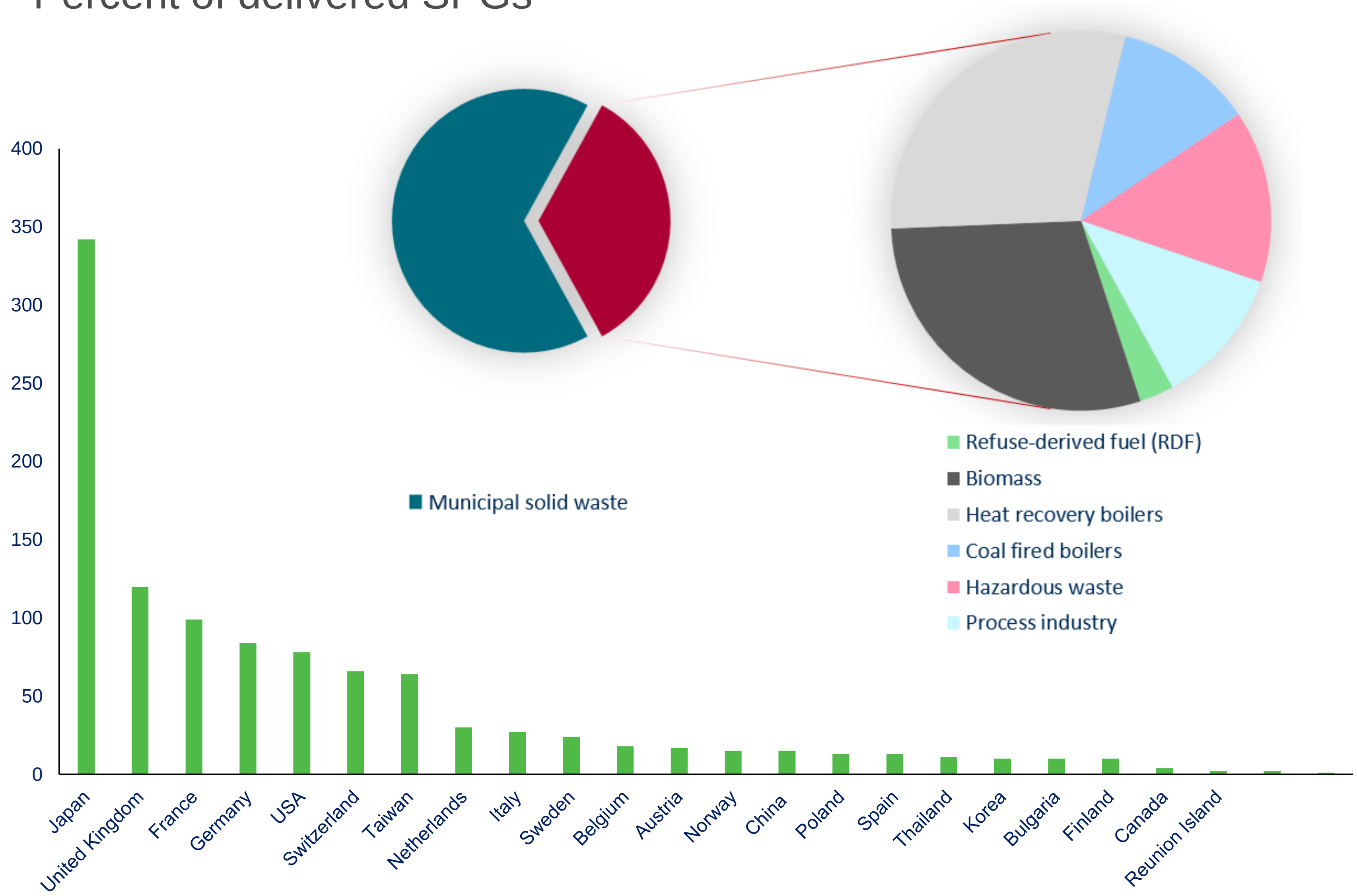
AF&PA February 2025
Sarah Henke

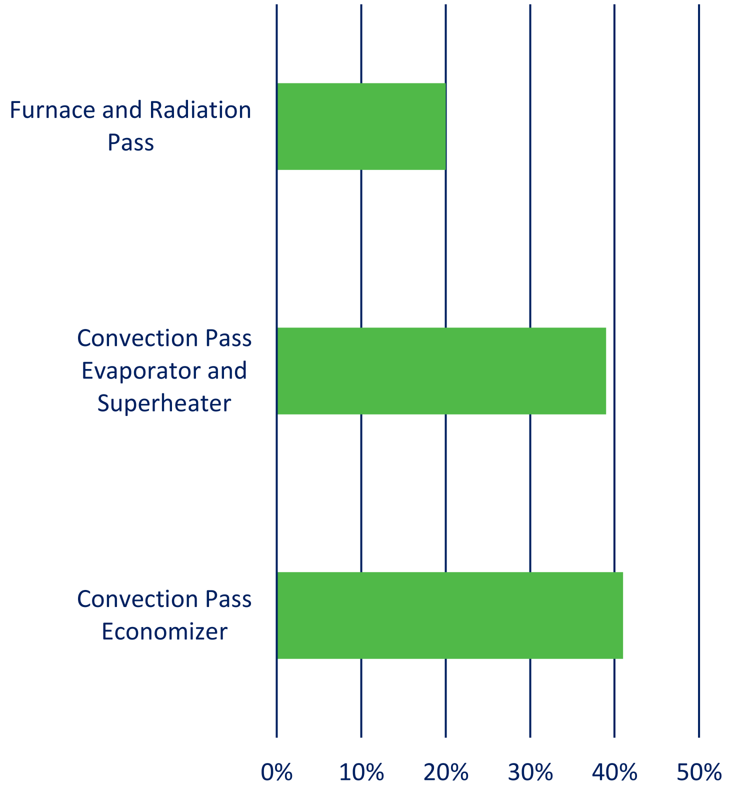
Technology Origin

- 3rd generation is comprehensive step forward utilizing Shock Pulse Generators as mechanism for cleaning
- Technology developed and patented in 2009 by Explosion Power GmbH
- Broad application for utility and industrial boiler designs
- Ability to clean from upper furnace through air preheaters
- Over 1200 units installed at over 150 facilities worldwide
- Valmet has a distribution agreement with Explosion Power for North America

Application Range

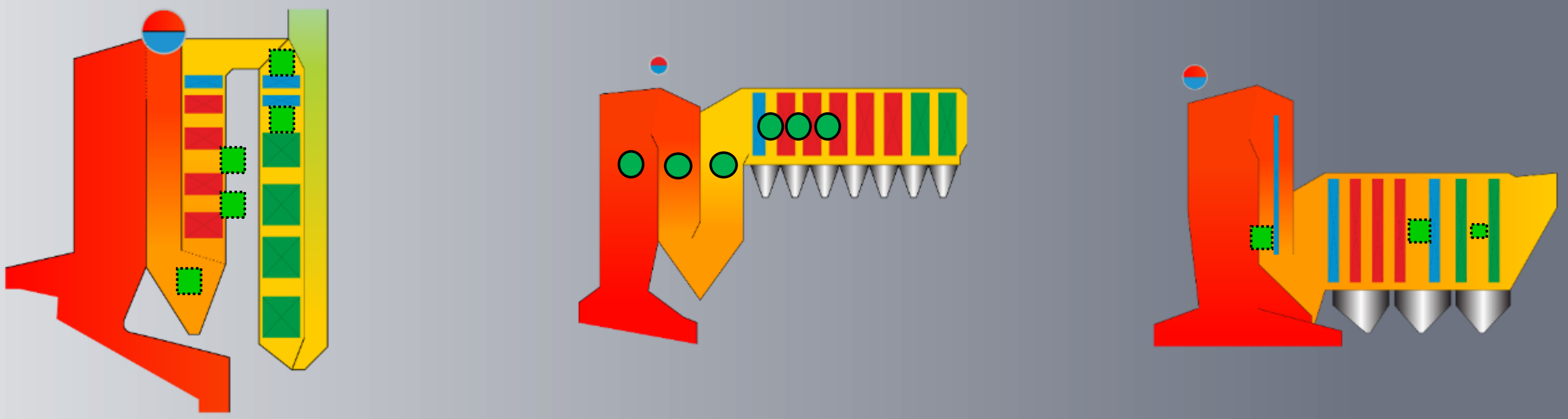
Percent of delivered SPGs





Valmet

Application Range



22 KPPH → Steaming Rate → 2209 KPPH

8.2 ft → Boiler Width → 78.7 ft

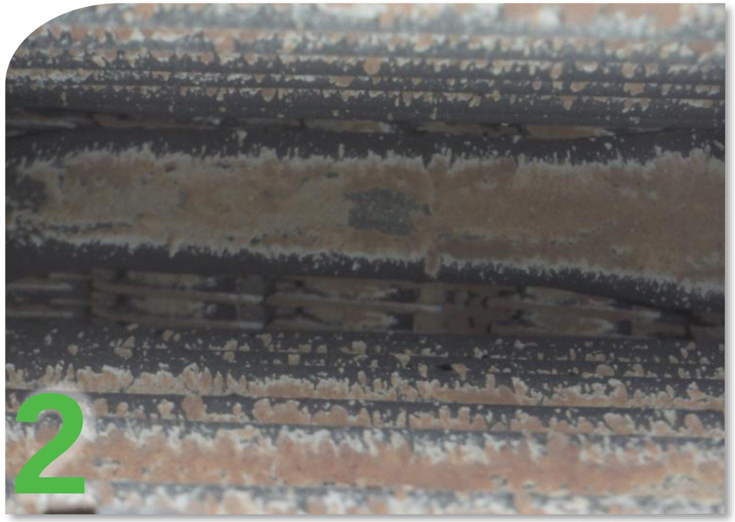
392 ^{o}F → Temperature → 2732 ^{o}F

SPG Advantages

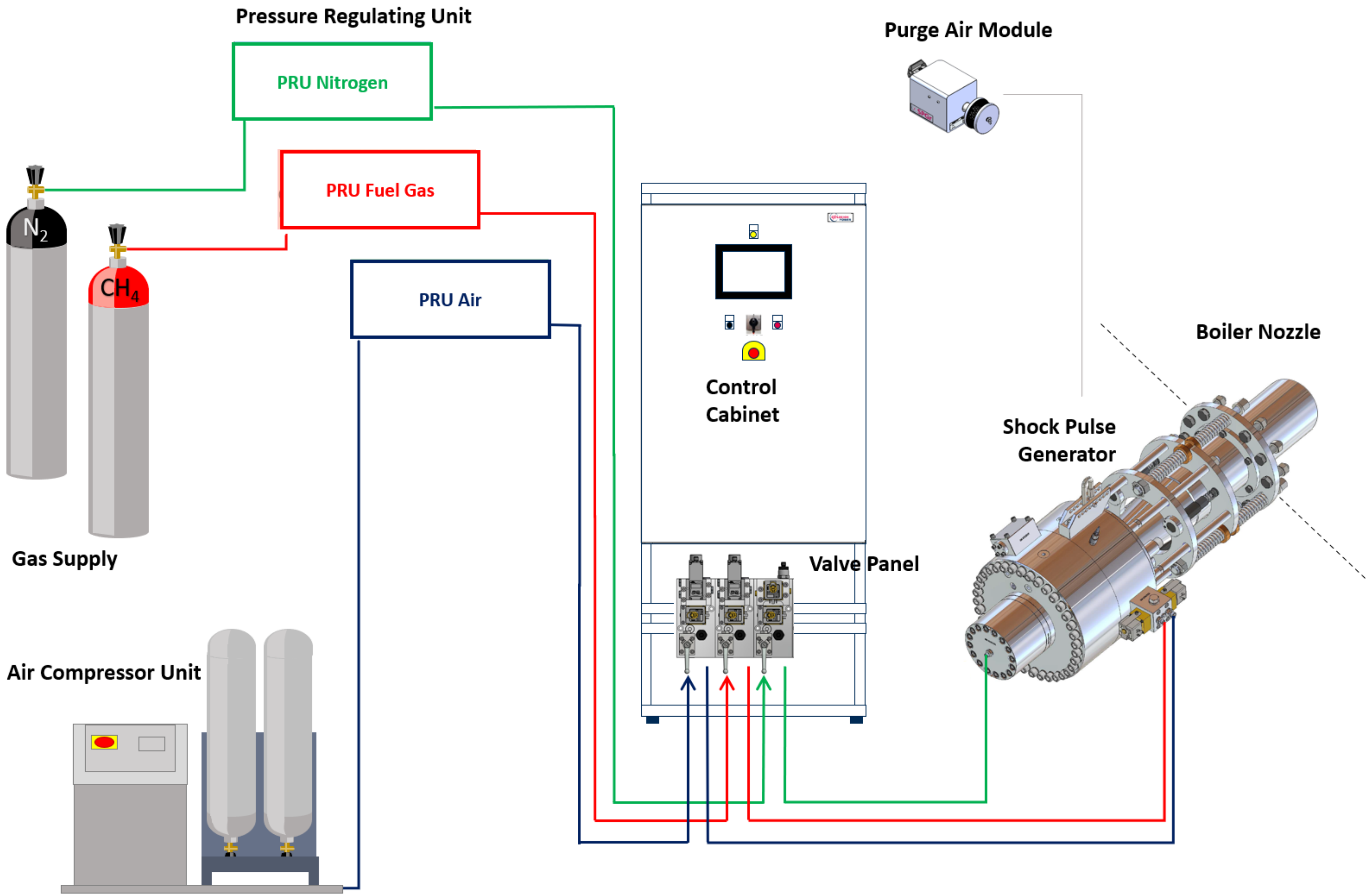
- Most efficient boiler cleaning nevertheless gentle towards boiler tubes (no abrasion)
- Lower flue gas temperatures
- Higher boiler efficiency
- Higher plant availability due to extended period of operation
- Less cleaning required during boiler shutdowns
- Fast and easy installation

Regular Sootblower operation

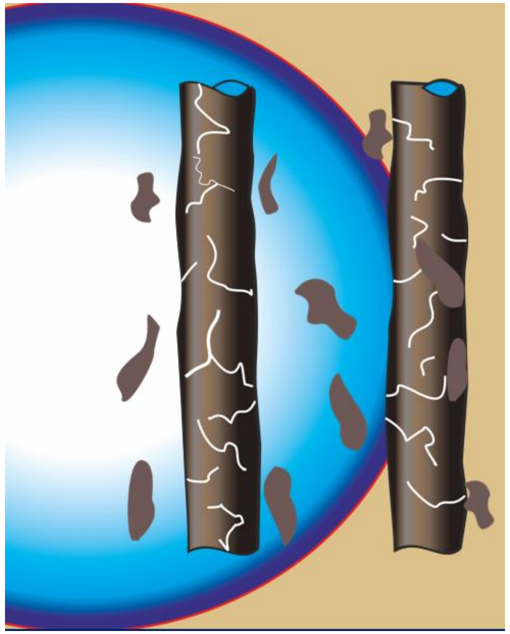
5 months after only SPGs



System Setup SPGr

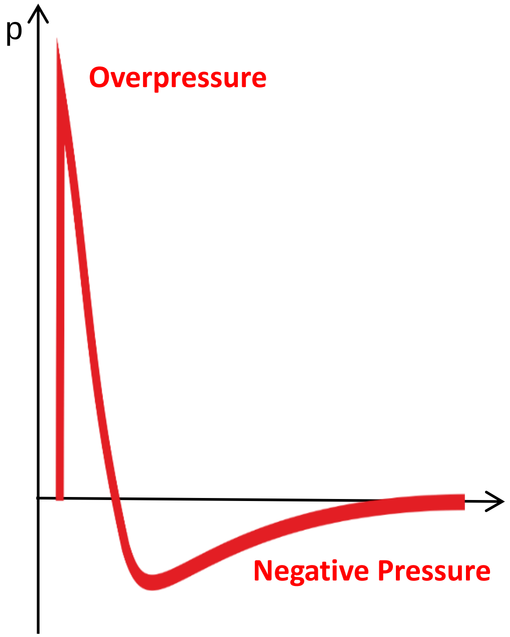


Main cleaning mechanism of the shock pulse



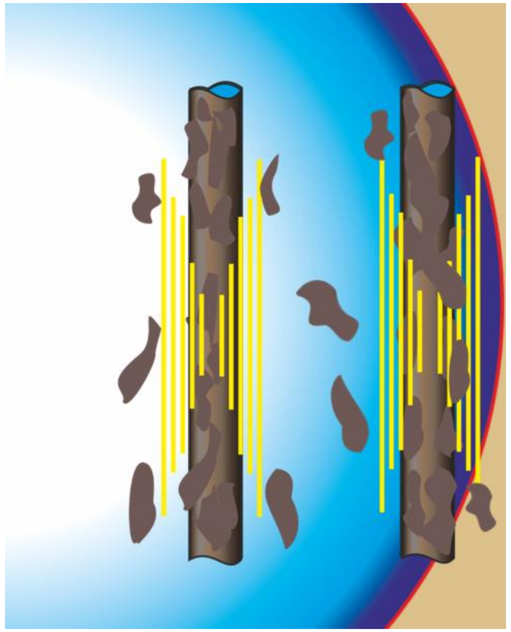
Impact-sound vibration

- Induction of an impacted-sound vibration within the fouling
- Generation of tension and compressive stress
- Initiation of cracks inside the fouling; Support of the fouling removal.



Pulling and suction effect

- According to the Friedlander wave form the shock peak is followed by a zone with negative pressure
- This pulling and suction effect promotes the removal of the fouling



Short-term vibration

- A short-term vibration of the tube-bundle is initiated by the shock wave
- This supports removal and cleaning effect

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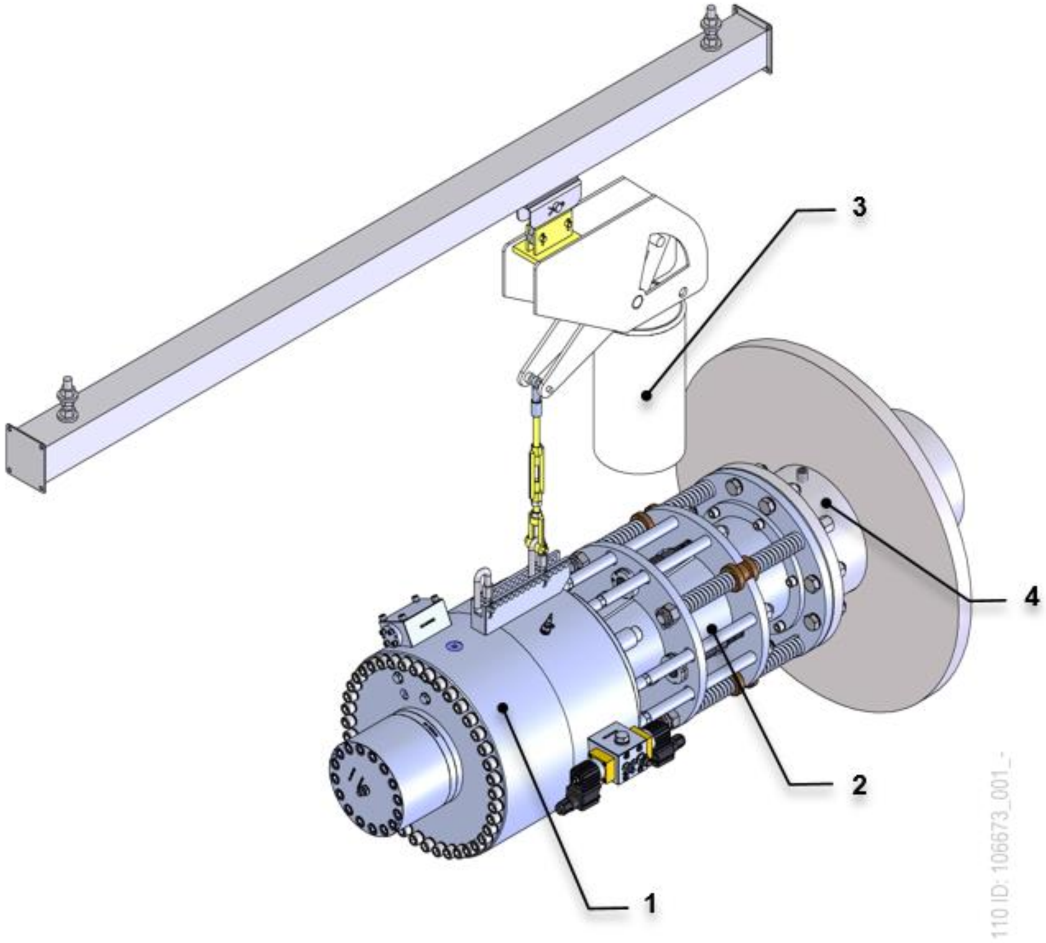
Main Components



1 Shock Pulse Generator
2 Spring Bracket and Discharge Nozzle
3 Suspension with crane rail and constant hanger
4 Boiler flange

Environmental Benefits

Eliminating Sootblower Steam in a Recovery Boiler

- **Background**
  - 74 total sootblowers
  - 70,000 lb/hr of sootblower steam= 932,000 MMBTU/year
  - SPG natural gas use= 500 MMBTU/year, air compressor = 80.2 MMBTU/year

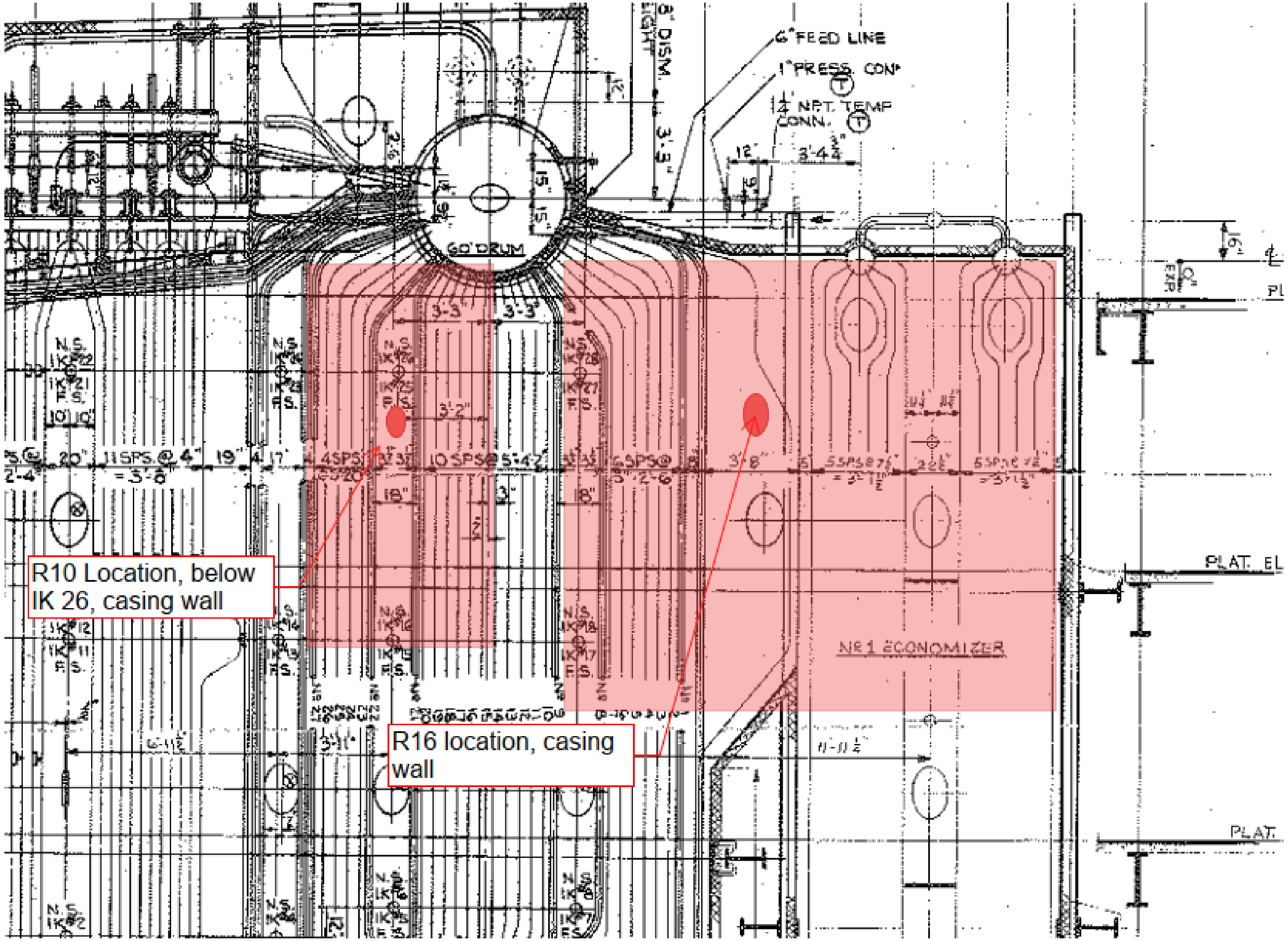
- **If all sootblowers are replaced…**
  - 6.8% reduction in energy cost/salable Ton paper board (932,000 MMBTU/year)
  - 12% reduction in fossil CO_2/salable Ton paper board (53,000 T CO_2/year)
  - 7.5% reduction in RB flue gas volume to Precipitator
  - 0.5% reduction in mill water usage (75 MGal/year)

GPI Texarkana Trial

Background

- **Goal: CO_2 reduction and Sootblower steam savings**

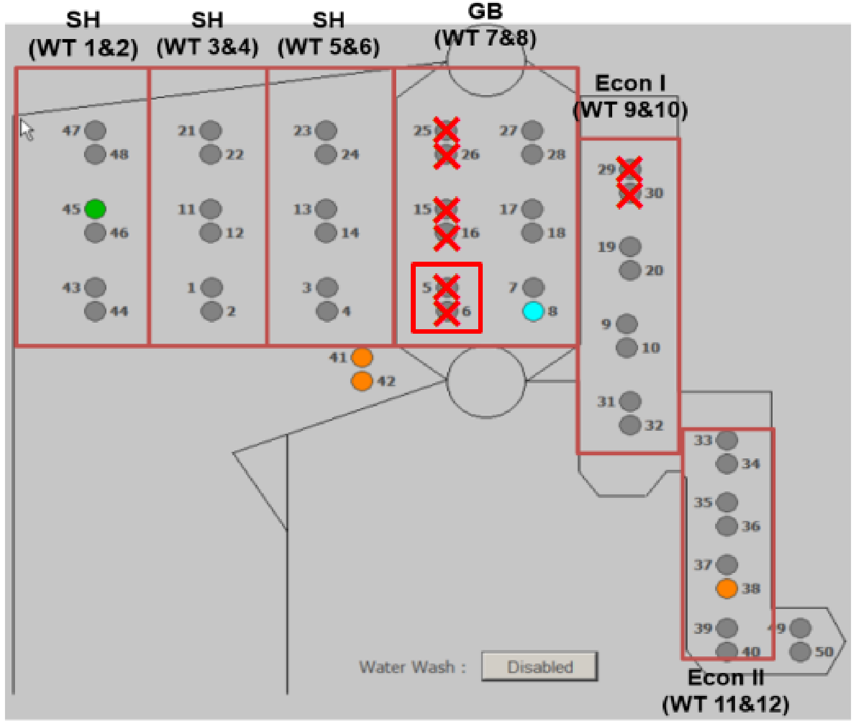
- R10 located in Boiler Bank
- R16 located in-between Boiler Bank and Economizer
- 9th floor, boiler right hand side wall
- The shaded area is the predicted spg effective cleaning area



Texarkana Trial Results

Ongoing

- Seeing a reduction in SB steam
- No indications of boiler pluggage
- 6 sootblowers out of service
- Working to optimize pulse sequence



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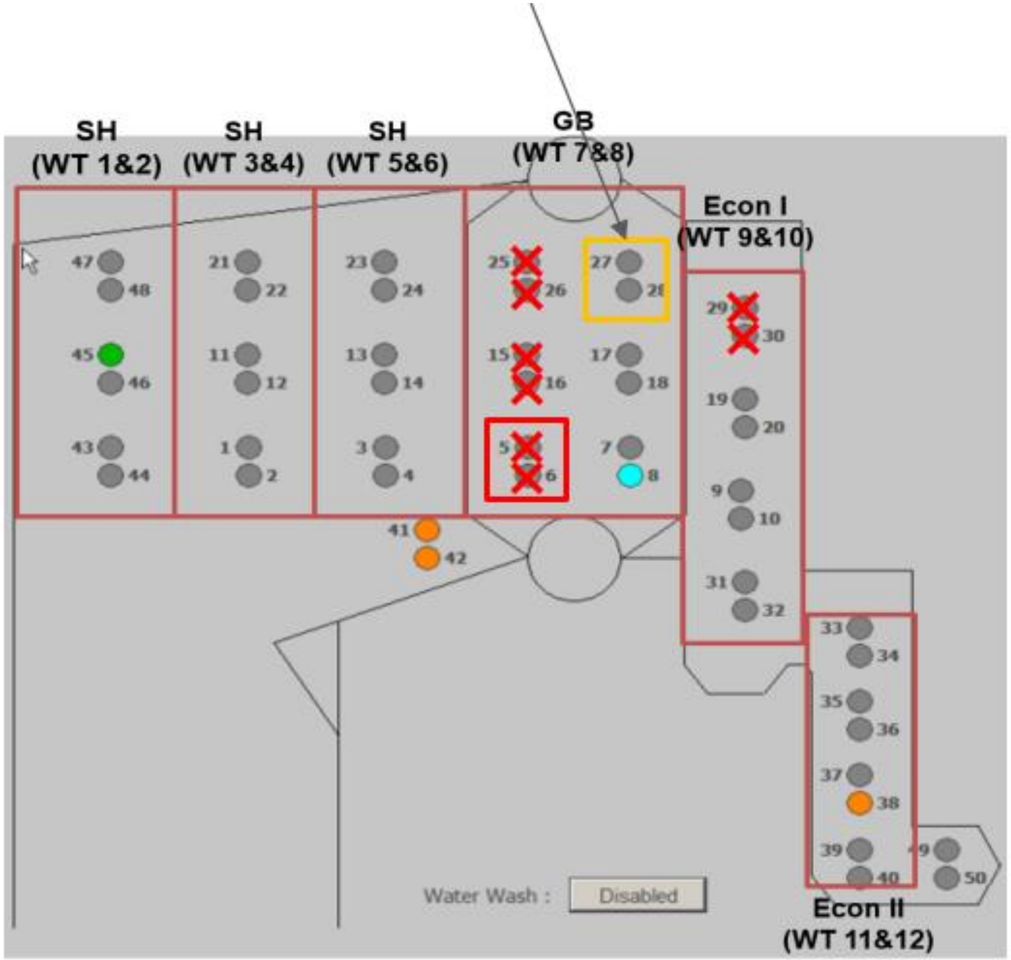
GPI Texarkana Trial

Path Forward

- Work to optimize pulse sequence
- Further decrease sootblower steam and the # of sootblowers in service
  - Sootblowers 27/28 then 19/20

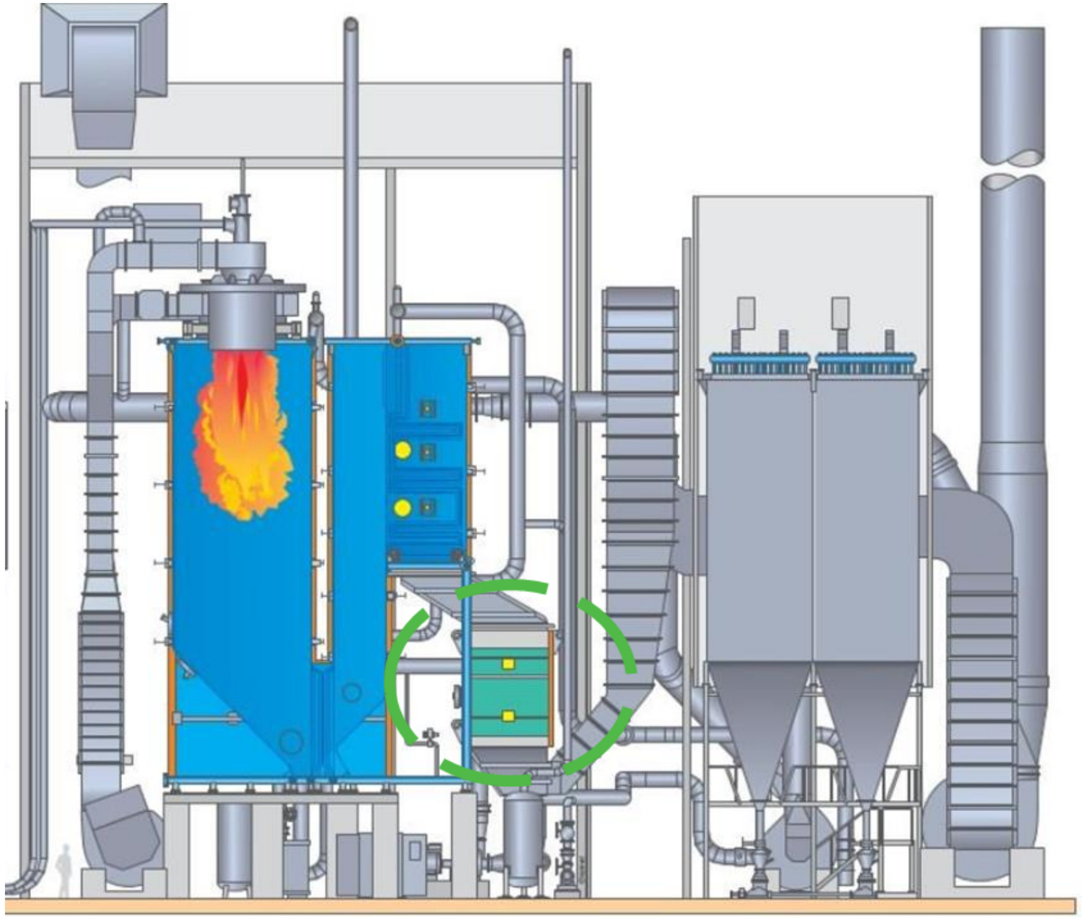


New Installation – Helen BFB

Challenges

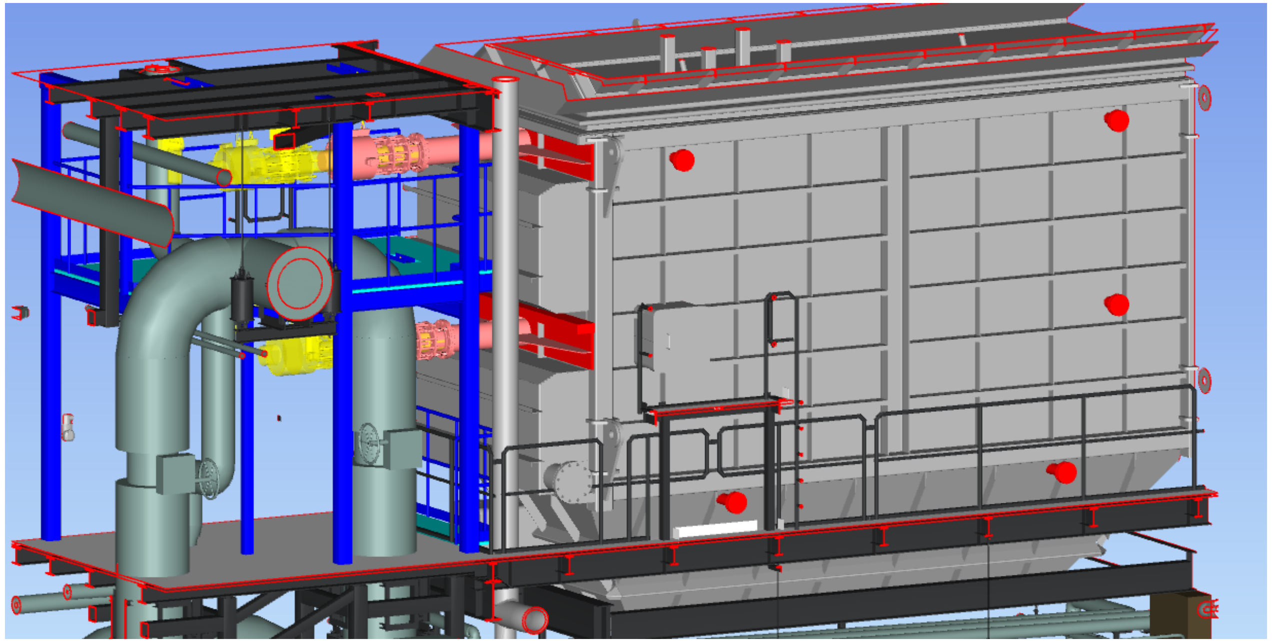
SaK6 Powdered wood pellet boiler, 92 MWth

- Annual operation time increased since 2018
- Challenges in pellet powdering
  - →Unburned in furnace, heat surfaces and in fly ash
- Last HX surfaces are a pair of finned ecos
  - Steam and infrasonic cleaning
- Finned economizers foul heavily
  - Limits boiler load due to too high exit temperature
  - Requires cleaning outages during production period (3 times last year)
  - High pressure drop in flue gas



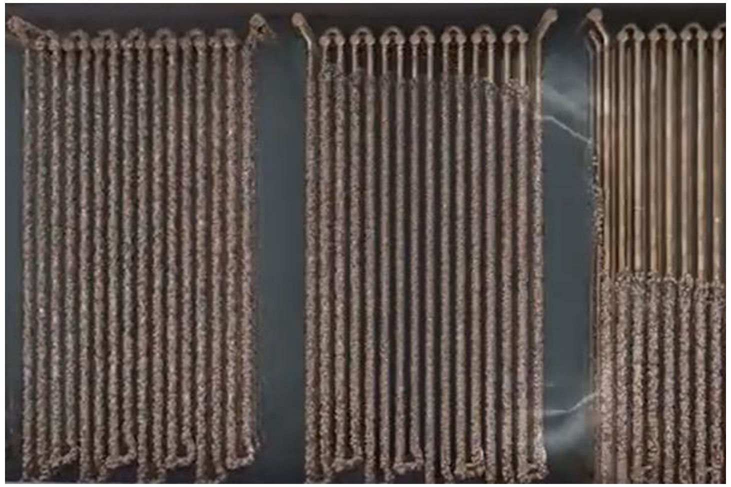
Concept

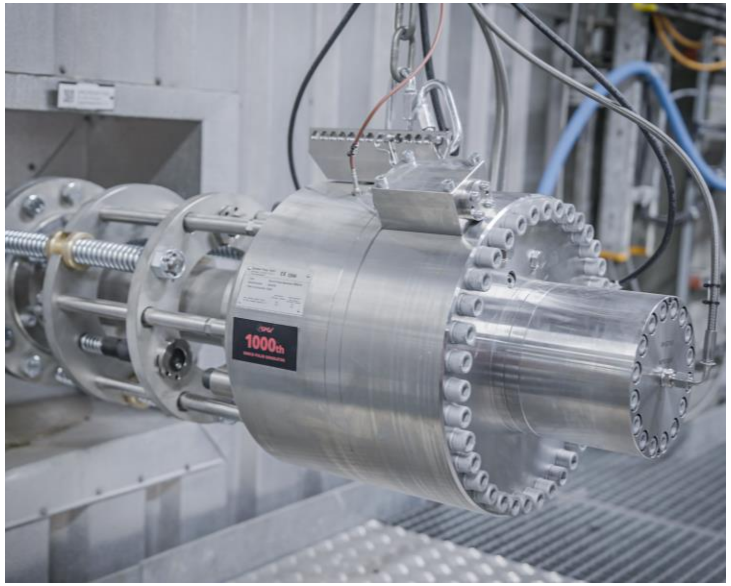
- Removal of existing steam rake sootblowers
  - 3500 mm x 500 mm cylinder of free space needed in the firing zone
- Installation of SPGr16 above both ECO packages
- New platforms for SPG maintenance
- Openings for on-line explosion cleaning in the corners of front wall of the eco casing
- Startup April 2025



Key Takeaways

- Improved cleaning efficiency compared to other cleaning technologies;
  Higher boiler efficiency due to lower exhaust temperature
- Higher plant availability
- Less unplanned shutdowns for cleaning
- No thermal abrasion of boiler pipes
- Reduce sootblowers and steam consumption
- Improved CO_2 plant performance
- Opportunity in many different types of applications





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Valmet
FORWARD

Model-Based Recovery Boiler Intelligent Sootblowing Optimization

Simon Youssef
Sales Support Engineer – Global Parts & Service

Jeremy A. Brown
Performance Engineer – Global Parts & Service

AF&PA Recovery Boiler Conference – Atlanta, GA 2025

AGENDA

01 Titanium™ Performance Suite Intelligent Sootblowing

02 Heat Transfer Manager (HTM™)

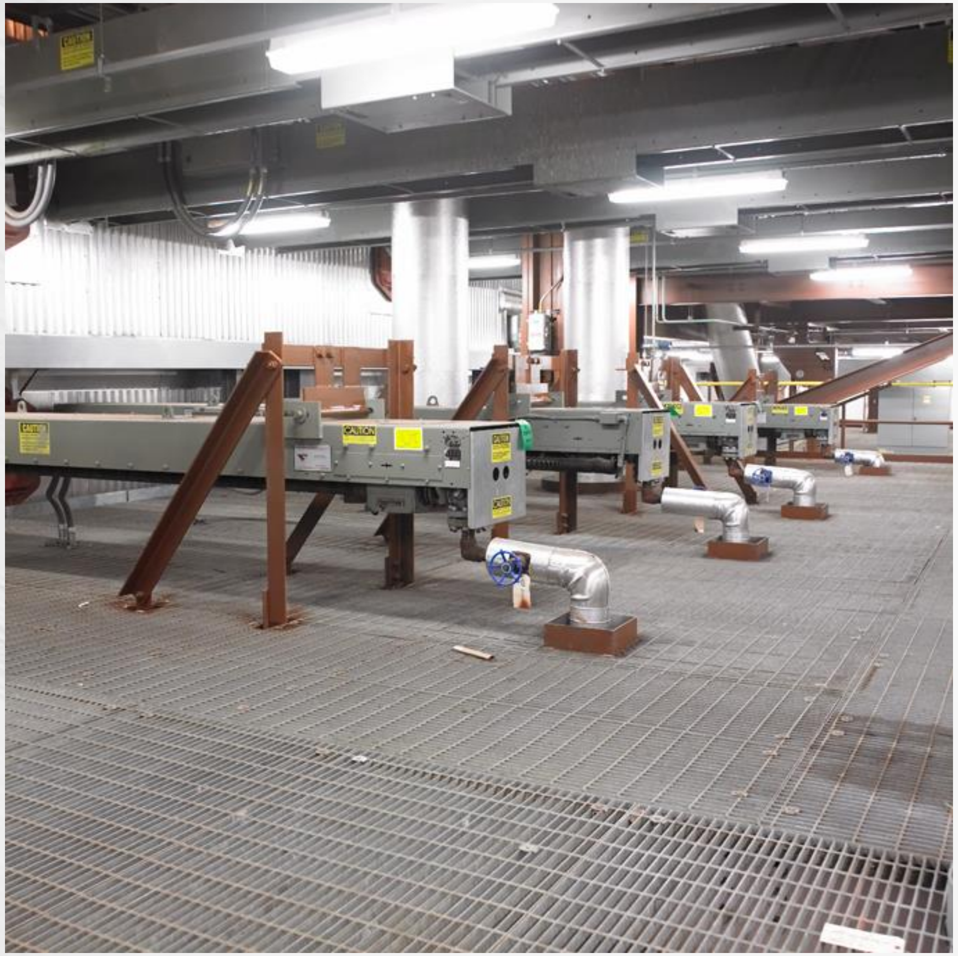
03 Enhanced Clean and Priority Sootblowing

04 Case Study

05 General Discussions

Diamond Power
Boiler Cleaning Systems

Intelligent Sootblowing Experience

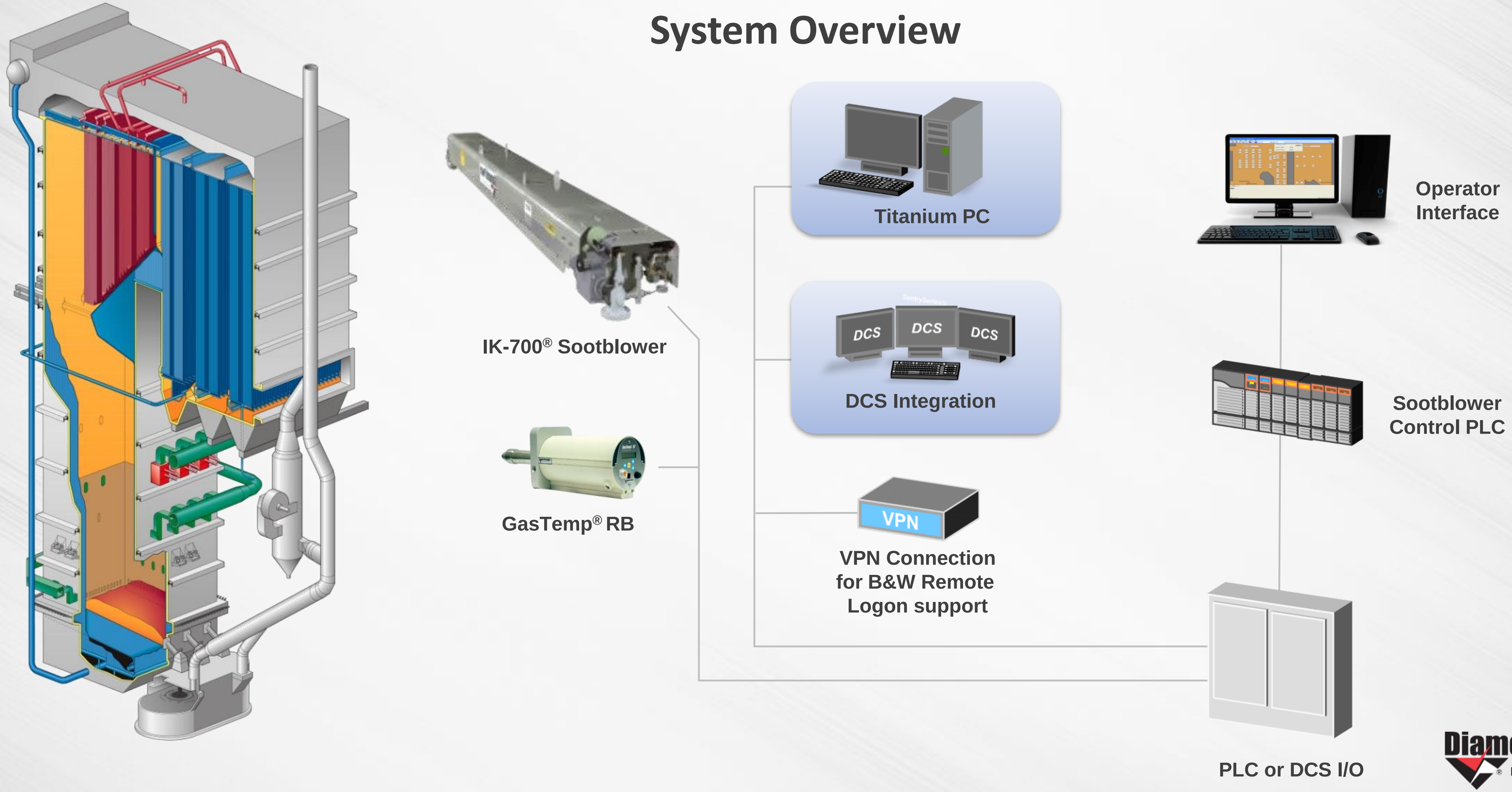


- 1,500+ sootblower control systems sold through the years
- 300+ Intelligent Cleaning Systems Supplied through Diamond Power
- Includes 60 model based ISB systems in operation
- We were the original ISB supplier, starting in the early 1990’s
- Largest market share in boilers

Diamond Power
Boiler Cleaning Systems

Titanium™ Performance Suite

System Overview



Diamond Power® Boiler Cleaning Systems

Titanium™ Performance Suite

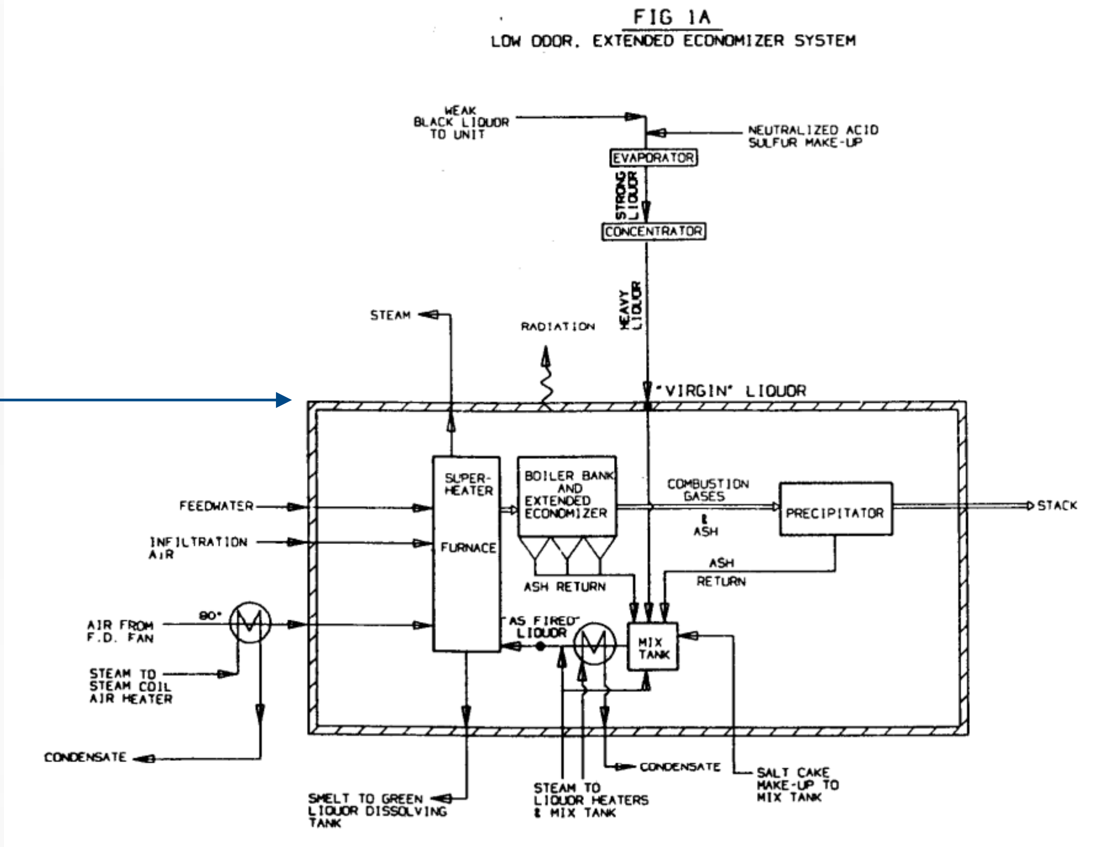
Intelligent Sootblowing with HTM™

- Software Optimization Package
  - Runs on Server/High Performance PC
  - Communicates w/ DCS or PLC for data and control
- Designed to run full boiler model in real time
  - Unit-specific boiler performance model is generated for all types of boilers
  - Utilizes measured steam/water temperatures entering and leaving each component and gas measurements at economizer exit
  - Heat Transfer Manager™ (HTM) provides Cleanliness Index (Kf) for each boiler component
  - Cleanliness Factor (Kf) is the relative measure of the actual versus expected heat transfer

Diamond Power®
Boiler Cleaning Systems

Titanium™ Performance Suite

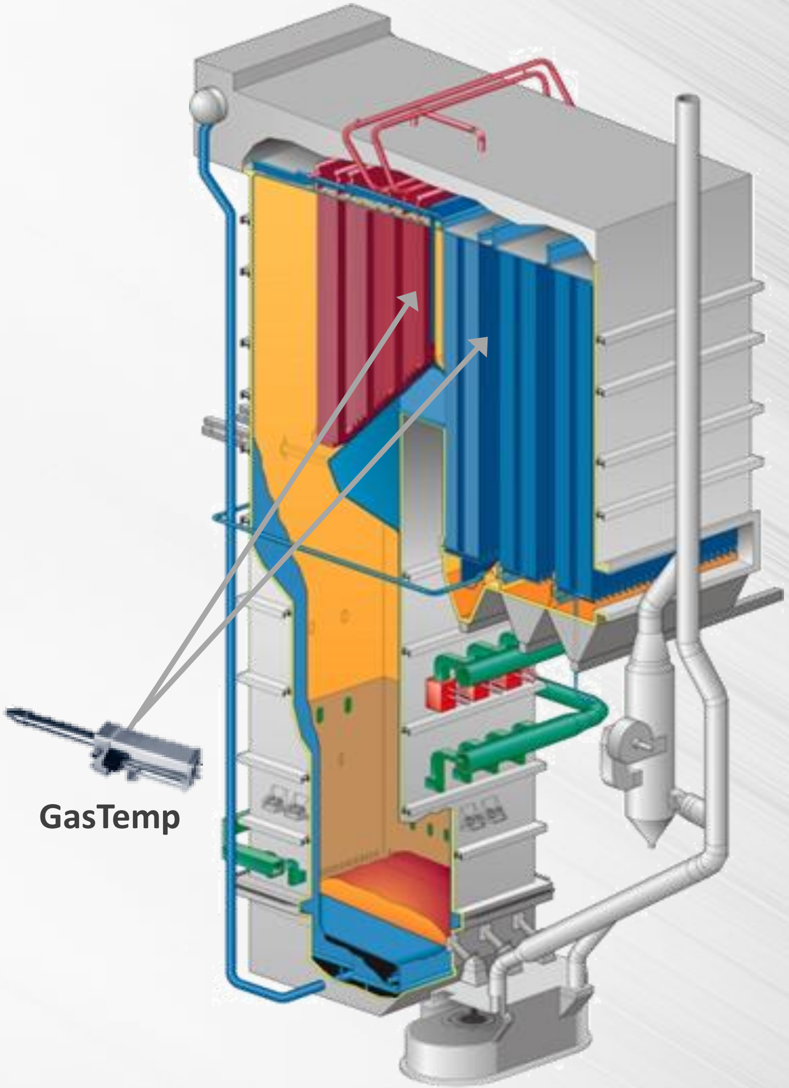
Typical Boiler Parameters Used for HTM Model
1. Drawings and information sufficient to geometrically model the unit – full size, scalable drawings, if available. Information should include at least the following: a) General arrangement drawings to show equipment arrangement and layout. b) Furnace width and depth and screen information. c) All tube outside diameters, thicknesses, materials, side spacing and back spacing. d) For each section, the number of tubes deep and sections wide. e) Connecting piping routing. f) For non-B&W Boilers: i. Boiler Performance Summary Sheet. ii. System schematic similar to example here:
2. Any modifications to the original unit arrangement not done by B&W
3. Both Virgin and As-Fired Black Liquor fuel ultimate analyses and HHV
4. As-fired Black Liquor mass flow rate
5. As-Fired Black Liquor Solids mass flow rate, or % Solids
6. Smelt chemical composition (if available)
7. Saltcake or Sulphur make-up rate and constituents
8. Original Predicted Performance Summary Sheet
9. Tag list of analog data points with point descriptions from the data source (control system or historian) in an Excel spreadsheet format. Also include a set of full load data



Diamond Power
Boiler Cleaning Systems

Titanium™ Performance Suite

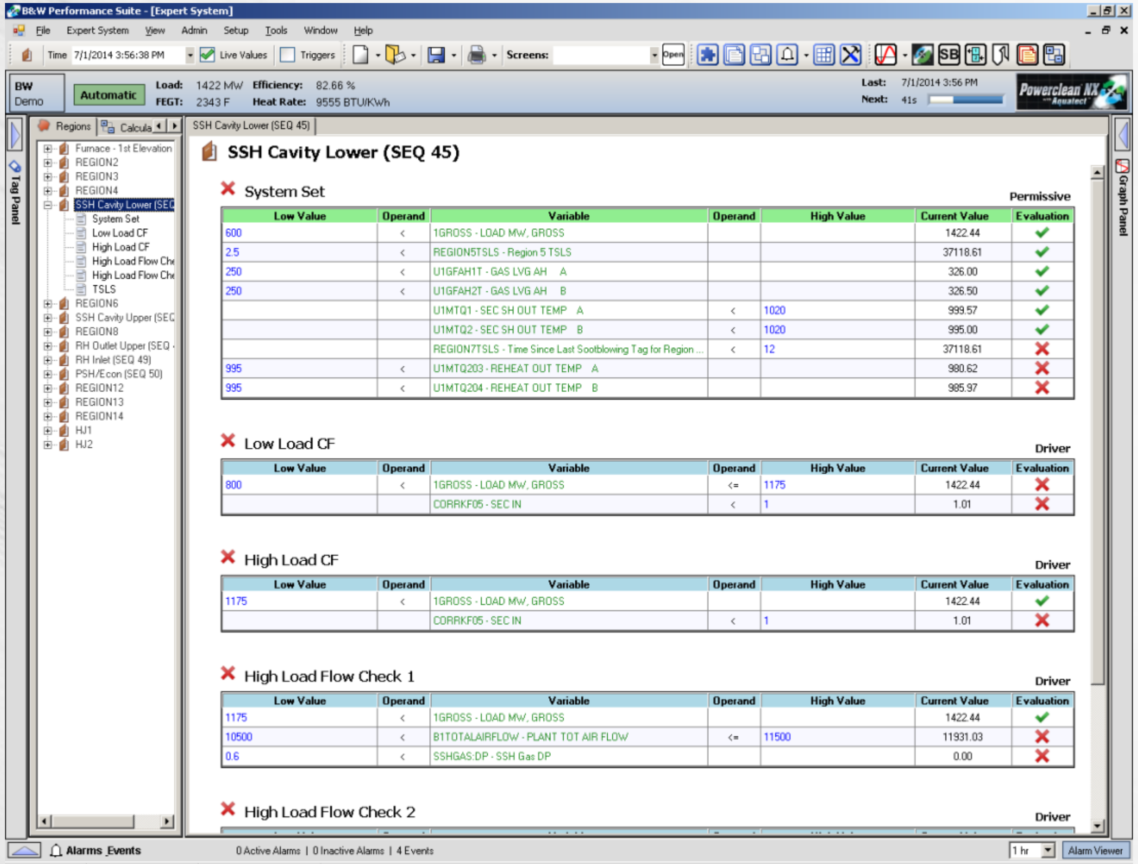
Typical Boiler Parameters Used for HTM Model
1. All steam-side and water-side fluid inlet and outlet temperatures for each heat trap, including: a) Economizer inlet and outlet temperature. b) Primary SH outlet temperature. c) Secondary SH bank inlet and outlet temperature. d) Feedwater temperatures entering and leaving condenser. e) Attemperator spray temperature.
2. Fluid Pressures a) Main steam pressure. b) Drum pressure.
3. Flow measurements: a) Main steam flow. b) Feedwater flow. c) Blowdown flow. d) Attemperator spray. e) Primary, Secondary and Tertiary air flow. f) Auxiliary fuel flow.
4. Air and gas temperatures including: a) Primary, Secondary and Tertiary Air temperatures. b) Gas temperature leaving economizer. c) Gas temperature entering Generating Bank (Instrumentation will likely need to be added for this data requirement). d) O_2 leaving economizer.
5. Any extraction flows between the economizer and final SH outlet. Temperature and pressure of flows are also needed.



