Selection of Becker Post-Dryout Experiments for IUQ and Validation of the SPACE Code

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***Keywords :** SPACE code, post-dryout heat transfer, inverse uncertainty quantification, SAPIUM

1. Introduction

An inverse uncertainty quantification (IUQ) of the reactor core wall heat transfer models of the SPACE code is undertaken for intermediate break loss of coolant accident (IBLOCA) analysis. Under the SAPIUM methodology [1], this quantification relies on a representative experimental database (SAPIUM Element 2). From this database, one subset of experiments is used to infer the model parameter uncertainties. The experiments not used in the quantification are reserved as an independent subset for validation [1]. A poor choice of the two subsets either biases the quantification or leaves it unvalidated. This work describes the screening of the Becker heated tube post-dryout database [2] and its separation into the quantification and validation runs used for the IUQ.

2. Methods and Results

The Becker database, summarized in Table I, comprises three vertical, uniformly heated round tubes (test sections TS1–TS3) with upward water flow.

2.1. Screening to a representative database (Element 2)

Following the SAPIUM Element 2 requirement that the database represent the phenomena and parameter range of the intended use, the 510 Becker runs were screened.

Table I. Becker post-dryout test sections and conditions.

Parameter	TS1	TS2	TS3
Inner diameter (mm)	14.9	10.0	24.69
Heated length (m)	7.0	7.0	7.1
Pressure (bar)	30–200	30–200	150–201
Mass flux (kg/m²·s)	500–3000	500–3000	780–2475
Heat flux (W/cm²)	10–125	9–85	29–94
Number of runs	334	138	38

The figures of merit (FoM) are the post-dryout wall temperature and the critical heat flux (CHF) location. Runs relevant to these quantities and possessing complete axial wall temperature traces were selected. Test section TS3 was excluded and reserved as an independent check, because its material and conductivity basis differ from those of TS1 and TS2. Screening yielded 155 runs, of which 105 are from TS1 and 50 from TS2 (Fig. 1).

These runs span the application relevant pressure range (30–140 bar), the full mass flux range (500–3000 kg/m²·s), and the heat flux envelope of these two sections. The upper end of this range corresponds to the IBLOCA operating pressure of 14 MPa [3].

2.2. Quantification and validation subsets

The separation of the 155 runs into quantification (103) and validation (52) subsets (Fig. 2) follows three principles of the SAPIUM good practice guidance [1].

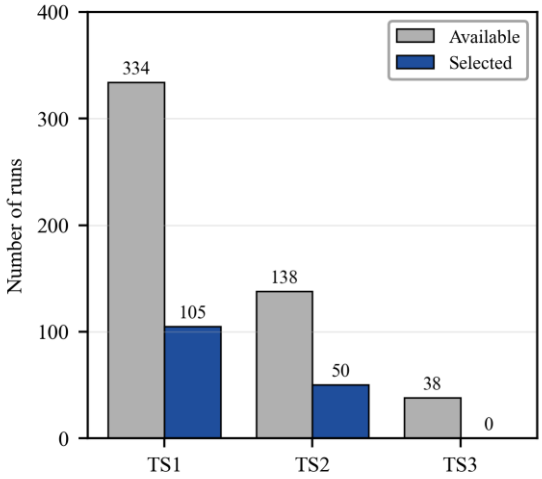

Fig. 1. Screening of the Becker database (510→155).

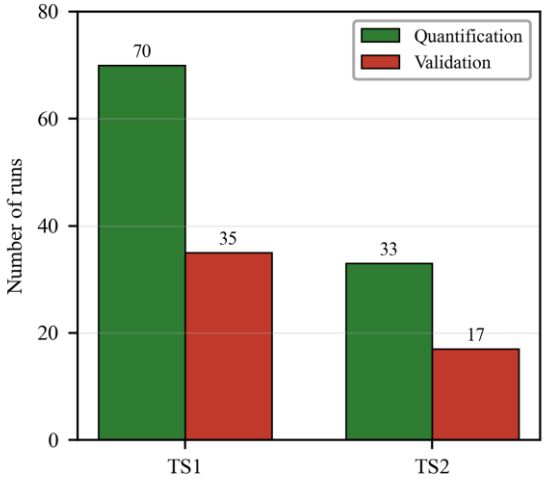

Fig. 2. Quantification (103) and validation (52) runs.

