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NDE overview

Greg Selby
Director, NDE

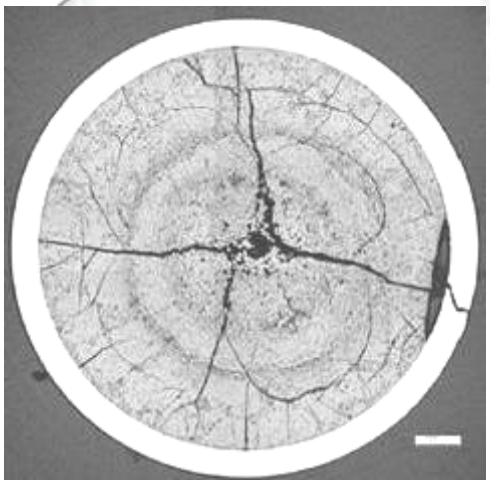
NRC Information Meeting
May 2010

EPRI NDE Program overview

NDE Program scope

NDE R&D for most parts of the plant

- Vessels & nozzles
- Pressurizer
- Piping and bolting
- Reactor Internals
- Steam generator
- Heat exchangers
- Buried piping
- Fuels
- Containment
- Spent fuel pool



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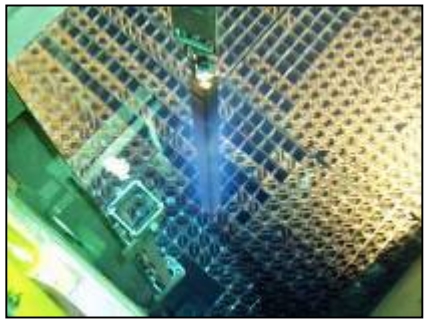
NDE Program provides support for several other EPRI Nuclear programs

The Nuclear Program's 10 Strategic Action Plans:



- ➢Materials Degradation/Aging (including Chemistry)
- ➢Fuel Reliability
- • High-Level Waste and Spent Fuel Management
- ➢Low-Level Waste and Radiation Exposure Management
- ➢Non-Destructive Evaluation
- ➢Equipment Reliability
- • Instrumentation & Control Modernization
- • Nuclear Asset/Risk Management
- • Safety Risk Technology and Applications
- ➢Advanced Nuclear Technology (new plants)

➢ *The NDE Program provides support to these Action Plans*

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Diversity of NDE Program mission

- Groundwater protection NDE
- Plastic piping
- New nuclear plant NDE issues
- Long-term operation
- Concrete
- Fuel
- Buried piping NDE
- NDE workforce

- MRP NDE support
- Global qualification support
- License renewal
- Technical support for emerging issues
- Risk-informed inspection

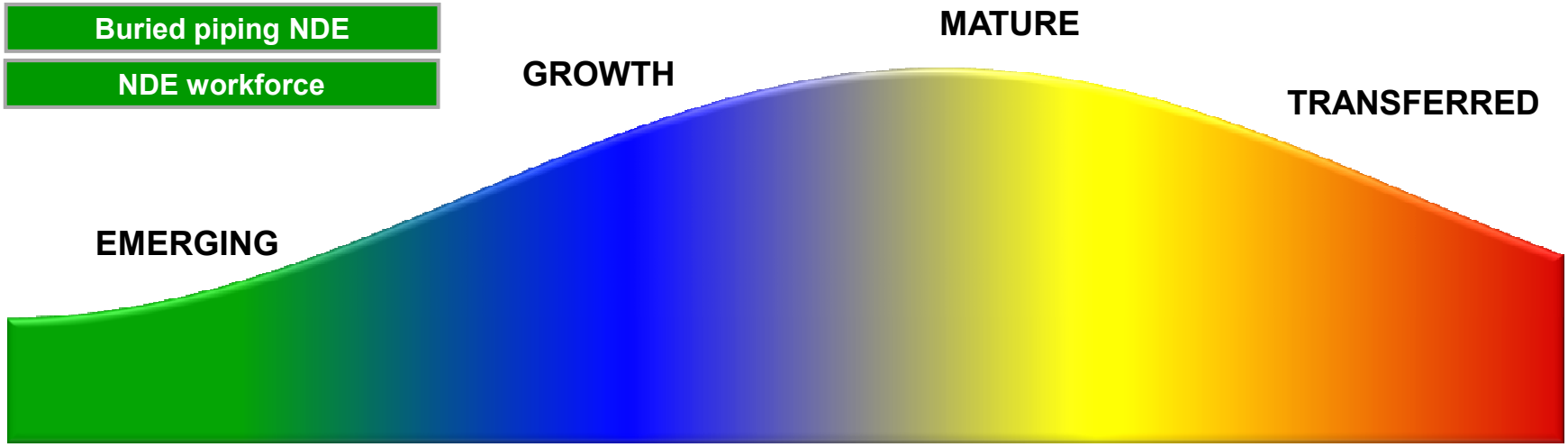
- BWRVIP NDE support
- SGMP NDE support
- Appendix VIII NDE qualification
- Training

Internal (to Generation)

- Turbine NDE

External (to vendors)

- Piping UT procedures
- Vessel UT procedures
- Phased array UT instrumentation



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Topics

- Concrete
- Buried piping
- Liners
- A few brief updates

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CR3 steam generator replacement

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NDE of the concrete

- Vendor used Impulse Response technique
  - Place a receiver (geophone) on the surface the concrete
  - Strike the concrete a few inches away, using an instrumented hammer
  - Received response is analyzed in the frequency domain
  - Produces a measurement called ‘mobility’
    - High mobility (>1.0): delaminated concrete
    - Low mobility (<0.4): sound concrete
    - The above values were developed on the CR3 containment and validated by removal of core samples

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Imaging in concrete

- EPRI has purchased a MIRA ultrasonic imaging system for concrete
  - Only two other units in the US:
    FHA
    CTL Group
- Took some images on CR3 containment

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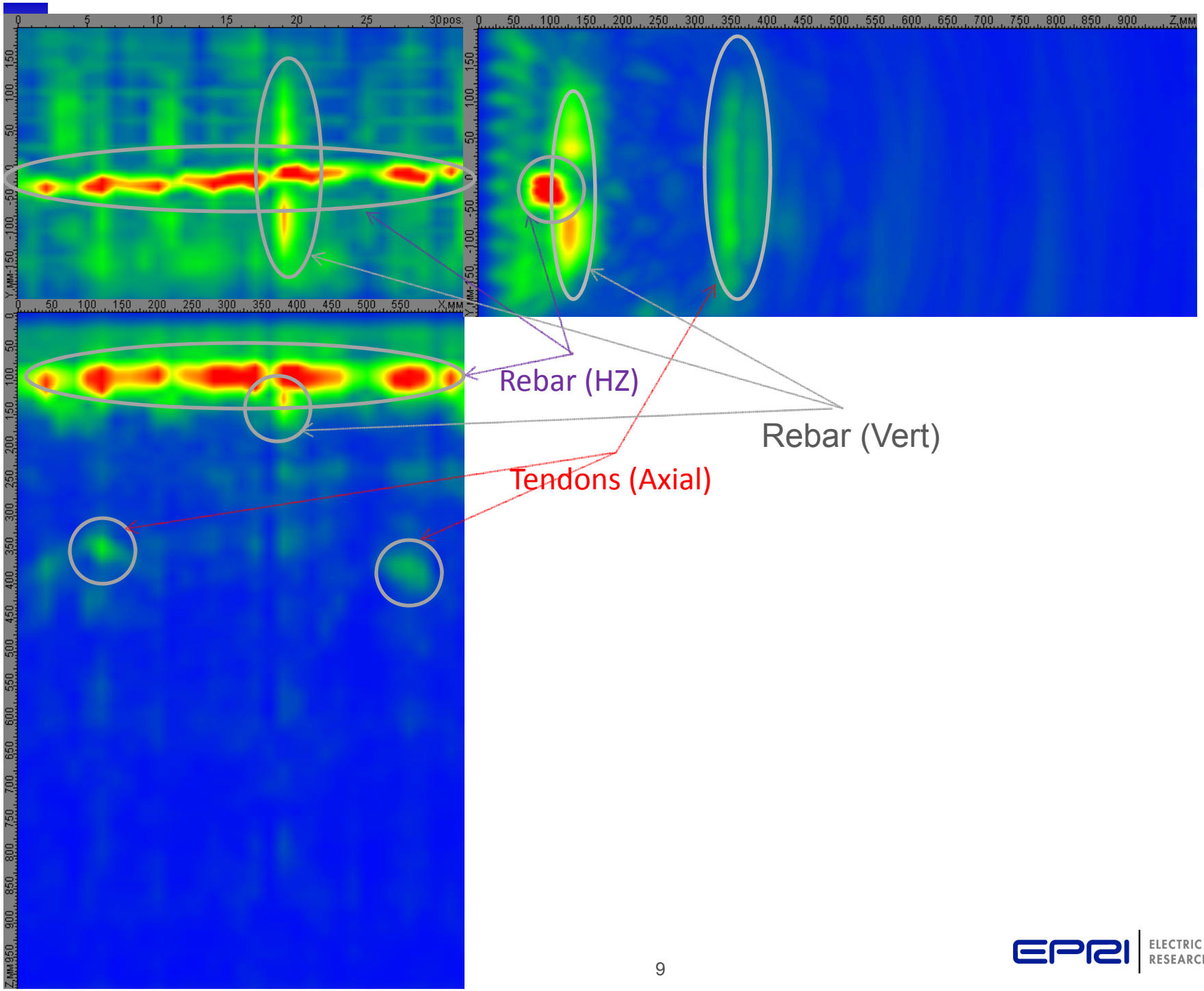

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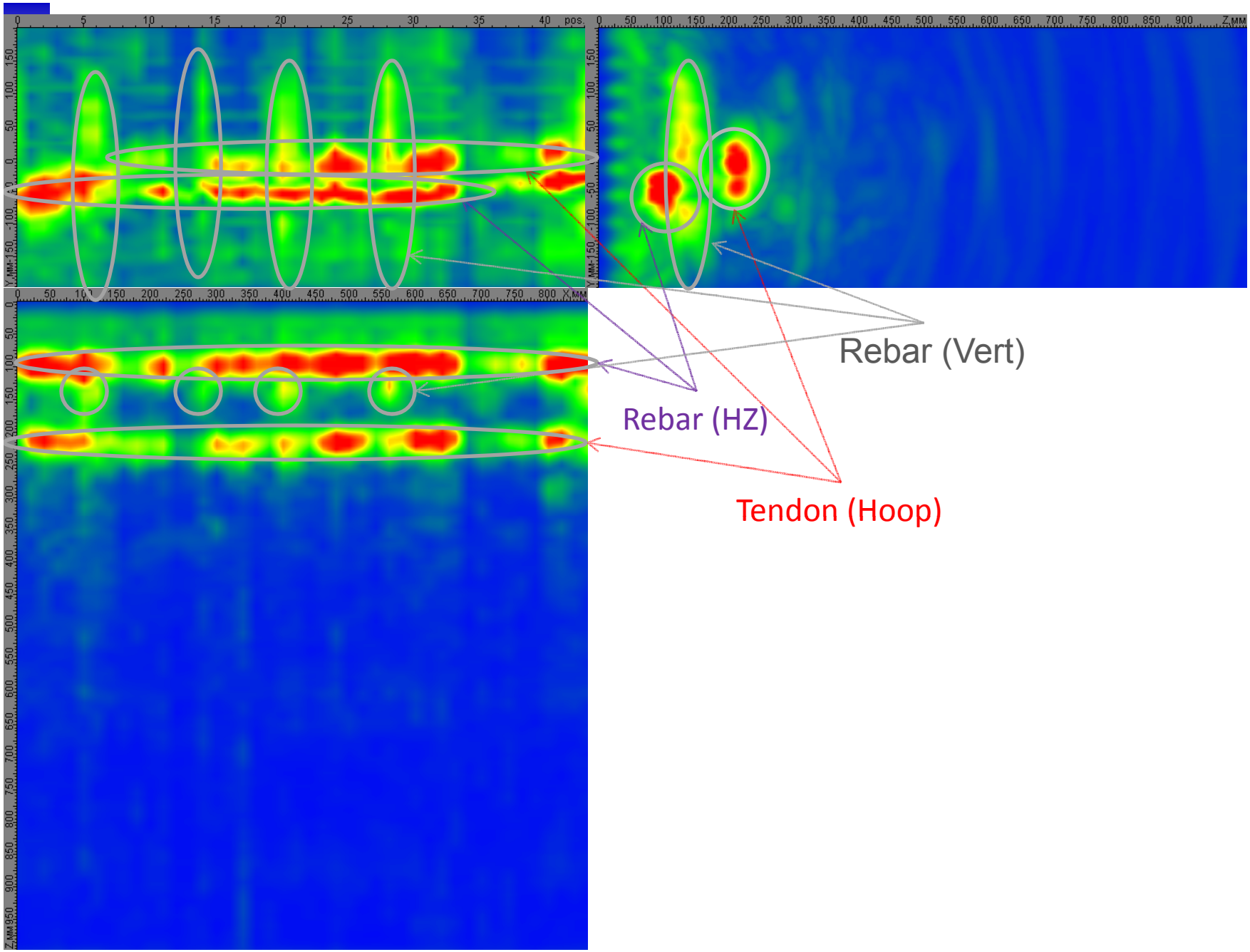

