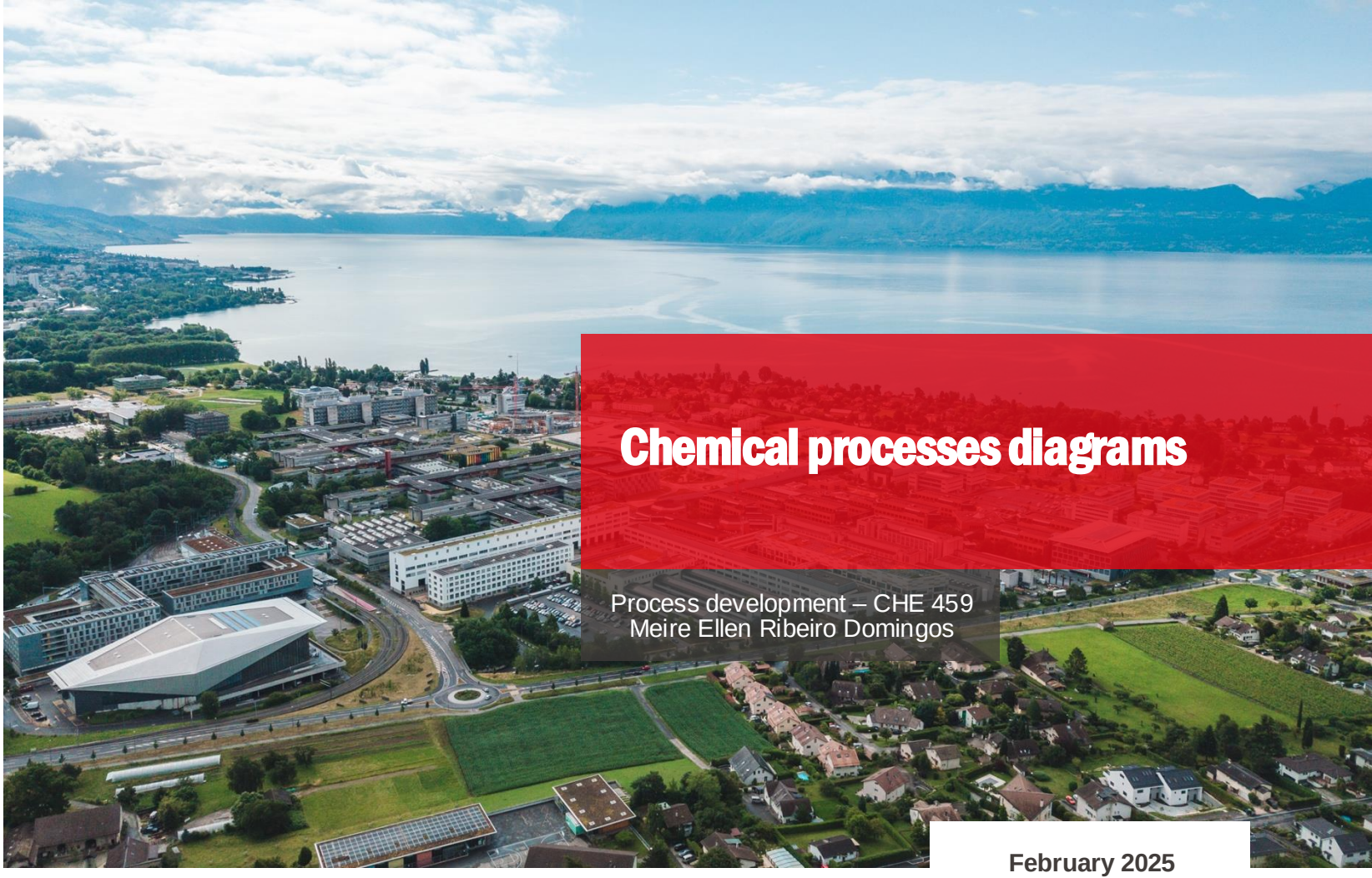


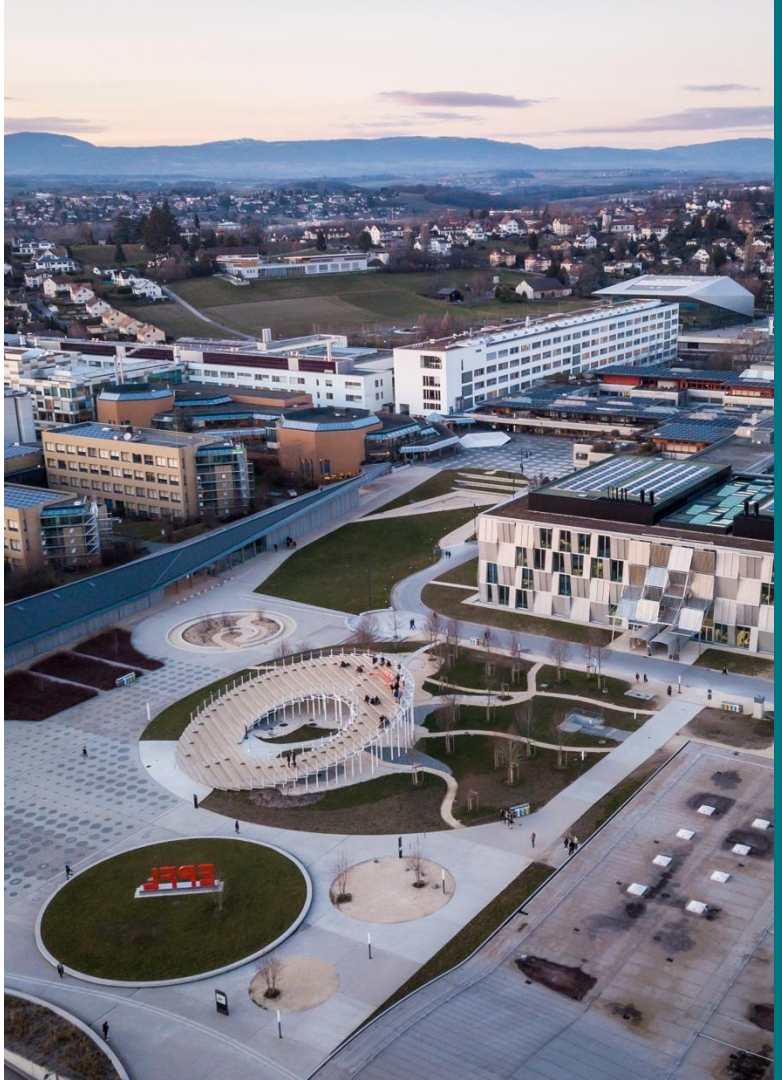
Chemical processes diagrams

Process development – CHE 459

Meire Ellen Ribeiro Domingos

February 2025

École polytechnique fédérale de Lausanne



OUTLINE

Overview

Block Flow Diagrams

Process Flow Diagrams

Piping & Instrumentation Diagrams

BFD example

Chemical Processes Diagrams

Chemical process diagrams are used to communicate information about a process.

- Block Flow Diagram (BFD)

  Material flows for important conversions and separations steps.

- Process Flow Diagram (PFD)

  Detailed material and energy flows, details of process units.

