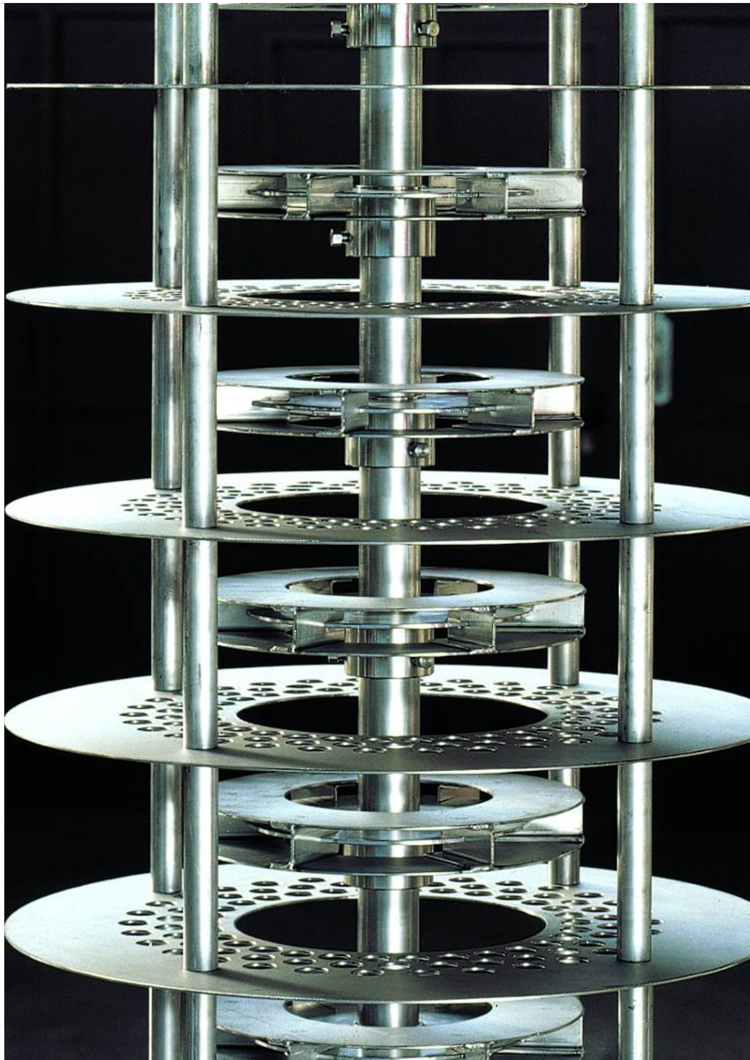
PIN NL Meeting | November 10th 2010 | Utrecht

Sulzer Chemtech

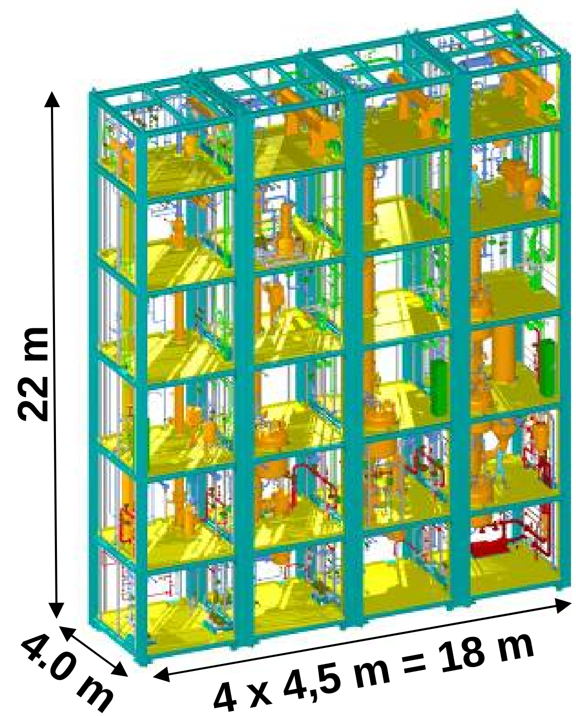
Title: Process Intensification In Real Life

Jeffrey FELIX, | Sulzer Chemtech Ltd. | Process Technology



Presentation overview

- Introduction of Sulzer Chemtech Process Technology
- Process Intensification by combining unit operations
- Concrete PI examples with pervaporation, distillation & crystallization technology



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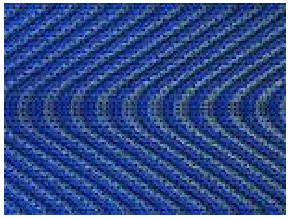
Leadership in Products & Applications

Mass Transfer Technology



Structured packing
Tray Technology

Separators
Demisters

Shell Alliance

Random packing

Tower Field Services

Maintenance, revamps & installation

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Process Technology

Membrane Technology

Crystallization Technology

Hybrid Process Plants

Film Evaporation
L/L-Extraction
Reactive Distillation

Mixpac Systems

Multi-component dosing, mixing and application systems

Process Technology
Global organization

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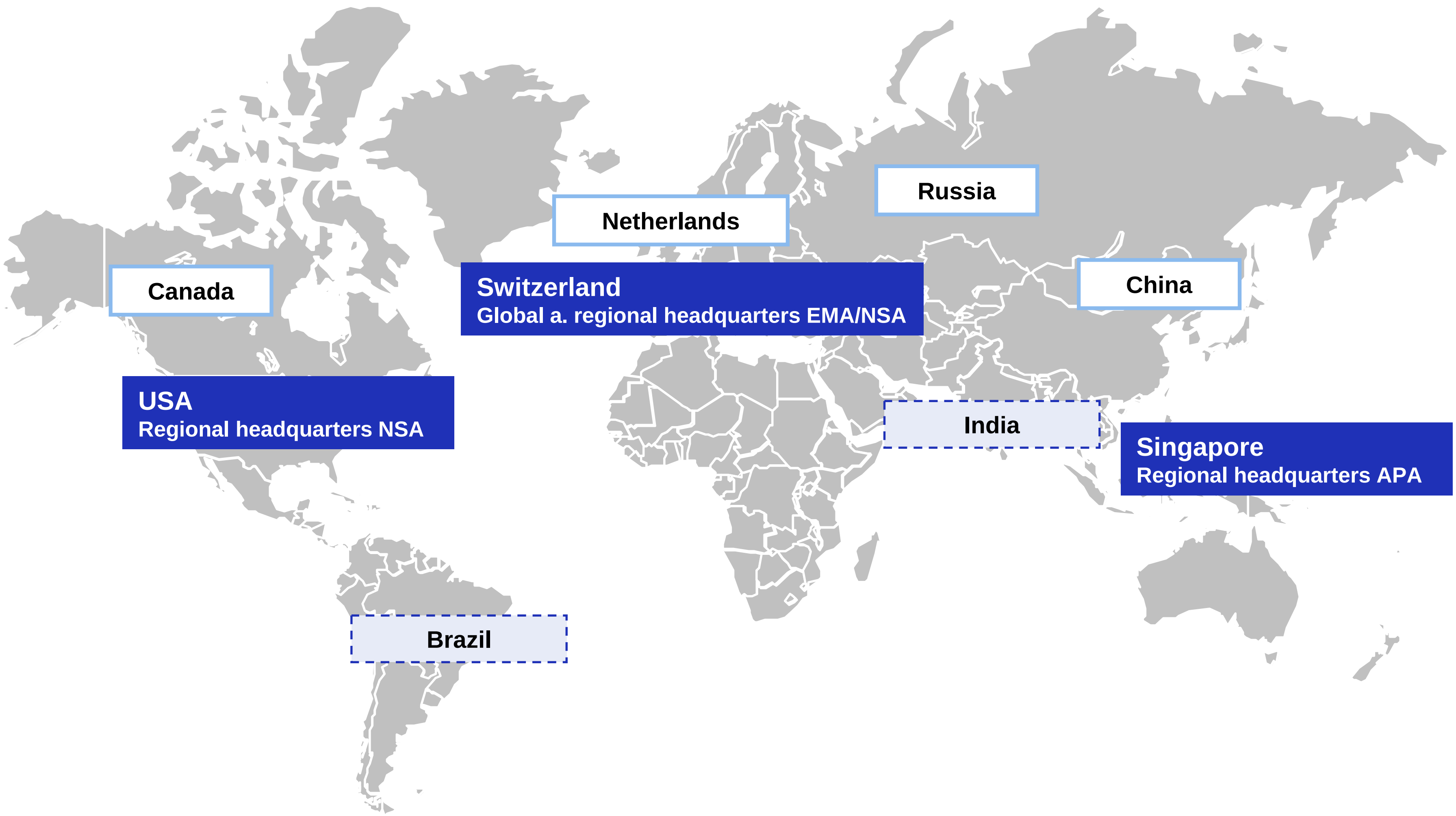

