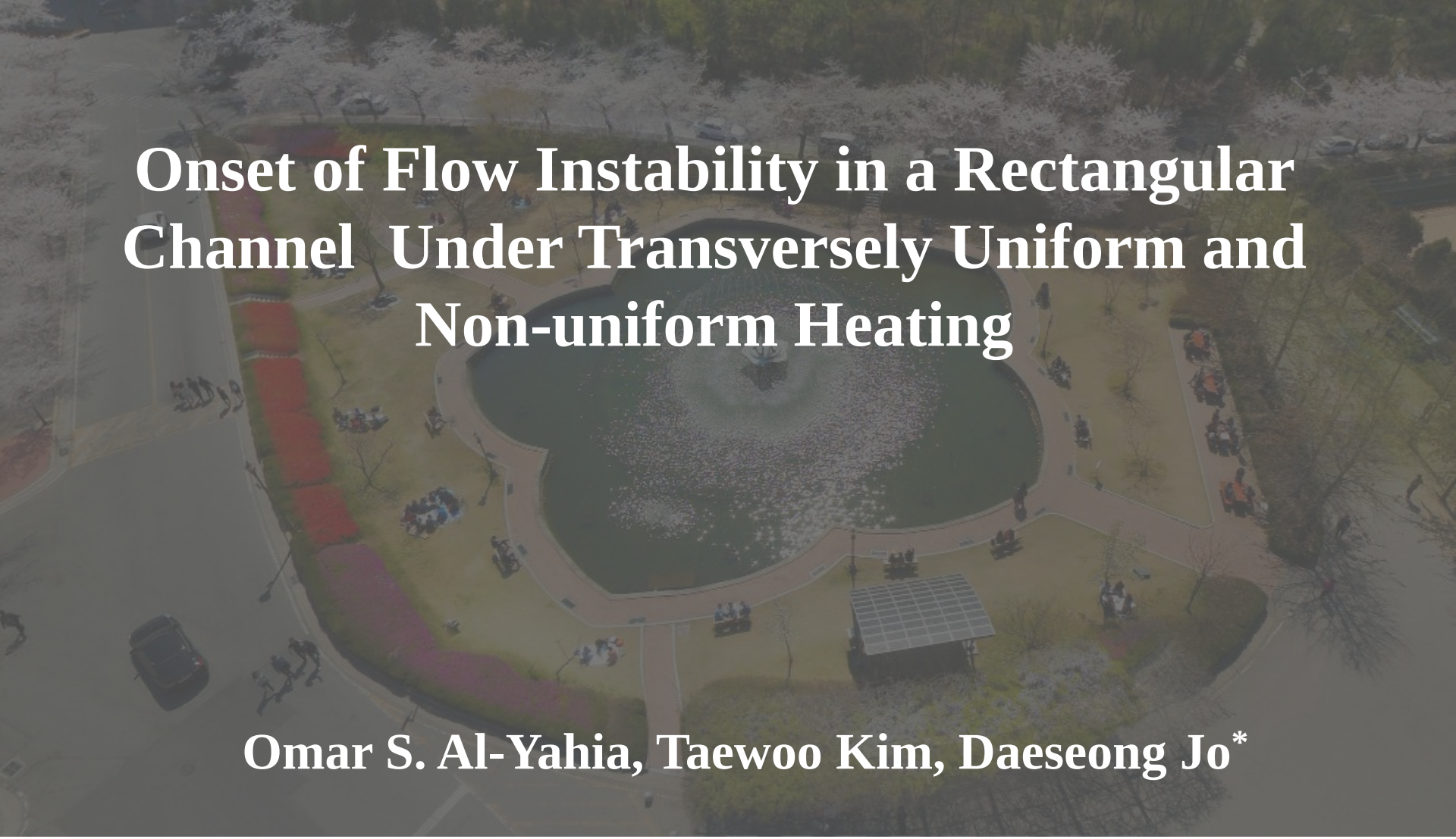

Onset of Flow Instability in a Rectangular Channel Under Transversely Uniform and Non-uniform Heating

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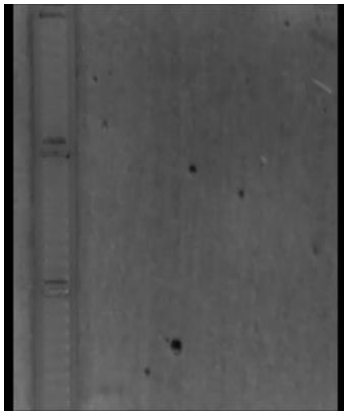
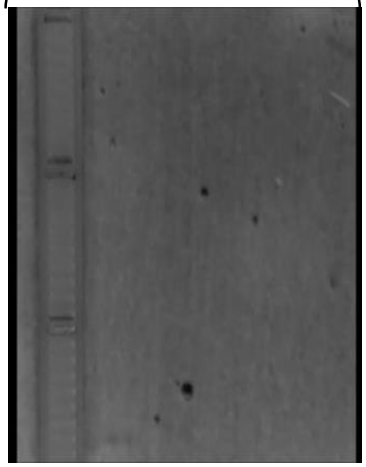


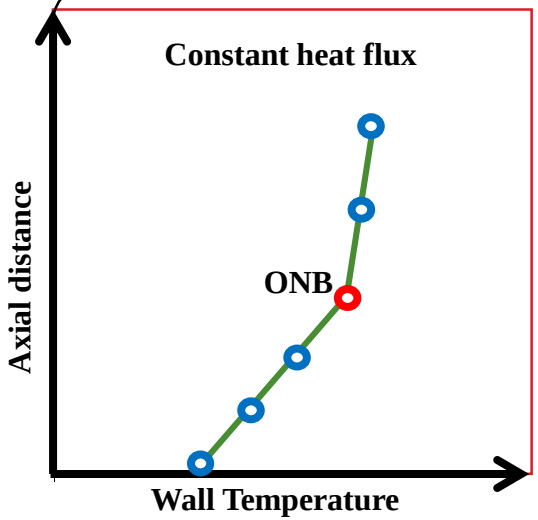
1. INTRODUCTION (1/2)

