

ADVANCED REACTOR, FUEL CYCLE, AND ENERGY PRODUCTS WORKSHOP FOR UNIVERSITIES

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Supercritical Water-Cooled Reactor (SCWR)

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*Workshop for Universities
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THIS RESEARCH AREA INCLUDES

- ◆ **Demonstrating technical feasibility of a LWR operating above the critical pressure of water, and producing low-cost electricity.**
- ◆ **The SCWR project is part of the Generation-IV program.**
- ◆ **The Generation-IV program calls for the development of:**
 - the next generation of nuclear systems for production of high-value energy products such as electricity and hydrogen (VHTR and **SCWR**), and
 - development of fast reactor systems for the actinide management mission. (GFR, LFR, SFR)



FY03 ACCOMPLISHMENTS

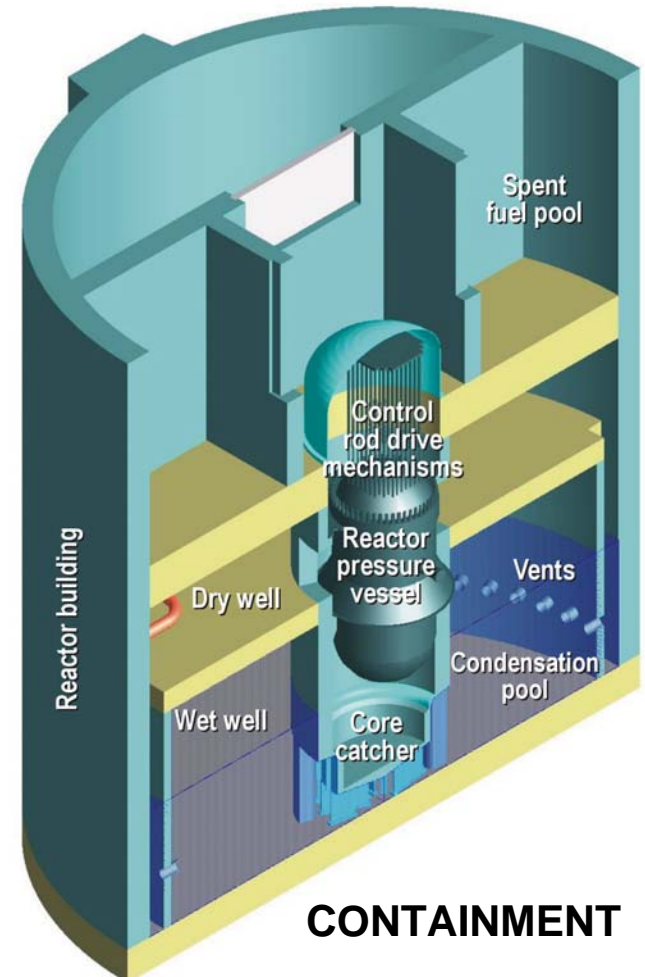
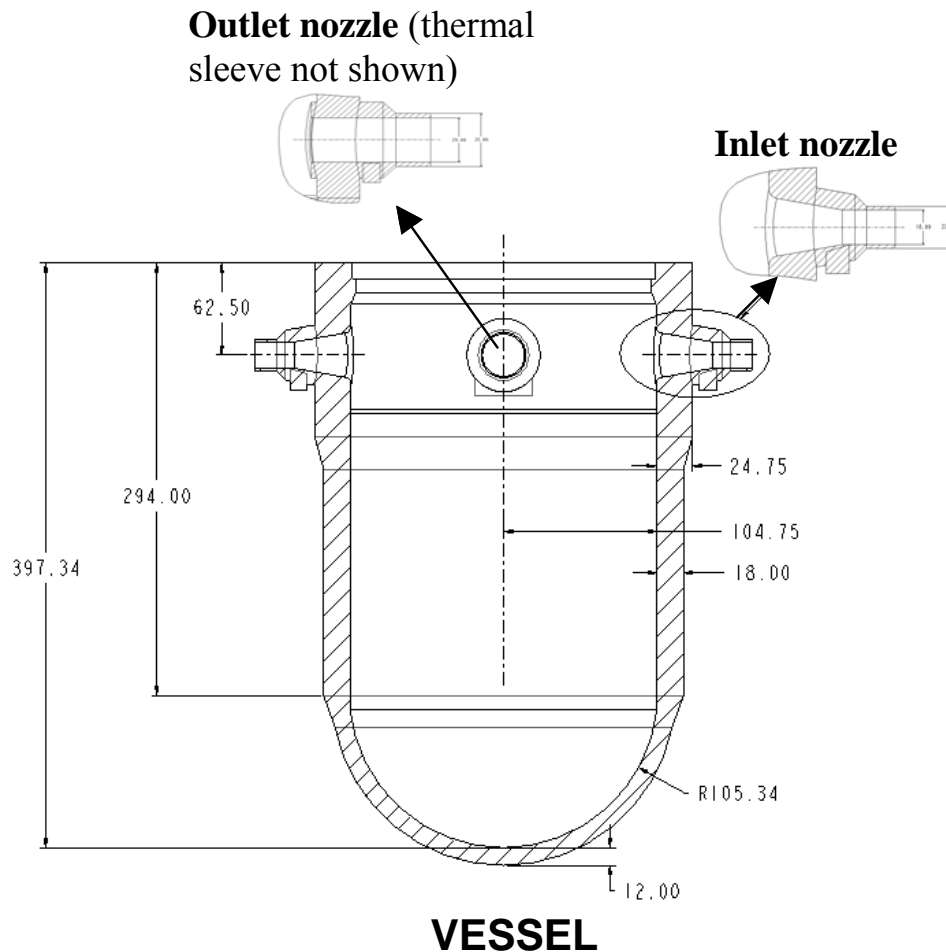
- Established U.S. reference SCWR design (INEEL)
- Identified candidate materials for all SCWR components (ORNL, INEEL)
- Demonstrated SCWR stability against core-wide oscillations (ANL)
- Developed conceptual design of SCWR containment and established requirements for safety systems (Westinghouse, INEEL)
- Designed power conversion cycle and identified control and start-up strategies (Burns & Roe)
- Tested two alloys in SCW (MIT, UMichigan)

