# Thermal Monitoring Concepts

*Gaining MW from better data*


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# Agenda: Gaining MW from Better Data

- Using non-invasive instrumentation to detect faults and improve MW output

- Recap of enabling technologies:
  - LoRaWAN wireless plant backbone and architecture
  - Wireless Gauge Reader
  - Clamp-on Pipe Wall Temperature Monitor
  - Wireless Liquid Level Monitor

- Use Cases:
  - Condenser Vacuum Pump Fault Detection – at PSEG
  - Cycle Isolation Valve Leak Detection – at Duke Energy
  - Steam Trap fault detection – at Xcel Energy and Vistra
  - Feedwater Heater level control – at Constellation Energy
  - Automate thermocouple data collection by operators - PSEG

# What problem are we solving?

- Optimal plant MW output depends on the proper flow, pressure and temperature parameters.
- Typical faults are valve leaks, stuck actuators, pneumatic miscalibration, leaking instrument air supply etc.
- Faults can reduce generation output, cause unplanned downtime, require expensive overtime work.
- Existing valves and gauges are NOT digitized – there is no automated monitoring, trending or alarming
- APR models cannot be used for fault detection.


# Difficulty of Digitizing Existing Plants

**Just to read a simple pressure process value:**

- Run wires (power and/or signal)
- I/O panels, termination
- Break seals, leak checks, material compatibility, safety checks
- Engineering assessment, documentation
- Process downtime
- Cybersecurity concerns


Typical traditional solution:
INVASIVE AND COSTLY

# Need for Non-Invasive Digitization Solution

## Non-Invasive Sensors:

- No breaking seals, no leak checks, no wetted parts
- Lightweight, no structural impact
- No power wires, no signal wires
- Little/no engineering review/analysis
- Takes minutes to install, no plant downtime required
- No new software to install, works with existing plant infrastructure

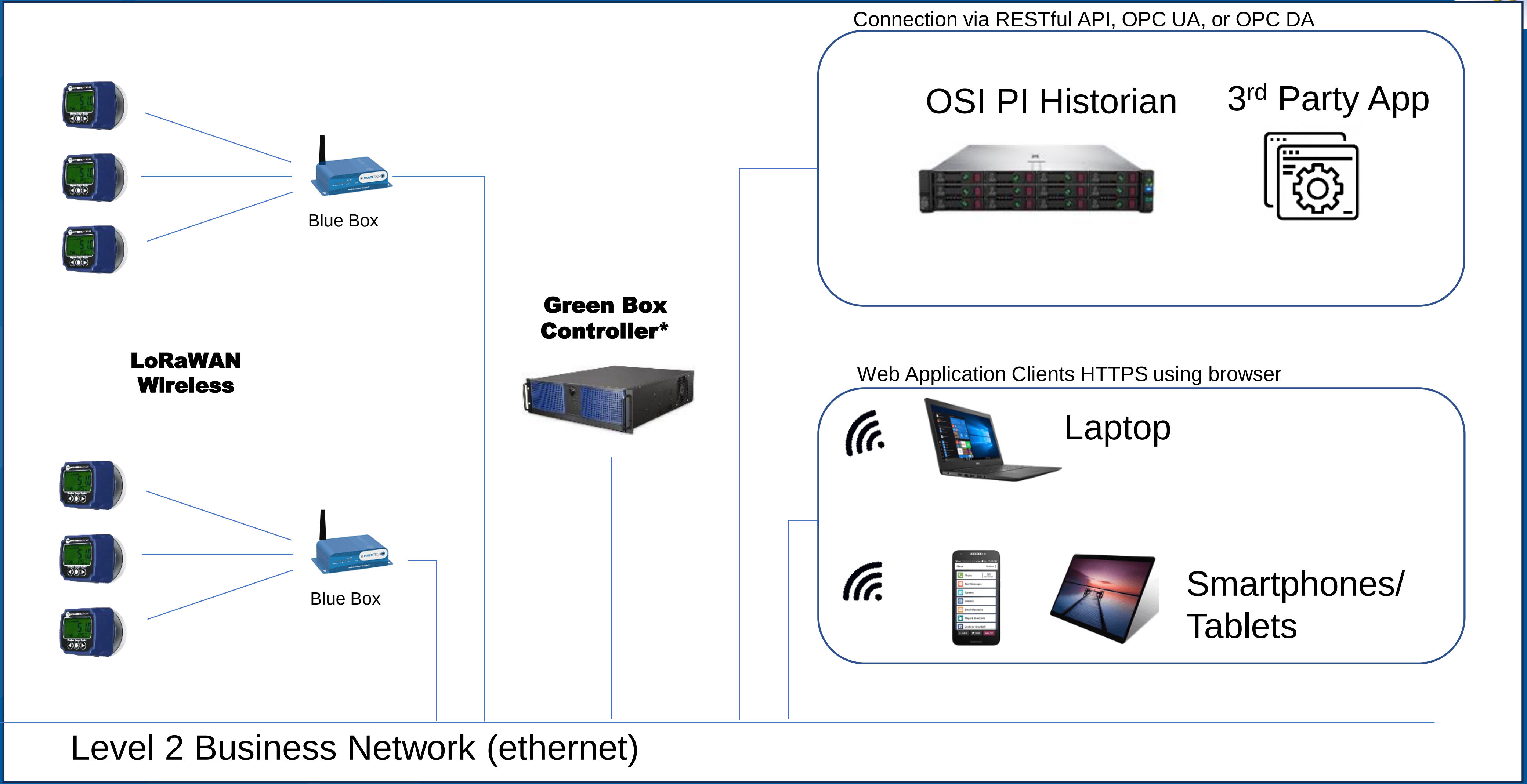
# Enabling Technology:
# Non-Invasive, Clamp on Wireless Sensors


