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ACOUSTIC EMISSION - FLAW RELATIONSHIP FOR IN-SERVICE MONITORING OF NUCLEAR PRESSURE VESSELS

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OBJECTIVE

The objective of the acoustic emission (AE)/flaw characterization program is to provide an experimental feasibility evaluation of using the AE method on a continuous basis to detect and analyze flaw growth in reactor pressure boundaries. This effort is based on the philosophy that AE offers the potential of being a valuable addition to current NDI methods with unique capability for continuous monitoring, high sensitivity, and remote flaw location. It is not viewed as a replacement for current methods, at least in the foreseeable future.

LICENSING AND SAFETY ISSUE

This program addresses the following areas of significance:

- Older reactors where effective inspection of the vessel by conventional methods is extremely difficult. AE can potentially be used to monitor these vessels to detect and locate active flaws, facilitate an estimate of severity based on AE, and localize shielding penetration location(s) for flaw inspection by conventional methods.

- Monitor vessel areas such as nozzles where conventional NDI is difficult and expensive. AE could detect the presence of an active flaw and maintain surveillance of flaw growth to minimize the need for conventional NDI.

- As a secondary benefit, AE systems provide a sensitive detector of leaks as well as cracking in piping. They can also be adapted to sensing flow - no flow in critical valves.

SCOPE

The program scope is described by three primary areas of effort:

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DISCLAIMER

- Develop a method to identify crack growth AE signals as unique from other innocuous but similar acoustic signals.

- Develop a relationship between measured AE and crack growth which will enable an estimate of flaw severity based on measured AE information.

- Demonstrate the total concept through off-reactor vessel tests and finally, on-reactor monitoring. This includes developing the necessary instrumentation system.

The program is structured to start with testing laboratory specimens to determine fundamental feasibility. Since theoretical transfer of these results to a full size structure is very questionable in this case, the next phase calls for testing on a heavy section (> 4 inch wall) vessel to establish criteria more directly relateable to a reactor vesel. Vessel testing is to include a simulation of pertinent reactor environment conditions (background noise, flaws exposed to pressurized and heated water, etc.) excluding nuclear radiation. The final phase requires installation and operation of a prototypic AE monitor sytem on an operating reactor on a test basis.

One of the important sub-phases in the general program calls for measuring and analyzing AE from HSST program tests - vessel fracture and irradiated fracture specimen tests.

All test work has by intent focused on ASTM A533 Grade B, Class 1 steel.

RESULTS

Major accomplishments to date include:

Completion of laboratory testing from which we:

(a) showed the feasibility of separating crack growth AE signals from other transient signals using pattern recognition methods
(b) developed an AE/fracture mechanics relationship for flaw interpretation
(c) measured and analyzed AE data from HSST vessel tests with positive results

- Established a location and facilities for performing simulated reactor vessel monitoring.

- Are negotiating for installation of an AE sensing system on a reactor.

Expanding on the accomplishments:

Identification of Crack Growth AE

Pattern recognition was tested as a means of identifying crack growth AE using a sample of about 225 AE signals from a growing crack in a laboratory test specimen and assorted noise signals. Figure 1 shows an example of the overt similarity between many of these signal types. Ten pattern recognition features were examined. Out of these, auto-correlation produced the most definitive result (Figure 2). Applying this as a decision rule to sort the data resulted in a 96% correct classification as shown in Figure 3. This same technique was subsequently tested on a data sample from a 3 inch wall cylindircal bend specimen with equally definitive results.

AE/Fracture Mechanics Relationship - Flaw Interpretation

In Figure 4, a composite of AE/crack growth data measured from laboratory specimens is presented. The two diagonal lines are "worst case" slope lines for room temperature and 550°F test conditions. Figure 5 shows the concept for using the experimental data as a base for estimating flaw significance using AE measured on a reactor. As can be noted, the laboratory data is in terms AE and crack growth per cycle. We are presently evaluating whether a "per cycle" or a time base represents the most realistic approach to applying the concept to a reactor circumstance. The format selected will be evaluated on a vessel test to be performed at MPA, Stuttgart, Germany in the first quarter of FY-81. The vessel test will attempt to simulate reactor environment with the exception of nuclear radiation.

