16th STS-AIChE Southwest Process Technology Conference

From Data to Decisions: AI-Powered Operational Excellence in Chemical Manufacturing

- **Girish Thenkurissi**

  Parag Shah

  Pravin Jathar

- **Ingenero Inc.**

Sept 22-23, 2025, University of Houston

Speaker Bio

- Girish holds a Bachelor's degree in Chemical Engineering and began his career as a Process Engineer in the petrochemical industry.

- He joined Ingenero in 2007 and has built deep expertise across different process technologies including linear alcohols, butadiene, ethane crackers, VCM, and Chlor-alkali.

- As Regional Area Manager, Girish leads Ingenero's analytics and modeling projects in Southwest Louisiana.

- He has successfully implemented AI-driven, real-time and open-loop analytics solutions that help clients unlock measurable value and drive process improvements.
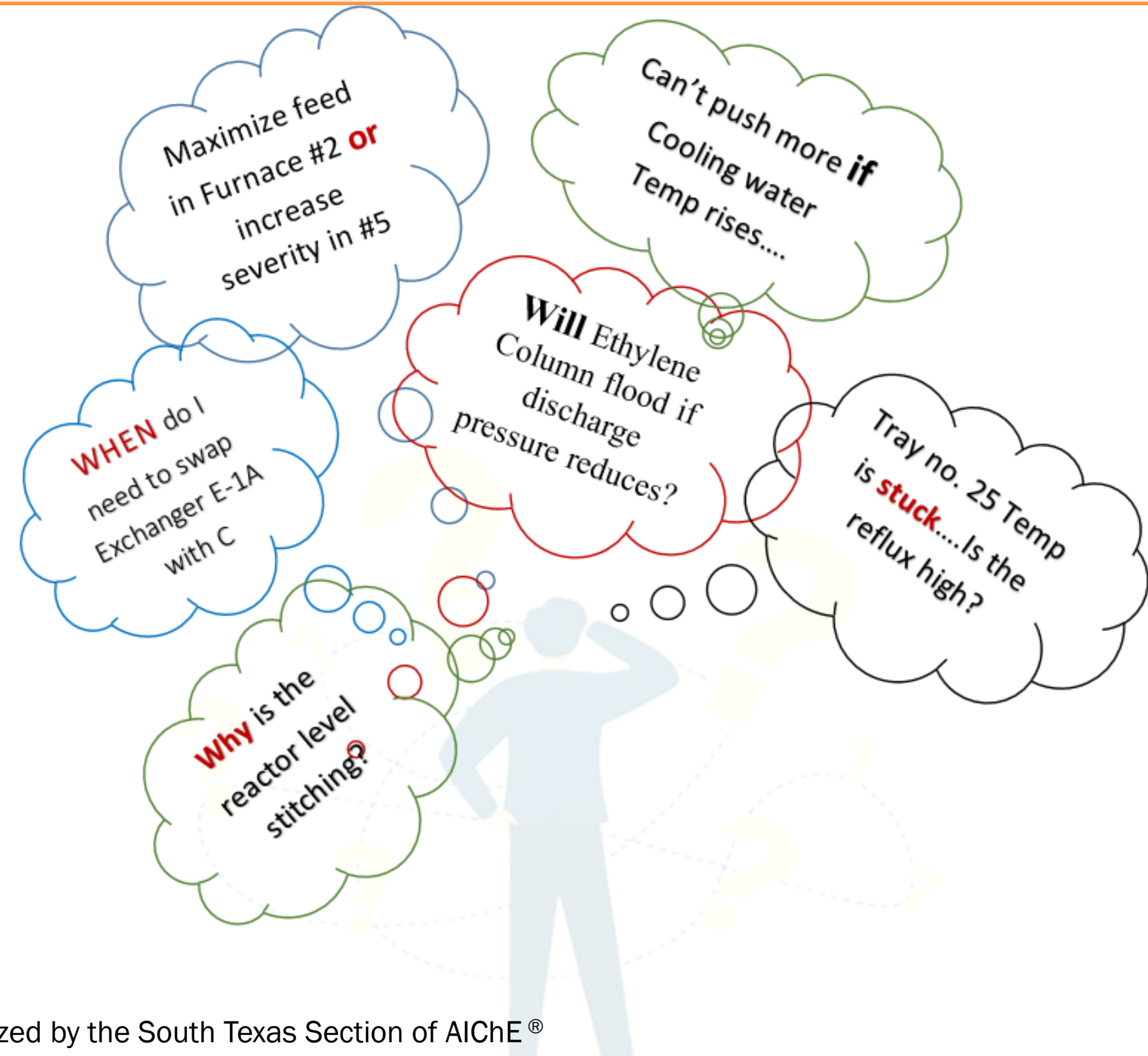
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Integrating Data Insights and Expertise for Operational Excellence

Industry 4.0: Leveraging the Data Explosion for Smarter Manufacturing

Industry 4.0 integrates smart, interconnected systems to transform manufacturing through digitalization.

- Instruments continuously collect real-time data from equipment, processes, and environments.

- Creates vast datasets from real-time historians, laboratory results, field readings, logs, maintenance records.

However, in most production environments, only a fraction of the data is analyzed while the rest remains archived.

From Data to Decisions

Integrate diverse data using AI/ML for predictive insights and...
Transform insights into actionable decisions, driving efficiency gains, cost savings, and continuous improvement

Smarter Decisions. Safer Operations. Stronger Performance

Capacity & Profitability Optimization

- Capacity improvement with measurable OAE gains and reduced downtime

- Overall and Unit level unified Production & Profitability Dashboards: Combine KPIs, cost, and capacity

- Predictive maintenance for downtime reduction.

- Cost effective debottlenecking, Real time hybrid models.