Wireless Gauge Reader

Wireless Steam Trap Monitor

Wireless Pipe Temperature Monitor

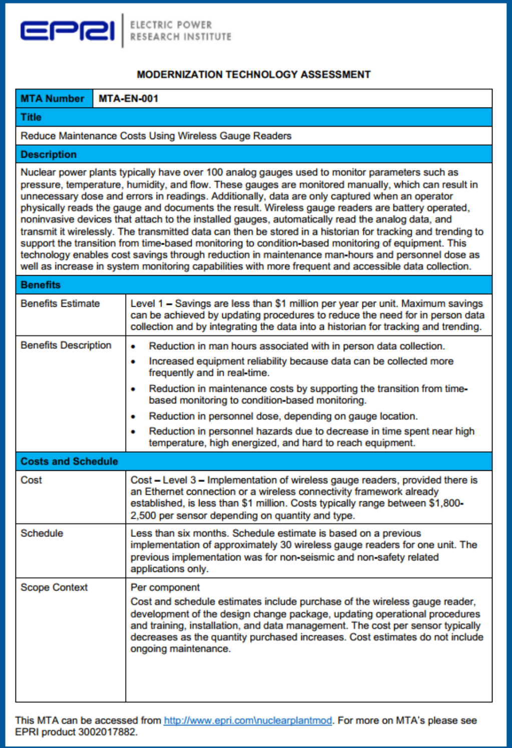
# LoRaWAN Wireless Backbone



# Current Deployments

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

* Pending Installation



ELECTRIC POWER RESEARCH INSTITUTE

**MODERNIZATION TECHNOLOGY ASSESSMENT**

| MTA Number | MTA-EN-001 |
|---|---|
| **Title** | |
| Reduce Maintenance Costs Using Wireless Gauge Readers | |
| **Description** | |
| Nuclear power plants typically have over 100 analog gauges used to monitor parameters such as pressure, temperature, humidity, and flow. These gauges are monitored manually, which can result in unnecessary dose and errors in readings. Additionally, data are only captured when an operator physically reads the gauge and documents the result. Wireless gauge readers are battery operated, noninvasive devices that attach to the installed gauges, automatically read the analog data, and transmit it wirelessly. The transmitted data can then be stored in a historian for tracking and trending to support the transition from time-based monitoring to condition-based monitoring of equipment. This technology enables cost savings through reduction in maintenance man-hours and personnel dose as well as increase in system monitoring capabilities with more frequent and accessible data collection. | |
| **Benefits** | |
| Benefits Estimate | Level 1 – Savings are less than $1 million per year per unit. Maximum savings can be achieved by updating procedures to reduce the need for in person data collection and by integrating the data into a historian for tracking and trending. |
| Benefits Description | • Reduction in man hours associated with in person data collection.<br>• Increased equipment reliability because data can be collected more frequently and in real-time.<br>• Reduction in maintenance costs by supporting the transition from time-based monitoring to condition-based monitoring.<br>• Reduction in personnel dose, depending on gauge location.<br>• Reduction in personnel hazards due to decrease in time spent near high temperature, high energized, and hard to reach equipment. |
| **Costs and Schedule** | |
| Cost | Cost – Level 3 – Implementation of wireless gauge readers, provided there is an Ethernet connection or a wireless connectivity framework already established, is less than $1 million. Costs typically range between $1,800-2,500 per sensor depending on quantity and type. |
| Schedule | Less than six months. Schedule estimate is based on a previous implementation of approximately 30 wireless gauge readers for one unit. The previous implementation was for non-seismic and non-safety related applications only. |
| Scope Context | Per component<br>Cost and schedule estimates include purchase of the wireless gauge reader, development of the design change package, updating operational procedures and training, installation, and data management. The cost per sensor typically decreases as the quantity purchased increases. Cost estimates do not include ongoing maintenance. |

This MTA can be accessed from http://www.epri.com\nuclearplantmod. For more on MTA's please see EPRI product 3002017882.

