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Integrating SPYRO™ Model into AVEVA’s Optimization, Steady-State & Dynamic Simulators

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TECHNIP ENERGIES

Streamlining Ethylene Plant Simulations Using Integrated SPYRO™ Model in AVEVA Software

Challenge

- Technip Energies' proprietary SPYRO™ program is the industry standard for modeling ethylene furnace operations. Modeling this industrial process becomes arduous as the intricate interplay of thousands of chemical reactions must be painstakingly accounted for. While SPYRO™ simulates the most important part of the ethylene production process, the furnace model needs to be incorporated into the larger ethylene plant flowsheet.

Solution

- SPYRO™ was originally a stand-alone design tool that has now been integrated into a variety of convenient platforms, among them AVEVA Process Optimization, AVEVA PRO/II Simulation, and AVEVA Dynamic Simulation.

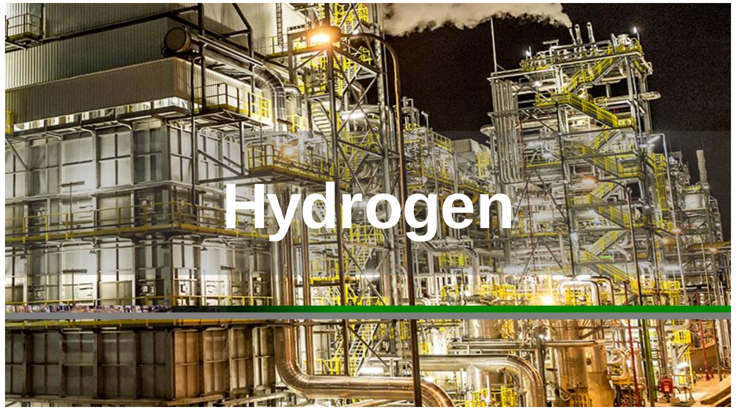
Results

- SPYRO™ offers flexibility in designing and supplying various types of ethylene plants.
- A streamlined interface with integrated SPYRO™ will simplify the overall mass balance and simulation of an ethylene plant, making the process more efficient and effective.

Technip Energies At A Glance

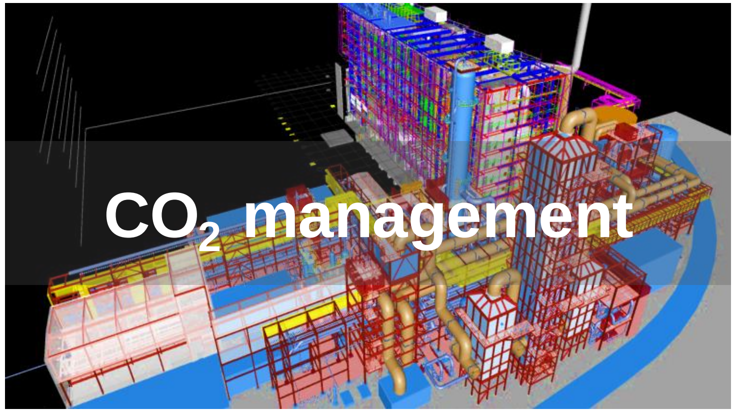
Listed on **Euronext Paris** Stock Exchange	Headquartered in **Paris** Registered in **The Netherlands**	**60+** years of operations
€6B Full year 2020 adjusted revenue	**A leading Project, Engineering & Technology company for the Energy Transition**	**€16.5B** Backlog at end September 2021
~15,000 Employees in 34 countries	**25+** Leading proprietary technologies	**450 projects** Under execution

Unlocking The Energy Chains Of Tomorrow



- A world leader with >270 plants delivered (>35% of installed base)
- Recognized partner of choice (Air Products)

- Key proprietary technologies in biochemicals and biofuels
- Introducing circularity to conventional ethylene production
- Notable alliances such as with Neste, Synova, Agilyx



- >50 references for CO_2 removal solutions
- Strategic alliance with Shell CANSOLV® on CO_2 capture

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01 Introduction to SPYRO™

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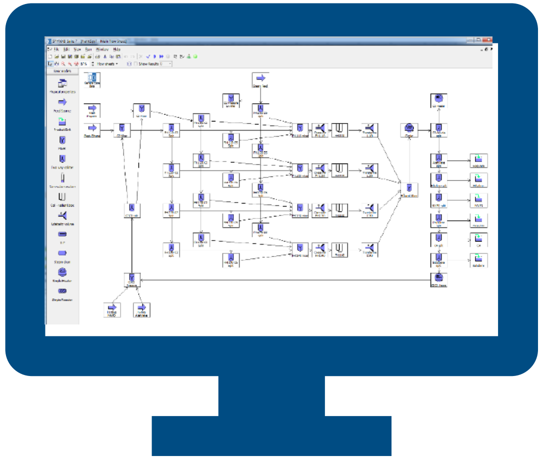
SPYRO™ Product Line

SPYRO™ is the market leader for simulation of steam cracking furnaces

- Used by Technip Energies for cracking furnace design
- Used by ethylene producers to simulate their furnace operations

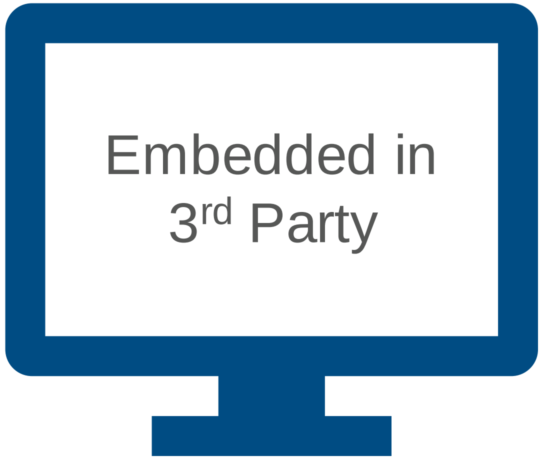
Our SPYRO™ software versions



SPYRO™

Offline Module

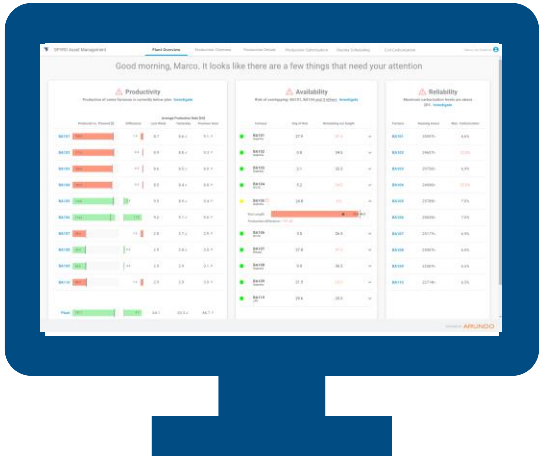
Running on Windows



Integrated SPYRO™

Online module APC & RTO

Running on Windows



SPYRO™ for Asset Management (SAM)

