School of Nuclear Science and Engineering

COLLEGE OF ENGINEERING

Scientific Research Topic Tied to an Engineering Problem

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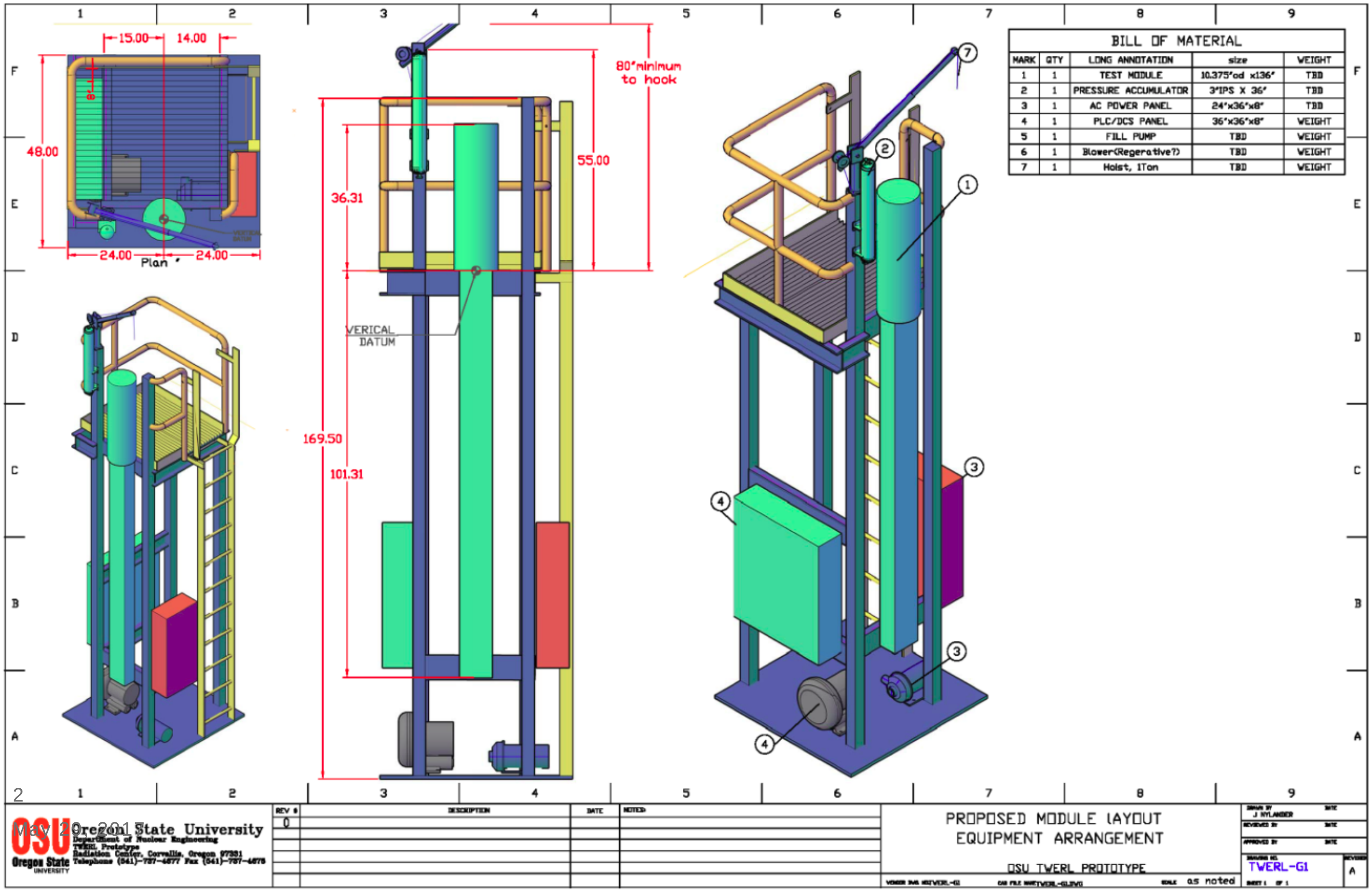
Outlines

- TRTL loop
  - Purpose of study
  - Capability of the facility
- Prospective research topics
  - RIA initiated transient CHF
  - Theoretical CHF model development
- Future work

