Experimental Objectives and General Scaling Methodology

VHTR Cooperative Agreement

Program Review Meeting

February 25, 2009

General Objective

- To determine the physical dimensions and operating characteristics of a test facility capable of simulating the important flow and heat transfer behavior of the VHTR during a DCC.
- Steps in scaling process.
  - Identify the thermal fluid processes that should be modeled.
  - Determine similarity groups to be preserved between the test facility and the full-scale prototype.
  - Establish priorities for preserving these similarity groups.
  - Ensure that important phenomena have been identified and addressed through the similarity groups.
  - Provide design specifications for the test facility and test program.
  - Quantify biases due to scaling distortions since it is unlikely that all similarity groups will be preserved.
  - Identify the critical attributes of the test facility that must be preserved to meet Quality Assurance requirements.
- Drawn from the NRC's Severe Accident Scaling Methodology.

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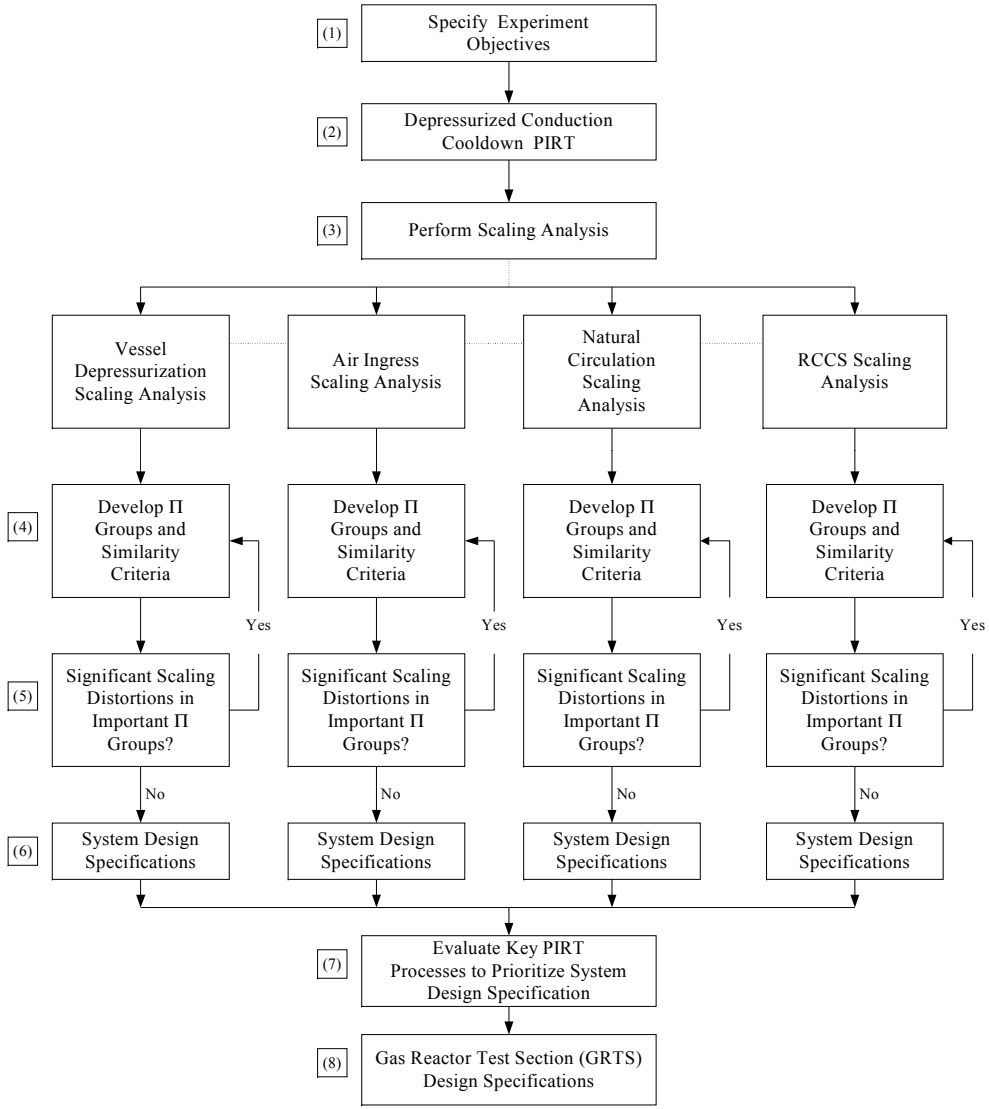
General Scaling Methodology



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Experimental Objectives

- High Temperature Test Facility (HTTF) designed to model the DCC transient.
  - Initiated by a double-ended break of the annular hot gas duct that directs the flow into and out of the reactor vessel.
  - Four distinct phases.
    - Depressurization.
    - Air ingress by lock exchange.
    - Air ingress by molecular diffusion.
    - Natural circulation.
  - Reactor Cavity Cooling System (RCCS) standard operation.
  - Modular design to allow for the examination of different core types.
    - Prismatic block.
    - Pebble bed.
- Other scenarios examined for applicability of facility.
  - PCC.
  - Normal operations.

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Experimental Objectives

- Design objective of generating the experimental data pertaining to the DCC transient scenario.
  - Lower plenum temperature profiles during lock-exchange air-ingress at the onset of transient.
  - Effects of lower plenum structures on lock-exchange phenomena.
  - Rate of air-ingress by molecular diffusion.
  - Time to onset of air natural circulation.
  - Radial heat conduction temperature profiles.
  - Estimates of thermal radiation heat transfer rates.
  - High temperature loop natural circulation flow rates following the air-ingress phase.
  - Effects of flow bypass flow area on the transient behavior.

