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November 30, 1982

1CAN118205

Director of Nuclear Reactor Regulation
ATTN: Mr. J. F. Stolz, Chief
Operating Reactors Branch #4
Division of Licensing
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Subject: Arkansas Nuclear One - Unit 1
Docket No. 50-313
License No. DPR-51
Request for Information Concerning
Inservice Inspection of Reactor
Coolant Pump Flywheels for Arkansas
Nuclear One, Unit No. 1

Gentlemen:

The purpose of this letter is to respond to your September 14, 1982, letter (1CNA098204) which requested additional information concerning AP&L's proposed acoustic emission inspection of the reactor coolant pump flywheels for ANO-1. The information requested and our responses are provided in the attachment to this letter.

As background information, this follows our letter to you dated August 18, 1982, (1CAN088203) wherein we requested that the volumetric method of acoustic emission inspection of ANO-1 RCP flywheels be considered as a suitable alternative to the ultrasonic testing method of inspection. The acoustic emission testing method was formerly presented to the NRC at a meeting in Bethesda, Maryland on August 24, 1982. The questions in your September 14, 1982, letter, which prompted our responses herein attached, are a result of that meeting.

Sincerely,

John R. Marshall

A047

John R. Marshall
Manager, Licensing

JRM:DET:rd

Attachment

ATTACHMENT TO 1CAN118205

REQUEST FOR INFORMATION
CONCERNING
ISI OF RCP FLYWHEELS
FOR
ARKANSAS NUCLEAR ONE, UNIT NO. 1

NRC Request No. 1

"Describe the measures in terms of disassembly of components, manpower and plant outage time that would be required to meet the existing Technical Specifications to perform the volumetric and surface examination of the flywheel using conventional nondestructive examination methods. Describe the physical restriction in terms of existing access (scan length) that prevents performing an ultrasonic examination of the keyway area of the installed flywheels."

AP&L Response to NRC Request No. 1

Disassembly of components to permit adequate access to apply ultrasonic inspection of the RCP flywheels would require:

1. Field disassembly of the flywheel from the rotor which was never intended in the original design and which is not recommended by the pump manufacturer.

2. Because the flywheels are of a "shrink-fit" design, high temperatures "in-situ" would have to be applied to physically remove them from the rotor.

The entire rotor assembly removal would involve the following considerations:

1. Removal of RCP restraint girders.

2. Removal of interfering structural support girders.

3. The rotor and upper guide bearing housing can only then be removed as a unit (25 tons, 16 feet long).

4. A specially designed stand would have to be constructed in a low radiation work area to support the rotor and upper guide bearing housing.

It is estimated that a 12 week outage will be required in which 960 man-weeks would be required to complete the task with approximately 120 man-rem total radiation exposure being experienced for all four pumps. Total cost would be in excess of $1,500,000 without considering the cost of required outage time and purchased replacement power.

The physical restrictions of the existing access are such that convenient location on the outside diameter of the flywheel to permit 360° UT surveillance by straight beam and typically 13° longitudinal angle beam projection through the radial thickness of the wheel is not available. It should also be borne in mind that the areas of high stress in the flywheel configuration have been identified by photo elastic modeling to be extremely local in the keyway area and shaded by the bolting in the ligament area of the flywheel. In addition the close proximity of the peak keyway stresses and hence the location of crack onset (as identified by photo stress analysis) are less than 1/4 of a keyway width from the inner surface of the flywheel which produces the classical UT surface reflection and defect masking effects. There is no other suitable access for inspecting the critical high stress areas of the flywheel using UT and the possibility that when stationary, any service generated cracks would be closed, thus tending to be opaque to all but the most elaborate immersion multi-beam UT techniques, renders the question of volumetric inspection by UT as moot.

NRC Request No. 2

"Describe the number of flywheels that will be examined and the extent of volumetric coverage of the acoustic emission examination."

