Observation of Departure from Nucleate Boiling under different flow rates

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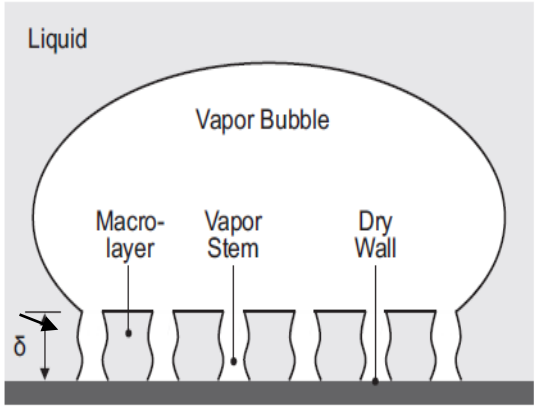
01 Background and Objective

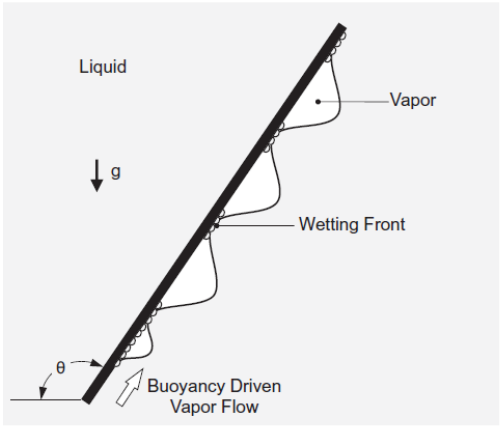
- Departure from nucleate boiling (DNB) is a phenomenon that happens when nucleate boiling turns into film boiling above a certain heat flux, known as critical heat flux. A good understanding on it is significant in terms of fuel integrity.

- Huge efforts were made for mechanistic model development to replace correlations.

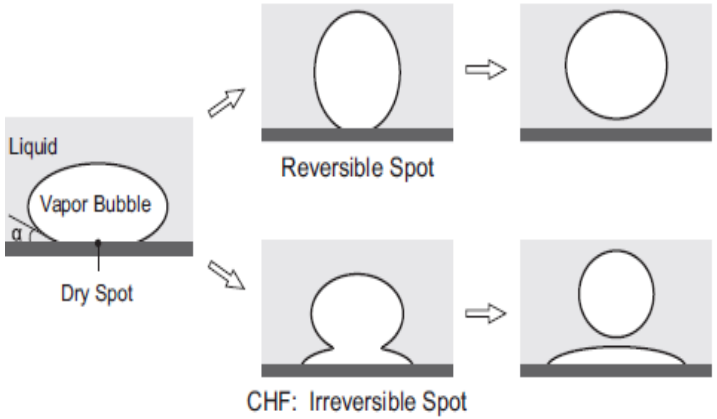
- For validation of the mechanistic models and measurement of constituting parameters, this research focuses on optical and thermal observation of DNB.



Macrolayer dryout.
(Haramura and Katto, 1983)

