SFT « Sprays et gouttes » - Paris 02 oct. 2014

Amélioration des performances énergétiques d’un échangeur pas brumisation

F.Trinquet

irstea

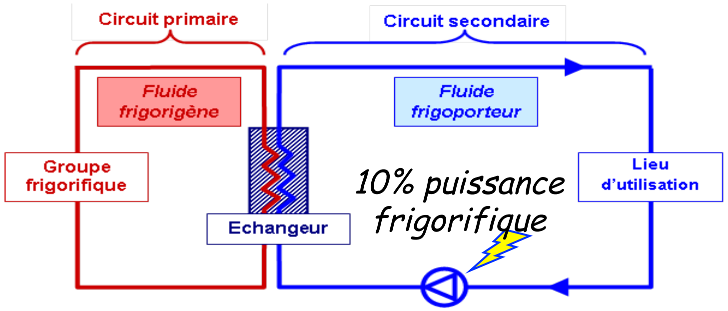
- Travaux de l'équipe ENERFRI

- Spray : Impact sur un échangeur à air

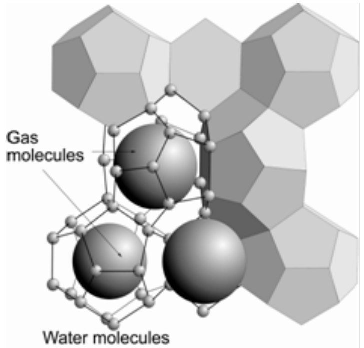
- Travaux de l'équipe ENERFRI
  - *Coulis d'hydrates*
  - *Matériaux à changement de phase*
  - *Réduction de charge*

- Spray : Impact sur un échangeur à air

Coulis d'hydrates

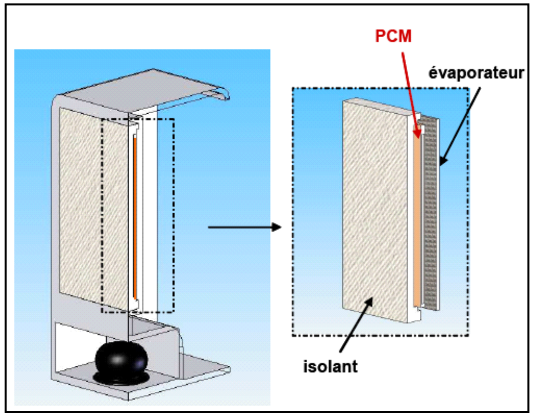


- Secondary refrigeration
  - ⇒ Containment of refrigerants
  - ⇒ Reduction by a factor of 10
- Two phase secondary refrigerant
  - High energy density : Slurry of 25% (100 kJ/kg) ~ 5 x Monophasic liquid (ΔT=5°C)
  - Increase the energy efficiency of the system (offset losses : pumps, exchanger)
- Applications
  - Air conditioning, Distribution Networks (Japan), Storage …
- What is a hydrate?
  - Like crystal compound of ice water molecules forming cages, which trap other molecules, ex : CH_4, CO_2 …
- Interest for refrigeration
  - Equivalent latent heat or > than the ice.
  - Stable at T > 0 (air conditioning)
  - Formation by injecting CO2 (non-mechanical)



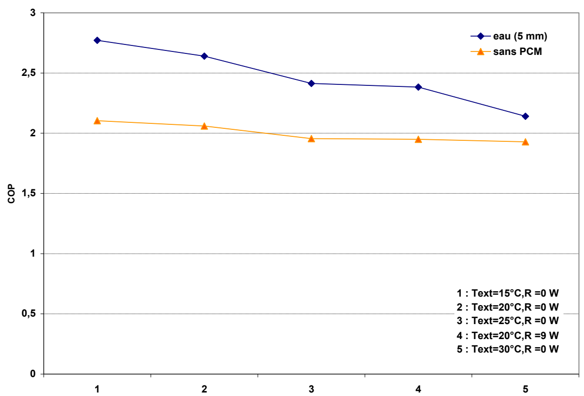
Coulis d'hydrate de TBAB
Tanasawa et Takao, 4th Int. Conf. on Gas Hydrates, Yokohama, 2002

Matériaux à Changement de Phase (MCP)

