

Remote Start-ups

And how to use Plant Data and
Dynamic Training Tools

Brimstone Sulfur Symposium Presentation
September 14, 2021

Comprimo®

comprimo@worley.com

worley.com/comprimo

Agenda

1. Licenser Activities after Design
2. Comprimo Insight
3. Comprimo Immerse
4. Questions



A large industrial facility, possibly a refinery or chemical plant, with multiple levels of steel structures, pipes, and storage tanks. The image is overlaid with a semi-transparent blue filter.

1 Remote Commissioning and Start-up Learnings

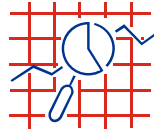
Typical Post Process Design Package Activities by Licensor



Detailed Engineering Reviews

May include the following:

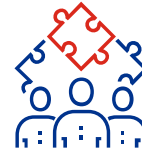
- HAZOP
- 3D Model Reviews
- For Construction Drawings
- Vendor Drawings



Operator Training

Classroom setting:

- Process Theory
- Start-up and Shutdown Scenarios
- Troubleshooting



Plant Inspection

Evaluation of installation details

- Meeting of intent of design
- Meeting of process flow
- Meeting of heat maintenance of the plant
- FAT participation
- Catalyst installation (could be part of)
- Overall readiness for start-up



Start-up

May include the following:

- Tuning of our ABC control loops
- Dryout of refractory
- Catalyst installation and blows
- Light off burners
- Introduction of acid gas
- Conditioning of SUPERCLAUS catalyst
- Sulfiding of TGTU catalyst
- Performance Test

Detailed Engineering Reviews

- Limited impact due to Covid
 - Virtual tools are pretty good for reviewing drawings, models and participating in HAZOPs/Model Reviews
 - Interaction with Customer is different
 - Harder to gauge understanding and knowledge of customer engineers and operators
- Tools like Teams, Zoom, Bluebeam, etc work well
- Time zone difference can complicate reviews with meetings happening in the middle of the night

Operator Training

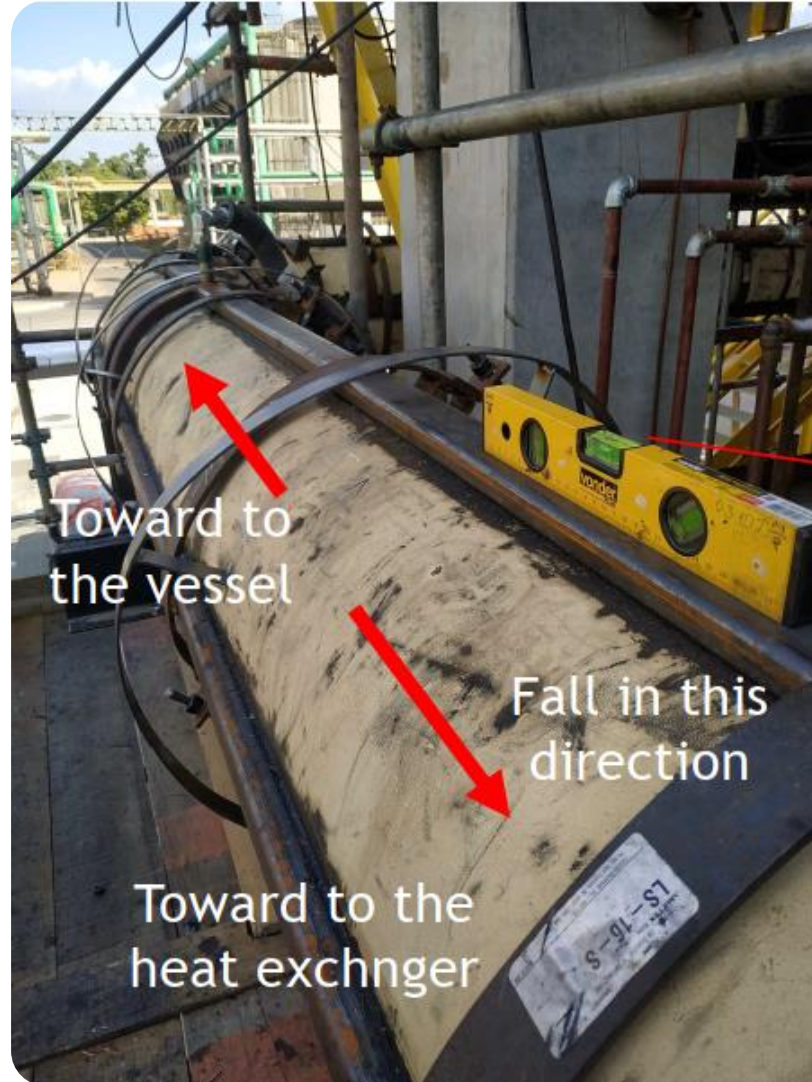
- Virtual Training is possible
 - In general positive experience
 - Virtual Tools are adequate for training
 - Possibility for online capture of presentation
 - Translators can be included in the meeting for limited English language capabilities
 - Interaction with Customer reduced
 - Dependent on Customer though
 - Not easy to determine whether the customer absorbs the material
 - Distraction
 - Time zone issues

Plant Inspections

- Use of local office to travel to site for inspection
 - Inexperience in sulphur Technology
 - P&ID check is easy
 - Things like inspection of proper installation of tracing, slope, etc may be missed easily
- Use of photos and videos to inspect the plant remotely
 - Hardhat equipped with Hololens2/RealWear
- Eliminating the need for a plant inspection all together

Slope

- Rundown lines
- Condensers
 - Can go unnoticed for years
 - sulphur carry-over issues



Tail Gas and Valve Heating

- Intent to maintain wall and valves above sulphur freezing
- With insulation installed, not sure this would be caught remotely

