NRC Research and Technical Assistance Report

INTERIM REPORT

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Contract Program or Project Title: ACOUSTIC EMISSION/FLAW RELATIONSHIPS FOR INSERVICE MONITORING OF NUCLEAR PRESSURE VESSELS

Subject of this Document: MONTHLY PROGRESS - JANUARY-FEBRUARY 1981

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Date of Document: March 19, 1981

Responsible NRC Individual and NRC Office or Division:
Dr. Joe Muscara
Metallurgy and Materials Research Branch, RSR

This document was prepared primarily for preliminary or internal use. It has not received full review and approval. Since there may be substantive changes, this document should not be considered final.

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Prepared for
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

INTERIM REPORT

NRC Research and Technical Assistance Report

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March 19, 1981

Dr. Joe Muscara
Metallurgy and Materials Research Branch
Reactor Safety Research Division
Nuclear Regulatory Commission
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Washington, D.C. 20555

Dear Joe:

MONTHLY LETTER REPORT - JANUARY-FEBRUARY, 1981
ACOUSTIC EMISSION CHARACTERIZATION OF
FLAW GROWTH IN A533B PRESSURE VESSEL STEEL
FIN. NO. B2088

ACCOMPLISHMENTS

- A533B insert for ZB-1 vessel test machined to shape.
- Tested a specimen of degraded German KS07 steel to be included in the ZB-1 vessel test.
- Visited TVA at Watts Bar 1 reactor to discuss details of AE system installation.
- Differential sensor and preamplifier testing completed.
- Completed AE monitor system fabrication.
- AE weld monitoring demonstration performed in Germany.
- Started AE monitoring of HSST irradiated fracture specimen testing.
- Presented a mid-year program review.

VESSEL TEST

Fabrication of an A533B steel insert for the ZB-1 vessel test was initiated in late December 1980 under a contract with MPA,

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Stuttgart, Germany. Machining of the insert to shape from material supplied by PNL has been completed. Preparation of three flaws in the 59" x 28" x 4-3/4" insert is being delayed until R. J. Kurtz's planned visit to MPA in late March. Purpose of the visit is to inspect and accept the work to date plus detailed discussion of the critical procedure for machining and precracking the three flaws.

In our most recent telephone contact with MPA (March 4), they indicated they did not yet have authorization to proceed with fabrication of the ZB-1 test vessel. The delay apparently revolves around selection of a fabricator. We were assured that there was no question of the test proceeding. This is still a point of concern, however, because of the effect of this delay on initiation of the test. It appears that September or October 1981 is now the earliest that testing could start.

A sample of the German KS07 steel insert which is intentionally degraded material has been obtained for acoustic characterization. The concern is that with the multitude of cracks in the material, it may be so "noisy" under load that it would interfere with effective AE monitoring of the rest of the vessel. One specimen of the material has been tested under cyclic load with the results shown in Figure 1. These results would indicate that the material should not represent a serious noise problem. Additional specimens will be tested.

REACTOR MONITORING

Agreement has been reached with TVA to install an AE system on Watts Bar 1 reactor for testing. The site was visited January 20-22 by PNL and NRC personnel to make preliminary determinations on locations to monitor, identify problem areas, and determine timing requirements. Results of the visit are summarized in a letter included as Appendix A of this report. Briefly, the installation must be completed by September 1981. The locations selected for monitoring are:

- #2 inlet nozzle.
- #2 cold leg pipe.
- A 10" accumulator line that tees in #2 cold leg. We plan to install some type of crack growth specimen on the surface of the 10" pipe.

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- A segment of the vessel cylinder with the included portion of the fabrication girth weld.

Current activities on this effort focus on resolving specific sensor locations to achieve effective monitoring of the selected locations. Also, a differential waveguide sensor/preamplifier combination has been tested to determine their resistance to temperature effects. The sensor is stable to 350°F and the preamplifier to 300°F with military specifications components. These will be suitable for all locations except the bottom of the vessel. Fabrication of differential sensors and preamplifiers for reactor installation is in process. The incentive for a differential system is to provide added protection against electrical transient signals from various sources.

