DAEDALEAN ASSOCIATES, Incorporated

PROGRESS REPORT NO. 10

THE APPLICATION OF THE INTERNAL FRICTION NONDESTRUCTIVE EVALUATION TECHNIQUE FOR DETECTING INCIPIENT CRACKING OF BYPASS LINES AND PIPES IN BOILING WATER REACTOR PIPING SYSTEMS

Submitted to:

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NRC Research and Technical
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OBJECTIVES

The objective of this program is to determine the feasibility of applying the internal friction NDE technique, as developed by DAEDALEAN ASSOCIATES, Inc., to the in-service inspection of BWR recirculation bypass lines. Data collected in laboratory tests which model the hostile reactor environment will be used to evaluate changes in internal friction detected in an operating BWR in order to identify incipient cracking in bypass lines.

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PROGRESS DURING THE REPORTING PERIOD

The following is a report of the trip to Battelle Northwest Laboratory by DAI engineers to perform testing of 4 inch diameter simulated bypass lines utilizing Battelle Northwest Laboratory's Project Demonstration Loop (PDL).

Operation of the PDL commenced on Friday, March 30, 1979. As discussed in Progress Report No. 9, Ray Brasfield, David Fresch and Bruce Jachowski were at Battelle on March 26, 1979 to instrument the 4" pipe specimen and gather initial data.

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Mr. Brasfield returned to DAI on Friday afternoon once PDL operation was underway. Mr. Fresch and Mr. Jachowski remained to carry on the first pipe data acquisition and to train Battelle personnel for the follow-on pipe testing.

The parameters of PDL operation are as follows:

H_2O Temperature: 288°C

H_2O Pressure: 1250 psig

Ram Load Cycle: 90 minute period

60 minutes full load ∿ 130 kips

10 minutes descending

10 minutes minimum load ∿ 4 kips

10 minutes ascending

Data collection was carried out during both full tensile load and minimum load. Output transducers are B&K 4366 accelerometers denoted A-1 and A-2 on Figure 1. Accelerometer A-1 is located on top of the pipe 1-1/2" downstream of the weld centerline, A-2 is mounted on the underside of the pipe 1-1/2" upstream of the weld centerline. A B&K 4810 mini-shaker is used to excite the pipe at several natural resonances. The mini-shaker is mounted on top of the pipe 3-1/2" to the left of the weld centerline.

The pipe specimen was found to have strong natural resonances at approximately 1825 Hz and 2225 Hz. Under full tensile load applied by the hydraulic rams, the resonant frequencies shifted upward slightly (5-25 Hz). Other resonances were

found in the 4000 to 5000 Hz range but did not show repeatable decay patterns, therefore, data collection concentrated on the two frequencies mentioned.

As data collection progressed, Mr. Fresch and Mr. Jachowski trained Battelle personnel in the application of the internal friction damping technique. By April 6, 1979, Battelle technicians were adequately trained to provide assistance and conduct the data acquisition under supervision, so Mr. Jachowski returned to DAI. During the reporting period, Richard Watson, Dennis Getchell, David Ortiz, Pete Smith and Jerry Duece, all of Battelle, were trained in the application of the technique.

During the first 22 loading cycles, a large variability in the specific damping capacity values for both resonant frequencies was noted. This is believed to be a function of the seating of the loading collars on the pipe. Beginning with load cycle 23, consistent base line data was obtained.

The first indication of crack inception was found after load cycle 173 with the rams at minimum load, exciting the pipe at $\sim$ 2220 Hz. Accelerometer A-2 detected the change with a log decrement $\alpha = 89.5 \times 10^{-4}$. Prior to cycle 173, the mean α value was 66.6×10^{-4} with a standard deviation of 5.3×10^{-4}. Using the student's t = distribution, the α value of 89.5×10^{-4} is outside the 99.5% confidence interval. Crack initiation is further indicated by the return to base line values of α during subsequent load cycles until cycle 206, at which time A-3 gave a

measured α of 95.1 x 10^{-4} and at cycle 207 when A-1 had a measured α of 106 x 10^{-4}. Both values are outside the 99.95% confidence interval. The return of the α value to base line levels after the initial indication is explained by past observation that the dislocations and their associated high local stresses leading to crack initiation, increase material damping significantly, and the initial crack growth relieves the stresses which are causing the increased damping.

After 272 load cycles, the α values for both accelerometers increased dramatically when the pipe specimen was excited at $\sim$ 2225 Hz. With the hydraulic rams at minimum load, both accelerometers showed α values of about 130 x 10^{-4}. With the rams at full load the following cycle, A-1 and A-2 measured α values of 114 x 10^{-4} and 139 x 10^{-4}, respectively. During these load cycles the first significant acoustic emissions were noted, and subsequent measured α values decreased to the base line range. Between load cycles 280 and 284 the internal friction damping of the pipe began steadily increasing from the base line to the range of 75 - 100 x 10^{-4} when the pipe was tested under minimum tensile load at $\sim$ 2225 Hz. This increase was preceded by α values which ranged as high as 140 x 10^{-4} between load cycles 273 and 281 when the pipe was tested at 2250 Hz under full tensile load. Testing at 1825 Hz with full tensile load showed a decrease in α values between 273 and 278 load cycles, with values starting to rise at cycle 279 and