PT locations

PT presence

PT potential expansions

Process Technology
Core activities and markets

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Technologies	Extraction, distillation, crystallization, membrane, evaporation, absorption, polymer & reaction technology
Segments	Fine & specialty chemical, pharmaceutical process industry, food industry, polymer production
Products and services	▪ Engineering services (conceptual, basic & detail) ▪ Customer testing, process validation, production of samples, toll production ▪ Process equipment, modular plants, skids
Process applications	▪ Solvent recovery ▪ Product purification ▪ Hybrid processes and solutions ▪ Temperature sensitive separations ▪ Polystyrene, PLA, EPS
Key success factors	▪ Solving complex and difficult separation problems ▪ Supplying advanced, highly efficient process equipment and complete plants ▪ Extensive experience in combining unit operations

Process Technology
Unit operations, Products and Equipment

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Unique experience in unit operations

- Evaporation
  - Falling film (FFE)
  - Wiped thin film (TFE)
  - Short path (SPE)
- Distillation / rectification
  - Structured packing
  - Random packing
  - Trays
- Liquid / liquid extraction
  - Static columns
  - Stirred columns
- Fractional crystallization
  - Falling film
  - Static system
  - Suspension crystallization
- Membrane systems
  - Pervaporation / vapor permeation
  - Pressure driven membrane solutions




Process Technology
Development competence

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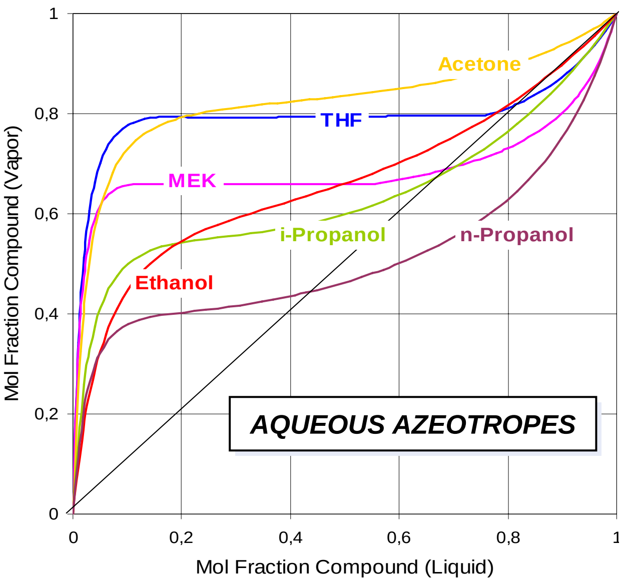
- **Process Engineering Studies**
  - Conceptual design
  - Process optimizations / debottlenecking
  - Process synthesis, development and simulation

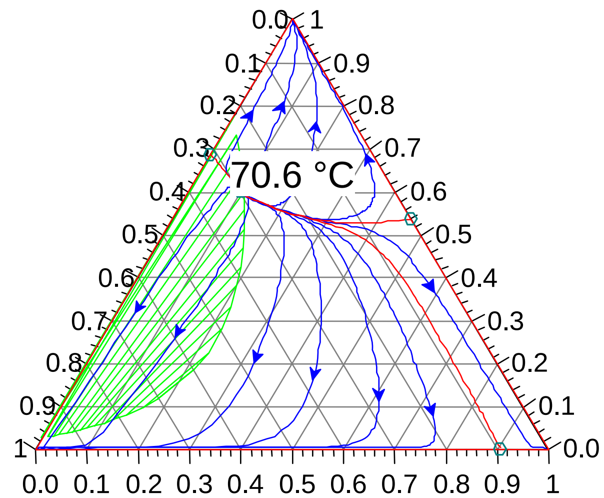
- **Test Centre**
  - Standard laboratory and pilot equipment for development, pilot and toll processing
  - Testing and validation of distillation, absorption, crystallization, liquid-liquid extraction, film evaporation and membrane processes as well as reaction, devolatilization and mixing tests for polymeric systems

- **Process- & Basic Engineering**
  - Process design, simulation, PFD
  - P&ID, Basic Engineering



Process Technology
Hybrid Approach

- Screening of possible unit operations
  - Experience / reference units / plants
  - In house know how
  - Literature / databases
  - Process simulation
  - Bench scale feasibility tests for promising unit operation



- Combination of unit operations to most cost effective hybrid process
- Validation
  - Process simulation
  - Pilot scale tests / sample generation
- Basic Engineering
- Detail Engineering
- Supply of (key)equipment or skid mounted unit
- Commissioning of turn key hybrid system

Hybrid Processes
Features of specific unit operations

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Distillation

- Robust process with high mass transfer rates in liquid and vapor phase
- Phase separation is rapid and complete

Crystallisation

- Separation at low (melting) temperatures
- Separation of mixtures with close boiling components
- Very high specific purification is possible

Liquid-Liquid-Extraction

- Low temperature selective separation @ at mostly ambient pressure
- High throughput @ low energy consumption

Vapour permeation / Pervaporation

- Independent of vapor–liquid equilibrium
- Direct solvent dehydration of azeotropics and close-boilers without entrainer

Pressure driven membrane (UF/NF/RO)

- No phase transition leads to low energy demand
- Separation based on molecule size

