Westinghouse Hot Cell Facility and Laboratories

The Westinghouse Churchill site is a Nuclear Science User Facilities (NSUF) Partner Laboratory

Westinghouse

Table of Contents

Capabilities Overview

The Westinghouse Hot Cell Facility and Laboratories are located in Churchill, Pennsylvania (USA), approximately seven miles east of Pittsburgh. Our facilities, which are a Nuclear Science User Facilities (NSUF) Partner Laboratory, provide a unique combination of experienced personnel and laboratory capabilities.

We specialize in materials and chemistry evaluations through laboratory testing of both unirradiated and irradiated samples. Our staff, which has more than 700 combined years of materials and chemistry evaluation experience, supports a broad range of worldwide customers including nuclear utilities, universities and government entities.

We offer one-stop service for our customers. We can arrange for shipment of test materials to and from our laboratories and offer final radiological waste disposal upon completion of the work. Further, we can supply long-term secure storage of test materials upon request.

The Churchill site underwent a multi-million-dollar renovation in 2014, including upgrading a majority of the laboratory capabilities. The facility consists of two buildings containing laboratory and office space, along with several additional auxiliary buildings.

The facility is a restricted-access secure site, but both national and international customers and researchers are welcome to observe, oversee and actively participate in ongoing work.

The site includes: five hot cells, extensive autoclave facilities, microstructural characterization laboratories, analytical chemistry laboratories, machining capabilities and mechanical testing laboratories. In addition, we have access to countless support capabilities worldwide within Westinghouse and our affiliate and subsidiary companies.

We support both rapid-turnaround projects as well as mid- to long-term research efforts. We routinely evaluate a wide range of parts for our customers, from small metallic chips to components weighing several thousand pounds.

Our overriding objective is to provide our customers with the data they require in a flexible but safe working environment. Our superior safety record has enabled us to operate continuously for almost 40 years.

Specific Areas of Expertise Include:

- Handling and evaluating activated and contaminated materials
- Comprehensive capabilities for nuclear plant component failure analysis
- Machining of test specimens from irradiated components
- Mechanical testing, microstructural characterization and analytical chemistry laboratories
- Inclusive cold and hot autoclave facilities for corrosion evaluations
- Surveillance capsule design, fabrication and examination
- Custom design and fabrication of irradiated materials testing hardware
- Fuel crud and sludge analysis
- Radioactive material shipping and disposal
- Non-destructive evaluation
- Scaled and customizable test loops for assessing component performance in light water reactor conditions

Westinghouse Churchill Site, Churchill, Pennsylvania (USA)

Westinghouse manages state-of-the-art laboratory facilities that provide empirical data to support our customers and business lines in the technical areas of chemistry and materials

We provide a broad range of failure analysis services for unirradiated and irradiated components. Recent examinations have included: austenitic stainless-steel welds, electrical components, pressurizer heaters, pump seals, carbon steel containment liner plates, baffle bolts, zirconium in-core instrumentation components, springs and control rod drive mechanism head penetrations.

Investigative techniques include, but are not limited to:

Surface Examinations

We perform a visual examination of the as-received component and document, with high-resolution digital photographs, the overall condition of the component, as well as any unusual findings such as the presence of surface defects, discoloration, oxidation, corrosion, pitting, wear, cracking and deformation. We use the results from the initial surface examinations to help define subsequent component sectioning and additional examinations.

Non-Destructive Examinations

We offer non-destructive examinations including dye penetrant exams, ultrasonic testing and eddy current testing.

Metallographic Examinations

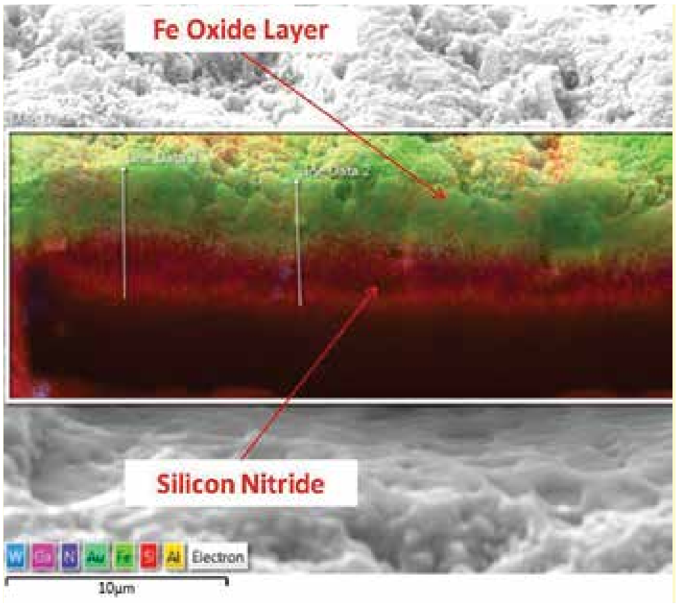
We can perform metallographic examinations to determine material microstructure, such as grain size and inclusion distribution, and we can do this on selected cross sections removed from the part, which can be taken transversely to any cracks present in the component. We normally conduct the metallographic examinations in the "as-polished" and "polished and etched" conditions to establish the location, depth and distribution of degradation and cracking and their relationship to the local microstructure. We can also obtain information regarding potential surface attack phenomena, crack initiation location, crack propagation direction and crack morphology.