Transient Test Loop(TRTL) facility



TRTL facility

- Provide operational and benchmark test data for the water loop test vehicle to be used in restarted TREAT facility
- Provide data for the study RIA induced power transient CHF
- TRTL Features:

- Water loop
- Forced flow
- Electrical heated
- Exponential power ramp

RIA induced power transient CHF

- Control rod driven system failure – sudden change of fission rate introduced to the reactor
- Pulse shaped power increase
- Local boiling phenomenon
- Rapid increase of heat surface temperature result in boiling
- DNB/low quality CHF problem involved.
- Film boiling weaken surface heat removal.
- If the heat cannot be removed effectively, the fuel will eventually melt. (TREAT fuel rod test/ other in-pile test)

Bessiron 2007. *Modelling of Clad-to-coolant Heat Transfer for RIA Applications*

- PATRICIA program to simulate boiling test in NSRR
- Electrical heated rod, vertical
- Higher CHF value compare to steady state pool boiling case

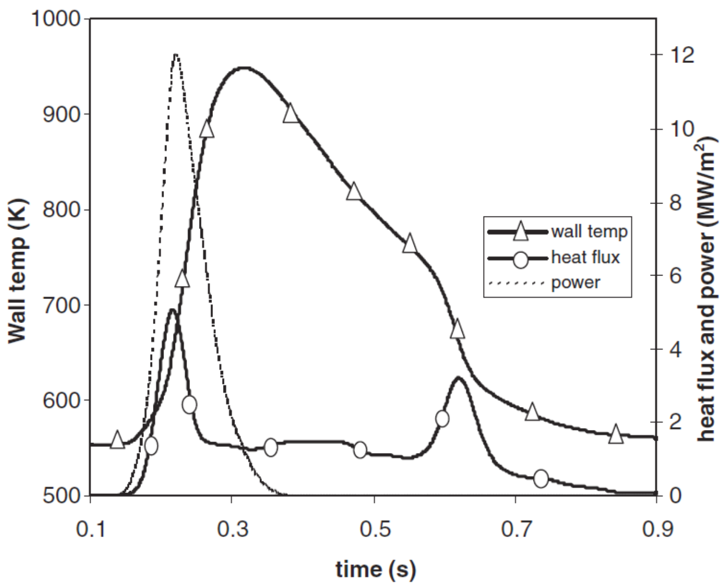
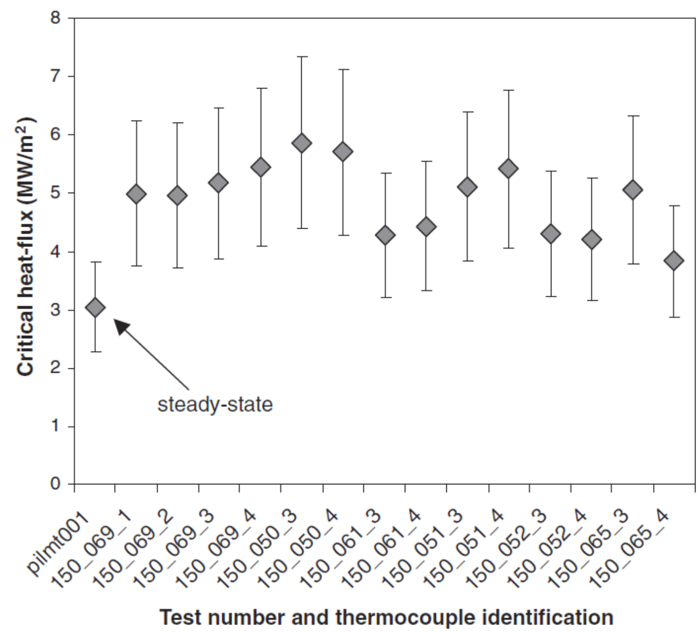
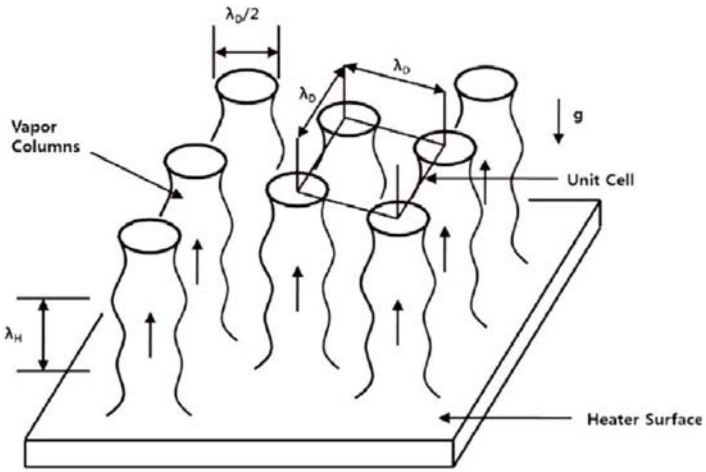