Hybrid Processes and application examples
Reactive Distillation

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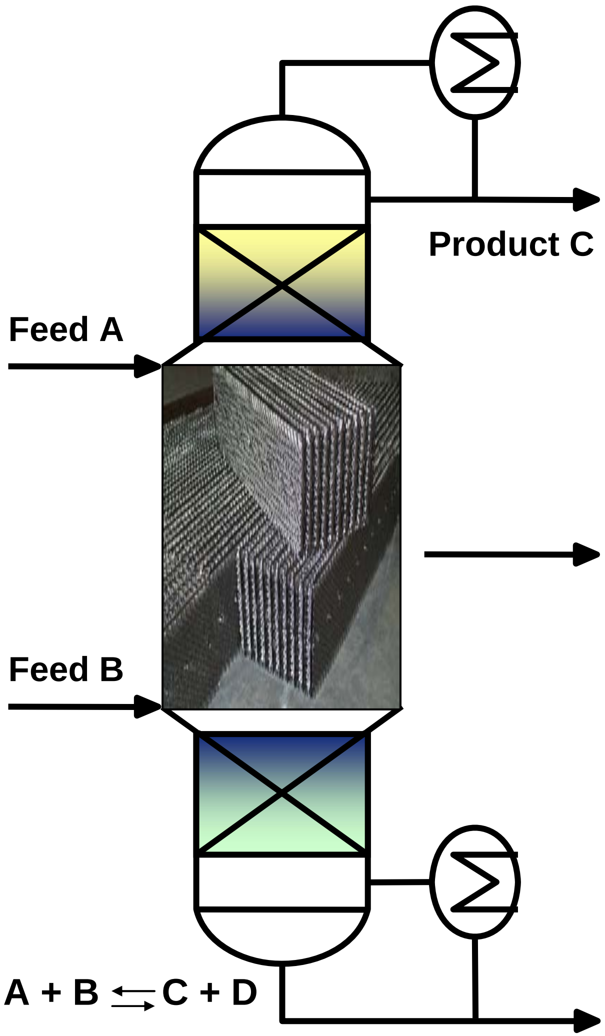
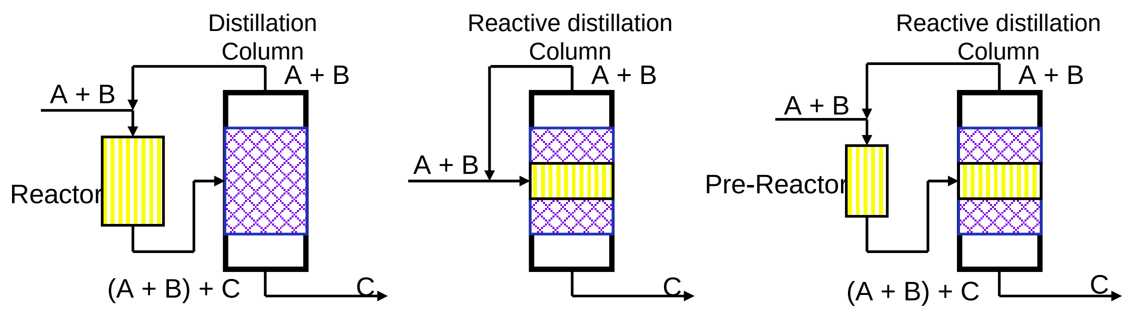


Combine Reaction and Separation in *ONE* Column



Conventional Flowsheet for Reactor and Distillation

Reactive Distillation Flowsheet

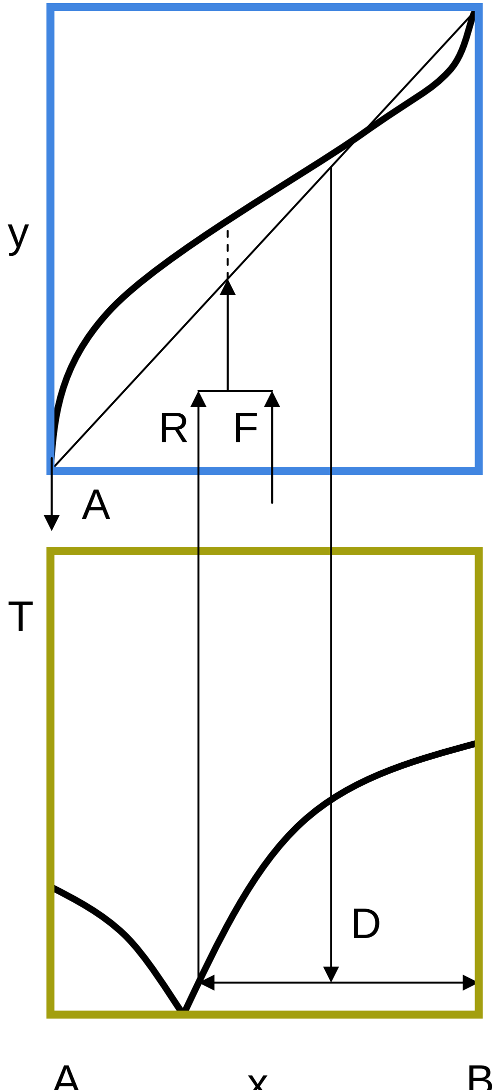
Reactive Distillation with Pre-Reactor

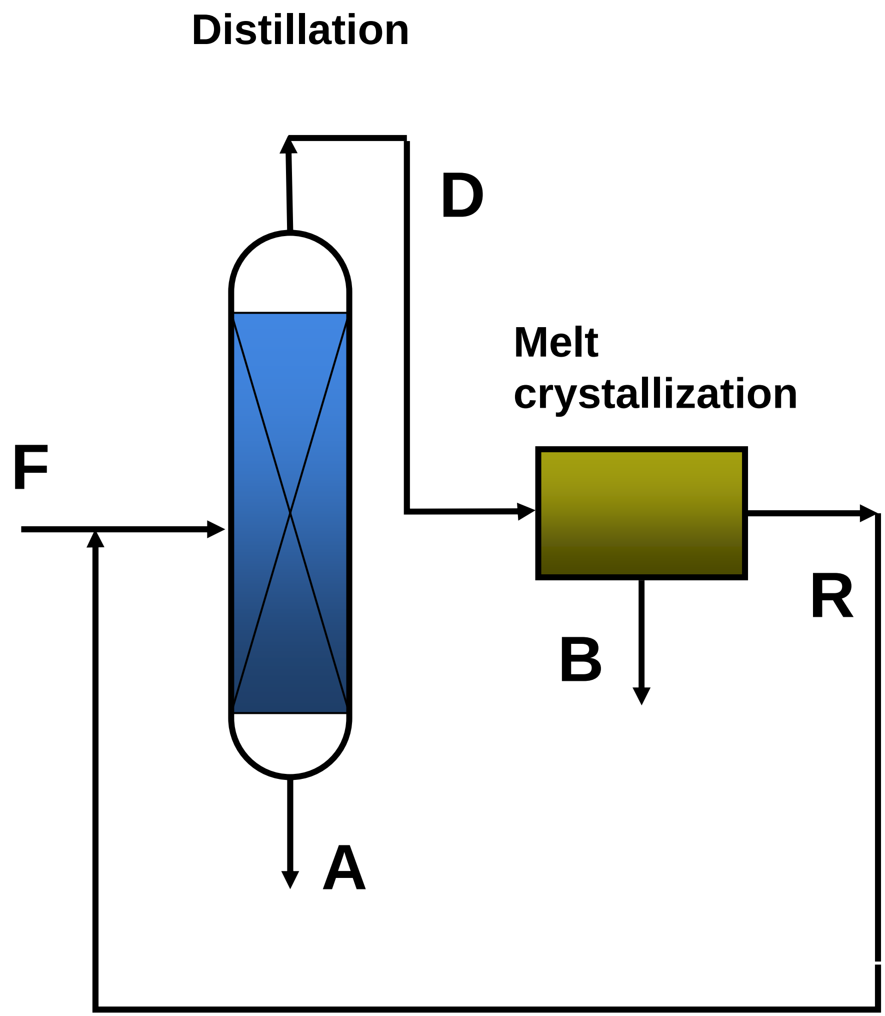
Reactive Distillation Processes

- **Acetate Technology**
  - Synthesis of Methyl, Ethyl & Butyl Acetate
  - Hydrolysis of Methyl Acetate
- **Acetalisation**
  - Synthesis of Methylal
  - Removal methanol from Formaldehyde
- **Fatty Acid Esters**