All Constraints Have been Eliminated other than offline equipments
  » Changed HCl to Rx-1 from 173.75 to 178.15 TPD of HCl.
Base Case: VCM Production of 2.374 MMPPD. Can be sustained by above changes. Refer to RunLog Sheet for details of changes

+ New Case: VCM Production increment from 2.374 to 2.474 MMPPD.
VCM Production will be locked at 2.474 MMPPD.
Furnace Load increased from 109 / 109 / 211 to 114 / 114 / 221 GPM respectively.
EDC Import from EDC Unit changed from 511 to 591 TPD.
Running Auto Elimination Algorithm for first time.   Go to this Step
  » Changed HCl Load to Rx-3 from 358.49 to 374.53 TPD of HCl.
Running Auto Elimination Algorithm for Second time to make sure all constraints have been eliminated.   Go to this Step
✓ New Case: VCM Production increment from 2.374 to 2.474 MMPPD - Can be sustained from above changes.
Final EDC Import from EDC Unit: 569 TPD

+ New Case: VCM Production increment from 2.474 to 2.574 MMPPD.
VCM Production will be locked at 2.574 MMPPD.
Furnace Load increased from 114 / 114 / 221 to 119 / 119 / 231 GPM respectively.
EDC Import from EDC Unit changed from 569 to 649 TPD.
Running Auto Elimination Algorithm for first time.   Go to this Step
  » Changed HCl Load to Rx-3 from 374.53 to 403.73 TPD of HCl.
Running Auto Elimination Algorithm for Second time to make sure all constraints have been eliminated.   Go to this Step
✓ New Case: VCM Production increment from 2.474 to 2.574 MMPPD - Can be sustained from above changes.
Final EDC Import from EDC Unit: 610 TPD

INGENERO
Excellence Through Insight

- Auto Eliminate Constraints
- Get Results Here
- Clear Earlier Case Run Log
- ▲ Increment VCM 50 TPD
- Clear Both (VCM-Max+RunLog)

A tool integrating diverse data—from design and operations to logistics—to maximize production across 10 manufacturing units developed for a client

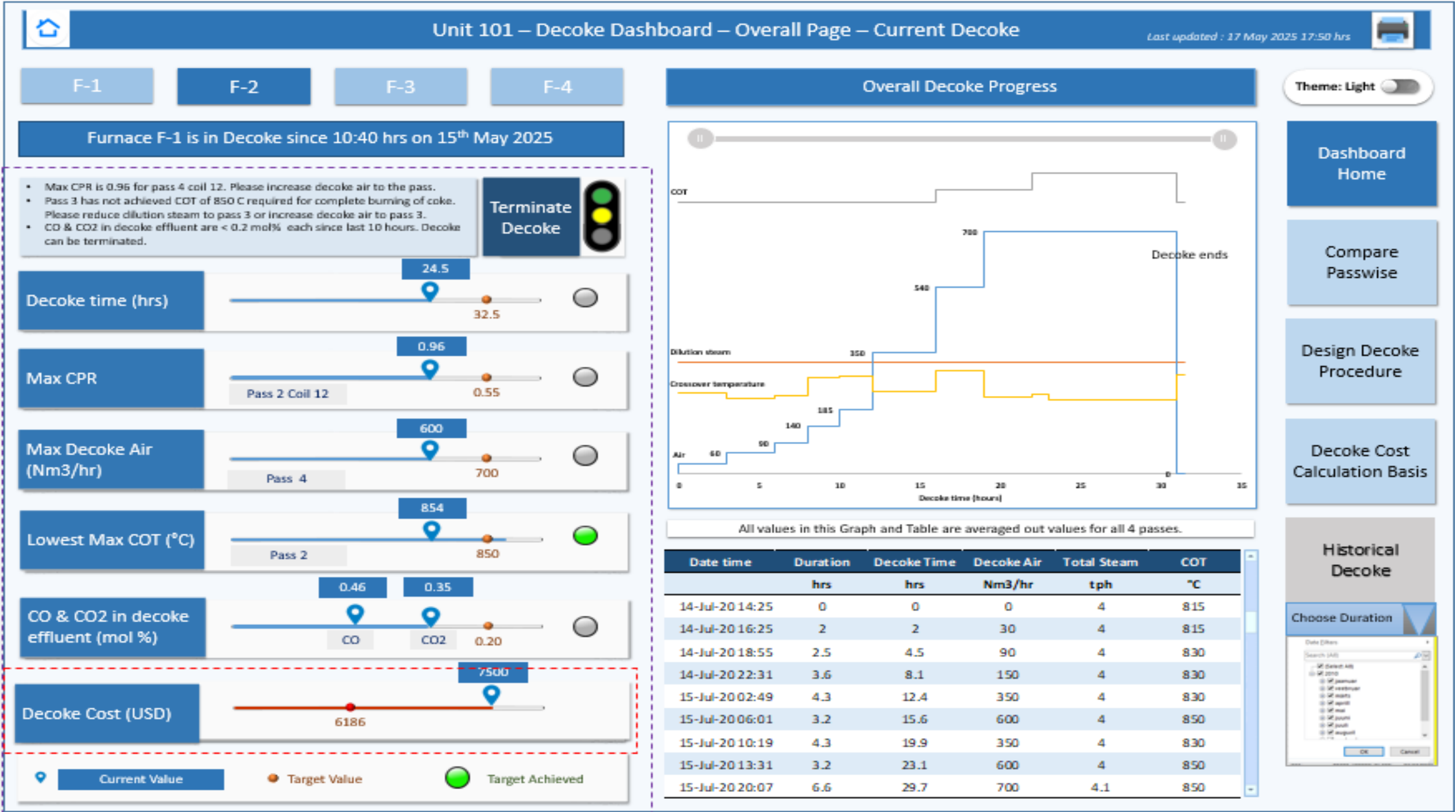# Turning Diverse Plant Data into Actionable Insights

Time and Cost Reduction

Target: Reduction in decision latency and manual coordination efforts

Integrated LIVE Dashboard: Merge operations, maintenance, and logistics

Automation of tasks, Process control and APC improvement

Gen AI: Enable knowledge capture, SOP guidance, and faster troubleshooting

Unit 101 – Decoke Dashboard – Overall Page – Current Decoke

Last updated : 17 May 2025 17:50 hrs

| F-1 | F-2 | F-3 | F-4 |

Furnace F-1 is in Decoke since 10:40 hrs on 15th May 2025

- Max CPR is 0.96 for pass 4 coil 12. Please increase decoke air to the pass.
- Pass 3 has not achieved COT of 850 C required for complete burning of coke. Please reduce dilution steam to pass 3 or increase decoke air to pass 3.
- CO & CO2 in decoke effluent are < 0.2 mol% each since last 10 hours. Decoke can be terminated.

