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NUCLEAR REGULATORY COMMISSION

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

SUBCOMMITTEE ON METAL COMPONENTS

PUBLIC MEETING

Room 1046
1717 H Street, N.W.
Washington, D.C.

Thursday, December 2, 1982

The Subcommittee on Metal Components met, pursuant to notice, at 8:40 a.m., Paul Shewmon, Chairman, presiding.

ACRS MEMBERS PRESENT:

PAUL SHEWMON
HAROLD ETHERINGTON

ALSO PRESENT:

S. BUSH
R. McCLUNG

DESIGNATED FEDERAL EMPLOYEE:

A. IGNE

ALSO PRESENT:

R. BAER
J. COLLINS
W. HAZELTON
C. SERPAN
J. MUSCARA
Y. CHANG
G. DAU
J. QUINN
R. STONE
M. BEHRAVESH
L. BECKER

P R O C E E D I N G S

MR. SHEWMON: This is an open meeting of the Advisory Committee on Reactor Safeguards Subcommittee on Metal Components. I am Paul Shewmon, the subcommittee chairman. The ACRS member present today is Harold Etherington. Also present as consultants are Spence Bush and Bob McClung.

The purpose of the meeting is to review the NRC research program on non-destructive examinations in steam generators for FY-84 and 85. In addition, NDE capability to detect surface flaws in pressure vessels and stainless steel piping will be discussed.

The meeting is being conducted in accordance with the provisions of the Federal Advisory Committee Act and the Goverbnment in the Sunshine Act. Mr. Al Igne is the designated Federal employee for the meeting.

Rules for participation have been announced as part of the notice of the meeting in the Federal Register.

A transcript of the meeting is being kept. The acoustics in this place are not the greatest, so if you are back over in there, we may get you to try to go to a microphone before you speak.

We have not received any written statements or requests for oral comments.

I guess, by way of introductory comments, there has been a feeling over the last several years, especially in pressure vessels but also probably in stainless steel, we hoped that there weren't cracks there, and there probably weren't. That was the good news. The bad news was, we weren't sure we could find them if there were. This is a cause for discomfort or some concern on the many people's part. I think more recently there have been a series of events that have gotten the industry's interest and a group of people looking harder at this subject.

So I am looking forward to hearing what we have today. I look upon this as a way to have a good discussion of what progress we have made with regard to the reliability of finding significant flaws, if they are there, as well as getting a start on our statutory requirements of looking into the NRC's research program.

With that, unless there are some other comments or questions by members at the table here, I will ask Bob Baer to start out talking about I&E's presentation on in-service inspection.

MR. BAER: Actually, I have provided Al Igne with a revised agenda, which I would like to try and follow this morning.

Basically, I was going to try to give an introduction and an overview as to what we are doing and why, and then ask Gary Dau of EPRI to describe part of the validation program we are doing, and then ask Joe Collins of I&E to talk about some of the results of the validation program and some plant specific results that we have obtained so far. Then Dr. Serpan is going to talk about research activities. All of this is connected with large diameter BWR piping.

One of the things that Al asked me to do was to be sure to bring people up to date on Nine Mile Point results. Actually, there is nothing new on Nine Mile specifically. There was a briefing of either the subcommittee or the full committee early in October on Nine Mile, and the status has not changed.

Basically, at Nine Mile Point, we found in March of 1982 that the furnace sensitized safe ends were leaking during a hydro. The safe ends are classified as service sensitive, and they are checked, I think, with each refueling with UT inspection, and nothing was found nine months earlier. They then confirmed that it was intergranular stress with corrosion cracking, and it was decided to replace the safe ends.

The licensee then decided to check some of the remaining large diameter pipes, and they checked an elbow near the pump and found intergranular stress corrosion cracking.

MR. BUSH: May I ask a facetious question. Look at the top line, it doesn't seem to have changed since 1969.

MR. BAER: As you know, Dr. Bush, I am not a metallurgist or a UT expert, but I am starting to get pretty good statistical data. The dripping water on a hardhat was an effective way of finding cracks.

MR. BUSH: The reason I made that comment was, we saw exactly those same lines on Nine Mile Point on the safe ends leaks ten years ago.

MR. BAER: The licensee went on to start inspecting some of its other large diameter piping, and he selected welds that were generally in low radiation zones. He looked at about 40 percent of his welds, and on every one of these he had indications of stress corrosion cracking, and he decided that he would replace all of the reactor cooling system piping.

Once he made that decision, except for some samples provided to EPRI, as far as I know there has been no more examination of that piping. He decided, as I said, that he was going to replace it. He had enough evidence to show that he had significant problems.

Certainly Nine Mile activity results were enough to get us, both NRR and I&E, quite concerned with this problem, and it has been a lingering concern for a number of years, although people had thought that the large diameter piping that was furnace sensitized was not going to be a major problem.

Based on the Nine Mile results, we had a meeting with the BWR -- We actually had a meeting with GE and later with a number of BWR licensees. At that meeting, the staff expressed their concern with to both the adequacy of the sampling plans, especially with regard to large diameter piping, and UT methodology.

These were largely licensees that were going to be refueling this fall, and they presented their current plans for inspection of large diamter piping, and a discussion of the methodology they were using.

The consensus reached was that the sampling plans were generally adequate. These varied quite a bit from utility to utility. Monticello was going to inspect all welds in large diameter piping, the one extreme, and the othe extreme was that Millstone 1 was going to inspect about seven welds, seven out of roughly 100.

The discussion quickly focused on the difficulty or the question of whether the existing methodology was able to detect cracking if it existed. The doubts on the effectiveness of UT examinations were not resolved at this meeting, and as a result the staff decided that the most meaningful action, for a short-term action, would be to proceed with the UT methodology validation program, which will be discussed in a little more detail, slightly more by me and a lot more by Gary Dau and Joe Collins.

This meeting, by the way, with the owners group was at the end of September of this year, and we issued IE-Buleeting 82-03 on October 14. In the bulletin and in our own staff discussion, we made it clear that the future actions would depend a lot on the results of the validation program and the plant inspection results.

Let me say just a few words about what the bulletin is doing. The bulletin, although it was sent to all licensees for information, was addressed for action to nine BWR plants. These are the plants that were refueling this fall through the end of January, 1983.

It was just coincidental that these turn out to be largely the older BWR plants. There is some concern or indication that the stress corrosion cracking has an age aspect to it. So by having some of the older plants in here, we thought we would be getting some good data. Also, the obvious safety concern was to have each plant inspected and make any necessary repairs before returning to service after this fall's refueling.

The bulletin basically required four actions on the part of these licensees. One was to demonstrate the effectiveness of the UT methodology. Secondly, to provide results of inspection, these would be plant specific inspections. Thirdly, describe the corrective action if cracks are detected. As part of this was to submit their overall sampling plan. What I am merely going to focus on is the first of these.

As I said, we will have some discussion of the results of inspections to date. I am just going to try to give an overview of the validation program before turning this over to Gary to go through this in a lot more detail. We worked closely with EPRI, and EPRI really took the lead on this in arranging for a demonstration program.

The bulletin required that the licensees have the organization that was going to perform the UT examination demonstrate the validity of their technique using the same basic equipment, instrumentation, procedures, code and representative personnel.

EPRI obtained from Nine Mile Point various pipe samples. These samples were slightly radioactive, so they set up an arrangement for a blind test at the Battelle-Columbus facility. The individual utility UT vendors came in and attempted to characterize the cracks in these samples, or the lack of cracks in some samples. As I said, they used essentially the same technique that they were using and were going to use at the plant site.

We had an arrangement where we had two NRR staff members witnessing each of the demonstration validation programs. Joe Collins from my branch and a regional inspector were at, I believe, everyone of the validations.

Did Warren Hazelton substitute for you once, Joe?

MR. COLLINS: No.

MR. BAER: The idea was that Joe Collins would observe the consistency or the variation between various UT organizations. The regional inspector was there to, one, observe how the organization was performing the examination, and to make sure that that same organization used the same procedures, equipment, et cetera, when they were performing plant specific tests. In this way, we felt that we got a good check or assurance that the organization wasn't doing a super-job at Columbus, and then going back to their own plant and doing a sloppy job.

Then the adequacy of the demonstration was sort of judged jointly by I&E, Joe Collins, and the specific regional inspector who happened to be there at the time. I guess about half of the people, at least on the first run-through, passed and were judged to be acceptable, and the other half were not, but I will let both Joe and Gary get into that in a lot more detail.

This completes my part of the presentation. I was just trying to present an overview as to what we have been doing. I was looking for the NRR types because I am sure we are going to get into some discussions, after you see the results to date, of where we are going. It is certainly not absolutely clear at this point.

MR. BUSH: May I ask a question, and this is more procedural. I could take one of the companies that has a large number of teams, let's say, RET-XYZ Corporation, and they may actually have plants that they are currently examining in two or three regions at the same time. How did you handle that?

MR. BAER: Hopefully they were going to be using "representative teams."

MR. BUSH: That is the other thing I was going to ask you. I would like a definition of representative. My opinion is that the operator is one of the major variables in this equation.

MR. BAER: I think that has turned out to be the case. Since I was not there observing the test, I think maybe Gary and Joe could handle that.

My personal concern was that these organizations would send their superstars for the validation and then send "other people" to the actual plant site. That may be the case, but if they were the superstars, they weren't too great.

As you will see, there is a real difficulty there because people get burned out, and you can't say, "Here, I want this team to do every plant," because then we would be violating our regulations on dose. So it is a problem, and there is no real resolution.

MR. BUSH: What about the procedural question. As I said, without naming companies, I am aware of some right now who are in the process of examining plants in Region I and in Region II and in Region III in the same timeframe. You know, you were talking about having essentially the regional inspector there. Did that mean that you had three inspectors there when XYZ was there?

MR. BAER: Joe.

MR. COLLINS: We had representatives from each region at this capability test, both to examine their procedures, to assure ourselves that they were consistent in their planning procedures. Now, there were procedural problems, don't get me wrong, because many of these procedures simply were following code, and there were procedures. By actual review, it was readily apparent that there was going to be some failures.

One of the reasons the regional people were there was definitely to see that the outcome of this performance capability test, when we critiqued their procedures, that these procedures were changed in a manner such that they were applied at the site in a more specific manner to what we were trying to detect. So we had some continuity there.

MR. BUSH: Joe, I think you understand my concern. Obviously, an inspector who is getting the information second-hand or third-hand is not going to approach it the same way as one who is actually physically there during the examinations made by this particular company. That is why I was asking the question.

MR. COLLINS: That is true, and that is what we were trying to make sure, that if there were the so-called super-level IIIs at the performance capability test, that the information that they had gleaned from this was actually transferred to the level IIs and the level Is, that they were actually doing that job.

We recognized this early on because we have been forced into this confrontation before.

MR. BAER: This might help a little bit. Do I recall correctly, Joe, that in Region II the UT organization was going to do Hatch and Brunswick, and perhaps one other, and they are all fortuitously in one region. I think the plants in Region I turned out to be, at least initially, using different vendors.

MR. COLLINS: There have been some changes since that performance capability program. Examination has been on-going and it is still on-going. Maybe we could get into those, and I could show you some of the changes that have been made that we feel the performance capability program is directly responsible for.

MR. SHEWMON: One of the reasons I particularly wanted you here or somebody at your level from I&E is that I am interested in what the regulations are. When Joe commented, he didn't say that they were just following code, but that was the implication that they were following code.

Later in the day, we will get into Reg Guide 1.150, and again there is a question of, indeed, what will the NRC's position be and what is being done to define what are accepted procedures or regulations and what aren't.

Apparently there is some kind of a de facto agreement that you can enforce by way of Bulletin 82-03, but how you do that is not quite as clear to me. So I would be interested in knowing what the regulatory status of this exercise you have been going through at West Jefferson is, and what the plans are for having it be formal a year from now.

MR. BAER: I think maybe the appropriate time would be at the end of at least the piping part.

MR. SHEWMON: All right.

MR. BAER: There is really not much in the way of formal regulations other than results of the Pipe Crack Study Group, NUREG-0313.

MR. SHEWMON: That had nothing on procedures in there. It is just frequency, how often they have to do things on what is sensitized, or whatever the word is, or is not sensitized piping. You are evolving different procedures now.

Does Joe say, if you don't do it my way, I will hold my breath until I get red in the face, or what sort of status is there here?

MR. BAER: I don't have a very good crystal ball, but I guess I find it hard to believe that, in terms of regulations, we will ever get down to that detailed requirements, other than perhaps to have people demonstrate the validity of the methodology.

MR. SHEWMON: You mean that there is going to be no regulation on what is an acceptable procedure for inspecting stainless steel pipe; I find that incredible.

MR. BAER: I am not in "the regulation business," but in the past, as an agency, when we have tried to write very prescriptive regulations --

MR. SHEWMON: Nobody is talking about very prescriptive regulations, that is a strawman.

Are you going to wait until the Code Committee gets around to doing something?

MR. BAER: NRR was supposed to be in attendance here, and they are. This is the part that they definitely have the lead on. I&E and the regions are helping to gather information, but it will be NRR --

MR. SHEWMON: We will get to him later.

One of the things you are doing now is enforcing the rules. Where could I find a copy of those rules that you are enforcing through your West Jefferson exercises? Is this I&E Bulletin 82-03 as close as I get?

MR. BAER: It is probably as close, other than the regulations on in-service inspection with reference to Section 11 of the code.

MR. BUSH: There are about three lines in 50.55(a).

MR. SHEWMON: So the regulations consist of some ad hoc, unrecorded conversation between an I&E inspector and an applicant, and that is the basis for the regulations. Is that what you are telling me?

MR. BAER: The regulation, you know better than I do, refers to Section 11 of the code and says, "You are to do in-service inspection per a certain plant." There is a pipe study crack group result that says, "If we, NRR, declare something sensitive, you have to do inspections on a more frequent basis or provide justification for not doing it." This went out under the cover of an NRR generic letter.

Beyond that, in terms of a regulation or something that has the weight of a regulation, I am not aware of anything else. Even a bulletin is a requirement only in the sense -- The only part of a bulletin that is legally enforceable is that we require them to respond under oath and affirmation. If they say, "We are not going to do any of this. Go to hell," which has not happened, we will issue them an order. If they do do something, they have to report truthfully under oath and affirmation.

MR. SHEWMON: There are inspections and inspections, and some are better than other inspections, and that is what you are trying to improve at West Jefferson. It is the main purpose of the meeting, to see both what technology is available, but also what technology is being required?

I am getting nothing back from you. I realize that it may not be your union to do it, but it certainly is the NRC's responsibility to define what they think are adequate inspection procedures. I am trying to learn what is the device for that being done, and I am not getting very far.

MR. BAER: Could I suggest that we have Gary Dau of EPRI and Joe Collins discuss what they have found so far, because I don't think as yet we, as an agency, have tried to focus on the next step.

In our bulletin, we make a commitment that by January 15, we will at least inform the next group of BWR licensees of what is required. I will be frank, it is muddy to me in my mind, because of the problems thus far, despite the efforts at West Jefferson, the results don't show that the UT examinations all that effective in finding problems, at least at Monticello and -- let me limit it to Monticello.

So a regulation that would require more frequent inspections from the Pipe Study Crack Group doesn't seem to be at least the whole answer, and maybe not much of the answer. Improving the technique is certainly part of the answer. How one implements that, I don't we have really come to grips with.

NRR really is anxious to say something.

MR. MUSCARA: Joe Muscara, NRC Research Office, to try to answer your question for you.

You realize we have work going on through research with respect to inspection of piping, and reliability of inspection. We are planning on producing regulatory guides that address the problem of what are acceptable procedures based on the results of Pipe Crack Study Group, or requirements for qualification of procedures, equipment and personnel, and criteria by which one should conduct qualification and how to, in effect, evaluate the qualification.

MR. SHEWMON: That is Research and Standard, that is the name of your division now?

MR. MUSCARA: It is the Research Office. There is no Standard.

MR. SERPAN: The Division of Engineering Technology, Office of Research.

MR. SHEWMON: Okay. I guess if you had told me that before you reported to Minogue, I would have said, Research and other people write regulations. Now you will write regulations.

MR. SERPAN: Reg guides, and regulations.

MR. SHEWMON: Yes.

MR. CHANG: Si Chang from NRR.

I am pretty sure, from this Battelle-Columbus exercise, there will definitely evolve some improvement in the procedures, but I don't know which vehicle they will take to reach that improvement, either through the code or through EPRI's proposal, or maybe through the NRC. I am sure that this will result in an improvement in the procedures.

MR. SHEWMON: In a sense, I am asking questions that nobody can answer today, and I realize that. What I would like to get out of the meeting, though, is some type of agreement that indeed something like that needs to be done, and a year from now there will be at least a draft.

MR. MUSCARA: The regulatory guide I am talking about has already been scheduled and planned. It was put off for a while because all of the technical information was not in. That is being gathered, and we are planning within a year to have all the information required to write a proper guide on the acceptable procedures and on how to qualify procedures, personnel and equipment.

MR. SHEWMON: That means that a draft will be circulating in a year?

MR. MUSCARA: Yes.

MR. SERPAN: Chuck Serpan from the Research Office.

In fact, we are going to take the results of what we are doing in the PNL program, and we are going to try to get that into the upgrade of this Bulletin 82-03.

What is going to happen, tomorrow, Joe Collins has a meeting with Steve Doctor and fellows from NRR, and we are all going to get together and try to transfer as much as we can from what has been done at P&L right now into a further order for the other BWR inspections. This has to get out by the 15th of January.

So, we are getting the results of our research work into that right now, and we are trying to upgrade whatever requirements are going to come out for follow-on inspections.

MR. BUSH: For the record, I was told earlier this week that NUREG-0313 is being extensively revised on the basis of what has has occurred. This was more

hearsay than anything else, but I see Si Chang nodding
his head, so I presume that that indeed is the case.

MR. CHANG: Yes.

MR. BUSH: They need one more piece of information.

MR. SHEWMON: Thank you.

Whose turn is it now?

MR. BAER: I will now turn this over to Gary Dau of EPRI.

MR. DAU: Thank you, M. Chairman.

I am Gary J. Dau from the Electric Power Research Institute. I want to thank the subcommittee for the invitation to review our program on improved stainless steel pipe inspection and pressure vessel inspection to date.

The agenda that we prepared was prepared earlier than the one that we are working to today. However, I think we can accommodate both your interests, as expressed by the recent agenda, as well as our presentation.

The items that we intend to cover today are listed here, and they are in the handout that Bob Stone is just passing out.

The pipe work will cover from this point. The vessel work will be in the afternoon according to the current schedule, if there are no objections to proceeding along that line.

The pipe work, and what we intend to present has a much broader overview than is indicated by the present agenda, but I think we will address the questions you have there. If there are no objections to that type of operation, I would like to move ahead.

The NDE Center that EPRI has sponsored and is now and is now being operated by J.A. Jones Applied Research Company, is a unique operation. It is dedicated to technology transfer and training of personnel for the electric utility industry. It is in a strong position in our overall R&D program in attempt to help move the research results into the field as quickly and as efficiently as possible.

I would like to have the presentation start out with an overview of what the center is, and what its objectives are, because it will be referred to in many of the presentations that follow. To do this, I would like to introduce Mr. Bob Stone, who is Vice President of J. A. Jones, and also heads up the Inspection Division. He will give an overview of the center.

MR. SHEWMON: While you are waiting for that, will you tell me how you are listed in the Charlotte phonebook?

MR. STONE: We are listed as the EPRI NDE Center, and the J.A. Jones Applied Research Company.

MR. SHEWMON: I am glad to hear that you are, but the operator could not find it.

Please go on when you are ready, Bob.

MR. STONE: First of all, I would like to thank you for the opportunity to tell you about the EPRI NDE Center, and the program that we are developing there.

The Electric Power Research Institute sponsorsmany projects to improve NDE methods for in-service inspection in the electric utility industry. In order to shorten the time that it takes to place these new developments into routine use, a contract was placed with the J. A. Jones Applied Research Company in 1979 to organize, construct and operate the EPRI Non-Destructive Evaluation Center.

Our purpose is to provide field qualified NDE equipment, procedures and people to the utility community, while operating in a manner that is totally dedicated to their work and to their interests.

I would like to emphasize that we at the Center only work on problems related to the utility industry, and at this particular point largely concentrating on nuclear plant situations.

The project's purpose is being accomplished by what we call technology transfer, and we call out all actions that are required to move developing NDE technology into routine field use. This includes training, very specifically because the NDE Center charter precludes us from doing any inspection activities in nuclear fossile plants.

A small fraction of our resources is also dedicated to working with the academic community in developing programs for training of NDE personnel.

During the final stages of planning for the center, EPRI expanded the scope of the activities to include the boiling water reactor owners group pipe remedy demonstration and training facility. Both the facility and the program were expanded at that time.

This particular program involves technology transfer activities associated with the repair or the replacement of recirculation piping which is either considerd too vulnerable to IGSCC or which has already cracked.

Thus, there are two basic programs at the NDE Center. One involves NDE technology, and the other BWR pipe remedy and repair activities. I am responsible for the NDE program, and I am going to confine the remainder of my comments to this particular program.

This is the center on a very pretty North Carolina day. It was completed and dedicated on February 26, 1981. The facility has 67,000 square feet combining offices, open laboratories where we evaluate equipment without any restraints as to fuel configuration or radiactive situations. Our bays, where we demonstrate NDE technology under simulated field conditions. Then adequate supporting facilities for storage, machining, fabrication of mock-ups, and so forth.

This is a view in our NDE bay. This shows one of our hybrid reactor vessel shell and some retired steam turbine rotors.

This shot is looking at the end of our NDE mock-ups of two recirculation steam generator tube systems, these are on your left, one representative of the C-E configuration and one representative of the Westinghouse. In the back, you can see the edge of or once-through steam generator mock-up.

The NDE Center programs are very strongly based on the use of the most realistic samples that we can lay our hands on. Whenever possible, we use actual samples removed from service in our qualification and validation activities.

At present, our program is focused on the non-destructive examination of steam generators, primarily the tubing, the BWR stainless steel piping, steam turbines, and heavy sections, such as reactor vessels and reactor coolant pumps. These areas, of course, all have great significance to the industry and to the NRC, and the significance is affected very greatly by the capability of non-destructive examinations for each one of those areas.

In each area, we have a task master manager, who is very dedicated in the NDE community for his basic background and capability. But also we have concentrated a great deal on people with some degree of real field experience, having moved technology from research to field in past activities.

I will only touch in any detail on the BWR and the heavy section program since that is the area we are addressing today, but the programs in steam generators and steam turbine inspection are also making major contributions to the industry.

Technology transfer is a nice buzzword. We have been through the process enough now that we are beginning to see some common elements in the process. The center has to survey the status of industry problems and the potential NDE solutions. These may be commercially available solutions, or combinations thereof, or research NDE techniques that are coming down the pike. So we basically have to stay in very close touch with all elements of the equation, from the R&D vendor to the working level utility engineer, to the regulatory individual.

The evaluation of potential solutions is a next step that we finding in the process. This is normally a comparative exercise between candidate technologies, and we are very careful and have very carefully QAed activities to minimize the biases that we would have in these evaluations.

When we determine that an NDE system is valuable and viable through the determination process, then it is demonstrated first in our simulated field conditions in the high bay, and then in the field. This phased validation of performance is a key part of field qualifying equipment.

The final and necessary step that we are seeing again and again is that the repetitive feedback, and the lessons we have learned in the field applications, provide continuing improvement in the new technologies.

The BWR stainless steel pipe inspection task area involves the transfer to the industry of technology for inspecting IGSCCs that we are very interested in and talking about today. It also includes support of such exercises as that which occurred recently at Battelle-Columbus Laboratory, the validation of inspection agencies' techniques for the utility industry.

Some of the new research and development and equipment that we have under evaluation at the center will be discussed in more detail later. I will just mention this as part of an evaluation process that is going on with respect to an automatic pipe inspection system.

The equipment on the left is a commercial instrument that has been developed on the basis of EPRI developed technology. The device is operator-trainable and provides assistance to the manual inspector by helping him to classify whether the UT indication is either a crack or not a crack, one of the very key problems in the inspection process of the IGSCC.

Note that there is a pipe sample by the instrument, and also some documentation behind. There are a number of pipe samples that EPRI has made that we have also been able to obtain access to from some of the plants which provide a very valuable base for both training and qualification of new techniques.

A typical ISI problem previously was that many inspectors had never seen the reflection of the signal from IGSCC, and if they did, they didn't know what it was. We have in excess of 50 of these samples with controlled IGSCC that people are using for training and qualification.

This particular record is an indication of the type of documentation we have on those samples. This is a fluorescent penetrant record. Each boiling water reactor utility has recently received a sample, as well as a documentation book containing the information on all the available samples. Thus, they can swap out between samples that have axial cracks and circumferential cracks, and so forth.

These are activities at one of our recent workshops for the industry on IGSCC inspection. The emphasis here is very much on hands-on work. In fact, yesterday and the day before, we had a similar workshop involving NRC staff going through some of the same inspection processes.

The heavy section task, I think, provides a very useful example of the NDE Center role on equipment that has recently been developed by EPRI that we transfer to routine use in the industry.

This is a miniature linear accelerator, and it is called the Minac. It is a highly portable, very powerful X-ray machine that allows radiographic inspection to be performed in radioactive plant situations, which hitherto was not feasible from a technical standpoint, because it could not be done with a radio-isotopic source.

The equipment was evaluated and improved at the center. Here the utility's designated in-service inspection vendor is being trained in our radiography booth. Note that we have anti-contamination clothing. They are placing the Minac in a pump mock-up, which has been positioned in our RT booth to be representative of the type of constraints and boundaries that existed at the particular plant they were going to. We determine these in a pre-inspection survey of the plant.

Here the Minac is being used as part of a system to perform the ASME code mandated inspection of the circumferential welds of the reactor coolant pump. The center evaluated and approved the equipment. We trained the necessary in-service inspection personnel that were designated by the utility in a formal training course that we developed, as well as the utility supervisory personnel, again in a formal training course, and supported three pump inspections within eight months after this equipment came to our plant.

MR. SHEWMON: That is an inspection for what?

MR. STONE: It is an inspection for the circumferential weld. There are typically three circumferential welds in a cast stainless steel model 93 Westinghouse reactor coolant pump. These vary in thickness from eight to 12 inches and they are uninspectable by ultrasonics because of their metallurgical characteristics. So before the Minac existed, there was no viable technology to perform this mandated inspection.

I will be frank with you, we are quite proud of the record in eight months of what was accomplished in the service of the industry.

We are now beginning a similar sequence of activities on the development of inspection systems for the reactor vessel. The first of these system is scheduled for delivery in about a year, and Dr. Quinn will be providing specific details on these this afternoon.

Two modes of training activities have been illustrated. Thus far, the IGSCC inspection workshops are workshops that we have to give the industry, regulatory individuals, and the R&D community a snapshot in time of where technology stands at that point.

The Minac training that you saw, we have termed in-service inspection team training. When we have evaluated the technique, we say that it is ready for field application. Then we train the teams that are designated by the utilities who actually do t e inspection.

In addition, we have developed other generic types oftraining at utility request. The first such course developed has been in visual examination. Three training levels are offered in this course, and the emphasis is on preparation of the utility personnel to perform the required visual examinations in the ISIs.

This was an area where there was great diversity and assumed requirements in practice, and we have put together a course. We have had over 100 people come to the center, utility people primarily, for this course. The material has been put together and it is now being used in initial draft form at the utilities for training their people. When they choose to utilize our documentation, we audit their course. So this course has been highly successful.

MR. BUSH: Bob, does that cover VT-1, VT-2, and VT-3 history?

MR. STONE: Yes, three levels.

This is one of our classroom sessions. You can see some of our training materials down here on the desk. Similarly, our laboratory session. All training course work that we do at the center is very precisely documented and QAable by the utilities. Most of them are choosing to use our qualification services, the training that we provide, and the documentation as a part of the documentation for certification.

I would mention that we have had an interesting situation on the visual training course. We decided to be rather tough in the formatting of the course and demanding. We are failing between 25 and 30 percent of the people who come to our courses. We have not gotten any bad feedback.

We have practical exams where if the individuals do not find a certain percentage of items that have been identified to us by the utility as of concern to them, they fail regardless of what other passing score they have made on the routine examinations.

MR. SHEWMON: Is this VT-1, 2 and 3 something that the NDE Center has made out?

MR. BUSH: There is a specific ones that cover the aspects where that type of thing such as missing bolts or cracked bolts --

MR. STONE: The condition of the snubbers, the condition of hanger rods. What we saw was a very wide divergence of practice in the utility groups that came to us.

One visual examination might be walking the line to see if a particular hanger is in place. Another utility might have the individual go up a ladder with a detailed checklist and see if the settings, the condition of any shafts, and all sorts of things. So we have configured the course to be very detailed, and the utility can use that portion of it that they feel is appropriate.

To summarize, we feel that we have gathered an excellent staff and resources, and constructed a facility, and we are in place, and in business, and I think functioning well. These allow us to operate dedicated NDE pipe remedies for the service to the utility industry.

I had ten minutes. I could talk for many hours on my favorite subject, but I would like very much to invite any of you to come to the center, either individually or to have a meeting with us. We would be honored, and we would very much appreciate the opportunity to show more of our activities.

Thank you.

MR. SHEWMON: Thank you.

MR. STONE: Are there any questions?

MR. SHEWMON: One, and I don't know which one of you people would want to answer it.

Ten or 15 years ago, I was associated with Argonne, and one of the people there was developing pumps anti-current techniques. One of the problems was, if you had a better mousetrap, nobody particularly wanted to develop it because the market was for not too many items. That has to be a clear one.

I would be interested in your comments on that kind of technology transfer, and how it handles them. I am almost tempted to say, let's talk about Bob McClung's multi-frequency, but I will pick on him separately, I guess.

It is a small market. There are development costs. I don't know whether there is much overlap with the Defense end of things. How would you approach that?

MR. STONE: I maybe can comment on the Minac. I am sure Gary can comment more philosophically.

The Minac was an exact situation such as this. It was proven to be a development that had usable applications. The approach in that case, there were really no takers in the ISI community to buy one because the applications market was fairly limited.

So the NDE Center Services Company of our parent company bought the two instruments that are in existence, and we essentially lease those to the utilities for these inspections. The utility selects its ISI vendor. We train the people in the utilization of that equipment, and we are supporting them in a mechanical sense in the inspection.

Our role there is much like a Hertz Rental Car Agency. We keep the car running well. We give driver training course, and we put a couple of expert mechanics in the backseat.

MR. SHEWMON: Is this Minac related to something that a small college might buy, or did you have to write your specs completely for it, and then go out for bids?

MR. DAU: It was the result of an R&D effort. The first prototype, which is still in the prototype stage, was used in a pump inspection at Ginna. In fact, you are asking about technology transfer, I think there is a case where we found that the utility had written into their inspection plan the use of Minac for pump inspection.

We found out about it about six or nine months later, and at that time the development of the program was for a general high energy radiographic sort. We reconfigured our R&D effort to converge on pump inspection, and working with the utility we came up with a prototype device and the necessary mechanical manipulator for that. The utility invested almost as much money as we did in providing the mechanical support end of it.

In fact, in the conduct of that first inspection, we got more running hours on that new unit than we were ever able to get in the test lab because we were on the critical path with the utility.

We prefer to operate in that mode, but the thing that occurred almost immediately was, many utilities wanted it immediately and that then forced us to look at how do we deliver this capability to the industry and maintain the best that we could the normal customer/supplier type interaction.

The institute policy is that we won't do routine in-service inspection. So that required us to look at different approaches of transferring ownership of that prototype gear, and we worked out an arrangement with a different division of J. A. Jones.

They bought the equipment and they leased it to the utilities. The utility then makes a decision as to who is going to use it, whether their own staff or an ISI vendor would use it. Part of the condition is that that group will be trained by the NDE Center for proper operation.

What has complicated the whole situation a we see it, we still need access to at least one of those units to complete our R&D efforts. So we have parallel paths here that really have divergent objectives in mind. Because of the dedication of the people involved, and their wanting to see this technology succeed, it is working quite well so far, and I think it will succeed.

This is a real life situation that we are facing, and we have licensed the company to manufacture, but the total market is likely to be ten.

MR. BUSH: It comes up again on anti-current or UT also, where there is a fair amount of evolution.

I can give a classic example. In 1963, we have had major problems with steam generators with stress corrosion cracking, and we took Hugo Levi's breadboard dual parameter/dual frequency system, and it performed in certainly an outstanding fashion. We were able to characterize unequivocally with regard to size, depth, et cetera.

That was 20 years ago. That system has been developed, but the number in the field in active use is extremely limited. The technique and the technology, you might say, exist, but the incentive for making that next move does not exist to the degree that is necessary.

MR. SHEWMON: Can I get a catalogue and buy one, or do I have to go to somebody's breadboard.

MR. DAU: Today, you can obtain multi-frequency instruments that will do that, but that has only been possible in the past two years. One is made in France.

MR. SHEWMON: Are there other questions?

MR. STONE: Thank you very much.

MR. BUSH: I think I would second Bob's last comment. I believe that members of the ACRS would find -- Maybe I am biased, but I think they would find a day's visit there is quite interesting, particularly if there were people there actually in the classroom type sessions, because I think it is a very interesting experience. I know, I have done it personally. I think it is an excellent chance to see the way things are going and what can go wrong.

MR. DAU: I would like to issue a standing invitation to the committee to meet there any time they wish. We would be happy to host it. We will put you on the mailing list for all the course offerings also, if you would like that.

MR. SHEWMON: Along with the telephone number.

MR. DAU: I have that etched on my brain right now. If you would like, I can give you that.

I would like now to move to the discussion on pipe inspection status.

First, I would like to go over an overview of the agenda for this subject. I will start out by giving a background on how we got to where we are. I have a review of current practice which focuses on a lot of the issues that were addressed earlier on Nine Mile Point, the response to I&E Bulletin 82-03, some workshops, and pipe inventory.

We will talk about the status of some advanced systems, and the surveillance pipe test facility, and then a weld crown contouring machine that is oriented toward pipe inspection, removin some of the burden of pipe inspection.

By way of background, all of you will recall in 1975 there was quite a concern raised by some of the 4-inch bypass lines leaking in BWRs and this was IGSCC. EPRI at that time had been in existence about a year-and-a-half or two years, and we decided that we would try to do something to identify the status of the technology.

Some we obtained some service removal samples and conducted a round robin using five teams that had been involved in a series of inspections required by January 1975 NRC action. We had a limited number of samples, so you should not read any statistical significance here because we simply didn't that big a data base.

We did notice some performance variables, and those teams that did the detailed plotting and the ray tracing did better, and that is something that we are seeing reinforced today.

We synthesized an optimum procedure and required all people to use that same procedure and the same instrument, and we could see no overall improvement. What we did observe, at least from the bare numbers that we had, was that it did not help the better teams, but it did bring up the performance of the lower teams.

The better teams turned out to be some of those that were fresh to the problem. They really went at it in a very, very consciencious manner. I am not saying that the others didn't, but they had a lot of other experience that was involved with inspecting components other than those affected by IGSCC.

After-the-fact analysis showed that many cracks were detected, that is to say, a UT signal was present, but it was classified incorrectly. In other words, UT was viable and a return signal was noted, but the operator decision was incorrect.

Our near-term response at that time was that we were looking at ways to try to improve the field performance. The dual element transducer work came out of that, and was performed by Southwest Research Institute. A three to one signal to noise increase was noted on that particular configuration of transducer. It is now available commercially by at least two firms in the U.S. There is a report out, EPRI Report NP 1153, August of 1979, that gives a lot of the details.

We did benchmarking against some thick wall sections that were obtained later from the KRP plant in Germany.

MR. SHEWMON: Does dual element here mean that -- I have heard Whiting talk about something that adjusts the film thickness and maybe the angle.

MR. DAU: We are talking about a transducer/receiver slightly angled toward one another about a common centerline. One axis is a transmitter and the other is a receiver.

MR. SHEWMON: This is different.

Go ahead.

MR. DAU: It is a way of increasing signal to noise.

We also developed a recognition of the need for IGSCC samples, both for evaluating the technology and for the benefit of training. Starting then, working with the German utility, we obtained KRB plant samples. Later, we had IHI in Japan manufacture samples for us. We a significant inventory of that. Still later, we had a lot of the IHI methodology transferred to the PNL facility at Battelle. So we have brought some of the technology back from Japan and have it here in the U.S.

Another thing that came out of this exercise is problem definition, the error source classification concept that we have used to guide our work. I would like to go over that briefly with you. Mr. Mel Pedes of the EPRI staff did this work, and it is to indicate a way to look at the problem. We don't have all of the absolute numbers we would like here.

The problem on this axis is to measure the probability of error versus crack depth. This is a normalized flaw size axis. There seem to be three classes of errors that we could identify in this earlier round robin exercise.

The physical limit, which meant that you simply didn't get a UT signal back, the flaw was too small to reflect energy. Today's information, I think, is showing that that limit is somewhere below 3 to 5 percent of wall thickness, and it is probably not a controlling factor in the inspection problem.

The procedural aspects of it are important. I think our experience shows that there is an optimum procedure that is needed, so we have more standardization, but that is not going to solve the problem entirely.

It seems that the biggest problem is in this area of signal identification. How do you separate an IGSCC signal from all of the other reflectors that might be in the pipe, and these other reflectors may be from jointness match, weld stack-ups, drop-throughs, and things of that nature from the fabrication process.

So in our long range effort three to five years ago, we started in trying to concentrate in this activity, and I will review where we stand on that in the advanced work that follows after we review the current practice.

At this time, I would like to move on to the current practice, and I would like to introduce Dr. Mohamed Behravesh, who is with J. A. Jones, and is also the Deputy Director of the Inspection Division.

He will review the Nine Mile Point Inspection results, the industry's and the Institute's response to I&E 82-03, IGSCC workshops that we have put on, a swell as pipe inventory, our sample inventory.

MR. BEHRAVESH: After the Nine Mile Point incident, there were several different studies trying to find out why the inspection results in 1981 were different than in 1982, and why all of a sudden things were found in 1982, while the records of 1981 were not showing anything.

We scheduled a meeting with the ISI agency that performed the inspection at Nine Mile Point, as well as the utility. They brought all of their data to us. We spent two days with them going over the data. The people who were there were, as I said, people from the utility, people from the inspection agency, from the NDE Center, as well as EPRI.

What we decided to do was to look over the raw data, what work was available, and to see what differences existed in the recorded data.

At the start, I should say that there were no definite conclusions as to why the results were different, so I will say some things, but there are really no definite conclusions as to why the results are different. There are some considerations, however.

MR. SHEWMON: Were the inspections done by the same team?

MR. BEHRAVESH: By the same agency, and the same individuals.

MR. SHEWMON: The agency is also what has been called the UT vendor.

MR. BEHRAVESH: Correct. Nuclear Energy Services was the inspection agency for both years.

There are some general considerations. One of them is the problem of inspection of safe ends as well as the balance of the plant which has been large diameter recirculation pipes. Safe ends were examined year to year because they were part of an augmented inspection, and the balance of the plant was not. So the two have to be separated.

Furthermore, lots of inspection results in 1982 were after the discovery of leak. You have to recognize the psychology of ISI, after everybody knows that there is something in there, so changes are that everybody would be a little bit more consciencious.

With these two general considerations, there are some observations that we have made, and they are the following:

When it comes to large diameter piping, there are only two joints that are in common in the 1981 and the 1982 inspections. So the data is limited only to two welds.

The 1981 procedure was on the basis of 10 percent notch, and they also had a 50 percent recording level, and that is well-known that that is not sufficient. So the procedure itself, at least, is not sufficient for detection of IGSCCs because some of these signals happen to have lower amplitude and we see them at lower amplitude all the time.

MR. SHEWMON: Is that the code required procedure?

MR. BEHRAVESH: That is the code required procedure.

MR. SHEWMON: That is still the code required procedure, and still the minimum that the NRC requires, except for whatever Joe can get them to do out west; is that right?

MR. MUSCARA: There is a new code case out that includes the program. There are, for example, more requirements.

MR. SHEWMON: For the record, do you know what that is?

MR. MUSCARA: It is M-335.

MR. QUINN: That code case has also been implemented and come through committee as a revision to Appendix 3 of Section 11. It was first a code case, and now it has been slightly improved and revised.

MR. SHEWMON: So that is not set down in the regulations, but maybe it can be referenced to be required.

MR. MUSCARA: It is not a requirement.

MR. SHEWMON: I am trying to find out what words the NRC could use and does use in its regulations.

MR. BUSH: In that respect, Paul, I am quite sure that the reg guide that cites the applicability of the code case is behind times, because the last time I looked at it there was six months, at least, lag. So it wouldn't be referenced in the reg guide either.

MR. SHEWMON: Bob, did you have something else?

MR. STONE: I have no comment.

MR. SHEWMON: Go ahead.

MR. BEHRAVESH: Furthermore, the probe that was used in 1981 was a larger probe, and a probe of this size, I know, will have a lower sensitivity to IGSCC.

Unground crown welds will inhibit the axial crack, and that is always a problem. The time spent scanning and recording is considerably less and lower in 1981 than in 1982. Of course, there might be several factors involved, but again the information is obtained from the raw data.

Then there is another thing. The difference between 1981 and 1982, the inspection agency as well as the utility people happened to take part in two workshops, IGSCC workshops at the Center. One time, three of them came, and at another time, four of them came. By September of 1981, or a little after that, we provided them with an IGSCC sample. In early March, March 7 and 8, 1982, they were again at the center. Of course, this cannot be quite so substantiated, but it is a factor.

These are people who took part in a workshop and then went back to the plant and the performance happens to be better.

Now looking at numbers specifically for the two weld joints in the recirculation piping, these are the two weld joints 10W and 36W, the results in 1981 and the results in 1982. This table is in your handout.

Indications were not found in 1981, and small amplitude indications were found in 1982. The UT instrument was pretty much the same, there are no significant differences between these instruments.

The search unit, as I mentioned, in 1981 was slightly different. In 1982, they have gone to a smaller search unit. The calibration box was the same.

The sensitivity of calibration and scanning is the same, except that in 1982 the scanning had a higher sensitivity level. That still does not mean that they would record at a higher level, but at least they give themselves more chance of seeing something if it is there.

The temperature difference between calibration blocks and components remained the same. The level of qualification or certification of inspectors is almost the same level, level II and level I, level III and level II, and level II and Level i.

One factor which stands out is the time that is spent on inspection. I have a little footnote that I would interpret for you here. In 1981, an hour and 49 minutes were spent on three joints, whereas in 1982, three hours and 20 minutes were spent on a single joint. Considering that these joints are in welds of 28 inch diameter, which would correspond to something in excess of 90 inches of welds, half an hour for each weld hardly seems to be sufficient time if there are things to be seen.

Again, I would like to emphasize that the only thing that may possibly standout here is the difference in time, as well as the choice of the probe that was used. Recording levels are well-known. IGSCCs quite often occur at lower levels than are currently being recorded.

With this in mind, I would like to conclude my talk with respect to our review of Nine Mile Point results, with the emphasis that there are no clear-cut conclusions as to why they were found in 1982, and why they were not found in 1981, considering our approach, which is looking at the raw data rather than interpretation of statements of people.

The next item that I want to talk about is the NDE Center's response to I&E Bulletin 82-03.

We took part in a meeting here in Bethesda on September 27, 1982, where, as it was mentioned earlier this morning, NRC expressed a concern about the capability of the ultrasonic inspection of IGSCC in large diameter pipe, as well as the ability of these various schemes to perform a credible inspection. Immediately at the end of that day, by 4:30, we started working toward doing something, knowing that NRC was going to make it a requirement.

The very first thing we decided to do was to find a place to conduct this performance qualification. After two or three days, Battelle-Columbus was chosen because it was centrally located and it had hot-cell facilities.

Right at the same time, Nine Mile Point people were at our place reviewing the results. We selected specimens, and by a dedicated truck they went to Battelle-Columbus. Immediately, we started decontaminating these specimens, documenting them, doing ultrasonic inspections, having them ready. By October 6, all of this was done.

On the morning of October 7, representatives of NRC, some number, about eight or nine people, showed up at B. .elle-Columbus. We showed them everything that we done, and we showed them what we had in our hands, what would they like to do with it.

A plan was devised, and the following morning the very first teams arrived to go through this performance qualification. The teams were from Northern States and Commonwealth Edison. On October 12, Northeast Utilities showed up. By October 14, utilities represented by Southern Company Services, Georgia Power, Philadelphia Electric, Carolina Power & Light, Consumer Power, and Dairyland Power Coop showed up.

By October 15, the bulletin, so-called, hit the streets. By the time that the bulletin came out saying what was needed to be done, almost half of the activities were completed.

By October 19, word came out that some of these utilities failed the process of qualification and help is needed for them. We immediately started having workshops for them. On October 22, Northeast Utilities showed up again. On October 25 and 26, we conducted a workshop at NDE Center for those utilities that failed. On October 27, Southern Company Services, Carolina Power & Light, and Georgia power, and on October 28, TVA, and October 29, GPU.

From October 27 to October 29, all of those nine utilities that were at risk in this bulletin had gone through. There will be a lot more said with regard to results in later discussions, and I would not mention any more with regard to that here.

MR. DAU: Mohamed, would you make a comment about the samples.

MR. BEHRAVESH: One of our objectives all along has been to keep the specimens pristine, to keep the information about their ground state confidential. As a result, I am not going to mention here what was in these samples.

I was under the assumption that this is a public meeting, and in fact it is, and I will not mention. I would further like to request that those who would discuss this do not mention about how many cracks, or how long, how deep, what kind. That information can be exchanged privately.

We have tried our best to keep these specimens pristine, and in fact they are covered such that their ID geometry and the location of flaws is not known to anybody except people at the NDE Center, as well as the regional inspectors who have the responsibility of giving a pass or fail grade to a team.

There are things that are involved with regard to addressing the IGSCC in pipes, and I would like to move slightly to some of the activities that we have.

The evaluation of a commercially available micro-processor assisted manual instrument for manual ISI. The instrument does automatic signal interpretation, that is, there is crack or no crack.

It is user-trainable in the sense that the operator can show a collection of crack to noise to it, and the instrument will learn the crack characteristics of those and can move right next to the table and be tested on an unknown flaw.

It holds up to seven training sets. That is, at a given time, the instrument has seven different training sets in it that can be applied to different problems. For example, take the problem of different size piping and different schedules, as well as it is in a single module that weighs no more than no more than 35 pounds. We have had it in our hands for two or three months, and we are still continuing with its evaluation.

People from I&E and regional people did

observe this instrument in a sort of semi-private session at Battelle-Columbus, and its performance with the Nine Mile Point specimens, which I would not like to discuss. If they wish, they can discuss it.

Part of the difficulty with the current technique in ultrasonic inspection is acquisition of data and having precise positional information. As Gary mentioned a little while ago, the difference between good teams and bad teams traditional has been the accuracy and precision with which they record position information.

We are looking toward a system that you can go in the field, acquire data, and bring that data outside the field, and conduct an off-line analysis, that is, assuming a mechanized pipe scanner, which we now have, by the name of Amap, which Gary will get to later, a signal digitizer and recorder which is also partly available, and putting some code considerations in that process -- by code consideration, I mean calibration and percent DAC, and what threshold level to record. All of this results in a cassette or a tape that you can bring off-site. You can do data reduction, do automated analysis, as well as replay that data for a level III to conduct conventional analysis by plotting.

The advantage of an approach like this is that he would have the capability of doing repeated analysis without having to go inside the containment to take a second look at the signal.

With all of these advanced techniques, and signal detecting techniques, there is one concern that has existed all along, and that is the signal processing approaches that are currently being used. They are all either empirically based, or statistically based. In order to get them accepted, one must establish their physical principles, those physical principles that underlie why the given item works or not.

This was a problem, and our approach to that was, in the last four or five months, we gathered a group of experts in statistics, signal processing, scattering theory, waive propagation, physics, and various fields, and have them get together, go over the data, go over the approach, and see if they find any reason why these things work, and, furthermore, explain those areas where they don't work.

This activity just came to an interim conclusion at the beginning of November. An important outcome of this activity has been the establishment of the very first model of IGCSS that begins to explain some of the experimental results that we see. We consider this as being a very important accomplishment.

It is a first step, but it is a first step that has been long overdue.

Another activity that we have had, we have conducted a number of workshops --

MR. SHEWMON: Before you leave that, one of the things that would concern me some would be the probability that all IGSCCs aren't the same, even in physical geometry. I could believe it is the rather subtle things that would determine how a crack would branch in little different welds, or different kinds of piping. They might branch, and thus be physically different.

Have you done work on sort of the uniformity of the sample you wish to identify?

MR. BEHRAVESH: Let me make a couple of comments about the characteristics of IGSCC. Physically, w) ı you look at them, as much of them as you can see, there are almost no two that are alike. You have to take that just for granted, there are no two that are alike.

However, strangely enough, there are some characteristics of them as a class of reflectors that appears to be shared in common by all of them, and this is our saving grace. This is where the majority of emphasis is currently being put, find those things that are common among them that make them look alike, realizing the fact that no two of them are completely alide.

When discussion quite often between axial and circumferential in terms of the ultrasonic response, if they were both oriented the same way, we see little difference. In fact, it is where they occur and what orientation they have that ultimately affect whether they can be detected or not detected.

I would like to mention a couple more points, and stop.

We have a large inventory of cracks specimens, IGSCC specimens. Bob mentioned 50, and we have 50 good ones, but in fact we have more than 100. Some of them are not as good as the others. Every BWR utility in the U.S. and abroad, those that are members of the BWR Owners Group, have been given a specimen and they routinely exchange these samples and get others from us.

Right now, the people at Oyster Creek have four or five specimens from us to train their people. This occurs routinely. We have had several IGSCC workshops. We had one in September of 1982, and some 35 people attended from BWR Owners, ISI vendors, and NRC headquarters and regional people.

We had one in a manner of quick response to address the Nine Mile Point exercise. Furthermore, we had one yesterday for eight people from NRC, from the regional office, as well as the headquarters. We found that it was an excellent opportunity. We found that to be very fruitful. I don't know what they thought of it, but Warren is nodding his head back there.

Thank you very much for you kind attention.

MR. DAU: To bring you up to date on where we stand on the agenda. We have covered the items up to there, and I am going to use a series of 35-millimeter slides to go over the status of some of what we term the integrated system for pipe inspection.

Before I do that, though, I would like to make a couple of comments as to what composes an integrated pipe system, the electronics, the control, the scanner, the signal analysis equipment, I think that is in this block, the instructions of what the electronics are to do, the so-called software, another major portion of, the pulser receiver, and UT transducer, and the scanner, the device that moves the transducer about the pipe. They all need to be put together in the system to work well.

Our initial emphasis was to just cover these two because we were given some assurance that these activities, the scanner, the pulser and the transducer were adequate. As we moved along, with the precision that you can get in the micro-processor technology, we began to find weak spots in the conventional technology, and we had to go back and develop improved scanners.

We came up with a new transducer arrangement, and we had to make some modification of the pulser in order to get the very stable signals that we needed for signal analysis.

So what started out to be the two parts of the problem, we had to finally address all five.

(Slide.)

MR. DAU: On the screen, you see this diagram again just to orient you. What we are really aiming at in this case is to do something about the signal classification activity, and also to address this issue (indicating). The outcome of that, we believe, will drive this detectability of physical limits down to a much lower level as well.

(Slide.)

MR. DAU: If you take a normal pulse, this is what you see on the screen. If you expand that and look at the total information content, you see that there should be a lot of information in here, and we are trying to deal with this additional information other than the time amplitude to help make decisions about flaws.

(Slide.)

MR. DAU: As an example, and this was taken quite a while ago, but here is a raw signal, the so-called RF signal. There is an IGSCC in here for a tenth of a millimeter beat, which in that particular case, I think, is around 5 or 7 percent of wall thickness. By doing some time averaging, you can clean this up and you eliminate a lot of the other signals here.

So this is work that went on three or four years ago, and it is the basis of a feasibility study to continue. So, our effort is really oriented trying to adopt technology that is quite well known in the sonar and medical field to deal with the inspection problems that we face.

Our first problem was IGSCC detection in stainless pipe. I think if we had to pick a more difficult one, we would find that very challenging and difficult to do, but one of the reasons we did it was, we recognized from the start that that was about the only component that we could deal with where there was any hope of having a reasonably large base sample to work with.

We are beginning to learn how to make IGSCC, and we couldn't predict, or we didn't want to predict all of the samples that we now have for service removal as well, but certainly the cost factor of sample preparation was important.

(Slide.)

MR. DAU: When you work with the computer people, the first thing they do is learn how to write checks on your account.

(Slide.)

MR. DAU: This is the electronic hardware, the three boxes here. This is basically affordable computation system where you put in the instructions here and then you record the data output on another magnetic set. You also have a paper tape printout from the reader -- for the operator at that point. This is an interface box that is used to match with any scanner within certain characteristics.

You can use either a standard CRT terminal, which is shown here --

(Slide.)

MR. DAU: -- or for field operations that can be replaced with a hand-held scanner. In the softwear development activity, there is a lot of work in prompting and English language communications to a large extent. So this reminds you, if you want to change the scanner, if so, you press a button and go on. There are a lot of flexibilities built into these systems.

(Slide.)

MR. DAU: Again, the paper tape printout which gives you position information, what the decision was that the decision algorithim reached, and that is your immediate feedout. You also contain all that information on magnetic cartridges for further analysis.

(Slide.)

MR. DAU: It is portable. It was designed to be air transportable, to meet a lot of the ISI requirements. This is also part of our survivability program. We ship it across country on commercial airlines, and the baggage handlers do our tests for us.

(General laughter.)

(Slide.)

MR. DAU: We have gone through generations of scanners. This was about ten years ago, a device that was originally designed to inspect butt welds for a specific configuration. We started working with this system, recognizing that it had some limitations. Notice it does have a hard shoe, and in this particular case we are working on an elbow and you cannot inspect the entire circumferential elbow with this setup.

That served us well, but the limitations also created some problems for us. So, we go back maybe five years ago, and this represents another improvement in the technology. This was developed by EG&G at the Idaho Nuclear Engineering Laboratory. Again, a track or a gear type attachment to the pipe. The scanner moves here, and the transducer head is included in here (indicating).

(Slide.)

MR. DAU: This is an underside of that. In this case, we move from a hard shoe which is non-formable or deformable to pipe roughness to a membrane here that is filled with oil. The transducer sits in here (indicating). It gives you a lot more flexibility and dependability.

Now, recently, we have reduced the volume of this by a factor of eight by some good engineering practice.

(Slide.)

MR. DAU: We came up with a new scanner. The scanner is magnetic wheels attached to a piece of sheet iron. It can be clamped down tight. The transducer head sits in here, and this is the device that is a factor of eight smaller than the previous side.

We have one being developed, an advanced model of this that will be hopefully smaller yet, to give you a factor of one and a half to two decrease in size.

MR. SHEWMON: That was an oil-filled roller that rolled over the surface?

MR. DAU: It is not a roller. It is sort of a sheeting. It moves along the pipe, and you use a jelly-like coupling between that deformable membrane and the piping.

MR. SHEWMON: So you still have to go in and coat it with something.

MR. DAU: Yes. The scanner dimensions here have been reduced, as you can see here, with a hard shoe, with about three and a half inches clearance versus eight. Some are eight to twelve inches as in the previous slide. With the transducer head, the lube filled one is about four and a half inches. Just to show you how it looks upside down, the design spec was to be able to put this scanner mounted on a pipe and have it alligned to the precision needed within three minutes. So the ALARA factors were factored in in the original specs.

(Slide.)

MR. DAU: It is also portable. Here is the carrying case. And these sheet metal devices allow for the magnetic factors to attach and are very inexpensive to manufacture. The gear for one of the previous scanners was about $9,000 in expensive sheeting that, that is getting up to the total cost of this unit, upon its introduction.

(Slide.)

MR. DAU: Another scanner that is under development -- Oh, I would say that this scanner with both the hard transducer type and the new transducer have units of those, and are now going through an evaluation shakeout prior to taking them to the field.

We hope to have that completed in 1983, and the earlier the better, and we are looking for all ways to accelerate that schedule. It does address some of the needs in the field.

MR. MC CLUNG: Excuse me, Gary. Does the ferrous scrap go completely around the pipe. The illustrations seemed to imply that it was only part way around the piping.

MR. DAU: What we have here is only part way around. We are looking at a way to make it go completely around. We could certainly make it go 270 or 300 degrees if necessary, but we have drawings of how to make it 360 degrees. We haven't worried about that too much yet.

(Slide.)

MR. DAU: Now, the scanner shown here is very much in the prototype stage, and lags in development behind the other one considerably, but it has some very unique characteristics. We call it a self-ranging scanner, SRS for short. It has the ability to be driven to the area you want to inspect, do the inspection, and then drive it on. It can even pass branch connections like this (indicating).

There are three contact points. One is this wheel (indicating). There is an abrasive coated wheel on the back side of this area, two around on this side, and you have an ice tong arrangement with compression forces holding it against the pipe. It can move around in the circumferential direction on command.

(Slide.)

MR. DAU: Then you can put it in this configuration, change the wheel direction 90 degrees, drive it by a branch connection, and if this was a weld, then you could move up and do the inspection here.

(Slide.)

MR. BUSH: Gary, could that handle the welds at the branch connection?

MR. DAU: This one? No, not at the present time. Notice this is the same transducer that was on the A-mass scanners that we were trying to build some commonality into these.

(Slide.)

MR. DAU: I am going to move on and show you a few slides, and then I will go back. We have completed the advanced inspection portion of it. These slides will be on the surveillance test. I will show those now, and then go to the vu-graphs to save the trouble of changing between the audi-visual medium.

This is a large surveillance pipe test, a 26-inch diameter pipe with a circumferential weld here, loading jacks at the four corners, and the graphite wool technique was used as an artificial way to initiate cracks on the IV of the weld. This is put on during normal operation.