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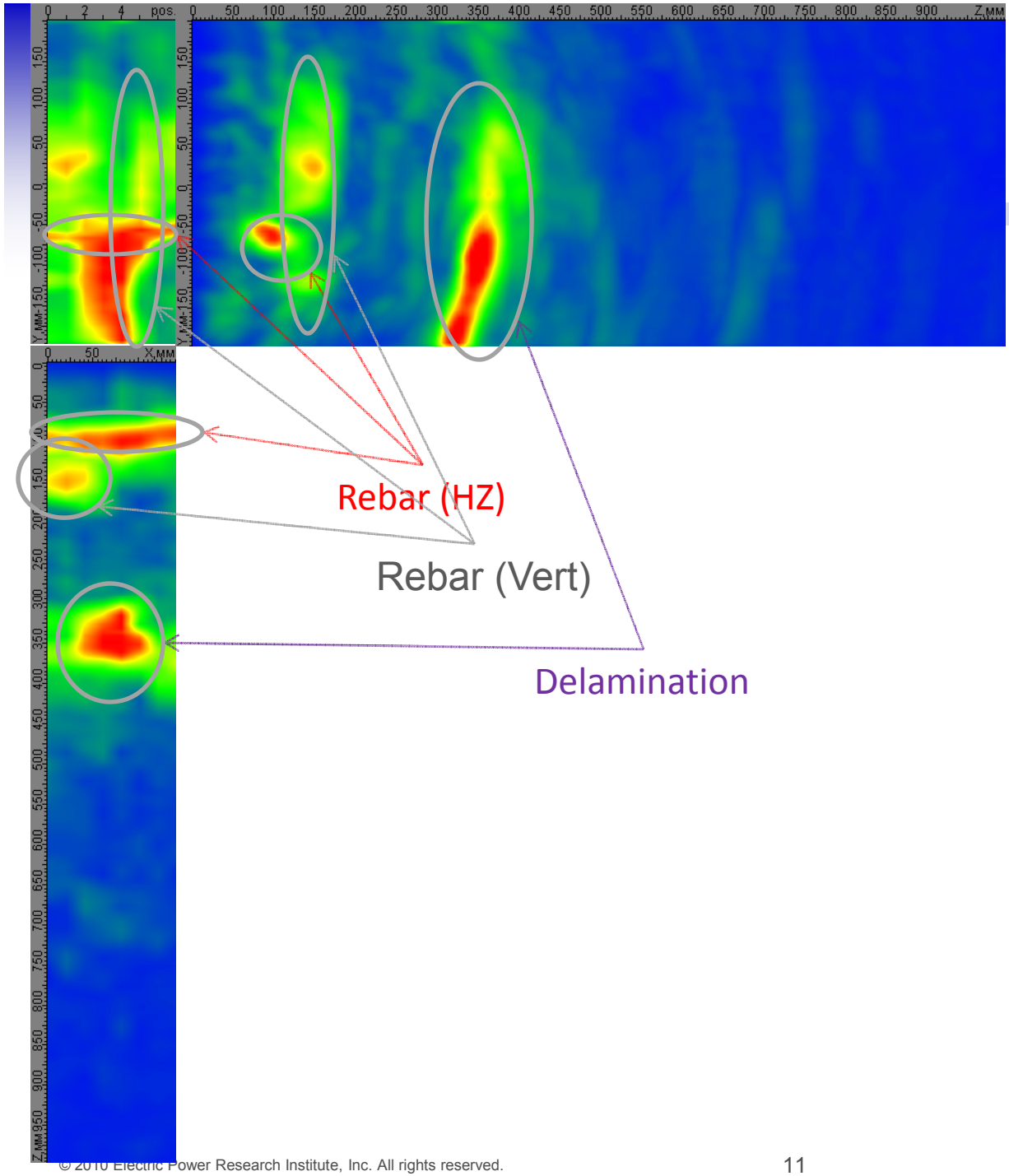

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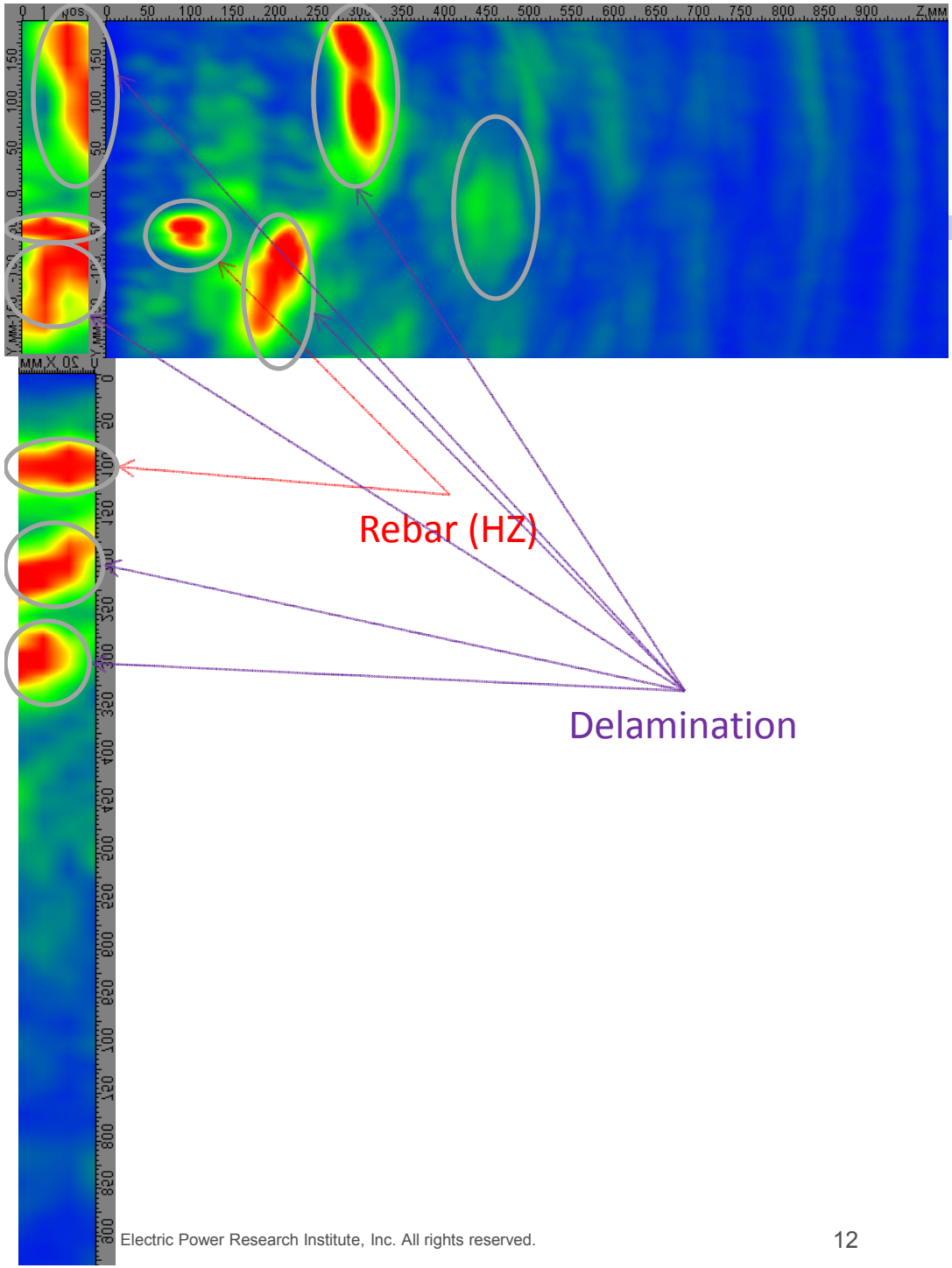

