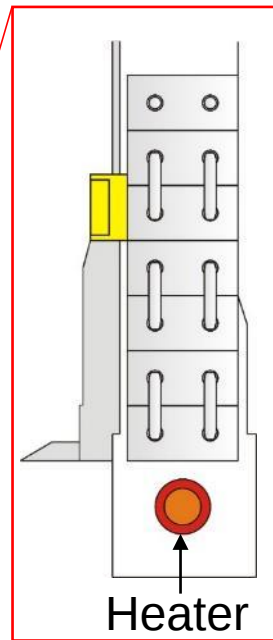
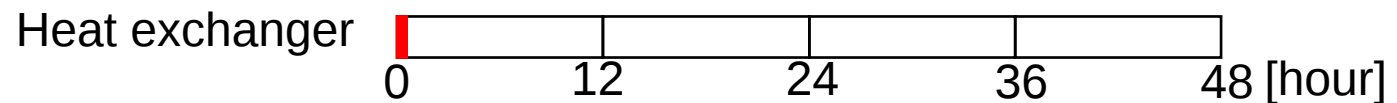


中性子ラジオグラフィを用いた 除霜時の融解水挙動の観察

◎ 塩川貴大(関西大)	松本亮介(関西大)
西浦雄人(関西大)	槇原拓郎(関西大)
齊藤泰司(京都大)	伊藤大介(京都大)



Frost formation on the heat exchanger



- ◆ 熱交換器への着霜は霜が**熱抵抗**および**流動抵抗**になるために機器の効率を低下させる.
- ◆ 熱交換器の性能を維持するために霜を取り除く**除霜運転**が定期的に行われる

Domestic refrigerator

Frost Cooling surface



(a) Frost formation

Meltwater penetration



Water

(b) During defrosting



(c) Completion defrosting

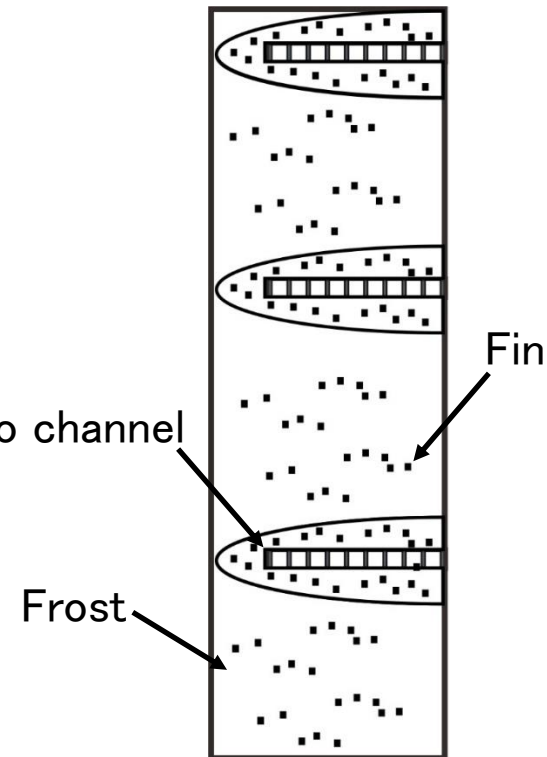
- 空気と氷の多孔質層からなる霜層が冷却面上に形成される
- 加熱により霜層を取り除くが融解水は霜層内へ浸透する
- 融解水は離脱するが一部が残存する



出典：ダイキン工業株式会社ホームページより

https://www.daikinaircon.com/green_multi/technology/index.html

Microchannel heat exchanger



Frosting

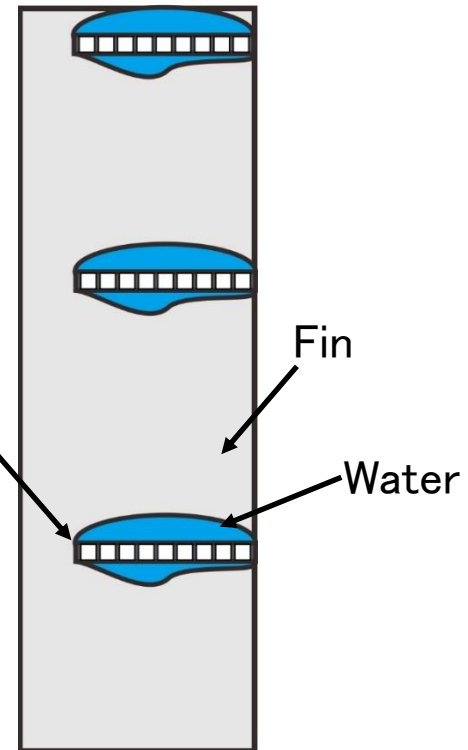


出典：ダイキン工業株式会社ホームページより

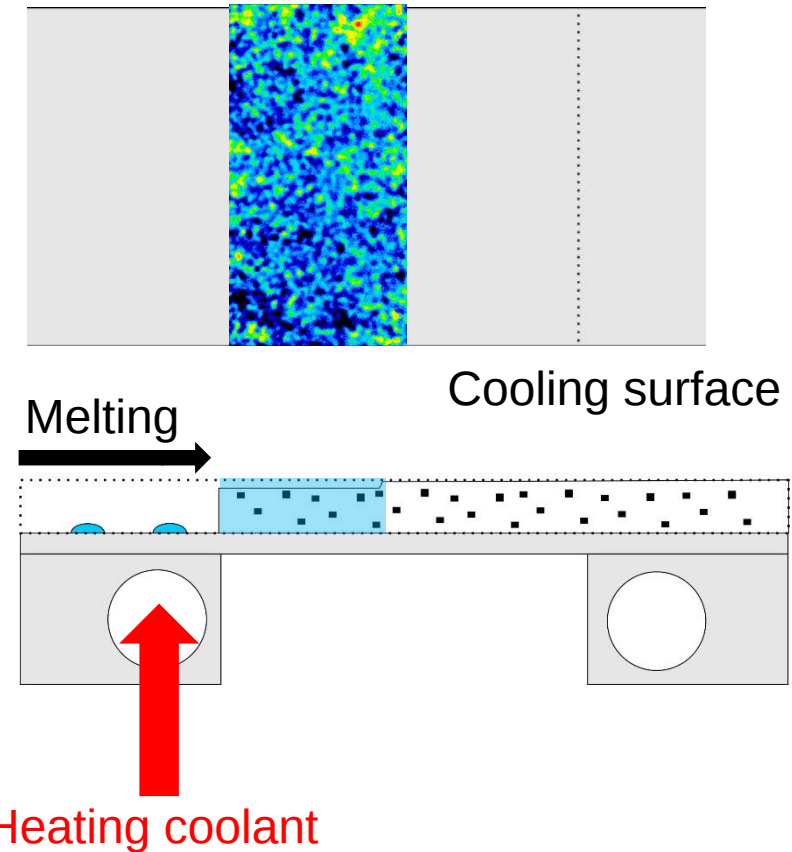
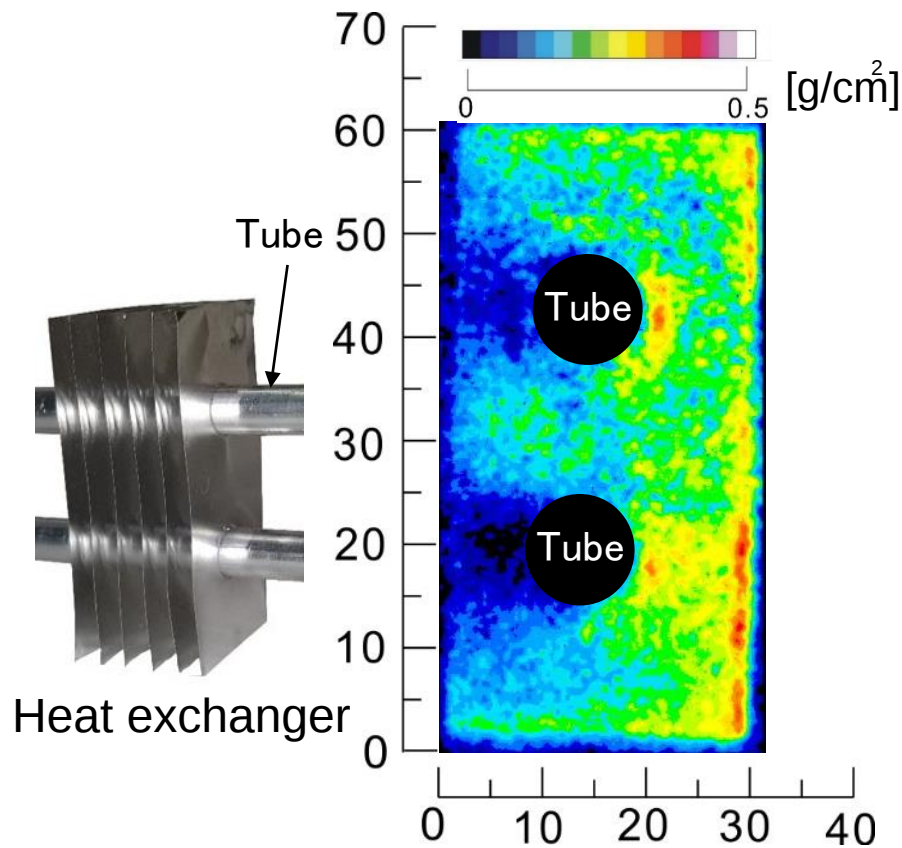
https://www.daikinaircon.com/green_multi/technology/index.html

