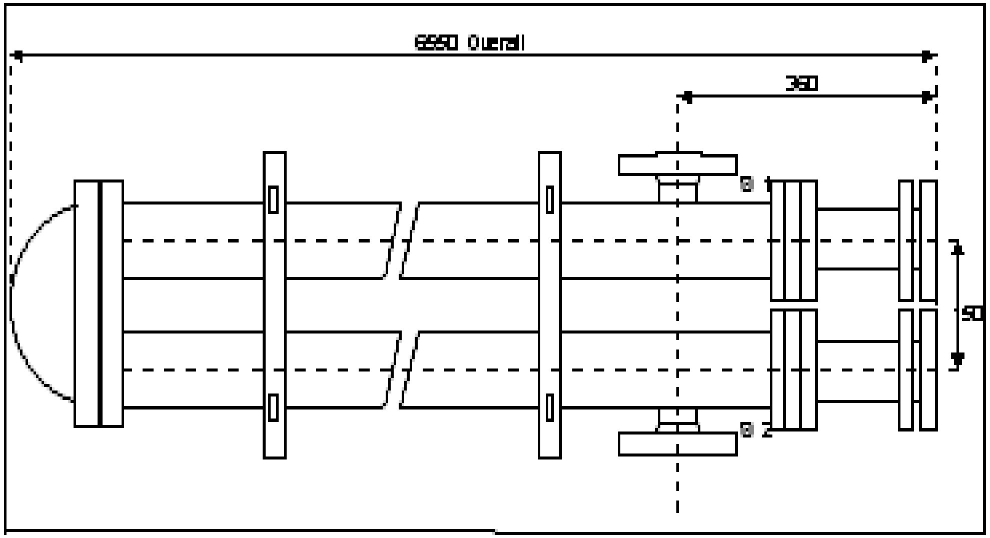
Heat Exchangers in ASPEN Plus



Objective

Introduce the unit operation models used for heat exchangers

Introduce the HeatX & MHeatX block

Model a shell and tube exchanger

Heat Exchanger Models

- Heater - Heater or cooler
- HeatX - Two stream heat exchanger
- MHeatX - Multi-stream heat exchanger

Heater

Heater performs these types of single phase or multiphase calculations:

- Bubble or dew point calculations
- Add or remove any amount of user specified heat duty
- Match degrees of superheating or subcooling
- Determine heating or cooling duty required to achieve a certain vapor fraction

Working with the Heater Model

- The Heater block mixes multiple inlet streams to produce a single outlet stream at a specified thermodynamic state.

- Heater can be used to represent:
  - » Heaters
  - » Coolers
  - » Valves
  - » Pumps (when work-related results are not needed)
  - » Compressors (when work-related results are not needed)

- Heater can also be used to set the thermodynamic conditions of a stream.

Heater Input Specifications

- Allowed combinations:
  - » Pressure (or Pressure drop) and one of:
    - ➢ Outlet temperature
    - ➢ Heat duty or inlet heat stream
    - ➢ Vapor fraction
    - ➢ Temperature change
    - ➢ Degrees of subcooling or superheating
  - » Outlet Temperature or Temperature change and one of:
    - ➢ Pressure
    - ➢ Heat Duty
    - ➢ Vapor fraction

Heater Input Specifications (cont'd)