Terminate Decoke

Decoke time (hrs): 24.5 / 32.5

Max CPR: 0.96 / Pass 2 Coil 12 / 0.55

Max Decoke Air (Nm3/hr): 600 / Pass 4 / 700

Lowest Max COT (°C): 854 / Pass 2 / 850

CO & CO2 in decoke effluent (mol %): 0.46 / 0.35 / CO / CO2 / 0.20

Decoke Cost (USD): 7500 / 6186

Overall Decoke Progress — Theme: Light

Dashboard Home · Compare Passwise · Design Decoke Procedure · Decoke Cost Calculation Basis · Historical Decoke · Choose Duration

All values in this Graph and Table are averaged out values for all 4 passes.

Date time	Duration	Decoke Time	Decoke Air	Total Steam	COT
	hrs	hrs	Nm3/hr	tph	°C
14-Jul-20 14:25	0	0	0	4	815
14-Jul-20 16:25	2	2	30	4	815
14-Jul-20 18:55	2.5	4.5	90	4	830
14-Jul-20 22:31	3.6	8.1	150	4	830
15-Jul-20 02:49	4.3	12.4	350	4	830
15-Jul-20 06:01	3.2	15.6	600	4	850
15-Jul-20 10:19	4.3	19.9	350	4	830
15-Jul-20 13:31	3.2	23.1	600	4	850
15-Jul-20 20:07	6.6	29.7	700	4.1	850

Current Value · Target Value · Target Achieved

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Empowering sustainable, compliant, and efficient operations through AI/ML tools
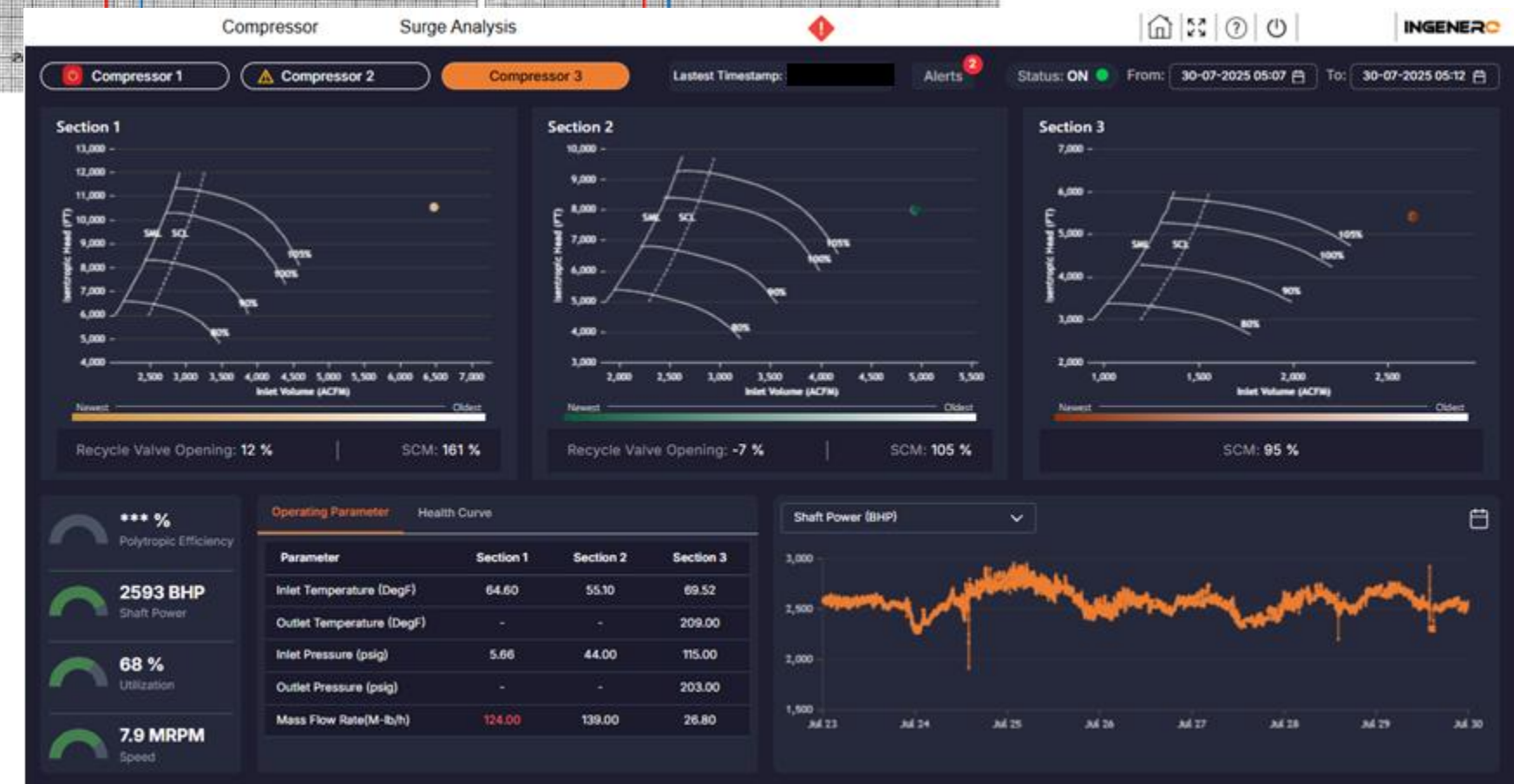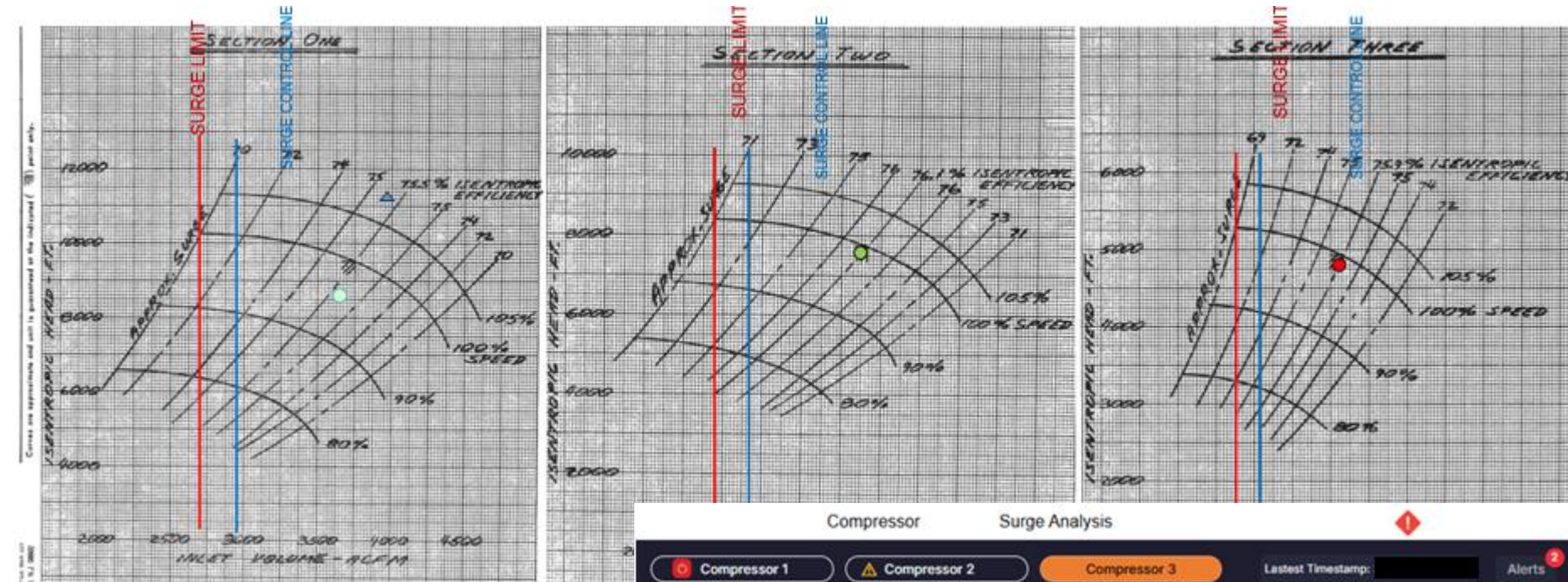
Safety and Compliance

