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NUCLEAR REGULATORY COMMISSION

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

SUBCOMMITTEE ON ELECTRICAL POWER SYSTEMS

Room 1130

1717 H Street, N. W.
Nuclear Regultory Commission
Washington, D. C.

Thursday, May 28, 1981

The ACRS Subcommittee on Electrical Power Systems convened, pursuant to notice, at 8:30 a.m. at 8:30 a.m.

ACRS MEMBERS PRESENT:

W. KERR, Chairman
J. EBERSOLE

CONSULTANTS PRESENT:

I. CATTON
W. LIPINSKI
Z. ZUDANS

DESIGNATED FEDERAL EMPLOYEE:

R. SAVIO

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NRC STAFF PRESENT:

A. HAN
Y. HSU
R. FEIT
E. WENZINGER
L. PHILLIPS
G. MILLER
J. ANDERSON
T. HUANG
H. SOLOMON

ALSO PRESENT:

J. LONGO
C. NEUSCHAEFFER
G. MENZEL
A. PURI
W. BURCHILL
J. BURGER
K. RODACK
E. KENNEDY
P. BAILEY
U. ESPOSITO
B. JOHNSON
W. LYMAN
D. GRESHAM

P R O C E E D I N G S

MR. KERR: The meeting will come to order.

This is a meeting of the Advisory Committee on Reactor Safeguards Subcommittee on Electrical Systems. My name is William Kerr. Present at the meeting today is also Mr. Ebersole, another member of the Committee, and as consultants we have Mr. Catton, Mr. Lipinski and Mr. Zudans.

The meeting is being conducted in accordance with the provisions of the Federal Advisory Committee Act and the Government in the Sunshine Act. Dr. Savio is the Designated Federal Employee in the meeting.

Rules for participation in today's meeting have been announced as part of the notice of the meeting published in the Federal Register on May 12, 1981. A transcript of the meeting is being kept and will be made available by June 4, of 1981.

It is requested that each speaker identify himself and use the microphone so that he can be recorded. We have received no written comments or requests for time to make oral statements from members of the public.

The purpose of the meeting is to discuss instrumentation for the detection of inadequate core cooling. In the course of the meeting today we hope to learn more about the present status of the requirements for such instrumentation and the schedule for its installation, something about the priority that is being assigned to this requirement in the context of the other post-TMI requirements.

It would be helpful if the staff could at least comment on the way in which they reached the reliability requirements for the systems, and we hope to get current details of the systems as they are being proposed, the availability of the systems, and any problems that may be associated with their procurement and installation. In short, this is meant to be a progress report for the education, I guess one could call it, of the ACRS so that we can get in touch with progress being made in this task and any problems that may have developed in projections for the future course of events.

As the first speaker in our presentation today we have Mr. Larry Phillips of the NRC Staff. Mr. Phillips?

MR. PHILLIPS: Good morning, gentlemen. I am Larry Phillips.

(Slide.)

MR. CATTON: Larry, before you get started on that, could you give me what your definition of an unambiguous, easy to interpret indication of what inadequate core cooling means?

MR. PHILLIPS: I'll try to. Maybe I can best explain it by giving an example of an ambiguous one.

If you have an overcooling transient whereby the primary system coolant shrinks and drains the pressurizer, the loop goes saturated. If you were relying on a saturation meter alone as an indication of an approach to inadequate core cooling, it would be giving you false information because you have got two possible conditions where you are saturated.

You have got this overcooling situation where you are not losing coolant, and you can recover without ever really being in danger of uncovering the core. Or, you could have a leak which created the same condition and would be approaching inadequate core cooling.

MR. CATTON: It's an anticipatory sort of thing?

MR. PHILLIPS: That's an anticipatory sort of thing. But part of the requirement is to be able to detect the approach of inadequate core cooling.

I am going to speak on the status of our review and the progress of the licensee submittals for inadequate core cooling instrumentation.

This first slide I have here is milestones we set up some time ago for our review. NUREG-0737 and Appendix B of NUREG-737 set the requirements or clarified the requirements and expanded on them for inadequate core cooling instrumentation.

It also described in detail what documentation was required on instrumentation. That was due for submittal on January 1, 1981. In general, we got some sort of a submittal from just about everybody, but the submittals -- most of them -- fell far short of the documentation that was asked for.

MR. KERR: In your view, could a licensee have known from II.F.2 what it was you wanted?

MR. PHILLIPS: Yes, I think as far as the documentation requirements go it was spelled out very clearly what we wanted, and I believe NUREG-0737 was clear on the thing also. And we had clarification --

MR. KERR: Where did one go? I mean, was the information somewhere other than in II.F.2?

MR. PHILLIPS: Yes, sir. II.F.2, with what was called Attachment 1 to II.F.2, which was thermocouple requirements, and then there was Appendix B, which spelled out the design requirements for the instrumentation.

MR. KERR: Okay. Well, I'm glad that the applicants or the licensees could understand that. I had some problems with it, but proceed.

MR. PHILLIPS: We also had clarification meetings in all the regions, for all regions.

MR. KERR: That's what I was asking. In other words, they didn't just have to depend on what was written. You told them in addition what it was you wanted?

MR. PHILLIPS: That's right. They asked questions and we took their comments, and, as a matter of fact, modified NUREG-0737 somewhat before it was published to take account of their comments.

MR. KERR: Okay.

MR. PHILLIPS: We contracted with Oak Ridge Laboratories to assist us in the review of the submittals, and this schedule really applies to the development of the review in conjunction with Oak Ridge, and called for generic questions and positions to be developed by April 1, 1981.

This would be on those systems which had been proposed in the January submittals, and we had two such systems -- excuse me, three. We had the Westinghouse delta P system, which was incorporated in a number of plants or proposed for a number of plants for liquid level.

We have the Combustion Engineering heated junction thermocouple system, on which the submittal is still incomplete, but which has been proposed for some plants. And we had Farley Plant install neutron detectors above and below the core.

MR. KERR: I'm sorry. What plants did?

MR. PHILLIPS: Farley, Alabama, Power Company -- Farley 1 and 2.

MR. CATTON: That's the EPRI system?

MR. PHILLIPS: That's the National Nuclear System and it's being tested by EPRI or being developed. EPRI is assisting in the development in some way. They are scheduled for a presentation on that.

Those questions and positions were developed in initial draft. The staff has reviewed them, has provided our comments back to Oak Ridge, and they are presently being finalized to be transmitted to the licensees or to Westinghouse.

MR. KERR: I guess I should know by now, but what is the significance of the term "positions developed"?

MR. PHILLIPS: Well, of course, in an ordinary SER licensing review, positions would be Q2s. We have Q1s, which are questions, and we have Q2s, which are more or less staff positions, which the applicant still has a chance to comment on and to try to attempt to get us to change our mind before we go out with an SER on it.

In this case we will have some additional information requirements, for we just need more information to complete our review. Those will be questions, and we will be taking some positions in the initial transmittal.

MR. KERR: Okay.

MR. PHILLIPS: And we expect those to be on schedule for the Westinghouse delta P system, for sure, and, depending on the status of our submittals, probably for the Combustion Engineering heated junction thermocouple system also.

We then scheduled for licensee submittal response by September 1, and for our development, then, in conjunction with Oak Ridge, of a generic SER and model technical specifications for the individual systems.

Installation is, you know, scheduled for January 1, 1982. I will speak to that, as to where the plans stand.

MR. KERR: Could you give me some idea of the relationship between a generic SER and a plant-specific SER?

MR. PHILLIPS: Yes. For the generic SER we will look at -- we are looking at the Westinghouse submittal description of their system and saying, in general, whether we feel that system is adequate to -- can be installed and calibrated, et cetera, to provide sufficient information to meet the NUREG-0737 requirements.

For the specific plants, we expect to review the actual installation and calibration and testing, the displays, as they have generated them, for the individual plants -- and that will vary quite a lot -- and the way that the individual specific systems are installed.

MR. KERR: When you say "are installed", you mean proposed to be installed, or --

MR. PHILLIPS: No, are installed. We will not review them prior to installation. We will review them after installation, and will review their calibration technique, methods, et cetera.

MR. KERR: So after installation they may be asked to change the installation?

MR. PHILLIPS: They could be told that some things they have are not adequate or do not --

MR. EBERSOLE: Mr. Chairman -- Larry, this sort of instrumentation is not new. It was discussed in the early spring of '74 in Diablo Canyon but rejected as not necessary.

At that time the applicant's argument was that the instrument would never see any level change. It would always be covered and, therefore, you would have no signal over the whole life of the installation.

And the second thing was, if you had it what would you do with it, inasmuch as you would be running flat out with everything to cover the core anyway and there was not much you could do to improve on that.

This was on the basis of engineering design operating at the minimum flow rates, assuming single failures, et cetera, would provide adequate core cooling.

The problem with that argument was that there were no means to lay on and recover from an accident, withdraw from the flat-out, complete flow process. You never had a way to withdraw from the full flow initial emergency flow rate and stabilize the accident.

Are there going to be emergency procedures associated with this new instrumentation which will permit that withdrawing and stabilization of the accident?

MR. PHILLIPS: There are emergency procedures associated with inadequate core cooling, yes. And they will tie in, at least, with procedures which will permit the withdrawal from the accident.

MR. EBERSOLE: All right. Thank you.

MR. CATTON: Will analysis be required to show the various kinds of things that one might anticipate?

MR. KERR: Have you read II.F.2?

MR. CATTON: I read that whole thing.

MR. KERR: Okay.

MR. PHILLIPS: Yes. Analyses are required and have been provided for the Westinghouse system and are being performed also for the Combustion system.

MR. CATTON: The reason I ask the question was the example you gave about the pressurizer and other parts of the loop. I don't know how the instruments would anticipate that, when all they are measuring is core melt.

MR. KERR: The example he gave was one that was ambiguous.

MR. CATTON: Yes. It is supposed to anticipate it.

MR. KERR: And what we want is unambiguous.

MR. CATTON: How do you make it unambiguous?

MR. KERR: You eliminate all the ambiguous ones.

That was his example.

(Laughter.)

MR. PHILLIPS: The reason for requirement for level instrumentation is to monitor coolant inventory. If we can monitor that, we know when we are approaching inadequate core cooling.

MR. CATTON: I understand that. I looked at the Westinghouse system and they basically have hot legs at the bottom and top of the vessel. That's twenty percent of the total inventory. If you had a couple more measurements elsewhere in the system you might monitor sixty or seventy percent of the core.

MR. PHILLIPS: Well, we have instrumentation that monitors --

MR. CATTON: When you say "monitor the inventory" you are monitoring something less than twenty percent of the total primary system inventory by only monitoring the vessel. If that's sufficient and you feel it is sufficient, then I have no problem.

MR. PHILLIPS: Yes, right.

MR. ZUDANS: Is it?

MR. CATTON: I don't think so.

MR. ZUDANS: At that point you are not really in an integrated monitoring. Are there no plans for that where you would keep it down, of every loop that's detectable, and keep account of all makeups? And if you start deviating by a certain percent in a given period of time you start looking for unidentified leaks? Is that possible?

MR. PHILLIPS: Yes, that's done, but on a much smaller scale. That is, it's looking for small leaks. But that's done --

MR. ZUDANS: That's not the real object. The small leaks are only the means of doing it. The real objective is to to tell the operator at any given time how many million pounds of water or steam does he have in the primary system.

MR. PHILLIPS: No one has proposed that as a method for monitoring a leak of this size that would lead you to inadequate core cooling in an hour or something of that nature.

MR. KERR: I think we got to installation, didn't we, January 1, '82?

MR. PHILLIPS: Yes, we got to installation.

The rest of our submittal requirements in NUREG-0737 would be satisfied, namely the calibration, description of the as-built system. In the qualification that would be submitted we would expect, on those systems which made the schedule, on the order of March '82, and by May '82 we would issue technical specifications and plant-specific approvals, implementation.

And we would not approve incorporation of the systems and incorporation of the emergency procedures for the systems until after this review was completed.

MR. KERR: Let's see if I understand.

The installation should be completed by January of '82, but they can't start using them until July of '82?

MR. PHILLIPS: That's right, at least not as a basis for operator actions.

MR. KERR: Well, for what else would you use it?

MR. PHILLIPS: Well, they can use them for calibration and generally to check the operability of the systems.

MR. KERR: You mean they could test them before that?

MR. PHILLIPS: Yes.

(Slide.)

MR. CATTON: In this II.F.2, under clarification item 4a, you indicated that it must indicate the existence of inadequate core cooling caused by various phenomenon. How are you going to measure that?

MR. KERR: Mr. Catton, I think we're trying to get through schedule. Could you let us run through that? Then we are going to get to somewhat more specific discussion.

MR. PHILLIPS: I think that type of thing can best be handled by Westinghouse. I hadn't allotted enough time to go into that. It will be done by the vendors, unless you want to ask me those questions.

MR. KERR: What I am going to want to do, and I'm going to try to avoid interrupting you also, is to let you run through the schedule part and then we will get to specific questions on the system, if you don't mind. Save the question. It's a good question.

MR. CATTON: That's fine.

MR. PHILLIPS: Okay. So as far as the progress in meeting that schedule, the licensee submittals were reviewed and we summarized those reviews by characterizing what positions the licensees were taking, as I will show you in a later slide.

We prepared the draft generic questions and positions -- Oak Ridge did -- and they have been modified, and they will be transmitted to the licensees.

MR. KERR: The generic questions were not plant-specific? Is that the significance of generic?

MR. PHILLIPS: Yes, that's correct.

MR. KERR: But you prepared them by looking at plant-specific submittals?

MR. PHILLIPS: Well, Westinghouse prepared a generic submittal on the delta P system, which actually included three different levels of display systems, of how the signals would be handled.

MR. KERR: I thought we were referring to plant-specific submittals that were due by January of '81.

MR. PHILLIPS: That's right. When the plant-specific submittals came in, some of them incorporated these generic submittals as the basis for their system.

MR. KERR: So the generic questions only had to do with those, not with the plant-specific stuff?

MR. PHILLIPS: That's right. None of the plant-specific submittals expanded on their specific installation. They just said, this is our system.

MR. KERR: Okay.

MR. ZUDANS: Is it true that generic refers, in this case, to a specific type of system and how that functions?

MR. PHILLIPS: That's correct.

MR. ZUDANS: Without making reference to any dimensions on anything like that for a specific plant?

MR. PHILLIPS: That's right.

MR. ZUDANS: And that includes -- that could be interpreted and displayed and what-not?

MR. PHILLIPS: Right.

MR. KERR: The purpose of the licensee submittal, then, really was just to get a commitment from licensee that he is going to use the system, because you didn't really give anything very plant-specific, except to say this is what I propose to use?

MR. PHILLIPS: That's right.

MR. LIPINSKI: This shows the work completed in July 1 and your earlier schedule showed the starting April 1?

MR. PHILLIPS: No, the draft questions and positions were to be drafted by April 1, the initial ones, and the staff review goes, and there have been some modifications, and we are working on finalizing them and they will be transmitted to the licensee by July 1.

MR. LIPINSKI: So the first interval was developing draft positions from January to April, and from April to July is developing your final questions and positions?

MR. PHILLIPS: That's correct.

(Slide.)

MR. PHILLIPS: This is a summary of where we stand on the plant responses that came in in January, and you have to understand that there are all sorts of ranges of responses, from people saying, "Well, we think we are going to use this type of system, but we're still considering another type," to "Yes, here's the Westinghouse delta P measurement system, which we are proposing," or to others saying, "Well, we just feel we don't need liquid level indication. We can't figure out anything we'd do with it if we had it. So, therefore, our conclusion is we don't need it."

And we have been attempting to categorize them. We have tried to -- we have placed them in certain categories, and it's possible somebody else could review the same material and switch them around somewhat differently. But this is the way we have done it.

For Babcock and Wilcox plants there are eight responses. Of those, two say we don't need level instrumentation and we're not going to put it in and --

MR. KERR: Now in this slide you refer to level measurement. Earlier we had referred to instrumentation to discover inadequate core cooling. Are those used synonymously?

MR. PHILLIPS: At this point I think you can say they are used synonymously, yes.

MR. KERR: Okay, I wanted to make sure we are talking about the same thing. Thank you.

MR. PHILLIPS: Six say, well, we are considering the various systems. We still haven't made a decision as to what we are going to do. And I think you could safely say that none of those six are going to come close to meeting the January schedule.

MR. LIPINSKI: Which two plants have no need?

MR. PHILLIPS: Arkansas Units 1 and 2 -- oh, I'm sorry. This is B&W. This is just Unit 1. The other one would be Three Mile Island 1.

The Combustion Engineering plants, we had one "no need." That's Arkansas 2, which took the same position as they took with 1. And four are still considering various systems. And three have commitments to the heated junction thermocouple system.

Of the Westinghouse, there are 29 responses. I want to emphasize these are only operating plants we are talking about here. Two commitments to the heated junction thermocouple system, two commitments to the National Nuclear system, and 18 commitments to the Westinghouse delta P system, and seven are still considering various systems.

MR. ZUDANS: When you spoke about SERs, was that meant for the entire requirements of II.F.2, or just for water level instrumentation? Those SERs that you were talking about.

MR. PHILLIPS: Oh, yes. They are just for water level instrumentation.

MR. ZUDANS: Okay. Thank you.

MR. KERR: Now you have me confused, because I thought you said you were using reactor level instrumentation as synonymous to inadequate core cooling.

MR. PHILLIPS: Let me try to clarify. We have an inadequate core cooling system of instrumentation. In general, we think of this system being comprised of subcooling monitor, which, by itself, is ambiguous, of core exit thermocouples, which will tell you when you are in an overheated condition, and of the water level instrumentation, which will remove the ambiguity from the subcooling monitor.

So the only system which is a problem at this point, at least for BWRs, is the water level instrumentation. And that's what this discussion is about, is the water level instrumentation.

MR. KERR: Well, then, the schedule for submittal that we talked about in previous slides is for the ICC or the reactor level.

MR. PHILLIPS: It's for the entire system. I'm sorry. I should have clarified that. It addresses the entire system.

MR. KERR: Thank you.

MR. EBERSOLE: Larry, GE has had to face the problem of survivability of this sort of instrumentation ever since they started designing the plants, but the BWRs haven't had to -- this water problem, early on, about survivability in the face of the large LOCA. Now I don't believe in that any more than anybody else does, but one must ask the question, is this instrument supposed to survive such a violent event, and if it does, how much of it has to be left to provide information? That was one of the essential questions about the boiler, because it needs level instrumentation to invoke certain safety responses after a large LOCA.

It was automatic circuitry then. Here it's compounded by the fact this is not automatic apparatus. This is visual information for the operator, and whether one needs redundancy is rather open.

MR. PHILLIPS: That is one of our review areas -- the survivability to the large LOCA. We don't expect that it be operable during the large LOCA. We do want it to survive. We do want to know if it will perform after the LOCA. We want to know the meaning of any signal we get out of there.

We have not made a hard requirement at this point that it do that. That is still under consideration. But as a minimum we want to know what that signal means if we have a large LOCA.

I'm not going to go through the next three slides. They are in your packet and they give you the details for individual plants which I have just summarized. They tell you which plants are looking or committed or whatever.

I think I might mention that Oconee or Duke Power Company for their B&W plants have recently come in and given us a presentation where they are considering or proposing or looking -- taking a hard look -- at hot leg delta P instrumentation, where their tap would be at the top of the candy cane where they have a vent. And we have told them that yes, we would look at this and consider it, if it's a satisfactory complement to the other instrumentation, such as core exit thermocouples. So that is a recent plus, I think, on the development.

MR. KERR: Larry, there are certainly a good many other post-TMI requirements than this one, which I think is a very important one. In arriving at your schedules and positions on this, do you have any feel for how many other SERs the licensee is being -- or now SER, but how many other similar submittals that require SERs and questions at an operating plant the licensee is being required to go through at this point? Is it ten or fifteen, or three or --

MR. PHILLIPS: Well, it is certainly more than ten, I would say. I can't really quantify it, but it's a large number.

MR. KERR: Has anybody on this staff or any group of people on the staff ever thought about the possibility of somehow combining a number of these so they are handled together rather than all of these separate issues, so that also one can maybe even set some priorities? Or is that being done sort of automatically?

MR. PHILLIPS: I really can't speak

authoritatively on all of that, but there is some effort along that line. And there has been an attempt in NUREG-0737 to more or less make dates coincide and they are still worth going along that line, and I am sure you are aware there is a rulemaking proceeding being negotiated on the entirety of NUREG-0737, and this instrumentation is included in that.

MR. LIPINSKI: On the plants that are listed as not needed, is there a schedule as to the resolution of that question?

MR. PHILLIPS: Well, that would be taken care of by the rulemaking proceeding. If it becomes a rule, of course, that will set the tone for when it has to be in.

MR. KERR: What is it that would be a rule? 737 or parts of it?

MR. PHILLIPS: It's being negotiated on all of 737. Now it may not be 737, as it now exists. There may be some modifications there, and particularly the schedule is being -- changes in schedule are being considered in conjunction with all of the items in there.

And there is a provision, I believe, in it, as we have always generally held to be true, that for individual plants where they have made a bona fide effort to install the systems and have shown progress, that we would consider a later schedule on a plant-by-plant basis. There is something of that nature in the proposed rule.

MR. LIPINSKI: Where is the schedule for rulemaking in connection with your schedule?

MR. PHILLIPS: It's not here.

MR. LIPINSKI: Do you know what the schedule is?

MR. PHILLIPS: I'm not speaking to it. It's being handled by Projects and it's being negotiated with the Commission. But we are proceeding on the NUREG-0737 as apparently it exists. The rule would be just a means of enforcement.

MR. ZUDANS: I would like to return back to Dr. Kerr's question whether or not there is a uniform or global effort in progress at the NRC to make it easier on the licensees to coordinate the number of different requirements that come from different places to which they have to respond, so they can respond in some global fashion.

I understand there is a memo that addresses exactly that question and explains how it's going to be done. Maybe it's in a limited scope.

MR. PHILLIPS: I'm sorry. I missed the --

MR. ZUDANS: The idea of requirements that came about after the Three Mile Island accident situation. There were many requirements -- this and that, plus such things like this. I understood there is an activity in progress whereby licensees will have a chance to combine requirements from different directions, that come from different directions, and have a global response to address it, rather than little pieces.

I understood there was a memo written by Dr. Eisenhut to Mr. Denton that lays down the ground rules.

MR. PHILLIPS: I believe there is something of this nature in progress. And I think it's pretty much what Dr. Kerr --

MR. ZUDANS: Could we lay our hands on that memo and see how specific that is?

MR. PHILLIPS: That may be. I just don't have a lot of knowledge of what's going on.

MR. ZUDANS: I wrote yeterday.

MR. KERR: You wrote yesterday to ask for the memo, or you saw it?

MR. ZUDANS: No, I heard that such a memo exists.

MR. KERR: You have a better grapevine than we have, apparently.

(Laughter.)

MR. ZUDANS: It would be interesting, because I think it's a very positive effort.

MR. KERR: Does anybody on the staff know the memo to which Mr. Zudans may be referring, or does he have some secret source of information unavailable to the rest of us?

MR. ZUDANS: I can get the precise reference after lunch.

MR. KERR: Okay.

MR. PHILLIPS: I can just say we are proceeding with our review and in the light of 0737 as it exists now, and we don't expect any significant changes to that, other than perhaps some relaxation on schedule, when it appears as a rule.

Dr. Kerr, I have asked Oak Ridge to briefly describe their review of the systems and and some of the review criterion that they are looking at.

MR. KERR: That's part of this presentation?

MR. PHILLIPS: Yes.

MR. KERR: Larry, do you have a copy of II.F.2 there so that I can --

MR. PHILLIPS: No, I don't. Here's one over here.

MR. KERR: On page II.F.2-2, under a section entitled "Clarification", let me see if I understand the clarification. Under 3, for example, licensees and applicants are required, among other things, to evaluate the merits of various instruments. Does that mean in addition to the one proposed a licensee is supposed to say I've looked at three others and here's the way I evaluate them? Or, does it mean various instruments that are a part of his system?

MR. PHILLIPS: This is referring to instruments to monitor water level and to monitor other parameters indicative of core cooling. So, yes, that means essentially looking at several types of water level instrumentation and deciding which will do the best job and also looking at core-exit thermocouples or any other magical way.

MR. KERR: Well, why, if an applicant proposes a satisfactory system, do you want him to submit something that gives an evaluation of several systems in the light of the limited amount of resources that we all have to do evaluations and prepare analyses? I'm reading from page II.F.2-2.

MR. ZUDANS: Various instruments to determine what the water level --

MR. KERR: I'm not asking for your interpretation of this. I want Larry's interpretation. I think you're telling me that you are asking them to look at two or three systems and say, here's the way they work and I chose this one. Is that --

MR. PHILLIPS: That's correct. You have to put this in perspective. This requirement was established before we were anywhere near as far along as we are now in the selection of what system will do the job, and the applicants --

MR. KERR: I still don't see why -- maybe this is irrelevant because the time has passed. Is it?

MR. PHILLIPS: It's not if somebody comes in with a system which we consider unsatisfactory and they say this is the only system that will do the job.

MR. KERR: I can understand why you could ask somebody to come in with a satisfactory system. I don't understand why you ask them to come in with an evaluation of several systems. This just seems like make-work to me.

MR. EBERSOLE: On the other hand, Bill, they must have a basis for choice. Surely they didn't pick up the first system.

MR. KERR: Of course they do, Jess, and they have a basis for getting up and going to bed, but I don't see that that's relevant to submitting a plan for doing something and the staff evaluates it and decides it is good or it isn't.

MR. PHILLIPS: Well, let's say basically that every applicant will go through this process, presumably, to arrive at a system.

MR. KERR: That's right. But why have it submitted to you, because it makes work for him and for you which it seems to me is irrelevant to what's going on.

MR. PHILLIPS: Well, we feel that it's pertinent to our review of the various systems to determine has he indeed selected the system that's best for his plant.

MR. KERR: But we don't ask an applicant to select the best system, Larry. We ask him to select one that will work. Nowhere in the rules does it say that one has to select the best system.

MR. PHILLIPS: Many of them have selected one that won't work and claim that none of them will work. And if they claim that, we want to see how they arrived at this logic.

MR. KERR: Well, since you don't believe it anyway, I don't see what the submittal does. You are convinced that some will work, so you aren't going to believe the submittal that says none will work.

MR. PHILLIPS: That's right, unless he can submit new information which is very new to us, that we have never heard of before.

MR. KERR: It seems to me like with the mountains of paper that are submitted anyway that this sort of adds to it, but that is perhaps irrelevant.

MR. CATTON: What happens if the applicant chooses the vendor's system. For example, a Westinghouse plant chooses to just take off the shelf a Westinghouse system. Do they have to go through this exercise again, too?

MR. PHILLIPS: Again?

MR. CATTON: It says licensees and applicants are required to provide --

MR. PHILLIPS: Well, do you understand here the first part of this requirement refers to the design analysis to support the final instrumentation, that we need to review the instrumentation adequacy?

MR. KERR: I certainly think that's relevant.

MR. PHILLIPS: I think the second part on evaluating the merits of various instruments, based on the submittals we have seen, it's really not a lot of paper or work. They don't go into a great deal of detail on this.

MR. CATTON: They just refer to the Westinghouse system?

MR. PHILLIPS: No, in general they say there are five or six types of systems that we have looked at to evaluate whether they will work or not, and we have dismissed this one because of that, and this one because of that. Some of them say we dismissed them all, and we don't need a system anyway.

(Laughter.)

MR. EBERSOLE: Larry, way off in the distance is a thing called standardization. I guess this is the antithesis of that. Are we seeking, by having these people look into these various methods perhaps focusing on what will be a good system?

MR. PHILLIPS: Yes, that's true.

MR. EBERSOLE: Thank you.

MR. KERR: On the following one, number four, I guess I am not sure what the licensee is being told, except that the system must work.

But on number five, what is meant by "the indication must give advanced warning of the approach of ICC"?

MR. PHILLIPS: Well, that would be a situation where we have drained the pressurizer. We have gone saturated. We essentially want to monitor the coolant inventory, the fact that we are losing coolant and going to a condition whereby we might get to core uncovery and inadequate core cooling.

So that some of these situations take a very long time to develop, and the operator may have a half hour, an hour, even more, whereby he can take actions to prevent core uncovery.

MR. KERR: Give me an example of something that would be an advanced warning.

MR. PHILLIPS: Level monitoring instrumentation -- either the heated junction thermocouple system or the delta P measurement system.

MR. CATTON: That's not very much advanced warning, is it?

MR. PHILLIPS: It depends on the nature of the event. It can be up to three hours. You've got small breaks that can take like up to three hours to get to the top of the core.

MR. KERR: So in a sense anything that is abnormal about the cooling system could be considered an advanced warning of inadequate core cooling, almost.

MR. PHILLIPS: Yes, I would say, for instance, your subcooling monitor is an advanced warning, but it's ambiguous. So you need something like the level system to go to in order to remove the ambiguity.

So that's the reason we say that's part of the system that will give you your first indication, but you still have to be able to interpret it.

MR. KERR: I'm trying to get some feel as to whether what you are talking about is very general, which seems to me is what you are talking about now.

It says the cooling system is not performing in its normal mode and anytime it's not performing in its normal mode then you know that something is probably wrong, so you might have inadequate core cooling.

On the other hand, you might ask for a monitor that says in five minutes you are going to be in trouble. You aren't asking for that, apparently.

MR. PHILLIPS: No, we are not asking for in five minutes, but we are asking for a monitor that says we are saturated and we are losing coolant and going towards core uncovery.

MR. KERR: Well, suppose that you weren't saturated and were still losing coolant?

MR. PHILLIPS: We want to see that too.

MR. KERR: So you are asking for general things that says the cooling system is in an abnormal mode?

MR. PHILLIPS: That's right.

MR. LIPINSKI: Do you take the extreme case of ATWS? Or a partial failure to scram with loss of flow?

MR. PHILLIPS: No, we haven't considered ATWS.

MR. LIPINSKI: That's not in your boundary of inadequate core cooling?

MR. PHILLIPS: Well, I just say we haven't considered it. I don't know of any reason why these wouldn't work for that situation. I don't know what would be different, offhand.

MR. KERR: Now, on page three of this same document -- I'm sorry, page II.F.2-3, under number 10, where an applicant is enjoined to do a human factors analysis, which I think is very good, because one is in effect saying one ought to know something about the way in which an operator is going to use this information and whether he will have it in usable form, I think, and whether he will be trained to use it.

Was the same sort of analysis performed by the Staff in their setting up the requirements for the instrumentations? I mean, for example, when they required 16 thermocouples and core maps and stuff like that. Did you go through this kind of logic which said this is the sort of information an operator will need and here's how he will use it?

MR. PHILLIPS: Yes.

MR. KERR: Okay.

Then how did you decide on 16 thermocouples rather than 12 or something like that?

MR. PHILLIPS: Okay. It was a process --

MR. KERR: I'm using that as an example.

MR. PHILLIPS: It was a process. Well, first of all, in the development of these requirements we were looking at operating reactor plants, so we looked at what they had in the way of thermocouple instrumentation. I think all of them had at least 20 or something of that nature.

And we looked at, well, what do we need for this requirement? Well, if we had four in a quadrant, it would be -- it would give very good coverage. And it essentially was something that everyone should be able to do with their existing systems. So that entered into it -- what they have now, plus the fact that we felt that this was entirely adequate to have four per quadrant. So that's essentially how we arrived at the minimum number.

And, as far as the display goes, and usefulness, that was an analysis performed by the Human Factors Branch, and those various considerations went into laying out the requirements for display.

MR. KERR: So the 16 was based on the fact that you thought people could get 16, and 16 seemed like a good number?

MR. PHILLIPS: Sixteen seemed adequate, and people could get 16.

MR. KERR: Now, on page II.F.2-5, reference is made to primary operator displays. What is meant by a primary operator display, as contrasted, I guess, with the secondary operator display of something? The nomenclature would probably be clear if I were more familiar with 0737.

MR. PHILLIPS: Essentially this is the definition right here. Primary operator display, I guess we use the word "primary" because we considered that this was a display that the operator would normally be using and it would be his spatially-oriented core map on, for instance -- this includes spatially-oriented core maps on a CRT.

MR. KERR: This is contrasted with the backup display on number 3?

MR. PHILLIPS: That's right.

MR. KERR: So he's got to have two displays -- a primary and a backup?

MR. PHILLIPS: Correct.

MR. KERR: Was this based on any sort of analysis of the probability of the incidents and the other information that operators would need?

As I read 2 it strikes me that one is asking for quite a lot of information -- a spatially-oriented core map, whatever that is, a selective reading of core-exit temperatures continuous, on-demand, consistent with parameters pertinent to operator actions, direct readout and hard copy capability, alarm capability. It seems to me you almost have to have one operator dedicated to following inadequate core cooling information, if one ever gets in this situation.

Was this requirement made in the context of an overall consideration of things that operators would have to be doing if an accident like this occurred and taking into account the number of operators available? Because, you remember, one of the criticisms associated with the TMI control room was that the operators had maybe more information and alarms than they could comprehend.

MR. PHILLIPS: Yes, well, the Human Factors Engineering Branch was an integral part of forming these requirements, and that is part of their mission, to do that.

MR. KERR: And they looked at this in connection with the total accident that might be occurring and not just assuming that the only thing going on was inadequate core cooling indication?

MR. PHILLIPS: I would assume so. That was part of their review.

MR. KERR: Well, it's also part of your responsibility, isn't it, to make sure they did a good review?

MR. KERR: We are all in this together and we don't want to flood the operator with so much information that he can't comprehend it. It just strikes me that if I were concerned with nothing else but inadequate core cooling -- I don't know, I haven't looked at this in a lot of detail, but it just strikes me that one is asking for quite a lot. I mean trend information, for example. What does one have in mind there?

MR. PHILLIPS: Well, I think what one has in mind is if you have a computer and you have the capability of storing trend information, if you get into a condition such as Three Mile Island, rather than having operators tied up taking down data by hand and transmitting it back to whoever is looking at it every half hour or hour or so forth, all you have to do is punch a button and it all comes out.

MR. KERR: So this is not really for the use of the operators but rather for people in Lynchburg or Bethesda or whatever.

MR. PHILLIPS: It is for both. The operators are interested in that too, I would assume, and this is the very reason we have it.

MR. KERR: You aren't really saying you want trend information. You are saying you want to be able to record what has been happening as a function of time and have it available.

MR. PHILLIPS: That is essentially what trend information is. It will go on the disc and computer and it will be called out on demand and tell you what has happened.

MR. KERR: So you are really just asking for information storage capability.

MR. PHILLIPS: That is right.

MR. KERR: And from that you can get whatever you want.

MR. PHILLIPS: Yes.

MR. KERR: So if you ask for trend information and somebody came in and said I am taking data every "x" minutes and storing it and you can punch a button and get it, that would satisfy you.

MR. PHILLIPS: Absolutely, yes.

MR. KERR: Okay.

MR. PHILLIPS: In my opinion, these requirements lessen the load on the operator because they essentially automate everything.

MR. KERR: Well, that doesn't necessarily lessen the load on an operator because they may not know what is going on at all. What is meant by appropriate alarm capability shall be provided consistent with operator procedure requirements?

MR. PHILLIPS: Well, for instance, if the operator is supposed to take a certain action in his procedure when the average of the top five temperatures get to 1200 F., then there should be an alarm that tells him, hey, the average of the top five temperatures is 1200 F., you had better go take your action.

MR. KERR: But again, one would almost think this was fashioned in the context of one operator and one alarm. Presumably we are talking about an accident in which there may be a lot of things going on and a lot of alarms. Why do you need another alarm for this if a guy has a procedure and knows what he is to do? Isn't the alarm likely to be more confusing than helpful?

MR. PHILLIPS: No. The alarm is going to tell him that it is time for him to take action. Basically he is required to take an action; that is an aid to him to tell him it is time to take the action.

MR. KERR: But almost certainly there will be combinations of things that will require action, not just one set of data, so you are going to wind up, I would guess, with a whole lot of alarms if you have to say that any combination of variables which requires an operator to take an action requires an alarm, aren't you?

MR. PHILLIPS: Well, no.

MR. KERR: I mean if you take that seriously.

MR. PHILLIPS: In this case I think we are talking about -- well, yes. But as part of that, if he gets an alarm, part of his action may be to look at your entire inadequate core cooling board, and if this is true and that is true and this is true, then depressurize the steam generator, something of that nature.

MR. KERR: I guess I just have some vague uneasiness about alarms in contrast to information.

MR. PHILLIPS: Well, it says appropriate alarms.

MR. KERR: I know it does, and that is why I asked what it meant. Is it deliberately left ambiguous so you will see what people come up with, or do you have something in mind?

MR. PHILLIPS: No, it is all reviewed in conjunction with the emergency procedures, the total emergency procedures.

MR. KERR: But they don't yet exist, do they, since they are part of the tech spec?

MR. PHILLIPS: The emergency procedures are developed in combination with the system.

MR. KERR: I don't mean ambiguous as a pejorative term, but it was left unspecific because you wanted people to study and come up with something and you don't yet have any set ideas?

MR. PHILLIPS: That is right. We have some notions but we don't have any specific requirements, and we want to see what they propose, yes.

MR. EBERSOLE: Larry, there have been cases where due to improper cooling rates in the primary systems of PWRS they have raised a void in the vessel. I forget which plant that was. But they detected this by indirect methods, the resilience of the volume in the pressurizer, et cetera, et cetera.

Is it your intention to be able to do this by more direct methods?

MR. PHILLIPS: Yes. As a matter of fact, they were very confused for some long period of time and we don't think that is good, and we would expect that this type of level instrumentation would detect that sort of position.

MR. KERR: Now, in writing specifications for instrumentation and procedures, is it going to be taken into account that presumably the operators using this will be trained rather differently than were operators that were faced with accidents two years ago?

MR. PHILLIPS: They will be trained differently, yes. Was that taken into account in writing the emergency procedures?

MR. KERR: No, I mean will it be taken into account in your final consideration of these systems and procedures?

MR. PHILLIPS: Yes. Operator training and procedures are taken into account.

MR. KERR: No, I am not making my question clear. Presumably the operators will be better and differently trained than would have been the case three years ago.

MR. PHILLIPS: Yes.

MR. KERR: Will that be specifically considered in arriving at the instrumentation systems and procedures?

MR. PHILLIPS: Our general position on this is that the better training and the higher level of operator awareness which now exists as a result of Three Mile Island is partially the justification for allowing plants to continue to operate until they can get these systems installed. We expect that this awareness level may not exist forever, and I believe I would say that our emergency procedures should be prepared as if there were no higher awareness level.

MR. KERR: I just don't understand that at all. You are saying you are preparing procedures not for well-trained operators and not for aware operators but for --

MR. PHILLIPS: No, I didn't say that.

MR. KERR: I said that and I am trying to understand what you are telling me. We are going through, I think, a very important program which we hope will produce better trained and more aware operators, and it seems to me if they are to be made use of, the instrumentation systems and procedures ought to be geared to the fact that there are better trained and more aware operators.

That doesn't mean it is any l ss stringent; it just may be different because you are depending on a man who presumably has a better understanding of what is going on. I would think that ought to be taken into account in planning. Is it not being?

MR. PHILLIPS: Yes. The procedures we are requiring as part of the development of the system -- that it be consistent with the procedures that are developed and that the operator training is being emphasized in conjunction with those procedures. We are requiring a high degree of operator training in conjunction with all of the emergency procedures.

MR. KERR: A high degree of operator training is a nice statement. It is different, it seems to me, than having someone who is responsible for reviewing these systems and thinking about them to look specifically at the kind of training operators are getting to see if the operator is likely to understand and be able to make use of this kind of information in these systems.

It seems to me human factors engineering if it is to mean anything has to take into account operator training and capabilities as an interface to the systems and procedures.

MR. PHILLIPS: That is correct, and it does.

MR. LIPINSKI: As part of the analysis is a failure modes and effects analysis being asked for? Do you have instrumentation now that is being called for, and given that a failure now occurs within this instrumentation, it could lead the operator to look at the wrong information and draw the wrong conclusions? Are you looking at failure modes and effects analysis as to what he is going to see depending on where the failure occurs?

MR. PHILLIPS: That is part of our review.

MR. LIPINSKI: Are the vendors being asked to supply this? Are you going to do the FMEA?

MR. PHILLIPS: In our documentation requirements we don't have per se provide a failure modes and effects analysis. We feel that with the analyses that are being presented and with our normal review process and our questioning, that we will be performing that type of effort, yes.

MR. LIPINSKI: What about the probabilistic risk assessment, because most of these systems are calling for more taps on high pressure systems, giving you a higher probability for small LOCAs. Hopefully we will not see the need for this instrumentation over the life of the plant, but the question is are we going to get several small LOCAs as a result of having installed this equipment? Have you looked at that aspect of it?

MR. PHILLIPS: Well, yes, that is a consideration in the design review. Oak Ridge will speak somewhat to that. But as a rule, the taps are too small. They won't be in the class of a LOCA even if they were to break and leak in that the makeup system would keep ahead of them.

MR. CATTON: Don't you also attempt to use existing penetrations?

MR. PHILLIPS: Yes.

MR. CATTON: So it doesn't really change.

MR. LIPINSKI: There are more taps being placed on this entire primary system. Every place they want to put a delta P cell in, there's at least two taps in the system..

MR. PHILLIPS: For the most part they are using existing penetration.

MR. LIPINSKI: But I have to put in two additional lines in order to lead them somewhere; if either one of these two lines break, I have a source for leak.

MR. KERR: Other questions?

MR. ZUDANS: I think your discussion with Dr. Kerr resulted in a statement that the operating procedures are consistent with the level of training of operators.

MR. PHILLIPS: Yes, I think that is a fair statement.

MR. ZUDANS: And so is this new instrumentation.

MR. PHILLIPS: Yes.

MR. KERR: Other questions?

You say you now have a presentation from someone from Oak Ridge?

MR. PHILLIPS: Yes.

MR. KERR: Let's have it.

MR. PHILLIPS: John Anderson.

(Slide)

MR. ANDERSON: I am John Anderson from Oak Ridge National Laboratory, and I represent a staff of people with various expertise in instrumentation and thermohydraulics of reactor systems who have been engaged by NRC to give technical assistance on the review of reactor vessel instrumentation as proposed by the applicants.

(Slide)

This, of course, is in response to 0737, Section II.F.2, which we have been discussing.

(Slide)

We have been looking initially at what Larry called the generics of metals, which were preliminary, early ideas by the applicants on their approaches. These consisted of four systems, two of which Larry has alluded to in some detail, the differential pressure system submitted by Westinghouse and the heated junction thermocouples submitted by CE.

The other two systems which were submitted was one using ex-core neutron detectors developed by National Nuclear and the one being pursued by EPRI, and another proposal by a company called Davco, which used a microwave system. We have been looking at the very limited information we got in a preliminary way on LOCAs.

Subsequently we did get more detailed formal submittals from the Westinghouse and CE systems. We have not yet received anything on any of the other systems.

(Slide)

In order to perform this evaluation we have attempted to use two sets of criteria, which I will explain a little. Of course the one set are the ones we have been discussing this morning that come from 0737, and the other set are those that we have ourselves developed as instrument designers and system analysts that we feel are important that may not have been touched upon specifically in the detailed requirements but are nonetheless important.

I think some of those things have been discussed this morning and we think they are important, like the human factors aspects and the ambiguity aspects.

(Slide)

The criteria we are developing as a result of our preliminary reviews by which to judge these sytems we have broken down into some categories. The installation-specific criteria. One of the more important ones is the requirements on the operator, and this relates to the question of ambiguity.

The information must be understandable and interpretable in a way that he does not have to make too many interactions with other instrumentation, particularly if it is in other locations, in order to make a determination of vessel water level, and that is the question of ambiguity.

There is first of all the interpretation, and secondly the interpretation of validity, which is another important consideration. Some of the proposals do have the possibility for errors that may not be apparent to the operator, and one of the things we are looking for is ways to validate by diverse observations that the information is indeed correct.

MR. KERR: Mr. Anderson, in this review process do you have anybody on your staff or do you have access to anyone who has power reactor operating experience?

MR. ANDERSON: Yes, sir, we do. They have not taken a very active role yet, but we do have two gentlemen who have Navy experience and one who has power plant experience as a licensed operator.

MR. KERR: I would think input from somebody who has actually been an operator would be helpful, and you apparently do have that as a possibility but not a very active role.

MR. ANDERSON: That is correct, inasmuch as we are looking primarily at the technical aspects of the instrumentation. That is our principal effort but we do have access to these people.

MR. KERR: The human factors people would lead me to believe that one should not decouple a human being from the instrument, and operators can become confused in a lot of different ways which one might not know about unless one had been an operator. It seems to me such an input would be helpful.

MR. ANDERSON: Admittedly, our background in power plant operating experience is very limited. We have a great deal of experience in research reactor operation and people who have been involved in various ways.

MR. KERR: I recognize that and I think it is valuable. On the other hand, I have seen both research reactors and power reactors, and I would say any resemblance between the two is almost coincidental.

(Laughter.)

MR. ANDERSON: I would argue that in some other forum.

(Laughter.)

MR. EBERSOLE: Mr. Anderson, on the extremes that you have to consider in this, there is the extreme that you might say is failure to recognize a condition which calls for emergency action including reactor shutdown and taking emergency cooling actions.

There is the other extreme, which I think the going rate is something like $1 million a day or so or whatever, but anyway it is a large amount of money, which you must consider as to what to do if you have in fact instrument indication that erroneously indicates that you should take emergency action and causes you to shut down and lose "x" days of operation.

This latter aspect, I think, is more often than not not really considered, and I wondered what your rationale is about these two extremes of requirements on this.

MR. ANDERSON: We are very sensitive to that consideration. In fact, you have known Mr. Epler, who was one of my mentors for many years and very sensitive to what he refers to as bed springs, the instigation of unneeded action.

So I cannot cite to you a specific case that we have uncovered in this instrumentation, but we are very sensitive to the false indication to the operator that leads him to take action which penalizes the reactor for his lack of information or error, and that is a very important consideration, I agree.

This falls into the general category of factors consideration, in which we also have an active program and interest.

(Slide)

One of the categories that we have very little information on yet by which to make any sort of an evaluation is the calibration and verification procedure. We do think it is important, and particularly verification, both prior to operation -- that is, to verify that it does indeed measure and indicate what it is alleged to -- and secondly, that it will continue to do so in adverse circumstances.

The redundancy and diversity requirements are outlined in 0737, and again, it is sort of in the middle ground between the human factors consideration and instrumentation considerations on how one actively validates and cross-checks to make sure that his information is correct so that he doesn't take unwarranted action which will penalize the reactor.

MR. LIPINSKI: This is the part of the failure modes and effects analysis?

MR. ANDERSON: We don't anticipate a formal failure modes and effects analysis, as you consider it. However, the elements of an FMEA in terms of our general considerations are there.

MR. LIPINSKI: Isn't there a possible pitfall such as if you don't do a good FMEA you could end up with a system that would give the operator ambiguous information where he will take action? I am puzzled by your response.

MR. ANDERSON: Certainly that is a possibility. I guess I don't have a very good idea of what sort of an FMEA you have in mind.