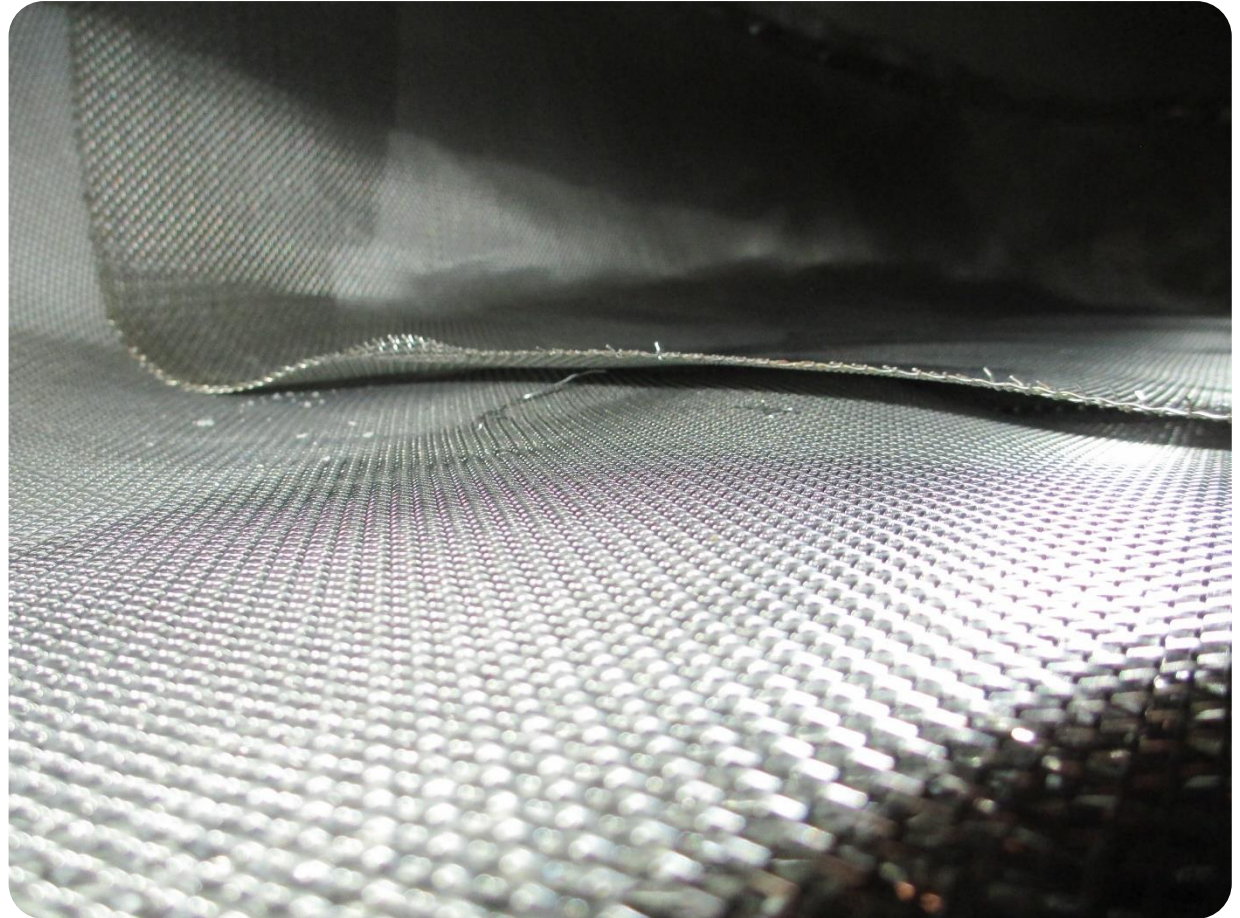


Catalyst Loading

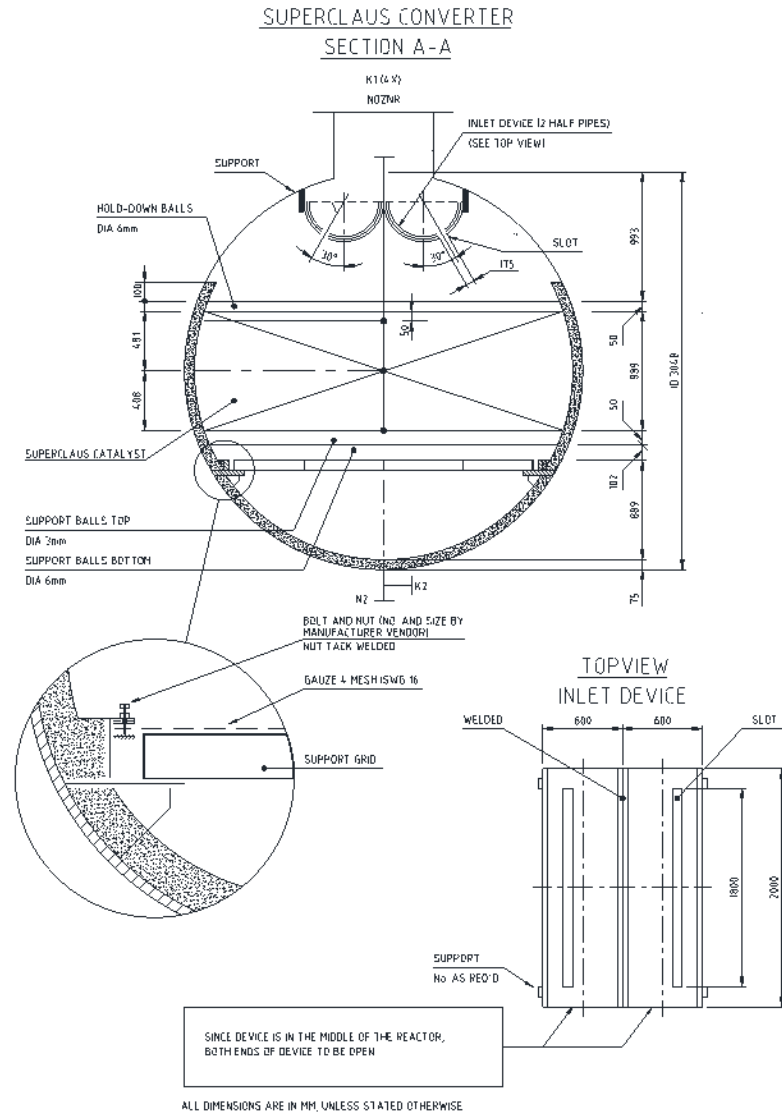
- Use of photos is adequate for the installation of grid, mesh and catalyst
- Inspection items can be addressed immediately if in person
- And if pictures are taken only of the loading, things could be missed:

Mesh Installation

- With pictures of a reactor only would this be caught?
- In person, these details can be caught as one can walk through the reactor
- Would it be fixed if remote?



