Non-Invasive Digitization of Nuclear Plants

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Presenters

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- M&DC Centre Analyst, Bruce Power
- Prior experience:
  - Project Engineering Lead, Valves
  - Responsible System Engineer, Bruce A Station Engineering

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- Operations leader, Plant Hatch
- Prior experience:
  - System Operations Manager, Plant Hatch
  - Licensed Senior Reactor Operator Nine Mile Point Nuclear Plant, Exelon
  - Nuclear submarine service, US Navy
- US Navy Nuclear Power Program

Harry Sim

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- Founder, inventor & patent holder
- Prior experience:
  - VP Honeywell Automation Control
  - Payload Director, NASA STS-40 Mission
- MBA Insead, France
- MS+BS Electrical & Mech Engineering, Control Systems, Stanford University

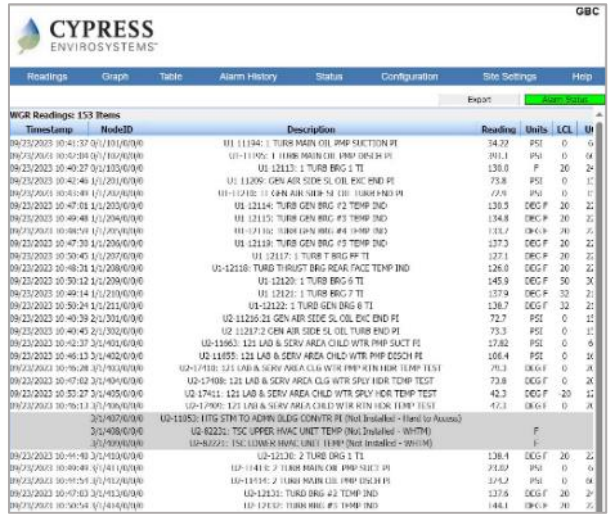
Problem: Most Plant Data is NOT Digitized

Solution: Non-Invasive Sensors – 5 Minute Install

Connection via
RESTful API or OPC

Historian

HMI

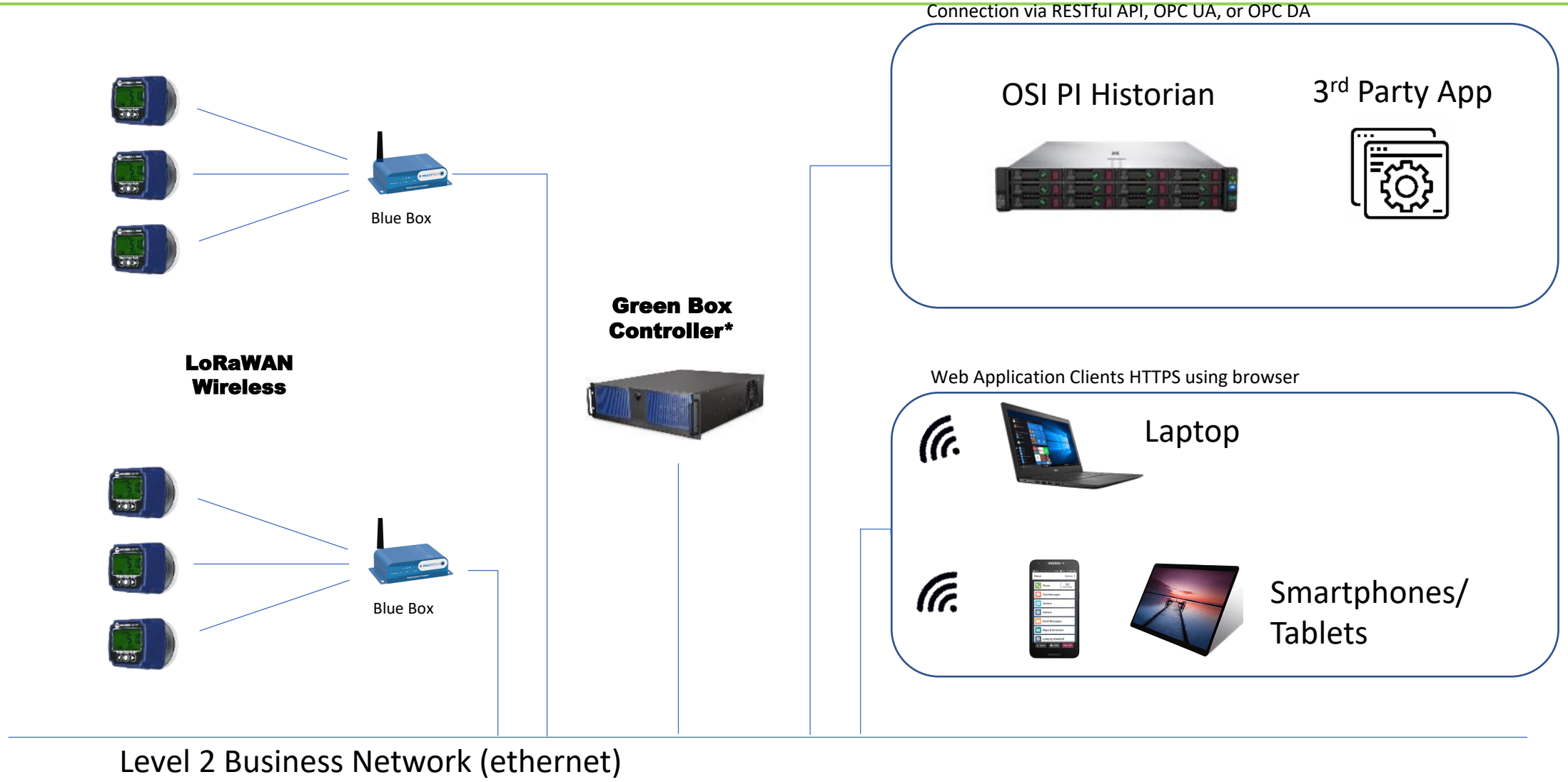


Wireless, battery operated, does not touch plant process:
~10% the cost of traditional instrumentation, 5 minute install

Installation Example

Outdoors, RCA, Seismic, Safety Related Areas

Integration with Plant Data Network – Cyber Approved



Non-Invasive Sensors

Wireless Gauge Reader

Cycle Isolation Valve Monitor

Wireless Temperature and Humidity Monitor

Wireless Rad Monitor

Webcam Digitization
(machine vision)

Vibration Sensors

Wireless Transducer Reader
(thermocouples, 4-20mA, 0-5V, dry contacts, RS-232 etc.)

Magnetic Mount Thermocouple

Void Detection

Drone Integration
(machine vision)

Wireless, Battery Operated, Non-Invasive, Install in Minutes
10% Cost of Traditional Approaches

Operational Experience and Use Cases

Southern Nuclear

Nuclear Fleet:

- Hatch, 2 reactors, BWR, Georgia, USA
- Vogtle, 4 reactors, PWR, Georgia, USA
- Farley, 2 reactors, PWR, Alabama, USA

Bruce Power

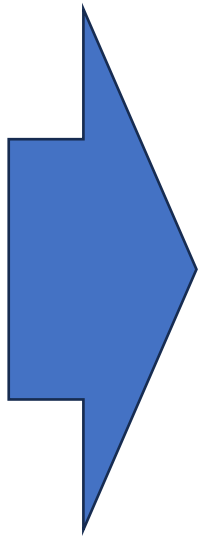
Nuclear Fleet:

- Bruce A, 4 reactors, HW PWR, Tiverton, ON
- Bruce B, 4 reactors, HW PWR, Tiverton, ON

Plant-wide Engagement – Broad benefits

DEPARTMENT:

- Operations
- Maintenance
- Engineering
- Chemistry
- Radiation Protection
- Monitoring & Diagnostics Center



BENEFITS:

- Improve operator efficiency
- Equipment fault detection/reduce unplanned downtime
- Reduce maintenance cost – enable condition-based maintenance
- Optimizing plant thermal performance
- Improve worker safety – ALARA, heat stress
- Troubleshooting crash cart, emergent needs

Condition Based Monitoring – FRF Filters

Need:

- Apply Condition Based Monitoring to FRF filters. Replace consumables only when data shows it is necessary.
- Note: FRF Filters remove impurities which can cause damage or malfunction to the hydraulic system.

Solution:

- Use WGR's to monitor and trend delta pressure across FRF filters.
- Replace filters at designated delta P.

Benefit:

- Maintain system performance by ensuring low filter delta P
- Ease burden on Operations by improved monitoring and forecasting of filter changes

Thermal Performance: Valve Cycle Isolation Monitoring

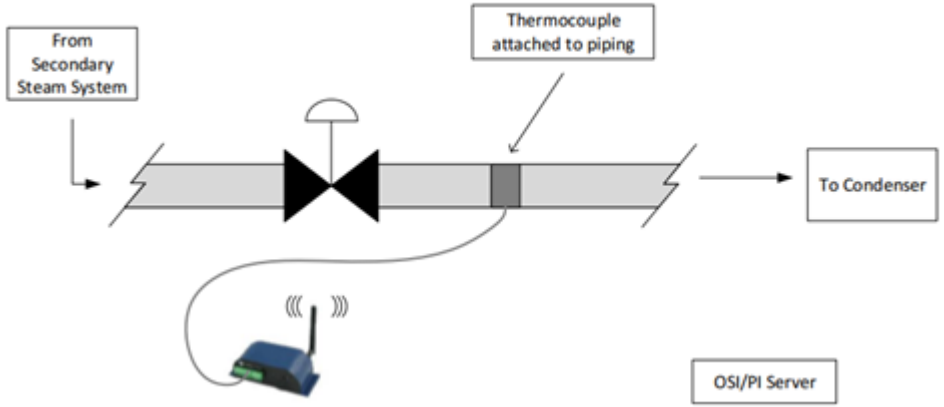
Need:

- Monitor steam system isolation valves for signs of passing

Benefit:

- Detect and prevent valves from passing steam directly to the condenser, increasing the number of MW's available to the grid.
- Save operator & engineer time to monitor valves in the field
- Project expected to pay for itself within 2 years of execution

Detect Leaking Valves



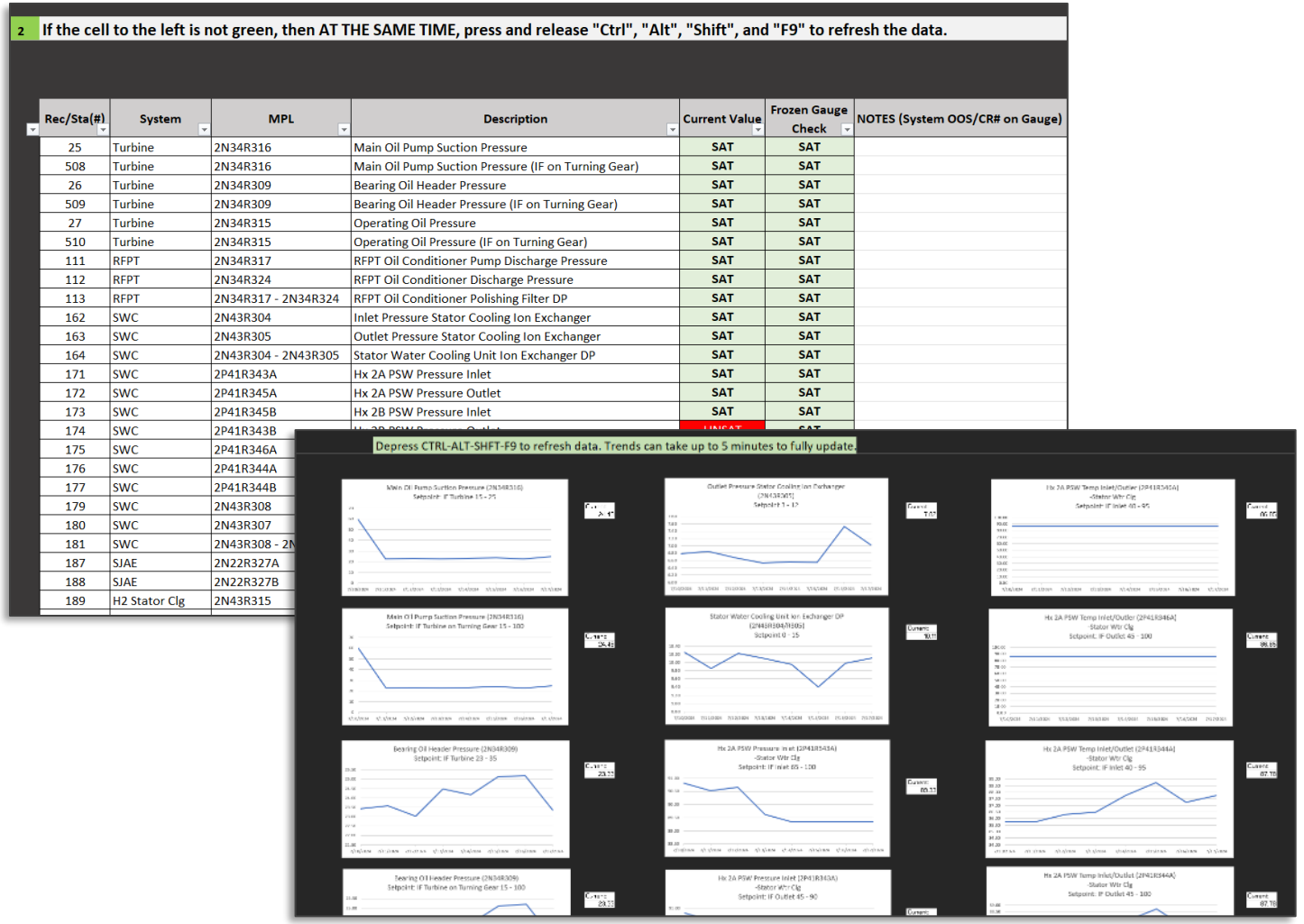
Operator Efficiency: Operator Rounds Dashboard

Concept:

- Collect rounds data throughout day using WGRs
- Operators can review trends and identify abnormalities at start of shift
- Plan and prioritize work more efficiently

Benefit:

- Reduce operator time by 2 hours per shift
- Faster response to excursions / emergent issues



2 If the cell to the left is not green, then AT THE SAME TIME, press and release "Ctrl", "Alt", "Shift", and "F9" to refresh the data.

Rec/Sta(#)	System	MPL	Description	Current Value	Frozen Gauge Check	NOTES (System OOS/CR# on Gauge)
25	Turbine	2N34R316	Main Oil Pump Suction Pressure	SAT	SAT	
508	Turbine	2N34R316	Main Oil Pump Suction Pressure (IF on Turning Gear)	SAT	SAT	
26	Turbine	2N34R309	Bearing Oil Header Pressure	SAT	SAT	
509	Turbine	2N34R309	Bearing Oil Header Pressure (IF on Turning Gear)	SAT	SAT	
27	Turbine	2N34R315	Operating Oil Pressure	SAT	SAT	
510	Turbine	2N34R315	Operating Oil Pressure (IF on Turning Gear)	SAT	SAT	
111	RFPT	2N34R317	RFPT Oil Conditioner Pump Discharge Pressure	SAT	SAT	
112	RFPT	2N34R324	RFPT Oil Conditioner Discharge Pressure	SAT	SAT	
113	RFPT	2N34R317 - 2N34R324	RFPT Oil Conditioner Polishing Filter DP	SAT	SAT	
162	SWC	2N43R304	Inlet Pressure Stator Cooling Ion Exchanger	SAT	SAT	
163	SWC	2N43R305	Outlet Pressure Stator Cooling Ion Exchanger	SAT	SAT	
164	SWC	2N43R304 - 2N43R305	Stator Water Cooling Unit Ion Exchanger DP	SAT	SAT	
171	SWC	2P41R343A	Hx 2A PSW Pressure Inlet	SAT	SAT	
172	SWC	2P41R345A	Hx 2A PSW Pressure Outlet	SAT	SAT	
173	SWC	2P41R345B	Hx 2B PSW Pressure Inlet	SAT	SAT	
174	SWC	2P41R343B		UNSAT	SAT	
175	SWC	2P41R346A				
176	SWC	2P41R344A				
177	SWC	2P41R344B				
179	SWC	2N43R308				
180	SWC	2N43R307				
181	SWC	2N43R308 - 2N				
187	SJAE	2N22R327A				
188	SJAE	2N22R327B				
189	H2 Stator Clg	2N43R315				

Depress CTRL-ALT-SHFT-F9 to refresh data. Trends can take up to 5 minutes to fully update.

Credit: Operator Dashboard developed by J. Plumb, Operator at Duke Energy, Oconee Nuclear Plant

Condition Based Maintenance: Pump Seals

- Automated remote monitoring of reactor recirculation pump seals
- WGR used to collect analog gauge readings for upper and lower seal pressures to assist in fault detection
- Benefits:
  - Reduce operator time to necessary to read gauges
  - Faster identification and troubleshooting of problems
  - Minimize down-time
  - Reduce dose exposure (in BWR)

Operator Efficiency: Feedwater Level – Machine Vision

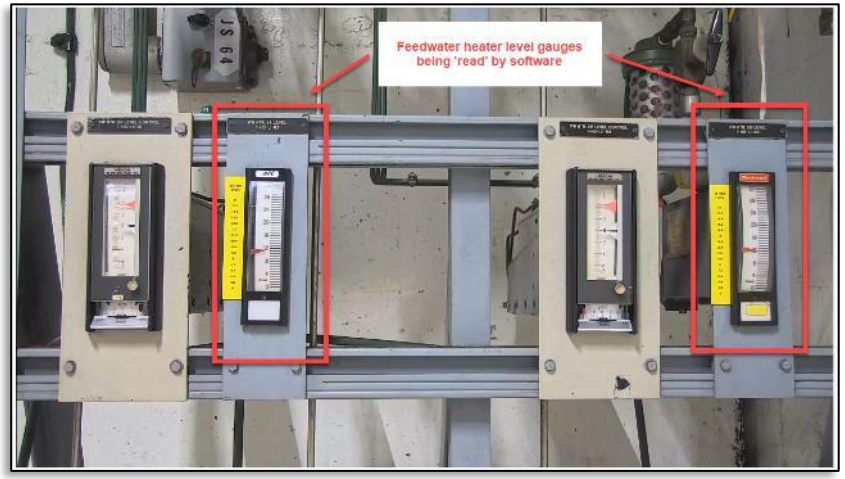
Duke Brunswick

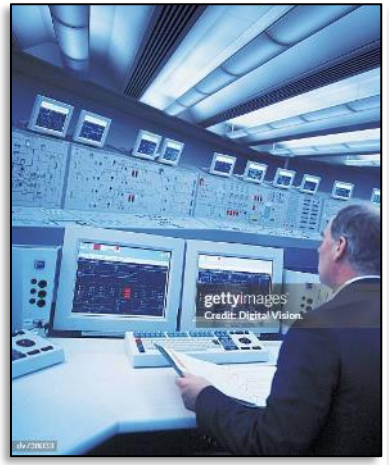
Need:

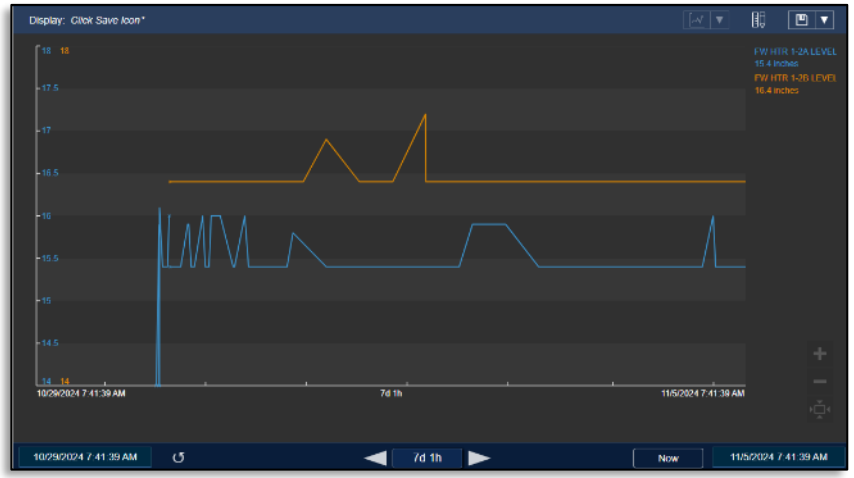
- Automate data collection from feedwater heater including heater level.
- Prior issue resulted in heater taken offline for repairs.
- Must rely on vertical gauge local indicator.

Solution:

- Install Panasonic IP camera, use GBC machine vision capability to digitize image.
- Data can be stored in PI Historian.
- Operator can look at digitized trend data on PI Vision instead of just watching webcam video.







Data collected and displayed via PI Historian

Environmental Monitoring: Sump Pump Hour Meters

- As part of a Groundwater Protection Plan, Cypress installed wireless gauge readers on sump pump hour meters to track electrical manhole sump pump run-time.
- No current method to monitor sump levels automatically.
- If tritium is detected the sump pump runtime data may be useful to determine where it came from.
- Catch two types of faults:
  - Pumps not running when they should (sump level too high)
  - Pumps running too much (must be a leak)

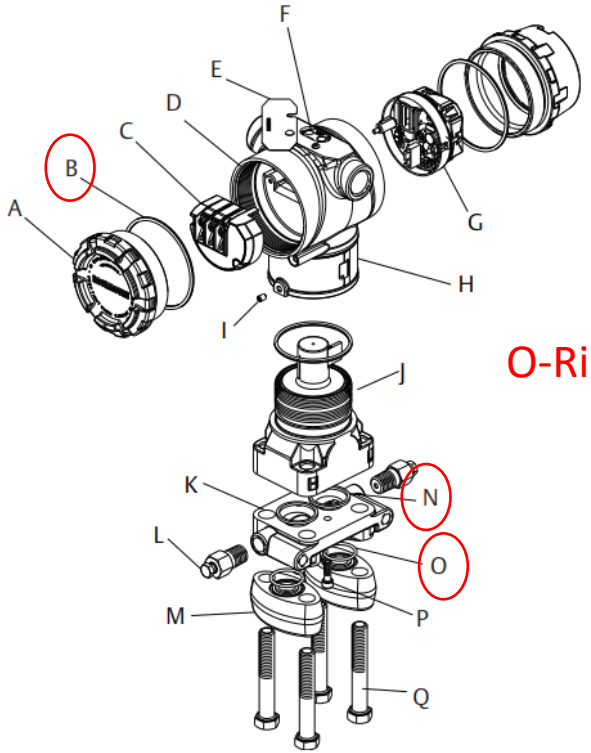
Local area temperature monitoring for Environmental Qualification life extensions

Duke Fleetwide

Concept:

- In many cases the EQ qualified life calculations assume the worst-case condition ambient temperatures.
- These temperatures usually have a significant amount of conservatism in them. Using actual temperature data could potentially result in decreasing the frequency of component replacements.
- This can have a significant cost savings to the plant due to the cost of nuclear qualified electrical components.
- Cypress WHTM's provide temperature data to allow for extension of EQ qualified life. It is expected that an investment of $200,000 can save over $2M through 20-year span of plant operation (PWR).

Example of devices / components affected



O-Rings (PFTE)

A. Cover
B. Cover O-ring
C. Terminal block
D. Electronics housing
E. Configuration buttons cover
F. Local configuration buttons
G. Electronics board
H. Name plate
I. Housing rotation set screw (180 degree maximum rotation without further disassembly)
J. Sensor module
K. Coplanar flange
L. Drain/vent valve
M. Flange adapters
N. Process O-ring
O. Flange adapter O-ring
P. Flange alignment screw (not pressure retaining)
Q. Flange bolts

Minimize Downtime: Crash Cart for Emergent Issues

Southern Hatch

Need:

- Plant needs data quickly to troubleshoot, diagnose and correct emergent issues.

Concept:

- Use Crash Cart with non-invasive sensors to collect data
- Pre-approved, ready to install in 30 minutes.

Benefit:

- Avoid lengthy engineering reviews and approvals to add sensors
- Minimize operator man-hours
- Reduce plant downtime

ALARA/Safety: Dry Well Temp & Humidity Monitoring

Need:

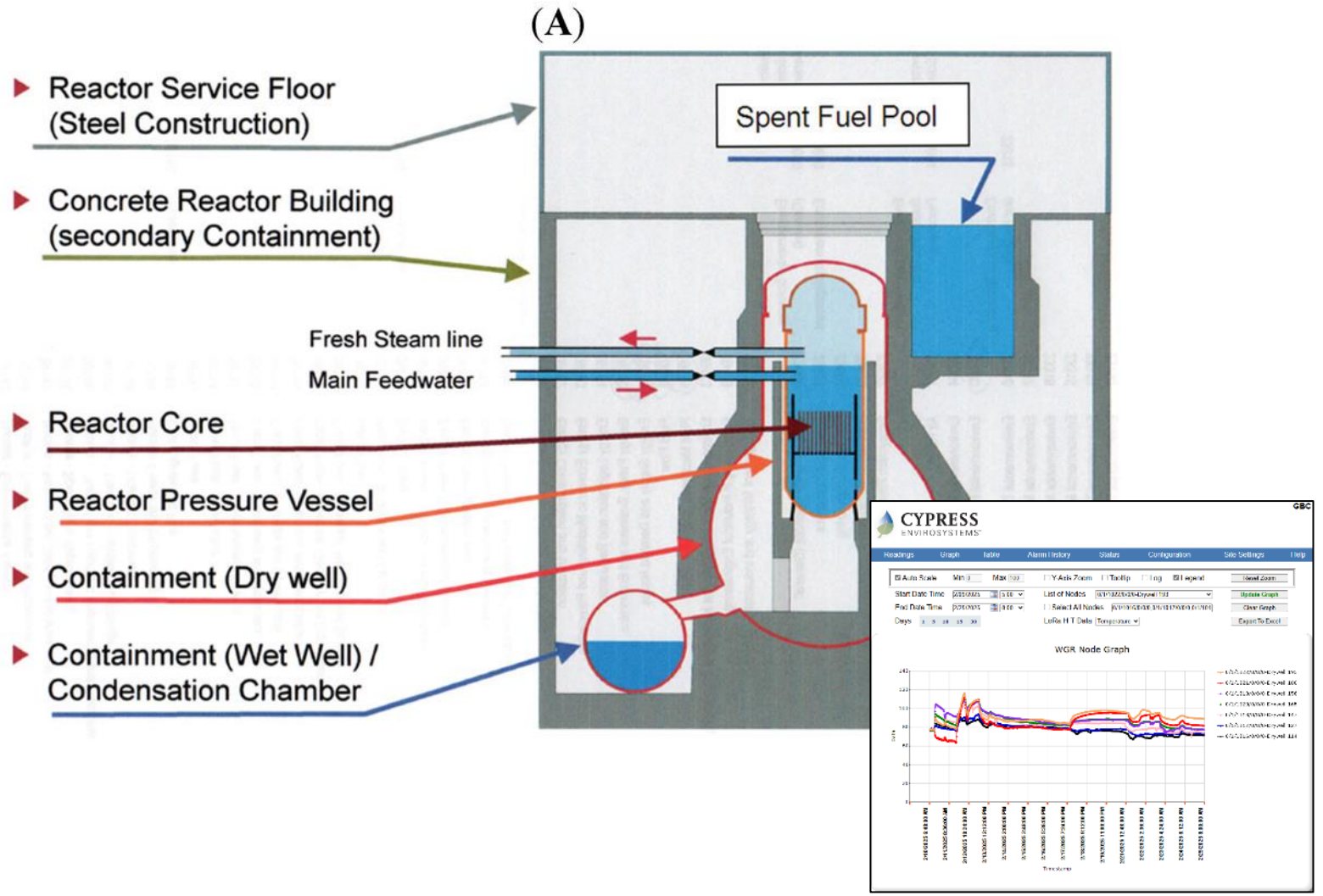
- During outage: Monitor temperature and humidity for worker safety (heat stress).
- Minimize time and dosage exposure for RP Tech to gather data each shift.

Solution:

- Use magnetic mount temporary non-invasive Wireless Temperature and Humidity Monitors.

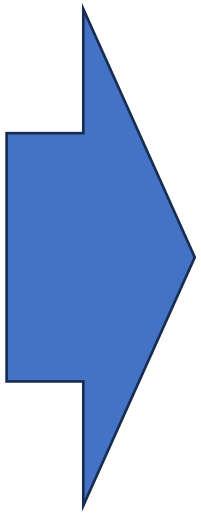
Benefit:

- Save 1.5 Man-hours/day, 45 Man-hours outage total
- Reduce 8 mrem/day, 240 mrem outage total radiation exposure
- Reduced Industrial Safety exposure



Enhancement - Wireless Remote Radiation Monitor

Commercially Available
Radiation Meter



External
Battery Pack

Add-on
Wireless Digit Reader

- Real-time wireless mobile radiation dose rate monitor
- Battery operated: does not require power nor communications wires
- No need to install additional wireless network (uses Blue Box Gateway and GBC)
- Data via OPC or RESTful API available to PI Historian, 360 Plant Walkthru Software etc.

Design Modifications: Condensate Booster Pump Seal Continuous Monitoring

Southern Hatch

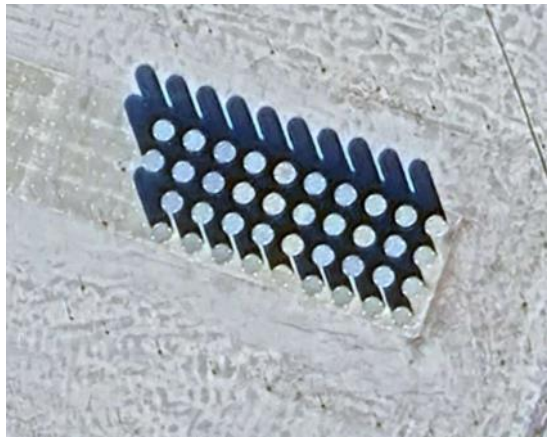
Application:

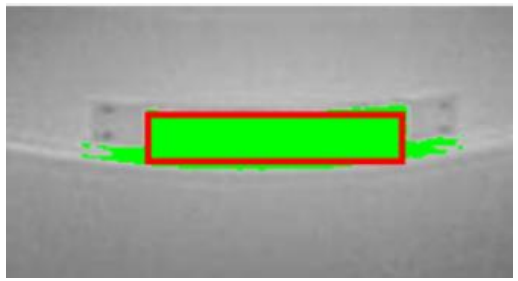
- Design Mod to upgrade Unit 2 condensate booster pump seals
- Added six WGRs as low-cost method to digitize/enable continuous monitoring of seal pressures.

Benefit:

- Minimize design time and cost to allow continuous monitoring.
- Enable automated equipment health monitoring and fault-detection.

In-Progress: Drone + Machine Vision Dry Cask Inspection





Skydio Drone

- May be piloted
- Or autonomous

Skydio Dock

- “Garage” protection
- Recharging
- Data download

Condensate vacuum pumps and valves monitoring

- Monitor condensate vacuum pumps and valves pressures, temperatures, valve position
- Undetected faults can cause >2 MW thermal performance impact
- Trending of data enables early fault detection – data sent to GE Smart Signal
- Improves operator efficiency – reduces need for manual readings.
- Reduces maintenance cost – condition based maintenance

Use of WGRs to confirm valve transfer function

Read Temperature, Pressure

Read Valve Actuator Position

Void Detection in Pipe Flows
(Gas Accumulation Monitoring Program – GAMP)

- Ultrasonic technology to detect gas voids
- Wireless method expected to be approved by NRC imminently
- Non-invasive, clamp-on, wireless
- Avoids scaffolds, man-hours to manually perform void test.