Diamond Power® Boiler Cleaning Systems

Expert System

Expert System Editor Screen

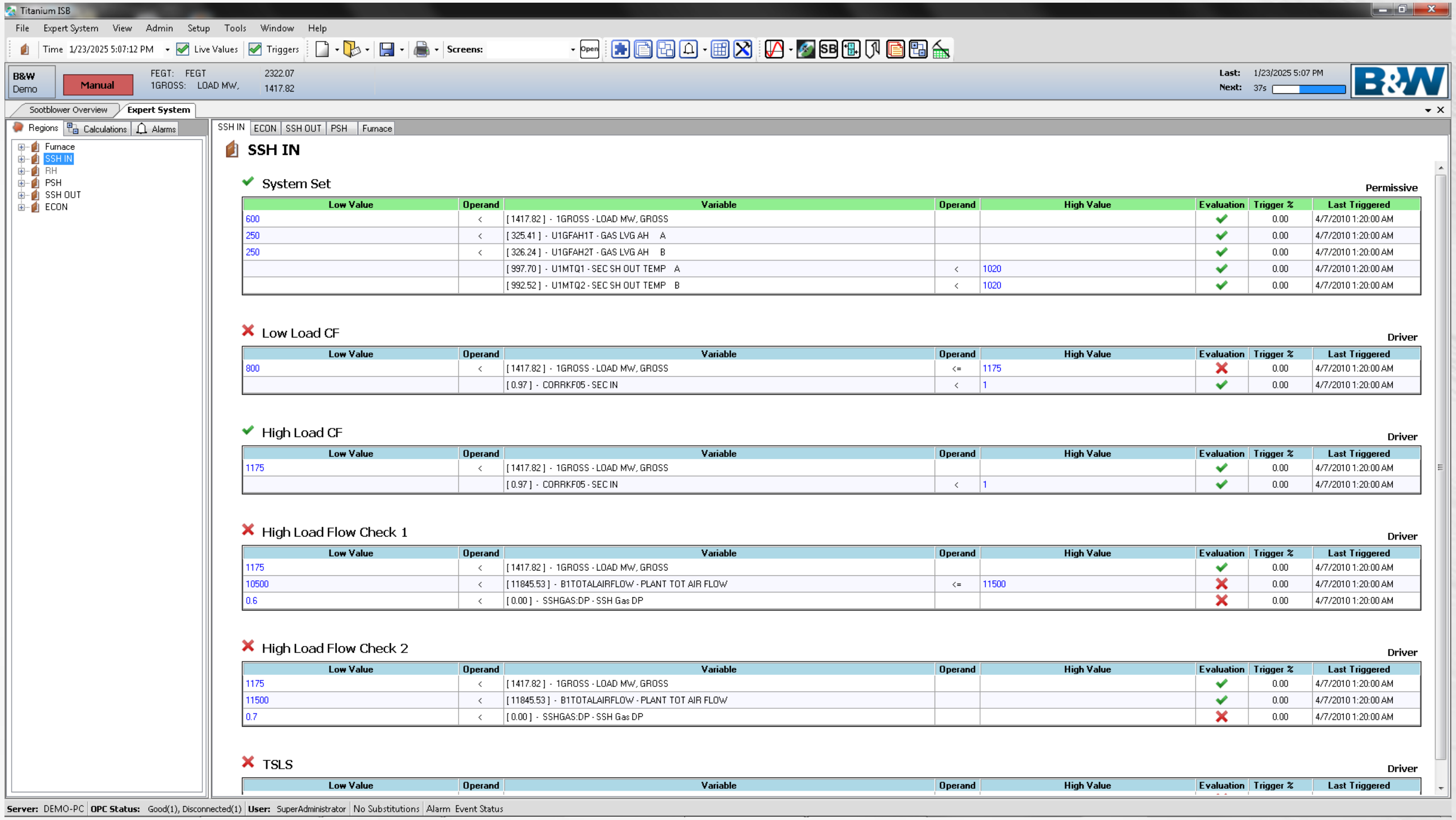


- **Flexible decision logic**
  - Straightforward strategies based on boiler performance and/or key operational values (i.e., EGOT)
  - More complex strategies to cover unit-specific requirements
- **Decision logic components**
  - ***Permissives*** – captures conditions that must be met to initiate cleaning
  - ***Drivers*** – conditions that cause cleaning to occur
  - ***Stops*** – causes blowing to stop when boiler performance met
  - ***Holds*** – pauses blowing during transients
- **User-friendly**
  - Logic not hidden from user
  - Easy-to-understand logic
  - Logic easily modified

Diamond Power® Boiler Cleaning Systems

Cleaning Strategy Tracking

- Calculates the contribution of key parameters to blowing initiation in areas of the boiler
- Effective for tracking and analyzing cleaning strategies
- Analysis drives cleaning strategy improvement



Diamond Power® Boiler Cleaning Systems

Titanium ISB Priority Sootblowing

- Tracks impact of blower operation to calculate a blower effectiveness
- Dynamically sequences blowers based on effectiveness and time
- More effective blowers operated more often
- Time element ensures no blowers are skipped

Main Blower and Queuing Overview Screen

Sootblowing Queue Overview

Show History

Queue Level: 0

Region Name	Blower Group Name	Device Set ID	Enqueue Time	Last Run Time	Blower Count	MATS Exceeded	Queue Level Time Exceeded
Economizer	IK 109-110	3	1/23/2025 11:27:15 AM	1/23/2025 12:24:32 AM	2	False	True
Reheat Pendant	IK 71-72	3	1/23/2025 11:27:22 AM	1/23/2025 12:24:32 AM	2	False	True
Secondary SH Outlet	IK 43-44	3	1/23/2025 11:27:28 AM	1/23/2025 12:24:32 AM	2	False	True
Nose Arch	IK 1-2	3	1/23/2025 11:27:41 AM	1/23/2025 12:24:32 AM	2	False	True

Queue Level: 1

Region Name	Blower Group Name	Device Set ID	Enqueue Time	Last Run Time	Blower Count	MATS Exceeded	Queue Level Time Exceeded
Reheat Pendant	IK 65-66	3	1/23/2025 11:26:58 AM	1/23/2025 12:24:32 AM	2	False	True
Platen	IK 21-22	3	1/23/2025 11:27:18 AM	1/23/2025 12:24:32 AM	2	False	True
Secondary SH Inlet	IK 23-24	3	1/23/2025 11:27:33 AM	1/23/2025 12:24:32 AM	2	False	True

Queue Level: 2

Region Name	Blower Group Name	Device Set ID	Enqueue Time	Last Run Time	Blower Count	MATS Exceeded	Queue Level Time Exceeded
Primary SH	IK 83-84	3	1/23/2025 11:27:36 AM	1/23/2025 12:24:32 AM	2	False	False

Queue Level: 3

Region Name	Blower Group Name	Device Set ID	Enqueue Time	Last Run Time	Blower Count	MATS Exceeded	Queue Level Time Exceeded
Reheat Horizontal	IK 91-92	3	1/23/2025 11:26:46 AM	1/23/2025 12:24:32 AM	2	False	False

Starting

Region Name	Blower Group N
Secondary SH Inlet	IK 37-38

Active

Region Name	Blower Group

Recently Active

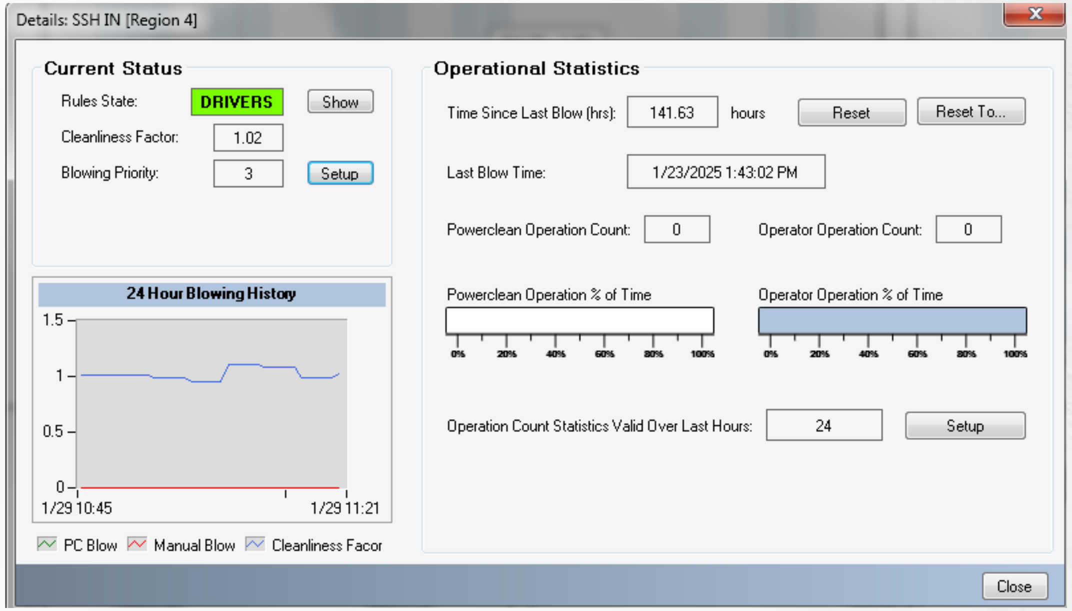
Region Name	Blower Group Name	Last Run Time

Sootblowing Queue

Blower	Queue Level	Queue Time (minutes)
IK 109-110	1	1.34
IK 71-72	1	1.23
IK 43-44	1	1.12
IK 1-2	1	0.92
IK 91-92	2	1.83
IK 65-66	2	1.63
IK 83-84	2	0.99
IK 21-22	3	1.29
IK 23-24	3	1.05

Diamond Power® Boiler Cleaning Systems

Blowers & Regions Status



Boiler Performance Information

Load: 300 GPM | FEGT: 1800 F | Efficiency: 64.94 % | Gross Heat Rate: 820 MKBTU/HR

Enable All Regions

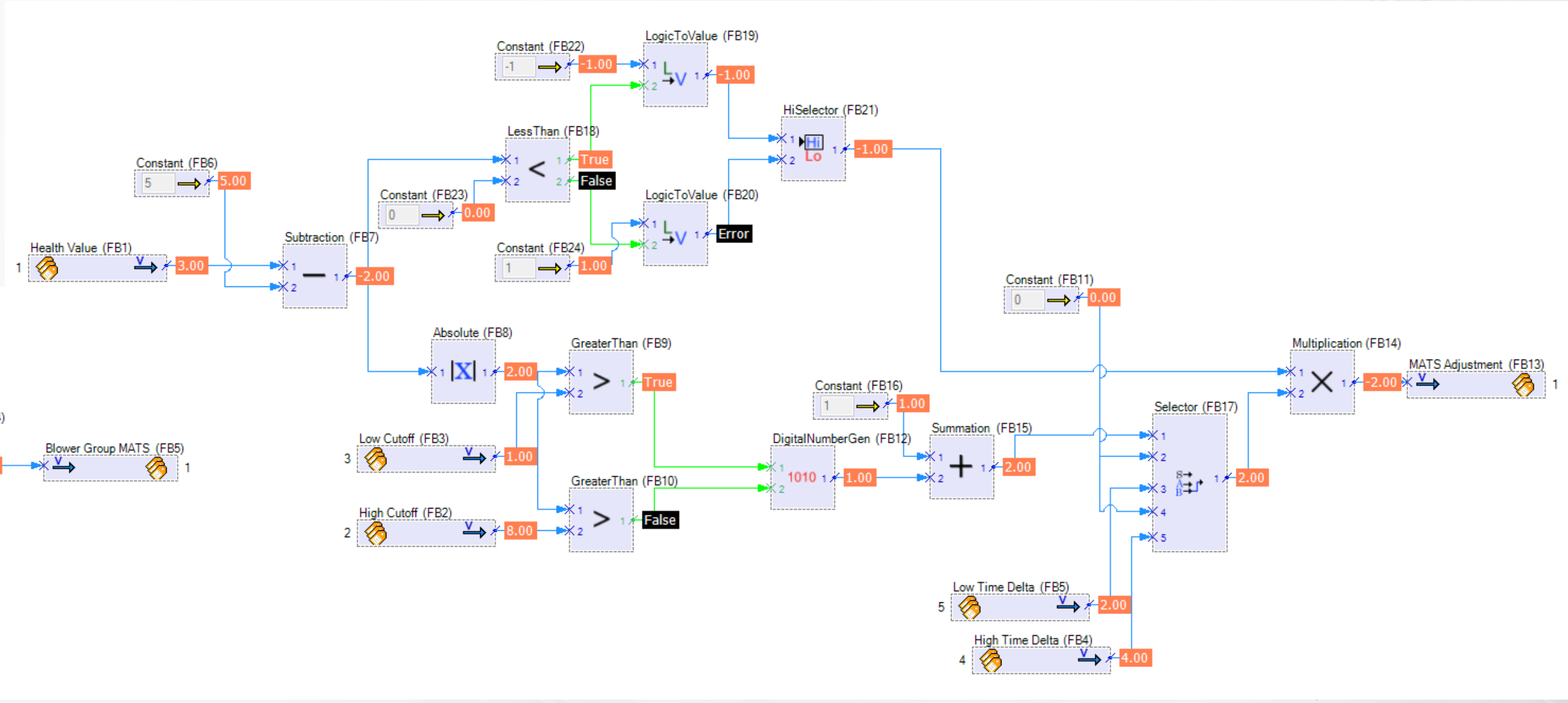
Disable All Regions

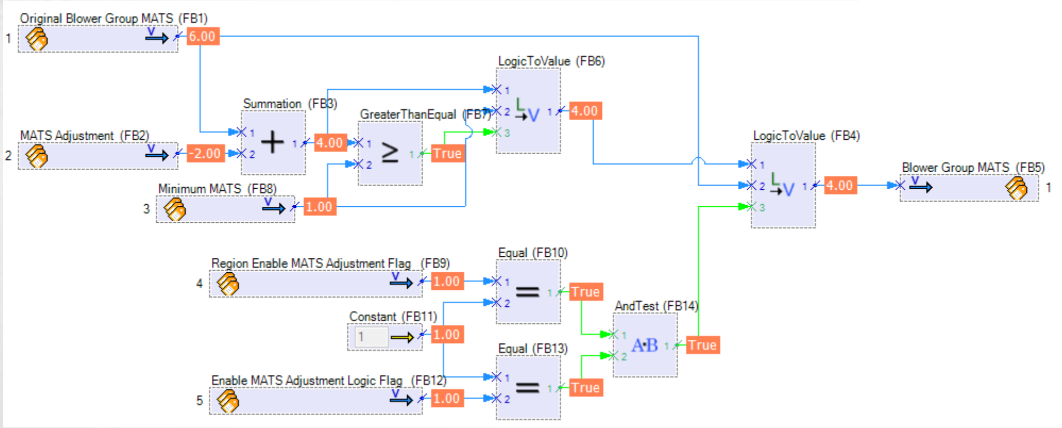
Region Name	Region CF	Region State	Rule State	Blowing Order	Time Since Last Blow		
SH	0.65	Good	Ready	3	3:16	Rules	Enabled
GenBank	1.03	Good	Ready	2	2:30	Rules	Enabled
Economizer	0.61	Moderate	Ready	1	1:20	Rules	Enabled

Diamond Power® Boiler Cleaning Systems

Enhanced Sootblower Cleaning

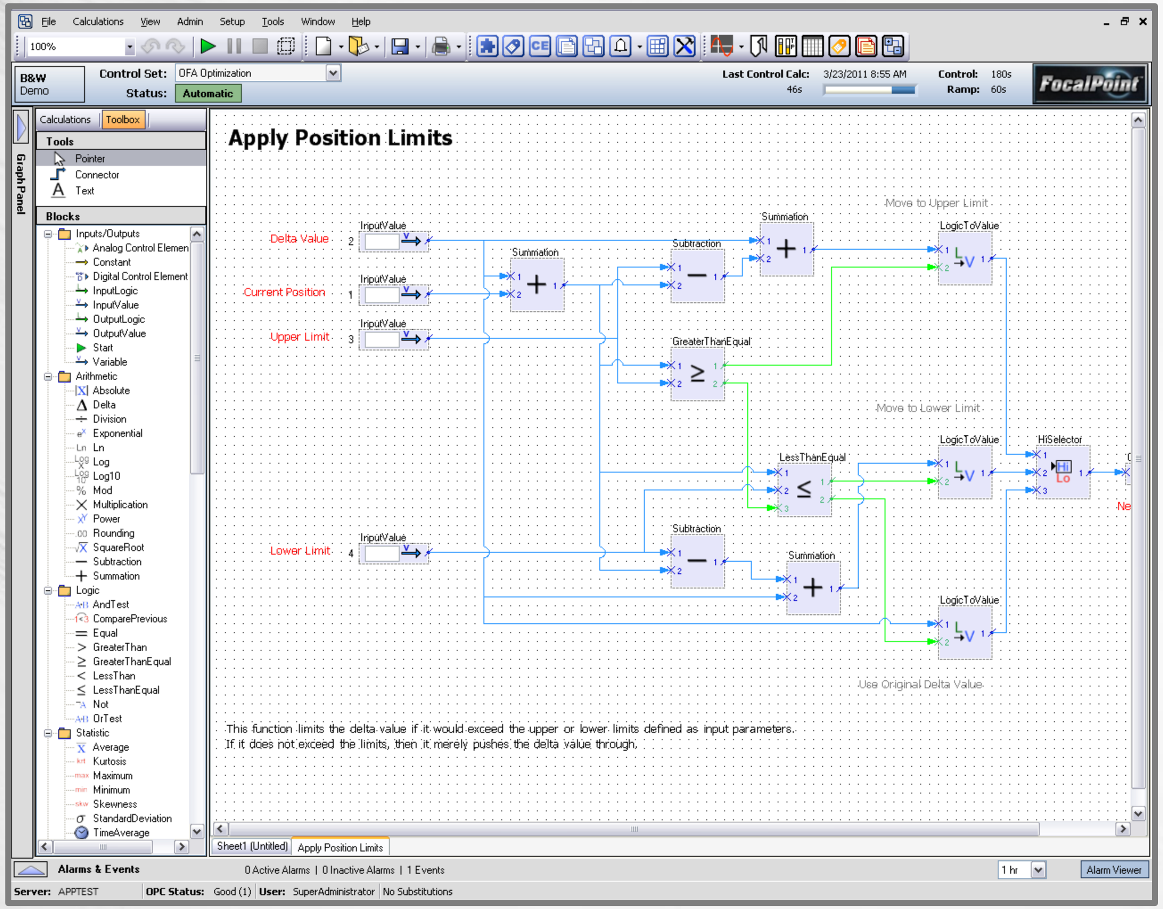
- Option for units that need continuous device operation
- Automatically adjusts *Maximum Allowed Time for Sootblowing (MATS)*
  - General region health calculation
  - Calculated Kf value
  - Other performance evaluation
- Dynamically increases or decreases MATS values for sootblowers based on performance





Titanium ISB Custom Calculations

Calculations Creation and Editing Screen

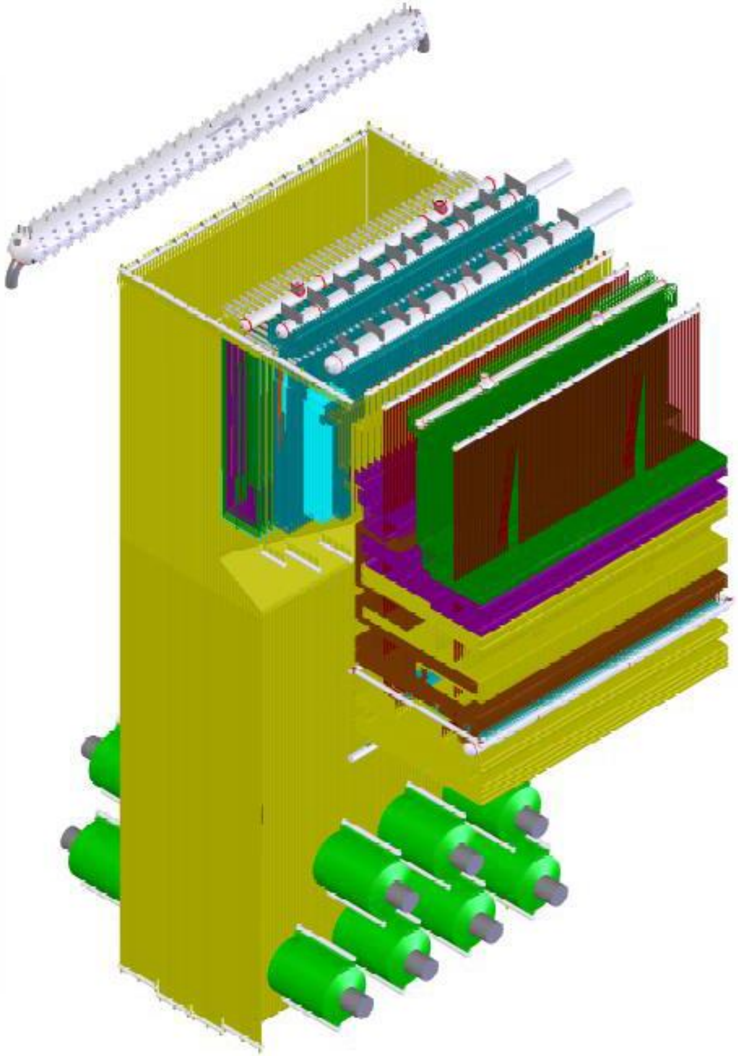


- Titanium provides a suite of tools to develop custom calculations and logic
- Custom calculations are created using the Calculation Editor
  - Function block approach
  - Intuitive drag-and-drop interface
  - Simple flow chart layout
  - Wide array of algorithms, models, calculations and logic functions
- Calculations can be created and/or modified online
- Results of custom calculations can be used in cleaning strategies

Diamond Power Boiler Cleaning Systems

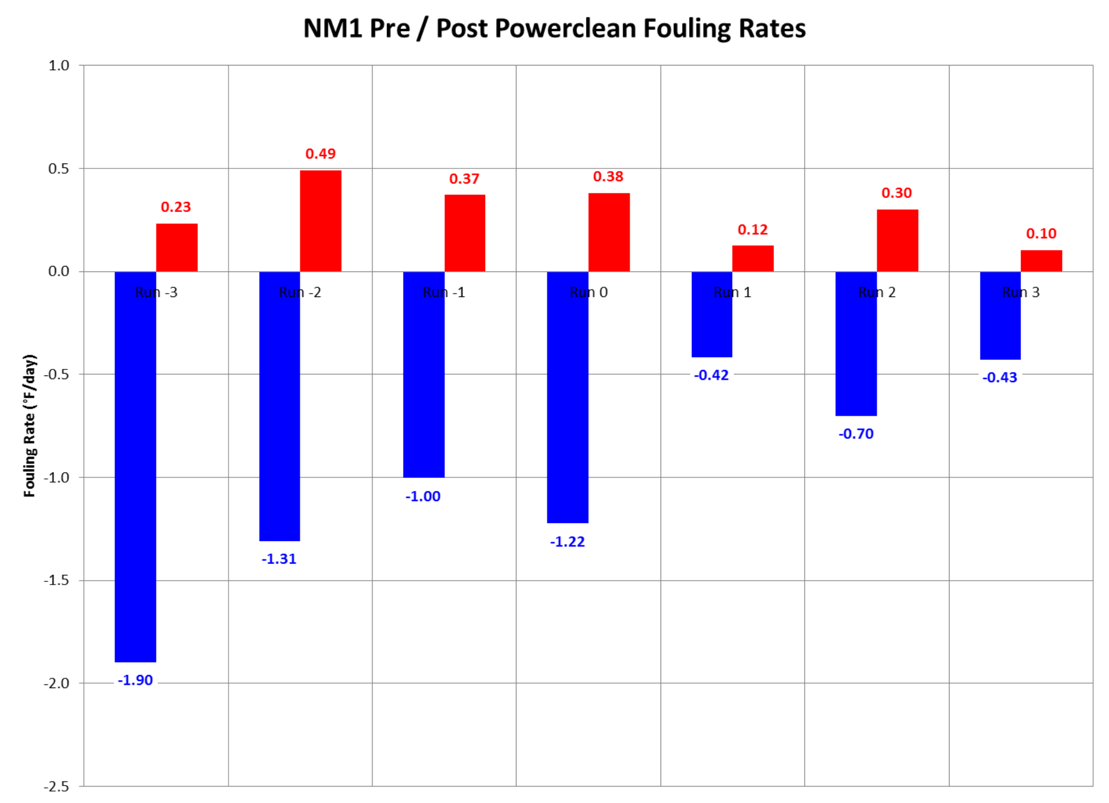
Utility Boiler Case Study Overview

- Located Midway Between St. Louis and Memphis on the Mississippi River
- 2 x 615 – 625 MW Units
- Commercial in 1972 (Unit 1) and 1977 (Unit 2)
- 14 Cyclones (Pressurized)
- Designed for Southern Illinois Coal
- 100% PRB since 1994

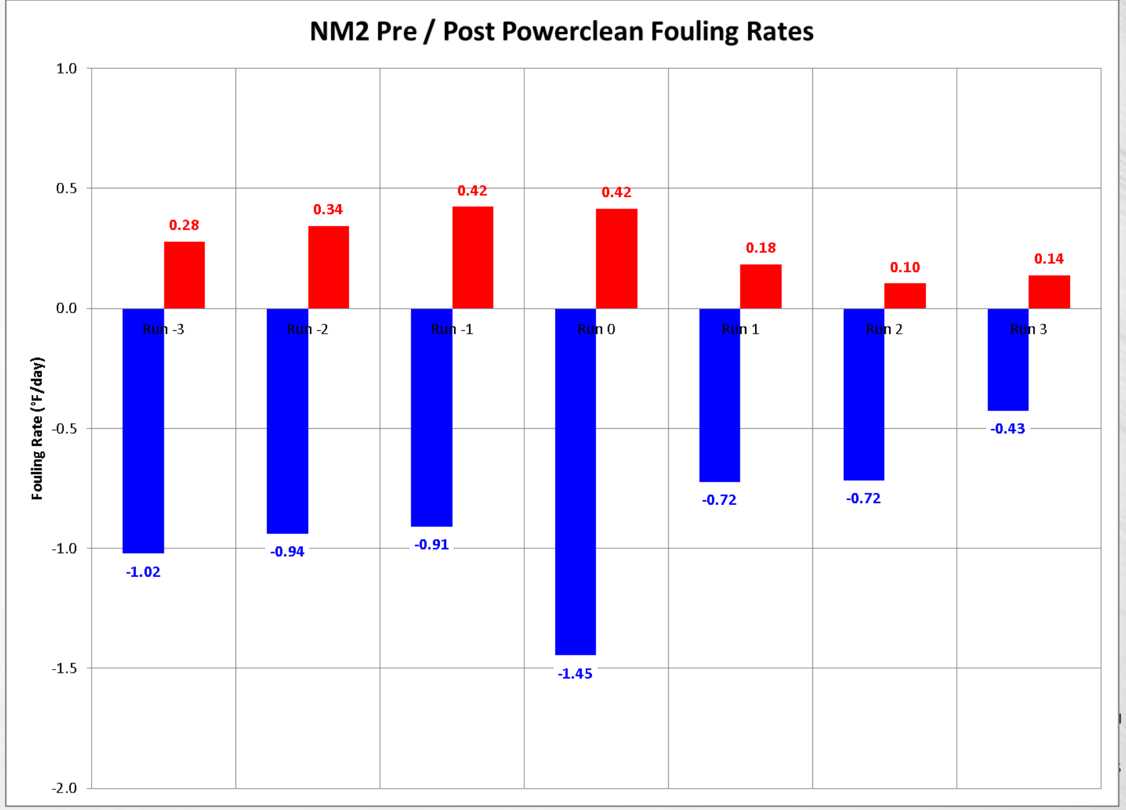


Results

NM1 Run #	Start	End	Run Time (days)	SSH Fouling Rate at Full Load (°F/day)	Economizer Fouling Rate at Full Load (°F/day)
Run -3	01.26.2012	04.13.2012	78	1.90	0.23
Run -2	11.16.2012	04.27.2013	162	1.31	0.49
Run -1	06.16.2013	12.03.2013	170	1.00	0.37
Run 0	12.11.2013	03.31.2014	110	1.22	0.38
Run 1	04.10.2014	09.12.2014	155	0.42	0.12
Run 2	10.11.2014	04.14.2015	185	0.70	0.30
Run 3	05.09.2015	02.29.2016	296	0.43	0.10



NM2 Run #	Start	End	Run Time (days)	SSH Fouling Rate at Full Load (°F/day)	Economizer Fouling Rate at Full Load (°F/day)
Run -3	04.14.2012	09.21.2012	160	-1.02	0.28
Run -2	10.02.2012	04.03.2013	183	-0.94	0.34
Run -1	04.15.2013	09.13.2013	151	-0.91	0.42
Run 0	11.01.2013	03.17.2014	136	-1.45	0.42
Run 1	03.28.2014	10.31.2014	217	-0.72	0.18
Run 2	11.09.2014	03.13.2015	124	-0.72	0.10
Run 3	05.21.2015	04.13.2016	328	-0.43	0.14



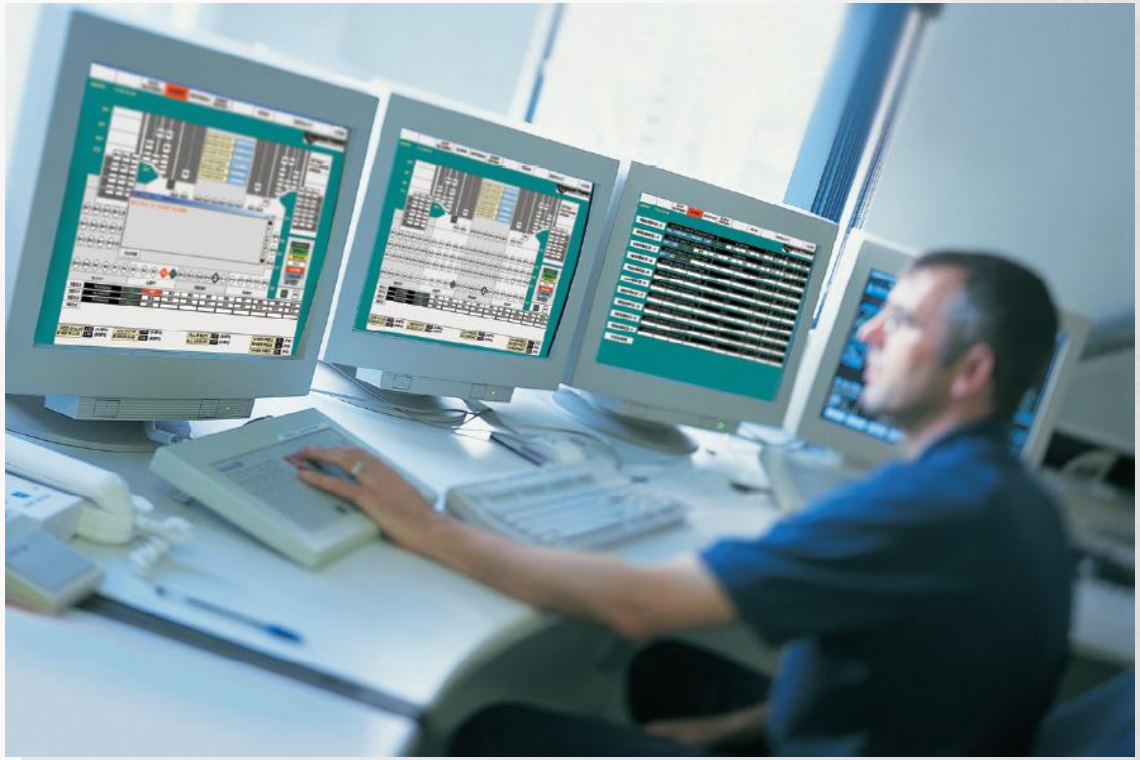
Summary

- Sootblowing targeted in the areas which are actually dirty
- Forced cleaning outages are less frequent
  - Loss revenue savings
  - Reduced cost for mechanical offline cleaning
- Fouling rates reduced in Secondary Superheater
- Application of boiler model and cleanliness factors successfully extended run times for both units

Diamond Power® Boiler Cleaning Systems

Controls Engineering Support

- **ISB Tuning**
  - Regular reporting summarizing boiler cleaning activities
  - Review of system Rules and Setpoints
  - System Adjustments and Recommendations
- **Periodic Software Maintenance Updates**
  - Added Features
  - System Updates
  - Software Patches
- **Alarm and System Health Reviews**
  - Report of frequent alarms
  - Troubleshooting Recommendations and Assistance
  - Blower Availability/Reliability
- **Training for Plant Operators, Engineers and Technicians**



50+ units monitored under support contracts

Diamond Power
Boiler Cleaning Systems

Titanium™ Performance Suite

Intelligent Sootblowing Control - Benefits
✓ Optimizes overall sootblower usage
✓ Delivers proper cleaning per boiler sections
✓ Reduces sootblowing related O&M costs
✓ Provides consistent operation across load range and operating shifts
✓ Allows operators to focus on other tasks

Diamond Power® Boiler Cleaning Systems

— Questions? —

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Jeremy Brown: jabrown@babcock.com

Correlation between Green Liquor TTA and Density

Honghi Tran and Xiaosong Mao

University of Toronto, Toronto, ON, CANADA

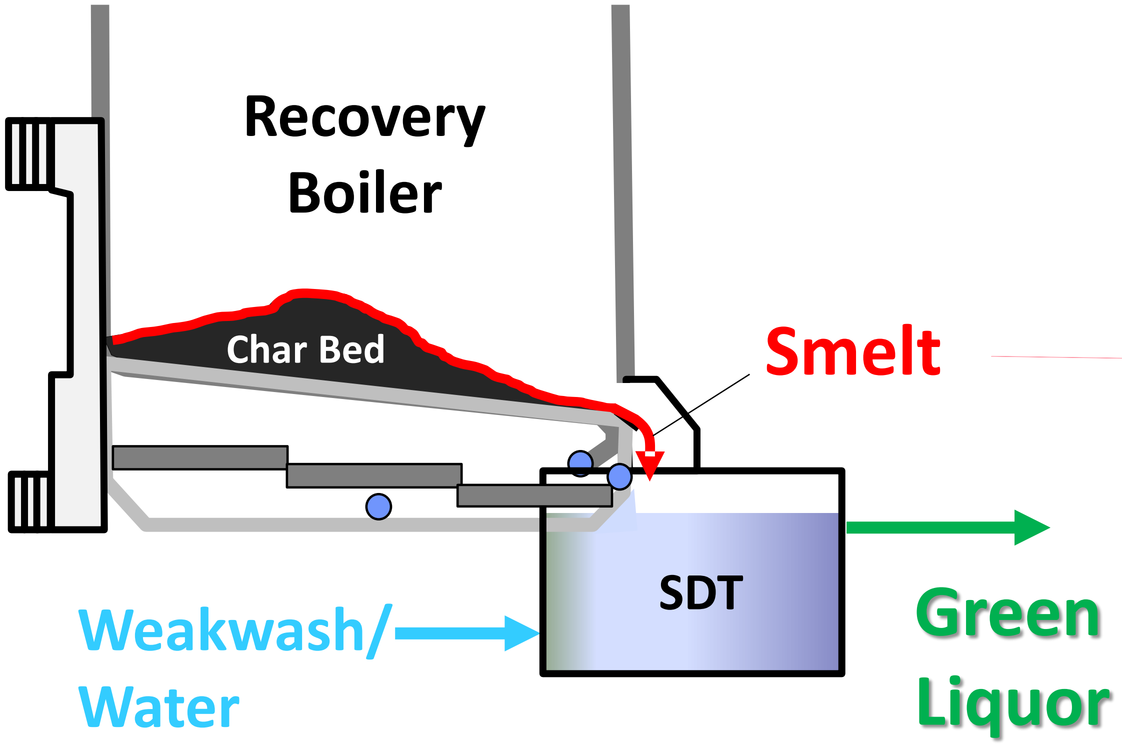
AF&PA Recovery Boiler Program Annual Meeting and Conference
Atlanta, GA, February 5, 2025

Presentation Outline

- Background
- Green liquor TTA vs. density
- Factors affecting TTA and density
- Correlation between TTA and density
- Case studies
- Summary

Background

- Green liquor is produced by dissolving molten smelt from recovery boilers with weakwash/water in the smelt dissolving tank (SDT)



$Na_2S + Na_2CO_3$

Green Liquor (GL)

- An aqueous solution containing mainly alkali carbonate (CO_3), sulfide (S), hydroxide (OH), sulfate (SO_4) and chloride (Cl)
- Converted into white liquor in the causticizing plant for use in digester
- Composition, concentration and flowrate of GL are important parameters in both chemical recovery and pulping operations

Factors Affecting GL Composition

- Smelt composition
  - Black liquor composition
  - S/Na_2 ratio
  - Recovery boiler lower furnace operating conditions (air flow and distribution, reduction efficiency, etc.)
- Weakwash composition

Factors Affecting GL Concentration

- Smelt flow rate
  - Stable operation
  - During smelt surge
- Weakwash/water flowrate
- Degree of mixing and retention time in the SDT
- Concentration
  - Conventionally expressed as either “TTA” or “Density”
  - Needs to be stabilized and well controlled

Green Liquor TTA

- **Total Titratable Alkali** = $[CO_3] + [S] + [OH] + [SO_3]$
  - $[CO_3]$, $[S]$, $[OH]$ and $[SO_3]$ are respectively concentrations of carbonate, sulfide, hydroxide and sulfite
  - [ ]: concentration in lb/ft^3 Na_2O or g/L Na_2O
  - $1\ lb/ft^3 = 16\ g/L$ or $1\ g/L\ Na_2O = 1/16\ lb/ft^3$
- More often: $TTA = [CO_3] + [S] + [OH]$

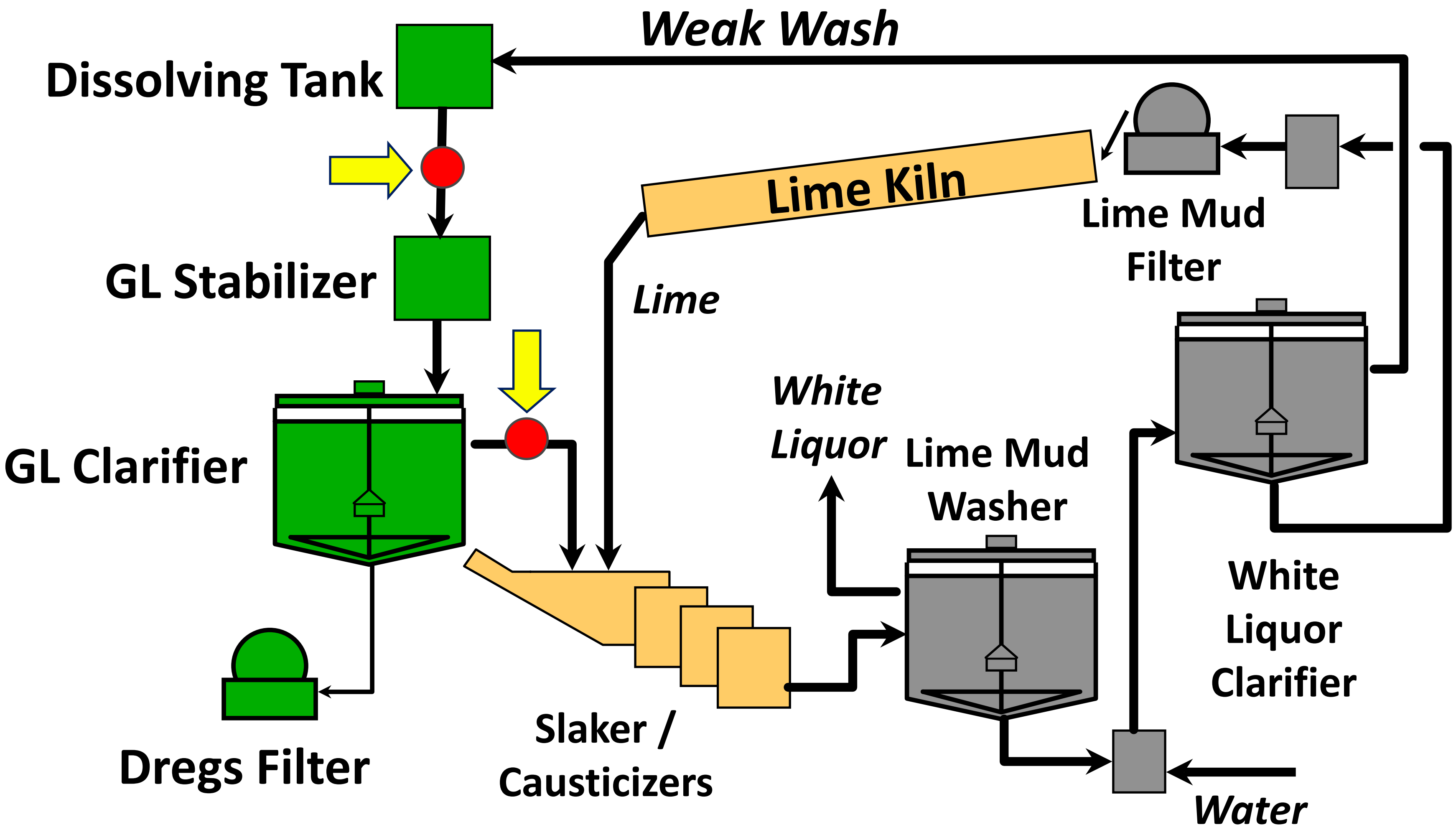
Green Liquor TTA

- Controlled by adjusting weakwash/water flow to the smelt dissolving tank
  - Smelt flow cannot be controlled!
- Typical TTA: about 120 g/L (or 7.5 lb/ft^3)
- Range: 112 - 128 g/L (or 7 - 8 lb/ft^3)

Green Liquor Density

- Density = Liquor Mass / Liquor Volume
- Often expressed as specific gravity (S.G.) taking into account the effect of liquor temperature on volume
  - Higher T → Larger volume → Lower density
- Controlled by adjusting weakwash/water flow to the SDT
- Typically S.G.: ~1.19 ± 0.02

TTA and Density Measurement Points



TTA and Density Measurement Methods

Older Mills

- Measurements are done manually on-site or in mill labs
- TTA
  - “ABC” titration test
  - Time consuming: Once every 4 to 8 hours
- Density
  - Baumé (°Bé) test
  - Simple mass/volume test

TTA and Density Measurement Methods

Modern Mills

- Constantly measuring/monitoring
- TTA
  - Automatic titrators, on-line analyzers (Valmet, Andritz, FITNIR, etc.)
- Density
  - Refractometers, radiometric systems, nuclear density gauges, etc..
- Allowing good monitoring of TTA and density without the need for frequent manual liquor sampling

TTA vs. Density

- TTA is essentially the "strength" of green liquor, as such it should correlate well with density
- How TTA and density correlate is not well understood
- Some mills have better correlations than others

→ *The focus of this work*

TTA vs. Density

- Although both are indictors of green liquor concentration/strength, but density is much easier to measure/monitor than TTA
- Density is the same as TTA, except that
  - It also includes the mass of dregs, suspended particles (in the case of raw GL) and other non-titratable alkali (Cl^-, SO_4^{2-}, etc.)
- As such, TTA and Density should be <u>linearly</u> correlated
- Mill experience is often not the case
  - Relationship between TTA and Density often scattered or not correlated well

Recovery Boiler R&D Subcommittee Questions

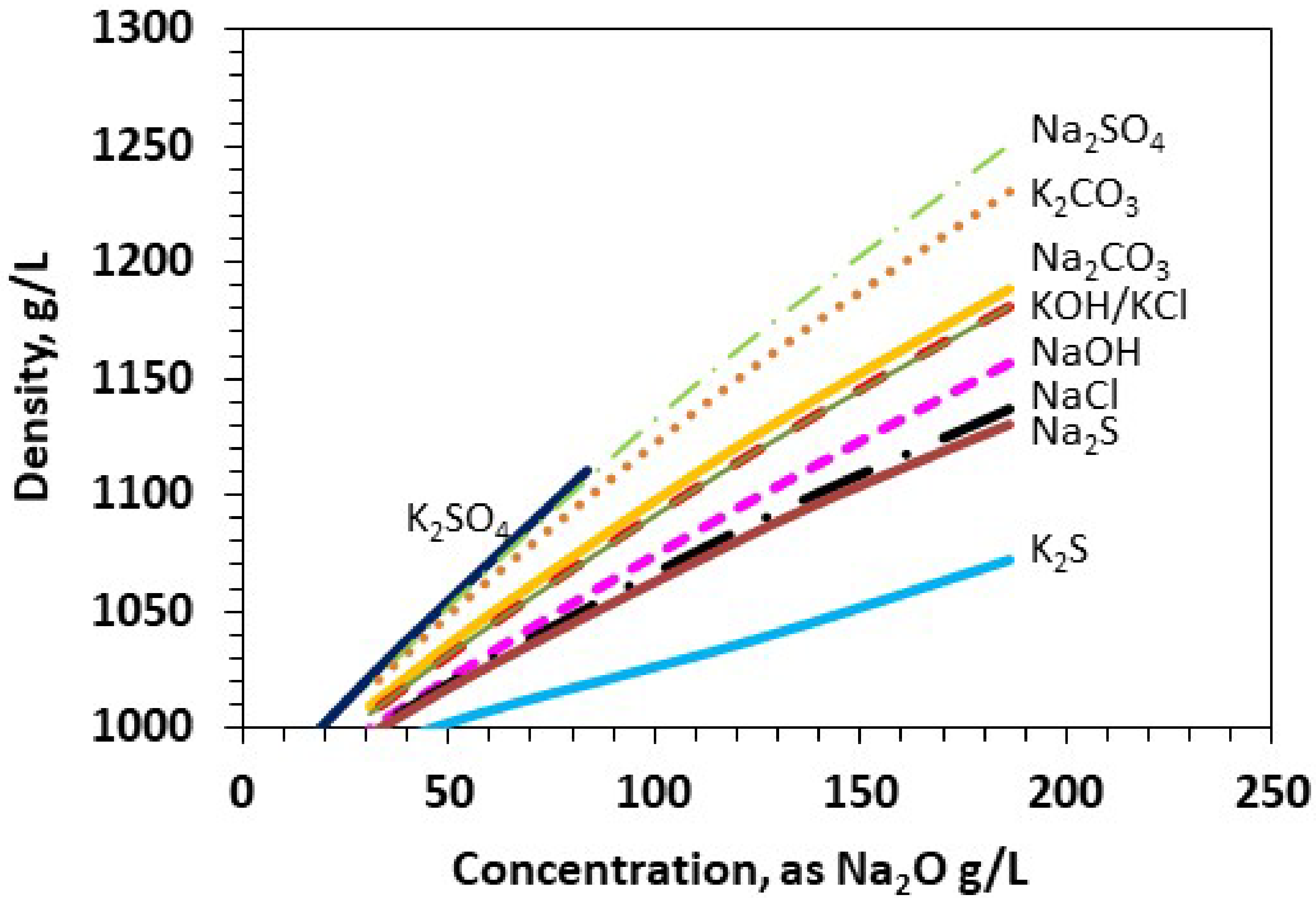
- Questions were often raised at AF&PA annual R&D Subcommittee meetings in past years
  - What is the relationship between TTA and density?
  - Why are they sometime well correlated and sometime not?
  - What can be done about it?
- These questions let to our research work at the University of Toronto in 2015

Research at the University of Toronto

- Performed mostly by Sue Mao and summer students
  - Laboratory experiments
  - Theoretical calculations using OLI (a commercially available thermodynamic software for aqueous solution applications)
  - OLI has been intensively in various projects related to green/white liquor chemistry
- Results were presented at the 2016 Annual Consortium Research Review meeting in Toronto

Density of Pure Chemical solutions at 95^{o}C

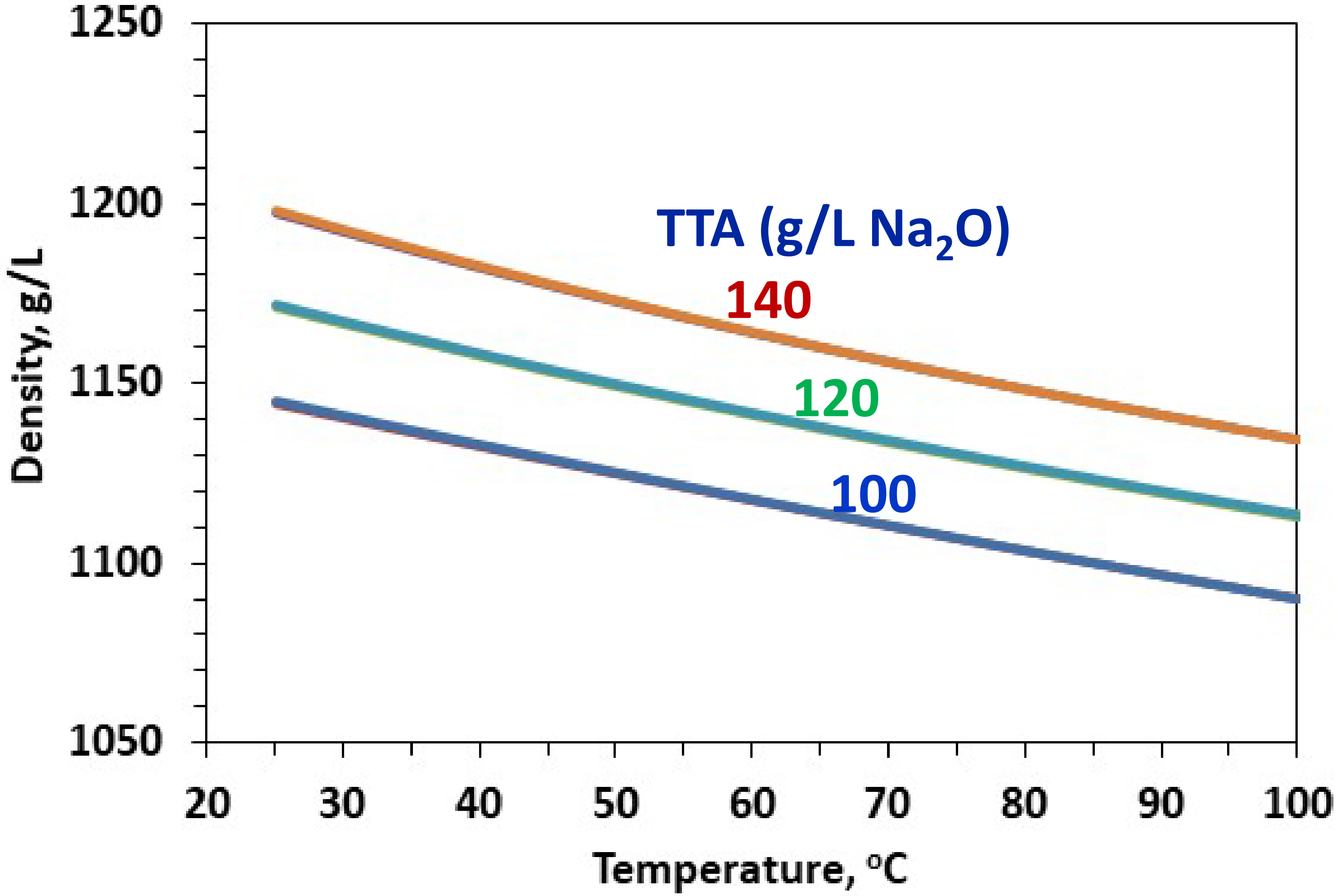
(Calculated using OLI)



- **Order of influence**
  - **SO_4 > CO_3 > OH > Cl > S**
- **K (potassium) compounds > Na (sodium) counterparts**
  - **Since K content in GL is much smaller than Na content, its effect is insignificant**

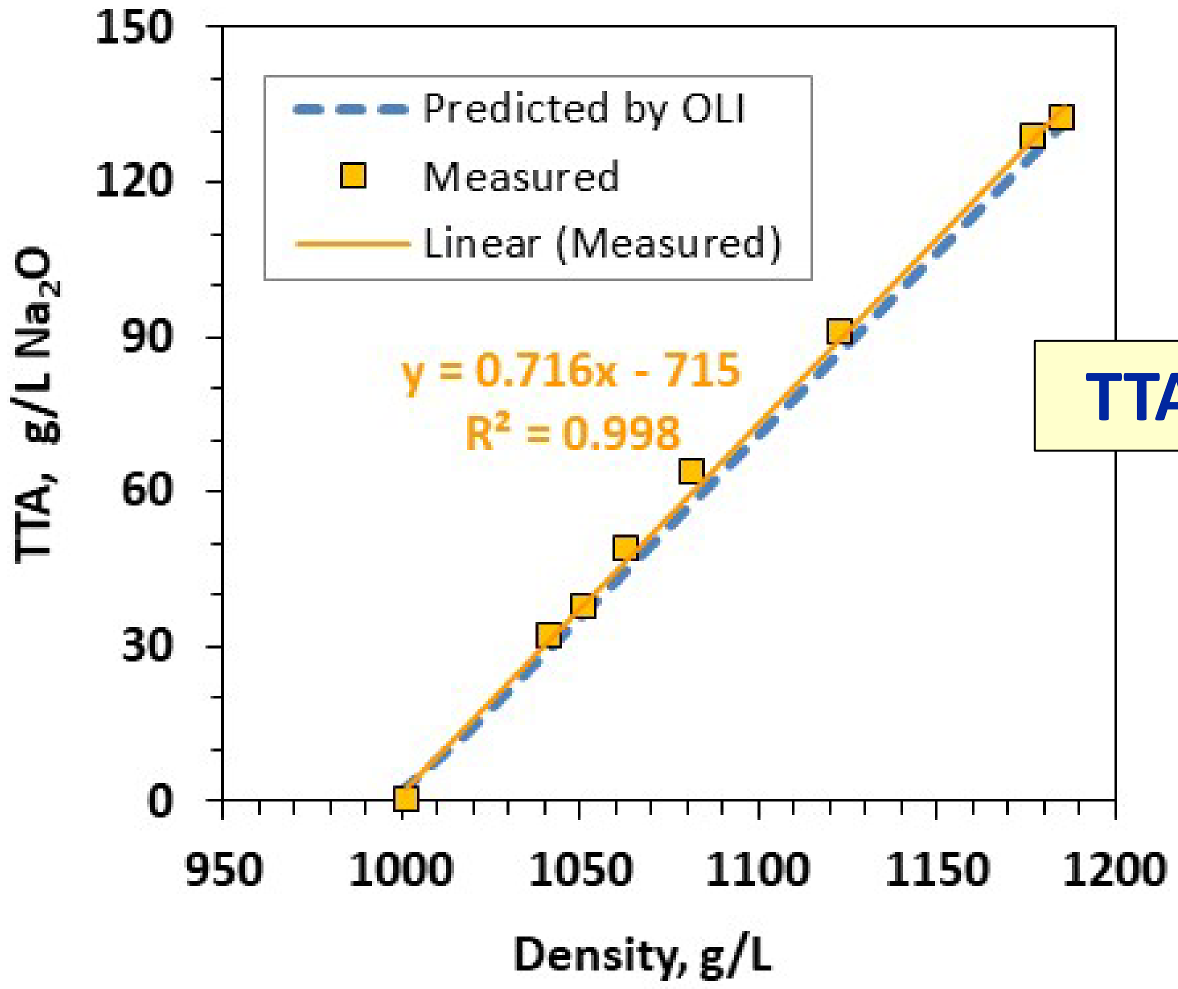
Effects of Liquor Temperature and TTA on Density

(Calculated using OLI)



Correlation between TTA and Density at 95ºC

Calculated using OLI (a commercial thermodynamic software)



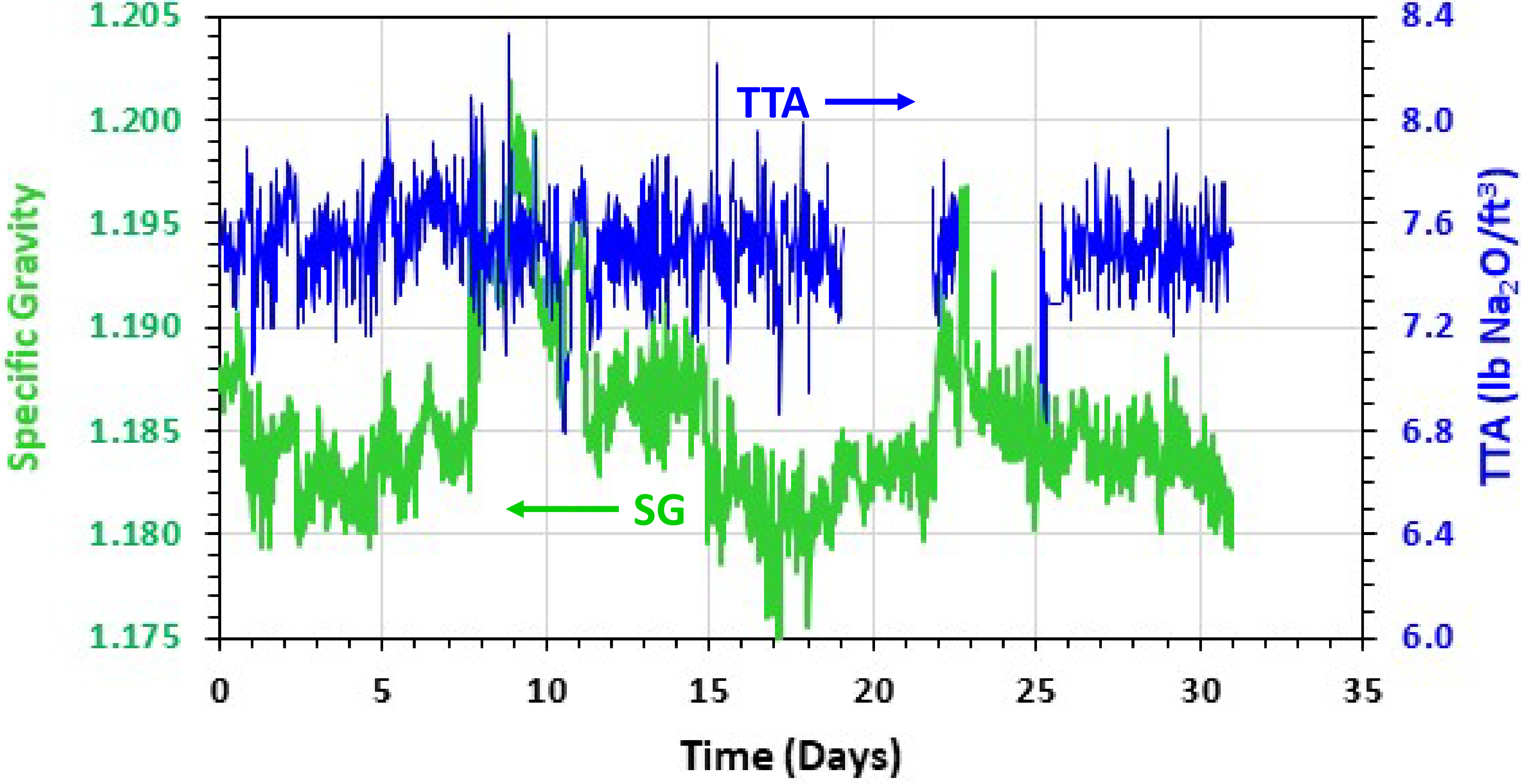
- **Linear correlation:**

TTA (g/L Na_2O) = 0.716 x Density (g/L) - 715

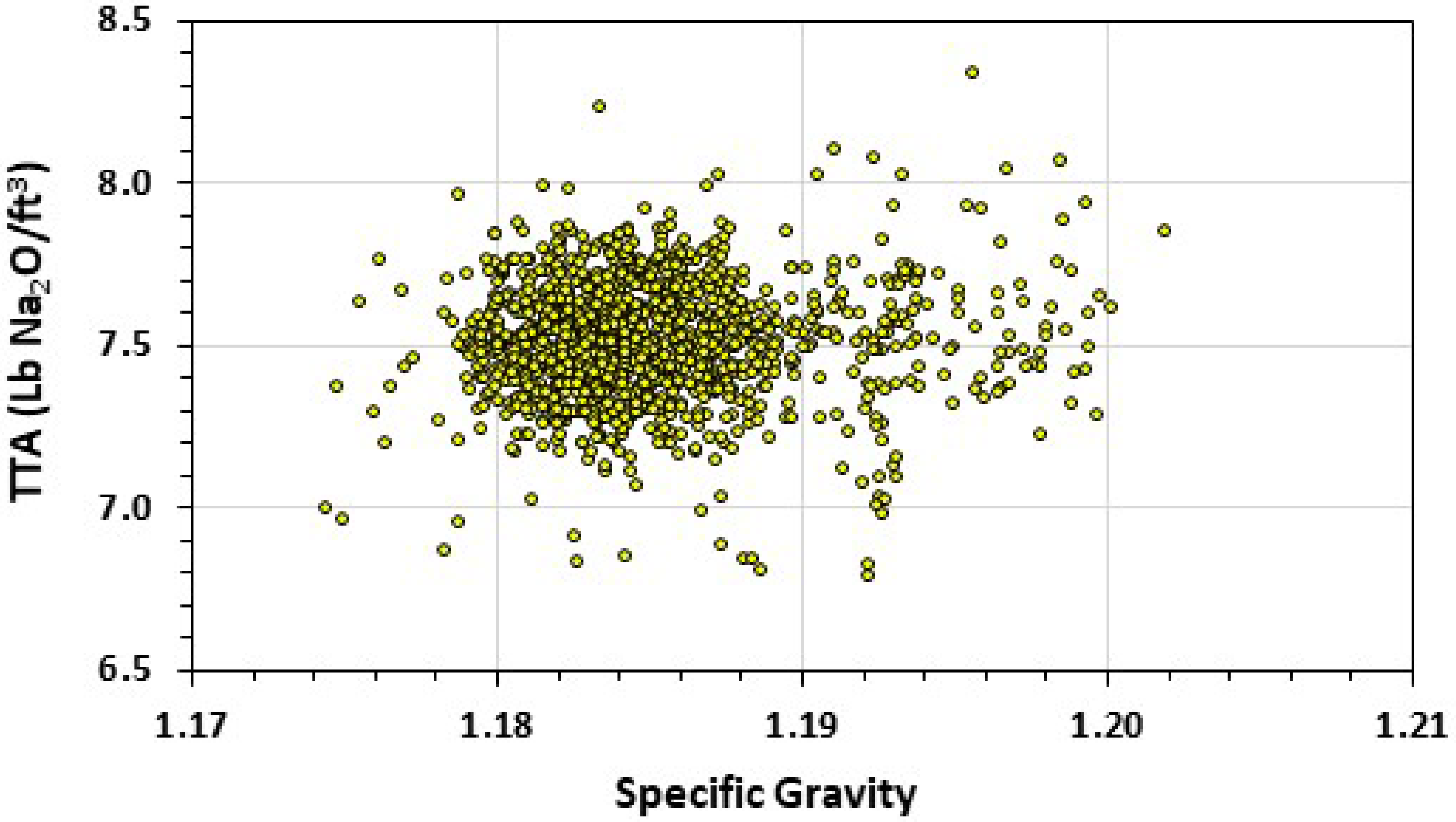
A Case Study

- Density (SG) and TTA data collected from a kraft mill in US
- One month (31 days) of data
- Each data point: 30 minutes of moving average of the second values
- Total number of data points: 1487

Change in TTA and Density (SG) with Time

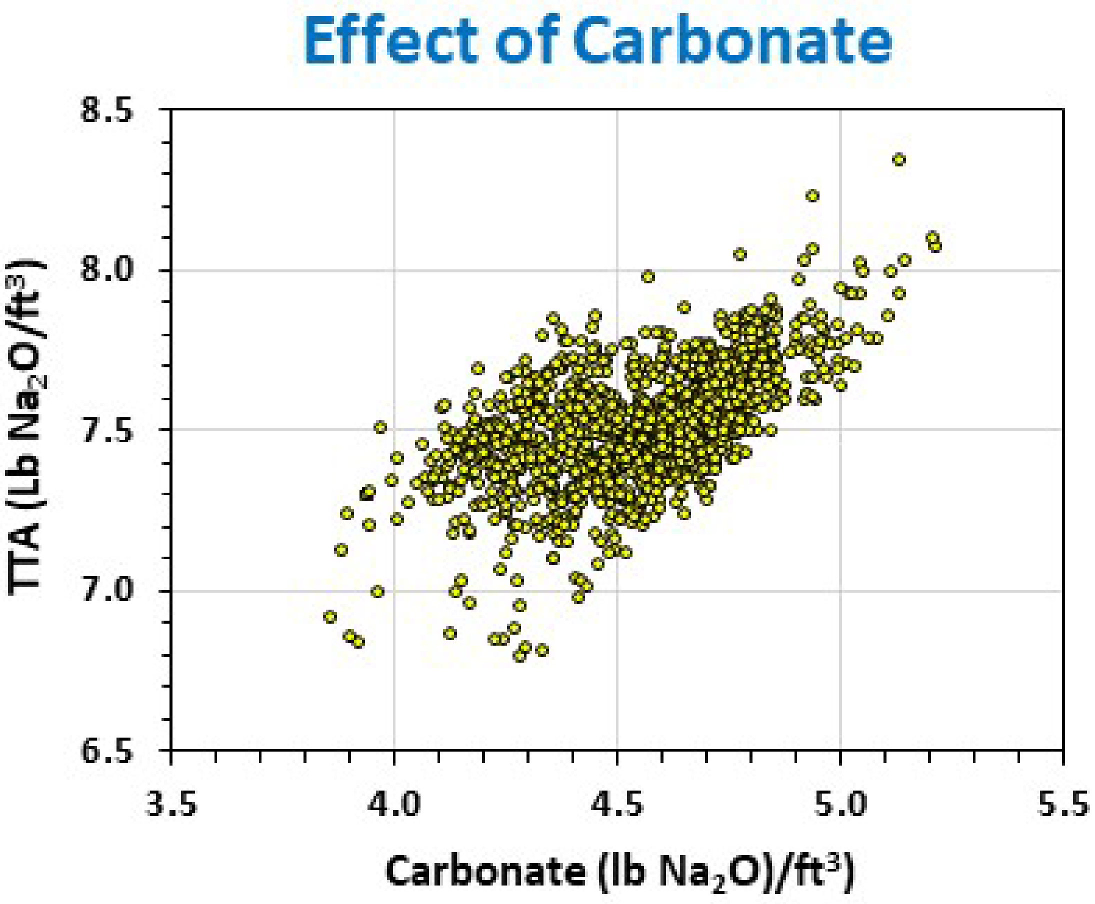


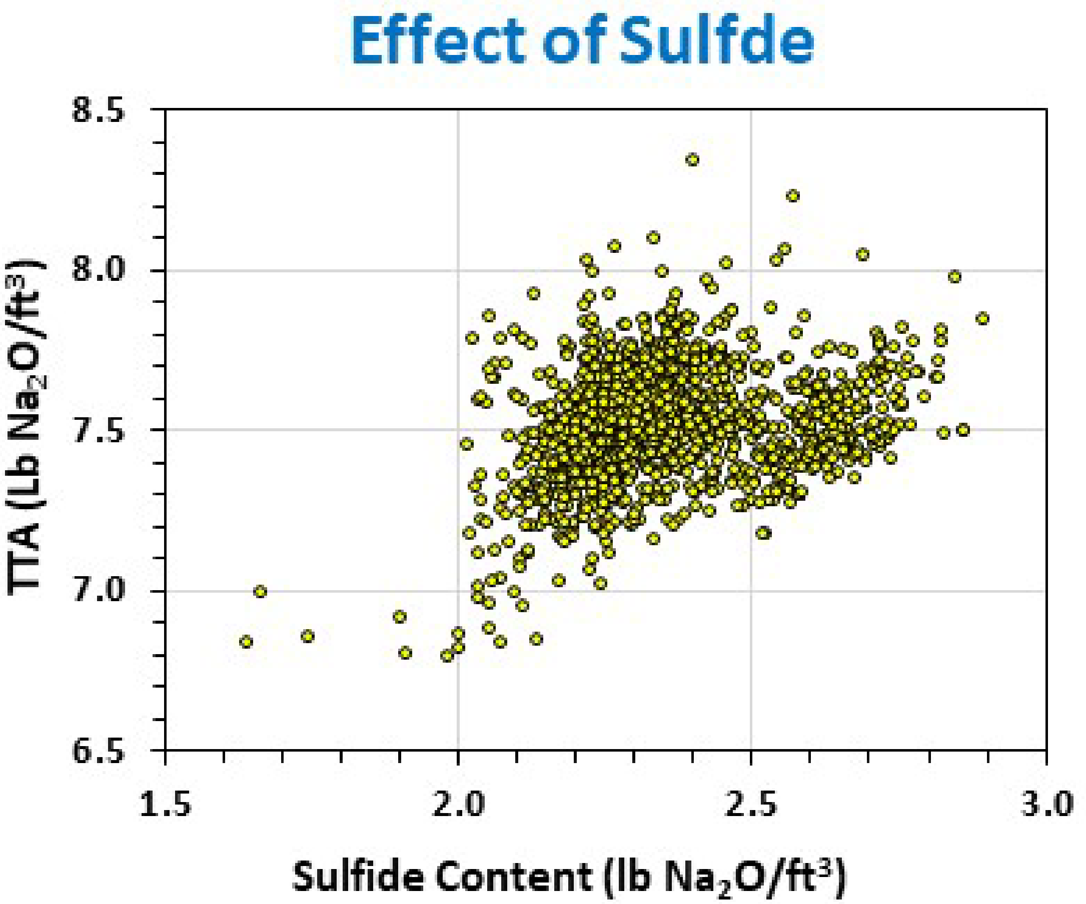
TTA vs. Specific Gravity (SG)



➔ *No correlation*

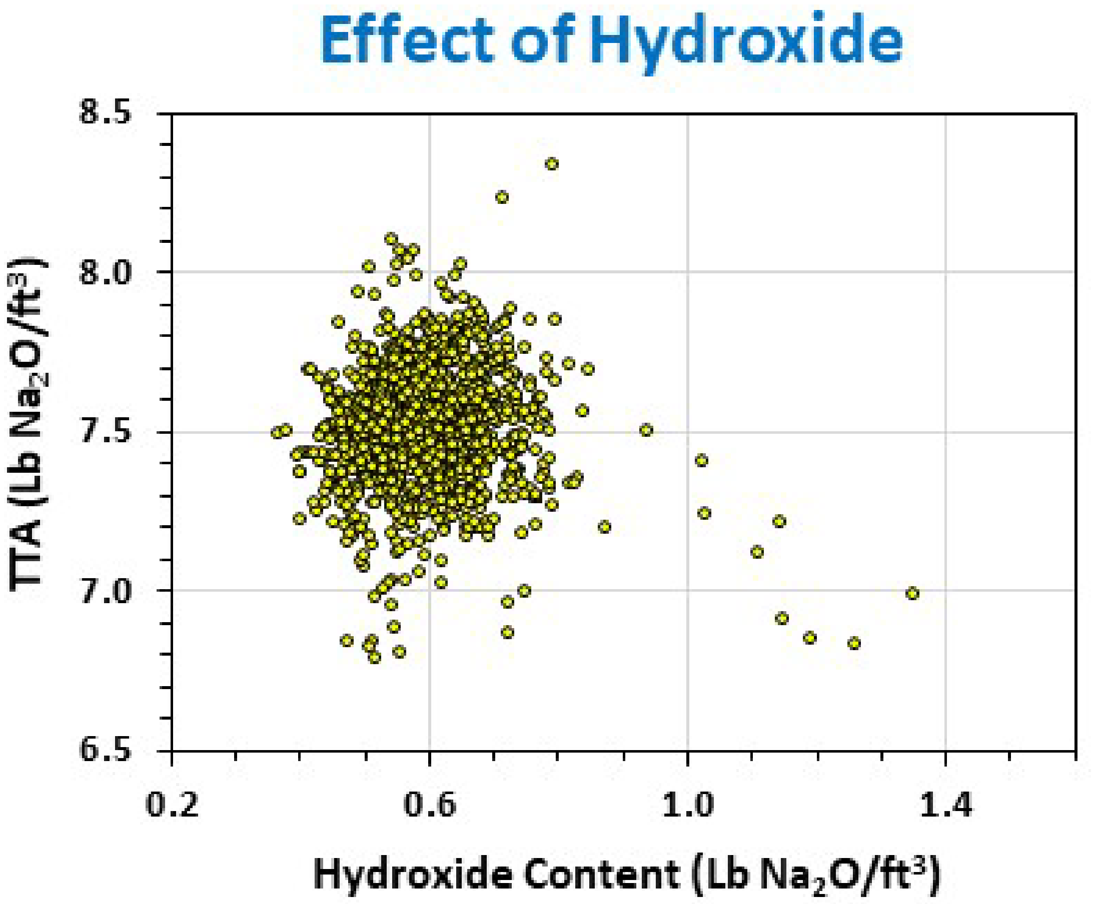
Effects of Carbonate & Sulfide Contents on TTA