- Piping & Instrumentation Diagram (P&ID)

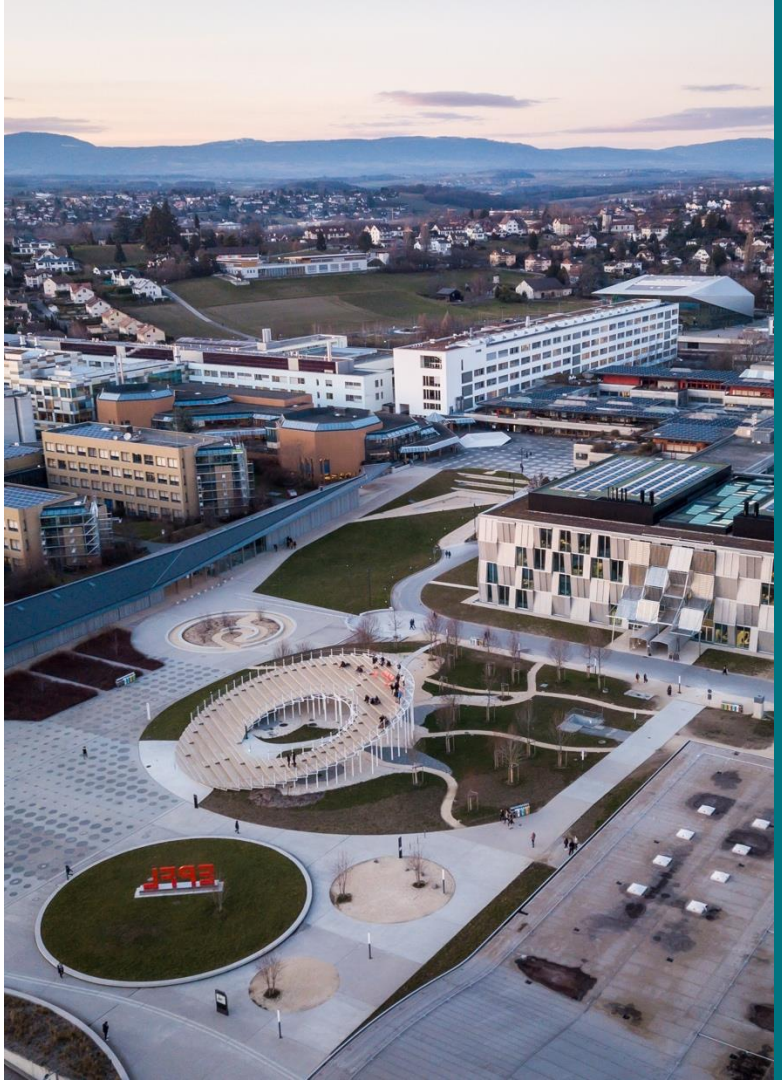
  Piping details, valve details, instrumentation (T, P and level measurements).

Turton, Richard, et al. Analysis, synthesis and design of chemical processes. Pearson Education, 2008.

Tools

Draw.io (open source)

- Windows/Mac installer: https://github.com/jgraph/drawio-desktop/releases/tag/v23.1.5
- Web version: https://app.diagrams.net/



OUTLINE

Overview

Block Flow Diagrams

Process Flow Diagrams

Piping & Instrumentation Diagrams

BFD example

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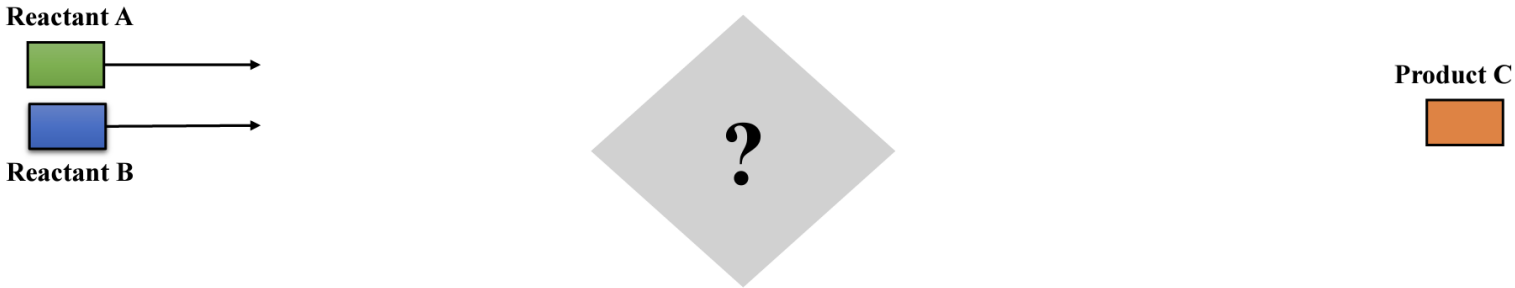
Block flow diagram

- A block flow diagram (BFD) is a drawing of chemical processes used to simplify and understand the basic structure of a system.
- Initial step to convert a written problem into a simple graphical representation.
- BFDs are used to compare options at the early stage of process development.
- This diagram consists of a series of blocks connected with input and output flow streams.
- It contains the main informations given in the problem statement, such as: operating conditions (T, P), flows, conversion, recovery, etc.
- Each block represents a single equipment or a complete stage in the process. BFD is basis for conceptual process development (PFD).

BFD construction



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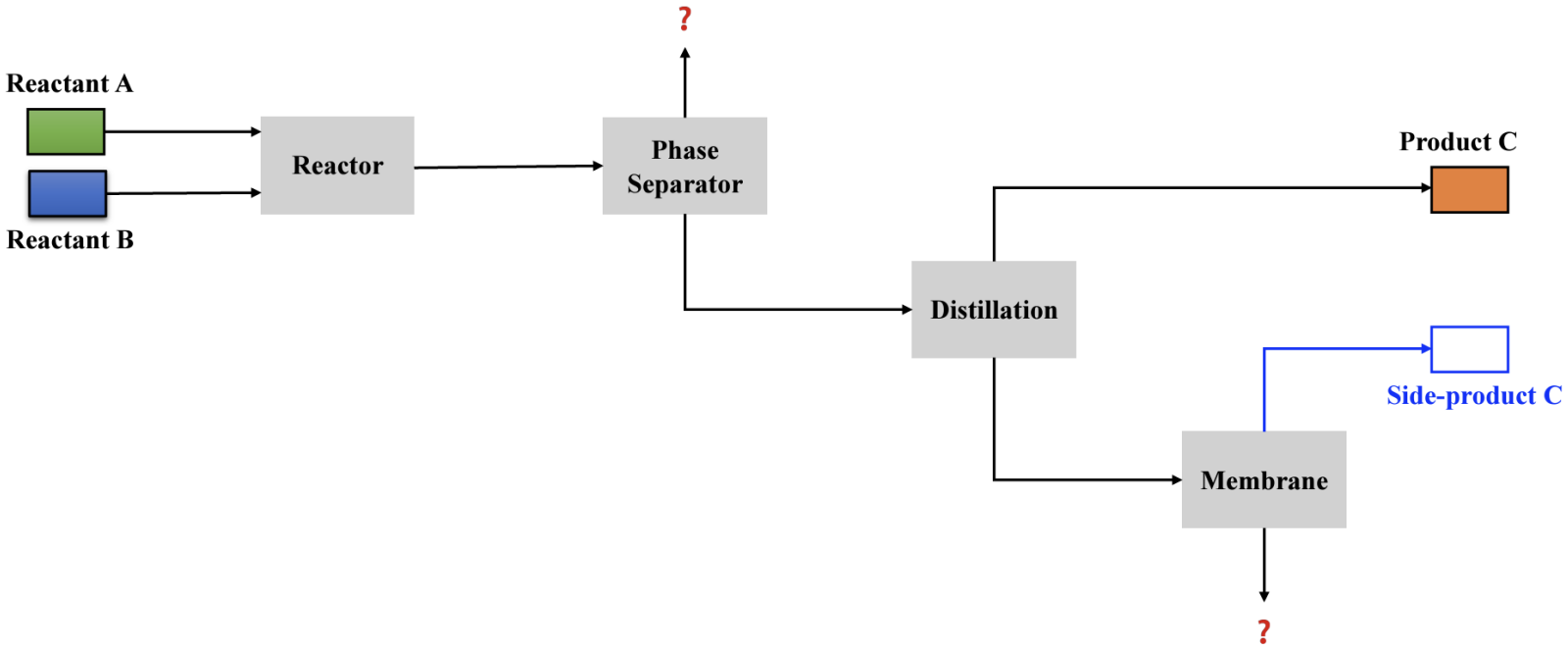
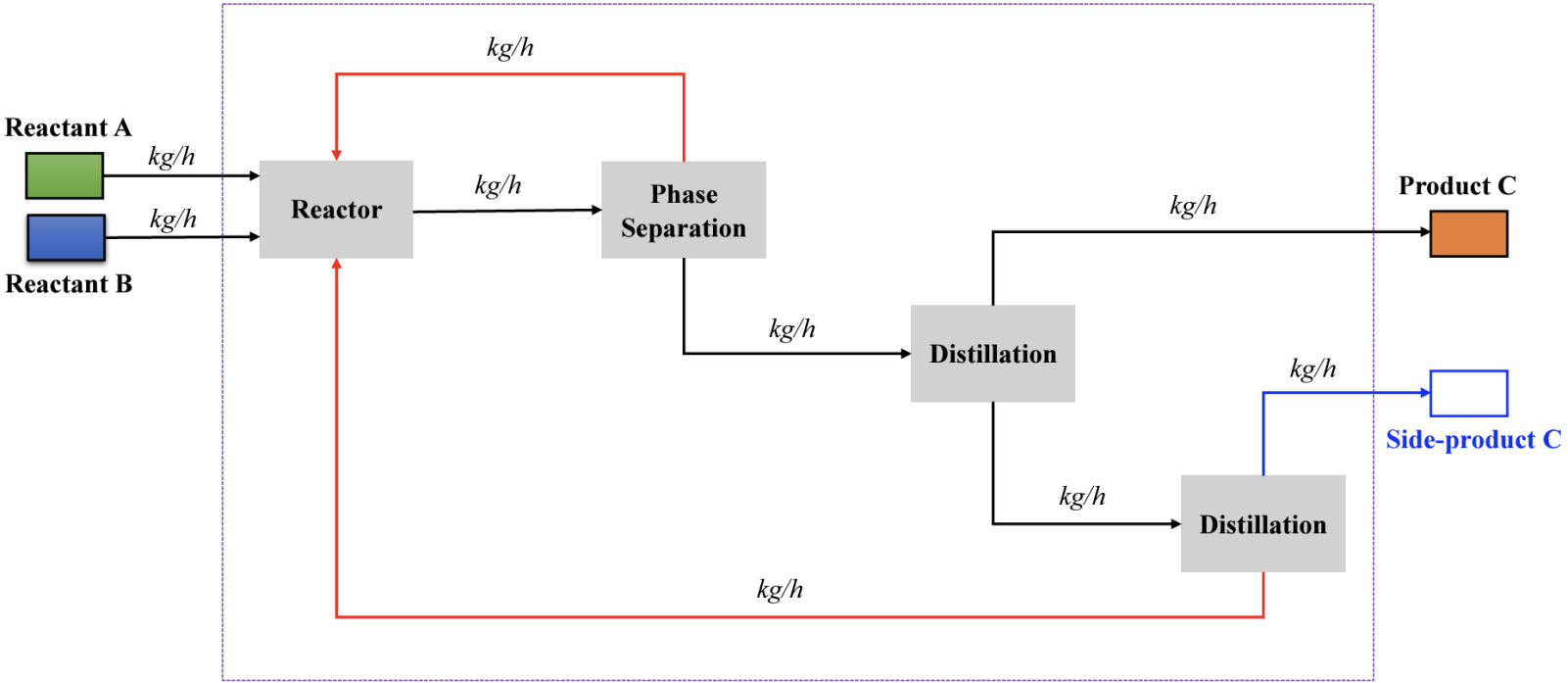
BFD construction