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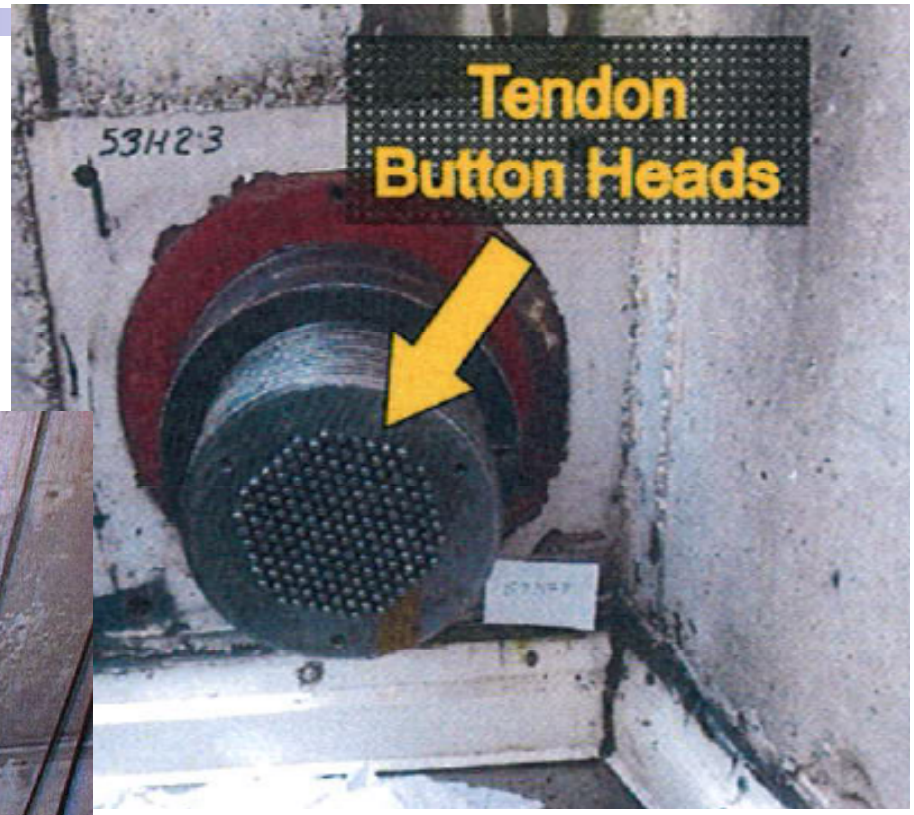
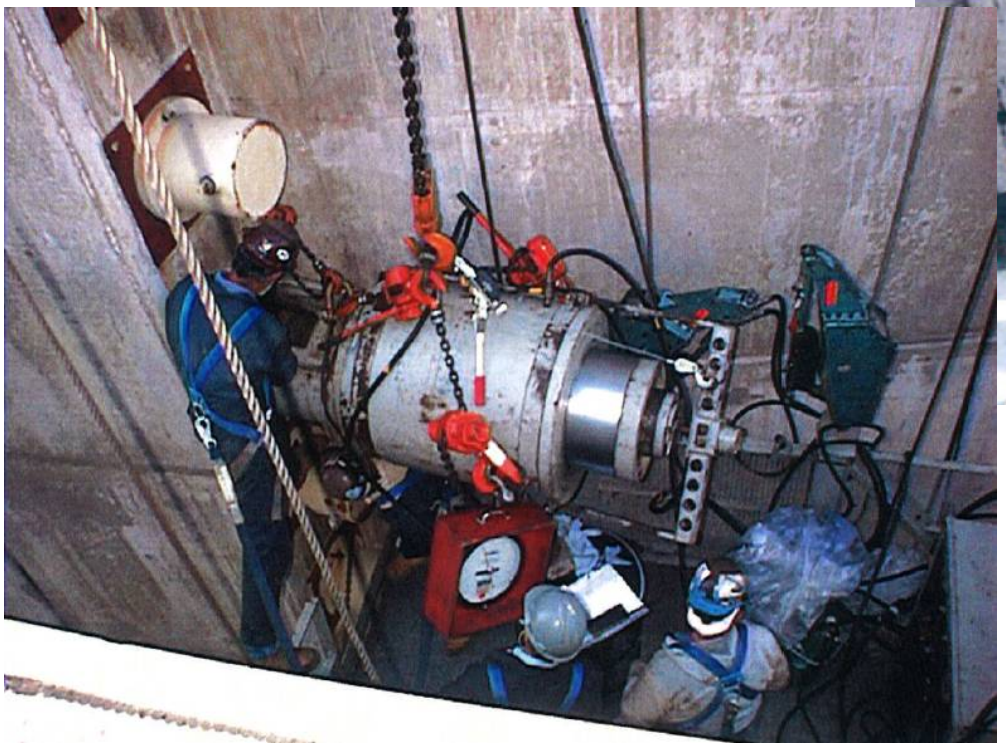
Post-tensioning tendon load

- Related – exploring the possibility of using UT or strain gauges to measure the load on the tendons
  - Would be much cheaper than measuring the load by lifting





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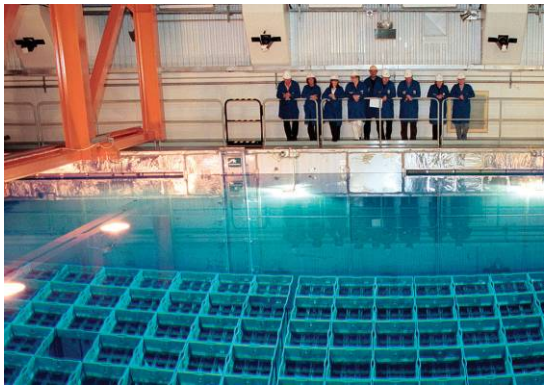
Current activities related to concrete: Nuclear Sector

- Concrete ageing in Long Term Operation of nuclear power plants
- Embedded sensors in concrete to monitor aging in new plants
- NDE techniques for concrete inspection
- Identify other R&D needs in concrete within this sector

Containment delamination



Leaks in spent fuel pools

Beam failure in cooling tower

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Current activities related to concrete: All Sectors

- Identify R&D needs within these sectors
- NDE techniques for concrete inspection

Some concrete structures of interest and potential other EPRI concrete activities

- Foundations for transmission towers – (PDU)
- PCCP pipes – (nuclear and coal)
- Chimney stacks – (coal and biomass)
- Cooling towers – (nuclear, coal and renewables)
- Concrete dams – (generation)
- Use of coal fly ash in concrete – (environment)
- Absorption of CO2 by rubble-ized concrete

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Topics

- Concrete
- Buried piping
- Liners
- A few brief updates

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Snapshot

- Overall approach: support compliance with NSIAC initiative deadlines
  - Benchmark the needs
  - Continue to develop improvements even if they won't be available by those dates
  - Leave delivery system development for the NDE service and equipment vendors
- Completed work
  - Buried pipe guided wave reference document (how-to for utilities)
  - NDE vehicle for 3' – 12' diameter piping (successful – licensing to vendors)
  - Initial assessment of guided wave UT (not the silver bullet but does have its uses)
  - Developed a buried pipe test facility (Charlotte, NC)
- Future work
  - NDE state-of-the-art document (draft 3Q2010)
  - Assessment of additional technologies
  - Continue development of NDE for mid-size pipe (12" – 36") as needed

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Focus – field trial of a buried pipe technology from another industry

- UT delivered by pigs traveling through the pipe
  - Hydrocarbon industry: movement of oil and gas products
  - Regulated by DOT; periodic measurement of the wall thickness
  - Significant limitations for most nuclear buried pipe inspections
- Field trial April 2010
  - US PWR
    - Licensee is recoating its 18” ECP line
    - This NDE field trial was added as a peripheral activity
  - Vendor: A. Hak Industrial Services B.V. (Netherlands)

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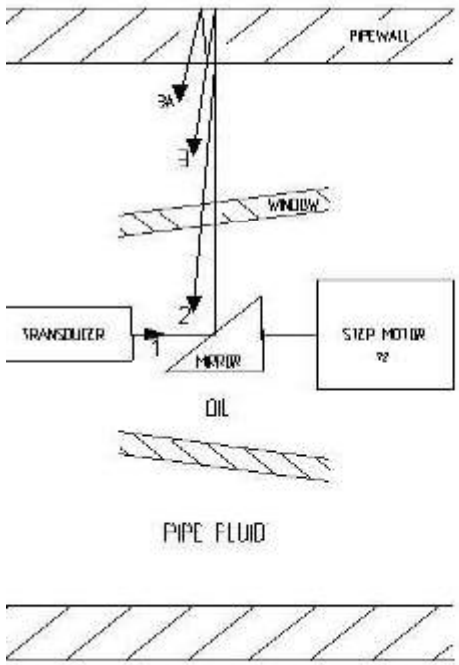
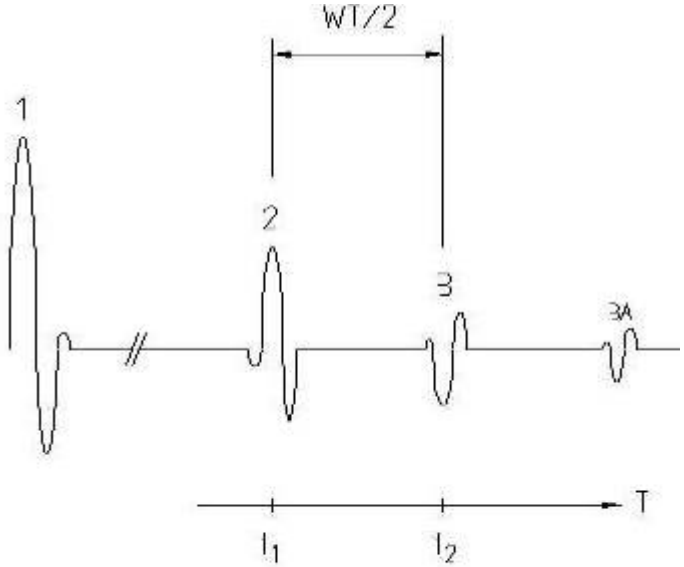
Ultrasonic principle – central transducer, rotating mirror





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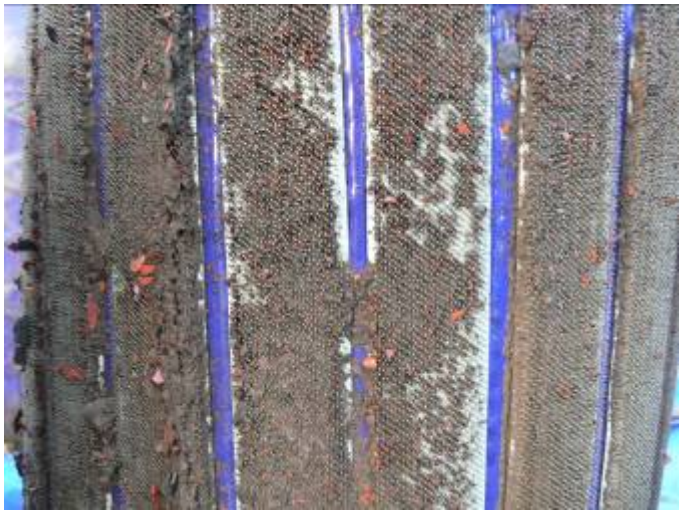
Cleaning Pigs

Must clean the pipe first



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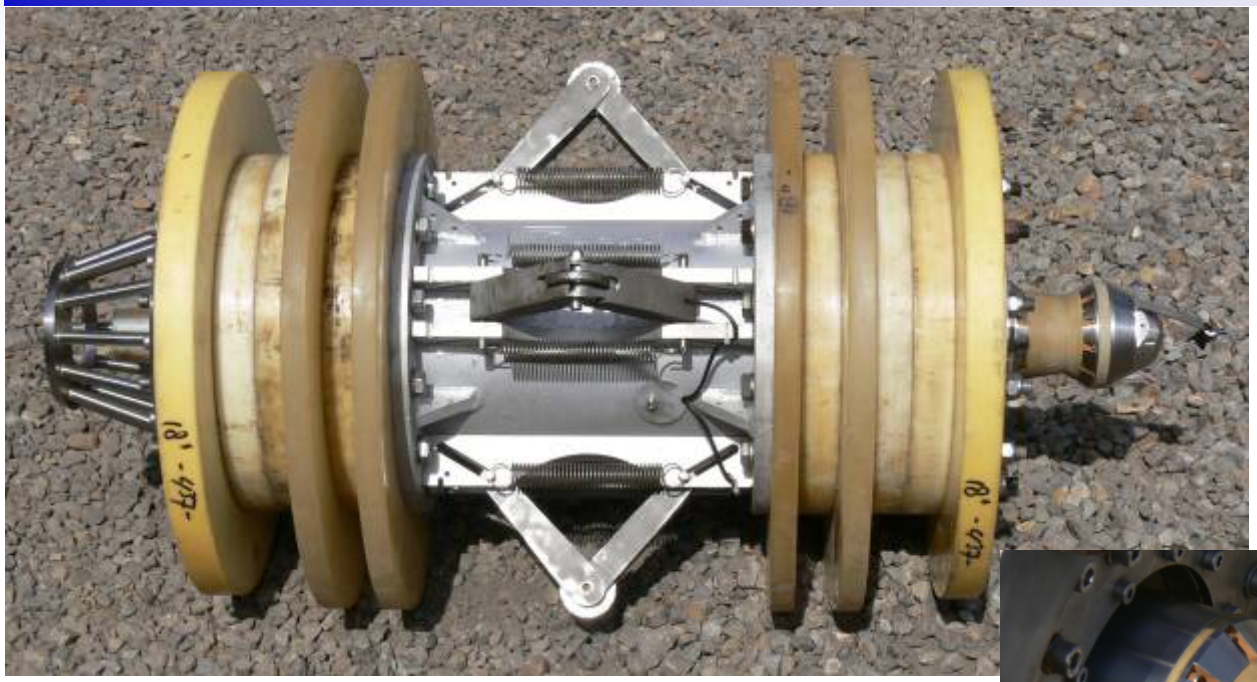
Inspection Pig



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Pig Launch and Retrieval Stations
Installed for this purpose

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Data Acquisition System

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Performance

- Scanning
  - ~2300 feet of piping
  - Line contained several elbows
  - Cleaning pig ~20 minutes per cleaning run
  - < 2.5 hours once started
  - No significant issues with data acquisition
- Data acquired
  - Circumferential direction ~2 degree increments
  - Axial direction ~10 mm
  - ~11.5 million measurements
  - No data in the elbows
- Limitations
  - Pipe must be flooded
  - Inside surface must be clean
  - Inside surface coatings may be prohibitive
  - Inside surface pitting or corrosion may be prohibitive

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Topics

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Liners

- ¼” stainless steel liners on concrete structures
  - Spent fuel pool
  - Fuel transfer canal
  - Reactor cavity

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Eddy Current Sensor

Transmit-Receive Eddy Current Flexible Sensor

The scans made on these welds have been performed with a flexible prototype probe which contains only few coils. However, this represents accurately the type of results which might be reached with the complete flexible array probe.

