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4 June 2025

SAIMM 2025

GC Technology & Digitalisation

AGENDA

- Gas Cleaning Technology
- Tail gas scrubbing
- Digitalisation

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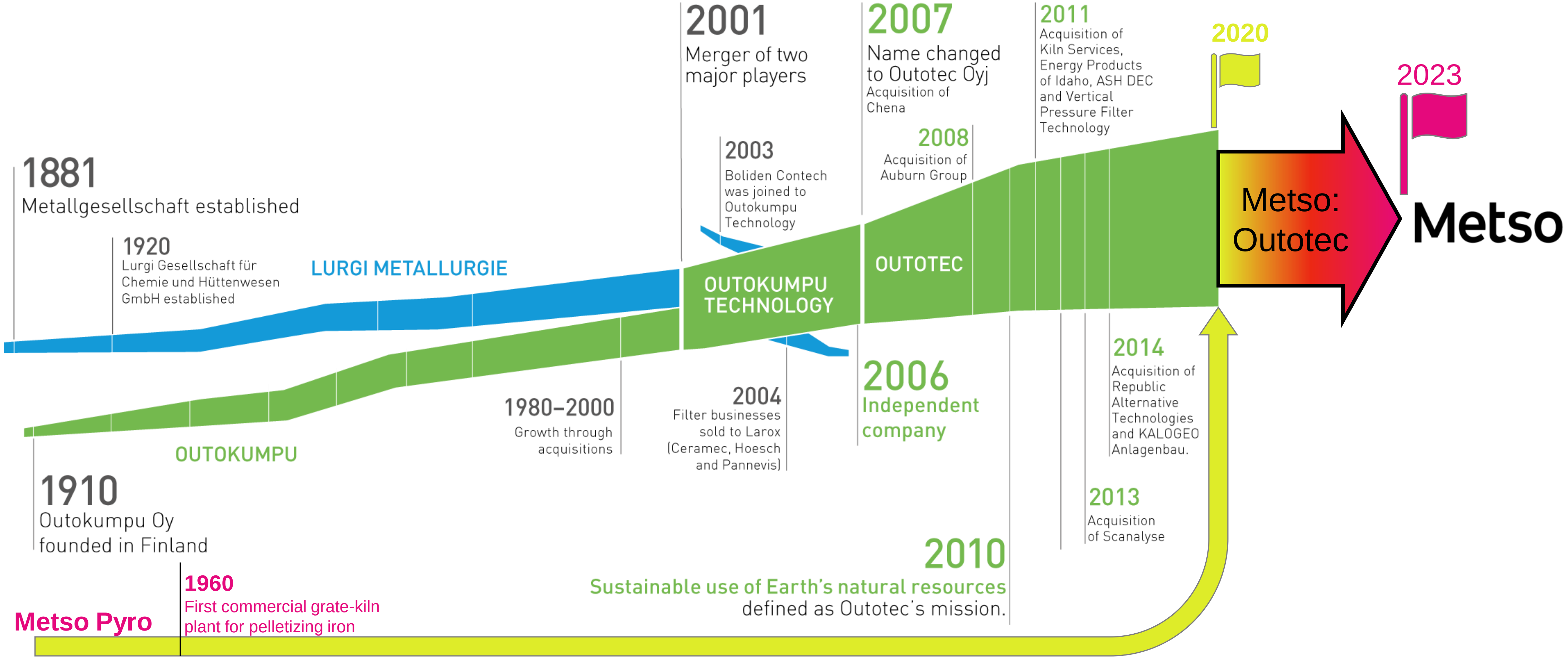
Metals and Chemical Processing (MCP) BL
A century of accumulated expertise



AGENDA

- Gas Cleaning Technology

Declining ore grades

Various publications confirm decreasing valuable metal content in ore bodies

Metal	1880-1900	1950-1960	today
Gold	22-23 g/t	5 g/t	1.94 g/t
Silver	1,175 g/t	154 g/t	98.4 g/t
Copper	7.60 %	1.35 %	0.95 %
Lead	14.42 %	10.41 %	3.50 %
Zinc	15.68 %	10.42 %	7.77 %

“Peak Silver and Mining by a Falling EROI”, Commodities / Gold & Silver, Steve St Angelo, Nov 04, 2009, http://www.marketoracle.co.uk/Article14756.html

Impurities in the gas cleaning plant

… and the consequences

Decreasing valuable ore metal contents lead to..

…increasing amounts of unpleasant impurities, i.e.

- Arsenic
- Hydrogen chloride
- Hydrogen fluoride
- Mercury
- Selenium

... which directly affects…

- the overall efficiency of the gas cleaning plant
- the quality of the acid produced downstream
- the lifetime of downstream plant and equipment

Reduction in valuable ore metal content

Implications

- Increased throughput to compensate for the decreased head grade
- Lower pressure drops in the scrubber to handle increased gas flow rate
- Operational/maintenance challenges due to increased accretions/deposits
- Increased problems of corrosion
- Sulfuric acid quality
- … the list goes on

It is highly likely that the gas cleaning section may operate outside its design specification and thus require retrofit/upgrading

Consequences for the acid plant operation/1

- Arsenic (As_2O_3)
  - Below 600 °C, saturation of catalyst and reduced catalyst activity
  - Above 600 °C, volatile compound $V_2O_3{*}As_2O_5$ can be formed and some long-term loss of activity due to permanent vanadium losses
- Selenium
  - Reduces catalyst activity
  - Harmful effect only at temperatures below 400 °C; initial activity is restored after heating
- Dust
  - Accumulates in the catalyst bed and on candle filters
  - Accumulations on the catalyst increases pressure drop and reduces throughput

Consequences for the acid plant operation/2

- Heavy metals (Pb, Hg)
  - Deposits result in significant catalyst activity loss
- Fluorides (F^-)
  - Reacts with the catalyst silica support, forming volatile SiF_4, and deposition of silica gel on the catalyst surface has been observed
  - Mixture of HF and H_2SO_4 is a strong oxidizing agent
- Chlorides (Cl^-)
  - At high concentrations, $VOCl_3$ is formed leading to vanadium loss
  - Significant attack/corrosion of steel equipment in the acid plant

Examples for Impurity Impact on Sulphuric Acid Plant

- Improper design and operation of gas cleaning plant means higher maintenance costs also in the acid plant!!

