RECOVERY BOILER TECHNOLOGY TRENDS IN PAST AND IN FUTURE

Kari Haaga, Valmet Technologies Oy

55th Anniversary International Recovery Boiler Conference
June 6, 2019

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Abstract

Recovery Boiler Technology trends in past and in future

New developments in technology have made it possible to take advantage of the economy of scale when building new big pulping lines and increasing capacities of existing mills. Therefore, the recovery boilers had to grow in size in order to meet the targeted production capacities. Excellent process and availability experiences from big boilers already from 1990's has made it possible to develop even bigger XL and XXL size recovery boilers which are nowadays "standard" in many market areas when new pulp mills are built.

High power recovery boilers have become more and more common in pulp mill industry as electricity price has increased. Electricity produced by recovery boilers is seen as green energy in many countries meaning incentives to electricity price which make high power feature investments more profitable. Already in 1970's better tube materials with stainless steel outer layer (composite tubes) were started to develop to furnace walls for better corrosion resistance. After those times modern boilers have had many different type of composite or overlay welded materials in lower part of furnace and superheaters. High power boilers are needing also strict K and Cl control for minimizing risks of fouling and corrosion. Therefore, ESP ash treatment systems had to be developed and nowadays there are Ash Leaching and Crystallization systems in operation in many mills.

One important item in development of recovery boilers is safety. This means personnel safety, environmental safety and equipment safety. This has lead for example certain technical solutions such as smelt spout robots which are rodding smelt spouts and openings already in many boilers.

Todays' recovery boilers have the latest design from environmental point of view; all NCG and vent gases are burnt in recovery boiler compared mills decades ago when all odorous gases went to atmosphere. CNCG burning in recovery boilers started in the beginning of 1990. After that CNCG burning has been standard nearly in all recovery boiler deliveries without causing any problems to boilers' safe operation.

Gas emissions from recovery boilers have changed drastically during years. When black liquor dry solids content was at the level of 60% then especially SO_2 emissions were high. This also caused acidic sulfates formation meaning sticky ash which then increased fouling and corrosion in recovery boilers. When black liquor dry solids content reached the level of 75-80% then SO_2 emissions started to be insignificant. Nowadays, most challenging emission is NOx. Low NOx is requiring air staging as a primary method meaning many combustion air feeding levels in the furnace. Trend seems to be even tougher limits and therefore new secondary methods have been developed. Presently NOx scrubbers are already in operation in China where targeted NOx is <100 mg/Nm^3.

Automation has been developed very rapidly since Valmet introduced first Distributed Control System (DCS) 1979. Computing power was quite limited on early years for complex flue gas calculations etc., but when next generation Valmet XD DCS was released in 1987 it enabled whole new world for advanced process control development. Our first Recovery Boiler Optimizer was developed and delivered for Kemi Oy in 1991. Original targets which where; less human errors, maximum steaming rate, better cleanability, increased safety in all conditions are still valid today.
Nowadays Valmet Recovery Boiler Optimizer is the most comprehensive advanced process control for Recovery Boilers including different modules for controlling sootblowing, furnace combustion and steam production. New innovations have brought up for measuring and controlling for example reduction rate which is one of the most important process parameters in recovery boilers. Leak detection system is one new innovation for even safer boiler operation.

Today industrial internet and big data are hot topics in the industry. There’s a trend towards analyzing huge amount of data and utilizing that to improve asset reliability. Some examples are predictive maintenance and process key performance indicator follow-up applications which include advanced analytics. There is also a demand for performance centers where global and local network of service professionals are ready to back up boiler operation and can even predict on coming challenges before anything critical occurs and give consulting services.

Existing and future measurement, modelling and control technologies allow us to see all the time deeper and deeper to recovery boiler process during the operation. This open up new opportunities to see critical operational limitations better and enable on time recommendations or decisions for related operation targets. This increasingly sharper window to the process enable continuously safer, cleaner and more efficient operation of Chemical Recovery Boiler

SUOMEN SOODAKATTILAYHDISTYS
FINNISH RECOVERY BOILER COMMITTEE

Recovery Boiler Technology trends in past and in future

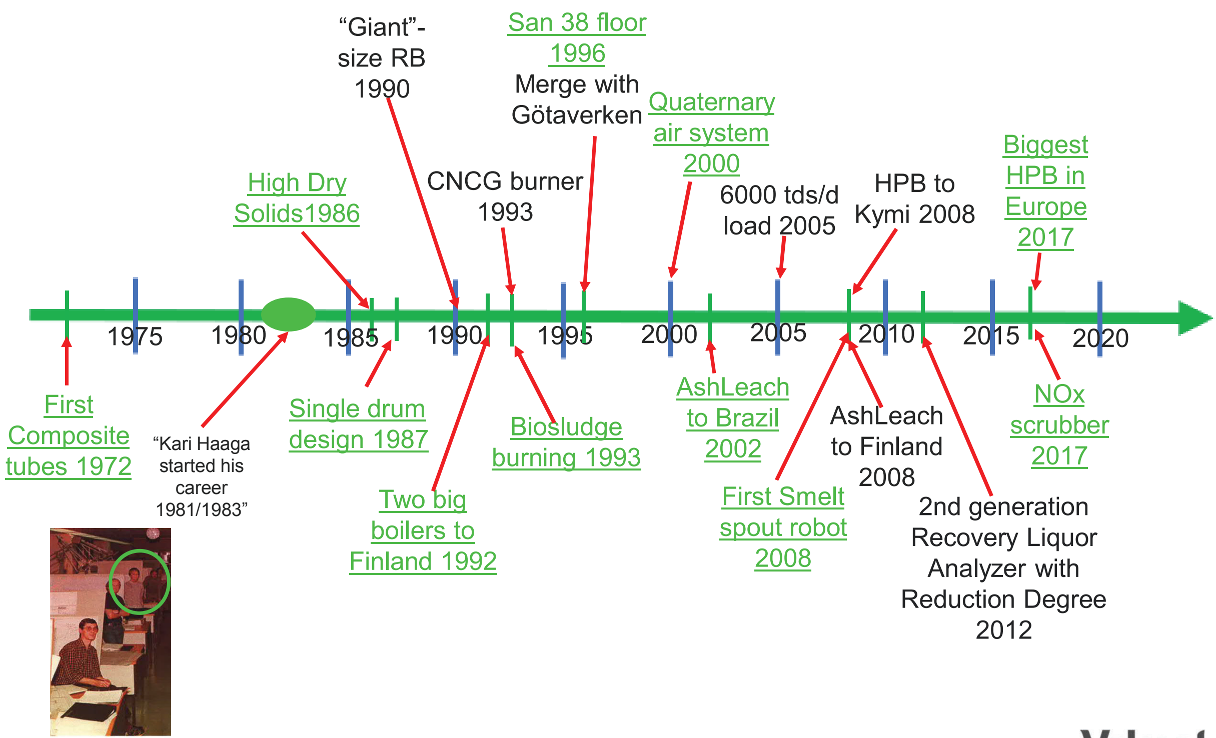
Kari Haaga

Timo Laurila

June 6, 2019 55th Anniversary International Recovery Boiler Conference

Recovery Boiler Technology trends in past and in future

Most “interesting” developments in RB technology



1972 Composite tubes

Membrane wall designs

Corrosion of tubes in the lower section of recovery boiler furnaces is a well-known problem. Corrosion has been found to be especially rapid in boilers where the steam pressure is over 64 bar. The quality of liquor and smelt also affects the speed of corrosion.

We have carried out extensive research in this field and have solved corrosion problems connected with high pressure and temperature.

The pictures on the right show the three alternatives used for tube protection. The top picture shows tube studding. This is the cheapest solution and gives a tube service life of 3 to 6 years.