Sensors installed on the bottom of the vessel will be subjected to 550-600°F. There is at least one commercial sensor which will withstand this temperature. We wish to minimize use of these sensors because of the high cost.

AE MONITOR SYSTEM

Fabrication of the AE monitor system for vessel testing and reactor monitoring has been completed. Laboratory testing of the system performance is in process. At the outset, this consists of introducing signals into the system from a tape to verify that the various subsystems function as an integrated system. The final testing planned is to install the system on a cylindrical vessel where AE signals can be generated as well as artificial signals to verify system performance.

DEMONSTRATION OF WELD MONITORING USING AE

A subcontract was negotiated with GARD to perform AE monitoring of a test weld in Germany. A test plan was approved by PNL, GARD, NRC and IZFP prior to testing. The test was performed the week of February 16 at Oberhausen, Germany.

The total weld (1350 x 250 mm) will be inspected by radiography and ultrasonic methods for comparison of flaw indications with AE results. A section of the weld about 300 mm long will be destructively examined at MPA for positive determination of flaw description and location. Evaluation of this portion of the test is expected to be completed by the end of June 1981. The balance of the weld (approximately 1000 mm) will become

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one of the specimens to be examined under the PISC II Program. Results from this will not be available for two to three years.

A copy of the "Quick Look" report on test results is attached as Appendix B of this report.

HSST IRRADIATED FRACTURE SPECIMENS

Fracture testing of unirradiated and irradiated weld specimens under the HSST program provides a rare opportunity to also gain insight to the effect of irradiation on AE during crack growth. Testing of a dummy specimen at NRL has been AE monitored to verify technique and identify problems. Figure 2 shows preliminary results from this test. The primary point to be observed from this plot is the relation that can be drawn between AE and each load cycle. A much more extensive analysis of AE versus fracture mechanics will be performed for the actual test specimens. This test showed that the basic technique was satisfactory, however, there is a severe transient noise problem associated with the test facility. Modification of the monitor system to use differential sensors is expected to overcome this problem.

The first irradiated 4T specimen test on February 22, 1981 produced marginal AE results which are being evaluated. Subsequent investigation showed that a modified commercial differential preamplifier used has degraded the system sensitivity seriously. This preamplifier was used as a necessary expediency to meet the NRL test schedule. Having identified the problem, a new set of differential preamplifiers have been fabricated to a PNL design and thoroughly tested. These show about 20 dB increase in sensitivity over the modified commercial units. These will be used on the next irradiated specimen test which NRL expects to run the last week of March.

NRL states that all of the 4T test specimens are weld specimens and that there are companion unirradiated specimens for each of the irradiated. Based on this information, we plan to monitor two more irradiated specimens and the two unirradiated companions.

REPORTING

A mid-year review of program results and projections was presented February 25, 1981 at NRC RSR offices in Silver Springs, Maryland.

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SCHEDULE AND FUNDING

A revised program schedule is presented in Figure 3. The primary changes are those reflecting the delay in the vessel test schedule and the recently established schedule for AE system installation on Watts Bar 1 reactor. Vessel fabrication by MPA is a critical path item of increasing concern. Continued delay on this element will infringe further on our original plan to sequence vessel testing and reactor monitoring whereby reactor monitoring would benefit from knowledge gained from the vessel test. We do not feel that reactor testing can be delayed because we agree with and are committed to completion of the program in FY-83.

FY-81 funding is summarized in Table 1. The item under Projected Remaining FY-81 Costs labeled "Laboratory Tests to be Defined" concerns the consideration discussed at the mid-year review to perform some laboratory testing this year addressing hydrotest and/or piping characterization. Such tests have not yet been well defined. They would be reviewed with you prior to any action.

PLANS FOR MARCH

- Inspect A533 insert for ZB-1 vessel test and initiate flaw generation.
- Design sensor layout for Watts Bar installation.
- Continue testing AE monitor system.
- Monitor one irradiated fracture specimen test.
- Prepare sensor layout for ZB-1 vessel test.
- Fabricate sensors and preamplifiers for Watts Bar installation.