SO_2-Blower

Gas-Gas-Heat Exchanger

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Examples for Impurity Impact on Sulphuric Acid Plant

Gas Duct

Candle Filters

Acid plant must produce high quality acid

…. if you want to sell it!

Impurity	
Appearance	Water Clear
Colour	40 Hazen
Hg (Mercury)	< 0.5 ppm
Fe (Iron)	< 25 ppm
Ni (Nickel)	< 1 ppm
Cr (Chromium)	< 1.5 ppm
Mn (Manganese)	< 0.3 ppm
SO_2 (Sulphur Dioxide)	< 30 ppm
Cl^- (Chloride)	< 2 ppm
F^- (Fluoride)	< 5 ppm

Impurity	
NH_4^+ (Ammonium)	< 1 ppm
NO_3^- (Nitrate)	< 5 ppm
As (Arsenic)	< 0.2 ppm
Cu (Copper)	< 0.2 ppm
Cd (Cadmium)	< 0.02 ppm
Pb (Lead)	< 0.3 ppm
Zn (Zinc)	< 0.1 ppm
Sb (Antimony)	< 0.02 ppm
Bi (Bismuth)	< 0.02 ppm
Se (Selenium)	< 0.1 ppm

Requirements for the gas cleaning section

In order of priority:

- Safe quench of process gases
- High scrubbing efficiency
- Removal of aerosols
- Removal of gaseous impurities
- Ensure water balance of acid plant
- Specific gas treatment, e.g.
  - Mercury removal
  - Halide removal

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Quenching - OTOVENT^{TM} Quench

Features:

- Venturi type Quench
- Gas inlet from top at temperatures up to 1200°C
- Gas quenching to saturation
- Pre-dedusting of process gas
- Overflow Weir with tangential water inlet:
  - Distinct hot and cold gas zone
  - Defined gas / liquid interface
  - Avoidance of dust accretions
- Two independent quench liquid circuits :
  - Increased Plant Safety and Availability
- High quench and scrubbing efficiency
- Integrated settling tank possible

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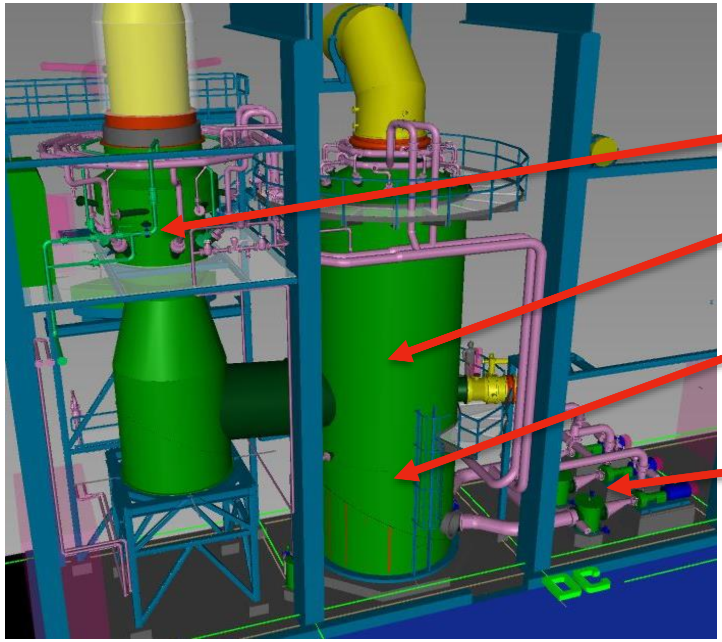
Quenching: OTOVENT™

With retention tower

- Designed for high retention time in the quench tower to allow for growth of fine condensed particles such as As, Se, etc.



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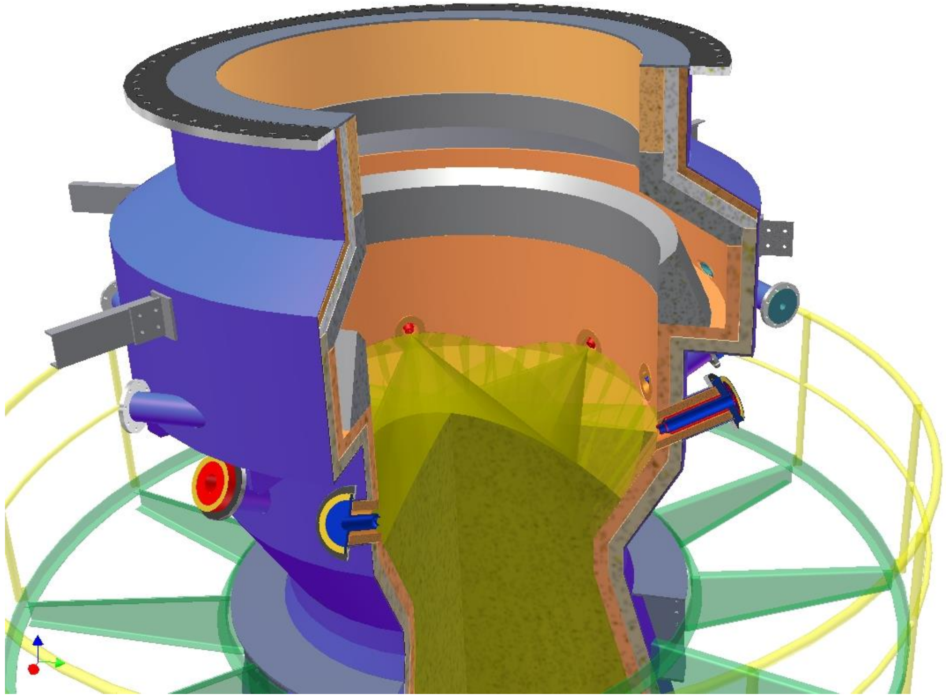
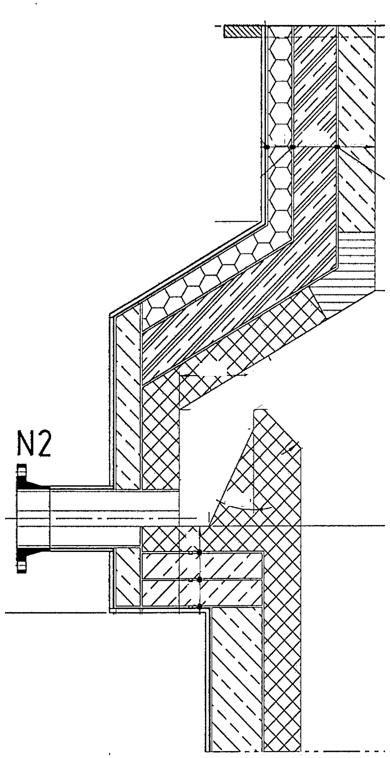
Quenching - OTOVENT™ Quench