Fractographic Examinations

We can conduct fractographic examinations on open crack surfaces, if present, to establish the crack initiation site(s), propagation direction(s) and the general cracking morphology. Light optical and scanning electron microscopy techniques can be used to establish the presence of beach marks and fatigue striations or to establish if cracking exhibits a transgranular or intergranular morphology.

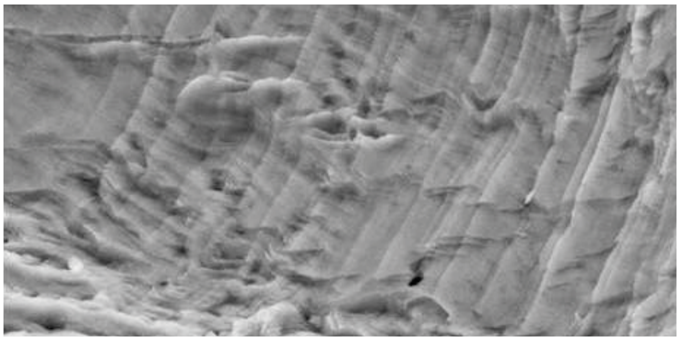
Chemical Evaluations

We can provide chemical evaluations of the base material, surface deposits, crack deposits and weld metals, using energy-dispersive spectroscopy (EDS) techniques, X-ray diffraction and/or wet chemical analysis techniques. For detailed surface characterization, we use a scanning electron microscope (SEM) EDS system equipped with a focused ion beam mill.



Focused ion-beam / SEM-EDS results from oxide deposits on reactor coolant pump seal package

Transgranular stress corrosion cracking in austenitic stainless steel



Fatigue striations in austenitic stainless steel

Fabrication

Westinghouse has fabricated approximately 450 surveillance capsules for the worldwide commercial nuclear fleet. The reactor vessel of a commercial nuclear power plant contains six to eight surveillance capsules. The surveillance capsules contain mechanical property specimens machined from the identical heat of material used to fabricate the reactor pressure vessel.

Included in the capsule are specimens machined from plates, forgings, welds and heat-affected zone material, and also Charpy V-notch, tensile and fracture mechanics specimens. Westinghouse maintains a secure storage facility that contains approximately 350,000 pounds of archive pressure vessel steel material.

Dosimeters, including pure iron, nickel, copper, niobium, aluminum-cobalt (Al-Co) (0.15 percent Co) and cadmium-shielded Al-Co wires, along with U-238 and Np-237 (or niobium), are also placed within the surveillance capsule and are subsequently evaluated post-irradiation to determine the measured fluence at the specific capsule location within the vessel.

Westinghouse maintains an archive pressure vessel steel material inventory consisting of approximately 350,000 pounds of material

Fabrication and assembly of surveillance capsules for Westinghouse's newly constructed plants in China

Testing

Irradiated surveillance capsules are removed from reactors during normal refueling periods over the design life of the plant. The removal schedule is based on the requirements of ASTM E185-82.

Our hot cell facilities perform post-irradiation testing and evaluation of the surveillance capsule specimens, which are shipped to Churchill after removal. We monitor the effects of neutron irradiation on the reactor vessel beltline materials exposed to actual operating conditions and perform testing remotely in our hot cells. Westinghouse analyzes the dosimeters contained in the surveillance capsule and calculates the neutron fluence exposure. We have tested approximately 185 surveillance capsules for commercial plants worldwide, which equates to hot cell testing of more than 10,000 irradiated Charpy specimens and approximately 2,000 irradiated tensile specimens.

In-cell Charpy V-notch test machine

Storage

Westinghouse provides a variety of radioactive specimen and component storage options for our customers, for both the short-term and the long-term. The majority of specimens and smaller-sized components are securely stored in the Churchill site's underground storage facility.

The storage facility consists of 100 underground tubes, each approximately 10 feet tall. These tubes have been used to store radioactive specimens and small-sized components for more than 35 years and currently contain approximately 20,000 individual irradiated pieces.

Shipping

Westinghouse personnel maintain current certifications for air and ground shipping of radioactive materials, nonradioactive hazardous materials and hazardous waste. We maintain a variety of Type A and industrial packages and also have experience with various Type B shipping containers.

(Top) Westinghouse shipping containers warehoused for radiological material transport / (Bottom) Westinghouse shipping casks for transporting highly activated material specimens

Surveillance capsule cask with integrated stand for shipping and receiving long capsules

Disposal

Westinghouse supports the radioactive waste disposal needs of our customers. Specifically, we provide characterization, segregation, packaging and transport of waste shipments, including disposal of Class A, Class B and Class C waste. Shipments can be transported to a variety of disposal facilities within the United States.

