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Deterministic Sensitivity Studies and Correlation Analysis for Evaluating the Impact of Uncertainty Variables on LBLOCA Consequence

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Introduction

❑ Best Estimate Plus Uncertainty (BEPU)

- Increasingly applied to LBLOCA evaluation
- Identification of uncertainty parameters and their quantifications
  - Essential task but still difficult and challenging
  - Impact of UP: important in early BEPU methodology
  - Wilks' method: consideration of many uncertainty variables
- Ill-considered addition of uncertainty parameters
  - might increase the total uncertainty
- Concentration of important uncertainty parameters

❑ Previous Studies

- APR-1400 LBLOCA were analyzed with 18 uncertainty parameters
- Multiple linear regression analysis (MLRA) for evaluating the impact of uncertainty variables on LBLOCA

Introduction

Objectives

- Results of the multiple linear regression analysis (MLRA) should be validated
- Correlation analysis and deterministic sensitivity studies were additionally performed
- Comparison of those results were made

Statistical Analysis

❑ BEPU Calculations according to KINS-REM

- LBLOCA by 100% DEGB at RCP Discharge Leg using MARS-KS
- 3rd order Wilks method (124 calculations) and 18 UPs

No	Models/Variables	Distribution	Mean	Uncertainty
1	Gap conductance	Uniform	0.95	0.55
2	Fuel conductivity	Uniform	1.0	0.153
3	Core power	Normal	1.0	0.01
4	Decay heat	Normal	1.0	0.033
5	Groeneveld CHF	Normal	0.985	0.2638
6	Chen nucleate boiling	Normal	0.995	0.1505
7	Chen transition boiling	Normal	1.0	0.149
8	Dittus-Boelter liquid convection	Normal	0.998	0.127
9	Dittus-Boelter vapor conv.	Normal	0.998	0.127
10	Bromley film boiling	Normal	1.004	0.1864
11	Break CD	Normal	0.947	0.0706
12	Pump 2-f head	Uniform	0.5	0.5
13	Pump 2-f torque	Uniform	0.5	0.5
14	SIT pressure (MPa)	Uniform	4.245	0.215
15	SIT inventory (m^3)	Uniform	49.95	4.65
16	SIT temperature (K)	Uniform	308	14.0
17	SIT loss coefficient	Normal	18.0	2.33
18	IRWST temperature (K)	Uniform	302.5	19.5

Statistical Analysis

< Rank of influential uncertainty parameters for blowdown PCT >

Rank	Correlation	Multiple linear regression
1	Fuel conductivity	Fuel conductivity
2	Gap conductance	Break CD
3	Break CD	Gap conductance
4	Groeneveld CHF lookup table	Groeneveld CHF lookup table
5	Pump 2-f head multiplier	Pump 2-f head multiplier
6	Core power	Core power
7	-	Dittus-Boelter vapor convection correlation
8	-	Chen transition boiling correlation
9	-	Decay heat

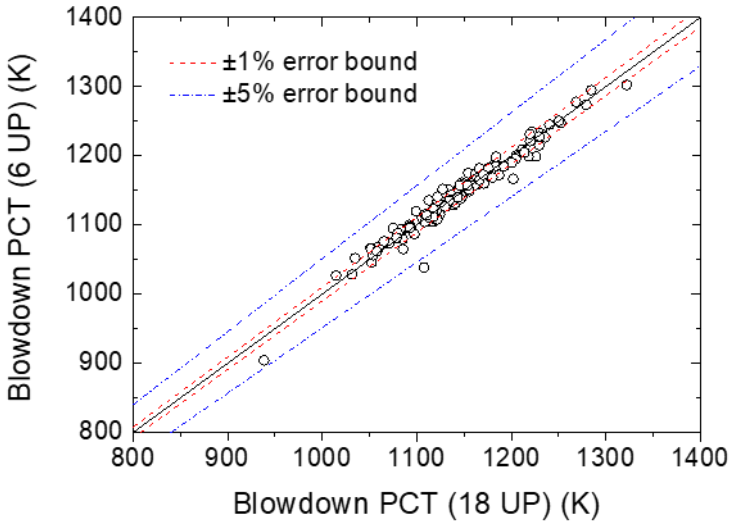
< Rank of influential uncertainty parameters for reflood PCT >