AP&L Response to NRC Request No. 2

The upper flywheel on each of the four (4) reactor coolant pumps will be examined. Each flywheel is an annular section of ASTM A-516 Grade 60 steel plate shrink fitted over eight (8) radial spokes. Pertinent dimensions are:

Thickness	3 inches
Inside Diameter	30.4 inches
Outside Diameter	72.0 inches
Spoke Thickness	2.5 inches
Spoke Radial Length	9.2 inches
Hub Diameter	12.0 inches

The extent of volumetric coverage of the acoustic emission examination will be the full volume of the annular section of the flywheel.

NRC Request No. 3

"Describe the method of heating the flywheel to produce the applied stress. Discuss the measures that will be taken before and during the examination to assure that the desired stress and temperature distribution are achieved in the actual flywheel."

AP&L Response to NRC Request No. 3

The applied stress is produced in the flywheel by raising the mean temperature in the spokes to a temperature difference of approximately 150°F between the flywheel rim and spoke. The spokes will be heated in contiguous pairs by ganged pairs of ½ kW flat plate Chromalox strip heaters built to straddle the spoke thickness of 2½ inches.

Each web will have four ganged pairs of heaters along the radial length, which will extend for 12 inches along the axial length of the web. The ganged pairs of heaters will be individually power controlled. Three temperature sensors will be mounted on the flywheel spoke along the radial direction and 3 more temperature sensors will be positioned at the flywheel/spoke and bolting high stress location (as identified by photo-stress tests).

The magnitude of thermal stress is calculated by elastic theory using the general expression

$$\sigma_{max} = \frac{K\ E\ \alpha\ \Delta T}{(1-\upsilon)}$$

where:

- K is a function of shape and temperature distribution which, for a relatively simple shape in a homogenous material, is generally between 1/2 and 1.0. For the flywheel assembly, a value equal of 0.67 (ie $1-\upsilon$) is utilized.
- E is Young's Modulus
- α is the coefficient of thermal expansion
- υ is Poisson's ratio

Thus, as reported in our August 18, 1982, submittal, the above expression indicates a stress of 25.6% of yield will be added to that induced in the assembly by the shrink fit. The stress will be wholly complementary to the shrinkage stress since both are the result of temperature differences between annular flywheel and spoked assembly. It is significant that the shrinkage stress in the stationary flywheel is the highest in-service stress. Measures taken before the examination to assure the desired stress and temperature distribution are achieved include photo-stress modeling to (1) simulate the shrinkage and spoke heating strains and (2) to identify the high stress positions. Also, an approximately 100° angular segment of the full sized flywheel mass has been built and heated to establish the heatup cycle, to optimize the locations of the temperature sensors, and to establish the rate of change of thermal stress for a given heating cycle.

<u>NRC Request No. 4</u>

"What is the calculated critical flaw size as a result of flywheel overspeed during a postulated LOCA transient?"

<u>AP&L Response to NRC Request No. 4</u>

Figure 1 shows the critical crack length in the keyway area of the flywheel at two dynamic fracture toughness (K_{id}) values as a function of flywheel speed.

The operating temperature of the flywheel is between 70°F and 120°F which corresponds to temperatures between 80°F and 130°F above the RT_{ndt} of the flywheel plate. At these temperatures, it was calculated (see our Topical

Report BAW-10040 December 1973) that the lower bound dynamic fracture toughness values for the flywheel material at the normal operating temperature are between 67 ksi $\sqrt{in.}$ and 109 ksi $\sqrt{in.}$

NRC Request No. 5

"Describe the acceptance/rejection criteria in terms of Severity Index. Estimate the maximum flaw size that could exist in the keyway area if the lowest Severity Index is produced during the test. Provide a qualitative estimate of the flaw size that must be detected by acoustic emission before supplemental examinations would be performed."

