SteamDry

Opportunities and challenges in superheated steam drying (SSD): A paper industry case

Funded by the European Union

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No GA 101137906.Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

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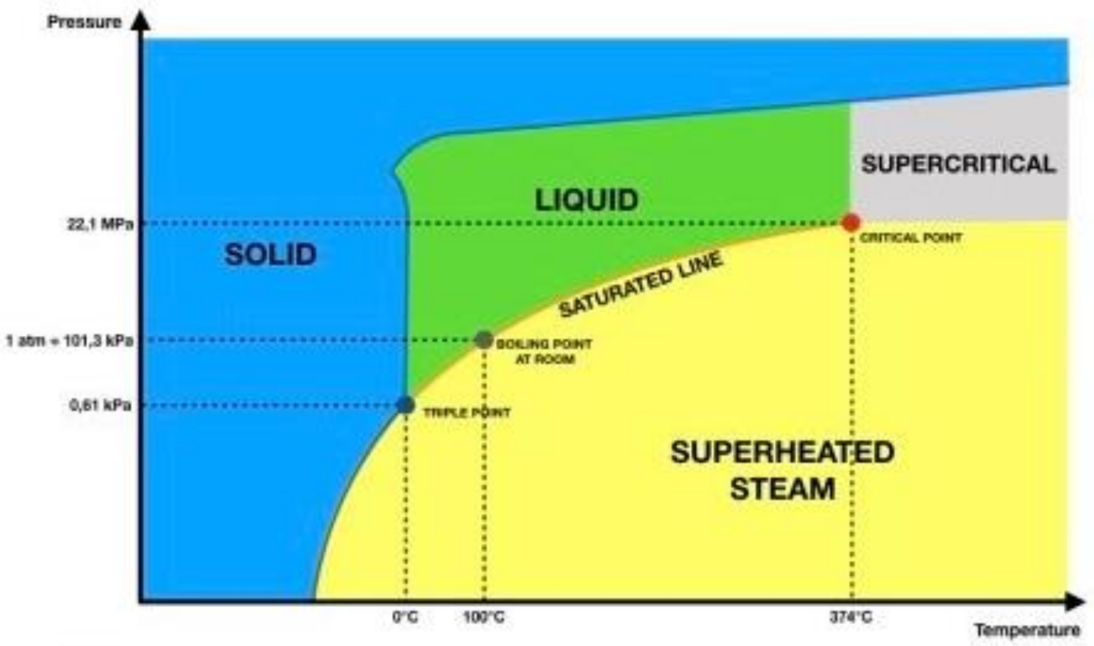
Outline

- Superheated steam drying (SSD)
  - Advantages
- Current applications
- Case: paper industry
  - Dryer concepts
  - Challenges to be solved
- Conclusions and Outlook

Superheated steam drying (SSD)

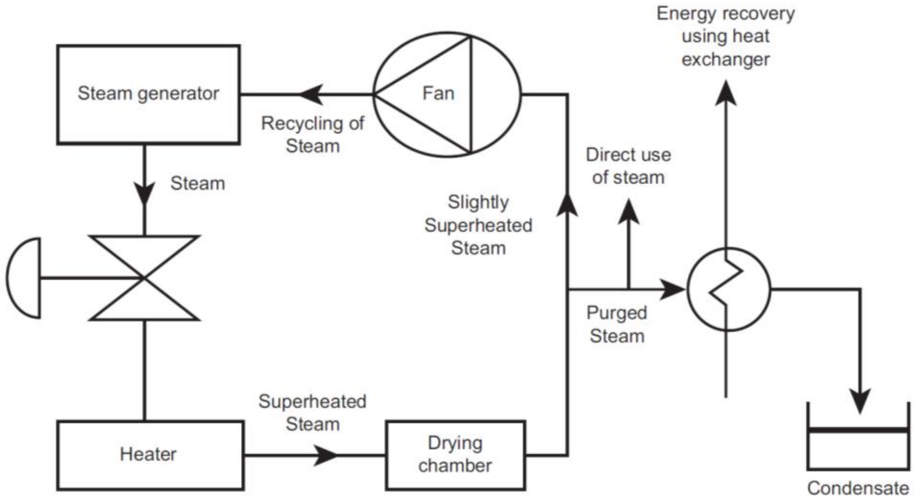
- Principle known for almost 100 years
- Definition superheated steam: “Steam at a temperature higher than its vaporization point at the absolute pressure where the temperature is measured”
- The steam is not saturated, hence water can be evaporated and become part of the steam
- Product temperature increases to the evaporation temperature



