Transmission of Information by Acoustic Communication along Metal Pathways in Nuclear Facilities
Project Overview

• Goals and Objectives
  – Demonstrate ability to transmit information through physical boundaries at a nuclear facility

• Participants (2020)

• Schedule
  – Y1: developed system requirements and implemented ultrasonic communication setup on a pipe
  – Y2: demonstrated ultrasonic data transmission on room temperature pipe
  – Y3: demonstrated ultrasonic data transmission on elevated temperature pipe
Accomplishments

• Communication System Specification
  – Communication system at a nuclear facility would transmit information on steel pipes already in place for nuclear reactor operation
  – Focused on information transmission of information in an out of the containment building
    • Identified charging line stainless steel pipe of chemical volume control system (CVCS) as viable conduit for information transmission
    • Pipe penetrates containment wall through a tunnel in concrete sealed on both ends by steel plates

Accomplishments

- Developed Ultrasonic Communication System on Elevated Temperature Pipes


Typical environmental stresses on containment isolation function components:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Normal</th>
<th>Accident</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>50-120 °F</td>
<td>300 °F</td>
</tr>
<tr>
<td>Pressure</td>
<td>atmospheric</td>
<td>70 psig, max</td>
</tr>
<tr>
<td>Relative Humidity</td>
<td>30-100 %</td>
<td>100 %</td>
</tr>
<tr>
<td>Radiation</td>
<td>50 rads/hr</td>
<td>150 Mrads/hr</td>
</tr>
</tbody>
</table>

Accomplishments

• Ultrasonic image transmission on a heated pipe
  – Used the ASK transmission protocol implemented in GNURadio environment
    • SS304 2.375” OD schedule 160 pipe heated to 50°C and 150°C
    • LiNbO₃ transducers with carrier frequency is 728 kHz
    • 10KBps data rate (bit pulse duration is 100µs)
    • ISI suppressed with RRC filter, BER ~10⁻³

90KB Image

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Accomplishments in 2020

- **Deliverables**

- **Publications/Presentations**
Accomplishments in 2020

• Publications/Presentations

• Commercialization
  – Received request from information from Canadian Utility
Accomplishments Over Project Lifecycle

- **Publications/Presentations**
  - **Journal papers (2)**
    - *IEEE Transactions of Ultrasonics, Ferroelectrics and Frequency Control*
    - *Nuclear Technology*
  - **Conference papers (14)**
    - **Seven** in Proceedings of *IEEE International Ultrasonics Symposium (IUS)*
    - **Five** in *Proceedings of IEEE International Conference on Electro/ Information Technology (EIT)* (including **Best Paper Award**)
    - **One** in *Proceedings of Nuclear Plant Instrumentation, Control, and Human-Machine Interface Technologies (NPIC&HMIT)*
    - **One** in *Transactions of ANS Winter Meeting*
  - Submitted **R&D100** application
  - Project work profiled **twice** by ANL Media Office

- **Patents**
  - **US Patent Application 15/947,303 has been filed in 2018.**
Technology Impact

- **Advances the state of the art for nuclear application**
  - Provides capability to transmit information across physical barriers at a nuclear facility using in-place piping infrastructure

- **Supports the DOE-NE research mission**
  - Develops new means of secure and accident-resilient communication at a nuclear facility applicable to different reactor types

- **Impacts the nuclear industry**
  - Helps to increase safety of existing and future nuclear power plants

- **Will be commercialized**
  - US Patent Application 15/947,303 has been filed in 2018.
  - Received request from information from Canadian Utility
Conclusion

• Demonstrated information transmission on nuclear grade stainless steel pipe using ultrasonic transducers
  – Demonstrated high-bitrate ultrasonic transmission of images on a pipe at simulated normal and post-accident conditions

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