Verification Tests performed for Development of an Integral Type Reactor

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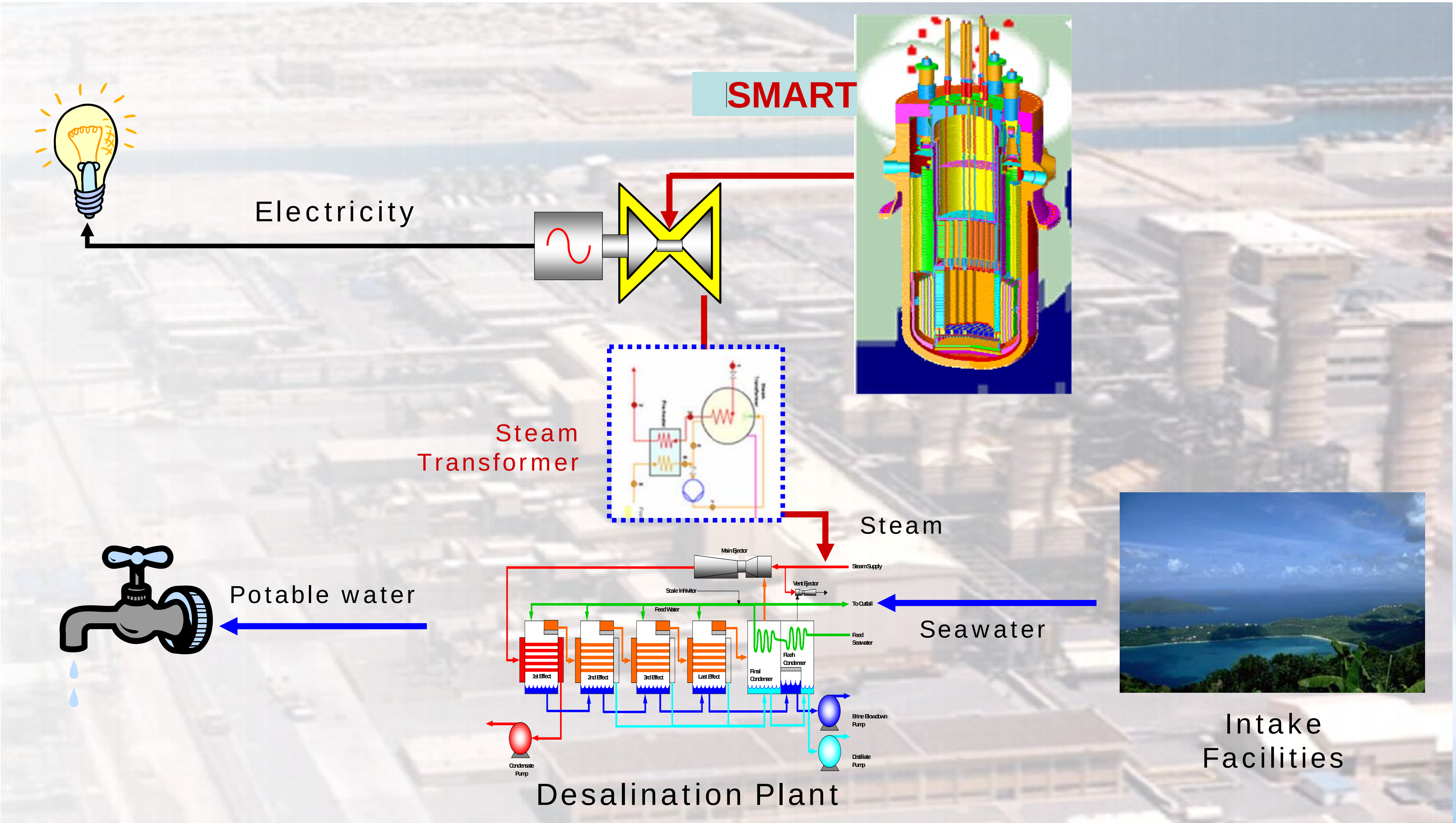
SMART

