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Dear Dr. Busby:

The NDE workshops on the development of R&D roadmap under the materials aging and degradation pathway of the LWRS program were held at Oak Ridge National Laboratory during July 30th to August 2nd, 2012. As the NDE technical lead for the piping fatigue task, I hosted a full day workshop on August 2nd, 2012. A summary of activities and the list of subject matter experts who attended that workshop are enclosed.

Sincerely,

Sasan Bakhtiari
Nuclear Engineering Division

**LWRS NDE Workshops**
**Fatigue Workshop Summary**
**August 2, 2012**

Light water reactor sustainability (LWRS) nondestructive evaluation (NDE) Workshops were held at Oak Ridge National Laboratory (ORNL) during July 30th to August 2nd, 2012. This activity was conducted to help develop the content for the NDE R&D roadmap under the materials aging and degradation (MAAD) pathway of the LWRS program. The workshops focused on R&D needs in four areas: cables, concrete, reactor pressure vessel, and piping. A selected group of subject matter experts (SMEs) from DOE national laboratories, academia, vendors, utilities, and regulatory body were invited to each workshop. A technical presentation was initially given by a materials degradation expert to help better define the problem and to identify potential inspection and monitoring gaps. That was followed by a number of short presentations by NDE and structural health monitoring experts on promising technologies and methodologies to address long term materials degradation issues. A folder containing the presentation materials, instructions for the conduct of each meeting, and expected inputs from SMEs was provided to all workshop participants. The technical presentations were followed by a brainstorming session involving active participation by all SMEs to identify the gaps and propose R&D actions to address the needs. The participants were divided into three working groups for the breakout sessions to work on common R&D themes identified earlier. The reports provided by working groups were subsequently discussed among all participants and R&D actions were prioritized through an open voting process. The results of the workshops on the development of NDE R&D roadmap under the MAAD pathway will next be drafted into a summary report and will be submitted to the program lead (Jeremy Busby, ORNL). The NDE technical leads will circulate the draft report of their workshop among the participants for final review and comments. Upon completion, the final R&D roadmap report for each area will be submitted to the program lead.

The LRWS NDE workshop on piping fatigue was held on August 2nd, 2012. The list of SMEs who attended the workshop is attached. The first presentation to help identify the materials degradation issues associated with environmentally assisted fatigue was made by Dr. S. Majumdar who is a senior mechanical engineer at ANL with extensive expertise in this area. He is also one of the technical leads involved with the LWRS program working on development of mechanistic models for prediction of residual life of rector components subject to environmentally assisted fatigue. In summary, the first presentation identified locations in LWRs where problems are more likely to occur. Those locations include: weld heat affected zones; vulnerable spots associated with dead flow zones or places where the local chemistry is different from bulk chemistry; thermal stratification and thermal striping zones; locations affected by off-design transients; initiation sites caused by manufacturing flaws (e.g., scratches and dings). The presentation also identified certain gaps for monitoring of environmentally assisted fatigue crack initiation that needs special attention including measurement of oxygen/hydrogen content in the water during transients (start up, shut down, etc.), wide-area sensors and instruments for detection of cracks that initiate from places not identified during design as high stress regions (i.e., surprise failure incidents), and novel NDE techniques for early detection of cracks and loss of protective oxides in view of the fact that the actual degradation locations are often hard to predict. A series of presentations were made subsequently on promising NDE and monitoring techniques for detection, diagnostics and prognostics of fatigue damage in primary piping systems and the associated components. The talks — S. Bakhtiari (ANL), J. Wall (EPRI), B. Regez/S. Krishnaswamy (Northwestern Univ.), and A. Chattopadhyay (Arizona State Univ.) — covered a wide range of conventional NDE and monitoring methods as well as emerging sensors and techniques, most of which are currently being implemented for non-nuclear applications. A brainstorming session was conducted next during which the SMEs were

asked to provide their input to help define R&D actions needed to address the gaps discussed earlier. A major objective of the brainstorming session was to identify those sensors and techniques that have the most promising commercial viability and fill a critical inspection or monitoring need. Some common themes regarding R&D needs identified by the working groups included techniques for early pre-cursor detection, fatigue crack initiation and growth monitoring (below current conventional NDT limits and for welds, base metals, bends/elbows, and long pipe sections), robust sensors for harsh environments (elevated temperatures – >200$^{o}$C), sensors for in situ materials characterization and for feature sizes usually examined by laboratory techniques (e.g., oxide coating assessment), global screening — as opposed to local examination methods — for early detection of damage, and development of improved signal processing, data analysis, and sensor fusion algorithms for better sensitivity to early detection of defects. A separate common team among the working groups was the development of a sample database for the evaluation of all NDE and monitoring techniques (i.e., design of experiments to define numbers and classes). A number of NDE and monitoring techniques employing acoustic/ultrasonic, thermal, electromagnetic, micromagnetic, and optical (visual, laser) sensors were also identified as viable candidates for further evaluation. Following the brainstorming session, the proposed NDE R&D needs were prioritized and ranked based on an open voting process. The results are currently being drafted into a summary report and will be submitted next to the program lead for the MAAD pathway under the LWRS program. A more detailed NDE R&D roadmap report based on outcome of the workshop for piping fatigue will be submitted to the program lead in early September, 2012.

**LWRS NDE Workshops**
**Fatigue Workshop Attendee List**
**August 2, 2012**

| Name | Affiliation |
|---|---|
| Sasan Bakhtiari | Argonne National Laboratory |
| Leonard Bond | Iowa State University |
| Cy Smith | Oak Ridge National Laboratory |
| Dwight Clayton | Oak Ridge National Laboratory |
| Pradeep Ramuhalli | Pacific Northwest National Laboratory |
| David Brenchley | Pacific Northwest National Laboratory |
| Wes Hines | University of Tennessee, Knoxville |
| John Lareau | WesDyne |
| James Wall | Electric Power Research Institute |
| Venu Varma | Oak Ridge National Laboratory |
| Thomas Rosseel | Oak Ridge National Laboratory |
| John Burke | Nuclear Regulatory Commission |
| Jamie Coble | Pacific Northwest National Laboratory |
| Richard Wright | Idaho National Laboratory |
| Mike Anderson | Pacific Northwest National Laboratory |
| Kevin Newell | Zetec, Inc. |
| Glenn Light | Southwest Research Institute |
| Saurin Majumdar | Argonne National Laboratory |
| Aditi Chattopadhyay | Arizona State University |
| Bradley A. Regez | Northwestern University |
| Carol Nove | Nuclear Regulatory Commission |