2024

AF&PA
RECOVERY BOILER PROGRAM
ANNUAL CONFERENCE

FEBRUARY 7, 2024
ATLANTA, GEORGIA

American Forest & Paper Association
Recovery Boiler Committee

American Forest & Paper Association

AF&PA RECOVERY BOILER PROGRAM
2024 ANNUAL CONFERENCE
ATLANTA, GEORGIA

Atlanta Airport Marriott
Southern Ballroom

AGENDA

Wednesday, February 7, 2024

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 - Frank Navojosky - International Paper
8:10 am	Operation & Maintenance Subcommittee Report - Wes Hill - Georgia-Pacific
8:15 am	Research & Development Subcommittee Report - Greg Burns - Domtar
8:20 am	Recovery Boiler Large Tube Leak Statistical Analysis - Rudy Haraga - Fornax Services
8:50 am	BLRBAC Activities Report - Dean Clay - Boiler Services & Inspection, LLC (BSI) - BLRBAC ESP Subcommittee Secretary
9:05 am	Risk Based Inspection and Maintenance of Recovery Boiler Sootblowers through Systematic NDT, Real-Time Sensor Measurements, and Visual Walkdown - Danny Tandra - Clyde Industries
9:35 am	Coffee Break (Florida/Tennessee/Alabama Room – 1st Floor)
9:50 am	Recovery Boiler Char Bed Modernization - Gene Sullivan - SHB Power Plant Engineering
10:20 am	Accelerated Value Capture by Automated Data Collection and Analysis. - Bentley Sherlock - Gecko Robotics
10:50 am	Recovery Boilers and Dissolving Tank Training Simulators - Dave Gadai & Johan Ostberg - Valmet
11:20 am	Bed Chemistry Reactions/Gasification Reactions and Control Strategies - Honghi Tran - University of Toronto

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<u>Wednesday, February 7, 2024</u> (Continued)

12:00 noon	Lunch (B+PDR Restaurant – 1st Floor, near Lobby)
1:00 pm	Automated Liquor Guns and Automated Carryover Measurement - Sam Miller - Andritz
1:30 pm	Recovery Boiler Inspection & Evaluation - Nick Folster - Babcock & Wilcox
2:30 pm	Boiler Tube Leak Detection - Travis Conner & Chad Cheney - Valmet
3:00 pm	Coffee Break (Florida/Tennessee/Alabama Room – 1st Floor)
3:15 pm	Recovery Boiler Optimization Technologies: Software, Hardware, and Data Benchmarking - Wenli Duo - FPInnovations
3:45 pm	Finnish Recovery Boiler Committee Report - Katri Hukkanen – Finnish Recovery Boiler Committee
4:15 pm	Advanced Monitoring, Alarming, Control, and Troubleshooting for Recovery Boilers - Travis Conner - Valmet
4:45 pm	AF&PA Recovery Boiler Operational Safety Seminar Update - Dean Clay - Boiler Services & Inspection, LLC (BSI) - BLRBAC ESP Subcommittee Secretary
5:00 pm	Closing Remarks, Questions, & Adjourn

- The BLRBAC ESP Subcommittee Report presented by Dean Clay in the Tuesday, February 6, 2024, O&M Subcommittee Meeting is included in this Conference Presentation Book as the 2nd to last presentation.
- The AF&PA Recovery Boiler Program Report presented by Wayne Grilliot in the Tuesday, February 6, 2024, Subcommittee Meetings is included in this Conference Presentation Book as the last presentation.

* **TAPPI Book Sale:** Wednesday February 7, 2024 (9:30 am – 3:30 pm) outside the Florida Room
<u>25% Discount on the Kraft Recovery Boilers, Third Edition Book and other Select TAPPI Books!!! Plus, no Shipping Cost!!!</u>

AF&PA POLICY STATEMENT ON COMPLIANCE WITH ANTITRUST LAWS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

American Forest & Paper Association

Fornax Services, LLC

Recovery Boiler Large Tube Leak Statistical Analysis

February 2024

www.thefornax.com

Where boilers, engineering, and software meet passion.

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Fornax Services, LLC

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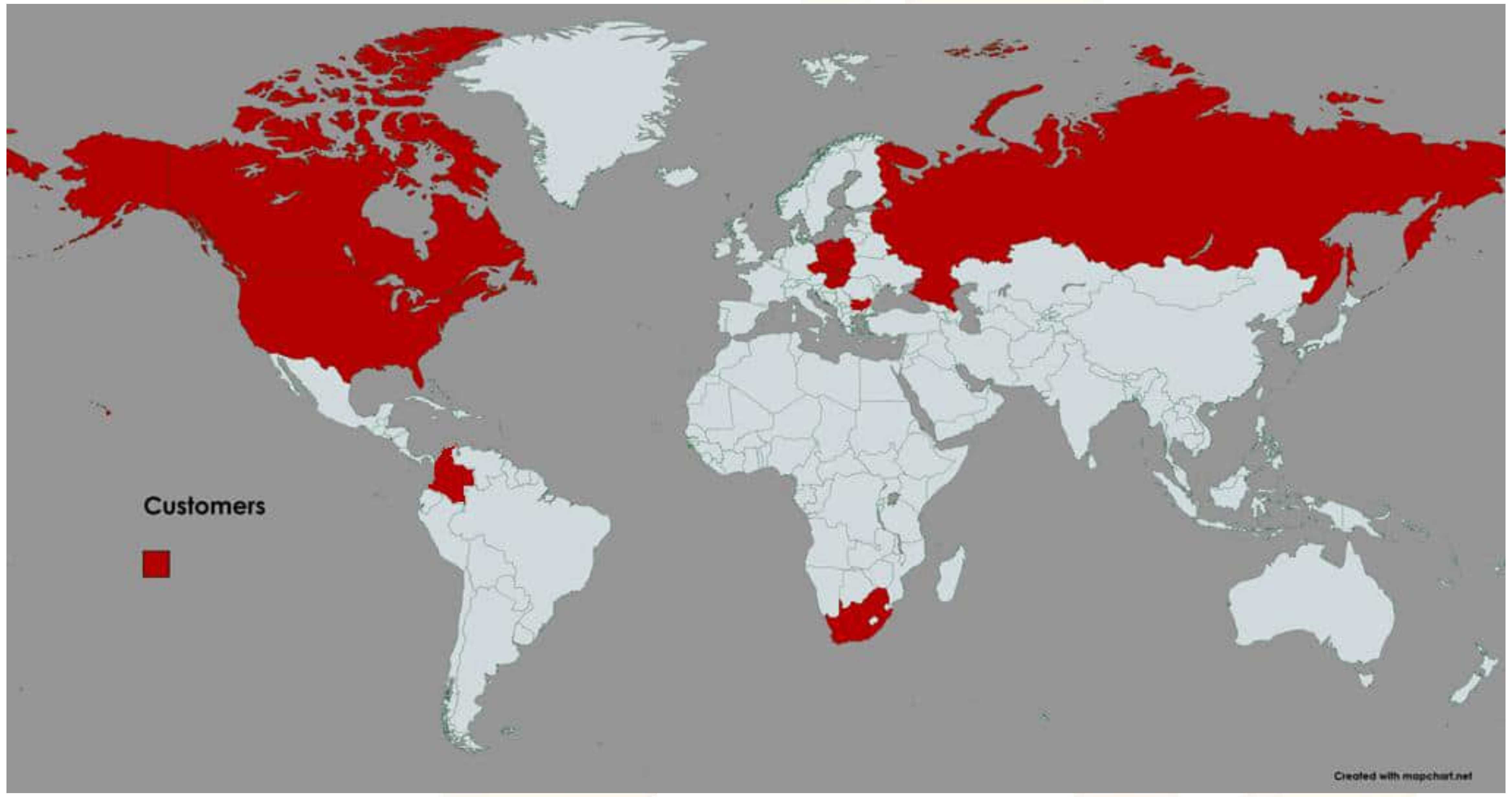
Fornax Services, LLC

- Started 2019
- 10 Countries Served
- 23+ years of experience
- BLRBAC, TAPPI members



BLACK LIQUOR RECOVERY BOILER ADVISORY COMMITTEE

TAPPI

Recovery Boiler Explosion History

	< 1960's	1960's	1970's	1980's	1990's
Combustible Gas Explosions					
Auxiliary Fuel	8	10	6	2	(1)
Pyrolysis Gas		3	2	4	2
Smelt-Water Explosions					
Pressure Part Failure	8	9	19	10	2
Black Liquor System					
wash water		1	2		1
black liquor		7	3	2	
Spout Leaks			2	2	1
Wash Water	1	2	4		
Miscellaneous		3			
TOTAL	17	35	38	20	6

Source: BLRBAC

Recovery Boiler Explosion History

BLRBAC RECOMMENDED GOOD PRACTICE
Recommended Post-ESP Procedure for Black Liquor Recovery Boilers

Table 4. Time Delays in Smelt-Water Explosions

(with successful rapid drain initiated)
(all times in minutes)

Water Source	Leak Size, in.	Time Delay to Initiate Rapid Drain	Time From Water Entry to Explosion	Explosion Delay After Start of Rapid Drain	Damage
Screen	2.5 broke	0.1	0.1	≈0	Minor
Floor	two ruptured	0.5	0.5	≈0	Moderate
Wall	9 × 2.5	0.5	0.5	≈0	Moderate
Wall	2 × 14	2	2	≈0	Major
Wall	7 × 2.5	1	3	2	Moderate
Gen. Bank	rupture	5	5	≈0	None
Screen	2 broke	2	5	3	Moderate
Gen. Bank	broke	2	10	8	Slight
Screen	6 × 3	11	13	2	Major
Wall	5 × 2.5	5	20	15	Moderate
Floor	2.5 split	5	20	15	Moderate
Wall	5.5 × 2.5	6	20	14	Major
Roof	8 × 2.5	5	25	20	Major
Wall	pinhole	10	30	20	Slight
Wall	8 × 3	22	34	12	Moderate
Screen	3/16 × 1	25	35	10	None
Bullnose	6 × 1.25	40	45	5	None
Screen	8 × 2	70	85	15	Moderate
Floor	½ crack	0	195	195	Extensive

(drain to mud drum only)

Water Source	Leak Size, in.	Time Delay to Initiate Rapid Drain	Time From Water Entry to Explosion	Explosion Delay After Start of Rapid Drain	Damage
Floor	1/32 hole	5	8	3	None
Gen. Bank	2.5 broke	9	9	≈0	Moderate
Screen	1.5 × 3/8	3	30	27	Major
Wall	½ crack	1	90	89	Slight

(no successful drain intiated)

Water Source	Leak Size, in.	Explosion Time Delay, min.	Damage	Comments
Wall	5 × 2.2	0.5	None	no drain system
Wall	1/8 × 3/16	3	None	no drain system
Wall	6 × 3	6	Major	no drain system
Screen	7 × 2	10	Moderate	leak not recognized
Screen	2 × 4	15	Major	no drain system
Floor	1 × 1/4	65	Major	leak not recognized
Screen	Four ruptures	70	Major	ESP system failed to operate
Screen	2.5 broke	95	Major	no drain, drum level maintained
Superheater	2.5 broke	120	Major	burned out bed with leak there
Wall	1/8 hole	210	None	no drain, burned bed out
Superheater	2.5 broke	225	Moderate	boiler filled and fired on gas
Wall	1/4 × 1/16	735	Minor	no details available

Source: BLRBAC

BLRBAC PRE-2021 Recommendation

3.5 Sudden, Large Tube Leak Indication

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 low drum level condition concurrent with 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 low drum level and 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 both a high furnace pressure Master Fuel Trip (MFT) and a low drum level MFT occur. For this logic:

- The high furnace pressure MFT (+ FD fan trip) setpoint shall be reviewed. Consider involving the OEM and insurance carrier if any time delays are installed.

- The low drum level MFT setpoint shall be reviewed. Consider involving the OEM and insurance carrier if any time delays are installed.

  When both trips occur within 45 seconds of each other, the feedwater control valve shall be driven closed and revert to manual. Additionally, an alert/alarm message shall appear to the operator indicating both trip conditions have occurred and that this may be the sign of a large tube leak.

It is recognized that operating upsets other than large tube leaks can result in a concurrent high furnace pressure and low drum water level. After determining an ESP is not required, the operator is not prevented by the control system from opening the feedwater control valve, or from putting the control valve back into automatic. Additional data (leak detection system, other boiler specific parameters) should be evaluated before allowing feedwater back into the recovery boiler.

When this control logic is implemented it remains the operator's responsibility to determine the correct next course of action and additional boiler specific training should be given to all operators regarding the implications and symptoms of a sudden large tube leak.

Source: BLRBAC

Recovery Boiler Explosion, 2018 – Case Study

FURNACE FLOOR – SMELT-WATER EXPLOSION

SPRING 2018-21	
Classification:	**Smelt-Water Explosion 163**
Co, Mill, Location:	**Daishowa Marubeni International, Peace River, Alberta Canada**
Unit Data:	RB#761401,1990, , B&W, Drums - 2, DCE - NO, Floor - Sloped to rear
Unit Size:	5.5 MMlb DS/day, 766000 lb/hr steam, 940 PSIG, 850ºF, 1125 PSIG Design
Incident Date/Time:	September 22, 2017, Earliest Indication: 9/22/2017 at 13:33
Downtime hrs, leak/total:	1176 hrs
ESP?	**YES**
Leak/Incident Loc:	Furnace Floor, Where front wall bends into the floor
How discovered:	Boiler Trip, Boiler trip on low drum
Wash adjacent tube:	NO
Root cause:	Mechanical Damage, Sootblower lance tube broke away from flange weld and punctured floor tube. Reason for lance tube failure being analyzed.
Leak detection:	YES
Bed cooling enhanc	YES
Last full inspection:	Jun-17
Sequence of events:	At 13:33 on Sept 22nd a low drum level alarm came in on the DCS. The control panel operator took steps to save the boiler but at 13:38 the boiler tripped on low level. During the 5 min window of the trip there were 8 alarms that came in for high pressure in the furnace. As soon as the boiler tripped the operators pulled the liquor nozzles from the boiler as they normally would. There was nothing noticed or heard around the second floor nozzles that would have indicated any kind of smelt water reaction happening, or any popping of any kind. The panel operator and shift engineer began trouble shooting from the control panel to determine probable leak location and operators were sent up the boiler to inspect the gen bank and economizer sections as these are where we have experienced leaks in the past. Our economizer hoppers had water on the downcomers instead of liquor due to a start up from a mill maint outage two days prior resulting in plugged hoppers a couple times. Because of this we did not have an indication that our liquor solids were being diluted from a possible econo or gen bank leak. The operators isolated the water to the hoppers and conducted an inspection of the econo and gen bank hoppers. There were two more alarms for high furnace pressure at 13:47 and 13:50, but still nothing that pointed directly to water contacting smelt. Operators had cleared the upper furnace and were just going to head down. The shift engineer was considering ESP'ing the boiler when the large explosion occurred at 14:04:27, followed by the ESP at 14:04:33. At the time of the explosion an operator was close to the dissolving tank and did not hear anything from the boiler until the actual explosion.

	Additional Information: The high furnace pressure alarm is set at +10 mm H2O; the delayed high furnace pressure trip setting is +125 mm H2O, the instantaneous trip is +200 mm H2O. The furnace pressure did not reach the high trip setting until the explosion occurred. According to trend data, it appears that a peak of +40mm H2O was reached prior to the explosion. The existing large sudden leak logic requires the furnace pressure to reach 125mm H2O in combination with a low drum trip, so the feedwater control valve was not closed by this logic. This logic is being reviewed to determine if the high furnace pressure setpoint should be lowered. During the troubleshooting after the low drum trip, prior to the explosion, the feedwater control was left in manual at 37% OP to try and maintain some drum level, not thinking there was a furnace leak. Feedwater flow was approx. 50 l/s for

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	the first 10 mins after the low drum trip and then the output was reduced to 25% on the feedwater valve and the flow to maintain drum level was approx. 25-30l/s for the 15 mins prior to the explosion incident.
Repair procedure:	Components damaged by the explosion were replaced as needed to run the boiler.
Future prevention:	

Source: BLRBAC

Recovery Boiler Explosion, 2019 – Case Study

06:26:26	RB Leak Indication software issues a Trasar alarm
8:02:48	RBLI issues a Mass Balance alarm
9:35:00	15-minute rolling FW/Steam Differential exceeds 50 kpph
10:46:40	Master Fuel Trip on High Furnace Pressure, >+4"
10:47:25	High Feed water flow prevents Large Leak Logic trip
10:48:02	First FW/Steam Differential alarm issues at 300 kpph
10:48:23	Drum level finally reaches low trip point, 58 seconds too late for large leak logic
11:04:19	Drum level positive, FW flow reduces, but not to zero
11:11:40	Upward trend in FW/Steam Differential reported to operator
11:12:00	Water observed coming from the ash hoppers
11:16:00	Water observed in the center of the Generating Bank
11:19:47	Explosion occurred
11:20:03	ESP initiated

Source: BLRBAC

BLRBAC POST-2022 Recommendation

15.8 Sudden, Large Tube Leak Logic

After a smelt water explosion event in March 2020 (REFERENCE BLRBAC F2020 Minutes, Incident 2020-36); this logic has been revised to recommend activation with only a high furnace pressure MFT condition. The reason for this change is because some feedwater systems can overtake feedwater flow on the large tube leak and not have a low drum level. The subcommittee also recommends leaving the large tube leak logic in for ID fan trip first out conditions. The operator can check his first outs and do the large tube leak check sheet in a timely manner that will not add that much restart time and provide insurance on proper checks before reopening the feedwater control valve.

Source: BLRBAC

Recovery Boiler Large Tube Leak Detection

High Furnace Pressure Trip:

Set at value that's designed to protect furnace walls from buckling due to high furnace pressure. (Function of buckstay strength and design)

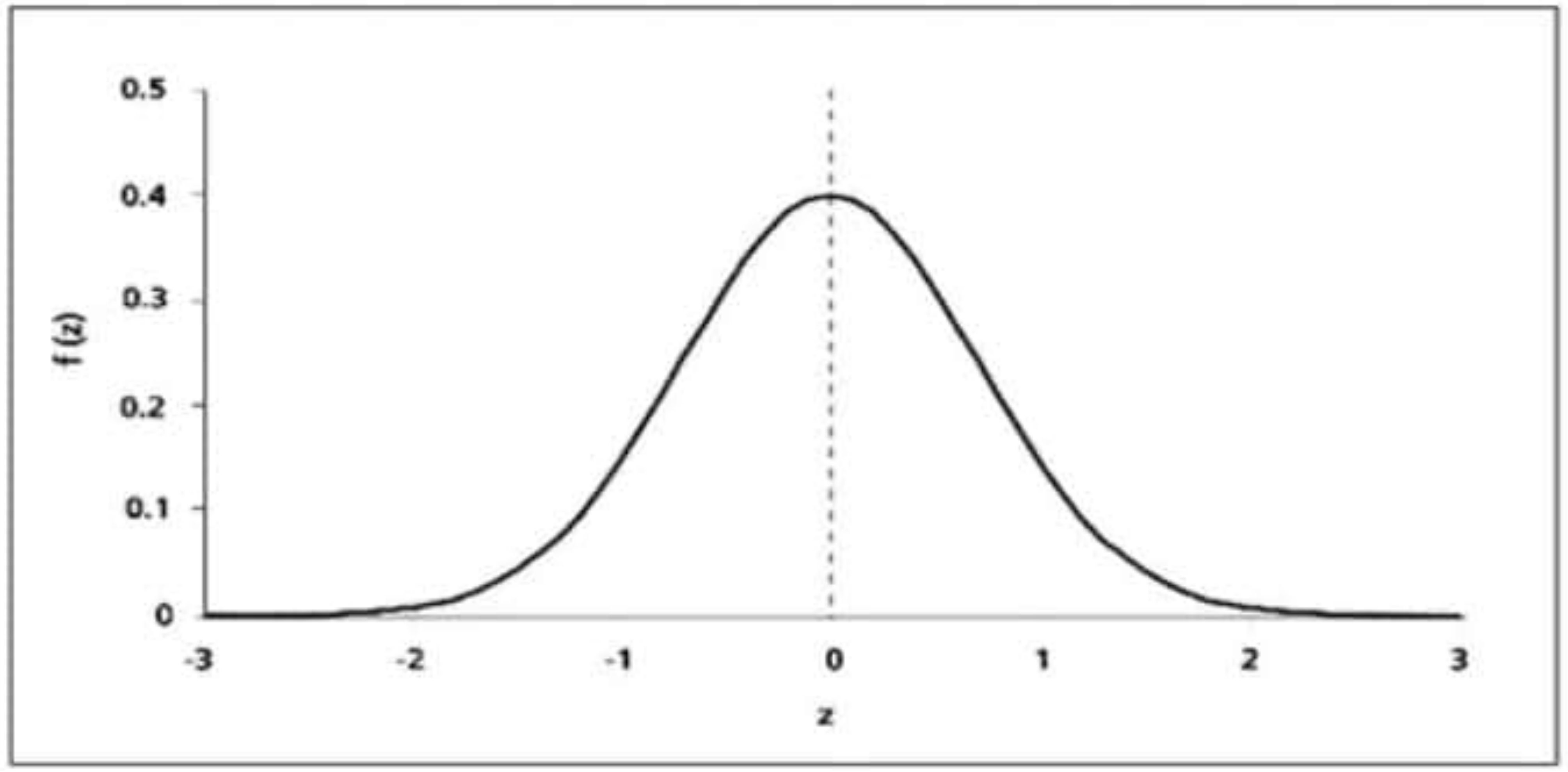
Low Drum Level Trip:

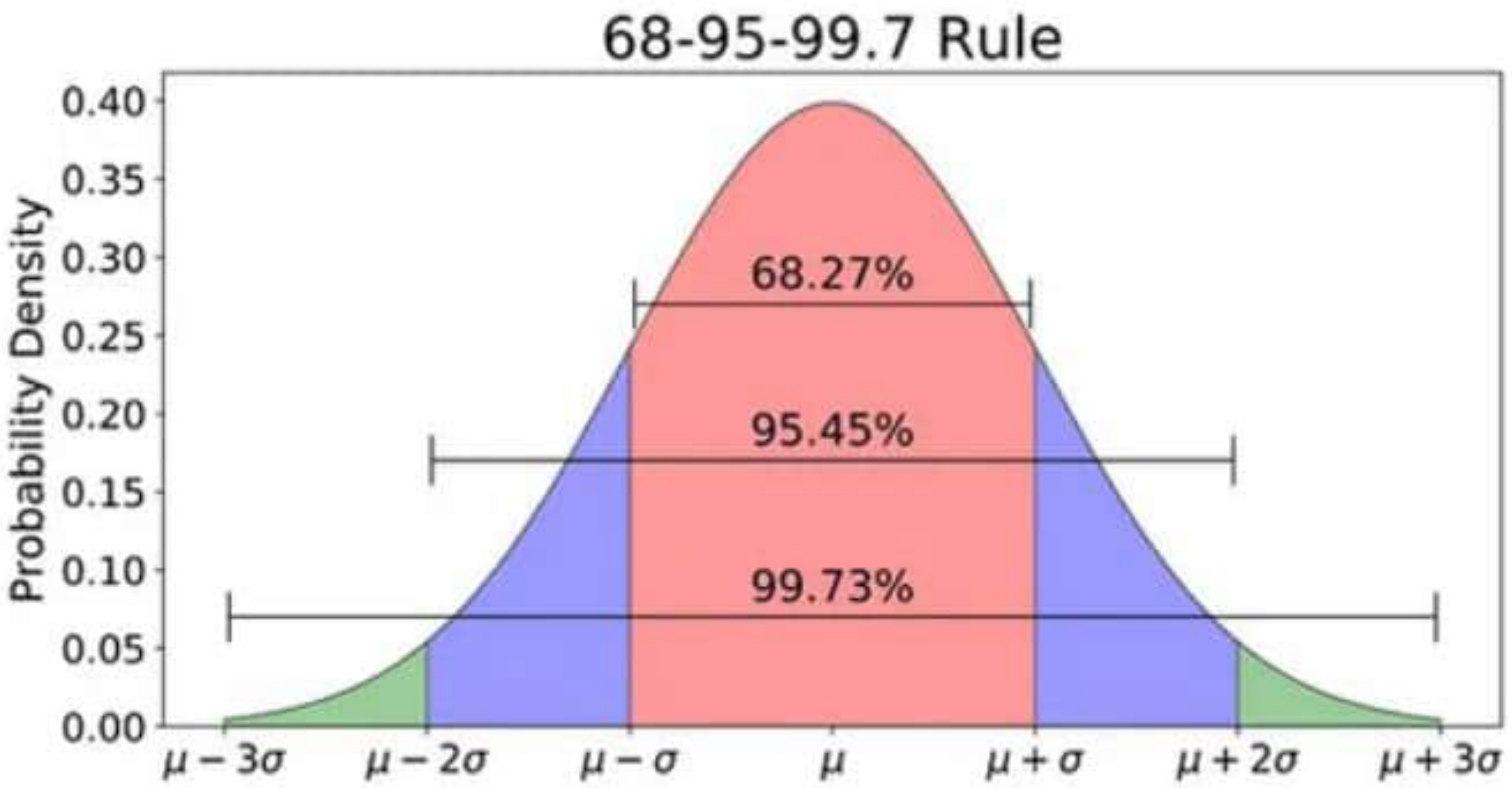
Set at a value to ensure that all water tube / pipe circuitry (especially at the top of the boiler – roof tubes, top of generating bank tubes for 2 drum units) is flooded and thus cooled by water. Otherwise overheating and failure of tubes is possible.

Neither one of these trips are designed to even consider tube leaks. As such they (trips) are not reliable indicators for large tubes.

Source: BLRBAC

Statistics – Basic Refresher





Normal Distribution:

It is a symmetrical distribution that occurs in nature very often. Many natural datapoints fit this distribution and its probability density curve.

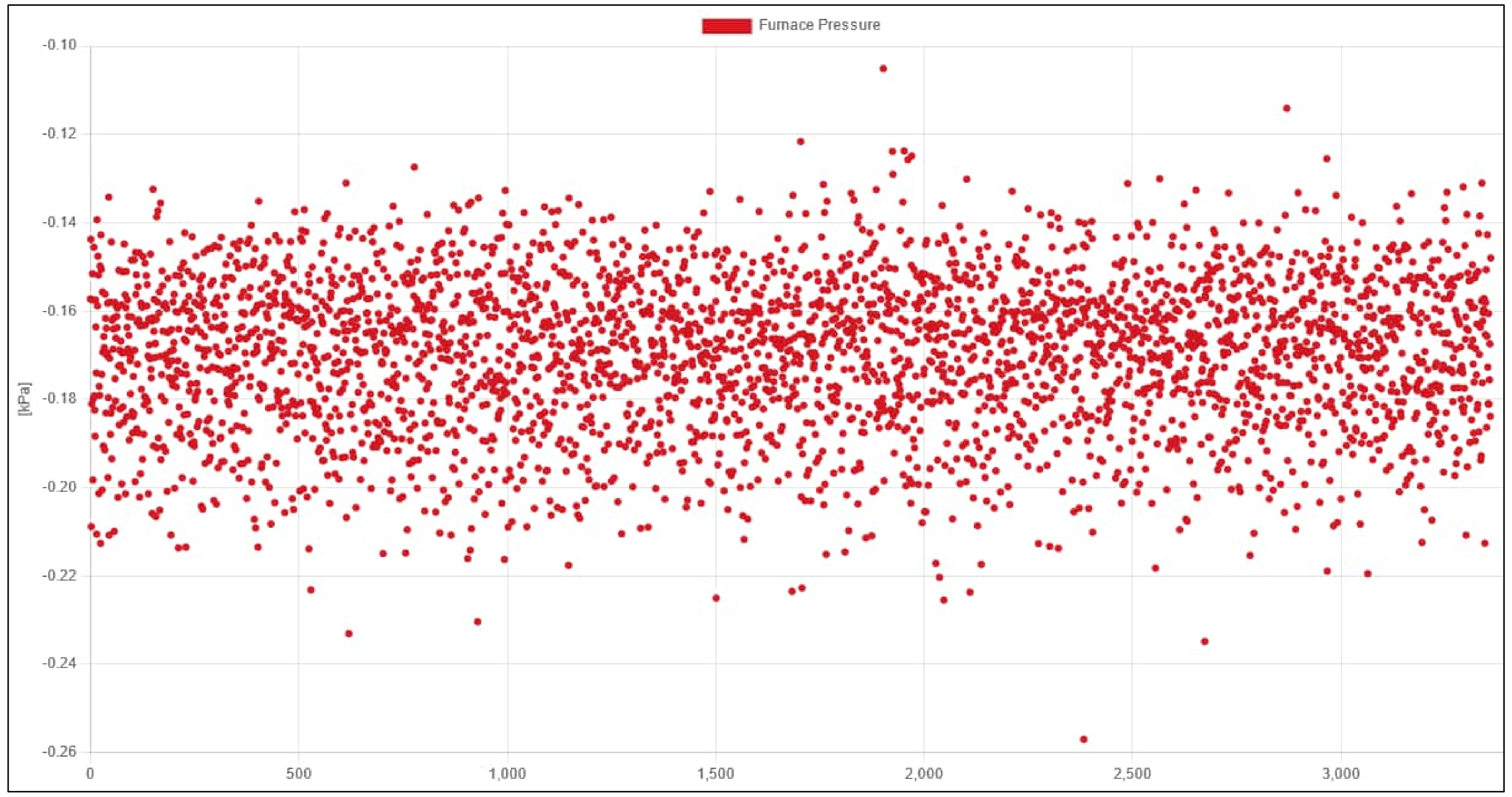
99.73% of data fall within 3 standard deviations from the average**.**

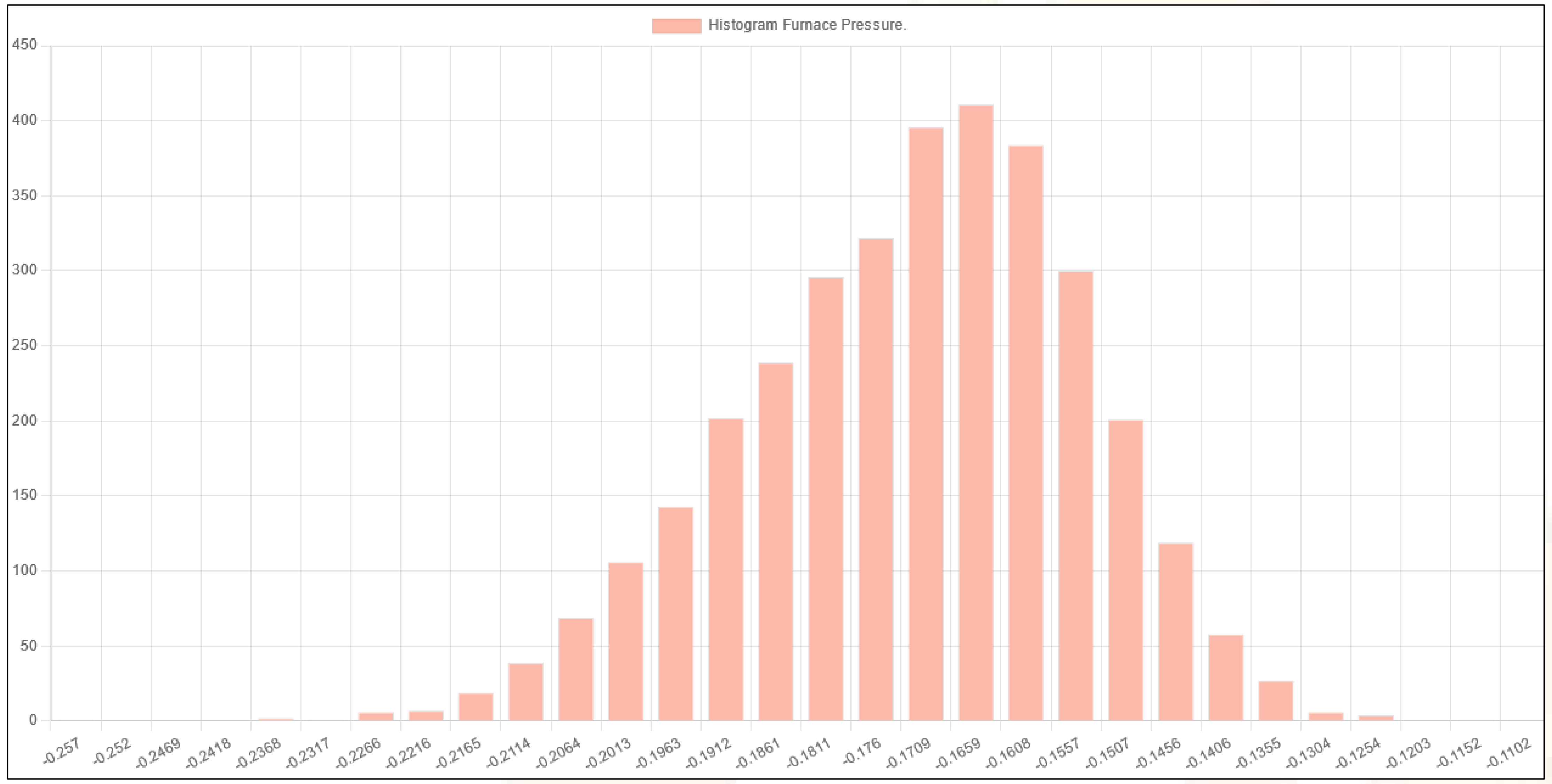
σ (sigma) = Standard Deviation

99.7% of data are within 3 σ :
1 σ event: 1 in 3 events
2 σ event: 1 in 20
3 σ event: 1 in 370

4 σ event: 1 in 31 560
5 σ event: 1 in 3 483 046
6 σ event: 1 in 500 000 000
7 σ event: 1 in ???
8 σ event: 1 in ???

Furnace Pressure – Case Study

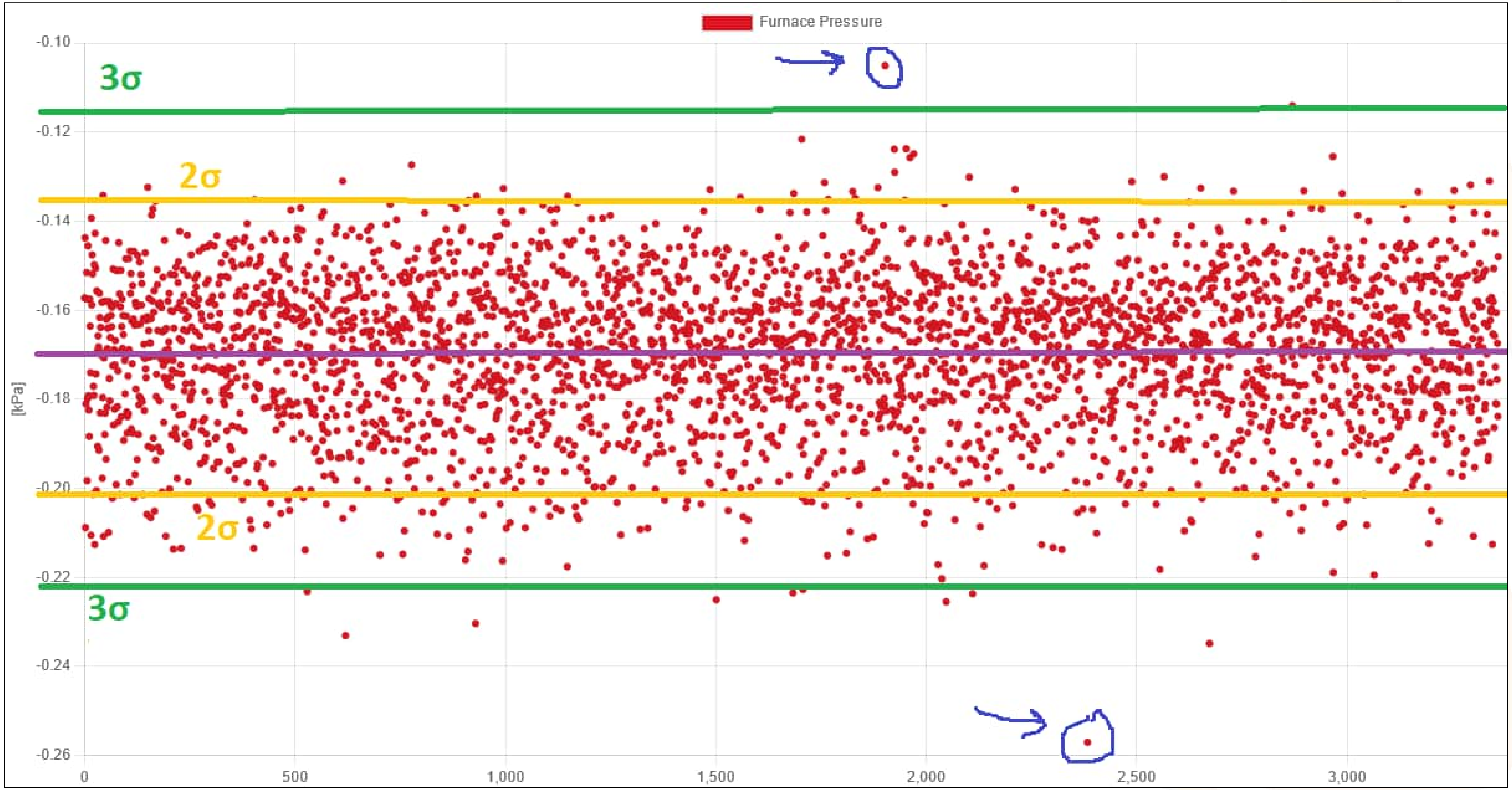




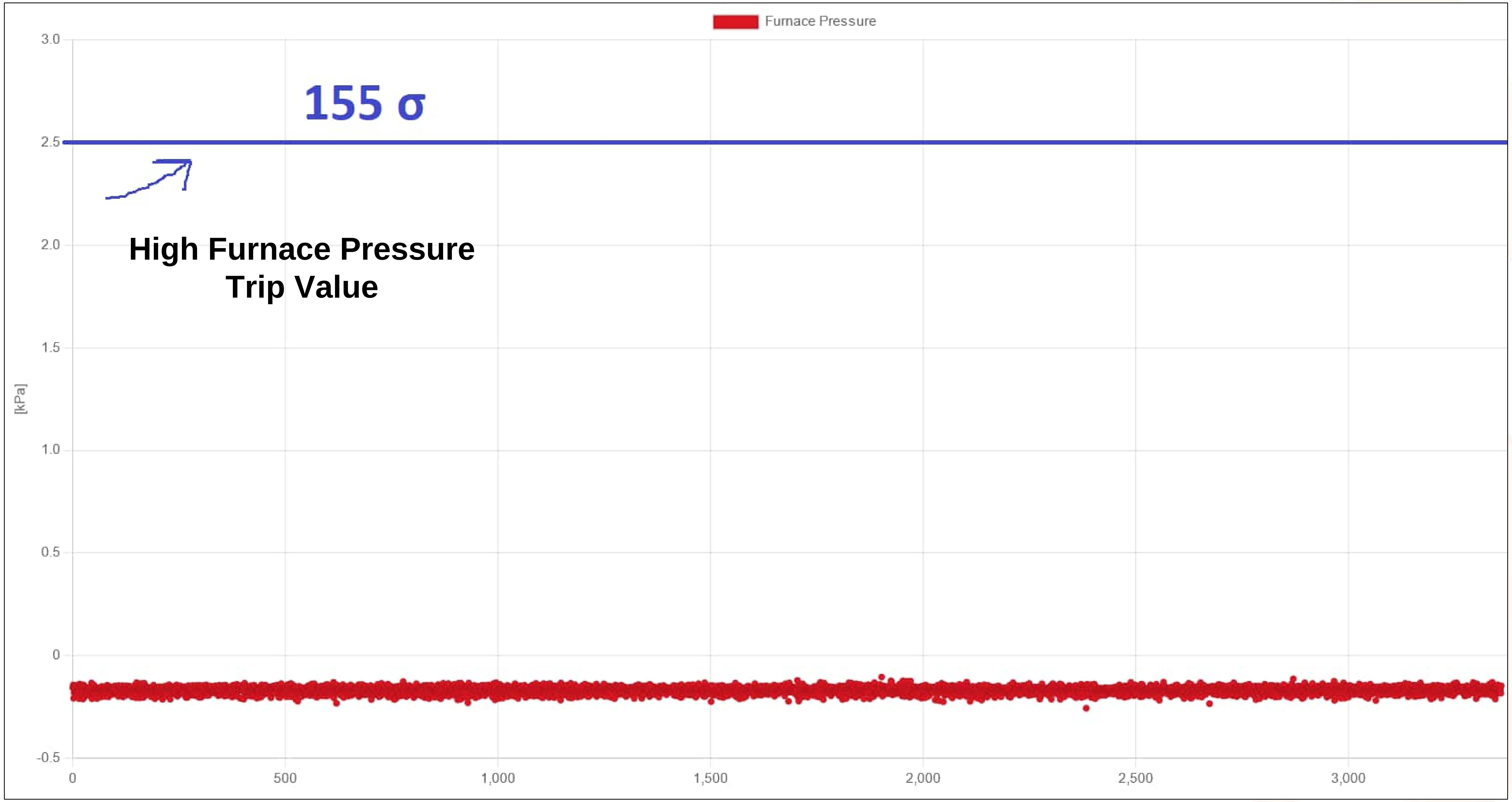
Histogram is slightly skewed to the right. Not perfectly symmetrical. As such, normal distribution does not apply accurately, however it can still be used for approximation. In such a case statistical anomalies are still correct within the order of magnitudes.

Average Pressure: -0.1700 kPa
Standard Deviation: 0.0169 kPa

Furnace Pressure – Case Study

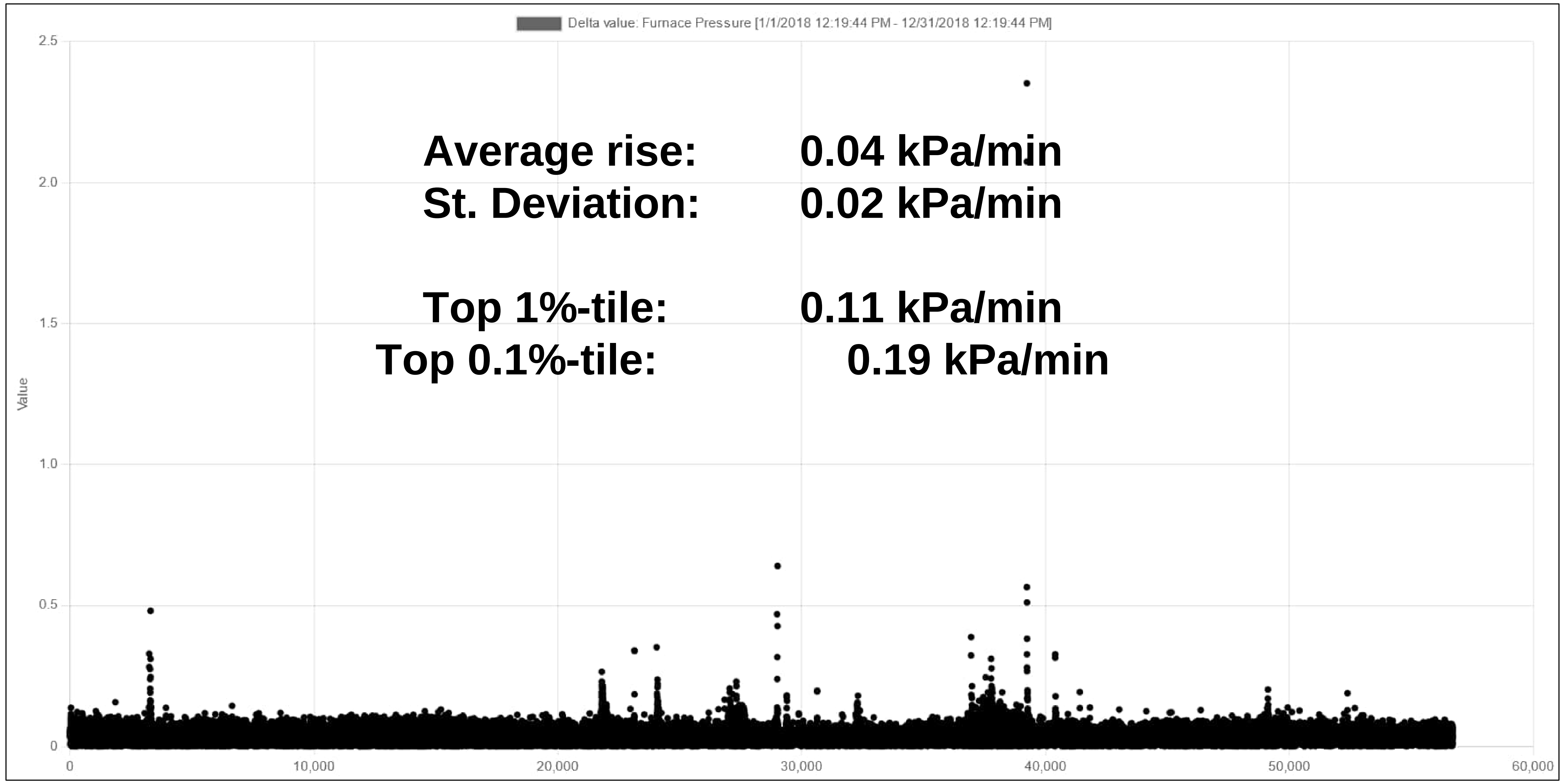


Furnace Pressure – Case Study



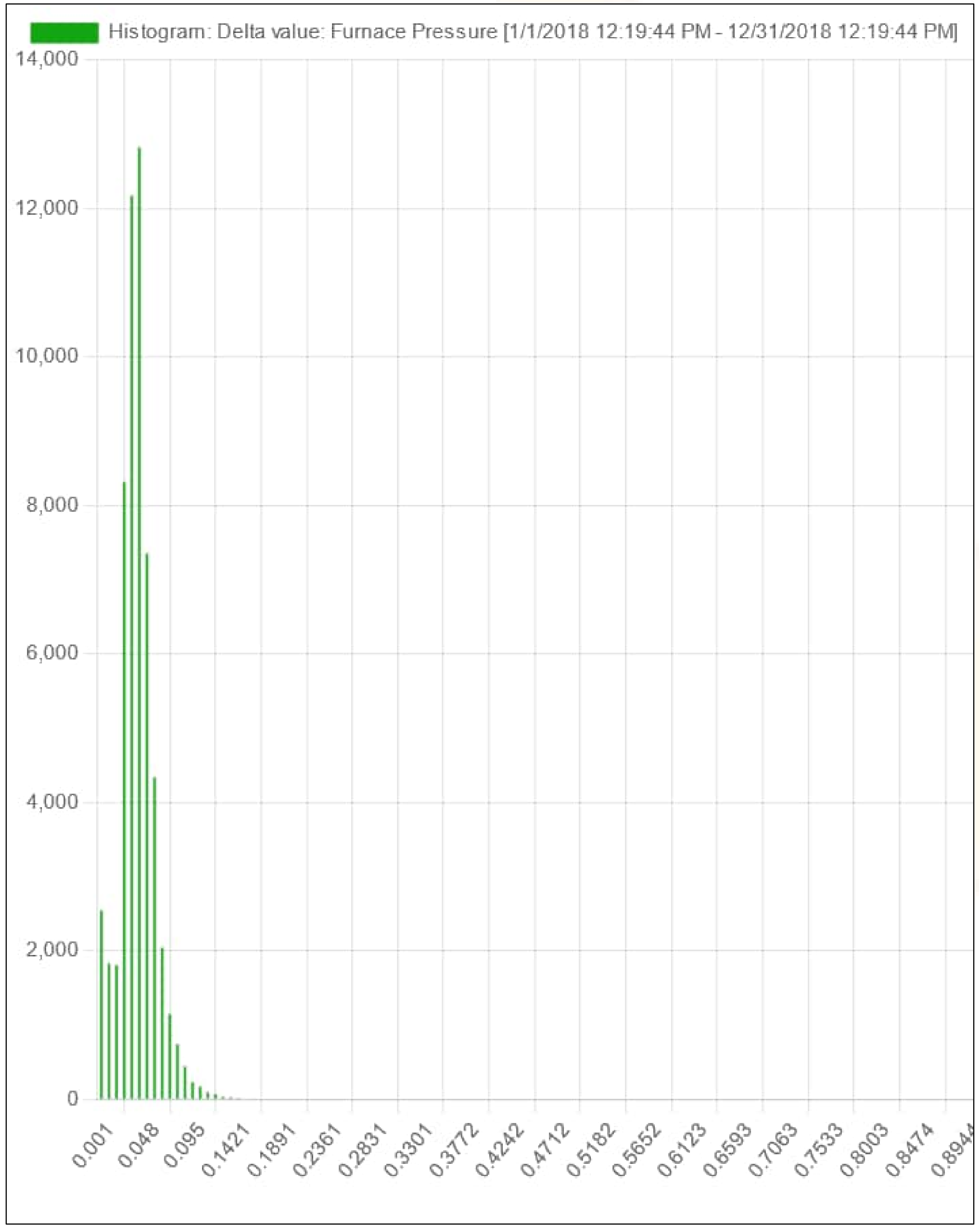
Furnace Pressure – Case Study

Furnace Pressure RISE Statistics

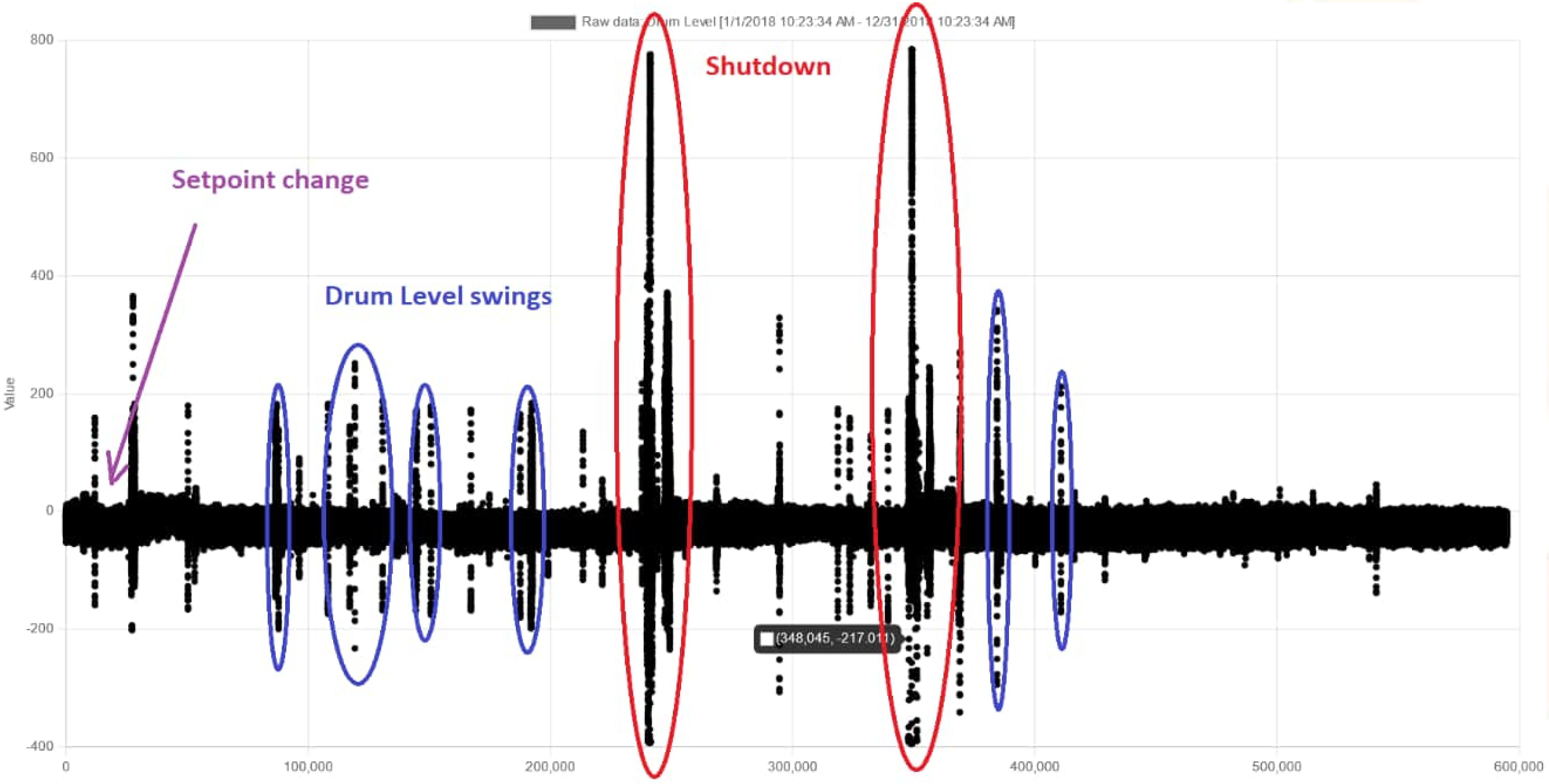


Average rise: 0.04 kPa/min
St. Deviation: 0.02 kPa/min

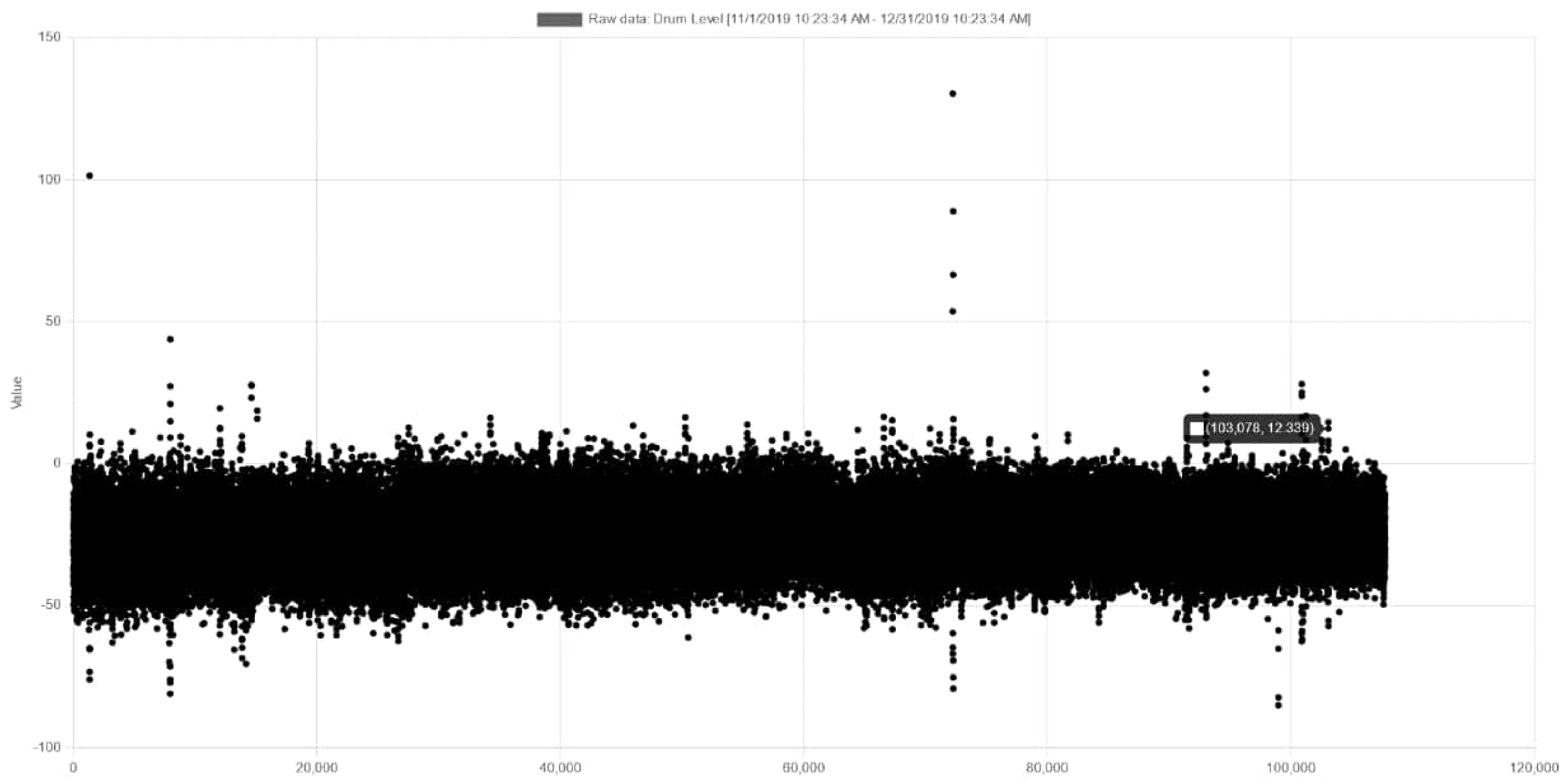
Top 1%-tile: 0.11 kPa/min
Top 0.1%-tile: 0.19 kPa/min

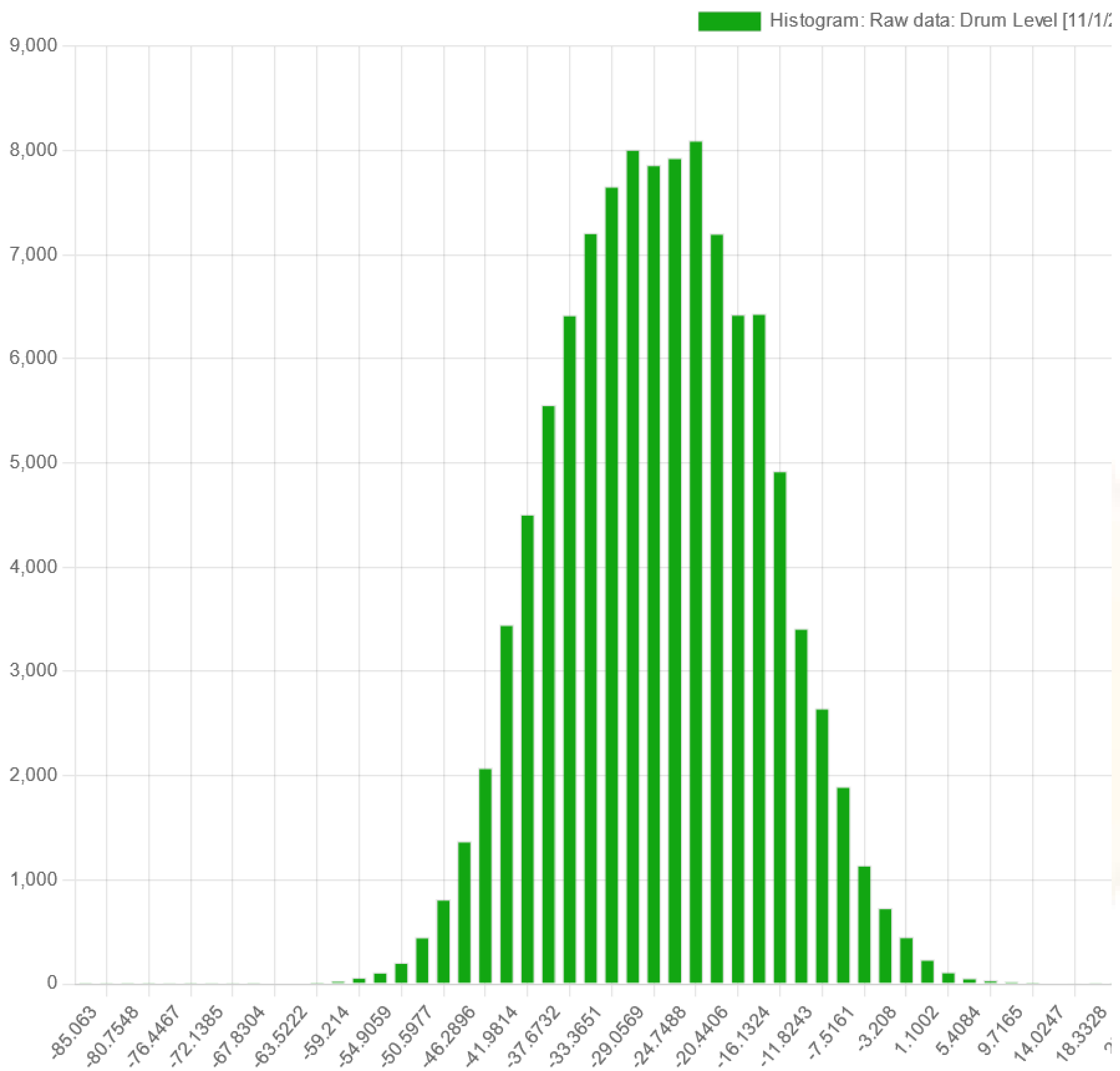


Drum Level – Case Study



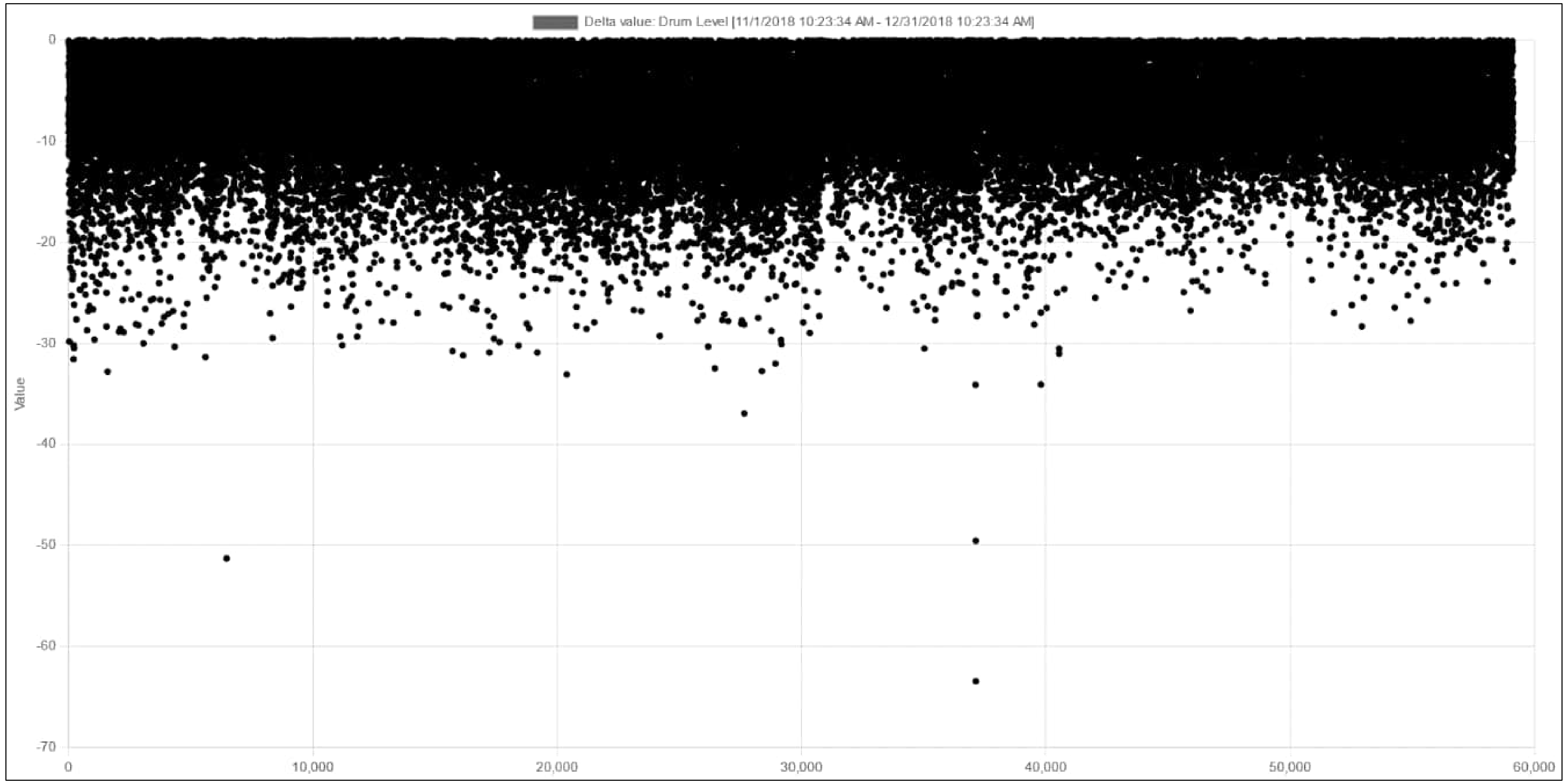
Drum Level – Case Study

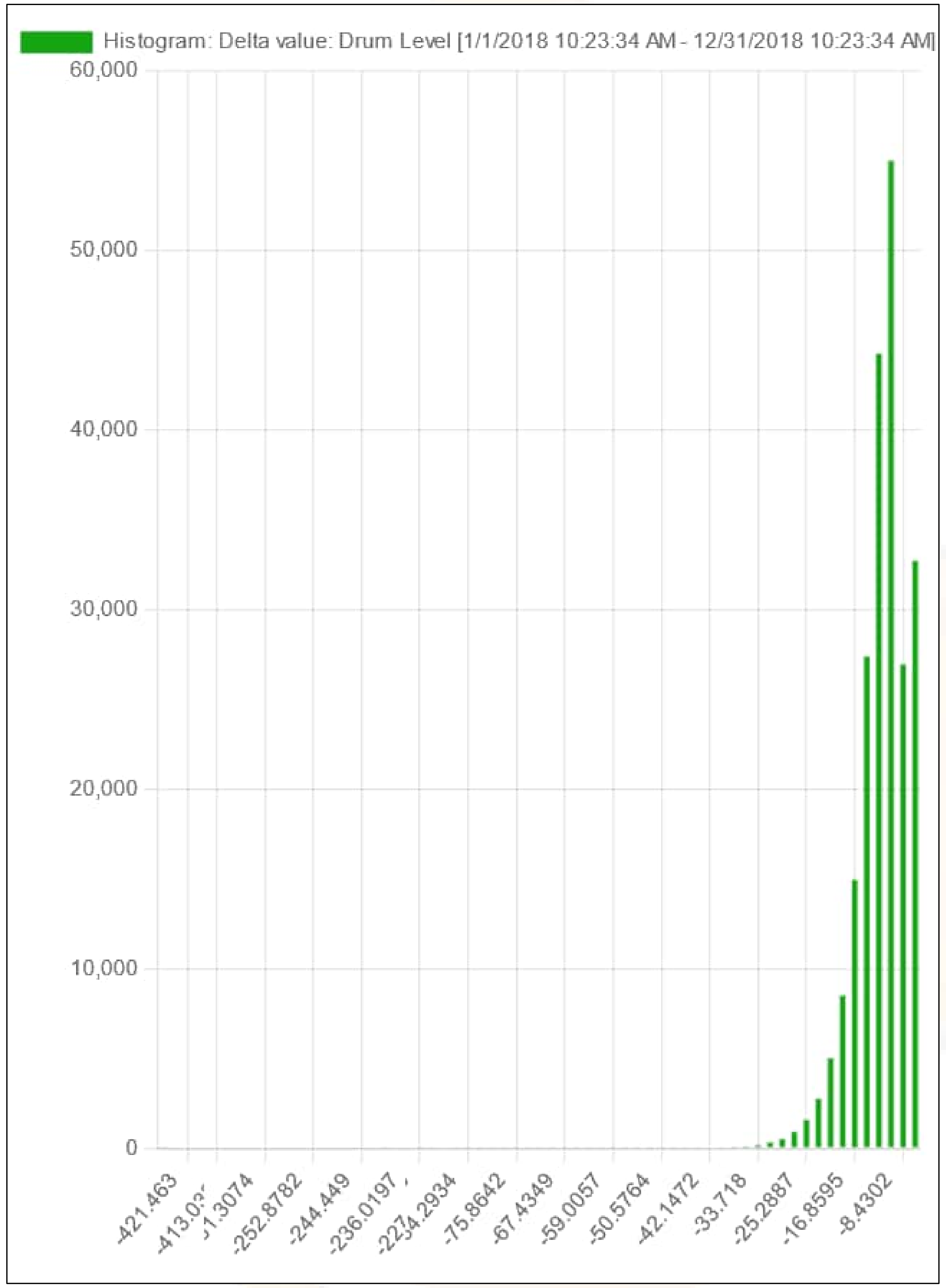




Drum Level – Case Study

Drum Level DROP Statistics





Recovery Boiler 1 - Case Study

Drum level drop of 38 mm/min happens only in 4 sigma events.

Furnace pressure rise of 0.19 kPa/min happens only 4 sigma events.

4 sigma events is about 16 minutes per year.

What's the probability of hitting 0 at two games of rullete at the same time with 31,000 numbers in each rullete?

What's the probability of hitting 0 at a game or rullete with 31,000 numbers?

Large Tube Leak Detection Algorithm

Determine average and standard deviations for FURNACE PRESSURE RISE for YOUR SPECIFIC BOILER.

Determine average and standard deviations for DRUM LEVEL DROP for YOUR SPECIFIC BOILER.

Create a variable that combines BOTH of the ABOVE, with Time element, and calculates how many standard deviations you are currently operating from your SPECIFIC's BOLER reference point.

Display, Plot, and Alarm the variable as a Large Tube Leak Detection Variable.

$$\boldsymbol{\sigma_{LD} = f\{\sigma_{DL'}\,\mu_{DL'}\,\sigma_{FP}, \mu_{FP}, time\}}$$

Large Tube Leak Detection Algorithm

Disadvantages:

Large tube leaks only!

Uses 2 variables (at the moment) only.

Detects abnormal operations but not if control system over-rides = Large tube leaks only.

Benefits:

Parameters Tuned to Each Boiler
Can be done with historical data

Requires statistical analysis only

Can be back tested (and tuned) for FALSE alarms with historical data AND for TRUE alarms (tube leaks) if such occurred.

Single equation variable can be easily implemented into your existing DCS system
No 3rd party hardware required
No new indicators required

Very CHEAP

Large Tube Leak Detection Algorithm

$$\sigma_{LD} = f\{\sigma_{DL}, \mu_{DL}, \sigma_{FP}, \mu_{FP}, time\}$$

This equation can save a boiler (and a life).

Questions

Questions

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BLRBAC

Report on 2023 Activities and 2024 Plans

Dean Clay for 2024 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 8 – 10, 2024**
    - **1 week shift, due to Easter**
  - Be sure to check the dates of future meetings
  - Scheduled October 7 – 9, 2024 Meeting
  - 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
- Note – BLRBAC is incorporated.

BLRBAC Meeting Location News

- Spring 2024 at "normal" Sonesta Atlanta Airport North Hotel
- Fall 2024 meeting is in planning to move to the Hilton Atlanta Airport Hotel. This is NOT Final YET
  - 1031 Virginia Ave, across the interstate from the Sonesta
  - BLRBAC conducted an email survey on the location change
    - 125 of 127 responses chose the Hilton (survey was Sonesta or Hilton)
  - Has a free airport shuttle (hopefully will operate more frequently); has indoor and outdoor pools.
  - BLRBAC is finalizing contract with Hilton, formal announcement at Spring 2024 Meeting
- 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 Internet Site

- blrbac.net
- Guidelines and questionnaires
  - Latest versions
  - Draft revisions for review
    - Interested persons are urged to review and provide comments, before the revisions are voted on for approval.
- Articles of Association & Operating Procedures
- Meeting registration forms and information
- Meeting minutes, current and past (to 2001)
- RBs in Service, U.S., Canada
  - Help keep the lists up to date, name changes, closures

Registration

- MetroConnections is now handling BLRBAC meeting registrations. A link is provided on blrbac.net, credit cards are accepted.
- Meeting Registration is now $500, in advance
  - At door $525
- Free hotel shuttle to and from airport/MARTA
- Spring 2023, 191 registered
- Fall 2023, 200 registered

Recent Meetings

- Spring 2022, first in-person in 2 years, 184 registered
- Fall 2022, in-person, 171 registered
- Registration increased to $500 to cover rapidly increasing expenses (BLRBAC is nonprofit)

BLRBAC Internet Site, Current Posted Guidelines (2023 last revs.)

- **Recommended Good Practice For Design, Operation, and Testing of the Emergency Shutdown System for Black Liquor Recovery Boilers (Dated: April 2023)**
- **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: February 2016)**
- **Personnel Safety & Training (Dated: April 2018)**
- **Application of Rotork Actuators on Black Liquor Recovery Boilers (Dated: October 2005)**
- **Boiler Water Management Guidelines for Black Liquor Recovery Boiler (Dated: 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: April 2017)**

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 Internet Site, Documents for Review and Comments

Copper Induced Cracking in Boiler Tubes – May 2019 Draft

Boiler Water Management Guidelines for Black Liquor Recovery Boilers – Section 31. 5.1 Revisions – 2018 Draft

Fire-Protection-for-DCE-2021-Draft

Waste Streams Document Revision Summary 6_21

Waste Streams Document (for reveiw)

BLRBAC Instrumentation and Classifications Guide Feb 2023 revision jcb

BLRBAC ISC E&I Qualification EC submittal for reveiw

BLRBAC Chemical Cleaning Guideline Water Treatment SC

BLRBAC Executive Committee

Revised after Spring 2023 Meeting

- **Chairman – David von Oepen, WestRock**
  - **By vote in Fall 2023, term extended to Fall 2024**
- **Vice Chairman – Frank Navojosky, International Paper**
- **Operator Rep. – Gregory Burns, Domtar**
- **Insurance Rep. – Jimmy Onstead, FM Global**
- **Boiler Mfg. Rep. – John Phillips, Andritz**
- **Treasurer – Brad Osborne, Electron Machine**
  - **Len Olavessen retired, after 22 years of service as Treasurer**
- **Secretary – Everett Hume, FM Global**

BLRBAC Subcommittees (10)

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

- Review the posted BLRBAC Minutes to see what the subcommittees are working on

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.
- 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

Risk Based Inspection & Maintenance of RB Sootblowers

AF&PA Meeting – Atlanta, GA, USA
February 7th, 2024

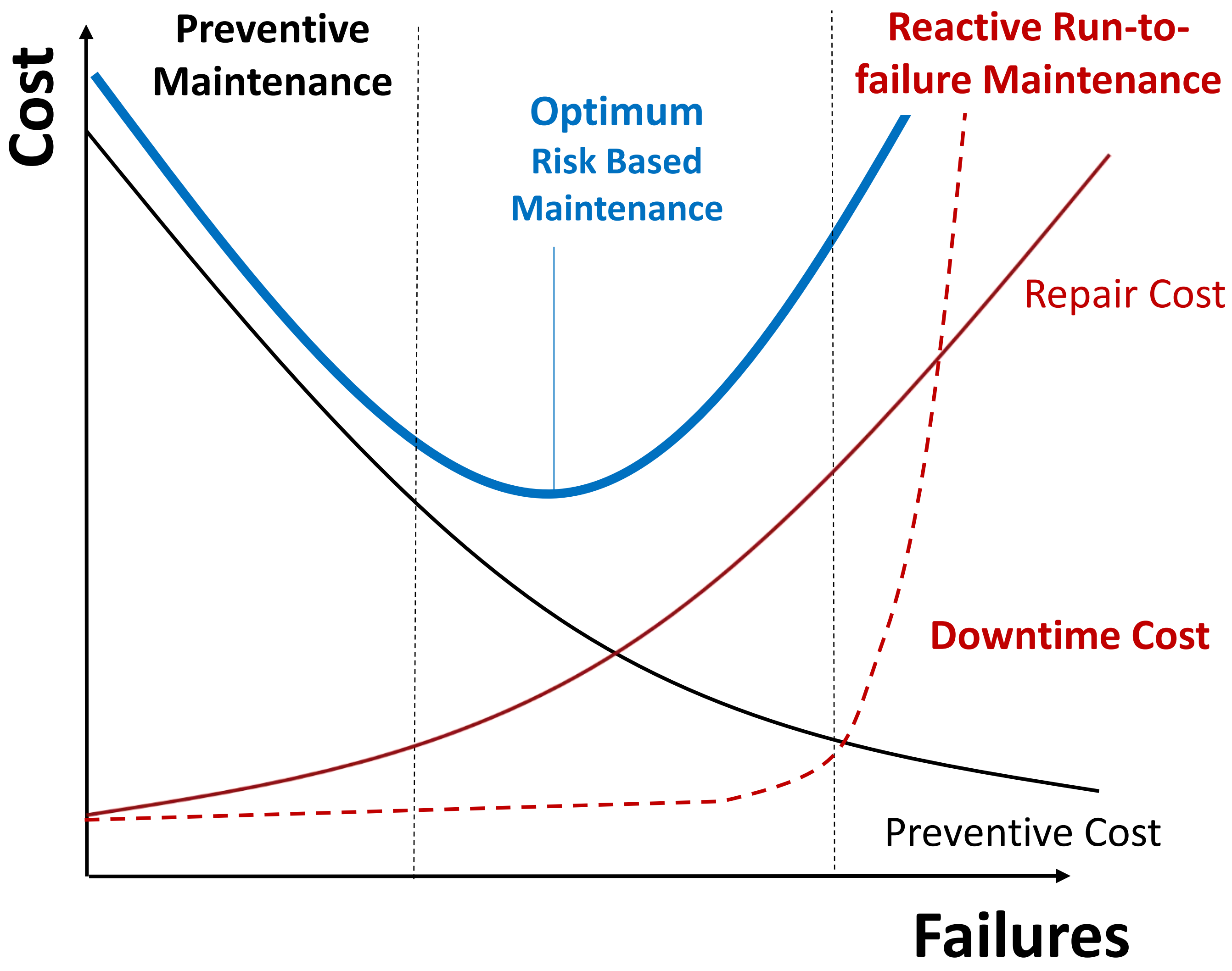
MAINTENANCE APPROACH

- Risk Based Maintenance
- Why? Because without a systematic maintenance approach, we would never have enough resources to maintain the sootblowers as suggested in the "sootblower manual"
  - Most manuals were written as if we are only maintaining one sootblower at chest level elevation.
  - Many mills have various types of sootblower with different and complicated part # to maintain

2

Maintenance

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



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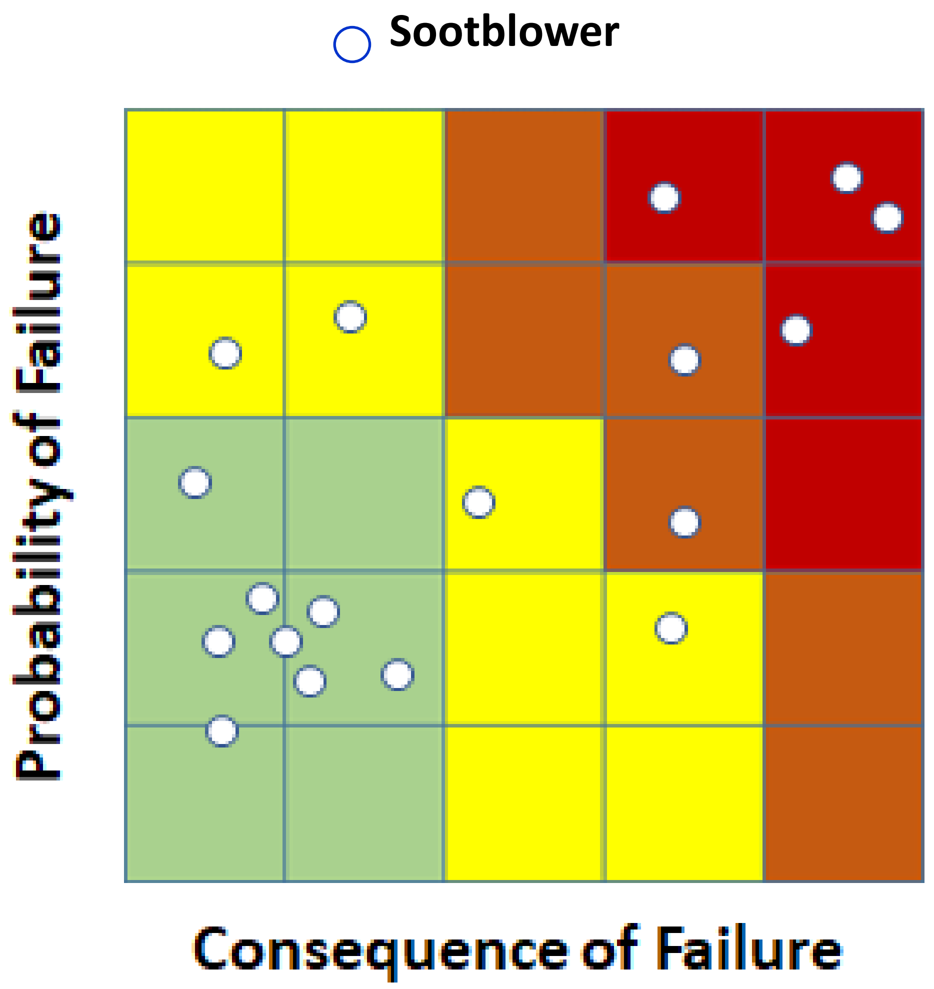
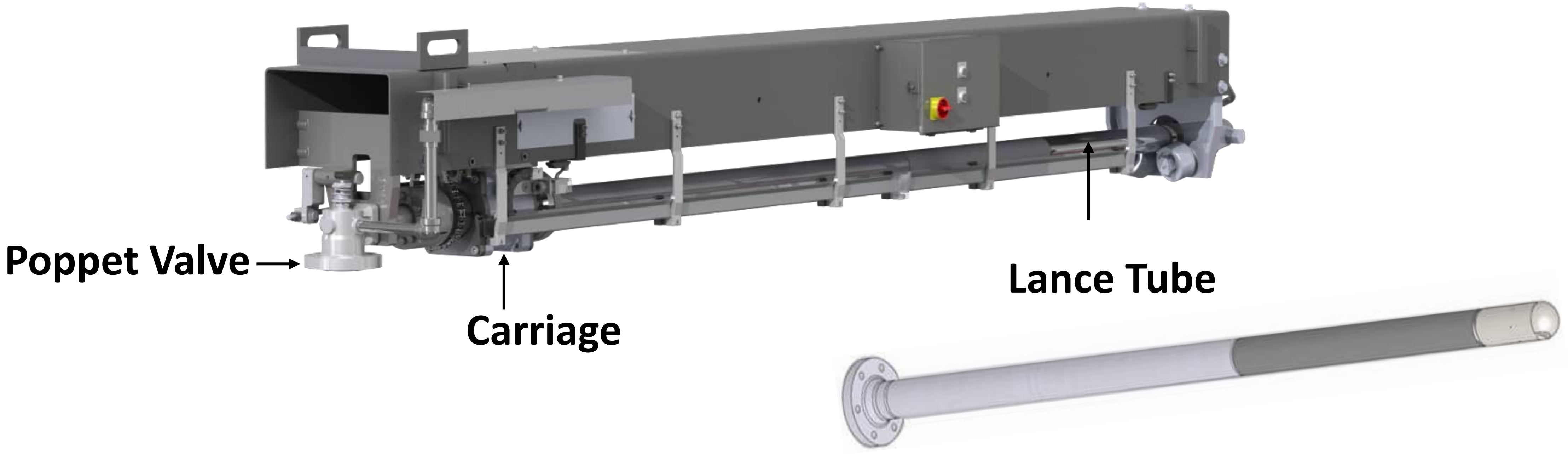
Risk Based Inspection (RBI)

- RBI assesses the probability of failure (PoF) and the consequence of failure (CoF) associated with each sootblower
- The key success factor to maintain a large quantity of sootblowers under limited maintenance resources is **<u>to know your risk and maintenance priority</u>**!
- What are the available tools?
    - Systematic NDT
    - Real-Time Sensor Measurements
    - Visual Walkdown



Systematic NDT

- Lance tube receives the hardest abuse and NDT is one of the most effective tool we can use to determine its Fitness To Operate.