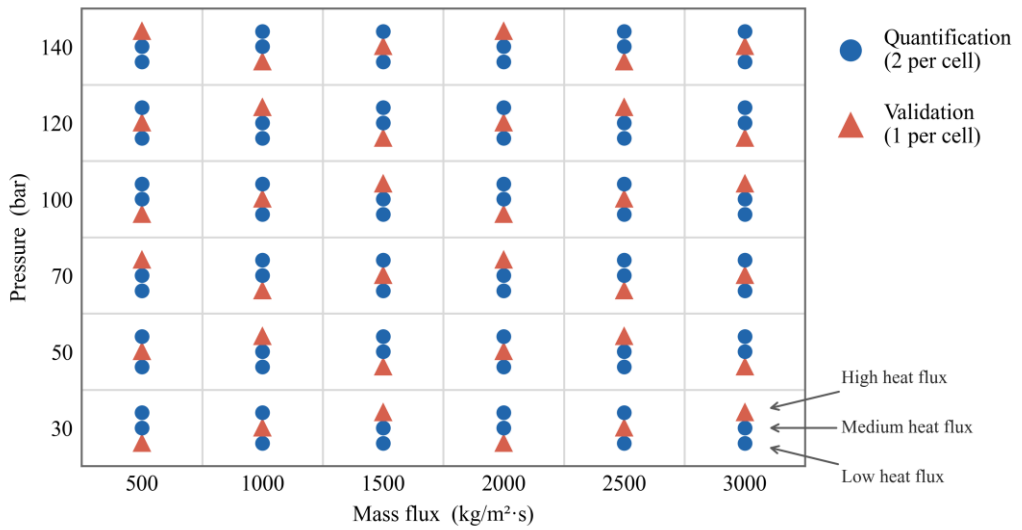

Fig. 3. Stratified selection scheme, illustrated for TS1 (6 pressure × 6 mass flux levels). Three heat flux levels (low, medium, high) are sampled per cell. One is assigned to validation (rotated cell-by-cell) and the other two to quantification.

First, the validation experiments must be independent of the quantification. They are those not used to infer the parameters, so the validation is genuinely independent. Second, because SAPIUM judges database adequacy by the completeness of its coverage of the application domain rather than by a prescribed number of experiments, both subsets must maintain representative coverage of that domain. Third, to make validation an interpolation rather than an extrapolation, the two subsets must span the same parameter space.

To realize these principles, the split was constructed on a stratified grid of the operating space, with the selected runs of each test section organized by pressure and mass flux level. Because the heat flux strongly influences both the CHF location and the post-dryout wall temperature, each pressure–mass flux cell was sampled at low, medium, and high levels. Within each cell, one heat flux level was assigned to validation and the remaining two to quantification, with the validation level rotated cell-by-cell so that the validation runs span the entire heat flux range, including the safety relevant high flux extreme (Fig. 3). This construction preserved the joint coverage of pressure, mass flux, and heat flux in both subsets. A successful validation therefore reflects predictive adequacy within the quantified domain.

2.3. Coverage and balance

Both subsets show comparable marginal distributions in each operating parameter and include the two tube diameters (TS1 and TS2) in similar proportion, so neither the extreme conditions nor a single geometry is concentrated in one subset. They therefore support an unbiased quantification and a meaningful, non-extrapolative validation.

3. Conclusions

A 155-run database (103 for quantification, 52 for validation) was selected from the 510-run Becker post-dryout database by FoM relevance and completeness screening, following SAPIUM Element 2. Test section TS3 was reserved as an independent check, and the validation experiments are those not used in the quantification. These two groups form the basis for the subsequent PAPIRUS based IUQ [4] of the SPACE wall heat transfer models.

ACKNOWLEGEMENTS

This work was supported by the Korea Institute of Energy Technology Evaluation and Planning (KETEP) and the Ministry of Climate, Energy & Environment (MCEE) of the Republic of Korea (No.20224B10200020).

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