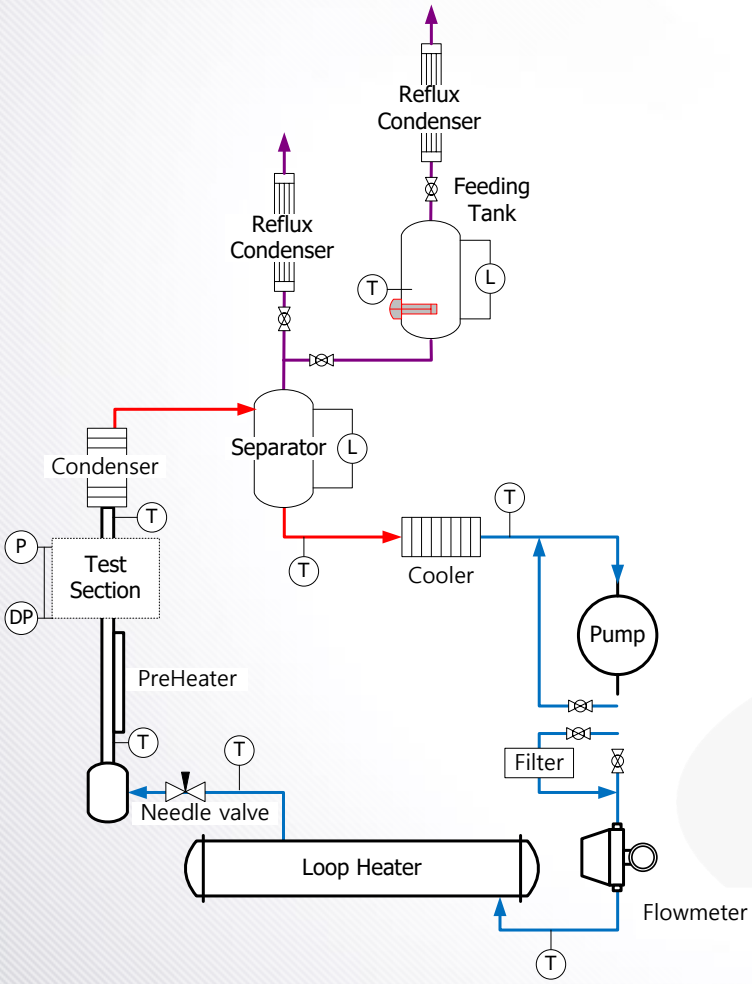


Interfacial lift-off model
(Galloway and Mudawar, 1993)



Hot/dry spot model
(Yagov, 1988)

02 Experimental facility



Test condition

Flowrate: 0 – 1000 kg/m^{2}s

Inlet Temperature: 70 – 130 °C

Pressure: 0.1 – 0.5 Mpa

Power supply

AC Power.

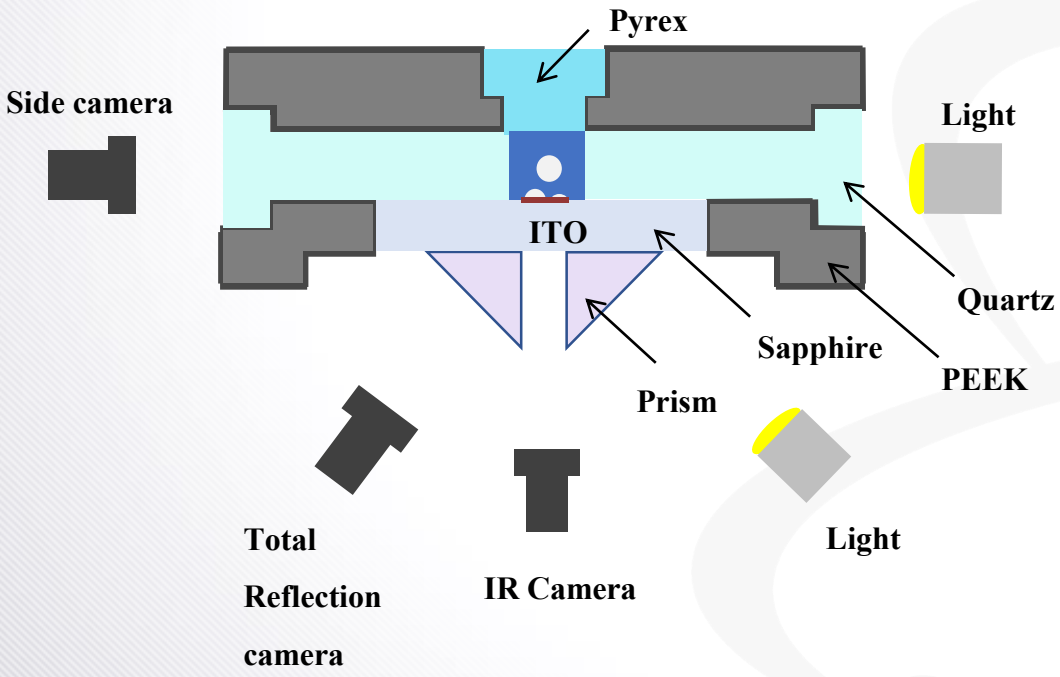
Control and Data acquisition- National Instrument.