HSST Test Results

Two intermediate vessel tests at ORNL under the HSST program have been monitored for AE and the results analyzed. Figure 6 gives a composite of the results in terms of AE versus stress intensity factor "K". Considering the differences in test conditions for the two cases (200°F versus -5°F and different flaw sizes), these results are viewed as being very encouraging. Both of these tests

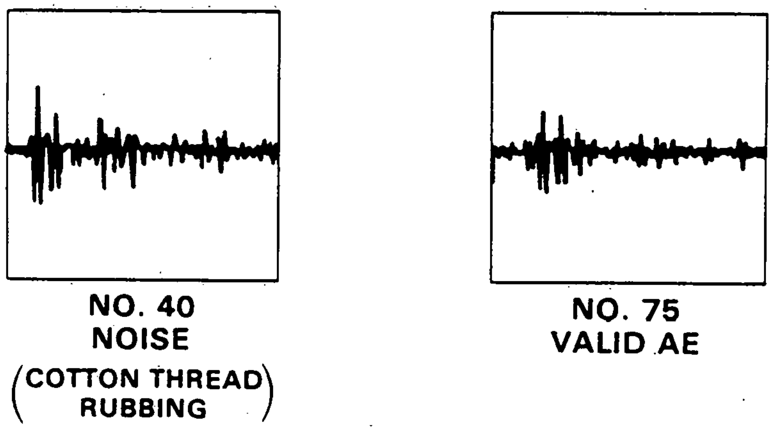

Figure 1. Sample Digitized Waveforms from Pattern Recognition Study.

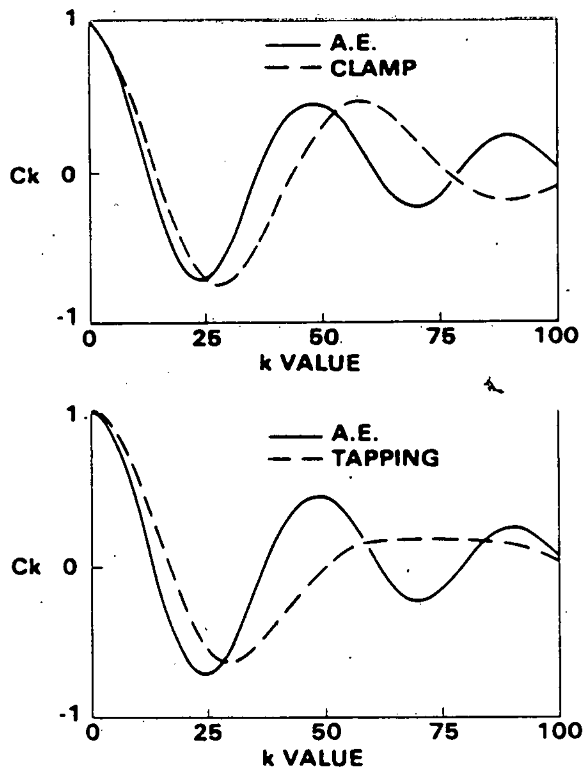

Figure 2. Autocorrelations for AE and Noise Waveforms.

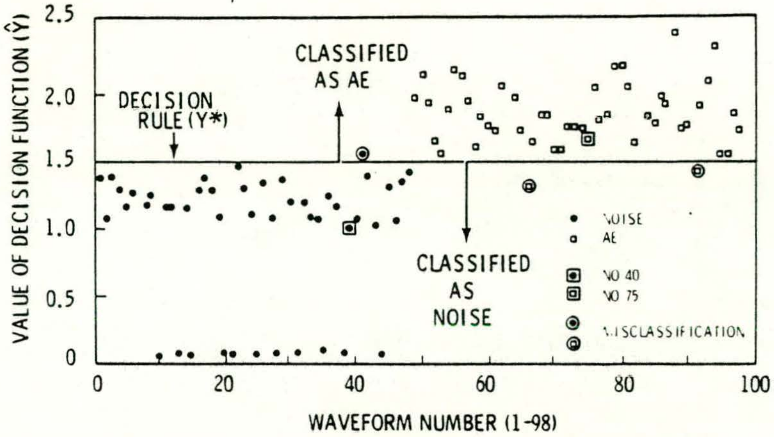

Figure 3. Results of Pattern Recognition Analysis of Valid AE and Noise (96% Successful Classification).

