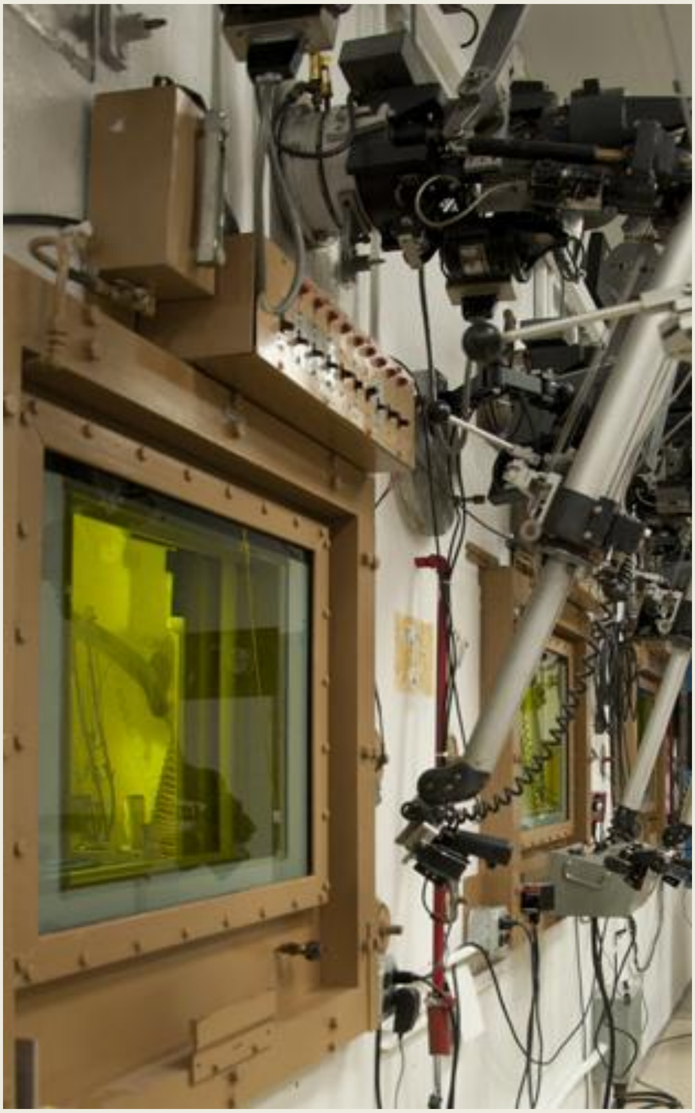
1332 Beulah Road
Pittsburgh, PA 15235 USA

A Proud ATR NSUF Partner Laboratory

Materials Center of Excellence (MCOE)

Hot Cell Facility and Laboratories

August 2014



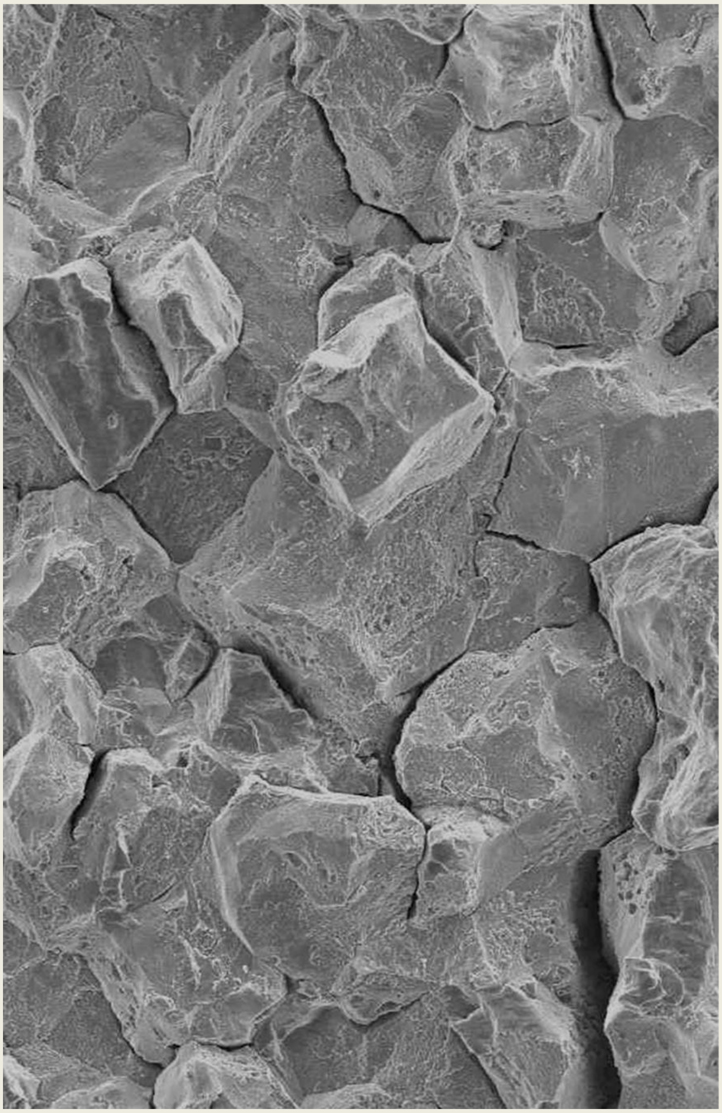


Table of Contents

Capabilities Overview

The Westinghouse MCOE Hot Cell Facility and Laboratories are located in Churchill, Pennsylvania (USA), approximately 7 miles east of Pittsburgh. The facilities provide a unique combination of experienced personnel and laboratory capabilities.

The facility specializes in materials evaluations through laboratory testing of both unirradiated and irradiated materials. Our staff, which represents over 700 combined years of materials evaluation experience, supports a broad range of worldwide customers including, but not limited to, nuclear utilities, universities, and government entities.

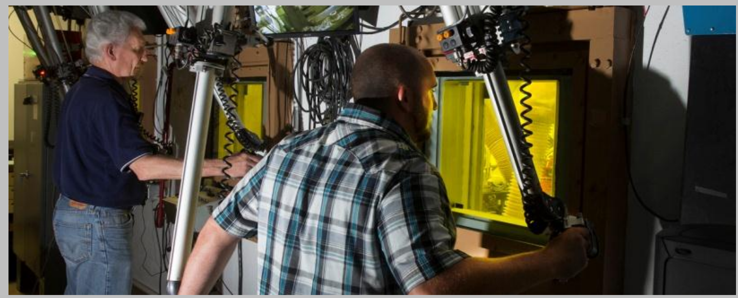
We offer a 'one-stop-shop' approach to our customers in that we can arrange for shipment of test materials to and from our laboratories and we offer final radiological waste disposal upon completion of the work effort. Further, we can supply long term secure storage of test materials upon request.

The site, although in existence since 1955, has recently undergone a multi-million dollar renovation including upgrading of a majority of the laboratory's capabilities. Currently, the facility predominantly consists of two buildings containing laboratory and office space along with several additional auxiliary buildings.