Cloud based

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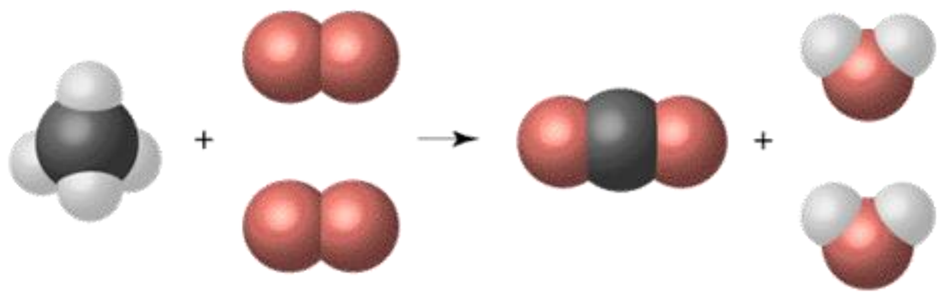
SPYRO™ Kinetic Scheme

	KS9002	KS9306	KS7
Components	124	128	218
Radicals	20	20	27
Reactions	>3000	>3000	>7000
C-range	C_1-C_{42}	C_1-C_{42}	C_1-C_{37}

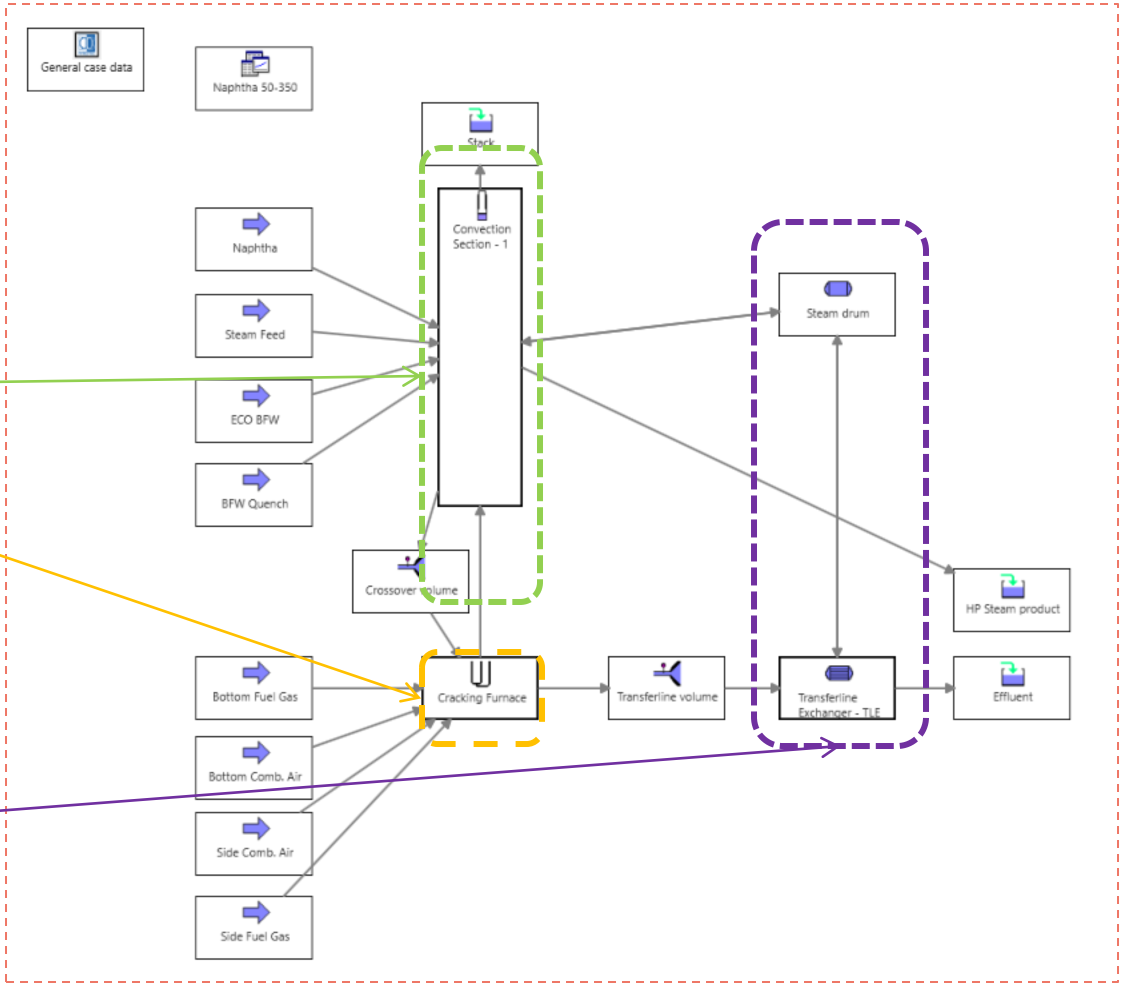
- KS9002 → KS9306: Little more detail in small olefins (C5, C6 and C7)
- KS9306 → KS7: Extended detail in heavier components (>C12)