Tampella has also clad tubes in the lower section of furnaces by welding with stainless steel electrodes (middle picture). This gives a service life of over ten years. The most modern method, shown in the bottom picture, is to use composite tubes with a stainless steel external layer. A useful service life of over twenty years is achieved this way. To further reduce the risk of corrosion caused by over-heating and thermal stress, Tampella uses narrow fins in membrane walls.

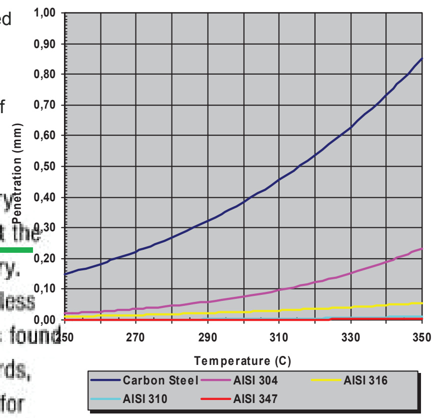
Power Lines in the beginning of 1991

Valmet

1972 Composite tubes

Corrosion in furnace tubes

- When boiler steam pressures increased then also furnace tubes surface temperatures increased ➔ risk of corrosion

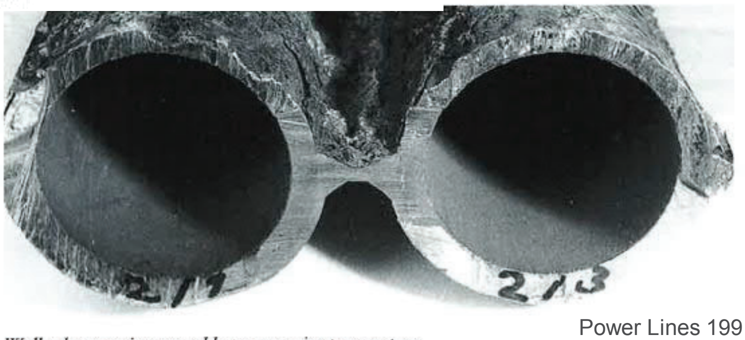


CORROSION-RESISTANCE OF STAINLESS STEEL

Extensive field experiments were conducted on test panels of various materials in a Finnish recovery boiler during a six year period in the late 1960s and early 1970s. At the end of the test series, it was evident that the composite tubes with stainless steel AISI 304 cladding had remained totally intact. This was a clear message to the boiler manufacturer that this material would be a good substitute for carbon steel tubes in the most critical part of the boiler.

Encouraged by these findings, Tampella Power Inc. was the first company to build a black liquor recovery boiler using composite tubes in the lower part of the boiler (1973). This boiler appeared to be huge success from the standpoint of corrosion. It is no wonder that many boilers have since been built using composite tubes.

The results were confirmed in laboratory tests conducted in severe test conditions at the Finnish Pulp and Paper Research Laboratory. The critical corrosion temperature for stainless steel AISI 304 in sulfidizing conditions was found to be around 500 °C (932 °F), in other words, far above the operating temperature, even for high pressure boilers. Figure 3 gives the original results.



Wall tube corrosion caused by an excessive temperature.

Power Lines 1991

Valmet

1972 Composite tubes

First composite 304L installation

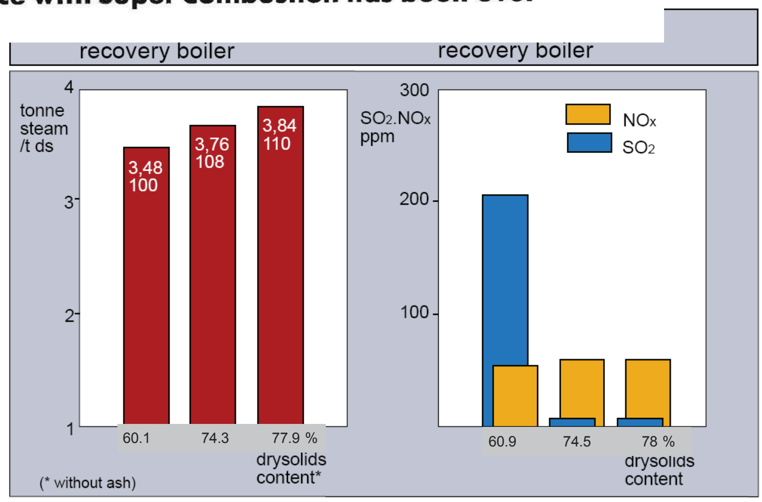
The Tampella Power boiler at Assi, Lövholmen, Sweden. The composite tubes were initially installed to a height of 6 meters (19.68 feet) in 1972. Twenty years later, they were still undamaged. In May 1991, the composite level was raised by 4 meters (13.1. feet) and newly designed air ports were installed by Tampella Power.

Power Lines in the beginning of 1991

1986 High dry solids firing

Super combustion system

Tampella Power's Super Combustion system, based on the super concentrator, has been functioning on a plant scale for a full five years with excellent results. The first full scale production super concentrator was actually installed in March 1986. It was retrofitted to the recovery boiler (775,000 lb/h – 350 tds/24 h) at Pori Paper's Aittaluoto sulfate pulp mill in Pori, Finland. Pori Paper is part of United Paper Mills; its experience with Super Combustion has been overwhelmingly positive.