Control: Power, Pump RPM

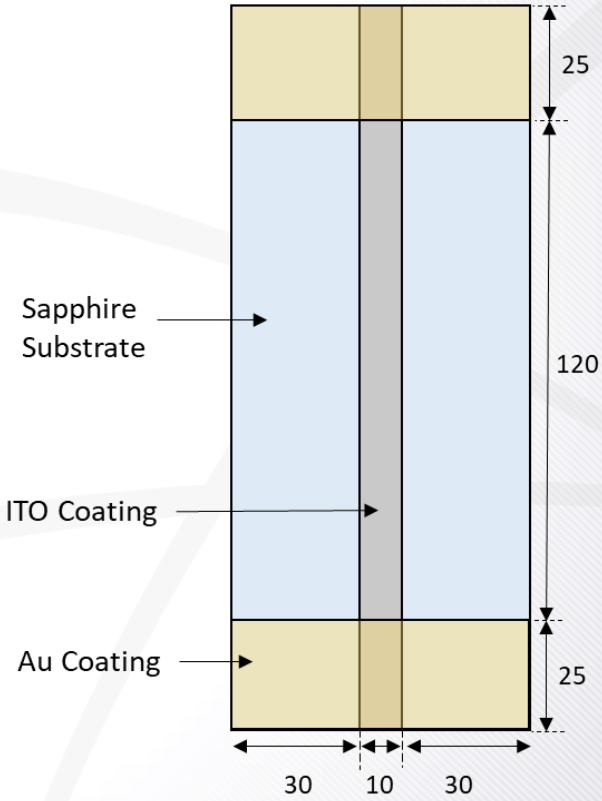
Acquisition: Pressure, Temperature, Flowrate, Power

02 Test section

Cross-sectional flow path: 15 mm X 15 mm
ITO Size: 10 mm (width) X 120 mm (length)



Arrangement of cameras around the test section (top view)



ITO coating on the sapphire substrate (unit: mm)