Fig. 1 Clad outer temperature, heat flux and power, PATRICIA-PWR test 150_065



Steady state CHF models based on hydraulic instability

- Zuber pool CHF model(1959): analytical, considering hydraulic instability(HI)



$$q''_{\max} = \frac{\pi}{24}\rho_g h_{fg}\left[\frac{\sigma g(\rho_f-\rho_g)}{\rho_g^2}\right]^{\frac{1}{4}}$$

- Kutateladze (1948) same results as Zuber.
- Lienhard and Dhir(1973)

$$q''_{\max} = 0.149\rho_g h_{fg}\left[\frac{\sigma g(\rho_f-\rho_g)}{\rho_g^2}\right]^{\frac{1}{4}}$$

- Other models for subcooled boiling, pool/pipe, horizontal/vertical surfaces. Etc.

Sakurai et al., studies on Heterogeneous Spontaneous Nucleation(HSN)

- Sakurai & Shiotsu 1977, exponential heat to platinum wire in water under various pressure.
  - Time period > 0.1s, same mechanism (HI) with ss CHF, with a time lag
  - Time period < 0.1s, unknown mechanism (not HI)
- Sakurai et al. 1992, exponential heat to horizontal cylinder in liquid nitrogen under various pressure.
  - Observed a direct transient from non-boiling regime to film boiling without reaching nucleate boiling.
  - An explosive burst of HSN bubble generation in originally flooded cavities is the other mechanism of transient CHF

Bessiron et al. 2007.