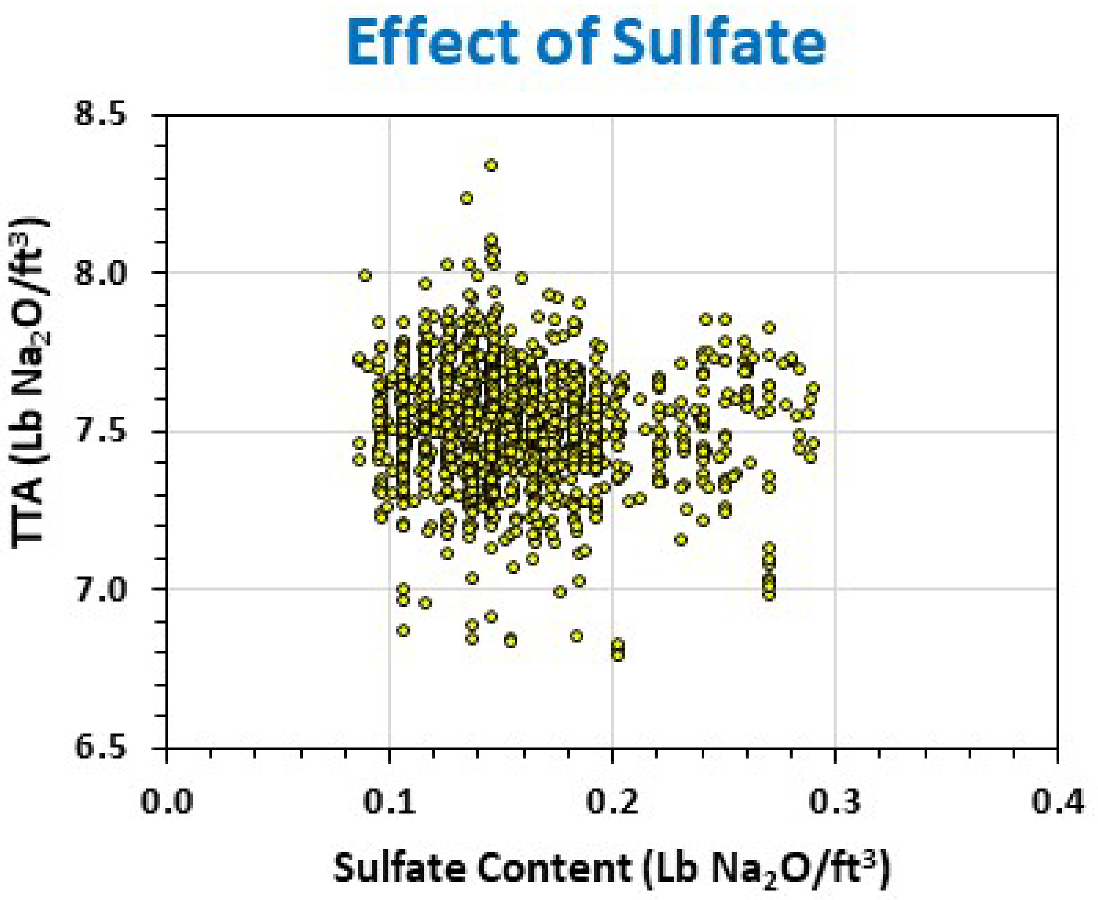




➔ *Some or weak correlation*

Effects of Hydroxide & Sulfate Contents on TTA





➔ *No correlation*

Results of This Case Study

<u>Correlation with TTA</u>

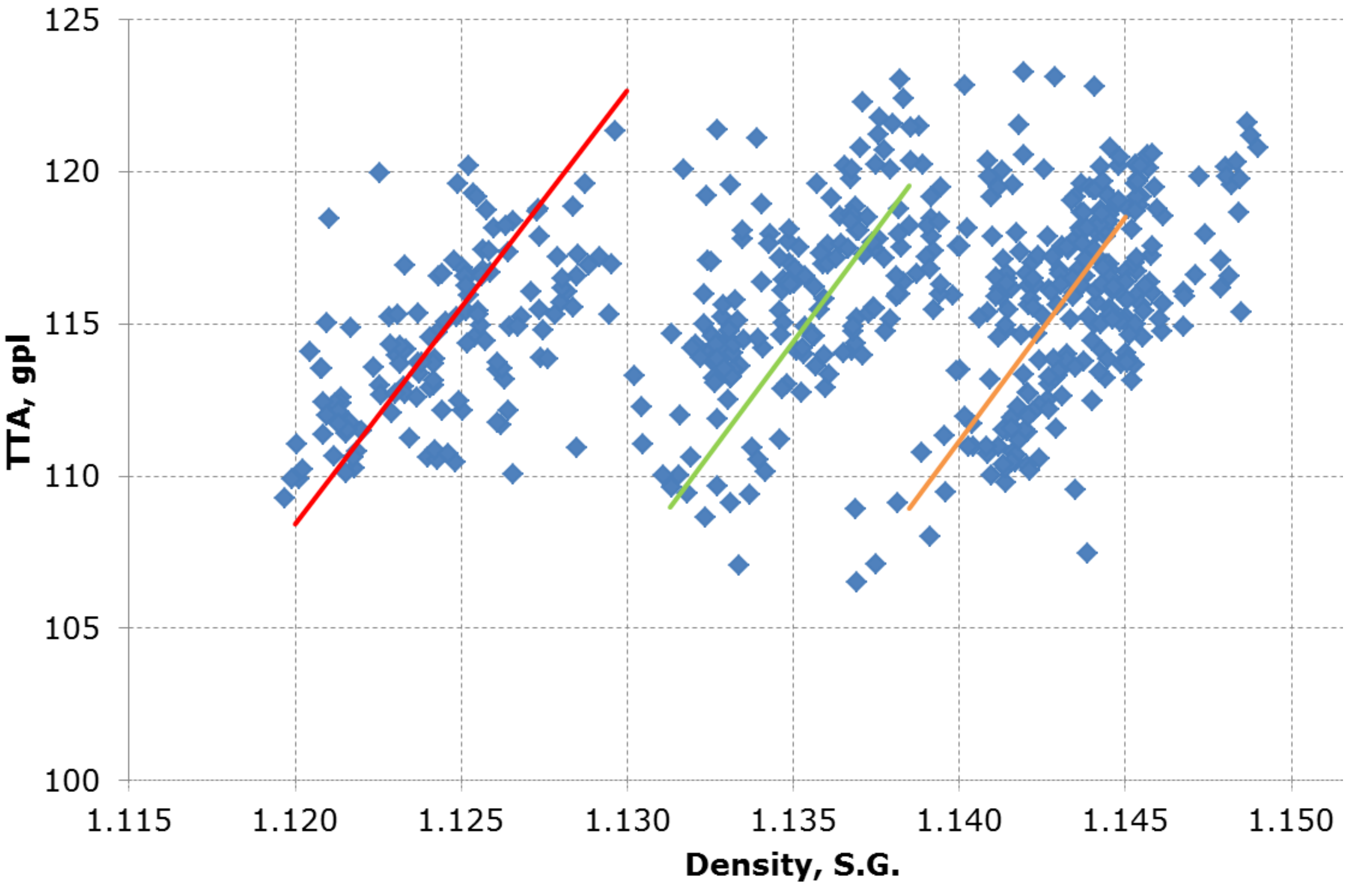
- **Density: No**
- **Carbonate: Some**
- **Sulfide: Weak**

Major components in GL

- **Hydroxide: No**
- **Sulfate: No**

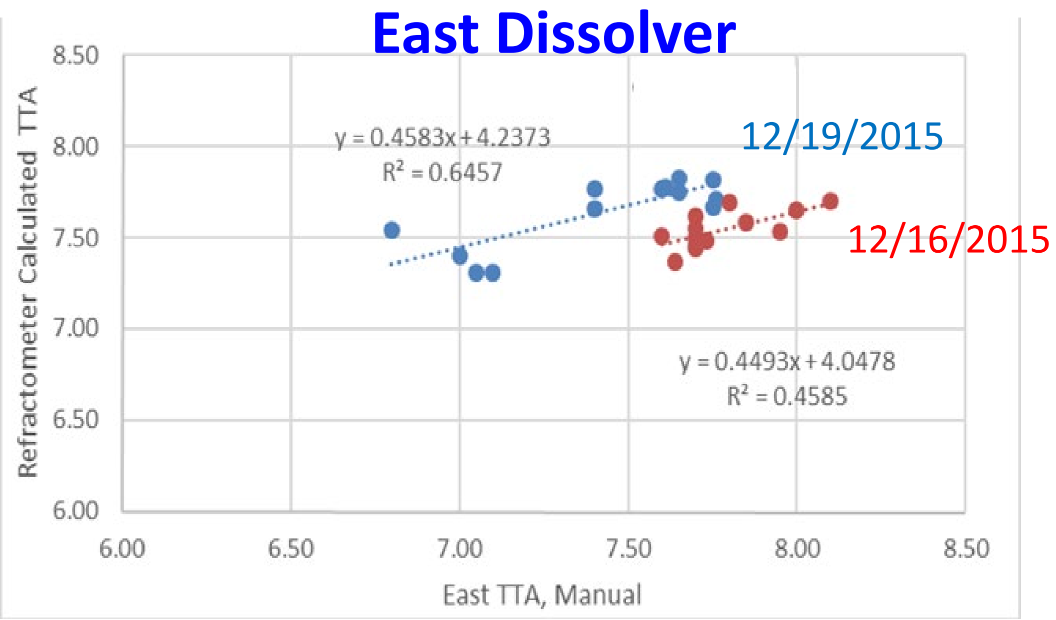
Minor components in GL

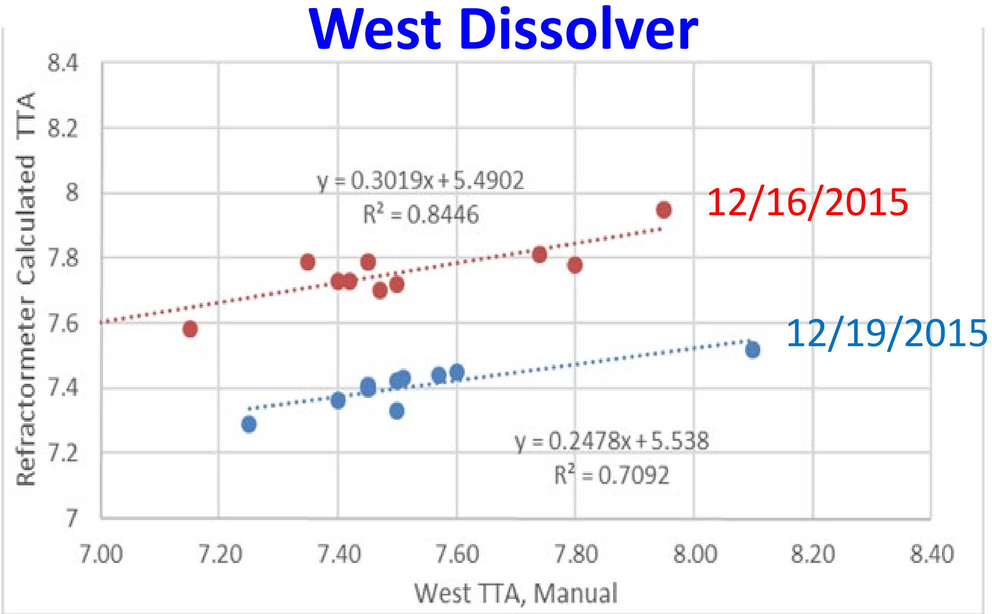
Case Studies by FITNIR



- Scattered, but consistent with OLI prediction, showing some correlation between TTA and Density

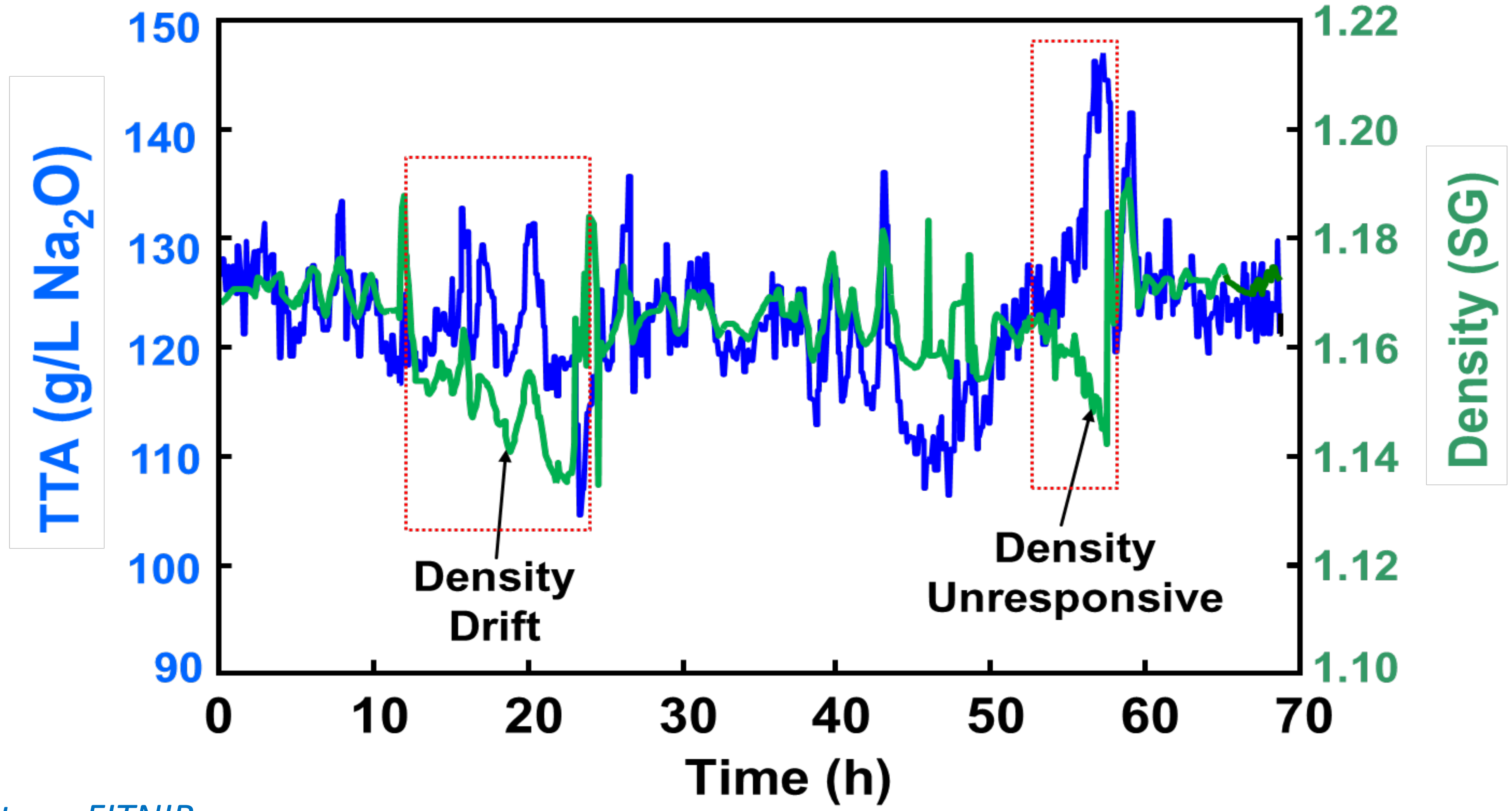
Manual vs. Refractometer TTA





- Two data set, Dec-16 and Dec-19, 2015 from FITNIR
- Relatively good correlations between actual manual testing and refractometer TTA

Density tends to Drift



Courtesy: FITNIR

Summary

- The main factor affecting TTA and density is the dilution factor of weakwash
- In theory, green liquor TTA and density should be closely correlated
- Density can be used to indirectly indicate TTA if
  - Sampling points are close
  - Temperature-corrected value
  - Results obtained from analyzers are reliable

Acknowledgements

- Members of the Research Consortium at the University of Toronto
- Thanh Trung of FITNIR for the use of data
- Mills which provided us with operating data

IMPACT OF AUXILIARY FUEL CO-FIRING WITH BLACK LIQUOR ON RB MAINTENANCE AND RELIABILITY

2025 AF&PA RECOVERY BOILER CONFERENCE

FEBRUARY 5, 2025

ANDRITZ

ENGINEERED SUCCESS

IMPACTS OF AUX FUEL CO-FIRING WITH BLACK LIQUOR ON RB MAINTENANCE AND RELIABILITY

01 BACKGROUND

02 LOWER FURNACE PROBLEMS

03 UPPER FURNACE PROBLEMS

04 SUMMARY

BACKGROUND

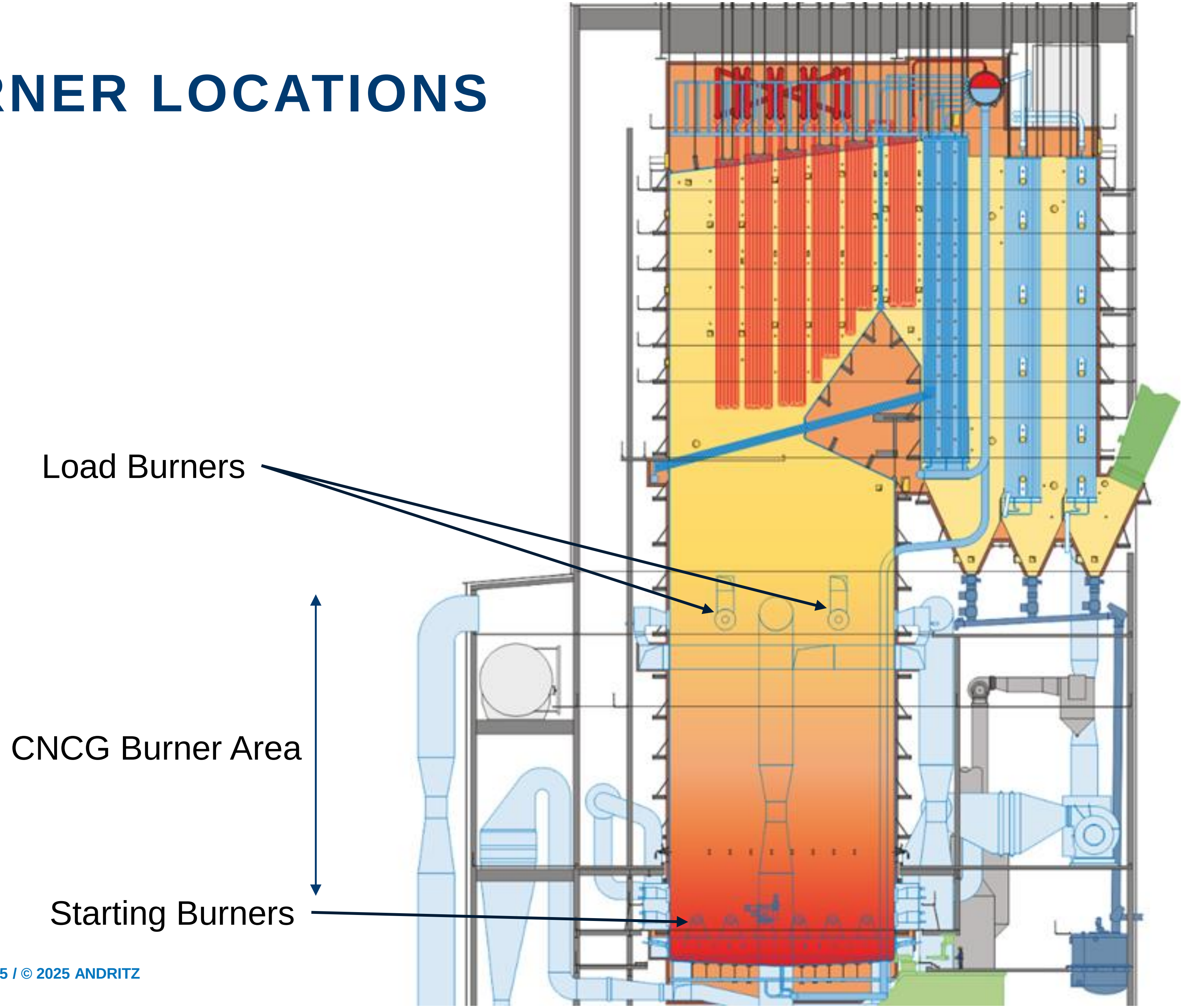
Increased Occurances of Smelt Leaks, Composite Tube Cracking and Lower and Upper Furnace Corrosion have been reported in North America, South America and Europe.

Reported Damage Include:

- Chronic Smelt Leaks at Floor to Sidewall Seals
- Chronic Smelt Leaks at Smelt Spout Seal Box Mounting Plates
- Widespread Corrosion of Carbon Steel Floor Tubes
- Membrane and Tube Cracking of 304L Composite Waterwall Tubes Mid Furnace
- Severe Corrosion of Ferritc SH Tubing

Common Thread Has Been Increased, Prolonged Co-Firing of Aux. Fuel Burners with Black Liquor.

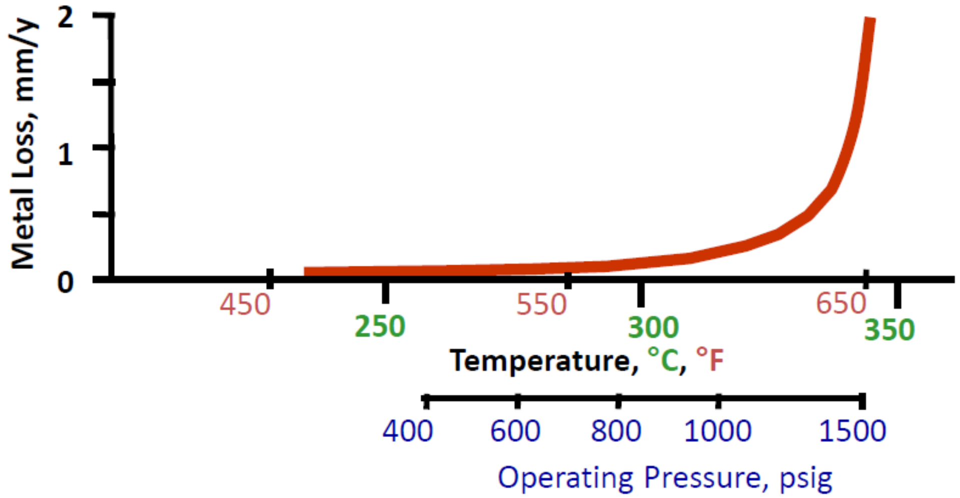
TYPICAL BURNER LOCATIONS



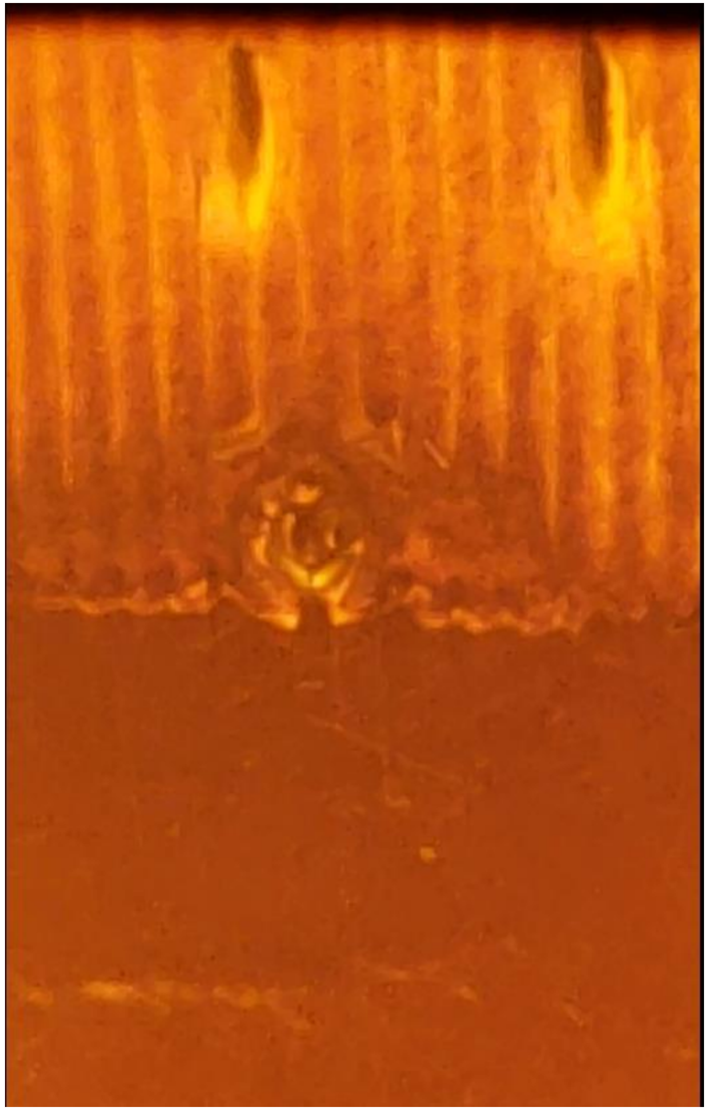
FURNACE AND SH DAMAGE/CORROSION

In RBs, driver is high temperature sulfidation and Thermal Fatigue

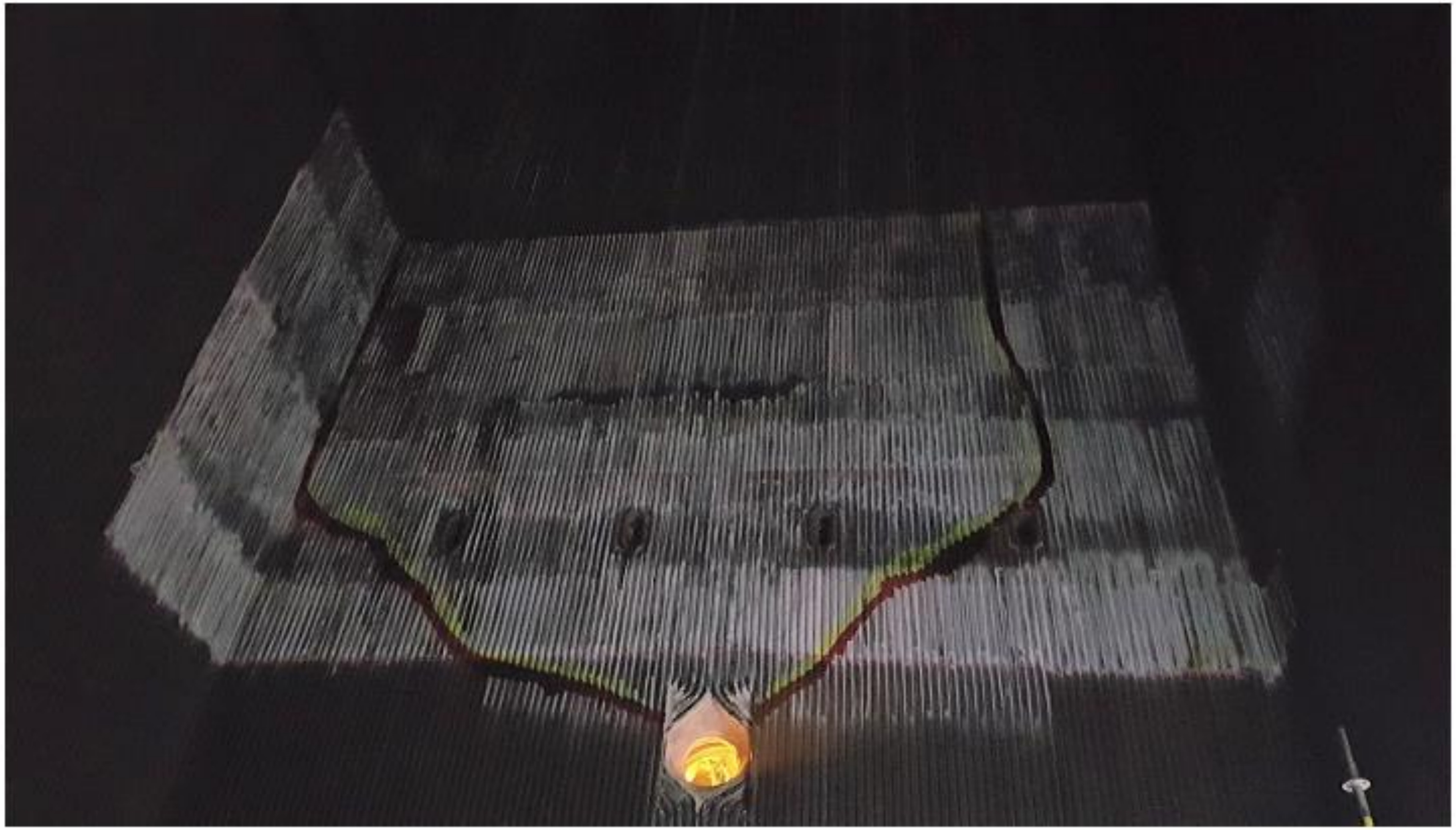
- Above 600°F metal temperature (~1,000 psi drum P), corrosion of CS furnace tubes can be very aggressive
- Need at least 18% chromium to prolong life
  - Composite/Weld Overlay Furnace Tubing (Cannot use solid SS tubing per ASME Section I)
  - Composite/Weld Overlay/Solid SS for SH tubing
  - Thermal Spray Coatings/Chromizing Less Common Due to Quality Issues
- Excessive Aux Fuel Use Should be Minimized – Thermal Fatigue Damage Can Occur
- Avoid Spraying Liquor Directly Onto Furnace Walls
- Minimize Carryover Of Unburned Liquor Into Upper Furnace
- Fast Flowing/Dripping Smelt Causes SH Erosion-corrosion Damage



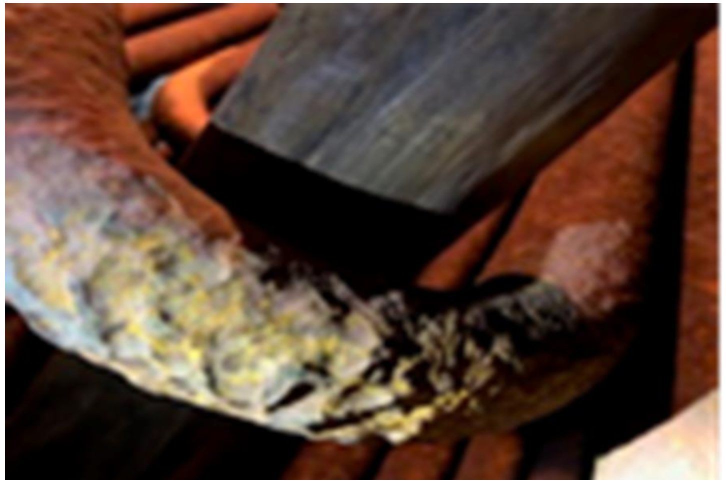
LOWER FURNACE DAMAGE EXAMPLES

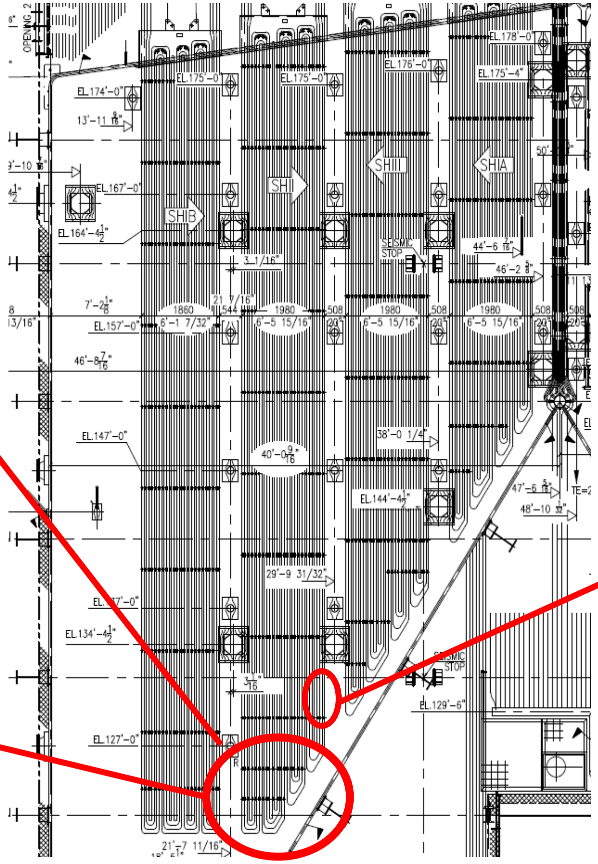


MID FURNACE CRACKING DAMAGE – 304L COMPOSITE TUBING AND MEMBRANE



EXCESSIVE CORROSION OF SH AFTER PROLONGED CO-FIRING OF LOAD BURNERS

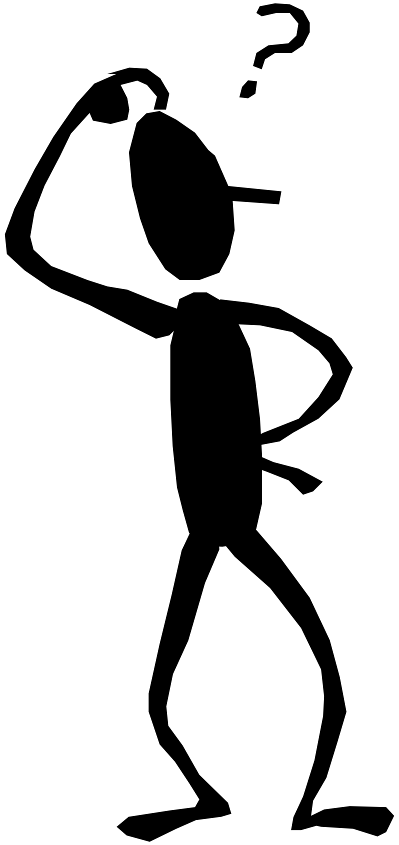




SUMMARY

- Minimize Co-firing Aux Fuel Burners Wherever Possible. RBs Are Not Power Boilers.
- Starting Burners Are Used For Start-up, Shutdown And Stabilizing The Bed In Upset Conditions. Over-use Can Increase Carryover, Ruin Reduction Efficiency, Cause Smelt Leaks At Floor Seals And Spout Seal Boxes And Result In Floor Tube Damage, Thermal Fatigue Damage And Floor Tube Overheat Failures.
- Load Burners Can Cause Damage In The Upper Furnace And SH Regions.
- All Starting And Load Burners Should Be Evenly Distributed At The Minimum Necessary Heat Input For The Task At Hand.
- If Long Term Co-firing With Liquor Cannot Be Avoided, Be Prepared To Do Additional Inspections That Focus On Areas That Burners Can Cause Damage To.

Questions?



LEGAL DISCLAIMER

IRmadillo: In-Situ Device for Green and Black Liquor Analysis

Real-time process monitoring of
liquids | slurries | emulsions

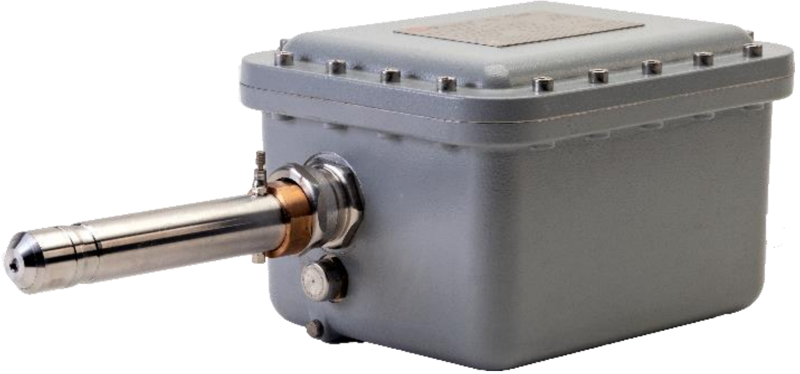
Richard Salliss
Sales Director

AF&PA 5th February 2025

Who are we?

Formed in 2013, Keit is a spin-out from the UK government space research centre near Oxford, UK.

Our technology was originally designed for a Mars research project and has since been developed and improved for use in the process industries as a **robust** real time process analyzer.



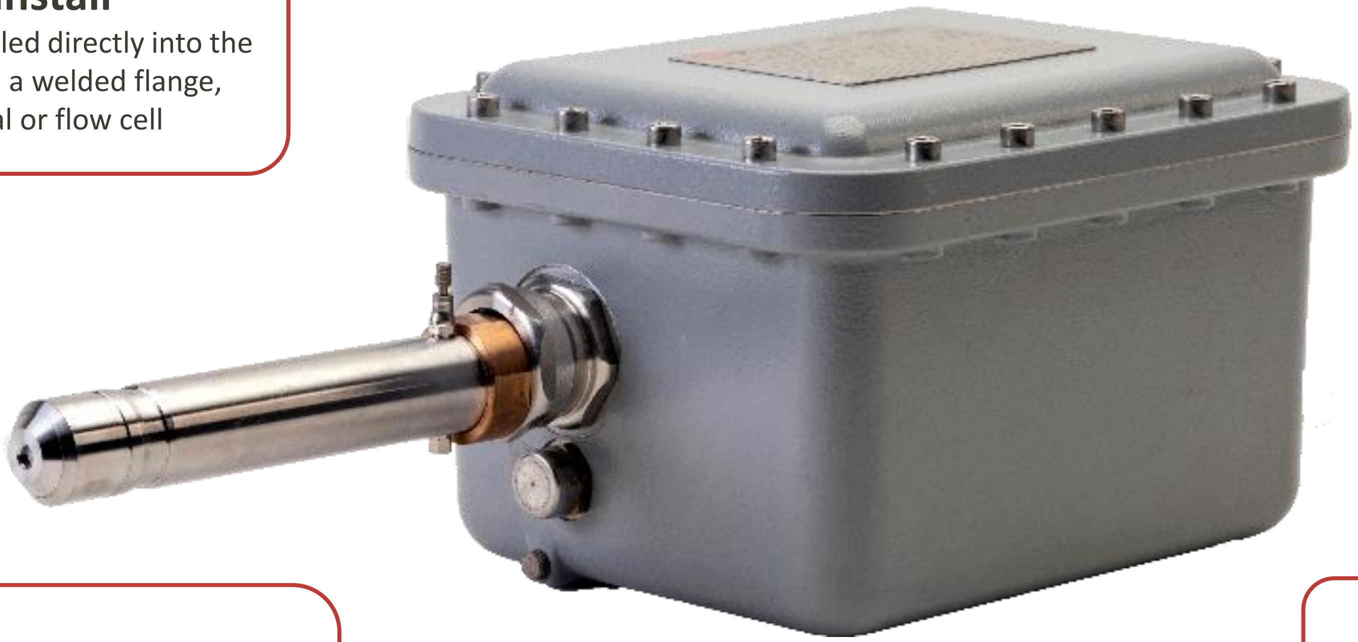
Why Spectroscopy?

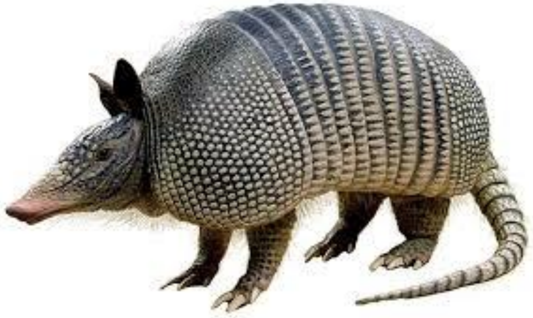
Would you like to know in REAL TIME what's going on inside your process?

IRmadillo ‘static optics’ FTIR spectrometer

Easy to install
The probe can be installed directly into the process – either with a welded flange, compression seal or flow cell

Robust, rugged and reliable
The IRmadillo was built to operate in process plants and potentially explosive atmospheres.



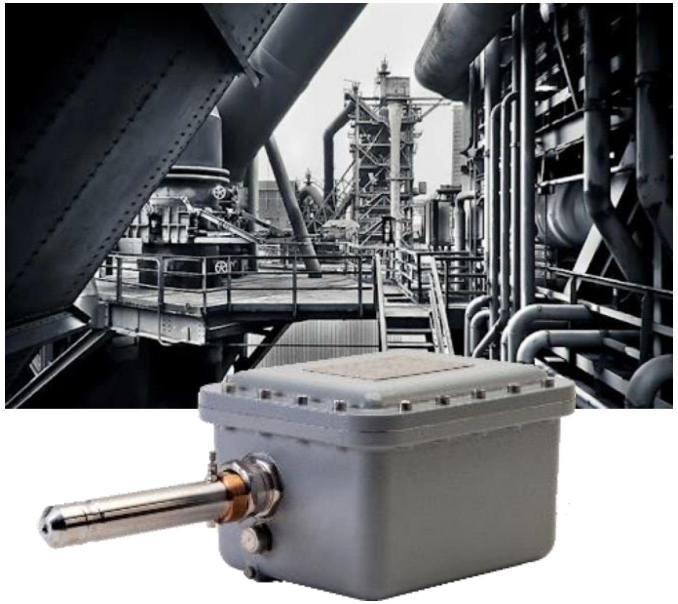


Simple, contact-sensing probe
The diamond window makes contact with the process fluid to start measuring instantly

Calibrated to measure your chemistry
Predictive models turn the mid-infra red spectra into composition data – **in real time**

Communicates directly with your DCS
The IRmadillo’s controller connects to your control system via Modbus or OPC-UA for real-time measurements communicated directly into your DCS, SCADA or PLC

IRmadillo for Measurement, Control & Optimisation

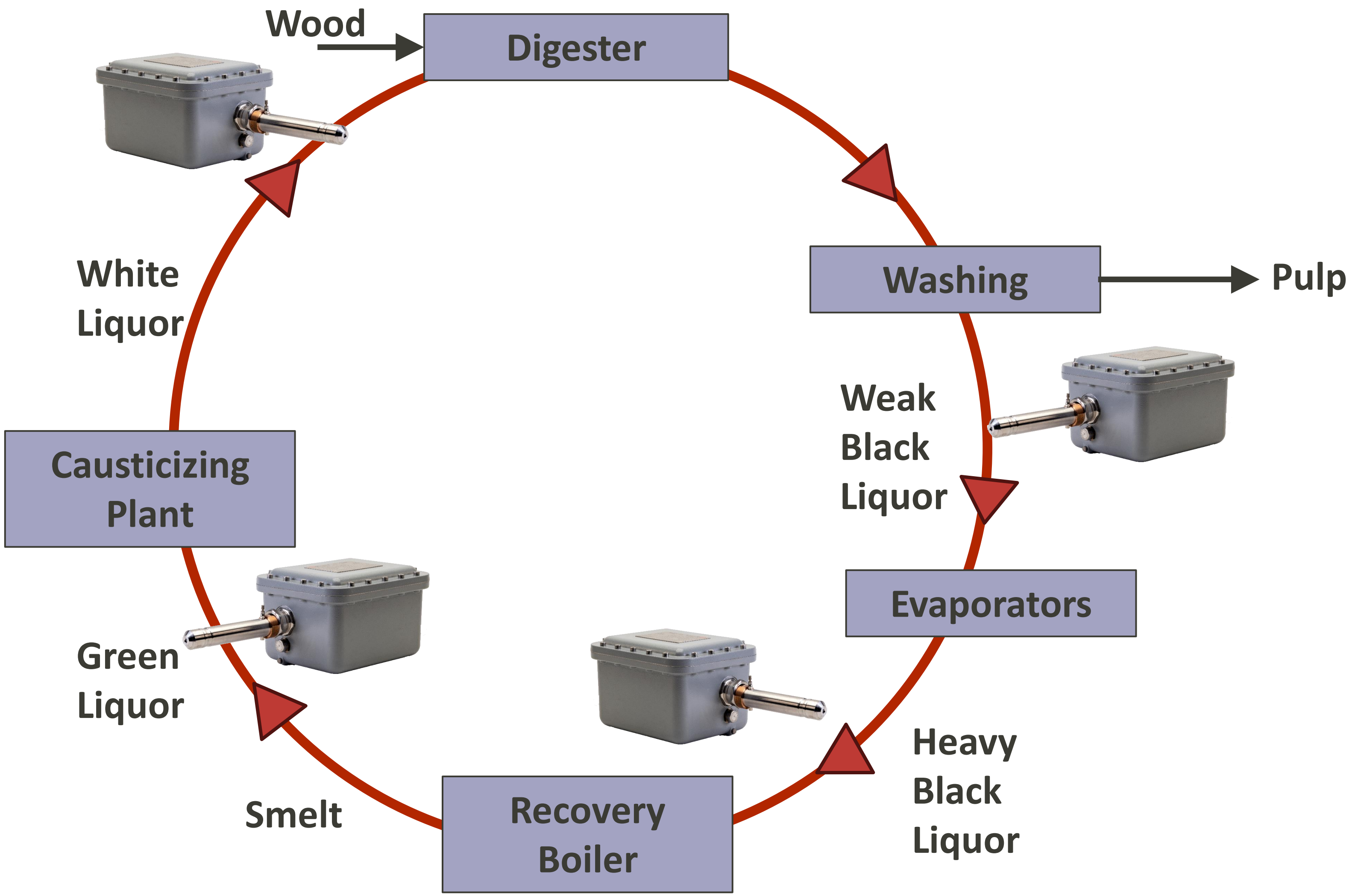


IRmadillo FTIR

Real time concentration values

- Insight
- Action
- Control
- Optimisation

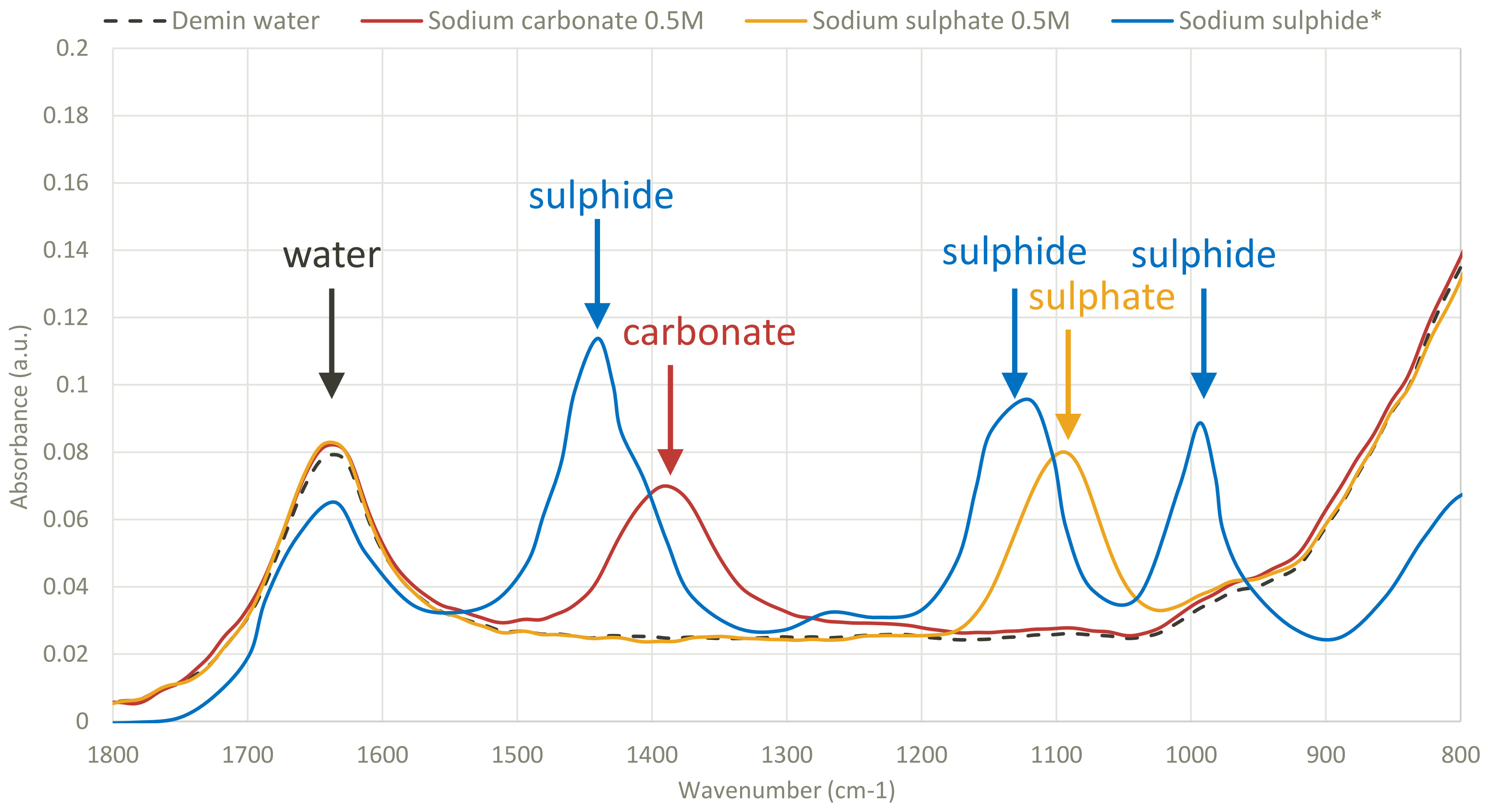
What can IRmadillo measure?



Sodium Carbonate
Sodium Sulfide
Sodium Sulfate
Sodium Hydroxide
Dissolved Lignin
Tall Oil Soap
Oxalate
Thiosulphate

Reduction Efficiency
Residual Effective Alkali
Causticising Efficiency
Effective Alkali
Total Titratable Alkali

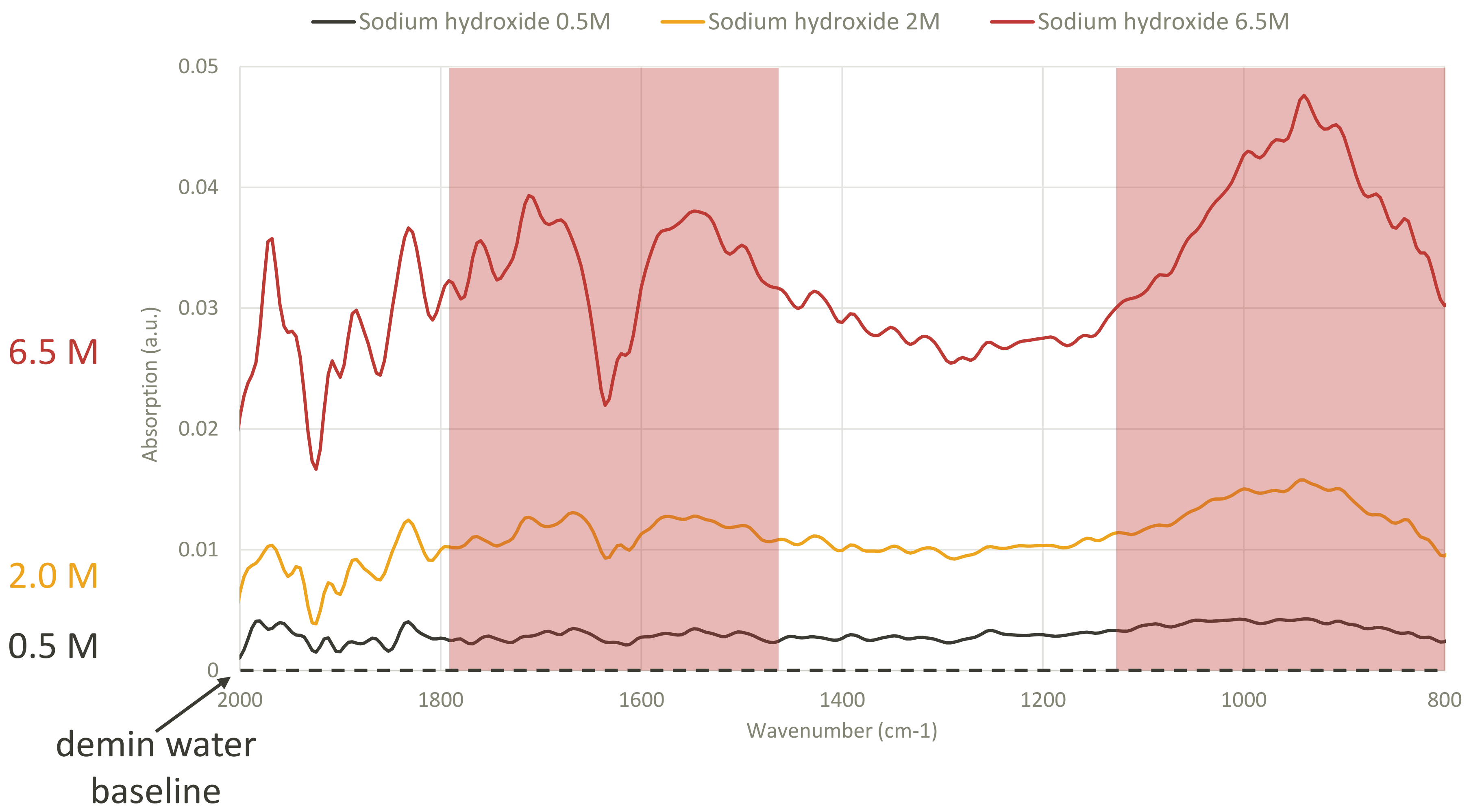
Example absorbance spectra



- IR "fingerprint region" 800-1800 cm^{-1}
- Different chemicals have distinct patterns in this region
- IR is additive: a mixture of two (non-interacting) components shows the sum of the individual spectra

*Sodium sulfide spectrum taken from a different FTIR instrument and intensities are for indication only

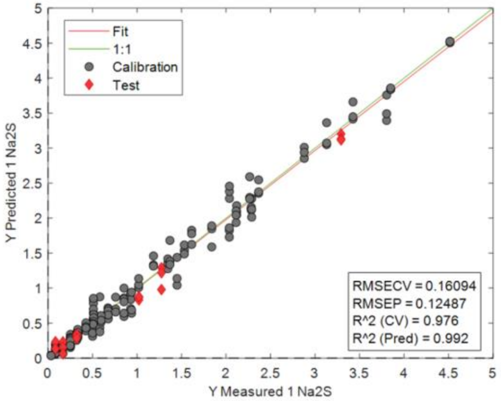
Spectral features: Sodium hydroxide



- NaOH doesn’t behave like an “oscillator”
- Na^{+} atoms order water molecules and change their bond vibrations
- Chemometric models ‘see’ changes we struggle to detect visually
- The graph shows NaOH solutions with demin water subtracted
- Chemometric models use *all* wavenumber data rather than peaks

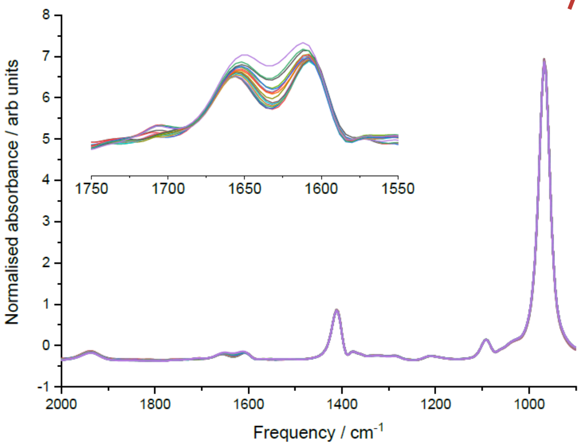
Building a calibration model

Reference concentrations by HPLC, titration etc



Calibration model building

Spectra obtained from IRmadillo



Model exported to IRmadillo

Model ‘tuned’ online

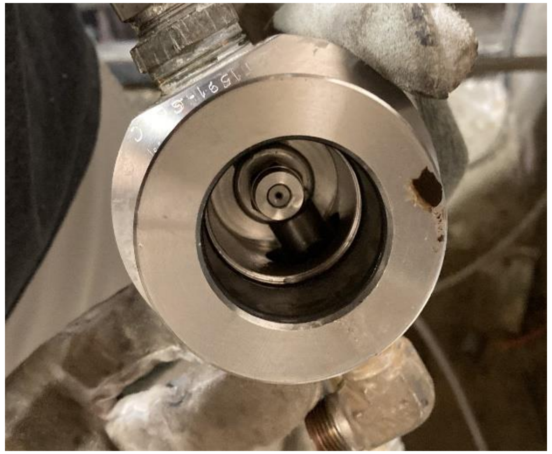
Example IRmadillo installations

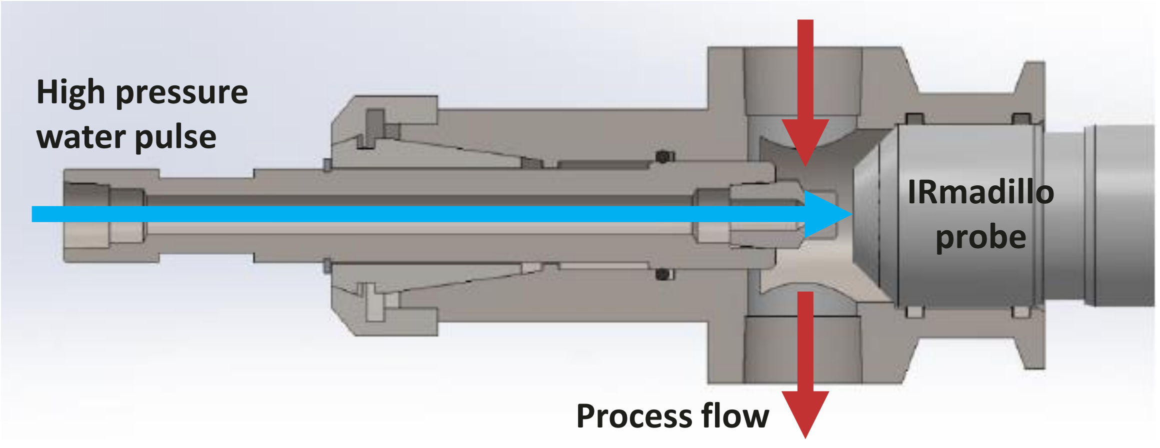
Several field-ready installation options:
- Welded flange
- Flow cell
- Port tube, flange and cradle

What about fouling of the probe?

- Directing a high-pressure jet of water at the diamond window for 10 seconds prevents scale or fouling from becoming a problem.
- The cleaner can be used at custom intervals using the electronic timer system, set at 30 minutes as standard.
- This is available in either a flow cell form or by installing into a custom pipe spool piece.
- IRmadillo can be calibrated with a ‘fouling model’ which can indicate the need for cleaning

In-situ cleaner: flow cell





Why Install IRmadillo in Kraft mills?

Install point	Measure	Why?	Expected Benefit
Green liquor	Reduction Efficiency (RE)	• Enable increase in average RE	• Increase sulfidity • Reduced sulphate deadload • Save energy
Green liquor	Total Titratable Alkali (TTA)	• Enable TTA control • Enable causticizing efficiency(CE) measurement and control	• Prevent overliming • Reduce lime consumption • Reduce carbonate deadload • Save energy • Debottleneck evaporators
White liquor	Effective Alkali (EA)	• Optimise digester feed • Enable causticizing efficiency(CE) measurement and control	• Prevent overliming • Reduce lime consumption • Reduce carbonate deadload • Save energy • Debottleneck evaporators • Increase digester capacity
Black liquor	Tall Oil/Extractives	• Improve tall oil soap recovery	• Stabilise recovery boiler • Maximise yield of tall oil
Black liquor	Residual effective alkali (REA)	• Maintain REA at or above target	• Prevent lignin precipitation • Prevent evaporator fouling
Black liquor	Dissolved lignin/COD	• Optimise brownstock washing	• Save energy • Debottleneck evaporators • Reduce chemical losses

In addition: reduction in manual sampling -> HSE benefit

Example - Green Liquor

Scandinavian customer wanted to improve both the recovery boiler and recausticizing processes through feedback and feedforward controls.

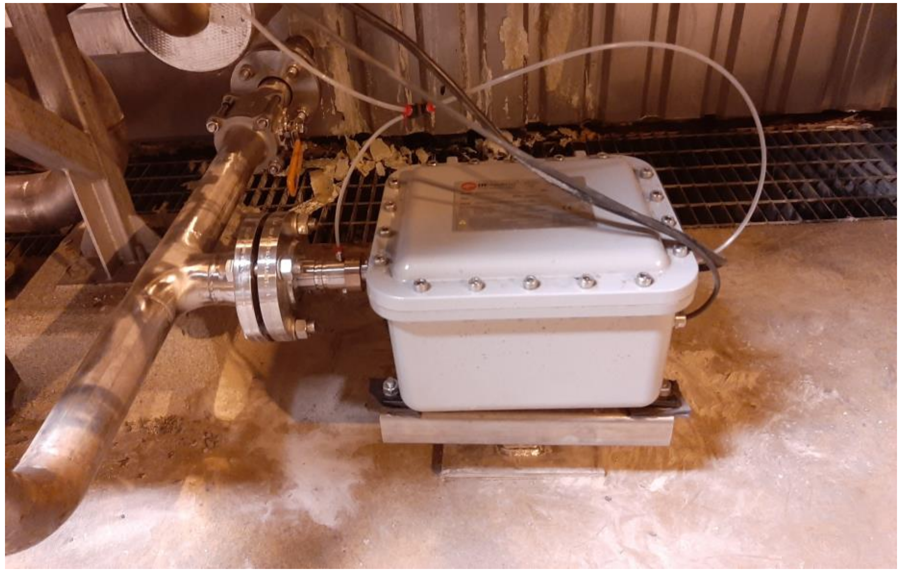
IRmadillo installed with a 2” ANSI flange fitted into the **outlet of the smelt dissolving tank** measuring green liquor.

Models produced for:

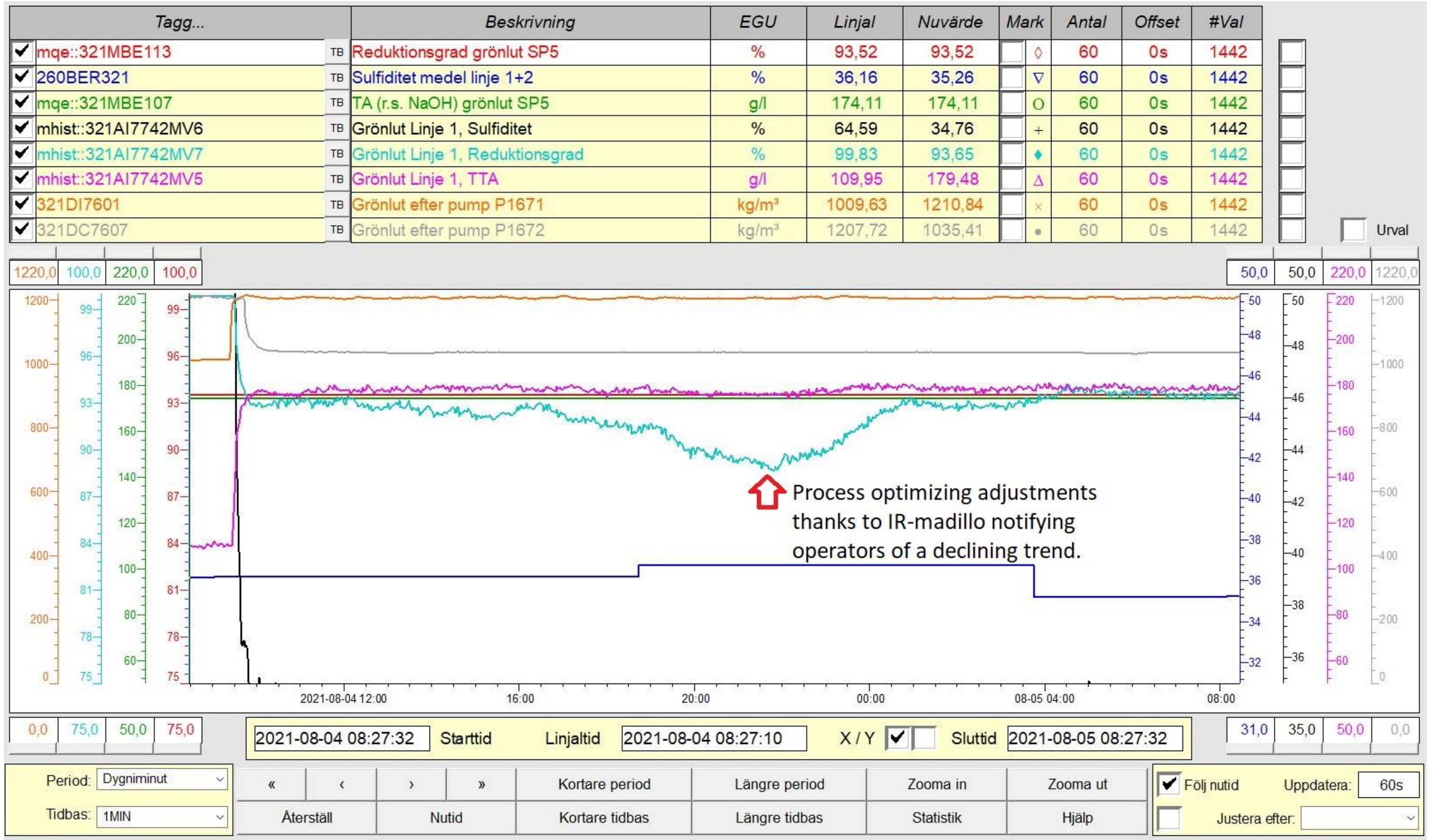
- Sodium carbonate
- Sodium sulphide
- Sodium sulphate
- Total titratable alkali

- **Reduction Efficiency** is calculated in DCS

Line is periodically washed with weak green liquor to clean and prevent scale formation on the line and the instrument.



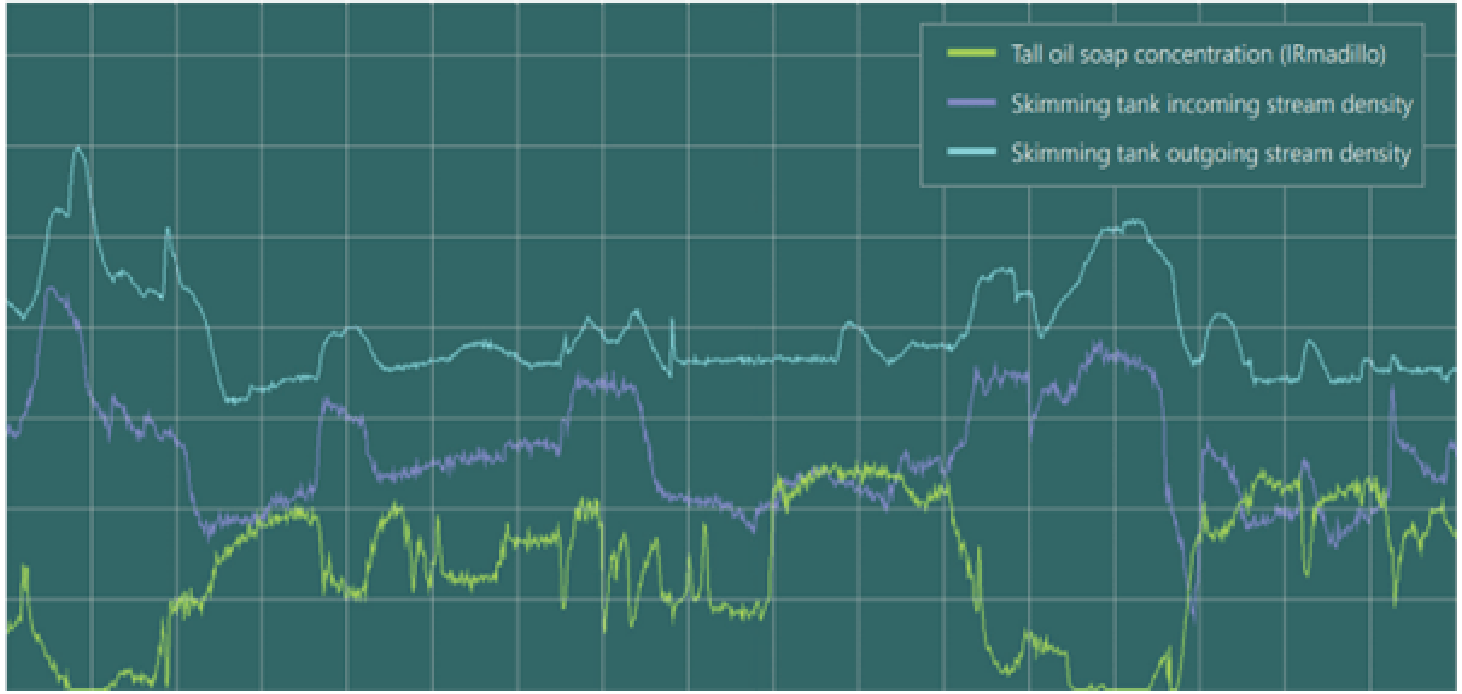
Example - Green Liquor



DCS trend showing IRmadillo predictions alongside process data

Reduction efficiency (shown in light blue) was beginning to decrease over time. The IRmadillo measurement alerted the operators to this and enabled them to make adjustments quickly which restored the desired operating conditions from 87 ➔ 93 %.

Example: Weak black liquor



IRmadillo was installed in **weak black liquor tank outlet** to deliver real-time actionable data. IRmadillo allows online monitoring of **REA** and **tall oil** for optimizing tall oil soap recovery.