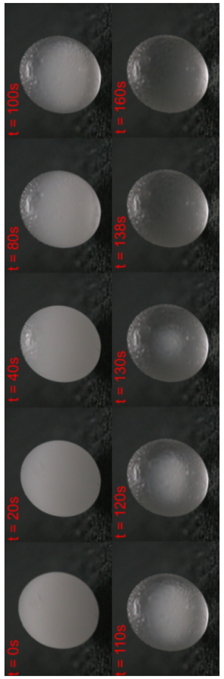


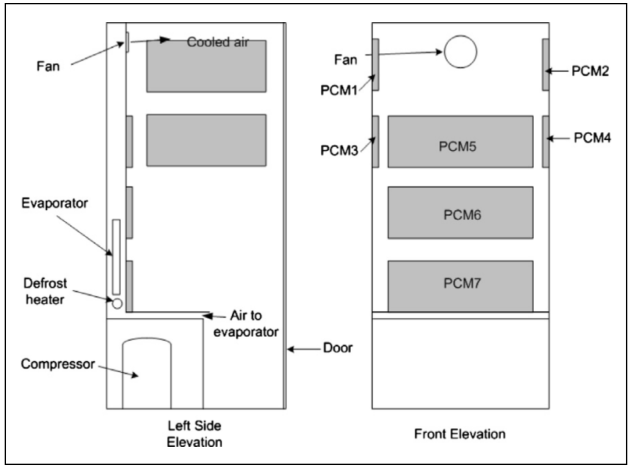
domestic refrigerator

K. Azzouz (2008)

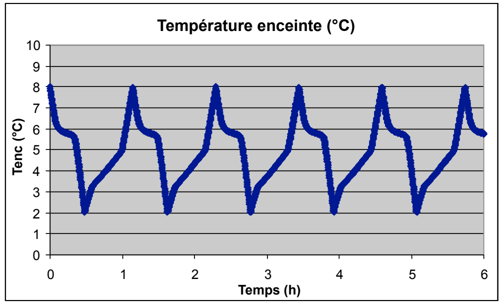


→ Amortization of temperature changes
→ Up to 30% savings on COP
→ Autonomy





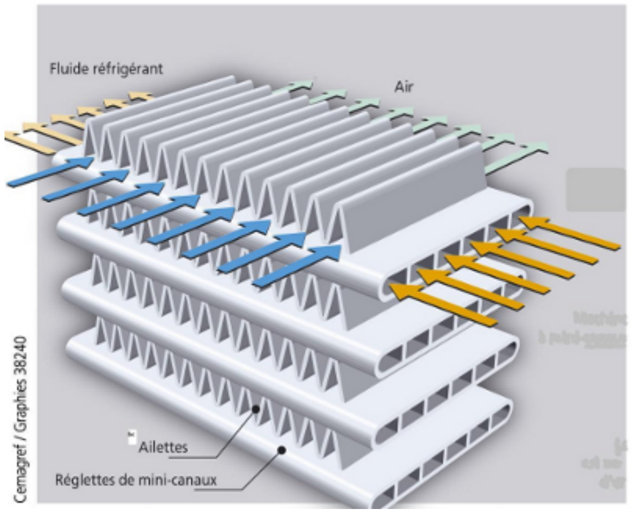
Positionnement des plaques de M.C.P. dans le congélateur - B. Gin et *al.* (2010)



F.Trinquet, L. Fournaison, D. Leducq, A. Delahaye

→ Energy savings to defrost and door openings (~ 50%)
→ Limit the number of starts the chiller
→ Stabilize the temperature in the enclosure

Réduction de charge



→ Under control technology for condensers automobile air conditioning.
→ Compact, lightweight.
→ Reduced internal volume : load reduced refrigerant.
→ Thermal performance.

→ Refrigerant distribution.
→ Behavior frosting / icing.

→ Some results …

Installation	Classique	Charge réduite
Constructeur	**Searle MDA 22-6**	**mini-canaux Valeo**
D_{int}	**7,93 mm (3/8")**	**1,49 mm**
V_{int}	6 l	0,77 l
L_{totale}	**122 m (4x30,3)**	**250 m (2x32x7x0,56)**
S_{air}	**33 m²**	**32 m²**
$S_{frigorigène}$	**3,0 m²**	**1,5 m²**
Pas ailettes	**2,12 mm**	**1,28 mm**
Coeff. d'échange	20 W/K	32,8 W/K
Débit d'air	**5 200 m³/h**	**5 100 m³/h + VEV**

- 87% (V_{int})
+ 40% (Coeff. d'échange)

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- Spray : Impact sur un échangeur à air
  - *Contexte de l'étude*
  - *Moyens mis en œuvre*
  - *Résultats*

Contexte de l’étude

- **Goals**

→ **Significant reduction in the amount of energy compared to traditional systems.**

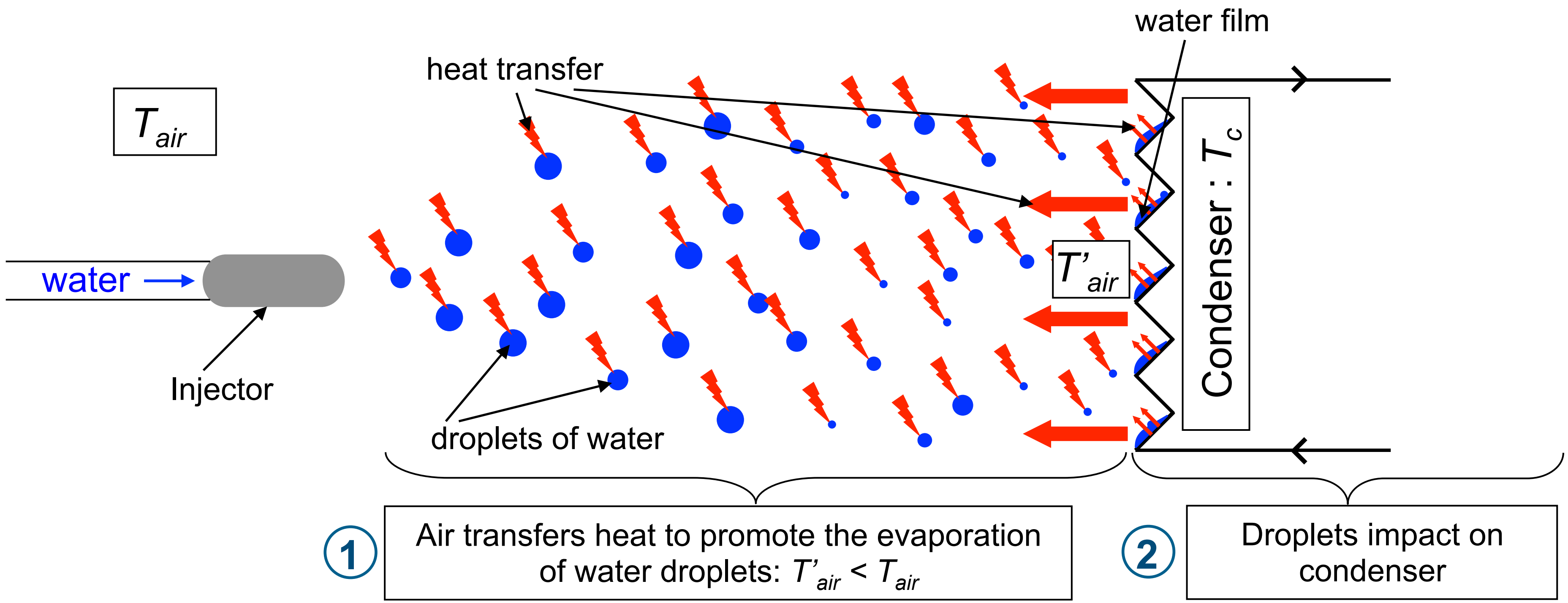
→ **Operating conditions during high ambient temperatures.**