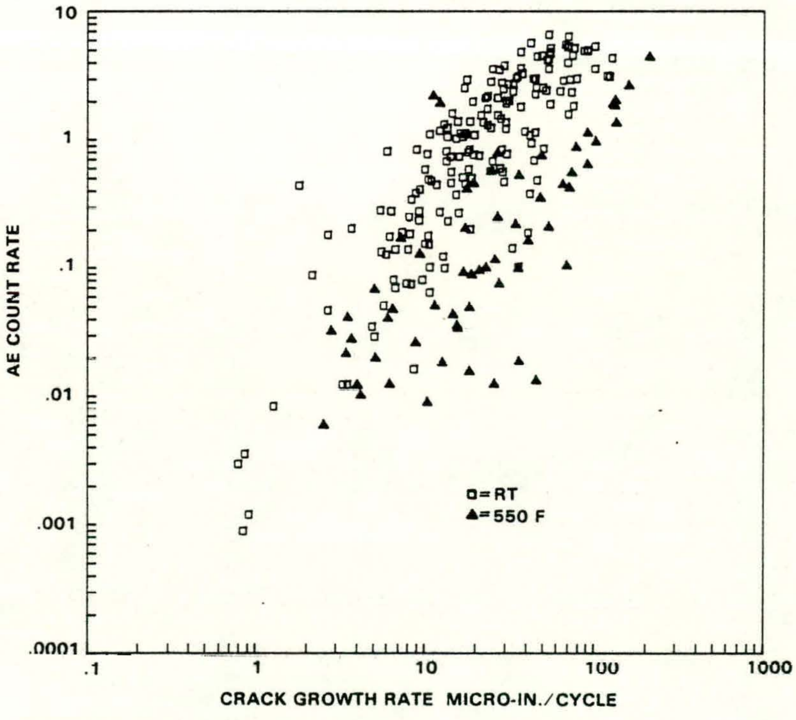

Figure 4. Experimental AE Rate Versus Fatigue Crack Growth Rate.

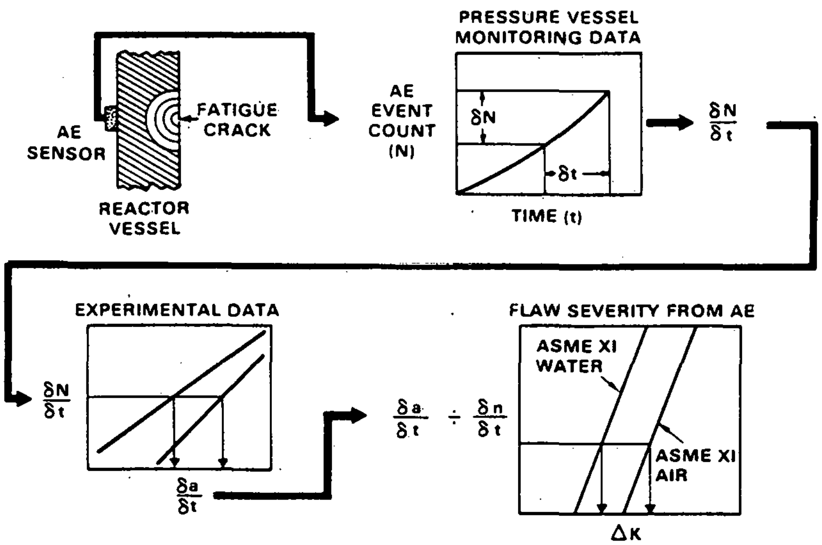

Figure 5. Schematic Procedure: Determination of Flaw Severity During Operation.

