

Application to Refuel the NRU Reactor Past the Guaranteed Subcritical Condition

2010 July 5

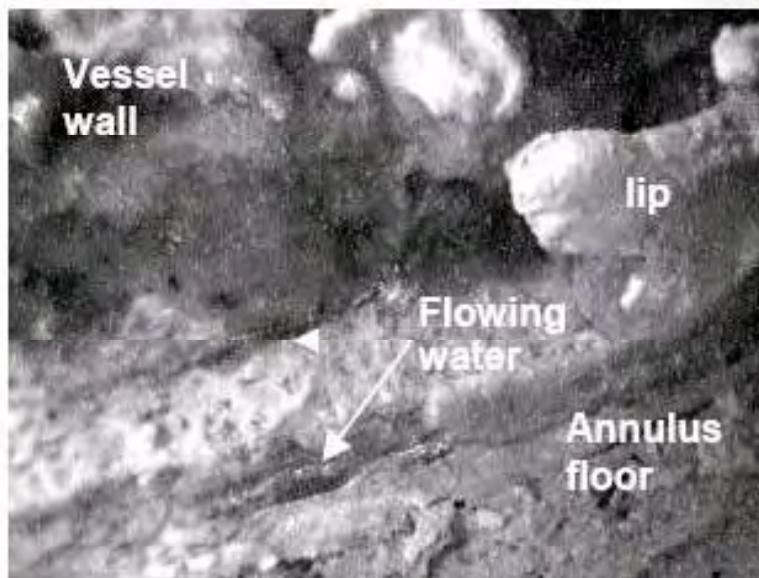


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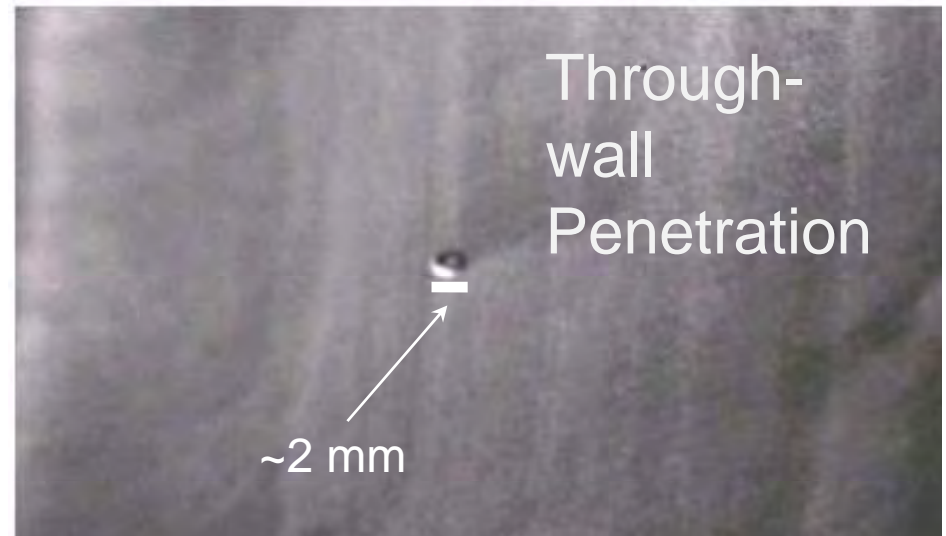
- Leak and Vessel Condition Assessment
- Repair of NRU Vessel
- Mitigation of Leaks and Similar Events
- Additional Work to Improve NRU Safety and Reliability
- NRU Fitness for Service
- Preparations for Return to Service
- Summary

NRU Vessel Leak



Water seeping through corrosion on outer vessel wall

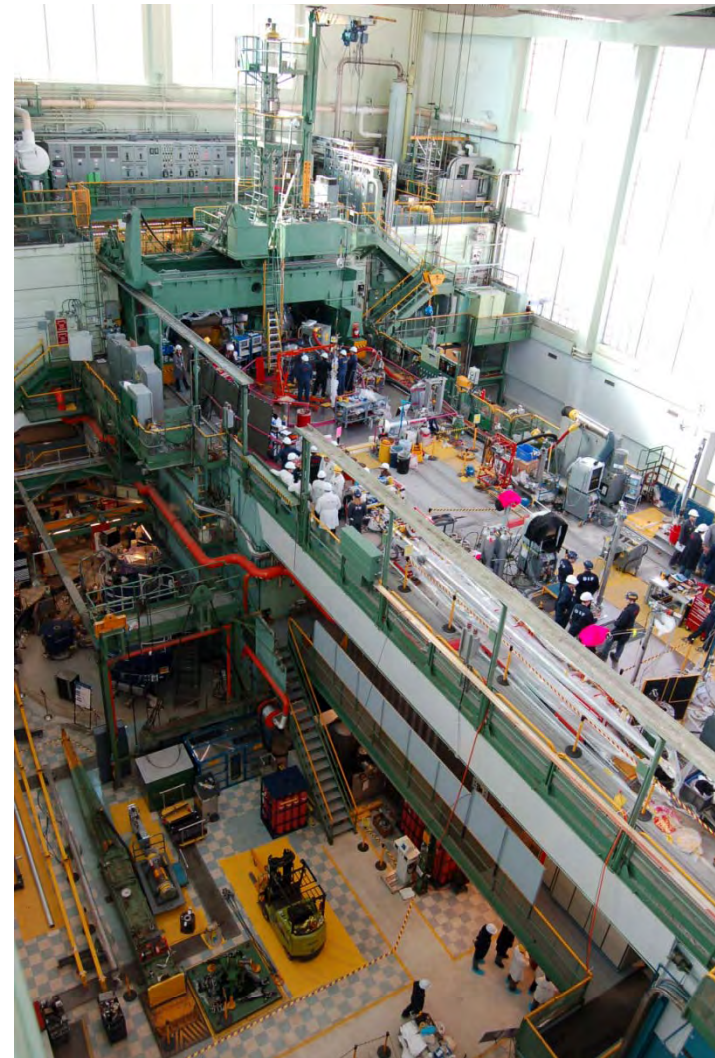
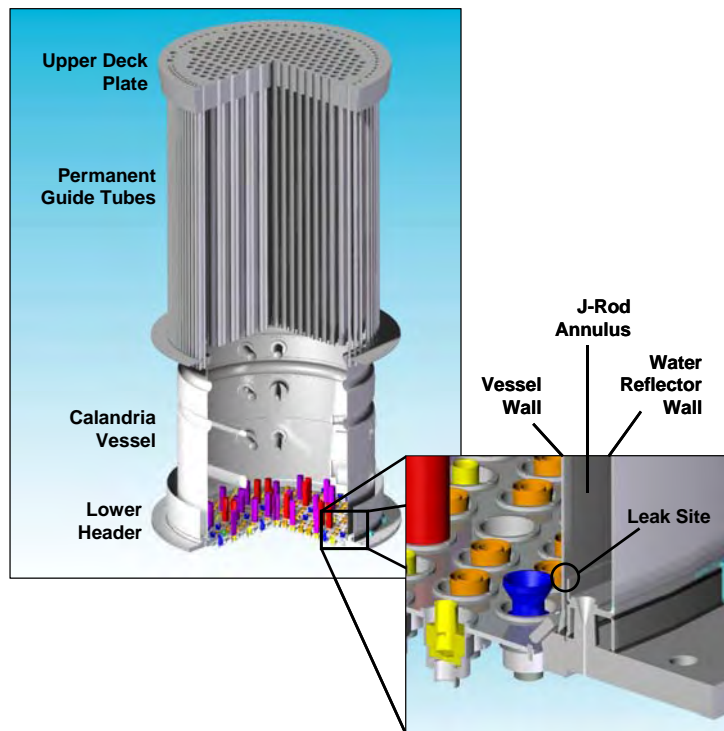
Small hole on inner vessel wall found after surface preparation for welding



