中性子線CTによる超臨界水熱合成反応器内混合状態のin-situ観察

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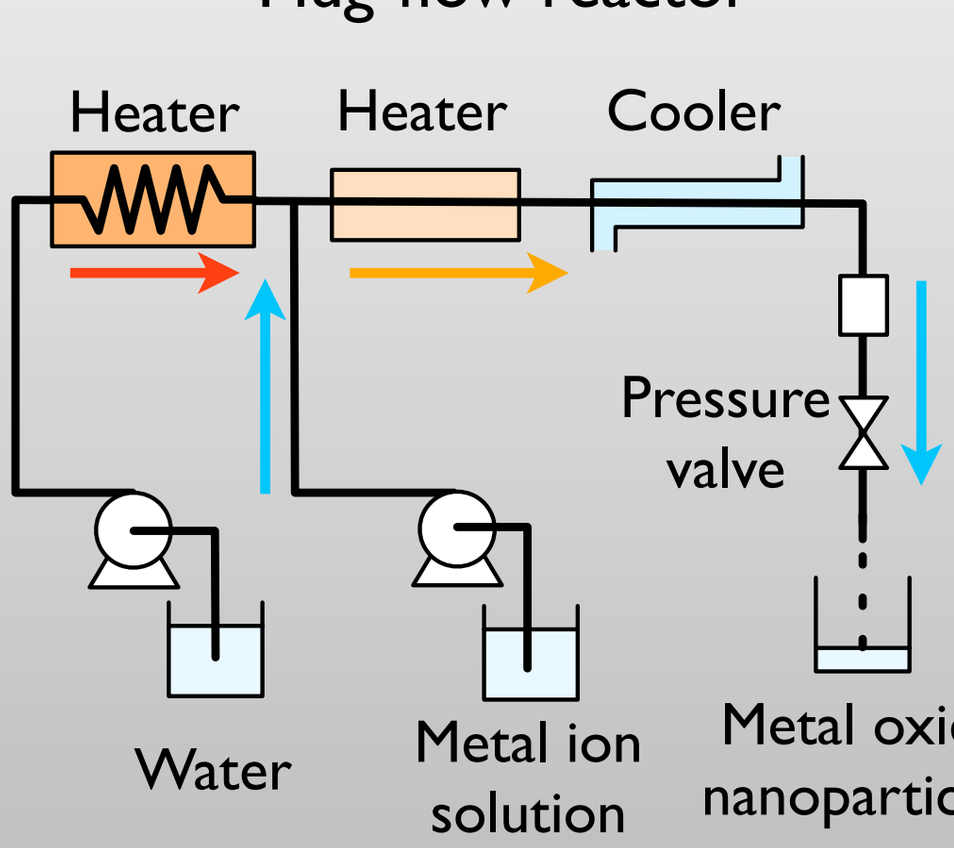
Hydrothermal synthesis

Hydrothermal synthesis of metal oxide nanoparticles

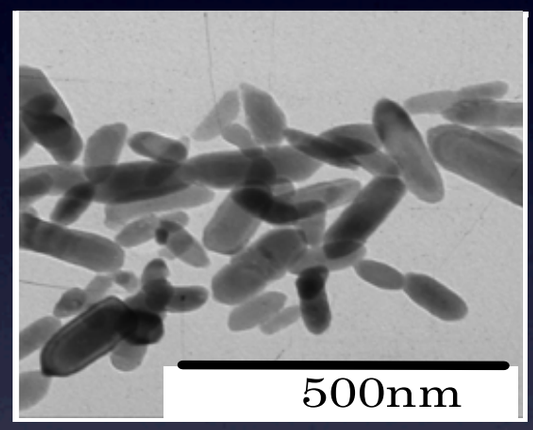
$$Zn^{2+} + 2H_2O \rightarrow Zn(OH)_2 + 2\,H^+$$
$$Zn(OH)_2 \rightarrow ZnO + H_2O$$

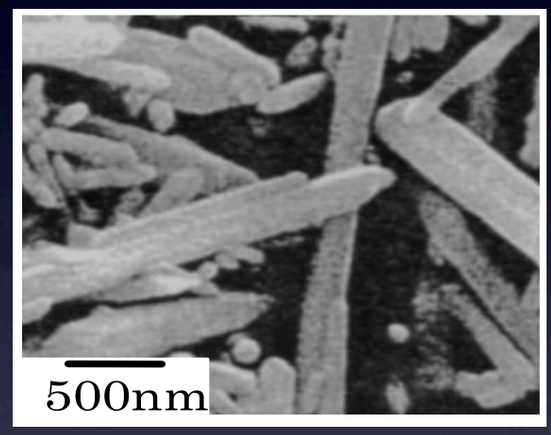
Plug-flow reactor

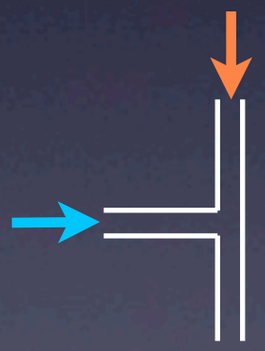


Effects of mixing

ZnO





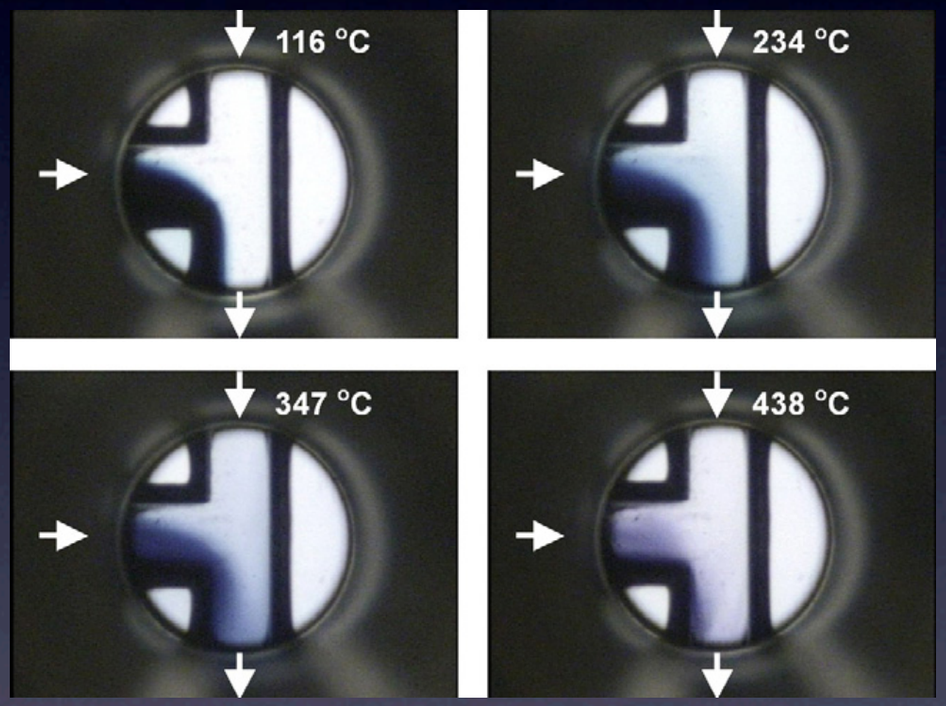


T. Adschiri, *et al.*, in Materials Chemistry in Supercritical Fluids, Research Signpost, 79–97 (2005)

Mixing of supercritical water and reactants affects the products

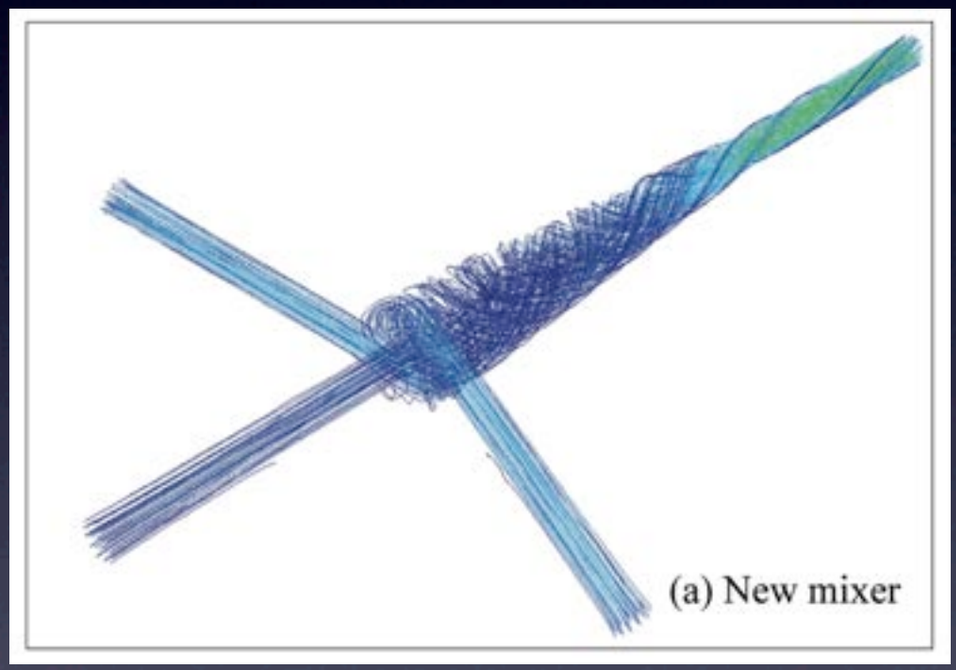
Visualization techniques

View cell



Aizawa, *et al.*, *J. Supercrit. Fluids* **43**, 222 (2007).