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Systematic NDT

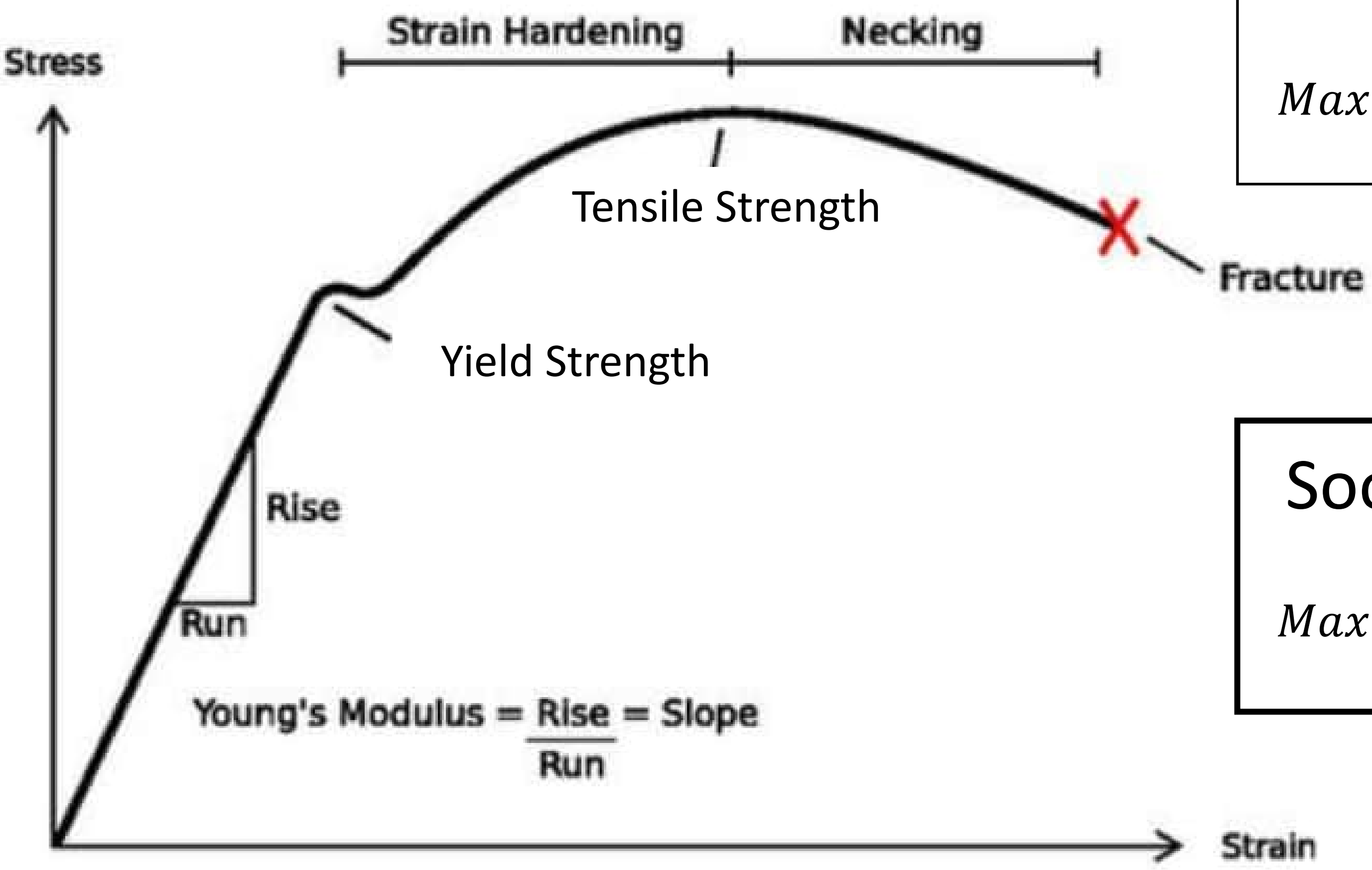
- The traditional approach is to hire NDT company to do time-based (yearly) inspection for **all** lance tubes.
  - But who determines the lance's fitness to operate?
  - What code to use? ASME?
  - New construction (*as if the lance is brand new*) or post-construction?
  - The traditional approach often leads to
    - Ineffective risk management: because we are dealing with large lance tubes data that is difficult to follow up (*i.e., small cracks or thinning that were deliberately left untouched with the intent to follow the growth over several inspections often not being followed up or "mysteriously disappear")*
    - Expensive repair / replace decisions: because new construction code is used instead of post-construction.

Lance Tube Code

- What design code we need to use for Lance Tube?
- Companion Guide to the ASME Code Volume 1, page 444 – 446 produces Figure 100.1.2 (B) which indicates that sootblowers is **NOT** under the jurisdiction of BPVC (Boiler & Pressure Vessel Code).
- Rather, it is under B31.1 power pressure piping code.
- But B31.1 is NOT written for sootblower application:
  - Unlike stationary power piping, Lance tube experiences much higher stress loading (i.e., it is rotating while being inserted into a boiler. It holds its own weight like a cantilever)
  - Lance is not a pressure vessel because there are at least two nozzles to relieve steam pressure

Lance Tube Code

- Hence, the code used for lance tube has to be **more stringent** than standard than B31.1



B31.1

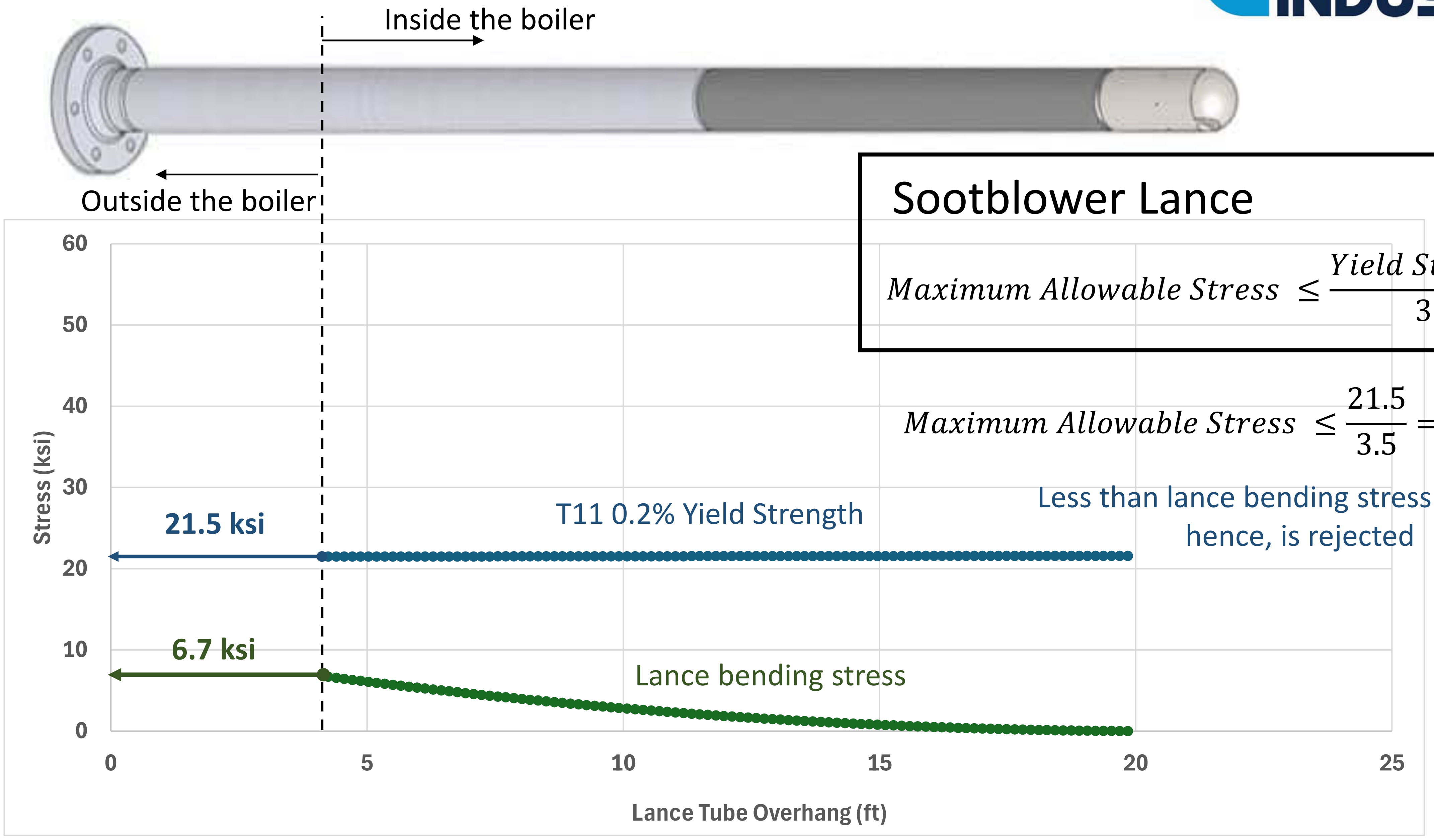
$$Maximum\ Allowable\ Stress\ \leq \frac{Tensile\ Strength}{3.5}$$

More stringent than B31.1

Sootblower Lance

$$Maximum\ Allowable\ Stress\ \leq \frac{Yield\ Strength}{3.5}$$

Fitness To Operate Test



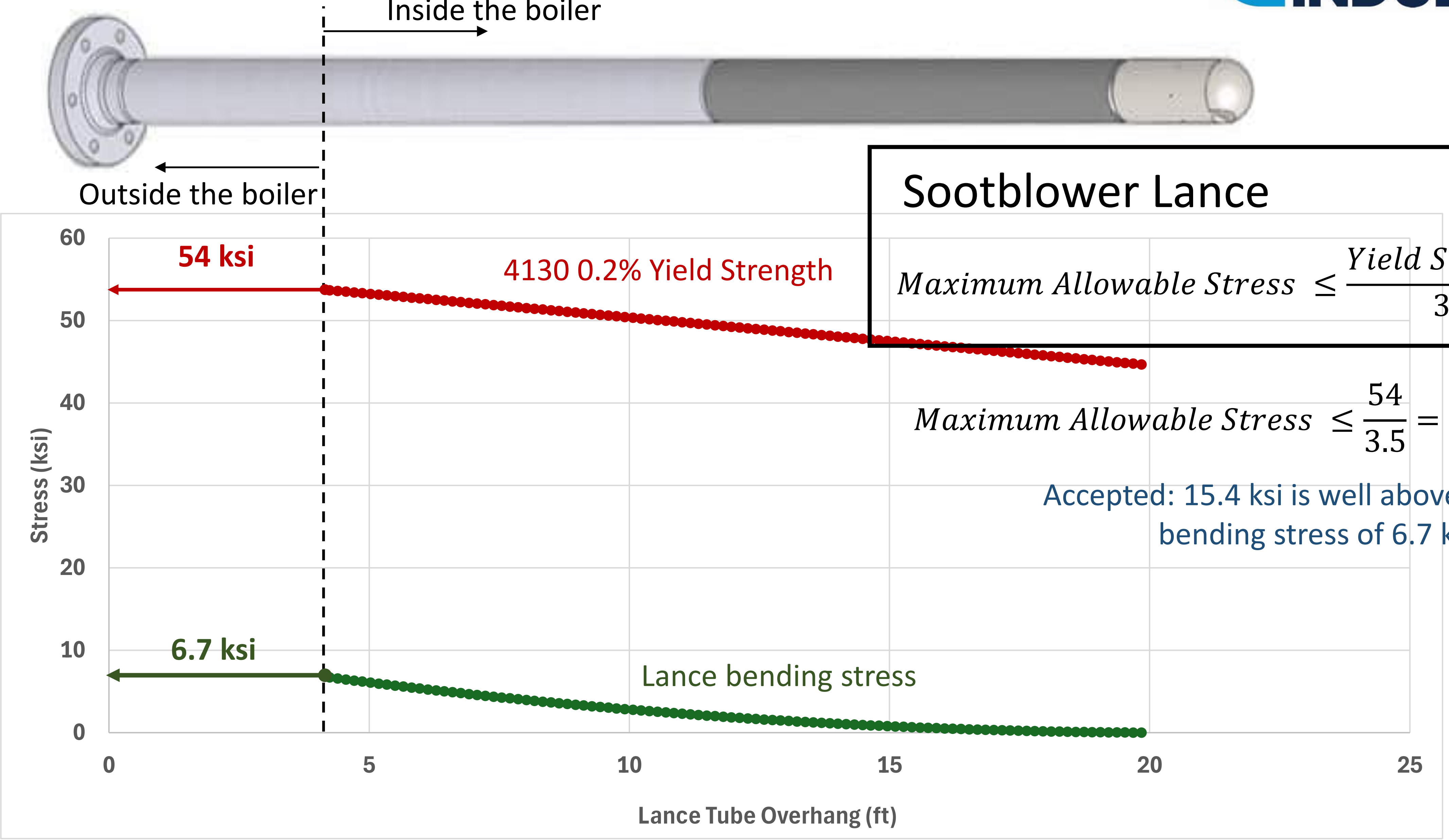
Sootblower Lance

$$Maximum\ Allowable\ Stress\ \leq \frac{Yield\ Strength}{3.5}$$

$$Maximum\ Allowable\ Stress\ \leq \frac{21.5}{3.5} = 6.1\ ksi$$

Less than lance bending stress of 6.7 ksi, hence, is rejected

Fitness To Operate Test



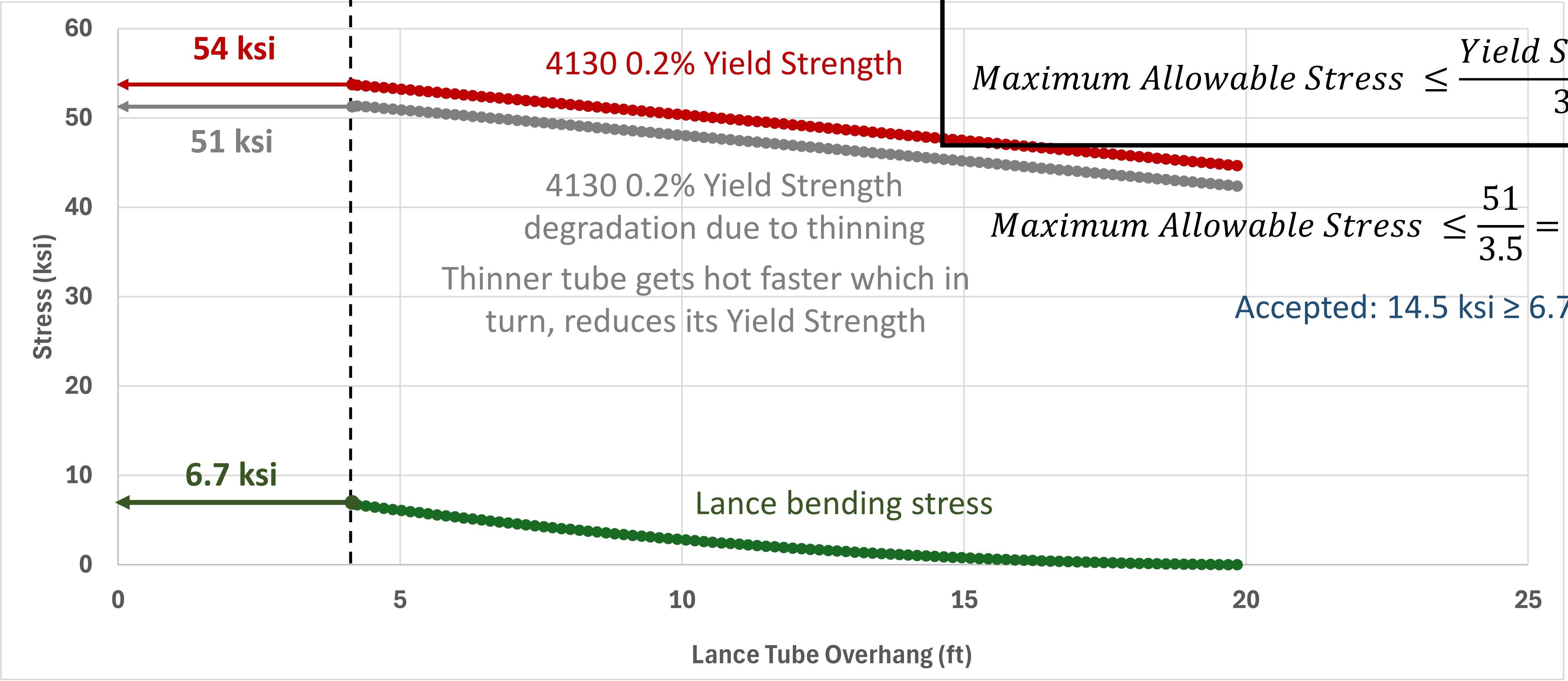
Sootblower Lance

$$Maximum\ Allowable\ Stress\ \leq \frac{Yield\ Strength}{3.5}$$

$$Maximum\ Allowable\ Stress\ \leq \frac{54}{3.5} = 15.4\ ksi$$

Accepted: 15.4 ksi is well above the lance bending stress of 6.7 ksi

Fitness To Operate Test



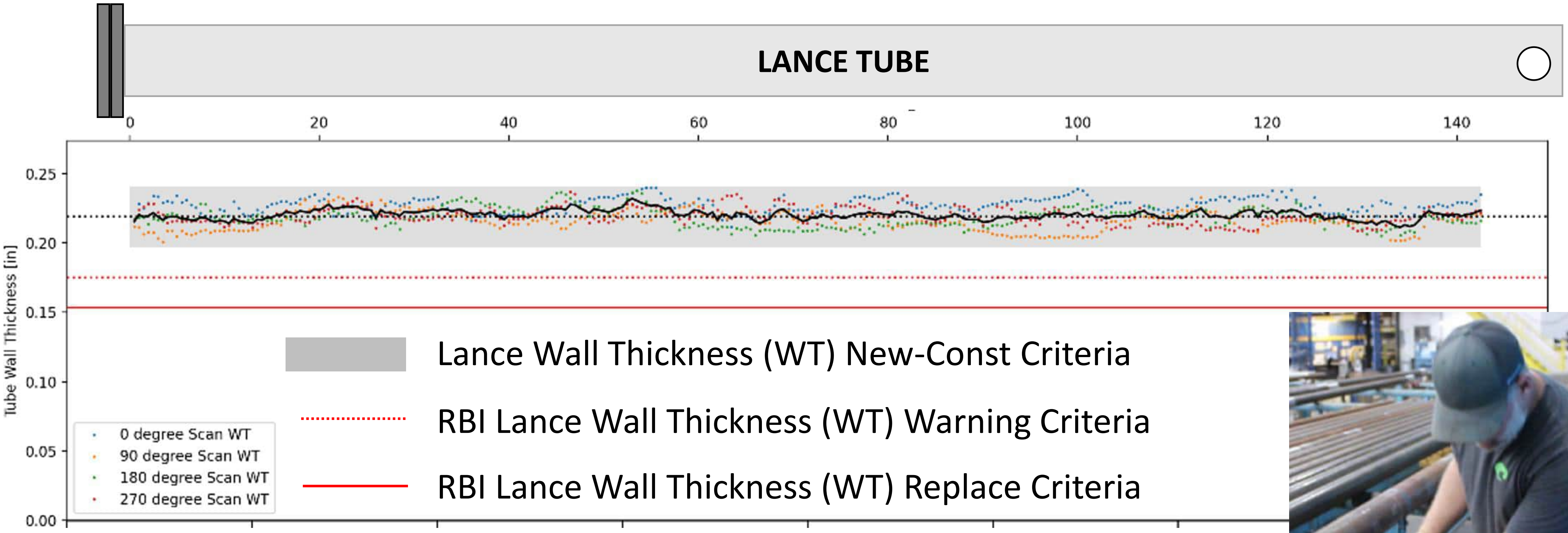
Sootblower Lance

$$\textit{Maximum Allowable Stress} \leq \frac{\textit{Yield Strength}}{3.5}$$

$$\textit{Maximum Allowable Stress} \leq \frac{51}{3.5} = 14.5\ ksi$$

Accepted: 14.5 ksi ≥ 6.7 ksi

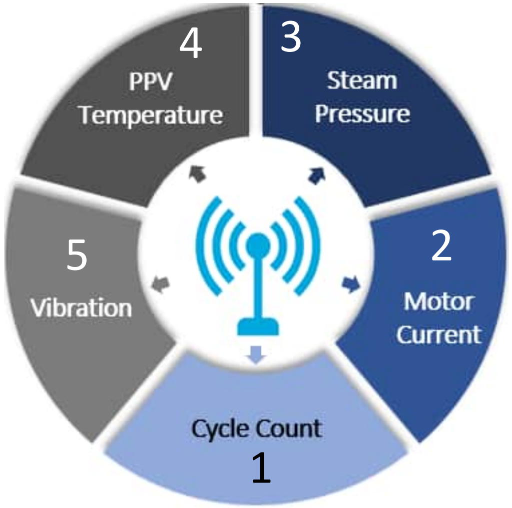
Lance NDT Code



- **<u>It is labor intensive</u>**; this is the reason why it is recommended to use RBI and do the inspection only for selected lance tubes (*i.e., not for yearly all lance inspection because it is harder to follow up*)

Lance Tube NDT

- Focusing on selected few lance tubes will allow us to perform thorough inspection (i.e., *avoiding "mysterious crack disappearance"*) and it is easier to follow the growth rate (*crack / thinning*) over the next inspections.
- How then to select which tube to be NDT?
  - **Real-Time Sensor Measurements**
  - Visual Walkdown



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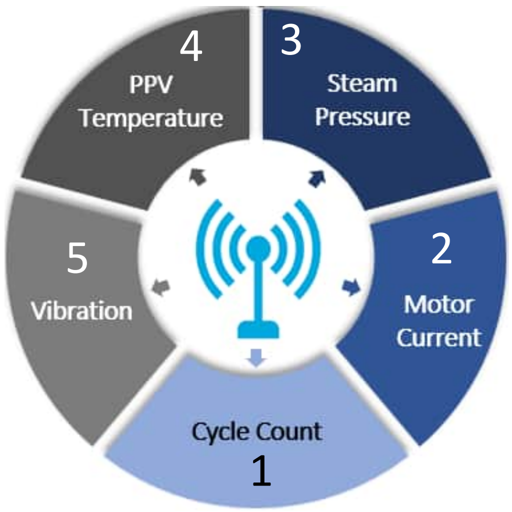

Lance will be put into **higher priority** for NDT if it has

1. *High cycle count*
2. *Abnormal motor current (i.e., abnormal load)*
3. *Low / fluctuating steam pressure (i.e., insufficient cooling)*
4. *High PPV temp (i.e., leaking poppet valve)*
5. *High Vibration*

Lance Tube NDT

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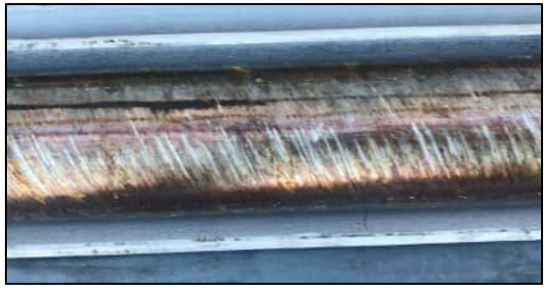
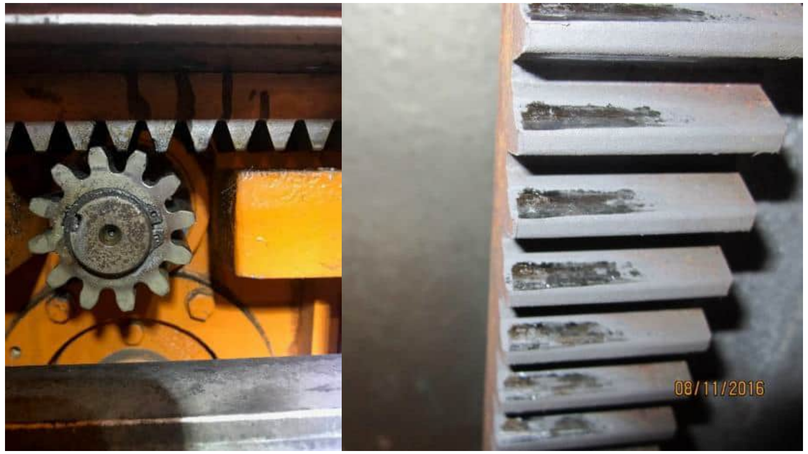
  - **Visual Walkdown**



Uneven scoring of feed tube (i.e., sign of misalignment)

Lance will be put into **higher priority** for NDT if

- Visual inspection shows a sign of abnormal loading



Three Key Takeaways

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

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

3. Use a more **systematic NDT** on selected sootblower lance, instead of the traditional time-based all lance inspection.

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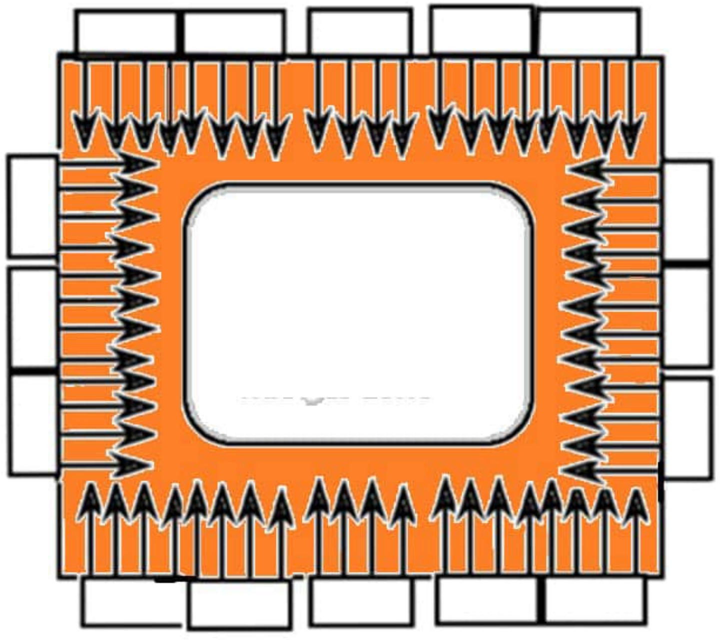
Recovery Boiler Char Bed Modernization

Gene Sullivan
SHB Power Plant Engineering

AF&PA Recovery Boiler Conference
February 7, 2024

Why primary air system is OUTDATED

- **"Wall Painting" no longer a necessity: --** Liquor concentration at the spray typically greater than 65% today versus 40% to 45% with the first RB in 1929. Wall shedding significantly reduced.
- **High Risk Design:** -- Many small port openings focus creates high exposure of "problems". Topography formation is random and leads to bed disturbances.
- **Poor Coverage:** -- Poor air jet penetration leads to "close-in" (near wall) combustion that crates high radiation heat flux to nearby tube walls increasing tube wall thinning.
- **Slow Speed of Convergence:** -- Inorganic cooking chemicals transition from solid to smelt is slow. This results in greater weight load and heat residence time within the furnace and need for "larger" floor area.
- **High Support Requirement:** -- more equipment and operators needed to maintain safe, stable, and efficient operations.
- **Creates poor flue gas flow formation:** -- 4 wall uniform airflow feed pushes & concentrates flue gas flows upwards at center of furnace that increases vertical speeds, carryover and greater SO2 emissions.



Conventional Primary Air

CBM = New Primary Air

CBM Primary is effective, simple, and lower risk.

1. CBM units on two side walls only
2. Safe, Simple, Stable, Efficient, & Environmentally friendly
3. PA set at 30% - 35% of total airflow but can be reduced.
4. Flip/Flop strong/weak jets to “sweep” bed, back & forth.
5. CBM ports replace ~ 85% of original primary port openings!

The US Patent Office has granted SHB patent protection for CBM.

CBM air-jets create low-elevation suspension burning. Ideal for some low-level spray.





~ 85% reduction in primary port openings! Replaced with straight wall tubes.

Why Change to CBM

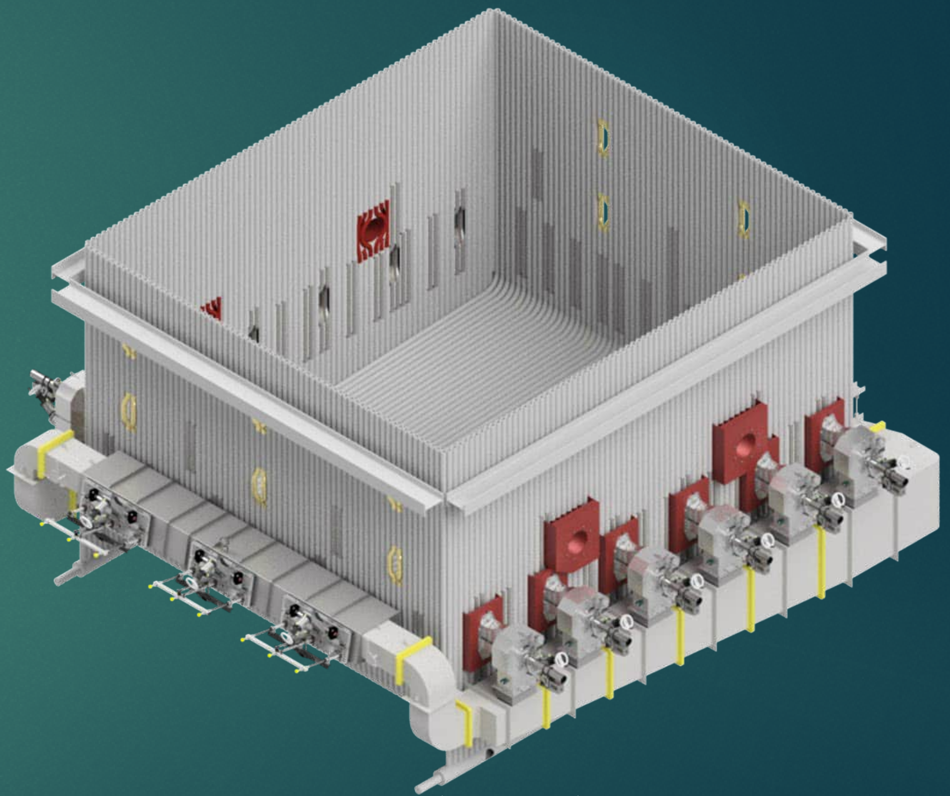
Why Change Primary Air System?:

- Reduces "close-in" burning near walls.
- Faster spray to smelt reduces bed inventory.
- Reduce SOx emissions and carryover
- Uniform & constant smelt runoff without floaters
- Improve disturbance rejection capability
- More liquor burning capacity & turndown range.
- Reduces "dregs" load within green liquor.

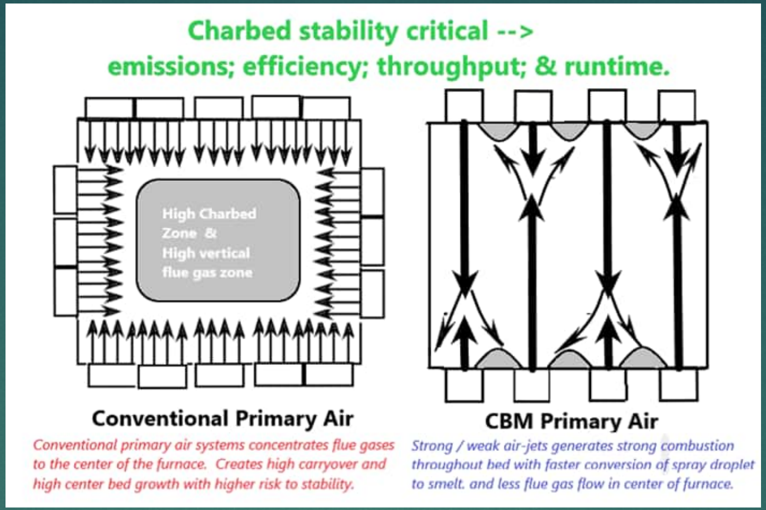
Advantages of CBM

- Greater combustion stability at all load ranges.
- Reduce carryover & sootblowing steam usage.
- Strong, even, smelt runoff without "floaters"
- Less molten char reach upper furnace
- Reduce auxiliary fuel usage: startup & shutdown.
- Greater stability allows reduction in percent primary airflow.

CBM Primary Air System



Smelt wall primary air ports used for rodding access not airflow.



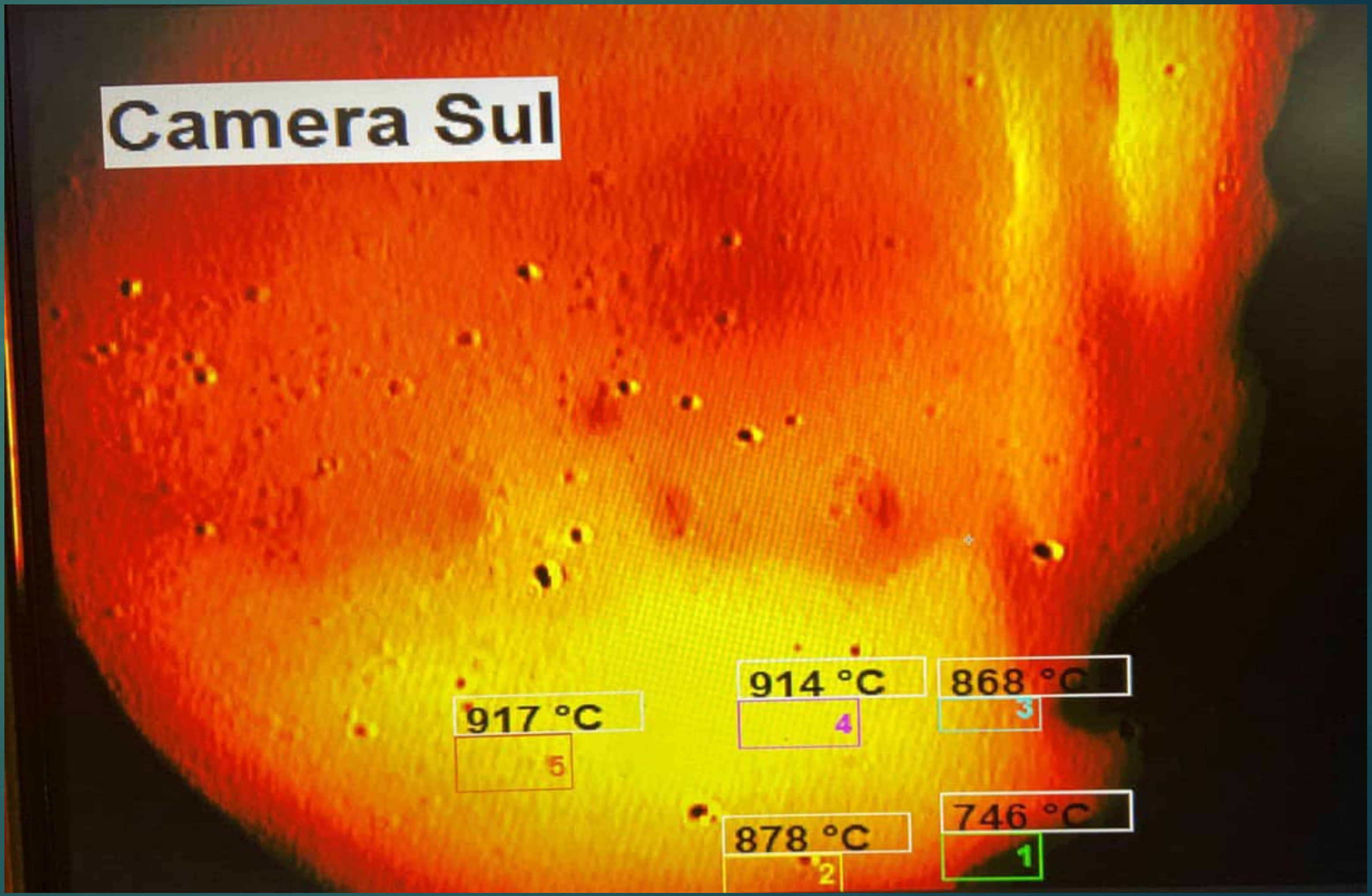
The air system at right animation has 5 levels of air injection. CBM primary, 2 secondary air; & 2 tertiary air levels.

The load at right side is at 22% overload from maximum previous from left side CFD animation.

The lighter "intensity" of color at right side is result of "droplet" carryover tracking. This means there is less spray droplet carryover at right side animation.

Strong furnace heat = opportunity to move some liquor spray lower or reduce % PA flow

- Inventory of liquor solids within the bed will be consistently lower for the same maximum loading.
- Primary air penetration across the complete bed width.
- Charbed zone temp (by IR camera) increase ~ 120 deg C.
- Greater solids fired possible with reduced carryover & SO2 emissions.
- Eliminates risk of many small openings.
- Spraying 50% of liquor below the secondary port openings will reduce the spray droplet aerodynamic drag forces by more than 50% and increase chemical reduction efficiency!



CBM + Low-Level Liquor Spray Makes Sense

1. **Improves Char Bed Stability, Efficiency, & Safety**
   1. Hotter bed zone temperatures = faster conversion to smelt.
   2. Lower bed inventory = greater overload capacity.
2. **Increased "Disturbance Rejection" capability**
   1. Stronger thermal inertia within char bed
   2. Back & forth sweeping action "levels" bed
3. **Reduces operations/maintenance Costs**
   1. Reduces aux fuel consumption – startup or shut down!
   2. Reduces sootblowing steam consumption
   3. Reduces maintenance around port wall opening tubes, & sootblowers
4. **Potential for some percentage of Low-Level Liquor Spray**
   1. Bed Zone hi-thermal inertia -> increases LL-Spray reality!
   2. Sootblowers treat the symptom, they do not solve the problem.
5. **Reduces Risk**
   1. ~85% reduction in primary port openings
   2. Substantial reduction in stack emissions – SO_2, particulate, NO_x

Recovery Boiler Char Bed Modernization

Thank You!

The video files are too large to play in this copy of the presentation.
For copies of the videos or more information about this presentation,
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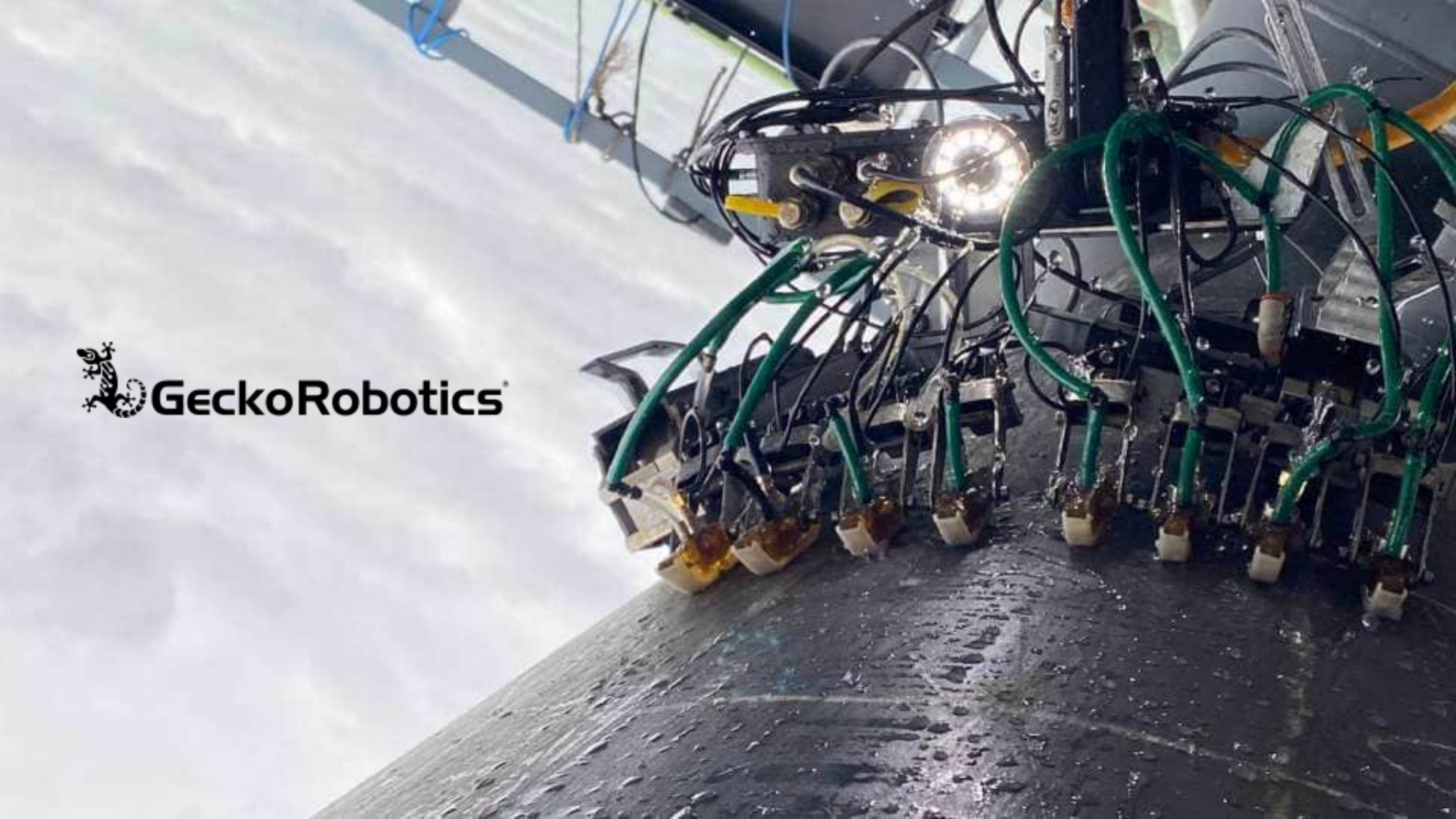

GeckoRobotics

Accelerated Value Capture by Automated Data Collection and Analysis

AF&PA Recovery Boiler Conference

February 7, 2024

Atlanta, Georgia

gecko robotics

New Year – Safety Equipment

Important to check the safety equipment before each use.

This applies to seat belts, harnesses, ladders, safety glasses, hardhat, etc.

Fall Protection needs routine inspections. Hard hats do expire and need to be replaced. Don't forget those smoke detector batteries as well.

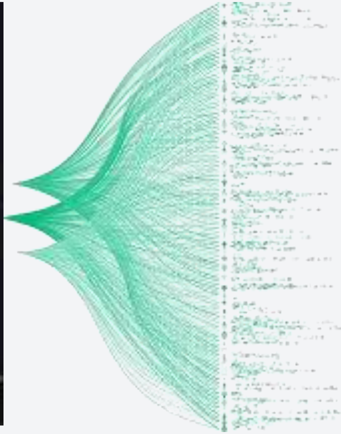
Safety First

Timing is Key

- **Optimal Decision Making (Collect & Share Data Fast)**
- **Minimum Outage Time (Define & Prioritize Risk)**
- **Optimized Supply Chain (Allocate Resources)**
- **Accelerated Value Capture**

gecko robotics

Gecko empowers decision makers with data infrastructure.



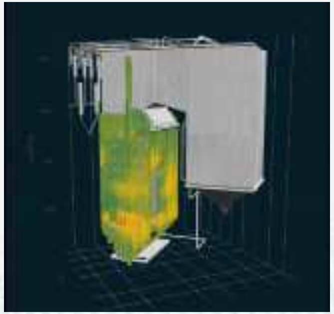
It starts with getting the data.

Empowerment by Data

VALUE CAPTURE LOOP

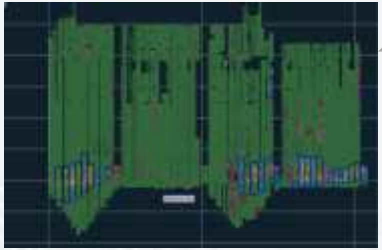
1. DEFINE ASSET CONDTION: (High Quality Data; Minimum Data Gaps; Rapid & Expert Data Analysis)

2. PREDICT FAILURE RISK, MODE, SCOPE & TIMING: (High Quality Data & Data Analysis; Coordinated Site, Corporate & Consulting Expertise)



3. OPTIMIZE REPAIR PLAN FOR FAILURE RISK & RESOURCE LOAD: (Quality Data & Data Analysis; Coordinated User & Supplier Expertise)

4. EXECUTE OPTIMIZED PROACTIVE REPAIRS: (Refine Scope With Real Time Outage Data)



Empowerment by Data

VALUE CAPTURE LOOP

KEY PARAMETERS:

High Quality Data = Timely, Objective, Repeatable, Accurate, Flexible Storage, Easy to Share, Easy to Analyze

Minimum Data Gaps = Collect high quality data from as much of the asset as possible. Use objective direct measurement as much as possible. Retain raw data in a form that can be easily shared and analyzed with improved future methods. Collect multiple data sets with different methods.

Rapid & Expert Data Sharing & Analysis = Establish analysis process early. Continually update and maintain analysis process to adapt to changing conditions and possible future states. Maximize flexibility of data and analysis sharing between site, corporate and consulting teams.

Well Defined Repair Cost, Failure Risk and Value of Lossed Production = Common definition processes system wide. Maximize process automation with real time process checking. Maximize ease of process adaptation to changing conditions and new technology and process knowledge.

Example: Furnace zone of 4 walls, 150 tubes per wall and 60 feet high in elevation (upper furnace from clad line to bull nose for a larger boiler). Robot speed at 30 ft/min.

Using 2 robots scanning approximately every 0.25 inch of height on every tube, with 3 paths per tube for 48 readings per path per foot at a 75% data acceptance validation rate, for a total of 3,888,000 data points.

- **RUG starts 0.5 shifts after base platform scaffold is finished.**
- **RUG inspection complete with team cleared out after 2 shifts.**
- **Computer validated data available starting the end of 2nd shift.**
- **No additional scaffold or cleaning needed.**
- **Total time to complete with all data validation is 3.5 shifts.**
- **Raw data rate is 3,888,000 points/3 shifts = 1,296,000 points/shift.**
- **Net data rate is 3,888,000 points/3.5 total shifts = 1,110,857 points/shift.**

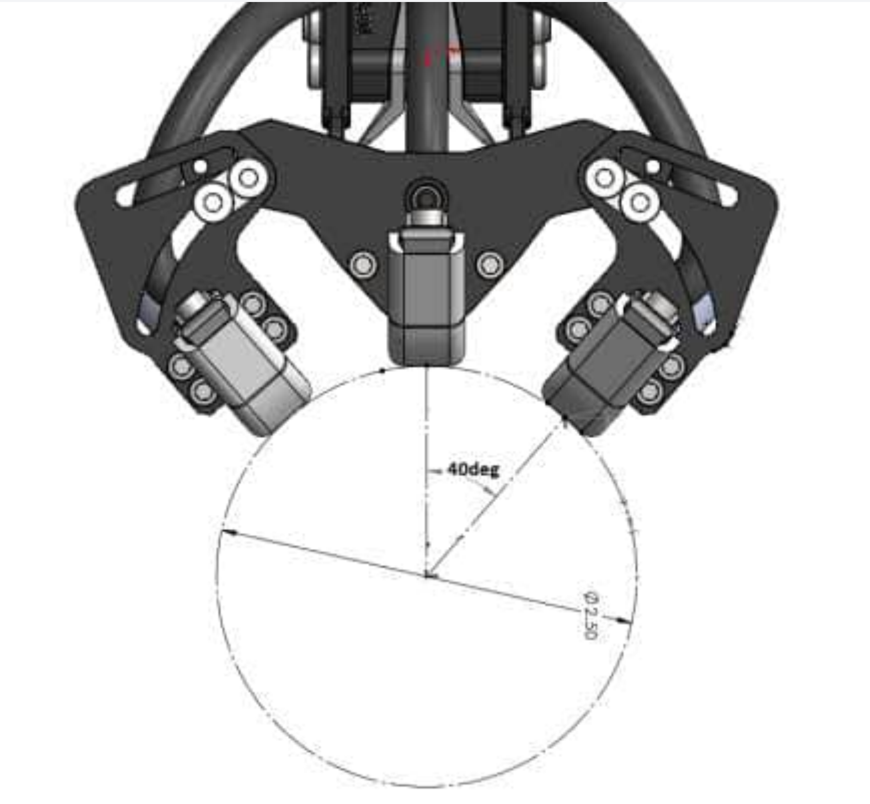
gecko robotics

Gecko Method

- **Up to 250 ft vertical travel height from launch point.**
- **Typical 24 UT Sensors scanning in parallel.**
- **3 to 30 ft/min robot travel speed.**
- **Average 1150 scans per elevation foot per robot path.**
- **Travels over 0.5” tall weld beads.**
- **Travels over cladding or weld overlay.**

gecko robotics

Simultaneously collect HD photos, co-located with UT data.



- **Approximately 0.25” between readings on long tube axis at 30 ft/min robot travel speed.**
- **Robot can be slowed to 6 ft/min for 0.050” between readings.**
- **40 degrees between center and left or right.**
- **Approximately 0.87” between readings around tube circumference.**
- **Sensors can be rolled 12 degrees left or right if desired, to increase scan paths.**

Gecko Method

Q: What is the coupling media used? And how much is required?

A: Service water, about 1.5 GPM. Water provided directly from a plant water connection. Have used fire water.

Q: What other plant utilities are required?

A: Single Phase 120 V or 240 V

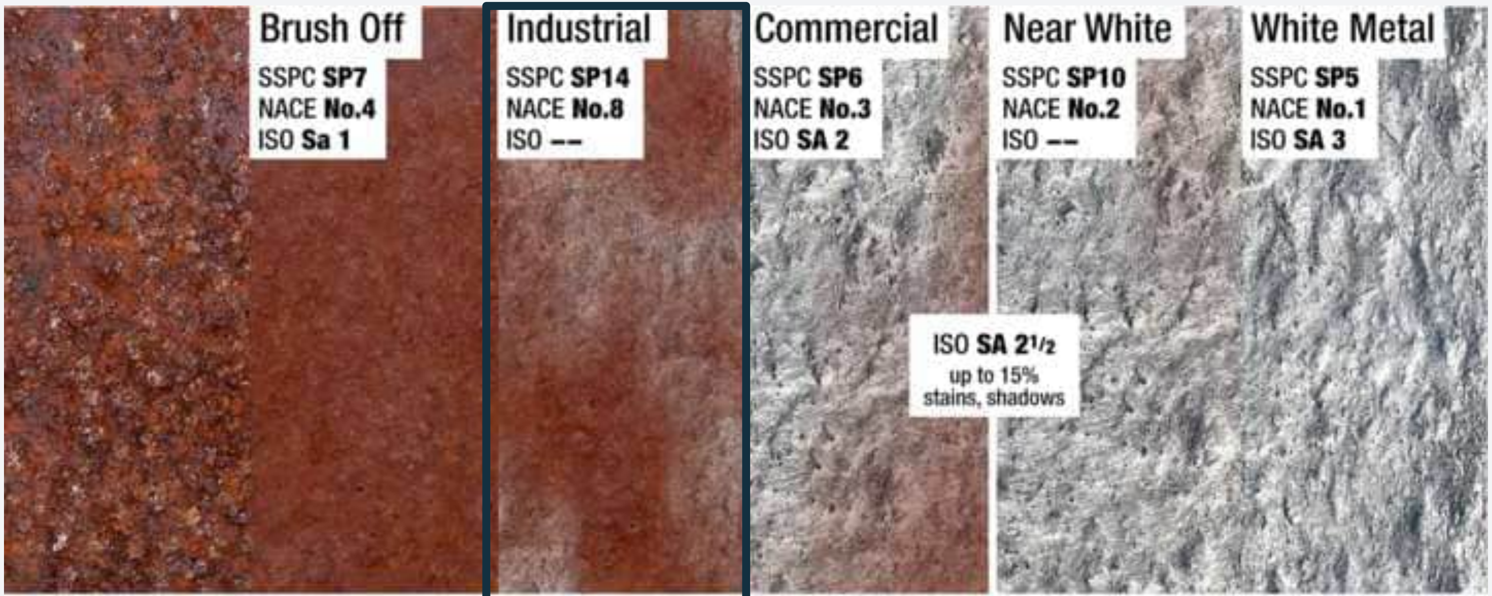
Q: Cleaning?

A: Job dependent. Typical surface is NACE/SSPC “Industrial” (NACE #8, SSPC14)

Q: Who operates the robot?

A: 1 inspector operates the robot and a 2nd Level II NDE inspector reviews the inspection data as it is collected on our computer platform.

Gecko Method

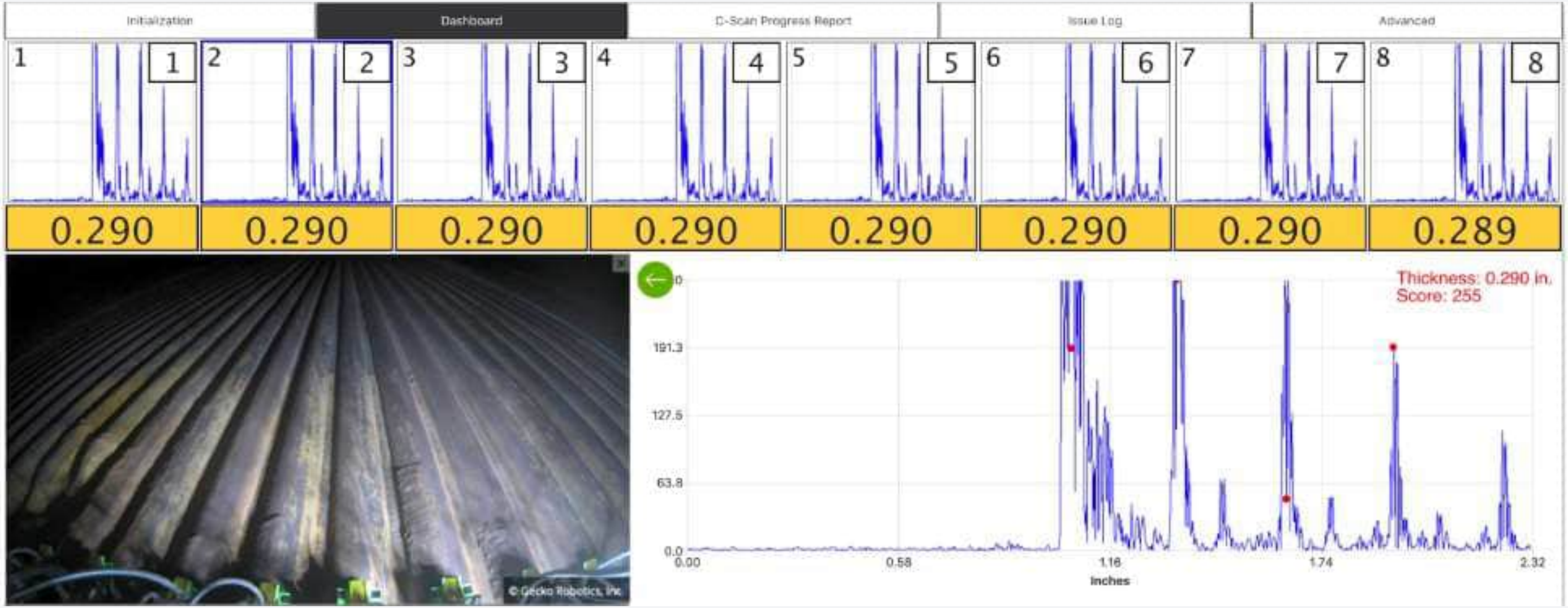


	Brush Off	Industrial	Commercial	Near White	White Metal
Loose Material	None	None	None	None	None
Tight Material	100%	up to 10%	None	None	None
Stains, Shadows	100%	100%	up to 33%	up to 5%	None

NACE/SSPC "Industrial" (NACE #8, SSPC14)

gecko robotics

Gecko Method



Sensors are calibrated before the inspection starts.
Data collection is continuously monitored for quality.

A-Scans

Amplitude Scan (A-scans)

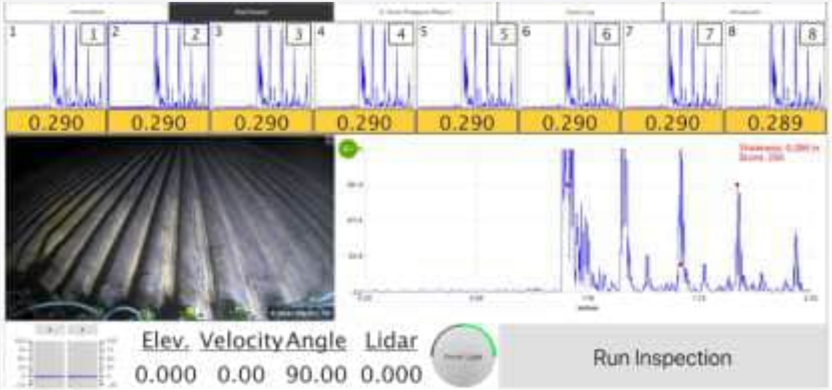
One dimensional graph where ultrasonic echo amplitude is plotted as a function of time.

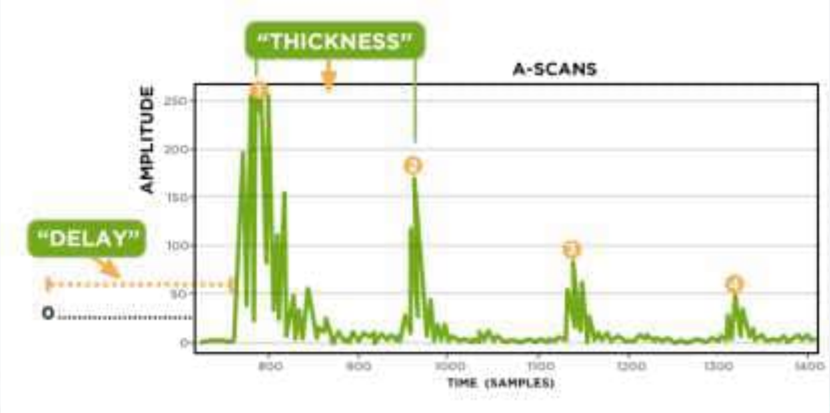
- Each A-scan produced by a single sensor
- TOKA robots have 8-128 sensors

Gecko's proprietary algorithms measure data quality

- Invalidate and remove low quality readings
- Material thickness measurements are high quality and actionable
- Building blocks for B-scans and C-scans

Gecko retains all A-Scan meta data





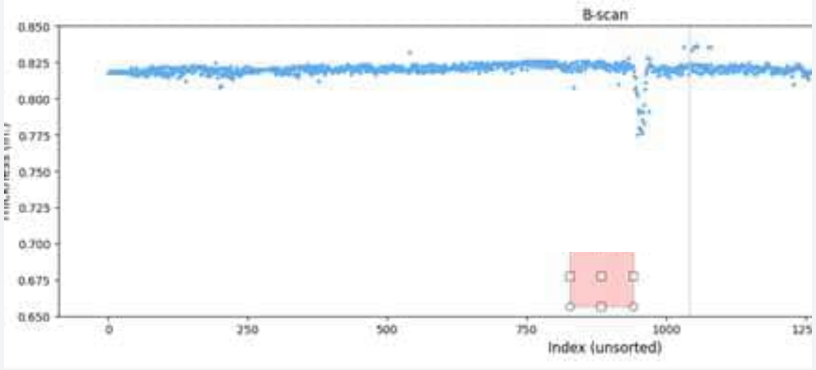
B-Scans

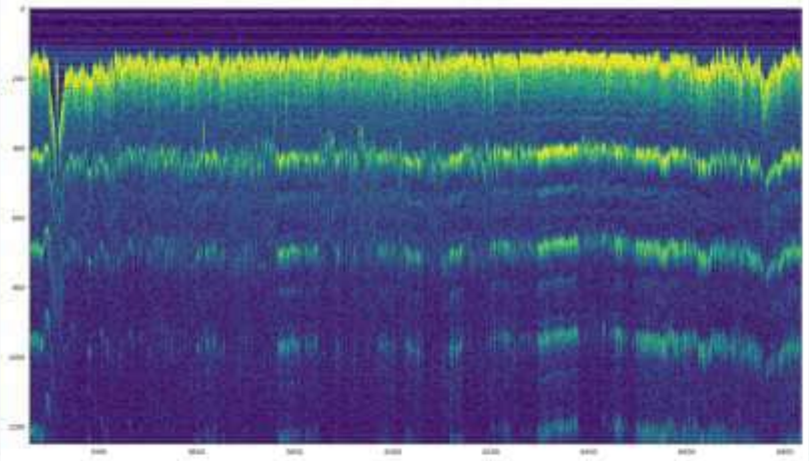
B-scans: two-dimensional, cross-sectional views of the inspected material depicting thickness measured at different positions over time.

- A-scan readings from a single sensor in a single run

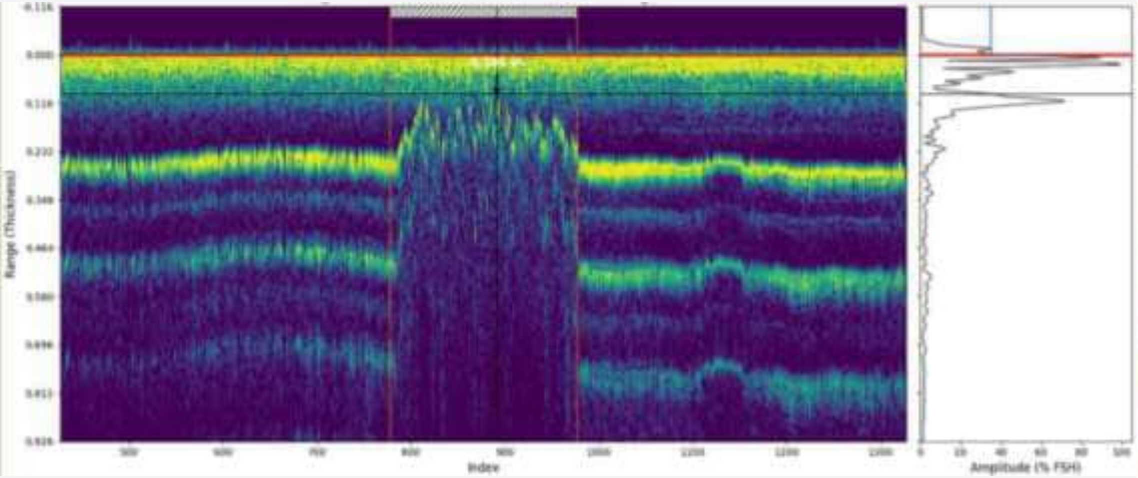
Scatterplot of one sensor (top): shows the tube wall thickness on the Y-axis vs the data scan location along the X-axis. Note the dip in wall thickness near sample point 900.

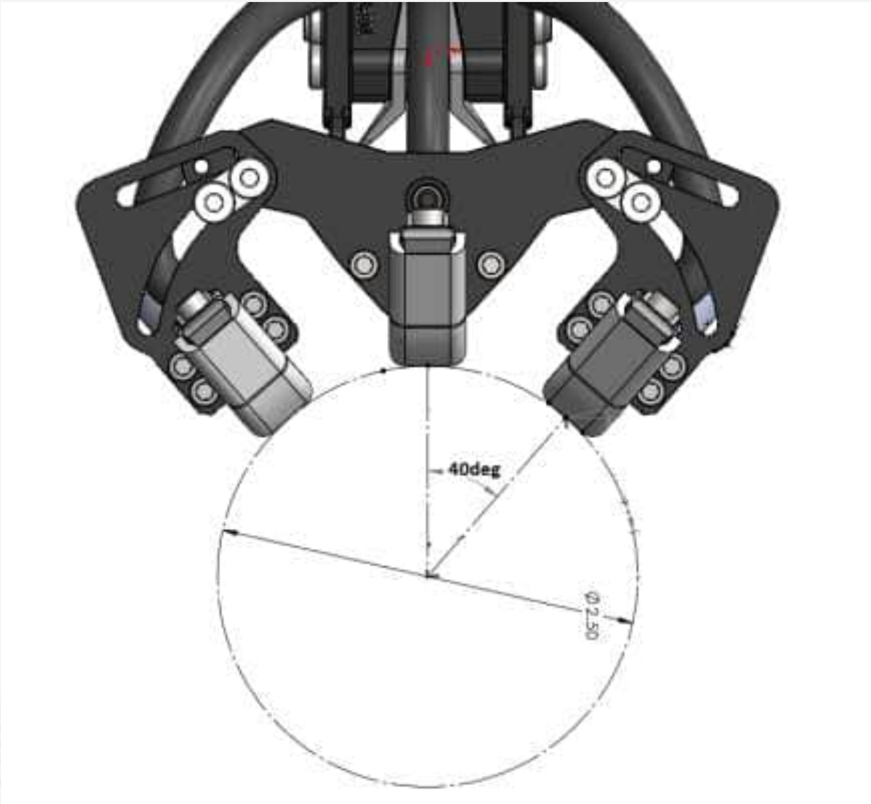
Waterfall plot (bottom): uses color to create patterns & represent amplitude where yellow is high amplitude and dark blue is low amplitude.





Under Deposit Corrosion





Significance of general corrosion, per NBIC Part 2 Paragraph 4.4.7.2.h.1:

"For an area affected by a general corrosion in which the circumferential stresses govern the MAWP, the least thicknesses along the most critical plane of such an area may be averaged over a length not exceeding:

"The lesser of one-half the vessel diameter, or 20 inches for vessels with inside diameters of 60 inches or less."

If applied to a 2.5" diameter tube, the length to be averaged for this procedure is 1.25". The RUG spans of 0.87" between readings circumferentially and 0.25" between readings longitudinally both meet this criteria.

Manual Method

Furnace zone of 4 walls, 150 tubes per wall and 60 feet high in elevation (upper furnace from clad line to bull nose for a larger boiler).

Manual UT: Scan 3 points per tube at elevation bands 6 feet apart at every tube across, for a total of 19,800 data points.

- **Scaffolding to access area takes 4 shifts.**
- **Cleaning and scanning takes 2 shifts.**
- **Tearing down the scaffolding takes 2 shifts.**
- **Total time to complete is 8 shifts.**
- **Raw data rate is 19,800 points/2 shifts = 9,900 points/shift.**
- **Net data rate is 19,800 points/8 total shifts = 2,475 points/shift.**

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Manual Method

Tube	1			2			3			4			5			6			7			8			9		
Elevation	L	C	R	L	C	R	L	C	R	L	C	R	L	C	R	L	C	R	L	C	R	L	C	R	L	C	R
60	0.201	0.185	0.139	0.151	0.188	0.154	0.121	0.166	0.184	0.129	0.125	0.152	0.163	0.148	0.160	0.124	0.162	0.135	0.121	0.163	0.121	0.149	0.179	0.171	0.203	0.154	0.129
59																											
58																											
57																											
56																											
55																											
54	0.149	0.126	0.183	0.160	0.180	0.141	0.122	0.168	0.141	0.203	0.200	0.155	0.153	0.126	0.200	0.120	0.177	0.158	0.154	0.191	0.188	0.173	0.202	0.179	0.174	0.202	0.148
53																											
52																											
51																											
50																											
49																											
48	0.133	0.168	0.122	0.176	0.202	0.125	0.164	0.167	0.184	0.173	0.139	0.182	0.121	0.158	0.172	0.136	0.129	0.145	0.186	0.143	0.196	0.120	0.165	0.128	0.159	0.179	0.194
47																											
46																											
45																											
44																											
43																											
42	0.147	0.169	0.121	0.123	0.155	0.178	0.185	0.179	0.177	0.133	0.135	0.183	0.169	0.141	0.135	0.168	0.142	0.195	0.176	0.172	0.181	0.176	0.148	0.140	0.195	0.145	0.167
41																											
40																											
39																											
38																											
37																											
36	0.153	0.169	0.167	0.126	0.184	0.168	0.192	0.185	0.169	0.133	0.146	0.147	0.195	0.194	0.131	0.174	0.180	0.172	0.121	0.125	0.142	0.161	0.128	0.197	0.135	0.163	0.154
35																											
34																											
33																											
32																											
31																											
30	0.185	0.141	0.145	0.198	0.168	0.155	0.198	0.155	0.195	0.154	0.128	0.178	0.186	0.124	0.130	0.191	0.138	0.165	0.202	0.172	0.200	0.161	0.186	0.139	0.177	0.123	0.176
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28																											
27																											
26																											
25																											
24	0.165	0.159	0.173	0.154	0.196	0.175	0.201	0.156	0.144	0.173	0.140	0.156	0.131	0.128	0.155	0.140	0.179	0.163	0.200	0.161	0.148	0.174	0.152	0.200	0.124	0.145	0.145
23																											
22																											
21																											
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19																											
18	0.172	0.166	0.143	0.127	0.193	0.153	0.199	0.203	0.122	0.145	0.130	0.139	0.133	0.148	0.123	0.146	0.178	0.183	0.166	0.184	0.134	0.157	0.147	0.164	0.187	0.166	0.182
17																											
16																											
15																											
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12	0.202	0.162	0.159	0.144	0.143	0.147	0.168	0.171	0.178	0.178	0.158	0.202	0.148	0.129	0.160	0.154	0.185	0.159	0.129	0.193	0.162	0.149	0.202	0.164	0.134	0.145	0.133
11																											
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6	0.160	0.181	0.192	0.136	0.166	0.167	0.200	0.142	0.130	0.139	0.188	0.132	0.135	0.180	0.150	0.168	0.146	0.175	0.131	0.159	0.184	0.164	0.182	0.157	0.201	0.180	0.154
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1																											
0	0.202	0.143	0.181	0.123	0.179	0.194	0.153	0.150	0.183	0.189	0.126	0.123	0.187	0.165	0.145	0.124	0.180	0.161	0.174	0.131	0.147	0.181	0.174	0.136	0.133	0.183	0.177

Tube	10			11			12			13			14			15			16			17			18		
Elevation	L	C	R	L	C	R	L	C	R	L	C	R	L	C	R	L	C	R	L	C	R	L	C	R	L	C	R
60	0.163	0.193	0.144	0.139	0.201	0.131	0.131	0.126	0.177	0.149	0.203	0.130	0.187	0.160	0.188	0.143	0.200	0.130	0.169	0.180	0.164	0.135	0.169	0.202	0.150	0.192	0.130
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48	0.202	0.167	0.189	0.154	0.141	0.178	0.172	0.201	0.161	0.188	0.203	0.181	0.181	0.134	0.147	0.127	0.141	0.128	0.136	0.183	0.172	0.190	0.146	0.133	0.201	0.132	0.141
47																											
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42	0.177	0.166	0.187	0.123	0.138	0.133	0.188	0.195	0.176	0.131	0.137	0.162	0.131	0.165	0.125	0.159	0.189	0.164	0.192	0.152	0.127	0.120	0.129	0.169	0.122	0.163	0.187
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36	0.136	0.127	0.131	0.130	0.194	0.126	0.182	0.142	0.189	0.165	0.173	0.182	0.120	0.197	0.162	0.169	0.152	0.197	0.189	0.201	0.145	0.173	0.131	0.153	0.189	0.188	0.173
35																											
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30	0.175	0.152	0.160	0.176	0.156	0.156	0.139	0.198	0.161	0.144	0.127	0.182	0.165	0.177	0.198	0.162	0.186	0.164	0.142	0.184	0.164	0.130	0.124	0.159	0.168	0.163	0.183
29																											
28																											
27																											
26																											
25																											
24	0.172	0.146	0.123	0.202	0.121	0.145	0.176	0.122	0.148	0.169	0.201	0.201	0.124	0.136	0.156	0.159	0.128	0.128	0.173	0.155	0.138	0.173	0.199	0.197	0.179	0.186	0.191
23																											
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18	0.161	0.164	0.130	0.157	0.173	0.123	0.160	0.183	0.126	0.193	0.152	0.172	0.180	0.178	0.178	0.199	0.136	0.200	0.163	0.147	0.193	0.139	0.183	0.156	0.159	0.128	0.135
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12	0.191	0.191	0.179	0.203	0.143	0.199	0.189	0.140	0.129	0.126	0.187	0.150	0.168	0.168	0.179	0.182	0.142	0.142	0.124	0.148	0.169	0.188	0.131	0.127	0.163	0.190	0.158
11																											
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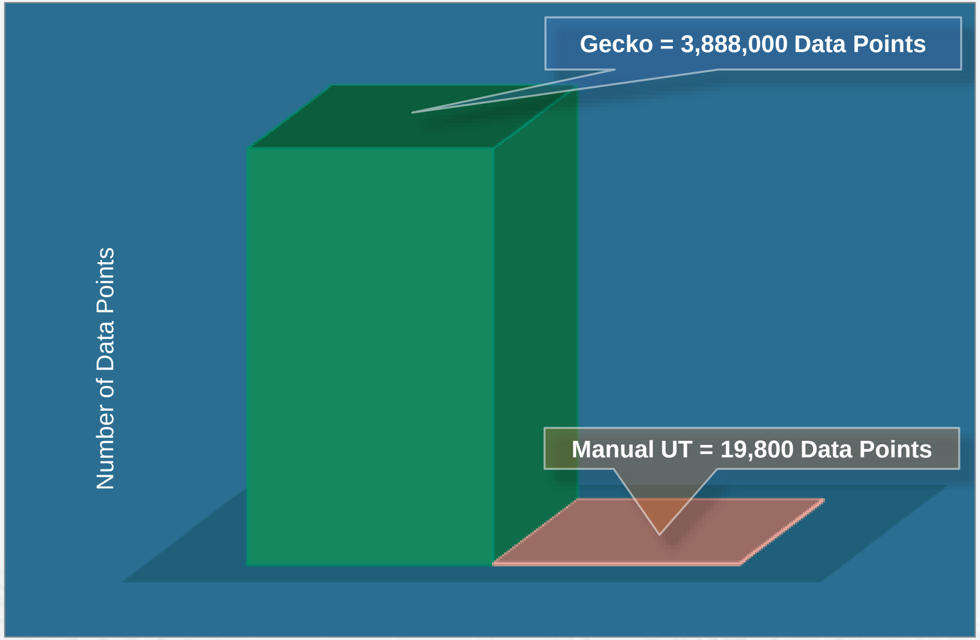
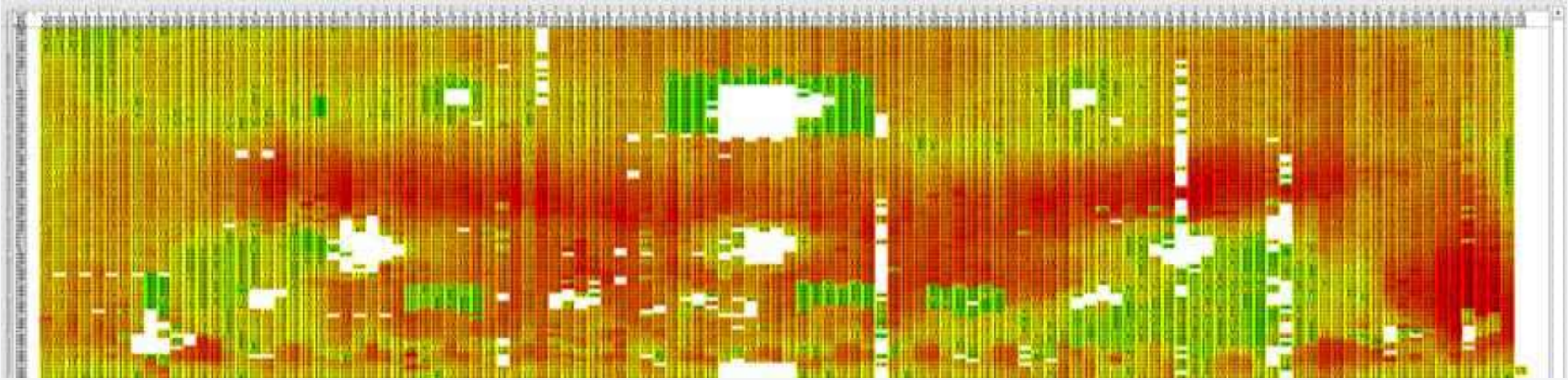
6	0.139	0.143	0.133	0.171	0.170	0.159	0.122	0.163	0.187	0.134	0.130	0.123	0.138	0.141	0.126	0.146	0.197	0.193	0.194	0.186	0.145	0.158	0.198	0.124	0.141	0.160	0.186
5																											
4																											
3																											
2																											
1																											
0	0.199	0.163	0.188	0.122	0.161	0.136	0.203	0.202	0.132	0.166	0.171	0.126	0.143	0.158	0.126	0.181	0.154	0.163	0.201	0.152	0.188	0.165	0.172	0.123	0.137	0.122	0.179

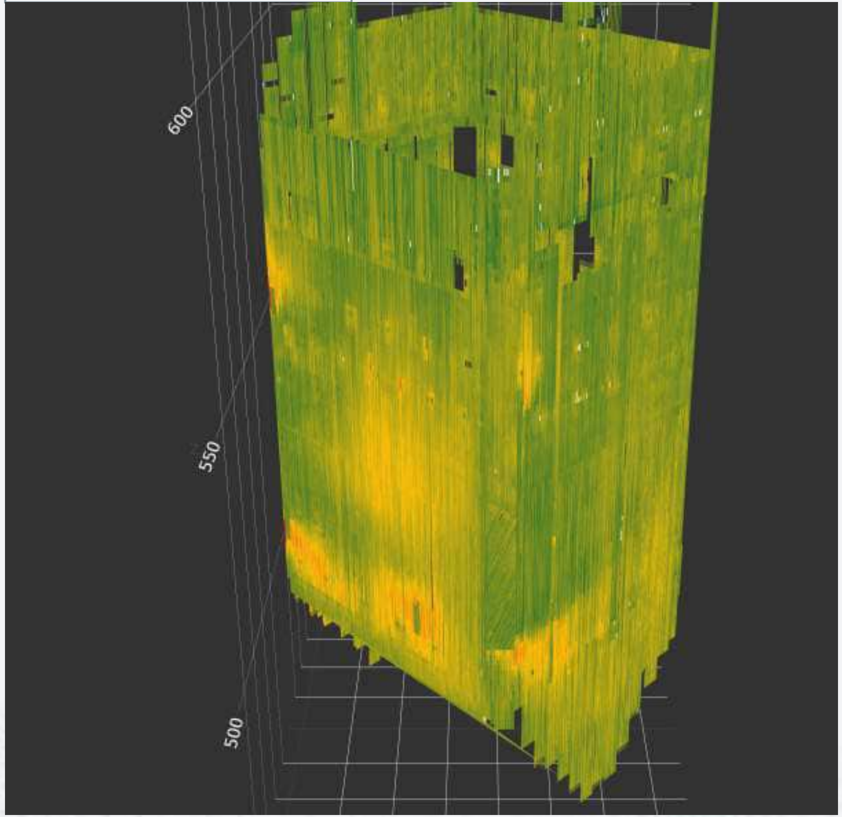
Failures Happen Where We Don't Look



RUG is 200 times more likely to find localized thinning.