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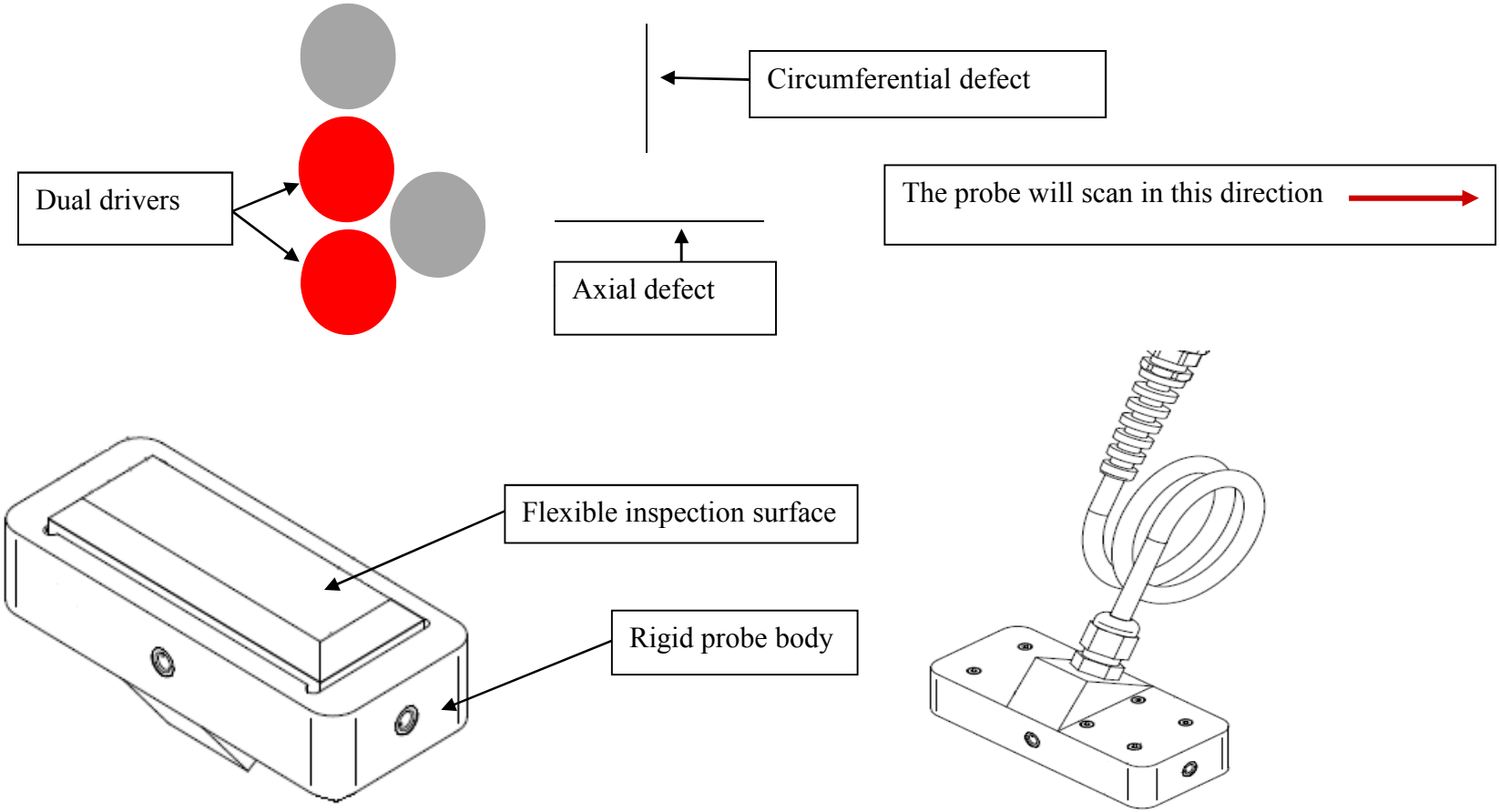
Eddy Current Sensor Design

– Nondestructive Testing Update – Sensor Coil Configuration



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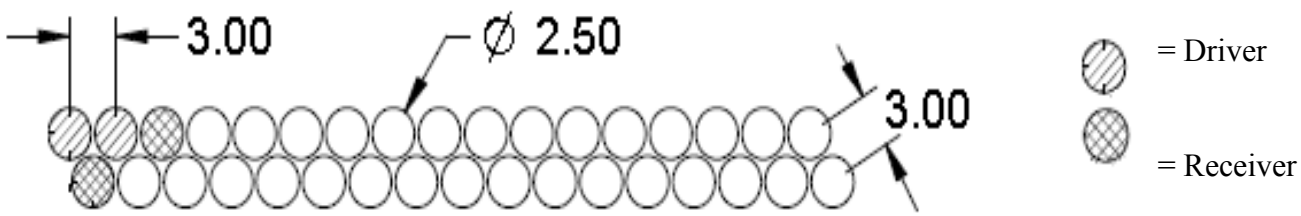
Eddy Current Sensor Design

– Nondestructive Testing Update – Sensor Coil Configuration

– This probe would contain 32 coils and the array would be ±47mm wide. There would be a total of 62 channels (32 axial channels and 30 axial channels) in transmit-receive mode dual driver. The figure below represents the proposed array configuration.



Solution	Strength	Weaknesses
3mm coils, distanced in the axial orientation and adjacent in the circumferential direction, transmit-receive mode (single OR dual driver	•Good scan definition •Less sensitivity to lift-off •More defined signal shape	•Detection of short defects •Smaller signal amplitude (mostly on small defects) •Small horizontal offset due to permeability changes

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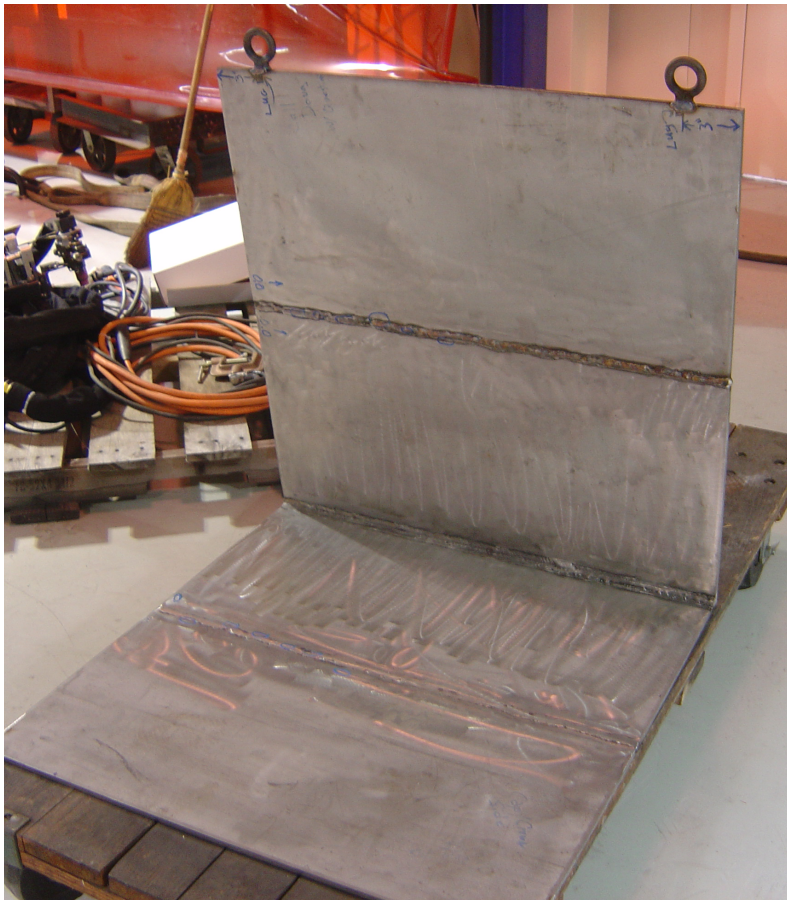
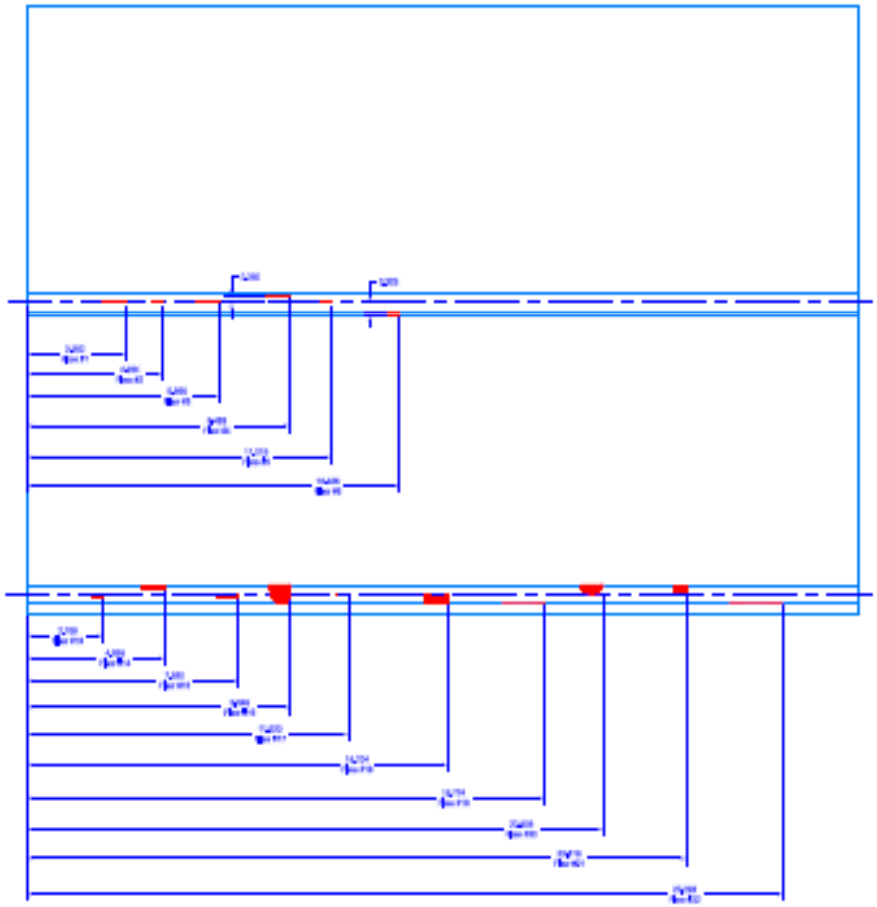
Mock-Up Information