Location of Heavy Water Leak

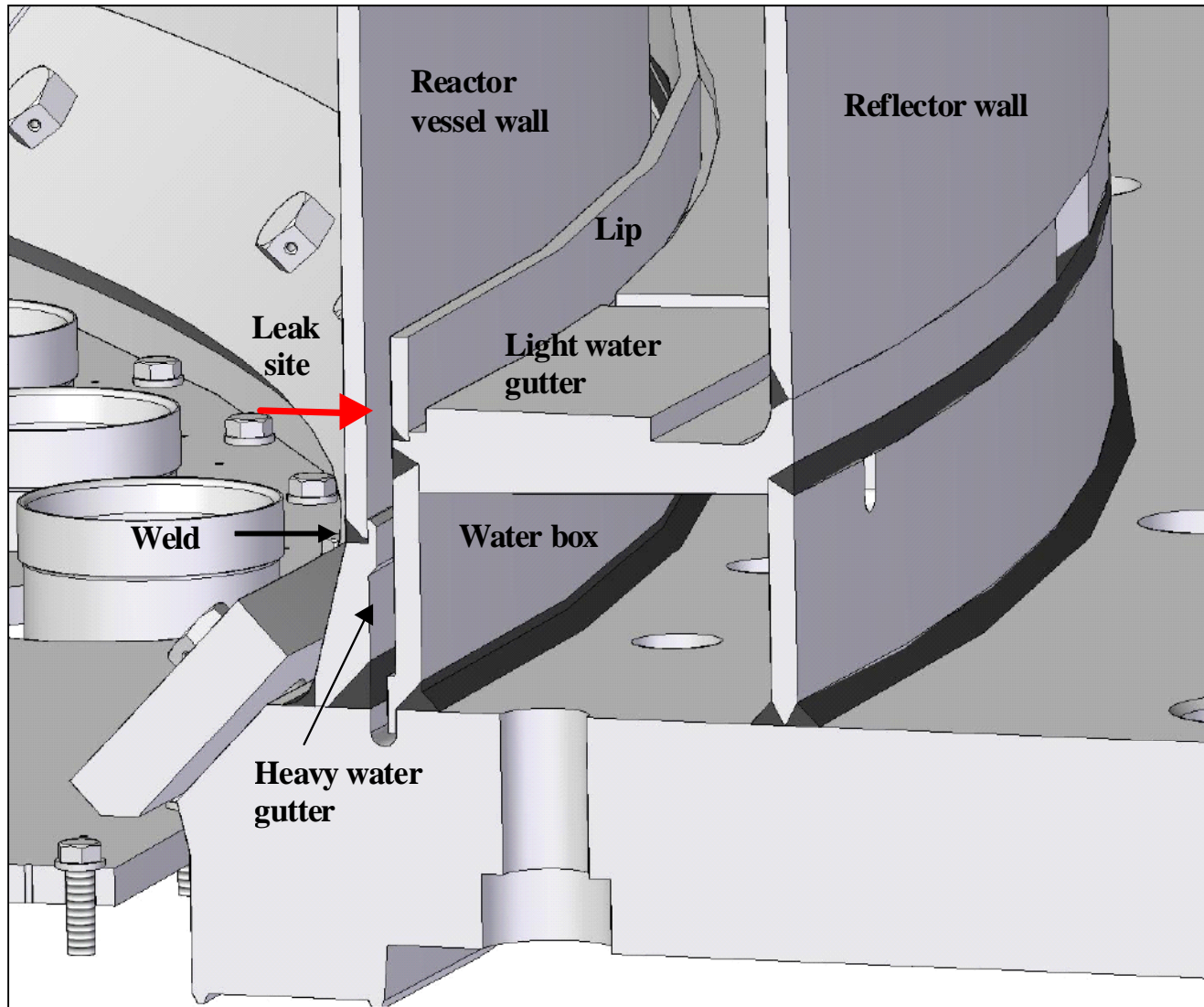
Accessing the leak site location:

- Apertures of 12cm
- Elevation of 9 meters
- Deck plate diameter 3.7m
- High radiation environment



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Schematic Showing Location of Leak



Condition Assessment of Vessel



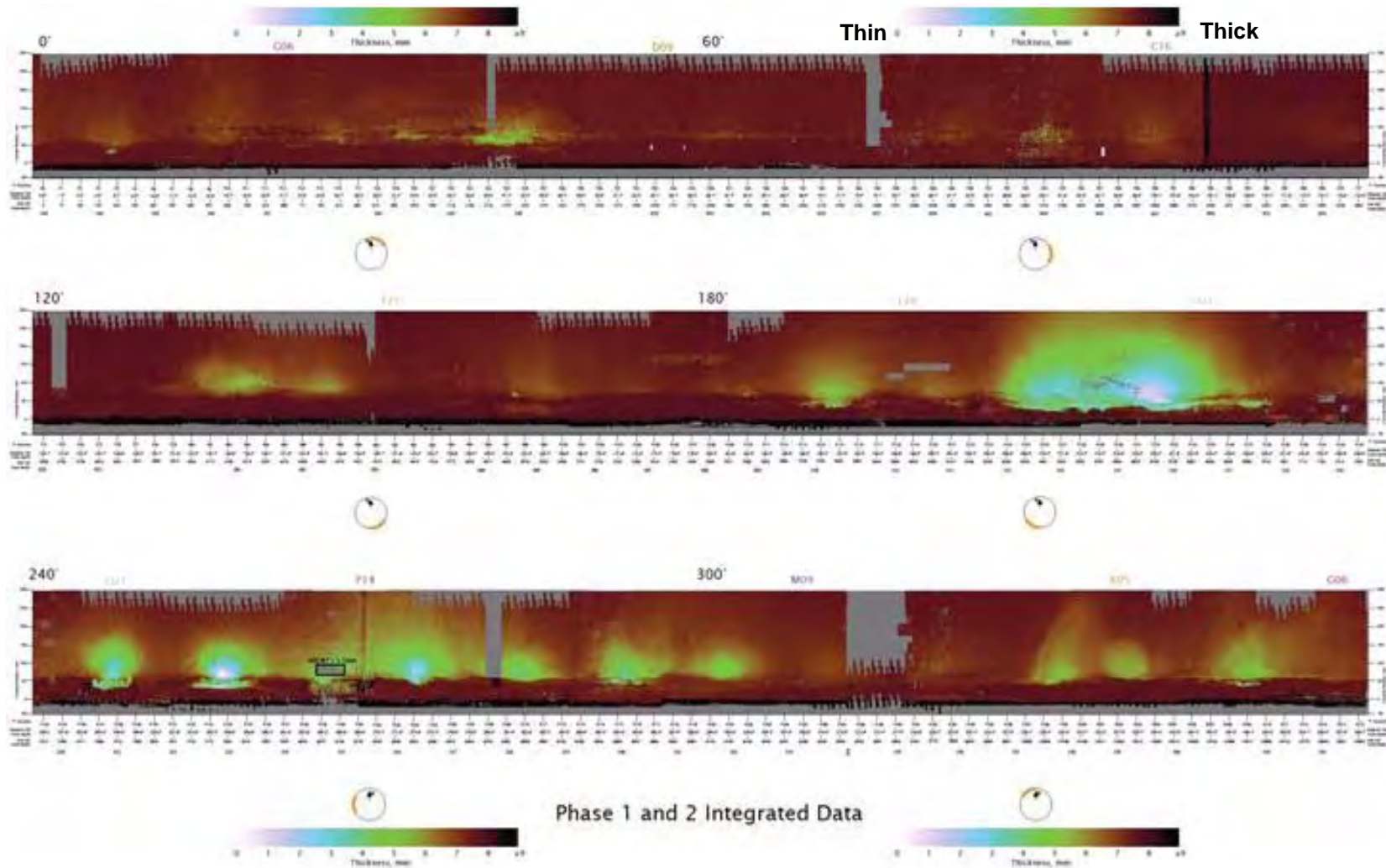
Non-destructive examination:

- Remote video inspections
- Ultra-sound examination
- Eddy current probes
- Over two million data points
- Four phases

One of largest single NDE inspection campaigns ever carried out in the nuclear industry.



NDE Wall Thickness Results



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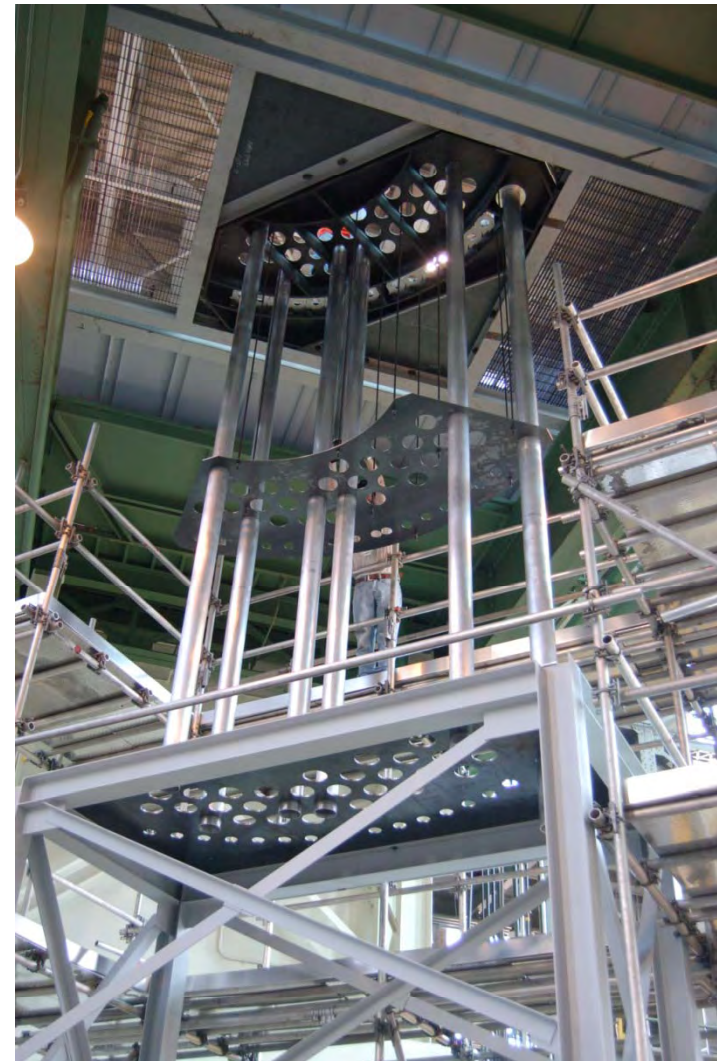
NRU Reactor Vessel Repair



- Construct mock-up of NRU
- Design tooling
- Manufacture tooling
- Qualify processes
- Training on mock-up
- Qualification of welders
- Execute repairs
- Certify repairs

The equivalent of over 300 employees have been engaged full time in return to service activities