Data Analysis

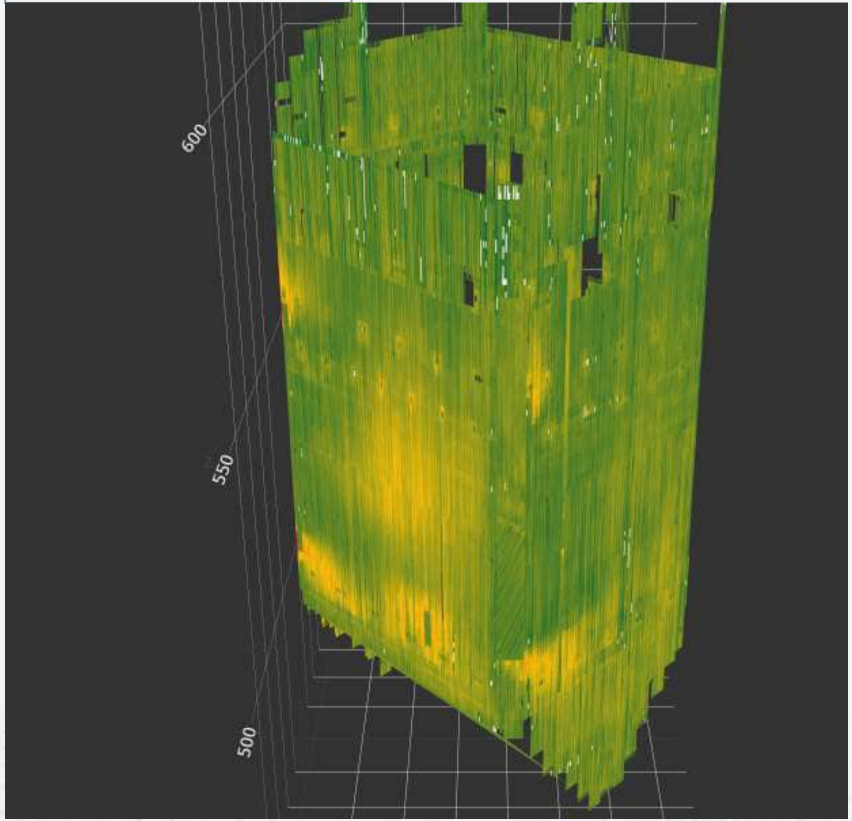




3D View of a utility boiler RUG Scan. Total Elevation of Scan = 140 feet. Grid sized one per tube in twelve-inch-tall data bins. For the example above, each data bin contains about 120 validated readings (40 per path).

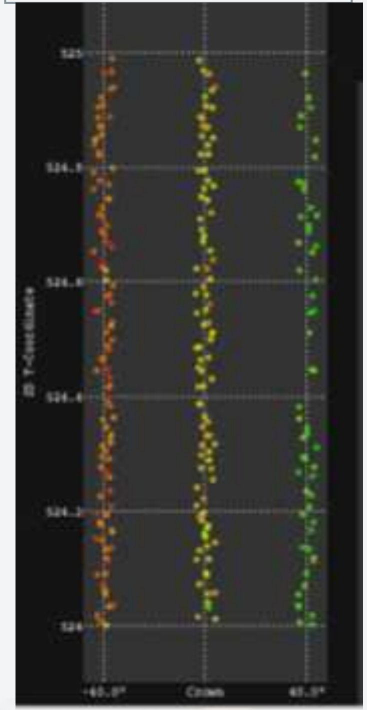
The value shown for this view is the minimum reading.

Data Analysis

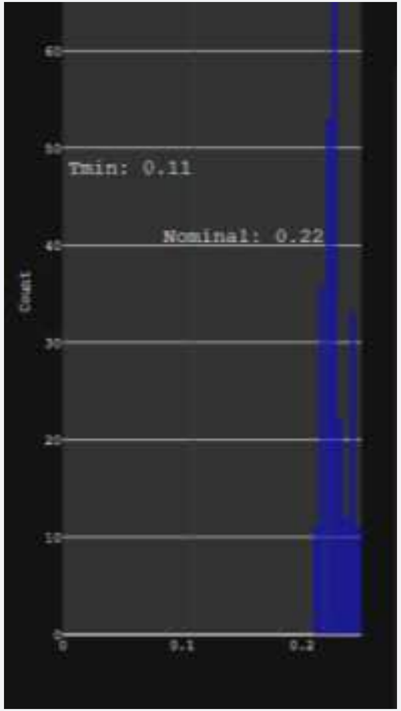


The value shown for this view is the average of the 30 lowest readings.

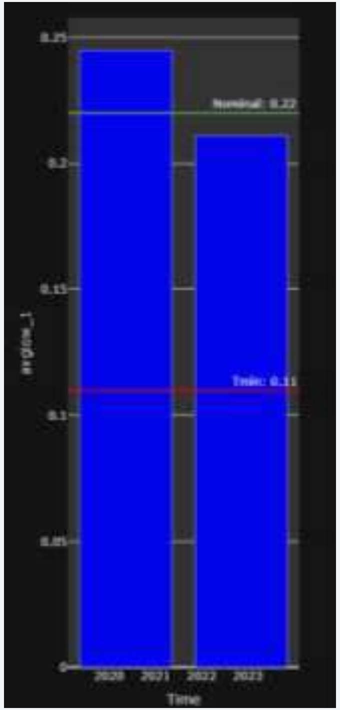
Data Analysis



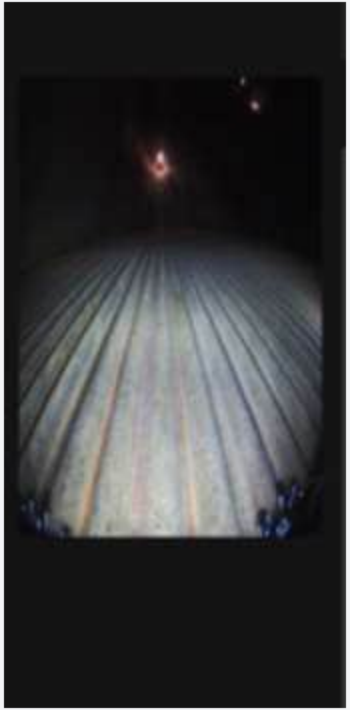
Scatterplot



Histogram

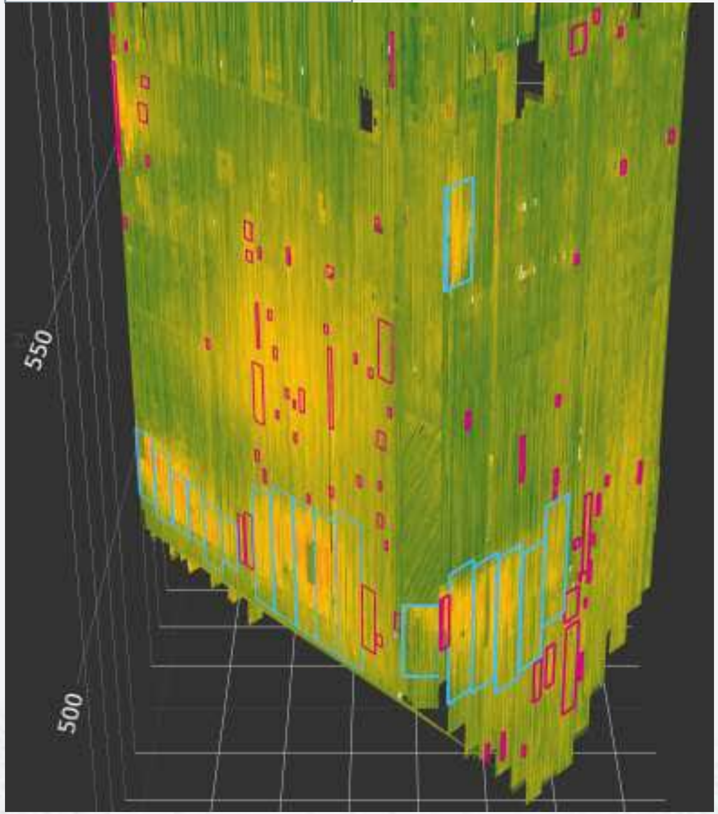


Loss Rate



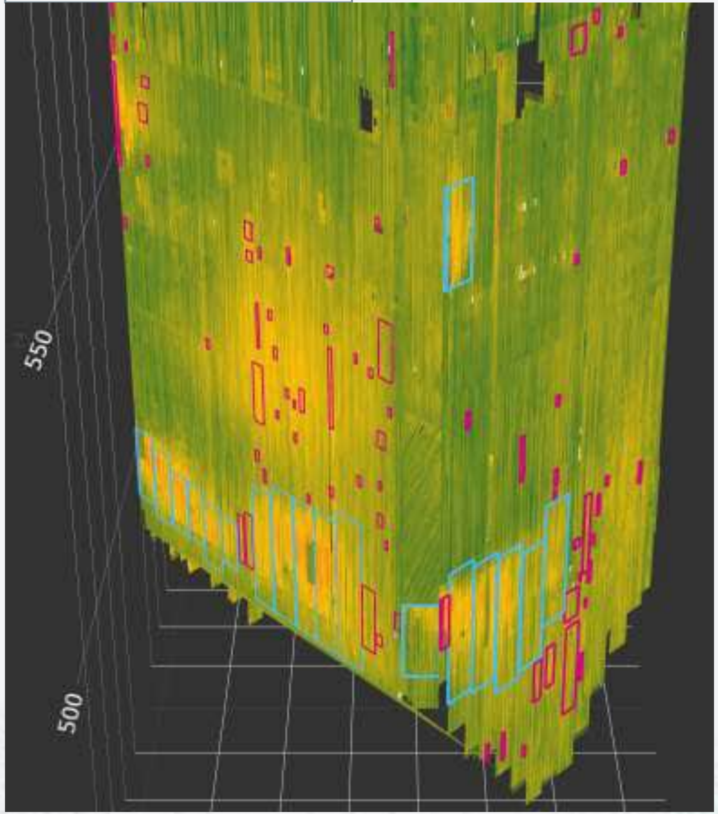
Photograph

Data Analysis



Gecko software recommends new panels in blue boxes and weld overlay repairs in red boxes, based on Gecko data and user defined parameters (repair methods, relative cost of repair methods, expected failure date based on measured thickness and local wastage rate, etc.)

Data Analysis



Optimized Planning:

- Maximize Resources (Owner and Consulting Engineering, Supplier Capacity, Etc.)
- Consistent Process Fleet Wide
- Integrate Multiple Data Layers From Same or Similar Units
- Retain Subject Expertise
- Rapid Adaptation to Future Paradigms and Knowledge
- Faster Decision Making
- Accelerated Value Capture

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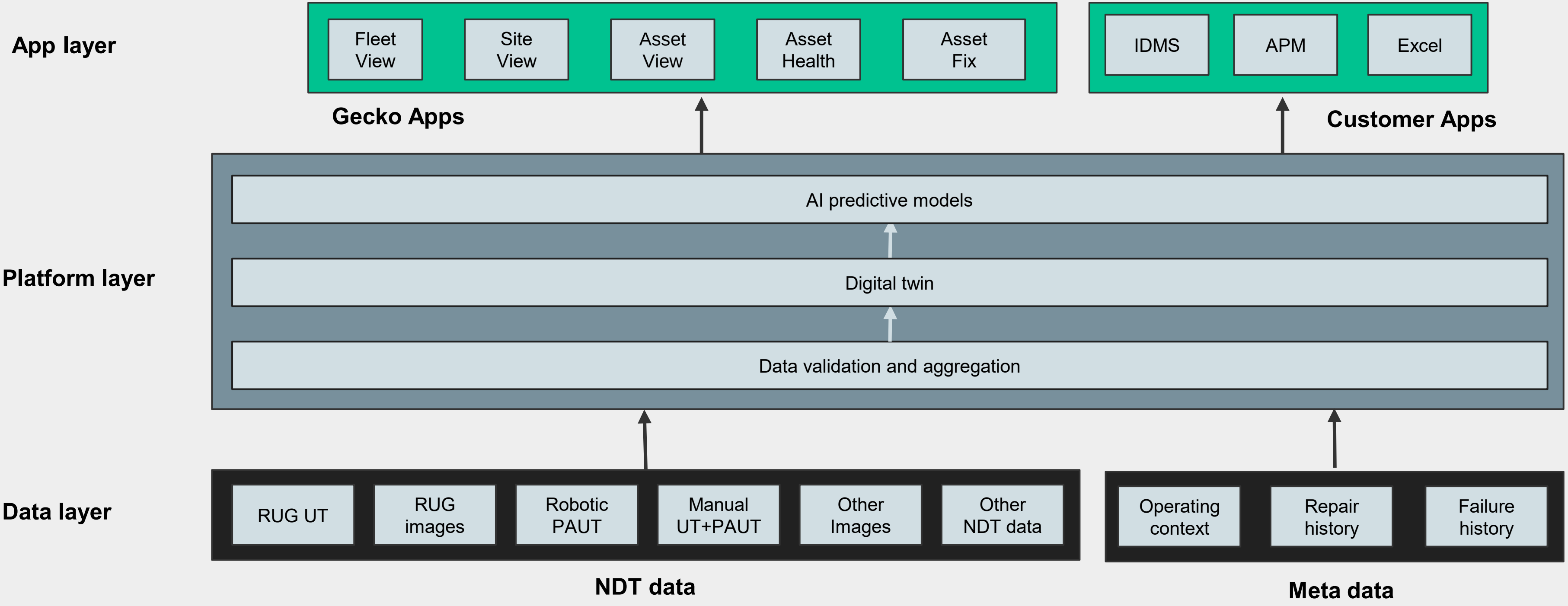
The Gecko Advantage

AI for the Built World



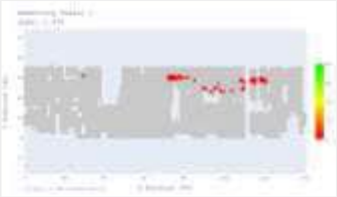
The Gecko Advantage

The Gecko Advantage

Increase production, decrease CapEx, increase safety, and lower environmental risk

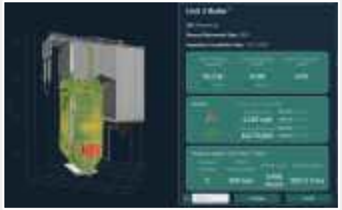
Asset Health Data

Unearth opportunities by seeing what has been invisible



Future Risk Assessment

Reliably forecast asset life and potential hot spots



Repair Planning

Model and automate different repair plans and their predicted outcomes

Stack Rank Prioritization

Easy-to-interpret dashboard to compare and prioritize decisions, for precision maintenance and capital

Expose hidden opportunities

Act on the best opportunities

The Gecko Advantage

Optimal Decision Making (Collect & Share Data Fast)

Minimum Outage Time (Define & Prioritize Risk)

Optimized Supply Chain (Allocate Resources)

Accelerated Value Capture

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Recovery Boiler and Dissolving Tank Training Simulators

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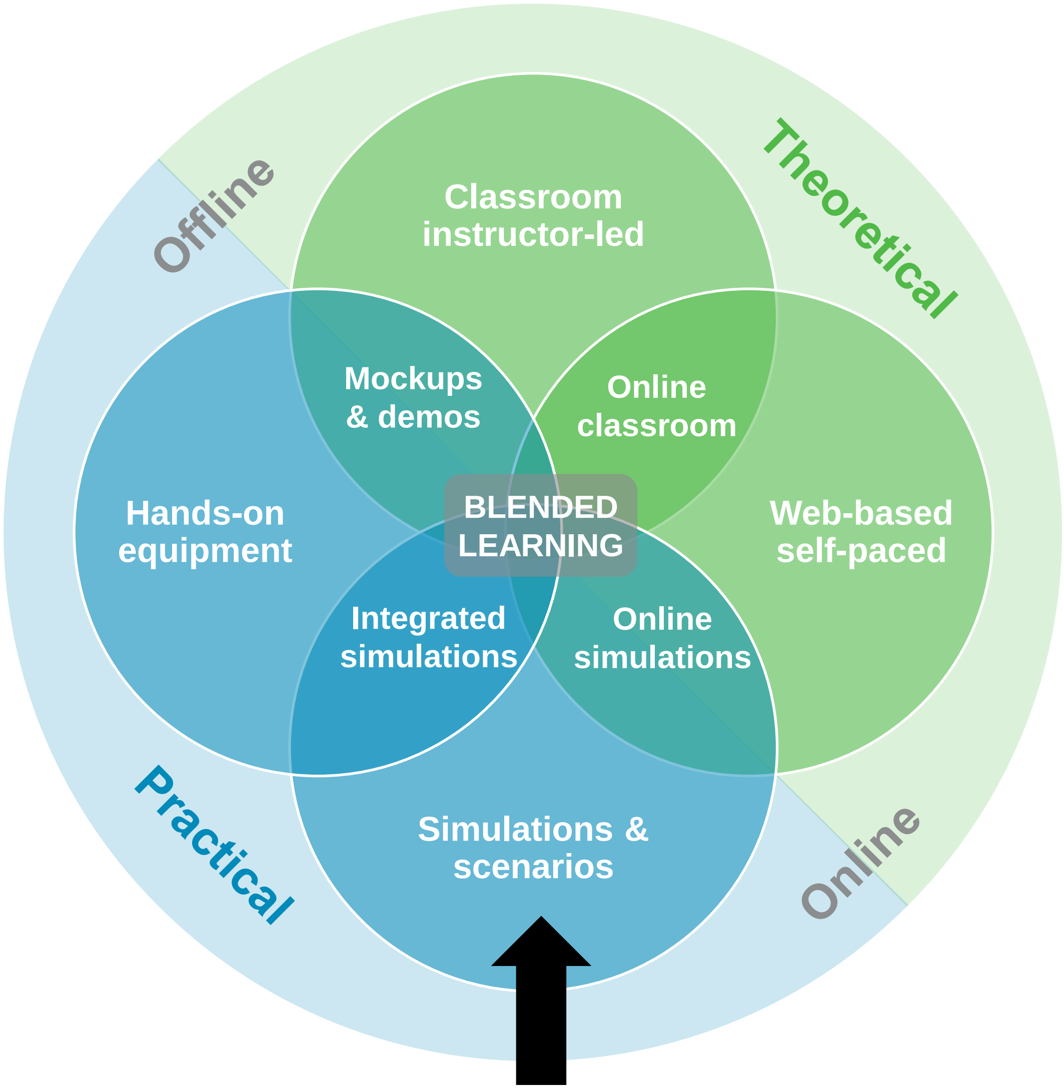
tel: +17044143501
dave.gadai@valmet.com

Johan Östberg
tel: +46 31 50 13 92
johan.ostberg@valmet.com

Learning methodology

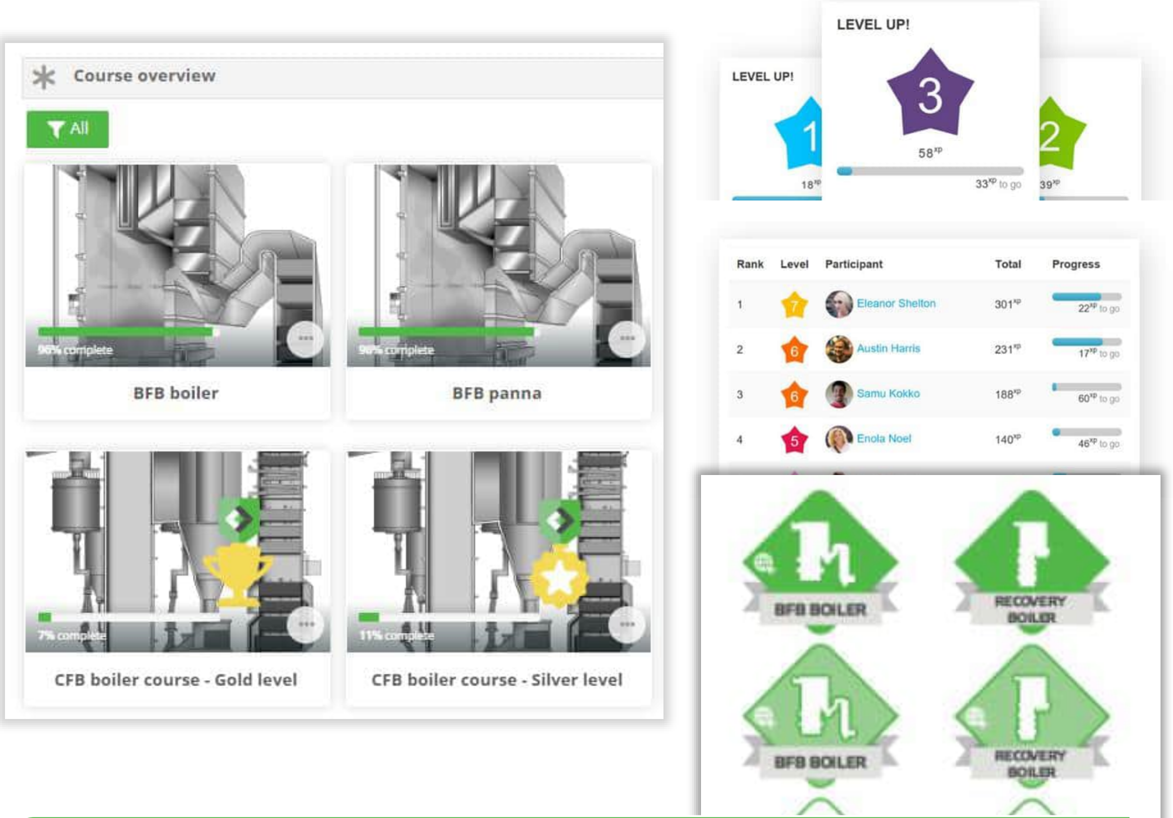
Blended learning approach for Employees

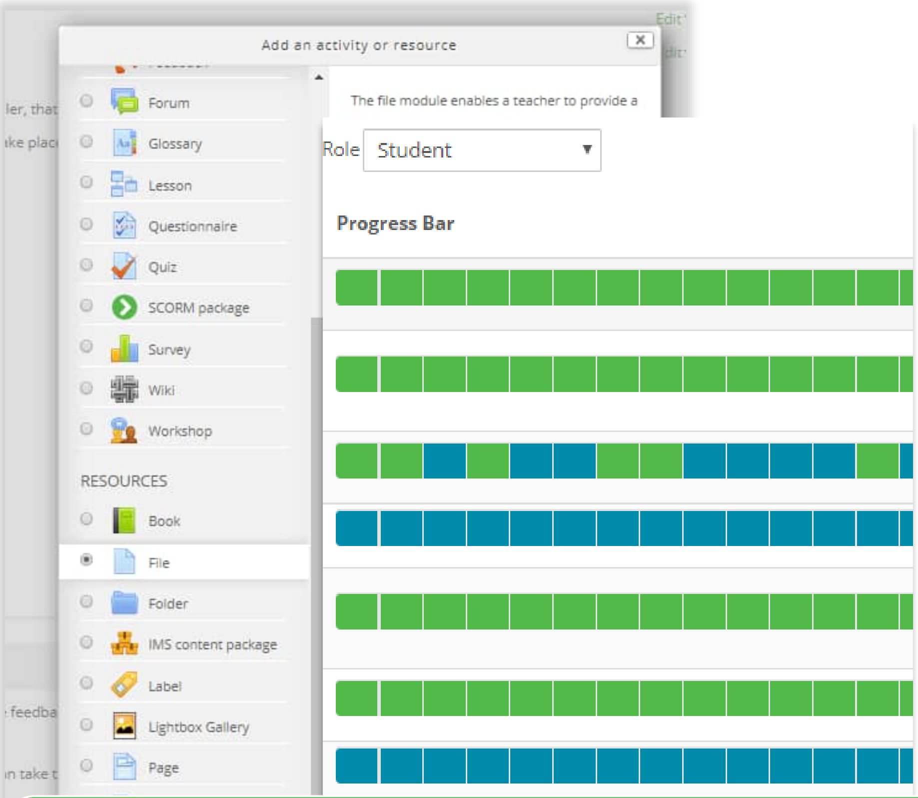


Valmet

Valmet Online Learning

24h access & No installation





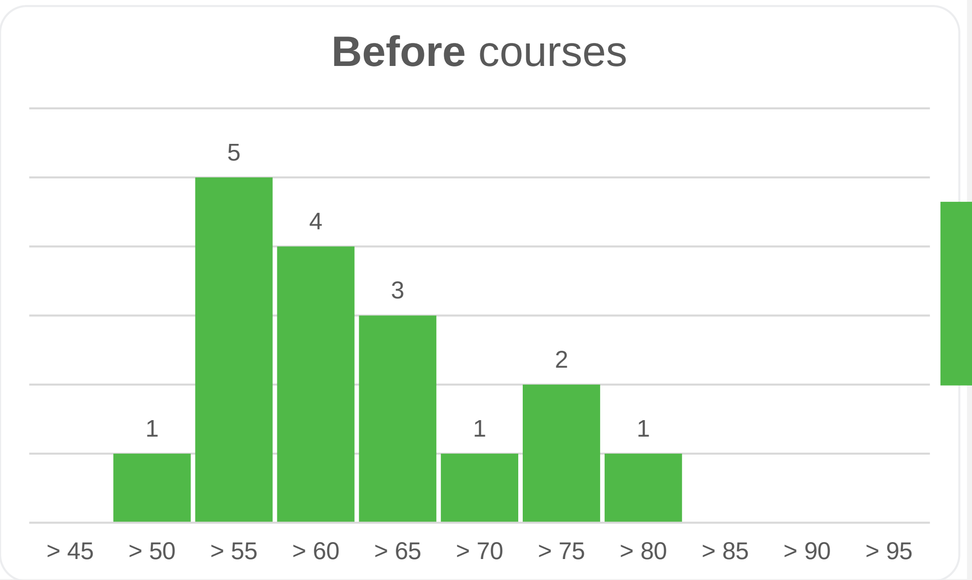
Student role:
Student dashboard
Courses & Quizzes, Badges

Manager role:
Tools for reporting and creation of content

Results in comparison Quiz 1 & Quiz 2

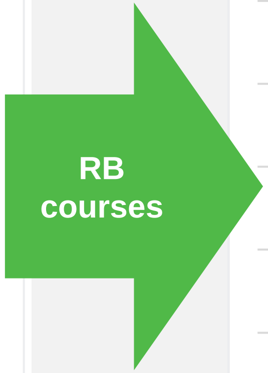
Pulp mill All groups

Correct answers 63% average



The results range from 50-85% correct answers

17 Participants

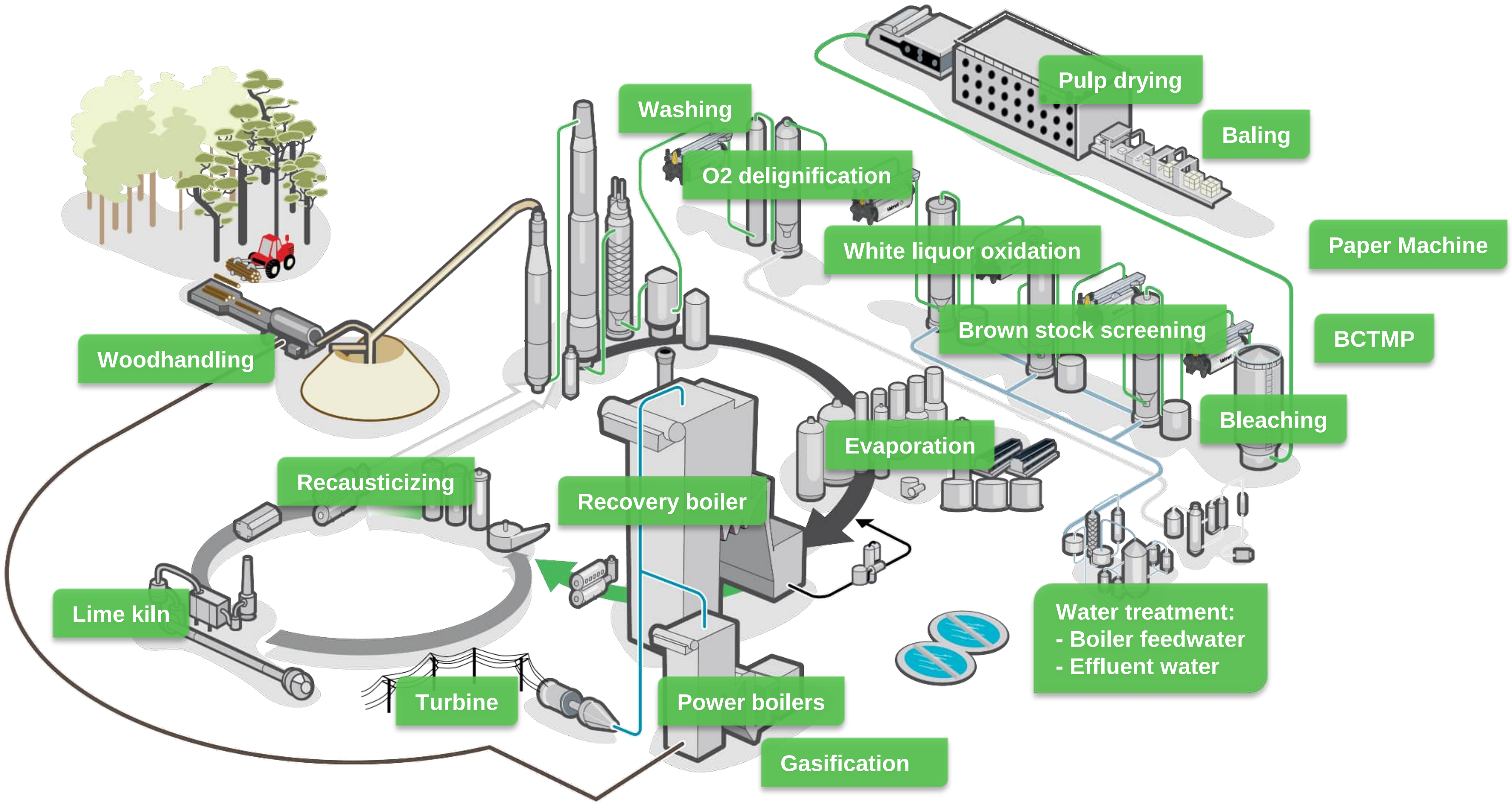


Correct answers increased to 83% average

The results range from 70-95% correct answers

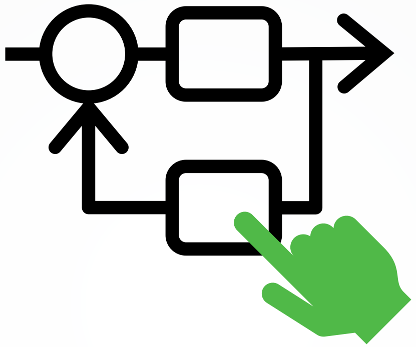
7 Participants

Valmet Simulators and Process Control



Why

New personnel



New control system

New process

Types of Training Simulators

Tailored and Reference

	Tailored	Reference
Process models Calculations, equations describing the process	Valmet process model library (common for all simulators)	
Plant design Flowsheets, process descriptions etc	Customer's plant	Valmet reference plant (RB.CFB,BFB)
Logic Controls & interlocks	Copy of DCS logics	Standard logics build in simulator
Interface Displays, face plates, trends, alarm lists etc	Copy of DCS displays	Standard interface
	DCS coupled	Reference

Reference Training Simulator

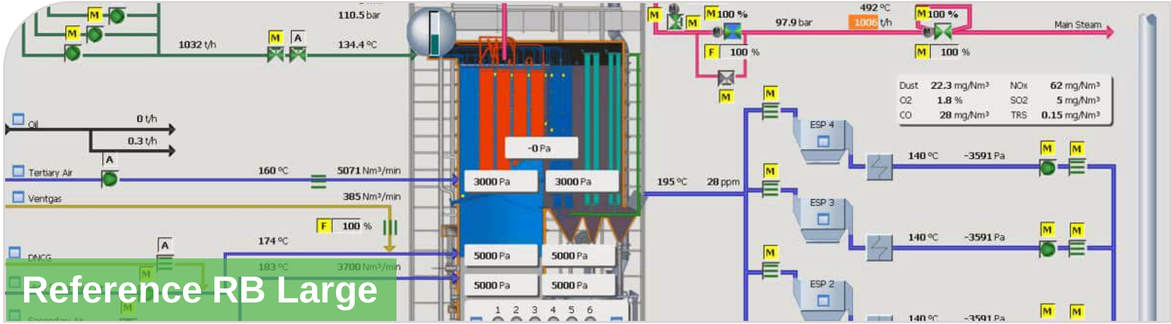
Practical training with built-in exercises

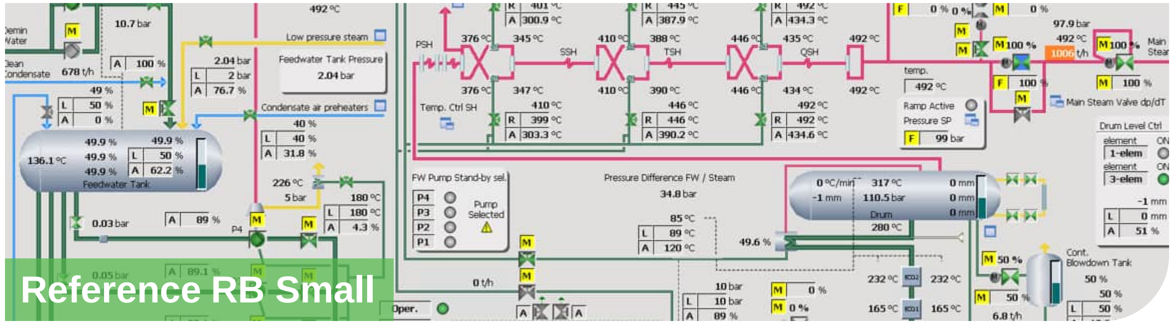
- Based and built according to a **Typical plant** in boiler design and operating modes – with Valmet DNA interface
- Realistic behavior and simulation exercises matching those of a characteristic Recovery boiler
- **On-site training** with Valmet Expert, explaining the process and operation and use the reference simulator as a dynamic training tool
- Rehearse safety & emergency events, start-up & shut-down procedures

It was very interesting to see how simulation can help you learn a lot in such a short time.

Valmet Reference Training Simulators

Now available in the cloud





Reference RB Large

- Furnace MCR: 14 770 000 lb DS/day
- Steam: 2 270 000 lb/h (2770 kpph)
- Steam pressure: 1420 psi(g)
- Steam temperature: 910 °F
- 12 start burners
- 3 load burners
- CNCG Burner

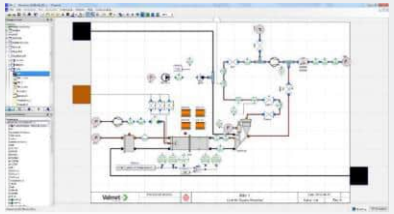
Reference RB Small

- Furnace MCR: 5 071 000 lb DS/day
- Steam: 850 000 lb/h (850 kpph)
- Steam pressure: 1420 psi(g)
- Steam temperature: 910 °F
- 6 start burners
- CNCG Burner

Main usage of Valmet Training Simulator, tailored

Available for all DCS systems

1.



Verification of process design with simulator

- Real design data from project
- Process balances verified

2.

Complete testing in FAT

- DCS – Simulator test, after FAT
- >200 errors and improvements normally found in FAT
- PID loop tuning

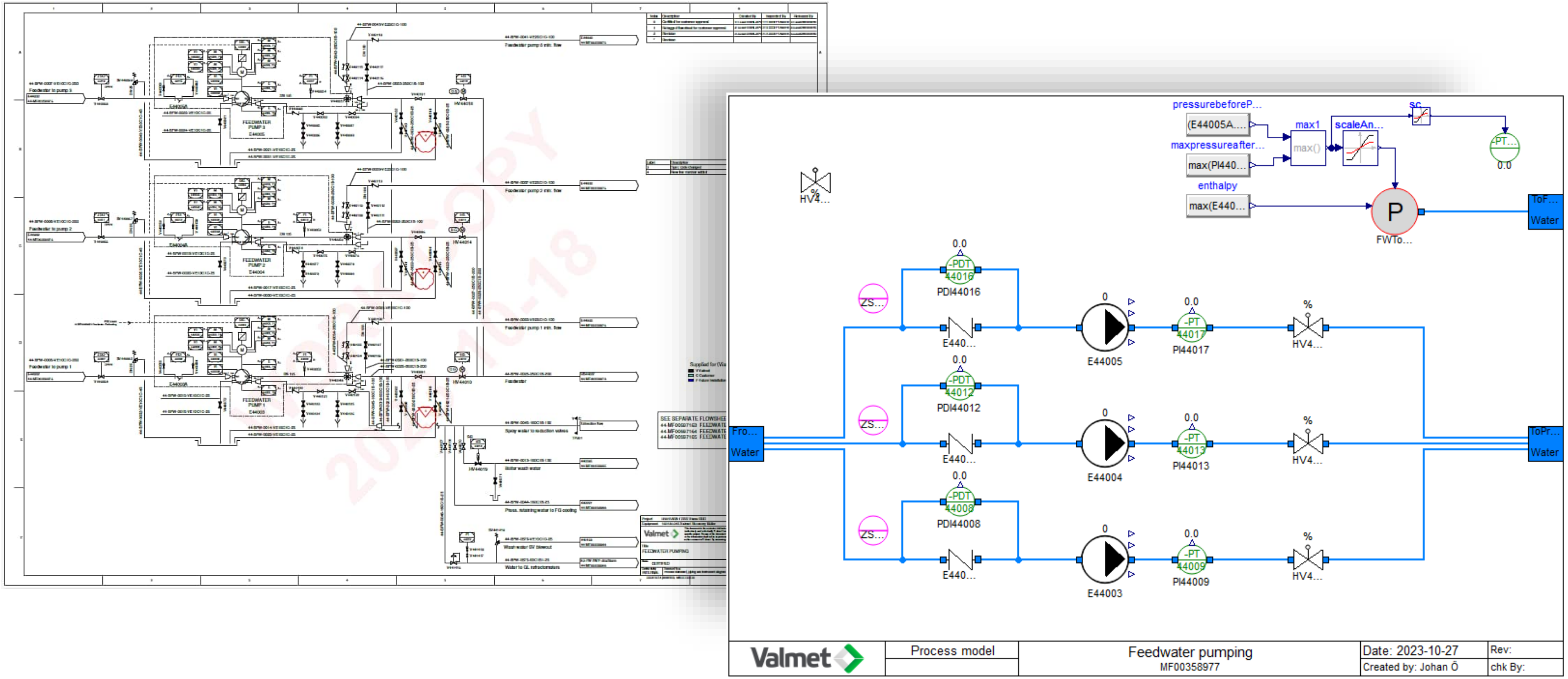
3.

Simulator training

- Fully dynamic process simulations
- A copy of the “real” DCS
- Customized
- Excercises to practice difficult process situations

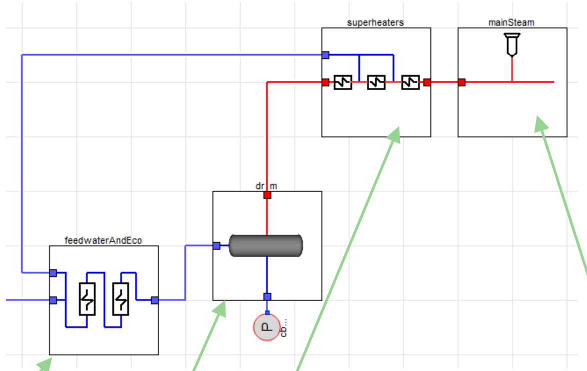
Modelling principles and examples

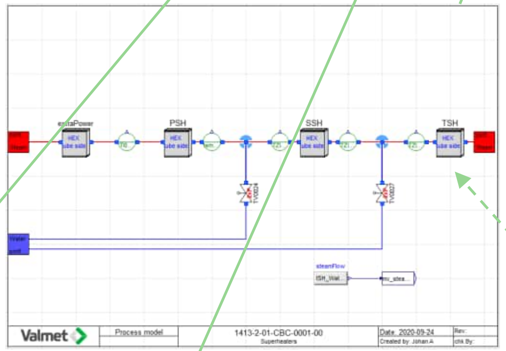
– Dynamic process models are created as in the P&ID

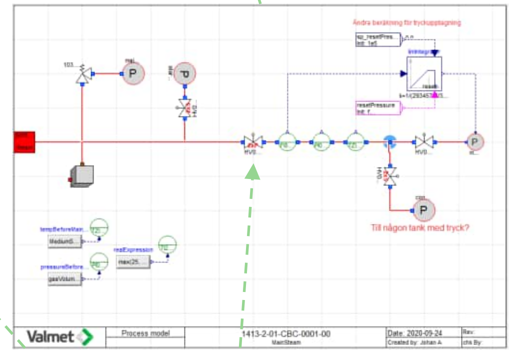


Modelling principles and examples

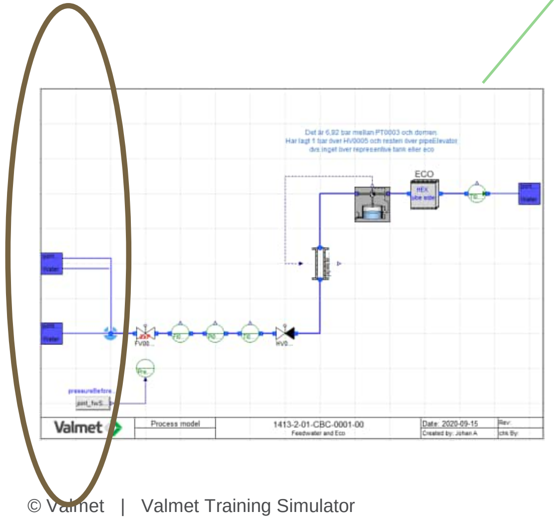
How modules are connected

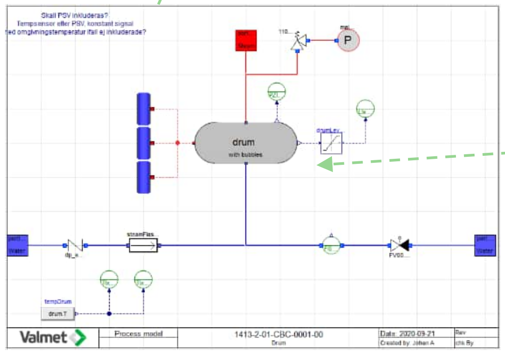






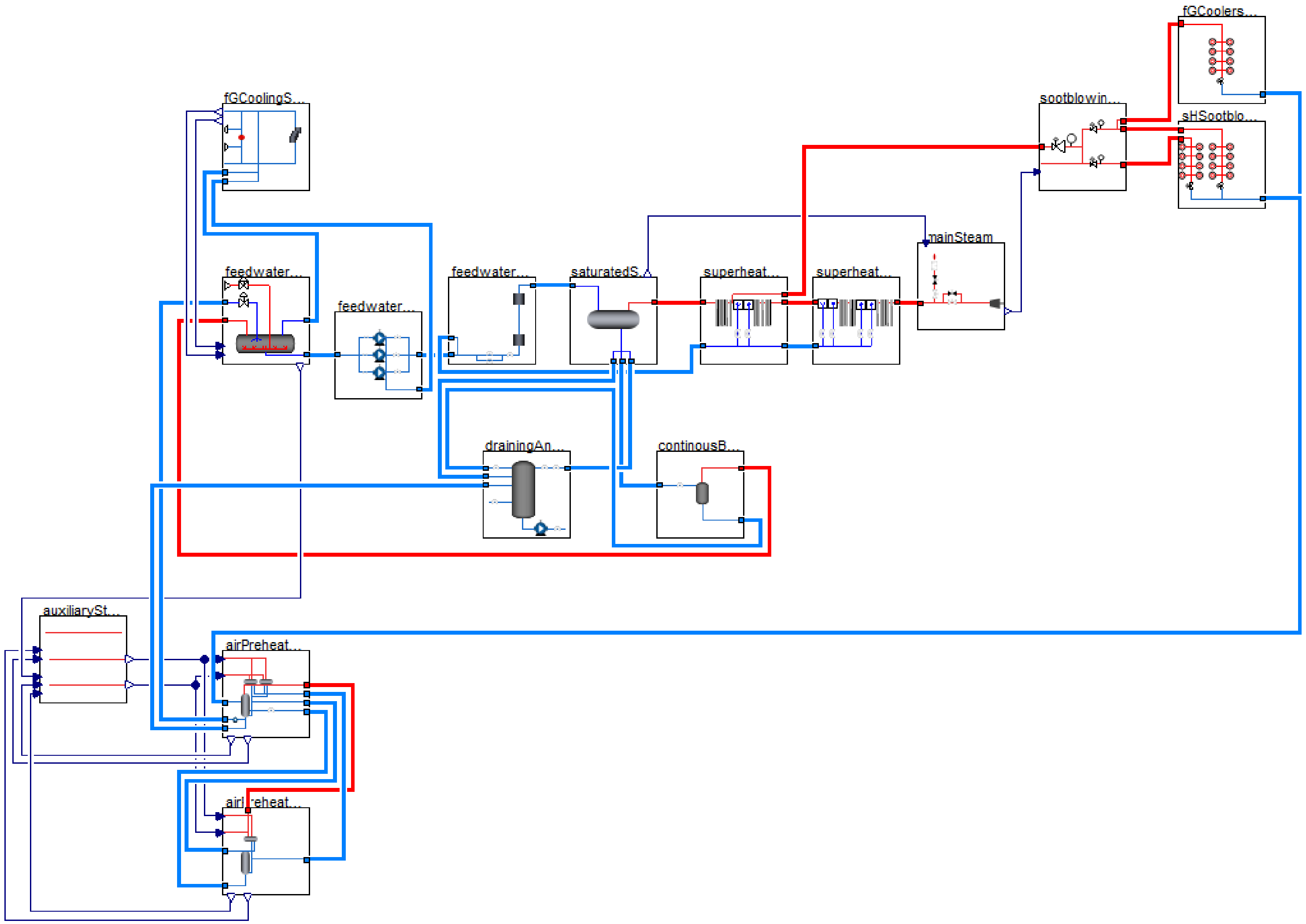
Connectors to/from other modules



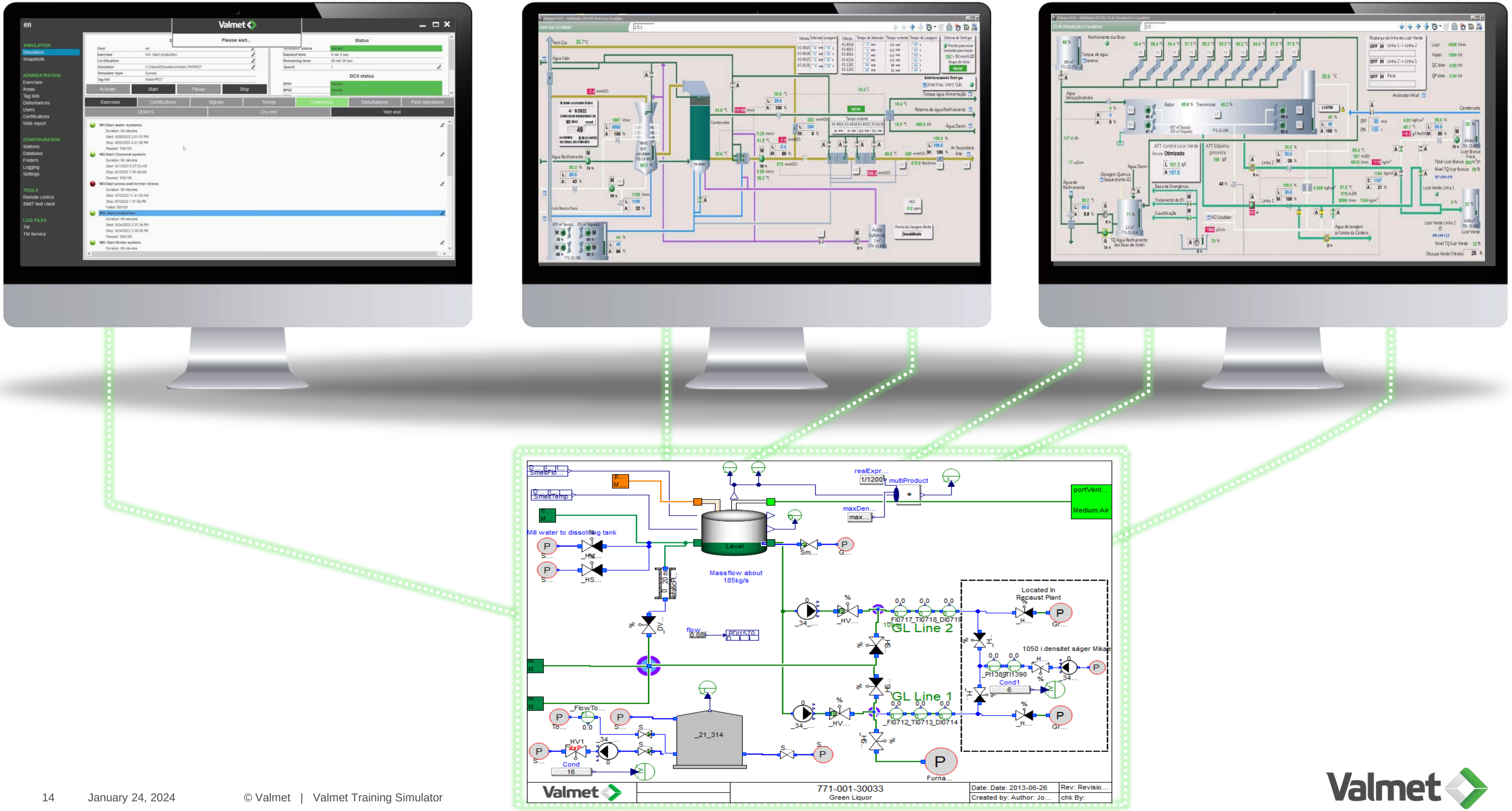


Models for drum, superheaters, valves, sensors etc.

Complete model water and steam



  | Valmet Training Simulator


Mill water to dissolving tank
Massflow about 185kg/s
realExpr...
multiProduct
maxDen...
portVent...
Medium:Air
GL Line 2
GL Line 1
Located In Recaust Plant
1050 i densitet säger Mika
771-001-30033
Green Liquor
Date: Date: 2013-06-26
Created by: Author: Jo...
Rev: Revisio...
chk By:

Valmet Training Simulators

Training based on scenarios and disturbances

Standard scenarios

- Preparations for boiler start-up
- Furnace purge and ignition
- Boiler pressure increase
- Prepare for black liquor firing
- Start black liquor firing, DNCG firing, sootblowing
- Increase load
- Auxilliary firing, CNCG, methanol, switching between fuels.
- Normal shutdown
- Green liquor line switch over
- Rapid drain
- Tertiary air fan trip
- Feedwater pump trip and pump change over

Example of disturbances

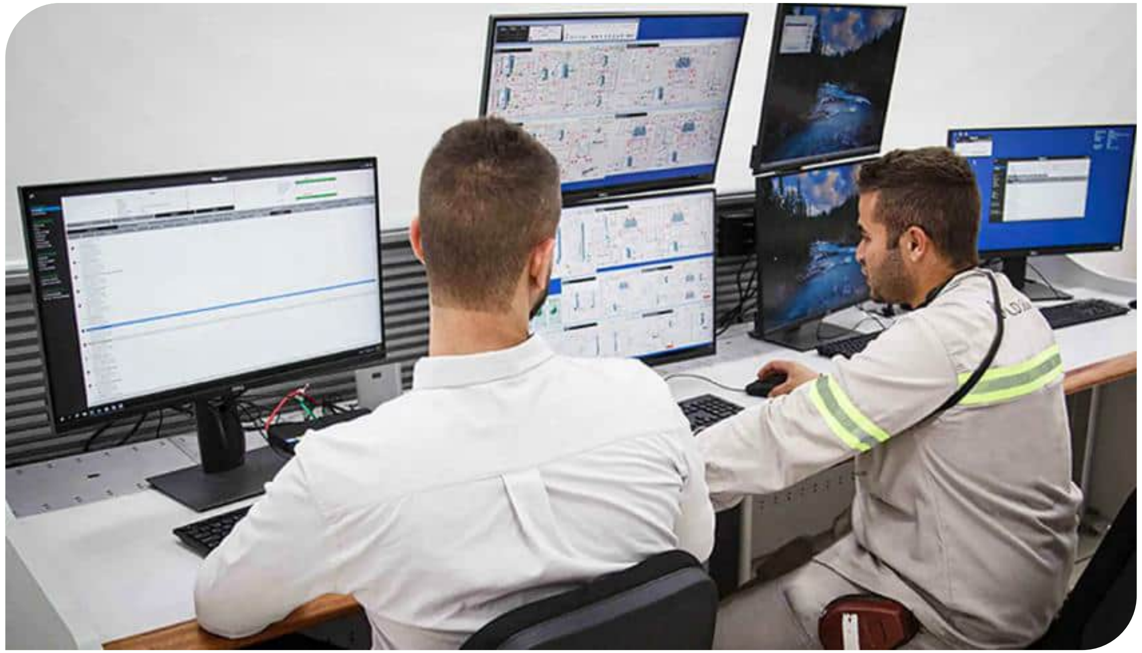
- Pump malfunction
- Wall leaks
- Induced draft fan failure
- Electrical black out
- Low/High furnace pressure
- Total loss of black liquor supply to furnace
- Low liquor solids
- High dissolving tank density, high temperature or low tank level, agitator malfunction

Demostration of Simulator

Valmet

Simulator training

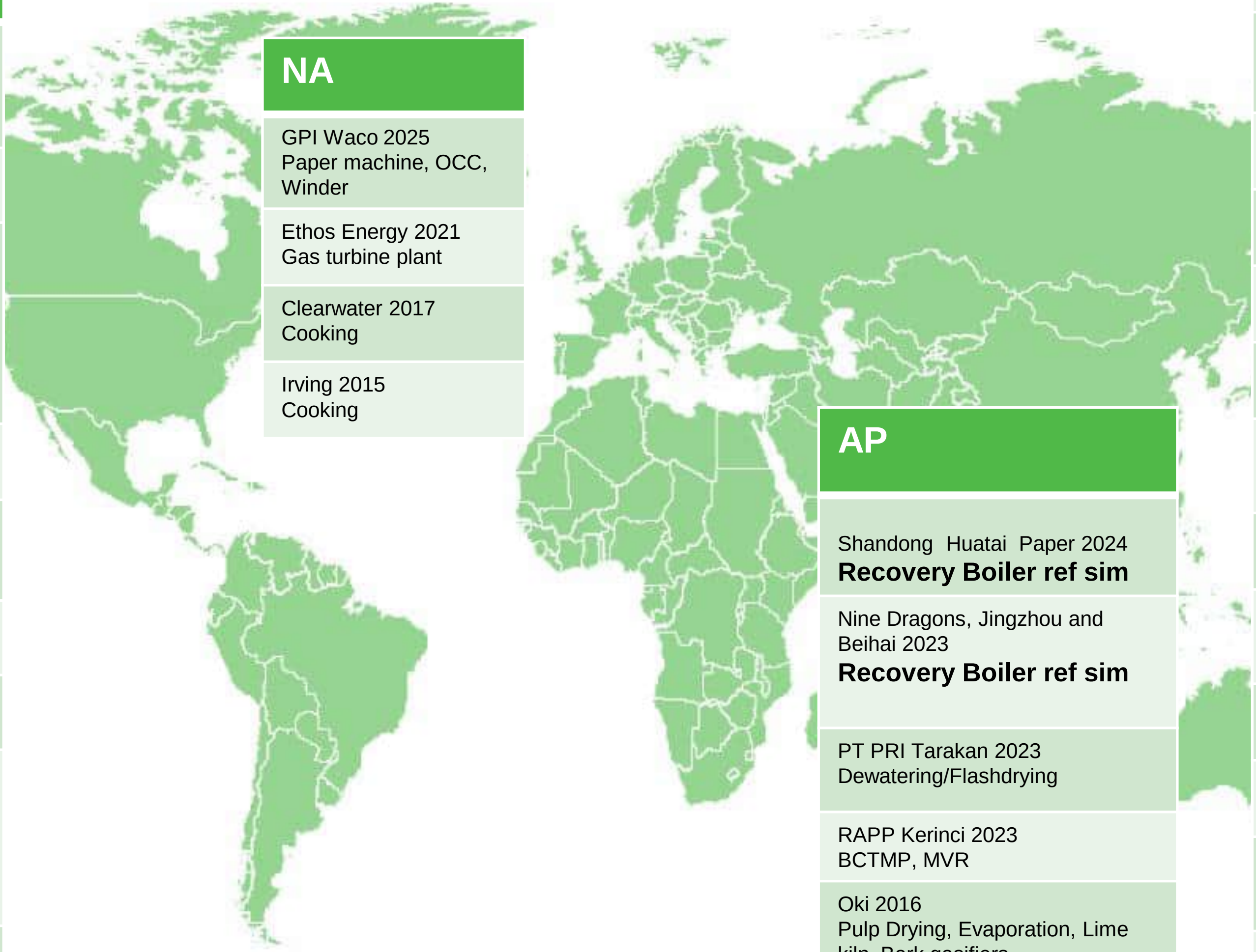
LDC Amadeus, Brazil



SCA Östrand, Sweden

Recent references

Valmet Simulators used in DCS testing and training



SA

CMPC Guaiba 2023
Recovery boiler,
Cooking, Fiberline, Pulp drying, WLP, Evaporation

Klabin Puma 2022
Paper machine, Cooking, Fiberline

Amadeus 2021
Recovery boiler,
Cooking, Fiberline, Pulp drying, White liquor plant, Evaporation, Power boiler, Boiler feed water, raw water, effluent treatment, Ozone, TG, Wood handling

Klabin Puma 2021
Paper machine, Cooking, Fiberline

Arauco Mapa 2020
Recovery boiler,
Pulp drying, Baling, Power boiler

Arauco Valdivia 2019
Batch cooking

CMPC Laja 2017
Recausticizing, Lime kiln

CMPC Guaiba 2015
Recovery boiler,
Cooking, Fiberline, Pulp drying, White liquor plant, Evaporation, Power boiler, Boiler feed water, ClO_2 plant, Effluent treatment

Suzano Maranhao 2013
Recovery boiler,
Cooking, Fiberline, Pulp drying, Baling, White liquor plant, Evaporation, Power boiler, Turbine, Boiler feed water

NA

GPI Waco 2025
Paper machine, OCC, Winder

Ethos Energy 2021
Gas turbine plant

Clearwater 2017
Cooking

Irving 2015
Cooking

AP

Shandong Huatai Paper 2024
Recovery Boiler ref sim

Nine Dragons, Jingzhou and Beihai 2023
Recovery Boiler ref sim

PT PRI Tarakan 2023
Dewatering/Flashdrying

RAPP Kerinci 2023
BCTMP, MVR

Oki 2016
Pulp Drying, Evaporation, Lime kiln, Bark gasifiers

EMEA

DS Smith Viana 2024
Recovery boiler

Södra Cell Mörrum 2024
Batch Cooking

Metsä Fiber Kemi 2023
Recovery boiler,
Drying, Cooking, Fiberline,

Otrviken 2022
CTMP

Naistenlahti 2022
Power plant

Södra Cell Mörrum 2022
Recovery boiler

C-Green 2021
HTC

Rosenthal 2020
Recovery boiler

Bratsk 2019
Evaporation

Kilpilahti 2019
3 Power boilers, Turbine, BOP

Naantali 2018
Power boiler, Turbine, BOP

SE Enocell 2019
Batch cooking

SK Piteå 2018
Cooking

SCA Obbola 2015
Cooking

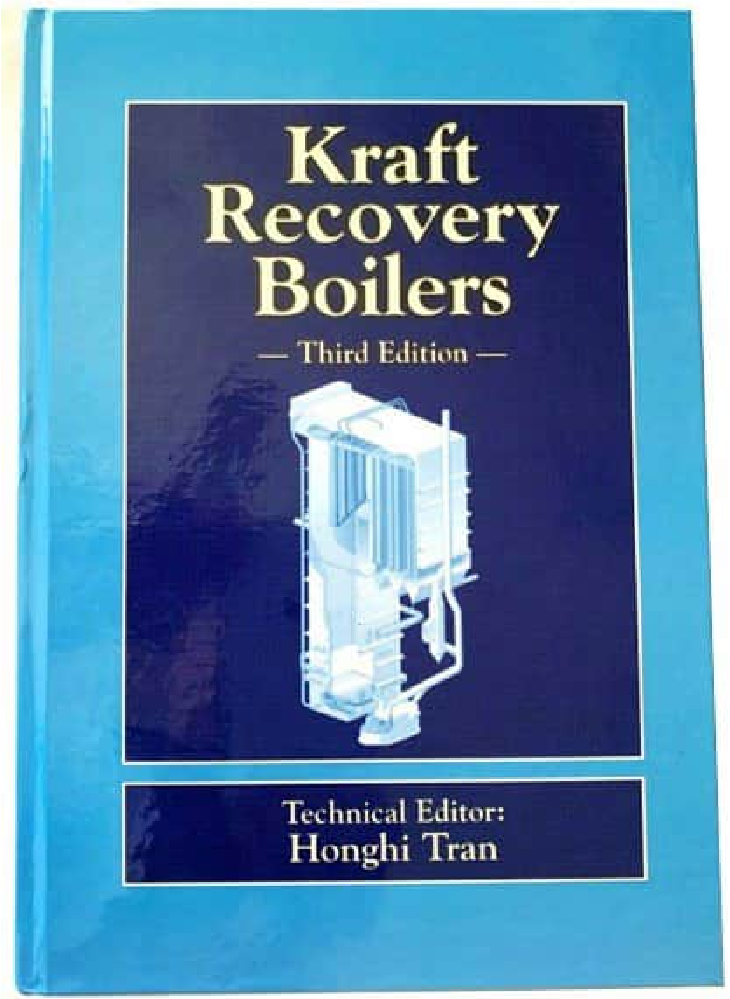
SCA Östrand 2017
Cooking, Fiberline, Evaporation

Recovery Boiler Char Bed Chemistry and Control Strategies

Honghi Tran
University of Toronto
Toronto, ON, CANADA

AF&PA Recovery Boiler Program Annual Meeting and Conference
Atlanta, GA, February 7, 2024

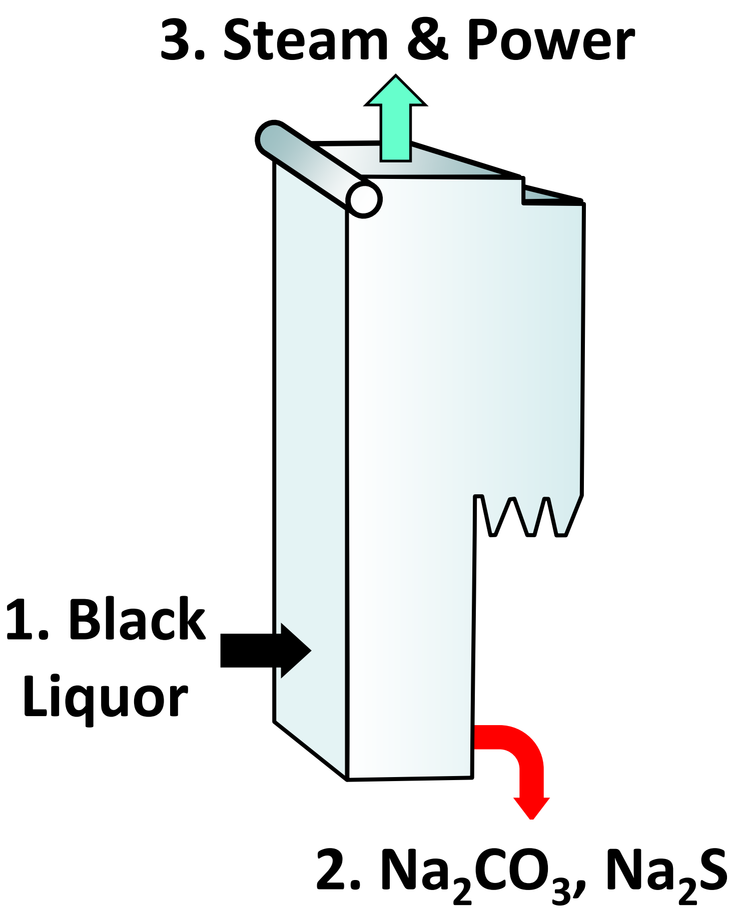
Reference – "Kraft Recovery Boilers" Book



- Chapter 2 – Recovery Boiler Chemistry
- Chapter 5 – Black Liquor Burning Processes
- Chapter 6 – Char Bed Processes

Recovery Boiler's Three Main Functions

1. To process black liquor safely through combustion
2. To recover pulping chemicals as Na_2CO_3 and Na_2S from Na and S in the black liquor
3. To generate steam and power from the heat of combustion

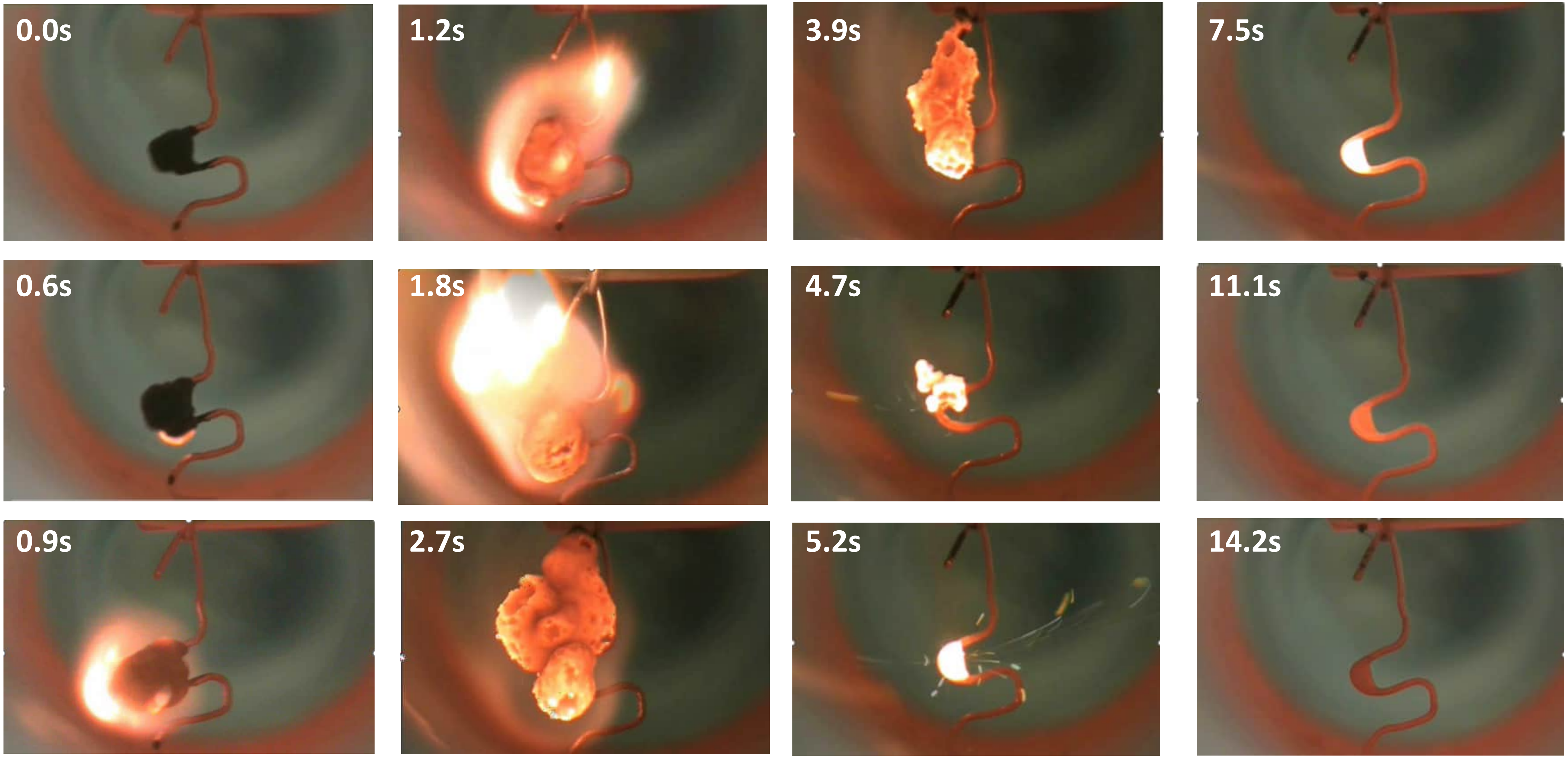


This presentation focuses on how Na_2CO_3 and Na_2S can be effectively regenerated in the recovery boiler

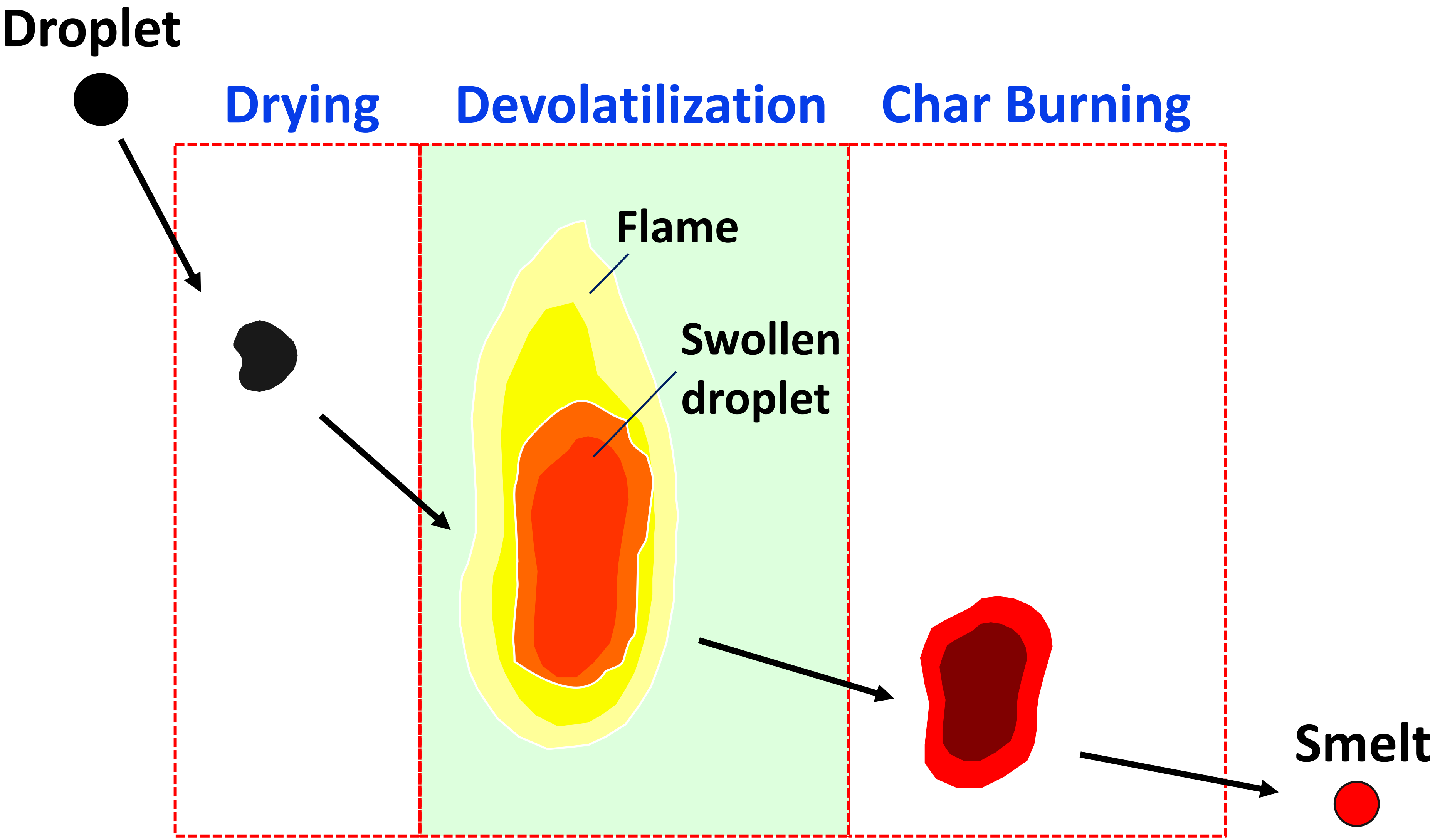
Presentation Outline

- Black Liquor Droplet Burning and Lower Furnace Operations
- Char Bed Chemistry
- Char Bed Dynamics
- Sulfate-Sulfide Cycle and Implications for Bed Control Strategies
- Summary

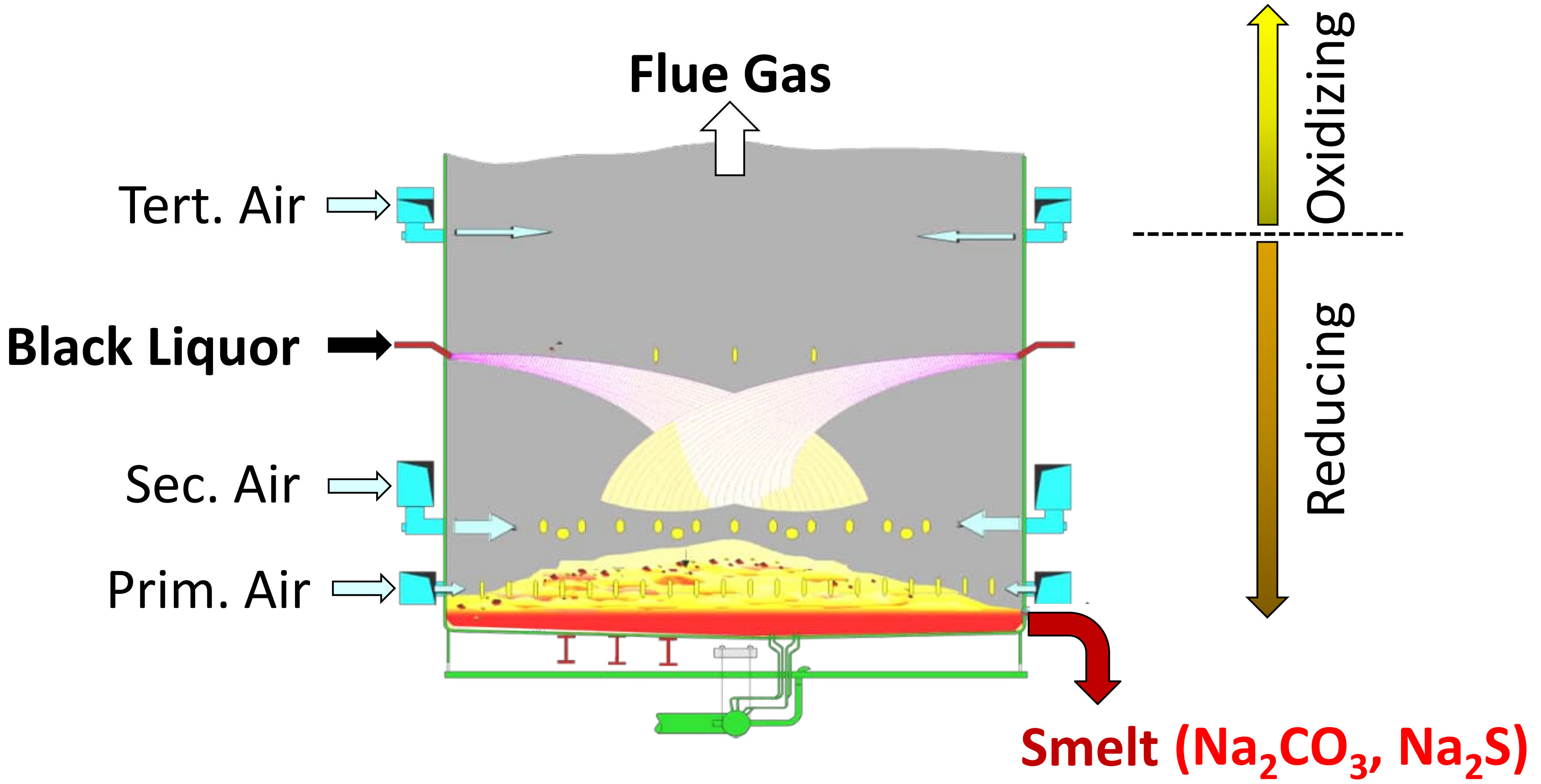
Burning Droplet of Black Liquor (800ºC, air)



Black Liquor Burning Stages



RB Lower Furnace Operation



- Na_2CO_3 forms <u>READILY</u> during black liquor combustion, while Na_2S can form <u>ONLY</u> under a strong reducing condition.