- Zero unplanned safety events; proactive safety culture enabled by data

- Predictive analytics for potential safety hazards and risks identification

- Real-time monitoring with smart sensors for early detection of abnormalities or malfunctions

- RCA, what-ifs, avoid future occurrences.

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Transformation – From Data to Real-World Impact

05 Business Impact
Improved reliability, reduced downtime, cost savings, enhanced safety, and higher profitability.
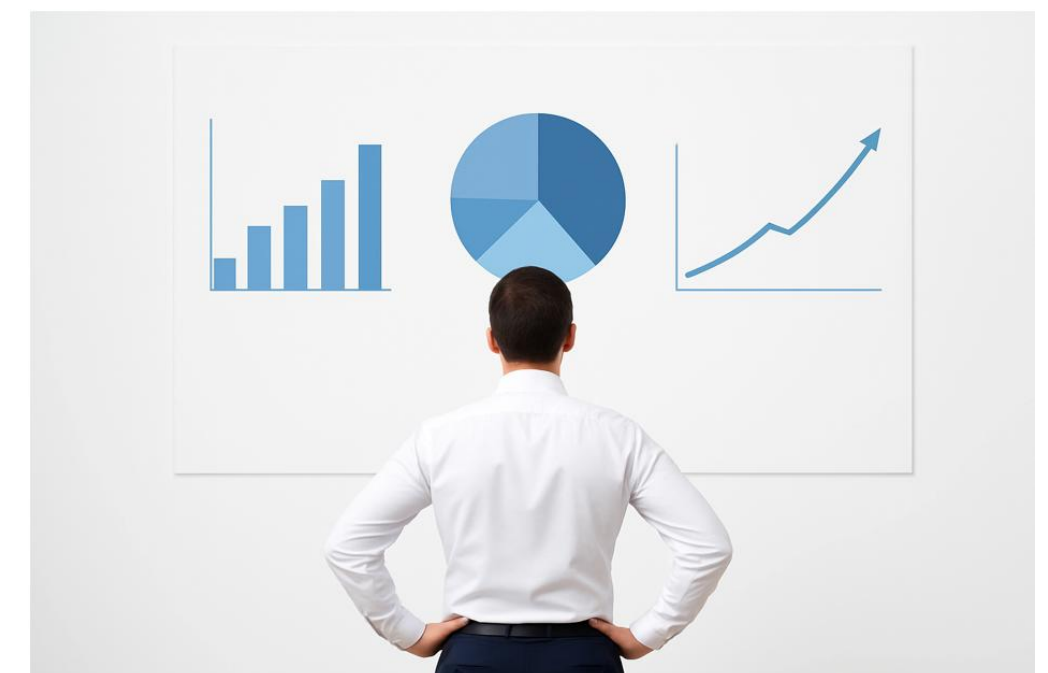
04 Decision Support
User-friendly dashboards and alerts that guide operators and engineers.

03 Actionable Insights
Key findings such as anomaly detection, efficiency gaps, or optimization opportunities.

02 AI/ML Models
Algorithms trained to detect patterns, predict outcomes, and optimize performance.

01 Preprocessing
Cleaning, filtering, and structuring data to remove noise and make it usable.

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Where Transformation Delivers – Case Studies

Combining right analytics tools to customize a solution that delivers value

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Case Study 1: Chlor-Alkali Evaporator Performance

Hybrid AI/ML models increased evaporator run-length to deliver higher uptime and greater efficiency

INGENERO developed models and monitoring tool assisted the operations in increasing the availability and capacity

Circulation pump motor amps
condensate flow
Feed Flow
Vapor flow to evaporator heater
Steam condition and flow
Temperatures of the liquor
Sulfate concentration

U-factor equation

+

AI

=
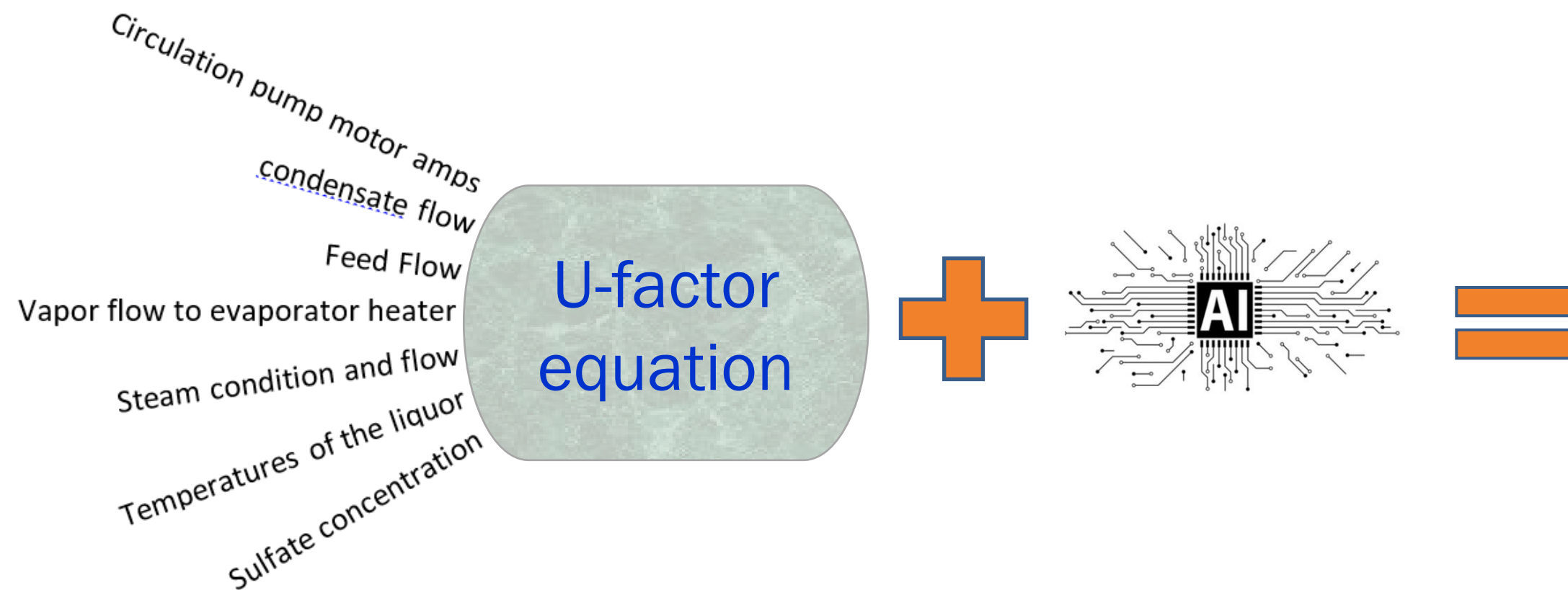
Benefits

$ 1.5 Million
Annual Savings

~4000 tons
Caustic production increase

170%
increase in run length

10 days
of downtime reduction per year

Evaporator Fouling Monitoring Solution

Case Study 2: Membrane Cell Maintenance

Predictive-analytics tool pinpoints underperforming cells for targeted maintenance, cutting unplanned downtime, reducing maintenance cost and load restrictions while boosting production

INGENERO enabled the unit to identify and rank underperforming cells by severity, allowing targeted replacements and optimized maintenance, which reduced costs and boosted production
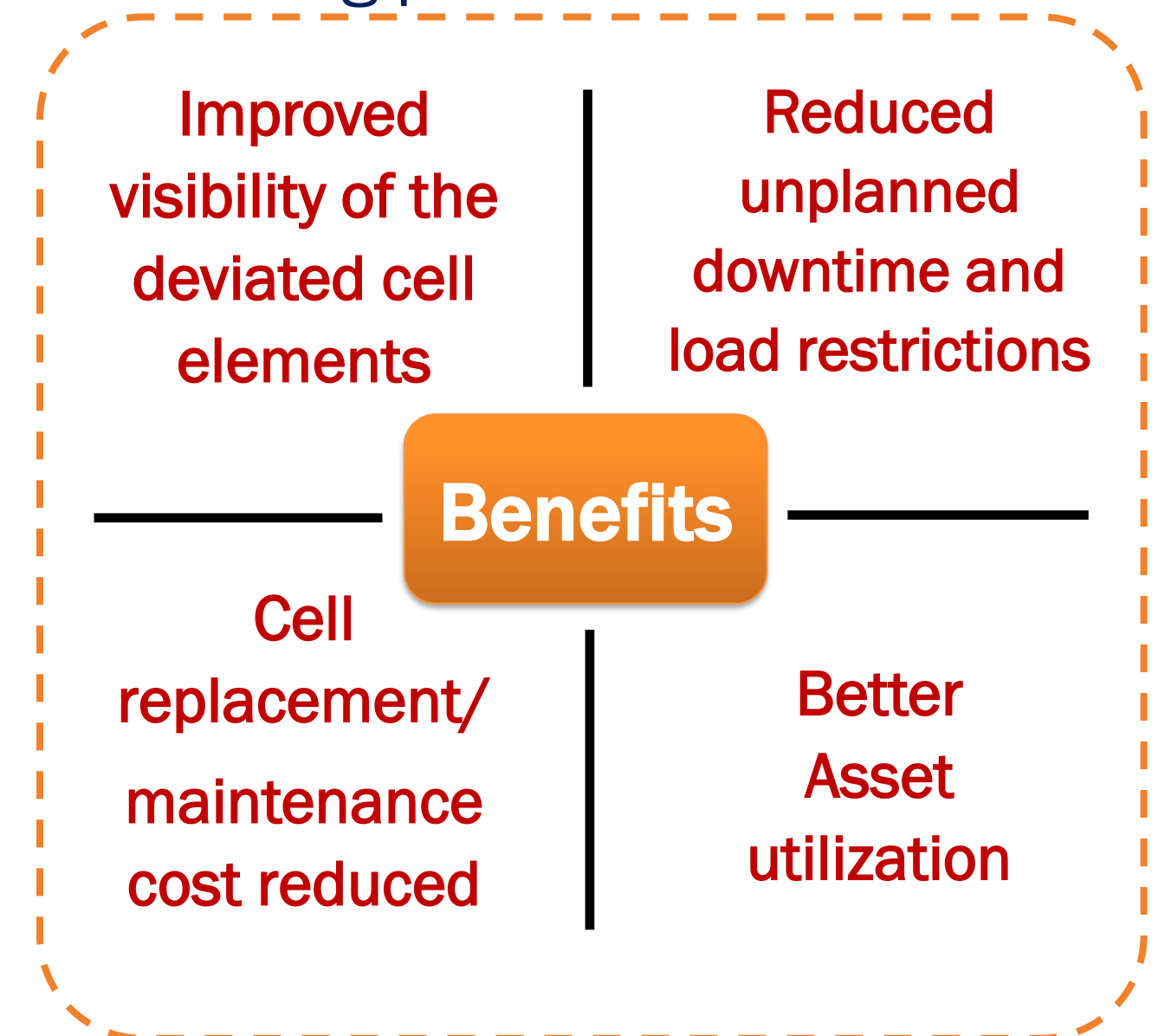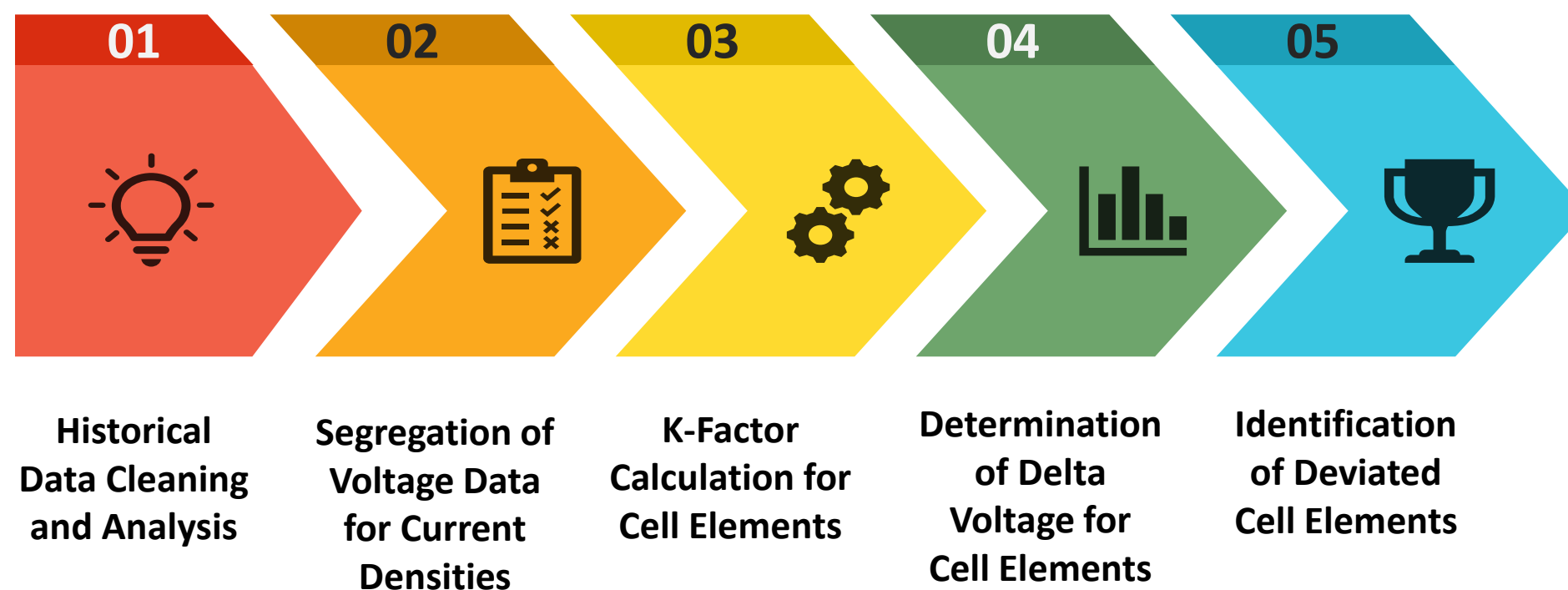
01 Historical Data Cleaning and Analysis

02 Segregation of Voltage Data for Current Densities

03 K-Factor Calculation for Cell Elements

04 Determination of Delta Voltage for Cell Elements

05 Identification of Deviated Cell Elements

Benefits

Improved visibility of the deviated cell elements

Reduced unplanned downtime and load restrictions

Cell replacement/ maintenance cost reduced

Better Asset utilization

Case Study 3: Real-Time Furnace Intelligence with AI/ML

Hybrid models turned furnace data into real-time intelligence—predicting coking, detecting instrument issues, and optimizing operations to boost yield, cut energy use, and extend run lengths.

Harnessing AI/ML-powered intelligence to dissect available data and tackle key challenges, such as:

Identifying differential coking

Instrumentation and analyzer issues

Optimal parameters for maximizing yield and capacity

Higher energy consumption

Elevated Temperatures in Convection Sections

To identify differential coking both kinetic and AI/ML modeling were used.

Kinetic Modeling
- Predicts conversion and COTs
- Soft sensor for Effluent analyzers
- Enables run length prediction

ML/AI Modeling
- Detects faulty instrumentation
- Identifies heat flux and hot spot issues
- Evaluates de-coking process effectiveness

Turning Data into Actionable Insights
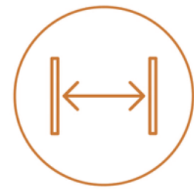
Live Gap analysis

Deviation tracking

Multiple scenarios evaluation

Optimum parameters for safe and reliable operation

Emissions tracking

ALERTS AND RECOMMENDATIONS

Emission: Stack combustibles _____ are exceed ____ ppm. Suggest to adjust firing or air register/ stack opening.