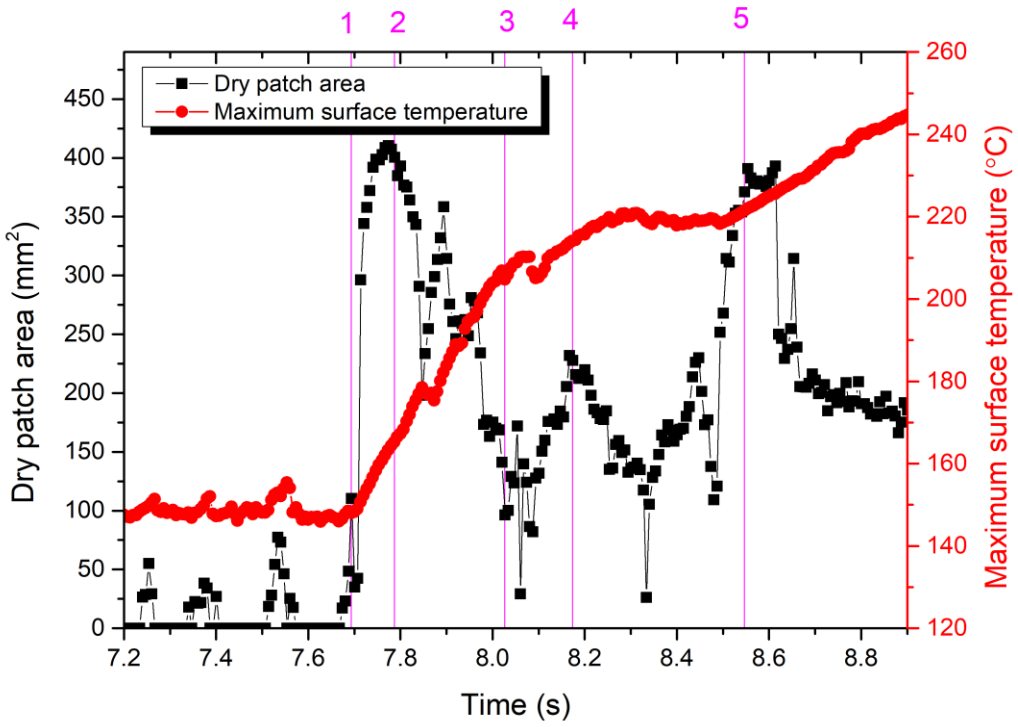
03 Test condition

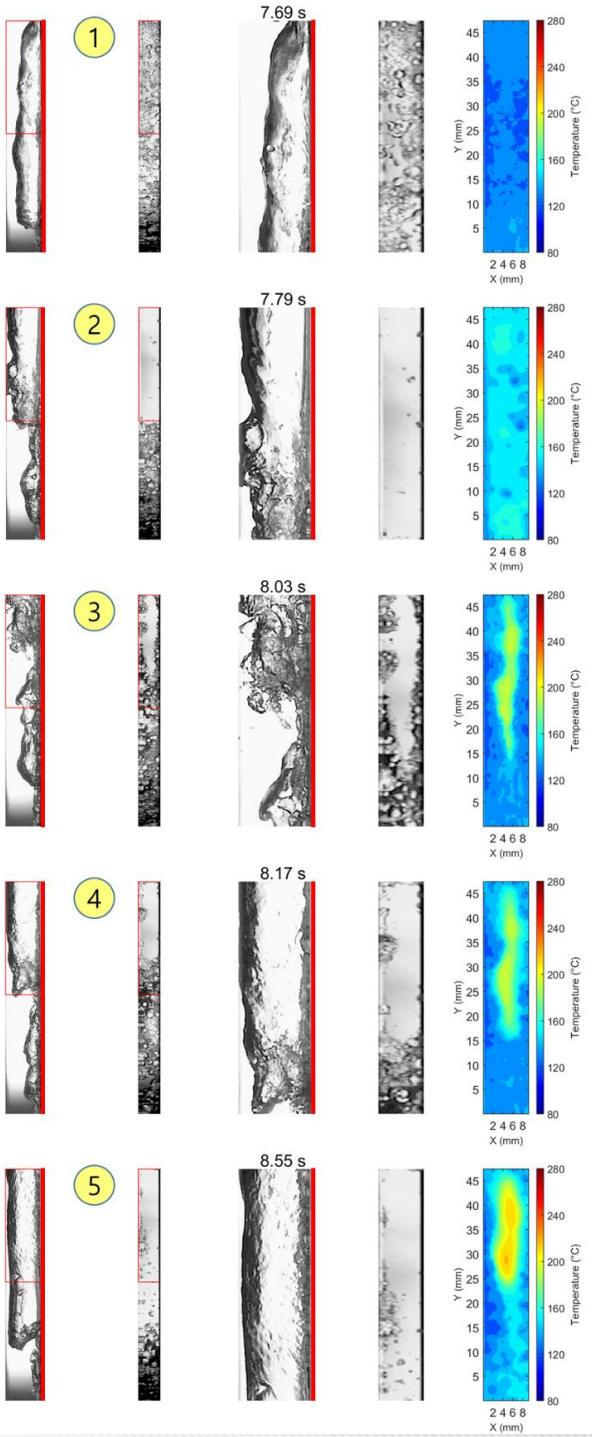
The main control parameter was flow rate.
Inlet temperature and ITO resistance (~chemical reaction) was similar.