SMART Desalination Plant



System integrated Modular Advanced ReacTor

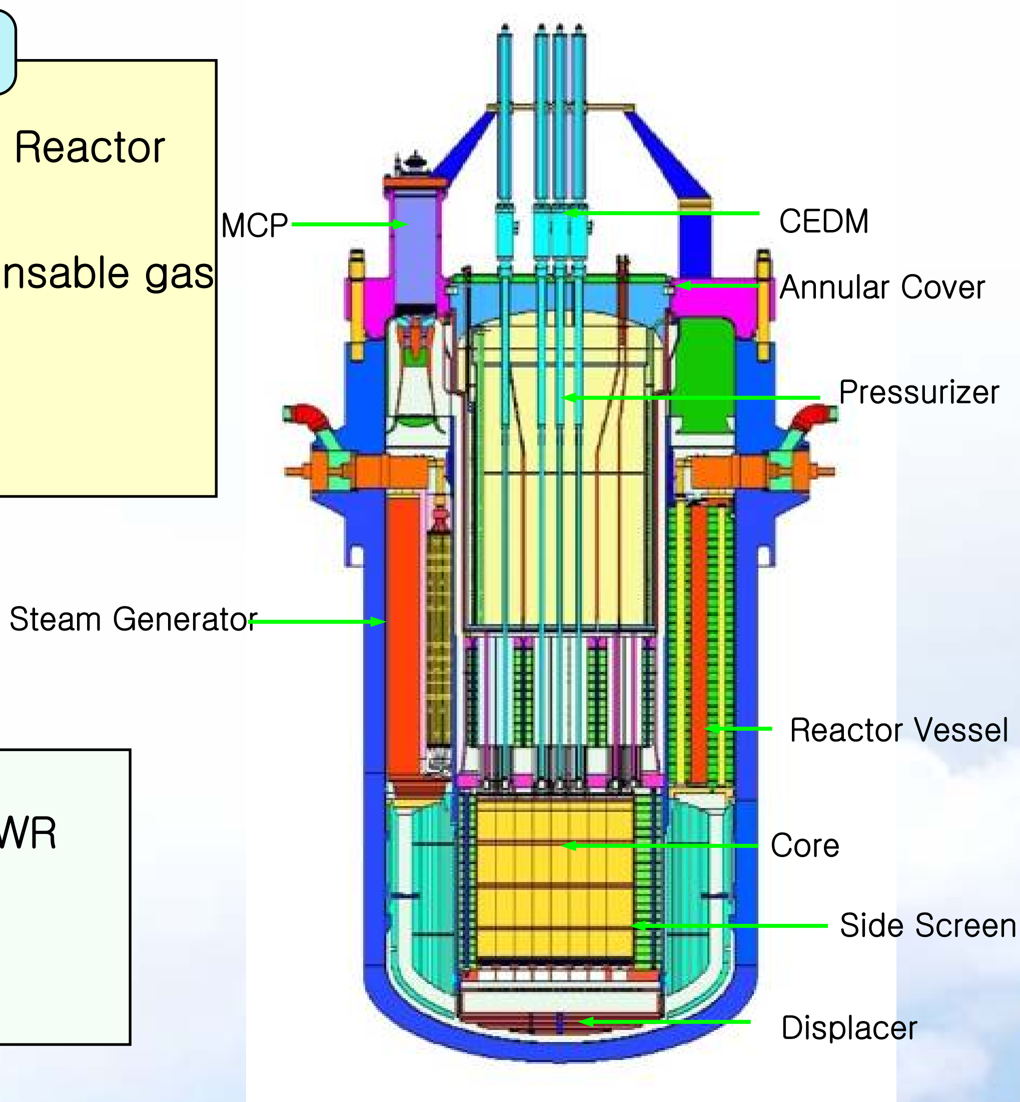
SMART Design

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

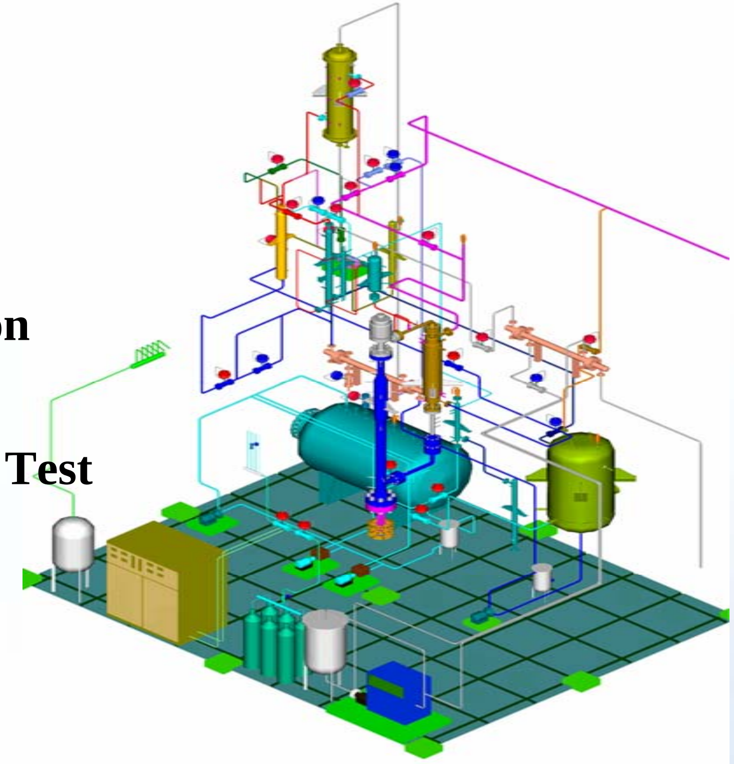
CHARACTERISTICS

- 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

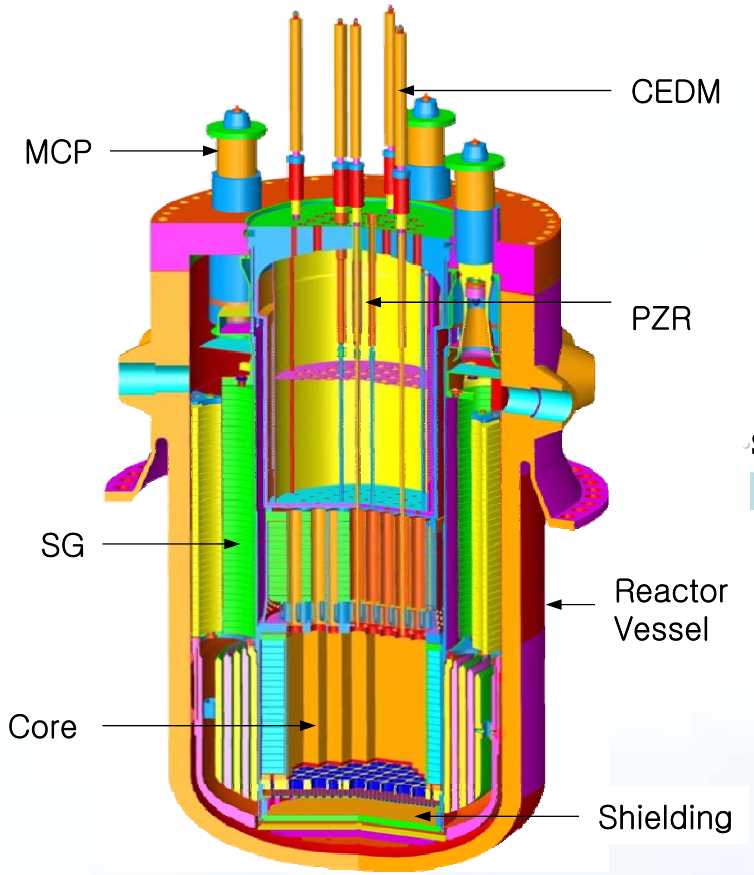
Integral Test

❑ VISTA Facility

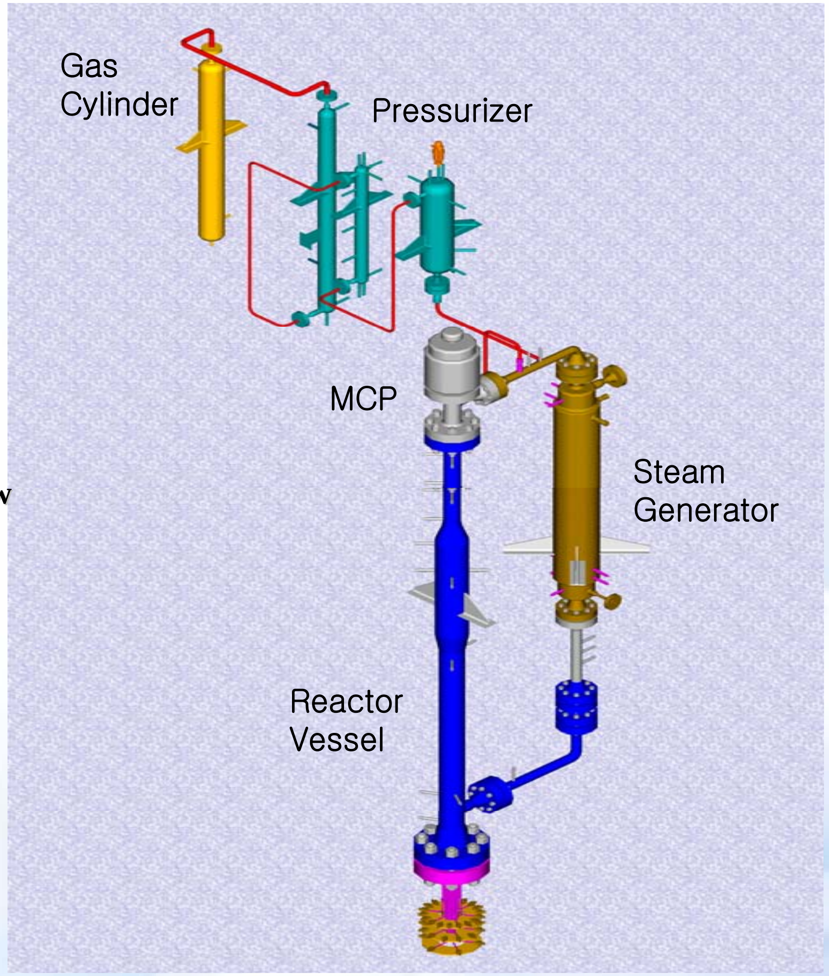
- **1/1-height, 1/96-volume of Prototypic SMART, SMART-P**
  - ✓ **Design pressure/temperature : 17.2 MPa/350 ^{o}C**
  - ✓ **Nominal core heater power : 682 kW (Max. 819 kW)**
- **Purposes**
  - ✓ **Overall T-H performance during normal operation (start-up, heat-up, cooldown)**
  - ✓ **PRHR test during 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

