RIC 2008

The OECD-NEA ROSA Project

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March 13, 2008

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Motivation

As a means of supporting the Agency's Safety Goal Strategies, the USNRC's Office of Nuclear Regulatory Research (RES) has endeavored to develop and maintain an infrastructure of expertise, facilities, analytical capabilities, and data to support regulatory decision-making.

OECD-NEA ROSA Project:

Through experiments in the Rig of Safety Assessment (ROSA) Large Scale Test Facility (LSTF),…

… provide further technical basis for accident management (AM) measures for prevention of severe core damage in design-basis and beyond-design-basis accident situations relevant to light water reactors (LWR).

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OECD-NEA Agreement

Under the auspices of the Nuclear Energy Agency (NEA) arm of the Organization for Economic Cooperation and Development (OECD), …

… the USNRC partners with regulatory organizations from 12 different countries to sponsor investigations of the following safety issues:

- Thermal stratification during emergency core cooling injection;
- Unstable phenomena such as water hammer;
- High power natural circulation;
- Natural circulation with superheated steam;
- Primary cooling through secondary depressurization;
- Abnormal small-break loss-of-coolant-accidents (SBLOCA)

Participants gain insight from experimentation and obtain data for the validation of computer codes

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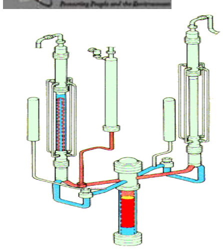
Facility Description



The LSTF is currently configured for the 5th phase (ROSA-V) of the ongoing ROSA Program.

Full-height primary system typical of a 3423 MWt Westinghouse-type 4-loop pressurized water reactor (PWR)

- **Volumes**: 1/48 scale of ref. PWR
- **Elevations**: most preserved to ensure accurate simulation of natural circulation
- **Flow areas**: 1/48 scale in pressure vessel and 1/24 scale in steam generators (SG)
- **Core power**: 10 MWt, which is 14% of scaled rated power in ref. PWR.
- **Fuel assemblies**: 1008 electrically heated rods. The diameter, pitch, and length of the fuel rods and control rod guide thimbles designed to be the same as 17 X 17 fuel assembly in ref. PWR.
- **Frictional pressure losses:** equal to those in ref. PWR for scaled flow rates.

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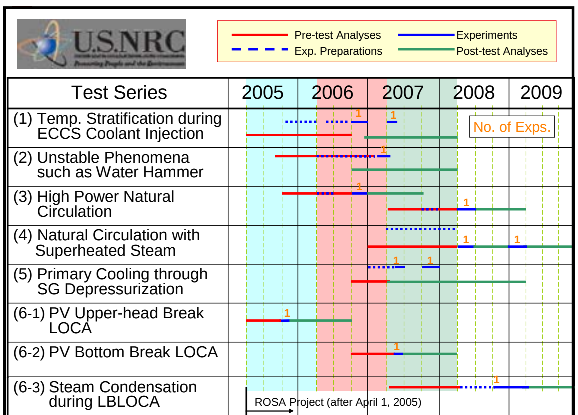

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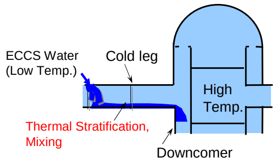
Test Series 1: Temperature Stratification during ECCS Injection

- Testing Objective: to obtain 3-dimensional temperature distribution in the cold legs and the downcomer during transient conditions
- Motivation: Under certain conditions, transient temperature variation is a concern for pressurized thermal shock (PTS) in view of plant aging and life extensions
- Two tests conducted:
  1. ECCS injection under steady-state natural circulation
  2. ECCS injection under SBLOCA conditions
- Injections were from HPIS and ACC



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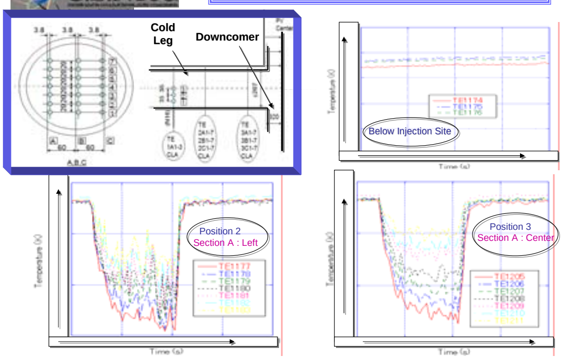
Temperature Distributions Along Test Section



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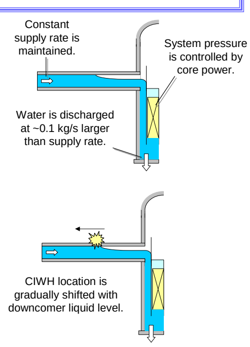
Test Series 2: Unstable Phenomena

Condensation-Induced Water Hammer (CIWH)

- Testing Objectives: to obtain detailed transient thermal-hydraulic data concerning CIWH and clarify onset criteria.
- Motivation: CIWH may occur during AM measures which cool the core through the rapid depressurization of SG secondary side.
  – Insight and data can be used in auditing advanced reactor designs, such as the EPR, which employ this AM.



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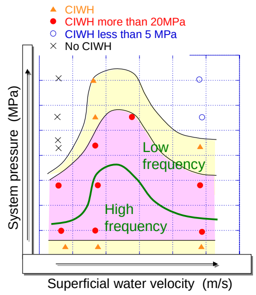
Unstable Phenomena: Condensation-Induced Water Hammer (CIWH)

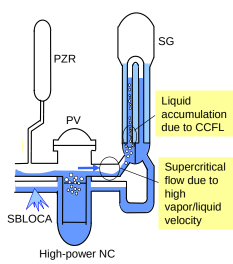
Initial Findings:

- System pressure affects frequency of large pressure pulses.
- Transformation to slug flow at high pressure conditions is induced as well as at low pressure conditions. CIWH noise at high pressure condition, however, is very small.
- Map subject to influences of pipe length, diameter, and angle.
- Large pressure pulses are easily induced at certain water flow velocity conditions (0.08 - 0.09m/s), even under high pressure.

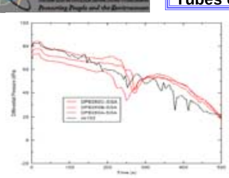


Test Series 3: High Power Natural Circulation

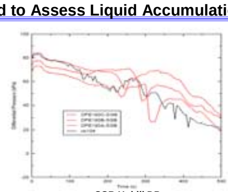
- Testing Objective: To investigate the behavior of a PWR that fails to SCRAM (ATWS) after being subjected to a 2.8-inch break in a cold leg
  - Phenomena/processes of interest
    - Natural circulation at high core-power
    - Supercritical flows in the hot legs
    - Rapid SG Secondary depressurization
- Motivation: High core power leads to higher steam flows that can effect the performance of the SGs in reflux mode.
  - Insight and data can be used in auditing advanced reactor designs, such as the EPR, which employ this AM.
- Initial Findings:
  - Asymmetrical behavior of primary loop coolant due to SG Secondary Depressurization
    - In loop without pressurizer, two-phase natural circulation continued until pressure reached well below 1 MPa
    - In loop with pressurizer, natural circulation stopped before accumulator injection
  - Non-uniform flow in SG U-tubes
  - Hot-leg flow became supercritical



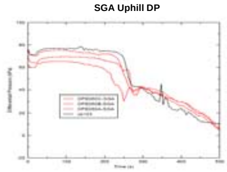
Differential Pressures in Steam Generator Tubes Used to Assess Liquid Accumulation



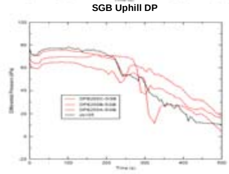
SGA Uphill DP



SGB Uphill DP



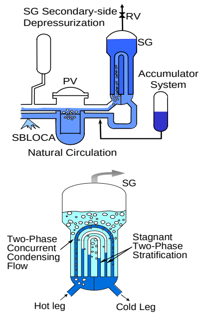
SGA Downhill DP



SGB Downhill DP

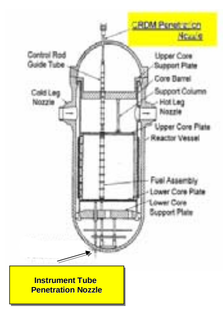
Test Series 5: Primary Cooling Through SG Depressurization

- Testing Objective: To investigate the behavior of a PWR that experiences a 0.5% break in a cold leg and has rapid SG depressurization employed as a cooling strategy.
  - Non-uniform flow distribution in SG tubes
  - Effect of noncondensible gases (NCG) on SG performance
- Motivation: More data is needed to better understand and model the thermal-hydraulic phenomena inherent in this AM strategy.



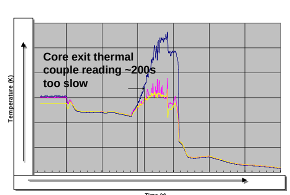
Test Series 6: Abnormal SBLOCAs

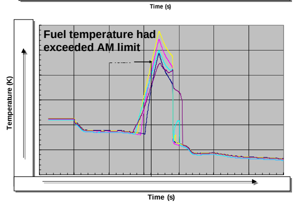
- Testing Objective: To investigate the behavior of a PWR subjected to SBLOCA scenarios extrapolated from actual plant observations.
  - Upper head break: 1.9% cold leg equivalent. (Equivalent to the ejection of one whole CRDM)
  - Lower head break: 0.1% cold leg equivalent. (Equivalent to the ejection of one whole instrument tube)
  - Effect of (SG) secondary-side depressurization as accident management (AM) strategy initiated after core exit temperature reaches 623K
- Motivation:
  - Primary water stress corrosion cracking (PWSCC) in the penetration nozzle of the control-rod drive mechanism (CRDM) could cause a SBLOCA at the vessel head of a PWR.
  - PWSCC around the circumference of two instrument-tube penetration nozzles on the lower-head of a PWR could cause a SBLOCA.
  - Experimental conditions:
    - Total failure of high pressure injection (HPI)
    - Loss of off-site power



Test 6-1: Experimental Findings

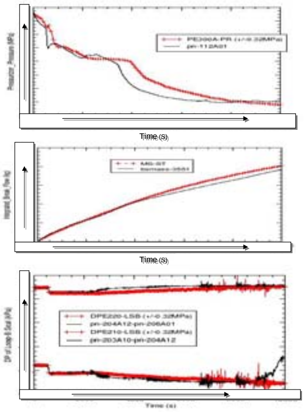
- Core exit thermocouples not affected by reflux condensation; multidimensional steam flow exiting core caused delayed temperature response
- Liquid level in upper-head controlled break flow
- Relatively large break size resulted in fast primary depressurization
- Effectiveness of AM strongly dependent on timing of core-exit temperature indication





Test 6-2: TRACE Results/Experimental Findings

- Predicted primary-side pressure falls too rapidly early in the transient and core uncovery is predicted to occur about 500s too early.
- Break flow is accurately modeled
- The AM action aided in cooling the primary system until gas inflow started from the accumulator injection system.
- Loop seals in loop with pressurizer did not clear



Experiments to be Performed in 2008 and 2009

- Test Series 4: Natural Circulation with Superheated Steam
  - Motivation: The natural circulation of superheated steam may occur during beyond design basis transients such as station blackout.
    - The correct prediction of this phenomena is necessary for the accurate prediction of a SG tube rupture during a severe accident.
- Test Series 6-3: Direct-Contact Condensation During LBLOCA
  - Motivation: To investigate the effect of direct-contact condensation on containment pressure