TMT & Coking: Consider adjusting burner firing pattern acro____ east side coil _____ to avoid uneven conversion ____ coils. Value at 500.54
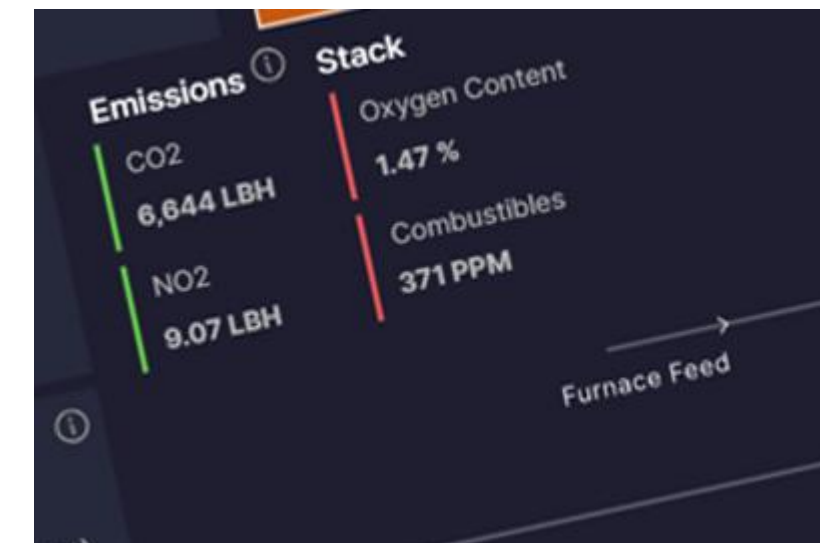
Actionable insights
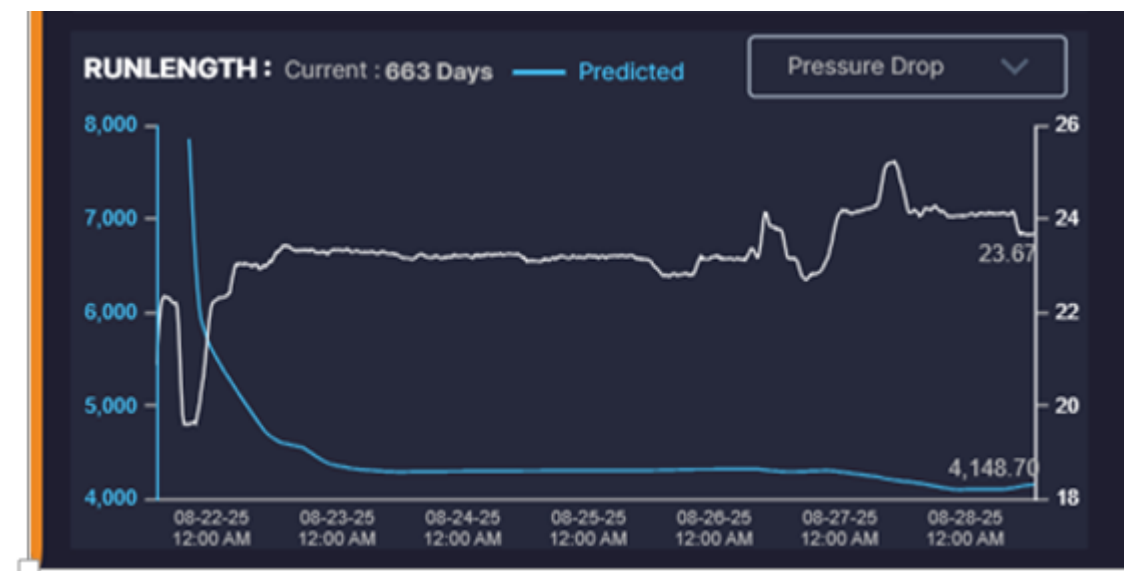
Coking and run length prediction

Case Study 4: Stabilizing Operations with Surge Modeling

Live Performance Mapping Helps Prevent Surge, Stabilizing Refrigeration Compressor Operations

Ingenero developed a Live Performance Map that displays real-time operating points with safe margins, providing accurate surge prediction and ensuring stable compressor operation.

Provide real-time visibility to plant operations and asset engineers

Suggest proactive adjustments optimizing compressor performance

Prevent surge events while minimizing **excessive power consumption**

Modeling: First principle thermodynamic models and equations of state

Utilizing proprietary tools compressors with multiple inlets and common discharge was analyzed

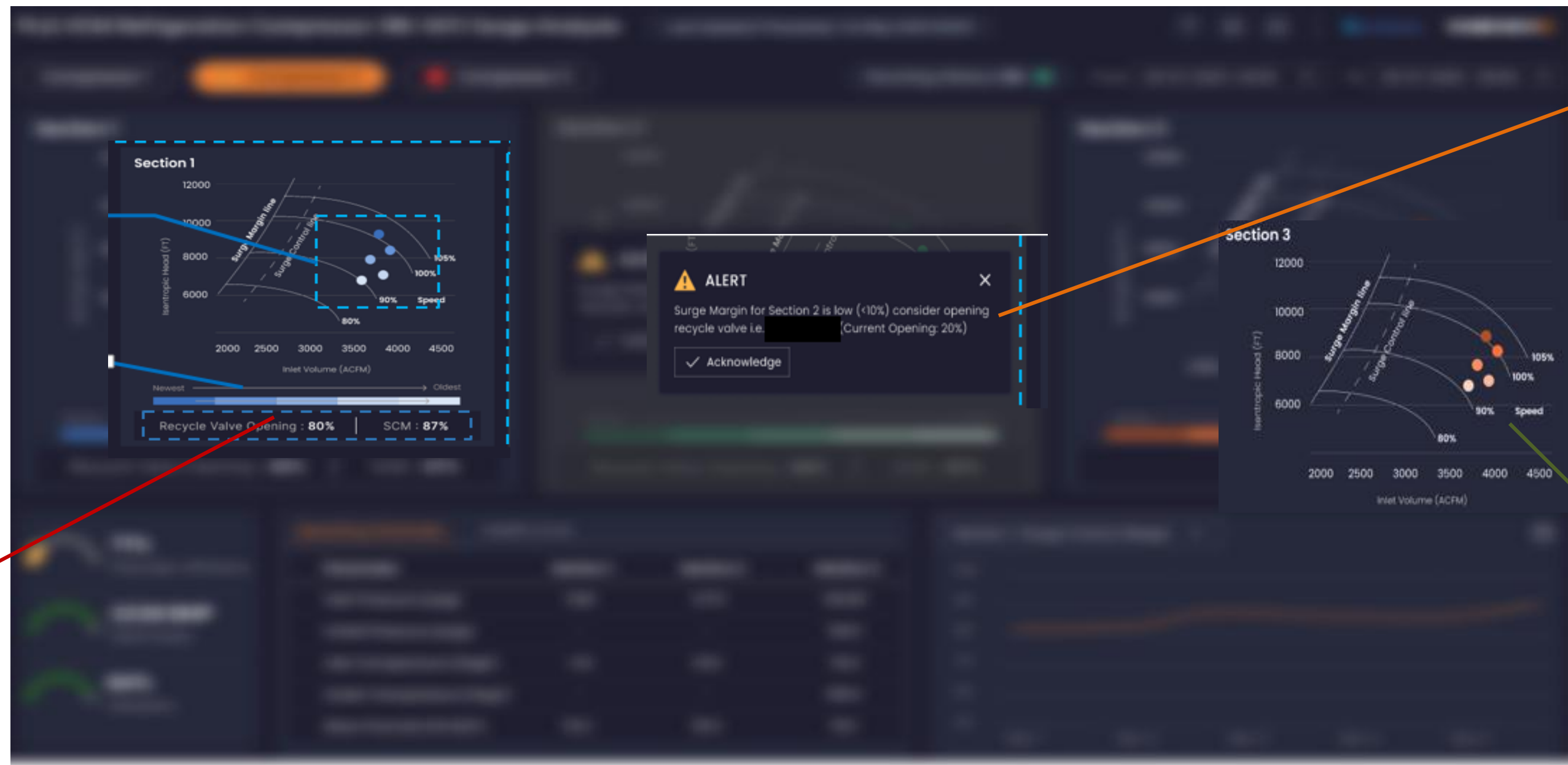**Validation:** Instrumentation and data accuracy using design data and simulations