Yours very truly,

P. H. Hutton

P. H. HUTTON
Project Manager

PHH:kw

Attachments

Table 1

AE/FLAW CHARACTERIZATION PROGRAM

SUMMARY OF FY81 COSTS

Total Funding:	Expense - FY81		$500.0K
	- FY80 carryover		122.0K
		Total	$622.0K
	Capital - FY81		$ 31.0K
	- FY80 carryover		14.4K
		Total	$ 45.4K
Cost to 3/1/81:	Expense - Spent*		$302.0K
	- Balance		320.0K
	Capital - Spent*		$ 41.0K
	- Balance		4.4K

*Includes outstanding commitments

Major FY81 Cost Elements to Date

Irradiated Specimen Tests	$ 15.0K
Vessel Test Preparation including Fabricate A533 Insert	77.0K
AE Monitor System	61.0K
Sensor System Improvements	19.0K
Reactor Installation	11.0K
Pattern Recognition	23.0K
AE Weld Monitor Demonstration	45.0K
General - Reporting, Travel, Program Management	51.0K
Total	$302.0K

Projected Remaining FY81 Costs

Expense

Vessel Test Preparation	$ 30.0K
Vessel Test and Analysis	100.0K
Irradiated Fracture Specimen Monitoring	20.0K
AE Monitor System Fabrication and Testing	25.0K

Table 1

(cont'd)

Projected Remaining FY81 Costs - cont'd

Expense - cont'd

Reactor Installation of AE Sensing System	$ 40.0K
Weld Monitor Demonstration	5.0K
Pattern Recognition Refinement	20.0K
Laboratory Tests to be Defined	40.0K
Reporting, Program Management, Travel	40.0K
Total	$320.0K