Westinghouse Materials Center of Excellence Laboratories and Hot Cell Facility, Churchill, Pennsylvania (USA)

The facility is a restricted-access secure site but we welcome both national and international customers and researchers to observe, over-see, and in many instances, actively participate in on-going work.

The site includes extensive laboratories for the evaluation of both irradiated and unirradiated materials. Facilities include, but are not limited to, 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 which are available worldwide within Westinghouse and our affiliate and subsidiary companies.



MCOE radiological technicians operating hot cell manipulators

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.

As a commercial facility, we are able to offer both fixed-price and time and material contracts with standard terms and conditions and we are fully committed to completing work for our customers on-budget and on-schedule.

Our overriding objective is to provide our customers with the data they require in a flexible but safe working environment. We are exceptionally proud of our superior safety record which has enabled us to operate continuously for almost 40 years. We have never experienced a stop-work event and we have not had a lost work-time incident of any kind in over twelve years.

Specific Areas of Expertise Include:

- Nearly 40 years of site operations with in-depth experience 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
- Leading experts in surveillance capsule design, fabrication and examination
- Custom design and fabrication of irradiated materials testing hardware
- Fuel crud and sludge analysis expertise
- Radioactive material shipping and disposal expertise
- Nondestructive evaluation expertise

MCOE'S Mission

Provide experimental evidence to support materials and processing solutions for our customers and support industry technical initiatives.

Hot Cells – High Level and Low Level Hot Cells

The Westinghouse Hot Cell facility includes five individual hot cells which are referred to as the high level cell, the low level cell, the A cell, the M cell and the SEM cell. The hot cell facilities consists of a total of 10 remote handling stations with shielded viewing windows and manipulators.

Four of the hot cells are multi-functional in that the equipment inside these cells is routinely re-configured as needed to meet the requirements of our customers. When not in use, contaminated equipment is stored on-site in our radiological storage building. The fifth hot cell is solely dedicated to scanning electron microscopy (SEM) examinations of highly irradiated materials.

Three of the cells became operational in 1975 and two additional cells were subsequently built and became operational in1992. All five hot cells have been operating continuously since start-up. During this time, it is estimated that approximately 700 hot cell projects have been completed for a wide variety of world wide customers.

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 (i.e., 24’ L x 5’ D x 12’ H) and is constructed with extremely thick high density poured concrete walls (i.e., minimum wall thickness of 27”) for additional radiological shielding.

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

The high level cell is multi-functional and is routinely re-configured to meet the needs of our customers. Work performed in this cell includes, but is not limited to, machining, cutting, grinding, milling, photography, ultrasonic measurements, etc.

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.

MCOE radiological technician performing work in the high level hot cell using remote cameras and live video feed monitors

MCOE’s high level hot cell with four remote handling stations (right) and low level hot cell with three remote handling stations (left)

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’ L x 6’ D x 10’ H and is constructed with 12” to 24” thick poured concrete walls.

The low level cell has 3 remote handling stations and, like the high level cell, is equipped with multiple remote cameras with live video feed viewing monitors.

This cell is multi-functional and is routinely re-configured to meet the needs of our customers. Work performed in this cell includes, but is not limited to, Charpy testing, tensile testing, immersion density measurements, eddy current examinations, photography, dimensional measurements, etc.

A through-wall transfer tube connects the high level hot cell and the low level hot cell. This transfer tube allows the transfer of specimens and tools between the two cells.

Background radiation fields in the low level cell are generally of the order of 400 Rad/hour.

Eddy current examination in low level hot cell of approximately 800 pound section with full penetration flame cut from retired reactor pressure vessel head

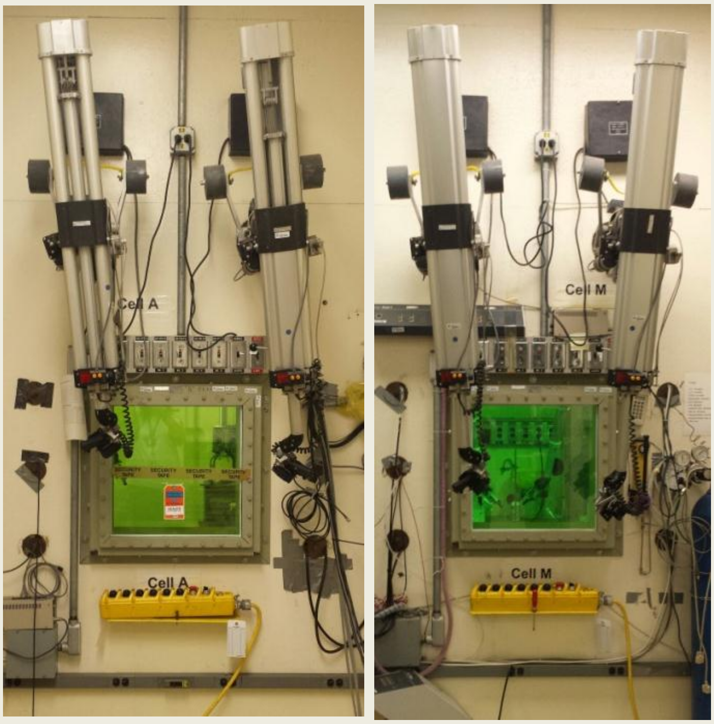
Hot Cells – Auxiliary Hot Cells and SEM Hot Cell

A and M Auxiliary Hot Cells

The A and M auxiliary cells are both fabricated from multiple steel plates approximately 10” thick. These two cells have dimensions of 6’ L x 6’ D x 11.5’ H. 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 multi-functional and are routinely re-configured to meet the needs of any particular project or customer.

Examples of work performed in these two cells include, but are not limited to, loading and unloading of autoclaves, hydrogen analysis, laser micrometer measurements, metallographic specimen preparation, laser welding, etc.



MCOE auxiliary hot cell A (left) and M (right)

SEM Hot Cell

A small isolated hot cell solely dedicated to scanning electron microscopy (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 therefore 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.

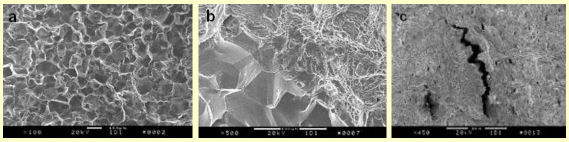
We have upgraded this SEM to a 2012 Tescan Vega3 XMU which is a variable pressure SEM enabling the investigation of non-conductive specimens in the uncoated condition.

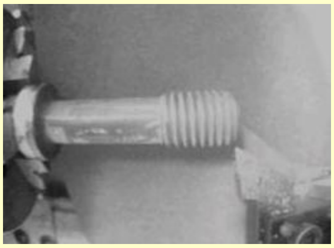
MCOE SEM hot cell viewing window with manipulator (left) and 2012 Tescan Vega3 XMU SEM (right)

Expert In-Cell Machining, Testing, Welding and Measurement Capabilities

MCOE has extensive expertise regarding in-cell machining, testing and measurements. Capabilities include in-cell machining of test specimens from a wide range of irradiated components and/or part shapes. We have in-cell machined thousands of o-rings, tensile specimens, compact tension specimens, fracture toughness specimens, etc.

