Integrated System Test Facility
Miller/Martin
IST Overview Video
IST Objectives

- Integrated system performance
- Evaluation model development support
- Licensing support (ASME NQA-1 Compliant)

Insights
- Operational evaluations
- Design basis event data using configuration controlled systems and certified data acquisition system
- Natural Circulation (one or two phase)
- Fuel pin dry-out, pre-cursor to DNB under various flow regimes
- Control and protection systems development

Flexible and adaptable platform for broad testing applications

Concurrent testing capabilities serving multiple stakeholders
## IST Design

<table>
<thead>
<tr>
<th>Design</th>
<th>Local Architectural and Engineering Firm</th>
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<tbody>
<tr>
<td>Material</td>
<td>Standard SST pipe and fittings wherever possible</td>
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<tr>
<td>Standards</td>
<td>ASME Section I &amp; VIII as required and B31.1 test system piping</td>
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</table>
| Components Accommodated | • Integral reactor loop consisting of reactor vessel, steam generator, reactor coolant pump, and pressurizer  
  • Reactor Vessel with 60 pin heater array capable of 1.8 MW (mPower optimized)  
  • Integral economizer once through steam generator  
  • Pressurizer vessel with 6kW heater  
  • ECC system consisting of automatic depressurization trains and LOCA line |
| Design Conditions       | • 650°F  
  • 2500 psig |
IST Arrangement

Feedwater and Steam
- Main Condenser
- DA Relief
- Manual Vent
- Reactor Coolant Pump
- FW Heater
- Cleanup Heat Exchanger
- Feedwater Cleanup Pump
- Dosing Pump

Inv and Purif
- RCP Pump
- RCP Surge Tank
- NC Valve
- Non Regenerative Heat Exchanger
- CCW Return Pump
- CCW Return
- CCW Supply Pump
- CCW Supply

Component Cooling
- Chiller System
- CCW Return Pump

Reactor Coolant and SG
- Pressure Relief
- PZR Heaters
- Nitrogen Press
- Low Pressure Automatic Depressurization Valve
- Intermediate Pressure Injection Tanks
- Refueling Water Storage Tank
- High Pressure Automatic Depressurization Valve
- RWST Injection Valve

Emergency Core Cooling
- Pressure Relief
- LP Vent
- Containment Simulation Tank
- Nitrogen Supply
Control Logic

- Readily adaptable control Logic designed to operate valves, pumps, heaters, control boundary conditions providing for high fidelity, highly repeatability tests.
Quality Data Stream: HFS that acquires, manipulates, stores and post processes data signals within the IST infrastructure.

Quality Signal: System response generated from a calibrated source transferred through HFS that acquires, manipulates, stores and post-processes data within the IST QDS.
Data Signals

- Sensors convert process conditions (temperature, pressure, chemistry, component, etc.) to analog signals
- Analog signals are converted to digital either through onboard digital conversion or through analog to digital characterization modules
Data Acquisition

- All-digital, serial, two-way communications system
- Protocol through either High Speed Ethernet (HSE) or Foundation fieldbus protocols
- Fieldbus network includes segment system to reduce hardware requirements, reduce troubleshooting effort and organize the field network
Data Integrity and Auditing

- Real-time and historical verifications of signals included in the IST quality data stream
- Data obtained prior to storage on application stations
- Audit verifies data is not compromised during signal transmission
Data Storage

- Two redundant storage servers, allows access to real-time and historical data
- Quality record repository for use in safety-related processes
Simulated Core Heater TC Layout and Pin Array

- 1.8 MW, 4 Groups
- Adjustable radial profile
- Symmetric Cosine Axial Power Profile
- 160 Thermocouples located at 4 different elevations and 4 reference orientations
Removable Test Sections

- 5’ above core, 4” Schedule 160 Stainless Steel Pipe
- 5” blind flange in the spillover region between steam generator, pressurizer, and riser.
- Convenient location for a variety of testing measurements or material investigations
- Steam test sections available throughout the steam system. Saturated through 80°F of superheat available depending on flow rate
IST Testing: SG & NC

Steam generator heat transfer testing
- Plateaus from 20% to 120%
- Focus on superheat and shroud heat transfer
- IST RELAP 3D modeling of feed and steam temperatures

Natural circulation testing
- Steam created in core – carried over to IEOSTG – Condensed in SG tube.
- Water level reduced over time to show flow signature
- RCS flow: IST vs RELAP5
LWR/SMR Design Basis Events

Loss of AC Power
- IST reactor coolant pump variable frequency drive set to create flow coast down signal expected during a pump trip.

Loss of Coolant Accident
- 1” - 4.56” equivalent break sizes
- Utilized IST ECC HPADV and LPADV trains, IPIT injection and RWST injection
LWR/SMR Application Domain

Primary Side Conditions
- Pressure, < 2500 psia
- Temperature, < 630°F
- Void fractions, > 0%
- Mass flux, ~1000 lbm/s-ft²
- Vessel water levels, < 70 ft
- LHGR, < 18 kW/ft
- Subcooling, < 40 °F

Containment
- Pressure, < 60 psig
- Temperature, < 250 °F

ECCS (active & passive)
- High Pressure, < 2300 psia
- Low Pressure, 15 – 650 psia
- Temperatures, 100 – 250 °F

Secondary Side Conditions
- Pressure, < 1200 psia
- Temperature, < 600°F
- Void fractions, < 100%
- Mass flux, ~100 lbm/s-ft²
- Vessel water levels, > 0 ft
- LHGR, < 18 kW/ft
- Superheat, < 90 °F
Physics Requirements By Scale
Physics Requirements By Scale

Fluid-dynamics
- Pressure loss
- Turbulence and mixing
- Thermal stratification
- Flow instabilities
- Interfacial area
- Interphase forces
- Entrainment
- Cavitation
- Flow-induced vibration

Heat transfer
- Forced convection
- Natural convection
- Mixed convection
- Radiation
- Conduction
- Two-phase evaporation and condensation
- Boiling
- Thermal striping
Similarity Assessment

Geometry

Material

Power

Fluid

Energy Dissipation

Depressurization

Natural Circulation
Conclusions

- Preserved phenomena in the core region include:
  - Heat transfer correlations and relationships
  - Flow patterns and regimes that develop in the riser, between the riser, core bypass and core, and in the core
  - Water content of the boiling core
  - Water content in the riser above the core
  - Water level in the downcomer

- Preserved phenomena in the steam generator includes:
  - Heat transfer/Boiling effects associated with secondary water inventory
  - Condensation with and without non-condensable gases
Conclusions

- The IST is available to the DOE, NRC and industry
- IST can fulfill objectives for LWR testing and serve as a proving ground for emerging technologies
- Representative RELAP 5 3D model of the IST
- Adaptable DCS, DAS, and integral test loop for rapid changes based on testing/data requirements
- Verified data stream integrity
- Known scaling representation
Questions?

- Additional information, including contact information:
  
  www.caer-ist.org