Fluid / solid heat transfers in the metallurgy cooling processes. Constellium approaches and issues

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GDR TransInter2
Aussois, septembre 2024

Constellium

Constellium At A Glance

Constellium is a **leader** in transforming aluminium into advanced solutions, and in **recycling**.

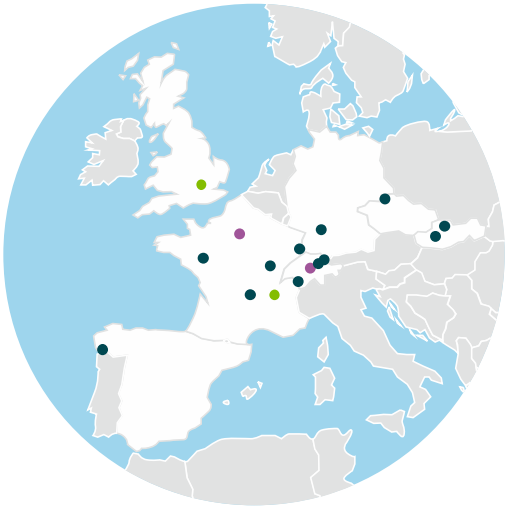
We manufacture **innovative**, lightweight, aluminium products in a responsible way, mostly for the **packaging**, **automotive**, and **aerospace** markets.

We are a **public company** listed on the **NYSE** (NYSE: CSTM).

100+ years of experience	**~12,000** employees	**25** production facilities
3 R&D centers	**€7.2 bn** 2023 revenue	**32 bn** equivalent of used beverage cans (UBCs) recycled

Where We Operate

- Baltimore, MD
- Plymouth, Michigan, U.S.
- Bowling Green, Kentucky, U.S.
- Lakeshore, Ontario, Canada – JV
- Muscle Shoals, Alabama, U.S.
- Ravenswood, West Virginia, U.S.
- San Luis Potosí, Mexico
- Van Buren, Michigan, U.S.
- White, Georgia, U.S.



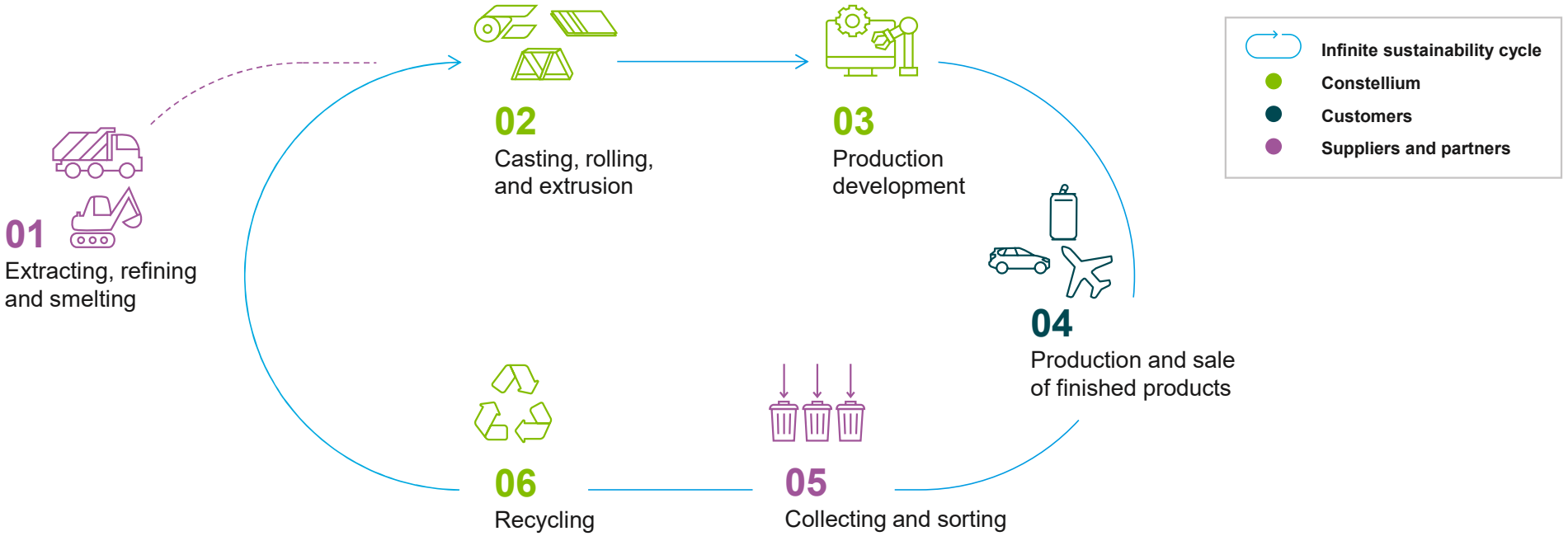
- Paris (HQ)
- Zurich
- C-TEC, Voreppe, France
- University Technology Center, Brunel University London
- Děčín, Czech Republic
- Dahenfeld, Neckarsulm, Germany
- Gottmadingen, Germany
- Issoire, France
- Levice, Slovakia
- Montreuil-Juigné, France
- Neuf-Brisach, France
- Nuits-Saint-Georges, France
- Singen, Germany
- Valais, Switzerland
- Vigo, Spain
- Žilina, Slovakia