BFD construction



- Flow rates of raw materials, intermediates and products
- Simple mass balance around process boundaries

Conventions and Format Recommended

- **1.** Operations shown by blocks.
- **2.** Major flow lines shown with arrows giving direction of flow.
- **3.** Flow goes from left to right whenever possible (recycles go right to left).
- **4.** Light stream (gases) toward top with heavy stream (liquids and solids) toward bottom.
- **5.** Critical information to the process can also be supplied (e.g. reaction & conversion, operating conditions, emissions, waste treatment)
- **6.** If lines cross, then the horizontal line is continuous and the vertical line is broken (hierarchy for all drawings in this book).
- **7.** Simplified material balance provided.

Turton, Richard, et al. Analysis, synthesis and design of chemical processes. Pearson Education, 2008.

Conventions and Format Recommended

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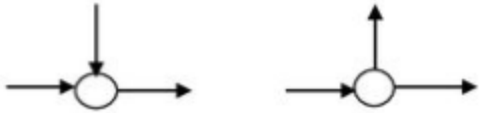
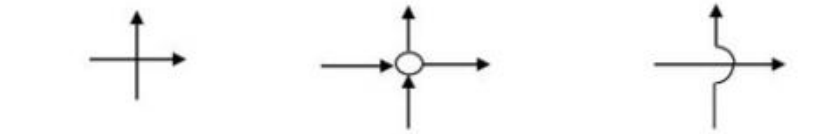
- Mixer and splitter

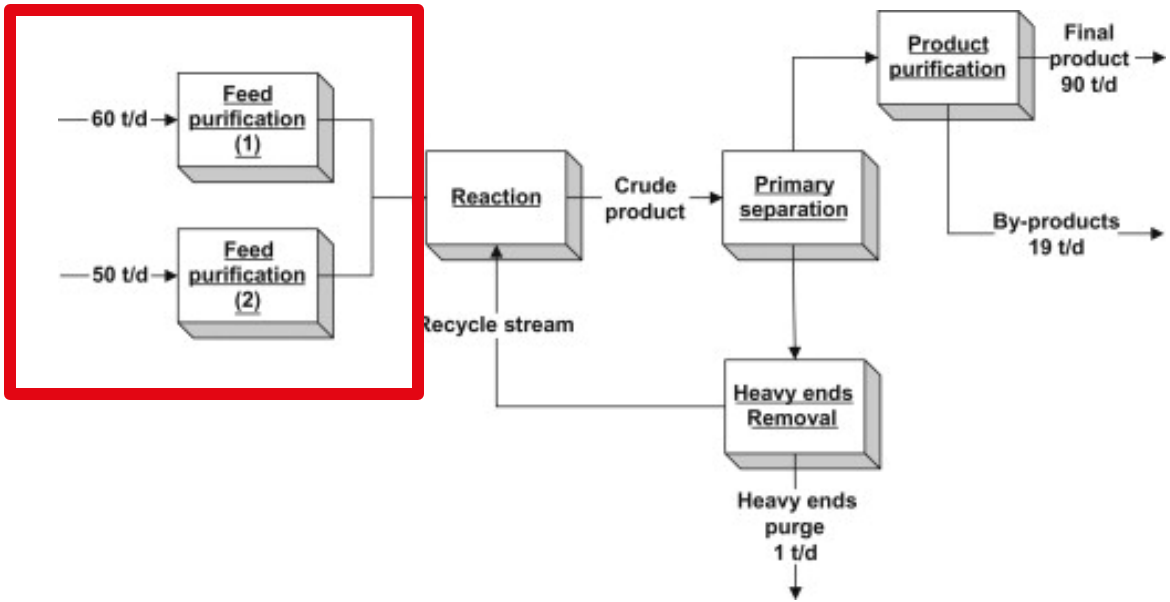


- Avoid crossing streams. If streams must cross, you need to indicate whether they mix or not.



General example of a BFD

- Two feed streams enter the unit. Each is purified; they are then mixed with one another and sent to the reaction section. The material leaving the reaction section—a mixture of product and unreacted feed materials—goes to a separation unit. Product is sent to purification; unreacted feed returns to the reaction section.



Ian Sutton, in Process Risk and Reliability Management (Second Edition), 2015

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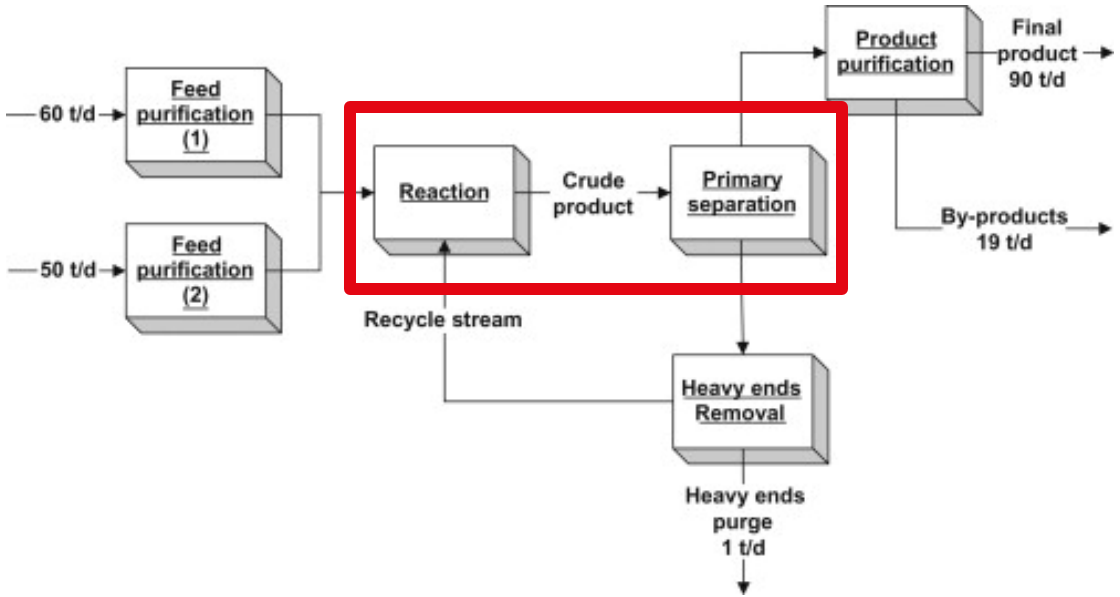