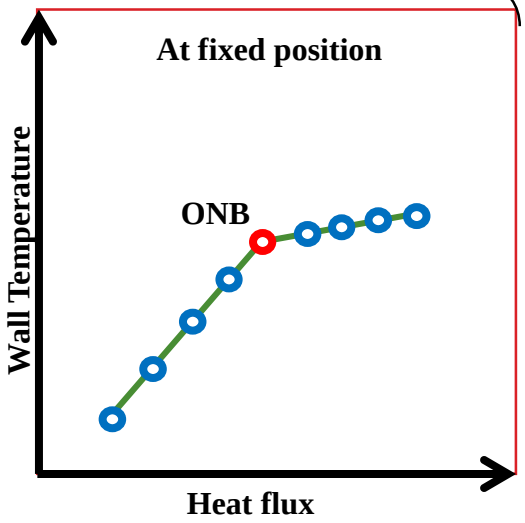
ONB observation

1- Visualization

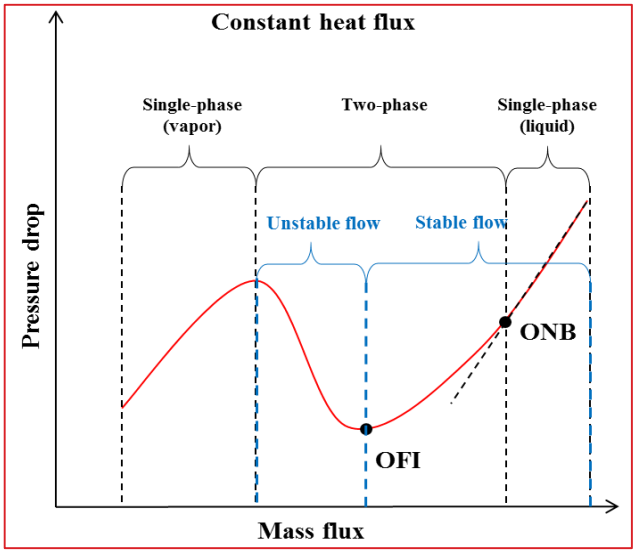


2- Wall temperature measurement





OFI observation

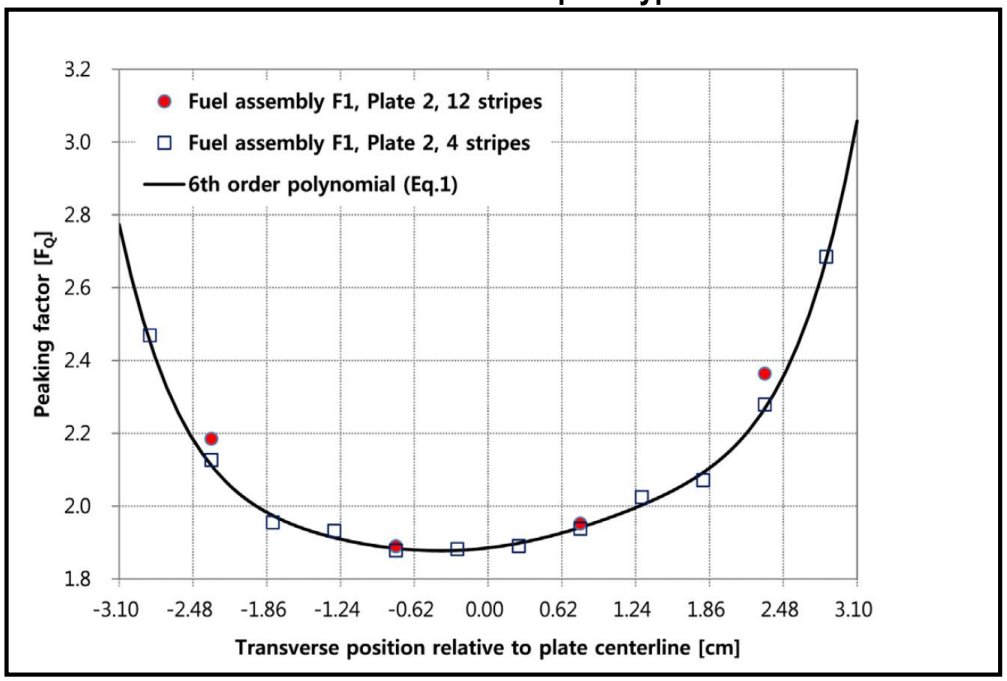


The minimum point on pressure drop-mass flux curve is referred to the OFI incipience

1. INTRODUCTION (2/2)

- ONB is local phenomena depending on the local heat flux and wall temperature.
- OFI depends on the total thermal power deposited in the flow channel
- In the plate type fuel research reactors, the power distribution is non-uniform along the axial direction as well as the transverse direction

Transverse heat flux distribution in the plate type fuel research reactor



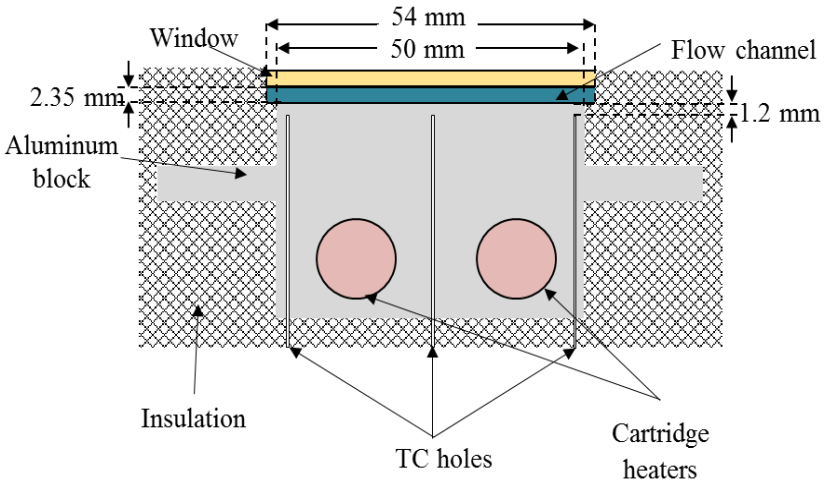
Study Objective:

- Investigate the effect of transverse power distribution on the ONB and OFI incipience.
- Compare the thermal hydraulic behavior of ONB and OFI between uniform and non-uniform heat flux distribution.

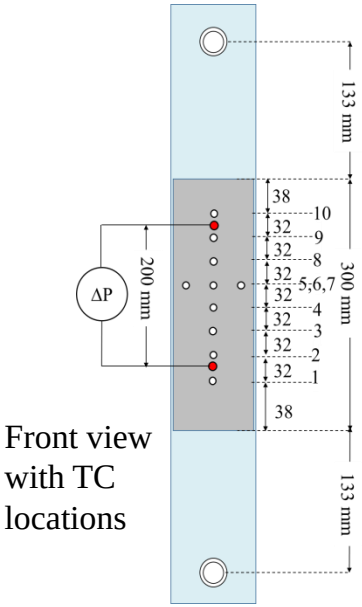
*Jo, D., Seo, C.G., 2015. Effects of transverse power distribution on thermal hydraulic analysis. Progress in Nuclear Energy 81, 16-21.

2. EXPERIMENT SETUP (1/4)

Uniform test section



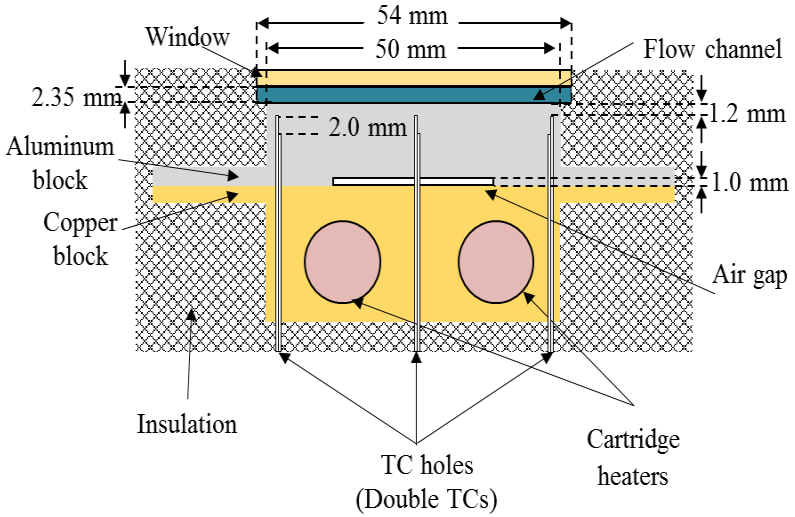
Cross sectional view



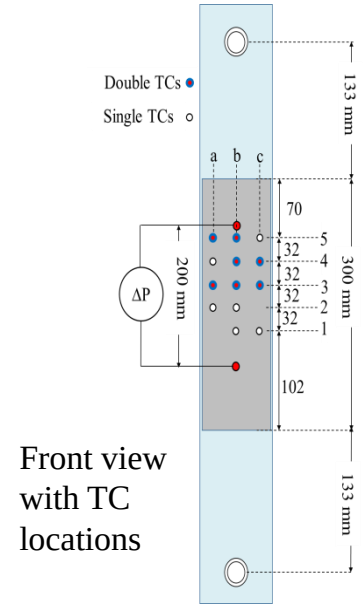
Front view with TC locations

- Two SUS316L cartridge heaters
- Aluminum block
- 10 single thermocouples (TCs)
  8 TCs distributed axially
  2 TCs distributed transversely