Full Height Mock-up of NRU Reactor



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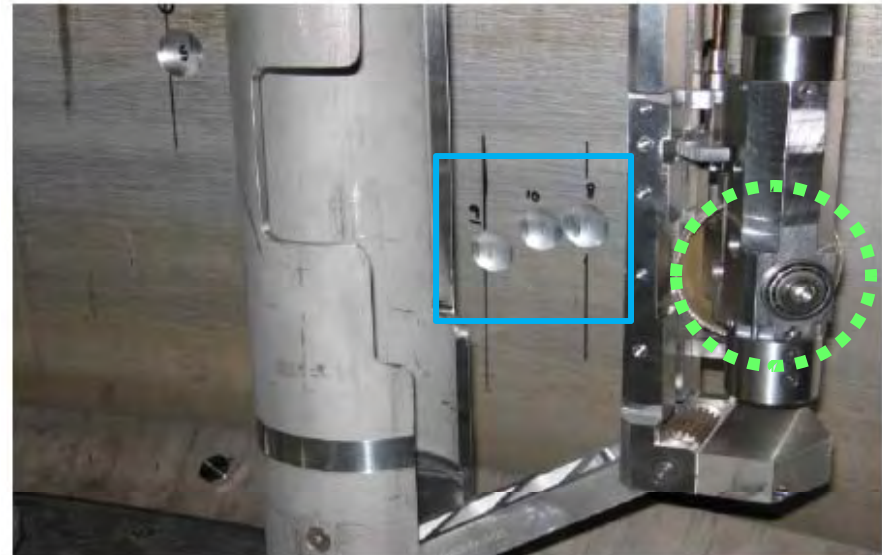
Removing Samples from Vessel Wall



Samples from vessel wall:

- Nature of the corrosion
- Analysis of vessel material
- Final welding qualification & tests

35 years of irradiation has rendered the material unique; there exists no reference in the world to guide development



Scoops and Coupon



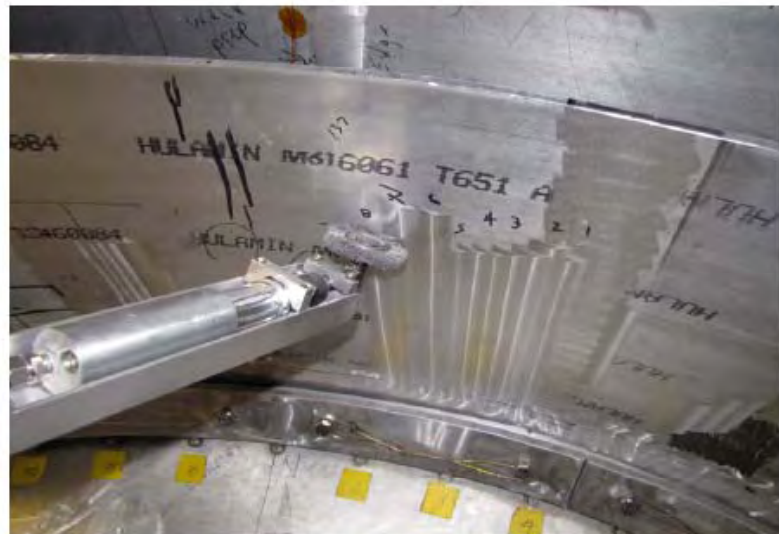
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Tooling to Clean Vessel Wall

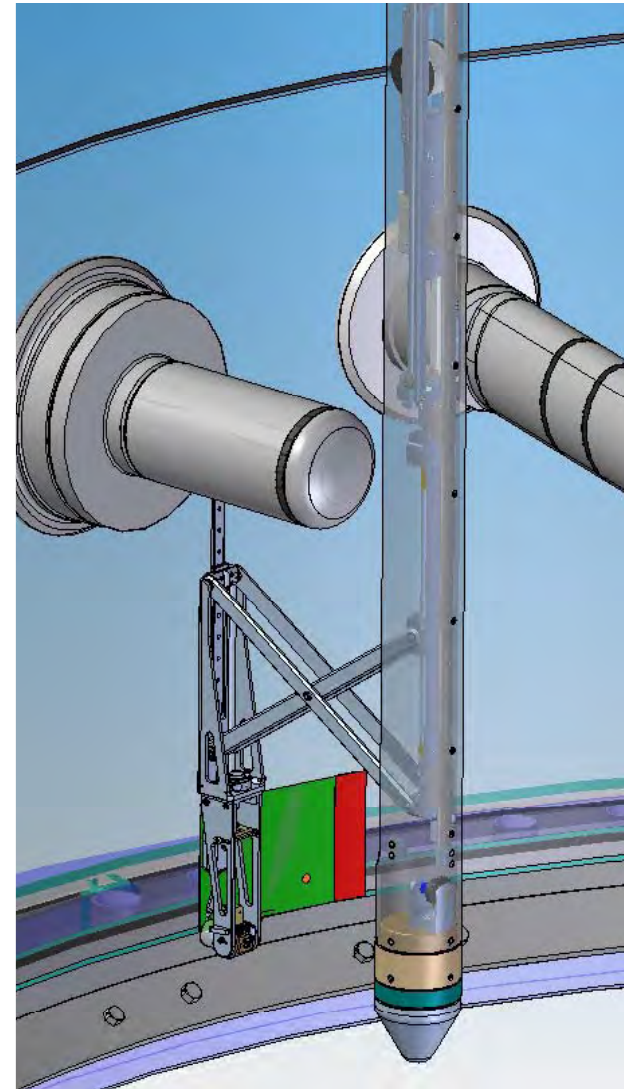
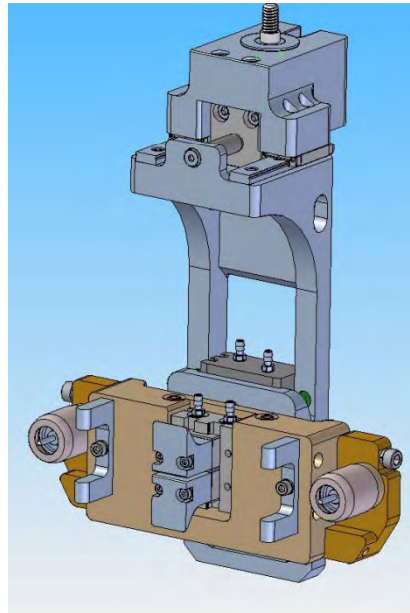
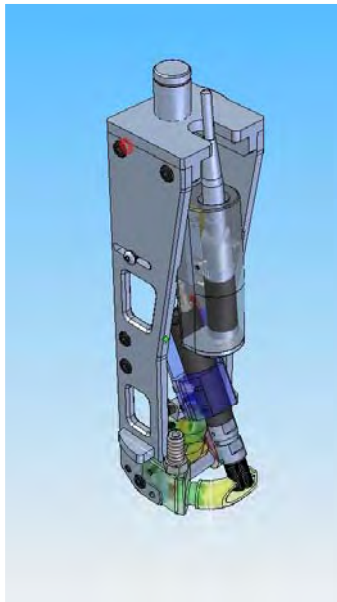


Cleaning of the vessel wall:

- Critical step in welding process
- Removes gibbsite layer from vessel
- Tool designed and built by AECL



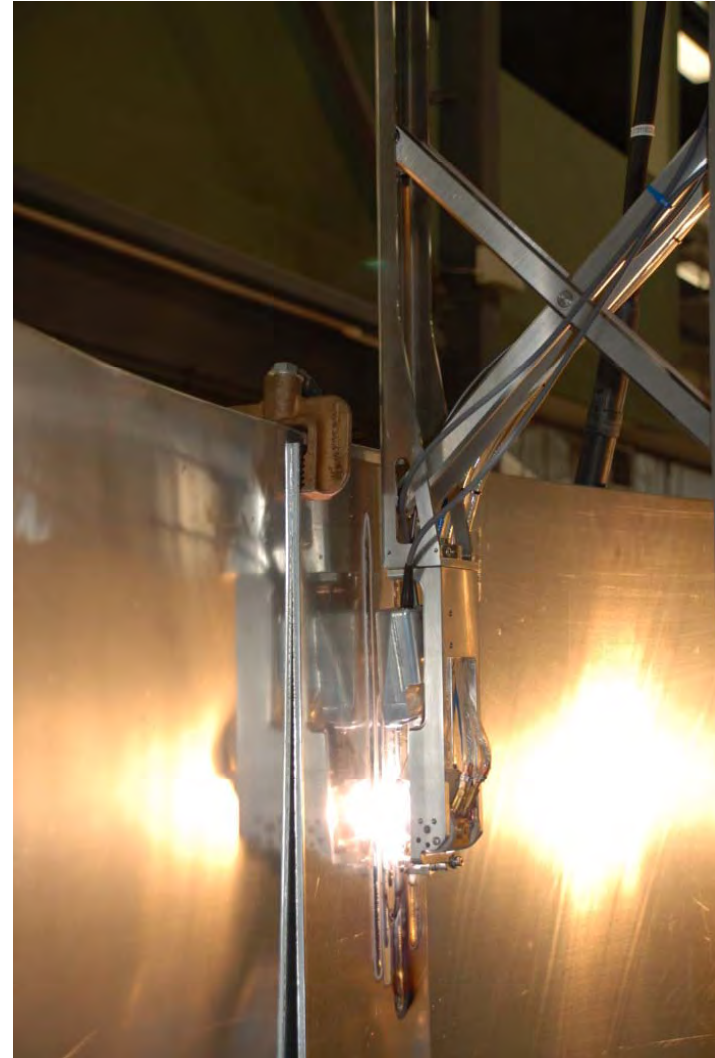
Remote Welding Tools



More than 40 unique tools were conceived, designed, fabricated, commissioned and used in NRU Vessel Repair.