AP&L Response to, "Describe the Acceptance/Rejection Criteria in Terms of Severity Index." (Request 5a)

The Severity Index, as set down in ASTM E569-76/ASME E00096-B-1137, is the basis for grading acoustic emission sources. A E International, who will inspect the ANO-1 flywheels under stress, has further refined the grading of acoustic emissions as a result of their 12 years of structural and pressure vessel testing for the nuclear industry. (See Appendix)

The severity grading is essentially based upon acoustic energy output per unit stress, correlated with source location. The thermal loads induced in the flywheel, which will have the same effect on the flywheel rim as the original manufacturing and service loads, will be arranged to be incrementally greater so that a correlation is developed in terms of increases in incremental loading and severity grading effects.

An acceptance/rejection criteria, per se, will not be applied in total because of the state-of-the-art. However, the acoustic emission grading system has a common basis in that (1) all emitting sources will be graded and located with a calibrated system, and (2) all sources that are active due to incremental increases in load between that of the static state and service stress of 62.5% yield and 90% yield, respectively, will be further investigated by plotting the increase of signal magnitude in stress/load and with other methods.

Innocuous signals will be handled in two ways:

1. The Arrival Time Processor (ATP) microprocessor utilizes an energy scaler function which is designed to eliminate innocuous signals on a basis of signal amplitude and pulse duration. If, for example, the detected signal has a peak amplitude of greater than 20V peak-to-peak or has a duration greater than 2.5 milliseconds, then it is recognized by the system as being an innocuous signal and is not processed. If innocuous signals should fall within this criteria, then the ECHO and HOTSPOT source location and analysis computer programs will indicate their positions as being outside the area of interest.

2. There is only one obvious source of spurious signals, which is the fillet weld attaching the spokes to the hub of the flywheel. Such signals, if innocuous, will be eliminated by the ATP microprocessor as described above - If they are true acousitic emissions, then ECHO and HOTSPOT programs will identify their source of origin as the shaft.

Crack progression measurement is determined by the rate of acoustic energy output from the defect area. As the crack progresses, it releases increasing amounts of acoustic energy. This energy, as processed by the ATP energy scaler, is registered in the ATP memory and utilized by the ECHO and HOTSPOT computer programs for determining defect severity.

In addition, changes in the energy release rate will be documented on a chart recorder for operator recognition and cognizance.

Figures 2 and 3 show these two functions for growing cracks in structures.

AP&L Response to, "Estimate the Maximum Flaw Size that could Exist in the Keyway if the Lower Severity Index is Produced During the Test." (Request 5b)

It is presumed that the question requires a prediction of the largest flaw size that could go undetected using the lowest severity index.

The same A E International equipment, staff and inspection principals used on two different nuclear plants will be utilized for the proposed flywheel inspection.

(a) From "NDT-Acoustics Inservice Inspection of the NSSS of Kernkraftwerk-RWE-Bayernwerk GmBH (KRB) Gundremingen, West Germany," Final Report No. XN-234, dated June 1974, it was reported that three (grades C and C+) acoustic sources (defects) were detected, located and analyzed during this test. Subsequent U.T. examination revealed a defect of 110mm(4-23/64") at the location determined by A E International.

(b) From "NDT-Acoustics Integrity Analysis of the Gemeinschaftskraftwerk Tullnerfeld GmBH (BKT) Nuclear Power Plant)," Final Report No. KN-347 dated January 1976, it was reported that 29 (grade C) acoustic sources (defects) were detected and analyzed on the reactor pressure vessel and main piping of the PPCS during this test. Using the same A E International equipment as was used on (KRB), a 95mm (3-3/4") crack was determined by subsequent U.T. examination at the location determined by A E.

By comparison to the above, A E Internatinal inspection applied to a large homogeneous, high grade, relatively geometrically uniform body such as the flywheel, reduces considerably the deleterious effect of electronic screen out of any spurious background.

AP&L Response To, "Provide a Qualitative Estimate of the Flaw Size that must be Detected by Acoustic Emission before Supplemental Examination will be Performed." (Request 5c)

Since the A E International Volumetric Inspection tool is designed to locate and determine if a defect is growing, and not to determine its size, AP&L will investigate by other means all Grade B sources detected during two consecutive tests which show a relatively steady, slow, growth rate or during two consecutive tests showing a relatively fast growth rate.