MR. LIPINSKI: A blockage of an impulse line that doesn't give you the right delta P, and if you are cross-checking then your answer would be I have other sources of information to verify that the single source is unreliable at this point and I have two other sources that give me the vote, that say source one is wrong and the other two are correct, and if one is wrong and the other two are correct, how do I distinguish which is the right one.

MR. ANDERSON: Certainly we will be making this kind of consideration. We just haven't called it an FMEA.

MR. EBERSOLE: Mr. Anderson, when you start picking up information for operators -- well, I notice your listing up there doesn't include coincidence requirements, and I think there may be something buried in diversity which takes the place of it. But with just redundant channels feeding into an operator rather than into an automatic system, one inevitably comes into the conflict between two channels and how are you going to auctioneer two channels?

You can't do it. What logic are you using about getting duplicate or coincident information to the operator before he takes the rash action of shutting down when he shouldn't?

MR. ANDERSON: This criteria is pretty specific in 0737 in the appendix to the extent that two channels of redundant information is permitted provided that you have some diverse means to affirm that if they disagree, which one is correct. I think that is what you are alluding to. It is necessary to have some method of validation. Whether it be a diverse indication or three or four redundant channels instead of two, a validation method is necessary.

MR. EBERSOLE: Before you take operator action.

MR. ANDERSON: Right. And from the human factors standpoint, that should be easy. He shouldn't have to perform an FMEA in order to make that judgment when his plant is in trouble.

Number four, output during normal operation is another degree of validation; that is, operators tend to have much more confidence in an instrument which is active during normal plant operation than they do in one which is dormant, except when the emergency arises.

And it is our feeling, and I think it is the NRC's staff position that these vessel level measurements should be active during normal operation as well as for during emergency conditions.

Five and six are a little bit vague and not really technically in the realm of our review. However, we believe that they may significantly impact choices of systems. Larry was talking about this earlier, the need to look at various ways of accomplishing the goal here. And one of the important considerations is the impact on retrofit, including cost, penetrations which may lead to increased probability of leaks and so on; and so we don't really have a very formal plan fo- doing this, but I put it on here to indicate that this is in our minds, that this is a consideration that we all need to be thinking about. And of course, interference with refueling is in the same category.

MR. KERR: Now, does this imply that you consider that you have some responsiblity to comment on that to a licensee or that those are criteria that would cause you to accept or reject a particular system?

MR. ANDERSON: Our role is advisory to the staff, and if we feel like we have discovered something of sufficient import to make a recommendation to the staff for a licensing action, we would do that; but we are not in a position to require anything of the licensee.

MR. KERR: Well, I used "you" as part of the organization, since you are being employed by NRC, so I was using the term collectively. I recognized that ORNL doesn't have licensing responsibility, but you do pass on recommendations to the staff, and if you think it's serious, you would call that out.

MR. ANDERSON: Certainly we will, and that's why they're on this slide.

(Slide.)

In the sensor and transducer specific criteria, we'll jump to number four. There is a specific requirement for environmental qualification of all the instrumentation used. And then jump back to number one where here we are not looking so much at the survival qualification as we are the opportunities for misindication resulting from temperature damage or effects such as temperature variations in the lines or the delta Ps, is something we're looking at very carefully because it has potential for influencing the accuracy of the indication. And so we felt it appropriate to emphasize that a little bit.

Accuracy and resolution is an area that is elusive, to say the least. It's a difficult criteria to establish in terms of inadequate core cooling and even in terms of how accurately one needs to measure the water level in order to take action with regard to core cooling. And so we do not have hard and fast pass-fail numbers developed yet. We are approaching it in a more deliberate way and hoping for some interaction from the applicants.

MR. KERR: II.F.2 occasionally refers to a availability of 99 percent for various parts of this.

MR. ANDERSON: That's for the indication part, yes.

MR. KERR: Well, the indication part shouldn't be a lot more accurate or a lot less accurate than the rest of the system, should it or shouldn't it?

MR. ANDERSON: The 99 percent is reliability or availability rather than accuracy, I believe.

MR. KERR: Well, is there any relationship between availability and accuracy in your view?

MR. ANDERSON: Certainly they are related.

MR. KERR: My question really was going to be are you taking that into account in your efforts to evaluate appropriate accuracy and resolution? Did the 99 come from some sort of general agreement that that is an appropriate number, or is that going to be completely separate from your accuracy and resolution consideration?

MR. ANDERSON: I'm not sure I'm qualified to answer that, but I will attempt to anyway. The 99 percent, in my impression, came from what is practical in terms of computerized display systems and microprocessor systems that are anticipated to be used in the display end.

In the front end the actual sensors, the measurements, the penetrations and power sources are required to meet the 1-E characteristics of safety systems, so there is sort of a breakpoint between display, and that number of 99 percent was established to permit the use of computerized display systems.

MR. KERR: I'm not quite sure what it means becau- it talks about providing 99 percent availability for each channel. I'm not sure what "channel" means in this case, whether it means that one is going to have four or five channels so that the system reliability will be greater than that, or whether it means the display reliablity is about that.

Do you know?

MR. ANDERSON: My interpretation is that that is indeed per channel, so that for multiple channels you would expect a somewhat higher availability than 99 percent.

MR. KERR: But on a quantitative basis that has very little influence on what you're doing here with accuracy and resolution.

MR. ANDERSON: That's right. It is not directly coupled to accuracy-resolution. You can have very good accuracy and very poor availability and reliability or vice-versa.

MR. KERR: Well, why would one want to do that? I don't see too much point in having an extremely reliable sensor if the display system is not very reliable. Help me out.

MR. ANDERSON: There is some justification for it if -- well, it depends on the accuracy that one needs. I think probably the best example is the evolution of the protection systems.

MR. KERR: I didn't make my question very clear. It seems to me that in order to use information one has to know what it is. Now, if the display system is not very reliable, no matter how accurate and reliable the sensor is, I don't see that you can buy very much, and I must be missing something. It seems to me there has to be some coupling, a fairly significant one, between those associated reliabilities, or you are doing a lot of work on a sensor which will never be reflected when the information gets to the user.

MR. ANDERSON: Yes, Larry.

MR. PHILLIPS: Dr. Kerr, that's the reason for the backup display system. That would be used when the computer is down. And the philosophy on the reliability is that those components which are accessible during an accident and can be repaired, don't have to be 100 percent up; so the computer could be placed back into service, and in the meantime you would rely on the backup system.

MR. KERR: I'm not trying to argue the merits of the 99 percent. I'm trying to get some idea of whether one is associating the reliability of the system with the reliability of the display. It seems to me one cannot completely disassociate them.

MR. ZUDANS: You're saying the same thing. In other words, is anyone looking at the reliability and availability of the entire system from sensors to display?

MR. PHILLIPS: The answer is yes. When you say 99 percent, that means the entire system, the entire channel.

MR. ZUDANS: Not according to that text. That text said "display."

MR. PHILLIPS: We have redundancy on the rest -- well, it says "The primary and backup display channels should be designed to provide 99 percent availability for each channel with respect to functional capability." So it refers to the whole channel.

MR. KERR: I guess I'm still not asking the question very well. What I'm trying to do is get some idea as to whether this reliability requirement is coupled to some sort of total system reliability requirement or whether 99 percent was just sort of arbitrarily picked because one felt it could be attained for channels.

MR. PHILLIPS: The 99 percent was picked, as John said, because it could be attained for the computer displays, and we considered that the computer displays were accessible and could be repaired, and that the backup system would serve in the interim.

MR. ANDERSON: I think I understand the essence of your question. In the rest of the system beside the displays for which this number was specified to specifically allow the use of computing equipment -- the rest of the system is required to meet all the Class 1-E requirements which hopefully will achieve better than 99 percent availability. So the displays are the weak point of the system. Although there is not a number assigned to it, the rest of the system is expected to have higher reliability than the display.

MR. KERR: And that's because it's felt that can be attained and not because it's necessarily needed, I guess, because it must not be needed; otherwise, the computer systems would have to be better.

MR. EBERSOLE: All I see of this is it's just a convenience factor. You're going to have a CRT display so he can look at it from the front of the board or some place off one channel and read it until that fails, and then he's going to have to go to the real instrument someplace else, is that correct?

MR. ANDERSON: There is a requirement for a backup system of a diverse nature which will improve the overall reliability hopefully well above that 99 percent figure and make the display system then commensurate with the reliability of the overall measurement system, which hopefully is higher than 99 percent.

MR. KERR: What I read and what led me to ask the question is the statement, "The primary and backup display channels shall be designed to provide 99 percent availiability." I don't quite know what that means, because I don't know what redundancy exists. But my question really was is this in the context of a total system reliability, and I think what you're telling me, and it's not necessarily unreasonable, is that number was chosen because one felt it could be attained; and the rest of the system may be significantly more reliable because it is felt that better reliability can be obtained for it.

Now, it would strike me that in the best of all worlds one might ask what sort of reliability do I need for delivering information to an operator; and if the answer is 99 percent is good enough, then you don't require more than that for the total system. If the answer is 99 percent isn't good enough, then maybe you have to do something else but I realize we aren't maybe to that point yet.

MR. ANDERSON: As you pointed out, the 99 percent is per channel; therefore, the overall reliability of the display system is much better.

MR. KERR: I don't know whether it is or not, because I don't know how many channels are being required. I don't know anything about them. I don't have the total reliability specification.

MR. ANDERSON: The redundancy requirements are specified in 0737.

MR. KERR: In order to achieve what sort of reliability?

MR. PHILLIPS: The primary display channel is spoken of as a channel, and the backup display channel is a channel. Each are to have 99 percent reliability. If my memory is correct, I believe the required safety instrumentation redundancy level was pretty nearly 99 percent, too. I believe that that number happens to come out to about what we can do with a computer display system.

MR. KERR: Thank you.

MR. ANDERSON: Another troublesome area is the criteria for response characteristics: how fast should the measurement level system respond? Again, we have not yet developed hard and fast acceptable numbers, and what we expect in this area is the analysis of the applicants to show that they can detect the approach to an adequate core cooling, which generally means a decreasing fluid level, in time to take appropriate corrective action.

MR. KERR: Are you thinking about time constants of seconds, minutes, hours, microseconds?

MR. ANDERSON: I would expect it to be in seconds. Again, there's a problem here in defining the type of accident in which one insists that this work. I don't think anybody is expecting this to provide them useful information during a large break LOCA, because things are happening too fast for them to give them any useful information.

MR. KERR: I think you could almost use a dipstick with a large LOCA.

(Laughter.)

MR. ANDERSON: You're doing all you can anyway, and whether you know or not probably isn't much help anyway. So this is one of the things we have iterated several times with the staff, and we have not yet really established a hard and fast judgment criteria, but we expect to do it on a rational basis that says for a class of actions at least this will allow us the detection capability of decreasing water level, which will allow the operator to take appropriate action.

MR. KERR: In effect, what you would expect to do, to establish this you expect to look at some scenarios and try to establish how soon one needs to know something, or have you decided what approach you're going to use?

MR. ANDERSON: We have not made that decision firmly. That is one of the areas in which we have been iterating with the staff, and we realize there are problems of arbitrary specification of something that is meaningless.

MR. ZUDANS: Wouldn't it appear to be more appropriate to picture a number of scenarios, say here are the transients that I want to be able to follow with this instrumentation, and then derive the minimum requirements for your time constants, rather than taking an instrument and looking at the mechanistic characteristics and say here is the constant that this instrument can live with, and here are the transients that this could follow?

MR. ANDERSON: Yes. That is generally the approach we have been taking. For example, we have been looking at some LOFT and SEMI-SCALE data on the certain break sizes and the rates of changes of water level associated with those break sizes and trying to categorize these generally. But we are still in that process, and we have not established anything further.

MR. CATTON: Would most of this be part of the analysis presented to you by the applicant?

MR. ANDERSON: Hopefully it would be included in the analysis by the applicants, but we have not yet seen that kind of analysis from any applicant.

MR. CATTON: So you don't have a set yet?

MR. ANDERSON: We do not.

MR. ZUDANS: I guess the applicant would not do any more analysis than the criteria by which his analysis will be judged required?

MR. ANDERSON: I suspect that's true. If I were an applicant I would certainly take that position.

MR. ZUDANS: So you're kind of forced to set up the criteria before you see the results?

MR. ANDERSON: We hope to at least give guidance on our concerns. Whether we are able to establish hard and fast criteria or whether we will do that cooperatively with the applicants remains to be seen.

MR. CATTON: They would have to specify what analysis needs to be done, I think.

MR. KERR: Well, I certainly don't want to condemn all licensees to that category. It seems to me that if one took this requirement seriously, he'd want to make sure the system worked; and I believe there must be some people out there who feel that way.

So I would just hope that one might see some meaningful analyses. I'm going to still believe in virtue and things like that.

(Slide.)

MR. ANDERSON: Lastly, we have a category of accident and post-accident monitoring in which we have lumped some things related to the adverse effects on the measurement. Hopefully you don't reach core uncovery, but if you do, we are looking for the adverse effects on the measurement itself with the idea that we want to be able to reliably measure the water level after an uncovery -- that is, the recovery from an uncovery -- and verify the instruments are still giving us a valid indication after an accident.

MR. KERR: Excuse me, Mr. Anderson. Are these five things characteristics which the system is expected to indicate or incidents which it is expected to survive?

MR. ANDERSON: Survival.

MR. KERR: Okay.

MR. ANDERSON: Survival.

MR. KERR: Okay. Thank you.

MR. ANDERSON: In none of these would we expect it to detect. We simply want it to survive and provide reliable indication, at least after if not during this.

Number two is the effect of internals movements, including a flow blockage or anything which might involve damage to sensors internally that might destroy the ability of the measurement to be made after some limited accident.

Another problem may be water hammer or large pressure surges which may damage certain types of instrumentation, and in this case some may be more susceptible to this kind of damage than others. For example, I would expect the DP cell to be more sensitive to water hammer and pressure surges than a heated junction thermocouple.

We're not attempting to make a relative judgment, simply trying to establish some criteria for evaluating the validity under these circumstances.

Flow variations may occur for various reasons, and in fact, some of the Idaho tests indicate that there may be reverse flow regions during blowdowns in an undamaged reactor, and this may lead to errors in some types of measurements. And we are looking very carefully at this.

Some believe the void fraction itself in a two-phase system may affect the validity of the measurements to some degree, and we are also looking at this very carefully from a fundamental viewpoint.

MR. ZUDANS: One question. From your work to date could you identify a distinct superiority of one system as compared to others?

MR. ANDERSON: I would not want to make that judgment. I'm not sure it's even in our mandate to attempt to make such a judgment. We're hopefully looking at the adequacy of any and every system rather than trying to compare them.

Obviously we have compared merits, and there are advantages and disadvantages of all we've looked at, and some that haven't even been proposed that are some of our pets. We are in the instrument development business, too, and one of our favorites is unfortunately not very well along in development, and it has tremendous capability but isn't very far along in its development.

MR. ZUDANS: It's kind of strange. It is not human nature not to make choices. When you look at two things you immediately decide which one you want.

MR. ANDERSON: We have found advantages and disadvantages to both. For example, the delta P system obviously has the advantage of the continuous measurement level. It is subject to a number of errors that the heated junction thermocouple is not. The heated junction thermocouple measures level at discrete, so therefore its resolution is poor by comparison, but on the other hand is probably more reliable.

MR. CATTON: It also uses a heat transfer coefficient in essence.

MR. ZUDANS: Go on. You're doing fine.

MR. ANDERSON: I wanted to point out some of the things we are looking at, because we're very much interested in these characteristics, but I don't want to get into a position of comparing one to another at this stage. I don't think it's appropriate.

MR. ZUDANS: I understand we will have presentations on individual systems. What would be nice, if you could think about this and maybe tell us more. I like this kind of analysis because it tells what are the salient features.

MR. ANDERSON: Let me consult both with the timing and with Larry. I do have some preliminary results for judgments on these systems which I can go over for you if there is time.

MR. ZUDANS: If the Chairman permits, I would love to hear it.

MR. LIPINSKI: Some of the plants are sitting on the fence waiting to make a decision. Aren't they waiting for the evaluation on the various systems that are being proposed in order to decide which represents the best system that they should install?

MR. ANDERSON: I'm sure they are, and we'll be happy to share all the information we have that is not proprietary with anyone who comes to us.

MR. PHILLIPS: Dr. Kerr, may I make a comment, please?

MR. KERR: If it's relevant and succinct.

(Laughter.)

MR. PHILLIPS: Yes, I think there is a limitation in what we can do here. We are reviewing these systems to see what is acceptable. We review reactors for acceptability. We don't tell people hey, vendor X has the best reactor or vendor Y's reactor is safest or whatever. So I don't think we want to get in the business of saying one system is better than another as long as it's acceptable. I think that's up to the licensees to make that judgment.

MR. LIPINSKI: But along the same lines, if you have the pros and cons and you list what the good points and bad points are with respect to each system without drawing a conclusion, and someone else that looks at these evaluations can draw their own conclusion.

MR. KERR: I don't think we want to change policy. We've been told that if we get on the telephone and talk with Mr. Anderson, he'll give us all the input we need, and he'll swear he didn't say it in public, and he won't have said so. Maybe. I don't know, but --

MR. ZUDANS: Just for Larry's benefit, I didn't ask you the question, I asked him, so --

MR. CATTON: I might mention that in this document, NUREG-CP-0016, there is a table, and they list drawbacks and disadvantages for the various systems that one could use.

MR. KERR: Are there any further questions of Mr. Anderson?

Thank you, Mr. Anderson.

Mr. Phillips, does that complete what you wanted to say at this point?

MR. PHILLIPS: Yes, it does.

MR. KERR: I have scheduled next a presentation by Northeast Utilities, but I'm going to take ten minutes before we begin that presentation, if you will permit me.

(Recess.)

MR. KERR: What happened to Northeast Utilities?

MR. PURI: They're right here.

MR. KERR: Okay. We are ready to begin.

MR. PURI: Could I get the lights here maybe?

MR. KERR: Yes, sir. If I can find the right switch, you can.

MR. PURI: Thank you.

Do you want us to begin or wait for the rest of the panel?

MR. KERR: I want you to begin, please, sir.

MR. PURI: Okay.

MR. KERR: I'll tell them what you said.

MR. PURI: It's going to be short.

Dr. Kerr, members of the committee and the people present here, I guess the primary objective of --

MR. KERR: Excuse me. For the record you need to tell your name.

MR. PURI: I am Mr. Puri from Northeast Utilities. We are here to give our perspective, Northeast Utilities' perspective and not an industrywide perspective really.

We are actively involved in this program. We have been from the onset of this particular requirement; but I would just like to state a few sentences here or paragraphs of how we got to this stage.

Following the TMI incident there came about a requirement that we should have instrumentation which can provide a better status of the core cooling, i.e., the inadequacy of the core, if there is any heavy loss or inventory or exactly what is happening.

The initial requirement that we saw was look at the existing instrumentation and tell us if it is adequate to support an ICC event, and to look at additional instrumentation to see if it can further enhance the understanding of the operator with respect to the ICC event.

All of the utilities have in essence looked at the instrumentation. They have installed subcooling margin monitors and looked at the core-exit thermocouples and a host of other parameters, and the conclusion is that we do have instrumentation that does give the operator sufficient information on the status of an ICC event.

I would agree with Mr. Phillips that it could be unambiguous, but only to the extent that it does not give you a vessel level indication. I think in the initial phases of the development we talked more about vessel level rather than ICC event. If you look at 578 it talks about vessel level monitoring.

It's because we have adequate instrumentation that we are still operating. I think that is a very important aspect of this. We are looking for instrumentation that is going to enhance the operator's understanding of an ICC event.

The idea of providing additional instrumentation either for water level or for monitoring an ICC event is a noble idea, and I think Northeast Utilities in their 1-1-81 submittal essentially concurred with that statement.

What we are finding difficult to understand or really live with is that we are being asked to incorporate a system which has not been fully tested yet. We have real doubts whether it's going to enhance the safety of the plant in a real sense.

We have heard a lot of arguments this morning, and I think you posed some very interesting questions on whether we're going to create problems rather than solve problems. If you put in a DP cell system or heated junction thermocouple system, both these systems inside the reactor are excellent. I think within the confines of the reactor both systems give you good water level indication, but you have to look at the total system, because in order to work in conjunction with other instrumentation -- there is no idea in anyone's mind as to how exactly this instrumentation will be used.

Without such basic understanding of what we're going to do with this piece of information, it seems hard for us to understand why we're being asked to install it. We are not being irresponsible I think as a utility. We have instrumentation, and we are supporting a lot of R&D effort in the industry. We are supporting the development of the heated junction thermocouple system. We have some doubts about that system as to what exactly we will do with the information, the procedures, the reliability of the whole system.

We pose an important question: What happens if one channel fails, because if this is supposed to assess existing instrumentation and help the operator establish the status of the reactor coolant, I don't think those questions have been answered, quite frankly.

I have a few points I have made with respect to the limitation of this instrumentation and its limited range of application. I think we fully understand this is not a system which is going to be relied upon for a broad range of LOCA events. We are talking about very small break LOCA events, events where the operator can actually take some action. For a fast event, he just sits and watches, I think, and hopefully things go better.

For the small break LOCAs are we going to create some additional LOCAs? That is the part which was talked about this morning. We have looked at the failure mode analysis of the system, and I think we should.

The next item is the practicality of installation. It seems fine that we should install a system. The practicality is another question. If we decide to go with a heated junction thermocouple system, it poses some severe hardships. You have to go to a power plant, make modification and installation into a reactor. Chances are you may never use this piece of hardware for the life of the plant. And yet we are going to spend a lot of money, possibly have some shutdowns as a result of this instrumentation over the life of the plant; and I think we should ask ourselves these questions, how useful is instrumentation.

The last one is the availability of --

MR. CATTON: When you make this kind of an assessment, how useful will this instrumentation be, do you keep in mind TMI-2 and what was happening there, and what would you do if you had that piece of information?

MR. PURI: Exactly, sir.

MR. CATTON: You do that?

MR. PURI: Most certainly.

MR. CATTON: And so far your conclusion has been that none of this would have helped you --

MR. PURI: I think we have looked at -- in TMI-2 there was information about core exit thermocouples. What he did not have was a subcooling margin monitor. We have that. We have installed one. With respect to operator procedures there was information, but he didn't rely on it.

MR. CATTON: There was information at a distance.

MR. PURI: The core exit thermocouples, we have -- I think there is agreement among most of us that we will be utilizing that piece of information in support of a small break LOCA; so that piece of information which was available to the operator was really not being utilized by him. It was telling him that things were happening inside the core, but it was totally ignored.

MR. ZUDANS: Well, what you're saying is equivalent to this statement that with already installed instrumentation in addition to what was in there before, you could have been in a much better postion in TMI-2.

MR. PURI: I think we are, really. Really, I think all --

MR. ZUDANS: And you wouldn't need the physical water level, an unambiguous indication.

MR. PURI: I'm not sure if I understand the last part of the question.

MR. ZUDANS: You do not believe that you need an unambiguous water level indication.

MR. PURI: Maybe I didn't clarify myself. I would not go that far. I definitely think the idea of giving an operator an unambiguous indication of an ICC event, whether that be water level indication or any other form of instrumentation indication, which I do not know what it is, quite frankly -- I think that would be useful if you have absolutely, without any reasonable doubt it is an unambiguous piece of information, but can you really have one?

The two systems that you're going to hear about this afternoon, I think we should question these two systems and say are they really going to be unambiguous over the full range of operation that we talked about.

MR. ZUDANS: So you're really not questioning the need but the capability to provide such instruments.

MR. PURI: Certainly. And I'm questioning the fact that if you're not going to get some realistic gains in safety, maybe we should step back and look at our original requirement. There is nothing wrong in admitting that what you asked may be rather difficult to meet.

I don't think that many utilities who have agreed to provide such instrumentation, we, being one of them, have made a statement that we have agreed to install a system by any given date. We have agreed to support the development of a system. Our evaluation has concluded that any given system is probably going to solve our needs better than the other but beyond that I don't think we have made any commitments. We cannot make any commitments and still be responsible engineers.

I think after having talked about this, the practicality, and about the adequacy of this particular instrumentation system, I would like to talk about schedules. The existing schedule is a 1-1-82 installation date. I really think that this is going to be impossible to meet with the current state of development of instrumentation systems.

The testing that I have seen that is being done to date to some degree is limited. It certainly will not be completed in a time frame that would allow us to install this system. One may say that testing will be completed the day before we're supposed to have the system installed in the plant, but certainly you don't make plans for installation on the day before. You make it a year ahead. And it's not prudent to start making plans a year ahead, start preparing for this particular event and then find out we don't think the system is reliable.

MR. KERR: In our discussions with Mr. Phillips the impression I got from Mr. Phillips' comments was that licensees might install the system by 1-1-82, test it later, and even later write an evaluation, and even later than that get a staff SER, and then somewhere around July of '82 it might be incorporated into technical specifications.

Is that your understanding of a possible schedule?

MR. PURI: Yes, but I have difficulty --

MR. KERR: I just want to make sure that we both understood Mr. Phillips to mean the same thing.

MR. PURI: Yes, I think we do understand that.

MR. ZUDANS: I have some problems. When you said no utility has committed to installation of this instrumentation, and that's not what Phillips says. There are 16 that committed to install it.

MR. KERR: He said Northeast Utilities.

MR. PURI: I'm talking about my utility.

MR. ZUDANS: Sorry.

MR. PURI: For the record if you're interested, we do have both Westinghouse and CE plants, and our evaluation was since the instruments themselves were not tested, our evaluation had to be beyond the reactor region itself. We had to evaluate the system based on the reliability, how reliable would their system be against another.

We did our own failure mode analysis, and the conclusions were that the electrical cable is probably far more reliable, at least the way we understood it, than the tubing would be. That's not to say the tubing cannot be made reliable, and I think Westinghouse is working to do it.

I'm not here to oppose any particular system, but we don't have any experience on the reliability of tubing. We are certainly now getting experience on the reliability of cabling. The qualification of cabling is a rather new thing. That is important.

MR. ZUDANS: I can see how you would not want to install a system where you are not certain that it will do the job.

MR. PURI: That's right.

MR. ZUDANS: And from what you feel now, it would be premature to install anything until it's really fully tested, because you just don't know whether it will do the job or not.

MR. PURI: I will go a step further. Not only fully tested, but we also should know what we should do with that piece of information. Are we going to operate a plant with that? What are we going to do with a piece of ICC information that the operator gets. Where are the plant positions? Those are important aspects of improving plant reliability.

MR. KERR: Again I have to refer to our earlier discussion, but my impression was that the licensees and the NRC staff were together developing procedures and eventually would develop technical specifications.

MR. PURI: Sir, we are working towards that goal. In fact, we are supporting development of the heated junction thermocouple system as part of the CE owners groups.

MR. KERR: No. I'm talking about procedures, not thermocouples. You said there were no procedures so you wouldn't know who to use them, and I thought Mr. Phillips indicated that he expected procedures for use of these systems to be developed as part of the total process.

MR. PURI: Maybe Mr. Phillips can shed some light on this. I am not aware of any guidelines from the Commission as to how this system is to be used.

MR. PHILLIPS: Well, both of the systems that have been proposed, guidelines have been submitted for use of the systems. Guidelines have been submitted, procedures have been developed at individual plants in accordance with those guidelines, and they will be reviewed exactly the same as were their proposals for use of existing instrumentation in the interim.

MR. PURI: We have submitted, I think -- I shouldn't say "think." I'm pretty confident about that. Our documents address the cooperation of the existing instrumentation in support of that.

MR. PHILLIPS: Yes, but by the same procedure when you submit a new system or the additional instrumentation system, we will expect you to submit guidelines and procedures for its use. Those guidelines are being provided already.

MR. KERR: I think this is sort of like one has faith in the springtime. One plants flower seeds, waters them, fertilizes them, and they grow, and flowers blossom.

MR. PURI: But I think you know what to do with the flower when it grows.

(Laughter.)

MR. KERR: Then you put a little horse manure on and it helps things.

(Laughter.)

I mean what one has to expect is that as one learns more about the instrumentation and the way it works that the procedures will be developed. I mean, isn't that logical?

MR. PURI: It is, and to some degree I tend to agree with you but --

MR. KERR: I'm assuming that you were being candid when you said that you thought a system that really would work would be of assistance to the operator.

MR. PURI: I totally agree with that.

MR. KERR: If that's the case, I would guess you could develop some appropriate procedures. I mean, after all Northeast Utilities has had a good bit of experience up to now in operating reactors.

MR. PURI: Certainly we do, but not knowing exactly what --

MR. KERR: You have good engineers. You don't know yet, but clever engineers working with operators can devise procedures.

MR. PURI: The same clever engineers I think said in our last submittal that we have adequate instrumentation right now, but yet we are being asked to provide additional instrumentation.

MR. KERR: But I'm assuming that you became convinced that there existed an unambiguous system which you said, I think, that you would find quite helpful, good idea. You aren't sure it exists yet, but if you became convinced it existed, then I bet you could develop a procedure. I'd be willing to bet on you.

(Laughter.)

MR. PURI: I don't doubt at all that we can draw up a procedure. I'm just not sure as to what the intentions of the Commission are, what they would intend to do with that.

MR. KERR: The safe operation of that reactor is not going to be determined by the Commission; it's going to be determined by you guys. Now, the Commission may get in your way on occasion; they may assist you on occasion. But if that instrumentation system is to be any good, you guys are going to have to understand it and use it. It's as simple as that.

MR. ZUDANS: In fact, you already did that when you made your submittal saying this is what we need it for, that's what we have, and then I asked the question before you admitted that if you had a reliable water level indicator, whether you could believe in its indications under all conditions, then it certainly would be a good addition to whatever you have now.

MR. PURI: It will complement what we have right now.

MR. ZUDANS: So you have no argument against instrumentation.

MR. PURI: Maybe time will tell what I'm talking about.

MR. KERR: If you're arguing against lousy instrumentation, you have at least two allies and maybe five.

(Laughter.)

MR. PURI: I think right now we are not sure about it. Well, I hope that I am -- I am not very familiar with the way the ACRS interacts with the Commission, but I think the point to be made here is that we do not have a reliable instrumentation system for providing or supporting an ICC event, either entry into or recovery from.

Such is certainly not available today, and it seems that we should recommend that the instrumentation dates, installation dates be more consistent with the development efforts.

MR. KERR: From what you've seen up to this point what do you think would be a realistic implementation date?

MR. PURI: Well, it can't be 1-1-82. I think we've told the Commission so. It's hard for me to tell you a realistic date. That's why we did not commit to one, because the program is still being conducted by various vendors. All they're going to do is conduct a program for either DP cell or heated junction thermocouple as it's going to perform inside the reactor. Outside of that you have to complement it with other pieces of instrumentation like how is the heated junction thermocouple system going to work in conjunction with the core exit thermocouples or the subcooling margin monitor. All these instrumentations go together to form an ICC instrumentation.

That phase we have not done yet. We have not evaluated -- we have not completed our evaluation at least to at least guarantee ourselves that we are not going to create a problem rather than solve one. I think we are beyond that stage regardless of what industry tells you.

MR. KERR: You guys have a few other things to do than just evaluate these thermocouples and DP cells, I recognize, but you can conduct a foot-dragging evaluation, or you can conduct an expedited evaluation. Which kind are you working on?

MR. PURI: We're working on a very expeditious evaluation. In fact, I personally chair a committee which is looking at installation of the heated junction thermocouple system in the Westinghouse plant. I'm not saying we're going to install one, but we're certainly looking at the capability.

MR. KERR: Do you think it's realistic to expect installation say by 1986?

MR. PURI: I hope we will have answers whether the system is any good or not by that time definitely. I think we will have answers before that.

MR. KERR: By '85?

MR. PURI: We are looking at our completion of the testing inside the reactor to be completed toward the latter part of this year. We're talking about qualification programs to be completed towards the end of '82, and I think installation dates have to be after that.

MR. KERR: So it might even be as early as 1984 realistically.

MR. PURI: If the system was developed, we would look at '84.

MR. KERR: So you and the staff are only two years apart at this point.

MR. PURI: We're only three years apart if such a system can be developed that definitely enhances the safety of the plant. We're talking about millions of dollars here and more millions of dollars if the system is useless, because we will be having unnecessary shutdowns as you have indicated.

MR. EBERSOLE: Just a brief question. In view of your comments, again although I doubt that we will ever see a large LOCA but maybe an intermediate one, if we have a severe LOCA, as you know, we are well designed to cope with this thing in the short term, conceding a certain degree of failure of equipment.

The analysis proceeded to a point where everybody agreed that if you got "X" GPM flow into the reactor vessel, you would surely cool it and there would be little or no damage.

Are you well equipped now with procedures to stabilize this thing say a month later, then go into a realistic problem as TMI-2 had to do to really shut down such an accident and attempt to recover such aspects, such portions of the project as would be worth recovering without instrumentation of this sort?

Are you ready to say oh, I can reduce core flow down to 10 percent of what I originally needed or I can begin to cycle the pumps and go to evaporative cooling and treat the now quiescent reactor more or less as a boiler? And I think the reactor -- take the vessel head off, et cetera, et cetera.

Are you that far along in your planning?

MR. PURI: I personally don't feel qualified to answer that question, sir. I trust we are since we are operating, and I trust we have looked at that.

MR. EBERSOLE: Is the staff aware of any plans that they have in that connection? This is longterm activities after a rather significant loss of coolant accident.

MR. PHILLIPS: I am not aware of them.

MR. EBERSOLE: I'm not either. I don't think they exist.

MR. PURI: I am personally not qualified to tell you how we would respond to such an accident.

MR. EBERSOLE: It is at this time that one might say this is the final 1 percent of the total investment you put in the ECCS equipment to make it functional.

MR. PURI: Are you saying this instrumentation would complement such an accident?

MR. EBERSOLE: It wouild complement such an accident like that.

MR. CATTON: Some of it might even be necessary.

MR. PURI: Would you say that following a large break LOCA we are really talking about essentially the core remaining covered?

MR. EBERSOLE: Yes.

MR. PURI: And I think we have recognized that as an important facet, and I think in our evaluation we're now setting out the acceptance criteria for the survivability of instrumentation.

We have said that this instrumentation should give us an indication of the water level at least up to the hot legs following an accident. In fact, we've taken some additional steps to avoid trying to design the portion of the hardware into which the system is incorporated, to the same guidelines as we designed -- we have Section 3 requirements for designing internals, but really we are now talking about survivability of the hardware going into a plastic range.

What we are primarily interested in is are we going to get an appropriate signal, and here I'm talking about a heated junction thermocouple. I'm sure similar holds for the DP cell. We are testing it for that reason.

MR. EBERSOLE: Do you have some use for it in the long term following a major accident?

MR. PURI: We will have core exit thermocouples.

MR. EBERSOLE: They only tell you that you are where you shouldn't be.

MR. KERR: Are there other questions?

In the earlier part of your presentation you made the statement that chances are you would never have to use this system, I think.

MR. PURI: I hope we don't.

MR. KERR: Was that just a casual remark or have you actually gone through an analysis of accident scenarios using something like the WASH-1400 approach and have calculated the probability that you will get into such a situation?

MR. PURI: I wouldn't say it was a casual remark, but then I would not say an in depth study has been conducted of the type you are talking about. But I would say there have been significant studies done in the area of fraction mechanics which lead us to believe that a large break LOCA is highly improbable, if not definitely improbable.

MR. KERR: Now, wait a minute. Are we talking about a large break LOCA or a small break LOCA?

MR. PURI: I did not mention large break, but further investigation into the fraction mechanics utilizing that as a tool -- there is some indication that most of the primary piping that we're talking about is not going to fail in the mode that people are expecting it to.

MR. KERR: We have had enough failures already of various kinds of pipes, valves, seals.

MR. PURI: Valves are a different situation.

MR. KERR: But any of these can produce a small break LOCA; that is, a small flow loss of coolant.

Now, are you prepared to say that the chances are very slim that that will occur in your plant?

MR. PURI: No. I did not say that.

MR. KERR: Well, I wouldn't either, so I would think you would want to be prepared to deal with that eventuality. Whether this particular system will do it or not, I think you have legitimately raised a question.

Okay. I misunderstood you. I thought you were saying that that eventuality was very small.

MR. PURI: We said the range of application of this type of instrumentation for very small breaks where you have a very slow transient like a PORV leakage, you're talking about very slow transients really similar to what you saw at TMI-2.

MR. EBERSOLE: I believe you said that all of your plants are PWRs?

MR. PURI: We have a BWR, our Millstone-1.

MR. EBERSOLE: And it depends very heavily on level indication, and you are not looking at it in the perspective as to what might be useful there for PWRs in emergency modes?

MR. KERR: Do you understand that question?

MR. PURI: I don't comprehend that question.

MR. EBERSOLE: I'm saying that type of reactor is heavily dependent on level indication for a variety of things, including automatic functions. That's in the normal mode. It also relies on this in the emergency modes to ensure adequate core cooling.

MR. PURI: It does.

MR. EBERSOLE: In the event your PWR's descend-- this might be argued about PWR vendors to that level of operation --that is a comparative situation to your present boilers that you have in your Millstone plant. You may need level instrumentation.

MR. PURI: I think we would have indication of any abnormality in the coolant for the subcooled margin monitor. The PWR obviously cannot rely upon it.

MR. CATTON: Doesn't that give you an indication of the reliability of delta P for pressure level or liquid level?

MR. PURI: I stated earlier that we had no doubts that a DP cell would give you a good indication of water level, and it is being used in the industry.

MR. CATTON: Unreliable.

MR. PURI: Most unreliable. The question here is not the DP cell, not whether it can measure water level. The question is of the system performance and the same holds true for the heated junction thermocouple. That also is capable of giving you water level. It has demonstrated so in the various tests, and I think LOFT in itself uses a thermocouple type system for water level indication.

There's no doubt either of the systems are going to give you water level indication. How ambiguous or unambiguous it's going to be -- you've got to look at the whole system. That's really important.

MR. KERR: Other questions?

Thank you, sir.

MR. PURI: Thank you very much.

MR. KERR: We next show a presentation by Combustion Engineering.

MR. LONGO: Good morning, and I'm happy to say good morning. I think we are somewhat on schedule.

My name is Joe Longo, and I usually make presentations before you on emergency core cooling systems. Today I'm talking about inadequate core cooling instrumentation, so you just change the first and last letters of the acronym. The middle two are the same.

MR. KERR: I'm glad to know that, because when I first saw that acronym I was sure it was an exotic Italian wine.

(Laughter.)

MR. LONGO: I may go into business.

(Slide.)

I wanted to invent another acronym because the term "inadequate core cooling instrumentation" in my mind is not descriptive of what we are trying to do. What we are trying to do with the inadequate core cooling instrumentation is to provide instrumentation to assist the operator to prevent an inadequate core cooling incident. These instruments are supposed to work while we still have adequate core cooling, in my mind.

I will use the ICCI acronym because it's generally accepted and will be easier to transfer the information, but I would like to leave you with the impression that the instrument is to prevent getting into that situation.

(Slide.)

The agenda for the CE presentation is I will present an overview of the CE approach. The numbers in parentheses are the approximate times that we intend to take. Mr. Menzel will present an evaluation of how we got to the position we have, and then Mr. Neuschaefer will present the actual hardware description and the testing process.

(Slide.)

I thought I would start this overview with a list of the requirements. NUREG-0737 is the one that is most specific. The other NUREGs are dealt with on a peripheral basis and are required by NUREG-0737.

(Slide.)

I think I would like to spend a few minutes talking about how we view the approach to and the leaving inadequate core cooling.

We have defined these different intervals. Interval 1 is the primary system coolant reaches saturation conditions. This should be the point at which the operator should be alerted that things are not going right.

Interval 2 is a fallen level of the coolant in the upper plenum.

Interval 3, 3-A and 3-B are th- fallen core level and the rising core level.

And Interval 4 is the rising level of coolant in the upper plenum.

If you have instrumentation to cover these intervals, then you have adequate instrumentation for monitoring inadequate core cooling.

(Slide.)

The inadequate core cooling interval instrumentation that we will be talking about toda; is the subcooled margin monitor which will give an indication of the degree of subcooling in the reactor system, so it covers Interval 1; the reactor vessel level measuring system which will give a liquid level above the core which will cover Intervals 2 and 4; and then we rely on the core exit thermocouples to cover Intervals 3-A and 3-B.

MR. CATTON: Is that unambiguous, the 3-A, 3-B?

MR. LONGO: I don't know what you mean, sir.

MR. CATTON: If I'm just measuring cc-olant exit temperature and I do a simple calculation, it's a heat transfer coefficient and probably a number of other things I could think of, and I could get the same exit temperature a number of ways.

I could vary the amount of steam flow that's coming up from the system. That would cool it if I increased it. Decrease it, it could get hotter and you could interpret that as rising and falling level.

MR. KERR: Could I reinterpret your question and just say demonstrate to me during your presentation that that's unambiguous? Would that be satisfactory?

MR. CATTON: You could reinterpret it that way, but then he might get off on the wrong tangent.

MR. KERR: No, but that's what you really want.

MR. CATTON: That's right.

MR. LONGO: Let me try to answer the question directly. If the level is falling, for example, in the system, the core exit thermocouples will always continue to read higher.

MR. CATTON: That's correct.

MR. LONGO: So you will always see that the level has fallen by watching the exit core thermocouples unambiguously. I think the case you might be referring to is I happen to look at it after the accident occurred when it was at full power, as a case where the accident appeared when it was at a different power, you might have different levels by the core exit thermocouple.

MR. CATTON: If I'm seeing they're partially uncovered and stable, now if I see the exit temperatures start to rise a little bit, I can think of several ways that could occur. It could occur just because of a decreased steam flow.

MR. LONGO: With decay heat, sure.

MR. CATTON: I could see it falling, and I could think that gee, I'm recovering level; but what it could be is that I've pushed the liquid up a little bit. I've generated a lot of froth, and I've cooled it down. I've given you two examples now.

MR. LONGO: The first one I can picture with decay heat over a long period of time.

MR. CATTON: The second one is if you were to somehow get a burp of a little bit more water up in the core, you shove the water up to where the pins are hot, you get a lot of entrainment. You think gee, I've really got it, that temperature is falling very fast; but really you don't. You may pick it up later, and that's why I asked the question before, what is meant by unambiguous, easy to interpret.

I don't see the core exit temperatures give you unambiguous, easy to interpret interpretation of inadequate core cooling.

MR. LONGO: I guess we're on opposite sides. I believe it does. I believe if the operator is looking at a trend meter on the core exit thermocouple, he will be able to tell if his core is getting into trouble.

MR. CATTON: You have three variables that you don't know very well. One is heat transfer coefficient; the second is liquid level that you are trying to infer; and the third is the actual flux of steam and so forth open to the dry region of the core.

You don't know those three things. If you don't know them, you don't have an unambiguous core exit temperature, because all three play a role.

MR. LONGO: I may not know the actual values of those, but I do know the trends they will go to.

MR. CATTON: That's true. And if the only requirement is gee, I'm getting into trouble or gee, I may be getting out of trouble, then you're all right. But I don't know if that's the requirement.

MR. LONGO: That's what I'm really looking for here. I want to tell the operator that whatever he's done has helped him or he needs to do more.

MR. CATTON: I give you an example where it looks like it has helped him, but it may not.

MR. LONGO: I think if you're talking about the burp, I think he can correct himself. The one with decay heat, that's really a long term type of thing, and I believe at that point the steam flow won't change it that much.

MR. KERR: Help me a little. How is the operator going to get in trouble with your second example? He is failing the thing and he sees the temperature go down, but he doesn't stop failing because it's still above water temperature, so what trouble does he get into?

MR. CATTON: If the approach you take once you got a problem is you just open up all the valves and let it rip, then my concerns go away.

MR. KERR: That's not the approach I take, but the approach I take if water is below the top of the core is to let water flow in.

MR. CATTON: If you want an unambiguous, easy to interpret indication of inadequate core cooling, you're not going to get it. All you'll know is you're in trouble.

MR. KERR: Easy to interpret and unambiguous I would interpret operationally in that it's information that an operator can use. It seems to me under the circumstances you have described -- I may be wrong -- that the operator would continue to fail and unambiguously he would continue to fail.

Now, what am I missing?

MR. CATTON: Well, I guess you have no idea how bad off you are for one thing.

MR. KERR: But what you want is information you can use until you either do something or do nothing, I think.

MR. LONGO: That's the point. I think if you say do I know the level where it is, I have no argument with your concern. But I asked the question why do I have to know the level? As an operator I think I want to know am I getting into trouble, or am I recovering from trouble.

MR. KERR: My approach may be all wet, Ivan. It's not a didactic question.

MR. CATTON: It's not really clear to me what this means either, and if I interpret it, then I would like to know if --

MR. KERR: Among other people, ACRS is guilty of this language, so you probably ought to ask that committee some time what it meant. That is perhaps part of the problem, but I would interpret "operational" to mean that you would want information on which you could act, but that's a very private interpretation maybe.

MR. EBERSOLE: I can see what Ivan considers ambiguous the operator might not, because you're going to take the same action anyway.

MR. CATTON: If that's what the staff intended, I have no problem.

MR. KERR: The question is what should we intend if we are trying to avoid difficulty. I think you're saying that that would be your approach.

MR. LONGO: That's correct, yes. I believe that what the core exit thermocouple will do is show the operator a level change.

MR. CATTON: One thing it doesn't do for him is tell him how bad off he is.

MR. LONGO: I think it does better than any other instrumentation I've done.

MR. CATTON: I think level plus core exit temperature does a little better job.

MR. LONGO: What you really would like to do is measure th clad temperature.

MR. CATTON: Or the way I could get an estimate of the heat transfer coefficient and know whether it's increasing or decreasing by what I'm doing. And I don't know that by just having core exit, because these other variables can play a role as well.

MR. LONGO: I don't know what the level all the way to the bottom of the core may buy you. If, for example, the accident occurred from hot shutdown, you could go all the way to the bottom of the core and not be in too much trouble.

So you would see a bottom level of the core, and you might alarm the operator. The core exit thermocouples, on the other hand, would know that. On the other hand, if the accident occurs from full power, then if you drop four feet or so into the vessel, you're going to get into a degraded core condition. The core exit thermocouples will tell you that, whereas the level will just tell you where you are.

MR. CATTON: That's true. Level without the core exit temperatures is equally bad.

MR. LONGO: I'll accept that level is an additional piece of information, but if you're really trying to avoid inadequate core cooling, I personally believe that core exit thermocouples are the best instrumentation that I know of now.

MR. CATTON: I would agree. You surely can't do without them

(Slide.)

This started out to be an overview.

(Laughter.)

I will just throw this on the board and mention that we use the combination of RTDs and pressurizer pressure for our subcooled margin measurement. We use heated junction thermocouples located in the probe in the upper plenum to measure the level in the upper plenum, and we use core exit thermocouples to measure the effect of the falling level below the core.

MR. LIPINSKI: There are eight of those heated junctions per probe up there. What is their spacing?

MR. LONGO: That is plant specific.

MR. LIPINSKI: Are they a foot apart, two feet apart?

MR. LONGO: About a foot apart.

MR. LIPINSKI: Thank you.

(Slide.)

MR. LONGO: I would like to leave you with the impression, however, that since we --

MR. CATTON: How do you deal with the anticipatory statement that's in the requirements in 0737?