Fluid dynamics simulation



Design of mixer

Wakashima, *et al.*, *J. Chem. Eng. Jpn.* **40**, 622 (2007).

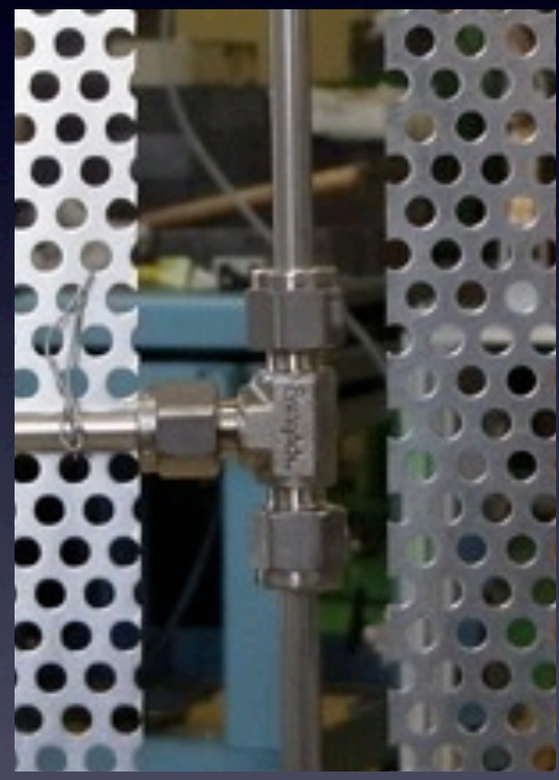
Visualization of real apparatus

Previous studies revealed

- Buoyancy force
- Density difference
- Natural convection
- Cascade down

- Reactor design
- Rate of heating
- Mixing time

Shape of our mixing components

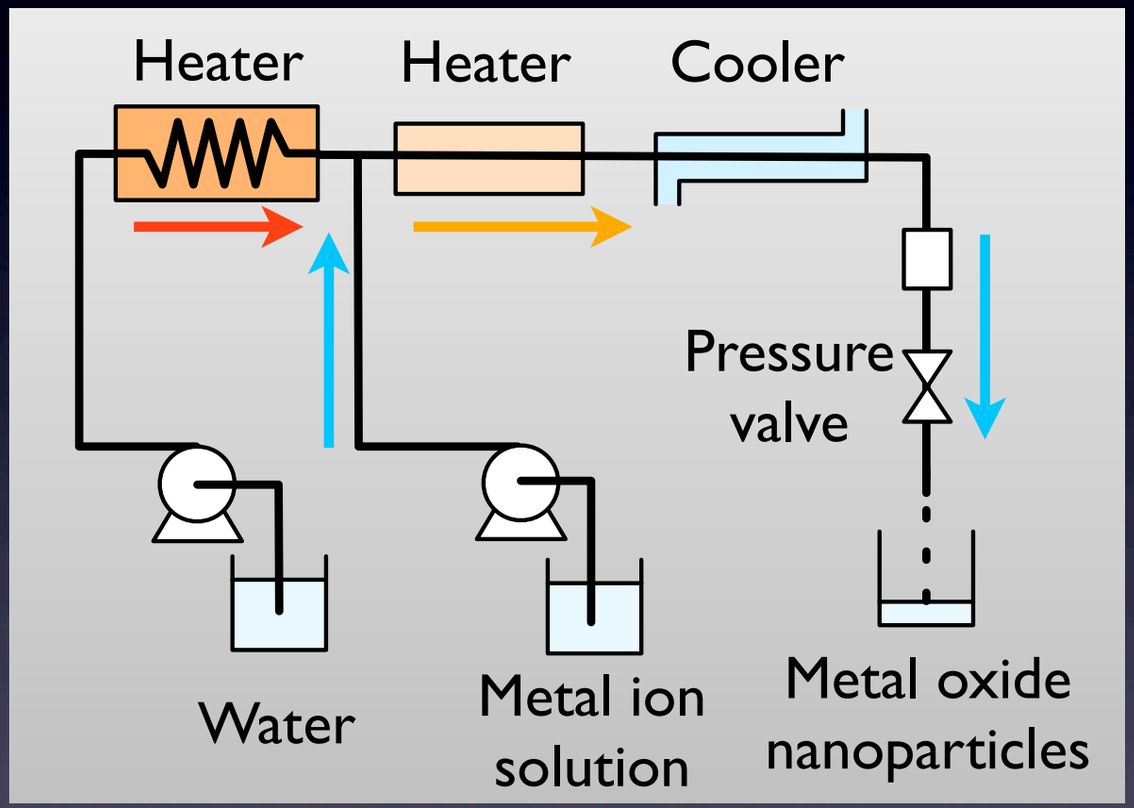


How the streams mix in the real apparatus ?

→ Neutron radiography

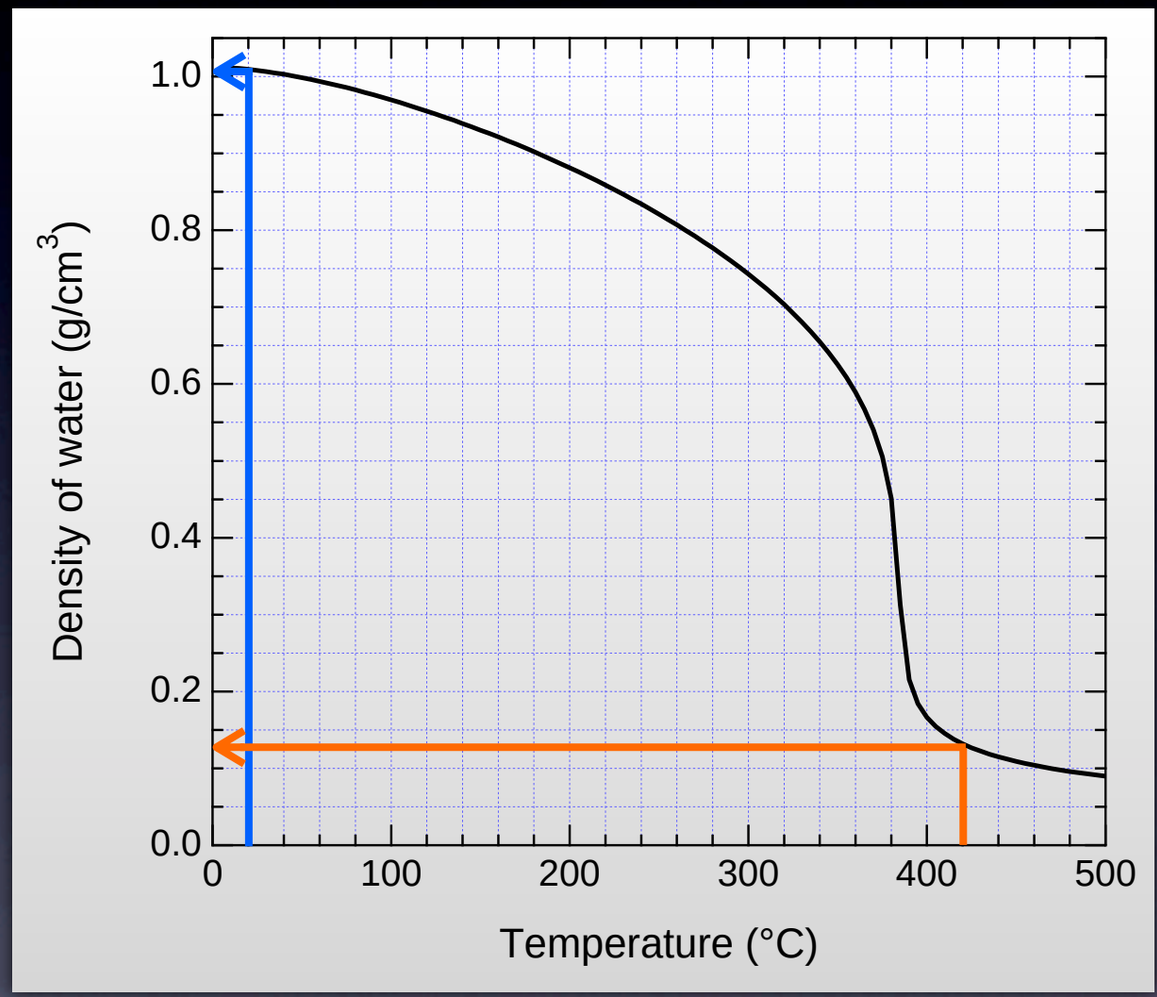
Why neutron radiography ?