Topical reports are available from SCWR SIM upon request .



FY03 ACCOMPLISHMENTS

The SCWR can make substantial use of existing LWR technology in the nuclear island.

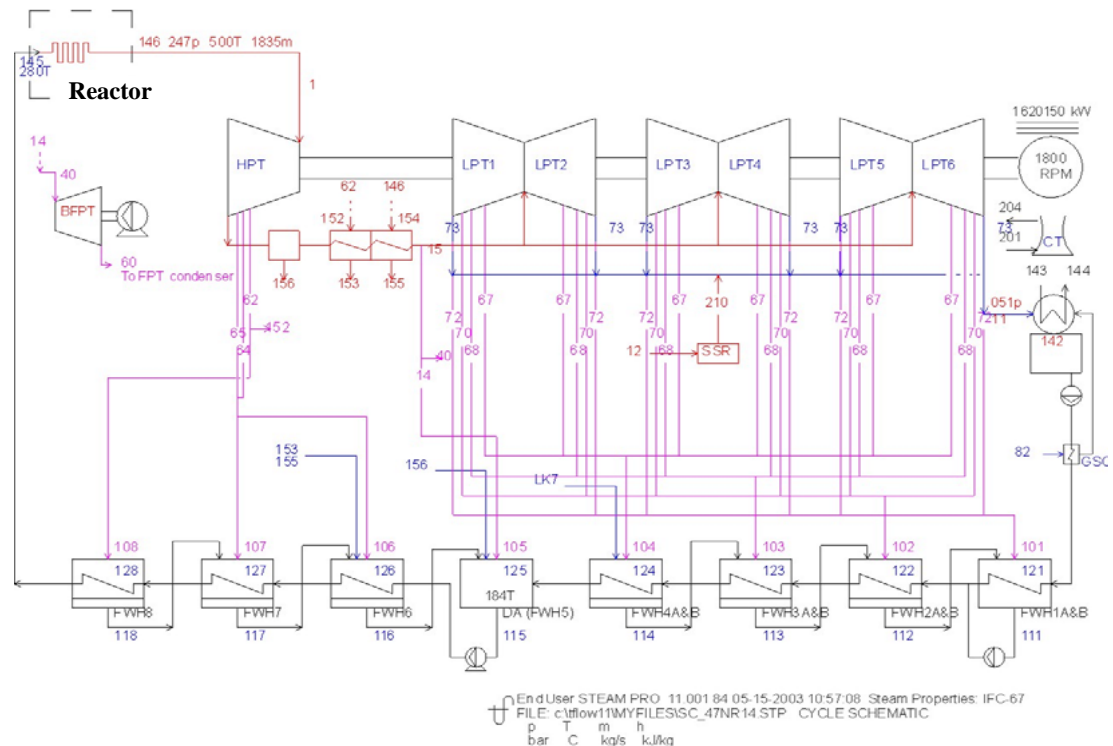




FY03 ACCOMPLISHMENTS

The SCWR can achieve high thermal efficiencies making extensive use of available supercritical fossil plant technology in the balance of plant.

- Rotation speed 1,800 rpm
- Single-shaft turbine-generator
- One HPT/IPT and three LPTs (six flow paths)
- Two main steam lines
- MSR between the HPT/IPT and the LPTs
- Eight feedwater heaters
- Steam turbine-driven feedwater pumps
- Water cooling with natural draft cooling tower

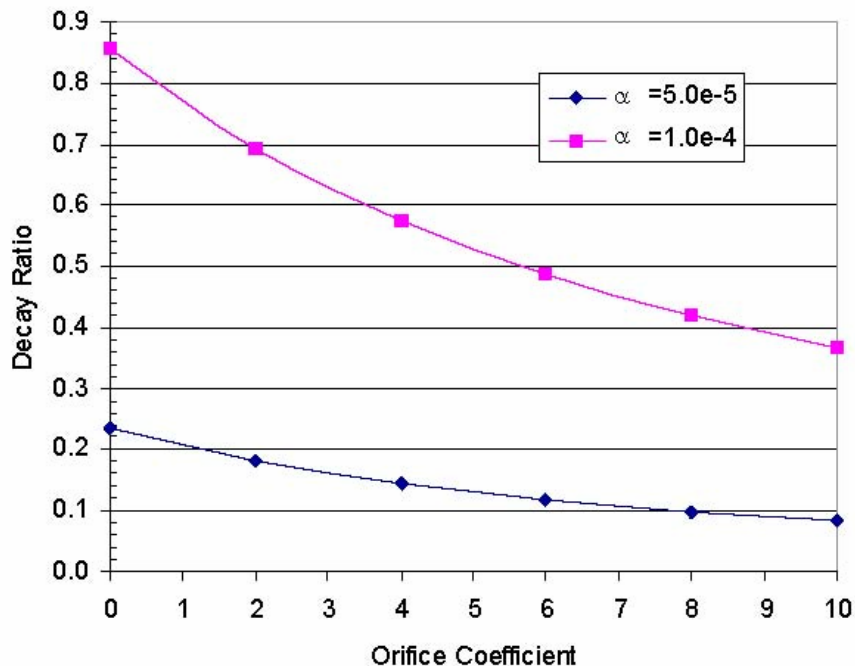


POWER CONVERSION CYCLE



FY03 ACCOMPLISHMENTS

Based on preliminary one-dimensional analyses, the SCWR appears to be stable with respect to thermal-hydraulic and thermal/nuclear oscillations because of its relatively low coolant reactivity feedback coefficient.