In-cell testing capabilities include, but are not limited to, tensile, fracture toughness, compression, crack growth rate, slow strain rate, etc.





Thread removal

Head removal

Initial stages of in-cell machining of a tensile specimen from a highly irradiated bolt (thread removal)

Radioactive Materials Support

Storage

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

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

Shipping

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

Disposal

MCOE can support 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 U.S.

Westinghouse irradiated surveillance capsule shipping casks

Corrosion Laboratory

The MCOE corrosion and stress corrosion cracking (SCC) laboratory consists of 22 fully automated autoclave pressure vessels. The autoclaves have pressure vessel capacities of 1 or 2 gallons and are rated up to 34.5 MPa (5,000 psi) and 482°C (900°F).

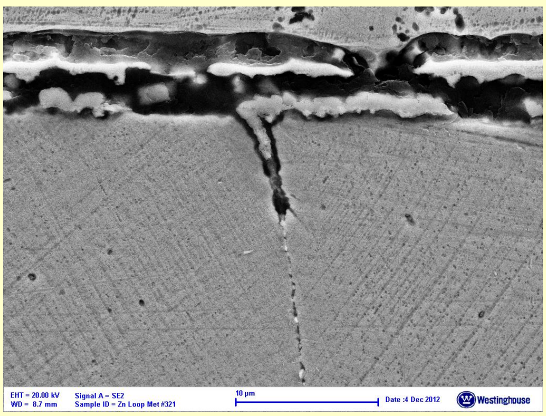
Four of the available autoclaves are equipped with load frames with load capabilities up to 2,720 kg (6,000 lbs).

Each autoclave is automatically controlled with operating read outs sent to a central server. MCOE researchers are able to access this information remotely from off-site allowing for test monitoring and data interrogation.

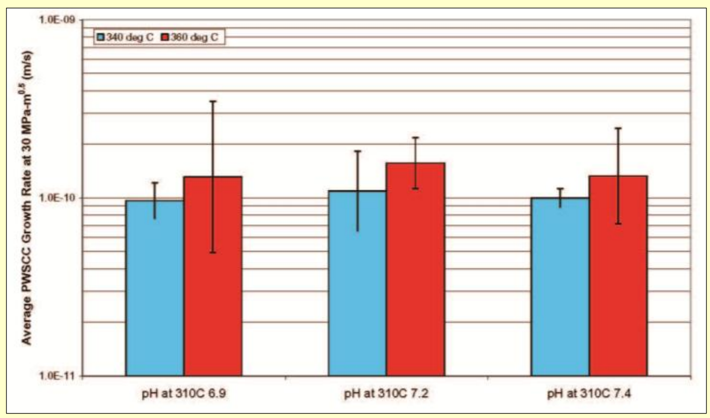
Numerous specimen geometries and autoclave conditions can be utilized to evaluate a variety of material properties under temperature, pressure, environment and stress, including, but not limited to, corrosion, wear, SCC initiation, and SCC growth.

Autoclave laboratory (18 of the 22 available autoclaves shown)

Autoclaves equipped with load frames



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



Average crack growth rates as a function of pH for Alloy 718 at 644°F and 680°F (340°C and 360°C); data normalized to K = 30 MPa√m

Corrosion Testing of Irradiated Materials

MCOE has extensive background in corrosion testing of irradiated materials with an emphasis on irradiated assisted stress corrosion crack initiation testing. We have developed the largest crack initiation database worldwide for irradiated stainless steels; the database contains results for greater than 100 test specimens. Note that the results included in this database represents numerous different heats of stainless steel with specimen neutron exposures ranging from low dpa up to 76 dpa.

MCOE is currently refurbishing our irradiated autoclave facilities. The new facilities will include state of the art equipment with initial testing focusing on crack initiation with subsequent crack growth rate testing capabilities.

Westinghouse

Analytical Chemistry Capabilities

Chemistry Laboratory

MCOE 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:

- GC
- UV-VIS
- FTIR
- TGA
- Inert atmosphere glovebox
- Electrochemical potentiostats
- Particle size analyzer
- Zeta Potential/DLS instrument

Ion Chromatography

MCOE's ion chromatography equipment is used to detect 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_4^{3-}, etc.) and low-ppb levels of detection for polyatomic cations, alkali and alkaline earth metals and some transition metals.

Analysis of radioactive specimens can be performed using this equipment.

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

Autotitration

The autotitration unit is used primarily for automated measurement of H_3BO_3 in autoclave water and reactor coolant, and can be modified to analyze other species as well.

Analysis of radioactive specimens can be performed using this equipment.

Microwave Digestion

A microwave digestion system is available to support ICP-MS sample preparation. The system used concentrated acids at up to 22C 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

Inductively Coupled Plasma-Mass Spectroscopy

MCOE's inductively coupled plasma-mass spectroscopy (ICP-MS) system is used to measure elemental concentrations down to low ppt levels.

Components of fuel crud and steam generator sludge are routinely characterized using this equipment. In addition, measurements to determine alloy composition and to support autoclave testing are also performed.

Analysis of radioactive specimens can be performed using this equipment.

Agilent 7700x ICP-MS with autosampler

Hydrogen Analysis

The LECO RHEN-602 measures hydrogen in metal and oxide samples. MCOE has 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

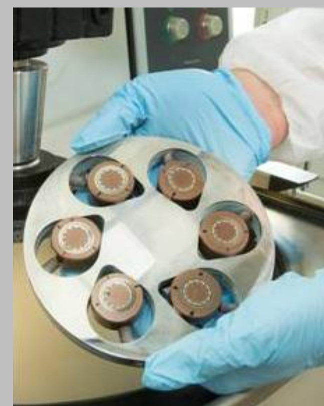
MCOE has a newly refurbished and well appointed metallographic specimen preparation laboratory for preparing metallographic sections for both macroscopic and microscopic examination. The laboratory provides expert specimen sectioning, plating, mounting, grinding, polishing, cleaning, etching and pickling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

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

The laboratory is equipped with three automatic polishers, including a 2011 Struers AbraPol-20 high capacity programmable polishing machine. Complete polishing of specimens can be provided, including diamond suspensions down to grain sizes of 1 μm and, if requested, further polishing with a wide selection of active oxide suspensions down to grain sizes of 0.02 μm.

A wide variety of etching and pickling capabilities are available. Both standard and electrolytic etching methods can be performed in conjunction with a vast selection of metallographic etchants.

The laboratory includes 3 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.