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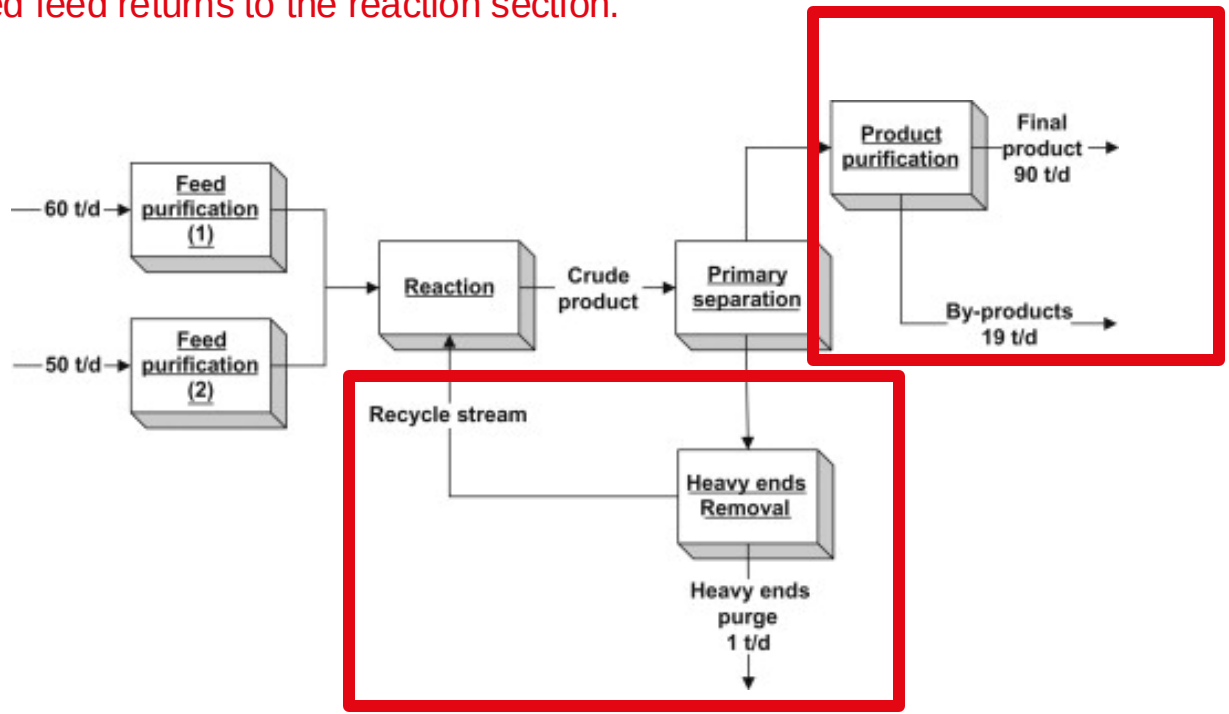

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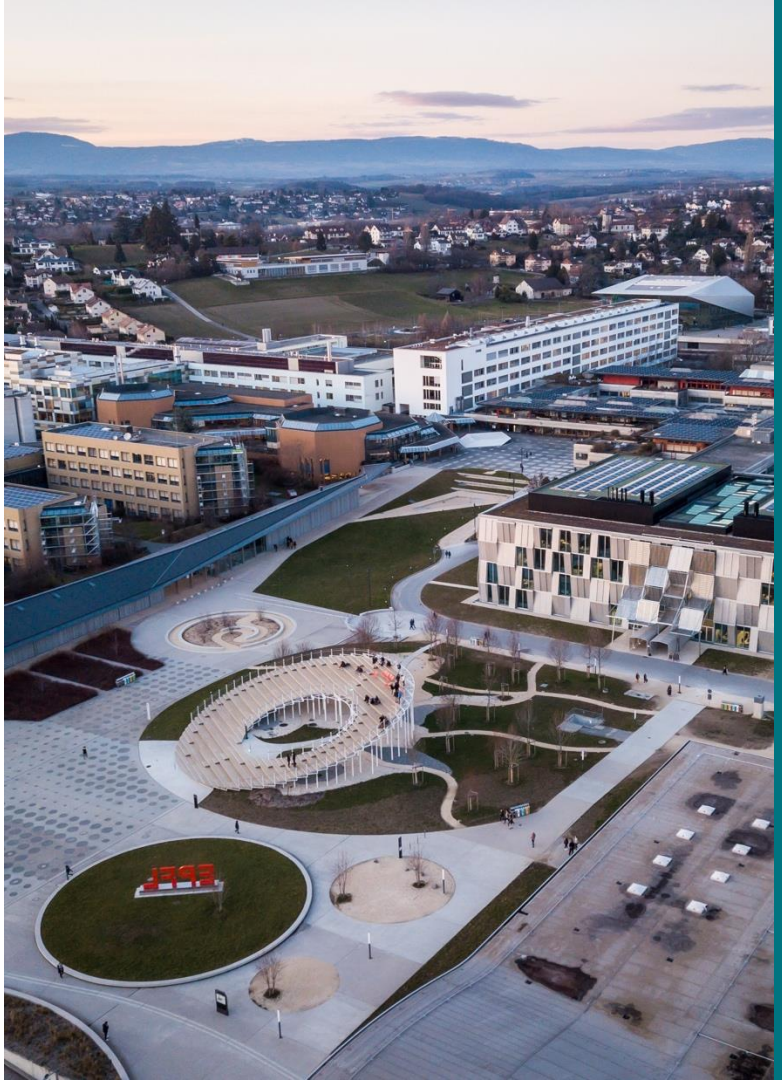