Capital

Signal Conditioning Equipment	$ 4.4K
Total	$ 4.4K

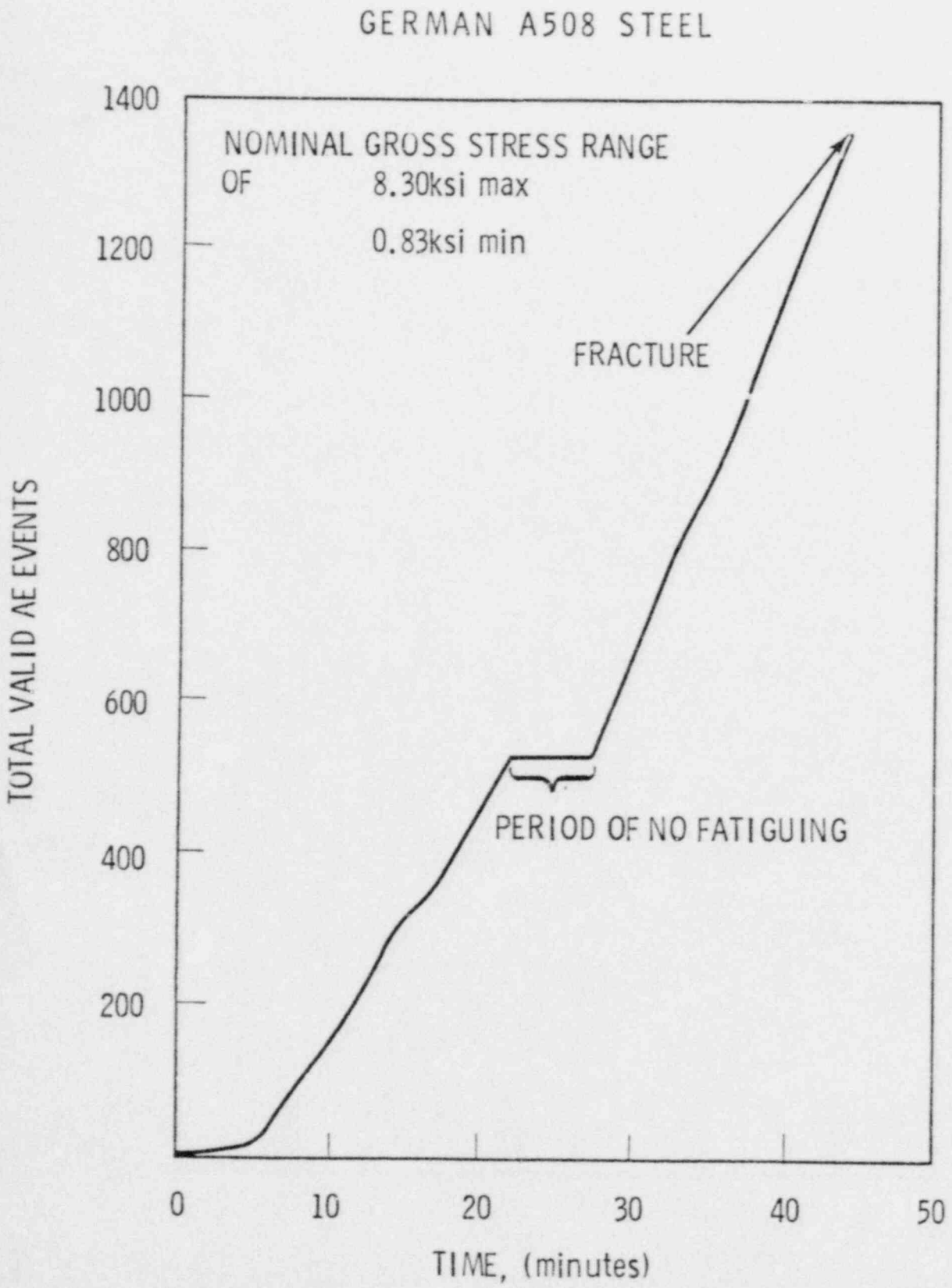

Figure 1. Acoustic Response from Cyclic Loading of KS07 (A508) Degraded Steel.

Figure 2. AE Data From Calibration Specimen Test 2/7/81 - HSST Irradiated Fracture Test Program