From Risk to Reliability

Real-time visibility of operating points, where the darkest shade represents the latest point and progressively lighter shades indicate previous timestamps.

Alert Pop-Up: A real-time alert will notify operators if any section is operating close to the surge limit.

Recycle valve opening and surge margin indicators will support faster and more informed decision-making.

Surge Control Line: Added to enable proactive operator action before reaching the surge limit.

Case Study 5: Integrated Data-Driven Tool for Ongoing Optimization

Ingenero developed an integrated data-driven tool for chemical complex that understand key component balances, simulates higher production scenarios, provides insights to eliminates constraints, and identifies opportunities to optimize capacity and asset performance.

| 10 Units. One Integrated Data-Driven Tool:	Optimization Across Every Unit:
- Data from Design, Individual Equipment Capacity, Max, Best Day Demonstrated, Turn down… - Simulated data for intermediate streams - Logistics, storages, transfers simulated	- Component, Unit wise, Equipment wise balance - Simulates higher starting product, final product, intermediate production scenario - Automatic elimination of constraints - Identifies bottlenecks at higher than current production levels

Key Takeaways from AI-Driven Solutions

Leverage AI/ML to transform raw data into actionable insights, addressing critical operational challenges in chemical manufacturing.
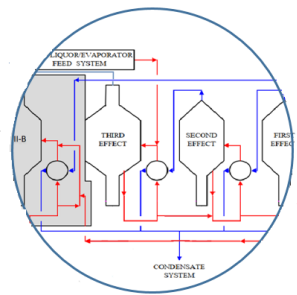
- *Prediction of 'boil-outs'* in evaporator help **increased** run-length **by 170%,** resulting in increasing caustic production and **benefits worths $1.5MM**

- *Ranking of cell elements* by severity for targeted interventions optimized maintenance, **slashing costs** while **enhancing asset utilization**, avoiding production constraints
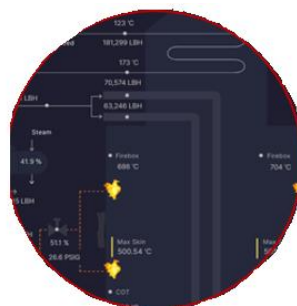
- *Predictive-analytics solution delivered actionable furnace insights—including coking trends—extending run lengths, improving yields and capacity, and **increasing production by 6% without CAPEX**.*
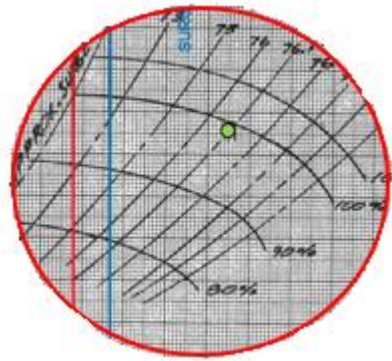
Key Takeaways from AI-Driven Solutions

AI/ML solutions convert raw data into actionable insights to tackle critical manufacturing challenges.

- *Analytics-enhanced compressor surge model* integrates first-principle equations and OEM performance curves into a monitoring system, validated for accuracy, delivering real-time visibility to plant operations and asset engineers, preventing surge events, and minimizing excessive power consumption for optimized performance.
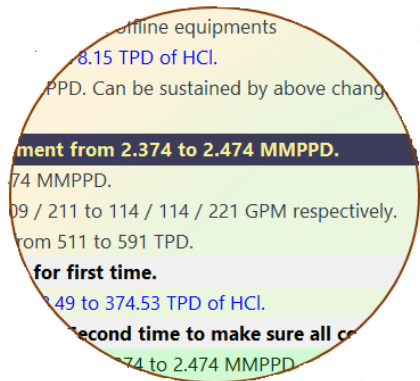
- *Optimization tool integrates* data from 10 units' design, equipment capacity, max/best day performance, turndown, and simulated intermediate streams, logistics, storage, and transfers. It achieves unit balance, simulates higher product production, eliminates constraints, identifies bottlenecks for enhanced operational efficiency

These solutions enhance efficiency, reduce costs, and improve safety by turning complex data into precise, actionable decisions.

The Power of AI in Chemical Manufacturing

Transformative Impact: AI shifts chemical manufacturing from reactive to proactive, enabling data-driven decisions that optimize performance and profitability.

Proven Success: The examples demonstrate tangible gains—shorter downtime, higher yields, and lower energy use—achievable across diverse processes.

Scalability and Adaptability: AI solutions are flexible, scaling from single furnaces to entire plants, adaptable to varying feedstocks and operational constraints.

Competitive Edge: Companies adopting AI gain a first-mover advantage in efficiency, cost, and sustainability, positioning them as industry leaders.

Thank you