Data from consultant report

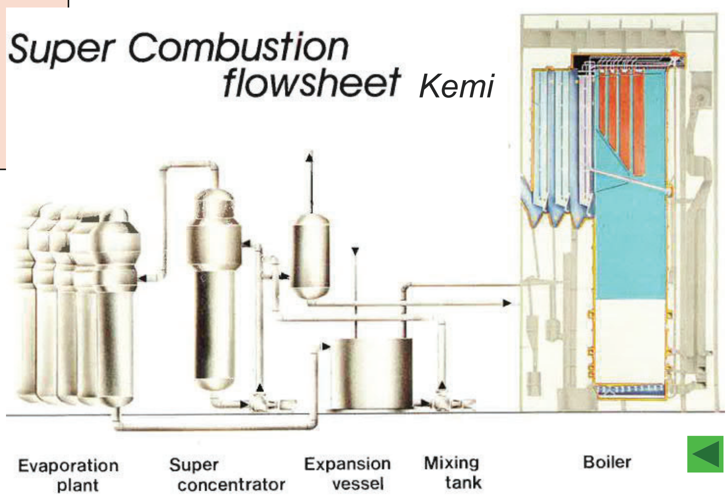
1986 High dry solids firing

First Super Concentrator

Experience of Super Combustion at Rosenlew, Pori, Finland

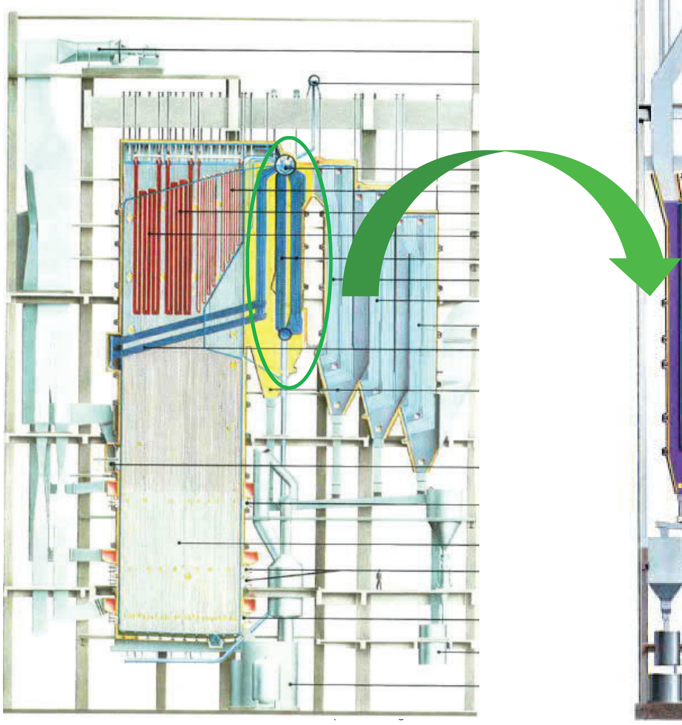
Increased dry solids content 61% ➔ 80%

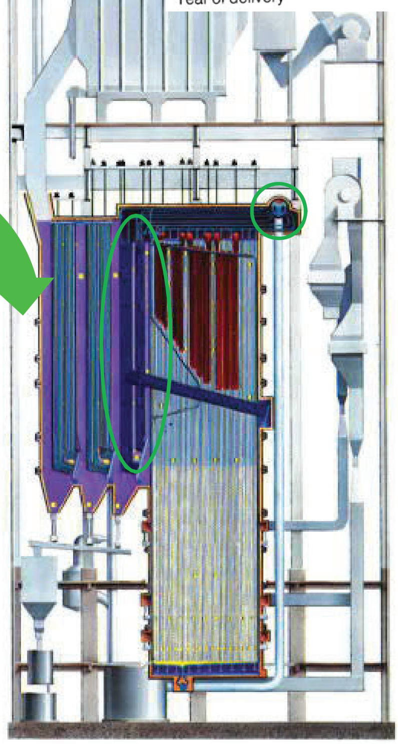
- Reduction efficiency 95% ➔ 97%
- SO_2 100-400 ppm ➔~0
- Na_2CO_3 in ash 5% ➔ 15-20%
- H_2S 5-10 ppm ➔~0
- Recovery boiler steam production increased by 10%
- Availability of the boiler improved - less plugging
- Sootblowing steam consumption decreased
- Super concentrator availability good - boil-out once a week



1987 Single drum design

First single drum design delivery in 1987





Korsnäs-Marma Aktiebolag, Sweden

Fuel: Sulfate liquor	1550 tds/24h
Steam generated	245 t/h
Superheater outlet temperature	450 °C
Superheater outlet pressure	64 bar
Year of delivery	1987

Wider side spacing of elements ➔ less fouling.

No numerous tubes welding to drum(s)

No thick drum wall thickness ➔ faster start-ups

Better supports of tubes and elements

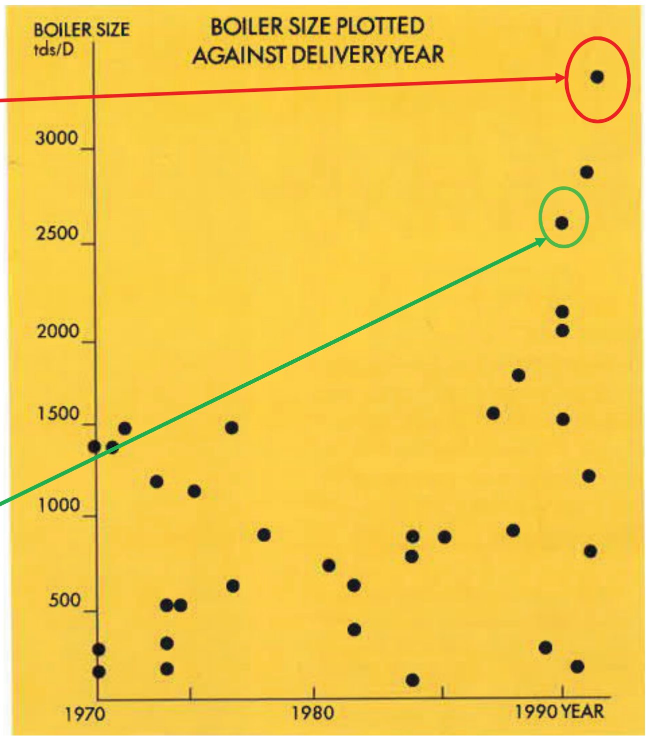
No near mud drum corrosion

1990, 1994, 2005 Capacity increase of RB

One of the two recovery boilers will be the largest in the world. It will be delivered to Enso's Kaukopää Mills in 1992 and it puts Tampella Power Industry top of the world league as far as large recovery boilers are concerned.

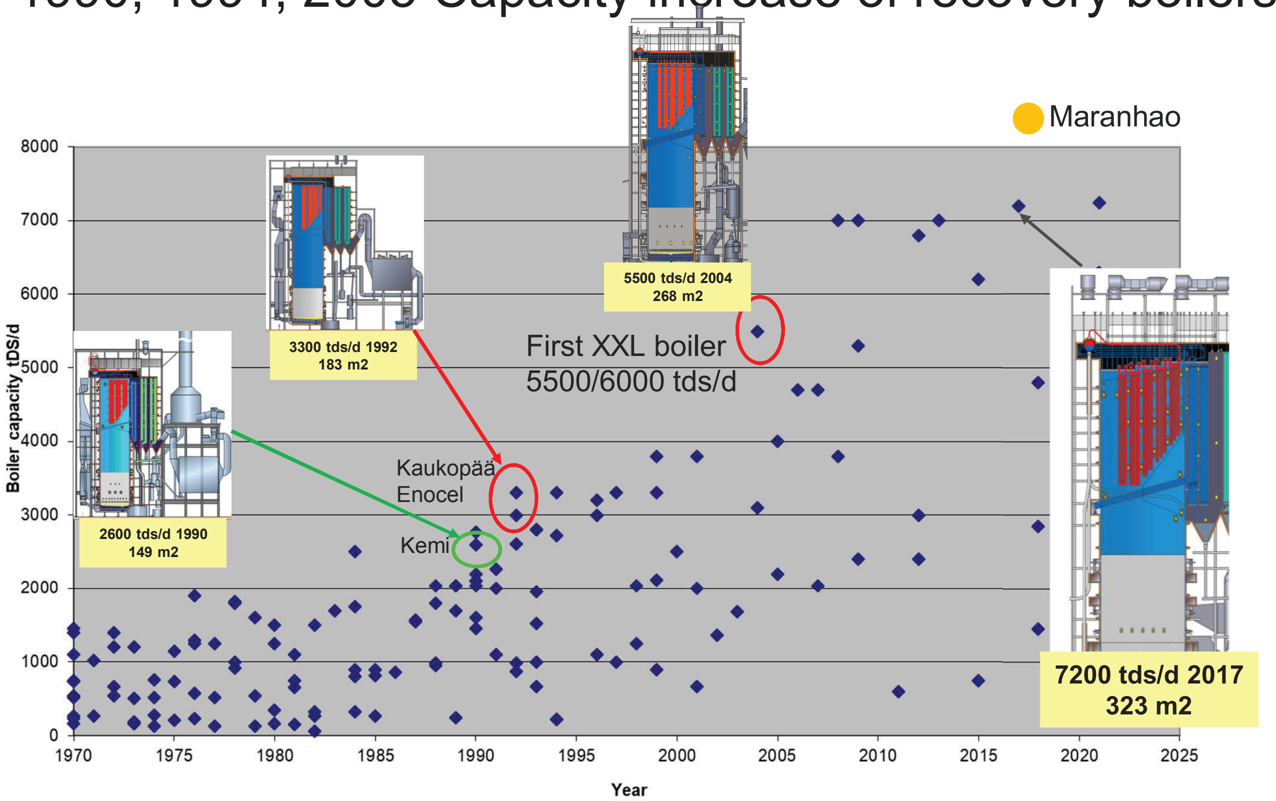
The Kaukopää pulp mill produces 500,000 tons of pulp a year, yet the boiler, which has a maximum capacity of 3,300 tonnes d.s./24h (7,275,000 lb/h), will alone be sufficient to meet its needs.