Palo, 2018

Superheated steam drying (SSD)

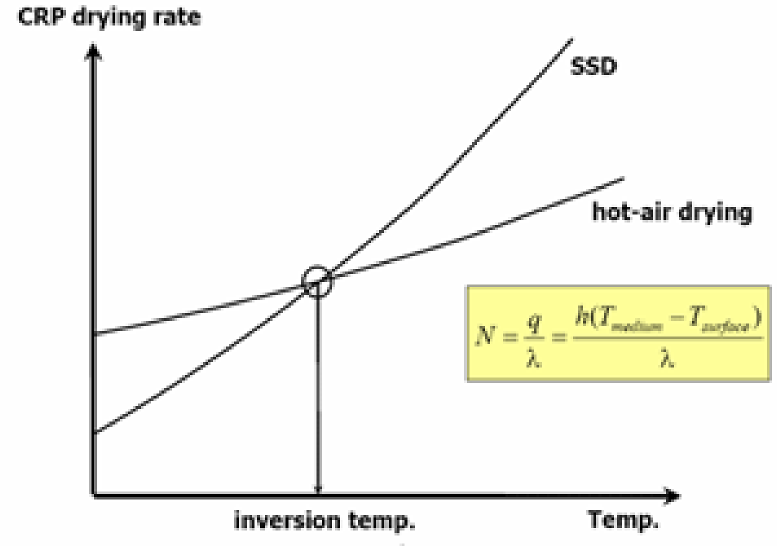
- Operation pressure determines the drying temperature
- Three sorts of dryers
  - Low pressure (5-30 kPa) – heat-sensitive products (fruit and vegetables)
  - Atmospheric pressure
  - High pressure (2-25 bar) – surplus steam more easily reused
- Net energy consumption can be as low as 700-1000 kJ/kg water evaporation (Mujumdar, 2007) → 10-20% of energy consumption air drying



Sehrawat et al., 2016

Drying rates of SHS vs air

- Higher drying rates are possible for SHS in constant rate period (CRP) depending on steam temperature
  - Thermal conductivity
  - Heat capacity



Devahastin, 2008

- The inversion temperature depends on the flow conditions, more turbulence lowers the inversion temperature
- Typically, in the range of 160-350°C (equal mass flow steam and air)

- The drying rate in falling rate period is higher in SHS:
  - No resistance of moisture diffusion in its own vapour
  - No case-hardened skins (water-impermeable) are formed in SSD

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SSD - Advantages

- Energy reduction → only when surplus steam is utilized!
- Easier to recover energy of SHS than from moist air
- Higher drying rate, when above the inversion temperature, compared with air → smaller dryer
- No oxidation
- Minimum risk of fire or explosion
- Process can be fully electrified