Inlet Distributor

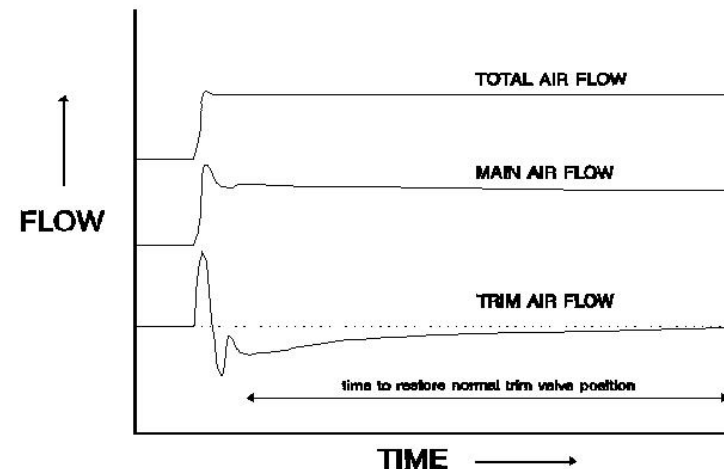


Tuning of ABC control system

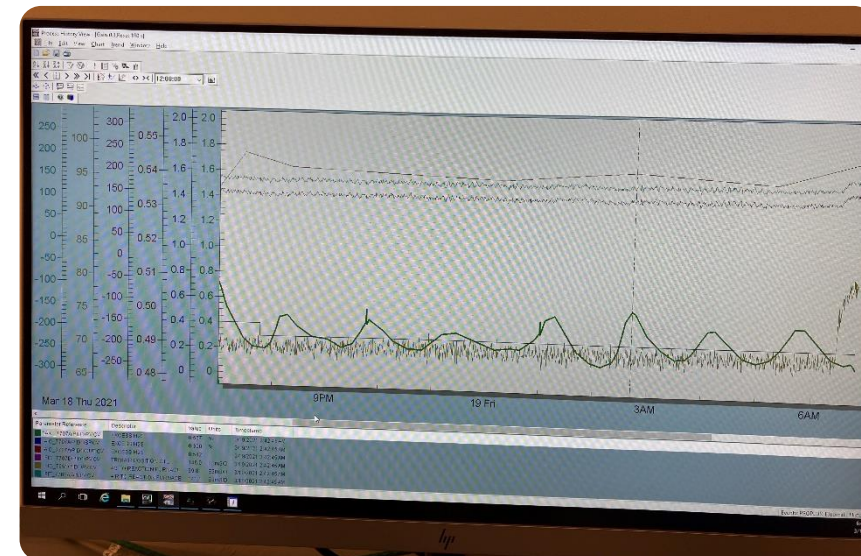
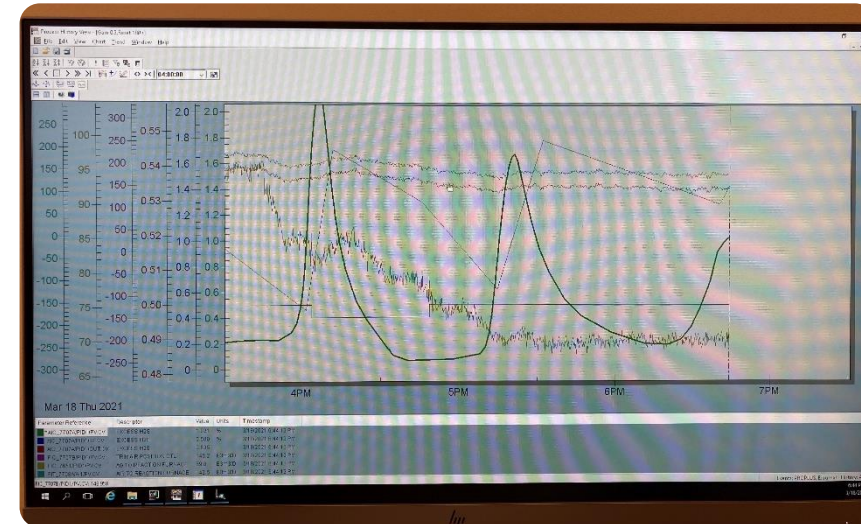
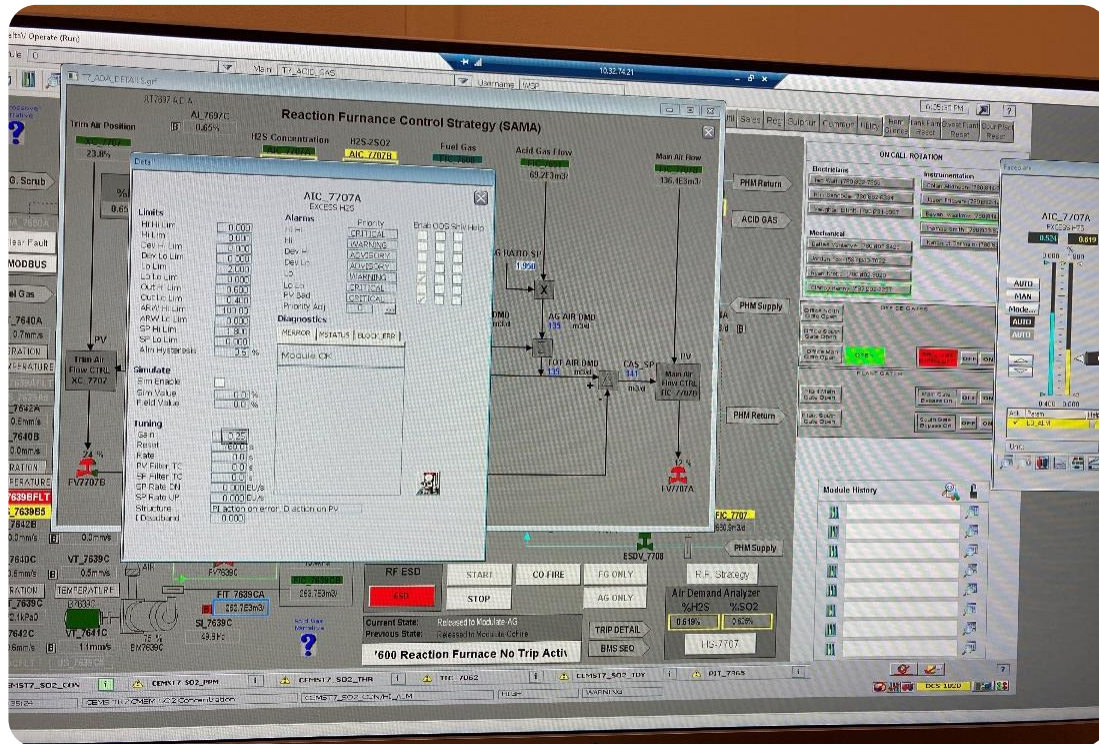
- Comprimo's Advanced Burner Control System
 - Interaction between Main and Trim Air valve following a setpoint function
 - Tuning of three loops
 - Total Air Control Loop
 - Trim Air Valve position Control Loop
 - Tail Gas Analyzer Feed back Control loop
 - Typically done by Comprimo Process Engineer or Process Control Engineer

Tuning of ABC control system

- Done remotely with cameras pointing to DCS screens to observe trends
 - Minor adjustments were provided via instructions
 - Renewing trends
 - Remote access to the historian data would allow closer monitoring of the status of the tuning