Non-Uniform test section



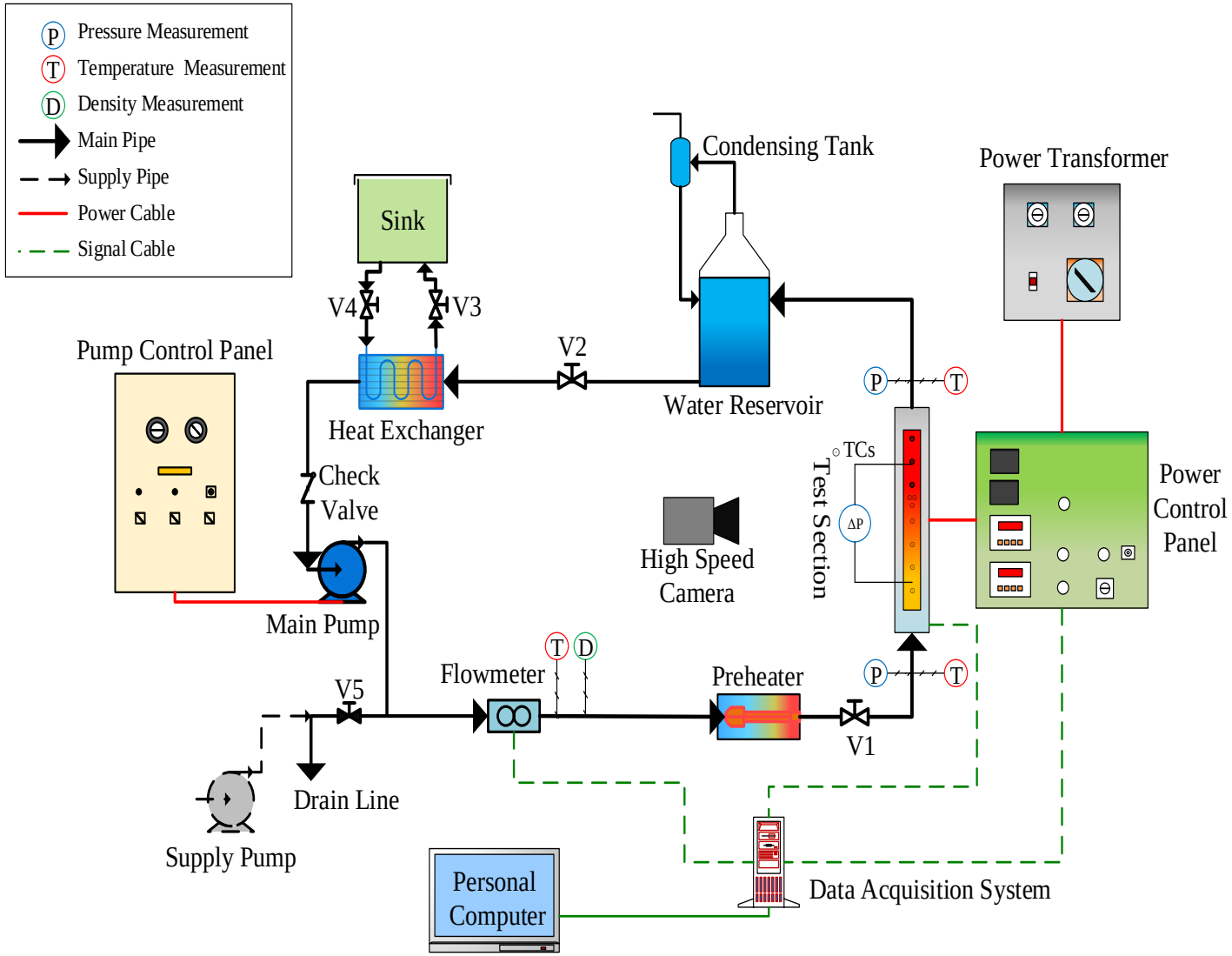
Cross sectional view



Front view with TC locations

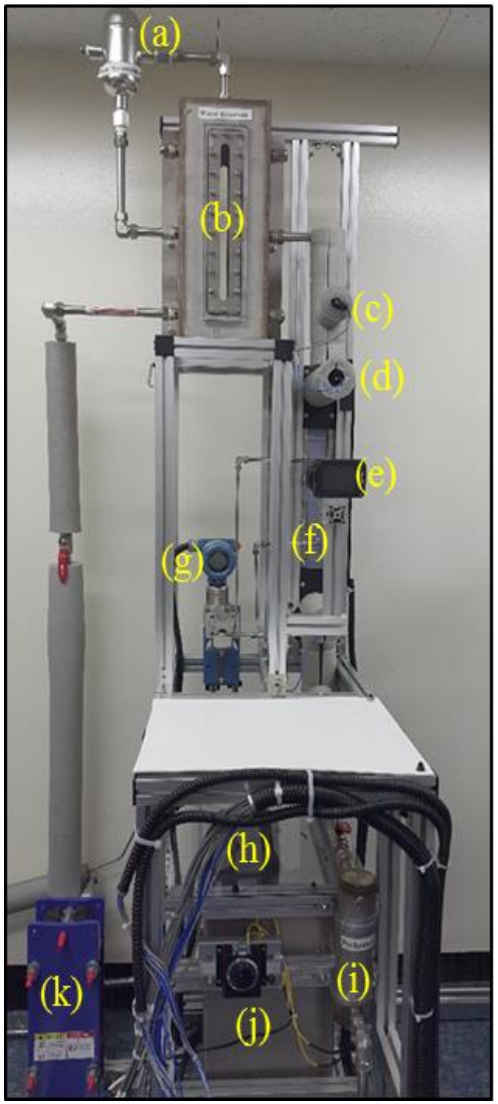
- Two SUS316L cartridge heaters
- Copper block
- Air gap
- Aluminum block
- 6 single thermocouples (TCs)
- 7 double thermocouples (TCs)