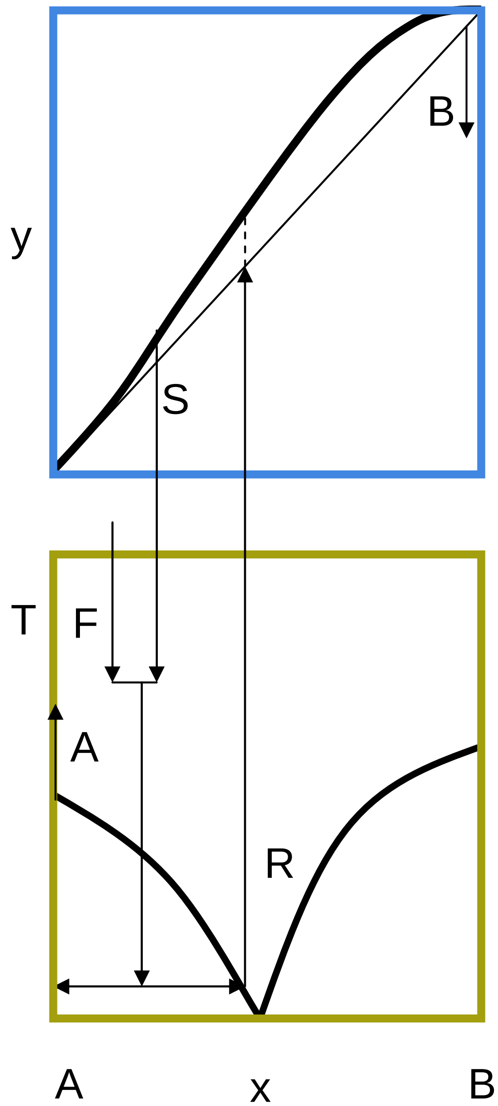
Hybrid Processes
Crystallization and Distillation I

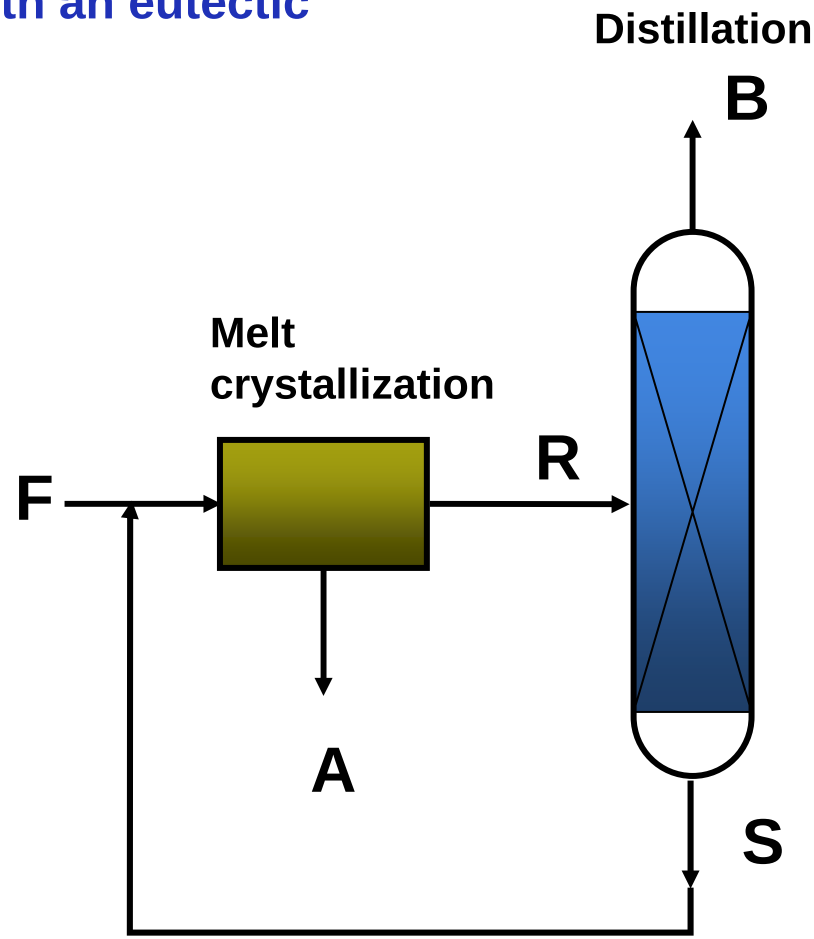
Separation of a binary mixture with eutectic and azeotrope