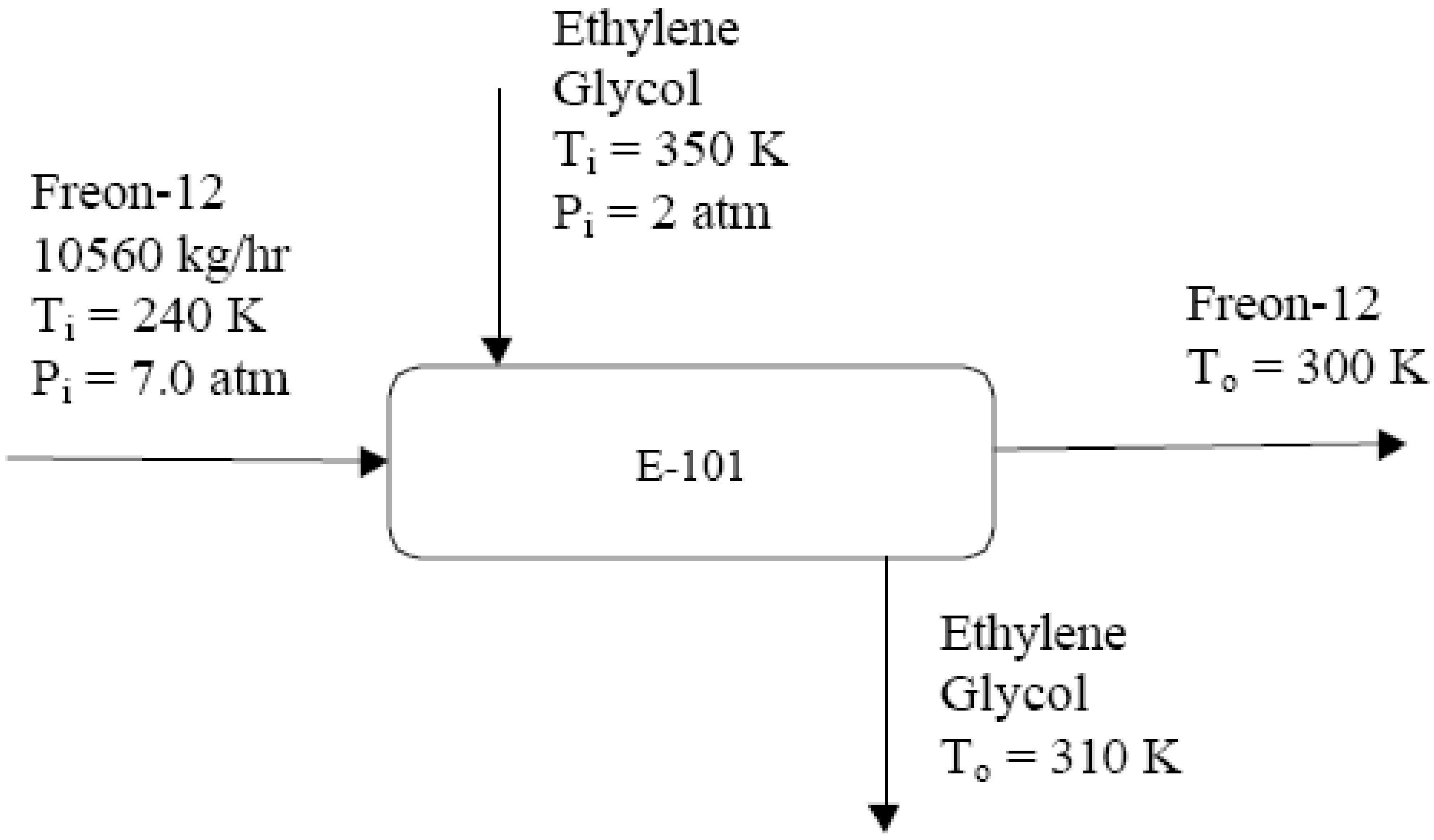
- For single phase use Pressure (drop) and one of:
  - » Outlet temperature
  - » Heat duty or inlet heat stream
  - » Temperature change
- Vapor fraction of 1 means dew point condition, 0 means bubble point

Heat Streams

- Any number of inlet heat streams can be specified for a Heater.
- One outlet heat stream can be specified for the net heat load from a Heater.
- The net heat load is the sum of the inlet heat streams minus the actual (calculated) heat duty.
- If you give only one specification (temperature or pressure), Heater uses the sum of the inlet heat streams as a duty specification
- If you give two specifications, Heater uses the heat streams only to calculate the net heat duty.

Heater (Example)

Schematic:



NRTL-RK

HeatX Model

- HeatX can perform simplified or rigorous rating calculations
- Simplified rating calculations (heat and material balance calculations) can be performed if exchanger geometry is unknown or unimportant
- For rigorous heat transfer and pressure drop calculations, the heat exchanger geometry must be specified.