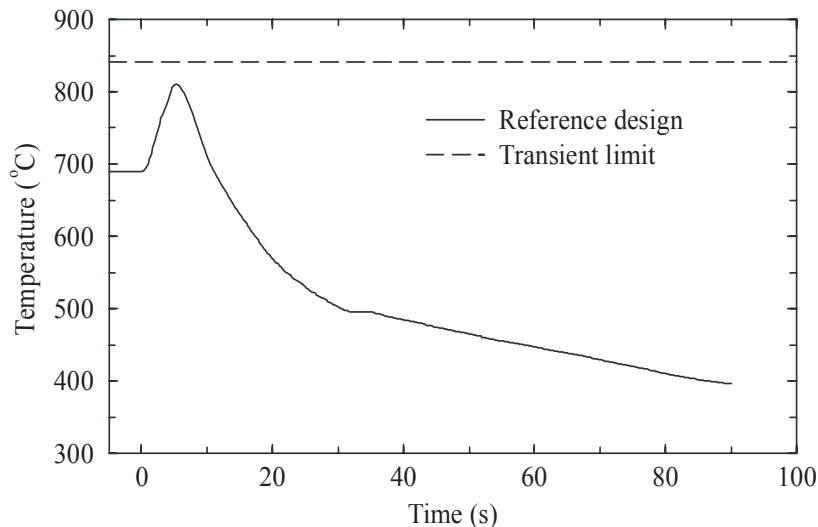
- Due to the axial variation of the coolant density, the SCWR (like the BWR) is potentially susceptible to thermal and thermal-nuclear coupled oscillations.
- NRC will likely require demonstration of the ability to predict the onset of instabilities.



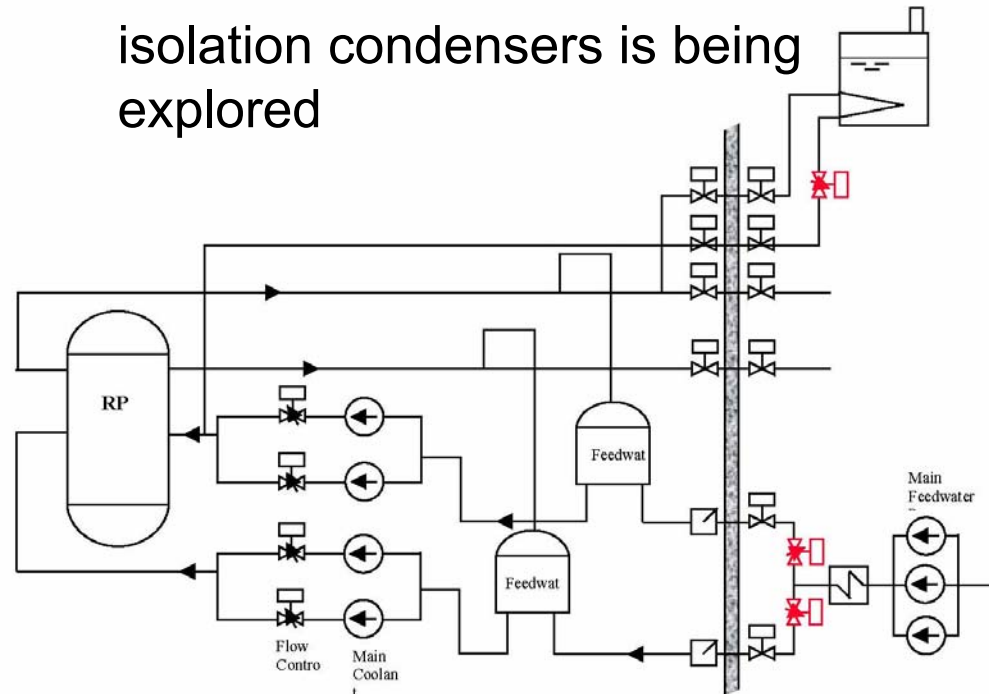
FY03 ACCOMPLISHMENTS

The importance of the loss of feedwater as a key abnormal (possibly limiting) event has been recognized.

