KNF-
FUEL-05

Optimal Critical Heat Flux Correlation Package

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Critical Heat Flux(CHF) is a condition that the heat transfer from the heated surface of fuel rod in the reactor core to the liquid coolant is deteriorated causing overheating of the fuel rod surface resulting damages on the heated surface of fuel rod and leakage of radioactive materials into reactor primary system(reactor coolant system), consequently deteriorating the safe operation of the nuclear power plant. In order to prevent this from happening, it is crucial to develop an optimal CHF correlation through experiments and predict accurate CHF conditions. Since the 1950's, many studies have been conducted about CHF phenomenon and predictable methods have been developed. These developed prediction models like the CHF correlation are based on the experimental data with limited range. Therefore, experiments must be performed whenever the operating conditions are changed and/or the fuel assembly design features are changed. The CHF correlation must be developed based on and applied with accurate experiments.

Description

● Background

- An analysis of thermal margin for operating nuclear power plant and a safety analysis to demonstrate safety should be performed with an approved CHF correlation.
- CHF directly affects nuclear power plant operation and safety.
  - Develop and apply a correlation to predict CHF which cannot be measured during operation, and varies depending on the operating condition.
- To develop a CHF correlation, the following procedures are required.
  - The experimental data reflecting the characteristic of fuel assembly and analysis code to analyze the data
  - Regression analysis for determining and optimizing the correlation functional formula and coefficients
  - Verification/Validation of correlation

● Purpose and Necessity

- Applying the changed CHF correlation is generally done during improving fuel assembly performance but it can also be applied to ensure the safety or change the operation strategy.
- The specific procedures in development/ verification and inspection/approval process must be followed when applying the CHF correlation.
- To create CHF experimental data(facility/ procedure), the corresponding laws and regulations, quality assurance requirements must be fulfilled.

● Principle, System configuration, Work Procedure(or Work Scope)

- CHF correlation is developed by performing a CHF test with reduced-size simulated assembly(test section) and collecting the characteristics/ information of occurrence of CHF at reactor normal operating condition and safety analysis condition.
- The power by fission of the reactor is simulated as electrical heating of the fuel rod.

- The test consists of a test plan and an essential test section and is performed in accordance with the corresponding laws and regulations, quality assurance requirements.

Distinctiveness

● Characteristic

- Providing a customized CHF correlation package satisfying corresponding quality assurance and regulatory requirements
  - Applying the best explanatory CHF correlation to maximize the thermal margin(To increase operation flexibility and to enure safety)
  - Applying a different kind of CHF correlation to maximize the thermal margin(Considering system change and and to minimize follow-up tasks)
  - Applying a conservative CHF correlation to maintain a potential safety(Baseline CHF correlation)
- Standardized development/verification procedure with high reliability
  - Standardization of CHF correlation development procedure : CHF correlation development system(CHOPPER), prevention of human error and reduction of required time in the entire process of development/verification of CHF correlation
  - Applying stabilized validation technique : Repetitive cross-validation system
- Proven technology : Licensing approval domestically and from overseas(USA, UAE)
  - CHF correlation
  - Reactor core design and safety analysis using CHF correlation
- Possibility of constructing a KNF operated test facility and developing a baseline CHF correlation in the future
- Possibility of verifying all correlations based on the experimental data other than CHF correlation

● Benefits

- Increase safety in operating the nuclear power plant and save cost by providing exclusive services such as CHF test execution, CHF correlation development/licensing
- Improve customer reliability by obtaining patent licenses and approvals from domestic and overseas organizations
- Gain a competitive advantage in technology against overseas rival companies

Experience

- Best Explanatory CHF correlation(As of March 2023)
- Conservative CHF correlation(As of March 2023)

Deliverables

- Establish test plan and execute tests(for customer)
- Develop and verify/validate CHF correlation
- Prepare licensing report and support of licensing review
- Amend design code and analysis for application
- Training and technical support

Technology Readiness Level (TRL)

Actual system proven through operation

Business Model

Technology Transfer

Licensing

Joint Search

Service Execution

Others

● Best Explanatory CHF correlation(As of March 2023)

Title of correlation	Type of Fuel assembly	Status of license	Applied NPP
WRB-2	16ACE7	Overseas introduced technology, Approved(South Korea)	Kori Unit 2
NGF	17ACE7	Approved(South Korea)	Kori Units 3/4, Hanbit Units 1/2, Hanul Units 1/2
KCE-1	PLUS7	Approved (South Korea and Overseas – USA, UAE)	Domestic OPR1000(12 NPPs), Domestic/Foreign APR1400(10 NPPs)
KNF-X	HIPER17	Approved(South Korea)	In planning
KCE-1M	HIPER16	Approved(South Korea)	Under application to review for South Korea
KNF-H	HIPER16	Approved(South Korea)	In planning

● Conservative CHF correlation(As of March 2023)

Title of correlation	Type of Fuel assembly	Status of license	Applying NPP
W-3	Variety	Overseas introduced technology	Specific accident condition
Macbeth	Variety	Overseas introduced technology	Specific accident condition