Rank	Correlation	Multiple linear regression
1	Groeneveld CHF lookup table	Groeneveld CHF lookup table
2	Fuel conductivity	Fuel conductivity
3	Chen transition boiling correlation	Chen transition boiling correlation
4	Gap conductance	Gap conductance
5	Core power	Core power
6	-	Dittus-Boelter vapor convection correlation
7	-	Decay heat
8	-	Break CD
9	-	Pump 2-f head multiplier
10	-	SIT water inventory

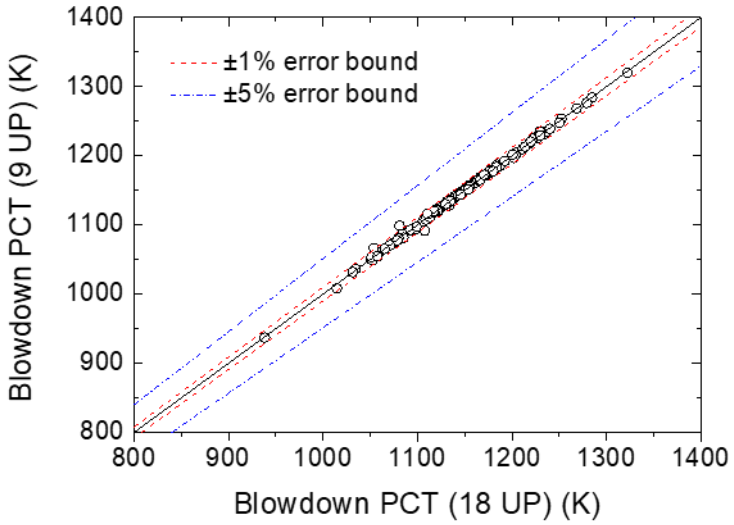
Deterministic Sensitivity Studies

❑ Deterministic sensitivity studies (1)

- Parameters which were evaluated to have little influence on PCTs, were excluded in the BEPU calculations by setting their mean values
- Blowdown PCT



Comparison of blowdown PCT from the correlation analysis



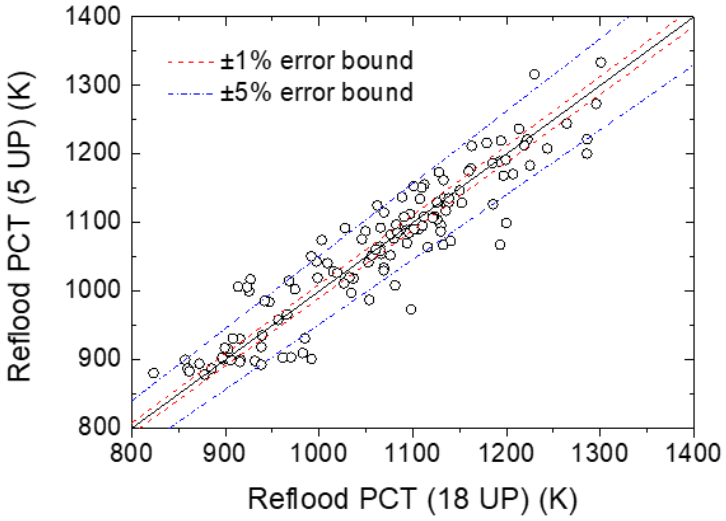
Comparison of blowdown PCT from the regression analysis

  - Consideration of only 9 parameters could fully explain the variation of blowdown PCT

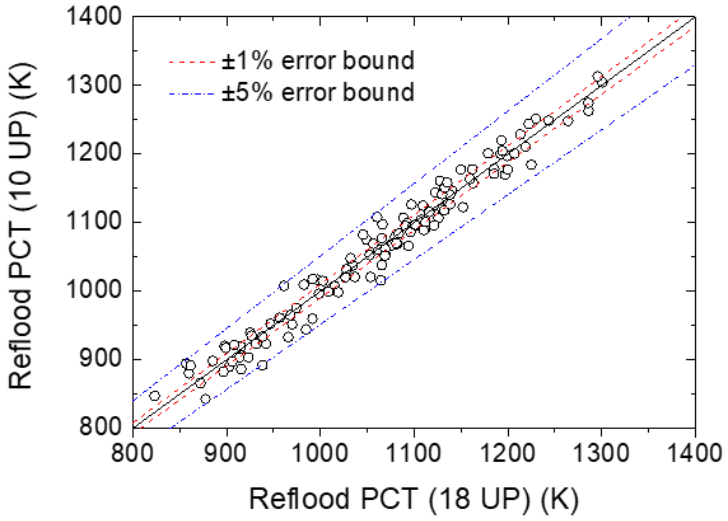
Deterministic Sensitivity Studies

❑ Deterministic sensitivity studies (1)