As part of Metsä-Botnia's investment program, Tampella Power delivered a giant-size (2600 t ds/24 h - 5,750,000 lb ds/24 h) recovery boiler to the Kemi Mills in 1990. The design features of this large boiler, including the multi-level air system, were important technological advances.



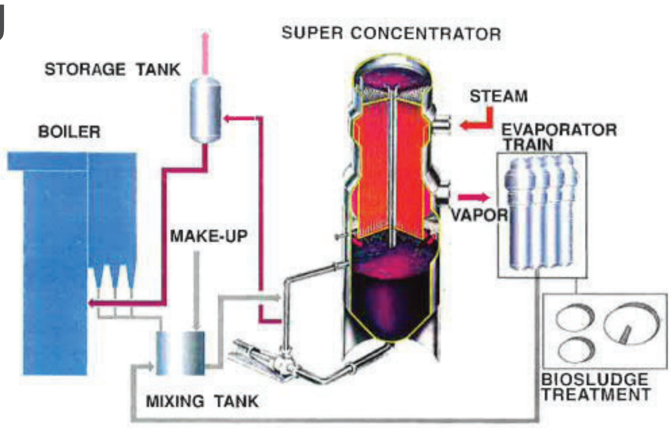
Power Lines 2/1990, 1993

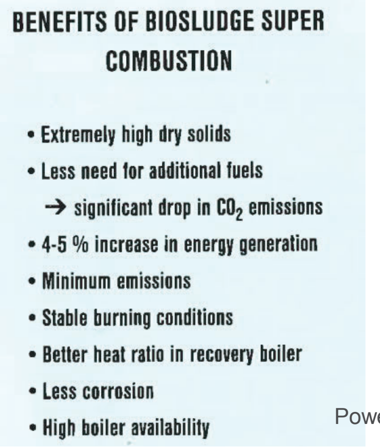
1990, 1994, 2005 Capacity increase of recovery boilers



1993 Biosludge burning

- The Metsä-Botnia Kemi Pulp Mill was the first mill in the world to burn biosludge in a recovery boiler.
- Mechanically dewatered biosludge is mixed with weak black liquor and concentrated in a conventional evaporation plant equipped with a pressurized Super Concentrator unit.
- Disposal of biosludge in a recovery boiler offers an economically and environmentally attractive alternative




BENEFITS OF BIOSLUDGE SUPER COMBUSTION

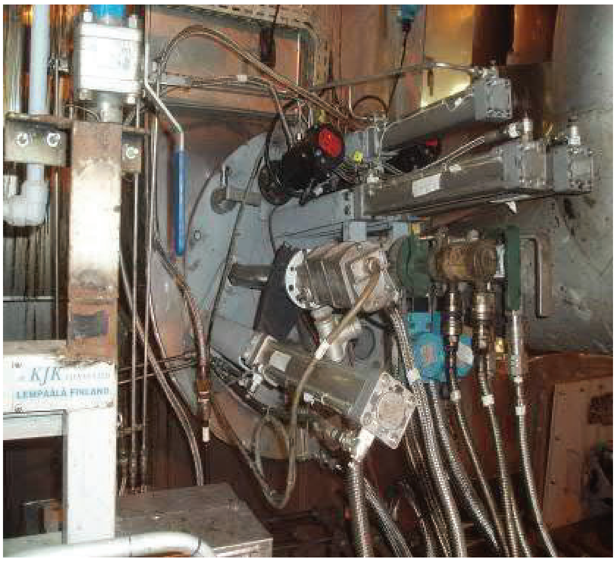
- Extremely high dry solids
- Less need for additional fuels
  → significant drop in CO_2 emissions
- 4-5 % increase in energy generation
- Minimum emissions
- Stable burning conditions
- Better heat ratio in recovery boiler
- Less corrosion
- High boiler availability

Tampella Power also supplied a super concentrator for concentrating the mixture of black liquor and biosludge. The high dry solids content mixture (1 % biosludge, 99 % black liquor) is burned in the recovery boiler. The delivery also included an odor control system for the highly concentrated gases released from the chemical recovery lines and the super concentrator.

Power Lines 1993

1993 CNCG burner

- CNCG burning started in recovery boilers in the beginning of 1990 at MB Kemi mill
- After that CNCG burning has become a standard in new boiler deliveries
- CNCG burning has proved be safe way for controlling odorous emissions of the pulp mills and recovering sulfur chemicals. However, back-up burning places are needed; separate incinerators, torch, Power Boiler,….
- During last years mostly it has been discussed when those gases can be started to burn in recovery boilers

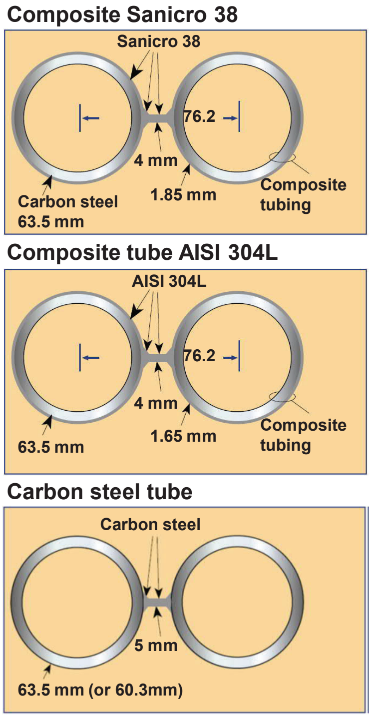


1996 Sanicro 38 floor

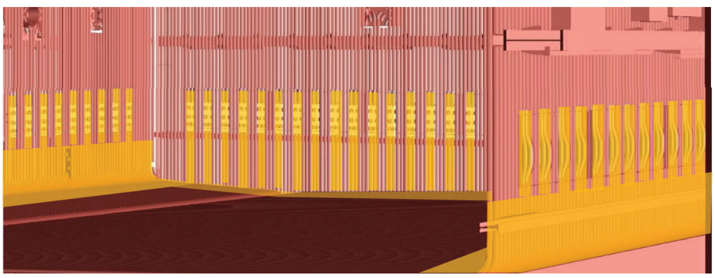
Floor made totally with Sanicro 38 material in Rauma RB

Sanicro 38 floor has now been in operation for 23 years with extremely good results