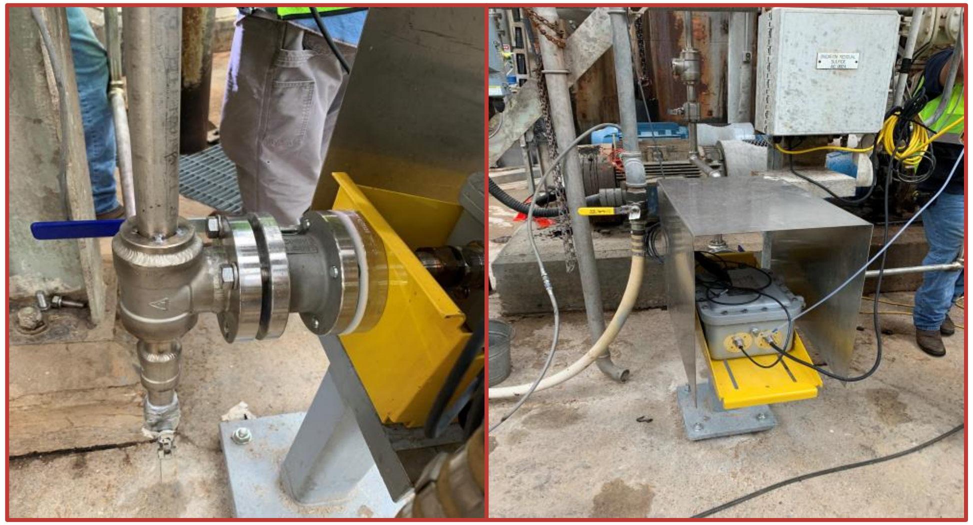
- The DCS trend above shows:
  - tall oil soap concentration measured by the IRmadillo in outlet from the skimming tank.
  - incoming and outgoing stream densities.
- These relationships enabled equipment modifications to stabilize densities and maximize tall oil soap recovery.

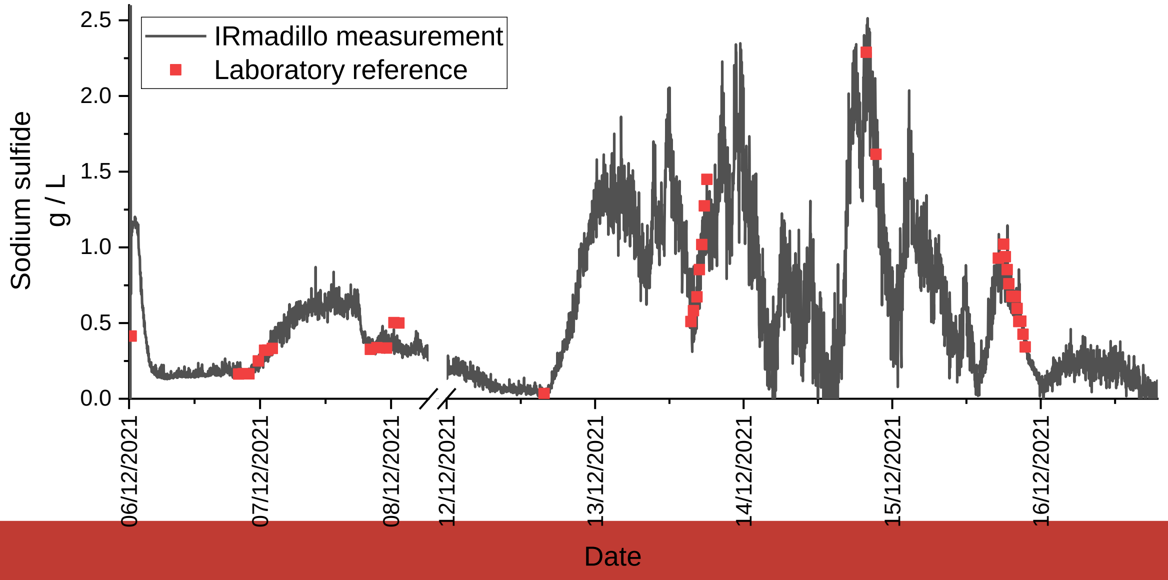
Example: Strong black liquor

- IRmadillo installed in strong black liquor and calibrated to measure Na_2S to prevent formation of H_2S (hydrogen sulfide) in the direct contact evaporator section of the recovery boiler.

- Optimisation of black liquor oxidation allows maximum heat recovery from black liquor whilst staying below emission limit – only possible with real time measurement from IRmadillo

- Additional measurements have since been added to the calibration, including:
    - Tall oil soap
    - Oxalate
    - Thiosulfate
    - REA
- Since boiler reconfiguration, IRmadillo is now being repurposed to measure green liquor





Why IRmadillo?

Robust
Easy to Install
Low Maintenance
The Power of Mid Infra-Red

Reliable, Real-Time
Process Insight

Safety,
Efficiency &
Profitability

Questions & Answers

For more information

Visit: www.keit.co.uk
Contact: richard.salliss@keit.co.uk

Typical model performance (Kraft)

Green Liquor

Species	Range	Error (RMSECV)
Na_2CO_3	91.0 – 107.0 g/L	1.2 g/L
Na_2SO_4	5.0 – 25.0 g/L	1.6 g/L
NaOH	1.0 – 7.0 g/L	0.75 g/L
Na_2S	50.0 – 63.0 g/L	1.2 g/L

White Liquor

Species	Range	Error (RMSECV)
Na_2CO_3	14.0 – 28.0 g/L	0.46 g/L
NaOH	78.0 – 92.0 g/L	1.2 g/L
Na_2S	45.0 – 70.0 g/L 50.0 – 63.0 g/L	3.5 g/L 1.2 g/L

Weak Black Liquor

Species	Range	Error (RMSECV)
REA	8.0 – 12.5 g/L	0.72 g/L
Tall Oil	0.07 – 0.58 g/L	0.12 g/L
NaOH	11.4 – 18.6 g/L	0.59 g/L
Na_2S	11.4 – 24.6 g/L	0.47 g/L

Strong Black Liquor

Species:	Range	Error (RMSECV)
REA	2.5 – 5.0 %ods	0.25 %ods
Tall oil	0.0 – 12.0 g/kgds	0.95 g/kgds
Total dissolved solids	46.0 – 56.0 %wt	0.96 %wt
Na_2S*	0.0 – 3.0 g/L	0.24 g/L

* Data from separate installation

NORAM

The LignoForce™ Process Energy Impacts

Shadan Mostafavi

Jon Foan

Stuart Gairns

NORAM Engineering & Constructors Ltd.

AF&PA Recovery Boiler Conference and Meetings

February 2025

Presentation Outline

- NORAM Overview
- LignoForce™ Overview
- LignoForce™ Advantages
- LignoForce™ Flowsheet
- LignoForce™ Energy Impacts

Company Overview

- Private Canadian company established in 1988.
- Provide technology solutions in equipment and engineering packages to multiple industries
- The NORAM Group of companies includes
  - Engineering and Design Offices
  - 3500 m^2 Research & Development Lab
  - 7000 m^2 Fabrication Shop

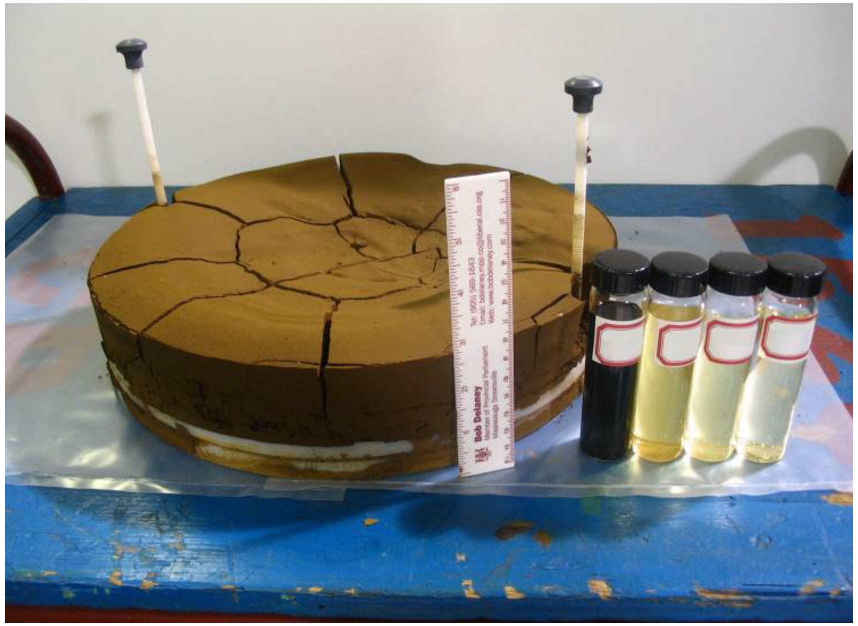
Pulp and Paper Technologies

- LignoForce™ - Lignin Recovery Process
- PDP™ - Process for chloride or potassium purge
- CleanFlow™ - Recausticizing Capacity Increase
- OptimumAcid™ - NCG-Acid Process for sulfur balance
- IsoFlo™ - White & Black Liquor Oxidizers

LignoForce™ Process

Overview

- Developed by NORAM and FPInnovations to recover lignin from kraft black liquor.
- The first commercial LignoForce™ plant was commissioned in 2016 at the West Fraser Mill in Hinton, Alberta, Canada.
- Benefits of Lignin Recovery
    - New, high-value revenue stream for mills
    - Fossil fuel replacement
    - Increased pulp production



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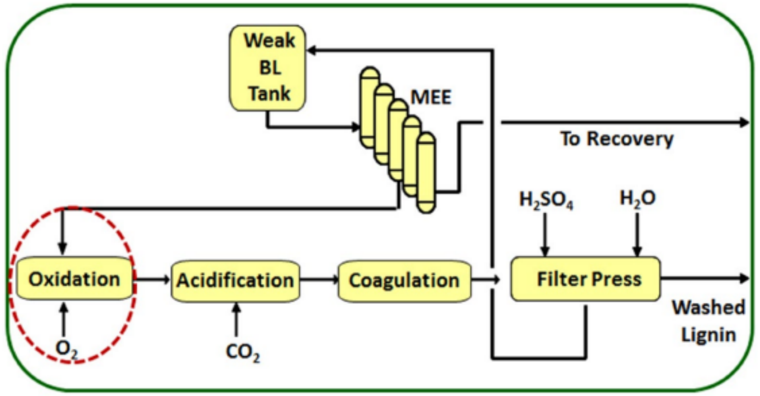
LignoForce™ Process

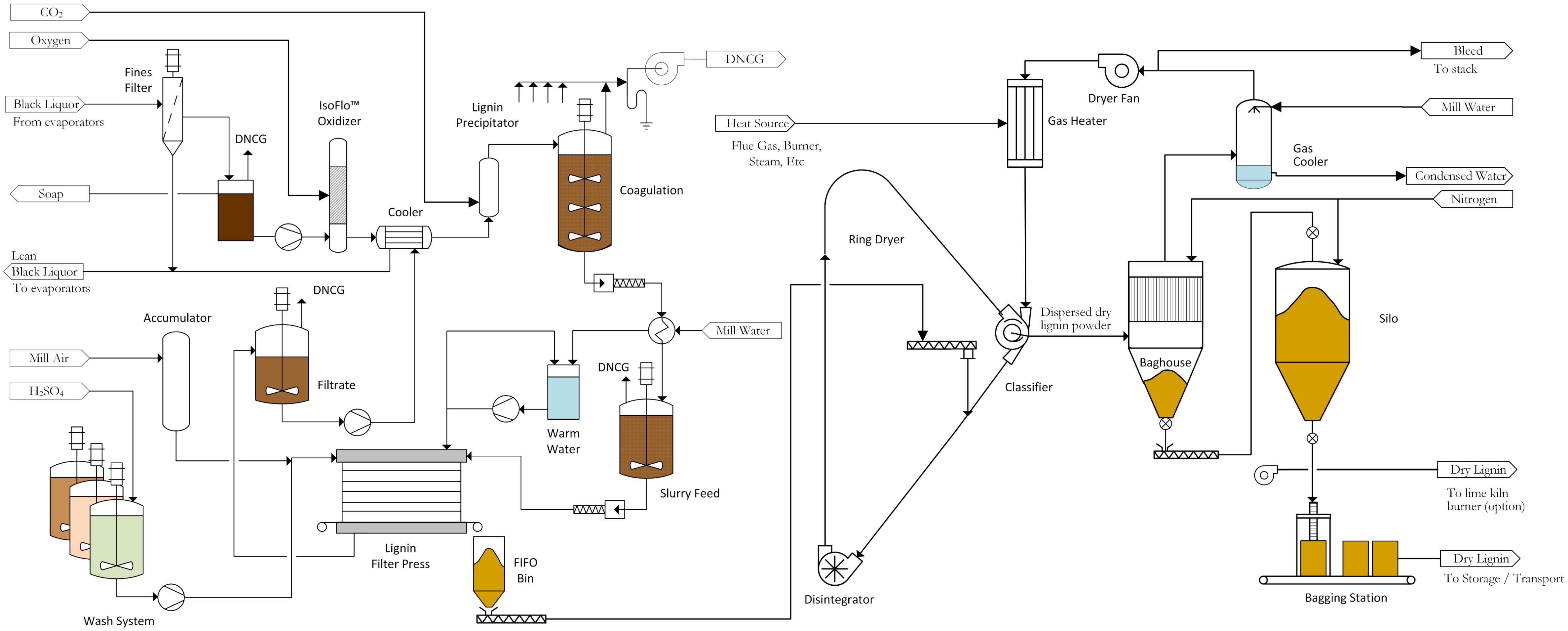
Advantages

- Eliminates H_2S emissions
- Reduces product odour/VOC
- Reduces CO_2 consumption
- Improves filtration rates
- Low ash content



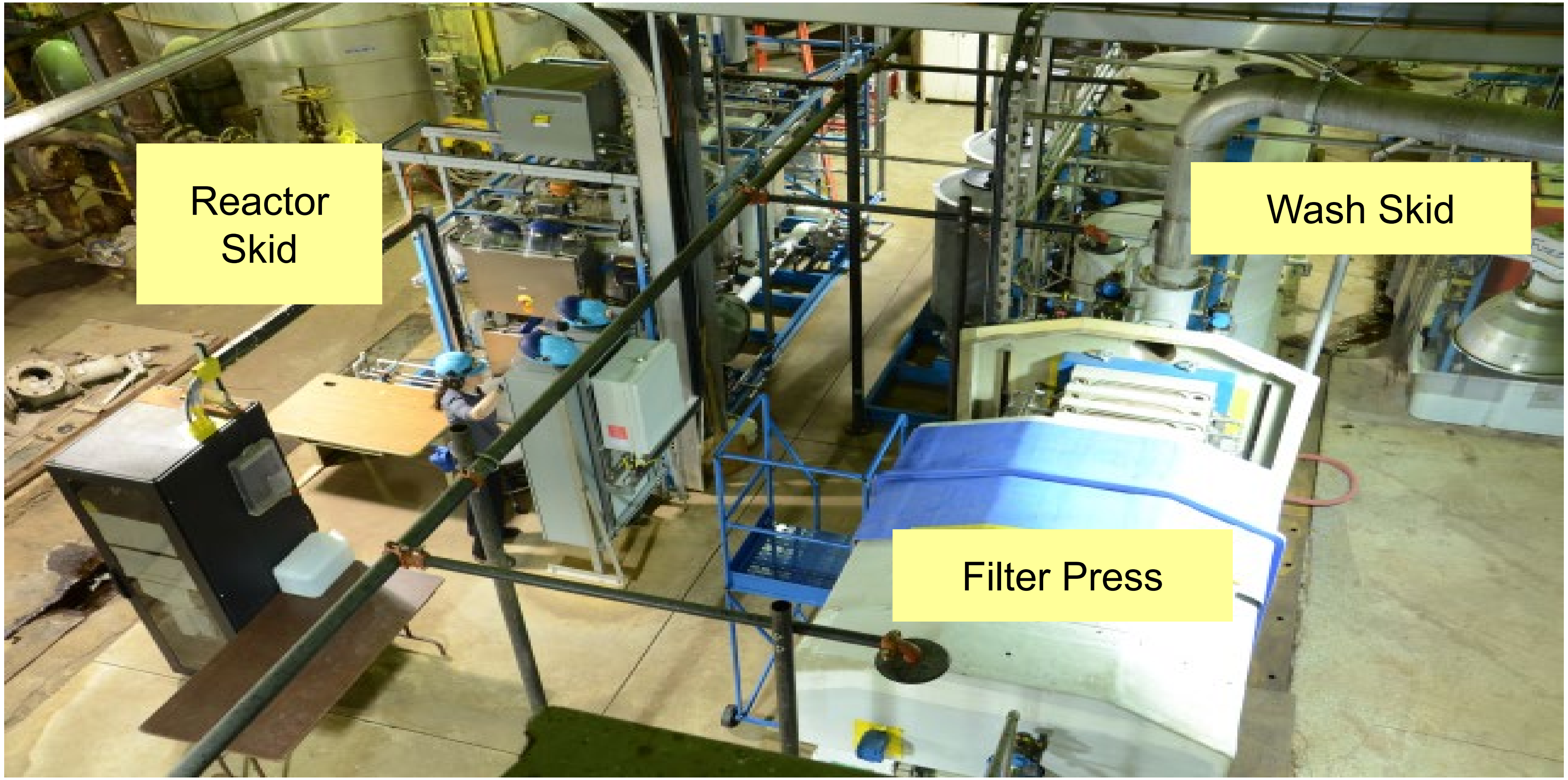
LignoForce™ Process

Overall Flowsheet



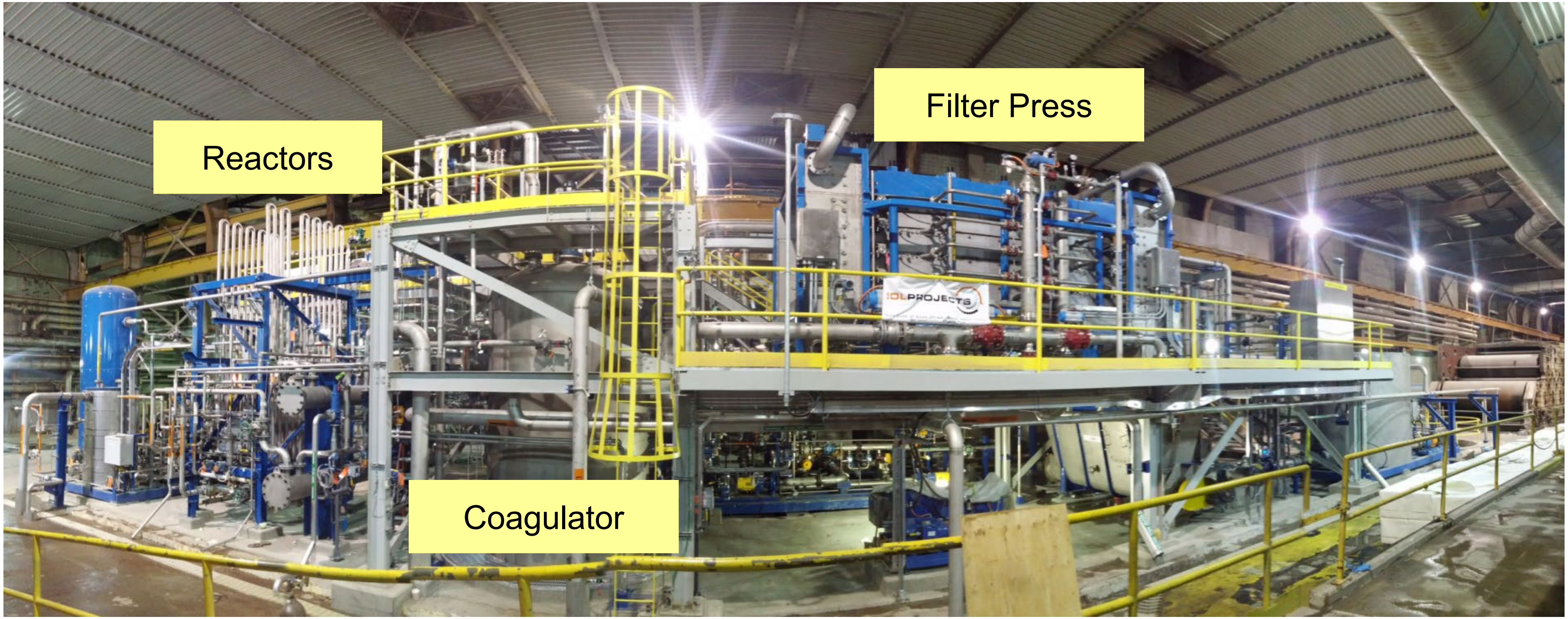
LignoForce™ Pilot Plant

Installed 2011, Thunder Bay, Ontario



Full Scale 30 TPD LignoForce™ Plant

Commissioned 2016 at West Fraser, Hinton, AB



Effects on Kraft Mills

Based on a 50 MTPD Lignin Plant in a 1000 MTPD Mill

- Reduction in black liquor heating value
- Potential pulp production increase
- Evaporator load increased
- Steam production decreased
- Hot water production
- Mill sodium: sulfur balance
- Estimated energy consumption

NORAM

Effects on Mill

Recovery Boiler

- Lignin removal reduces the black liquor heating value.
- Lower heating value of liquor allows more black liquor to be burned in recovery boiler, allowing for more pulp production.
- Assuming a typical black liquor HHV of 15 MJ/kg (6450 Btu/lb):
  - Removing 50 TPD lignin reduces the black liquor HHV by 2%.
  - Additional 46 TPD pulp can be produced to maintain the heat input to the recovery boiler.
  - The black liquor solids firing rate will be increased by 2%.
- The limits on solids firing rate, digester and other process bottlenecks need to be evaluated.

Effects on Mill

Evaporators

- The water added for lignin washing is returned with the black liquor filtrate increasing the steam required in the evaporators.
- For a 50 TPD LignoForce Plant:
  - 500 LPM of 26% black liquor is removed from evaporator train.
  - 600 LPM of 20% black liquor is returned to the evaporators.
  - Additional 1.6 tonnes/hr steam is required based on a steam economy of 5.
- Additional evaporator load from increased pulp production should be considered.
- Heat released in black liquor oxidation can be used to reheat the black liquor filtrate returned to weak black liquor or evaporators.
  - 700 KJ/s heat is generated from a 5% Na_2S content in black liquor solids.
  - The heat released can save 1.2 tonnes/hr LP steam.

Effects on Mill

Steam

- Reduction in black liquor HHV reduces steam generation.
- Increased black liquor feed can maintain the heat load, but increased pulp production increases steam demand.
- Additional steam needs to be generated in power boiler(s):
  - To offset any reduction in steam generation from the recovery boiler.
  - To meet the increased demand from additional pulp production and water load to the evaporators.
  - To heat up the inert gas used in the lignin drying process.
- Impacts on electrical energy generation need to be evaluated.

Effects on Mill

Mill Water / Heat Reuse for a 50 TPD LignoForce Plant

- Mill has the option to use part of the heat released during oxidation to heat mill water.
- Mill water used to cool black liquor slurry to filtration temperature, heated to warm water temperature.
- Warm water used for lignin washing, filter press cloth washing, and to cool oxidized black liquor to precipitation temperature.
- Hot water is returned to mill at ~75°C.
- The hot water produced can offset steam that may otherwise be required to heat mill warm water to higher temperatures.

Effects on Mill

Sodium Sulfur Balance

- Sulfuric acid used for washing adds sulfur.
- Net addition to recovery is 2.3 kg S/MT pulp for high purity lignin.
- A common practice is to sewer sodium sesquisulfate, $Na_3H(SO_4)_2$, from ClO_2 generator to maintain the sodium: sulfur balance.
    - 9.4 kg/ton pulp sesquisulfate needs to be purged.
    - 2.5 kg/ton pulp Na will be purged with sesqui.
    - 4.3 kg/ton pulp makeup NaOH is required.
- An NCG-Acid plant converting NCGs and sulfur to sulfuric acid and producing 3 tonnes/hr of high-pressure steam could be used to address the excess sulfur and eliminate the need for purging.

Effects on Mill

Estimated Energy Consumption of a 50 TPD Plant

- The electrical energy consumption to produce wet lignin (60% solids):
  - 430 kW of total installed power
  - 170 kW of average operating power

- The electrical energy consumption of the equipment in the drying process:
  - 216 kW of total installed power
  - 175 kW of average operating power

- ~1.7MW of thermal energy (equivalent to 3 tonnes/h LP steam) is added to the inert N_2 in the drying loop. The source of that heat can be hot flue gas, steam, natural gas.

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Effects on Mill

Summary

- Impact on Recovery Boiler
  - Reduces black liquor calorific value, allows more black liquor to be burned and more pulp to be produced.
- Impact on Evaporators
  - More steam required to evaporate the water load from the lignin plant.
- Impact on Steam/Power Generation
  - More natural gas required for the increased steam demand.
  - Potential reduction in electrical energy generation.
- Impact on Mill Sodium: Sulfur Balance
  - Net addition to recovery is 2.3 kg S/MT pulp for high purity lignin.
  - Additional sodium makeup chemical required.
- Energy Consumption
  - 350 kW of operating power and 1.7 MW of thermal energy needed to produce 50 TPD dry lignin.

NORAM

Questions?

Email: smostafavi@noram-eng.com

NORAM Engineering and Constructors Ltd.

AUTOMATION AND DIGITALIZATION

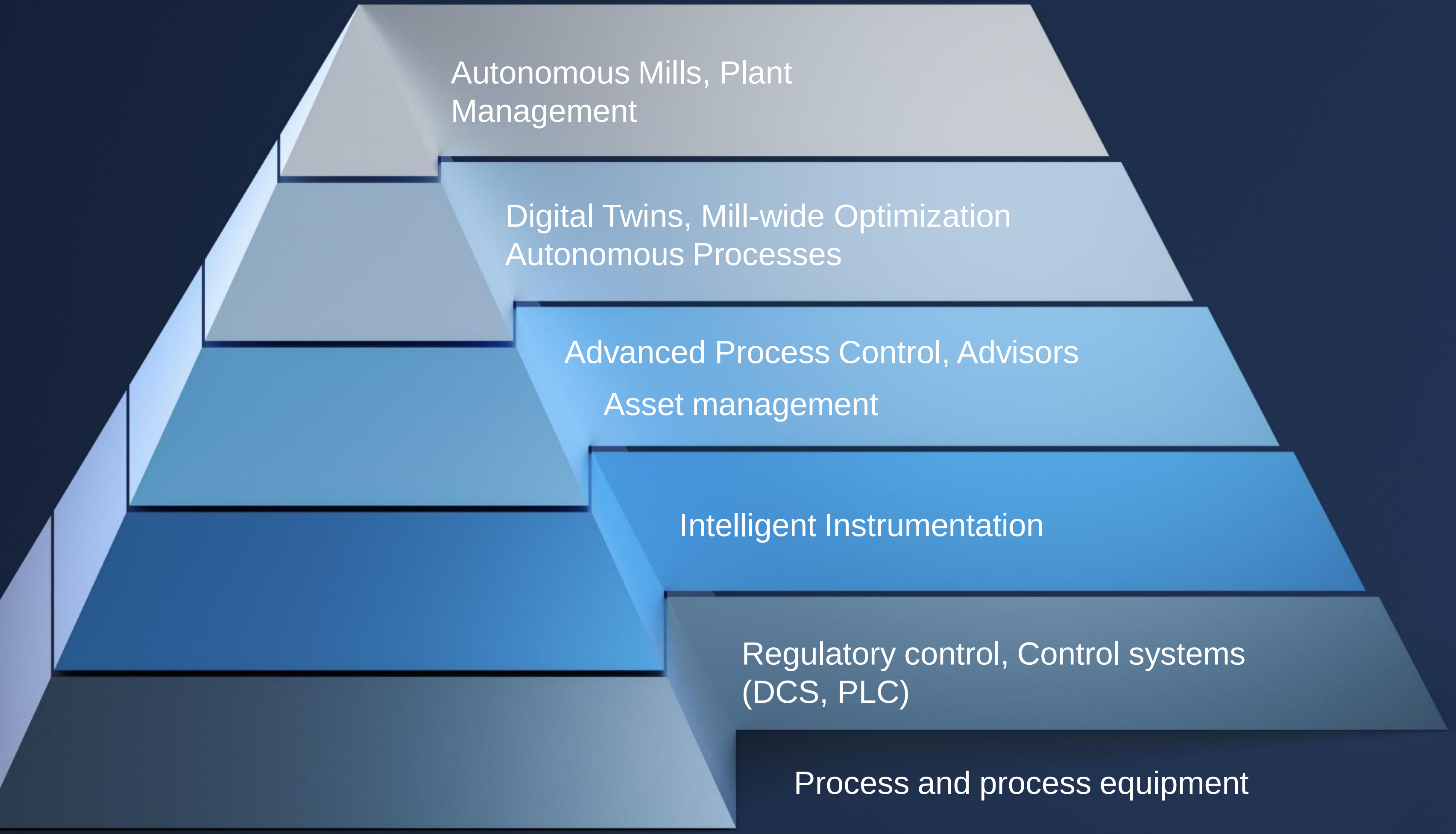
SMART PRODUCT TECHNOLOGY

AF&PA – FEBRUARY 2025

ANDRITZ

ENGINEERED SUCCESS

AUTOMATION AND DIGITALIZATION PYRAMID



Metris
ANDRITZ Digital Solutions

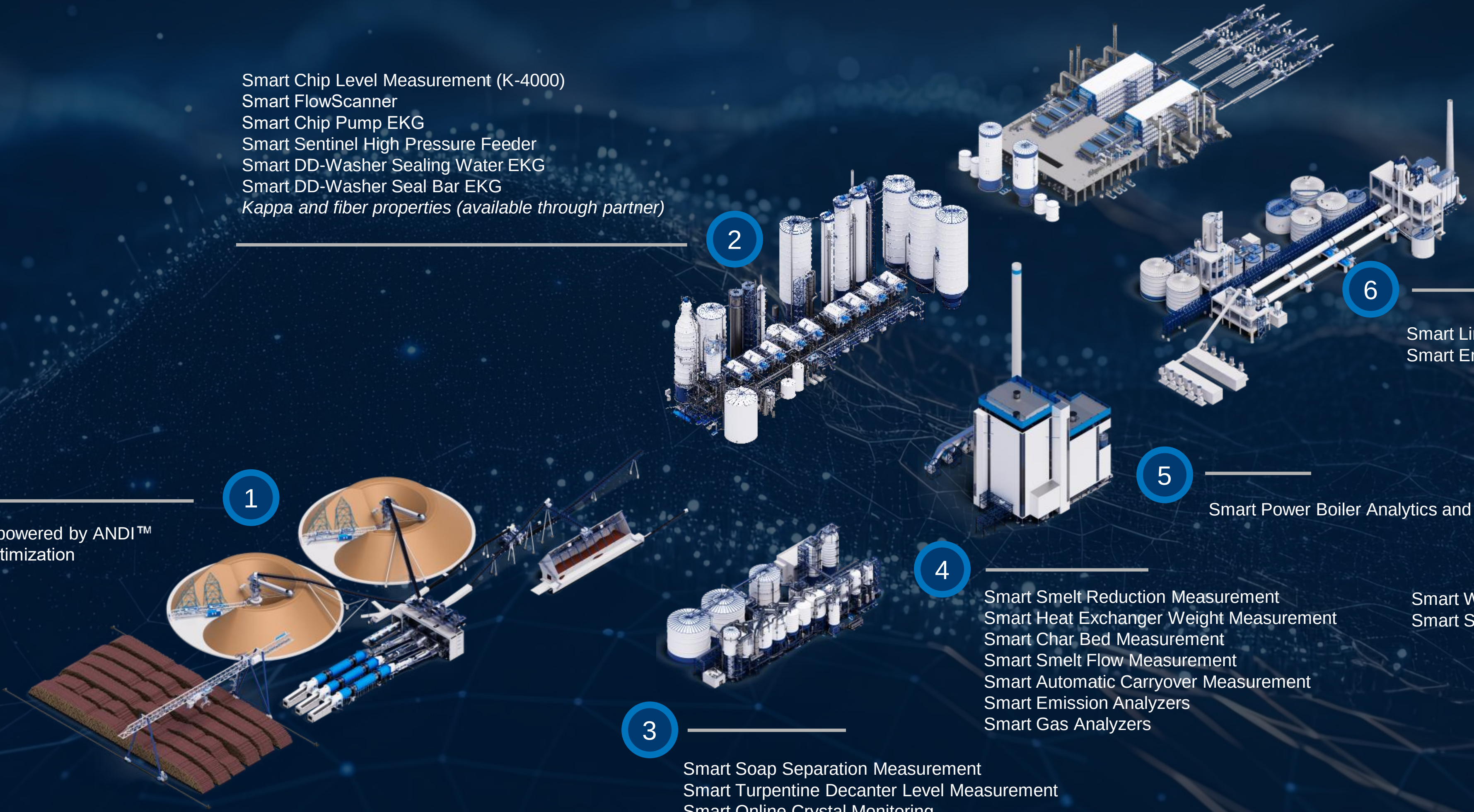
Smart Series
ANDRITZ Intelligent Instruments

ANDRITZ Automation
Electrification & Instrumentation

ANDRITZ Pulp & Paper

SMART SERIES

1 WOOD PROCESSING
2 FIBERLINE
3 EVAPORATION PLANT
4 RECOVERY BOILER
5 POWER BOILER
6 WHITE LIQUOR PLANT
+ Decision Support Wall



2
Smart Chip Level Measurement (K-4000)
Smart FlowScanner
Smart Chip Pump EKG
Smart Sentinel High Pressure Feeder
Smart DD-Washer Sealing Water EKG
Smart DD-Washer Seal Bar EKG
Kappa and fiber properties (available through partner)

6
Smart LimeDry Solids Analyzer
Smart Emission Analyzers

5
Smart Power Boiler Analytics and Monitoring - BOA

1
Smart Autonomous Logyard powered by ANDI™
Smart Woodyard Process Optimization
Smart Log SCAN
Smart Bark SCAN
Smart Scan Chip Analyzer
Smart Chipper EKG
Smart Crusher EKG

4
Smart Smelt Reduction Measurement
Smart Heat Exchanger Weight Measurement
Smart Char Bed Measurement
Smart Smelt Flow Measurement
Smart Automatic Carryover Measurement
Smart Emission Analyzers
Smart Gas Analyzers

Smart Water Leakage Advisor
Smart Smelt Spout Robot

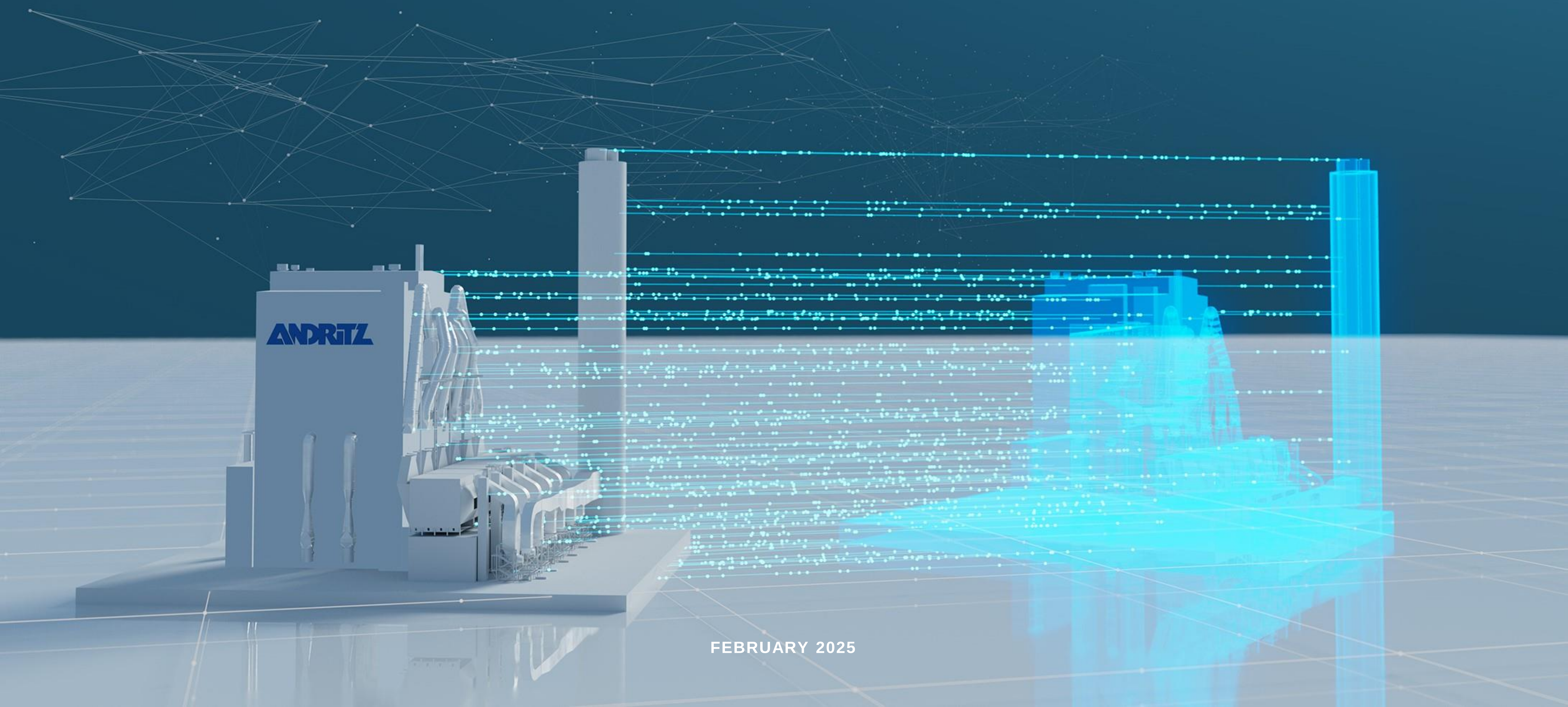
3
Smart Soap Separation Measurement
Smart Turpentine Decanter Level Measurement
Smart Online Crystal Monitoring

AF&PA – 2/5/25 Agenda

- Smart Smelt Reduction Measurement
- Smart Char Bed Measurement
- Smart Smelt Flow Measurement
- Smart Automatic Carryover Measurement
- Automated Shatter Jet Adjusters

  (future Smart product)

SMART SMELT REDUCTION MEASUREMENT



FEBRUARY 2025

SMART SMELT REDUCTION MEASUREMENT

BENEFITS

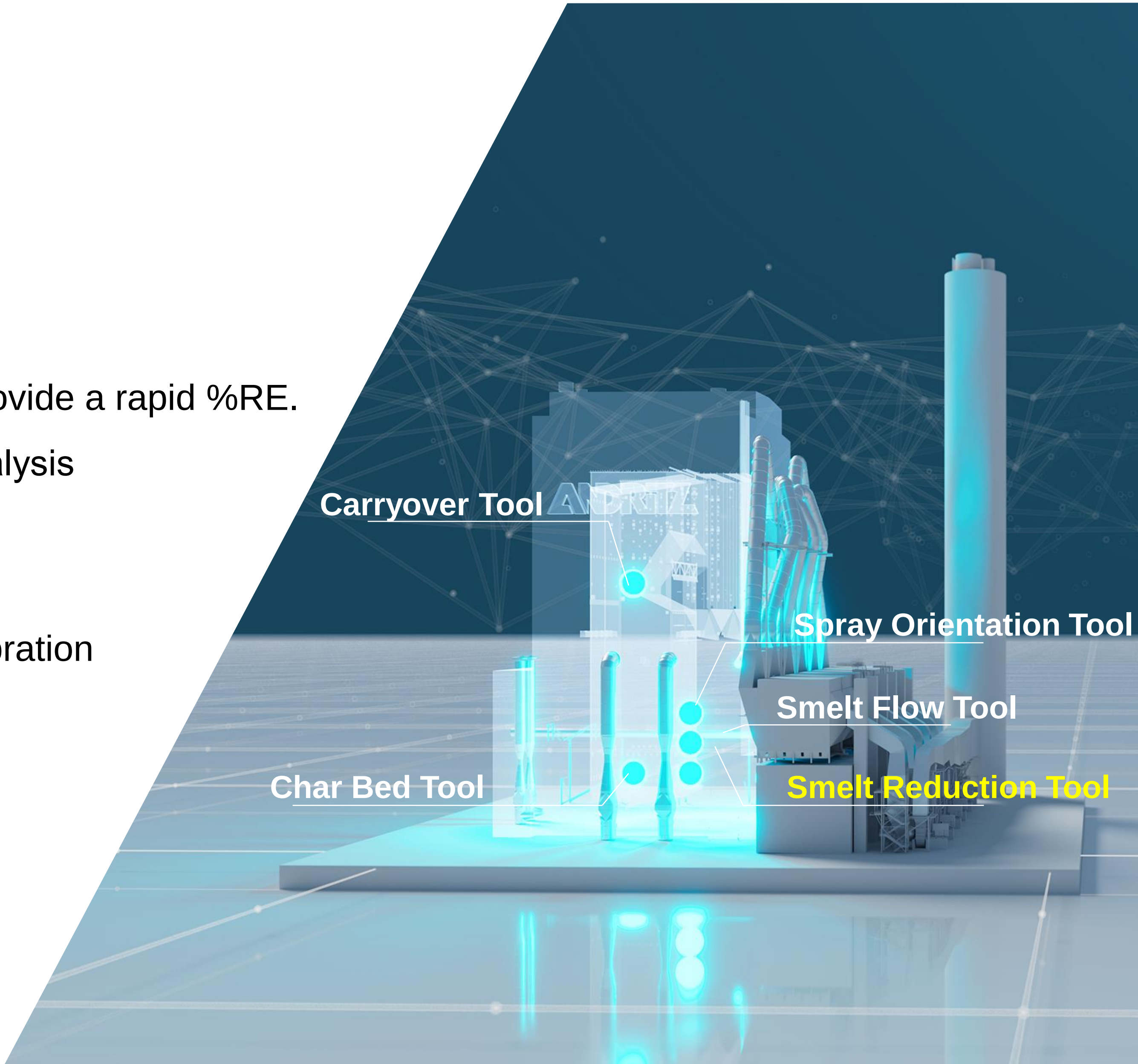
- Improves Productivity
- Reduces Operating Costs

WHAT IT IS

- Digital visual analysis of smelt sample to provide a rapid %RE.
- AVA logs the results for future trending / analysis

FUNCTION

- Manual testing is input by operator for calibration
- Possible to automate sampling with Robot



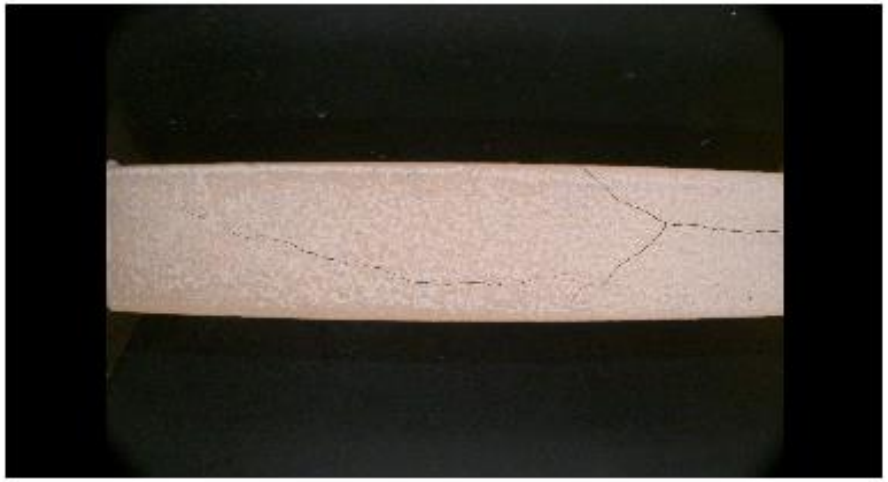
SMART SMELT REDUCTION MEASUREMENT

Video of sample collection / analysis with robot

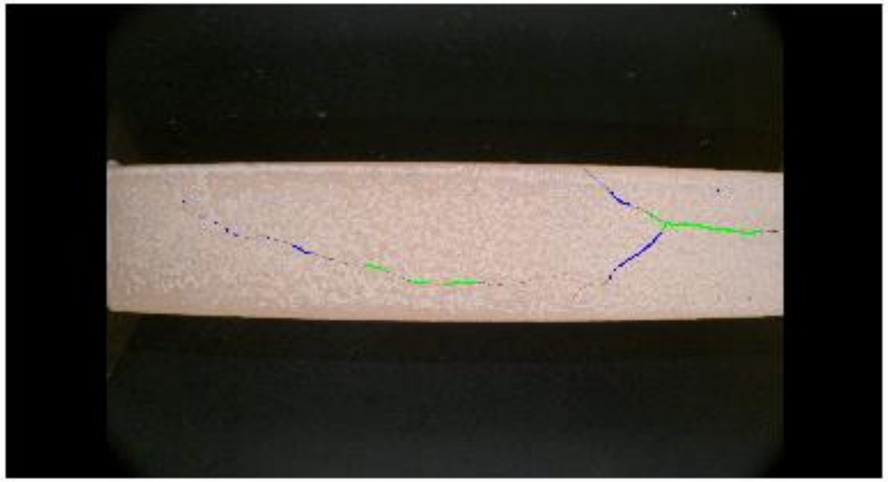
SMART SMELT REDUCTION MEASUREMENT

EXAMPLE PRE/POST ANALYSIS

Original



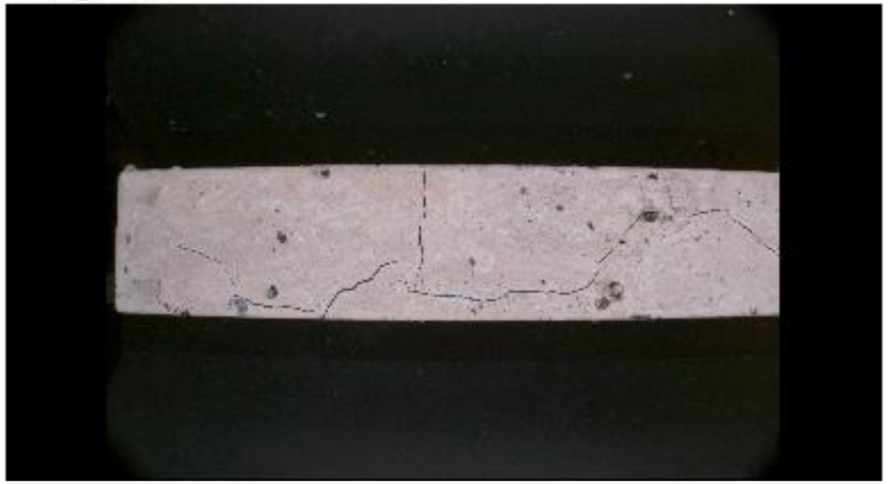
Analyzed



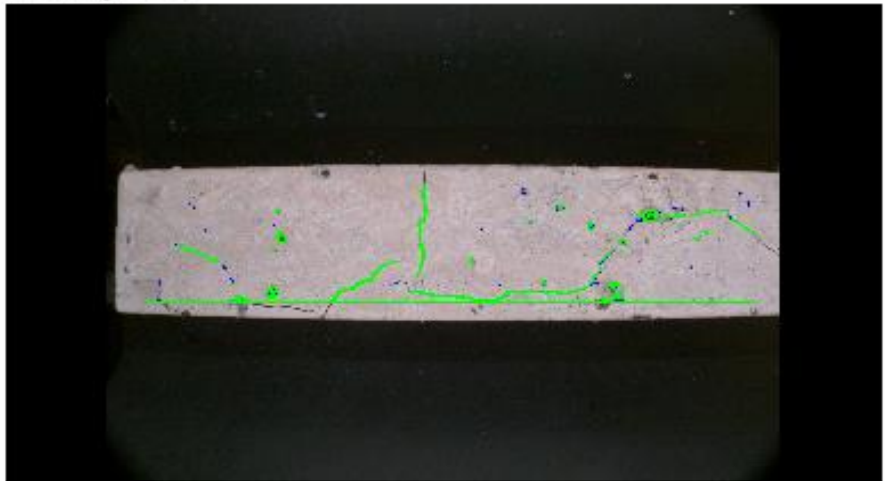
Result

Reduction 76.86%

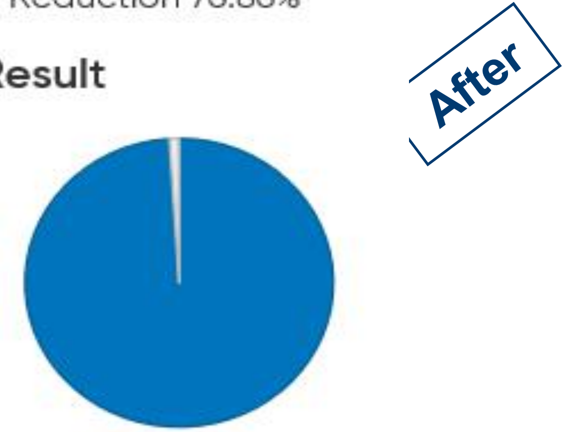
Original



Analyzed



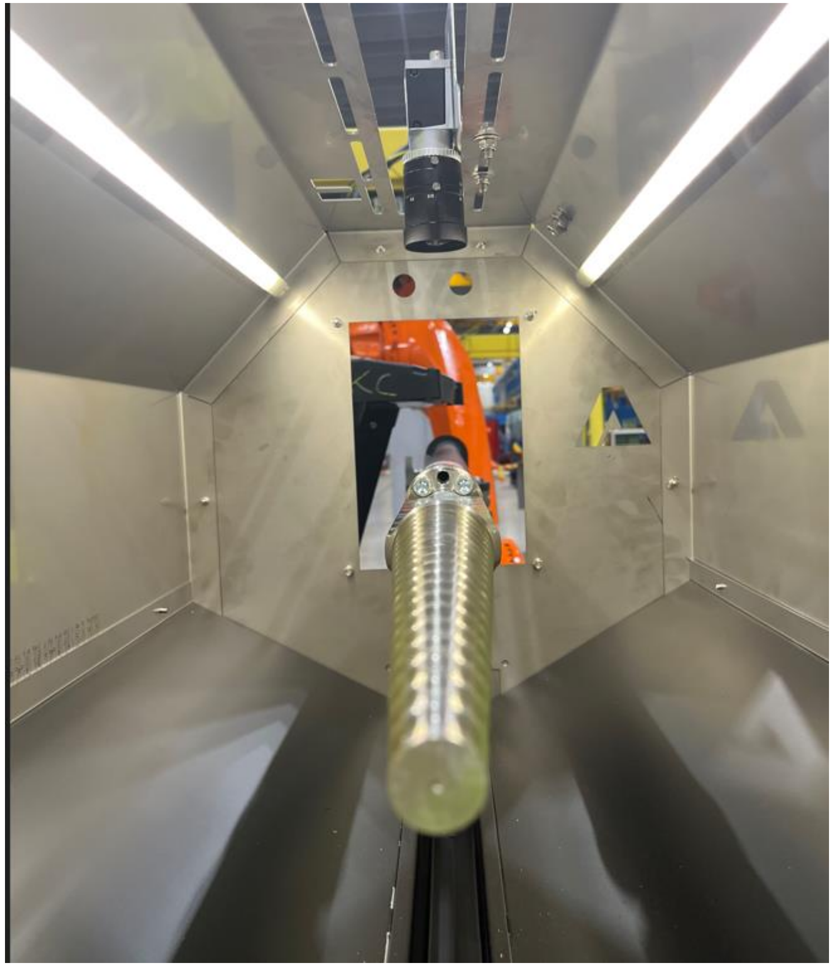
Result

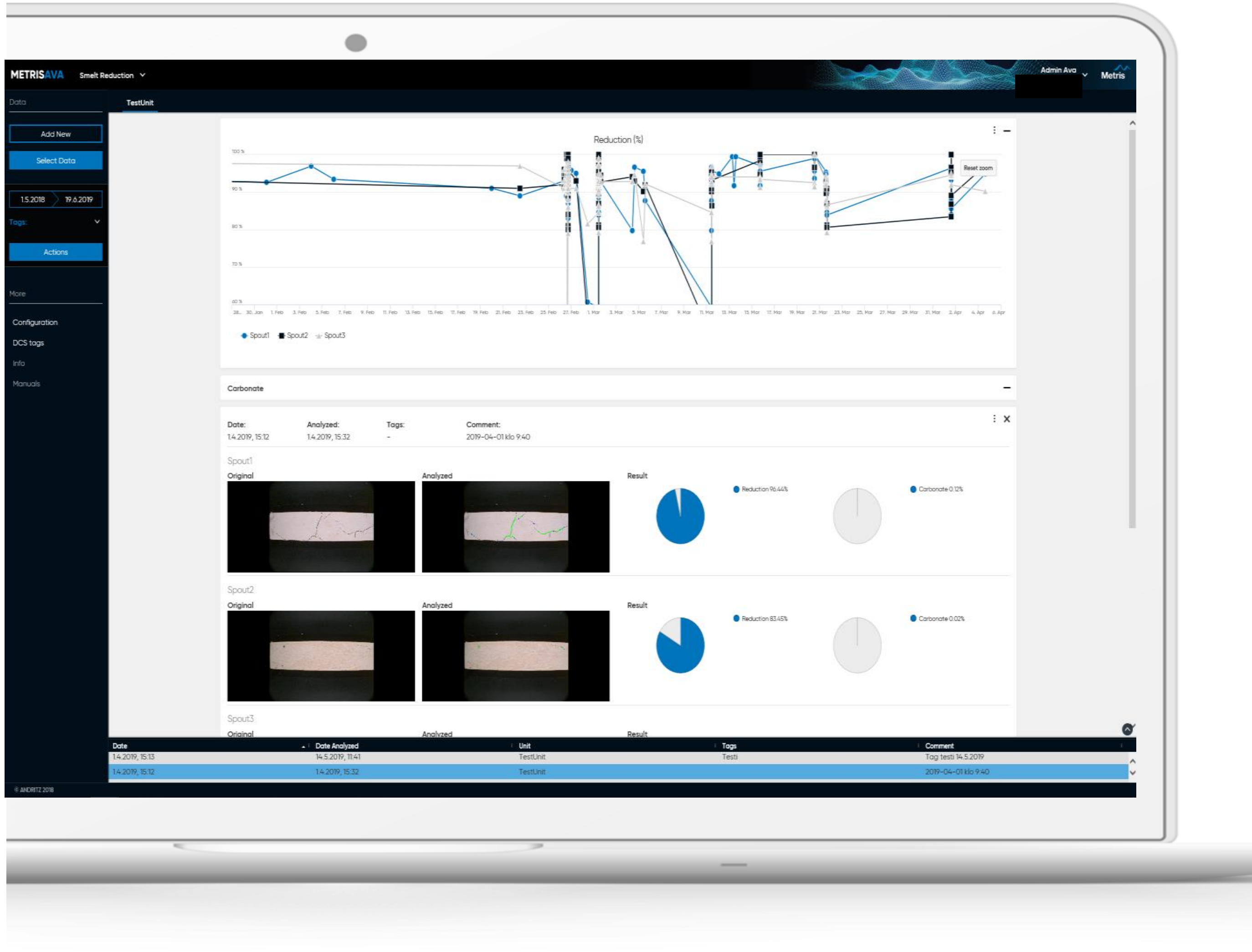


Reduction 98.99%

SMART SMELT REDUCTION MEASUREMENT

SMART %RE ANALYSIS





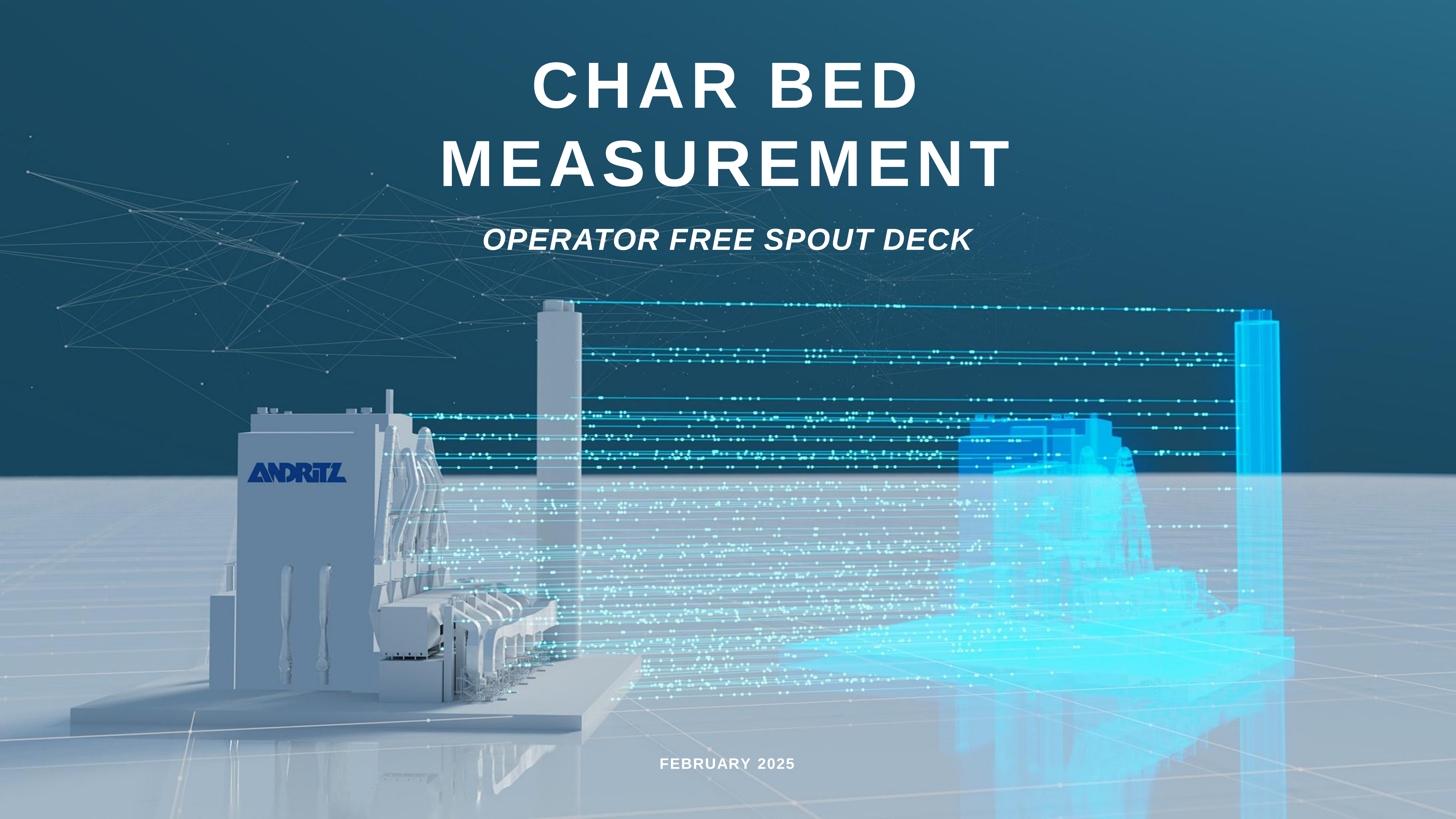
AVA JUSTIFICATION – REDUCTION EFFICIENCY EX.

Mill B operates at **3.7mmlbs/day** with a Reduction Efficiency averaging around **88%**.
The mill can achieve Reduction Efficiency of **96%+**, but results are not sustained.
Operators typically operate to 4% excess O_2 due to fear of “black-out” conditions.

WL Mass Flow Digester Heat Input	(10klb/hr) (1.29MMBtu/hr) (693 Tonne CO_2/yr)	→ $65,900	RE = +8%
Evap Mass Flow Evap Heat Input	(25klb/hr) (4.6MMBtu/hr) (2,473 Tonne CO_2/yr)	→ $233,400	<u>$706,300/yr</u>
Excess Oxygen @ Stack Boiler Steaming Rate	(1.5%) +5.3kpph (2,898 Tonne CO_2/yr)	→ $309,300	
FD / ID Fan Loads	(1,396MWh)	→ $97,700	

CHAR BED MEASUREMENT

OPERATOR FREE SPOUT DECK



FEBRUARY 2025

SMART CHAR BED MEASUREMENT

SMART SOLUTIONS

BENEFITS

- Improve safety
- Improve process stability

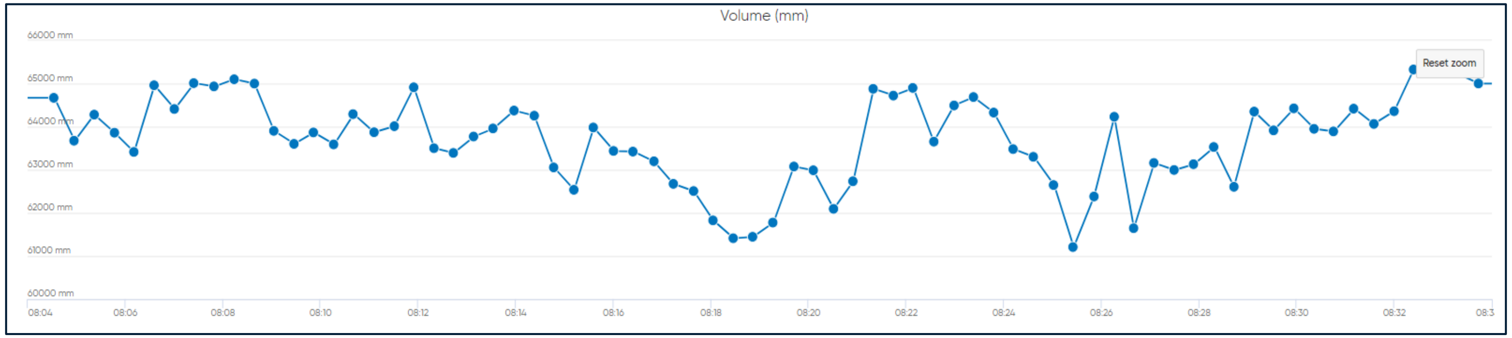
WHAT IT IS

- Digital visual analysis of char bed volume, highest point, and 3D model

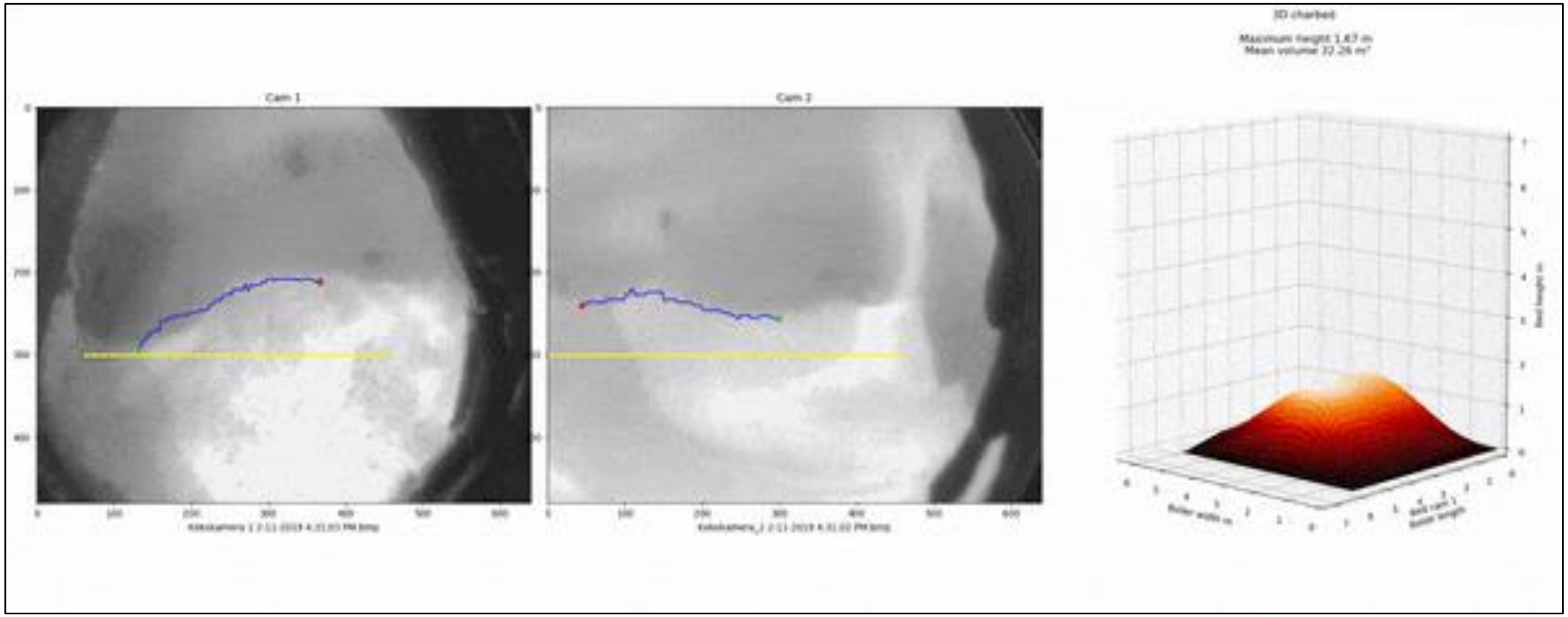
FUNCTION

- Two (2) functional bed cameras are used to map the boiler floor and provide data (any style bed camera)
- Provides information for RB tuning by operator
- Can be integrated into Advanced Control Expert (A

AVA CHAR BED ANALYZER
OPERATOR FREE SPOUT DECK

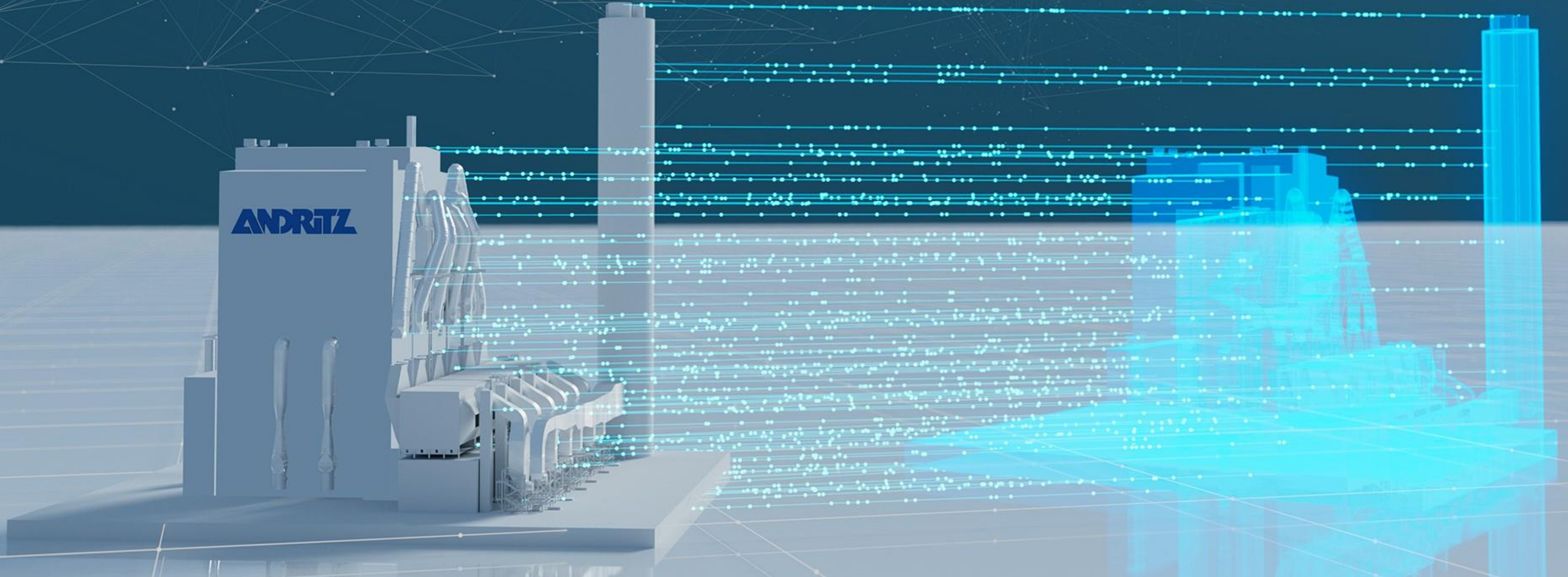


- Uses the mill's existing bed cameras
- Real time 3-D model
- Calculates variables such as bed volume and bed height
- Feedback to the DCS for operator alarming.



