Sensitivity Analysis of RCW Temperature on the Moderator Subcooling Margin for the LBLOCA of Wolsong NPP Unit 1

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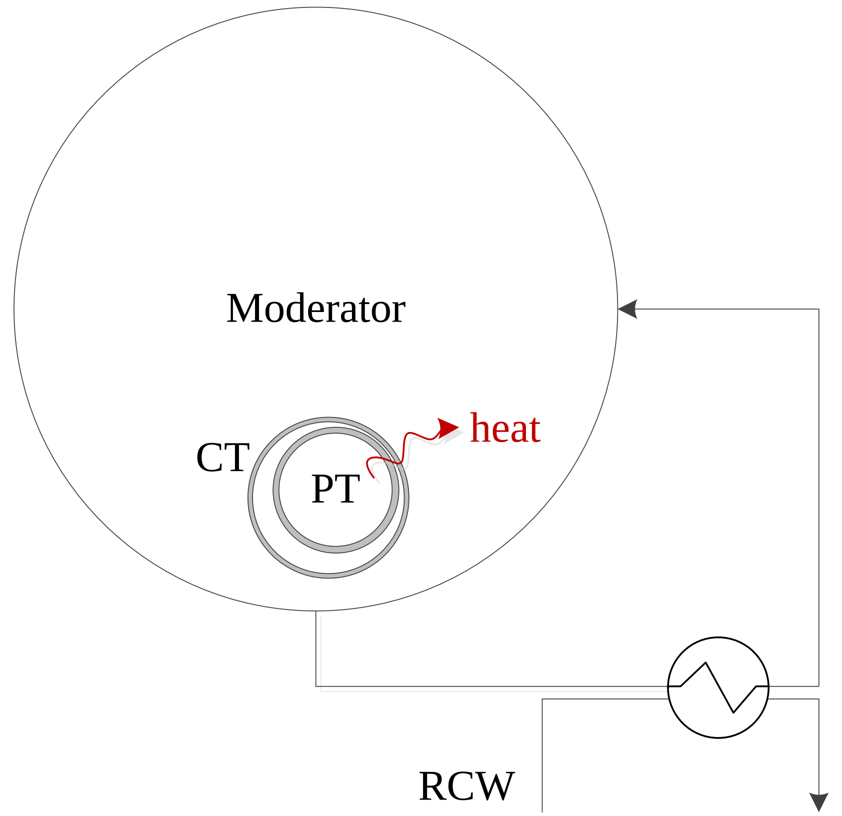
Contents

1. Introduction

✓ *BACKGROUND*

- Heat removal from the Primary Heat Transport System (PHTS) to Moderator by PT/CT contact in the CANDU reactor is one of valid heat removal methods when the LBLOCA with LOECI occurs.
- The moderator subcooling margin has to ensured in order that heat removal through the moderator is available.
- Thus, the moderator subcooling margin has been analyzed using the MODTURC_CLAS code in the LBLOCA FSAR PART C & F.