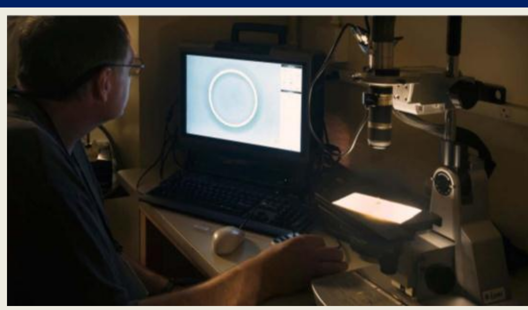


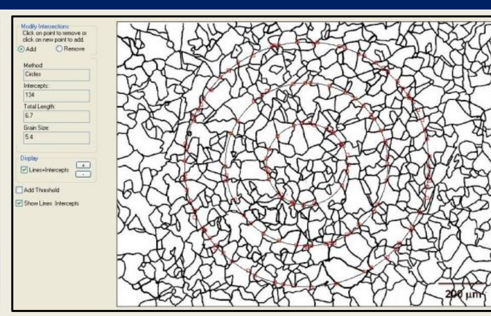
Irradiated Metallographic Specimen Preparation

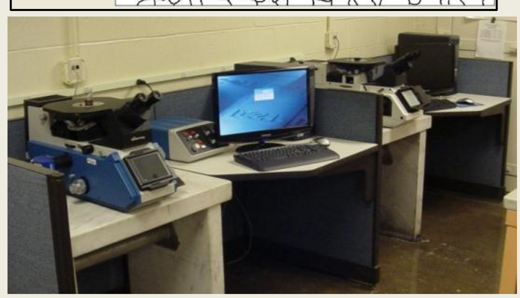
Irradiated metallographic specimen preparation facilities are contained in a restricted-access radiologically controlled work area located behind the MCOE Hot Cells. This area allows for complete metallographic preparation of moderately irradiated and contaminated specimens. For highly irradiated or 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 use for the 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.







Scanning Electron Microscopy

The MCOE laboratory facilities includes four scanning electron microscopes (SEMs), each with varying capabilities. A summary of these instruments and their uses is as follows:

Tescan LYRA-3 GMU FIB/SEM

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

Zeiss SUPRA-40 FE-SEM

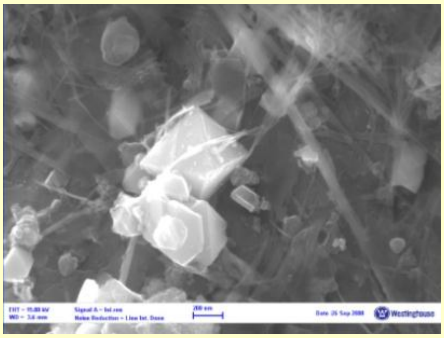
- High resolution SEM for evaluation of unirradiated specimens
- Equipped with an 80mm^2 SDD XEDS detector for ultra-high count rates for elemental identification and mapping (ideally suited for high-res/low voltage imaging of non-conductive specimens)
- Equipped with a fast EBSD detector/camera for grain orientation and crystallographic information of polished samples

Tescan Vega-3 XMU SEM

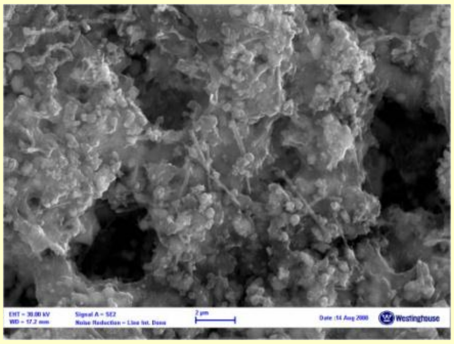
- Attached to SEM Hot Cell (refer to Hot Cell section)
- Analysis of radioactive specimens can be performed using this equipment

RJ Lee (now ASPEX) PSEM

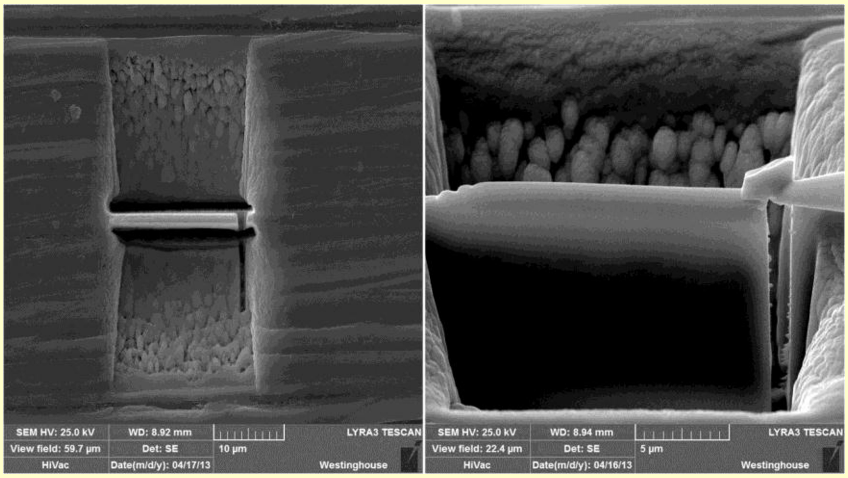
- Variable pressure SEM with a large specimen chamber for the evaluation of large components
- Equipped with EDS capabilities (SiLi detector)
- Analysis of radioactive specimens can be performed using this equipment



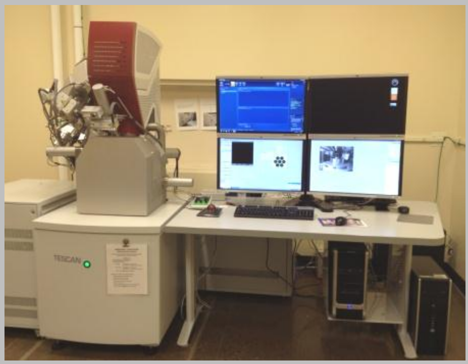
Oxide deposits on the ID surface of an Alloy 600 steam generator tube



High resolution image of boiling chimneys in a fuel crud flake



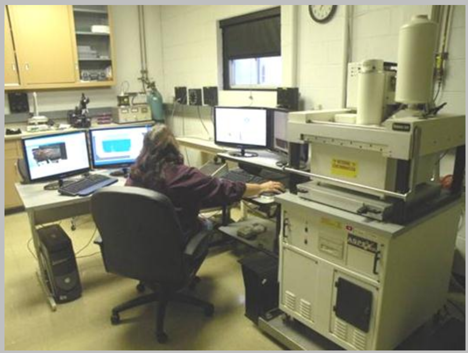
FIB preparation of irradiated stainless steel specimen for subsequent transmission electron microscopy evaluation



Tescan LYRA-3 GMU FIB/SEM

Zeiss SUPRA-40 FE-SEM

Tescan Vega-3 XMU SEM (attached to SEM Hot Cell)



ASPEX Variable Pressure SEM

Transmission Electron Microscopy

MCOE's transmission electron microscope (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 (XEDS) detector for TEM-XEDS and STEM-XEDS analysis.

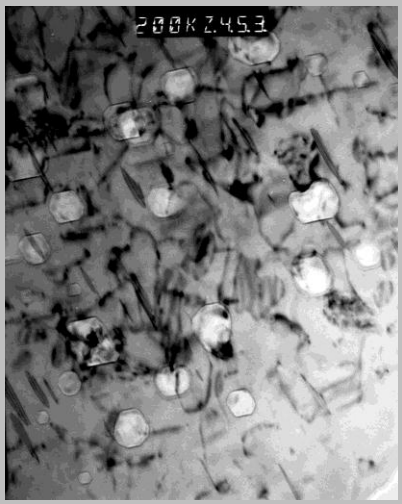
For TEM imaging, we will be installing (if I recall correctly) a Gatan Orius SC1000B, which is an 11 MP CCD camera in late August.

