SUPERCritical Water Nuclear Steam Supply System: Innovations in Materials, Neutronics and Thermal-Hydraulics

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SCWR Research Objectives:

• Design and fabrication of out-of-pile SCW test facilities for current & future utilization in R&D

• Fuel-cladding surface modification to improve clad-water compatibility, corrosion and wear (Task I: UW Madison is the lead - Anderson/Sridharan)

• Neutronics analyses of thermal SCWR core design with modified fuel-cladding materials (Task II: Argonne is the lead with UW assisting - Kim/Wilson)

• Fundamental study of SCW stability and heat transfer under natural/forced circulation conditions (Task III: Argonne is lead with UW - Cho/Anderson)
SCWR Progress in FY 2002

- Cladding samples obtained, PSII surface modification and low-temperature tests begun

- SCW corrosion and thermal-hydraulics loop design/construction completed at UW (final setup).

- Neutronics codes benchmarking begun with nominal SCWR thermal design with improvements

- Thermal-hydraulic heat transfer and stability models developed and analyses begun

- SCW simulant CO₂ flow stability loop designed and construction begun at ANL
Design of SCW loop

Primary purpose is to study corrosion in flowing system

- Rectangular loop 3m x 2m
- Loop I.D. 0.042 m
- Loop design, construction, materials and testing to ASME code

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ANL - SC Stability Loop

Primary purpose is to study heat transfer and SC CO₂ stability.
KEY OBSERVATIONS on SCWR

- Current designs have not taken full advantage of the neutronic/thermal-hydraulic coupling that is inherent in SCWR systems (e.g., economics)
- Materials is the enabling technology and needs base funding that parallels reactor development
- Chemistry impacts on materials is a key feedback
- The key operational safety issue is control/stability
- The key accident safety issue is accident timing (i.e., critical flow, degraded heat transfer, system timing)
What about Neutrons?

The largest data gap in both supercritical and subcritical radiolysis is in the yields from neutron radiolysis.

(McCracken, et al, 1998) used sophisticated Monte Carlo scattering codes and reasonable assumptions about the energy dependence of yields in heavy ion radiolysis.

Neutron yields have been reported in some experiments University of Tokyo YAYOI fast reactor by Sunaryo, et al. (Sunaryo, et al, 1994; 1995; 1995a) Results of the two groups do not agree. McCracken et al (McCracken, et al 1998) suggest the Tokyo results are flawed by impurity contamination.

Amazingly, there are no experimental measurements of neutron radiolysis yields at any temperature for the PWR neutron spectrum.
Nuclear reactor can produce a flux of neutrons sufficient to cause radiolysis of SCW this will allow us to understand the chemistry specifically the $O_2$ concentration which can be added to our flow loop to test corrosion in typical reactor coolant compositions.
SCWR Chemistry Loop in the UWNR

Beam port number 2 in UW nuclear reactor

Schematic of proposed loop for SCW neutron radiolysis

Anticipated neutron flux at temp is ~ $10^{11}$ n/cm²/s (0.16 watts/g) which is sufficient to result in detectable levels of radiolysis (1.6e-6 moles/liter/s)
Novel SCW reactor designs proposed by ANL/UW