Microchannel heat exchanger

Micro channel



Defrosting

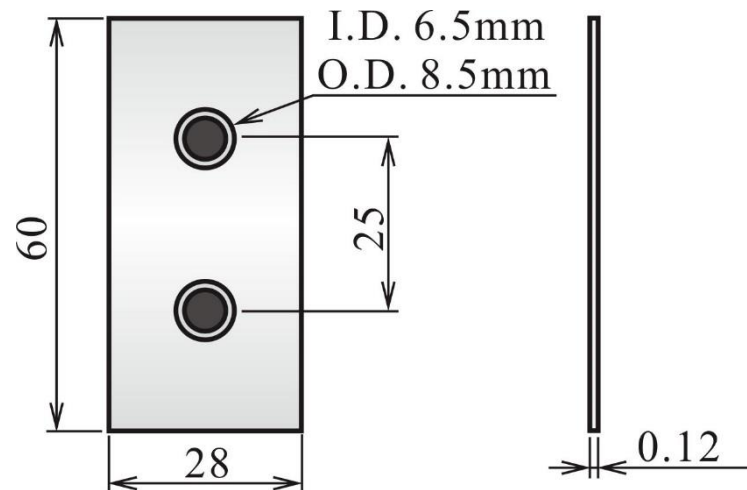
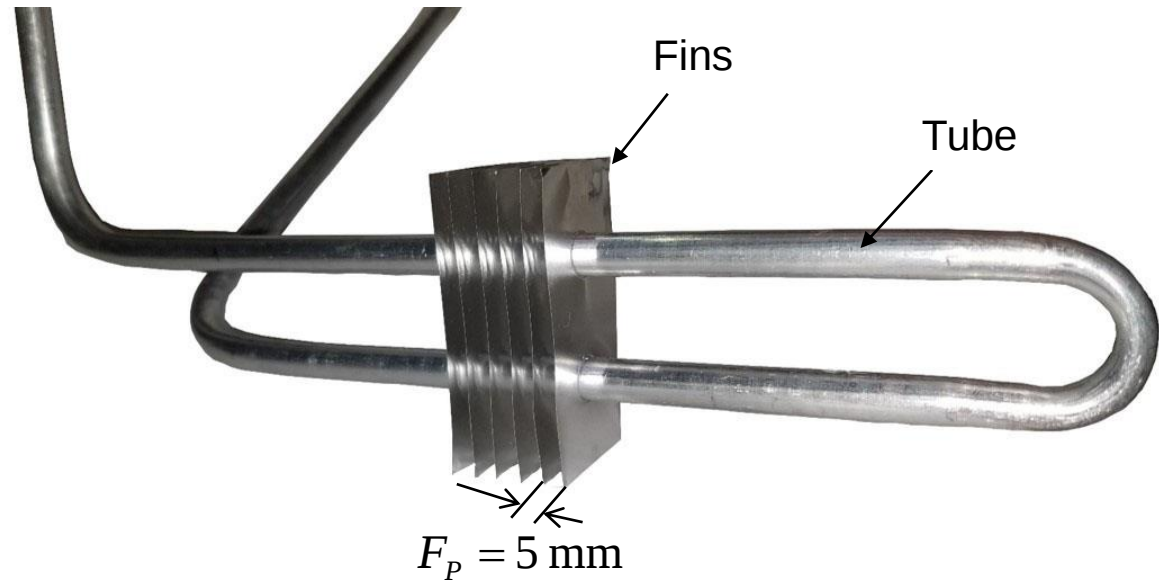


研究目的

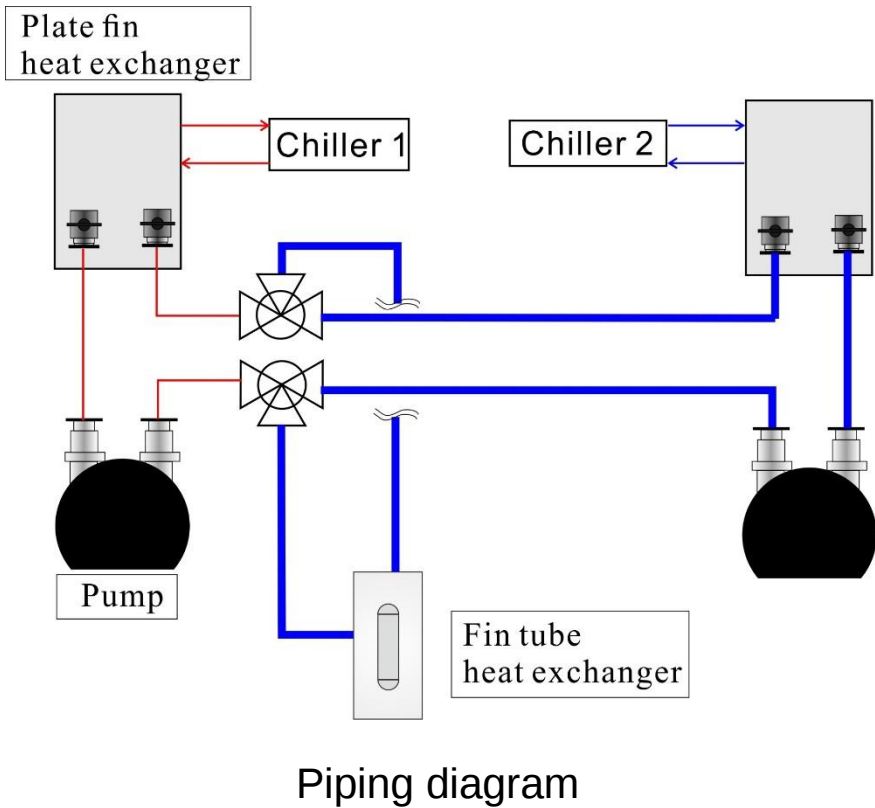
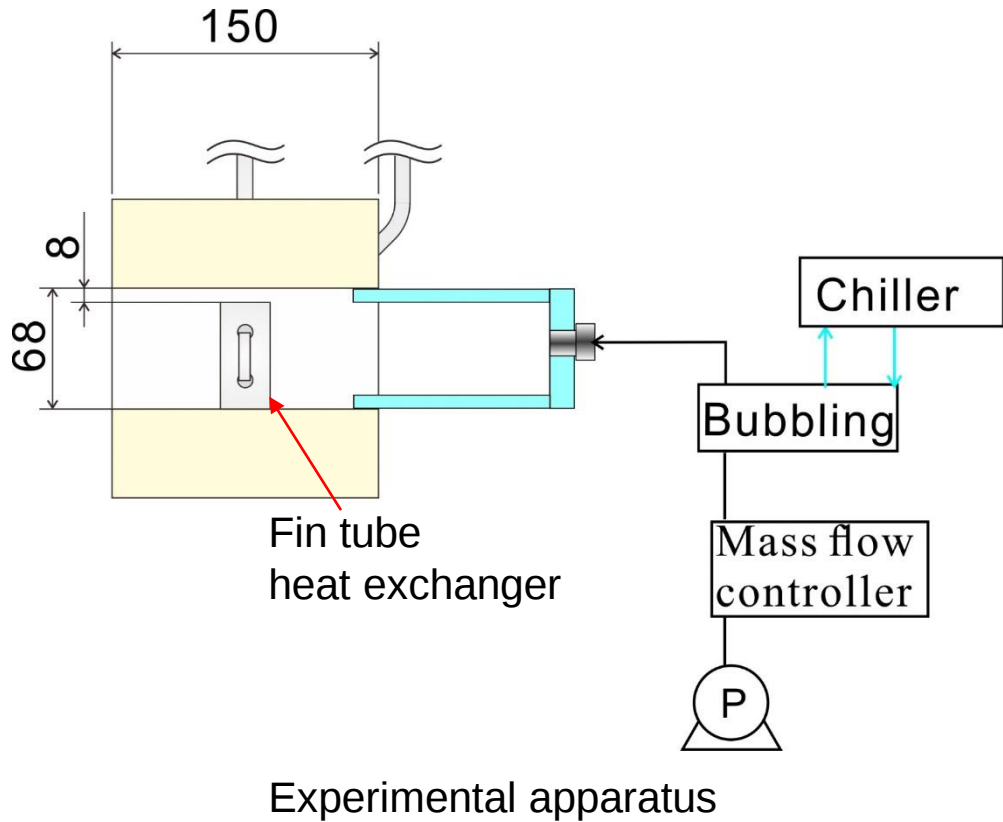
除霜時における熱交換器の融解水挙動の観察および
単一垂直平板上での除霜時における温度の変化を観察する