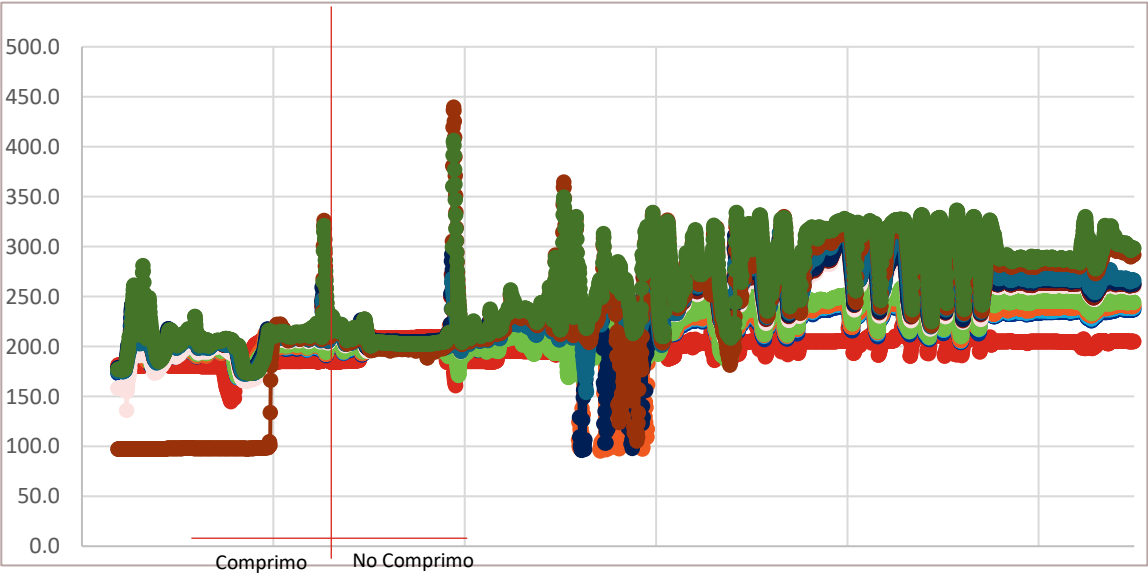
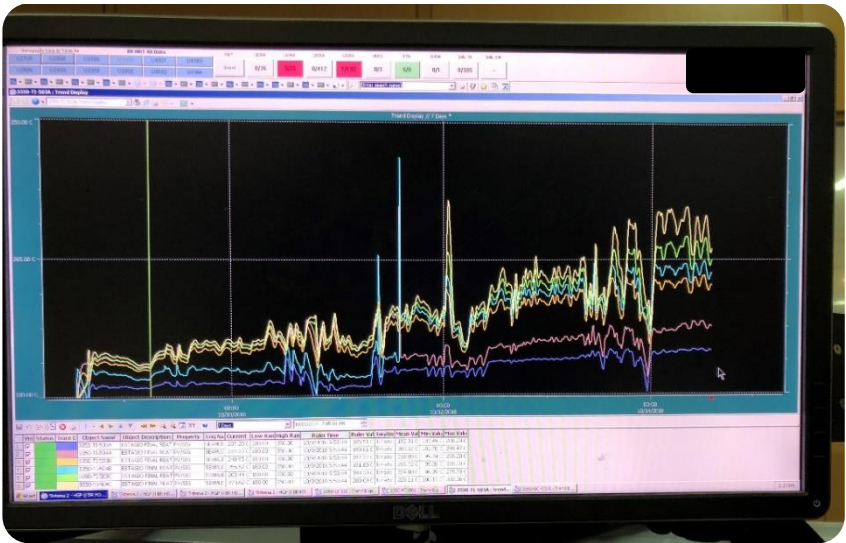
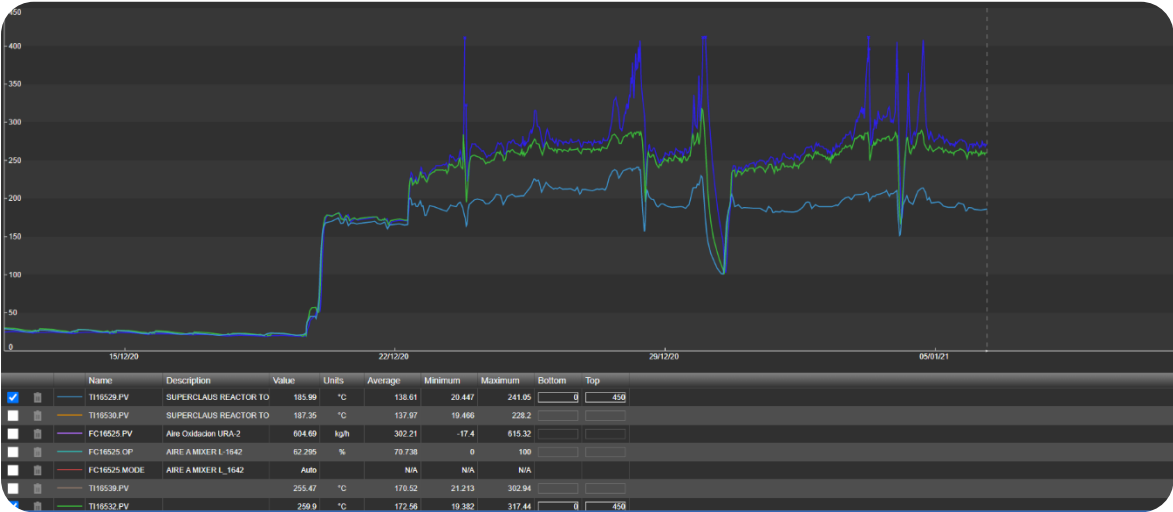
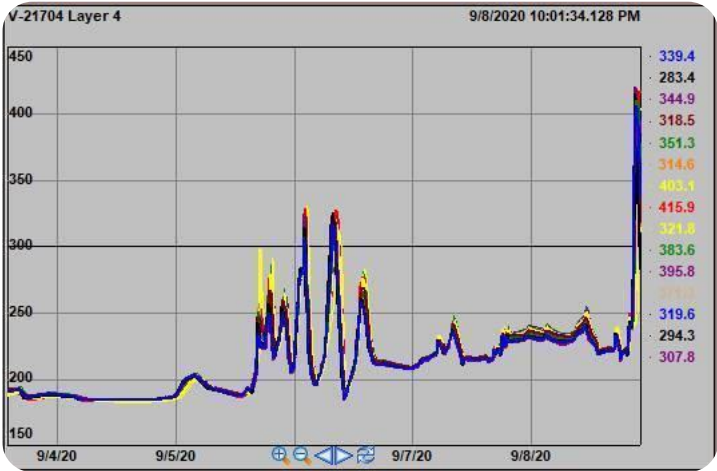
Tuning of ABC control system



Start-up Support

- “The Devil is in the Details”
 - No direct contact with operators
 - Continuous training exercise for operators
 - The presence of a Comprimo engineer results in higher attentiveness
 - Conditioning of SUPERCLAUS catalyst or TGTU catalyst presulfiding comes with potential risks
 - Higher risk when done remotely due to “lack” of attentiveness
 - Increase in response time, meaning that upsets take longer to recover

Temperature Runaways



Start-up Support

- Higher Risk during Start-up
 - Unfamiliarity of Operators with new Technology
 - Unfamiliarity of Operators with Comprimo way of things
 - Single button light off of burners
 - Use of tracking signals
 - Logic for Start up and Shutdown
 - Operators don't see what SME sees.

Start-up Support – Trying to circumvent COVID

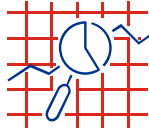
- Customer adamant about Site Support
 - Two week quarantine upon arrival
 - Customer not ready due to COVID related supply issues
 - Several incidents during on-site presence due to COVID
 - Test and potential for isolation/quarantine
 - Other standards for plant operations
 - Changed to remote support in the end with previously discussed limitations

In-depth technical assessment of a sulphur plant



Evaluate

Collection of available historian data, P&ID's and PFD's. Assess operation normal, and current facility pinch points.



Benchmark

Review the data and benchmark the performance against design objectives and industry best practices for:

- Technology
- KPI's
- Equipment
- Instrumentation
- OPEX



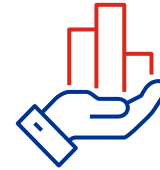
Interview

Interviewing asset management & site staff to fully understand operating issues, limits, operating philosophies and economic drivers.



Develop

Development of solutions that combine economic value with fully implementable changes.