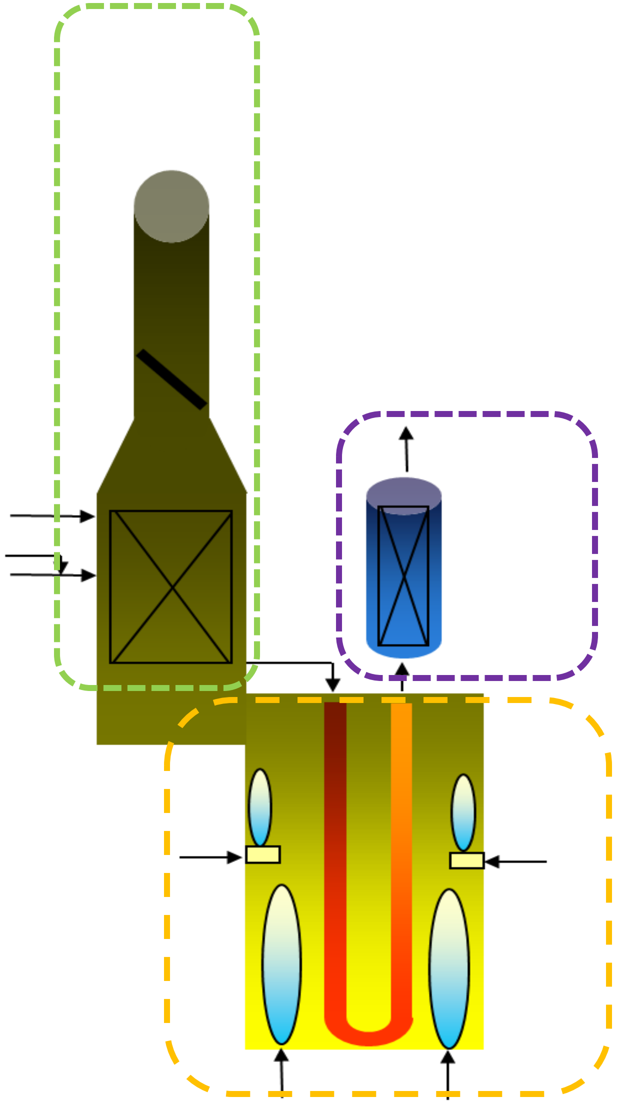


Full furnace on SPYRO

Full Furnace Simulation

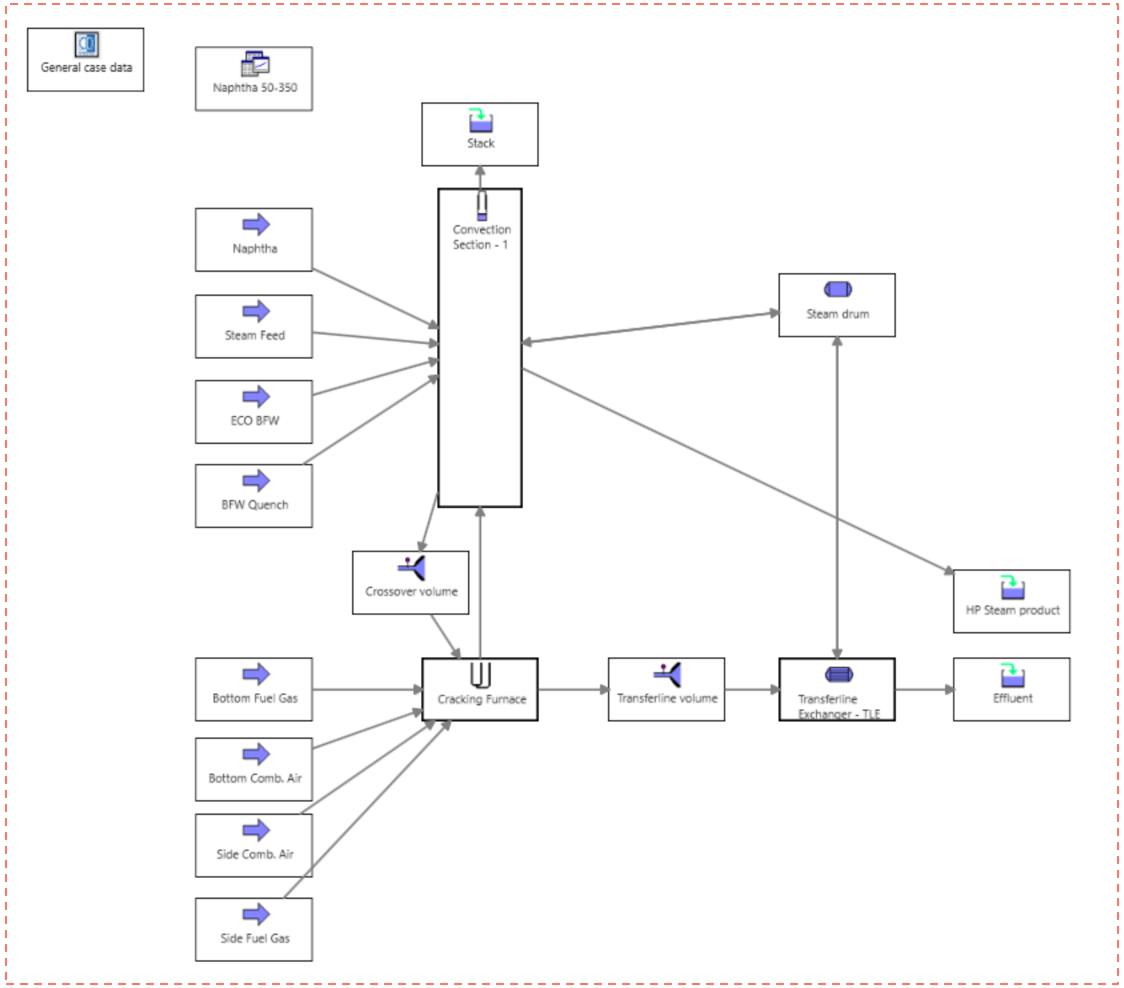
- Convection Section
- Radiant Section
- TLE and Steam drum





SPYRO™ Steam Cracking Furnace

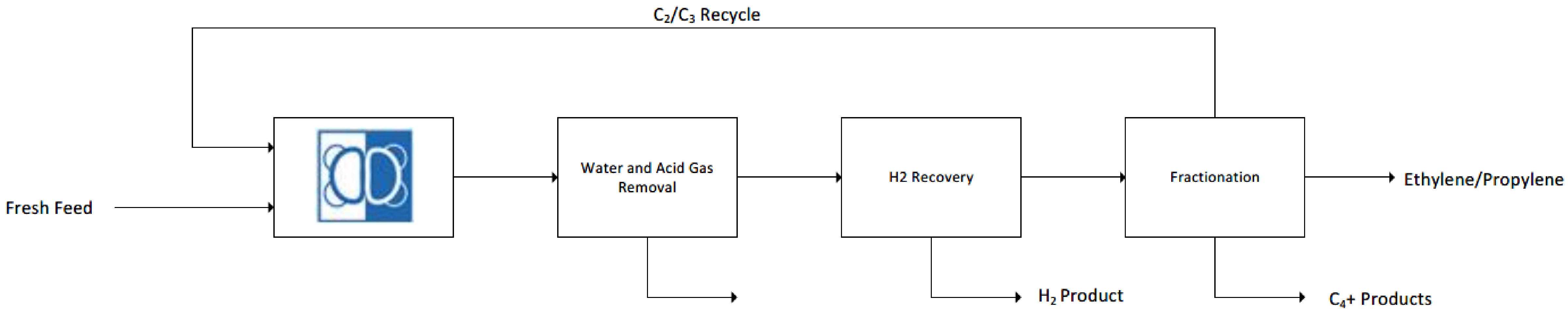
Offline simulation of furnace operations



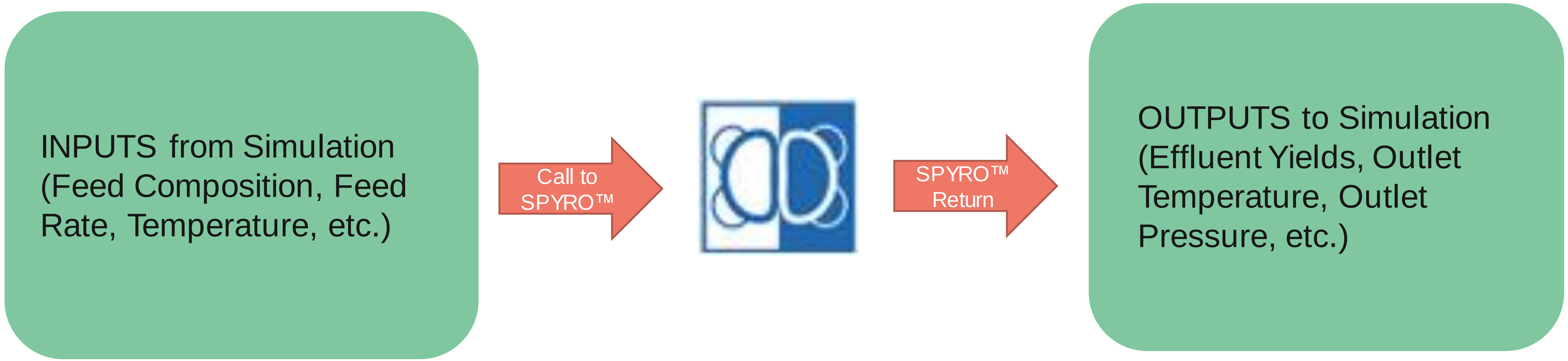
- **Product yields**
- **Coke formation**
- **Fuel gas, HP steam, etc.**

- Feedstock evaluation
- Optimization of operating conditions
- Prediction of furnace run lengths
- Generation of input data for production planning

Overview of an Ethylene Plant



Running Integrated SPYRO™ in AVEVA Process Optimization



Integrated SPYRO™

What inputs does Integrated SPYRO™ need?