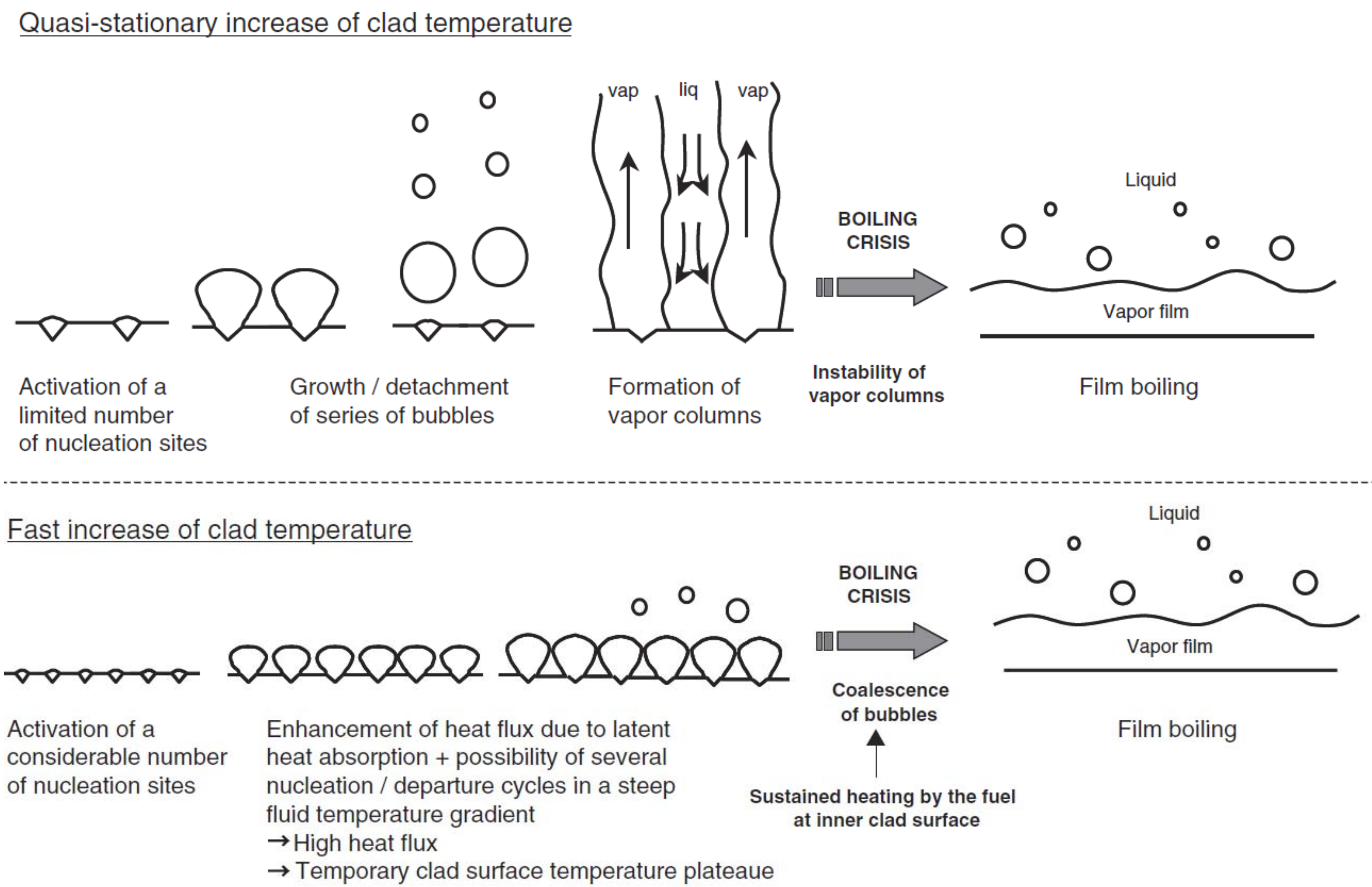


Fig. 8 Boiling Crisis mechanism in stationary and transient conditions

HSN study: Park et al. 2012 photographic study

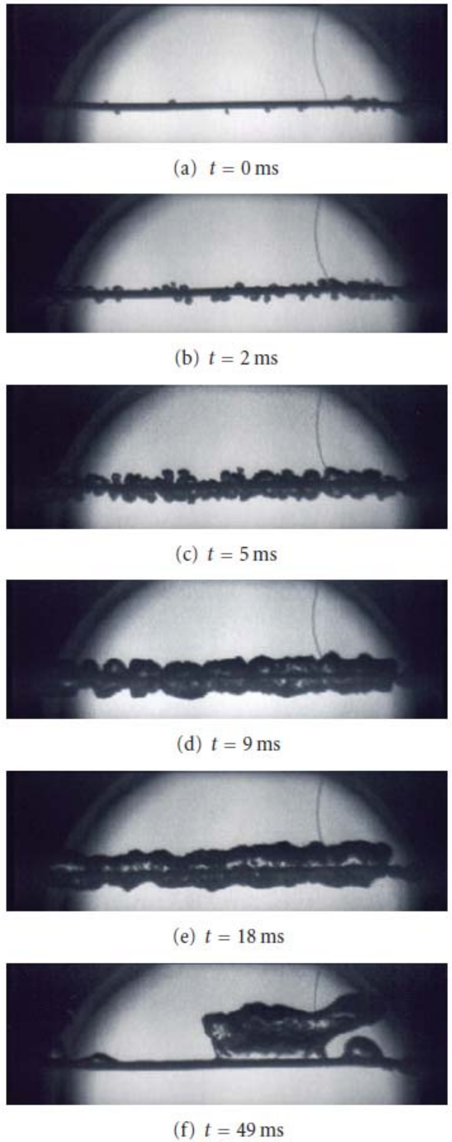


FIGURE 10: Vapor film behavior during semi-direct transition to film boiling for a period of 0.01 s at atmospheric pressure in saturated water.