→ **No risk of bacterial growth : Legionella type for example.**

→ **Optimize water consumption in this type of installation.**

Contexte de l'étude

- **Some principles**

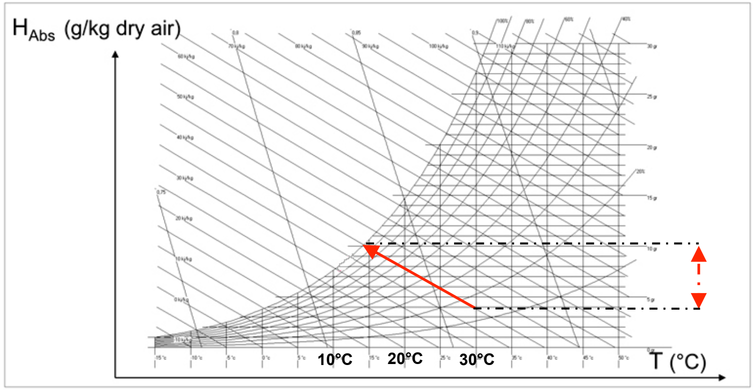


→ **Possibility of lower T_c therefore increased COP**

Contexte de l'étude

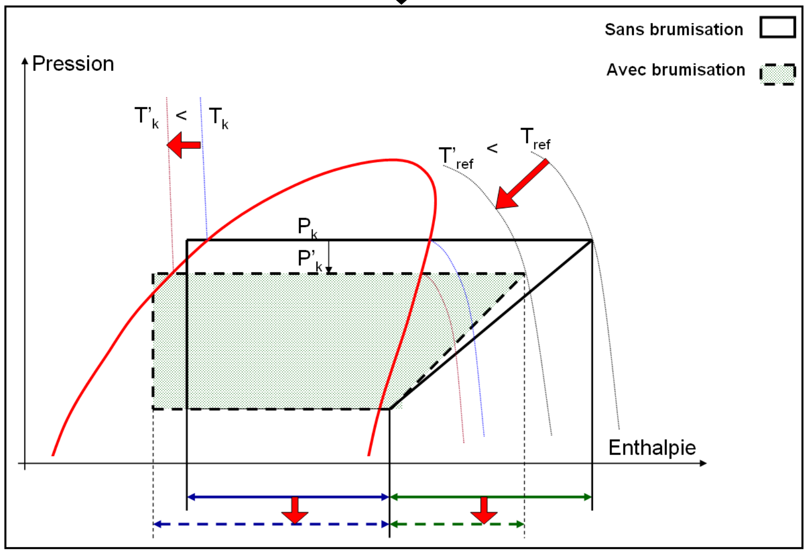
- **Moist air and chiller**

Initial conditions :
30°C & 15%HR
After spraying :
15°C & 100%HR



Amount of water injected to saturate the airà (100%HR)

Performance of the chiller



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Moyens mis en œuvre

- **Theory and numerical tools – J.Tissot PhD 2011 (Lemta/Irstea)**

Two-phase flow

[Collin, 2006]

Lagrangienne approach : Spray

Eulérienne Simulation : moist air

Droplets in air :

-Position
-Speed
-Size
-Temperature

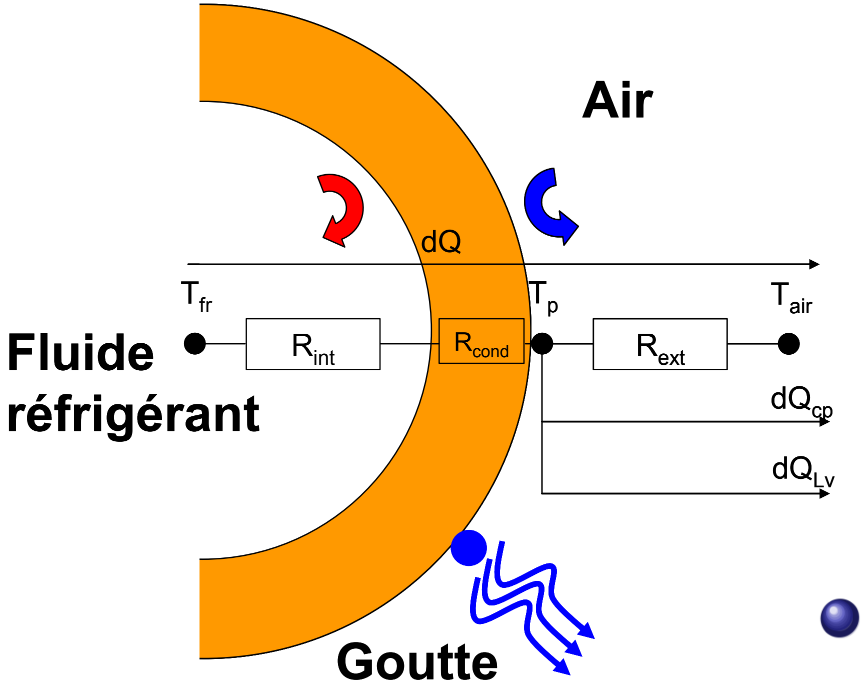
Air properties :