Spent Fuel Pool Liner Mockup





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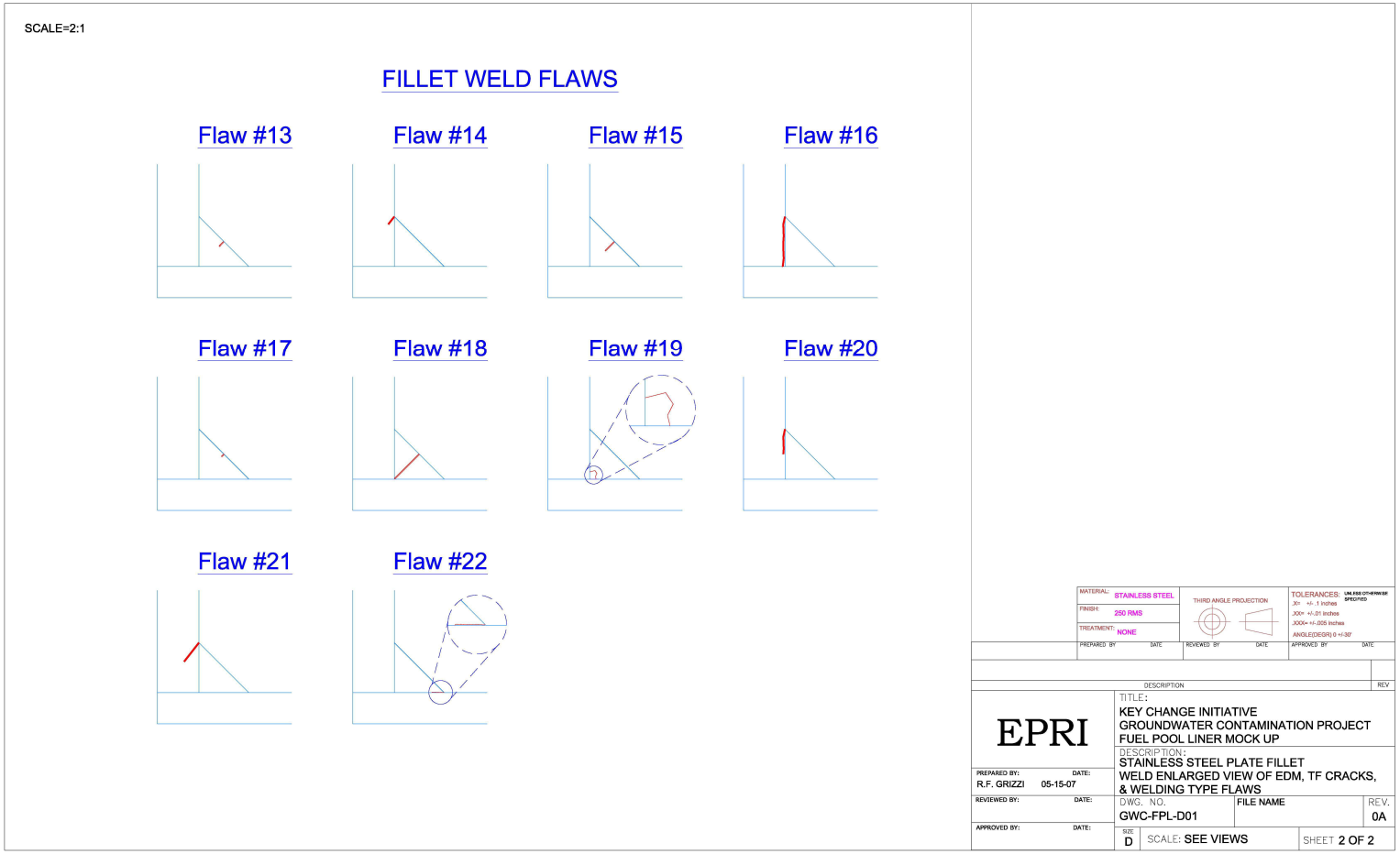
Mock-Up Information Details



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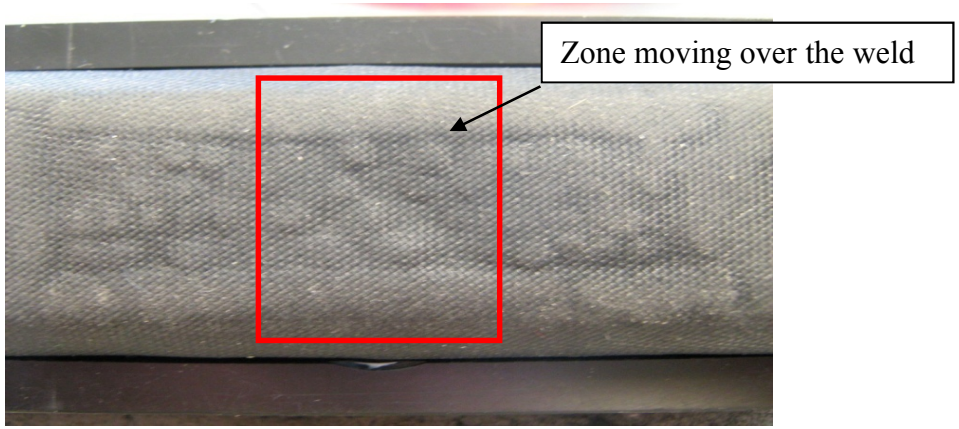
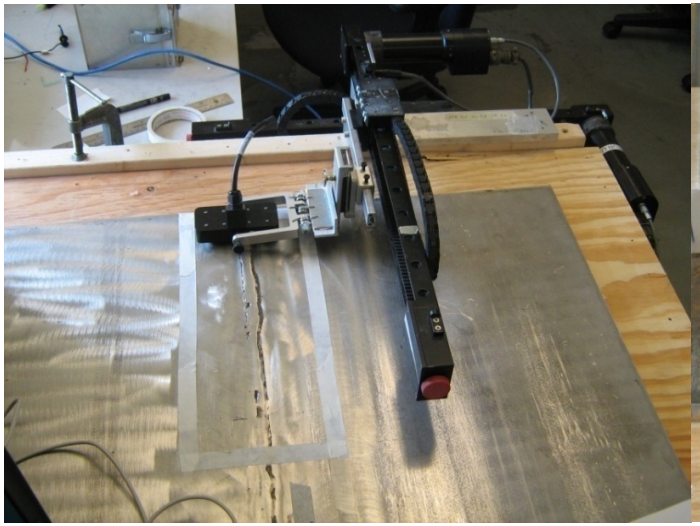
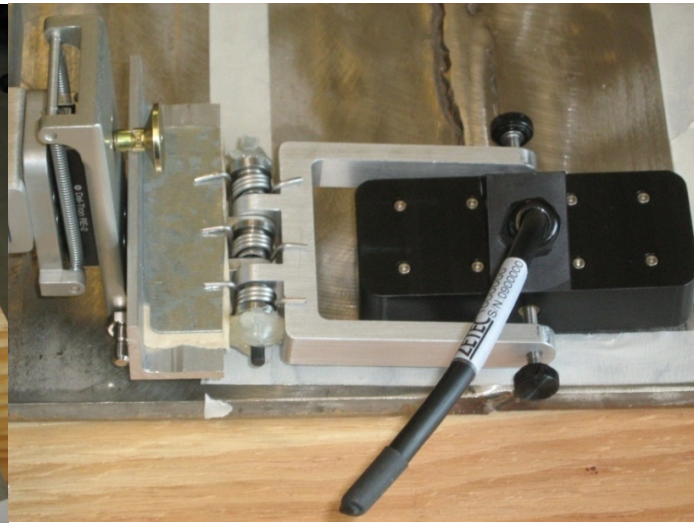
Sensor Scans







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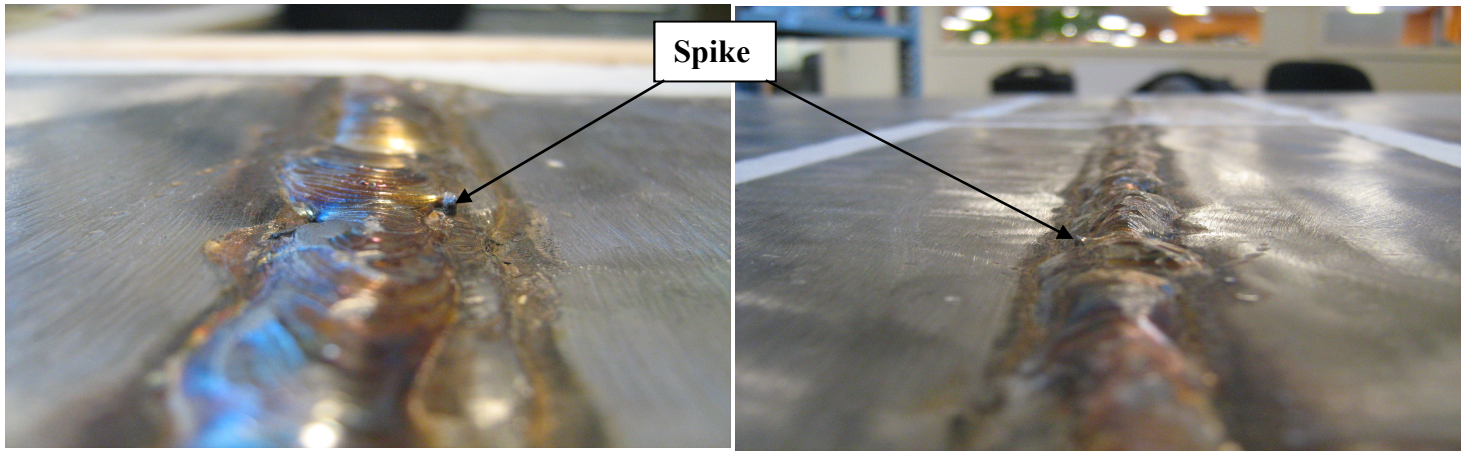
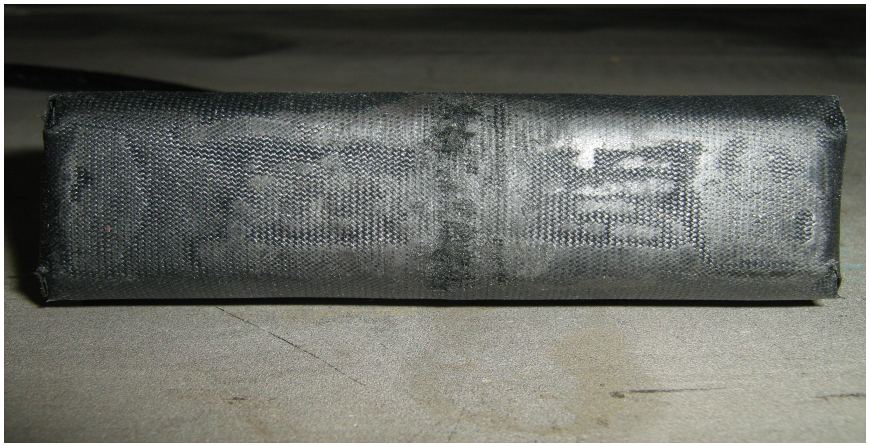
Sensor Abrasion Test on Rough Weld