SMART SMELT FLOW MEASUREMENT

OPERATOR FREE SPOUT DECK



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SMART SMELT FLOW MEASUREMENT

SMART SOLUTIONS

BENEFITS

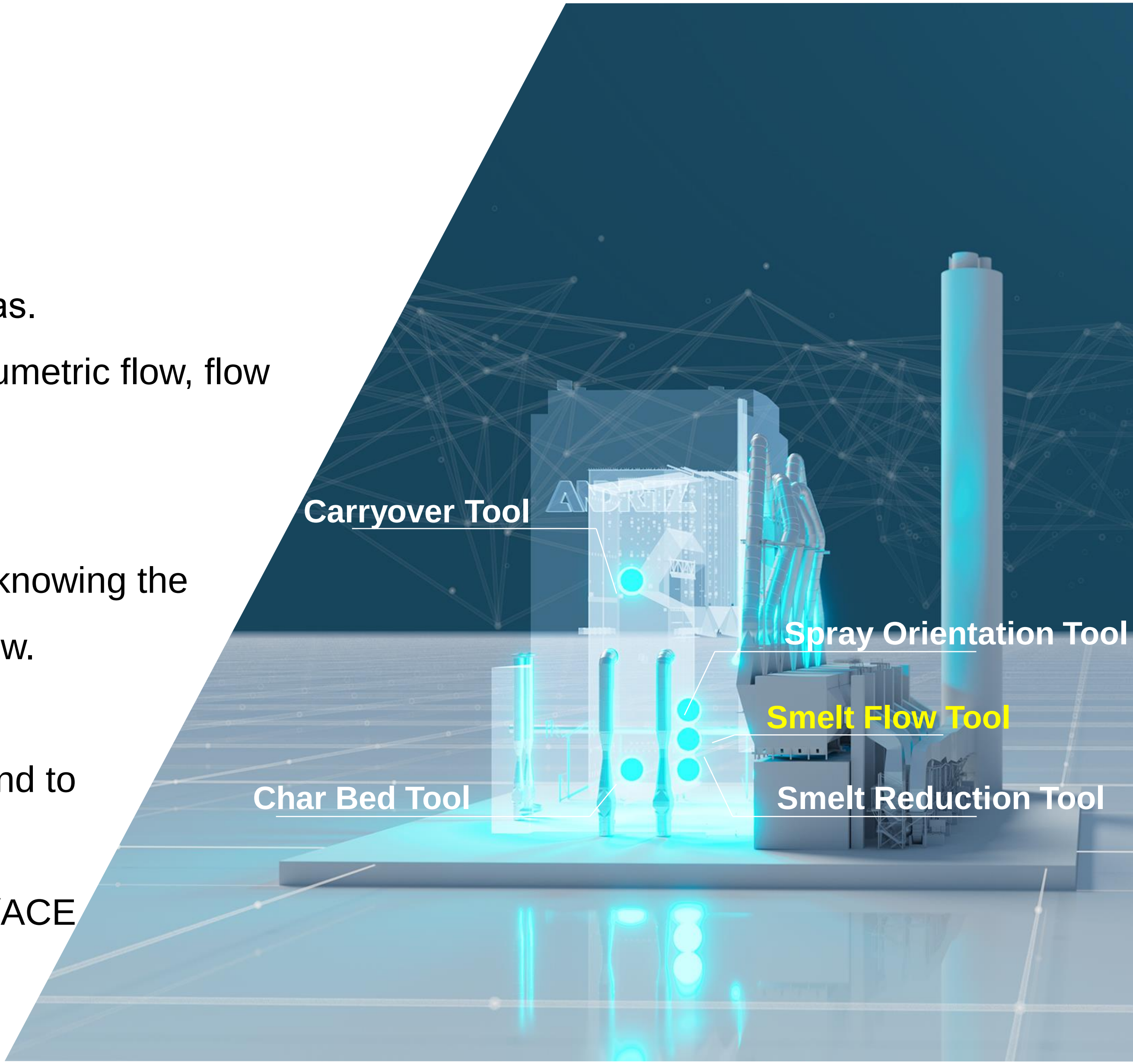
- Improve safety
- Improved controls

WHAT IT IS

- Visual analysis of mill's smelt flow cameras.
- Provides variables like smelt velocity, volumetric flow, flow width and fouling factor.

FUNCTION

- Camera analytics tracks velocity of smelt, knowing the spout shape / design, can correlate to a flow.
- Provides information for operator alarming
- Has been used to automate hood doors, and to prioritize a robot's cleaning sequence
- Can be used as an input for TTA control w/ACE
- *Spout orifice monitoring in development*



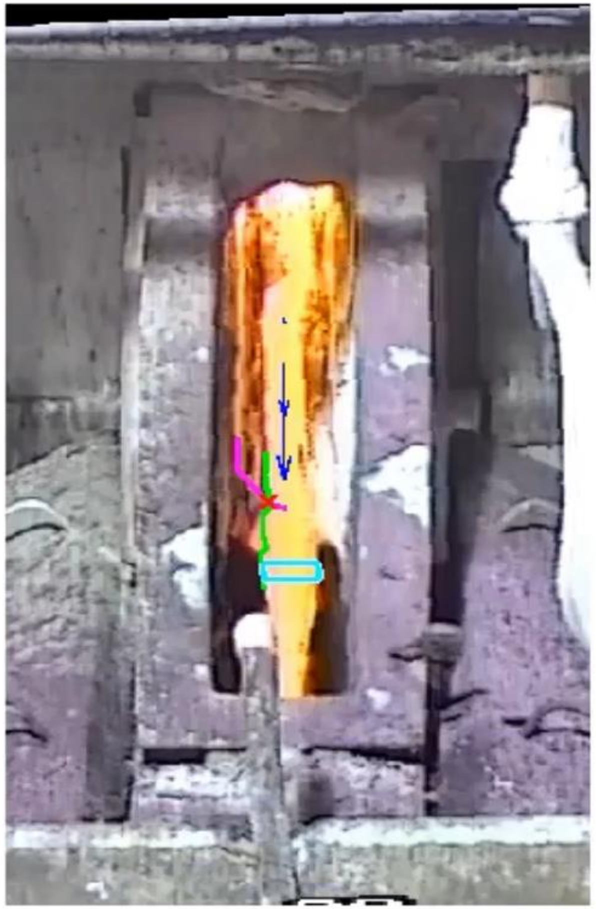
SMART SMELT FLOW MEASUREMENT

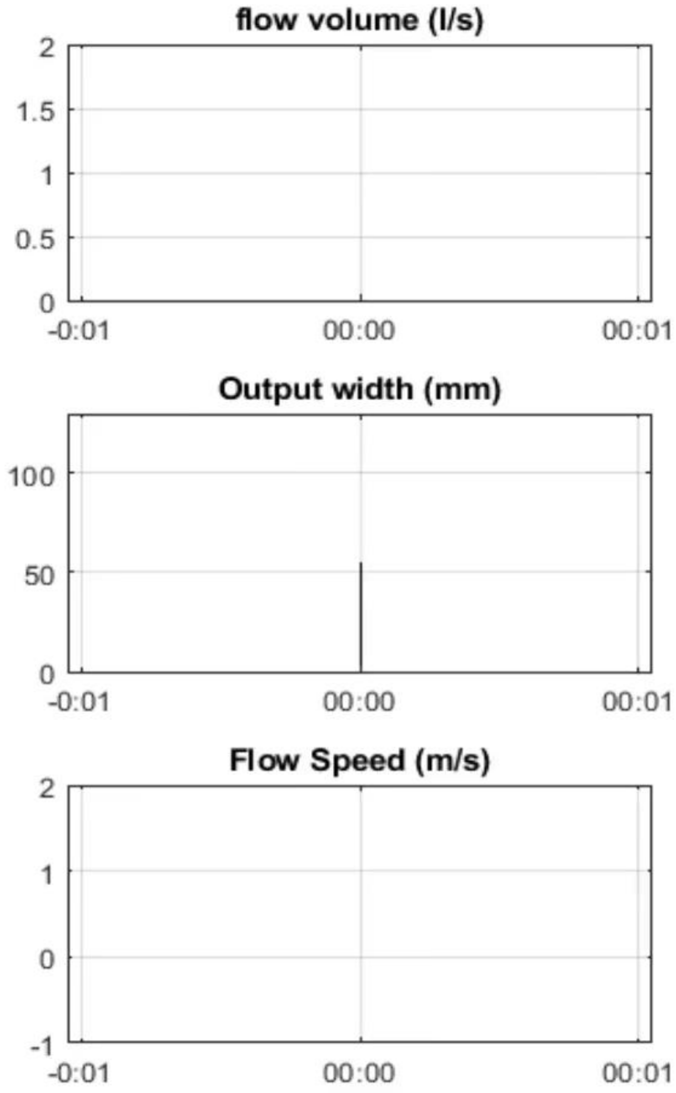
Camera requirements

- Quality resolution

- Focused / fixed view to include
  - Spout orifice
  - Spout trough (full length)
  - Tip of spout and slightly beyond

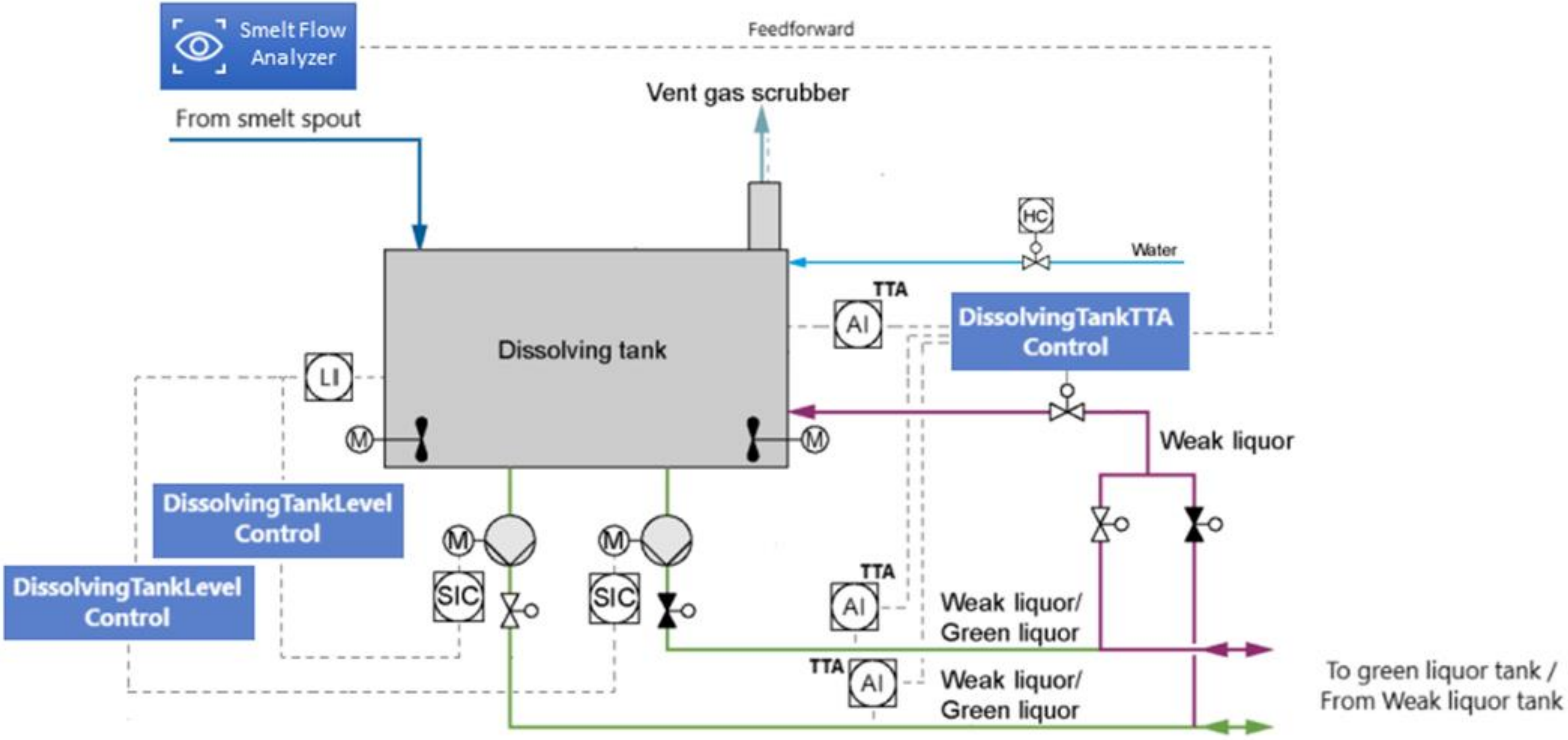
SMART SMELT FLOW MEASUREMENT





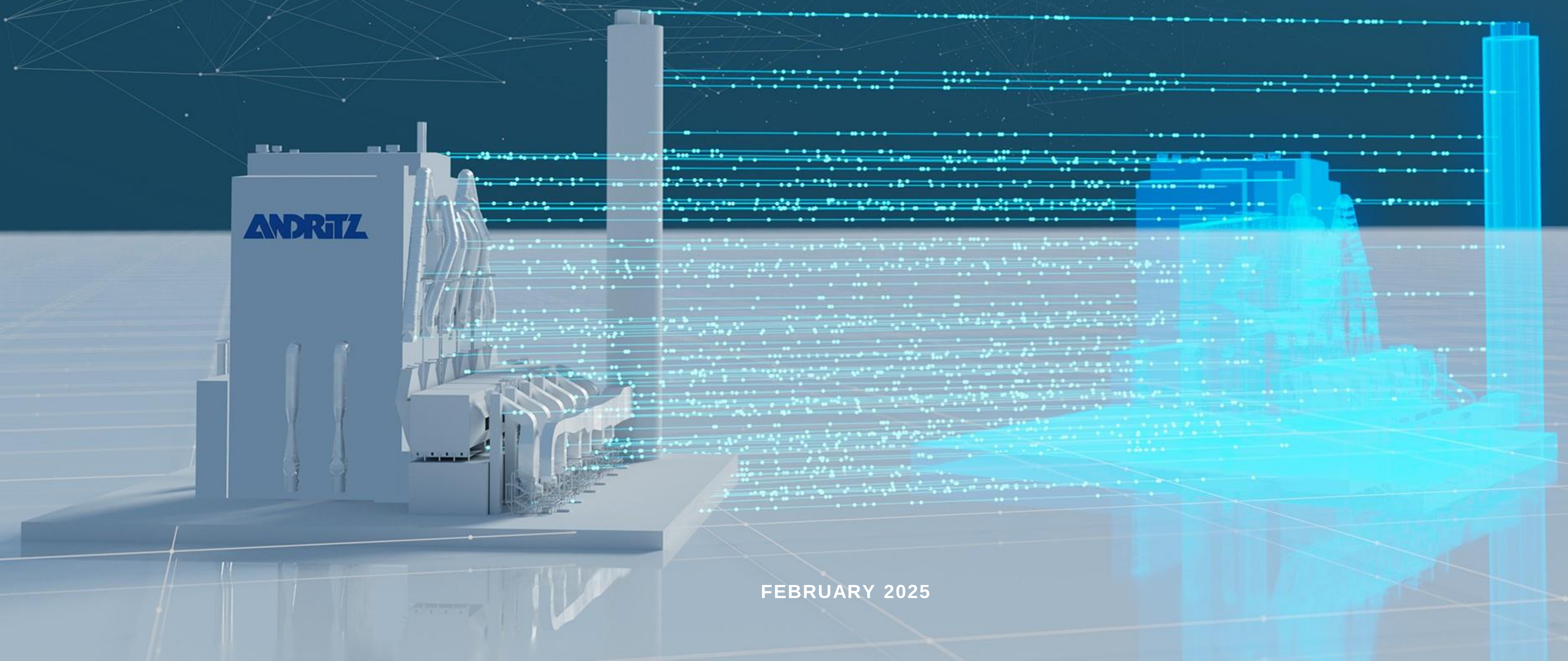
COMBUSTION ACE

DISSOLVING TANK TTA CONTROL



SMART CARRYOVER MEASUREMENT

OPERATOR FREE SPOUT DECK



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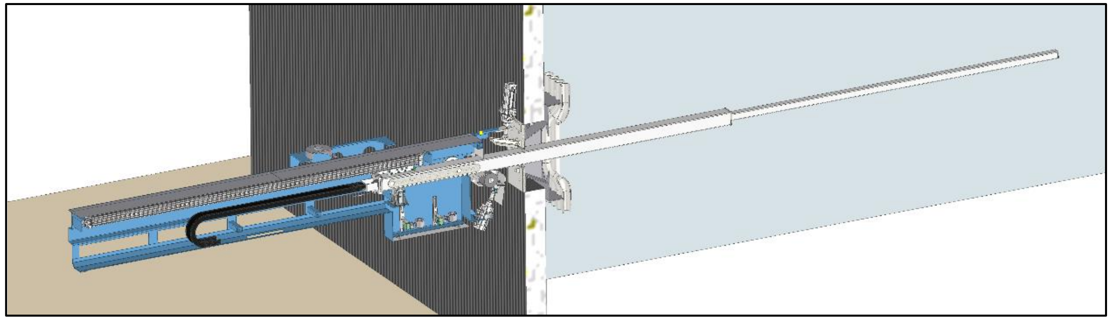
CARRYOVER IN RECOVERY BOILER

From Manual Sampling to Automatically Sampling

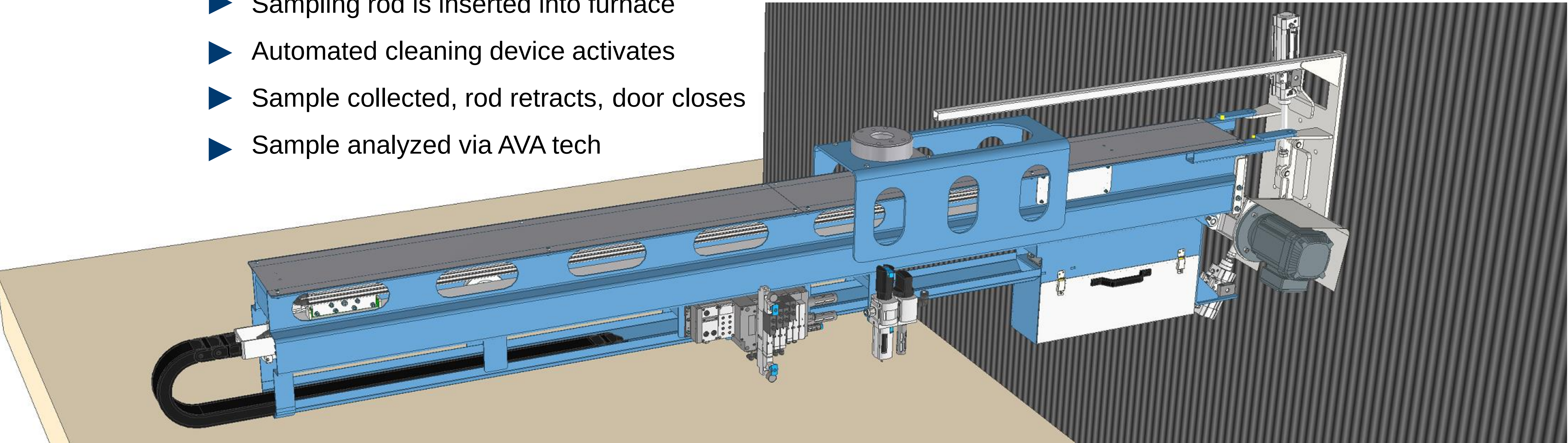
BENEFITS

- Improve Safety
- Improved monitoring / tracking
- Improved tuning



FUNCTION

- Piston actuated door opens
- Sampling rod is inserted into furnace
- Automated cleaning device activates
- Sample collected, rod retracts, door closes
- Sample analyzed via AVA tech



AUTOMATIC CARRY-OVER MEASUREMENT (ACM)

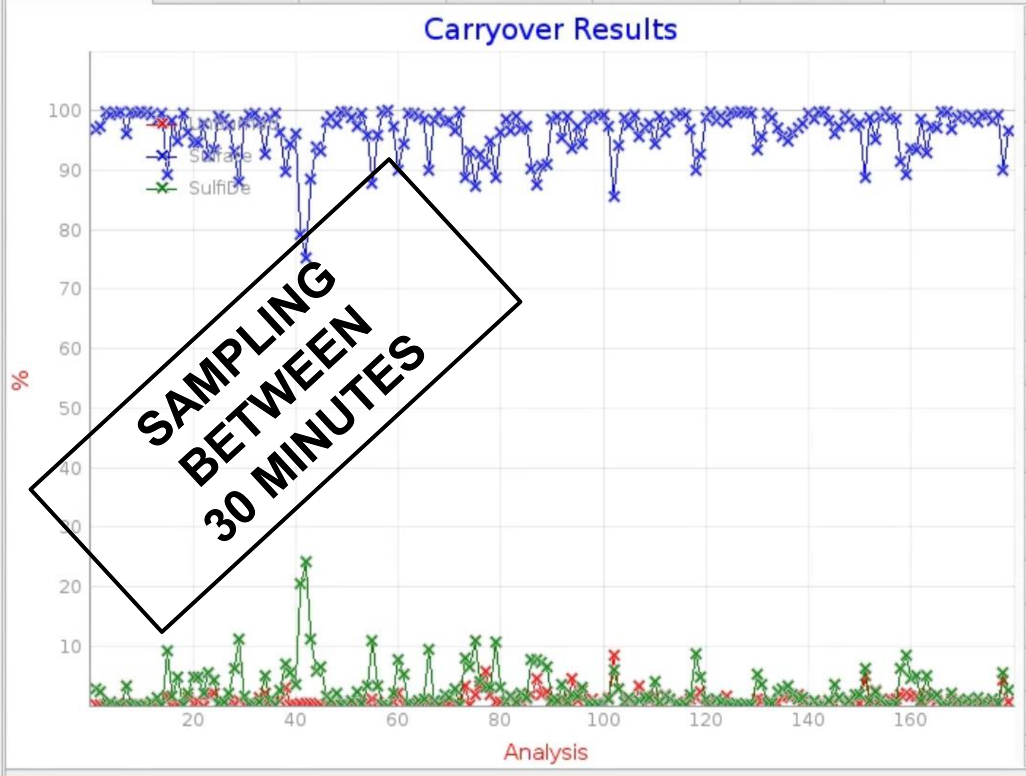
A C M - Automatic Carryover Measurement

08:57:00: Measurement Complete
09:18:37: Taking picture
09:18:57: Measurement Complete

TIME UNTIL NEXT MEASUREMENT: MEASUREMENT PAUSE
COOLING TIMER: WAITING FOR COOLING TIMER
PICTURE TIMER: NOT WAITING

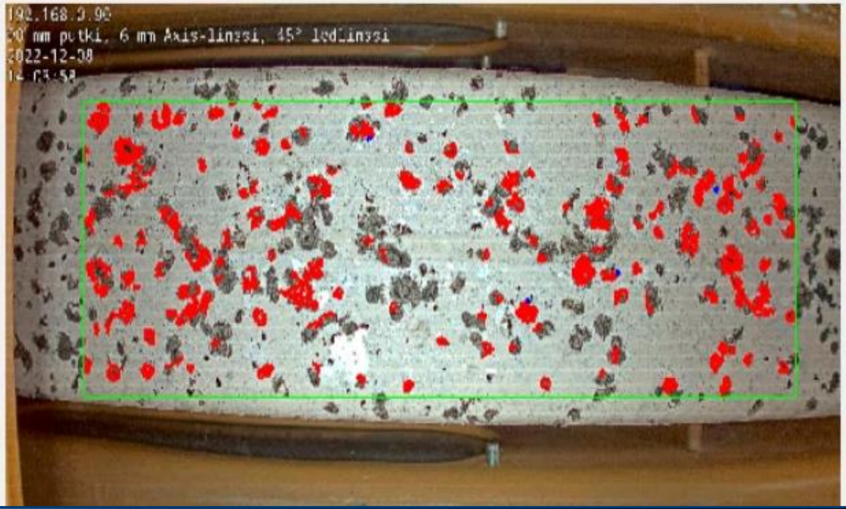
Measurement | Results | Log | Configuration | Tester

ACM 1 Front | ACM 1 Back | ACM 2 Front | ACM 2 Back | ACM 3 Front | ACM 3 Back



	sulfide	ınburne	Other
1	2.57	0.7	96.73
2	5.64	4.38	89.98
3	0.49	0.26	99.25
4	1.26	0.41	98.33
5	0.15	0.47	99.38
6	0.55	0.11	99.34
7	1.44	0.51	98.05
8	0.78	0.07	99.15
9	1.22	0.18	98.6
10	0.47	0.22	99.31
11	0.89	0.37	98.74
12	2.04	1.07	96.89
13	0.02	0.24	99.74
14	0.19	0.05	99.76
15	1.9	0.87	97.23
16	1.54	1.09	97.37

LATEST ANALYSIS	08.12.2022 14:04:14
unburned	0.03
Sulfide	5.11
Other	94.86



AVA ACM

Technical details

Compact design

- Easy and fast start-up
  - Adapter plate to boiler opening enabling installation during boiler normal operation
- Machine safety integrated into design
  - Small free space requirement

Interface points during installation

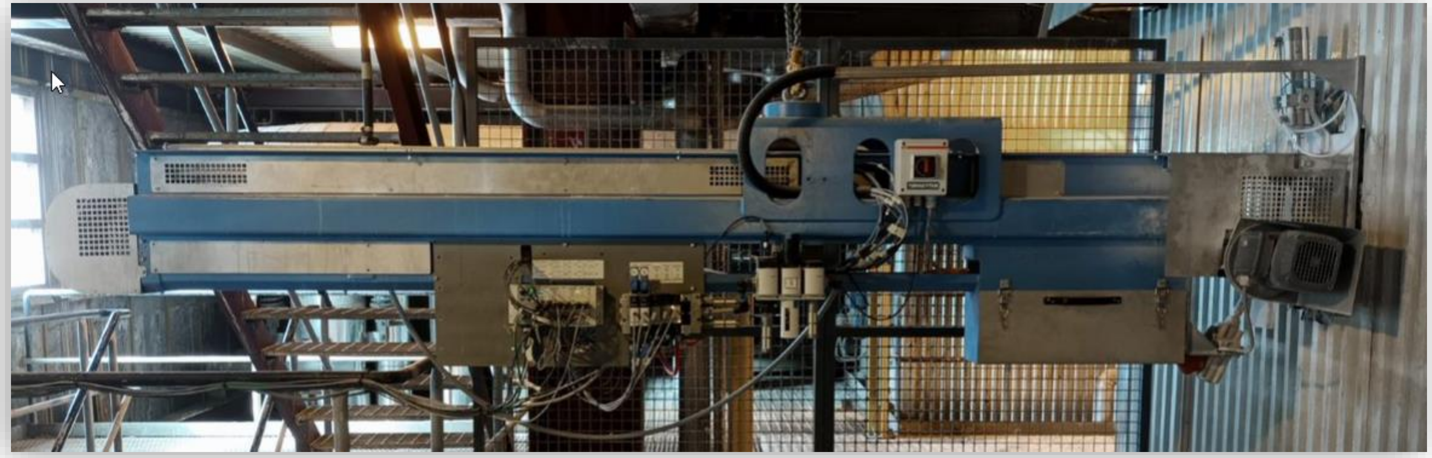
- Opening at the boiler for mechanical installation
- Electricity feed (230 VAC)
- Pressurized air (cooling, pneumatics)
- DCS connection for transferring measurement results

High availability

- Simplified movements
- Low need of maintenance
- Collects sample every 30minutes

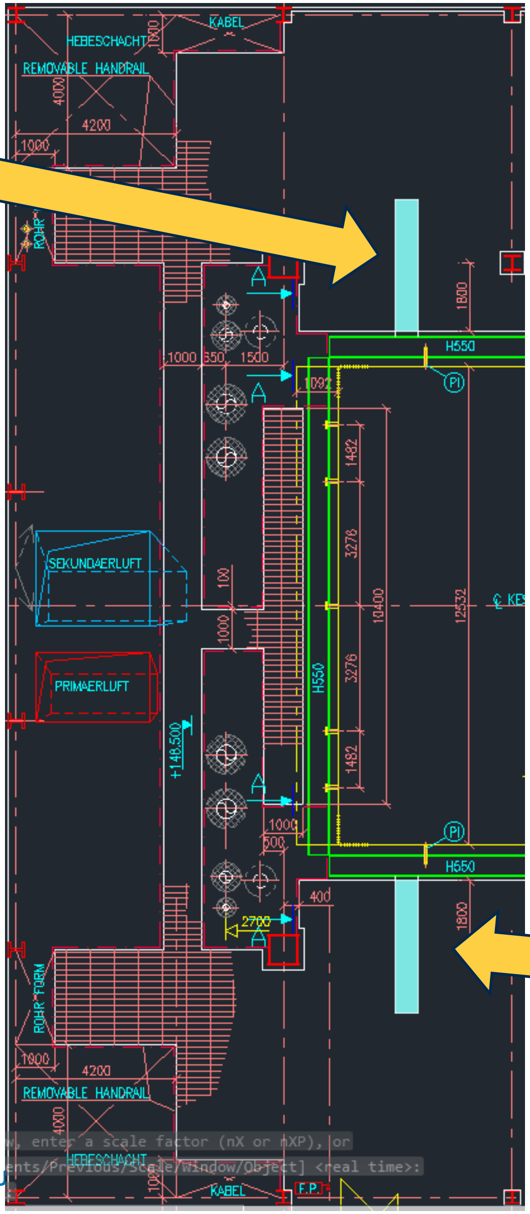
Delivery / Installation

Two devices to measure left & right side walls.
Mounted near the nose arch.



AVA ACM – EX. LAYOUT

Proposed location at left side wall

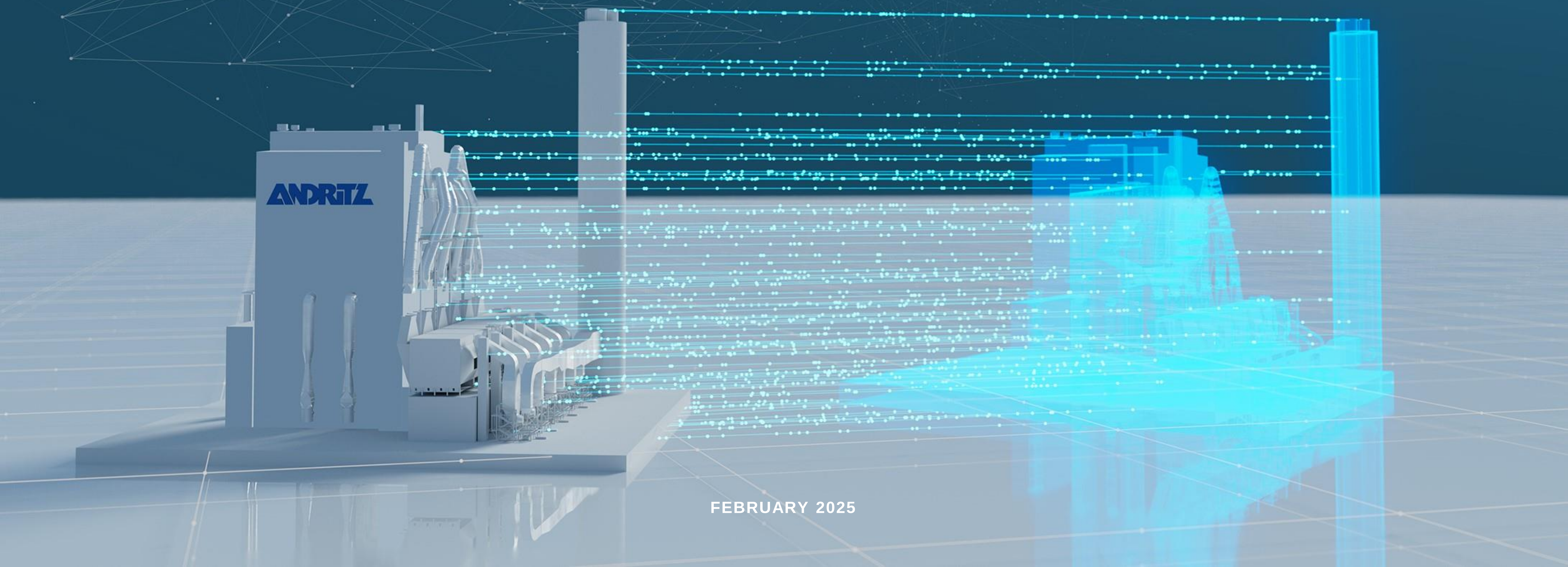


Proposed location at right side wall

One ACM device needs appr. 12’ x 2’ space (length x width)

AUTOMATED SHATTER JET

OPERATOR FREE SPOUT DECK



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AUTOMATED SHATTER JET POSITIONER

Future SMART series product

BENEFITS

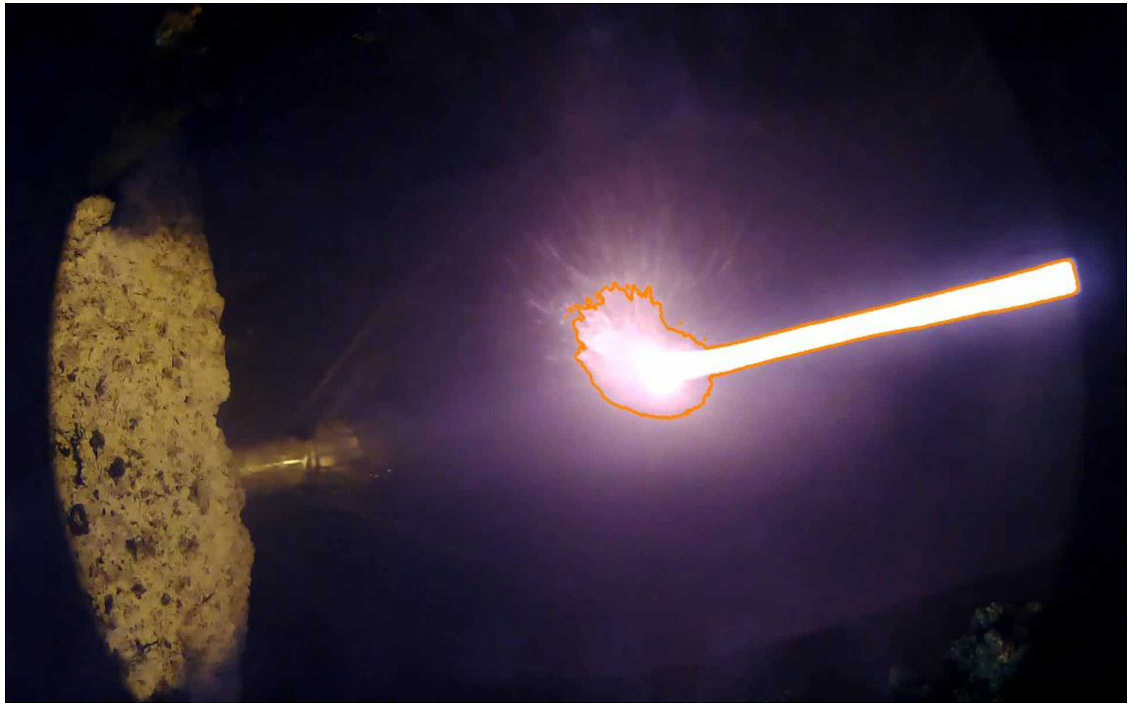
- Improve Safety
- Reduce Operating Costs

WHAT IT IS

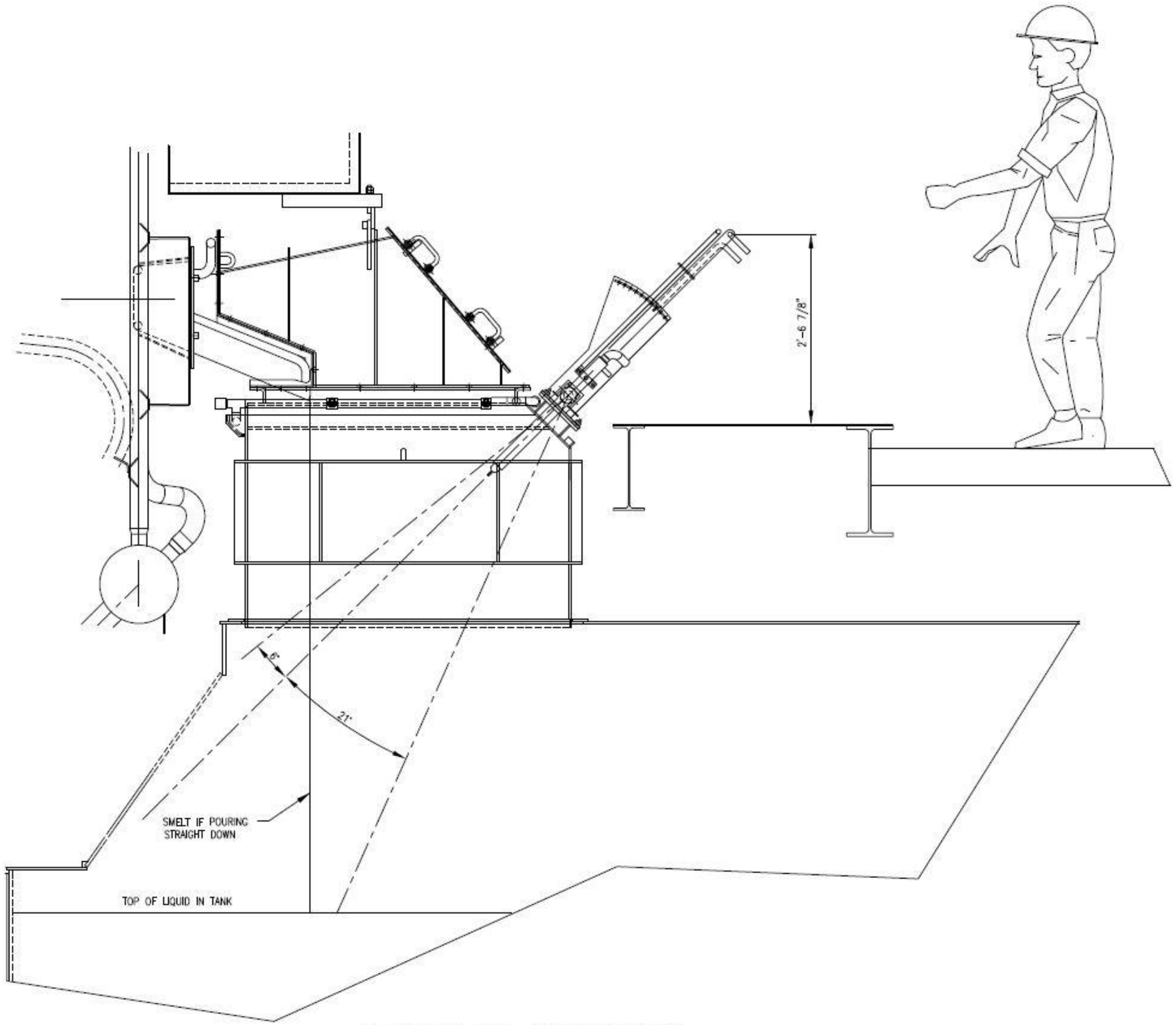
- Cameras are used to identify shatter pattern
- Adjustments are made by operators remotely

FUNCTION

- Simple system consisting of modified Andritz Shatter Jets mounted with remote actuators
- Future state will become fully automated to maximize the smelt shattering

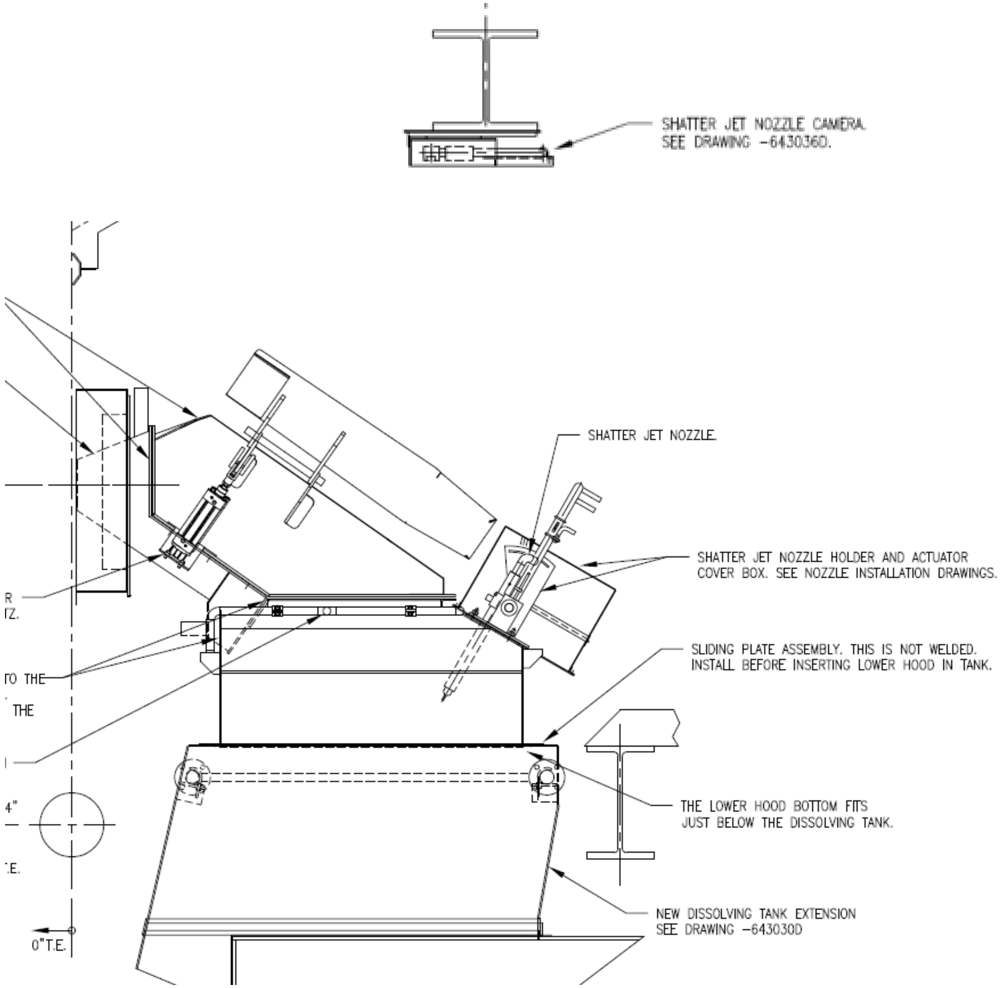


SHATTER JET POSITIONER MOUNTED ON HOOD

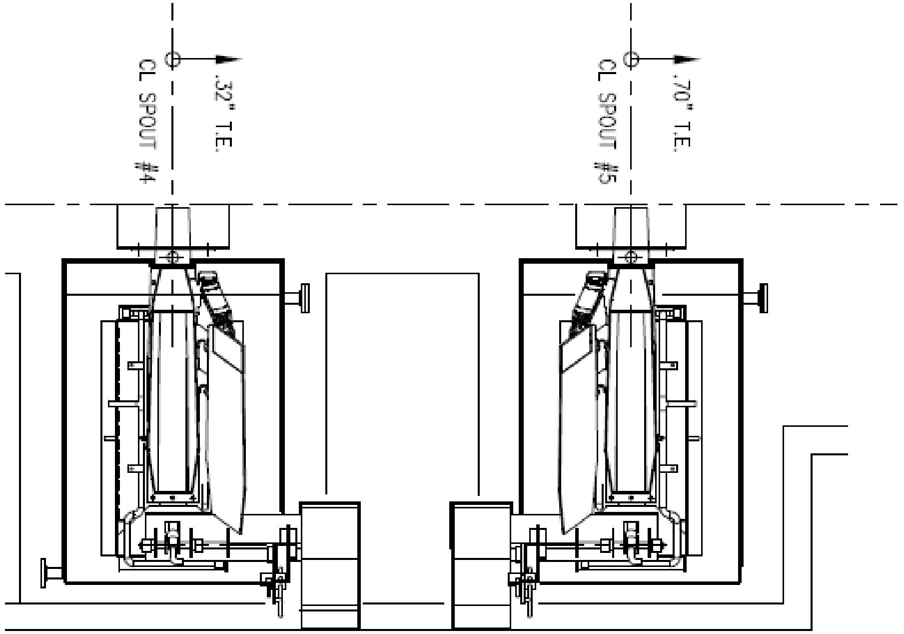


SHATTER JET ADJUSTMENTS

AUTOMATED SHATTER JET ADJUSTER

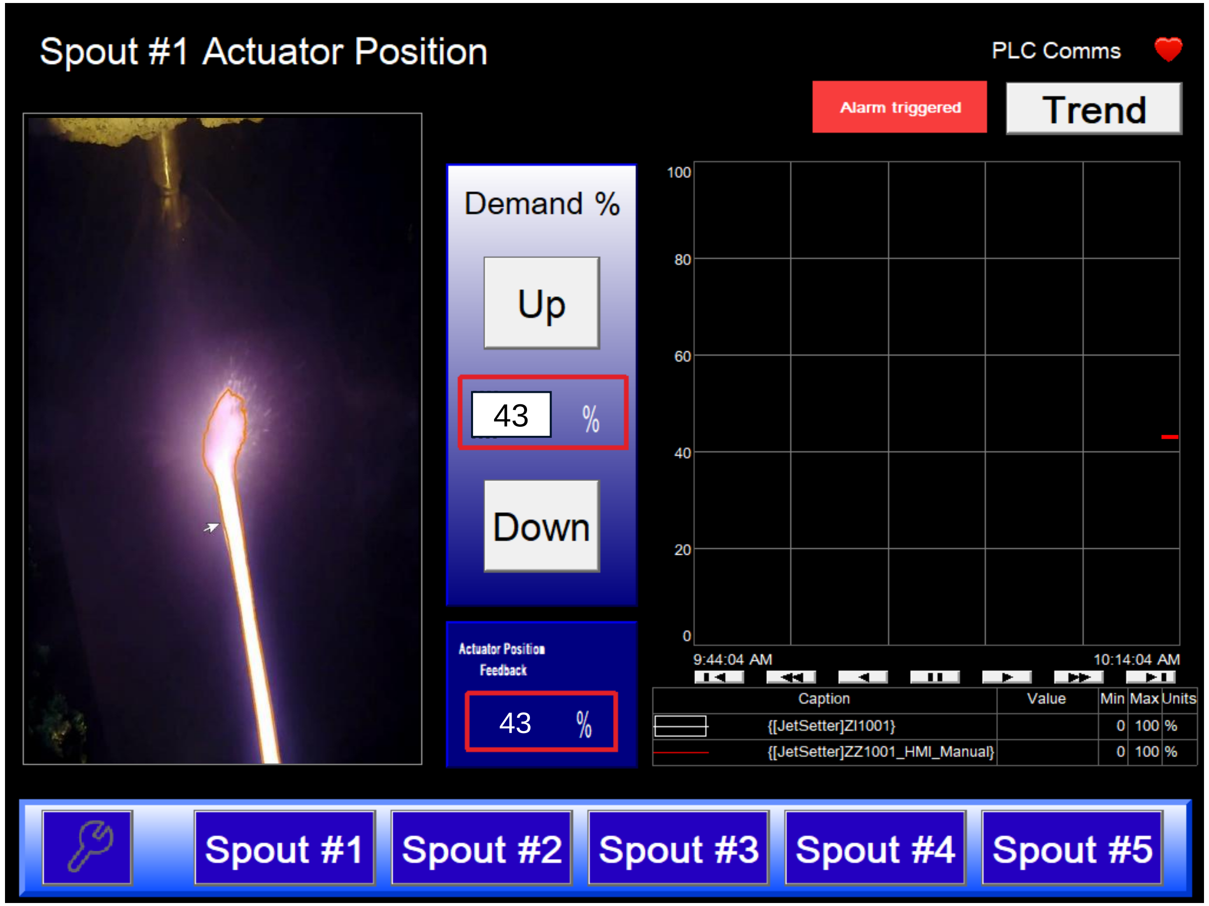


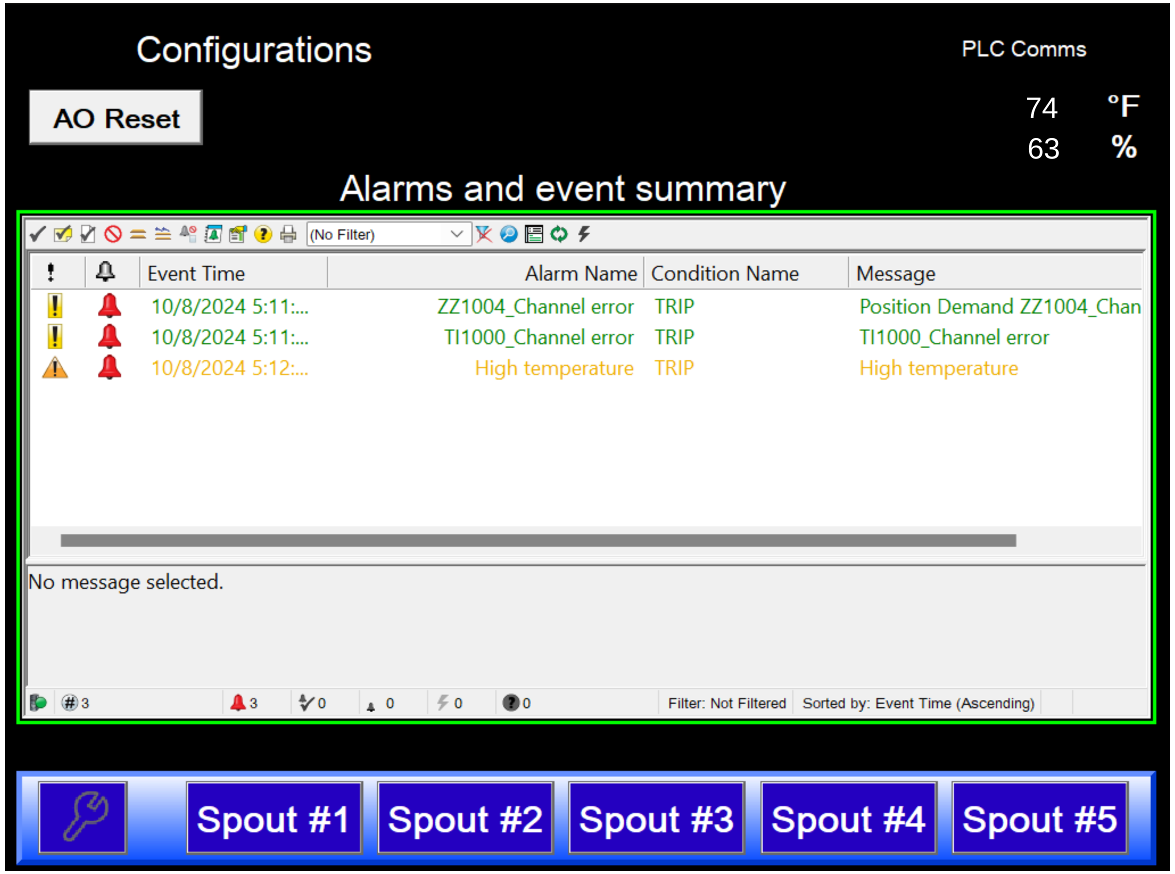
Side View



Plan View

AUTOMATED SHATTER JET ADJUSTER





LEGAL DISCLAIMER

OnGuard™ *i* Controller with Leak Alert System

Jeff Armstrong
Boiler Applications Group

February 5, 2025

Agenda

1. Recovery Boiler Leak Detection - Purpose
2. Common Methods and Challenges
3. Solenis Approach
4. Artificial Intelligence

No. 1 Reason for RB Leak Detection: Safety

The introduction of steam/water into a Recovery Boiler furnace can cause water to mix with molten smelt, leading to violent chemical reactions, including a catastrophic explosion.

When a leak is suspected in an area near the furnace, operations may initiate an Emergency Shutdown Procedure (ESP).

Not all leaks require ESP, so part of leak detection protocol is determination of leak location and whether to ESP.

ESP – Not an ideal boiler shutdown

Thermal Stress on Boiler

Frozen Smelt Bed

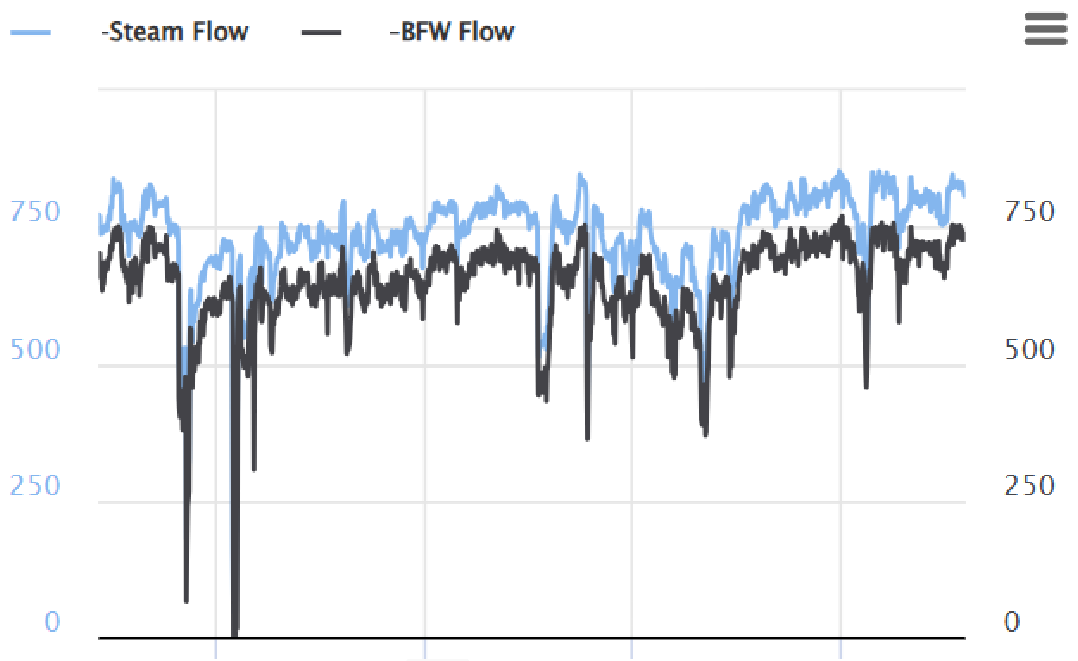
Mandatory Area Evacuation Protocol

Extended Downtime or Production Loss

Energy Loss

Administrative Follow-up and Reporting

Common “In House” Leak Detection Methods



- Steam and Boiler Feedwater Differential and/or Water Mass Balance
  - May apply averaging, filters, offsets
  - Dedicated monitor screen in CR
  - Alarm on large differential
- Operator Walk-down
  - Sights and sounds (sootblowing off)
  - Helps verify **location**
- Combined signals – “Large Leak ESP”
  - Tracks 2 or more parameters
  - Includes additional leak indicator(s)
  - When aligned, trigger operator ESP

Additional Leak Indicators (to mass flow)
(Reference TAPPI Technical Information Paper (TIP 0416-23)

High furnace pressure

Induced draft (ID) fan - increased speed/load

Noise from the furnace or convection passes

Falling drum pressure

Drum pressure differs from header pressure

Steam drum water levels indicate differently at different transmitters

Difficulty maintaining steam drum water level

Falling flue gas temperature

Localized smelt bed blackout

Popping/spitting at smelt spouts

Color change in smelt at spouts

Trouble keeping spouts clear

Wetness on clean-out rods

Falling O_2% of flue gas

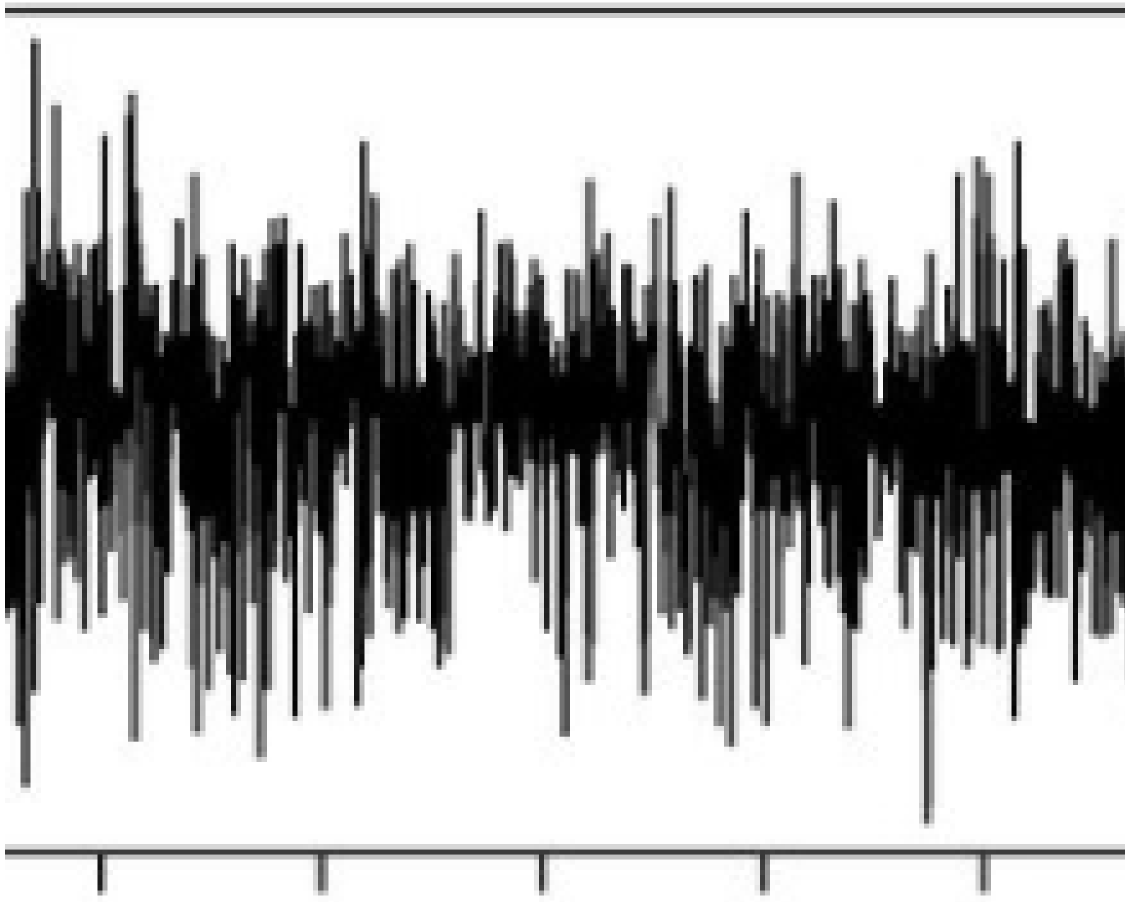
Increased sparking in electrostatic precipitator TR sets

Falling percentage of the solids in the black liquor due to water leaking into ash hoppers – if black liquor used to sluice

Steam/water seen through boiler openings/ash hoppers

Leak Detection Challenges

- Noisy, highly variable data streams
- Speed of detection
- Sensitivity (ability to detect small leak)
- False alarms (operator walk-downs)
- Leak location (determine if ESP)



The Solenis Approach

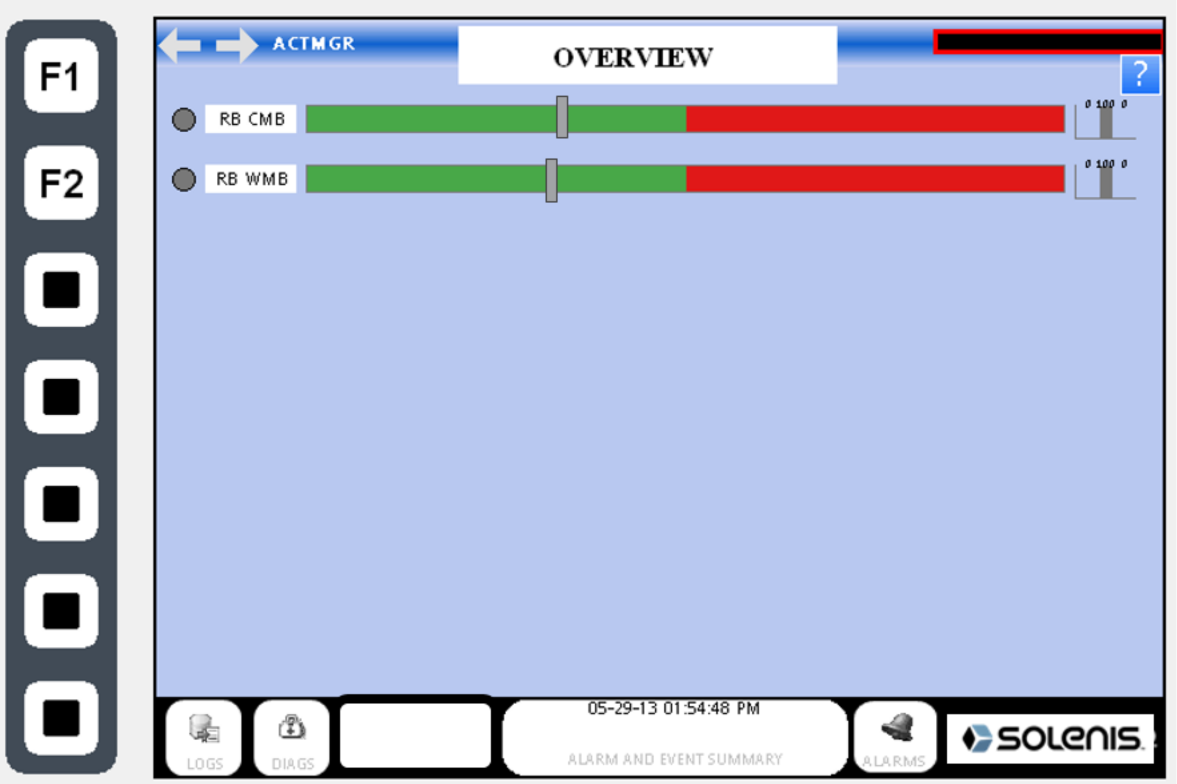
OnGuard^{TM} *i* Controller

- HMI (PLC) – 80% of control algorithms
  - Performance based control
- Coprocessor - Proprietary programs
  - Fuzzy logic
  - Knowledge based control (self calibrating)
- Gateway (cellular, LAN, DCS)

Solenis Leak Alert

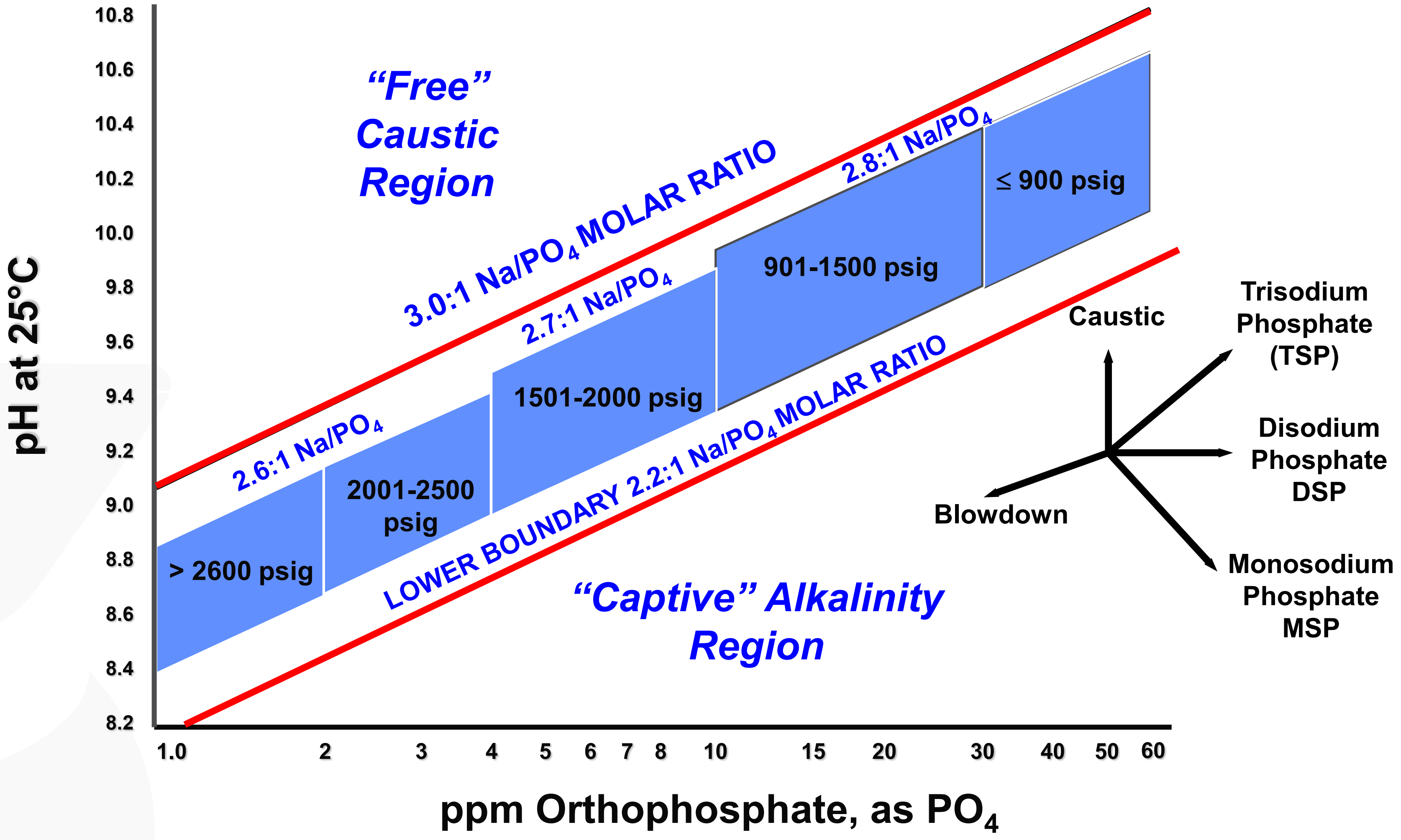
Standard Leak Alert Program (StatMonitor)

- Water Mass Balance (WMB)
- Chemical Mass Balance (CMB)

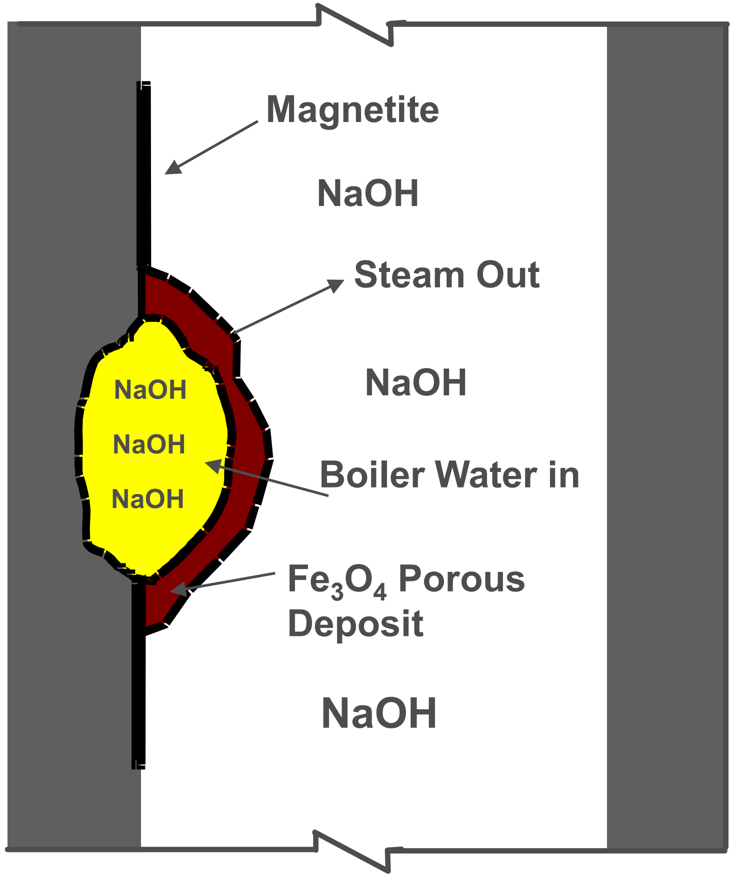


What About Leak Mitigation via Internal Treatment?