MR. LONGO: Thank you. I think I can show it with this next slide.

(Slide.)

The next slide I have on the board here takes a typical small break accident where the two-phase level is dropping, and it drops below the core. And what I want to show you is what the three types of instruments would record and what the operator might see.

At the early stages he would see that the subcooled margin monitor is going to reflect that he is at saturation Interval 1. That's anticipatory as far as I am concerned. He now knows that he's got something that is out of the ordinary.

Now he gets into a saturation condition and his subcooled margin monitor is ambigous, and you don't see any effect here; and then the heated junction thermocouple system in the upper plenum will start to show a core level change.

MR. CATTON: What will the heated junction thermocouple show if the pumps are on and you just start to get flow?

MR. LONGO: It will show a level change. I think with the pumps on there is some delta P in the upper plenum we have to consider, and one of the reasons I mentioned how we set up the locations of the thermocouple spacing is that effect.

I think right now -- right now, of course, the rule is that when you reach SAA signal, you trip the pumps. We are considering the fact that if the operator forgets to trip the pumps, what will he show.

MR. CATTON: I don't think they show you a whole lot if you've got pretty good flow.

MR. LONGO: They measure a degree of heat transfer, but they are really a monometer. What we have is a separator tube, and so the heated thermocouples will see a level, a collapsed level because we have a separator tube on the outside, and so what they are measuring then is heat transfer between all liquid and all steam, and it's really a pressure probe in that sense. So it isn't an increase in flow will increase, and you will see a difference; what we are really measuring is the level.

MR. KERR: Could I ask -- this may be premature in your planning, but Mr. Phillips and I discussed the alarm.

If you were at the point at which you were alarming your system, would you alarm when the saturation meter becomes saturated, or has your thinking gotten that far along?

MR. LONGO: I would like to defer that to Mr. Neuschaeffer's presentation.

MR. KERR: Okay. Sure.

MR. LONGO: While we are at saturation and while the upper plenum has been falling, the level has been falling, core exit thermocouples have been following the saturation line.

Now, the level falls below the core. The core exit thermocouples record a degree of superheat. As the operator has taken some action -- in this case it was assumed to increase the HPCI flow -- the core level starts to rise. The core exit thermocouples record a decreasing level of superheat. The level rises into the upper plenum, and you will see a level here. That is Interval 4. So the operator then can determine that the subcooled margin monitor, the heated junction thermocouple system and the core exit thermocouples, he can determine all the intervals.

(Slide.)

MR. LONGO: I would like to define a CE-recommended ICC equipment.

I think at this point I should mention that the functional requirements in some of the studies on ICC were funded by the CE Owners' Group. The hardware designs themselves are CE's and after Mr. Puri's talk I will mention quickly that what you are hearing from me are CE's opinions, not the owners'.

The CE-recommended ICC equipment, then, would consist of the following sensing devices: pressurizer pressure sensors; hot and cold leg RTDs; upper plenum thermocouples; the heated junction thermocouples; and core-exit thermocouples. Inside our heated junction thermocouple probe we not only measure the level with the heated junction but we also measure the temperature in the upper plenum.

If you want to look at what I will call interval instrumentation, the subcooled margin monitor is made up of the RTDs, the upper plenum thermocouples and the pressurizer pressure, together with a processor to determine that you are or are not at saturation. So you can buy, as people have, just this instrument alone.

The reactor level monitoring system consists of a heated junction thermocouple and also, with a processor, you can just buy that particular instrumentation and the core-exit thermocouples.

CE, in terms of system processor and display, has a qualified safety parameter display system and a critical function monitoring system. And we offer this together with the interval instrumentation as our recommendation for an ICC system.

MR. KERR: Excuse me. What is the significance of the term "qualified"?

MR. LONGO: It's qualified in terms of safety grade.

MR. KERR: Would you come to a mike, please, sir, and give us your name?

MR. NEUSCHAEFER: My name is Carl Neuschaefer. I am going to cover that in a presentation. But basically the qualified safety parameter display system is that the 1E portion is qualified to the 1E standards and so forth.

MR. KERR: Thank you.

MR. LONGO: Finally, part of our recommended ICCI system is the operator. And in those terms we believe ICC guidelines and training is necessary.

(Slide.)

MR. LONGO: I would like to then summarize the overview with this activity matrix chart.

Basically, you have a cross here. The subcooled margin monitor, the heated junction thermocouple, the core-exit thermocouples, interval instrumentation, safety parameter display and the critical function monitor system, as the process and display instruments.

And along the side here is the development phase -- the hardware design, the hardware itself, the qualification, II.F.2 documentation, operator guidelines and training.

And across here is the position we are in at this present time. The crosses mean that the hardware design is more or less complete. The reactor vessel level measuring system, the first one, is scheduled to be delivered in '82, along with the safety parameter display system and a critical function monitoring system.

MR. KERR: When you say the first one is due to be delivered -- to whom? To a purchaser or to be available for you to test or --

MR. LONGO: To a purchaser.

MR. KERR: And is that in January of '82 or December of '82?

MR. LONGO: It's before June of '82, hopefully.

MR. KERR: Okay.

When it says operator guidelines to be modified, does that mean --

MR. LONGO: To be modified to incorporate --

MR. KERR: So the guidelines that may exist need to be modified to include that?

MR. LONGO: That's correct.

MR. KERR: So in effect the guidelines that have to do with this are to be developed?

MR. LONGO: That's correct. There are ICC guidelines at present. We use this type of equipment -- if we used it they would have to be modified.

MR. LIPINSKI: This activity matrix doesn't show any interaction with NRC. What happens if you do a hardware design -- at what point do you interact with NRC and have to go back to the drawing boards?

MR. LONGO: We have interacted with NRC at least three meetings that I am aware as we have progressed.

NRC has not finalized the requirements and there may be changes. And we are quite concerned that we get involved quickly before this so we know the changes.

MR. LIPINSKI: There may be some recycling as you go through each step in this matrix.

MR. LONGO: Hopefully we don't expect any big surprises. We have talked to the NRC. Hopefully we are tracking them.

MR. ZUDANS: I guess you have said that you know exactly what you need and you also know what you need it for and how you are going to use it. Is that a correct statement?

MR. LONGO: I didn't get that.

MR. ZUDANS: And also how you are going to use that?

MR. LONGO: I believe so, yes.

MR. ZUDANS: The previous speaker was completely lost on that point. How come you are so much more advanced?

MR. LONGO: I can only ask for myself.

MR. KERR: I think that was a statement that was a statement and not a question, wasn't it?

MR. ZUDANS: But it's a large discrepancy. Why is it that one feels he doesn't know what he needs it for?

MR. KERR: Some people lead, some follow.

MR. LONGO: I think the perspective is certainly different between a vendor and a utility. And he has an approach to things and we have ours.

MR. ZUDANS: Maybe I misstated. Maybe you know what he needs and not what you need.

MR. LONGO: I would let him speak to that.

MR. ZUDANS: Okay, and he may not take that. Okay.

MR. KERR: Does that complete your overview?

MR. LONGO: Yes, and now I'd like to introduce Mr. Menzel.

MR. KERR: Let me make certain there are not any further questions. Are there? I guess there are not.

Thank you, sir.

MR. MENZEL: My name is Gerhard Menzel. I work for Combustion Engineering in the ECCS Analysis Unit, and my presentation will give you an overview of a study which we have done to evaluate the use of various instruments for the purpose of detection of inadequate core cooling.

(Slide.)

In my presentation I will cover, specifically, four items -- definition of ICC, the general requirements for ICC instrumentation. These two topics basically set the framework under which we did the evaluation of the instruments.

The third item is a summary of the actual work which was done in the study, namely the evaluation of instruments. And in the fourth item, this is which instruments -- the instruments which we selected for our ICC instrumentation system.

Essentially it's the sensors that go in the system, which was shown in the overview presented to you.

MR. LONGO: Gerhard, I've been told from the back they can't hear you.

MR. MENZEL: Is that better now? Okay.

(Slide.)

Let me start out with a definition of ICC. As it was apparent from the discussion this morning, the term ICC is used by many different people in many different contexts and sometimes loosely.

In general, from everything which is written, you certainly can infer that it refers to impairment of core heat removal and, in particular, heat removal from the fuel to the coolant.

Now basically we think that one could rephrase it in a way so that inadequate core cooling occurs when the cladding temperatures exceed coolant temperatures significantly. Now this is a somewhat general definition and for practical terms we would like to have it somewhat more tangible.

Now there is actually, in the response from the NRC staff to a report by Babcock & Wilcox you do find a definition of ICC that reads as follows: "The core is in a state of inadequate core cooling, where the two-phase level has fallen below the top of the core, and the core heat-up is well in excess of conditions that would be predicted for a small break."

Now basically that kind of definition we adopted when we looked at various ICC instruments and, in particular, the fact that one talks about core uncovery. That puts you in the direction of a loss of inventory accident, typically something like a LOCA. Now core heat-up well in excess sort of brings somewhat up the question what is "well in excess".

Now it turns out when you do the evaluation of instrumentation you find that an exact definition of cladding temperature number and what you assume in ICC is really not necessary, because your instrument has to detect not only the existence of ICC but also the approach to ICC.

Now it did turn out in our work, it helped us just practically doing our work -- we assumed that ICC would exist if the cladding temperature would be above 2200 degrees. Everything below it we would call either approach to ICC or return from ICC.

(Slide.)

MR. MENZEL: Now in the next slide I have listed a number of somewhat general requirements in terms of what kind of function ICC instrumentation should be able to perform.

Well, number one, very much discussed, unambiguous, easy to interpret indication of ICC. That really comes right out of NUREG-0737. Indication of ICC really has to be seen in the context of approach to, existence of, and return to flow, and this is shown in the second line. Again, it comes right out of NUREG-0737.

Now from, again, everything one reads, you come to the conclusion -- at least we come to the conclusion -- that the basic intent is to make sure that the integrity of the fuel is maintained. That is really what is behind avoidance of inadequate core cooling.

So we think during the core uncovery phase of the event the instrumentation should provide an indication of inadequate core cooling rather than a specific water level indication, as is sometimes found in publications. I think this pertains to the discussion before between Dr. Catton and Joe Longo about water level versus getting a closer indication of what actually happensn to the cladding temperature.

Number four, different instruments can be used to cover the range from normal operation to complete uncovery. You need not have to have one instrument because you can have a complement of instruments.

And five is not so much a requirement as at first a very general indication or thought of how we would use the instrument. We suspect that the maximum utilization of these ICC instruments would occur during events which proceed slowly enough so that the operator can observe the instrument and can utilize the instrument displays. So that typically would say we expect these instruments to primarily be used during small breaks, rather than the blowndown phase of a large break.

MR. KERR: Mr. Meizel, I may be making a separation that is illogical, but it seems to me that to some extent one might talk about two extremes of an approach which would be used here.

One extreme would be a system which was geared to provide a maximum understanding of what was going on in a core region for somebody who had the capability to take the data and understand. At the other extreme, one might think that the system which was geared to provide the maximum guidance to an operator -- that is, to tell him what to do without understanding, necessarily, why. But unambiguously he would know what to do.

Now have you thought about your instrumentation system in that context? What is the proper mix of telling the operator what to do without worrying too much about whether he understands, and what is the proper mix of information which he needs for an understanding?

I think engineers tend to be on the end of the spectrum where they want to provide understanding. I don't know if that's the wrong end, but it seems to me that somebody, in designing this system, must give some thought to where in that spectrum one wants to put a given system.

MR. MENZEL: We haven't really come to a final decision or conclusion about that point. But, as you mentioned, from an analytical point of view, there is a somewhat different aspect than what the operator has and we see that when we talk to plant operators in general.

We see that right now the operator has instructions for a number -- to mitigate a number of accidents -- emergency procedure guidelines. And we see that value of that instrumentation primarily in giving the operator additional information, number one, that he has diagnosed the accident right. Number two, that the actions which his procedure guidelines tell him to do, that they have to expect success.

MR. EBERSOLE: Mr. Menzel, concerning item 3, it looks like you would want to put a rate specification in there, because I think if you are dealing with a large loss of coolant rate, I think everybody knows it's almost impossible to follow that level during that transient.

On the other hand, if it's very slow, then it's very desirable to follow it and have anticipatory knowledge that you are going to get in trouble before you get in trouble with core heat-up. So shouldn't you put a rate qualification on item 3 about how fast you are uncovering the core or losing inventory above the core?

MR. MENZEL: Well, we typically find that in one of the what we call small breaks, the uncovery goes on the order of many inches per second, maybe several feet per second, while in the larger of the small breaks it is a couple inches per second.

We have done some calculations as part of this study to find out, for instance, how long the core-exit thermocouple would lag behind recognizing when a certain amount of uncovery has occurred. And we have numbers for that. It turns out it's on the order of 100 to 200 seconds.

For accidents we had a level in the range of a couple inches per second. It also turns out that it comes in the approach to ICC, while you are losing inventory in the upper head, how fast you want to detect it. And, again, there our heated junction thermocouple measurement is capable of tracking events which go a couple of inches per second.

MR. EBERSOLE: Thank you.

MR. ZUDANS: On the previous question -- not this one, the one before -- the choice between two approaches, better understanding of what's going on scientifically or providing operator with information so he can cope better with the system, it seems like you have chosen the second one already, in principle, because your item number 3, for example --

MR. MENZEL: I think I would put it this way. The second one offers itself much more easily than the scientific approach, and I think it basically comes about the role of the core-exit thermocouples. You really need to know what the cladding temperature was, or is it important to know that the cladding temperature goes up, what you see by the core-exit temperature going up, which means things are still getting worse. When the superheat temperature turns around and falls, things are getting better. Basically, we believe that for the operator that that is sufficient information.

Now for analysts to do a post-mortem on the accident, that is a different question.

MR. KERR: I asked the question. I guess I'm going to continue to ask it because parallel to your effort, or perhaps completely reversed from it, as you know, there is a tremendous program that involves better trained, more understanding operators. And I worry that we are going to have these much better trained and more understanding operators with nothing to understand, because everything will be so simply and straightforward that they will just punch buttons.

I don't know that this is necessarily bad, but if the new systems are going to be so foolproof that nobody has to understand them, we may be overdoing the operator training thing. It's just a sort of a nagging question in my mind, and I'm not sure anybody is really thinking carefully about where these two things fit together.

I don't mean it's necessarily your responsibility.

MR. MENZEL: I just want to say, not being an operator I'm not sure I can answer that.

MR. KERR: But you must be an operator in some sense, because you are designing systems to be used by the operators.

MR. MENZEL: Yes.

MR. KERR: And if they don't fit we're going to be right back in -- somewhere we don't want to be.

MR. LONGO: Professor Kerr, let me address your question a little bit.

I think we are going to have better trained operators and also better trained analysts. In order to try to get that happy medium, we have had instituted workshops at Combustion where we had the analysts and the operators working together on the guidelines, and so it's progressing along that path.

MR. KERR: Well, that just seems logical.

MR. ZUDANS: And your program in fact includes the ICC guidelines and operator training, so you are not to give him just a bunch of buttons and say push this or that, but he will know -- he will be trained ahead of time what that should do. That kind of makes you feel comfortable, though, unless there's something else wrong.

The total picture is being looked at in this context, just not a single instrument.

MR. KERR: If you feel comfortable about that it makes me feel comfortable.

(Laughter.)

(Slide.)

MR. MENZEL: In the next two slides I will show in a nutshell the results of this instrument evaluation which we have performed.

And, basically, let me preface it by saying that we look -- we looked at what we call primary indicators of ICC. This would be sensors which give you indication, which gives you a more or less direct signal about the state of the coolant or about the state of the coolant in the reactor vessel, for instance, something like level inventory.

One should not forget that in addition to these kind of what we call primary indicators, there are in the plant a number of what we call secondary indicators which certainly can be used to obtain additional understanding about conditions which might lead to inadequate core cooling. This is, for instance, flow rate for high pressure pump injection, the status of the steam generator level flow pressure, the current of the pump motors.

These are examples of additional information which can be used to find out what the status is.

Now the way this slide is set up, in one column we have a list of the sensors. In another column we have the indication which is provided by the particular sensor, in the third column the clarify of the signal which is really a short word for nonambiguity of the signal. And in the last column, the development status of that particular sensor, which means of that particular instrument system.

I started out with the heated junction thermocouples, which are in the level measurement flow. There we basically have two kinds -- the heated junction thermocouples and regular thermocouples. The heated junction thermocouple gives you an indication of the liquid inventory in the overhead, in the upper plenum, and, as it was said before, it's done by measuring the collapsed water level above the fuel alignment plate, or, more specifically, the collapsed water level between the fuel alignment plate and the upper head of the reactor vessel.

Now the regular thermocouples, they give you an axial temperature distribution in the upper head, in the upper plenum of the reactor. And basically, together with a pressure indication from it, one can determine subccoling saturation or superheat.

In those cases the signal we consider good in terms of its proportional to the effect you are measuring. It's essentially nonambiguous and it gives you a fairly simple indication of the effect you are looking at. The level measurement, the development of the reactor vessel level measurement system has been completed.

The next thing we looked at was core-exit thermocouples. Most of ours are accurate with thermocouples in the core-exit. Typically they actually sit a little bit above the fuel alignment plate in the instrument tubes, and these core-exit thermocouples give you an indication of the fluid temperature at the core-exit, which means they tell you the temperature of what leaves the core. So this, then, gives you an indication of the state of the coolant.

Now from it one can infer what cladding temperature might be in the core. Now the indication for the signal quality relative to the fluid temperature is good. Lag times we calculate typically on the order of one to two hundred seconds. Inferring the cladding temperature is presently only fair, and it is a consequence that in order to make the inferment you have to know quite a bit about power shape and have to make an operating history, decay heat, how long you are in the accident, and it depends to some extent on how much of an analytical effort you want to expend to make that connection.

We find that in order to make a reasonable accurate connection you have to spend quite a bit of analytical effort, which at this certain time we certainly feel as guidance for the operator we don't think is necessary.

MR. KERR: May I go back to an earlier statement? You said lag times were from, up to one hundred seconds or something. It was a lag time between what and what?

MR. MENZEL: That's calculated. The thermocouples sit inside of a guide tube, inside an instrument tube. So it's the time calculated between a certain temperature that's calculated to occur at the elevation of the thermocouple until that thermocouple actually measures that temperature. It's essentially a conduction type calculation.

MR. KERR: To which thermocouple did one refer when you made that statement?

MR. MENZEL: The core-exit thermocouple.

MR. KERR: Thank you.

MR. ZUDANS: I have a question. On your first item, under 2, axial temperature distribution, what makes it vary, actually?

MR. MENZEL: In each of our measurement globes we have eight measurement elevation, eight sensors actually distributed. So in every one of these sensors it contains a heated junction thermocouple pair and a regular thermocouple pair. So in each of these axial locations you can measure what the fluid temperature is.

MR. ZUDANS: That I think I understood. But what I am looking for is physical scenarios where that temperature will vary.

MR. MENZEL: Well, as you might recall, in the evaporated or fast cooldown event, one of our reactors --

the temperature in the upper plenum was not as mixed as in the rest of the system, so the temperature in the upper plenum was in saturation and the temperature in the rest of the system was subcooled.

MR. ZUDANS: However, if it is at saturation, you will just have one single temperature going up and down, and aren't there situations anticipated where that temperature will vary in the upper plenum axially?

MR. MENZEL: For a small break we don't visualize it.

MR. ZUDANS: There's no heat added, no heat removed, or anything like it?

MR. MENZEL: That's right.

MR. LONGO: You have heat from the walls.

MR. MENZEL: You do have some amount of heat from the walls, but in general we would expect that you measure absolute temperatures that give you a saturation temperature.

MR. ZUDANS: So that would give you not much of an information, just some confirmation of what the gross temperature --

MR. MENZEL: If the accident proceeds like we calculate it, it wouldn't. But if you have something else, for instance, like a cooldown which is too rapid, then you would see a difference.

MR. CATTON: What is the response time of your heated thermocouples?

MR. MENZEL: That was based on tests we have run on the order of a few seconds.

Well, after you look at core-exit thermocouples, it is sort of reasonable and logical that you look at how good would the in-core thermocouples be.

And basically, I guess, they sort of -- the incentive would be that is closer to measuring the actual cladding temperature than what you would do measuring the fluid temperature in the core-exit.

Well, what you would actually measure is the middle temperature inside of a guide tube, where physically these in-core thermocouples are located. The signal quality would be good. Now, again, from that signal one could infer the cladding temperature.

At the present time we have not really done enough work to know very well what the response or how the connection between in-core thermocouple temperature and cladding temperature would be. So at the present time it is undetermined. So far that was only a conceptual approach which we have been looking at.

Next on the list here is self-powered neutron detectors. That comes out of the experience of Three Mile Island where one did find that after the reactor was shut down that some SPNDs did show a signal change quite measurably. And that, in general, is thought to occur with the occurrence of core uncovery.

Well, it turns out that the tests which have been done with SPNDs afterwards, one really could not reproduce that temperature response in the same way as was observed at Three Mile Island. So at the present time we would say the quality of that particular signal is poor.

MR. KERR: I'm sorry, the temperature response, you say? I thought it was a response to increase the neutron leakage. I really was interpreted as the temperature response?

MR. MENZEL: Well, you see a signal and it's generally acknowledged that that might have occurred during a time when that particular SPND location was uncovered.

MR. KERR: But I thought from your comment that there was some indication that the response occurred because the detector got hot. I had not heard that explanation before.

MR. MENZEL: That's the explanation I am familiar with, but I see somebody --

MR. KERR: He said it was a response --

MR. BANDA: It's a temperature response as determined experimentally. But the temperature is not.

MR. KERR: He said it was a temperature response, and I think is that was verified experimentally. Am I repeating you correct?

MR. BANDA: Yes, you are.

(Slide.)

MR. MENZEL: Okay. Then let us go into the final slide, which shows the summary of the --

MR. CATTON: Is that interpretation consistent with the recent experiments at LOFT?

MR. MENZEL: LOFT has cobalt sources and it's a question of shielding. So when the mixture level drives up, the shielding level shows some indication.

Next on the list is RTDs and the hot leg. They show the fluid temperature in the hot leg. Their signal quality is good. They exist.

Now in theory you can think that you could infer from them also cladding temperature. Now this is quite a bit away from actual uncovery of the core. As you get superheat, it goes to the exit of the core, and you finally measure superheat in the outlet of the reactor vessel and the outlet of the pipe.

We basically think that that inferment is not very good. One basic reason is that there is very much a chance that during that time you probably are in the reflux boiling type heat transfer mode, so that condensate is running back into the hot leg pipe, and at least some of the RTDs would not actually show superheat. It would show saturation conditions.

The last two items are really the basic sensor. One is the ex-core neutron detectors and first we looked just at one, using the source range. That basically gives you a measure of gross voiding and in theory could give you an indication of the mixture level in the core, but we did find that the signal there is quite a bit of time after the accident, a concentration of boron and concentration of deuterium in that coolant.

So this signal, at best, we could say is fair. The ambiguity of the signal is relatively high. But once you look at one ex-core neutron detector you can think, when I have many or several stacked up, because then you would not really depend on the change of the signal magnitude. You would get a profile. Well, we still -- the signal quality improves, but we still see the basic problem that over time, and depending on the concentration of boron and deuterium, we can get changes in the signals.

And, again, we would call it right now, fair.

MR. KERR: I would say those data are much easier to interpret after you already know what has happened.

MR. MENZEL: That's right.

Well, if you look at these two slides it comes fairly easy. There is some good, and some are poor and some are in-between. Considering the fact that some of these instruments are existing, some of them are just a concept.

(Slide.)

MR. MENZEL: One can come up with the following list of sensors which together could make up the ICC instrumentation system. And what I have listed here is the sensors in the first column, the information they tell you about, and how it relates to the phases of inadequate core cooling.

RTDs, together with the pressurizer -- the system pressure -- tell you about the state of coolant in the reactor vessel and it's particularly measured in the hot leg.

Now, together with the thermocouples -- and that's the absolute thermocouple in the level measure and also in the pressurizer, they give you the state of the coolant in the reactor vessel above the fuel alignment plate. State of the coolant basically means it tells you if you are subcooled, saturated, or superheated. So you get an indication during the phase of approaching or returning to ICC, and, in particular, you get it in the early phases or the very late phases of the accident, which are listed here essentially under subcooled conditions.

MR. MENZEL: In a typical event, especially if you look at a small break, first the coolant system goes from subcooled to saturation, and then the water level reduces in the upper plenum because you have the whole coolant, and during this phase the heated junction differential shows you the water inventory which is left above the fuel alignment plate. And again, the indication, the phase of ICC is approached to or returned from ICC during a time the core is still covered.

Then finally, the third item or the third group of sensors here are the core exit thermocouples. They show the fluid temperature, which we had mentioned before. One can get an indication of the cladding heatup. Now, they covered the range of approaching ICC and returning from ICC when the core is uncovered or the existence of ICC, and that is somewhat depending on how you define -- at what point you can cure ICC.

So basically we come up with four types of sensors, pressure, RTDs, thermocouples and the core exit thermocouples. Basically you can think that they are put in three types of instrumentation system: saturation margin monitor, reactor vessel level measurement system, and core exit TC system.

This is the end of my presentation.

MR. KERR: Thank you, sir.

Are there questions?

I am going to suggest that we take a ten-minute break between this and the next presentation if I may.

(Recess.)

MR. LONGO: Our next speaker, Dr. Kerr, is Carl Neuschaefer.

MR. KERR: Thank you, sir.

Let me say a bit about logistics.

How long is your presentation likely to take, Mr. Neuschaefer.

MR. NEUSCHAEFER: I would say at least an hour, depending on questions. It could take that long.

MR. KERR: Let's see. The total Combustion Engineering presentation, including questions, was scheduled for an hour and a half.

MR. NEUSCHAEFER: I can reduce it.

MR. KERR: So that means what we have heard up till now would have been scheduled for about a half-hour, and I would judge it took three times that long. If I used the same arithmetic, I would get about three hours for your presentation.

MR. NEUSCHAEFER: No, sir, I don't think I will survive that long up here, I assure you. I would say it is a good hour, though.

MR. KERR: Well, I don't want to keep you from saying what needs to be said, but could we maybe make it come out 45 minutes? That is what I would like to do and then stop for lunch at I guess it would be 1:15, and then begin the Westinghouse presentation immediately thereafter.

Now, for those of you who are planning afternoon schedules, I am not going to be here past about 5:00 because I have a 6:15 plane, so I am going to fit whatever fits into about that time period.

Thank you, sir. If you will begin.

MR. NEUSCHAEFER: What I plan to do, then, is move quite briskly. If you want me to stop, then please stop me. I will slow down wherever you would like me to.

MR. KERR: I doubt if I will slow you down.

(Laughter.)

(Slide)

MR. NEUSCHAEFER: What I will be presenting is an integrated approach to a number of individual licensing requirements and technical issues resulting from TMI, with particular emphasis on the inadequate core cooling subject.

(Slide)

My objectives for the presentation primarily are to provide as much information as I can in the time period allotted to the committee. More specifically, what I will be presenting is an integrated accident monitoring system approach to address ICC and a number of other interrelated requirements. In addition, I will be discussing the specific ICC instrumentation and information, and then I will be discussing the reactor vessel level system and the test program for the development of the reactor vessel level system.

(Slide)

By way of a roadmap, after a brief introduction I will then get into the integrated accident monitoring system approach to address a number of requirements that have resulted from TMI, in particular the ICC issue. The way I intend to approach that is first by looking at a system overview of the integrated accident monitoring system and then looking in more detail at the individual pieces that make it up.

Then having set the stage for this integrated accident monitoring system, I would like to then focus on the inadequate core cooling subset of that accident monitoring system. Having discussed the inadequate core cooling instrumentation, I would like to focus once again down to another level of detail, and that is the reactor vessel level system per se.

There I will cover the design base for the heated junction thermocouple system, the system design itself and the extensive test program that has been conducted to date.

(Slide)

Following TMI there have been a number of licensing requirements and technical issues that have arisen independently to some extent, but if you step back and take a look at those, there is a common thread, and one common thread is the ultimate objective is to improve the man/machine interaction aspects of nuclear power plants to provide an improvement in the emergency responsiveness to accidents, and that is what this integrated accident monitoring system and ICC is really all about.

(Slide)

The approach I intend to discuss consists of the addition of some improved instrumentation such as the reactor vessel level and then some computerized processing and display systems that have the capability to process relevant and irrelevant information and display it to the operator in a concise manner.

(Slide)

This slide shows an overview, a block diagram, if you will --

MR. KERR: Excuse me, Mr. Neuschaefer. I won't dwell on this very long. But in one slide you tell me that the ultimate objective is to improve the man/machine interaction so that one has improved emergency response to accidents. Then on the next slide you refer to this as an approach to licensing requirements.

Had I not seen that I would have thought that one considered that emergency response real. I could interpret the language which refers to it as an approach to licensing requirements to be in contrast to something you considered real. Is that language deliberate or accidental?

MR. NEUSCHAEFER: I guess we are referring to this slide right here, I believe. The wording "licensing requirements" basically was the impetus for a lot of thought and study that went into the system that I will be describing.

(Slide)

MR. KERR: Well, that bothers me a little bit. I know you have to be licensed, but I also would like for us to deal with real problems in addition to licensing requirements.

(Slide)

MR. NEUSCHAEFER: I think the technical issue was reawl.The technical issue was stated here and I think it is obvious from TMI that the man and the machine have to get together.

MR. KERR: Okay, I feel better.

(Slide)

MR. NEUSCHAEFER: This is a block diagram of the acc nt monitoring system. Basically the accident monitoring system is a computerized system to process information and provide it in a display format usable by the operator. This particular system consists of two redundant 1-E qualified processors, namely, the qualified safety parameter safety display system -- and we'll talk more about that -- which processes all the safety-related information to qualified information necessary to assist the status of the plant.

In addition to that there is another major piece, which is what we refer to as the critical function monitoring system, which is the primary vehicle for providing information to the operator, and in fact is based on two fundamental concepts. One is the safety functions concept and the second is the ability to display large amounts of data in a fashion using graphic techniques. We'll talk a little bit more about that.

MR. KERR: Am I seeing two identical systems inside the dotted box?

MR. NEUSCHAEFER: That is correct. That is to imply that those are dual independent channels.

MR. KERR: Thank you.

MR. ZUDANS: Do they work off the sensors?

MR. NEUSCHAEFER: The sensors are also independent and dual.

MR. ZUDANS: Thank you.

(Slide)

MR. NEUSCHAEFER: The critical function monitoring system portion of the accident monitoring system is basically an advanced minicomputer-base system to process signals and perform a number of functions, primarily to provide information to the operator in a number of other offsite facilities to aid in understanding the status of the plant. The critical function monitoring computer does things such as input processing where it checks validity of inputs coming in, looking for bad ones and sorting them out.

In addition it does a display processing task where it may have hundreds of inputs and what it will do is sort those inputs based on the safety function concept into three tiers of information: an overview, a more detailed system-level presentation, and then down to a diagnostics level.

In addition the critical function monitoring computer performs the critical function algorithm calculations, which is the monitoring of the safety functions, the basic safety parameter display system, that minimum set of information to assess the safety status of the plant in a quick overview sense.

It also provides capability for trending historical data storage and retrieval and outputs the various total and offsite facilities to provide selected portions of information.

MR. KERR: Are you describing something that exists in concept or hardware of what?

MR. NEUSCHAEFER: This exists in hardware. There is one plant currently going into operation very shortly that has this approach and has presented it to the staff and ACRS in the licensing dockets about a month ago, so it is real.

MR. CATTON: Which one?

MR. NEUSCHAEFER: SONGS.

MR. CATTON: Oh, San Onofre.

MR. LIPINSKI: Your computer exists in single form. What availability numbers are you shooting for?

MR. NEUSCHAEFER: Ninety-nine percent on the critical monitoring system. In addition to that, there are two 1-E channels on top of it. You basically have three channels of computer system. The system alone is shooting for 99 percent by itself not counting the other two channels in the 1-E computer system.

MR. KERR: What does "shooting for" mean?

MR. NEUSCHAEFER: Did I use that term? I am sorry. It is designed for 99 percent availability.

(Laughter.)

MR. KERR: Does your equipment usually operate according to design?

MR. NEUSCHAEFER: Generally speaking, I believe so.

MR. KERR: Okay.

(Slide)

MR. NEUSCHAEFER: The other channels, the 1-E processing portion of that monitoring system I showed is what we call the qualified safety parameter display system, qualified denoting that it is the 1-E portion. This is basically some microprocessor phase signal processing and display equipment, and in here are the processing capabilities for the inadequate core cooling function.

In particular, the heated junction thermocouple processing, the core exit thermocouple processing, the saturation margin calculation, and in addition, processing of other safety parameter display.

MR. KERR: What is an ASPDS? Was that a QSPDS?

MR. NEUSCHAEFER: This stands for qualified safety parameter display system. I apologize for the abbreviations.

MR. KERR: As long as I understand them, I don't have any problem with them.

(Slide)

MR. NEUSCHAEFER: That was a quick overview of what we believe is an integrated system approach to a number of accident-monitoring-related requirements, of which ICC is just one issue. There are other issues in terms of accident monitoring which we believe this one system integrates and provides one system to the operator rather than a piecemeal approach of a number of systems.

MR. KERR: Could you if you have the time and the inclination indicate what fraction of Reg Guide 1.97 is covered by this system?

MR. NEUSCHAEFER: It has the capability to address all of 1.97 inputs. It is designed to input and process all of the 1.97 parameters and then some.

MR. KERR: Is it designed to do that in SONGS, for example?

MR. NEUSCHAEFER: It currently has the capability to be upgraded to that. SONGS has not been into that level of involvement yet.

MR. KERR: Thank you.

MR. ZUDANS: On that slide you had the qualified safety parameter display system. What is the list of parameters that you have under that?

(Slide)

MR. NEUSCHAEFER: That list basically is not totally developed yet.

MR. ZUDANS: But you said an existing system.

MR. NEUSCHAEFER: For SONGS that is right. That list is being developed right now, in fact.

MR. ZUDANS: I see. So it is not quite existing.

MR. NEUSCHAEFER: There is a list of safety parameters which people believe to be sufficient to assess the safety status of the plant. However, there are several lists in existence: NSAC, AIF, each have their own version of the safety parameter list. Combustion also has their own version. There is still some work left to converge on what a unique list is.

MR. ZUDANS: It is kind of a negotiating stage between you and NRC?

MR. NEUSCHAEFER: I think that is what it will end up, yes.

MR. ZUDANS: And the other parameters are listed there on the left?

MR. NEUSCHAEFER: Those are the specific ICC parameters that are the subject of this meeting.

In particular, this will be the subset of the parameters.

MR. ZUDANS: In the CET slide you showed, you have already made up your mind as to what is going to be shown and how and the software is all developed for them, or what?

MR. NEUSCHAEFER: Not 10[illegible] percent, but about 99 percent. I will show you one idea of how we intend to approach it. The actual software and displays for SONGS have not been finished in total yet for ICC. For the other portions of the system they have been, yes.

(Slide)

That was a quick overview of a fairly large number of issues. What I would like to do now is focus on the inadequate core cooling subject and look now at the portion of the accident monitoring system which addresses inadequate core cooling. I think we have heard a lot of it so I will speed it up even more.

We have heard about the complement of primary sensors, and that is what this slide shows. I won't repeat them again.

(Slide)

The types of information that are processed from those sensors are basically three functions. One is saturation calculation which utilizes temperature inputs from the reactor's coolant system RTD, its temperature inputs from the core exits and temperature inputs from the upper plenum and head, from the heated junction thermocouple. And based on those three temperature locations it will calculate saturation margin at all three locations and provide that information as an output.

MR. LIPINSKI: Why isn't the heat junction going up to 2300 the same as the core exit?

MR. NEUSCHAEFFER: The thermocouple used in the heated junction thermocouple is basically identical to the core exit thermocouples. It is a Type K thermocouple. The thermocouple itself has the ability to go to 2300, which is the usual range of that type thermocouple. However, there is a material limitation on the heater itself, basically because it is copper, which melts at around eighteen something.

MR. LIPINSKI: Okay, so the function with the heater to 1800, but the thermocouple will still go to 23?

MR. NEUSCHAEFER: Yes, and the processing has the ability to go that high.

MR. EBERSOLE: Let me ask you a question about your earlier slide that shows the two boxes, the two channels of Class 1-E.

(Slide)

MR. NEUSCHAEFER: Was this the one?

MR. EBERSOLE: Yes. I take it that what really has happened here is that all your post-accident monitoring systems are consolidated into at least a pair of channels, solid state equipment channels.

MR. NEUSCHAEFER: It is not meant to replace all of the post-accident monitoring inputs. This is a processing and display system which is meant to integrate all of that footage of control board.

MR. EBERSOLE: But I am talking about the earlier slide.

MR. NEUSCHAEFER: This is in duplication to all the existing instruments in the plant that would normally be --

MR. EBERSOLE: No, it will be over and above those.

MR. NEUSCHAEFER: Over and above.

MR. EBERSOLE: Then I can take, if I choose to, like I might have to take like ANO-2 where they were having quite frequent problems with the solid state equipment because of ambient temperature problems, I can take the hypothesis that both of these sets go bad and if I don't have an accident I am in good shape, right?

MR. NEUSCHAEFER: Yes.

MR. EBERSOLE: I am going to assume as you talk about this that it is going to go blind on me at any time and I want to make it do so.

MR. NEUSCHAEFER: All three channels.

MR. EBERSOLE: Yes.

MR. NEUSCHAEFER: All right.

MR. EBERSOLE: Thank you.

(Slide)

MR. NEUSCHAEFER: I am going to skip the next slide which is reactor vessel level because we are going to talk about that in detail, and I'll come back and spend more time with that.

The third piece in the ICC processing is the core exit thermocouples. The first was saturation. The second was the level. The third is the exit thermocouples. The function of the processor is to take the thermocouple inputs and convert them to temperature and provide that information as an output.

(Slide)

If we look for a moment -- someone asked the question of what the displays would be. I can't show you the specific displays because they are not designed right now for ICC, but the way we would display the ICC information, ICC, although it is a very important and separate subject, is really nothing more than one of the essential safety functions, and that is core heat removal.

They are synonymous, and as such the safety parameter display system monitors all the safety functions, including core heat removal. The ICC displays will thus be a subset of the core heat removal displays, and this shows the hierarchy of the type of information that might be available for ICC.

On a higher level, there would be an alerting or an alarm that one of the critical functions, in this case core heat removal, was in jeopardy. That would be the first indication. It would just simply tell the operator core heat removal is in jeopardy. It is telling him one of the safety functions is in jeopardy.

The next level of display that he could call up --

MR. KERR: Could one give some example of what might cause that alarm? Are you going to get to that?

MR. NEUSCHAEFER: No, I was not, but I could. Anything related to core heat removal, and there are a number of ways we remove heat from the core. Any indication that there was a lack of core being removed ---

MR. KERR: I just want a for example.

MR. NEUSCHAEFER: Saturation. The fact that you are no longer subcooled.

MR. KERR: Okay.

MR. NEUSCHAEFER: The second level of information now might sector in on our display specifically dedicated to inadequate core cooling, and it would show the type of information that we showed earlier and I will show on a separate slide again. It would trend the parameters of interest to ICC, namely, what is happening to the saturation conditions.

MR. EBERSOLE: This stuff is so fast. Would it show reactivity spike as inadequate core heat removal?

MR. NEUSCHAEFER: A reactivity spike would show up as a reactivity safety function.

MR. EBERSOLE: You would damp it so it would lock in as inadequate heat removal? I mean this is fast equipment It could be so fast that you could have a spike of inadequate heat removal.

MR. CATTON: Well, but the thermocouples would lag.

MR. EBERSOLE: But the flux function doesn't lag.

MR. KERR: Yes, but it shows if you have a spike of reactivity, that doesn't necessarily have to be a lot of power.

MR. EBERSOLE: I know that, but this is so fast that if it read it and locked in, it would look that way.

MR. NEUSCHAEFER: The system doesn't lock in. It is an information system.

MR. EBERSOLE: Maybe you damp it. I don't know. Or maybe you put tinder legs in it or something. Do you follow me? I mean solid state equipment is just practically instantaneous.

MR. NEUSCHAEFER: I think I understand but I am not quite sure. You are saying if you had a spike at some point --

MR. EBERSOLE: It would be a momentary indication of inadequate heat removal.

MR. NEUSCHAEFER: -- that this system would respond to that. It would give you an indication that you had a reactivity excursion when in fact --

MR. EBERSOLE: As a matter of fact, if it fed information into a processor that you had core heat removal --

MR. NEUSCHAEFER: This system doesn't latch in. If you had a spike it would see it, respond to it and if the spike went away, the alarm condition would go away.

MR. EBERSOLE: Oh, it will go away. It doesn't lock in.

MR. NEUSCHAEFER: No.

MR. EBERSOLE: Okay. It will go away.

MR. NEUSCHAEFER: It monitors actual inputs.

MR. EBERSOLE: You can't swing the needles that fast. Needles, for heaven's sake. I am an antique.

(Laughter.)

MR. NEUSCHAEFER: In addition to the trend information, there is a third level of display capability the operator can access for further diagnostic information. For example, we would display a core exit thermocouple map. That is it, it would be a picture showing the core geometry and all the thermocouple locations in the core and it would show the temperature of each and every thermocouple and how each and every temperature is changing.

MR. KERR: What do you mean by how it is changing?

MR. NEUSCHAEFER: The temperature was changing and one particular thermocouple was moving, the map would actually update the value of temperature on line continuously.

MR. KERR: It would show the current -- Okay, thank you.

(Slide)

MR. NEUSCHAEFER: You saw this one earlier, but in that second level of display the operator would have one of the pieces of information that would be primarily useful as the trend of parameters.

MR. KERR: How do you decide, for example, that it is helpful for an operator to have a picture of the core with every thermocouple and digital numbers by each one? It sounds great, but what leads you to the conclusion that you need that as compared to one thermocouple or two?

MR. NEUSCHAEFER: The actual displays themselves and the type of information that goes on the displays, we have people in our human factors group basically that do that. These are people that conduct studies with the operators who are involved in human factors engineering of creating displays.

MR. KERR: Is this black magic so that you can't explain it to me in simple terms? Do you understand how they reach that conclusion?

MR. NEUSCHAEFER: Fundamentally it is to provide the information in a concise manner from an operations point of view.

MR. KERR: Is there a clear distinction in your mind that you are satisfied that they made the right decision in putting all the information on instead of two thermocouples, for example?

MR. LIPINSKI: May I ask a question? Is this used for normal operation to see what your power distribution is while you're running?

MR. NEUSCHAEFER: Let me respond to the first question. Yes, I am satisfied because if you look at the hierarchy displayed from an operator's point of view, when he sees all those thermocouples he is down at the diagnostic level.

(Slide)

He has already been through two higher levels of what's going on. He is down at the diagnostic level. Now, he wants to know where in the core is the trouble, and the only way you can know that is to have all the information.

MR. KERR: What is he going to do with that information? What is he going to do differently if he knows that Thermocouple A is hot and Thermocouple C is not?

MR. NEUSCHAEFER: It is probably going to tell him some assymetric situation in the core.

MR. KERR: I am not talking about the information. What I am trying to find out what he does.

MR. NEUSCHAEFER: What action he takes?

MR. KERR: Yes. Opens the valve, pushes the button or something.

It may be an unfair question. I'm just trying to understand how you come to these conclusions.

MR. NEUSCHAEFFER: It would be a general answer at best, because each operator is goin to be trained in his own way of doing things.

MR. KERR: It's quite easy, I think, to provide an operator with one hundred times as much information as he needs in order to do something, and that may not be all bad.

On the other hand, if you go through a number of scenarios, at least for those scenarios you can sort of decide here's the information he needs in order to make decisions. Have you done one or the other of these, or some combination thereof?

MR. NEUSCHAEFFER: Yes, we have, and that's the hierarchy combination. For him to have gotten down to the core-exit thermocouple map, I must assume that if he asked, he was going to do something based on the information. Otherwise, he never would have gotten there.

The first thing he would have gotten is a simple, hey, core heat removal is in jeopardy. Now he would take his actions.

MR. KERR: So your answer is you don't know what he is going to do on the basis of that information. But since he asks for it he must have something in mind?

MR. NEUSCHAEFER: Is that what I said?

MR. KERR: Well, that's what I thought you said. I may have misinterpreted you.

MR. NEUSCHAEFER: I was trying to sort the large amount of information. There are large amounts of information. It's not all dumped on the operator. What's provided in the hierarchy is first information that tells him what the situation is and then he can go to more detailed levels of information to proceed to take action to obtain feedback on his actions that he's taking and so forth.

MR. KERR: So in a sense this is designed for the educated operator who may not have anticipated all procedures ahead of time, but is smart enough to ask for information. That's my statement, not yours.

MR. NEUSCHAEFER: I'm not sure how to answer that.

MR. KERR: I guess it wasn't a question.

MR. EBERSOLE: When he looks at the CET map, he's going to see a dynamic state of affairs. It's going to change from state to state, from condition to condition, and so forth. When he looks at the RVSLM map, it's going to be the same thing all the time -- no change, right?

What's going to tell him about how often to look at it, what to see, if anything? As I look at it, RVSLM is just going to be a steady reading of normalcy. Are we going to perturb it? He's not going to see any level?

MR. NEUSCHAEFER: At which point is this?

MR. EBERSOLE: I'm talking about the reactor veseel level instrumentation. It just sits there. To have a recorder on it would be ridiculous.

MR. KERR: He'll never ask, so you'll never get down to that level unless he has an accident, unless he's just curious.

MR. EBERSOLE: It's just a bunch of dead parameters.

MR. NEUSCHAEFER: No, the level information is always available.

MR. EBERSOLE: But it's not going to say anything.

MR. NEUSCHAEFER: Under full normal power operation it's probably true.

MR. EBERSOLE: And so will the saturation meter information. There's nothing there.

MR. NEUSCHAEFER: That's right.

MR. EBERSOLE: So what are we going to do? Just display it in front of him on periodic intervals or what?

MR. KERR: Doesn't he have to punch a button or something to get these displays?

MR. NEUSCHAEFFER: Yes.

MR. KERR: So he won't get that unless he asks for it, Jess.

MR. EBERSOLE: Yes.

MR. ZUDANS: Or if he's curious enough to see how it stands, he can push the button.

MR. EBERSOLE: All right.

MR. KERR: If he gets bored at 2:00 a.m. he might ask it what's there.

MR. EBERSOLE: He'd be very disinterested in a set of readings that never changed at all.

MR. NEUSCHAEFER: In a normal situation, even power sits there.

MR. EBERSOLE: But this is solid for years.

MR. KERR: We hope.

MR. EBERSOLE: Well, maybe it's interesting when he's down for a fuel change. Go ahead.

MR. ZUDANS: On this CET map you said that you already designed a system where you would have ditigal map of temperatures of different thermocouple locations.

MR. NEUSCHAEFER: Yes.

MR. ZUDANS: Did you consider, instead of that, drawing isotherms?

MR. NEUSCHAEFER: That's another approach, I suppose.

MR. ZUDANS: That would be an interesting visual approach as to how the thing looks.

MR. NEUSCHAEFER: That's another approach, certainly. There is a recognition approach here, and that's in the upper level display, which is the critical function display, not necessarily isotherm, but it's a critical function.

MR. ZUDANS: I guess one has to see the details. Once you decide your negotiations with NRC, then you know what your parameters are, and then you will have a system.

MR. NEUSCHAEFER: The safety parameters are clearly defined. The only thing that has some question is the inputs that you use to assess the safety functions, and they are somewhat plant-dependent. For example, core heat removal.

What parameter is going to core heat removal? Well, we went through what we believe to be the parameters. Some plants may use a DP cell or some other parameters, so there is that degree of flexibility in what measurements you make to determine whether the safety function is being met. Not all plants have unique sets of informati-n. That's what I meant before when I said the li-- / specific parameters still has further conclusions to be reached.

MR. LIPINSKI: Prior to TMI, did CE cores have core-exit thermocouples?

MR. LONGO: Yes.

MR. LIPINSKI: If I recall, they are part of your computer system to determine the flux mapping.

MR. NEUSCHAEFER: That's correct.

MR. LIPINSKI: Given the system for operational reasons I have to determine what the thermocouple readings are. Is there another place that I go to to get this information other than what you are showing here for operational reasons?

MR. NEUSCHAEFER: No, the same system would be used in normal operations.

MR. LIPINSKI: So the core map is used to determine what the performance of that core is over core life from beginning to end of life?

MR. NEUSCHAEFER: It could be used in normal performance. That's correct.

MR. LIPINSKI: I need that for other reasons. You are showing us, for accident cases where I want to check on core heat removal. But for other reasons I also want to know what the performance of that core is from beginning of life to end of life, as a function of control rod positions and boron dilution. You also use that information for kilowatts per foot calculations.

But here you are giving me a concise display that I can use for operational purposes.

MR. NEUSCHAEFER: For operational purposes?

MR. LIPINSKI: Core performance -- just general core performance.

MR. NEUSCHAEFER: That's correct. I have been highlighting accident scenarios, but the system is not meant to sit in a corner and only be called upon during an accident.

MR. LIPINSKI: That's why I'm trying to make the point now. You've got the map here and it's generalized, so it has additional information used to determine how that core is performing over its life from beginning to end of life.

MR. NEUSCHAEFER: That's correct.

MR. KERR: Please continue.

(Slide.)

MR. KERR: If we didn't ask you any questions, how much longer would it take?

MR. NEUSCHAEFER: Half an hour, twenty minutes.

MR. KERR: Okay. No more questions.

(Laughter.)

MR. NEUSCHAEFER: Let me talk about the reactor vessel level system.

Let me just say with this slide that back in the early development stages, one of the first things we did was set forth the design basis for what a level system should do, what we want it to do. This slide merely summarizes some of the key things. Some of the key parameters are directness of measurement, something that could be backfitted and installed in a reasonable, practical manner, and something that would be useful to an operator.

(Slide.)

Now we looked at a lot of different instruments in terms of what we felt we would want to develop, and there are lots of ways to measure liquid level -- delta P cells, heated junction thermocouples. That's not the issue. The issue is can you make one of those level instruments work in a pressurized water reactor environment or application.

All of the concepts, level instruments will measure level in a tank, but will they do it in a reactor vessel? That's the real issue. We chose heated junction thermocouples, because it was direct in terms of what it measured. It was in the vessel. It measured the fluid and heat transfer of the fluid, and it was simple. There were also a number of other reasons shown on this slide, among them the fact that thermocouples have been used in an in-vessel application, a fairly simple principle.

Another desirable feature was the fact that under normal conditions the pot will be full. From an operational point of view, if I'm the operator, I want to know if the instrument is working. How do I know if it's working. I'm not about to drain the vessel to see if the level instrument is working. I want to know if it's working so I can depend on it. You want to do operability checks.

Well, the thermocouple has the ability to do operability checks because it's nothing more than a temperature measurement. You read the temperature output, compare it to the other thermocouples. You can also compare it to the exit thermocouple temperatures. You can do primary and secondary calorimetrics to find out whether the temperature is being measured. You can check operability of power.

It also had the ability to be installed in a reasonable manner with a minimal impact.

MR. EBERSOLE: You are going to change the heating rate from time to time to see if it's working?

MR. NEUSCHAEFER: You can do that also. You can manipulate the heater power to determine the response. That's correct. You can also do current step response techniques to determine operability.

(Slide.)

Moving right along, let's talk about the system design itself. This slide shows an overview of what the system consists of, that is, their level system. It's basically two channels of information.

Let me look at one channel. The other channel is identical. There is a probe, and we will talk about what it consists of. Basically it consists of eight sensors, and I'll come back and describe that in more detail, and then there are some signal processing equipment which processes those inputs and provides the outputs. And the heater control function, we'll come back to that in more detail.

In an overview sense there is two channels of level measurement information, two probes both providing redundant level measurement. There are eight sensors in each probe, providing eight discrete measurement points.

(Slide.)

What I would like to do now is show you what the probe consists of. This is a diagram of the probe assembly. Now the probe assembly consists of this outer tube, which is a separator tube. And that separator tube functions to create a collapsed level. As we all know, in some situations in a reactor vessel there is no level. It's nothing more than two-phase frothing mess. What level are you measuring?

The function of this separator tube is to separate that frothing mess into a liquid level and non-liquid and tell you basically how much liquid is up there, above the core.

Inside the separator tube now are eight pairs of heated junction thermocouple sensors. A sensor is defined as a heated junction and an unheated junction, covered by a splash shield. I'm going to come back to this.

MR. CATTON: You don't trap water under the splash shield?

MR. NEUSCHAEFER: That's correct. There are ports on the top and bottom for drain and communication with the outside, besides the fact that it sits inside the separator tube.

(Slide.)

Let me try and construct what the probe looks like. Let me start from the basic thermocouple. There are eight of them. Looking at just one of the thermocouples, it's basically a dual thermocouple. There is a single Chromel-Alumel junction and a second Chromel-Alumel junction. The second one is surrounded by the heater.

Our design is basically a five-wire thermocouple which allow us to measure the unheated junction temperature, the heated junction temperature, and also the differential temperature. That's the differential temperature which would be used to measure level, differential temperature being directly related to the heat transfer coefficient and that being used to determine whether it is liquid or not liquid.

The other junction outputs are used for temperature monitoring and heater control. That's the bare heated junction thermocouple, and they've been used for some years to measure liquid level. In fact, American Standard owns one patent on the use of heated junction thermocouples for liquid level.

(Slide.)

Okay, again, the problem was to take the liquid level device and make it work in the reactor vessel. One of the things you determine is if a significant amount of moisture gets on the heated junction it's going to cool it, so one of the things you want to do is protect it from condensation, from backsplashing, and so forth.

What you see here now is the thermocouple junctions, again the unheated and the heated junctions. The heater is around here. Surrounding the heated junction is what we refer to as a splash shield. Its mission is to keep spurious liquid from hitting the heated junction. We are going to talk more about that in the test results, coming up, to show you how the design evolved.

(Slide.)

MR. LIPINSKI: What are the dimensions we are looking at here? Half inch in diameter? An inch in diameter?

MR. NEUSCHAEFER: Basically it's about one-eighth of an inch diameter. The separation between the junctions is about four-and-a-half inches.

MR. CATTON: Separator tube?

MR. NEUSCHAEFER: Separator tube is less than an inch, so the entire probe is less than an inch in diameter, so about 875 mils.

MR. LIPINSKI: So you don't have to worry about any wetting or meniscus?

MR. NEUSCHAEFER: That's correct. The heated thermocouple junction pair and the splash shield are defined as a sensor, for the sake of this discussion. Those sensors, eight of them, are then positioned inside the separator tube at eight axial locations and they are integrally bound, fixed.

Each of the sensors are brought electrically, independently, so that the loss of any sensor does not lose the functioning of the probe. So basically not only do you have two channels, you have two channels with eight sensor locations of redundancy. That's the probe.

(Slide.)

MR. LIPINSKI: Where's your main pressure seal to bring this through the primary system?

MR. NEUSCHAEFER: Basically the seal plug right here is the first primary pressure boundary.

MR. LIPINSKI: So all of the thermocouple cables are integral and then they are sealed within that seal plug?

MR. NEUSCHAEFER: That's correct.

(Slide.)

My objective was to present a lot of information. I apologize. I think I overdid it with all the slides.

The probes now are processed in a signal processing piece of equipment, which happens to have been a microprocessor. It could have been done a lot of ways. We chose that because they are relatively reliable and cheap. They can do fairly intelligent functions and that allows us to do some additional things than just simply processing temperature outputs.

For example, we can now do some displays. We can also do the heater control logic in the same box. We can also do some on-line diagnostics and a number of other things.

The heater controller -- the thermocouple basically works upon the constant heater power. You put a constant heater power and look for the delta T, whether it's covered or uncovered. The reason we have the heater power controller is simply to protect the heater from burning out in the uncovered state. If you uncover the sensor there are situations where the heat transfer coefficient might in a depressurization type event, depressurize to very low pressures where the heat transfer coefficient gets very poor and you can conceivably burn out the heater.

So what the heater controller really does, it just runs back the heater below some temperature limit, and we monitor the heated junction temperature directly and never let it go above some limit. We always run back the heater, but never by any significant amount, because we always want to make sure there is sufficient signal strength there.

MR. ZUDANS: This sensor is essentially active? Its function depends on availability of power?

MR. NEUSCHAEFER: That's correct.

MR. ZUDANS: How do the other systems compare in that way in terms of sensors? Are they all active like DP, or --

MR. NEUSCHAEFER: Like other types? Most of the devices we looked at, delta P cells, ex-core detectors, all have some power source supply. They are all active in that they have power being supplied to them.

MR. ZUDANS: What happens if you lose that?

MR. NEUSCHAEFER: The way the design is set up, we have redundant heater controls. They're also accessible. There is no equipment inside containment. All the equipment is outside and accessible to be replaced. But each channel has redundant heater controls. In addition to that, there is a second channel.

MR. KERR: I can answer that question. It doesn't work.

MR. NEUSCHAEFER: A single channel will not work if you lose two heater controllers.

MR. ZUDANS: But there is resistance that can break and it doesn't matter what you do, it's not going to heat.

MR. NEUSCHAEFER: The heater itself? You could lose one sensor only, not the probe. There are eight sensors in a probe. You would still have information. It has lots of redundancy in that sense.

(Slide.)

Just to summarize quickly, two probes. Each probe has eight sensors. Each of those sensors are processed and provided as an output for display, and the heater control function is performed.

(Slide.)

What I'd like to do now is go through quickly the testing that we have gone through to develop and design the system that we have. And back to my original statement about the fact that it is a level measuring device much the same as others. The trick is to prove that it works in a reactor vessel application.

The way we set about designing and developing and improving that was a test program. So our entire design from the very beginning is based on a test program in addition to the analysis and design that went on.

(Slide.)

What I'd like to show now is the history, taking you all the way back to time zero and how the design evolved and how the testing steps aided the development and design of the probe up to the part where we demonstrated it to work.

I'm going to skip the next slide about our testing objective. I think we've already stated it.

The next one talks about our test program. Let me just say that the test program had three phases of testing, of which the first two are completed. The last one is merely a test drive. We built the car. The last thing to do is take it for a drive, and that's the last phase, which is our prototype test.

MR. LIPINSKI: Did you try to establish the reliability of the individual units as part of this testing?

MR. NEUSCHAEFER: In terms of qualifications?

MR. LIPINSKI: Mean times between failures on thermocouple junctions and heater elements.

MR. NEUSCHAEFER: That's part of our qualification program, which is also going on in parallel. This is performance testing, which is also another effort known as qualification testing, with reliability established.

(Slide.)

In addition to our own test program, we have gotten supplemental information from a number of independent agencies, of which Oak Ridge National Labs and Idaho and MIT is conducting some independent tests of level measuring devices. In fact, they have one of our developmental versions of the probe under test up there.

(Slide.)

Our phase one test program was mainly a proof of principle testing. And what I will be showing you in the next few slides is a sequence of test programs that were conducted to get us to the point of saying that we have achieved proof of principle. I am going to go all the way back to time zero, when we took a basic heated junction thermocouple and show you how the design of the splash shield and the probe separator tube evolved as a result of the testing program.

Am I going too fast, too slow?

MR. KERR: You're not going too fast.

(Slide.)

MR. NEUSCHAEFER: This first slide shows a bare heated junction thermocouple. There is no splash shield, no separator tube, just the performance characteristics of the heated junction thermocouple.

What you see is thermocouple output -- think of it in terms of delta P -- versus heater power applied, and what you see is the flat lines are basically covered sensors. They are in liquid. The steep slope lines are uncovered in steam. And what you see is there is a very distinguishable difference in the heat transfer coefficient. And this is the delta P output when you are covered in liquid versus when you are in steam.

And you also see that when you are covered in liquid, no matter how much heater power you pump into it, the liquid acts as an infinite heat sink basically and it has no effect on the delta P output. Once it's uncovered you can pump more and more heater power into it and increase the delta P output, and that's the basic principle by which the heated junction thermocouple works.

MR. EBERSOLE: Pardon me. There's an intermediate phase, but it's covered in froth. You can't really see that. It looks like liquid, doesn't it?

MR. NEUSCHAEFER: It depends on what the void fraction is. There's a switching problem. That's the function of the splash shield and the separator tube, you're right.

(Slide.)

Having a bare heated junction thermocouple, the first trick was to look at those in-between states, those voided conditions and see what the thermocouple did. Where we were able to do that is in conjunction with Oak Ridge National Labs, at their test stand, where we were able to examine the thermocouple output as a function of void fractions and in fact we saw that yes, the thermocouple switches, but it takes a relatively high void fraction for it to switch. Basically it has to be dry.

Those intermediate void fractions will make it look like it's wet. That led us to the fact that you need a splash shield, and as a result we went back to CE to develop a design for splash shields. We built an atmospheric hydraulic test chamber that actually simulated the conditions in the vessel, and then we tested a number of shield designs before we finally selected the one that we believe to be operable. Shown here is that test vessel.

(Slide.)

This is basically a plexiglass tank, so we had visual communication with the testing. Inside the tank is a CEA shroud to mock up the actual installation of the reactor vessel and then the probe itself. And then you see here one of the sensors and the splash shield.

The test vessel has the ability to add and take out water and also to inject air into the bottom to create that bubbly, two-phase mixture.

(Slide.)

With the splash shield, we have observed the fact that we could measure continuously the heat coefficient transfer of void fraction because we're calibrated to do that. However, all we are interested in is covering liquid or not covering liquid. But it has the ability to do what you said, measure heat transfer coefficient. That requires some further development, but I would not rule that out as a possibility. Right now we're strictly looking at level. Is it covered or not covered?

Shown here, the splash shield now is able to keep out liquids such that the device responds to varying void fractions. And now we have the makings of a device that can be used in a reactor vessel application.

(Slide.)

This was done under atmospheric conditions. We wanted to see if the same thing would hold true under high pressure thermal hydraulic conditions. So again in conjunction with Oak Ridge, at the thermohydraulic test facility, we were able to put one of our sensors in and piggyback some heat transfer tests in there to see how it would work under a very wide spectrum of accident conditions. And I have some of the results I would like to show.

They are more widely published in the Oak Ridge report. But shown here is one representative output from the film boiling test sequence. Plotted on this axis is differential output versus time. These are all transient responses now. And plotted here is the density or gamma densitometer output versus time.

Initially, in a saturated condition, the THTF facility, with a constant inlet flow and pressure, the fuel rod simulator heater power was cranked up to create a film boiling regime in the top region of the core, and the sensor was sitting just above the core. With the fuel rod simulator heater power being cranked up, eventually you put the top elements of the fuel bundle into a film boiling mode and uncover the top portions of the bundle and uncover the sensor. And what you see is the switching from a covered to an uncovered condition.

MR. CATTON: You have significant voiding before that occurs?

MR. NEUSCHAEFER: That's correct. You also see the sensitivity of the device following that voiding.

MR. CATTON: It looks like noise to me.

MR. NEUSCHAEFER: Well, it's not noise. It's actually void. It's not electrical noise.

MR. CATTON: I understand. But you have a difficult time calibrating that.

MR. NEUSCHAEFER: The only thing that's important is to be able to distinguish between an uncovered and a covered. All of this was extra information.

MR. CATTON: That extra information, though -- You have gone from a density of, it looks like, about 45 pounds per cubic foot down to something like ten before you get the strong change. Before that you just know that something's happened, because I don't see amplitude increasing in that lower scale.

You just know that something is happening. You have no idea how much change there is in void until you rach the point where it's quite high.

MR. NEUSCHAEFER: That's correct, but at this point you know that you are covered in liquid, and the sensor is telling that. At this point you know that you are not in liquid.

MR. CATTON: But you have no way of knowing in-between, except that something's happened.

MR. LIPINSKI: Look at the 35-minute point.

MR. NEUSCHAEFER: Right.

MR. LIPINSKI: Now drop down. Look how much your density has changed from zero to 35 minutes before you've made your abrupt change. You don't know what happened until you are between zero and 35 minutes.

MR. NEUSCHAEFER: I know I'm not in an uncovered state. I know the void fraction is changing.

MR. CATTON: But you don't know how much?

MR. NEUSCHAEFER: I don't care.

MR. LONGO: In the interest of speeding this along, he doesn't have a separator tube on it, so it's not the probe.

MR. EBERSOLE: He's in the boiling water reactor business.

MR. NEUSCHAEFER: You've got to keep in mind that we are way back in time, which is the sensors proving the principle of the sensor itself.

(Slide.)

The next slide is just another test sequence from THTF. This one happens to be, in a sense, that this was the normal test condition that was set up. And it's basically an inverted annular film boiling mode to simulate a rod ejection, which is not necessarily something that this thing would normally function for or we want the operator doing it so quick. You see that it did follow it. Subsequent to that test, after the recovered condition they had a rupture disk blow out on the facility. Within moments after that first test sequence and the unit went through a depressurization, basically like a small break, we also see device responding to it. At this point the heater power is being reduced because the pressure is dropping off just to protect the heater.

(Slide.)

What I would like to show now is up to that point we were just looking at the sensor, the thermocouples and splash shields.

Now the idea is to measure liquid level, how much liquid is in the 2-phase froth that's out there. Now that's the idea behind the probe assembly. We did some testing. First our atmospheric test chamber again. Now with the separator tube and the thermocouple inside with our probe, now we are going to look at level measurement, not just the bare sensor.

(Slide.)

Shown here is one cf the test resv.ts, basically what I call a transient two-phase test result. And what we were looking at here is --

(Slide.)

-- the vessel was initially full of water, covering the sensor. Then we inject air into it to create a frothy, turbulent, 2-phased mixture surrounding the probe assembly. Then we're going to drain out the inventory, open the drain, and just drain out the lic id. We are going to see whether or not the separator tube has the ability to separate that frothy 2-phase mixture and whether or not the sensor will uncover.

And what we will see is that even with the frothy two-phase mixture above the sensor, once the collapse level drops below the sensor it will switch. So we will see that it has the ability to tell you how much liquid is in that frothy two-phase mixture.

(Slide.)

Shown on the next slide is one set of results for drain and fill sequence, starting out initially with the heater covered, frothy 2-phase mixture, draining out the liquid. You see that once the heater starts to uncover, that's when it switches. In fact, the accuracy of the device is dependent on the heater link, which is about one inch.

So the accuracy is precisely within about an inch. It's a discrete device in terms of level. So it's accuracy is within a inch. As the heater uncovers you see the output switch, and likewise in a fill situation it will quench.

The difference between the two curves -- that historesis, if you will -- is because of two things -- one, the drain and fill routes were slightly different. More important is that in a drain test there is a slight film that has to be boiled off so that there is a slightly slower response, whereas in a quench it's almost an instant thing -- this response.

(Slide.)

The next set of slides I'll skip over, but it's basically MIT testing, which is much the same as I showed you. And there is one plot that shows the MIT results plotted on the same axis as the CE results, and it shows agreement.

(Slide.)

That was phase one, proof of principle.

The second phase of testing now was, okay, we believe we have a design. Let's go ahead and manufacture the design. Let's test the design and verify the complete design. And that was phase two, called design verification testing. And where we built, through the funding of our CE Owners' Group a dedicated test facility specifically to test the heat junction thermocouple probe under a complete spectrum of accident conditions.

(Slide.)

Shown schematically here -- I have some photographs here on the table, if someone cares to look at them, and some photographs of the probe itself. That might give you a little bit more perspective, rather than just the cartoon that's being shown.

Those test facilities consist of a fifteen-foot test vessel si- lating the upper plenum of the reactor vessel in which was installed a twelve-foot probe with a number of thermocouples at various locations.

We have the ability to add steam and water to create varying conditions, thermohydraulic conditions, in the test vessel. We have gamma densitometer information, temperature, pressure information and also we have the ability to perform top and bottom blowdown transient tests, in addition to static, dynamic, single phase and two-phase tests

(Slide.)

MR. KERR: One more minute.

MR. NEUSCHAEFER: Okay. I'll skip over the types of tests. Let me show you the response of the probe to a two-phase transient, and I'll skip over some of the others.

Shown here is the initial conditions, basically high pressure conditions. Here's the top sensor, a middle sensor and a bottom sensor for the three elevations that were tested. Shown on the bottom is the gamma densitometer versus time.

This is going to be a two-phase transient test similar to the atmospheric test we saw where we create this two-phase frothy mixture and then drain inventory out the bottom

We started out with the middle sensor covered, the top sensor uncovered, and we are going to be observing just the middle sensor's response to the uncovery. What we are going to see is that the densitometer will track the two-phase level and what we are going to see is, as we drain inventory, the heated junction thermocouple switches when the collapsed level inside the separator tube uncovers the heated area. Yet outside of it is a two-phase mixture still covering that same region, as indicated by the gamma densitometer.

So at this elevation, outside, it is still two-phase frothy mixture covering the heated junction, but it is switched, because in that two-phase mixture, there is not sufficient liquids such that there is a collapsed level below the two-phase mixture which the probe is responding to. This is just the opposite sequence when we fill it up again. And you will see that just the opposite effect takes place. This thing switches first, and then later the heated junction thermocouple.

That completes the forty-minute presentation.

MR. KERR: Thank you very much, sir.

I shall now declare a one-hour recess for lunch, after which we will have a closed presentation from Westinghouse which will take about an hour and a half. It is necessary, we will close that session because of the material being presented that's proprietary. So that the next open session will begin about 4:00. And I think that will permit us to complete most of what we had scheduled today, except for the discussion.

(Whereupon, at 1:30 o'clock p.m., the meeting was recessed, to reconvene at 2:30 o'clock p.m., the same day.)

AFTERNOON SESSION

(4:15 p.m.)

MR. KERR: You will want some lights, probably. Do you want it light, or dark?

MR. BAILEY: Light, to begin with, please.

MR. BAILEY: My name is Patrick Bailey. I am Program Manager in the Safety Analysis Department headed by Walt Lowenstein in the Nuclear Power Division at EPRI. I am manager of several R&D projects, including RP-1611, which relates to the development and testing of a non-intrusive water level measurement system that has been tested at Farley Unit One.

The purpose of my presentation is basically three-fold: One is to have information transferred about this project and EPRI activities to this subcommittee. The second is to more fully express some utility concerns that may not have already been expressed but have been related to me. And the third is to present some concerns that I have from the vantage point that I've seen as project manager of this particular project.

The handout that has been circulated in limited quantity contains copies of all the vu-graphs that I will present. Before beginning, I would like to present just a few points of clarification to clear up some problems that have occurred before in this meeting.

The most important is that EPRI is engaged in sponsoring near-term and long-range research and development in support of the U.S. utilities. It does not sponsor products in competition with any vendor, and in this regard we would like to make a statement that we are disappointed that Westinghouse saw fit not to allow us to attend the last closed session.

In regard to an Oak Ridge comment referring to the "NNC device being pursued by EPRI," we would like to correct that and have that read, "the NNC device that has been 'sponsored' by EPRI for testing purposes at Farley Unit One.

It should be pointed out that the EPRI project is less than one year old, and of all the instrumentation systems that have been talked about today ours is the only one that has been fully tested on an operational reactor. I find that rather interesting.

So with those preliminary comments, we will go into the formal presentation.

(Slide.)

The presentation will consist of five parts. Basically the first part will be a review of the EPRI project. I will talk a little bit about the testing program that was conducted with the cooperation of the Alabama Power Company at Farley Unit One.

I will talk a little bit about an internal review of water level measurement systems that is being conducted at EPRI.

I will mention briefly some utility liaison activities and some utility projects that have been occurring that have been briefly touched upon today.

And then I will make some conclusions.

(Slide.)

Project RP1611 is formally entitled "Development of a PWR Water Level Indicator." Its objective, as you can read, is to develop, test, and analyze the ability of a non-intrusive water level detection system to measure the water level in PWRs.

The idea originally started with Ed Zabrowski at NSAC. Some tests were performed, lead tests, to see the adequacy of the system; and this project developed out of that to see how well the system would work on a large PWR.

The scope of this particular project was to develop and test monitoring devices that would measure neutron and/or gamma flux external to the reactor vessel to perform the testing and analyses, and to review other systems as they were proposed.

The results I will present for draindown tests that we did perform at Farley Unit One. Other tests were performed at Trojan and I will not report those tests as they were done with a different system. I will comment on the instrumentation review that we are conducting internally.

(Slide.)

The contractor for the RP1611 testing was National Nuclear in Mountain View, California. A representative of that organization is in the audience.

As I mentioned, preliminary tests were performed at Trojan and, in addition, Rancho Seco. As part of our project, we designed and constructed five top detector assemblies -- I will show a slide of what they look like in a moment; and one large bottom assembly.

Four of the top assemblies were testing during November of 1980 at draindown tests at Farley Unit One that occurred about four days after a shutdown during a normal refueling outage, and the results have been compared with computer analyses. These are multi-group, multi-dimensional computer analyses that try to model the exact physics that occurred at that time.

The results of both the tests -- I'm sorry -- the results of the tests are being released formally by Alabama Power Company next month and should be to NRC, and will be available at that time.

The results of the computer analyses will be available soon afterward. Also, in addition, one of the top detector assemblies was installed above LOFT, above the top of the core at LOFT during the L3-5/L8-1 tests that were recently conducted, and some data was obtained from that test.

Further tests are being planned for sometime in 1982 by taking the four top detectors that were used on Farley Unit One, placing them on top of Farley Unit Two, and putting in the large bottom detector assembly in Farley Unit Two.

(Slide.)

This diagram shows an indication of what these detectors look like. The description is not fully written on the slide. The inner circles are BF_3 counters about two feet long, surrounded by about an eighth of an inch of lead pipe. Both detectors are in one box. The detector tubes and lead are surrounded by polyethylene moderator and put into a stainless steel box. The bottom of the box has essentially lead on the bottom running the entire length, and each box is about a foot wide, and about two-and-a-half feet long. This is called a "neutron detector assembly," and it weighs about 250 pounds.

Four of these detectors are placed in an arrangement similar to this slide, on top of Farley Unit One.

(Slide.)

Above the vessel, but not completely on top of it there is a flange running around the outside of the vessel. They were placed on the flange, so that the top of the vessel was physically located above the top of the detector. They were being placed somewhere in this (indicating) region during the draindown test.

This particular slide indicates what the full system would look like for the tests on Farley Unit Two. There was a problem getting this bottom detector assembly to fit inside of Farley Unit One because of high radiation problems, and the size of the bottom detector. It wouldn't fit very well. So we only obtained data using the top BF_3 counters. For the Farley Unit Two tests, we are hoping to be able to use both BF_3 counters for the shutdown portion of the test, or on 10 for looking at neutron count rate during operation, and taking a ratio of top-to-bottom counts. By taking that ratio, we would factor out the changes in power level such as during shutdown decay that occur, and in that way try to see if we can accurately get a count rate versus water level measurement.

The output of the detectors of course go through preamps in order to standard amplifiers and scaler electronics for counting purposes. If there are no questions on the detectors or these tests, I will move along to the next topic.

MR. KERR: Well, are you telling us that you are devising a system that will be tested? That you have a system that has been tested and it works? I do not get the message, I guess.

MR. BAILEY: Okay. The message -- I really have not told you what the results are of the tests. It is difficult to do that at this time because the have not been formally released by the utilities --

MR. KERR: I do not want to know all the details. As a basketball coach at the University of Michigan used to say: Save me the details; what was the score?

(Laughter.)

MR. KERR: I want to know: Does it work? Or not?

MR. BAILEY: The system will be able to detect water level as it approaches the top of the core. The accuracy of how well it can calculate the changes in water level near the top of the vessel is pretty much reactor-dependent and still needs further analysis.

MR. KERR: Okay. I interpret that answer to say: We have tested it, and we don't know whether it works or not.

MR. BAILEY: That would be a true statement.

MR. KERR: Okay. Thank you.

MR. EBERSOLE: I guess we might add to that: When do you think you might know something more about it that we could hear?

MR. BAILEY: Again, we are waiting for formal release of the test results from November from National Nuclear. We expect that tomorrow, honestly, and I have a Federal Express authorization to send that material to Alabama Power so that they will receive it next week, and they are in turn going to release it to the NRC. So by the end of next week --

MR. EBERSOLE: But no more.

MR. BAILEY: -- everyone should know the results of the tests.

In addition, computer analyses have been performed to pretty much substantiate the results of the tests. So that the physics is well understood. The principles of operation of the system are well understood.

(Slide.)

As you might know, some of the other systems have had problems with various other effects that would hamper the system. Such as in here (indicating), if you had a break in a fuel rod that might give you an ambiguous reading since you are measuring radiation. So there are problems of this nature.

I expect that an EPRI report will be forthcoming probably written by yours truly that summarizes both the data and the computer analyses that were performed in this project. That should be coming out probably within three months.

As far as our review activities for this and other devices, we have included vendor systems, national laboratory concepts that are being worked on, industry concepts, and proposals from various contractors looking for funding. For your information, I think the two best review references that I have found, one was a paper by Y. Y. Hsu, who is in the audience, presented recently at Cal Tech; and another is an Oak Ridge paper presented by Mr. Anderson, which is available. I have brought copies of both of these, if anyone is interested. They give a good review of all instrumentation.

(Slide.)

The instrumentation that I have heard about so far at this meeting I listed on this graph, as well as some others that haven't been discussed too well. You heard about the Westinghouse and the CE proposals. B&W, to my information, is proposing to use differential delta P measurements between the hot leg and the top of the vessel on new plants. Oak Ridge of course has been doing work with heated thermocouples, but also with ultrasonic and gamma flux monitors. EG&G has also been doing work with conductivity probes that are currently installed in LOFT for doing water level measurements on their instrument readout facility, and pressure transducers.

EPRI of course has had just this one project, a non-intrusive device. Other organizations have considered proposals for microwave devices, looking at basically reflected microwave energy; and also using heated resistance temperature detectors, or so-called "RTD"s.

(Slide.)

Internally what we have done is construct a table. I would like to point out that this table is about three months old and may not reflect current, up-to-date information. The idea here of this table is to try to contrast all of the various devices that have been proposed on some sort of common basis to find out the advantages and disadvantages of each. What I will do here is just scan down.

The various thermocouple devices: There has been talk about the core exit thermocouples being used; heated RTDs; delta P methods; level transducers --

(Slide.)

-- neutron detectors from the EPRI project; and also, by the way, from a project from Penn State University. The gamma thermometer has not received discussion yet. There is a Gamma Thermometer Interest Group at Oak Ridge, and I believ it is Duke Power who is very interested in that concept. The idea here is basically a thermocouple heated by gamma heating type design using either two or three thermocouples.

Oak Ridge has done a study showing that if you use three thermocouples in a gamma thermometer device, you are not only going to get the temperature at that point, but also a delta T which would be able then to give you water level reading as the level dropped across that point.

Ultrasonic devices: Basically it is a reflected signal, a microwave reflection signal.

Time-Delay Reflectometry was pointed out this morning as another option, I believe by B&W. I don't remember who pointed that out.

Another device is fission-counter proposals, an idea to basically put small BF_3 counters inside the vessel, along with small sources to detect change of moderator between source and detector.

(Slide.)

There are subcooling concepts. You load cells to weigh the vessel. Metal Oxide cable. And Meltable conductor: when the level passes a certain point, something would melt to give an indication.

(Slide.)

The activities that I have been involved with in this project have been mostly involved with utility liaison, trying to keep the utilities' interests known to myself and the results of our project known to them, to try to keep up-to-date on the owners' groups activities and the vendors activities.

Again, the gamma thermometers and RTDs have received less attention lately than they might deserve.

And I have been finding the status and positions of the various utilities. Regarding the 1/1/82 deadline that was discussed this morning, we saw that many utilities have already made commitments with various vendors for various systems. In conversations with some people today, it is not clear whether that list is completely accurate. What I would say is that some have contracted with the vendors. I would say that most utilities have not. And it is a true statement to say that some are reconsidering their position.

MR. KERR: Mr. Bailey, I think you said earlier that EPRI was concerned with short-term solutions of this problem? Did I mishear, or misinterpret? Or maybe "near-term" or whatever.

MR. BAILEY: Short-range R&D.

MR. KERR: Yes. What does that mean in terms of years that one might wait before such device would be operable in and installable? Two years? Twenty years?

MR. BAILEY: That would be a difficult question to answer. From what I have seen, I think the nearest amount of lead time that we've tried to obtain has been on the order of two to three years to get results that could be applied. To my knowledge, EPRI has not come up with a devic^ to give to the utilities and say, "Here is this device; you can now go use it." The one exception to that may have been a flow meter developed by Dave Kane for an application.

MR. KERR: So you are -- and by "you," I mean "EPRI" -- not involved in anything that would come close to meeting the current NRC time schedule? You are talking about some next-generation of plants, or something? Is that correct?

MR. BAILEY: That is correct. I don't think that EPRI is trying to put themselves in a position to provide material for the utilities' systems instruments for the utilities to use. They would, however, be cooperating in projects to see that result achieved, but not have it be solely EPRI.

MR. KERR: Now are you attempting for utilities or for the public good, or whatever, to evaluate existing available systems, not necessarily to say "this is the best one," but to say something --

MR. BAILEY: Right.

MR. KERR: -- which will provide -- where would ne find some information on what you have said, other than that chart you just showed?

MR. BAILEY: Presently, that is all that exists at this time. Like many others, I have --

MR. KERR: Is that expected to provide some guidance to a prospective purchaser? Because if I were a prospective purchaser, I wouldn't know how to use it. But then, I don't have that sort of money anyway.

(Laughter.)

MR. EBERSOLE: What is the product?

MR. KERR: I am trying to get some feel for what EPRI thinks of existing systems. Are you the person I should talk to?

MR. BAILEY: I think I am the closest at EPRI in that regard.

MR. KERR: How do we find out what you think about these systems?

MR. BAILEY: Ask.

(Laughter.)

MR. BAILEY: Insofar as a system-to-system comparison and making a recommendation, I think we would agree pretty much with the results of the Oak Ridge comparison, based on the data they had that thermocouples may be the best method for using -- based on the information that we've read.

However, this is in no way a recommendation to the various utilities to say that this is an EPRI position, therefore it is all right for us to do this.

MR. KERR: I am willing to have you put in as many caveats as you want. I just wondered if you had something that would be helpful to the subcommittee.

MR. BAILEY: I do plan on making some statements like that I think on the next, or final page.

MR. KERR: Okay. You see, I am interested in EPRI's research program in the future, but I am also interested -- maybe more immediately interested -- in what sort of comments do we make to the NRC about the immediate problem, which is those reactors out there that have got to install something on some time schedule.

MR. BAILEY: Okay. My comments that I would make would be: There are a number of devices that are being proposed that are being closely followed by the utilities and EPRI. No prototypes have been tested on real systems. Few prototypes have been tested on simulated systems. The tests that are being conducted in the near future by CE at their facility may provide good transient data for that system. As far as I know, the Westinghouse system is only being tested at Semiscale, and I am not sure of the status of the results of the tests that have been produced thus far because I was not in the room.

I would make the statement, personally, not as an EPRI position: It seems unfair that a utility be required to be forced to buy a system without knowing whether it will work; and then being perhaps required to replace it in the future because the NRC might find fault with it.

One of the comments I was going to make toward the end was that we have heard a lot of comments about how the utilities are going to provide the analysis of the system to their plant, and comparative analysis for other systems, provide guidance as to the use and procedures of that system, do a lot of the work, and it is not clear that they have the manpower or even the detail at the present time on the system to accomplish any of that.

MR. KERR: You remind me a little bit of the story that I think Joe Garrigola tells about some Yankee relief pitcher who came up with the bases loaded, and Carl Yastremski or Téd Williams, I guess, was next up. He sort of hesitated, and finally the pitching coach went out and he said, "What are you going to do?" And he said, "I am going to throw the ball to first base."

(Laughter.)

MR. KERR: You are sort of telling me that the utilities should throw the ball to first base.

MR. BAILEY: It is not clear where the ball is.

MR. KERR: Well, the NRC has tossed the ball to the utilities, it looks to me like.

MR. BAILEY: On an individual utility-by-utility basis.

MR. KERR: Yes.

MR. BAILEY: Right. And EPRI is there to provide R&D support. I hate to kind of defer, but it is not my position --

MR. KERR: If you don't have anything to say, in my view, the wise thing is not to say anything. And I think you are telling me that you don't see any systems that if you had a reactor you would be willing to install, except maybe --

MR. BAILEY: If I had a reactor, with the knowledge that I have I would not make a commitment to install any system.

MR. KERR: Okay. But that is not an official EPRI system -- or is it?

MR. BAILEY: I don't think EPRI has a position.

MR. KERR: So you are the nearest thing to an EPRI position that we can find, maybe?

MR. BAILEY: Yes.

MR. KERR: Well, I do not want to interfere with your presentation.

MR. BAILEY: Where are we?

MR. KERR: Utility status and positions.

MR. BAILEY: Right. Some that have commitments might like to reconsider their present commitment due to the information they now know.

(Slide.)

This slide I put together based on the information that I know about the programs that have been sponsored by utilities specifically on the heated thermocouple design at CE.

The participating utilities were Yankee Atomic, North East Utilities, Consolidated Edison of New York, and Consumers Power.

Tests were conducted at MIT under the direction of Peter Griffith basically for steady-state conditions and some limited transient conditions. It is not clear exactly what problems were found, but there appears to be two problem areas in the tests that were related to me. One was the probes having a problem of greater than 200 psi pressure; and that there is a problem with the outer steel cladding that it evidently unzipped during one test. The reason for this is not clear, and I am sure that CE may be able to fill in their version of that.

There might be a problem with outgassing of the magnesium oxide binder that surrounds the thermocouple leads, or it may have been a problem with overheating of the heater.

In addition, there were some problems identified for various transient conditions, given the current design of the thermocouple that they have.

MIT proposes to do future testing, but I was informed today that similar transient testings were already being considered to be performed by CE. So it looks as if that base is covered.

MR. CURREY: Excuse me, but could I add a few words to that?

MR. KERR: Why don't you wait until he is finished, if you will, please?

MR. BAILEY: Mr. Currey is the Manager of the North East Utility interest in that program.

(Slide.)

Basically, the conclusions that I would draw from the review that I have done is:

There is increasing and very serious utility involvement.

EPRI right now maintains an information liaision activity, and this one project, and that is currently the scope of our effort.

Again, the commitment information that NRC presented may be different than actually exists.

MR. KERR: I'm really not terribly interested in the commitment activity. I am more interested in what is available.

MR. BAILEY: All right.

MR. KERR: So your final conclusion is that the NRC deadline is inappropriate?

MR. BAILEY: And also that there does not seem to be an organized development and testing program that the utilities can fall back onto to make a choice.

That would conclude my status.

MR. KERR: Thank you, sir.

Questions? We have much less time than I had hoped to listen to NRC, but what we have we will make use of. So thank you, Mr. Bailey.

MR. HSU: My name is Yih-Yun Hsu of the Reactor Safety Research Office. Originally we planned to have three presentations -- my presentation on the evaluation, which apparently some people are quite interested in except we don't have a chance to go into detail; and then we also have Andrew Hon, who would report on the testing of various methods; and then we also have Oak Ridge people to report the testing of new instrumentation -- but we don't have time. So I will only make an extremely brief presentation.

One thing we have to make clear is that our job is to identify suitable techniques for the detection of an ICC.

(Slide.)

Our position is different from Regulatory, because what we do is we just look from a technical point of view. All the licensing issues we defer to them. So we make our consideration strictly on the technical point of view.

Also, we do not consider equipment qualification, and we do not consider human factors. These we leave to other people. What we do is prove the principle by testing. The reason we do test is because we have large facilities, many facilities we can put them in, and we have people who are experienced in instrumentation. So this is a very brief way of describing it.

(Slide.)

As I said, originally I was planning to describe various methods, just like the big table Mr. Bailey was showing, except we don't have time. So all I can do is show the nuclear and non-nuclear issues' technique, and we show them here.

MR. KERR: Okay, so that you really are not showing things that one could purchase within the next year or so, but rather principles that could be used if one were going to develop or detect --

MR. HSU: The only two we can find out is DP and the heated TC. That was presently available.

MR. KERR: Yes.

MR. HSU: And then there is one last item here that is also on the ultrasonic ribbon. There is one that has been tested at Oak Ridge, and we consider it is about the best we can think about.

(Slide.)

This is non-nuclear. Okay, we considered electrical impedience, liquid-level detectors, various sonic/ultrasonic devices including this, but also there is microwave and time-domain reflectometry. You can see that each one has a plus or minus. The details are spelled out in the CSNI report or paper that I presented at Pasadena, and we have about ten copies here.

So among the non-nuclear, sonic is the best.

Then we have also considered other ones, plus the last two are the ones I said we favored.

But about the nuclear devices we considered, including the exterior neutron detectors, which is the one EPRI reported, too; and we considered two of them. They are quite different. One is a top/bottom arrangement, which is the one EPRI reported. And there is a side arrangement which is the one at Penn State. We think that has more promise, and we intend to look more into that.

So in short, these two are the available ones we favor. And there are two new ones we think have promise. One is the side arrangement, side stream for the exterior detector. That is the plus here (indicating). And then also the ultrasonic ribbon.

(Slide.)

SPND is not very good because when the neutron activity is low, you don't get the information. And then we have --

MR. KERR: Are any of these so good that you are going to persuade licensing that they should wait awhile and install these better ones, rather than use the ones that you think are not now available but are not so good, or have you made up your mind?

MR HSU: We would rather have them go ahead with existing technology, but within a couple of years we probably will persuade them that for all the new ones they should put in these that are more promising.

MR. KERR: So they will put these existing ones in and then in four or five years, put in some better ones? Is that the idea?

MR. HSU: Well, we would show them the facts and try to persuade them. They make their decisions by looking at the factual information.

And we have a lot of test facilities such as at Oak Ridge and Idaho. We have tested the Oak Ridge TC, and the Navy TC, Oak Ridge ultrasonic, Idaho ultrasonic -- heated TC, and --

MR. KERR: Well, seriously, if we try to inject a little bit of -- I don't know how to put it -- but is it really your view that plants should put in a system next year, and then three or four years later go back and put in another system?

MR. HSU: No, no, no.

MR. KERR: Okay, then --

MR. HSU: The heated DP -- they are sufficient for today's use; but we think maybe we can find a better one, but --

MR. KERR: A better one for new plants? Or a better one for plants that have already put in the DP?

MR. HSU: My personal opinion is that the new ones, if they are retrofittable, for example the side stream is not expensive, but otherwise they don't have to put in, just stay with the way they have now. Then they can be for the new plants.

MR. KERR: Okay.

MR. HSU: Unless it is easy to retrofit.

MR. KERR: Okay, so much of what you are concentrating on I can interpret to be for new plants, and not for plants that are now operating? Correct?

MR. HSU: No, for operating. We are concentrating on them, too, with the heated TC and the DP ones we are concentrating on now for present plants. We have the Westinghouse DP that we are testing, and a whole bunch of heated TCs.

MR. KERR: No, but aside from the CE and the Westinghouse, most of what you are concentrating on is probably for new plants and not for existing plants. I am not trying to put words in your mouth. If I am misstating --

MR. HSU: One we are working on, the ultrasonic ribbon, will be for new plants. That is not for the old plants.

MR. KERR: Okay.

MR. HSU: So the summary is that we have, in our project we are going, or in our branch which is the Experimental Program Branch in the old Reactor Safety Division and now called Accident Evaluation Division.

(Slide.)

We do have a facility to evaluate the ICC instrumentation, and try to prove the principle, and then show which one is more promising. As I have shown here, the heated TC and ultrasonic is promising, and the DP of course could be valuable. There is some questionmark here, but they are viable.

Then we work on this for vendors. Our research group, and the national laboratories, and the regulatory people. And performing tests at Oak Ridge, we have thermal devices, the heated TC devices. At Idaho, Semiscale and so forth, we have a Westinghouse DP. By the way, new results just came up that we are not ready to report, yet.

So all this we plan to complete to meet the NRR requirement of December 31st, 1981, for the testing. Now for the further development we plan to go beyond that. That is for the new devices like ultrasonic ribbons.

MR. KERR: Does the NRC Research plan to develop an instrument?

MR. HSU: We do this way. We cannot legally say we are developing for the commercial application; but we do have an obligation to Regulatory to provide technical advice. So when we do all this R&D work, essentially what we do is we develop our own technical expertise. And when the national laboratory does that, they acquire that technical expertise, too. When they have that, they can also serve the Regulatory better.

So essentially it is to basically develop our expertise for the advisory function; but while we are doing that, we also could explore some new devices.

MR. KERR: I think the answer you are giving me could be translated to mean, "yes."

MR. HSU: Not in the primary sense. It is by default.

(Laughter.)

MR. ZUDANS: Dr. Hsu, if none of the real tests will be completed before January 1, 1981 -- tests that will allow an accurate determination of whether or not the system works -- in your personal opinion, not speaking for NRR, does it really make any sense to demand installation by that date?

MR. HSU: No, the tests -- I have full confidence that what we are testing now really is showing us --

MR. ZUDANS: But that is "confidence," not the test results.

MR. HSU: No, we have the test results already. We have quite a few test results.

MR. ZUDANS: We just heard, for example, CE make a presentation that everything looked rosy. Now the EPRI presentation came about and said that there are problems with 200 psi, already. How is that system going to perform in 2200 psi?

MR. HSU: Our test results on the heated TC at Oak Ridge and Idaho all show that the heated TC, except for the very high flow, everything looks real good.

MR. ZUDANS: The high pressures, too?

MR. KERR: Well, EPRI must not have seen your test results? Or do they have some additional ones?

MR. HSU: I don't know if they've seen the whole, complete results. I don't know, because I'm not EPRI and I don't know how much --

MR. KERR: They must have seen some that give them pause.

MR. HSU: Well, there were a whole bunch that we wanted to report today, but we didn't have a chance to give the report.

MR. KERR: So you are confident that by January of '82 there will be enough test results so that one can make a decision about installation?

MR. HSU: Yes, on the heated TC I can.

MR. KERR: But one might not be able to have the installation completed by then if he wanted to have test results before he made an installation?

MR. HSU: We will have the test results already out. Judgment is Regulatory's part.

