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Symposium on Advanced Sensors and Modeling Techniques for Nuclear Reactor Safety

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Experimental Evaluation of Critical Heat Flux in Downward-Facing Boiling on Flat Plate Relevant to In-Vessel Retention in Indian PHWRs

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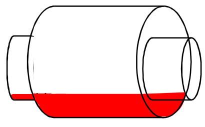
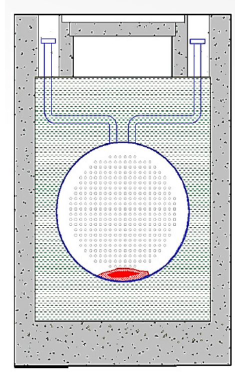
Introduction:

- In case of PHWR, the In-Vessel Retention (IVR) of corium is the only option for Fukushima type accident.
- Calculations have shown that if corium breaches the calandria vessel and enters the calandria vault, due to metal steam reaction and molten corium concrete interaction (MCCI), large amount of hydrogen (~> 2000kg) and other non-condensable gases will generate.
- There is also possibility of early containment failure. Hence, the only option is to contain the corium inside the calandria vessel and cool it from outside by calandria vault water.
- The vessel integrity is maintained only when imposed vessel wall heat flux due to corium shouldn't exceed boiling critical heat flux (CHF) on the vessel outer surface.
- In view of this, estimating the CHF is very important for evaluating the in-vessel retention strategy in Indian PHWR



PHWR Vessel

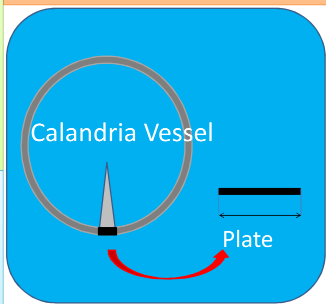


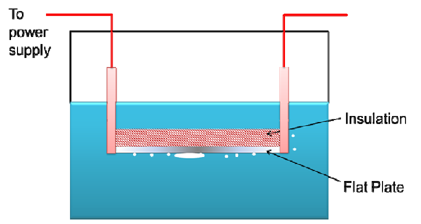
Issues:

- Numeral large scale studies have been done for estimation of on nucleate boiling critical heat flux.
- Most of the experimental studies were done on the geometry of hemispherical vessel and different material like carbon steel, cooper, aluminium, etc.
- But these studies cannot be applied to PHWR due to
  - ✓ Hemi- or Toro spherical geometry (PWR) whereas PHWR is cylindrical geometry
  - ✓ High height-to-diameter ratio in PWR whereas PHWR has high low height-to-diameter ratio
  - ✓ Corium composition and vessel material is different

Objective:

- Evaluation of temperature distribution at the outer vessel walls under the in-vessel retention through external reactor vessel cooling condition at different heater power.
- Determination of heat transfer coefficient in different regime.
- Determination of limiting heat flux

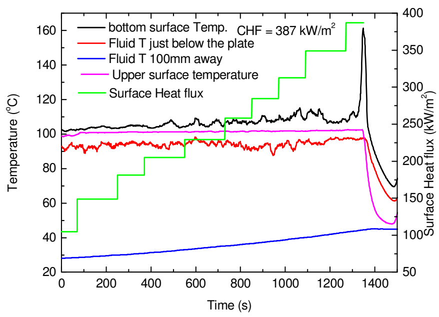




Test setup

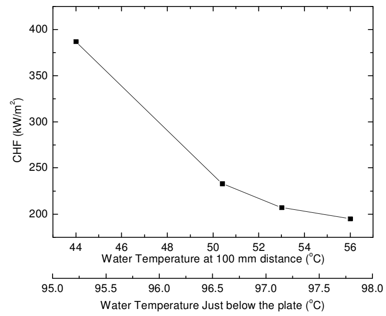
Experiment

- ❖ **CHF studies on downward facing flat plate simulating bottom of calandria vessel of PHWR**
- ❖ **Test section details:**
  - ✓ SS 304L
  - ✓ Length : 400mm
  - ✓ Width: 100 mm
  - ✓ Thickness: 3 mm



Major Findings

- ❑ The CHF was found to be 387 kW/m2 at bulk water temperature of 45 ℃
- ❑ CHF occurred at 387 kW/m² and it decreased to 200 kW/m² gradually and becomes almost saturated when the bulk temperature became 56 °C



S.N.	Experiment	CHF Limit at 0°
1	Calandria vessel	387 kW/m²
2	Theofanous Configuration I	300 kW/m²
3	Theofanous Configuration II	490 kW/m²
4	Cheung, SBLB	434 kW/m²