OUTLINE

Overview

Block Flow Diagrams

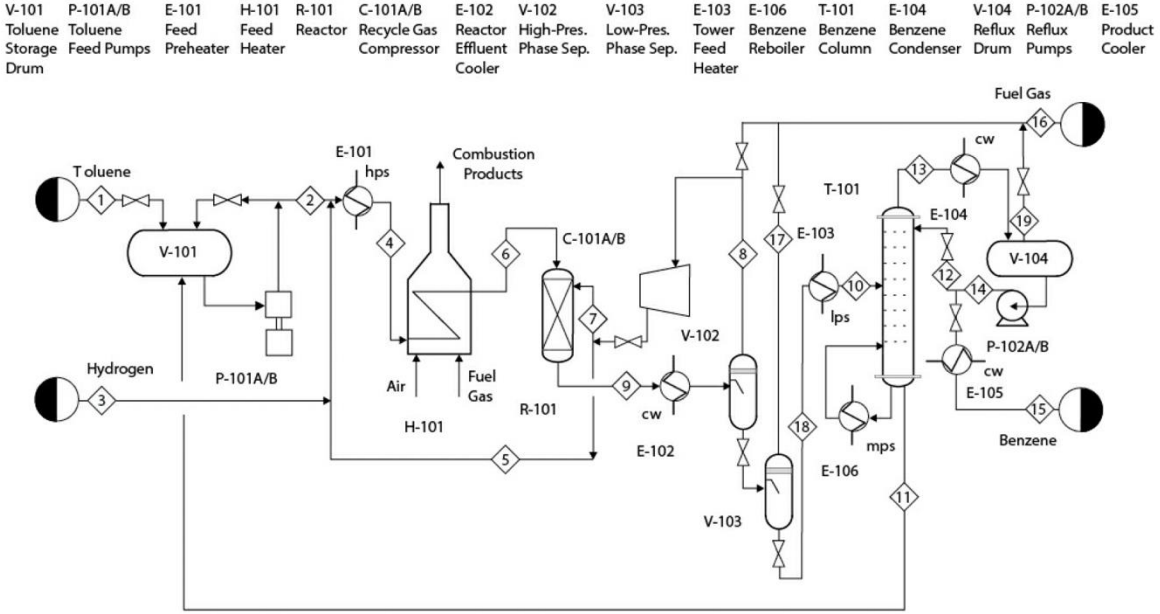
Process Flow Diagrams

Piping & Instrumentation Diagrams

BFD example

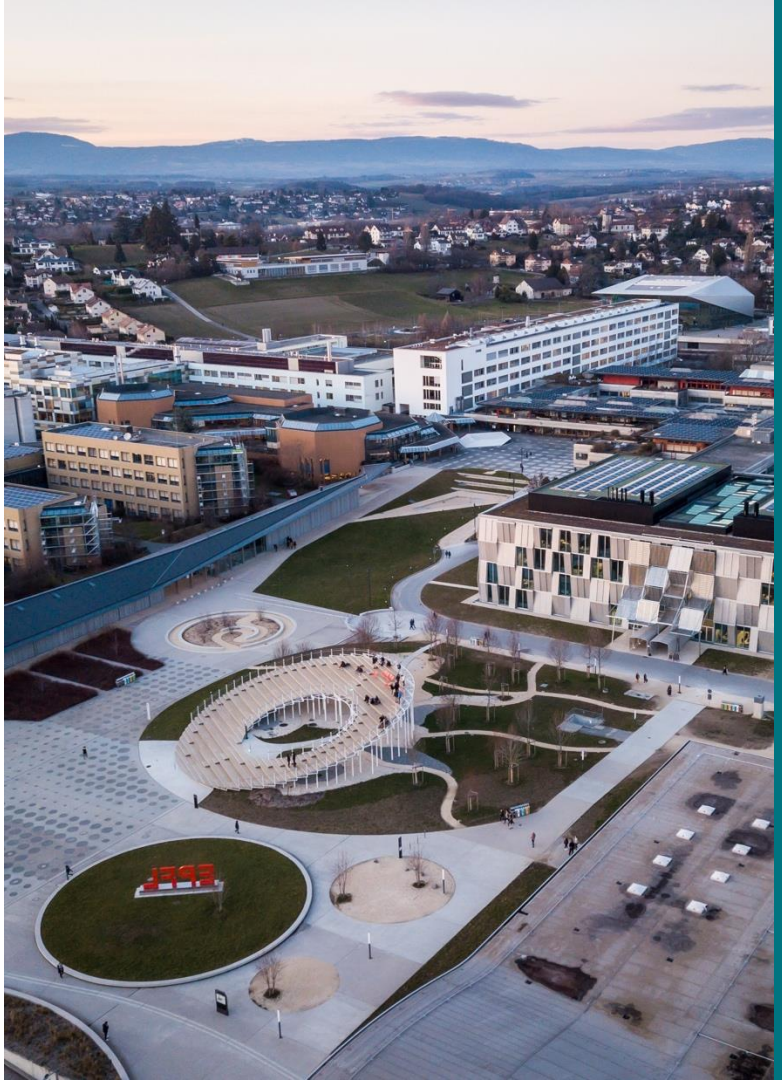
Process flow diagram

- Use of symbols for process streams (raw materials, products) and process units.
- Naming of process streams and process units
- Process streams details: T, P, phase and composition
- Process units details: T, P and catalyst



PFD for the produciton of benzene via the hydrodealkylation of toluene.

Turton, Richard, et al. Analysis, synthesis and design of chemical processes. Pearson Education, 2008.



OUTLINE

Overview

Block Flow Diagrams

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Piping & Instrumentation Diagrams

BFD example

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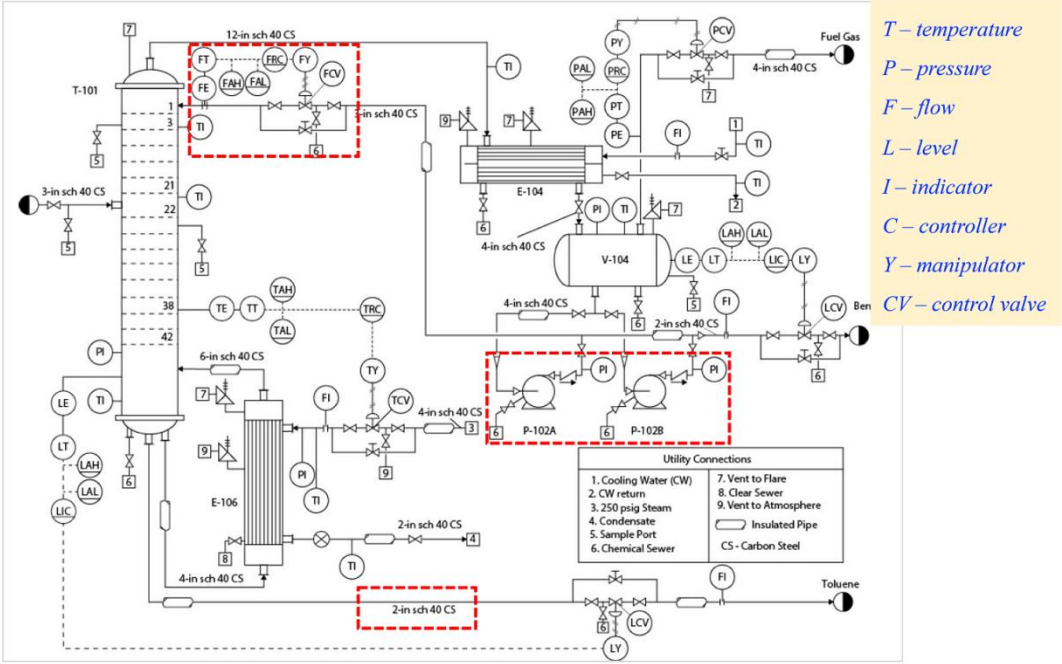
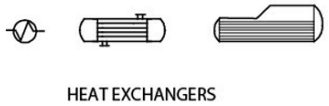
Piping and instrumentation diagram (PI&D)

- Details of piping
  - Size, materials of construction, insulation)
- Details of instrumentation
  - T, P and level measurements
  - Control loops
  - Valves (manual, automated)
  - Drains & vents
- Spare units (A/B)



Turton, Richard, et al. Analysis, synthesis and design of chemical processes. Pearson Education, 2008.

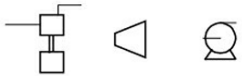
Symbols and Terminologies for PFD and P&ID



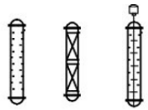
HEAT EXCHANGERS

FIRED HEATER

STORAGE TANKS



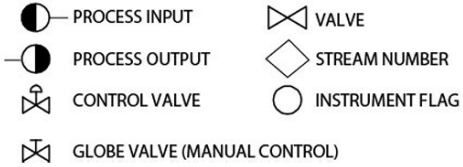
PUMPS, TURBINES, COMPRESSORS

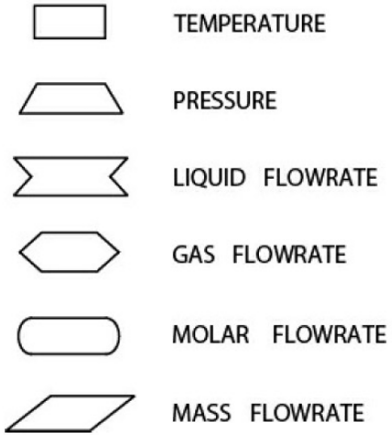


TOWERS

VESSELS

REACTORS





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Process development

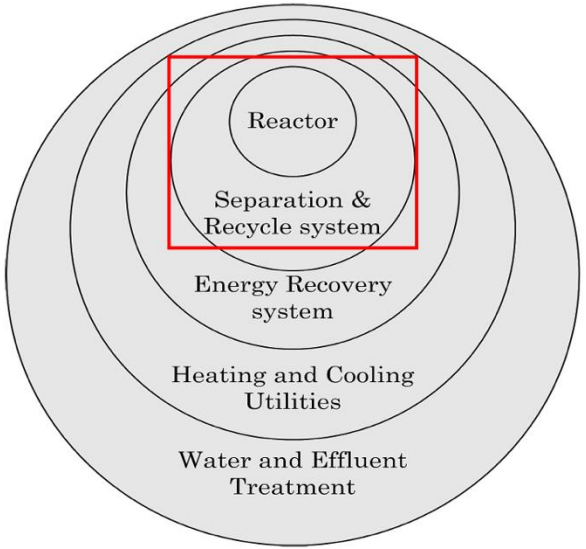
- Selection of raw materials
- Selection of reaction pathway
- Selection of separation units(BFD)