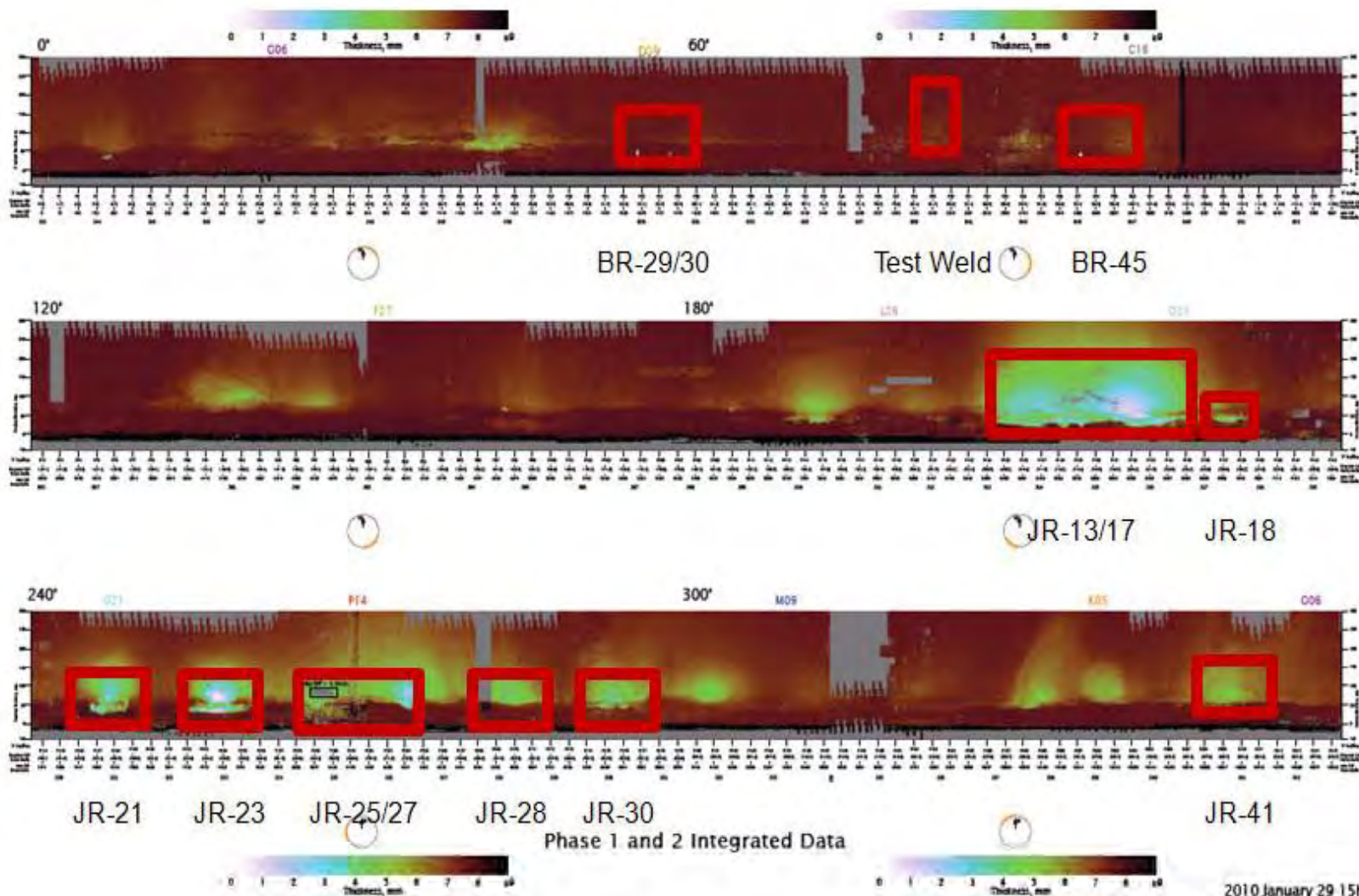
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Remote Welding Tools in the Mock-up



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Locations of the Test Weld and Repair Sites



2010 January 29 15h30
PROTECTED - SENSITIVE | PROTÉGÉ - DÉLICAT
211-150207-021-000

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Ensuring Success of Weld Repairs



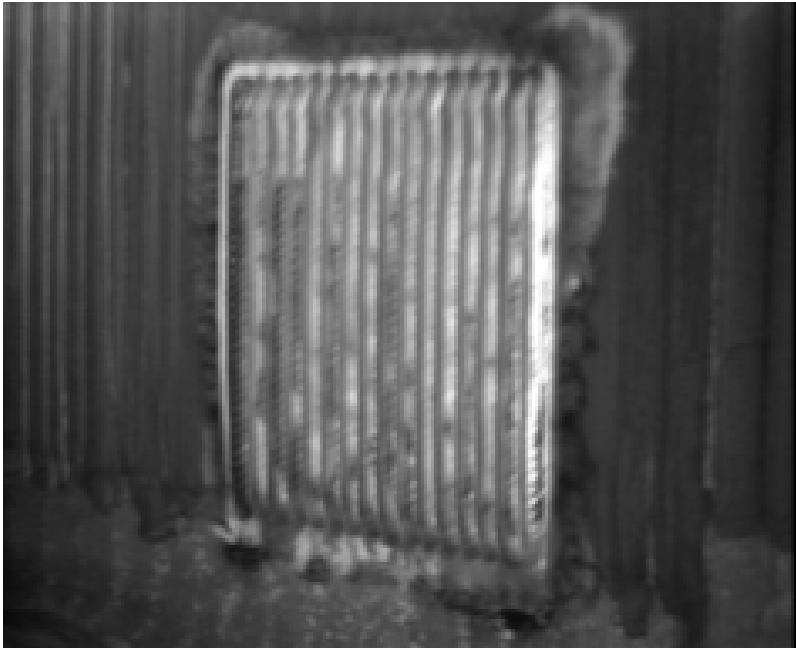
For each repair site:

- Weld development
- Welder qualification & reliability
- Integration testing
- Actual repair work
- NDE & Certification of repair

First weld inside NRU vessel:

- Completed December 03, 2009
- Welding head inside NRU
- Wall area of full thickness
- Analyzed through NDE and scoop sample

Weld Buildup Strategy



Beads of weld are applied directly onto vessel wall to build up thickness

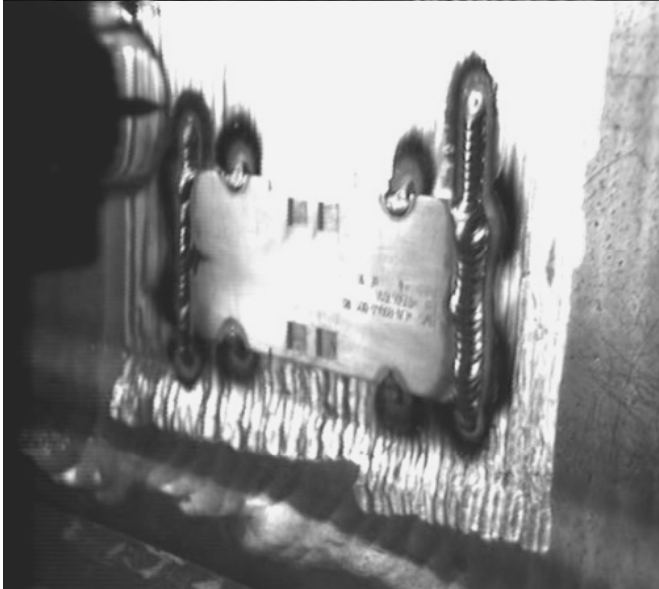
Beads are applied either vertically or horizontally



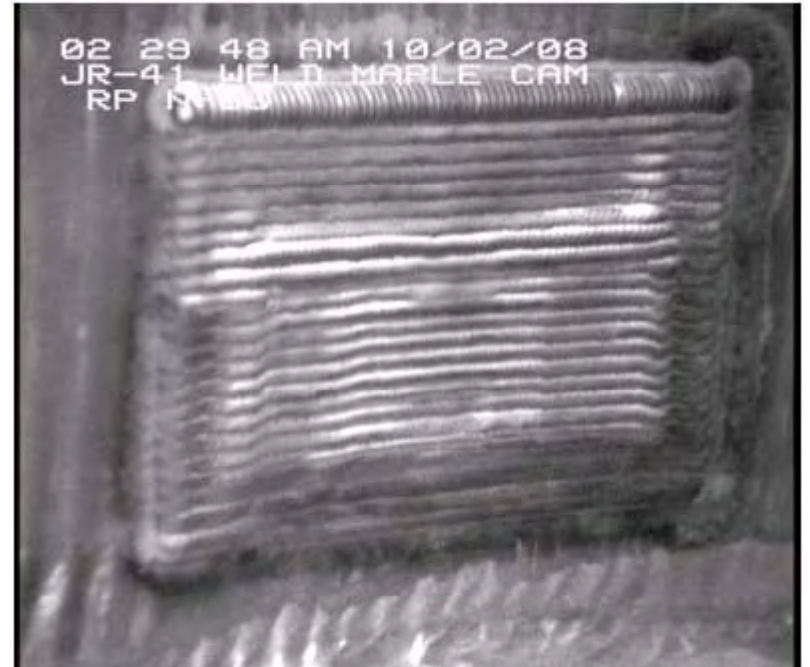
Repair at JR-41 – The Leak Site



Backing strip placement



Backing strip welding



Final Weld Overlay

Backing Strips with Buildup Strategy



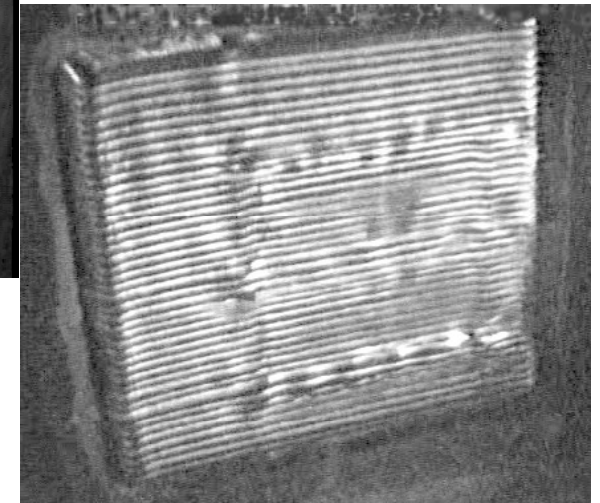
First:

One or more plates are tacked & fillet welded onto the vessel wall to act as backing strips



Then:

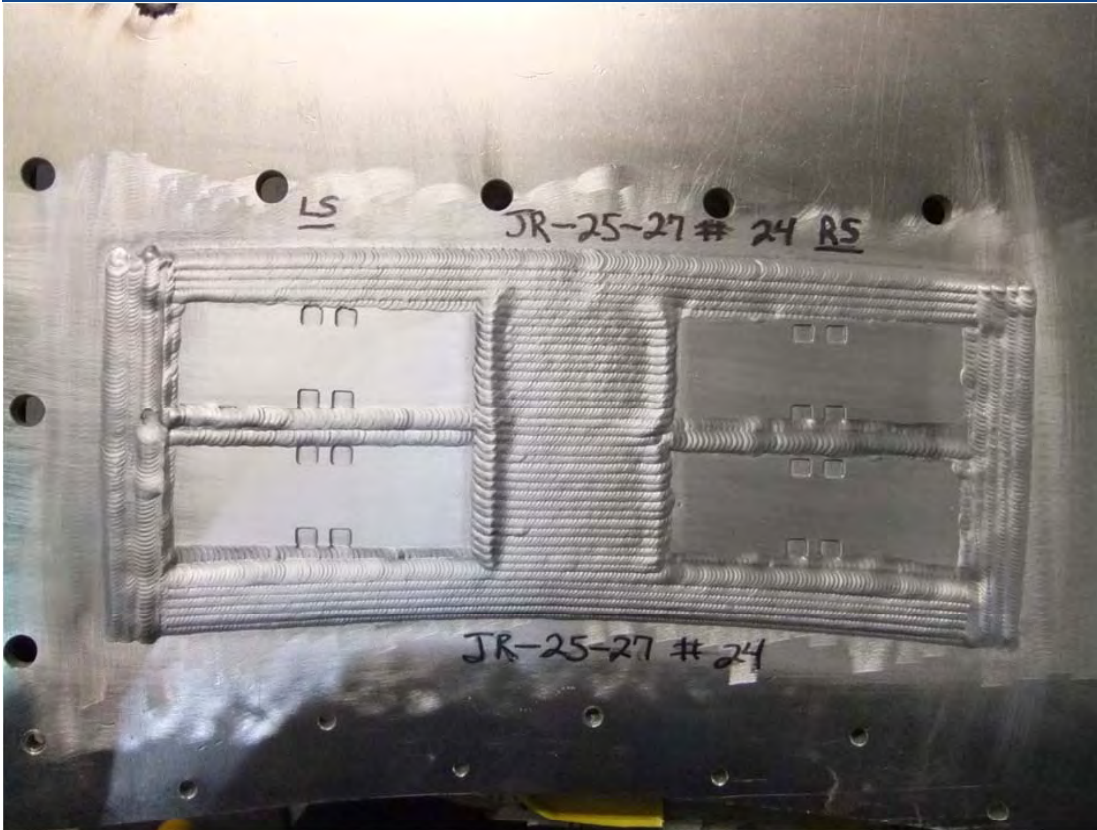
The plates are outlined in a “window pane” of weld overlay



Finally:

The plates and window pane are overlaid with weld beads to build up to the specified thickness

Structural Plates and Weld Buildup Strategy

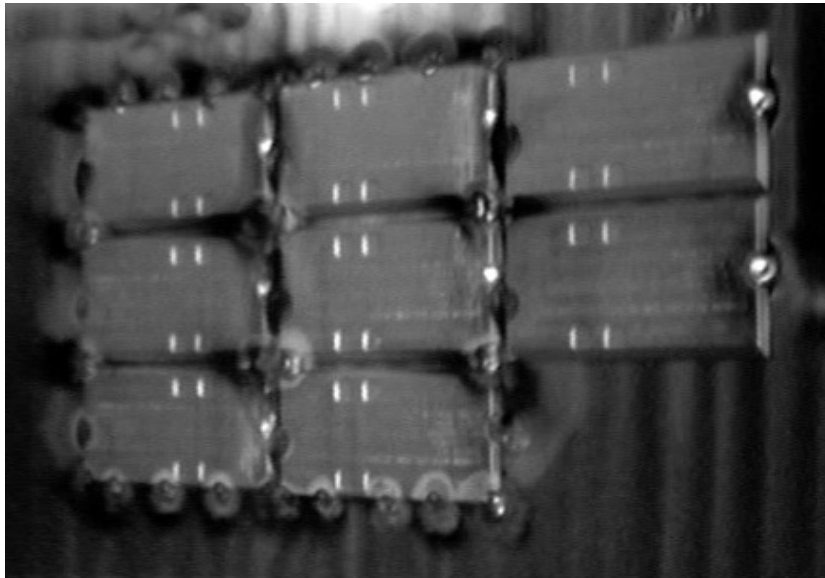


Structural plates are first tack and fillet welded in place then surrounded by a weld buildup

All weld repairs executed remotely from 9 meters away through a 12cm aperture in a radioactive environment



Repair at JR-13/17 – The Final Site

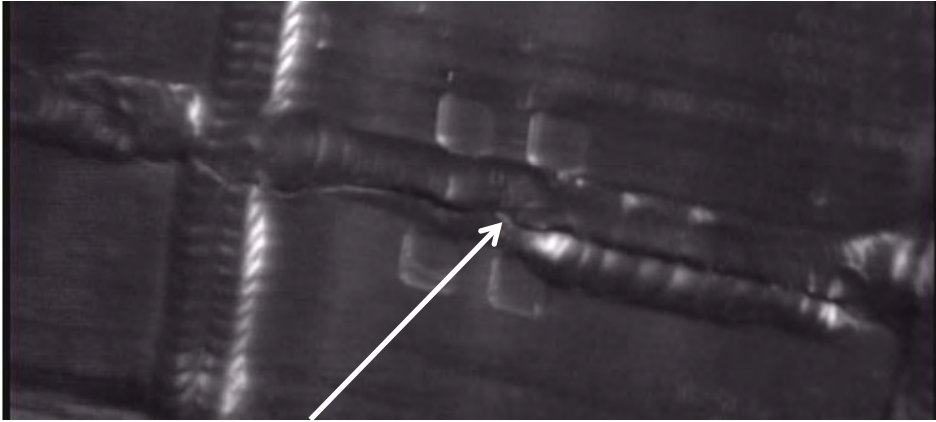


1250 cm² repair area
3x3 array of structural plates
Nine unique welding processes

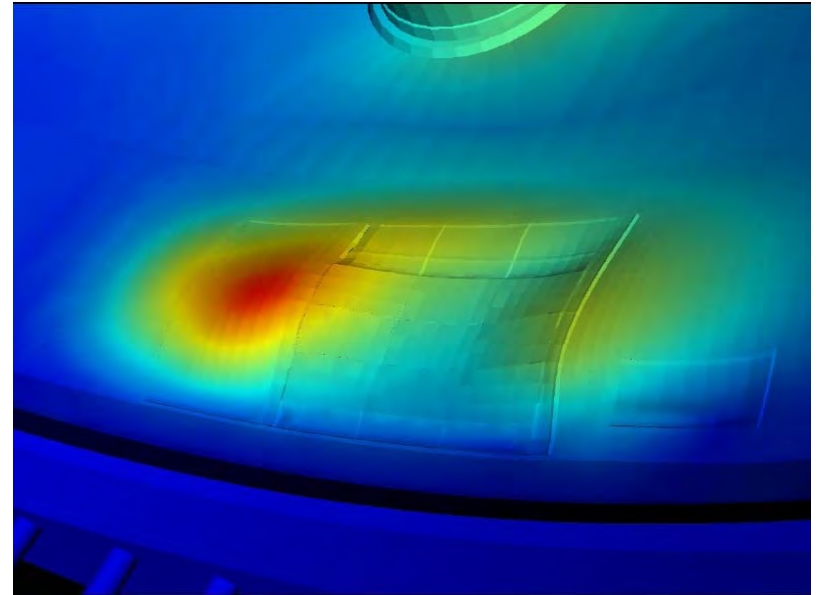


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Crack in Repair at JR-13/17



Crack above bottom right plate



Map of deflection from Welding



Final Repair

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Weld Inspection Results

	B29	B45	JR31	JR28	JR21	JR41	JR18	JR23	JR25-27	JR13-17
ET (surface)	G	G	G	G	G	G	G	G	G	G
UT (HAZ)	G	G	G	G	G	G	G	R	G	G
UT (wall thickness)	G	G	G	LF	LF	G	G	G	LF	LF
UT (plate to weld)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	G	LF