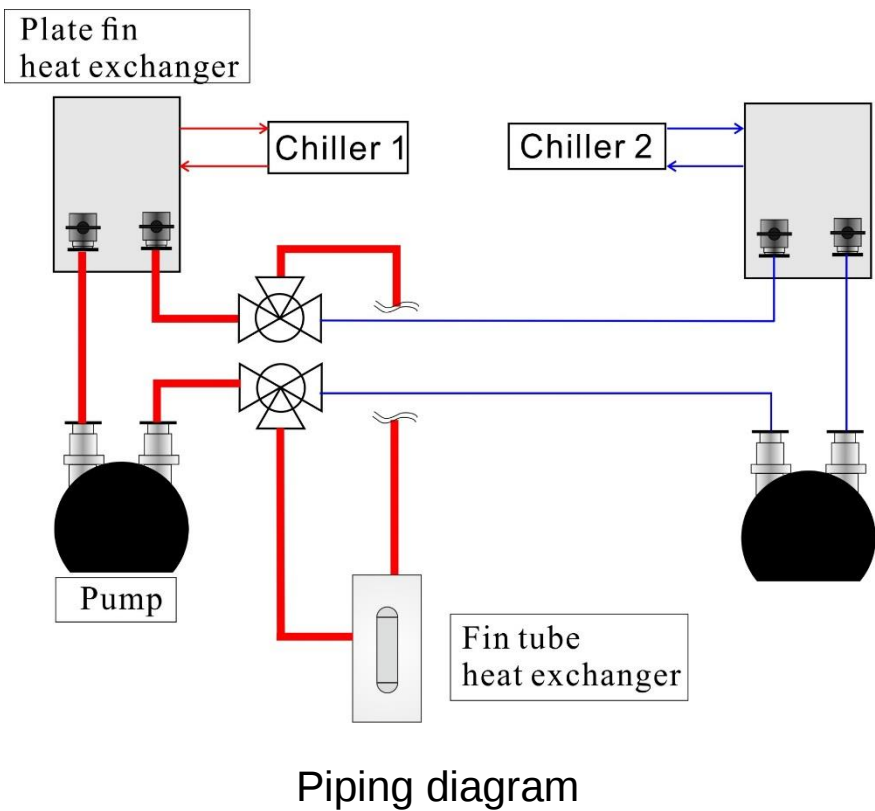
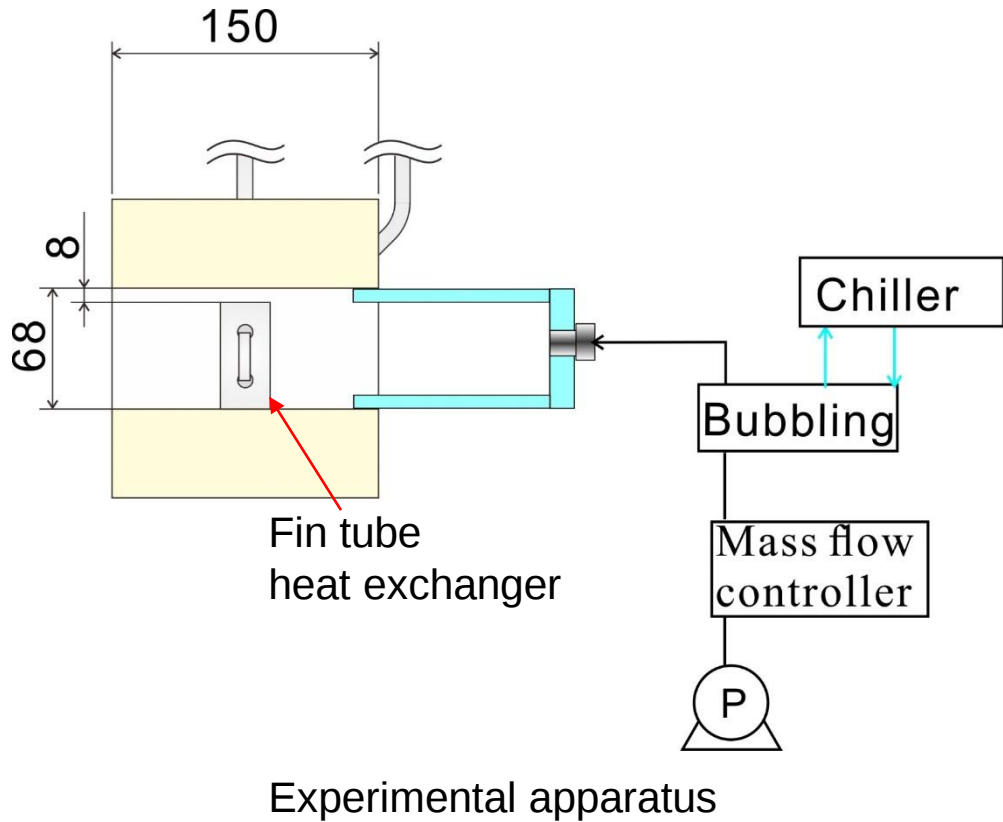
Domestic refrigerator



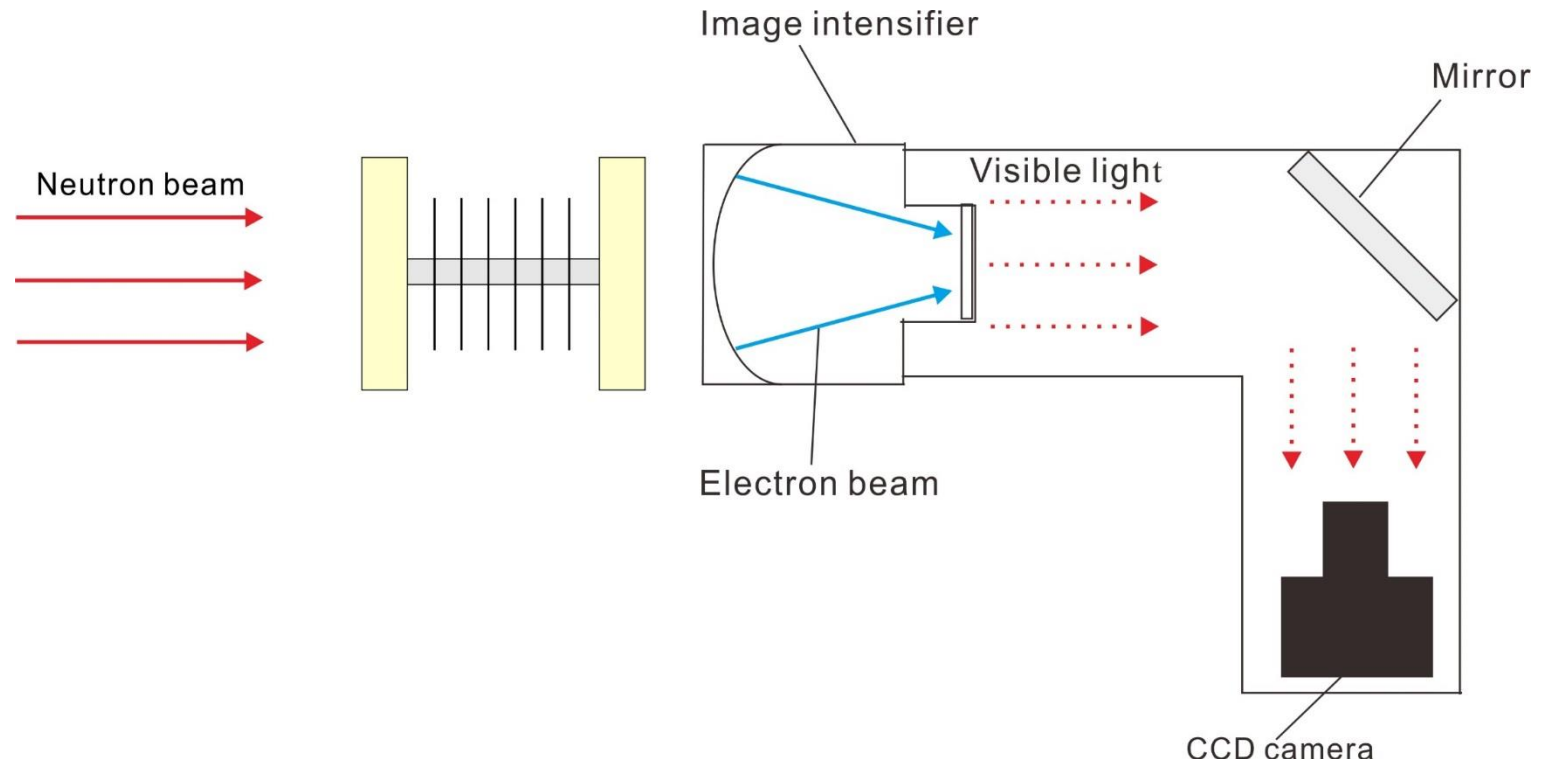
Frosting time : 65 min 52sec
Defrosting time : 11min 30 sec
Chiller 1 : 1 °C
Chiller 2 : -25 °C
Air velocity : 50cm/sec