Plug-flow reactor



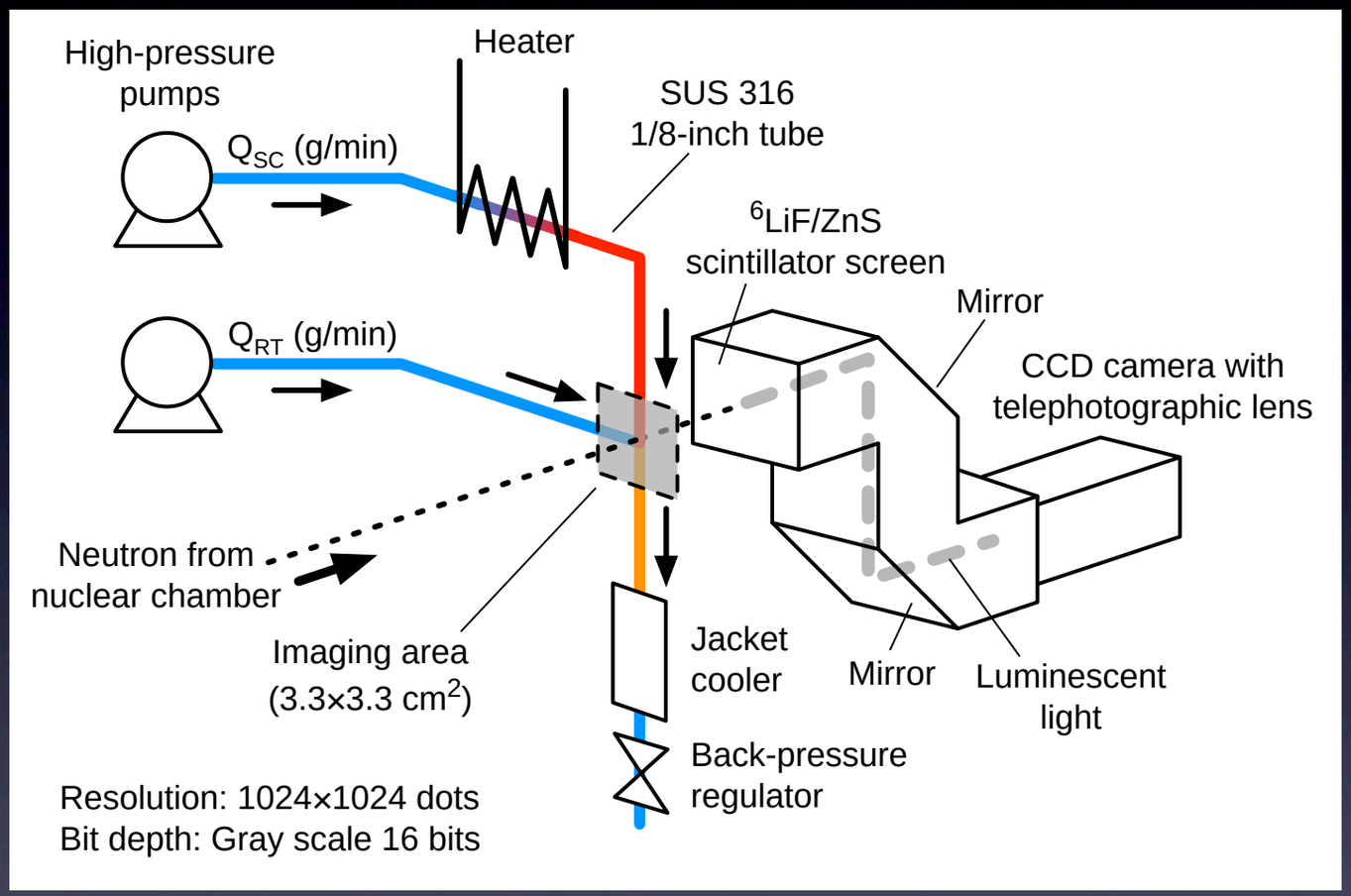
300~400°C, 25 MPa

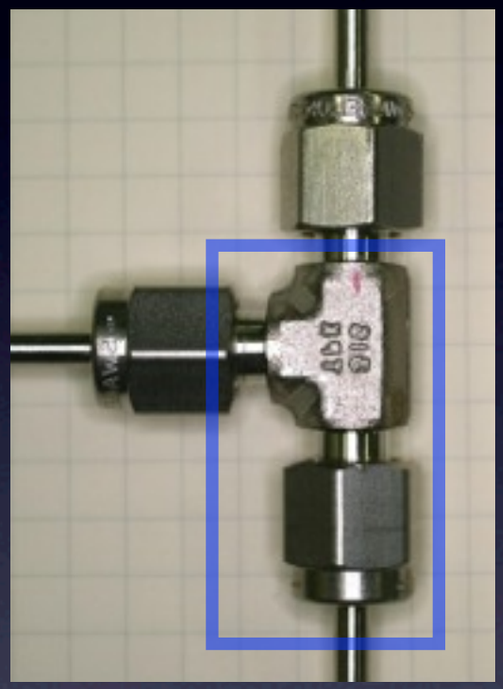
Density of water @ 25 MPa



Density of water drops at the mixing point.

Previous studies

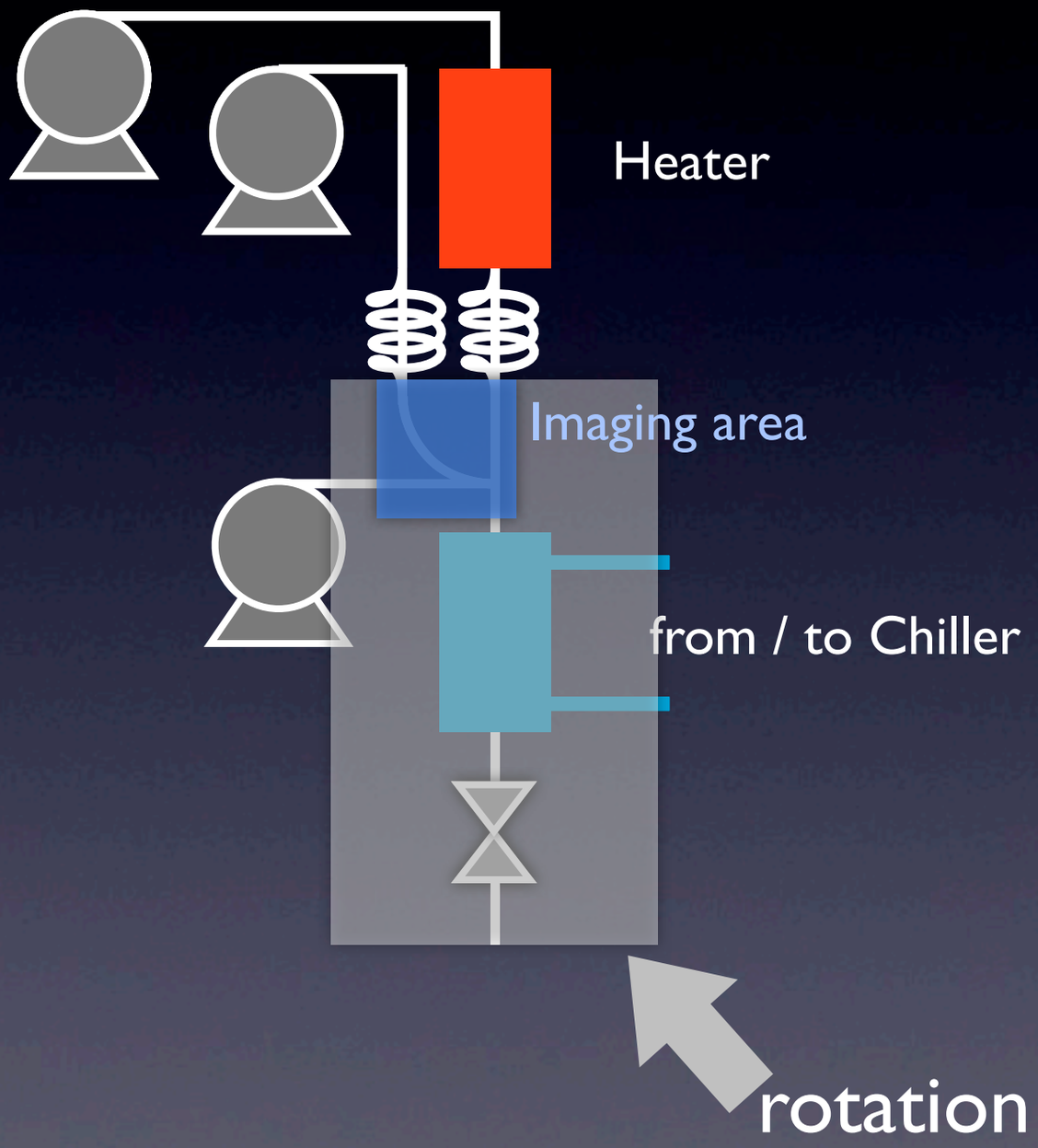




Averaged images were obtained.

→ CT experiments

How to obtain CT images ?