Test number	Flow rate (kg/m^2s)	Inlet temperature (°C)	ITO resistance (Ω)	Note
1	1002	94.9	60	
2	1002	94.5	60	Used for analysis
3	501	94.5	60.2	
4	500	94.7	61.1	
5	499	94.7	60.8	Used for analysis
6	250	96.3	60.7	Used for analysis

04 Test Result

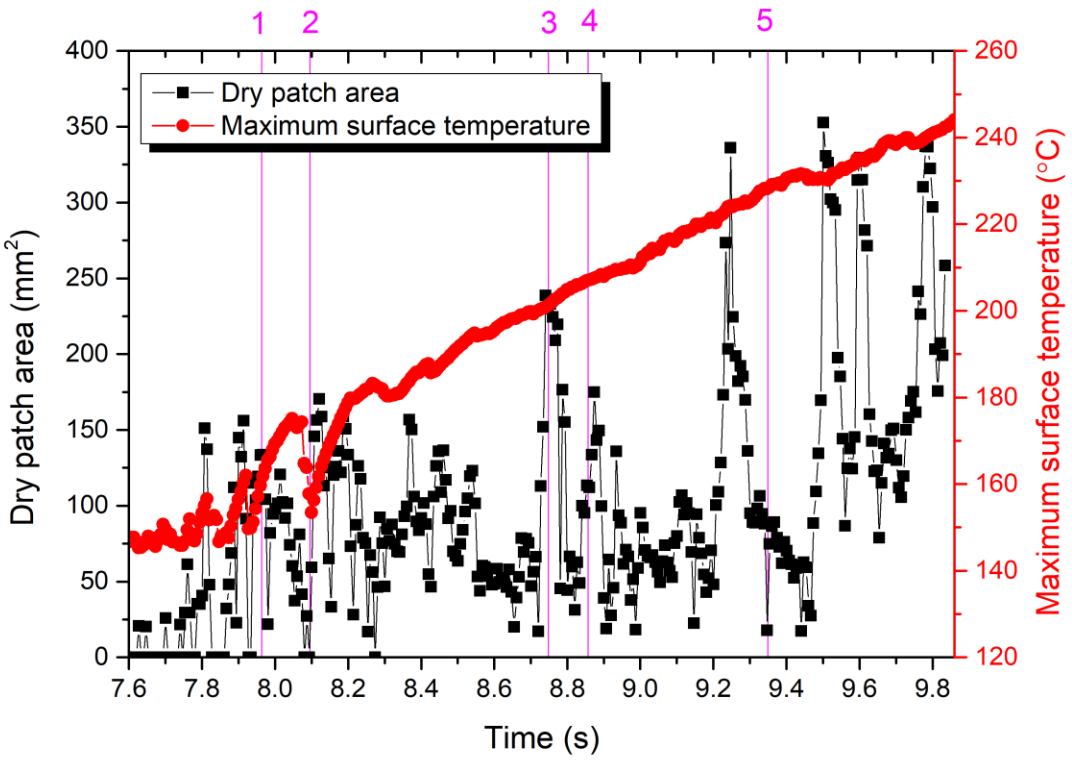
At 250 kg/m^{2}s, intermittent coming of vapor slugs led to formation of dry patches, and DNB.

