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Wireless Ultrasonic Monitoring of Gas Voids in Nuclear Piping

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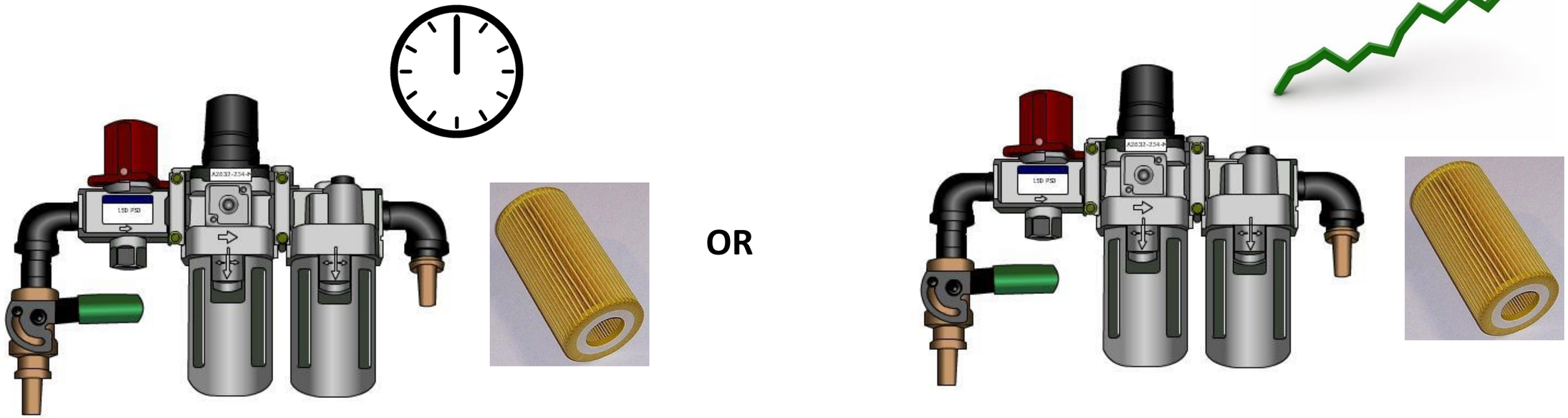
Background of Gas Voids

- Accumulation of gas voids could adversely affect operation of emergency cooling systems
  - Lines are generally stagnant and allow for gas to accumulate in the line
  - Ability to impact cooling pumps, cavitation damage, etc
- NRC issued Generic Letter 2008-01 “Managing Gas Accumulation in Emergency Core Cooling, Decay Heat Removal, and Containment Spray Systems” in 2008, which created a need to monitor
  - Locations are often at high-points in the line, require scaffolding and manual access
  - Periodic intervals for testing are typically monthly or quarterly
  - Issues with radiation exposure, planning, scaffolding for access, etc., result in increased safety risks for personnel and increase cost

Gas Void Monitoring Can Be Expensive

- Current method
  - Technician takes ultrasonic measurements at piping high points
    - Can be difficult to access, require scaffolding, and be in radiation zones / containment
  - If unacceptable results operations vents pipe
  - Repeated inspections at the same location
    - ~40 locations per month at some facilities
  - Drivers NRC GL 200801, INPO SER 2-05, and NEI 09-10
- EPRI Vision
  - Permanently install ultrasonic sensor(s) on pipe connected to a battery-operated ultrasonic system
  - Pulse transducer on defined schedule
  - Transmit data through wireless network to monitoring center
  - Alert generated if an unacceptable gas void is detected

Simple Example of Health Monitoring



OR

Time based intervals normally more conservative than condition based.
Automate condition based maintenance tasks.