- Changchun, China – JV
- Nanjing, China

- **3** Corporate Offices
- **3** R&D Centers
- **25** Manufacturing Plants

Our Contribution to the Aluminium Value Chain

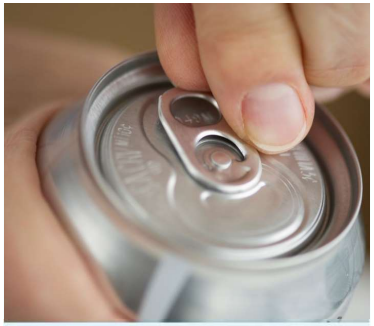
We transform aluminium into rolled and extruded products and automotive components, partnering with our customers to develop new and sustainable solutions. We recycle throughout the process to achieve **full circularity of the value chain**



Our Markets

Strong and **light**, and **fully recyclable**, **aluminium** is the **sustainable material of the future,** from soft drinks to cars and planes, and much more.

Packaging



Major global supplier of aluminium coils and sheets for beverage and food cans, wine and spirit closures, aerosols, luxury cosmetics and more

Automotive

Leading provider of aluminium rolled products and extrusion-based components, for lighter and safer cars

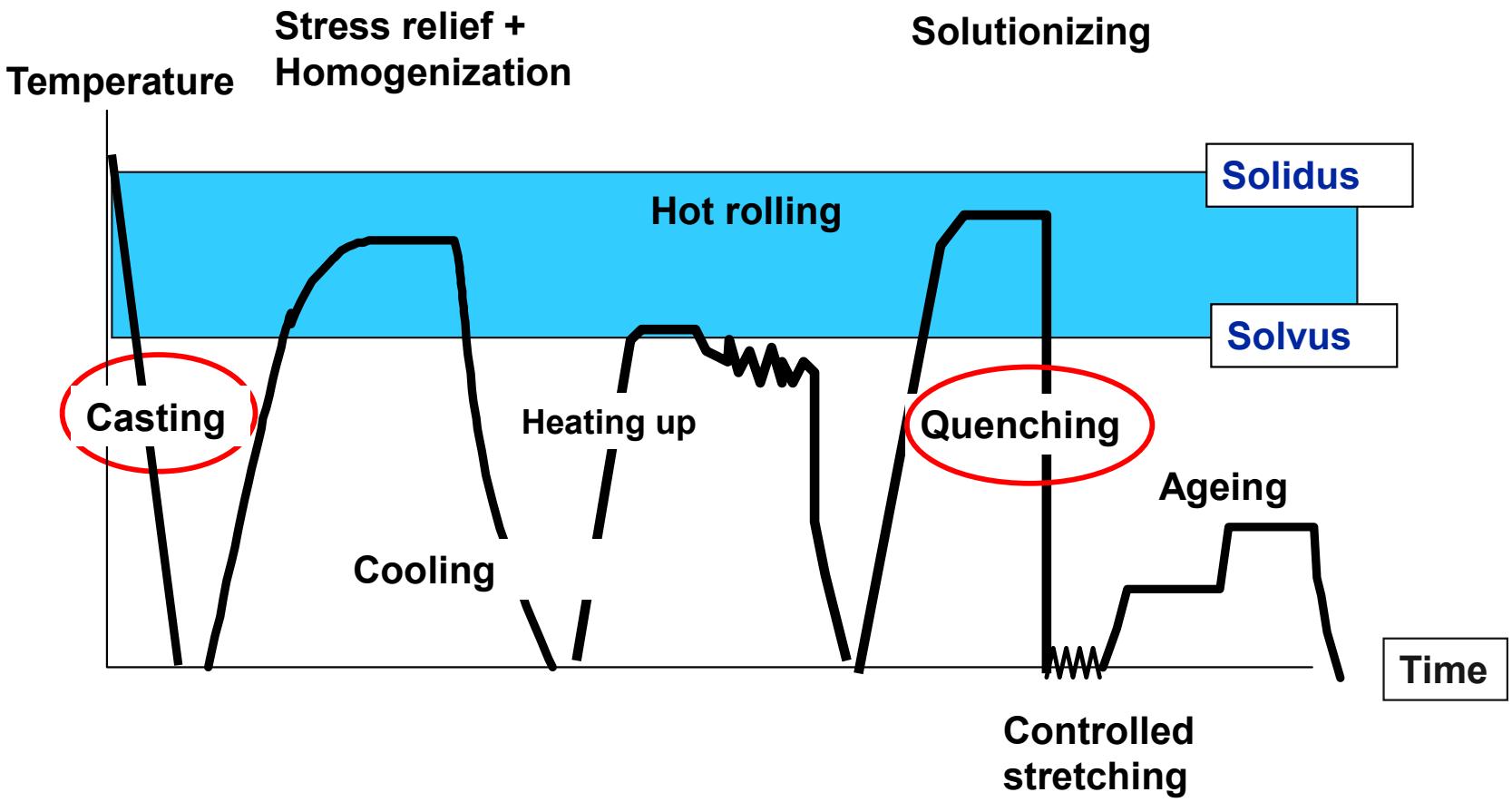
Aerospace

Key partner of aerospace manufacturers providing plates, sheets and extrusion solutions, and a leader in aluminium-lithium technology with Airware®

Specialties

Provider of **a wide range** of lightweight and high-performance solutions for the **transportation** and **industry** markets, and dedicated solutions for the **defense** market