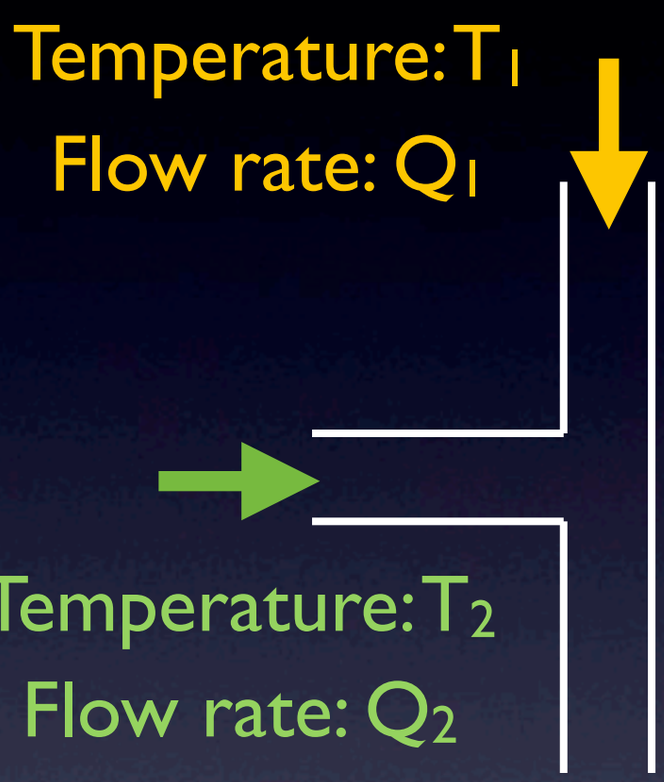


Heater

Heater

Imaging area

Experimental condition



Q_1 (g/min)	T_1 (°C)	Q_2 (g/min)	T_2 (°C)	T_{mix} (°C)
12.0	~386	3.0	31	373
12.0	~385	6.0	30	335
6.0	30	12.0	~391	355
2.0	28	7.0	~384	355

Outer diameter: 1/8 inch
Inner diameter: 2.3 mm

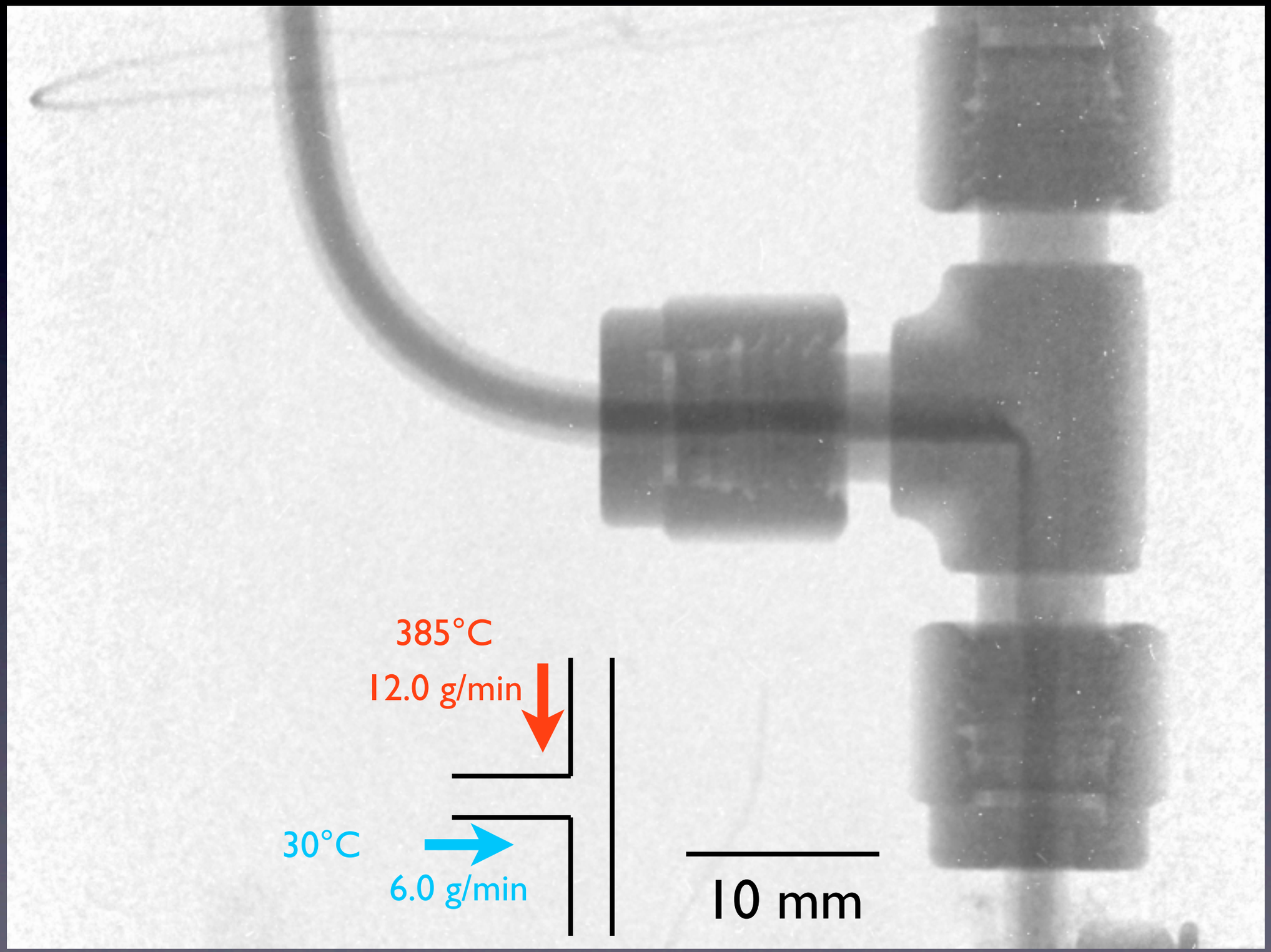
P = 25 MPa

Imaging area: 65×65 mm^2

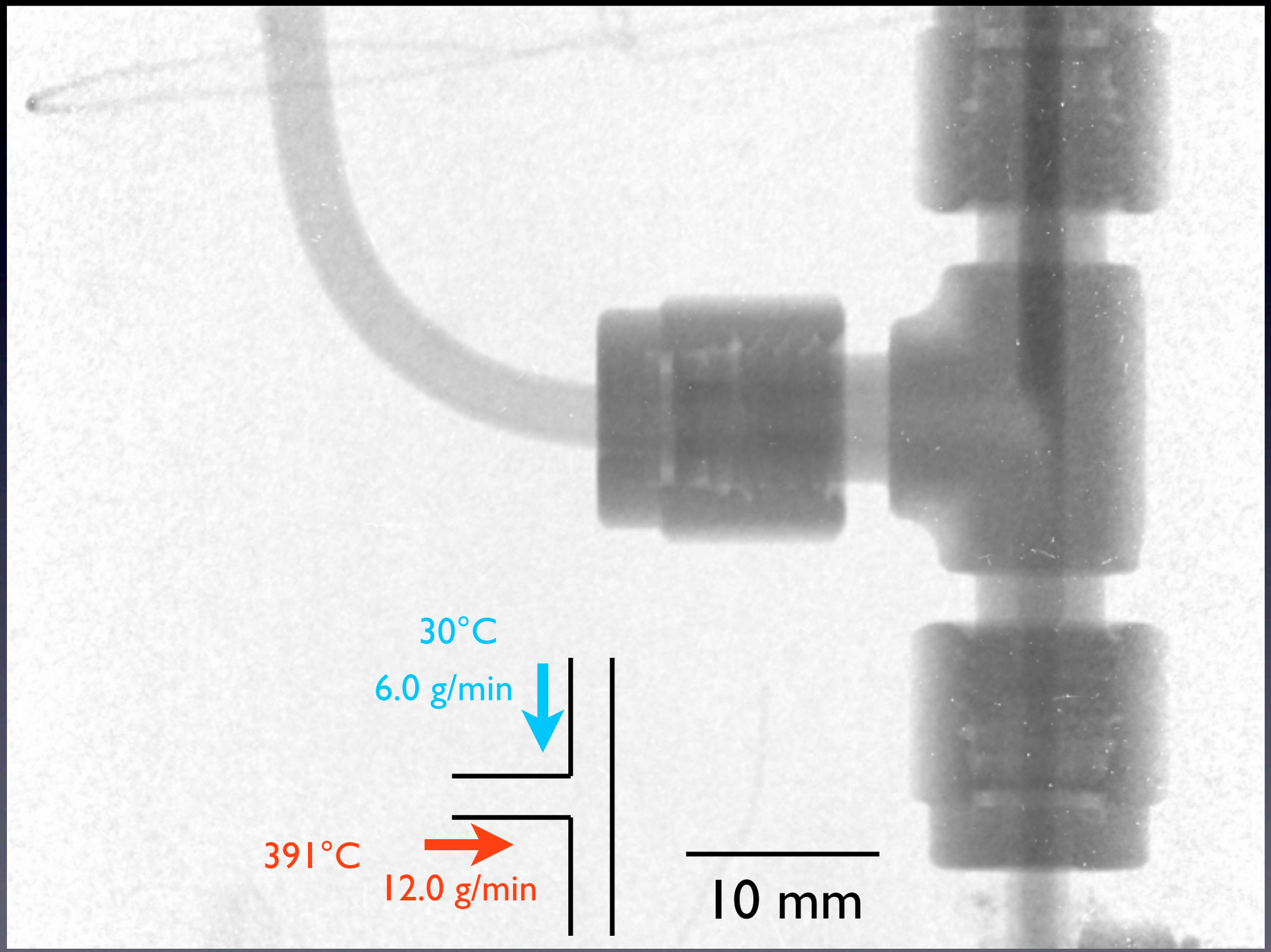
60 s for 1 image
200 images for one condition