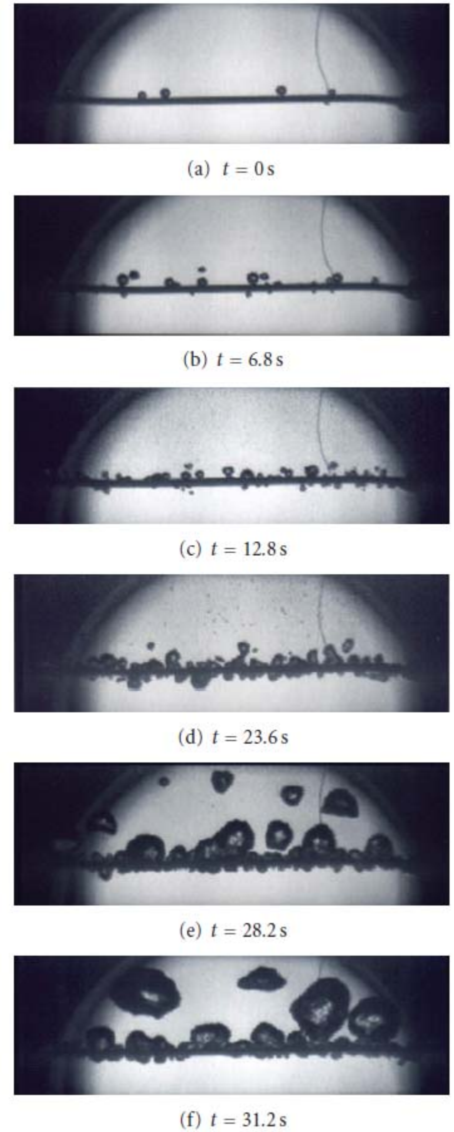
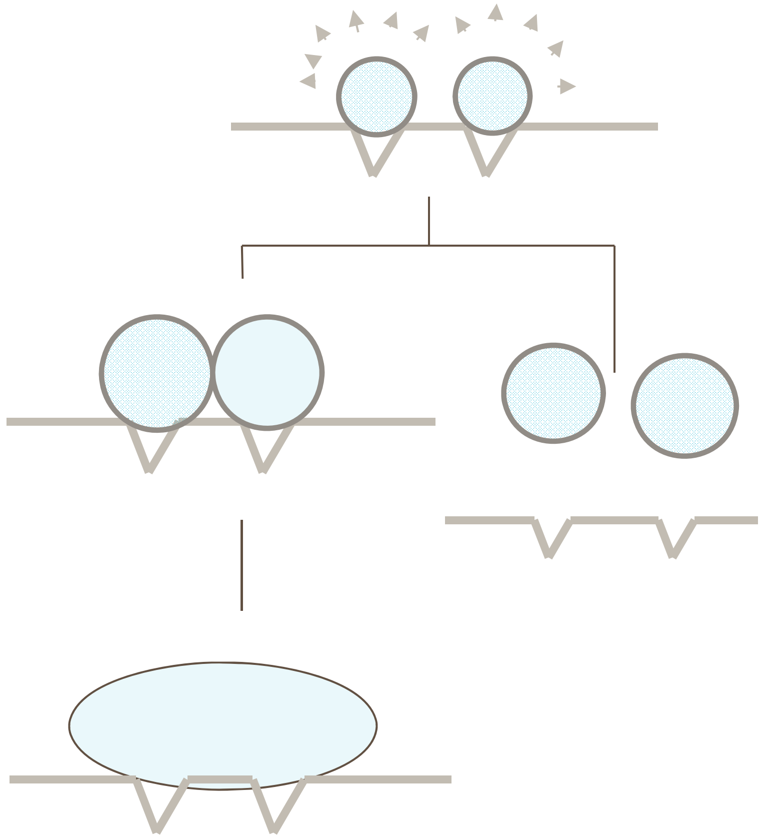
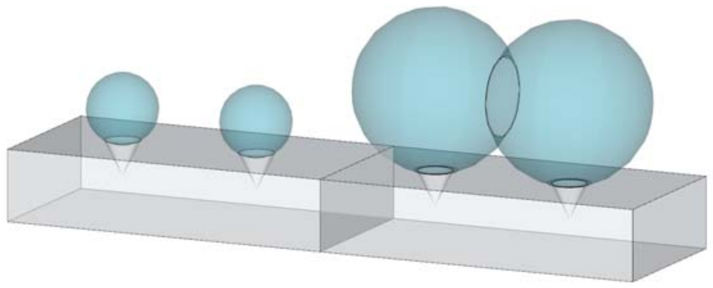


FIGURE 9: Vapor film behavior during transition to fully developed nucleate boiling (FDNB) for a period of 10 s at atmospheric pressure in saturated water.