In the event a Grade B active defect is detected, the test parameters will be held steady for a short period of time while additional transducers are added to more accurately locate and identify the source of emission.

NRC Request No. 6

"Since we consider acoustic emission as a developmental technique, we request that you submit the proposed examination procedure for review prior to performing the test. We also request that you submit a final report that documents the results of the examination."

AP&L Response to NRC Request No. 6

An examination procedure is being finalized by H.A.F.A. International Co. for utilization during the 1R5 refueling outage. A copy of the procedure, and a final report that documents the results of the examination will be forwarded to the NRC as requested; however, we do not anticipate our providing NRC with the requested test procedures to impact our schedule for performing the test itself. Record keeping and reporting of the results will follow guidelines set forth in Section XI of the ASME Boiler & Pressure Vessel Code, 1980 Edition, up to and including the Winter 1980 Addenda.

APPENDIX TO 1CAN118205

SOURCE SIGNIFICANCE GRADING

The ASME recommended practice "Standard Acoustic Emission Examination During Application of Pressure,"* January 1975, recommends the use of three structural significance levels for the grading of detected and analyzed acoustic emission sources (discontinuities). These grades and A E International's criteria for establishing grade levels are defined as follows:

Grade A - Significant to Physical/Structural Integrity

A. Acoustic energy release rate - positive and at least 20 percent increase per unit stress increment.

B. Source significance number (ER) = "*" or "1".

C. Cross-correlation:

1) Stress correlation required over two or more stress increments encompassing stress range from at least 10 percent below normal operating stress to at least 10 percent above normal operating stress.

2) Cross-correlation by three or more transducer set combinations.

3) For cyclic testing data, source detected energy output should increase by relative energy number of at least seven on each pressure cycle.

D. Relative energy number (ER) = 10 to 20.

1) ER = 10 to 15 if cross-correlated by three additional data sets with location accuracy of 95 percent.

2) ER = 15 to 20 if cross-correlated by two additional data sets with location accuracy of 97 percent.

*Footnote

ASME Publication E00096-B-1137 - The grading is categorized as: - (A), sources considered to be sufficiently severe to be evaluated by other nondestructive examination methods; (B), sources considered to be pertinent and recorded for future comparison with sources detected in subsequent examinations; and (C), sources considered to be innocuous and not required to be further evaluated nor subsequently correlated.

Grade B - Predominant but Insignificant to Structural Integrity Under Conditions of Imposed Test

A. Acoustic energy release rate - stable and less than 10 percent increase per unit stress increment.

B. Source significance number (ER) = "*" - "1" or "2".

C. Cross-correlation:

1) Stress increment correlation required by one or more stress increment data sets in stress range from at least 20 percent below to at least 10 percent above normal operating stress.

2) Cross-correlation by at least two or more transducer set combinations.

D. Relative energy number (ER) = 7 to 10.

1) Cross-correlated with location accuracy of at least 95 percent with ER of 7 to 10.

Grade C - Minor and Insignificant to Structural Integrity

A. Acoustic energy release rate - stable and less than 10 percent increase per unit stress increment.

B. Source significance number (ER) = "1" - "2" or "3"

C. Cross-correlation:

1) Stress increment correlation required by one or more stress increment data sets.

2) Cross-correlated by at least two sensor set combinations.

D. Relative energy number (ER) = 4 to 7.

1) Cross-correlated with location accuracy of at least 93 percent and ER of 4 to 7.