Welding Capabilities

Our hot cells have a long history of irradiated materials welding, with some of the earliest in-cell welds performed on highly irradiated stainless steels approximately 30 years ago in support of vessel repair efforts at Savannah River. We have the expertise to design and fabricate remote welding fixtures for various types of welds on highly radioactive materials. We provide the following specialty welding services:

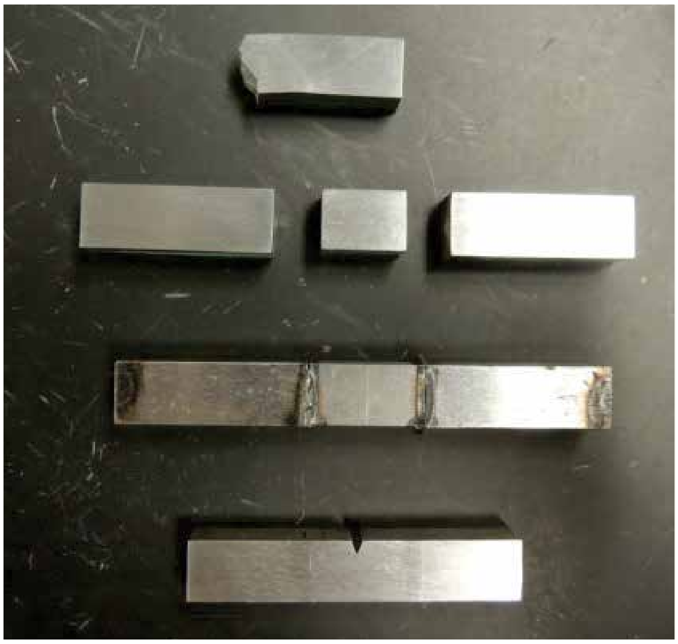
- Resistance welding
- Shielded metal arc welding (SMAW)
- Gas tungsten arc welding (GTAW)
- Gas metal arc welding (GMAW)
- Laser welding

Neodymium-doped yttrium aluminum garnet (Nd:YAG) laser welding head with video feedback system, air knife and multi-axis positioning

Resistance Welding – Charpy Impact Specimen Reconstitution

We pioneered work in the area of irradiated Charpy specimen reconstitution and have successfully developed a robust approach that is now being implemented in the commercial nuclear industry. Irradiated Charpy specimen reconstitution gives new life to previously irradiated and tested Charpy specimen halves, providing important data quantifying the effects of radiation-induced aging on reactor vessel materials under operating conditions.

In this approach, the fracture faces of the broken irradiated Charpy specimen are removed, creating a specimen insert. Unirradiated end tabs are welded to the specimen insert using resistance welding. Welding temperature is monitored and carefully controlled, ensuring that the radiation damage accumulated in the specimen insert is not affected during attachment of the end tabs. The welded specimen is then machined in-cell to the final ASTM E23 Charpy impact specimen dimensions. The reconstituted Charpy impact specimen can then be tested or reinserted into a surveillance capsule for further irradiation.



Various stages in the Charpy impact specimen reconstitution process

Westinghouse Advanced Loop Tester

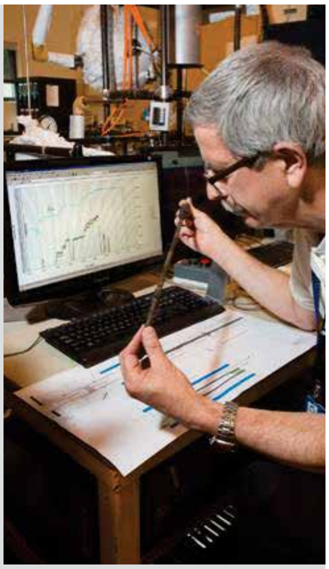
We custom designed and fabricated the Westinghouse Advanced Loop Tester, or WALT Loop, in our laboratories.

In the loop tester, crud with characteristics similar to that formed in operating pressurized water reactors (PWRs) is deposited on a heated rod surface, allowing for the study of fuel crud thermal hydraulics. Crud thermal parameter variations, as a function of crud thickness, crud morphology and fluid conditions, can be directly measured and systematically evaluated.

We have used this test facility in several studies, including, but not limited to:

- Dry-out and hot spot tests in support of the industry goal of zero fuel failures
- Testing to evaluate unexpected changes in core power distributions in operating reactors known as crud-induced power shifts or axial offset anomalies
- Support of an industry research program to assess the impact of zinc addition to PWR reactor coolant

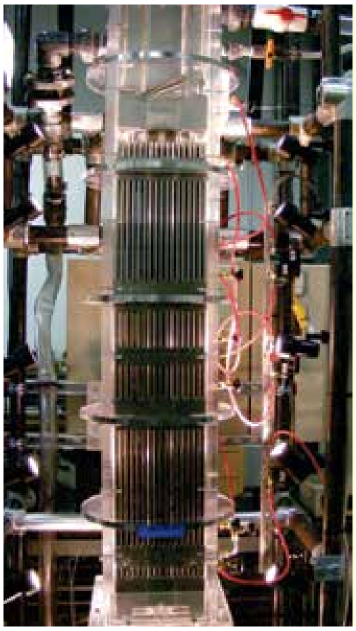
Westinghouse Advanced Loop Tester



Visual examination of fuel rod simulant after exposure in the WALT Loop

Loss-of-coolant Accident Debris Blockage Test Facility

This custom designed and fabricated test facility is available to evaluate the in-vessel effects of particulate, fibrous and chemical debris that pass through the sump strainer following a loss-of-coolant accident (LOCA).



LOCA debris blockage test facility

Tests are performed here on representative one-third-height scale fuel assemblies using various fiber, particulate and chemical precipitate debris loads to examine the pressure drop across the fuel assembly. Other tests examine the effect of various fuel inlet nozzle designs on debris capture and flow blockage. The objective is to identify the maximum sump strainer debris bypass loads that can be tolerated in a LOCA event and that do not result in unacceptable pressure drops across the mock-up fuel assembly.