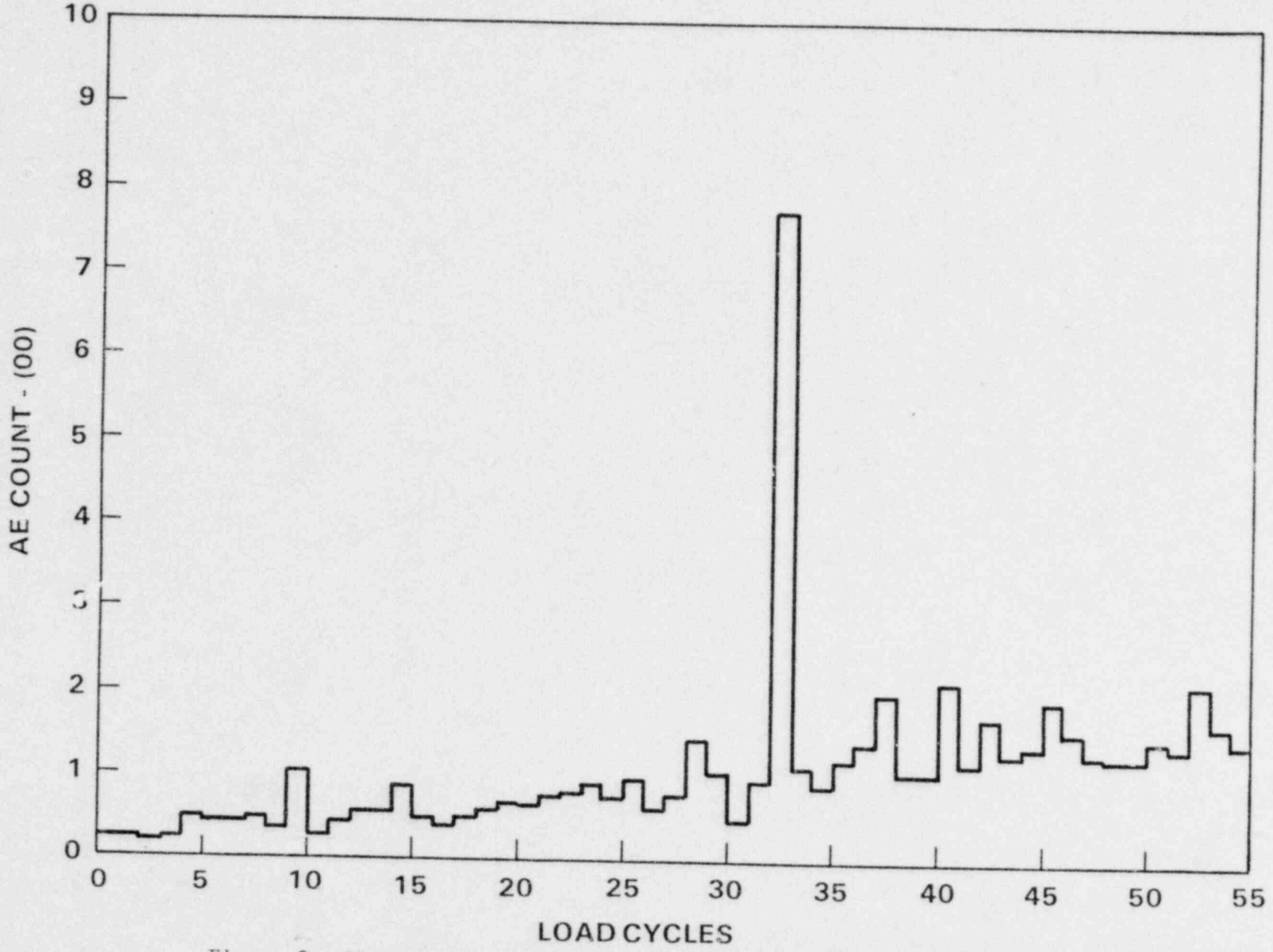

Figure 2. AE Data From Calibration Specimen Test 2/7/81 - HSST Irradiated Fracture Test Program