HeatX Model (Cont'd)

HeatX can model shell-and-tube exchanger types:

» Counter-current and co-current

» Segmental baffle TEMA E, F, G, H, J and X shells

» Rod baffle TEMA E and F shells

» Bare and low-finned tubes

HeatX Model (Cont'd)

- HeatX performs:
  - » Full zone analysis
  - » Heat transfer and pressure drop calculations
  - » Sensible heat, nucleate boiling, condensation film coefficient calculations
  - » Built-in or user specified correlations

- HeatX cannot:
  - » Perform design calculations
  - » Perform mechanical vibration analysis
  - » Estimate fouling factors

HeatX Calculation Modes

- **Shortcut**

  Performs simple material and energy balance calculations, and is used where geometry is unknown or unimportant. Can be used for design, rating and simulation calculations.

- **Detailed**

  Geometry needs to be specified. Can be used for rating and simulation calculations only.

- **Rigorous**

  Is used for design, rating, simulation and maximum fouling calculations. Integrates Aspen Plus with more detailed exchanger design/rating softwares.

HeatX Calculation Type

- **Design:**
  Area/Geometry is determined.

- **Rating**
  Determined whether given exchanger is over-designed or under-designed for a given duty

- **Simulation**
  Outlet conditions are predicted for inlet conditions

- **Maximum Fouling**
  Determined maximum fouling reached in an exchanger at which duty can be fulfilled