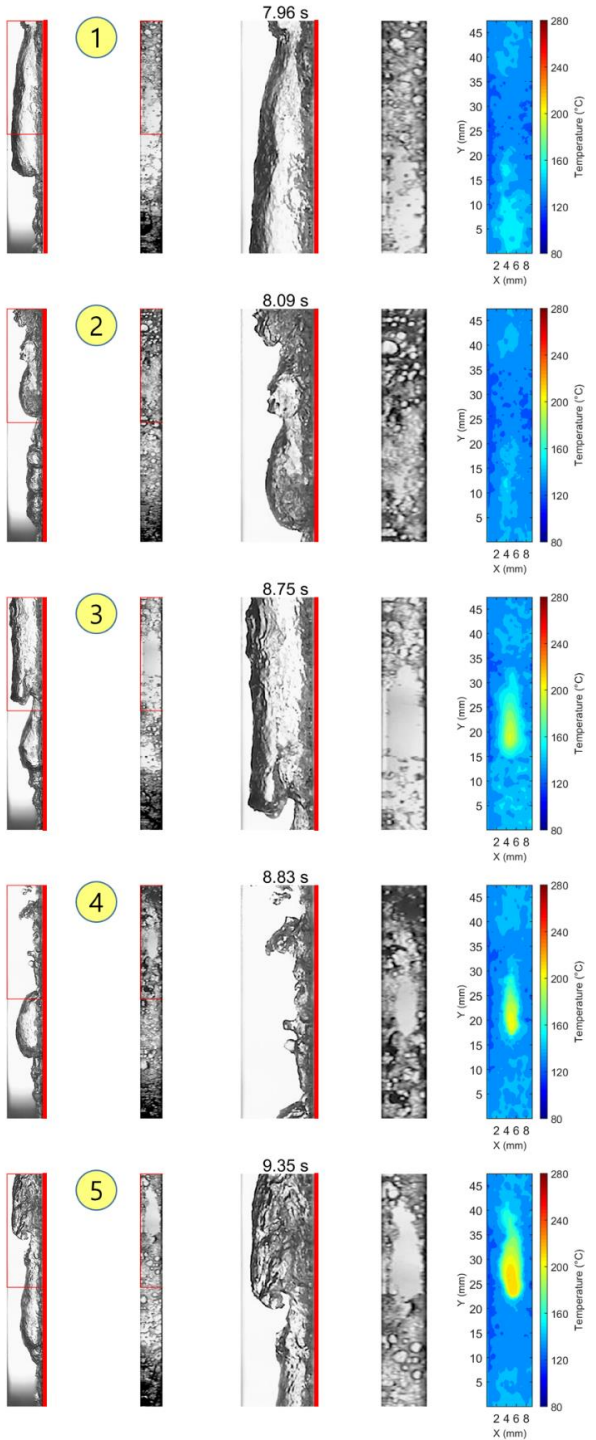




04 Test Result

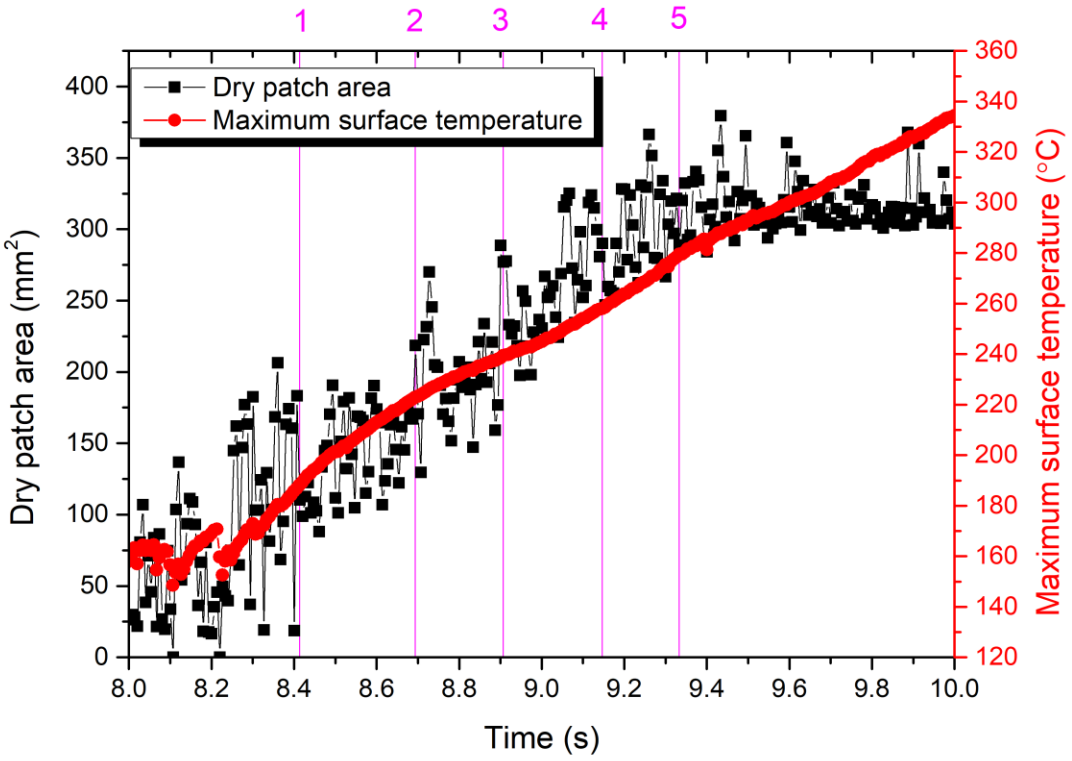
At 500 kg/m^{2}s, because of the weaker water slug, the dry patch lasted for a shorter period and the temperature rose steadily and slowly.