- Temperature
- Humidity
- Speed

Moyens mis en œuvre

- **Theory and numerical tools – J.Tissot PhD 2011 (Lemta/Irstea)**

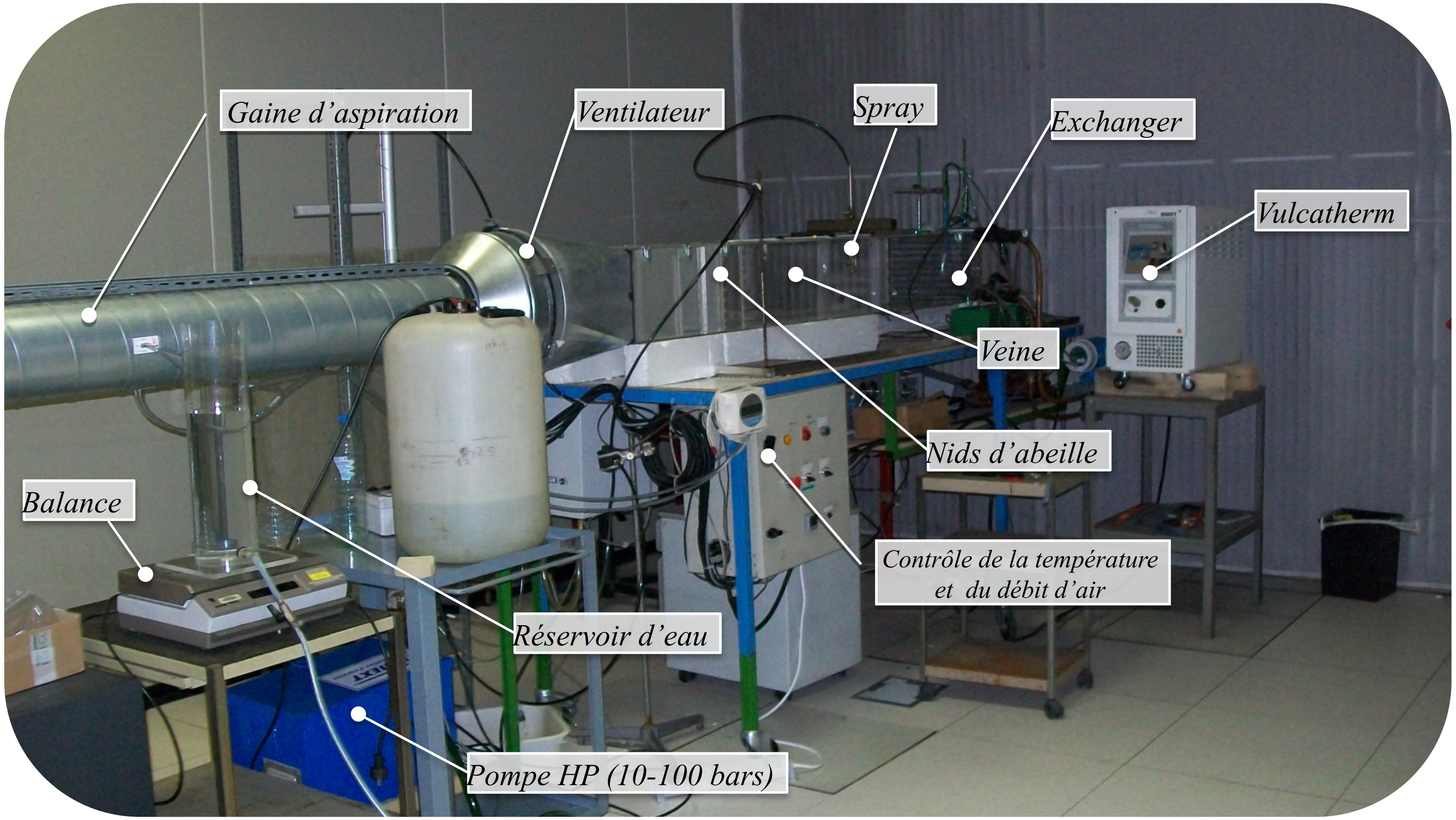
Heat transfer _



$$dQ = \frac{1}{R_{\text{int}} + R_{cond} + R_{ext}} \left(\left(T_{fr} - T_{air} \right) + \left(dQ_{Lv} + dQ_{cp} \right) R_{ext} \right)$$