Congruent Control- Key is Na:PO_4 (pH is relative to Na)

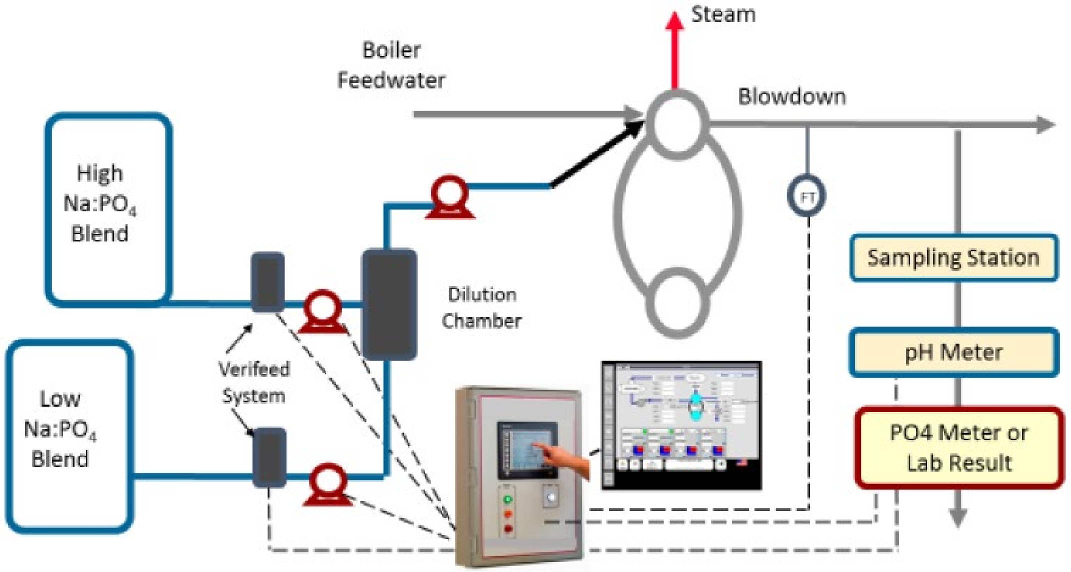


Under Deposit Concentration Mechanism



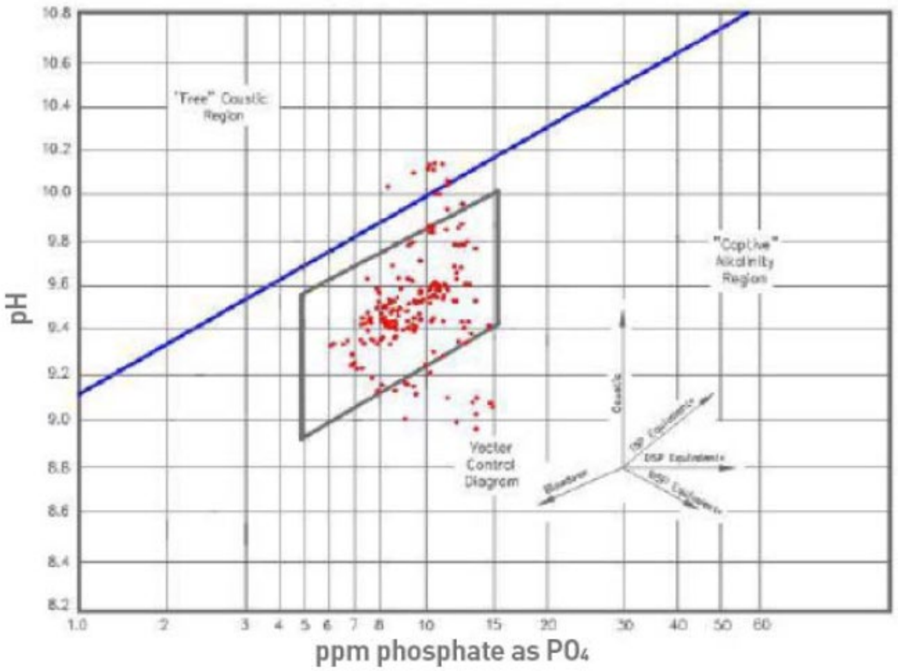
Boiler pH/PO_4 Control (BPPC)

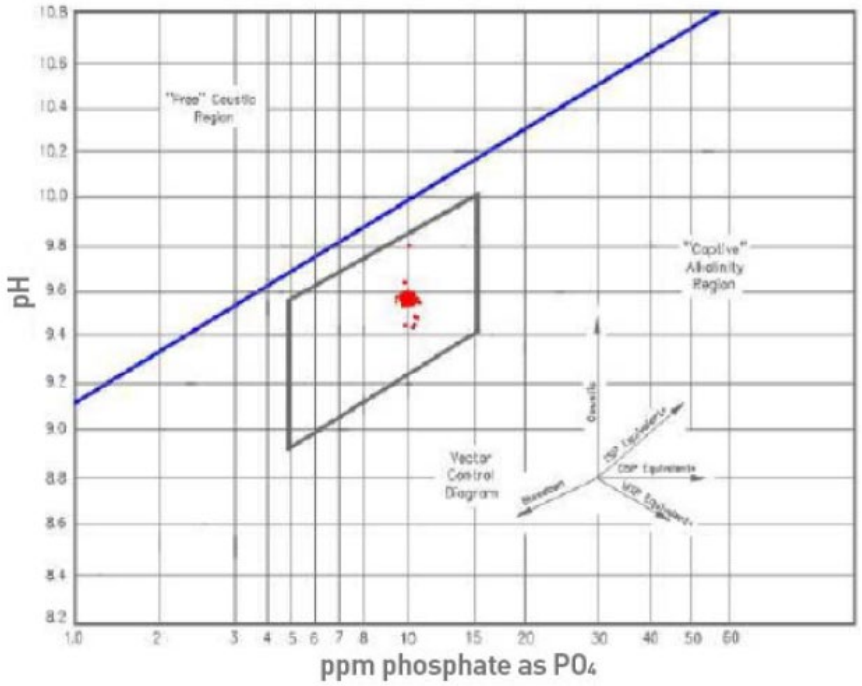
- *OGiC* plus online pH and phosphate
    - pH relative to sodium
- Chemical pumps with feed rate verification
- Blowdown flow meter
- Enhanced control is achieved by:
    - Targeting ppm PO_4 to blowdown flow
    - High and low $Na:PO_4$ chemical blends
        - Both fed continuously
        - OG*i*C determines ratio to target pH
    - OG*i*C "learns" system, self-calibrates
        - Changing loads
        - Changing BFW quality
        - Lag time



Boiler pH/PO_4 Control (BPPC)
The power of the *i* Controller

- Before BPPC with variable BFW quality





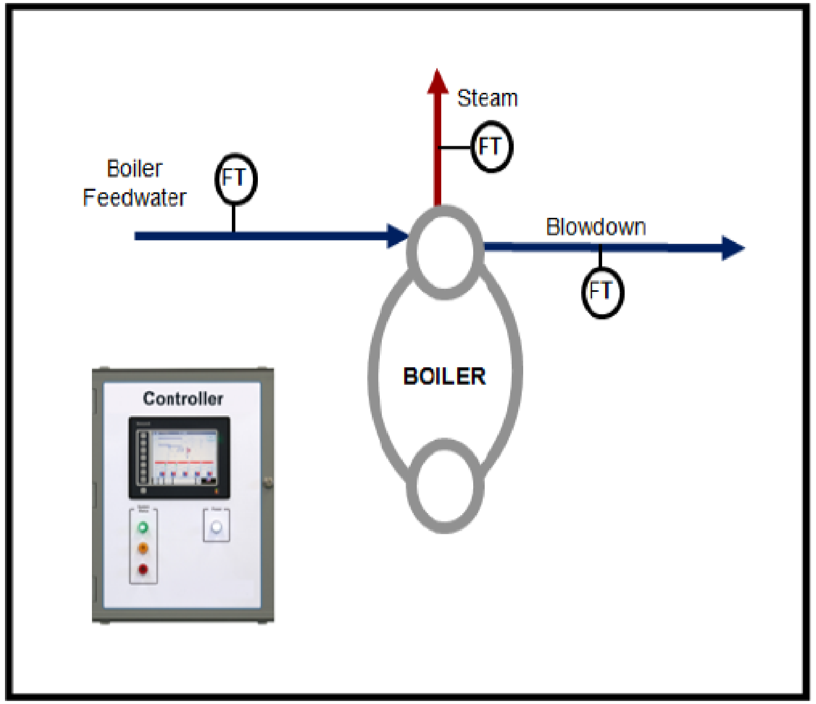
- With BPPC, same BFW quality variation

Desire +95% TIB

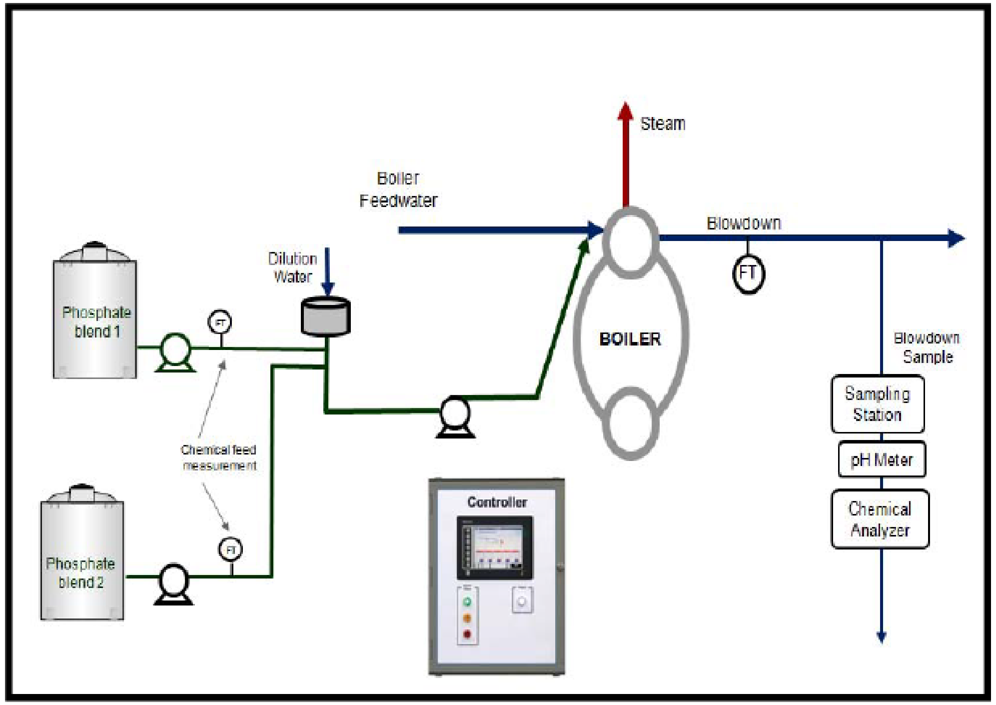
Leak Alert

Equipment Needs

Water Mass Balance



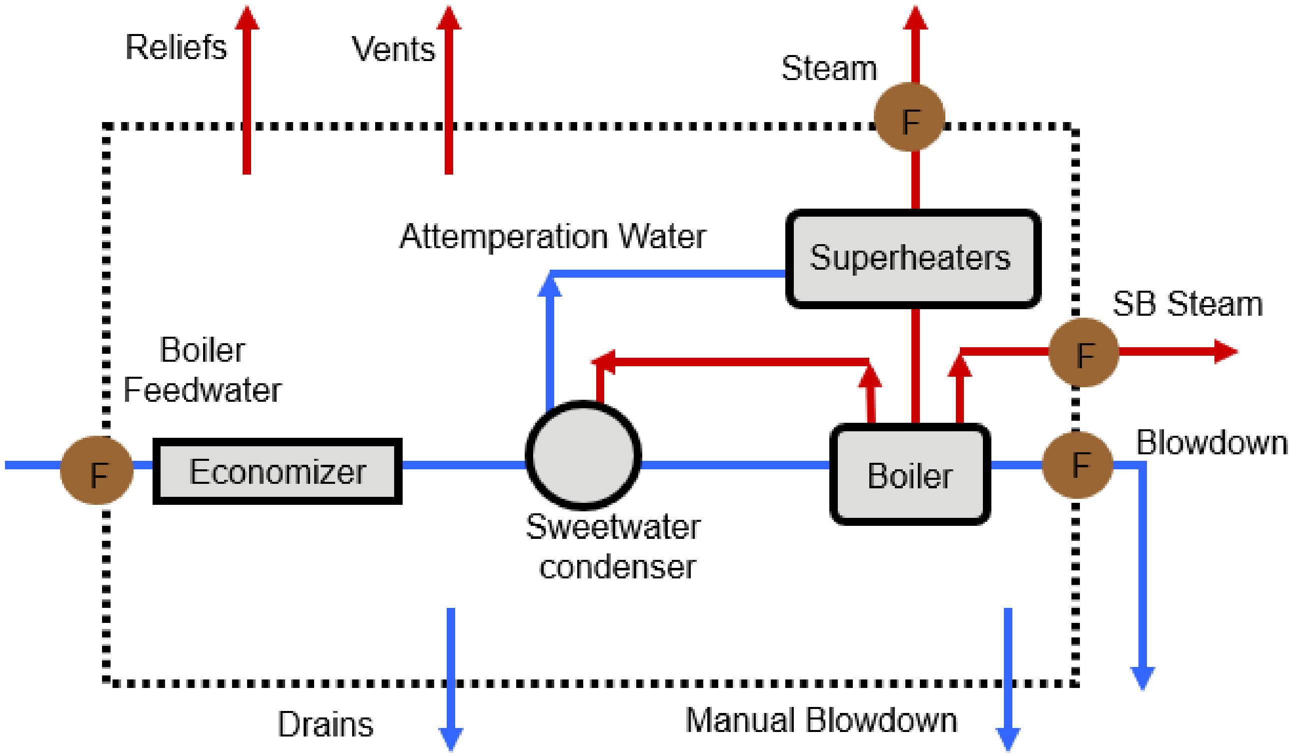
Chemical Mass Balance



What does WMB imbalance suggest?

Unaccounted loss of steam or water, not necessarily inside the boiler

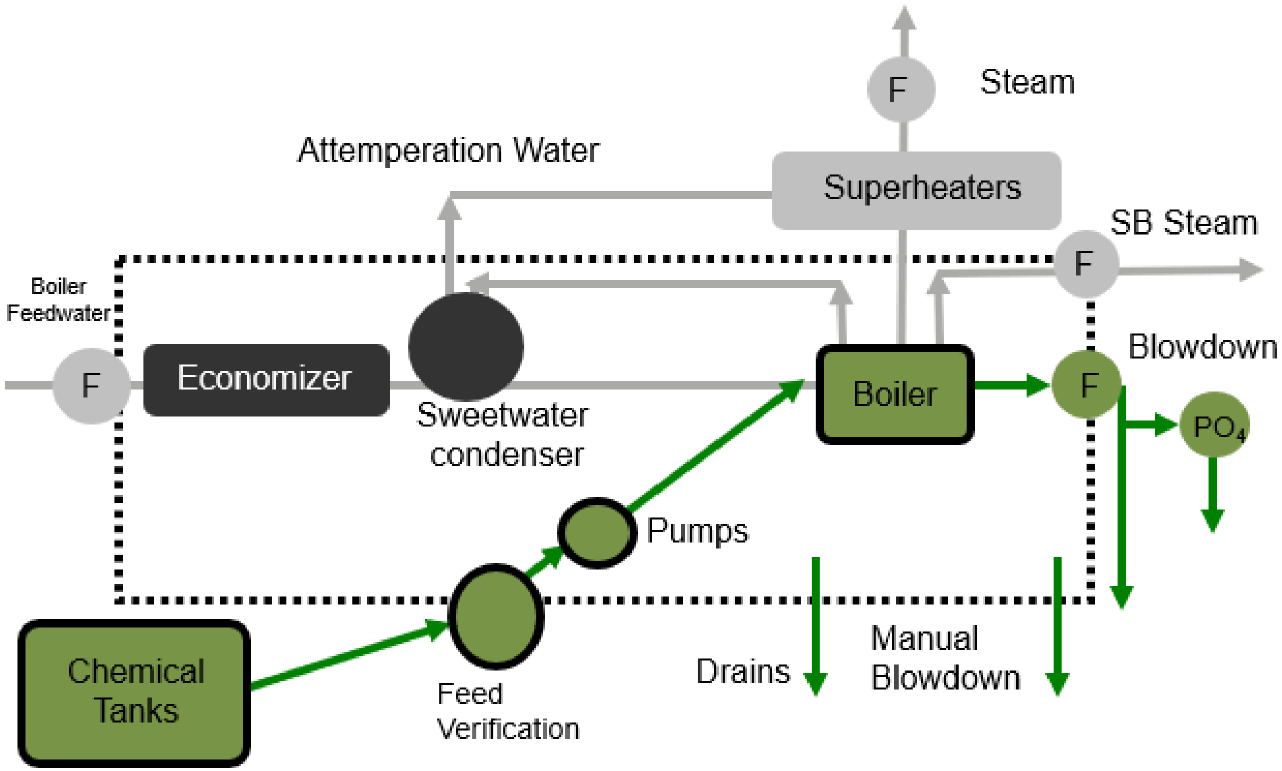
- **Economizer Leaks, BFW downstream of meter, Attemperation Water, Sweetwater Condenser (exterior)**
- **Superheater Leaks (or steam upstream of meter)**
- **Cycled-up Water Leak, includes Steam Drum and BD (upstream of meter)**
- Vent Valves
- Drains
- Manual Blowdown
- Sootblower Steam
- Faulty Meters
- Over-pressure Control Valve Open



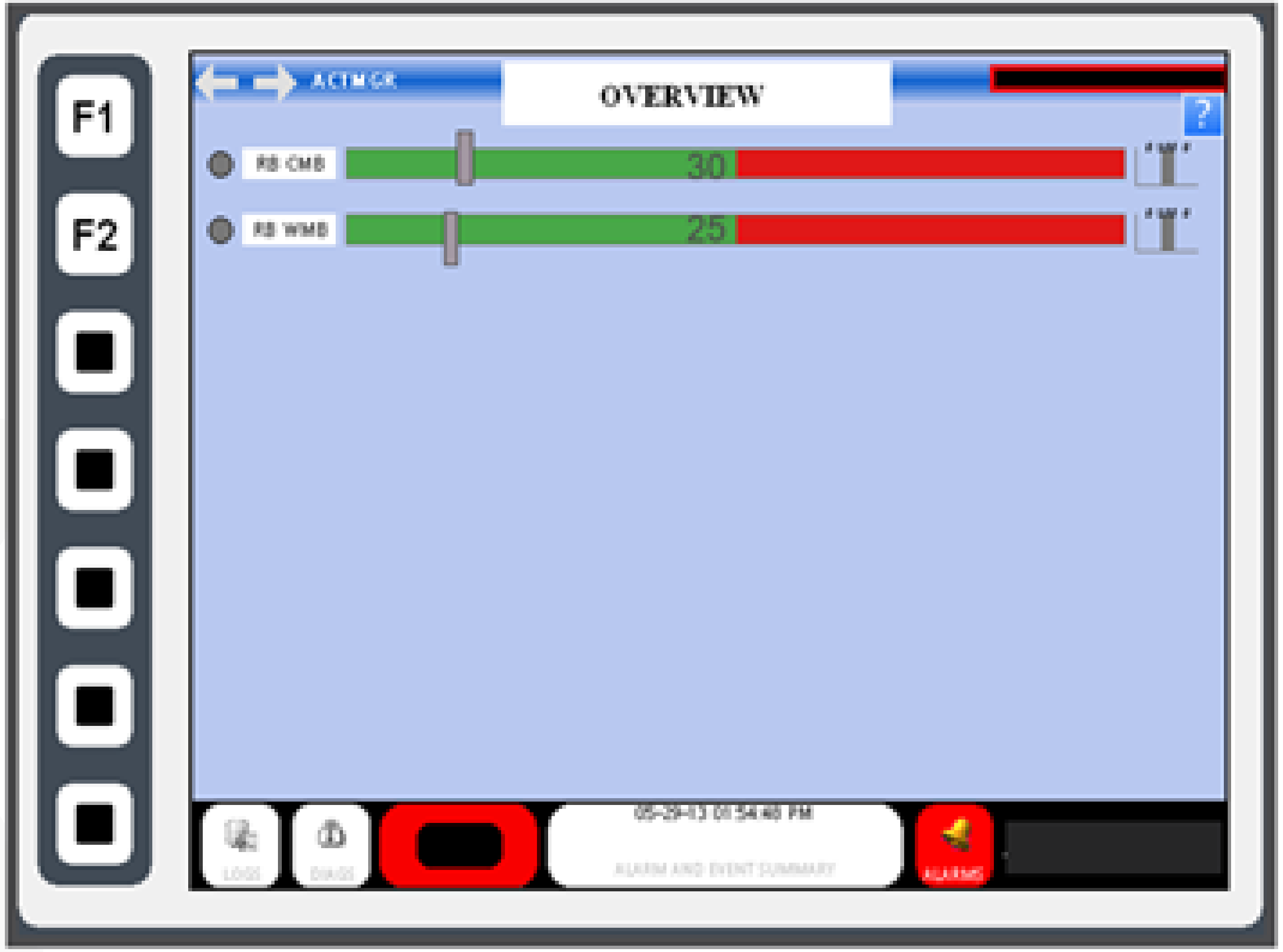
What does CMB imbalance suggest?

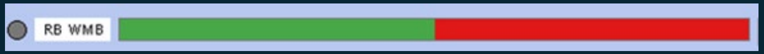
Unaccounted loss of chemical (phosphate)

- **Cycled-up Water Leak**
- Blowdown (before Meter)
- Drains
- Manual Blowdown
- Faulty BD Meter
- Faulty PO_4 Meter
- Chemical Leak
- BFW Hardness
- PO_4 Hide-out



The Leak Alert Display



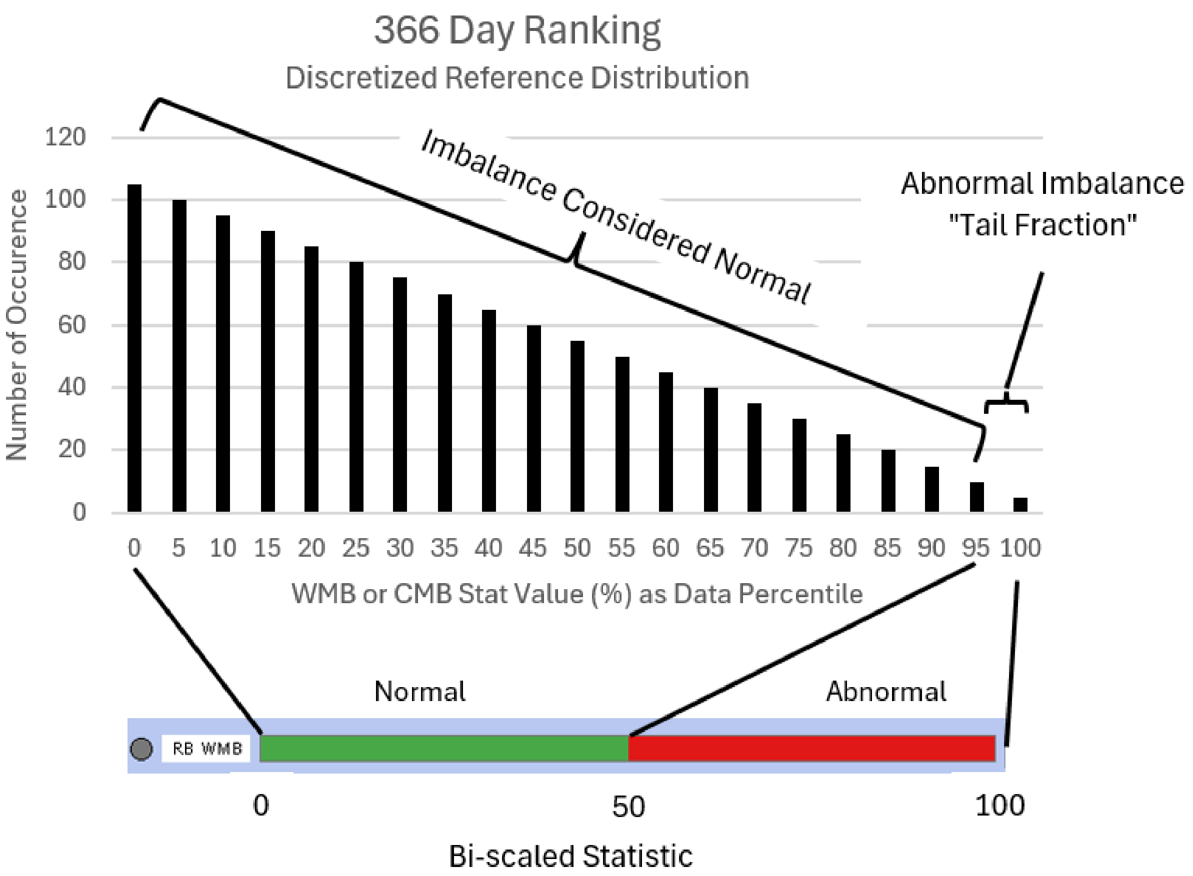


Leak Alert Principal Steps for WMB and CMB

- System is reporting statistical possibility of leak, **RED** means “go look”
- Proprietary data filtering and smoothing prior to WMB/CMB calcs
- WMB and CMB “Statistics” are then calculated
  - WMB Statistic is “by what percentage” influent exceeds effluent
  - CMB Statistic is “by what percentage” the measured PO_4 is below that which is expected
- System calculates WMB/CMB stats on 1 and 10 hr. averages
  - 1-hour useful for large leaks, 10-hour useful for small leaks (both adjustable)
- Largest daily stats are ranked on value (smallest to largest) and frequency of occurrence with previous 366 days – creates a reference distribution

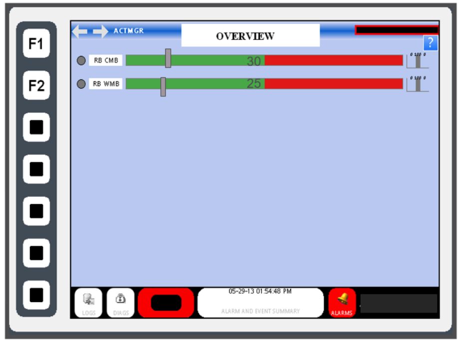
Leak Alert Bi-Scaled Statistic

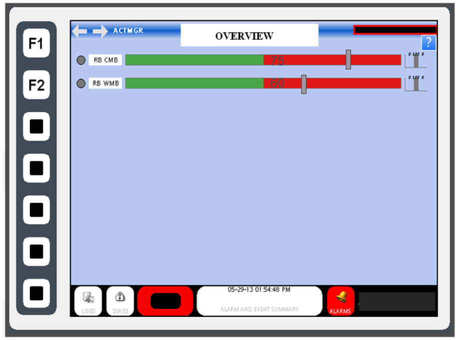
Tail Fraction strikes balance between sensitivity (minimum detectable leak size) and number of false alarms



As value moves from 0 toward 50, the data is moving toward the abnormal zone, yet “normal”.
As value moves from 50 toward 100, the data is becoming more extremely abnormal.

Where to look based upon Leak Alert Alarms





WMB	CMB	Leak Potential
Green	Green	None Indicated
Red	Red	Cycled Boiler Water
Red	Green	Economizer, Superheater (or Cycled Boiler too small for CMB to detect)
Green	Red	Chemical leak, High BFW hardness, PO_4 hide-out, (or Cycled Boiler too small for WMB to detect)

Interpretation can take time:

- Recognize alert
- Interpret information
- Decide to act
- Complete action

Artificial Intelligence (AI) Medical Discoveries

- Diagnosis of rare genetic disorder from analysis of a photograph of a child's face.
- Lung cancer and thyroid issues detected from voice analysis.
- Schizophrenia detected by subtle eye motion.
- Covid-19 detected from audio of human coughs.

Additional Leak Indicators (Reference TAPPI TIP 0416-23)

Blue **indicates potential existing data stream**
Bold – Possible AI (video/audio) detection

- High furnace pressure - steady or erratic
- Increased speed/load of the induced draft (ID) fan
- **Noise from the furnace or convection passes**
- Falling drum pressure
- Drum pressure may be different from header pressure
- Steam drum water levels indicate differently at different transmitters
- **Difficulty maintaining steam drum water level**
- Falling flue gas temperature
- **Localized smelt bed blackout**
- **Popping/spitting at smelt spouts**
- **Color change in smelt at spouts**
- **Trouble keeping spouts clear**
- Wetness on clean-out rods
- Falling O2% of flue gas
- **Increased sparking in electrostatic precipitator**
- Falling percentage of the solids in the black liquor
- **Steam/water seen through boiler openings**

AI is Here

Solenis has a dedicated AI team plus 3rd party contractors

- Well-defined customer goal - what to accomplish?
- Requires substantial data to train AI – can it be acquired at reasonable cost?
- Caveat - Limited actual leak data for supervised learning
- Willingness to share data w/Solenis –so we can implement pattern learning, perhaps “Cloud to Cloud”?
- For audio/video data requires massive storage capacity
- AI Takeaway – Solenis is engaged in improving leak detection with AI

Questions?

jarmstrong@solenis.com

Mitigating High Intermediate Superheater Steam Temperatures

J. Stephen Campbell, Jr., P.E.
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Overview

Introduction: Importance of Temperature Management

Superheater Sizing

Parametric Study of Superheater Performance

Mitigating High Intermediate Superheater Steam Temperatures

Conclusions

Superheater Steam Temperatures

Other than process requirements, why is this important?

- Higher steam temperatures mean higher tube metal temperatures
- Can lead to superheater corrosion
- Particularly an issue in recovery boilers

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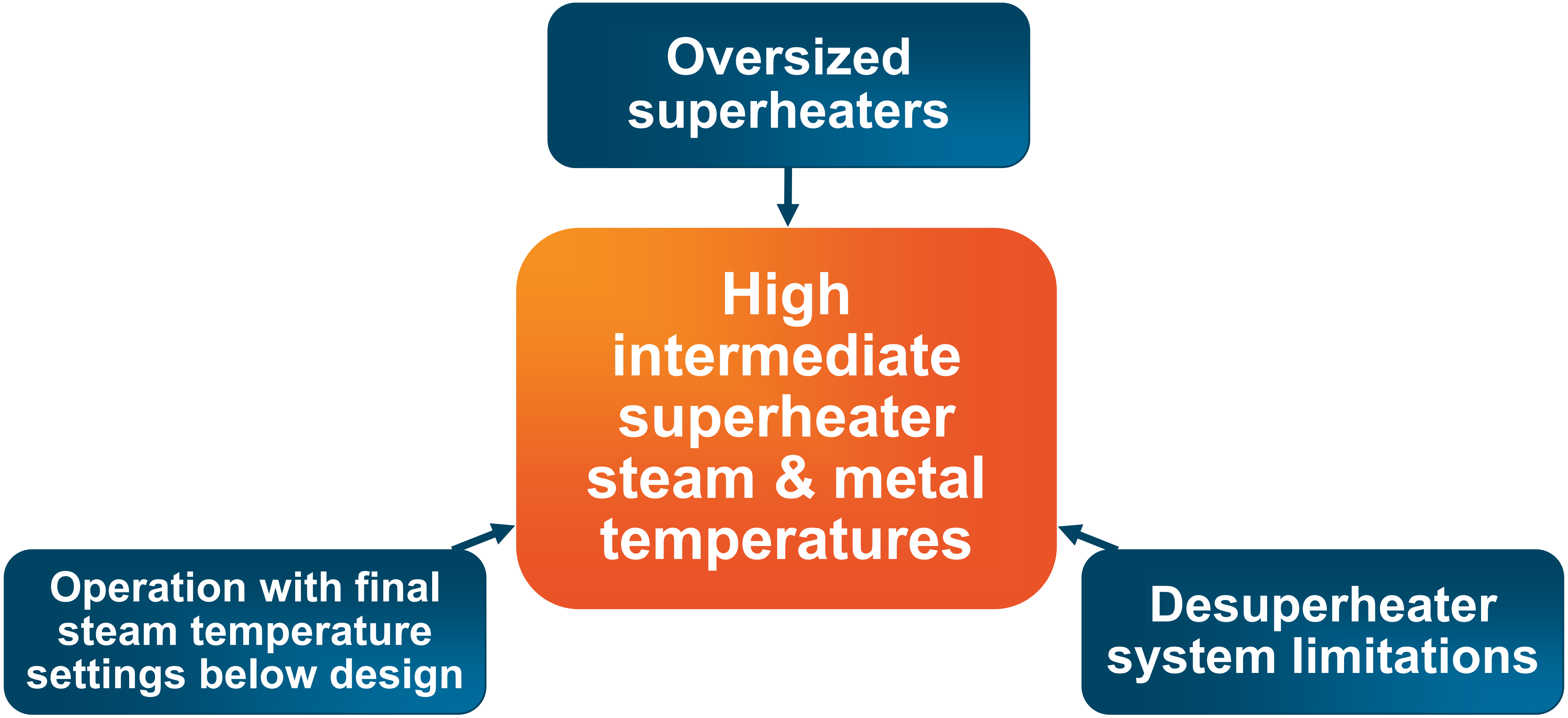
Causes of Superheater Corrosion



Challenges in Sizing Superheaters

Changing design parameters

- e.g., changes in fuel properties from the design fuel

Design performance margins

- Superheaters are sometimes oversized to provide margin to achieve predicted final steam temperature
- Oversized superheaters carry less financial risk for designer; corrosion issues often do not occur during warranty period

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Adequate superheater sizing requires reasonably precise predictions of several variables:

- Furnace exit gas temperature (FEGT)
- Heat transfer to superheater
- Fuel composition and heating value
- Excess air level and its impact on flue gas flow rate

Factors Influencing Predicted FEGT

Geometrical factors

- Boiler volume
- Superheater location relative to nose arch

Combustion properties

- Amount of heat released from furnace
- Flue gas quantity and composition

Local flue gas temperatures

- Air delivery elevations
- Combustion air distribution between levels
- Mixing within furnace

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Deviations from Predicted FEGT

Factors influencing FEGT prediction accuracy

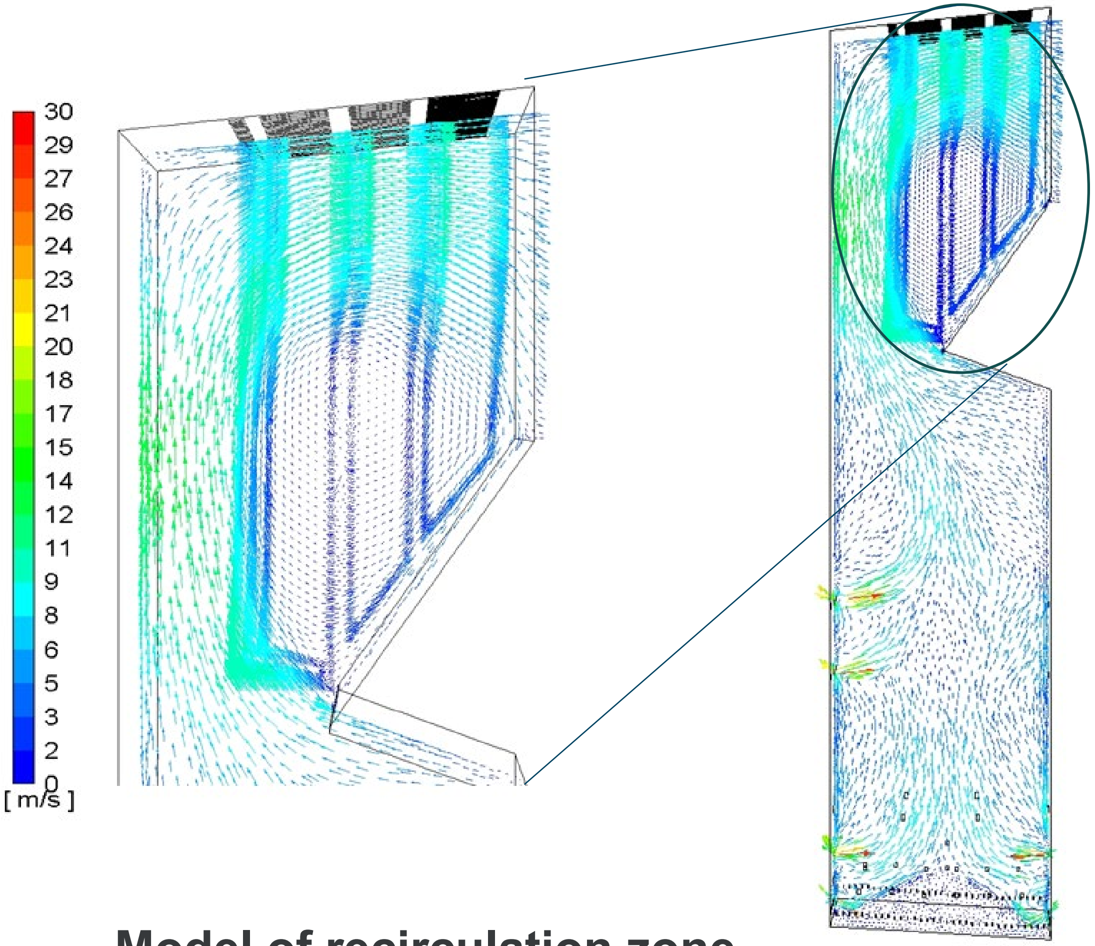
- Smelt bed temperature
- Heat transfer surface fouling/slagging
- Flue gas flow stratification

Effects of FEGT deviation

- Overpredicted FEGT: final steam temperature fails to meet target
- Underpredicted FEGT: oversized superheater

Heat Transfer and Superheater Design

- Actual heat transfer is less than theoretical heat transfer
  - External tube deposits increase thermal resistance
  - Flue gas velocity profiles can be stratified due to geometrical factors



Model of recirculation zone above nose arch

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Accounting for Heat Transfer Efficiency

Two methods:

1. Assume a heat transfer coefficient for external tube deposits and incorporate into calculations
2. Reduce theoretical heat transfer coefficient according to fouling factors from the literature

$$A_c = 1 - \frac{h_{t,actual}}{h_{t,theoretical}}$$

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Considerations Behind Fouling Factors

Fuel type and composition

- Fuels that create more deposits have higher fouling factors
- Fouling factors for recovery boilers are typically >50%
- Fouling factors for biomass boilers are generally lower

Furnace geometry

- Recirculation zone over nose arch creates flow stratification
- Higher fouling factor reflects resulting lower heat transfer

CFD modeling is useful in predicting fouling factors

- Verify heat transfer calculations
- Indicate need for adjustments to fouling factors due to non-uniform flue gas flow

Changes in fuel quality and excess air level compared to design parameters may also lead to an oversized superheater

Higher moisture content than design fuel → Lower efficiency → More flue gas generated at same steaming rate

Higher excess air level than design value → Lower efficiency → More flue gas generated at same steaming rate

Both factors are common for biomass-fired boilers

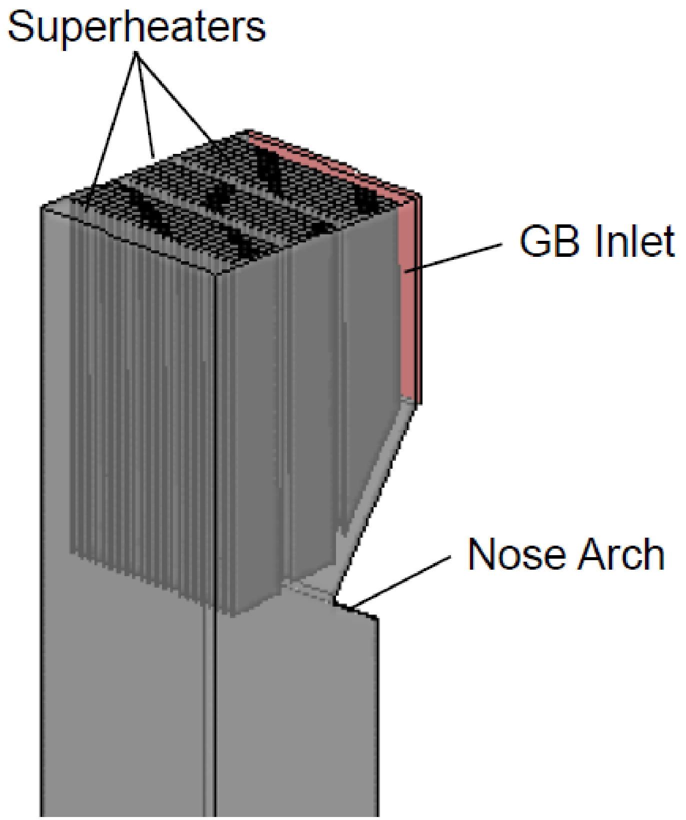
Parametric Study

The basics

- Determine the impact of certain variables on superheater sizing and intermediate steam temperatures
- Based on recovery boiler data collected by Jansen

Assumed system elements

- Two-stage superheater with a single inter-stage desuperheater
- Desuperheater spraywater flow supplied by a sweetwater condenser (SWC)
- Flue gas flow: co-current secondary superheater (SSH) followed by counter-current primary superheater (PSH)



Superheater arrangement used for parametric evaluation

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Operating Loads and Assumptions

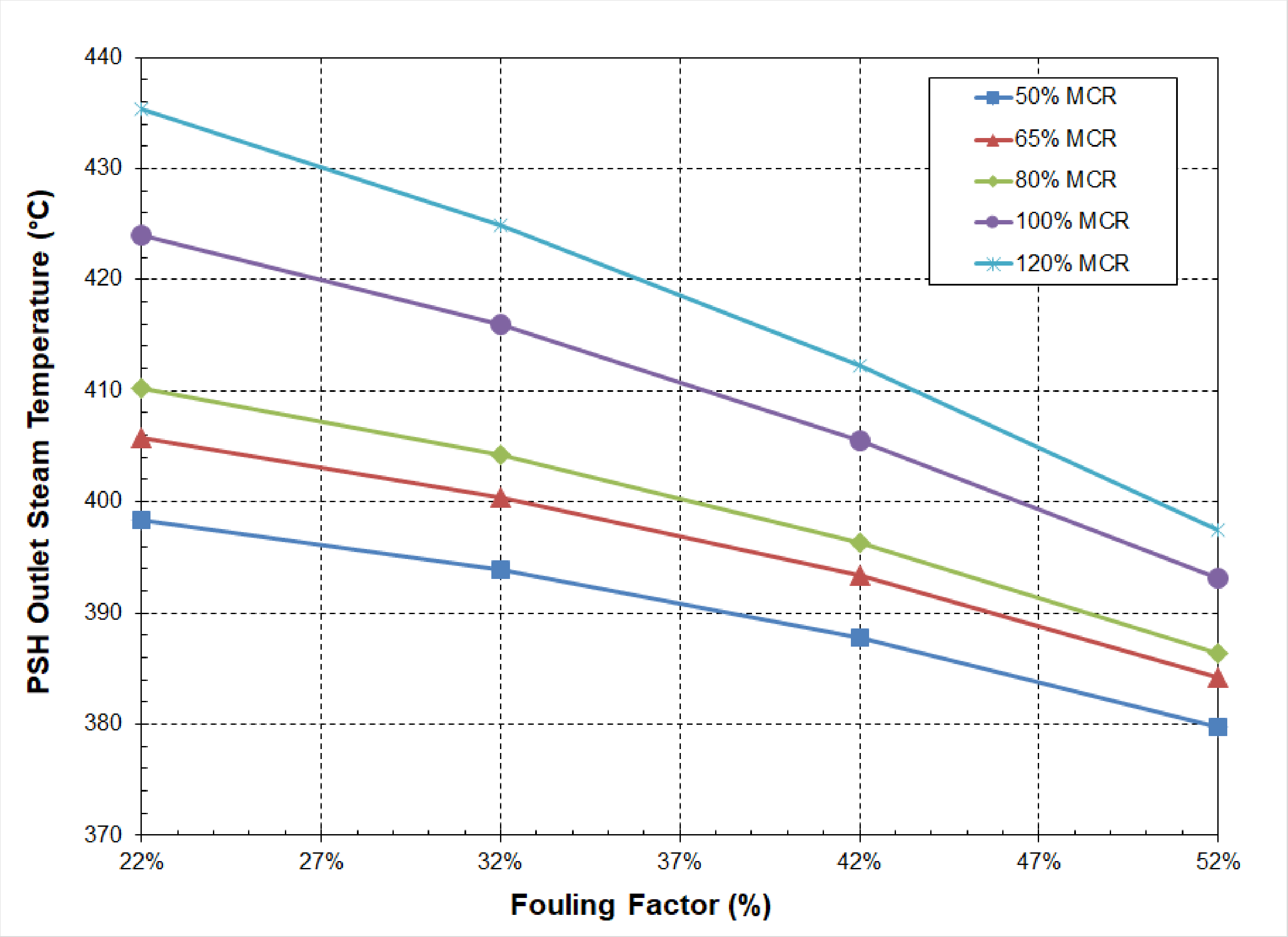
Intermediate steam temperatures and desuperheater flow rates were calculated for:

- Maximum continuous rated (MCR) steam flow
- 120% MCR
- 80% MCR
- 65% MCR
- 50% MCR

Key assumptions:

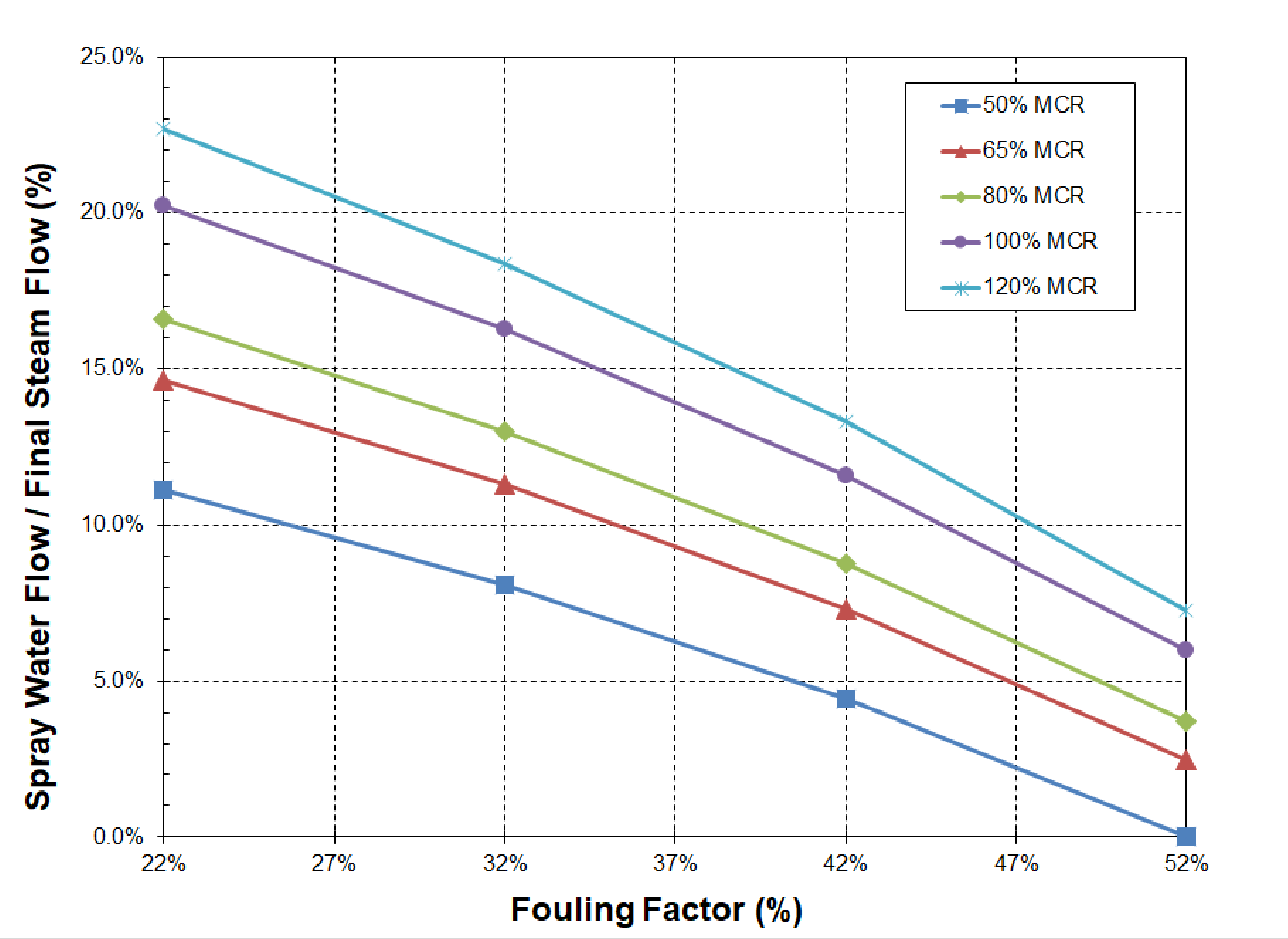
- Designed for a final steam temperature of 470°C (878°F)
- Designed for a final steam pressure of 102 bar(g) (1,480 psig)
- Baseline fouling factor of 52%
- Final steam temperature achieved at all steam loads except 50% MCR

Impact of Superheater Fouling



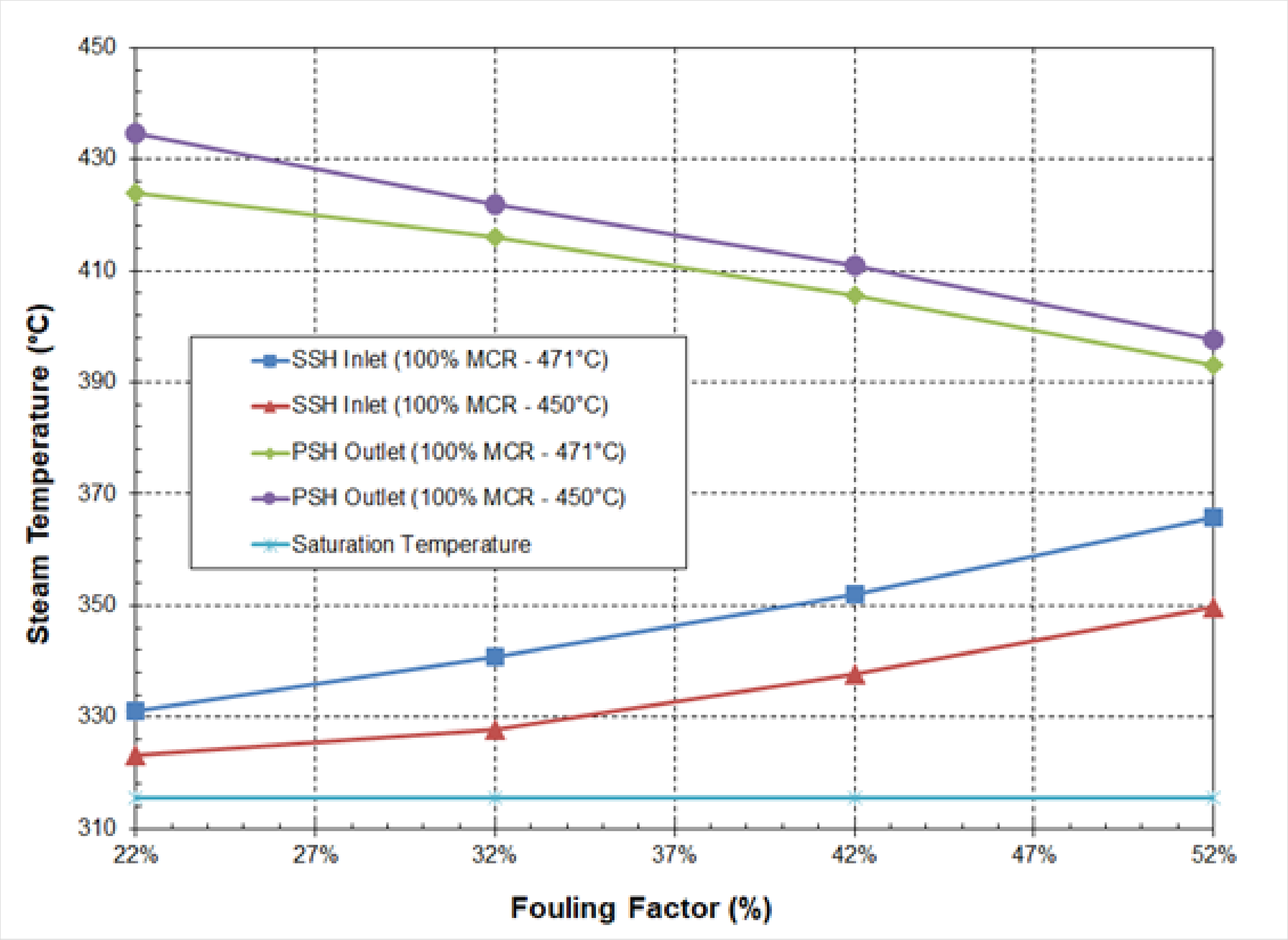
As fouling decreases below design level, heat transfer increases, leading to higher PSH outlet steam temperatures

Impact of Superheater Fouling



Higher PSH outlet steam temperatures lead to increased desuperheater spraywater demand

Impact of Final Steam Temperature Setpoint



- Reducing the final steam temperature setpoint causes more heat capture in the PSH, hence higher PSH outlet temperatures
- Higher PSH outlet temperatures can lead to increased PSH corrosion
- The SSH inlet temperature will drop as the final temperature setpoint is reduced
- This can lead to SSH inlet temperatures near saturation for clean superheaters

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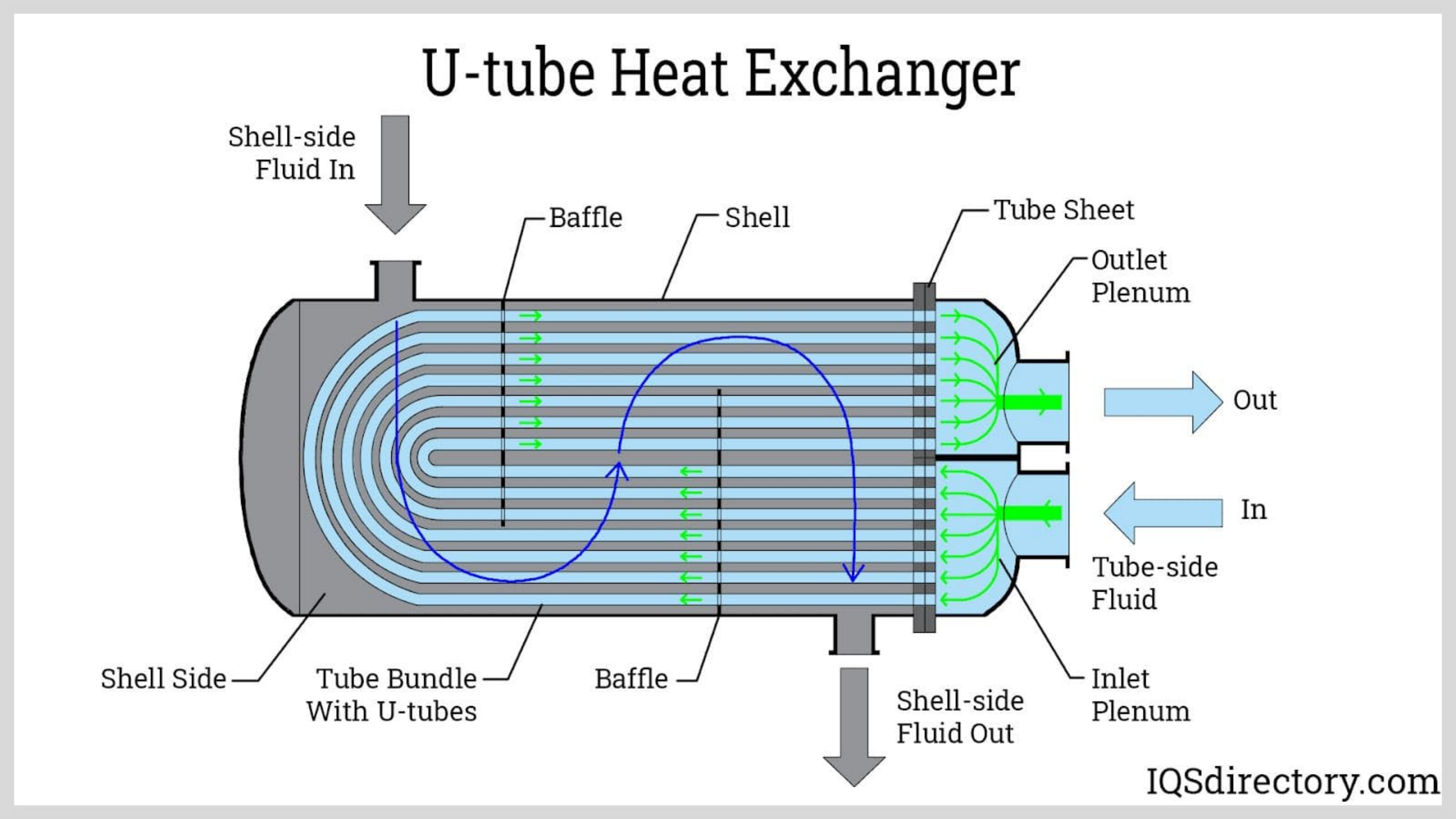
Sweetwater Condensers (SWCs)



“Shell and Tube Heat Exchangers”, IQSdirectory.com. IQS Directory, 2024. https://www.iqsdirectory.com/articles/heat-exchanger/shell-and-tube-heat-exchangers.html.

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SWC Performance Limitations

Flow limitations

- Due to internal friction losses
- Function of the piping dimensions, flow rate, control valve sizing

Condensing capacity limitation

- Function of the condenser surface area, feedwater flow, inlet feedwater temperature
- Especially sensitive to inlet feedwater temperature when SWC is downstream of an economizer

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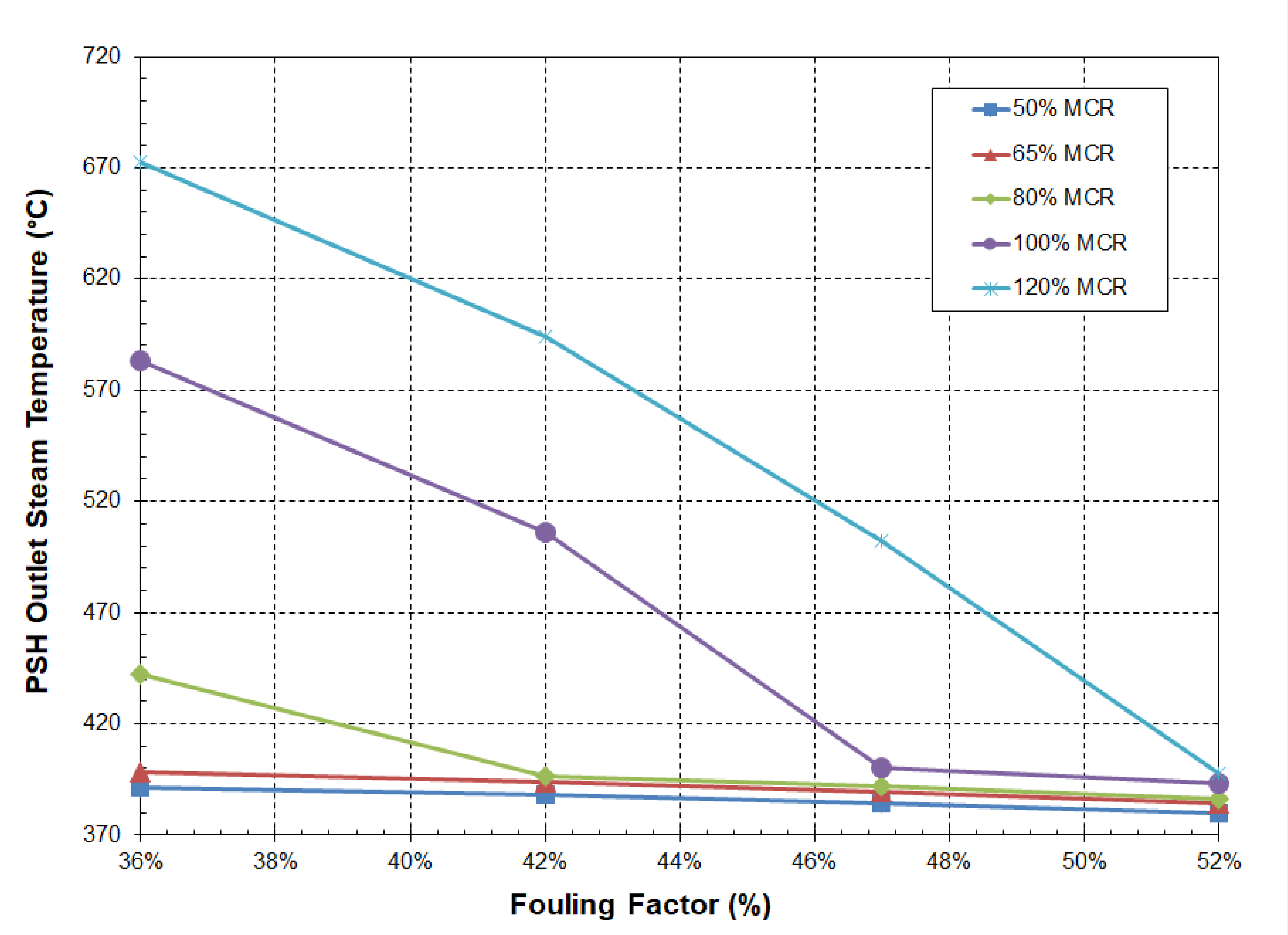
SWC Performance at High Desuperheater Water Flow

Desuperheater systems are sometimes designed to operate with SWC condensing capacity that is less than the system flow capacity

Potential for two-phase flow within desuperheater at higher flow rates

Significant increases in system losses and changes in control characteristics

Exceeding SWC Capacity



- SWC designed to condense 10% of MCR steam flow
- Inlet feedwater temp = 246°C (SWC is downstream of econ.)
- As SWC capacity is reached, overall superheater temperatures increase
- Steep increase in PSH outlet temperature
- More pronounced at higher boiler loads

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SWC Capacity and Desuperheater Performance

Operation beyond SWC capacity

Attemperation system at flow limit

Upsizing desuperheater control valve may not help

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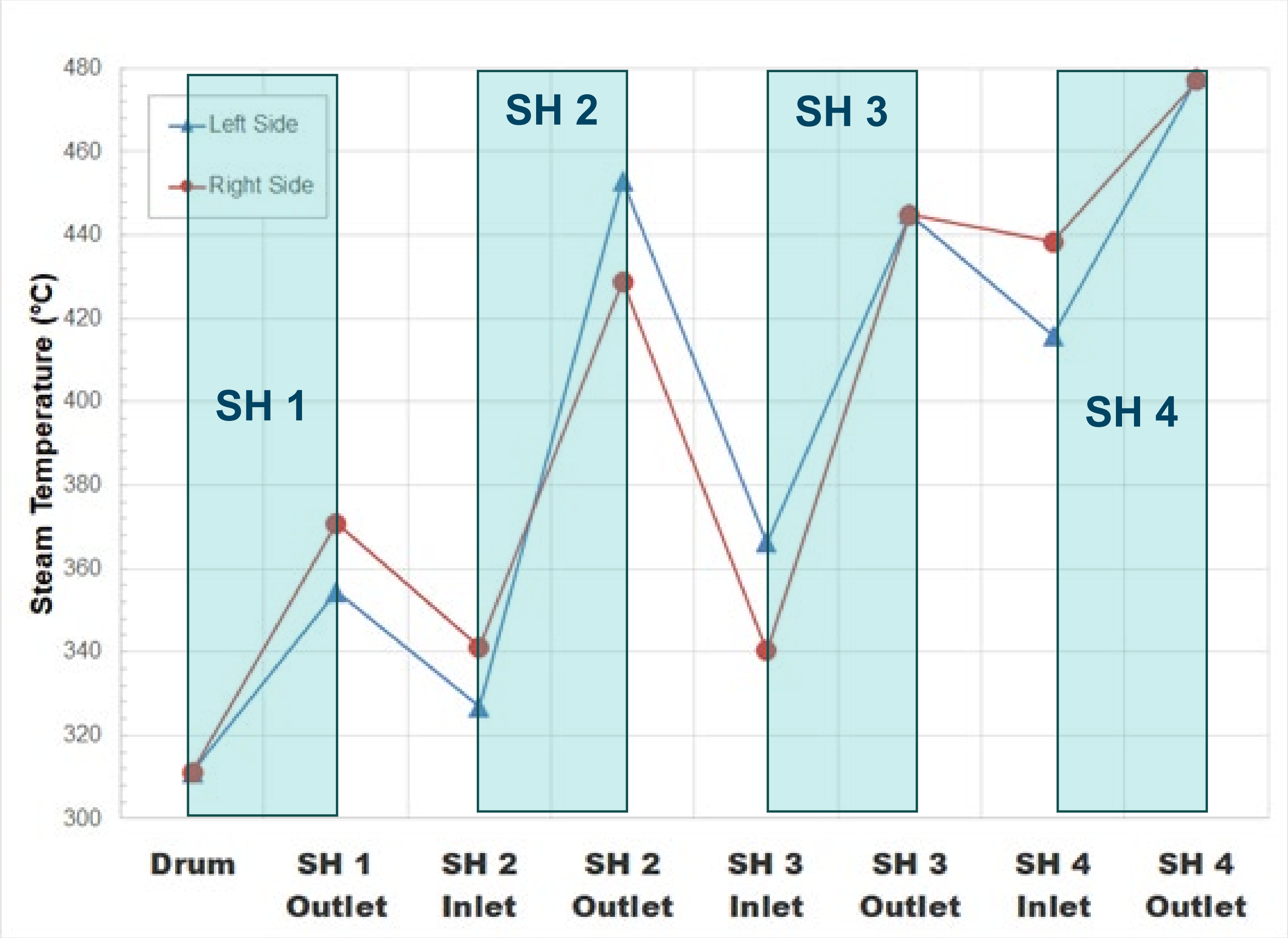
Challenges with Complex Modern Superheaters



- Four superheater stages, six desuperheaters
- Tube corrosion in stages 2, 3, and 4
- Imbalanced flue gas temperatures

Mitigating High Intermediate Steam Temperatures

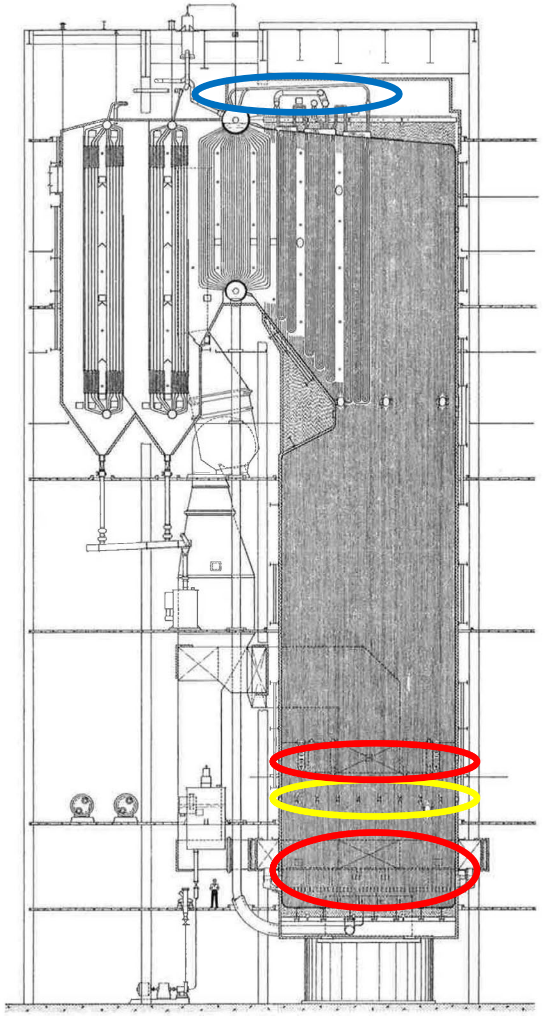
Non-surgical options:

Optimize combustion

- Liquor firing: gun type, gun size, header pressure
- Combustion air: good jet penetration, side/side and front/rear balance

Optimize attemperator control

- Ensure proper valve travel
- Consult controls specialist



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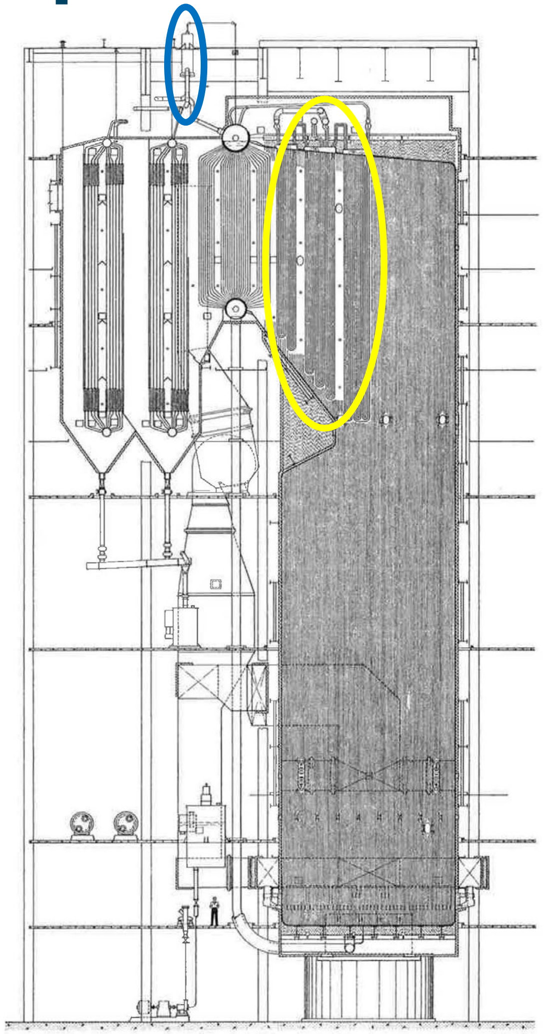
Mitigating High Intermediate Steam Temperatures

Surgical options:

Modify SWC system

- Install larger SWC
- Rearrange feedwater piping to supply SWC before economizer

Remove superheater surface area



Conclusions

Proper sizing in superheater design is crucial

- Design challenges include fouling conditions, FEGT, flow profile uniformity
- CFD modeling assists in improved predictions

Diagnosis of performance issues in existing superheaters requires detailed analysis

- Field data collection is key
- CFD models provide insight of current and potential future arrangements and settings
- Potential solutions to mitigate corrosion and reduce intermediate steam temperatures
  - Optimize combustion air and liquor systems
  - Optimize attemperator system performance
  - Modify attemperation system
  - Remove superheater surface

Thank you!