1996 Sanicro 38 floor

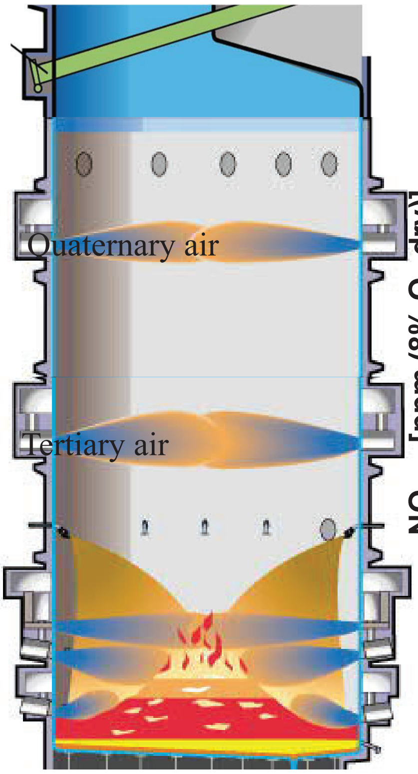


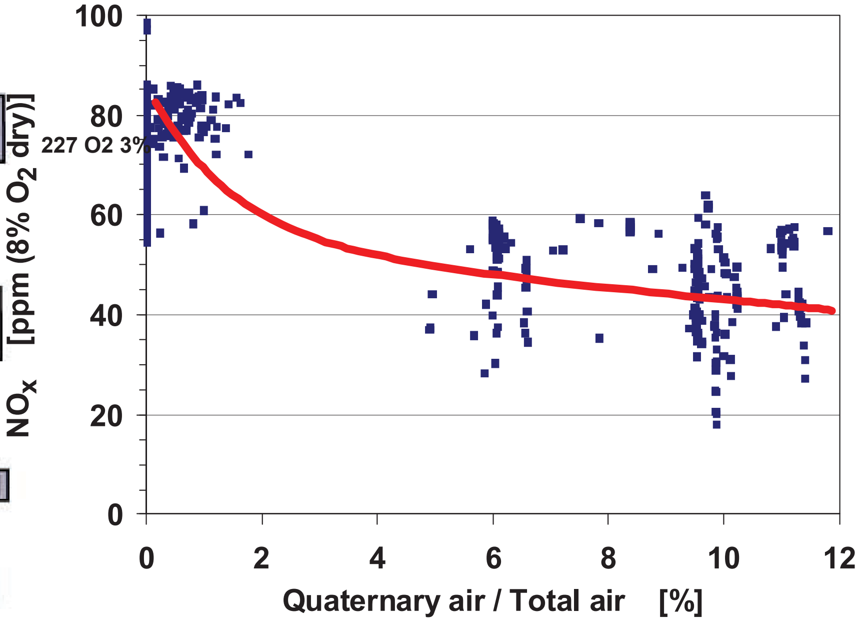
- Nowadays very common material selection in lower part of recovery boilers' furnace is:
  - Middle part of floor is carbon steel (SA/A-210 A-1)
  - Front and rear wall corners are Sanicro 38 material
  - Bended tubes in primary air ports are made by Sanicro 38 material
  - Rest part of furnace up to highest combustion air level is made by AISI 304L composite tubes
- <u>Also totally Sanicro 38 floors have been delivered to some boiler cases. Then Sanicro cut point has been above primary air ports on all walls.</u>
- <u>Sanicro 67 material has been tested</u> mainly in primary air port openings in some boilers



2000 Quaternary Air System

Primary method: Air staging with Quaternary air

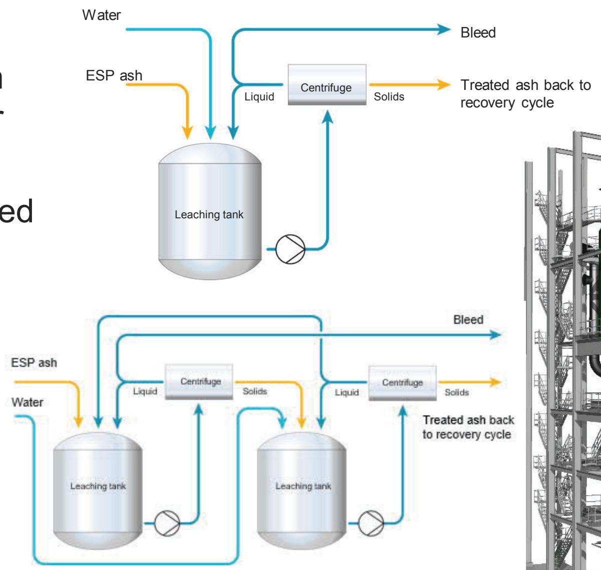




2002 Ash treatment systems

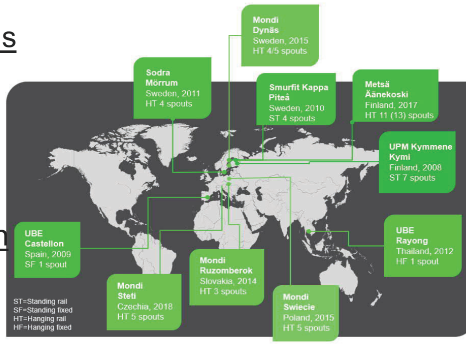
Ash Leaching and crystallization

- Non-process elements like chlorine (Cl) and potassium (K) accumulate in the liquor cycle of a pulp mill
- Cl and K concentrations need to be controlled to avoid excessive <u>fouling and corrosion of boiler's heat transfer surfaces</u>
- Ash treatment processes have been developed for <u>purging of Cl and K with minimum losses of cooking chemicals</u>

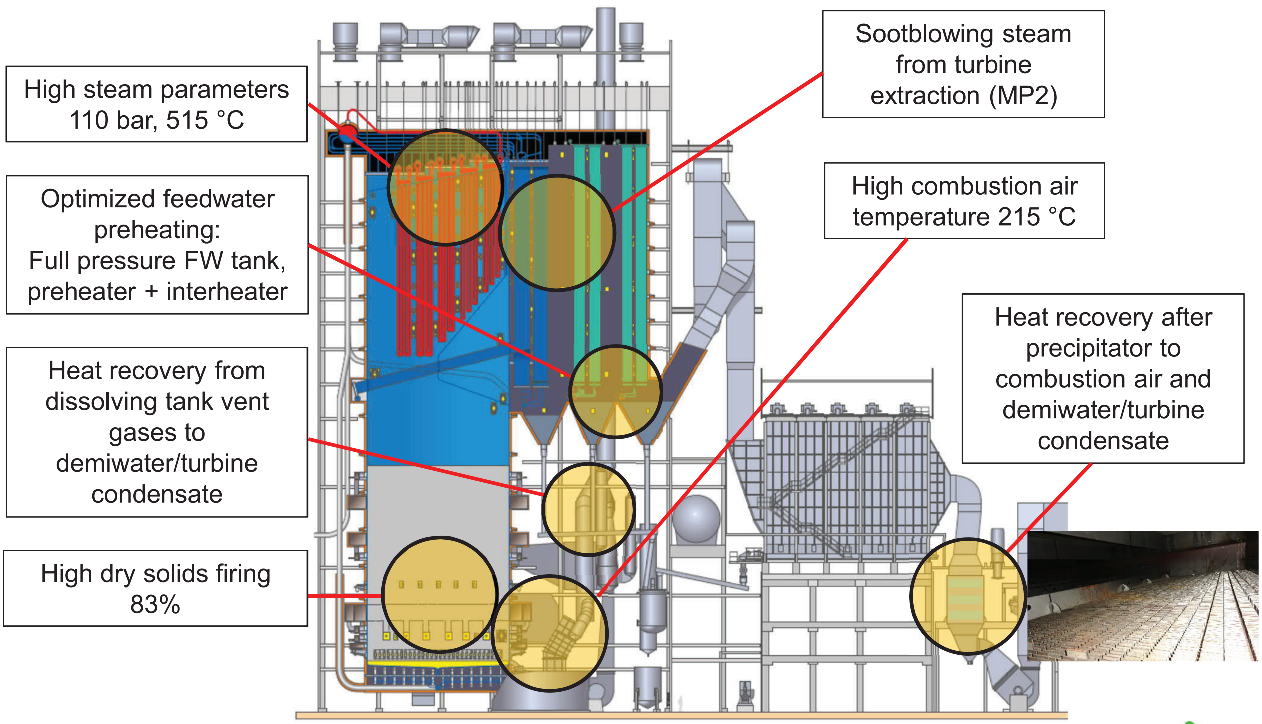


2008 First Smelt Spout robot to Kymi

- Safety – less manual work close to the spouts **<u>decreases risk of personal injuries</u>**
- Stable smelt flow and trouble-free operation
- Saves money - Cleans spouts regardless of operator workload
- Persistent 24 hours careful cleaning
- <u>Hinders the boiler spout openings from plugging</u>
- <u>Splendid observation Cameras from robot tip too area coverage</u>
- Extends the lifetime of the spout
- <u>10 robots in operation and one in delivery</u>