Recommendations

Solutions with business case justification across multiple types of solutions. Solutions are prioritized based on ROI and ease of implementation.

1. Operating Philosophies, KPI's, Operating Targets
2. Training Sessions, Training Simulator, **Comprimo Immerse**
3. Digital Dashboards, **Comprimo Insight** ML Applications, Instrumentation, Control systems
4. Reliability Assessments, Equipment Care Plans, Root Cause Failure Analysis (RCFA's)
5. Plant Expansions, Equipment Replacement, New Technology

A large industrial sulphur plant with complex piping, scaffolding, and storage tanks, overlaid with a semi-transparent blue filter.

2

Comprimo **Insight**
Sulphur plant performance analysis

Comprimo Insight

Improve performance. Cut costs. Reduce emissions.

Comprimo Insight is an easy-to-use dashboard tool that allows you to quickly evaluate your plant's health.

It works by giving you access to our sulphur plant experts, who review and assess your data and give you recommendations to improve performance.



What to expect from Comprimo **Insight**

A continuous performance monitoring system benchmarking a plant performance

- 1 Thermal stage temperature estimation
- 2 Catalyst activity monitoring and catalyst lifetime prediction
- 3 Ammonia and BTX destruction prediction
- 4 WHB tube sheet & outlet temperature calculation
- 5 Pressure profile monitoring and early detection of potential sulphur plugging
- 6 Monitoring reactor temperature
- 7 Benchmarking of actual plant operation against original design intent
- 8 Instrument checks
- 9 Generation of reports with input from Comprimo technology specialists
- 10 Access to our technology experts

Benefits of Online Monitoring by Licensor



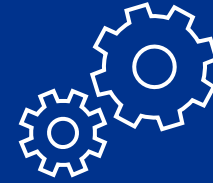
Improved equipment life



**Improved uptime and
capacity availability**



**Predictive maintenance
and turnaround planning**



**Reduced unplanned
shutdowns**



Reduced emissions



**OPEX reductions through
improved catalyst life**



**Provision of early
warning of operation
problems**



**Timely support from our
experts with access to
detailed plant data**

SO2 in the stack (ppmv), dry value

SO2 avg	SO2 min	SO2 max
1,554	1,496	1,808

Sulphur Recovery Efficiency (%)

SRE avg	SRE min	SRE max
99.29	99.17	99.32

AAG flow rate (kg/h)

AAG avg	AAG min	AAG max
5,700	5,666	5,743

SWAG flow rate (kg/h)

SWAG avg	SWAG min	SWAG max
1,427	1,233	1,534

H2S Claus tail gas (mol%)

H2S avg	H2S min	H2S max
0.40	0.25	0.65

Average SRE (%)

99.29

Sulphur Production (TPD)

138

Sulphur to Atmosphere (TPD)

0.98

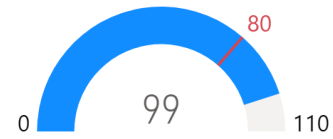
SRU on-stream factor

1.00

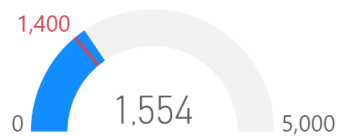
SelOx on-stream factor

1.00

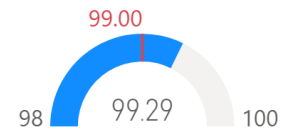
Average Plant Load (%)



Average SO2 stack (ppmv)



Average SRE (%)

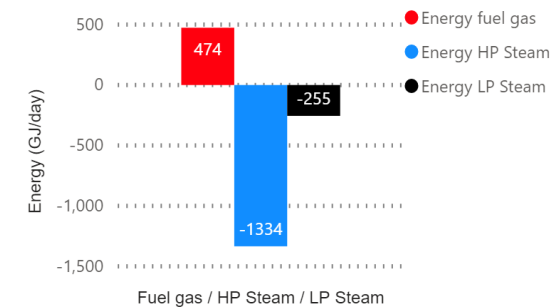


Outlet temperature SC reactor (°C)

Temp avg	Temp min	Temp max
242	238	248

Comprimo Insight

Equivalent energy consumption (GJ per day)



Fuel gas is consumed, HP and LP steam are produced.

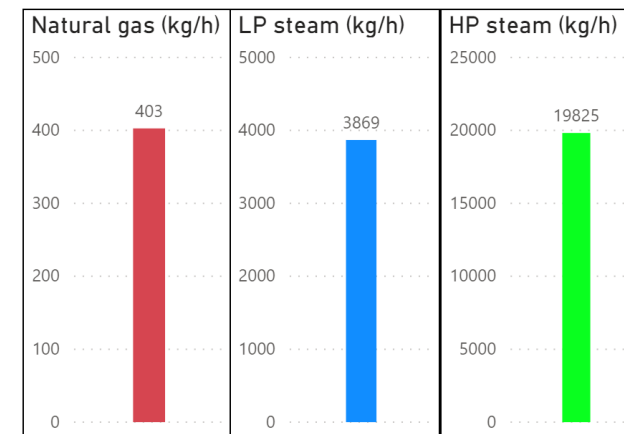
Net equivalent energy (MJ/Ton sulphur)

-8,072

Net CO2 (TPD)

-40

	Last Values	Target Values
First Claus reactor inlet temperature (°C)	240	> 230°C
Second Claus reactor inlet temperature (°C)	210	210°C
Third Claus reactor inlet temperature (°C)	191	195°C
Fourth SelOx reactor inlet temperature (°C)	215	195°C - 220°C
H2S tail gas (mol%)	0.40	0.5 mol%
Final condenser outlet temperature (°C)	127	< 130°C



	Average Values			Target Values
First Claus reactor bottom bed temperature (°C)	307			> 290°C AND < 310°C
Second Claus reactor bottom bed temperature (°C)	228			> 220°C
Third Claus reactor bottom bed temperature (°C)	193			ca. 195°C
Fourth SelOx reactor bottom bed temperature (°C)	242			244 ± 5°C
SO2 tail gas (mol%)	0.004			< 0.04 mol%
Reaction furnace pyrometer/Thermocouple/Calculated (°C)	2	1,378	1,307	> 1250°C
Ammonia destruction pyrometer/Thermocouple/Calculated (ppmv)	5,000	41	95	< 50 ppmv
Incinerator temperatures (°C)	750	762		> 700°C AND < 850°C