peaking over 200 x 10^{-4} during cycle 284. Although these peak values were not sustained during subsequent cycles as crack growth proceeded, the damping capacity of the pipe was increased as the cracking became more significant and base line values were not attained again after this activity. A great deal of acoustic emission activity was noted as the rams unloaded after load cycles 284, 285, and 286. High α values and acoustic emissions continued through load cycle 375, at which time David Fresch returned to DAI. Battelle personnel continued monitoring the pipe specimen. As of load cycle 463, the pipe had not broken. Measured α values for A-1 at 2225 Hz from load cycle 380 through load cycle 463 averaged 96.7 x 10^{-4}, a 45% increase over the average of the first 200 load cycles, indicating permanent damage to the pipe section. Table 1 shows the base line mean α values for measurements up to the first indication of cracking, as well as the 99.95% upper confidence limits and the first occasions where the measured α value exceeded these limits.

UNANTICIPATED TECHNICAL OR MANAGEMENT PROBLEMS

None

ANTICIPATED PROBLEMS

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None

REQUIREMENTS FOR CHANGES IN KEY PERSONNEL

None

SUMMARY OF IMPORTANT TRIPS, CONFERENCES, MEETINGS AND BRIEFINGS

None

ANTICIPATED COST AND COMPLETION SCHEDULE

Based on the progress to date, it is anticipated that the program will be completed on time and within the estimated cost.

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HYDRAULIC RAMS AT MINIMUM LOAD

ACCELEROMETER	FREQUENCY	NO. SAMPLES	MEAN α	σ_α	$\sigma_{\bar{\alpha}}$	99.95% UCL	α IND.	LOAD CYCLE AT IND.
A-1	1820	77	56.1	4.1	0.47	70.2	71.5	279
A-2	1820	74	55.7	3.8	0.44	68.8	71.8	279
A-1	2220	48	65.9	5.9	0.86	86.7	106	207
A-2	2220	39	66.1	5.2	0.83	84.6	89.5	173

HYDRAULIC RAMS AT MAXIMUM LOAD

ACCELEROMETER	FREQUENCY	NO. SAMPLES	MEAN α	σ_α	$\sigma_{\bar{\alpha}}$	99.95% UCL	α IND.	LOAD CYCLE AT IND.
A-1	1825	78	61.9	6.7	0.76	86.0	214	284
A-2	1825	80	59.8	11.6	1.3	99.2	213	284
A-1	2250	42	63.4	7.0	1.1	88.2	114	273
A-2	2250	45	64.1	6.4	0.95	86.8	139	273

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TABLE 1

BASE LINE DATA AND FIRST INDICATIONS OF CRACKING

PIPE SPECIMEN NO. 1 - BATTELLE N.W.