The test loop consists of a 250-gallon mixing tank system with temperature control and a mixing pump, a recirculation system, the test column and a computer monitoring system.

Thermal Hydraulics Testing High Bay

We offer a versatile high bay facility for thermal hydraulic testing. The ceiling height of 43 feet allows for the design and fabrication of large test loops and the testing of large components.

Condensate return testing tank and measurement equipment

We have two test loops for measuring the potential for core inlet blockage, a four-inch intermediate loop and a chemical effects loop.

We also have two additional test facilities in this high bay, one to measure condensation flow on Westinghouse **AP1000®** plant containment domes and another to evaluate moisture separator performance.

Zinc Effects Test Loop

We performed multi-year crack initiation testing in this test loop to demonstrate that zinc additions to the primary system of operating PWRs increase the primary water stress corrosion cracking resistance in Alloy 600 and associated Alloy 82/182 weld metals. Westinghouse tested specimens machined from control rod drive mechanism nozzles and reactor vessel outlet nozzles from three PWRs. Zinc injection was performed for more than 10 years in one of the PWRs prior to removal of the nozzle material, while the other two PWRs did not inject zinc.

We removed surface films from some specimens and gave intentional zinc exposures to other specimens. Comparison crack initiation test results showed a significant benefit in crack initiation time for specimens with zinc in the surface films due to improved oxide characteristics. Similar trends were observed for Alloy 690 and the associated Alloy 52M/152 welds.

Custom-built test rig for evaluating impacts of zinc addition to light water reactor coolant on stress corrosion crack resistance

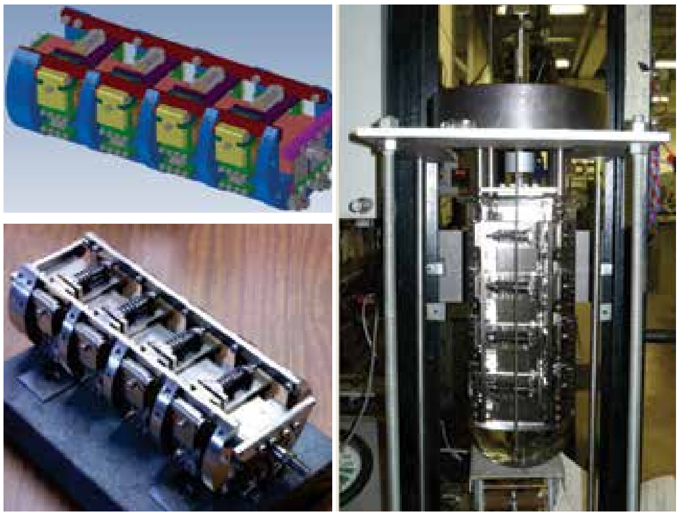
High Temperature Steam Oxidation Unit

This test unit can provide high-temperature steam exposures of numerous specimens simultaneously to evaluate the effects of oxidation on the behavior of fuel cladding alloys under simulated LOCA conditions. Multiple specimens are exposed to flowing steam for predetermined times at temperatures up to 1,200 degrees C (2,192 degrees F). A water quench of the specimens is typically performed immediately after steam exposure.

High-temperature steam oxidation equipment used for evaluating LOCA effects on fuel cladding materials

Wear Test Rig

This custom designed and fabricated test rig simulates wear through well-controlled sliding of specimen material combinations under identical wear conditions, including load, stroke, cycles and environment. Testing can be performed on numerous wear couples to provide a relative evaluation of wear performance under representative plant operating conditions.



(Top-left) Solid model of the sliding wear test fixture with specimens
(Bottom-left) Photograph of the sliding wear test fixture, and
(Right) Wear test fixture shown in mechanical test frame ready for testing

Reactor Coolant Pump Seal Testing Laboratory

This laboratory specializes in testing and qualifying of commercial, safety-related components that are required to operate under extreme conditions.

The primary test equipment we use in this laboratory is a static test loop designed for high temperature, high pressure testing of reactor coolant pump mechanical seals. The loop simulates severe operating conditions such as those expected after a station blackout. The laboratory not only tests for basic continued functionality of the components under extreme environments, but we can also obtain precision measurements of axial growth in components due to thermal expansion.

We have supported hundreds of mechanical seal tests here.

Reactor coolant pump seal static test rig

Our hot cell facility includes five individual hot cells. These hot cells consist of 10 remote handling stations with shielded viewing windows and manipulators.

Four of the hot cells are multifunctional in that the equipment inside these cells is routinely reconfigured, as needed, to meet customer requirements. When not in use, contaminated equipment is stored on-site in our radiological storage building. The fifth hot cell is solely dedicated to SEM examinations of highly irradiated materials.

We have completed approximately 700 hot cell projects for a variety of customers worldwide.

High-level Hot Cell

The high-level cell was initially designed and constructed to accommodate the size and radiological conditions associated with a full-sized Westinghouse commercial plant fuel assembly. As such, this particular cell is relatively large (24 feet long x 5 feet deep x 12 feet high) and is constructed with extremely thick high-density poured concrete walls (minimum wall thickness of 27 inches) for additional radiological shielding.

The high-level cell has four remote handling stations and multiple remote cameras with live video feed viewing monitors. A heavy-duty manipulator with a hoist capability of 1,000 pounds is available in the high-level cell.