2. EXPERIMENT SETUP (2/4)

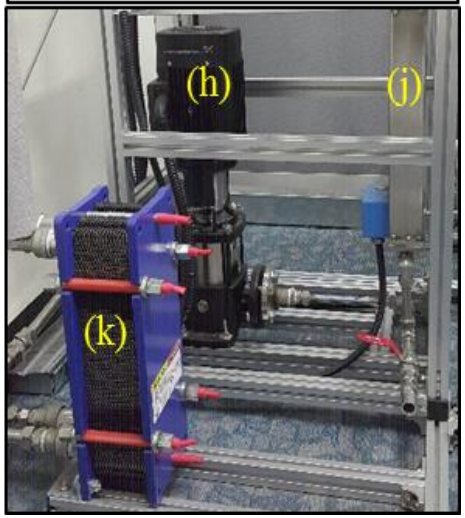


Schematic diagram for the experimental facility

2. EXPERIMENT SETUP (3/4)

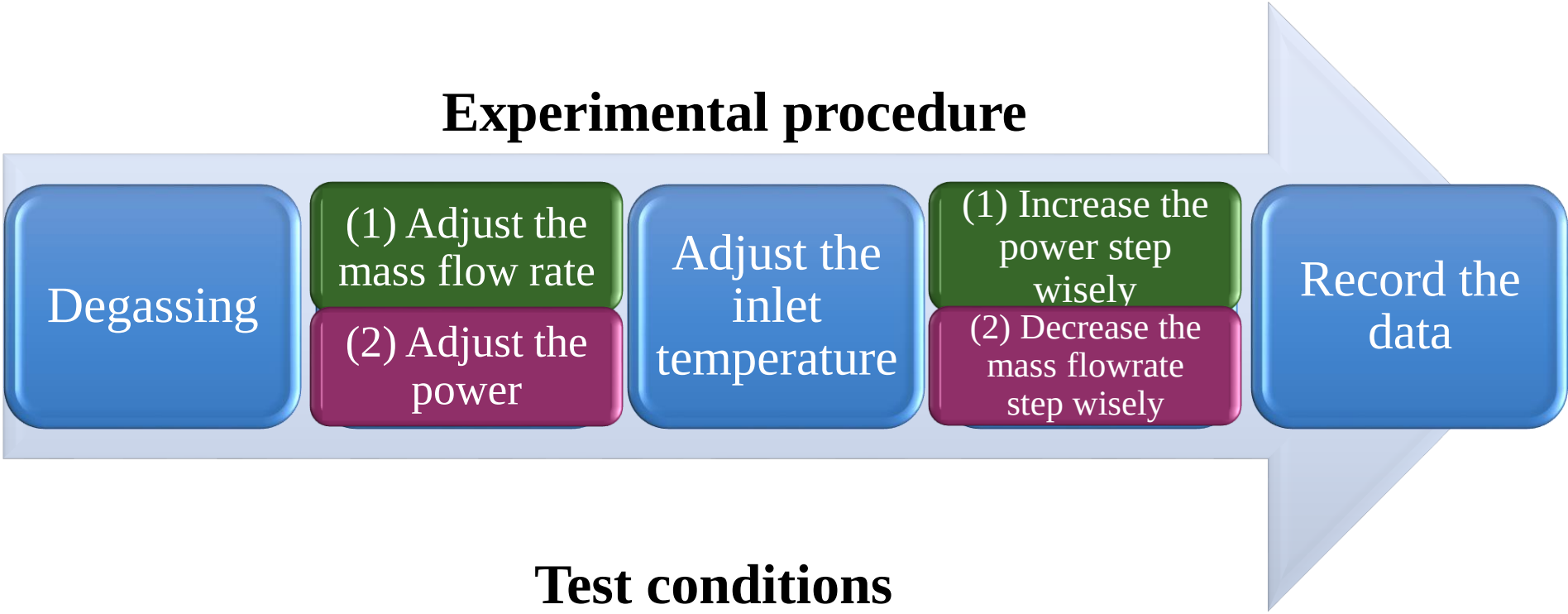


(a) Condensing Tank
(b) Water Reservoir
(c) Pressure Transducer
(d) Thermocouple
(e) High Speed Camera
(f) Test Section
(g) Pressure Transmitter
(h) Pump
(i) PreHeater
(j) Flowmeter
(k) Heat Exchanger



2. EXPERIMENT SETUP (4/4)

Experimental procedure

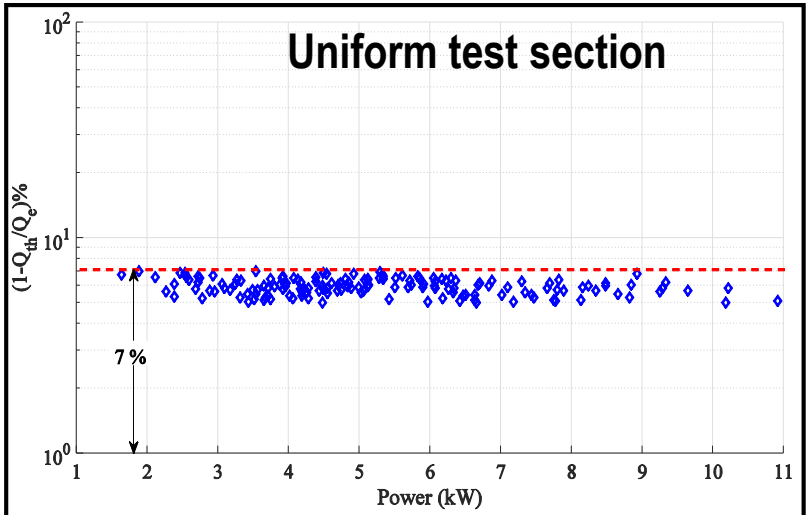


Test conditions

Parameter	Value
Flow rate [kg/s]	0.030-0.130
Heat flux [kW/m^2]	100-800
Power distribution	Uniform/Non-uniform
Inlet temperature [C]	35-65
Pressure	atm~
Hydraulic diameter [m]	0.004504

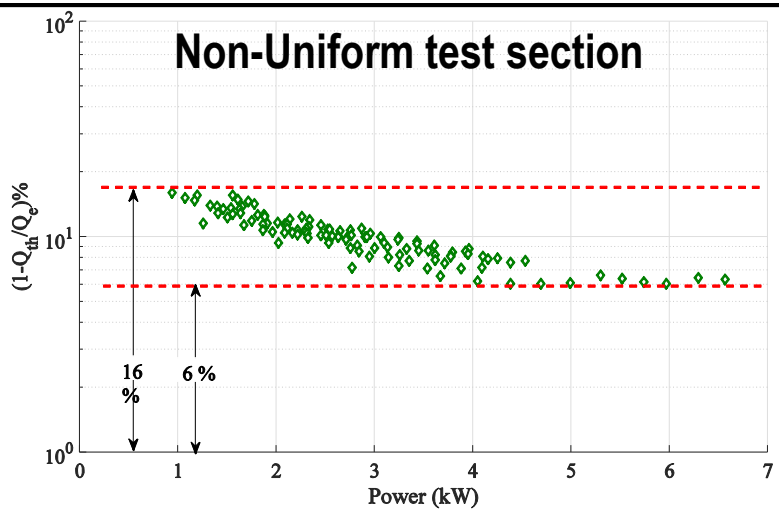
3. Data reduction

By comparing the applied electric power Q_e with the imposed thermal power Q_{th}, the energy losses is approximately 7 % and 10 % for uniform and non-uniform test section, respectively.