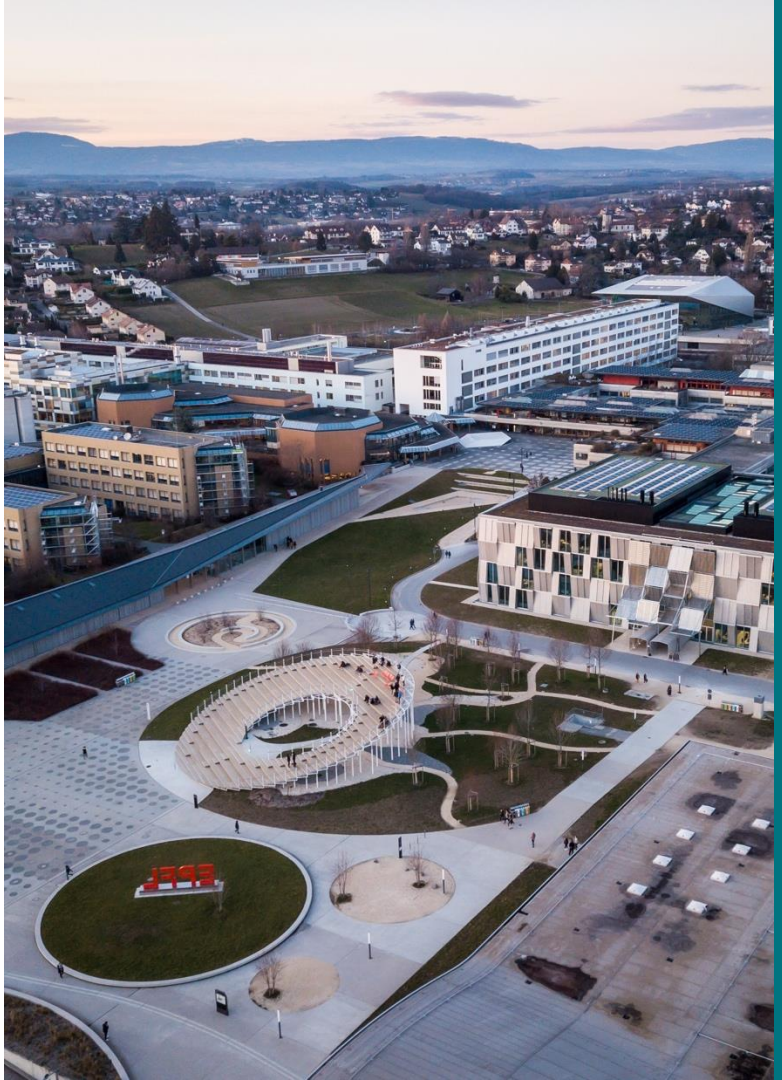
- Mass & energy balances
- Energy integration
- Waste management (PFD)

- Equipment selection & sizing
- Capital and operating costs
- Process control & safety

- Basic engineering (P&I diagram)
- Detailed engineering (Constructions)

- Comissioning & startups





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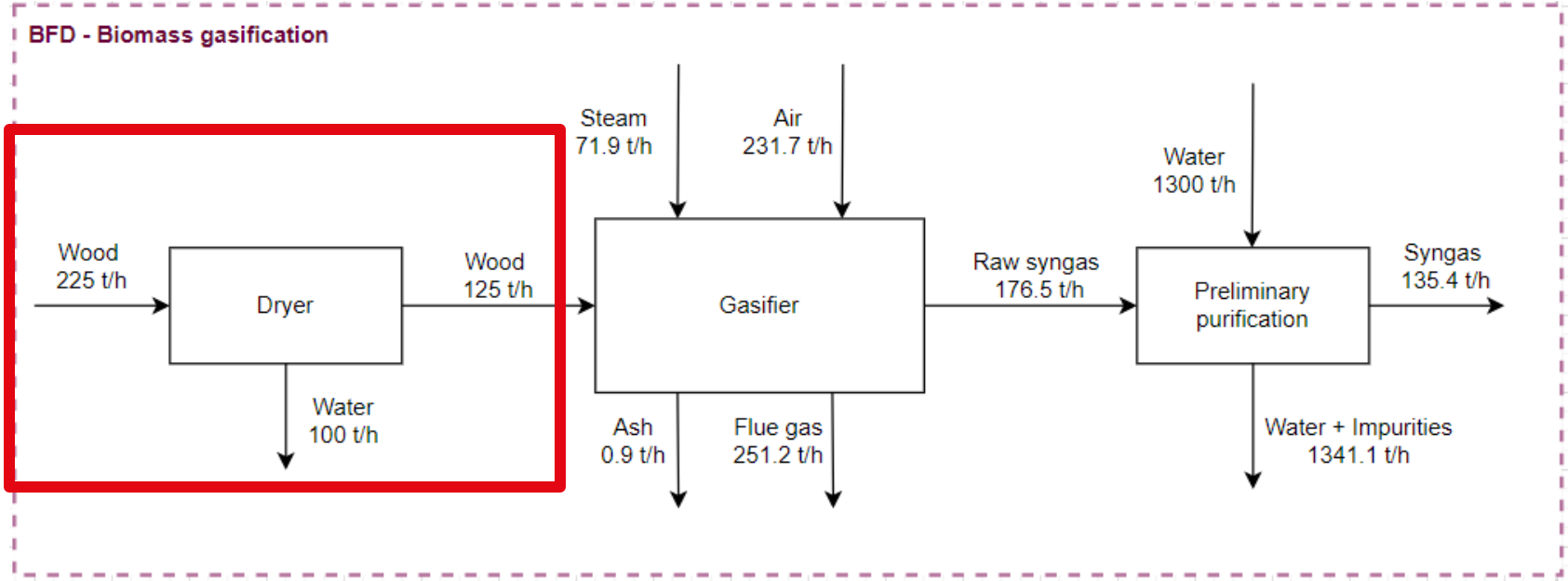
BFD example

Example – biomass gasification

The large moisture content of wood is reduced to about 10% in a rotary dryer. In the gasification step, the carbonaceous materials in the wood are converted into a gaseous mixture called syngas. Steam is used as the gasification medium, whereas the combustion with air of a fraction of the char produced in the wood pyrolysis step supplies the heat required by the endothermic drying, pyrolysis and reduction reactions. After the syngas produced leaves the gasifier it is cooled down and scrubbed with water, in order to remove the impurities that may affect the downstream equipment.



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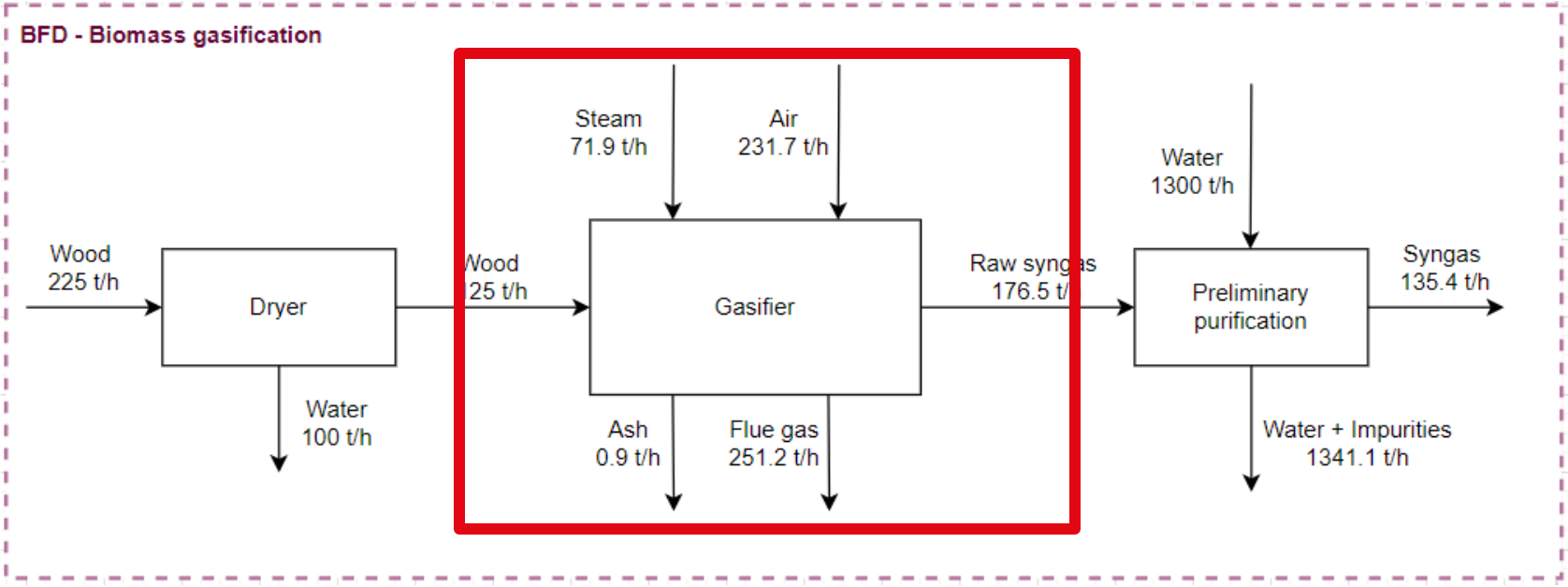