Moyens mis en œuvre

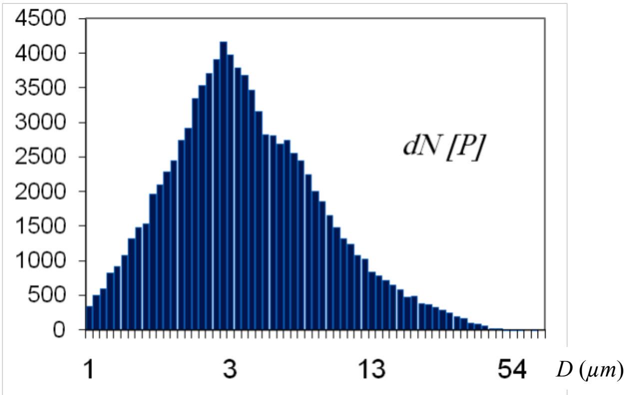
- **Laboratory pilot**



Moyens mis en œuvre

- **Metrology developed**

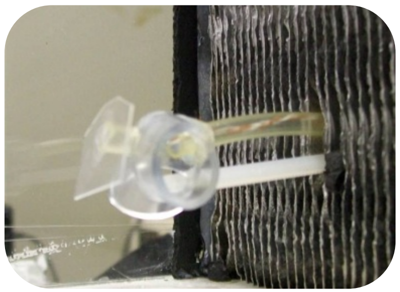
Particle size

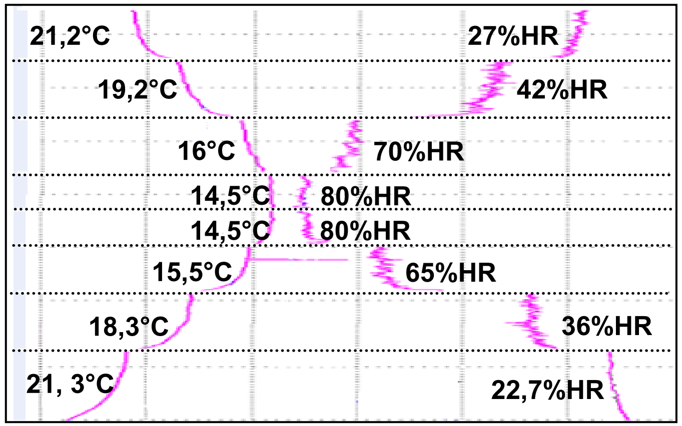


Spray angle

Temperature & humidity

Thermometers





hygrometers

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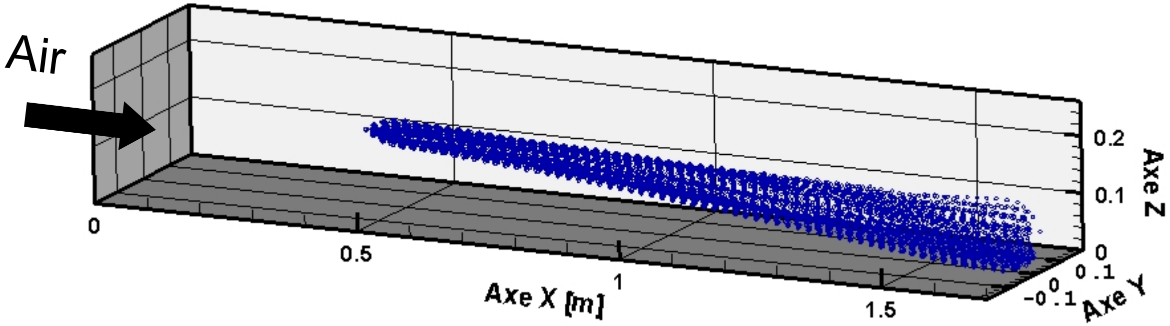
- **Numerical results**

Trajectory with the air flow (50 µm)