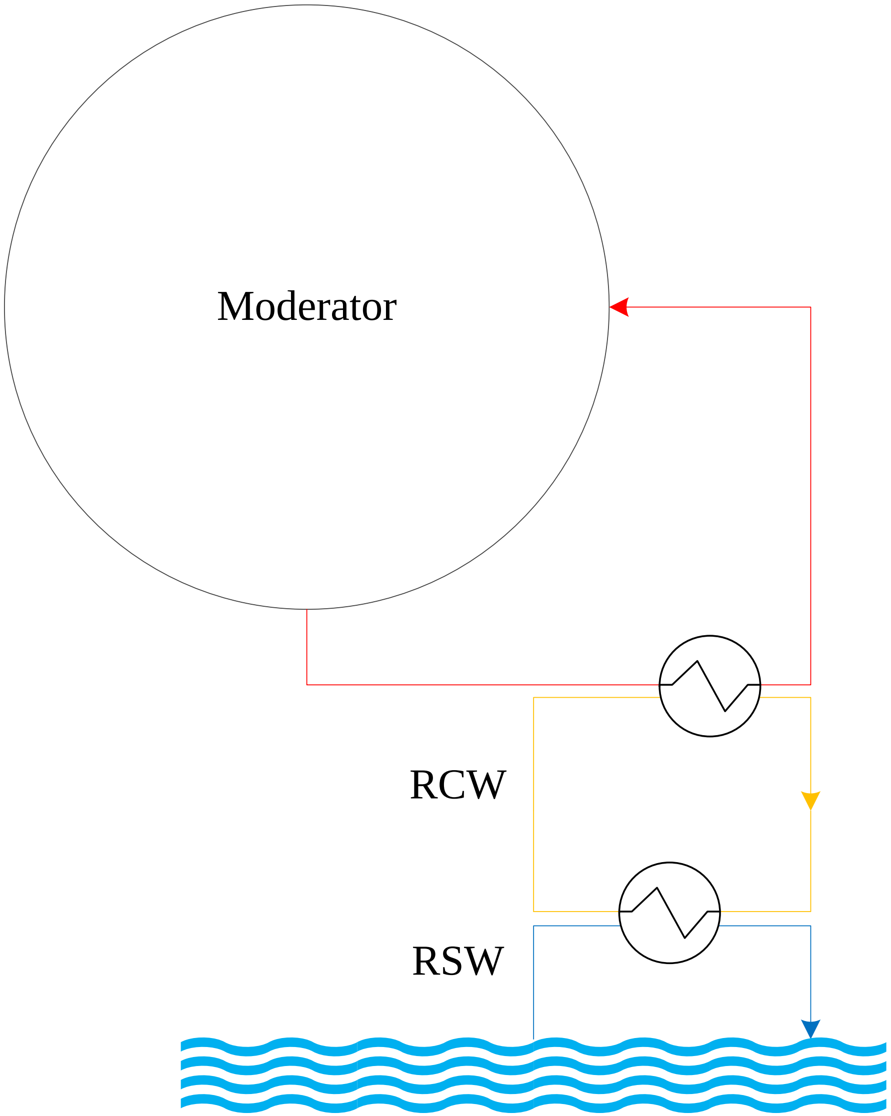
1. Introduction

✓ *PROBLEM*

- Performance of moderator Hx depends on RCW temperature. And also the temperature is affected by see water temperature.

- Sea water temperature is gradually increasing by global warming. So it will cause increase of RCW temperature inevitably.

- Therefore, sensitivity analysis is performed to obtain information and insight about the relation between RCW temperature and the moderator subcooling.



2. *Methodology and Assumptions*

- ✓ *MODTURC_CLAS code*
  - A computational fluid dynamics (CFD) software, MODTURC_CLAS V2.9-IST, was used to analyze the moderator subcooling margin following a LBLOCA with LOECI in the Wolsong unit 1.
  - This code was developed to predict the CANDU moderator temperature distribution in normal operation, or available subcooling during postulated LOCAs for which the moderator is required to act as a heat sink.
  - It is a customized version of the more general code TASCFLOW, which includes additional moderator specific models and parameters.
- ✓ *METHODOLOGY*
  - The same methodology used in LBLOCA Part F (LBLOCA with LOECI and Loss of Class IV Power) is employed to assess the moderator subcooling.
  - First of all, Header conditions (pressure, void fraction, enthalpy) are calculated using by the CATHENA.
  - PT/CT contact time at each channel and bundle, maximum PT temperature at contact time, and heat load to the moderator are calculated using the heater conditions in single channel analysis.
  - Subcoolings at each row in moderator are estimated using the heat load to the moderator in MODTURC_CLAS code.