Separation of a binary mixture with an eutectic





Hybrid Application Examples
Crystallization and Distillation

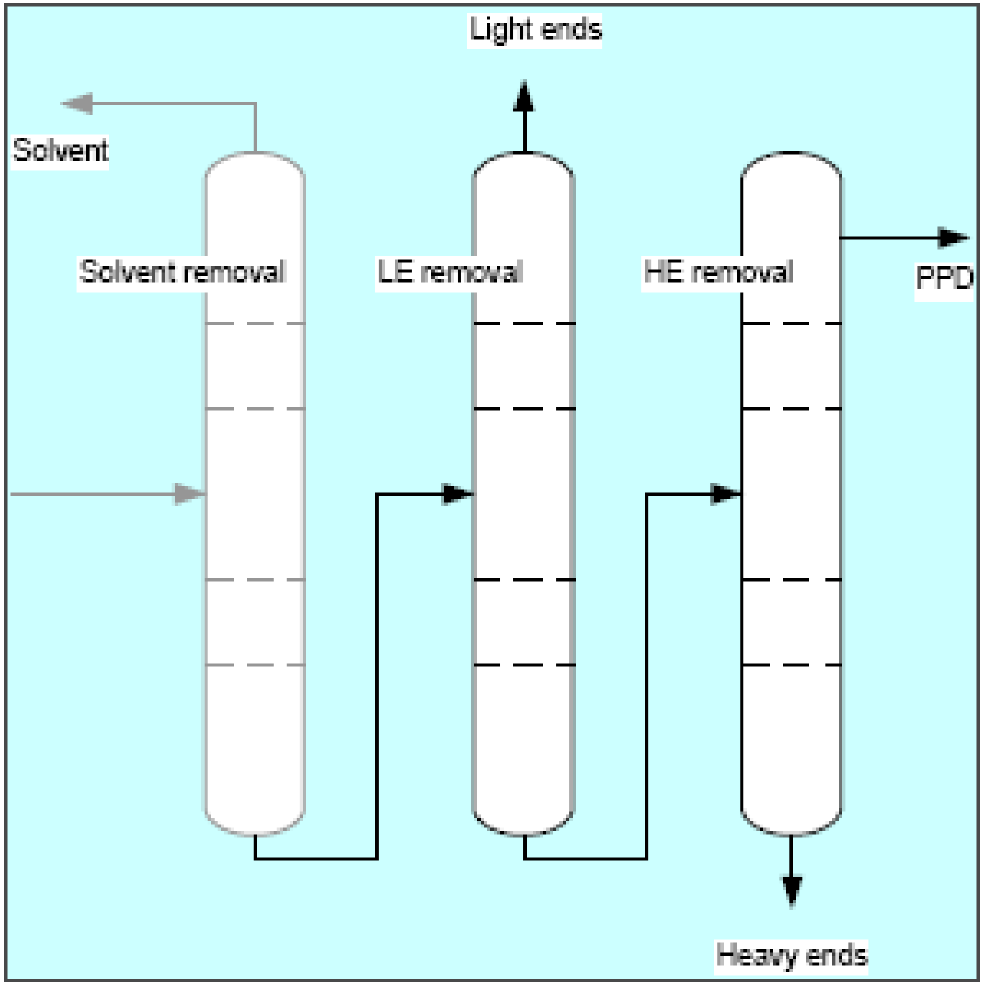
KEY APPLICATIONS

- (ultra) high purities
- color / odor removal
- isomer separation

APPLICATION EXAMPLES

- Dichlorobenzene Isomer Separation
- Nitrochlorobenzene Isomer Separation
- Nitrotoluene Isomer Separation
- Chlorotoluene Isomer Separation
- Meta-Xylene Purification with Ethylbenzene as byproduct
- MDI Isomer Separation and Purification
- Bisphenol A Purification
- Caprolactam Purification
- DMT Purification
- Trioxane
- Monochloroacetic Acid
- High Purity Benzoic Acid
- Glacial Acrylic Acid
- Glacial Lactide
- Naphthalene Purification
- Para-tert. Butylphenol Purification
- Anthracene/Carbazole Separation and Purification

Hybrid processes Crystallization and Distillation
Application example



Lay-out before extension

Hybrid processes Crystallization and Distillation
Application example

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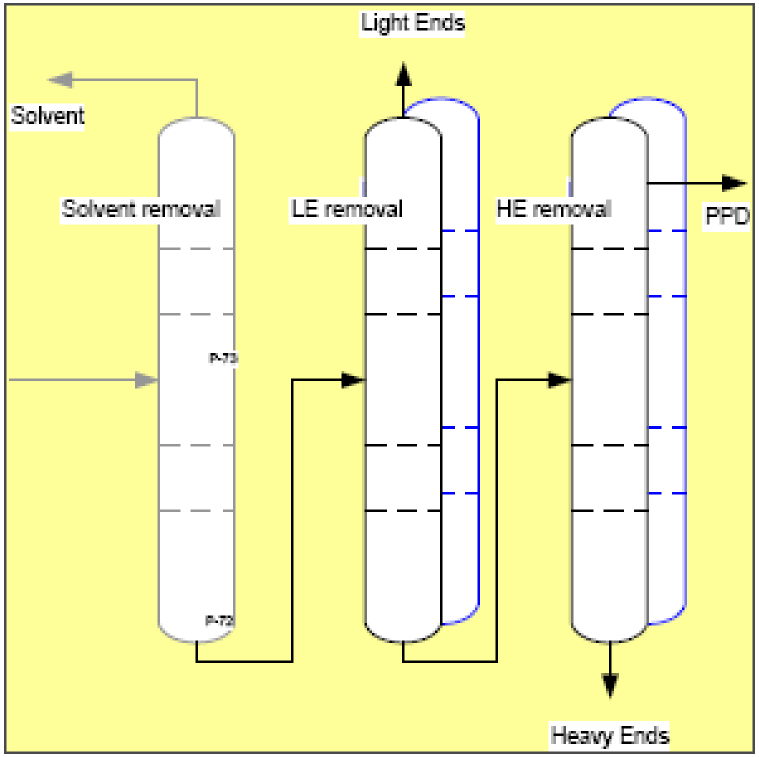
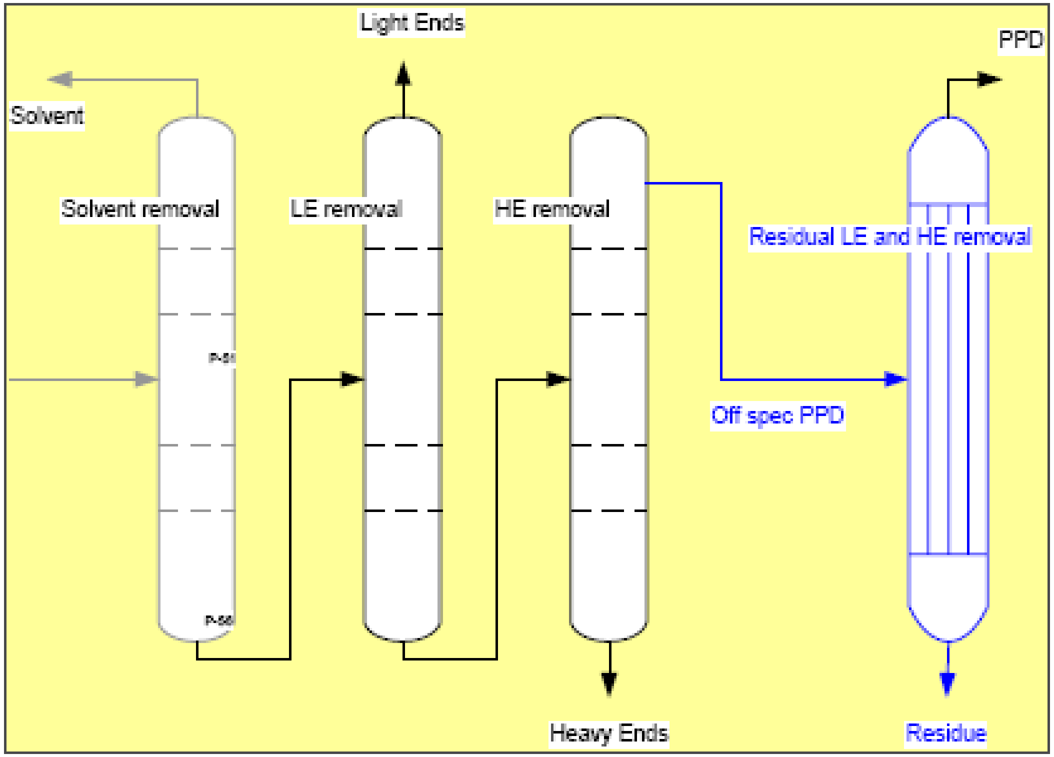
Conventional option



Hybrid option



Expansion scenario’s

Hybrid processes Crystallization and Distillation
Pro’s & con’s: why melt-crystallization?