V_{air} = 1 m.s^{-1}

T_{air} = 298 K

HR = 30%



Spray

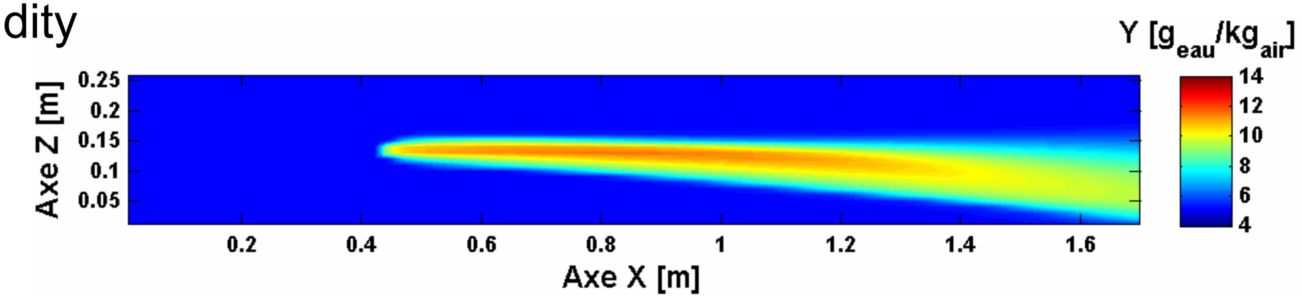
$\dot{m}_{spray}$ = 1,5 l.h^{-1}

V_{spray} = 10 m.s^{-1}

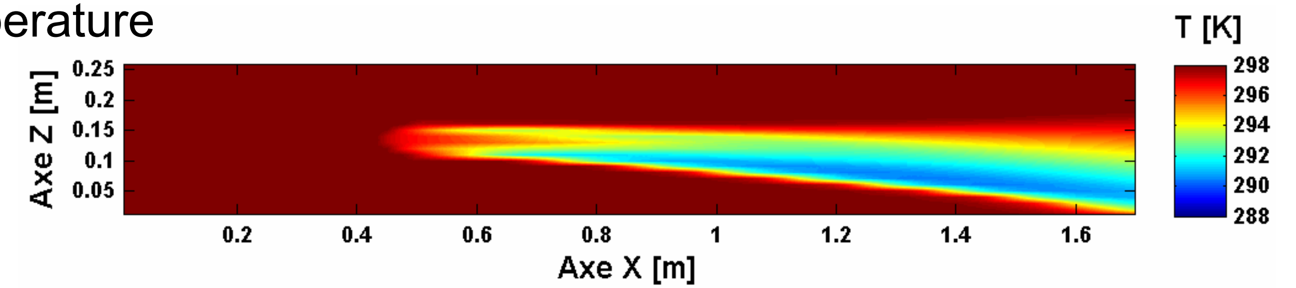
T_{spray}= 298 K

Φ = 72°

Humidity



Temperature



- **Numerical results**

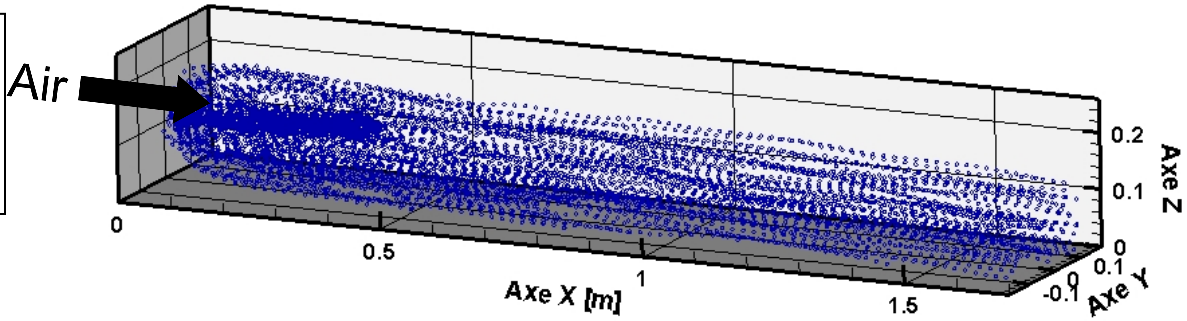
Trajectory against the air flow (50 µm)

Spray

V_{air} = 1 m.s^{-1}

T_{air} = 298 K

HR = 30%



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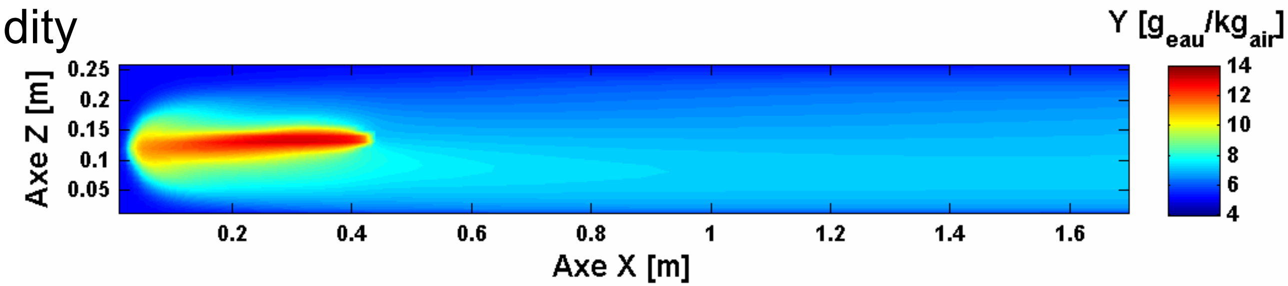
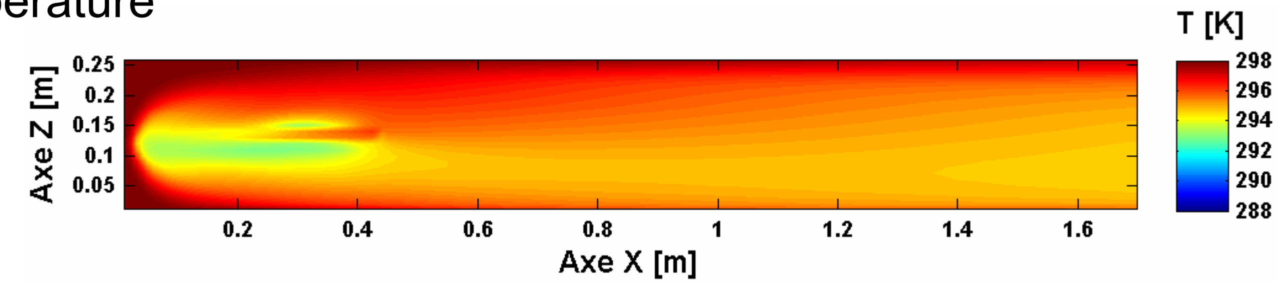


Temperature



Résultats

- **Comparison between expérimental résults and numerical simulation**

T_{air} = 298,2 K

HR : 30 %

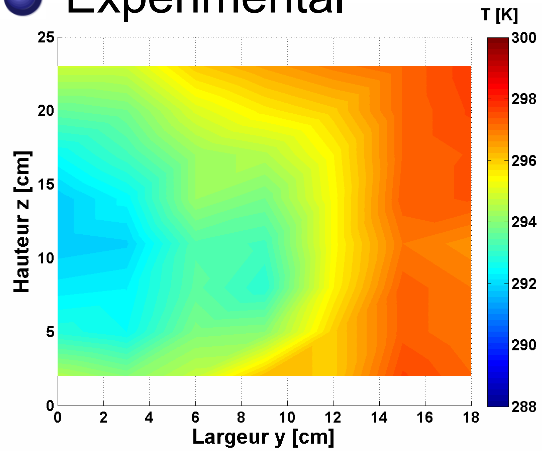
$\dot{m}_{spray}$: 1,4 $l.h^{-1}$

$\dot{m}_{air}$: 0,1 $m^3.s^{-1}$

Distance [cm]	Mean température [K]	
	Experimental	Numérical
5	295	294,9
20	295,1	294,7
40	294,9	294,6
60	294,8	294,6