Components of Structural Health Monitoring (SHM)

1 – Overall implementation – existing on-line monitoring guides & groups

2 – Obtain Data

Sensors are available and being developed

3 – Transport Data

Wi Fi, EMC concerns addressed

Distributed Antenna Systems (DAS) commercially available

5 – Utilize Data (Transform to Information)

Many algorithmic and analytical solutions exist

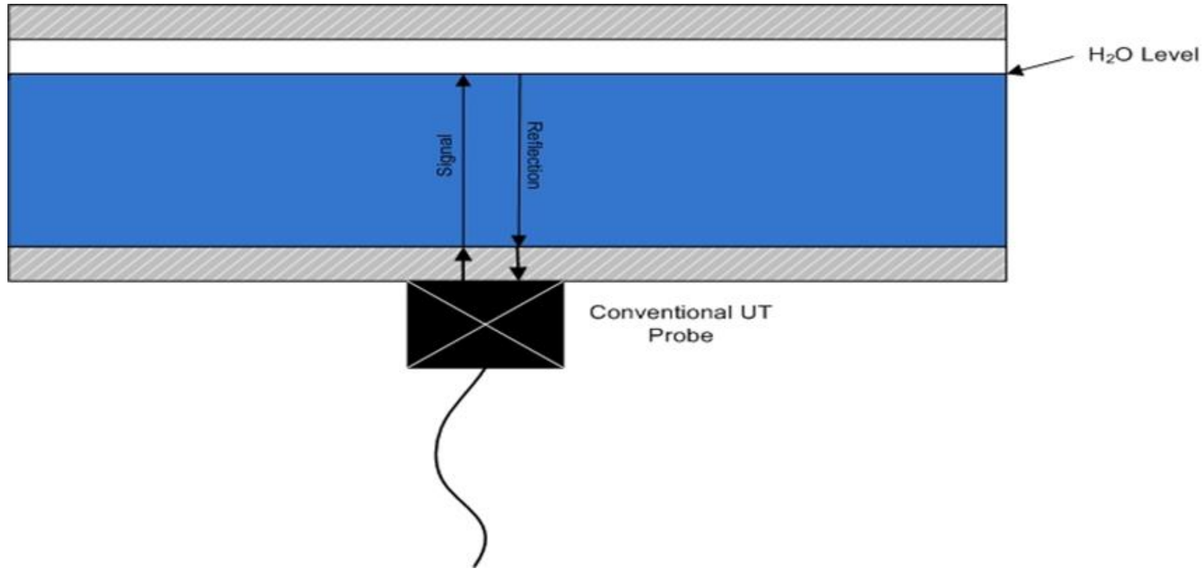
4 – Cyber security – solutions exist

Benefits of Wireless UT Monitoring of Gas Voids

- Minimize safety risks to personnel performing examinations
  - Reduce radiation exposure
  - Eliminate climbing activities with equipment
- Reduce costs of performing exams
  - No need for planning and scheduling exams
  - No need for scaffolding
  - No impact on other plant activities
- Recorded data of exam results
- Automated notifications to plant personnel and operators
- Trending