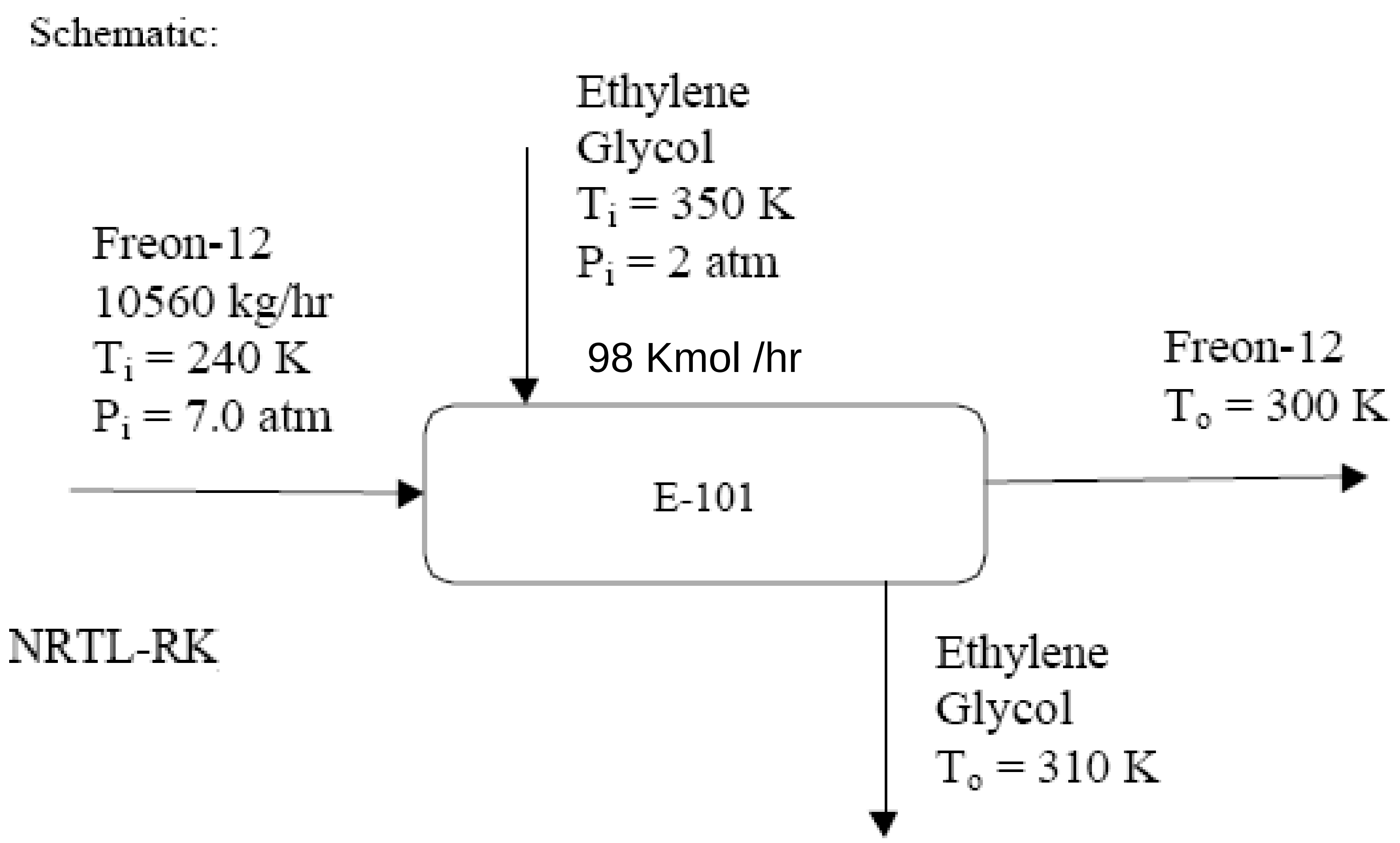
HeatX Input Specifications

- Select one of the following
  - » Heat Transfer Area or Geometry
  - » Exchanger Duty
  - » Constant UA
  - » For cold or hot outlet stream
    - ➢ Temperature
    - ➢ Temperature Increase/Decrease
    - ➢ Temperature Difference
    - ➢ Temperature Approach
    - ➢ Degrees of Superheat/Subcool
    - ➢ Vapour Fraction

HeatX Input Specifications

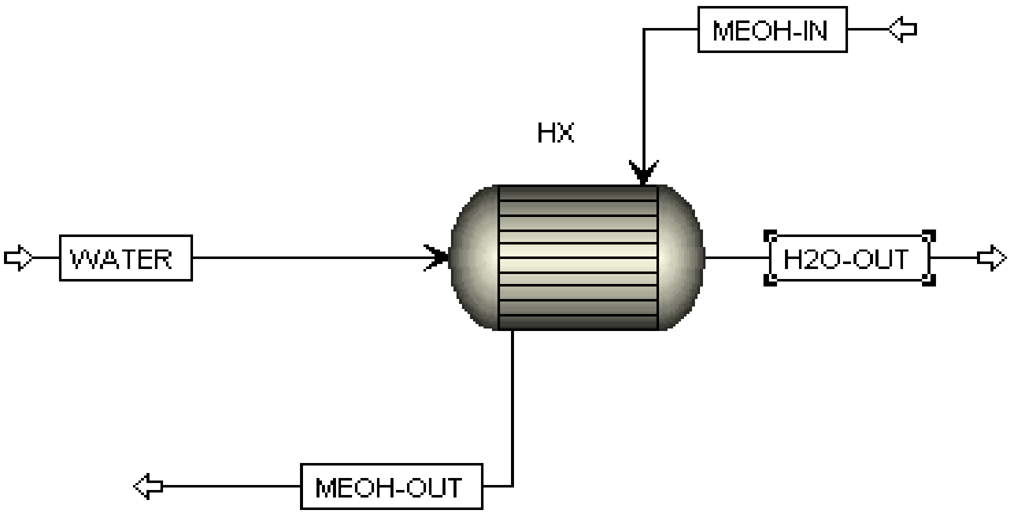
- **Other inputs include:**
  - » **Inside Shell diameter**
  - » **Tube length, diameter (inner/outer), pitch, number**
  - » **Baffle type, number, cut**
  - » **Nozzle diameters for shell/tube**

HeatX (Example)



- Find area for above duty.
- Simulate for 25 sq.ft and find the exit temperature.
- Rate for 25 sq.ft.