Growth of bubble

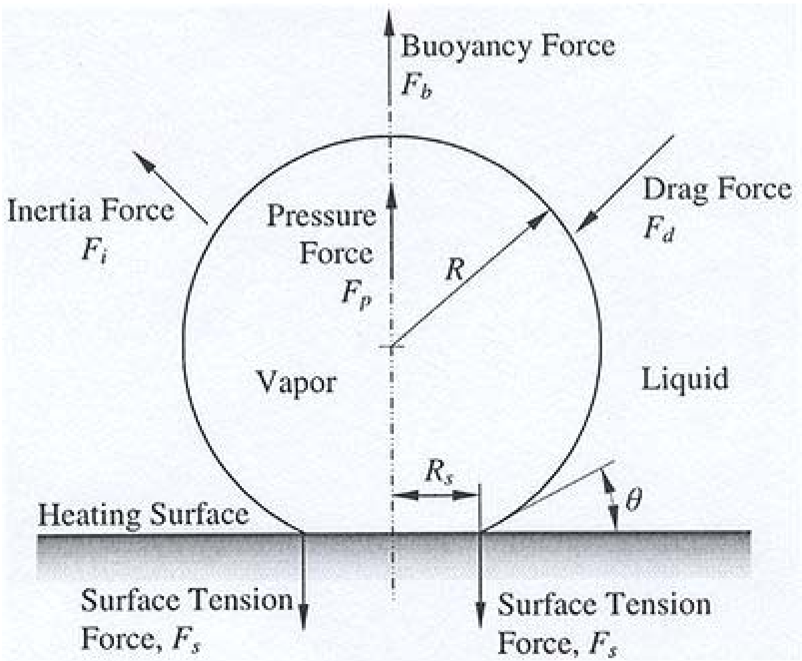


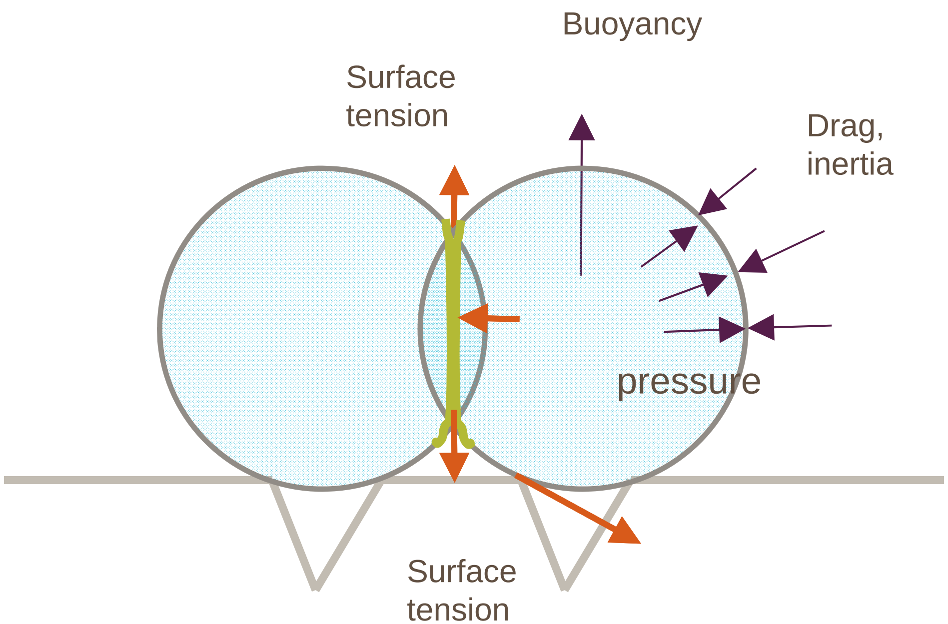


HSN:

- More effective sites activated
- Bubble grow and coalesce to form a film before reaching departure diameter
- Models needed:
  - Bubble growth rate
  - Bubble departure diameter
  - Nucleate site density(distance between 2 sites)
  - Bubble coalesce mechanism to form a film.

Bubble force balance





Future work

- Operational test and benchmark test to be performed in TRTL facility
- Power ramp test will provided thermal hydraulic data when CHF is reached.
- Since no analytical model has been published to describe the HSN mechanism, a theoretical model will be derived.
- The HSN model will be applied to study the RIA type power transient CHF.