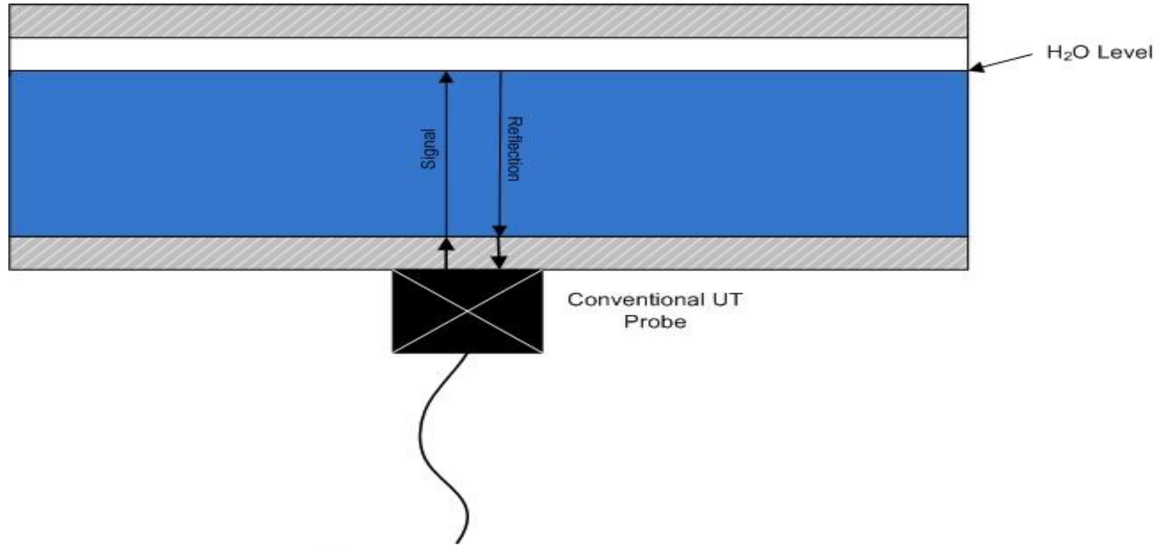
Gas Void Monitoring

- Initial tests demonstrated measurement of water level in a mockup using low voltage driven UT sensors
- Wireless ultrasonic sensors were successfully integrated with DAS on second field trial
  - Data was wirelessly uploaded to monitoring software
- Looking at issues and associated costs for power options of battery vs. cable
- System could be used to remotely monitor gas voids
  - Reduce cost associated with building scaffolding and personnel dose
  - Could be designed to automatically alert operators when systems need to be vented



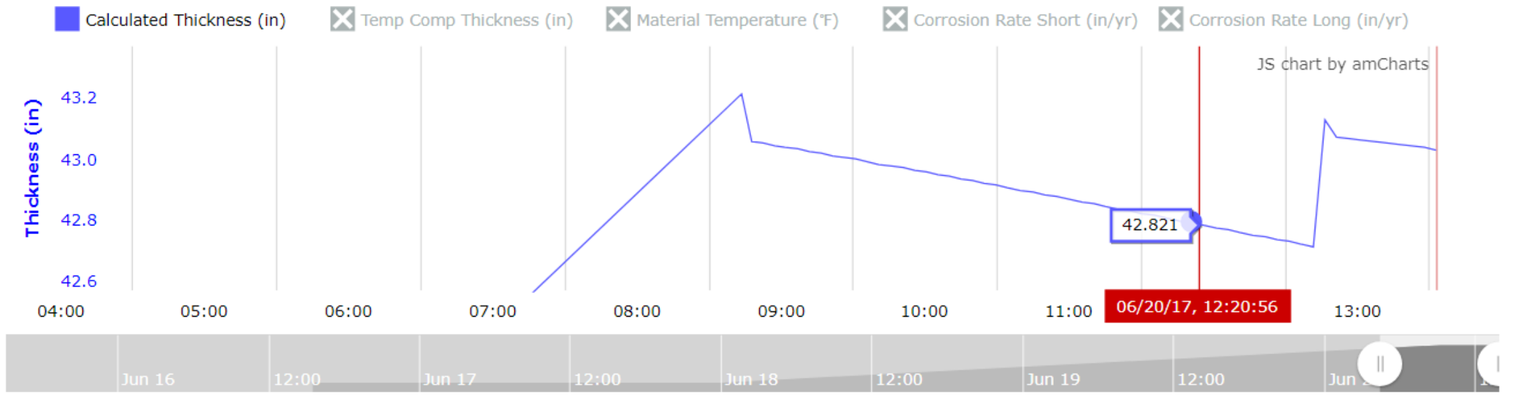
Permanently installed sensor for gas void detection and sizing