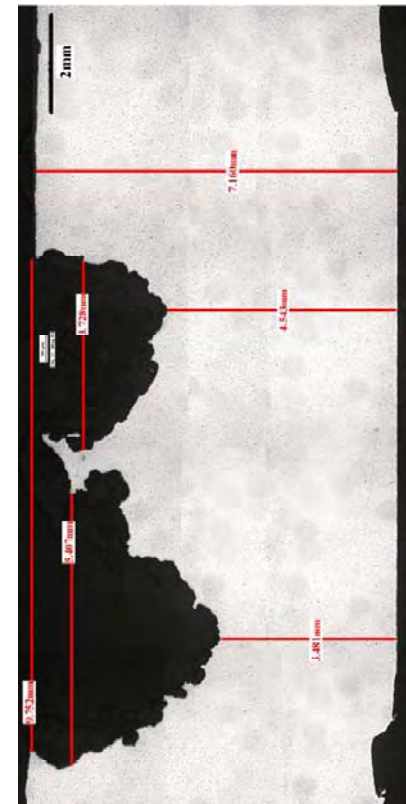
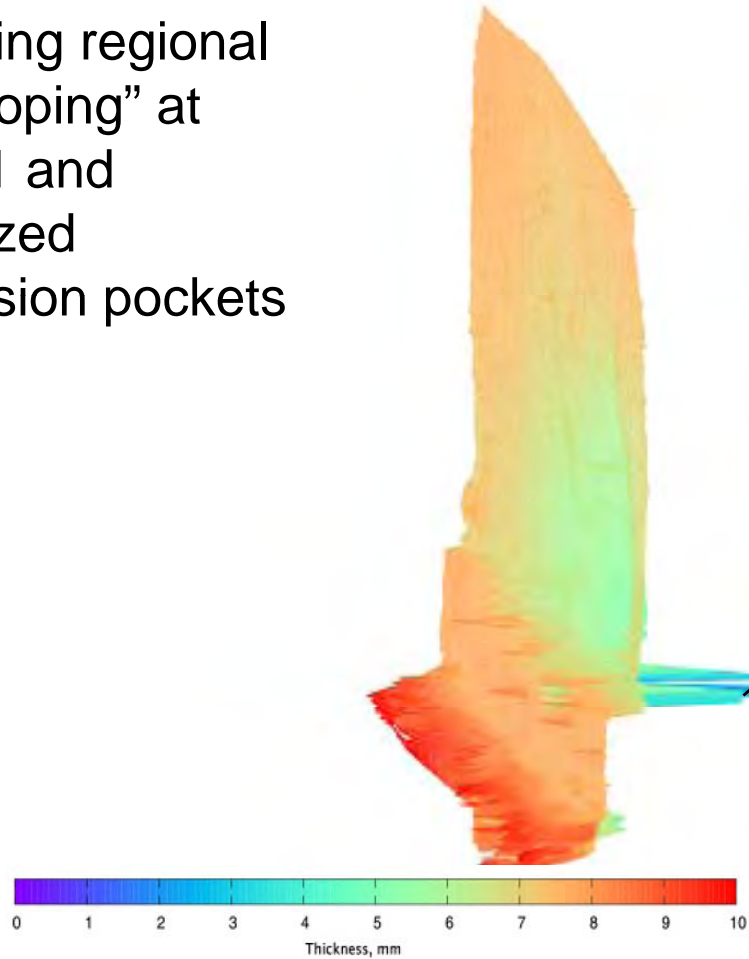
G – No indications **R** – Reportable Indication **LF**- Lack of Fusion

Leak Test Results

- In-service leak test, witnessed by responsible authority, did not find any evidence of water leakage from the vessel.
- Trace amounts of tritium found in the annulus between vessel and reflector, but no signs of moisture.
- Additional visual inspection undertaken of the inside of the vessel where tritium was detected – no flaws or imperfections found.
- Tritium levels decreased, and did not increase with subsequent drain and refill of the vessel.

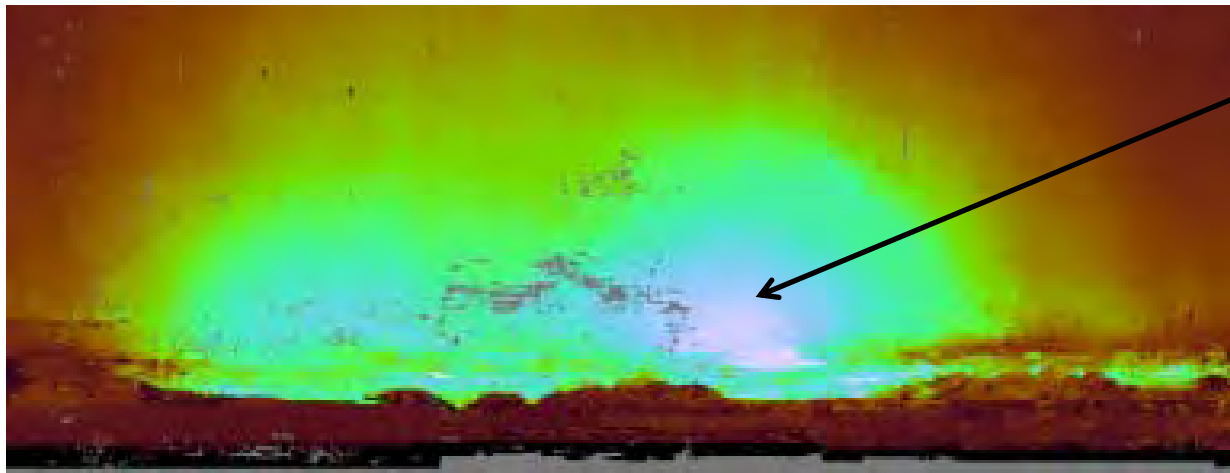
Corrosion Mechanism

NDE results showing regional “scalping” at JR-41 and localized corrosion pockets



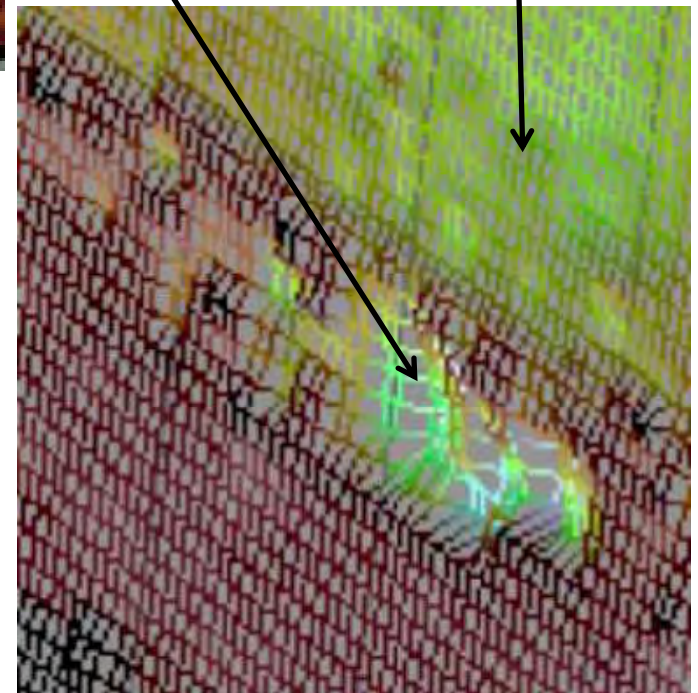
Metallography of coupon showing corrosion pockets at JR-41

Corrosion Mechanism - Related Aspects



Regional Wall Loss

Localized
Corrosion
Pockets



Corrosion mechanism related to formation of nitric acid from air and water leakage into annulus:

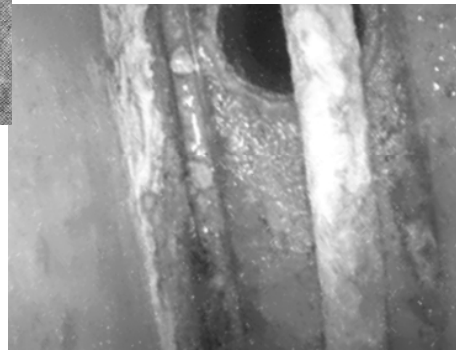
- acidic water contacting vessel results in regional wall loss
- local corrosion cell produces corrosion pockets at water line

Vessel Annulus - Preventing Corrosion

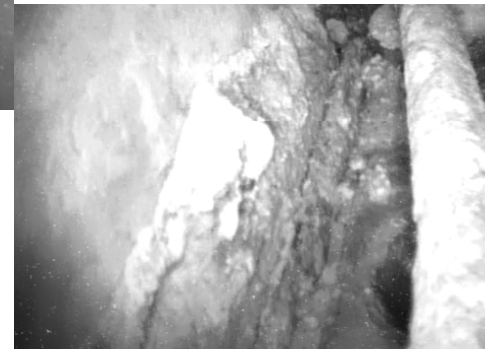


1 – as built

On going monitoring of condition of annulus will be integrated into annual maintenance outage of NRU



2 – May 2009



3 – leak location

Reducing water pooling and air ingress:

- clearing drains
- reducing debris
- sealing water and air leaks
- improved CO₂ distribution