EPRI
Plant
Modernization
Toolkit

# Condensate Vacuum Pump Fault Detection

PSEG Salem

# Thermal Performance: PSEG Salem

- 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 Wireless Gauge Readers to confirm valve transfer function


Read Temperature, Pressure


Read Valve Actuator Position

# Valve Cycle Isolation
Duke Energy Fleetwide

# Valve Cycle Isolation

## Cycle Isolation: Monitoring for Better Usage

By Greg C. Alder | Published in Valve Magazine

*One of the largest controllable losses in power plants is leakage-based energy loss. These losses, which have been documented at more than 400 British Thermal Units per kilowatt hours (Btu/kWh) in some cases, are often overlooked because of the difficulty in spotting them in systems that have hundreds of potentially leaking valves.*

### CYCLE ISOLATION AND ITS BENEFITS

*Cycle isolation is the process of recapturing lost power by monitoring valve system flows for potential leakages through downstream temperature information. It is used in all types of power plants.*

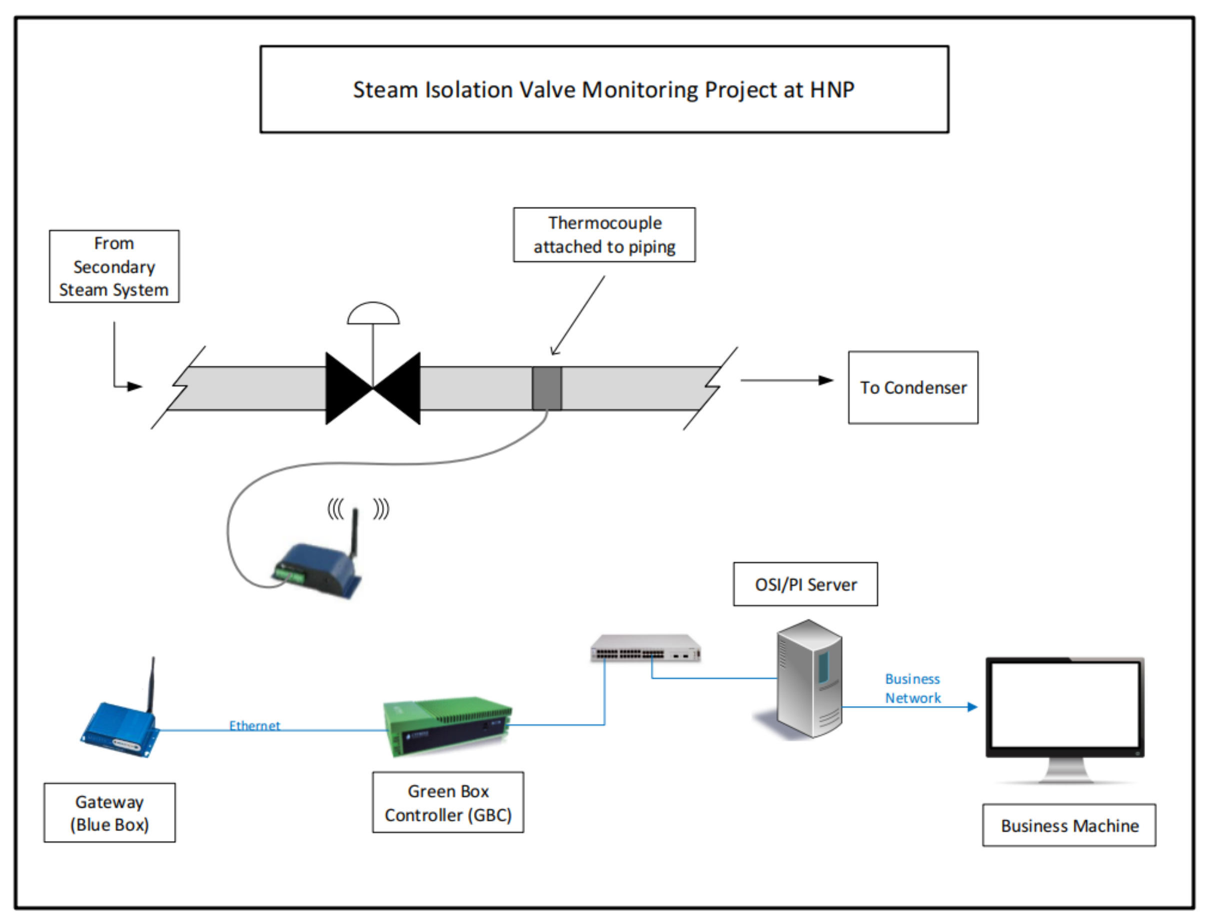
*These temperatures can be collected manually from plant walk-downs or from real time data when available. The data collected is then used to generate leakage data and alerts. By monitoring the flows within a cycle (called internal isolation) and accounting for all flows entering and leaving a cycle (called external isolation), cycle isolation technology assures that all steam and water flows are going to their proper destinations, maximizing efficiency and minimizing energy losses from leaks.*

# Monitoring Steam Cycle Isolation (Shut off valves)

- Objective: Detect unintended leakage when valve is fully shut
- Rationale: Leaks can seriously degrade plant thermal performance
- Method: Monitor pipe temperature
- downstream of valve – hot = leak
- Current Practice: Manual examination (via IR gun) of temperature taps every three months.
- Proposed Practice: Automate regular temperature data – trends will identify faults before they impact plant performance

# Clamp-on pipe wall temperature monitors

Detect Leaking Valves Using Temperature Sensors – Duke Energy




Duke Energy
- Fleetwide - ~400 valves

PSEG
- Hope Creek – 147 valves
- Salem - ~40 valves

Vistra Luminant
- Comanche Peak – 227 valves and steam traps

Xcel Energy
- Monticello – ~80 valves
- Prairie Island - ~120 valves

# Steam Valve - Details

Shutoff valve

Upstream Temperature Tap

Insulated Pipe

Downstream Temperature Tap


Temperature Tap with rubber cap removed

Temperature Tap interior, with access to pipe wall and pipe insulation

# Cypress Wireless Transducer Reader (WTR)

Aluminum Mounting Plate

Wireless Transducer Reader (WTR)

Steel braided thermocouple wire

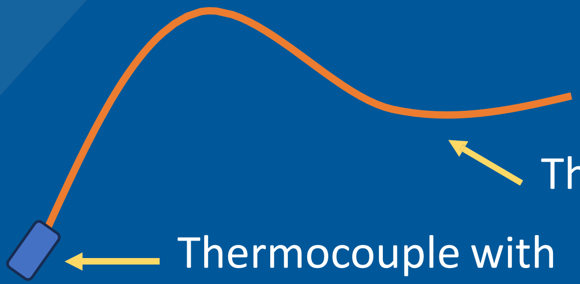
Existing Unistrut

Thermocouple inserted into temperature tap

# WTR Mounting on Unistrut

Unistruts
with Channel Nuts

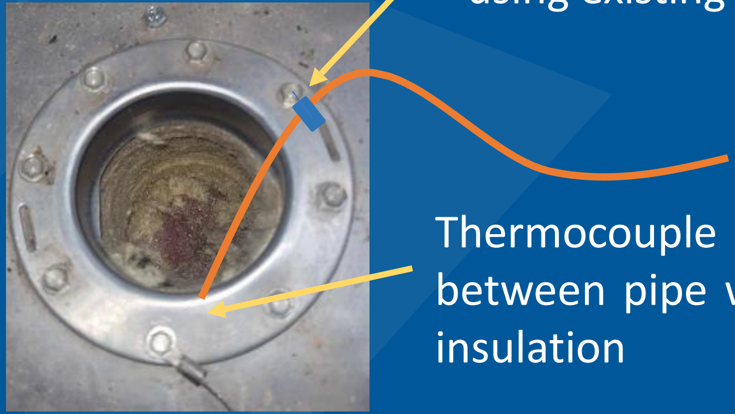
# Thermocouple Insertion to Temperature Tap



Thermocouple wire

Thermocouple with protective sheath

Cable strain relief, attached using existing screw.