2. Methodology and Assumptions

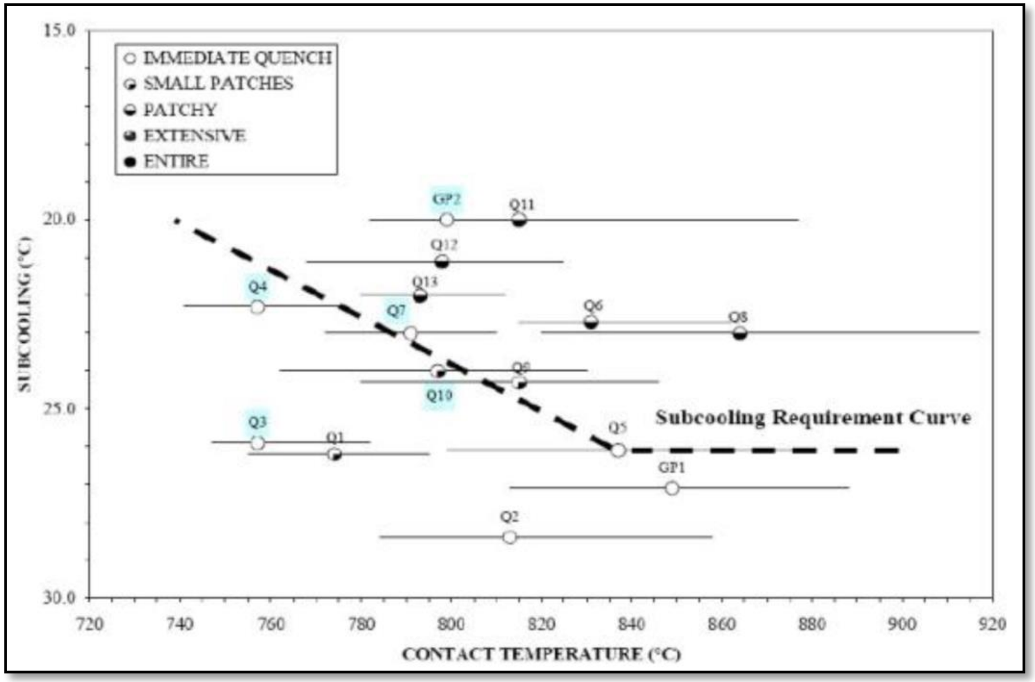
✓ *METHODOLOGY*

- Required subcooling is needed to obtain subcooling margin. The required subcooling is estimated by using "the Moderator Subcooling Requirement Curve using Glass-peened Calandria Tubes".

- This curve present the subcooling requirement for early heat-up due to PT/CT ballooning contact that was obtained using experimental results from full-scale tests plotted in terms of subcooling versus PT temperatures at the time of PT/CT contact.

- Maximum PT temperature obtained from single channel analysis is applied to right curve to estimate required subcooling.

- Subcooling margin is evaluated by subtracting the required subcooling estimated by subcooling requirement curve from the available subcooling calculated by MODTURC_CLAS code.



Moderator Subcooling Requirement Curve using Glass-peened Calandria Tubes

2. Methodology and Assumptions

✓ *METHODOLOGY*

- The analysis results shown in FSAR LBLOCA Part F are yielded based on the RCW temperature of 35℃.
- In the present study, 38℃ and 39℃ RCW temperature are also assumed to predict the moderator minimum subcooling margin.
- Lastly, these three cases will be compared.