Sensor Surface after 350m on Rough Weld
Containing One Spike

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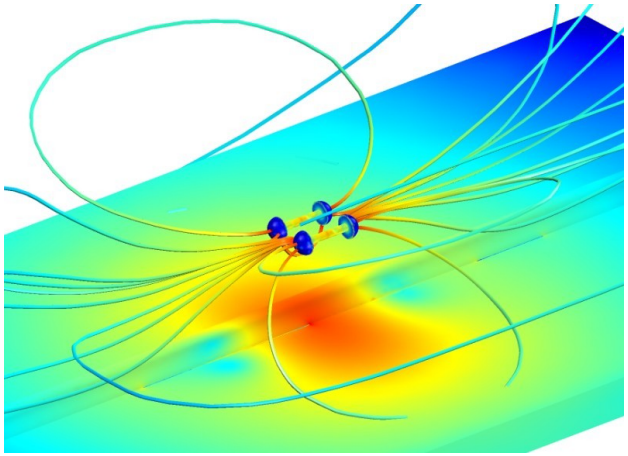
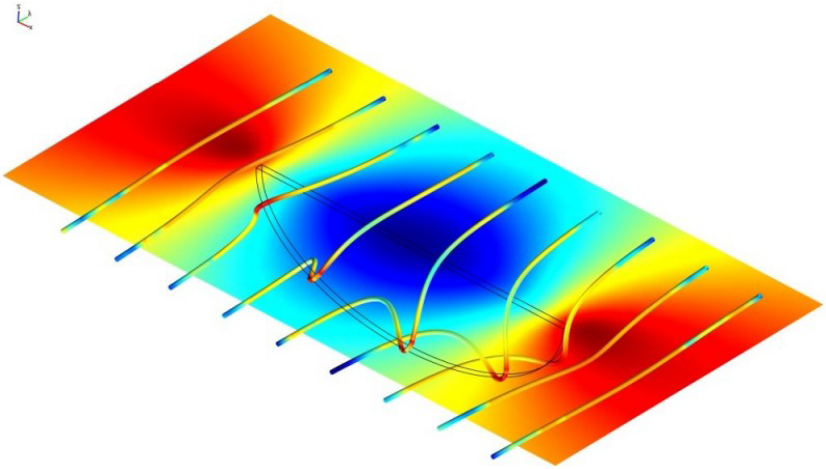
Alternating Current Field Measurement (ACFM)

- Use to locate surface breaking flaws
- Used extensively in carbon steel material but sensors can be modified for stainless steel application



One or more induction coils are placed above the metal structure to be inspected. A 5kHz current induces an alternating magnetic field above the plate.
The magnetic field induces an eddy current, which flows across the surface of the plate. This is indicated in orange on the plate.



The eddy currents flow across the surface of the plate, until they encounter a surface breaking defect. The eddy currents are forced to flow around or beneath the defect. The eddy currents in the middle of the defect are forced downwards, away for the surface. This causes a drop in the magnetic field, shown in blue.

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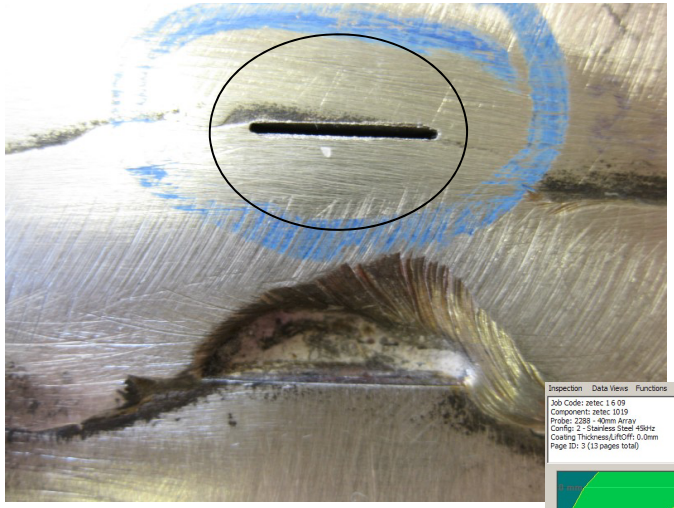
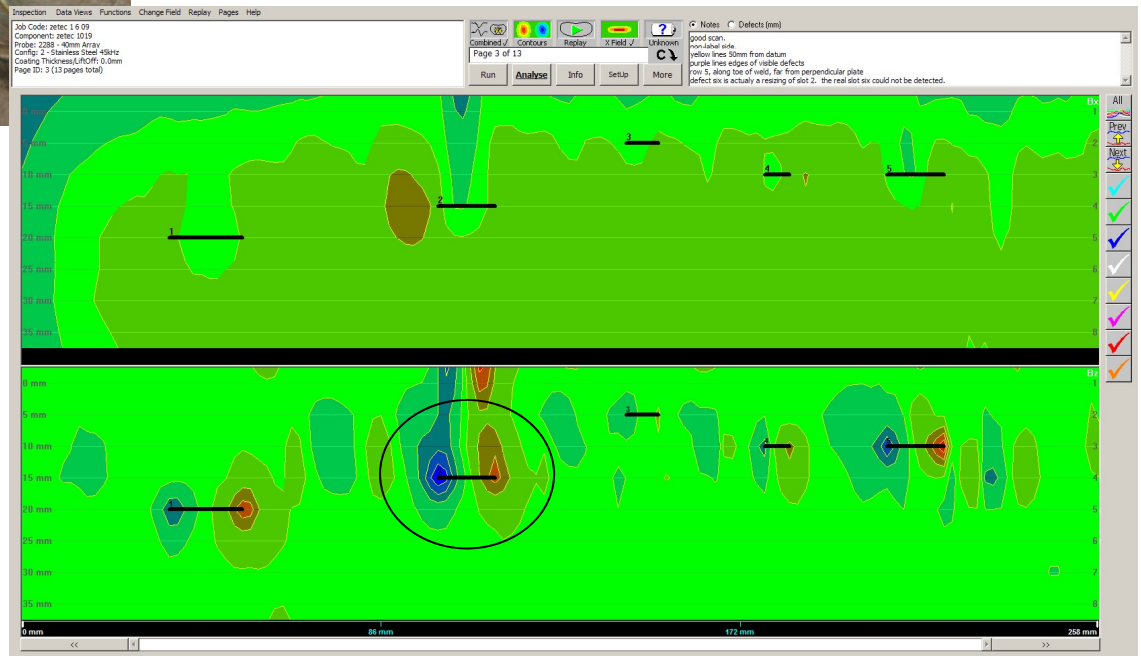
Alternating Current Field Measurement (ACFM)





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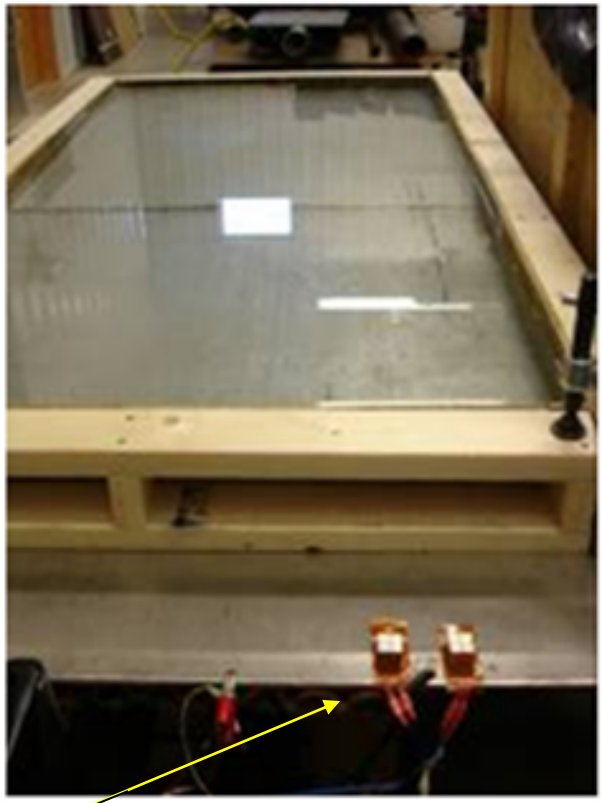
Guided waves: SH-Wave EMATs



Location 3

Aimed at plug weld with notch

Dual element SH wave EMATs

Location 1

Aimed at plug weld without notch

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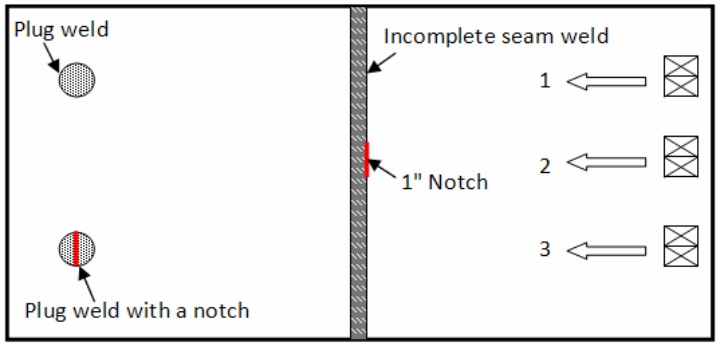
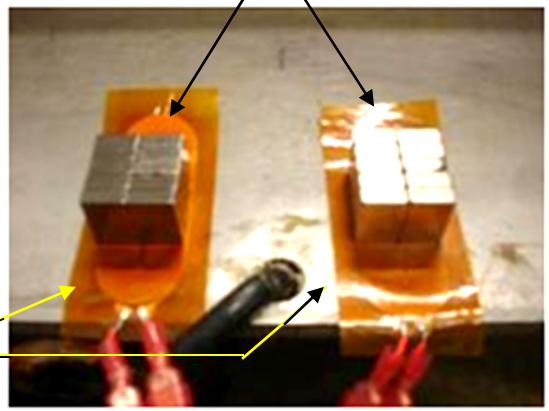
Results (SH-Wave)