FIGURE 1 TO 1CAN118205

Critical Crack Length in the Keyway Area
of the Flywheel at Two Dynamic Fracture
Toughness Values as a Function of Flywheel Speed

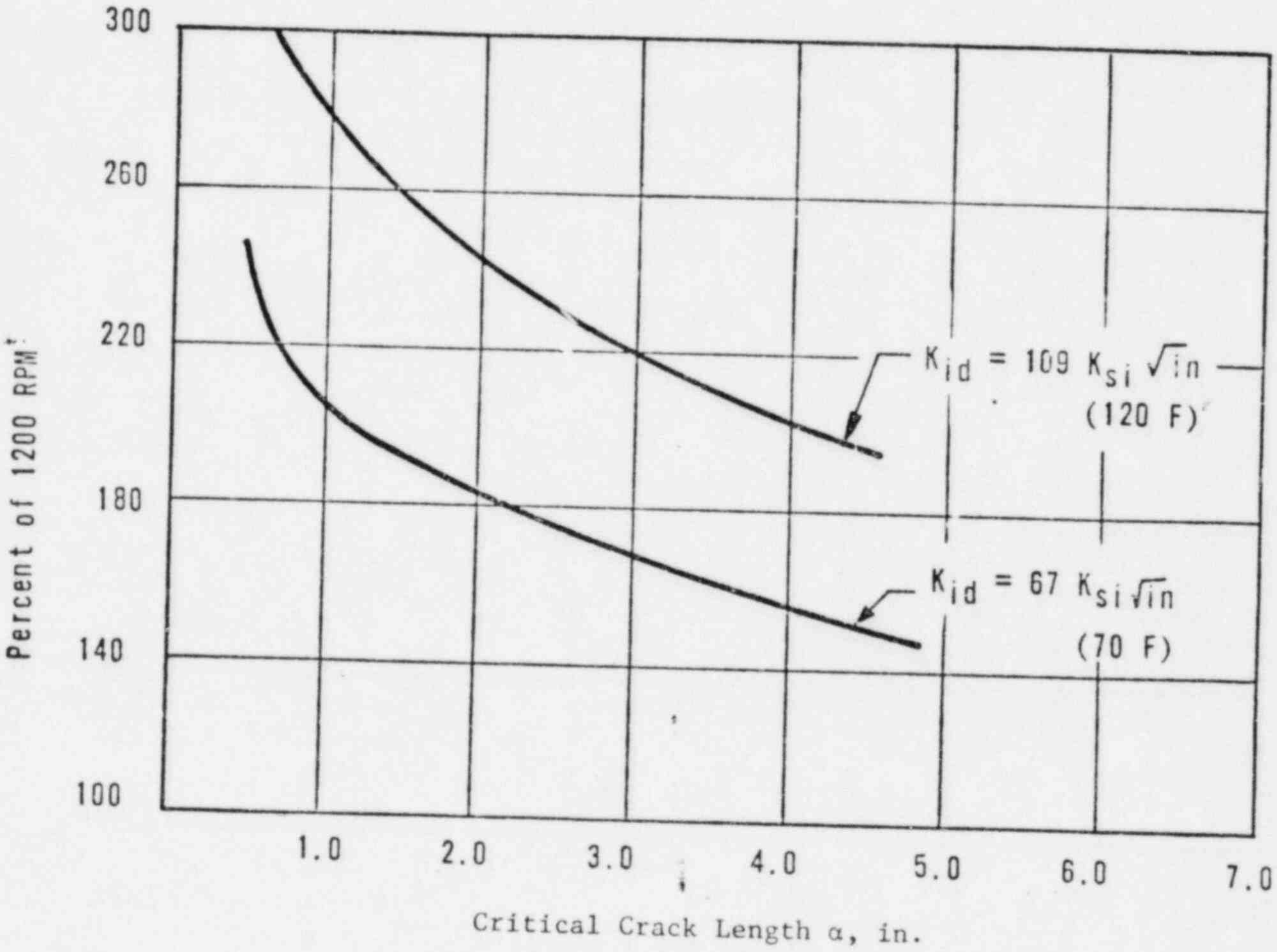


FIGURE 2 TO 1CAN118205

Arrival Time Processor Showing Critical Crack Growth in Section of Gas Transmission Pipeline