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Non-Destructive Testing on Suspected SAC Locations

Thomas Kapperman and James Saxon III

Applied Technical Services

Applied Technical Services, LLC.

Engineering, Testing, Consulting and Inspection Services

Applied Technical Services

History and Overview

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Since our founding in 1967, ATS has established an excellent reputation within the businesses, industries, and legal professions. ATS has rapidly grown and expanded its testing services to become unmatched in the industry. We can take a closer look for you to help find the technical answers and solutions you need for any situation.

Our Mission

Deliver Assurance Through Precise Technical and Professional Services

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ATS Locations

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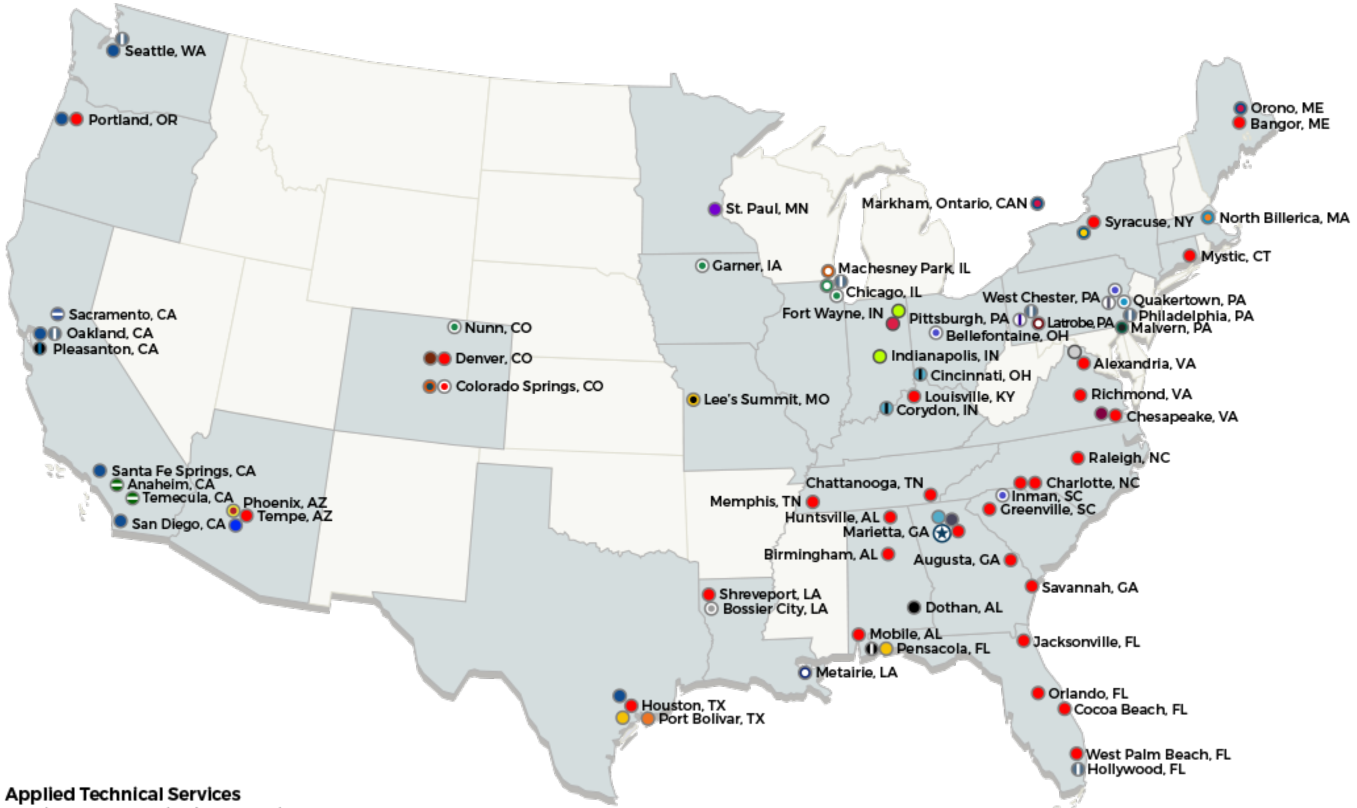

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Stress-Assisted Corrosion (SAC)

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What is it?

A corrosion fatigue mechanism, cyclically fractures magnetite scale in boiler tubes and pipes in a network pattern related to stress acting on the internal surface. Steel exposed at the fractured scale corrodes a bit to reestablish the protective scale layer, producing a surface locally more susceptible to continual fracture of the scale layer in the established pattern. The resulting damage typically is a cluster of parallel, elongated pits, grooves and fissures. Since SAC depends on the local stress, more than one affected place can occur in one tube header or pipe. In cross-section the damage is characterized by blunt-tipped, trans-granular cracks. From the multiple cracks one or two cracks ultimately predominate and penetrate far into and ultimately through the component wall.

Stress-Assisted Corrosion (SAC)

Fig. 1. Stress-assisted corrosion (SAC) damage in the internal surface of a 75 mm (3-in.) OD steel boiler tube with the scale removed to expose the crack-like damage.

Stress-Assisted Corrosion (SAC)

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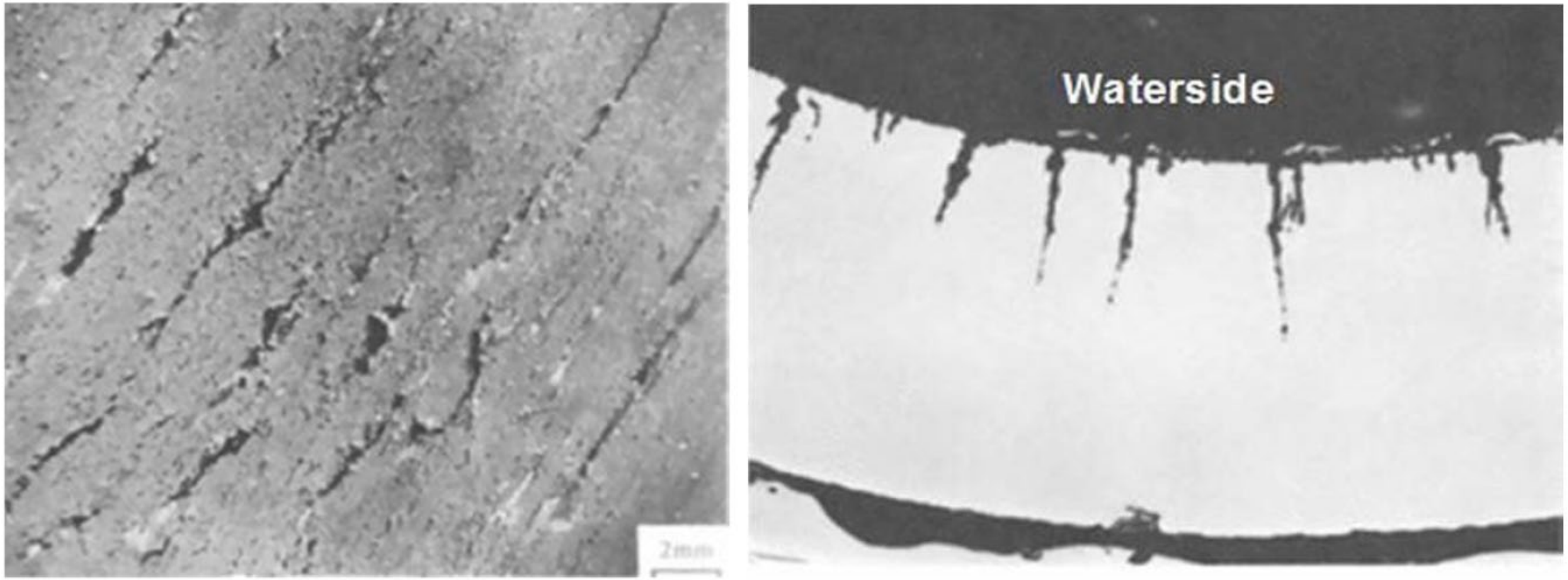

Fig. 2. Internal surface (left) and cross-section (right) of hot wall from 65 mm (2.60 in.) tube in a power boiler (*1*).

Stress-Assisted Corrosion (SAC)

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Contributing factors to SAC

- SAC occurs where the local strain exceeds 0.2%, i.e., exceeds the steel yield strength.
- Components operating at higher temperature (pressure) are more susceptible to SAC because magnetite scales fracture more easily and reform more slowly in higher feedwater temperature.
- SAC is more likely and grows more rapidly in boiler feedwater with higher dissolved oxygen content, typically resulting from inadequate feedwater deaeration or periodic emptying of the waterside. Boilers restarted with nondeaerated water are more susceptible to SAC damage.
- Acid cleaning to remove scale inside boiler tubes and headers does not, per se, exacerbate SAC but often is followed by leaks because chemical cleaning unblocks scale-filled fissures and grooves.
- SAC damage associated with external attachments on tube and pipe does not automatically reduce the component's pressure rating because of the attachment's reinforcing effect.

Stress-Assisted Corrosion (SAC)

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Why is it of concern?

- SAC can affect all types of pressurized carbon steel boiler components – tubes, pipes, headers and drums. Because corrosion rates are slow, SAC rarely affects boilers <10 years old but affects about 50% of boilers >20 years old. SAC growth rates are accelerated by higher levels of dissolved oxygen in the feedwater and more frequent scale fracturing stress cycles. Boilers that see more trips and service cycles are more likely to have SAC.
- Corrosion fatigue failures occur near support attachments, usually in water-wall tubing but also in economizer tubing, particularly where there is high heat flux and where stress from high restraint can develop. Typical locations include attachments for wind-box casings, buckstays and scallop-bars; also, where tubes connect to headers and to other tubes.

Stress-Assisted Corrosion (SAC)

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Inspection frequencies

- Conservatively, every power, recovery and biomass boiler > 15 years old should be inspected for the presence of SAC every 3 years.
- If the presence of SAC is confirmed, the scope of inspection should be expanded and repeated annually.

Stress-Assisted Corrosion (SAC)

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Qualifications of non-destructive testing (NDT) personnel

- Every NDT technician should be trained and certified in each NDT inspection method they use. The NDT Contractor's practices and procedures for certifying their technicians should be reviewed by a knowledgeable mill representative (KMR) for compliance with regulations relevant to the job.
- In the United States and Canada, respectively, NDT technicians should be certified in accordance with: SNT-TC-1A - American Society for Nondestructive Testing or Canadian General Standards Board.
- Technician certification records should be reviewed by the KMR before testing is done.
- The mill may require additional documentation to confirm a technician has the skill and recent experience or training for the specified testing, or to interpret results produced by qualified technicians. It always is good practice to require NDT technicians to directly show their competence in using a specific NDT method to detect and accurately size the particular type of defect or damage symptom of interest, using test specimens with real or synthetic defects, before the technician is allowed to do the NDT.
- Written NDT procedures are essential and should be reviewed by the KMR before the agreed testing commences.

Stress-Assisted Corrosion (SAC)

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Notes

- For every type of NDT, a written test procedure should be developed and qualified by a Level 3 technician in the appropriate method. Appendix A has requirements for qualifying NDT technicians.
- Regardless of which written, qualified NDT procedure is used, it is essential to pre-qualify the technicians who will use it to find and size SAC damage in representative damaged specimens.

Stress-Assisted Corrosion (SAC)

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Applicable methodologies

Detection:

- Requires internal access
  - Eddy current testing (ECT): uses electromagnetic induction to detect and characterize surface and sub-surface flaws in conductive materials.
  - Remote visual inspection (RVI): uses borescopes to visually identify SAC. Limited by cleanliness.
- Can be performed externally
  - Magnetic particle testing (MT): used for detecting surface, and shallow subsurface, discontinuities in ferromagnetic materials. With the use of a portable yoke on a direct current (DC) setting, can detect the presence of internal cracks that are within 3 mm (0.12 in) of the external surface of the boiler tube or header.

Stress-Assisted Corrosion (SAC)

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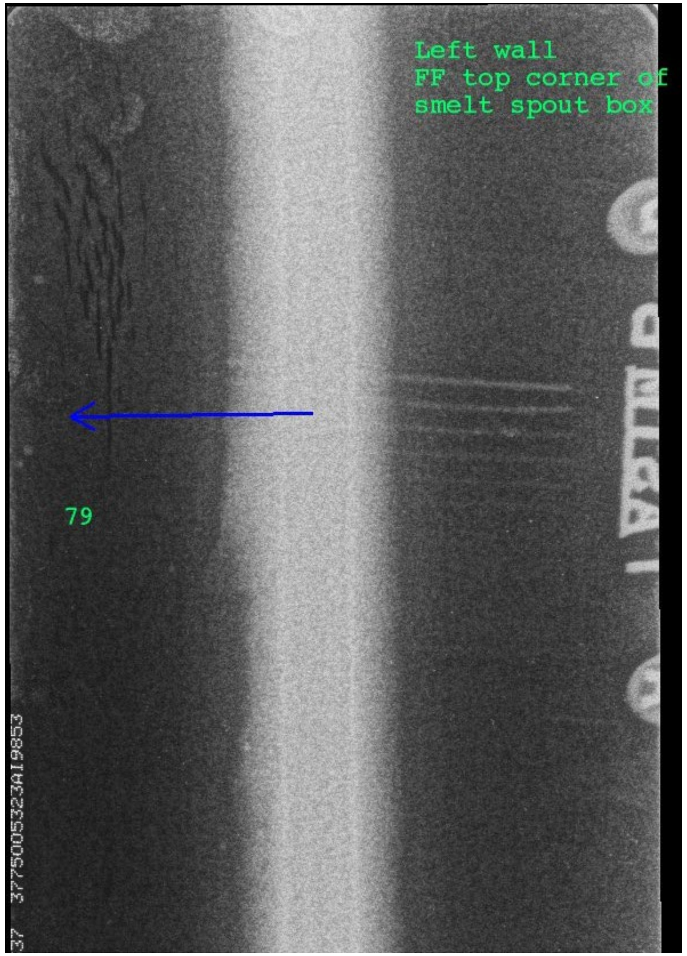
Applicable methodologies (continued…)

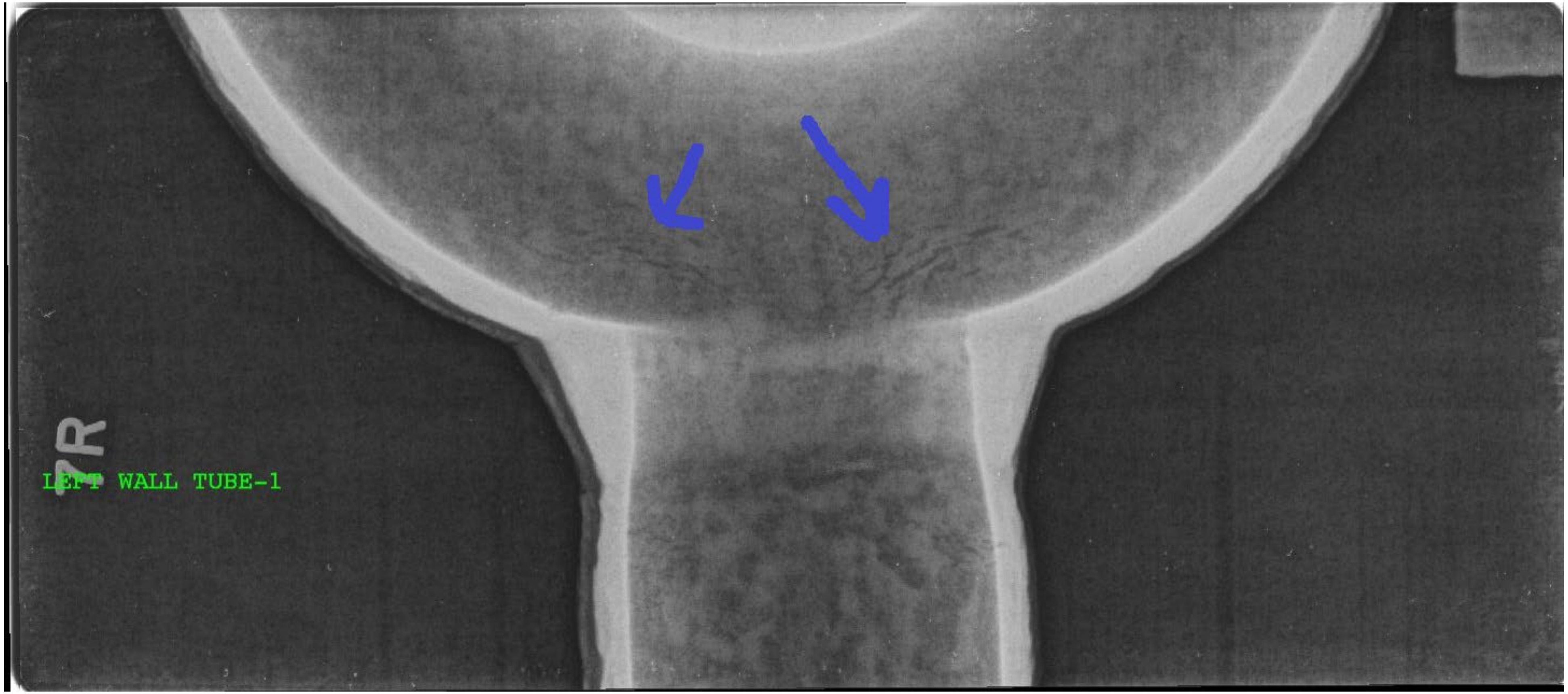
Detection:

- Can be performed externally and volumetric
    - Radiographic testing (RT): bombards the component with either x-rays or gamma radiation to expose and develop an image on media whether film, phosphorous plates, or an electronic panel. Requires limiting access to the surrounding area(s) to prevent exposure to harmful x-rays or gamma radiation. Affected areas can be reduced with the use of either computed radiography or digital radiography in combination of various x-ray and gamma radiation sources. Requires access to both sides of the component and limited by orientation and ability to quantify severity.
    - Ultrasonic testing (UT): induces sound waves into the component to measure the sound reflection and determine component thicknesses and flaw characteristics. Conventional shear wave or more advanced phased-array techniques and equipment can be used to detect and size SAC. Limited by surface condition of component (must be smoothly dressed).

Stress-Assisted Corrosion (SAC)



Stress-Assisted Corrosion (SAC)



Stress-Assisted Corrosion (SAC)

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Record keeping

- Essential to any SAC inspection program is record keeping. Original construction documents; detailed trips, service, leak and repair records; and detailed SAC inspection location records aid in comprehensive inspections and add value to risk analysis.

Lunch and Learn

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Want to learn more

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2025 International Chemical Recovery Conference – Toronto!

- <u>September 24-26, 2025</u> (Wed – Fri)
- Location: University of Toronto's Chestnut Conference Centre, located at 89 Chestnut Street, Toronto, Canada
- Information:
  - Website: https://event.fourwaves.com/icrc2025/pages
  - Abstract Deadline Feb 17, 2025
  - Paper Deadline May 9, 2025
  - Mandeep.Rayat@utoronto.ca>
  - Nikolai.DeMartini@utoronto.ca

American Forest & Paper Association

Minimizing Unplanned Outages and Recovery Boiler Maintenance Costs Utilizing On-line Pulsed Detonation IMPULSE® Cleaning

Introduction

There are continuing and expanding challenges related to safe and effective on-line cleaning of recovery boilers.

The large quantity and low melting temperature of the ash make black liquor one of the most difficult deposits to remove with conventional sootblowers.

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Introduction

Sootblowers on a recovery boiler must operate on a nearly continuous basis to keep the boiler in operation.

The tremendous number of moving parts and the heavy workload required of the sootblowers demands constant attention and ongoing maintenance to keep them operational.

Introduction

The effective and proactive use of a pulsed detonation cleaning system greatly increases boiler efficiency, eliminates the extremely high cost to operate and maintain the sootblowers, and decreases unplanned outages — all of which will result in significant annual savings.

Introduction

Pulsed detonation or “IMPULSE®” cleaning technology has proven to provide dramatic improvements in online cleaning of fouled surfaces when compared to traditional sootblowers and other existing cleaning systems being used.

Unique Challenges of Recovery Boiler Operations

Unique Challenges of Recovery Boiler Operations

The large quantity and extremely tenacious nature of the deposits generated in a black liquor recovery boiler are some of the most difficult deposits to remove.

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Unique Challenges of Recovery Boiler Operations

Factors such as high operating cost, high maintenance cost, ineffectiveness at maintaining heat transfer rates, and negative impact on mechanical component life are all problems that may affect the various cleaning technologies.

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Unique Challenges of Recovery Boiler Operations

The use of a pulse detonation cleaning system offers a very distinct advantage over other types of cleaning techniques on a recovery boiler.

This type of proactive cleaning system is particularly beneficial where the combustion process produces a highly reactive gas stream.

Unique Challenges of Recovery Boiler Operations

As high temperature flue gas contacts the much cooler heat transfer surface, coarse ash particles will cause inertial impaction.

When buildup and masking of the heat transfer surface happens, heterogeneous condensation between the pre-existing deposits and the vapors of volatilized compounds in the flue gas will occur.

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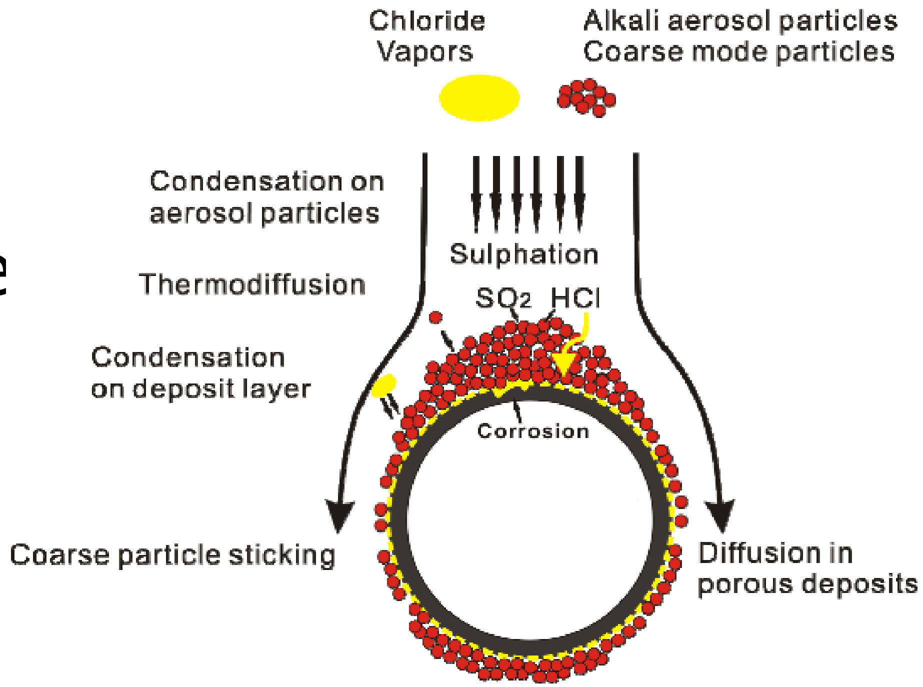
Unique Challenges of Recovery Boiler Operations

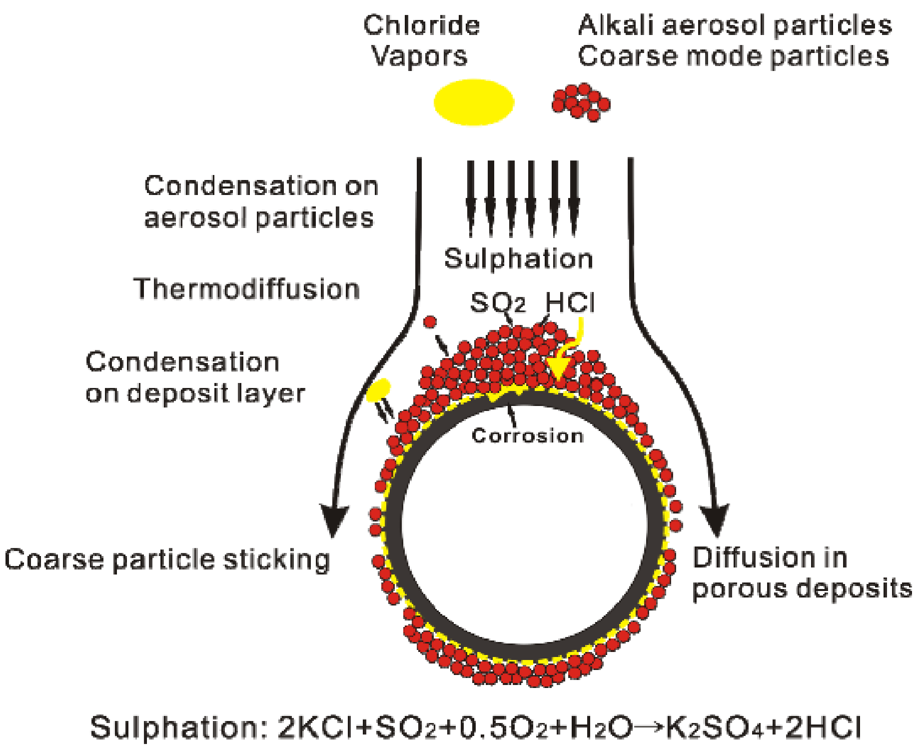
The supersaturation of salts, e.g., Na2SO4, K2SO4, or KCl, can cause formation of new particles by nucleation. This process is called thermophoresis.



Sulphation: $2KCl+SO_2+0.5O_2+H_2O \rightarrow K_2SO_4+2HCl$

Unique Challenges of Recovery Boiler Operations

The produced alkali silicates and/or mixed alkali and/or calcium chlorides/sulfates that deposit on the heat-transfer surface cause accelerated fouling and corrosion.



Using frequent and proactive shockwave energy from pulsed detonations to clean the heat transfer surfaces in boilers

Shockwave Cleaning

The use of high intensity shockwaves has proven to provide dramatic improvements in online cleaning of fouled surfaces when compared to traditional sootblowers and other existing cleaning systems being used.

Shockwave Cleaning

Pulse detonation (or IMPULSE®) cleaning is **not** in reference to the use of dynamite, detonation cord, or manually inserted bags of gas that create open air detonations within the boiler have significant cost, risk and liability associated with them.

Shockwave Cleaning

The pulse detonation impulse or shockwave is created through a rapid combustion process. The basis for this rapid combustion technology has roots deep within the aerospace research and development field where high-throughput, pressure-rise combustion has the potential to radically change the design of future propulsion systems.

Background of the IMPULSE® cleaning technology

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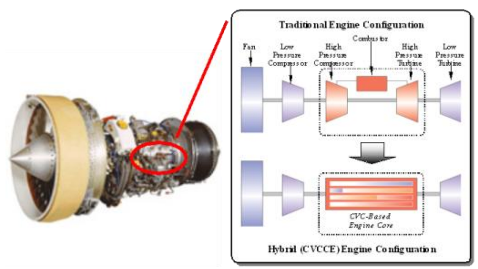
Background of the IMPULSE® cleaning technology

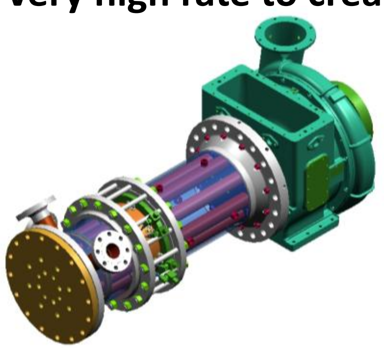
The IMPULSE® cleaning technology is a derivative of GE Aviation's pulse detonation propulsion development at the GE Global Research Center.

A pulse detonation engine detonates a mixture of fuel and air to create supersonic shockwaves.

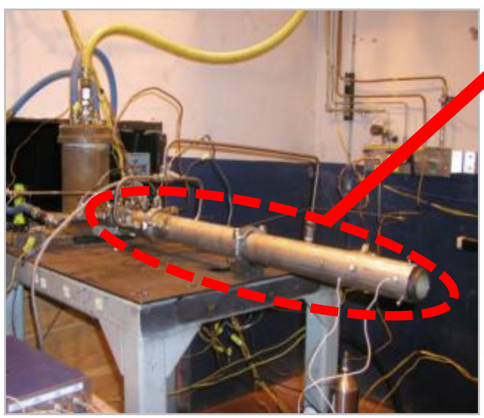
Engineers at GE Energy determined that the technology could serve as a powerful and very effective boiler cleaning system. The technology was adapted to replace the traditional acoustic horn driver with a pulse detonation shock tube, and the system was introduced to the coal fired utility market in 2006.



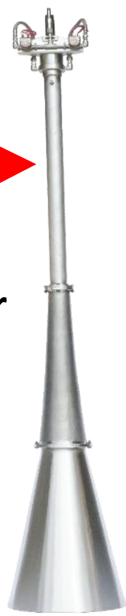
A pulse detonation engine is designed with a large number of combustion tubes all cycling at a very high rate to create thrust



A single 2" shock tube used for bench testing



Replaced acoustic driver with combustion tube



75 hz Acoustic Horn

Pulse Detonation Cleaner

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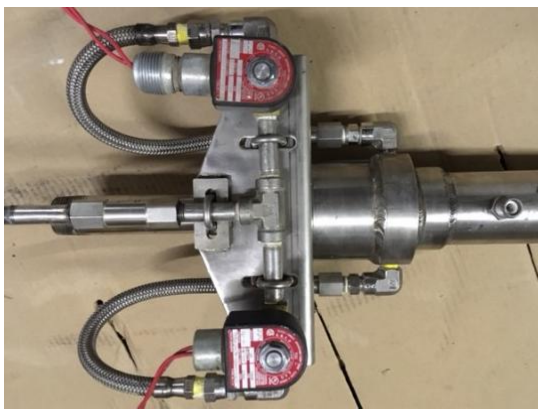
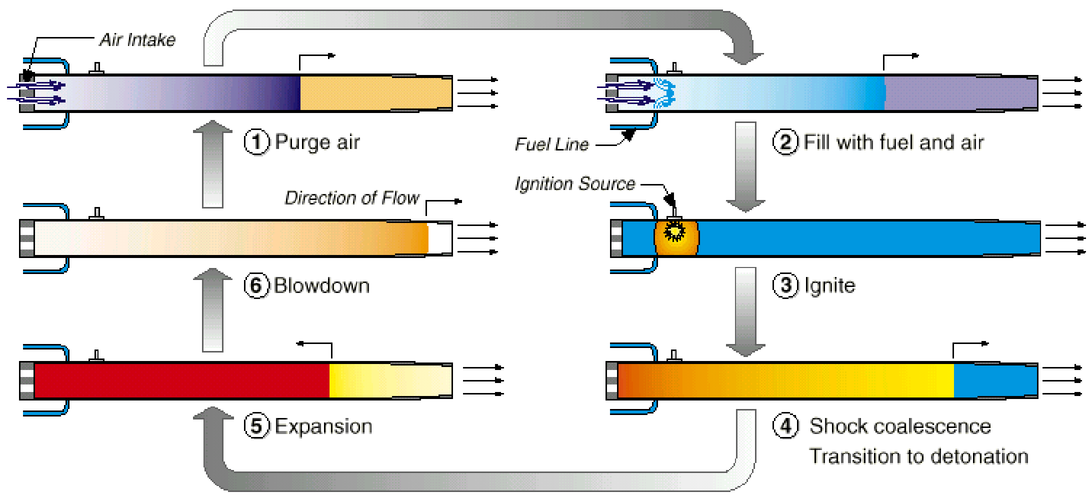
How It Works

Formation of an impulse or shockwave

1. **Cyclic combustion event creates supersonic impulses**
2. **Injection of fuel and air into an integral mixing chamber followed by ignition and combustion**
3. **Shockwave is result of the acceleration of a flame to supersonic speeds over short distance and time**



Combustion Chamber Mixing Head



High Energy Impulse Wave

High Speed Video Capturing flame acceleration- 3 MS clip

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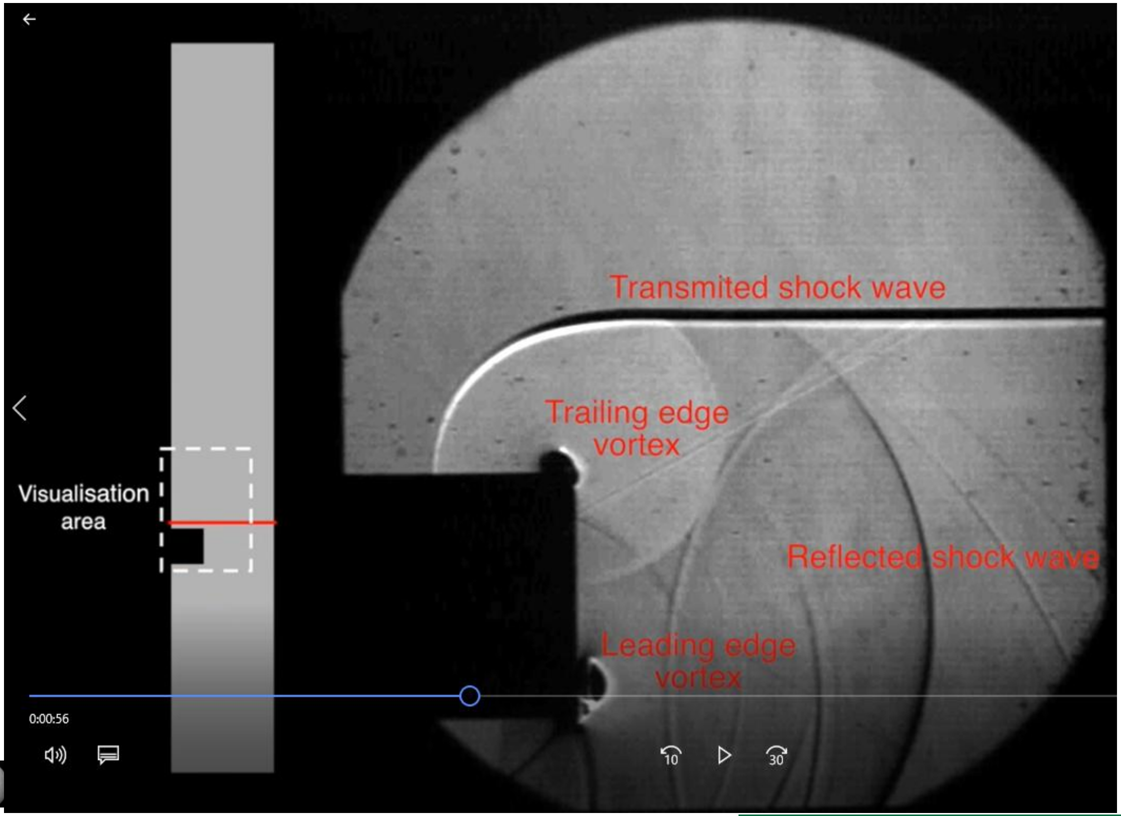
How It Works-Understanding Shockwaves

Cleaning energy consists of compression and rarefaction waves with omni-directional vectors.

When a detonation occurs in the combustion tube, a shockwave is generated, characterized by a sharp rise in pressure and a tremendous amount of reversing airflow with it.

The IMPULSE Cleaner creates high velocities combined with a high density front, and ultra-low pressures behind the shock, create an infinite amount of multi-directional high/low pressure vectors that serve as extremely effective cleaning energy.



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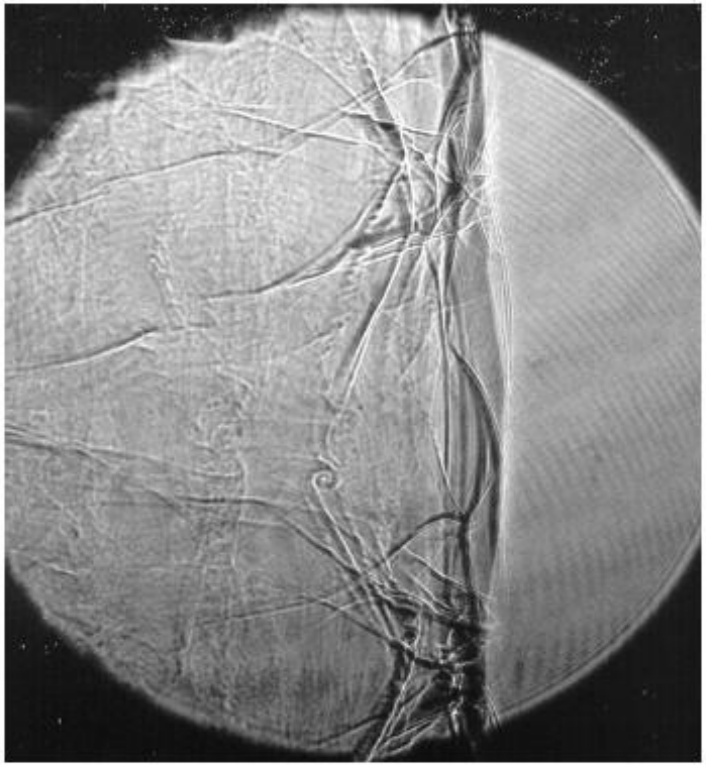
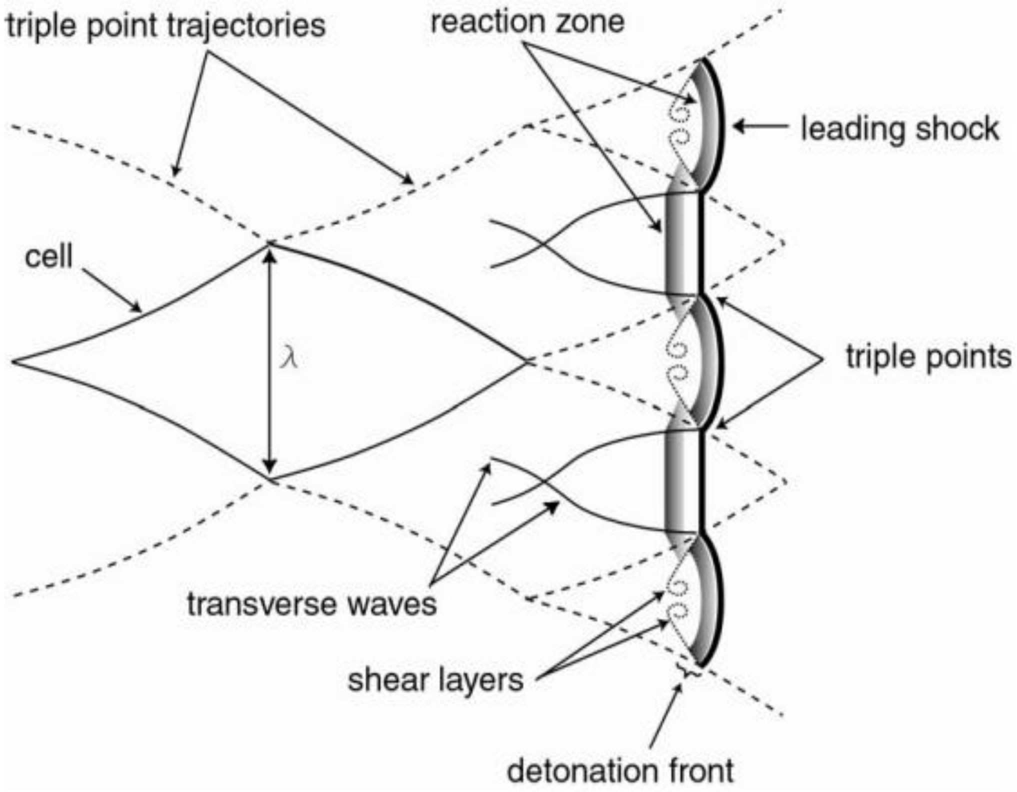
How It Works-Understanding Shockwaves

Cleaning Wave Structure

Cleaning energy consists of compression and rarefaction waves with omni-directional vectors.





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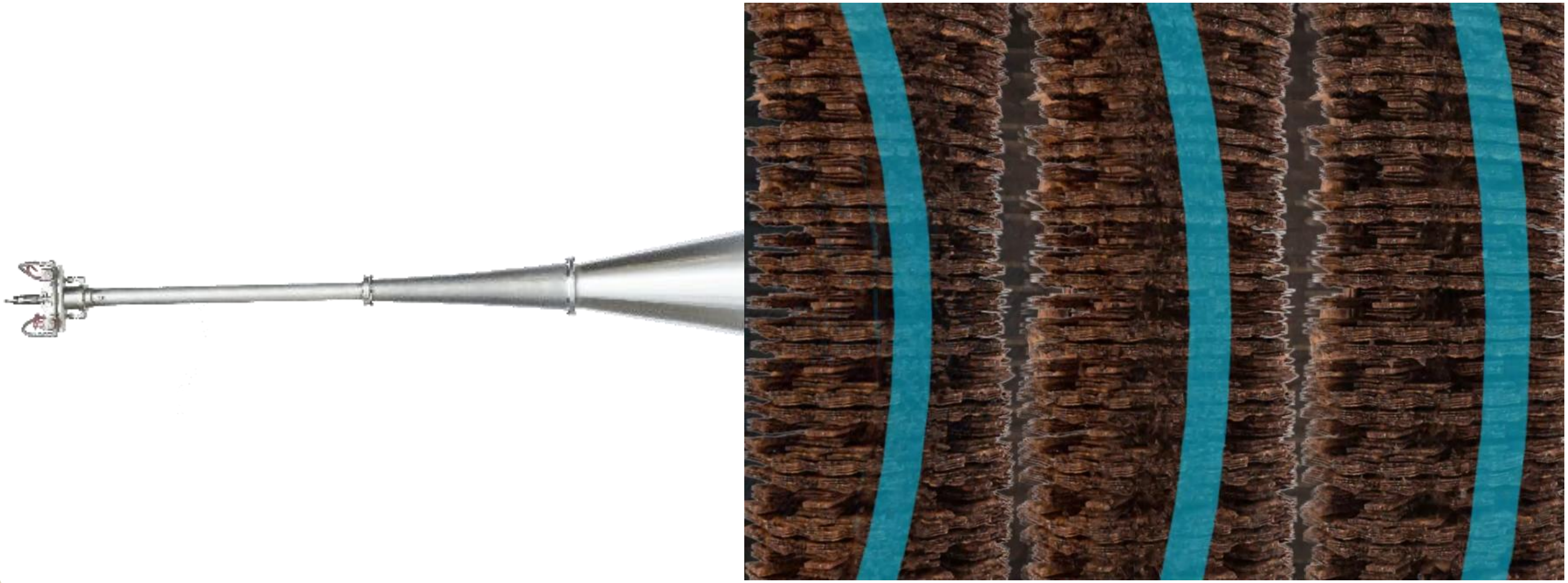
How It Works - Shockwave Cleaning Action

Operated at 2 impulse bursts per second for a total of 20 to 30 repetitive, penetrating shockwave impulses.

The abundant repetition of the highly focused and directed shockwaves provides an intense amount of cleaning energy, first fracturing embedded deposits, then methodically working them out and away from the heat transfer surfaces by an effective combination of a highly pressurized supersonic front followed by a rarefaction or low-pressure displacement and trailing eddy current.



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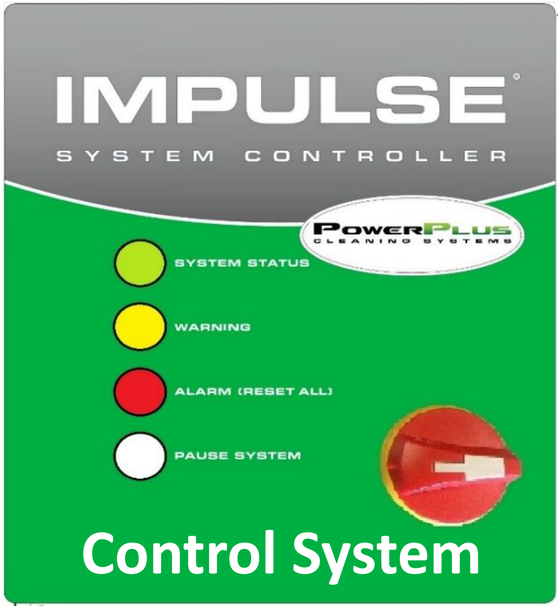
IMPULSE Cleaning System Specifications

Specifications - System Consists of:

Electrical	110/220 VAC
Fuel	Ethylene gas (C2H4)
Fuel consumption	Based on operation
Impulse/cycle	20 to 30 bursts (typical)
Cycle frequency	Every 30 min. to 1 hour (typical)
Oxidizer	Plant Air
Air Consumption	100-120 SCFM @ 70-90 PSI
Material	Stainless steel



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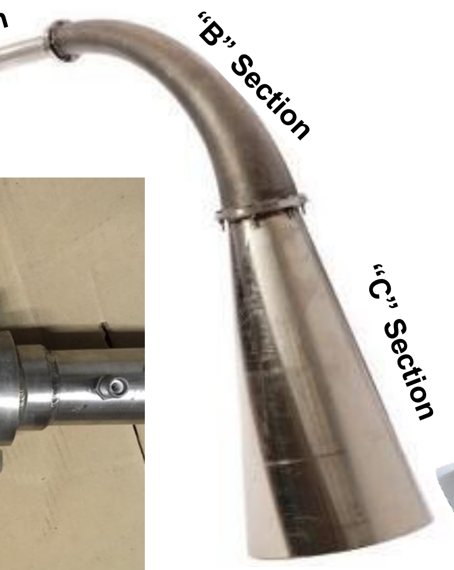
System Specifications

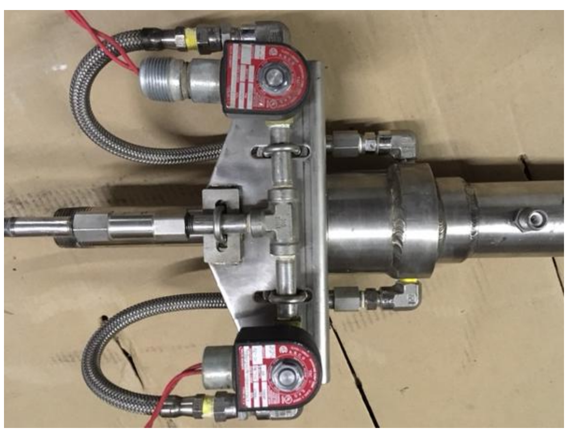
The IMPULSE Cleaner is constructed from 3 separate pieces that are bolted together in the field.

The “A”-section, also referred to as the combustion chamber, is fabricated from stainless steel and is about 55”to 71” long and two to 3 inches in diameter. (depending on model)

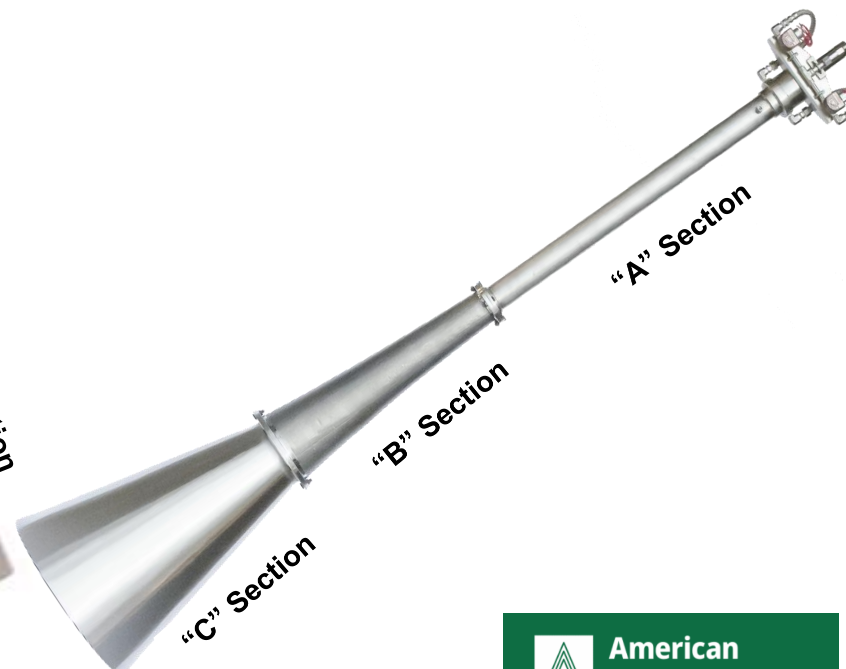
The “B”-section is a casting that diverges from two-inches out to approximately 6 inches in diameter over an axial length of 30 inches. There are 2 options: a straight or curved version. The curved section has a 90-degree bend in it, which allows for a slim mounting profile.

The “C”-section diverges from 6 inches out to 10 inches over an axial length of 15 inches and is typically located inside the boiler, or it can be recessed so it is mounted flush with the inside wall of the boiler.





Mixing Head



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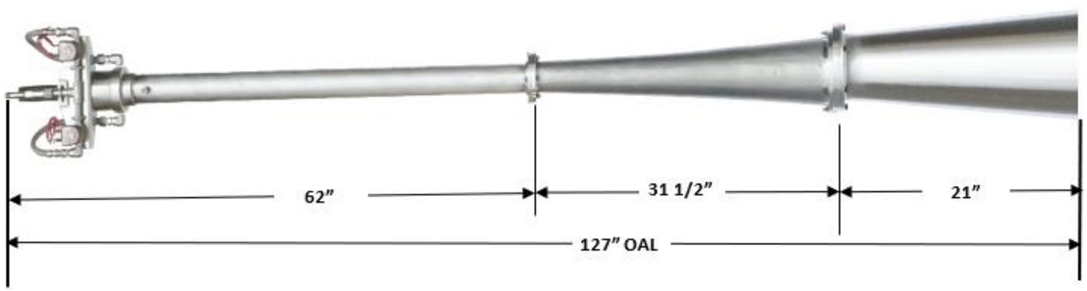
IMPULSE® Cleaner Available in 3 Models/Sizes

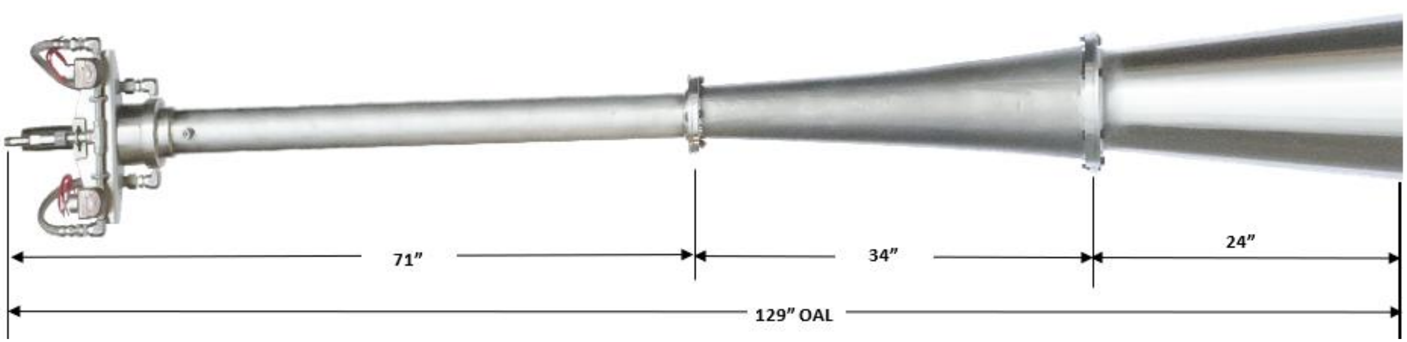
Model 2.0

Model 2.5



Double the output of the 2.0

Model 3.0



Four-times the output of the 2.0

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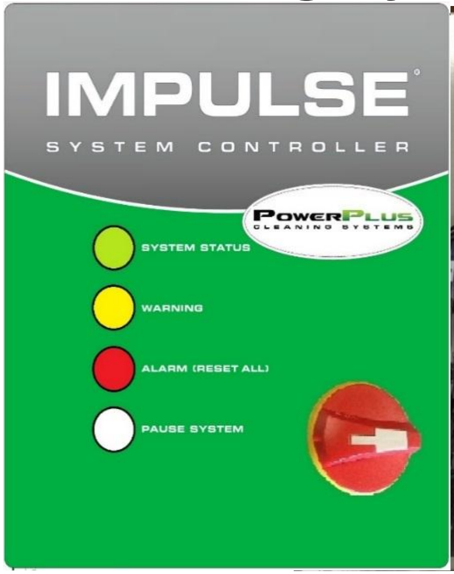
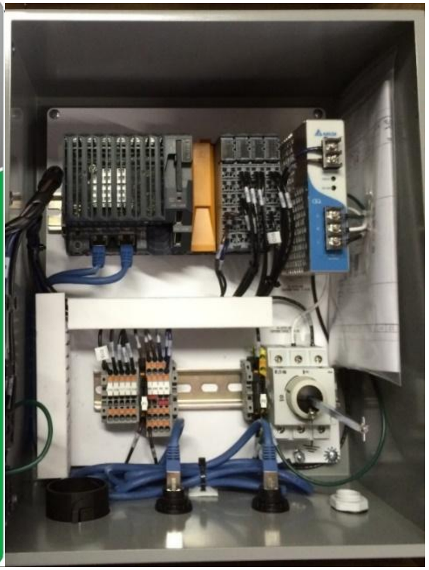
System Specifications

IMPULSE® Cleaning System Controller

CPU Exterior





CPU Interior

FEATURES INCLUDE:

- Continuous monitoring of critical parameters to ensure safe operation
- Solid state components provide greater reliability and allow for easy repair.
- Very robust multi-spark ignition system.
- Constant monitoring of gas and airline pressures.
- Rotary Disconnect Safety Closure (Lock/Tagout)
- Wireless connection capability (optional)
- Remote diagnostic capability (optional)

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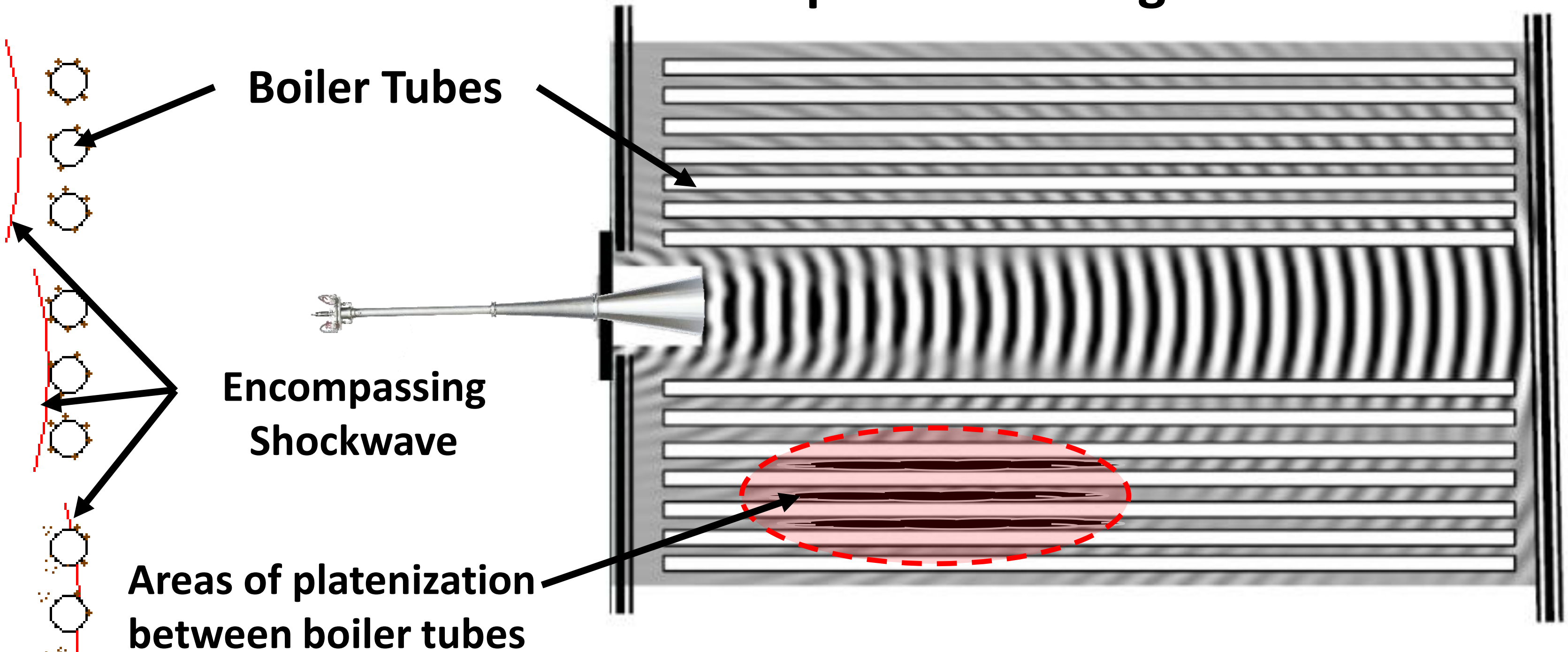
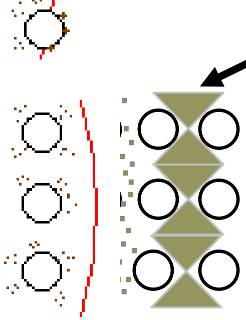
IMPULSE Cleaner Placement and Operation

Placement and Operation

Impulse Cleaning Action





- Intense cleaning waves approach tube surfaces, encompass tube surfaces, transition around to back side, reconnect, and continue travelling.
- Non-Line-Of-Sight Cleaning
- Deep Penetration throughout tube bundle
- Non Erosive

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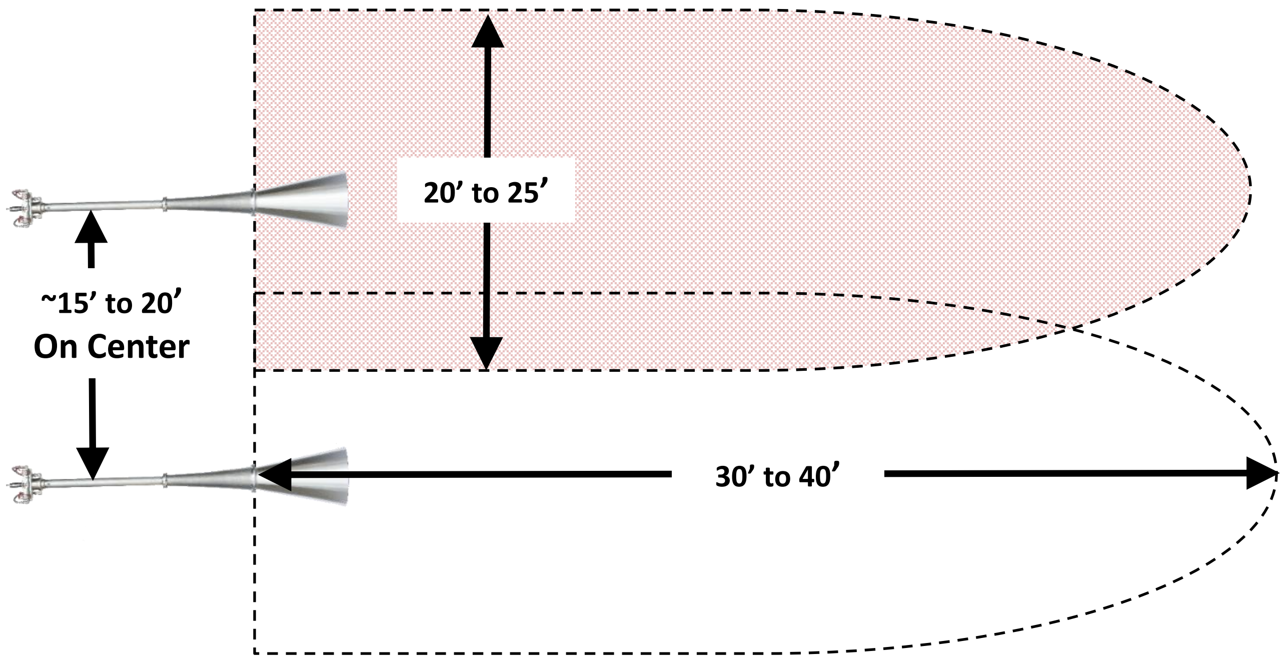
Placement and Operation

The proper operation of an impulse cleaner relies on achieving a suitable installation configuration.

The approximate*cleaning pattern of an impulse cleaner, subject to process conditions, is generally 20 to 25-foot side to side by 30 to 40-foot deep.



Note* Cleaning patterns will vary based upon IMPULSE model used, as well as the temperature, boiler design, obstructions and internal components

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Experience Cleaning Many Different Applications

Introduced to the market in 2006 with documented/successful experience on a wide range of applications

- Coal Fired Boilers
- Pet Coke Fired Boilers
- Waste to Energy Boilers
- Wood Fired Boilers
- Industrial Heat Recovery (Reformers, Oxidizers, Recuperators, Calciners, etc.)
- Heat Recovery Steam Generators (HRSGs)

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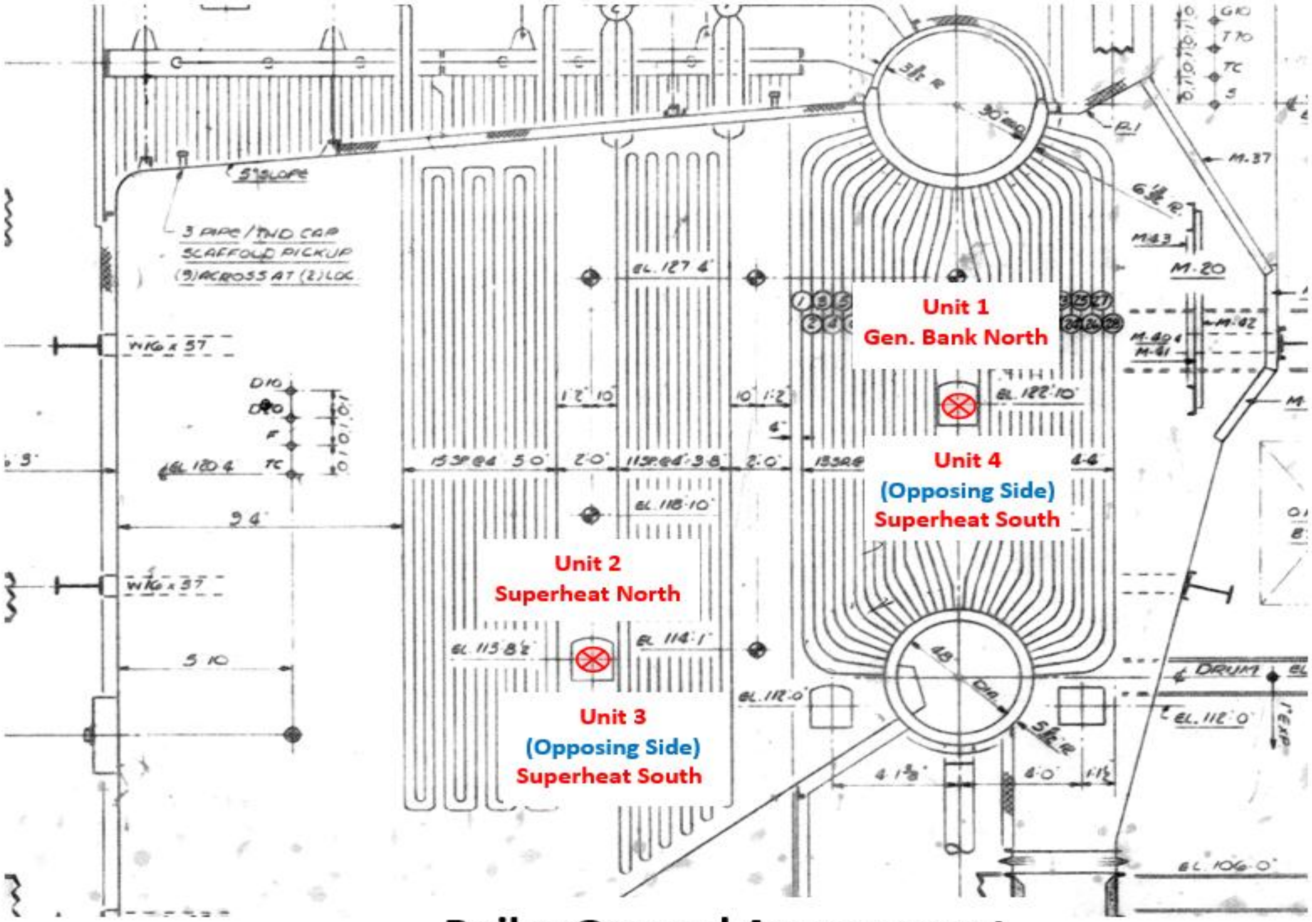
Case Histories
Documented Results

Case History #1
Biomass Boiler

Biomass poultry litter boiler in Northeast

INSTALLATION DETAIL

A total of four (4) IMPULSE cleaners were installed on the 50 MW Zurn boiler. Two (2) IMPULSE cleaners were installed on the North Side of the boiler and two (2) IMPULSE cleaners were installed on the South Side of the boiler through existing access door openings, directly opposing each other, at the locations highlighted below. The the distance across the boiler is approximately 34 ft.