- Convergence Option
  - COT / Severity / Conversion of Ethane or Propane / Radiant Wall Temperature
- Pressure
- At the coil inlet, coil outlet, or effluent
  - Feed Composition and Dilution Steam Ratio
- Feed Flowrate
- Coil Inlet Temperature
- Coke Thickness

Position	Name	Description
1–4	-	Reserved
5	NKEY	Key component number if CONOP1 specifies convergence on conversion.
6	CONOP1	Type of convergence for severity / conversion / temperature, see below.
7	CONVAL1	Severity / conversion / temperature, required if CONOP1≠ 0.
8	CONOP2	Type of pressure convergence (0=coil inlet, 1=coil outlet, 2=effluent).
9	CONVAL2	Coil outlet /effluent pressure [kgf/cm^2 abs.], required if CONOP2 ≠ 0.
10	TOLF	Convergence tolerance [–], see below.
11–138		Feed Composition on dry weight basis [dry wt%]. See Appendix A for component indices.
139	-	Binary option flag (0 – 3)
140	-	Type of output in DSPYOUT (0/1)
141	FLOWR	HC flow rate [kg/hr]
142	DS	Dilution steam ratio
143	CIP	Coil inlet pressure [kgf/cm^2]
144	Trw	Radiating wall temperature [°C]
145	CIT	Coil inlet temperature [°C]
146	DpAdia	Pressure drop in transfer line [kgf/cm^2]
147–166	COKET	Coke thickness for tube 1–20 [m]
167	FLUXP	Adjustment parameter for flux profile
168	HCOE	Adjustment multiplier for heat transfer coefficient
169	FRIC	Adjustment multiplier for friction factor
170	FOULC	Adjustment multiplier for fouling coefficient
171	PARCO	Adjustment multiplier for coke thermal conductivity
172	COKAD	Adjustment multiplier for coking

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Integrated SPYRO™

What does the user get out of Integrated SPYRO™?

- Effluent Yields
- Radiant Wall and Coil Outlet Temperatures
- Absorbed Duty
- Process Pressure and Temperature Profiles
- Maximum Tube Metal Temperature
- Heat Flux and Tube Skin Temperature Profiles
- Coking Rates
- Information Passed Back to APO Model

Position	Description
1–128	Effluent Composition [dry wt%]. See Appendix A for details.
129–136	Reserved
137	Coil inlet pressure [kgf/cm^2]
138	Pressure drop across coil [kgf/cm^2]
139	Radiant wall temperature [°C]
140	Coil outlet temperature [°C]
141	Absorbed duty [kcal/h/coil]
142	Number of tubes per coil
143–163	Process temperature profile (Tube 1 through NTUBE plus the transfer line immediately following the last tube) [°C]
164–184	Process pressure profile (Tube 1 through NTUBE plus the transfer line immediately following the last tube) [kgf/cm^2]
185–204	Maximum tube metal temperature (Tube 1 through NTUBE) [°C][1]
205–224	Heat flux profile based on inside surface area (Tube 1 through NTUBE) [kcal/hr/m^2]
225–244	Coking rate (Tube 1 through NTUBE) [mm/30 days]
245–644	Tube skin temperature profile per collocation point [°C]

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02 SPYRO™ in PRO/II

SPYRO™ in PRO/II (Available Q1 2024)

AVEVA is currently developing a SPYRO™ Unit Operation in PRO/II

- Scheduled to be released along with the next release of PRO/II
- Integrated SPYRO™ license will be required
- No additional licenses will be needed for PRO/II

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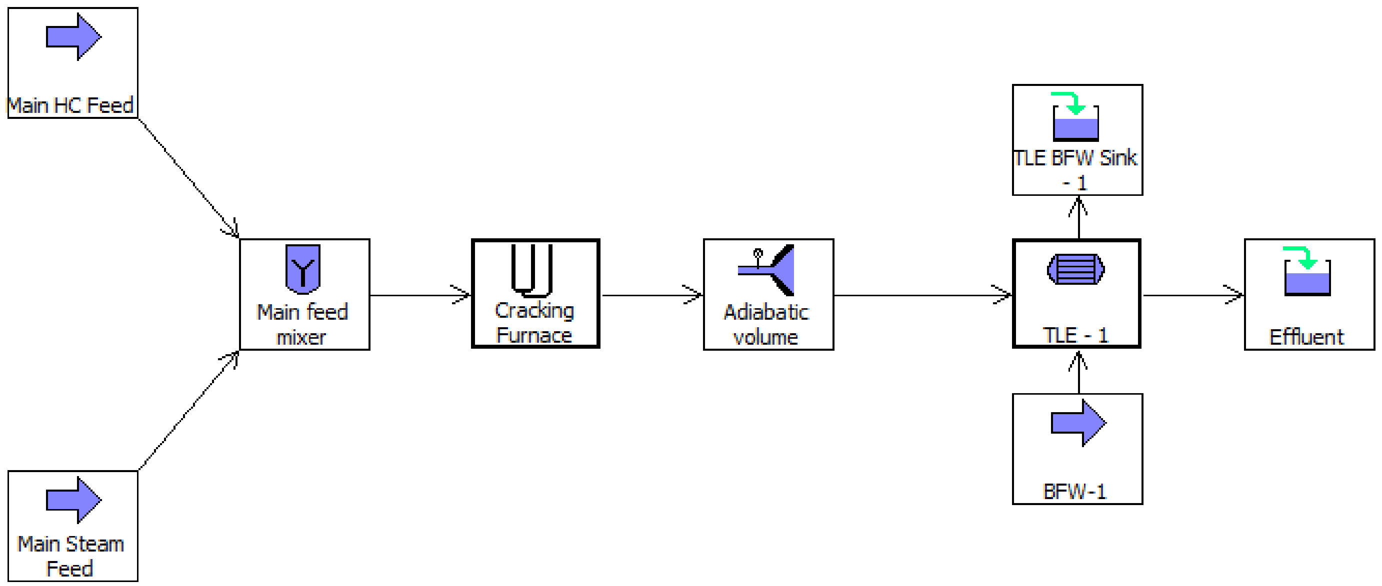
Features to Be Included

- Compatibility with KS9306 and KS7 SPYRO™ Kinetic Schemes
- Ability to converge on all available convergence options available in Integrated SPYRO™
- Ability to input coke thicknesses in the radiant section of the SPYRO™ files
- SPYRO™ output data will be able to be exported to an Output Report
- TLEs can be included in SPYRO™ geometry files
- Multiple SPYRO™ unit operations can be used in the same simulation

SPYRO™ Geometry File

SPYRO™ Geometry File is used by Integrated SPYRO™ when called from PRO/II



Component Mapping

A default mapping will be provided depending on the SPYRO™ kinetic scheme

- KS9306 contains 128 components
- KS7 contains 213 components

Mapping is not one-to-one

User can change mapping, but not the components

SPYRO - Component Mapping

UOM Range Help

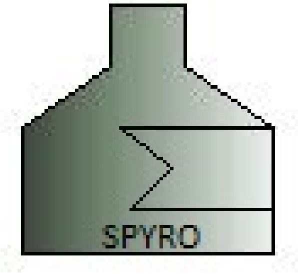
SimSci	SPYRO	Input to SimSci Components	SPYRO Component Output
NC15	NC15	0.333	1
NC15	NAF15	0.334	1
NC15	ISO15	0.333	1
1EICOSE	NAF20	0.333	1
1EICOSE	EIC1	0.334	1
1EICOSE	OLC20	0.333	1
2MNP	OLN11	1	1
C10CYH	OLN16	0.334	1
C10CYH	OLC16	0.333	1
C10CYH	EXA1	0.333	1
C9BZ	C15AR	1	1
C14BENZ	C20AR	0.5	1
C14BENZ	DNA20	0.5	1
NC20	NC20	0.5	1
NC20	ISO20	0.5	1
1PNAP	C15CO	1	1
C10NAPH	C20CO	1	1
1HEPTYNE	DIA7	1	1
TED1	DIA14	1	1
4IPDPH	DNA15	1	1
NC32	CH32	0.25	1

OK to PFD | OK | Cancel | Cancel to PFD

Exit the window after saving all data

SPYRO™ – PRO/II Interface Summary

- AVEVA is developing a new unit operation in PRO/II that will allow Integrated SPYRO™ to be run from the PRO/II flowsheet
  - This new unit operation is scheduled to be released along with the next release of PRO/II
- SPYRO™ geometry file provides the coil geometry to be simulated
- KS9306 and KS7 will be compatible with this new unit operation
- SPYRO™ output data will be accessible via the PRO/II output reports
- Multiple instances of SPYRO™ can be called in the same flowsheet



03 SPYRO™ for Dynamic Real-time Environment (SPYDRE)

Integrating SPYRO™ into AVEVA Dynamic Simulation

What?

- **SPYRO™ is Technip Energies' proprietary software for an ethylene cracker yield model for furnace design and performance prediction**

How?

- **The hydrocarbon cracking reaction kinetic model set and radiant coil heat transfer embedded in SPYRO™ is integrated into the ADS OTS via DLL I/O**

Why?

- **Take advantage of the rigorous radiant coil cracking solution provided by SPYRO™ in ADS OTS to predict overall system dynamic behavior**
  - Overcome limitations of regression-based OTS models

First Principle High Fidelity Dynamic Model of an Ethylene Furnace

Rigorous Comprehensive Simulation of Key Equipment in an Ethylene Unit/Furnace

- Radiant Coils
- Radiant Furnace
- Convection Section
- Transfer Line Exchangers
- Recovery Section

Simulate Ethylene Unit/Furnace Operating Transitions

- Start-up/Shutdown
- HSSB to Cracking and vice-versa
- HSSB to Decoking and vice-versa
- Trip condition to HSSB

Customized Furnace Model

Case-by-case Configuration of Ethylene Unit/Furnace

The dynamic simulation model is built and tuned specifically for each individual application

Detailed information obtained from Client's engineering design and vendor documentation is used to develop sections in the model when supplied

Hardware

- Radiant coils
- Radiant furnace
- Steam drum
- TLEs
- Piping
- Control valves
- Convection banks
- Controls
- Transmitters
- ID Fan

Sources

- P&IDs
- GAs
- 3D Plant models
- Erection drawings
- Isometric drawings
- Vendor datasheets
- Instrument datasheets
- Mechanical Assembly and Shop drawings
- Cause and Effect matrix