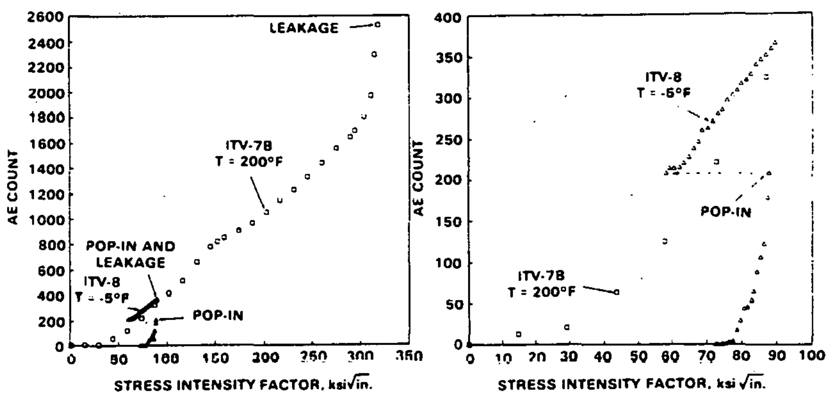

Figure 6. AE Results - HSST Vessel Tests.

involved montonic loading to failure at a machined flaw. A concept for applying these results to evaluate flaws using AE data from a hydrotest circumstance is shown in Figure 7.

Simulated Reactor Vessel Test

After comparing three options for a vessel test (two in the U.S. and one in Germany), vessel testing at MPA, Stuttgart, West Germany was selected as the site for this work. There are advantages from the standpoint of both cost and time schedule. An additional incentive is the opportunity to monitor two vessel tests at MPA. The vessels are about 5 inch wall, 70 inch O.D. and 110 inches long. Present plans call for the testing to start in October, 1980.

Reactor Installation

Potential for installing an AE monitoring system on an operating reactor is currently being discussed with Philadelphia Electric and Commonwealth Edison. The objective is to install three AE sensing arrays on a reactor by the end of FY-80.

KEY MILESTONES

FY-80

- Complete Lab Testing
- Develop Application Relationships
- Prepare Demonstration Instrument System
- Arrange for Off-Reactor Vessel Test
- Install Sensing System on a Reactor

FY-81

- Complete Off-Reactor Vessel Test
- Refine Relationships
- Install Demonstration AE Instrument System on Reactor

FY-82

- Complete First Year Reactor Monitoring
- Fabricate Prototypic AE Monitor System
- Install Prototype on a Reactor

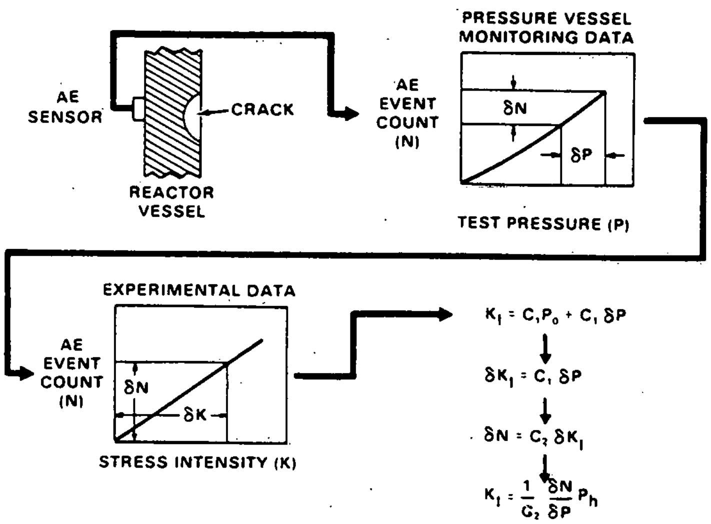

Figure 7. Schematic Procedure: Determination of Flaw Severity During Hydrotest.

KEY MILESTONES - Continued

FY-82 - Continued

- Prepare Code Case
- Characterize Piping Material

FY-83

- Complete System Modification
- Complete Technology Transfer
- Obtain Code Acceptance