Thermocouple inserted between pipe wall and insulation

Cut notch on rubber cap to allow thermocouple wire to pass through

# Steam Trap Fault Detection

Xcel Energy, Vistra

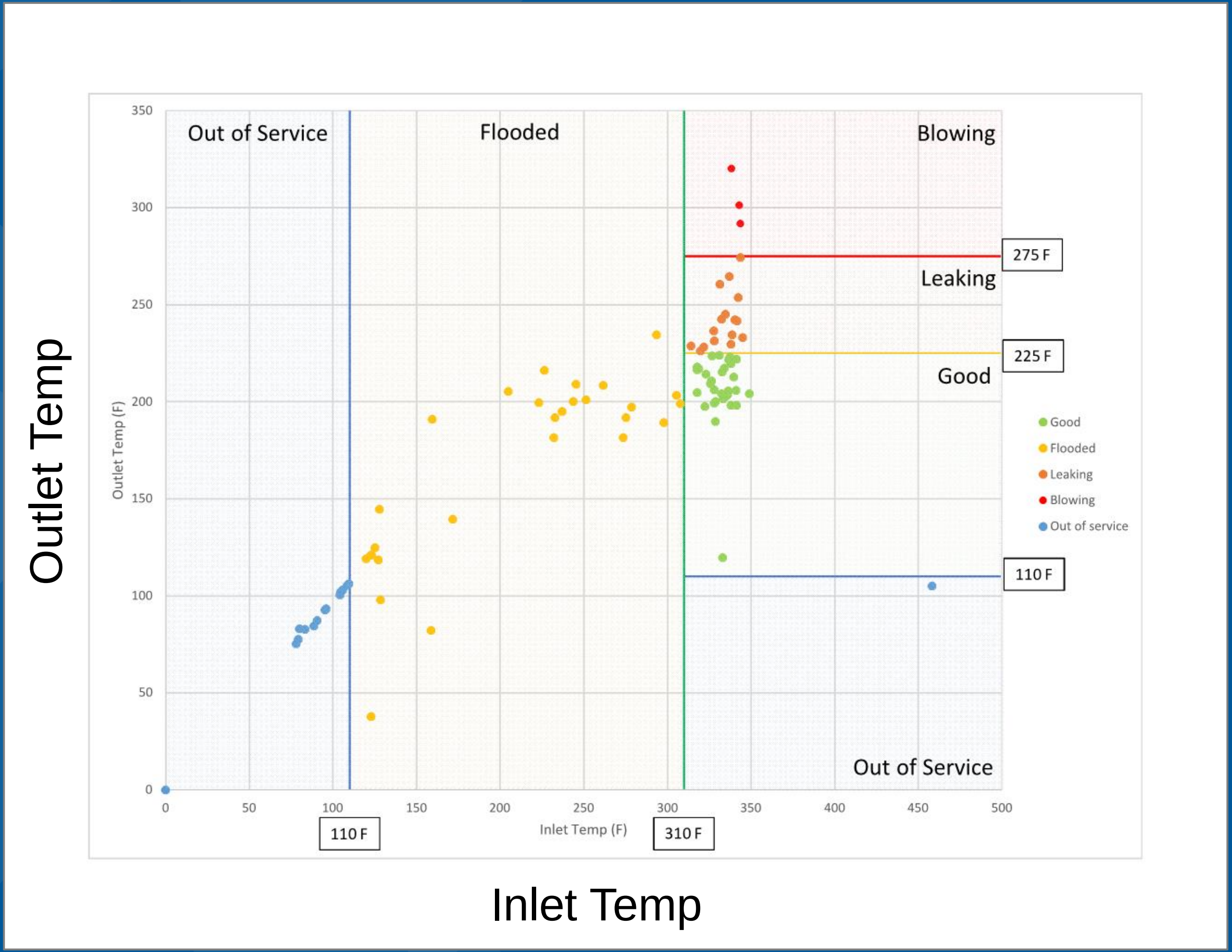
# Steam Traps - Overview


- Mechanical devices used to separate condensate (liquid part) from dry steam
- No sensor, no communication
- Common failure mode: leak dry steam along with condensate.
- Alternate failure mode: blocked, causing water hammer and potential plant damage.

# Wireless Steam Trap Monitoring

- Wireless, battery-operated steam trap monitoring system from Cypress Envirosystems.
- Leverage existing wireless infrastructure of Blue Box Gateways and Green Box Controllers already approved and installed at Monticello.
- Monitor steam trap inlet and outlet temperatures using clamp-on thermocouples.
- Obtain temperature sample every four hours – battery life of at least five years.
- Transmit temperatures to OSI PI Historian for fault detection and analysis.
- Use temperature data to detect steam trap faults – leak, blocked, flooded etc.
- May use hand-held acoustic analyzer to independently confirm steam trap fault.