Boiler General Arrangement

Biomass poultry litter boiler in Northeast

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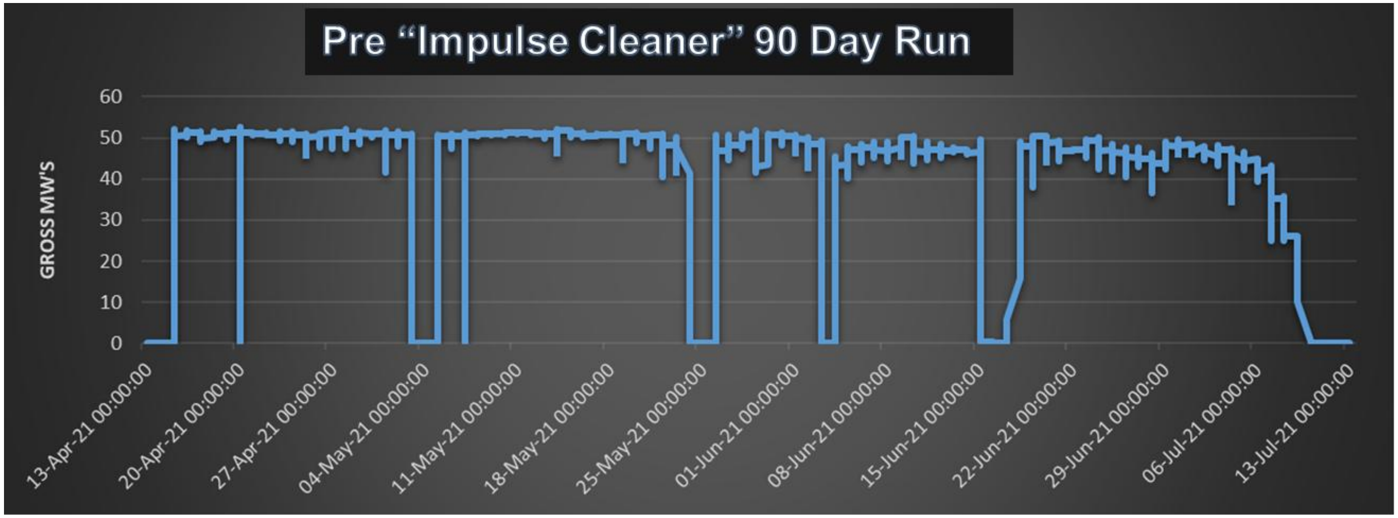
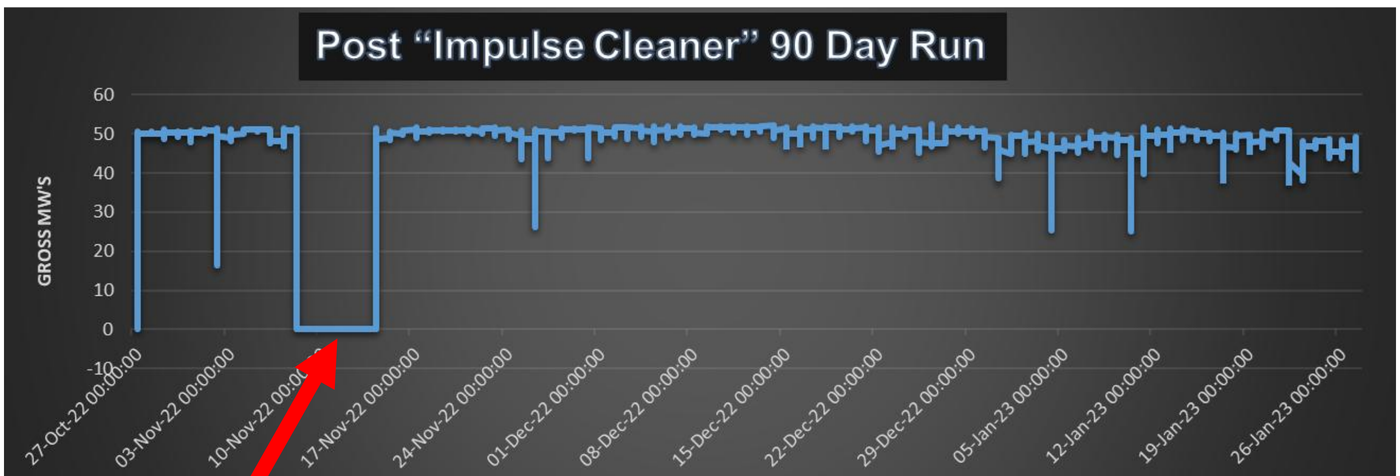
Biomass poultry litter boiler in Northeast

Before Installation: Forced Outages to clean 7 times in 90 days





High fouling fuel

Note: The above outage was due to a mechanical failure unrelated to buildup or pluggage in the boiler

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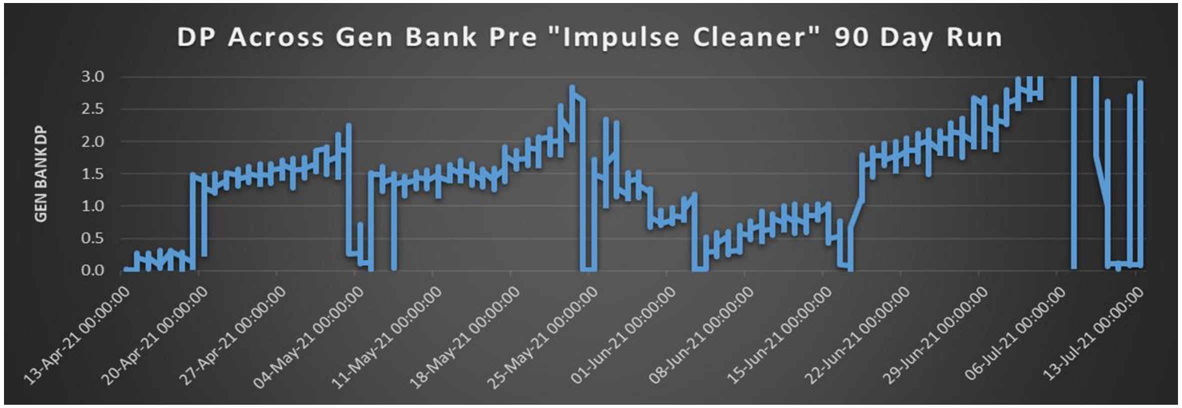
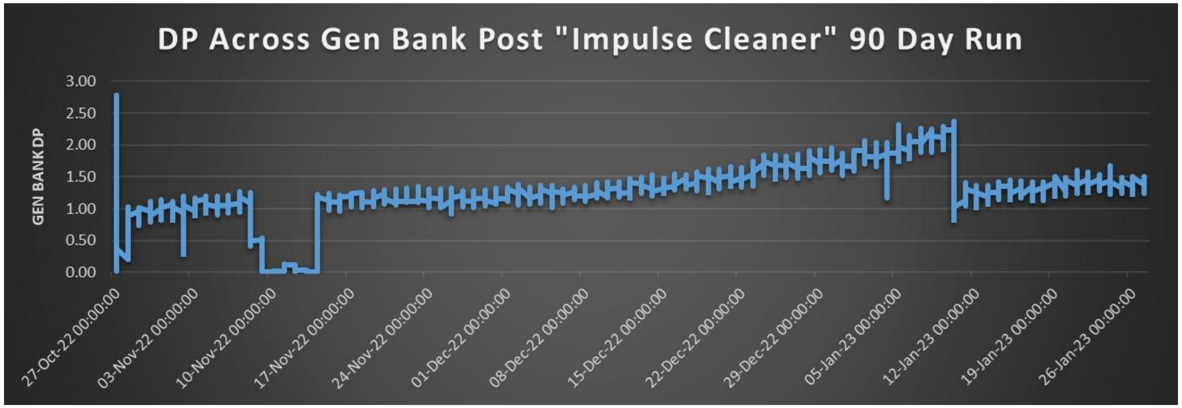
Biomass poultry litter boiler in Northeast

Economizer Gas Outlet Temperature Reduced 20°F





Following the installation of IMPULSE cleaners- Generating Bank after 90+ days of operation

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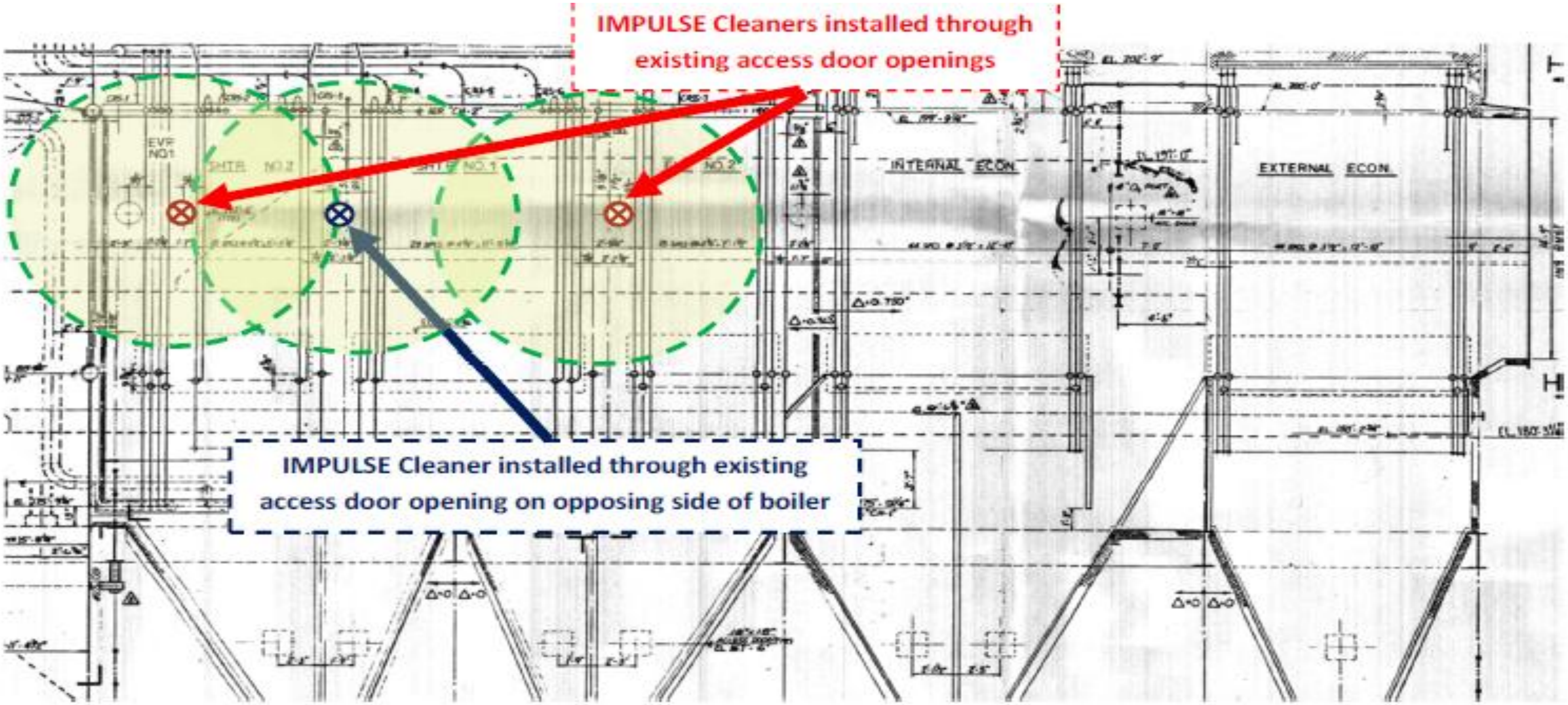
Case History #2
Waste to Energy Boiler

Waste to energy boiler in the Midwest

DESCRIPTION OF INSTALLATION

A total of three (3) IMPULSE cleaners installed on a Waste to Energy boiler at a large midwestern facility; two (2) IMPULSE cleaners installed on North side of the boiler, and one (1) IMPULSE cleaner installed on the South side of the boiler. The first cleaner on the North is located in the Secondary Superheat and most problematic area of the boiler, the second cleaner is on the South and is located in the Primary Superheat, the third and last cleaner is on the North side located in the Evap 2 section of the boiler.



Elevation View

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Waste to energy boiler in the midwest

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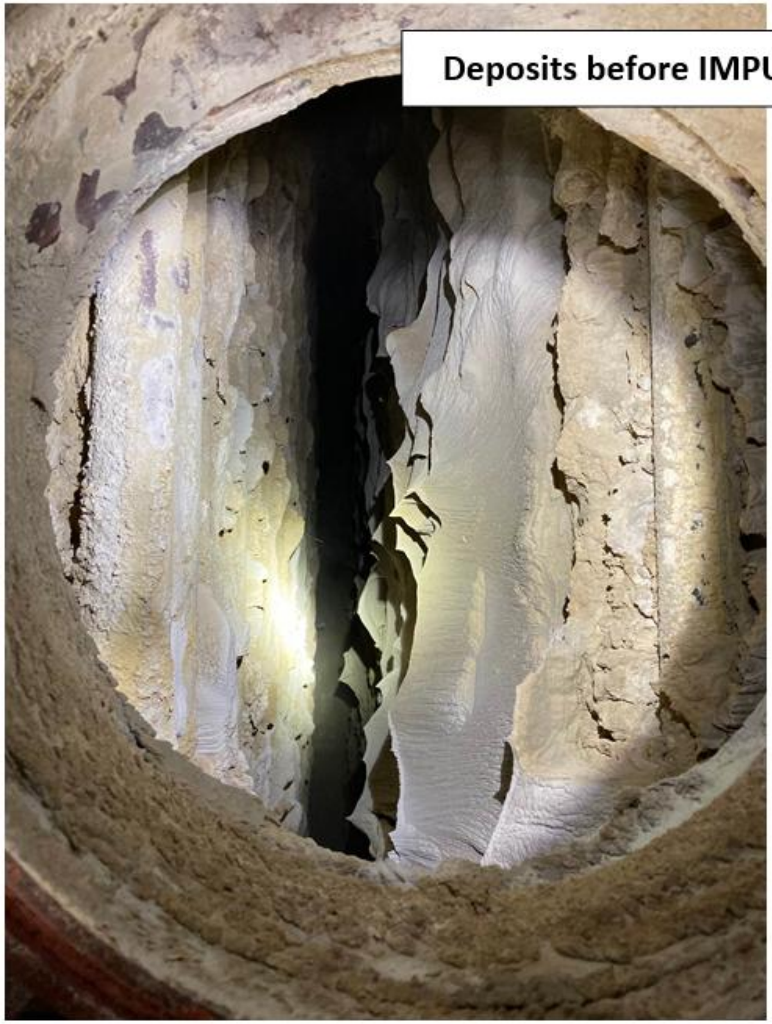
Waste to energy boiler in the Midwest



Deposits before IMPULSE cleaner installation

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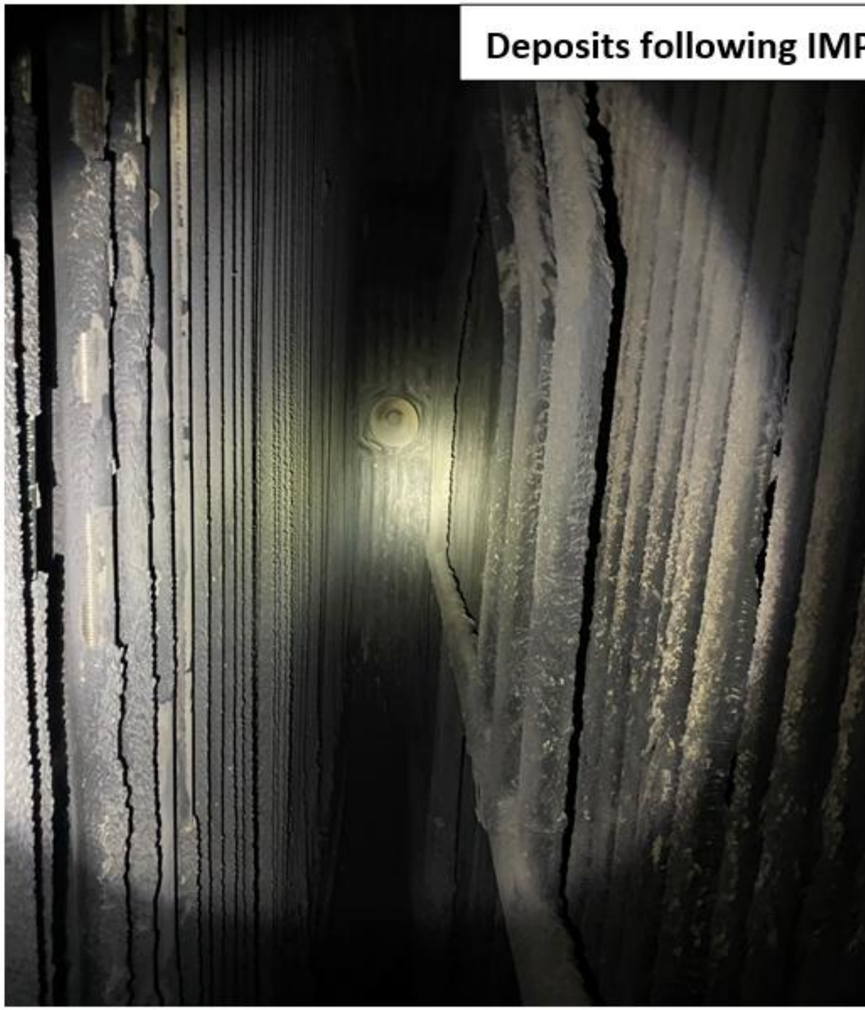
Waste to energy boiler in the Midwest

Deposits following IMPULSE cleaner installation



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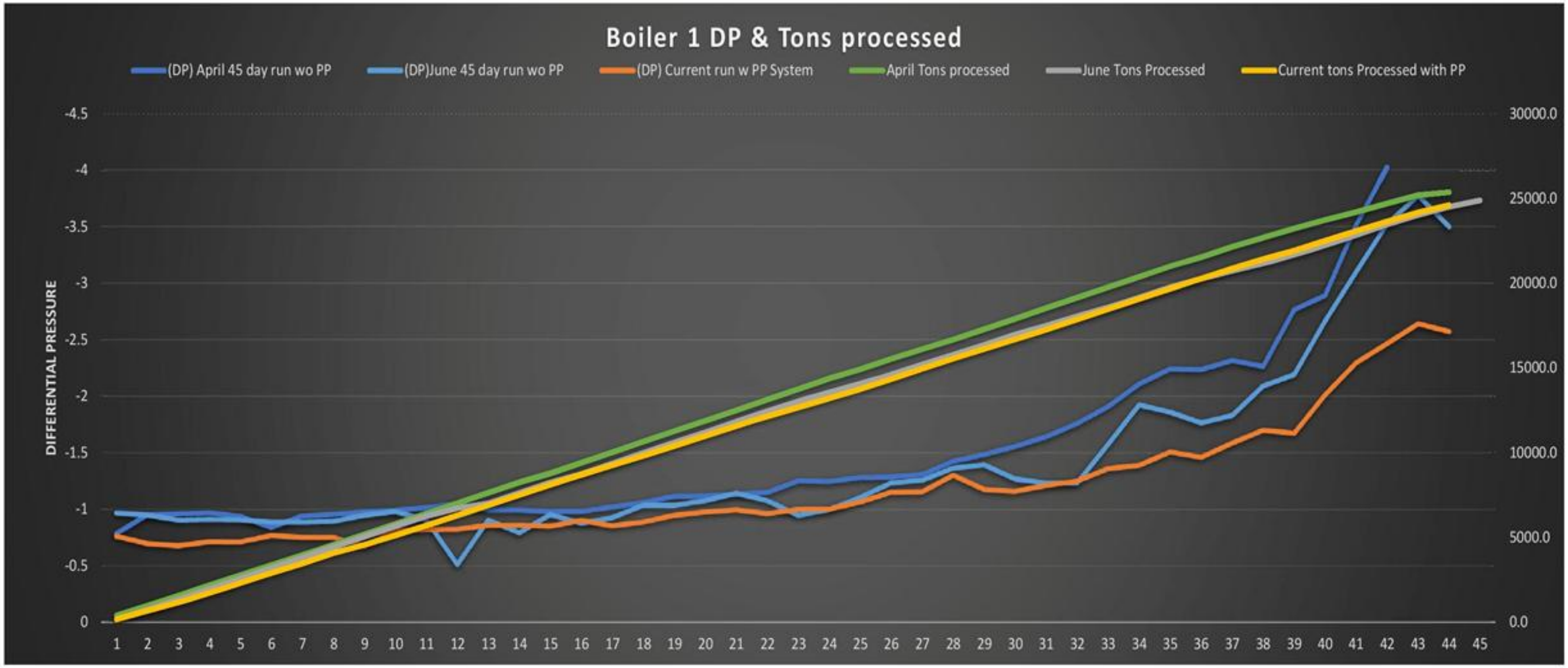
Waste to energy boiler in the Midwest

COMPARATIVE RESULTS

Typical differential pressure prior to the installation of the IMPULSE cleaners after only 45 days of operation averaged 3.5 to 4”. Differential pressure following the installation of the IMPULSE cleaners after 45 days of operation reduced to 2.5”.



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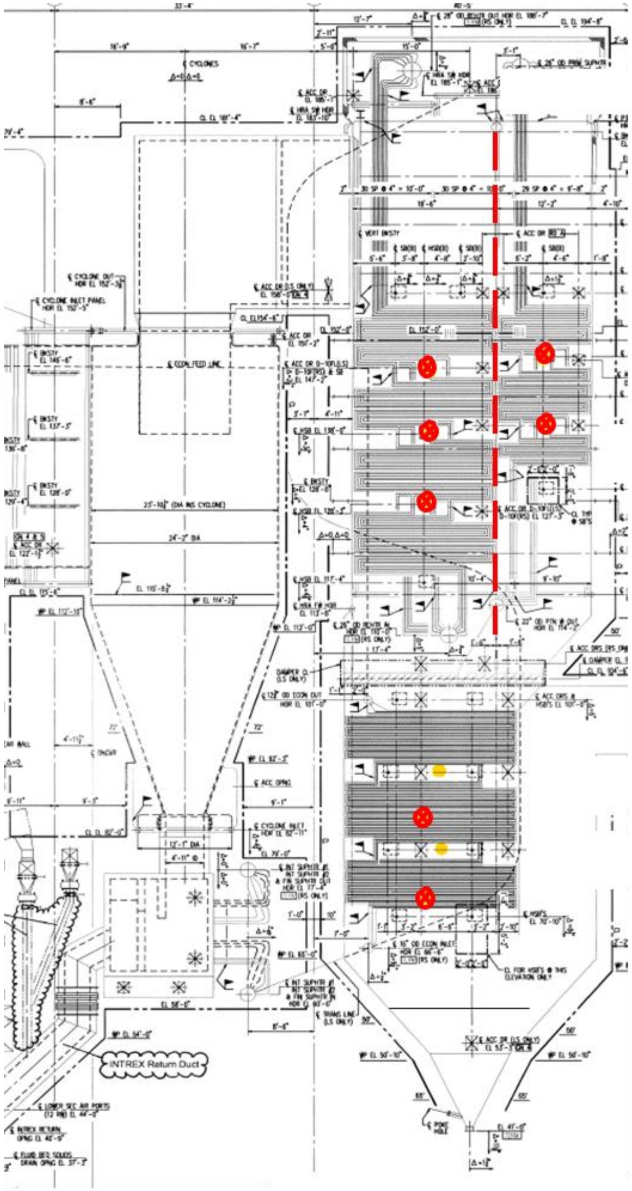
Case History #3
Utility Boiler

CFB boiler at a Southern utility



Two Identical 297.5 MW Foster Wheeler Circulating Fluidized Bed Combustors (CFBs) Burning a fuel-diverse mix of Petcoke, Coal, and Refuse.

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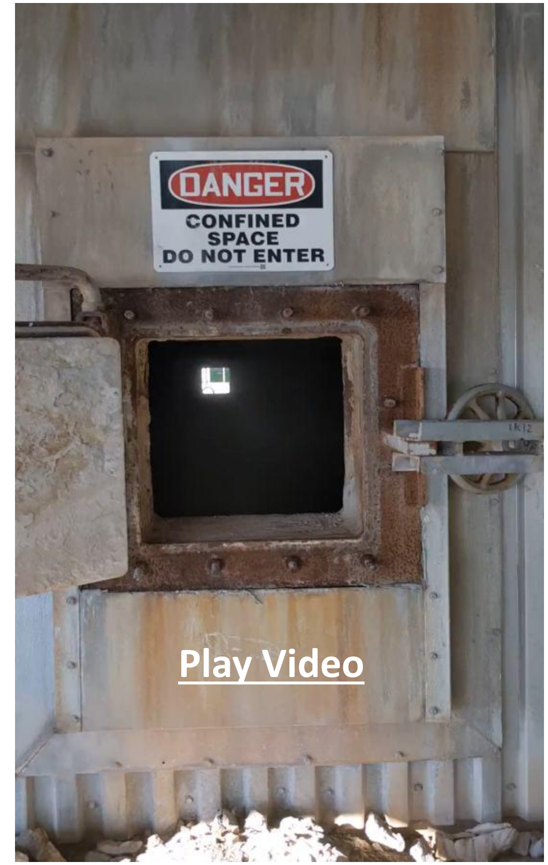
CFB boiler at a Southern utility

Note:

Boiler had been cleaned with Det-Cord prior to installing and commissioning the IMPULSE cleaner.



***Sootblowers totally replaced**

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CFB boiler at a Southern utility

Results

The IMPULSE cleaning systems were installed on the Unit 2 boiler in December of 2020.

On July 26, 2021, the facility reported that the Unit 2 boiler with the IMPULSE cleaning system installed had realized a 2.5% improvement in heat rate.

Additionally, based on reporting from their fuels group the Unit 2 boiler was burning much less fuel to produce the same output as the Unit 1 boiler, stating that the Unit 2 boiler was $1.07 per MW cheaper to run than the Unit 1 boiler.

The only difference that they could see between the two boilers is the use of the IMPULSE cleaning system.

Subsequently the facility installed an additional 14 IMPULSE cleaners in 2022 for their Unit 1 boiler.

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Final Thoughts

Pulse detonation (or IMPULSE®) cleaning key points

- The design of the IMPULSE cleaner does not utilize any moving parts and doesn't require frequent and costly maintenance or repair.
- The IMPULSE cleaner consumes a minimal amount of fuel providing a very low ongoing operational cost.
- The IMPULSE cleaner does not scavenge steam/reduces steam use (cost of steam).
- The aggressive/proactive use provides effective cleaning <u>without</u> erosion or damage to the heat transfer surfaces.
- The shockwaves are encompassing and penetrate deeper into the tube bundle than the traditional sootblower "line of sight" cleaning.
- The IMPULSE cleaner requires minimal intrusion into and out of boiler, has minimal installation footprint and minimal installation costs.

Final Thoughts/Questions

Thank You!

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Flame Speeds for Methane, Propane and Ethylene

TABLE I - PREDICTED RELATIVE FLAME SPEEDS

NACA

Fuel	Equivalence ratio (a)	Activation energy according to thermal theory (kcal/g-mole)	Initial temperature (°C)	Flame temperature (°K): Theoretical adiabatic (b)	Flame temperature (°K): Based on sodium D-line (c)	Equilibrium radical pressure (total pressure of 1 atm) (d): p_H (adiabatic)	p_H (sodium D-line)	p_{OH} (sodium D-line)	p_O (sodium D-line)	Predicted maximum flame speed, relative to max. flame speed at 25° C (cm/sec): Thermal unimolecular (e)	Thermal bimolecular (f)	Square-root law (g)	Experimental flame speed (cm/sec)
Methane	1.122 (10.5 volume percent)	51h	-132	2053	2008	0.270×10^{-3}	0.203×10^{-3}	0.282×10^{-3}	0.003×10^{-3}	10.5	10.1	11.9	13.4
			-73	2090	2045	.340	.265	.407	.005	17.5	17.1	18.8	19.2
			25	2153	2108[1]	.520	.395	.635	.013	34.0	34.0	34.0	34.0j
			34	2159	2114	.558	.408	.665	.014	35.9	36.0	35.5	35.5
			94	2197	2152	.670	.517	.890	.023	50.0	50.9	47.3	48.0
			150	2231	2186	.810	.630	1.13	.036	66.0	68.2	60.0	62.0
			206	2268	2221	.980	.770	1.45	.057	85.6	89.7	74.6	80.0
			261	2298	2253	1.16	.915	1.80	.084	107.7	114.5	90.5	95.0
			344	2345	2300	1.48	1.17	2.44	.141	148.2	160.9	118.3	133.0
Propane	1.049 (4.2 volume percent)	38k	-73	2204	2149	0.460×10^{-3}	0.299×10^{-3}	1.17×10^{-3}	0.052×10^{-3}	22 .8	22.2	23.0	23.5
			25	2253	2198	.590	.420	1.62	.086	40.2	40.2	40.2	40.2j
			29	2255	2200	.607	.432	1.65	.088	41.3	41.3	41.1	41.5
			93	2288	2233	.700	.525	2.00	.124	55.5	56.4	54.4	56.4
			149	2317	2262	.860	.627	2.38	.169	70.2	72.5	67.8	69.2
			204	2345	2290	1.00	.737	2.80	.228	86.8	91.0	82.6	87.0
			260	2371	2316	1.18	.855	3.26	.300	105.7	112.3	98.7	105.0
			343	2412	2357	1.43	1.07	4.10	.460	139.0	150.6	126.9	141.2
Ethylene	1.165 (7.5 volume percent)	40l	-73	2302	2198	1.13×10^{-5}	0.629×10^{-3}	0.94×10^{-3}	0.035×10^{-3}	35.8	33.0	37.5	35.5
			25	2352	2248	1.46	.855	1.28	.061	64.0	64.0	64.0	64.0j
			34	2356	2252	1.48	.875	1.32	.064	66.9	67.0	66.6	68.8
			94	2386	2282	1.72	1.02	1.64	.093	88.3	89.8	86.0	86.0
			150	2413	2309	1.98	1.17	1.95	.126	111.3	114.8	106.1	103.7
			206	2440	2336	2.23	1.35	2.33	.171	137.6	144.0	128.0	126.0
			261	2465	2361	2.50	1.53	2.70	.222	166.1	176.1	151.0	153.0
			344	2504	2400	3.00	1.83	3.39	.331	218.2	236.8	189.8	196.0

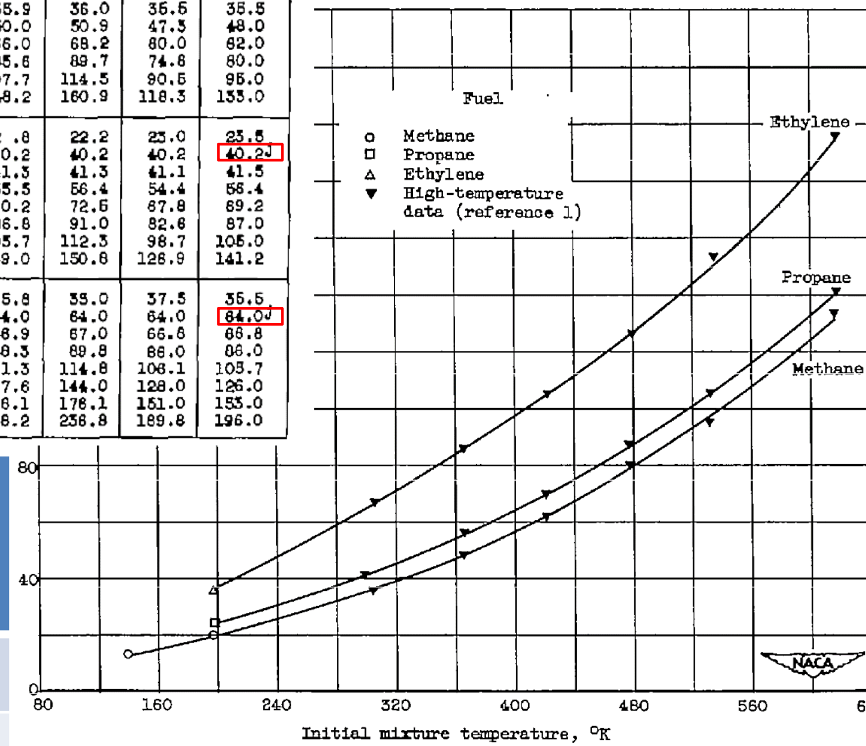

Figure 5. - Effect of initial temperature on maximum flame speed.

Combustion Gas (Initial temperature 25°C)	Comparative Flame Speed (cm/sec)
Methane (H4)	34.0
Propane (C3H8)	40.2
Ethylene (C2H4)	84.0

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SUOMEN SOODAKATTILAYHDISTYS
FINNISH RECOVERY BOILER COMMITTEE

FINNISH RECOVERY BOILER COMMITTEE REPORT

Iiris Honkavaara

Content

- Overview of the Finnish Recovery Boiler Committee
- Recovery Boilers in Finland
- Incident statistics 2004-2024
- Recent projects of the FRBC
- Latest FRBC events

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

Introduction

- The **34** members of the Committee include pulp mills, recovery boiler manufacturers, a number of insurance, engineering and inspection companies and research organizations in Finland
- The committee consists of the board and five subcommittees:

BOARD (12 mbrs.)

DURABILITY SUBCOMMITTEE (19 mbrs.)

ENVIRONMENTAL SUBCOMMITTEE (10 mbrs.)

AUTOMATION SUBCOMMITTEE (9 mbrs.)

BLACK LIQUOR SUBCOMMITTEE (13 mbrs.)

PROGRAM SUBCOMMITTEE (8 mbrs.)

SUOMEN SOODAKATTILAYHDISTYS
FINNISH RECOVERY BOILER COMMITTEE

Personnel of the FRBC

Sara Suur-Hamari

Durability, Environmental

Iiris Honkavaara

Automation, Black liquor

Elina Mikkonen

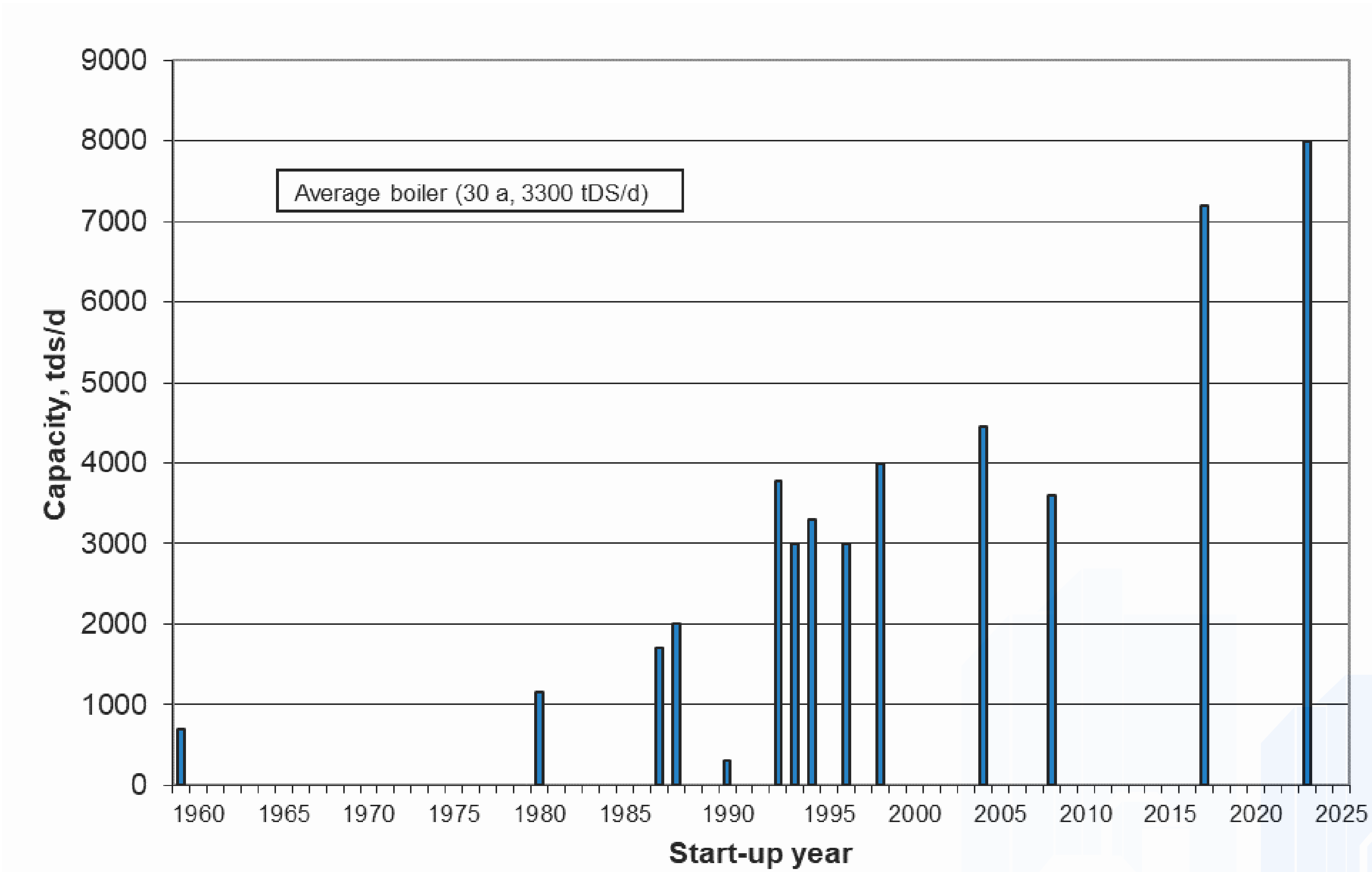
Program, Events

SUOMEN SOODAKATTILAYHDISTYS
FINNISH RECOVERY BOILER COMMITTEE

Finnish Recovery Boilers

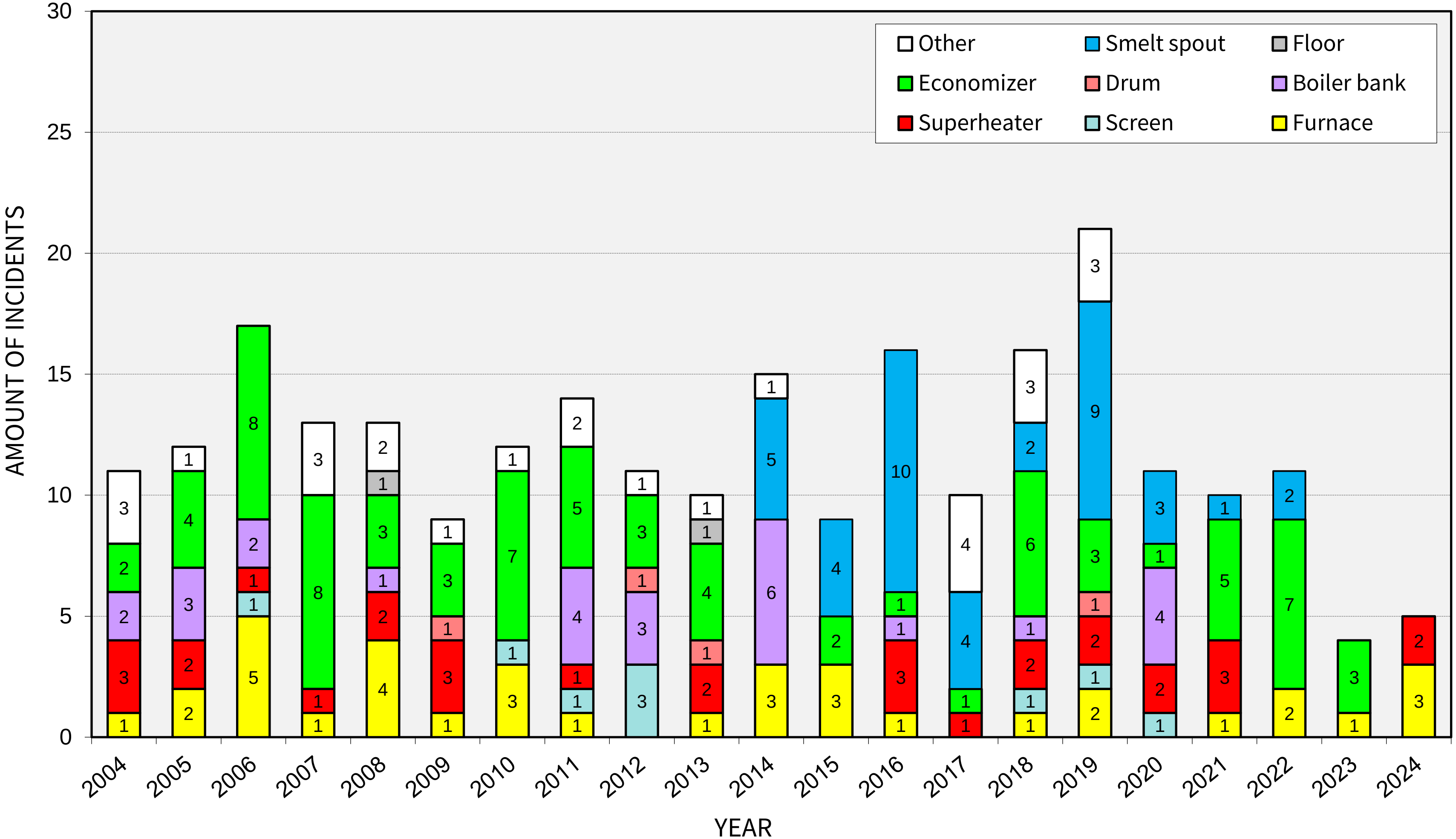
- **14** boilers in **13** mills
  - Oldest: MM Kotkamills, **1959**
  - Newest: Metsä Fibre Kemi, **2023**
  - Largest: Metsä Fibre Kemi, **8 000 tDS/d**
  - Smallest: Stora Enso Heinola, **300 tDS/d**
- Average boiler age: **30 yrs** (1994)
- Average capacity: **3 300 tDS/d**
- Combined capacity: **46 200 tDS/d**

Finnish Recovery Boilers



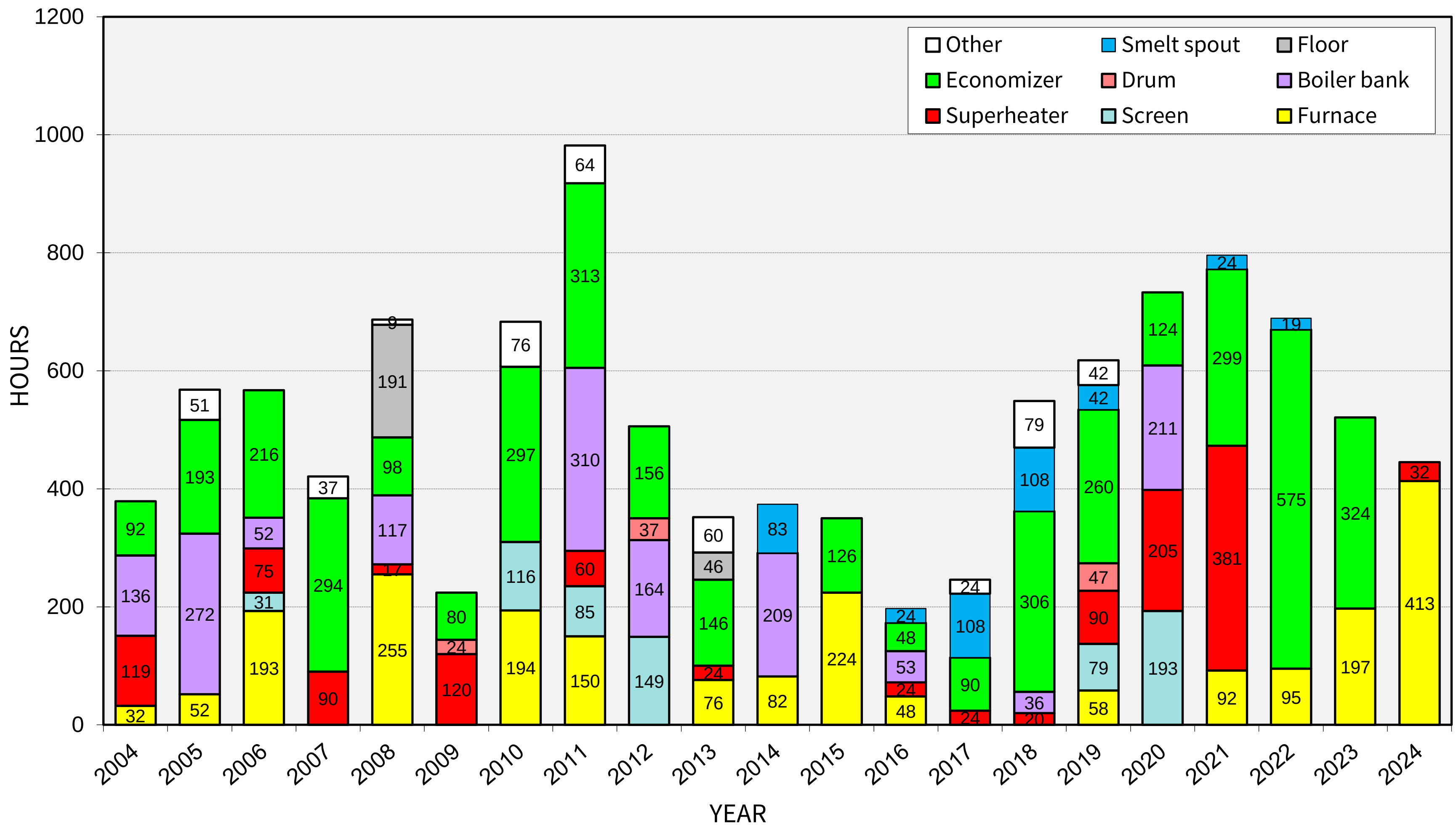
SUOMEN SOODAKATTILAYHDISTYS
FINNISH RECOVERY BOILER COMMITTEE

REPORTED INCIDENTS 2004-2024



SUOMEN SOODAKATTILAYHDISTYS
FINNISH RECOVERY BOILER COMMITTEE

DOWNTIME 2004-2024



Projects 2023-2024

Durability subcommittee

- Review of Recovery Boiler Availability and Reliability (In co-operation with Automation subcommittee)
- Internal Deposit Monitoring and Management in Recovery Boiler (In co-operation with Swedish-Norwegian Recovery Boiler Committee)
- Drying Time Experiment for Recovery Boiler Refractory Masses
- Cracking and Damage Mechanisms of Compound Pipes
- Study on the Drying Times of Refractory Masses in Recovery Boilers
- Recommendation for clad welding penetration of wall and floor composite tubes in black liquor recovery boiler furnace (translation into English)

Projects 2023-2024

Black liquor subcommittee

- Changes in the Quantity and Composition of Fly Ash as Boiler Load Increases
- Effect of High Kappa Cooking in Black Liquor Properties
- Superheater Surface max. Temperature Change in Relation to Boiler Size, Parts I-II

Projects 2023-2024

Environment subcommittee

- Utilization of Potassium from Recovery Boiler Ash
- Literature review of the green liquor dregs
- Update of NCG handling Recommendations – Translation into English
- Separation and Utilization of Salts from Recovery Boiler Ash
- Towards Carbon-Negative Future of the Pulp and Paper Industry (BECCUS)
- Study of the POP Compounds in Green Liquor Dregs

Projects 2023-2024

Automation subcommittee

- Risk assessment -example
- Review of Recovery Boiler Availability and Reliability (in co-operation with Durability subcommittee)
- Data Transfer between Information Systems in Recovery Boilers – Using OPC UA as an Example
- Reliability of Continuous Measurements of the Liquor Cycle
- Electrical Safety Systems of the Boiler Plant – Update

Published recommendations

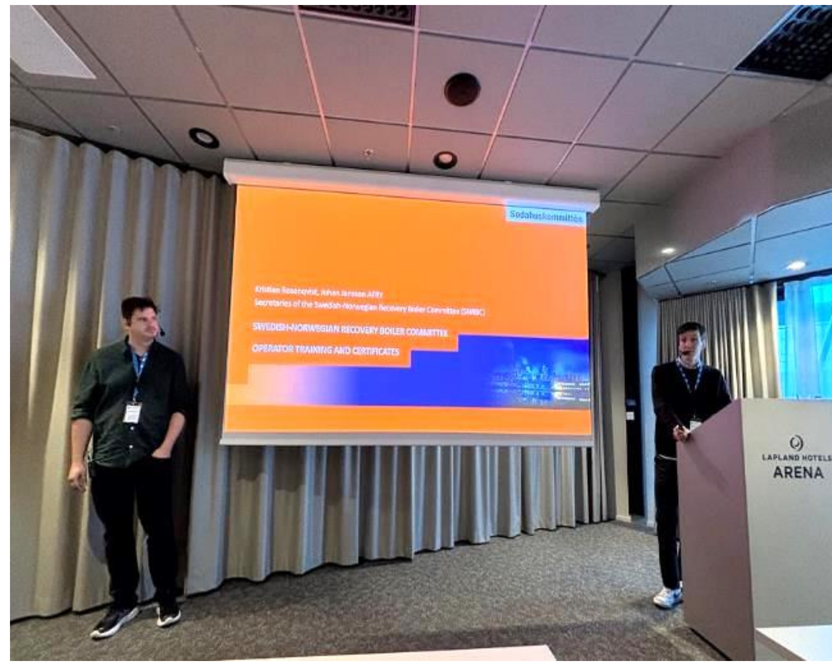
- Recommendation for clad welding penetration of wall and floor composite tubes in black liquor recovery boiler furnace (translation)
- Recommended procedure for incineration of non-condensible gases, Rev. C, May 31, 2023

60th Anniversary Seminar

- June 5th-7th, 2024
- Helsinki-Stockholm-Helsinki cruise
- About 120 international participants
- Lecturers from Finland, Canada, USA, Brazil and Sweden
- Seminar theme: ”Past, Present and Future”
- The FRBC team ready to get on board ➔

Recovery Boiler day 2024

- October 24th 2024, Tampere
- About 140 participants
- Most presentations in Finnish
- The SNRBC representatives providing information from their Committee ➔



Other events: Chief Engineer 23.1.2025, Operator day 13.3.2025

SUOMEN SOODAKATTILAYHDISTYS
FINNISH RECOVERY BOILER COMMITTEE

Additional info on the FRBC website

https://soodakattilayhdistys.fi/frbc-in-brief/

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A More Integrated Approach to Optimizing Recovery Boiler Operation

Dr. Andrew K. Jones

The Challenge and Benefits of Making Recovery Boiler Operational Improvements

- Identification of Potential Improvements
- Quantifying Benefits
- Identifying Priorities
- Implementation of Improvements
- Sustaining Improvements
- Capital Upgrades versus Operational Improvements
- Working with Outside Parties (Vendors and Consultants)

Identification of Operational Improvements

- Fully leverage your data collection systems
  - Make sure tags are properly identified and updated (remove duplicate tags!)
  - Collect and store data at the appropriate interval
  - Organize your data using asset trees for easier updating and sharing
  - Integrate operational data with test data
- If you are not measuring PROPERLY then you can't improve!
  - Chemical Reduction Efficiency a prime example
    - Mill testing inaccurate and too infrequent in most cases
  - Fouling rates
    - Pressure drop IS NOT measuring correctly…
  - Smelt spout operation
    - Quantify the operation of spouts (surrogates for smelt flow)

Identification of Operational Improvements

- In order to identify improvement opportunities, you need three critical pieces of information
  - Where am I at?
  - What is best practice for my equipment?
  - What are my "handles", the ways in which I can make the targeted improvements
- Example – Fouling Improvements
  - Water wash every 6 months and 8% of MCR (boiler rating) steam used for sootblowing
  - Best practice – annual waterwash and 4% of MCR steam used
  - Handles – lower furnace operation, sootblower operation, liquor chemistry

Quantifying Benefits

- Start with a proper mass and energy balance on the affected equipment!
- Have a good understanding and obtain agreement regarding the cost of utilities and chemicals associated with the improvement
  - Don't be arguing about this at the time you are seeking to justify this work
- Pull in process experts to understand what the real costs are:
  - Both items you might miss and those you overestimate
  - Examples
    - Chemical Reduction Efficiency improvements typically have limited impact on chemical makeup costs
    - Smelt flow stability can have many knock-on effects downstream

Identifying Priorities

- The magnitude of a benefit is clearly the best way to prioritize BUT other considerations are important too:
  - o Do you have the resources and funding to go after the items?
  - o Do you need an outage to make improvements?
  - o Do you want to make this change first to identify capital needs sooner?
  - o Can you get operator compliance to make this operational changes (more on this later)

Implementation of Improvements

- An implementation plan MUST take into consideration your current work systems
  - Making a change and implementing a new work system has a low probability of success.
- A Work System
  - How process settings are communicated
  - How process settings are improved
  - How operator compliance is measured
  - The software used to manage this process
- (Opinion) Most operational changes fail because of issues with the Work System

Implementation of Improvements – Instrumentation, Control System Components

- A proper implementation of an operational improvement must also identify the improvements required to instrumentation and control system equipment
  - Repair/Recalibration of existing equipment – ex dampers, flow meters, pressure sensors, temperature sensors
  - Identify new equipment to fill in information gaps – measurement of fouling on heat transfer surfaces for examples
    - This may require additional justification via either making operational improvements with existing equipment to identify remaining gaps or by reference cases where the value of this additional information can be quantified
- Rapid advancements in instrumentation capability and ease of integration into mill data systems is a huge opportunity
  - WiFi/Cellular enable data collection
  - Spectral methods of measuring process stream properties

Implementation of Improvements – Open Loop Control

- In order for an operational change to be successful alignment is required from the operator all the way up to the mill manager
  - Operator – they actual make the change and must understand why, how and when to make the change – They have to turn the knob in some fashion…
  - Area Supervision – Providing operator training, motivation and feedback when implementing the change
  - Mill Management – Resource the effort (strike a balance between sustain and improve activities), consider incentives linked to the operational change

Implementation of Improvements – Closed Loop Control

- Don't forget there is always the opportunity to take the human out of the loop when implementing an operational change
  - With a good control system the operational change is often simply the adjustment of a control system constraint
  - Example – improving lower furnace operation by tying the liquor temperature to the percent solids of the liquor.
- If the closed loop controls are not in place then there are two options:
  - Validate the benefits and the need for closed loop control by first operating in open loop control (this takes time and discipline)
  - Rip the bandage off and go straight to closed loop control (this takes operator training and engagement)

Sustaining Improvements

- Make the best way to operate a recovery boiler the EASIEST way to run the recovery boiler
  - Especially important when seeking to implement closed loop control, make it easier to keep controls on versus going to manual
    - You must track uptime of critical supervisory control loops
    - Be aware of ways supervisory controls can be defeated (i.e. use of biases)
- Address reasons why operators deviate from desired operating ranges
  - Limits unachievable – if so adjust
  - Not clear on value –if so address why the limits are important
  - Not clear when out of range operation is occurring – if so review alarms and trending tools
- As an area supervisor be clear and consistent on your instructions and expectations
  - When transitioning to new position ensure that your replacement gives a consistent message

Capital Upgrades Versus Operational Improvements

- Addressing operating limits and operational stability should be considered versus any capital upgrade
  - Example – using consumed air (heat input) control on a steam limited recovery boiler versus making a capital investment to address steaming limits
- Is the return versus the improved operating condition still justifying the capital upgrade?
  - If so then this makes for more confidence in the value of the capital upgrade
  - If not then you have prevented a poor return investment
- Implementing a capital upgrade without first ensuring good stable operating practices may result in underutilizing the capability of the capital upgrade

Working With Outside Parties

- What level of domain knowledge do outside consultants and vendors have?
  - Do they know the full impact of their recommendations, data from any instruments or equipment upgrades
- Are they willing to partner with you?
  - Longer term commitment versus a "one-and-done"
  - Putting "Skin in the game" placing some of their margin at risk
- Think about their motivations and whether this is consistent with providing you with bias free recommendations on your most effective path forward.
- Most importantly you also must be willing to commit to this relationship to make it work – resources, consistency of engagement

Key Takeaways

- You can't improve if you don't know your current state (data is key)
- Making operational changes stick is challenging and requires a deliberate approach
  - Do you want to be solving the same issue in three years?
- Operational improvements are cheaper and faster than capital improvements and should always be considered as a possible precursor to a capital project
- There are lots of opportunities to leverage improved instrumentation to better understand your recovery boiler
- Select your partners carefully, are they aligned with your goals and best interests?
- You also need to commit to the process for it to be successful

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BLRBAC

Report on 2024 Activities and 2025 Plans

Dean Clay for 2025 AF&PA Recovery Boiler Annual Conference

BLRBAC Basics

Black Liquor Recovery Boiler Advisory Committee

- Objective - promote improved safety of recovery boilers through the interchange of knowledge, experience and data.
- Meetings in April and October in Atlanta
  - **next meeting April 7 – 9, 2025**
  - Fall 2025 dates are listed as October 6 – 8, 2025
    - AF&PA Recovery Boiler Operational Safety Seminars, in-person, are planned immediately following the close of BLRBAC, both Spring and Fall 2025, starting Wednesday @ 1pm.
  - Be sure to check the dates of future meetings
  - Recent survey confirmed majority wanted to continue with 2 in-person meetings per year
- Members are from recovery boiler: operating, manufacturing and insuring companies.
  - Only Members can vote
  - We have many (and encourage) associate members with direct interest in recovery boiler safety
- Note – BLRBAC is incorporated.

BLRBAC Meeting Location News

- Spring 2024 was at “normal” Sonesta Atlanta Airport North Hotel
- **Fall 2024 meeting was our first at the Hilton Atlanta Airport Hotel**
- Meeting Location History
  - Until April 1987, meetings were held at the “low-rise” Hilton Hotel; a total rebuild forced BLRBAC to move, to the then Harvey Hotel (same hotel, name changes: Crown Plaza, Sonesta, did I miss a name?) was chosen for the move.

BLRBAC Meeting Location News

- Fall 2024 Meeting went quite well, with generally very positive feedback from attendees on our new Hilton location.
  - There were some issues on staffing for the lobby restaurant and the lobby bar.
    - Hilton is learning the needs of BLRBAC
- Fall 2024 had 256 registered; our past average has been around 200 – 210 registered.
  - Spring 2024 had 176 preregistered plus 20 at-door

BLRBAC Fall 2024 Exec Committee Election

- Nominating committee presented slate of proposed new candidates.
  – Members present approved the candidates by vote
- Chairman – Frank Navojosky, International Paper
- Vice Chairman – Gregory Burns, Domtar
- Operating Company Representative – Dave Tjaarda, Smurfit Westrock
- Manufacturing Company Rep – Evangelos Townsend, Babcock & Wilcox
- Insurance Company Rep - Jimmy Onstead, FM

BLRBAC 2024 Past Exec Committee Recognition

- David von Oepen, Smurfit Westrock, had served as our Chairman since 2019, and was term-limited. We thank him for his extended service, especially for leading BLRBAC thru covid.
- Everett Hume, FM, was our Secretary since 2014. We relied heavily on his experience and knowledge. He played a key role in setting up our current blrbac.net website. Everett has retired from FM.

BLRBAC 2025 Executive Committee

- Frank Navojosky retired from International Paper on 1/1/2025. BLRBAC Bylaws state that the officers are elected from among representatives of Regular members, and as he is no longer employed by an Operating company, a Manufacturer or an Insurance company, he had to resign as BLRBAC Chairman. Per communication from BLRBAC, the current Exec Committee is:

- Chairman – Gregory (Greg) Burns, Domtar
- Vice Chairman – David (Dave) Tjaarda, Smurfit Westrock
- Operating Company Representative – Scott Moyer, Smurfit Westrock
- Manufacturing Company Rep – Evangelos (Ev) Townsend, Babcock & Wilcox
- Insurance Company Rep - Jimmy Onstead, FM
- Treasurer – Brad Osborne, Electron Machine (appointed position)
- Secretary – Daniel Franco, retired Smurfit Kappa, Recovery Specialist (appointed position); email danielf721@gmail.com

- Daniel will post the new Exec Committee contact information on blrbac.net by this Friday

Past Chairmen of BLRBAC

1962 – 1963	C. William Conaway
1964 – 1965	James B. Smith
1966 – 1969	John M. Osborne
1970 – 1971	Dick W. Jebbink
1972	Al Logan
1973 – 1974	Norman L. Heberer
1975 – 1976	Russ J. Delvin
1977 – 1978	Frank W. Moulton
1979 – 1990	Herbert D. Couture, Jr.
1991 – 1996	Lon M. Schroeder
1997 – 1998	Ron McCarty
1999 – 2000	Jules Dominguez
2001 – 2002	Wayman Thompson
2002 – 2004	Dean Clay
2004 – 2006	Karl Morency
2006 – 2010	Len Erickson
2010 – 2014	Scott Moyer
2014 – 2017	John Gray
2017 – 2019	Dave Slagel
2019 – 2024	David von Oepen
2024 – 2024	Frank Navojosky
2025 –	Gregory Burns

BLRBAC Internet Site

- blrbac.net
- Guidelines and questionnaires
  - Latest versions
  - Draft revisions for review (7 documents listed)
    - 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

Registration

- MetroConnections is now handling BLRBAC meeting registrations. A link is provided on blrbac.net, 2 months ahead of the meeting; credit cards are accepted.
- Meeting Registration is $500, in advance
  - At door $525
- Free hotel shuttle to and from airport/MARTA
- All attendees are strongly encouraged to make their hotel registrations at the Hilton Atlanta Airport (until the BLRBAC block is filled)

BLRBAC.net Internet Site, Current Posted Guidelines (2024 last revs.)

- **Recommended Good Practice For Design, Operation, and Testing of the Emergency Shutdown System for Black Liquor Recovery Boilers (Dated: October 2024)**
- **Safe Firing of Black Liquor in Black Liquor Recovery Boilers (Dated: Fall 2023)**
- **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: 2024)**
- **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: 2023)**
- **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: June 2021)**

BLRBAC Updated Guideline Example, SFBL

FALL 2023 Summary of changes–

All SFBL figures redesigned to obtain clear copy for publishing and revising in the future.

Ch. 6.1 Remove definition of black liquor divert valve and black liquor divert (pg 15); redundant.

Chapter 3.5 Revise large tube leak logic (pg 20-22).

Sudden, large tube leaks in recovery boilers can introduce large quantities of water into the furnace area in a short period of time. Often such leaks result in a high positive furnace pressure. Additionally, even though the boiler is likely to have tripped on either low water or high furnace pressure, if the operator does not intervene, the feedwater control valve is driven towards its full-open position in a continuing effort by the drum level control system to restore drum level, thereby creating a continuing supply of water for the leak. A review of incidents reported to BLRBAC shows that there have been times operators did not recognize positive furnace pressure as being caused by a large tube leak and did not immediately initiate an ESP. For this reason, it is recommended to add control logic to recovery boilers to drive the feedwater control valve closed and switch the valve control to manual when a high furnace pressure Master Fuel Trip condition occurs. For this logic:

- The high furnace pressure MFT setpoint should be reviewed to ensure that it is set at a low level (typically ~+2" TO 4 " w.c.) to protect personnel and equipment from significant flame and liquor exhaust at open ports.

Plus, 5 more pages of changes

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 (resigned), Chairman
- Personnel Safety, Benjiman Ward, Chairman
- Instrumentation, John Browning, Chairman
- Waste Streams, Paul Seefeld, Chairman
- Fire Protection in Direct Contact Evaporator, Stephen Cox, Chairman
- Materials & Welding, Laura Nicol, Chairman
- Water Treatment, Tom Przybylski, Chairman
- Publicity & News, Matt Paine, Chairman

How to Participate in a BLRBAC Meeting

- Check the schedule for Open Subcommittee meetings, on Monday
  - Closed meeting are for subcommittee members only, to allow focus on assigned tasks.
  - Open meetings can be found in both the morning and afternoon.
- Attend an open meeting that interests you
  - Review the posted subcommittee agenda (available in the meeting schedule in the advance registration materials), and minutes from the previous meeting on the website
  - Usually, they will also accept visitor questions on their guidelines, or related topics. You can always send questions ahead of time to the subcommittee Chairman.

Participating in BLRBAC – cont'd

- Tuesday morning is the ESP Subcommittee open meeting, all submitted incidents are reviewed.
  - Attendees have printed incident summaries.
  - Basic information, boiler leak locations and some leak photos are shown on a large screen.
  - Be prepared to take notes to share when you get back to your mill/company.
- Tuesday, afternoon is the Operating Problem Session, submit questions ahead of time, or go to the microphone. Please share.
- Sunday and Monday nights have supplier sponsored Hospitality events, go and meet people. Tuesday is a single, jointly sponsored, Activity Night, go and meet.

Participating in BLRBAC – cont'd

- Wednesday morning is the Main Committee meeting, BLRBAC business is covered.
  – Changes to Guidelines are voted on, if ready for vote.
  – Each Subcommittee provides a report on their meeting
- Reports from AF&PA, TAPPI and Western Canada BLRBAC (if available)
- Two short technical presentations of recovery boiler topics of interest
  – Technically this is after main meeting adjournment
  – Finishes before Noon