DISTILLATION

- general applicable (if volatile)
- proven technology
- engineering correlations available
- known technology at customer
- lab & pilot units available

However

- high operating temperature (boiling point >> degradation)
- energy intensive
- limited purity (VLE depending)
- isomer separation difficult
- close-boilers difficult to separate

CRYSTALLIZATION

- applicable for product
- proven, but ‘innovative’ technology
- confirmation pilot tests needed
- new technology for customer
- lab & pilot units available

- lower operating temperature (melting-point >> no side reactions)
- lower energy consumption
- high purity (limited by eutectic point)
- no problem with isomer, close boilers or azeotropic separation

Hybrid processes Crystallization and Distillation
Application example

Summary:

- Yield for crystallization of impure mixtures is poor due to phase diagram limitation of the product system
- Crystallization from impure mixtures requires multistage operation that leads to larger equipment and higher energy demand
- Distillation can, at relatively low energy demand, separate the bulk of impurities easily
- Combining the strong points leads to an ideal basis for a hybrid solution and a lower investment @ lower energy consumption
- RESULT : **HYBRID OPTION CHOSEN AND INSTALLED**

Debottlenecking (Base Case*)
Isopropanol Entrainer (azeotropic) Distillation

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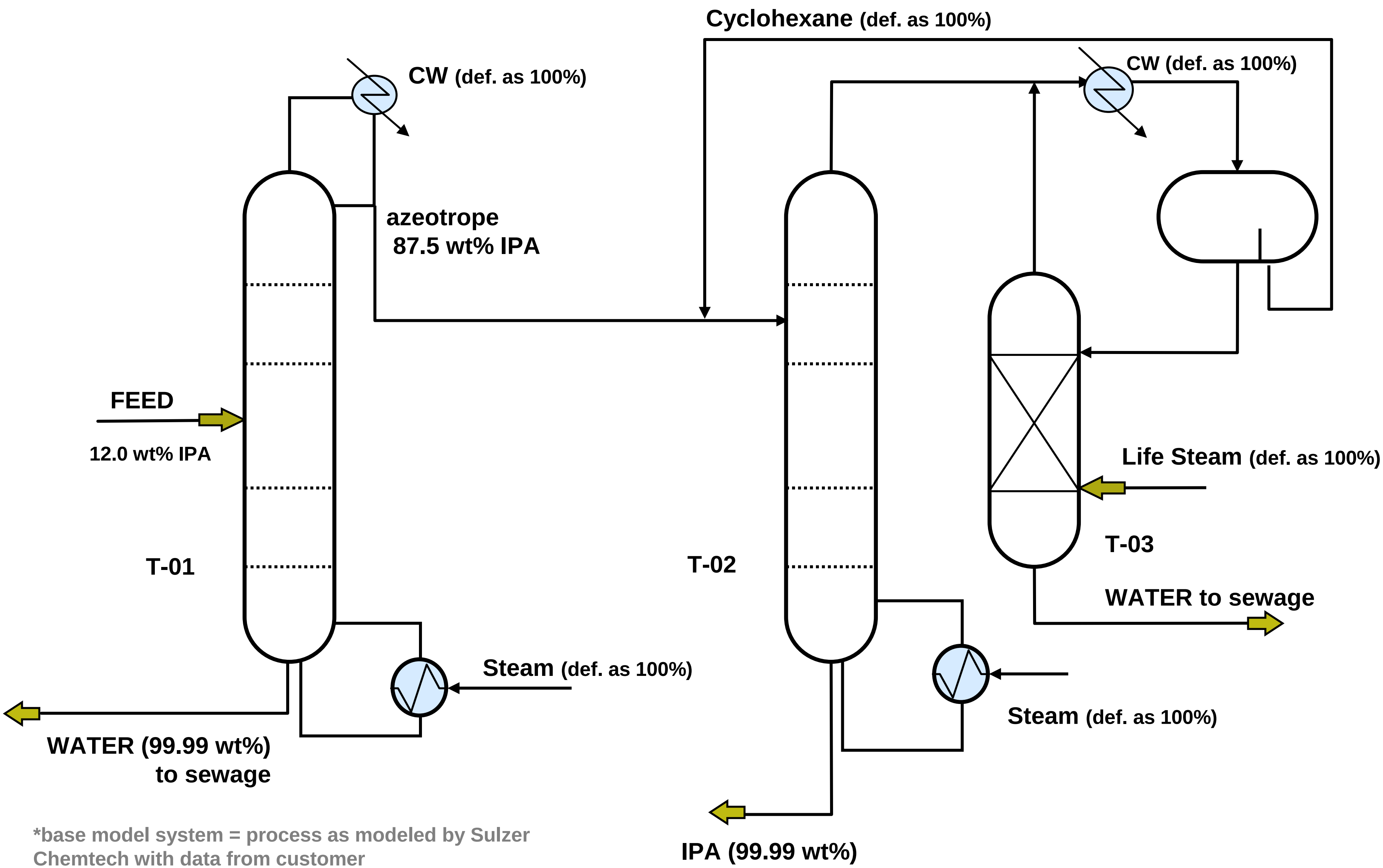
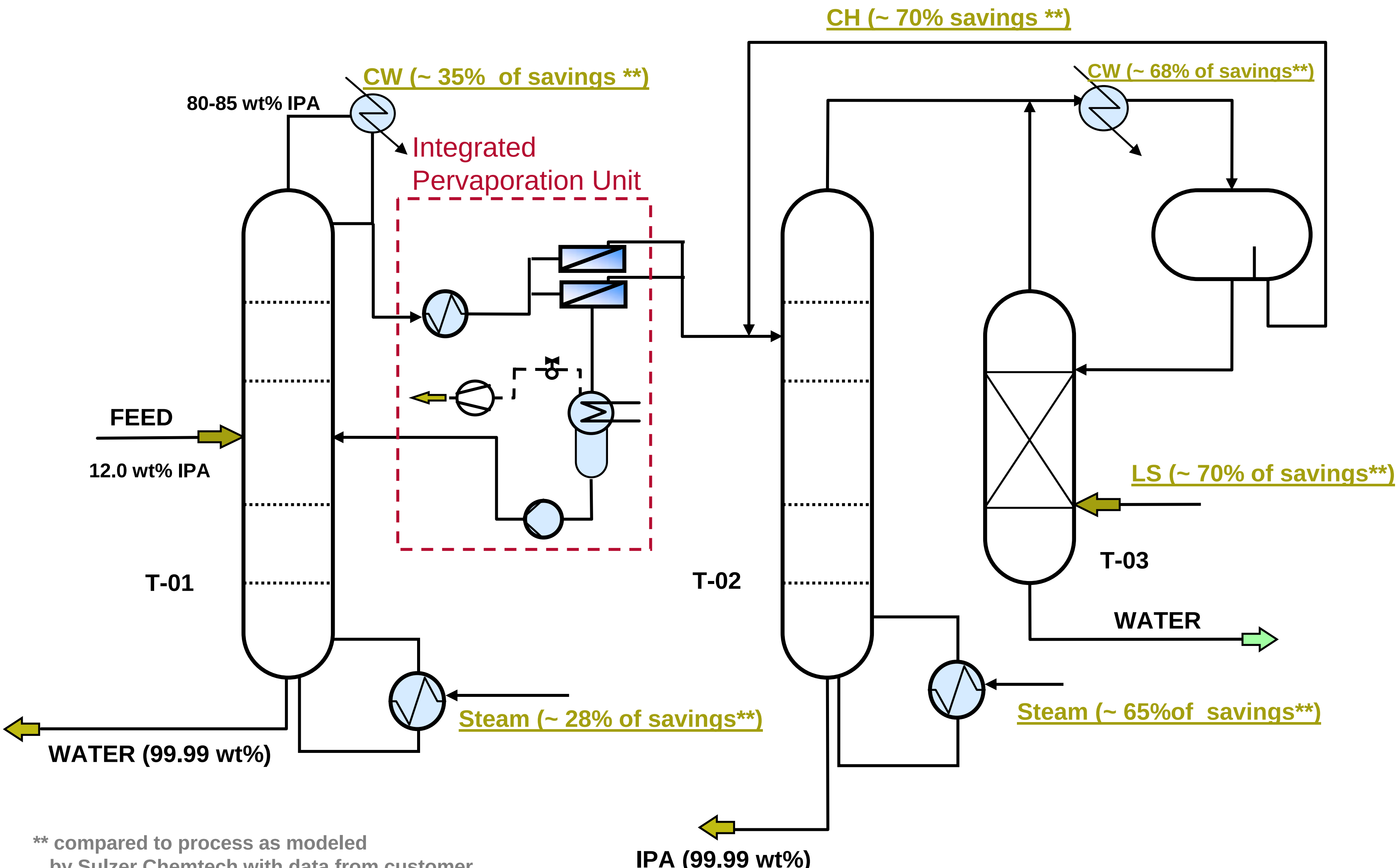