HeatX Example



- **Cooling 100 lbmol of methanol (14.7 psia, 150 F) to 100 F using 3000 lbmol of water (14.7 psia, 50 F).**
- **Find area for above duty.**
- **Simulate for 155 sq.ft and find the exit temperature.**
- **Rate for 155 sq.ft.**
- **(Use RKS-BM property method)**

Plots

- Plots can be made with variables heat duty, temperature, vapour fraction and pressure
- Plots for both hot side and cold side can be plotted

Exercise (Detailed Mode)

- Run the exchanger under detailed mode.
- Geometry to be supplied as:
  - » Shell Diameter 3 ft, tube pass 1
  - » 60 bare tubes, 15 ft length, pitch 31 mm, 21 mm ID, 25 mm OD,
  - » 5 Segmental baffles, 15% cut
  - » All Nozzles 100 mm

- Find the % over-design/under-design in rating mode
- Find the hot outlet temperature in simulation mode

Rigorous Mode

- More detailed and accurate design calculations can be carried out
- Separate Interface is also available
- Geometry is checked conforming to TEMA Standards

HeatX versus Heater

- Consider the following:
  - » Use HeatX when both sides are important.
  - » Use Heater when one side (e.g. the utility) is not important.
  - » Use two Heaters (coupled by heat stream, Calculator block or design spec) or an MHeatX to avoid flowsheet complexity created by HeatX.

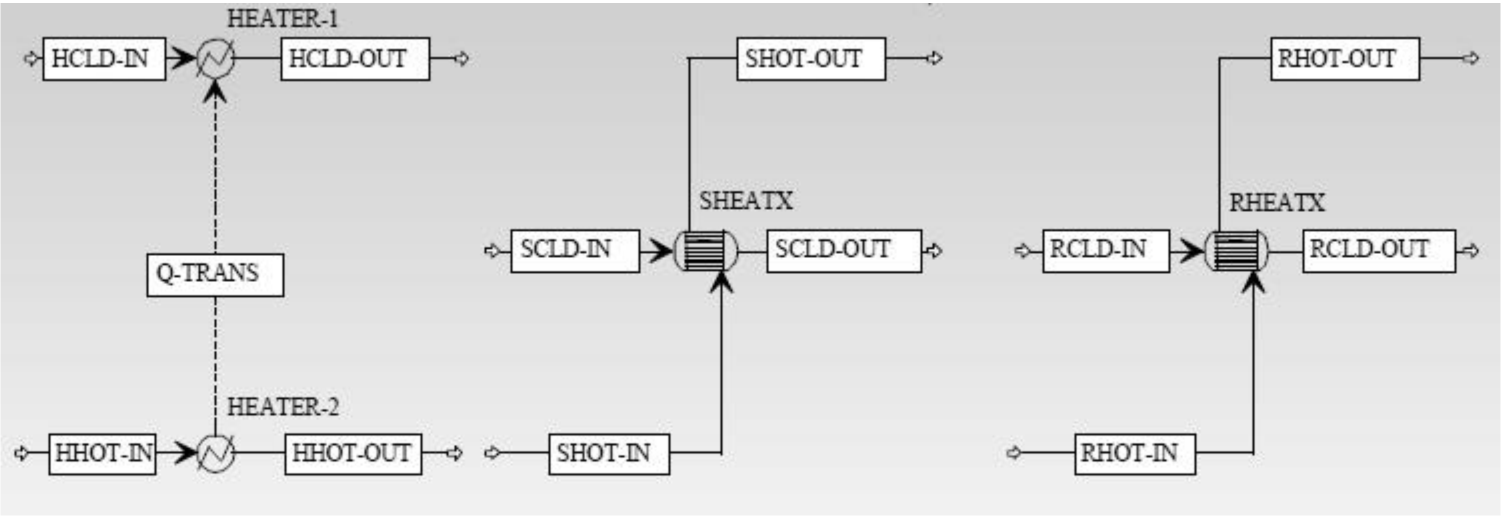
HeatX workshop

Objective:

Compare the simulation of a heat exchanger that uses water to cool a hydrocarbon mixture using three methods: a shortcut HeatX, a rigorous HeatX and two Heaters connected with a Heat stream.

- Hydrocarbon stream
  - » Temperature: 200 C
  - » Pressure: 4 bar
  - » Flowrate: 10000 kg/hr
  - » Composition: 50 wt% benzene, 20% styrene, 20% ethylbenzene and 10% water
- Cooling water
  - » Temperature: 20 C
  - » Pressure: 10 bar
  - » Flow rate: 60000 kg/hr
  - » Composition: 100% water

HeatX workshop (cont'd)



-- Start with the General with Metric Units Template.

