Verification Tests performed for Development of an Integral Type Reactor

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SMART Desalination Plant

System integrated Modular Advanced Reactor
**SMART Design**

**DESIGN CONCEPT**
- Small sized integral type Pressurized Water Reactor
- Elimination of the possibility of LBLOCA
- Self controlled pressurizer by a non-condensable gas
- Low power density and Boron free core
- Passive system for the decay heat removal
- Simplification of system/components

**CHARACTERISTICS**
- Enhance safety comparing with existing PWR
- Shorten construction period
- Reduce liquid radioactive wastes
Experiments for the SMART Program

- Integral Effect Tests: VISTA

- Separate Effect Test
  - Core and Steam Generator Flow Distribution Test
  - Two-phase Critical Flow with Nitrogen Gas Test
  - Critical Heat Flux Test
  - Flow Instability Test
  - Thermal Mixing and Heat Transfer Test
  - Fuel Assembly Pressure Drop Test
  - Major Components (MCP,CEDM,SG) Performance Test
Integral Test

VISTA Facility

- 1/1-height, 1/96-volume of Prototypic SMART, SMART-P
  - Design pressure/temperature : 17.2 MPa/350 °C
  - Nominal core heater power : 682 kW (Max. 819 kW)

Purposes

- Overall T-H performance during normal operation (start-up, heat-up, cooldown)
- PRHR test during natural circulation
- Investigation for accident Scenarios
- Database for design optimization of SMART reactor and code validation

VISTA : Experimental Verification by Integral Simulation of Transients and Accidents
SMART vs. VISTA Design

Scale Law

- Gas Cylinder
- Pressurizer
- MCP
- Steam Generator
- Reactor Vessel
- Shielding
- Reactor Vessel
- SG
- Core
- CEDM
- PZR
- MCP
VISTA Facility
Loss of coolant flow @111sec
- 100% core power & High MCP speed

Rx is tripped by the HPP Trip signal @117sec
- HPP setpoint : 16.44MPa

After trip(@117sec)
- MCP trips and natural circulation of primary coolant is obtained (10%)
- Primary system slowly cools down by the PRHRS
Thermal Hydraulic Behavior during CEA Ejection Accident

- **Power step increase from 723kW to 760kW @170sec**
  - 100% core power & High MCP speed
- **Primary pressure increases until it reaches HPP trip setpoint (16.44MPa)**
- **After trip(@577sec)**
  - MCP trips and natural circulation of primary coolant is obtained (10%)
  - Primary system slowly cools down by the PRHRS
Natural Circulation Analysis by MARS 3.0

- **MARS 3.0 code**
  - 1-D and 3-D system analysis code for thermal hydraulic analysis of the light water reactor transients
  - Developed by consolidating and restructuring the RELAP5/MOD3.2 and COBRA-TF codes
  - SMART specific models
    - Helically coiled SG
    - Pressurizer with non-condensable gas
  - Performed natural circulation analysis
    - Comparison of RELAP5/MOD3 results
    - Data of VISTA experiment
Natural Circulation Analysis by MARS 3.0

- Primary Pressure
- Secondary Pressure
- Secondary Temperature

- Secondary Flow
- PRHR Pressure
- HX in-out Temp.
Two-Phase Critical Flow with Non-Condensable Gas at High Pressure Conditions

- Some possibility of SBLOCA at the top of SMART reactor
- Two-phase critical flow experiments in the presence of nitrogen gas are performed at KAERI using CFTL
Critical Flow Test Loop (CFTL)

- Short pipe (20 mm ID, 300 mm length) at sub-cooled & saturated conditions
- Small-diameter pipe (11 mm ID, 1000 mm length) at sub-cooled & saturated conditions
An empirical correlation is developed as follows:

\[ \frac{G_{n2}}{G_{\text{water}}} = 0.378 + 0.600 \cdot e^{-\left(\frac{Q_{n2}}{Q_{\text{water}}}\right)/0.195} \]

Applicable ranges:

- Pressure Range: 3.7 ~ 10.5 (Mpa)
- Water Temperature: sub-cooling to saturated condition
- Non Condensable Gas flow rate: 0.008 ~ 0.22 (kg/s)

The standard deviation of the predictions of the present empirical correlation from the experimental values is 7.1 \%. 

\[ R \equiv \frac{G_{n2}}{G_{\text{water}}} \]

\[ +10 \% \]

\[ -10 \% \]

Theoretical R

Experimental R

Standard deviation = 7.05\%
Water CHF Test

Technical Data
- Max. press. and temp.: 16 MPa and 347 °C
- Flow rate: 3 kg/s
- Test section power: 450 kW DC, 970 kW AC
- Working fluid: De-ionized water
Freon CHF Test

Test section

DC 60 Volts, 12000 Amp.
CHF Correlation

\[ q''_{\text{CHF}} = \frac{A \cdot F_1 - \chi_{\text{in}}}{C \cdot F_2 \cdot F_{APS} + \left[ \chi(z) - \chi_{in} \right] \cdot F_3} \cdot q''_{\text{local}}(z) \]

- \( q''_{\text{CHF}} \) = Critical heat flux
- \( q''_{\text{local}}(z) \) = Local heat flux
- \( \chi(z) \) = Local thermodynamic quality
  (calculated by MATRA-SR code)

![Graph showing SSF-2 correlation]

Mean M/P = 1.003
Std. Dev. = 0.079
No. of data = 372 (water)
Design Verification Tests

- **Tests**
  - High Temperature and High Pressure Test
  - Heat Transfer test for Pressurizer
  - Material Corrosion Test

[Diagram showing various test sections and equipment, labeled as High Temperature and High Pressure Test, Heat Transfer test for Pressurizer, and Material Corrosion Test.]

[Graph showing weight gain over exposure time for different materials: Zry-4, Zr-1Nb, K2, K6.]

- **Material Corrosion Test**
 Summary

- SMART is a safety enhanced, economically viable and environmental friendly nuclear power plant for power generation and seawater desalination.

- The SMART system adopted commercial reactor design technologies as well as innovative designs and inherent safety features.

- SMART verification tests including comprehensive experiments was conducted to demonstrate overall performance of the SMART system.

- Advanced design features implemented into the SMART system has been proven through various tests and experiments.