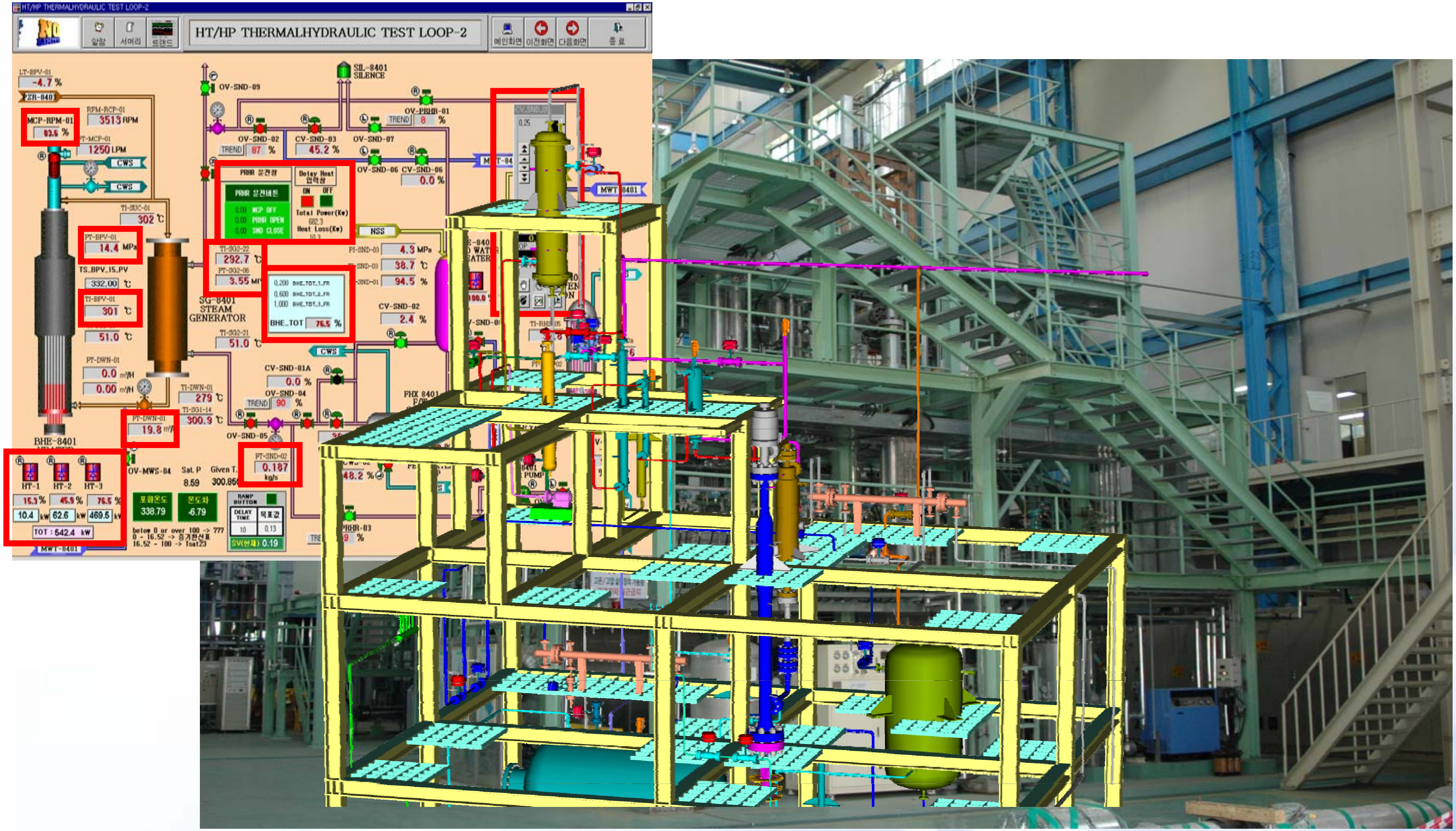
SMART vs. VISTA Design



Scale Law



VISTA Facility



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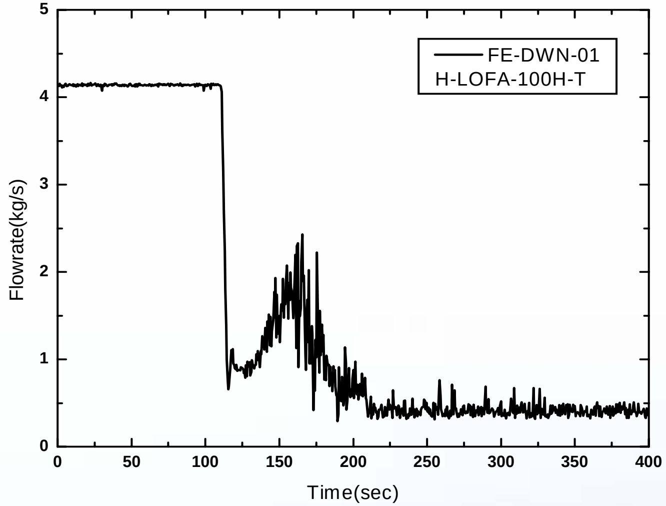
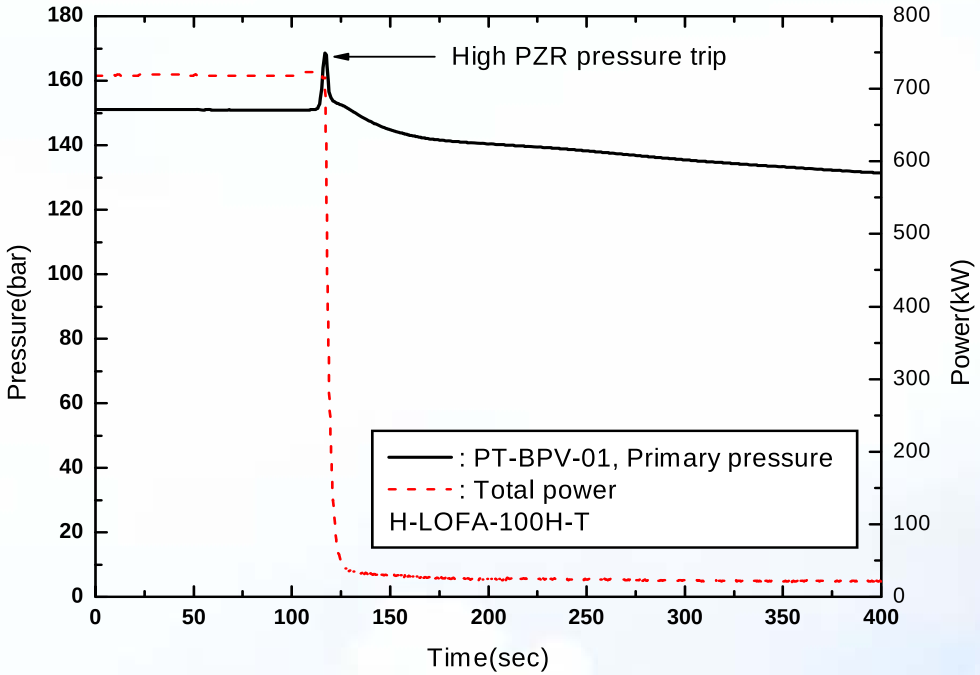
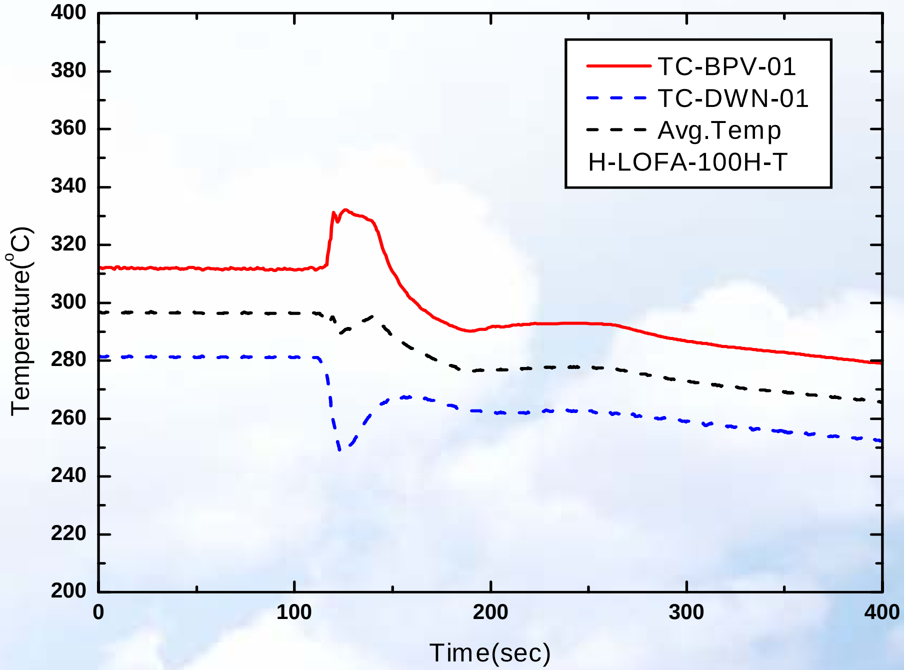
Thermal Hydraulic Behavior during LOFA

- **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*







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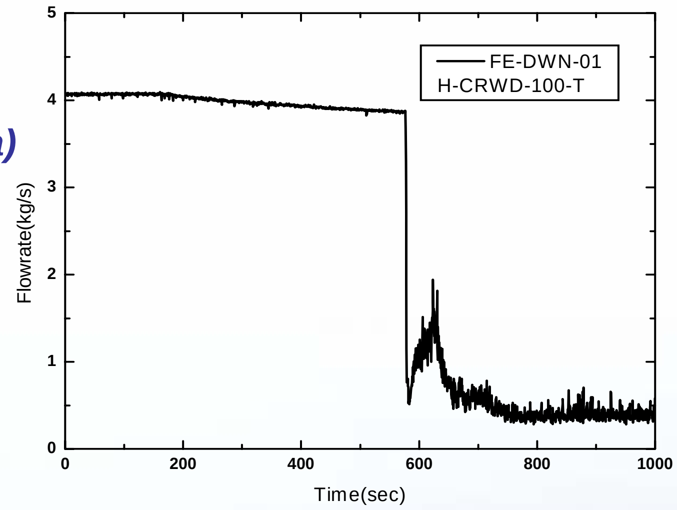
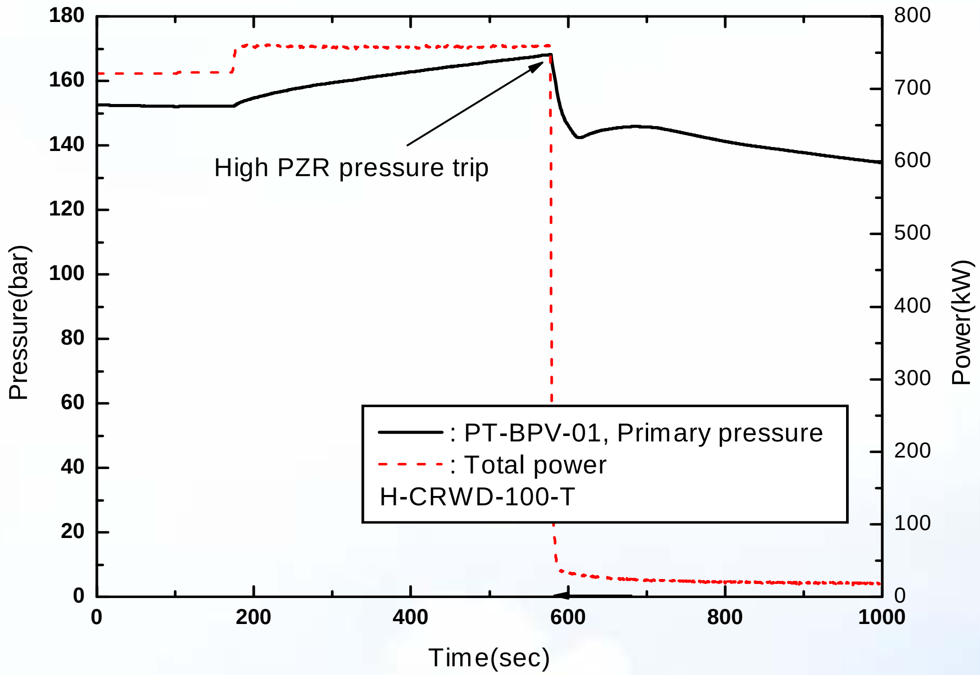
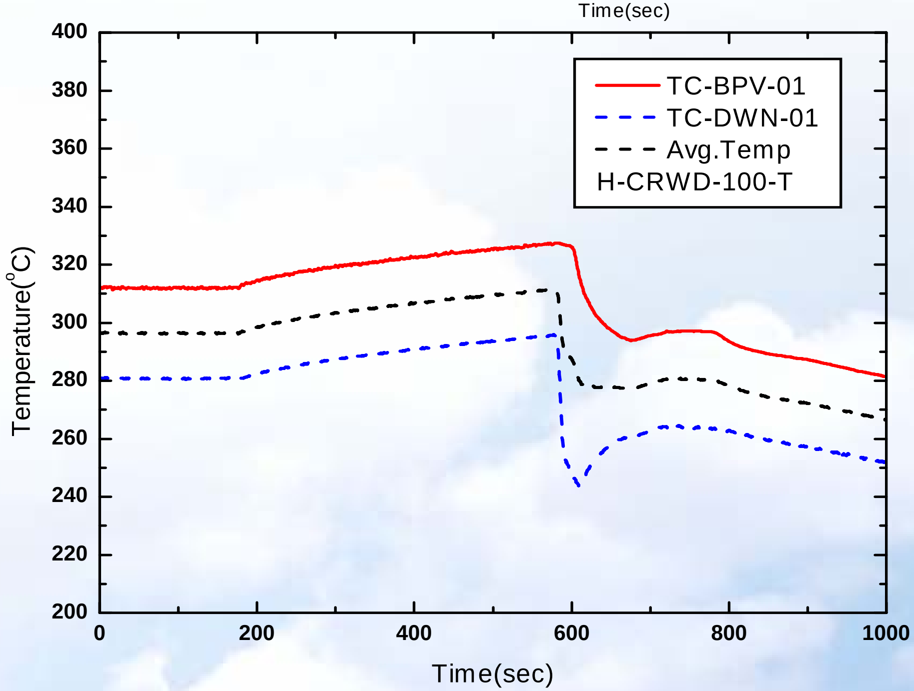
Thermal Hydraulic Behavior during CEA Ejection Accident

- *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*







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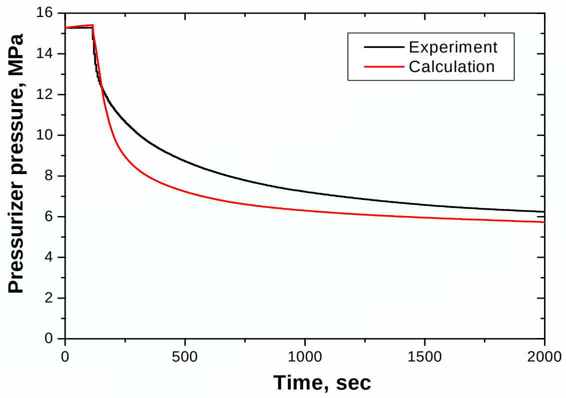
Natural Circulation Analysis by MARS 3.0

❑ MARS 3.0 code

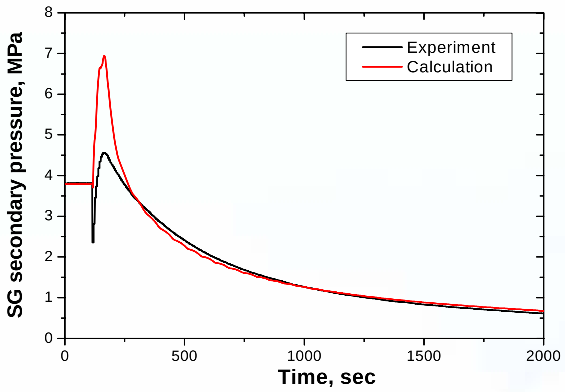
- 1-D and 3-D system analysis code for thermal hydraulic analysis of the light water reactor transients
- Developed by consolidating and restructuring the RELAP5/MOD3.2 and COBRA-TF codes
- SMART specific models
  - ✓ Helically coiled SG
  - ✓ Pressurizer with non-condensable gas
- Performed natural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