MR. KERR: So the test results come out on December 31, and the installation is supposed to be completed by January 1. Right?

(Laughter.)

MR. ZUDANS: That gives you 24 hours.

(Laughter.)

MR. KERR: Well, things are speeding up.

MR. HSU: Well, we were really planning to give a more detailed, orderly presentation, and then you would have seen our test results on the heated TC.

MR. KERR: I apologize for the disorder that we sort of enforced upon you. I am sorry, because I know that you have worked hard to prepare this.

MR. HSU: No, we're not worried about that; but what I worry about, for example, is Dr. Zudans' question about the test results. We did have information that we were planning to report.

MR. KERR: Well, perhaps you can make that available to us --

MR. HSU: I have already handed it out.

MR. KERR: Perhaps we can discuss this at a later meeting. I hope we will be able to.

MR. HSU: That's right. Thank you.

MR. KERR: Are there any questions?

(No response.)

MR. KERR: Well, gentlemen, I am sorry to any of you who did not have time enough to make the proper presentation, and we do appreciate the information provided.

I would like to ask the two consultants if, in light of our schedules, you will communicate with Mr. Savio any comments you have. I would hope that Dick and I can put something together for a fairly early consideration by the ACRS, at least information and maybe some recommendations about schedules.

Are there any further comments that the consultants would like to make?

Mr. Ebersole?

MR. EBERSOLE: The only thing that I could comment on is this rather terrible disparity between EPRI, CE, and the Oak Ridge people. I got an impression from EPRI that the methods proposed by CE and ORNL are not all that good.

I think something ought to be done to rationalize the differences.

MR. ZUDANS: And with the --

MR. KERR: As we say in the academic community, that is left as an exercise for the student.

(Laughter.)

MR. KERR: But the EPRI people must be communicating with the utilities, and they certainly talk on a regular basis with NRC. So we do need to explore that further, I agree.

MR. ZUDANS: I had a question. Dr. Esposito said that he gave a report to you on the DP that describes in detail their analysis and how they did certain things.

Do you think that we could get that report?

MR. ESPOSITO: You probably have it.

MR. ZUDANS: We probably have it?

MR. ESPOSITO: I can't say for sure, but we will check into it.

MR. ZUDANS: I see. We may have it and just don't realize it.

MR. ESPOSITO: That is possible.

MR. KERR: Further questions or comments?

Yes, sir?

MR. BAILEY: I would like to make one comment in EPRI's behalf in regard to the discrepancy with the heated thermocouple. I think the problem may be that we are using different thermocouples and different designs in different facilities; and that a side-by-side comparison of similarities and differences has to be performed in order to understand why we are seeing the results that we are seeing.

MR. KERR. Have you been testing a CE-heated thermocouple? Or an EPRI-heated thermocouple? Or an Oak Ridge-heated thermocouple? Or none of the above?

MR. BAILEY: What was reported to me was evidently a CE prototype thermocouple being tested at MIT under the sponsorship of four utilities.

MR. KERR: Okay. Any further questions or comments?

Mr. Lipinski?

MR. LIPINSKI: One comment on the sheath splitting. Years ago when we tried to instrument EVWR, we encountered that same problem. We traced it down to moisture being absorbed into the insulation. Then when it was heated, it would expand and force the stainless steel sheath to come apart. Then it took a very careful preparation, and once it was dried out that the end of the couple had to be sealed when it came out from the pressure environment such that moisture could not penetrate down that insulation again.

MR. EBERSCLE: So it may be nonrepresentative?

MR. LIPINSKI: It could be a function of who fabricated the thermocouple.

MR. BAILEY: That could be quite true.

MR. KERR: Thank you, gentlemen. The meeting is adjourned.

(Whereupon, at 5:00 p.m., the meeting of the Electrical Systems Subcommittee on Core Water Level Measurement Devices was adjourned.)

* * *

NUCLEAR REGULATORY COMMISSION

This is to certify that the attached proceedings before the

____

in the matter of: ACRS - SUBC. ON ELECTRICAL POWER SYSTEMS

Date of Proceeding: May 28, 1981

Docket Number: ______________________

Place of Proceeding: Washington, D. C

were held as herein appears, and that this is the original transcri thereof for the file of the Commission.

ANN RILEY

Official Reporter (Typed)

Ann Riley

Official Reporter (Signature)

NUCLEAR REGULATORY COMMISSION

This is to certify that the attached proceedings before the

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Jane W. Beach

Official Reporter (Typed)

Jane W. Beach

Official Reporter (Signature)

Phillips

STAFF REVIEW SCHEDULE FOR NUREG-0737 SECTION II.F.2

MILESTONE	DATE
LICENSEE SUBMITTAL - DESIGN DESCRIPTION AND SUPPORTING ANALYSES	JANUARY 1, 1981
GENERIC QUESTIONS AND POSITIONS DEVELOPED	APRIL 1, 1981
QUESTIONS AND POSITIONS TRANSMITTED TO LICENSEES	JULY 1, 1981
LICENSEE SUBMITTAL - RESPONSE TO STAFF QUESTIONS AND POSITIONS	SEPTEMBER 1, 1981
GENERIC SERs AND MODEL TECHNICAL SPECIFICATIONS ISSUED	DECEMBER 1, 1981
INSTALLATION	JANUARY 1, 1982
LICENSEE SUBMITTAL - QUALIFICATION OF THE SYSTEM FOR OPERATION	MARCH 1, 1982
ISSUE TECHNICAL SPECIFICATIONS AND PLANT SPECIFIC APPROVALS IMPLEMENTATION	MAY 1, 1982
REVIEW COMPLETE (PLANT SPECIFIC SERs ISSUED)	JULY 1, 1982

STAFF REVIEW PROGRESS FOR NUREG-0737 SECTION II.F.2

THE PWR LICENSEE SUBMITTALS WERE REVIEWED

DRAFT GENERIC QUESTIONS AND POSITIONS HAVE BEEN DEVELOPED BY ORNL AND MODIFIED BY THE STAFF

GENERIC QUESTIONS AND POSITIONS TO BE TRANSMITTED TO LICENSEE BY JULY 1, 1981

SUMMARY OF PWR OPERATING PLANTS RESPONSE TO
NUREG-0737 SECTION II.F.2 REQUIREMENTS
REACTOR LEVEL MEASUREMENT
(MAY 26, 1981)

BABCOCK AND WILCOX PLANTS

THERE ARE EIGHT RESPONSES INCLUDING 2 NO NEED, AND
6 STILL LOOKING

COMBUSTION ENGINEERING PLANTS

THERE ARE EIGHT RESPONSES INCLUDING 1 NO NEED,
4 STILL LOOKING, AND
3 COMMITMENTS, (HJTC)

WESTINGHOUSE ELECTRIC PLANTS

THERE ARE TWENTY NINE RESPONSES INCLUDING
2 COMMITMENTS (HJTC),
2 COMMITMENTS (NNC),
18 COMMITMENTS (DP), AND
7 STILL LOOKING.

SUMMARY OF OPERATING PLANTS RESPONSE TO

NUREG-0737 SECTION II.F.2 REQUIREMENTS

REACTOR LEVEL MEASUREMENT

B&W		Installation Schedule		
Plants	Detector Type	On-time	Delay	No Schedule
ANO 1	Not Needed			
Crystal River 3	ΔP Hot Leg Level Inst.		No schedule specified	
Davis Besse 1	Review of current available system			No commitment
Oconee 1, 2 & 3	ΔP Hot Leg Level Inst.			
Rancho Seco	ΔP Hot Leg Level Inst.			
Three Mile Island 1	Not needed			
Summary	2 not needed 6 still looking		no commitment all plants	8

SUMMARY OF OPERATING PLANTS RESPONSE TO

NUREG-0737 SECTION II.F.2 REQUIREMENTS

REACTOR LEVEL MEASUREMENT

CE		Installation Schedule		
Plants	Detector Type	On-time	Delay	No Schedule
ANO 2	Not Needed			
Calvert Cliffs 1 & 2	Based on HJTC results		1983	
Ft. Calhoun	HJTC's		Fall 1982	
Maine Yankee	HJTC Probable			
Millstone-2	CE HJTC			
'alisades	Support HJTC			
St. Lucie 1	Per C-E O G		will provide after completion of CE program	
Summary	1 Not Needed 4 still looking 3 HJTC			4 nc commitment

SUMMARY OF OPERATING PLANTS RESPONSE TO

NUREG-0737 SECTION II.F.2 REQUIREMENTS

REACTOR LEVEL MEASUREMENT

W		Installation Schedule		
Plants	Detector Type	On-time	Delay	No Schedule
Beaver Valley	ΔP	1/1/82		
Cook 1 & 2	ΔP	1/1/82		
Farley 1 & 2	Neutronic (EPRI)	Complete Deve. 1/1/82	Refueling outage 1982	
Ginna	No Selection			
Haddam Neck	Prefer CE HJTC		will provide after completion of CE program	
Indian Point 2	ΔP			
Indian Point 3	ΔP	1/1/81		
Kewaunee	No Selection			
North Anna 1 & 2	ΔP, Per W	1/1/82		
Point Beach 1 & 2	ΔP, Per W			
Prairie Island 1 & 2	No Selection			
Robinson 2	ΔP, Per W			
Salem 1 & 2	ΔP, Per W	1/1/82		
San Onofre 1	No Selection			
Surry 1 & 2	ΔP, Per W	1/1/82		

W		Installation Schedule		
Plants	Detector Type	On-time	Delay	No Schedule
Trojan	ΔP, Per <u>W</u>	1/1/82		
Turkey Point 3 & 4	HJTC, Per CE		will provide upon completion of CE program	
Yankee Rowe	No Selection			
Zion 1 & 2	ΔP, Per <u>W</u>	Installed		
Sequoyah 1	ΔP, Per <u>W</u>	1/1/82		
Summary	2 per CE 2 per NNC 7 no commitment 18 per <u>W</u>	16	3	10

Anderson

Criteria for Evaluation of Reactor Vessel Coolant Level Instrumentation

by

J. L. Anderson

Instrumentation & Controls Division

ornl

presented to

Advisiory Committee on Reactor Safety

Washington, D. C.

28 May 1981

ORNL is providing assistance to the NRC Division of Systems Integration for evaluation of reactor vessel coolant level instrumentation proposed by the nuclear industry and the utilities in response to "TMI Task Force Action Plan II.F.2" in NUREG 0737.

ornl

Two sets of criteria are combined in this evaluation:

- Criteria which reflect the regulatory viewpoint (from NUREG 0737 II.F.2, Appendix B);

- Supplemental evaluation criteria reflecting instrumentation characteristics developed by ORNL.

ornl

Second stage draft evaluations have been prepared for two submissions:

- the differential pressure level systems developed by Westinghouse
- the heated junction thermocouple system developed by Combustion Engineering

Evaluations have also been made for two other preliminary proposals for level systems:

- the microwave level system being developed by Davco
- the ex-core neutron detector system being developed by National Nuclear Corp.

A. Installation Specific Criteria

1. Requirements for Operator
   a. system must not present ambiguous or confusing information to operators
   b. system should provide for rapid access to pertinent information
   c. information should be self-sufficient and not require reference to procedures
   d. validity of measurements obtained by automatic self-verification should be incorporated into display

A. Installation Specific Criteria (cont.)

2. Calibration and verification procedures should be specified
3. Redundancy or diveristy cross-checking procedures should be specified
4. Output during normal operation to provide assurance that system is operating
5. Impact of retrofit or replacement
6. Interference with refueling

B. Sensor and Transducer Specific Criteria

1. Resistance to temperature damage or effects (e.g. T/C decalibration or breakage)
2. Accuracy and resolution
3. Response characteristics (e.g. time-constant)
4. Commitment to environmental qualifications per NUREG 0737

C. Accident and Post-accident Monitoring

1. Effects of core uncovery
2. Effects of reactor internals movement (e.g. flow blockage, damage to sensors)
3. Effects of pressure changes (water hammer, depressurization)
4. Effects of flow variations (high velocity, reverse flow)
5. Effects of coolant void-fraction

Longo

IAOPICCI

INSTRUMENTATION TO ASSIST OPERATOR

IN PREVENTING AN INADEQUATE CORE

COOLING INCIDENT

AGENDA FOR C-E ICCI PRESENTATION

1.	OVERVIEW OF C-E APPROACH	J. LONGO	(20)
2.	EVALUATION OF ICCI	G. MENZEL	(20)
3.	COMPONENTS & TESTING	C. NEUSCHAEFER	(50)

REQUIREMENTS

NUREG 0737 - SECTION II.F.2 "INSTRUMENTATION FOR DETECTION OF INADEQUATE CORE COOLING"

NUREG 0696 - SECTION 5 "SAFETY PARAMETER DISPLAY SYSTEM"

- SECTION 1.5 "AVAILABILITY OF BACKUP SAFETY PARAMETER DISPLAY"

- "TREND RECORDING OF SAFETY RELATED PARAMETERS"

NUREG 0588 - ENVIRONMENTAL QUALIFICATION REQUIREMENTS FOR SAFETY RELATED COMPONENTS

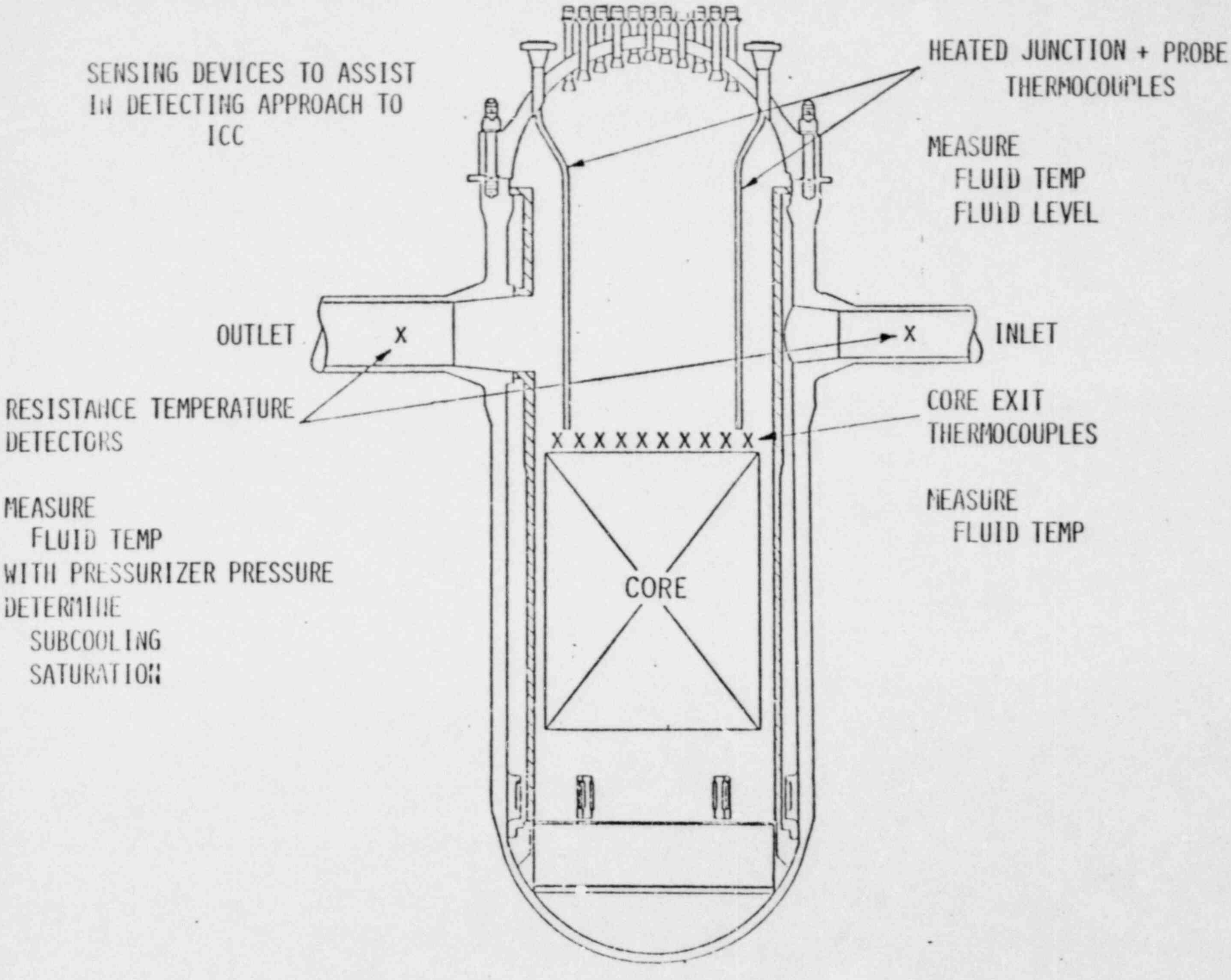
REG. GUIDE 1.97 - INSTRUMENTATION REQUIRED FOR ACCIDENT MONITORING

PROGRESSION OF INTERVALS LEADING TO AND RECOVERING FROM ICC

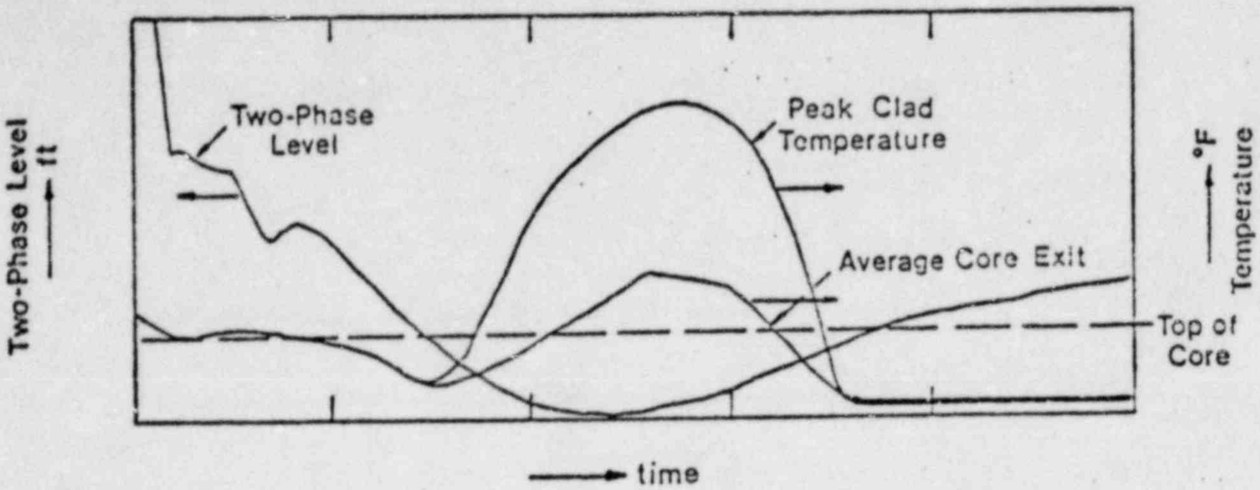
INTERVAL	DESCRIPTION
1	PRIMARY SYSTEM COOLANT REACHES SATURATION CONDITIONS
2	FALLING LEVEL OF COOLANT IN UPPER PLENUM
3	CORE UNCOVERY
3A	FALLING CORE LEVEL
3B	RISING CORE LEVEL
4	RISING LEVEL OF COOLANT IN UPPER PLENUM

ICC INTERVAL INSTRUMENTATION

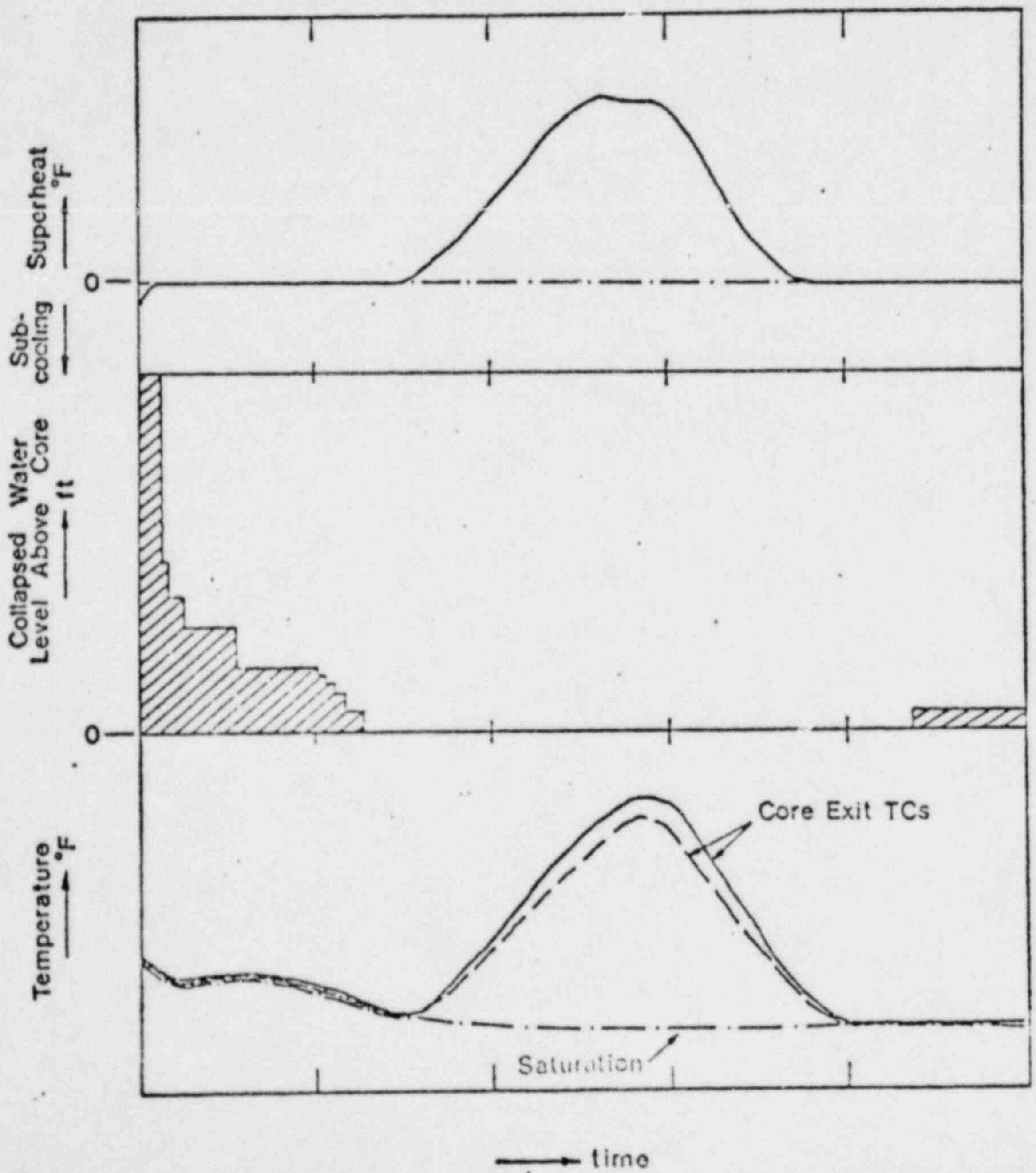
INSTRUMENT	INDICATION	INTERVAL
SMM	DEGREE OF SUBCOOLING IN RCS	1
RVLMS	LIQUID LEVEL ABOVE CORE	2,4
CET	COOLANT EXIT TEMPERATURE	3A,3B


SENSING DEVICES TO ASSIST IN DETECTING APPROACH TO ICC
HEATED JUNCTION + PROBE THERMOCOUPLES
MEASURE
FLUID TEMP
FLUID LEVEL
OUTLET
X
X
INLET
RESISTANCE TEMPERATURE DETECTORS
CORE EXIT THERMOCOUPLES
X X X X X X X X X X
MEASURE
FLUID TEMP
WITH PRESSURIZER PRESSURE
DETERMINE
SUBCOOLING
SATURATION
MEASURE
FLUID TEMP
CORE

PLANT PARAMETERS



ICC INSTRUMENTATION DISPLAY



C-E RECOMMENDED ICC EQUIPMENT

I. SENSING DEVICES

A. PRESSURIZER PRESSURE SENSORS
B. HOT AND COLD LEG RTD'S
C. UPPER PLENUM TC'S
D. HEATED JUNCTION TC'S
E. CORE EXIT TC'S

II. INTERVAL INSTRUMENTATION

A. SUBCOOLED MARGIN MONITOR (SMM)
   1. RTD'S
   2. UPPER PLENUM TC'S
   3. PRESSURIZER PRESSURE
   4. PROCESSOR
B. REACTOR VESSEL LEVEL MONITORING SYSTEM (RVLMS)
   1. HEATED JUNCTION TC'S
   2. PROCESSOR
C. CORE EXIT TC'S

III. SYSTEM PROCESSOR AND DISPLAY

A. QUALIFIED SAFETY PARAMETER DISPLAY SYSTEM
B. CRITICAL FUNCTION MONITORING SYSTEM

IV. OPERATOR

A. ICC GUIDELINES
B. TRAINING

C-E ICC ACTIVITY MATRIX

	SUBCOOLED MARGIN MONITOR	RVLMS (HJTC)	CORE EXIT TC'S	SAFETY PARAMETER DISPLAY SYSTEM	CRITICAL FUNCTION MONITOR SYSTEM
HARDWARE DESIGN	X	X	X	X	X
HARDWARE	X	FIRST ONE IN '82	X	FIRST ONE IN '82	
QUALIFICATION	X	IN PROGRESS	IN PROGRESS	IN PROGRESS	
II.F.2 DOCUMENTATION	IN PROGRESS				
OPERATOR GUIDELINES	TO BE MODIFIED				
TRAINING	TO BE MODIFIED				

PERFORMANCE EVALUATION OF

ICC INSTRUMENTS

DEFINITION OF ICC

GENERAL REQUIREMENTS FOR ICC INSTRUMENTATION

EVALUATION OF INSTRUMENTS

ICC INSTRUMENTATION

DEFINITION OF ICC

INADEQUATE CORE COOLING OCCURS WHEN CLADDING TEMPERATURES EXCEED COOLANT TEMPERATURES SIGNIFICANTLY.

NRC DEFINITION:

CORE IS IN A "STATE OF INADEQUATE CORE COOLING" WHENEVER:

1. THE TWO PHASE FROTH LEVEL FALLS BELOW THE TOP OF THE CORE AND

2. THE CORE HEATUP IS WELL IN EXCESS OF CONDITIONS THAT HAVE BEEN PREDICTED FOR CALCULATED SMALL BREAK SCENARIOS FOR WHICH SOME CORE UNCOVERY WITH SUCCESSFUL RECOVERY FROM THE ACCIDENT HAVE BEEN PREDICTED.

FOR EVALUATION OF INSTRUMENTATION, EXACT DEFINITION OF ICC CLADDING TEMPERATURE LIMIT IS UNNECESSARY BECAUSE DETECTION OF APPROACH TO/RETURN FROM ICC IS AS IMPORTANT AS DETECTION OF EXISTENCE OF ICC.

GENERAL REQUIREMENTS FOR

ICC INSTRUMENTATION

1. PROVIDE UNAMBIGUOUS, EASY-TO-INTERPRET INDICATION OF ICC (NUREG-0737)

2. DETECT THE APPROACH TO, EXISTENCE OF AND RECOVERY FROM ICC (NUREG-0737)

3. DURING CORE UNCOVERY, INSTRUMENTATION IS TO PROVIDE INDICATION OF INADEQUATE COOLING RATHER THAN SPECIFIC WATER LEVEL INDICATION

4. DIFFERENT INSTRUMENTS MAY BE USED TO COVER THE RANGE FROM NORMAL OPERATION TO COMPLETE CORE UNCOVERY

5. MAXIMUM UTILIZATION OF INSTRUMENTS IS EXPECTED TO OCCUR DURING EVENTS WHICH PROCEED SLOWLY ENOUGH FOR OPERATOR TO OBSERVE AND TO UTILIZE INSTRUMENT DISPLAYS.

INSTRUMENTS INCLUDED IN EVALUATIONS

FOR ICC INSTRUMENTATION SYSTEM

SENSORS	INDICATION PROVIDED BY SENSOR	CLARITY OF SIGNAL	DEVELOPMENT STATUS
HEATED JUNCTION DIFFERENTIAL THERMOCOUPLES/ THERMOCOUPLES OF RVLMS	1) LIQUID INVENTORY IN UPPER HEAD/ UPPER PLENUM	GOOD	DEVELOPMENT COMPLETE
	2) AXIAL TEMPERATURE DISTRIBUTION IN UPPER HEAD/PLENUM	GOOD	
CORE EXIT THERMOCOUPLES	1) FLUID TEMPERATURE AT CORE EXIT	GOOD	EXIST
	2) INFER CLAD TEMPERATURE	FAIR	
IN-CORE THERMOCOUPLES	1) METAL TEMPERATURE INSIDE GUIDE TUBE	GOOD	CONCEPT
	2) INFER CLAD TEMPERATURE	UNDETERMINED	
SELF-POWERED NEUTRON DETECTORS	INDIRECT MEASURE OF MIXTURE LEVEL	POOR	EXIST

SENSORS	INDICATION PROVIDED BY SENSOR	CLARITY OF SIGNAL	DEVELOPMENT STATUS
HOT LEG RTD (5 EACH)	1) FLUID TEMPERATURE IN HOT LEG	GOOD	EXIST
	2) INFER CLAD TEMPERATURE	POOR	
EX-CORE NEUTRON DETECTOR (ONE, SOURCE RANGE)	INDIRECT MEASURE OF GROSS VOIDING.	FAIR	EXIST
	INDIRECT INDICATION OF MIXTURE LEVEL IN CORE.	FAIR	
EX-CORE NEUTRON DETECTOR (STACK OF 5, SOURCE RANGE)	SAME AS ONE EX-CORE DETECTOR, BUT MORE AXIAL RESOLUTION	FAIR	CONCEPT

ICC INSTRUMENTATION

SENSORS	INFORMATION PROVIDED	PRIMARY INDICATORS DURING
1. RTDs OF SMM, PZR PRESSURE	1A. STATE OF COOLANT IN REACTOR VESSEL HOT LEG	APPROACH TO/RETURN FROM ICC UNDER SUBCOOLED CONDITIONS
2A. TCs OF RVLMS, PZR PRESSURE	1B. STATE OF COOLANT IN REACTOR VESSEL ABOVE FUEL ALIGNMENT PLATE	
2B. HEATED JUNCTION DIFFERENTIAL TCs OF RVLMS	2. WATER INVENTORY IN REACTOR VESSEL ABOVE FUEL ALIGNMENT PLATE	APPROACH TO/RETURN FROM ICC, CORE COVERED
3. CORE EXIT TCs	3. FLUID TEMPERATURE WHICH GIVES INDICATION OF CLADDING HEATUP	APPROACH TO/RETURN FROM ICC, CORE UNCOVERED. EXISTENCE OF ICC

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS,
SUBCOMMITTEE ON ELECTRICAL POWER SYSTEMS

MAY 28, 1981 MEETING

ON

INADEQUATE CORE COOLING/CORE WATER LEVEL INSTRUMENTATION

PRESENTATION ON INTEGRATED ACCIDENT MONITORING SYSTEM
APPROACH TO ICC/RVLMS
CARL H. NEUSCHAEFER

INTEGRATED ACCIDENT MONITORING SYSTEM

APPROACH TO

NUREG-0737, "CLARIFICATION OF TMI ACTION PLAN REQUIREMENTS"

INCLUDES: I.D.1 CONTROL ROOM DESIGN REVIEWS

I.D.2 PLANT SAFETY PARAMETER DISPLAY CONSOLE

II.F.2 INADEQUATE CORE COOLING INSTRUMENTATION

III.A.1.2 EMERGENCY SUPPORT FACILITIES

REGULATORY GUIDE 1.97

OBJECTIVES

1. PRESENT C-E'S INTEGRATED ACCIDENT MONITORING SYSTEM TO ADDRESS NUREG-0696, 0737, AND 1.97 REQUIREMENTS AND FUTURE EXPANSION.

2. DISCUSS ICC INSTRUMENTATION/INFORMATION.

3. PRESENT REACTOR VESSEL LEVEL MONITORING SYSTEM (RVLMS) DESIGN.

4. PRESENT RVLMS TEST PROGRAM AND TEST RESULTS.

OUTLINE

OBJECTIVES

I. INTRODUCTION

II. INTEGRATED ACCIDENT MONITORING SYSTEM

A. SYSTEM OVERVIEW

B. CRITICAL FUNCTION MONITORING SYSTEM

C. QUALIFIED SAFETY PARAMETER DISPLAY SYSTEM

III. INADEQUATE CORE COOLING INSTRUMENTATION

IV. REACTOR VESSEL LEVEL MONITORING SYSTEM

A. DESIGN BASIS

B. SYSTEM DESIGN

C. TESTING

I. INTRODUCTION

FOLLOWING TMI-2, PLANT MONITORING NEEDS HAVE BEEN DEFINED FOR:

1. CONTROL ROOM DESIGN REVIEW

2. EMERGENCY RESPONSE FACILITIES

3. ICC DETECTION INSTRUMENTATION

4. ACCIDENT MONITORING INSTRUMENTATION

THE ULTIMATE OBJECTIVE BEING TO IMPROVE THE MAN-MACHINE INTERACTION ASPECTS OF NUCLEAR POWER PLANTS TO PROVIDE IMPROVED EMERGENCY RESPONSE TO ACCIDENTS.

C-E's APPROACH TO THESE LICENSING REQUIREMENTS INCLUDES:

A. IMPROVED INSTRUMENTATION

MORE DIRECT, UNAMBIGUOUS INDICATIONS OF IMPORTANT PARAMETERS IN PARTICULAR INADEQUATE CORE COOLING INSTRUMENTS INCLUDING

- SUBCOOLED MARGIN MONITORS
- HEATED JUNCTION THERMOCOUPLE LEVEL MONITORS
- UPGRADED CORE EXIT THERMOCOUPLE SYSTEMS

B. QUALIFIED SAFETY PARAMETER PROCESSING/DISPLAY

C. CRITICAL FUNCTION MONITORING APPROACH

A NUCLEAR POWER PLANT CAN BE MAINTAINED IN A SAFE AND STABLE CONDITION IF A LIMITED SET OF CRITICAL FUNCTIONS ARE PROPERLY PERFORMED.

II. INTEGRATED ACCIDENT MONITORING SYSTEM

A. SYSTEM OVERVIEW

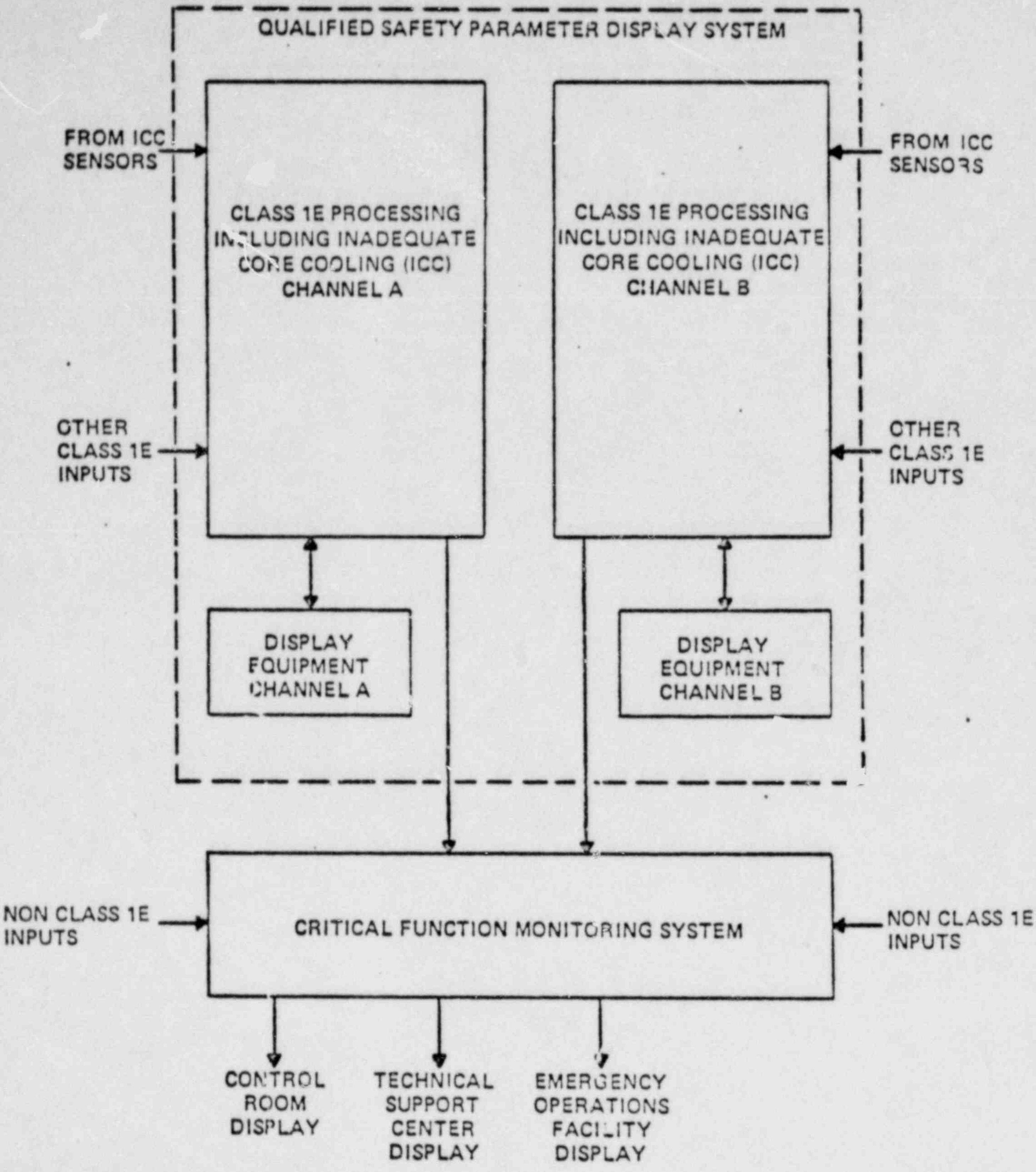
B. CRITICAL FUNCTIONS MONITORING SYSTEM

C. QUALIFIED SAFETY PARAMETER DISPLAY SYSTEM

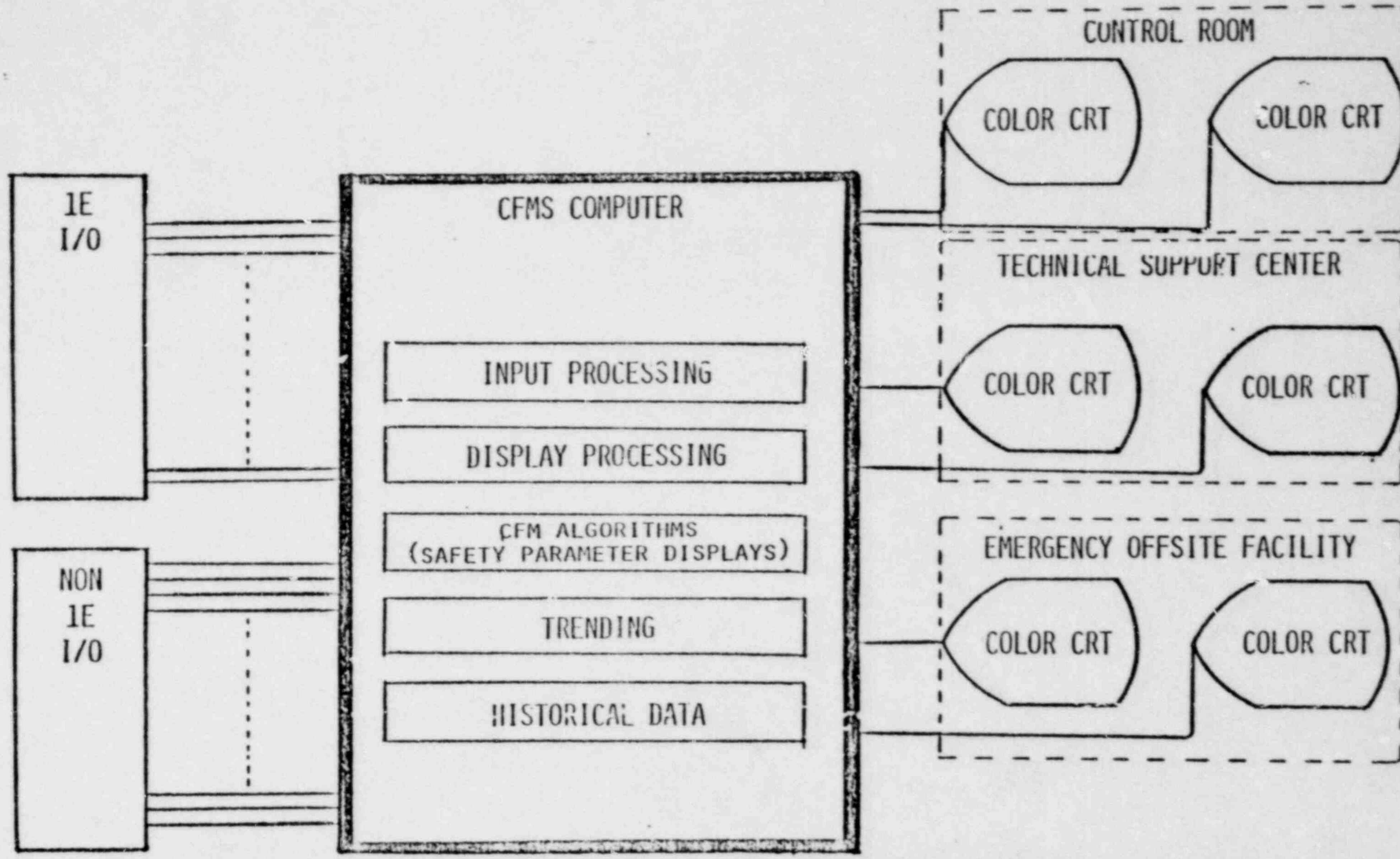
i. ICC INSTRUMENTATION/DISPLAY

ii. OTHER SPDS PARAMETERS

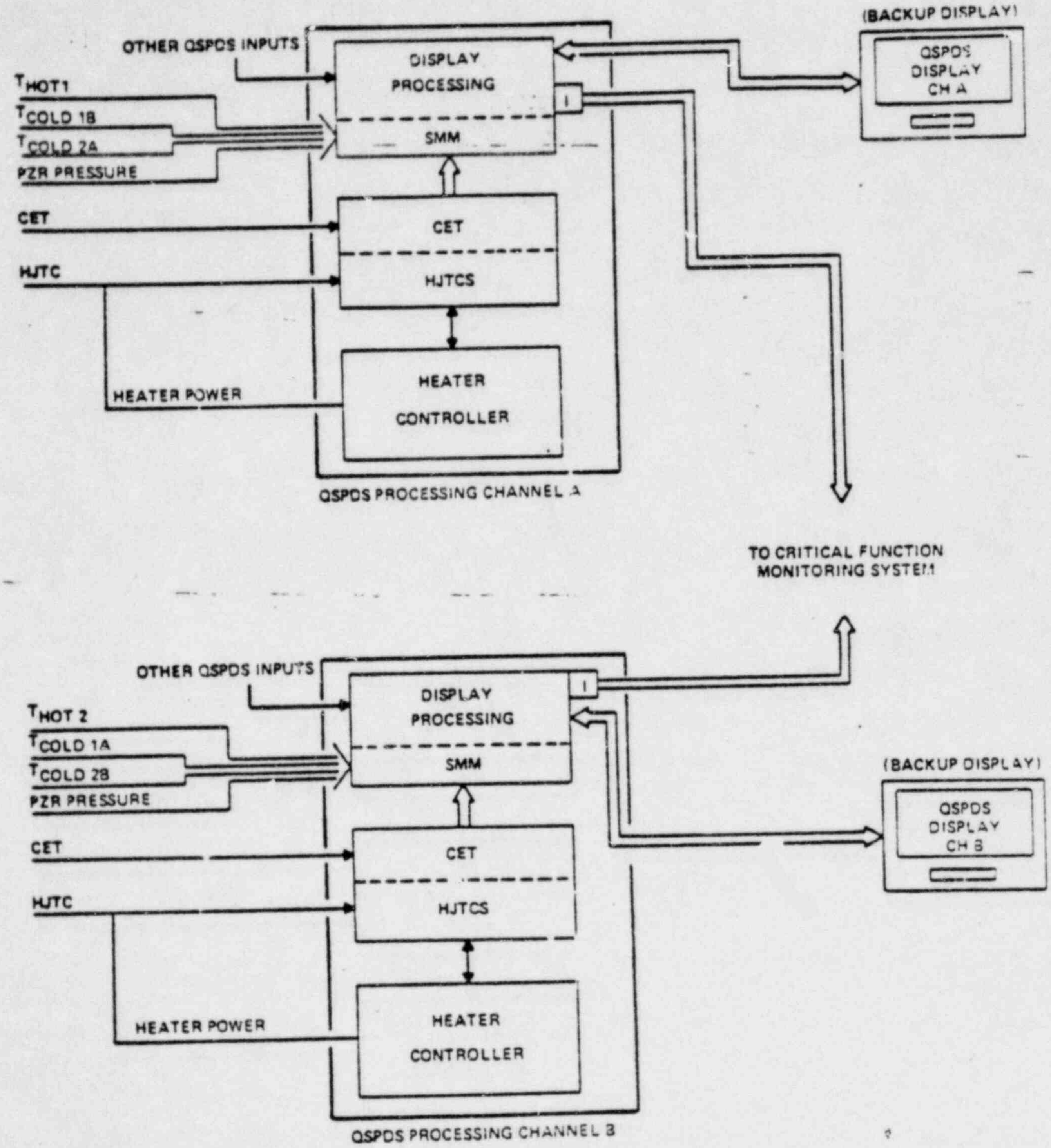
ACCIDENT MONITORING SYSTEM OVERVIEW



CRITICAL FUNCTIONS MONITORING SYSTEM



QUALIFIED SAFETY PARAMETER DISPLAY SYSTEM



III. INADEQUATE CORE COOLING INSTRUMENTATION

ICC DETECTION INSTRUMENTATION DESCRIPTION

A. SENSOR DESCRIPTION

SENSOR	LOCATION	NUMBER
RTDs	HOT LEGS, COLD LEGS	1 HOT LEG & 2 COLD LEGS/CHANNEL
PRESSURE	PRESSURIZER	1 PRESSURE/CHANNEL
HJTC PROBE ASSEMBLY	IN VESSEL ABOVE FUEL ALIGNMENT PLATE	8 SENSORS/CHANNEL
CETs	IN VESSEL ABOVE CORE	PLANT SPECIFIC

B. PROCESSING DESCRIPTION

o UPGRADED SMM

1. INPUTS

INPUTS	PROCESSING RANGES
RTDs	0 - 750°F
PRESSURE	0 - 3200 PSIA
MAX. TEMP. FROM HJTCS	100 - 1800°F
REP. TEMP FROM CETs	100 - 2300°F

2. FUNCTION

CALCULATE MARGIN TO SATURATION BASED ON HIGHEST TEMPERATURE INPUT AND LOWEST PRESSURE INPUT.

3. OUTPUTS

TEMPERATURE MARGIN (INCLUDES SUPERHEAT)
PRESSURE MARGIN AVAILABLE

o RVLMS

1. INPUTS

	PROCESSING RANGE
HEATED JUNCTION TEMPERATURES	100-1800^{o}F
UNHEATED JUNCTION TEMPERATURES	100-1800^{o}F
DIFFERENTIAL TEMPERATURES	100-1800^{o}F

2. FUNCTIONS

DETERMINE LIQUID INVENTORY.
DETERMINE UPPER PLENUM/HEAD FLUID TEMPERATURE.

3. OUTPUTS

LEVEL ABOVE FUEL ALIGNMENT PLATE.
UNHEATED JUNCTION (OR FLUID) TEMPERATURE.

- CORE EXIT THERMOCOUPLES (CETs)

1. INPUTS

INPUTS	PROCESSING RANGE
CETs	100-2300°F

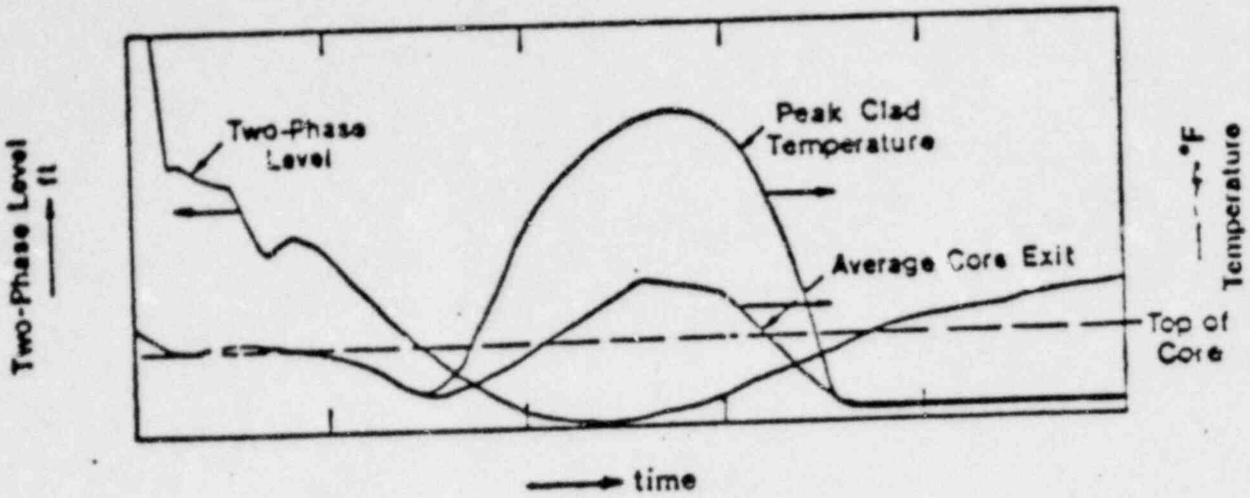
2. FUNCTIONS

   PROCESS CET TEMPERATURES FOR DISPLAY
   CALCULATE REPRESENTATIVE CET TEMPERATURE

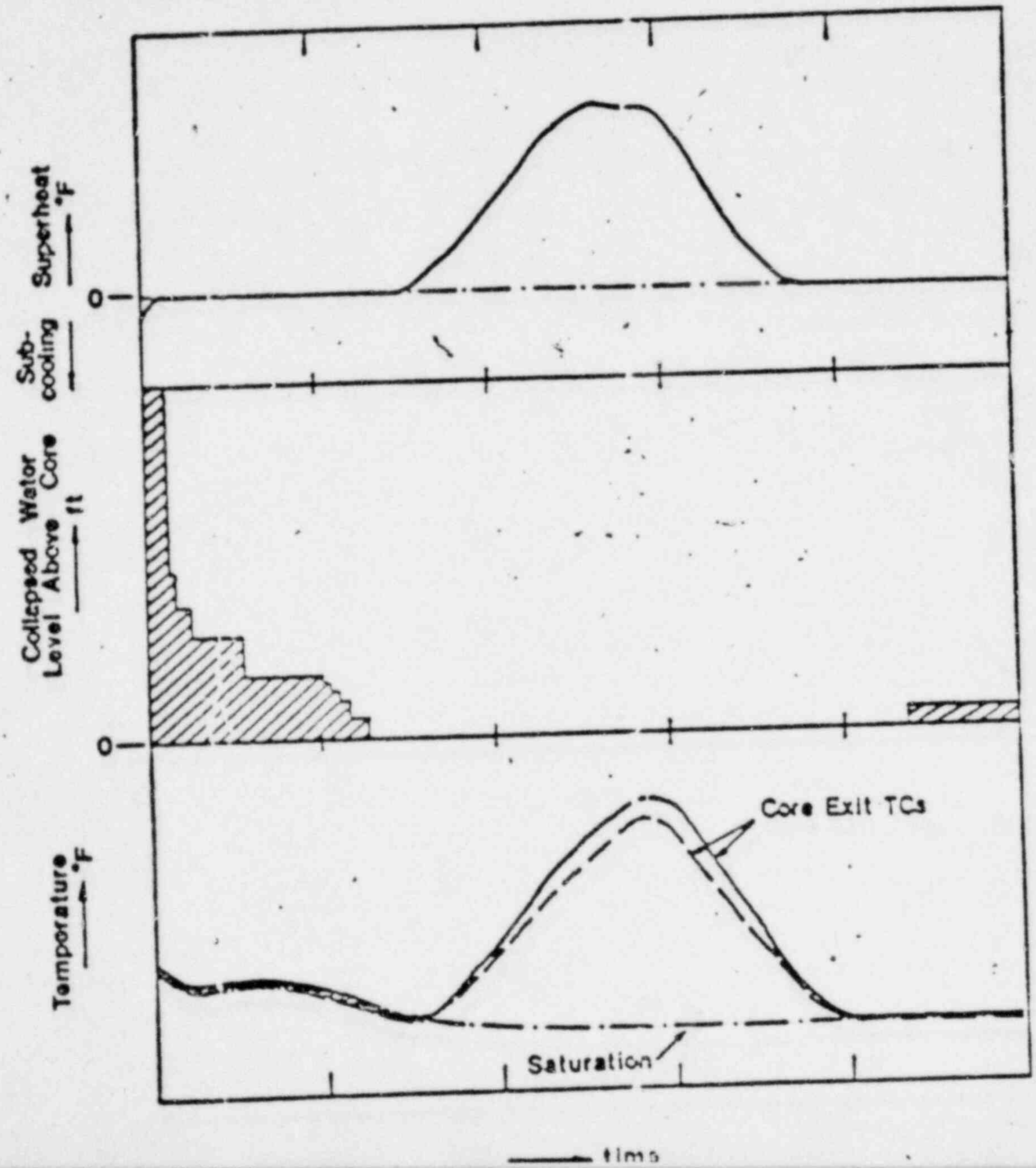
3. OUTPUTS

   CORE EXIT THERMOCOUPLES TEMPERATURES.
   REPRESENTATIVE CET TEMPERATURE.

PLANT PARAMETERS [Calculated]



ICC INSTRUMENTATION DISPLAY



REACTOR VESSEL LEVEL MONITORING SYSTEM

A. DESIGN BASIS

TMI/NUREG-0578/0737 -

PROVIDE DIRECT UNAMBIGUOUS INFORMATION RELATED TO CORE COOLING ADEQUACY.

1. DIRECTLY MEASURE THE LIQUID LEVEL IN THE REACTOR VESSEL REGION FROM FUEL ALIGNMENT PLATE TO TOP OF VESSEL HEAD.

2. PROVIDE THE OPERATOR WITH AN ALARM ALERTING HIM THAT THE VESSEL INVENTORY HAS BEEN AFFECTED.

3. PROVIDE THE OPERATOR WITH LEVEL INDICATION TO MONITOR THE STATUS AND TREND OF COOLANT INVENTORY DURING AN INCIDENT AND TO PROVIDE RAPID FEEDBACK INFORMATION ON HIS ACTIONS RELATIVE TO INVENTORY CONTROL.

4. CONTINUALLY RECORD THIS INFORMATION FOR TIME HISTORY ANALYSIS BOTH DURING AN INCIDENT AND POST INCIDENT.

5. DESIGN TO POST ACCIDENT MONITORING CRITERIA.

6. MINIMIZE IMPACT ON EXISTING NSSS DESIGNS (INCLUDING STRUCTURAL DESIGNS AND REFUELING IMPACTS).

HJTC RVLMS/DESIGN FEATURES (CONTINUED)

DESIGN FEATURES

1. DIRECT IN VESSEL MEASUREMENT
   A. IN VESSEL DISCRETE PROBES
   B. NO OTHER COMPENSATION SIGNALS REQUIRED
2. SIMPLE CONSTRUCTION
   A. NON-HYDRAULIC DEVICE
   B. NO MOVING PARTS
   C. NO IN-CONTAINMENT ELECTRONICS
   D. NO EXTERNAL PIPING
3. OPERABILITY CHECKING AT POWER
4. REDUNDANCY
5. NO CHANGES TO EXISTING REFUELING PROCEDURES
6. COMPATIBLE WITH PWR INSTALLATIONS
7. DIRECT REACTOR VESSEL TEMPERATURE MEASUREMENT

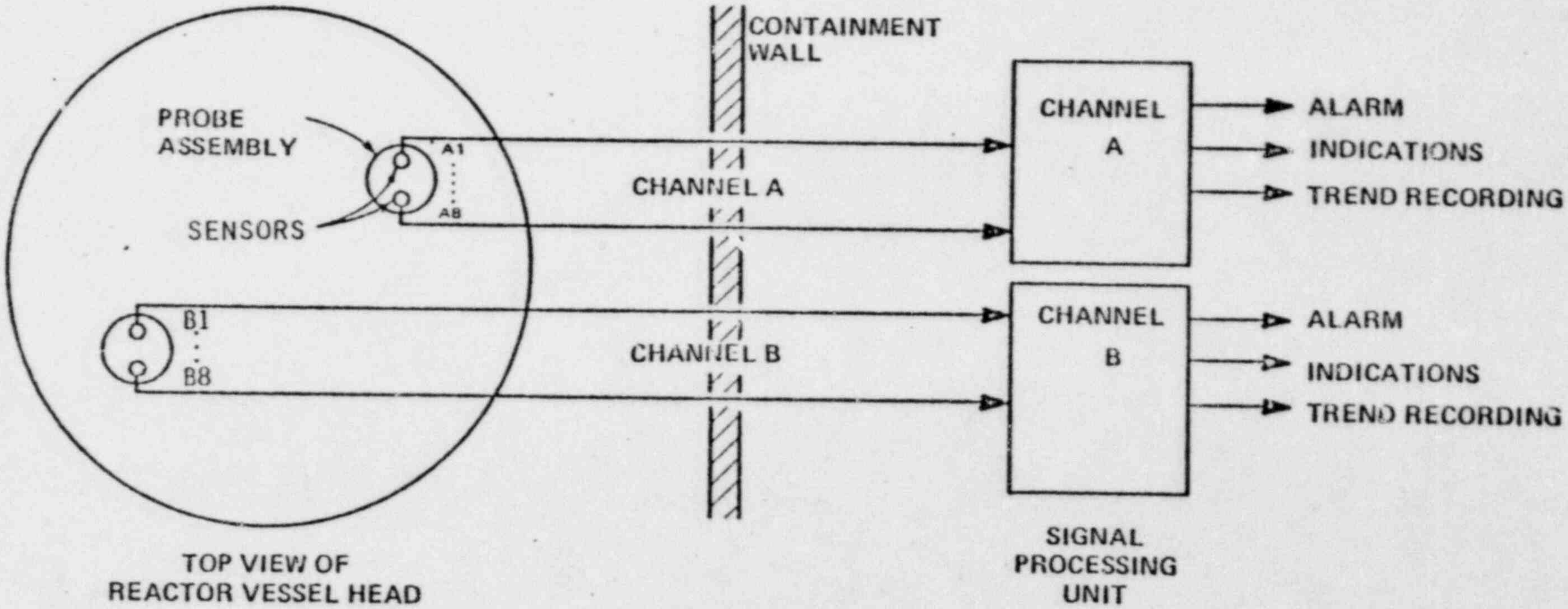
B. SYSTEM DESIGN

1. HJTC PROBE ASSEMBLY

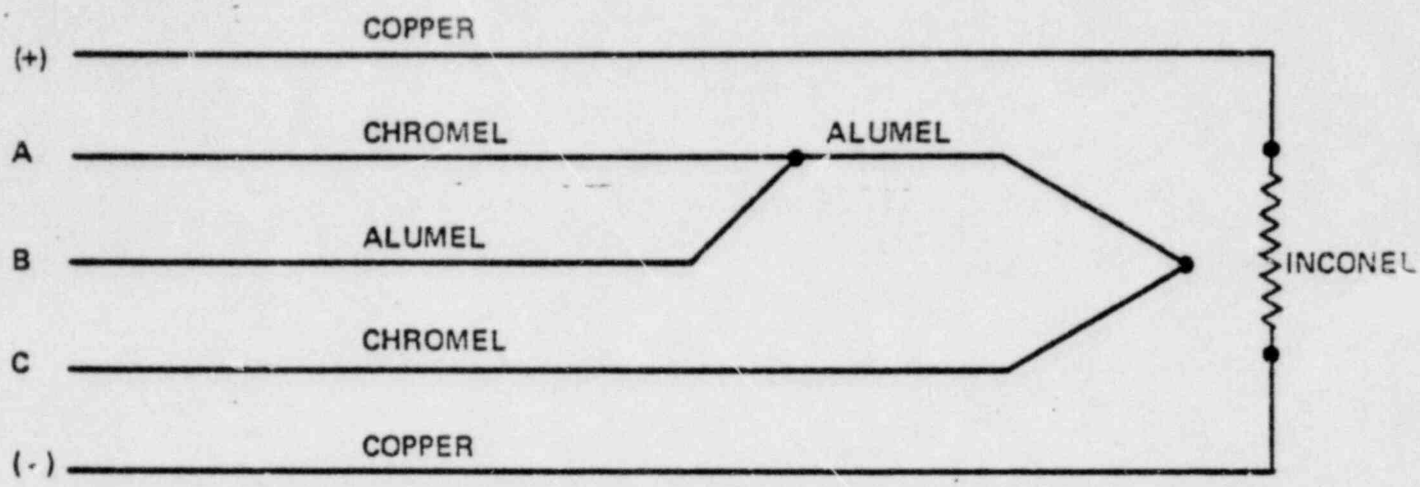
2. SIGNAL PROCESSING/CONTROL

SYSTEM DESIGN

HJTCS FUNCTIONAL CONFIGURATION

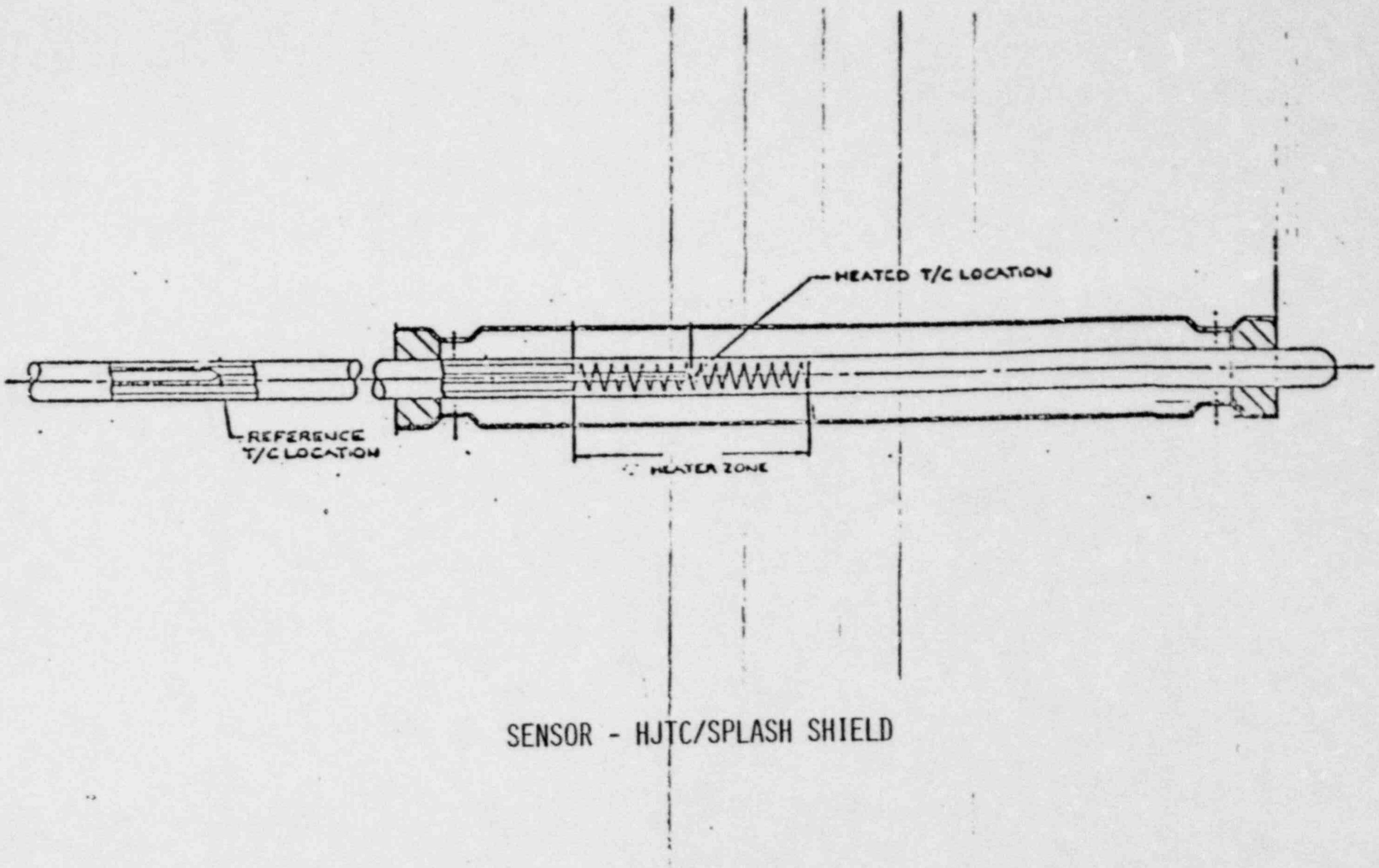


1. HJTC PROBE ASSEMBLY



V (A - B) = ACTUAL TEMPERATURE, UNHEATED JUNCTION
V (C - B) = ACTUAL TEMPERATURE, HEATED JUNCTION
V (A - C) = DIFFERENTIAL TEMPERATURE

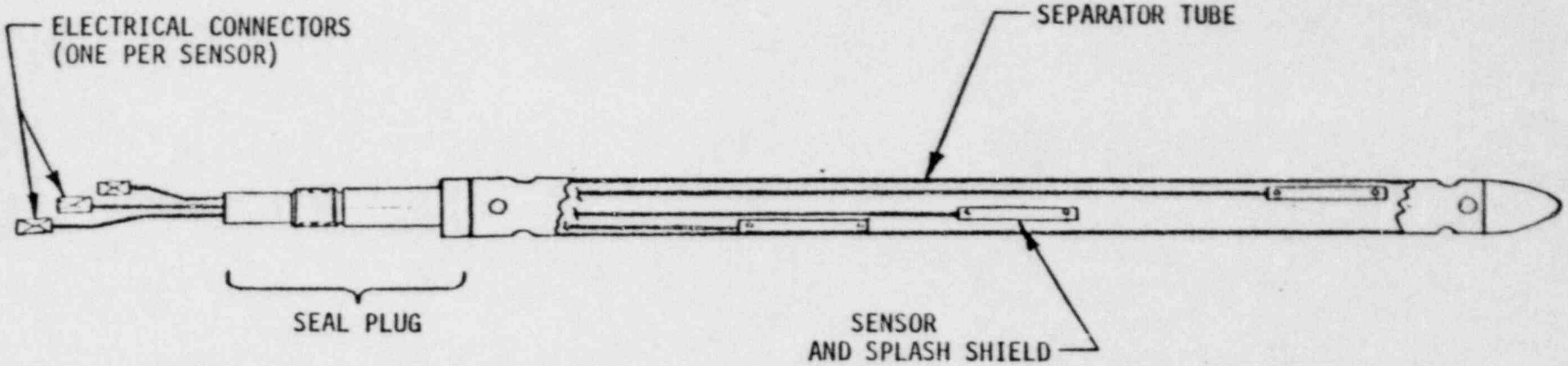
ELECTRICAL DIAGRAM OF H.J.T.C.



SENSOR - HJTC/SPLASH SHIELD

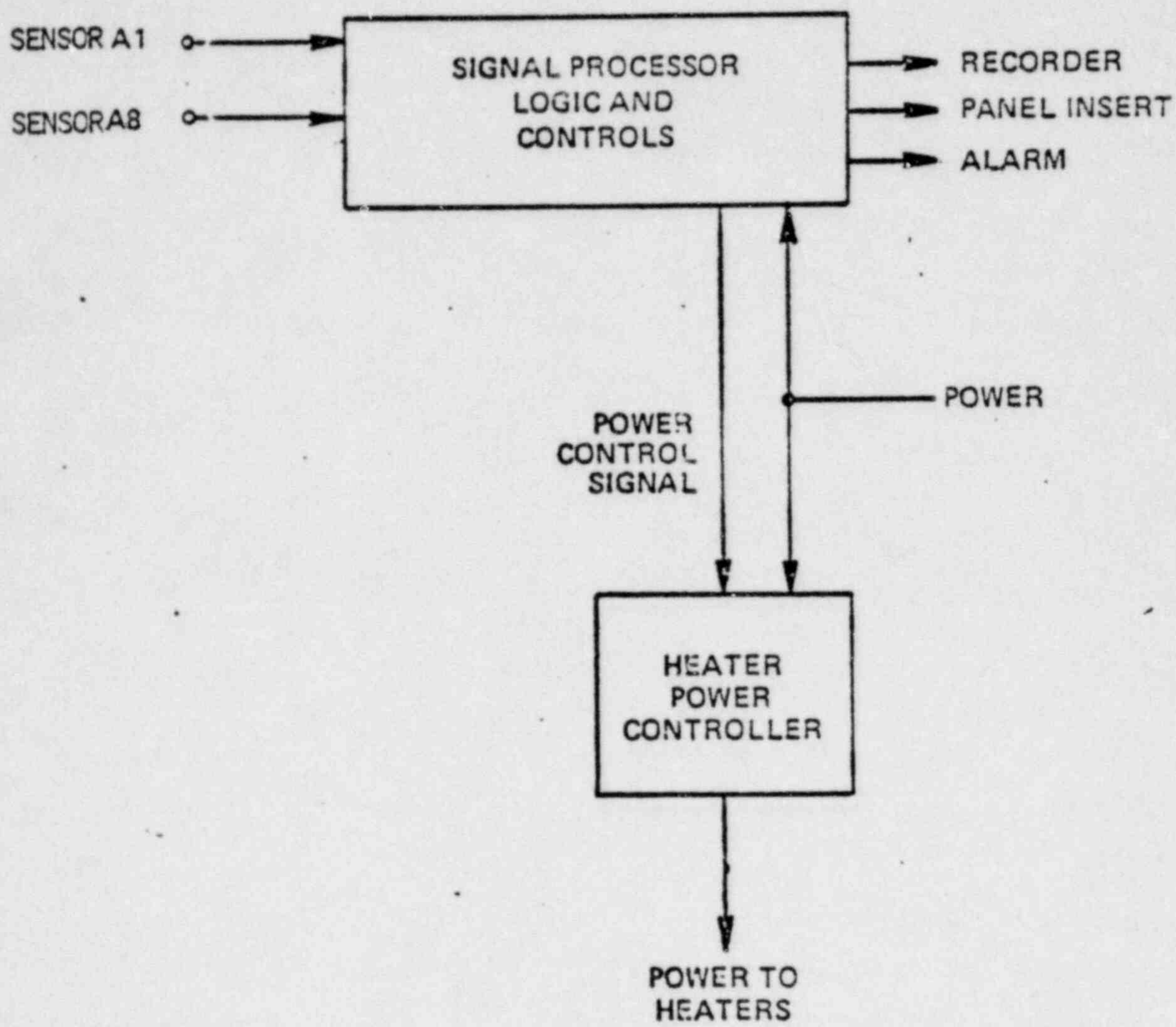
HEATED JUNCTION THERMOCOUPLE

PRCBE ASSEMBLY



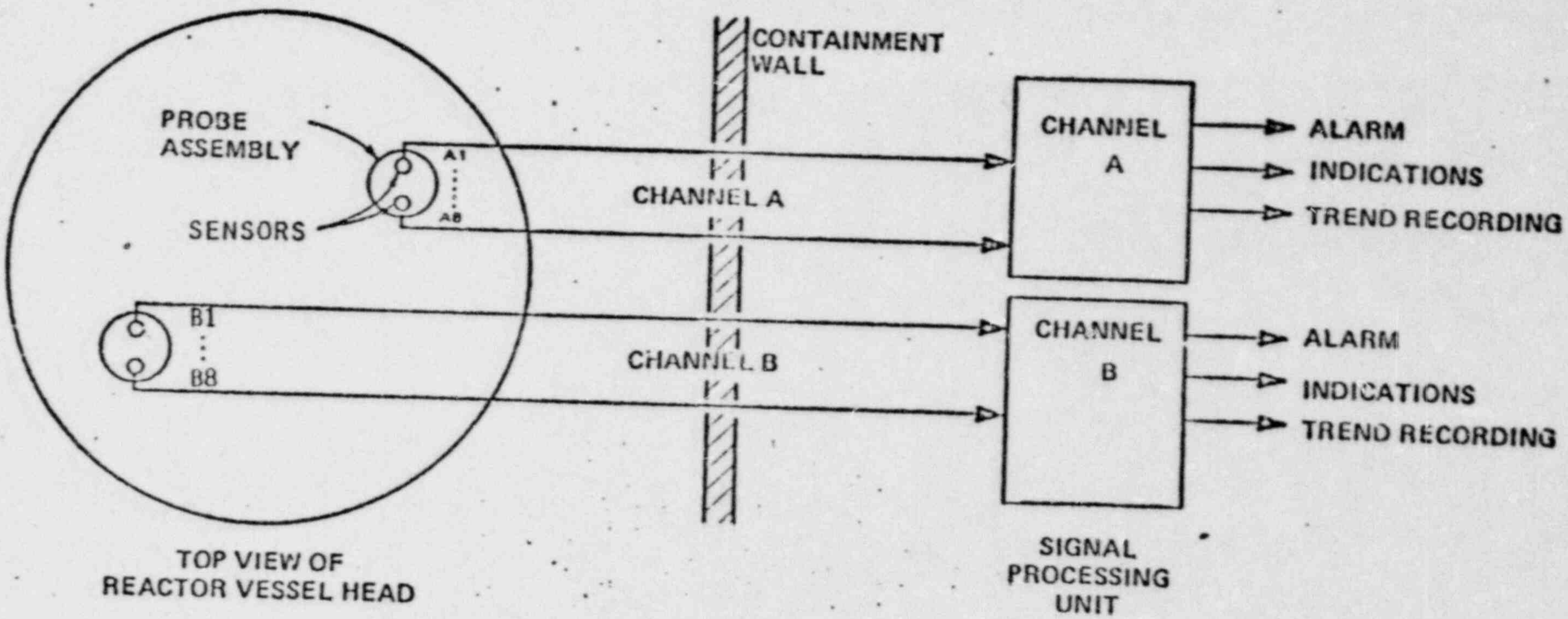
SIGNAL PROCESSING/CONTROL

TYPICAL CONFIGURATION
(ONE CHANNEL SHOWN)



B. SYSTEM DESIGN

HJTCS FUNCTIONAL CONFIGURATION



C. TESTING

TEST OBJECTIVE

THE IMPORTANT OBJECTIVE FOR ANY LEVEL MEASUREMENT SCHEME IS TO DESIGN AND VERIFY THAT IT WILL PERFORM ITS FUNCTION IN A PWR REACTOR VESSEL APPLICATION. THUS, THE PRIMARY TEST OBJECTIVE IS TO DESIGN AND VERIFY THE ABILITY OF THE C-E HJTC/RVLMS TO MEASURE LEVEL UNDER A SPECTRUM OF SIMULATED REACTOR VESSEL T/H CONDITIONS REPRESENTATIVE OF NORMAL AND ACCIDENT CONDITIONS.

1. TEST PROGRAM

C-E HAS RELIED ON ENGINEERING DESIGN/ANALYSES AND EXTENSIVE TESTING TO DEVELOP, DESIGN, AND VERIFY HJTC SYSTEM OPERATION. THE TEST PROGRAM IS COMPRISED OF THREE PHASES:

A. PHASE I - PROOF OF PRINCIPLE/DEVELOPMENTAL TESTING - COMPLETE

B. PHASE II - DESIGN DEVELOPMENT - COMPLETE

C. PHASE III - PROTOTYPE TESTING

INFORMATION/DATA HAVE BEEN OBTAINED FROM RELATED DESIGN AND TESTING BEING PERFORMED BY INDEPENDENT AGENCIES:

A. OAK RIDGE NATIONAL LABORATORY, ADVANCED TWO PHASE FLOW INSTRUMENTATION PROGRAM TESTING

B. IDAHO NATIONAL ENGINEERING LABORATORY, EG&G

C. MASSACHUSETTS INSTITUTE OF TECHNOLOGY

2. PHASE I - PROOF OF PRINCIPLE TEST SUMMARY

C-E HAS COMPLETED SENSOR PROOF OF PRINCIPLE TESTING. THIS TESTING HAS DEMONSTRATED THE FEASIBILITY OF THE HJTC DESIGN TO MEASURE LEVEL IN SIMULATED REACTOR VESSEL T/H CONDITIONS AND PROVIDED THE BASIS FOR THE DESIGN/MANUFACTURING SPECIFICATIONS.

TEST PERFORMED	DATE	RESULTS
1. AUTOCLAVE - C-E	4/80	OUTPUT DIFFERENCE FOR STEAM AND WATER.
2. TWO PHASE FLOW - ORNL	6/80	BARE SENSOR SENSITIVITY TO VOIDS NEGLIGIBLE.
3. ATMOSPHERIC AIR/WATER - C-E	7/80	SPLASH SHIELD INCREASES SENSOR SENSITIVITY TO VOIDS.
4. HIGH PRESSURE, THTF - ORNL	9/80	CONFIRMED SENSOR SENSITIVITY AT PRESSURE AND TEMPERATURE.
5. ATMOSPHERIC AIR/WATER - C-E	10/80	LIQUID LEVEL IS ACCOMPLISHED IN SEPARATOR TUBE.

HJTC AUTOCLAVE TEST WITH 5" TC SPACING

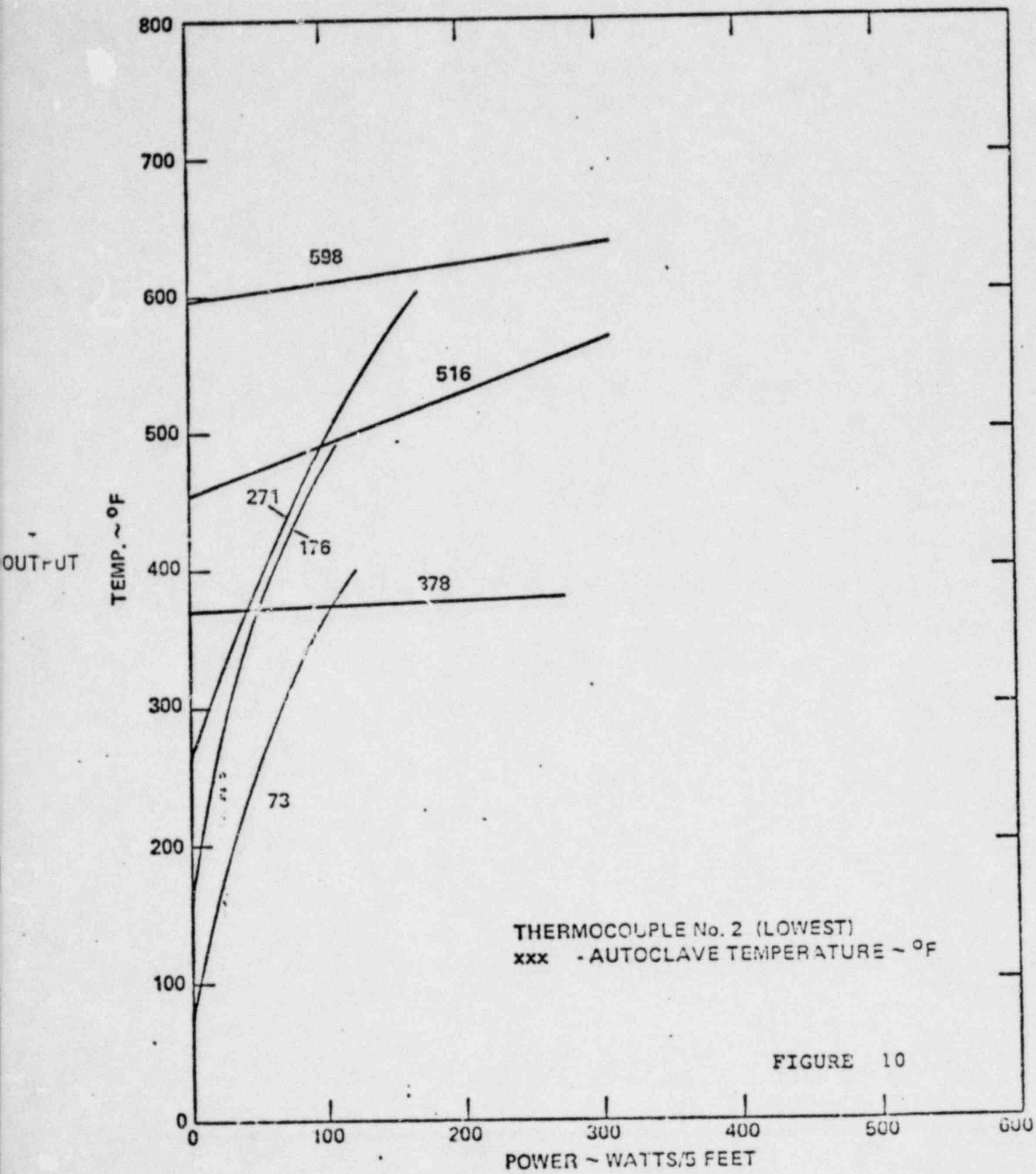
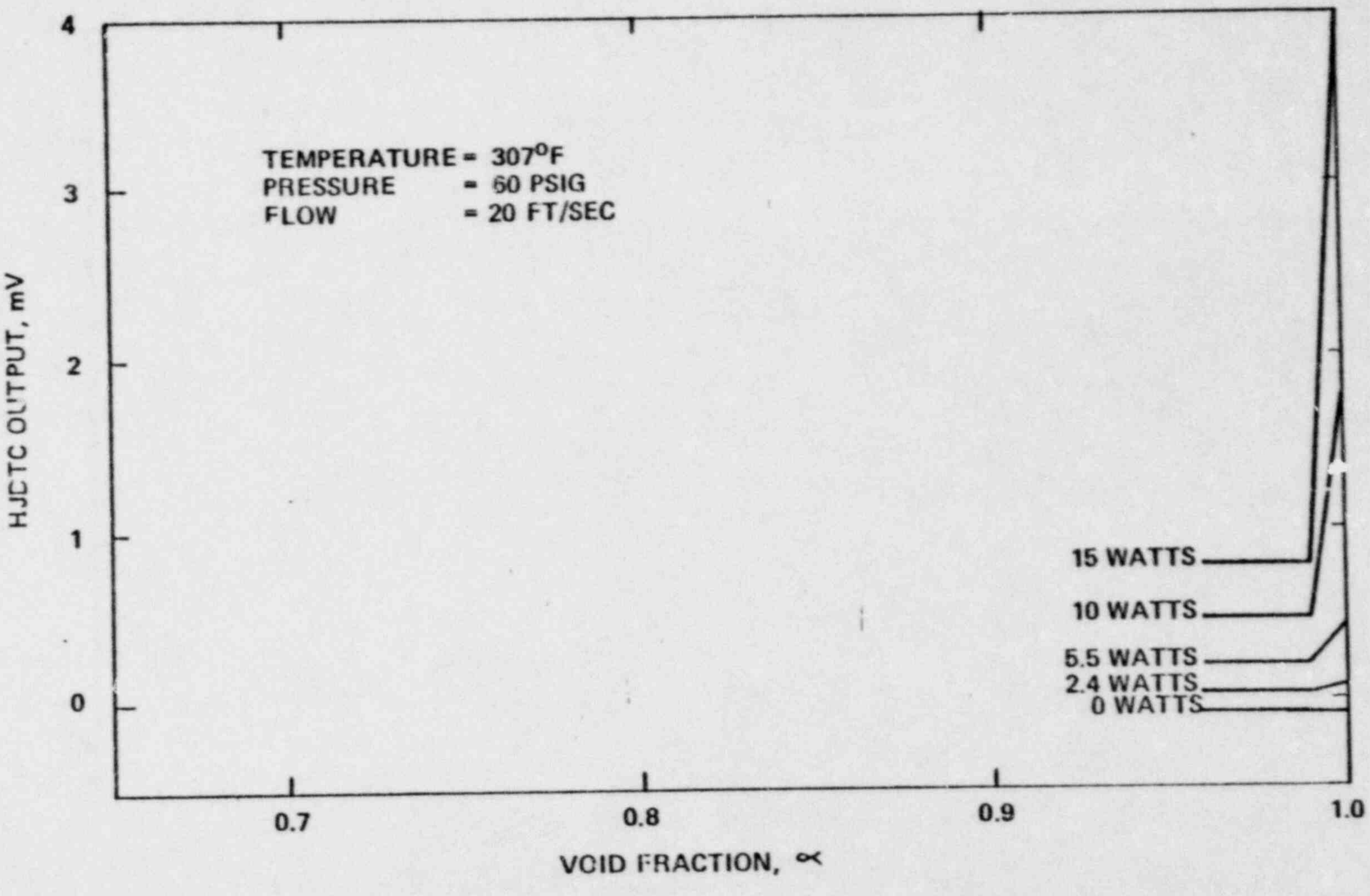
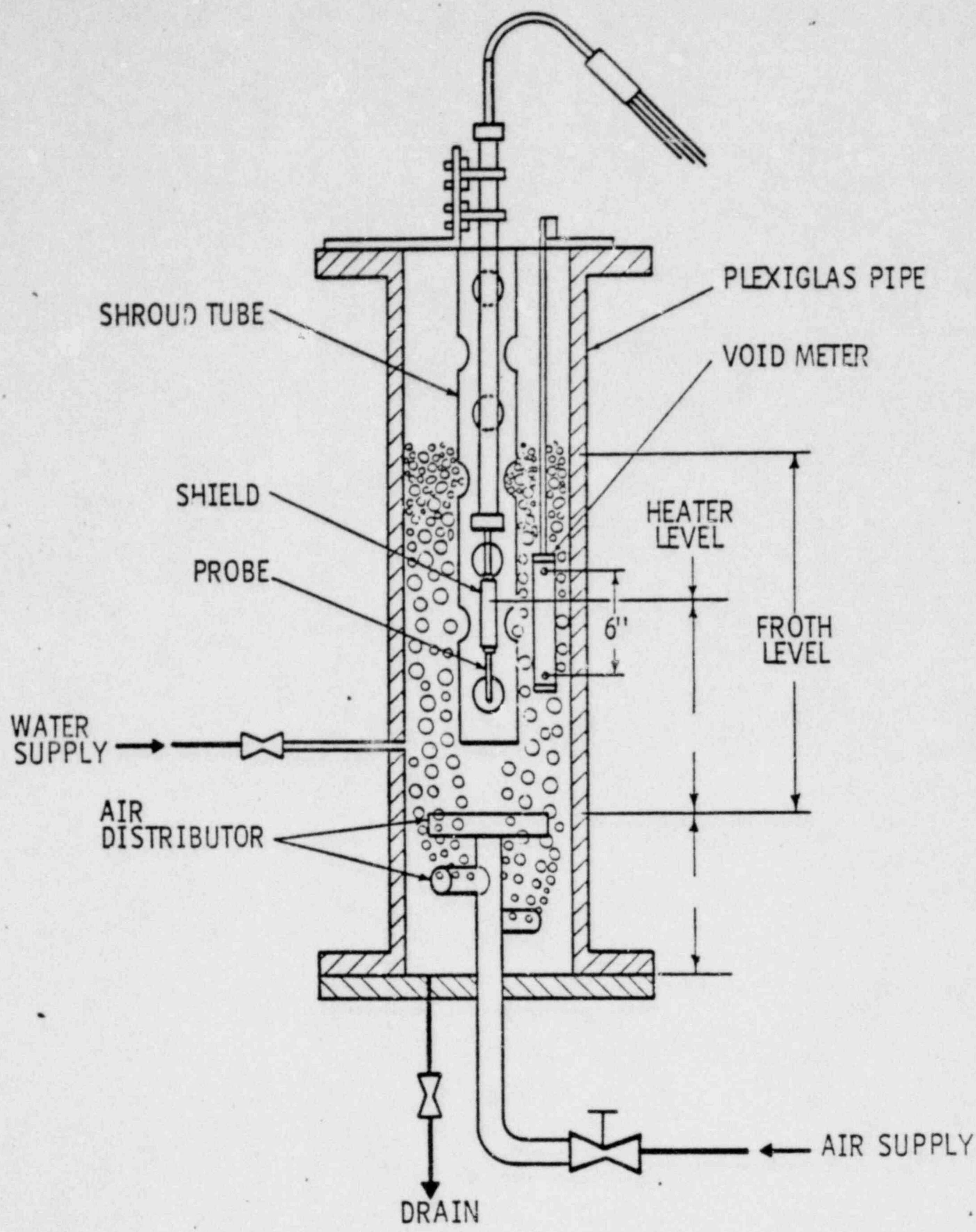


FIGURE 10

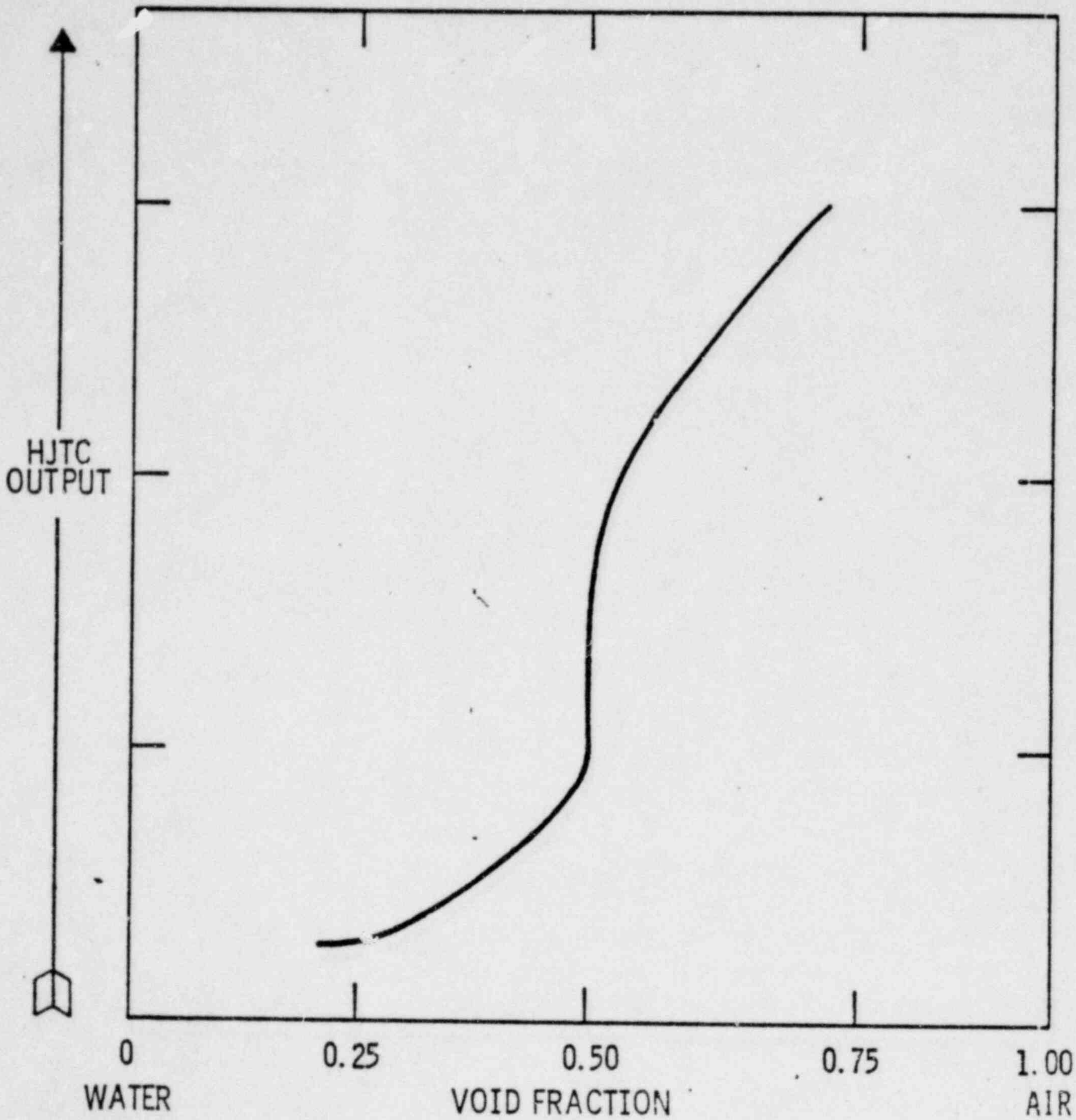
HJDTC OUTPUT vs VOID FRACTION





AIR-WATER TEST APPARATUS

ATMOSPHERIC AIR-WATER TESTS
(C-E)



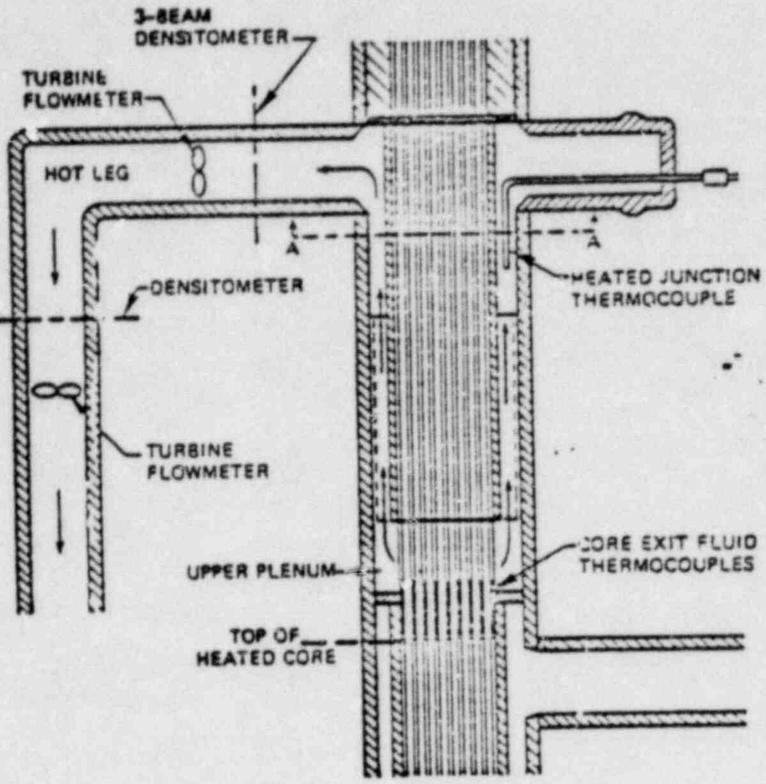


Fig. 3a. Schematic of upper part of THTF test section and outlet piping showing locations of HTC and other instrumentation.