MR. SHEWMON: We are running over schedule a bit.

MR. DAU: I will speed up.

This is another view of it.

(Slide.)

MR. DAU: Some of the equipment you saw before in the electronic system. I show it here because it has been in continuous operation to support this function for over a year and a half since the shakeout.

(Slide.)

MR. DAU: We have a transducer that was mounted on there at 300 degrees C for about a year's time now, which is a very significant achievement in itself. That means you could leave the transducer in place to monitor a crack during operation.

(Slide.)

MR. DAU: We have continuous records as well as periodic inspections.

(Slide.)

MR. DAU: Now I am moving into the weld crown device. One configuration of the weld crown creates quite a problem for inspection. The device we have under development, we machine this off so that this is a smooth transition.

(Slide.)

MR. DAU: This is a prototype device which, if you take it in terms of an external aid, this whole arrangement then rotates around the pipe.

(Slide.)

MR. DAU: This is the unit being tested in March at the NDE Center, a series of welds on this pipe.

What is the time schedule? I could give you some more details about that surveillance pipe test if you would like. I can take about two vu-graphs.

MR. SHEWMON: I guess I would rather get to your sum-up, I think.

MR. DAU: On piping or the entire presentation?

MR. SHEWMON: What I am looking at is sort of 15 minutes beyond the schedule, and I want to have a break in here, so I don't know quite what you have yet.

MR. DAU: I am ready to stop the discussion on pipe inspection right now.

MR. SHEWMON: Okay, why don't we do that?

Are there any questions or comments on this?

MR. BAER: One question, Gary. When would you project these automated systems being available for in-plant inspections? What is your crystal ball?

MR. DAU: First of all, 1983, and we are trying to push that as far into the plant for evaluation qualification in 1983. We are trying to push that date towards the earliest part of the year as possible, but we are limited on resources like everybody else is. It is just a question of time and money.

MR. MC CLUNG: A question, Gary, on the ALN. I guess it is very much related to the question that was just asked about when would this be ready either on a voluntary or perhaps a required basis. I have a question about the improvement in results with such a system. Is it better than the Superstar performer? Does it bring everyone up to the level of the Superstar? Just what does it do for inspection quality versus the man now in the field?

MR. DAU: Well, hard data is what the NDE Center is all about generating to answer questions like that. We don't have all of those numbers yet. To back up a step, the instrument that Mohammed mentioned for the manual inspection is generating more data there, and I think it will meet or exceed what Superstar is doing. That is the preliminary look. I don't have the hard data, but we will be generating that within the next four to six months.

And the other system, the totally automatic system, because the principles are very much the same, should match that.

MR. SHEWMON: Why don't we take a ten-minute break here and come back?

(Whereupon, a brief recess was taken.)

MR. SHEWMON: Let's see. Next we hear from I&E. Joe, are you ready?

Joe is not sure he's big enough to take care of himself, Bob. He wants to have you here.

MR. BAER: Joe came back from that EPRI workshop late last night and his car wasn't working at the airport.

MR. SHEWMON: It was a hard night.

MR. COLLINS: He didn't get too much sleep, I guess.

MR. BUSH: While you're getting prepared there, do you have any handouts, Joe? Are there any handouts?

MR. COLLINS: No. I just finished preparing this at 4:00 o'clock, 4:30 this morning. So some of this will be extemporaneous because of the way the situation fell on me. There wasn't much I could do about it.

MR. SHEWMON: We appreciate your being here.

MR. COLLINS: Well, to open the discussion, you heard some of the work going on in the EPRI-NDE center and their role in this whole program. They did establish a sample availability.

(Slide.)

They did make a very detailed sample

characterization. This was within the constraints of a very short lead time, as Mohamed has discussed with you. They did establish channels of interface for capability testing between the utilities, the NRC Staff, and the ISI vendors or ISI agencies, if you will.

Throughout this program, which is continuing, because we are not through at Battelle with this work, they are continuing to maintain objectivity throughout the performance of the capability tests.

As Mohamed also pointed out, he did review this characterization of the samples quite in detail, and later on through my discussion I will ask Mohamed to come back, because I want him to discuss that a little bit with you. I am afraid that I might disclose something about the pristine conditions of the samples, and that would be unfortunate. So I'm going to ask him to come back in a few minutes to discuss this with you.

My bottom line here is that I think EPRI did a commendable role, both consistent with their charter and that part of the industry's function.

(Slide.)

I think that should be really recognized.

Now, I have one thing that I would like to clarify here for you, if I will -- may. That is the performance capability testing. I choose to refer to this as the performance capability demonstration concept, as opposed to a validation program. I hope to develop some rationale for this, because there are some essential ground truths on this issue.

First of all, there's no formal qualification program established industry-wide. Number two, the question of the generic implications raised by the Nine Mile Point conditions is number two. Of course, there are time constraints necessary to answer these two above questions.

In summary, this performance capability demonstration testing that we did was based on a matter of judgments within the framework which we had to work with, and of course I must admit, you may formulate a lot of criticisms and questions, and hopefully as I go through this I can, through my own rational way, provide you with some answers to them.

(Slide.)

Now, to get these in the proper order here. They never come in the same order you would like them to.

I want to, in pursuit of my defense of what we did, to revisit a little history on the problem in itself. This brings to mind quickly, in 1965, is when it all started, there was not much appreciated at that time. I am sure that experience here in the room will immediately say that is Dresden 1.

Then in 1969-1970, of course, that recalls to mind the Nine Mile Point core spray event. Ironically, this is where it started back again around the wheel. 1974 to 1975, of course, was the problem with the bypass valve line cracking in the BWR plants, and of course the reactor water cleanup lines were starting to show some of the epidemic and the first pipe crack study group went to work to review this whole issue.

In 1978 to 1979, there was a second pipe crack study group formed, which essentially reviewed the work of the first pipe crack study group in this area of the types of material that are believed to be sensitive to the problem of IGSCC.

The first pipe crack study group issued their work in 1979 through NUREG-75/067. They come to this conclusion, that the reactor coolant pressure boundary is susceptible to stress corrosion, which may cause cracks similar to those discovered in similar piping.

(Slide.)

The second pipe crack study group published the results of their work in NUREG-0531 in 1979. Their conclusion, based on their review of the first pipe crack study group's work and their own work in revisiting the problem: They did concur with the previous findings and decided there is little evidence to indicate IGSCC will not occur to some degree in the large diameter pipes in the U.S.

I think it is quite obvious that Nine Mile Point demonstrated that this conclusion is absolutely correct. As you will see, this conclusion here takes on added dimension when I start getting into the results of the inspections that are now ongoing in the plants. Of course, this information has already been addressed, so I will move right along into the other areas.

So that is one of the background history which provides impetus to us to push on and provide some demonstration capability, and that is one of the prime decisions that entered into item one of 82-03, IE Bulletin 82-03.

(Slide.)

With regard to the plants covered by this bulletin, they are limited to the nine plants. I have just indicated Nine Mile Point down here as being repaired, but that has been covered previously. These are the plants involved. These are the ones that are shut down now. These are the schedules, Monticello and Hatch. The reasons for those question marks will become apparent when I discuss the findings of those two plants.

And here is the ISI organizations which we have to contend with. You will note quickly that there are ISI agencies in direct relationship to the licensees. That is really the matrix that was worked with at Battelle and the basis for the program, and to look at each one of these individuals within this matrix as they apply back to those plants (Indicating).

Here are some interesting things that I want to discuss, and hopefully I will not overlook them. We do have several here that have not been scheduled for work. We have not completed our performance capability demonstration work with Magnaflux, and GE has expressed an interest, coming in under the sponsorship possibly of CPL or others, to provide an overview in the event that there are some other additional identifications of defects that are found. So they want to feel confident and competent in their efforts also.

I would make one point here, this note. The ISI schedule has slipped to January here because the people have reached the level of exposures for this order, and of course some of these, particularly in this group (Indicating), of the ISI agency will have a problem here.

MR. SHEWMON: Joe, this is good, but to a certain extent secondary to what I am particularly interested in hearing from you. I would like you -- you may want to continue over these quickly, but if you could shift to what the procedures are that you are insisting on or your group is insisting on for people who pass this test and get certified.

You bring up GE and I know GE has some procedures which were different from what the code was and indeed different from what were used at Nine Mile Point, I guess, the first time around. And I would particularly like to hear your evaluation of these if I could.

MR. COLLINS: I will delve into those as I go along, Dr. Shewmon. And I wanted to step right into the program now as it was set up.

What I would like to do now is to call on Dr. Baer to briefly describe two things: the collection of the samples, the characterization of the samples. And then I am going to come back and discuss some of the ground rules. There was a consensus of the group, and I want to proceed right into some of the results.

MR. SHEWMON: Okay. Very briefly, I hope.

MR. BEHRAVESH: How briefly? How many minutes?

MR. SHEWMON: One, two.

MR. BEHRAVESH: As we said, very briefly.

We had to work with what was available to us. What was available to us at the time was five specimens, three of them from safe end to elbow, two riser to elbow, and this resulted in 100 inches of weld. 100 inches of weld was what was available to us.

The activity was performance qualification, but prior to performance qualification our interest was in determining that whether these flaws in these specimens were detectable to begin with or not, that is using different procedures, what made the procedures different from each other in essence, aside from the name of the vending agency, is what type of plot they used, what type of calibration standards they had. And these were the major elements, and furthermore what kind of a recording level they used.

So in order to do that, we had four teams of us, EPRI, and some people from the vending agency. We went over the entire specimens.

(Slide.)

We collected ten sets of data on these specimens, knowing where the flaws were. We documented the flaws ahead of time. So we used variations of frequencies, variations of transducers -- dual element, single element -- variations of sizes from the different manufacturers. And furthermore, we characterized this, calibrated on the slide rule, did the calibration.

The spectrum of results were generated on every single specimen. Now, this in itself could be called validation in a sense, this preliminary effect, that is, whether these flaws are detectable to begin with or not.

The entire spectrum of data collected on each flaw was handed over to the NRC people, as well as the regional inspector.

(Slide.)

Then furthermore, we decided to do other things, to establish the differences between parameters of calibrations: side-drill hole versus notch on those calibration specimens that were provided by the Nine Mile Point for these specimens. And the results are nothing strange. For the side-drill hole you find that the sensitivity appears to be higher by some 6 dB on one calibration block but 80 on another calibration block. It's known by everybody, it's confirmation.

After that you have these specimens, now. What are you going to do with them? What are you going to require? That's when the NRC people came. We had an entire day of meetings with them at Battelle Columbus on October 7, an entire day which went through the evening.

Finally, what was decided is the following.

(Slide.)

For example, suppose we have a specimen and this is its ground state. How are you going to say that this was inspected and how it was inspected? Well, one way to do it was the following: Let's say that this length of specimen represents a certain number of cells of this material whose state must be assessed and established with regard to having a crack or no crack.

(Slide.)

So let's put a grid on it. Let's require it of those people. After all, these one-inch grids represent the point of view of the transducer, and what you inspect at one location has little bearing on what you inspect at other locations. These could be required as individual inspections, could be, provided that all other things were taken into account.

Then ask him to go and have a grid like this and say, crack or no crack, with the result like this.

(Slide.)

If somebody came here and wrote down, crack, crack, crack, crack, on these locations, that constituted a correct call. If there was no "C/NC" here, that constituted a miss. If this was here a crack call and if there was no flaw here, somebody had recorded "CC", that constituted a false alarm.

Now, which is good, which is bad? In any given flaw, again the NRC people, in consultation with their consultant, decided what is major in this specimen. If somebody misses that, that's bad. There are some things that are there that are detectable, but at very, extremely low amplitudes. Just because we have seen it in establishing original data, that may not pose a requirement on any inspection agency to be able to do the same.

So all of these considerations went into it, went into it and resulted in the pass/fail that was given. And if I can have another 20 seconds to flip through several slides, that would give you a better feeling of what --

(Slide.)

This is the type of sample that arrived at Battelle and we were literally with a hammer trying to knock the contamination off of it. It was a very quick activity.

(Slide.)

Every one of them was decontaminated, cleaned, documented carefully.

(Slide.)

Everything about them recorded, and the entire result was presented to the NRC, and some of their faces here are quite familiar here. We went over everything, what is doable, what is not doable, to what extent, and then immediately the next morning there came the inspection teams. There is Kevin Ward looking over the inspection being performed by a Commonwealth Edison team.

(Slide.)

They are observing the inspection being performed by the team on behalf of Northern States Utilities. I see Warren Hazelton there.

(Slide.)

There is Martin Tom. Everything was observed during those activities at Battelle and collectively the group got together and made their decision. And our role was simply the role of a provider, a facilitator of the entire activity.

Thank you.

MR. SHEWMON: Let me bring up -- when you talked about those surface flaws, and I will bring the question up again, did you try to get into what was a significant flaw? I guess by this I mean the depth or the cross-sectional area or something of that sort, which is in a sense the bottom line. Or when you came to the leaking ones, did you see the differences there or did you get the leaking section into your sample?

MR. BEHRAVESH: Several points. We had no specimens that we were concerned about depth measurement in. Again, at the risk of not expressing too much about the data, the question of depth measurement was not of concern. The reliability of the depth measurement is so low and so bad that our guess is considered to be as good as anybody else's guess in coming up with the depth of the specimen.

Now, the length measurement we can do. Length measurement we can do. And the question of significance of a flaw, they decided -- it was like this, that in the base line data if it is easily detectable then they have to be able to detect it, too, unless the ones that were given away were the ones that had very low amplitude and you could detect them if you knew they were there.

MR. SHEWMON: So we are bypassing the significance for now, is that a fair summary?

MR. COLLINS: From the depth --

MR. SHEWMON: Any surface crack is significant?

MR. COLLINS: From a depth standpoint, we did not go in that direction. We absolutely cannot discount that from the experience that we have had at Nine Mile

Point and the experience that has been shown at Monticello.

MR. SHEWMON: Okay, go ahead.

MR. COLLINS: We simply didn't take that into account in this particular program. We were looking for, can these be detected by the techniques that the ISI agencies are using in their procedures.

(Slide.)

MR. BAER: Maybe I can qualify one thing. Correct me if I'm wrong, Joe or Mohamed, but the samples that were used at Columbus were the large bore piping, and none of those at Nine Mile had exhibit through wall crack. The safe ends at Nine Mile did have the leakage, and I don't think they were a part of this program because they were of smaller diameter pipe. Is that correct, Joe?

MR. ETHERINGTON: Would any of these cracks be detected by an old time boiler with this hammer?

MR. COLLINS: No.

MR. SHEWMON: We could talk about the way they used to use the hammer, but go ahead.

MR. BAER: It's a small diameter, but the safe ends were not a part of this program.

MR. COLLINS: To continue where Mohamed left off, the consensus then after review of this work that EPRI had done to characterize the samples, it was generally decided then that some groundrules should be set up; very simple groundrules.

The first one was that the ISI agency use -- they perform the test just like they would on a production weld and we would obtain copies of these procedures for during this timeframe. The level I and level IIs perform the inspection. That didn't pan out so well because as you already recognized, they sent a lot of their Superstars to examine all five welds, and Mohamed showed you any indications they identified. We wanted a copy of the raw data before they leave the plant and then, of course, the NRC will give the licensees the result as the final data is submitted.

Most of them chose to say this is our final data at that moment, and then we could render a judgment as to how well they did perform in their testing and the rating. And I will get into that in a little bit.

Also, they complete the grid with the specific requirement that they call out what they see as cracks or no cracks as (C) and (N) designations, as Mohamed has pointed out on the grid. Let me say this one thing and I will move on. In the performance capability, cracking was understood because that was -- out at the Nine Mile Point plant they understood this. However, there are some surprising results even with foreknowledge.

(Slide)

Some of the results -- the matrix we have involved 11 licensee ISI agency test groups. There were nine groups of the original matrix completed with a 9/4 type rating. What this simply means is the fact that of the nine groups, unsurprisingly there are four of those groups subject to retraining because of the failure to identify a significant level of the defects that are presently in the specimens, and it is based on the judgment of the group that these defects should have been seen by well-planned and established p.ocedures.

We still have this program ongoing at Battelle at the present time; we simply have not gotten through all the ISI agencies involved. But the results to date do infer that there is a need for establishing training and qualification programs for the ISI efforts over the long term.

To further elaborate on this somewhat extemporaneously, in looking at procedures, some of the procedures -- and this has been identified in the region -- the procedures are based on code requirements. And, of course, the sensitivity levels, the reporting levels, the recording levels that are in those procedures are significantly different from the amplitude conditions that you would normally see from these types of defects. And that is a significant situation.

MR. BUSH: Joe, a question you may address later, and if so, you can hold it until then. I understand that at least some of the teams or the companies not only use what I would call code procedures, code frequencies, et cetera, but they have additional ones that they may be using. They might use an L wave instead of an S wave, for example. Did you -- obviously, you accepted what they were doing, but did you do an evaluation of such factors?

MR. COLLINS: Not entirely at that depth. In fact, we still have the data I'm presenting here which is preliminary because I have to bring in all of the regional people back together, sit down and go through these different things. Because, just citing an example, in one instance of failure they did not identify anything. No indications apparent at all from their procedural approach.

This raises the question of what is the status of that plant now with the conditions which I will discuss with some of the others in terms of the generic issues we are now faced with. We have such things as have been pointed out before by Dr. Dau; the variances still persist, transducer sizes, plotting strictly metal path distances on details, plotting some of the other variances where we felt it was apparent to us the reasons they missed these defects.

One amplitude, as one sees it, using their particular procedures, was lower. They didn't fall within the bounds of code evaluation acceptance criteria, although very definitely cracks. And there are a whole host of these things that start to precipitate out of these approaches.

Another thing, there was less appreciation as to location. If the experience factor was a total -- and, I believe there had been an effort at the NDE Center -- the thin wall piping, the training and sampling on that and the examples now available on the thick wall piping, this should have become immediately apparent to them and they would have done a much better job and there would have been quite a bit of improvement here.

The other thing is what is shown by procedure is not necessarily what they do. There is a sublevel of effort that goes on thinking up here. We've noticed this finite following of that procedure was not accomplished in all cases.

MR. McCLUNG: Joe, could I raise a question? You say that in some instances the procedure was not followed. Was it observed that they were exceeding the requirements of the procedures, or perhaps not living up to the requirements of the procedure?

MR. COLLINS: In most cases, they were going beyond the procedure. Some of the level IIIs that were there recognized that there was an IGSCC problem in the plant because experience has dictated that to them and they have been involved.

They looked at these in that regard, taking things down on the 20 percent back level, changing transducers, looking at different angles, looking at other things that were within their repertoire of magic, if you will, to come to the conclusions simply because any thicker wall pipe, the defects have a different location as compared to the thin wall pipe.

MR. BUSH: What you're really saying is that if they rigorously followed the procedure the track record would probably be even worse.

MR. COLLINS: Yes. And one of the people who stood right there said do it like the procedure non-deviation. In reviewing the procedure it was predictable that they would not find the defects because they had not done a detailed cross-section plot of metal path conditions. And that is an absolute must in this situation.

(Slide)

Another one. We'll go on now -- how is my time? This is some of the summary results of the plant-specific inspections to date. Of course, as you know, Nine Mile Point, the status has been discussed with you. Monticello, we did 100 percent of the recirculation system piping welds. They were ultrasonically inspected.

The reason for this particular part, as was explained to us by the utility, they were changing their lagging. They were seeking the opportunity to do all the welds and to provide, recognizing what we were seeking is does a generic issue, simply because in the review of the Nine Mile Point there were no unique things presented by GE's discussion of their review of the plant conditions. Namely, the water chemistry conditions of the piping material, certification, all these other unique factors that may lead to why Nine Mile Point was unique didn't precipitate out.

In Monticello, they find one 22-inch recirculation header weld, which is an end cap to pipe, which required repair due to the IGSCC. This was confirmed by radiography, having both some circumferential cracks and some actual cracks. There were 12-inch recirc riser pipe welds. These were elbow to pipe welds. These required repair.

There is a story within this Monticello and it would certainly appear on the record.

In the first instance here, in the recirculation lines, some of the crack indications identified by the ISI organization, as I understand, were low level thickness, through wall, expressed at some 10 percent of the wall thickness that could be estimated with the state-of-the-art approach.

The decision was made to repair those four by the over-cladding technique, and the preparation of the surface weeped. They uncovered conditions which suggest in some instances the intergranular attack may precede the rupture mechanism in a step manner. That is my own speculation because as it was explained to me, these were small drops, weep type condition.

They had these four finished (indicating); this one was completed and proceeded to hydro to the requirements of the code. And diligent examination, visual examination, showed that there was another one that occurred. This leaves open to question: in spite of our efforts for performance capability, there is still something escaping. And I think the factor is reliability and certainly a need for establishment of a formal qualification program to take all of these conditions into account.

MR. BUSH: Joe, your one word was really on the strong side. Did you mean rupture or that you will certainly have through wall with substantial leakage? There is a difference.

MR. COLLINS: I think you'll have through wall, but these as they were explained to me -- there was a drop that would form, they would wipe it off, another drop would form, they would wipe it off. This brings into question the effectiveness of the leak detection system.

I am personally aware -- and I do believe on a personal basis that these will proceed through because they were in local conditions; these weren't continuous, apparently.

MR. BUSH: I have no argument with that. You used the word "rupture." "Rupture" infers that the pipe is going to break.

MR. COLLINS: I'm sorry if I said that.

MR. BUSH: I just wanted to clarify for the record what you meant.

MR. COLLINS: Should I say crack growth condition.

MR. BUSH: No question about that.

MR. McCLUNG: Joe, were the actual inspection personnel at Monticello the same individuals who participated in the qualification tests at Battelle, or is this the case where there were representatives at Battelle from the inspection agency?

MR. COLLINS: I asked that question directly to the inspection agency. They had done about a 30 percent level themselves. Also, -- but this is hearsay, but discussing it with them, it was a level I that called out the end cap problem, identified the end cap problem and caused them to take a second look. They did conclude that it was cracked. It was re-radiographed and confirmed to be cracked in the weld.

MR. SHEWMON: I didn't understand the answer to the question. You said there were 30 percent -- sort of about one-third of the people who took part in the Monticello inspection had gone through the West Jefferson program? What was this 30 percent number?

MR. COLLINS: The inspection agency that performed the work at Monticello, the people that performed that work at Monticello were at our performance capability test.

MR. SHEWMON: Thirty percent of them were?

MR. COLLINS: No, the two that were involved with Monticello. Two level IIIs. They did 30 percent of the work involved in this plant in inspection.

MR. SHEWMON: Okay.

(Slide)

MR. COLLINS: Hatch 1 -- .

MR. SHEWMON: How many more viewgraphs do you have?

MR. COLLINS: Oh, just the results of the plant findings to date.

MR. SHEWMON: Well, we're running behind

again. Thank you.

MR. COLLINS: I'll try to hurry. The UT inspection now in progress. They did select an original sample to start 19 recirculation system welds, and there are 11 RHR system welds. They do see linear indications. It's a question of is it IGSCC or what are these indications? They are found in the following:

There's one 20-inch elbow to pipe weld in the RHR. One 28-inch one, again, in the elbow to pipe weld in the reactor coolant piping. Four 22-inch manifold cap welds on the reactor coolant, and one 22-inch branch connection, which is the saddle type, on the reactor coolant.

This was performed with foreknowledge of the findings at Monticello. Because of these findings, they did an additional 19 welds in which they find favorable results. They are continuing -- the licensee is now continuing to evaluate this problem with respect to that plant. And, of course, some options, considerations for further characterizations of these indications and possibly further additional sampling examinations and the repair methods, should they get into that requirement.

MR. BUSH: Joe, you have no dates on those. Can you kind of put us in perspective as to did that occur -- and I think I know the answer, but -- was it two days, two weeks, two months ago, or what was the situation?

MR. COLLINS: This data was handed to me last evening.

MR. BUSH: I suspected that was the case.

(Slide)

MR. COLLINS: Quad Cities for the present time seems to have -- based on the sample seems to have escaped the problem for the moment. This represents a 10 percent sampling level of effort.

(Slide)

Millstone, one of the vintage plants. The systems, of course, are the recirculation system where they examined some 12 welds. The low pressure coolant injection is three, the reactor water cleanup was three, isolation condenser was seven, and there were two others that I must come back and fully identify.

The IGSCC was identified in one of the isolation condenser welds outside containment. I believe you will recall that that isolation condenser system was upgraded to a Class I, and this seems to be a continuation of the original problem found inside containment. There is nothing surprising there.

(Slide)

Gentlemen, that concludes what I have to say at the present time.

MR. SHEWMON: Do you have your first viewgraph again, or at least, on that you said that you thought there was a need for a formal training and qualification program. And what else? What other needs do you see or -- go ahead.

MR. COLLINS: I think Dr. Dau has covered a lot of these situations in the background. I don't think we've seen anything different here.

MR. SHEWMON: What I'm trying to get at, though, is what you think is needed to improve the quality of the inspection. One of your recommendations or comments has been there is a need for formal training and qualification.

MR. COLLINS: Yes.

MR. SHEWMON: What else, or what do you try -- okay. What else? Or is that the main need, as you see it?

MR. COLLINS: At this particular time, discussing the metallurgy, we go back in history and look at the whole history of the problem which has been discussed. I would make one comment at this point in time; that back in 1970 when we did consider the problem at Nine Mile, and looking at the situation of the chemistry controls in the plant, we recognized the partitioning effect of oxygen in the radiology. There was a potential for this to be a problem at that point in time.

The materials themselves were called into question on a generic basis. That was the implication at that point. We could go into that further if you care to at this point in time.

MR. SHEWMON: Any other questions?

MR. BUSH: Well, I don't expect an answer, but I guess my evaluation would convince me that so long as we have systems where the operator is a major variable -- in other words, he's the interpreter -- unless we could somehow or other -- and I'm not sure training is the answer -- raise the level of correct interpretation, we are going to keep facing this problem. It is not an IGSCC problem. I can cite it in several industries with several types of cracks. The Air Force has the same problem; they get 50 percent reliability detection, 95 percent confidence, about 90 percent of their teams and 10 percent or 95 percent confidence -- obviously, the individual is going to be a big factor, which I think is beyond the scope of what I&E can do but I don't know how we solve it.

MR. COLLINS: Well, my comment here on this training qualification was made within the context of the state-of-the-art of the work that is now ongoing. I think that can be improved.

I think that as new technology evolves, there is a good reason for training those people into that technology and transferring the technology through various approaches.

MR. SHEWMON: I think another big positive step has to be to have them indeed calibrate things. If they are looking for a crack, they do it on a crack, not on somebody's drilled hole.

MR. McCLUNG: I was going to raise the point that the techniques are very operator-dependent. We all recognize that. We look at validation studies at Battelle for those people who are in attendance. But as Spence pointed out earlier, there are probably quite a number of other people that will be actively scrubbing the pipe.

Are there going to be some steps taken to assure some sort of on-site certification or something to assure that the man doing the inspection has had the proper training, such as perhaps EPRI is providing, and as Dr. Shewmon indicated also, a variable within the calibration standard, whether you drill a hole or not or preferably, certification of the capability to find the flaw.

And another thing that's a variable -- there are many variables in ultrasonic examination that we recognize, of course, -- the validation should be performed by reputable equipment. There are variations in transducers and ultrasonic instruments even with the same name tag. And perhaps some consideration should be given to some on-site demonstration with the actual equipment that is going to be used, the actual operators and perhaps some realistic standards.

I wanted to raise the question with Mohamed. I've got my own opinion of the answer. There are some extensive specimens of IGSCC in smaller pipes. You don't have this sluggage rate in the large diameter pipes. How useful would the smaller pieces be in training or in validating an inspection of the 28-inch pipe?

MR. BEHRAVESH: It is hard to prove that they are the same. However, we have up to now no reason to believe that they are drastically different in terms of the characters of the reflectors.

Now, where IGSCC occurs in a large-diamater pipe is different than when it occurs in a small-diamater pipe. But the character and the characteristics of the crack, we find them to be very much alike on the basis of what we know today. What is available today is much better than what was available 2 years ago.

MR. MC CLUNG: So training on those specimens would give a big step up toward assurance that the man doing -- the person doing the job would be qualified?

MR. BEHRAVESH: Yes.

MR. BUSH: Let me make one point if I may. It's a point that Joe made, and the point that Bob inferred; that is, that there is a written procedure and the people who do well use the written procedure as a starting point to do a lot of things beyond that.

Now, as soon as you move to other teams in the same company that have that procedure but do not necessarily have that same approach to the problem, I think there is a very finite probability -- I would say a very high probability -- that their track record will not be the same, which means that you have either to modify the procedure to put in these little quirks of how you rotate or how you shift from one set of transducers to another.

And so any assumptions that are made that a given team and a given company who has done very well, that that will be on a one-to-one translation to another team from another company I think is in error. That's my personal point of view.

MR. COLLINS: Let me say something in defense of that. We did recognize that particular problem and made direct comments to the utility in this program. They willingly accepted it and recognized the fact was that that procedure must deal specifically with IGSCC, the techniques that they use must be corrected, and that that procedure must be updated, that training must go forth to their Level Is and Level IIs. And they didn't back down, they pushed ahead with it.

MR. BUSH: I agree completely with that. That has to be done because if you don't do it, I think you are simply back where you can have no common basis. We saw the same thing in the industrial cooperative program under PVRC.

MR. COLLINS: Dr. Bush, to go one step further, we did go through this monitoring program at the site with our regional inspector to assure ourselves that that transfer of information was actually duly outlined, and that work did go forward, and it did.

MR. BUSH: Very good.

MR. SHEWMON: That's all then. Thank you very much. You have my permission to go home and go to bed.

MR. COLLINS: It has been a long day.

MR. SHEWMON: Mohamed, you said that there was a move to get a cracked pipe in the hands of each utility. Is it the implication of that that it would be used for some of this on-site calibration and training that Bob brought up?

MR. BEHRAVESH: Not only was there a move, it's a reality now. They have had it for the last year or so. Now, what we have seen is that the people who have had it, the representative people from the utility, came, went through the workshop, and when they went home they took a specimen with them and they used that to further train other people within the utility. And although they own one specimen, they have access to a far larger number.

One specimen is what they own, but we give them a specimen as they want, and the majority of our specimens -- we are like a library -- the majority of our specimens on a given day are outside the center.

That is what they are using, and we are seeing the results of it. We are seeing the results of it, that the people are much more in tune with he problem of ultrasonic detection of IGSCC.

Now, there are good ultrasonic inspectors, but what it takes to make him skilled in IGSCC detection is what is now just becoming available.

MR. SHEWMON: Gary.

MR. DAU: I would like to make an additional comment to that. These samples were provided to the utilities as part of the BWR Owners Group. One of the observations that I made is that a lot of the people who have been at the workshops and who are working with these samples are the utility personnel that are working hard to upgrade their own skills. The majority of the ISI is still conducted by outside vendors. And I am not sure that we have gotten through the process of getting all that information to the vendors themselves.

MR. SHEWMON: Let me comment to the Staff. One of the reasons that I beat on you, and I guess will continue to, from the regulations point of view is it was brought u at the break that the utilities are under a lot of pressure to keep costs down. So the beam counters say, you go out and you get the cheapest inspection team that you can.

The cheapest inspection team is the one that uses minimum procedures, and the minimum procedures are defined by the code. So how we, in a sense, give the utilities the ability to go out and get a better procedure applied to their plant and pay for it is at least part of why it would be nice to have it in the form of regulations. Okay.

MR. BAER: If I could just add one comment. It relates particularly to the recent findings on Monticello. They observed -- their terminology was three types of cracks: ones they called axial; ones they called circumferential; and the ones that gave them the biggest problems that we know of, the ones that Joe referred to where they really didn't call, in some cases, didn't call a crack at all, or in some cases a very minor crack or the ones they called spiral. And I don't think that's really the right term, but the crack is very close to the weld itself.

I don't think -- maybe procedures would help, but I don't think it was a question of them trying to do a sloppy job. Apparently, it was really to get the right angle and distinguish a crack from a weld is really a skill that at least in most cases is not available.

MR. SHEWMON: I suspect losing pipes, I will kid you when you come down h.e about you'll find more by UT or by leaking, but it is still going to continue to be an effective way to find them.

MR. BAER: Yes. As a matter of fact, I don't even know if Joe is aware of this, we had the NRR/IE interface Wednesday before Thanksgiving, what they were using at Monticello on their latest hydro was a moisture-sensitive penetrant into the weld, one that they found -- this is beyond the ones that they discussed here -- was because the penetrant changes color.

And there were several others that they were evaluating then, and we didn't have any details. They indicated there was some indication of color change.

MR. BUSH: Just to comment, the question about significance came up. And about 2 years ago I persuaded the ASME group that was concerned with flaw evaluation to give serious evaluation to establishing how much you can stand with regard to having a crack in an austenitic pipe, because it was my assumption at that time that sometime in the next 3 or 4 years we were going to be faced with another large crack out at Duane Arnold and it would be very nice to have on the shelf the technique to evaluate this and say, well, we can buy 6 months before we have to make a repair.

It was really a question in the plant. I am sorry to say that we missed it by about 2 months. We had the procedure in hand. It had been approved to levels. It indicates you can afford to have a very large flaw in this material, but it really wasn't available at the magic time for Nine Mile Point. So we were about 6 months out of phase. I think it may help other utilities.

The idea is not to say, I can run this plant forever, but it may say, I can buy 6 months' time to the next long outage. And I think that is definitely a value.

MR. MC CLUNG: I would like to offer another comment relative to Dr. Shewmon's about the utility buying the lowest bidder to perform the inspection. Another point that was made in the comments data was the amount of time allotted to an examination of the weld and the variation in results. This also can be a factor of how much time a utility will allow an inspection team to get in and get out. We saw it took a great deal more time to do a valid job.

MR. BAER: It is partially economics, but there is man-rem there also. Once the inspector has gotten his quarterly dose, that is it for that quarter.

MR. SHEWMON: The last comment, Joe, and then we go on to Serpan.

MR. COLLINS: I just wanted to add something to what Dr. McClung said. There is a subtlety now existing. We have got to face it somehow, and I want to say this in support of the training qualification program. We cannot overlook the situation with regard to burnout of people. The slippage that occurred in Brunswick, there is a direct relationship there.

Secondly, the lowest bidder is one item that is pervasive in itself. The next one is that these levels are exceeding their dose. Third, there are younger people practically gun fodder now being trained to do this work, and we don't know where we stand with them.

MR. SHEWMON: On that cheerful note, we go on to what Research will do for us.

(Laughter.)

MR. SERPAN: My name is Charles Serpan. I am head of the Materials Branch in the Office of Research. I will be very brief at the outset today, and I expect that I will not take the full hour this afternoon describing our research programs.

What I want to do is simply start off and let you know that we are here, that we run research programs in nondestructive examination of materials, and we will show you what those are.

(Slide.)

The important programs that we have got are a large one at Pacific Northwest Lab. It's called Integration of Nondestructive Reliability and Fracture Mechanics. That program is aimed primarily now at piping inspection, but it also have very important pressure vessel components.

The principal investigator, Steve Doctor, is here today, and he will have the majority of the research presentation time. He is going to tell you what they've been doing in those programs.

This is a utiliation of SAFT-UT. We have transfered the work to the University of Michigan, and now we are attempting to get it in the field. This work is oriented at a much better resolution of flaws by ultrasonic testing, and we are working to make it a real-time detection as well.

I would like to drop down here to this program at Argonne. We have a large environmental-assisted cracking program. That has a small component in it of nondestructive examination, looking at ways to discriminate between intergranular stress corrosion cracks and geometrical reflectors. It is quite new, and it is not mature yet.

The rest of these programs, acoustic emission, eddy current, and the large steam generator tube integrity program, that is primarily eddy current, and I will not go into that at all.

MR. SHEWMON: What does "AE" stand for?

MR. SERPAN: Acoustic emission.

(Slide.)

I would just like to quickly introduce what we are up to in the research work related to Nine Mile Point. Pacific Northwest Lab has developed for us under that large program a lab characterization method and piece of equipment that is now in use at the EPRI NDEC Center for characterization of the actual transducers and equipment. This already says that.

The information has been published in NUREG/CR-2264, and those specific methods are being adopted and being written up as ASTM standards. So the work from the research standard is actually getting out into use.

PNL is now working on developing procedures, equipment, and personnel qualifications. It's the sort of thing Joe Collins needs to lay on people when they do this sort of work. We have already come up with the one NUREG -- I should say PNL has -- NUREG-2468, which is the state of practice review of ultrasonic in-service inspection of Class 1 piping.

They have also observed the trials at Battelle-Columbus, and tomorrow they will be starting making recommendations for update of I&E Bulletin 82-03.

Finally, I would just like to review again completely the things that we have underway that are related to the code and reg guide activities.

(Slide.)

The PNL research work was the basis for the code case N-335, which you have already heard about this morning, upgrading the rules for UT examination of similar and dissimilar metal piping welds. Reg Guide 1.150 was very generously upgraded. A revision of it at least was provided by the industry. We are now working on turning that into Revision 1 of that reg guide. We don't have a schedule on it yet, but we are working on that.

MR. SHEWMON: Is that going to come up again today?

MR. SERPAN: Yes. Jack Lance is going to talk about that. But the status is the industry's efforts on that have been transfered to us, and we are now in the process of reworking that to get that into the revision.

MR. SHEWMON: Jack Lance won't be here, but Gary Dau's going to do that.

Let me mess up your schedule some anyway. That is out as a reg guide. You can now offer a revision to that whenever you want to. It has to go through your internal review. It then goes out for comment?

MR. SERPAN: Yes.

MR. SHEWMON: And that, if you had the reg guide ready to send out for comments now, it would be Rev. 1 on the street and in force a year from now or 6 months from now?

MR. SERPAN: I would guess about a year.

MR. SHEWMON: That is even after you had it all written and internally approved?

MR. SERPAN: It's on that order because it has to go through CRGR, it has to come back through the ACRS. We do have to get the comments back in. So it has to go through all of that business.

MR. SHEWMON: I was thinking of that as internal. But you're saying after you have had it in your division approved, then it takes a year?

MR. SERPAN: Oh, yes. Or on the order of that. It is a long time to get all these people scheduled.

MR. BAER: And in fairness, Dr. Shewmon, as a reg guide to then there has to be some implementing piece of paper that requires plants to do it. A reg guide per se is not a requirement until somebody writes a letter.

MR. SHEWMON: Spence told me yesterday that it's possible that the ASME people could move faster, but I was skeptical. But he is probably right.

MR. BUSH: I said possible, not probable.

(Laughter.)

MR. SERPAN: To finish up, we have a reg guide on the books that we are attempting to work on ultrasonic testing of austenitic piping and welds. This reg guide is under development. What we are waiting for is research work so that we know what in the world to write and have it accurate.

What is going on at PNL right now is what is necessary to go into that reg guide, but again it's going to take time to get it out.

MR. SHEWMON: Is it possible that PNL could run a 1-day workshop for you or something to get industry input before it goes out for comments? Or what would be the mechanism there?

MR. SERPAN: We intend to get very intense with PNL right now in this area because I understand Warren Hazelton is in the process of upgrading, what is it, 0103-13, which is looking for stress corrosion cracks. And that certainly is looking at that information as well.

We are going to get PNL in. They might not even know that yet, but we are going to get you guys in very soon with Warren and the NRR staff and try to find out what it is your have, what you can transfer, and we will get the people from Argonne in as well. We will try to get those people in. If we can do it this month, I would like to. But you may not want to come back to Washington this month. But it's going to be very soon because he's working on it.

MR. SHEWMON: Some holiday at the end of the month may interfere with that.

MR. SERPAN: I am sure.

Lastly, within this area of code and reg guide activities, a lot of what we have to do is build up a data base of information for the code acceptance. We are working on that in the area of the eddy current, steam generators very much, and acoustic emission detection, in addition to getting all of this base data.

That's all I want to say right now. I want to turn it over to Steve.

MR. SHEWMON: The acoustic emission is the PNL?

MR. SERPAN: Yes. That's also PNL.

MR. SHEWMON: Let me make one comment to PNL.

You are PNL?

MR. SERPAN: Yes. But they're not the acoustic emissions people.

MR. SHEWMON: When Mohamed was talking this morning about getting acceptance by giving a physical basis for what he was getting in the UT, I guess, instead of just a statistical correlation, I hope that when he gets that procedure worked out he sends a copy up to the PNL people unless they have done better than they were a year ago.

MR. SERPAN: That's all I had, as I said, at this point. Oh, I am sorry, Joe.

MR. MUSCARA: Joe Muscara, NRC Research Office. Just a short comment in the acoustic emission work which was overlooked in the presentation. It is aimed at acoustic leak detection using acoustic emission for the characterization.

MR. DOCTOR: Since we are running behind, I have got about a half-hour's worth of presentation. I am wondering do we want to delay that since I am on right after lunch also, and tie those things together?

MR. SHEWMON: Why don't we go on. We'll do a half an hour now.

MR. DOCTOR: The vessel is scheduled for after lunch.

MR. SHEWMON: With an hour hiatus in between for lunch.

(Slide.)

MR. DOCTOR: I do have handouts. Greg and Tom, can you pass those out, please?

My presentation today is in the handouts. I would like to start off by first identifying the program. It is referred to as the integration of NDE reliability and fracture mechanics. I am the program manager. At Battele. Dr. Joe Mascara is the program manager here at the NRC. The program presentation will focus on what the programmatic impact is on Nine Mile Point and the near surface crack detection problem.

I will give a short review of early work, the work that went into the N335 code case. I will talk about the current work with regard to these two items, and some of the future work that we are involved with.

(Slide.)

MR. DOCTOR: In order to give you an idea as to what the overall objectives were of the program, to see how that provides data that impacts the two issues that are on the agenda today, the program objectives were to determine what current ISI reliability is in the field today using probabilistic fracture mechanics to determine what the impact of the NDE unreliability is, to evaluate what kind of improvement we can achieve with advanced improved NDE techniques, and finally, to take this information and work it into the appropriate codes.

(Slide.)

MR. DOCTOR: The scope of the work is specifically dealing with the effectiveness, reliability, and adequacy of ISI as it pertains to primary piping systems for service-induced cracks or defects and the pressure vessel with heavy emphasis on the near surface crack detection problem.

(Slide.)

MR. DOCTOR: I have one vu-graph here with regard to the early work that I wanted to kind of summarize, because I think it is extremely important. Most of the work is a series of parametric studies that are reported in the Phase 1 report, which is this NUREG-1696, published in October of 1980.

At that same time, we also incorporated these recommendations into a rule which was sent out by the NRC. Specific items that were addressed was calibration sensitivity. The recommendation was that the recording level should be lowered from 50 percent to 20 percent DAC, reporting from 100 percent to 50 percent. They recommended that they use a semicircular notch of a one-half aspect ratio depth allowed by the code.

In essence, these have been incorporated into the code case N335.

We recommended also that instead of a 45-degree sheer to use 60-degree sheer. We felt this made an improvement with regard to defects that were surface-connected but not normal to the surface. This particular item did not make it into the code case. We are still advocates, however, of it.

In the evaluation of the data with regard to sizing, we were unable to find a single technique that would provide very accurate sizing for all service-induced defects of interest. In terms of the existing code, the scan overlap was only 10 percent. We felt this should be substantially improved. Our recommendation was that on two adjacent scans we should get a recordable signal from a semicircular notch.

In essence, this is incorporated into the code.

We also on a parametric study came up with limitations on the size of the search unit. It became very evident from that data that if you use too large a search unit, small defects would be missed. We also made a recommendation with regard to the austinitic and dissimilar metal welds that the inspection of the procedures, equipment, and personnel should be qualified.

MR. BUSH: Steve, before taking it off, I think that was an unfortunate selection of words on sizing, because I think what you really mean is that no one procedure or technique will cover everything, but perhaps by combinations one could do it. It sounds as if nothing will work, and I don't think that is your intent.

MR. DOCTOR: That is true. Except in the case of IGSCC, we have not been able to find anything that has worked reliably with respect to IGSCC.

MR. MC CLUNG: On the recording levels of 20 percent and 50 percent which you indicate are in code case N335, are those requirements consistent with what we are seeing on these recent Nine Mile Point validation requirements? Will this find the IGSCC which is of concern?

MR. BEHRAVESH: I really don't like to -- by answering your question, I would be giving data away, and I can't answer that.

MR. SHEWMON: Bob, the good part is, I think, everybody agrees that it is a step in the right direction.

MR. BUSH: Well, I can answer it on the basis of the extensive British data. I still think it is inadequate. I think you really have to consider 20 percent in the near surface region, and I apply this across the board to almost all classes of defects.

MR. DOCTOR: I think these are very positive steps forward with regard to improving the current code.

MR. MUSCARA: They require 20 percent, but it also requires that if an inspector believes he is looking at a crack regardless of the amplitude level, he needs to record that.

MR. DOCTOR: That is true. That is in the code case. It, however, was not one of our recommendations that we made at that particular time. Since then, we will agree with that and we most heartily support it.

MR. BUSH: For the record, since it hasn't come up yet, the code actually regressed. For some period of time, it required 30 percent stack reporting. After a lot of arguments, it went to 50, 100 percent, which unfortunately I wasn't able to fight sufficiently. As I say, this is the first step, but it is a necessary step.

MR. DOCTOR: I have some data showing the performance of this with regard to the piping round robin data. Let's move on to that piping round robin, because this is the data that impacts the issue of Nine

Mile Point.

(Slide.)

MR. DOCTOR: The objectives of the piping round robin were specifically to measure the current level of inspection reliability as practiced in the field, to determine what the sources and the magnitude of inspection errors are, and thirdly, to determine what the information that is needed is in order to develop an inspection reliability model.

With that, then, one can extend the results to other conditions, such as different pipe diameters, different wall thicknesses, et cetera.

(Slide.)

MR. DOCTOR: The materials that were used in this piping round robin consisted of ten-inch Schedule 80 containing thermal fatigue cracks, ten-inch Schedule 80 IGSCC, centrifugally cast stainless steel, and a carbon steel that had a stainless steel ID cladding. These are materials that are used in the primary piping systems in all U.S. reactors.

(Slide.)

MR. DOCTOR: The test matrix that was developed is shown here. We wanted to evaluate not only the current field practice that was being employed. We also wanted to evaluate improved procedures that we developed there at PNL. The inspection conditions were laboratory and difficult, laboratory meaning the specimens laying on a bench; the difficult condition was the specimen was in a very awkward position where the inspector had a difficult time making measurements, seeing both where his hand was located and the scope at the same time.

The numbers shown here reflect the number of trials that each of the inspection teams were subjected to, numbering about 250. There were six inspection teams, so we are looking at roughly 1,500 measurements.

One condition that is shown here is near sight and far sight access. Near sight would be like a pipe-to-pipe weld where you could see the defect without going through the weld itself. Far sight access would be similar to a pipe-to-component weld configuration where, in order to see the defect that would lie on the component side, the ultrasonic beam had to traverse through the weld itself.

(Slide.)

MR. DOCTOR: Very quickly, this is an example of one of the typical test specimens. This happens to be a piece of the clad faritic. This is the cladding shown here. The pieces are roughly 18 inches in length and about eight inches in overall width.

(Slide.)

MR. DOCTOR: What is shown in this next vu-graph is the difficult inspection position, as you can see. This is a ten-inch pipe located here. The inspector is actually laying on the floor to perform the inspection.

This happens to be the level 2 making the inspection. Level 1 is recording the information. Typically, a level 3 does the evaluation, as shown here. We have an observer that was present during all inspections. The key thing here is that the level 2 is making the decision as to what is to be recorded for further evaluation by the level 3. That is an extremely important point, because if he doesn't record something, then the level 3 has nothing to evaluate.

(Slide.)

MR. DOCTOR: In order to address some of the concerns about the team members that participated in this round robin, there were a total of six teams, so we had six certified level 3's, level 2's, and level 1's. We have got in a tabular form here the average experience in years for each of the inspectors, ranging from four to 23 with an average of 10.2 years.

The average number of PSI's and ISI's that the level 3's participated in was 28. The range was from seven to 62. The level 2's were quite experienced: as you can see here, 7.4 years of experience; 16.7 inspections that they were involved in. And, of course, the level 1's were very inexperienced.

Again, I point out that this is a very key element right now in terms of if this gentleman does not record something, it will not be evaluated.

(Slide.)

MR. DOCTOR: Now, I have got to establish two definitions, because I am going to be presenting some results that are really the heart of the work. These are recording probability. The recording probability is the probability that the signal from a defect will exceed the recording threshold. Second, there is the probability of detection. This is the probability that the signal will be recorded and correctly interpreted as a defect.

Those are the two parameters that you are going to see plotted in the next seven vu-graphs showing the results of the round robin.

(Slide.)

MR. DOCTOR: Okay. This particular vu-graph plots probability of detection. This is the probability that you get a recordable signal and that it is interpreted as a defect versus percent through wall for clad faritic near sight access condition, and this is the field condition. We termed this code for these plots. It is a condition for which the teams would actually be employing while they are making a conventional inspection.

This is an average performance for all six teams that participate in the round robin. You can see here that basically for something that is about 15 percent through wall, there is roughly 80 percent probability of detection. That is quite good.

(Slide.)

MR. DOCTOR: The improved procedure is shown here, again, for the same identical conditions. The only difference between this and the previous plot is that in this particular case we have had them lower their recording threshold and also record anything that they thought was a crack. In all the trials that were conducted, they found every defect except for one.

In terms of false calls, that is what is shown plotted right here (indicating). They had about a 5 percent false call rate. That means five out of 100 specimens would be falsely identified as being defective when in fact they were not.

If you look at the comparison then between what they have performed here with their field procedure and the amount of improvement that we obtained simply by making those two changes, namely, lowering the recording threshold and calling anything that behaved like a crack, this is the performance that they obtained. It is a rather dramatic improvement, very nearly 100 percent, 96, as a matter of fact, for something that is 10 percent through wall, extremely good performance.

(Slide.)

MR. DOCTOR: We also evaluated the far sight access condition, what happens if they have to look through the weld and have the adverse properties of the weld interact with the beam. We wanted to try and determine what that effect was so we could look at the pipe to component type of weld configuration.

What is plotted here is that performance for far sight access, you see that they were roughly operating at about an 80 percent level of detection.

(Slide.)

MR. DOCTOR: Now, if we go on to centrifugally cast stainless steel, recognize that is not the Nine Mile Point situation, but it was one of the materials that we used. We want to have you observe that we have got defects that range roughly up to 40 percent through wall. This is the best performance of any team that looked at the centrifugally cast. Two teams declared it a no test. They felt they could not detect anything. And after going through part of the examination, they just said, we are not going to look at any more, because we absolutely cannot find anything.

The other three teams that were in the round robin ranged roughly here between 10 and 20 percent. This particular team has the appearance of working well. The difficulty here is that their false call rate is 50 percent. So they are essentially saying that 50 percent of the clean material is in fact defective.

So, what that does is, that essentially gives you an offset, a bias to this information. In effect, their actual performance is really ranging at best at about 30 percent, because if you look at the recording probability, every time they recorded something, they essentially called it a crack. So, in essence, you can shift them down and they really didn't do any better than any of the other teams. They just simply had a high false call rate that biased the information upward.

MR. SHEWMON: Stainless steel castings come in pump casings for Westinghouse plants. Is that right?

MR. DOCTOR: This is also primary piping for Westinghouse.

MR. SHEWMON: Westinghouse centrifugally casts their piping, too?

MR. DOCTOR: That's correct. What we are finding here is that in essence, you have got a very poor probability of detection for any kind of defect out to 40 percent through wall, a very low probability of detection for that material.

MR. SHEWMON: But the good news is that since it is faritic and it is PWR, there is not a track record of IGSCC. Is that right?

MR. DOCTOR: That is correct. To my knowledge, they have never found any cracks in the centrifugally cast stainless steel primary piping.

MR. MC CLUNG: Excuse me. You probably said this, but is this in the base metal, or are these flaws in the welds?

MR. DOCTOR: These flaws are all located from the edge of the weld root outwards. They are also all circumferential in nature. We have no axial welds in the data base -- excuse me, axial oriented defects in the data base.

MR. MC CLUNG: Coming from some who have performed some of the examinations, they felt they could get sound through the weld more easily than through the base material.

MR. DOCTOR: That is correct. The grain

structure within the weld is much smaller than the grain structure from the other metal.

MR. STONE: I just wanted to add a question. Is what you are showing here what you would term your near sight access team?

MR. DOCTOR: Yes, that's correct.

MR. SHEWMON: Onward.

MR. DOCTOR: Let's move on, then, to the material that pertains to the Nine Mile Point.

(Slide.)

MR. DOCTOR: What I have plotted here is the performance of the six teams, shown here by these various symbols. The thick, solid line here is the performance of the average of all six teams. We are plotting probability of detection versus percent through wall. The conditions are the IGSCC near sight access and the code or field practice.

As you can see, there is a fairly large variation here. The important thing to note is that in essence all of these teams were using an augmented procedure. This team located down here, the lowest one was using a code minimum procedure. So if one were to look simply at this data and reflect on performing a code minimum inspection at Nine Mile Point, your probability of detection is essentially 10 percent. You wouldn't expect them to find anything.

Furthermore, the false call rate exhibited by these teams in all cases -- I haven't plotted it to try to keep the graph from getting cluttered up with some additional samples, but they all range between 20 and 40 percent.

MR. MC CLUNG: Do you consider these to be the superstars from the various inspection agencies?

MR. DOCTOR: No. What we did when we set up the round robin was, we requested the teams provide us with a list of people that we could choose from. In two cases we had to take teams that were available. In the other cases, we had personnel to select from. So, yes, there were some superstars in there, but once you have some of those as well as some of the others, you could see from those tables in the amount of experience, the level 3, for example, had four years' experience up to 23 years of experience. So it spanned a rather large range, the average being 10.4 years.

MR. SHEWMON: You say the mean false call rate was 20?

MR. DOCTOR: Between 20 and 40 percent for these range.

MR. SHEWMON: On that last graph, that meant you drew your curve through there; now you draw it through zero. It is just how you felt that day, or your draftsman?

MR. DOCTOR: We are doing two different fits here. For the centrifugally cast, we had so little data that we simply connected the points together. In this particular case, what we have done actually, these points that are shown here are not the real data. What we have actually done is to take the real data, and we have made a fit to that data. We have used essentially what they called a probe it curve, which is the integral of the normal distribution.

The data is actually scattered around, and I will be showing you some graphs of what that kind of scatter distribution looks like. If I put all that data on here, it gets so confusing you won't be able to see anything.

MR. SHEWMON: That is beside the point of whether the curve should go through the zero, because that is where the probability interval goes to zero, whether it should go through 25 percent, because that's the most probable value of zero percent through wall. But go ahead.

(Slide.)

MR. DOCTOR: The other type of defect in the ten-inch pipe is shown here for again the same conditions as were seen in the previous vu-graph, except now these are thermal fatigue cracks. Thermal fatigue cracks are different from the IGSCC in terms of, we can place those wherever we want. With regard to drawing IGSCC, wherever they grow, that is what you take. We place defects from the edge of the root out to the break on the counter bore. We can also control the aspect ratio of them, and also these cracks tend to be very conservative because they have a very large residual compressive stress which reduces the amount of ultrasonic reflectivity that one obtains from those cracks.

We have again plotted the six teams here. With regard to the thermal fatigue, there is a correlation with the previous vu-graph in that this is the team that was using a code minimum procedure. The rest of these teams were using augmented procedures.

(Slide.)

If we sum together the performance for the previous two vugraphs and lump them together, this is the type of response we get. We say all ten-inch; that means both intergranular stress corrosion cracks and thermal fatigue cracks. This is the code minimum down here. These are the augmented procedures.

Okay. Now, that's one of the things that I think should be commented on with regard to the IE Bulletin 82-03, that with regard to the type of demonstration that they were performing you are going to eliminate people using these types of procedures, from using those in the field.

However, if you look at the overall performance based on this data base, you are certainly not going to be too happy about the performance here with regard to, oh, roughly 45 or 50 percent detection for cracks that are substantially through-wall. This is the near-side access condition.

MR. SHEWMON: Do you have any idea of what fraction of the cross-sectional area was flawed when you went through the wall in your test?

MR. DOCTOR: I don't follow your question.

MR. SHEWMON: I don't think it was very coherently asked. What I'm trying to get at is the fact that a pipe may weep may not make it unsafe. That is in a sense what Spence says they're not trying to quantify. It's not something one wishes to encourage, but you can imagine a very circuitous path through the wall which messes up an insignificant section of the cross-sectional area, and if that was the kind of flaw you had in there then I am not as bothered as if you say, gee, we had taken out what we generated, half of the ligaments in the cross-sectional area, through that pipe or around the circumference.

MR. DOCTOR: All right. In response to that, with regard to the thermal fatigue cracks that we placed --

MR. SHEWMON: SCC.

MR. DOCTOR: With regard to intergranular stress corrosion cracks, we have not been able to analyze those defects. So I can't answer your question as to -- there is intergranular attack to the curves kind of where the crack tip stops at, and whether or not that goes all the way through we don't know at this particular point.

We are doing some advanced technique assessments to see if we can't achieve significant improvements in these particular plots. So I don't know exactly what that cross-sectional profile looks like at this time. We are hoping to have that available by the end of the first quarter of the new calendar year, because we will be through with all of our advanced technique assessment at that time and I will be able to answer your question then.

(Slide.)

The next vugraph that I wanted to put up is a vugraph that shows essentially data that was collected under the same conditions as the previous vugraph. However, in this particular case they were using improved procedure. The improved procedure essentially amounted to going to a small transducer, low frequency with a lowered recording level.

Now you can see that in general we have a tighter clustering of the data. The average has substantially improved. However, you can still see a very large variability that exists even with this data, where everyone was using the same procedure and the same probe.