✓ *ASSUMPTIONS*

- The analysis results shown in FSAR LBLOCA Part F are yielded based on the RCW temperature of 35℃.
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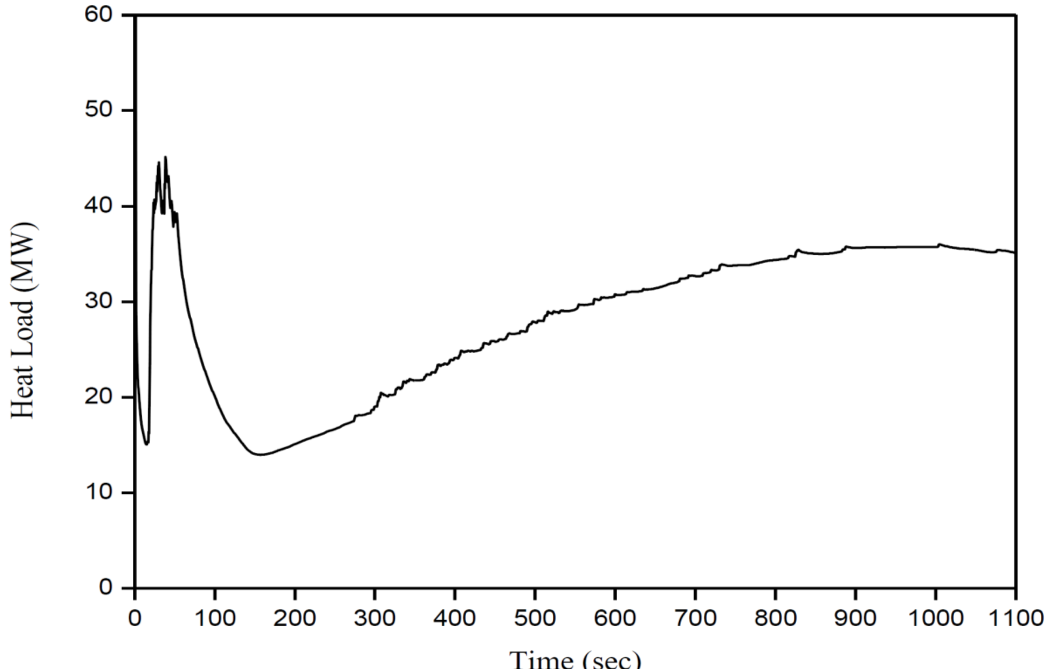
Thermalhydraulic Boundary Conditions for the Moderator Subcooling Analysis

Parameters	Value
Total moderator heat load	100 MW
Fraction of heat load in the core region of the moderator	0.939
Outlet temperature	70.6°C
Total inlet mass flow rate	1019 kg/s
Ratio of mass inflow at two inlet nozzle banks	49/51
Ratio of mass flow per inner/outer inlet nozzle compartments	38/62
Cover gas pressure	21 kPa(g)
Recirculating service water per heat exchanger	1125 kg/s
Recirculating service water temperature	35, 38, 39°C

3. Analysis Results

✓ *TOTAL HEAT LOAD TO THE MODERATOR CALCULATED BY SINGLE CHANNEL ANALYSIS*

- The total heat load to the moderator is shown in bottom graph when the LBLOCA with LOECI and Loss of Class IV Power is occurred.
- There are three peak in the graph. An initial peak in the heat load corresponding to the power pulse.
- Second and third heat load peak is caused by PT/CT ballooning contact and PT/CT sagging contact, respectively.