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Hierarchical Two-Tiered Scaling (H2TS) Methodology

- Four basic elements.
  - Subdivide the plant into a hierarchy of systems.
    - System→ subsystems→ modules→ constituents (materials)→ phases (liquid, vapor or solid).
    - Each phase can be characterized by one or more geometrical configurations.
    - Each geometrical configuration can be described by three field equations (mass, energy and momentum conservation equations).
    - Each field equation can incorporate several processes.
  - Identify the scaling level at which similarity criteria should be developed.
  - Perform a top-down (system) scaling analysis.
    - Address the effects caused by the interaction of its constituents which have been identified as important in the PIRT.
    - Develop similarity criteria.
    - Identify processes to be addressed in the bottom-up scaling.
  - Perform bottom-up scaling analysis.
    - Similarity criteria are developed for the specific processes of importance as identified in the PIRT.

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Hierarchical Two-Tiered Scaling (H2TS) Methodology

$$\frac{dV_k \Psi_k}{dt} = \Delta\left[Q_k \Psi_k\right] \pm \sum\left[j_{kn} A_{kn}\right] + S_k$$

$$\tau_k \frac{dV_k^+ \Psi_k^+}{dt} = \Delta\left[Q_k^+ \Psi_k^+\right] \pm \sum \Pi_{kn}\left[j_{kn}^+ A_{kn}^+\right] + \Pi_{sk} S_k^+$$

$$M_P \neq M_M$$

$$T_P\left[\Pi_{i,j}\right] = T_M\left[\Pi_{i,j}\right]$$

$$DF = \frac{\left[\Pi_i\right]_P - \left[\Pi_i\right]_M}{\left[\Pi_i\right]_P}$$

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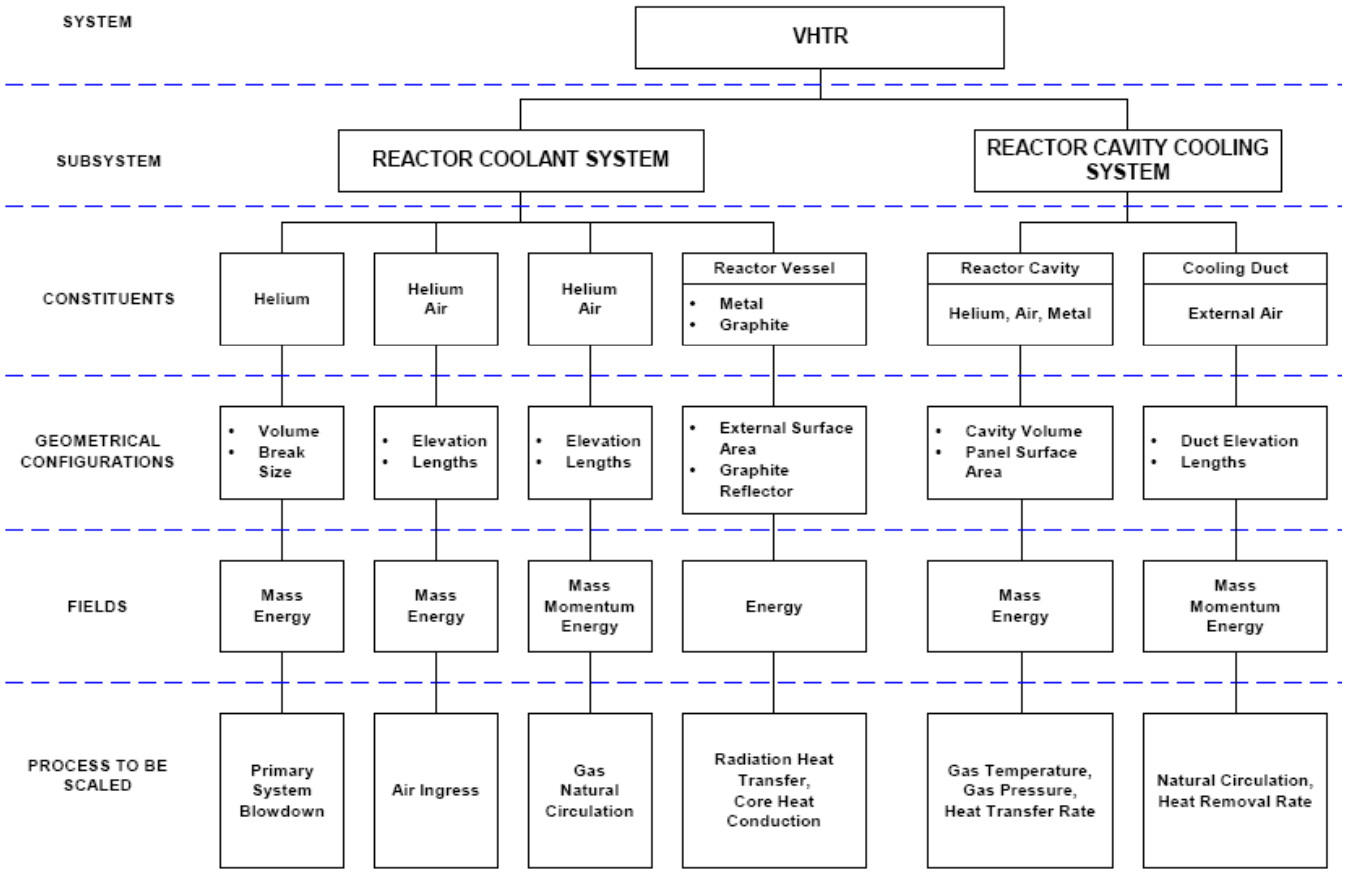
Hierarchical Two-Tiered Scaling (H2TS) Methodology



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Questions?

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