AREVA Technical Center

Scientific Thermal Hydraulic Testing Capabilities

Darryl Gordon
Manager, Project Development
Government Operations
Two phase flow: x=0.3
26 lb/s up to 330 lb/s

Thermal power
22 MW, 2685psi, 970°F

Electrical power
20 MW, 240V 83kA

Cooling capacity
33 MW

Heat Transfer Tests
Sump Clogging
Critical Heat Flux tests
LOCA Qualification
Pump Tests
Test Simulating Accident Scenarios
Critical Heat Flux in Natural Circulation
Steam Dryer and Separator Tests
Flow Induced Vibration
Valve Tests

Valve Tests

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Pump Tests

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Thermal Hydraulic Platform
Accredited Measurement Range & ILAC Acceptance

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>0°C - 1000°C</td>
</tr>
<tr>
<td>Pressure</td>
<td>10 Pa - 40 MPa</td>
</tr>
<tr>
<td>Volume flow rate</td>
<td>0,1 l/h - 1.500 m³/h</td>
</tr>
<tr>
<td>Mass flow rate</td>
<td>01 kg/h - 4.000 kg/s</td>
</tr>
<tr>
<td>Force</td>
<td>1 N - 10.000 kN</td>
</tr>
<tr>
<td>Momentum</td>
<td>up to 50.000 Nm</td>
</tr>
<tr>
<td>Distance</td>
<td>1µm - 10 m</td>
</tr>
<tr>
<td>Velocity</td>
<td>1 mm/s - 100 m/s</td>
</tr>
<tr>
<td>Acceleration</td>
<td>0,5 - 1.000 g</td>
</tr>
<tr>
<td>Current</td>
<td>1 mA - 85.000 A</td>
</tr>
<tr>
<td>Voltage</td>
<td>1 mV - 4 kV</td>
</tr>
<tr>
<td>Electrical power</td>
<td>up to 20 MW</td>
</tr>
</tbody>
</table>

Accredited Test Body
Under the term of ISO 17025:2005

International Laboratory Accreditation Cooperation; world wide cross acceptance e.g.:

- ANSI-ASQ National Accreditation Board (ACCLASS), USA
- China National Accreditation Service for Conformity Assessment (CNAS), People's Republic of China
- Comite Francais d'Accreditation (COFRAC), France
- Deutsche Akkreditierungsgesellschaft (DAkkS), Germany
- National Accreditation Board for Testing & Calibration (NABL), India
- Entidad Nacional de Acreditacion (ENAC), Spain
- United Kingdom Accreditation Service (UKAS), United Kingdom
Thermal-Hydraulic Platform
Unique in the World

Test Facilities
At our sites, we operate the following test facilities:

- **KOPRA** – Multifunction component test facility (fuel assemblies, CRDMs, valves)
- **BENSON** – high pressure thermal-hydraulic testing of separate effects
- **PKL** – Large scale test facility of a PWR primary loop with secondary side and auxiliary systems
- **PETER, BRIAN** – Fluid dynamic test facilities (PWR and BWR fuel assemblies)
- **SUSI** – sump strainer test facility
- **APPEL** – Pump test loop
- **GAP** – Large valve test facility

- **INKA** – Test facility for integral BWR tests
- **KATHY** – Multifunction thermal-hydraulic test loop
- **HYDRAVIB** – Vibratory validation of lower RPV internals
- **ROMÉO & JULIETTE** – RPV flow distribution in upper and lower plenum
- **CALVA** – Dynamic mechanical testing of components
- **MAGALY** – Vibration behavior of Rod Cluster Control Assembly (RCCA) and Control Rod Guide Assembly (CRGA) for various flow conditions
BWR Generation III+ Test Loop INKA

Integral Test Facility

Generation III+ BWR

Flooding Pool

Drywell

Pressure Suppression Pool

RPV

Flooding valve

Shielding/storage pool

Containment cooling condensers

Core flooding pool

Core flooding lines

Drywell flooding line

4 H₂ vent pipes

2 Overflow pipes

4 core flooding lines

4含 flooding lines

Drywell

3 Main steam lines

2 Feedwater lines

Reactor water clean-up system

Residual heat removal system
**INKA**

**Key data**

**Volumes**
- Flooding Pool Vessel: 219 m³
- Wetwell Vessel: 350 m³
- Drywell Vessel: 188 m³
- GAP/RPV: 125 m³
- Shielding/Storage Pool V.: 30 m³