Natural Circulation Analysis by MARS 3.0

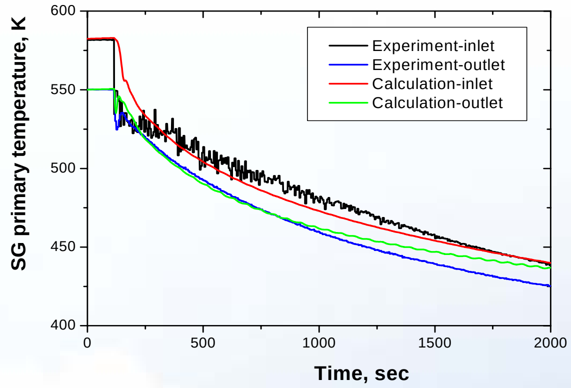
● **Primary Pressure**



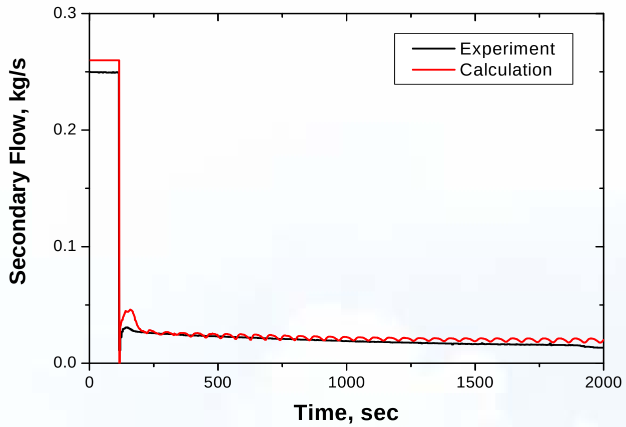
● **Secondary Pressure**



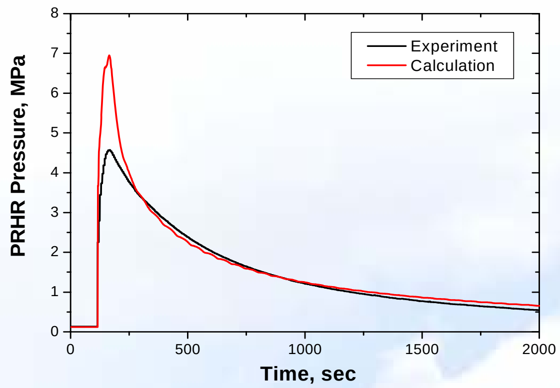
● **Secondary Temperature**



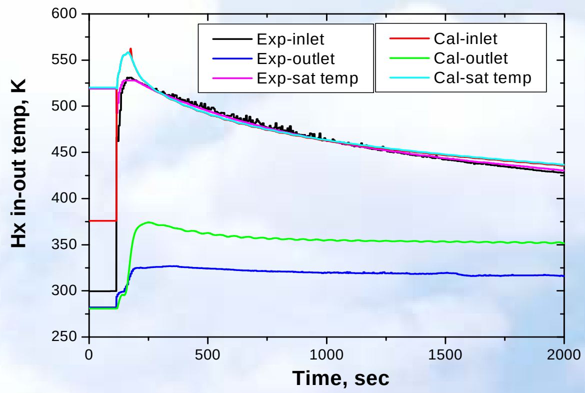
●**Secondary Flow**



●**PRHR Pressure**



●**HX in-out Temp.**



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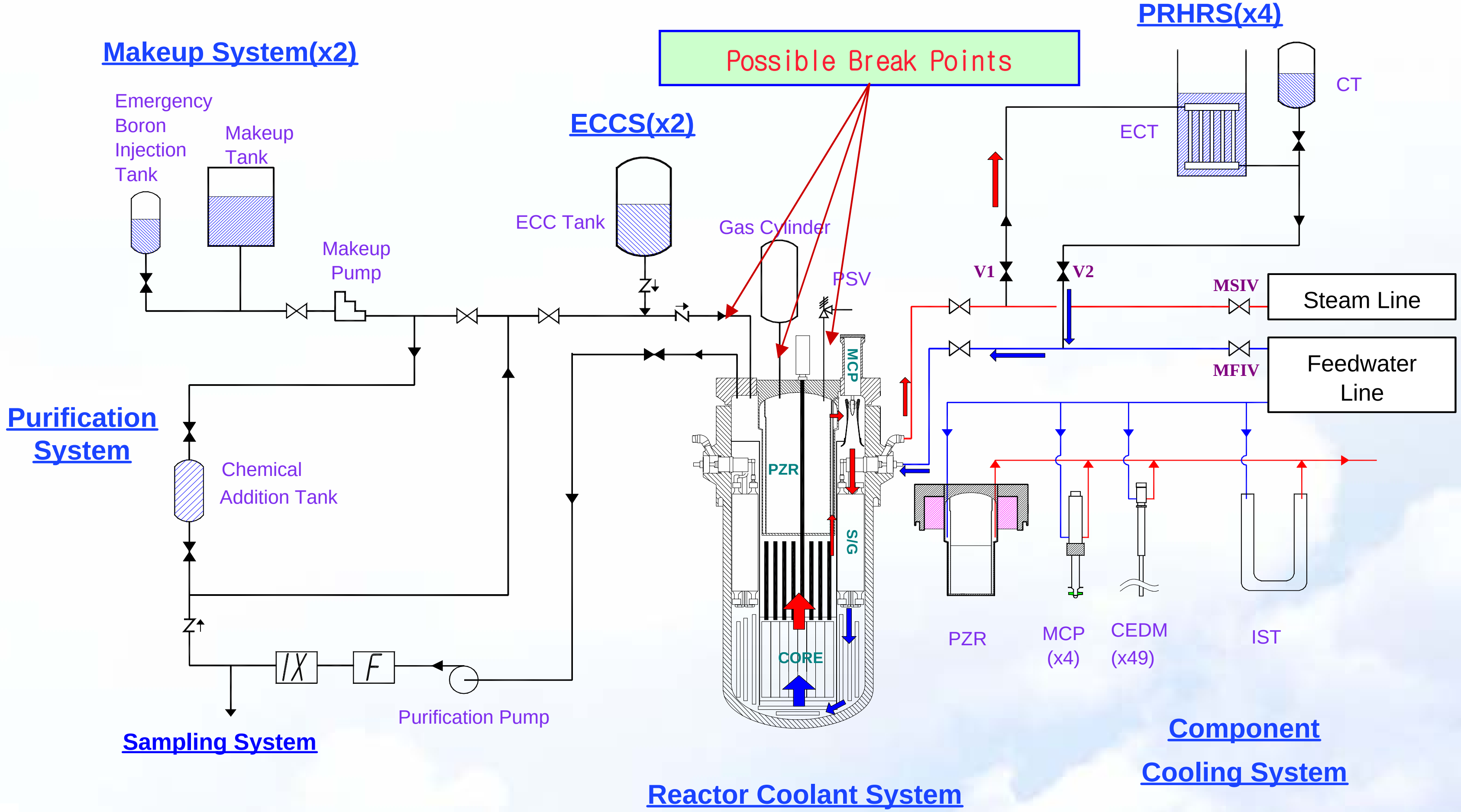
Two-Phase Critical Flow with Non-Condensable Gas at High Pressure Conditions

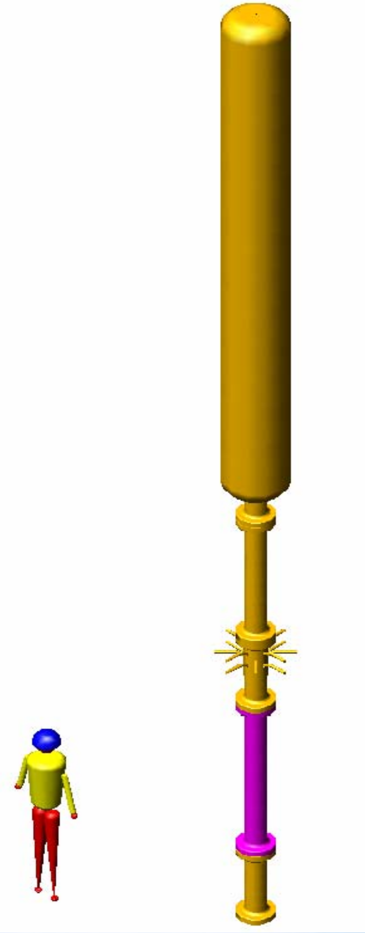
- Some possibility of SBLOCA at the top of SMART reactor
- Two-phase critical flow experiments in the presence of nitrogen gas are performed at KAERI using CFTL



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



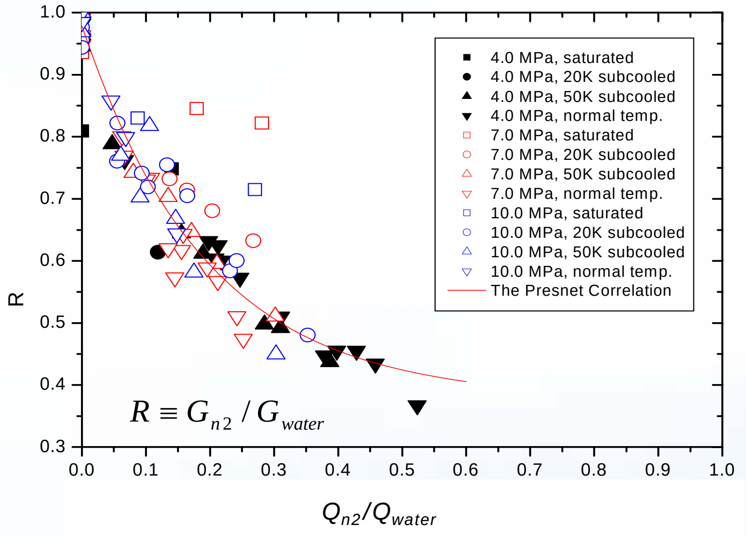
Critical Flow Rate – Correlation

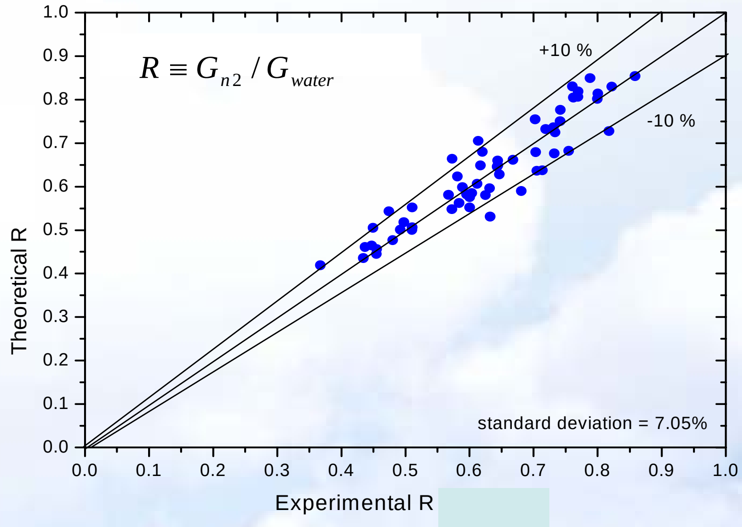
- **An empirical correlation is developed as follows:**

$$G_{n2} / G_{water} = 0.378 + 0.600 \cdot e^{-(Q_{n2}/Q_{water})/0.195}$$

- **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 %.**





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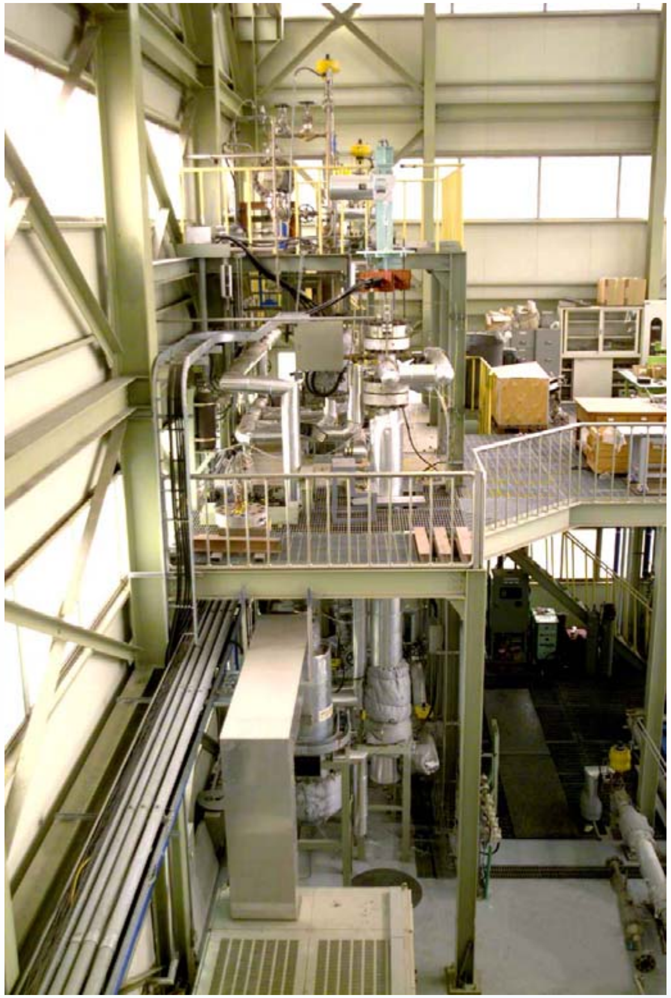
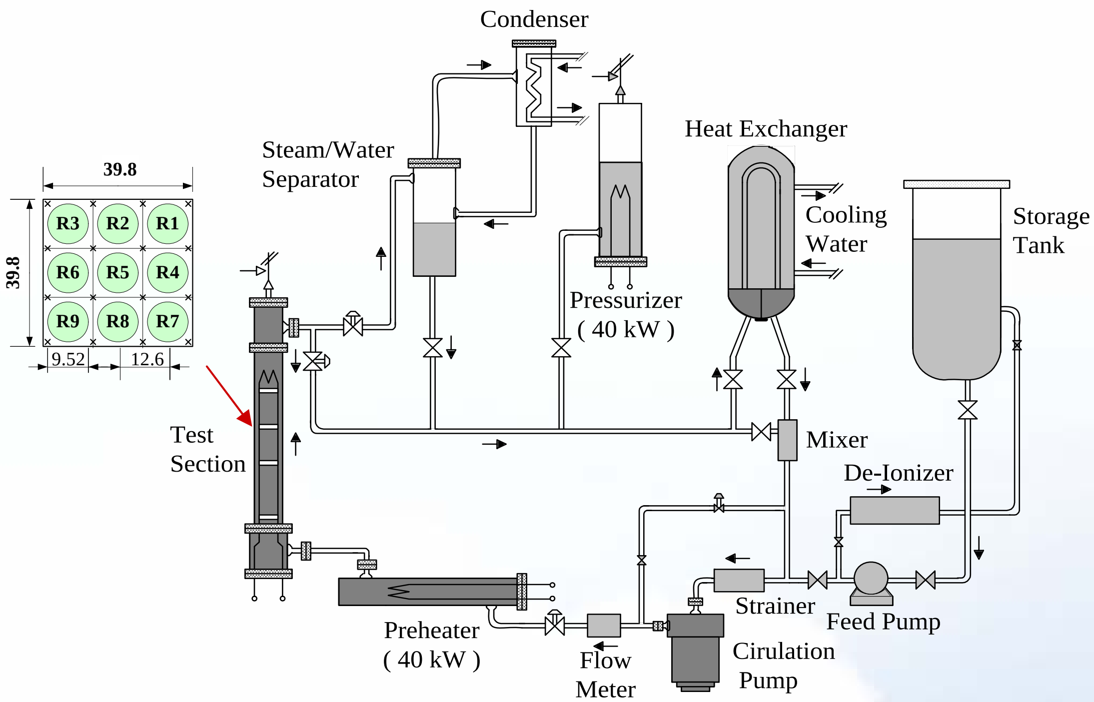
Water CHF Test