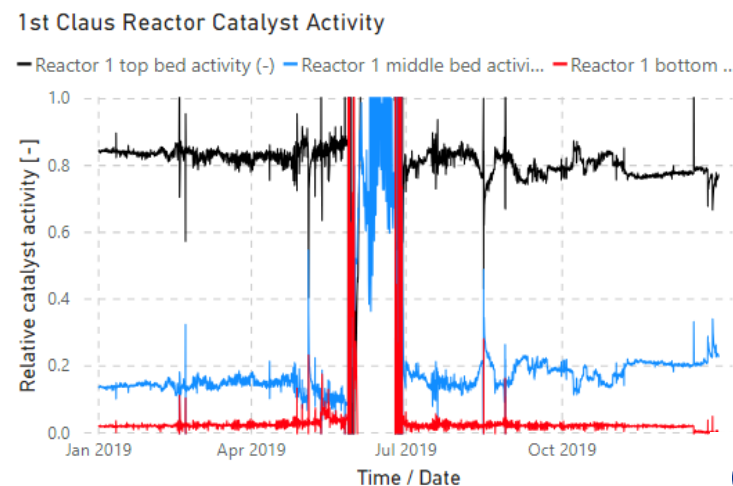
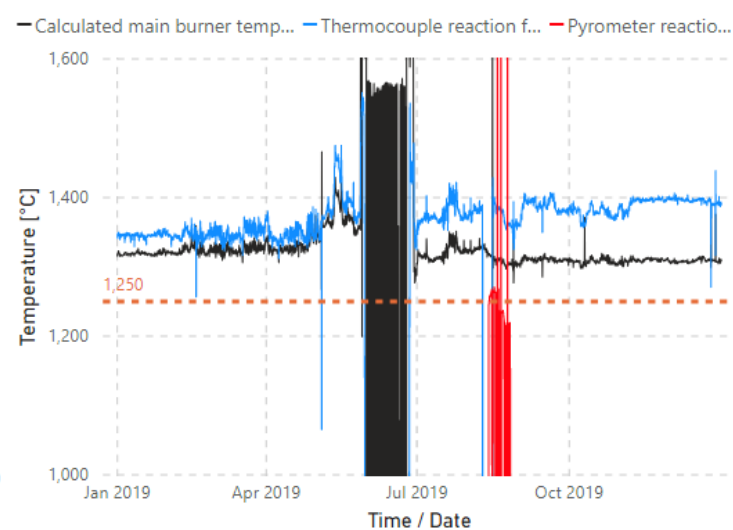
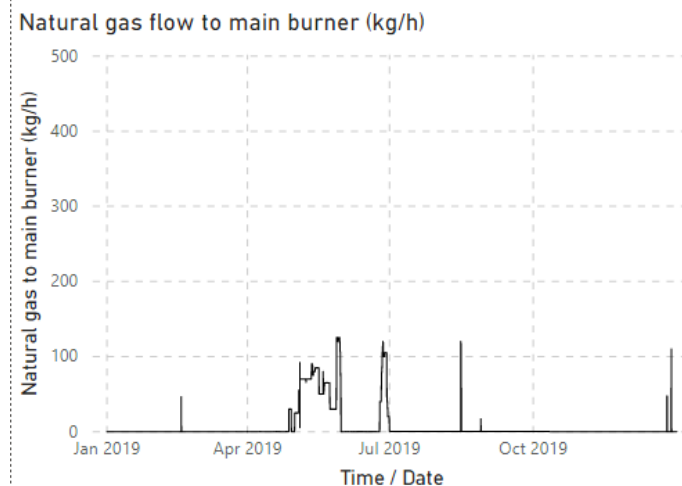
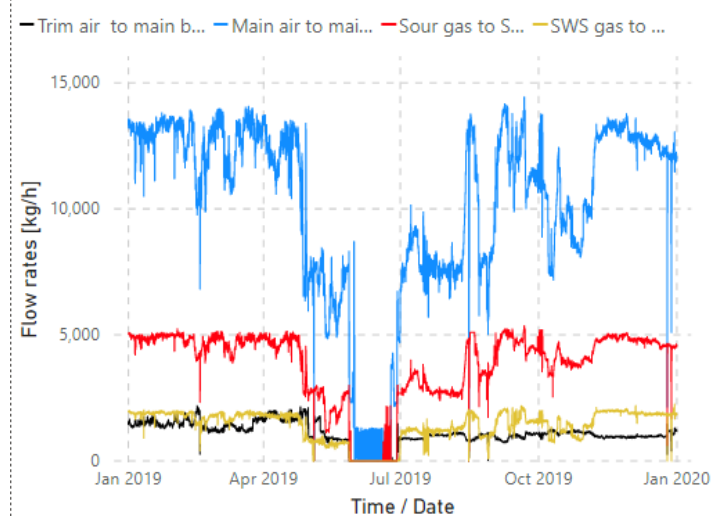


Figure top-left:

The combustion air varies due to variation in flow rate of the acid gas feed. A stable flow rate is required for optimal performance of the SRU. Recommendation is to investigate if upstream units can deliver stable flow rate.

Figure top-right:

The calculated and thermocouple show reasonable correspondence and above the minimum of 1250°C for ammonia destruction. The pyrometer is broken and need to be repaired.

Figure bottom-left:

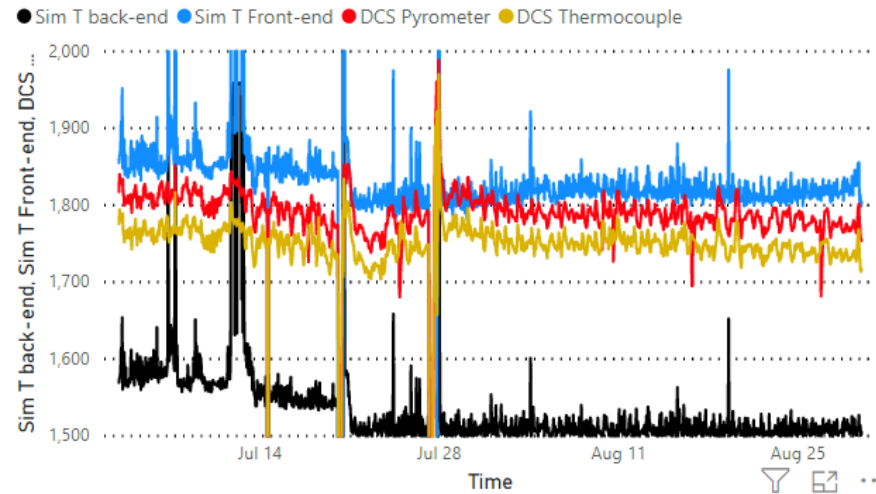
Natural gas co-firing was only used before the shut-down period, when the unit is at turndown and a few trip instances.

Figure Bottom-right:

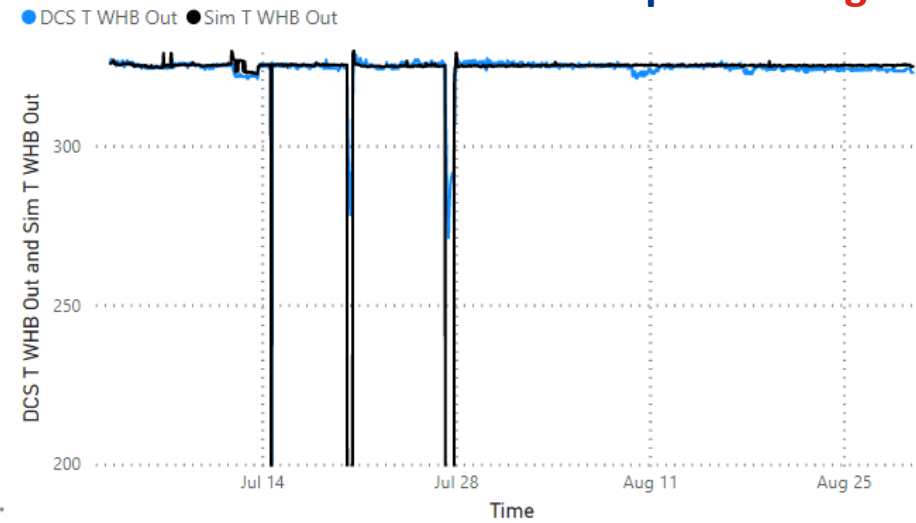
The catalyst in the first reactor shows adequate activity, showing good activity in the top layer and low activity in the middle. Also after the shut-down period, the catalyst performance is still good and no need to change-out is expected in the next year.