2012/10/23~25 @ B4, 5 MW

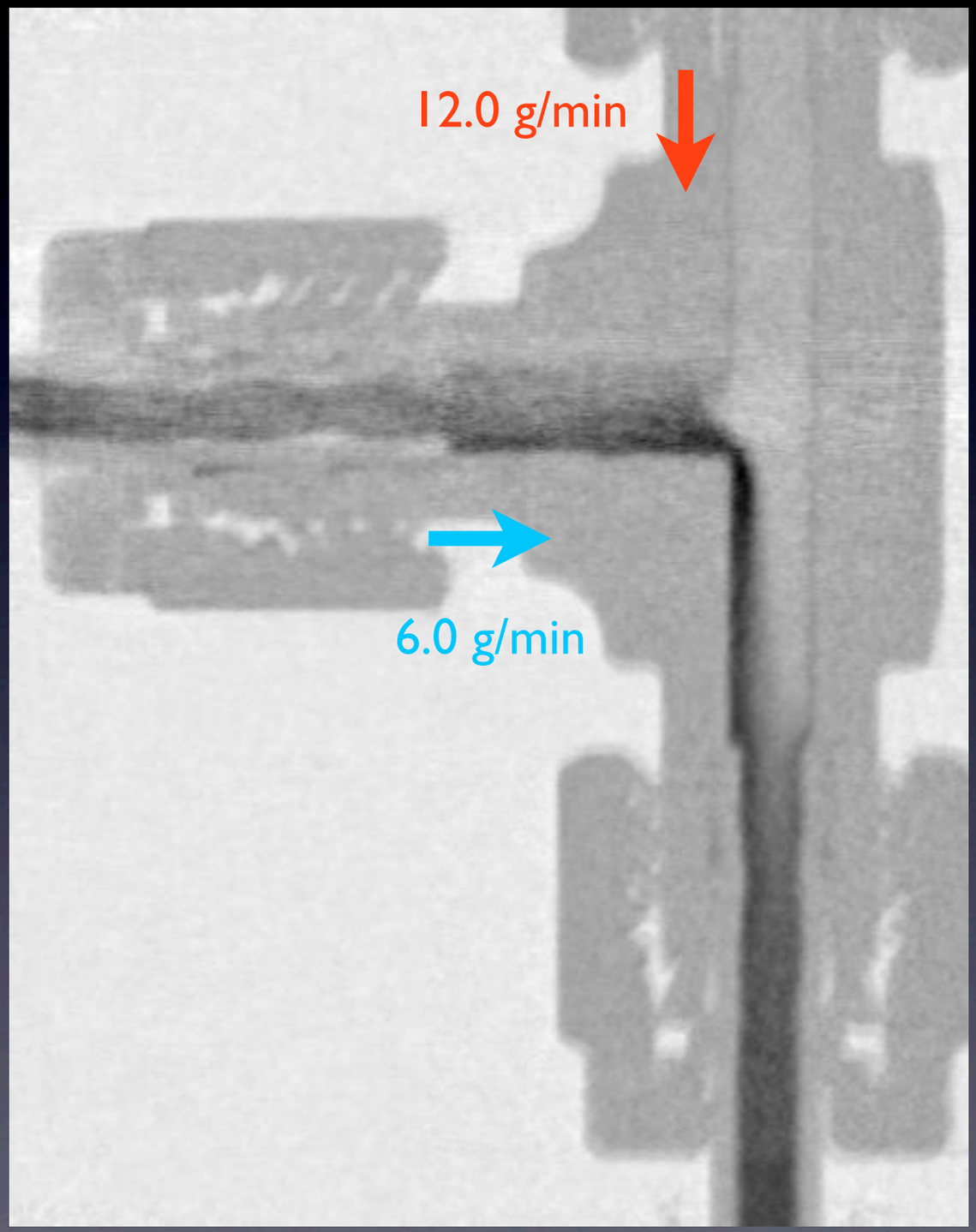
Heated water from top

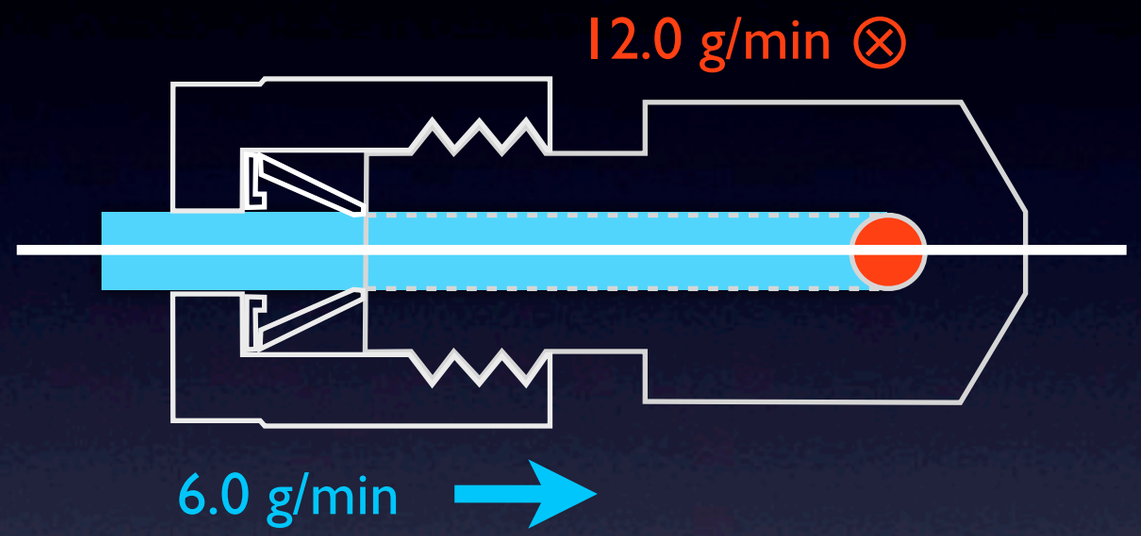


Heated water from side



Reconstructed image





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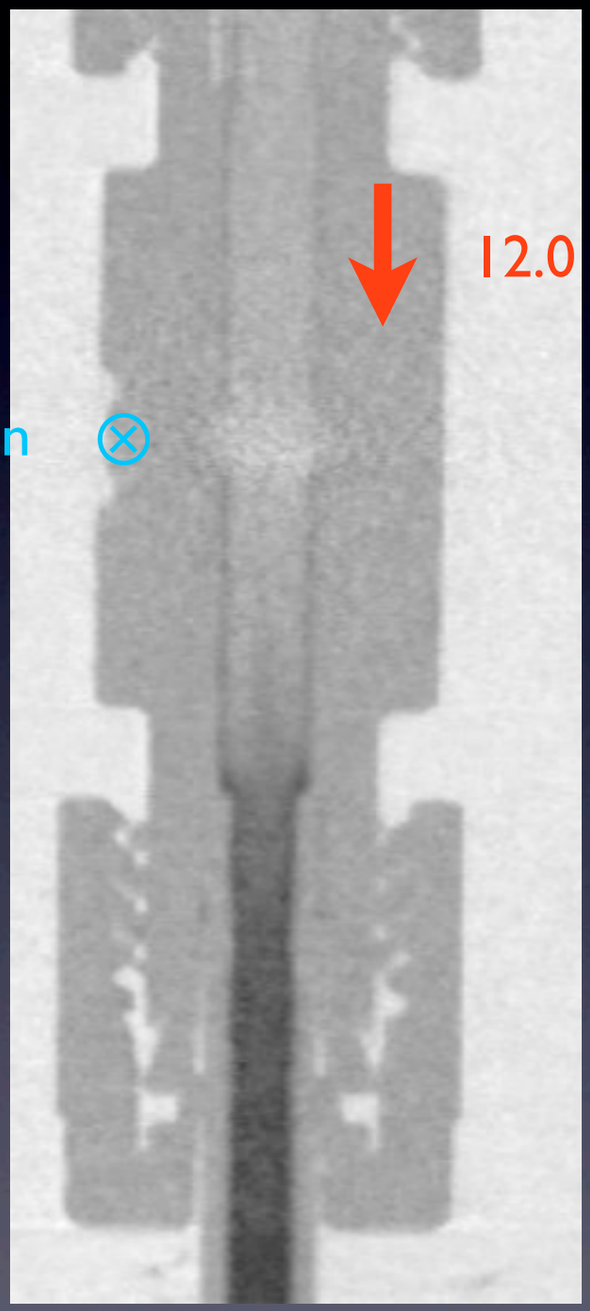