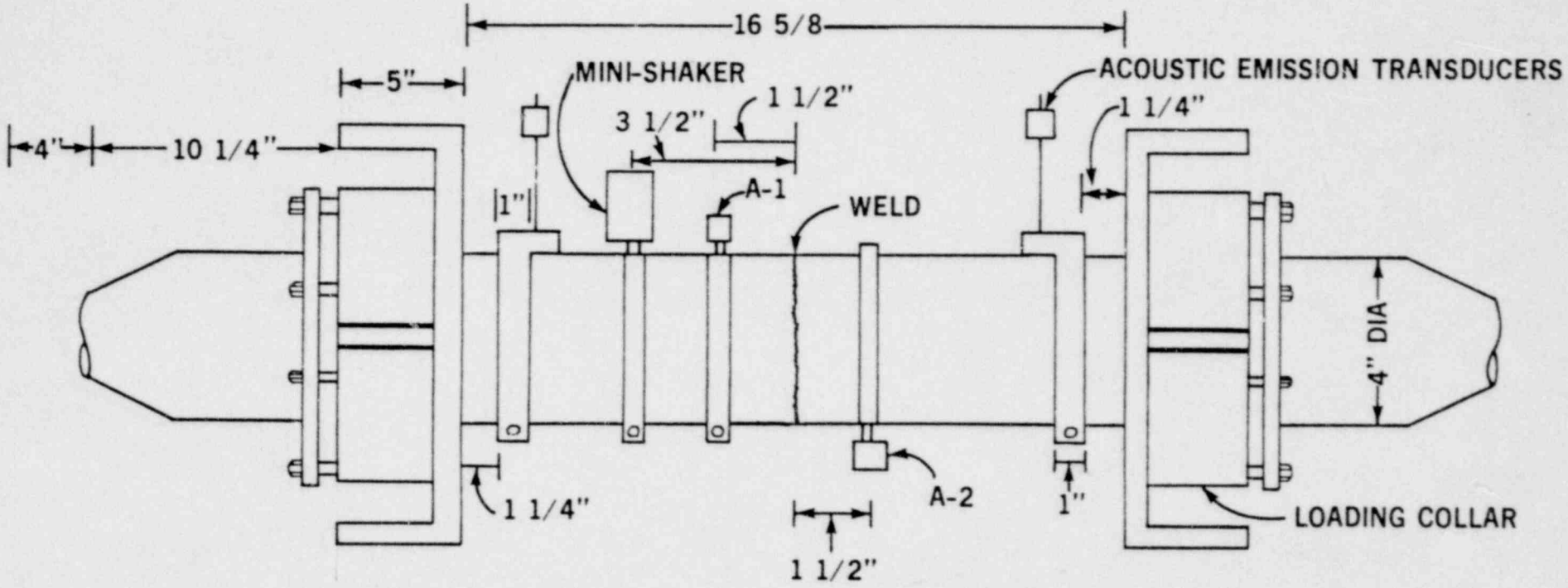

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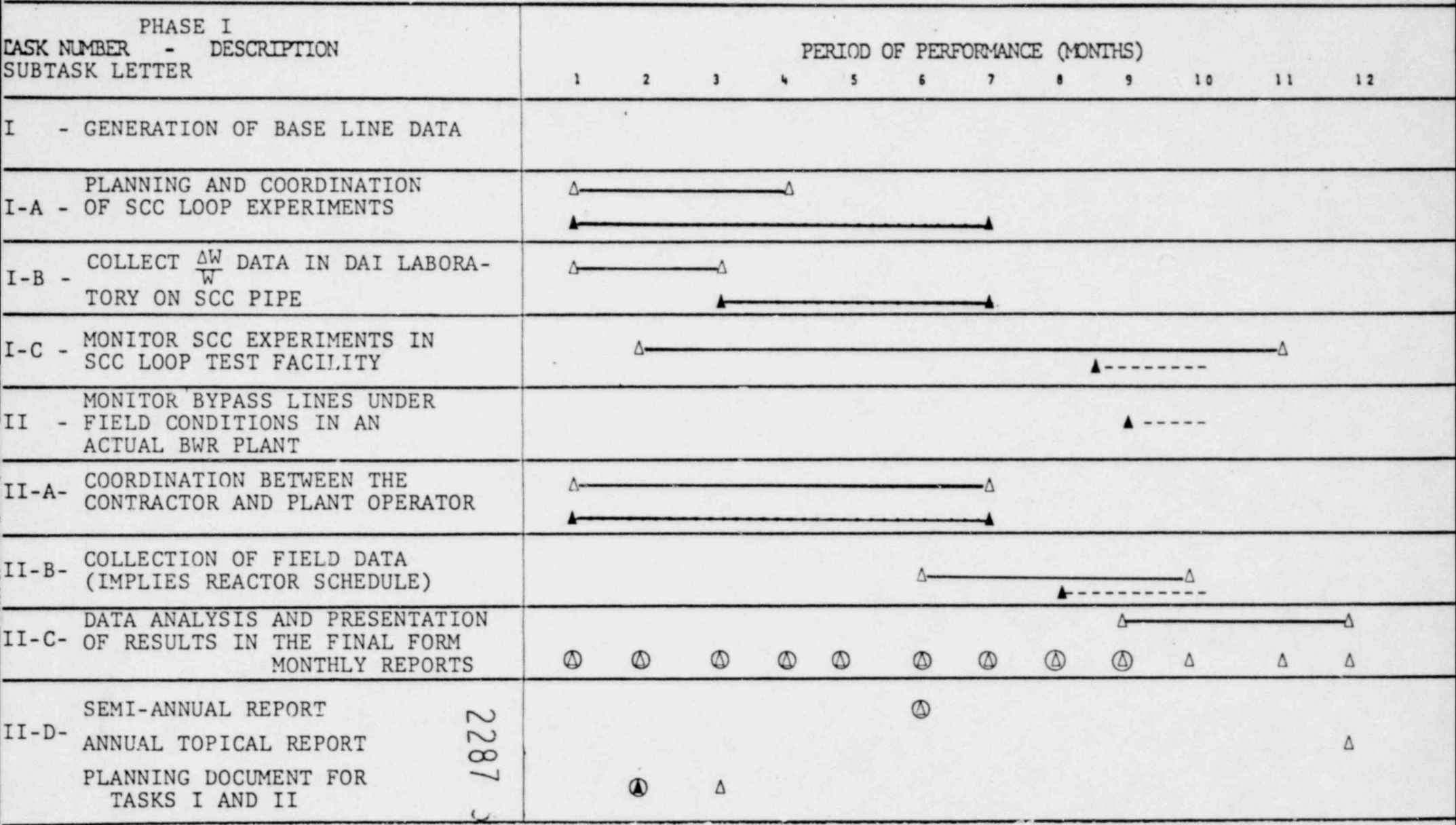
FIGURE 1 PDL SIMULATED BYPASS PIPE SHOWING TRANSDUCER LOCATION

GANTT CHART FOR PHASE I FOR THE APPLICATION OF THE INTERNAL FRICTION NDE TECHNIQUE FOR DETECTING INCIPIENT CRACKING OF BYPASS LINES AND PIPES IN BOILING WATER REACTOR PIPING SYSTEMS



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