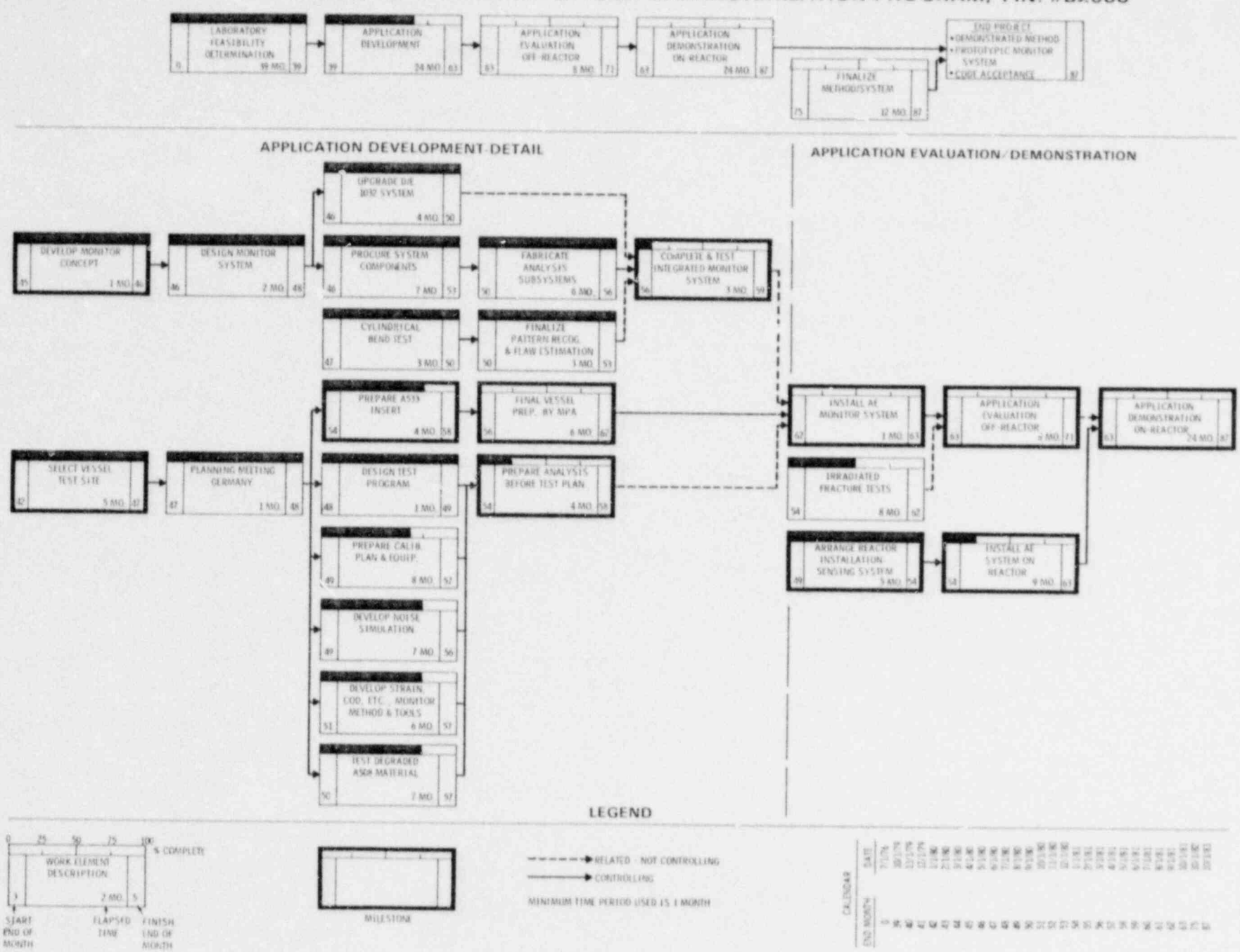

Figure 3. Program Schedule and Milestones

APPENDIX A

Summary of Results of Visit to
Watts Bar 1 Reactor Concerning
AE System Installation

Battelle
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Telex 15-2874

February 5, 1981

E. A. Merrick
Nuclear Standards & Materials
Division of Engineering Design
Tennessee Valley Authority
400 Commerce Avenue, W10D188
Knoxville, Tennessee 37902

Subject: ACOUSTIC EMISSION MONITORING OF WATTS BAR UNIT 1

Dear Ed:

There are several questions and points for clarification that have arisen from our visit to Watts Bar and subsequent discussions. My purpose in writing this memo is to list these items to make it easier for both of us to keep track of the information needs. The items I am aware of at this time include:

1) Schedule - Per our telephone conversation on February 3, 1981, we must complete installation of all AE equipment inside containment no later than September 30, 1981.

2) Monitoring Locations - Our present plan is to monitor:

   a) #2 inlet nozzle.

   b) #2 cold leg pipe.

   c) The 10" accumulator line that tees into #2 cold leg up to about the first elbow away from the cold leg. It is on this section of pipe we would like to attach a crack growth specimen which is as yet not fully defined.

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d) A segment of the vessel cylinder with the included portion of the fabrication girth weld. Relative to this item, is there any particular section of the girth weld that you would suggest monitoring?

3) Environmental Conditions - TVA will provide us with a map of environmental conditions (temperature and radiation -- we will assume 100% humidity) for:

a) adjacent to the vessel wall at the nozzle locations;

b) between the inner wall and the main biological shield wall;

c) outside of but adjacent to the main biological shield wall;

d) bottom end closure of the vessel; and

e) general area inside of containment such as near the penetration locations.

4) Seismic Qualification Requirements - TVA is sending us criteria for establishing seismic qualification of a monitor instrument.

5) Vessel Installation - We would like to obtain a drawing of the vessel installation relative to the support structure.

6) Insulation - TVA will provide us with a drawing(s) of mirror insulation installation in the areas of interest. A question relative to the insulation: Is it acceptable to penetrate the insulation with a tube about 1/4 to 3/8 inch O.D. for placement of a waveguide?