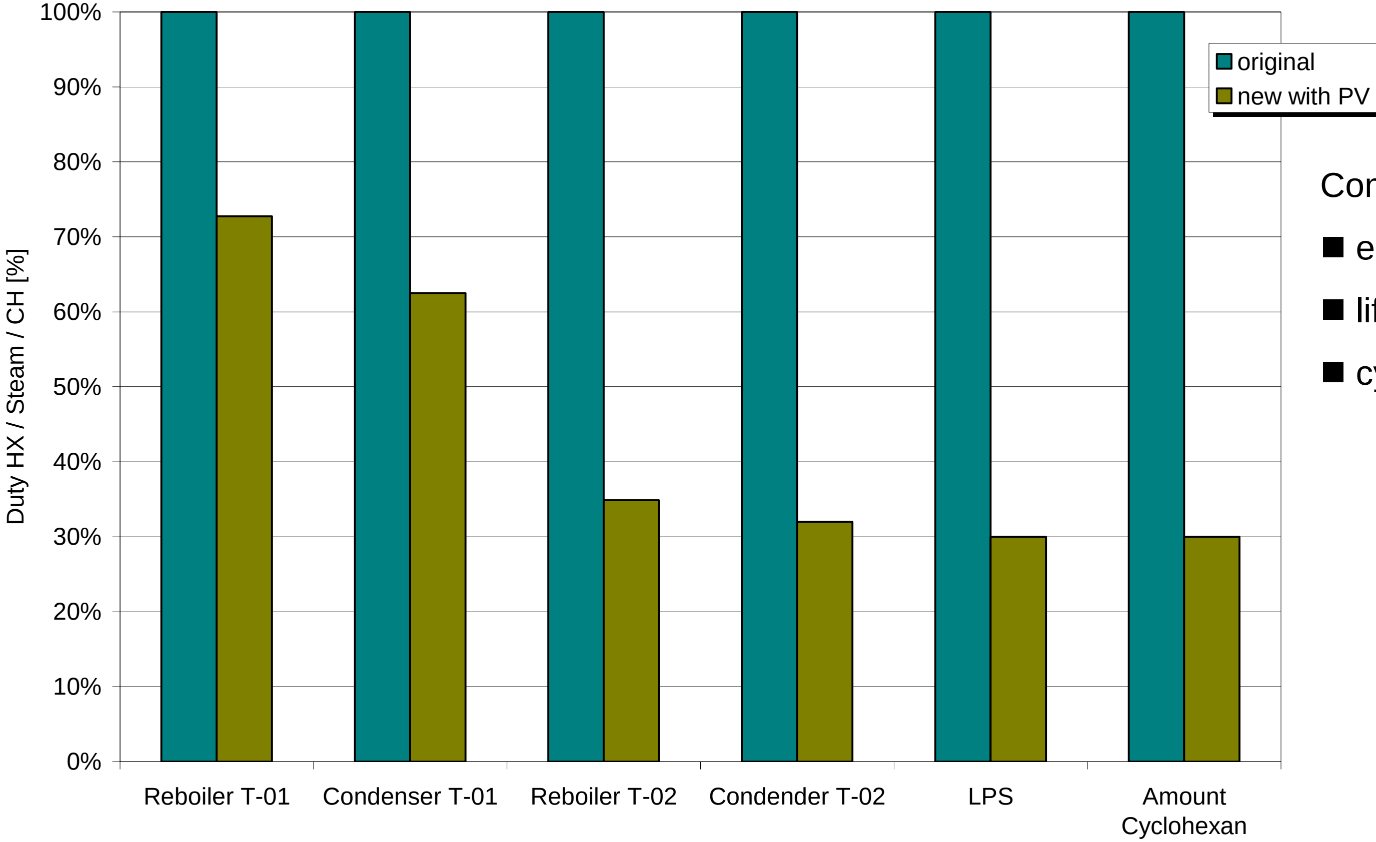
*base model system = process as modeled by Sulzer Chemtech with data from customer

Energy Efficient Hybrid System
(existing setup with low investment integrated PERVAP™)



** compared to process as modeled
by Sulzer Chemtech with data from customer

Isopropanol recovery
Utility overview



Comparison

- energy demand
- life steam
- cyclohexane circulation

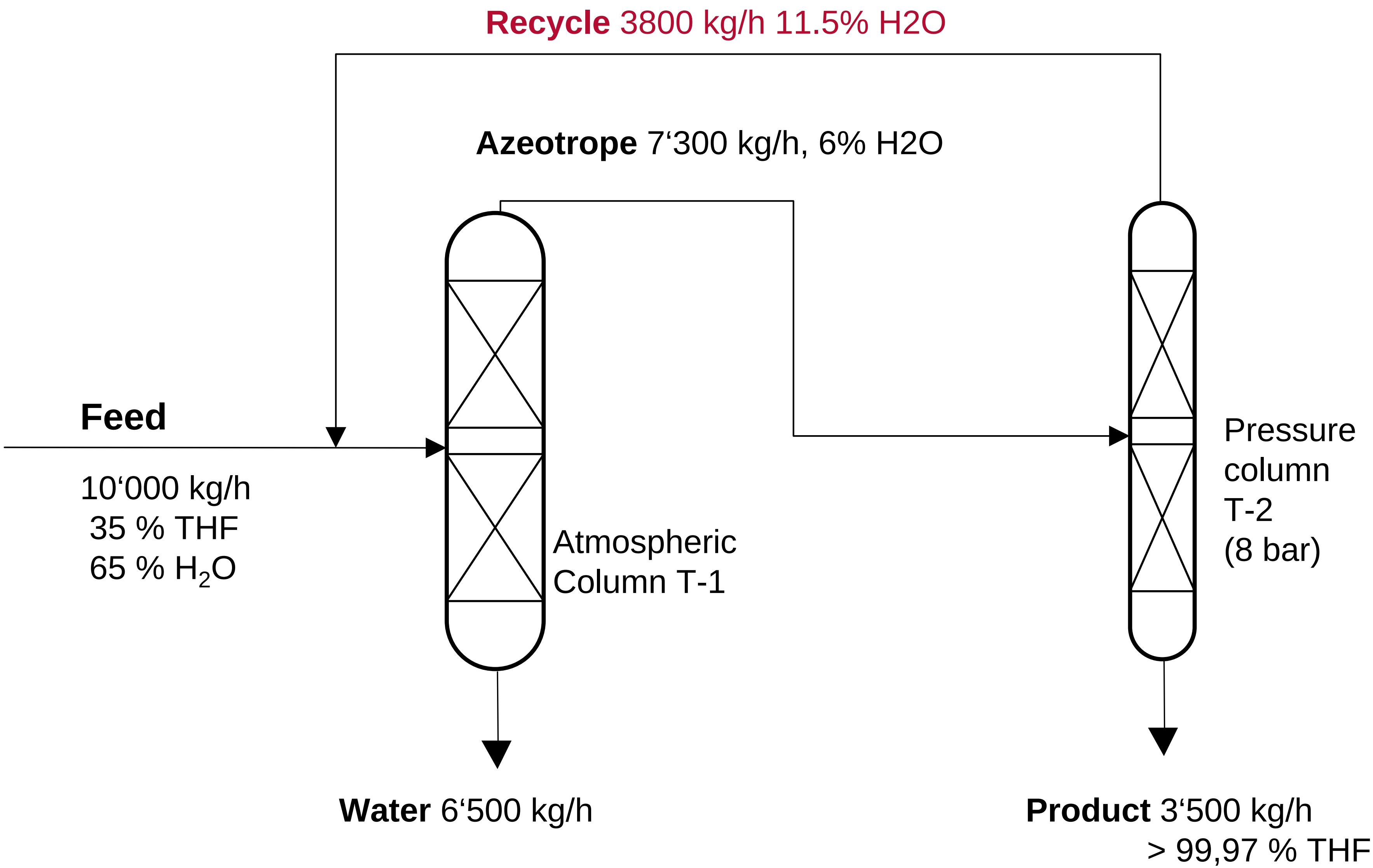
Utility costs (per ton product)	Cost Base		original	with integrated PV
Steam (average)	25	€/ton	100 %	55 %
Cooling Water	0,8	€/m^3	100 %	49 %
Total			**100 %**	**52 %**