**Scaling**
- Heights: 1:1
- Components size 1:1
  - EC and CCC: 1 out of 4
  - Vent pipe: 1 out of 16
- Volumes: 1:24
  - GAP/RPV 1:6,3
  - Shielding/St. Pool V. 1:88*
  *with additional heat exchanger

**Supply: 22 MWth**
## Key Data of Similar Test Loops

<table>
<thead>
<tr>
<th>Facility</th>
<th>Drywell (m³)</th>
<th>Wetwell (m³)</th>
<th>RPV pressure (bar)</th>
<th>Power Supply (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>INKA</td>
<td>420</td>
<td>300</td>
<td>89/160</td>
<td>22</td>
</tr>
<tr>
<td>PANDA (CH)</td>
<td>198</td>
<td>234</td>
<td>10</td>
<td>1.5</td>
</tr>
<tr>
<td>PUMA (US)</td>
<td>14</td>
<td>18</td>
<td>10.3</td>
<td>0.5</td>
</tr>
<tr>
<td>Tiger (JP)</td>
<td>30</td>
<td>-</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>THAI (DE)</td>
<td>60</td>
<td>-</td>
<td>14</td>
<td>1.5</td>
</tr>
<tr>
<td>APEX (US)</td>
<td>No Containment</td>
<td>32</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>
Perfomed Tests (and ongoing)

- AREVA R&D-Program (-2013)
  - Single Component Tests in full scale
    - Emergency Condenser
    - Containment Cooling Condenser
    - Passive Core Flooding System

- EASY-Project (2015-2018) funded by German Government
  - Partners: GRS, TUD, THD, RWTH
  - Integral Effect Tests
    - Simulation of LOCA (MSLB, FWLB etc.) and non-LOCA (SBO) scenarios
    - Interaction of Passive Systems
    - Code validation (ATHLET, COCOSYS)

Future

- EASY-ip (application to EURATOM work program)
  - Partners: GRS, CEA, EdF et al.
  - Integral tests on passive systems (Passive components scalable)

- RCIC-pump

- Other applications for INKA
  - Tests with active systems
  - Subjects from Gen-II plants
Objective
Investigation of PWR T/H behavior under accident condition

Key Features
► 4-loop configuration
► All primary and secondary-side operational and safety systems
► Extensive instrumentation (> 1500 measurement positions)
More than 200 integral tests since 1977 at AREVA GmbH in Erlangen

- PWR thermo-hydraulic system behaviour under accident conditions
- Effectiveness of measures for accident control
- Data base for code validation
- Demonstration of safety margins
- Training of PWR operating personnel
- Solving of PWR safety concerns
- Operated at AREVA in Erlangen, Germany
i1: Investigations on T/H phenomena related to two-phase flow modelling of two-phase flow phenomena related to LB-LOCA (2 runs)

i2: LOCA-related parameter studies (IB- and SB-LOCA) - 2 options
   i2.1: SB-LOCA- Impact of nitrogen on cool-down/heat removal
   i2.2: IB-LOCA, Counterpart Testing with LSTF/ATLAS
   i2.2: IB/SB-LOCA- Influence of certain parameters on depressurization

i3: Studies on boron dilution - 2 options
   i3.1: Failure of RHRS, confirmation of conclusions on boron dilution for 3-loop plants
   i3.1: Parameter studies on boron dilution following SB-LOCA

i4: Investigations on cool-down procedures – 2 tests
   i4.1: Upper head void formation during cool down under loss of offsite power (complementary to test G6.1)
   i4.2: ELAP (extended loss of AC-power): cool-down with feed water from mobile pump after secondary side depressurization

i5: Concluding investigations on boron precipitation (LB-LOCA) - 1 test

i6: Open test with topic to be defined during project progress
Access to AREVA NP Facilities

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Additional information can found at the AREVA Technical Center web page: