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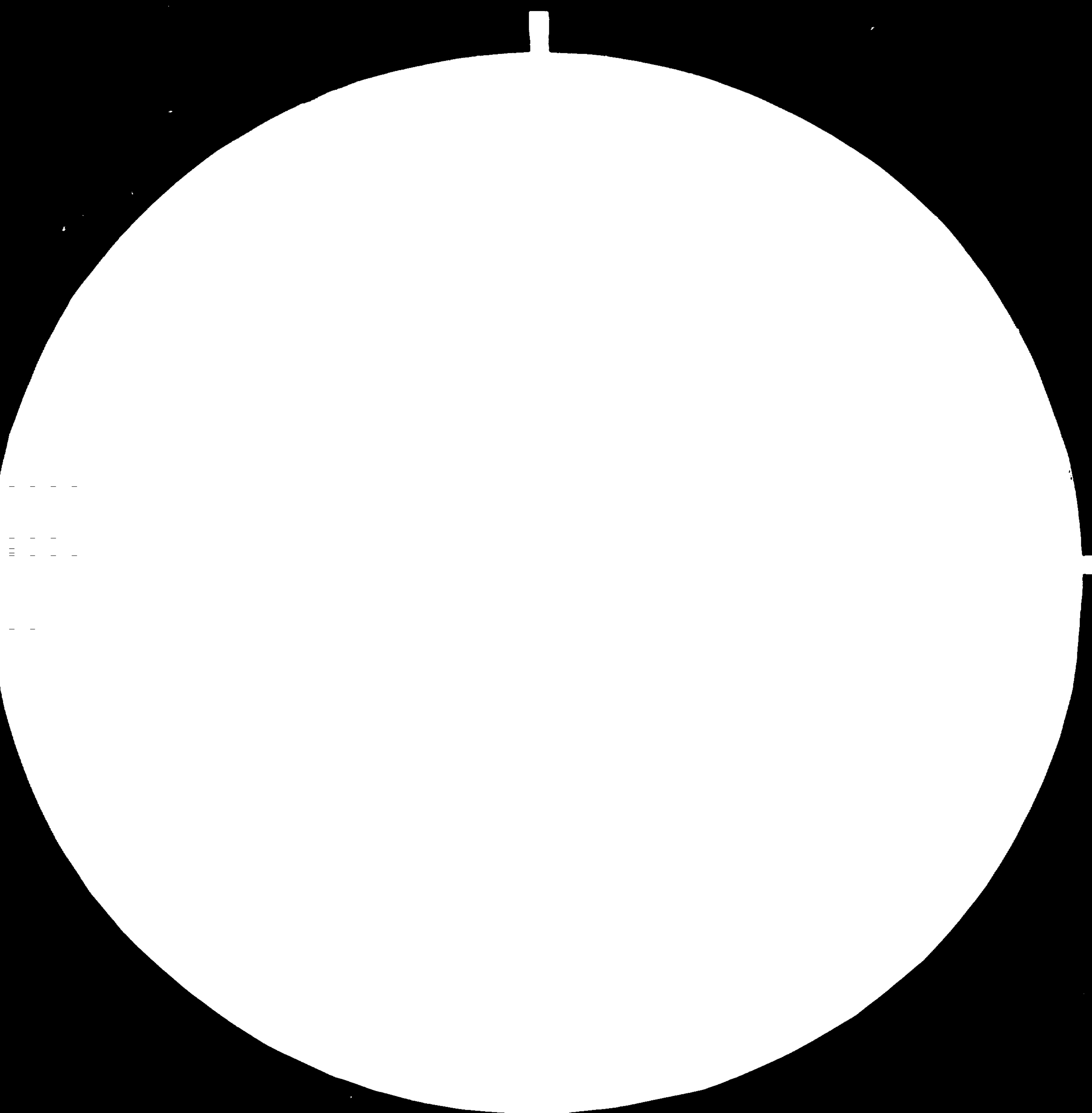

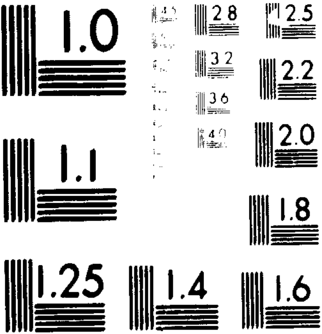

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A PROGRAM FOR APPLICATION AND INTERPRETATION OF ACOUSTIC EMISSION TECHNIQUES IN NONDESTRUCTIVE TESTING

by

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INTRODUCTION

Acoustic Emission technology has progressed over the past two decades to the point that many practical uses have evolved. The technology is finding its major uses in two areas of investigation. One, the study of materials characterization and fracture processes and, two, nondestructive testing. Any research and development program to develop acoustic emission techniques for nondestructive testing must also by necessity include investigation into material characterization and fracture processes in order to be complete. One must attempt to characterize the process to be measured in the field, in the laboratory when possible, in order to better interpret data accumulated in a test on a structure. Therefore acoustic emission differs from other methods of nondestructive testing in that a unique calibration standard cannot be defined. It is a new technique and finds its major use in areas where conventional techniques are found lacking; for example:

1. Acoustic emission can give real time measurements of a failure process and therefore is well suited for continuous monitoring of a structure.

2. Acoustic emission is most sensitive to fracture processes involving propagation of cracks, whereas radiography or ultrasonic methods do not easily detect tight cracks.

3. Coverage of very large areas of inspection can be achieved quickly and inexpensively on very complex structures. Radiography and ultrasonic techniques can become very expensive if 100% inspection of large structures are required.

4. Acoustic emission techmiques are useful for the inspection of thick wall castings, whereas these types of structures are difficult to inspect with radiography and ultrasonics.

The major disadvantage of acoustic emission techniques in

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comparison to other techniques are as follows:

1. A crack must be growing in order to be detected. This necessitates stressing the structure to be monitored in some manner.

2. A unique calibration standard is not available that will allow flaw size to be estimated.

3. Conditions are sometimes encoun tered where very expensive and sophisticated instrumentation is required in order to separate signals from a growing crack from signals due to extraneous sources.

CNEA/INEND PROGRAM

The purpose of this assignment is to defind a research and development program in acoustic emission technology for Atomic Energy Commission personnel. The success of any research and development program is dependent on four primary ingredients.

1. Enthusiastic and qualified personnel.
2. Equipment-tools, etc., to carry out a program.
3. Support and encouragement of management.
4. Practical experience in carrying out experimentation.

The INEND group meets the criterion of 1 and 3 above but is deficient in 2 and 4. There appears to be adequate support equipment, i.e., test machines, welding apparatus, electron microscope etc., to satisfy the second criterion but no acoustic emission instrumentation to carry out the most fundamental aspects of a program. Without acoustic emission instrumentation criterion 4 (i.e., gaining practical experience) also cannot be satisfied. With this in mind, the following recommendations are made.

1. Budget a minimum of $ 40,000 (dollars US) for basic instrumentation - fiscal year 1979. $ 150,000 (Dollars US) - fiscal year 1980 (computer system).
2. Carry out investigations suggested in the following section of this report.

ACOUSTIC EMISSION INVESTIGATIONS

A research and development program that could have some immediate impact on problems facing the Atomic Energy Commission has been identified from conversations with the following personnel.

1. Lic. Marta Granovsky.
2. Eng. Alfredo Hey.
3. Lic. Juan Carlos Crespi.
4. Dr. Eduardo García.
5. Lic. María Eugenia Saggese.
6. Eng. Norberto Curto.

Each of these individuals is working on programs whose results could be enhanced by use of acoustic emission testing. By doing so, it would provide not only practical experience for personnel but also fundamental information that can be later used to ensure the safety of structures used in atomic power plants as well as other large structures. Therefore the following investigations are proposed.

1. Investigation in the use of acoustic emission techniques for the detection of stress relief heat treatment cracking (SRHT cracking).
2. Investigation in the use of acoustic emission techniques for detection of crack growth in low cycle fatigue.
3. Investigation in the use of acoustic emission techniques for the detection of hot cracking during welding of aluminum alloys.
4. Investigation in the use of acoustic emission techniques for the detection of cracking during oxide formation in titanium alloys.
5. Investigation in the use of acoustic emission techniques for the detection of laminar tearing following welding of structural steels.
6. Investigation in the use of acoustic emission techniques for measurement of cracking in bypass tine in Atucha Reactor.

Each investigation will now be discussed in more detail.

<u>Investigation N°1.</u> Investigation of the use of acoustic emission techniques for the detection of (SRHT) cracking in reactor grade steels.

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Over the past decade millions of manhours have been spent and great volumes of scientific data have been accumulated in the study of SRHT cracking in reactor grade steels. A recent review publication entitled "A Review of Work Related to Reheat Cracking in Nuclear Reactor Pressure Vessel Steels", contained 162 references of work related to this topic. The last paragraph of their concluding remarks stated:

"Possibly of greater significance are the unanswered questions concerning the control and engineering significance of strength weld reheat cracks. Welding techniqu-s cannot reliably eliminate the problem, although some degree of control can be exercised, for example, by minimising heat input. Avoidance of cracking hinges more on appropriate steel selection. However, alloy segregation in plates and forgings is believed to be a crucial factor and this means that total avoidance of cracking even in low susceptibility grades is not assured. Whilst there is a general trend towards the use of the low susceptibility grades, i.e., SA 533 grade B Class 1, SA 508 Class 3, 20MnMoNi55, throughout the world, it needs to be recognised that many existing reactor pressure vessels could contain reheat cracks in structural welds. This review has shown the scarcity of information on the engineering behaviour of such crack networks, the behav iour of which, it is believed can only reliably be determined by tests on full scale joints or model vessels. Predictions based on fatigue crack growth laws involve several assumptions which lead to uncertainty and, whilst useful, do not give adequate confidence".

Following these concluding remarks one of the recommendations for future work was to "continue development of ultrasonic and other NDE techniqu4s to enable reheat cracks to be detected in thick structural weldments". It is interesting that only a few of these hundreds of papers were devoted to NDE. One paper reported that acoustic emission techniques had been used to detect reheat cracks, but to my knowledge very little if any foilowup work has been reported.

An investigation into SRHT cracking using acoustic emission

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would be designed to accomplish the following:

1. Determine Signal level caused by reheat cracks.
2. Determine accuracy of location of reheat cracks.
3. Correlate signal amplitudes and density of signals to crack size and crack distribution by metallographic techniques.

If these three objectives can be accomplished it will provide the following information:

1. For a given temperature, at what time do the cracks form. This is still a major unknown that 10 years of research has not been able to answer.

2. Test criterion for the acoustic emission inspection of Atucha II pressure vessel during heat treatment can be formulated to determine where and of what magnitude stress relief heat treatment cracks are forming.

Accessory Requirements for Investigation.

1. Specimen requirements: A Vinchier-type specimen of a material which exhibits SRHT cracking and a furnace for heating.

2. Instrumentation requirements: Acoustic emission instrumentation - 2 channel location ability, amplitude distribution and counts output to XY recorder. High temperature differential transducers or wav e guides with access to both ends of specimen.

3. Personnel requirements: one metallurgist, one physicist or engineer and technical assistance.

4. Accessory equipment: metallographic tools, including SEM.

5. Estimated time to complete: six months.

Investigation N°2. "Investigation in the use of Acoustic Emission Techniques for Detection of Crack Growth in Low Cycle Fatigue".

This investigation is designed primarily to provide operator train ing and experience in the use of acoustic emission instrumentation. It will provide the operator experience in detecting crack initiation, the signal characteristics of crack growth and failure

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as well as provide experience in the precision in which a crack can be located in one dimension.

A report will be forwarded to the principal investigator giving details of specimen preparation and instrumentation requirements.

Investigation N°3. "Investitation in the use of acoustic emission techniques for the detection of hot cracks during welding of Aluminim Alloys."

One can find many references in the open literature reporting on the use of acoustic emission techniques to monitor weldments. Most of these references contain results of the detection of signals caused by cracking in weldments due to the addition of contaminants during the weld pass. Few have dealt with the problem of potential crack formation during normal welding processes and correlation of the acoustic emission signals with the actual defects.

This investigation will provide experience in the use of acoustic emission techniques and some of the problems encoun tered while monitoring during welding.

Accessory requirements.

1. Specimen: A standard weld specimen at least 15 inches in length - width unimportant.
2. Instrumentation requirements:
   a) Two channel location capability.
   b) Differential transducers and preamplifiers.
   c) Amplitude distribution and counts output to XY recorder with time base on X-axis.
   d) Oscilloscope for visual observation of signals.
3. Metallographic tools.
4. Personnel requirements: Physic ist and Metallurgist team.
5. Estimate 3 months to complete.

Investigation N°4. "Investigation in the use of Acoustic Emission Techniques for the Detection of Cracking During Formation of Oxide

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Layer on Titanium Alloys".