Figure 3

HJTC RESPONSE DURING ORNL THTF FILM BOILING TESTING - SMALL BREAK T/H CONDITIONS

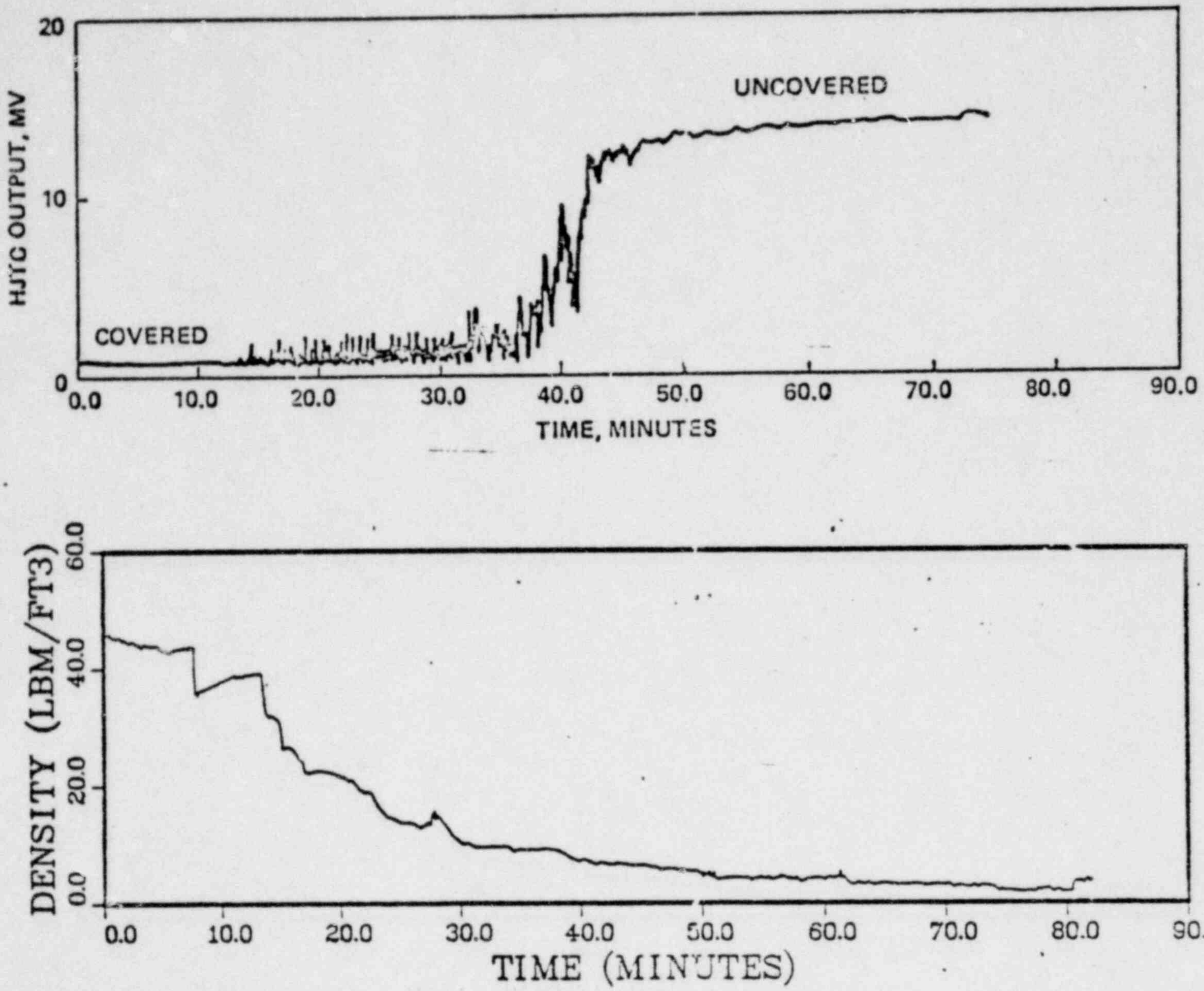
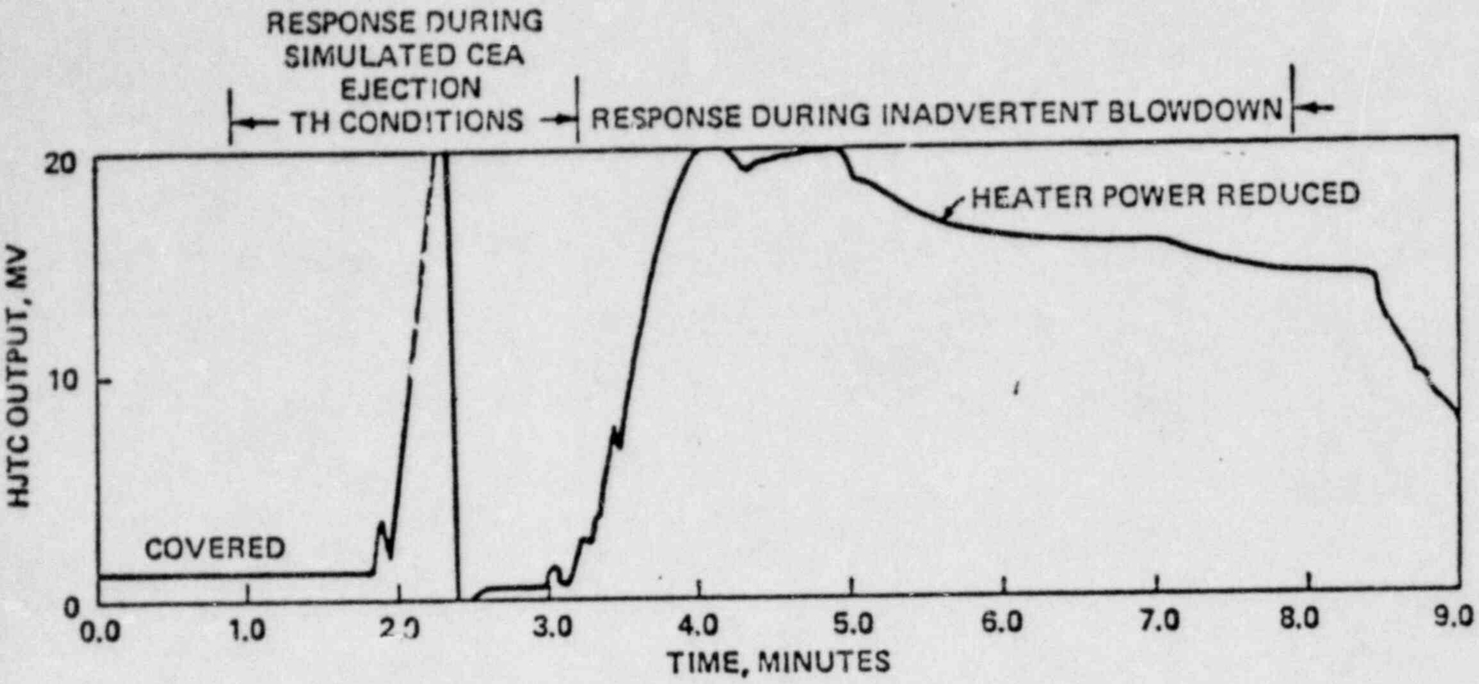
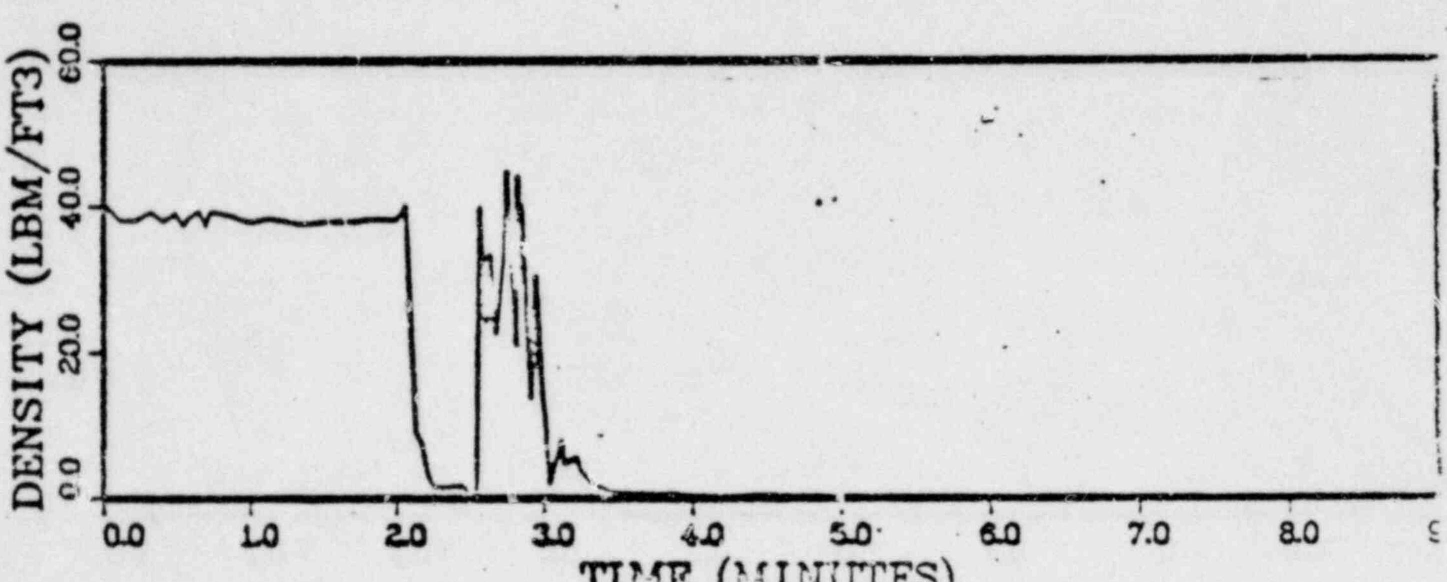
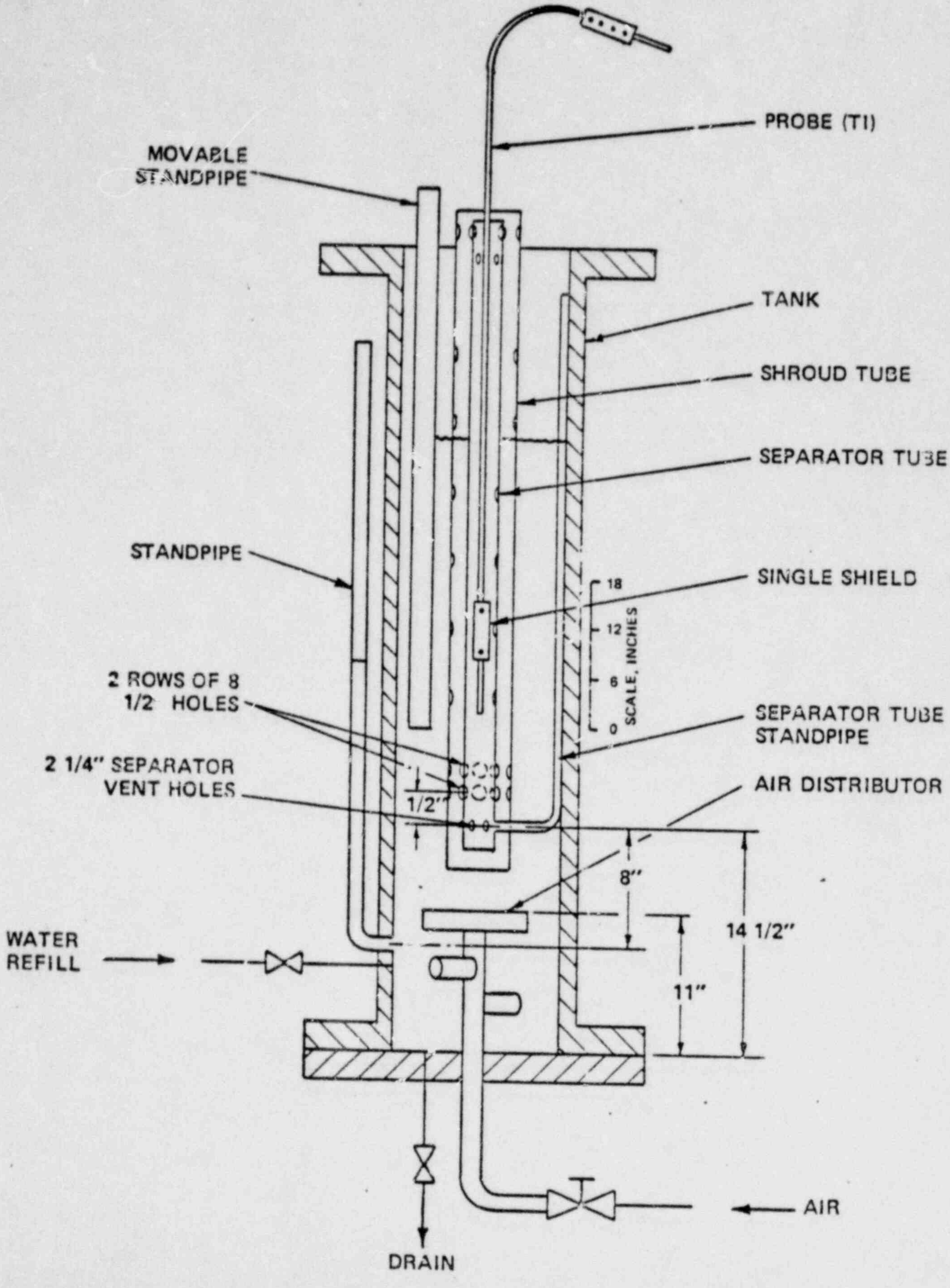


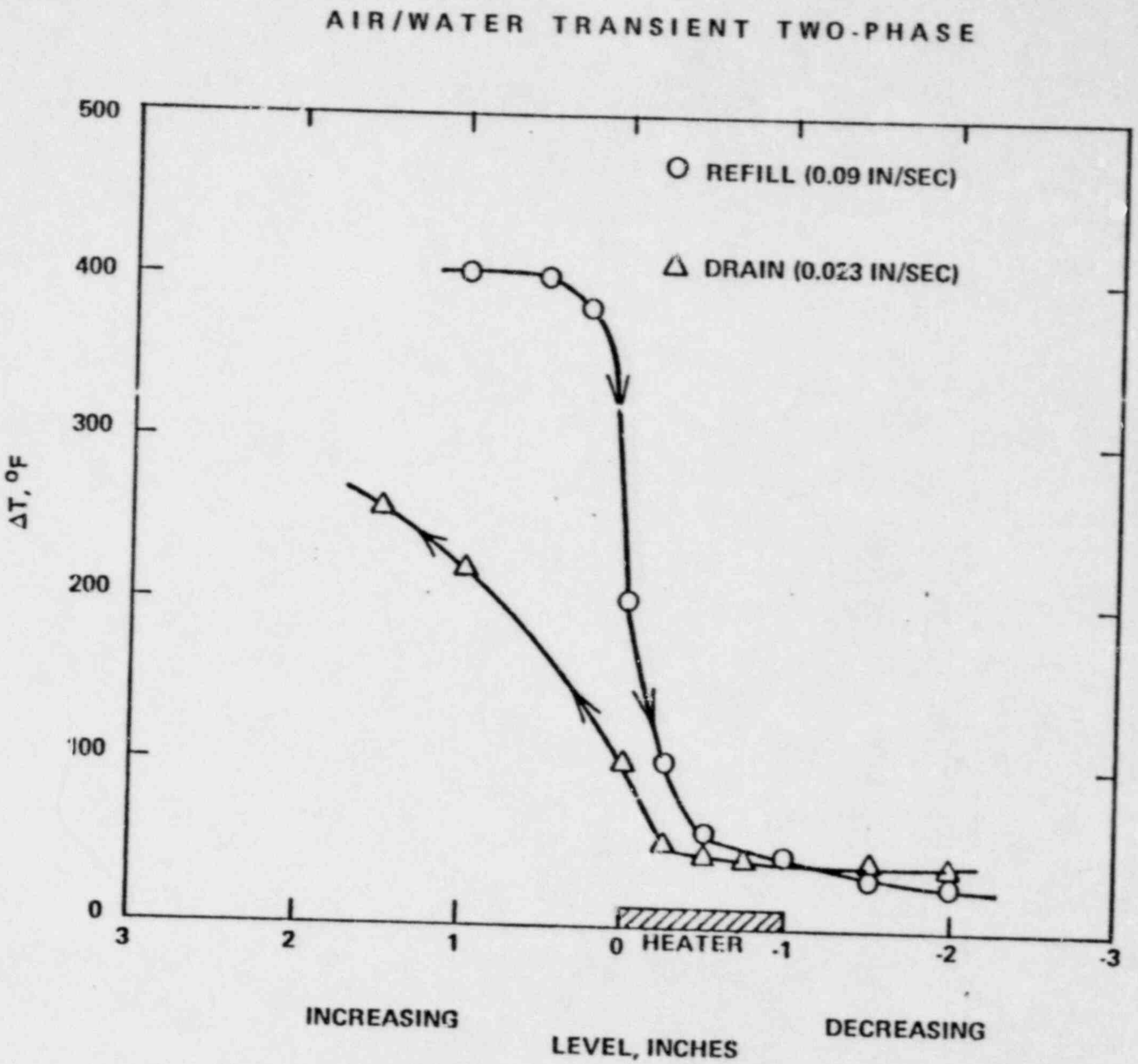
Figure 4

HJTC RESPONSE DURING ORNL THTF TESTING - CEA EJECTION/BLOWDOWN TRANSIENTS

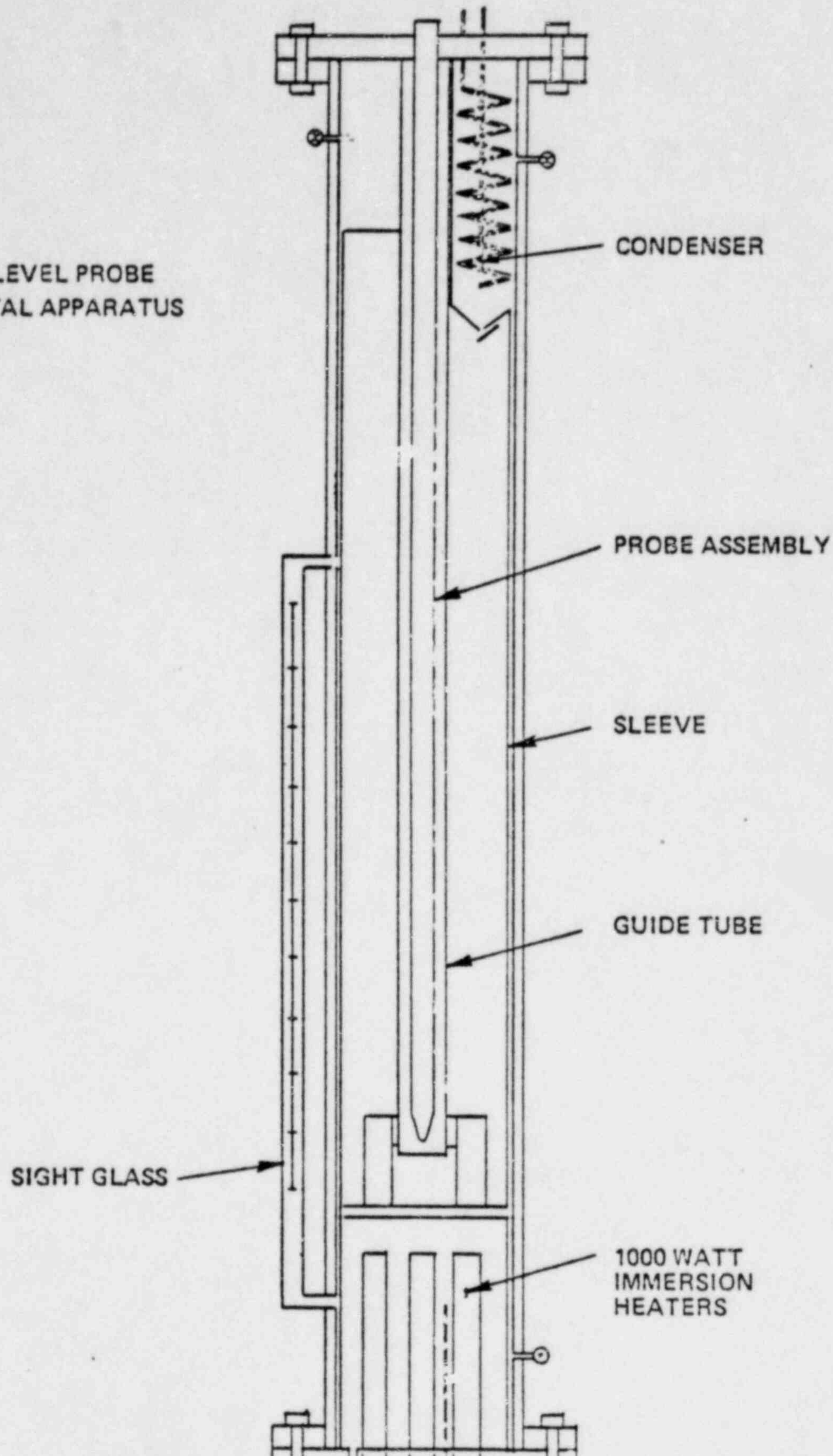




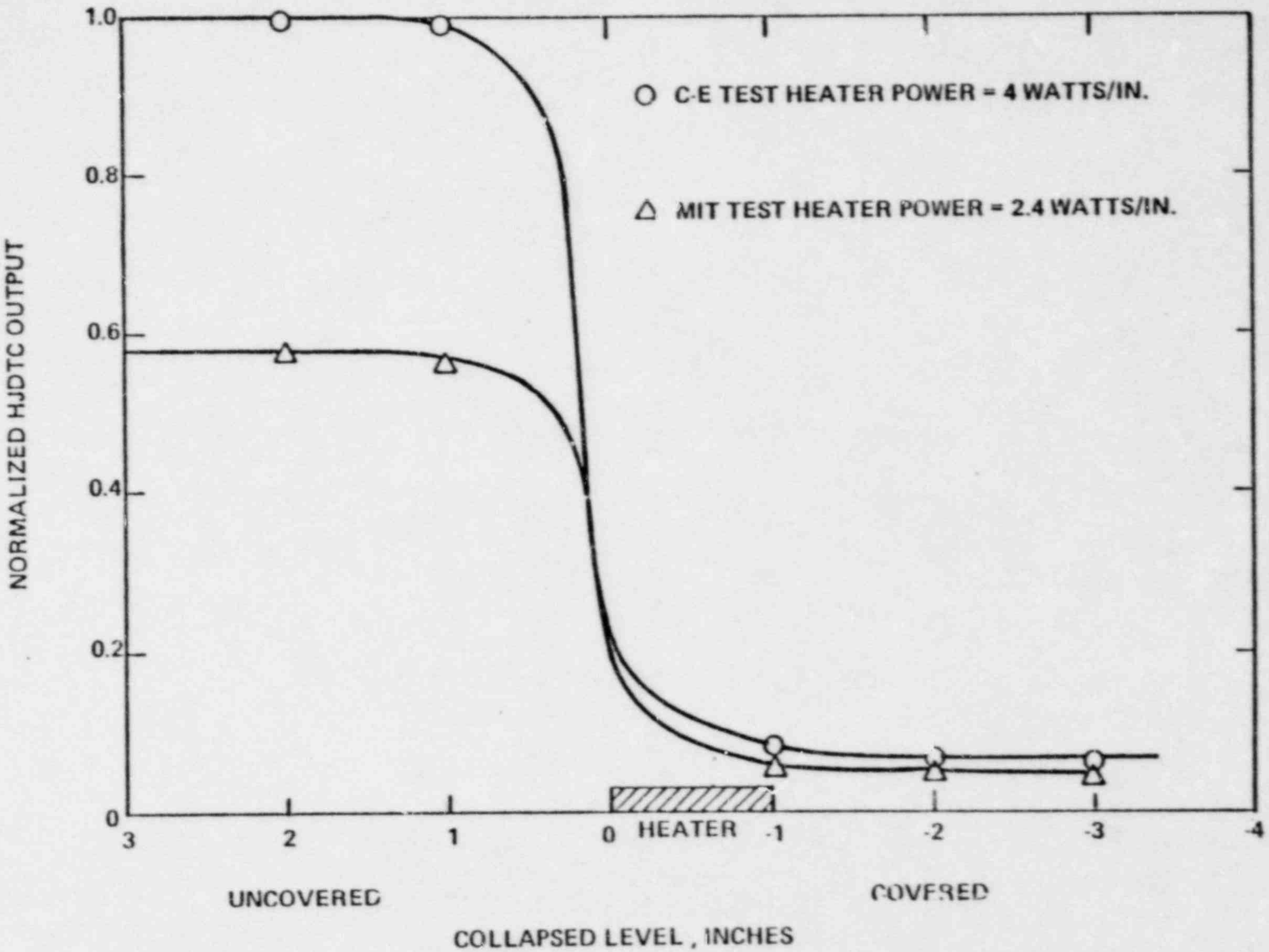

PROBE (TI)
MOVABLE STANDPIPE
TANK
SHROUD TUBE
SEPARATOR TUBE
STANDPIPE
SINGLE SHIELD
18
12
6
0
SCALE, INCHES
2 ROWS OF 8 1/2 HOLES
SEPARATOR TUBE STANDPIPE
2 1/4" SEPARATOR VENT HOLES
AIR DISTRIBUTOR
1/2"
8"
14 1/2"
WATER REFILL
11"
AIR
DRAIN


AIR/WATER TRANSIENT TWO-PHASE
O REFILL (0.09 IN/SEC)
Δ DRAIN (0.023 IN/SEC)
500
400
300
200
100
0
ΔT, °F
3
2
1
0
HEATER
-1
-2
-3
INCREASING
LEVEL, INCHES
DECREASING

MIT CORE LEVEL PROBE
EXPERIMENTAL APPARATUS



MIT C-E STATIC TWO-PHASE

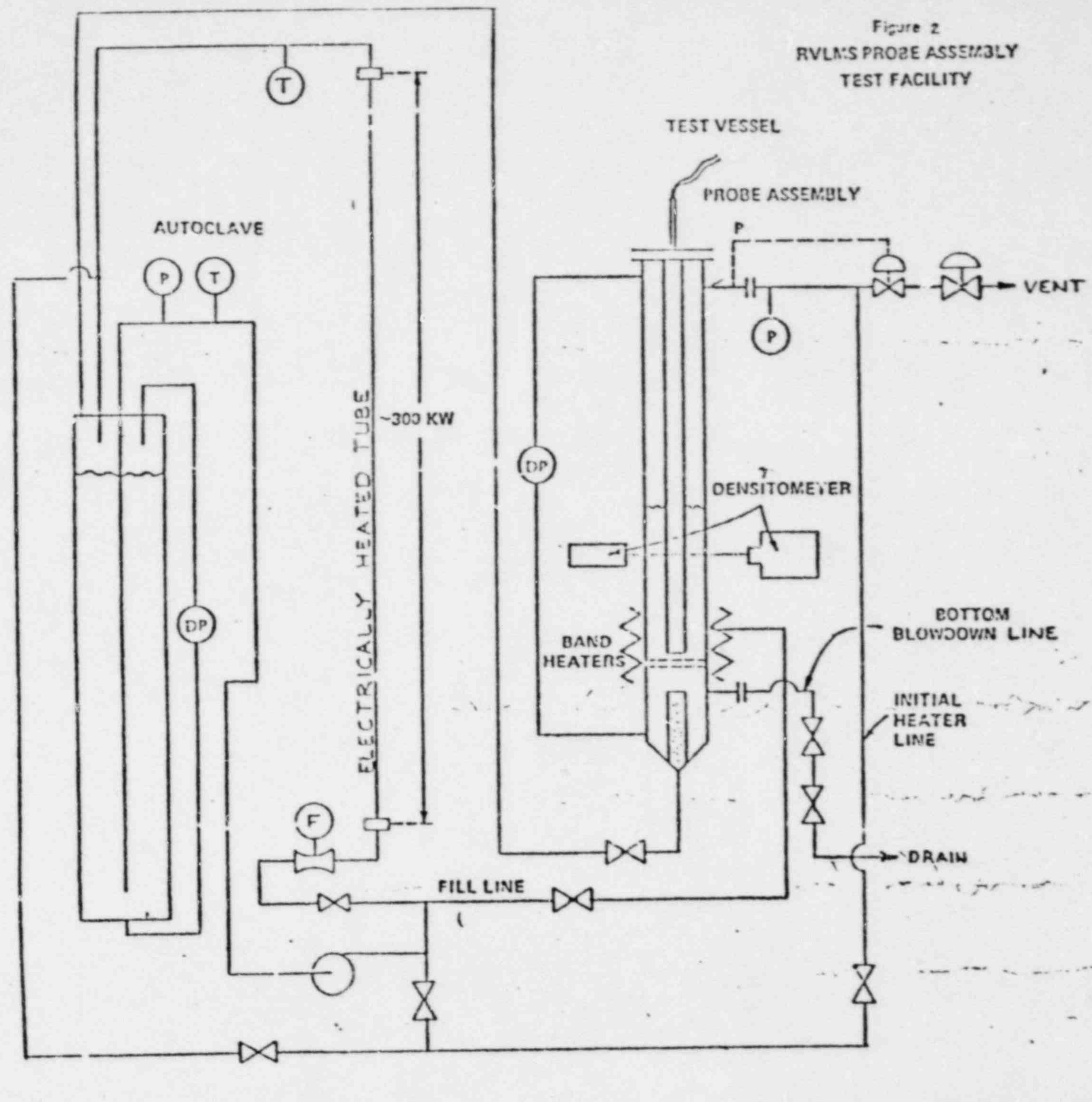


4. PHASE II - DESIGN DEVELOPMENT TESTING

OBJECTIVE: TO VERIFY AND COMPLETE THE DESIGN AND MANUFACTURING SPECIFICATIONS.

SCHEDULE: TESTING IS COMPLETED.

Figure 2
RVLMS PROBE ASSEMBLY
TEST FACILITY



DESIGN VERIFICATION TEST TYPES

1. STATIC WATER LEVEL
2. TRANSIENT WATER LEVEL
3. SENSOR THERMAL RESPONSE
4. STATIC TWO-PHASE LEVEL
5. TRANSIENT TWO-PHASE LEVEL
6. BLOWDOWN FROM BOTTOM
7. BLOWDOWN FROM TOP

5. PHASE III - PROTOTYPE TEST

OBJECTIVE: TO PERFORM A COMPLETE SYSTEM TEST WITH A PRODUCTION PROTOTYPE RVLMS AND SIMULATED ACCIDENT T/H CONDITIONS.

SCHEDULE: TO BE COMPLETED END OF 1981, BASED IN PART ON COMPLETION OF PHASE II TESTING AND HARDWARE AVAILABILITY.

EPRI

EPRI ACTIVITIES IN WATER LEVEL INSTRUMENTATION SYSTEMS FOR PWRS

DR. PATRICK G. BAILEY
SAFETY AND ANALYSIS DEPARTMENT
NUCLEAR POWER DIVISION

PRESENTED AT THE:

ACRS ELECTRICAL SYSTEMS SUBCOMMITTEE MEETING ON
WATER LEVEL INSTRUMENTATION SYSTEMS,
MAY 26, 1981,
WASHINGTON, D.C.

ELECTRIC POWER RESEARCH INSTITUTE

EPRI PRESENTATION TO

THE ACRS ELECTRICAL SYSTEMS SUBCOMMITTEE

MAY 28, 1981

WASHINGTON, D.C.

1. RP1611 PROJECT DESCRIPTION AND SCOPE

2. NON-INVASIVE WATER LEVEL TESTING PROGRAM

3. INSTRUMENTATION SYSTEMS REVIEW

4. UTILITY LIAISON ACTIVITIES AND PROJECTS

5. CONCLUSIONS

1. EPRI PROJECT RP1611

"Development of a PWR Water Level Indicator"

OBJECTIVE: To develop, test, and analyze the ability of a non-intrusive water level detection system to measure water level in existing PWRs.

SCOPE: Developed and tested neutron and gamma flux monitoring devices for ex-vessel measurements.
Performed testing and analyses.
Review other proposed and developed systems.

RESULTS: Draindown tests at Trojan and Farley Unit One.
EPRI internal instrumentation systems review.

2. NON-INVASIVE WATER LEVEL TESTING PROGRAM

CONTRACTOR: National Nuclear Corporation,
Mountain View, California

TEST PROGRAM: Preliminary tests in Trojan and Rancho Seco.

- Construction of 5 top detector assemblies and one large bottom assembly.
- Testing of 4 top assemblies during November 1980 draindown tests at Farley Unit One.
  - Tests performed approx. four days after reactor shutdown.
  - Results compared with computer analyses.
  - Documented results to be presented by Alabama Power Company to the NRC in June.
- Testing of one top detector assembly in LOFT L3-5/L8-1 tests.
- Planned tests of 4 top assemblies and large bottom assembly in Farley Unit Two, est. 1982.

Figure 5. Design of Neutron Detector Assemblies to be Used in the Planned Tests at Farley Unit One and LOFT Above the Core

~250 lbs

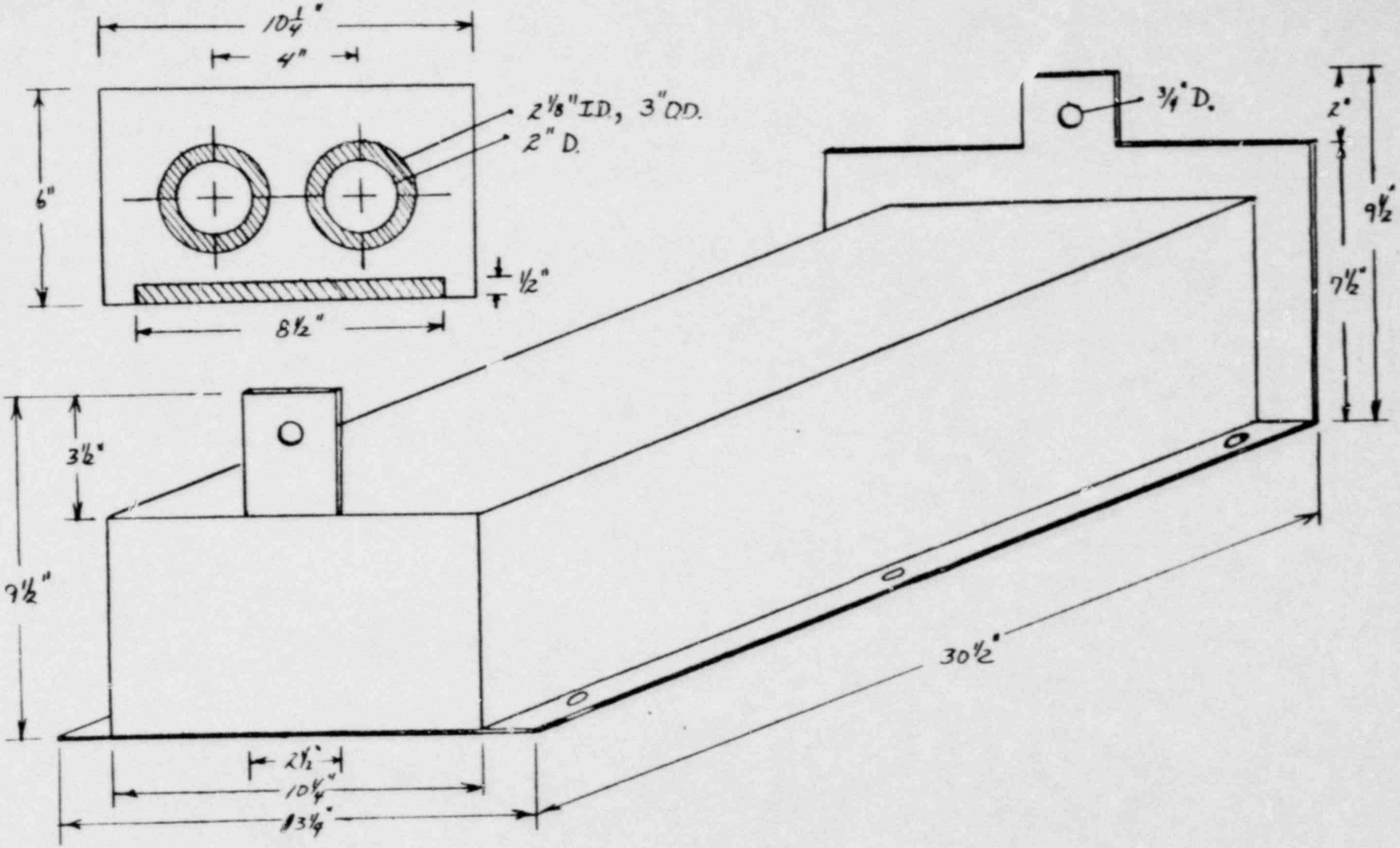
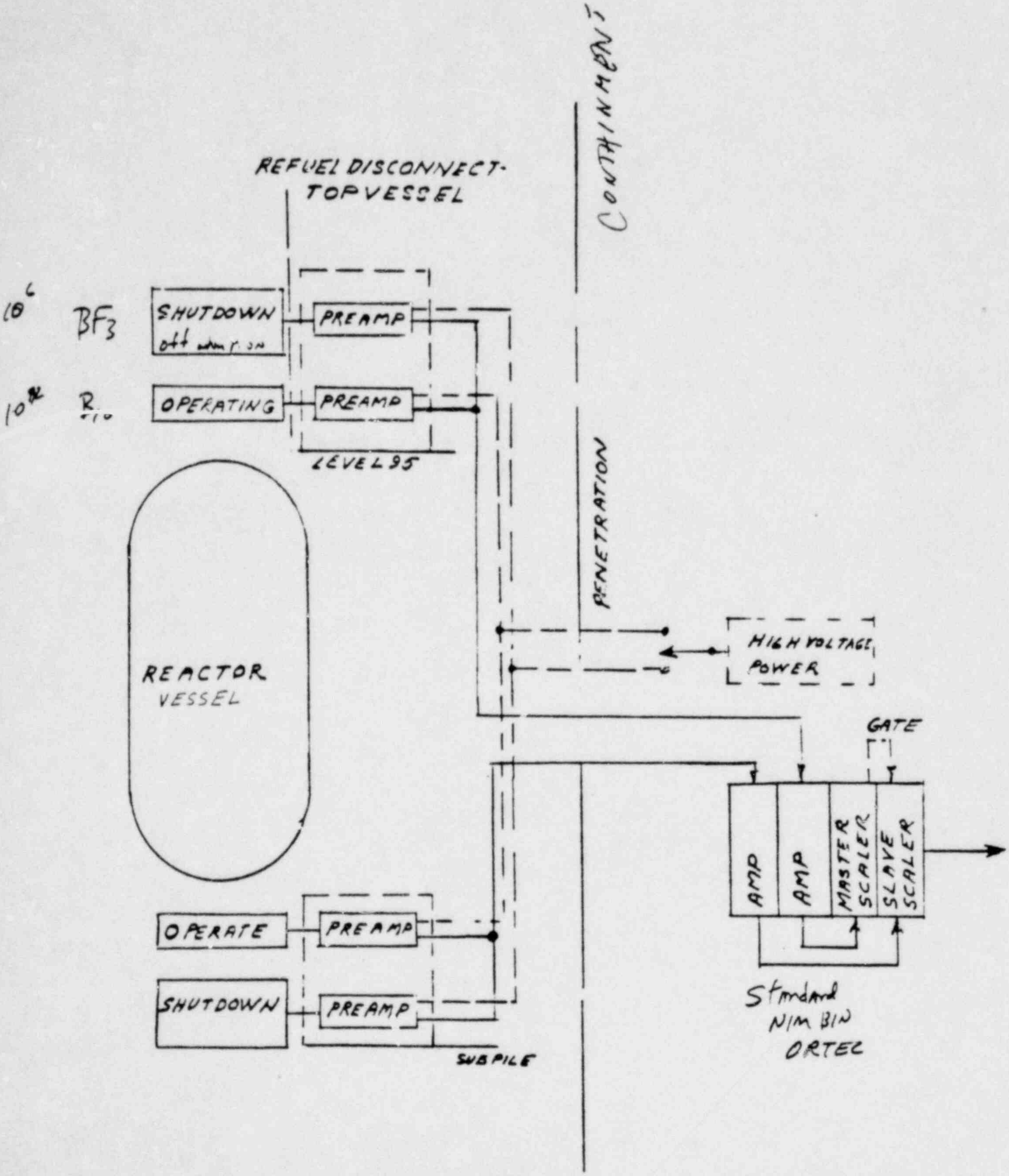


Figure 6. Schematic Arrangement of Detector Locations for the Farley Unit ~~One~~ Two Test.



3. INSTRUMENTATION SYSTEMS REVIEW

INCLUDES: VENDOR SYSTEMS
NATIONAL LABORATORY CONCEPTS
INDUSTRY CONCEPTS
POTENTIAL CONTRACTOR PROPOSALS

OTHER SYSTEMS REVIEW REFERENCES:

1. PAPER BY Y. Y. HSU, N. N. KONDIC, AND A. L. HON: "MODERN MEASUREMENT TECHNIQUES FOR INADEQUATE CORE COOLING OF NUCLEAR REACTOR CORES", PRESENTED AT CSNI MEETING AT CAL. TECH., MARCH, 1981.

2. PAPER BY R. L. ANDERSON: "STATE OF THE ART FOR LIQUID LEVEL MEASUREMENTS APPLIED TO IN-VESSEL COOLANT LEVEL FOR NUCLEAR REACTORS", ORNL PRESENTATION, UNDATED (1980).

INSTRUMENTATION LIST FOR MEASUREMENT OF REACTOR VESSEL WATER LEVEL

VENDORS

- W: ΔP SYSTEM
- C-E: HEATED THERMOCOUPLE SYSTEM
- B&W: DIFFERENTIAL PRESSURE MEASUREMENT (NEW PLANTS)

NRC

- ORNL: HEATED THERMOCOUPLES
  - ULTRASONIC DEVICES
  - γ-FLUX MONITORS
- EG&G: THERMOCOUPLE DESIGNS
  - PRESSURE TRANSDUCERS
  - CONDUCTIVITY PROBES

EPRI

- NNC: NON-INTRUSIVE RADIATION DETECTORS

OTHER

- FCI: HEATED RESISTANCE TEMPERATURE DETECTORS
- DAVCO: MICROWAVE DEVICES

PGB:AV 2-19-81

INSTRUMENT	DEVELOPER /SPONSOR	STATUS	MEASURES	INTERPRETATION	REMARKS
Heated Thermocouple	Oak Ridge/NRC	Preliminary Exps.	Local heat transfer	Phase of local fluid	Simple installation Discrete local conditions Response time ~10s Not sensitive to void fraction
Clad Thermocouple	EG&G/NRC	Prototypical System Tests (LOFT)	Local temperature	Local Fuel clad temp.	Gives state of fuel directly Difficult to install No indication of fluid condition
In Core Thermocouples		Conceptual	Temp. inside guide tube	Clad temperature	Infers level only after clad heat up.
Core Exit Thermocouple		Operational (Some reactors)	Core Exit Steam Superheat (temperature)	Extent of core Uncovery	Existing instrumentation Cannot distinguish between saturated phases Requires analysis to interpret
Heated RTD	Oak Ridge/NRC	Preliminary Exps.	Local heat transfer	Phase of local fluid	Discrete levels. Response time ~10s Not sensitive to void
DP transducer. Hot leg to top of vessel.	W EG&G/NRC B&W	Prototypical System Tests (LOFT)	Pressure difference	Average density between taps. (Level)	Not affected greatly by flow No indication of distribution Flashing in lines during depressurization
DP Across vessel	W	Conceptual	Pressure difference	Density, level	Affected by flow No indication of distribution Flashing in lines during depressurization To be tested in semi-scale facility 3/11
Liquid level transducer	EG&G/NRC	Prototypical System Tests	Local Conductivity	Phase of local fluid	Fast response. Local measurements. Affected by droplets Unknown lifetime

.NSTRUMENT	DEVELOPER /SPONSOR	STATUS	SURES	INTERPRETATION	REMAR
Neutron Detectors	ORNL/NRC NNC/EPRI	Concept System Testing	Neutron flux (BF-3)	Collapsed Liquid Level	In-place detectors not helpful Top-bottom detectors attractive Sensitive to low levels above core Unknown lifetime
Gamma-Thermometer	ORNL/-	Concept	Heat Transfer	Phase of local fluid	Simple rod design Radiation Heating Theoretical Analysis 3 TC design Untested 2 TC design used for power (Scanpower)
Ultrasonic	ORNL/NRC	Lab Exps.	Reflected vibrational waves	Density profile	Simple ribbon design Complex signal processing Vibration sensitive Vessel penetration Unproven
Microwave	DAVCO/-	Concept	Reflected High Frequency FM Waves	Density profile	Simple waveguide design Complex signal processing Complex vessel penetration Unproven
Time-Domain Reflectometry	ORNL-B&W/-	Concept	Reflected pulse waves	Density profile	Simple two-conductor design Self-calibrating Available hardware Electrical vessel penetration Sensitive to physical contact Unproven
Fission-Counter	SAI/-	Concept	Neutron Thermalization	Phase of local fluid	Neutron source & counter design Available sources & counters Insert in guide tubes Unproven

INSTRUMENT	DEVELOPER /SPONSOR	STATUS	SURES	INTERPRETATION	REMAR
Subcooling Monitor (RTD & Press)	CE	In plant	Pressurizer P Hot leg T	Existence of saturation & superheat	No indication of core conditions
Load Cell	Battelle	Conceptual	Buoyancy on tube or rad.	Average density	Affected by flow May simplify leads
Metal oxide cable	Battelle	Conceptual	Overall conductivity	Liquid level	Very slow response No response to void
Meltable Conductor	Battelle N.W.	Conceptual	Conductivity	Melt temp. has been exceeded	Can only be used once No assistance to operator during recovery.

4. Utility Liaison Activies

Utility interests and projects.

Relationship to RP1611

Utility / Owner's Group / Vendor Activities

- Gamma Thermometers (Duke, TVA, ORNL)
- RTDs (NE, ORNL, Fluid Components Inc.)