- Reflood PCT



Comparison of reflood PCT from the correlation analysis



Comparison of reflood PCT from the regression analysis

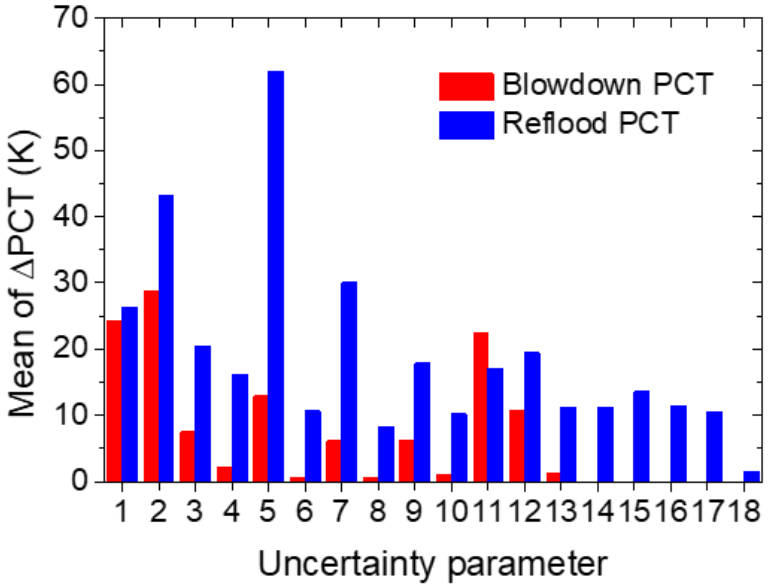
- Data from correlation analysis were highly scattered and there were significant differences
- MLRA showed that the degree of data dispersion was reduced

Deterministic Sensitivity Studies

Deterministic sensitivity studies (2)

- Only one variable of interest was fixed to be the mean value
- PCT differences between the two results were calculated a follows;

$$\Delta\mathrm{PCT}_i = \left| PCT_{18,i} - PCT_{17,i} \right| \quad (\mathrm{i} = 1,2,\cdots,\mathrm{n})$$



Mean of ΔPCT for uncertainty parameters

Deterministic Sensitivity Studies

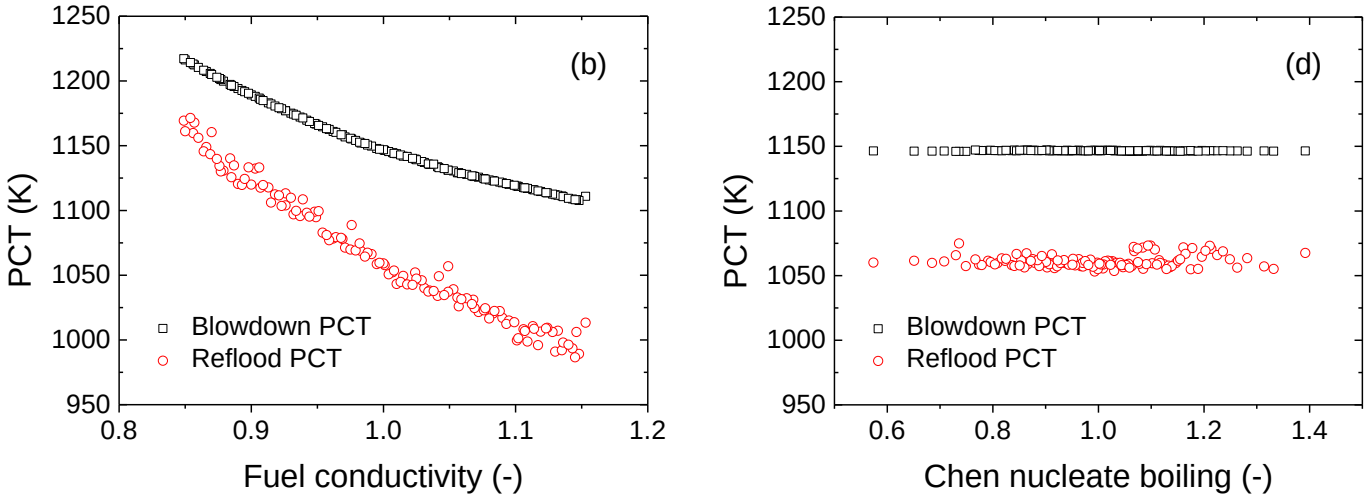
Deterministic sensitivity studies (2)