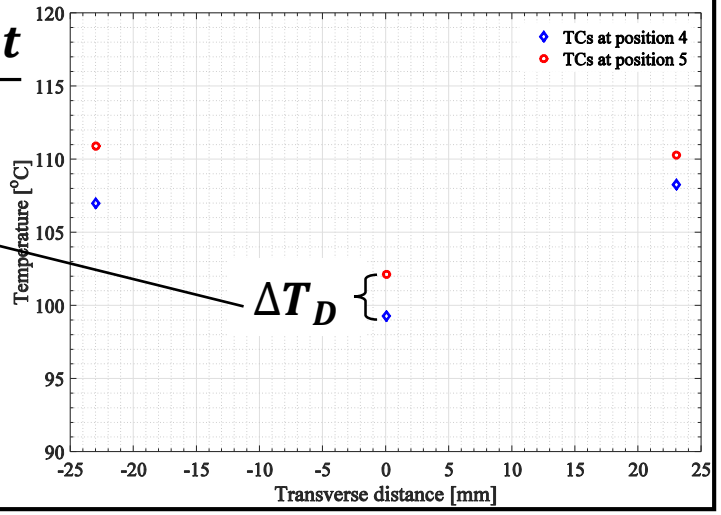
$$T_w = T_{TC} - \frac{q"_{loc} t}{k}$$

$$q"_{loc} = q"_{avg} = \frac{Q_e}{A_h} \times 0.93$$



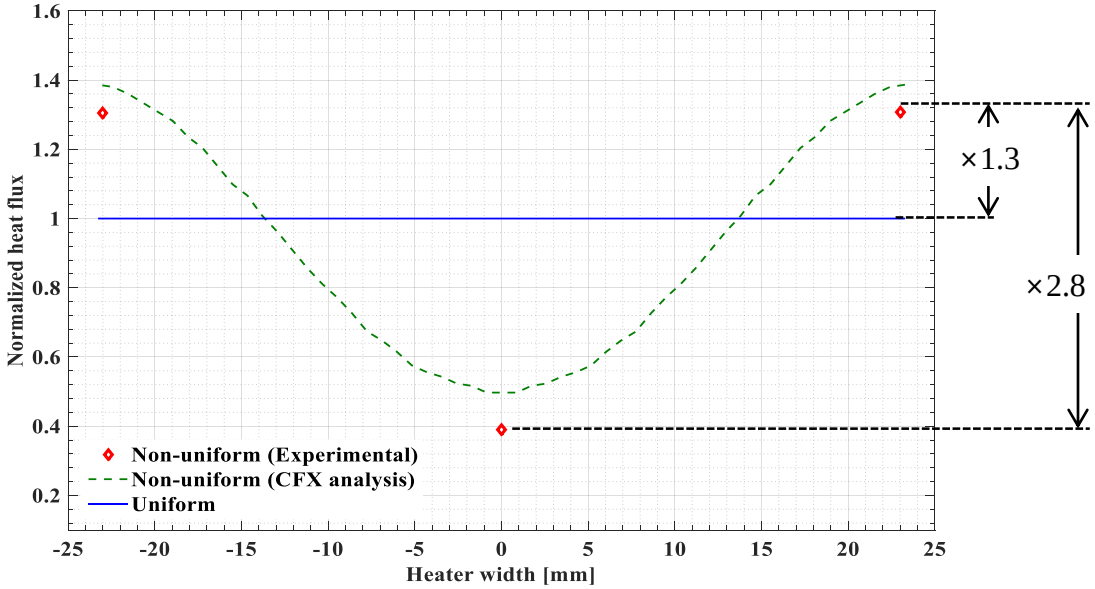
$$T_w = T_{TC} - \frac{q"_{loc} t}{k}$$

$$q"_{loc} = \frac{k}{x} \Delta T_D$$

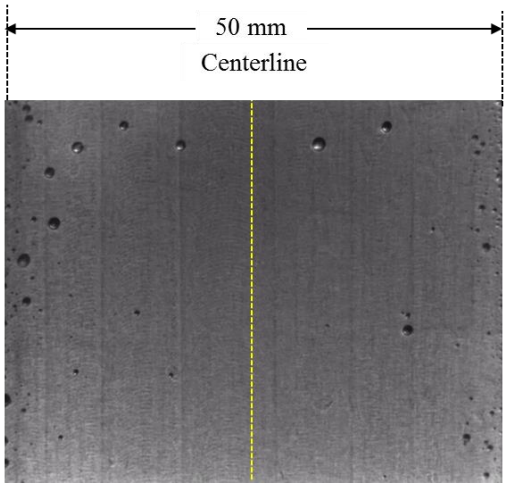


4. Results and Discussion (1/7)

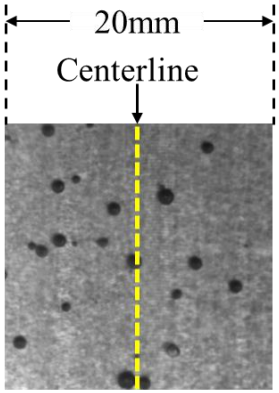
- The local heat flux for the uniform test section is similar at any location on the heated surface.
- the local heat flux near the edges is much higher than the middle part of the non-uniform heated section.



Transverse normalized heat flux distribution (at 3.9 kW)



(a)

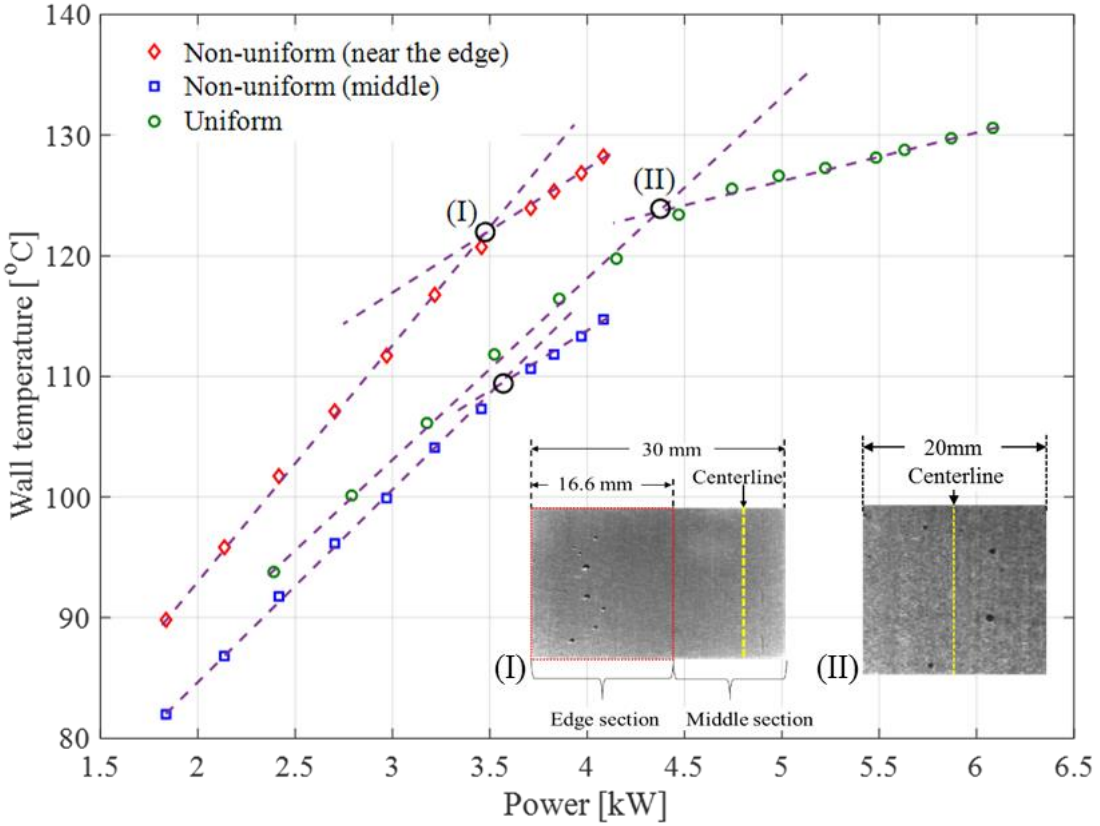


(b)

ONB incipience on the heated surface; (a) Non-uniformly heated surface, (b) Uniformly heated surface.