Presentation Outline

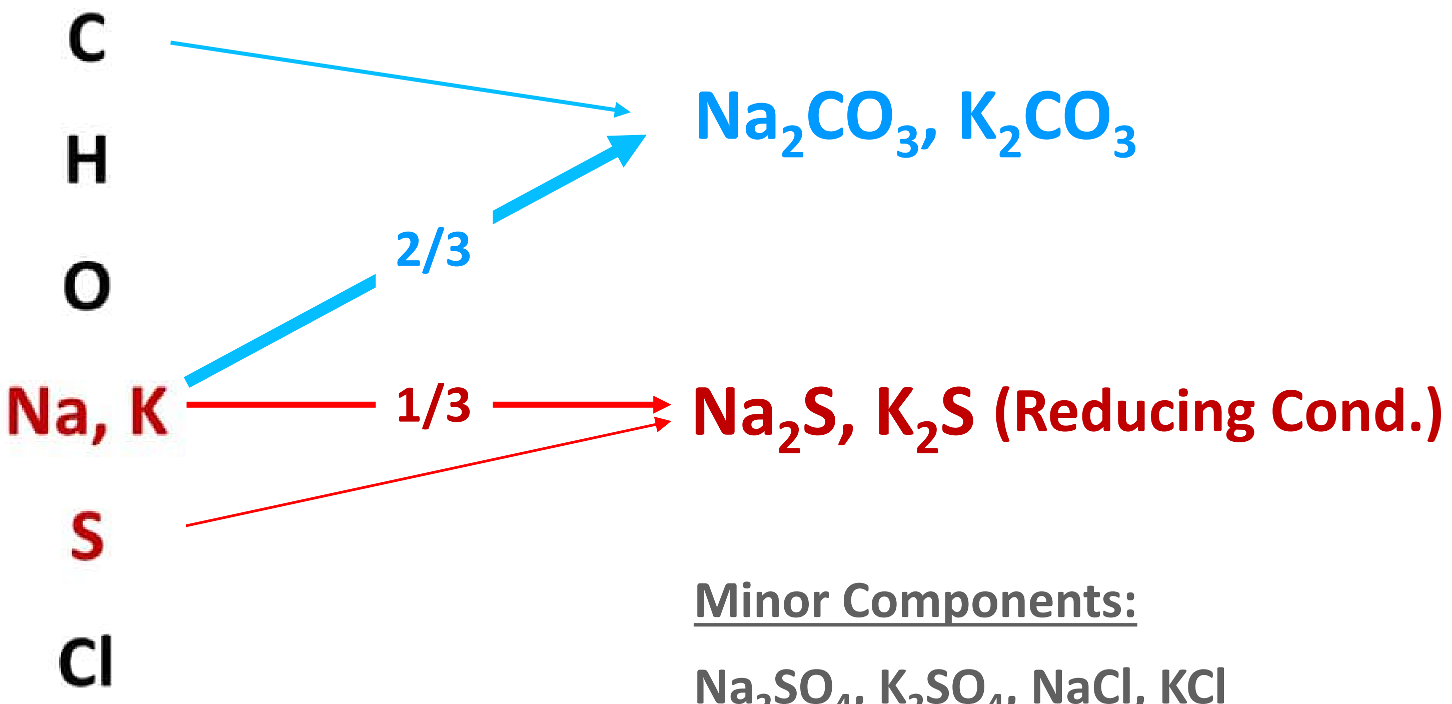
- Black Liquor Droplet Burning and Lower Furnace Operations
- **Char Bed Chemistry**
- Char Bed Dynamics
- Sulfate-Sulfate Cycle and Implications for Bed Control Strategies
- Summary

Basic Char Bed Chemistry

As-Fired Black Liquor Composition

(750 liquor samples; various wood species)

	Typical	Range
% Solids	72	65 – 85
HHV, MJ/kg	13.7	12.3 – 15.4
HHV, Btu/lb	5900	5300 – 6600
Composition		
C, wt% d.s.	33.9	30 – 40
H	3.4	3.2 – 4.0
O	35.8	34 – 38
Na	19.6	17 – 22
S	4.6	3.6 – 5.6
K	2.0	1 – 3
Cl	0.5	0.1 – 4



<u>Minor Components:</u>

Na_2SO_4, K_2SO_4, NaCl, KCl

Char, impurities

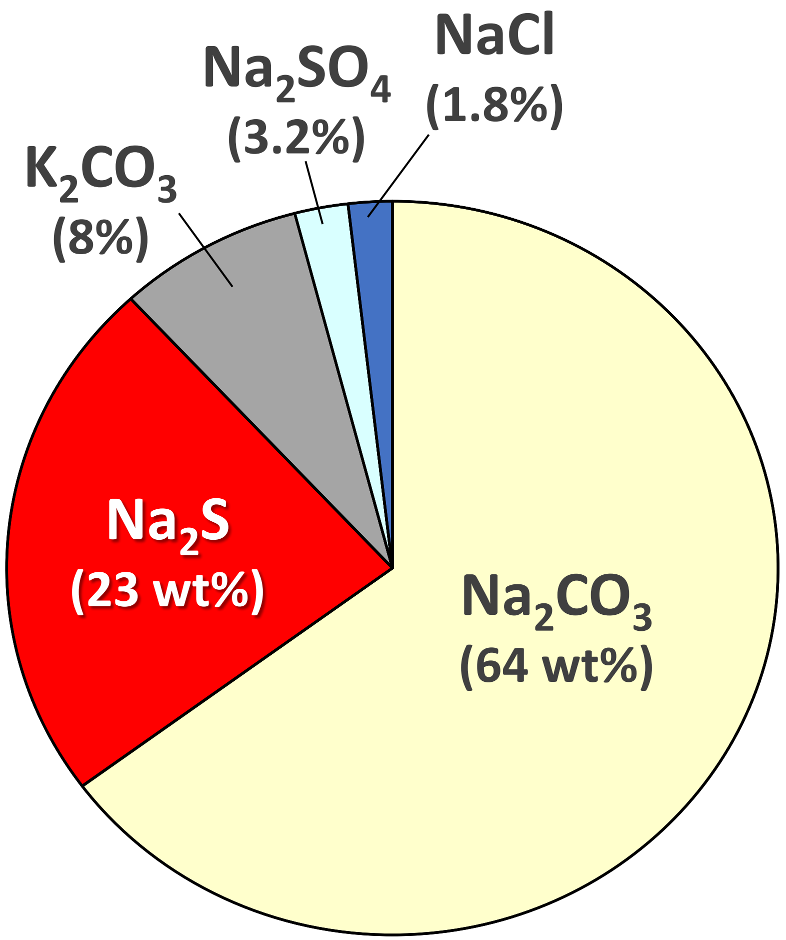
Smelt Production: ~ 0.45 kg/kg BLS

Typical Smelt Composition

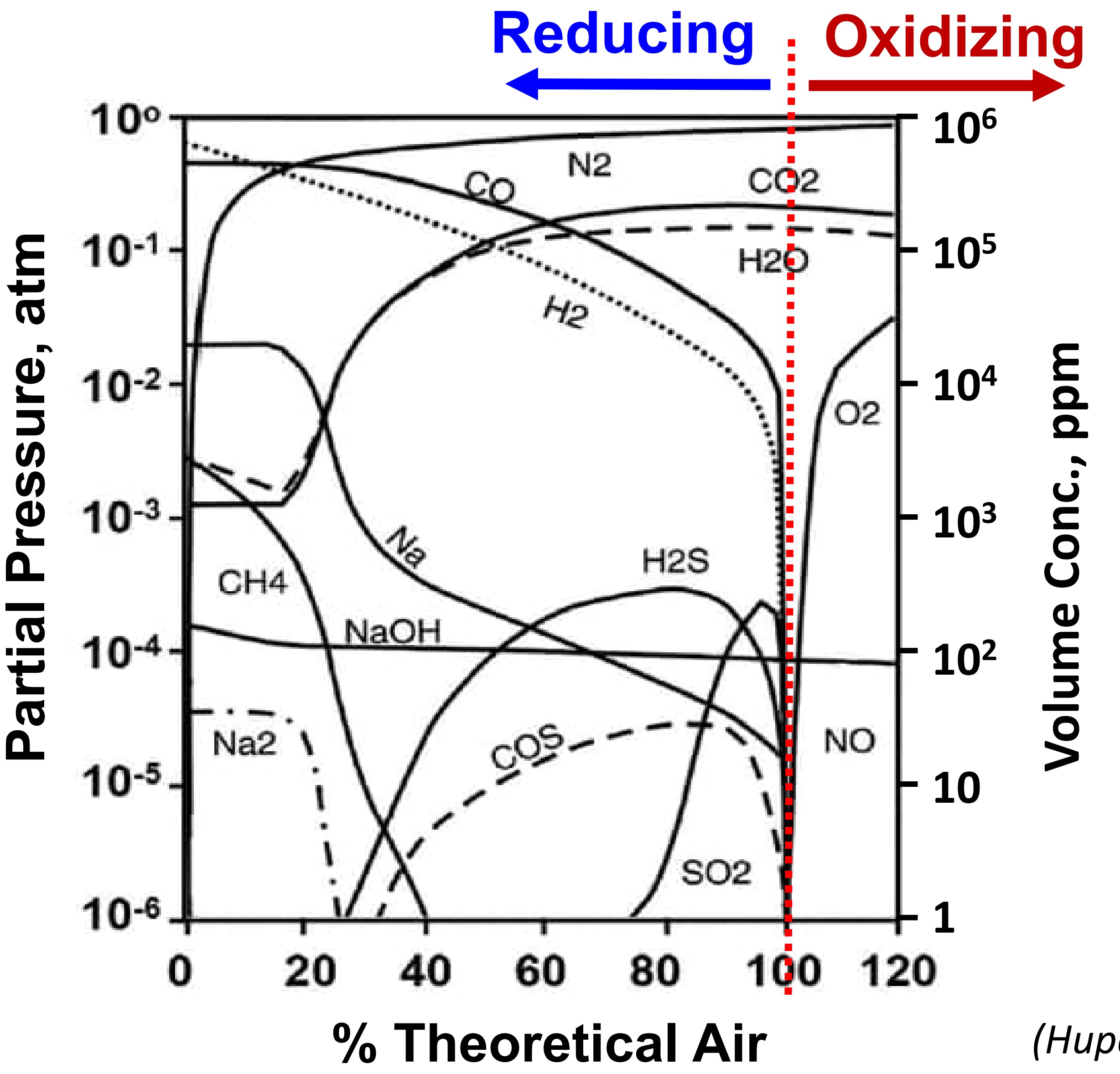
(Excluding char and impurities)

Affected by:

- Liquor sulfidity
- Reducing conditions
- Cl and K contents in black liquor



Effect of Air/Fuel Ratio on Gas Composition

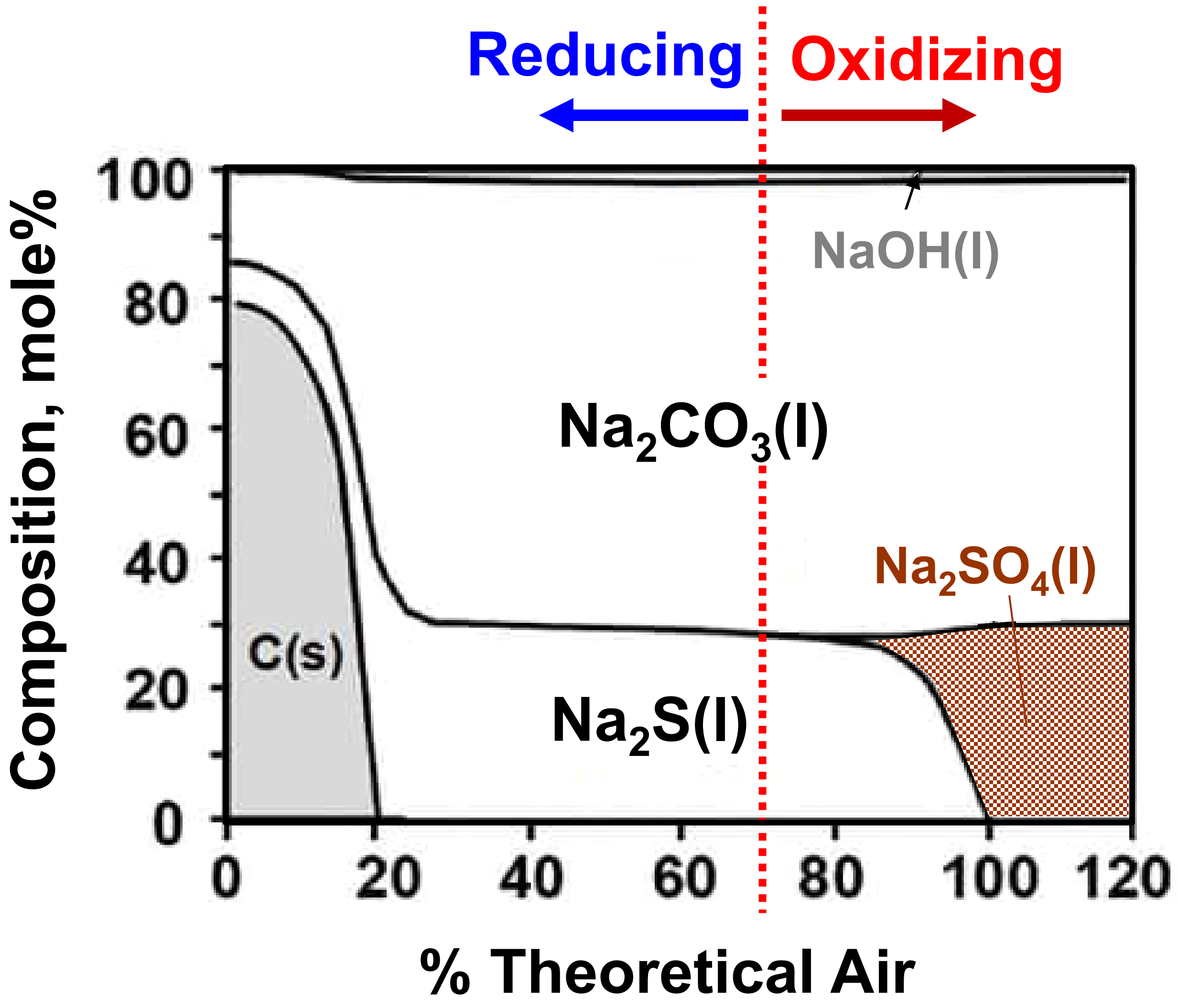


- **Note the presence of SO_2 and reduced gases (CO, H_2, H_2S) under reducing conditions and their absence under oxidizing conditions**

➔ Tertiary air is needed for complete combustion.

(Hupa, M., Åbo Akademi U., Finland)

Effect of Air/Fuel Ratio on Smelt Composition

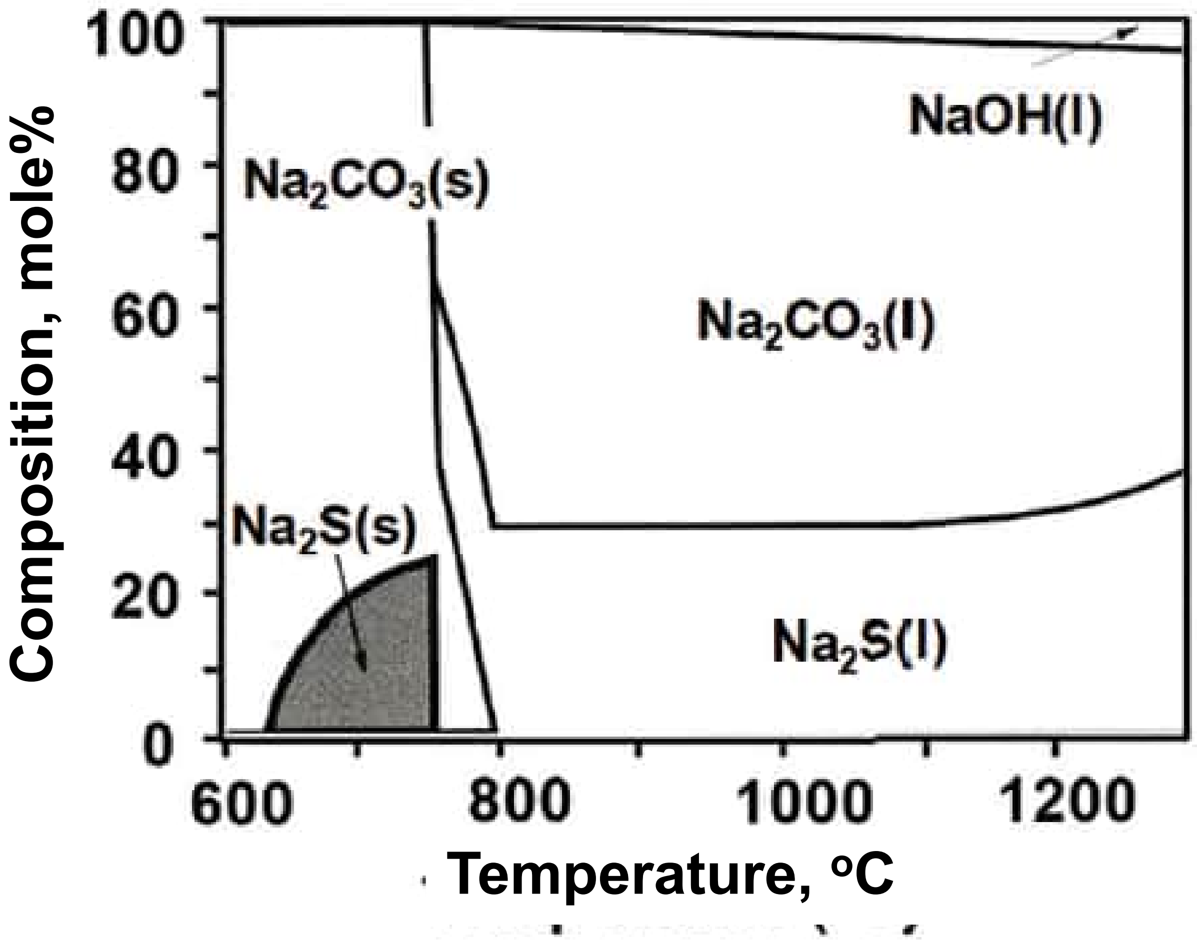


➔ *In order to obtain high reduction efficiency, the combined prim. + sec. air flow rate must be less than 75% theoretical air or ~ 70% total air*

(Hupa, M., Åbo Akademi U., Finland)

Effect of Bed Temperature on Smelt Composition

Theo. Air/Fuel Ratio = 0.7, Black Liq. S/Na_2 molar ratio = 0.3

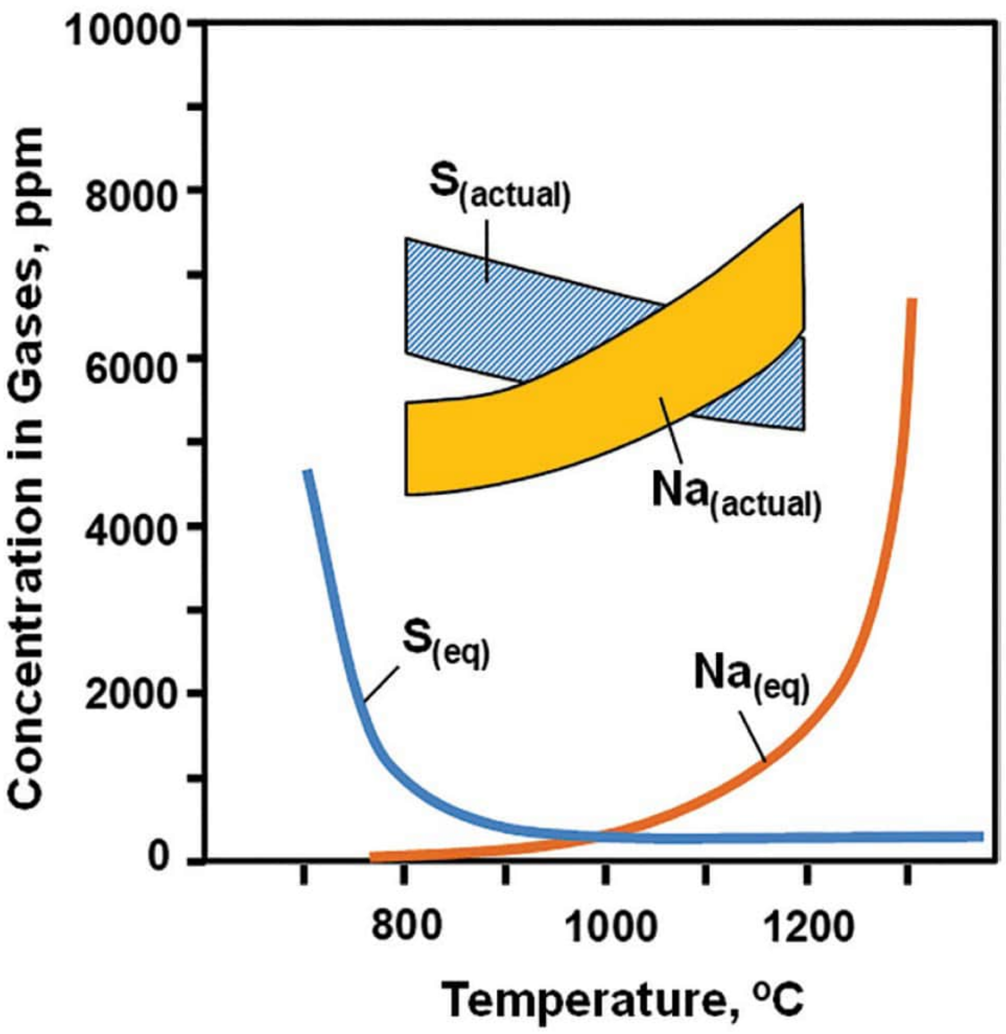


➔ Under normal boiler operating conditions, bed temperature has no/little effect on smelt composition

(Hupa, M., Åbo Akademi U., Finland)

Effect of Bed Temperature on S and Na Release

Theo. Air/Fuel Ratio = 0.7, Black Liq. S/Na_2 molar ratio = 0.3



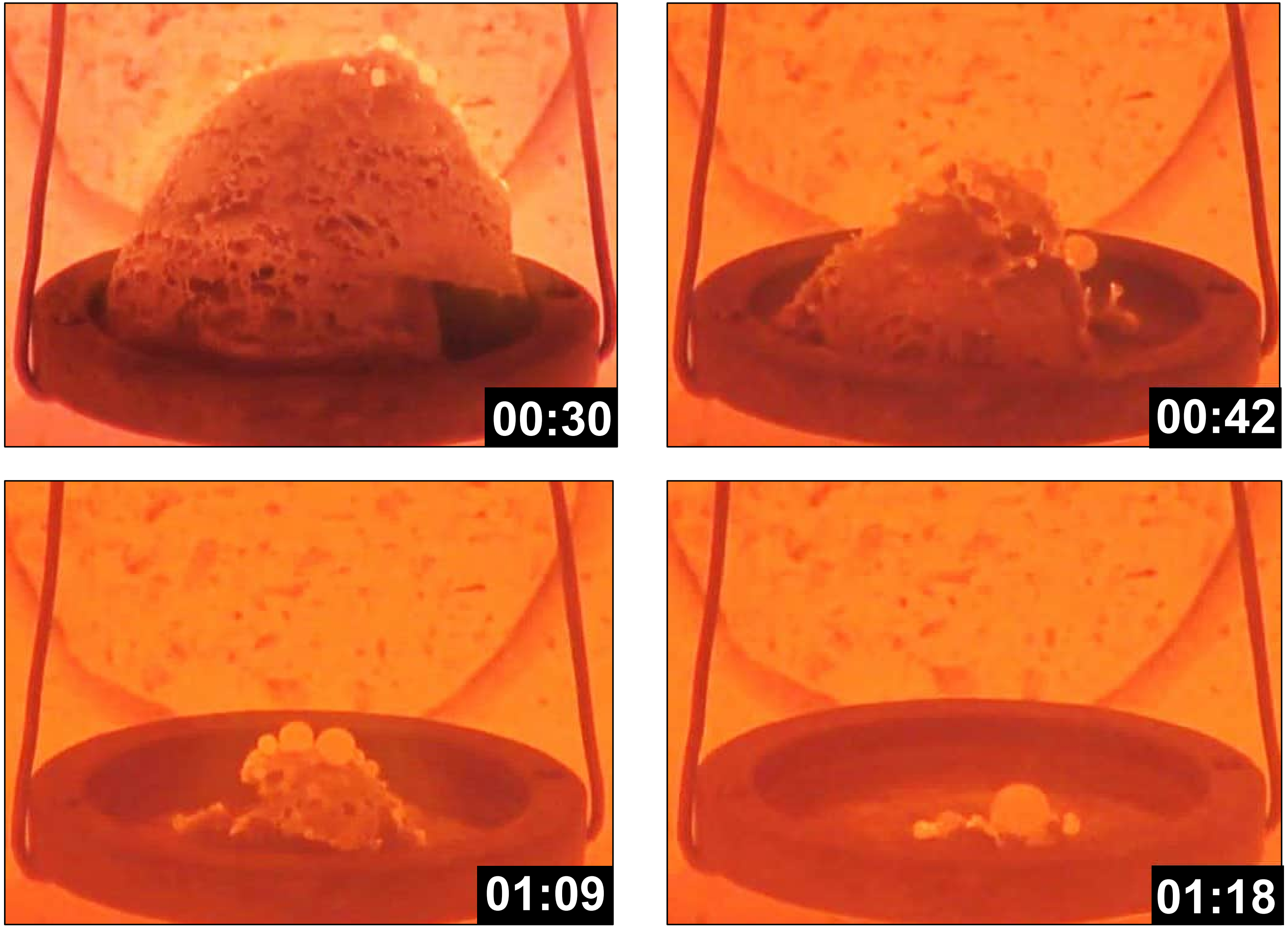
- As T_{Bed} increases, S release decreases while Na release increases
- Although trends are the same, actual values are significantly higher than thermodynamic predictions

(Hupa, M., Åbo Akademi U., Finland)

Presentation Outline

- Black Liquor Droplet Burning and Lower Furnace Operations
- Char Bed Chemistry
- **Char Bed Dynamics**
- Sulfate-Sulfate Cycle and Implications for Bed Control Strategies
- Summary

Char Burning and Smelt Formation

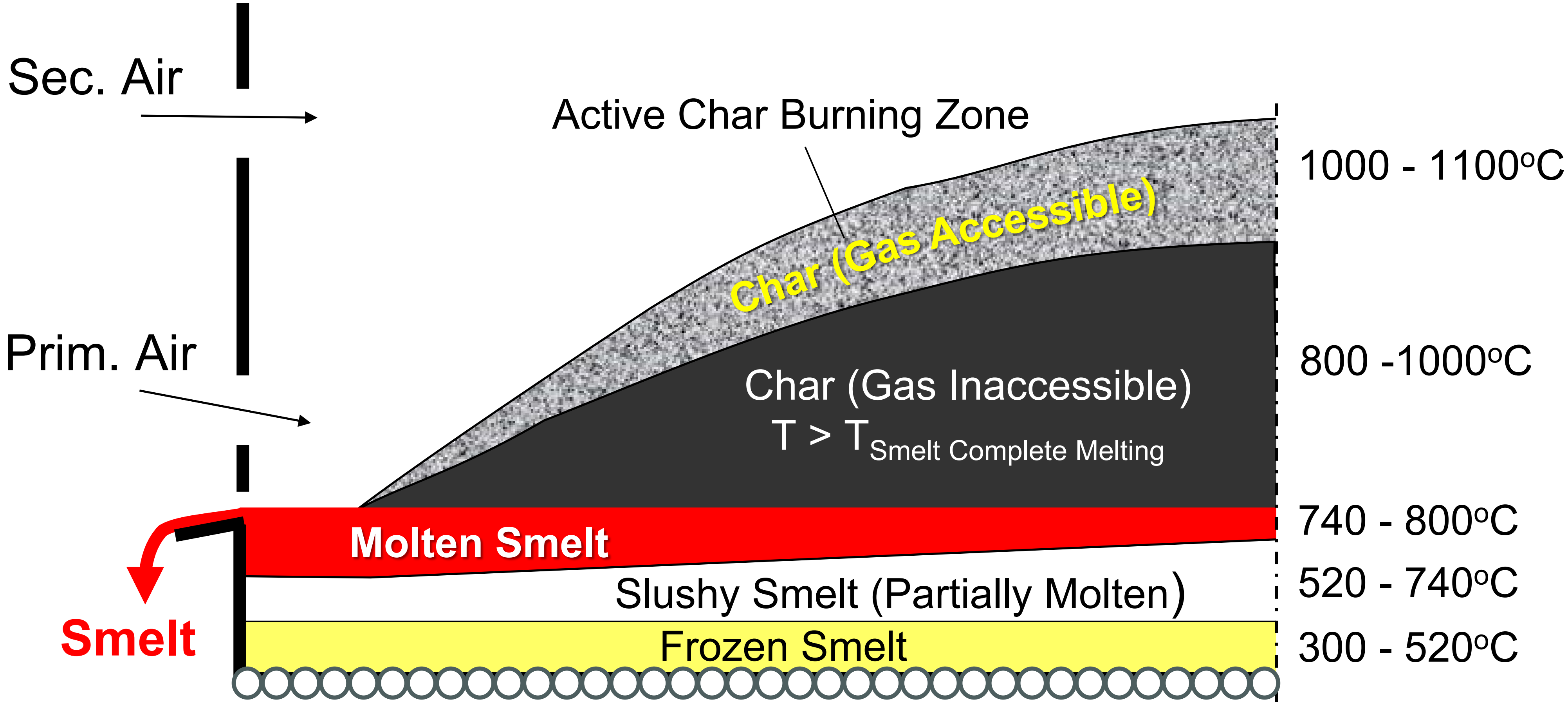


(Time in mm:ss)

Implications for Char Bed Formation

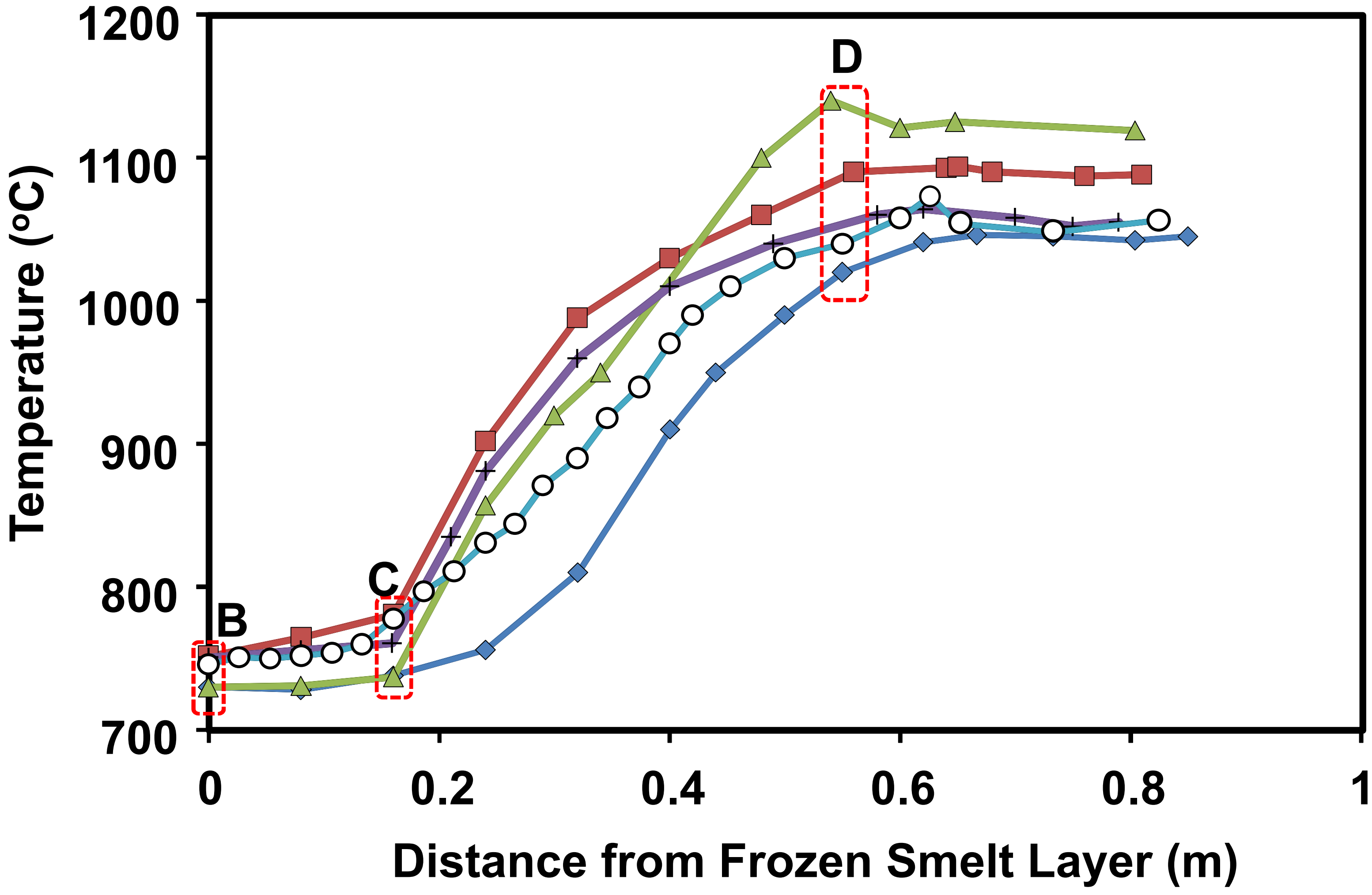
- As BL droplets land on the char bed, they dry, devolatilize, swell, burn and form char and molten smelt drops
- As char burns off, molten smelt drops coalesce into larger/heavier drops
- Molten smelt drops either roll down on the bed surface or percolate through the porous char layer, and form a molten smelt pool on the furnace floor

Char Bed Structure (Decanting Bottom)



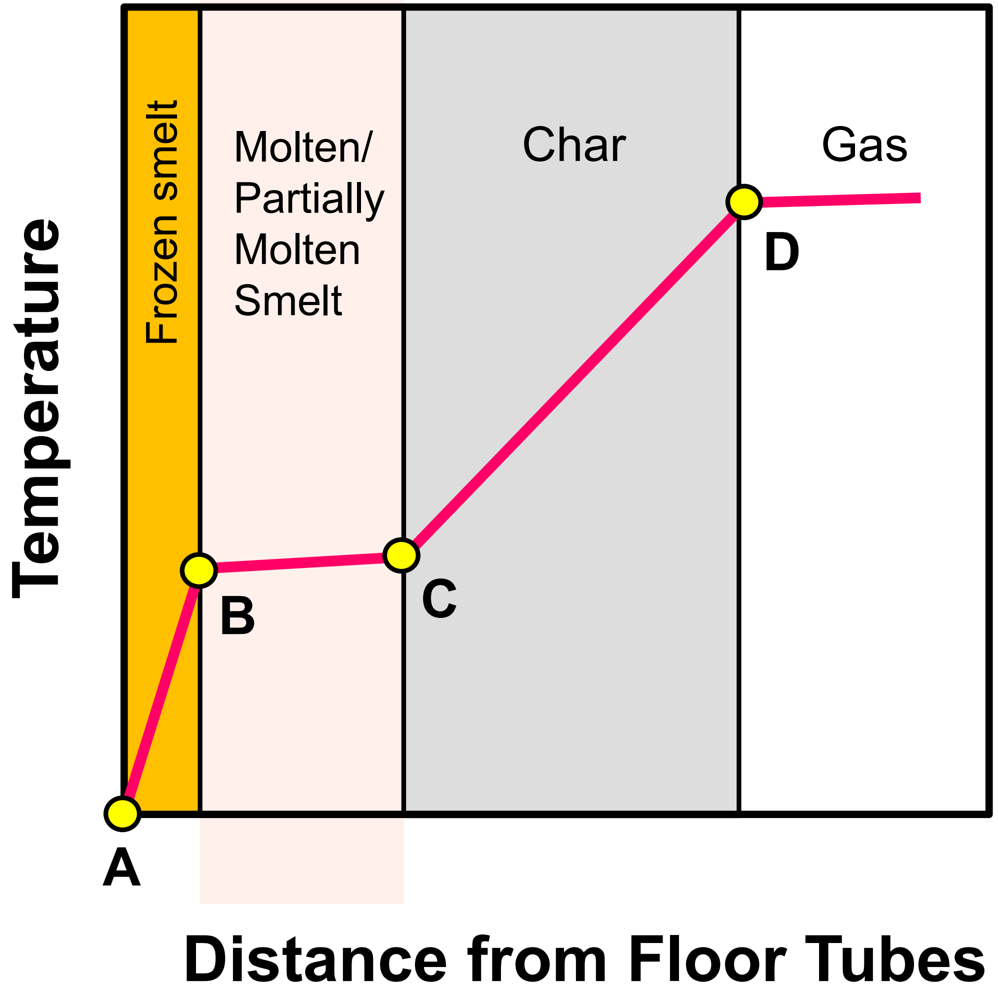
(Grace T.M. & Tran, H.N., "Kraft Recovery Boilers – 3rd Ed.", Chapter 6, p. 104)

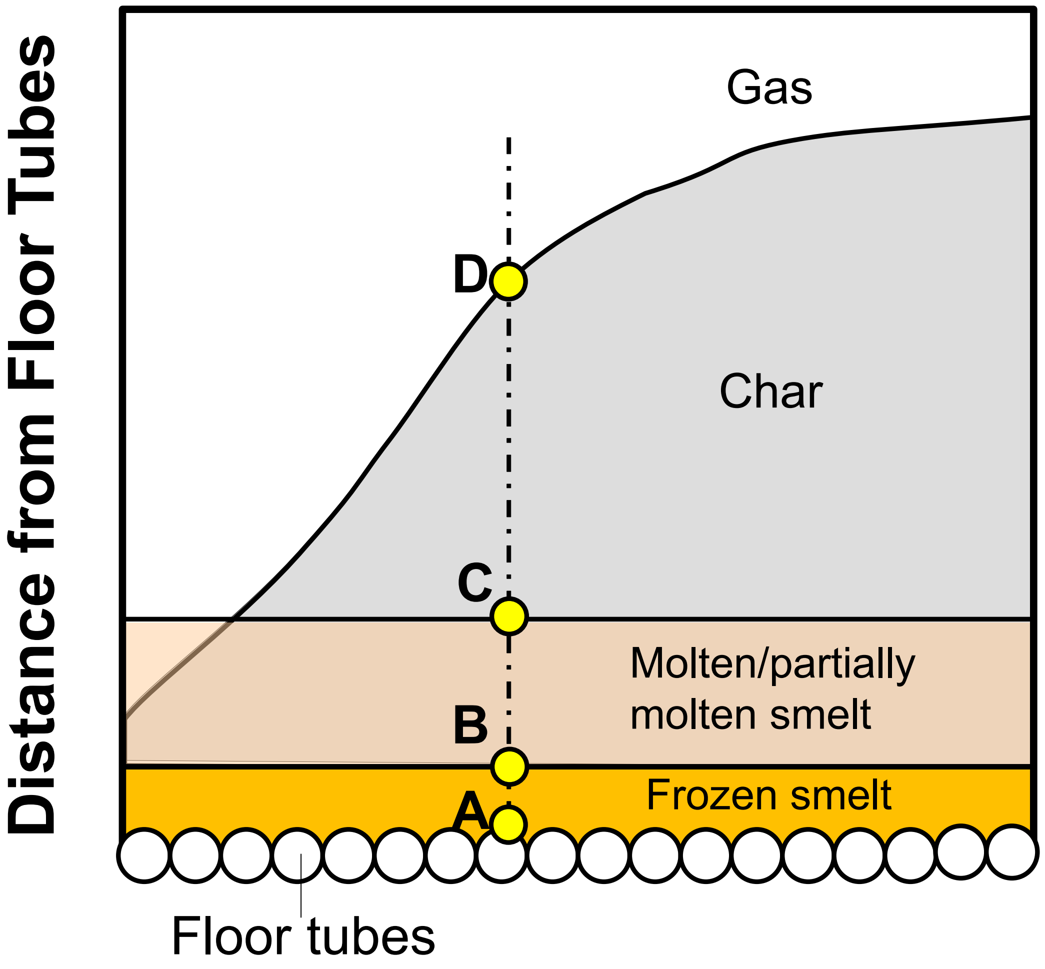
Char Bed Temperature Profiles



Tavares, A, Tran, H.N., Reid, T. TAPPI J. (1998)

Char Bed Temperature Profiles





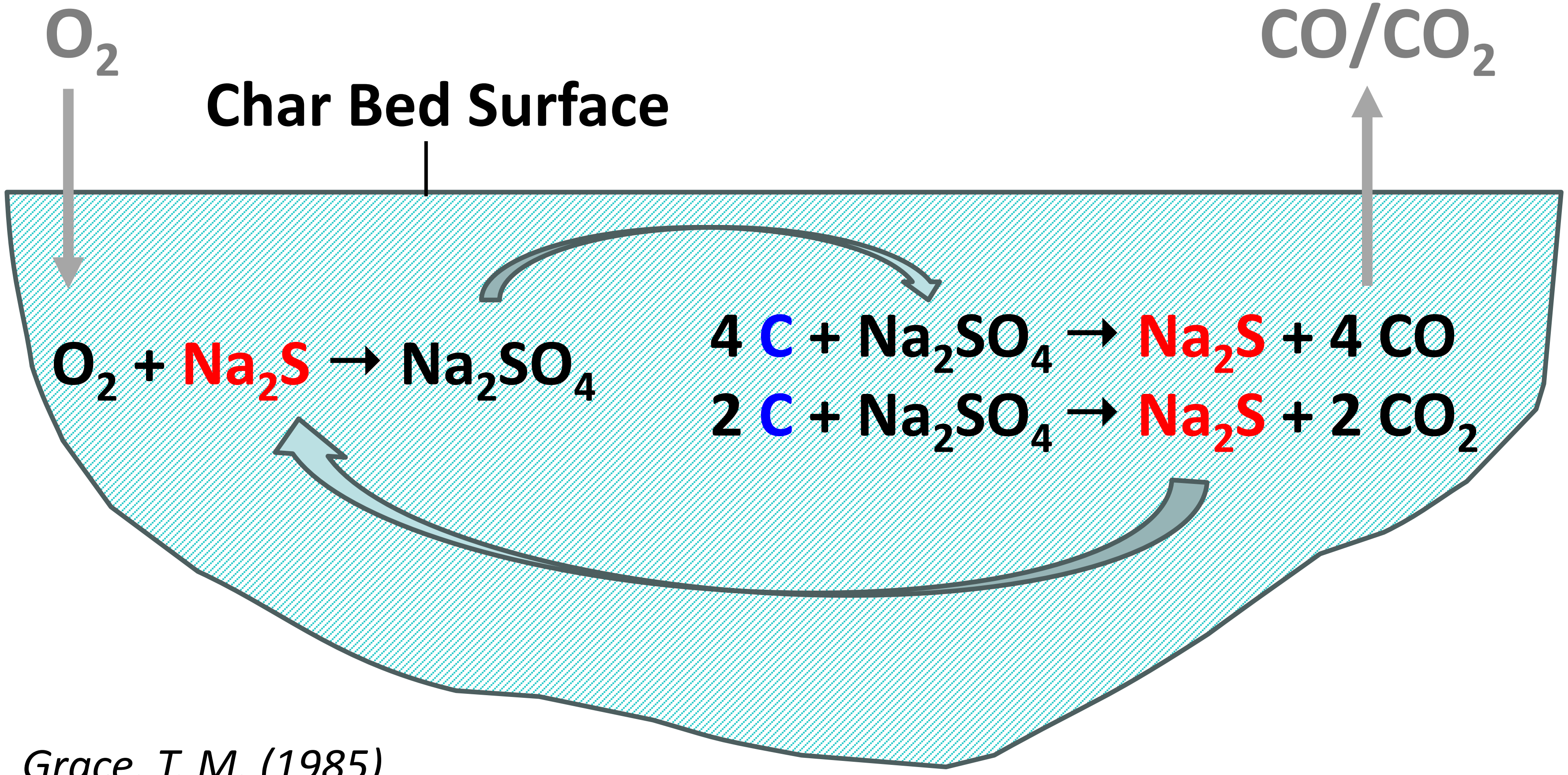
Factors Affecting Char Bed Characteristics

- Liquor droplet size and distribution
  - Spray nozzle type, tilt angle
  - Liquor temperature, pressure, viscosity, solids content, etc.
- Liquor swelling property
- Liquor heating value
  - Organic content, solids content
- Primary/secondary air
  - Air temperature, pressure, flowrate, distribution, air port configurations, etc.

Presentation Outline

- Black Liquor Droplet Burning and Lower Furnace Operations
- Char Bed Chemistry
- Char Bed Dynamics
- **Sulfate-Sulfide Cycle and Implications for Bed Control Strategies**
- Summary

Sulfate-Sulfide Cycle in Char Bed

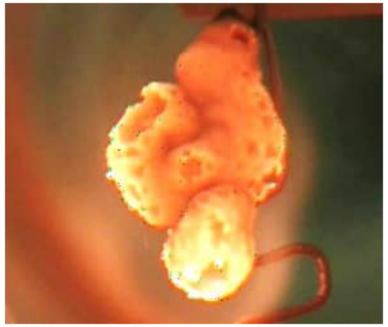


Grace, T. M. (1985)

Dr. Thomas M. Grace
(1939-2021)

Implications - 1

- In a burning char particle, both sulfate reduction and sulfide re-oxidation can occur simultaneously.
  - The net result is simply carbon burnup.



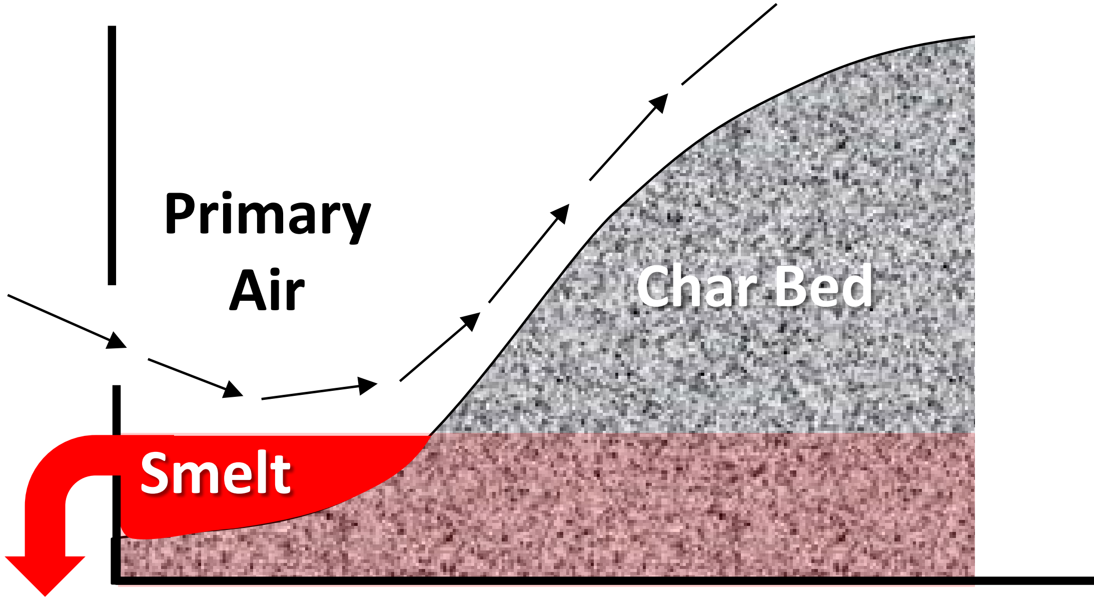
- If temperature is sufficiently high and O_2 mass transfer is limiting, the carbon burning will keep the reduction high until most carbon is depleted.
- Reduction of sulfate to sulfide is an inherent part of black liquor burning and occurs easily.

Implications - 2

- No need to maintain an oxygen-starved environment in the lower furnace to achieve good reduction.
- In fact, oxygen-starved environment can be counterproductive to good reduction
  - It decreases the combustion rate leading to low bed temperatures → low sulfate reduction rates
- The best way to get good reduction is to keep a hot bed through active char combustion.

Implications - 3

- The exothermic sulfate-to-sulfide reaction is an important means for carbon burning in the bed, particularly around the primary air ports.
- The sulfide in molten smelt after the carbon is burned off is easily oxidized back to sulfate. This should be minimized since it lowers the overall reduction efficiency.

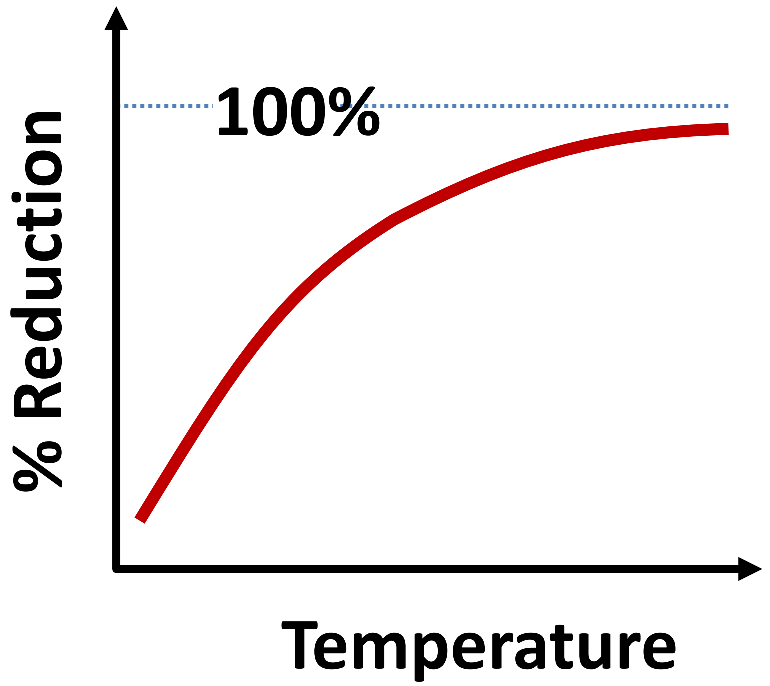


Implications - 4

- Molten smelt flowing toward the spouts needs to be shielded from direct contact with air. This is one of the primary functions of the char bed.
- Boilers operating with low-to-medium sized beds, sulfide re-oxidation is the main cause of low reduction efficiency.
- Other causes of low reduction efficiency include:
  - Excessive entrainment of air through spout openings
  - Relatively large amounts of molten smelt running down the walls
  - Molten smelt raining down from the upper furnace
  - Lack of intimate contact with carbon

Summary

- Na_2CO_3 forms readily during combustion, while Na_2S can form only under a strong reducing condition
- Good reduction requires the presence of char and high bed temperature
- If reduction is already high (~ 96%), increasing temperature does not help much
- Strategies are provided for minimizing sulfide reoxidation



Thank You

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ANDRITZ Digital Solutions

AUTOMATED LIQUOR GUNS

PULP & PAPER

ANDRITZ

ENGINEERED SUCCESS

AUTOMATED LIQUOR GUN

SMART SOLUTIONS

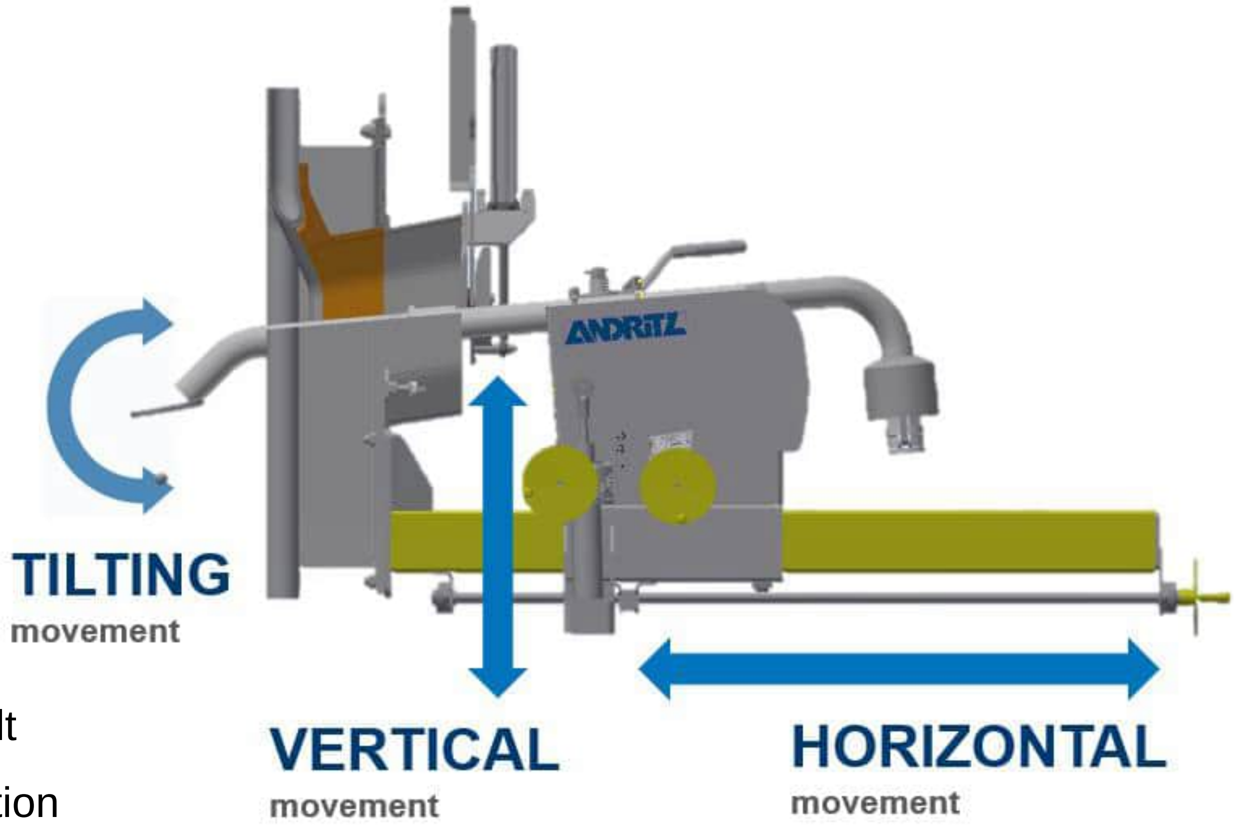
Metris
ANDRITZ Digital Solutions

BENEFITS

- Improve Safety
- Improve Combustion Stability
- Extend nozzle lifetime

HOW IT WORKS

- Liquor gun is mounted in fixed burner rack
- Rack can be provided to use either manual handwheel adjustments or motorized
- Capable of adjusting vertical, horizontal, and tilt
- Automated cleaning device maintains combustion stability and minimizes operator interaction
- Equipped with gun door for safe gun change



PICTURES

Manual configuration

Metris
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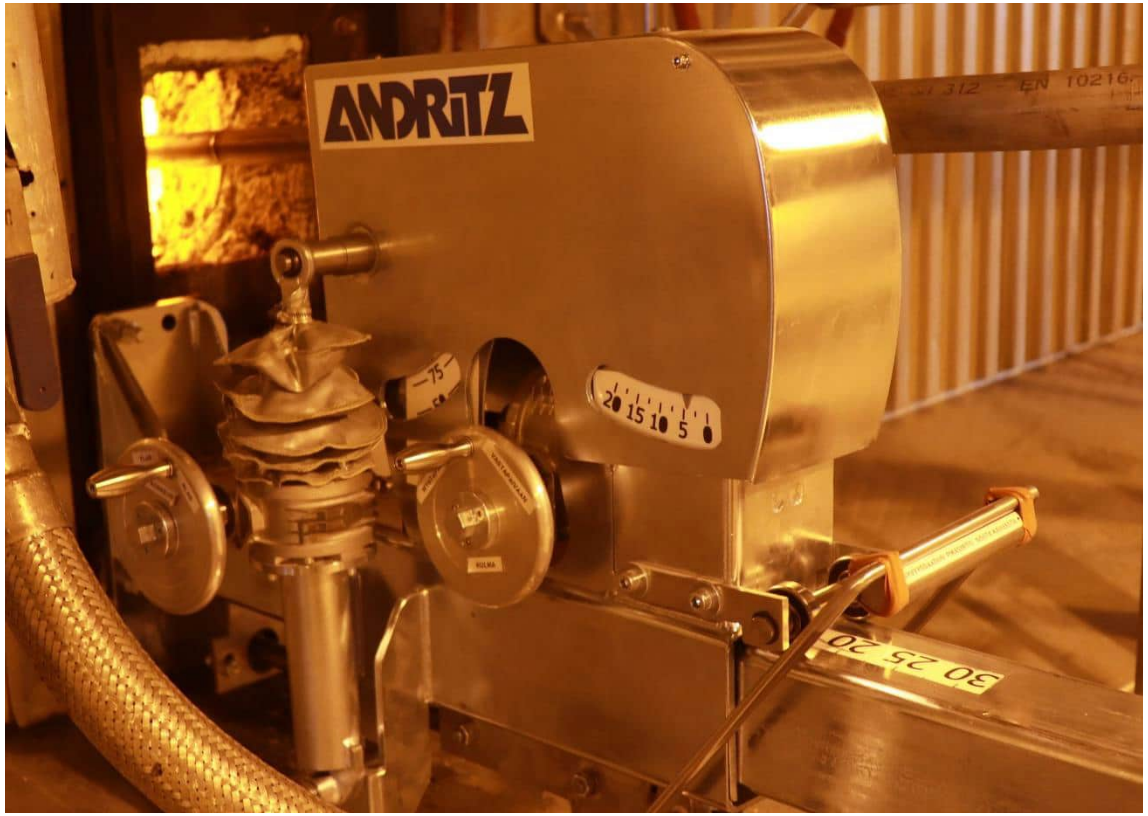
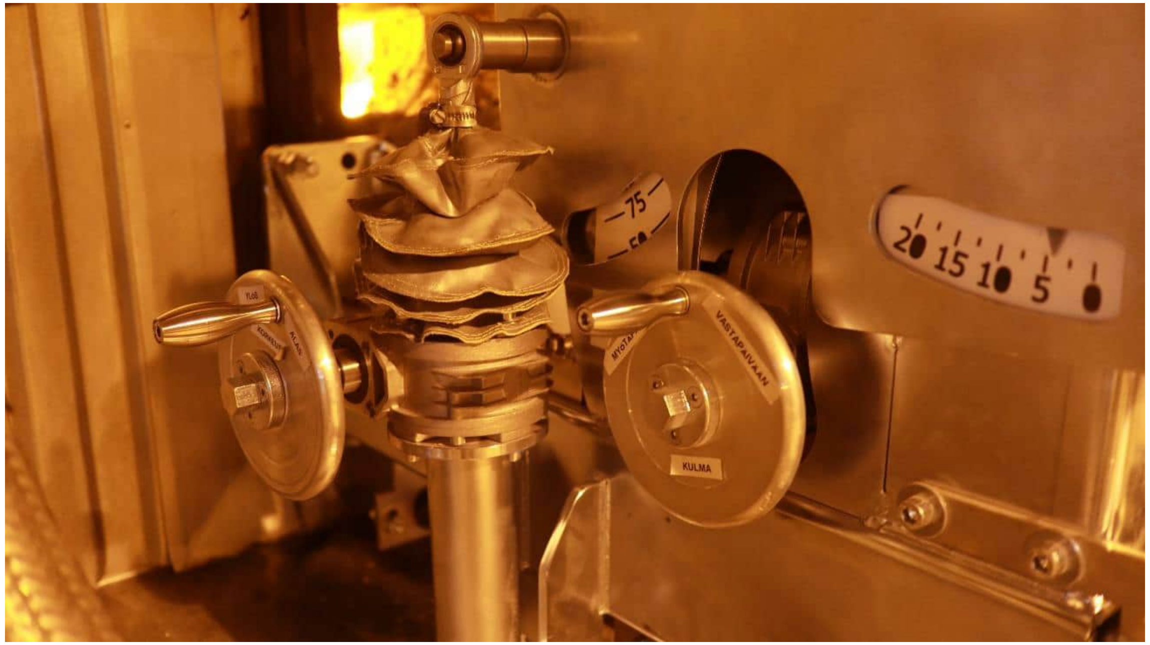


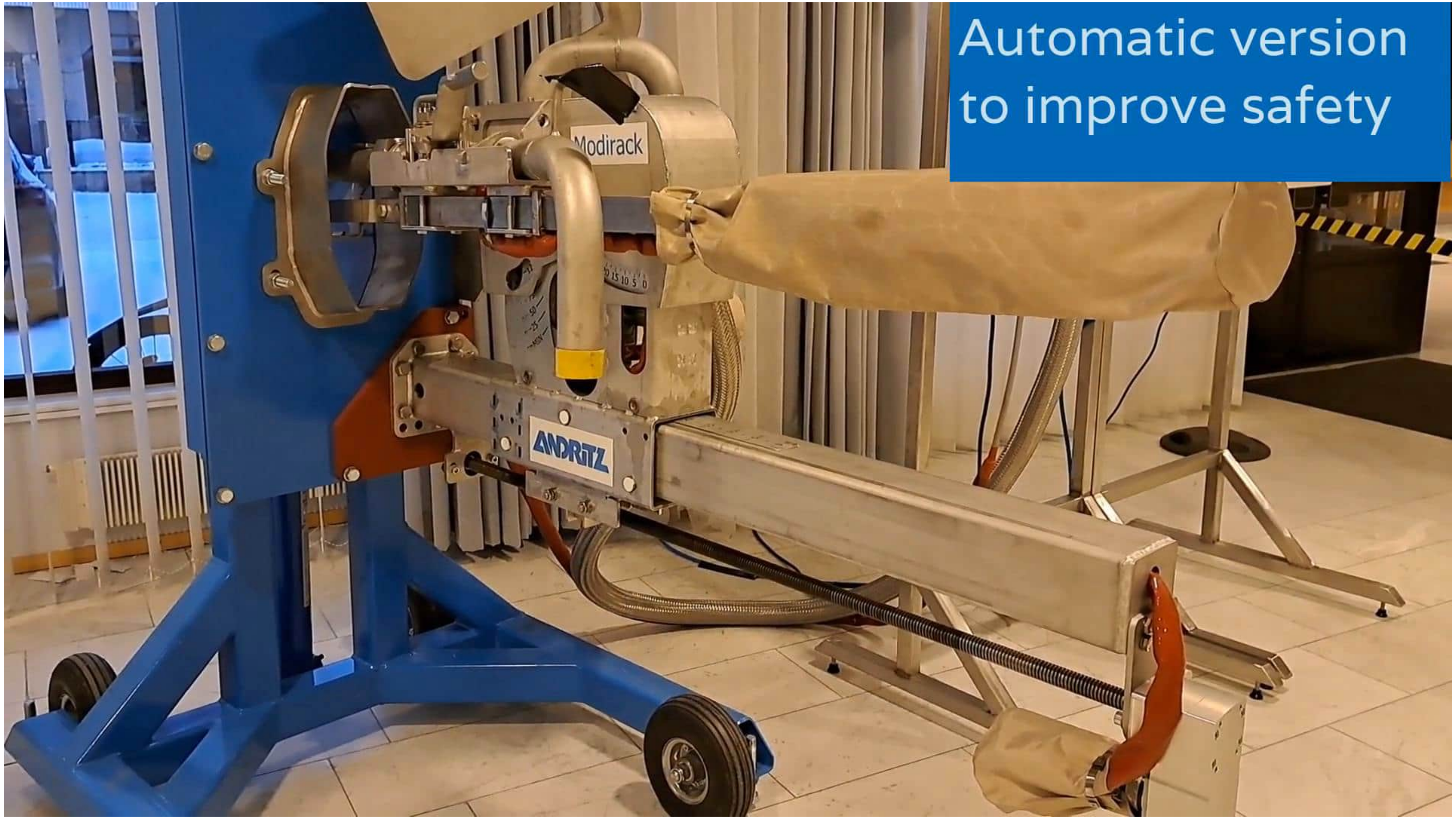


HORIZONTAL NOZZLE MOVEMENT

Manual configuration

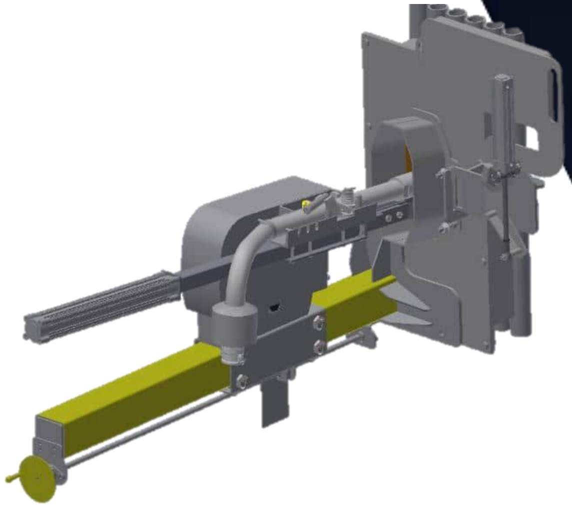
HORIZONTAL NOZZLE MOVEMENT

Automated configuration

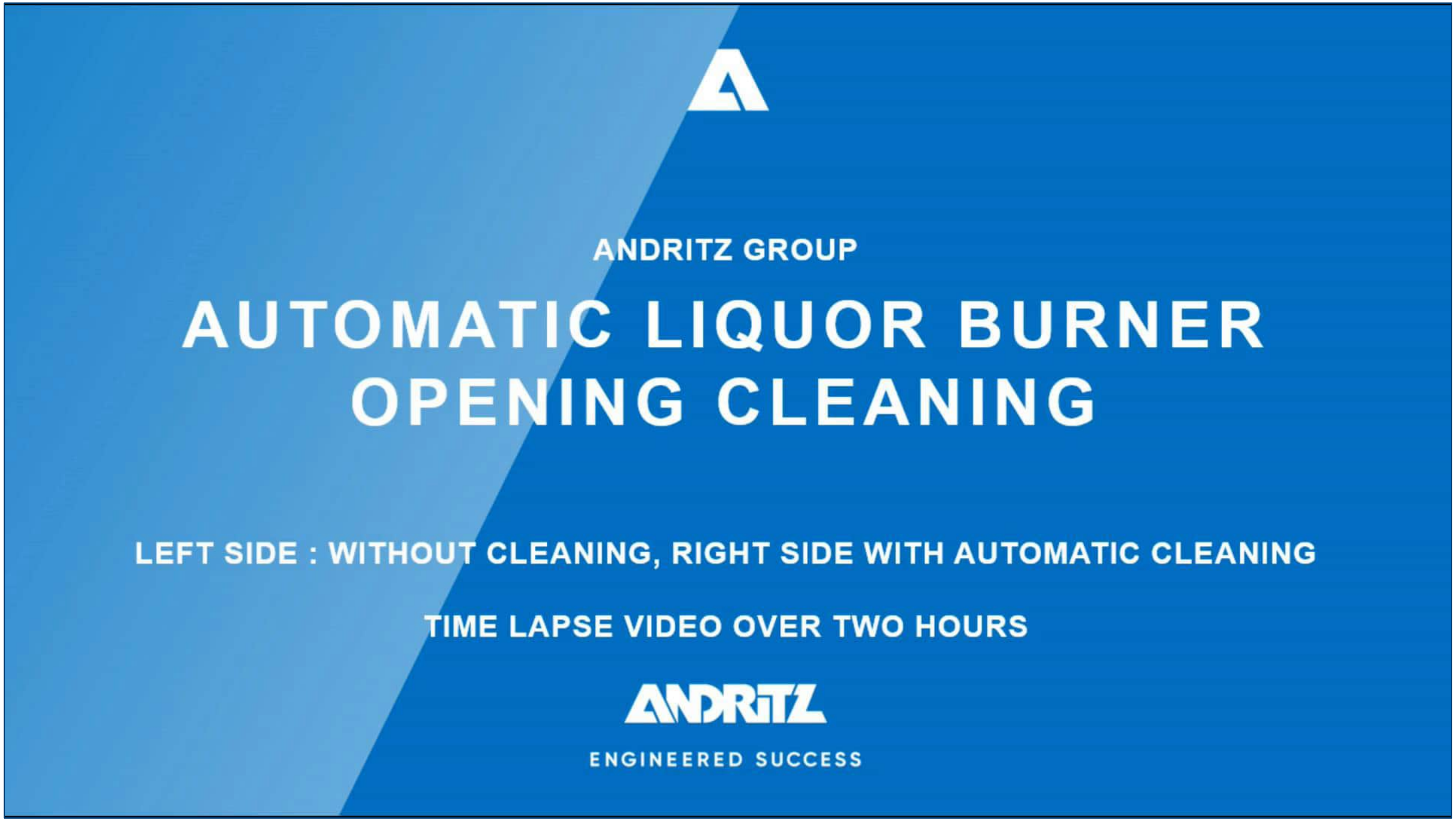


AUTOMATIC NOZZLE CLEANING

- Pneumatic cylinder operated cleaning blade
- Adjustable cleaning cycle time
- Automation which prevents blade to stuck / not reaching the end of the working cycle



AUTOMATIC NOZZLE CLEANING



AUTOMATION BENEFITS

IMPROVED safety

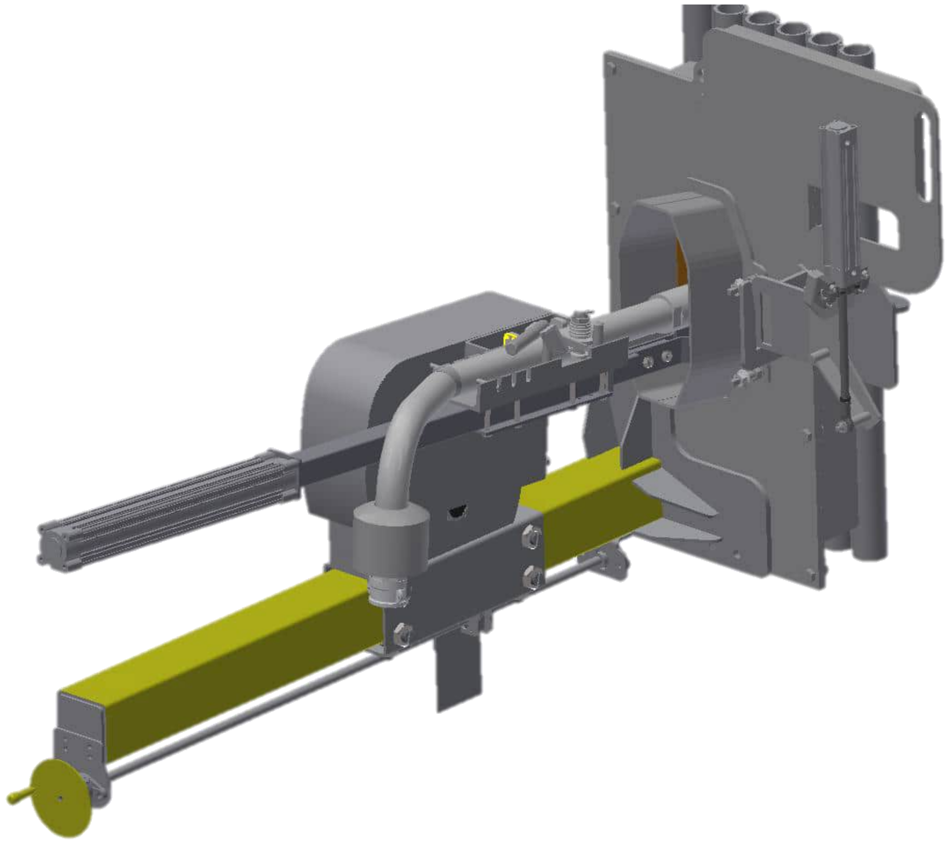
IMPROVED boiler balance

EXTENDED nozzle lifetime

AUTOMATIC burner spooling

AUTOMATIC burner insertion/ejection

REMOTE Burner position adjustments



Metris
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AUTOMATED CARRYOVER MEASUREMENT (ACM)

PULP & PAPER

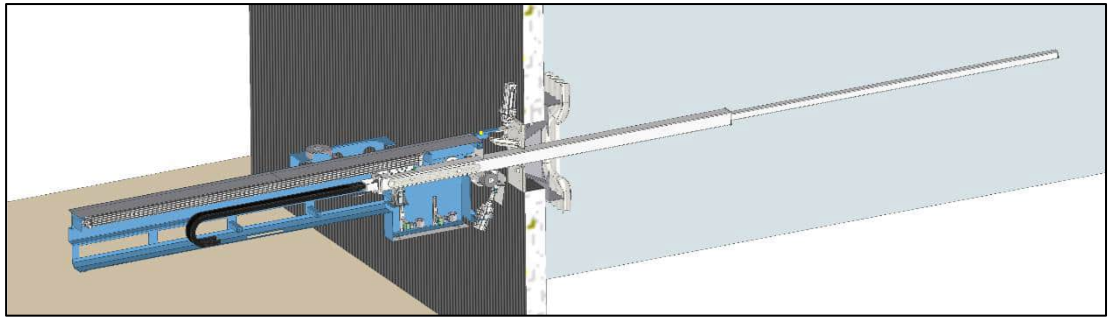
ANDRITZ
ENGINEERED SUCCESS

CARRYOVER IN RECOVERY BOILER

From Manual Sampling to Automatically Sampling

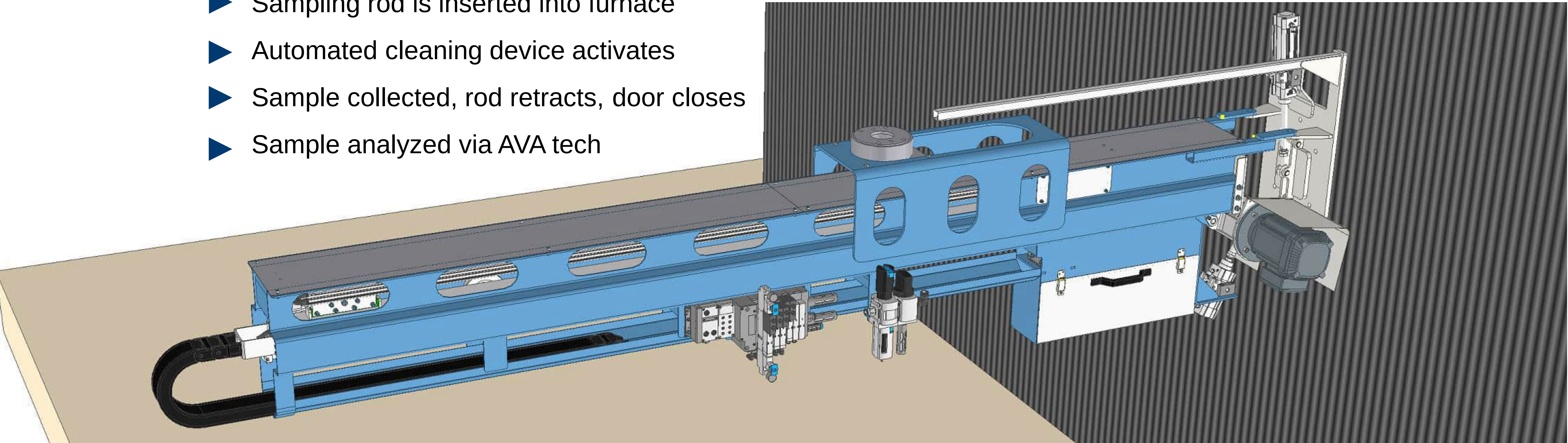
BENEFITS

- Improve Safety
- Improved monitoring / tracking
- Improved tuning

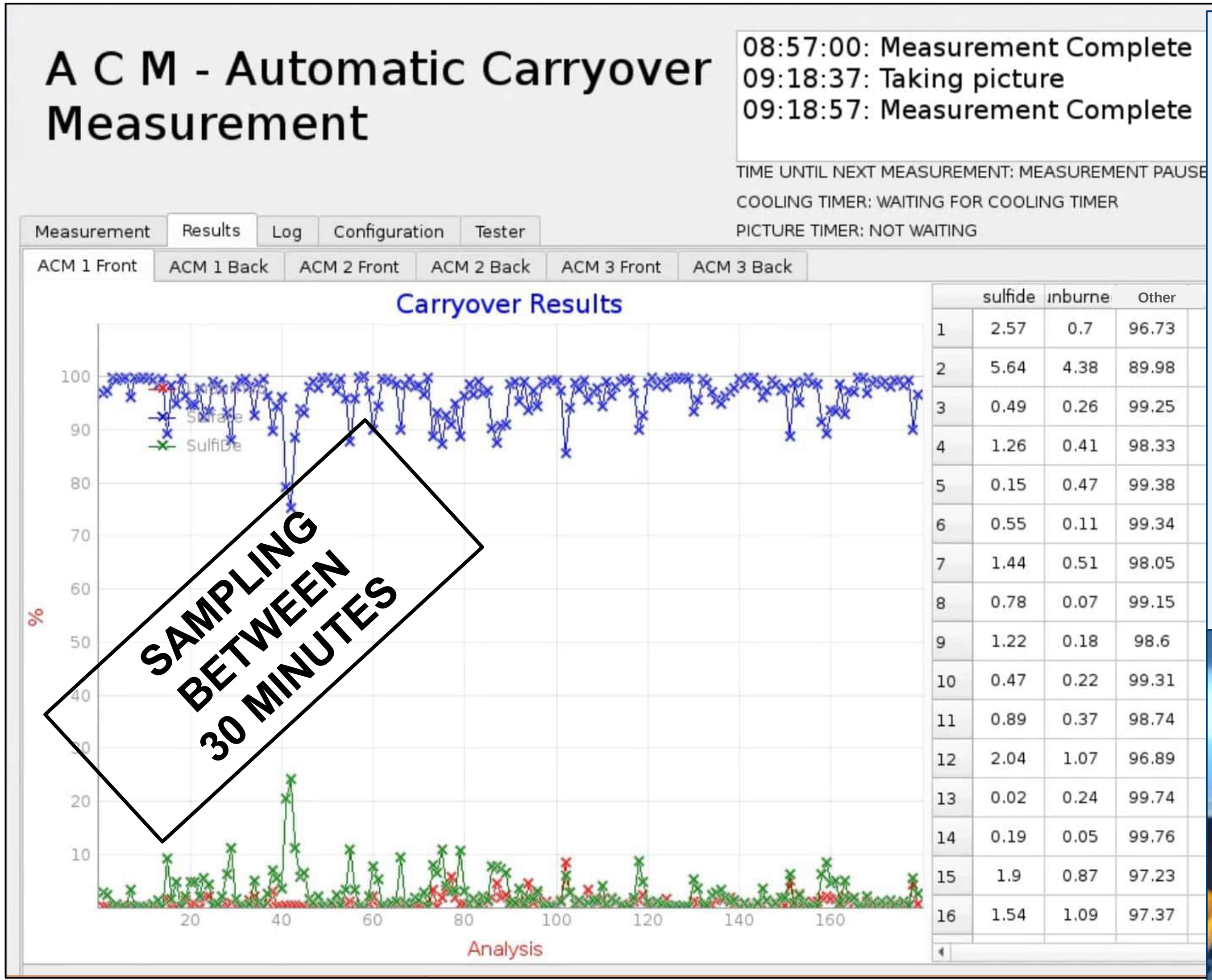


HOW IT WORKS

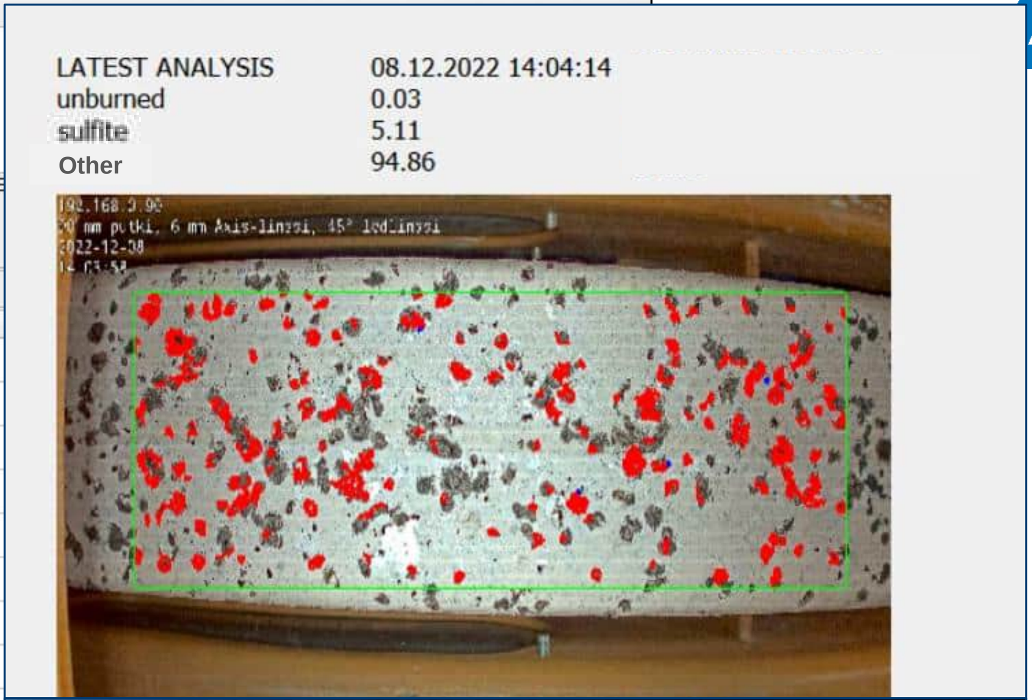
- Piston actuated door opens
- Sampling rod is inserted into furnace
- Automated cleaning device activates
- Sample collected, rod retracts, door closes
- Sample analyzed via AVA tech



AUTOMATIC CARRY-OVER MEASUREMENT (ACM)



	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



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 in design
  - Small free space requirement

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.