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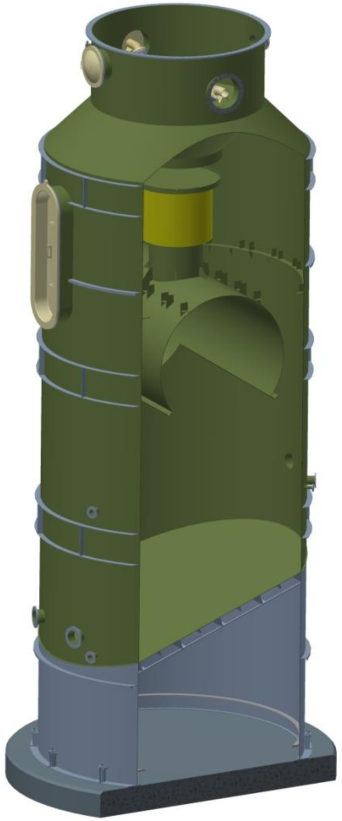
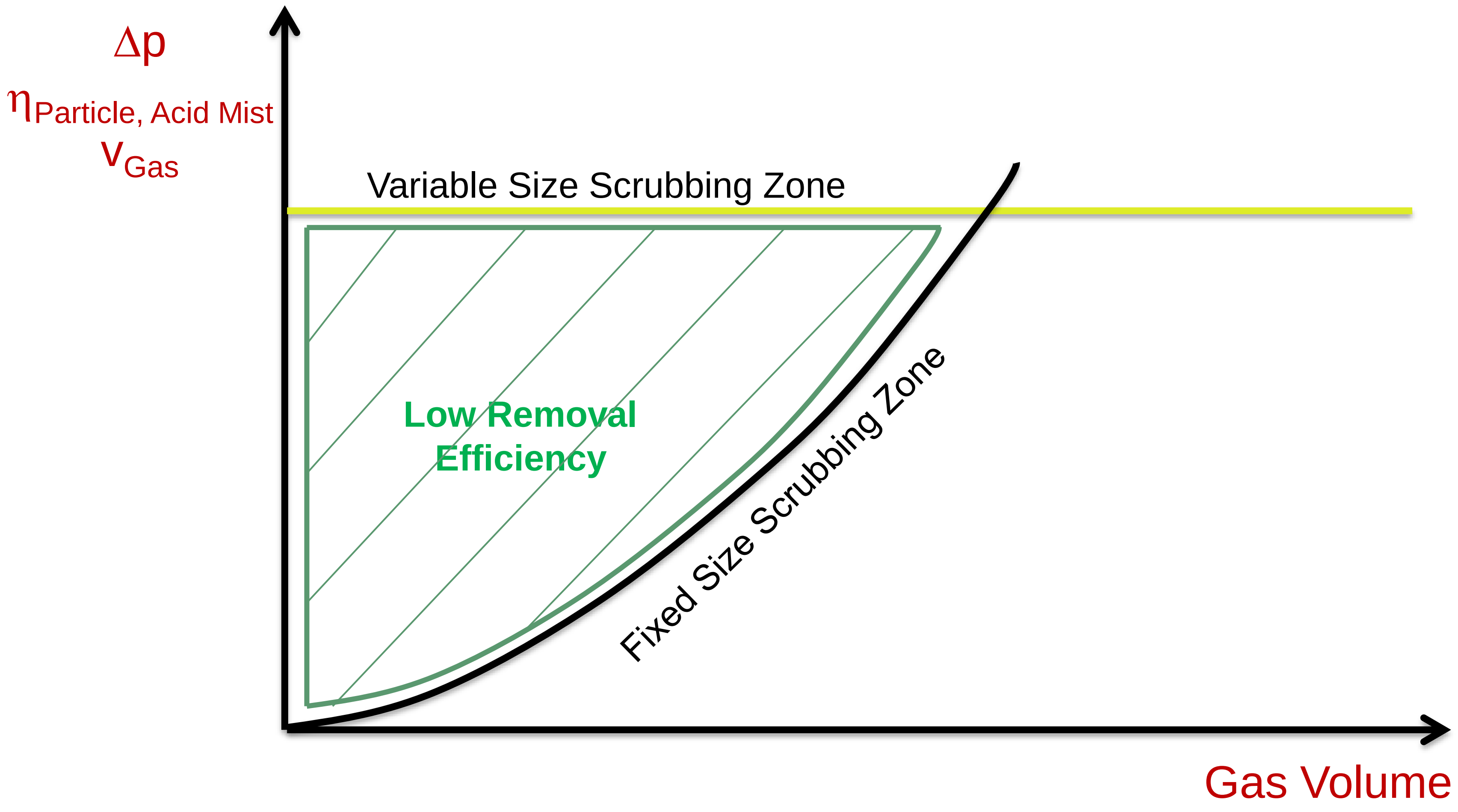
Scrubbing: High efficiency scrubber



High efficiency scrubber with adjustable pressure drop and adjustable scrubbing zone, to maintain high solids removal efficiency at varying levels of turndown

- Constant scrubbing efficiency at fluctuating gas volumes
- Wide range of gas volume flow rates from 10,000 to 350,000 Nm³/h possible
- Removable scrubbing zone for reduced maintenance
- Optimized process solution considering reduced life-cycle costs
- Retrofitting fully considered in the design