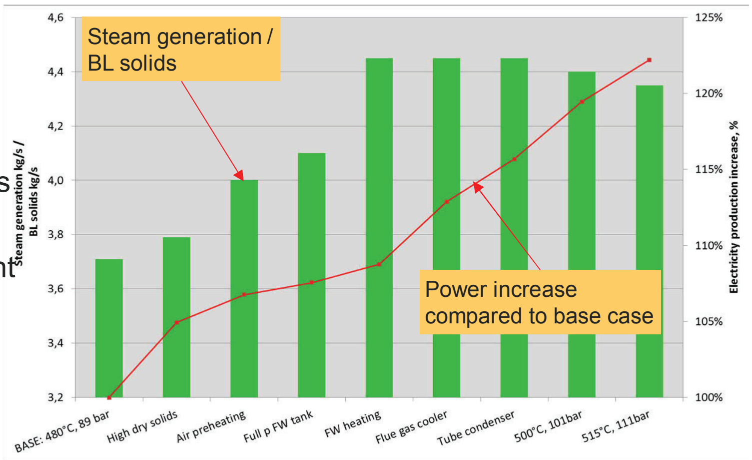
2017 Biggest High Power Boiler in Europe



2017 Biggest High Power Boiler in Europe

Effect of high power features on steam and electricity production

- Black liquor dry solids 83%
- Main steam parameters 110 bar, 515°C
- Combustion air temperature 215 °C
- Flue gas outlet temperature optimized together with feedwater preheating concept; after flue gas cleaning (ESP) further cooling to 130-135°C in flue gas coolers
- Heat recovery from dissolving tank vent gas
- Feedwater preheating
  - full LP pressure feedwater tank 143°C
  - preheater before economizer (MP1 steam) ➔ feedwater into the economizer I 185°C
  - interheater between economizers (MP2 steam)



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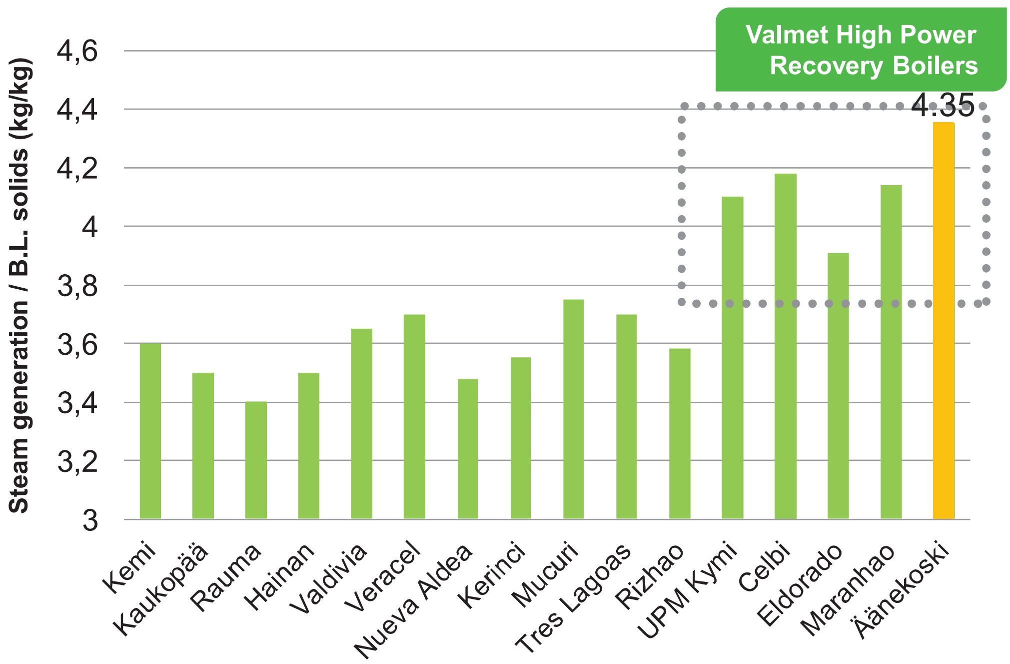


2017 NOx scrubbers, Recovery Boilers

Tightening NO_x emission limits

NO_X	Typical emissions	Europe BAT* Emission limit	China Emmission limit 2020
mg/Nm^3 @ 6% O_2 dry gas	120-250	120-200	100

*Industrial Emissions Directive 2010/75/EU

2017 NOx Scrubber

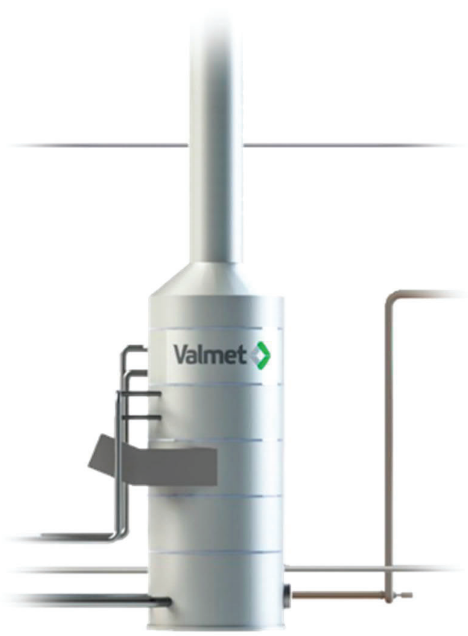
ClO_2 or O_3 as oxidation agent in deNOx scrubbers
For Recovery boilers and Lime Kilns

ClO_2 is available in most pulp mills. Its used in bleaching

- Low energy consumption compared to the Ozone NOx process
- High selectivity , (NO to NO_2/N_2O_5 Oxidizes in milliseconds)
- Oxidized NO_2 will easily dissolve in scrubber liquor
- Easy start-up of ClO_2 based NOx scrubber, reliable

O_3/O_2 gas mixture is used for NO_x oxidation

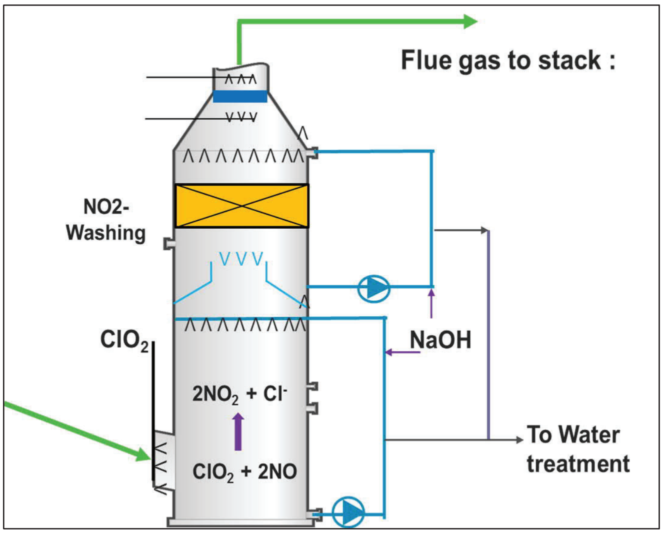
- O_3/O_2 mixture is blown with carrier air to scrubber inlet
  - Rapid NO oxidation to NO_2
- NO_2 washed into scrubbing liquid
- O_3/O_2 gas mixture produced in special ozone generator
- Already commercial technology used in power boilers