# Fault Detection for Steam Traps




- Fault detection rules configured and stored in Green Box Controller

# Background – Rationale for Steam Trap Monitoring

- Use a heating boiler to generate steam for HVAC heating needs.
- The boiler is fired by Fuel Oil #2.
- The steam is distributed to various plant locations where space heating is required.
- Steam traps are installed throughout the steam network to drain condensate.
- The steam traps have a typical failure rate of about 10% per year – they leak steam when they fail - undetected leaks can cost thousands of dollars per year.
- In the past, manual steam trap audit were performed to identify and replace faulty traps. The last audit was done more than four years ago.
- Objective of this proposal:

  Install automated wireless steam trap monitoring system to detect and correct faults in a timely manner - reduce fuel oil consumption and cost.

# Existing HVAC Heating System - Summary

| | | |
|---|---|---|
| **Heating system (Boiler)** | | |
| Fuel Type | Fuel Oil | #2 |
| Fuel consumption | $884,000 | per year |
| Fuel Cost per gallon | $4.00 | |
| Estimated boiler efficiency | 85% | |
| Estimated cost of steam | $30 | per 1,000 lbs |
| | | |
| **Steam Trap Population** | | |
| Number of steam traps | 245 | units |
| Steam pressure | 50 | psi |
| Trap type | Inverted bucket mechanical | |
| Average trap failure rate | 10% | per year (per manufacturer) |
| Time since last trap survey | 4+ | years |

# Cash Flow Projection

| | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 | Year 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Cost to install monitoring | 612,500 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 |
| Cost to replace faulty traps | 22,050 | 14,700 | 14,700 | 14,700 | 14,700 | 14,700 | 14,700 | 14,700 | 14,700 | 14,700 |
| Fuel Oil savings | -294,081 | -294,081 | -294,081 | -294,081 | -294,081 | -294,081 | -294,081 | -294,081 | -294,081 | -294,081 |
| Manual audit savings | -10,000 | -10,000 | -10,000 | -10,000 | -10,000 | -10,000 | -10,000 | -10,000 | -10,000 | -10,000 |
| Net Cash Flow | 330,469 | -277,381 | -277,381 | -277,381 | -277,381 | -277,381 | -277,381 | -277,381 | -277,381 | -277,381 |
| Cumulative Cash Flow | 330,469 | 53,088 | -224,293 | -501,674 | -779,055 | -1,056,436 | -1,333,817 | -1,611,198 | -1,888,579 | -2,165,960 |

| | |
|---|---|
| **Payback period** | **2.2 Years** |
| **NPV @12%** | **$1,532,797** |
| **IRR** | **84%** |

# Automate Thermocouple Data Collection

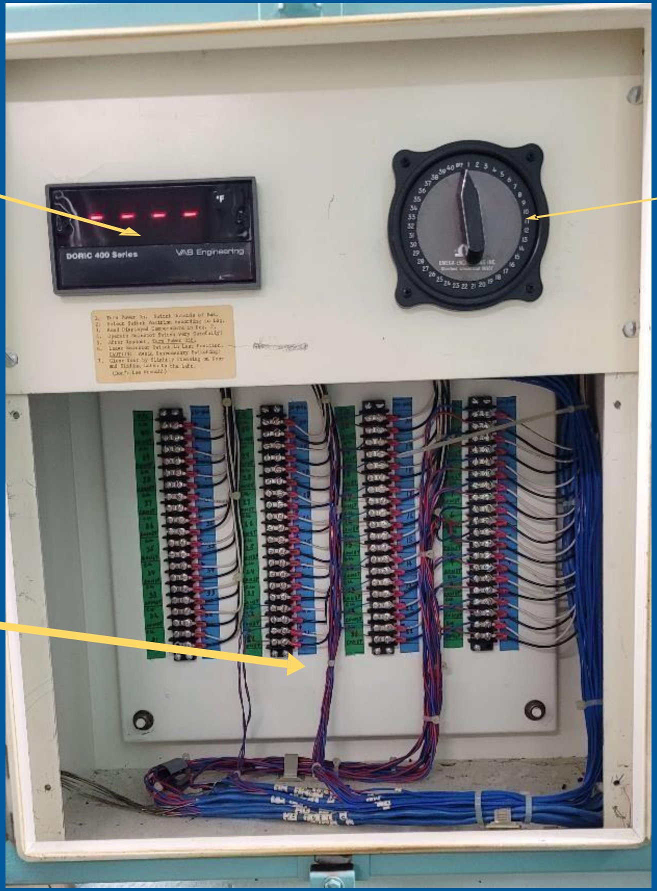
PSEG Hope Creek, Xcel Energy

# Manual Thermocouple Monitoring – Typical

Temperature Display

Thermocouple Selector dial

Thermo-couple connections (>100)