High-level hot cell with four remote handling stations (right) and low-level hot cell with three remote handling stations (left)

The high-level cell is multifunctional and is routinely reconfigured to meet the needs of our customers. Work performed in this cell includes: machining, cutting, grinding, milling, photography and ultrasonic measurements.

Background radiation fields in the high-level cell are generally of the order of 1,000 rad/hour; however, individual components under examination in the cell can have radiation fields approaching 7,000 rad/hour near contact.

Low-level Hot Cell

The low-level hot cell is adjacent to the high-level hot cell and is used for a wide range of irradiated material testing and measurements. The cell measures 17.5 feet long x 6 feet deep x 10 feet high and has 12- to 24-inch-thick poured concrete walls.

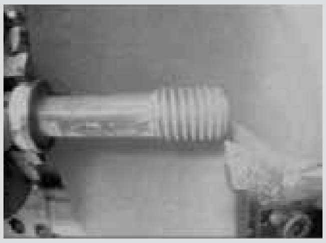
The low-level cell has three remote handling stations and, like the high-level cell, has multiple remote cameras with live video feed viewing monitors.

This cell also is multifunctional and is routinely reconfigured to meet customer needs. Work performed in this cell includes: Charpy testing, tensile testing, immersion density measurements, eddy current examinations, photography and dimensional measurements. A through-wall transfer tube connects the high-level hot cell and the low-level hot cell, allowing for the transfer of specimens and tools between the two cells.

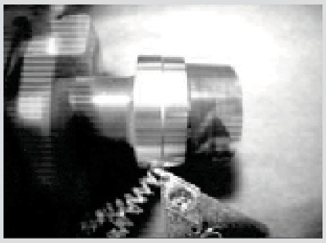
Expert In-Cell Machining, Testing, and Measurement Capabilities

Our personnel have extensive expertise in in-cell machining, testing and measurements of test specimens from a wide range of irradiated components and part shapes. We have in-cell machined thousands of O-rings, tensile specimens, compact tension specimens and fracture toughness specimens.

In-cell testing capabilities include: tensile, fracture toughness, compression, crack growth rate and slow strain rate.



Thread removal



Head removal

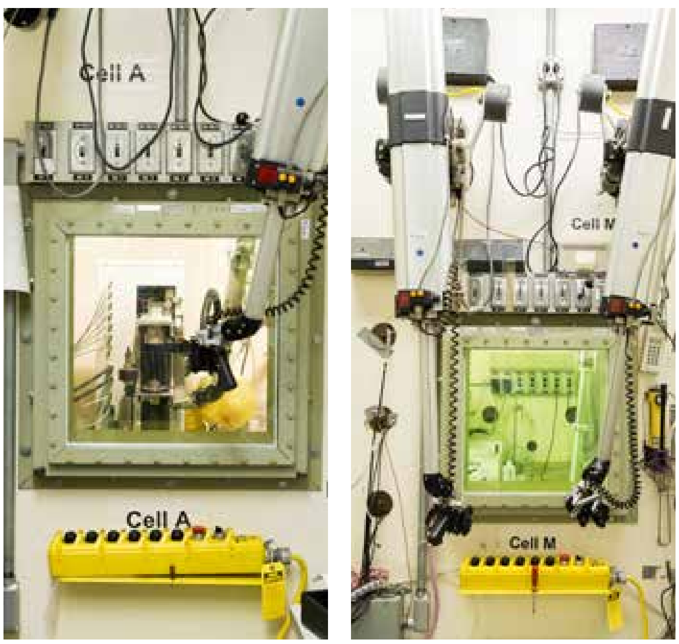
Initial stages of in-cell machining of a tensile specimen from a highly irradiated bolt

A and M Auxiliary Hot Cells

The A and M auxiliary cells are both fabricated from multiple steel plates, approximately 10 inches thick. These two cells have dimensions of 6 feet long x 6 feet deep x 11.5 feet high. The A and M cells are stand-alone isolation cells and are not connected to each other or to the high-level and low-level cells.

Similarly to the high- and low-level cells, the A and M cells are multifunctional and are routinely reconfigured to meet the needs of a particular project or customer.

Examples of work we perform in these two cells includes: loading and unloading of autoclaves, hydrogen analysis, laser micrometer measurements, metallographic specimen preparation and laser welding.



Auxiliary hot cell A (left) and M (right)

SEM Hot Cell

A small, isolated hot cell solely dedicated to SEM evaluations of highly irradiated samples is located a floor above the high-level hot cell. An elevator consisting of a small specimen platform and a gear-motor-driven cable connects the high-level hot cell to the SEM hot cell, thus allowing transfer of highly irradiated specimens from the high-level cell directly into the SEM hot cell.

The SEM is not located inside the SEM hot cell but instead abuts one of the SEM hot cell walls. An access door in the hot cell wall can be opened and the SEM, which is positioned on a moveable track system, can be slid into place against the hot cell wall. The SEM specimen chamber door opens into the hot cell, and manipulators are used to remotely move the specimen from the specimen elevator platform into the SEM specimen chamber.

We have upgraded this SEM to a 2012 Tescan Vega3 XMU, which is a variable pressure SEM enabling the investigation of non-conductive specimens in the uncoated condition.