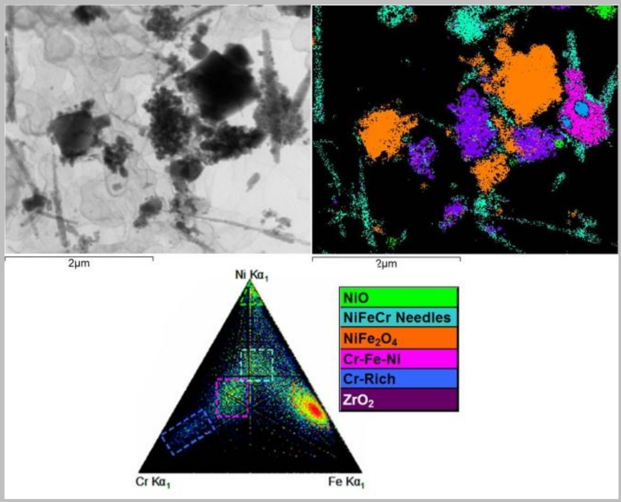
Analysis of radioactive specimens can be performed using this equipment.

Specimen Preparation

MCOE 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

Auger Electron Spectroscopy

Auger electron spectroscopy (AES) is used to determine the elemental composition of conductive and semiconductive surfaces by detecting Auger electrons emitted from the top few angstroms of a specimen surface. The kinetic energy spectrum of the electrons is analyzed to identify the atom of the electron's origin and its concentration. By using an argon sputtering gun to remove successive layers from the surface, elemental depth profiling can also be obtained.

MCOE's AES is equipped with an *in situ* fracture stage permitting the chemical analysis of pristine fracture surfaces.

Analysis of radioactive specimens can be performed using this equipment.

VG Microlab 310D Auger Electron Spectrometer

X-Ray Diffraction

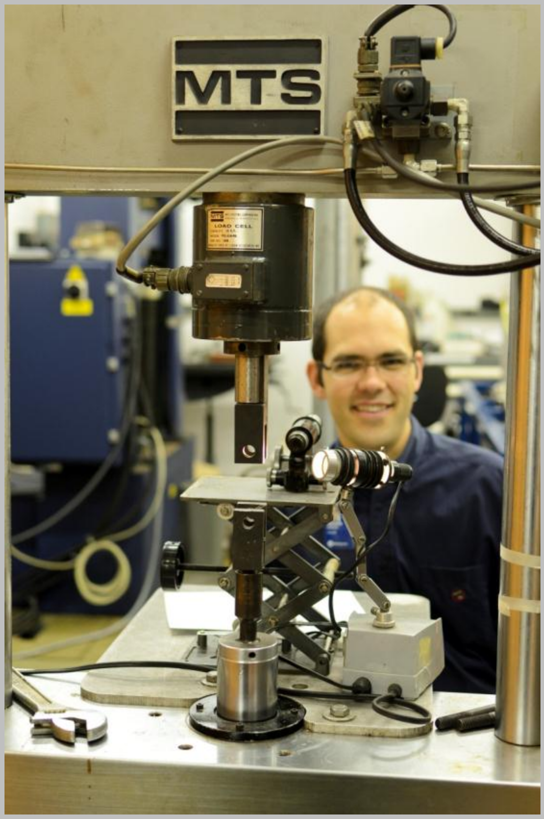
X-ray diffraction (XRD) identifies materials by measuring diffracted X-rays from microcrystalline sample. MCOE's XRD is equipped with a high speed Si strip detector, which has increased our data acquisition times by approximately 20 to 100 times. In addition, the equipment includes specialized X-ray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

Analysis of radioactive specimens can be performed using this equipment.


PANalytical X'Pert Pro MPD X-Ray Diffractometer

Mechanical Testing Capabilities

Multiple types of mechanical testing capabilities are available, both for unirradiated and irradiated materials.



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

- 4 MTS test frames (3 servo hydraulic frames and 1 electromechanical frame) ranging from 6,750 lb to 100,000 lb load capacity
- 2 Instron test frames (1 servo hydraulic and 1 electromechanical) ranging from 25,000 lb to 50,000 lb load capacity

In-cell mechanical testing includes the following equipment:

- 90 KN (20,000 lb) servo-hydraulic test machine (for J, K and master curve testing)
- Instron 250 KN (56,000 lb) 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 lb load frames attached to four 5,000 psi/900°F autoclaves)
- Similar to creep testing, crack growth rate testing of irradiated materials can be performed in autoclave environments

Custom Testing Facilities

Westinghouse Advanced Loop Tester

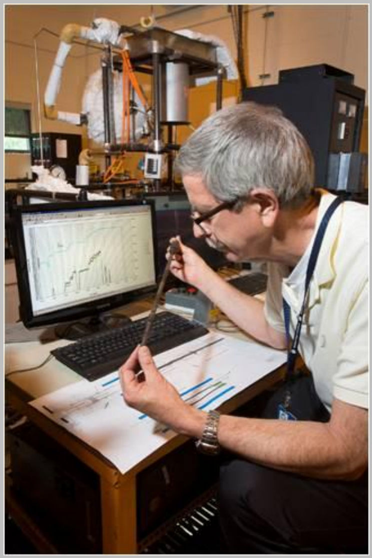
The Westinghouse Advanced Loop Tester, or more generally referred to as the WALT Loop, was custom designed and fabricated at the Westinghouse laboratories. This facility deposits representative crud on a single fuel rod allowing for the study of fuel crud thermal hydraulics.

In this test loop, crud with characteristics similar to that formed in operating pressurized water reactors (PWRs) is deposited on a heated rod surface. Crud thermal parameter variations as a function of crud thickness , crud morphology, and fluid conditions can be directly measured and systematically evaluated using this unique facility.

This test facility has been utilized 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 Electric Power Research Institute program to assess the impact of zinc addition to PWR reactor coolant

Westinghouse Advanced Loop Tester



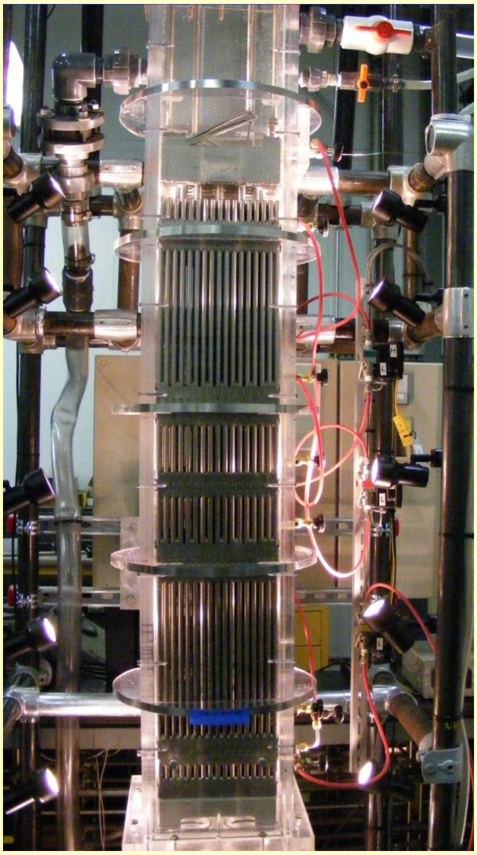
Visual examination of fuel rod after WALT exposure

Loss of Coolant Accident Debris Blockage Test Facility

This custom designed and fabricated test facility is used to perform testing 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).