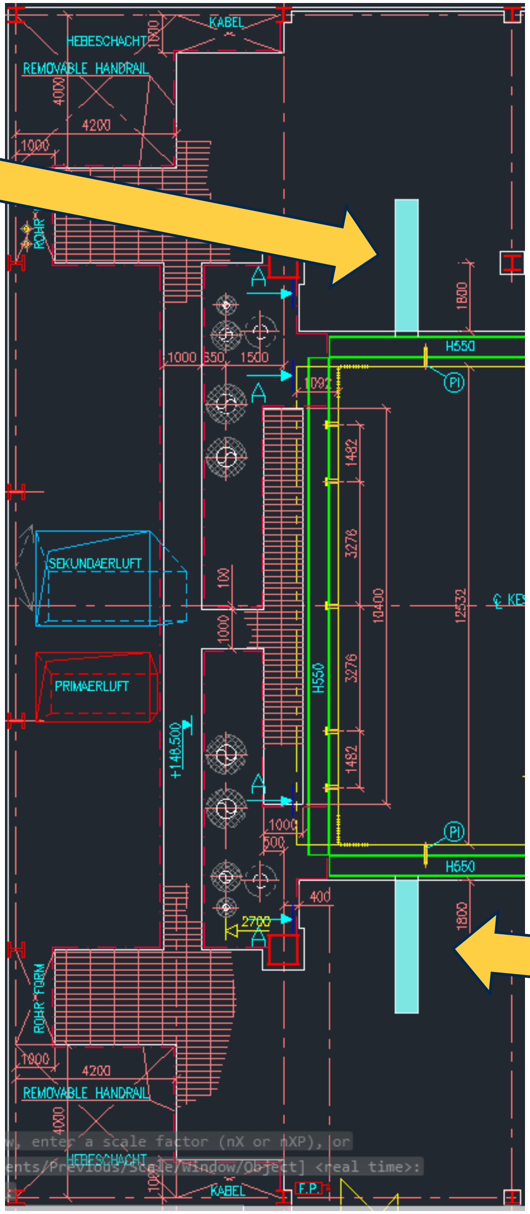
Interface points during installation

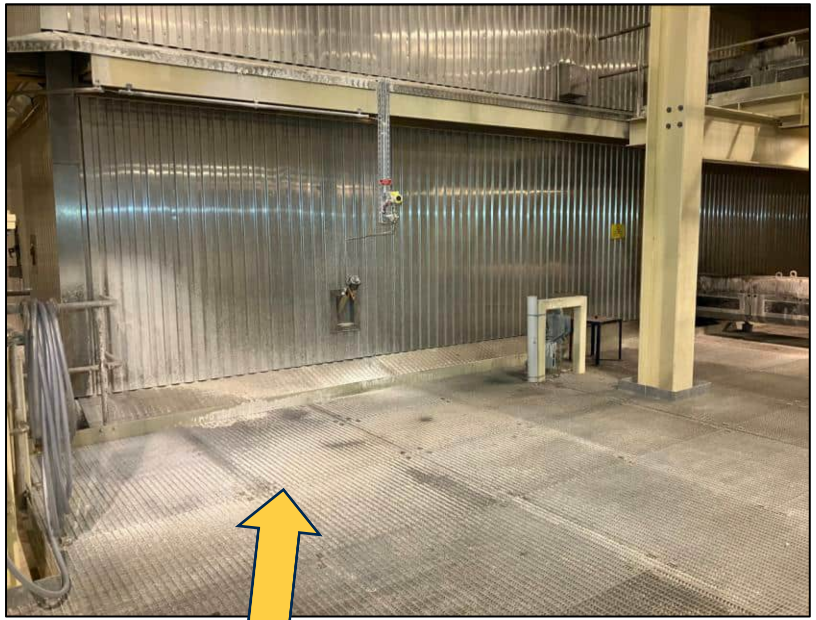
- Opening at the boiler for mechanical installation
- Electricity feed (230 VAC)
- Pressurized air (cooling, pneumatics)
- DCS connection for transferring measurement results

AVA ACM – EX. LAYOUT

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

Proposed location at left side wall





Proposed location at right side wall

THANK YOU!

For more information please contact:

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Sam Miller
Cell: 678-533-9431
Samuel.Miller@andritz.com

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Recovery Boilers & "Looking Under the Rug"

Nick Folster - 7-February-2024

B&W GP&S District Service Engineer & Air Heater SME

Safety Share

1 Minute 4 Safety

Take Frequent Computer Breaks

My Hands and Arms …
Every 30 minutes I stretch my hands and fingers wide and shake them out.

Every chance I get I rest my hands in a thumbs-up position.

My Eyes …
Every 20 minutes I look off into a distance of 20 feet or close my eyes for 20 seconds

My Seated Body …
Every 30 minutes I get up and move about 30 footsteps or I stand to stretch and shake out the stress

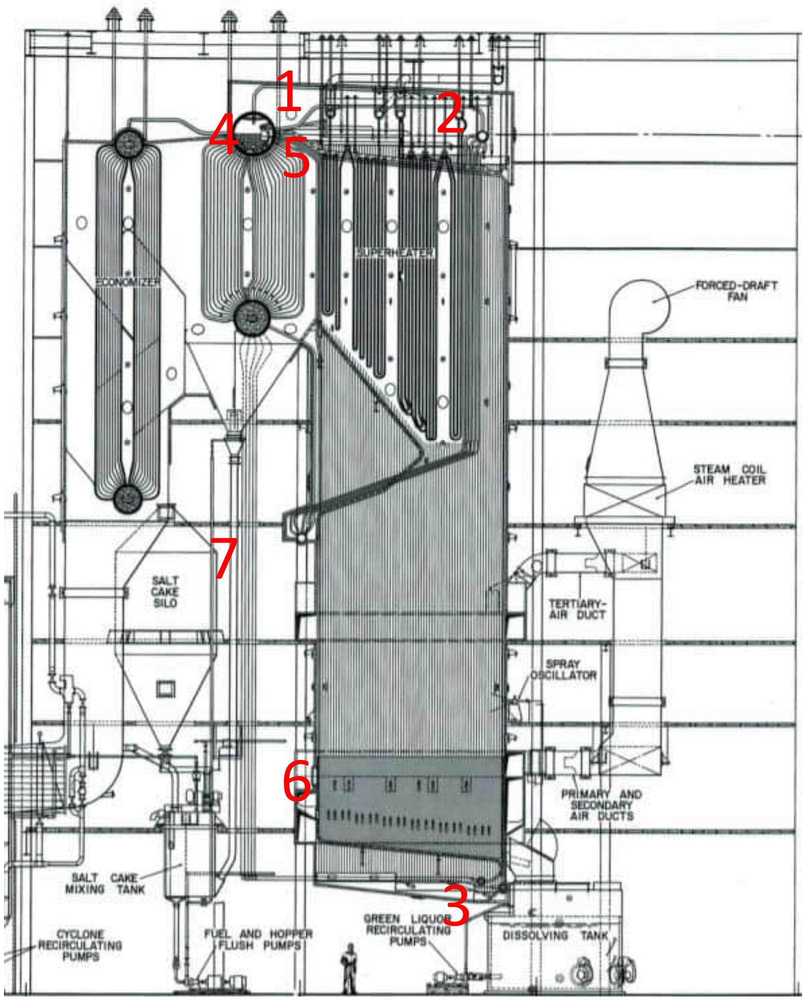
Recovery Boilers & “Looking under the Rug”

- The thrust of this presentation is to identify a number areas of Recovery Boilers (especially older units) which are not typically inspected on a regular basis

- Various areas of concern will be identified along with the corresponding NDE method that B&W would recommend to evaluate the condition of a given component

Areas of the Boiler to be Discussed

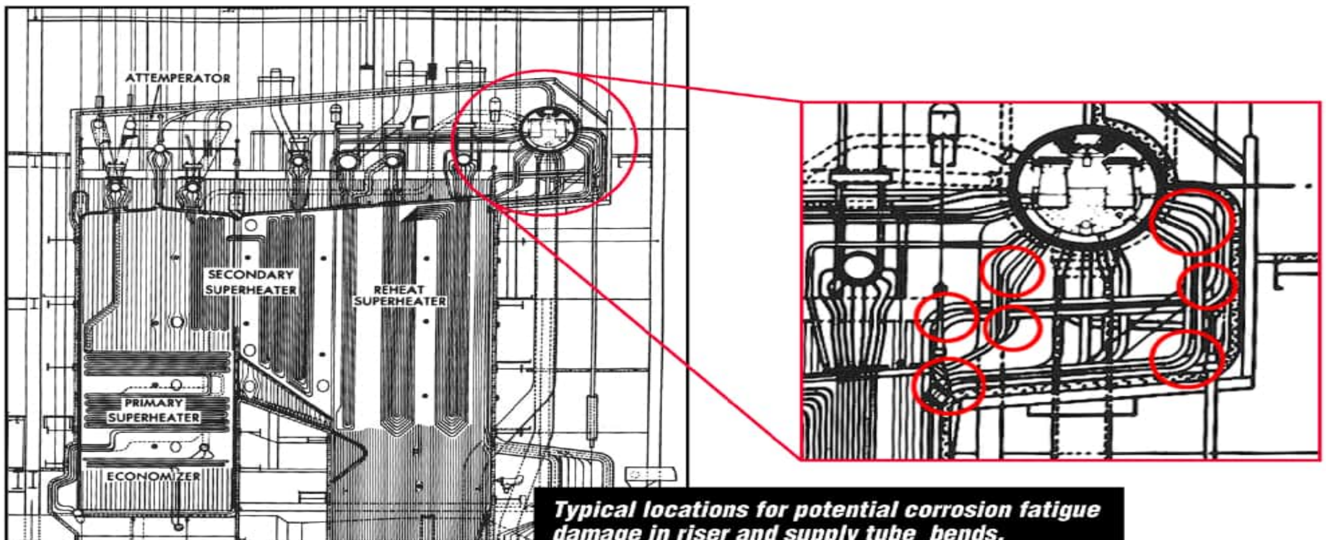
1. Riser Tubes
2. Riser & Tube Attachment Fatigue & Corrosion
3. Horizontal Supply Tubes
4. Feedwater Pipe Sleeve Erosion
5. Rear Wall Tubes at Steam Drum Interface
6. SAC at Tube Wall Attachments
7. External Downcomers



1. Riser Tubes

- Corrosion fatigue damage has been found on the inside of riser tubes with in the tube bend radius typically along the neutral axis of the bend
- These "cracks" often initiate at internal pitting attack locations and propagate through the tube wall

Figure from PSB-55



Typical locations for potential corrosion fatigue damage in riser and supply tube bends.

1. Riser Tubes – Contributing Conditions

- Poor water chemistry control
  - high dissolved O2 and pH excursions
- Extended service time of original tubing
- Cycling conditions
  - Repeated startups & shutdowns lead to flexing
  - Creates cyclic stresses that are highest in the neutral axis of the bends

Photo shows catastrophic tube rupture that is possible with corrosion fatigue.

Figure from PSB-55

1. Riser Tubes - Inspection

- The most effective method of detecting corrosion fatigue damage is ID video probe inspection
  - Good for initial assessment and locating
  - Does not allow for direct determining of crack depth
- Additional NDE methods utilized in determining crack depth include:
  - Radiographic examination
  - Angle beam ultrasonic inspection
- Recommend inspecting if component is over 20 years old
  - Develop an inspection cycle to inspect elbow every five years

2. Riser & Tube Attachment Fatigue & Corrosion

- Fatigue and corrosion cracking in the penthouse area of older two drum recovery boilers have been experienced in the following areas:
  - Specific tube attachments
  - Riser bends
  - Riser relief tubes
- Many of these areas are in the refractory sealed area of the penthouse and in many cases all of these areas can develop stress assisted corrosion due to waterside conditions combined with cumulative fatigue cycles.

2. Riser & Tube Attachment Fatigue & Corrosion

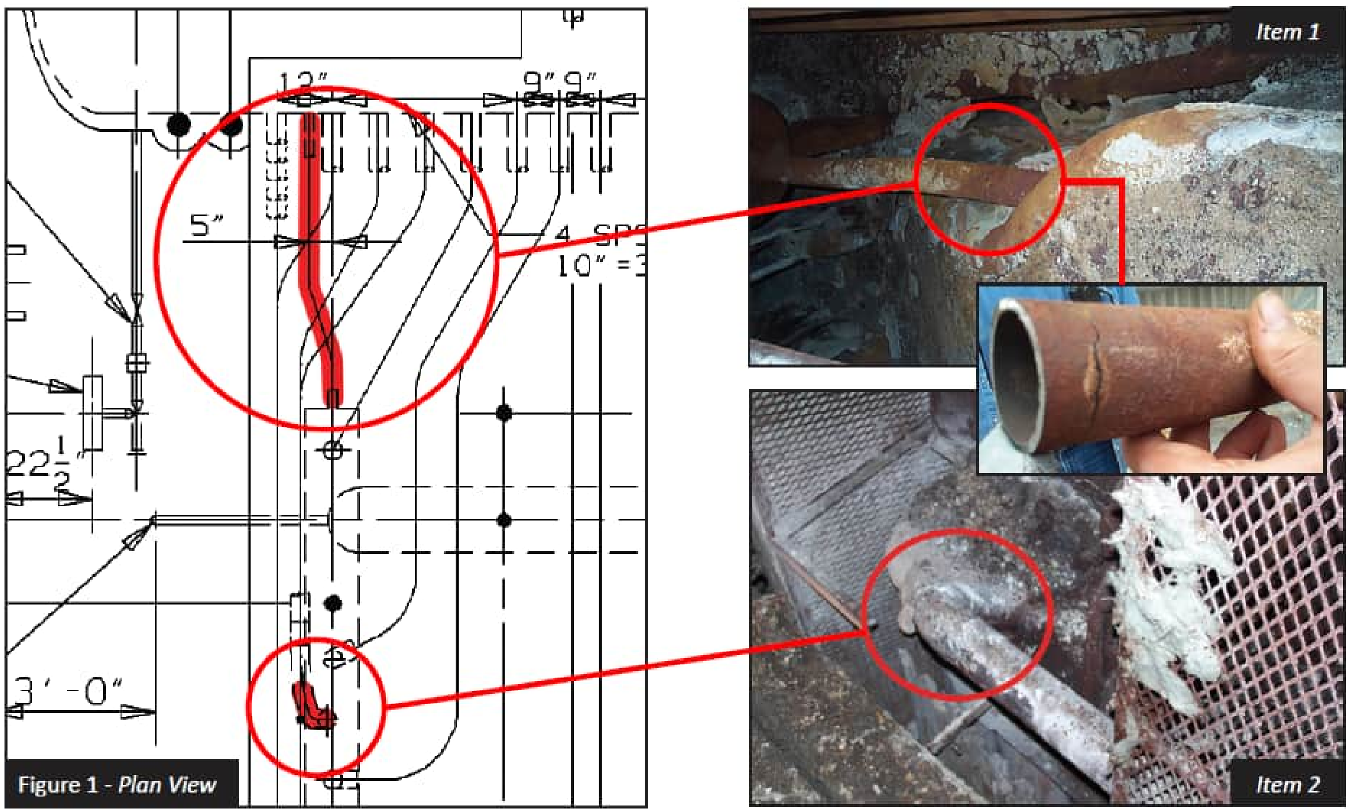


Figure 1 - *Plan View*

2. Riser & Tube Attachment Fatigue & Corrosion

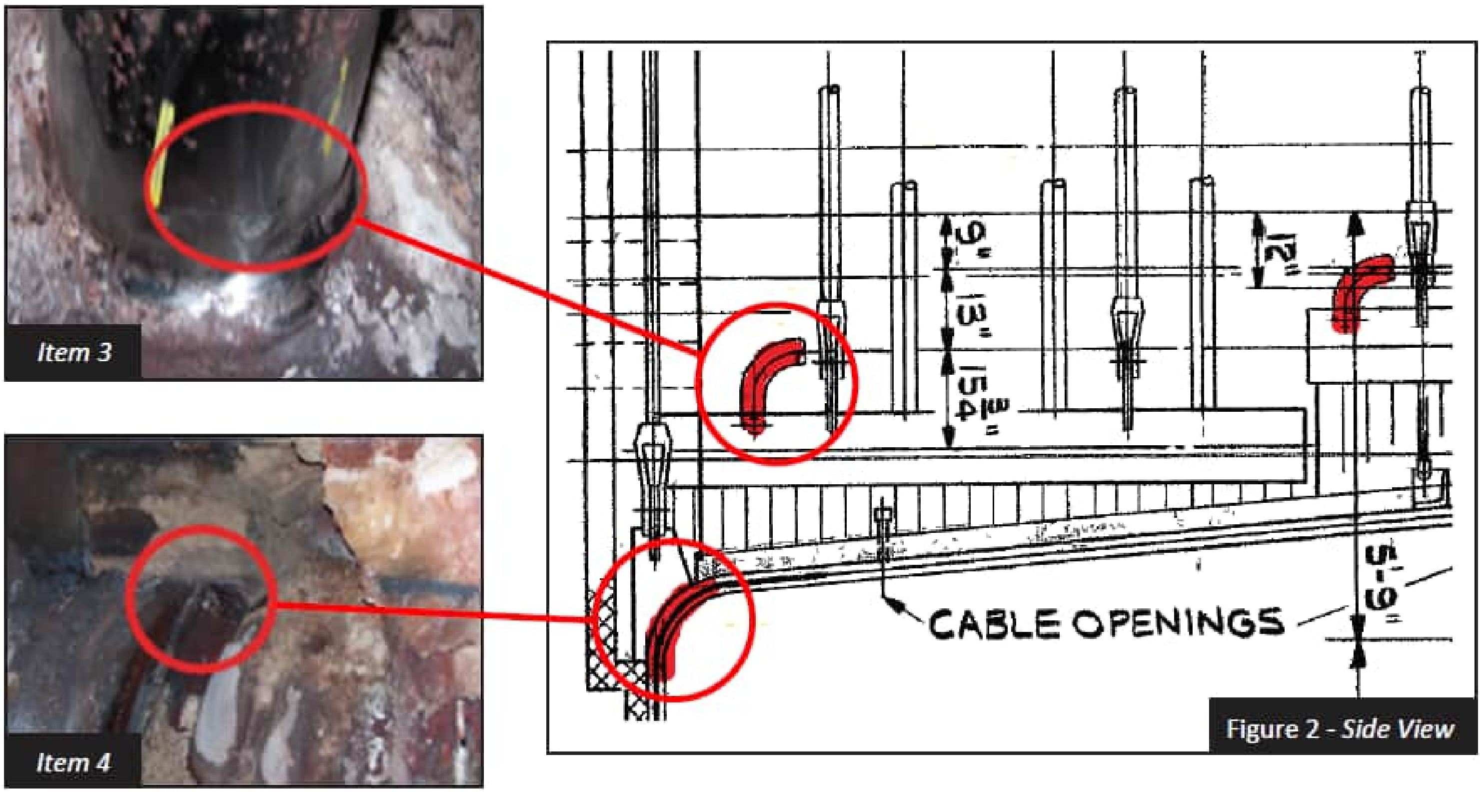


Figure 2 - *Side View*

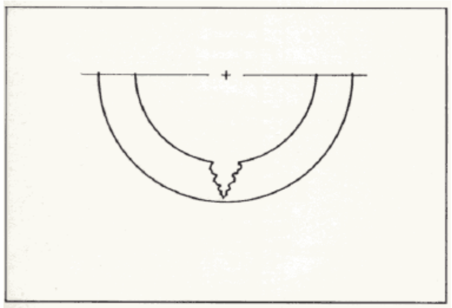
2. Riser & Tube Attachment Fatigue & Corrosion

- **Inspection**
- To date, the only proven NDE technique to prove positive detection of corrosion damage within the various discussed areas is radiographic testing

3. Horizontal Supply Tubes

- The supply tubes of older units are often be an area of concern, as these areas often do not completely drain when the boiler is drained often leading to a residual “ribbon” of fluid that can remain along the bottom of the tubes
- When left to atmospheric conditions during extended outages or extended out of service periods, corrosion and pitting can form along the 5 and 7 o'clock positions of the tube

Figure from PSB-2



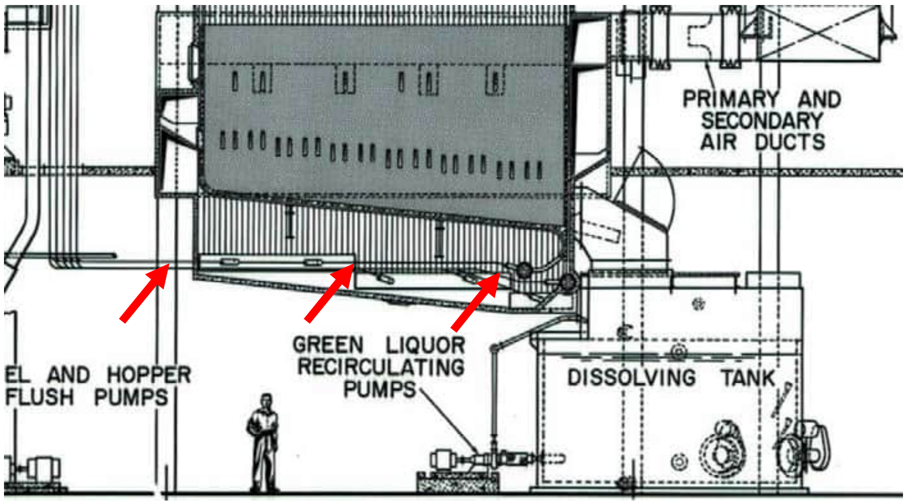
3. Horizontal Supply Tubes

- Over time this corrosion line can be caused and aggravated by the following:
  - Inadequate flushing of horizontal tubes after chemical cleaning
  - Out-of-service corrosion due to air & water exposure
  - Improper chemical cleaning
- Tubes with long horizontal runs, especially those with sagging, non-drainable and low spots should be inspected
- Supplies could be made from electric-resistance welded (ERW) material
  - Tubing: SA-178 Grade A, C, or D
  - Pipe: SA-53 Type E Grade A or B

3. Horizontal Supply Tubes

Inspection methods include the following:

- Ultrasonic flaw detection
- Radiography
- Video probe inspection
- Tube sampling
- For ERW tubes: examine the weld line via boroscope

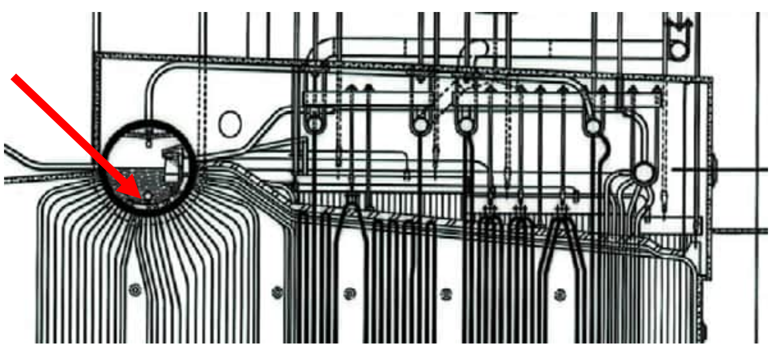


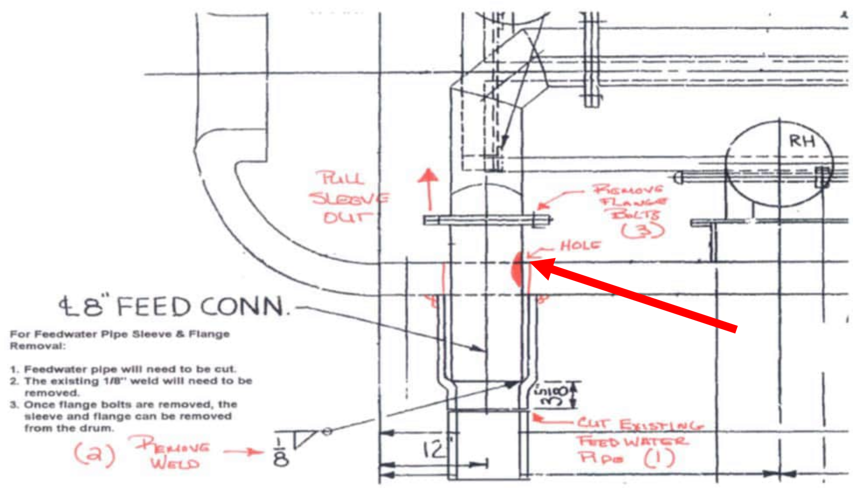
4. Feedwater Pipe Sleeve Erosion

- Due to age, older units are starting to experience feedwater sleeve pipe erosion within the thermal sleeve area of the drum.
- This can cause reduces feedwater pressure and flow through the feedwater distribution line due to perforation in this sleeve.

4. Feedwater Pipe Sleeve Erosion - Inspection

- A visual inspection of the feedwater sleeve from the inside of the steam drum. May require breaking of the feedwater flange connection inside the drum to look down and/or borosope the feedwater sleeve.





5. Rear Wall Tubes at Steam Drum Interface

- This is a particular area of Recovery Boilers is often inspected less due to salt cake buildup and or refractory and casing covering. This has resulted in a number of tube failures across multiple units.
- These areas should through cleaned during outages and the tube stub to drum interface thoroughly inspected.

6. Stress Assisted Corrosion (SAC)

- Stress Assisted Corrosion (SAC) was first identified as an issue in recovery boilers in the late 1980's.
- The most likely location for the internal corrosion and cracking is where an exterior circumferential weld is used to support attachments to the furnace wall tube.
  - Scallop bars used to for floor seals, windboxes and wall boxes in the lower furnace were common locations.
  - Recent inspections on older boilers have found SAC at access door wall boxes in the upper furnace where scallop bars are welded to the furnace tubes to support the wallbox attachment.

6. Stress Assisted Corrosion (SAC)

- While most cracking has been found at circumferential welds, some cracking has been found at vertical welds with larger throats.
- Radiographic examination is the only technique that can accurately detect this internal corrosion cracking.
- Newer boiler designs have changed attachment methods to minimize SAC
  - Use of filler bars instead of scallop bar

6. SAC at Tube Wall Attachments

Figures from PSB-29

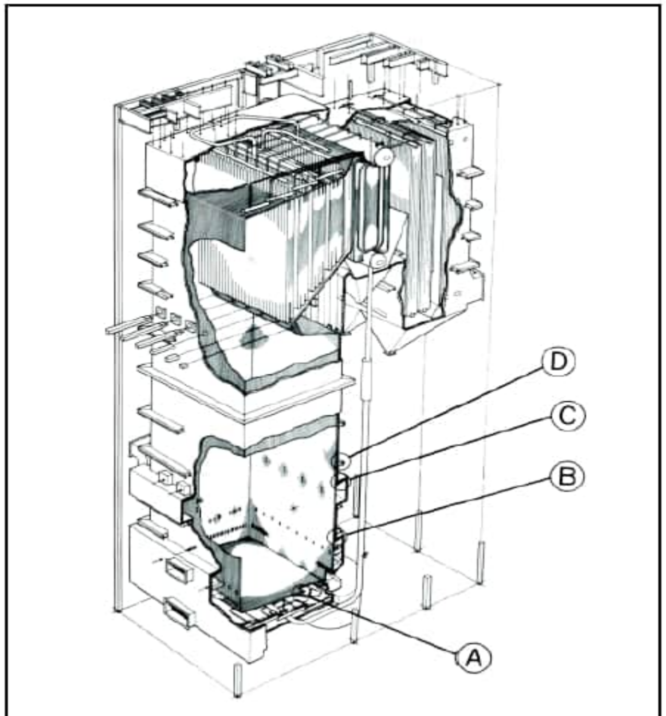


Figure 1: Welded locations where damage has been found.

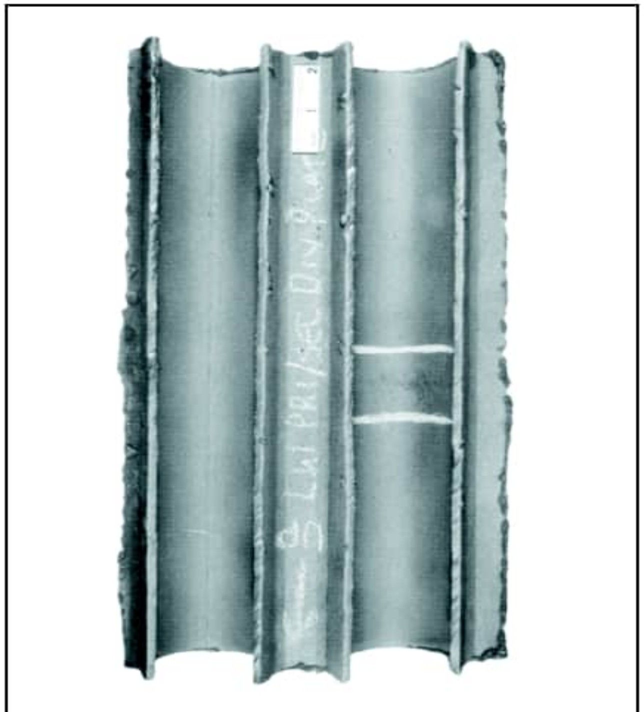
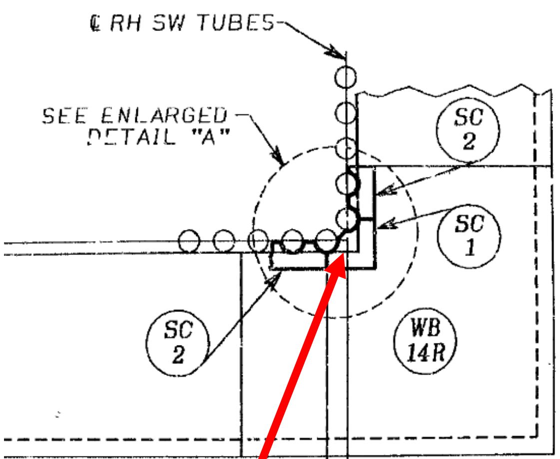
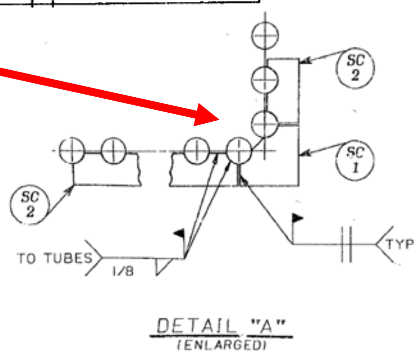


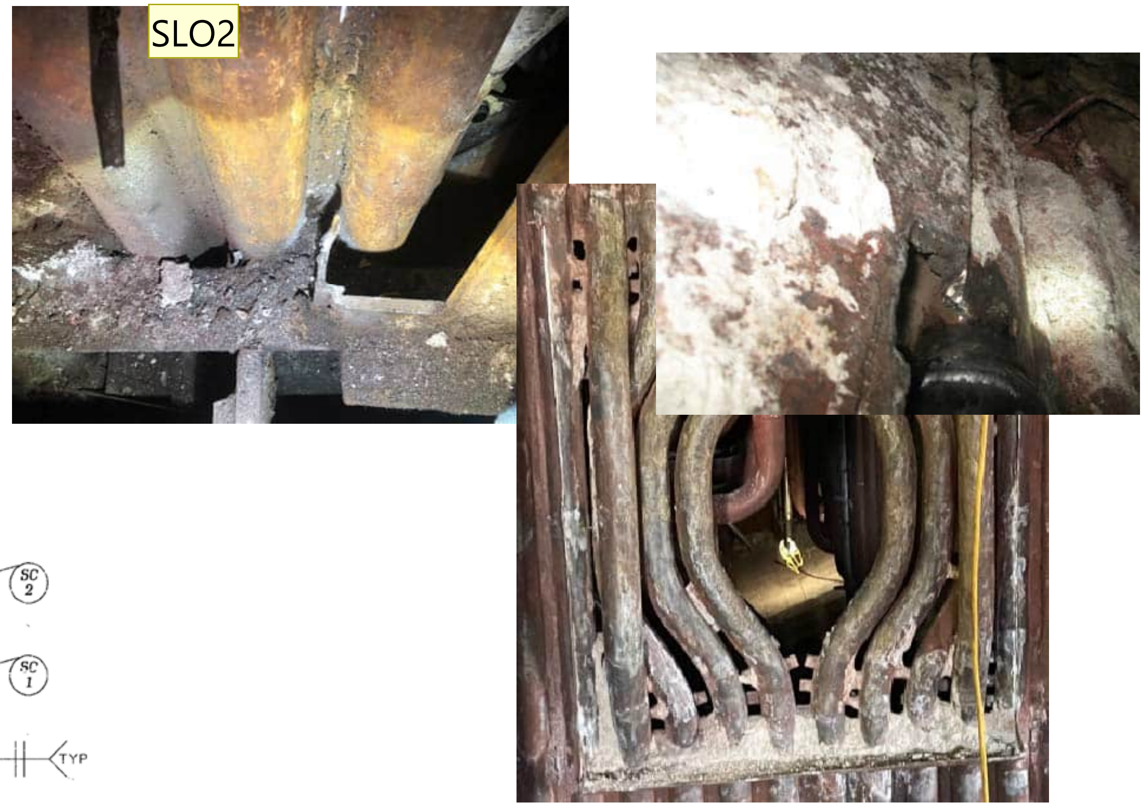
Figure 2: Left sidewall primary/secondary division plate – waterside surface corrosion.

6. Stress Assisted Corrosion (SAC)



Old Scallop Bar Design





Slide 21

SLO2 Osborne, Steve L, 2/1/2024

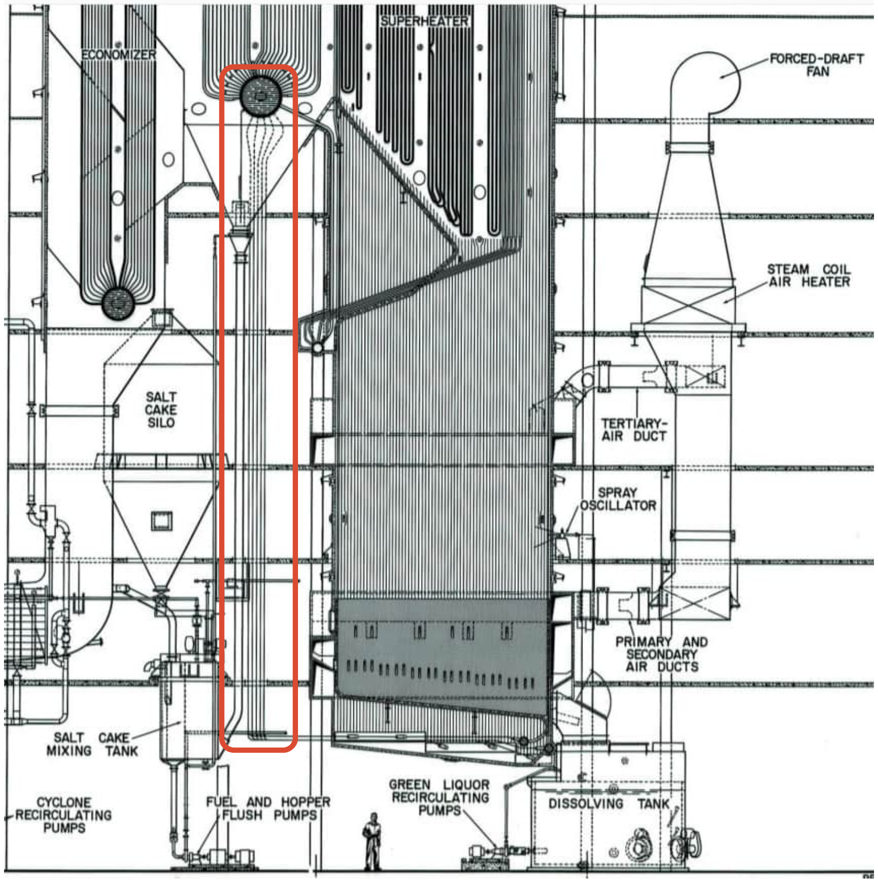
7. External Downcomers

- Recovery boilers built before 1970 used multiple 4” OD tubes from the mud drum down to the lower furnace headers as supply tubes
  - Newer boilers use one large downcomer on each side of the mud drum
- These multiple supply tubes are often forgotten during major maintenance outages for lower furnace panel replacement
- Small diameter tubes are grouped in bundles which make inspection challenging

7. External Downcomers

- From the mud drum, a borescope inspection of the entire tube length at regularly scheduled intervals is recommended.
  - Look for any potential indications – linear, red oxide deposits
  - If indications are identified – Additional NDE performed to determine severity (UT, RT)
- Smaller diameter downcomers could be made from electric-resistance welded (ERW) material
  - Tubing: SA-178 Grade A, C, or D
  - Piping: SA-53 Type E Grade A or B
  - Boroscope inspection and examine the weld line
- Check for cold side corrosion and verify the minimum wall
  - Ultrasonic Thickness Testing – IRIS, conventional thickness, corrosion scanning, etc.

7. External Downcomers



PSB & TSB listings

- PSB-2: Out-of-Service Corrosion Failure of Horizontal Downcomer, Supply, and Riser Pressure Part Connections
- PSB-29: Stress-Assisted Corrosion: Boiler Waterside
- PSB-55: Corrosion-Fatigue Failures of Riser Tube Bends
- TSB - Riser and Tube Attachment Fatigue and Corrosion: Location and Evaluation Experience - 2006

Additional Information

- PSB-58: Care Management and Maintenance of Older Boilers
- BR-1635: "Boiler Fitness Survey for Condition Assessment of Industrial Boilers
- BR-1701: Standard Recommendations for Pressure Part Inspection during a Boiler Life Extension Program

PSB's & TSB's

- To obtain copies of the PSB and/or TSB's mentioned in this presentation please visit:
  - https://www.babcock.com/home/about/resources/plant-and-technical-service-bulletins/
- Or you can contact your local B&W Field Engineering Services office

Questions?

Boiler Diagnostics Systems

Enhancing Recovery Boiler Leak Detection with Measurements

Travis Conner

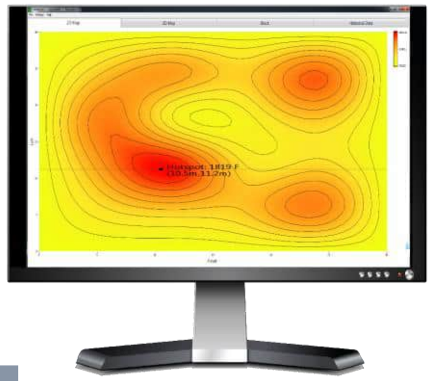
Solution Manager • AS NA Solutions Management

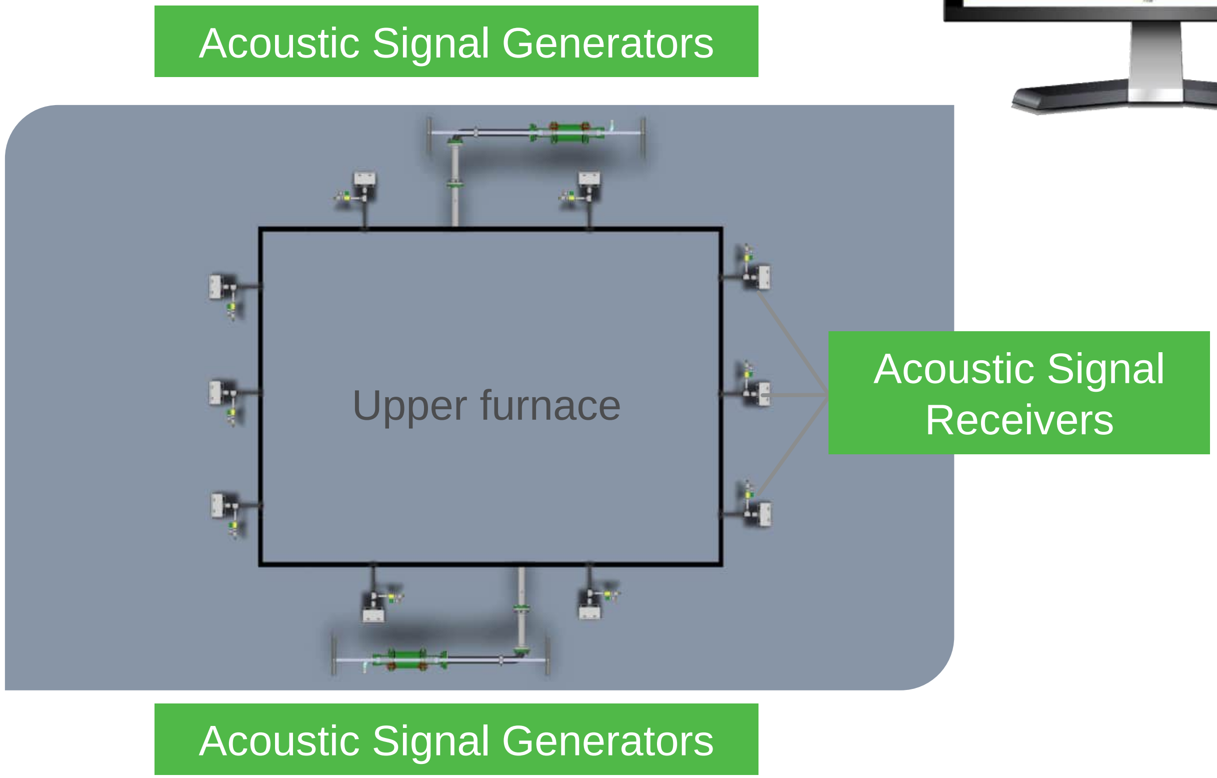
Start audio call Start chat Send email

Combustion symmetry measurement for recovery boiler

Valmet Acoustic Pyrometer

- **Liquor carryover**
- **Flue gas temperature profile and symmetry**
- **Absolute flue gas temperatures to superheaters**
- **Immediate leak detection**





Recovery Boiler Tube Leak Detection

- Automatic leak detection systems
  - Steam/Feedwater chemical and mass balances
  - Indicators such as furnace pressure, ID fan speed, drum pressure, drum level, flue gas temperature, etc

- Most recovery boiler leaks are detected during operator walkdowns or require confirmation of the leak and leak location by operator inspection
  - Listening for change in noise in furnace, visual inspection, observation of smelt bed

- Ideally a leak detection system will eliminate the hazard:

1. Detect and locate small growing leaks reliably before they become large leaks and cause a hazard
2. Detect and locate large sudden leaks fast and reliably
3. Display concentrated information to the operator for fast decision making in critical conditions as well as provide detailed timely information for further analysis all from the safety of the control room

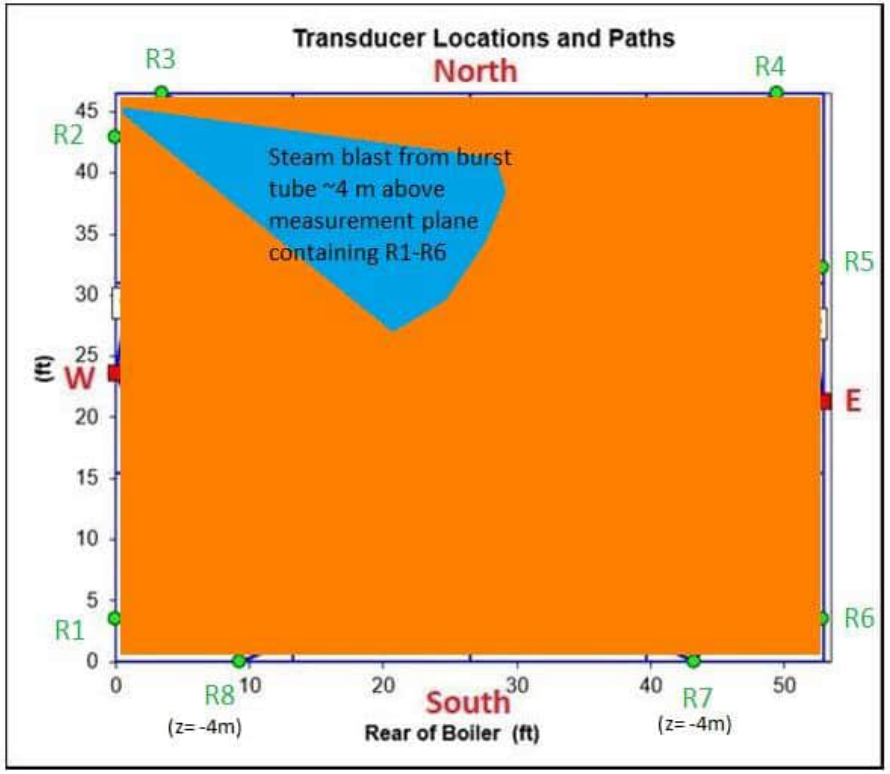
Our Solution

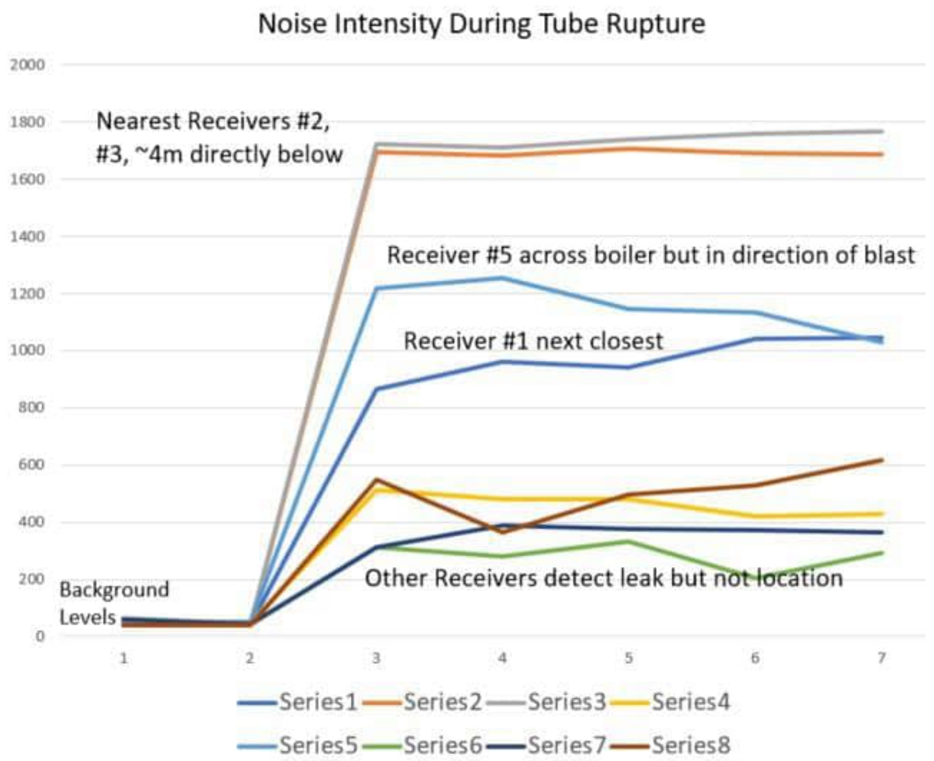
Acoustic Signal Receivers with signal processing computer and Modbus TCP/IP connection for DCS communication

- Provides analog output
  - Current solution allows operators to manually identify the leaks and take appropriate actions
  - DCS integration possible
- In addition to big leaks, able to detect **small to moderate leaks** undetected by other solutions
  - Other solutions can detect big leaks, however, fail to detect small to moderate leaks which can continue for hours before the leaks become bigger
- **Able to provide an approximate location of leak** based on receiver readings
  - For instance: leakage occurring at North-West corner

Valmet

Leak Detect Case Study





What Happened (as determined by later investigation)

Around 5:02:36 AM +/- 30 seconds, a water-wall tube burst about 4 m above the sensing plane (just above the bottom of superheaters) in the NW corner of the boiler. Even though the leak was large enough to force the boiler to shutdown or potentially go into an unstable operating condition, it took operators 15 minutes using other boiler data to realize there was a problem and implement a controlled shutdown. During these 15 minutes the boiler suffered additional damage and added additional risk personnel that that may have been working in the area.

What Valmet Leak Detection sensed.

At 5:03:05 AM the system recorded a massive increase in the noise levels on all system sensors. The nearest sensors were near their max and at equivalent levels suggesting, immediately that there was a large steam leak nearby and between sensors #2 & #3 (either above or below). Even across the boiler and 4 m below the main sensing plane (8 m below leak) sensors #7 and #8 measured a factor of 10 higher noise levels at this time. If the Leak Detect system would have been connected to the DCS, 14 minutes of damage and risk could have been avoided.

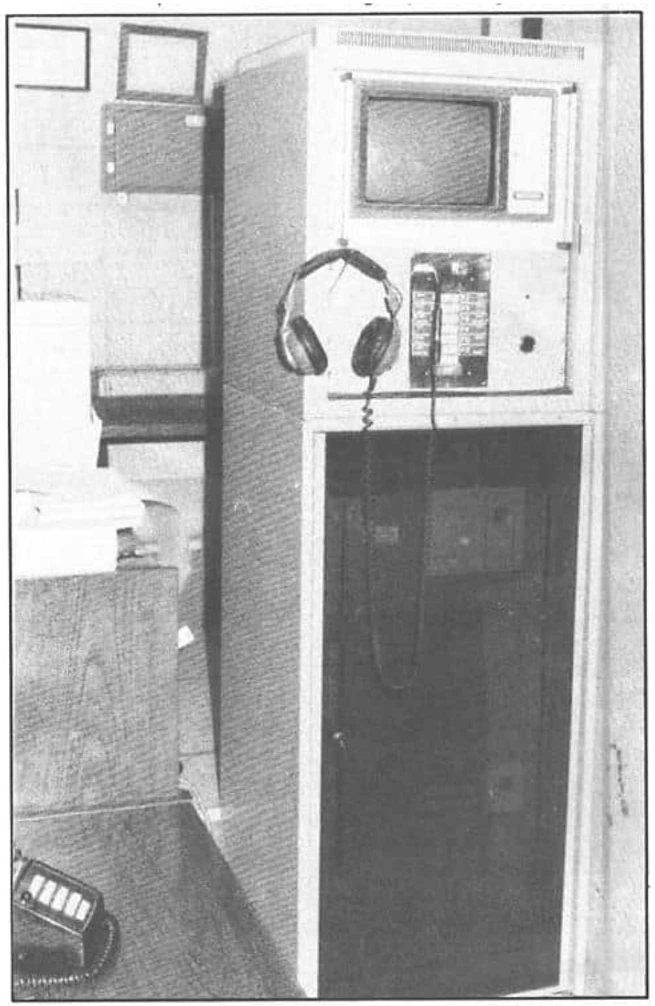
Valmet

Past Attempts on Recovery Boiler

Initial Issues:

1) Custom hardware needed for system architecture did not allow system to be flexible
2) Circuitry available at the time couldn't handle data from all 8 sensors quickly enough
3) System was not easily accessible by operators

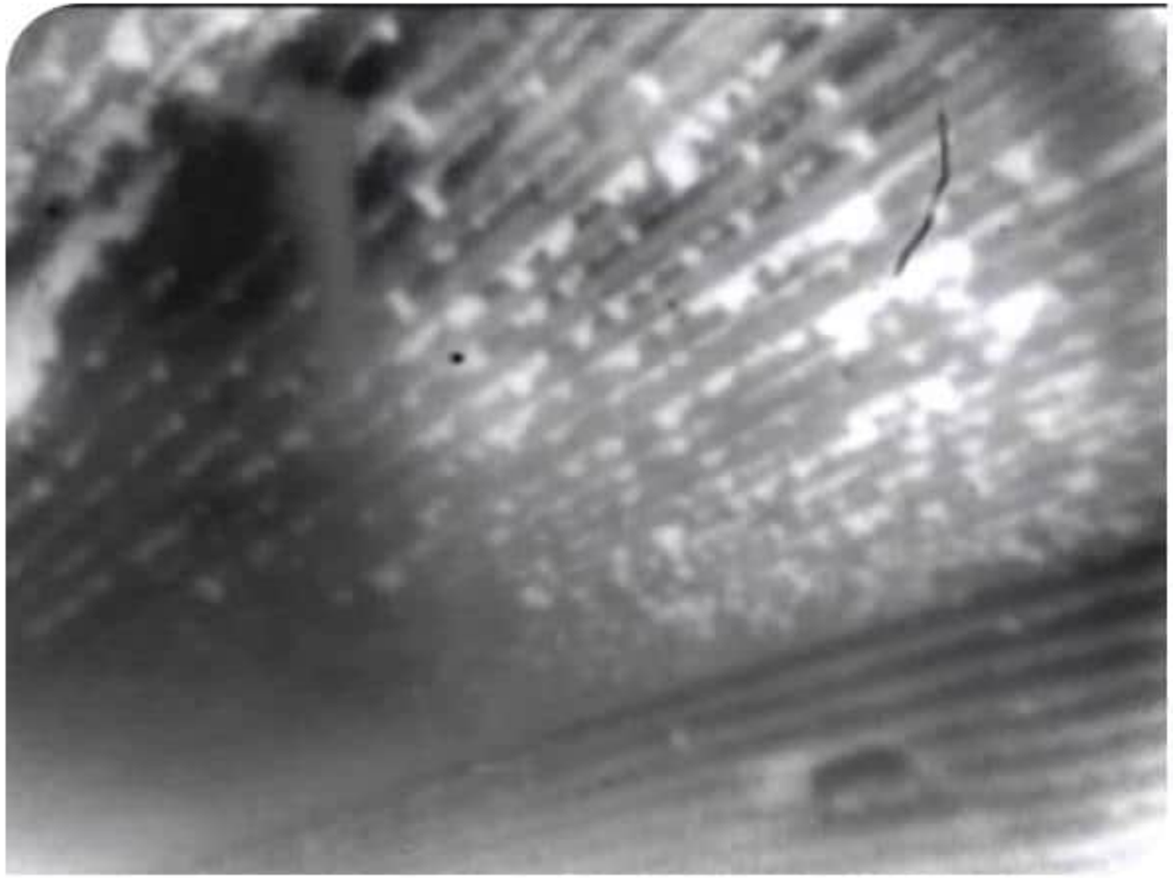
TAPPI Journal July 1990

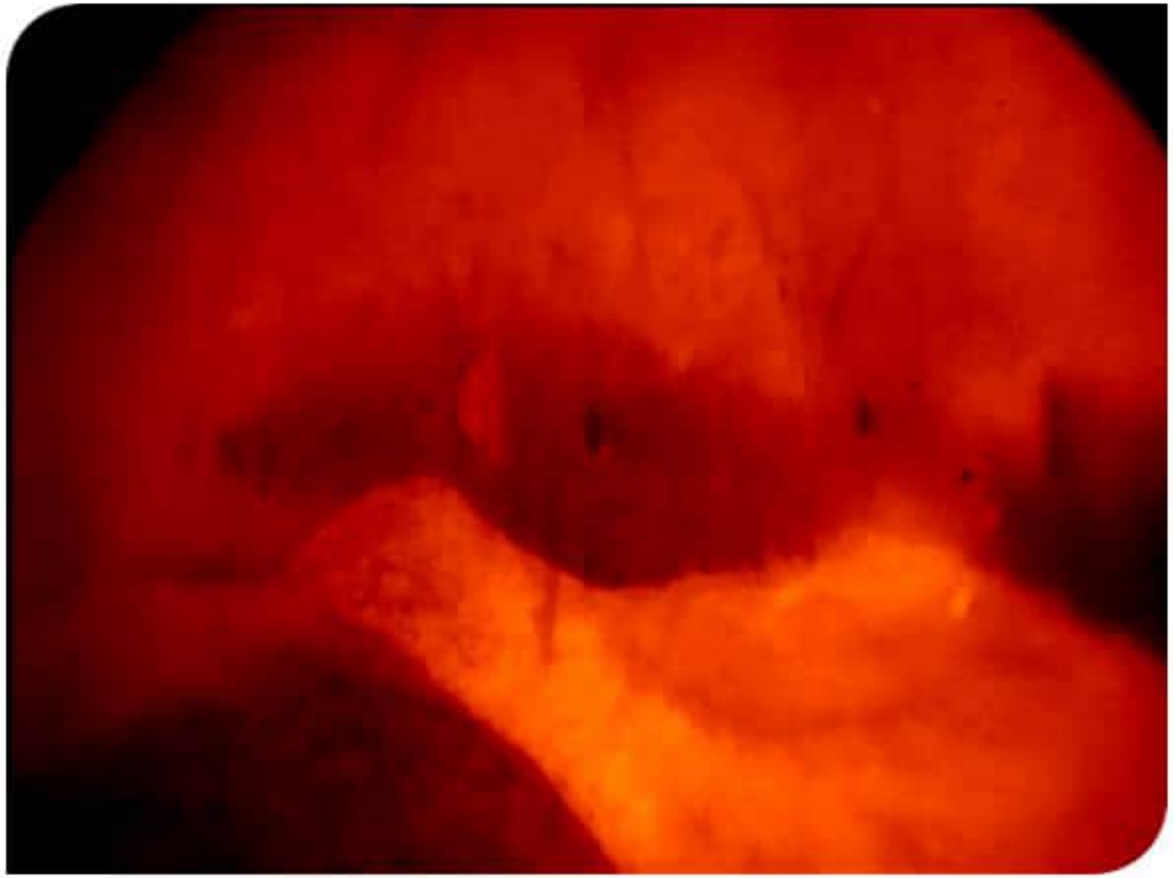


Valmet

Issues to Overcome

1) Sootblowing is more frequent on recovery boilers: resolve with sampling frequency
2) Acoustic method is not effective below liquor guns: cover with bed camera

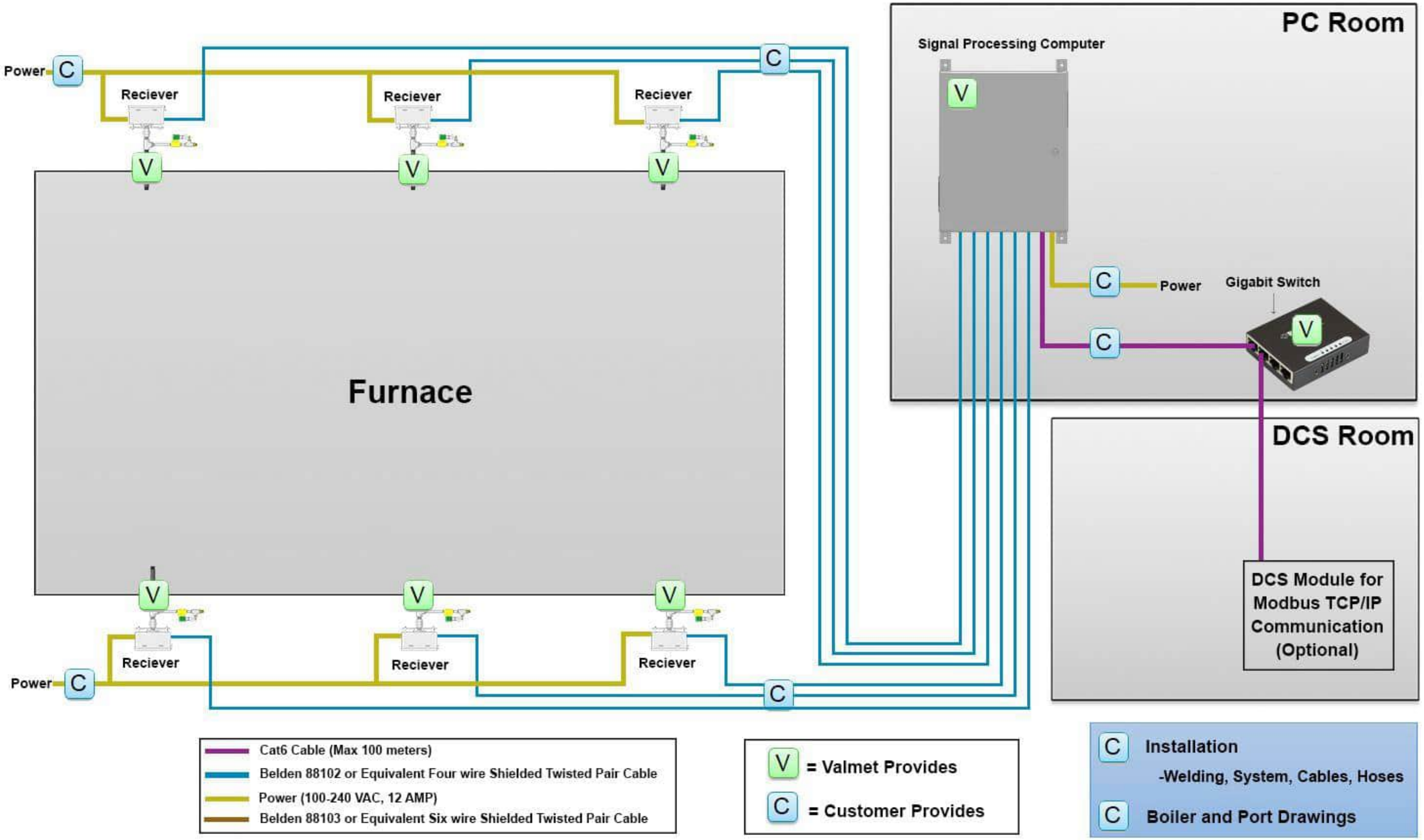




Valmet

Installation Requirements

Example Set-up

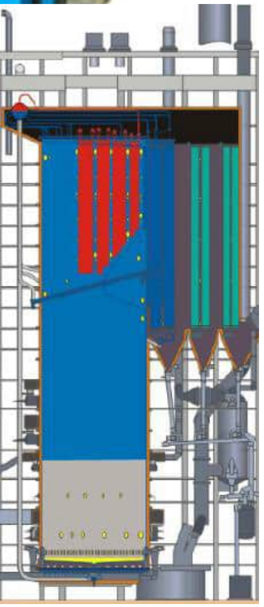


Questions

- Travis Conner, 757-902-0929, travis.conner@valmet.com
- Chad Cheney, 682-306-0876, chad.cheney@valmet.com

Valmet

FORWARD



Recovery Boiler Optimization Technologies:
Software, Hardware, and Data Benchmarking

AF & PA Recovery Boiler Conference

February 6 - 7, 2024

Wenli Duo

FPInnovations

Vancouver

Thunder Bay

- World’s largest not-for-profit forest institution in R&D, tech transfer
  - 100 years old
- New techs for P&P industry, e.g.
  - Cellulose Nano-Crystallites
  - Kraft Lignin Precipitation
  - Cellulose Filaments
- Expertise, e.g.
  - Wood fibre supply
  - Pulp, paper, biomaterials
  - Biomass energy
  - Decarbonization
  - **High temperature processes**

Montreal

Quebec City

Thermochemical Processes

- FPInnovations Collaborates with Pulp-Paper Mills on
  - Chemical Recovery Boilers
  - Biomass Power Boilers
  - Lime Kilns
  - Biomass Gasifiers, Pyrolyzers, Hydrothermal Processes, etc.
- Developed and Applied Boiler Optimization Technologies
  - Methodology
  - Software, Hardware, and Data Benchmarking
  - Measurements on industrial boilers during combustion operation at P&P mills
  - Case studies – problems and solutions

Side Topic: Biomass Power Boilers and Lime Kilns

Part of the technologies for recovery boilers also applicable elsewhere

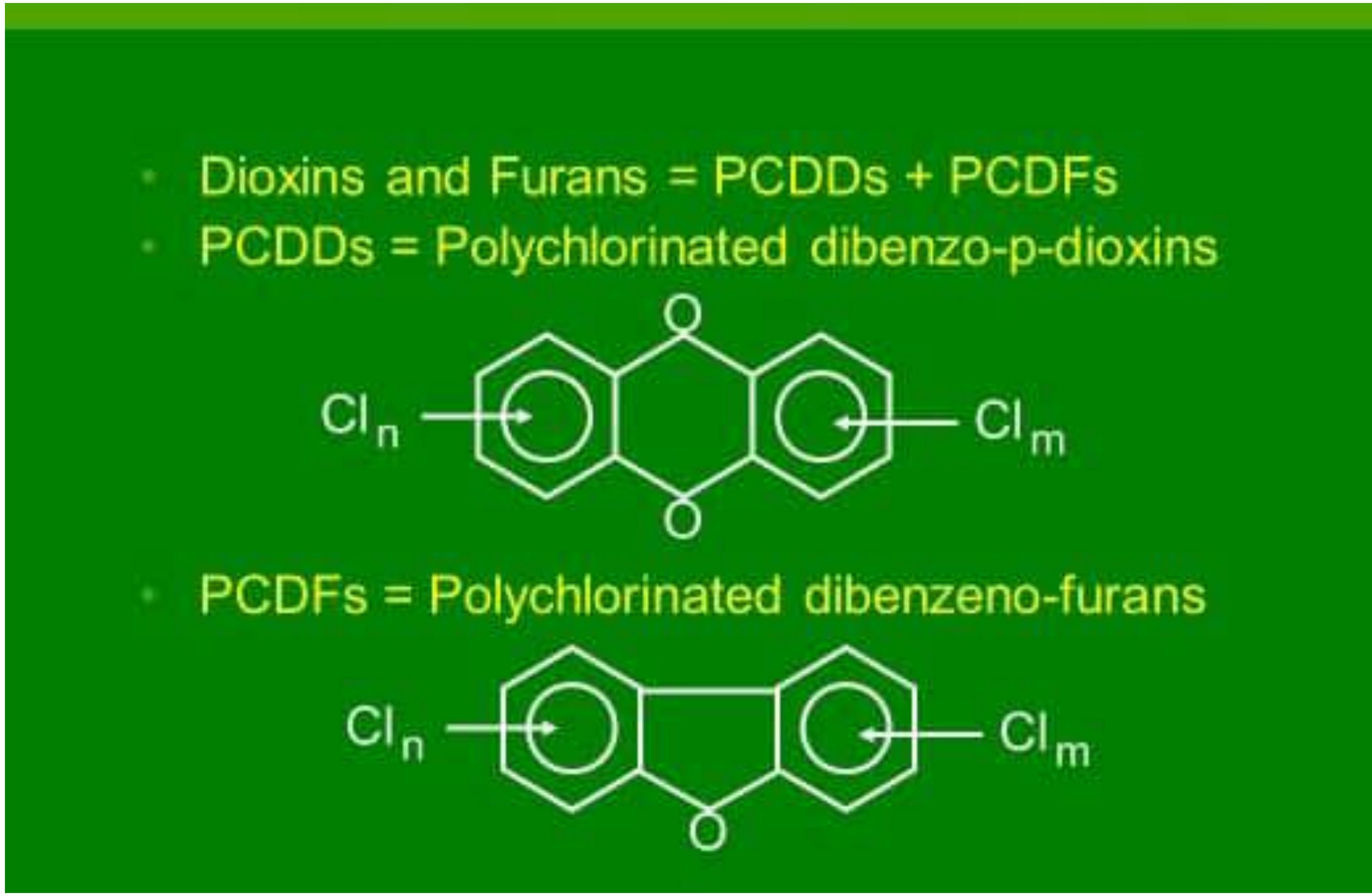
- Benchmarking of lime kiln design and operation data
  - Comprehensive data survey via questionnaire with 200 questions
  - Received data for 90% of the lime kilns in Canada
  - Big database for lime kiln decarbonization and process digitalization
- Optimization of biomass power boilers for more bioenergy
  - Improving fuel and air systems
  - Flue gas emission monitoring and reduction
- Research and development of industrial solution to lower dioxin-furan formation and emissions
  - Biomass boiler burning chloride-containing hog fue
  - Biomass boilers burning plastic-containing demolition waste

Control of Dioxin and Furan Emissions from Biomass Boilers

PCDD/Fs

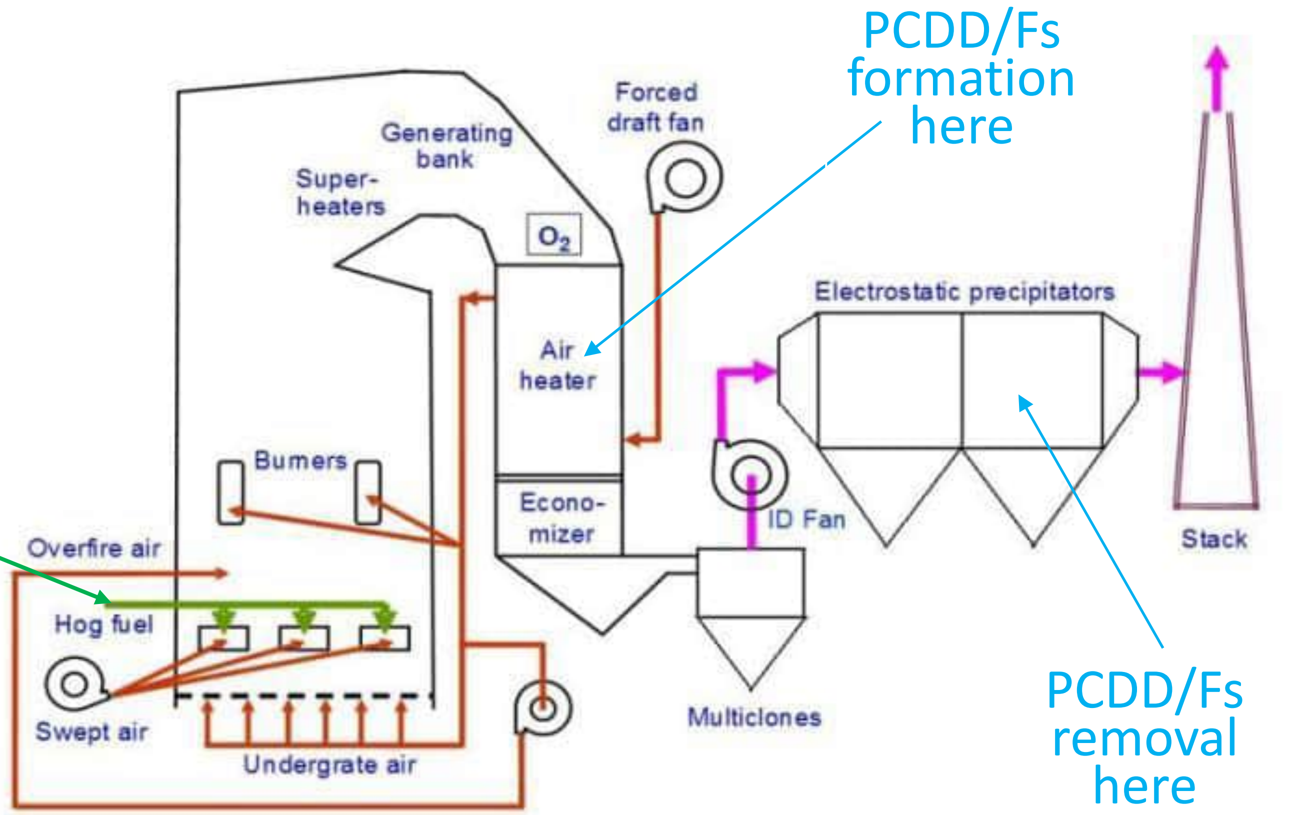
- Can be formed in boilers burning biomass containing Cl
- Very special and extremely toxic
- Stringent permit
  - on the order of 10^{-9} g TEQ/m^3

Chlorinated dioxins and furans (PCDD/Fs)



Example of Salt-Laden Hog Fuel and Power Boiler in Coastal BC

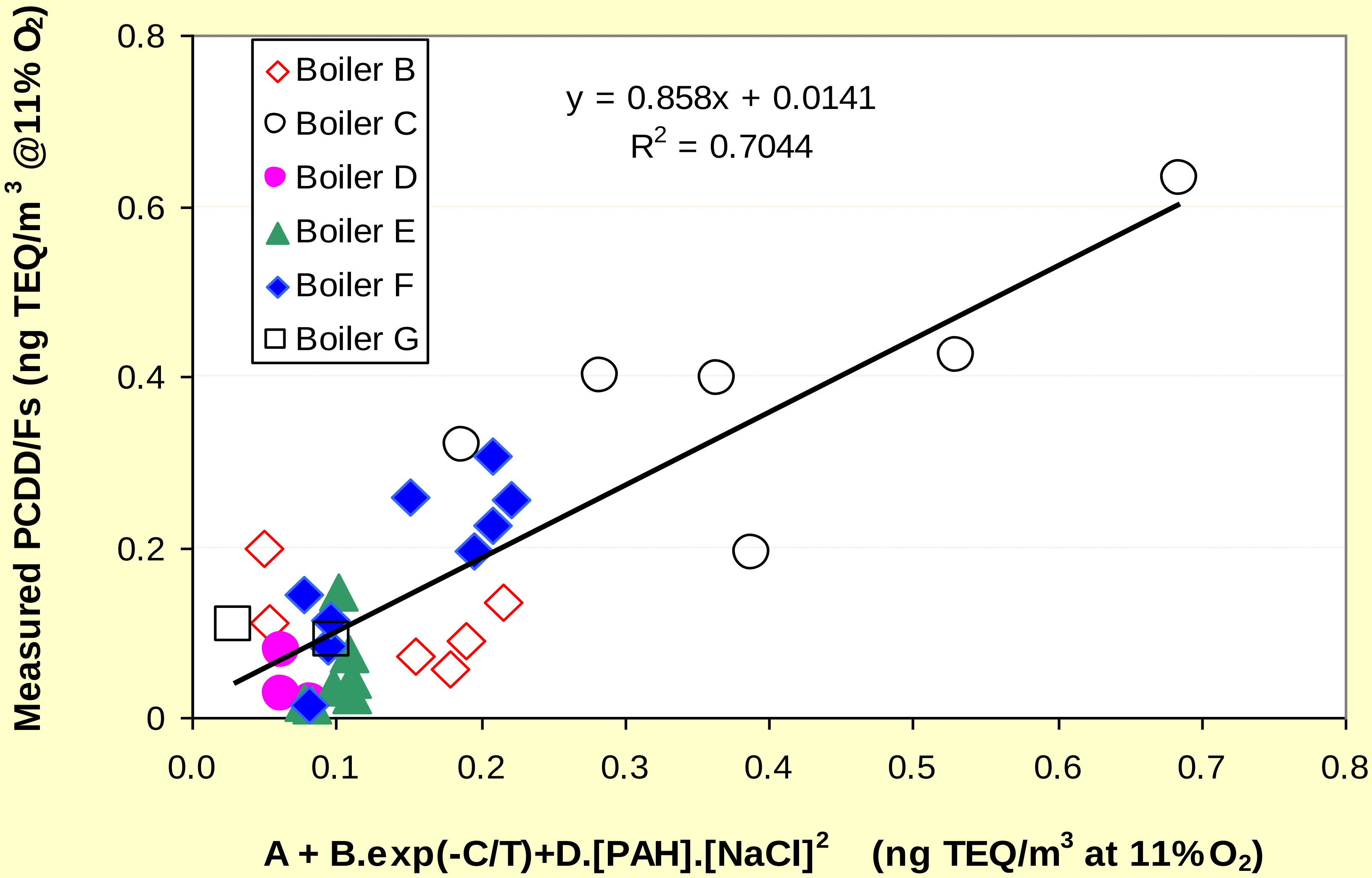
Fluidized-bed sand and hog fuel piles



Bubbling fluidized bed biomass boiler

Inter-Mill Data Correlation of Boiler Stack Emissions

- Our model for dioxin formation and emissions
- Data from 6 salt-laden hog fuel power boilers in British Columbia (BC) with ESP
- Control measures (T, [Cl], etc.) following the model reduced dioxin emissions in BC by 68%



A,B,C,&D are fitted parameters; T is temperature in K;

PAH is HMW PAHs in stack in μg/m^3; NaCl is in % of hog

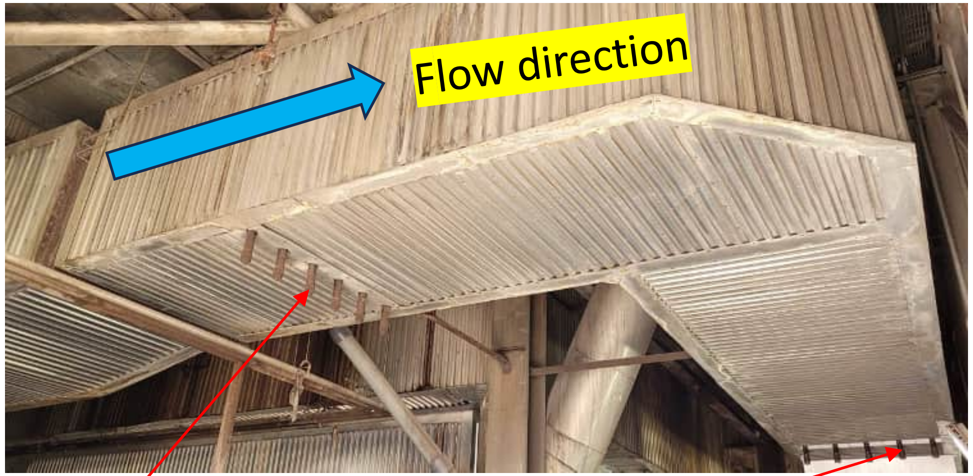
Main Topic: Recovery Boiler Optimization Technologies



- Need for recovery boiler optimization or Problems to deal with
  - How to increase black liquor firing rate
  - How to reduce carryover and ash deposits
  - How to avoid or minimize boiler pluggage and reduce unscheduled shutdowns
  - How to meet the emission permits or GHG target
    - H_2/TRS, PM (opacity)
    - SO_2, NO_x, CO
    - CO_2, i.e., minimize fossil fuel usage
  - How to increase sulfur reduction efficiency
  - How to minimize burnout of e.g. smelt and air ports, liquor nozzles, etc.
  - How to prevent accidents, including black out
  - Bad incidents occurred after some boilers were upgraded
  - Most mills wish to increase RB thermal efficiency, while some wanted to decrease it.

Two-Phase Approach to Recovery Boiler Optimization

- Phase-1, Learn to understand and prepare for boiler tuning
  - Send a questionnaire to the mill for design & general operation data and sample analysis results
  - Review, analyze, and incorporate the data in benchmarking
  - First mill visit to prepare for boiler optimization trials
    - Find if suitable ports for measurement and sampling are available on air, flue-gas and ash ducts
    - If not, identify suitable locations for new installations
    - Determine how many ports are needed and where exactly they should be installed based on the duct dimensions
    - Suggest what the mill should prepare for trials in our second mill visit



6 existing air-flow measurement ports

5 new air-flow measurement ports

- Phase-2, Optimization trials
  - Conduct measurements on running recovery boiler for baseline evaluation
  - Adjust operating parameters for RB optimization trials
  - Conclusions and recommendations

Software Developed to Standardize Installation of Sampling Ports on Air Duct for Flow Measurement

Calculate

- how many measurement taps are needed and
- where exactly they should be installed.

Go to Sheet "DuctData" to type in duct description and dimension information; then come back and

Click the following "Package" to start calculation

Package

Software Developed to Generate Forms for Flow Measurement in Air Duct Using Pitot Tube and Flowrate Calculation

Forms show how

- How many traverses for the pitot tube in each port and where to stop inside the duct

Forms also contain

- Calculating equations

Go to Sheet "DuctData" to type in duct description and dimension information; then come back and

Both "DuctData" and "Existing Ducts" spreadsheets must be present in this E

However, the "Existing Duct" spreadsheet can be empty or anything there

Click the following "Package" to start calculation

Package

Company =	AF&PA				Barometric Pressure (kPa) =			
Mill =	Atlanta, GA				Air Static Pressure (inH2O) =			
Facility =	RBs				Duct Air Temperature (°C) =			
Date =		Ref Date = ########			S-Pitot Coeff =			
Start time =					Actual Velocity (m/s) =		#DIV/0!	
End time =					Air Volume Flow (m3/h@25°C) =		#DIV/0!	
					Air Mass Flow Rate (MT/h) =		**#DIV/0!**	
Duct =	**PA Substream ducty to F**				Duct X-Sectional Area (m2) =		2.230	
		Velocity Pressure (ΔP), inH2O				**Average ΔP =**		inH2O
Ports on Longer side		Port - 1	Port - 2	Port - 3	Port - 4	Port - 5		
Stop - 1 at 0.152 m or 6.0 in	Reading - 1							
	Reading - 2							
	Reading - 3							
	Reading - 4							
	Average	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
Stop - 2 at 0.457 m or 18.0 in	Reading - 1							
	Reading - 2							
	Reading - 3							
	Reading - 4							
	Average	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
Stop - 3 at 0.762 m or 30.0 in	Reading - 1							
	Reading - 2							
	Reading - 3							
	Reading - 4							
	Average	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
Stop - 4 at 1.067 m or 42.0 in	Reading - 1							
	Reading - 2							
	Reading - 3							
	Reading - 4							
	Average	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
Static Pressure, inH2O								
Air Temperature, ºC								

FPInnovations

Software - Survey of Design and Operating Data

- Part of the questionnaires for

Design and upgraded data

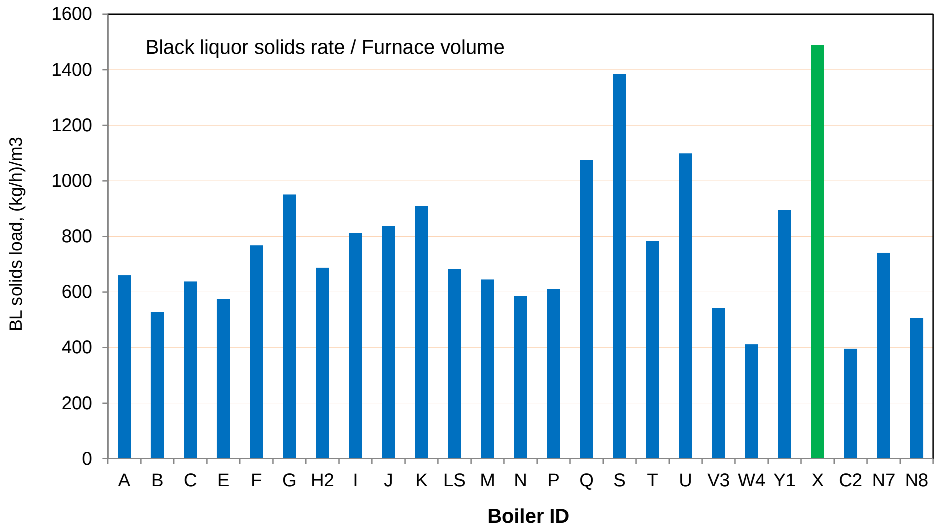
	Information Needed for Optimizing Chemical Recovery Boilers (RB) by FPInnovations		
	Company Name, Mill Location (City, Province/State, Country) If your mill has more than one RBs, fill in Sections 2, 4 and 5 for each RB.		
1. Mill Information			
	Products (Bleached/Unbleached Kraft Pulp, Dissolving Pulp, Sulfite Pulp, TMP, Paper, Tissue, Packaging, Tall oil, Terpentines, Lignin, Methanol, Sugars/derivatives, Methane/Biogas, BioOil, CO2, etc. List one or more)		
	Main product -1 (Product and annual tonnes)		
	Main product -2 (Product and annual tonnes)		
	By product -1 (Product and annual tonnes)		
	By product -2 (Product and annual tonnes)		
	Co-Generation of electricity (yes or no)		
	Installed Power Generation Capacity		
	Steam Turbine (Back pressure and/or condensing?)		
	List all the boilers OTHER than the present one as described in the following		
	Type of fuel used in (each) OTHER boiler (e.g. black liquor, bark/biomass, coal, oil, natural gas, etc.)		
	Steaming rate for (each) OTHER boiler		
	Steam temperature and pressure for (each) OTHER boiler		
2. Description of Black Liquor and Recovery Boiler Systems			
No.	Recovery Boiler Characteristics	Data	Unit (if applied)
1	Boiler name (called by mill staff)		
2	Boiler Maker and Type (One or two drums, decanting, sloping, etc)		
3	Year of installation		
4	Original max steam rating		
5	Upgrading history (what, when and by which company?)		
6	Current max steam rating (MCR)		
7	Design max steam temperature		
8	Design max steam pressure		
9	Does the boiler have screen tubes		
10	Fuel for burners		
11	Are NCGs burned (DNCGs/CNCGs/SOGs) and where introduced (e.g. with tertiary air)?		
12	How many air levels		
13	How many FD Fans		
14	Pollution control device (ESP or scrubber, or both)		
15	Where is ID Fan located (e.g. before or after ESP)?		
16	Are there (how many) sampling (or observation) ports on the front wall at bullnose level?		
17	Boiler width (Internal Left to Right wall)		
18	Boiler depth (Internal Front to Rear wall)		
19	Height from the floor of the boiler to its bullnose		
20	Height from the floor of the boiler to its ceiling/roof (not boiler housing ceiling)		
21	Boiler design throughput (dry solids rate)		
22	Boiler design hearth heat release rate (indicate LHV or HHV)		
	Black Liquor Processing System	Data	Unit (if applied)
23	**Attach analysis for chemical composition of as-fired black liquor if available**		
24	% of pulping feedstock from soft wood		
24	REA of black liquor		
25	Where is sample for REA taken?		
26	How is REA of as-fired black liquor adjusted?		
27	Type and Number of Effects of black liquor evaporators		
28	Type and number of bodies of Concentrator(s)		
29	Is Direct contact evapoator used and what type?		
30	Direct or indirect heater for as-fired black liquor ?		
31	Is salt-cake added, or how to make up Na and S?		
	Current (Typical) Recovery Boiler Operating Data	Data	Unit (if applied)

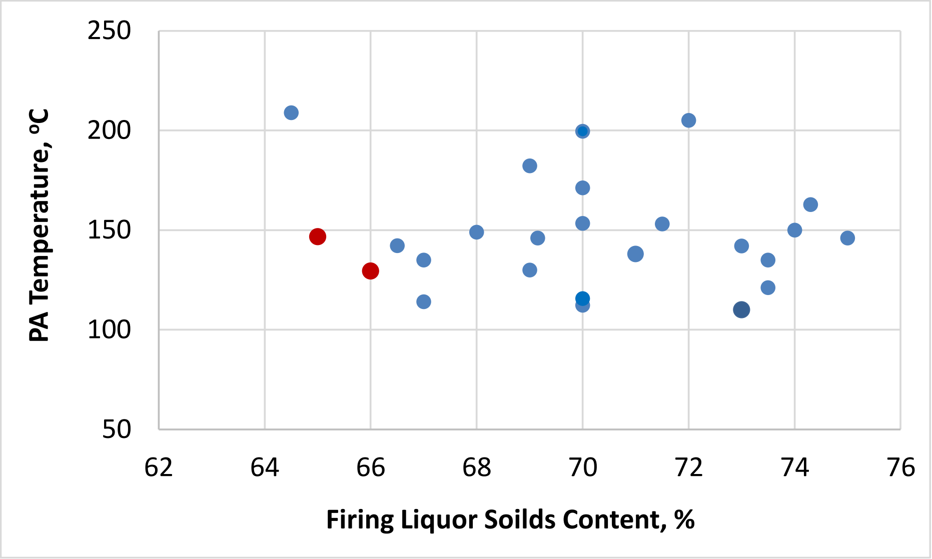
DCS operating data

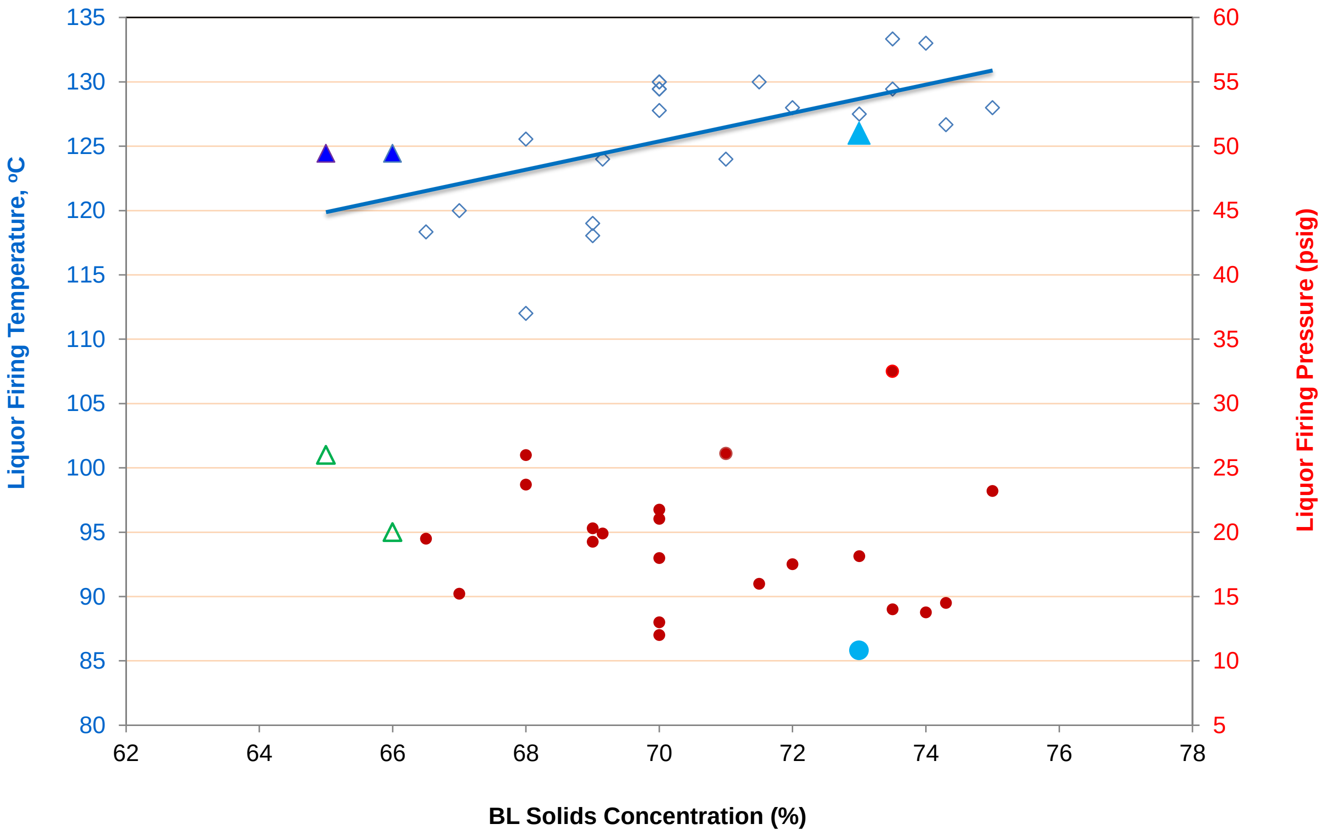
Time	Digester Pulp Production	White Liquor Sulfidity to Digester	%AA/wood	REA	BLiquor flow into furnace	As-fired BLiquor solids		BLiquor Temp.	BLiquor header Pressure	soap flow	PA flow	PA Pressure	Right Wall SA Flow	Right Wall SA Pressure	Left Wall SA Flow	left Wall SA Pressure	TA Flow
	(t/d)	(%)	(%_	(%)	(l/min)	(%)	(%)	(°C)	(kPa)	(l/min)	(m^3/min)	(kPa)	(m^3/min)	(kPa)	(m^3/min)	(kPa)	(m^3/min)
1/1/2017 0:00	713.7651978	30.2000008	18.2999992	8.39999962	670.520203	68.7397766	68.0490417	121.541924	115.474396	0	1392.654	0.963406384	696.1548462	2.353466511	695.1401367	2.368495226	428.5903931
1/1/2017 1:00	724.461853	30.7000008	18.2999992	8.89999962	678.713257	68.7029419	67.9894028	121.063667	117.096779	0	1393.23	1.019510388	689.5253906	2.357979774	693.8616333	2.333436251	425.311615
1/1/2017 2:00	708.3603516	30.7000008	18.2999992	8.89999962	598.008484	68.5823135	67.9297638	121.093971	100.718681	0	1389.288	1.017443538	694.7581787	2.326250076	696.3048096	2.412046909	422.0328369
1/1/2017 3:00	5.885338783	30.7000008	18.2999992	8.89999962	600.767334	68.3013229	67.8701248	120.8993	101.932129	0	1375.716	0.995919108	703.8163452	2.342666626	695.0819702	2.420507431	418.7540588
1/1/2017 4:00	5.896627903	30.7000008	18.2999992	8.89999962	598.932312	68.3295898	67.8104782	121.00013	100.721443	0	1399.443	1.040467501	699.2817383	2.379888058	699.5249634	2.430917978	419.6556396
1/1/2017 5:00	5.907917023	30.7000008	18.2999992	8.89999962	600.415039	68.3125381	67.7508392	121.020805	99.3677521	0	1389.446	1.106234431	685.1239014	2.319067717	695.6830444	2.343343735	425.2034302
1/1/2017 6:00	5.919205666	30.7000008	18.2999992	8.89999962	598.982056	68.2653427	67.6912003	120.875465	100.729538	0	1398.764	1.036579013	696.0140991	2.332845449	683.3713989	2.295001984	430.7512207
1/1/2017 7:00	5.930494785	30.7000008	18.2999992	8.89999962	600.698364	68.2644577	67.6509323	121.00605	102.091324	0	1392.756	1.059488773	690.7689209	2.385602236	668.9630127	2.452979803	436.2990417
1/1/2017 8:00	5.941783905	30.7000008	18.2999992	8.89999962	599.47345	68.1044998	67.6334229	121.010216	103.038551	0	1384.331	1.000877857	693.3822021	2.3377707	691.7227173	2.436828852	441.8468323
1/1/2017 9:00	5.953072548	30.7000008	18.2999992	8.89999962	601.251343	68.1828003	67.6159134	121.027054	102.573814	0	1394.611	1.049450517	690.1139526	2.337104559	691.6522827	2.386212349	447.3946533
1/1/2017 10:00	5.964361668	30.7000008	18.2999992	8.89999962	601.172607	68.1882477	67.5984039	121.002777	102.278297	0	1393.038	1.060339451	686.5177002	2.337829351	696.8646851	2.426457644	452.9424438
1/1/2017 11:00	5.973154545	30.7000008	18.2999992	8.89999962	761.65564	69.8725586	70.3117676	105.744072	52.2235146	0	1390.047	0.992098093	693.0665894	2.339616776	684.9814453	2.33774519	692.9633789
1/1/2017 12:00	5.973154545	30.7000008	18.2999992	8.89999962	760.803955	69.6564407	70.0649033	105.351143	48.1324692	0	1475.784	0.980705321	502.3753967	2.350434065	501.9485474	2.326356411	693.8041992
1/1/2017 13:00	5.973154545	30.7000008	18.2999992	8.89999962	759.052368	69.7092896	70.0852585	105.140732	48.3127556	0	1471.3	1.026487112	502.5988159	2.341980934	500.7457581	2.410101652	694.6450195
1/1/2017 14:00	5.973154545	30.7000008	18.2999992	8.89999962	758.830627	69.6047363	70.0850143	104.733856	49.0083427	0	1487.782	0.989045799	500.3195496	2.347975969	504.091156	2.360517979	695.4858398
1/1/2017 15:00	5.973154545	30.7000008	18.2999992	8.89999962	759.022949	69.741272	70.1881561	104.325531	49.7039337	0	1472.761	0.977978408	489.4691467	2.36177063	484.4345093	2.301289558	696.3266602
1/1/2017 16:00	5.973154545	30.7000008	18.2999992	8.89999962	761.525513	69.7470551	70.2298508	104.122261	50.3995247	0	1386.935	0.831803024	498.1903381	2.34693408	504.1878967	2.319585085	1102.313232
1/1/2017 17:00	5.973154545	30.7000008	18.2999992	8.89999962	759.651855	69.849617	70.2686996	103.855125	51.4710999	0	1391.012	0.84437269	500.6762085	2.345488787	503.9047241	2.415038586	1105.798828
1/1/2017 18:00	5.973154545	30.7000008	18.2999992	8.89999962	760.814636	69.7653809	70.2217941	103.61837	52.9994125	0	1387.407	0.818589449	498.3874207	2.359160423	506.7554321	2.379304886	1109.284302
1/1/2017 19:00	5.981233597	30.7000008	18.2999992	8.89999962	760.972778	69.8678436	70.2561264	103.3769	51.4831123	0	1392.243	0.809060395	500.6304626	2.305408955	495.8058472	2.312383652	1112.769775
1/1/2017 20:00	6.007295132	30.7000008	18.2999992	8.89999962	759.310303	69.7545319	70.2274704	103.088234	51.8224525	0	1388.813	0.78157264	495.3852844	2.32013011	497.1117554	2.262848854	1116.255249
1/1/2017 21:00	469.2819214	30.7000008	18.2999992	8.89999962	758.849365	69.6684189	70.0994339	103.12719	52.1617966	0	1395.736	0.767552912	487.1919861	2.392445326	496.8092651	2.328749418	1119.740723
1/1/2017 22:00	665.3845825	30.7000008	18.2999992	8.89999962	757.475891	69.5569763	70.1208496	102.670135	53.1135864	0	1383.667	0.794621527	484.4679565	2.435478687	496.0075684	2.41768074	1123.226196
1/1/2017 23:00	736.7000732	30.7000008	18.2999992	8.89999962	710.505493	66.8875427	67.2549667	120.120773	131.931107	0	1389.09	0.798873067	499.7643127	2.332845211	497.0974121	2.376433611	1120.776367
1/2/2017 0:00	735.3907471	30.7000008	18.2999992	8.89999962	1097.07117	66.6138153	67.3853607	120.913849	90.0494537	0	1476.539	0.991563678	693.7958984	2.369048119	687.9721069	2.27084136	438.8619385
1/2/2017 1:00	721.765625	29.2000008	18.2999992	7.4000001	1211.08118	66.4649887	67.2992783	120.968018	105.815613	0	1479.009	1.037479162	694.3330078	2.346287727	690.2731934	2.370015621	436.1026917
1/2/2017 2:00	806.5482788	29.2000008	18.2999992	7.4000001	1242.71191	66.520134	67.1143341	121.039146	109.527847	0	1364.687	0.858504057	706.6982422	2.324912786	707.3796997	2.387147903	433.3434143
1/2/2017 3:00	879.6883545	30.2999992	18.2999992	7.4000001	1250.62427	66.3539886	66.9699173	121.000816	108.934311	0	1342.521	0.908878326	695.5176392	2.352772951	698.498291	2.324442625	430.584137
1/2/2017 4:00	901.5638428	30.2999992	18.2999992	7.4000001	1249.03918	66.140976	66.8202362	120.984673	108.340775	0	1343.718	0.949926257	697.5504761	2.315849781	696.2862549	2.411276579	427.8248596
1/2/2017 5:00	869.5500488	29.1000004	18.2999992	7.30000019	1250.78076	65.8739166	66.6879044	120.978142	111.55941	12.2080526	1336.595	0.97166729	704.6077271	2.356304646	692.6364746	2.303996563	425.0656128
1/2/2017 6:00	824.0563965	28.8999996	18.2999992	7.19999981	1286.39294	65.7155228	66.5555801	121.073936	113.960678	17.818943	1351.275	0.902300894	700.1303101	2.348112345	697.232605	2.404559612	422.3063354
1/2/2017 7:00	911.5714722	28.8999996	18.2999992	7.19999981	1289.30969	65.8153	66.5826797	121.081505	113.650337	17.818943	1345.381	0.919276714	705.0679321	2.337874651	695.8284912	2.328674316	419.5470581
1/2/2017 8:00	937.4130249	28.8999996	18.2999992	7.19999981	1292.84363	65.9150772	66.5101395	120.97097	113.339996	18.6227455	1344.572	0.916331351	703.8796387	2.31205678	690.0407715	2.269474745	418.5882874
1/2/2017 9:00	937.8486938	28.5	18.2999992	7.19999981	1292.25635	65.9486694	66.4862366	120.397194	113.029648	19.4060993	1348.514	0.912131786	693.2512207	2.336420059	699.8466797	2.364950418	418.1989441
1/2/2017 10:00	938.2843018	28.5	18.2999992	8.60000038	1290.72778	65.9771881	66.6896744	120.5298	112.719307	19.4029541	1340.803	0.979549706	690.5828247	2.344385386	687.9315796	2.292713881	417.8096008
1/2/2017 11:00	938.7199707	28.1000004	18.2999992	8.60000038	1289.57861	66.0219574	66.7795715	120.564377	113.133743	19.4013805	1348.26	0.972036302	696.0491333	2.363360167	675.4628296	2.44354701	417.4202576
1/2/2017 12:00	939.1556396	28.1000004	18.2999992	5.4000001	1286.71313	66.1072388	66.8195572	120.482124	113.882332	19.3809319	1347.605	1.051011682	702.9961548	2.352114677	697.9908447	2.436361313	417.0309143
1/2/2017 13:00	939.5913086	28.7999992	18.2999992	5.4000001	1303.05127	66.0631943	66.8724976	120.563553	114.630913	19.3887959	1349.235	0.956558645	691.4160767	2.350764036	694.2149658	2.338359356	416.641571
1/2/2017 14:00	940.0269775	28.7999992	18.2999992	6.5999999	1299.57898	66.2687149	66.9980927	120.537628	115.379501	19.4029541	1333.809	1.009043097	702.7241821	2.348449945	702.0521851	2.393113375	416.2522583
1/2/2017 15:00	940.4625854	29	18.2999992	6.5999999	1279.79529	66.5221634	67.2076187	120.561501	116.12809	19.3935165	1359.111	0.938216925	697.8551025	2.335887671	693.2405396	2.3213799	415.862915
1/2/2017 16:00	939.6080322	29	18.2999992	7	1271.08301	67.0195389	67.7058411	120.513474	116.876678	19.3998089	1345.485	1.007751346	703.62677	2.323599815	689.4447632	2.302596092	416.1562195
1/2/2017 17:00	938.4343262	28.7999992	18.2999992	7	1276.13708	67.6310349	67.9090652	120.581635	117.625259	19.391943	1346.796	1.077694416	695.9978027	2.346126556	694.2675781	2.320687532	416.5557861
1/2/2017 18:00	937.2605591	28.7999992	18.2999992	7	1271.5874	67.4492416	67.9745941	120.457634	117.961922	19.3998089	1351.376	1.005683064	696.7888184	2.351575851	702.0425415	2.414264917	416.9553833
1/2/2017 19:00	936.086792	28.7999992	18.2999992	7	1264.68713	67.8357162	68.3071899	120.54023	117.478828	19.3982353	1345.984	1.060749412	697.2678223	2.360358	694.2645874	2.416383743	417.3549805
1/2/2017 20:00	900.1295776	29.3999996	18.1000004	7	1255.38074	68.4622955	68.692009	120.400696	117.91703	19.3935165	1341.555	1.032373786	689.1063232	2.349648237	706.6452637	2.325190544	417.7545776
1/2/2017 21:00	935.1414795	29.3999996	18.1000004	7	1251.76306	68.670723	68.9410477	120.551643	117.792183	19.3856525	1340.319	1.009056807	695.0135498	2.356388569	702.6513672	2.394730568	418.1541443
1/2/2017 22:00	916.394104	29.3999996	18.2999992	7.9000001	1246.16821	68.7154694	68.9365692	120.499016	118.788803	19.3979187	1343.874	0.988922238	693.1173706	2.358891726	702.3425293	2.275904655	418.5537415
1/2/2017 23:00	873.9180908	29.7000008	18.2999992	7.9000001	1246.35437	68.7957611	68.9180603	120.450722	119.785416	19.3856525	1344.883	1.040279984	714.2224121	2.316396475	694.2773438	2.329951286	418.9533386
1/3/2017 0:00	982.1019287	29.7000008	18.1000004	10.1999998	1248.87927	68.5350723	68.4965286	120.515198	119.523041	19.4013805	1336.247	1.038691759	690.0385742	2.270655632	694.3650513	2.319515705	418.0623779
1/3/2017 1:00	990.3980103	29.7999992	18.1000004	10.1999998	1246.80225	68.6928635	68.8349228	120.561996	119.218491	19.3903694	1353.98	1.065670133	677.3439941	2.37514782	690.3237915	2.283139944	417.1211548
1/3/2017 2:00	990.3352661	29.7999992	18.1000004	6.30000019	1246.88782	68.6514664	68.7318192	120.562721	119.394356	19.3825054	1362.421	1.108400822	678.2133179	2.38782382	691.6704102	2.32389617	416.1799316

Benchmarking of Data from Survey

e.g., BLS firing rate can be a reference for increasing your RB load







Software to Estimate Air Distribution & Penetration in Furnace

- Our software is in Excel
- CFD modelling?
  - We did not do CFD model ourselves
  - We collaborated with others, e.g. PSL

Combustion air system:	SECONDARY
Date:	2023-11-10
Time:	8:52 / 9:44
Barometric pressure:	inches of mercury
Barometric pressure:	101000 Pascal
Windbox Ave. Temperature:	168 degree Celcius

SECONDARY AIR SYSTEM_Recovery Boiler System INPUT Conditions WINDBOX DATA

			Bottom					Top										Bottom	Top	
Port	Orientation	Function	Pressure in inches of H_2O			Port	Port	Pressure in inches of H_2O			Port	Port	Damper settings		# of	# of ports	# of remaining	Effective opening/port		Windbox
#	1=NE; 18=NW for R-wall, go L to R		Reading 1	Reading 2	Average	Opening	cleanliness	Reading 1	Reading 2	Average	Opening	cleanliness	WB	Velocity	ports	Closed	ports			Ave. T (°C)
1 Front	East	Camera Port	0.24	0.33	0.29	100%	90%	-1.67		-1.67	0%	0%			1	0	1	90%	0%	168
2 Front	East	Start Burner Port	-1.12	-0.93	-1.03	100%	90%	-1.67		-1.67	0%	0%			1	0	1	90%	0%	168
3 Front	East	Air Port			0.00	0%	0%	-1.67		-1.67	0%	0%			1	0	1	0%	0%	168
4 Front	East	Air Port			0.00	0%	0%	-1.67		-1.67	0%	0%			1	0	1	0%	0%	168
5 Front	East	Start Burner Port	-0.18	-0.27	-0.23	100%	90%	-1.67		-1.67	0%	0%			1	0	1	90%	0%	168
			8.60		8.60	0%		-1.67		-1.67	100%	0%			0	0	0	0%	0%	168
		Big Air Port	0.00		0.00	0%		-1.67		-1.67	100%	0%			0	0	0	0%	0%	168
		Air Port	5.50		5.50	0%		-1.67		-1.67	100%	0%			0	0	0	0%	0%	168
		Air Port	11.50		11.50	0%	0%	-1.67		-1.67	100%	0%			0	0	0	0%	0%	168
1 Right	North	Air Port	7.82	7.59	7.70	90%	85%	-1.67		-1.67	10%	0%			1	0	1	77%	0%	168
2 Right	North	Air Port			0.00	100%	0%	-1.67		-1.67	0%	0%			1	0	1	0%	0%	168
3 Right	North	Start Burner Port	1.98	1.67	1.82	100%	95%	-1.67		-1.67	0%	0%			1	0	1	95%	0%	168
4 Right	North	Air Port	7.47	7.43	7.45	100%	90%	-1.67		-1.67	0%	0%			1	0	1	90%	0%	168
5 Right	North	Start Burner Port	1.68	1.93	1.80	100%	95%	-1.67		-1.67	0%	0%			1	0	1	95%	0%	168
6 Right	North	Air Port	7.27	7.41	7.34	100%	95%	-1.67		-1.67	0%	0%			1	0	1	95%	0%	168
7 Right	North	Air Port			0.00	100%	0%	-1.67		-1.67	0%	0%			1	0	1	0%	0%	168
8 Right	North	Start Burner Port	2.54	2.17	2.35	100%	90%	-1.67		-1.67	0%	0%			1	0	1	90%	0%	168
9 Right	North	Air Port	6.63	6.15	6.39	100%	90%	-1.67		-1.67	0%	0%			1	0	1	90%	0%	168
10 Right	North	Start Burner Port	2.13	1.78	1.95	100%	85%	-1.67		-1.67	0%	0%			1	0	1	85%	0%	168
11 Right	North	Air Port	6.40	6.11	6.26	100%	95%	-1.67		-1.67	0%	0%			1	0	1	95%	0%	168
		DNCG Port			0.00			-1.67		-1.67		0%				0	0	0%	0%	168
	North	Air Port			0.00		20%	-1.67		-1.67		500%				0	0	0%	0%	168
1 Back	West	Camera Port	1.38	1.54	1.46	100%	100%	-1.67		-1.67	0%	0%			1	0	1	100%	0%	168
2 Back	West	Air Port	13.06	12.92	12.99	10%	100%	-1.67		-1.67	90%	0%			1	0	1	10%	0%	168
3 Back	West	Air Port	13.21	12.96	13.09	10%	100%	-1.67		-1.67	90%	0%			1	0	1	10%	0%	168
4 Back	West	Air Port	13.15	13.49	13.32	10%	100%	-1.67		-1.67	90%	0%			1	0	1	10%	0%	168
								-1.67		-1.67	100%	0%			0	0	0	0%	0%	168
		Air Port	6.20					-1.67		-1.67	100%				0	0	0	0%	0%	168
		Air Port	11.60				0%	-1.67		-1.67	100%				0	0	0	0%	0%	168
	1=SW; 18=SE for L-wall, go L to R										100%									
1 Left	South	Air Port	3.34	2.75	3.05	90%	90%	-1.67		-1.67	10%	0%			1	0	1	81%	0%	168

Design data | PA | SA | TA | QA | Summary | Port area | List&Factor | Flue gas velocity | Jet Expansion Calc. | ...

Test Matrix for Different Samples

- Many mills take samples “randomly”
  - BL, GL, ash samples collected on different days or weeks apart
  - Analysis results obtained this way can’t be correlated
- We take each set of samples on the same day, e.g.
  - Strong BL, As-fired BL samples
  - Green liquor/smelt samples
  - Ash deposits, GB/Econmz ash, ESP ash samples
- Test matrix is developed for cost-effectiveness
  - Parameters to be analyzed for depend on the boiler issues
  - Correlate such test results to find the cause of operating issues

Reminder: All samples should be part of active flow, not accumulated old stuff or deposits

The whole set of samples should be taken on the same day when the boiler system is running steady state at normal high load

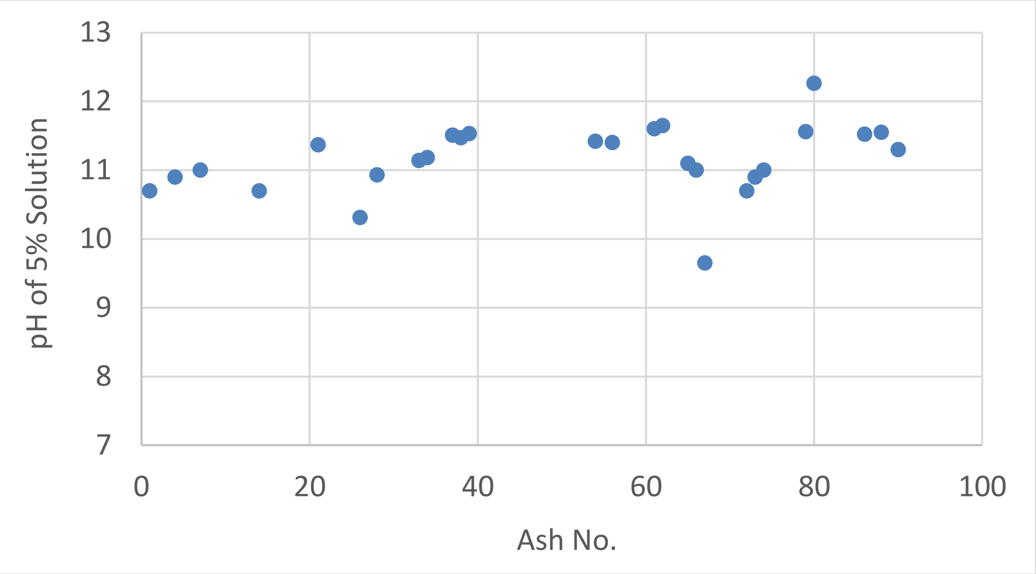
Sample Set	During operation under conditions-1	Sample Set	During operation under conditions-2
Sample Type	As-fired black liquor	Sample Type	As-fired black liquor
Sample Date and Time		Sample Date and Time	
Sample Bottle	with large mouth	Sample Bottle	with large mouth
Size of Bottle	1 L	Size of Bottle	1 L
How many bottles	2	How many bottles	2
Total Amount of Sample	2 x 1 L	Total Amount of Sample	2 x 1 L
Sample Type	Green liquor in Dissolving Tank	Sample Type	Green liquor in Dissolving Tank
Sample Date and Time		Sample Date and Time	
Sample Bottle	1 L	Sample Bottle	1 L
Amount of Sample	1 L	Amount of Sample	1 L
Sample Type	Recovery boiler ash	Sample Type	Recovery boiler ash
Sample Date and Time		Sample Date and Time	
Bottle for Each Sample	500 ml	Bottle for Each Sample	500 ml
Amount of Sample	>250 ml	Amount of Sample	>250 ml

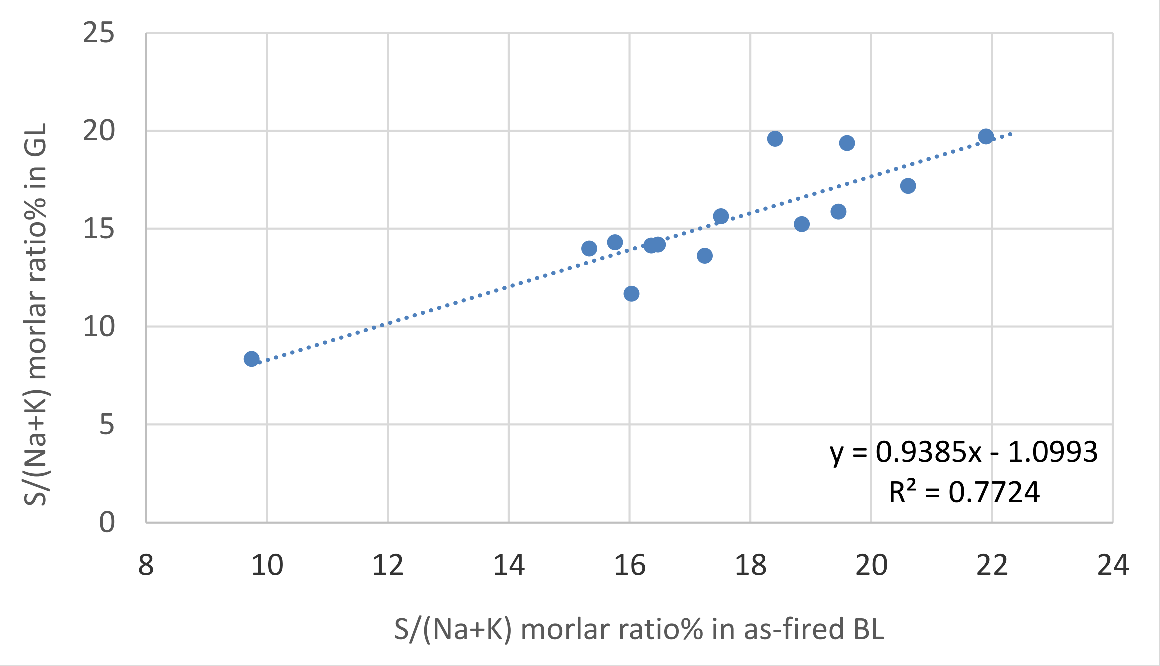
Sample ID			under conditions-1			under conditions-2		
Sample type			ESP Ash left	ESP Ash right	Economizer Ash	ESP Ash left	ESP Ash right	Economizer Ash
Sample date and time								
Moisture content	%	moist basis	X	X	X	X	X	X
Loss on ignition (carbon content)	%	OD	X	X		X	X	
Chloride	%	OD	X	X	X	X	X	X
Sodium chloride	%	OD						
Carbonate	%	OD	X	X	X	X	X	X
Sodium carbonate	%	OD						
Sulfate	%	OD	X	X	X	X	X	X
Sodium sulfate	%	OD						
K	%	OD	X	X		X	X	
Na	%	OD	X	X		X	X	
S	%	OD	X	X		X	X	
Total S / total Na weight ratio		OD						
$Na_2CO_3 : Na_2SO_4$ weight ratio		OD						
Sticky temperature	°C							
pH of 5% solution		OD	X	X		X	X	
All metals ICP scan:			X	X		X	X	
Ca	mg/kg	OD						
Mg	mg/kg	OD						
Fe	mg/kg	OD						
Mn	mg/kg	OD						
Al	mg/kg	OD						
Zn	mg/kg	OD						
P	mg/kg	OD						
Si	mg/kg	OD						
Ba	mg/kg	OD						

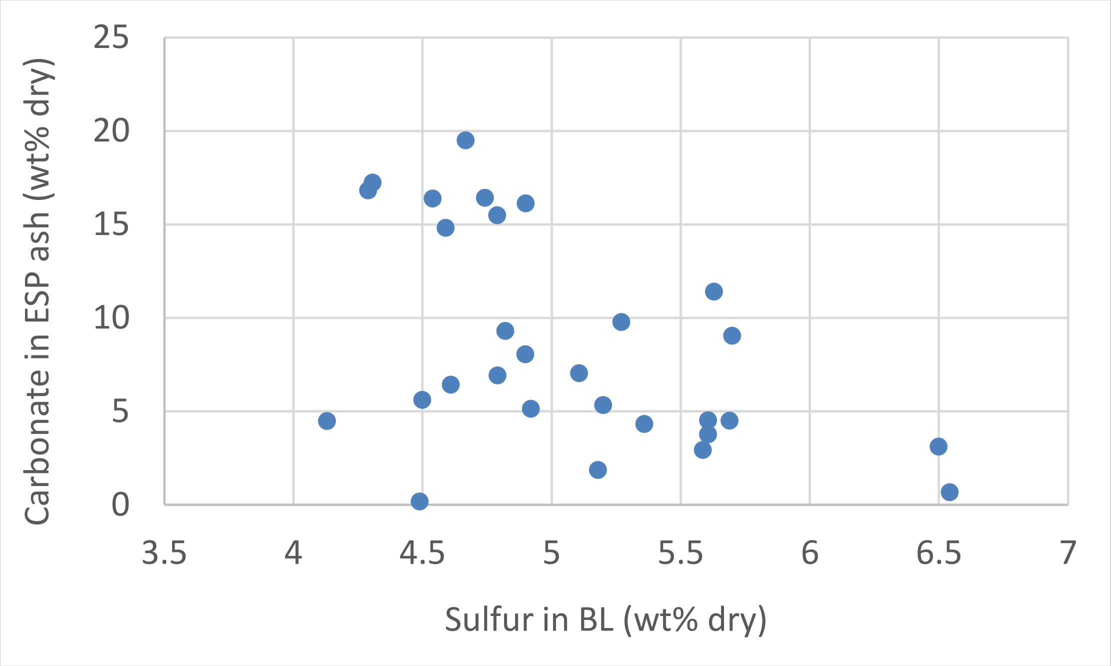
Samples to be collected | BL | DT green liquor | Ash

Benchmark of Sample Test Results

- Some mills have many samples tested, but the results are not really used
- Some ask lab to analyze for Na, K, Cl contents
    - But missed the important species of S
    - Pity, S is given by ICP with Na and K, no extra cost

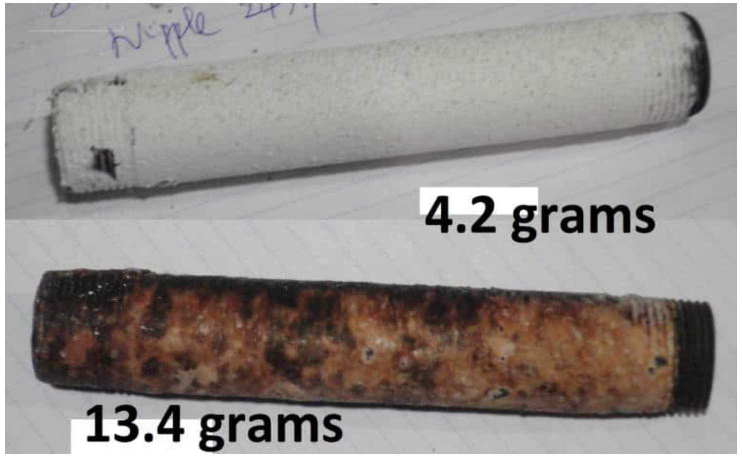






Hardware – Tools and Devices for Tests on Running RBs

- Pitot tubes, incl. S type pitot tube probes, manometers
- Static pressure probes
- Thermocouples
- Two units of portable camera purchased from Valmet
- Probes for measuring carryover in upper furnace
- Pieces made internally
  - Ash samplers for use in vacuum process



Practical Solutions to Minor Troubles

- e.g. Handling pressurized hot combustion air (up to 300 ^{o}C) during tests

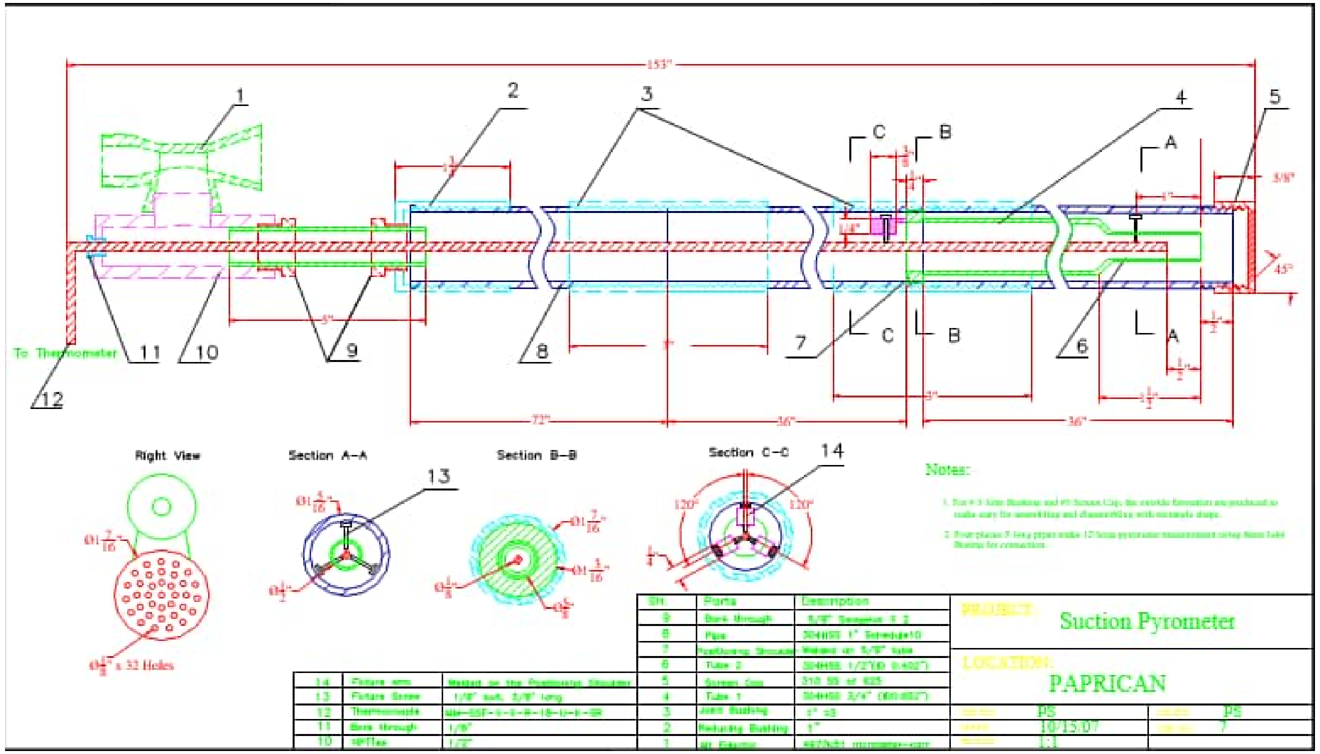
FPInnovations

Hardware - Instruments

- Developed probes and sampling system of gas analyzer for continuous measurement of flue gas composition and emissions

Tools for Measuring Furnace Temperatures

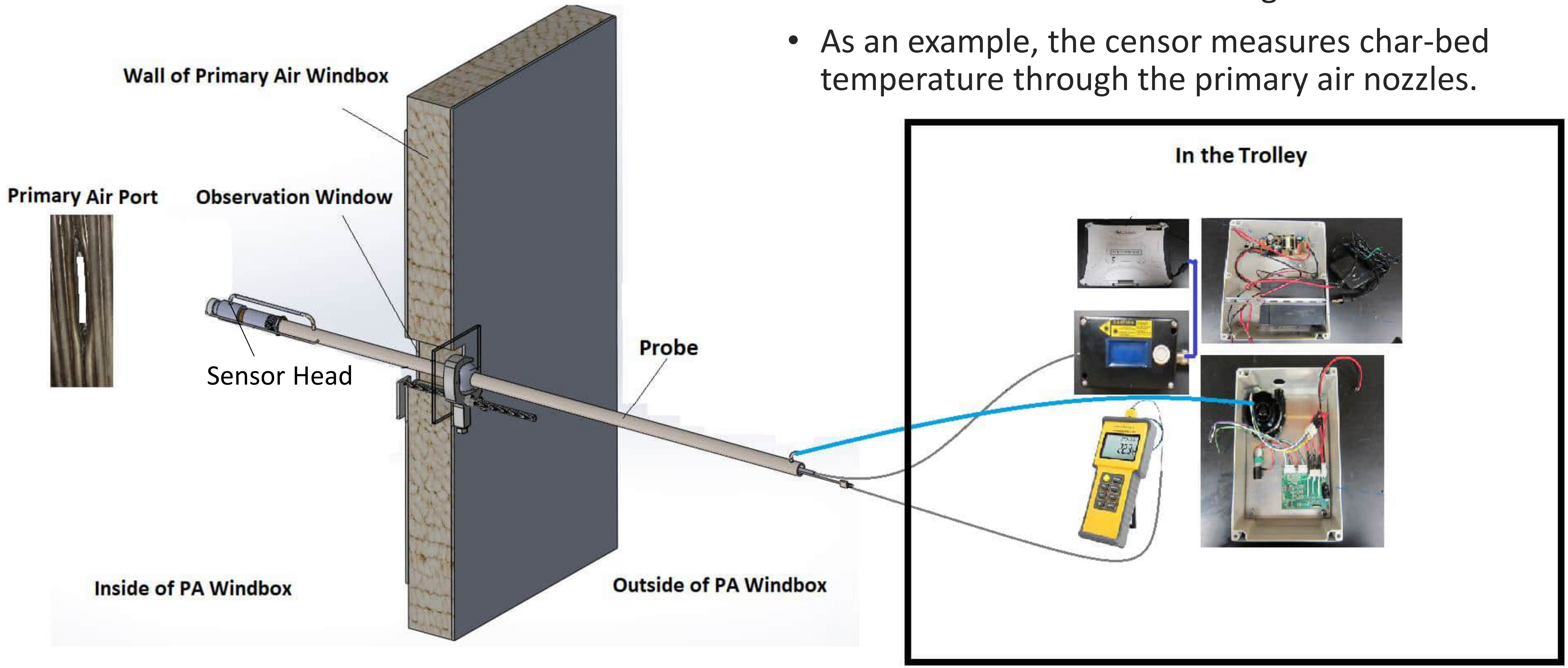
- Thermocouples
- Suction pyrometer
- Laser gun pyrometer



- Enough? Not really.
    - Need long time monitoring

FPInnovations Innovated New Type of Pyrometer System

- Auxiliary devices designed to keep the sensor head clean and cool while measuring
- As an example, the censor measures char-bed temperature through the primary air nozzles.

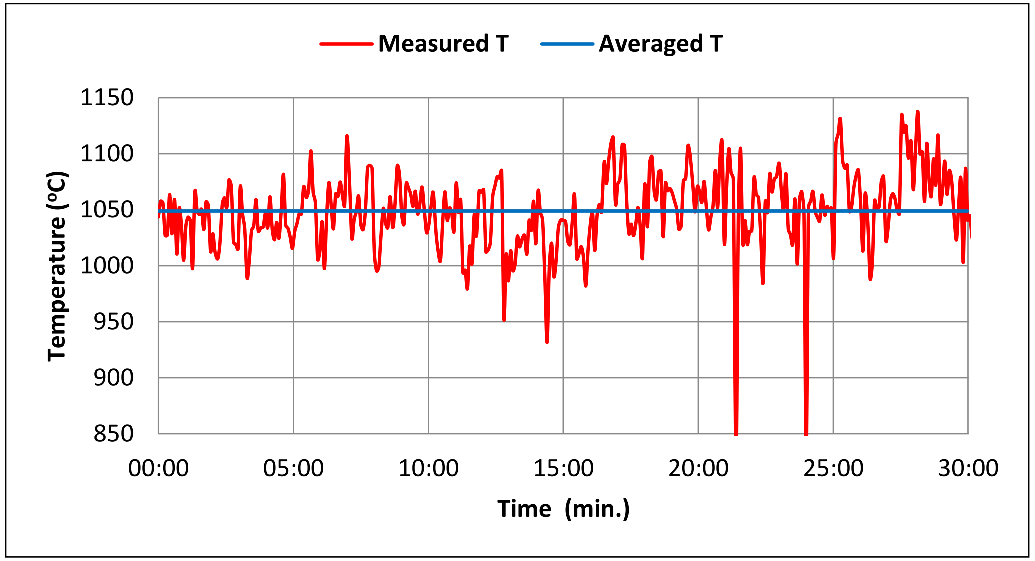


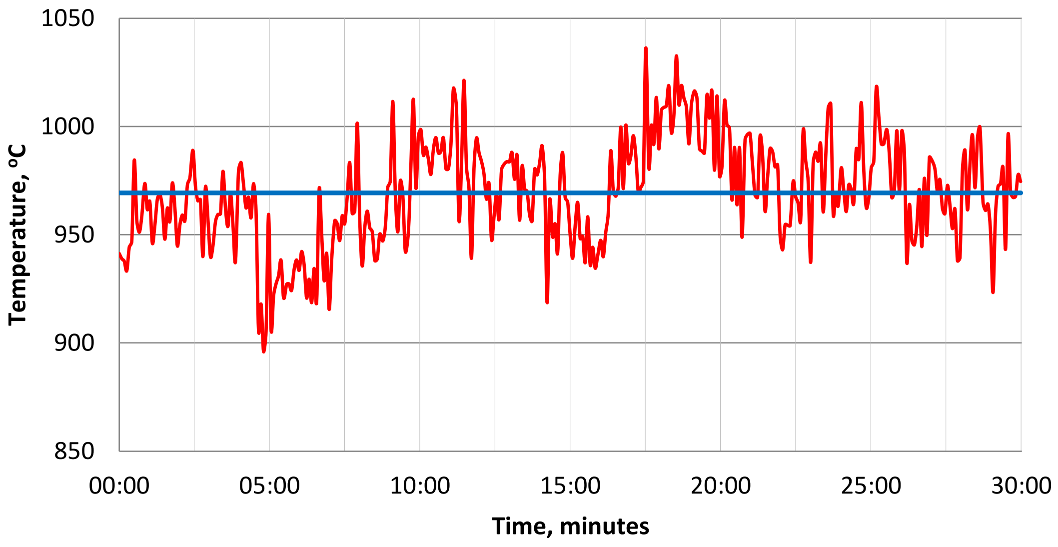
New Pyrometer Tested on Recovery Boilers

- Tested on different recovery boilers
- Sensor and probe can withstand harsh environment for long time
- Variations of the char bed temperature reflect the stability of the char-bed combustion in the furnace
- Char-bed temperatures measured with this new pyrometer were validated with a snapshot laser pyrometer

Recovery Furnace Char Bed Temperature

- Conducted measurements through PA ports on 4 running recovery boilers
- Recorded big fluctuations of char bed T
- It can be used for continuously monitoring
- Promising applications:
  - Char bed temperature during RB operation
  - Smelt temperature around the spout inlet
  - Furnace floor temperature during RB shutdown cooling





Case Study: Recovery Boiler K

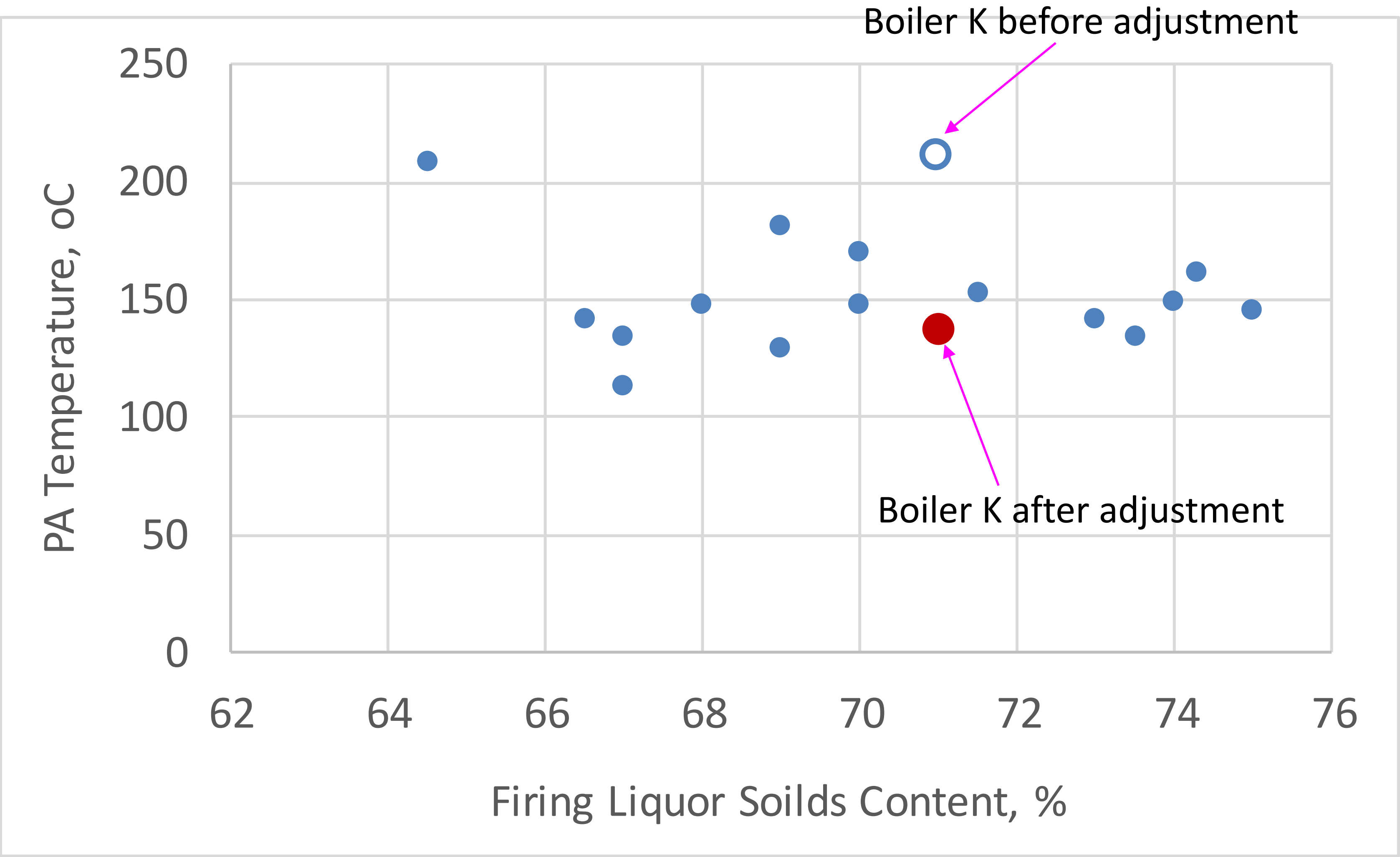
Issues

1. Steam capacity limited
2. Opacity or particulate emissions limited
3. TRS/H_2S emissions
4. Mill K wanted to max or further increase pulp production, however

Solutions

- Primary Air (PA) temperature lowered from 210 to 138 ^oC
  - Lower sensible heat input addressed Issues 1 and 4
  - Lower combustion temperature lowered fuming of alkalis for Issue 2
  - Saved steam for heating PA by 5 t/h to make electricity, benefit = $0.7 M/y
- Shifted air from Tertiary Air (TA) to Quaternary Air (QA) by 12 t/h
  - Improved air distribution addressed Issue 3
- Overall, optimized Boiler K, created benefits of $1.6 M/y for Mill K

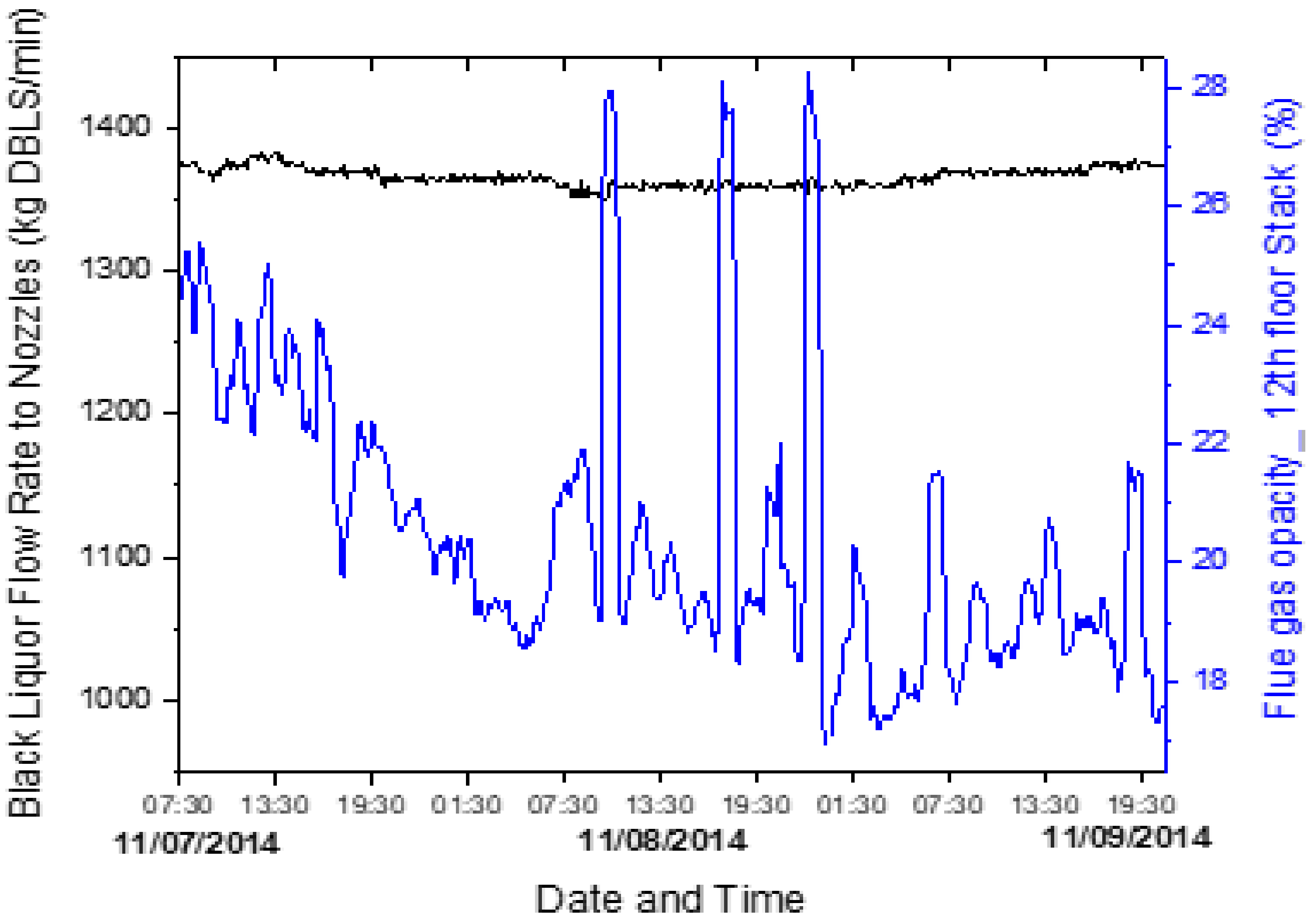
Primary Air Temperature for Boiler K in Benchmarking



Recovery Boiler Tuning for Opacity Control, Mill K

Results from 3-day trials

- Stable boiler load
- Opacity maintained at <25% except for the 3 spikes on Nov 8th caused by electrical trips



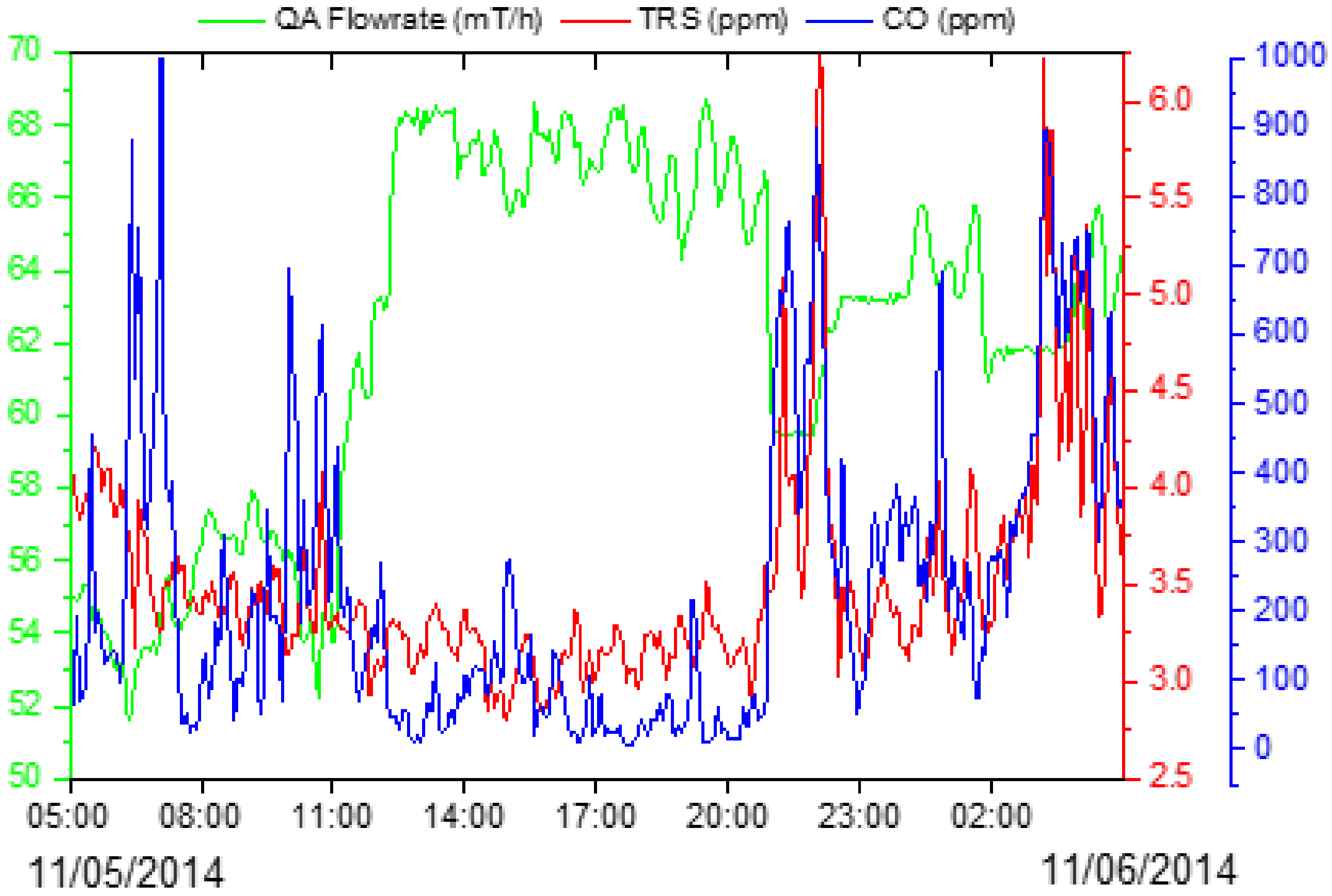
Solution to High TRS/H_2S Emissions, Mill K

Common practice at Mill K

- When TRS high, increase air flow
- When opacity hi, reduce air flow
- If problems unsolved
  - Lower firing rate

Innovative solution by FPI

- With the same total air flow
- Shifted more air from TA to QA for **better mixing/penetration**
- TRS/H_2S and CO emissions down, additional to lower opacity



Chemistry and Hydrodynamic Affect Opacity

- $2NaOH(g) + CO_2 = Na_2CO_3 + H_2O$
- $nNa_2CO_3 + Na_2CO_3 = (n+1)Na_2CO_3$
  - Particle grows thru better mixing
- $Na,KOH + HCl = Na,KCl + H_2O$
- $Na_2CO_3 + 2HCl = 2NaCl + CO_2 + H_2O$

- $Na_2CO_3 + SO_2 + 0.5O_2 = Na_2SO_4 + CO_2$
- $mNa_2SO_4 + nNa_2SO_4 = (m+n)Na_2SO_4$
  - Particles collide by improved penetration

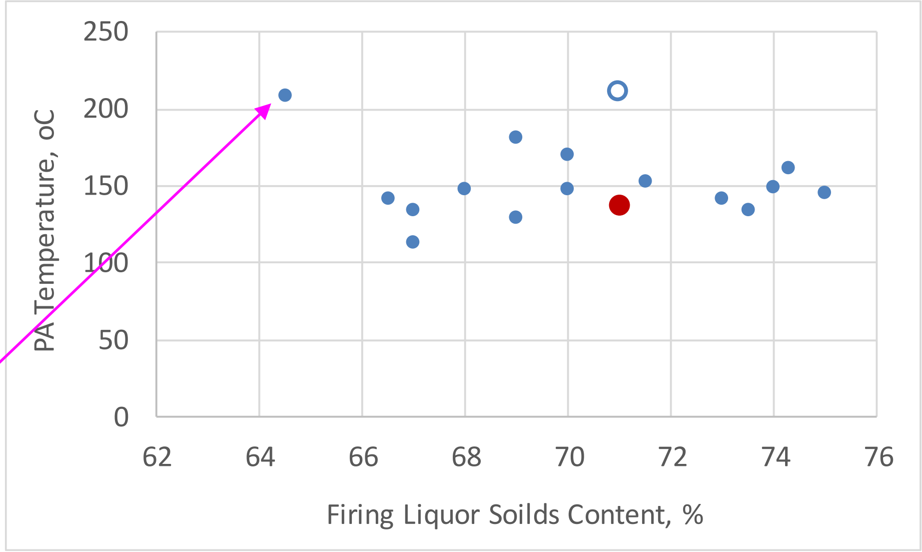
K and Cl contribute to stack opacity

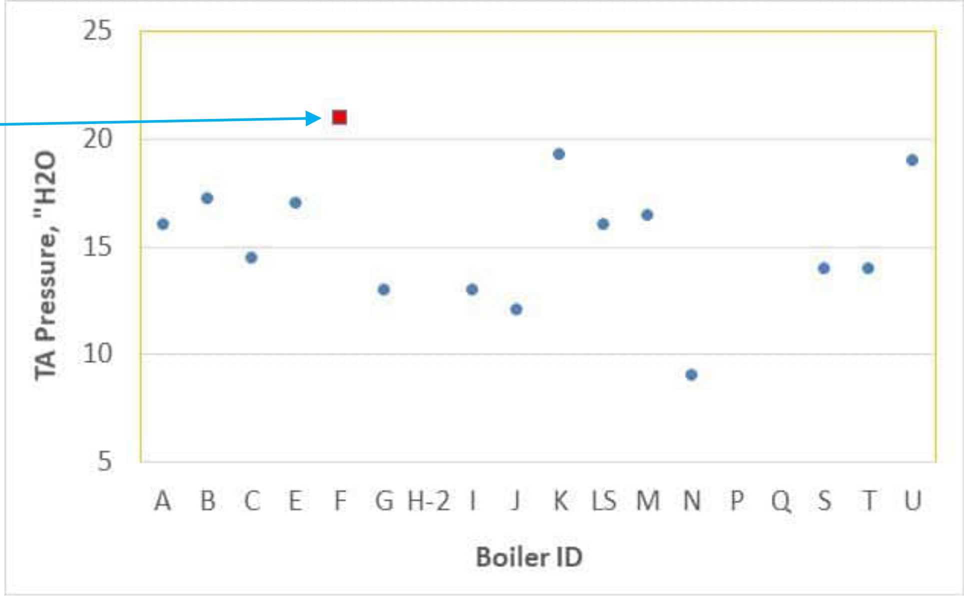
Samples, Mill K	Unit	Basis	**Economizer ash**	**ESP dust**
Sampling date			09-Oct	09-Oct
pH	pH	5% solutn	11.74	11.38
Carbonate	%	OD	16.0	5.77
Sulfate	%	OD	37.1	39.1
K	%	OD	6.51	7.71
Cl	%	OD	0.63	1.36

- Larger particles can be removed preferentially; Others increase opacity
- Reducing combustion temperature by lowering air temperature helped opacity control

Case Study: Recovery Boiler F

- Issues
  - High TRS after restart from extended shutdown
  - 3 months efforts could not solve it
  - Mill had to reduce black liquor firing rate
    - Big loss from reduced pulp production
- We did data Survey and Benchmarking
  - PA Temperature was high
  - TA pressure was high P=23.5” W.C.
  - For a given flow, high P means small port opening
- Conducted trials
  - Kept the same PA temperature but
  - Lowered the TA pressure

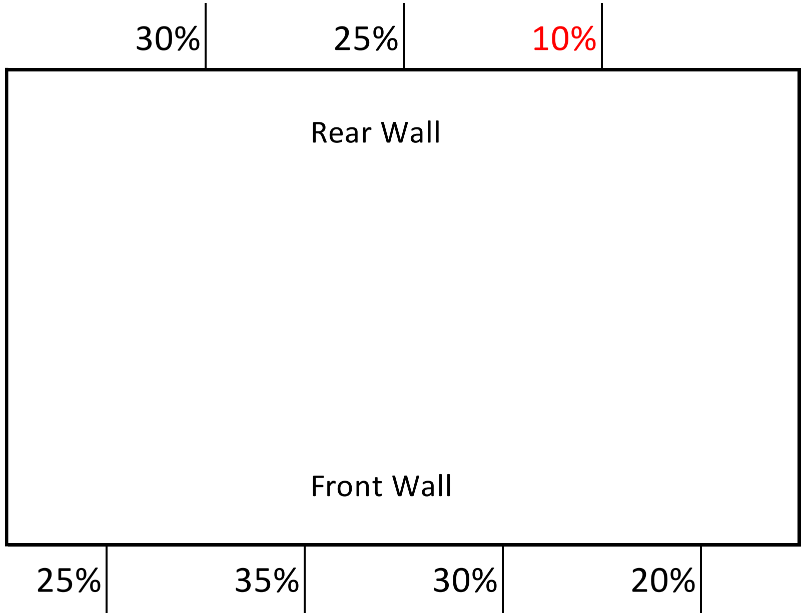




Improve Tertiary Air (TA) System of Recovery Boiler F

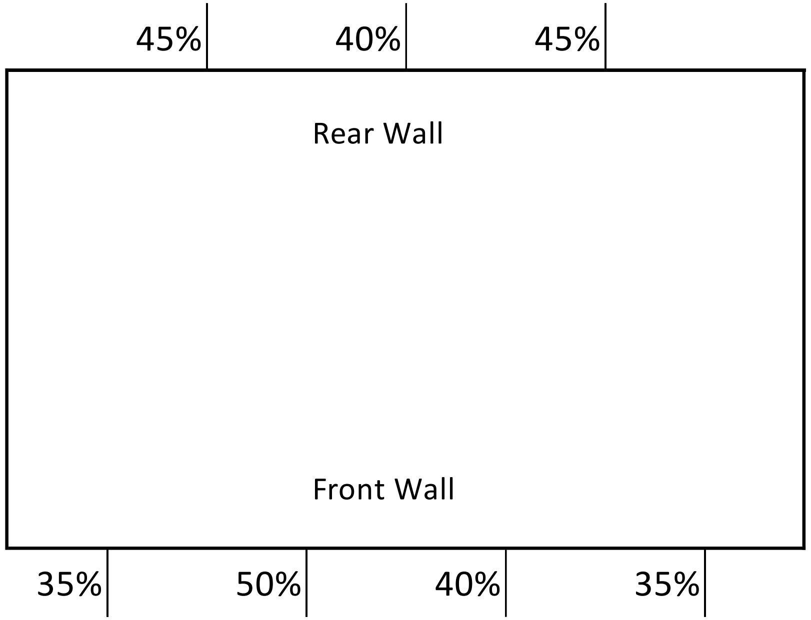
- Root cause
  - TA pressure too high
  - TA distribution and penetration not good

- Solution
  - Reduced TA pressure so increased port opening
  - Made port opening more uniform with “bias”
  - Increased TA flow



Tertiary air port opening - Baseline

P = 23.5” W.C., TA flow = 159 kpph



Tertiary air port opening - after tuning

Optimized: P = 18” W.C., TA flow = 186 kpph

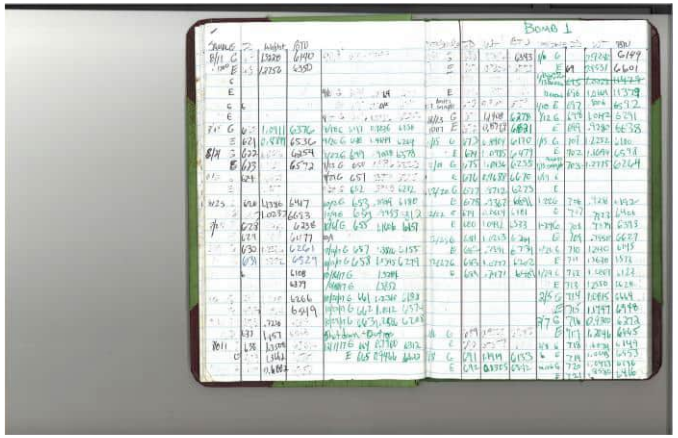
Results of Optimization of Recovery Boiler F