Aerospace plate process
Many heats-up and cooling down



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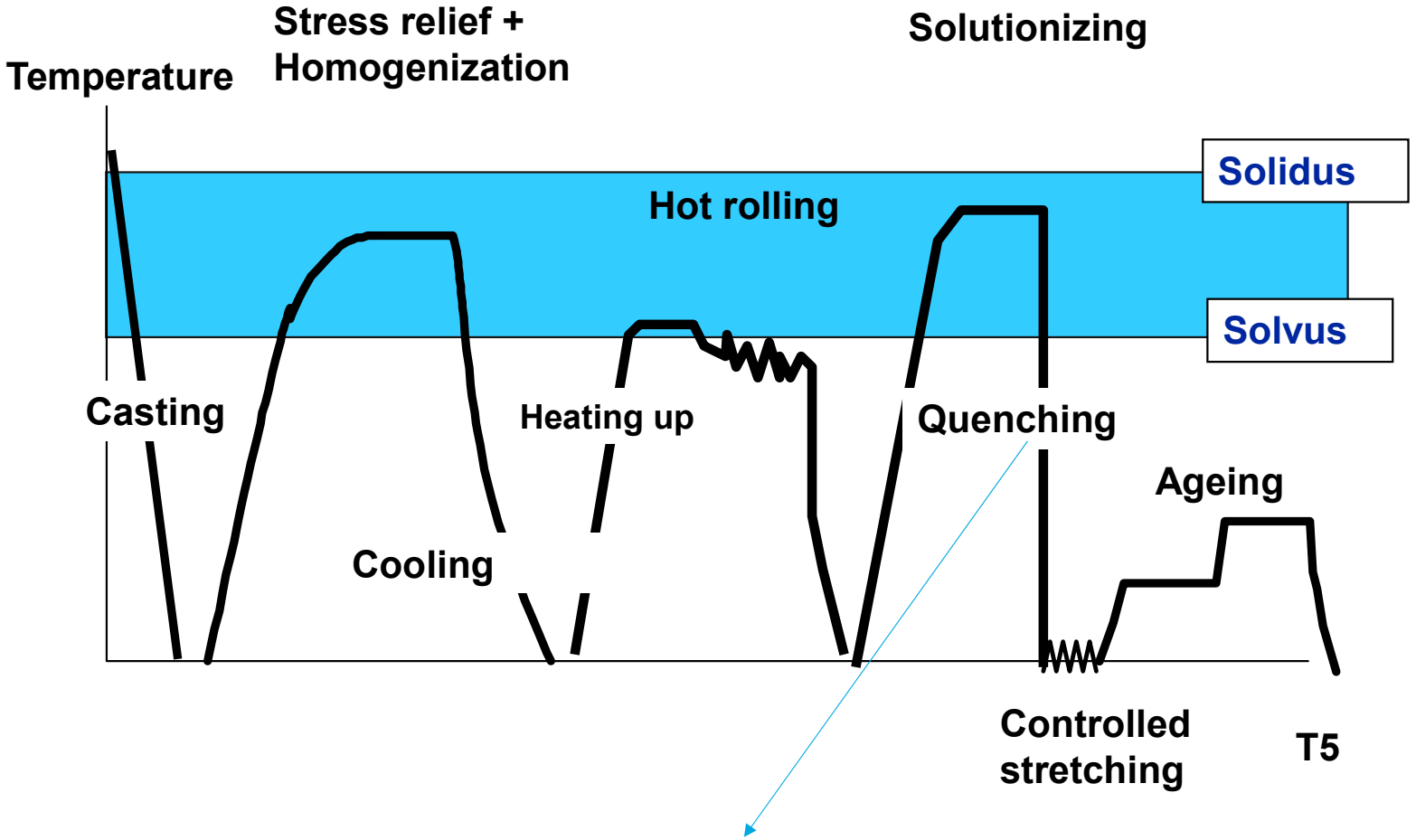
Quench issues

Aerospace plate process



Diversity of quench technologies in aluminum industry
2 main families : immersion et spraying

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Thermal modelling of quenching and cooling process: what is at stake ?

- Objective : master the thermal path history of the product during its quench because:

  - Final properties (mechanical, corrosion resistance) highly depends on the quench thermal. Quench process must be reproducible

  - Quench rate is often a compromise between:
    - Mechanical properties → product qualification
    - Distortion during quench → quench processability
    - Internal stresses after quench and stretching → product machinability

Quench HTC laws : a wide subject

- Quenchant
  - Ground water or river water → chemical composition depends on each site
  - Deionized water → stable composition
  - PAG (polymers) additives can be added, e.g. « aquaquench » (Houghton) for immersion quench
  - Emulsion (water + oil + surfactant) rolling (lubrification + cooling) → each composition has a specific thermal behavior.