- Natural circulation within the vessel does not occur \Rightarrow loss of feedwater flow coincides with loss of core flow



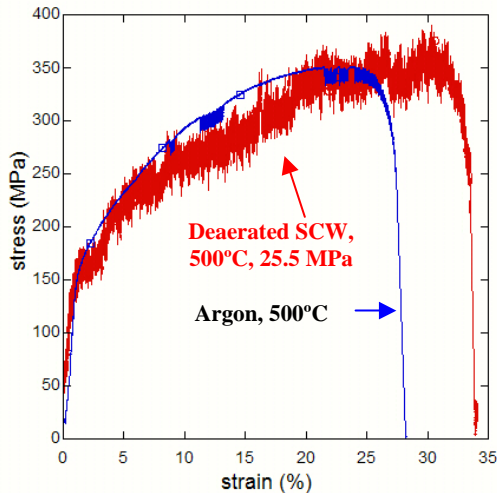
- Currently an approach based on feedwater tanks and isolation condensers is being explored





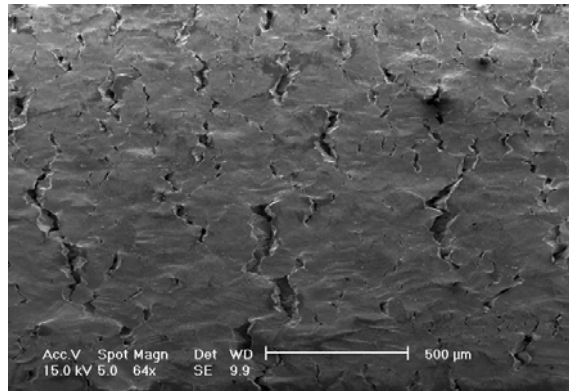
FY03 ACCOMPLISHMENTS

Limited corrosion and stress-corrosion testing of traditional alloys in high-temperature water has shown that finding materials that would perform satisfactorily in the SCWR environment will be a challenge.

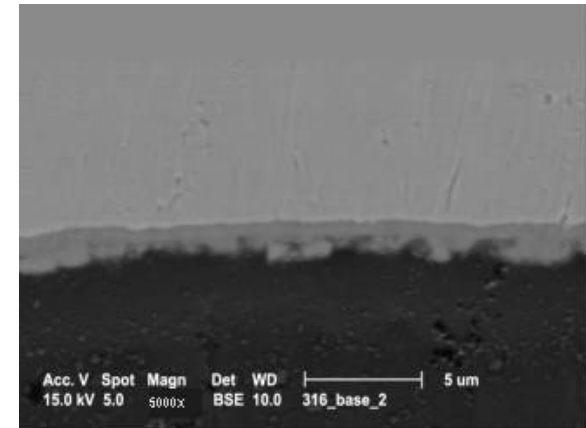


Stress-strain curves for 316L in argon and deaerated SCW at 500°C.

Alloy	304L	316L	625
Test duration (hr)	230	305	500
Strain to failure (%)	25 ¹	33	48
Max stress (MPa)	290 ¹	280	680
Yield strength (MPa)	100	100	270
Fracture surface	Intergranular and ductile. Intergranular cracks initiated fracture	Ductile with intergranular cracks on the sides	Intergranular and ductile. Intergranular cracks on the side surfaces
Surface intergranular crack density (#/mm ²)	7	NM	25



Alloy 625 surface after failure in deaerated SCW



SEM backscattered electron image of a cross-section of 316L exposed to deaerated SCW for 305 hrs at 500 °C and 25.5 MPa.