- TRS emissions reduced and well under control
- Recovery boiler stabilized with consistently high boiler load
  - No capital cost, no other cost
  - Even no chemical analysis cost
- Pulp production rate becomes even higher than expected
  - Benefits recognized by Mill F: $3 M/yr for multiple years

Case Study: Recovery Boiler P

One of the pages of test record for

- Heating value of black liquor



- Severe issues with boiler P after upgrading
  - Difficult to control char bed
  - Smelt leaking
  - Primary air ports burn-out
  - Frequent boiler shutdowns
- Lots of efforts by international firms/experts
  - 400 black liquor samples tested for heating value
    - What a waste !
    - In contrast to our test matrix
  - Changed BL spray nozzles, etc.
  - Problems remained until
- FPInnovations was contacted

Troubleshooting Recovery Boiler P

Measured char bed temperature thru PA ports

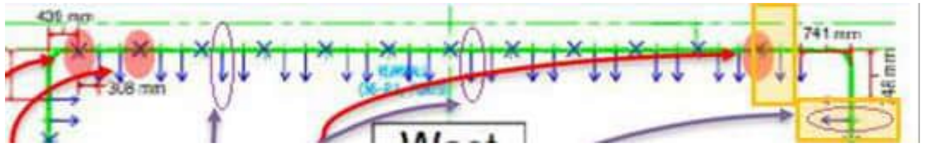
- T near front wall < 980 C, too low
- T near rear wall > 1100 C, way too high
  - Smelt leaks on the rear wall or at the corners

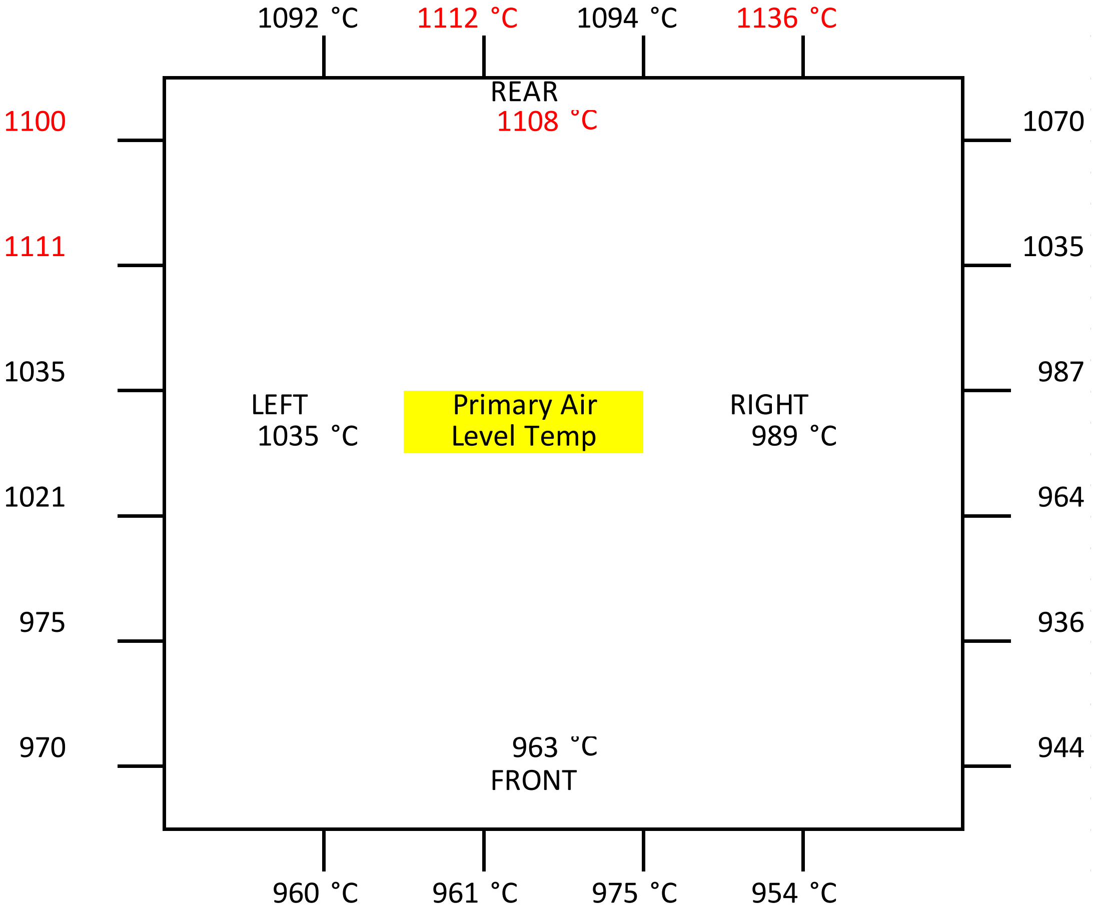
FPI reviewed CFD modeling from the designer, and found a mistake in the new air system design

- Our mathematics confirmed this as the root cause
- Too much SA and too strong SA jets from the front wall caused excessive liquor on or near the rear wall, resulting in the boiler walls being damaged there

FPI optimized the boiler, resolved the disaster; still no problem multiple years later

- Estimated benefits likely >$10 M
- Corporate confirmed a value of $3.3 M profit





Case Study: Recovery Boiler Y

- Boiler ceiling accumulated heavy deposits while firing 3.6 mmlb/d BLS in Jan 2023.
  - The boiler had to be cleaned by thermal shedding or water washing
- Our evaluation identified the root cause
  - No air dampers nor flow meters were installed on the TA & load burner ducts in the last upgrading
  - Poor function of the load-burner damper shifted much TA flow to the big load-burner, but not known
  - The great “chimney” effect from the load-burner port caused heavy carryover
- Mill improved the load-burner damper in maintenance in Sept and reopened two TA ports which should have not been blocked.
- Boiler ceiling could be maintained much cleaner while firing 3.9 mmlb/d BLS in Oct.
  - Increased firing rate from 3.6 to 3.9 mmlb/d means $6 M/y of benefits

Deposits around the corner of front superheater & boiler ceiling

Left side, January

Center Left , January

Right side , January

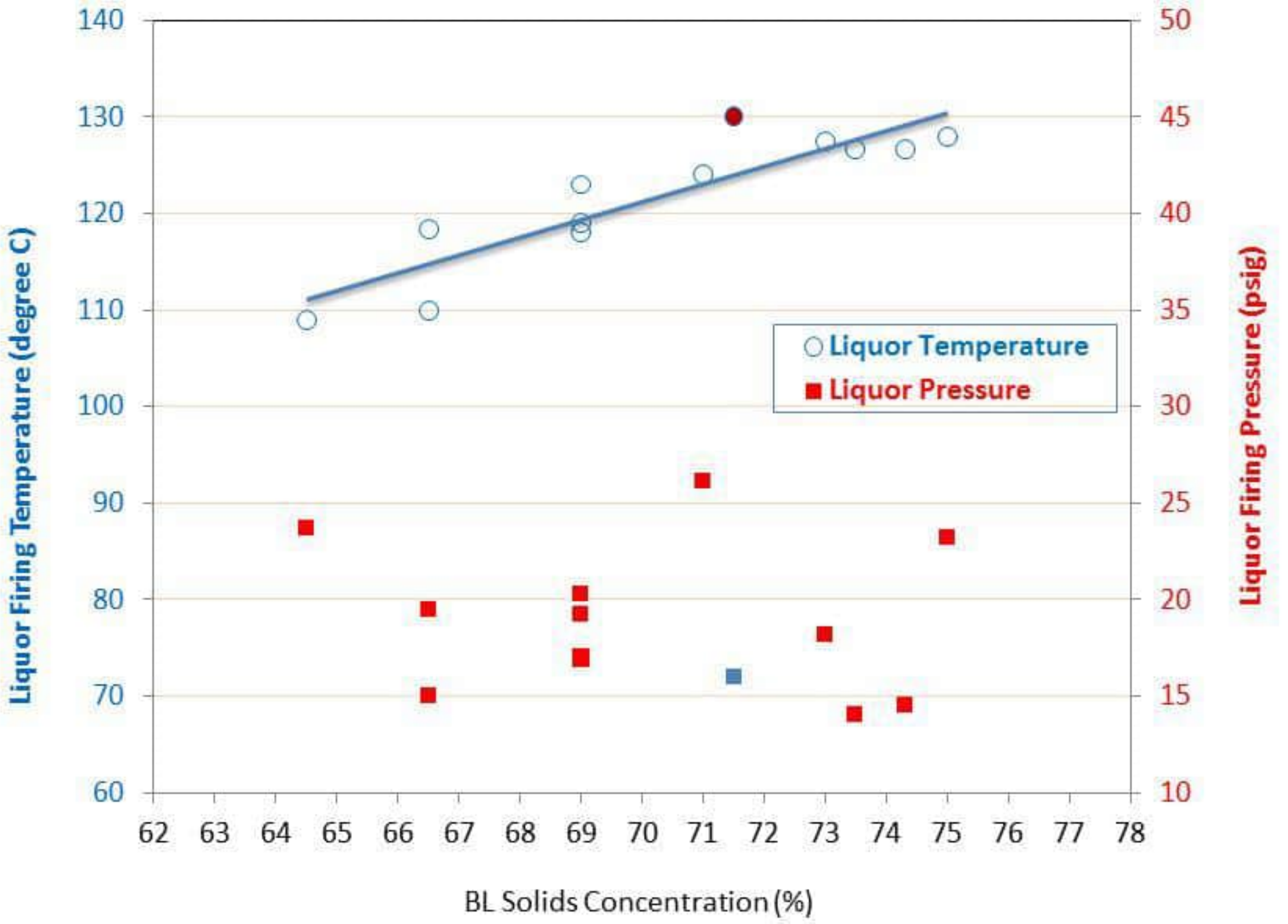
Left side, October

Center Left , October

Right side , October

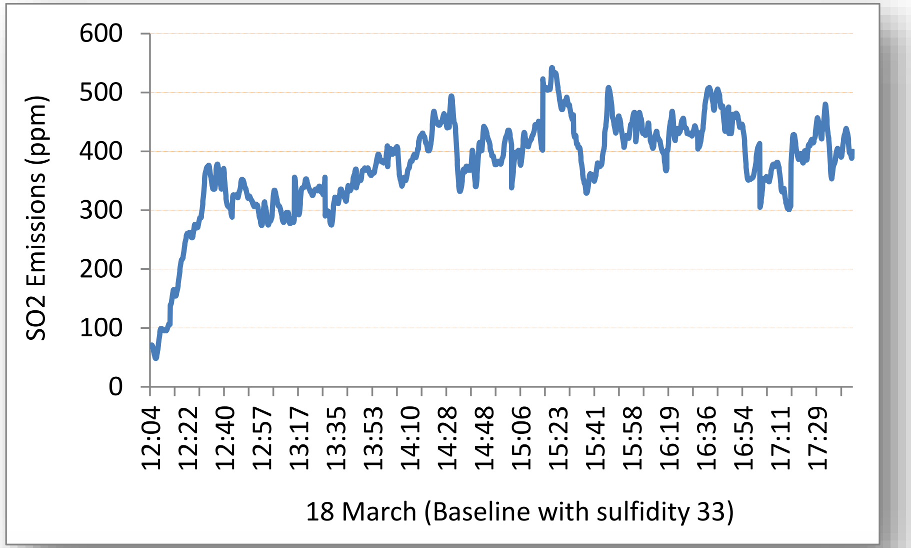
Case Study: Recovery Boiler I

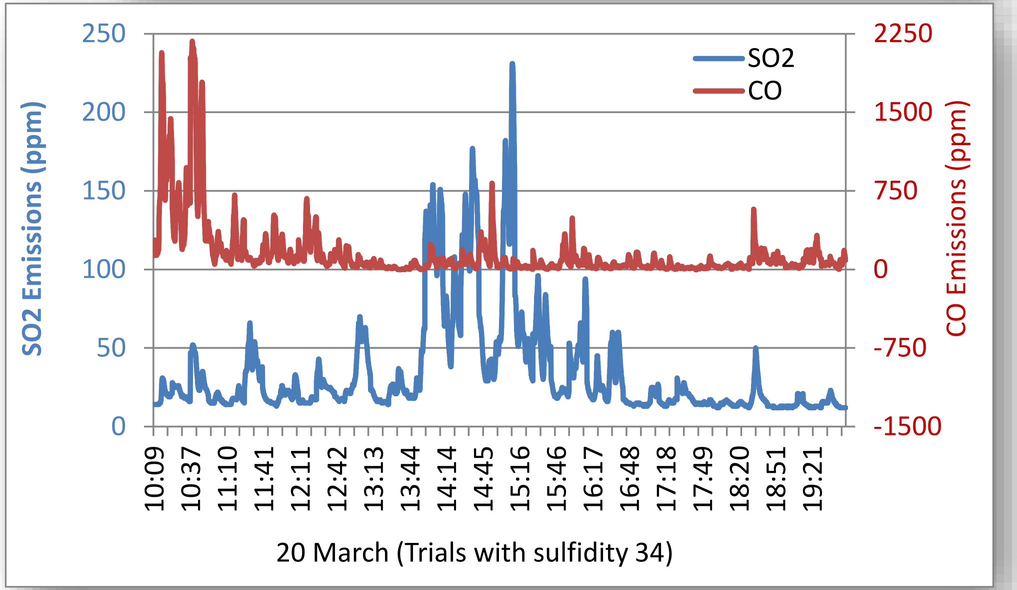
- Issues in 2013
  - High SO_2 emissions – the mill had to pay a penalty
  - Boiler pluggage
- Benchmarking found RB-I had highest liquor firing T
- Tried on Mar 20th
  - T was reduced from 129.5 to 128 ^oC
  - As a surprise, liquor pressure also down from 15.5 psi to 14.4 psig



Reduction of SO_2 Emissions from RB-I

- Baseline average SO_2 = 374 ppm from Recovery Boiler I
- Lowered BL firing temperature to the level never tried before
- Performance improved dramatically to 13-34 ppm SO_2





Time	NO, ppm	CO, ppm	CO_2,%	O_2, %	SO_2, ppm
Mar 20	63.4	150	15.7	3.8	34
Mar 21	69.3	387	17.4	3.4	13

Carryover also Improved

- Baseline
  - March 14, 2013,
    - West: 13.7 g/10 min, East: 14.9 g/10 min
- after Adjustments
  - March 20, 2013
    - West - Left port: 6.4 g/10 min, East - Right port: 12.5 g/10 min

Trials by FPI on 80 Boilers at Canadian and US Mills

- Benefits of $0.2 – $8 M/yr for a single mill
- Total $60 M/yr over the past 20 years
- Worth all the efforts

a. $8.89 M/y on Boiler A1 for British Columbia (BC) plant, 2004
b. $1.51 M/y on Boiler C, Québec (QC), 2005
c. $1.62 M/y on Boiler E, BC, 2005
d. $0.50 M/y on Boiler D, QC, 2007
e. USD $1.20 M/yr on Boiler PF, US, 2008
f. $0.43 M/y on Boiler G, BC, 2011
g. $1.35 M/y on Boiler A22, BC, 2011
h. $1.75 M/y on Boiler E2, BC, 2011
i. $1.16 M/y on Boiler A12, BC, 2012
j. $1.53 M/y on Boiler H, Manitoba, 2012
k. $3.74 M on Boiler X, BC, 2013
m. $1.0 M/y on Boiler TR, Ontario (ON), 2013
n. $0.25 M/y on Boiler T2, ON, 2015
o. $1.64 M/y on Boiler DR, QC, 2015
p. $0.50 M on Boiler SR, ON, 2015
q. $6.9 M/y on Boiler RR, BC, 2016
r. $2.7 M/y on Boiler RED, QC, 2016
s. $1.0 M on Boiler RR2, BC, 2016
t. $1.0 M/y on Boiler U, QC, 2017
u. USD $0.51 M/yr on Boiler RA, US, 2017
v. $1.6 M on Boiler U2, QC, 2018
w. $2.7 M/y on Boiler CR, BC, 2018
x. USD $2.45 M/yr on Boiler RL, US, 2018
y. $0.61 M/y on Boiler LI, Maritime, 2019
z. $3.0 M/y on Boiler RR-3, BC, 2020

Acknowledgement

- Members of FPInnovations
- Collaboration with many Canadian and US pulp-paper mills
- NRCan, BC government
- Colleagues at FPInnovations

OUR NAME IS INNOVATION

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SUOMEN SOODAKATTILAYHDISTYS
FINNISH RECOVERY BOILER COMMITTEE

Finnish Recovery Boiler Committee Report

AF&PA Recovery Boiler Conference 2024

February 7th, 2024

Katri Hukkanen

Content

- Overview of the FRBC
- Overview of recovery boilers in Finland
- Incident statistics 2003 - 2023
- Committee activities

Overview of the FRBC

Introduction

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

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

FRBC Members

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

- Total 32 members, including 13 pulp mills
  – 28 voting members, 3 universities
  – An annual member fee is collected from the Committee members

FRBC Organisation 2023

Annual Meeting
28 voting members

Board
Chairman*: Kari Saari, UPM
+ 11 members + secretary (*S.V.*)

*Chairman term is 2 years

Secretariat
Katri Hukkanen
Sakari Vuorinen
Emma Kärkkäinen
Päivi Lampinen

Durability sub-committee
14 members + secretary
(Katri Hukkanen)

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

Automation sub-committee
8 members + secretary
(Katri Hukkanen)

Black Liquor sub-committee
12 members + secretary
(Emma Kärkkäinen)

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

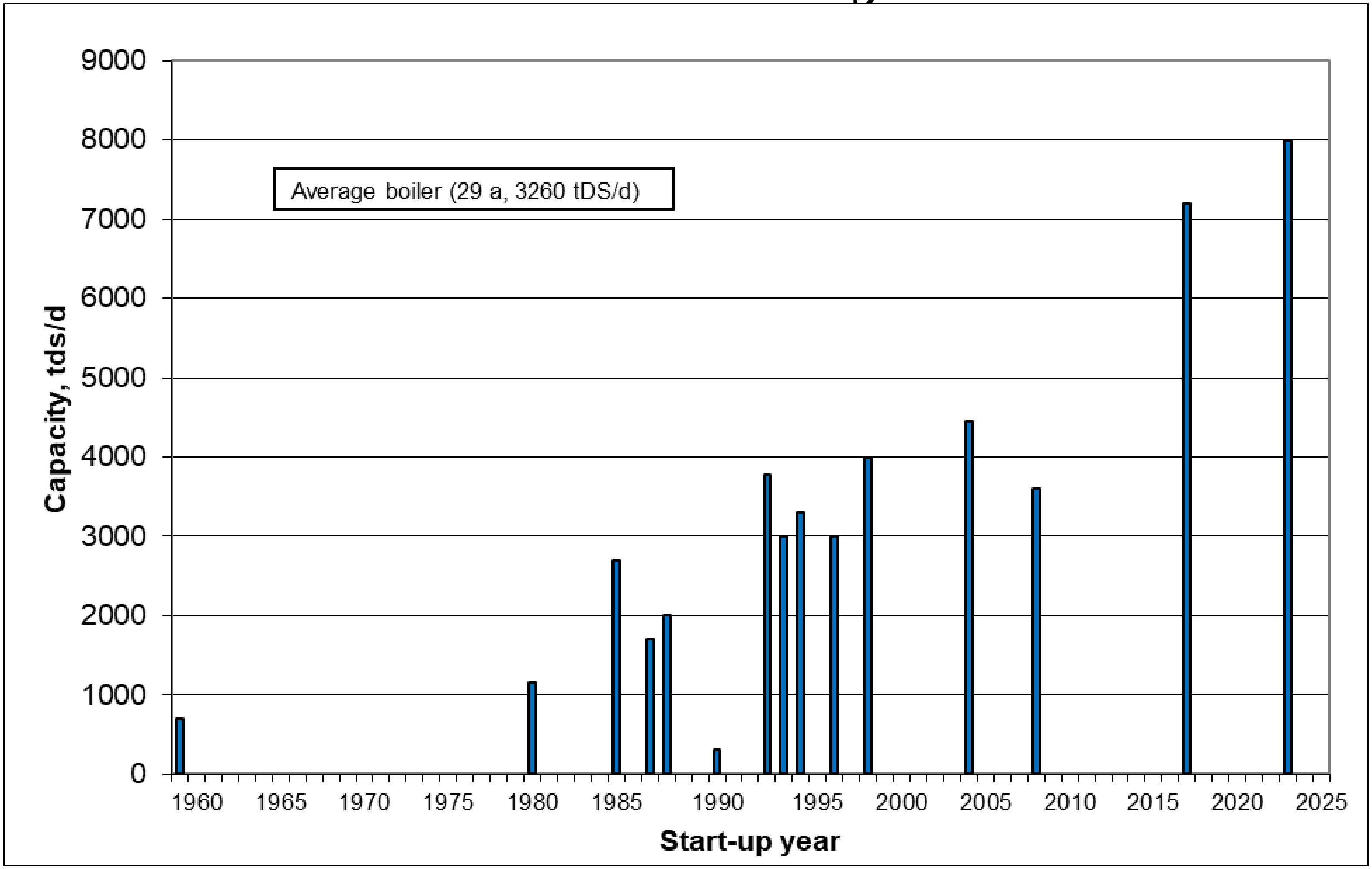
SUOMEN SOODAKATTILAYHDISTYS
FINNISH RECOVERY BOILER COMMITTEE

Overview of Recovery Boilers in Finland

Finnish Recovery Boilers

- Number of recovery boilers 15
  - The oldest started-up in 1959, MM Kotkamills
  - The newest started-up in 2023, Metsä Fibre Kemi bioproduct mill
  - The largest 8 000 tDS/d, Metsä Fibre Kemi bioproduct mill
  - The smallest 300 tDS/d, Stora Enso Heinola mill
- Number of mills 13
- Average boiler age 29 yrs (1994)
- Average boiler capacity 3 260 tDS/d
- Combined capacity 48 880 tDS/d

Finnish Recovery Boilers



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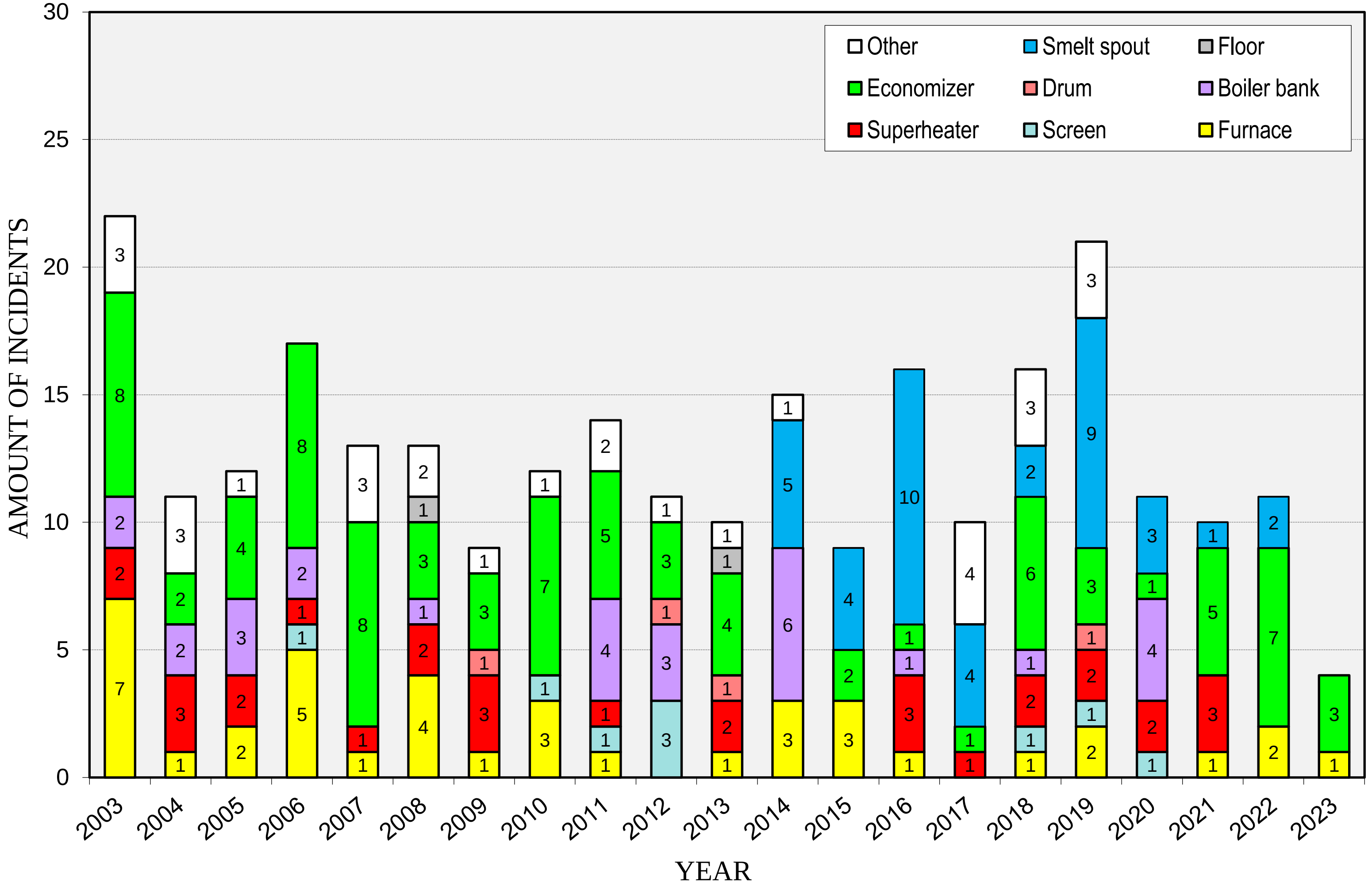
Recovery Boiler Incident Statistics 2003 - 2023

REPORTED INCIDENTS 2003-2023



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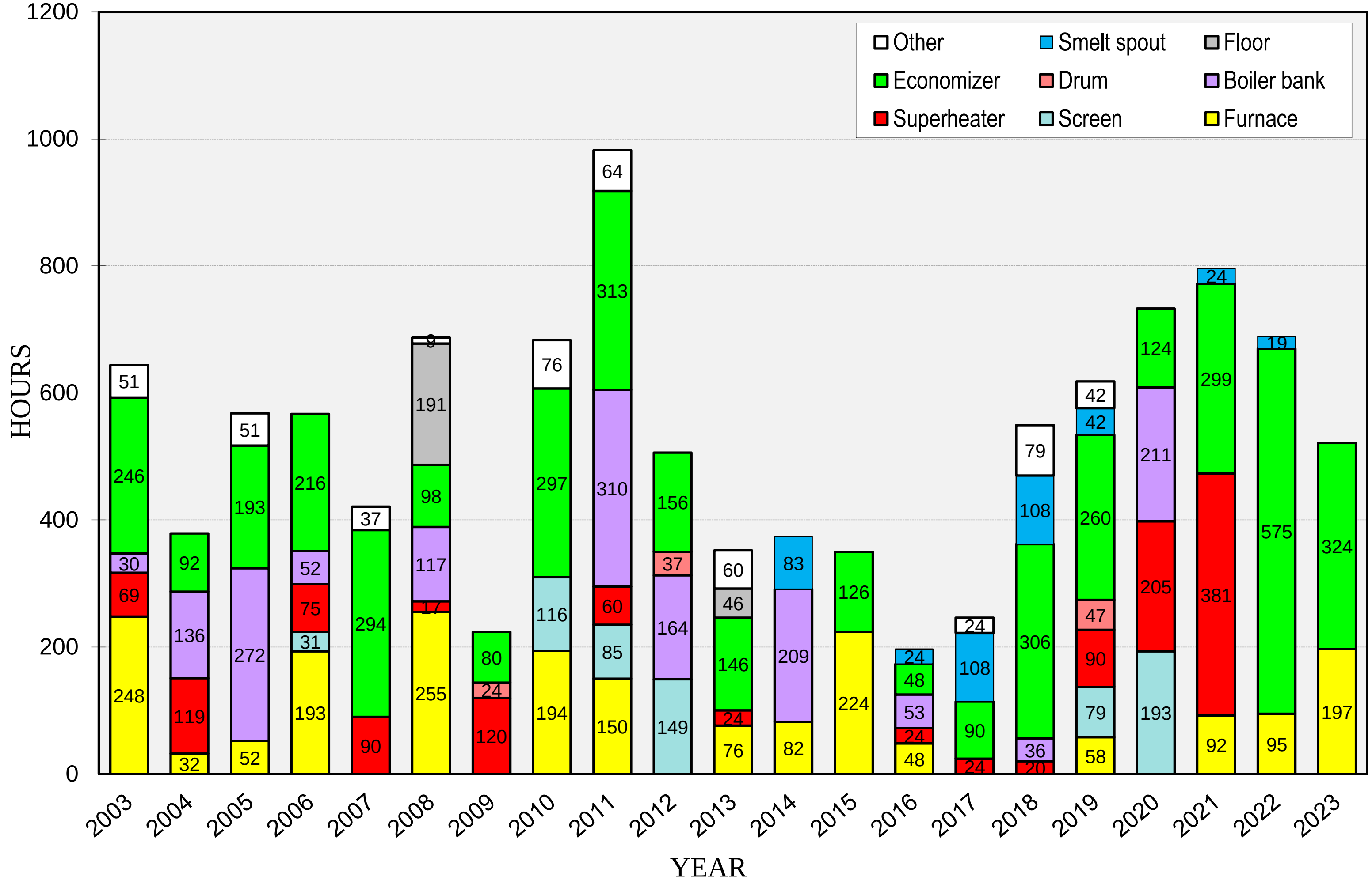
DOWNTIME 2003-2023



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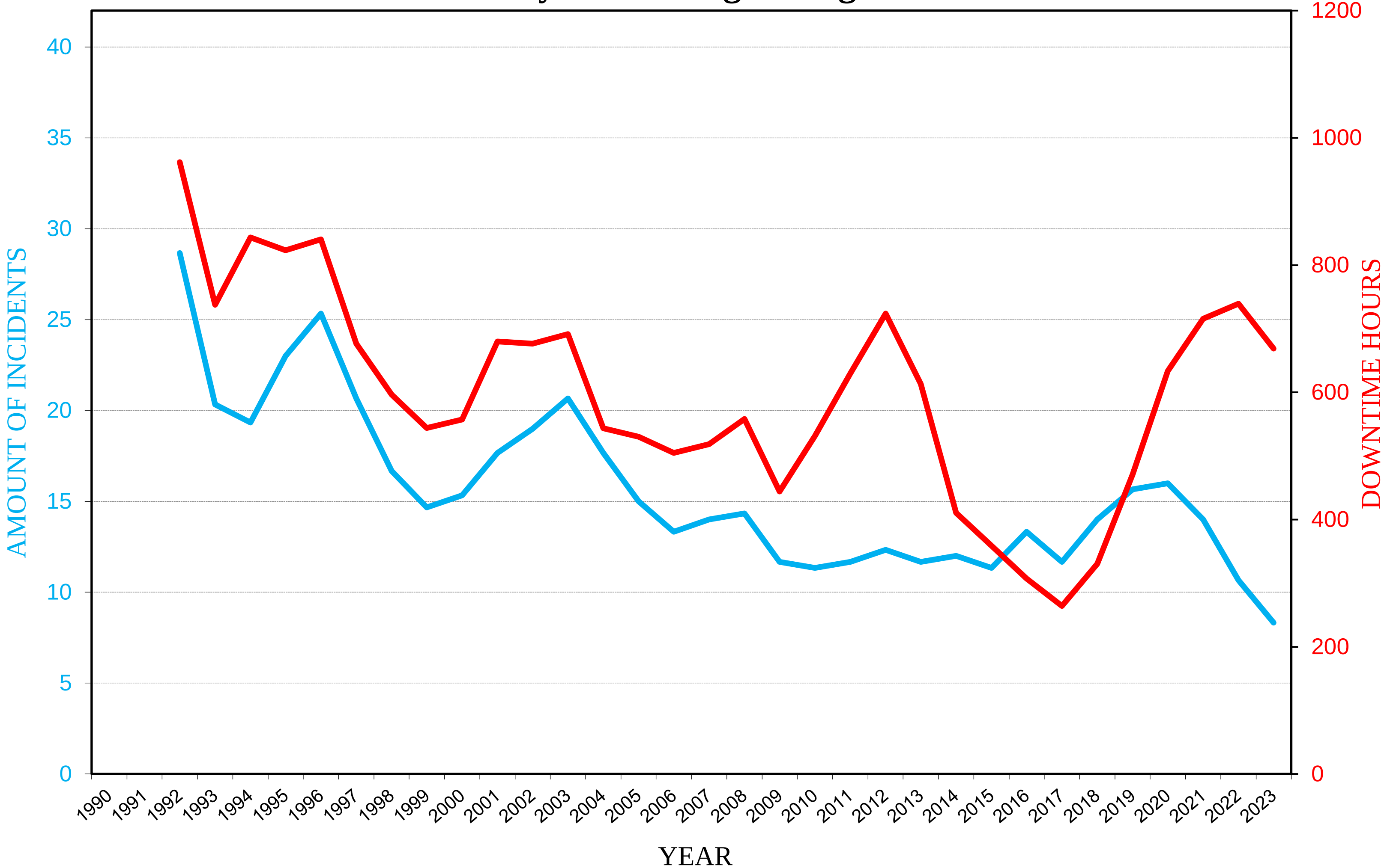
FINNISH RECOVERY BOILER COMMITTEE

INCIDENTS & DOWNTIME
3-year running average



Committee Activities

Activities

- Events
  - “Recovery boiler day” seminar was arranged on November 2nd 2023, in Helsinki
  - “Chief Engineer Day” seminar was arranged on January 25th, 2024 in Varkaus (mill visit to Stora Enso Varkaus mill)
  - “Operators’ day“ seminar will be arranged in March 2024

60th Anniversary

- FRBC arranges an international seminar on a Tallink Silja Helsinki-Stockholm-Helsinki cruise on June 5-7, 2024
- The theme for seminar: Continuous development of recovery boiler technology - Past, Present and Future

Projects 2022-2023

Durability sub-committee

- Update of material recommendation: Pipe peeling and S0-piping alignment + translation into English
- Development of the recovery boiler operator safety clothing
- Review of recovery boiler ceramic structures, parts I & II
- Crazing and damage mechanisms in compound pipes
- Review of recovery boiler availability and reliability

Black liquor sub-committee

- Superheater surface max. temperature change in relation to boiler size, parts I-II
- Effect of high kappa cooking in black liquor properties

Projects 2022-2023

Environment sub-committee

- POPs in green liquor dregs
- List of Finnish thesis works related to recovery boilers
- CCUS (Carbon Capture, Utilization and Storage) in pulp mills
- Translation of the update of NCG handling recommendations into English
- Separation and utilization of salts from recovery boiler ash

Automation sub-committee

- Electrical safety systems of boilers (update)
- Cybersecurity in pulp mills and recovery boilers
- Data transfer between information systems in recovery boilers – using OPC UA as an example
- Reliability of continuous measurements of the liquor cycle

POPs in green liquor dregs

- Persistent organic pollutants (POPs) are a group of typically halogenated organic compounds, that are resistant to degradation
- POP waste is regulated in the EU POPs regulation (EU 2019/1021) and the Finnish law.
- POPs regulation is updated regularly. The new limits (EU 2022/ 24003) are in action from 10.6.2023 onwards
- In this project, green liquor dregs about to be landfilled were analyzed for dioxins, furans and PAHs

POPs in green liquor dregs

- 10 Finnish pulp mills participated
  - Bleached pulp: 3 mills
  - Unbleached pulp: 3 mills
  - Both varieties: 2 mills
- Dioxin and furan contents were significantly lower than those specified in the POPs regulation
- PAH contents were also minimal in the samples

Analysed by Eurofins Nab Labs Oy, Titaanitie

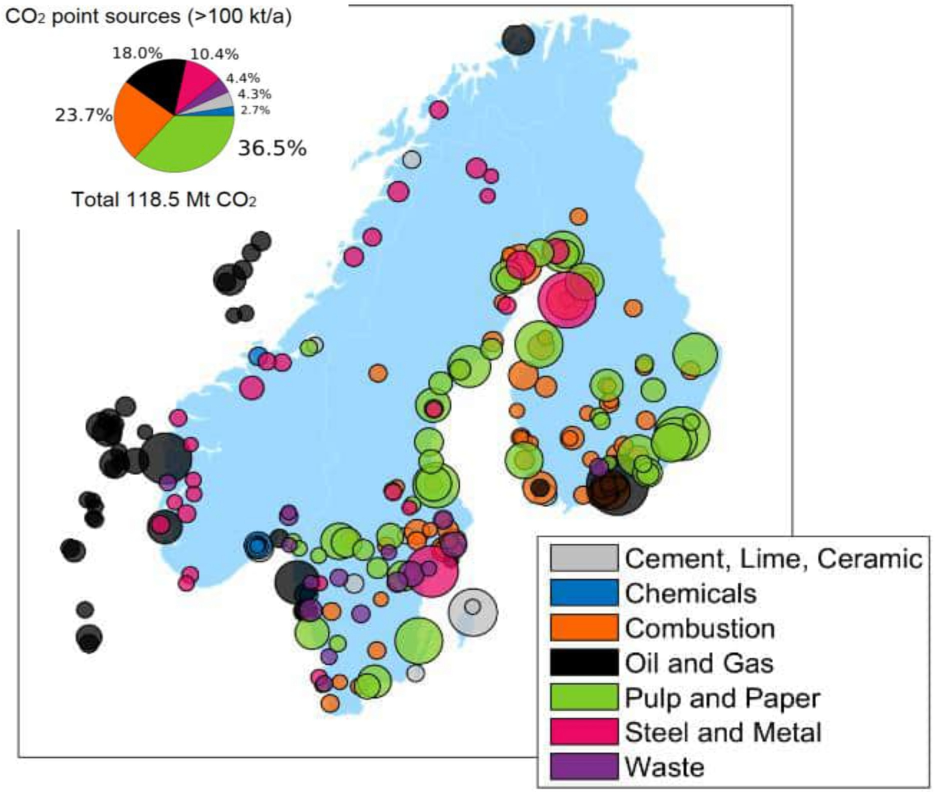
	SCAN-N 22	SCAN-N 32	SCAN-N6	SCAN-N 4	Gravimetric, internal method	
MILL	Dry matter, %	Carbonate CO3-	Sulphate SO4, water soluable	Chloride Cl-, water soluable	Unburned coal	Unit
A	46.4	18.6	0.02	<0,01	4.5	% dw
B	36.3	16.9	0.07	0.14	2.3	% dw
C	56.0	36.1	0.08	0.04	1.4	% dw
D	43.3	31.1	<0,01	<0,01	1.8	% dw
E	74.0	22.7	0.08	<0,01	6.7	% dw
F	44.4	23.3	0.08	<0,01	9.2	% dw
G	30.1	32.4	0.15	<0,01	14	% dw
H	54.2	44.3	0.02	<0,01	0.48	% dw
I	42.3	34.3	0.1	<0,01	3.2	% dw
J	49.3	19.4	0.02	<0,01	0.95	% dw
AVG	47.6	27.9	0.1	0.1	4.5	% dw
MIN	30.1	16.9	0.02	0.04	0.48	% dw
MAX	74.0	44.3	0.2	0.1	14.0	% dw

"<" = Result is under the quantification limit of the analysis method
ND = not detected; dw = dry weight

Towards carbon-negative future of the pulp and paper industry - BECCUS

LUT University

- Work based on modelling and calculations
- Targets of the thesis:
  1. Mapping methods for carbon capture
  2. Assessing the effect on pulp mill operations
  3. Cost assessment
  4. Review of relevant politics



Towards carbon-negative future of the pulp and paper industry - BECCUS

LUT University

- Conclusions
  - It would be possible to capture 100 000 tCO_2 in several Finnish pulp mills
  - The chosen method in this work was conversion to methanol
  - The energy balance or carbon capture system does not limit the capacity
  - At least for now, the largest limit to capacity becomes from the limited level of electricity available from the grid
  - The development of EU regulation will affect the power-to-x market significantly

Full thesis in English available at: *https://lutpub.lut.fi/handle/10024/165810?show=full*

SUOMEN SOODAKATTILAYHDISTYS
FINNISH RECOVERY BOILER COMMITTEE

Additional info on the FRBC website

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

https://soodakattilayhdistys.fi/60th-anniversary-international-recovery-boiler-conference/

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

Recovery Boilers

Advanced Monitoring, Alarming, Control, and Troubleshooting

Travis Conner

Solution Manager • AS NA Solutions Management

Start audio call   Start chat   Send email

Automation Hierarchy

Intelligent control space

Mill-wide optimization

Automated process coordination & optimization

Sub-process optimization (APC)

Wood yard
- Chip quality target and feedback from pulp mill

Fiberline & Pulp dryer
- Yield
- Residual Alkali
- Washing efficiency
- Final brightness
- Pulp quality

Recovery line
- Black Liquor dry solids
- Reduction efficiency
- White liquor concentration
- Make-up need

Power boiler & Steam network
- CO2 emission
- Emissions
- Supplementary fuel usage
- Electricity production balance / energy trading

BCTMP
- Pulp quality

Paper Machine Line
- Furnish quality
- Stock blend
- Ash balance
- Charge
- Paper strength
- Dimensional stability
- Optical properties
- Surface properties
- Basis Weight
- Dryness
- Formation
- Bulk
- Quality data transfer to Converting

Converting
- Warp/Curl
- Moisture and Temperature
- Coating
- Speed maximization

Process automation

- Process controls (DCS)
- Machine controls (MCS)
- Quality controls (QCS)
- Drive controls
- Safety controls (SIS)
- Information management
- Condition monitoring

Analyzers, measurements & profilers

Wood yard:
- Chip moisture

Fiberline & Pulp dryer:
- Kappa and Brightness
- Fiber properties
- Pulp quality
- Alkali concentration
- Consistency
- Profilers

Recovery line:
- Green liquor
- White liquor
- Recovery boiler ash
- Combustion symmetry

Power boiler & Steam network:
- Biomass moisture
- Corrosion
- Fuel bed camera
- Flue gas temperature symmetry

BCTMP:
- Pulp Properties
- Shive Content
- Freeness
- Brightness
- Consistency

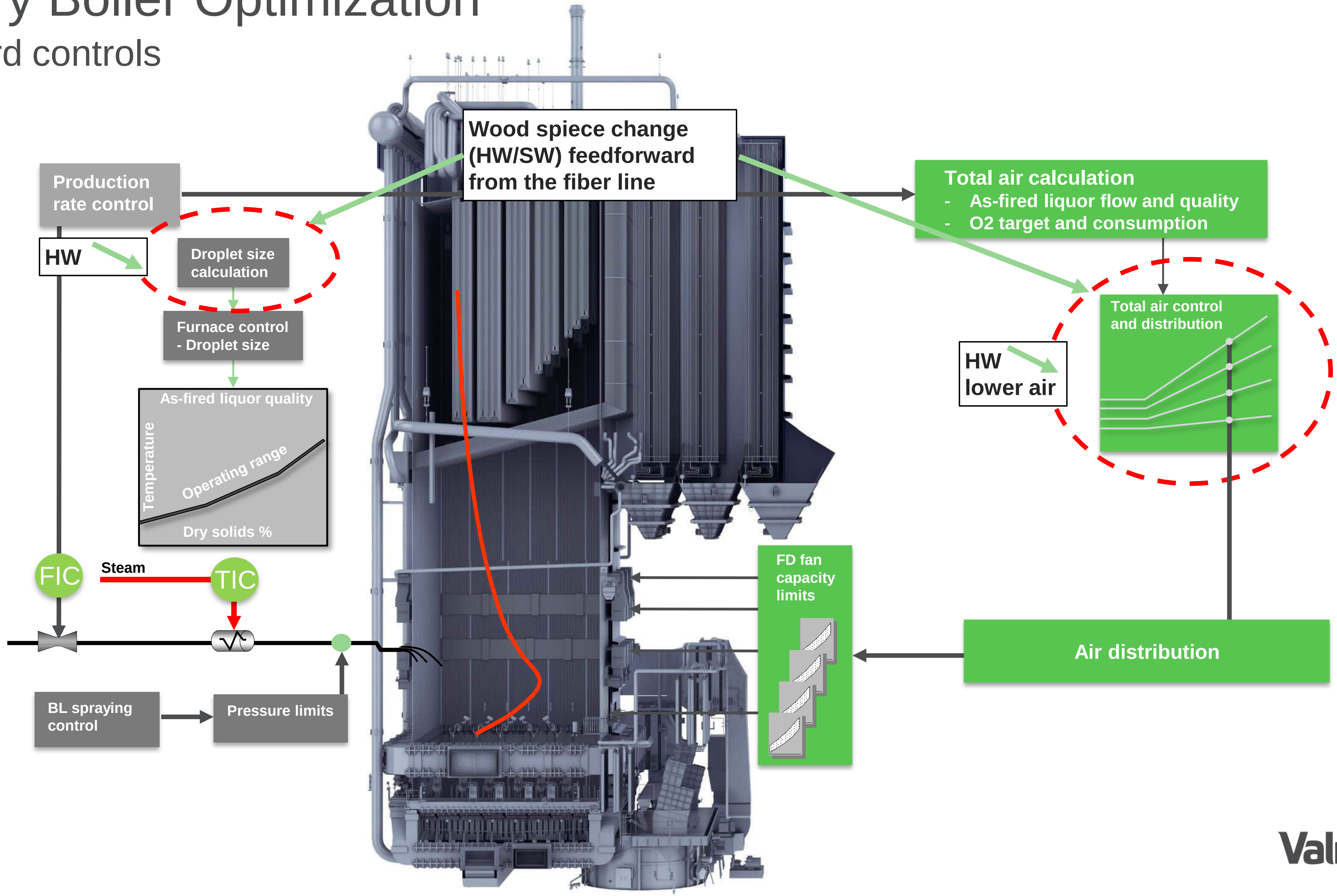
Paper Machine Line:
- Fiber prosperities
- Pulp quality
- Consistency
- Quality measurements
- Machine vision
- Profilers

Converting:
- Quality measurements
- Machine vision
- Profilers

Valmet

Recovery Boiler Optimization

Feedforward controls



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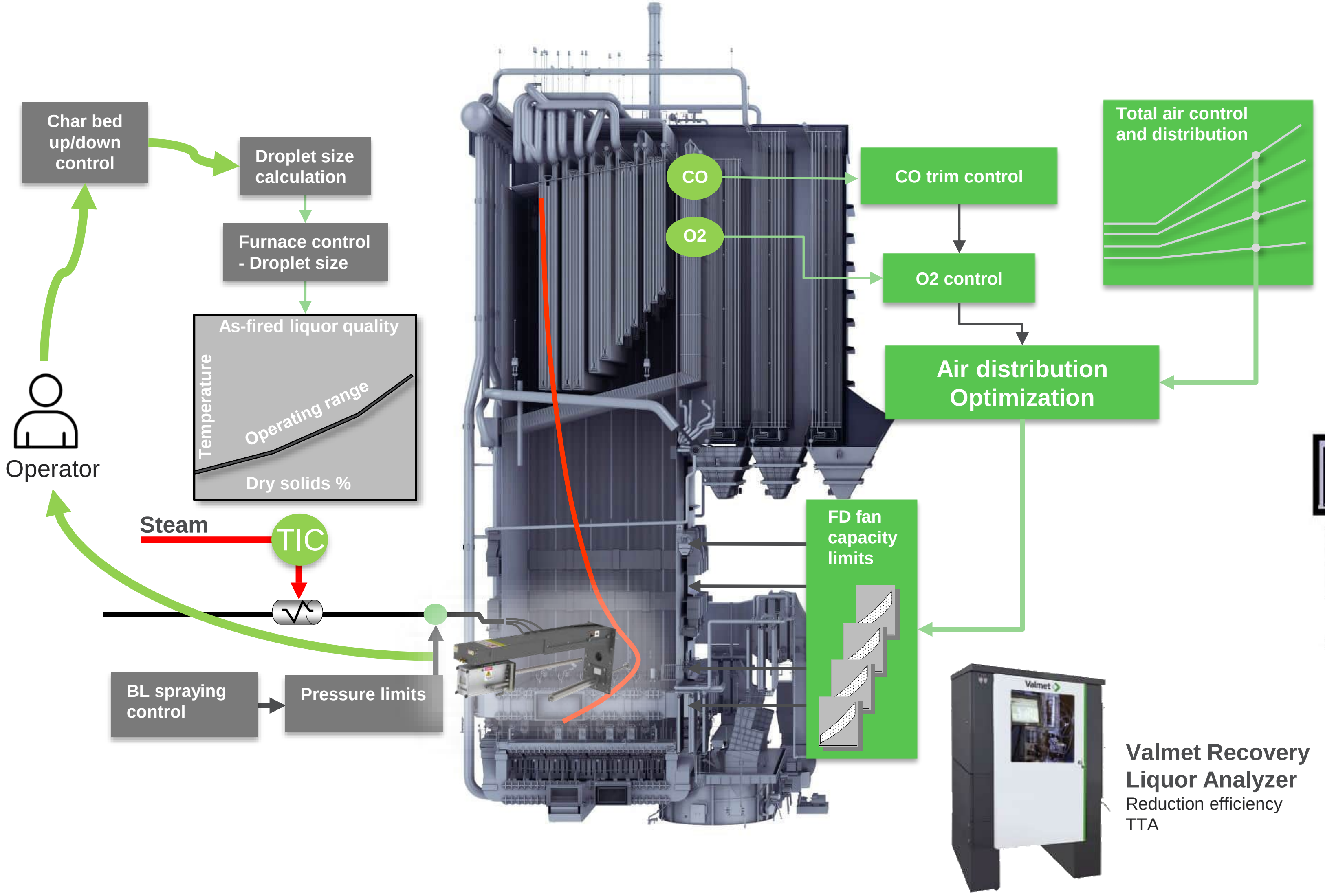
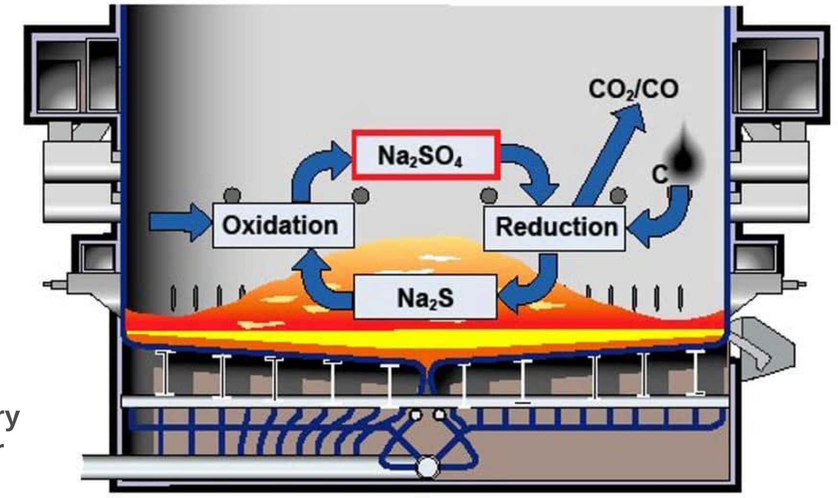
Recovery Boiler Optimization

Feedback controls



Reduction efficiency control

- Reduction reaction is strongly dependent on the bed temperature
- High enough temperature keeps the reaction on the Na2S side with minor reoxidation
- Targets to:
  - Air distribution optimization
  - Liquor droplet size optimization



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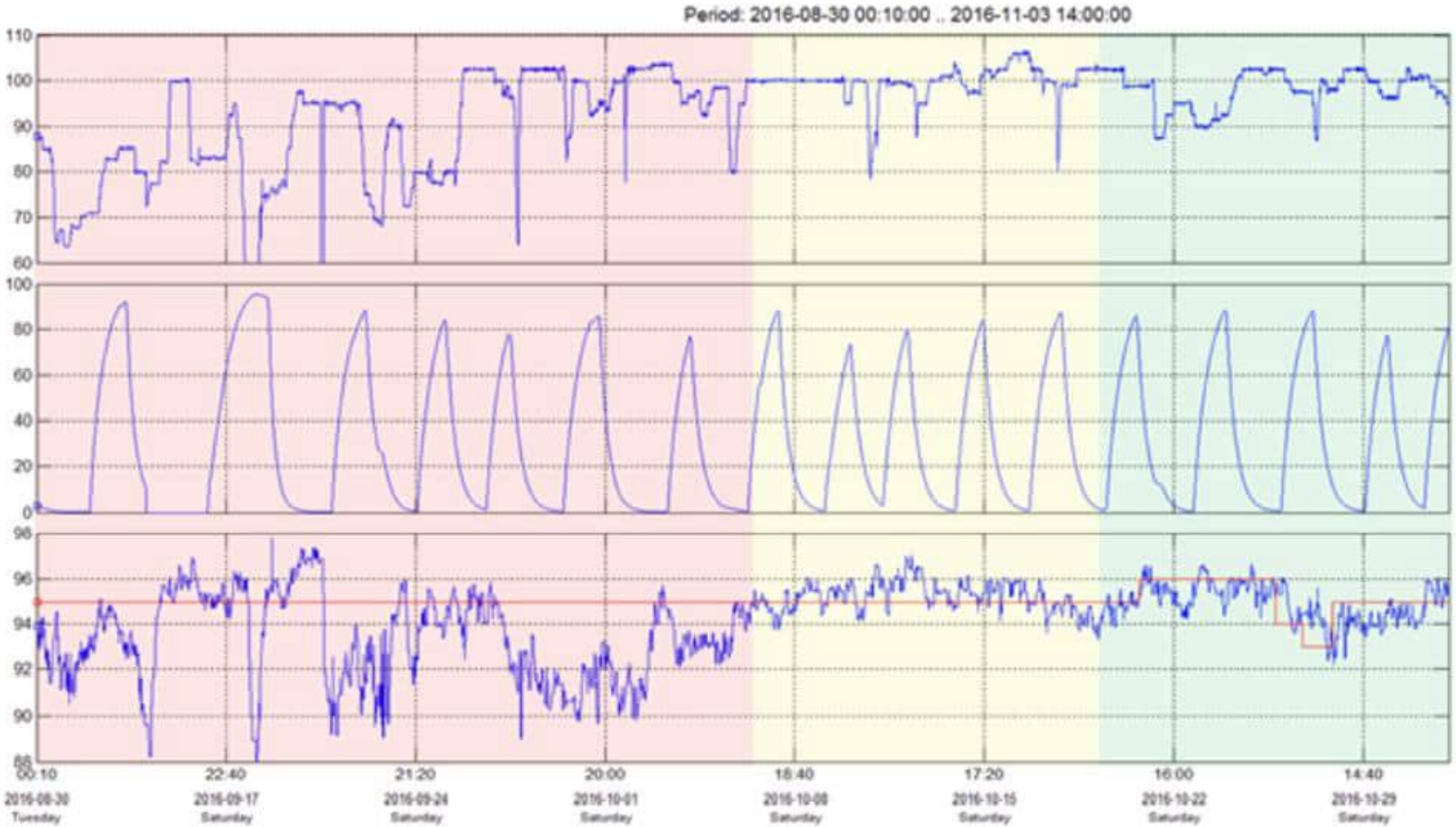
Reduction Efficiency Control Results Example

Boiler Load

Softwood Percentage

Reduction Efficiency



Stabilizing control level ON, Reduction OFF
Average RR 93.6%
STDev 1.96

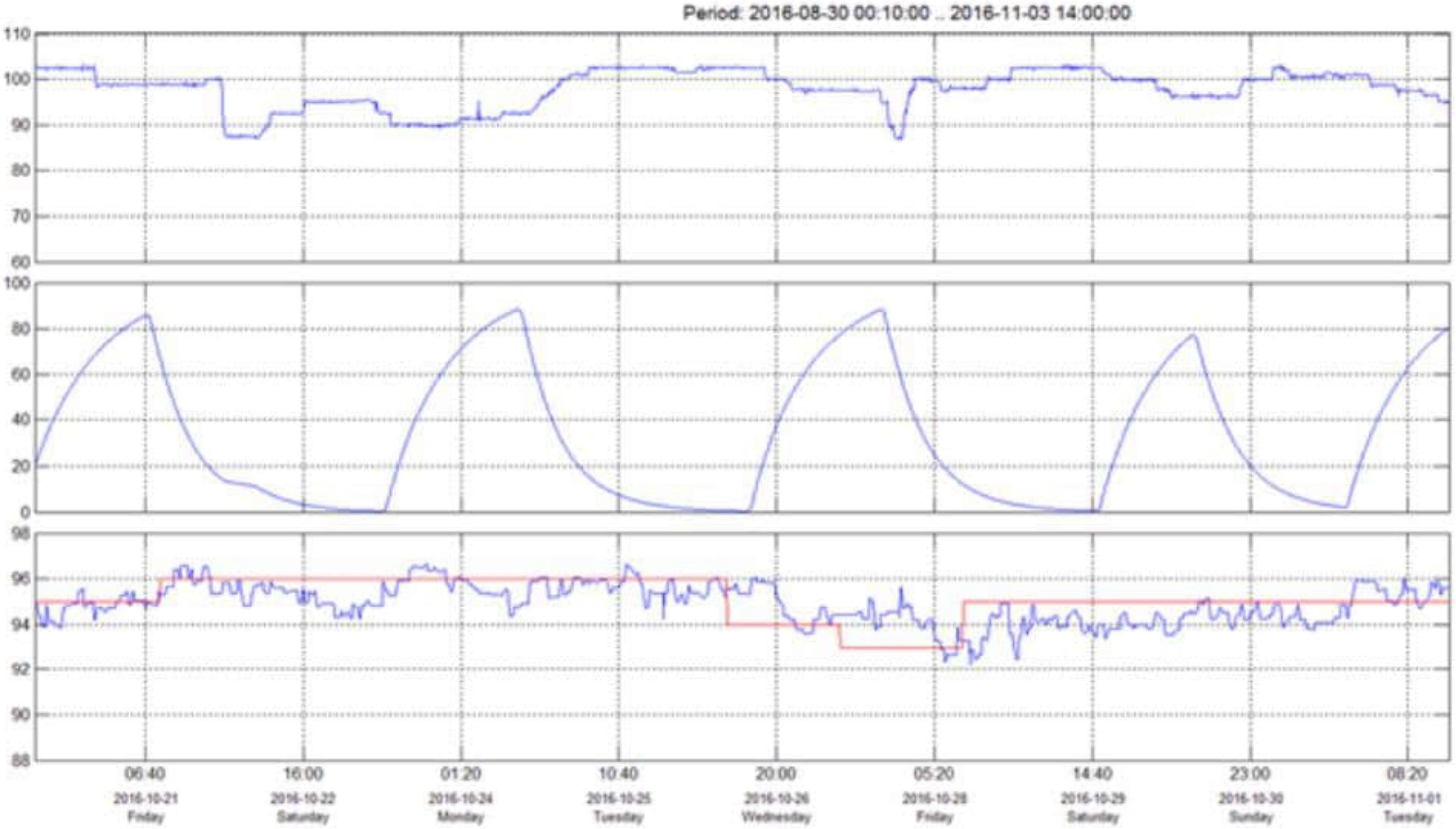
RR control ON
Average RR 95.3%
STDev 0.67

Reduction Efficiency Control Results Example

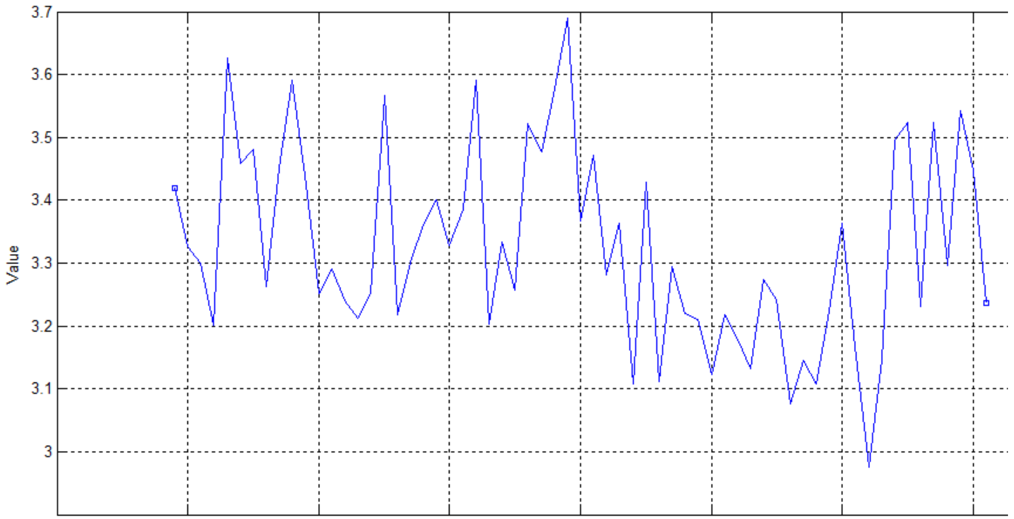
Boiler Load

Softwood Percentage

Reduction Efficiency



Example Steaming Rate Stabilization



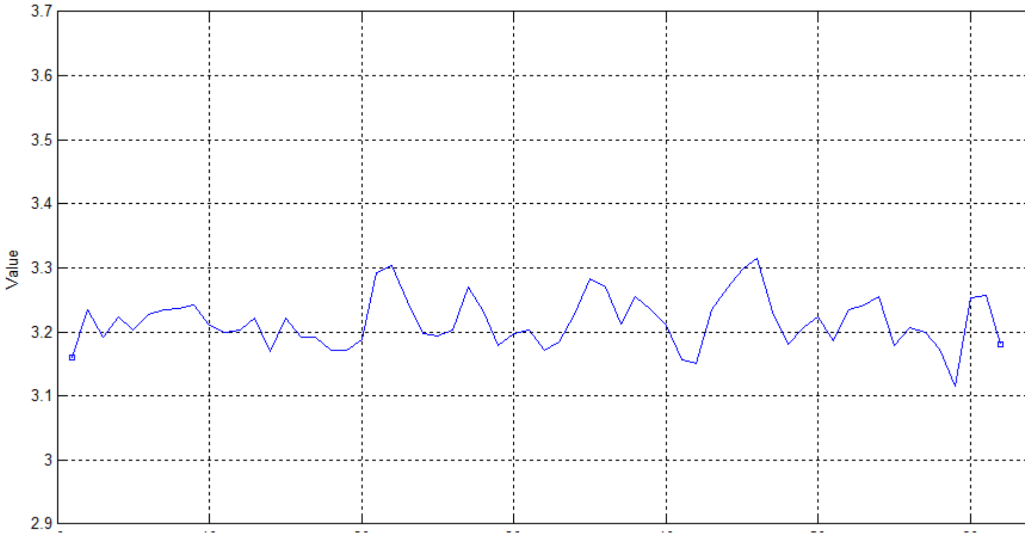
Without combustion optimizer
Steaming rate ton/tonDS

Average	3.326
deviation	0.1563
Min	2.976
Max	3.689

Max steam production 110 ton/h

Steaming rate, ave+2*deviation = 3.5286
Max boiler load 748 tDS/d

Steam production 100 2 t/h



With combustion optimizer
Steaming rate ton/tonDS

Average	3.216
deviation	0.0401
Min	2.314
Max	3.115

Max steam production 110 ton/h

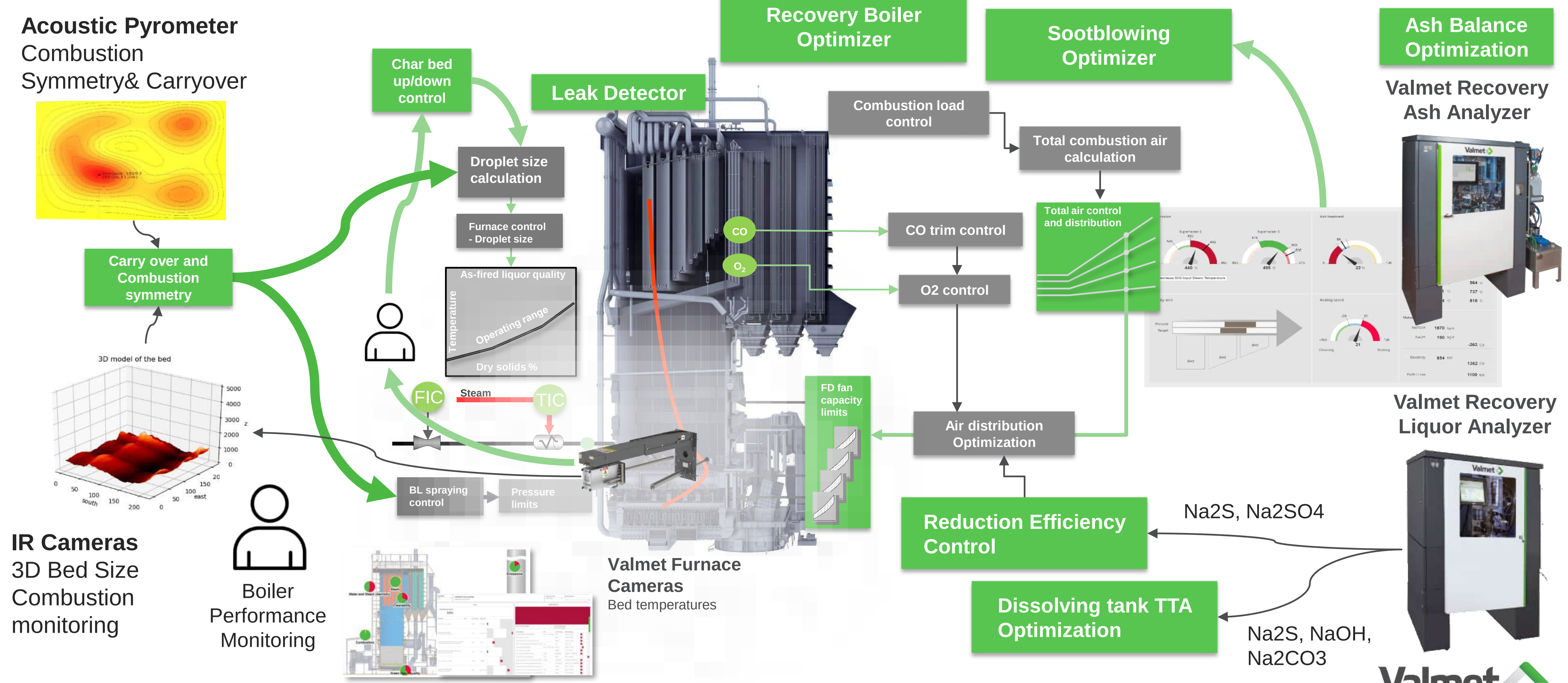
Steaming rate, ave+2*deviation = 3.2962
Max boiler load 801 tDS/d

Steam production 107.3 t/h
Increase of liquor throughput 7 %
Increase of steam production 7.1 %

Recovery Boiler Optimization

Toward autonomous operation

Energy Efficiency
Production Capacity
Environment
Operational safety



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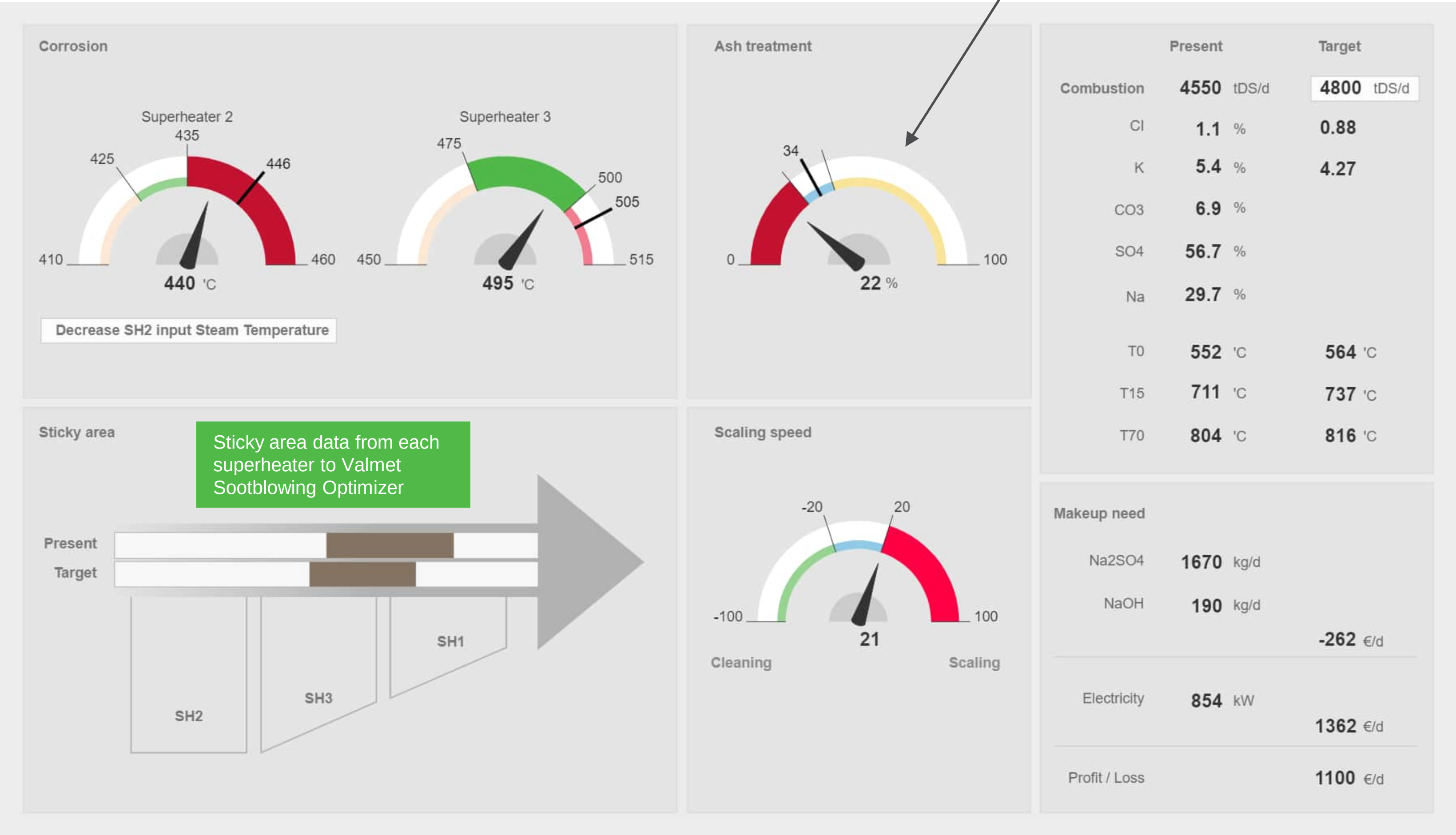
Example Operator Advisory Tool

Current ash treatment is 22% and advised target is 34%



Advisor calculates the online status of:

- Corrosion risks
- Steam temperature targets
- Sticky area
- Scaling speed
- Advised change to ash treatment amount

After advised change:

- New ash chemistry
- Operation costs change
- New sticky area
- New maximum steam temperature targets

Summary

- Advanced monitoring and control of recovery boilers
  - Requires as much good data as possible
  - Applies engineering principles to assist operators beyond the human capacity
  - Must provide value for operators and owners to minimize safety risks, improve environmental performance, reduce operating costs and increase productivity

- Questions?
  - Travis Conner, 757-902-0929, travis.conner@valmet.com

Valmet

Valmet
FORWARD

AF&PA

RECOVERY BOILER OPERATIONAL SAFETY SEMINAR

American
Forest & Paper
Association

Operational Safety Seminars

- The **O&M Subcommittee** sponsors the **Recovery Boiler Operational Safety Seminars**
  - Objective: **Safe Operation of Recovery Boilers**
- Operators, Supervisors, Superintendents, Maintenance Professionals, Engineers, Steam Chiefs, and Managers attend.
  - Note, attendance is limited to members of companies and mills that operate recovery boilers. AFPA Member company attendees receive a 50% discount on registration fees.
- **Training continues to increase in importance,** as more senior operators and supervisors retire
- Companies have found these Safety Seminars to be an important part of their **Safety & Training Programs**

Operational Safety Seminars

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

- ➢**Team Exercises** help operators and supervisors make the important decision: **When to ESP a Recovery Boiler**
  - The Case Studies are based on recent **actual BLRBAC Recovery Boiler Incidents**
  - **Eight (8) new Case Studies** for each Safety Seminar Yearly Series

- ➢Over **4,700** people have attended the seminars since they were started in 1985

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

Operational Safety Seminars

2023: Total 6 seminars were completed, 4 Virtual Online and 2 In-Person; for 2022 seminars, 4 were all virtual.

2023 Virtual Seminars

- March 22, 2023 - (7:45 am – 4:30 pm) Eastern Time – **54 Attended**
- April 20, 2023 - (7:15 am – 4:00 pm) Pacific Time – **56 Attended**
- September 20, 2023 - (7:45 am – 4:30 pm) Eastern Time – **33 Attended**
- November 2, 2023 - (7:15 am – 4:00 pm) Pacific Time – **20 Attended**

- More people can attend due to the lower registration fee (50%)
- **+** No travel time or cost, and less time off the job!

Operational Safety Seminars

2023: Two (2) In-Person Recovery Boiler Operational Safety Seminars were completed

- May 23 - 24, 2023, at Marriott Atlanta Airport – **28 Attended**
- October 4 – 5, 2023, following the Fall BLRBAC Meeting, in the Sonesta Atlanta Airport North – **29 Attended**
- Format is 2 half-days, starting at noon and ending at noon the next day, which allows for more travel options and for more time for attendees to exchange ideas.
- In-Person cost is $500 per person for member companies
- Attendees are split into teams, each team has its own table
  - We try to mix companies/mills between the teams, to enhance sharing

Operational Safety Seminars

2024 Plans: Four (4) Recovery Boiler Operational Safety Seminars

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

- March 20, 2024 – (7:45 am – 4:30 pm) Eastern Time **(Virtual)**
- April 10-11, 2024 – **In-Person**, immediately following Spring BLRBAC, Sonesta Atlanta Airport North, 2 half-Days
- May 16, 2024 - (7:15 am – 4:00 pm) Pacific Time **(Virtual)**
- October 9-10, 2024 – **In-Person**, immediately following Fall BLRBAC, possibly at Hilton Atlanta Airport Hotel (will be new BLRBAC hotel), 2 half-Days

People

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

Introduction

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

Introduction

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

BLRBAC Previous Year Incident Summary Review John Andrews

Interlocks and Interlock Bypassing
(BLRBAC Instrumentation Subcommittee Guidelines)

Dean Clay

Review Of ESP Subcommittee Learnings
John Andrews

2022
Case 1 - 4

Dean & John

Recovery Boiler Explosion History Review

Comments on Prevention of Explosions

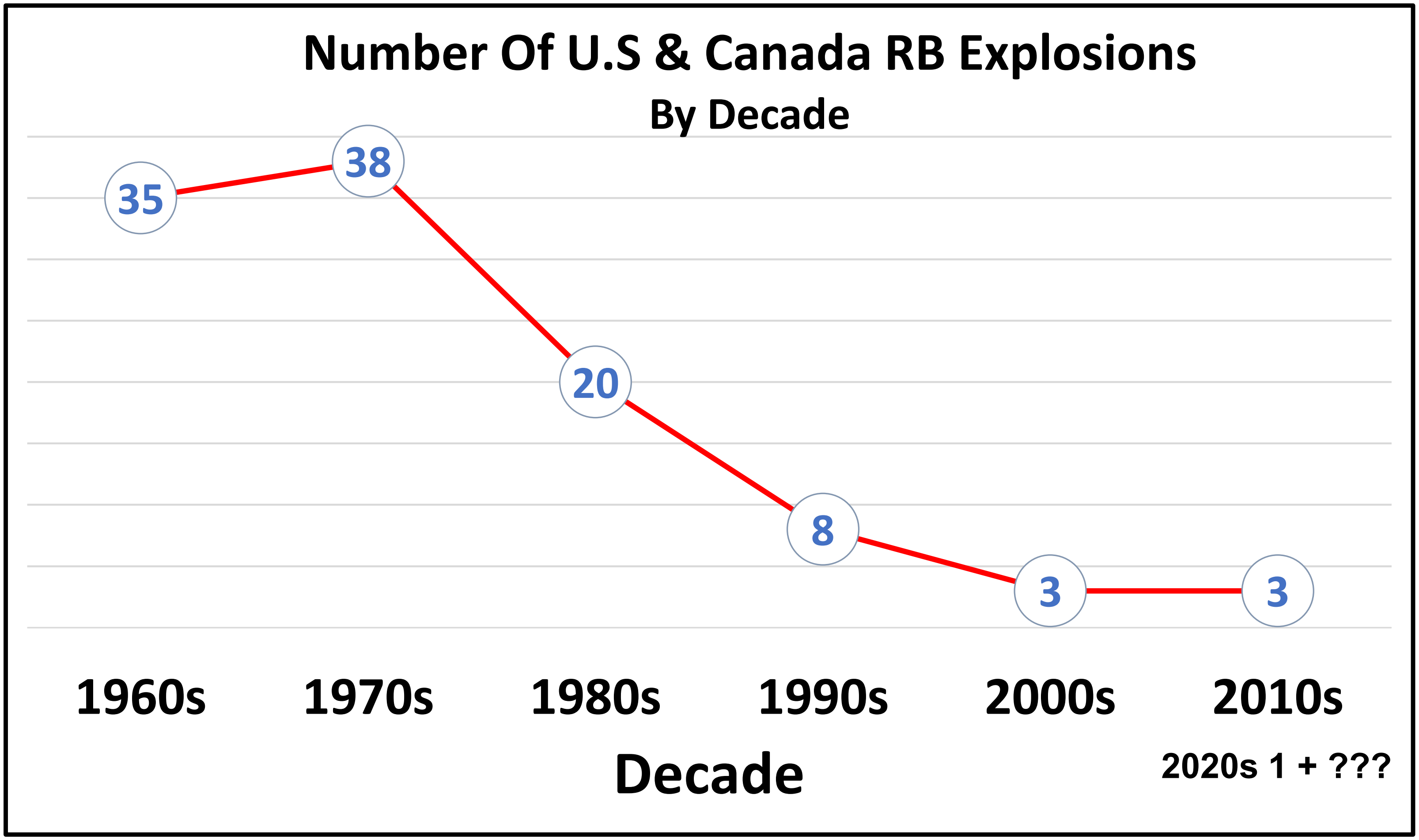
Dean Clay, BSI, BLRBAC ESP Subcommittee Secretary

AF&PA RB Operational Safety Seminars 2022

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

Potential Catastrophe

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


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

Progress on Explosion Control

- Nearly 4 explosions per year in 1960s and 1970s

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

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

External Resources

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

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

Prevention of Recovery Boiler Explosions

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

BLRBAC Recommended Sudden, Large-Leak Logic, Revised SFBL Fall 2023

- ❑ **Drive the feedwater control valve closed and switch the valve control to manual when a high furnace pressure Master Fuel Trip (MFT) occurs.**
  - ❑ **Review setpoint of Hi Pressure Trip, recommended to set to relatively low level, +2" – +4" H_2O.**
  - ❑ **Additionally, an alert/alarm message shall appear to the operator indicating the Large-Leak logic condition has occurred and that this may be the sign of a large tube leak.**

BLRBAC Recommended Sudden, Large-Leak Logic (continued)

- When this control logic activates it remains the operator's responsibility to determine the correct next course of action
  - Additional boiler specific training should be given to all operators regarding the implications and symptoms of a sudden large tube leak. Use of a checklist is recommended.
- If it is determined an ESP is not required, the operator can open the feedwater control valve, or can put the valve back into automatic.
- After opening feedwater, consider an additional alarm if drum level recovery time exceeds normal duration, possibly indicating a large tube leak still exists.