What this indicates, I think, is the variability that one has to contend with with regard to variations from team to team. I think that is one of the good justifications for why one needs, for very operator-dependent systems, to qualify those particular team members, so that you can at least establish a minimum level of performance for them that they all have to meet to tighten this cluster up.

This type of variation simply, I think, is too large to have in any kind of a reliable inspection out in the field.

(Slide.)

With regard to the far side access, with regard to the ten-inch, this is the kind of performance we achieved. This shows the type of scattering of data that we have. This shows the fit to that data, and this is the false call rate that the six teams obtained. If you look at this, essentially their false call rate was equal to their best call. So our conclusion is that they really cannot see defects on the far side of the weld.

We have done experiments with regard to mapping the energy trasferred across the weld and it simply does not go to the regions where you are anticipating it being located. Correspondingly, you are not seeing defects that you need to find.

MR. SHEWMON: You can hurry on towards your conclusions.

MR. DOCTOR: The Nine Mile Point's three comments are shown here.

(Slide.)

I think that based on the results that I have shown, we can certainly say that the people at Nine Mile Point, when they made their inspection in '81, were certainly not using an optimized technique, because the probability for detection was substantially greater than zero. If in fact there were a substantial number of defects in the piping at that time, it would appear that they should have at least seen some of those.

If they were performing, as Mohamed indicated earlier, a minimum code type inspection, based on the data that he showed, the results that I showed, the performance of a minimum code inspection would simply not have found anything.

We feel that the piping round robin results and also the Nine Mile Point demonstration establishes the need for trying to reduce some of the variability that exists in the data. We feel that the bulletin and also the demonstration is a significant thrust in the right direction to try to resolve some of these variabilities.

(Slide.)

The conclusions of the round robin are in this vugraph. We can simply say that for the clad ferritic we think you can have a highly effective examination, essentially at 100 percent, by simply increasing the inspection sensitivity. Inspection from either the near or the far side for that material is extremely good.

For centrifugally cast ultrasonic alloy, to date we consider that material to be uninspectable. We tried radiography with regard to it and did not get results any better than what we found with the UT. We have done a little bit of work with SAFT UT and we've gotten some encouraging results from that work.

With regard to the rough stainless steel, the feeling is that current field practice for inspection of the far side is totally ineffective. We found that with our improved procedure we had a modest improvement, effectively 20 percent.

MR. SHEWMON: Is that on near or far side?

MR. DOCTOR: That's on near side. If you look at the matrix, we only tested that for the near side inspections. Certainly you're going to miss code rejectable defects. It is not as effective as 50 or 60 percent POD for something halfway through-wall.

MR. SHEWMON: What is code rejectable in stainless steel piping?

MR. DOCTOR: The code asks you to calibrate on a ten percent notch. That is your reporting level. Anything that exceeds that is what is considered code rejectable. They don't tell you what a minimum kind of defect is, but anything that exceeds that reporting level should be rejected.

MR. SHEWMON: This is independent and ten percent of the wall thickness?

MR. DOCTOR: That's correct.

MR. CHENG: That's not quite true.

I am C. Y. Cheng from NRR.

Actually, the code does provide a table for different ratios, but the different flaw sizes vary around 10, 11, 12 percent. So it's not always 10 percent.

MR. DOCTOR: Yes, but it's approximately that.

MR. SHEWMON: Okay, thank you.

MR. DOCTOR: The bottom line here is that there is a large variation and we feel that through efforts of training and qualification of the personnel, procedures and equipment, you can reduce those. That is the summary remarks that I had for the piping round robin work performed at PNL.

MR. SHEWMON: Thank you. It's been an interesting program.

Why don't we adjourn until 1:30 -- recess. Pardon me, I used the wrong word.

(Whereupon, at 12:35 p.m., the meeting was recessed. to reconvene at 1:30 p.m. the same day.)

AFTERNOON SESSION

(1:35 p.m.)

MR. SHEWMON: Are we about ready, aside from the fact that there is nobody but me here from the ACRS? Now we have just doubled the number here.

MR. MC CLUNG: Butch is here in spirit. He is back.

MR. SHEWMON: That's so nobody will take his chair, I guess.

Now, my agenda at least says this afternoon for the first part we concentrate on Reg Guide 1.150. The actors are Serpan, Doctor, and Dau. Is that about right?

MR. DOCTOR: Yes.

MR. SHEWMON: All right, go ahead.

MR. DOCTOR: Thank you, Paul.

(Slide.)

I am going to be talking this afternoon about first near-surface crack work because that does definitely impact the Reg Guide 1.150. I think there are a couple of basic important points that should be kept in mind. It is important to detect small near-surface flaws because of their potential adverse effect on vessel integrity that these may have during a pressurized thermal shock event.

Field procedures that are currently in practice typically gate out the near-surface region. Current ASME Code procedures are not sensitive to the near-surface defects. Regulatory Guide 1.150 tries to address this particular problem but does not specifically solve it. If we look at work that has been performed elsewhere, Europeans did have the problem of under-clad cracking and have developed specific probes to reliably detect these cracks.

TNL, at the direction of the NRC, was to evaluate the European techniques for their applicability to U.S. pressure vessels.

(Slide.)

Now, in terms of the techniques that one should consider, these are shown here. There is a near-transducer L-wave, a longitudinal or professional air wave that is used by the Europeans. It's by far the most predominant technique used by them. In the U.S. people are using this technique as well as a single transducer L-wave, shear wave. The Europeans, primarily the French, have utilized focused transducer. And the other way you can inspect is using a full V-type of inspection mode.

I am going to present results, make a comparison of these techniques here. We are going to be evaluating these two but not have done that as yet.

MR. SHEWMON: These two were the focused and and the full V?

MR. DOCTOR: They were focused and the full V.

(Slide.)

Obviously, the thing about the U.S. reactors that make them unique is the fact that they have different surface roughness conditions on the IV clad. The surface roughness impedes the inspection. What we have taken --

MR. SHEWMON: That's because the Europeans have machined theirs since year one and we never have?

MR. DOCTOR: That's correct. There has never been a requirement on U.S. vessels as to the quality of that IV surface finish. The Europeans have a very strict specification for that. Some of the real old European plants didn't, but essentially the last 10-15 years all of those do have a very tight specification on them.

We have evaluated several different techniques with regard to coming up with an assessment of what that surface roughness is and its impact on inspectability. I will be talking about the use of an LVDT linear voltage differential transformer for measuring surface roughness.

One of the things that we have found to date in terms of the surface roughness is that the clad block must have the same surface roughness condition as the areas that are to be inspected, which is really restating what is already in the code.

(Slide.)

In the LVDT approach as shown here, what we have plotted is surface amplitude in mils, which is in this case 1/1,000ths of an inch. It ranges from plus or minus 50 mils for the vertical scale, and we are just showing you a representative scan across the weld clad beads for a 4-inch length.

What we would do is go in on the surface of our specimen, make a number of scans, and then compute an RMS average for that. What is shown in the lower portion here -- I hope all of you can see this -- is the as-clad condition. The estimate that we came up with for the RMS roughness of that surface was 12.6 mils.

When we did a light grinding on that surface, we essentially knocked off the tops of these peaks here, and it's shown here by the flattening that occurs. A relatively minor amount of grinding produced a roughness of about a factor of a half. I will show you the results that were taken on specimens with this roughness versus this roughness condition (indicating).

You should note that if one is using a 1-inch probe in terms of length, if we were to place it in context, the surface, it would only be contacting it in a few places, whereas if you put it on this surface, you can see that there is quite a bit of contact.

(Slide.)

The result of that is shown here. If one does a simple analytical beam tracing approach, you take a perfectly ideally smooth surface and map the rays coming out, it should form a curve roughly like this.

The two surface conditions that I just showed you in a previous vuegraph are shown here in these two vuegraphs. This is the one for which the grinding has been applied to the surface. You can note that there are quite a few rays that are still coming through, and most of them are still concentrating in this area. If we go to the as-welded condition, you can see that very few rays get through and the rays are literally scattered all over. So your beam has been totally broken up. It's like going through the fraction grading.

So when you try to perform an inspection on this surface, the sound field that actually gets in to where a defect might be located is drastically different from what you would like it to be.

(Slide.)

Now, we have conducted measurements using a number of different approaches. For the as-clad manual metal arc using the stiff procedure, we went through and we evaluated 70-degree shear single, 60-degree shear single, and 70-degree longitudinal dual for the as-clad condition. Using these two probes, we were not able to detect any of the signals. They were way down in the noise, and they could not be recognized as clearly originating from a defect.

Using the 70-degree longitudinal, we were able to detect all 24 of those particular defects. If we come up with an average response relative to DAC -- DAC is simply our calibration, our reference level -- we obtain a level of plus 1.1 dB. One thing you have to keep in mind was this was at the optimal location for that particular response. If one was just randomly scanning, it is unlikely that you would hit that particular point. With the roughness that was there, this signal jumped around very dramatically from spatial position to spatial position.

So even though we were able to detect these, it took a very concentrated effort in order to pull out those signals. It had essentially a small ratio.

MR. ETHERINGTON: Is there a simple explanation as to why such a small change from 60 to 70 makes such a big difference?

MR. DOCTOR: For between here and here?

MR. SHEWMON: Single and dual.

MR. DOCTOR: Yes. And it's also the wave length. This is the shear mode; this is longitudinal.

MR. ETHERINGTON: Oh, yes, yes. I was reading the wrong column. I am sorry.

MR. SHEWMON: The dual is inherently quieter because it's not casting and receiving both?

MR. DOCTOR: It's zone-focused, so it doesn't see a lot of back-scattering of the curves. That's one of the major things. The other thing is that it is longitudinal and you have a longer wave length, which means it tends not to get as much back-scattering.

MR. SHEWMON: I have heard something developed at BAM that they call a schlong or a snake. BAM has a procedure which is a two-crystal which is separated. Is that what this is?

MR. DOCTOR: Yes. That is what this technique is. I just never heard it referred to as a lang.

MR. SHEWMON: Pardon me. I am probably wrong then.

(Slide.)

MR. DOCTOR: If we go in and now look at the ground condition, ground clad, we smooth the surface up, what is the effect? The number of cracks that were not detected, as you can see, from the 70-degree shear, seven were missed; 60-degree shear, six were missed. Using 45-, 60-, and 70-degree longitudinal, none of the defects were missed; all 24 were found.

What I mean by "defects," I should have stated this earlier, there were 24 cracks that are roughly 1/2 of an inch deep with approximately a 1-to-3 aspect ratio. They are grown by a variety of different techniques. That's what we're talking about in matrix 1. We're using these to determine what are the best crack-growing procedures, but they're all roughly a half-inch in depth.

MR. QUINN: In the paren metal?

MR. DOCTOR: Yes. That's going from the base metal interface now. It does not extend through the cladding.

MR. QUINN: That's metal arc weld cladding again?

MR. DOCTOR: Yes. All this is on manual metal arc. The slide before this was the unground case. This is the ground case with the 12- and the 6-mil RMS roughness.

The thing of importance is to look at this lower column with regard to the amplitude of the detected cracks relative to the DAC level. In the first three techniques they were a negative below the reference level. So if you were scanning with just a 60-dB increase, on the average you would see about half of these defects coming above that level and half would be below that level.

Correspondingly, with these two techniques, the average was plus 1.2 and plus 2.7. So all of these, if you were scanning hot, would have been actually detected. I think that's a very important point.

Based on this work, we feel that the relatively minor amount of grinding of the surface roughness of like 6 mils is really a still rather rough surface. If you look at pictures of it, it is rather gross. You can see it from that profile. And yet by using these techniques we are finding that you getting a very effective inspection for these half-inch depth defects.

When you go to correspondingly smaller defects, we are going to have to evaluate, and that is one of the next things we will be doing is evaluate the performance of these on the smaller defects.

We are also looking at how much grinding does one really have to do before the surface is considered inspectable. It is somewhere between the 12 and the 6.

We don't know where that is right now, but we feel that by running some additional experiments, we can tie that down.

(Slide.)

We have also been doing some work with regard to depth of defects. We are showing here the response for a number of notches that were placed into a block in which we actually know what the depth is. We go in and measure the depth using the 60 longitudinal. You can see this correlates very nicely. We have an extensive amount of data for 40, 60, and 70 degrees on cracks.

We have not done the destructive assay, so we don't know the correlation is. But on a couple of selected samples, it looks like it's going to be pretty good.

(Slide.)

I would like to conclude this discussion with regard to the near-surface crack detection with this summary vuegraph. Our conclusion is that the European technique -- namely, 70-degree longitudinal dual -- is very effective for very smooth surfaces. When we get to the unground manual and the single-wire case, the performance is marginal.

You have to do some grinding, we feel, in order to have a reliable inspection. Somewhere between that 12- and that 6-mil RMS roughness looks like the numbers that are in the ballpark of the requirement. We comment here that we feel that is really a relatively minor amount of surface preparation in order to get a rather dramatic improvement in terms of inspectability.

We firmly feel that all the clad vessel surfaces must be characterized prior to the inspection in order to ensure adequate inspection sensitivity because if it varies from location to location, if you're not making an appropriate adjustment in terms of changes in the surface roughness, you may not be performing a reliable inspection. So that has to be verified.

We feel that we need to specify calibration reflector criteria and flaw recording levels. Right now the 2 percent ASME notch is what is currently recommended by code. We feel that that is not adequate.

We also feel that with regard to near-surface techniques, right now until we get through with all of our analysis, those inspection techniques need to be evaluated by a test, qualified by a test.

MR. SHEWMON: Go back to the next to the last one again.

MR. DOCTOR: What I say here, in looking at -- the Europeans use a flat-bottom hole. We have evaluated the flat-bottom hole by taking one block that was made all at one time so things are pretty uniformly laid on it in terms of the manual metal arc concept. We drill in a whole series of flat-bottom holes according to the best we can do with regard to getting them aligned.

We found a 12-dB variation from one to another. That is the range of variability. That means the sensitivity of the test varies by 12 dB depending upon which one we select as our calibration reflector. We do not feel that is adequate.

We also looked at the 2 percent notch in the ASME code, and we do not feel that that is adequate. The thing that we have found that is the most reproducable is a 1/16th-inch side-drill hole. We have found variability of, at most, 5 dB on a series of those side-drill holes that we have placed in place. So that is what our recommendation is.

Then, based on that calibration reflector, that then says what the flaw recording level should be.

MR. SHEWMON: I have also heard people talk about the variation from one heat of steel or one plate of steel to another. Have you done any work on that, or do you have any recommendations on whether you could have a big difference between combustion circa 1968 and something else?

MR. DOCTOR: That's base metal. The reflector we are talking about, if this is the clad, let's say, here, and this starts the base metal, you'd place your calibration detector at this interface, so the only thing you're actually seeing is the cladding effects. The base metal properties have essentially very little impact. The dominant effect that we have found has been the surface roughness.

Now, once we get that down, there may be, you know, some variations within the cladding that we have to look at. We feel that there is going to have to be some kind of a verification test with regard to the amount of noise level that's produced on the A-scan after you've calibrated and gone back out on the reactor to verify that there are not any unknown properties like porosity that will possibly impact inspection.

MR. BUSH: Steve, a quick one. On the round-bottom holes, the amplitude or the signal is going to vary with the diameter of the holes. How many millimeter diameter holes?

MR. DOCTOR: 3-millimeter flat-bottom hole.

MR. BUSH: The Europeans use two different sizes pretty consistently.

MR. DOCTOR: It turns out that if you actually plot out the amplitude response from that, the curve comes out and goes up on each side and gives you the sensitivity of the test. The problem is that you've got, you know, orientation effects from the flat-bottom hole that are difficult to reproduce. You want them all to be normal, and it is extremely difficult.

(Slide.)

With regard to Regulatory Guide 1.150, our comments are that the current guide, as it is written, is not adequate. We feel that the implementation of the guide would not necessaily change current inspection practice. The reason for that is that it does not demand that you have to inspect the interface for under-clad cracks. It simply says you have to estimate those areas where you cannot detect -- or, excuse me -- estimate those areas that you cannot inspect, but it doesn't say that you have to inspect all of it.

Secondly, the reg guide contains what we consider technical requirements that really do not provide any useful information. For example, the unloaded pulsar output voltage, I being an electrical engineer can find no useful use of that particular information.

In terms of the ad hoc committee which Gary Dau will be talking about, we are very definitely in support of their recommendations. We think they are necessary. We think they do provide a technically better document, and that those changes should be incorporated into the Reg. Guide.

We do, however, feel that there are some additional areas for further improvement. Neither document references a minimum size defect to be detected at the clad base metal interface in terms of a minimum. We think that is something that is necessary, and particularly if you are going to talk about demonstrations as they are down here with regard to the ad hoc committee recommendation.

As I indicated earlier, the 2 percent notch based on the measurements that we have made and the correlation of those with regard to adequate sensitivity and reproducibility of that sensitivity for the examination, we feel that the one-sixteenth inch side drill hole is in fact better.

According to the way they have written the demonstration in the ad hoc committee report, we don't feel it is well enough defined for implementation. It is fairly vague on what they mean by that.

Those are the only comments that I really have at this particular point with regard to the Reg. Guide. What I would like to move on to is addressing what I feel would be improvements with regard to the IEB bulletin 82-03, that calls for demonstration.

MR. SHEWMON: Leave that on a bit. Let me talk to the group here. It seems to me one of the things we ought to consider doing today, or whether we want to do it today, is to urge the NRC to go ahead and put this revised 1.150 -- sorry, put the industry recommendations out as soon as we can, or study it, or what else should be put in it.

Let me lay that on you as a charge, if you will. So, as you look at these things, look at them with particular concern or interest, because there will be a short quiz at the end of the meeting. Okay?

MR. BUSH: I don't have any problem. I have a strong opinion as to what I want.

MR. DOCTOR: I am sure Gary Dau is going to go into this issue again when he makes his presentation, and perhaps there will be more discussion that will surface at that time.

(Slide.)

MR. DOCTOR: In regard to the question of the IEB bulletin 82-03, we feel that there are things that can be done to improve that. Ultimately, we feel that qualification is the end product of what they are striving for because the bulletin as we see it, a demonstration will eliminate very ineffective techniques, but it does not do anything to guarantee that in fact you are performing a very effective, reliable inspection out in the field.

We think that the qualification with an objective of providing proof of detection reliability by test is really what you are striving to achieve. The scope of that really applies to all of the nuclear components in the system, but specifically these are the ones where the critical problem currently exists, and these are the ones that are being highlighted and addressed, although it should be easy to expand it to include all the system.

(Slide.)

MR. DOCTOR: The critical elements that we see in qualification are the following. One needs to qualify independently equipment, procedure, and personnel. With regard to equipment qualification, we are talking about coming up, if you recall earlier when I was talking about the piping round robin results with recording probability. That is the probability that you get a response from an indication that will exceed the recording threshold. That can be determined by laboratory tests.

The procedures in a like manner are determined by laboratory tests. You can simply take the transducer and set it in a location where there is a known flaw and simply observe what the response is and come up with how well do these two work together in order to get, one, a large response with a good signal to noise ratio.

The third is personnel. Personnel is, given that you've got this level of performance, how efficient are they at using this, and how well are they able to interpret the information in order to make a correct call, a correct decision that it is a crack when in fact it is, and when in fact it is a geometry, that it is a geometry. That is a probability of detection curves, and that is determined by blind tests.

(Slide.)

MR. DOCTOR: I have redrawn that in a different form which I think may be a little clearer for people to understand. If we look at these critical elements as I have designated them, equipment, procedure, and personnel, one specifies performance parameters for those. These performance parameters in the case of equipment would be the transducers, the pulsers, and the receivers.

One then wants to ensure that for a reliable, reproducible measurement, that from one examination to the next, the system has remained in variance or it has changed only marginally. The way to do that is look at what the impact is of that on the recording probability curve. If it changes and deteriorates the curve, then it would deteriorate below this.

Procedure in a like manner has performance parameters. In this case, the performance parameter really is a recording probability curve. It is the interaction, the ability of this (indicating) working with this (indicating) to produce recording probability curves.

We say that the procedure and equipment pass if they exceed in this direction some reference curve that has been established. It fails if it is below that.

MR. SHEWMON: This is all very nice, and if I was a professor teaching a course in this, I would love to have curves like that. I have a good deal more difficulty with how sort of on one of the outbuildings at Nine Mile Point you are going to do, and especially the last one, to somebody with any kind of effectiveness. I mean, the first two, it seems to me we agree, and I can conceive of how they are going to be done. Will you tell me how the last one is going to be done in the field?

MR. DOCTOR: This is not going to be done in the field. The way we envision it is, equipment, procedures, and personnel need to be qualified prior to going to the field to make an inspection. In other words, if the procedure and the equipment being used does not provide one with a good response probability --

MR. SHEWMON: Let's assume the first two are done. I would like to hear the last one.

MR. DOCTOR: Okay. There are two philosophies with regard to this last one. One philosophy is that if I use fracture mechanics and I come up with a minimum POD curve that simply says the following, that if I am using a particular sampling plan and I know the rate of growth of defects, I know that the severity or the risk of missing a given size of defect leads to a through wall failure before the next inspection, and I have to have a very high POD for that particular crack size.

So, one can establish a POD curve based on that. All right? The other philosophy is, if I can't meet that, then I can find out what is the best and ensure that everybody is performing at that level.

MR. SHEWMON: Are you saying that what the NRC needs to do is come up with a certain set of flaws that they are concerned about, that these have to be calculated as to what is critical, and then we go to half of those and try to get a 95 percent probability that these can be detected with 50 percent certainty or something?

MR. DOCTOR: Right.

MR. SHEWMON: But then let's get back. You send each of these level 1's and 2's off to take a short course administered by someone, and at the end they see on a set of samples what they can do, and that crams them for the next year, or what?

MR. DOCTOR: We think it is just like welders. Welders on most jobs have to qualify before they start work on that job. Before a team can go in and perform an inspection on the plant, we believe they must be qualified, so they must be qualified each time they go in to perform an inspection on a plant if the equipment and procedures have in fact changed, but if they have qualified on a given set of equipment and procedures and can show that they still have that same performance and are qualified, there will be some stretch of time where obviously they should be allowed to use that.

If a procedure is changed, then they have to requalify.

MR. SHEWMON: Who would administer this?

MR. DOCTOR: That is an unknown at this particular point. I think it is going to take a combined effort of the industry, EPRI, NRC, people like that to administer such a program.

MR. SHEWMON: The licensing of 1's, 2's, and 3's is done by ASNT?

MR. MC CLUNG: The certification is done by the employer.

MR. SHEWMON: So level 1 at Commonwealth might be level 2 at TVA?

MR. DAU: Yes.

MR. SHEWMON: That is interesting.

MR. BUSH: Well, there are certain criteria but you can vary these criteria and make them more rigorous, and if one employer "wants more rigorous requirements," ASNT doesn't care.

MR. SHEWMON: Does everybody put out guidelines on what constitutes 1's, 2's, and 3's?

MR. MC CLUNG: Yes, they have guidelines to be used by the employer, but they are just that. They are guidelines. The employer can select, make it more stringent or less stringent as he chooses according to the feeling for his own job requirements.

MR. BUSH: ASNT has deliberately avoided moving into the standards area for obvious reasons.

MR. DAU: I would like to make a comment. Later on in the agenda I have an item on -- there is an ad hoc personnel qualification committee that has been assembled by the industry to deal with this issue after some discussions with the NRC. The whole question of qualification certification for inspection personnel. There are some holes in it that need to be filled.

MR. SHEWMON: Go to your next slide then.

MR. DOCTOR: Yes. This is the last one.

(Slide.)

MR. DOCTOR: The conclusions based on the work that we reviewed in terms of things that have occurred have identified certain shortcomings that we feel that qualification of the equipment, procedures, and personnel effectively provide a vehicle for kind of establishing a minimum performance level with regard to those identified shortcomings, but they do not obviate the need for research to improve them, so that you do not have to use highly qualified personnel if in fact you can make the techniques much more effective in terms of their performance and reduce the constraints on the skill of the operator to utilize it.

We believe that measurement methodology and characterization techniques exist for qualifying performance parameters. Those have been developed measuring the POD curves, recording probability curves. That type of measurement methodology exists. And for characterization of the equipment. That currently exists.

This is the area where our program has the prime emphasis, which is coming up with what is the acceptance criteria needed for giving a pass-fail to these various components, the equipment, procedures, and personnel.

That concludes my presentation.

MR. SHEWMON: Okay. Thank you very much.

Gary, are you next?

MR. DAU: Yes. I would like to introduce Dr. Jim Quinn from the Electric Power Research Institute. Jim is the project manager responsible for the heavy section inspection program specifically for pressure vessels, and he will cover this.

MR. SHEWMON: While he is getting ready for that, will you tell me whether there is a requirement now about recording all UT data and keeping it, or is enough of this done handheld such that a requirement is impractical or silly?

MR. DAU: I think the field records, if there is something reportable and recorded on those sheets, then there is a requirement that that be stored for I don't know the years.

MR. SHEWMON: Let me go back to Mohammed. You were saying this morning, I guess Joe Collins was, too, that there are certain tests or results on a tape out at West Jefferson which were in that case recorded and could be looked over by somebody else? I know I have heard people talk of recording it.

MR. BEHRAVESH: These are typically in a plant and recorded on data sheets, and the data sheets are the property of the plant owner as well as the inspection agency. At Battelle Columbus, data sheets are also recorded, and all the raw data exists on the work that was done on those specimens and the copies of that data is both in the hands of the NRC regional man as well as the utility.

MR. SHEWMON: It is using 100 percent DAC, and we don't find anything recordable, and we want to go back and see what it would be with a 20 percent DAC a year later, and there is absolutely no record in most cases.

MR. BEHRAVESH: That's correct. If it was not so-called recordable, then that data sheet with that data will say on it, no recordable indications.

MR. BECKER: There are a few organizations which have a strip chart recorded. It is kind of a gross recording of amplitude for the purpose that you just mentioned, that you can't go back and review the data. It is not as precise, but it does give you the circumferential location, the time and amplitude, but it is not -- unless it comes over their recording threshold, they don't go through the physical mechanisms of analyzing those flaws, but there is some record in some cases.

MR. BUSH: Paul, you notice he said a few. It is not 100 percent by any stretch.

MR. SHEWMON: Unfortunately, the people we get in here probably tend to be at one end of the spectrum, and on their good behavior that day.

(General laughter.)

MR. SHEWMON: You are up.

MR. QUINN: Thank you.

This is an outline of the presentation that we will be making on the EPRI pressure vessel inspection program. I will cover the subjects down to the buried flaw detection, subject number five, and I will then turn the presentation over to Larry Becker. We hope to keep it down to exactly one half of an hour.

(Slide.)

MR. QUINN: The objectives of our program are many. We are conscious of all the problems of inspection in pressure vessels. Because of the pressurized thermal shock issue, the underclad crack detection has taken highest priority recently. We are also looking at the problem of inspection for buried flaws in heavy section weldments because of the growing dissatisfaction with performance under Section 11. Historically, we have been working on flaw characterization, and a lot of that equipment is now nearly field ready, and you will see some detail of that flaw characterization equipment today.

We are also looking at alternative technologies, eddy current, and radiography techniques for both underclad as well as in-depth flaws.

(Slide.)

MR. QUINN: I hate to sound repetitive, but basically we are taking the viewpoint that both the procedures, the instruments, and the personnel must demonstrate capability rather than simply compliance to the code. I hope that this will not put us into any great conflict with codes at some future date, but we are looking very much at demonstrated capability.

(Slide.)

MR. QUINN: A quick cut at what we have done so far, and our approximate schedule on under clad crack detection. This year we have spent a great deal of effort evaluating existing technology, technology that was available say through the end of 1981. We are now beginning the evaluation of new under clad crack detection tools that are being used in the field that resulted from the focusing of the industry's attention on the pressurized thermal shock issue.

We hope to have that done by the middle of 1983, at which time we intend to commit to the design and fabrication of a near surface inspection tool which will be available through the NDE Center much along the lines of the availability of a MINAC through the Center for various ISI vendors working for utility companies on a lease basis.

(Slide.)

MR. QUINN: A program for in-depth flaws is phased approximately six months behind the near surface inspection. We intend to commit a year from now to the development also of a new in depth flaw detection capability and instrumentation, much of which, again, will be made available to the industry through the NDE.

(Slide.)

MR. QUINN: Historically, we have been working on characterization more particularly for buried flaws for a longer time than we have on the near surface detection problem. As a result of that, the acoustic holography work that has been the focus of our program for the last four or five years is now nearly field ready. We have had a demonstration of the acoustic holography system in a full field configuration two weeks ago at Combustion Engineering in Windsor, Connecticut. We intend to turn that instrument over after a few corrections of some minor problems which were discovered during that demonstration to the NDE Center for evaluation beginning the first part of next year, and we hope to be able to take that system to a preservice inspection some time in 1983.

We are also working on a commercialized version of a compact linear holography device that will be used on nozzles and pipes. We hope to have that commercially available by 1984. And we are also going to address the question of depth resolution, which is one of the criticisms of the holography technique, by comparing it to the Holosaft technique as developed by the Germans in Zaubruchen by mid-1983.

(Slide.)

MR. QUINN: If I can deal a little bit at length with the instrument which is now maturing, we call it the pressure vessel imaging system, or PVIS, for want of a better name. Basically, we see there are three versions of PVIS which are going to emerge. The first version, model one, is essentially the acoustic holography which piggybacks on a normal field useable pressurizer vessel tool. Model 1A will incorporate our first versions of under clad and in-depth improved detection technology, so it will replace the conventional pulsed echo techniques with equipment that we will develop as a result of our program.

In parallel with this, we are going to fabricate a number of test samples for thorough system qualification. That creates a lot of problems which I hope we have time to do into today.

Finally, if the need is clearly evident, we will have a second version, if the first version falls short of our goals, of a much improved detection capability. During this time period, approximately four-year time period, the PVIS, whether it is Model 1, 1A, or 2, will be available on a lease basis through the NDE Center to the industry.

(Slide.)

MR. QUINN: This is just for completeness of the approximate schedule of the program. Now, to demonstrate a little bit more about the pressure vessel imaging system.

(Slide.)

MR. QUINN: I am sure you are all aware that pressure vessels on PWR's are normally inspected by removing the contents of the containment vessel, the pressure vessel, and a manipulator is put down inside. There are two boom arms on this device. One is a conventional UT inspection device, pulsed echo device, and the other is an arm which is normally used for examining the bottom dome welds. In the case of the pressure vessel holography, we essentially put the holographic scanner on that arm. This is the configuration which was demonstrated at Combustion.

(Slide.)

MR. QUINN: Diagrammatically, we have the conventional system which is available, and we have integrated our system both with the Southwest design as well as the Combustion Engineering design, and we simply tack on the display system, the mini-computer driven holographic reconstructer, as well as the electronics and the scanner to apply to the holographic data.

(Slide.)

MR. QUINN: In more detail, we have here essentially the conventional front-end RF holographic interface and the display system. The only portion of this system which has not yet been demonstrated is this wave form digitizer and recorder which is designed essentially to record digitized data taken from any object found in the pressure vessel, so that we have a permanent record of the calibration runs on the pulsed echo system and the holographic system as well as an archival record of all of the returned echoes from the system.

So we have a far better record of any indications found in the vessel.

(Slide.)

MR. QUINN: The holographic scanner consists basically of a tripod which is pushed up against the pressure vessel wall, an XY scanner with higher precision speed than it normally operates at, and a transducer head that contains both a sheer wave as well as a longitudinal wave transducer to provide images in both modes.

(Slide.)

MR. QUINN: This allows us, for example, because the XY scanner frame can be rotated around, it allows us to take sheer waves images from any position around the object as well as the longitudinal wave image from over the object. It also, because of the size of the scanner, facilitates -- because the size of the scanner exceeds the necessary aperture to take the hologram -- it provides us with the ability to field near surface inspection and more advanced in-depth detection technology on a very quick response basis as those technologies are developed in the future.

I have in the handout several images of a metal object similar to water, but it is much more interesting to look at real objects underneath clad.

This is a side drilled hole taken at 45 degrees shear wave at one megahertz. We have here the uncorrected version. This is an uncorrected image of the side drilled hole. This is a depth of about four inches in steel. As you can see, the clad distorts the side drilled hole. It doesn't look much like a side drilled hole. This is a three-wire clad totally unground.

We attempted various types of corrections, and here is a correction which is done by a subtraction holography technique in which we subtract the hologram with the front surface from the hologram of the object in depth and obtain a much better image of the object. The longitudinal wave, the correction works better on the longitudinal wave than it does on the sheer wave. And unfortunately I don't have a longitudinal sheer wave image to show you. I would prefer to do so.

(Slide.)

If we look at these various clad surfaces, we can clearly see why this is. Here we have an example of all three, the strip, the multi-wire, and the manual. Notice not only the surface roughness increases when you go to the manual cladding, but also notice the interface between the base metal and the cladding also is considerably rougher with the manual arc.

(Slide.)

MR. QUINN: Here we have an example of some of the under clad crack blocks which we have built. I am now going to pass on to the discussion of underclad crack detection which we have been working on for the past year. This is a block which was built in Richland, Washington, and has been used on several programs to evaluate existing techniques.

(Slide.)

MR. QUINN: Since the dual probe has been a subject of considerable discussion this is essentially a schematic drawing courtesy of Battelle that shows the acoustic energy distribution patterns in the dual probe.

This is the 70-degree L-wave probe which has been used by BAM, RTD, Framatome, and EDF to detect underclad cracks in their pressure vessels in Europe.

(Slide.)

Once again, I would like to give full credit for this data to the Battelle people. Much of this work was done by the Battelle people. In fact, it was all done by the Battelle people. Our participation was to supply some samples to them to test on.

Basically this shows the results which Steve Doctor quoted. It essentially shows that strip clad has a fairly good signal to noise ratio for a crack which is essentially the size of the minimum critical crack size which has been calculated as being relevant to the pressurized thermal shock issue.

If you go down to the manual clad, to the unground clad, the situation gets worse and the probability of detection dies away.

MR. SHEWMON: What is the minimum crack size of relevance to the PTS issue?

MR. QUINN: As far as I know from the discussions I have had with the people, it's six millimeters depth.

MR. SHEWMON: A quarter of an inch?

MR. QUINN: A quarter of an inch.

(Slide.)

If we now look at what the French have done, as far as looking at the cracks that they have found in their nozzles and also in their tube sheets, what they have found, beginning in 1978 they found that their cladding process was putting these cracks into the nozzles and the tube sheets. And in order to respond to the problem of how do we know that the nozzles of all the reactors we're building in fact have cracks, they developed two techniques based upon the BAM/RTD technique for manual inspection, preservice inspection, and one for automatic focused probes for in-service inspection.

They went through a process of destroying inlet and outlet nozzles by first scanning the nozzles and then removing one inch, one-half millimeter at a time, the clad material and then the base material. And after removing a half-millimeter, they did di-penetrant and mag particle testing and then removed another half millimeter until swept all the way down to the base of all the indications.

Then they compared the destructive analysis to the NDE analysis and they found that the NDE techniques which they had developed had found all cracks greater than three millimeters.

MR. BUSH: Jim, I've been looking for what I call the probability of detection of these, because obviously this has a significant impact on what you can or cannot say with regard to the pressurized thermal shock issue of detection. I know the data exists. I've seen bits and pieces of it, but I have never seen the whole package.

MR. QUINN: It's on my desk in English and it will be out on the streets in two and a half months.

Please notice the number of cracks, 215 cracks here (indicating), 131 cracks here (indicating). That has something to do with the statistical relevance of the qualification technique later on.

That completes the slides. I have a few more vu-foils I'd like to go through.

(Slide.)

I think the significance of the Framatome results are interesting. One, they have been able to demonstrate that when you have smoothe, double-layer clad, whether it's machined-smooth or ground-smooth, that you can reliably detect to a very high reliability cracks that are one-half the critical crack size that are relevant to the pressurized thermal shock issue.

The second point is: Their situation is a little bit easier than ours because they do have the smooth clad. It's a little bit worse than ours because they have double-layer clad, which is thicker clad in many cases than we have. It is interesting that they found under-clad cracks both under the strip clad, which I think there have been a lot of papers in the open literature discussing that phenomena, but they also found it underneath the manual arc clad.

They also found some -- they don't have much data really relevant to under-clad cracks beneath cladding applied over weld metal. So that still remains a question in the belt-line area for the pressurized thermal shock issue.

It's also interesting that this evidence clearly shows that there is a backup position. You can ground the belt-line weld and do a very good inspection.

(Slide.)

The work that we are doing for the next year in under-clad crack detection: As I said, we've had a very good cooperative relationship with Battelle, Pacific Northwest Labs, where we've shared data and samples, leveraging both budgets. We have begun the evaluation of existing new techniques which are being used in the field for the inspection of belt-line areas of pressure vessels for near-surface flaws.

We got through a very rapid evaluation of the Combustion Engineering tool which was used at Maine Yankee. We found that it worked fairly well on the three-wire clad. The manual clad remains a problem. It's interesting that Maine Yankee essentially has all ground cladding. None of the cladding is as-welded.

We are planning next year three major projects for signal processing work. I think we are relatively enthusiastic about signal processing, because it does offer a standardization of test quality and a position essentially of the quality of the examination and the interpretation of the data upon all test crews. It also offers the opportunity to exactly record specifically the ultrasonic signals obtained from any reflector found in the vessel during the inspection.

We have three programs. One is a systematic study to try to determine detection probability, as well as characterization. One of the things we would like to do is be able to separate inclusions at the interface between the clad metal and the base metal from cracks. That's an important problem from the standpoint of the utility industry, because they don't want to be worried about inclusions that are not in the under-clad cracks.

We also are very enthusiastic about the ADI, the Adaptronics-4060 system which Mohamed talked about earlier this morning. We would like to evaluate it as to its effectiveness on classifying under-clad cracks.

Finally, there is a new system which has been developed by Pacific Gas & Electric Company, built by a small company, Dynacon Systems in California, which is essentially a third generation signal processing unit, which does a great deal of signal processing, time averaging, spatial averaging, and requires a trajectory of objects as a function of detector motion, et cetera, which looks very attractive and has shown in very preliminary data some surprising sensitivity to under-clad cracks using very large transducers that you would not expect to be sensitive to those cracks.

So we intend to do evaluation of that very soon, in the January-February time frame.

(Slide.)

Before I turn it over to Larry -- I'm running a little bit long -- I would like to talk about qualification sets of samples. What we would like to do is to build a permanent set of samples, both for under-clad cracks and in-depth cracks, in which we have a known distribution of the flaws of known types, in known locations, to provide essentially a blind testing of equipment and crews in order to act as a qualification for their use in the field.

To provide a statistically significant distribution of such flawed samples is unfortunately a very difficult problem, and the reason is very simple. Such blocks, and particularly the heavy section blocks, are expensive. If you look at simple binary statistics, you end up having to have thousands of flaws and hundreds of blocks.

In addition, if we are in fact going to implement such a program it would be cost effective to come to some agreement with the interested parties upon what are simplifying assumptions in order to reduce the number of blocks and the number of flaws before we commit to metal.

(Slide.)

Let me illustrate what I mean. Binary statistics tell me that if I want a 90 percent confidence level but my detection reliability, for example, is 99 percent, then I have to have a minimum of 230 flaws of a given type.

Now that could be a given size at a given orientation relative to the clad lay direction underneath a given clad type finished to a given surface finish. If I want to change the surface finish, I have to build another 230 flaws. That very quickly adds up to a lot of money, particularly if I end up with a technique that misses a couple.

You can see as I go down here the number of failures to detect, the numbers build up rather rapidly.

It's interesting to note that the French claim to be in an area on this zero line at the 215 to 131 flaws, that they are 98 to 99 percent effective. So the French demonstration I think is a model of the kind of demonstration we would like to do.

MR. BUSH: Of course, you don't have to use binary statistics. And I do not think you every would, to tell you the thruth.

MR. QUINN: No, I don't have to use binary statistics. And getting into the details of which statistics you'd like to use in order to reduce those numbers is of course something that is a topic which should be discussed to a great extent over the next month or two, not only within EPRI and the utility industry but also within the NRC I should hope.

(Slide.)

MR. BUSH: By the way, do you know that the NRC has a rather high-level ad hoc committee on this very thing that is available?

MR. QUINN: Yes, I'm aware that they do. I think we need to have more communication with them.

MR. SHEWMON: When you say "that is available," what do you mean?

MR. BUSH: I mean that on request, if there's a specific kind of problem, they're quite willing to look at it. I am a member of that committee, so I know, and that's what has happened. Two or three things have come in and the statisticians or the probability people will ac ually prepare a report and indicate where they think the weaknesses and strengths are. And I think that's really what you're asking for here, is the direction that would optimize the output and minimize what I call the input.

MR. QUINN: Yes, I think so, I think so, essentially an agreement upon what is the intelligent thing to do in order to provide a qualification to a given level of acceptance.

MR. BUSH: I would say if you would call Carl Bennett I would give you a 90-10 probability that he would be happy to have a good look at it.

MR. QUINN: He'll get a call next week.

At the present time, we have a number of evaluation blocks. We have some foreign stick blocks, which you saw an example of in some of these slides. These are used for under-clad crack detection. They contain various types of notches and mechanical fatigue cracks.

We are going to complete three more of those by the end of January. We have one seven-inch block which we really don't know what is in it. There are a lot of flaws in the weld, but we have to cut it up before we can determine what that is, and of course that is an expensive process and a process we would like to avoid in the future by having program flaws placed in these welds.

Finally, we've equipped the NDE Center to have a cladding capability so that we can do our own cladding and control exactly what kind of cladding is put on the blocks.

(Slide.)

These blocks at the present time, by January we shall have an inventory then containing more than 150 surface flaws which are really representative of flaws down to three millimeters and are oriented towards evaluating the effectiveness of detection techniques for pressurized thermal shock.

At that point, rather than -- well, there is one more slide I'd like to show you, then, before I get out of here. I'm taking a little bit too much time here.

(Slide.)

I would like to just show you some estimated costs of what these blocks are. Those four-inch blocks are 18K a piece. We built an 11-inch thick qualification block to qualify the technique for implanting fatigue cracks of known sizes in heavy-section welds two years ago in 1980. That was $100,000 in 1980, and I know because I paid the bill.

I have been told that some of the blocks for the nine-inch block for the UKAEA exercise with regard to DDT trials was $250,000. Westinghouse has built a nozzle to shell weld with a bunch of fatigue cracks in it using the same technique that we had developed together in 1980, and that block cost $400,000 and it did so because Westinghouse claims to have taken a loss and because we gave them the nozzle. Its present replacement cost is estimated at $6- to $700,000, and Serge Crutzen estimates the pisk nozzle at the shell weld at $750,000, as well.

MR. BUSH: Yes. That Ansalvo block really must have cost a mint.

MR. QUINN: That represents a significant fraction of our budget. So at that, I think I will truncate my presentation and turn the discussion now over to Larry for discussion of the NDE trial results, as well as --

MR. BUSH: While you still have the mike on, let me make a comment that is kind of a question. I think what you've indicated in your initial statement there about common grounds indicates that it's extremely expensive in time, money, et cetera, to do things in parallel. It seems to me that the efforts funded by Regulatory, funded by EPRI, funded by other sources, has to be seriously in parallel, because I don't think anybody can do a really good job doing it on their own. That is my personal opinion.

MR. QUINN: Yes, I agree.

MR. BECKER: Thank you. My name is Larry Becker, now with the NDE Center in Charlotte. I would like to take the opportunity to briefly discuss our evaluation of the DDT trials that were recently held in England. Dr. Bush has provided you with a detailed summary, which you may appreciate. I think it's a very good summary. I would like to quickly go over the program.

The defect-detection trials, DDT, were conducted in support of the U.K. PWR proposal. Their charge at the time they started was: If you can't meet certain minimum standards, you are more than likely not going to have a PWR in the United Kingdom. So they had a big objective; that was, to demonstrate the NDE effectivenss for all of the reactor pressure vessel inspections.

The trials were conducted over a 1-year period. They consisted of plates 1 and 2, which were flat plates. They contain subsurface as well as near-surface but not necessarily under-clad. They were within 10 millimeters or so of the surface.

(Slide.)

These were primarily fatigue cracks. However, they did have several welding defects also. Plate number 3 was an under-clad crack block with a nozzle dropout which had fabricated under-clad cracks. And the fourth was an inner corner nozzle. Both the plate and the strip clad were of a fairly high-quality, a very high quality, which they would expect to have on any PWR that they would order for delivery within the next 4 or 5 years.

Six teams participated. There were two French teams employing a focused-probe technique, one German team which was augmented by a couple of other teams, and three English organizations who participated in the trial.

MR. SHEWMON: Was that the Olympic team from each country?

MR. BECKER: Yes, indeed, it was. Well, let me correct that. The two French teams were exactly the same people that test in the field. They do both base-line and pre-service -- pre-service and in-service inspection, the French team.

The German team, the conventional people were field people from KWU, and they were augmented by BAM and IZFP in some of the sizing exercises.

The English team, you would have to call them pretty much all-star teams. They were the best people available, and there were quite a few high-powered scientists actually doing the work.

MR. SHEWMON: I hope that turns out to be an advantage.

MR. BECKER: Actually, Morris didn't do it, but he taught everybody how to do it.

A summary of the results.

(Slide.)

All six teams detected all 45 defects in plates 1 and 2. That is a very significant finding. They were not all necessarily sized correctly, but most of them were pretty close. There were a few errors which would have accepted unacceptable flaws, but there were very few of those.

Plate number 3, there are actually only three teams that participated in this test. All under-clad defects were detected. There were some in-clad defects that were missed by a few people, but the significant under-clad defects were detected, and sizing in that case was not a parameter.

In the nozzle inner corner radius, all defects were detected, and these were 5-millimeter or large-type defects in the inner corner radius of a -- basically something that looked like a PWR inlet nozzle. And sizing was excellent. I put down 2 millimeters, that is probably the maximum on the range. I will show you some brief examples. I don't want to take too long, but I did want to impress you with the quality of the output.

(Slide.)

These were the very best. Some of them are not quite this good. But the sizing accuracy in this case turned out to have a mean error of about 1 millimeter and a standard deviation of 3 millimeters. That was plate 1.

Plate 2 is similar. This is the one that contains welding-type defects, a little more difficult to look at. In general, all of the major defects are correctly sized.

MR. SHEWMON: These are slots?

MR. BECKER: It's a fatigue crack. You take a fatigue tensile bar, make it in the shop, and then they weld it into a coupon, the actual fatigue crack, and then that is implanted in the weld. So in this case these up here are fatigue cracks, and these down here are carbon cracks or different types of welding defects.

MR. STONE: Larry, I wonder if you would mention about the color coding there.

MR. BECKER: Oh, excuse me. The vertical linesd are the reported results, the dark color; and the green is the axial. In other words, the destructive analysis is the green, and the red is the reported results.

(Slide.)

This is the under-clad crack block. This is a slag entrapment in this one. These are very tiny reheat cracks, a whole line of them here. The small cracks are under-clad cracks. And the squares are various types of in-clad crack clad rather than under-clad type defects.

(Slide.)

This is the nozzle example. I would like to draw your attention to the very accurate sizing. The little green dots are the reported, and the red is the actual profile. And even on very circular flaws they were able to size it fairly well.

(Slide.)

To go over some of the conclusions that we might draw, we believe that they were very successful in demonstrating that a quality exam can be made on their quality of material. The best results were achieved by using a multiplicity of detection and sizing techniques. As a matter of interest, there was nobody that selected ASME or even the reg guide as a best choice of technique, although one team did use an ASME technique but it was highly augmented by other probes and a 10 percent recording level.

MR. SHEWMON: 10 percent DACs?

MR. BECKER: Yes. If you evaluate the

techniques, there is no real technological breakthrough required to do this. It is more an application of good engineering. I would like to comment that most of this data was permanently recorded and is available for analysis. And PNL, I believe, is going to record it to provide us an evaluation of how good our ASME techniques would have done on these blocks.

MR. SHEWMON: Wait a minute, let me ask a question I asked a little while ago again. If you were going to record what was done, you need something to give the coordinates of where the crystal is and you need a tape deck on the signal. Is that it? And these people had both, most people doing things in the U.S. plant don't? Is it that simple?

MR. BUSH: This is more like a vessel member.

MR. BECKER: Yes. This is where they did do it that way.

MR. BUSH: So this doesn't differ that much from U.S. techniques, to my knowledge; for the vessel only I am talking about.

MR. BECKER: The degree of recording is a little bit different. Maybe Wayne Flack could answer that a little bit better.

MR. FLACK: Would you repeat the question, please?

MR. SHEWMON: How the level of recording here, I guess -- if you are familiar with it -- corresponds with the level of recording usually done in this country? Is that the question?

MR. BUSH: This would be the automated systems, Wayne, in the vessels.

MR. FLACK: Yes, sir. On the mechanized systems that we use at Southwest Research -- and I think I can speak for at least several of the other ISI vendors -- the analogue records of the signals go down essentially to the grass level. You can't extract 10 percent data or whatever you would like. Typically, the data is analyzed in accordance with the requirements of the code, but additional data and more detailed analysis should be desired.

MR. SHEWMON: Okay. Thank you.

Gary.

MR. DAU: What he said is true, but it's not true universally. I think that is the key point. There are still people doing inspections that are not reporting it to the extent that Wayne just described.

MR. SHEWMON: And they're recording on vessels which meet all the regulations and codes applicable to ISI vessel inspections. Is that true?

MR. DAU: Yes, but it could be a data sheet and hand notes are written down on position maximum amplitude and that amount of limited data only.

MR. SHEWMON: Okay. Let me come back to another question. Now with your new hat and new boss, you have some association with what we are going to hear about next on the agenda, and this is the recommended changes to Reg Guide 1.150. How close would you say that is to what any of these teams used?

MR. BECKER: The basic difference is the recording level. They used a more sensitive test than 20 percent DAC.

MR. SHEWMON: A more sensitive threshold?

MR. BECKER: Correct. They recorded down to a lower level. It was highly augmented by near-surface techniques.

MR. SHEWMON: What does that mean?

MR. BECKER: Well, they used two or three different probes just to interrogate the first quarter T.

MR. SHEWMON: Quarter T is not cladding but the whole thing?

MR. BECKER: Yes. The first 3 or 4 inches of the vessel. Then the sizing techniques were not the simple DAC sizing, they were either -- well, it's a little difficult to go into, but they were considerably more sophisticated than the DAC sizing techniques that we have in the code. I think those are the basic differences.

MR. SHEWMON: When you say code this time, you're talking about what the industry's recommended procedure was, not the ASME code? Because my question had to do --

MR. BECKER: There is very little difference.

MR. SHEWMON: Okay. Thank you.

MR. BECKER: I would like to make one more comment on the area of reliability.

(Slide.)

This is a comment on the reg guide. I would like to describe our calibration facility. The impetus was supplied by Reg Guide 1.150. The basic objective, or a basic objective, of that reg guide was to achieve test repeatability. That is, if we tested it two times and we got differences in signals, we wanted to know why. You cannot do that. That requires a very good repeatability. You also have to know what you are actually using, and that is characterization. You have to know the parameters of the transmitter, the transducer, and any other equipment that was used.

So, in response to the reg guide, EPRI established a calibration and characterization laboratory which has the capability of performing these characterizations, and those services are now available to the industry.

(Slide.)

In your handout there is a technical brief describing the capability of the Center's facility. I might mention that most of the techniques that are used there were developed by NRC at Battelle-Northwest. And in fact, Battelle assembled the system for us.

Are there any further questions?

MR. SHEWMON: Questions?

(No response.)

MR. SHEWMON: Okay, thank you very much.

Now, you come to speak for Mr. Lance; is that right?

MR. DAU: Yes.

MR. SHEWMON: Come on up. What I would like to do, gentlemen, is to hear this presentation, take a break amongst the NRC presentations again. We will scratch the budget overview that Serpan had. We will talk about the steam generator and we will have the subcommittee discussion and we'll probably come close to that 4:00 p.m. scheduled quitting time.

MR. BUSH: Just a quick one. We had some stuff, I don't know if it was part of the package today or just for your information on, for example, -- I'm assuming the North Ana information is not really relevant to this meeting? I couldn't tell. It was attached to the packet.

MR. SHEWMON: Is that something only he got?

MR. IGNE: Yes, only he got it. We aren't still on it.

MR. BUSH: I assumed it might be part of the package.

MR. SHEWMON: Go ahead, Gary.

MR. DAU: My name is Gary Dau, I'm substituting for Jack Lance on the item dealing with the ad hoc committee.

First, I would like to give a brief rundown of the chronology of the events leading up to where we are today on this issue. About 1979 a draft of the document was put together for a draft reg guide for ultrasonic inspection of pressure vessels. I think one of the initial emphases at that time was primarily the belt line in the PWR systems. That was sent out for comment in this time interval between 79 and July 15th, when the final version was issued.

In July and August I was approached by several different people representing ISI vendors, as well as utilities raising quite a bit of concern about the reg guide and its impact in terms of how it could be implemented and would it be implemented in a repeatable fashion across the nation. There were some ambiguities in it based on the input that was received by EPRI.

Then we assembled a workshop which took place September 9, 1981. We wanted to determine the intent, limitations and remedies, if needed, to the comments that we were receiving informally. The presentations involved people from the NRC, ISI vendors, EPRI staff and NSSS vendors.

MR. SHEWMON: Any NRC representatives?

MR. DAU: Yes. Definitely. Warren Hazelton made one of the lead-off presentations on this, and the participation I think must have been about six or eight people throughout the meeting.

In the afternoon, Bob Zong began to try to winnow out possible actions that the utility industry could take. Through a series of straw votes, it became a consensus that with input from some of the NRC staff that was there, perhaps the best way to move forward was to form an ad hoc committee to draft recommendations and to submit these to the NRC.

So, that was the conclusion of that meeting. And Mr. Zong and myself then were given the charge to identify a chairman to lead that group. By mid-October we had convinced Jack Lance to chair that group.

We also met with what is termed the NDE Subcommittee. This is part of the EPRI utility advisory structure. We meet with them periodically, at least three times a year to review our research efforts and to get advice from them on how we could be most effective.

We did this for several reasons. First, this was the pioneering effort. Second, we wanted to get a broader base of support within the utility industry to carry forward on this. And we were received overwhelmingly with the advisory structure.

On November 5th we adopted a charter. In the handout there's a copy of the charter and the members. At that time, we resolved a couple of issues on how to approach this. Because it was a new effort and we were not quite sure how far you could push things, the committee decided to try to clear up the reg guide in terms of ambiguity, strengthen it where possible, but didn't feel that they could push it too far in terms of mandating new techniques that really had not been demonstrated adequately.

Also, it was recognized at that time that it had to deal with all LWRs. The reg guide was intended for that, so we had to be concerned about both the pressurized and boiling water inspections.

Through this timeframe, December, January, Februry, March, April, we had committee meetings. I highlight the April 15-16 meeting because we met with the NRC and the consultants to review the process to date. It turned out to be an extremely useful session. I think at the end of the day we had achieved more than what our objectives were for two days, and if any future activity like this goes on I would say get this type of interaction way up here on the calendar. It is needed very quickly and it makes it much more efficient.

In May, we reviewed by mail the comments, and we mailed a draft to the industry in gtneral for review. Appendix B in the ad hoc committee report, which I only have one cop; of here and I will leave it with Mr. Igne, but there's about 125 people on that list. We mailed it out with instructions on how to comment on that and gave them a month for return comments. At least 90 people on that list were utility people.

The committee met then on July 27th to review and resolve the comments that hd been returned by the people, and we received some well thought out comments. These revisions were then incorporated into the final draft, and we had a general meeting the next day here in Washington to present the outcome of that work back to the utility and the ISI vendor community. Dr. Muscara and Mr. Serpan attended that meeting.

Then in mid-August we formally submitted the document to the NRC.

(Slide)

The cover letter and some of the introductory material is included in the handout. You can get more detail from that. I think there are several significant items that came out of that. One is the ambiguities were removed from the intent of 1.150, and I think this really gelled at the meeting with the NRC people. It is something that the industry feels is implementable.

Technically, I believe it is somewhat more demanding than the original one. It recognizes the ID surface; most important, it recommends a greater sensitivity for the inspection of the inner 25 percent of the wall, and it uses the fracture mechanics to justify two levels of sensitivity. There was a discussion about whether 20 percent DAC is adequate sensitivity, and I think it is appropriate to have those type of discussions.

The key thing here is to recognize that perhaps two levels of sensitivity are appropriate.

MR. SHEWMON: Where and what would those be?

MR. DAU: What is stated in the guide is that the inner 25 percent should be 20 percent of DAC; the other 75 percent should be at the 50 percent level. And it is in this document that the concept of inspection performance demonstration was first put forward. I think that, tied with the fact that this is the utility's initiative, is very significant.

I am somewhat amused by some of the comments here today that this whole concept seems very much accepted today. When the committee was doing this, they had a lot of trepidation about this as to whether or not this would be acceptable. Today, it is an accomplished fact, or at least --

MR. SHEWMON: Tell me a little bit about how that demonstration works. Is it just a concept there, or does it talk about how it would be implemented?

MR. DAU: Well, the committee didn't really come to grips with the issue of the specific procedures, but they were very keen about having it there for several reasons. One of them is that it's a good way to get actual performance data prior to going in and doing the inspection. From this you can begin to work with the vendor or your own crews if the utility is doing it, and have a much better understanding of the reliability of the inspection that is being performed.

At that particular time, a lot of the blocks that Jim Quinn described were in the concept stage, and being budget-limited, we really couldn't commit to saying the blocks would be available at any given time. But it was in a conceptual format that there would be blocks available and a procedure could be set up.

This could be between the utility, the regional NRC people and the ISI vendor. When it really comes down to it, those are the people that are making a lot of these decisions.

I would like to keynote that last one again. It was the utility initiative, and that demonstrates a great deal of interest and commitment on their part to having a quality examination.

(Slide)

I am speaking here for Mr. Lance. I am going to offer some personal observations and identify them as my own and allow him the opportunity to not associate himself with them if he so chooses. But the committee members and, I believe, the industry as a whole is really dedicated to having the highest quality vessel examination possible, and we are willing to put out quite a bit of effort to help achieve this.

I have made a quick estimate about the amount of money -- and this is the lower bound of, say, $300,000 with the kind of funds to put this recommendation together. This doesn't count a lot of support work from subcommittee groups that worked with us.

It's a precedent-setting operation. I believe there was wide industry participation; the utilities were acting in concert, and there was very excellent NRC staff and their consultants and interaction and agreement on the key points. I think in the future if we should form such committees they will operate much more efficiently and, hopefully, less costly.

The process was completed from the committee's viewpoint with a very upbeat outlook toward efficient resolution of similar issues if they are required. However, I think it is appropriate to say that the long-term benefits -- I'm talking about attitude now -- is really going to be dependent on the NRC response to these recommendations. I think the industry is looking for a signal as to what is going to happen.

That really reviews the progress to date on this issue.

MR. SHEWMON: Okay, thank you. Any questions?

MR. BUSH: Just a quick one, Gary. Of course, I was happy to see the 20 percent DAC to the 25 percent wall, but I'm wondering did they ever do an analysis? I came up with the same figures a couple of years ago. I used kind of pseudo-fracture mechanics. Did you have someone actually do an analysis that would justify that value?

MR. DAU: Yes. In the report, we used the information that Ted Marston and his people have generated, and there are a couple of graphs in there that show the critical flaw size as a function through the wall. That plot is in the document and it is in Chapter 4, I believe.

MR. BUSH: I was looking at it but I guess I missed it. I was looking at it also in terms of the piping. We did not look at piping deliberately.

MR. STONE: Gary, were you going to mention the level III certification activities as a follow-on, or would that be later?

MR. DAU: Yes, I was, as soon as the questions were finished here.

MR. SHEWMON: Go on with that.

MR. DAU: The last item on the agenda and the last item in the handout deals with the pe sonnel qualifications issue. Based on some discussions with the NRC staff and the Quality Assurance Branch last May where they raised serious questions and concerns about the certification process of inspection personnel being used in plants today, the utility industry decided to form a similar ad hoc committee, only this time they are acting before there's any official position from the NRC to grapple with this issue and come up with an industry position on the certification and qualification of the inspection personnel.

That committee has been formed, a charter has been developed and it is included in the handout. The next scheduled meeting is next week on Tuesday and Wednesday, and at that time we'll set the specific course of action. And we are hoping to wind that up in a fairly short timeframe.

MR. SHEWMON: Thank you. A short time is six months, one year?

MR. DAU: I would hope it's less than six months. The people that we want on that and are on the committee are also highly involved with ISI outages right now. Several of them have also been involved with the exercise at Battelle Columbus on the pipe demonstration. The key people that you really want have the background and experience, but they also have a lot of other commitments.

Our original goal was to try to come up with this in, say, a four to six-month timespan. Hopefully, we can still keep to this, although we have slipped a lot.

MR. SHEWMON: Okay. Thanks. Having heard about what industry has done for us lately on this 1.150, could somebody please describe, from the staff, what the schedule and options are likely to be? And what happens to it now?

MR. SERPAN: Chuck Serpan from the Office of Research. We have the industry revision in our shop right now. We have sent it to PNL, we have asked them to look at it. We are in the process of deciding whether we are going to issue it right now or whether we are going to try to upgrade it very quickly.

MR. SHEWMON: Issue it?

MR. SERPAN: I'm sorry, not issue it but take it in that form and turn it into a document and start it through the appropriate approval process, which goes through CRGR, the Commission and all of that, as an appropriate Revision 1 to take it as is and run it through or to put some additions on it.

We are negotiating right now with the regs staff on how we want to proceed with that.

MR. SHEWMON: Let me back up for a minute. This was something that went out for comment, or it was issued as a regulation? I am a little bit confused about where we are legally. Reg. Guide 1.150. Is it issued?

MR. SERPAN: Yes.

MR. BUSH: It went through the comment stage. It had all the approvals.

MR. SERPAN: It is issued. It is on the street. It is in use. What we are talking about is Revision 1.

MR. SHEWMON: Okay.

MR. SERPAN: Does that answer the question?

MR. SHEWMON: Yes. It says we are meditating on it. We don't know what we are going to do.

MR. SERPAN: That's correct, and I intend to get that resolved within a week as to whether we are going to move with it or whether we are going to try to upgrade it a little bit, but we are going to move it out as soon as we can.

MR. SHEWMON: If we were going to try to upgrade it a little bit, what areas do you think we would try to upgrade or do you know?

MR. SERPAN: I am not sure.

MR. SHEWMON: Do you feel it is an improvement over what was there before?

MR. SERPAN: It is clearly a distinct improvement over what was there before, sure.

MR. ETHERINGTON: It has the same format, I suppose.

MR. SERPAN: Yes, it was done exactly in the same format. If one really wanted to take it now and type it and get it into the approval process, they did it exactly in that format.

MR. SHEWMON: Spence, did you have a comment?

MR. BUSH: Well, obviously, there are some areas where you would improve it. I think what one has to balance now is the time element versus that. If your incremental gain is 10 percent and the delay is three or four months to get it in the process, it is probably marginal. If it is 50 percent, and I think that you might have to iterate back at least to touch base pro forma with the initial body, at least to see that you are not going in different directions, and it could be done in a short time, then I think it would be of major value, but obviously that is a decision Chuck is faced with now.

MR. SERPAN: That is exactly where we are right now.

MR. ETHERINGTON: I suppose you would be

sympathetic to any utility that wanted to take exception, wouldn't you?

MR. SERPAN: I didn't understand that.

MR. ETHERINGTON: You have always insisted it was a legal guide.

MR. SERPAN: You have to ask those fellows if they are going to set that out.

MR. HAZELTON: Warren Hazelton.

Regulatory Guides are funny things.

MR. ETHERINGTON: That is why I asked the question.

(General laughter.)

MR. HAZELTON: It is just a guide. Basically, it gives information to the utility on what kinds of things we will accept. If you do it this way, we would like that. However, if you are going to do it some other way that you think is just as good, why, we will listen. And we do that all the time.

MR. ETHERINGTON: So my question to you is, it isn't harder than usual this time?

MR. HAZELTON: What we have essentially tried to do, and part of the problem that we have is, Serpan and I are trying to find out where some of the paper work is. We tried to put out a letter to the utilities telling them that a Regulatory Guide was issued and carried the implementation date of a couple of months, and the industry has come in with some suggested revisions to it to be put in the document, and we said we feel that these are acceptable alternatives to the procedures given in the guide.

Those are the regulatory words that we would use, acceptable alternative procedures, et cetera.

MR. ETHERINGTON: And you could do that fairly promptly? Is that right?

MR. HAZELTON: I just found out that it didn't look like that letter went out to the utilities.

MR. ETHERINGTON: Oh, you already had such a letter.

MR. SHEWMON: The NRC didn't.

(General laughter.)

MR. HAZELTON: I think the division of engineering did, but it didn't get out, according to the information that I have.

MR. ETHERINGTON: Thank you.

MR. SHEWMON: Yes?

MR. DAU: I would like to offer a comment. I don't disagree with Warren's interpretation of the Reg. Guide, but the committee members, and meeting with the regional people and the consultants, really feel that when a guide gets out, that it is really what has to be done, and it isn't advisory at all at that point. That was a lot of the initial concern about the ambiguities in the issued guidance now on the streets, and in force.

That is where some of the confusion and concern amongst the utility members comes from. It is considered advisory at one level, but when the utility man is sitting across the desk from the regional person, a lot of that discretion goes away, and they want to know that it is going to be the same in Region 1 as Region 2, Region 3, and Region 4.

MR. SHEWMON: Let me ask one question of the people at the table. Would anybody have any complaints with my going to the full committee and urging a letter that -- or urging whoever we need to urge that the division of licensing send out the recommendation that Hazelton's group has sent forward, and that the NRC then indeed approve this or write a letter saying they approve of this as an alternative. Would that bother you, Harold?

MR. ETHERINGTON: No, as long as -- I thought the industry recommendations were still under review.

MR. SHEWMON: There are two levels. One, are they an acceptable alternative to the procedures of 1.150, which is the Reg. Guide that has already been issued. The other is the role they would play in the revision, in Revision 1 of Reg. Guide 1.150, which is under consideration by research.

MR. ETHERINGTON: It is only the latter that is under consideration?

MR. SHEWMON: It is only Revision 1 that is under consideration.

MR. ETHERINGTON: If the principles are acceptable to the Staff, I think that course of action is good.

MR. BUSH: I think so. I think what it says is, it puts the good housekeeping stamp of approval on that document and says, if you use this in lieu of the existing 1.150, it doesn't stop the reanalysis and expanded 1.150 at some time in the future, but it certainly offers a very viable and a much more acceptable alternative to the existing guide.

MR. SHEWMON: Do you have any complaints with that, Don?

MR. MC CLUNG: No, I agree that accepting this as an alternate at this time would be very timely and very useful, I think.

MR. SHEWMON: The ACRS may be useful or useless. I won't get into that, but it seems to me that we do have the authority and influence to sort of inquire, gee, whiz, what happened to that, and do we need to write a letter to the Commission to get you to act on it, and that does have a lubricating effect on occasion. Yes?

MR. BUSH: After all, and it is in the Christmas spirit, too.

MR. STONE: I would just like to ask a question about the possibility of, instead of considering it as an alternate document, to consider it as in fact an interim replacement document if it is generally agreed to be an improvement and would possibly result in more uniform inspections and approaches across the region. That was just something I wanted to ask as a question.

MR. SHEWMON: It is my impression, and I would like to have Warren correct me, but the Reg. Guide that comes out says, has in it the usual caveat that you can always try to convince us that some other procedure is adequate, and what they send up as a letter to the NRC would say, this is an acceptable alternate. Now, that falls under the other.

Now, to say that it is a replacement for it is the same thing as Revision 1, and that would have to go through all these reviews.

MR. BUSH: And the lawyers would have all kinds of trouble with it.

MR. SHEWMON: So we can accomplish the same thing by saying this is an acceptable alternate, and if we can get that letter out from the NRC, then the utility can use whichever one they prefer, and from all we have heard, it is reasonably clear which one they would prefer. Does that sound -- Did any of the federal employees here to keep us from running amok care to change that?

MR. HAZELTON: That is the way I see it.

MR. SHEWMON: Okay. Let's take a ten-minute break, and then we will come back for the steam generators.

(Whereupon, a brief recess was taken.)

MR. SHEWMON: A couple of us now have 4:00 o'clock flights. If I could move -- I'm sorry, 5:00 o'clock flights; 4:00 o'clock adjourning time.

Why don't you go ahead.

MR. SERPAN: Then I can really keep it short, can't I?

Chuck Serpan again, from Research.

The programs that we have in steam generator and environmental degradation are shown here. I have an indication of the budget. It's worth pointing out on the steam generator tube integrity program, this uses the Surry generator at Battelle Northwest. The NRC puts about a million dollars a year into that program. We get $1 million a year from outside contributors. The French and Italians have signed up already at $200,000 a year. The Japanese are about to sign up, the Japanese have signed up. EPRI is about to sign up, and we hope to get $200,000 a year either from the owners group or from Taiwan.

The other program I will talk about in sequence, the steam generator tube integrity program. I hate to read you all of this stuff. The objective is to determine the integrity of service-degrated steam generator tubing and developing an independent basis for NRC evaluation of tube cracking inspection and plugging criteria.

(Slide.)

The scope you can read. Let me tell you what we've done. The most important one so far up through '82 isn't even on there. Tube burst tests have been conducted and with laboratory and -- laboratory machine and laboratory stess corrosion-induced cracking there. The tube burst tests are being used now as the basis for tube plugging criteria evaluation in NRC.

We have also up through this year come up with predictive equations for predicted integrity of degraded tubes, and we're running eddy current test detection trials on laboratory crack tubes.

Now, through '85-'86 on the program what we intend to do is validate those predictive equations for tube integrity, so that based on NDE results we can indeed tell you whether the tube is going to fail or whether it will be integral.

We have developed -- this is a big one in this program from the NDE standpoint. We will develop and evaluate state of the art and improved eddy current techniques in all the tubes in that steam generator. The results from that will be to develop and validate the in-service inspection plans, the frequency and criteria for updating of the reg guide and licensing basis.

MR. SHEWMON: This is a summary of what you are doing at several labs or what you are doing at PNL?

MR. SERPAN: This is only the steam generator tube integrity program at PNL.

MR. SHEWMON: That's all at Pacific Northwest?

MR. SERPAN: That's correct.

MR. SHEWMON: When you talk about the state of the art improved techniques, there certainly are improvements over the old single frequency procedure.

MR. SERPAN: The multi-frequency, for example.

MR. SHEWMON: Are many of those being used? Is that to evaluate?

MR. SERPAN: We've used the steam generator and round robin trials with the current techniques that are being used, as well as new and advanced, for example multi-frequency type, eddy current techniques. Any and all of those will be used to find out whether they are reliable and how well they work.

MR. SHEWMON: So when we look at that bullet you emphasized there, the two from the bottom, that will be done by a group of facilities through the facility at PNL?

MR. SERPAN: That's correct.

MR. SHEWMON: Using that data base to make a decision or do this development?

MR. SERPAN: That's right. It would be very similar to what Steve Doctor has used with pipe tests. These are the samples, these are the tubes. The teams will be coming through and trying out their techniques as well as the current ASME code techniques to validate how well it's being done and what is the best way to do it, and that way we will come up with a recommendation as to the best way to do it.

MR. SHEWMON: After that you'll take those pipes out and nondestructively examine them, or what?

MR. SERPAN: They will be nondestructively examined in the generator itself.

MR. SHEWMON: Did you mean destructively examined?

MR. SERPAN: That's right. They will be removed, the flaw verified, and they will be destructively verified.

(Slide.)

The next is a program at Brookhaven on stress corrosion cracking of PWR steam generator tubes. The purpose here is to develop a model to predict the service life of Inconel steam generator tubes under normal and abnormal conditions. The program's been running for a number of years. It's come to a number of conclusions.

(Slide.)

The results are that we have established the feasibility of protecting the stress corrosion cracking service life of Inconel 600 steam generator tubing. We've developed some initial data, and here in '85 we will get to the bottom line. We will define the predictive model for the proper constants and we will validate all of those constants using data from the retired steam generator.

This will be input to regulatory information to then make predictions on the life of the steam generator tubes based on the water, environmental and stess conditions, as well as the metalurgy of the system.

MR. SHEWMON: How many constants are we talking about?

MR. MUSCARA: Three or four.

MR. SERPAN: How many constants? At least a half a dozen constants.

MR. MUSCARA: Joe Muscara from NRC Research.

I think the question relates to how many constants are there in predictive equations. There are three or four constants. There are essentially two equations. One would predict crack rates and the other would predict initiation times. There are two constants that will be determined.

MR. SHEWMON: And you hope to get those constants out of looking at that steam generator?

MR. MUSCARA: The constants are being developed in laboratory tests under various conditions. You would hope then to take a look at tubes from the steam generator, that we know the service life, and see if we can predict what equations will develop.

MR. SHEWMON: Okay, thank you.

MR. SERPAN: To validate it using that Surry generator data.

(Slide.)

The next program is the environmentally assisted cracking in light water systems, done at Argonne. The objective is to develop an independent capability for the prediction, detection and control of pipe cracking in light water systems. This program is relatively new, so it's worth looking at the scope: To develop and evaluate advanced NDE techniques for leak detection and also inspection of stainless steel piping.

Here we are trying to use UT to discriminate between stress corrosion cracks and geometry, and there is limited success with that but it looks promising. We will be looking at evaluating potential deleterious effects of low temperature sensitization, evaluate vendor and EPRI-proposed corrective actions for generic cracking problems using alternate environments, materials, or altered fabrication techniques, and to develop a mechanistic understanding of stress corrosion cracking.

(Slide.)

We don't really have any results at this point in the program. I could give you a list of what we expect to get in '85, but I think you can read those. It's a relatively new program.

(Slide.)

The next is aging of cast stainless steel. The objective is to provide an independent assessment of cast stainless steel. The objective is to provide an independent assessment of the effect of long-time service at operating temperature on cast austenitic stainless steel components for nuclear service.

For this we are looking at components that have been removed from service, and we have material from the Gundrumian reactor in Germany, and we're also trying to do some long-term studies. What we hope to come out with by about '85 is to establish the metalurgical phenomenon and factors responsible for the toughness loss, to evaluate the degree and importance of toughness loss and correlate to time, temperature, material chemistry and so forth, and then to develop and evaluate solutions to the problem both for existing and for new plants.

(Slide.)

The second to the last one is on welding and repair of stainless steel. The objective is to develop a methodology for evaluating the acceptability of welded and/or repair welded stainless steel piping for light water service. The impetus for this program comes from incidents that have happened in the field where pipes have been repair welded many, many, many times, and you know that they are sensitized.

The objective of this whole program is to come up with a background of criteria so that you can write reg guides and procedures for the appropriate welding or repair welding of pipe in the field.

(Slide.)

PWR secondary side corrosion is the last topic. It's a very new program. In fact, it hasn't even started. We're proposing it for this year. It is to develop a data base on distribution of secondary side water ingredients between bulk and localized areas as a function of normal and upset operating conditions, and to perform corrosion testing under corresponding conditions to develop a basis for evaluating secondary side water chemistry optimization control and limits.

This program has been put up and proposed to get started this year in direct response to comments that have come from this Committee for the need for that kind of work, and I don't think there's any point in going through what we're going to have, especially in view of the time.

Are there any comments? I'm sorry it was quick.

MR. SHEWMON: Gary?

MR. DAU: Chuck, the program on weld repair you're talking about, is that dealing with weld repairs during fabrication or repairs made in service or both?

MR. SERPAN: I think it's both.

MR. SHEWMON: I have one question, not even related to what you had. That is, one of the large programs that we aren't going over this year is the HSST program, and you have in the past had a show and tell or review down there on an annual or something like that basis. Do you plan one of those in '83?

MR. SERPAN: We clearly will have one in '83, but I don't know when.

MR. SHEWMON: As you learn of that, would you keep us informed as soon as you can?

MR. SERPAN: Yes, sir, I certainly will.

MR. SHEWMON: Any other questions on this?

(No response.)

MR. SHEWMON: Okay. Thank you very much.

I guess at this point I'll adjourn the meeting, then, if there are no other comments.

(Whereupon, at 3:40 p.m., the meeting was adjourned.)

* * *

NUCLEAR REGULATORY COMMISSION

This is to certify that the attached proceedings before the

____

in the matter of: ACRS/Subcommittee on Metal Components

Date of Proceeding: December 2, 1982

Docket Number: ________________

Place of Proceeding: Washington, D. C.

were held as herein appears, and that this is the original transcript thereof for the file of the Commission.

Patricia A. Minson

Official Reporter (Typed)

Patricia A. Minson

Official Reporter (Signature)

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Jane N. Beach

Official Reporter (Typed)

Jane N. Beach

Official Reporter (Signature)

NINE MILE POINT, UNIT 1

- FURNACE SENSITIZED SAFE ENDS LEAKED DURING HYDRO IN MARCH 1982
  - NO CRACKS FOUND IN UT EXAM NINE MONTHS EARLIER
  - IGSCC CONFIRMED
  - BEING REPLACED
- INSPECTION OF PUMP ELBOW FOLLOWED - IGSCC CONFIRMED
- INSPECTION EXTENDED TO 28 INCH DIAMETER RECIRC PIPE
  - ~40% OF WELDS INSPECTED BY UT
  - ~ALL HAVE UT INDICATIONS
  - REPORTED TO NRC 8/82
  - BEING REPLACED

OVERVIEW OF NRC APPROACH

INITIAL CONCERNS WITH BOTH SAMPLING PLANS AND UT METHODOLOGY

MEETING WITH BWR LICENSEES

-- SAMPLING PLANS GENERALLY ADEQUATE

-- DOUBTS ON EFFECTIVENESS OF UT EXAMINATIONS NOT RESOLVED

DECIDED TO PROCEED WITH UT METHODOLOGY VALIDATION PROGRAM

IE BULLETIN 82-03 ISSUED ON OCTOBER 14, 1982

FUTURE ACTIONS DEPEND ON PLANT INSPECTION RESULTS

OVERVIEW OF VALIDATION PROGRAM

DEMONSTRATION BY UT VENDORS

- -- PERFORMED ON NMP-1 SAMPLES
- -- BLIND TEST
- -- SAME TECHNIQUES AS USED AT PLANT SITE

DEMONSTRATION WITNESSED BY IE (BETHESDA) AND REGIONAL INSPECTOR

- -- CONSISTENCY BETWEEN VARIOUS UT ORGANIZATIONS (IE)
- -- TECHNIQUE SAME AS USED AT PLANT SITE (REGIONAL INSPECTOR)
- -- ADEQUACY OF DEMONSTRATION JUDGED JOINTLY BY IE AND REGION

IE BULLETIN 82-03

ADDRESSED FOR ACTION TO:

MONTICELLO

BROWNS FERRY 2

QUAD CITIES 1

DRESDEN 2

MILLSTONE 1

HATCH 1

BRUNSWICK 1

OYSTER CREEK

DUANE ARNOLD

ACTIONS REQUIRED BY BULLETIN

- DEMONSTRATE EFFECTIVENESS OF UT METHODOLOGY
- PROVIDE RESULTS OF INSPECTIONS
- DESCRIBE CORRECTIVE ACTIONS IF CRACKS DETECTED
- SUBMIT SAMPLING PLAN

2

EPRI

SUMMARY OF EPRI WORK ON IMPROVED STAINLESS STEEL PIPE AND PRESSURE VESSEL INSPECTION

PRESENTED TO

METAL COMPONENTS SUBCOMMITTEE
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
US NUCLEAR REGULATORY COMMISSION
P. G. SHEWMON, CHAIRMAN

BY

GARY J. DAU
JAMES R. QUINN
EPRI

ROBERT M. STONE
MOHAMAD BEHRAVESH
F. LARRY BECKER
EPRI NDE CENTER
(OPERATED BY J. A. JONES APPLIED RESEARCH CO.)

ELECTRIC POWER RESEARCH INSTITUTE

DECEMBER 2, 1982

WASHINGTON, D.C.

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DECEMBER 2, 1982

WASHINGTON, D.C.

A G E N D A

DECEMBER 2, 1982

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AD HOC PERSONNEL QUALIFICATION COMMITTEE

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NDE CENTER'S ROLE
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nuclear news

A Reprint

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EPRI center well started on technology improvement

With its Nondestructive Evaluation Center (NDEC) in Charlotte, N.C., in full operation, the Electric Power Research Institute (EPRI) has moved aggressively into a new phase of safety R&D on nuclear plant hardware—an activity that complements the well-known programs of its Nuclear Safety Analysis Center (NSAC) and of the Institute of Nuclear Power Operations (INPO).

The new center, which was officially opened last year, was conceived by EPRI's Nuclear Power Division and its Nondestructive Evaluation Committee to fill an industry-wide need for improving the technology and techniques required for the in-service inspections that are the legal responsibility of nuclear plant owners and operators.

The committee, composed of technical experts from member utilities with operating nuclear power plants, concluded that a dedicated nondestructive evaluation center would ideally serve this need for an orderly, comprehensive, and efficient transfer of relevant technology and knowledge and for the development of scientific equipment and analytical methods. As conceived, the NDEC would give special attention to the need for rapid transfer of R&D results into field-qualified equipment and procedures.

The NDEC—a 67 000-square-foot facility of offices, laboratories, high-bay areas, classrooms, and shops—is located in the area of Charlotte known as University Research Park. It is managed for EPRI by the J. A. Jones Applied Research Company, which was formed as a subsidiary of J. A. Jones Construction Company for this purpose. Thomas A. Nemzek, president of the research company, manages the center.

The NDEC's programs span the spectrum of nondestructive tests required for nuclear plant in-service inspections, and its daily routine involves seminars and training sessions for personnel from member utilities. These sessions fulfill the center's mission for the transfer of technology and experience.

Special technical programs are directed at inspecting the steam generator tubes associated with pressurized water reactors, examining boiling water reactor piping, and analyzing the weld joints on pump and valve housings and nozzles and on reactor pressure vessels.

The versatile Minac

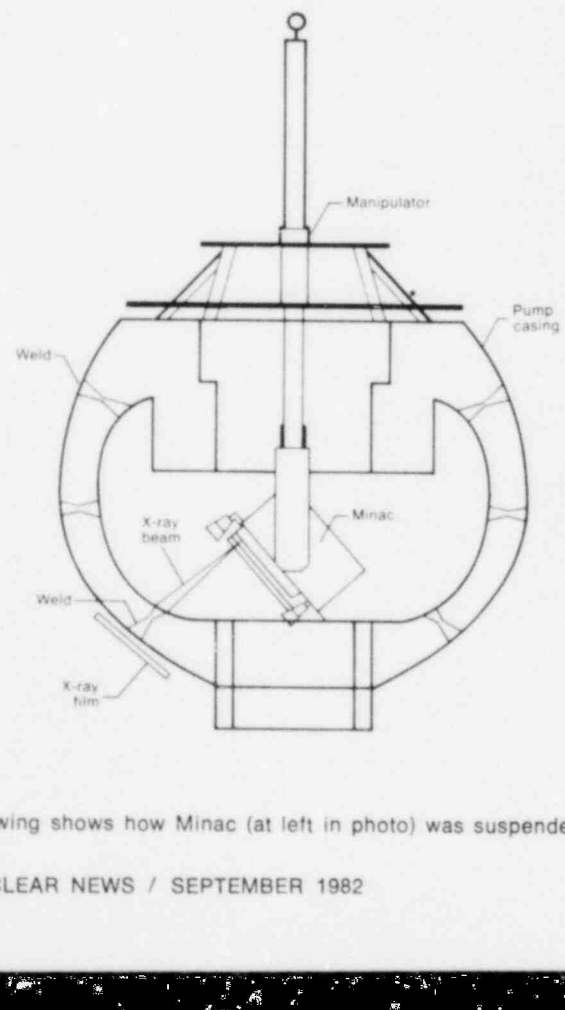
Highly specialized equipment and examination techniques have been developed for all these inspection areas; the center points with special pride, however, to its miniature linear accelerator (Minac), a portable device used to radiograph in place thick-section steel or other dense materials.

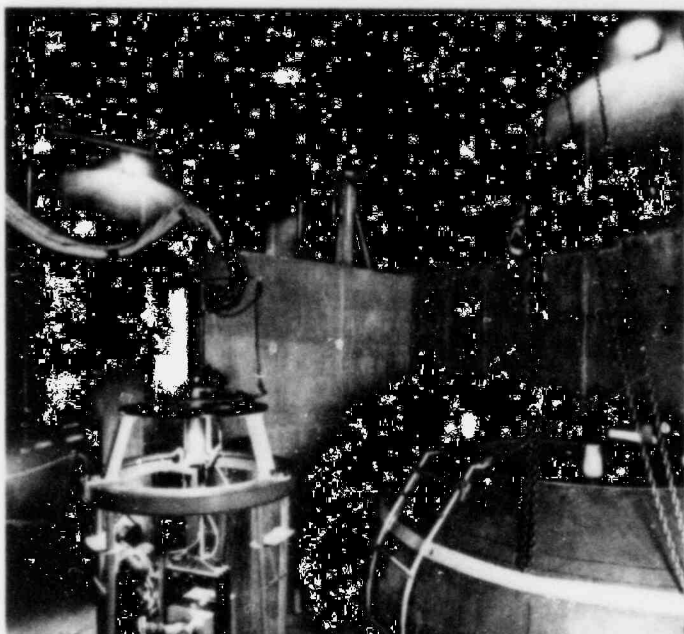
Although component manufacturers have used large, permanently installed high-energy accelerators for in-factory examination of thick steel sections, these kinds of inspections have not previously been readily available in the field, where radioactive isotopes—usually cobalt or iridium—have been the only practical radiation sources for on-site inspections.

Aside from difficulties in handling, the radioactive isotopes ordinarily do not provide radiography intensities high enough for the thick-section penetration. And so the Minac is seen as an important new tool for nondestructive testing in nuclear plants.

Developed by the Schonberg Radiation Corporation and EPRI, the Minac is roughly five times smaller than the conventional stationary accelerators used by component manufacturers, yet it has the requisite power plus the versatility of being portable.

The 3.5-MeV linear accelerator provides radiation emission of approximately 90 roentgens per metre per minute. It consists of four major components and associated cabling. These are: an x-ray head, measuring 18 × 18 × 25 inches and weighing 250 pounds; a power modulator; a cooling-water control system; and a control console. The complete system weighs about 700 pounds.





Drawing shows how Minac (at left in photo) was suspended within Ginna main reactor coolant pump

The Minac was used in its first field application in May 1981 at the Ginna nuclear power plant, owned and operated by Rochester Gas & Electric. It was used to make mandated checks on three circumferential electro-fusion welds joining four cast sections of a main reactor coolant pump.

The weld paths in the Ginna pump varied in thickness from about 8.5 to 11.25 inches. Because high radiation inside the pump would fog the film, the Minac head was suspended inside the pump cavity, and the x-ray film was positioned on the outside. This is a reversal of the usual manufacturer's inspection procedure. The control console was in a trailer outside the plant's containment structure some 200 feet from the actual inspection.

During this inspection, Minac was operated continuously for 100 hours, during which time 100 exposures were made at durations ranging from 20 minutes to 3.5 hours. Radiographs of excellent sensitivity (typically 1 percent) were achieved.

Subsequently, Minac was used successfully for reactor coolant pump inspections at Point Beach (Wisconsin Electric Power) and Turkey Point (Florida Power & Light) stations, and by Consolidated Edison at Indian Point to locate constrictions in the main steam lines. In the last instance, the Minac identified two main steam-line valves that were partially closed. The valves themselves were not inherently difficult to radiograph, but because the inspections were to be made with the plant at full power, they presented environmental problems of high temperatures and radiation, successfully coped with by the use of the Minac.

The Minac equipment is leased to electric utility companies through the J. A. Jones Applied Research Services Company. Training in its use is provided by NDEC personnel. It is still considered a protoype device, with modifications and improvements to be made as they become evident and are required.

NDEC technician evaluates computer-controlled ultrasonic inspection system

Evaluated at NDEC: automatic welding machine used to join BWR pipe segments

Other areas of emphasis

Other programs at NDEC involve steam generator tube inspections, BWR stainless steel pipe inspections, and turbine rotor inspections and lifetime predictions.

Steam generator tubes must be examined periodically to satisfy both legal and safety requirements governing high-pressure systems. The thin-walled tubes are inspected by induced eddy currents. Tube-wall defects perturb the current flow, and this is sensed in the induction coil. Signals from the coil are displayed remotely for interpretation by a data analyst, who assesses tube-wall integrity.

Since other influences—such as tube deposits, support plates, and irregularities on the inner surface of the tubes —are routinely encountered during tube inspections, these can confuse an analysis made by the single-frequency, eddy-current method. Accordingly, multiple-frequency eddy currents are induced to reduce the effects of such extraneous variables. The analyst samples the signals at different frequencies, and this provides a more reliable assessment of tube integrity. The NDEC is currently evaluating multiple-frequency eddy-current equipment to identify its capabilities and to optimize analytical procedures.

Regarding BWR stainless steel piping, NDEC conducts programs in ultrasonic testing to detect corrosion-induced cracks close to the welded joints; in particular, it manages a "BWR Owners Group Pipe Remedy Application and Demonstration Program" that seeks to devise methods and equipment to detect and correct intergranular stress corrosion cracking. The BWR owners group maintains a full-sized power plant piping configuration at NDEC, and it conducts frequent training sessions on topics such as "Welding and Machining Considerations for Pipe Remedy Applications" and "Shielding and Decontamination Considerations for Pipe Remedy Applications."

The NDEC also uses ultrasonics in its turbine rotor inspection programs. In this connection the NDEC is engaged in measuring the relative performance of various ultrasonic inspection systems available to utilities to help determine which is most suitable for their applications.

EPRI conducts a computerized rotor lifetime prediction program, called SAFER (*S*tress *A*nd *F*racture *E*valuation of *R*otors), which enables the utilities to analyze their rotors and to reach decisions concerning running, repairing, or retiring units. A workshop on the SAFER program, conducted in March 1982, was attended by 66 utility representatives.

Typical NDEC activities

The schedule of activities at the NDEC is typically brisk. For example, in March and April of this year the center conducted, in addition to the workshop mentioned above, the following activities:

- Rapid response to a utility regarding steam generator tube fretting and continued work with the same utility to develop special procedures for use during future outages.
- Loan of intergranular stress corrosion cracking specimens to domestic and foreign members of the BWR owners group.
- Intergranular stress corrosion cracking workshop for 35 utility and vendor in-service inspectors, including representatives from eight domestic utilities, three in-service inspection vendors, and two foreign utilities.
- Rapid response to utility—review and report on results of testing of steam generator tubes.
- Rapid response to utility, including on-site visit, to review eddy-current data associated with copper pitting problem.
- Formation of SAFER users group to coordinate use of future development of the EPRI-developed program. Fourteen utilities have agreed to participate.
- Minac application on Westinghouse Model 93 pump configuration for member utility plant.
- BWR owners group meeting for utility maintenance supervisors, to hear utility needs and preferences in development of informational materials. Twenty-two people participated, representing 11 domestic and 2 foreign utilities.
- Participation with the University of North Carolina at Charlotte and local utility in a course taught to senior engineering students with demonstrations and lab exercise, with NDE applications provided at the center. Course outline will be made available to other universities.
- Level II course in visual examination for utility personnel, with modules authored by a variety of knowledgeable people from the industry. Participants in the course received continuing-education units.
- Rapid response to a utility to investigate the use of Minac on main steam stop valve at a fossil plant.
- Construction of special mockup for utility use in qualifying machining procedures and equipment for major repair on site.

COVER: The Minac test setup at the Electric Power Research Institute's Nondestructive Evaluation Center (NDEC) in Charlotte, N.C. The large metal structure is a full-scale mockup used for demonstration and training with the Minac portable radiography system, positioned inside the structure.

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The 'infinite' matrix printer: a design case history
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SEPTEMBER 1982 THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC.

Power/energy

Finding the flaws in nuclear power plants

Nondestructive, remote testing techniques are necessary—and are being devised—to improve the operational safety of nuclear plants

Premature pinholes in the steam generator tubing of the Indian Point 3 nuclear power plant in New York State and vibration-induced wear of the Ringhals 3 nuclear steam generator in Sweden have one thing in common: they are typical of a worldwide rash of similar aging problems that are shutting down reactors or forcing them to operate at reduced power. And wherever nuclear plants remain down for inspection and repair, consumers storm at the resulting utility rate increases to cover the purchase of replacement power. To meet the problem, fresh nondestructive evaluation (NDE) techniques are being devised to give earlier warning of troubles that may threaten public safety or plant availability.

Research and development sponsored by the Electric Power Research Institute (EPRI) in Palo Alto, Calif., has led to these new NDE techniques:

- A high-energy, portable X-ray system for ensuring the integrity of thick metal reactor vessels and coolant pumps. The equipment can be placed where cumbersome conventional radiographic equipment cannot.
- Significantly improved ultrasonic methods to enable reliable detection and characterization of corrosion-induced cracks in pipes.
- Advanced eddy-current inspection equipment for steam generator tubing. The equipment uses multifrequency and multiparameter methods of suppressing extraneous variables.
- Automated inspection and evaluation systems capable of reducing plant downtime and the need for expert interpretation of data.

Before being used in nuclear plants, NDE approaches like these are undergoing rigorous field testing as part of a carefully developed program of technology transfer to a besieged electric utilities industry. In the U.S. the utilities are now suffering from Federal withdrawal of energy-related R&D funds, as well as from public opposition to nuclear power. But at a time when many are hard put to pay for the new technology, they find they also cannot afford not to have it.

Troubles were built in at the start

The present troubles of the nuclear power industry began years ago as plants were being built. According to NDE experts, the designers of the plants appeared to assume that nothing in the plants would fail. Because inspection requirements were less stringent at the outset, access for in-service inspection equipment was rarely planned realistically. Most in-service inspections were left up to the same contract services that inspected pipelines one day and perhaps aircraft the next. Flaws in nuclear plants went unnoticed, partly because of code requirements and partly because the conventional techniques and technology of nondestructive evaluation did not always transfer well to the burgeoning nuclear power industry. The original philosophy was that mechanical wear would cause most flaws, but experience has shown that environmental factors are more important.

Evan Herbert Contributing Editor

There are crucial differences between the components in nuclear plants and those of other industries. Everything tends to be larger, usually requiring assembly amid the more rugged conditions of a construction site rather than in a precisely equipped factory. On-site inspection of piping, vessels, and other components is far more difficult than factory testing. Many materials have nonhomogeneous properties; they produce signals under examination that mimic flaws. Once plants are in service, inspection is made more difficult by cramped quarters, heat, humidity, and especially radiation.

Among the most critical of nuclear power plant components are reactor coolant pumps. Inspection of their heavy metal sections, up to 30 centimeters thick, poses unusual difficulties. Though these components appear reassuringly massive, their continued integrity is so vital that in-service inspection every 10 years to satisfy certain ASME codes is mandated by law. Regardless of the NDE techniques used, the codes also require visual inspection of the pumps' inner surface.

Conventional X-rays too cumbersome

While X-ray devices would seem to be the most effective for nondestructive evaluation of heavy metal sections, their use is frequently inhibited by background radiation from the activated corrosion products on the objects being inspected. This radiation can fog the X-ray film before it can be exposed long enough to produce a useful image.

Conventional industrial radiography equipment can produce enough output energy—in the range of 4 to 25 megaelectronvolts—for satisfactory penetration of thick targets with only short exposure times. But this equipment is much too large and heavy for nuclear power plant inspection. Merely transporting 2½ tons of unwieldy components through the cramped maze of piping would be a major problem. In addition, the X-ray components would be too large to be placed inside valve and pump bodies and then manipulated to produce a succession of photographs of the critical weld areas.

In 1977 EPRI set out to develop a high-energy, miniature X-ray inspection device. The high-energy techniques existed, but the trick was to choose one that offered the best prospects for miniaturization. High-energy electrons can be converted into X-rays by collision with heavy metal targets, so the linear accelerator (Linac) looked like a good bet.

A Linac propagates a radio-frequency wave down an evacuated waveguide to establish electrostatic accelerating fields. Electrons are injected into the waveguide so they travel in the same

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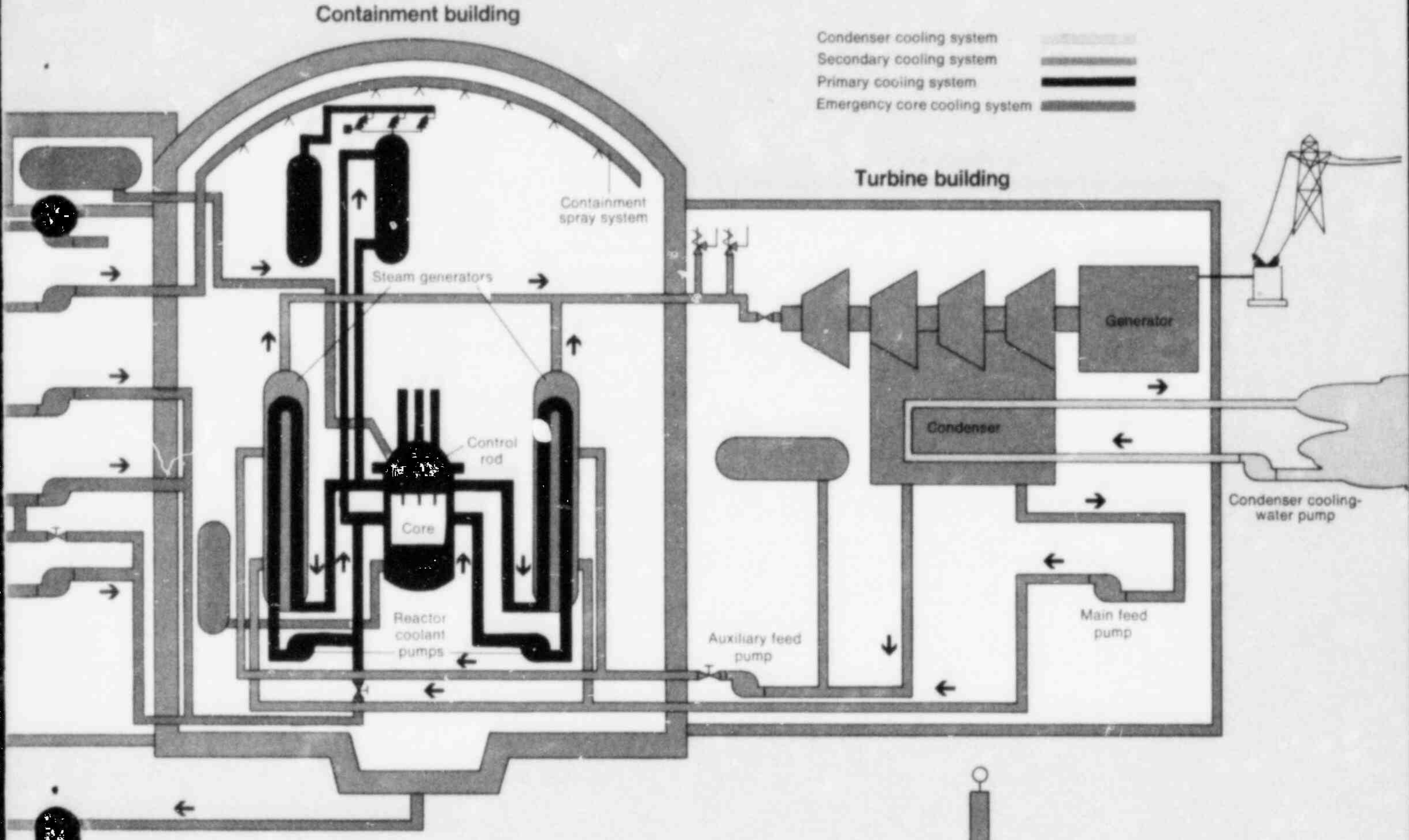
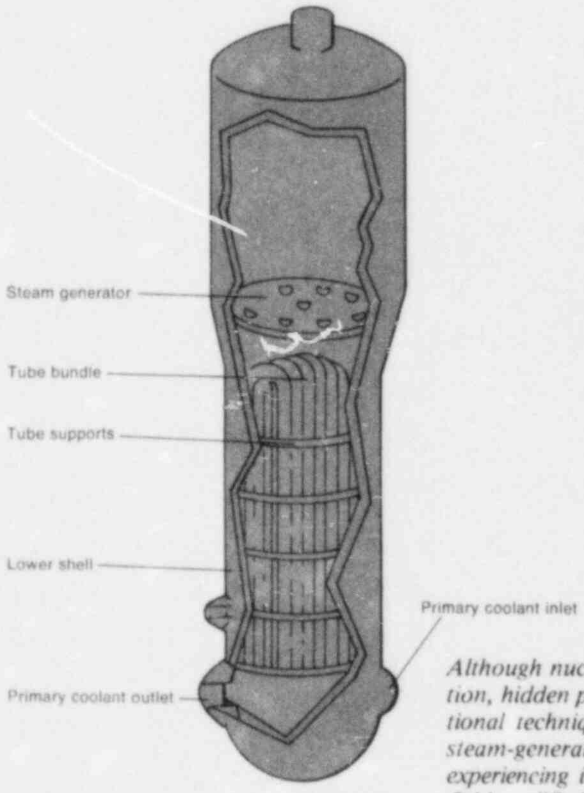
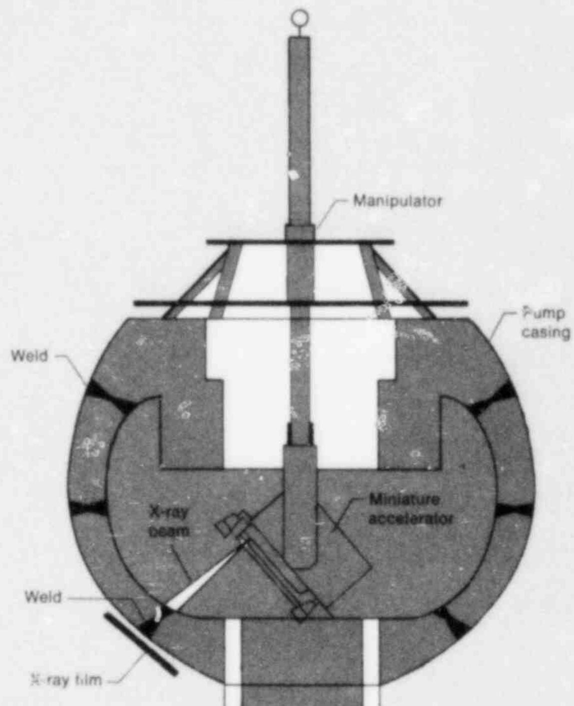






Although nuclear power plants [top illustration] are subject to periodic inspection, hidden problems have been popping up, apparently undetected by conventional techniques of nondestructive evaluation. Leaks have appeared in the steam-generator tubing [left], and stainless-steel piping has cracked after experiencing intergranular-stress corrosion. New NDE technology is now being field-qualified [above] to probe these vital areas more accurately.

Engineering the technology transfer

When problems began showing up in nuclear power plants in the early 1970s after the installations had passed prevailing inspection requirements, utilities in the United States became concerned that the techniques needed to inspect plant equipment were markedly different from what was commercially available. But the expense of developing specialized nondestructive-evaluation (NDE) technology was a problem in a nuclear power industry that has largely stopped growing, partly because of the troubles that better evaluation might have spotted in the first place.

To extract the industry from this chicken-and-egg dilemma, the utility-supported Electric Power Research Institute (EPRI) in Palo Alto, Calif., stepped up its R&D on NDE techniques. EPRI has been operating such a program almost since it was founded 10 years ago, so it had a leg up on solving the problems.

For the ailing U.S. nuclear power industry, there was need for a quick fix. After the Three-Mile Island accident in 1979, there were wholesale postponements and total cancellations of nuclear power projects. Today major designer-constructors of nuclear plants are shifting their activities to service and repair. Inspections of the 74 existing U.S. plants now are more frequent, and when the plants are down, the cost of replacement power can be in the neighborhood of $1 million per day, a cost legally passed on to consumers. A public unpredictably hit in the pocketbook or threatened by technology gone awry is unlikely to support nuclear power. Plant availability and safety have become leading issues, and significantly improved NDE could be one part of the response today.

But in 1979 it did not look as if the response could be quick. NDE techniques were slow, cumbersome, and highly dependent on expert interpretation. Field experts were scarce, and their inspection careers were limited by cumulative exposure to radiation. EPRI's attempt to improve NDE for the nuclear power utilities centered on these strategies:

- Ensuring sufficient numbers of adequately trained inspection personnel.
- Devising more portable inspection systems that required less set-up time, so teams could enter a work site, do their jobs quickly, and leave with less exposure to radiation than formerly.
- Developing automatic analysis techniques to reduce reliance on human interpretation of inspection system readouts.

None of these strategies were susceptible to quick-fix activities in the face of a genuine shortage of NDE research and engineering talent. The same people couldn't be called upon to do everything, nor were they always the best for everything needed. When EPRI analyzed attempts to form contractor teams to transform R&D into field-qualified equipment and procedures, it found that the available people had either a strong research or a strong applications orientation. Few researchers make good field engineers, and field engineers often are too busy with production requirements to appreciate the ripening fruits of research.

Certainly, EPRI reasoned, there was very little capability between these two poles to concentrate on effective transfer of technology from the laboratory to the field. And an industry group called the Nuclear Systems and Materials Task Force had stressed the need for *rapid* technology transfer.

When EPRI looked at foreign efforts in NDE research and transfer, it found two British operations that were pressing the development of field products. These were the Nondestructive Testing Applications Center, operated by the Central Electricity Generating Board, and the British Gas Corp.'s On-Line Inspection Center. In part, they became models for EPRI's Nondestructive Evaluation Center in Charlotte, N.C.

Quick start on faster fixes

Technology transfer is a fuzzy buzzword—easy to toss off, but hard to accomplish. EPRI was not set up to do it because policy required that it operate in a contract R&D mode, which is fine for long-term activities but sluggish for fast response to new generic problems. Moreover, EPRI did not want to become involved in a situation in which it might be accused of bias in promoting the commercial outcome of its own research.

What the institute did was put out a competitive request for a proposal for an independent contractor to run the NDE center. The center would establish the general applicability of a given R&D approach, whether by EPRI-funded projects or other research sources. It would quantify performance characteristics of inspection systems. The center would then do engineering development to optimize prototype in-service inspection systems. It would develop and document procedures for use of field-qualified equipment and would serve as an independent body of expertise in providing utilities with technical answers to inspection questions related to operational or regulatory situations.

A major hurdle for any development and adaptation of NDE technology is the need to work on actual power-plant components—steam-generator tubing, turbines, reactor-coolant pumps, stainless-steel piping—with a variety of flaws the inspection equipment should be able to detect reliably. Most such components are huge, hard to acquire, and often too contaminated to be handled safely by personnel in the ordinary laboratory.

So EPRI sought to establish a center where realistic samples and mockups could be used for equipment development and qualification and for refinement of inspection techniques and the training of personnel under simulated field conditions. The J.A. Jones Applied Research Co. in Charlotte was selected to design and manage the $4 million center, which opened in February 1981, a little more than a year after the contract was awarded.

The parent company, J.A. Jones Construction Co., had long been involved in energy-related projects. The center's manager is Thomas Nemzek, president of the applied research affiliate and formerly the director for the Division of Reactor Research and Development for the U.S. Atomic Research Commission/Energy Research and Development Administration. Mr. Nemzek established the center on a 9-acre site in the University Research Park in Charlotte and selected the technical staff.

The charters and responsibilities of the various divisions are carefully defined. The Inspection Applications and Technology Division is responsible for NDE technology evaluation, inspection systems evaluation, systems improvement and qualification, participation in initial field applications, and NDE training programs. The Repair Applications Division has identical responsibilities and is aimed at remedies for the problem of cracking in boiling-water reactor recirculation piping systems. A Field Applications Division consists of people with field experience who are charged with continuing field aspects of technology transfer and demonstration.

EPRI funnels the projects of its R&D contractors into the center for evaluation. EPRI's program manager for NDE, Gary J. Dau, is responsible for developing improved in-service inspection technology for commercial nuclear power reactors. A program related to the NDE activities but funded separately by the Boiling Water Reactors Owners Group is also being conducted at the center.

A carefully engineered program of technology transfer involves some field use for the intended inspection purpose, followed by modification or refinement as required, and then more field qualification by utility personnel—trained in its use at the center—to satisfy code, regulatory, insurance, or utility informational requirements. Qualification using adequately trained utility personnel enhances the probability of successful technology transfer and diffusion of the developments into industry. *—E.H.*

direction as the wave. The waveguide is so constructed that the principal wave and particle have the same velocity at all points; the electric field component of the wave is directed along the axis. This construction permits properly phased injected electrons to undergo continuous acceleration throughout the length of the waveguide.

The available Linacs, though, were large. Their size was determined by peak RF power, the frequency of the RF carrier, and the output energy desired. Confirmation that miniaturization was possible came from declassified military work on the folding of waveguides for airborne radar and other equipment. Studies showed that increasing the carrier frequency from the conventional 3000 megahertz to about 9000 MHz could reduce size substantially. Conventional microwave plumbing was available commercially, but the higher frequencies would require exquisitely precise machining and soldering of the plumbing.

For the development of the miniature accelerator, or Minac, EPRI turned to Schonberg Radiation in Mountain View, Calif. It is headed by Russ Schonberg, one of the original developers of the Linac at Varian. Meanwhile Rochester Gas & Electric in New York State conducted parallel development of equipment to manipulate the Minac during inspection of the reactor cooling pumps at its Ginna nuclear power unit.

Portable X-ray unit developed

This collaboration resulted in the development of a 225-pound X-ray mechanism measuring 18 by 18 by 30 inches and producing 3 MeV of energy. A conventional source with equivalent strength would weigh 3000 lb. The system consists of a radiographic head that can be placed 200 feet from the modulator power supply, which in turn can be about 100 ft from the control console. These lengths enable the Minac operator to use distance and available shielding, like building walls, to avoid exposure to radiation during inspections.

However, inspection personnel wearing anticontamination clothing must tape film to the outside of the component prior to each exposure. Obviously one cannot put all the film in place on a welded section and then sequence Minac, for fogging would be caused by background radiation. Though placing the film sounds simple, in some cases inspection personnel must endure 50°C in their cumbersome clothing.

Part of the technology-transfer process is to choose an equipment-development contractor likely to follow on with commercial hardware. Field demonstration adds to the momentum of the process, and Rochester Gas & Electric already had a stake in Minac's success with its own efforts on the associated manipulation system. So the Ginna nuclear plant near Rochester became the site of the first successful field application, with radiographic inspection of austenitic welds in a reactor coolant pump that had been in service for more than 10 years.

Shortly after these mid-1981 demonstrations at Ginna, a possible problem arose in Consolidated Edison's Indian Point 2 nuclear station, just north of New York City. The 24-inch steam-isolation valve design in this plant incorporates a flapper that drops to the closed position when pressure is reduced. There was a question as to whether this disk was lifting properly during normal operations; if it was not, there would be excessive line-pressure loss and reduced plant power output. Minac radiography defined the internal configuration of each operating valve without a costly shutdown of the plant. It pinpointed all malfunctioning locations and helped establish the required adjustments. Fixes were made during the next scheduled shutdown of the plant, and output was increased significantly.

Following those initial field demonstrations, a modified Minac and its manipulator, plus a mock-up of a reactor coolant pump, were installed at EPRI's Nondestructive Evaluation Center in Charlotte, N.C., for training of inspection and utility supervisory personnel. The modifications indicated that not everything could be anticipated in the development laboratory, and they underscored the importance of field qualification as part of technology transfer. Minac needed improvements in dosimetry, more instrumentation readouts, and revision of the cooling water circuitry to ensure stable operation regardless of plant water conditions. The manipulator was modified so that its mast and Minac could be handled as a single subassembly, markedly reducing the time the inspection team is exposed to radiation in the reactor's building.

The first field demonstrations had been conducted by the developers of the system. Now there were demonstrations by newly trained in-service inspection personnel from the Southwest Research Institute. These tests were conducted at the Wisconsin Electric Power Co.'s Point Beach nuclear plant, yielding more feedback of significance. A number of X-ray retakes were required because of the poor quality of the automatic film processor. This led to equipping Minac's transport van with its own high-quality film processor. It was found, too, that the transport van could be placed close enough to the containment buildings at most nuclear installations to enable it to serve as an operations control room, thus cutting the set-up time for inspections.

Minac is now fully booked for utility inspections, and Schonberg Radiation is extremely busy building additional Minac systems.

Tracking pipe cracks

Ultrasonics, long a mainstay of nondestructive evaluation, has also been undergoing improvement to meet the particular needs of the nuclear power industry. A major reliability issue in recent years has been pipe cracking in the primary system of boiling-water reactors (BWRs). Corrosion-induced cracks have developed close to the welded joints of stainless steel piping. The number of incidents has passed 200, or about 1 percent of the welds, since the first discovery in 1974. Pipe cracking is not classified as safety-related, but it does reduce plant availability and is therefore an economic problem.

The troubling aspect of the initial discovery of pipe cracking was that the affected pipes had recently been ultrasonically inspected in accordance with prevailing codes and procedures. Subsequently the cause of the cracking was found to be intergranular-stress corrosion, a phenomenon normally encountered in the heat-affected zone of a weld. But inspection of this zone by ultrasonics is unreliable because some properties of the base material and the intergranular-stress corrosion may inhibit detection of return echoes.

When there is a return, the inspection and analysis problem becomes one of differentiating signals caused by cracks from signals of comparable magnitude caused by geometric reflectors in or near the heat-affected zone. The cracks occur in various shapes and orientations, but conventional ultrasonics, calibrated on drilled holes or machined notches, will detect some cracks while missing others.

A major obstacle to the development of improved ultrasonics was the limited availability of flawed specimens. EPRI began to collect flawed equipment that had been removed from service. It was soon discovered that Japan, which was pursuing a zero-defects approach in most production, was manufacturing flaw samples that could be used to develop advanced NDE instrumentation. Since then other manufactured flaw specimens have become available in the U.S. from Battelle-Northwest.

The NDE center is evaluating a Manual Analog Call-Confirmer, which is designed to give an alarm when a crack is detected. Its sensitivity is excellent, but modifications are needed to reduce the percentage of false alarms. An automatic pipe-inspection system has been given prequalification tests on a mixture of weld specimens and pipe sectors containing intergranular-stress corrosion cracks. Field workshops on ultrasonics are held for in-service inspection vendors and utility personnel, but they are also attended by observers from the U.S. Nuclear Regulatory Commission and from EPRI's R&D contractors.

Predicting a turbine rotor's life

Although failures in steam-turbine generators are rare, the enormous stored energy can cause considerable damage, as emphasized by the catastrophic failure of a coal plant's turbine rotor in the Tennessee Valley Authority's Gallatin station in 1974. A typical rotor may weigh 150 tons and spin at 3600 revolutions per minute. At Gallatin there was brittle fracture of the rotor originating from a large flaw in the forging. The rotor broke apart.

Traditionally utilities have relied on the turbine manufacturer to provide in-service inspection and to make recommendations for restrictive duty-cycle operation, repair, or retirement of a unit. Because of the high cost and long lead time for rotor replacement, with loss of generating capacity during downtime, utilities have sought to make their own independent inspections and evaluations. EPRI's NDE center is measuring the relative performance of various ultrasonic inspection systems to help utilities determine which is most suitable for their own turbine inspections.

Most rotors have a central bore in which an ultrasonic probe can be placed to detect interior flaws. The material nearest the rotor bore is the most highly stressed, requiring the most sensitive and repeatable inspection. But conventional ultrasonic techniques have limited sensitivity in the very near bore region, so specialized ultrasonic methods and eddy-current techniques are being investigated.

One radical departure from present rotor-bore sonics uses multiple channels of highly focused immersion transducers. The EPRI-developed system, called Trees (turbine rotor examination and evaluation system), detects and measures the size of defects with less dependence on signal amplitude than previous methods. However, the cost of transferring this technology to the field is high, perhaps too high for each utility to own and maintain the equipment and operating crews, the computer services for data reduction and analysis, and so on. So the route to technology transfer of this complex and specialized system may become the purchase of Trees by a utility group, while training and support services continue to be provided by the NDE center. Each utility would still be responsible for its own rotor evaluations.

Nevertheless such evaluations may be more precise through use of EPRI-developed software for automatic rotor lifetime prediction. Software called Safer (for stress and fracture evaluation of rotors) is given a mathematical model of a particular turbine rotor. To this model of rotor geometry, data are added describing the flaws in the rotor that would affect the fracture mechanics. Safer automatically performs heat-transfer and stress calculations related to the fracture mechanics and determines the remaining life of the rotor.

Still, even software technology may be difficult to transfer to field use. Some Safer input parameters must be estimated because they are so difficult or expensive to obtain, so the NDE center is studying sensitivity to inaccuracies. Worse yet, most of the existing data on important rotor material properties, such as fracture toughness and crack growth rates, remain the proprietary information of manufacturers and are not available to the utilities that would use Safer. Consequently, the center is establishing a publicly available data base for use with the software.

Tubing breaks that brake the industry

In a pressurized water reactor, the steam generators are heat exchangers containing thousands of thin-walled tubes carrying water heated by the nuclear fuel. Tubing with walls only 0.038 to 0.055 inch thick is the major part of a barrier that keeps radioactive water from mixing with steam and releasing the steam in the containment building. So the tubing must be examined periodically to satisfy legal and safety requirements governing the operation of high-pressure systems.

In Sweden, for example, the tubing in Ringhals 3 was down to 10 percent of its original thickness when it suddenly leaked. The problem in the plant's Westinghouse Series D reactor appeared to be caused by turbulent currents where the water entered the steam-generator tubing. At full capacity, the currents caused vibration in the tubing, which rapidly wore it away. Operating a nuclear plant at less than full design capacity, however, is hardly an ideal solution for utilities.

So the steam-generator conditions that require careful watching include tube-wall integrity, sludge and debris profiling, support-plate and tube-sheet integrity, and dent profiling with subsequent estimation of tube strain. Here nondestructive evaluation calls for inducing eddy currents in a section of tubing. Defects in the tube wall are sensed by a coil in the tube bore, and the signals on a display are interpreted by an analyst. But the signals are not easy to detect and no less to interpret reliably because extraneous variables may be generated by tube deposits, support plates, and interior tube-surface irregularities.

Driving the coil at more than one frequency can reduce the effects of such extraneous variables, so the NDE center is evaluating commercial and advanced R&D eddy-current inspection equipment that uses multifrequency and multiparameter eddy-current methods.

By sampling at several different frequencies, signals from extraneous variables like support plates can be identified and differentiated from signals produced by actual defects. Then it is possible to suppress the extraneous signals and measure the depth of the defects.

Nevertheless, the accuracy of depth measurements is still affected by errors introduced by extraneous signals that are never fully suppressed. These signals continue to mix with the defect signals. Research at the NDE center is seeking to find the optimal suppression approaches.

The signal-processing problems in eddy-current and ultrasonic

The junkyard that becomes a flaw library

Like some avant-garde sculpture garden, nuclear power plant junk is neatly arranged around the yard of the EPRI Nondestructive Evaluation Center in Charlotte, N.C. These hulking components, collected from U.S. and foreign utilities, are not ordinary junk, but turbine rotors, pressure vessels, pipes, steam-generator tubes, and feed-water nozzles. Most contain service-induced flaws.

The collection is rare because flaws occur infrequently. Some of the components are so massive that their actual flaws are first analyzed, then removed and implanted in more transportable mock-ups for this pioneering reference library of known defects, used for NDE research. —E.H.

Automation may reduce inspection and repair time in the hostile environment of a nuclear power plant. Workers replacing piping in a boiling-water reactor recirculation loop are slowed by heat, humidity, and restricted view in their cumbersome anti-contamination clothing. Time at the task is strictly limited to minimize radiation exposure, so their progress is monitored on TV by the supervisor and the next team to take over. Repair team productivity will be enhanced by automatic lathes and welders now under test at the EPRI NDE center.

inspection methods are leading to the development of a signal-processing capability at the NDE center. Finite element eddy-current codes, developed under EPRI research contracts, have been programmed into the center's computer to help solve two-dimensional planar and tubular axisymmetric problems. The codes are applicable to magnetic and nonmagnetic materials. More powerful three-dimensional codes are to be completed next year.

Signal processing, which helps analyze and interpret inspection data, is a necessary first step in the development of "smart instrumentation." Microprocessor-equipped systems can be taught particular flaw-pattern recognition through adaptive learning; this could reduce the demand on experienced in-service inspection personnel, who are still in short supply. But the development of effective, reliable smart NDE instrumentation will require more engineers in this field, so the center is establishing relationships with universities and professional organizations to encourage an influx of qualified talent. Nondestructive testing in the industry may yet prevent it from self-destructing.

To probe further

Two workshops on eddy-current test techniques will be held at the Electric Power Research Institute's Nondestructive Evaluation Center in Charlotte, N.C., during the remainder of 1982, though dates have not yet been fixed.

An excellent overview of nondestructive-evaluation research and development may be obtained at the annual EPRI NDE Contractors Conference, to be held at the NDE center Nov. 2–3. A limited number of observers can be accommodated at the discretion of the center. Write Robert M. Stone, J.A. Jones Applied Research Co., 1300 Harris Blvd., P.O. Box 217097, Charlotte, N.C. 28221.

EPRI research project reports by its contractors detail ongoing and recently completed work in NDE. Eddy-current inspection of steam generators at the Ringhals reactors of the Swedish State Power Board is covered in *Secondary Water Chemistry at Ringhals Unit 2*, NP-2268 Topical Report (RPS170-1), $9. Resolution of multiple reverberation and excessive nonspecular sound-scattering problems is discussed in *Pulse-Echo Ultrasound for Steam Generator Tube-Support Plate Gap Measurement*, NP-2285 Final Report (RPS142-1), $12. *Field Experiences With Multifrequency-Multiparameter Eddy-Current Technology* are described in NP-2299 Final Report (RPS115-1), $13.50. Significant improvements in flaw detection and characterization have been achieved by a combination of linear-transducer array technology, advanced signal-processing concepts, and the adaptive learning network (ANL) pattern-recognition methodology, detailed in *Automatic Ultrasonic Imaging System With ANL Signal-Processing Techniques*, NP-2336 Topical Report (RP606, RP1125), $13.50. These EPRI reports may be ordered from Research Reports Center, P.O. Box 50490, Palo Alto, Calif. 94303 (phone 415-965-4081). Prices include surface postage. There is no charge for reports requested by EPRI member utilities, Government agencies, or foreign organizations having agreements with EPRI for information exchange.

A broader-based discussion of specialized nondestructive evaluation is represented in NTIS Published Searches, bibliographies containing abstracts and full citations of available reports, journals, patents, translations, and conference proceedings. The broadest search of NDE features 200 citations from the Energy Data Base: *Nondestructive Testing, March 1976–May 1980*, order as PB80-856842. Other helpful searches are *Nondestructive Testing of Pipes and Tubes, January 1976–July 1980*, PB80-851487; and *Nondestructive Testing of Structural Welds*, PB81-851818. Each Published Search costs $30 and is available from the National Technical Information Service, U.S. Department of Commerce, Springfield, Va. 22161 (phone 703-487-4650).

About the author

Evan Herbert becomes *Spectrum*'s newest Contributing Editor with this article. He has served as an expert on technological innovation to the U.S. assistant secretary of commerce for science and technology, and he originated *Information for Innovators*, an interdisciplinary information service for the National Technical Information Service. In his science journalism career, he has been executive producer of science programming for Boston's TV Channel 5 and was one of the original editors of *Innovation* and of *International Science and Technology*. During the formative years of the International Federation for Information Processing, he was active on various U.S. committees for the federation's congresses. ◆

STAINLESS STEEL PIPE INSPECTION

STAINLESS STEEL PIPE INSPECTION STATUS

G. J. DAU AND M. BEHRAVESH

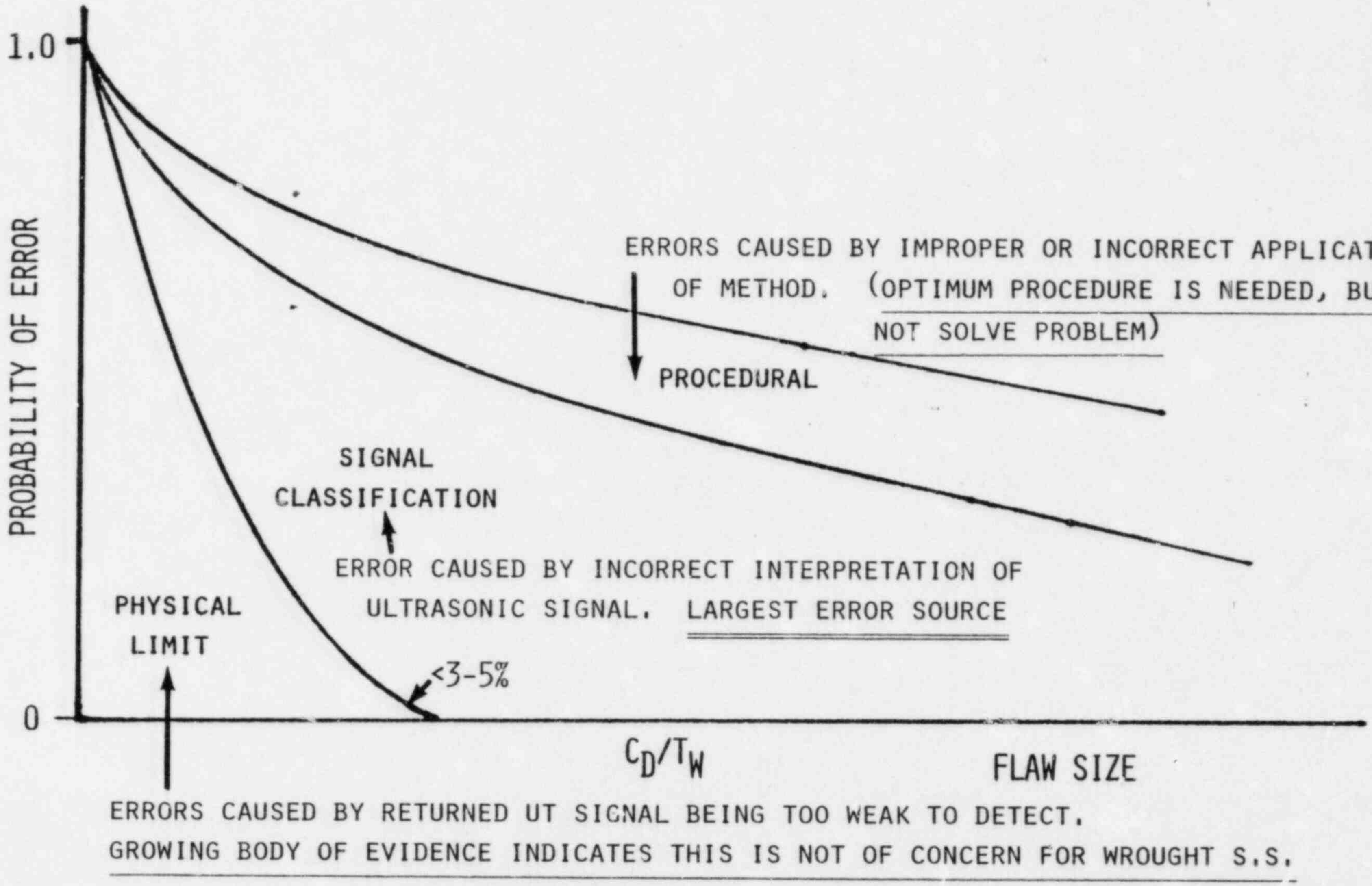
BACKGROUND	DAU
CURRENT PRACTICE	BEHRAVESH
• NINE MILE POINT REVIEW	
• RESPONSE TO I&E BULLETIN 82-3	
• IGSCC WORKSHOPS (ISI TEAMS, NRC)	
• IGSCC PIPE INVENTORY	
ADVANCED SYSTEMS	
• ALN 4060 (MICRO PROCESSOR ASSISTED MANUAL ISI)	BEHRAVESH
• AUTOMATED UT DATA ACQUISITION AND OFFLINE ANALYSIS	BEHRAVESH
• SIGNAL PROCESSING PHYSICS REVIEW PANEL	BEHRAVESH
• INTEGRATED SYSTEM FOR PIPE INSPECTION ---ALN 4000 ---SCANNER ---BOOTED TRANSDUCER ---PULSER ---SOFTWARE	DAU
SURVEILLANCE PIPE TEST (26"Ø)	DAU
WELD CROWN CONTOURING MACHINE	DAU

BACKGROUND

BACKGROUND (G. J. DAU)

- 1975-76 EPRI ROUND ROBIN OF IGSCC SAMPLES
- WIDE VARIATION IN PERFORMANCE OF 5 EXPERIENCED TEAMS
- PERFORMANCE VARIABLES NOTED:
  - ---THOSE WHO DID DETAILED PLOTTING, RAY TRACING DID BETTER
  - ---"OPTIMUM" PROCEDURE SYNTHESIZED BY EPRI PRODUCED NO SIGNIFICANT IMPROVEMENTS
  - ---AFTER-THE-FACT ANALYSIS SHOWED MANY CRACKS WERE DETECTED; I.E. UT SIGNAL PRESENT, BUT CLASSIFIED INCORRECTLY.
- RESULTANT EPRI RESPONSE
  - ---DUAL ELEMENT TRANSDUCER DEVELOPMENT 3:1 S/N INCREASE ON THICK WALL PIPE (NP 1153, AUGUST 1979)
  - ---RECOGNITION OF NEED FOR IGSCC SAMPLES
  - ---KRB PLANT SAMPLES, IHI MANUFACTURED IGSCC SAMPLES, TRANSFER OF IHI METHOD TO PNL
  - ---PROBLEM DEFINITION-ERROR SOURCE CLASSIFICATION TO DIRECT FUTURE WORK

INSPECTION ERROR CLASSIFICATION



CURRENT PRACTICE

REVIEW OF NINE MILE POINT ISI
1981 VS. 1982

GENERAL CONSIDERATIONS

- SAFE ENDS WERE PART OF THE AUGMENTED INSPECTION PROGRAM (NUREG 0313). BALANCE OF RECIRC. SYSTEM WERE NOT.
- PSYCHOLOGY OF ISI AFTER LEAK

RECIRC. PIPING, OBSERVATIONS

- THERE ARE ONLY TWO COMMON JOINTS IN '81 AND '82 DATA
- THE '81 PROCEDURE (10% NOTCH) REQUIRED A 50% DAC REPORTING LEVEL. IGSCC SIGNALS CAN BE LOWER.
- THE PROBE USED IN 81 (1/2" x 1", 2.25 MHz) WILL HAVE A LOWER SENSITIVITY TO SMALL DEFECTS
- UNGROUND CROWN MAY INTERFERE (OFTEN DOES) WITH DETECTION OF AXIAL CRACKS
- THE TIME SPENT ON SCANNING AND RECORDING IS CONSIDERABLY LOWER FOR '81 THAN '82.
- IGSCC EXPERIENCE OF INSPECTION PERSONNEL HIGHER IN 82 THAN 81 (AVAILABILITY OF IGSCC SAMPLES AND PARTICIPATION IN EPRI NDE CENTER WORKSHOPS)

NMP-1 RECIRC PIPE WELDS

COMPARISON BETWEEN 1981 AND 1982 RECORDS ON WELDS

P32-FW-10W AND P32-FW-36W

	1981		1982		
	P32-FW-10W	P32-FW-36W	P32-FW-10W	P32-FW-36W (April)	P32-FW-36W (May)
Indications found	None	None	5-10% DAC (100% DAC at + 10 dB)	20% DAC	50% DAC at +10dB
UT Instrument	MK-I	MK-I	USL-38	MK-I	
Search Unit	Aerotech 1/2"x1" Rect. 2.25 MHz	Aerotech 1/2"x1" Rect. 2.25 MHz	Aerotech 1/2" ϕ 1.5 MHz	Aerotech 1/2" ϕ 2.25 MHz	Aerotech 1/2" ϕ 1.5 MHz
Cal. Block	P8R-1.050-1	P8R-1.050-1	P8R-1.050-1	P8R-1.050-1	
Sensitivity (dB) Cal./Scan	72/78	72/78	42/62	31/41	38/58
Temperature (°F) Cal. Blk./Component	67/72	67/72	68/76	62/80	62/70
Scan & Record Time (Hr.Min.)	1.49[1]	1.49[1]	3.20[2]	5.30[3]	1.30[4]
UT Personnel (Level)	II,I	II,I	III,II	III,II	II,I

[1] Time for scanning 3 circum. welds (one side only) and 4 - 12" longi. welds (both sides).
[2] time for 1 circum. weld (one side only).
[3] Time for 4 circum. welds (one side only).
[4] Time for 1 circum. weld (one side only).

EPRI NDE CENTER
RESPONSE TO I&E BULLETIN 82-03

SEPT. 27, 1982	NRC EXPRESSES CONCERN
SEPT. 29, 1982	BCL CHOSEN AS VALIDATION SITE
OCT. 3, 1982	NMP-1 SPECIMENS ARRIVE BCL
OCT 6, 1982	DECON, PT & UT DOCUMENTATIONS COMPLETED
OCT. 7, 1982	NRC REVIEW AT BCL
OCT. 8, 1982	NORTHERN STATES/CECO
OCT. 12, 1982	NORTHEAST UTILITIES
OCT. 14, 1982	SCS, GP, PECO, CP&L, CP, DPC
OCT. 15, 1982	NRC BULLETIN 82-03 IS ISSUED
OCT. 19, 1982	HELP !!, WORKSHOP NEEDED
OCT. 22, 1982	NORTHEAST UTILITIES
OCT. 25-26, 1982	WORKSHOP AT NDE CENTER
OCT. 27, 1982	SCS, CP&L, GP
OCT. 28, 1982	TVA
OCT. 29, 1982	GPU

EPRI NDE CENTER

IGSCC SPECIMENS AND WORKSHOPS

SPECIMENS

AN INVENTORY OF MORE THAN 100 FLAW SAMPLES IN VARIOUS PIPE DIAMETERS AND THICKNESSES. BWR UTILITIES ROUTINELY BORROW AND/OR EXCHANGE SPECIMENS FOR THEIR PROCEDURE AND PERSONNEL QUALIFICATION NEEDS.

IGSCC WORKSHOPS

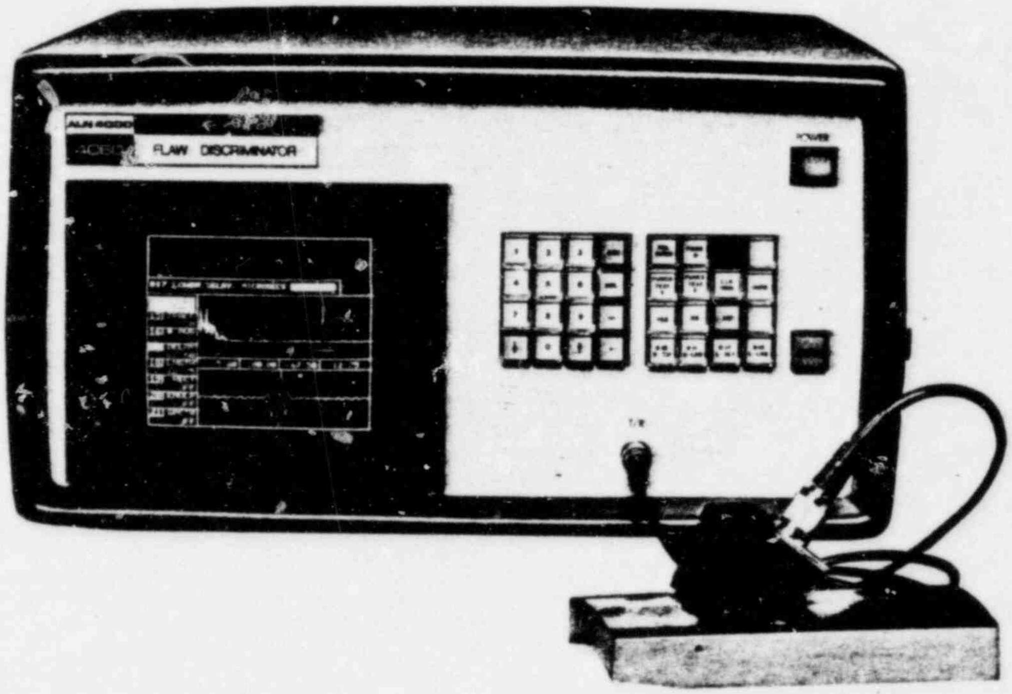
TYPICALLY 2 - 3 DAYS IN LENGTH, COMBINING A MIX OF LECTURES, DEMONSTRATIONS, AND MOSTLY HANDS-ON.

DATES	PARTICIPANTS
SEPT. 17-18, 1981	BWR UTILITIES, ISI VENDORS, AND NRC
MARCH 8-10, 1982	BWR UTILITIES AND ISI VENDORS
OCT. 25-26, 1982	BWR UTILITIES AND ISI VENDORS
NOV. 30-DEC.1, 1982	NRC

ADVANCED SYSTEMS

ALN 4060

MICRO PROCESSOR ASSISTED MANUAL ISI



- AUTOMATIC SIGNAL INTERPRETATION (CRACK/NO CRACK)
- USER TRAINABLE
- HOLDS UP TO 7 TRAINING SETS
- SINGLE MODULE, 35 LB.

AUTOMATED UT DATA ACQUISITION AND OFFLINE ANALYSIS

ON SITE

MECHANIZED PIPE SCANNER (AMAPS) + SIGNAL DIGITIZER AND RECORDER (ALN 4000) + SEC. XI CODE CONSIDERATIONS (CALIBRATION, % DAC) ⇒ POSITIONALLY ENCODED DIGITAL UT SIGNALS ON MAGNETIC TAPE

OFF SITE

DATA REDUCTION (% DAC, POSITION), AUTOMATED ANALYSIS (SIGNAL PROCESSING), LEVEL III REVIEW (PLOTTING/ DISCRIMINATION)

NOTE THE CAPABILITY FOR REPEATED REPLAYS AND ANALYSES AT DIFFERENT DAC LEVELS.

SIGNAL PROCESSING
PHYSICS REVIEW PANEL

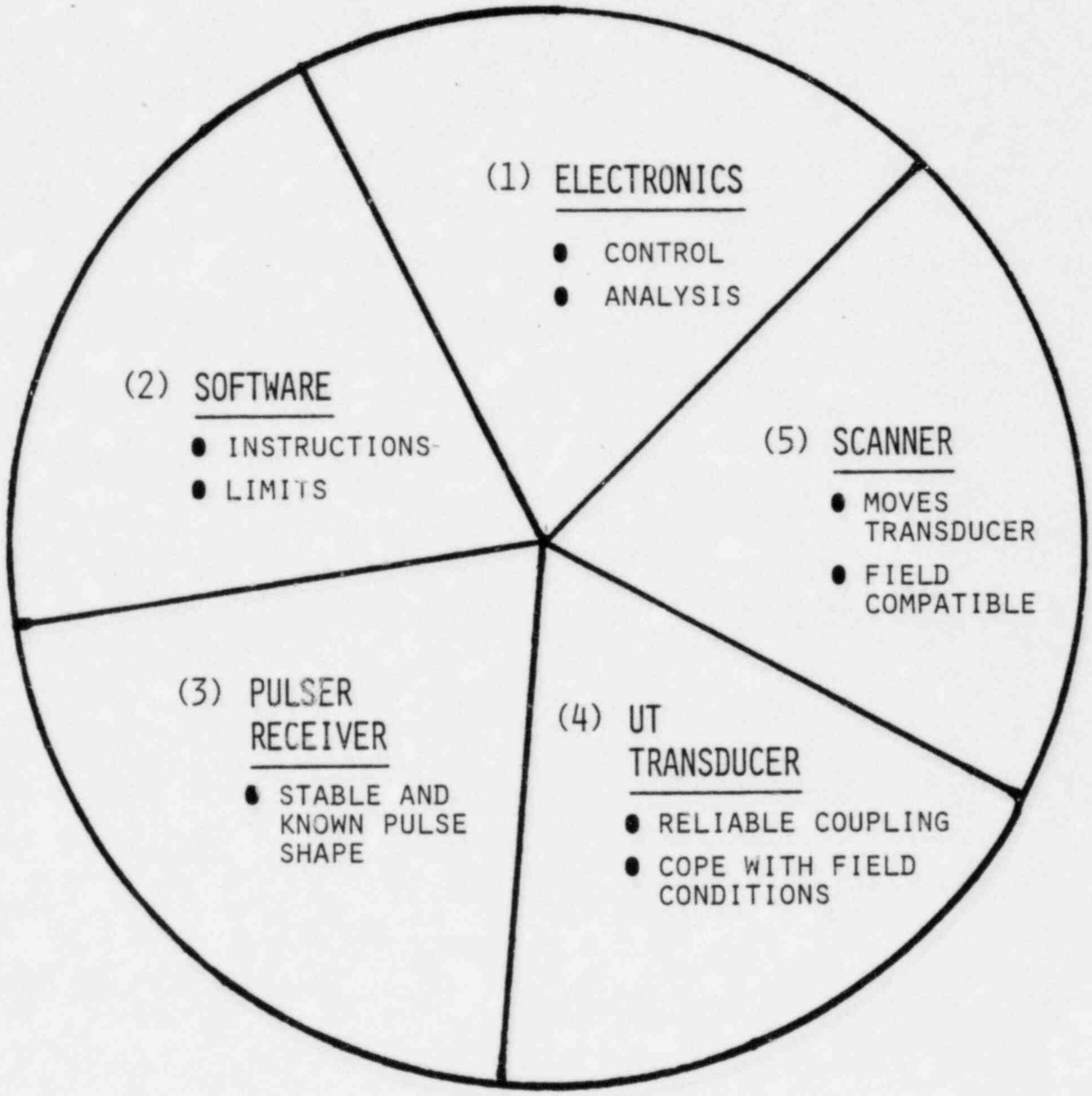
PROBLEM

THE SIGNAL PROCESSING/PATTERN RECOGNITION SCHEMES THAT ARE CURRENTLY APPLIED TO ULTRASONIC FLAW CHARACTERIZATION ARE MOSTLY BASED ON STATISTICAL AND/OR EMPIRICAL CONSIDERATIONS. TO SPEED THE ACCEPTANCE OF THESE NEW TECHNOLOGIES, THEIR UNDERLYING PHYSICAL PRINCIPLES MUST BE IDENTIFIED AND DEMONSTRATED.

APPROACH

A PANEL OF EXPERTS IN PHYSICS, ULTRASONICS, SCATTERING THEORY, STATISTICS, INSTRUMENTATIONS, AND SIGNAL PROCESSING WAS FORMED TO REVIEW THE CURRENT STATE-OF-PRACTICE AND ESTABLISH THE PHYSICAL PRINCIPLES BEHIND THOSE SIGNAL FEATURES THAT SHOW SIGNIFICANT POWER FOR FLAW DISCRIMINATION. THE PANEL CONCLUDED ITS ACTIVITIES IN NOVEMBER, 1982. AN IMPORTANT OUTCOME HAS BEEN THE GENERATION OF THE FIRST SIMPLE THEORETICAL MODEL OF IGSCC THAT BEGINS TO PREDICT THE OBSERVED EXPERIMENTAL RESULTS.

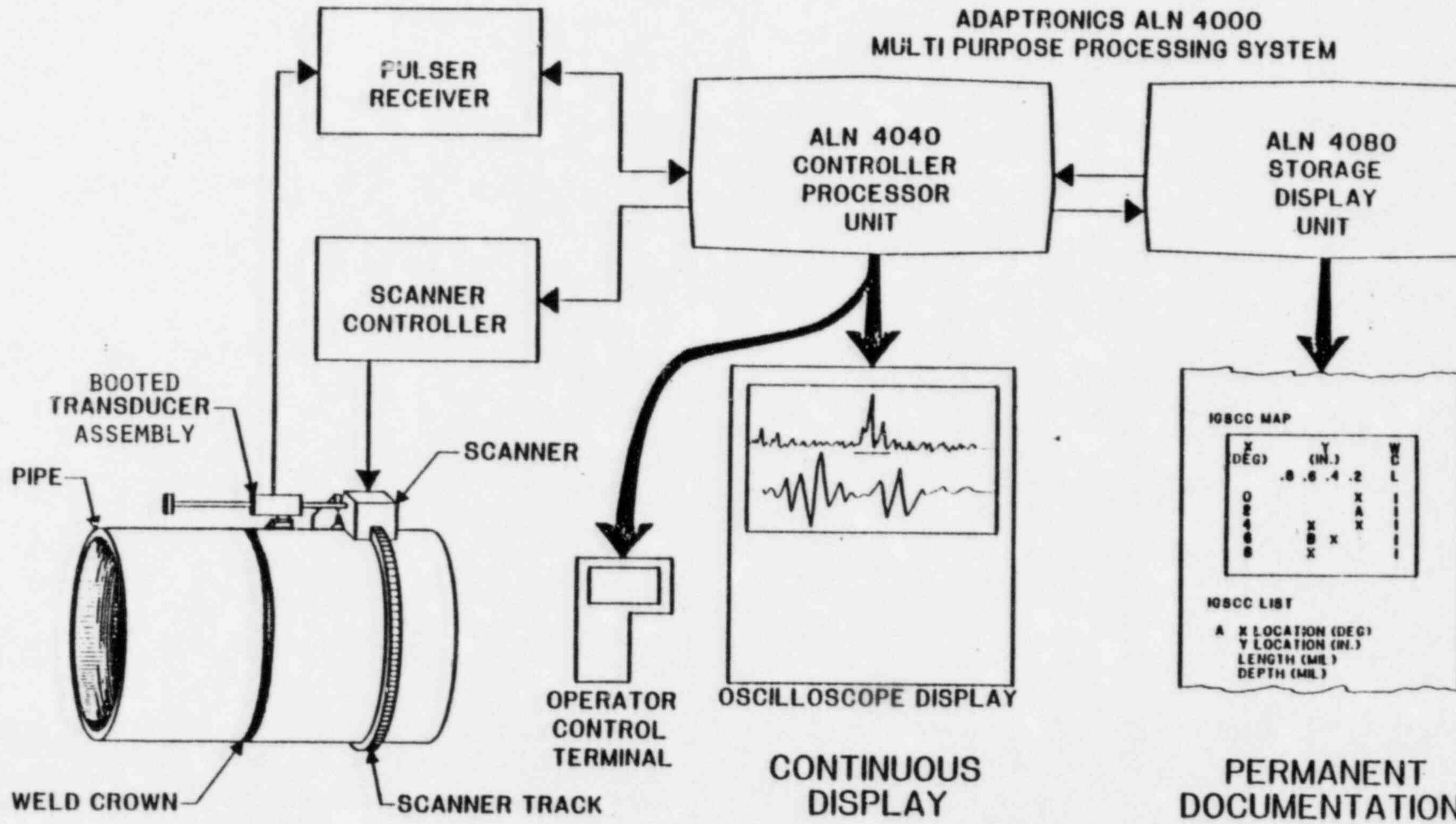
INTEGRATED SYSTEM FOR PIPE INSPECTION



ORIGINAL EPRI INTENT WAS TO DEVELOP ITEMS (1) AND (2) ONLY. HOWEVER, STATE-OF-TECHNOLOGY REQUIRED IMPROVEMENTS IN OTHER AREAS TO ACHIEVE RELIABLE SYSTEM.

AUTOMATIC SCANNING

AUTOMATIC FLAW DETECTION AND CHARACTERIZATION



EPRI DEVELOPED INTEGRATED SYSTEM FOR PIPE INSPECTION (ISPI)

(SYSTEM WILL BE ILLUSTRATED WITH 35MM. SLIDES OF ACTUAL HARDWARE)

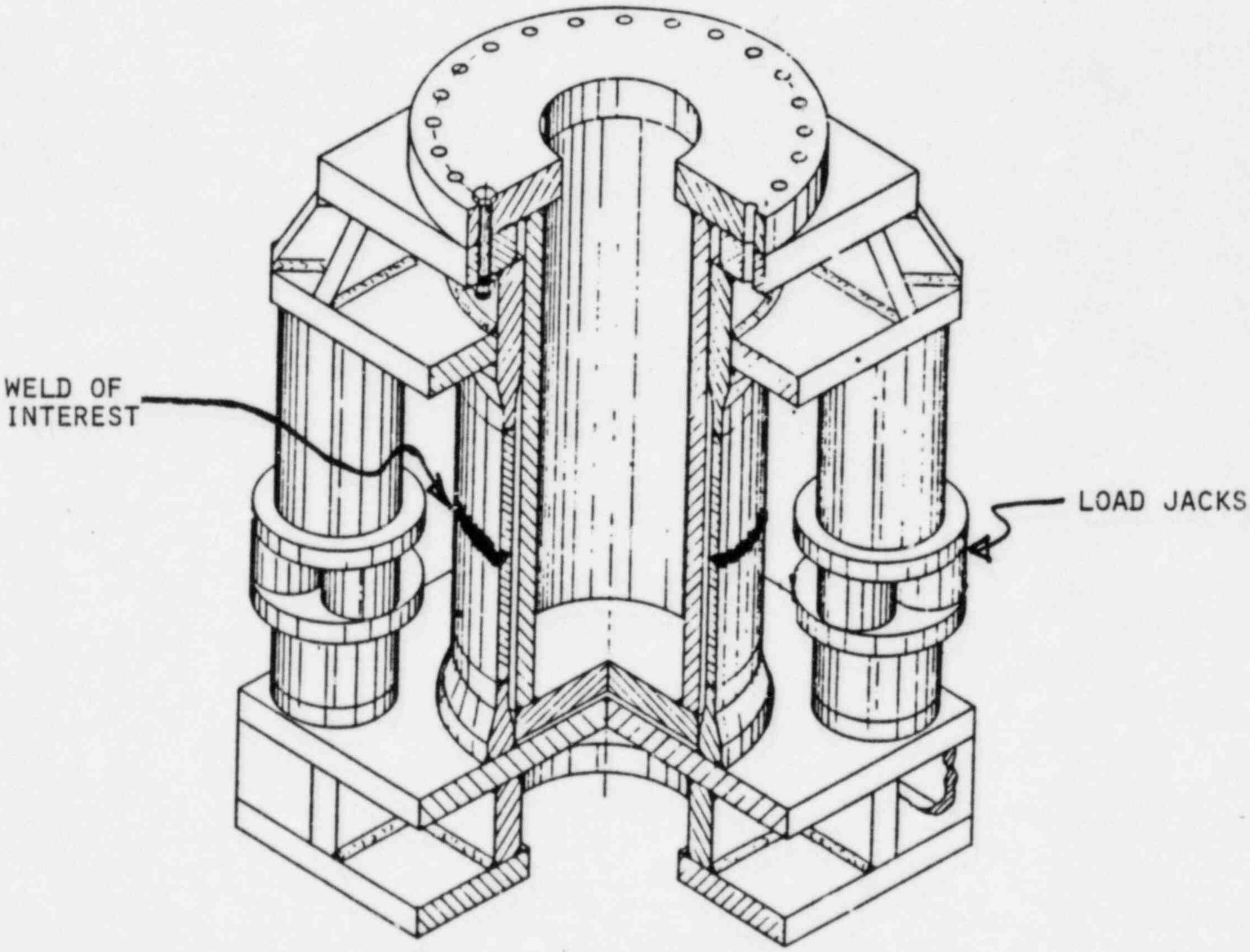
SURVEILLANCE PIPE TEST

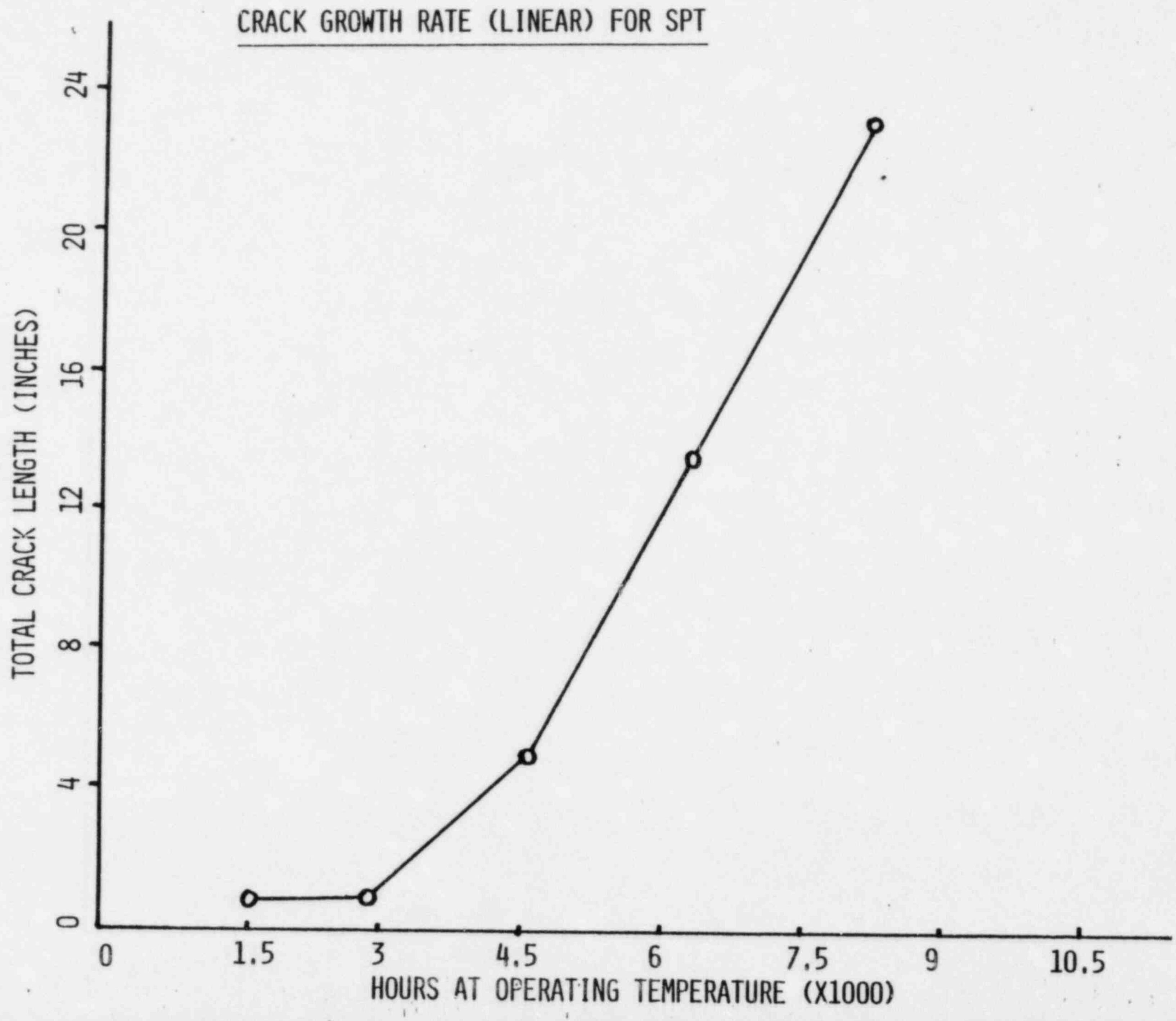
SURVEILLANCE PIPE TEST (SPT)

- 26"Ø; 1.2" WALL THICKNESS
- REALISTIC TEST BED FOR EVALUATING ULTRASONIC INSPECTION AND SURVEILLANCE DEVICES
- SIMULATES BWR OPERATION (P, T, $\%O_2$, LOAD)
- REVEALS CRACK GROWTH PATTERN

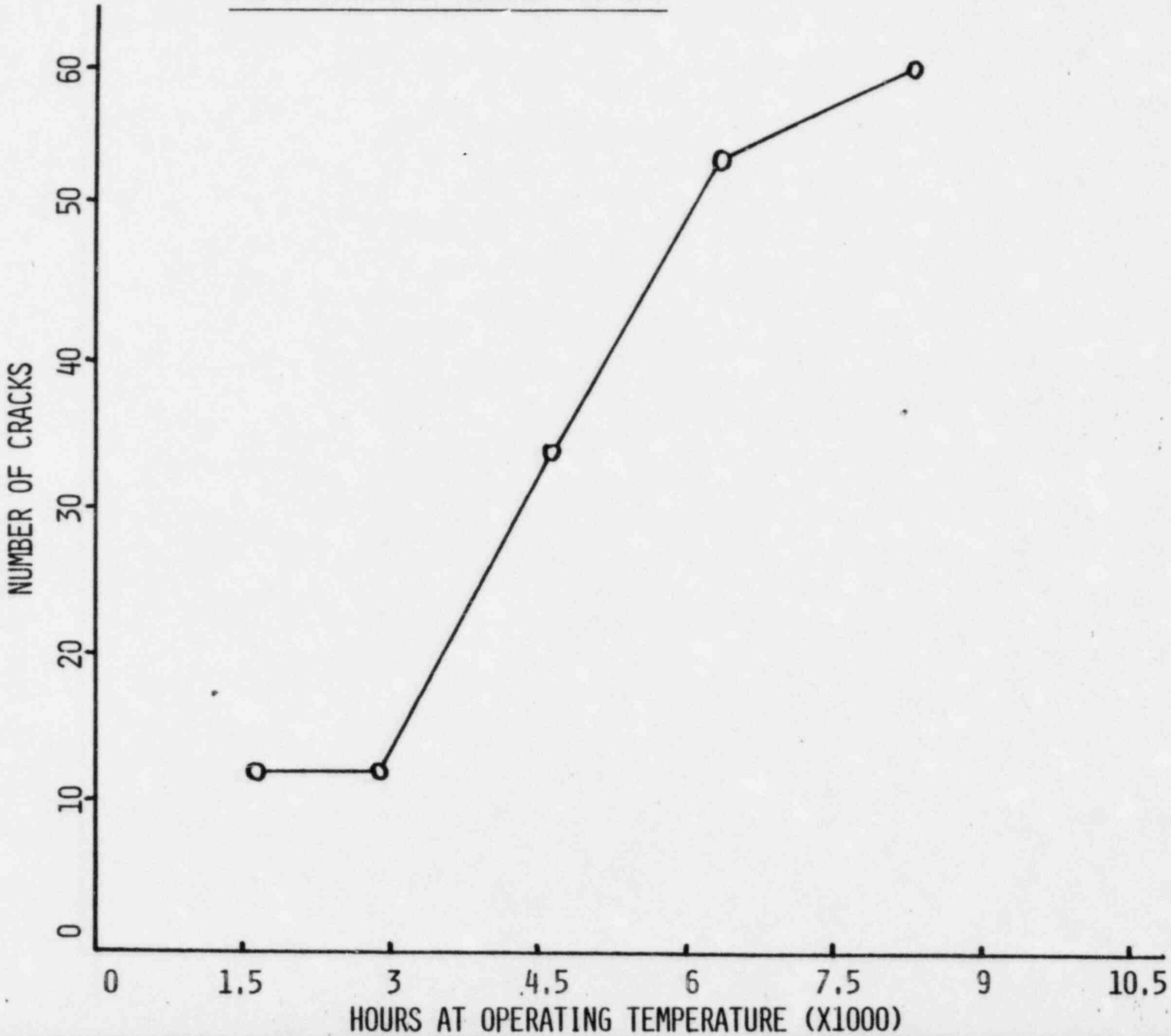
STATUS:

- CRACKS INITIATED BY GRAPHITE-WOOL METHOD
- TEAR DOWN AND INSPECTION EVERY 3 MONTHS
- ~8000 HOURS OPERATION
- ~15% OF TOTAL POSSIBLE LENGTH CRACKED (SEE FOLLOWING PLOTS)
- ONE BOAT SAMPLE REMOVED, DEPTH = 0.150"; LENGTH = 0.73"; WIDTH = 0.01"

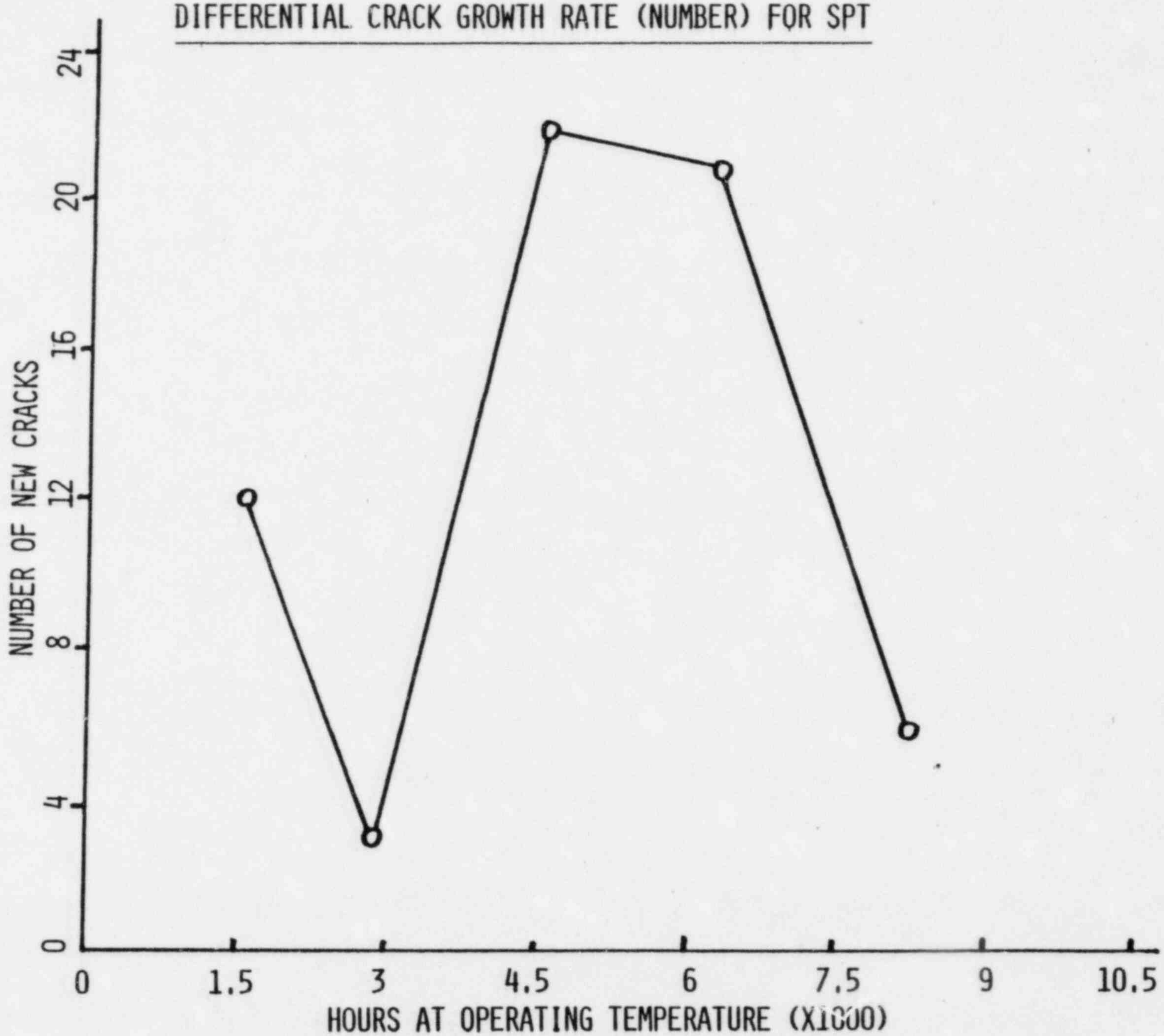



CRACK GROWTH RATE (LINEAR) FOR SPT
TOTAL CRACK LENGTH (INCHES)
0
4
8
12
16
20
24
0
1.5
3
4.5
6
7.5
9
10.5
HOURS AT OPERATING TEMPERATURE (X1000)

TOTAL NUMBER OF CRACKS FOR SPT



DIFFERENTIAL CRACK GROWTH RATE (NUMBER) FOR SPT



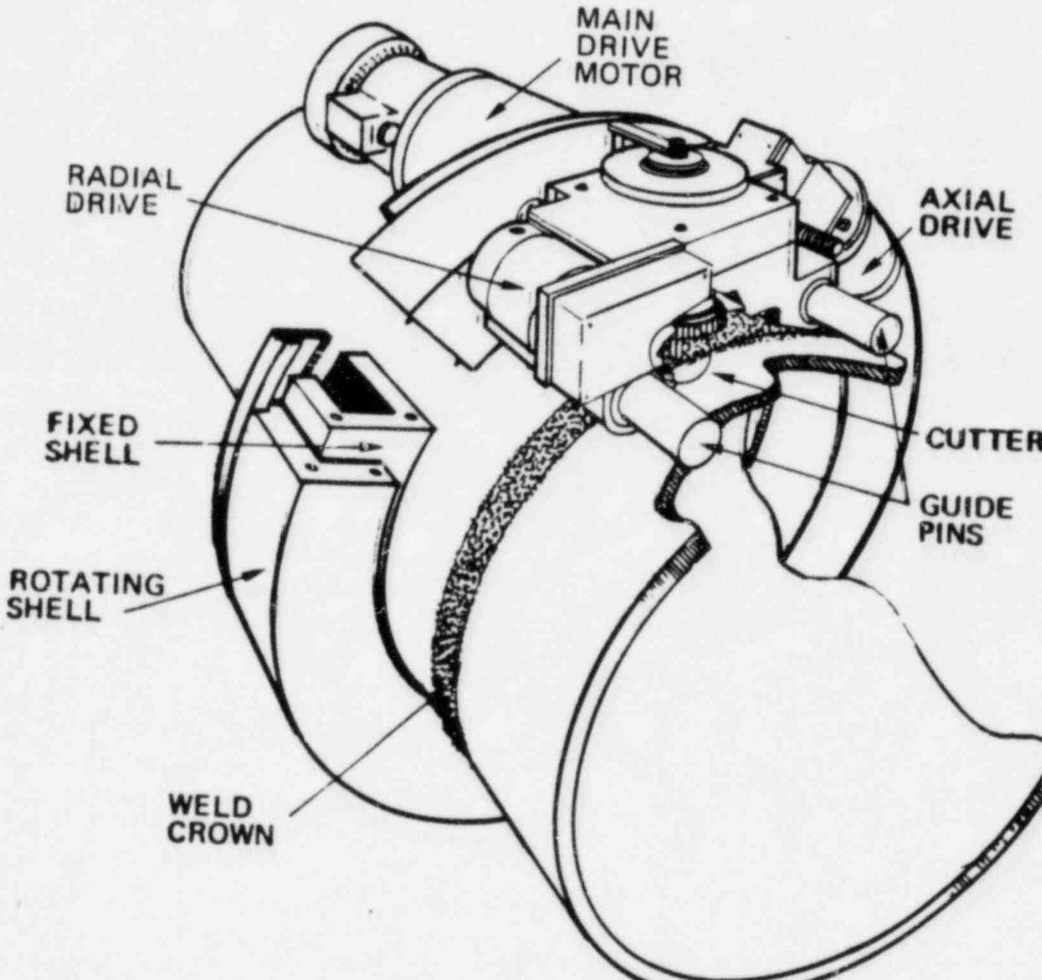
WELD CROWN CONTOURING MACHINE

WELD CROWN CONTOURING MACHINE

OBJECTIVE: RAPID, AUTOMATIC REMOVAL OF PIPE WELD CROWNS TO PERMIT MORE RELIABLE INSPECTION OF WELD AND HAZ

APPROACH: MICRO-PROCESSOR CONTROLLED EXTERNAL LATHE
---ACCOMMODATES, OVALITY, MISMATCH, ETC.
---EXPECT >5X REDUCTION IN TIME VS GRINDING, BETTER SURFACE

STATUS: ---PROTOTYPE EVALUATED ON 12" PIPE
---FINAL DEBUGGING UNDERWAY FOR 28" MODEL
---SCHEDULED FOR USE AT NINE MILE PT.



EPRI PRESSURE VESSEL R&D

EPRI PRESSURE VESSEL PROGRAM

OUTLINE OF PRESENTATION

1. EPRI PRESSURE VESSEL PROGRAM - J. R. QUINN
   - OBJECTIVES
   - METHODOLOGY
   - CURRENT MAJOR GOALS
2. PRESSURE VESSEL IMAGING SYSTEM (PVIS)
   - SYSTEM DESCRIPTION
   - SCHEDULE
   - DEMONSTRATION RESULTS
3. UNDERCLAD CRACK DETECTION ACTIVITIES
   - SUMMARY OF STATE OF THE ART
   - CURRENT ACTIVITIES
     - EVALUATION OF FIELD EQUIPMENT
     - EVALUATION OF NEW EQUIPMENT
     - TECHNOLOGY DEVELOPMENT
   - RELEVANCE TO PTS ISSUE
4. SAMPLE DESIGN AND FABRICATION
   - EVALUATION TEST BLOCKS
   - BLOCK DESIGN CRITERIA
   - COST ESTIMATES
5. BURIED FLAW DETECTION AND SIZING
   - CURRENT ACTIVITIES
   - SCHEDULE
6. SUMMARY OF DDT RESULTS--F. L. BECKER
7. TRANSDUCER CALIBRATION FACILITY
8. REG. GUIDE 1.150 REVISION

OBJECTIVES:

A. UNDERCLAD CRACK DETECTION

B. BURIED FLAW DETECTION

C. FLAW CHARACTERIZATION

D. ALTERNATIVE TECHNOLOGIES

METHODOLOGY:

ALL TECHNIQUES, INSTRUMENTS & PERSONNEL
ARE MEASURED BY DEMONSTRATED PERFORMANCE,
NOT COMPLIANCE TO THE CODE

CURRENT MAJOR GOALS

A. UNDERCLAD CRACKS

COMPLETED EVALUATION OF TECHNOLOGY TO 1981 IN 1982

EVALUATING NEW OR EMERGING TECHNOLOGY 1982--1983

DEFINE BEST APPROACH BY MID 1983, COMMIT TO FABRICATION

B. INDEPTH FLAWS

EVALUATE EXISTING TECHNOLOGY TO 1982 BY MID 1983

DEFINE BEST APPROACH AND COMMIT TO FABRICATION BY END 1983

C. CHARACTERIZATION

ACOUSTIC HOLOGRAPHY IS NOW NEAR FIELD READY (12/82)

ACOUSTIC HOLOGRAPHY FOR FIRST PSI IN 1983

LINEAR HOLOGRAPHY FOR NOZZLES AND PIPES READY BY 1984 (COMMERCIALIZED)

COMPARISON OF HOLOGRAPHY AND HOLOSAFT BY MID 1983

PRESSURE VESSEL IMAGING SYSTEM

PVIS*

APPROACH:

DEVELOP ACOUSTIC HOLOGRAPHY CAPABILITY FOR FLAW CHARACTERIZATION

INTEGRATE HOLOGRAPHY INTO EXISTING PWR RPV INSPECTION SYSTEM, FORMING "PVIS" MODEL 1

DEVELOP IMPROVED DETECTION FOR UNCERCLAD AND DEEP FLAWS AND INTEGRATE INTO "PVIS" MODEL 1A

FABRICATE TEST SAMPLES FOR THOROUGH SYSTEM QUALIFICATION

DEVELOP SECOND VERSION FOR ENHANCED DETECTION AND INTEGRATE INTO "PVIS" MODEL 2

"PVIS" AVAILABLE FOR INDUSTRY USE, VIA TRAINING AND LEASE PROGRAM

*PRESSURE VESSEL IMAGING SYSTEM

SCHEDULE 1/82 1/83 1/84 1/85 1/86

ACOUSTIC HOLOGRAPHY ----►

"PVIS" MODEL 1 ----------►

"PVIS" MODEL 1A ---------------►

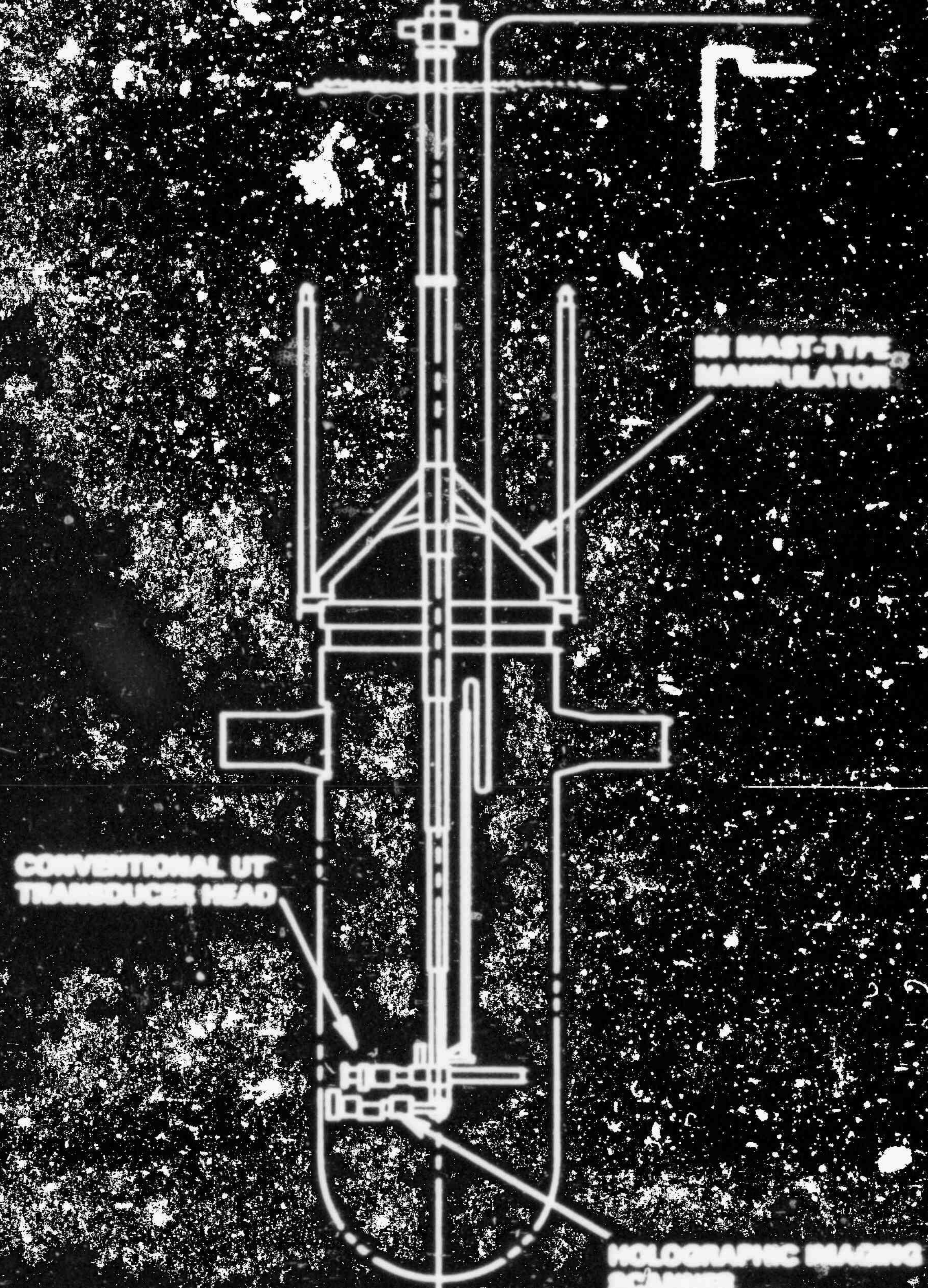
FABRICATE QUAL. SAMPLES -----------------►

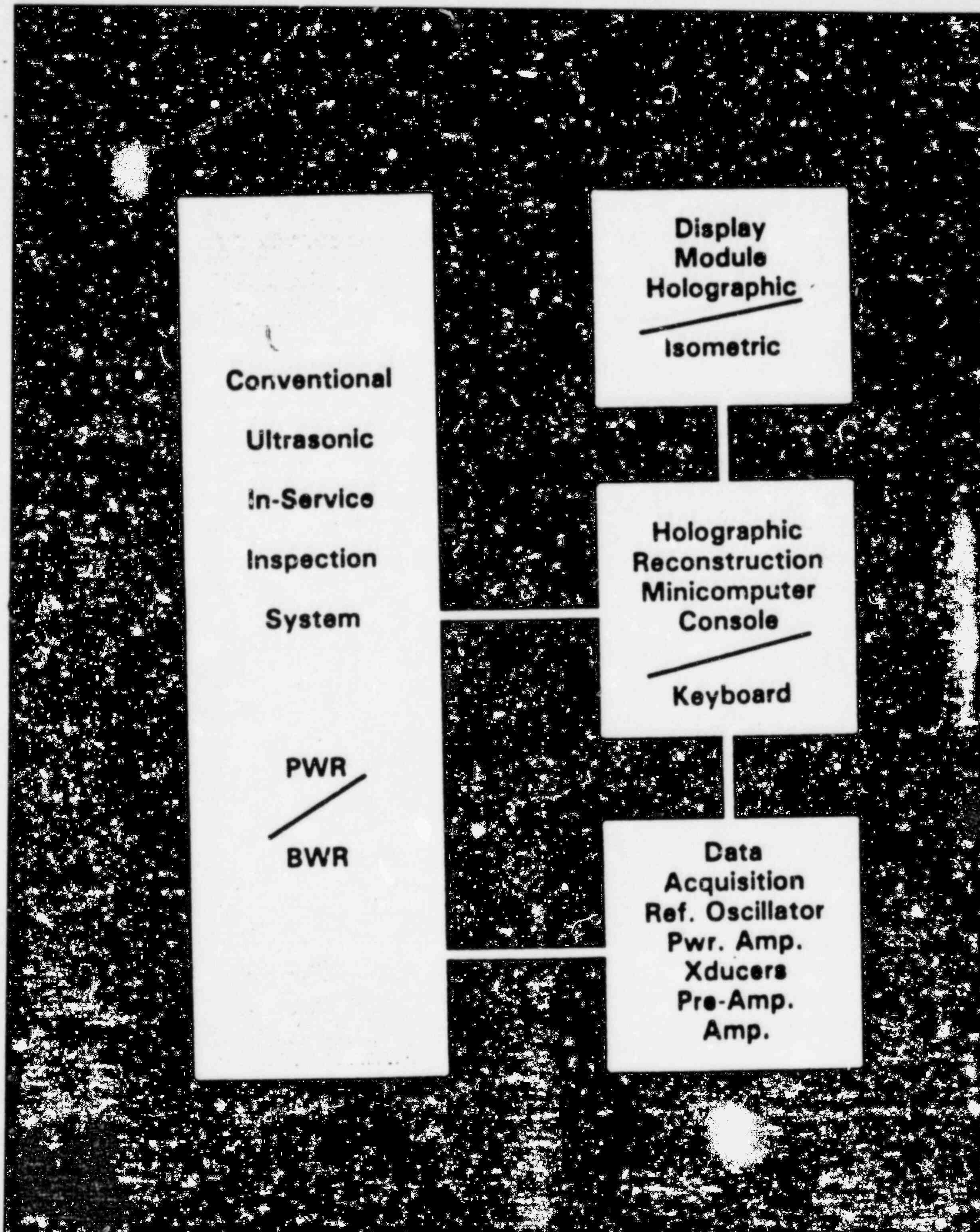
"PVIS" MODEL 2 -------------------------►

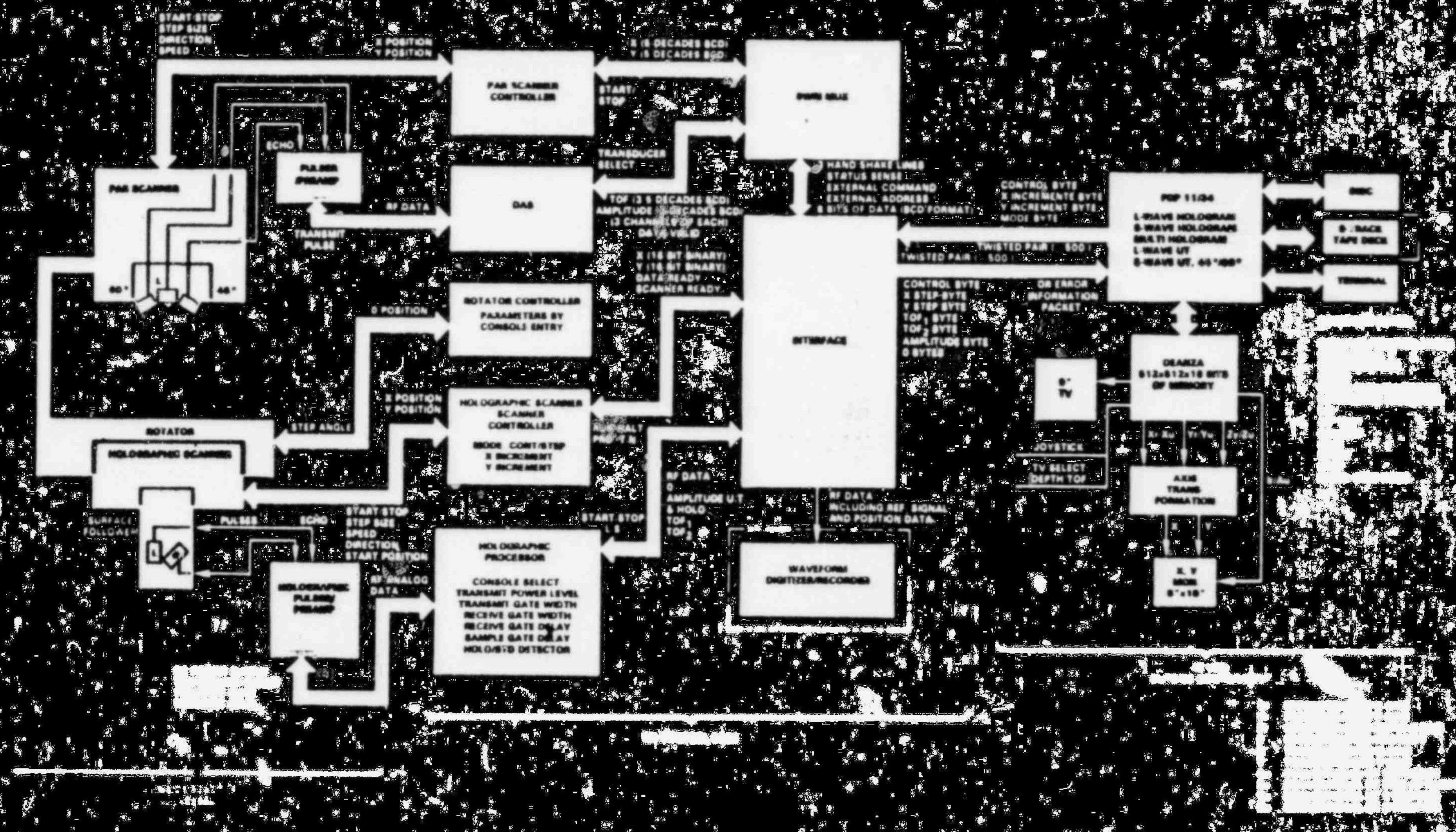
"PVIS" AT TMI-2 ----------------------------►

"PVIS" READY FOR INDUSTRY USE ----------------------------------►

PWR IN-SERVICE INSPECTION (ISI) CONFIGURATION

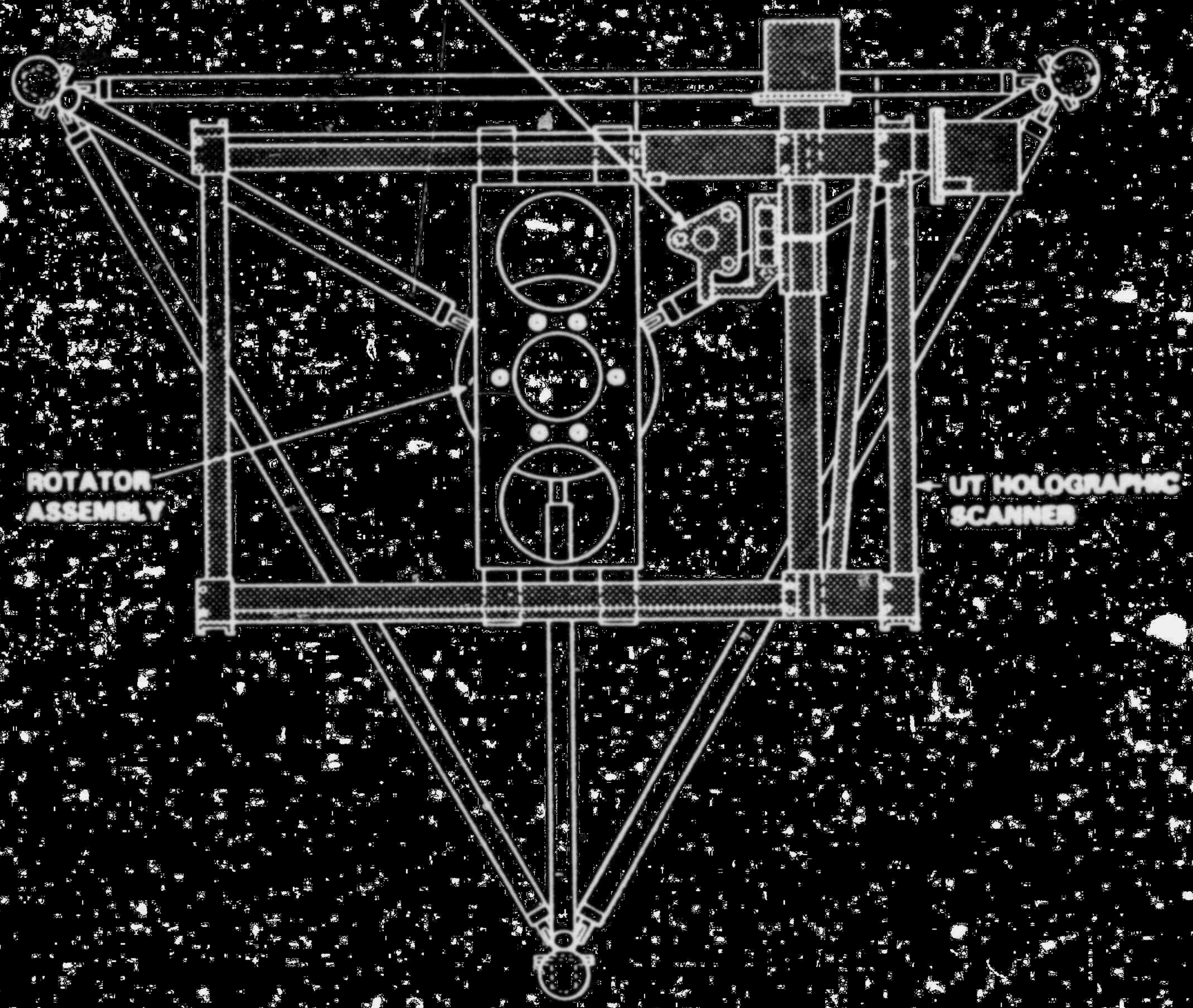



Display Module Holographic / Isometric
Conventional Ultrasonic In-Service Inspection System
PWR / BWR
Holographic Reconstruction Minicomputer Console / Keyboard
Data Acquisition Ref. Oscillator Pwr. Amp. Xducers Pre-Amp. Amp.

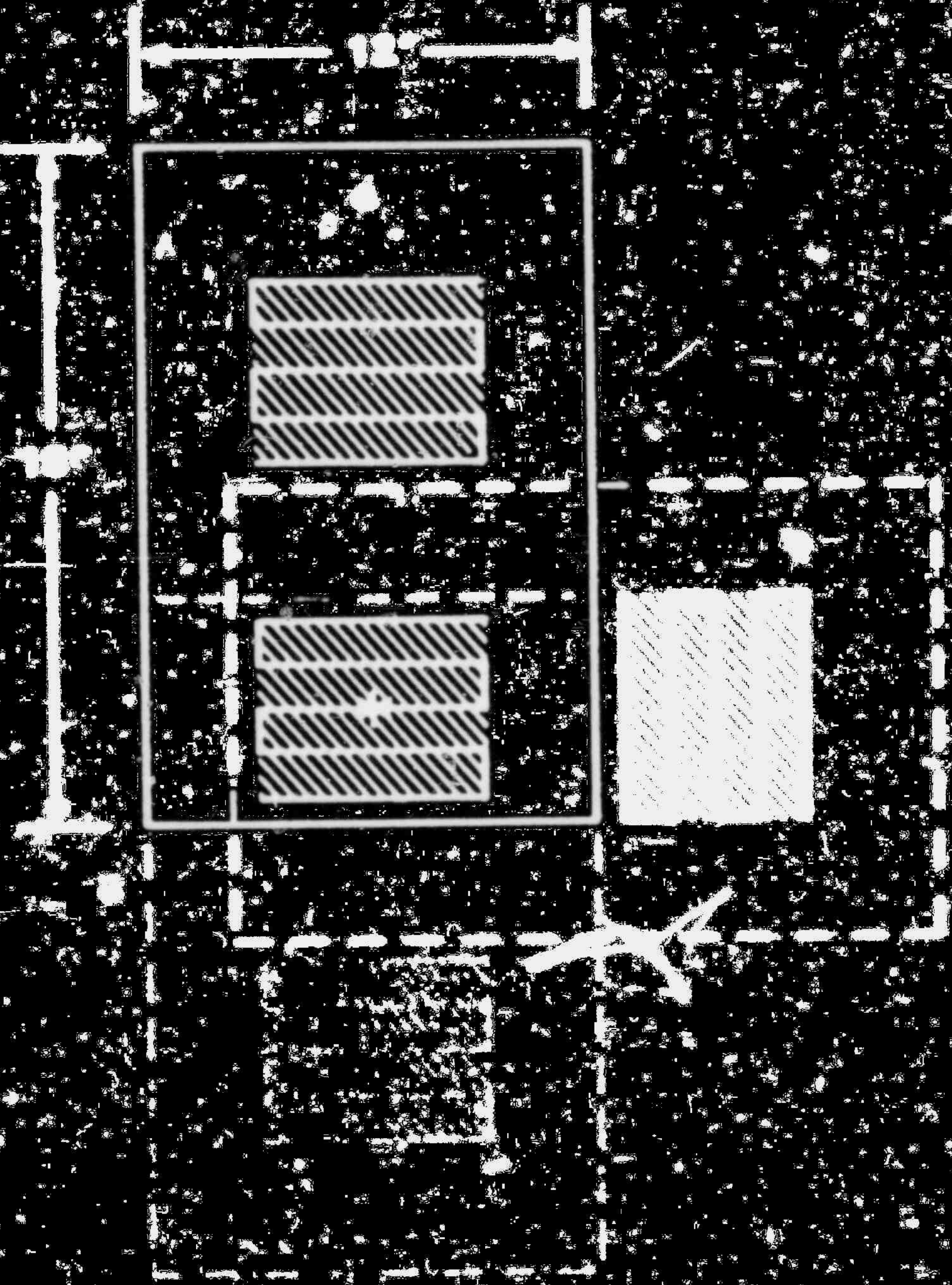


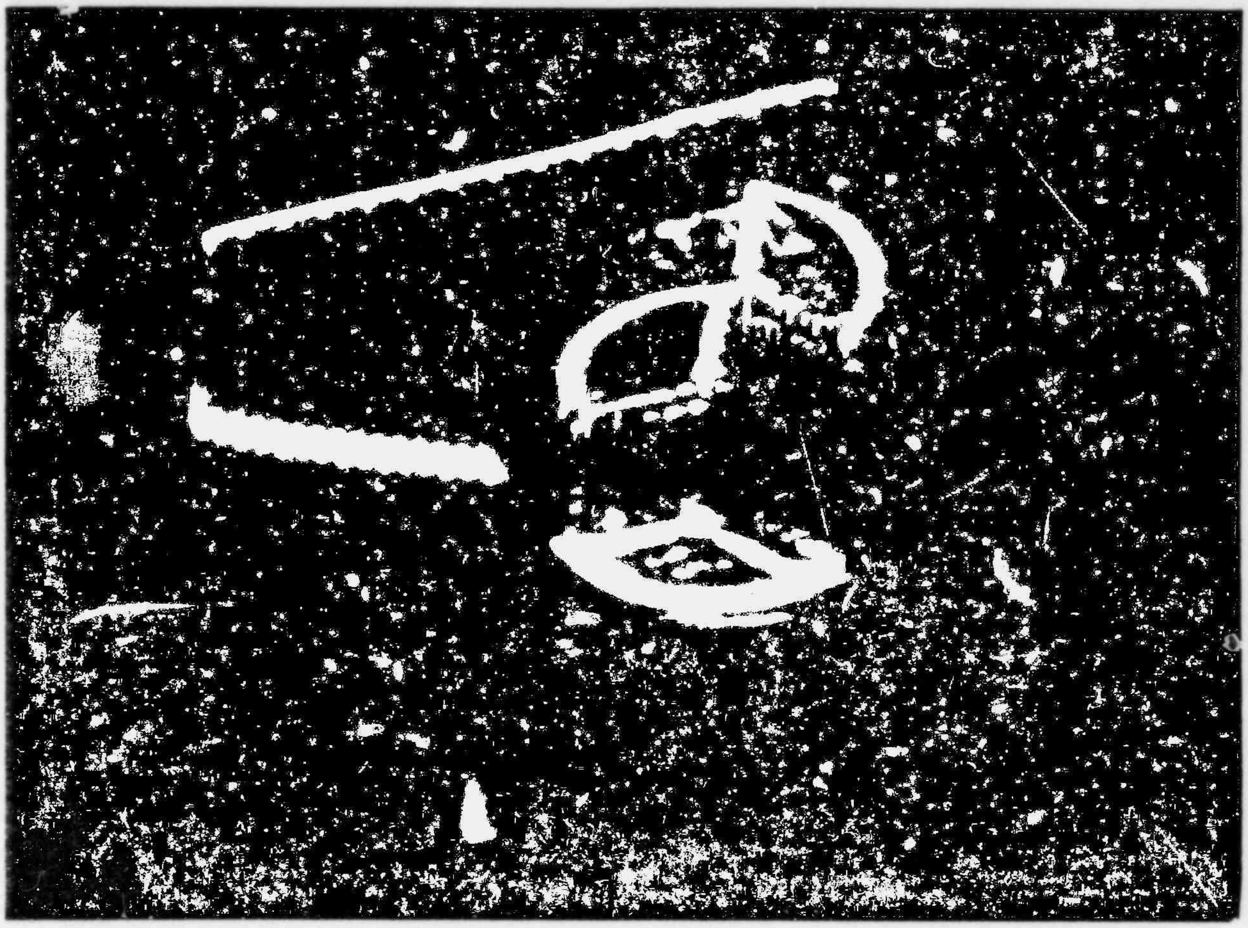
START STOP
STEP SIZE
DIRECTION
SPEED
X POSITION
Y POSITION
PAR SCANNER CONTROLLER
X (5 DECADES BCD)
Y (5 DECADES BCD)
START/STOP
PAR SCANNER
ECHO
PULSER PREAMP
RF DATA
TRANSMIT PULSE
DAS
TRANSDUCER SELECT
TOF (3.5 DECADES BCD)
AMPLITUDE (3 DECADES BCD)
(3 CHANNELS OF EACH)
DATA VALID
X (16 BIT BINARY)
Y (16 BIT BINARY)
DATA READY
SCANNER READY
60°
45°
ROTATOR CONTROLLER
PARAMETERS BY CONSOLE ENTRY
0 POSITION
HAND SHAKE LINES
STATUS SENSE
EXTERNAL COMMAND
EXTERNAL ADDRESS
8 BITS OF DATA (BCD FORMAT)
INTERFACE
CONTROL BYTE
X INCREMENTS BYTE
Y INCREMENT BYTE
MODE BYTE
TWISTED PAIR (500)
TWISTED PAIR (500)
CONTROL BYTE
X STEP BYTE
Y STEP BYTE
TOF BYTE
AMPLITUDE BYTE
0 BYTES
OR ERROR INFORMATION PACKET
PDP 11/34
L-WAVE HOLOGRAM
S-WAVE HOLOGRAM
MULTI HOLOGRAM
L-WAVE UT
S-WAVE UT, 45°/60°
DISC
9-TRACK TAPE DECK
TERMINAL
DEANZA 512x512x16 BITS OF MEMORY
9" TV
JOYSTICK
TV SELECT
DEPTH TOF
AXIS TRANS FORMATION
X, Y MON 8"x10"
X POSITION
Y POSITION
HOLOGRAPHIC SCANNER SCANNER CONTROLLER
MODE CONT/STEP
X INCREMENT
Y INCREMENT
STEP ANGLE
ROTATOR
HOLOGRAPHIC SCANNER
SURFACE FOLLOWER
PULSES
ECHO
START STOP
STEP SIZE
SPEED
DIRECTION
START POSITION
RF ANALOG DATA
HOLOGRAPHIC PULSER/PREAMP
HOLOGRAPHIC PROCESSOR
CONSOLE SELECT
TRANSMIT POWER LEVEL
TRANSMIT GATE WIDTH
RECEIVE GATE WIDTH
RECEIVE GATE DELAY
SAMPLE GATE DELAY
HOLO/STD DETECTOR
START STOP
RF DATA
AMPLITUDE U.T.
& HOLO
RF DATA
INCLUDING REF. SIGNAL
AND POSITION DATA
WAVEFORM DIGITIZER/RECORDER

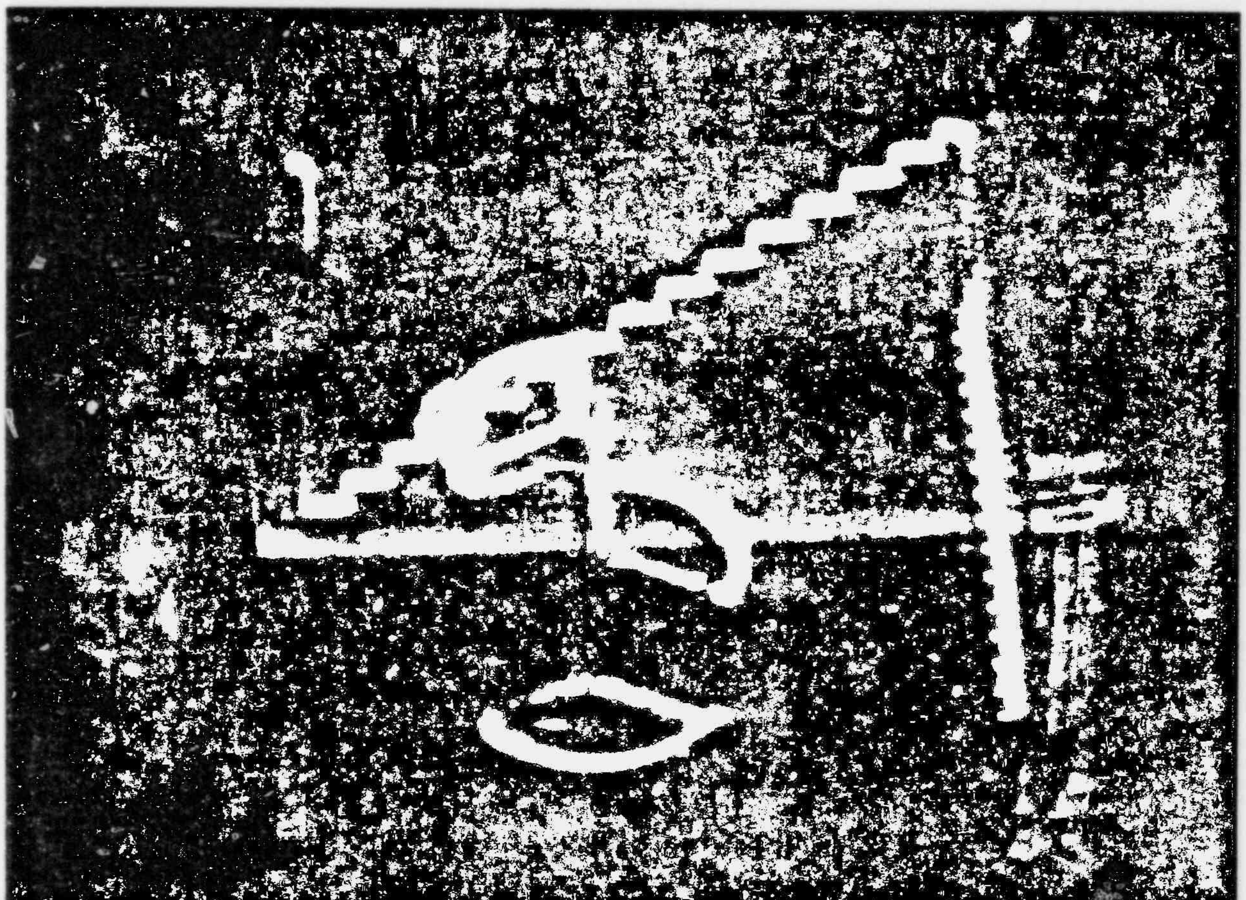
UT HOLOGRAPHIC SCANNER/ROTATOR ASSEMBLY



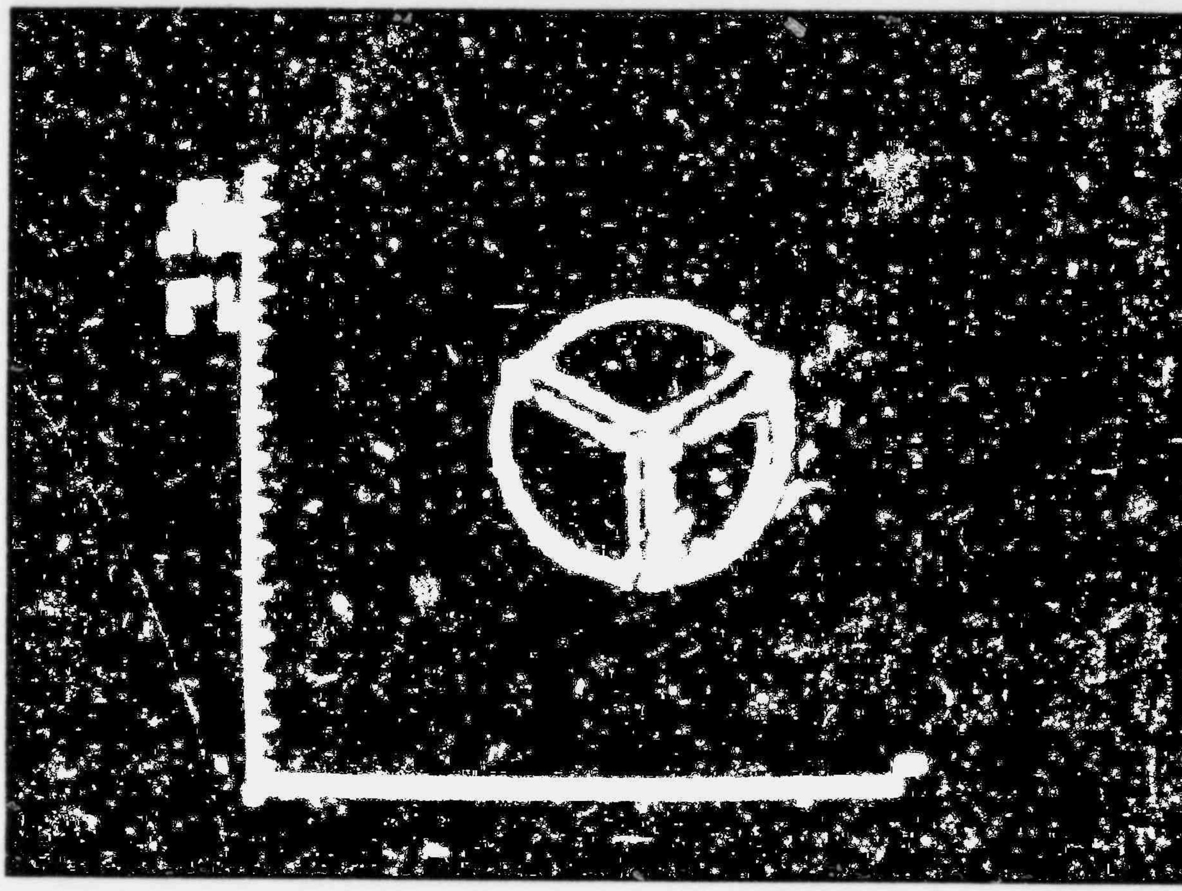
UT HOLOGRAPHIC SCANNING POSITIONS

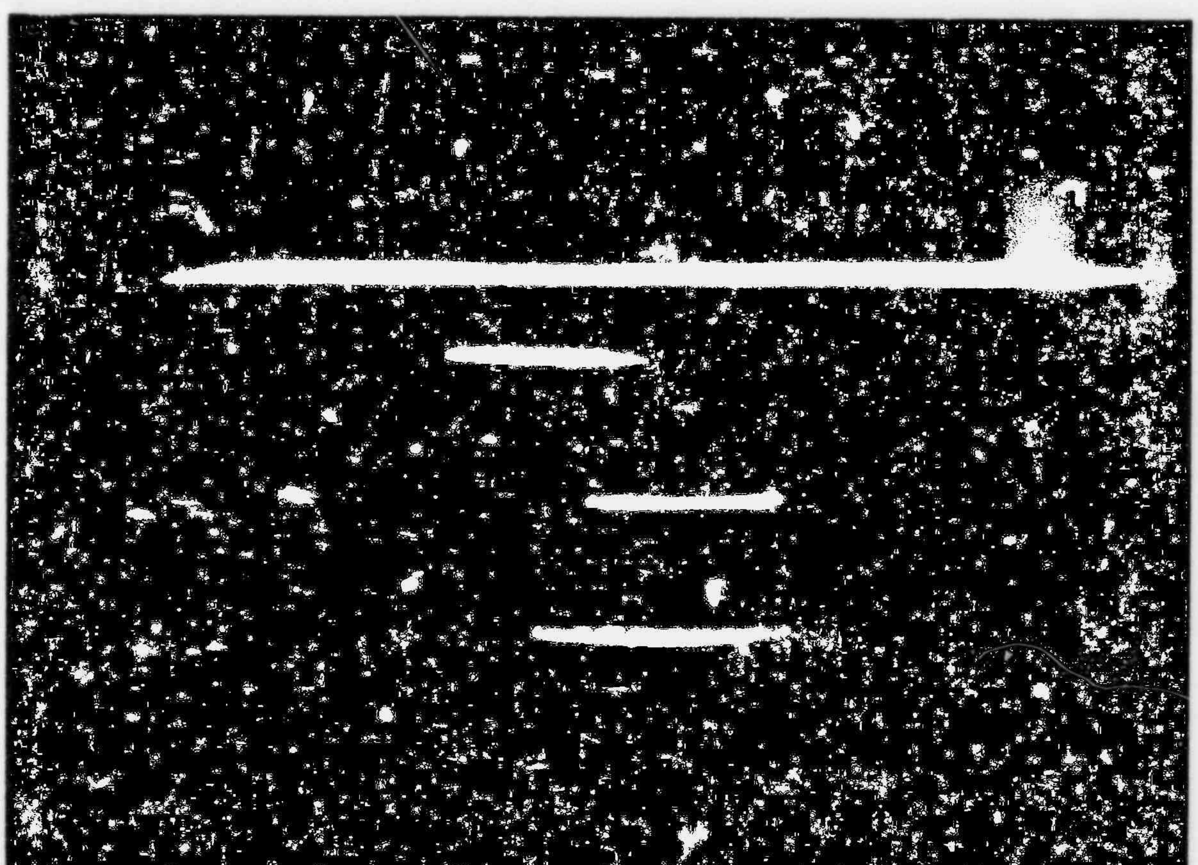




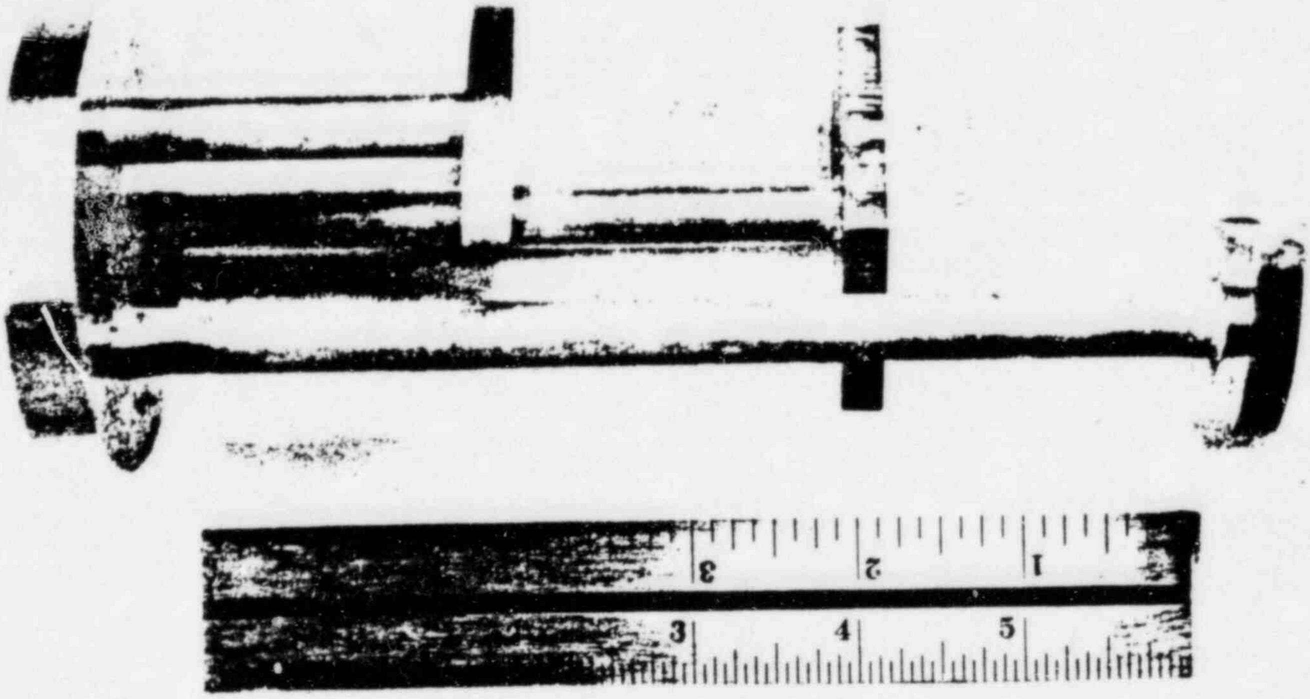


IMAGES CONTAINED ON 35 MM. SLIDE





IMAGES CONTAINED ON 35 MM. SLIDE



UNDERCLAD CRACK DETECTION

ESTIMATE OF RELATIVE DETECTABILITY
OF UNDER CLAD CRACKS GREATER THAN
6mm - OPTIMIZED SYSTEM

CLAD	FINISH	FLAW ORIENTATION	S/N RATIO dB 6mm CRACK	DETECTABILITY CONFIDENCE
STRIP	SMOOTH	$\perp$	18-24	VERY HIGH
STRIP	SMOOTH	$\parallel$	16-24	
SINGLE WIRE	SMOOTH	$\perp$	16-22	
STRIP	UNGROUND	$\perp$	18-20	
SINGLE WIRE	SMOOTH	$\parallel$	16-20	
STRIP	UNGROUND	$\parallel$	14-18	
MANUAL	GROUND	$\perp$-$\parallel$	10-16	HIGH
SINGLE WIRE	UNGROUND	$\perp$-$\parallel$	10-14	MODERATE
MANUAL	UNGROUND	$\perp$-$\parallel$	6-10	LOW

FRENCH CONNECTION

Contact - BAM/RTD

inlet nozzles (13) 126 cracks

outlet nozzles (5) 89 cracks

ALL CRACKS OF DEPTH > 3 MM. DETECTED

Automatic Focussed Probe

inlet nozzles (2) 65 cracks

outlet nozzle (1) 66 cracks

ALL CRACKS OF DEPTH > 3 MM. DETECTED

SIGNIFICANCE OF FRAMATOME RESULTS

1. UNDERCLAD CRACKS OF 1/2 CRITICAL CRACK SIZE IN PTS ISSUE CAN BE RELIABLY DETECTED BENEATH SMOOTH, DOUBLE LAYER STRIP CLAD AND GROUND MANUAL CLAD

2. FRAMATOME NOZZLE CLAD SURFACE WAS OPTIMUM FOR DETECTION, NOT SO FOR US BELTLINE WELDS

3. FRAMATOME NOZZLE CLAD IS DOUBLE LAYER, MANY US BELTLINES ARE SINGLE LAYER

4. UNDERCLAD CRACKS WERE FOUND UNDER MANUAL AS WELL AS STRIP, OVER BASE METAL, VERY LITTLE OVER WELD METAL

5. GRINDING OF US BELTLINE CLAD WOULD REPRODUCE FRENCH NOZZLE CONDITIONS

NEAR SURFACE PROJECT

1. EVALUATION OF SURFACE CAPABILITY IN COOPERATION WITH PNL/NRC

   SHARING OF DATA/SAMPLES, LEVERAGING OF BOTH BUDGETS

2. EVALUATION OF NEW TECHNOLOGIES--CE & W TOOLS

3. SIGNAL PROCESSING WORK

   SYSTEMATIC STUDY OF POTENTIAL FOR DETECTION AND CHARACTERIZATION

   EVALUATION OF LATEST SYSTEM--DYNACON

   APPLICATION OF ADI 4060 FOR EVALUATION PURPOSES

SAMPLE DESIGN AND FABRICATION

QUALIFICATION SET OF SAMPLES

GOALS:

- PERMANENT SET OF HEAVY SECTION SAMPLES WITH KNOWN FLAWS FOR BLIND TESTING OF EQUIPMENT AND CREWS
- PROVIDE STATISTICALLY SIGNIFICANT DEMONSTRATION OF INSPECTION PERFORMANCE IN SIMULATED ISI CONDITIONS

PROBLEMS:

- BLOCKS, FLAWS ARE EXPENSIVE TO FABRICATE
- STATISTICS AND NUMEROUS FLAW PARAMETERS REQUIRE THOUSANDS OF FLAWS, IN HUNDREDS OF BLOCKS
- NEED TO ACHIEVE CONSENSUS WITH NRC AND TECHNICAL COMMUNITY BEFORE FABRICATION, ON "REASONABLE" SIMPLIFYING ASSUMPTIONS TO REDUCE COSTS

NUMBER OF TESTS REQUIRED TO ATTAIN A GIVEN RELIABILITY (CONFIDENCE LEVEL = 90%) FOR A GIVEN NUMBER OF FAILURES

Number of Failures	Percent Reliability						
	99.9	99	98	95	90	80	60
0	2300	230	115	46	22	11	5
1	3900	389	195	78	38	18	9
2		530	265	106	53	25	12
3		670	335	134	67	33	15
•		•	•	•	•		
•		•	•	•	•	•	
•		•	•	•	•	•	
10		1540	770	308	154	75	36

SAMPLE DESIGN AND FABRICATION

EVALUATION TEST BLOCKS

A. 6 BLOCKS 4" THICK FOR NEAR SURFACE MANUAL, STRIP, AND MULTIWIRE CLAD GROUND AND AS WELDED NOTCHES AND MECHANICAL FATIGUE CRACKS

B. 3 MORE SUCH BLOCKS TO BE FINISHED BY 1/30/83

C. 1 7" BLOCK WITH 50" WELD CONTAINING MANY FLAWS MULTIWIRE CLAD, UNGROUND

D. NDE CENTER HAS CLADDING CAPABILITY

NOTE:

A. & B. ARE PERMANENT TEST PIECES WITH KNOWN FLAWS

C. MUST BE DESTRUCTIVELY EVALUATED TO DETERMINE FLAWS PRECISELY

NDE SCREENING BLOCK OPTIONS

- 9 BLOCKS APPROXIMATELY 20 x 24 IN.
- MANUAL, 3 WIRE AND STRIP CLAD
- RANGE OF SURFACE CONDITIONS FROM AS CLAD TO SHOP PRACTICE
- RANGE OF CLAD THICKNESS TO REPRESENT OLDER REACTORS
- MORE THAN 150 FLAWS
- AT LEAST 25% OF THE FLAWS ARE FATIGUE CRACKS OF SHORT ASPECT RATIO ≥ 4
- FLAW SIZE IN THE RANGE OF INTEREST FOR PT'S 3mm AND GREATER

FLAW SAMPLE COSTS

ITEM	COST EACH
4" THICK, CLAD WITH ~10 FLAWS (FATIGUE AND NOTCHES) (2 x 2 FEET) (EPRI)	18K
11" THICK, CLAD WITH PROGRAMMED AND CONTROLLED FATIGUE CRACKS (5) -- 3 x 3 FT. IN 1980 (EPRI)	100K
9" THICK, CLAD WITH 60" WELD AND PROGRAMMED AND CONTROLLED FATIGUE CRACKS -- 5 x 5 FT. IN 1982 (UKAEA)	250K
NOZZLE TO SHELL WELD WITH PROGRAMMED AND CONTROLLED FATIGUE CRACKS IN 1981-82 (UKAEA) BUILT BY WESTINGHOUSE AT A REPORTED LOSS WITH NOZZLES DONATED BY EPRI ESTIMATED REPLACEMENT COST (600 TO 700K)	400K
NOZZLE TO SHELL WELD FOR PISC II (S. CRUTZEN)	750K

BURIED FLAW DETECTION

BURIED FLAWS

CURRENTLY HAVE THREE ACTIVE PROJECTS

1. RP 1570-3 -- CE
2. RP 2165-2 -- W
3. RP 2165-3 -- DSI

1. & 2.

CE HAS USED SECTION XI TECHNIQUES ON EPRI 7" BLOCK

W HAS PERFORMED PARALLEL TESTS ON 4 PARTY BLOCKS
W WILL REPEAT TESTS AT NDE CENTER
(EPRI WILL PUBLISH W PRIOR RESULTS)

CE & W AGREE THAT INSPECTIONS TO MINIMUM SECTION XI STANDARDS WILL NOT RELIABLY FIND OR SIZE CRACKS AT OR ABOVE CRITICAL CRACK SIZE BURIED AT 1/8T TO 1/2T

W HAS SHOWN AN IMPROVED TECHNIQUE WHICH IS REPEATABLE, REPRODUCIBLE AND HIGHLY RELIABLE. W RESULTS WILL BE VERIFIED BY NDE CENTER PROCTORED EVALUATION TEST

3. DYNACON SYSTEM PRELIMINARY DATA SHOWS POTENTIAL EVALUATION TO BE COMPLETED 3/30/83

ALTERNATIVE APPROACHES

FOR UNDERCLAD CRACKS

- EDDY CURRENT TECHNIQUES
  - CONFIRMATION OF UT
  - CHARACTERIZATION

FOR BURIED FLAWS

- MINAC RADIOGRAPHY WITH IMAGE ENHANCEMENT
  AND FILMLESS TECHNIQUES

CURRENTLY IN FEASIBILITY PHASE

SUMMARY OF DDT RESULTS

DEFECT DETECTION TRIALS
(DDT)

- CONDUCTED IN SUPPORT OF SAFETY CASE FOR UK PWR PROPOSAL

- OBJECTIVE: TO DEMONSTRATE NDE EFFECTIVENESS FOR RPV INSPECTION

- FOUR TEST PIECES

  - 1 & 2 FLAT PLATES - SUBSURFACE AND NEAR SURFACE DEFECTS

  - 3 FLAT PLATE - CLAD AND UNDERCLAD DEFECTS

  - 4 NOZZLE - INNER CORNER DEFECTS

  (PLATE, AND STRIP CLAD OF HIGH QUALITY AND SMOOTH)

- SIX TEAMS PARTICIPATED

  - 2 FRENCH

  - 1 GERMAN

  - 3 ENGLISH

DEFECT DETECTION TRIALS

(DDT)

RESULTS

- PLATES 1 & 2
  - ALL 6 TEMAS DETECTED ALL 45 DEFECTS
  - SIZING BY THE THREE ENGLISH TEAMS WAS EXTREMELY GOOD
  - HOWEVER A SMALL NUMBER OF ASME UNACCEPTABLE FLAWS WERE SIZED AS ACCEPTABLE
- PLATE 3 CLAD AND UNDERCLAD DEFECTS
  - ALL UNDERCLAD DEFECTS DETECTED
  - SIZING WAS NOT A FACTOR
- PLATE 4 NOZZLE INNER RADIUS
  - ALL DEFECTS DETECTED 5mm OR LARGER
  - SIZING VERY GOOD 2mm

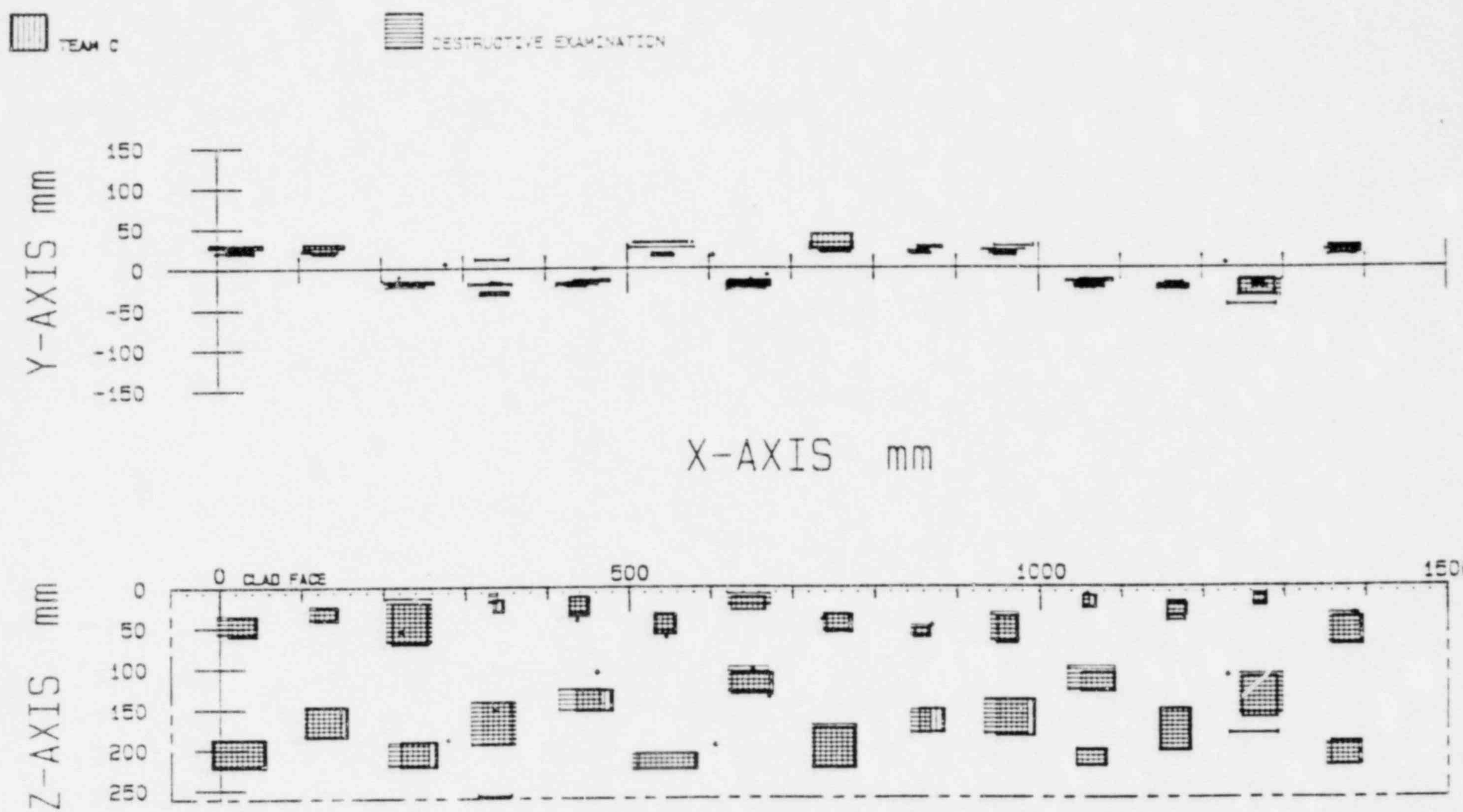


Fig. 15 TEAM C clad face. Examination of Plate 1

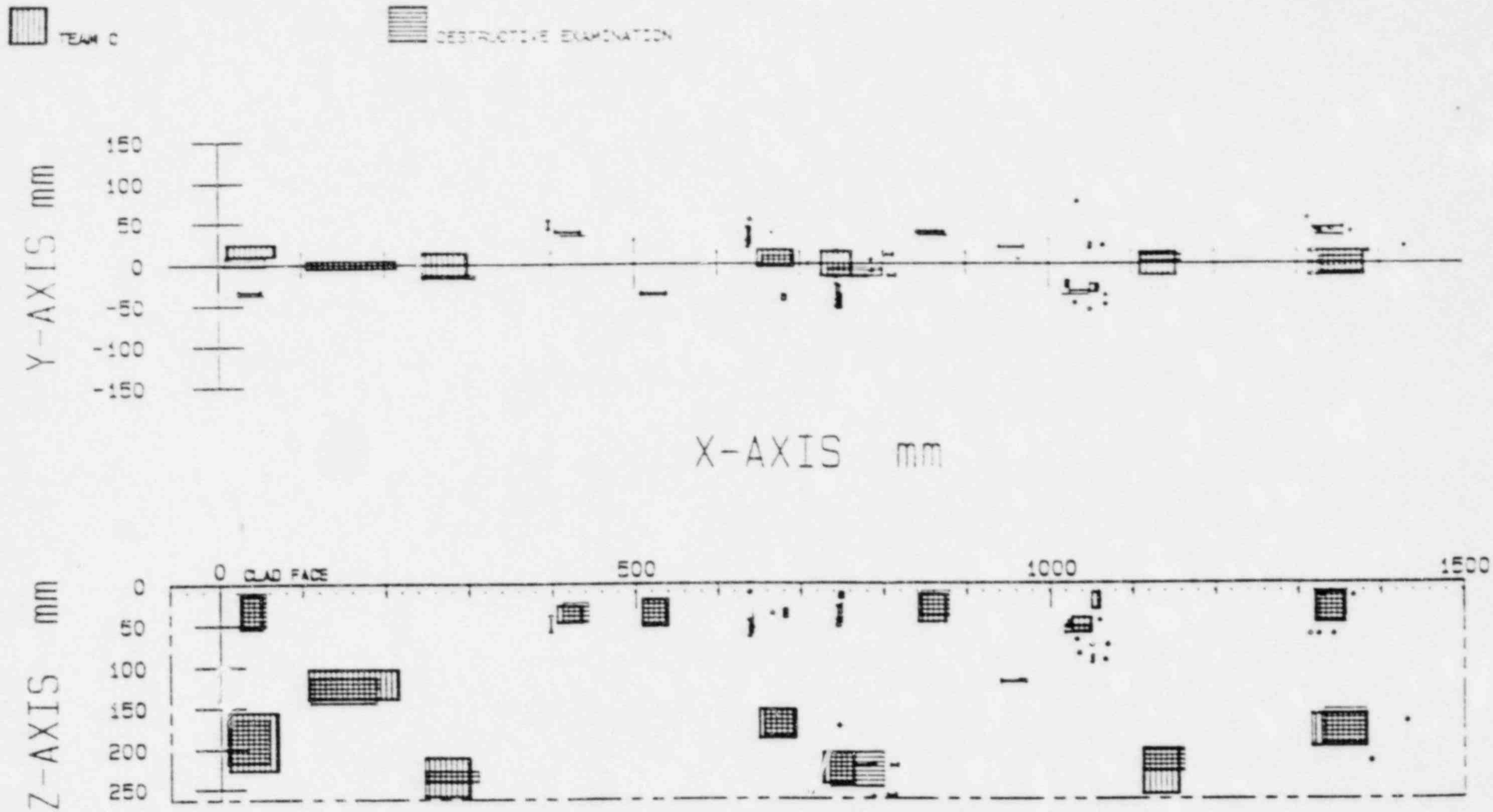


Fig. 17 TEAM C clad face. Examination of Plate 2

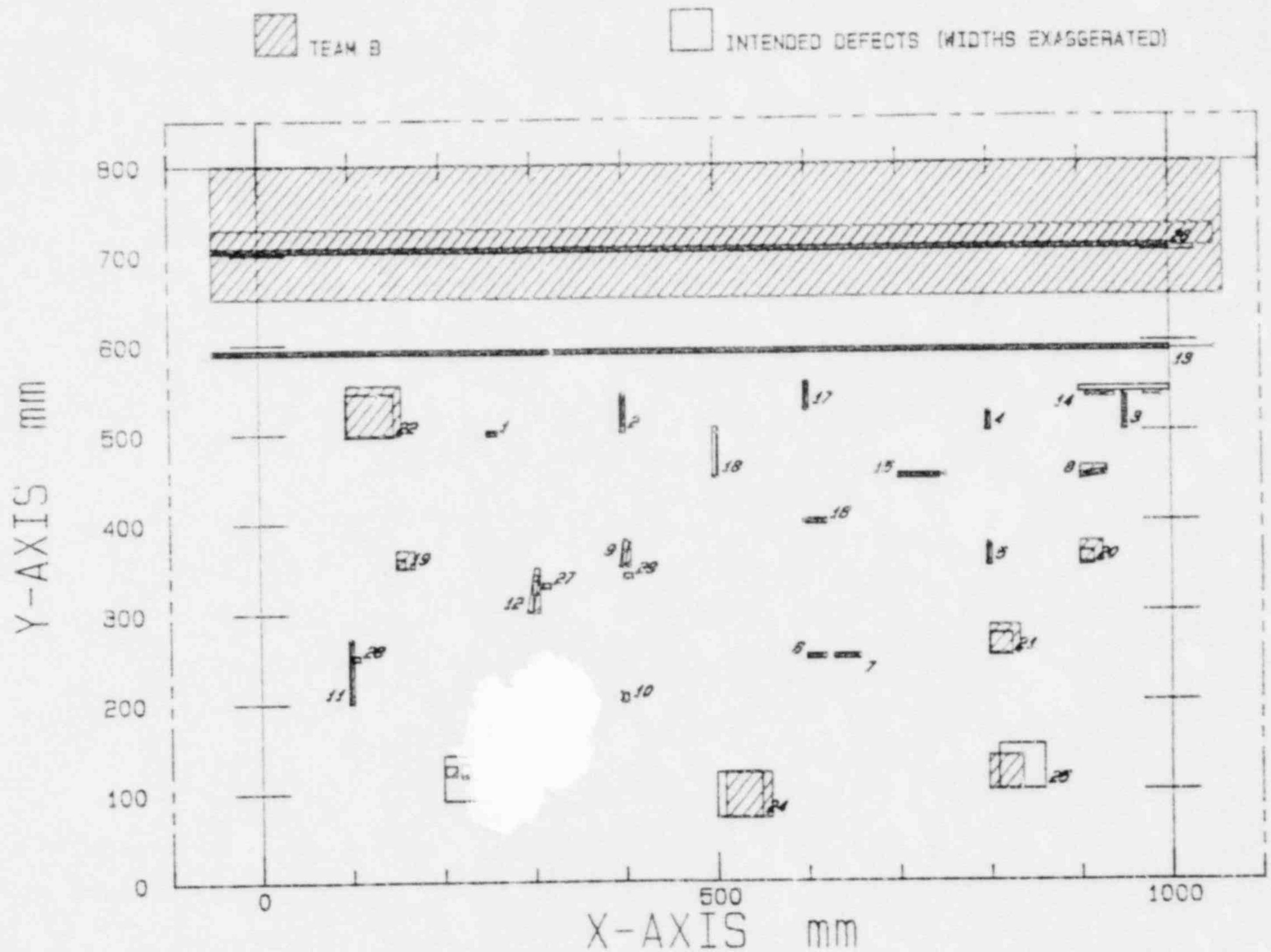
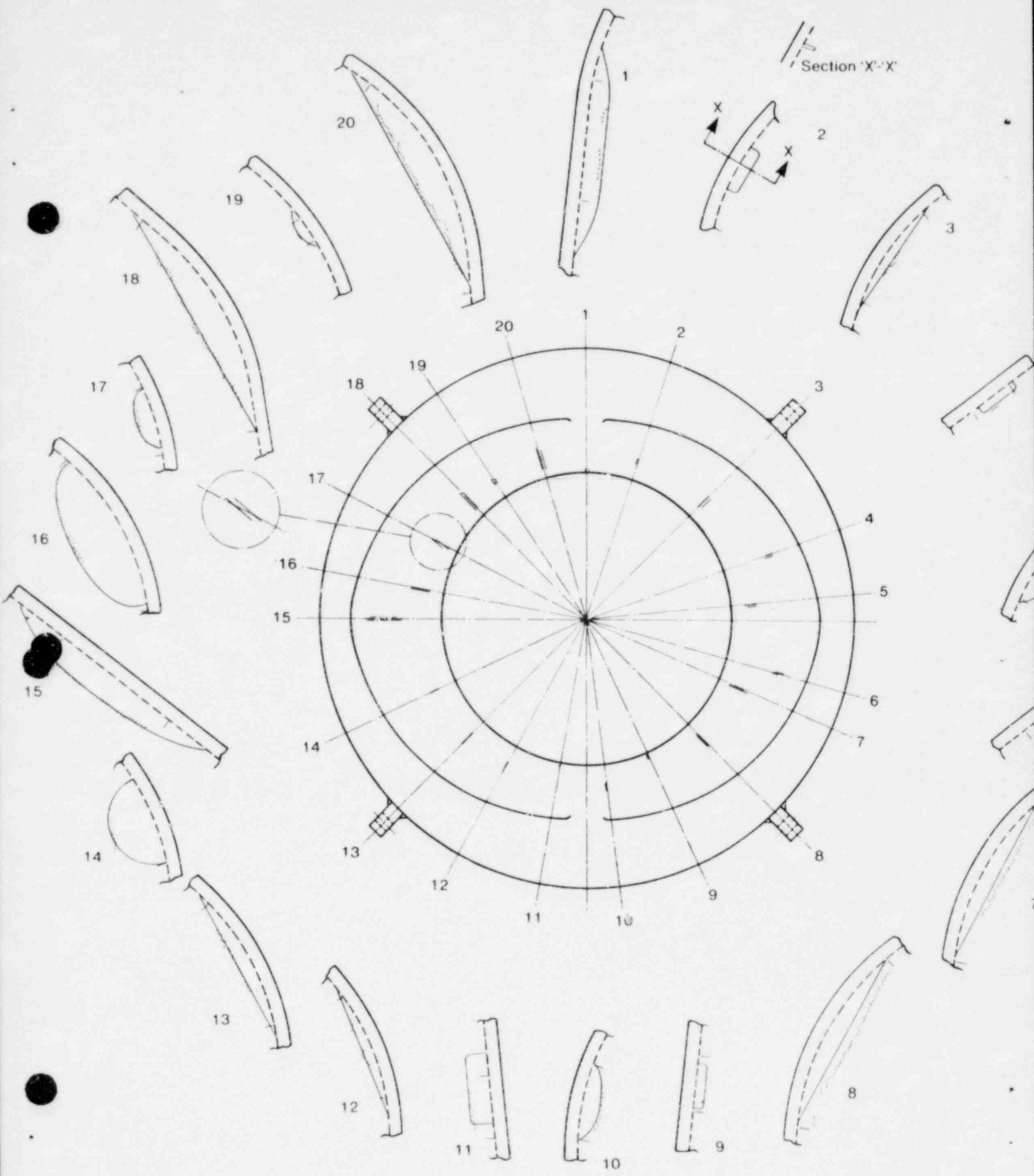
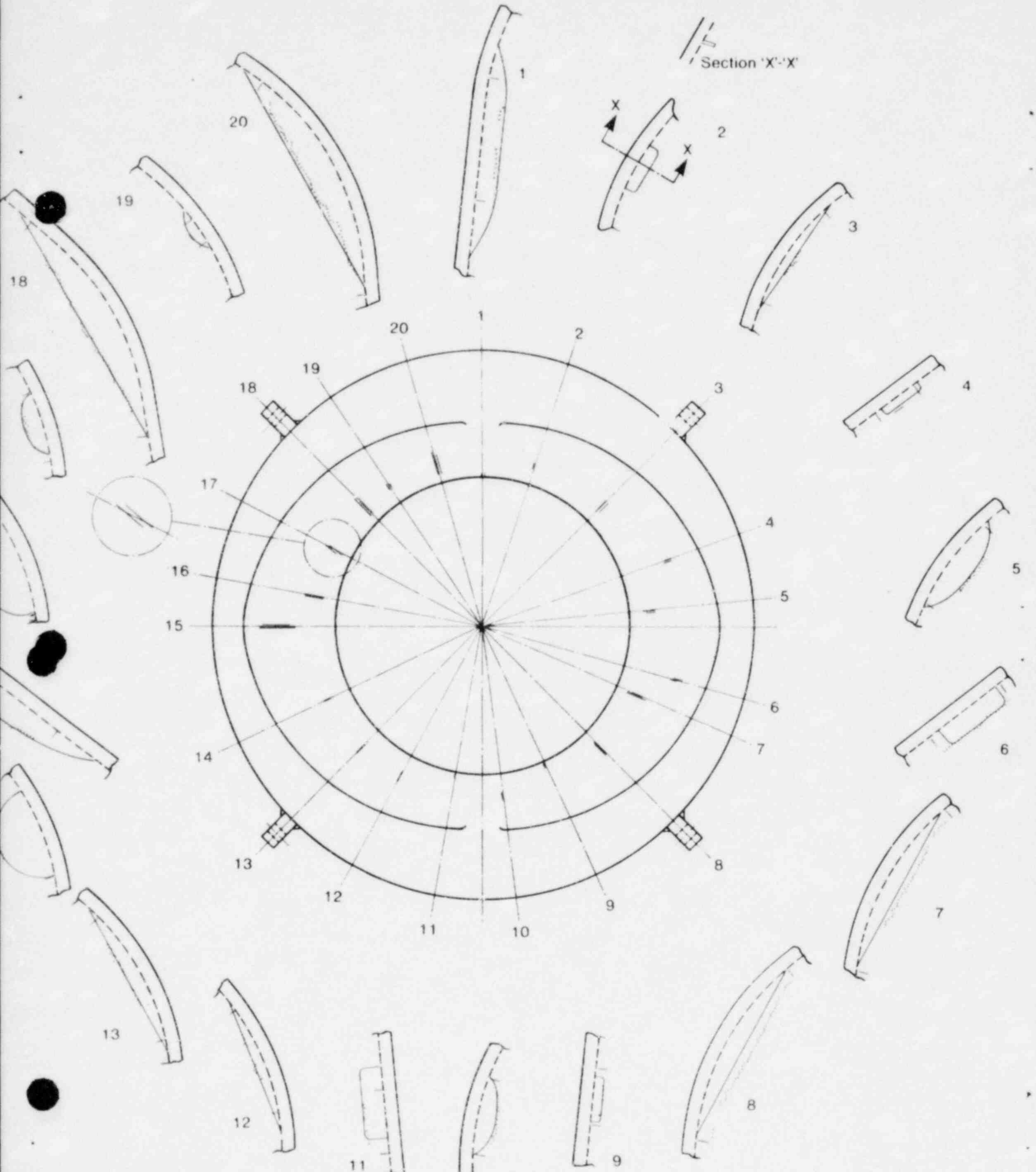


Fig 7. Results of examination of DDT plate 3 - Team B.



Section 'X'-'X'
X
X
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20



Section 'X'-'X'
X
X
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20

DEFECT DETECTION TRIALS

(DDT)

CONCLUSIONS

- AN ADEQUATE INSPECTION <u>CAN</u> BE PERFORMED ON A RPV OF THE QUALITY EXPECTED IN THE UK PROGRAM

- BEST RESULTS WERE ACHIEVED BY USING A MULTIPLICITY OF DETECTION AND SIZING APPROACHES

- NO TEAM SELECTED ASME OR REG. GUIDE 1.150 DETECTION AND SIZING RULES

- NO TECHNOLOGICAL BREAKTHROUGH WAS REQUIRED (APPLICATION OF GOOD ENGINEERING)

- FURTHER ANALYSIS OF RECORDED DATA CAN SHOW PERFORMANCE LEVEL OF ASME - REG. GUIDE 1.150 TECHNIQUES

TRANSDUCER CALIBRATION FACILITY

ULTRASONIC

TRANSDUCER - INSTRUMENT

CALIBRATION (CHARACTERIZATION)

- A BASIC OBJECTIVE OF REG. GUIDE 1.150 IS TEST REPEATABILITY

- CHARACTERIZATION IS NECESSARY TO ACHIEVE REPEATABILITY

- EPRI HAS ESTABLISHED A CALIBRATION AND CHARACTERIZATION FACILITY

  SERVICES ARE AVAILABLE TO ALL UTILITIES AND ISI VENDORS

EPRI NUCLEAR POWER DIVISION

RP1570-2

Technical Brief

New NDE Center Laboratory for Calibration and Characterization of Ultrasonic Systems

In response to the growing need for calibration and characterization of ultrasonic systems used in the nuclear industry, the EPRI NDE Center has established an ultrasonic calibration laboratory. The laboratory is capable of performing routine calibration services (within the tolerances of the National Bureau of Standards) and of characterizing individual ultrasonic element and ultrasonic system performance parameters.

Nuclear Regulatory Commission Regulatory Guide 1.150, "Ultrasonic Testing of Reactor Vessel Welds During Preservice and Inservice Examinations," and several independent investigations indicate the need for characterization and documentation of systems used for ultrasonic inspection. In several instances it has been shown that ultrasonic systems of the same nominal specifications do not provide equivalent performance. A major objective of Regulatory Guide 1.150 is a demonstration of reproducibility of test results. It is doubtful that this objective can be achieved without documentation of component and system performance characteristics.

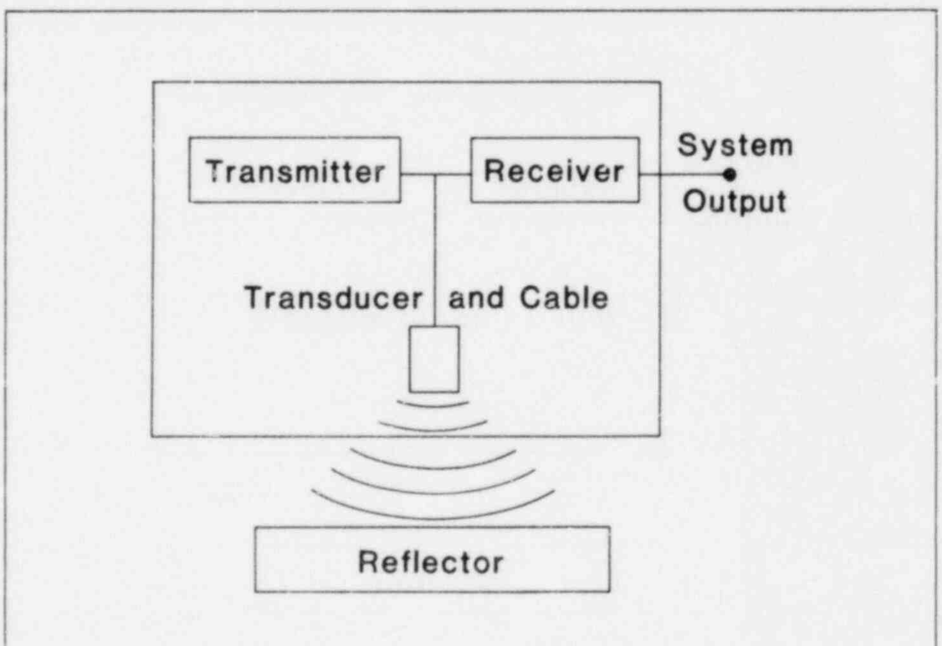
Approach

An ultrasonic system has three major components: a pulser or transmitter, the transducer and cable, and the receiver. Each component may interact with the other components as well as with the test reflector to yield a characteristic system output. These interactions are not necessarily linear. In order to achieve the goal of reproducibility, it is necessary to document the performance characteristics of the component parts as well as the overall system response.

Pulser. The pulser is the most nonlinear component in the system. However, its major characteristics—output impedance, spectral content, peak voltage, and pulse shape—can be measured. These output parameters are measured with 10Ω and 100Ω resistive loads.

Transducer and Cable. Transducers are the most variable component and the one most likely to change with use. Transducer characteristics that are measured include

- Peak frequency
- Upper frequency (–6dB from peak)
- Lower frequency (–6dB from peak)
- Bandwidth center frequency
- Percent bandwidth
- Radio frequency waveform
- Impedance



Ultrasonic system component interaction.

- Insertion loss or relative loop sensitivity
- Active element diameter or size (beam size at contact surface for transducer designed to operate on plastic shoes)
- Beam pattern in water
- Beam spread in water

Measurements of frequency impedance, and sensitivity parameters are based on the reflection from a large planar reflector immersed in water at a distance of 2 inches or less. Beam pattern parameters are mapped in water using a miniature hydrophone or ball reflector. A system capable of mapping sound beams in steel is planned to be operational in 1983.

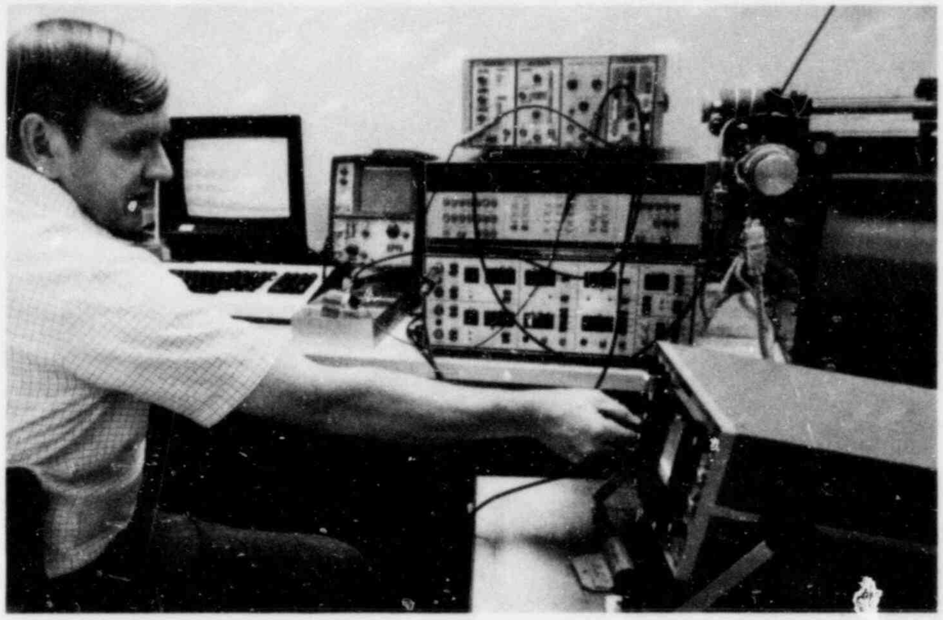
Receiver. The receiver section of the system is basically an amplifier, and its characterization is straightforward. Receiver characteristics that are measured include

- Band pass
- Noise
- Sensitivity
- Linearity

These characteristics are displayed in graphic or tabular format.

System. The final step in the process is characterization of the assembled system. This does require that the instrument have a radio frequency output. The spectral content, as well as the waveform, is recorded using the reflection from a large flat reflector at a distance of 2 inches or the nominal near-field length, whichever is less. This check assures that each system component operates compatibly and as expected based on individual component characteristics.

Characterization equipment used to quantify performance features of an ultrasonic test system.



Instrument controls such as damping, pulse length, frequency, reject, and video filtering can have considerable influence on performance characteristics. The influence of these control settings can be evaluated at both the component and system level.

Services

The EPRI NDE Center calibration and characterization laboratory is now in operation. The equipment and procedures of this laborato , nave been used to characterize ultrasonic systems as a part of the U.S. participation in the Program for Inspection of Steel Components round-robin tests completed at the NDE Center during the summer of 1982.

The NDE Center is prepared to offer calibration and characterization of ultrasonic equipment to utilities, to utility service contractors involved in NDE of commercial nuclear reactors and other power plants, and to NDE research and development organizations. This service will be offered on a cost recovery basis. For further information, contact B. Knipschield, EPRI NDE Center, (704) 597-6199, or Gary J. Dau at EPRI, (15) 855-2051.

RECOMMENDED REVISIONS TO

USNRC REG. GUIDE 1.150

REG. GUIDE 1.150 HISTORY

~ 1979	-	DRAFT INITIATED
7/15/81	-	FINAL VERSION ISSUED
9/10/81	-	WORKSHOP TO DETERMINE INTENT, LIMITATIONS AND REMEDIES
	-	AD HOC UTILITY COMMITTEE APPROACH RECOMMENDED
10/15-16/81	-	JACK LANCE AGREED TO CHAIR
	-	APPROACH REVIEWED WITH NDE SUBCOMMITTEE (EPRI UTILITY ADVISORY STRUCTURE)
11/5/81	-	AD HOC COMMITTEE ORGANIZED, CHARTER ADOPTED
DEC., JAN., MARCH, APRIL	-	COMMITTEE MEETINGS
4/15-16/82	-	MEETING WITH NRC AND CONSULTANTS (VERY USEFUL - PRODUCTIVE SESSION)
MAY	-	REVIEW OF 4/15-16/82 RESULTS (BY MAIL)
6/24/82	-	DRAFT MAILED TO INDUSTRY FOR REVIEW (APPENDIX B LIST) WITHIN ONE MONTH
7/27/82	-	COMMITTEE REVIEWED AND RESOLVED COMMENTS
7/28/82	-	FINAL DRAFT REVIEWED WITH INDUSTRY (APPENDIX B INVITED)
8/10/82	-	COMPLETED DOCUMENT TRANSMITTED TO NRC

SIGNIFICANCE OR RECOMMENDATIONS

- o AMBIGUITIES REMOVED FROM 1.150
- o IMPLEMENTABLE
- o TECHNICALLY, MORE DEMANDING
- o RECOGNIZES ID NEAR SURFACE AS MOST IMPORTANT; RECOMMENDS GREATER SENSITIVITY INSPECTION FOR INNER 25% WALL
- o STRUCTURAL MECHANICS USED TO JUSTIFY 2 LEVELS OF SENSITIVITY
- o INTRODUCES INSPECTION PERFORMANCE DEMONSTRATION CONCEPT
- o UTILITY INITIATIVE

PERSONAL OBSERVATIONS OF COMMITTEE PROCESS

G.J. DAU

- o COMMITTEE MEMBERS (AND INDUSTRY AS A WHOLE) DEDICATED TO HAVING HIGHEST QUALITY POSSIBLE VESSEL EXAMINATION

- o INDUSTRY COMMITTED MUCH TIME AND FUNDS TO DEVELOPMENT OF RECOMMENDATIONS

ESTIMATE:	Travel, Lodging, etc.	$ 90,000
	Salaries	180,000
	Support	25,000
		$295,000

- o PRECEDENT SETTING
  - WIDE INDUSTRY PARTICIPATION
  - UTILITIES ACTING IN CONCERT
  - EXCELLENT NRC STAFF, CONSULTANTS AND UTILITY INTERACTION AND AGREEMENT ON KEY POINTS

- o FUTURE COMMITTEES WILL OPERATE MORE EFFICIENTLY, LESS COSTLY

- o PROCESS COMPLETED WITH UPBEAT OUTLOOK TOWARD EFFICIENT RESOLUTION OF FUTURE SIMILAR ISSUES (IF NEEDED)

- o LONG TERM BENEFITS (ATTITUDES) DEPENDENT ON NRC RESPONSE TO RECOMMENDATIONS

ELECTRIC POWER RESEARCH INSTITUTE

EPRI

August 15, 1982

Mr. Charles Z. Serpan
Chief of the Materials Branch
U. S. Nuclear Regulatory Commission
Mail Station 1130SS
Washington, D.C. 20555

Dear Mr. Serpan:

Enclosed are 10 copies of the Recommended Changes to Regulatory Guide 1.150, "Ultrasonic Testing of Reactor Vessel Welds During Preservice and Inservice Examinations," proposed by the Ad Hoc Committee of the Electric Utility Industry. These Recommended Changes are the result of the work outlined in our letter of December 11, 1981. They represent a significant contribution of time and research effort on the part of the Committee members and their task force resource groups listed in Appendix A.

The Committee's efforts since December have focused on clarifying some sections of the Regulatory Guide and suggesting changes to other sections to place emphasis on demonstration of inspection capabilities rather than mandating specific techniques.

The Committee contacted ISI vendors as well as utility personnel and NRC staff and consultants for guidance while preparing this document. The NRC consultants and staff who attended our April meeting contributed a great deal to our work with their candid, objective comments on the draft document in progress at that time.

Although it is unrealistic to expect complete consensus on the resolution of complex questions such as those addressed in the Regulatory Guide and in our Recommended Changes, the Committee has received widespread industry support for the recommendations presented here.

We realize that the Committee's work represents an unprecedented response from the industry. We appreciated having you with us at our meeting in Washington, D.C., on July 28, acknowledging to the group the significance of this effort. We also appreciated your assurance that the document would receive careful consideration in the possible preparation of a revised Regulatory Guide 1.150.

As mentioned several times in the document and at the July 28 meeting, the Committee's goal is high-quality inspections of reactor pressure vessels, the same goal held by the NRC in preparing the Guide. Our Recommended Changes are intended to promote industry accountability in meeting that goal to the benefit of all concerned.

If you have any questions or comments, please direct them to either Mr. J. J. Lance or Dr. Gary Dau.

Sincerely,

Jack Lance

J. J. Lance, Chairman
AD HOC COMMITTEE ON REGULATORY GUIDE 1.150

Gary J. Dau

Gary J. Dau
Senior Program Manager
Nondestructive Evaluation

Robert F. Brandt
Frank Carr
C. David Cowfer
Mike Gothard
Harry R. Hesidence
Tony F. Lentz
Thurman Smith
Peter D. Watson
David E. Whitaker

cc: Committee members

FINAL REPORT

Recommended Changes
to
Regulatory Guide 1.150

"Ultrasonic Testing of Reactor Vessel Welds
During Preservice and Inservice Examinations"

Prepared
by

AD HOC COMMITTEE
of the
ELECTRIC UTILITY INDUSTRY

J. J. LANCE, CHAIRMAN

Robert F. Brandt
Frank Carr
C. David Cowfer
Gary J. Dau
Mike Gothard
Harry R. Hesidence
Tony F. Lentz
Thurman Smith
Peter D. Watson
David Whitaker

Presented to

U. S. Nuclear Regulatory Commission

August, 1982

1. INTRODUCTION

Background

United States Nuclear Regulatory Commission (NRC) Regulatory Guide 1.150, "Ultrasonic Testing of Reactor Vessel Welds During Preservice and Inservice Examinations," was issued on July 15, 1981, and generated considerable concern among affected utilities and their inservice inspection (ISI) vendors. In response to this concern, the Electric Power Research Institute conducted a workshop to focus discussion on the subject, to identify specific problems and to develop plans to eliminate these problems.

The workshop was held on September 10, 1981, with 91 people participating. Representatives of the USNRC, various utilities, and major ISI vendors offered comments and perspectives on the Regulatory Guide.

— Participants agreed that the Regulatory Guide's goal of assuring improved pressure vessel inspection was worthy and that guidelines for such inspections were needed. However, participants expressed significant doubt that the document as issued would achieve that goal. Participants not only questioned technical aspects of the document, but also expressed concern that the language of the document was unclear and subject to different interpretations by the utilities and various parties within the NRC. These concerns were amplified during the workshop by the apparent difference of opinion among members of the NRC regarding focus of the document.

At the conclusion of the workshop, a majority of utility members present favored the formation of an industry committee to develop recommended changes to the Guide which would meet the intended goal (i.e., improved pressure vessel inspection), but avoid the ambiguities in the present document. The Committee was formally organized on November 5, 1981. A Committee charter was developed and specific responsibilities assigned to the members. The charter, membership list and task group assignments are included here as Appendix A.

To elicit industry-wide participation in this project, the Committee mailed copies of the draft document to all member utilities and requested review and comment. A list of individuals who received the draft document is included here as Appendix B.

On July 28, 1982, the Committee met with industry participants in Washington D. C. to report on their work and to present and discuss the final draft of recommended changes contained in this document.

Organization of Report

This report documents the results of the Committee's efforts.

Chapter 2 summarizes the objections and concerns and the Committee's recommended changes to Regulatory Guide 1.150.

Chapter 3 presents the recommended changes, and Chapter 4 presents the technical justification for these recommendations.

Chapter 5 presents a summary of ongoing EPRI-sponsored research on inspection and structural mechanics pertaining to pressure vessel integrity and is included to inform the reader of the considerable investment the industry is making to improve both inspection and analytical techniques to assure the integrity of nuclear reactor pressure vessels.

Appendix A outlines the Committee charter, membership and assignments, and Appendix B lists industry participants in the review of the draft document.

2. SUMMARY

Objections and Concerns

The Committee, representing a major portion of the electric utility industry, concurs with the intent of Regulatory Guide 1.150, but the Committee has objections to it based on the following concerns:

- o The Guide as written is ambiguous and therefore subject to misinterpretation which could lead to unnecessary, potentially costly and time-consuming disagreements between the NRC and utilities.
- o The Guide is in some cases unimplementable.
- o The Guide is in some cases too specific and could encourage minimum compliance rather than best compliance, thus defeating its own intent.
- o The Guide does not allow enough flexibility for use of alternative or developing technologies to meet its goals.

The specific objections of the Committee are reflected in the language of its Recommended Changes, Chapter 3 and in its Technical Justification for these changes, Chapter 4.

Recommended Changes

In its Recommended Changes, the Committee has attempted to place responsibility for meeting the intent of the Guide on utility owners through basic qualifying criteria with guidelines for compliance rather than specific or absolute requirements for compliance.

In most cases, the ASME Code is quite specific in areas covered by Regulatory Guide 1.150 and can be applied as basic qualifying criteria. Owners would be allowed to use alternative methods to comply with these criteria provided they could demonstrate equal or more effective results.

The Committee believes this change will better meet the intent of the Guide, will allow more flexibility in compliance, and will encourage more accountability on the part of owners and their service contractors. The change may also stimulate the development of improved technology to perform the required inspections.

In determining its qualifying criteria, the Committee has taken into consideration not only the technical aspects of compliance, but also ALARA and cost benefits. Major considerations in these two areas are reducing radiation exposure for inspection teams and minimizing the length of time an operating plant is off-line during an inspection.

AD HOC COMMITTEE CHARTER

TITLE: AD HOC Committee for Development of Optimized Reactor Pressure Vessel Inspection Guides.

PURPOSE: The purpose of this Committee is to develop utility industry position for recommended revision of Reg. Guide 1.150 ("Ultrasonic Testing of Reactor Vessel Welds During Preservice and Inservice Examinations").

SCOPE: The scope of this activity is limited to the ultrasonic inspection of reactor pressure vessels. This action is being taken in an effort to promote a uniform approach to achieving high quality vessel inspection, while removing any ambiguities that may result from the recently issued Reg. Guide 1.150.

COMMITTEE COMPOSITION: The Committee will be composed of utility people experienced in Inservice Inspection. The minimum membership is eight (8) people. Task Groups may include ISI vendor personnel, NRC staff and consultants, and utility people. Each Task Group will be chaired by a utility person. EPRI staff will provide support activities as needed.

COMMITTEE CHAIRMAN: The Chairman shall be from a U.S. utility.

PROCEDURE: All decisions will be made on the basis of a vote of those present at the meeting. A simple majority of the membership will be considered as a quorum. A simple majority of those present will decide each issue. In absence of a quorum, a letter ballot will be issued with a response required within fifteen (15) days.

AD HOC COMMITTEE MEMBERSHIP

Name	Company	Address/Phone
Jack Lance, Chairman	Yankee Atomic Electric Company	1671 Worcester Road Framingham, MA 01532 Tel. 617-872-8100
David E. Whitaker	Duke Power	422 South Church Street Charlotte, NC 28242 Tel. 704-373-7602
Tony F. Lentz	Carolina Power & Light	Shearon Harris Plant P. O. Box 165 New Hill, NC 27562 Tel. 919-362-2006
Peter D. Watson	Northeast Utilities Service Company	P. O. Box 270 Hartford, CT 06101 Tel. 203-666-6911, Ext. 5692
Harry R. Hesidence	Houston Light & Power	P. O. Box 1700 Del Monte Tower, 9-B Houston, TX 77001 Tel. 713-877-4690
Robert F. Brandt	Public Service Electric and Gas Company	80 Park Plaza M/C 20B Newark, NJ 07101 Tel. 201-430-8441
Thurman Smith	Pacific Gas & Electric	Diablo Canyon Plant P. O. Box 56 Avila Beach, CA 93424 Tel. 805-595-7351
C. David Cowfer	GPU Nuclear	100 Interpace Parkway Parsippany, NJ 07054 Tel. 201-263-6570
Mike Gothard	Tennessee Valley Authority	1630 Chestnut Street Towers Chattanooga, TN 37401 Tel. 615-751-4988
Dr. Gary J. Dau	EPRI	P. O. Box 10412 Palo Alto, CA 94303 Tel. 415-855-2051
Frank Carr	Florida Power & Light Company	P.O. Box 529100 Miami, FL 33152 Tel. 305-552-3670

AD HOC NDE PERSONNEL QUALIFICATION COMMITTEE

AD HOC COMMITTEE CHARTER

TITLE:	AD HOC COMMITTEE FOR DEVELOPMENT OF QUALIFICATION REQUIREMENTS FOR NUCLEAR UTILITY EXAMINATION PERSONNEL.
PURPOSE:	The purpose of this committee is to develop and document minimum requirements for the qualification of NDE personnel who perform examinations of nuclear power plants. In addition, the committee is to develop a recommendation for implementation of the minimum requirements.
SCOPE:	The scope of this activity is limited to the personnel who perform examinations under the requirements of ASME Boiler and Pressure Vessel Code, Section XI, "Rules for Preservice and Inservice Inspection of Nuclear Power Plant Components".
COMMITTEE COMPOSITION:	The Committee will be composed of utility people involved in the qualification and certification of NDE personnel plus a representative from EPRI and a representative of the EPRI NDE Center. The minimum membership is eight (8) people.
COMMITTEE CHAIRMAN:	The Chairman shall be from a U.S. utility.
TECHNICAL LIAISON:	After formation of the committee, representatives from the ASME Section XI committee, INPO, ASNT or other organizations may be invited to participate. Task Groups, if used may include non-committee members such as ISI vendor personnel, NRC Staff and consultants, and other utility personnel. Each Task Group will be chaired by a committee member.
PROCEDURE:	All decisions will be made on the basis of a vote of committee members present at the meeting. However, a simple majority of the total membership will decide each issue. In the absence of a simple majority, a letter ballot will be issued with a response required within fifteen (15) days.

AD HOC NDE PERSONNEL CERTIFICATION COMMITTEE

Name	Company/Address	Telephone
Carl Osman Chairman	Carolina Power & Light M/S 7C3 411 Fayetteville Street P. O. Box 1551 Raleigh, NC 27602	919/362-2295
T. N. (Bud) Epps	Southern Company Services P. O. Box 2625 Birmingham, AL 35202	205/870-6300
Elmer Martinez	Consumers Power Company 1945 West Parnall Road Jackson, MI 49201	517/788-0455
Frank Carr	Florida Power & Light 9250 West Flager Street Miami, FL 33174	305/552-3670
Bob Brandt	Public Service Gas & Electric Nuclear Department P. O. Box 236 Hancocks Bridge, NJ 08038	609/935-6000 X4555
James Dickerson	Middle South Services P. O. Box 61000 New Orleans, LA 70161	504/569-4550
Pete Etzler	Tennessee Valley Authority 400 West Summit Hill Dr., W11D117 Knoxville, TN 37902	615/632-4857
Jerry Ray	Arkansas Power & Light P. O. Box 551 Little Rock, AR 72203	501/964-3138
Gary Dau	EPRI P. O. Box 10412 Palo Alto, CA 94303	415/855-2051
George Pherigo	EPRI NDE Center P. O. Box 217097 Charlotte, NC 28221	704/597-6131
Carl Shaw	Portland General Electric Co. Generation Fac. Engrg. Dept., SB-B 121 S. W. Salmon Street Portland, OR 97204	503/226-8043
Fred Hawksley	Niagara Mohawk Power Corp. 9 Mile Pt. Unit 1 Nuclear Station P. O. Box 32 Lycoming, NY 13093	315/343-2110 X1393

PRESENTATION

- FOCUS ON PROGRAM-MATIC IMPACT ON NINE MILE POINT AND NEAR SURFACE CRACK DETECTION
- SHORT REVIEW OF EARLY PIPING WORK
- CURRENT WORK
- FUTURE WORK

PROGRAM OBJECTIVES

1. DETERMINE THE RELIABILITY OF ULTRASONIC ISI PERFORMED ON LWR PRIMARY PIPING SYSTEMS
2. USING FRACTURE MECHANICS ANALYSIS, DETERMINE THE IMPACT OF NDE UNRELIABILITY ON SYSTEM SAFETY AS WELL AS THE LEVEL OF INSPECTION RELIABILITY REQUIRED TO ASSURE A SUITABLY LOW FAILURE MODE
3. EVALUATE THE DEGREE OF RELIABILITY IMPROVEMENTS WHICH COULD BE ACHIEVED USING IMPROVED AND ADVANCED NDE TECHNIQUES
4. BASED ON MATERIAL, SERVICE AND NDE UNCERTAINTIES, FORMULATE RECOMMENDED REVISIONS TO ASME SECTION XI AND REGULATORY REQUIREMENTS NEEDED TO ASSURE CONTINUED SYSTEM OPERATING SAFETY

NDE/FM

SCOPE

EFFECTIVENESS, RELIABILITY AND ADEQUACY OF INSERVICE INSPECTION

I PRIMARY PIPING SYSTEM

- SERVICE INDUCED DEFECTS (CRACKS)

II PRESSURE VESSEL

- NEAR SURFACE CRACK DETECTION
- ISI RELIABILITY STUDIES, PISC, PVRC, ETC

EARLY WORK

PARAMETRIC STUDIES - PHASE 1 REPORT, NUREG/CR-1696, RECOMMENDATIONS FOR PIPING (1980)

- CALIBRATION SENSITIVITY
  - RECORDING LEVEL LOWERED FROM 50% TO 20% DAC
  - REPORTING LEVEL LOWERED FROM 100% TO 50% DAC
  - SEMICIRCULAR NOTCH (a/ℓ ASPECT RATIO OF 0.5) OF DEPTH ALLOWED BY IWB-3514-2 AND -3
- INSPECTION ANGLE
  - 45° SHEAR AND 60° SHEAR
- SIZING
  - NOTHING WORKS UNIVERSALLY AND RELIABLY
- SCAN OVERLAP
  - ~~NOT~~ GREATER THAN THAT WHICH IS REQUIRED TO PROVIDE A RECORDABLE SIGNAL FROM A SEMICIRCULAR NOTCH ($a/\ell = 0.5$) ON TWO ADJACENT SCANS
- SEARCH UNIT SIZE
  - LIMIT SIZE AS A FUNCTION OF PIPE WALL THICKNESS
- AUSTENITIC AND DISSIMILAR METAL WELD INSPECTION
  - QUALIFICATION OF PROCEDURES, EQUIPMENT AND PERSONNEL
- CODE CASE N-335

NDE/FM
PIPING ROUND ROBIN

OBJECTIVE

1. MEASURE LEVEL OF CURRENT INSPECTION RELIABILITY
2. DETERMINE SOURCE AND MAGNITUDE OF INSPECTION ERRORS
3. PROVIDE INFORMATION FOR INSPECTION RELIABILITY MODEL

NDE/FM
PIPING ROUND ROBIN

MATERIALS

1. 10 INCH SCHEDULE 80S 304 SS (THERMAL FATIGUE FLAWS)

2. 10 INCH SCHEDULE 80 304 SS (IGSCC)

3. CENTRIFUGALLY CAST SS 32 INCH OD, 2 3/8 WALL

4. A106 CS 33 1/4 INCH OD, 2 3/8 WALL, SS CLAD ON ID

ROUND ROBIN TEST MATRIX

ULTRASONIC TESTING PROCEDURE	PIPE TEST MATERIAL	INSPECTION CONDITIONS (ENVIRONMENT)			
		LABORATORY		DIFFICULT	
		NEAR ACCESS	FAR ACCESS	NEAR ACCESS	FAR ACCESS
FIELD / IMPROVED	10-INCH STAINLESS STEEL (SS) FATIGUE	12	12	25 / 16	12
	10-INCH SS WITH IGSCC	12		25 / 16	12
	32-INCH CENTRIFUGALLY CAST SS	3		25 / 16	12
	33.5 INCH CARBON STEEL + SS CLADDING	3		25 / 16	12


B 616
B 617
B 618
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B 621
B-519
B-520
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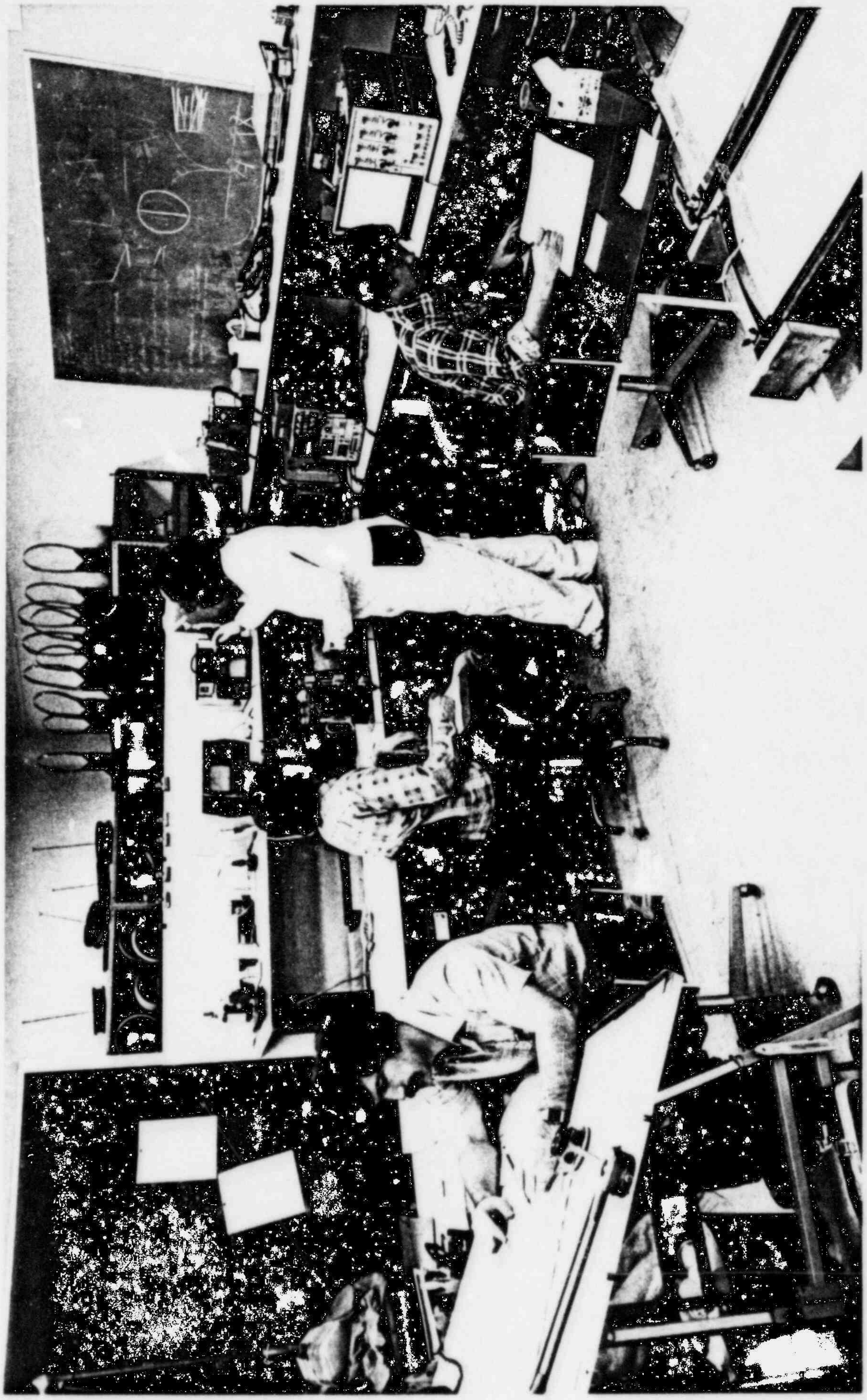
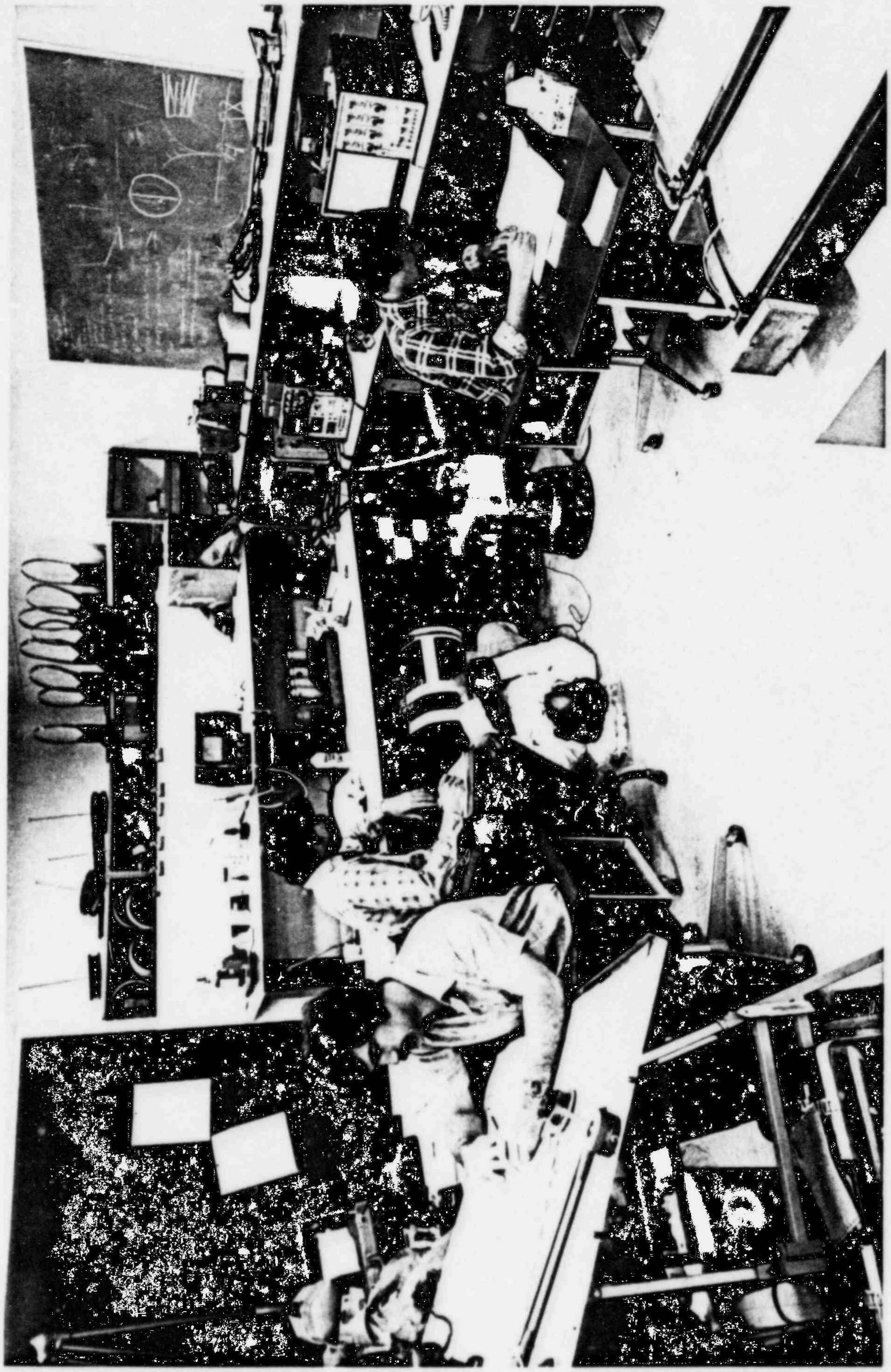
B-528



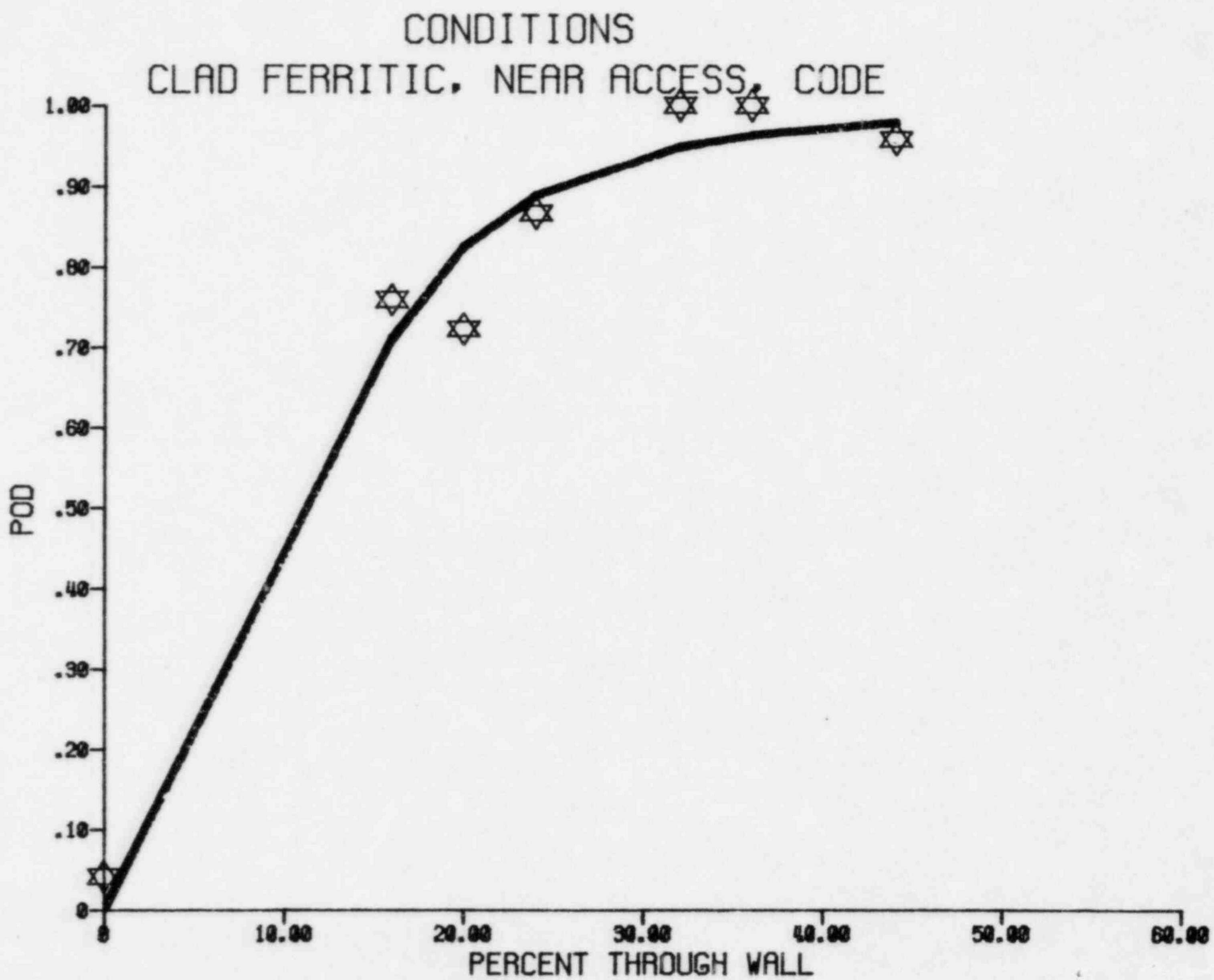


SUMMARY OF ISI TEAM MEMBER's QUALIFICATIONS

TEAM MEMBER CLASSIFICATION	AVERAGE EXPERIENCE IN UT - YEARS	AVERAGE NUMBER OF PSIs AND ISIs
ASNT LEVEL III	10.2 (4-23)	28 (7-62)
ASNT LEVEL II	7.4 (2.5-13)	16.7 (2-57)
ASNT LEVEL I	1.1 (0.5-2.5)	2 (0-5)

RECORDING PROBABILITY (RP) IS THE PROBABILITY THAT THE SIGNAL FROM A DEFECT WILL EXCEED THE RECORDING THRESHOLD

PROBABILITY OF DETECTION (POD) IS THE PROBABILITY THAT A SIGNAL WILL BE RECORDED AND CORRECTLY INTERPRETED AS A DEFECT



CONDITIONS
CLAD FERRITIC, NEAR ACCESS, CODE
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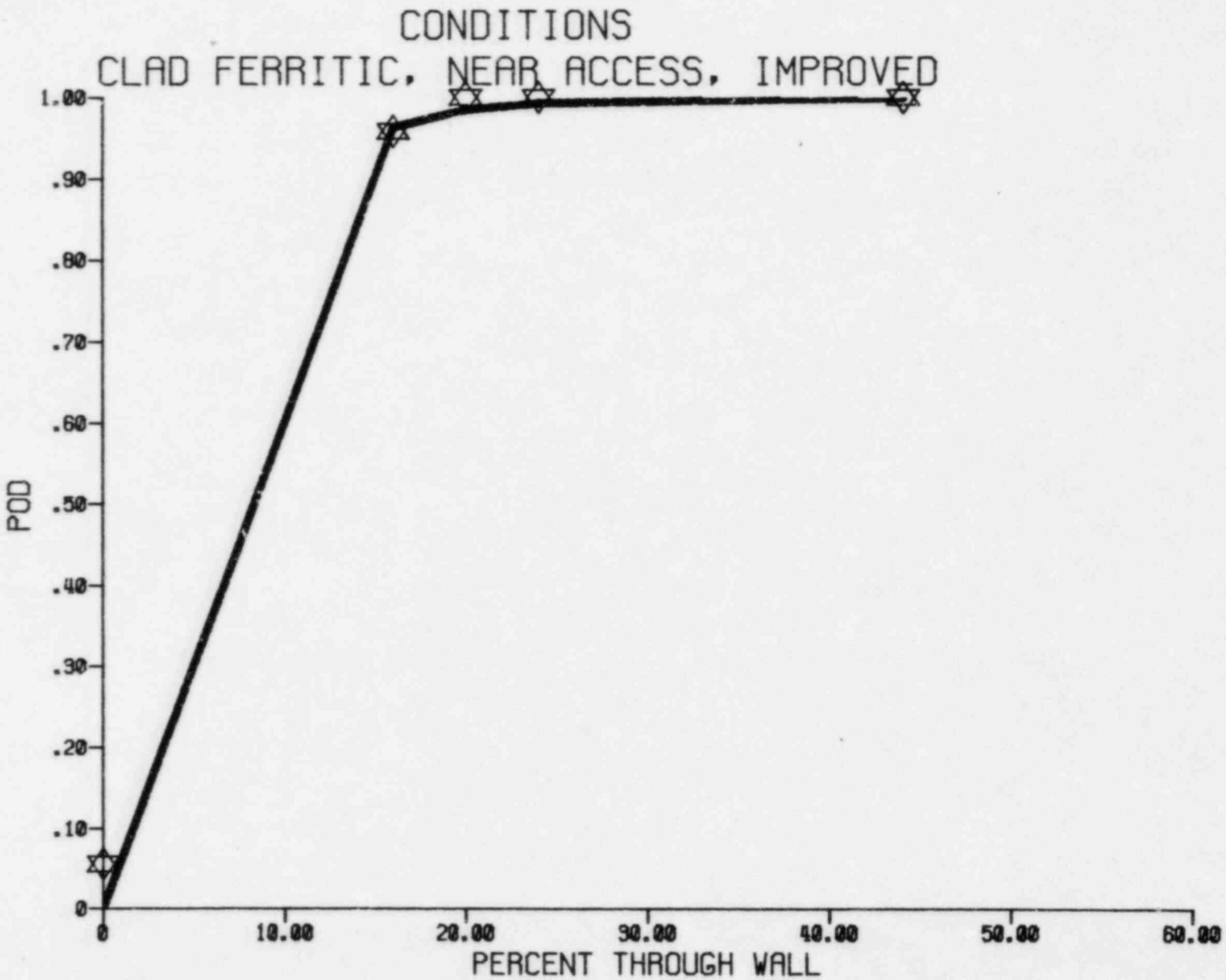
.90
.80
.70
.60
.50
.40
.30
.20
.10
0
POD
0
10.00
20.00
30.00
40.00
50.00
60.00
PERCENT THROUGH WALL