WORK IN PROGRESS FOR FY04

\$900k, 5 Work Packages, 8 Organizations

- 1. Safety system and containment design (Westinghouse)**
- 2. Stability analysis (ANL, MIT)**
- 3. RELAP analysis of start-up equipment/procedures (BREI)**
- 4. Corrosion testing (U-Wisconsin)**
- 5. SCC testing (U-Michigan)**
- 6. Water chemistry control system conceptual design (ORNL)**
- 7. Program management and design support (INEEL)**

Universities already are an integral part of the SCWR team



PLANS FOR FY05-07

Focus of the program for the next 3 years will be on:

- ◆ SCWR core neutronic, thermal and mechanical design, including investigation of non-conventional approaches (e.g., solid moderators, hydride fuels, etc.)
- ◆ Design of safety systems and containment to cope with key abnormal events
- ◆ Evaluation of dynamic power/flow instabilities
- ◆ Investigation of basic thermal phenomena for the SCWR (e.g., heat transfer and critical flow experiments, CFD methods, etc.)
- ◆ Corrosion and stress-corrosion cracking testing of promising materials for the SCWR core and vessel internals.



PLANS FOR FY05-07

SCWR core neutronic, thermal and mechanical design:

- Comparison of different approaches (e.g., hydride fuels, solid moderators, water rods)
- Fuel assembly and vessel internals conceptual design
- Neutronic/thermal-hydraulic coupled analyses
- Depletion calculations

Key milestone:

Identify viable core and vessel internals design (2006)

International collaborations:

Informal information exchange with GIF partners



PLANS FOR FY05-07

Design of safety systems and containment to cope with key abnormal events

- Conceptual design for reactor protection system, residual heat removal system, ECCS, reactor shutdown system, steam and pressure relief systems, containment structures, etc.
- Active vs. passive safety systems
- Resolve the total loss of feedwater issue

Key milestone:

Complete pre-conceptual design of ECCS and containment (2006)

International collaborations:

Informal information exchange with GIF partners



PLANS FOR FY05-07

Evaluation of dynamic power/flow instabilities

- Multi-channel instabilities + 3D kinetics
- Instabilities during start-up and transient overpower
- Experiments in SCW and surrogate fluid loops

Key milestone:

Complete preliminary stability analysis (2007)

International collaborations:

I-NERI with Canada



PLANS FOR FY05-07

Investigation of basic thermal phenomena for the SCWR

- Heat transfer experiments with SCW and surrogate fluids
- Critical flow experiments
- Validation of global codes (e.g., RELAP)
- CFD methods

Key milestones:

Complete construction and shipment of the test-section for the Erlangen facility (2006)

Complete design and construction of the choked-flow facility (2007)

International collaborations:

I-NERIs with EU, Canada and Korea



PLANS FOR FY05-07

Corrosion and stress-corrosion cracking testing of promising materials for the SCWR core and vessel internals

- Metal alloys (FM, Austenitics, Ni alloys), ceramics (e.g., SiC)
- Unirradiated, p-irradiated and n-irradiated samples
- Test in SCW at controlled temperature, pressure, oxygen, conductivity and pH

Key milestone:

Complete corrosion and SCC screening tests of unirradiated materials in supercritical water (2007)

International collaborations:

I-NERIs with EU, Canada and Korea



BUDGETS (FY03-04)

Functional Area	Tasks	Performers	FY 2003	FY 2004
System design and evaluation	Safety system conceptual design	Westinghouse	160	150
	Stability analysis and experiments	ANL	50	100
		MIT	/	100
	BoP design and analysis	BREI	50	60
Materials	Corrosion testing (unirradiated)	MIT (03), U-Wisconsin (04)	50	80
	SCC apparatus (hot cell)	U-Michigan	/	200
	Materials survey	ORNL	50	/
	Water chemistry	ORNL	/	50
	Analysis of corrosion results	ORNL	/	50
	Project management	INEEL	78	110
	Total		438	900