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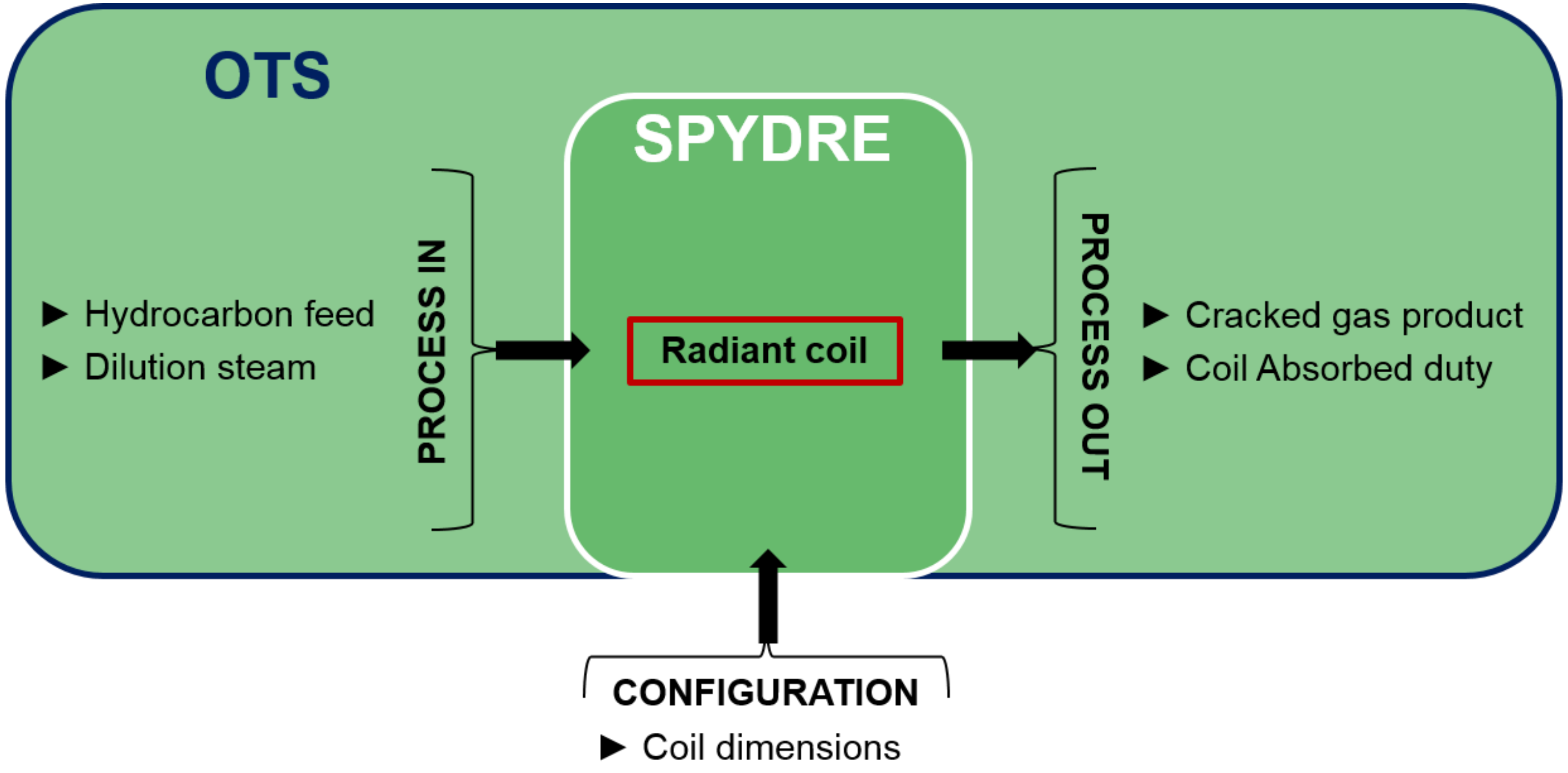
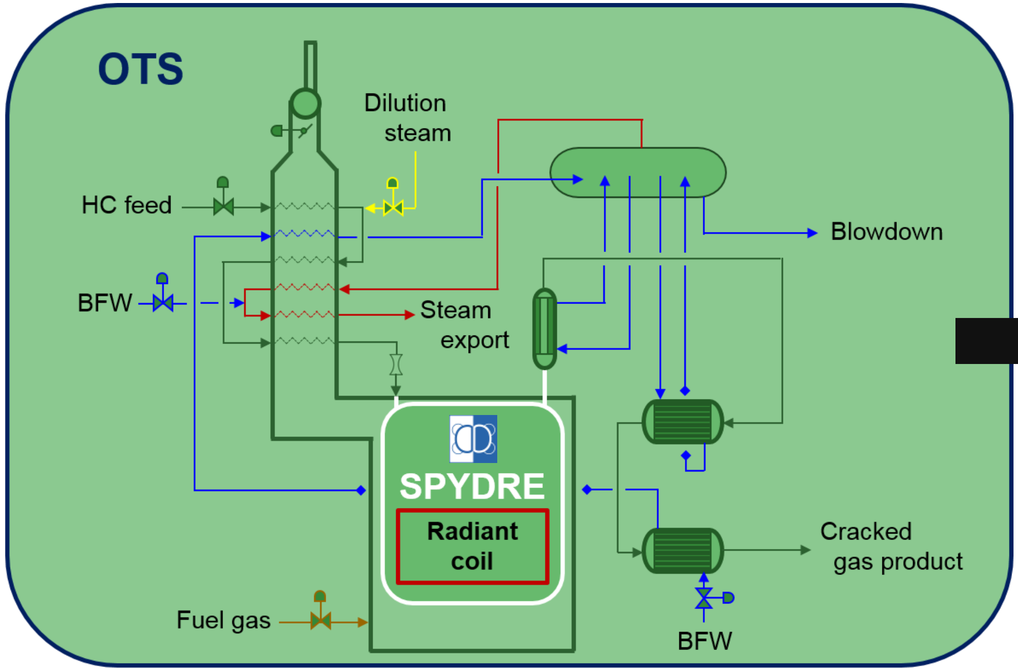
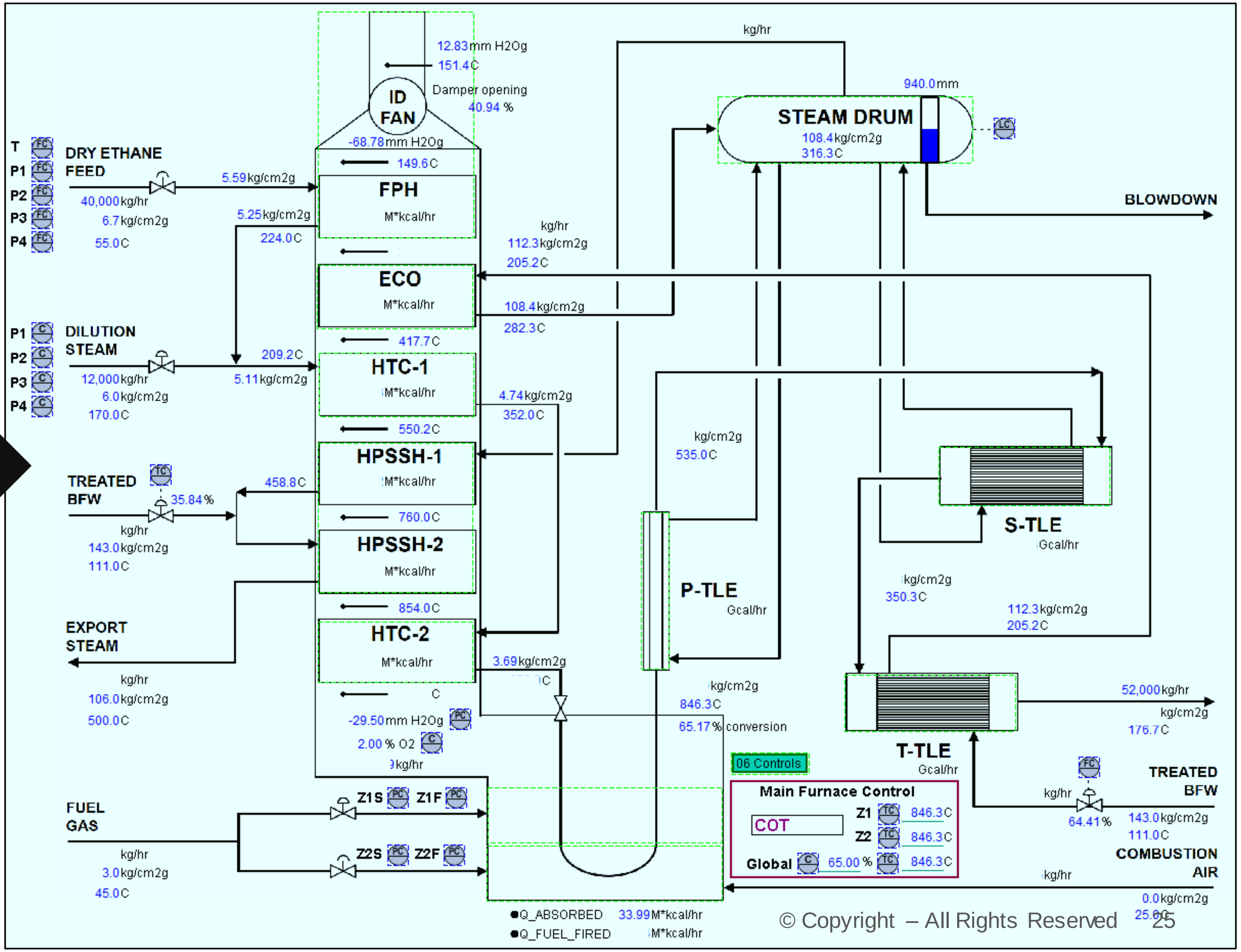
OTS Interface with SPYDRE