Analysis of Dissolving Tank Explosions
John Andrews

Based on report by Dr. Thomas M. Grace

2023
Case 1

Description of Events

The 15-minute steam vs feedwater differential alarm alarmed, operators followed the checks and walked the boiler down and did not find any obvious causes on walkdown, reached out for more assistance. Additional walkdown was completed with day tech where suspicious noises were heard around 8th floor at superheater.

Believed to have a superheater leak, liquor was pulled, bed burned out for 2 hrs and fire pulled. About the time of fire being pulled the FW operator reported the chemical test had dropped some on the feedwater. Inspection showed that there was no bed in the boiler and no longer smelting so decision was made to cool down the unit as planned on normal shut down, another test was run and came back relatively unchanged.

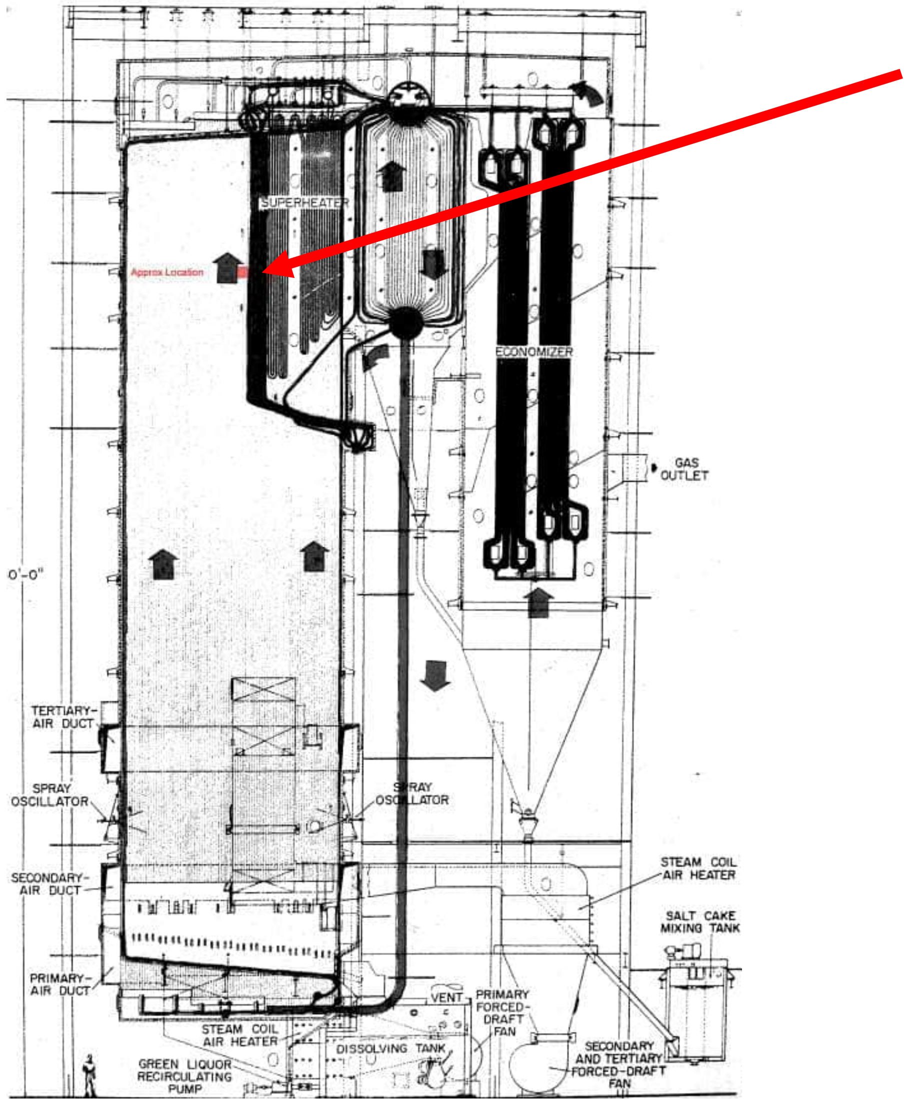
Tube Leak and Root Cause

2023 Case 1

Platen 6, row 1 loop 1, of the high temp superheater was the original leak, near a T&G attachment to the rear furnace screen tube. The superheater leak washed out the screen tube adjacent to it, resulting in three water leaks.

On hydro found a weeper on weld attachment (D-link) on Platen 9 row 5 loop 1 of low temp superheater

Initiating failure is believed to be a superheater tube leak adjacent to the attachment. The metallurgical report indicated the SH failure was due to erosion/erosion-corrosion initiated from the OD of the tube. However, the exact erosion mechanism is not readily apparent or present on adjacent tubes. (Sootblowers are on the opposite side of the thinning). Another possible root cause is the failure initiated at an old arc-strike or nick when attachments were installed.


SUPERHEATER
Approx Location
ECONOMIZER
GAS OUTLET
0'-0"
TERTIARY-AIR DUCT
SPRAY OSCILLATOR
SPRAY OSCILLATOR
SECONDARY-AIR DUCT
PRIMARY-AIR DUCT
STEAM COIL AIR HEATER
STEAM COIL AIR HEATER
SALT CAKE MIXING TANK
VENT
PRIMARY FORCED-DRAFT FAN
DISSOLVING TANK
GREEN LIQUOR RECIRCULATING PUMP
SECONDARY AND TERTIARY FORCED-DRAFT FAN

SH Tube Leak

Screen Tube Leaks

Tube Leak Detection Systems

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

A second goal is to also alarm large, sudden, leaks.

2020
Opportunities to Improve Recovery Operations

John Andrews

ESP Subcommittee

SUBCOMMITTEE REPORT – FRANK NAVOJOSKY

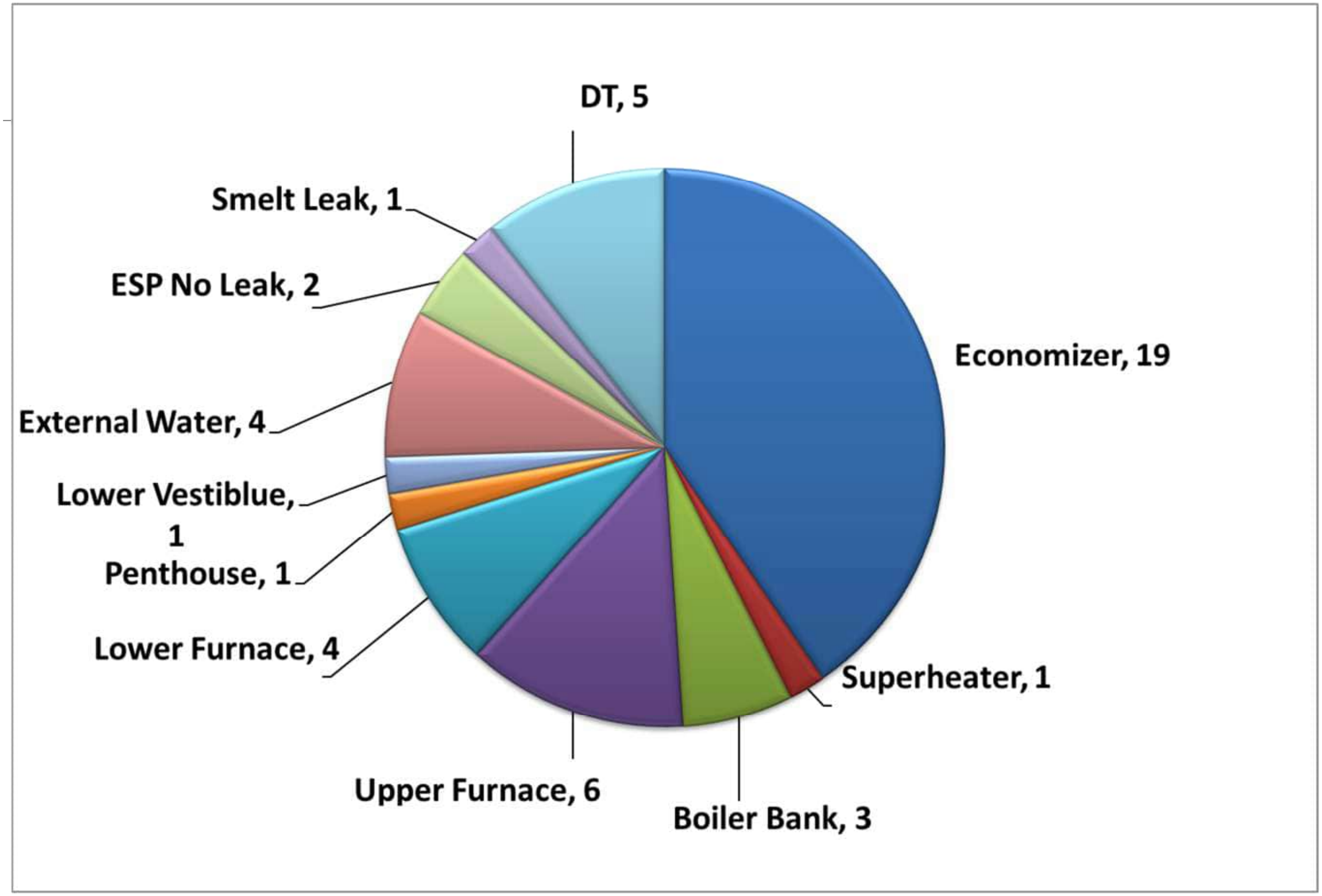
2023, SPRING & FALL COMBINED

Incident Questionnaire Review

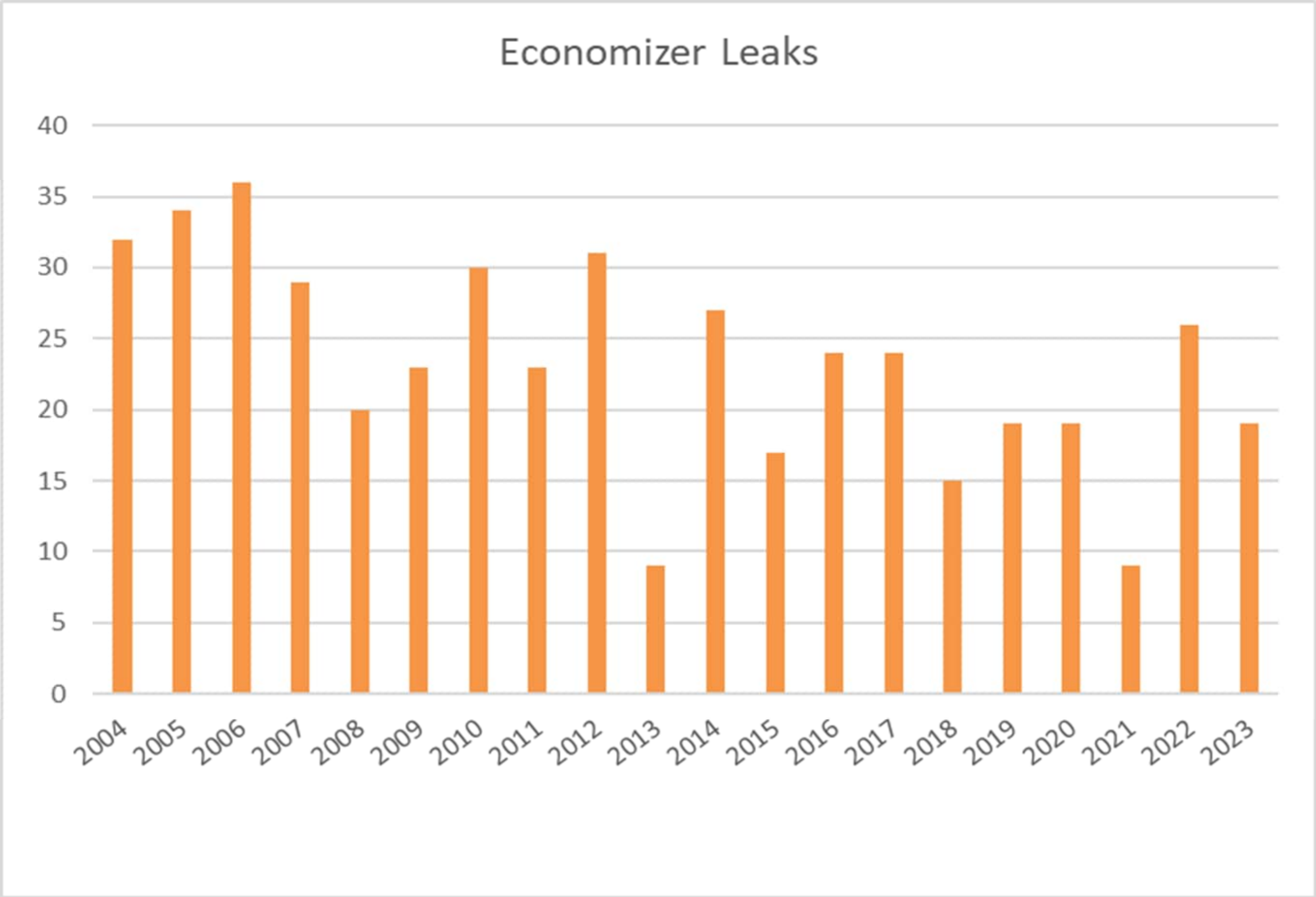
- 47 North American incidents (17 Spring, 30 Fall)
  - 0 Smelt Water Explosion
  - 1 DT Explosion
  - 12 Critical
  - 26 Non-critical
  - 4 DT issues
  - 1 Smelt leak
  - 2 ESP w/ No Leak
  - 1 External Water not in RB interior

- 12 ESP'd (2 w/ no leak, 1 ESP on a DT issue)
  - 12 Critical (2 found on Hydro)
  - 9 Critical in operation with a bed & 7 of these ESP'd
  - 78% of Critical ESP'd that Should ESP

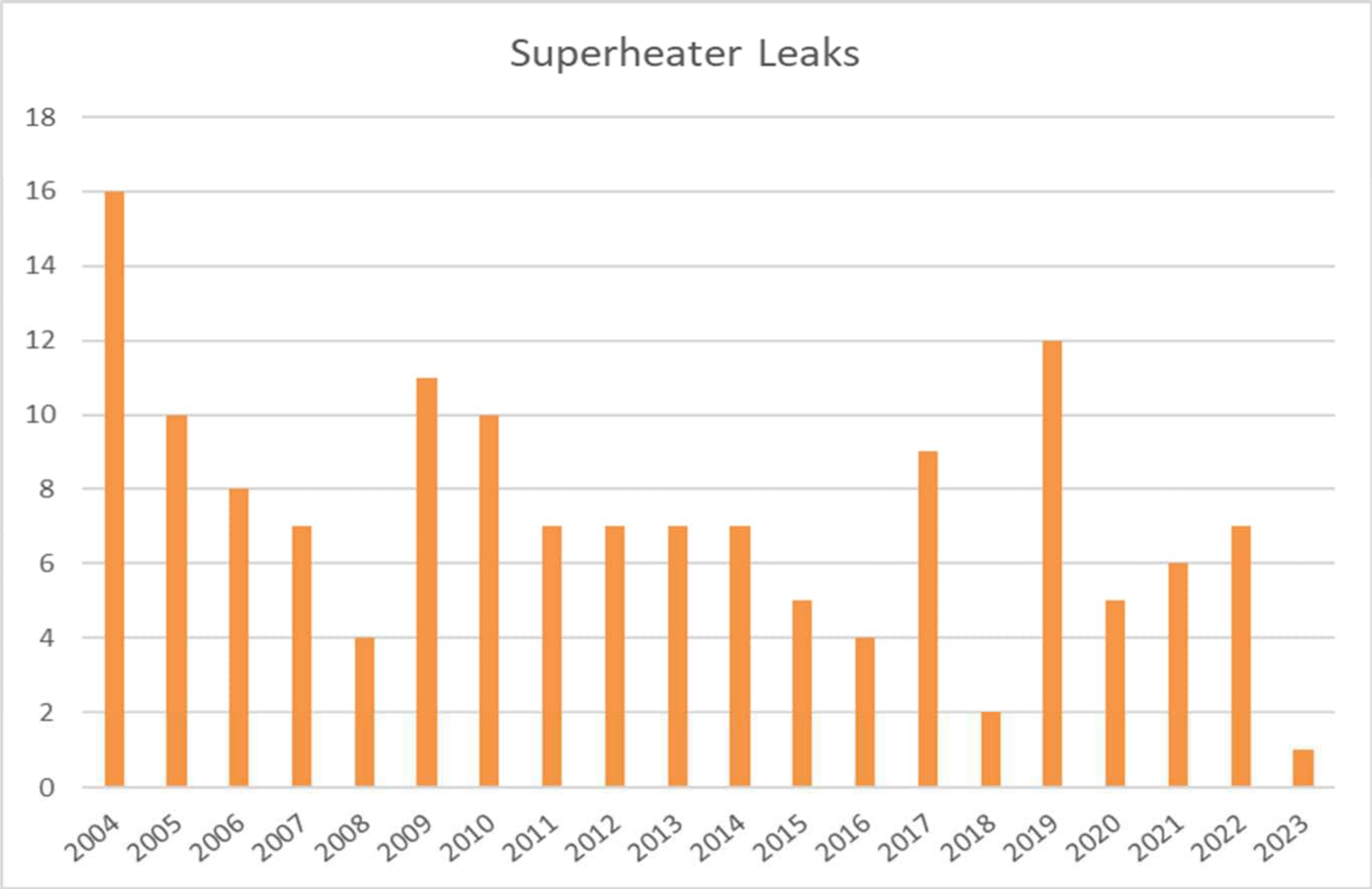
Incident Locations



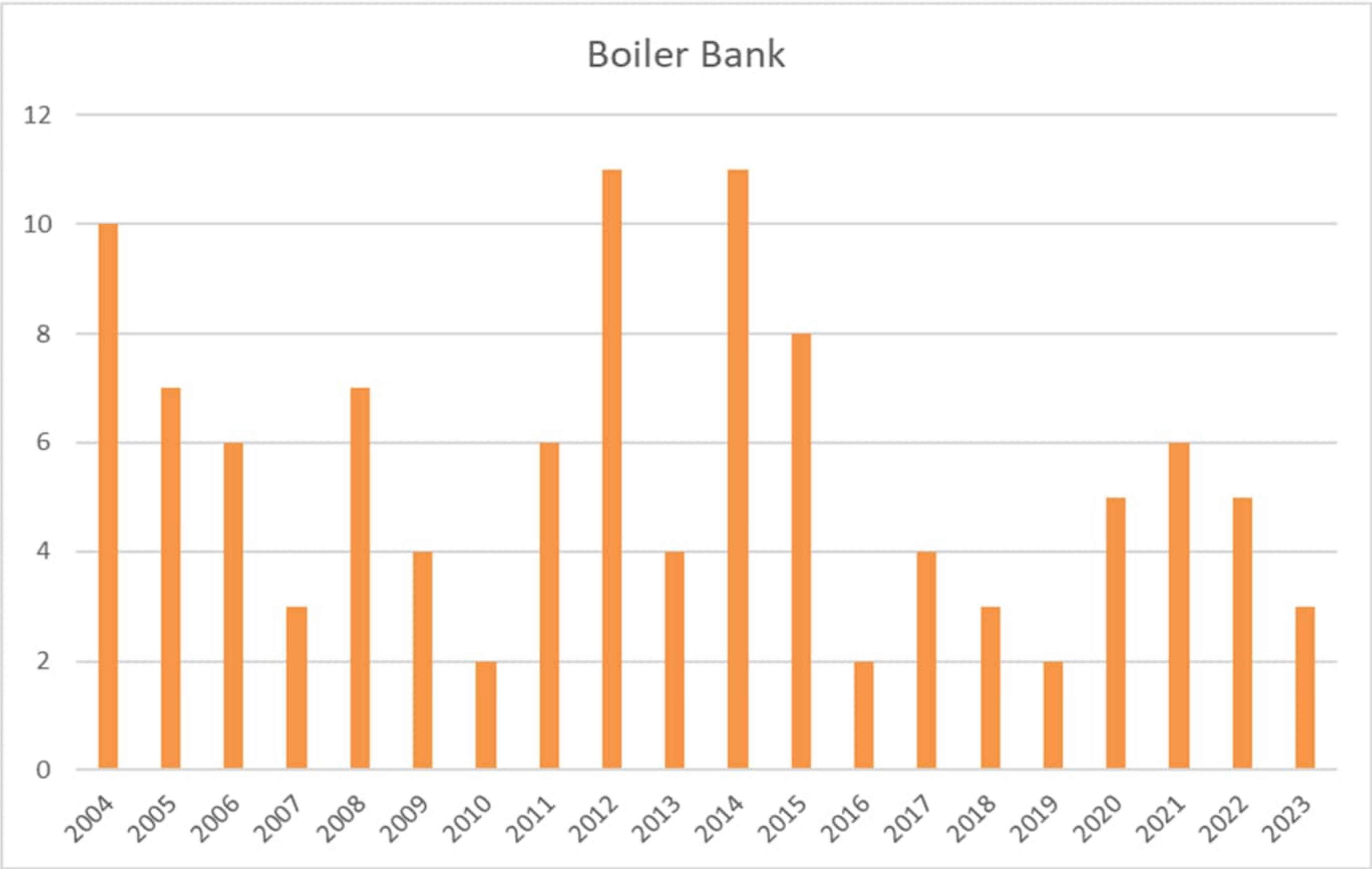
Boiler Component Leak trends



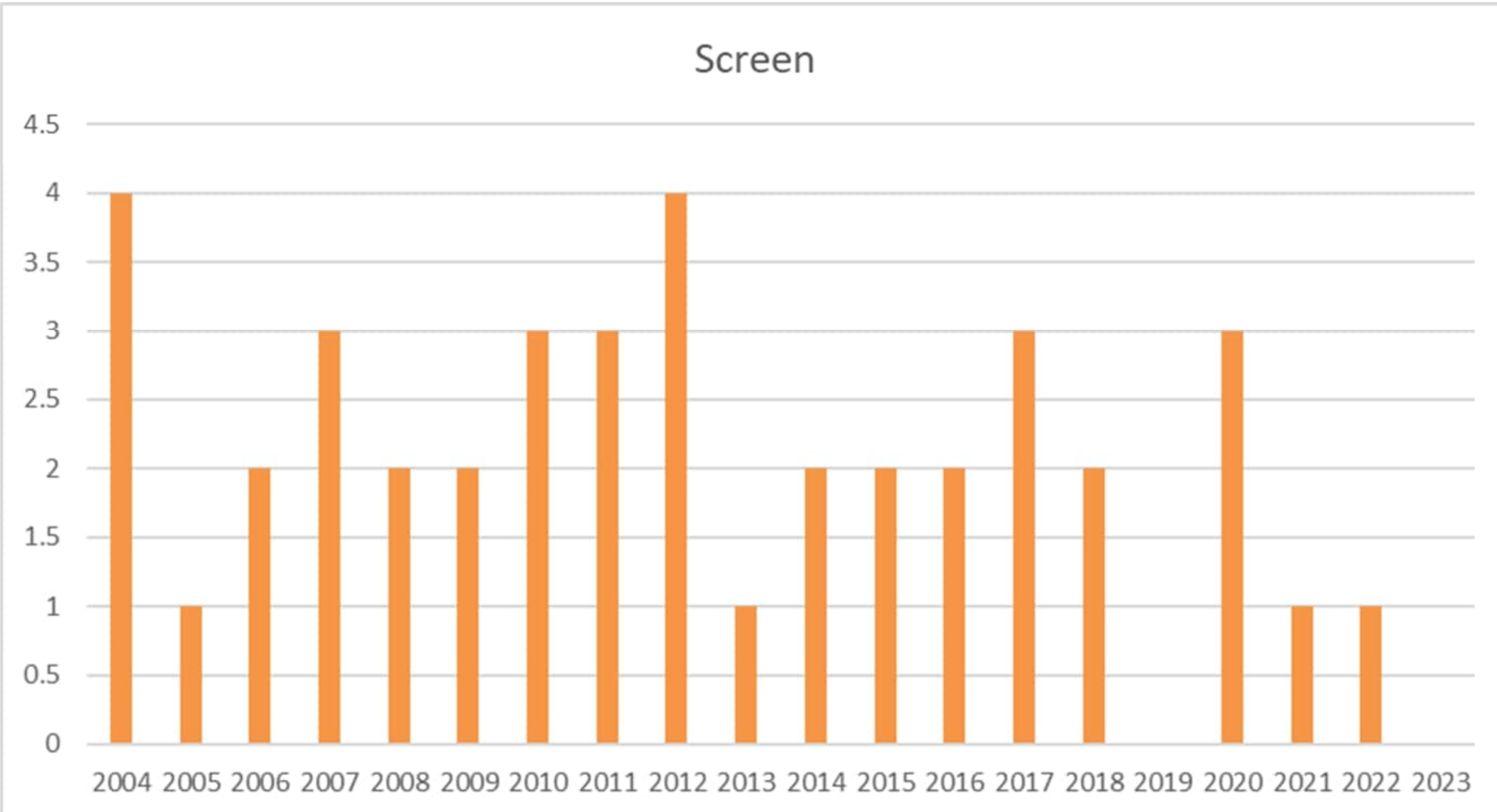
Boiler Component Leak trends



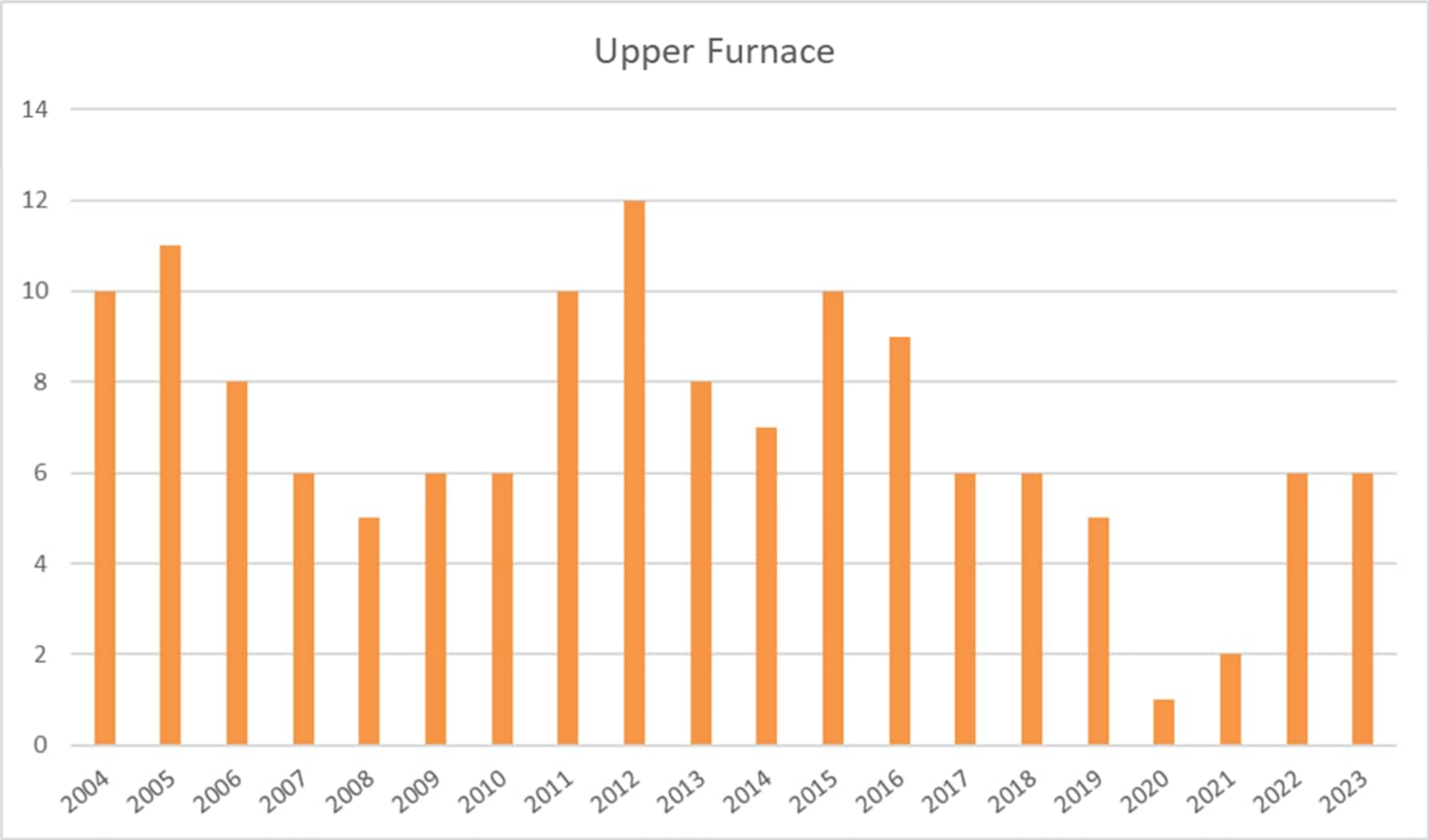
Boiler Component Leak trends



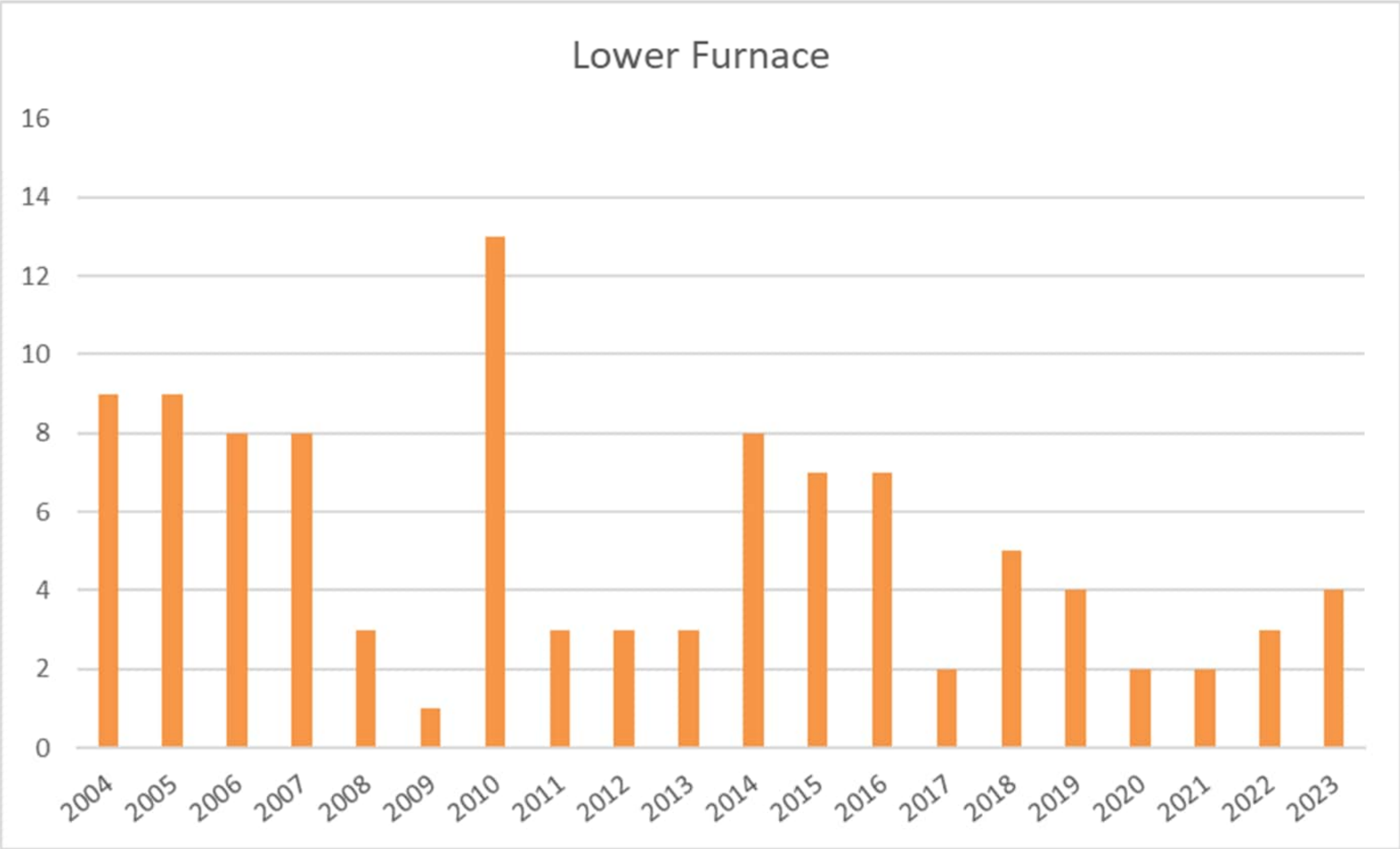
Boiler Component Leak trends



Boiler Component Leak trends



Boiler Component Leak trends



BLRBAC Reported Leaks (US + Canada) 2004 thru 2023

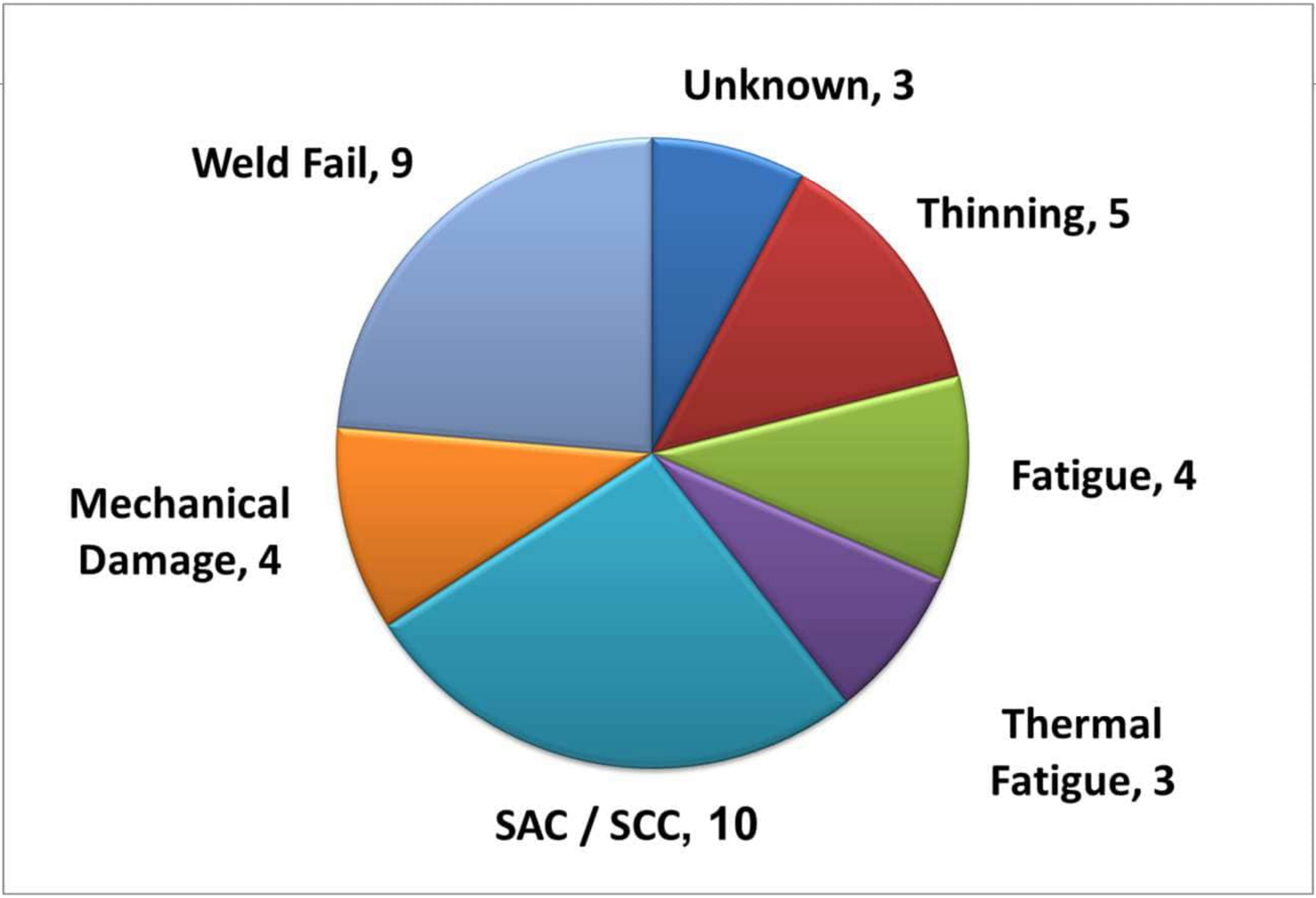
Location	20 Year Total	Average/Year
Economizer	466	23.3
Superheater	145	7.3
Upper furnace	140	7.0
Boiler Bank*	109	5.5
Lower Furnace*	104	5.2
Screen*	41	2.1
Smelt Spout	31	1.6

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

Incidents by Boiler Type

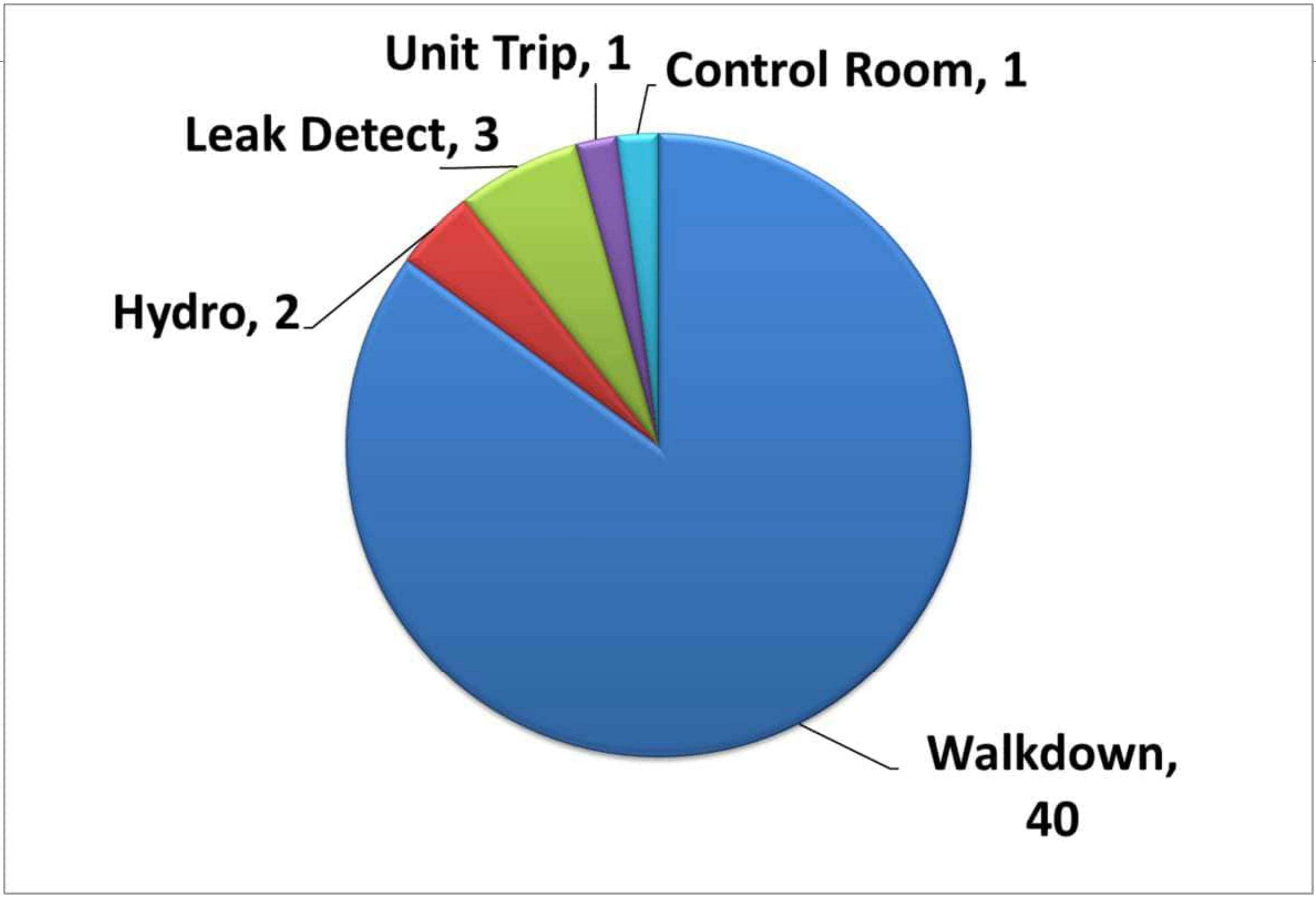
- Drums
  - 1 - 16
  - 2 - 31
  - 3 - 0
- Back End
  - Large Economizer - 38
  - Cascade - 3
  - Cyclone - 6

Leak Cause



Unknown, 3
Weld Fail, 9
Thinning, 5
Fatigue, 4
Mechanical Damage, 4
Thermal Fatigue, 3
SAC / SCC, 10

How Discovered



Leak Detection Systems

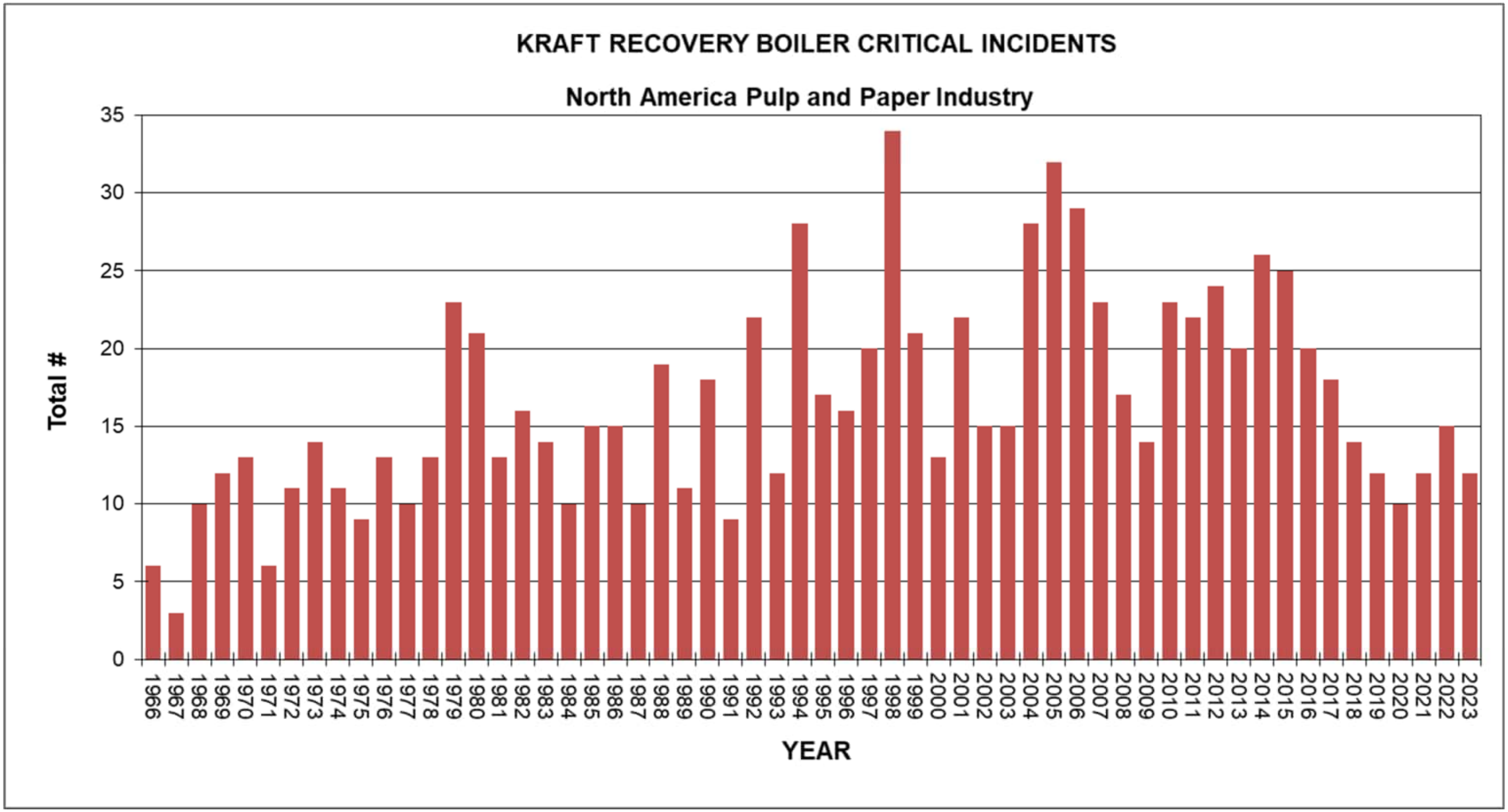
- Leak Detection Systems installed – 25 (53%)
  - Identified leak – 5
  - Confirmed leak - 3

Time to ESP from Initial Indication

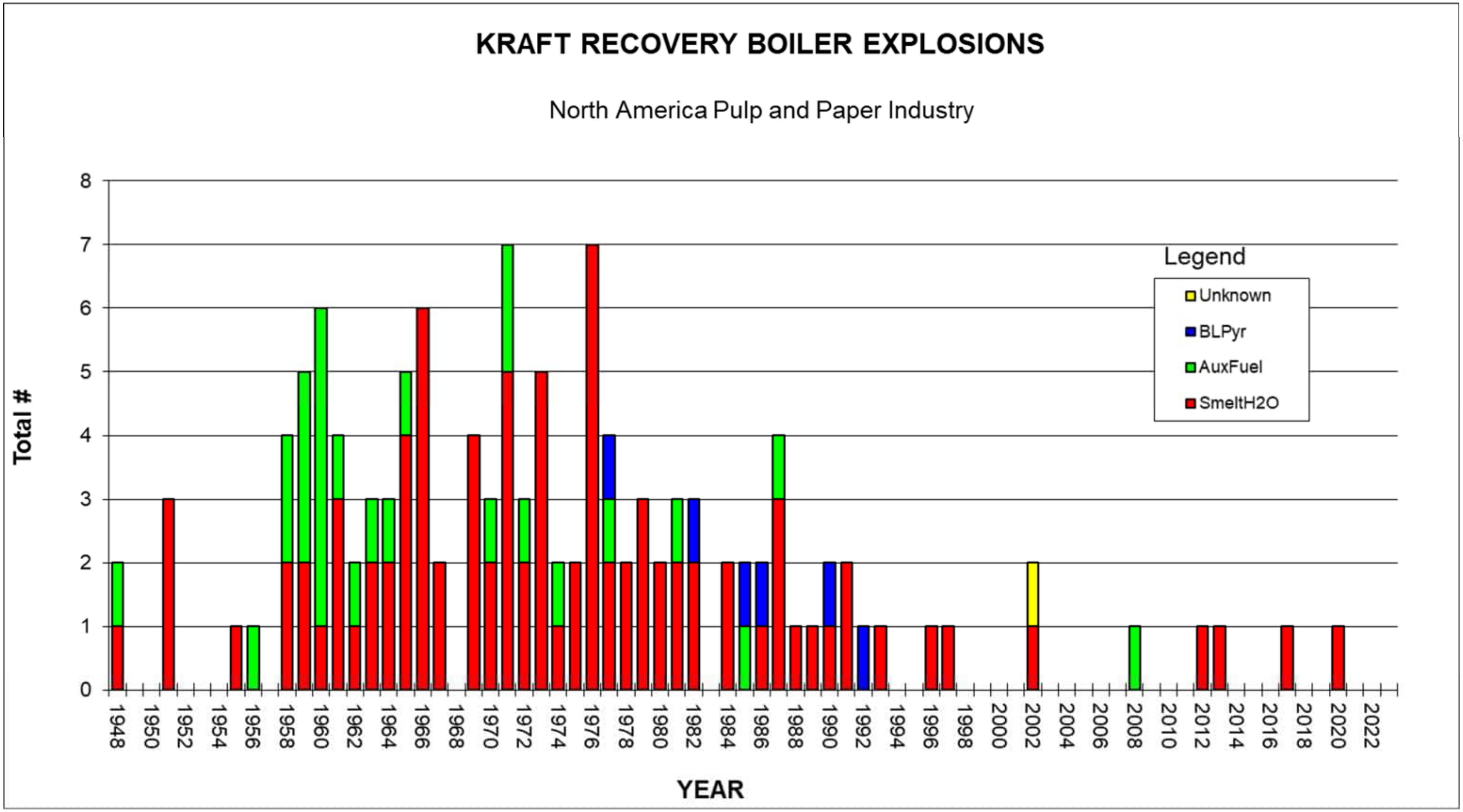
Ranged from 1 minute to 149 minutes

Median time was 40 min

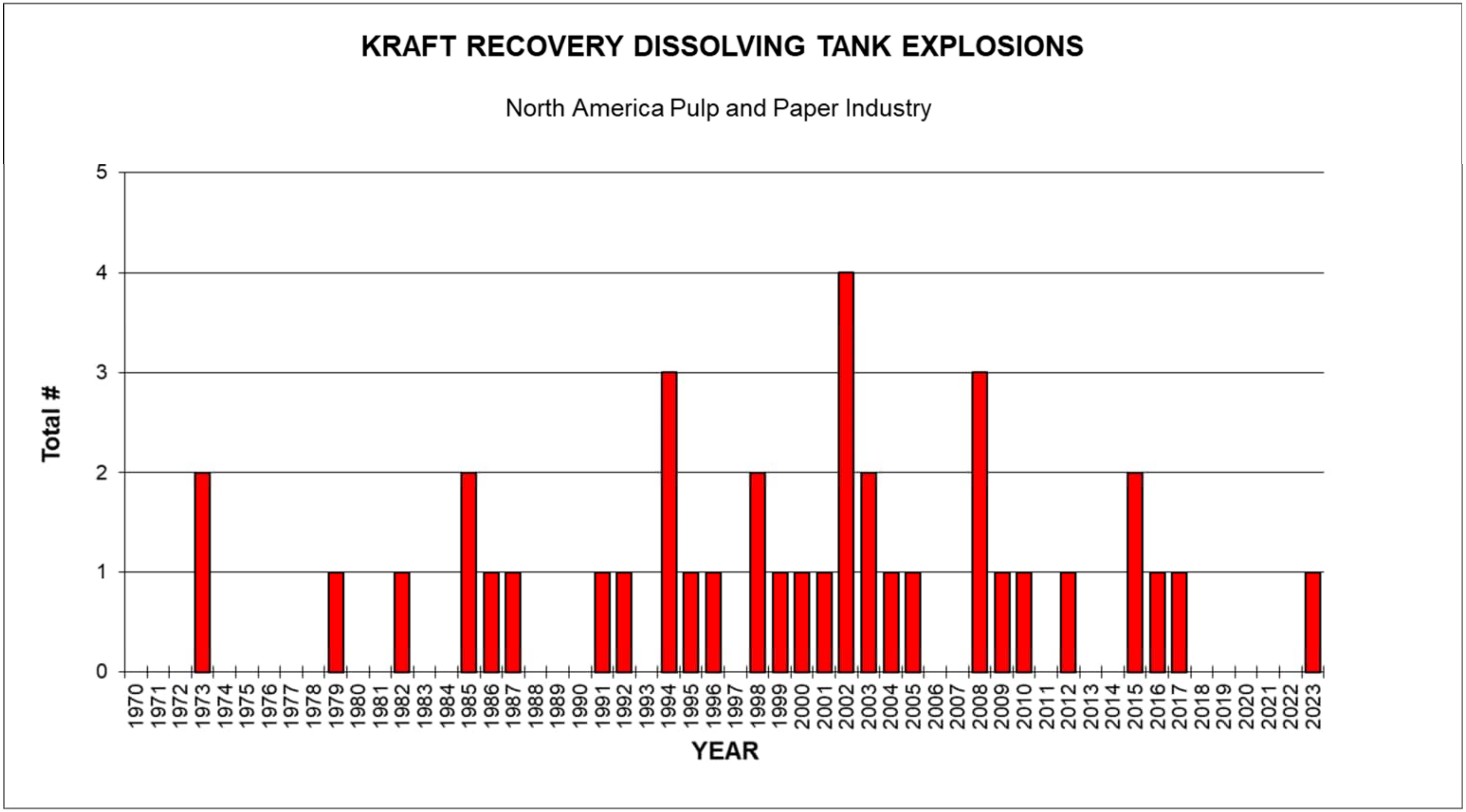
Critical Incidents to Date



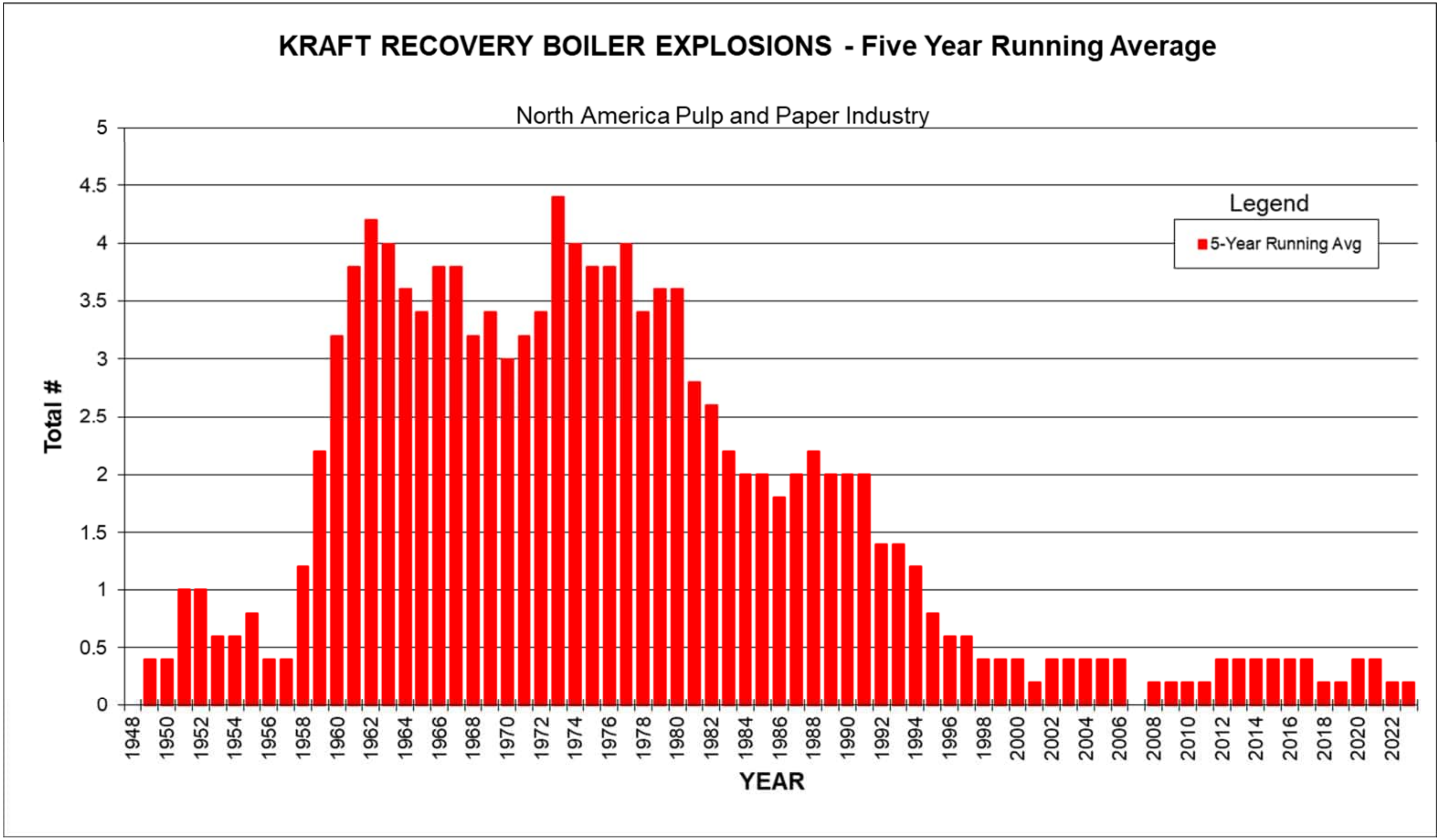
Boiler Explosion History



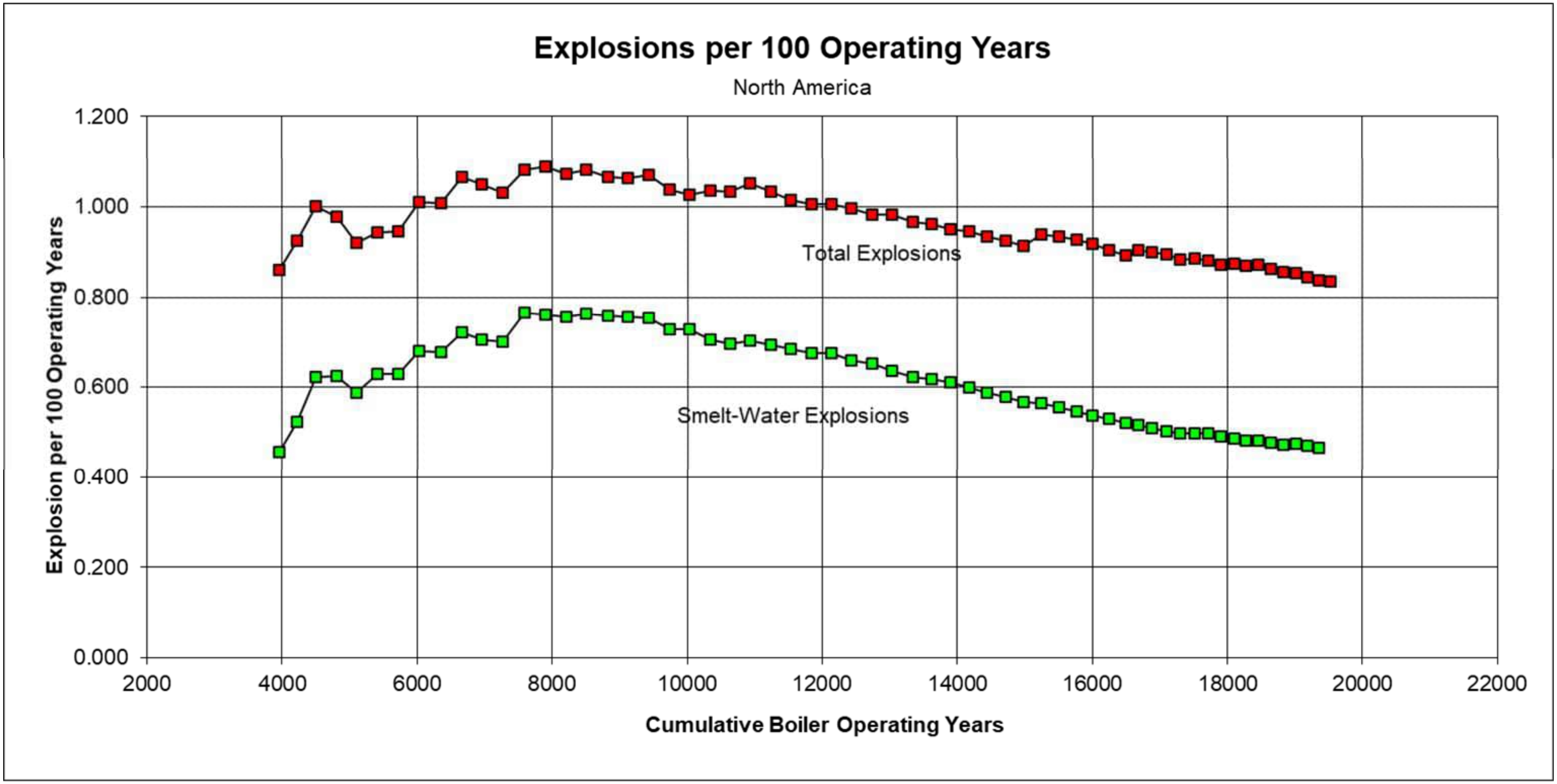
Dissolving Tank Explosions



Explosion History - Five Year Avg



Explosion History per 100 Oper Yr



Boilers in Service

- North American Total - 169

	US	Canada
Number	125	38
Avg Age	44	46.5
Max Age	71	76

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

Learnings (Number indicates incident number)

- Refractory exposed to smelt must be inspected and repaired on major outages. Eventually total refractory replacement may be required to maintain integrity. S23-01

- If smelt flows over pressure parts such as tubes and headers during a smelt leak, thickness checks of pressure part components is prudent. S23-01

- During smelt spout or dissolving tank issues, the senior most available operational person must be involved to look in and monitor the furnace to ensure the bed is observed for pooling. S23-02

- During master fuel trips and extensive liquor outage time, consider stopping the sootblowers to avoid dumping large amounts of sulfate rich material into the bed which will cause smelt to Jelly roll and increase the likeliness of spout pluggage. S23-02

- When all spouts plug, consider tripping ALL fuels (MFT) to the recovery boiler to prevent formation of pools. S23-02

Learnings (Number indicates incident number)

- Emergency dissolving tank agitation, such as steam spargers and air lances, is not meant to replace a failed agitator, unless the OEM has designed the tank for sufficient agitation with the loss of an agitator. Emergency back up agitation is applied to provide some agitation while the unit is being safely taken out of service. S23-03
- Critical dissolving tank instrumentation should be reliable and evaluated for critical spares to be on hand. S23-03
- Dissolving tank agitators must be maintained with a high degree of reliability and availability. Spare parts must be on hand for immediate repair. S23-03
- Dissolving tank amp alarms should be set as tight to normal operation without a large number of nuisance alarms. S23-03
- During periods of unreliable dissolving tank density instrumentation, a high frequency of manual density tests must be taken. The pot should be flowing. S23-03

Learnings (Number indicates incident number)

- All dissolving tank dilution sources must be able to be isolated from a safe location. S23-03

- Recovery boiler tube Leak detection system alarms should be set tight enough to indicate a leak but not cause frequent nuisance alarms. Consider testing the alarm sensitivity by simulating a leak (i.e. through a cracked valve). S23-06

- Inspect and maintain Economizer vibration restraints. S23-08

- Inspect the economizer main inlet feedwater line penetration through the casing to ensure the expansion joint is free to move. S23-08

- Consider inspection of lower vestibule supply tubes and downcomers for thickness and possible ERW weld or SAC issues using borescope, shear wave, thickness and or x-ray methods. S23-09

Learnings (Number indicates incident number)

- Cracks at attachment welds should be inspected with shear wave or x-ray to look for SAC prior to repair and to avoid the risk of welding over a defect that may spread later. S23-12, S23-13

- Ensure a poppit valve PM inspection system is in place to ensure leaking valves are replaced prior to causing tube damage from condensate. S23-14

- Sootblower wall box sleeves should extend beyond the face of the tube on the fireside to avoid SB condensate from running down lower SB opening closure plates and causing thermal cycle fatigue. S23-14

- Generating section sidewall refractory must be maintained to avoid sidewall casing overheating and burnout. S23-15

- Understand the boiler constructon to decide if the leak is critical or not to decide to ESP or not. S23-16

- Do not hydroblast refractory in areas such as floor to sidewall seal where the material can not drain and will create an abrasive slurry which can quickly erode or cut a tube. S23-17

- Always assume the worst possible scenario when investigating a pressure part leak and convince yourself it is not. S23-17, ALL

Learnings (Number indicates incident number)

- Ensure Panel operators are aware of pre-operational start up issues through improved checklists and SOPs, as well as unusual liquor characteristics such as temperature and sulfidity that could play into their decision process when deciding if there is a leak or not. F23-02
- Do not remove insulation/casing from pressurized feed-water piping or tubing to more closely identify a leak location. (personnel safety) F23- 03, F23-20
- Ensure an NDE program is in place to determine the integrity of feed-water piping for thinning etc. such as from Flow accelerated Corrosion (FAC). F23-03
- Rapid draining a boiler will not cause defects/leaks but can aggravate an existing defect to failure. Examine additional similar tubes for these defects that may have not yet failed. F23-04
- Steam Coil Air Heaters, which can put water into the furnace if coils leak, should have dams and drains ahead of the dams with alarms to indicate if water is reaching the dam. If coils are found to be leaking, they should be isolated and taken out of service and drained. F23-04

Learnings (Number indicates incident number)

- External water sources such as hose stations, floor drains, roof drains, etc. should be designed and maintained to ensure they will not put water inadvertently into an operating recovery boiler. F23-05
- Spout Hoods, Hood wash, shatter jets, etc. must be designed, adjusted, inspected and maintained as to not allow buildup in hoods and formation of potential klinkers as well as the inability to handle smelt runoffs should they occur. F23-06
- Liquor and air introduction to the furnace, as well as liquor flow load changes, need to be managed to ensure that the bed is controlled, does not slough off and large runoffs do not occur. Shatter jets must be designed adjusted and maintained to handle runoffs as best they can. F23-07
- Maintain proper sulfidity to ensure proper dissolving tank smelt shattering. Low sulfidity will aggravate dissolving tank conditions. Violent operations caused by low sulfidity can damage other smelt spout hood components such as hood wash and shatter jets leading to further deteriorating and unstable conditions. F23-08

Learnings (Number indicates incident number)

- When installing or making repairs on Economizer fins, the fin should be angled and not square cut to reduce stresses at the fin termination. F23-09
- Analyze tube internal and external deposits when possible to help determine the failure cause. F23-10
- Vibration restraints need to be inspected and maintained in economizers to minimize fatigue cracking. F23-11, F23-20
- Use caution when welding up a leak at an attachment, as the root cause may be SAC and welding over this type of defect can cause additional internal cracking and future leaks. F23-16
- Leak detection alarms can be loosely set to avoid nuisance alarms. Requiring a review of the trends on a regular daily basis can possibly identify leaks at an earlier stage. F23-18, F23-25
- Maintaining good deaerator performance and oxygen scavenger treatment can avoid potential oxygen pitting in the economizer F23-18

Learnings (Number indicates incident number)

- Hand hole cap as well as Nipples and caps have specific OEM weld procedures that must be closely followed to ensure full weld depth exists. F23-19
- Ask for the OEM or vendor instructions for handhole removal and replacement. There are a number of important details to follow. F23-21, F23-22
- When a sound is heard in the SH area, and the leak location cannot be positively identified, the leaking tube may be a roof tube, nose tube, screen or sidewall tube. This incident is a good example of the proper ESP action when the location cannot be positively identified. F23-23:
- When indications of a potential leak first occurs, assume the worst and convince yourself it is not for timely decision making. F23-24
- When an external wall leak is discovered, and the wall construction in the area of the leak is not known and water could have the potential to enter the furnace the proper action is to ESP. This incident is an example of the proper actions. F23-26

Learnings (Number indicates incident number)

- Need to do a dry out fire or run the SCAH's to reduce cold side corrosion after a water wash during outages. Aged and units prone to cold side corrosion need more extensive inspection. F23-27
- Condensate reduction and removal from sootblower systems through proper design and maintenance as well as proper maintenance of poppit valves is critical to reducing or eliminating tube damage from excessive condensate introduction into the furnace F23-28:
- Metal spray requires routine inspection and repair after application. All spalled areas must be checked for metal loss and corrosion barrier re-installed. F23-29
- Do not open doors to look if a smelt water reaction is suspected. F23-30
- Ensure proper design and installation of closure plates and ensure welds are adequate to transfer heat into the tubes and keep the closure plate cool. F23-30

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.

Incident Questionnaires

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

Blrbac.net New Documents Available

NEW DOCUMENTS

ESP Subcommittee Incident Learnings

blrbac-esp-incident-learnings-s05-thru-f22-122122

DOWNLOAD

How to Participate in a BLRBAC Meeting

how-to-participate-in-a-blrbac-meeting-110422

DOWNLOAD

American Forest & Paper Association

BETTER PRACTICES BETTER PLANET 2030

SUSTAINABLE PRODUCTS FOR A SUSTAINABLE FUTURE

AMERICAN FOREST & PAPER ASSOCIATION RECOVERY BOILER PROGRAM REPORT

BY

WAYNE GRILLIOT

FEBRUARY 6, 2024

AF&PA RECOVERY BOILER 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
- Identify the root cause of Recovery Boiler explosions and critical incidents
- Membership is open to all companies & mills that operate Recovery Boilers
- Activities are funded by membership dues

AF&PA Recovery Boiler Program

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

- **Frank Navojosky** – International Paper
- **Wes Hill** – Georgia-Pacific
- **Jeff Wagoner** – International Paper
- **Greg Burns** – Domtar

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**

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AF&PA Recovery Boiler Program

Two Standing Subcommittees

- **Operation & Maintenance Subcommittee**
  - **Frank Navojosky** – International Paper (Co-Chair)
  - **Wes Hill** – Georgia-Pacific (Co-Chair)
- **Research & Development Subcommittee**
  - **Greg 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

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

- **Team Exercises** help operators and supervisors make the important decision: **When to ESP a Recovery Boiler**
  - The Case Studies are based on **actual BLRBAC Recovery Boiler Incidents**
  - **Eight (8) New BLRBAC Case Studies each year for the Team Exercises**!

- Over **4,700** have attended the Seminars since they were started in 1985

- We continue to recommend all companies and mills seriously consider sending people to these valuable Safety Seminars

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Operational Safety Seminars

2022: Four (4) Online Virtual Recovery Boiler Operational Safety Seminars

- April 20, 2022 - (7:45 am – 4:30 pm) Eastern Time
- May 18, 2022 - (7:15 am – 4:00 pm) Pacific Time
- September 21, 2022 - (7:45 am – 4:30 pm) Eastern Time
- October 13, 2022 - (7:15 am – 4:00 pm) Pacific Time
- Safety Seminar Monitors
  - **Dean Clay**, BLRBAC ESP Subcommittee Secretary
  - **John Andrews**, Former BLRBAC ESP Subcommittee Chair
- More people can attend virtually due to the lower registration fee (50%)
- **+** No travel time or cost, and less time off the job!

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Operational Safety Seminars

2023: Six (6) Recovery Boiler Operational Safety Seminars

Four (4) Online Virtual & Two (2) In-Person

- March 22, 2023 – **(Virtual)** (7:45 am – 4:30 pm) Eastern Time
- April 20, 2023 – **(Virtual)** (7:15 am – 4:00 pm) Pacific Time
- May 23-24, 2023 – (**In-Person**) Atlanta Airport Marriott (2 Half-Days)
- September 20, 2023 – **(Virtual)** (7:45 am – 4:30 pm) Eastern Time
- October 4-5, 2023 **(In-Person)** Sonesta Atlanta Airport North
- November 2, 2023 – **(Virtual)** (7:15 am – 4:00 pm) Pacific Time

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 BLRBAC, at the Atlanta Airport Sonesta Hotel
- May 16, 2024 (**Virtual**), Thursday (7:15 am - 4:00 pm **Pacific Time**)
- September 2024 (**Optional Virtual One**)
- October 9-10, 2024 (**In-Person**), Wednesday afternoon/Thursday morning (**Eastern Time**) After BLRBAC, at the Hilton Atlanta Airport Hotel

Annual Conference & Meetings

2023 AF&PA Recovery Boiler Conference & Committee Meetings

- February 7-8, 2023, at the Atlanta Airport Marriott
- Record Attendance: **99 people attended!!!**
- Many of You Here Attended - **Thank You Very Much!!!**

2024 AF&PA Recovery Boiler Conference & Committee Meetings

- **February 6-7, 2024**, at the **Atlanta Airport Marriott**
- 1st Tuesday & Wednesday each February
- The Conference is open to everyone interested in Recovery Boilers
- **93 people registered. Down some, but still the 2nd highest.**
- **Thank you for joining us today & tomorrow!**

Smelt 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** is sponsoring some important research projects at the University of Toronto for improved safety and reduced operating risk of Dissolving Tanks
  - The 4 projects focus on:
    - **Dissolving Tank key operating conditions**
    - **Advanced monitoring techniques**
- The program builds on prior AF&PA studies and related research underway at the University of Toronto, funded by a consortium of 26 companies
- The projects are expected to be completed in 2023.

Best Practices

- The **O&M Subcommittee** formalized recommendations from the:
  - **"Dissolving Tank Survey and BLRBAC Incidents Study"**
    - Completed by Dr. Tom Grace
  - This project is complete
  - It is posted on our website and is available to everyone
- Next **O&M Subcommittee** Project
  - **Impact of extended run time on Recovery Boilers**
    - Operations, maintenance, risk, areas of concern, and criteria for allowing extensions
    - Work has started on this project

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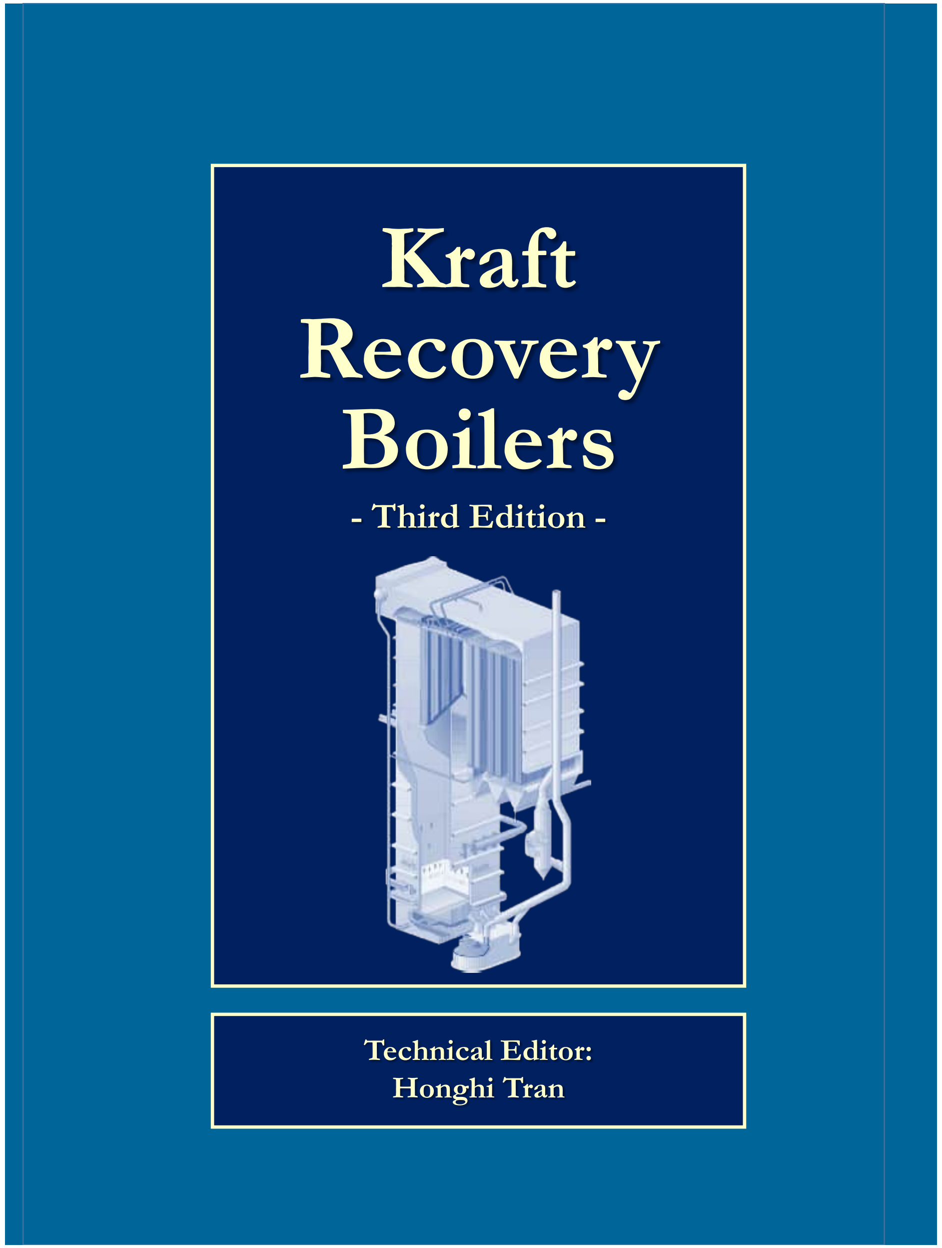


Kraft Recovery Boilers

- 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

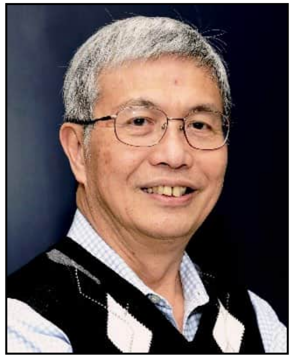
American Forest & Paper Association

TAPPI PRESS

Kraft Recovery Boilers “Blue Book”

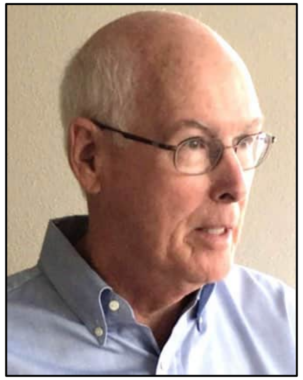
- **The AF&PA R&D Subcommittee** sponsored the publication of the new **Kraft Recovery Boilers, Third Edition** textbook
- **Dr. Honghi Tran** of the University of Toronto led the effort to author the new book
- Dr. Tran and 7 other world-renowned Recovery Boiler experts completed the 16 chapters of the new book
- Book sales have been very strong, with nearly **978 copies sold!!!**
- **In its 5th Printing already!!!**
- Available through **TAPPI Press.**
- The book is also part of the **TAPPI Kraft Recovery Operations Course**

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.

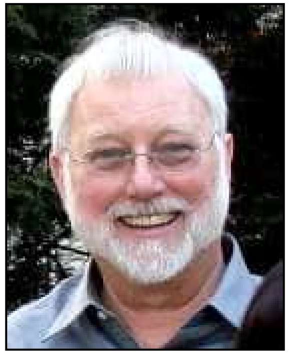
ANDREW K. JONES is a Senior Engineering Fellow at International Paper (IP) where he fosters the implementation on new process innovations. Previously he was the recovery boiler SME. He has been with IP since 1997. Previously he worked for ABB/Combustion Engineering leading an R&D group. He received his 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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Mobile: +1 (937) 602-1892

Questions?

Thank You!

American Forest & Paper Association

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SUSTAINABLE PRODUCTS FOR A SUSTAINABLE FUTURE