Tests are performed on representative 1/3 height scale fuel assemblies using various fiber, particulate, and chemical precipitate debris loads to examine the pressure drop across the fuel assembly. Tests also examine the effect of various fuel inlet nozzle designs on debris capture and flow blockage. The objective of this testing is to identify the maximum sump strainer debris bypass loads which can be tolerated in a LOCA event which do not result in unacceptable pressure drops across the mock-up fuel assembly.

The test loop is composed 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.



LOCA Debris Blockage Test Facility

Thermal Hydraulics Testing High Bay

A versatile high bay facility is available and is dedicated to thermal hydraulic testing. The ceiling height of 43 feet allows the design and fabrication of various large test loops and hence, the testing of large components.

Two test loops are currently being built for measuring the potential for core inlet blockage; the 4" Intermediate Loop and the Chemical Effects Loop.

Plans are also in place for building two additional test facilities in this high bay, one to measure condensation flow on AP1000 containment domes, and another to evaluate moisture separator performance.

Design and Fabrication of the 4” Intermediate Loop

Design and Fabrication of the Chemical Effects Loop

Westinghouse

Custom Testing Facilities

Zinc Effects Test Loop

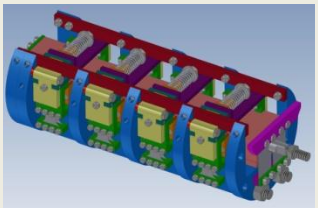
Multi-year crack initiation testing is being performed is this unique test loop to demonstrate that zinc additions to the primary system of operating pressurized water reactors (PWRs) increases the primary water stress corrosion cracking (PWSCC) resistance in Alloy 600 and associated Alloy 82/182 weld metals.

Specimens machined from control rod drive mechanism nozzles and reactor vessel outlet nozzles from three PWRs are currently in test. Zinc injection was performed for over 10 years in one of the PWRs prior to removal of the nozzle material while the other two PWRs did not inject zinc.

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

Wear Test Rig

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



High Temperature Steam Oxidation Unit

This test unit provides high temperature steam exposures of numerous specimens simultaneously to evaluate the effects of oxidation on the behavior of fuel cladding alloys under simulated loss of coolant accident conditions. Multiple specimens are exposed to flowing steam for predetermined times at temperatures up to 1200°C (2192°F). A water quench of the specimens is typically performed immediately after steam exposure. Testing is being performed to evaluate the behavior of new fuel cladding alloys under development by Westinghouse and to support new regulator guidelines.

Reactor Coolant Pump Seal Testing Laboratory

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

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

The facility has been developed and improved over the last five years and has supported hundreds of mechanical seal tests.

Surveillance Capsule Fabrication and Testing

Fabrication

Westinghouse has fabricated approximately 450 surveillance capsules for the world-wide commercial nuclear fleet. Fabrication began in the 1960s at the previous location of the Westinghouse Research Laboratories with the first capsule fabricated at the current MCOE Churchill site in 1974.

A commercial nuclear power plant contains six to eight surveillance capsules located inside the reactor vessel. The surveillance capsules contain mechanical property specimens machined from the identical heat of material used to fabricate the reactor pressure vessel.

Specimens machined from plates, forgings, welds and heat affected zone material are included in the capsule and include Charpy V-notch, tensile and fracture mechanics specimens. Westinghouse maintains a secure storage facility containing approximately 350,000 lbs of archive pressure vessel steel material.

Dosimeters, including pure Fe, Ni, Cu, Nb, Al-Co (0.15 percent Co) and Cd 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 lbs of material

Machining of surveillance capsule test specimens from archive material ingot

Fabrication and assembly of surveillance capsules for Westinghouse's AP1000 plants currently under construction in China

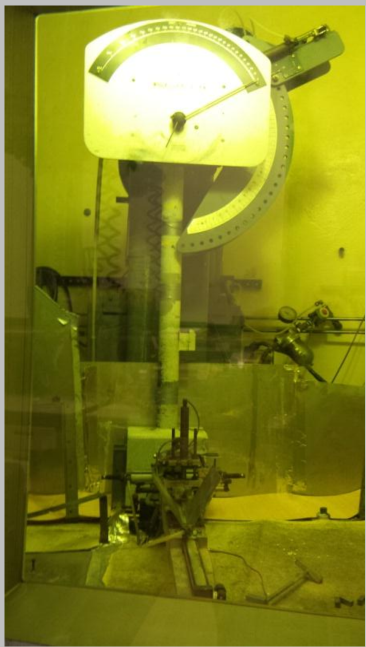
Testing

Irradiated surveillance capsules are removed from the reactor during normal refueling periods over the design life of the plant. The schedule for removal is based on requirements set forth in ASTM E 185-82.

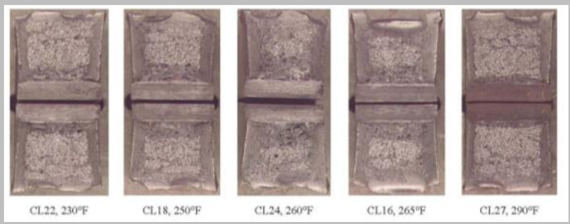
The irradiated surveillance capsules are removed from the reactor vessel and shipped to the Westinghouse MCOE hot cell facilities. Post-irradiation testing and evaluation of the surveillance capsule specimens monitor the effects of neutron irradiation on the reactor vessel beltline materials exposed to actual operating conditions.

MCOE performs the post-irradiation testing and evaluation of the reactor vessel material specimens and thermal monitors; testing is performed remotely in the MCOE hot cells. Westinghouse's Radiation and Analysis group analyzes the dosimeters contained in the surveillance capsule and calculates the neutron fluence exposure.

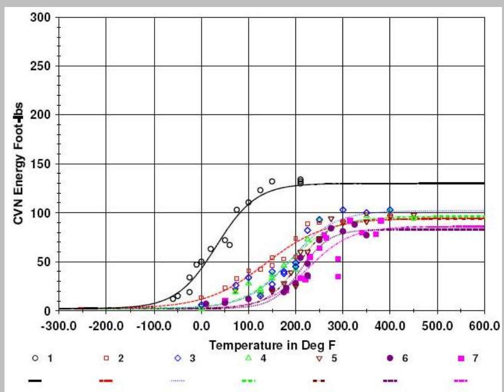
MCOE has tested approximately 185 surveillance capsules for commercial plants world wide. This equates to hot cell testing of over approximately 10,000 irradiated Charpy specimens and approximately 2,000 irradiated tensile specimens.



