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Intensive Review of the Thermal Hydraulic Safety Analysis Methodology for Chromium Coated Accident Tolerant Fuel

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1. Introduction

- **ATF: Accident Tolerant Fuel for enhanced fuel performance**

- **Recently a license for ATF Lead Test Rod (LTR) or Lead Test Assembly (LTA) loading for chromium (Cr) coated cladding is also being planned in Korea**

<International ATF development>

	Westinghouse	GNF	Framatome
Short term	· U_3Si_2 fuel · Cr coated, SiC composite cladding	· Conventional UO_2 · FeCrAl cladding	· Cr_2O_3 doped UO_2 · Cr coated M5 cladding
Long term	· SiC cladding	-	· SiC Cladding with Cr_2O_3-doped fuel

<Domestic ATF development>

Government	Research Institute	Period	Major achievement
MSIT	Korea Atomic Energy Research Institute	'17.03 ~ '21.12	Irradiation Test
MOTIE	KEPCO Nuclear Fuel Company	'17.12 ~ '22.11	prototype

1. Introduction

- **ATF: Accident Tolerant Fuel for enhanced fuel performance**
- **Recently a license for ATF Lead Test Rod (LTR) or Lead Test Assembly (LTA) loading for chromium (Cr) coated cladding is also being planned in Korea**
- **Cr coated cladding: CHF & quenching phenomena change**
- **Objective: to propose an improved safety analysis methodology for thermal hydraulic/safety analyses for the reactors loaded with Cr coated ATF**

<International ATF development>

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Short term	· U_3Si_2 fuel · Cr coated, SiC composite cladding	· Conventional UO_2 · FeCrAl cladding	· Cr_2O_3 doped UO_2 · Cr coated M5 cladding
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Best Estimate Safety Analysis

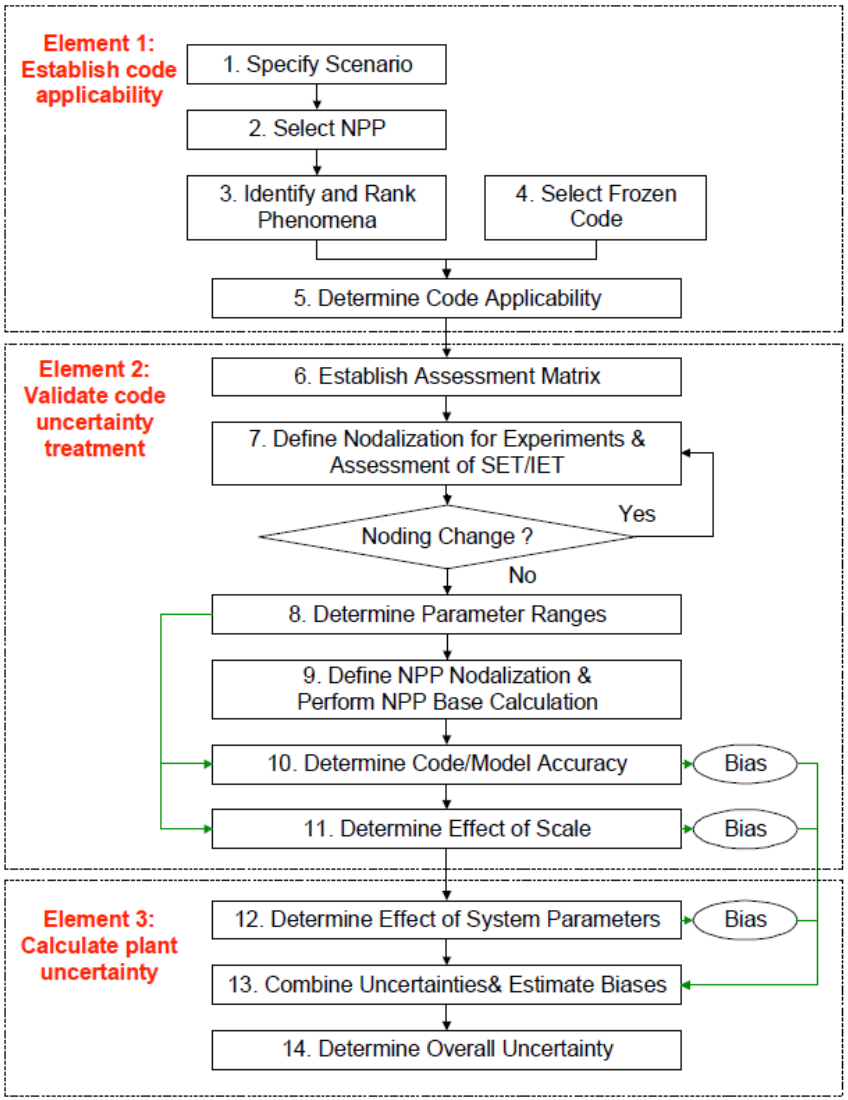
- After Fukushima accident the safety is tend to be strengthened and the best estimate approach is prefered

KINS-REM

- BEPU (Best Estimate Plus Uncertainty)
- 22Uncertainty parameters: 11 among them are related with the constitutive models in MARS-KS

Blowdown Models
(1) Groeneveld CHF lookup table(AECL)
(2) Dittus-Boelter liquid convection
(3) Dittus-Boelter vapor convection
(4) Chen nucleate boiling
Reflood Models
(5) Zuber CHF correlation
(6) Chen transition boiling
(7) Weismann TB (Transition Boiling) correlation
(8) Bromley FB (Film Boiling)
(9) QF (Quenching Front) Bromley correlation
(10) Forslund-Rohsenow FB correlation(reflood)
(11) Vapor correlation (reflood)

<Procedure of uncertainty quantification of KINS-REM>



3. Coating Effect on Thermal Hydraulic Models

■ CHF & Quenching change by Cr coated surface

- ▶ This is well matched trend with the classical boing heat transfer studies

■ Effect on MARS-KS model

- ▶ Wall heat transfer: surely affected including boiling heat transfer models
- ▶ Interfacial heat transfer: hardly affected

■ Influenced model for LBLOCA, SBLOCA and Non-LOCA

- **Factors affecting PCT**
  - ✓ CHF model or DNBR(Departure from Nucleate Boiling)
  - ✓ Nucleate boiling model: No direct studies on this, but it is reasonable to regard the nucleate boiling, which is the previous step to CHF, to be affected
  - ✓ Film boiling models: No direct studies on this, but it is reasonable to regard the film boiling, which is the next step to CHF, to be affected
  - ✓ Minimum temperature for the stable film boiling: The cladding surface change can alter the rewetting phenomena or Leidenfrost temperature, and resultantly the minimum temperature for the stable film boiling. This temperature affects the quenching time and this can affect the PCT
  - ✓ Thermal properties of cladding material with coating such as thermal conductivity and heat capacity
- **Factors affecting quenching time: It is not the direct parameters of regulatory concern, but itself affects the PCT**
  - ✓ Film boiling models: It affects Leidenfrost phenomena and the quenching time is changed.

4. Conclusions

- **The coating affects the surface properties and correspondingly following phenomena or relevant model should be importantly considered.**

(1) Factors affecting the PCT
- CHF model
- Nucleate boiling model
- Film boiling model
- Minimum temperature for the stable film boiling
- Cladding thermal property change

(2) Factors affecting the quenching time
- Film boiling model
- Minimum temperature for the stable film boiling

(3) Factors affecting the DNBR
- Critical heat flux model
- Nucleate boiling model

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THANK YOU