Mujumdar, 2006

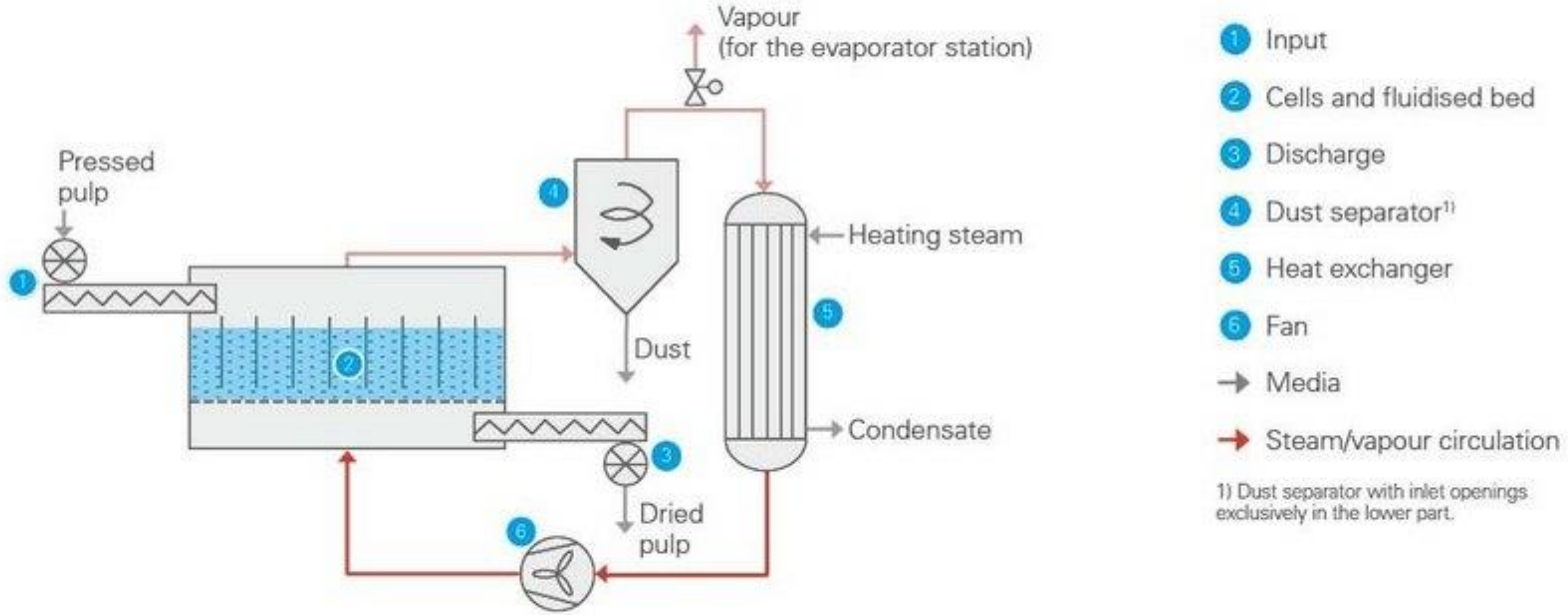
Current industrial applications

- Fluidized-bed drying of beet pulp (3-5 bar) – Cosun, the Netherlands (BMA) Fluidised Bed Steam Dryer | Efficient drying solutions from BMA (bma-worldwide.com)

- Fluidized-bed drying of pulverized lignite coal (atmospheric) – Coal Innovation Centre, Niederaussem (Germany) (RWE Power AG) https://www.ispatguru.com/wta-technology-for-drying-of-lignite-coal/

Fluidized-bed drying of beet pulp

- Working principle:



BMA, 2024

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Fluidized-bed drying of beet pulp

Advantages:

- Efficient use of surplus steam in evaporator station → thereby reduce energy demand
- Lock technology BMA prevents minimum steam losses
- Reduction of odours → happy neighbours
- Nutrients in pressed pulp are largely preserved

Fluidized-bed drying of pulverized lignite coal

Advantages for lignite coal drying:

- Large amounts of water needs to be removed
  - Input 210 tons/h raw lignite coal throughput
  - Evaporation capacity 100 tons/h

- Drying at inert atmosphere → ensure safety for the potentially explosive characteristics of dry lignite coal

- Drying temperature relatively low: evaporation at 110°C (slight overpressure)

Case: paper industry - EU-project SteamDry

- Superheated steam drying for sustainable and recyclable web-like materials

- Develop drying technology that saves 60% of energy compared to BAT for tissue and board industry

	CURRENT	STEAMDRY
ENERGY	~1100 kWh/ton	~450 kWh/ton
CO_2 (fossil)	0.45 tCO_2/t paper	No emissions
HEAT	30-40% lost to air	Latent heat recovered
SOURCE	Combustion	Electricity