Isopropanol recovery
Summary

- Entrainer volume can be reduced by more than 60 %
- Capacity increase up to 35 % possible
- Energy savings of 120 € per ton/hr of product:
- Annual operation costs PV: ~200’000 Euro/yr
- Simple payback for investment of complete pervaporation system: 2 – 3 years including site engineering, civil engineering & works and pervaporation skid

Tetrahydrofuran (THF)

Base Case : Pressure Swing Distillation



Tetrahydrofuran (THF)

Pressure Swing Distillation with Pervaporation Unit

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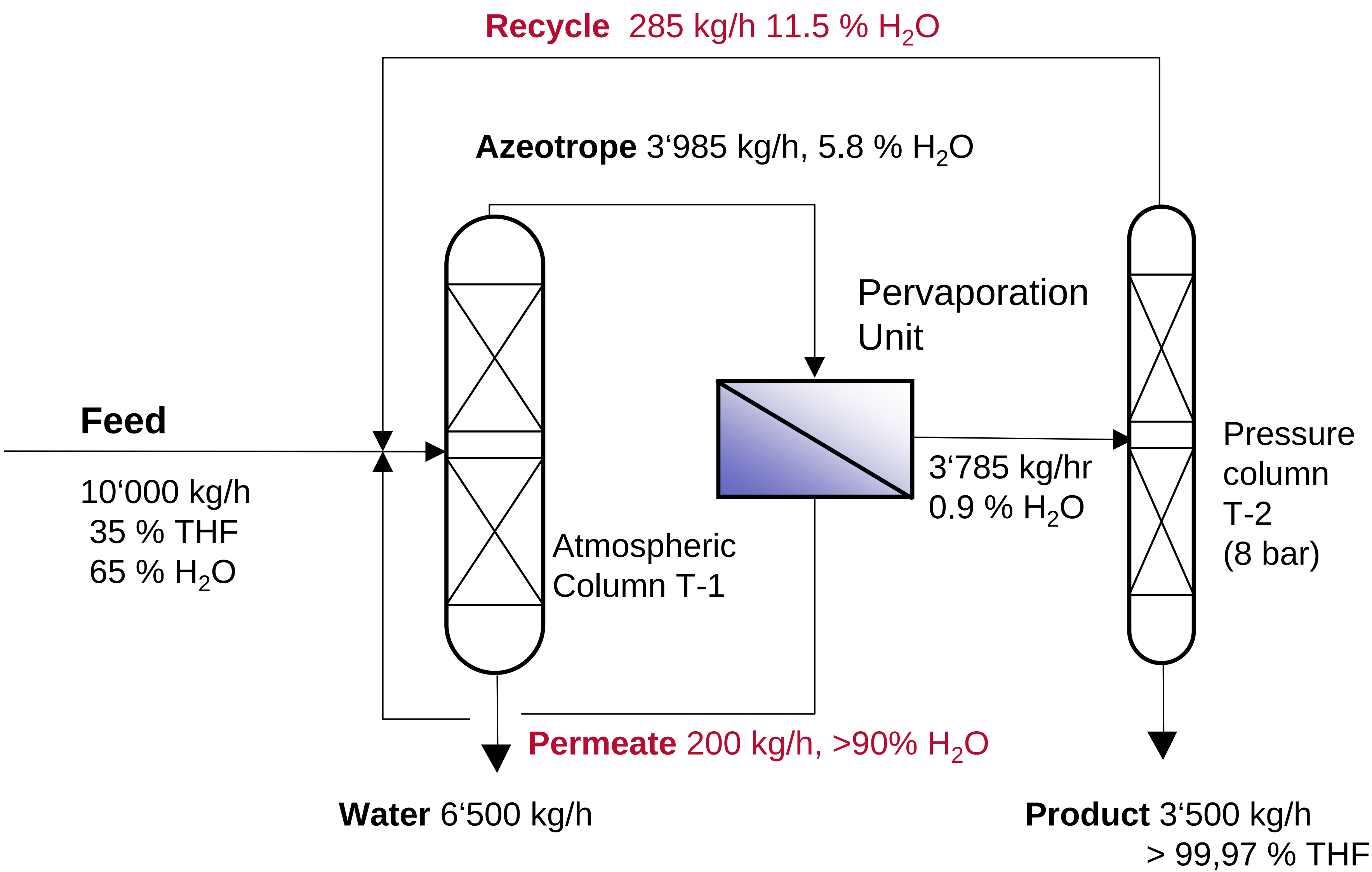

Tetrahydrofuran (THF)
Comparison Heat Balances

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Without PV

Steam 4 bara	MW	t/hr
Reboiler T-1	1.78	3.01
Reboiler T-2	1.22	2.05
Total steam	**3.00**	**5.06**

Cooling water 10 °C Δ T	MW	m3/hr
Cond. T-1	1.33	114
Cond. T-2.	0.91	78
Total CW	**2.24**	**192**

With PV

Steam 4 bara	MW	t/hr
Reboiler T-1	1.18	1.99
Reboiler T-2	0.30	0.51
PV Stage	0.20	0.34
Total steam	**1.68**	**2.84**

Cooling water 10 °C Δ T	MW	m3/hr
Cond. T-1	0.58	50
Cond. T-2.	0.21	18
Perm. Cond.	0.14	12
Total CW	**0.93**	**80**

Production 28.000 t/year > 99.97 wt% THF

- Decrease energy consumption or increase capacity with pervaporation
- Debottleneck and save energy within the same step

Thank you for your attention !
Questions ?

- Sulzer Chemtech Ltd.
  Process Technology

  Gewerbestr. 28
  4123 Allschwil (Basel), Switzerland

- Jeffrey FELIX
  Phone +31 651 844 828
  jeffrey.felix@sulzer.com

www.sulzer.com

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