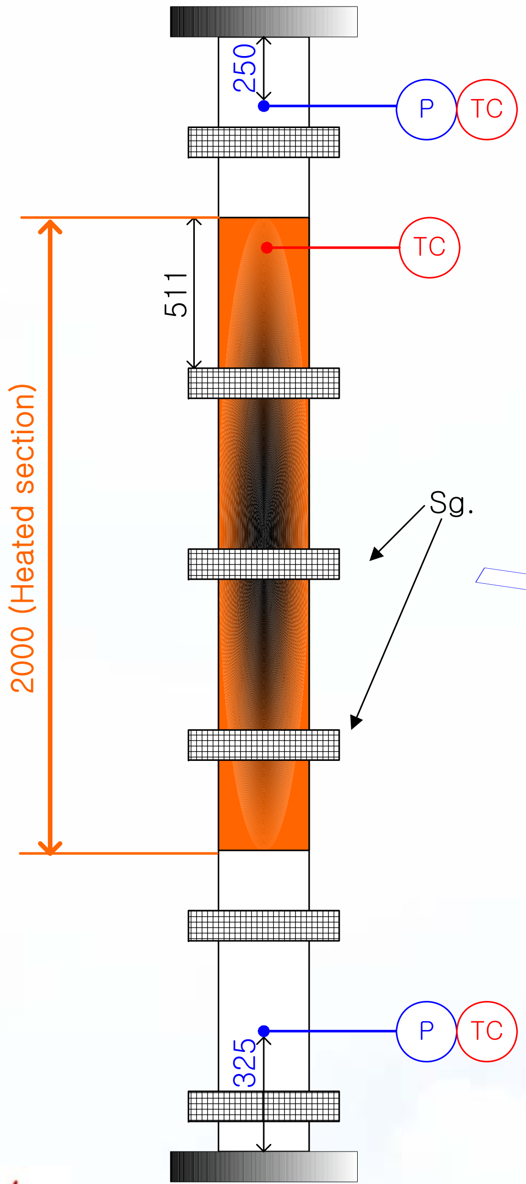




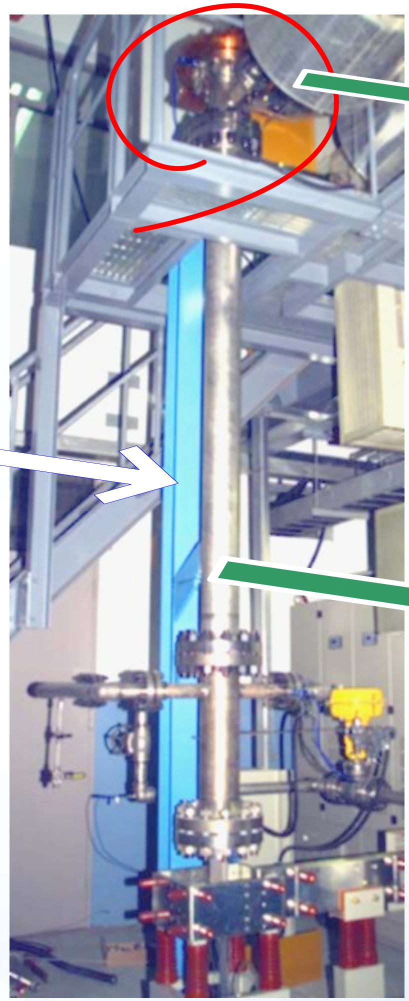
Technical Data

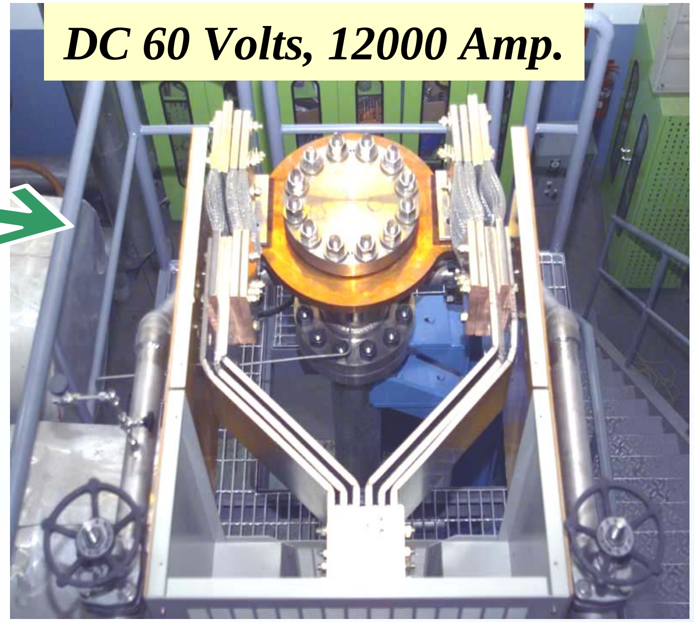
- Max. press. and temp.: 16 MPa and 347 ^{o}C
- Flow rate: 3 kg/s
- Test section power: 450 kW DC, 970 kW AC
- Working fluid: De-ionized water