In-cell Charpy V-notch test machine



Irradiated Charpy V-notch specimen post-test fracture surface appearance



Charpy V-notch impact energy as a function of test temperature for six irradiated surveillance capsules and corresponding unirradiated material

Failure Analysis Services

MCOE provides a broad range of failure analysis services for unirradiated and irradiated components. Recent examinations have included austenitic stainless steel lines, electrical components, pressurizer heaters, pump seals, carbon steel lines, baffle bolts, zirconium in-core instrumentation components, springs, and CRDM heat penetrations.

Cracked pressurizer heater

Cracked reactor coolant pump shaft

Investigative techniques include, but are not limited to:

Surface Examinations

A visual examination of the as-received component is typically performed with the results of this examination generally documented with high resolution digital photographs. The examination documents the overall condition of the as-received component as well as any unusual findings such as the presence of surface defects, discoloration, oxidation, corrosion, pitting, wear, cracking, deformation, etc. The results from the initial surface examinations help to define subsequent component sectioning and further examinations.

Non-Destructive Examinations

Non-destructive examinations including dye penetrant exams, ultrasonic testing and/or eddy current testing can be provided.

Metallographic Examinations

Metallographic examinations can be performed to determine material microstructure, i.e., grain size, inclusion distribution, etc. Examinations can be conducted on selected cross sections removed from the part which can be taken transversely to any cracks present in the component. The metallographic examinations are normally conducted 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. Information regarding potential surface attack phenomena, crack initiation location, crack propagation direction, crack morphology, etc. can be obtained.

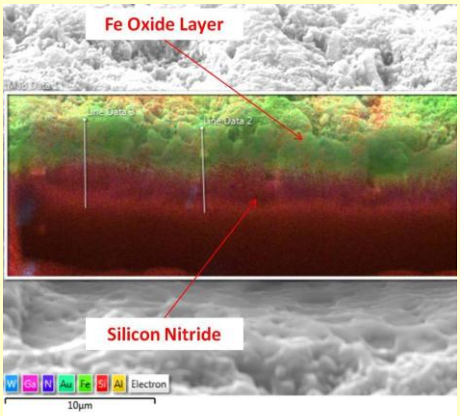
Fractographic Examinations

Fractographic examinations are conducted on open crack surfaces, if present, to establish the crack initiation site(s), propagation direction(s), and the general cracking morphology. The fractographic examinations can be conducted by light optical and scanning electron microscopy techniques to establish the presence of beach marks and fatigue striations or to establish if cracking exhibits an transgranular or intergranular morphology. The results are typically documented using photographs.

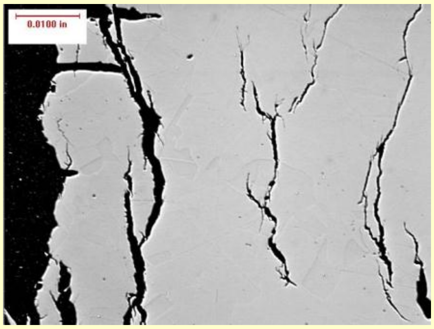
Chemical Evaluations

Chemical evaluations can be provided on the base material, surface deposits, crack deposits, weld metals, etc. Analyses can be performed using energy dispersive spectroscopy techniques, X-ray diffraction and/or wet chemical analysis techniques. Detailed surface characterization can be performed using a SEM-EDS equipped with a focused ion beam mill.

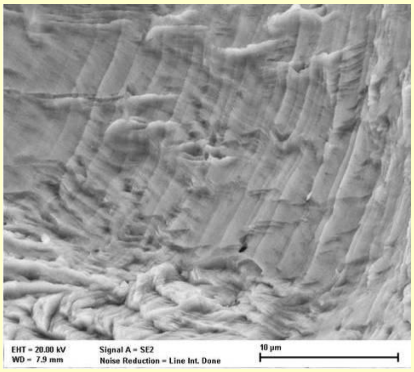
Pitting from microbial attack



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

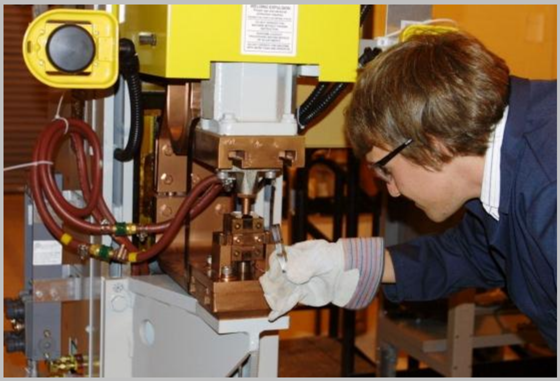
Specialty Welding Services

Welding Capabilities

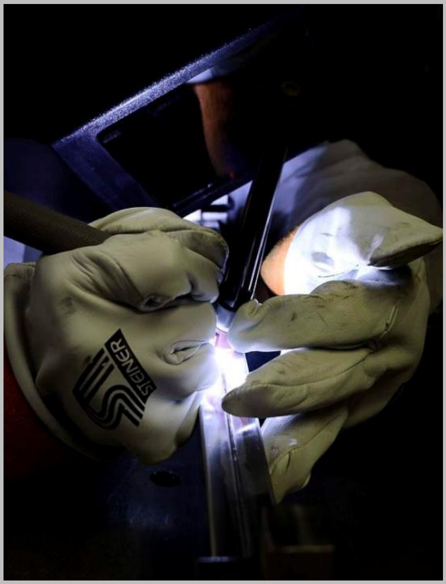
The Westinghouse Hot Cells have a long history of irradiated materials welding. Some of the earliest in-cell welds on highly irradiated stainless steels were performed in our hot cells approximately 30 years ago in support of vessel repair efforts at Savannah River. MCOE has the expertise to design and fabricate remote welding fixtures for various type of welds on highly radioactive materials.

MCOE provides the following specialty welding services:

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



Visual inspection of a test welds made using a resistance welding process



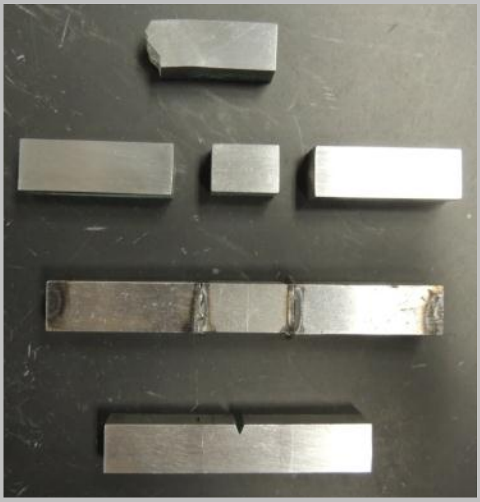
GTAW of a surveilance capsule

Nd: YAG laser welding head with video feedback system, air knife, and multi-axis positioning

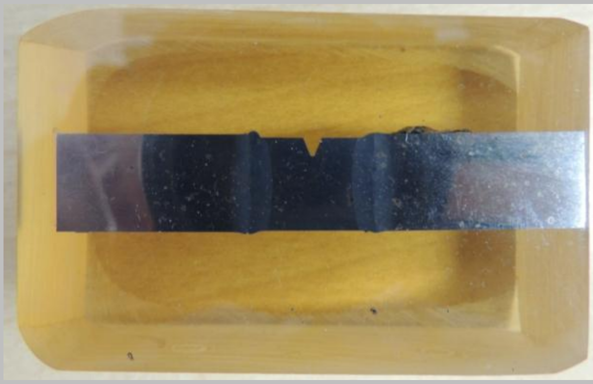
Resistance Welding – Charpy Impact Specimen Reconstitution

MCOE pioneered work in the area of irradiated charpy specimen reconstitution and has successfully developed a robust approach which 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 utilities with important data quantifying the effects of radiation induced aging on reactor vessel materials under operating conditions.