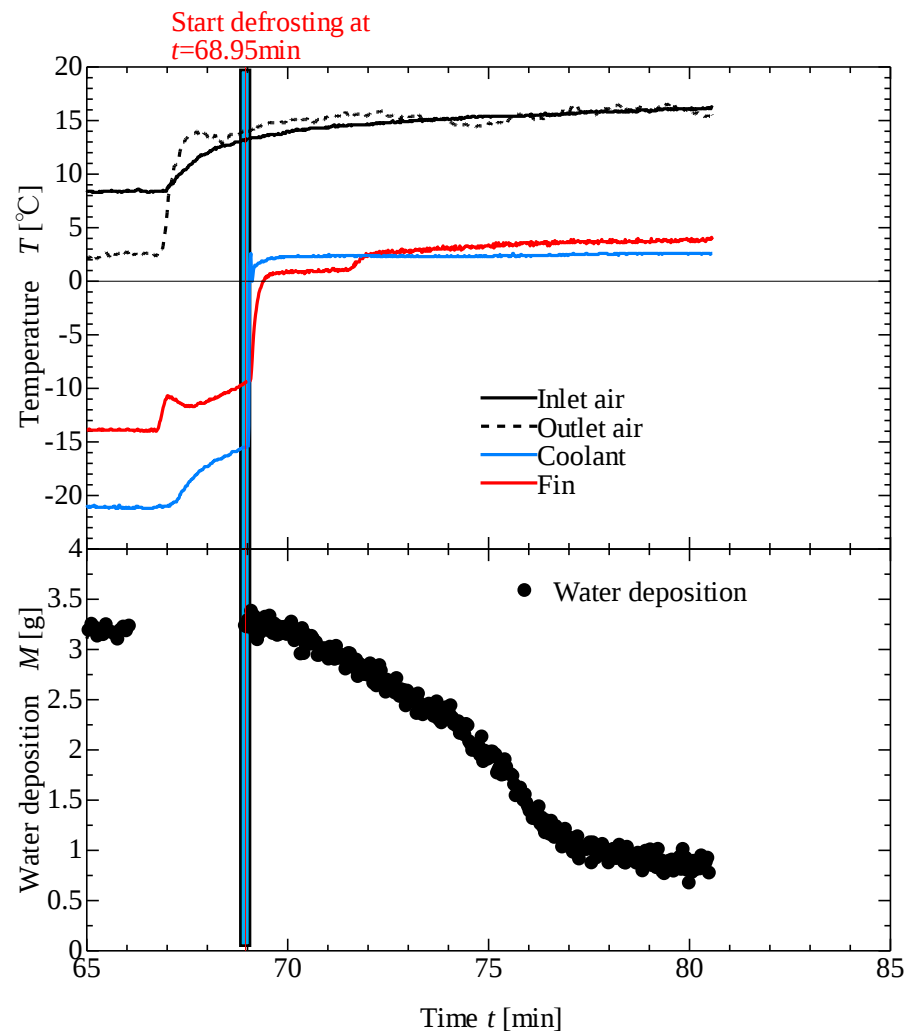
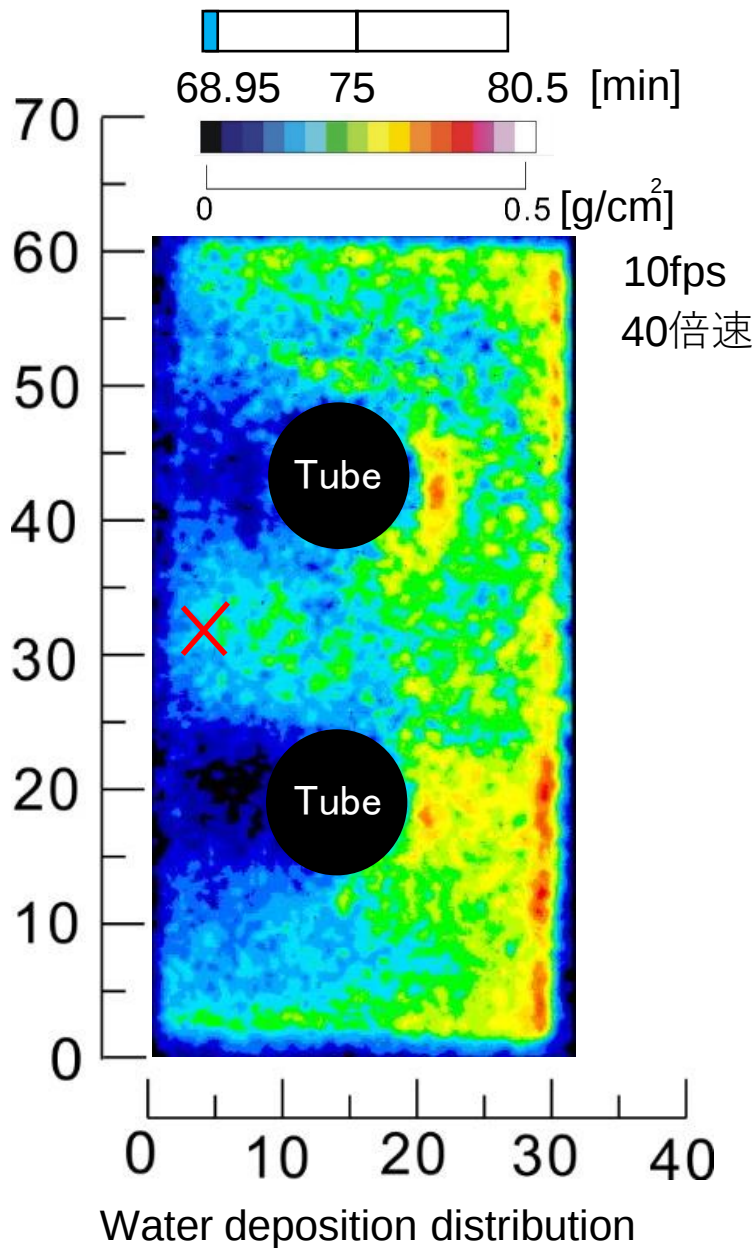


Frosting time : 65 min 52sec
Defrosting time : 11min 30 sec
Chiller 1 : 1 °C
Chiller 2 : -25 °C
Air velocity : 50cm/sec

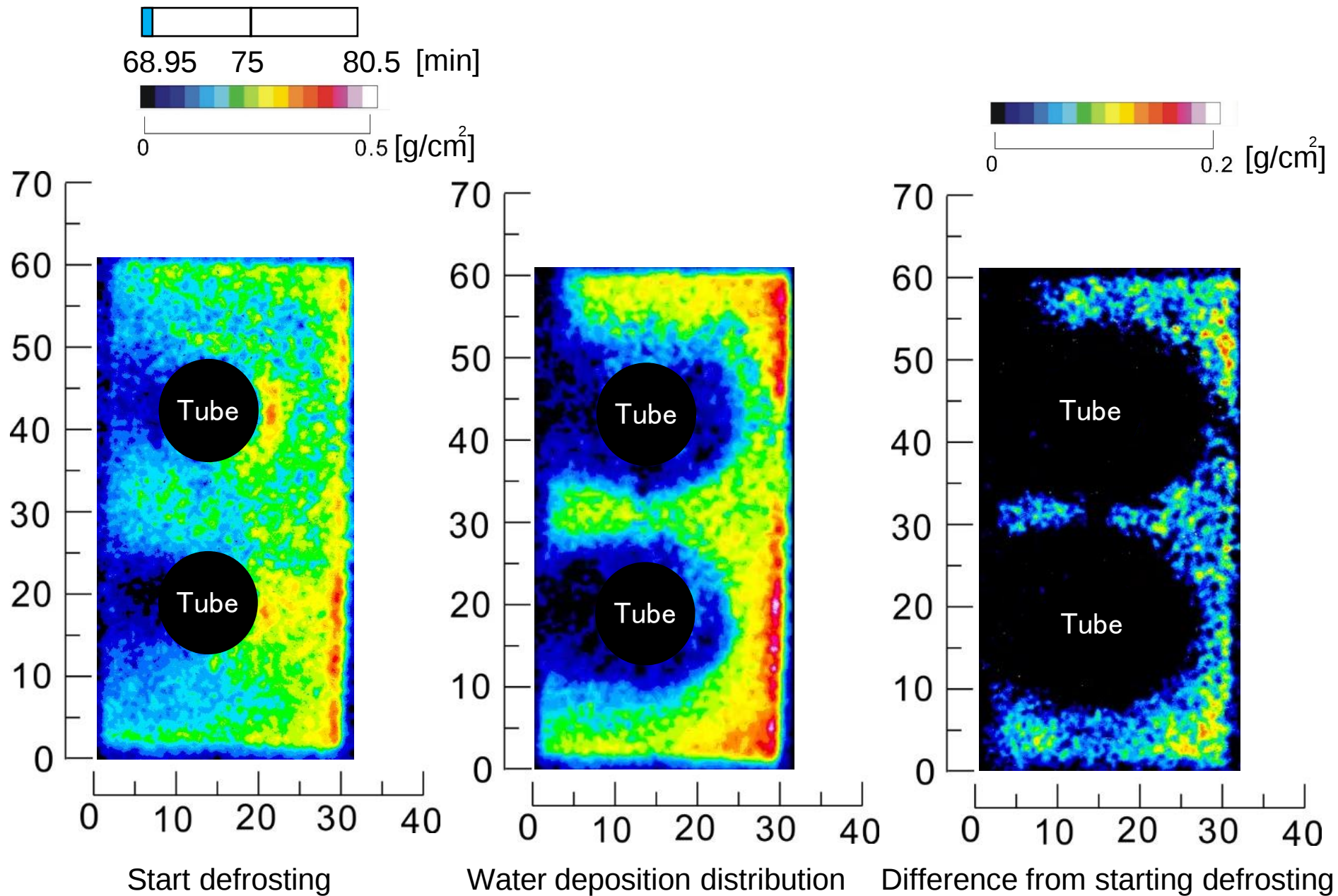


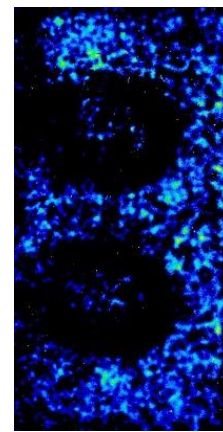
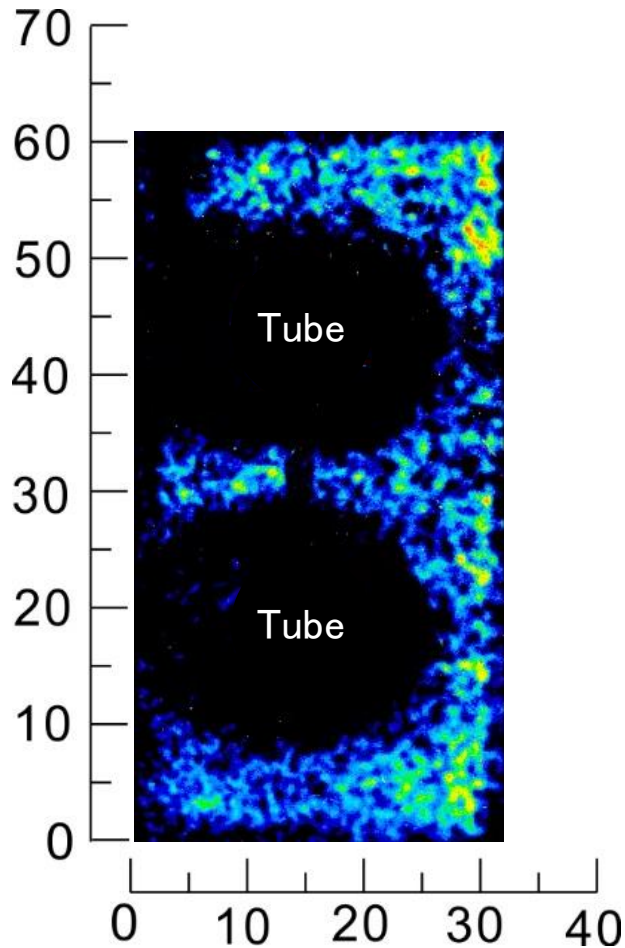
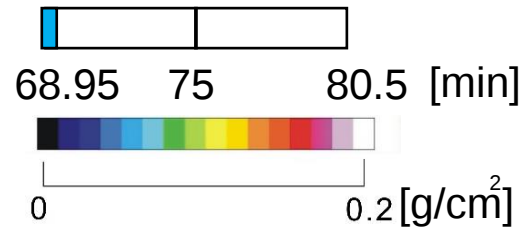
Photographing interval (frosting) : 4.3 sec
Photographing interval (defrosting) : 2.3 sec
Exposure time : 1.6 sec