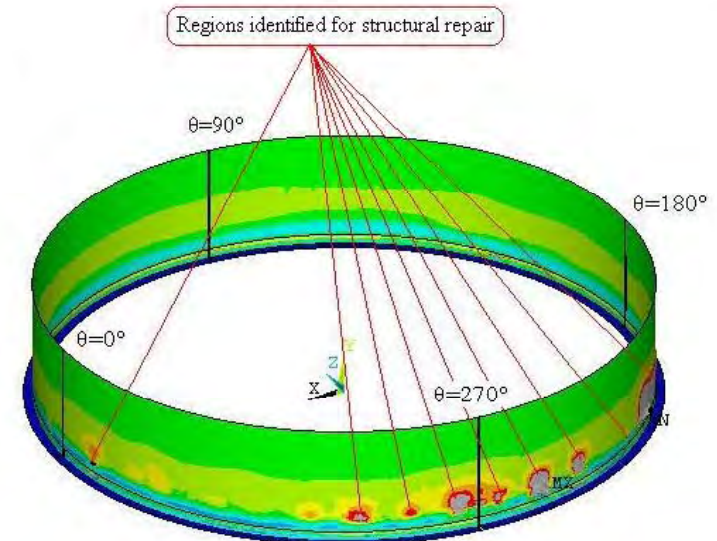
4 – remediation

NRU System Condition Assessments

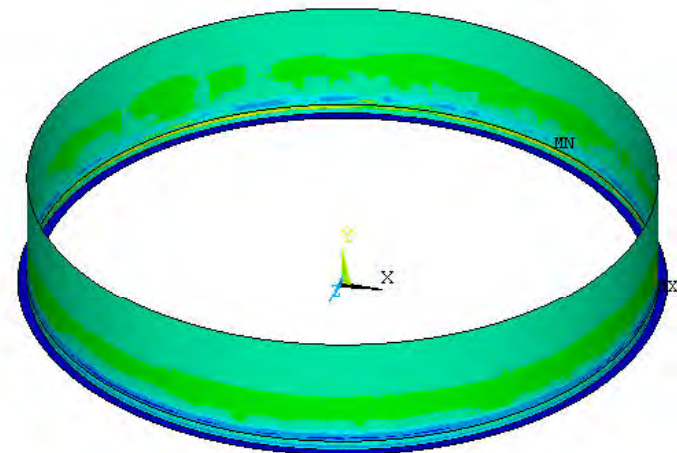
- Condition assessment process reviewed to ensure there is no generic problem with the process – nothing found
- Independent review by an expert panel used to verify results of the condition assessments – no additional gaps of safety significance found

NRU Fitness for Service

- Fitness for service demonstrates repaired vessel will maintain mechanical performance through the next operating interval
- Continued fitness for service will be verified through in-service inspections
- First maintenance outage to occur with 9 months of return to service, and annually thereafter, subject to review based on NRU performance and outage experience



Before and after repair stress field maps



Addressing Corrosion Pockets

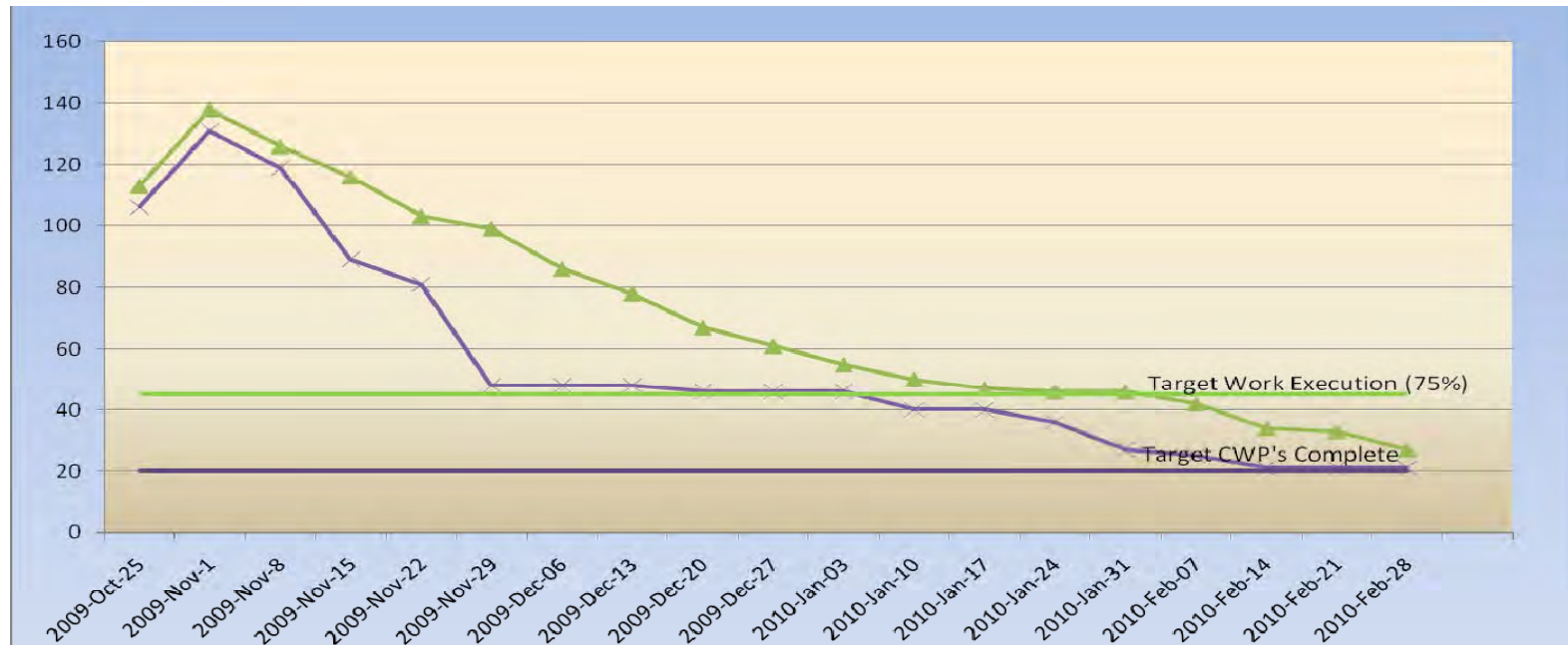
- In-service inspection assures ongoing structural integrity
- Inspection program and ongoing mitigation reduces, but does not eliminate, the potential for corrosion pockets
- Corrosion pockets do not impact structural integrity, but could lead to heavy-water leaks
- Tooling is being developed to effect a mechanical repair of a small leak without draining and removing fuel

Organizational Improvements

- Causes for NRU leak event assessed and point to improvements identified in a 2008/09 Safety Culture Survey
- Corrective actions rolled into AECL's improvement program – Voyageur Phase II
- Broad elements are:
 - Improve equipment reliability
 - Reinforce strong organizational behaviours (e.g. questioning attitude, etc.)
 - Improve problem identification and solution
 - Improve usage of OPEX
 - Improve standards for operation
 - Improve leadership and oversight
- Measures of improvement will include site and department level EFDRs, interim safety culture surveys, equipment reliability indicators, and a health index for the Corrective Action Program
- Resources and program improvements funded through ISRP

Extended Activities Program

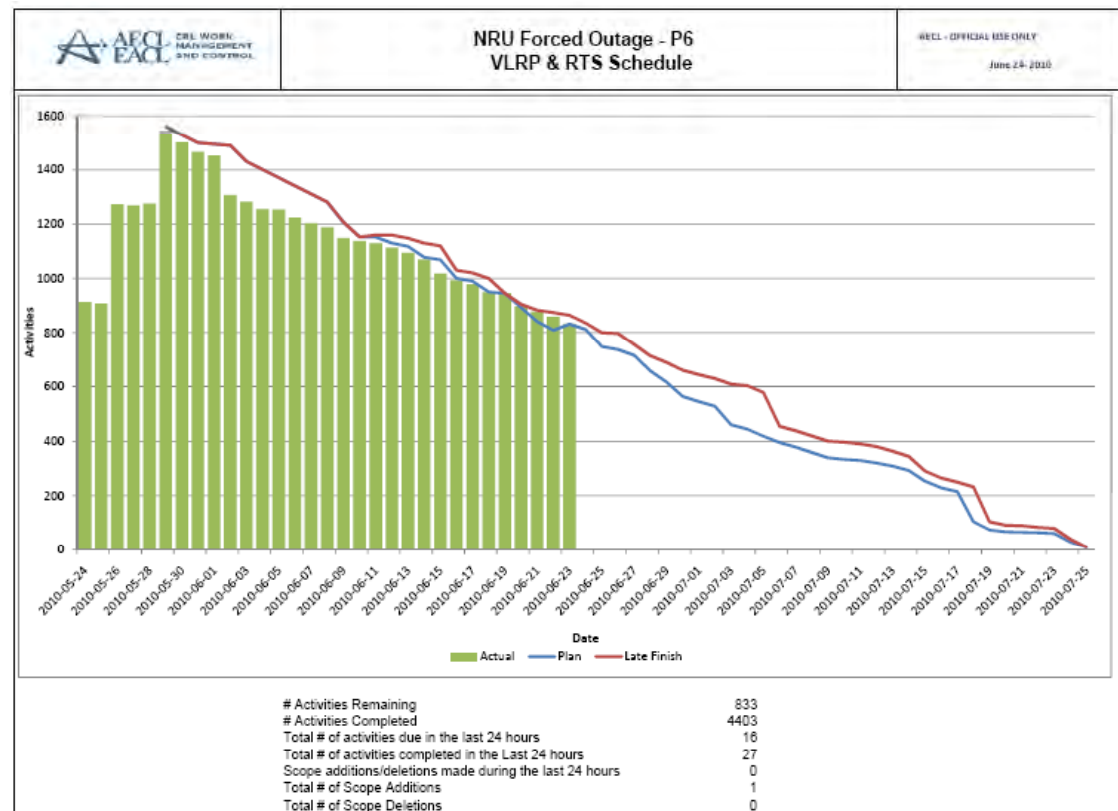
- All work requiring drained and defuelled completed, safety and reliability improvements made to various systems
- Safety System Upgrades walked down, findings reviewed, dispositioned and field work completed. Upgrades will be fully tested and confirmed fully capable of performing their safety functions as part of NRU readiness for service.