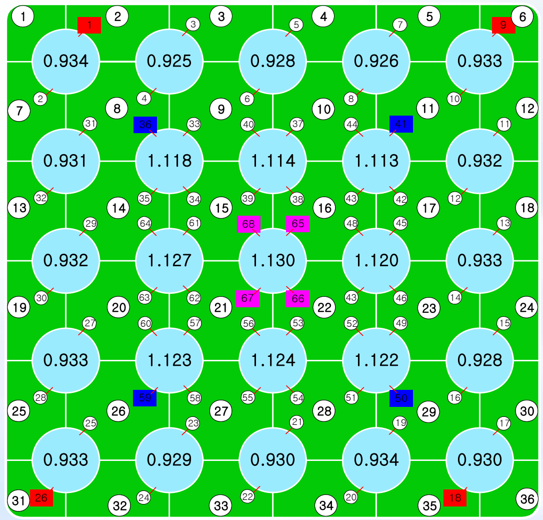
Freon CHF Test



Test section







CHF Correlation

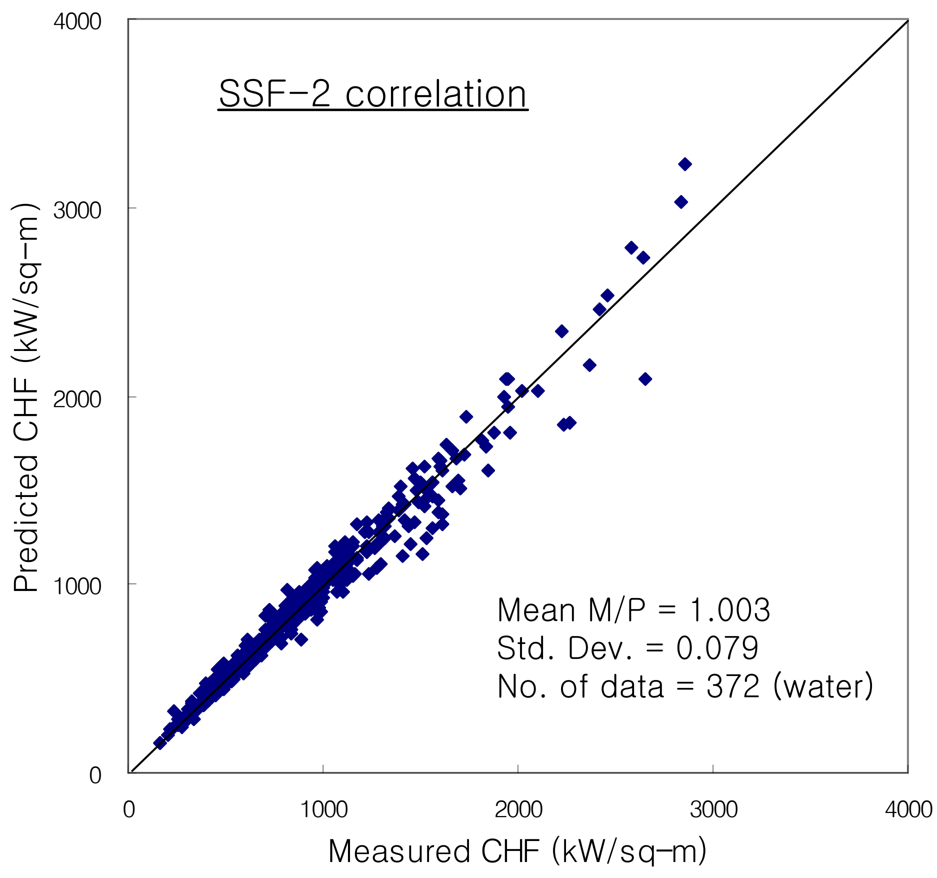
$$q''_{CHF} = \frac{A \cdot F_1 - \chi_{in}}{C \cdot F_2 \cdot F_{APS} + \dfrac{\left[\chi(z) - \chi_{in}\right]}{q''_{local}(z)} \cdot F_3}$$

q''_{CHF} = Critical heat flux

$q''_{local}(z)$ = Local heat flux

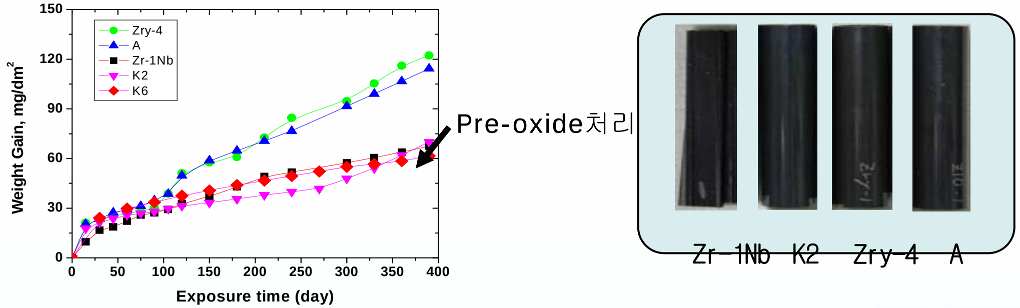
$\chi(z)$ = Local thermodynamic quality

(calculated by MATRA-SR code)

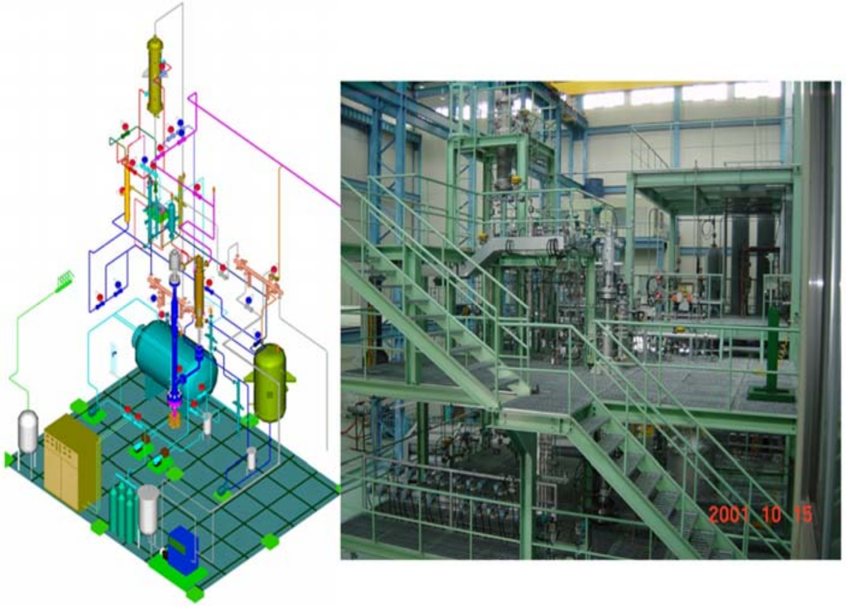


Design Verification Tests

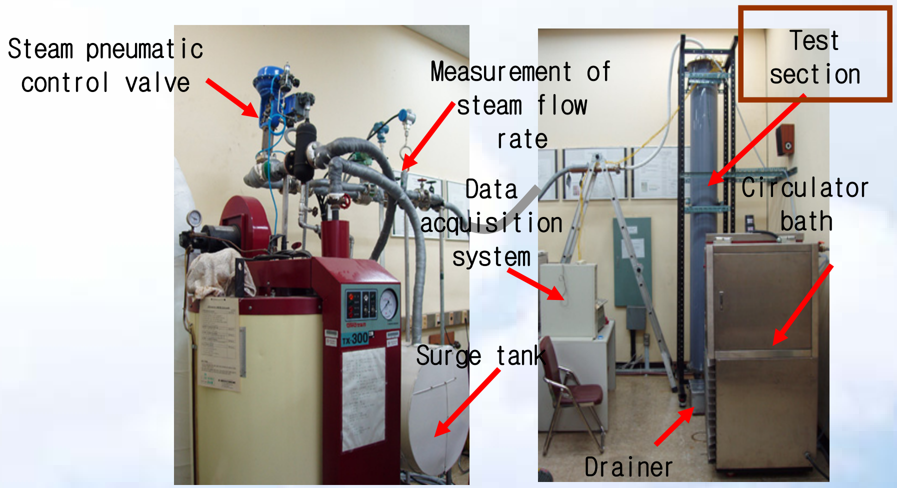
- Tests
  - High Temperature and High Pressure Test
  - Heat Transfer test for Pressurizer
  - Material Corrosion Test



Material Corrosion Test



High Temperature and High Pressure Test



Heat Transfer test for Pressurizer

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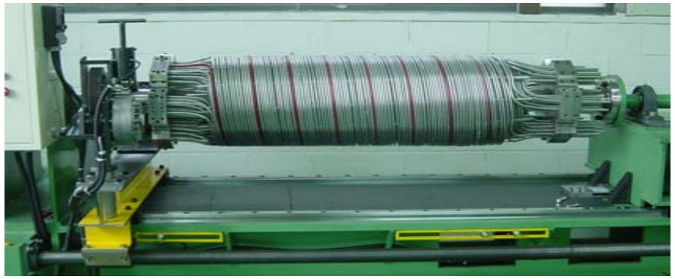
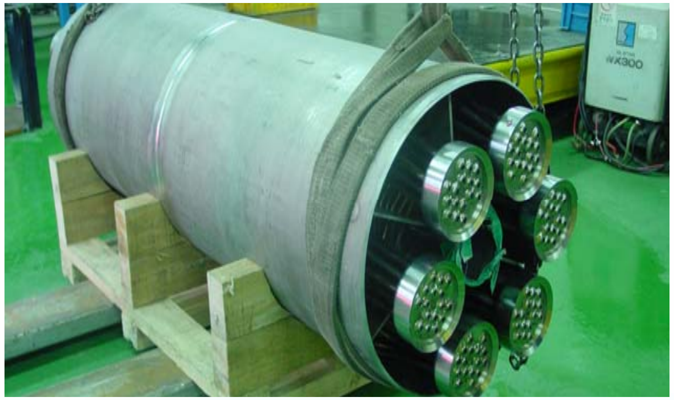
Major Components Development

❑ Steam Generator





❑ Main Coolant Pump

❑ MCP Performance Test

❑ CEDM

❑ CEDM Performance 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.