Scrubbing – Variable Scrubbing Zone

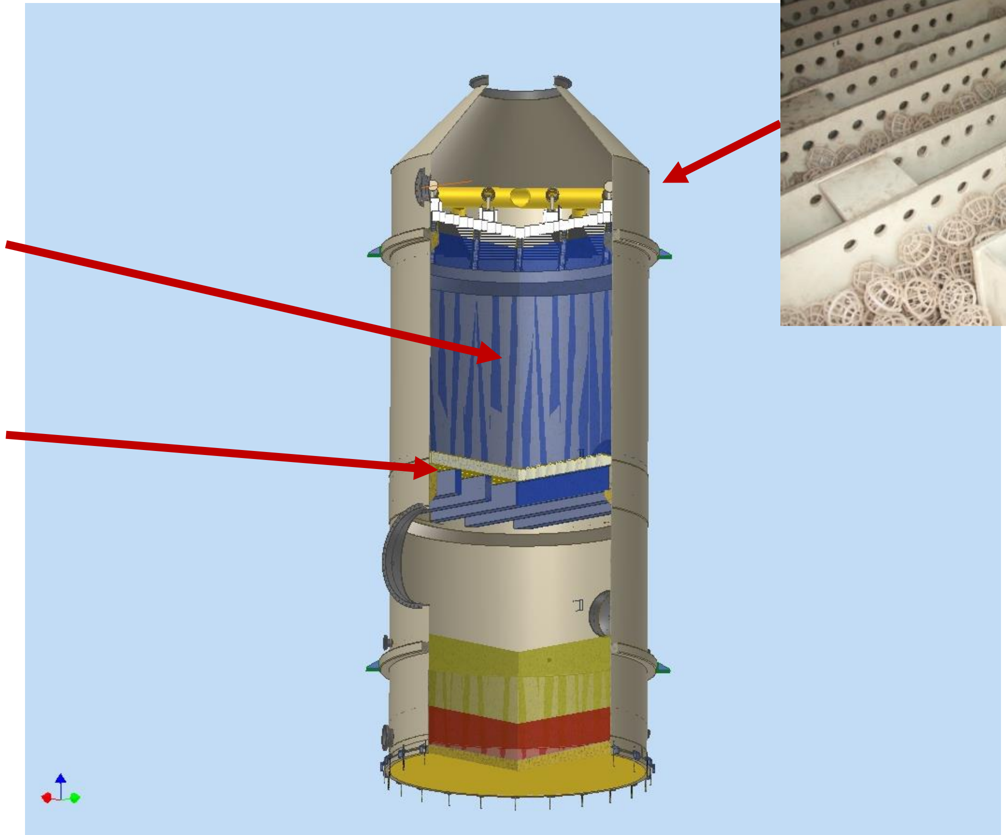


Cooling – gas cooling tower

- Cooling required in order to maintain the water balance of the sulfuric acid plant
- Removal of halides
- Cooling also enhances mercury removal efficiency in Hg tower

Random packing

Support for packing



Liquid distribution system

Wet electrostatic precipitator (W-ESP)

Metso’s Editube solution

Function

- Removal of sub-micron particles to < 1 mg/Nm^3
- Removal of acid mist
- Key equipment for As and Hg removal
- Key equipment for sulfuric acid quality

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HF-Removal - Sodium Silicate Dosing

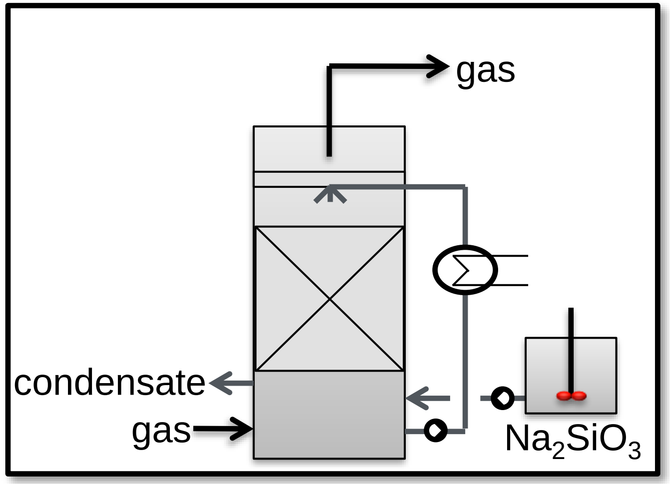
Reaction: $Na_2SiO_3 + 3\ H_2F_2 \rightarrow Na_2SiF_6 + 3\ H_2O$

Advantage:

Low investment cost
Very efficient removal

Disadvantage:

Risk of build-ups at overdosing or malfunction
Consumption of chemicals
Process control necessary