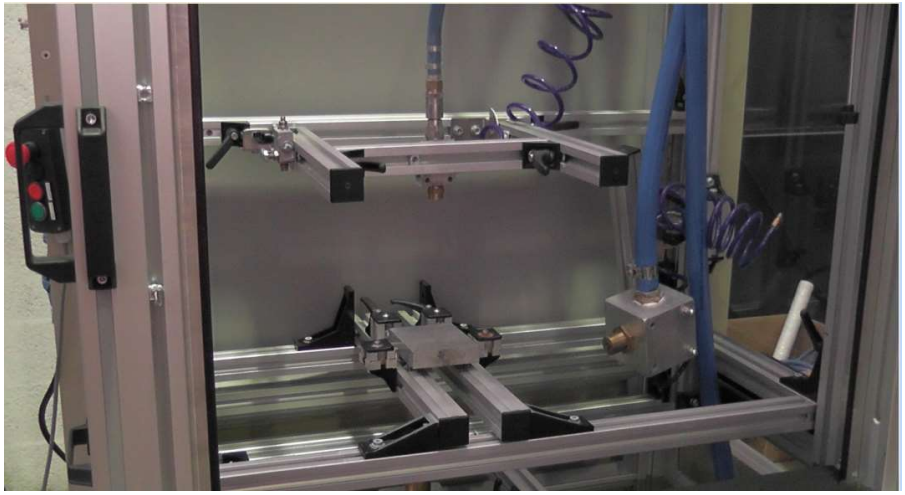
- Spray and jet technologies
  - Granulometry and impact speed of droplets is directly connected to the spraying technology and its set-up
  - Impact angle of spray or jet on the product to cool down
  - Streaming or only impact zone

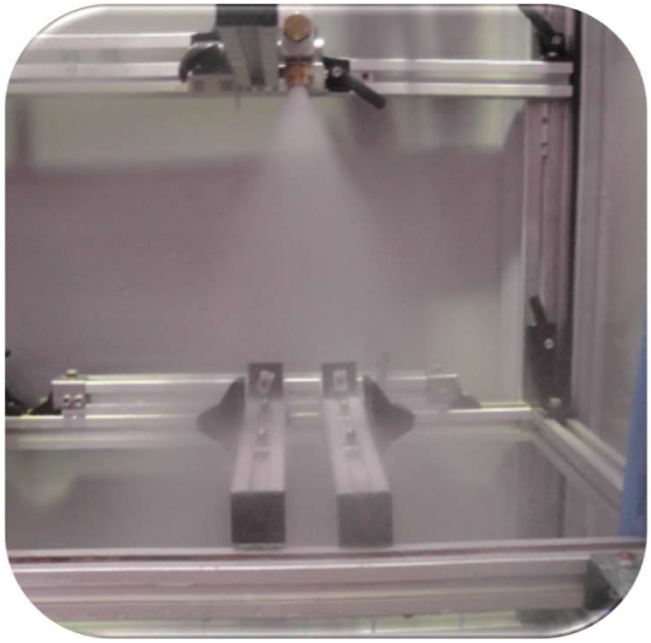
- Various product to quench (thickness)
  - Slab (500 mm), heavy plates (20 - 100 mm), sheet or strip (2 mm)
  - Extruded products (aerospace stringer for e/g.)

How we determine HTC quench laws ?