7) Signal Cables - Battelle is to provide information on the signal cables we have on hand to determine suitability for use between sensors and containment penetration. We need an estimate of cable length between the selected monitor areas and the containment penetration point.

8) Penetrations - Battelle will contact Harold Denny, TVA to obtain references for establishing the electrical characteristics of shielded, twisted pair panetrations.

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9) Acceptable Materials - We have compiled a list of materials normally used in the sensors and preamplifiers. Since you are sending a list of acceptable materials for use in containment, we will compare with that list and contact you regarding any that may not be identified.

10) Approval Document - Battelle is to prepare a detailed test plan for TVA approval. This is to include details of AE sensor system installation, monitor system location, test procedure, use of the results, and responsibilities.

Our current concentration is on determining specific sensor location and array patterns. We expect to complete this by the latter part of February. This is essential to determining penetration requirements and to preparation of a test plan. I will also be preparing a PERT chart schedule for accomplishing the installation within the next two weeks.

We very much appreciate the interest and cooperation displayed by you and the other TVA staff members relative to this work. This is a key contribution toward a successful effort.

Yours very truly,

P. H. HUTTON
Project Manager

PHH:kw

cc: Dr. J. Muscara (NRC)

APPENDIX B

Quick Look Report on Results from AE Monitoring of Test Weld in Germany

GATX

GARD, INC.

7449 NORTH NATCHEZ AVE
NILES, IL60648
312-647-9000

March 12, 1981

U. S. Nuclear Regulatory Commission
Division of Reactor Safety Research
Metallurgy and Materials Branch
Washington, D. C. 20555

Attention: Dr. J. Muscara

Subject: Acoustic Emission Weld Monitor Demonstration in Oberhausen, FRG.

Gentlemen:

During the period of February 16 thru February 23, 1981 the GARD, Inc./NRC acoustic emission weld monitor (AEWM) was demonstrated in Germany under Battelle PNL sub-contract B-B4419-A-1. The test took place in the Nuclear Fabrication Bay at Gutehoffnungshutte Oberhausen - Sterkrade.

The weld was fabricated in German pressure vessel steel type KS15 (20 Mn MONi55) by the submerged arc process using S3 NiMo wire and OP41TT flux. The weld was 250 mm thick and was of a single VEE configuration with a 16° included bevel angle. The length of the weld was 1.350 meters and the width of the completed test block was 1.1 meters. Approximately 1 meter lengtn of the completed weld will be used on the test block for PISC II. Welding was accomplished on a 24 hour a day basis and the weld required more than 300 passes over 5 days to complete. A total of sixteen intentional flaws were introduced into the weld during welding. These flaws consisted of small cracks, large cracks, porosity and slag inclusions.

The AEWM operated continually throughout the welding and three additional days of cool down monitoring and was practically trouble free. The only problems experienced were related to floppy disc drive failures during the first day of monitoring. These problems were eliminated by a field repair of the disc drive accomplished during a slack period on the midnight shift of the first days welding. The AEWM detected and for the most part seemed to properly characterize all of the intended crack and slag inclusion flaws both during their introduction and during re-excitation in successive weld passes. Porosity was detected and characterized mostly as non-crack during later passes after the introduction pass.

GATX

In addition to the planned flaws, several natural flaws (mostly slag inclusions in the runoff tabs) were detected, visually confirmed, and apparently correctly characterized.

The German participants in the test were very impressed with the operation of the weld monitor and, in fact, during the introduction of the final series of flaws, they actually depended on the AEWM to determine if the attempts to induce flaws were successful.

The observations communicated in this letter are obviously of a preliminary nature and we must await NDE as well as metallographic results before delivering the final verdict, however we feel confident that this demonstration and the resulting final correlation of AE results with NDE and metallography will make a major positive impact on the NDE community as far as in-process acoustic emission monitoring of welds is concerned.

Very truly yours,

D. W. Prine

D. W. Prine
Staff Engineer

DWP/br

cc: P. H. Hutton
Battelle PNL