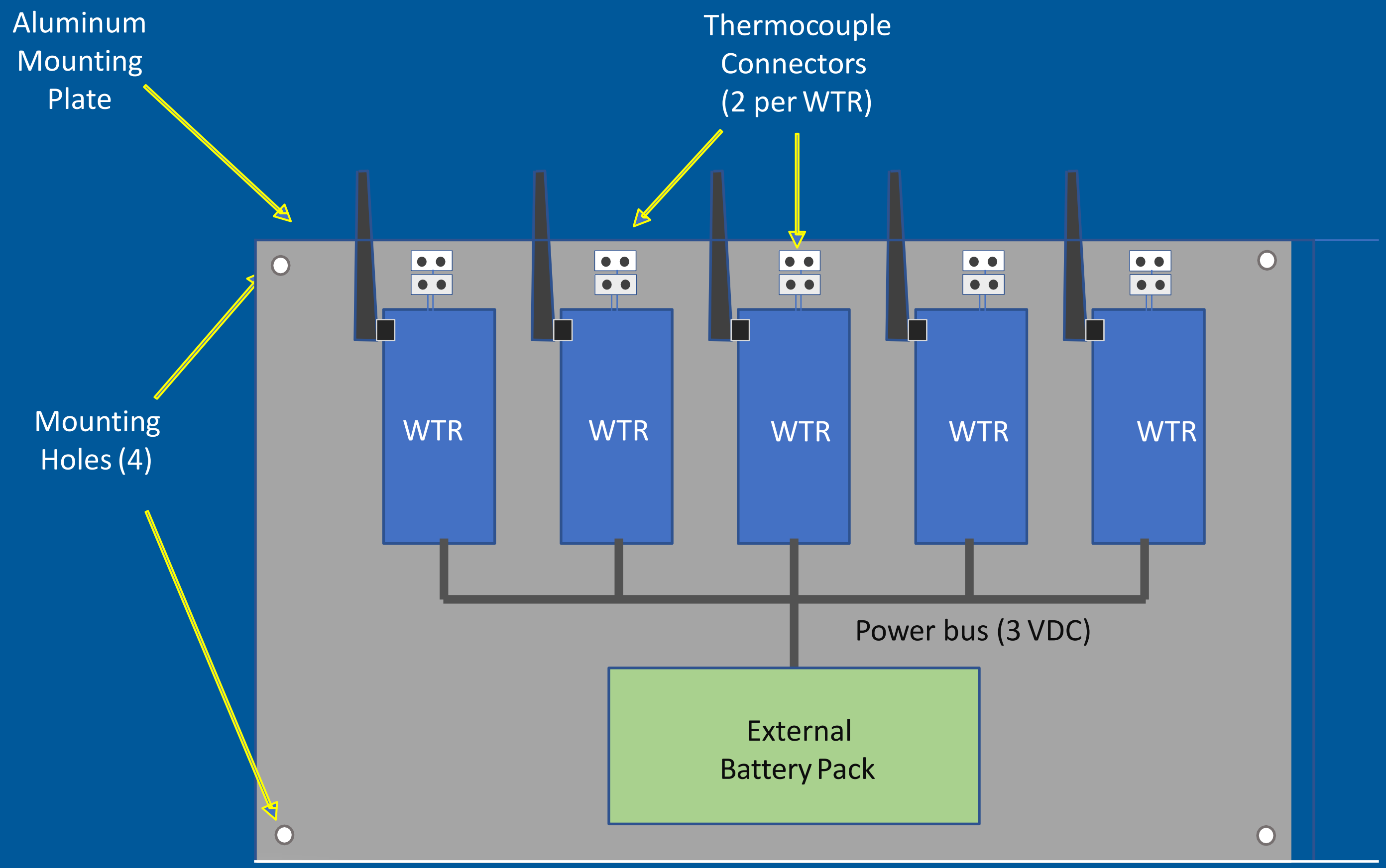



**Thermocouple Selector Panel for Manual Readings**

Handheld Thermocouple Reader

**Thermocouple Connectors for Manual Readings**

# Thermocouple Monitoring Panel – up to 10 TC input




- Each Module can accommodate one to five Wireless Transducer Readers (WTR's)
- Each WTR can accept up to two thermocouple (type J) inputs – will accept existing thermocouple connectors to plug in to Module
- WTR's will collect sample from thermocouples every 60 minutes.
- External battery pack accommodates 24 Li-On battery cells, type CR123A. Design already approved and used in Constellation nuclear plant (Calvert Cliffs).
- Design battery life: >3 years
- Changing full set of batteries will take about two minutes