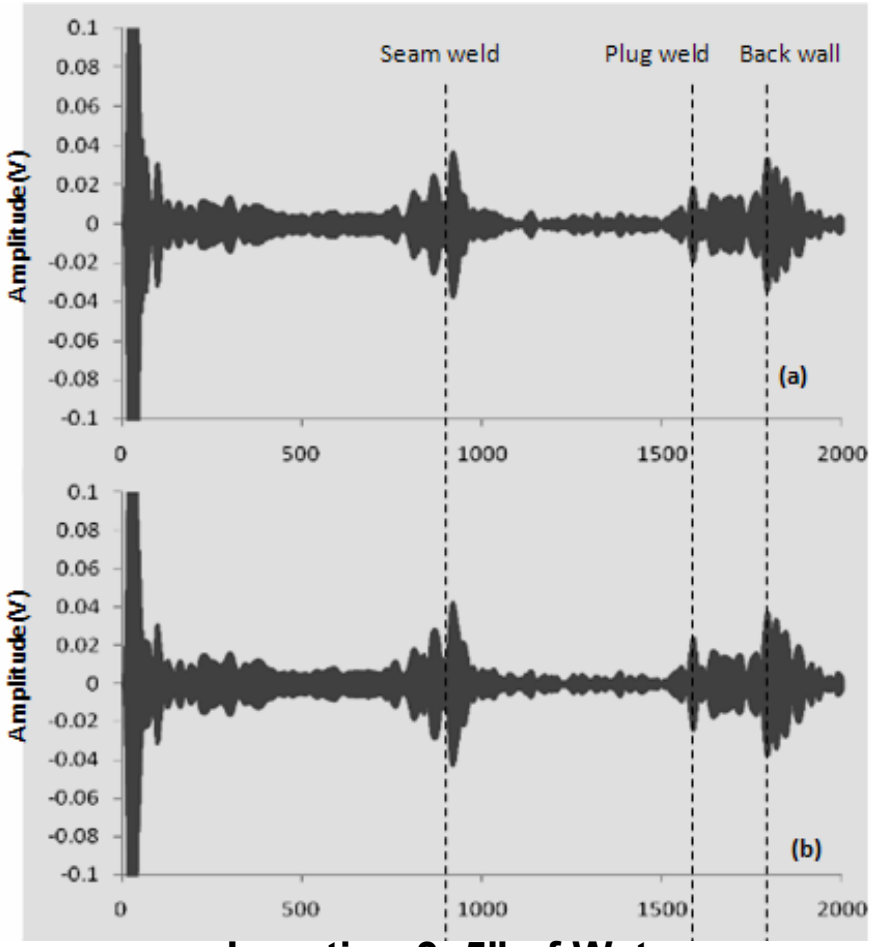
Magnet arrays



Coils

Duel element SH wave EMATs

Location 3, No Water



Location 3, 5" of Water

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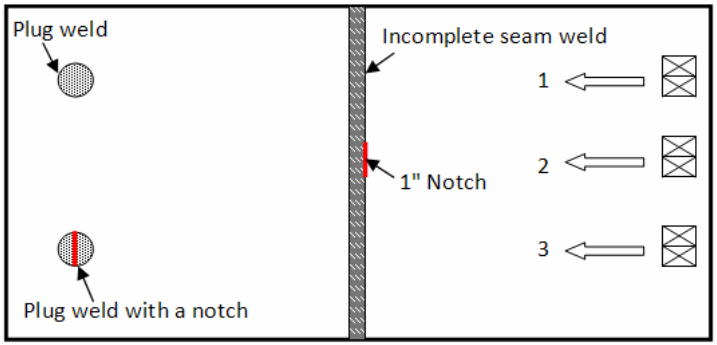
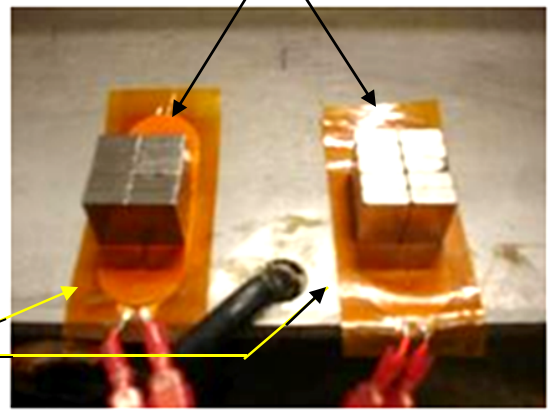
Results (SH-Wave)



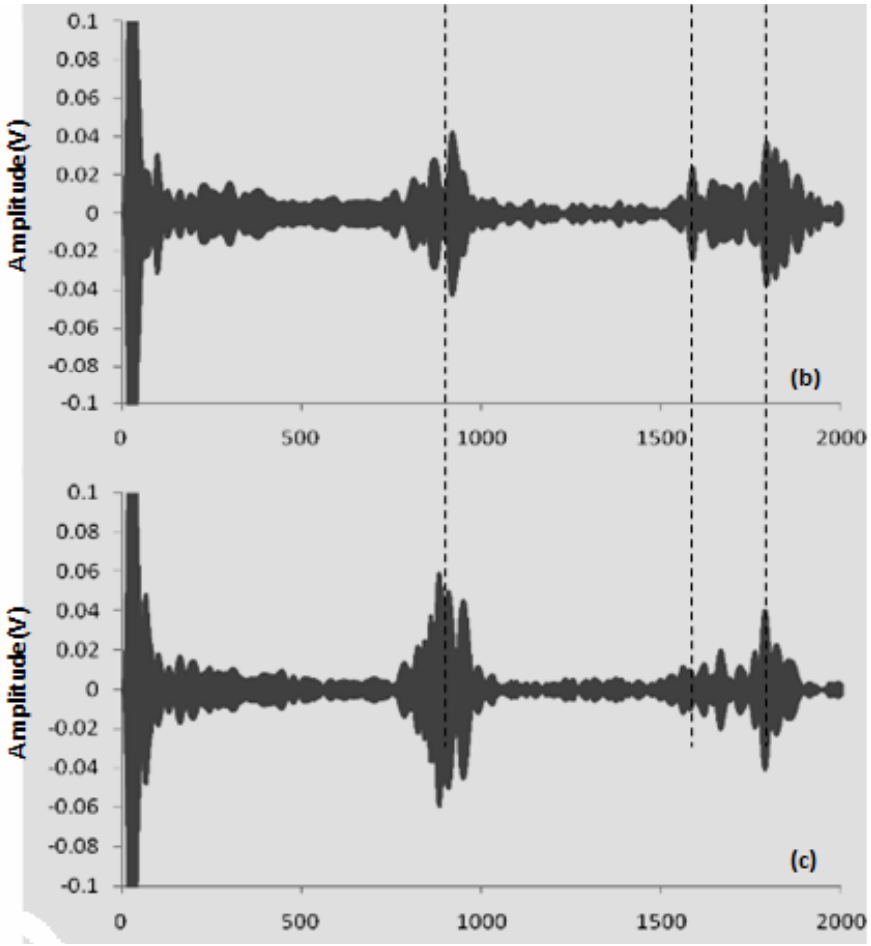
Magnet arrays



Coils

Dual element SH wave EMATs

Location 3, 5" of Water



Location 1, 5" of Water

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Topics

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Performance demonstration

- Mature
  - PDI
  - SGMP
- New
  - RPV upper head penetrations
- International EPRI PD assistance
  - Taiwan, South Africa, Brazil – using PDI
  - Korea – developing PDI clone
  - Sweden, Switzerland, Spain – ENIQ, leveraging PDI
  - Japan – developing own path

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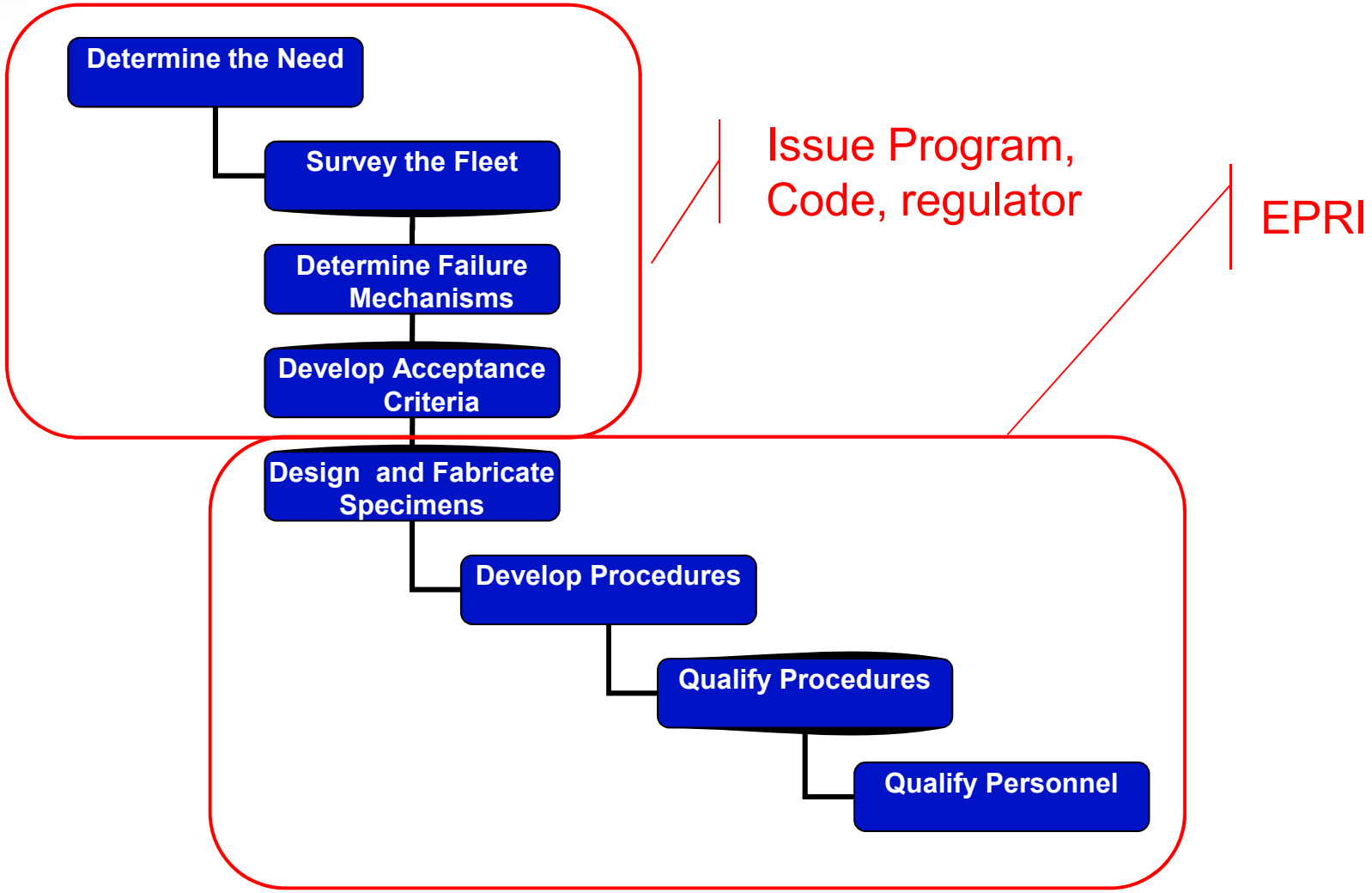
Trajectory of a PD program



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One-line updates

- POD (within xLPR)
  - DM weld POD study complete, published, public
  - Weld overlay POD study delayed due to heavy Spring schedule

- UT for rough and wavy surfaces
  - No solutions

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Remote visual examination

- PNNL is planning a round robin experiment on the capability of remote visual examination
  - Funded by RES
- PNNL and RES invited industry to participate in the planning and execution
  - There are several complex technical issues in doing laboratory studies of visual examination
- Coordination
  - Series of RES/PNNL/industry meetings, began 1/2010
- Plan
  - Phase 1: 'Dry run' of Phase 2; also try a few laboratory techniques
  - Phase 2: Field equipment, procedures, personnel
  - Phase 3: Enhancements developed based on Phases 1 and 2

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Discussion

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backup slides

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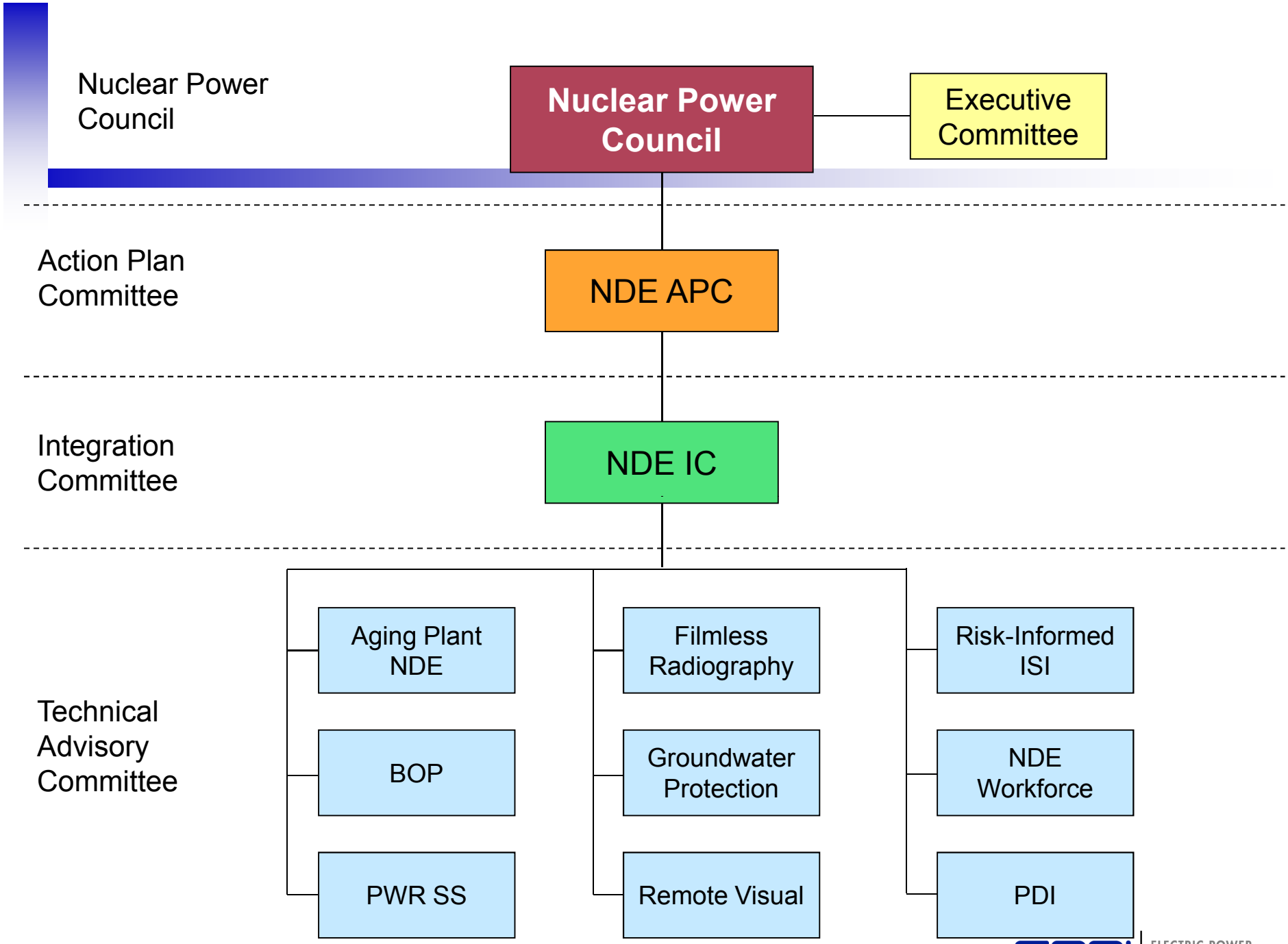