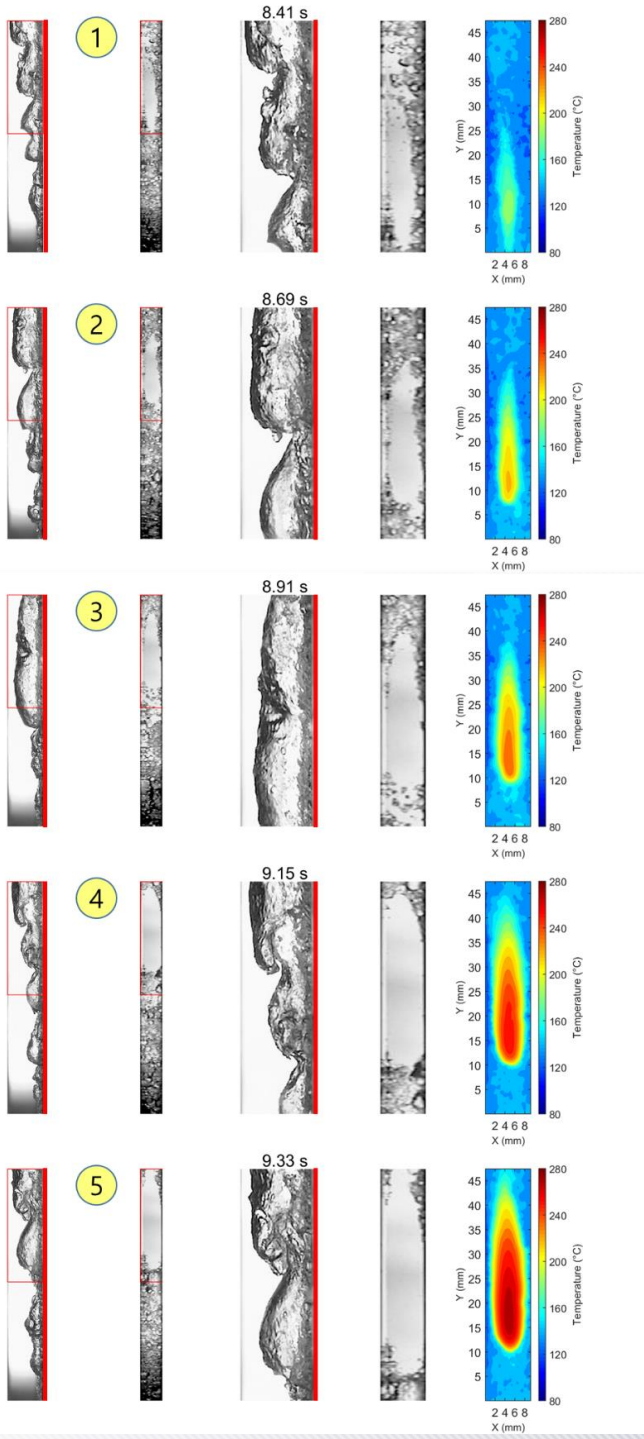




04 Test Result

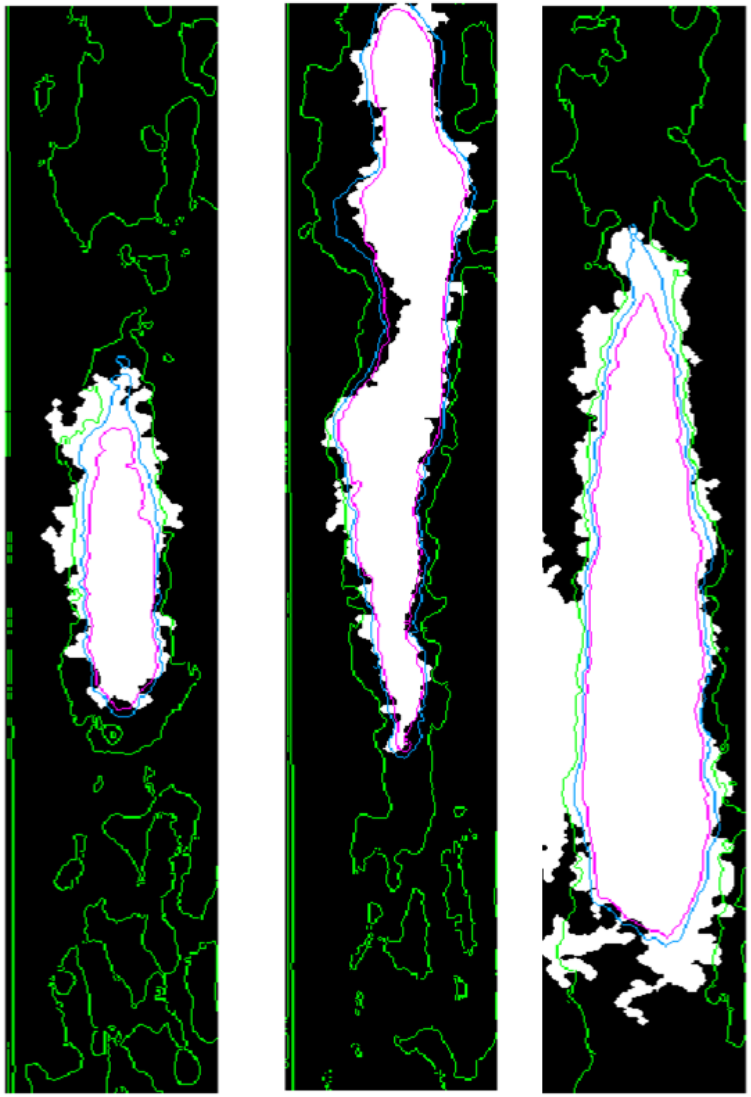
At 1000 kg/m^{2}s, the dry patch area oscillated but steadily rose in contrast to the huge fluctuation of dry patch area at lower flow rates.





04 Test Result

As per the thermal criterion in the dry patch model, the Leidenfrost temperature was set as the peripheral temperature. In this experiment, the Leidenfrost temperature of 150 °C.
The peripheral temperature similar in all the flow rates.



Dry patch (white) from total reflection views overlaid with contour lines at temperatures of 140 °C (green), 150 °C (blue), 160 °C (pink) (from left: 250 kg/m^{2}s, 500 kg/m^{2}s, 1000 kg/m^{2}s)

05 Conclusion and Future Work

- DNB phenomena under different flow rates were observed for a 120 mm long ITO heater using the total reflection technique and IR thermometry.
- The observation supported the dry match model.
- The peripheral temperature of dry patches was 150 °C, which was the Leidenfrost temperature for our test condition.
- At higher flow rate, smaller vapor slugs and subsequent weak water slugs led to stable and gradual growth of dry patches.

- In the future, in-depth analysis on the formation and life cycle of dry patches will be made.

THANK YOU