Case: paper industry

- The process of paper making is a water and energy-intensive process

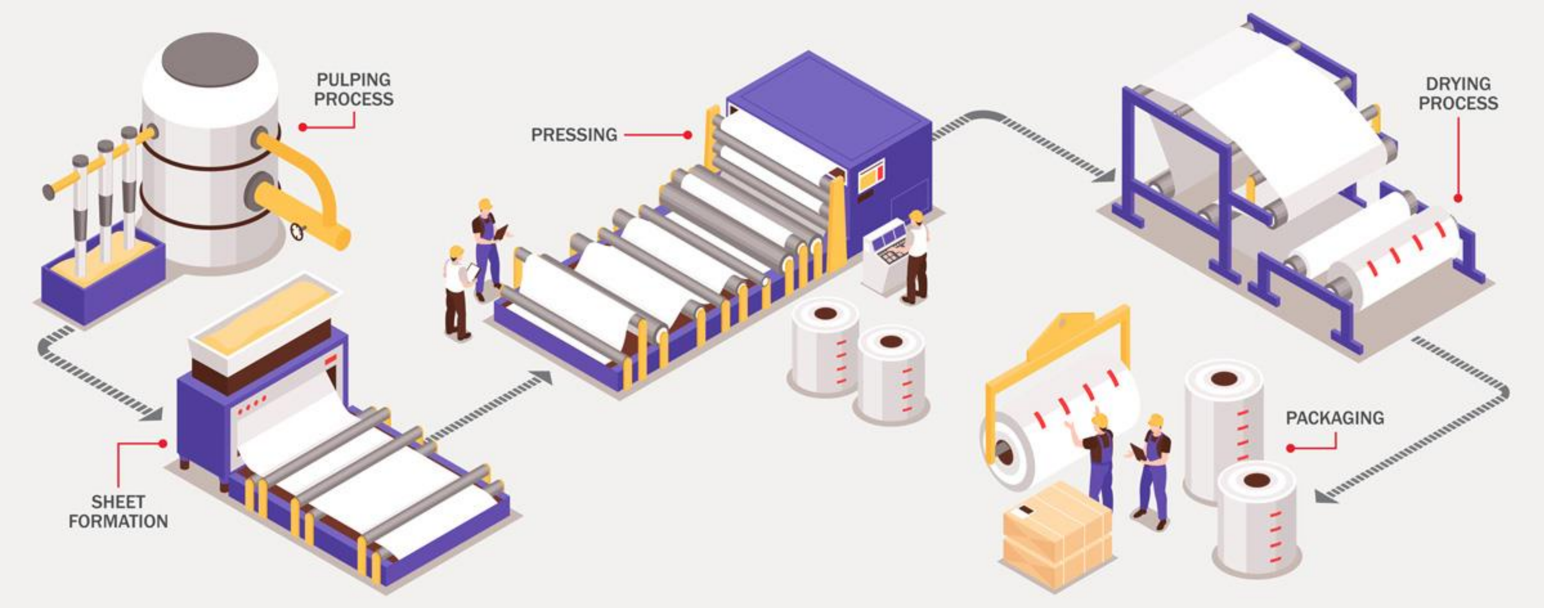