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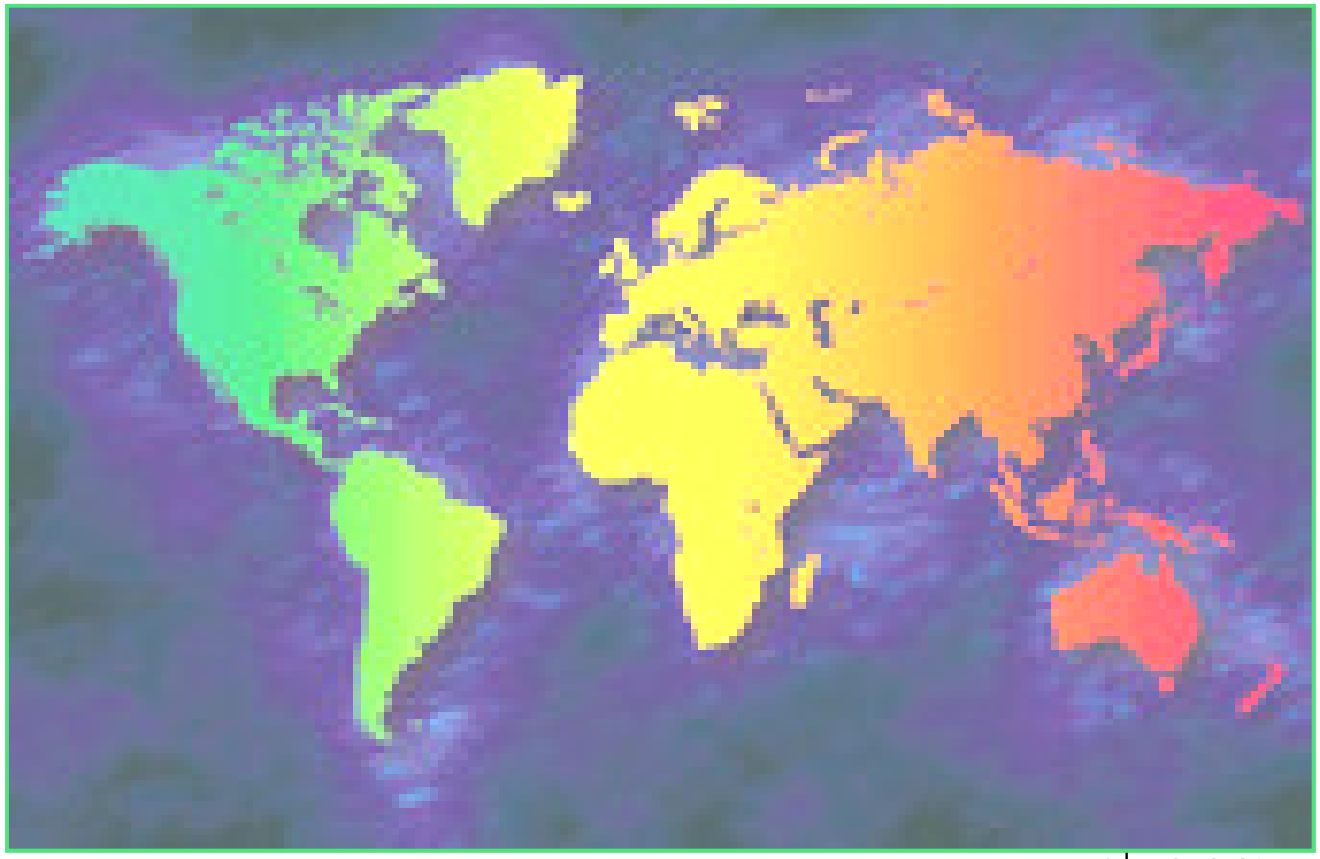
NDE Program International Engagement

- All US utilities

- Japan
- Korea
- Taiwan

- Mexico
- Brazil
- Canada

- France
- Spain
- Czech Republic
- Slovenia
- Switzerland
- Sweden *(Ringhals)*
- South Africa
- United Kingdom *(Rolls-Royce)*



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NDE new projects 2010+

Project Name	Cofund	2010	2011	2012	3-Year Total	2010 Total
NDE Data Conversion, Storage and Records Management	ANT	146	55	0	201	**146**
Evaluation of Filmless Radiography	ANT	150	150	150	450	**296**
Buried Pipe NDE Technology Assesment and industry support		74	79	0	153	**370**
Lasers for Crack Detection and Dimensional Inspections		104	209	186	499	**474**
Advanced NDE for Duplex, Carbon Steel and Ferritic SS Tubes	ANT	149	171	150	470	**623**
Low Frequency UT for Weld Overlays on Cast Stainless Steel		82	0	0	82	**705**
License Renewal Inspection Best Practices		63	72	73	208	**768**
HDPE Inspection Techniques and Assessment		217	171	65	453	**985**
NDE of Stress Corrosion Cracking at Nuclear Plants - Historical View		70	70	0	140	**1055**
NDE Applications for Selective Leaching		85	85	85	255	**1140**
PDI Weld Overlay Program - Test Specimen Library Expansion		625	495	0	1120	**1765**
Impact Study of the Application of Qualified Remote VT for IVVI		80	0	0	80	**1845**
Remote Field Technology Assessment for Piping Inspection		109	0	0	109	**1954**
Evaluation of Inside Surface NDE for Cast Stainless Steel		203	231	26	460	**2157**
NDE for Transfer Canal Inspection		114	131	139	384	**2271**
Ultrasonic Cable Equivalency Phase II		55	29	0	84	**2326**
Signal Processing Advancements for Cast Stainless Steel		100	100	50	250	**2426**
RI-ISI Infrastructure		82	166	93	341	**2508**

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NDE methods – status and availability

NDE Methods	Inside/ Outside	Technology	Application condition	Answers it provides	Drawbacks	Status
Magnetic Flux Leakage	Inside	Several vendors (petrochemical industry)	Drained or water filled	Pitting assessment	Tool is massive Requires long, straight runs, gentle elbows, etc. Pipe must be cleaned	Available today; this is the workhorse of gas transmission
Remote field eddy current	Inside	Several vendors (water utility industry)	Drained or water filled	Corrosion assessment	Pitting resolution not demonstrated Range limited by elbows, branches, valves	Available today.
RFET Transformer Coupling	Inside	Pre-stressed concrete lined pipe (water utility industry)	Drained or water filled	Wire breaks	No liner corrosion information	Available today
Deep Penetration Eddy Current	Inside	EPRI To be licensed for commercial use	Drained	Weld corrosion attack (including long seam)	Developed for detection of preferential corrosion at welds; would require additional optimization for use on general piping No pit depth information	Available today
Guided waves	Outside	Limited vendors	Local excavations to access pipe	General condition	-Screening tool - Limited range - Capability varies; complex -Shortage of examiners -Will not find isolated small flaws	-Available today -Application document published - EPRI studying capabilities
Ultrasound	Inside	Limited vendors (petrochemical industry)	Water-filled pipe	Accurate thickness (metal loss) Good coverage capabilities	May not find pits Pipe must be clean Must have access to introduce the pigs	First examination performed last week at ANO Capabilities need further assessment
Remote field eddy current - EPRI	Inside	EPRI - To be licensed for commercial use	Drained	Pitting – high spatial resolution	Range not limited by elbows, branches, valves	Under development Trial Seabrook 2011

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Above-ground assessment technologies *and* Delivery systems for NDE deployment

Above Ground Assessment	**Inside/ Outside**	**Technology**	**Application condition**	**Answers it provides**	**Drawbacks**	**Status**
Cathodic Protection Survey	Outside	Several vendors	Above ground walk survey	Pipe cathodic protection condition	Interfered by grounding grid and connecting pipes	Available today; standard
Area Potential Method (APEC)	Outside	One vendor	Above ground walk survey	Pipe cathodic protection condition Less interference from other structures	New, complex data analysis, limited experience	Available today
OD Coating Condition Surveys	Outside	DCVG, ACVG, Pearson, AC Attenuation Several vendors	Above ground walk survey	Coating condition	Limited accuracy; not highly sensitive	Available today
Delivery Systems	**Inside/ Outside**	**Technology**	**Application condition**	**Answers it provides**	**Drawbacks**	**Status**
Cable pulled	Inside	Several vendors	Water filled		Range limited by elbows	Available today
Self Contained (Pigs)	Inside	Several vendors	Water or gas pumped		Access limited by branches, valves Pipe cleaning req,	Available today
Guide-wire	Inside	EPRI To be licensed for commercial used	Drained	Addresses range and access limitations	Guide-wire installation precedes launch	Under development Trial Seabrook 2011

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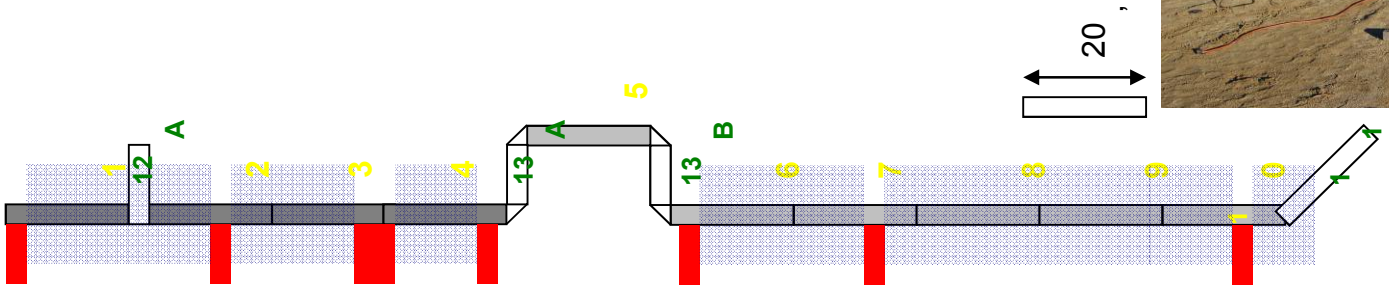
EPRI Buried Pipe Mockup Layout



Coal Tar Enamel

Coal Tar Epoxy

Access Point

Backfill

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