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



Metallographic mount of reconstituted charpy impact test specimen

Supporting Laboratories

Furnace Laboratory

The furnace laboratory included three 3-M Blue Box programmable air furnaces, a vacuum furnace and two biaxial creep furnaces. These furnaces allow for thermal annealing studies, hydriding experiments, quenching evaluations, etc.

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

3-M Blue Box air furnaces

Vacuum furnace

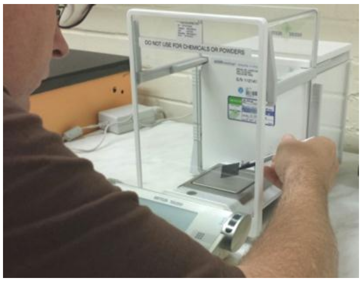
Biaxial creep furnaces

Balance Laboratory

The MCOE facilities include a precision balance laboratory for high accuracy weight measurements of solid samples. To maintain cleanliness, analysis of powder or chemical specimens is not permitted in this specific laboratory.

The laboratory includes two Mettler Toledo DeltaRange high precision balances positioned on granite tables and a Keyence LS-7601 high-speed, high-accuracy CCD digital micrometer.

The balances are used for a wide variety of specimen weight measurements including pre- and post-exposure measurements of corrosion, oxidation, and hydriding specimens. The digital micrometer is used for high-accuracy dimensional measurements on numerous types of laboratory specimens and has a repeat measurement accuracy of $\pm$0.15 µm.



High precision balance

CCD digital micrometer

Machine Shops

MCOE 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, etc. These on-site machining capabilities are invaluable for rapid in-house machining of many of the needed custom tools, fixtures, test rig components, and specimens without utilizing outside vendors.

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

Calibration Laboratory

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

Certifications, Safety and Security

Quality and Certifications

Westinghouse Electric Company and its subsidiaries are committed to meeting the quality requirements as stated in the Westinghouse Quality Management System (QMS).

The QMS applies to activities that affect the quality of items and services supplied by Westinghouse. It defines the basic requirements applicable to customer contracts and is a commitment to our customers. It serves as a directive for all functions in establishing necessary policies and procedures that comply with the requirements of ISO 9001:2008; and, in addition, as applicable for safety-related activities, 10CFR50 Appendix B; ASME NQA-1-1994 Edition and the following requirements as approved by Westinghouse for applicable locations and projects, as well as applicable local or country specific regulations.

- International Atomic Energy Agency (IAEA) GS-R-3 The Management System for Facilities and Activities
- ISO 14001, Environmental Management Systems Requirements
- OSHAS-18001 Occupational Health and Safety Standard (or similar)

It is the policy of Westinghouse Electric Company to provide items and services that meet the customer's contractual requirements and performance standards.

To implement this policy, Westinghouse has established and maintains a Quality Assurance Program to meet the requirements of: American Society of Mechanical Engineers (ASME), Boiler and Pressure Vessel Code, Section III, Division 1.

The Quality Assurance Program is described in the Quality Assurance Program Manual (WCAP-12308). This Program applies to all ASME Code related activities performed under ASME Code, Section III, Division 1 and the applicable Certificates of Authorization, and was developed to comply with regulatory, industry, statutory, and customer quality requirements imposed by customers or regulatory agencies for items and services provided by Westinghouse world-wide operations.

Safety

The Westinghouse Churchill Site Environment, Health, and Safety (EHS) organization is committed to maintaining occupational radiation exposures as low as reasonably achievable (ALARA). Specifically, the Radiation Safety Organization serves and guides our community of radiation workers.

The Churchill Site is committed to adequately training workers and to supporting its Radiation Protection staff in their efforts to keep radiation exposures ALARA. The guidance for how the Radiation Protection staff performs their duties to maintain the workers exposure ALARA is contained in Radiation Protection Procedures. The procedures are intended to provide a basis of continuity for how work is performed to ensure that the most current technologies and methods are applied to create a safe and efficient work environment.

The following programs outline the proper procedures and forms that are used while conducting radiological and safety activities at the Westinghouse Churchill Site:

1. Emergency Response Program
2. Fire / Safety Protection Program
3. Radiation / Safety Protection Program
4. Safety Compliance Program

These programs assure the safety of our employees, as well as any and all visitors to the site along with contractors and visiting Westinghouse personnel. The resident Radiation Safety Officer/EH&S Manager assures that these programs are up to date and implemented appropriately.

Security

The Westinghouse Churchill Site has 24/7 on-site security. The site is self-contained within a parameter fence which is monitored by on-site security guards and cameras. Proper procedures and protocols are established to allow for the security and safety of the site as well as its employees and visitors.

All Radiological Controlled Areas (RCAs) and associated materials and equipment are only accessible by authorized personnel that have been deemed "Trust Worthy and Reliable." All laboratory facilities and administrative areas are only accessible by properly badged personnel. Any and all visitors on-site are properly escorted by a Westinghouse Churchill Site employee.

In addition to the 24/7 on-site security, the site is also monitored by local law enforcement as well as Westinghouse Security located at Westinghouse headquarters.

Contact Information

For questions or to discuss how we can meet your laboratory needs, please contact:

Mr. Brian Burgos
Manager, Churchill Operations and Product Lead
Westinghouse Electric Company LLC
Primary Systems Design and Analysis
1322 Beulah Road, Building 302
Pittsburgh, PA 15235
Phone (Office): 1-412-256-1067
Phone (Mobile): 1-724-825-3027
Email: burgosbn@westinghouse.com

Dr. Michael Burke
Consulting Engineer
Westinghouse Electric Company LLC
Primary Systems Design and Analysis
1000 Westinghouse Drive, CWHQ3 -227B
Cranberry Township, PA 16066
Phone (Office): 1-412-374-4172
Phone (Mobile): 1-724-584-8909
Email: burkema@westinghouse.com

Dr. Art Byers
Fellow Scientist, Chemist
Westinghouse Electric Company LLC
Primary Systems Design and Analysis
1322 Beulah Road, Building 301
Pittsburgh, PA 15235
Phone (Office): 1-412-256-1678
Phone (Mobile): 1-412-715-4108
Email: byerswa@westinghouse.com

Ms. Paula Freyer
Fellow Engineer, Metallurgist
Westinghouse Electric Company LLC
Primary Systems Design and Analysis
1322 Beulah Road, Building 301
Pittsburgh, PA 15235
Phone (Office): 1-412-256-1771
Phone (Mobile): 1-724-513-9458
Email: freyerpd@westinghouse.com