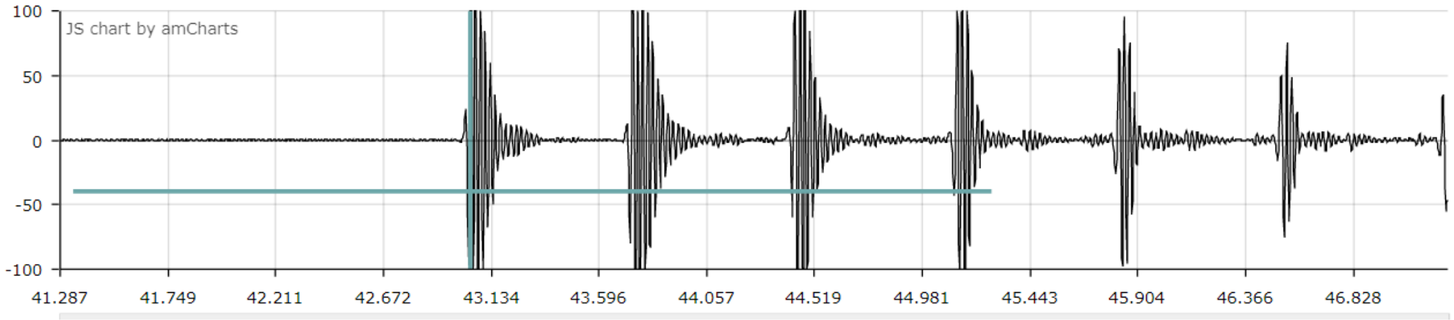
- Piezoelectric transducers applied to the bottom surface
- Linear array could provide a profile of the bubble
- Wireless transmit data
- Multiple units can be daisy-chained together
- Would alert operators when systems need to be vented
- Replaces manual measurements, building of scaffolding, and personnel doses



Permanent monitoring UT system

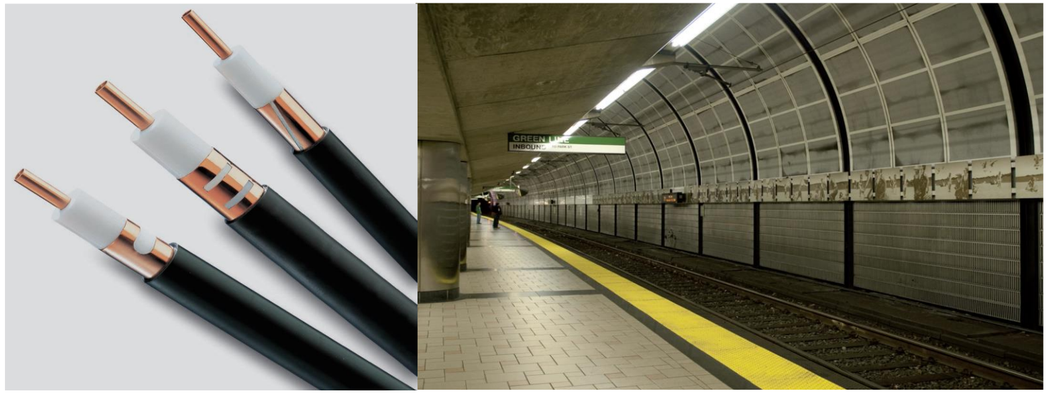
Gas Void Tests on Mockup in EPRI Hi-Bay





Wireless communication technologies for Nuclear Plant Environments

- NDE Structural Health Monitoring (SHM) technologies can leverage studies on Distributed Antenna Systems (DAS)
- Leaky wire
  - Generally coaxial cable with outer shield removed at locations to enable the cable to act as a set of distributed antennas
  - Has been used in mining environments where more common wireless technologies fail
- WiFi has had difficulty in plant environments



Gas Void Monitoring Deployment

- MicroPIMS sensors are mechanically clamped to the pipe
- Engineering Design Modification Package needs to be completed for each site to install sensors on safety related piping
  - EPRI developed a common design package document to facilitate installation at nuclear sites
- Wireless data and communication with sensors is done through a 900 MHz LoRaWan network
- Ultrasonic data can be sent to a local server for data storage and viewing
  - Alerts can be set based on desired criteria
  - Alerts can be used to know when and where properly vent the system

Summary

- Wireless ultrasonic transducers were tested in laboratory conditions to demonstrate monitoring of gas voids
- Placing sensors on the bottom side of the pipe enables water level to be directly measured
- Wireless sensors have since been deployed in a nuclear power plant with several others also planned
- A Distributed Antenna System (DAS) was used to set up a LoRaWAN wireless network for data communication
- Data can be transmitted to a local server or cloud storage service
- Alerts can be set up to notify plant personnel of any adverse conditions and any potential need to vent a pipe