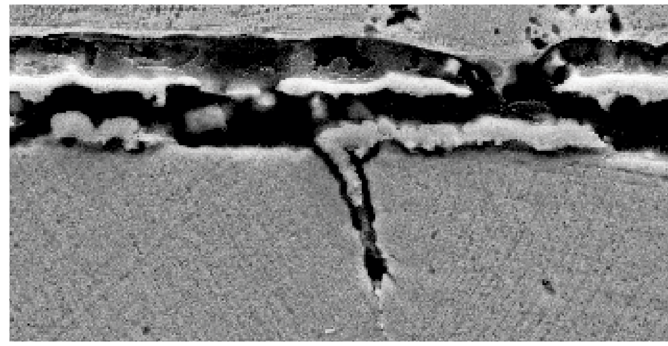
SEM hot cell viewing window with manipulator

Corrosion Laboratory

Our corrosion and stress corrosion cracking (SCC) laboratory consists of 22 fully automated autoclave pressure vessels. The autoclaves have pressure vessel capacities of one or two gallons and are rated up to 34.5 MPa (5,000 psi) and 482 degrees C (900 degrees F).

Four of the available autoclaves are equipped with load frames with load capabilities up to 2,720 kg (6,000 pounds). Each autoclave is automatically controlled with operating readouts sent to a central server. Researchers are able to access this information remotely from off-site, allowing for test monitoring and data interrogation.

Numerous specimen geometries and autoclave conditions can be used to evaluate a variety of material properties under temperature, pressure, environment and stress, including corrosion, wear, SCC initiation and SCC growth. Our laboratory contains the results for more than 100 test specimens and represents numerous different heats of stainless steel with specimen neutron exposures ranging from a low displacements per atom (dpa) value up to 76 dpa.



SCC along porous grain boundary in the absence of protective oxide surface films

Autoclaves equipped with load frames

Corrosion Testing of Irradiated Materials

Our MCOE personnel have extensive experience in corrosion testing of irradiated materials with an emphasis on irradiated-assisted SCC initiation testing. We have the largest crack initiation database worldwide for irradiated stainless steels.

(Left) Westinghouse's In-Cell Crack Growth Rate Test Assembly. (Right) Test fixture for loading six O-ring specimens for Internal Association for Six Sigma Certification (IASCC) initiation testing.

Analytical Chemistry Capabilities

Autotitration

We use the autotitration unit primarily for automated measurement of H_3BO_3 in autoclave water and the reactor coolant, and it can be modified to analyze other species as well. Radioactive specimens can be analyzed using this equipment.

Ion Chromatography

Our ion chromatography equipment detects minute quantities of anions and cations in water, using very little sampling volume. The equipment has low-ppb to sub-ppb limits of detection for common anions (F^-, Cl^-, Br^-, SO_4^{2-}, NO_2^-, NO_3^-, PO_3^-, etc.) and low-ppb levels of detection for polyatomic cations, alkali and alkaline earth metals and some transition metals. Radioactive specimens can be analyzed using this equipment.

Thermo-Dionex ICS-5000 Anion/Cation system with autosampler

Inductively Coupled Plasma-Mass Spectroscopy

Our inductively-coupled plasma-mass spectroscopy (ICP-MS) system measures elemental concentrations down to low-ppt levels.

We routinely characterize components of fuel crud and steam generator sludge using this equipment. In addition, we take measurements to determine alloy composition and to support autoclave testing. Radioactive specimens are analyzed using this equipment.

Agilent® 7700x ICP-MS with autosampler

Chemistry Laboratory

The Churchill site has a newly constructed and well-equipped chemistry laboratory for the evaluation of unirradiated materials. This laboratory contains six new fume hoods and substantial bench and cabinet space.

The following analytical equipment is contained in this laboratory:

- Gas chromatograph glovebox
- Ultra-violet visible spectrometer Electrochemical potentiostats
- Fourier transform spectrometer
- Thermogravimetric analyzer
- Inert atmosphere
- Electrochemical
- Particle size analyzer
- Zeta potential/data link server (DLS) instrument

Microwave Digestion

A microwave digestion system supports ICP-MS sample preparation. The system uses concentrated acids at up to 22ºC and 800 psig to achieve complete and rapid digestion of multiple intractable samples. This equipment is used to process radioactive samples.

CEM® MARS-5 Microwave Digestion System

Hydrogen Analysis

The LECO® RHEN-602 measures hydrogen in metal and oxide samples. We have one unit modified for remote operation in our hot cells and one unit for unirradiated specimen analysis.

Modified LECO RHEN-602 H-Analyzer (prior to hot cell installation)

Metallographic Specimen Preparation Laboratory

Unirradiated Metallographic Specimen Preparation Laboratory

We have a newly refurbished and well-appointed metallographic specimen preparation laboratory for preparing metallographic sections for both macroscopic and microscopic examination. It provides expert specimen sectioning, plating, mounting, grinding, polishing, cleaning, etching and pickling capabilities.

Two precision cutoff saws are available for initial specimen sectioning, if needed. Specimens can be hot mounted using one of two hot presses, and using either electrically conductive or non-conductive mounting compounds. They can be cold mounted using a variety of available resins. If specimen plating is desired for improved edge retention, we have a Cressington 108 auto-sputter coater for gold plating of specimens and a Technic, Inc. plating system for nickel plating of specimens.