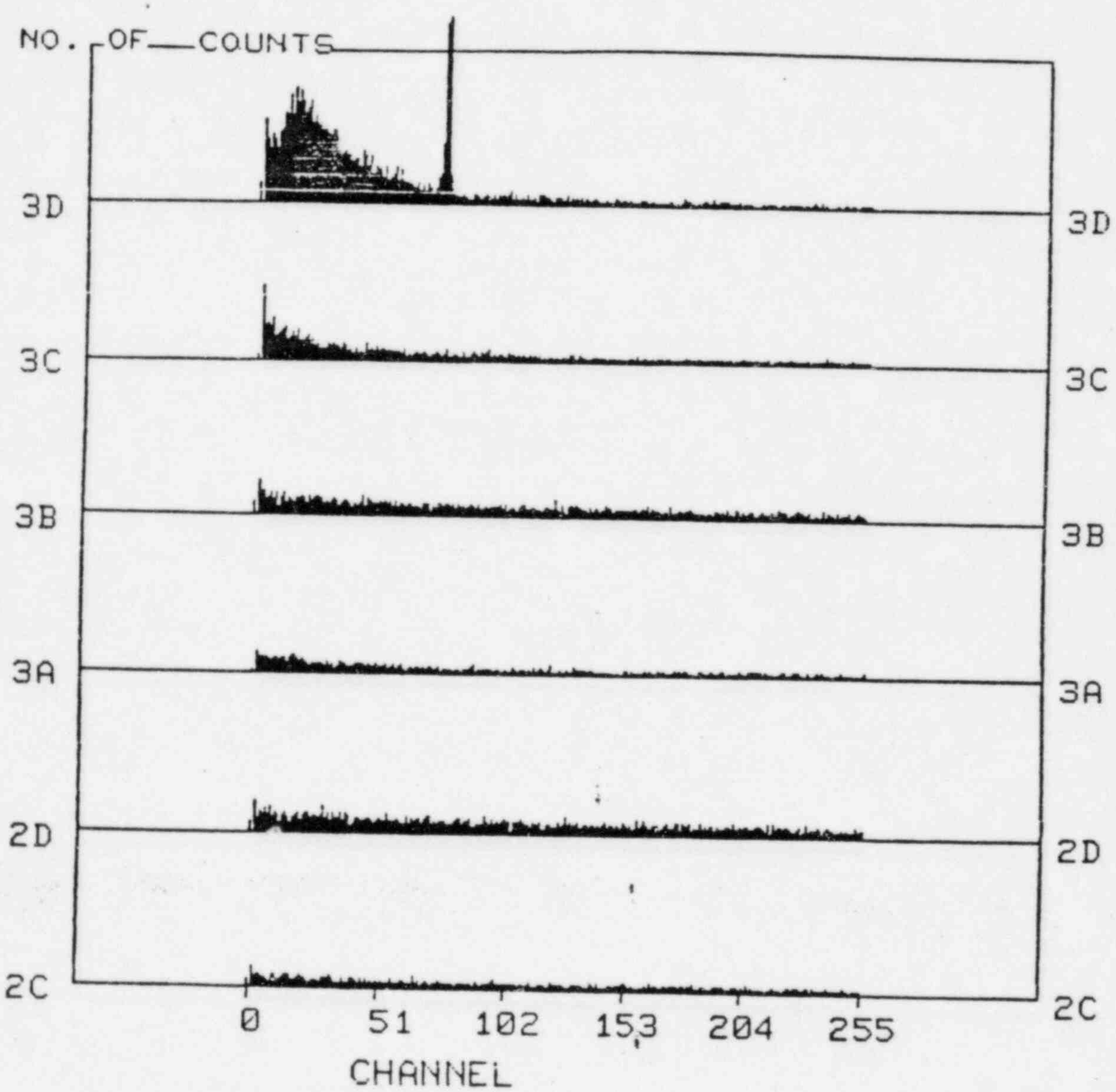
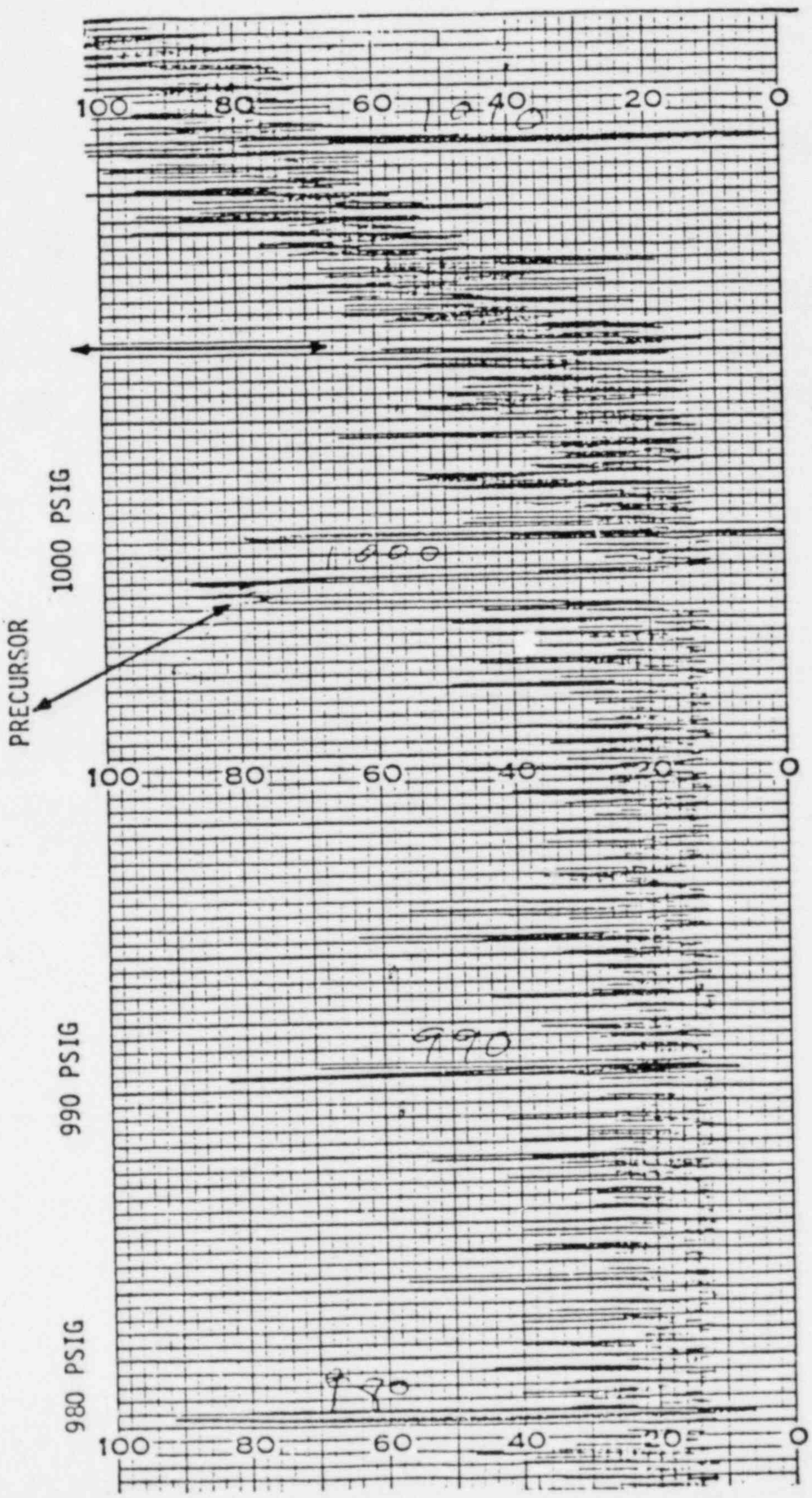


FIGURE 3 TO 1CAN118205

Precursor and Increase in Energy Release Rate
Chart Showing Crack Growth



ACOUSTIC ENERGY RELEASE RATE
MONITORING OF PIPELINE
(Vent Manifold)