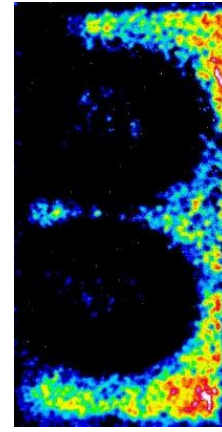


Water deposition and temperature history

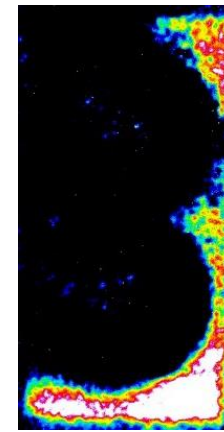




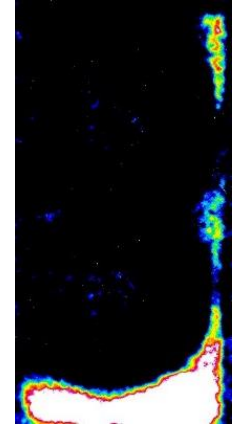
70.3 [min]



71.6 [min]

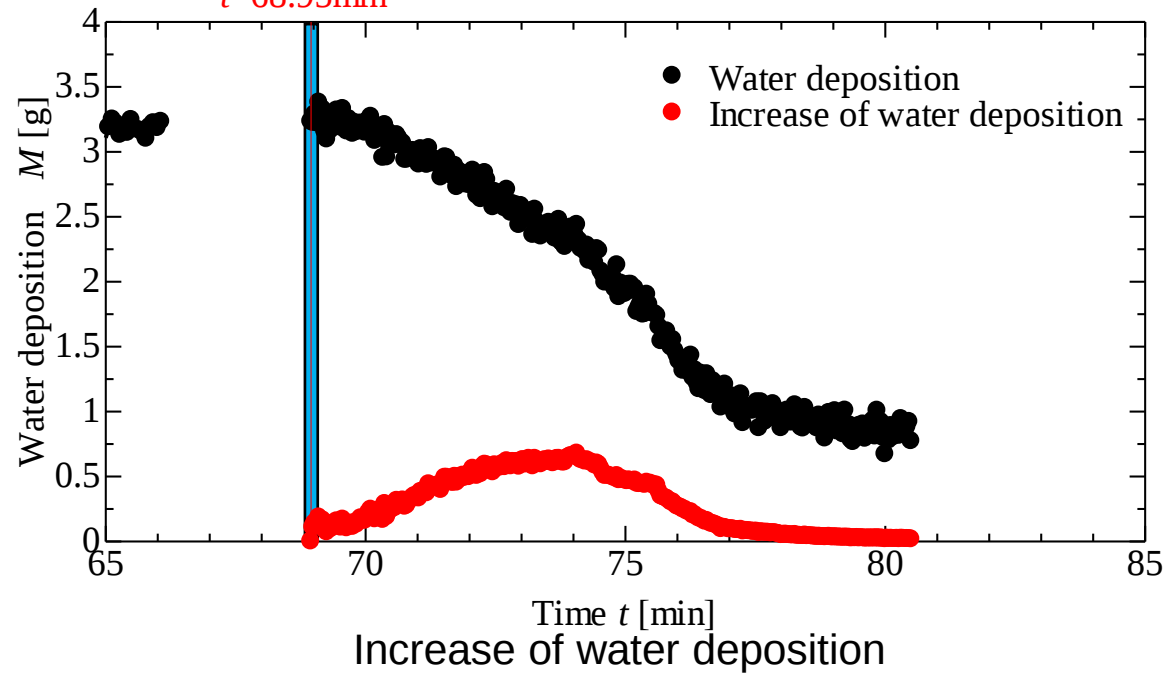


72.9 [min]



74.3 [min]

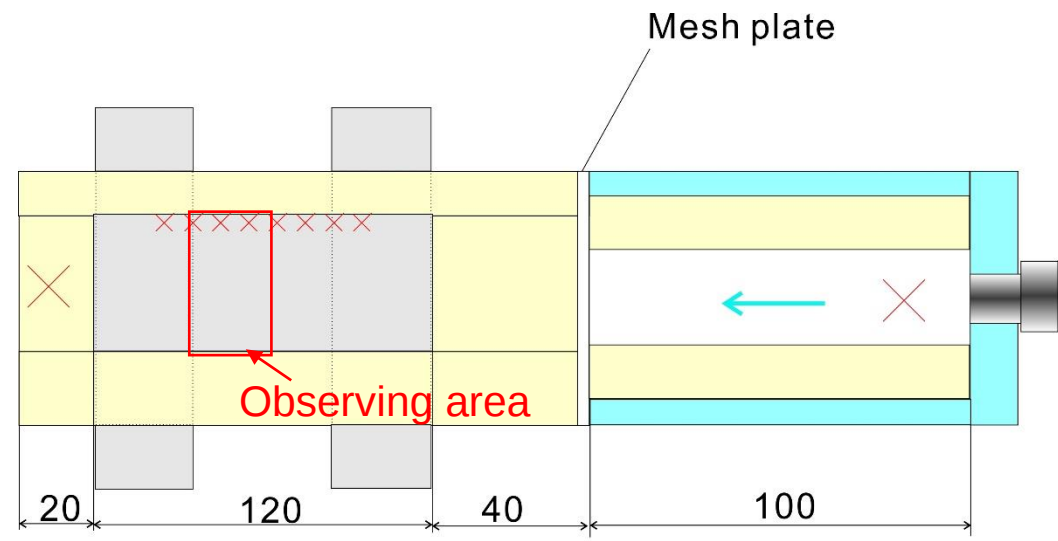
Start defrosting at
 $t=68.95\text{min}$



Water deposition distribution

Increase of water deposition

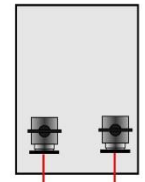
Chiller 1 : 1°C
Chiller 2 : -25°C
Air velocity : 50cm/sec
Frosting time: 62min 45sec
Defrosting time : 11min 18sec