Image: Dwyer Instruments

Case: paper industry

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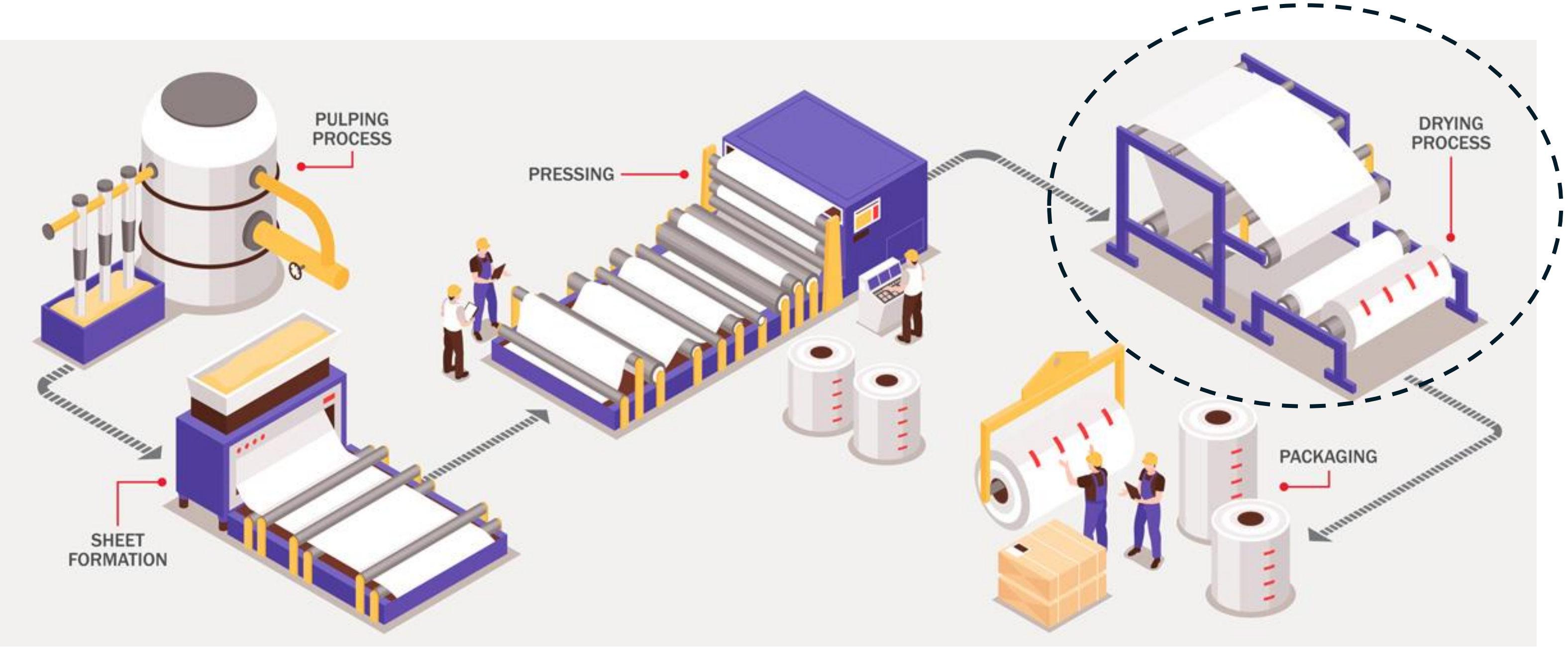