2017 NOx Scrubber

World's first recovery boiler with DeNOx scrubber

Sun Paper RB 450 t/d, Yanzhou, China



Test results have proven even NO_x 95% reduction rate

Nine NOx scrubbers are in operation or under delivery.
In all cases emission max 100 mg/Nm3

2017 NOx Scrubber

INTERNAL

Valmet Scrubber NOx References

Eleven scrubbers under construction or delivery

Customer	NOX scrubber Application	Delivery status	Start-up	NOx limit
Sun Paper Yanzhou	RB 450 tDS ClO_2 DeNOx scrubber	Delivered In operation	2017	100 mg/m3n
Sun Paper Yanzhou	RB 1000 tDS ClO_2 DeNOx scrubber	Delivered In operation	2018	100 mg/m3n
Sun Paper Yanzhou	RB 900 tDS ClO_2 DeNOx scrubber	Delivered In operation	2019	100 mg/m3n
Asia Symbol (Shandong) Pulp and Paper Co. Rizhao	NCG Incinerator O_3 DeNOx scrubber	Under construction	2019	100 mg/m3n
Asia Symbol (Shandong) Pulp and Paper Co. Rizhao	RB7500 tDS/d ClO_2 DeNOX scrubber	Under construction	2019	100 mg/m3n
Asia Symbol (Shandong) Pulp and Paper Co. Rizhao	RB7500 tDS/d ClO_2 DeNOX scrubber	Under construction	2019	100 mg/m3n
Asia Symbol (Shandong) Pulp and Paper Co. Rizhao	Lime Kiln ClO_2 DeNOX scrubbers (2 scrubbers)	Under construction	2019	100 mg/m3n
Asia Symbol (Shandong) Pulp and Paper Co. Rizhao	Lime Kiln ClO_2 DeNOX scrubbers (2 scrubbers)	Under construction	2019	100 mg/m3n
Sun Paper Zoucheng	RB 1600 tDS/d ClO_2 DeNOX scrubber	LOI	2019	100 mg/m3n

Recovery Boiler Automation

Path to maximum sustainable performance

Valmet

Recovery Boiler Automation and Optimization

Contents

Valmet

Long history in the Recovery Boiler Automation

Recovery Boiler Automation Forerunners and Developers

THANK YOU!

SE Kotka 1980
Damatic
1st Recovery Boiler Distributed Control System

ZP Rosenthal 1999
SIS
1st Safety Integrated System (HIMA)

MF Kemi 1990
Combustion Optimizer
1st Combustion and Sootblowing Optimization

SE Kemi 2001
Performance Contract
1st Recovery Line Performance Contract

MF Rauma 2005
Dissolving Tank
1st Dissolving tank TTA Optimization

SE Kemi 2012
Leak Detector
1st Recovery Boiler Water/Steam leak detection

SE Kemi 2016
Reduction Degree
1st Reduction Degree Optimization

1960
The Airmatic
a pneumatic measurement and control system

1970's
Elmatic-100 system, electronic instrumentation
Damatic, the first Distributed Control System (DCS)

1980's
Sensodec Condition Monitoring System
Damatic XD, modular second generation DCS

1990's
metsoDNA, Dynamic Network of Applications
SIS, Safety Integrated System

2000
Performance Contracts

2012
2nd generation Recovery Liquor Analyzer with Reduction Degree

2015
Valmet
Process and Automation Technology company

2018
Valmet Boiler Diagnostics Systems

2018
Valmet Performance Centers

- Single loops
- To Distributed Control Systems

- Digitalization
- Large mill information systems

- Value added services
- Multivariable controls

- Advanced diagnostics and KPI's
- Millwide performance development and optimization

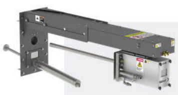
Valmet

Valmet Recovery Boiler Optimizer

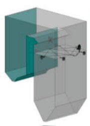
By far most comprehensive offering on the market

Valmet DNA

Valmet DNA based APC-platform can also connect to any other DCS



IR Bed Camera



Acoustic Pyrometer

Recovery Liquor Analyzer

Options marked with *

Combustion optimization

Combustion Symmetry and Emission management

- Air distribution
- Boiler load
- Liquor droplet size
- Bed management
- Reduction Efficiency (add-on) *
- Superheated steam temperature (add-on)
- Leak detector (add-on)

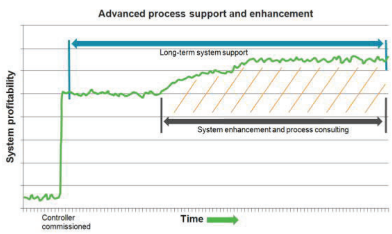
Dissolving tank optimization

- Valmet Alkali-R recovery liquor analyzer
- Na_2CO_3 solubility calculation *
- TTA-control *
- Dissolving tank mass balance stabilization (add-on)

Sootblowing optimization

- Fouling indicators
- Sootblowing efficiency indexing
- Adaptive intervals

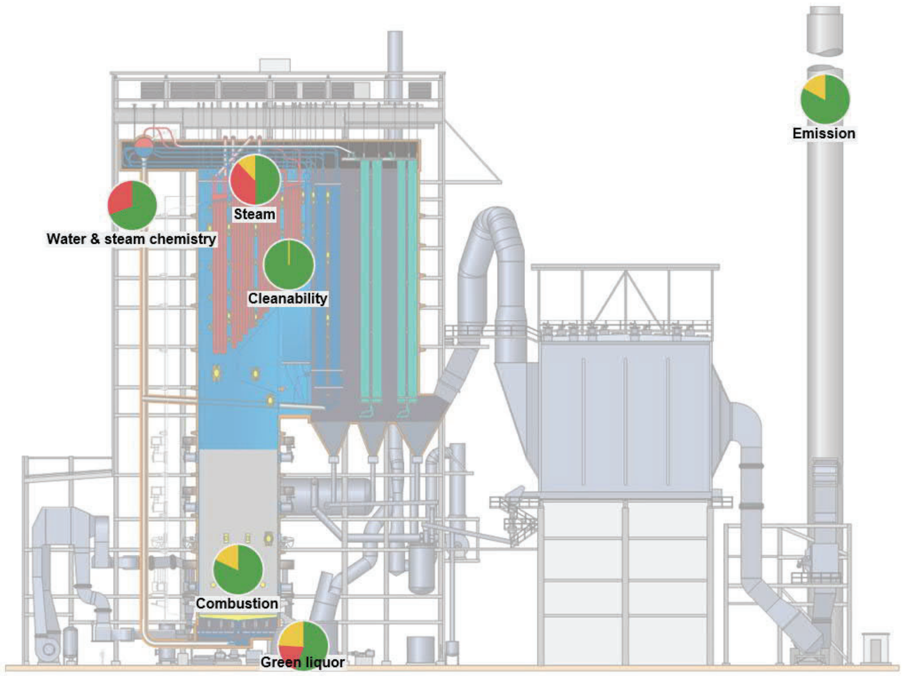
Performance Service



Valmet

Recovery Boiler KPI Monitoring

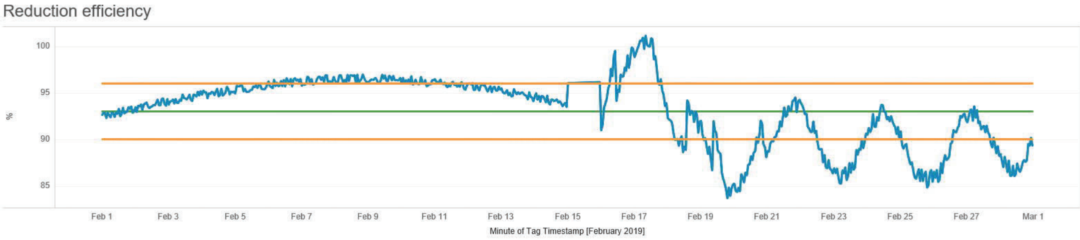
Cleanability	NORMAL	
Combustion	NORMAL	
Emission	NORMAL	
Green liquor	CRITICAL	
Steam	CRITICAL	
Water & steam chemistry	CRITICAL	