4. Results and Discussion (2/7)

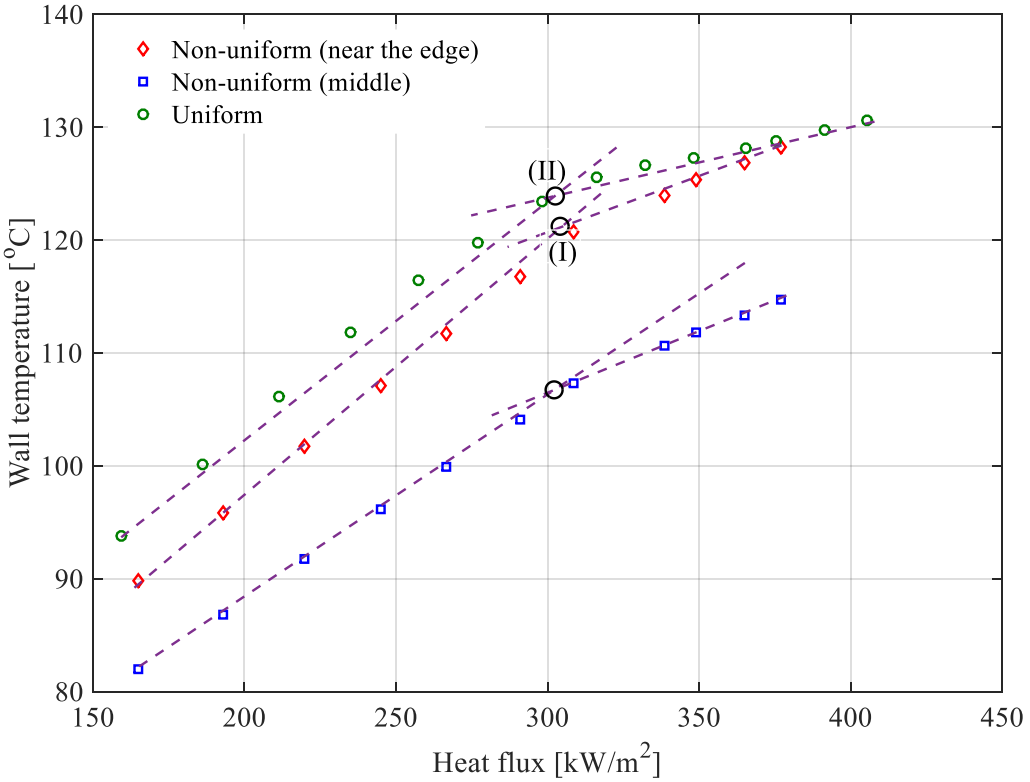
- The ONB incipience is local phenomenon that is highly depends on the local conditions such as the local heat flux rather than the total power deposited in the channel.
- The ONB in the case of non-uniformly heater occurs at power lower than the one for the case of uniformly heated surface due to high heat flux near the edges.



The ONB incipience for uniform and non-uniform heat flux, (Mass flow rate is 0.08 kg/s, Inlet temperature is 50 °C)

4. Results and Discussion (3/7)

- The local heat flux at the ONB is similar for the case of uniform and non-uniform heated test section, as well as the local wall temperature.

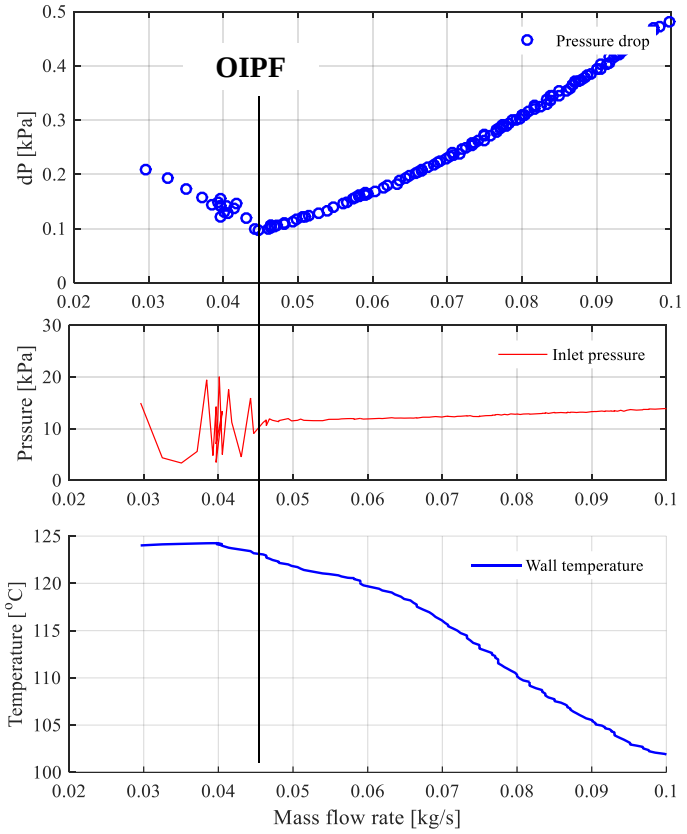


The ONB heat flux for the uniform and non-uniform test section (Mass flow rate is 0.08 kg/s, Inlet temperature is 50 °C).

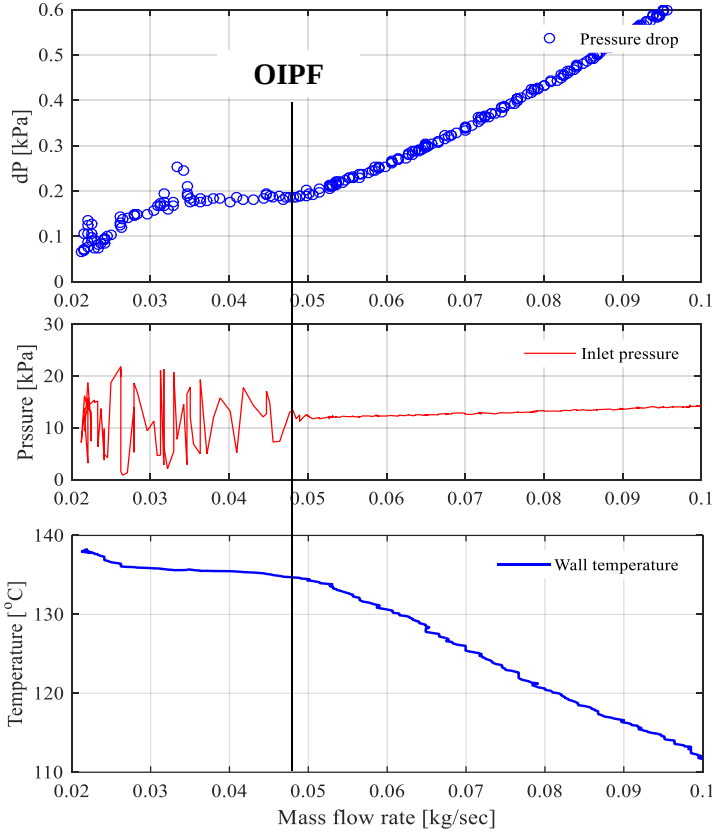
4. Results and Discussion (4/7)