The laboratory also has three automatic polishers, including a 2011 Struers® AbraPol-20 high-capacity programmable polishing machine. We provide complete polishing of specimens, including diamond suspensions down to grain sizes of 1.0 µm and, if requested, further polishing with a wide selection of active oxide suspensions down to grain sizes of 0.02 µm.

We also offer a wide variety of etching and pickling capabilities. Both standard and electrolytic etching methods can be performed in conjunction with a vast selection of metallographic etchants.

In addition, our laboratory includes three state-of-the-art Supreme Air® LV fume hoods. Two of the hoods are used for pickling/etching and acid neutralization. The third hood is dedicated to electrolytic polishing of foil specimens for transmission electron microscopy examination.

Metallographic preparation laboratory with example of as-polished samples

Irradiated Metallographic Specimen Preparation

We offer irradiated metallographic specimen preparation facilities in a restricted access, radiologically controlled work area behind the hot cells. This area allows for complete metallographic preparation of moderately irradiated and contaminated specimens. For highly irradiated or contaminated specimens, specimen preparation must be performed remotely in the M auxiliary hot cell.

Light Optical Microscopy

A full range of light optical microscopes are available for evaluation of both unirradiated and irradiated materials. A majority of the microscopes are connected to a site-wide imaging software, image analysis and image database system.

Specimen analysis and optical microscopy laboratory with example of digitized microstructure being evaluated

Mechanical Testing Capabilities

We offer multiple types of mechanical testing capabilities, both for unirradiated and irradiated materials.

Out-of-cell mechanical testing lab includes six additional test frames:

- Four MTS test frames (three servo-hydraulic frames and one electromechanical frame) ranging from 6,750 to 100,000-pound load capacity
- Two Instron® test frames (one servo-hydraulic and one electromechanical) ranging from 25,000- to 50,000-pound load capacity

In-cell mechanical testing includes the following equipment:

- 90 KN (20,000-pound) servo-hydraulic test machine (for J, K and master curve testing)
- Instron 250-KN (56,000-pound) screw-driven tensile machine (2011)
- 358J (254 ft-lb) Charpy impact test machine (instrumented for load-time data collection per ASTM E2298) (upgraded 2009)
- Creep tests can be performed in environments (i.e., 7,500-pound load frames attached to four 5,000 psi/900 degrees F autoclaves)
- Similar to creep testing, crack growth rate testing of irradiated materials can be performed in autoclave environments

Satec Systems Model 30WBN screw tensile machine

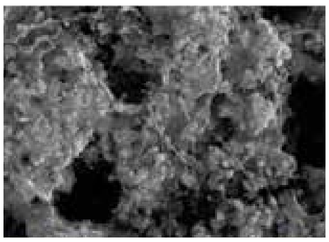
MTS Criterion Model 43 table top tensile tester with environmental chamber, show in close-up on right

The Churchill site's laboratory facilities include four SEMs, each with varying capabilities, as summarized below.

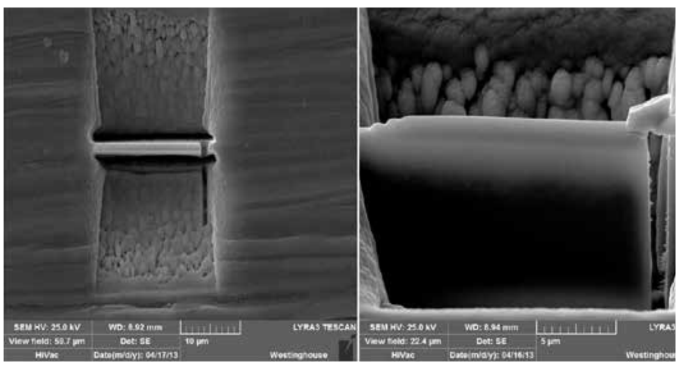
Tescan LYRA-3 GMU FIB/SEM

- Dual beam FIB, which is a variable pressure SEM with an Orsay Physics Canion focused ion beam (FIB) column
- Equipped with Oxford Instruments XMax 80 x-ray energy-dispersive spectroscopy (XEDS), Oxford electron backscatter diffraction (EBSD) detector, low vacuum secondary electron detector, mono-gas injection system and sample manipulator for making transmission electron microscope (TEM) lamella of irradiated materials
- Analysis of radioactive specimens can be performed using this equipment

Oxide deposits on the inside diameter surface of an Alloy 600 steam generator tube



High-resolution image of boiling chimneys in a fuel crud flake



FIB preparation of irradiated stainless steel specimen for subsequent transmission electron microscopy evaluation

Zeiss SUPRA-40 FE-SEM

- High resolution SEM for evaluation of unirradiated specimens
- Equipped with an 80 mm² silicon drift detector (SDD) XEDS detector for ultra-high count rates for elemental identification and mapping (ideally suited for high-resolution/low voltage imaging of non-conductive specimens)
- Equipped with a fast EBSD detector/camera for grain orientation and crystallographic information of polished samples

Tescan Vega-3 XMU SEM

- Attached to SEM hot cell (refer to SEM Hot Cell section)
- Analysis of radioactive specimens can be performed using this equipment

Zeiss® SUPRA-40 FE-SEM

Tescan Vega-3 XMU SEM (attached to SEM hot cell)