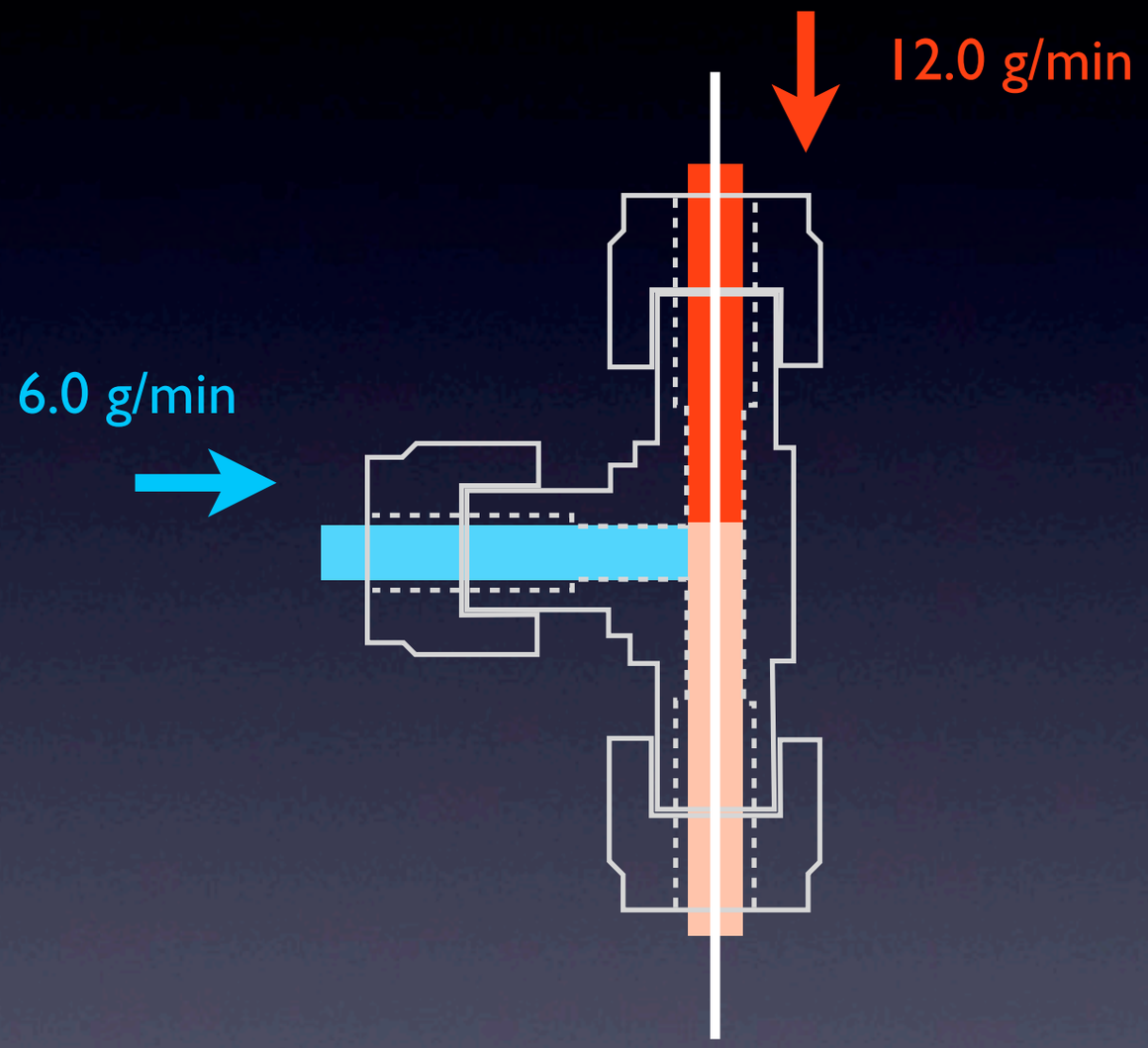

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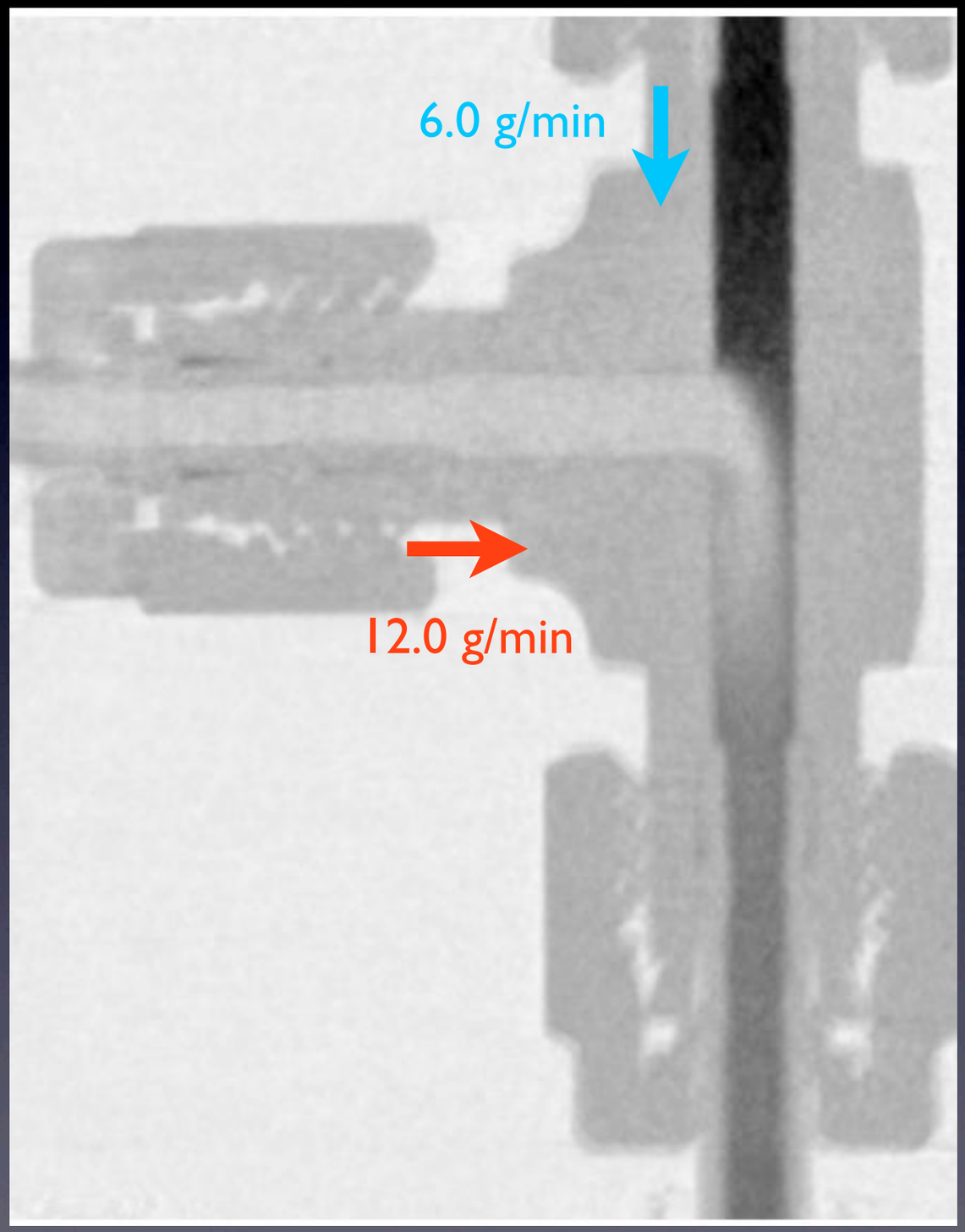