- Pressure drop is different, the inlet pressure fluctuation conditions are same

Uniform test section

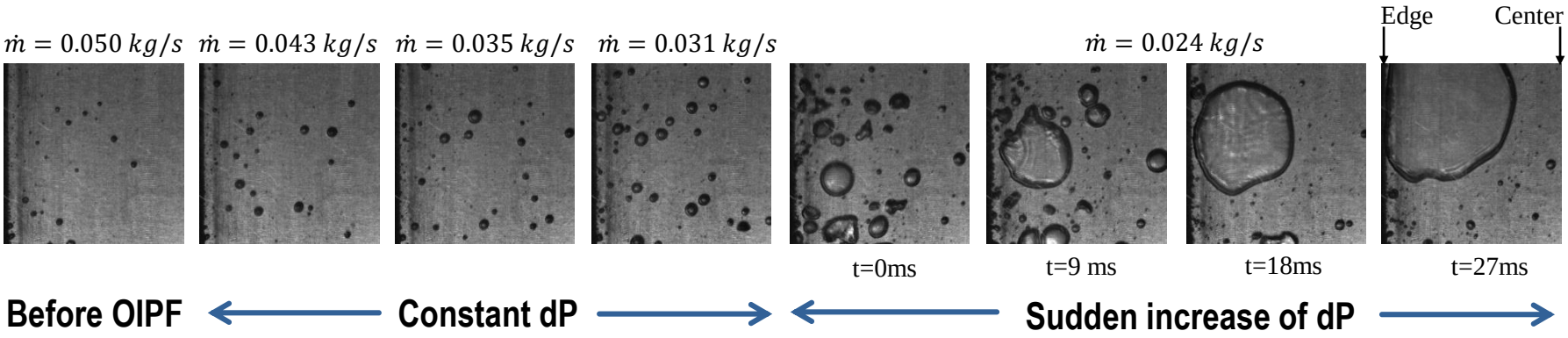


Non-Uniform test section



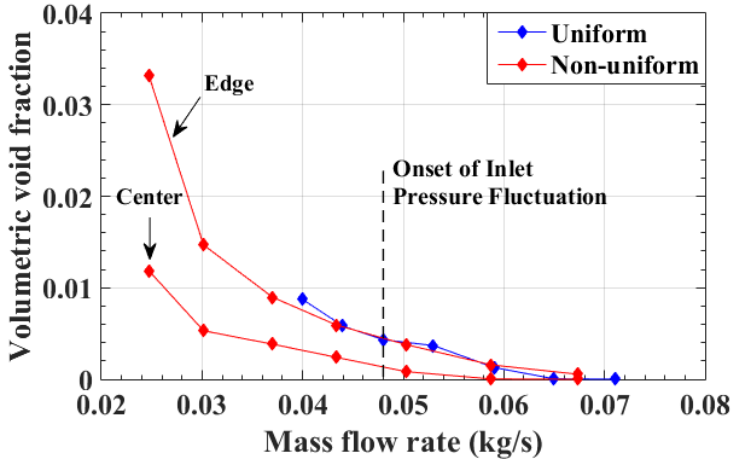
Thermal hydraulic parameters under ***constant power***
(Power 3.57 kW, inlet Temperature 50°C)

4. Results and Discussion (5/7)



Change of flow pattern under non-uniform heating

- In the case of non-uniform heating, the pressure drop after OIPF is not increased due to low void fraction in the middle.
- When the flow pattern changes to churn slug flow near the edge, the pressure drop suddenly increases.

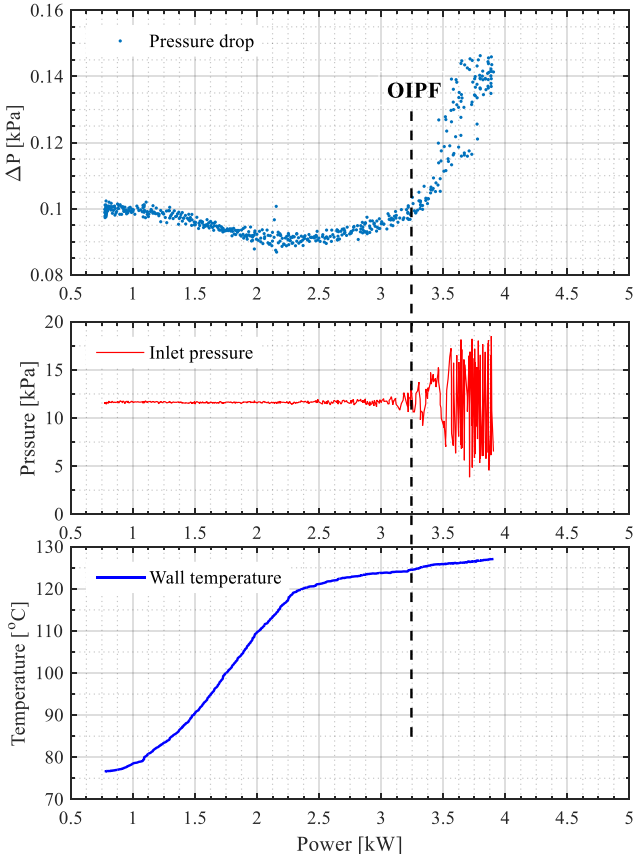


Comparison of void fraction under constant power (Power 3.00 kW, Inlet temperature 65 °C)

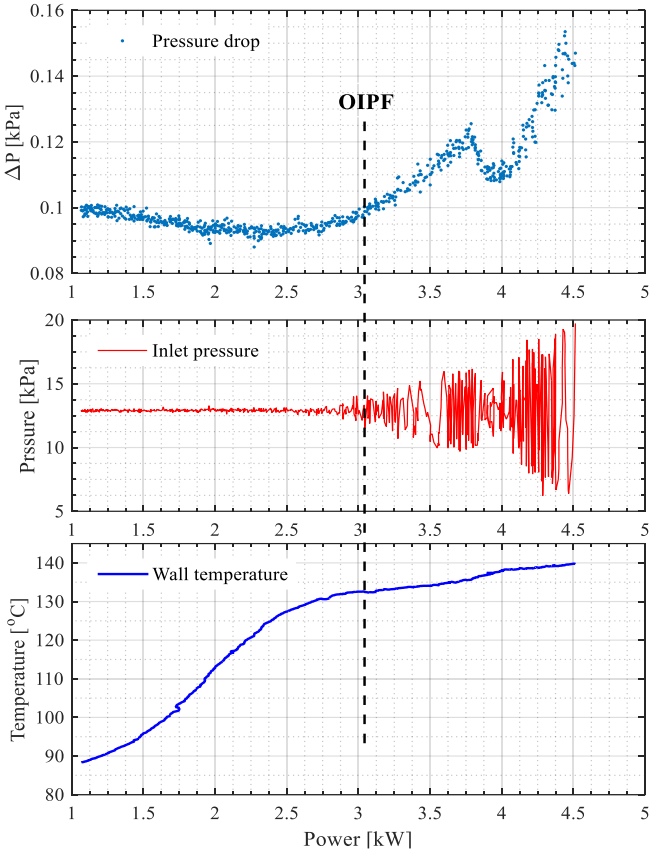
4. Results and Discussion (6/7)