Image: Dwyer Instruments

Drying process

- Input dryer (after press): 35-55% dry matter
- Output dryer: 95% dry matter

- Different dryer types are used:

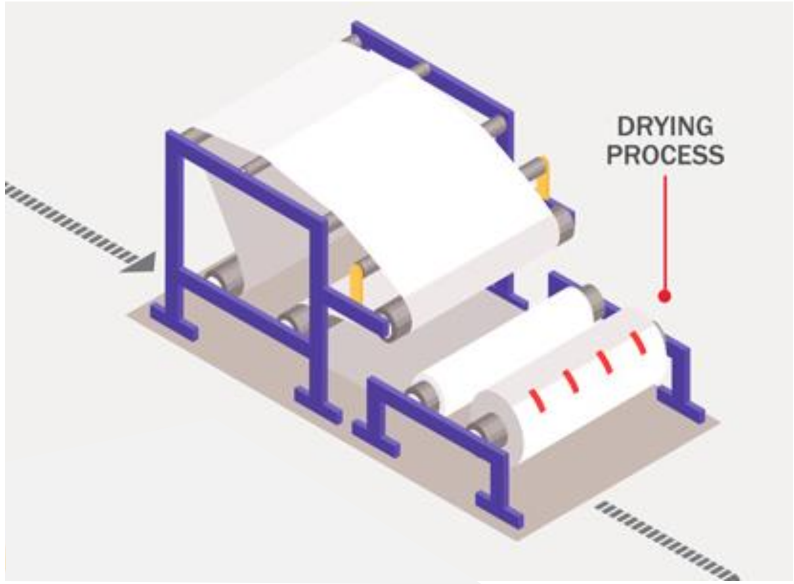


Image: Dwyer Instruments

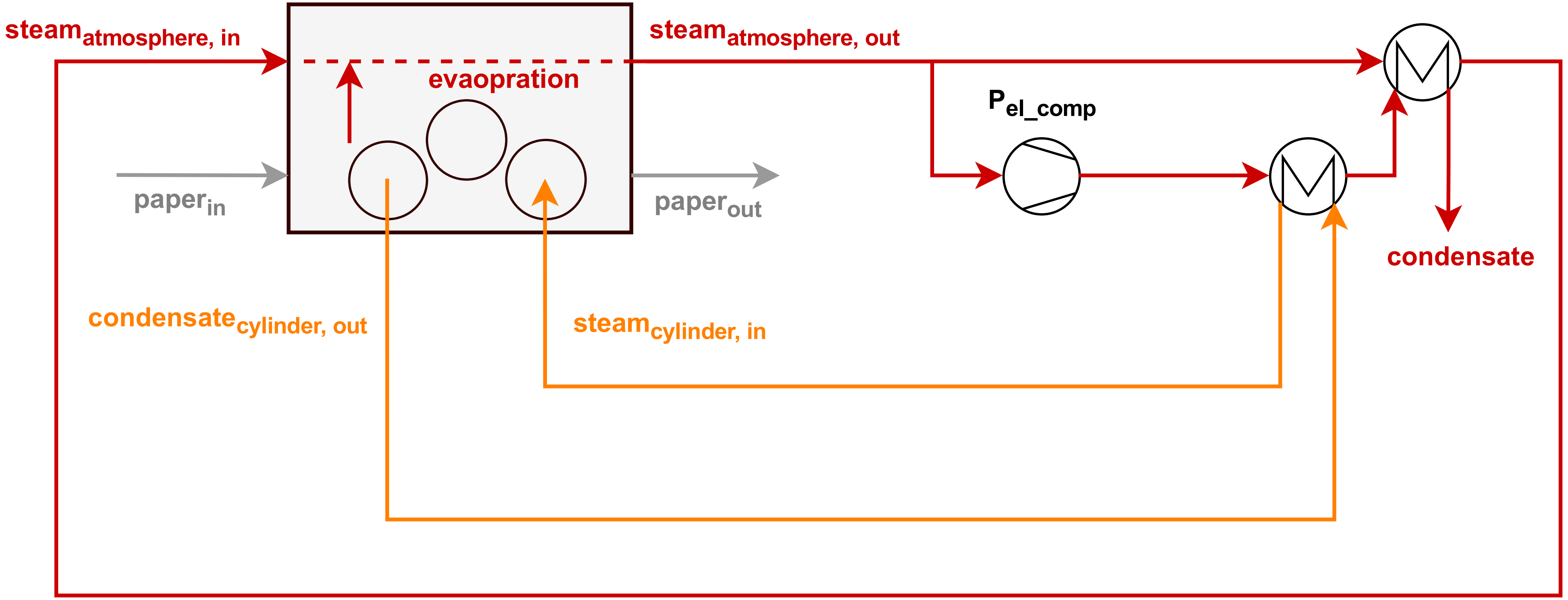
  - Multicylinder dryers (conductive drying)
  - Impingement dryers (convective drying)
  - Yankee dryers → tissue industry
    - One large cylinder containing steam with an impingement hood above
    - Combining conductive and convective drying

Multicylinder dryers (conductive drying)

- Multiple cylinders
  - Number depends on requirements/speed but in the order of 20-100 cylinders
- Cylinders are filled with saturated steam under pressure
  - Heat transfer to paper web mainly via cylinders (conduction)
- A hood with (pre-heated) air surrounding the cylinders
  - Mass transfer (evaporated water) via air in hood