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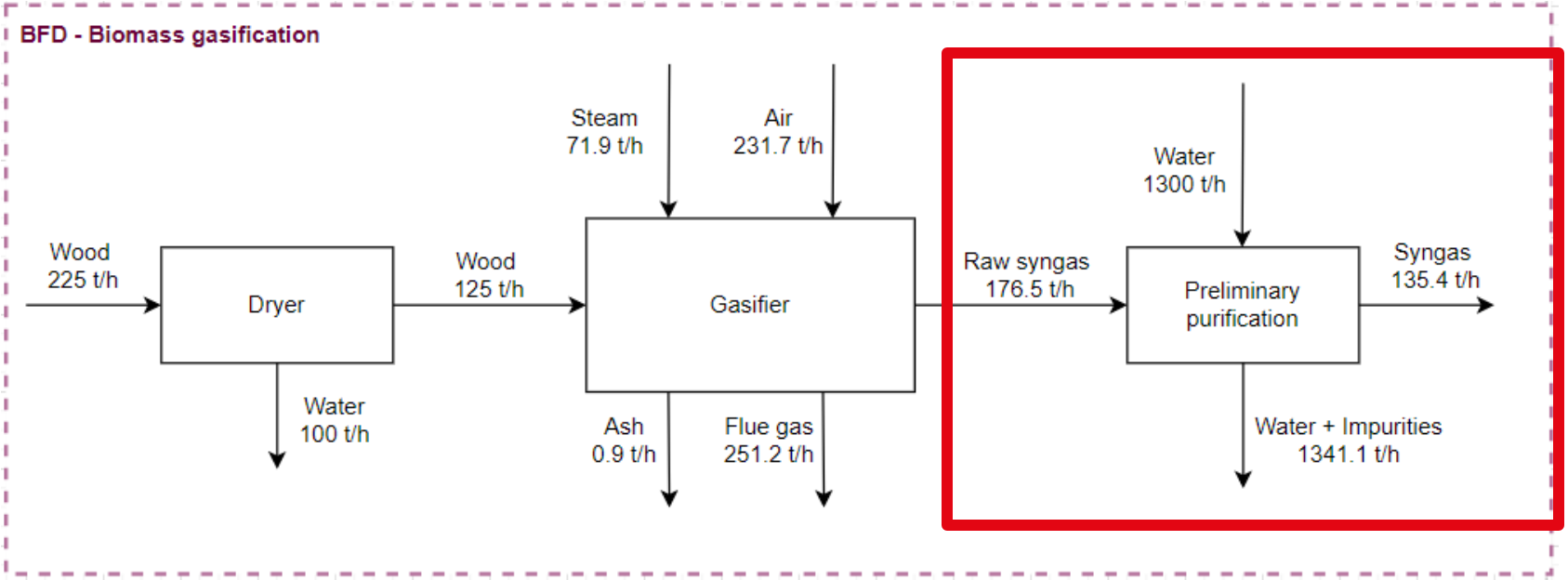

Example – Ammonia synthesis

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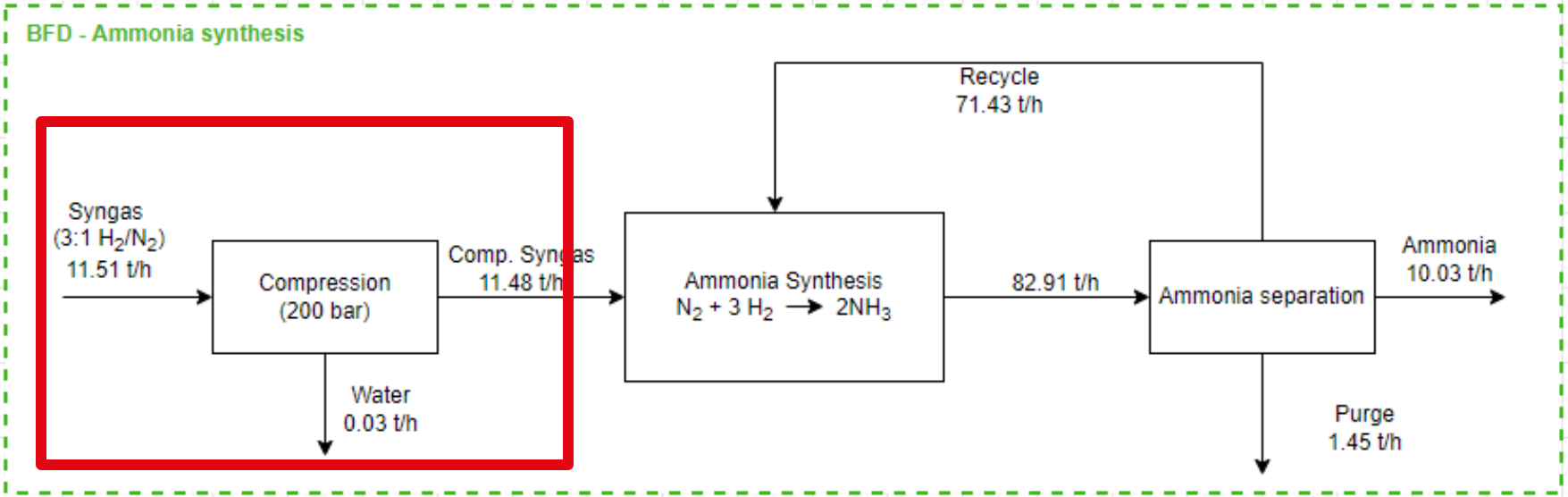
The purified syngas is compressed up to 200 bar and fed to a synthesis loop, where the H2/N2 mixture is partially converted into ammonia through a series of catalytic beds indirectly cooled. The reactor effluent is sent to the separation step, where the ammonia produced is condensed. Moreover, in order to prevent the built up of inerts in the loop, a portion of the hydrogen-rich gas is continuously purged, whereas the rest of the unreacted mixture is recycled to the converter beds.