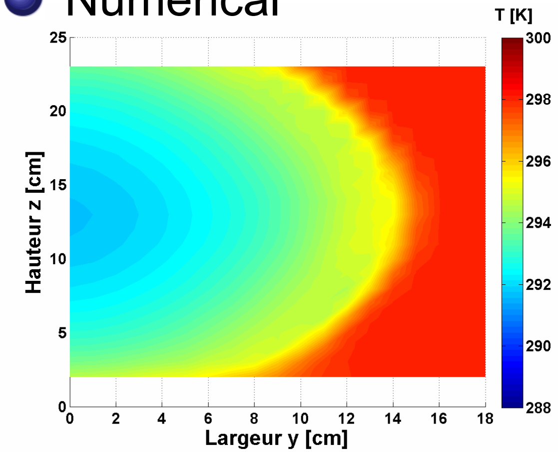
Low temperature variation with distance

- Experimental



At 5 cm of the injection point

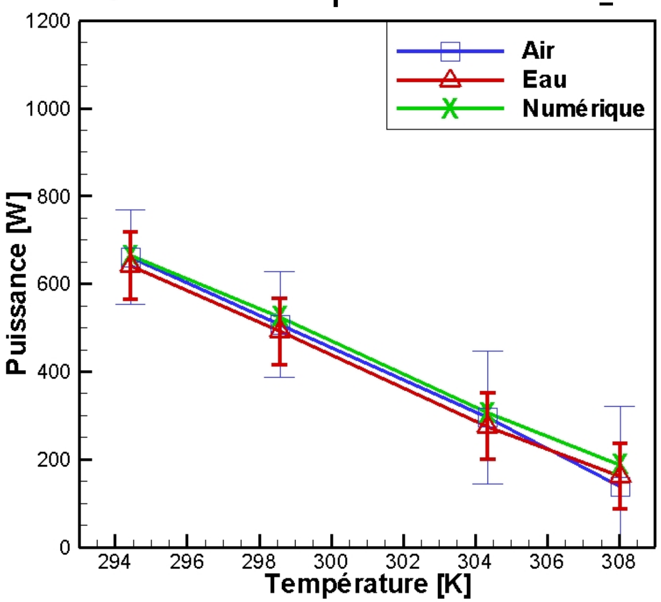
- Numerical



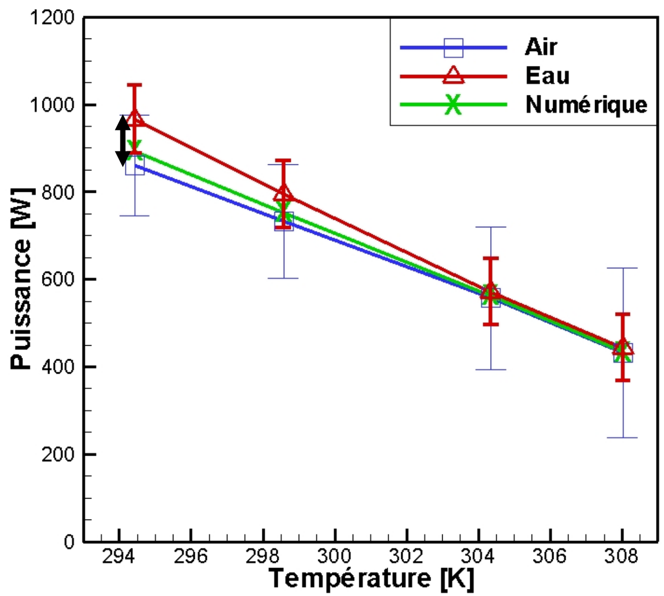
Résultats

- **Comparison between expérimental résults and numerical simulation**

Without pulverisation_

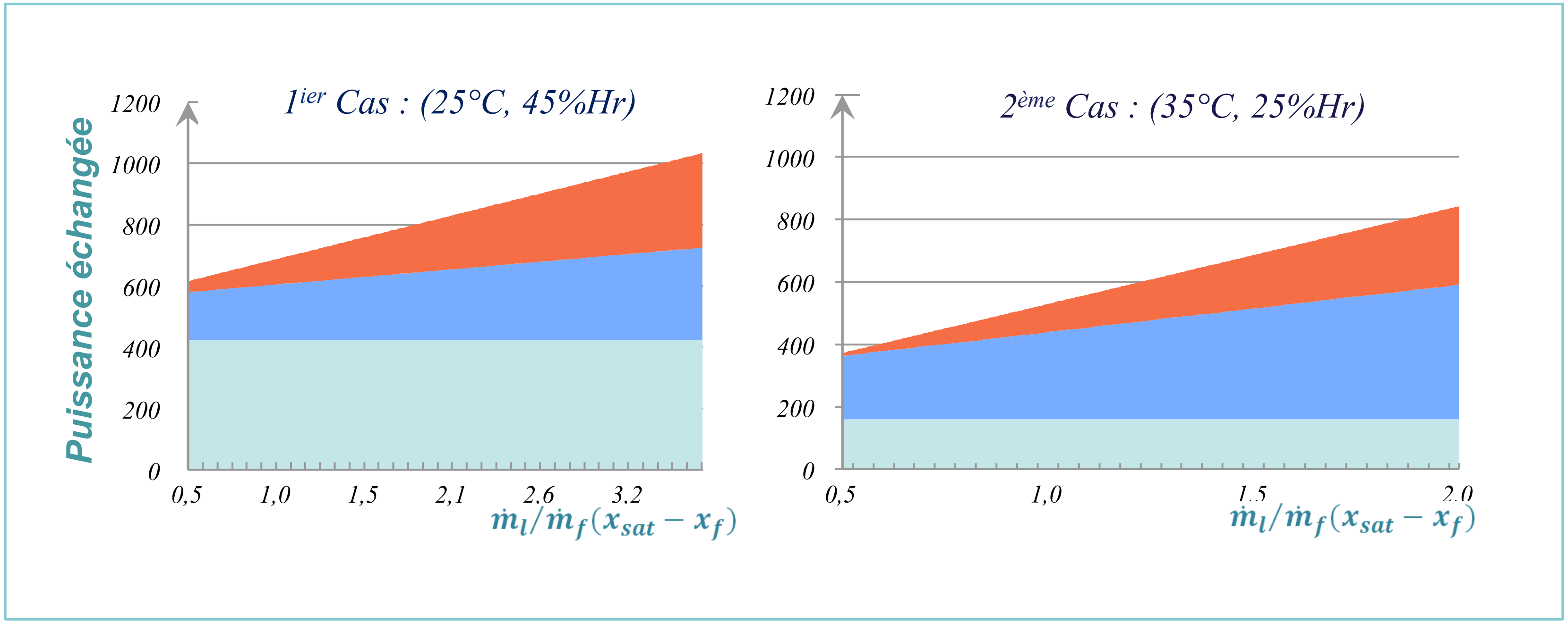


With pulverisation_



Résultats

- **Experimental results**



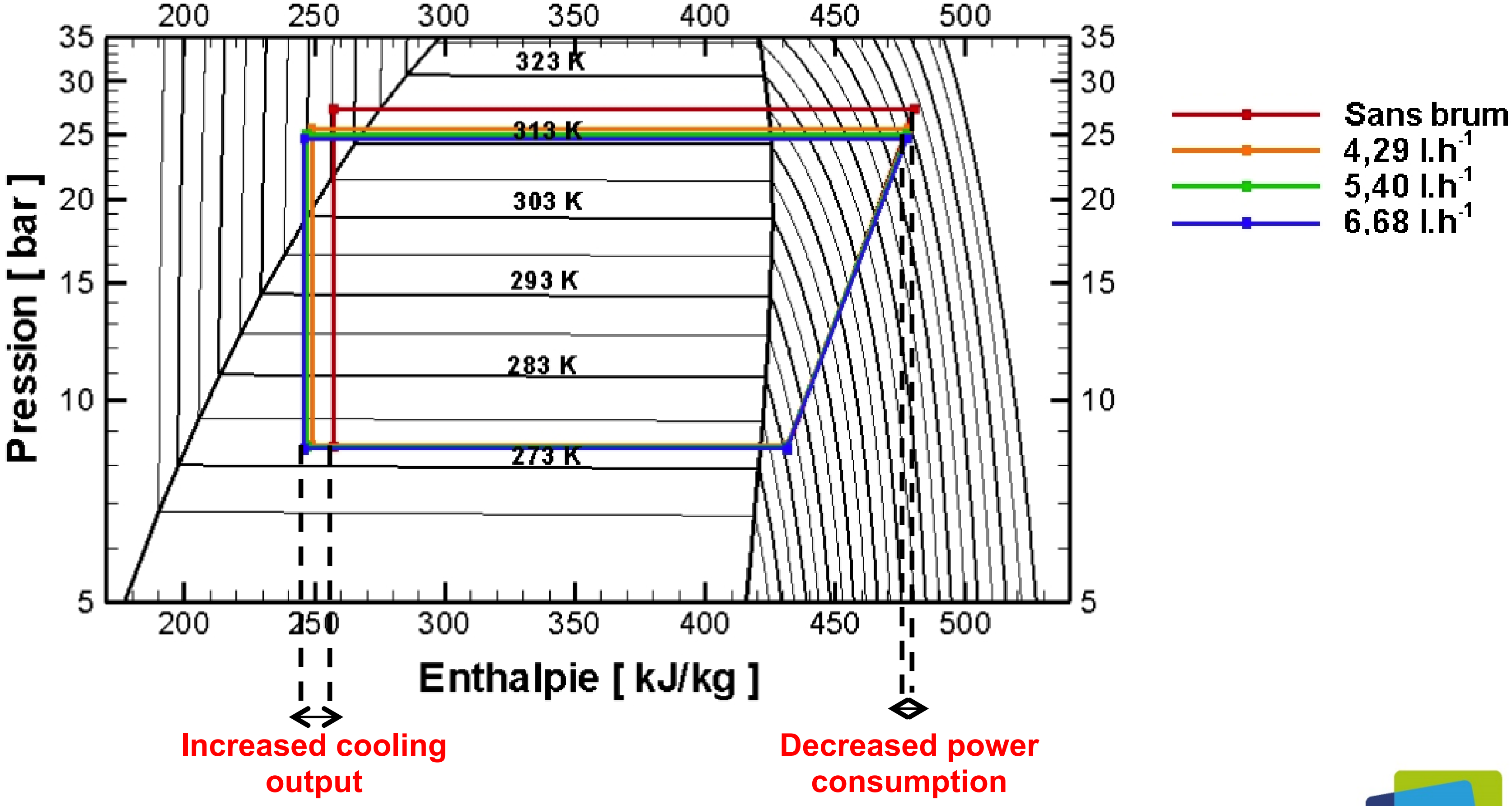
Droplets impzct

Cooling air

Exchanged power without spraying

Résultats

- **Effect of the spray on the chiller cycle (SprayPAC project – CIAT – ADEME)**



Résultats

- **Effect of spray on the chiller**

% Evaporation	**Up to 86 %**

(T_{air} = 293 à 308 K et HR = 47 à 20 %)

Power consumption	↘ **10 à 25 %**
Cooling production	↗ **6 à 8 %**

$$gain = \frac{\left| P_{sans\ brum} - P_{avec\ brum} \right|}{P_{sans\ brum}}$$

Coefficient of performance

COP	↗ **13,5 à 29 %**
COP with spraying system	↗ **9 à 23 %**

$$COP = \frac{P\ utile}{\sum P\ consommée}$$

Conclusion & perspectives

- ## Conclusion

→ Spraying against the current more effective :

Uniformity of temperature distributions upstream of the heat exchanger.

→ Identifying the part due to the impact of water droplets on the heat exchanger on the intensification

→ Implementation of a suitable metrology

→ Improvement of the coefficient of performance uo to 23% in our case of study

- ## Perspectives

→ Optimization of the system : development of experiemental and numerical tools

→ Droplets flow through a heat exchanger

→ Cost of the dispersion phase production