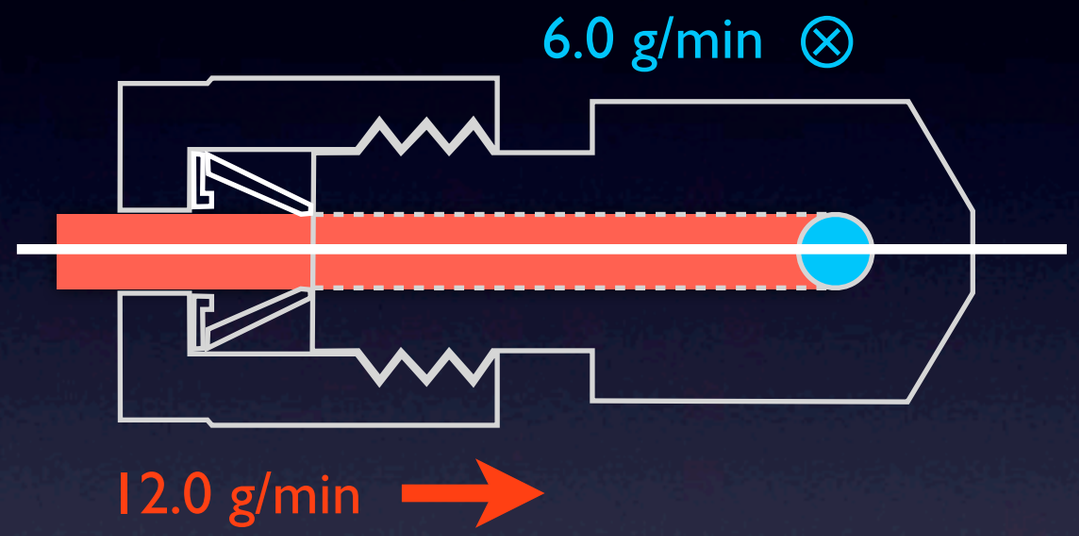

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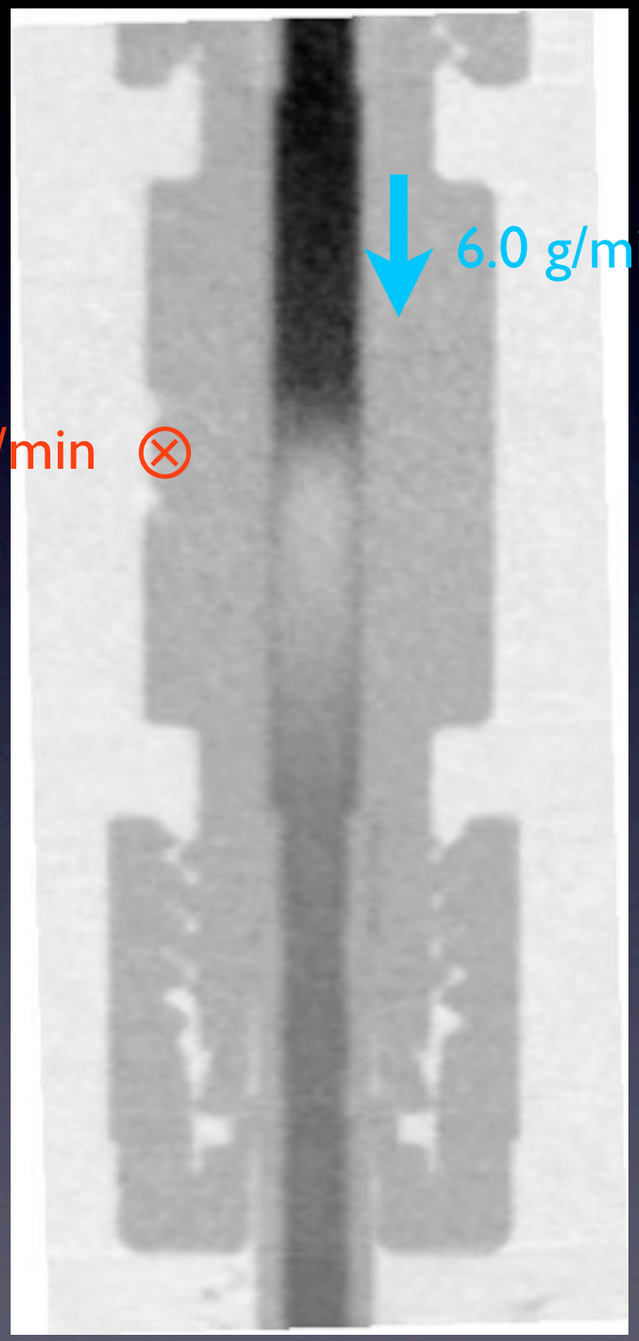

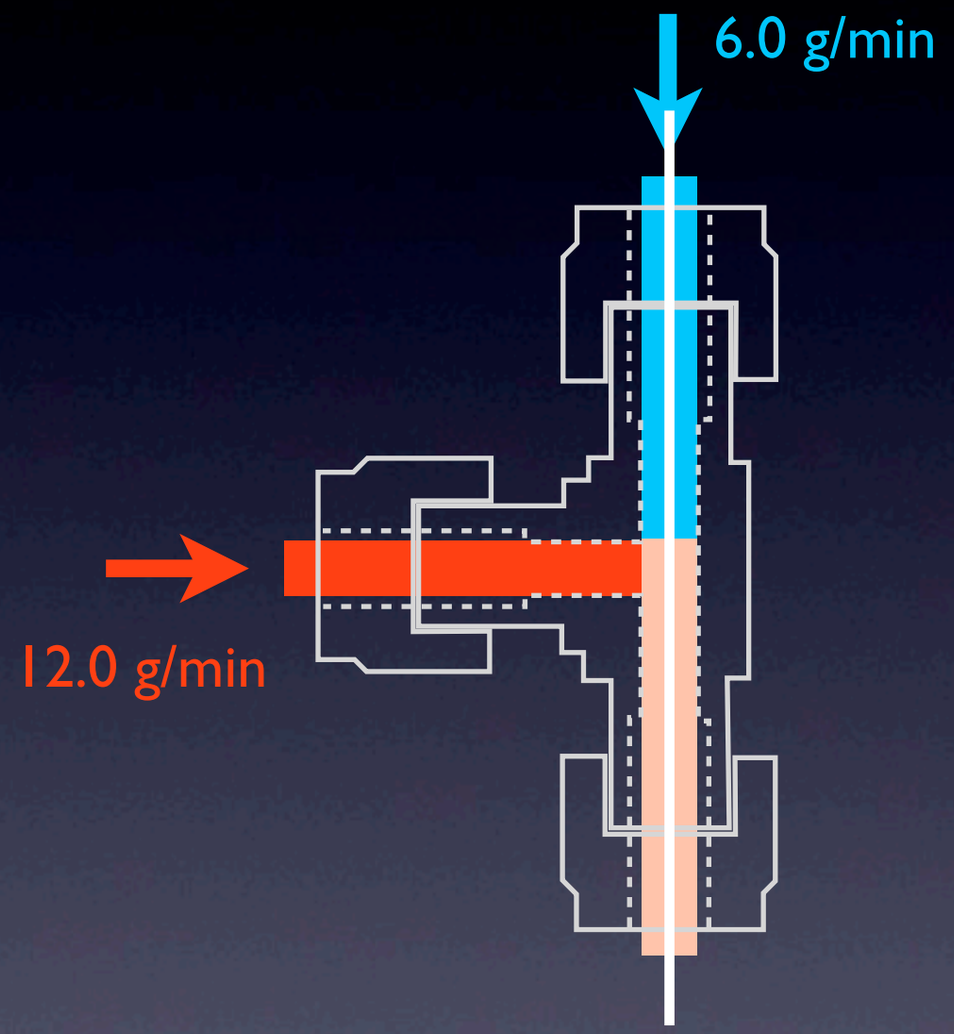

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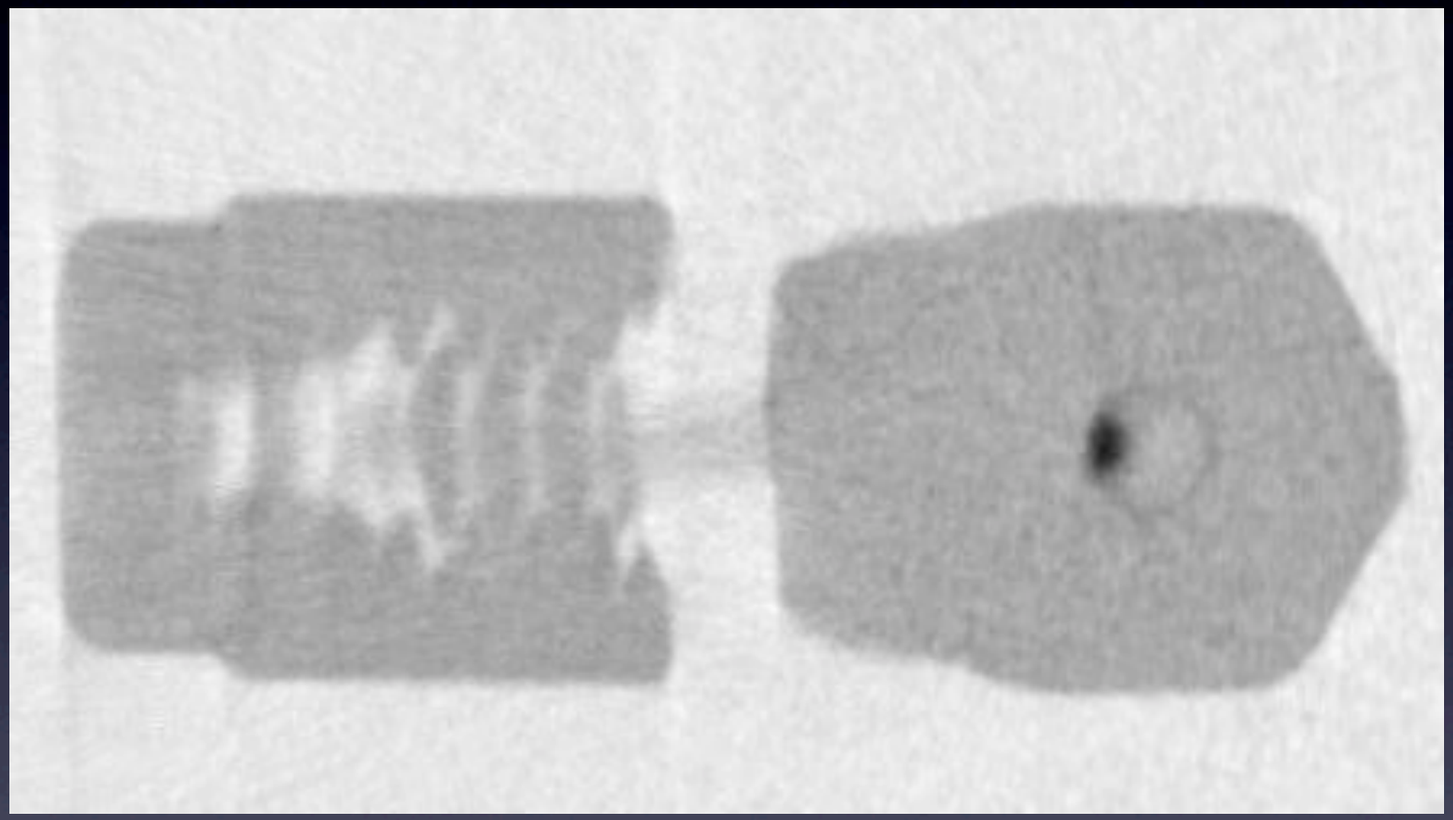