Comprimo Insight

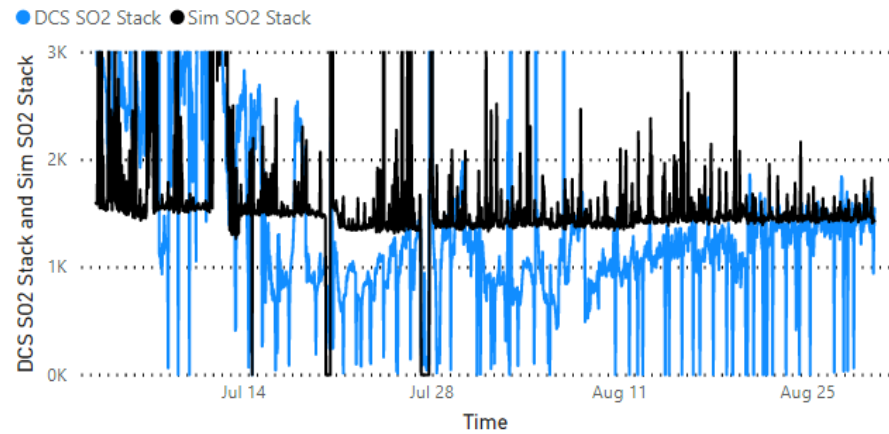
Sim T back-end, Sim T Front-end, DCS Pyrometer and DCS Thermocouple by Time



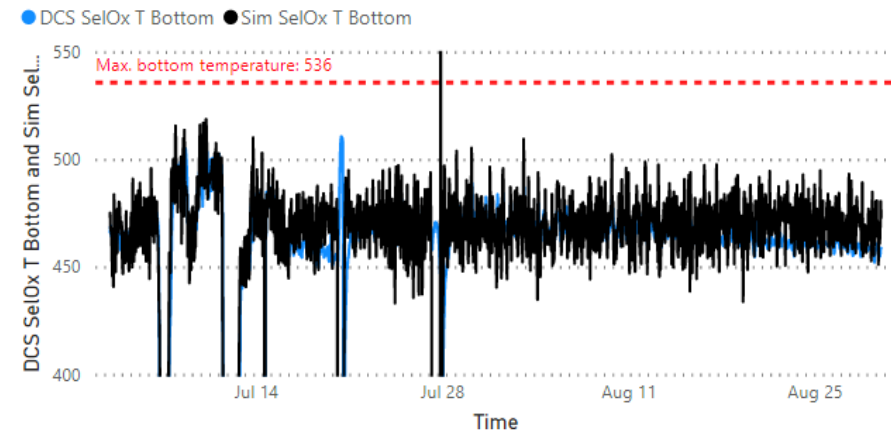
DCS T WHB Out and Sim T WHB Out by Time



DCS SO2 Stack and Sim SO2 Stack by Time



DCS SelOx T Bottom and Sim SelOx T Bottom by Time





03 Comprimo **Immerse** Understanding your sulphur plant

Comprimo Immerse

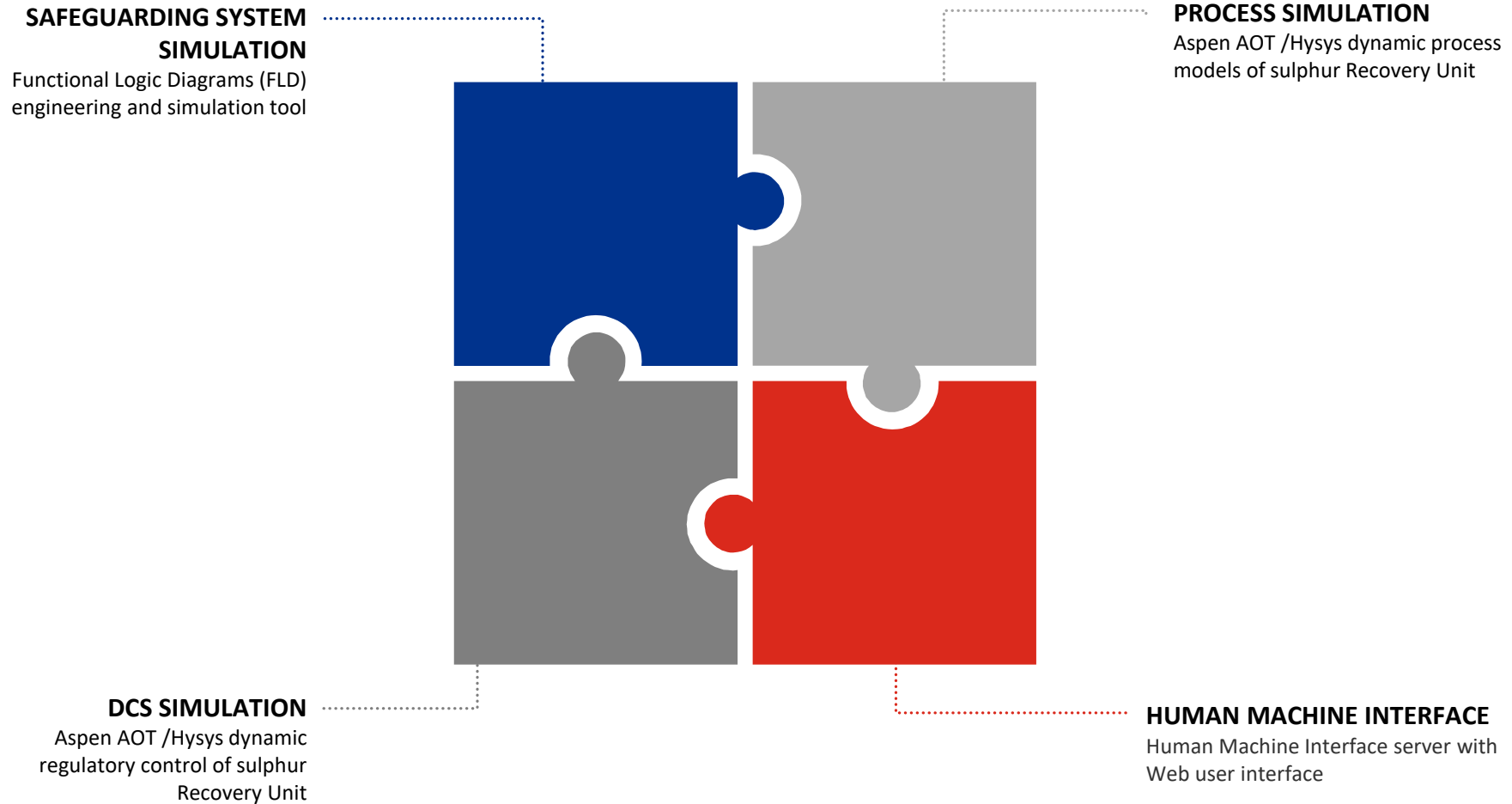
Train your operators. Reduce onboarding time.