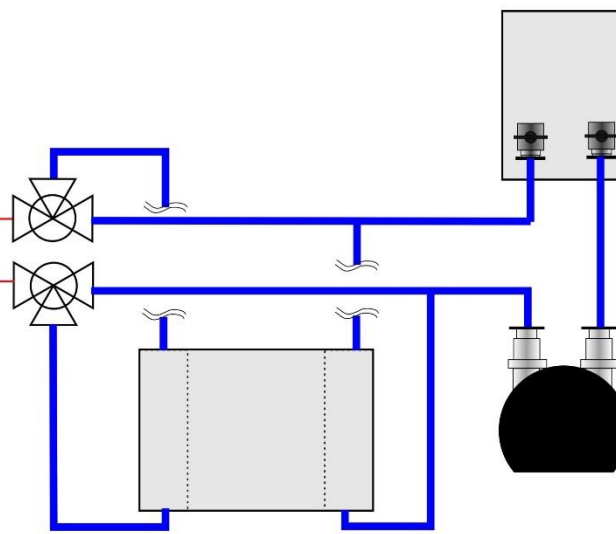
Cooling coolant

Experimental apparatus

Plate fin heat exchanger



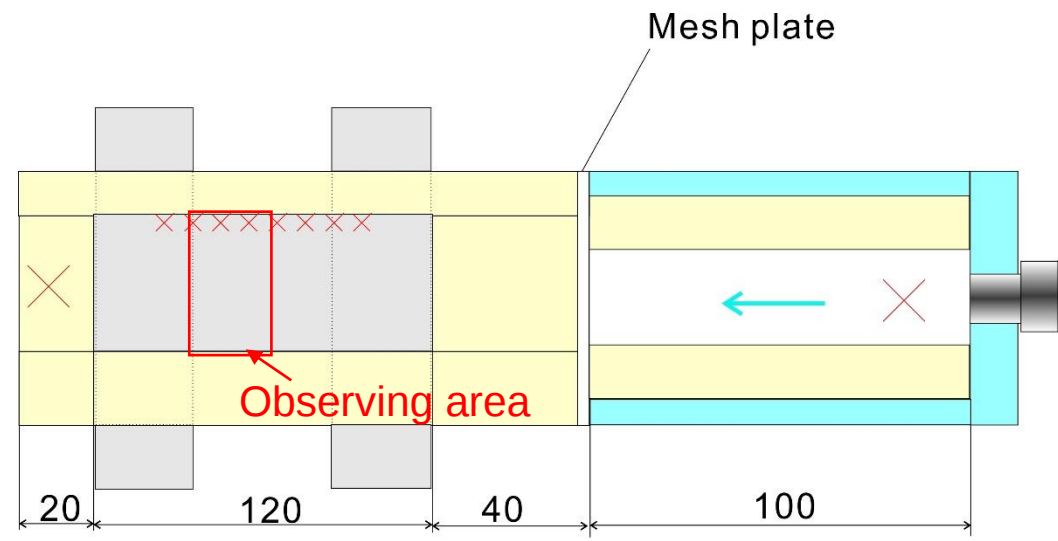
Pump



Test section

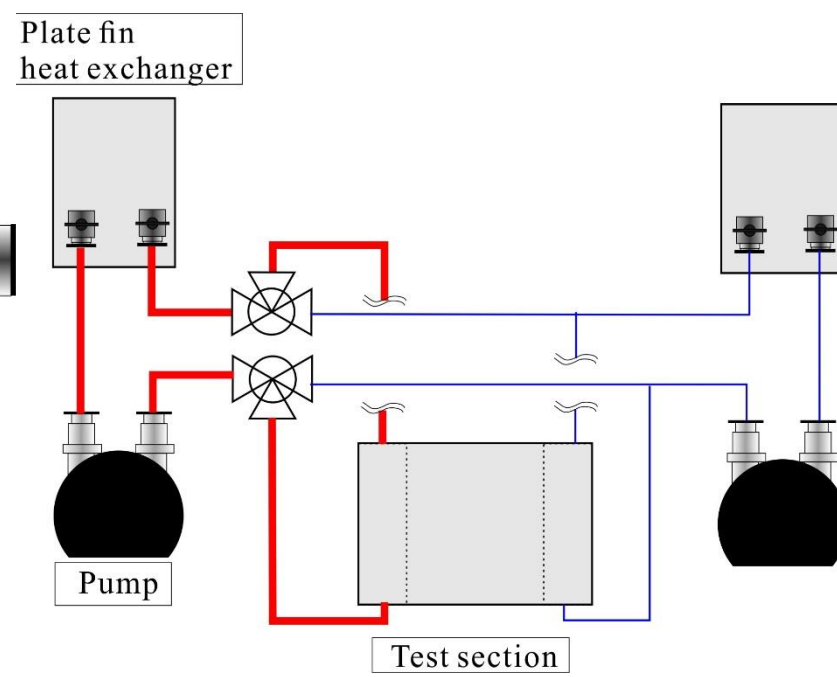
Piping diagram

Chiller 1 : 1°C
Chiller 2 : -25°C
Air velocity : 50cm/sec
Frosting time: 62min 45sec
Defrosting time : 11min 18sec