OptiRun dryer Valmet

SHS drying concept for multicylinder dryers



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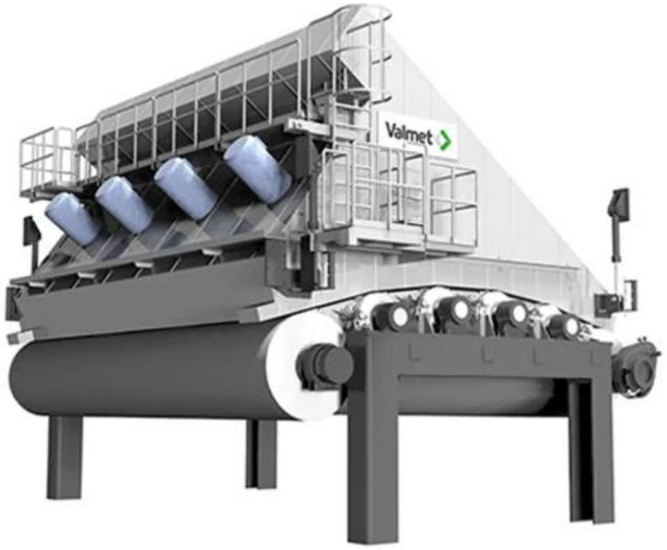
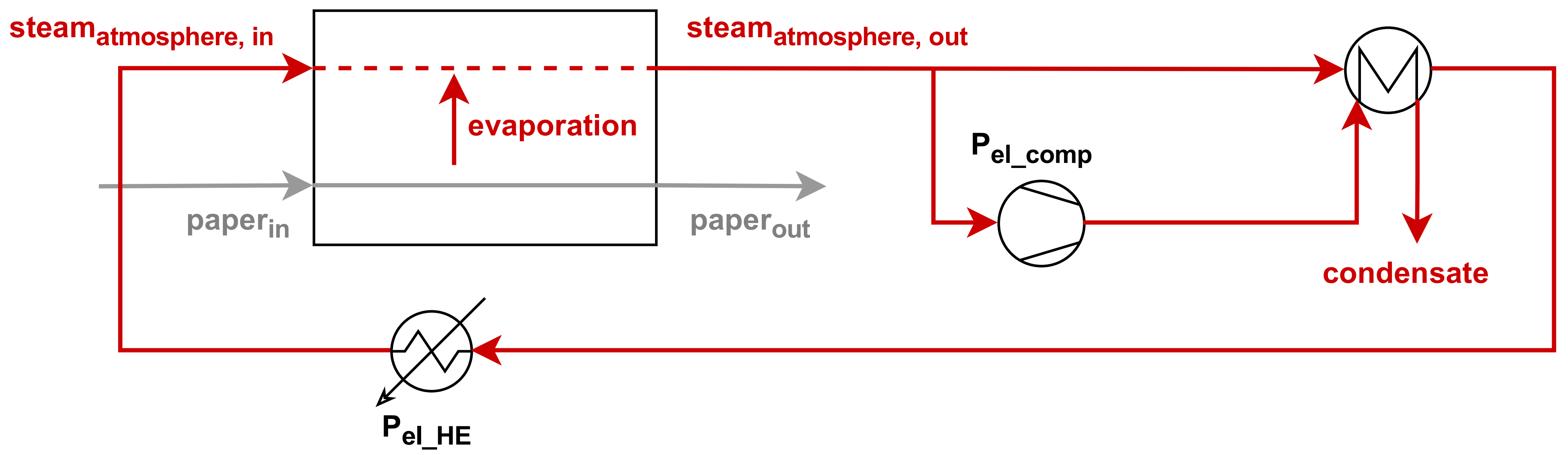
Impingement dryer (convective drying)

- High-velocity and high-temperature
  - Air temperatures typically > 300°C
- Air jets focus directly on paper web, breaking the stagnant boundary layer
- Only convective heat transfer



OptiDry Curl impingement Valmet

SHS drying concept for impingement dryer



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What needs to be done?

- Develop a pathway to superheat steam with electricity for a CO_2-free drying process
- Ensure high steam quality
- Develop an advanced control system for SSD dryer (digital twin)
- Pilot the SDD process for webs at relevant speeds (200 m/min)

Challenge: Ensure high steam quality

- With the SSD-technology steam is in direct contact with the paper web and will be recirculated
  - Risk of accumulation of contaminants:
    - Non-condensables entering the drying chamber
    - Dust/particles released from the fibre web

- Fouling needs to be kept at an acceptable level by
  - Prevention of dust and non-condensables entering the closed superheat steam loop
  - Removal of dust and non-condensables from the closed superheated steam loop

Prevention

Non-condensables

- Proper sealing of the feeding and discharge of SSD to prevent air infiltration
- More difficult than for pulp and coal since paper is one continuous sheet

Dust

- Understand effect of steam flow on fibre release and adapt process where possible

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Removal

Non-condensables

- Separation of air/non-condensables from superheated steam
  - Hydrophobic membrane
  - Condensation

Dust

- Separation of dust from steam
  - Cyclones
  - Filters

Prevent condensation!

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Approach

The work on prevention and removal of dust and non-condensables is carried out by WFBR, UT and Valmet

- PhD student Ahmed Saleem (UT) works on understanding fibre-fibre interactions and release of fibres from the paper web. WFBR works on the experimental validation.

- PhD student Felipe de Oliveira (UT) works on cleaning the superheated steam both from dust and non-condensables

- Valmet together with WFBR investigate the sealing solutions to prevent air from entering the SSD

Conclusions and Outlook

- SSD reduces energy consumption significantly when the steam is reused by:
  - Recirculation SHS
  - Recovery of latent heat from surplus steam

- Technology is not new → Industrial applications e.g. beet pulp and lignite coal

- High potential for SSD in paper industry → further developed in SteamDry
  - Develop and pilot technology
  - Ensure steam quality

- Other industries can also benefit from SSD
  - Drying of sensitive products
  - Microbial decontamination of foods

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Thank you for your attention!

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