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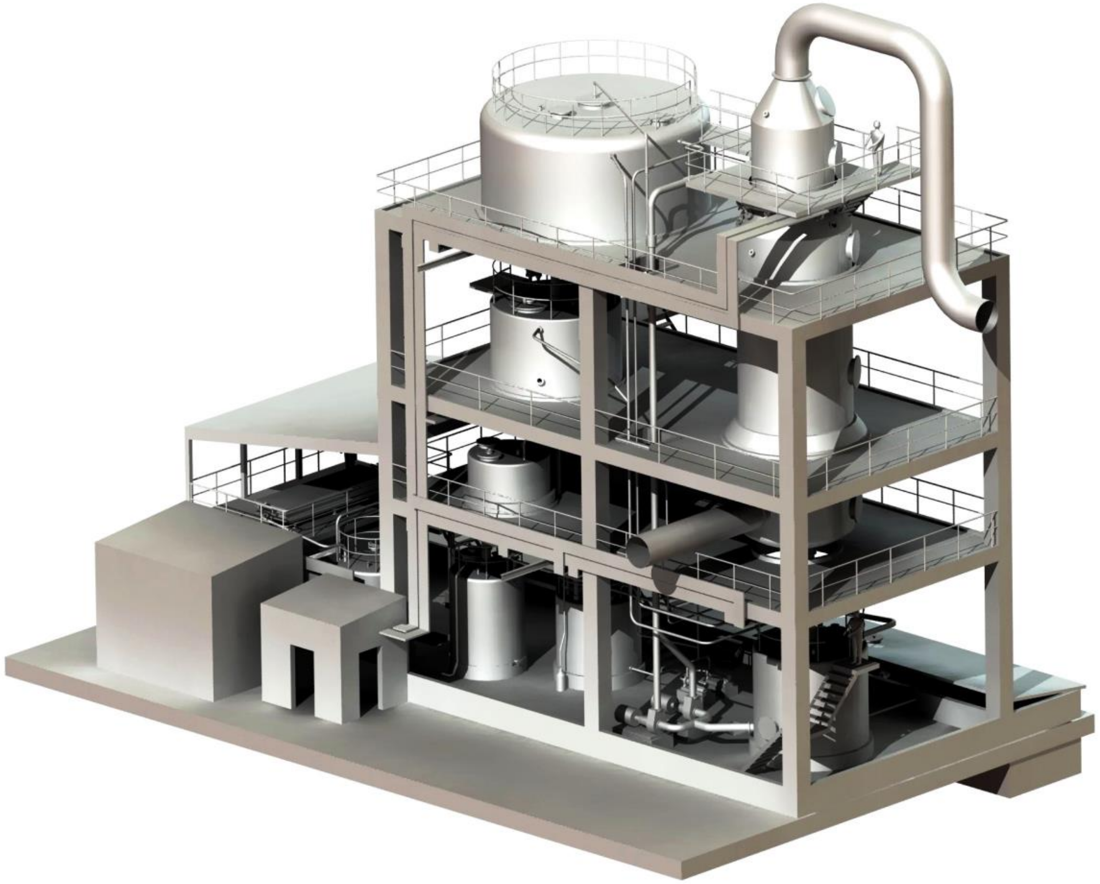
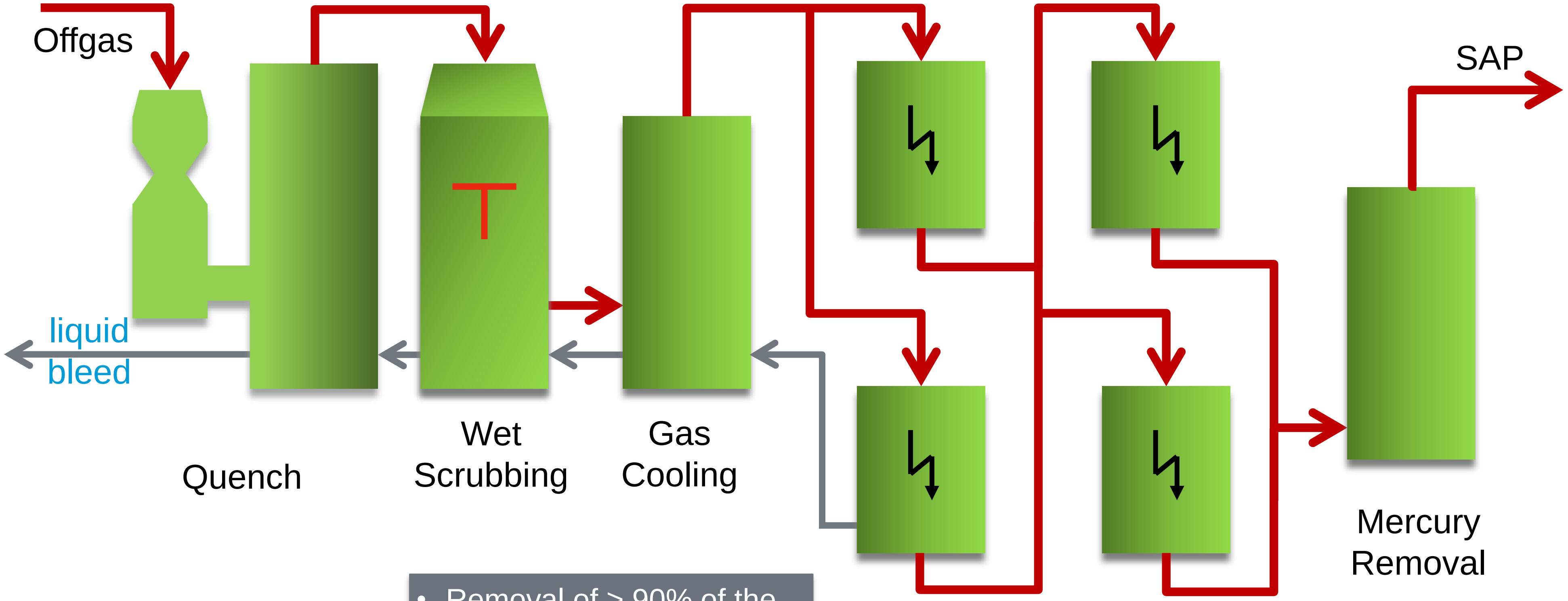
Metso’s mercury removal process



Removal of metallic mercury

- Scrubber reaction
  $Hg^0(g) + HgCl_2(l) \rightarrow Hg_2Cl_2(s)$
- Chlorination tank reaction
  $Hg_2Cl_2(s) + Cl_2(g) = 2\ HgCl_2(l)$

Wet removal of As and Hg



- Quenching
- Fumes particle formation/growth and pre-dedusting

- Removal of > 90% of the particles > 1µm
- Cooling (to maintain the water balance)
- Halide removal

- Removal of remaining small particles and mist

- Removal of metallic mercury

Gas cleaning
Summary

- As head grades decline further, focus on the gas cleaning plant performance in the complete pyrometallurgical process chain will inevitably increase
- If the increase in impurities is left unchecked there is a real likelihood that the life of the downstream acid plant will be severely curtailed
- A full review of the complete gas cleaning flowsheet needs to be carried out, involving capex improvements to meet future demands
- There will be an increase in the need for focused separation process technologies based on specific process requirements
  - For arsenic: increased retention time, high efficiency scrubbing, high performance W-ESP section will be required
  - For mercury: efficient gas cooling, high performance W-ESP section, well operated Hg removal plant will be required

AGENDA

- Tail gas scrubbing

#	Process	Absorption Agent	Reaction Product, other products	Effluent	comsumption	Handling of Product	Recommendation for size, Amount of SO2	Recommendation for plant size, Flow Rate, SO2-conc.	Remark
1	**Sulphuric Acid**	none	*sulphuric acid H_2SO_4, Steam can be produced*	weak acid originates in the wet gas cleaning system, weak acid is treated	electrical power, water,	sulphuric acid is base chemical and widely used	SO2: >100 tons/day, >4000 kg/hour,	Flow Rate = 5000 – 250.000 Nm3/h SO2: > 3 % by volume	proven process for SO_2-removal form gases with more than 4 % SO_2 concentration
2	**Sodium hydroxide scrubber**	Na(OH)	*Sodiumsulpate Sodiumsulphite NaSO4/3*	dissolved neutral salt, often can be disposed in river	**NaOH** electrical power, water	if disposal in river is not possible,	SO2:> 30 tons/day, 2000 kg/hour,	Flow Rate: < 50.000 Nm3/h	easy to operate SO_2-removal process, but high costs for absorption agent
3	**Lime / Limestone Scrubber**	Lime, $Ca(OH)_2$ Limestone, $CaCO_3$	*Gypsum, $CasSO_4$*$2H_2O$*	Bleed Flow from Gypsum wahing	**Ca-comp.** electrical power, water	Gypsum only can be sold if according to required quality	SO2: < 70 tons/day, 3000 kg/hour,	Flow Rate: > 100.000 Nm3/j SO2: < 1 % by volume	If O_2-content in the gas is low, gypsum may have a high SO_3-content. process is in use at power stations.
4	**Peracidox**	H_2O_2, Peroxide	*Sulphuric Acid, apporx. 50 %*	weak acid from wet gas cleaning system, is to be neutralized	**H_2O_2,** electrical power, water,	Acid (50 %) used directly or used for dilution of conc acid	SO2: < 30 tons/day, 2000 kg/hour	Flow Rate: > 50.000 Nm3/h SO2: < 1 % by volume	H_2O_2 is a very expensive reaction agent. Process is economic if internal use is possible.
5	**Regenerable SO2-Recovery-Processes**	none	*concentrated SO2 in liquid form*	weak acid originating in the wet gas cleaning system, to be neutralized	elec. power, **steam,** water, cool w	SO2 is used in some processes	SO2: < 100 tons/day < 4000 kg/hour	Flow Rate: < 50.000 Nm3/h SO2: < 10 % by volume	Usage of SO2 is to be ensured, Steam is consumed for this process
6	**dry SO2-removal processes**	Ca(OH)2	*Calciumsulphate and Calciumsulphite $CaSO_{3/4}$ * nH2O*	none	electrical power, **Ca(OH)2**	difficult to find possibilities to us the $CaSO_{3/4}$*nH2O	SO2: < 5 tons /day < 2000 kg/h	Flow Rate: < 250.000 Nm3/h SO2: < 0.5 % by volume	process is in use at power stations, SO_2-conc. < 20 g/Nm3
7	**Sulphur producing processes**	none	liquid or solidified *sulphur*	weak acid from wet gas cleaning system, weak acid is to be neutralized	electrical power, water **natural gas**	sulphur is a base chemical, can be sold if qualitiy is good.	SO2: < 100 tons/day < 4000 kg/h	Flow Rate: < 100.000	process requires high consumption of natural gas, is only feasible if other processes are not possible
8	**Ammonium-sulphate**	NH3, aqueous	Ammonium-sulphate	depending on further use	**NH3,** elec. power, water	depending on usage possibilites	SO2 < 100 tons/day (NH4)2SO4 < 200 to/day	Flow Rate: < 50000 Nm3/h SO2 < 1 – 2 %	(NH4)2SO2 usage as ferti. lCooperation with fertilizer comp. required.
9	**Sulfacid**	none	diluted sulphuric acid (20 – 40 %)	none	elec. power, pressure drop	for process, concentration, if available	SO2 < 10 tons/day, < 400 kg/h	Flow Rate: < 100.000 Nm3/h SO2 < 0.5 %	process is often applied in pigment production (TiO2)
10	**Dual-Alkali**	Limestone, Lime	Caustic Soda	Gypsum	elec. power, lime, caustic	similar to 3.	SO2 < 20 tons/day < 500 kg/h	Flow Rate: < 50.000 Nm3/h SO2 < 3 %	process is difficult to operate and complicated, only 2 references build
11	**Desonox**	none for SO2	diluted sulphuric acid (50 %)	none	power,	similar to all proc. producing acid	SO2 < 50 tons/day < 2 tons/day	Flow Rate: < 200000 Nm3/h SO2 < 1 %	process designed for simultaneous removal of SO2 and Nox in 2 cat
	others	absorptive processes, reaction agents	SO2, SO3, S, and other S-compunds	depending on process, weak acid,	electrical power, water, **react. agent**	depending on possibilities within battery limits of the factory			processes specially designed for a given application, very limited number of applications

:

Major Regenerative SO_2 Absorption Processes

Process	Based on	Developed by	~Year
Citrate Absorption	Citric acid buffer	Bureau of Mines	1975
Adipate Absorption	Adipic acid	SINTEF / Erga	1985
Phosphate (Erga) Process	Phosacid	Erga	1988
Cansolv (now Shell)	Amine	Consolv	2002
Solinox Process	Glycol	Linde	1990
Lurgi SOx Process	Xylidin	Lurgi	1980
Monsanto	Ethanolamine	Monsanto	1980
Wellmann-Lord	Na-sulfit/bisulfit	Wellmann- Lord	1970
SolvR	Amine	MECS	2015
Many Others	…….		

Emission reduction

The Peracidox® process

Peracidox® Process

- Oxidation based process for purifying very dilute gases from SO_2

Reaction principle

- $SO_2 + H_2O_2 \rightarrow H_2SO_4$

Benefits

- No additional by-products (only sulfuric acid produced)
- High conversion efficiency (virtually stoichiometric)
- Low investment cost
- High flexibility with respect to SO_2 content

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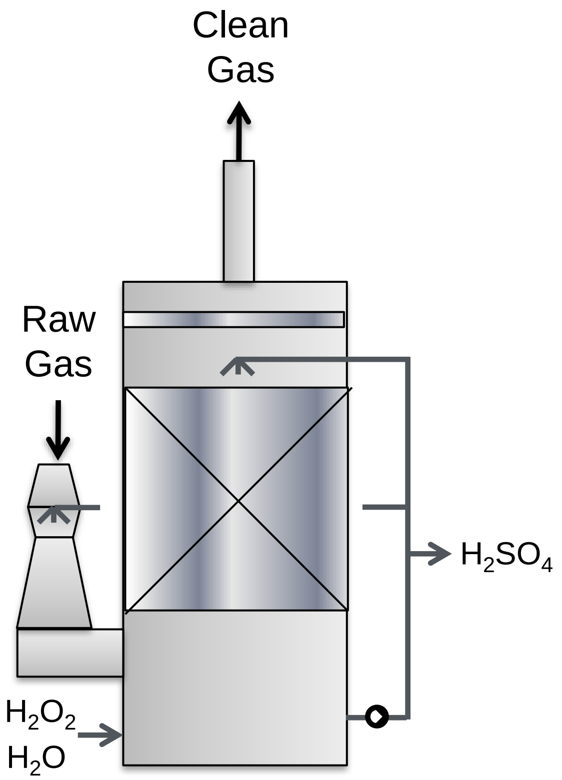
Tail Gas Scrubbing - Peracidox®-Scrubber