- Blowdown PCT
  - For parameters evaluated to be not influential from MLRA, the means of ΔPCT were less than ~ 1 K
- Reflood PCT
  - For the variables as not influential except for the IRWST water temperature, the means of ΔPCT were ~ 10 K
  - Which are similar to that of SIT water inventory evaluated as influential in the MLRA
- Parameters with the mean value of less than 2 K were excluded from the list of influential variable

Deterministic Sensitivity Studies

❑ Deterministic sensitivity studies (3)

- PCT variations with regard to single uncertainty parameter



  - Variations of blowdown PCTs were solely dependent on the values of the Ups without any perturbations
  - Reflood PCTs show certain perturbations
  - Some Δreflood PCT seem to be attributed to the inherent perturbed characteristic of the reflood PCT

Results and Discussion

❑ Rank of influential uncertainty parameters for blowdown PCT

- Correlation analysis showed a limitation in identifying the important uncertainty parameters
- MLRA could predict the same influential variables with those of deterministic sensitivity studies

Rank	Correlation	Multiple linear regression	Deterministic sensitivity
1	Fuel conductivity	Fuel conductivity	Fuel conductivity
2	Gap conductance	Break CD	Gap conductance
3	Break CD	Gap conductance	Break CD
4	Groeneveld CHF lookup table	Groeneveld CHF lookup table	Groeneveld CHF lookup table
5	Pump 2-f head multiplier	Pump 2-f head multiplier	Pump 2-f head multiplier
6	Core power	Core power	Core power
7	-	Dittus-Boelter vapor convection correlation	Dittus-Boelter vapor convection correlation
8	-	Chen transition boiling correlation	Chen transition boiling correlation
9	-	Decay heat	Decay heat

Results and Discussion

❑ Rank of influential uncertainty parameters for reflood PCT

Rank	Correlation	Multiple linear regression	Deterministic sensitivity
1	Groeneveld CHF lookup table	Groeneveld CHF lookup table	Groeneveld CHF lookup table
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3	Chen transition boiling correlation	Chen transition boiling correlation	Chen transition boiling correlation
4	Gap conductance	Gap conductance	Gap conductance
5	Core power	Core power	Core power
6	-	Dittus-Boelter vapor convection correlation	Pump 2-f head multiplier
7	-	Decay heat	Dittus-Boelter vapor convection correlation
8	-	Break CD	Break CD
9	-	Pump 2-f head multiplier	Decay heat
10	-	SIT water inventory	SIT water inventory
11	-	-	SIT water temperature
12	-	-	Pump 2-f torque multiplier
13	-	-	SIT actuation pressure
14	-	-	Chen nucleate boiling correlation
15	-	-	SIT loss coefficient
16	-	-	Bromley film boiling correlation
17	-	-	Dittus-Boelter liquid convection correlation

Results and Discussion

- Rank of influential uncertainty parameters for reflood PCT
  - Correlation analysis showed a limitation in identifying the important uncertainty parameters
  - MLRA showed more reasonable results than correlation analysis
  - MLRA could not identify uncertainty parameters below rank 11 of the deterministic studies
  - However, considering the fact that variations in reflood PCT for these uncertainty parameters are mainly caused by the inherent perturbation characteristic of the reflood PCT, it was shown that the multiple linear regression analysis could provide sufficiently reasonable results.

Conclusions

- Comparison of statistical methods and deterministic sensitivity studies
  - Correlation analysis showed a limitation in identifying the important uncertainty parameters
  - MLRA could provide reasonable assessment results in identifying influential uncertainty parameters and evaluating their importance.
    - Consideration of only 9 parameters could fully explain the variation of blowdown PCT
    - Identified 10 parameters to have an influence on the reflood PCT
    - Discrepancy is mainly caused by an inherent perturbation characteristic of the reflood PCT