# Further Use Cases Documented in WGR Users Group Library

# Non-Invasive Digitization Use Case Library

Jotform | Tables

**Use Case Library - Non-Invasive Nuclear Plant Digitization**

All changes saved at 9:44 AM

Share | Help

Case Library - Non-Invasive Nuclear Plant Digitization | + Add Tab

ch | Filter | Columns | Form | D

| Title of Use Case | Utility | Plant | T... | Depart... | Plant Location | Plant System or Sub-System | What improvements/benefits come from the data? |
|---|---|---|---|---|---|---|---|
| Enable condition Based Maintenance for condensate polisher filters | Constellation | Clinton | BWR | Maintenance | Turbine Building | Condensate Polishing System | Operator Efficiency, ALARA reducing dosage exposure, Maintenanc |
| Fault detection for Air Operated Valves for Feedwater Heaters | Constellation | Calvert Cliffs | PWR | Engineering | Turbine Building | Feedwater Tanks Air Operated Val... | Operator Efficiency, Fault Detection, Maintenance Effort/Consumab |
| Fault Detection for Stator Cooling Water Control Valves | Southern Company | Hatch | BWR | Operations | Turbine Building | Generator Stator | Operator Efficiency, Fault Detection, Maintenance Effort/Consumab |
| Improve efficiency of Operator rounds | Duke Energy | Oconee | PWR | Operations | Multiple | | Operator Efficiency, ALARA reducing dosage exposure |
| Fault Detection for Reactor Recirculation Pump Seals | Duke Energy | Brunswick | BWR | Engineering | Reactor Building | Reactor cooling | Fault Detection |
| DRAFT - Enhance operator efficiency for thermal performance monitori... | PSEG | Hope Creek | BWR | Operations | Turbine Building | Feedwater Heaters | Operator Efficiency, Fault Detection |
| Fault Detection for Transformers | Constellation | Calvert Cliffs | PWR | Engineering | Other | Transformers | Operator Efficiency, Fault Detection |
| Ensure personnel safety - Temperature and Humidity Monitoring | Constellation | Calvert Cliffs | PWR | Operations | Turbine Building | Work and storage environment | Operator Efficiency, Safety (e.g. Heat Stress, Confined Space etc.) |
| Improve groundwater management monitoring | Duke Energy | Brunswick | BWR | Chemistry | Other | Sump Pumps | Operator Efficiency, Fault Detection, Compliance (e.g. Environmenta |
| Implement Condition Based Maintenance of Condensate Polisher Demin | Energy Harbor | Davis Besse | PWR | Chemistry | Turbine Building | Condensate Polishing System | Operator Efficiency, Maintenance Effort/Consumables |
| Enhance Operator Efficiency for Monitoring Intake Screen | Constellation | Nine Mile Pt | BWR | Operations | Intake | Intake screens | Operator Efficiency |
| Improve personnel safety for negative pressure compliance monitoring | Constellation | Nine Mile Pt | BWR | Other | Multiple | Negative pressure locations | Operator Efficiency, Safety (e.g. Heat Stress, Confined Space etc.) |
| DRAFT - Condition based monitoring of lube oil filters | Constellation | Nine Mile Pt | BWR | Engineering | Turbine Building | Lubricating oil system | Fault Detection |
| Fault Detection - cycle Isolation Valve Temperature Monitoring | Duke Energy | Harris | PWR | Engineering | Turbine Building | Cycle isolation valves | Thermal Performance, Improves efficiency of the Thermal Performanc |
| Feedwater Heater Temperature Monitoring | Duke Energy | Robinson | PWR | Engineering | Turbine Building | Heater Drain | Troubleshooting/Emergent Issues |
| DRAFT - Fault detection for condensate vacuum pumps and valves | PSEG | Salem | PWR | Engineering | Turbine Building | Condensate pumps and valves | Operator Efficiency, Fault Detection, Maintenance Effort/Consumab |
| DRAFT - Fault detection & troubleshooting for containment moisture re... | Bruce Power | Bruce A | CAND | Engineering | Other | Dryer system for containment moi... | Operator Efficiency, Fault Detection, Maintenance Effort/Consumab |
| DRAFT - Safety Surveillance Monitoring remote monitoring | Luminant | Comanche Peak | PWR | Operations | Multiple | Safety related systems | Operator Efficiency, Fault Detection |

# Summary – Thermal Performance Monitoring

- Non-Invasive technologies can digitize legacy instrumentation with minimal cost and disruption
- Data captured can improve plant thermal performance
- Payback period can be very short – typically under one year
- Additional benefits: Operator effectiveness, reduced maintenance labor
- Extensive Operational Experience library of Use Cases, Specifications, and Best Practices available from existing users.

# Q&A

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