- Our goal : feed our thermal models and thermo-mechanical models with the most reliable HTC law as possible

- Only experimental approach
- Numerical approach sounds to us too challenging, expensive and not precise enough





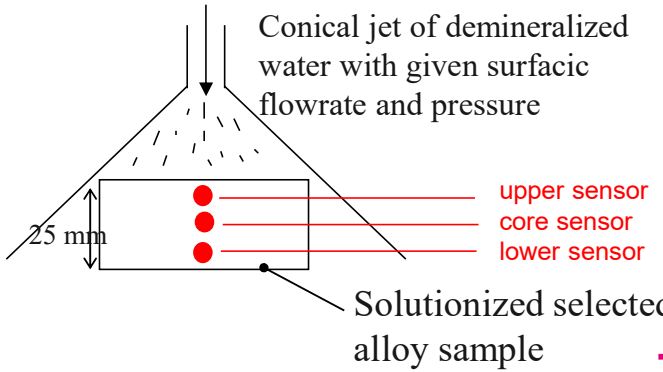
Surface rewetting when spraying

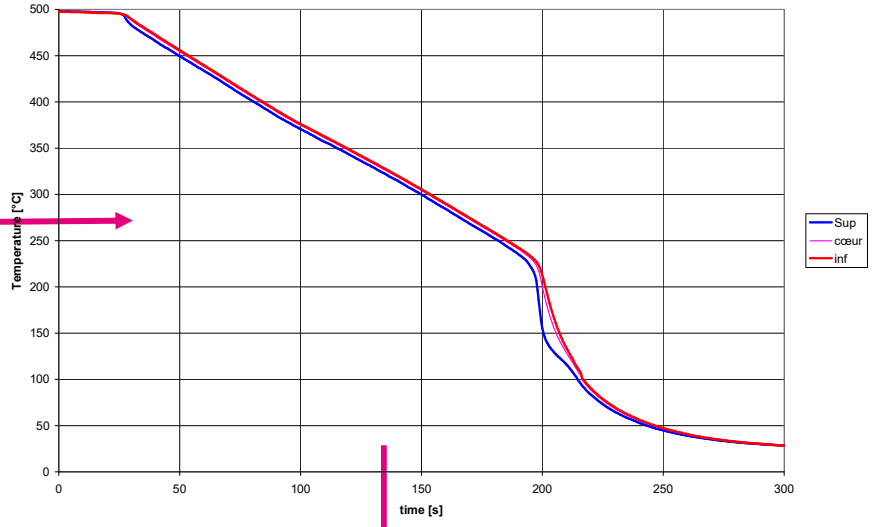
film from Camille Berthet – PFE UGA/ENSGI 2021

Trempe protocole classique avec film de caléfaction chassé

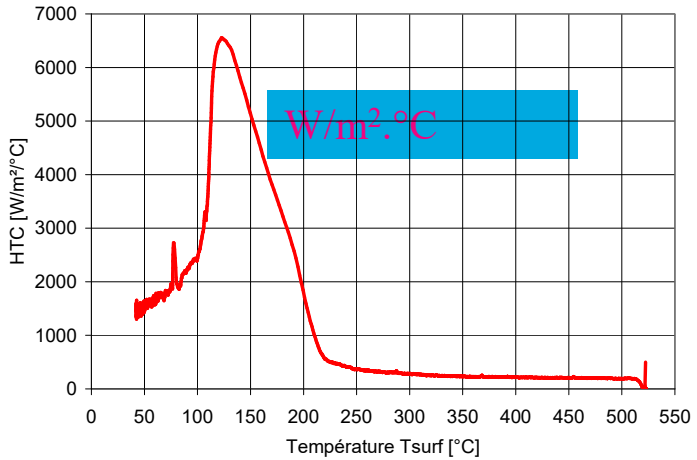
Table des annexes

1D inverse thermal model for full conical spray





HTC(T) ?



1D Inverse method for HTC calculation (function of Tsurface)

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Our need (casting and quenching applications)

- Improve our ability to determine our cooling HTC laws with/w.o streaming, with a reduced confidence interval.
- Criteria : be able to discriminate the effect of water quality and metal surface aspect on HTC curves.
- Understand what are the physical and chemical levers at stake in the relationship between:
  - Water quality and extracted heat flux
  - Structure / shape / rugosity of the metal surface, and extracted heat flux
- Interaction of sprays (array of nozzles) ?