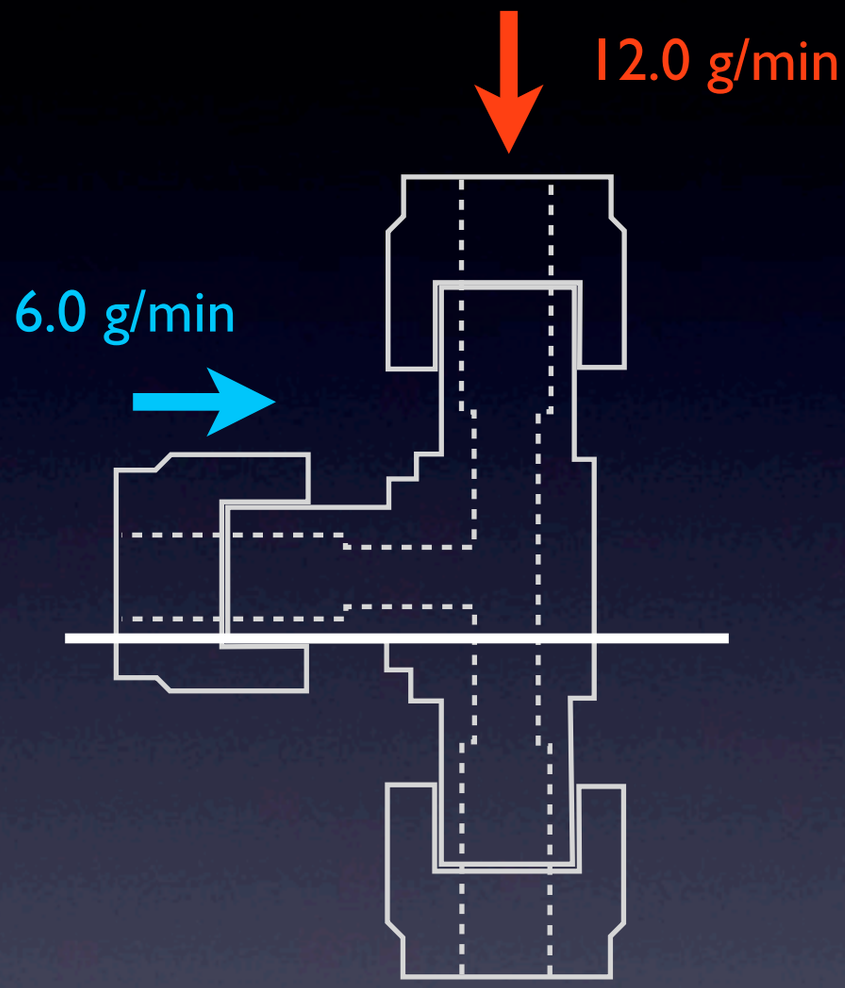

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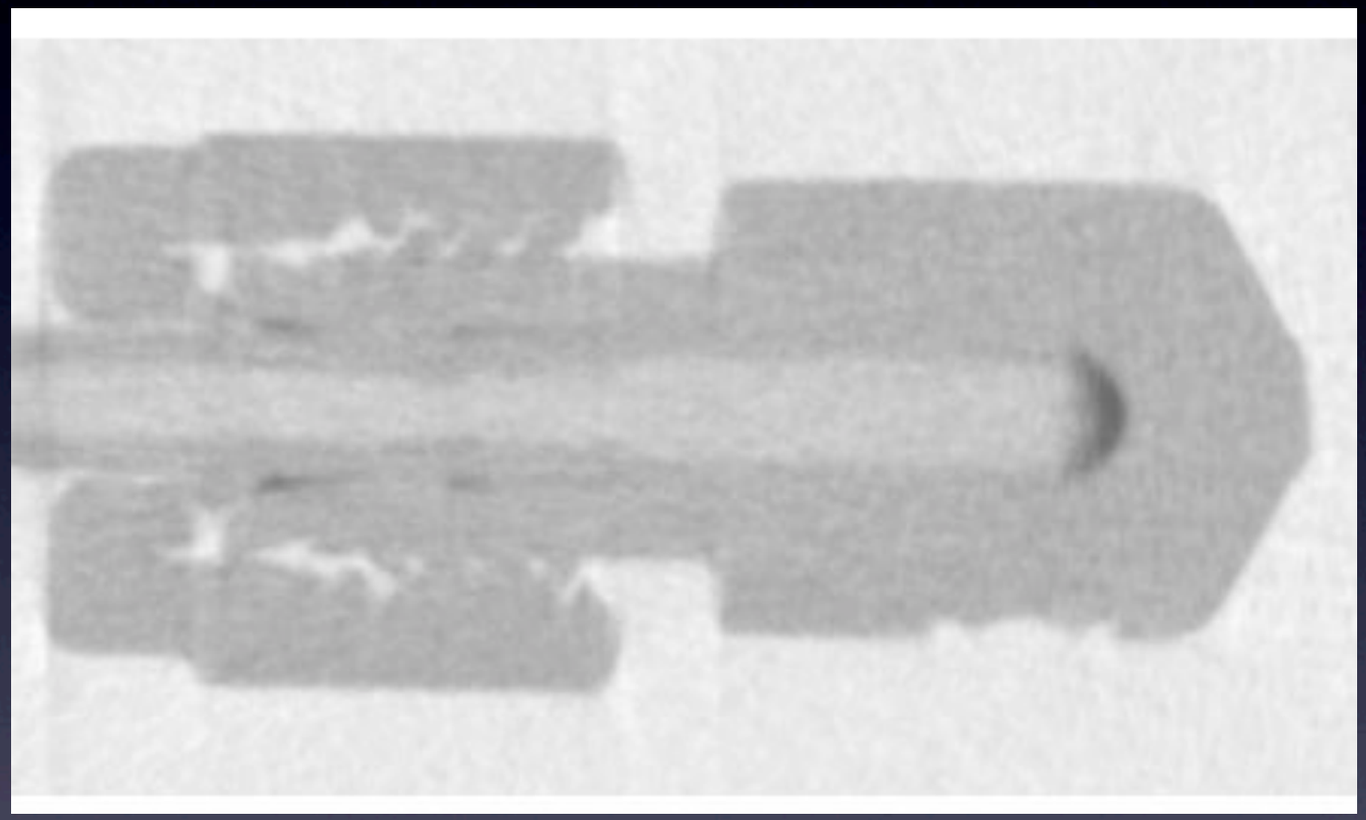

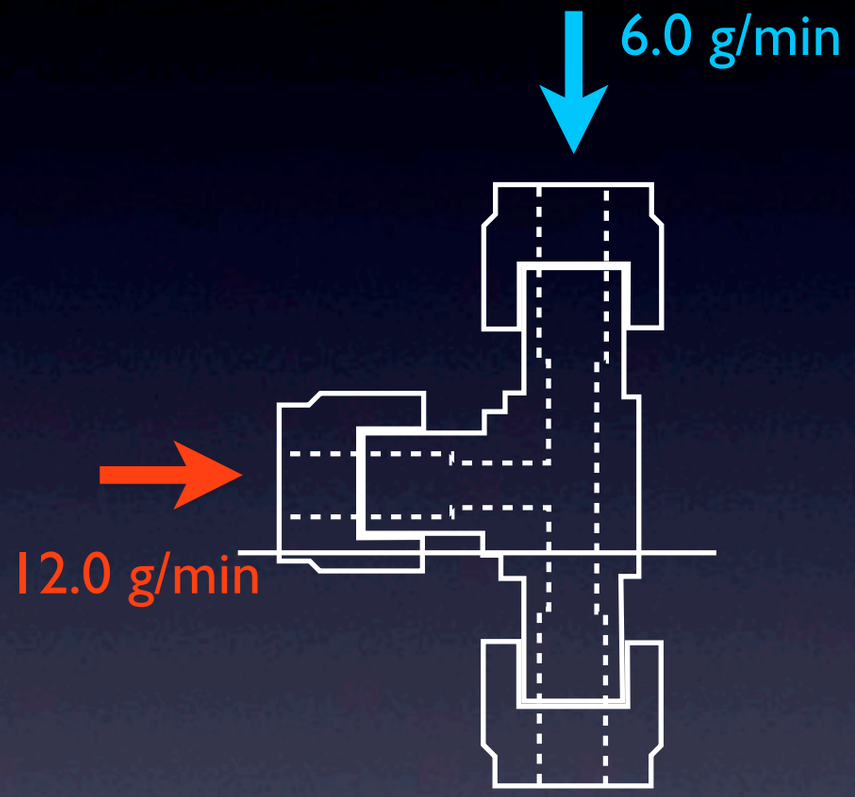

Summary

中性子線CT測定を行い、超臨界水熱合成反応器内の
流動・混合状態の３次元測定の可能性を示した。

今後の展開

- 流体シミュレーション計算の妥当性検証
- より解像度の高い観察
- 実際の生成物との比較

謝　辞

京都大学原子炉実験所　川端先生、齊藤先生、伊藤先生
神戸大学　竹中研のスタッフ及び学生の方々