Ethylene Furnace Overview in ADS OTS





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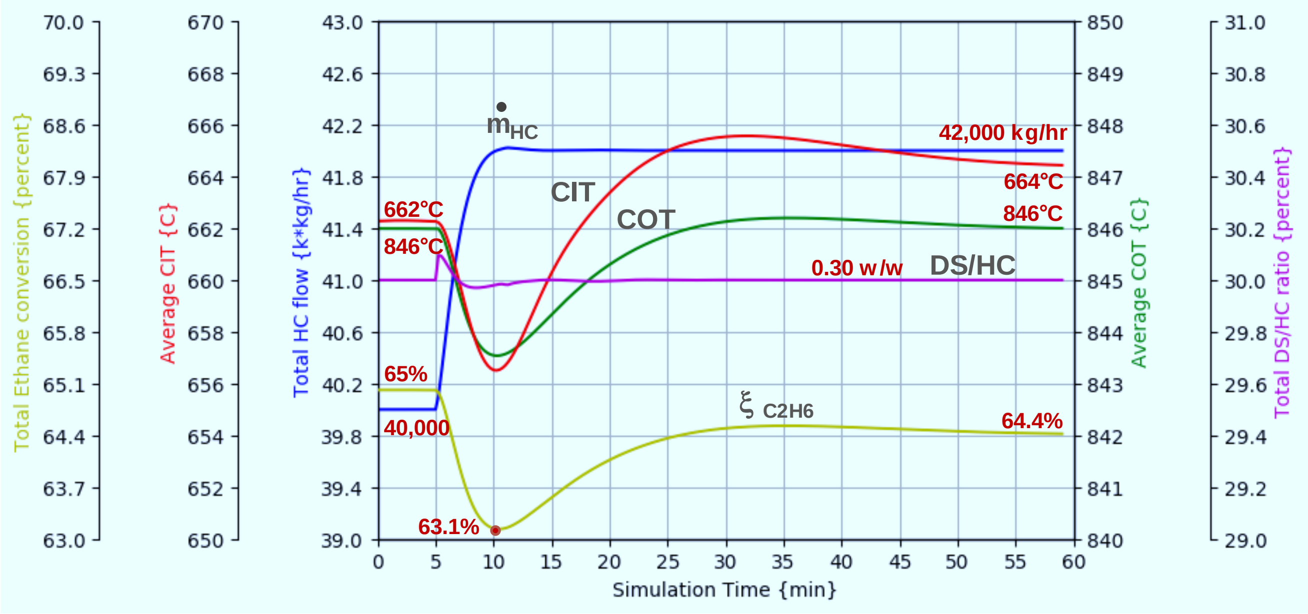
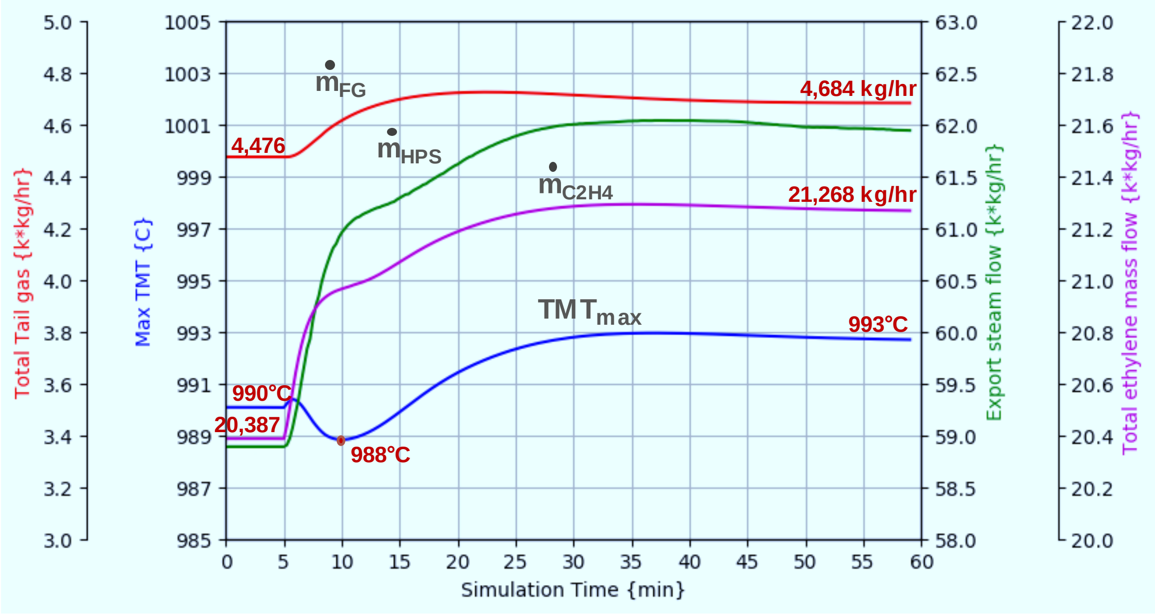
Transient Scenario #1

Increase Total HC Feed to Furnace by 5% with COT control

- Initial condition:
  - All 4 passes at 10,000 kg/hr HC each
  - COT = 846°C
- 97 wt% C2H6 dry basis in HC feed
- C2H6 Conversion = 65%

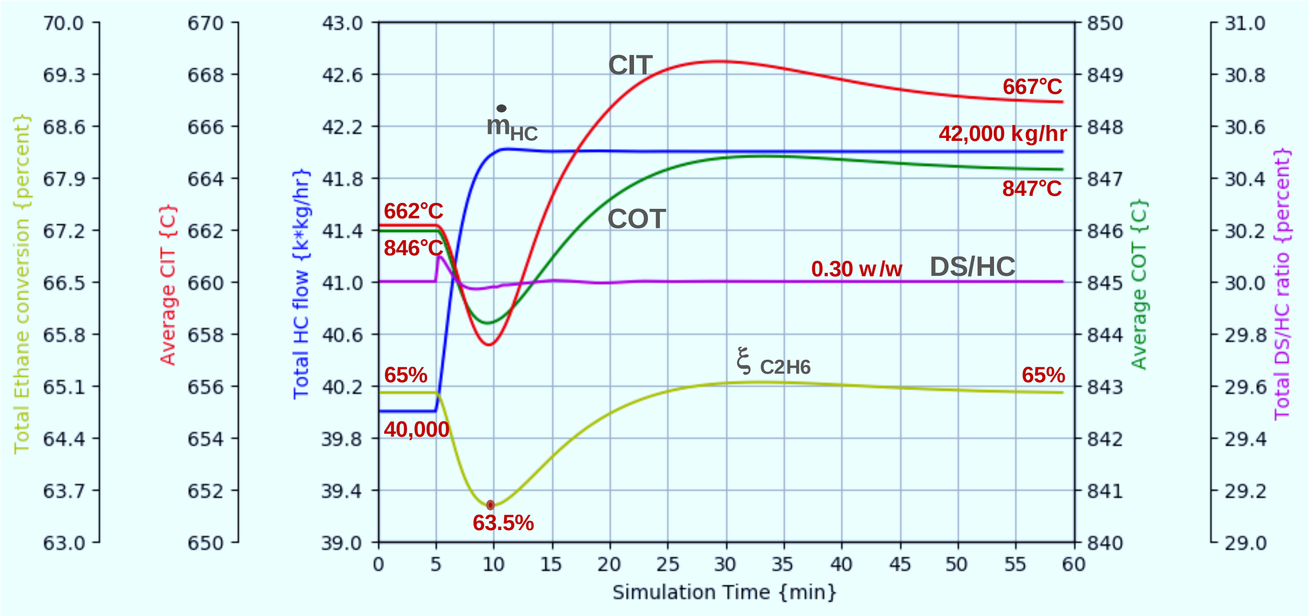


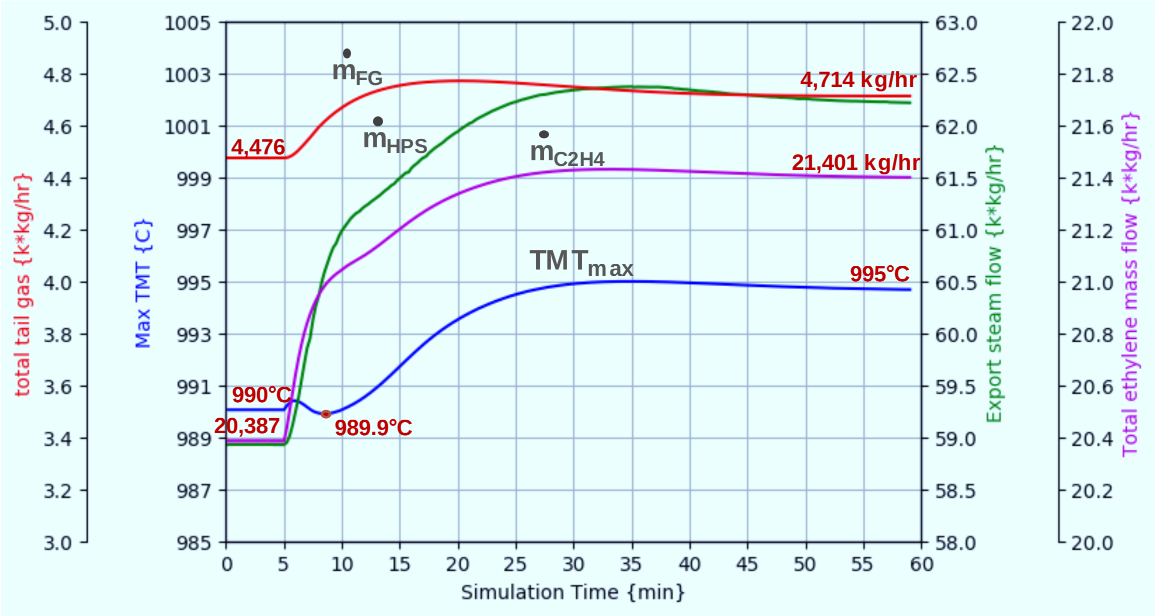


Transient Scenario #2

Increase Total HC Feed to Furnace by 5% with Conversion control

- Initial condition:
  - All 4 passes at 10,000 kg/hr HC each
  - COT = 846°C
- 97 wt% C2H6 dry basis in HC feed
- C2H6 Conversion = 65%





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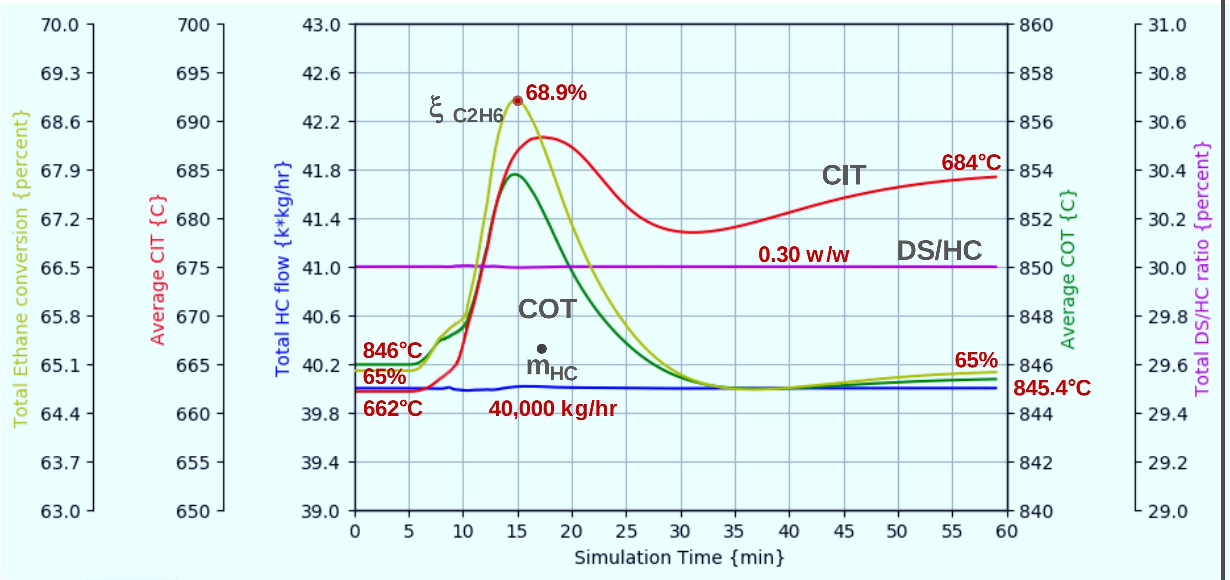
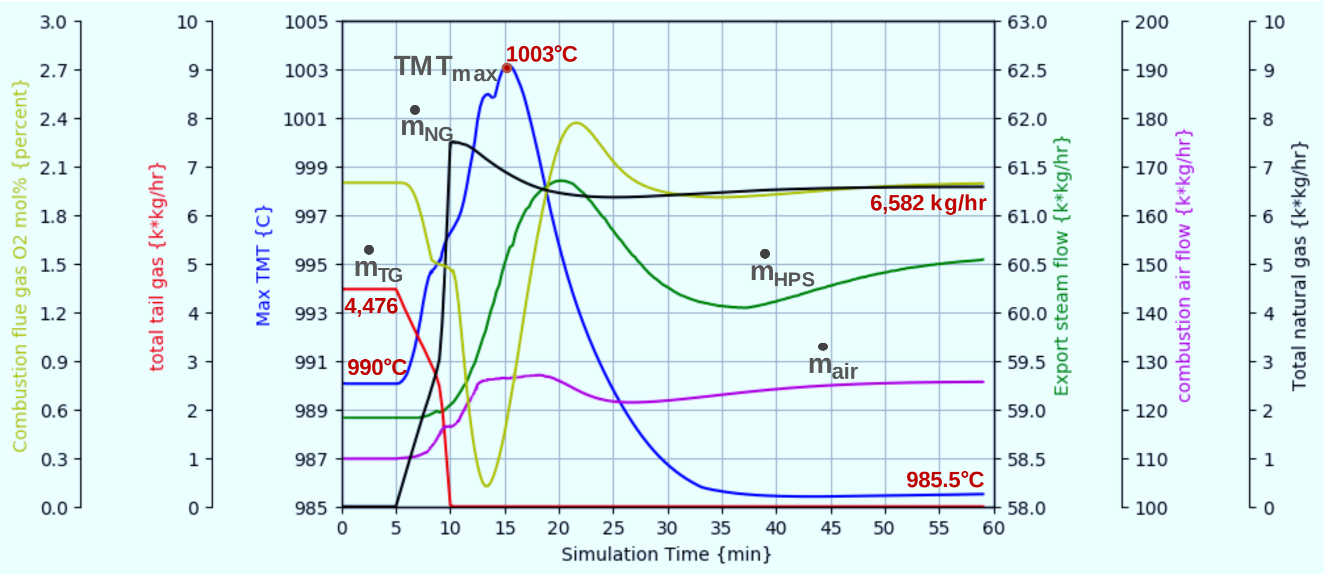
Transient Scenario #3

Transition Combustion Fuel from H2 Rich Tail Gas to NG

COT Control

- Initial condition:
  - Fuel gas:
    - 79 mol% H2 + 20 mol% CH4
  - COT = 846°C
- Final condition:
  - Fuel gas:
    - 100 mol% CH4
  - COT = 846°C





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Questions?

Please wait for the microphone.

State your name and company.

Please remember to…

Navigate to this session in the mobile app to complete the survey.

Thank you!

AVEVA