This type of investigation is ideally suited for acoustic emission techniques in that it requires real time information that can be achieved in no other way. This investigation involves heating a specimen to a fixed temperature and monitoring as a function of time for formation of cracks. It is complicated by the fact that the signals must be transmitted from the furnace to the acoustic emission transducers via wave guides.

Specimen requirements - Standard specimen used for oxide investigation with the exception that it must be fitted with two metal rods that will extend out of the furnace for the attachment of acoustic emission transducers.

Instrumentation Requirements.

1. Two channel location capability with spatial discrimination window.
2. Amplitude distrib ution and counts output to XY recorder.
3. Ramp generator time base for XY recorder.
4. Oscilloscope for visual monitor.
5. Audio monitor.

Accessory Equipment.

Metallographic tools and techniques for correlation of cracks with acoustic emission signals.

Time to complete - 2 months.

Investigation N°5. "Investigation in the use of Acoustic Emission techniques for the detection of Laminar Tearing following Welding of Structural Steels."

Laminar tearing of weldments is a problem that has been around for a long time. Much research effort has been extended to study this problem, but to my knowledge no one has been able to determine the time temperature relationship necessary for the tearing to begin.

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Acoustic emission signals should be present when laminar tearing occurs. Therefore plotting these signals as a function of time and temperature should allow further information to be gained concerning the process.

Specimen Preparation.

The standard coupon specimen may work satisfactorily, it may possibly need to be made longer in order to more accurately locate the source of signals.

Instrumentation Requirements.

1. Two channel location with spatial discrimination window.
2. High temperature transducers.
3. Amplitude distribution and counts output to XY recorder.
4. Ramp generator time base for recorder.
5. Oscilloscope for visual observation of signals.
6. Audio output of signals.

Accessory Equipment.

1. Welding machine.
2. Metallographic tools for signal correlation.

Personnel requirements.

1. Engineers, metallurgist team; 2 months.

Investigation N°6. Investigation in the use of acoustic emission techniques for measurement of cracking in bypass line on Atucha reactor".

Area of interest mon itoring b y acoustic emission techniques is being widely used. Several problems similar to the one at Atucha I have arisen world wide and many of these are being monitored by acoustic emission techniques. Before installing transducers on the pipe in the reactor it is suggested that some preliminary laboratory investigation be made in order to define mounting and placement of transducers as well as instrumentation sensitivity.

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A section of pipe similar to that monitored should be brought to the INEND laboratory. Artificial pulses will be injected into the pipe in order to determine the accuracy of location and the amount of signal attenuation present for a given frequency.

Information needed for in-service monitoring.

1. Dimensions and material of pipe and length to be monitored.
2. Operation characteristics - Temperature of pipe and enclosure, pressure, flow condition, radiation etc.
3. Distance from pipe to radiation-free area for main instrumentation installation, i.e., cable lengths must be defined.

Instrumentation requirements.

1. Two channel location capability with spatial discrimination window.
2. High temperature radiation resistent differential transducers with ability to drive cable.
3. Amplitude distribution, pulse width distribution, and counts to XY recorder or digital printer.
4. Alarm capability for preset conditions.
5. Oscilloscope.
6. Audio output.
7. Suitable clamps for attaching transducers without coupling materials.
8. Coaxial cables for signal routing.

Personnel requirements.

1. Physicist or engineer with electronic-technical support, and 3 months' preparation effort.

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CONCLUSIONS AND RECOMMENDATIONS

Following these investigations personnel should be adequately trained in the use of acoustic emission techniques for a variety of applications. This training should serve as a foundation for more advanced applications using more sophisticated instrumentation. The recommended capital equipment budget for 1980 would allow purchase of a multiple channel computer system which could be incorporated into the present mobile trailer used by INEND. This will provide capability for on site inspection of refinery vessels, bridges, gas storage vessels etc.

I strongly recommend that at least initially equipment be purchased to carry out these first investigations. I have personally witnessed many investigations delayed or ending up being cancelled because personnel were sidetracked into trying to develop their own instrumentation. It is fine to have a parallel effort if one can afford it to develop instrumentation for acoustic emission testing, but first take advantage of what is available and improve on it for specific applications rather than start from ground zero.

A specific set of instrumentation for carrying out these investigations will follow after my return to the United States. Information derived from this instrumentation can then be used for competitive bids if necessary.