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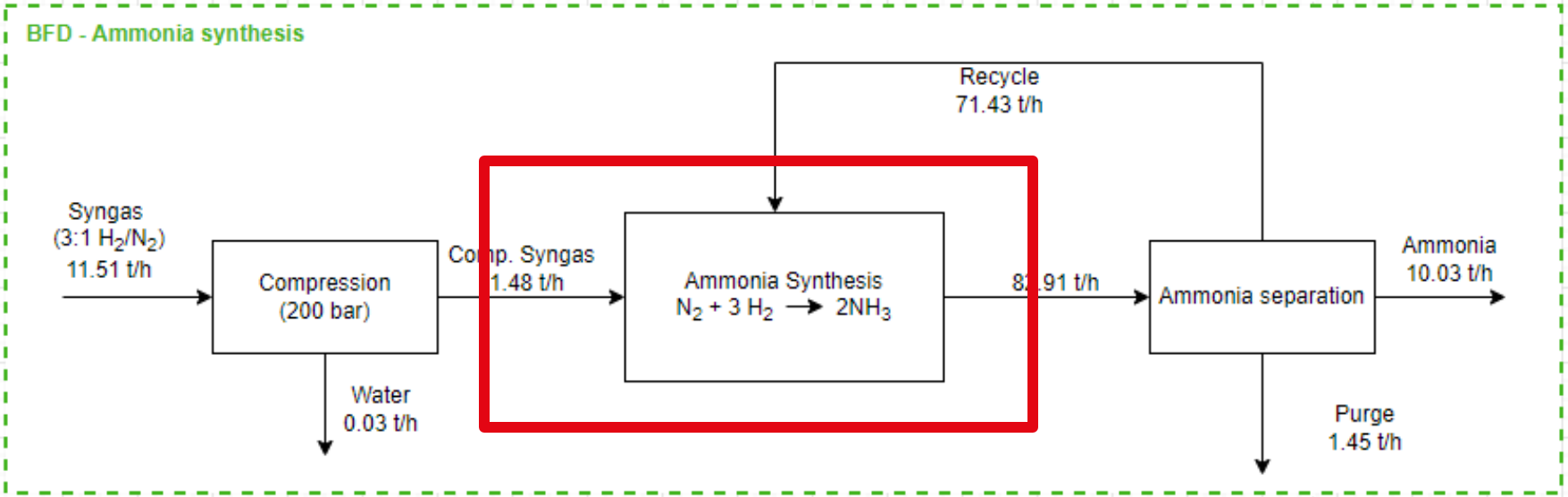

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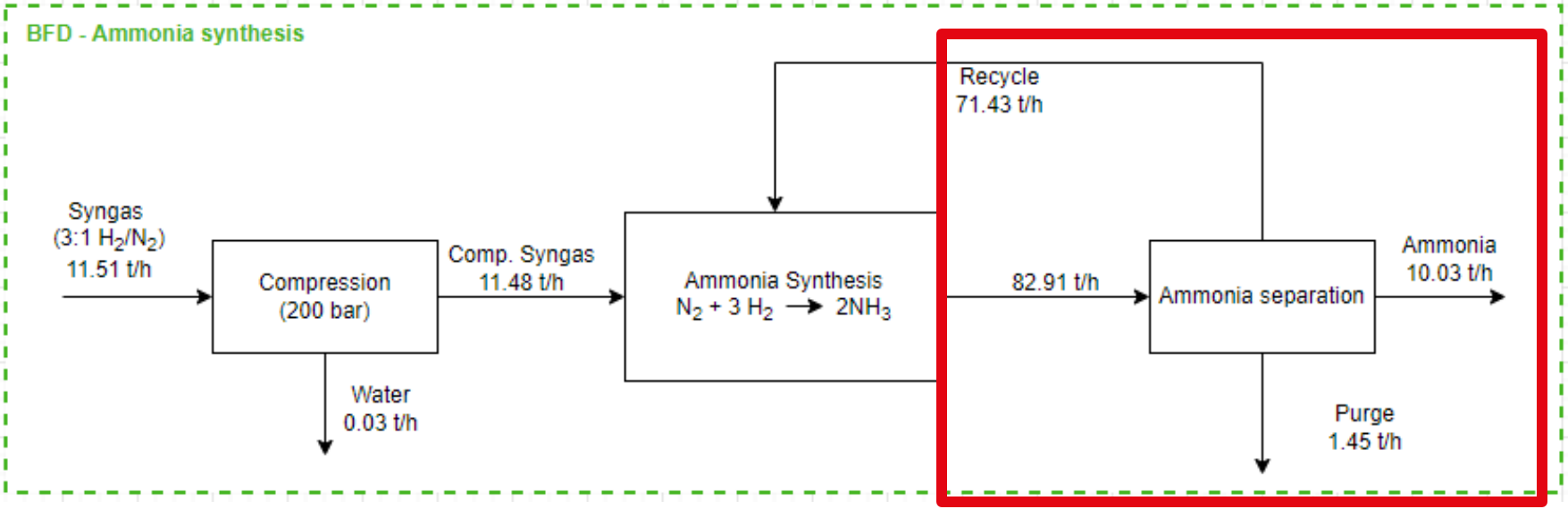

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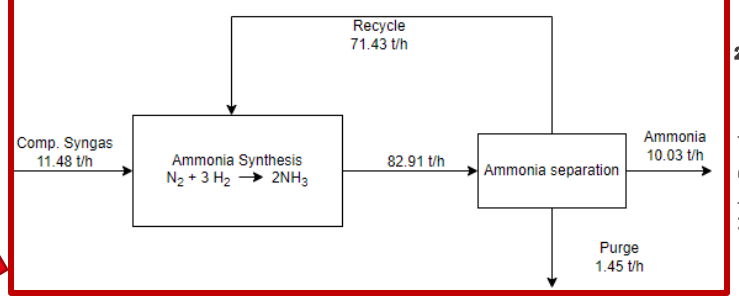

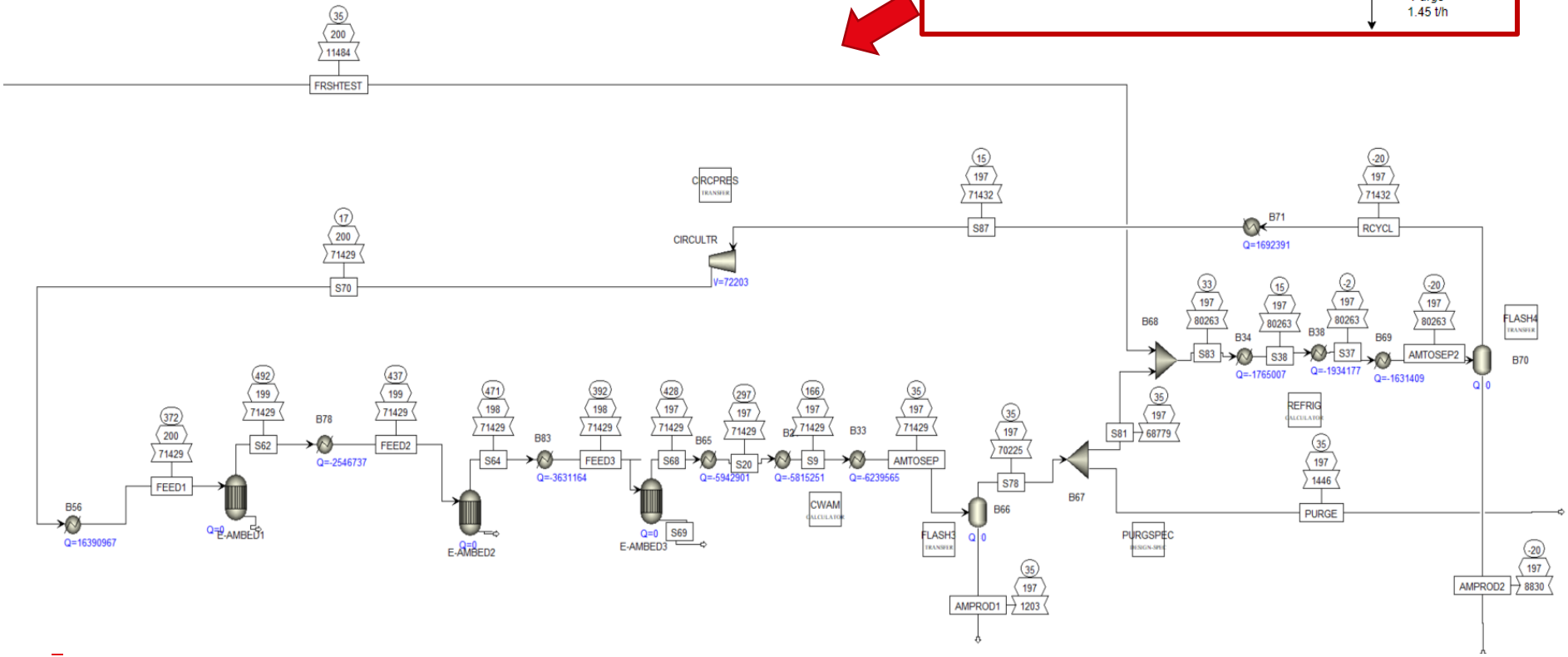

Thank you!

email: meire.ribeirodomingos@epfl.ch