Heating coolant

Experimental apparatus

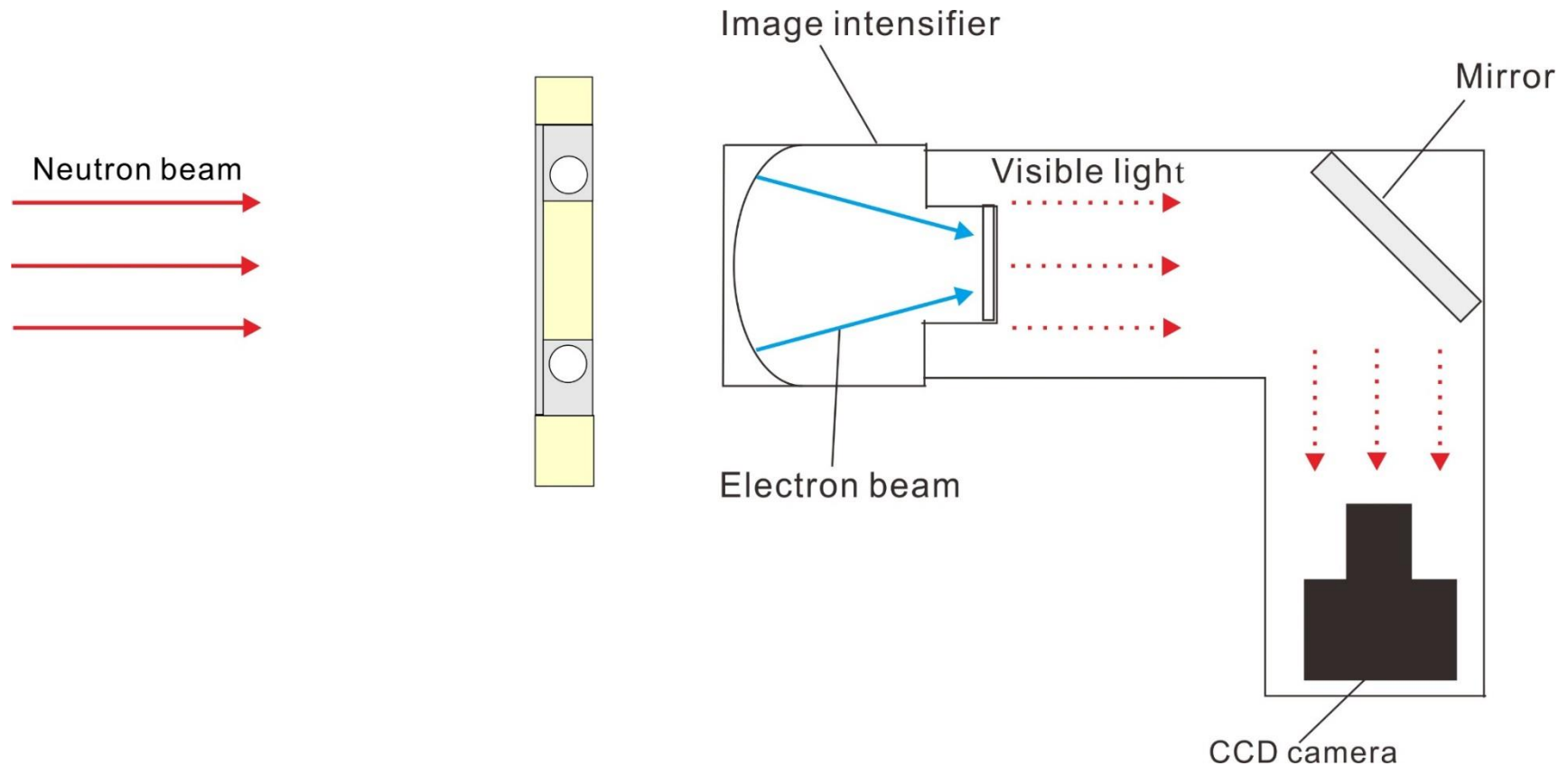


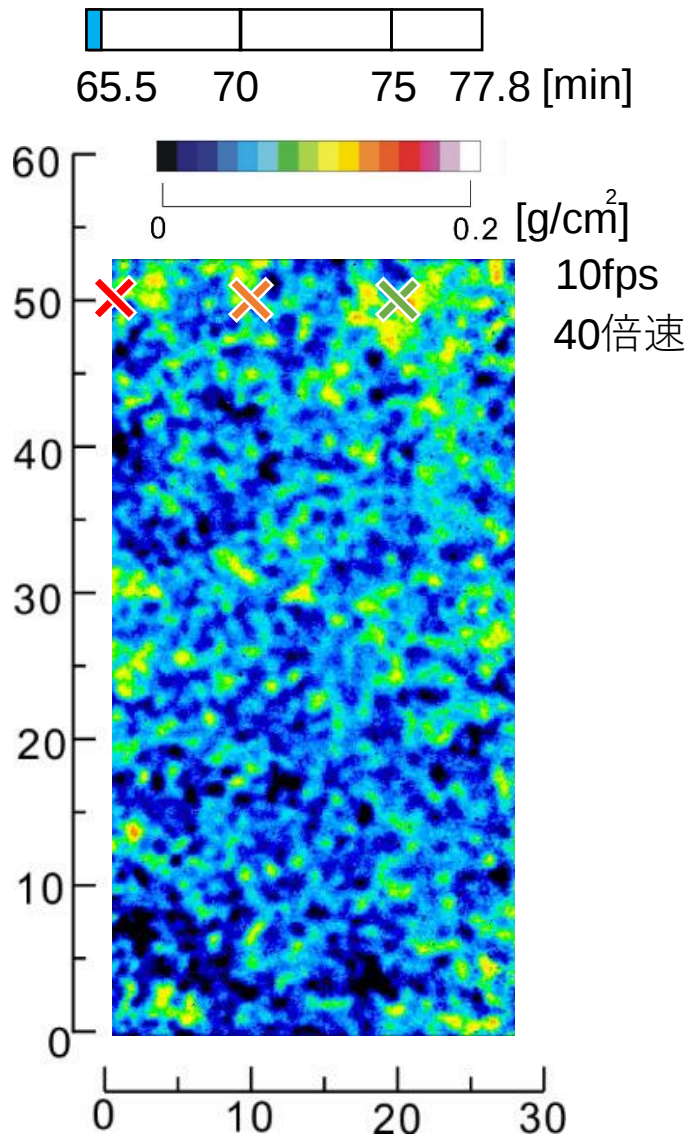
Piping diagram

Photographing interval (frosting) : 6.3 sec

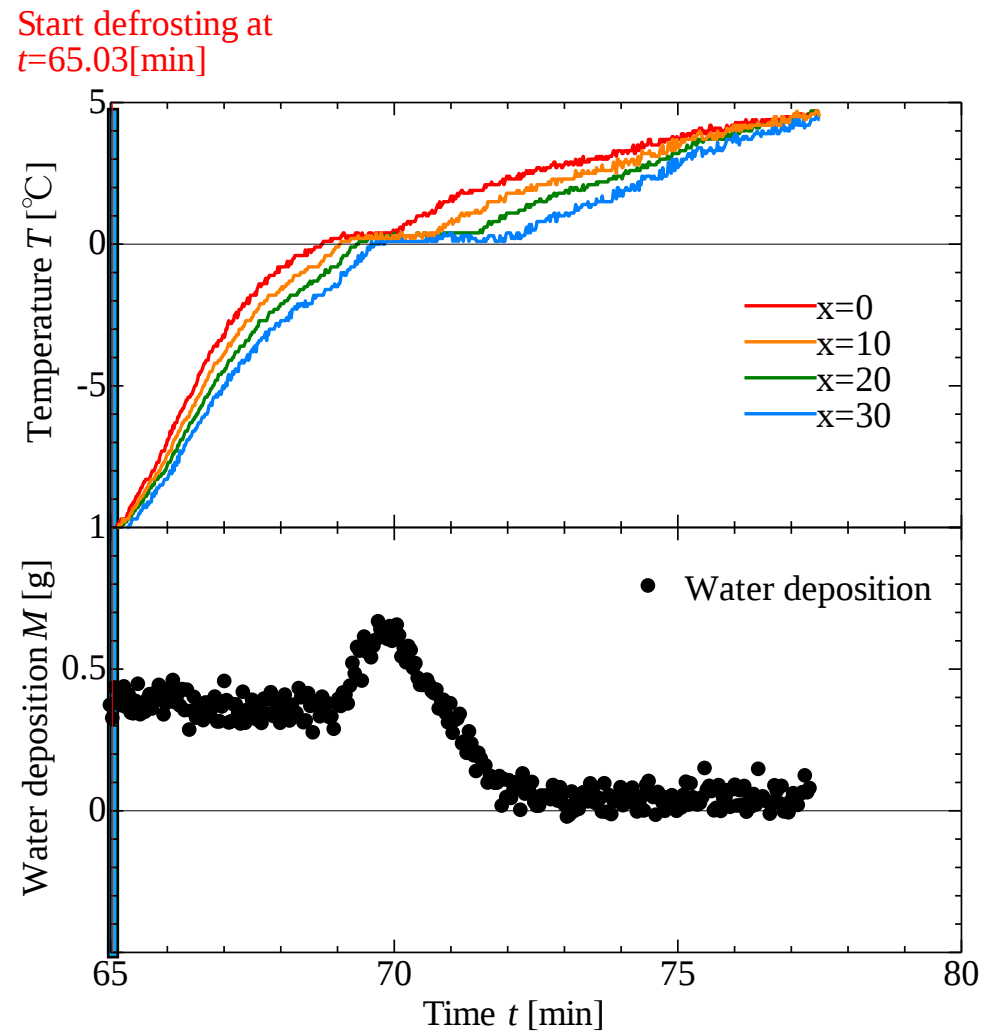
Photographing interval (defrosting) : 2.5 sec

Exposure time : 1 sec





Water deposition distribution



Temperature on the test plate

中性子ラジオグラフィを用いた融解水の観察の結果

- 熱交換器チューブ内へと高温冷媒を流すことで、チューブ周囲から霜が融解し、霜の残る領域へと融解水が浸透し、霜の融解とともに落下した.
- 熱交換器から離脱した水分量2gのうち0.5gの融解水が霜層内へと浸透することが確認された.
- 平板上における融解水浸透時には温度が0.3°C程度であった.

付録

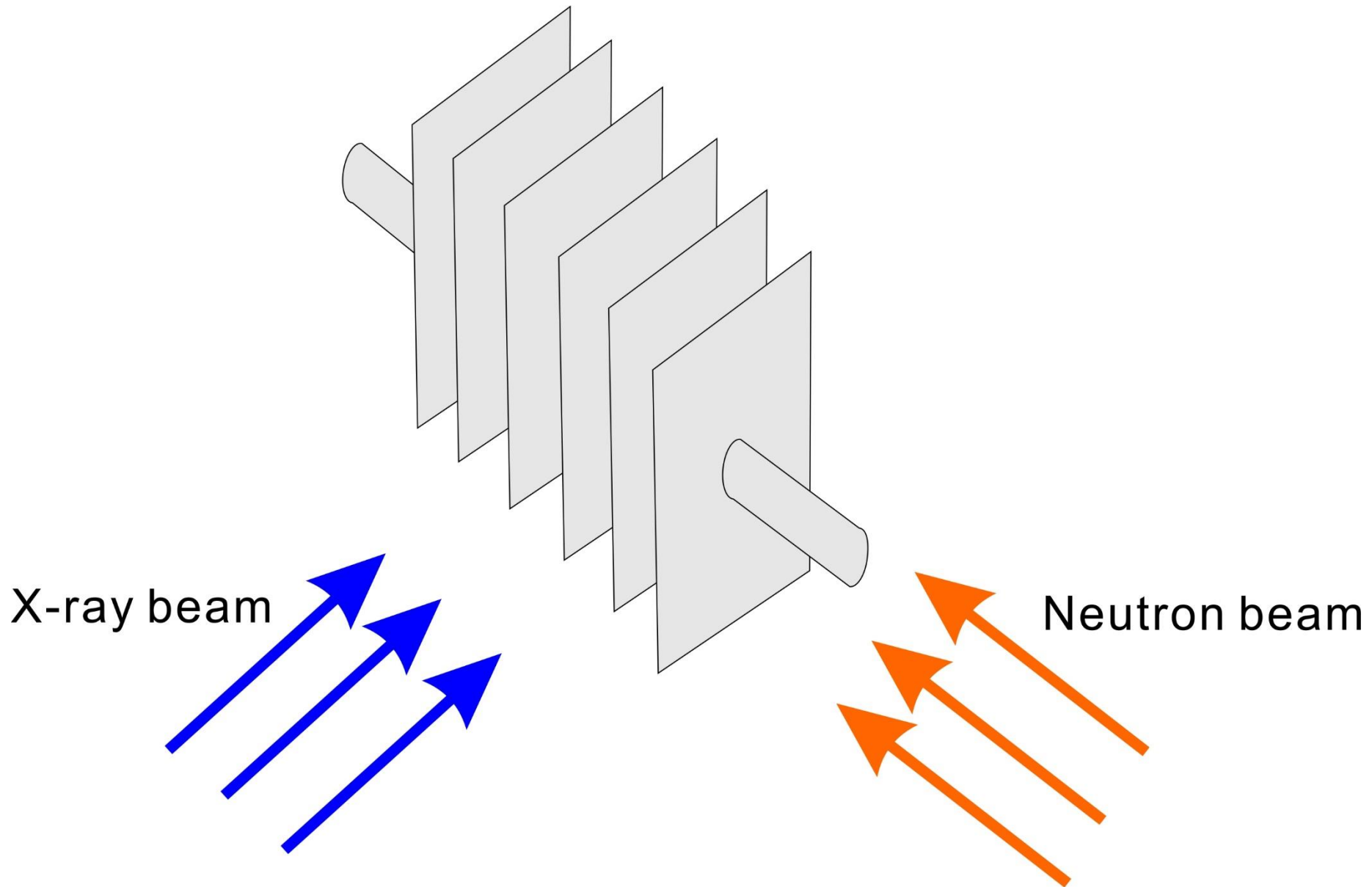
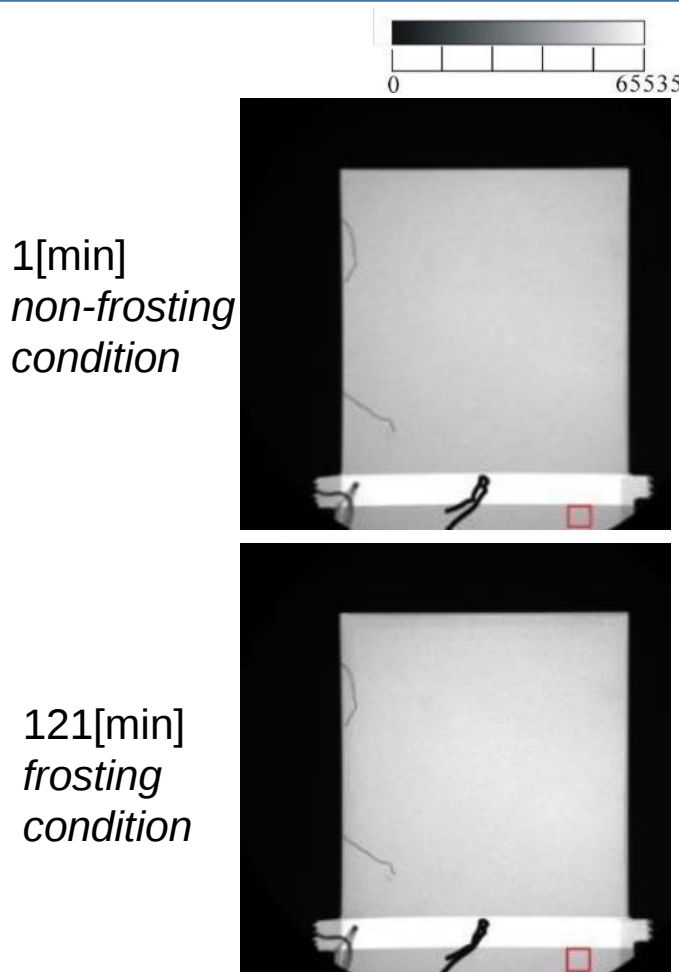


Image processing of the X-ray radiography to estimate the local water deposition rate



- ◆ Gray level of non-frosting condition
(attenuated by only the test section)

$$S_0(x, y, t_0) = G(x, y, t) \exp \left\{ -\rho_t \mu_{m,t} \delta_t(x, y) \right\} + O(x, y)$$

- ◆ Gray level of frosting condition
(attenuated by test section and frost layer)

$$S(x, y, t) = G(x, y, t) \exp \left\{ -\rho_t \mu_{m,t} \delta_t(x, y) \right. \\ \left. - \rho_w \mu_{m,w} \delta_w(x, y, t) \right\} + O(x, y)$$

- ◆ S is divided by S_0 , then, the X-ray attenuation by test section can be eliminated.

- ◆ The local frost deposition rate

$$m_{w,t} = \rho_w \delta_w(x, y, t)$$

$$= - \frac{\ln \left(\frac{1}{\beta} \frac{S(x, y, t) - O(x, y)}{S_0(x, y, t_0) - O(x, y)} \right)}{\mu_{m,w}}$$

X-ray radiography images

X-ray intensities are almost the same.
However, X-ray beam slightly
decrease by the frost layer.