NRU Return to Service

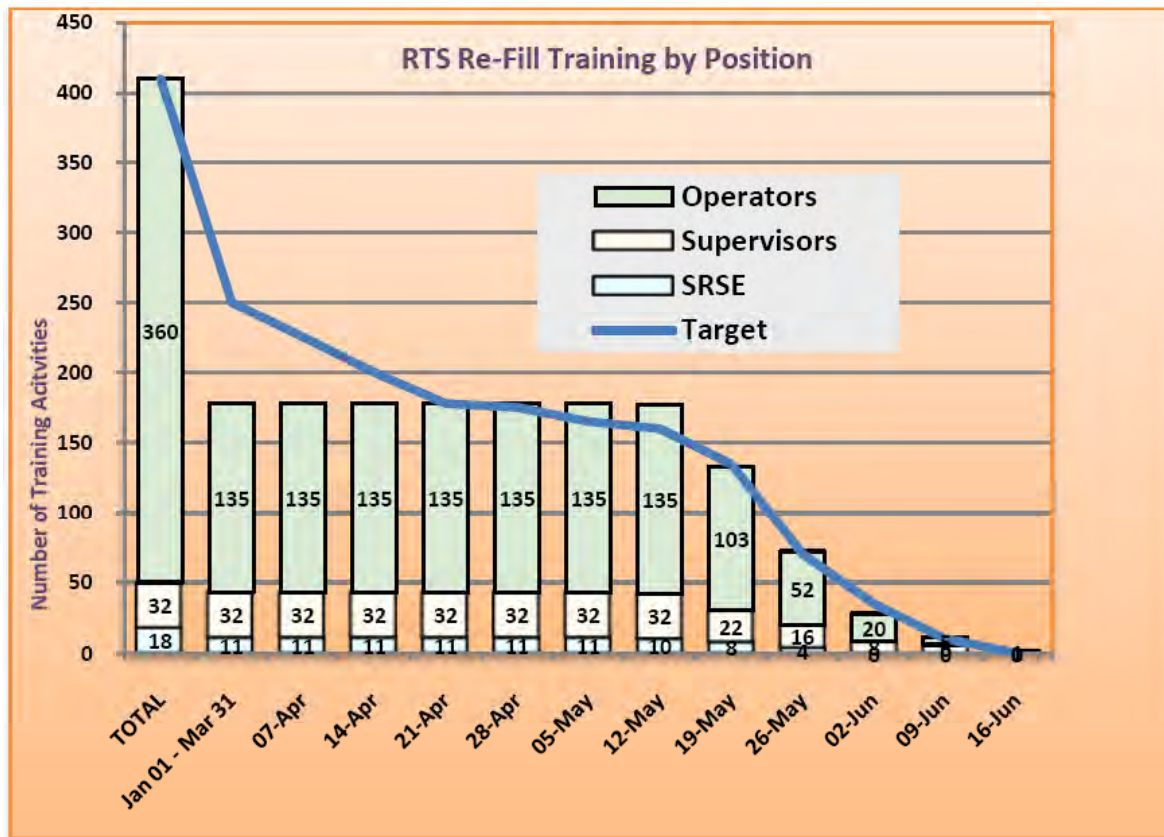
All systems to be verified fully operational based on a comprehensive readiness for service assessment

Detailed, interlinked, plan of all maintenance, testing, system configuration and training activities compiled and being worked down

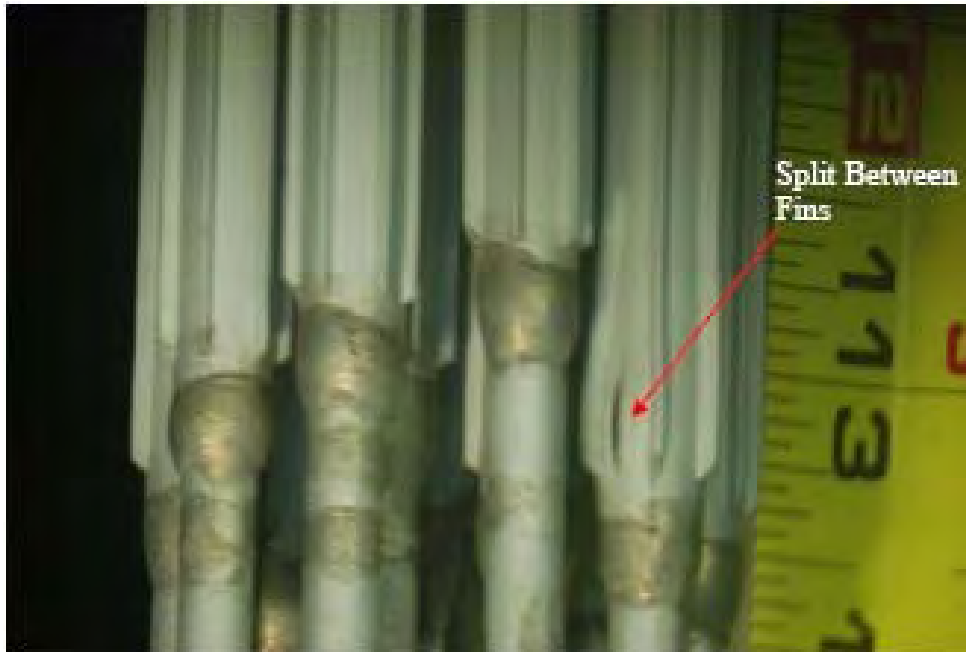


Training Activities

Staff are prepared for infrequently performed tasks (restart from extended shutdown), as well as activities not routinely performed during the outage

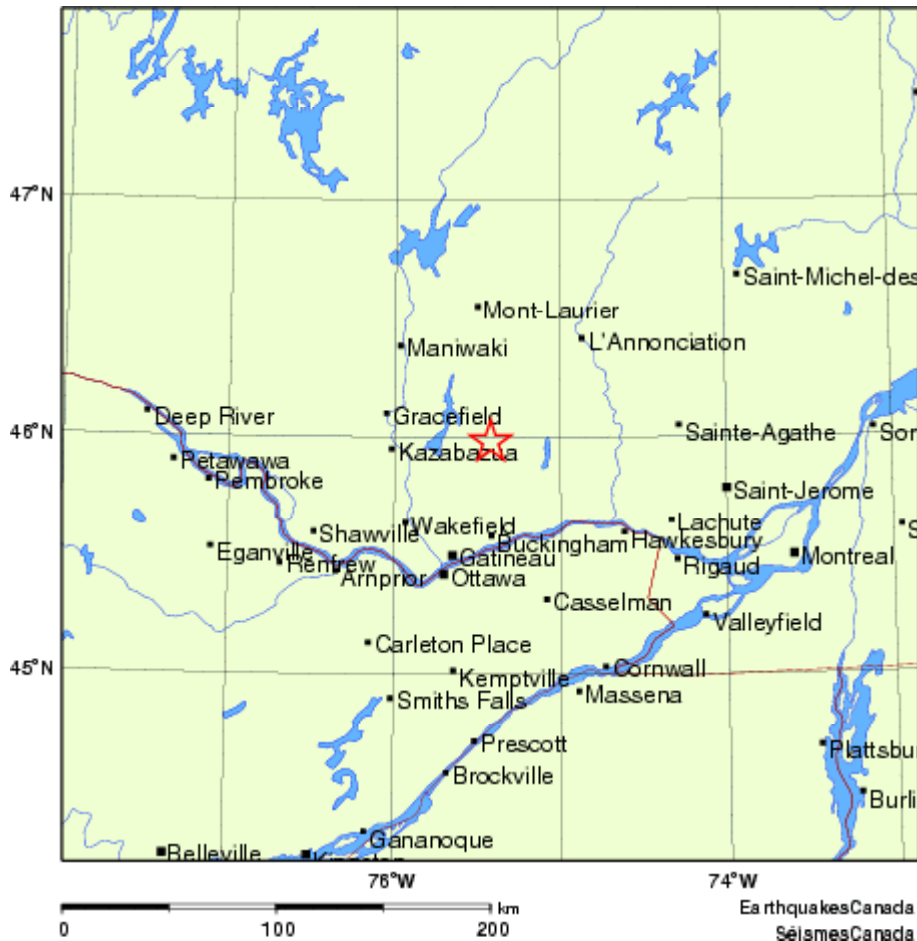


Assurance of Fuel Performance



- Fuel has been quarantined and will be screened for release
- The majority of the fuel to be loaded was in-reactor when there were indications that defected fuel had been removed
- Process for responding to rising activity levels has been formalized

June 23 Earthquake



- Earthquake was magnitude 5, centred north of Ottawa
- Peak ground acceleration at CRL: 0.006 g (magnitude <4)
- NRU's safety functions reinforced to withstand ~0.25 g (magnitude 6), seismic trip: 0.06 g
- Nuclear facilities and buildings were walked down following the earthquake to confirm no damage had occurred

Source: Natural Resources Canada
<http://earthquakescanada.nrcan.gc.ca>

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Up-to-date Status and Communications

www.NRUCanada.ca



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Summary

- NRU vessel has been repaired and is fit for service.
- AECL is confident that all requirements for safely restarting NRU have been met.
- Approval to reload fuel past the guaranteed sub-critical condition is requested:
 - allows full return to service, and
 - resumption of NRU operation and isotope production.

 **AECL EACL**