Conventional Testing

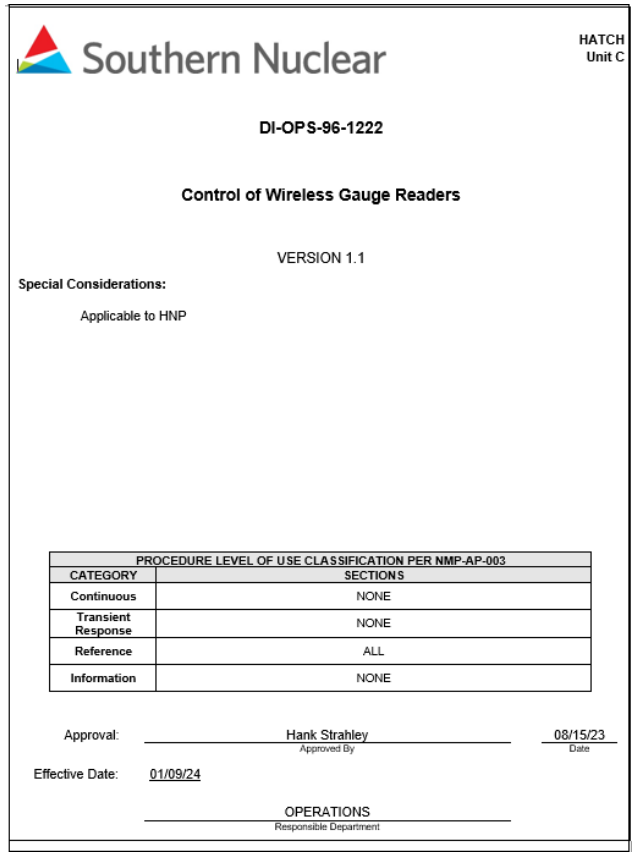
Steps	Efficiency (Time)	Cost ($)	Safety (Rad Exposure, climbing, crawling)***
Permitting/Planning	4 hr (3 containment & 1 aux)	-	-
Scheduling of two technicians	2 hr	-	-
Total examination time	6 hr (1 containment & 5 aux)	-	6 hr * 2 ppl = 12 hrs
Reporting time	2 hr (1 containment & 1 aux)		-
Scaffold tear down / build / inspection			-
Times per year	8 (2 trains/quarterly)	2	8 (2 trains/quarterly)
Total * 2 technicians	224 hours		96 hours

Wireless Sensor

Steps	Efficiency (Time)	Cost ($)	Safety (Rad Exposure, climbing, crawling)
Permitting/Planning	0 hr	-	-
Scheduling of two technicians	0 hr	-	-
Total examination time	0 hr	-	0 hr
Reporting time	1 hr		-
Scaffold tear down / build / inspection		-	-
Times per year	8 (2 trains/quarterly)	-	8 (2 trains/quarterly)
Total (1 data analyst)	8 hr	0	0 hrs

Stakeholder Engagement, Sustainable Adoption

- Clear procedures for tasks, roles, and ownership.
- Lots of training.
- Users Group to share OE and best practices – Industry wide group plus Southern chapter.
- Create library of Use Cases with documented benefits.
- PROACTIVE - DO NOT TAKE ADOPTION FOR GRANTED.



Southern Nuclear

HATCH
Unit C

DI-OPS-96-1222

Control of Wireless Gauge Readers

VERSION 1.1

Special Considerations:

Applicable to HNP

PROCEDURE LEVEL OF USE CLASSIFICATION PER NMP-AP-003	
CATEGORY	SECTIONS
Continuous	NONE
Transient Response	NONE
Reference	ALL
Information	NONE

Approval: Hank Strahley (Approved By) 08/15/23 (Date)

Effective Date: 01/09/24

OPERATIONS (Responsible Department)

WGR Deployments – 33 Nuclear Plants

- Duke Energy (Fleetwide: Oconee, Robinson, Brunswick, Harris, Catawba, McGuire)
- Southern (Fleetwide: Farley, Hatch, Vogtle)
- Xcel Energy (Fleetwide: Prairie Island, Monticello)
- PSEG (Fleetwide: Salem, Hope Creek)*
- Bruce Power (Canada)
- Constellation Energy (Calvert, Braidwood, Clinton, JAF, Nine Mile Point, Ginna, Peach Bottom)
- NextEra (Fleetwide: Turkey Point, St. Lucie, Point Beach, Seabrook)
- Vistra (Comanche Peak, Davis Besse, Beaver Valley)
- STP Nuclear (South Texas)
- Nebraska Public Power District (Cooper)
- Arizona Public Service (Palo Verde*)
- Entergy Vermont Yankee (1 unit – decommissioned)
- EPRI Charlotte - Nuclear Applications Center (installed)
- France EDF (pilot deployment)

* Pending Installation

International Atomic Energy Agency Innovation Award 2024

"The ISOP Innovation Awards aim to highlight and recognize innovative use cases within the nuclear power industry. This programme showcases practical applications of cutting-edge technologies and solutions that have been successfully implemented in operating nuclear power plants."

IAEA
International Atomic Energy Agency

Southern Nuclear

American Nuclear Society

Paper will also be presented at 2025 ANS Annual Conference, Chicago

Q & A