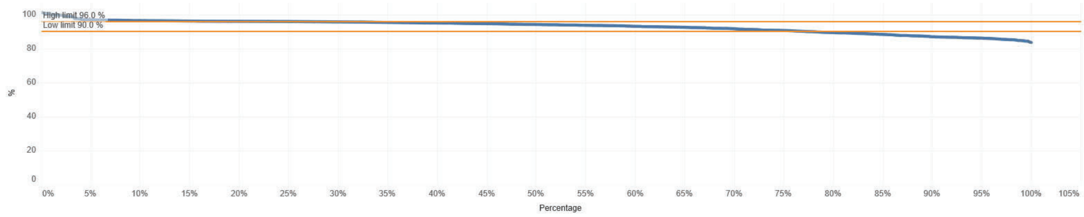
Green liquor quality monitoring

Reduction efficiency analysis as example

Reduction efficiency



Reduction duration curve



Site

Industrial Internet (624508)

Time selection

- Last 1 hour
- Last 24 hours
- Last 7 days
- Last 30 days
- Last 365 days
- Custom

Start date

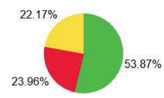
01/02/2019

End date

01/03/2019

Choose parameter

Reduction



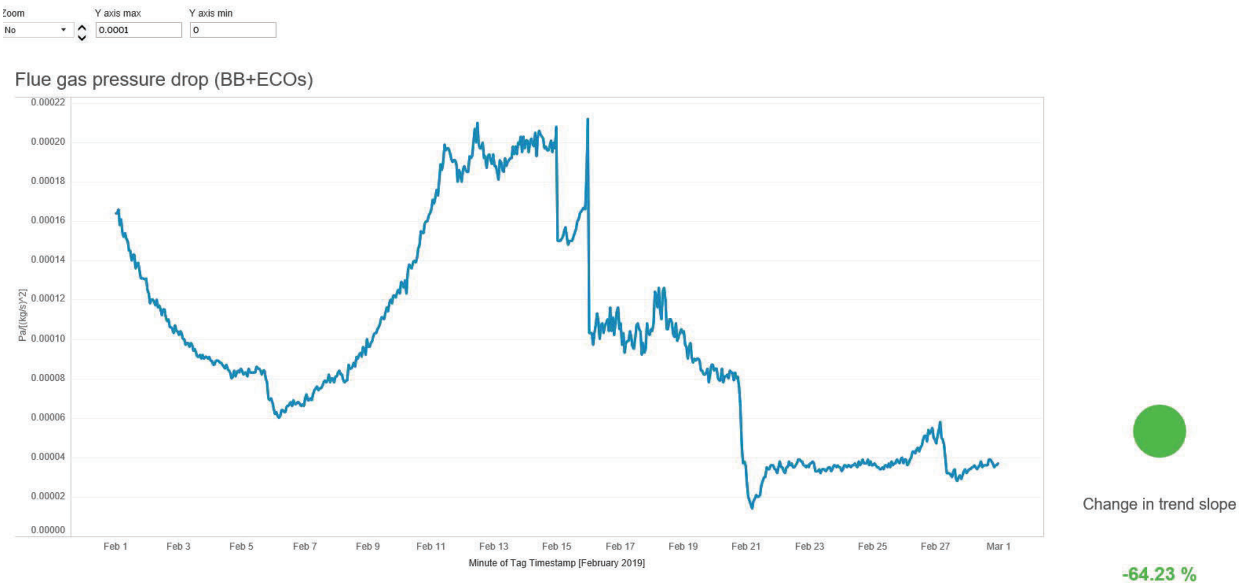
STD

3.8 %

Cleanability KPI

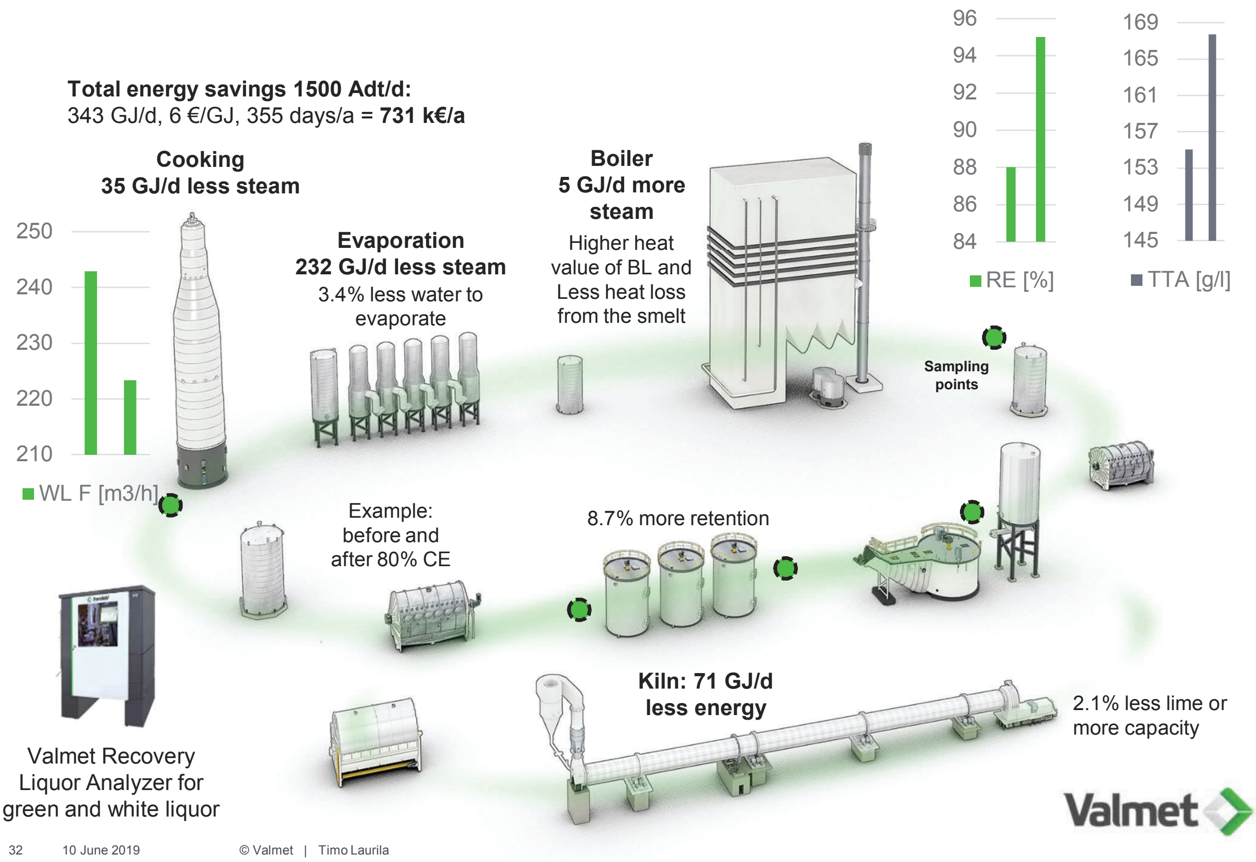
Analyzing scaling speed and direction

Cleanability



Benefits from good chemical recovery

Total energy savings 1500 Adt/d:
343 GJ/d, 6 €/GJ, 355 days/a = **731 k€/a**



Valmet
FORWARD