Reaction:

$H_2O_2 + SO_2 \longrightarrow H_2SO_4$

Features:

- Removal of SO_2 from tail gas
- Two stage process: Venturi + Packed Tower
- Efficient SO_2 removal
- Production of H_2SO_4 with up to 60% concentration

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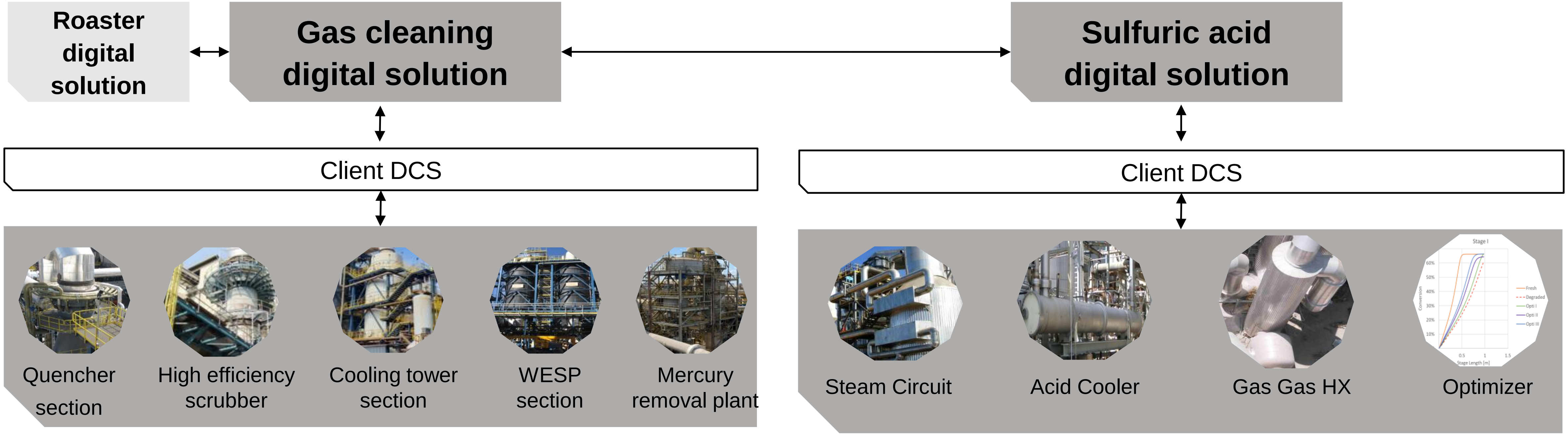
Digital Solutions

Overview

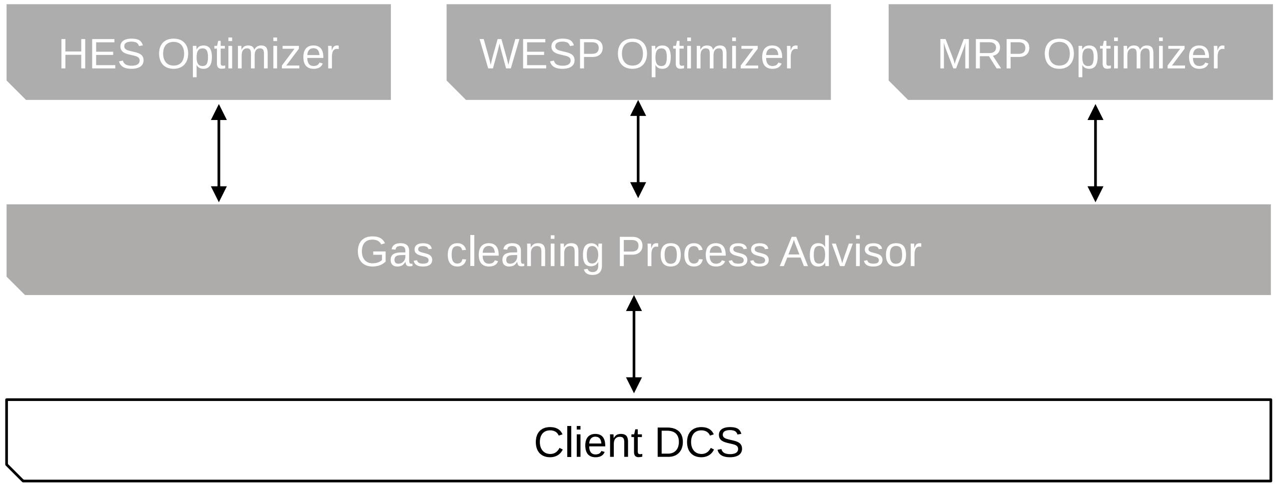


- **Gas cleaning**: WESP Optimizer, High Efficiency Scrubber Optimizer,Mercury Removal Plant Optimizer, Process Advisor
- **Sulfuric Acid**: Health monitor, Optimizer, Sequence assistant

Gas cleaning digital solution

Product offering

- Optimizers are productized and specifically developed for proprietary equipment
- Process advisor is tailored for each site based on existing instrumentation, enabling implementation in both greenfield and brownfield
- Process advisor manages plant level optimization boundaries and operational targets
- Seamless and standardized integration into customer DCS and IT environment



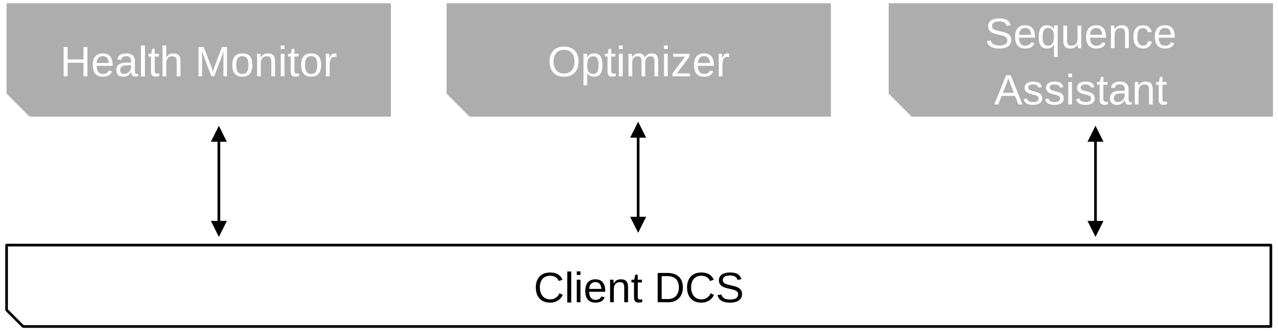
Digital application platform: Implementation in specific expert software (Metso ACT platform) outside of DCS: Higher flexibility, standardized integration and communication, and simple application tailoring to customer site