-- Use the NRTL-RK Property Method for the hydrocarbon streams.

-- Specify that the valid phases for the hydrocarbon stream is Vapor-Liquid-Liquid.

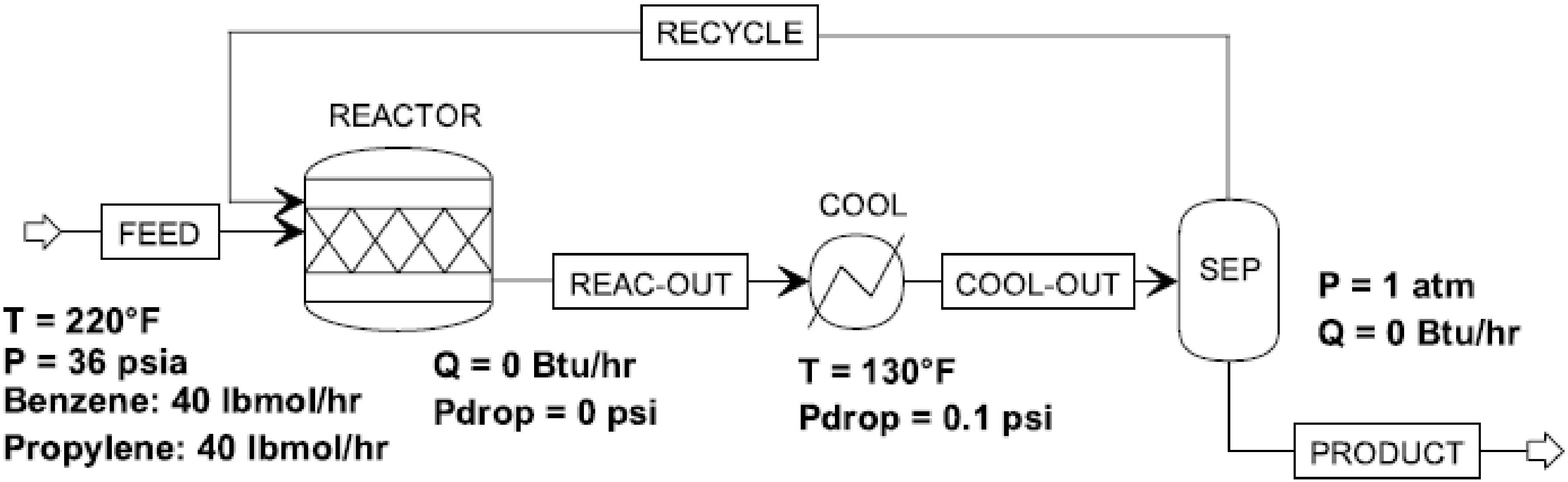
-- Specify that the Steam Tables are used to calculate the properties for the cooling water streams on the Block BlockOptions Properties sheet.

HeatX Workshop (cont'd)

- **Shortcut HeatX simulation:**
  - » Hydrocarbon stream exit has a vapor fraction of 0
  - » No pressure drop in either stream
- **Two Heaters simulation:**
  - » Use the same specifications as the shortcut HeatX simulation
- **Rigorous HeatX simulation:**
  - » Hydrocarbons in shell leave with a vapor fraction of 0
  - » Shell diameter 1 m, 1 tube pass
  - » 300 bare tubes, 3 m length, pitch 31 mm, 21 mm ID, 25 mm OD
  - » All nozzles 100 mm
  - » 5 baffles, 15% cut
  - » Create heat curves containing all info required for thermal design.
  - » Change the heat exchanger specification to Geometry and re-run.

Exercise

Example



$$C_6H_6 + C_3H_6 \rightarrow C_9H_{12}$$

Benzene Propylene Cumene (Isopropylbenzene)

90% Conversion of Propylene

Use the RK-SOAVE Property Method

Exercise

- **Objective: Model the heat exchanged between the process and utility streams using a HeatX block – first in the Shortcut mode and then in the Detailed mode**