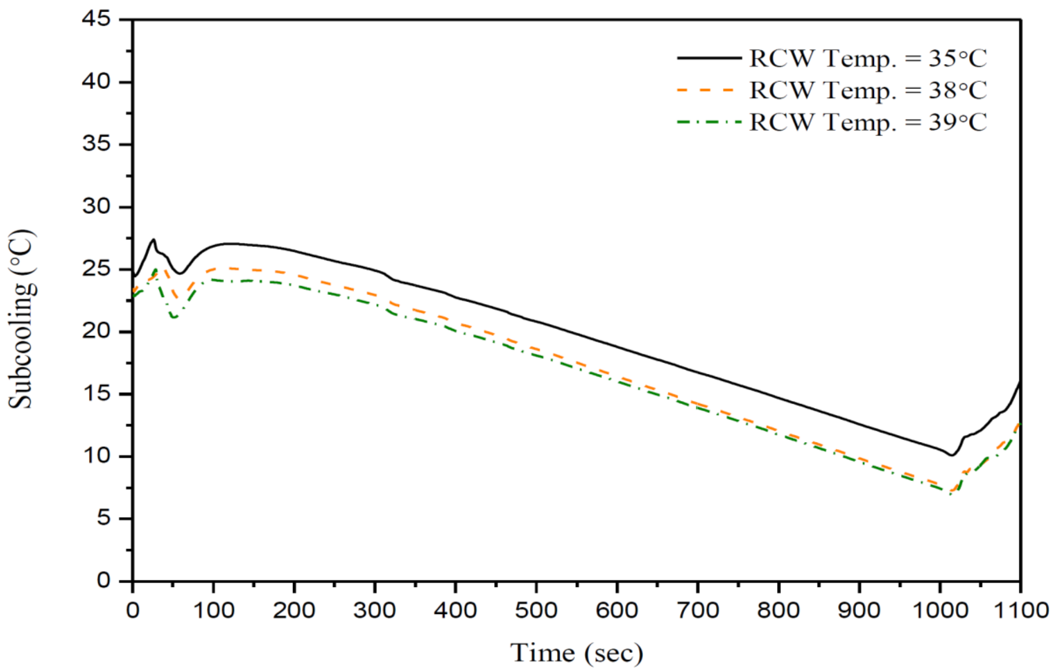
3. Analysis Results

✓ *AVAILABLE SUBCOOLING ESTIMATED BY MODTURC_CLAS*

- The minimum available subcoolings at fuel channel row A as a function of time for each RCW temperature conditions are shown in bottom graph. The reason of showing only the row A is that this row is placed the top of the calandria and has higher temperature than other lower rows.

- Since the moderator temperature is increased as the RCW temperature increases in quasi-steady state, the initial subcoolings are different each other.

- The moderator available subcoolings initially increase due to reactor trip, and then decrease as the heat load from PT/CT contact increases.
- After about 60 seconds the subcooling increases again because the moderator heat load decreases.
- The moderator pony motors start at 90 seconds, but deliver only one-quarter of the normal flow.
- The available subcooling continuously decreases until the operator re-starts the main motors at 1000 seconds.



3. Analysis Results

✓ *THE MODERATOR SUBCOOLING MARGIN*

- Values in red box is estimated by single channel analysis (CATHENA).
- Values in blue box is yielded by the moderator subcooling requirement curve.
- Values in green box is calculated by MODTURC_CLAS.
- As a result of this sensitivity analysis, if RCW temperature exceeds 39℃ the subcooling margin may not be ensured then LBLOCA with LOECI and Loss of Class IV Power occurs.

RCW Temp. (°C)	Channel Power (MW)	Bundle Location	Highest Row Location	PT/CT Contact Time (s)	Max PT Temp. @ contact time (°C)	Required Subcooling (°C)	Available Subcooling (°C)	Subcooling Margin (°C)
35	4	10	Row A	884	sagging	10	12.95	2.95
38	4	10	Row A	884	sagging	10	10.23	0.23
39	5	6	Row B	41.2	788	22.75	22.40	-0.35

4. Conclusions

- ✓ *The moderator subcooling margin has to be ensured to establish the moderator heat removal when LBLOCA with LOECI and Loss of Class IV Power occurs.*

- ✓ *However, sea water temperature is increasing gradually due to global warming.*

- ✓ *So it is necessary that sensitivity analysis of RCW temperature on the moderator subcooling margin to estimate the availability of the moderator heat removal.*

- ✓ *In the present study, the moderator subcooling analysis is performed using the same methodologies and assumptions except for RCW temperature used in FSAR LBLOCA Part F.*

- ✓ *As a result of analysis, it is conclude that the moderator subcooling margin may not be ensured when LBLOCA with LOECI and LOCL4 is occurred if RCW temperature exceeds 39℃.*