Optimization of single proprietary equipment up to the complete wet gas cleaning plant

Sulfuric acid digital solution

Product offering

- **Health Monitor** is continuously assessing the status of equipment and improving availability
- **Optimizers** are specifically developed for proprietary equipment to increase performance and efficiency
- **Sequence assistant** is supporting operators during complex operational scenarios
- Seamless and standardized integration into customer DCS and IT environment



Digital application platform: Implementation in specific expert software (Metso ACT platform) outside of DCS: Higher flexibility, standardized integration and communication, and simple application tailoring to customer site

Solutions for proprietary equipment up to the complete sulfuric acid plant

SADS Module Structure

Sulfuric Acid Digital Solutions

Health Monitor

- Steam circuit
- Acid Cooler
- Gas-Gas HX

Availability

Reliability

Operator skillset variability

Optimizer

- Converter
- ..
- ..

Performance

Efficiency

Environmental footprint

Operator skillset variability

Sequence Assistant

- Plant startup
- Plant shutdown
- Plant load change

Availability

Operator skillset variability

GC & SAP Digital Solutions

Value proposition

Utility Saving

- Optimized converter profile – low blower power
- Reduced energy consumption from blower with more accurate parameters from converter

Improved operation

- Ease of operation for stable and highly efficient production
- Optimum parameters in converter leads to better parameters and low emission
- More data available on converter performance
- Less frequent manual sampling

Maintenance prediction

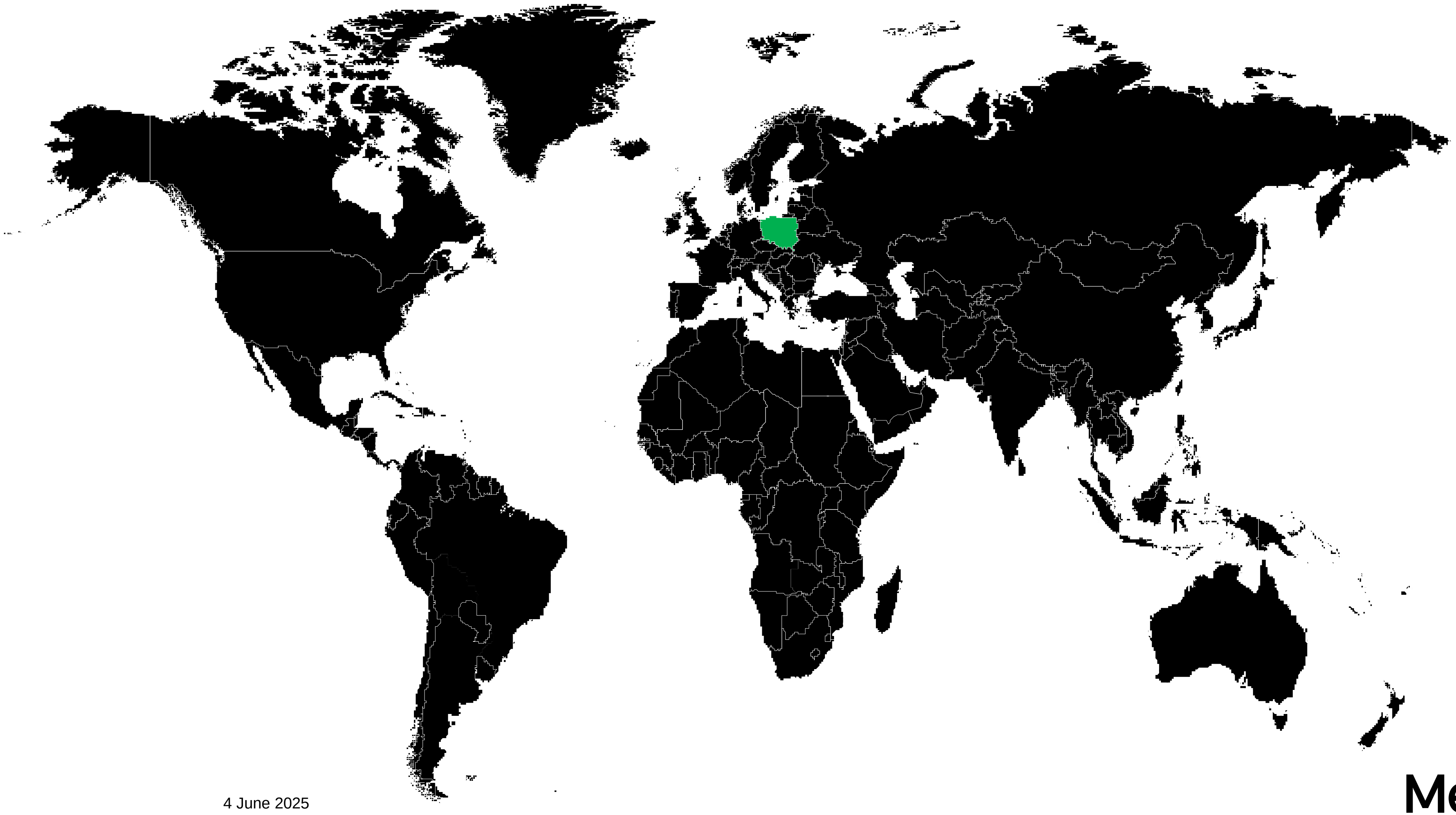
- Cleaning of plate heat exchanger and gas HX
- Identifying leak in steam circuit
- More accurate calculation on Gas Gas HX performance
- More accurate data for water balance calculation to identify steam leak

Operational know-how

- Overall plant performance indication
- Overall converter performance indication
- Overall HX performance indication
- Heat exchanger efficiency and operational parameters calculated and displayed
- Potential for improvements from optimizer calculations

Remote support and assistance

Faster and more accurate remote troubleshooting and support with SADS installed



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Partner for positive change

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