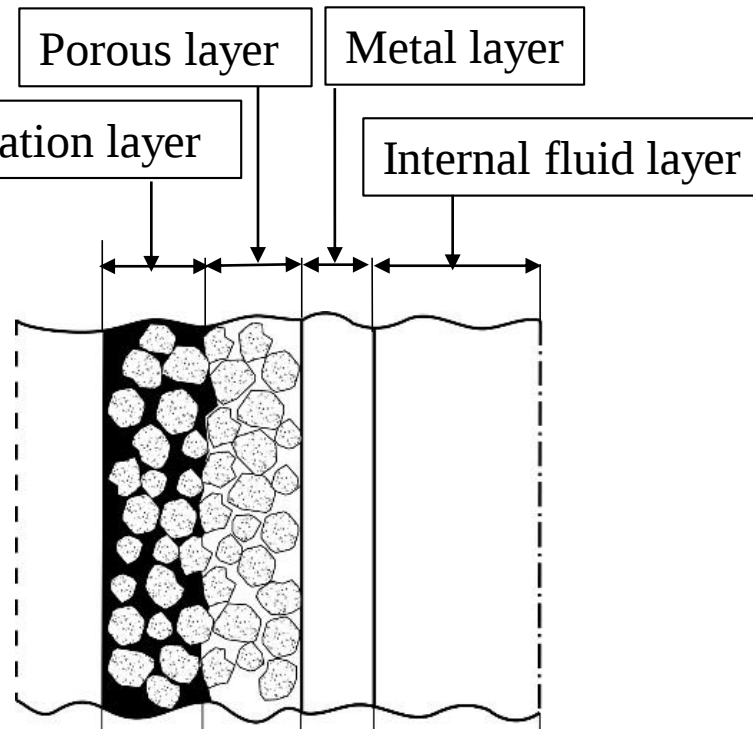
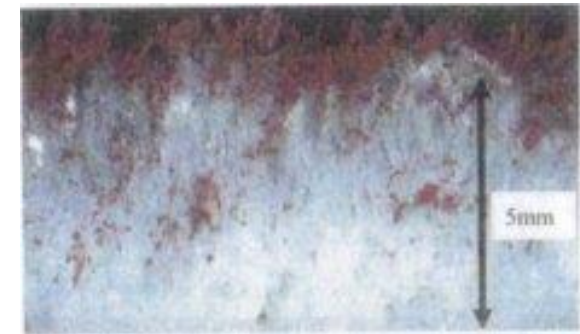


Fig.4 Melting model

参照:Katsuta, K *et al*, An Analytical Study of Defrosting by the Ambient Air Under Natural Convention, *Transactions of the japan society of Refrigerating and Air Conditioning Engineers*, 1983, 58(669), pp.645-650.(in Japanese)



$t=0$ [sec]



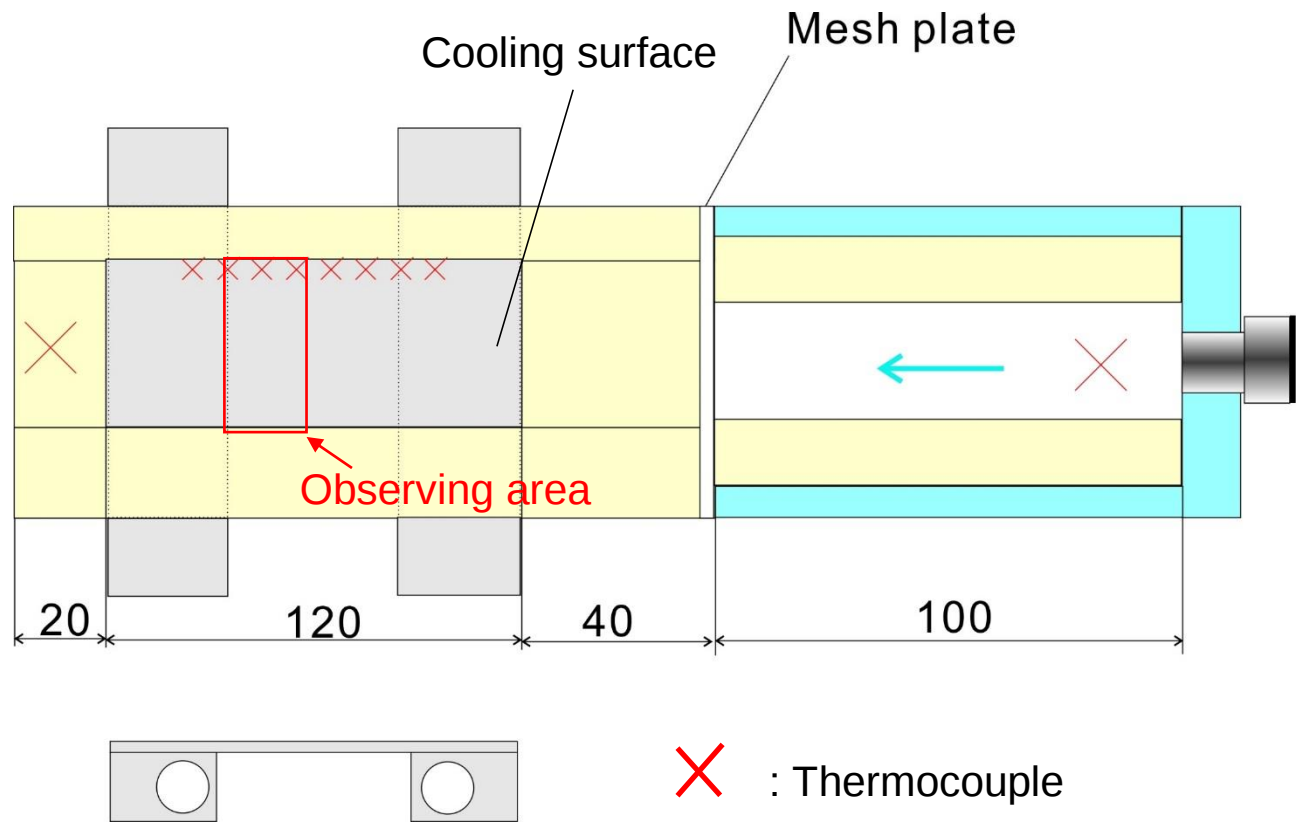
$t=180$ [sec]

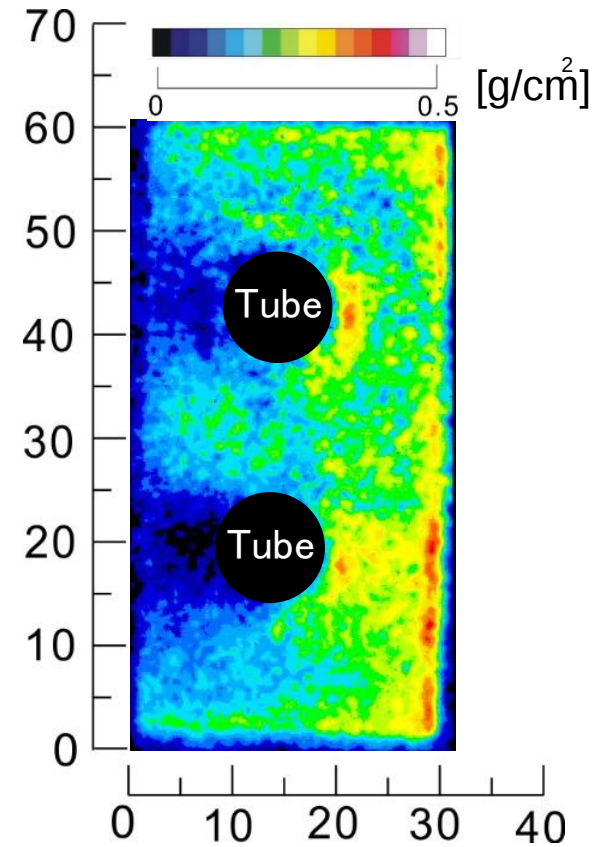
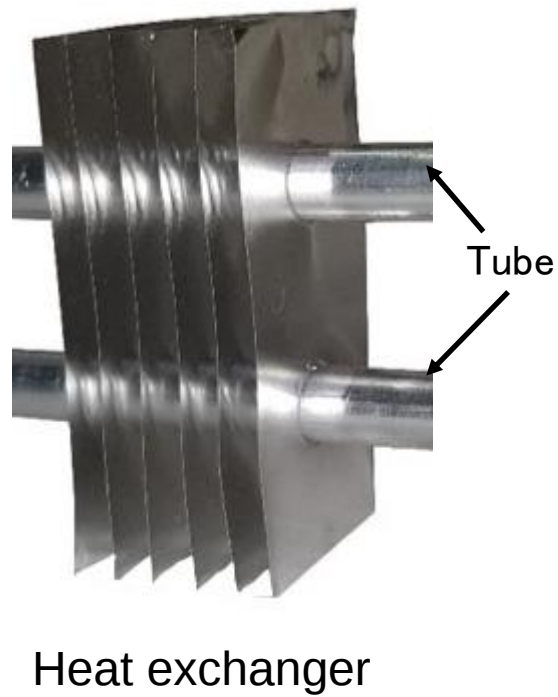
Fig.5 Water saturation

参照:N. Shimomura, and S. Katayama, A Study of Frost layer Change on Defrosting, *Transactions of the Japan Society of Refrigerating and Air Conditioning Engineers*, 31(2) (2014), pp.219-227. (in Japanese)

- ◆ 霜層内への融解水の浸透により霜層構造と熱的特性が変化するので、融解水の浸透挙動の定量的な評価が必要である

Photographing interval (froosting) : 6.3 sec
Photographing interval (defrosting) : 2.5 sec
Exposure time : 1 sec





研究目的

熱交換器上での除霜時における融解水の挙動の観察