Tescan LYRA-3 GMU FIB/SEM

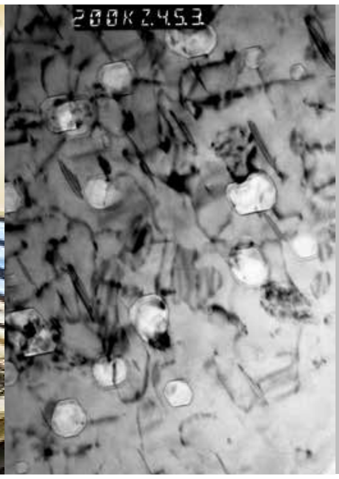
Transmission Electron Microscopy

Our TEM is an FEI CM30 with a scanning transmission electron microscope (STEM) detector with a LaB^6 source. This TEM is also equipped with a Si (Li) X-ray energy-dispersive spectroscopy detector for TEM-XEDS and STEM-XEDS analysis. Radioactive specimens can be analyzed using this equipment.

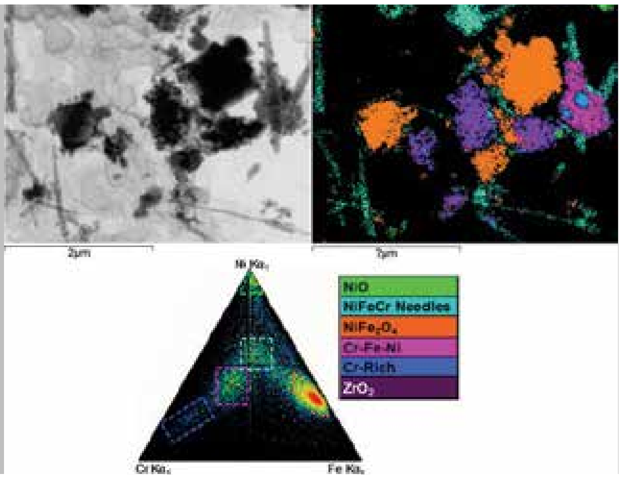
Specimen Preparation

We can provide both conventional grinding, polishing, and etching to perforation of TEM specimens, as well as FIB TEM specimen preparation.

FEI CM30 300-KV TEM equipped with an Oxford Instruments Si Li EDS system



TEM micrograph of highly neutron irradiated (i.e., ~33 dpa) stainless steel



STEM-XEDS of dispersed fuel crud

X-Ray Diffraction

X-ray diffraction (XRD) identifies materials by measuring diffracted X-rays from microcrystalline samples. Our XRD has a high-speed Si strip detector, which has increased data acquisition times by approximately 20 to 100 fold. In addition, the equipment includes specialized X-ray optics for performing X-ray micro-diffraction and residual stress measurements.

Radioactive specimens can be analyzed using this equipment.

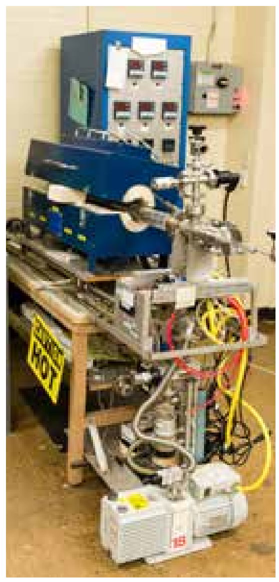
PANalytical® X'Pert Pro MPD X-ray diffractometer

Furnace Laboratory

Our furnace laboratory includes three 3M® Blue Box programmable air furnaces, a vacuum furnace and two biaxial creep furnaces, which allow for thermal annealing studies, hydriding experiments and quenching evaluations.

Multiple additional furnaces are located throughout the site in other laboratories.

3M Blue Box air furnaces



Biaxial creep furnaces

Vacuum furnace

Balance Laboratory

The Churchill site's facilities include a precision balance laboratory for high accuracy weight measurements of solid samples. To maintain cleanliness, we do not permit analysis of powder or chemical specimens in this laboratory.

This laboratory also includes two Mettler Toledo® DeltaRange™ high-precision balances positioned on granite tables and a Keyence® LS-7601 high- speed, high-accuracy charge-coupled device (CCD) digital micrometer.

We use the balances for a wide variety of specimen weight measurements, including pre- and post-exposure measurements of corrosion, oxidation and hydriding specimens. We use the digital micrometer for high-accuracy dimensional measurements on numerous types of laboratory specimens; it has a repeat measurement accuracy of +0.15 µm.

High precision balance

CCD digital micrometer

Machine Shops

Our machine shop capabilities include two cold machine shops and one hot machine shop, which are well equipped with lathes, drill presses, band saws, cut-off wheels, milling machines, grinding equipment, shear and bending equipment, large belt and flat sanding equipment. These on-site machining capabilities are invaluable for rapid in-house machining of many needed custom tools, fixtures, test rig components and specimens without using outside vendors.

Two of the machine shops machine radiologically-clean materials, with additional machining capabilities available for machining of both contaminated and irradiated materials, including expert hot in-cell machining capabilities.

Machine shop band saw, drill press, lathe and milling machines

Calibration Laboratory

To ensure measurement accuracy, personnel follow a rigorous equipment calibration program that is defined and controlled by detailed Westinghouse procedures. Currently, the site maintains approximately 400 pieces of calibrated laboratory equipment including inspection, measurement and test equipment. The majority of all equipment calibrations are performed annually.

www.westinghouse**nuclear.**com

11952