AMS’ SMALL BUSINESS INNOVATION RESEARCH PROJECTS
FOR NUCLEAR PLANT ON-LINE MAINTENANCE SYSTEMS

The Washington DC Section of
AMERICAN NUCLEAR SOCIETY

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A Treasure is Hidden in Every Nuclear Power Plant

What is it?

- Where is it?

- How to get to it?
What Can We Do With It?

- Improve reliability, availability, and productivity
- Identify problems in plant equipment and processes
- Predict when equipment may fail

All These Can Be Done Passively, Remotely, and While the Plant is Operating
What Happens When You Go To The Doctor

- Instrumentation
- Visual Inspection
- Acoustic Monitoring
Diagnostics and Corrective Action

Calibration

Feeling Good

Normal

Back at Work
Predictive Maintenance

- Radiography
- Vibration Analysis
- Oil Analysis (tribology)
What is the Treasure?

DATA
Where is it?
How to Get It?

Graph showing sensor output over time.
Sensing Line Blockages Can Be Dangerous (OLM Can Help)

![Graph showing frequency vs. pressure deviation](image)

- **Clean Pressure Transmitter Sensing Line**
- **Blocked Pressure Transmitter Sensing Line**
- **Partially Blocked**
- **Completely Blocked**

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Venturi Fouling is Detectable and Quantifiable by OLM

Venturi Fouling Can Waste Nearly 2% of the Reactor Power

- Indicated Power
- Actual Power

Venturi Fouling

FLOW
BWR Stability Measurements

Susquehanna NPP

Decay Ratio = 0.30

Stable

Unstable

Limit Cycle
Instrument Tube Vibration in BWRs

In-Core Instrument Tube

Fuel Box (~3Hz)

Before Plugging

Core Support Plate

Bypass Cooling

After Plugging

Instrument Tube (~3Hz)

Fuel Box (~5Hz)

Before Plugging

After Plugging

COHERENCE

FREQUENCY (Hz)

0.0
0.2
0.4
0.6
0.8
1.0

0 2 4 6 8 10
Core Barrel Vibration

- 6.5 Hz Related to Core Barrel Motion
- Low Frequency Signal That Caused Alarms

Graph showing % Power (Deviation From Mean) vs. Time (sec)

Core Barrel

Reactor Vessel

Thermal Shield

Reactor Vessel

Core Barrel

NOISE050-01
Results of The Testing
What if There are No Existing Sensors for Condition Monitoring? (Install Wireless Sensors)
Recent DOE Research Award (Phase III)

In-Containment Application of Wireless Technology for Online Condition Monitoring
Wireless Data Collection System Implemented at Comanche Peak Nuclear Power Plant Under DOE Project

Auxiliary Feedwater Pump

Heater Drain Pump Motor

AMS Accelerometer

Existing Triax Accelerometer

Existing Wireless Accelerometer

Wireless Data Collection System

AMS Accelerometer
Do Not Forget Cables and Connectors

Containment (Harsh Environment)

Control Room Area (Mild Environment)

I&C Cabinets (Analog or Digital)

Penetration ~150 meters
Recent Cable Connector Problem Added Two Weeks to the Outage of U.S. Nuclear Power Station
Melted Insulation Results in Forced Shutdown of U.S. Nuclear Power Station
How to Identify and Locate Problems in Cables

Thermocouple Lead Wires (High - Low)

Shield to Ground

Lead to Shield +

Lead to Shield -

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DOE Holistic Cable Condition Monitoring Project

Capacitance @ 100Hz

- Cable 3
- Cable 4
- Cable 5

- Dry
- Wet

Dissipation Factor @ 100Hz

- Cable 3
- Cable 4
- Cable 5

Dry
Wet
Development of MicroSensors for Cable Condition Monitoring

(DOE Project Jointly Performed by AMS and PAC: Ken Watkins)
Holistic Cable Diagnostic System

- Test Lead Compensation
- Default Equipment Settings
- Test Data Acquisition
- Data Review
- User Interface
- Data Qualification
- Statistical Analysis
- Historical Data Trending
- Similar Equipment Data Comparison
- Report Generation
- Data Storage

Cable Testing Database
**DOE SBIR PROJECTS**

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DRPI Diagnostic System Block Diagram

- DRPI Coil Signals
- Communication Link

Components:
- cRIO
- Switch
- Controller
- PXI Master Controller
- DRPI Diagnostic Display
ATR is launching a Life Extension Program (LEP) as well as a Reliability Centered Maintenance (RCM) program to improve reliability of rotating machinery and I&C systems.
NASA Airspeed SBIR for Indication Fault Detection
(Air France Flight Crash En Route from Rio de Janeiro to Paris)
NASA SBIR for Space Reactor OLM

Flow Sensor S₁
Temperature Sensor S₂
Pressure Sensor S₃

Residuals

\[ \Delta S₁ = S₁ - S₁E \]
\[ \Delta S₂ = S₂ - S₂E \]
\[ \Delta S₃ = S₃ - S₃E \]

Flow Estimate S₁E
Temperature Estimate S₂E
Pressure Estimate S₃E

Analytical Modeling Techniques

Input Layer
Mapping Layer
Bottleneck Layer
Demapping Layer
Output Layer

Position Transducers

Cooling Water IN
NaK IN

Cooling Water OUT
NaK OUT

Pressure Vessel

NaK Heater Head

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Conclusions

- Compliance
- Non Compliance