CONDITIONS
CLAD FERRITIC, NEAR ACCESS, IMPROVED
POD
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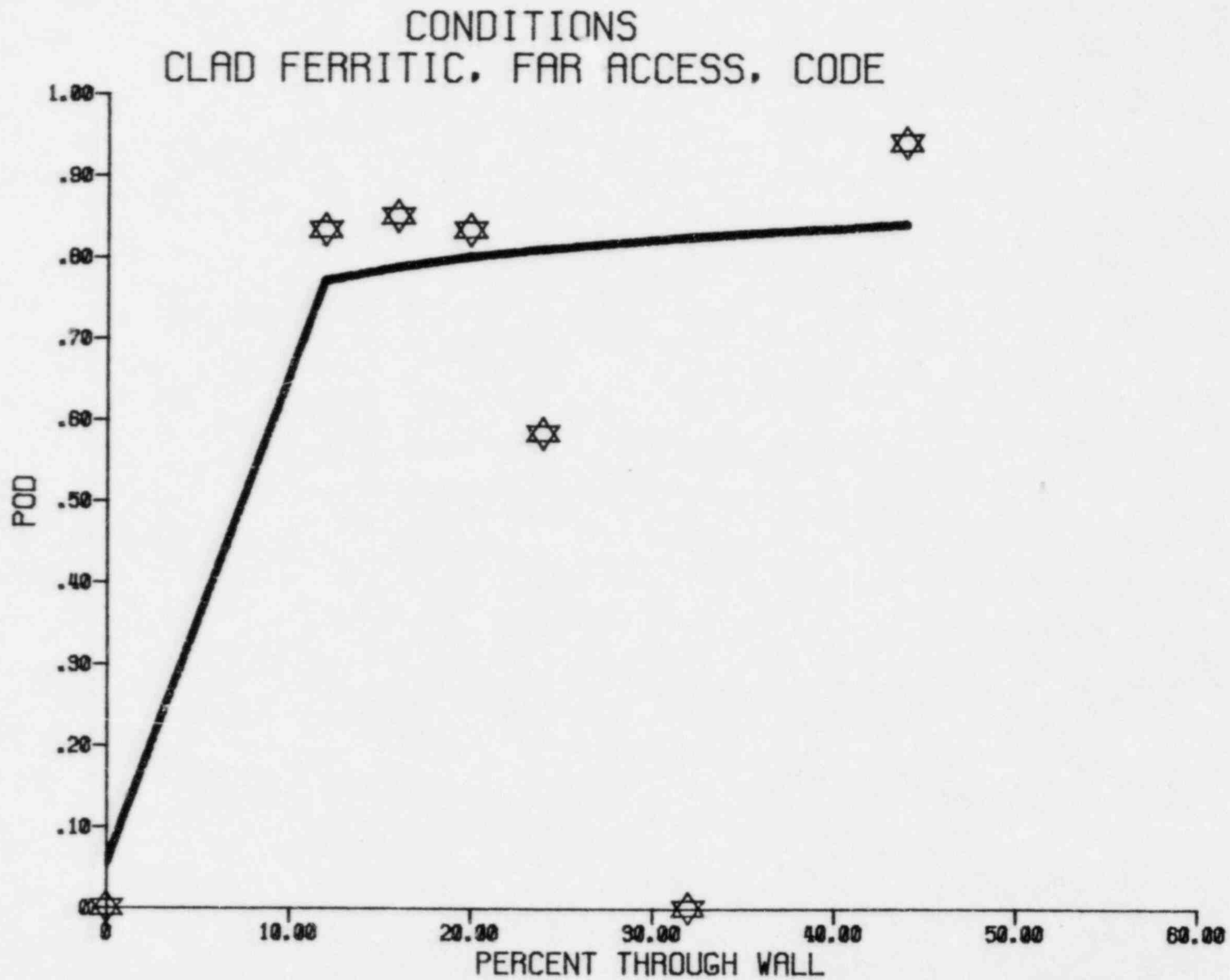
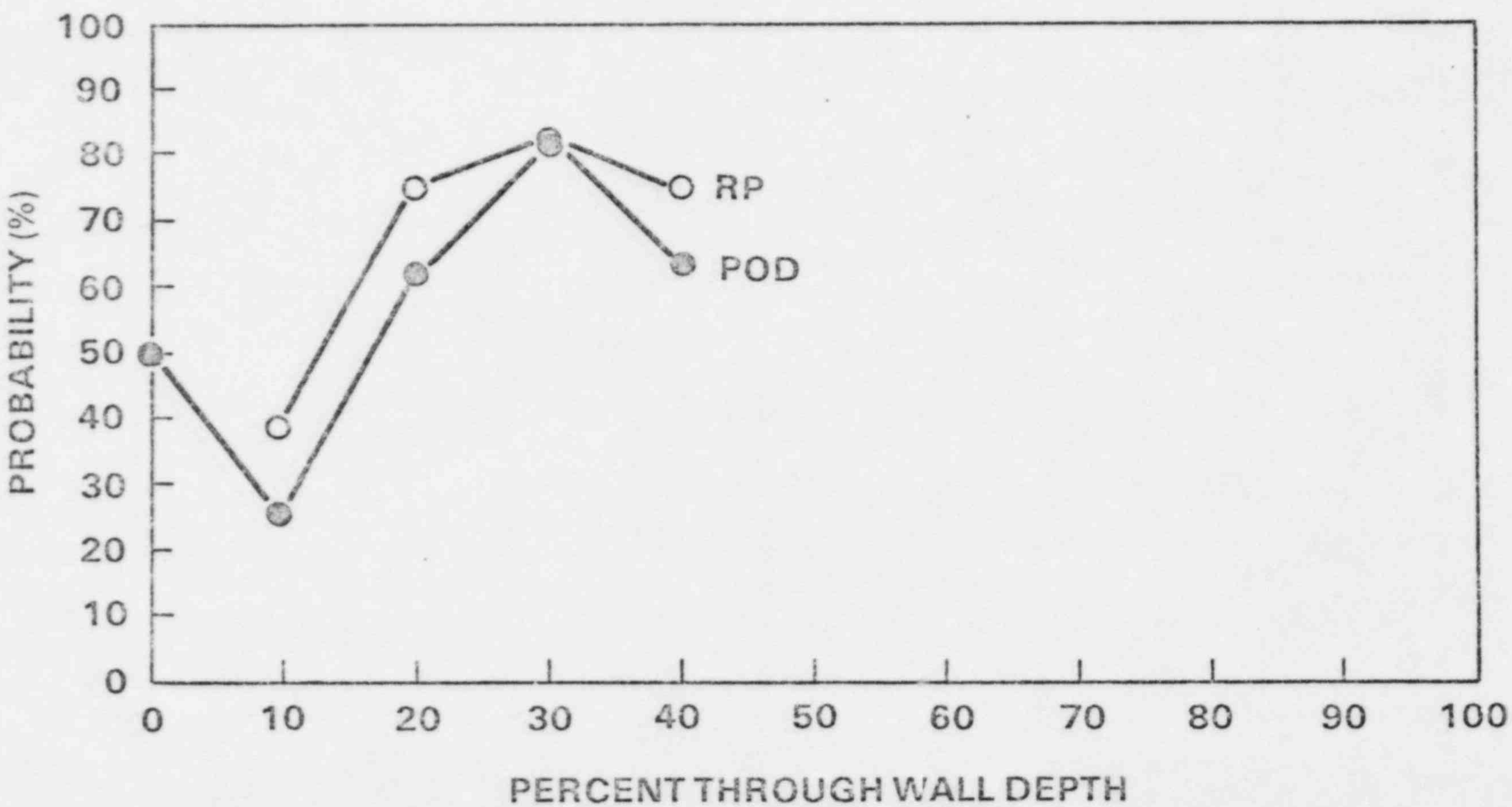
.80
.70
.60
.50
.40
.30
.20
.10
0
0
10.00
20.00
30.00
40.00
50.00
60.00
PERCENT THROUGH WALL



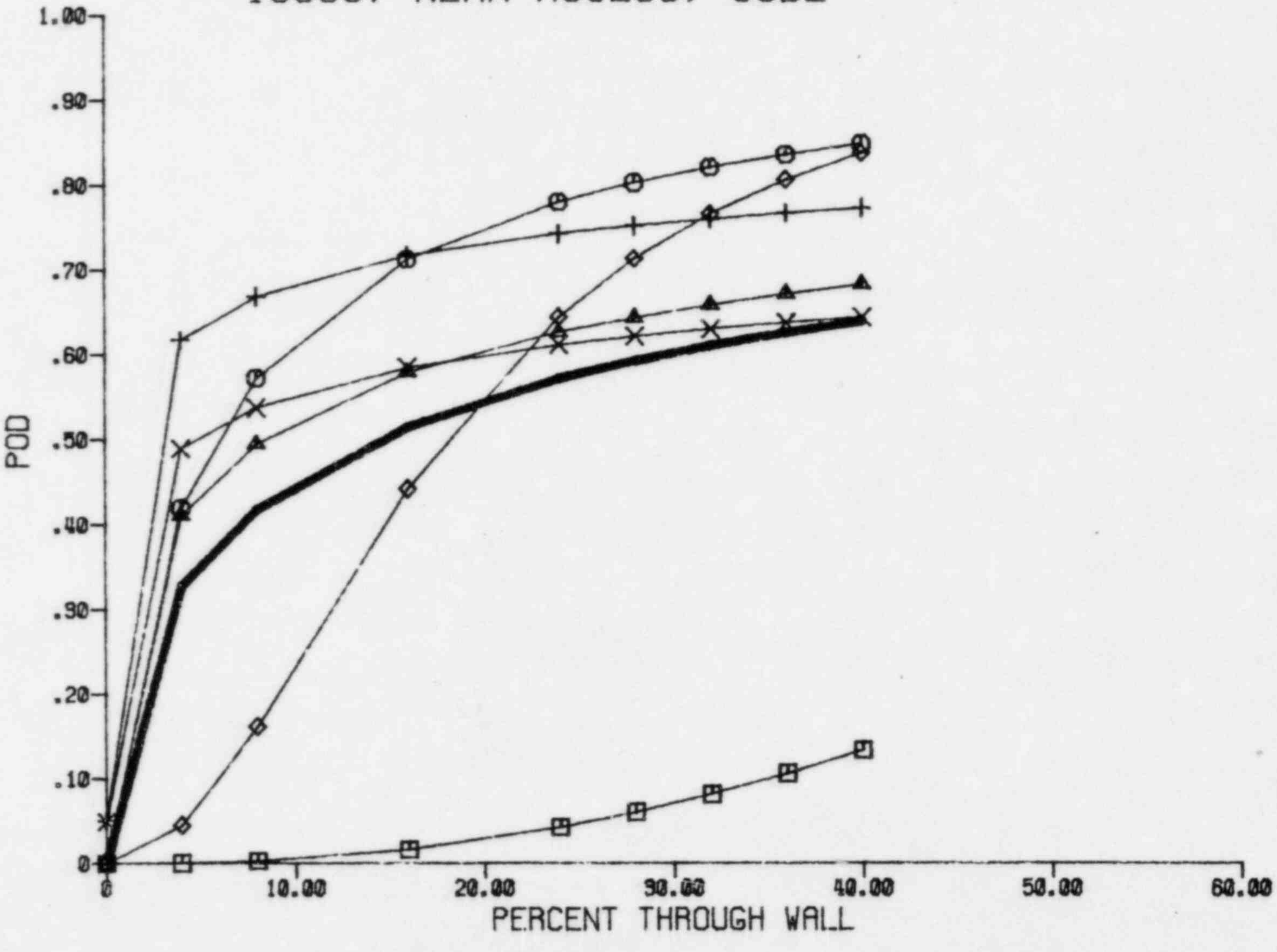
CONDITIONS
CLAD FERRITIC, FAR ACCESS, CODE
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
POD
0
10.00
20.00
30.00
40.00
50.00
60.00
PERCENT THROUGH WALL

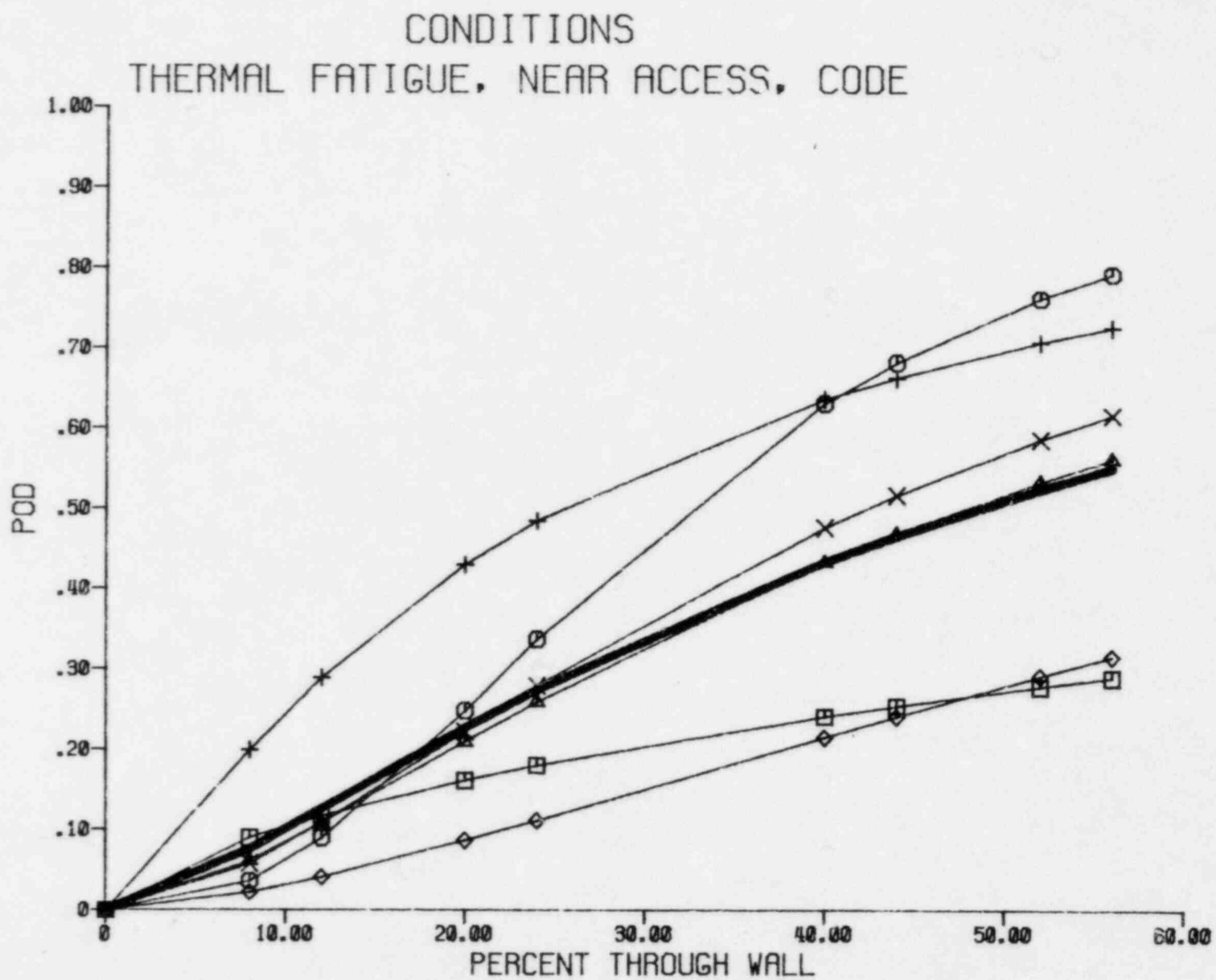
33 IN. OD 2.375 WALL CAST STAINLESS

ONE TEAM



CONDITIONS
IGSCC, NEAR ACCESS, CODE

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.80
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.60
.50
.40
.30
.20
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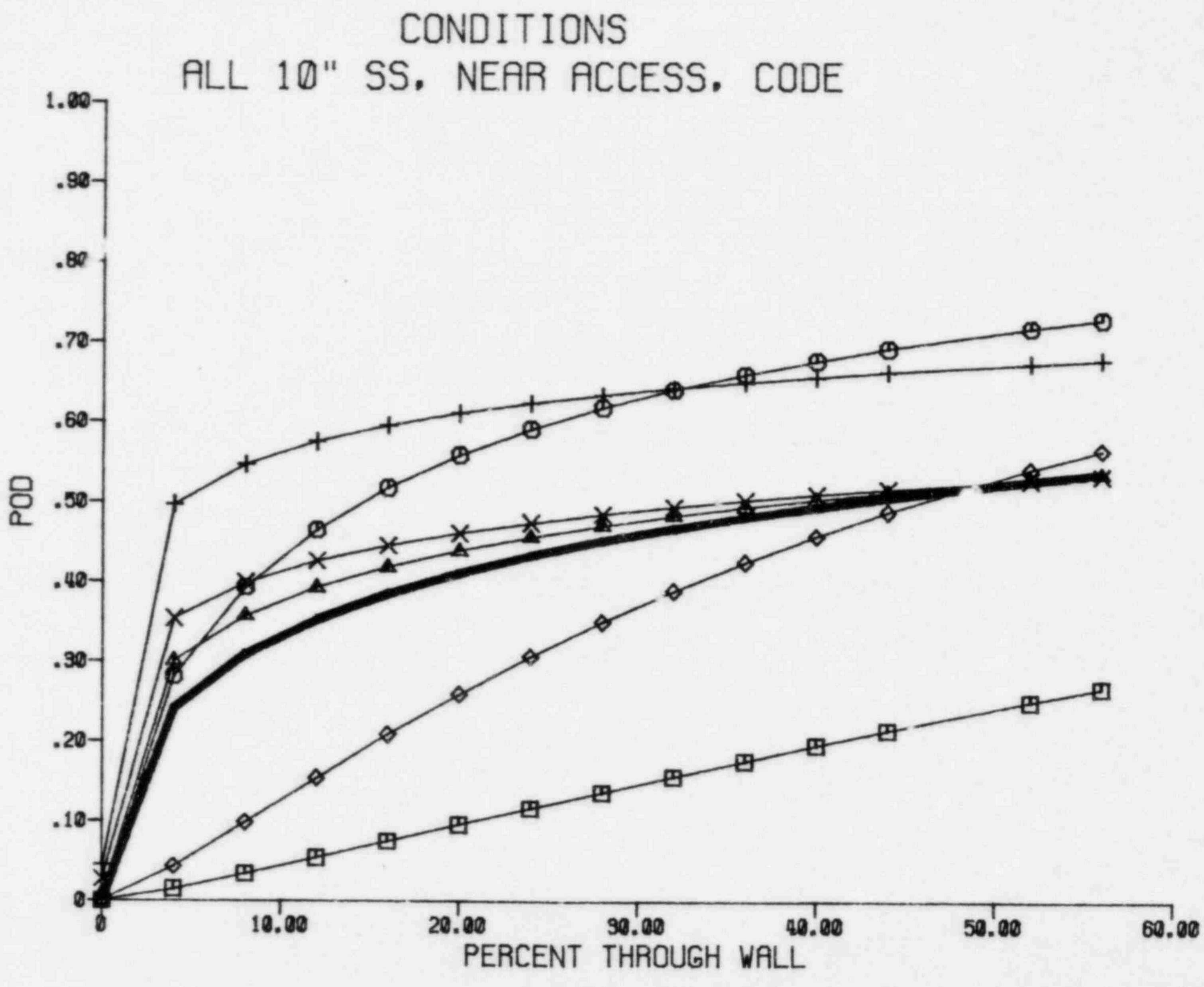
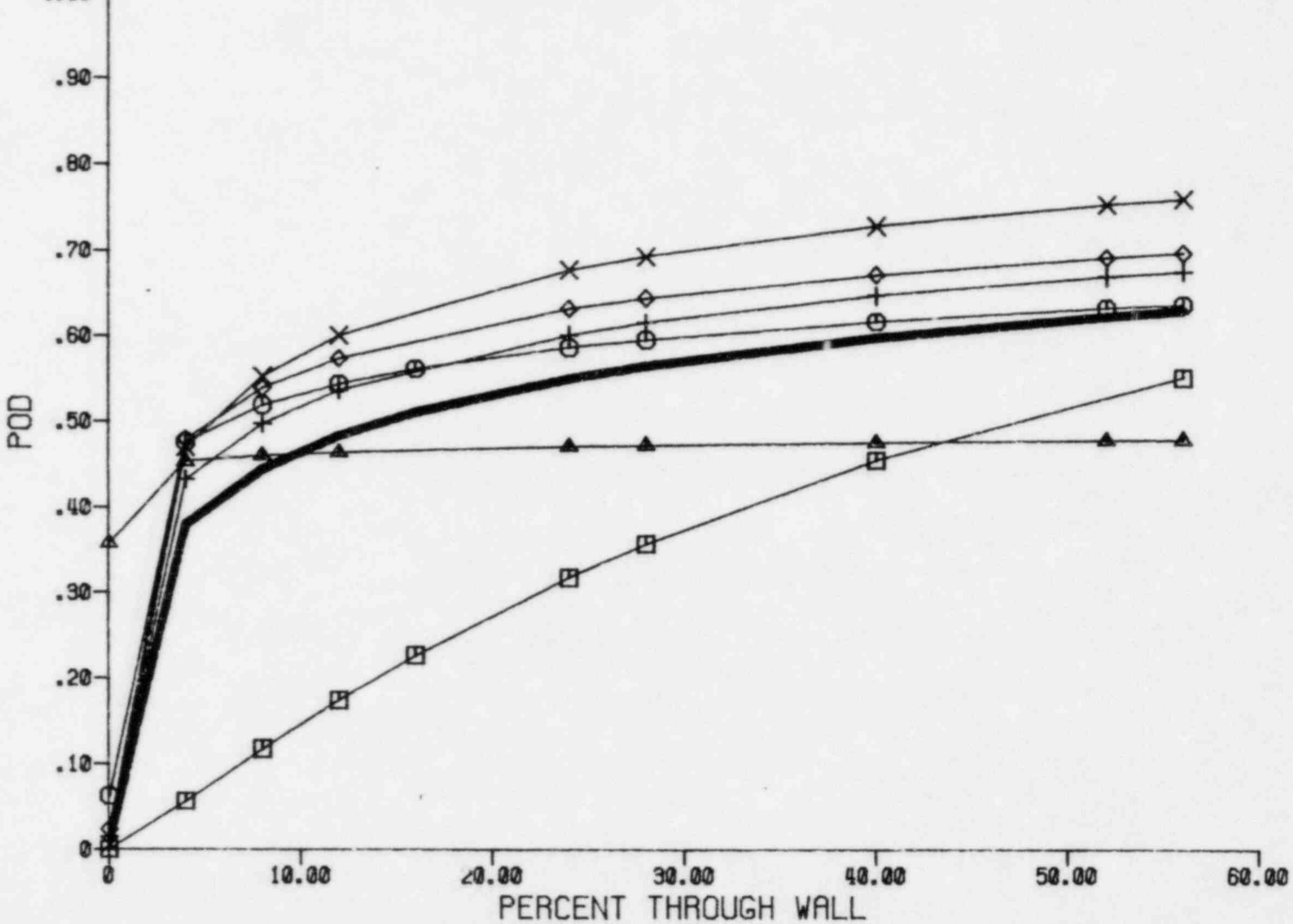
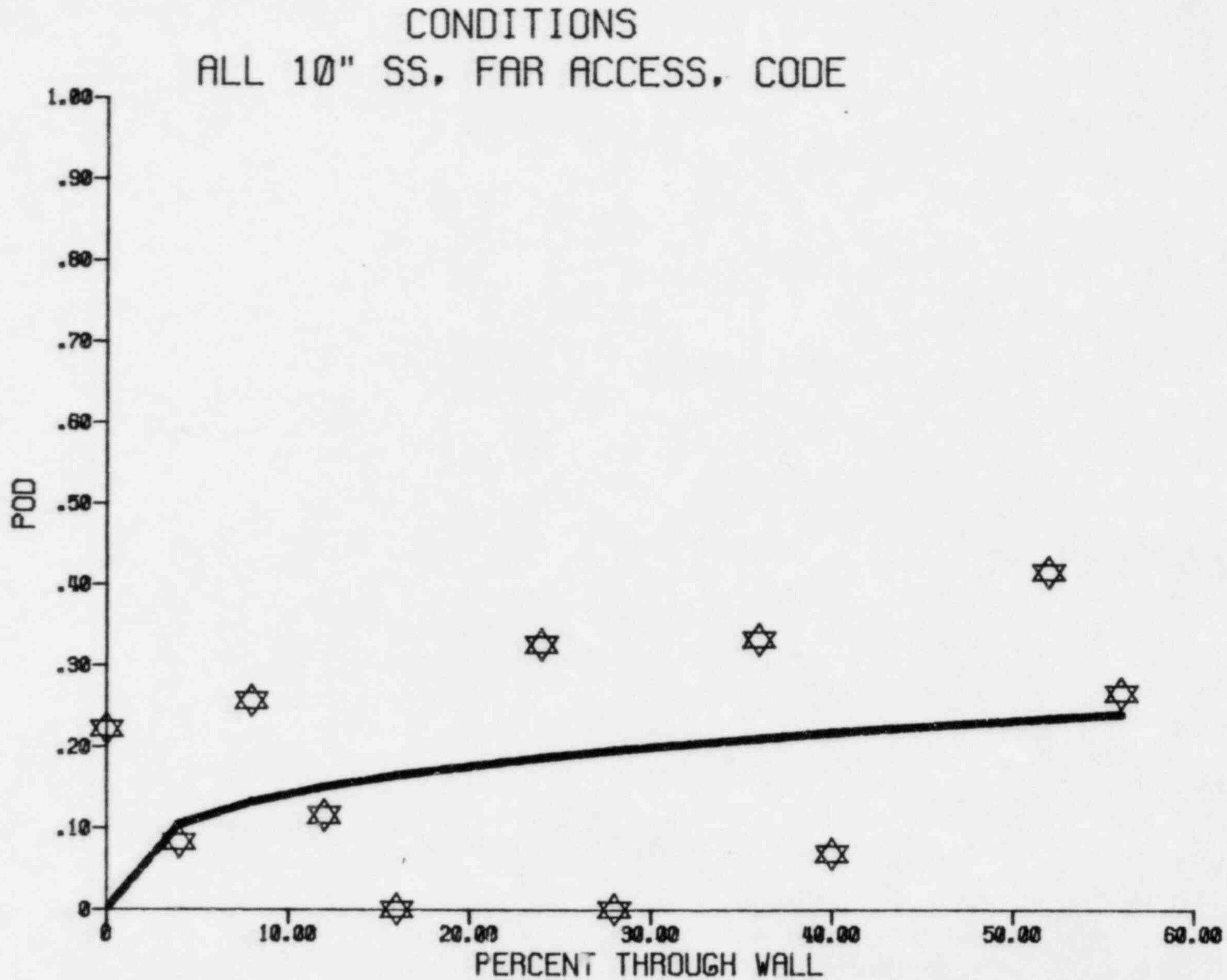
0
0
10.00
20.00
30.00
40.00
50.00
60.00
PERCENT THROUGH WALL


CONDITIONS
ALL 10" SS, NEAR ACCESS, CODE
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
0
POD
0
10.00
20.00
30.00
40.00
50.00
60.00
PERCENT THROUGH WALL

CONDITIONS
ALL 10" SS, NEAR ACCESS, IMPROVED




CONDITIONS
ALL 10" SS, FAR ACCESS, CODE
1.00
.90
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.30
.20
.10
0
POD
0
10.00
20.00
30.00
40.00
50.00
60.00
PERCENT THROUGH WALL

NINE MILE POINT

- BASED ON PIPING ROUND ROBIN RESULTS THE PROCEDURE USED AT NINE MILE POINT DID NOT APPEAR TO BE OPTIMIZED FOR DETECTION OF IGSCC
- PIPING ROUND ROBIN RESULTS AND NMP DEMONSTRATES THE NEED FOR QUALIFICATION OF PERSONNEL, EQUIPMENT AND PROCEDURES
- IEB 82-03 AND NRC-EPRI-BCL DEMONSTRATION A SIGNIFICANT THRUST IN THE RIGHT DIRECTION

CONCLUSIONS OF PIPING ROUND ROBIN

- CLAD FERRITIC
  - HIGHLY EFFECTIVE WITH INCREASED INSPECTION SENSITIVITY
  - EQUALLY EFFECTIVE INSPECTION FROM NEAR AND FAR SIDE
- CCSS
  - CONSIDERED UNINSPECTABLE
- STAINLESS STEEL
  - CURRENT US ISI PRACTICE IS INEFFECTIVE FOR FAR SIDE INSPECTION
  - IMPROVED PROCEDURE SHOWS MODEST IMPROVEMENT
  - NEAR SIDE INSPECTIONS PERFORMED TO CODE WILL MISS CODE REJECTABLE DEFECTS
- LARGE PERFORMANCE VARIATION IN CURRENT ISI FIELD PRACTICE RESULTS FROM VARIABILITY IN PERSONNEL, PROCEDURES AND EQUIPMENT

[illegible] - HERE IS TO ASSURE, TO THE EXTENT PRACTICAL, THAT AC[illegible] WELD DEFECTS OF CONCERN WILL BE (OR WERE) DET[illegible] CHARACTERIZED AS NECESSARY WITH THE REQUIRED REL[illegible]

PERFORMANCE CAPABILITY TEST RESULTS

- 11 LICENSEE/ISI VENDOR TEST GROUPS
- 9 GROUPS OF INITIAL MATRIX COMPLETED WITH A 9/4 RATING
- STILL ONGOING PROGRAM AT BCL
- RESULTS TO DATE INFER A NEED FOR AN ESTABLISHED TRAINING-QUALIFICATION PROGRAM TO SUPPORT ISI EFFORTS OVER THE LONG TERM.

T4
Collins

MILLSTONE I

System	U.T. EXAMINED
RECIRCULATION	12
LPCI	3
RWCU	3
ISOLATION COND.	7
OTHER	2

• IGSCC IDENTIFIED IN ONE(1) ISOLATION CONDENSER SYSTEM WELD - OUTSIDE CONTAINMENT

QUAD CITIES I

SYSTEM	TOTAL WELDS	TOTAL EXAMINED
28" RECIRC SUCTION & DISCH.	32	3
22" RECIRC RING HEADER	22	2
12" RECIRC RISERS	42	4
16" RHR	30	3
20" RHR	16	3

NO APPARENT INDICATIONS REPORTED

HATCH 1

- UT INSPECTION IN PROGRESS

- ORIGINAL INSPECTION SAMPLE
  19 RECIRC SYSTEM WELDS
  11 RHR SYSTEM WELDS.

  – LINEAR INDICATIONS (IGSCC ?) FOUND IN THE FOLLOWING:

  (1) 20" EL TO PIPE WELD - RHR
  (1) 28" " " " - RC
  (4) 22" MANIFOLD CAP WELDS - RC
  (1) 22" BRANCH CONNECTION (SADDLE TYPE) - RC

- UT INSPECTED 19 ADDITIONAL WELDS WITH FAVORABLE RESULTS

- LICENSEE CONTINUING TO EVALUATE PROBLEM.

SUMMARY RESULTS OF PLANT SPECIFIC INSPECTIONS TO DATE

NMP 1

All 5 RECIRC LOOPS, EXCEPT VALVES & PUMPS, BEING REPLACED DUE TO IGSCC

REPLACEMENT MAT'L IS TYPE 316 NG S.S. MATERIAL

MONTICELLO

- 100% OF RECIRC. SYSTEM PIPING WELDS U.T. INSPECTED

  - (1) 22" RECIRC HEADER WELD (END CAP TO PIPE) REQ'D REPAIR DUE TO IGSCC

  - (5) 12" RECIRC RISER PIPE WELDS (ELBOW TO PIPE) REQ'D REPAIR

- REPAIR CONSISTED OF OVERLAY WELD APPROACH
- RECIRC RISERS & END CAP SCHEDULED TO BE REPLACED NEXT REFUELING.

INTRODUCTORY COMMENTS AND INSTRUCTIONS

PRESENTED BY KAVIN WARD

10-8-82

1. USE YOUR PROCEDURE AND PERFORM JUST LIKE A PRODUCTION WELD. NRC WISHES COPY OF PROCEDURE.

2. LEVELS I AND II PERFORM THE EXAMINATION.

3. EXAMINE ALL FIVE (5) WELDS.

4. PLOT OUT ANY INDICATIONS.

5. THE NRC WANTS A COPY OF ALL RAW DATA BEFORE YOU LEAVE AND THEN THE FINAL DATA.

6. NRC WILL GIVE THE LICENSEE THE RESULTS AS SOON AS THE FINAL DATA IS SUBMITTED.

7. COMPLETE GRID WITH CRACK (C)/NO CRACK (N) DESIGNATIONS.

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TECHNICAL KNOWHOW DEDICATED FACILITIES

EPRI-NDE CENTER'S ROLE

- ESTABLISHED SAMPLE AVAILABILITY
- SAMPLE CHARACTERIZATION - SHORT LEAD TIME
- ESTABLISHED CHANNELS & INTERFACE FOR PERFORMANCE CAPABILITY TESTING
  - UTILITIES
  - NRC STAFF
  - ISI VENDORS
- MAINTAINED OBJECTIVITY THROUGHOUT PERFORMANCE CAPABILITY TESTS

EPRI STAFF'S ROLE IS COMMENDABLE!

PLANTS COVERED BY IEB 82-03

	SHUTDOWN	STARTUP	ISI ORG.
• MONTICELLO	NOW	?	LMT
• HATCH 1	NOW	?	SOUTH-SERV/LMT
• MILLSTONE	NOW	12-82	EBASCO/NUSCO
• QUAD CITIES	NOW	12-82	CECO/LIST
• BRUNSWICK 1	11-1-82[1]	5-83	LMT/SWRI
• DRESDEN 2	1-83	2-83	CECO
• OYSTER CRK	1-83	12-83	MAGNAFLUX/GPU
• DUANE ARNOLD	1-83	2-83	LMT
• BROWNS FERRY 2	NOW	1-82	LMT/TVA

1) ISI SCHEDULE SLIPPED to JANUARY

2) NMP 1 - BEING REPAIRED

3) 10 ISI ORGANIZATIONS INVOLVED

- SECOND PIPE CRACK STUDY GROUP
  - NUREG 0531 (1979)
  - STUDY CONCURRED WITH PREVIOUS PCSG FINDINGS AND CITED "THERE IS LITTLE EVIDENCE TO INDICATE IGSCC WILL NOT OCCUR TO SOME DEGREE IN LARGE DIAMETER BWR STAINLESS STEEL PIPING IN THE U.S."

- NUREG 0313 REV. 1 (JULY 1980)
  - RESOLUTION OF GENERIC TECHNICAL ACTIVITY A-42
    - GUIDELINES FOR REDUCING IGSCC
    - DEFINED NONCONFORMING, SERVICE SENSITIVE LINES
    - GUIDELINES FOR AUGMENTED ISI
    - ISI SAMPLING SCHEMES

- NUREG 0313 REV. 1 - IMPLEMENTED BY NRC GENERIC LTR 81-04 TO LICENSEES 2-26-81

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BWR-IGSCC
BRIEF

1965	
1969 - 1970*	
1974 - 1975	FIRST PIPE CRACK STUDY GROUP
1978 - 1979	SECOND PIPE CRACK STUDY GROUP

- FIRST PIPE CRACK STUDY GROUP
  - NUREG 75/067 (1975)
  - TYPES 304 AND 316 STAINLESS STEEL PIPING IN THE RCPB OF BWR'S IS SUSCEPTIBLE TO STRESS CORROSION WHICH MAY CAUSE CRACKS SIMILAR TO THOSE DISCOVERED IN THE BY-PASS LINES AND C.S. PIPING

* NINE MILE POINT CORE SPRAY EVENT

PIPING INSPECTION

AND

NEAR SURFACE NDE

ACRS METAL COMPONENTS SUBCOMMITTEE

DECEMBER 2, 1982

S. R. DOCTOR (PNL)

T5, 1

INTEGRATION OF NDE RELIABILITY AND FRACTURE MECHANICS (NDE/FM)

PACIFIC NORTHWEST LABORATORY (PNL)
OPERATED BY BATTELLE MEMORIAL INSTITUTE

PROGRAM MANAGER: S.R. DOCTOR

PRINCIPAL INVESTIGATORS: S.H. BUSH, G.P. SELBY,
F.A. SIMONEN, T.T. TAYLOR

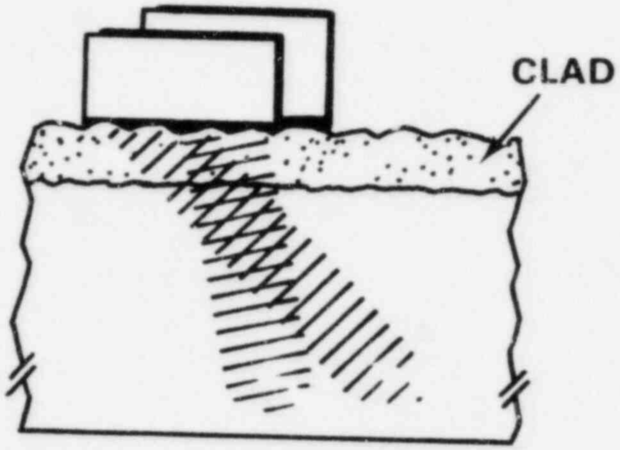
NRC RES/RSR PROGRAM MANAGER:
DR. JOE MUSCARA

NEAR SURFACE CRACK DETECTION

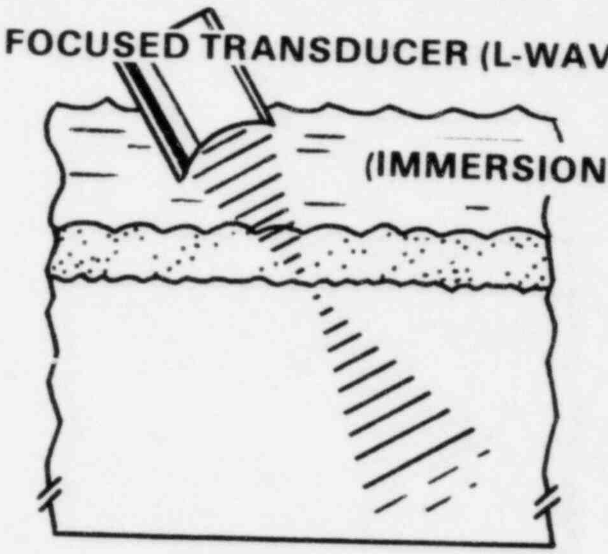
- IT IS IMPORTANT TO DETECT SMALL NEAR SURFACE FLAWS BECAUSE OF THEIR POTENTIAL ADVERSE EFFECT ON VESSEL INTEGRITY DURING A PRESSURIZED THERMAL SHOCK EVENT.
- FIELD PROCEDURES GATE OUT THE NEAR SURFACE REGION.
- ASME CODE PROCEDURES ARE NOT SENSITIVE TO NEAR SURFACE DEFECTS.
- REGULATORY GUIDE 1.150 TRIED TO ADDRESS THIS PROBLEM BUT DID NOT SOLVE IT.
- BECAUSE OF UNDERCLAD CRACKING IN EUROPEAN VESSELS, TECHNIQUES WERE DEVELOPED TO RELIABLY DETECT THESE FLAWS.
- PNL WAS DIRECTED BY NRC TO EVALUATE THE AVAILABLE EUROPEAN TECHNIQUES FOR ISI OF U.S. PRESSURE VESSELS.

NEAR SURFACE INSPECTION TECHNIQUES

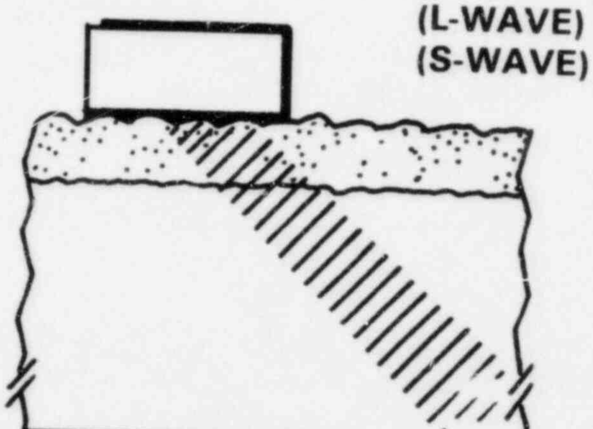
DUAL TRANSDUCER (L-WAVE)



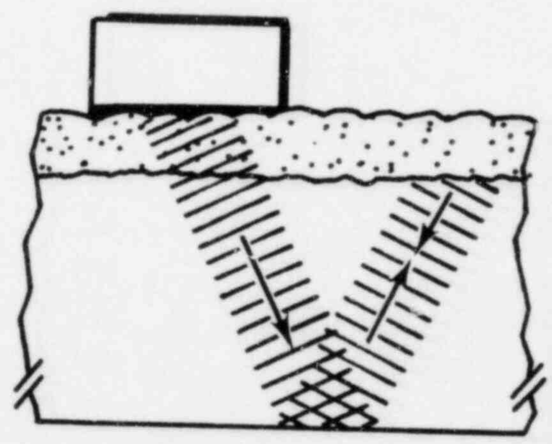
FOCUSED TRANSDUCER (L-WAVE)



SINGLE TRANSDUCER



FULL VEE (S-WAVE)



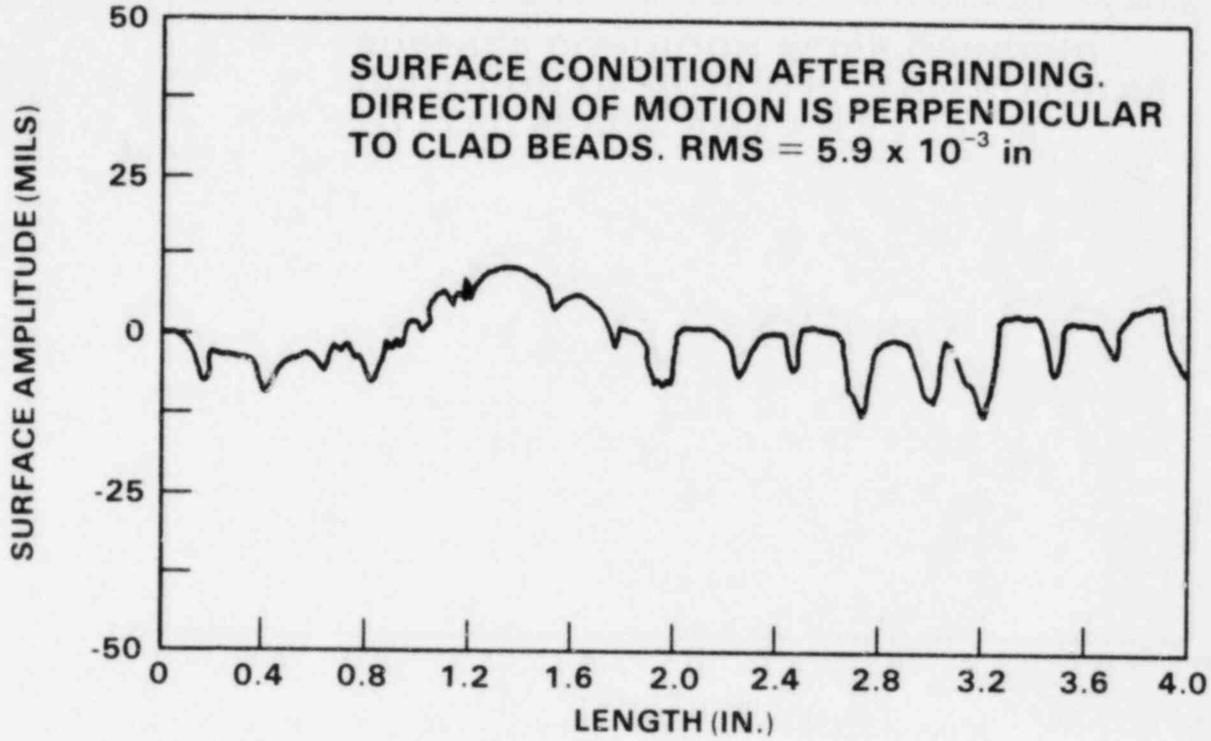
SURFACE ROUGHNESS

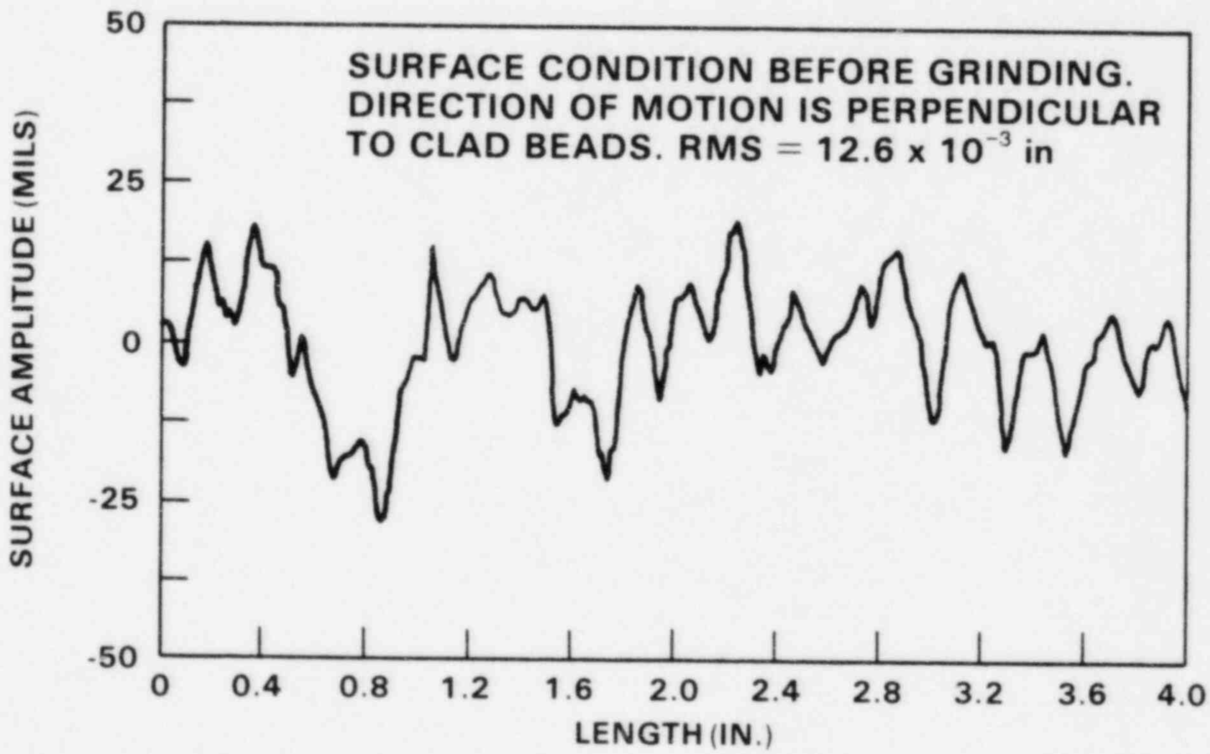
- IMPEDES INSPECTION

- EVALUATING IN-FIELD MEASUREMENT TECHNIQUES
  - LVDT
  - ULTRASONIC
  - EDDY CURRENT

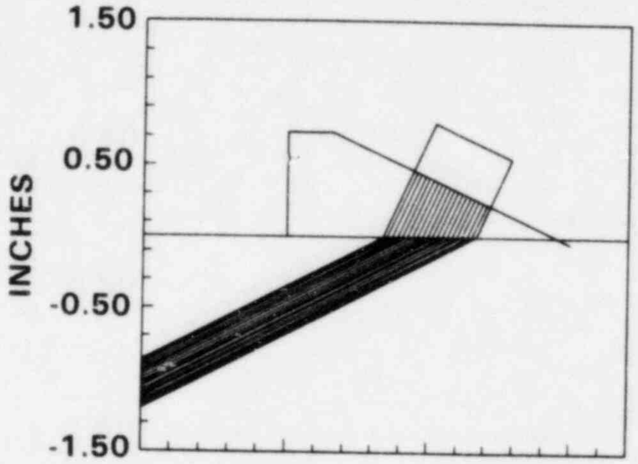
- CALIBRATION MUST BE PERFORMED ON A BLOCK WITH THE SAME SURFACE ROUGHNESS AS IS FOUND ON THE VESSEL AREAS TO BE INSPECTED

CLAD SURFACE PROFILE

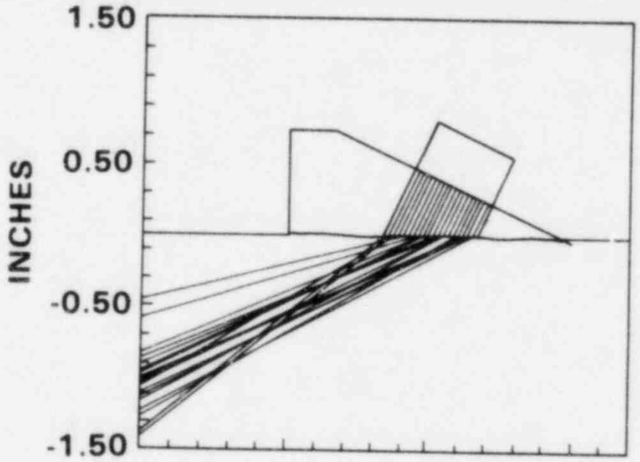




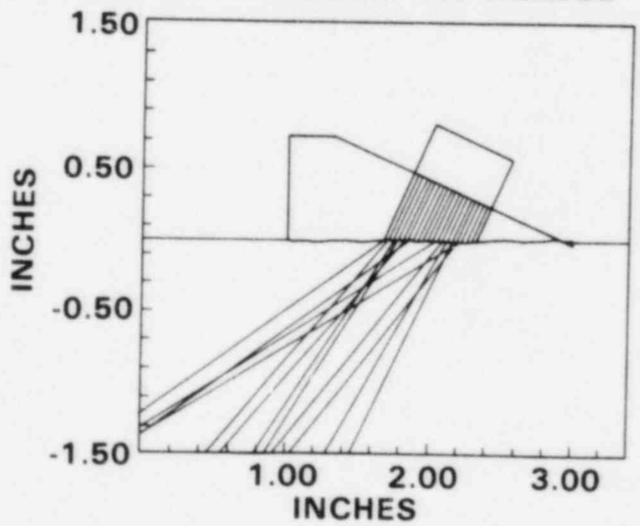
BEAM REFRACTION THROUGH IDEAL SURFACE



BEAM REFRACTION THROUGH HAND GROUND SURFACE



BEAM REFRACTION THROUGH "AS WELDED" SURFACE



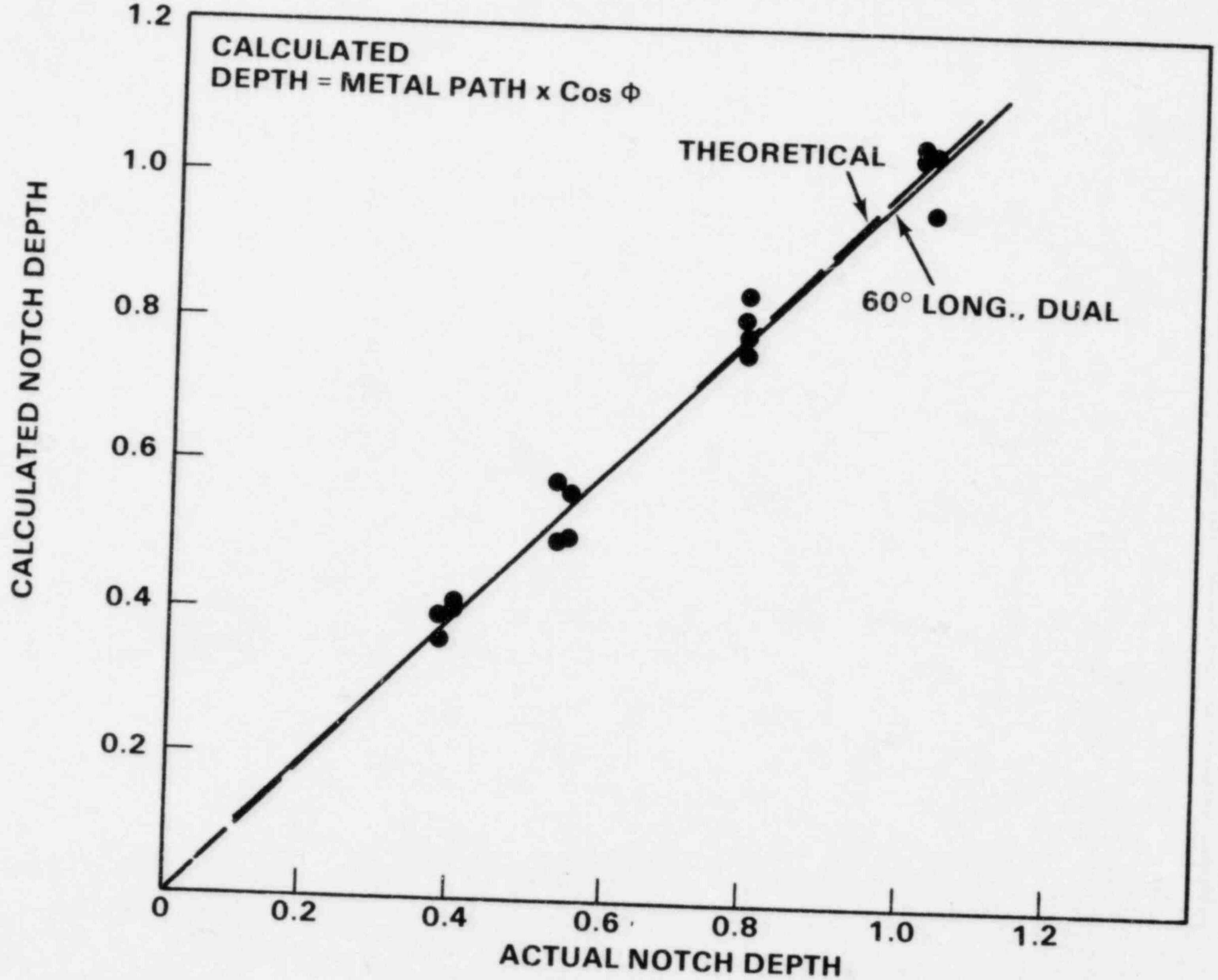
MATRIX 1
CRACK DETECTION PERFORMANCE
AS CLAD SMAW

	70° SHEAR SINGLE	60° SHEAR SINGLE	70° LONGITUDINAL DUAL
NUMBER OF CRACKS NOT DETECTED	24	24	0
NUMBER OF CRACKS DETECTED	0	0	24
AVERAGE AMPLITUDE OF DETECTED CRACKS (RELATED TO DAC)	—	—	+1.1 dB

MATRIX 1
CRACK DETECTION PERFORMANCE
GROUND CLAD

	70° SHEAR SINGLE	60° SHEAR SINGLE	45° LONG. DUAL	60° LONG. DUAL	70° LONG. DUAL
NUMBER OF CRACKS NOT DETECTED	7	6	0	0	0
NUMBER OF CRACKS DETECTED	17	18	24	24	24
AVERAGE AMPLITUDE OF DETECTED CRACKS (RELATIVE TO DAC)	-5.8 dB	-8.5 dB	-7.7 dB	+1.2 dB	+2.7 dB

CALCULATED DEPTH VS ACTUAL NOTCH DEPTH



CONCLUSIONS FOR NEAR SURFACE CRACK DETECTION

- EUROPEAN TECHNIQUE WORKS VERY WELL FOR GROUND SURFACES AND UNGROUND STRIP AND MULTIPLE WIRE
- FOR UNGROUND MANUAL AND SINGLE WIRE CLAD, THE EUROPEAN TECHNIQUE IS MARGINAL
- ONLY MINOR SURFACE PREPARATION REQUIRED FOR DRASTIC IMPROVEMENTS IN INSPECTABILITY
- ALL CLAD VESSEL SURFACES MUST BE CHARACTERIZED BEFORE INSPECTION TO ENSURE ADEQUATE EXAMINATION SENSITIVITY
- NEED TO SPECIFY CALIBRATION REFLECTOR CRITERIA AND FLAW RECORDING LEVELS
- NEAR SURFACE INSPECTION TECHNIQUES SHOULD BE QUALIFIED BY TEST

REGULATORY GUIDE 1.150

- CURRENT GUIDE IS NOT ADEQUATE
  - IMPLEMENTATION OF GUIDE WOULD NOT NECESSARILY CHANGE CURRENT INSPECTION PRACTICE
  - CONTAINS TECHNICAL REQUIREMENTS FOR INSTRUMENT CHARACTERIZATION THAT ARE NOT PRACTICAL FOR FIELD WORK AND DO NOT PROVIDE ADEQUATE INSTRUMENT CHARACTERIZATION

AD HOC COMMITTEE RECOMMENDED CHANGES TO REGULATORY GUIDE 1.150

- CHANGES ARE NECESSARY
- CHANGES PROVIDE A TECHNICALLY BETTER DOCUMENT
- CHANGES SHOULD BE INCORPORATED INTO REGULATORY GUIDE 1.150

T8

~~RECOMMENDATIONS~~ AREAS FOR FURTHER IMPROVEMENT TO REGULATORY GUIDE 1.150

- NEITHER DOCUMENT (GUIDE OR AD HOC REPORT) SPECIFIES THE MINIMUM SIZE OF DEFECT TO BE DETECTED AT THE CLAD/BASE METAL INTERFACE
- STUDIES SHOW THAT AN ASME 2% NOTCH IS NOT AN ADEQUATE REFERENCE REFLECTOR FOR CALIBRATION AT THE CLAD/BASE METAL INTERFACE
- THE NATURE OF PROCEDURE DEMONSTRATION SPECIFIED IN THE AD HOC COMMITTEE REPORT IS NOT DEFINED WELL ENOUGH FOR IMPLEMENTATION

QUALIFICATION

OBJECTIVE:

PROOF OF DETECTION RELIABILITY
BY TEST

SCOPE:

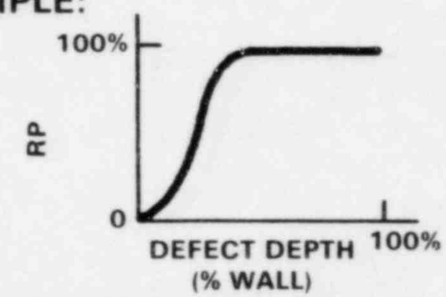
AUSTENITIC PIPING WELDMENTS IN SAFETY
RELATED SYSTEMS AND PRESSURE VESSEL
NEAR SURFACE AND SUBSURFACE EXAMINATION

CRITICAL ELEMENTS OF QUALIFICATION

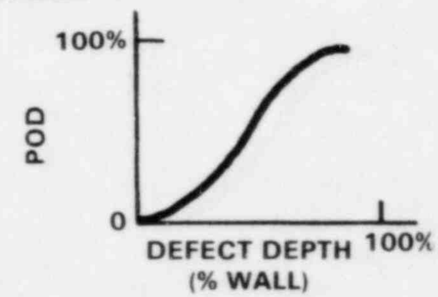
- EQUIPMENT
  - RECORDING PROBABILITY CURVE DETERMINED BY LABORATORY TESTS
- PROCEDURES
  - RECORDING PROBABILITY CURVE DETERMINED BY LABORATORY TESTS
- PERSONNEL
  - PROBABILITY OF DETECTION CURVE DETERMINED BY BLIND TEST

QUALIFICATION

<table>
<tr><th>CRITICAL ELEMENT</th><th>PERFORMANCE PARAMETERS</th><th>ACCEPTANCE CRITERIA</th></tr>
<tr><td>EQUIPMENT</td><td>TRANSDUCERS
PULSERS
RECEIVERS</td><td>ACCEPTABLE IMPACT ON RECORDING PROBABILITY (RP)</td></tr>
<tr><td>PROCEDURE</td><td>RECORDING PROBABILITY (RP)- ABILITY OF EQUIPMENT AND PROCEDURE TO ACHIEVE LARGE dB RESPONSE WITH GOOD SIGNAL TO NOISE RATIO</td><td>MEET OR EXCEED REFERENCE RP CURVE
EXAMPLE:



</td></tr>
<tr><td>PERSONNEL</td><td>PROBABILITY OF DETECTION (POD) - ABILITY TO WORK WITH THE EQUIPMENT AND PROCEDURE TO DETECT DEFECTS AND MAKE CORRECT CALLS WITHOUT HIGH FALSE CALLS</td><td>MEET OR EXCEED REFERENCE POD CURVE
EXAMPLE:



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CONCLUSIONS

- PISC, PIPING ROUND ROBIN AND NMP DEMONSTRATE THE NEED FOR QUALIFICATION OF NDE EQUIPMENT, PROCEDURES AND PERSONNEL
- MEASUREMENT METHODOLOGY AND CHARACTERIZATION TECHNIQUES EXIST FOR QUALIFYING PERFORMANCE PARAMETERS
- SPECIFIC ACCEPTANCE CRITERIA NEED TO BE DEVELOPED FOR QUALIFICATION OF INSPECTIONS