- Pressure drop is different, the inlet pressure fluctuation conditions are same

Uniform test section



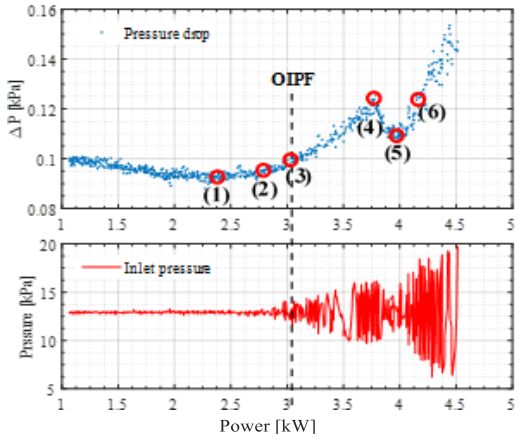
Non-Uniform test section

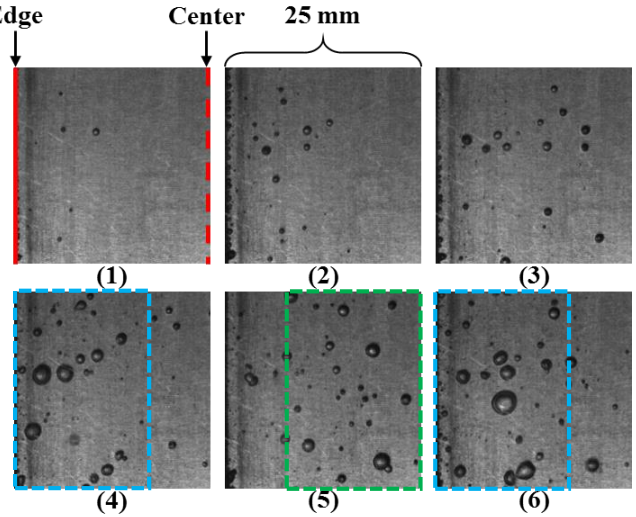


Thermal hydraulic parameters under ***constant mass flow rate***
(Mass flow rate 0.03 kg/s, inlet Temperature 50°C)

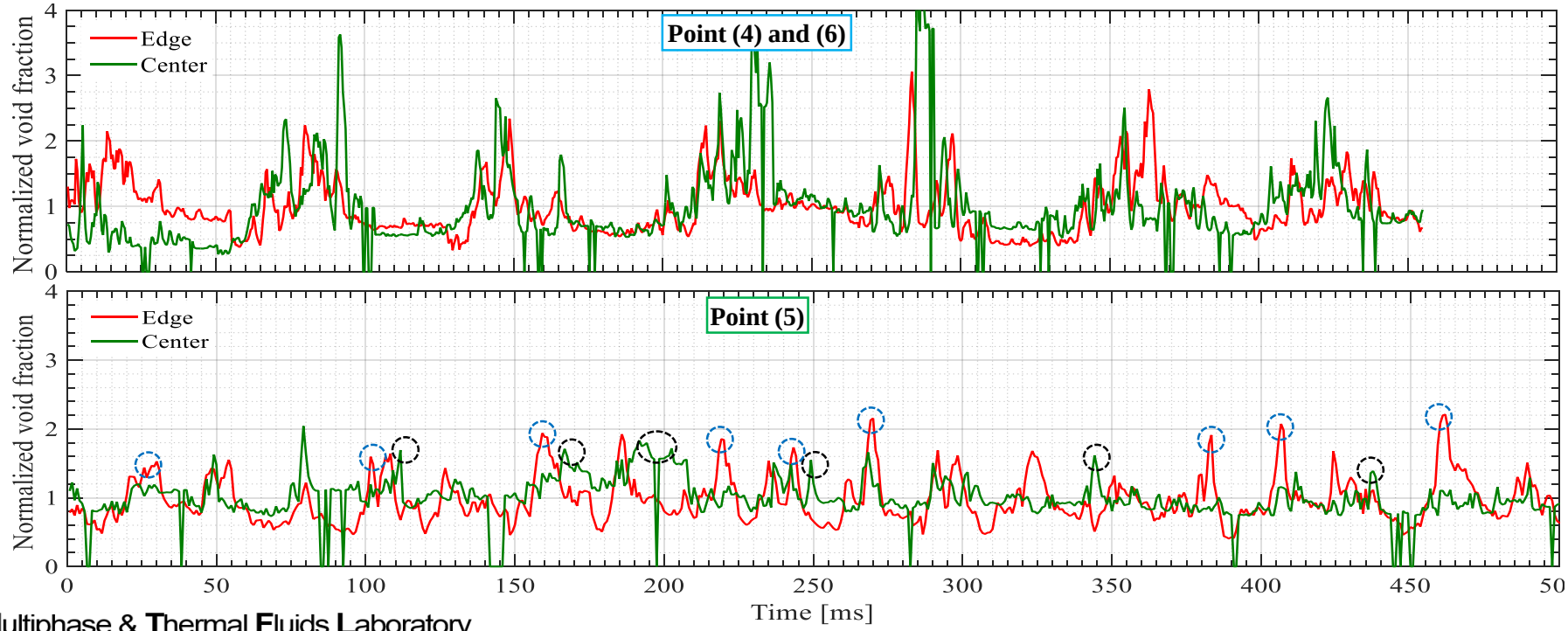
4. Results and Discussion (7/7)

Non-Uniform test section





- Different moments in bubbles generation and condensation between edge and center lead to have different pressure fluctuation behavior
- When the flow pattern changes between edge and center, the pressure drop changes.



5. Conclusion

(a) Effects of transversely heat flux distribution on the ONB and OFI are experimentally investigated through a narrow rectangular channel heated form one-side.

(b) At the same total power, the local heat flux of the non-uniformly heated surface is much higher than the one in the uniform case.

(c) ONB is local phenomena, it occurs at the same heat fluxes and wall temperature, even though the thermal power in the case of non-uniform heat flux is around 25 % less than the one in uniform case.

(d) OFI is global phenomena. OFI occurs at similar thermal power and mass fluxes for the same operation conditions.

(e) The differences in the heat flux distribution lead to different bubble behavior: the pressure drop behavior and void generation are different between uniform and non-uniform heat fluxes.

Thank you for your attention

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4. Al-Yahia, O.S., Jo, D., "ONB, OSV, and OFI for Subcooled Flow Boiling Through a Narrow Rectangular Channel Heated on One-Side", International Journal of Heat and Mass Transfer 116 (2018) 136-151.

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