Turn your operators into experts by immersing them in a digital replica of your sulphur plant.

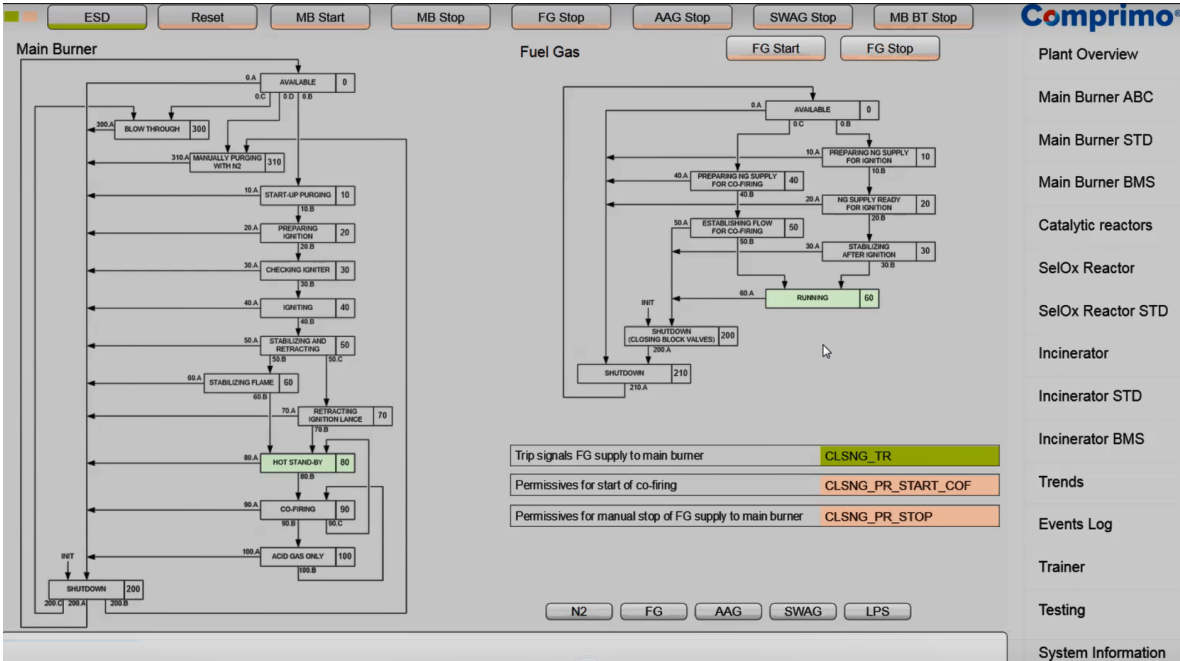
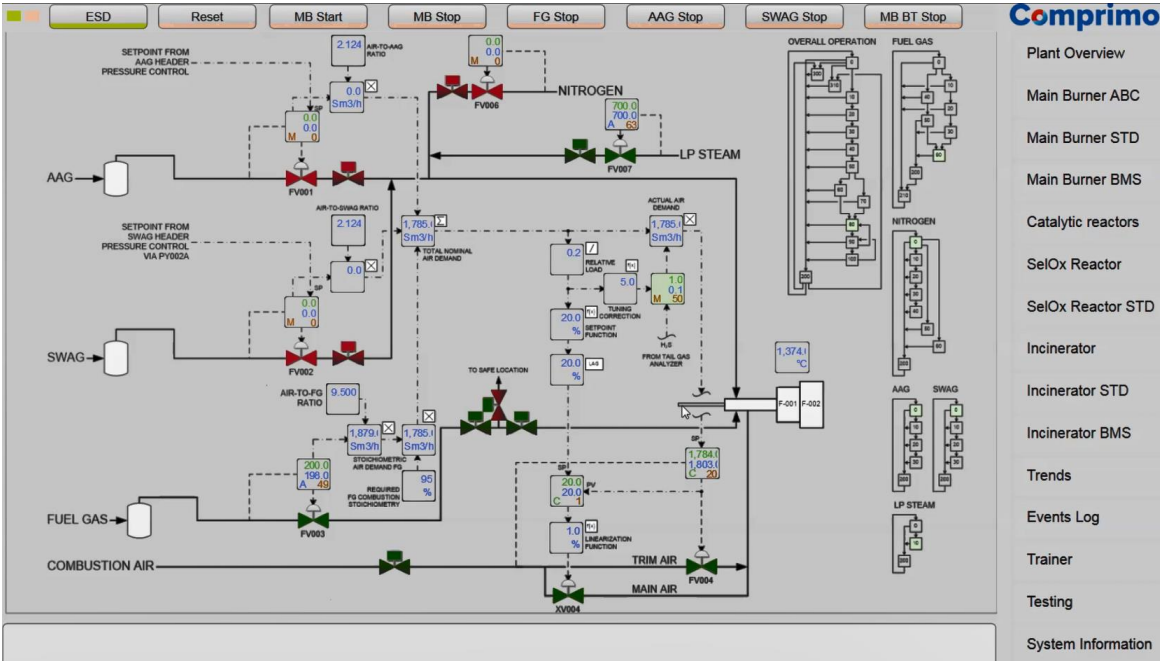
With Comprimo Immerse, you can assess the impact of any changes you make to your plant in a virtual environment first.



What to expect from Comprimo Immerse



The look and feel of Comprimo Immerse



Benefits of Dynamic Training Tool?

Provides real time simulator that mimics real plant operation



Better refresher training
and effective training of
new operators



Can be carried out
remotely



Standardise learning
across all personnel



Reduces overall training
costs



Operators achieve better
performance in a shorter
time



Gives the ability to correct
procedural errors prior to
online production



Expose all operators to
non-routine operations



Quicker recovery from
process upsets with
fewer equipment
stresses



We make your Sulphur our business



Marco van Son

Technology Manager

marco.vanson@worley.com

QA



worley.com/comprimo

DISCLAIMER

This presentation has been prepared by a representative of Worley.

The presentation contains the professional and personal opinions of the presenter, which are given in good faith. As such, opinions presented herein may not always necessarily reflect the position of Worley as a whole, its officers or executive.

Any forward-looking statements included in this presentation will involve subjective judgment and analysis and are subject to uncertainties, risks and contingencies—many of which are outside the control of, and may be unknown to, Worley.

Worley and all associated entities and representatives make no representation or warranty as to the accuracy, reliability or completeness of information in this document and do not take responsibility for updating any information or correcting any error or omission that may become apparent after this document has been issued.

To the extent permitted by law, Worley and its officers, employees, related bodies and agents disclaim all liability—direct, indirect or consequential (and whether or not arising out of the negligence, default or lack of care of Worley and/or any of its agents)—for any loss or damage suffered by a recipient or other persons arising out of, or in connection with, any use or reliance on this presentation or information.