Utility Status and Positions

- NRC Requirements regarding 1/1/82 Committment Deadline
- Some have contracted with vendors
- Most have not
- Some are reconsidering their position

UTILITY SPONSORED TEST PROGRAM:
C-E AND MIT THERMOCOUPLES FOR
UPPER PLENUM WATER LEVEL PROBES.

PARTICIPATING UTILITIES:

- YANKEE ATOMIC ELECTRIC COMAPANY
- NORTH EAST UTILITIES
- CONSOLIDATED EDISON CO. OF NEW YORK
- CONSUMERS POWER COMPANY

TESTING CONDUCTED AT THE MIT ENERGY LABORATORY (DR. PETER GRIFFITH)

- TESTIN C-E AND MIT T.C. DESIGNS
- C-E PROBE TESTED UNDER STEADY-STATE AND SOME TRANSIENT CONDITIONS (INCOMPLETE)
- C-E PROBES APPEAR ADEQUATE UP TO 200 PSIA
  - AND OUTER STAINLESS STEEL CLADDING APPEARS TO HAVE SEVER MATERIALS PROBLEMS ABOVE 200 PSIA;
    - CLADDING UNZIPS,
    - POSSIBLY OUTGASSING OF BINDER IN MAGNESIUM OXIDE.
- PROBLEMS IDENTIFIED FOR SINGLE PROBE MEASUREMENTS OF SPECIFIC TRANSIENTS (ST. LUCY COOLDOWN, RAPIDLY FLUXUATING PRESSURES, ETC.)
- MIT PROBES SEEM TO GIVE BETTER READINGS (REDESIGNED)
  - SOME TRANSIENT TESTS PERFORMED
  - FUTURE TRANSIENT TESTING BEING REQUESTED BY MIT

5. CONCLUSIONS

INCREASING SERIOUS UTILITY INTEREST AND INVOLVEMENT.

EPRI INTERNAL LIAISON ACTIVITIES AND REVIEWS.

UTILITY SPONSORED TEST PROGRAMS INDICATE POTENTIAL PROBLEM AREAS WITH PROPOSED SYSTEMS.

NO FORMAL ORGANIZED PROGRAM FOR QUALIFICATION AND TESTING OF PROPOSED SYSTEMS EXISTS.

1/1/82 NRC DEADLINE IS INAPPROPRIATE.

EVALUATION OF PROPOSED MEASUREMENT TECHNIQUES FOR REACTOR VESSEL WATER LEVEL MEASUREMENT

PRESENTED TO THE ACRS

MAY 28, 1981

BY

YIH-YUN HSU

EXPERIMENTAL PROGRAMS BRANCH

DIVISION OF ACCIDENT EVALUATION

OFFICE OF NUCLEAR REGULATORY RESEARCH

EVALUATION CRITERIA

OBJECTIVE

- TO DETERMINE WHETHER THE PROPOSED TECHNIQUE IS RELIABLE AND PRACTICLE.

CRITERIA

- DATA QUALITY
- QUALIFICATION/SURVIVABILITY
- RELIABILITY
- RETROFIT
- OPERATION CONSIDERATIONS

TYPICAL PWR OPERATION CONDITIONS

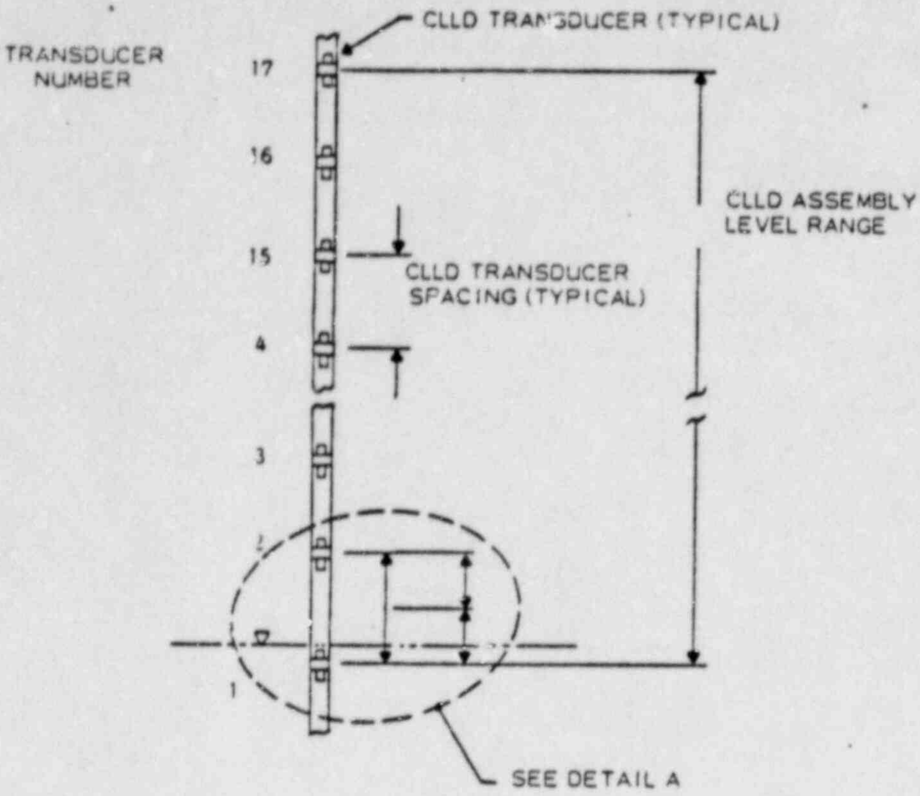
- VESSEL - ABOUT 20 CM STEAL
- TEMPERATURE - COOLANT - 400°C (750°F), INCORE - 1260°C (2300°F)
- PRESSURE - UP TO 20 MPA (2800 PSIG)
- RADIATION - > 10 DECADES
- WATER CHEMISTRY - $4.5 < PH < 10.5$, BORON - 0 TO 6000 PPM
- NOISE - ELECTROMAGENTIC (PUMPS, CONTROL ROD DRIVES), VIBRATION, RADIATION

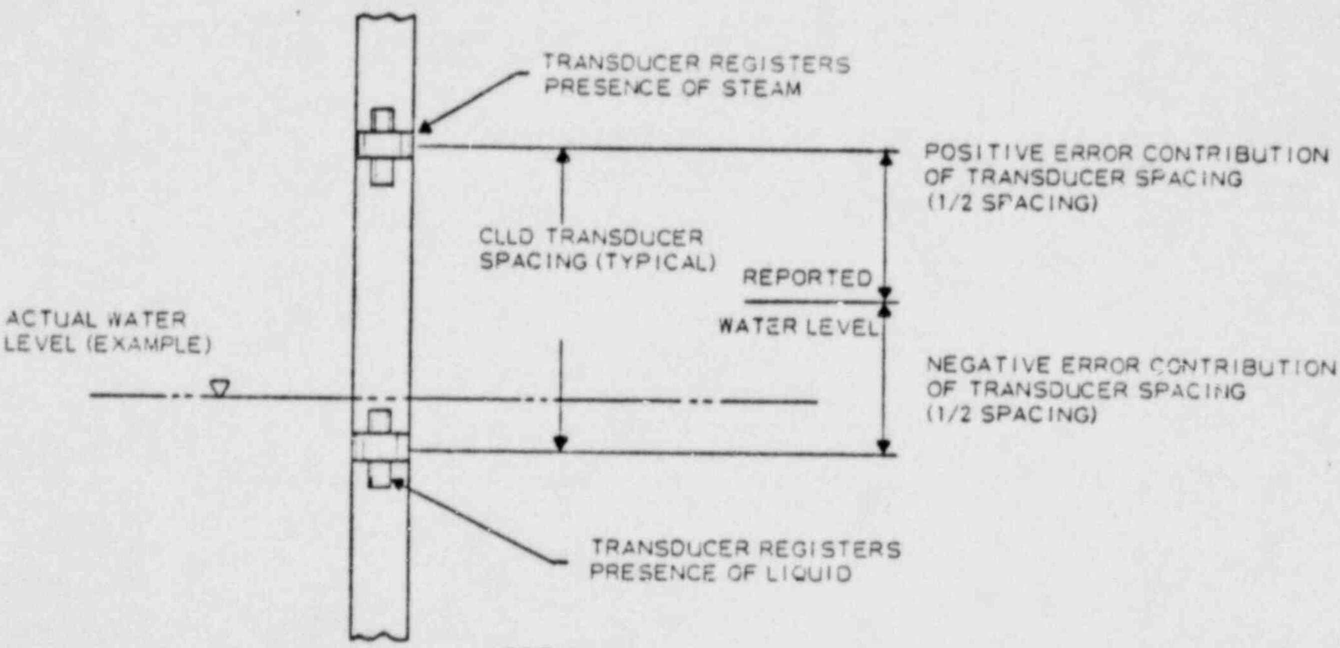
- NON-NUCLEAR
  - HTC AND RTD
  - DP
  - SONIC/ULTRASONIC WAVES
  - ULTRASONIC RIBBON
  - MICROWAVE
- NUCLEAR
  - SPND
  - GAMMA DETECTORS
  - SOURCE-RANGE NEUTRON DETECTOR
    - TOP BOTTOM
    - SIDE

	DATA QUALITY	DURABILITY	RETROFIT	OPERATIONS	RELIABILITY	REMARKS
Electrical Impedance LLD						Not recommended.
Sonic/Ultrasonic Propagation						Could be used now when calibration is available.
Sonic Propagation on Vessel						A possible backup system.
Sonic Pressure Pulse Reflection						There may not be available space for wave guide.
Microwave						Needs to be proven.
Time Domain Reflectometery						Not recommended.
Ultrasonic Ribbon						Needs development. Promising.

(CONTINUED)

	DATA QUALITY	DURABILITY	RETROFIT	OPERATIONS	RELIABILITY	REMARKS
SPND						Not recommended.
γ-Beam						It is still a viable alternative. May be useful after R&D.
Exterior Neutron Detector						Top/bottom location not proving side string promising.
Neutron Thermalization Moisture Gauge						Not proven.
Weighing						Not recommended.
Heated T.C.						A good local measurement.
Δp Cell						A viable method; BWR is using it.



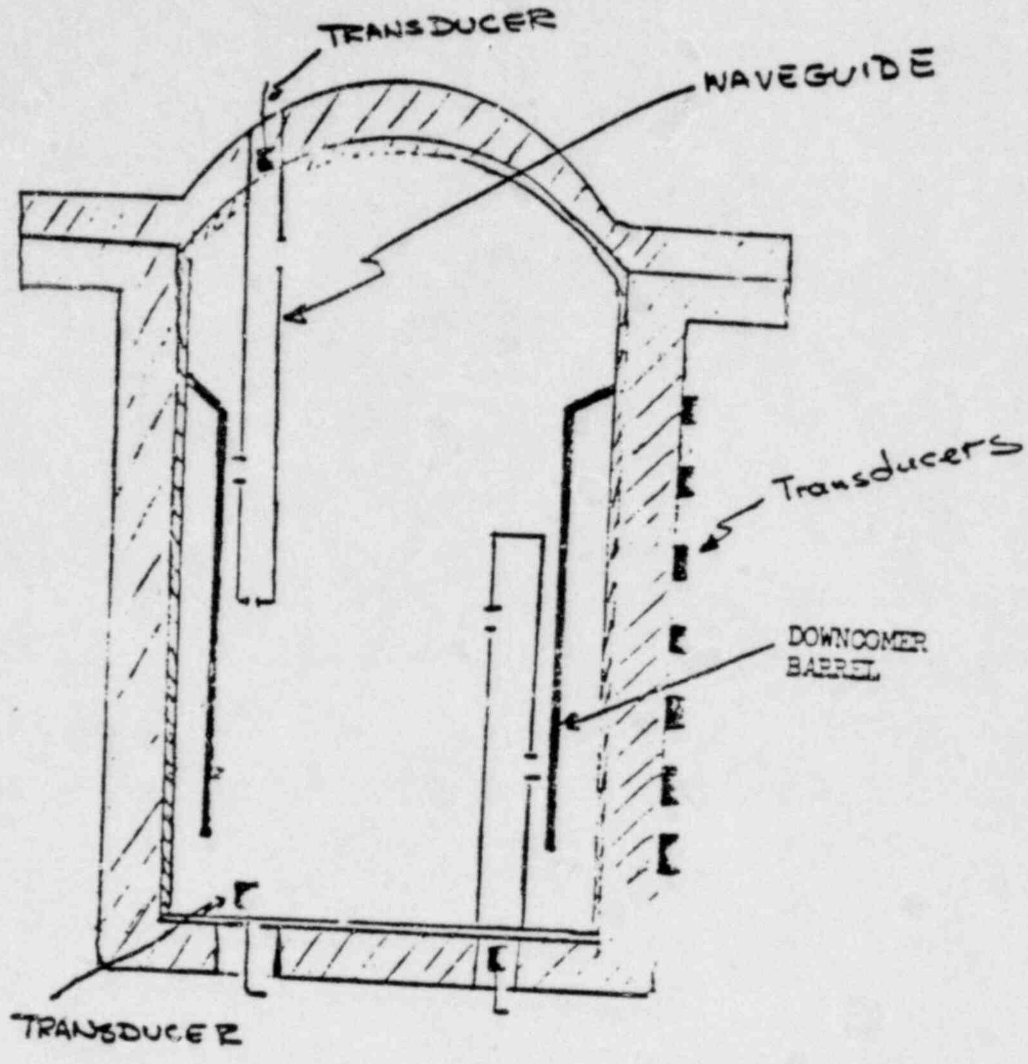


DETAIL A

FIGURE 3

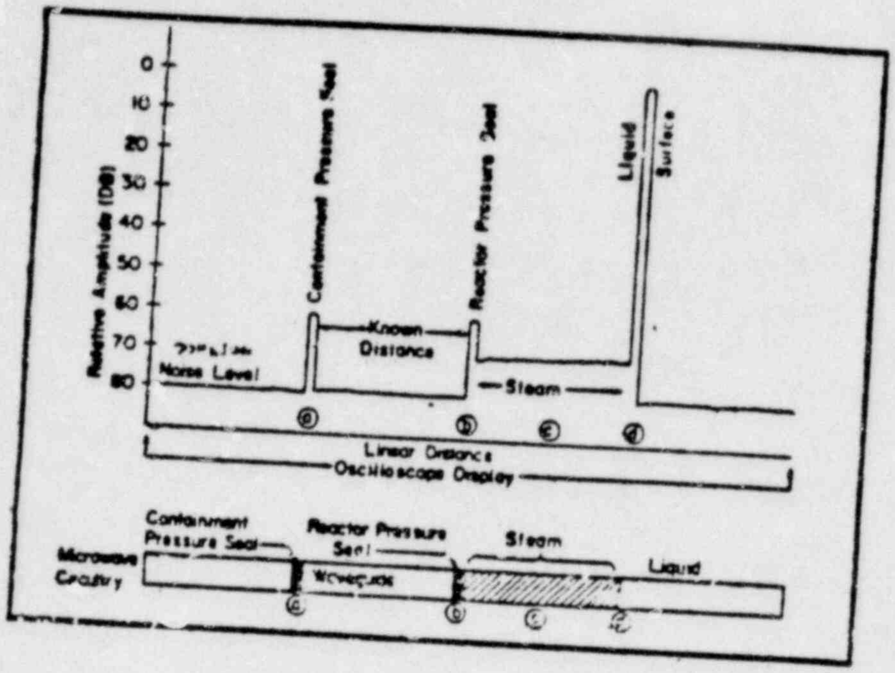
LEVEL ACCURACY AND RANGE DEFINITIONS FOR CLLD ASSEMBLIES

REACTOR VESSEL (NOT TO SCALE)



ARRANGEMENTS SKETCH FOR POSSIBLE ACOUSTIC/ULTRASONIC LEVEL MEASUREMENTS

Fig. 4.4



Relative Amplitude (DB)
0
10
20
30
40
50
60
70
80
Noise Level
Containment Pressure Seal
Known Distance
Reactor Pressure Seal
Steam
Liquid Surface
Linear Distance
Oscilloscope Display
Containment Pressure Seal
Reactor Pressure Seal
Steam
Liquid
Microwave Cavity
Waveguide

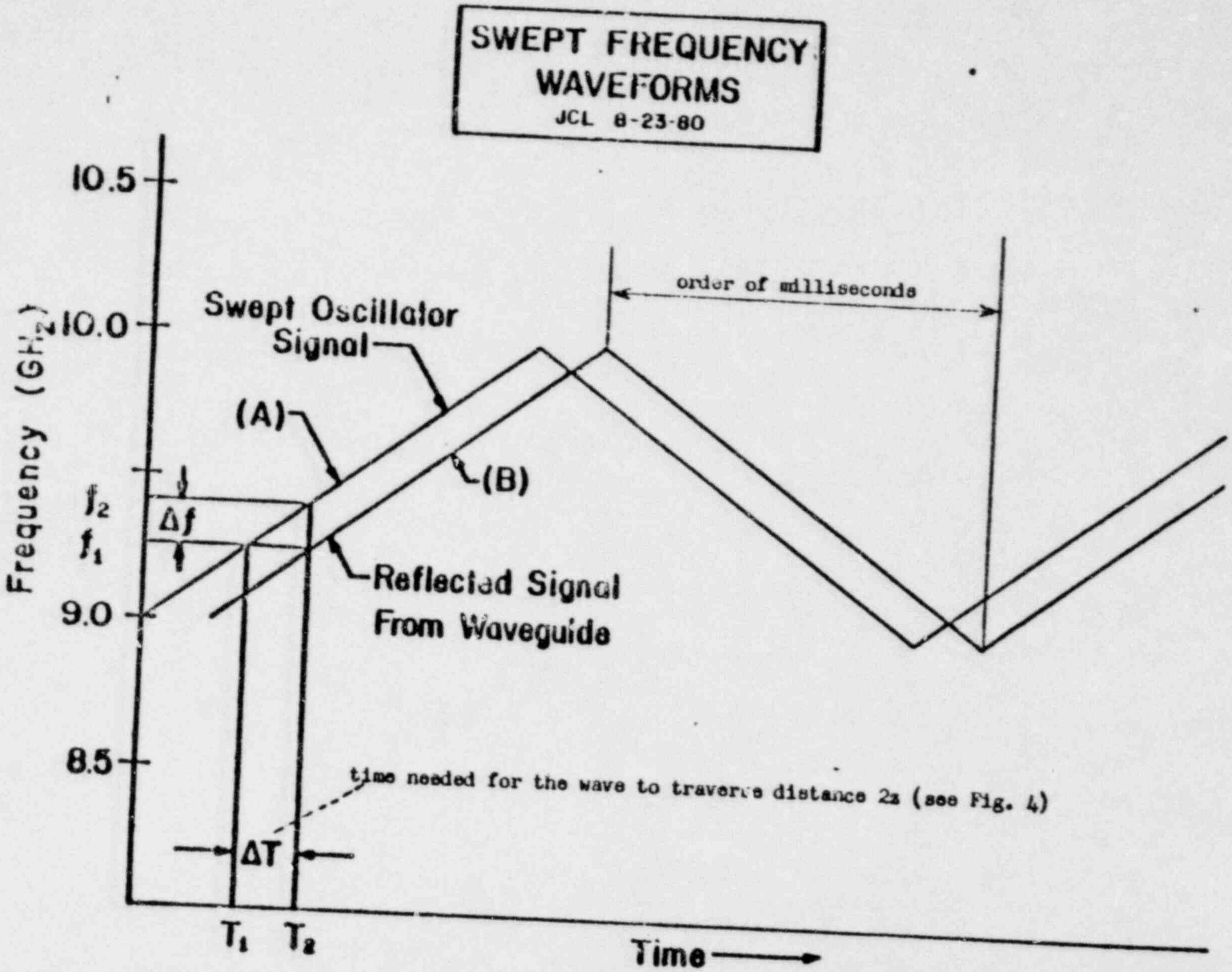
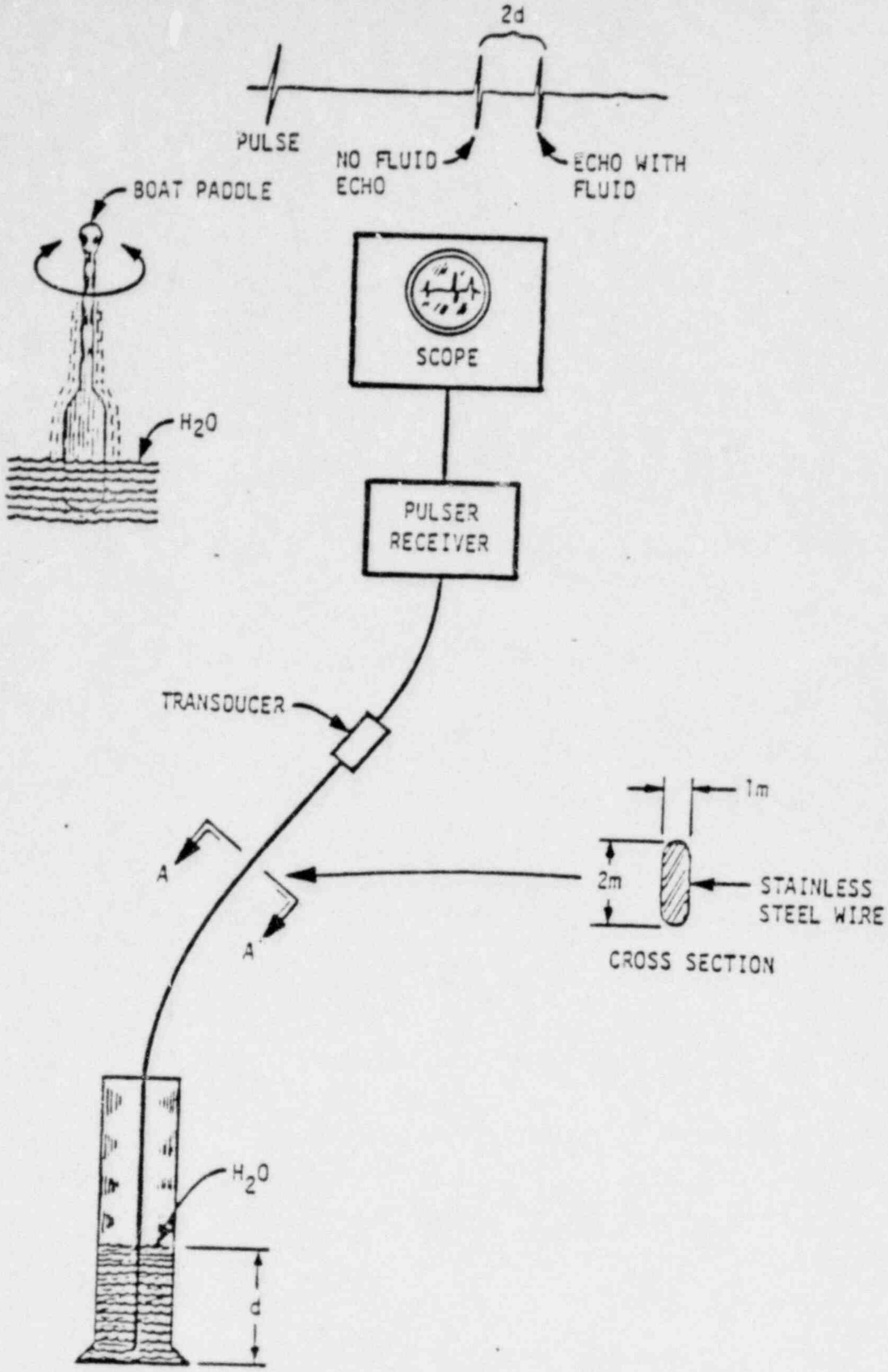

SWEPT FREQUENCY WAVEFORMS
JCL 8-23-80
10.5
10.0
9.0
8.5
Frequency (GHz)
Swept Oscillator Signal
(A)
(B)
f_2
Δf
f_1
Reflected Signal From Waveguide
order of milliseconds
time needed for the wave to traverse distance 2a (see Fig. 4)
ΔT
T_1
T_2
Time

Figure 3



TORSIONAL PULSE ON FLATTENED WIRE IS DELAYED BY DENSE MEDIUM MUCH LIKE A BOAT PADDLE IN WATER.

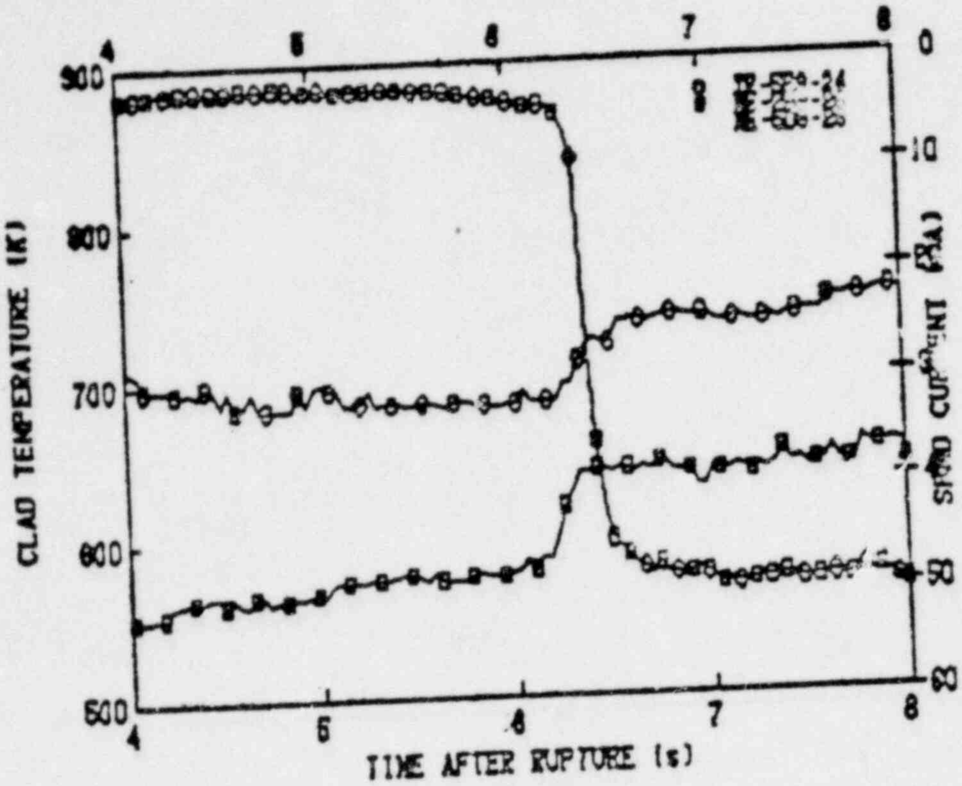


FIGURE 8: LOFT Central and Peripheral SPND Output Compared With an Adjacent Fuel Cladding Thermocouple During LOCE L2-3 Quench

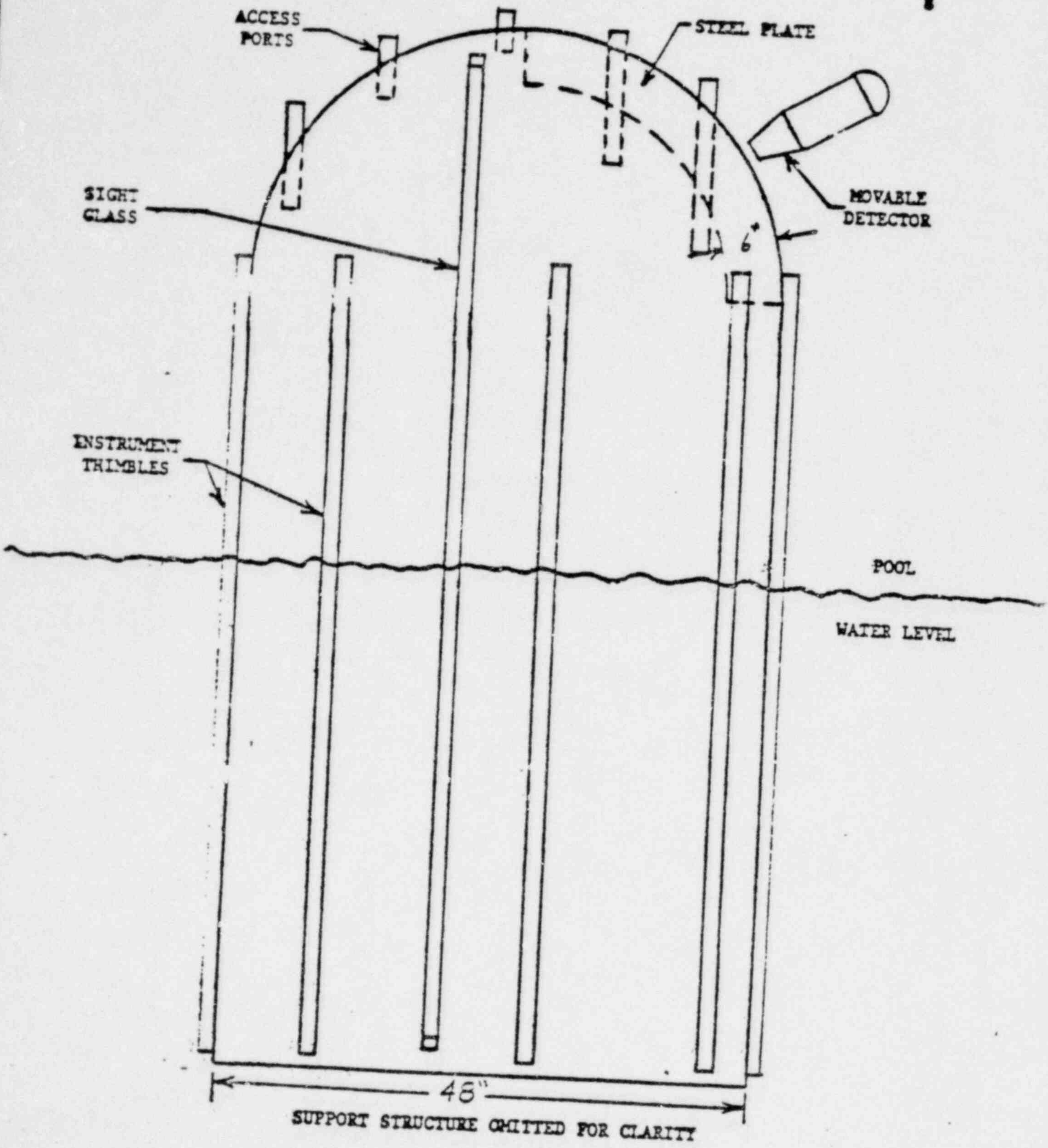


Figure 1. Test Vessel, Side View

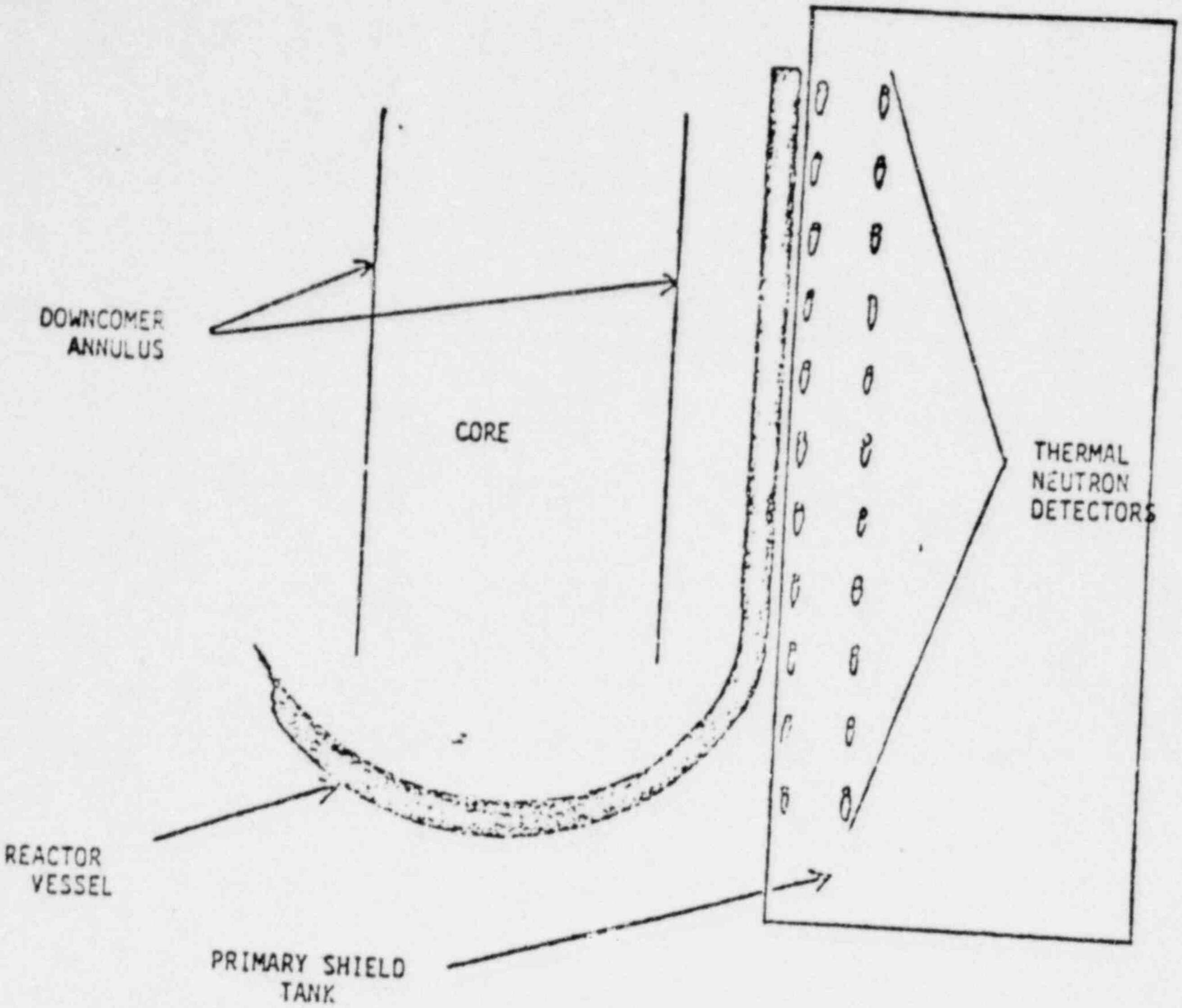

DOWNCOMER
ANNULUS
CORE
THERMAL
NEUTRON
DETECTORS
REACTOR
VESSEL
PRIMARY SHIELD
TANK

Fig. 4.11

Thermal Neutron Flux in Primary Shield Tank

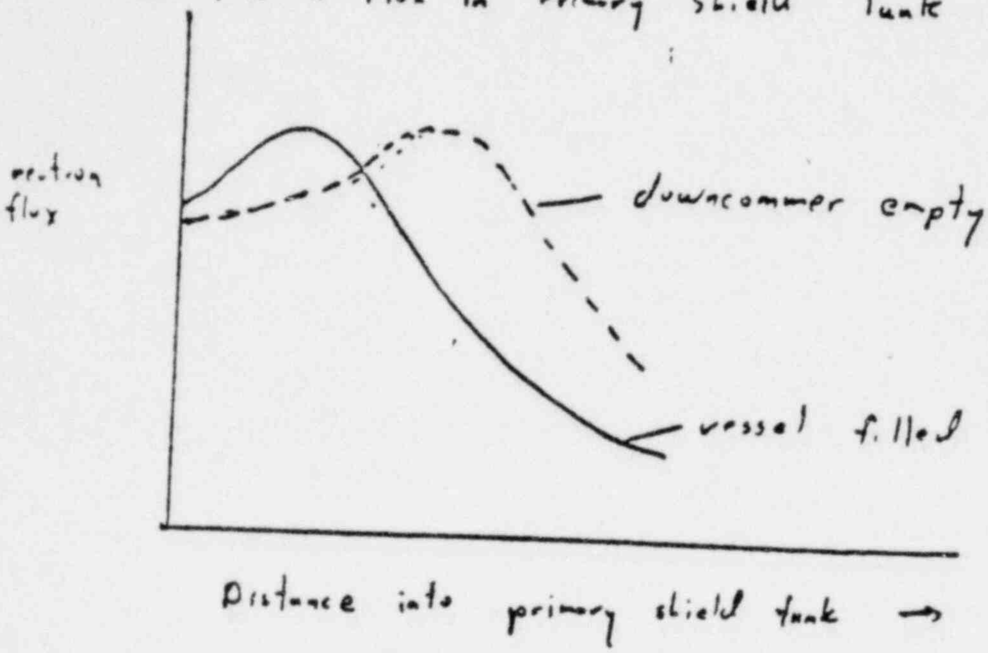
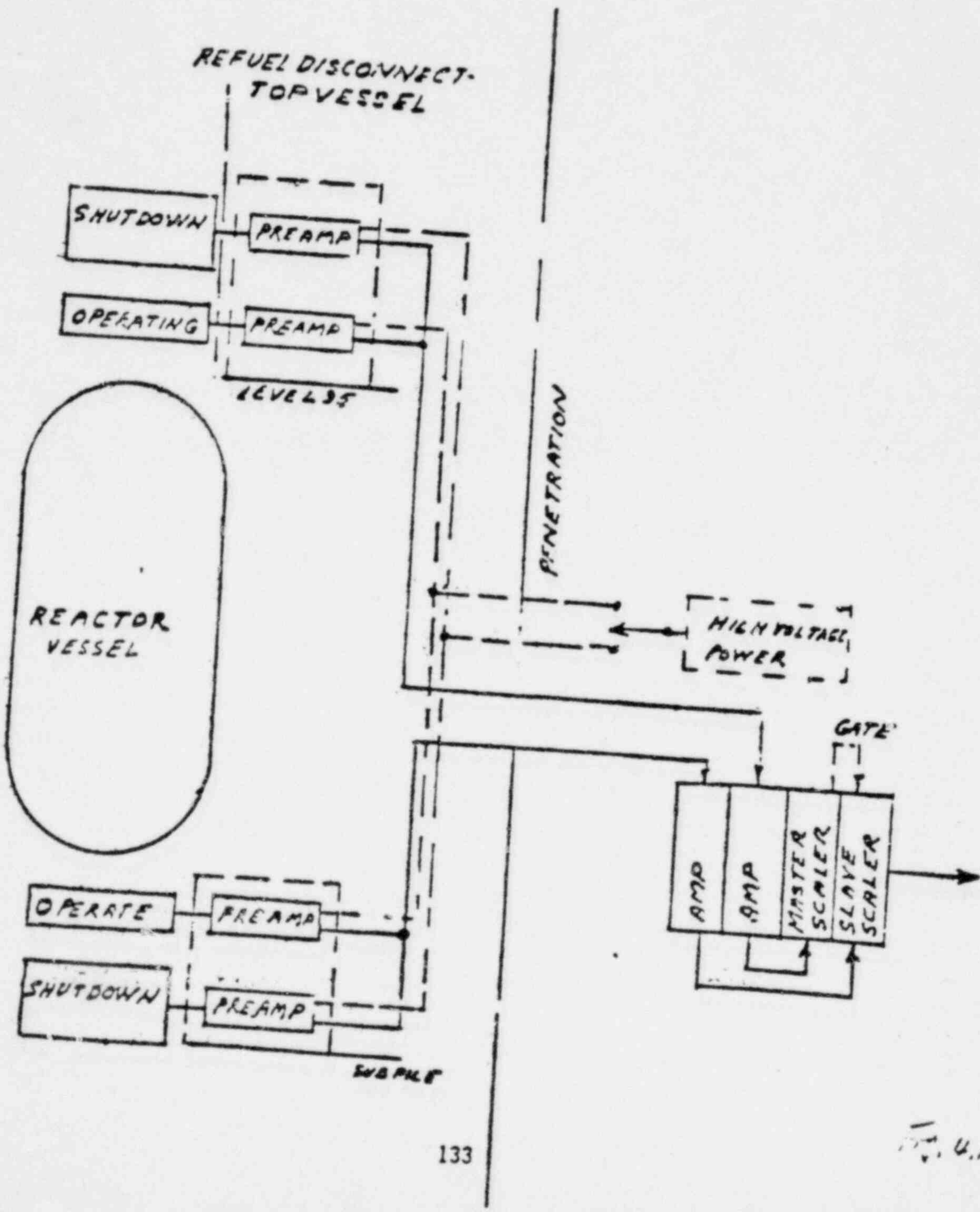


Figure 2

Fig. 2.12

Figure 2. Schematic Arrangement of Detector Locations for the Farley Unit One Test.



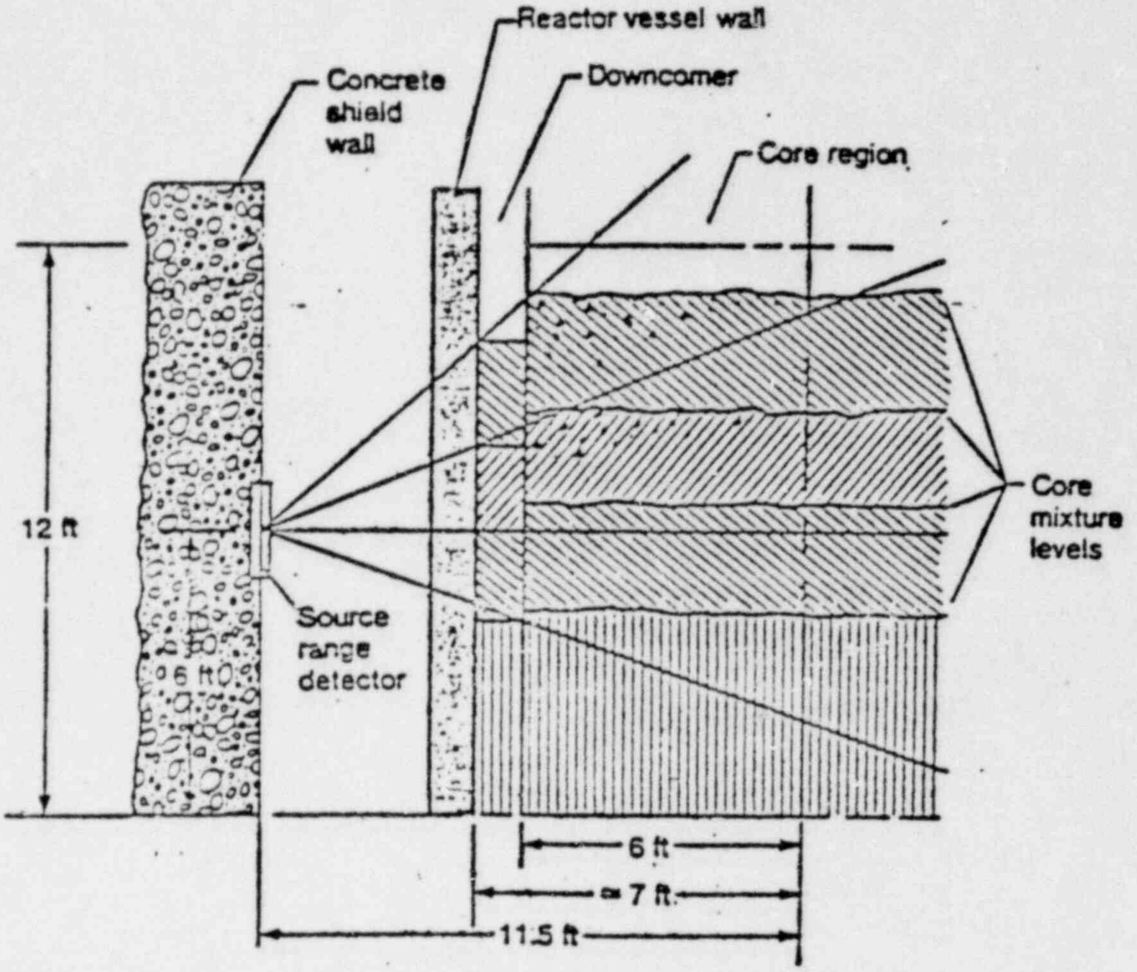


Figure 3. Source range neutron detector field of view versus core mixture level.

414

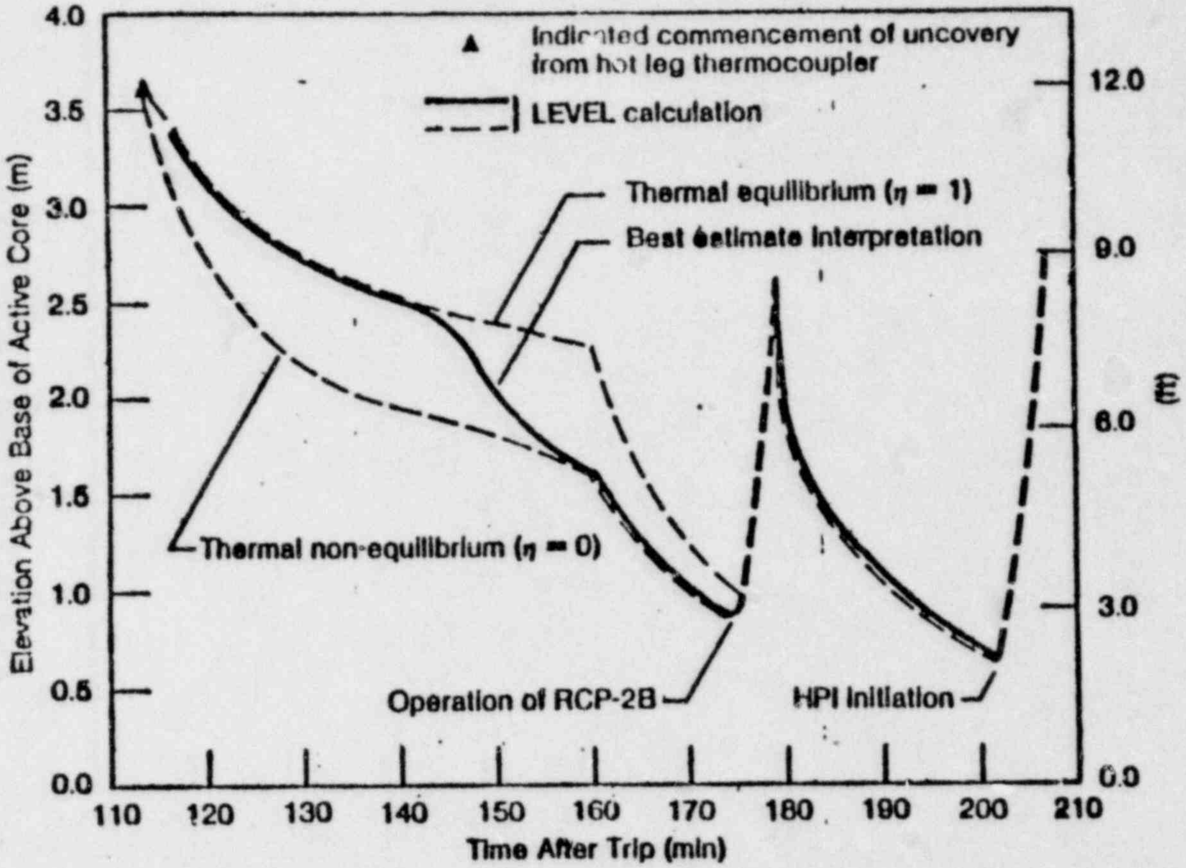


Figure 7. Calculated level path during uncovery of TMI-2 core. Solid curve is best estimate calculation.

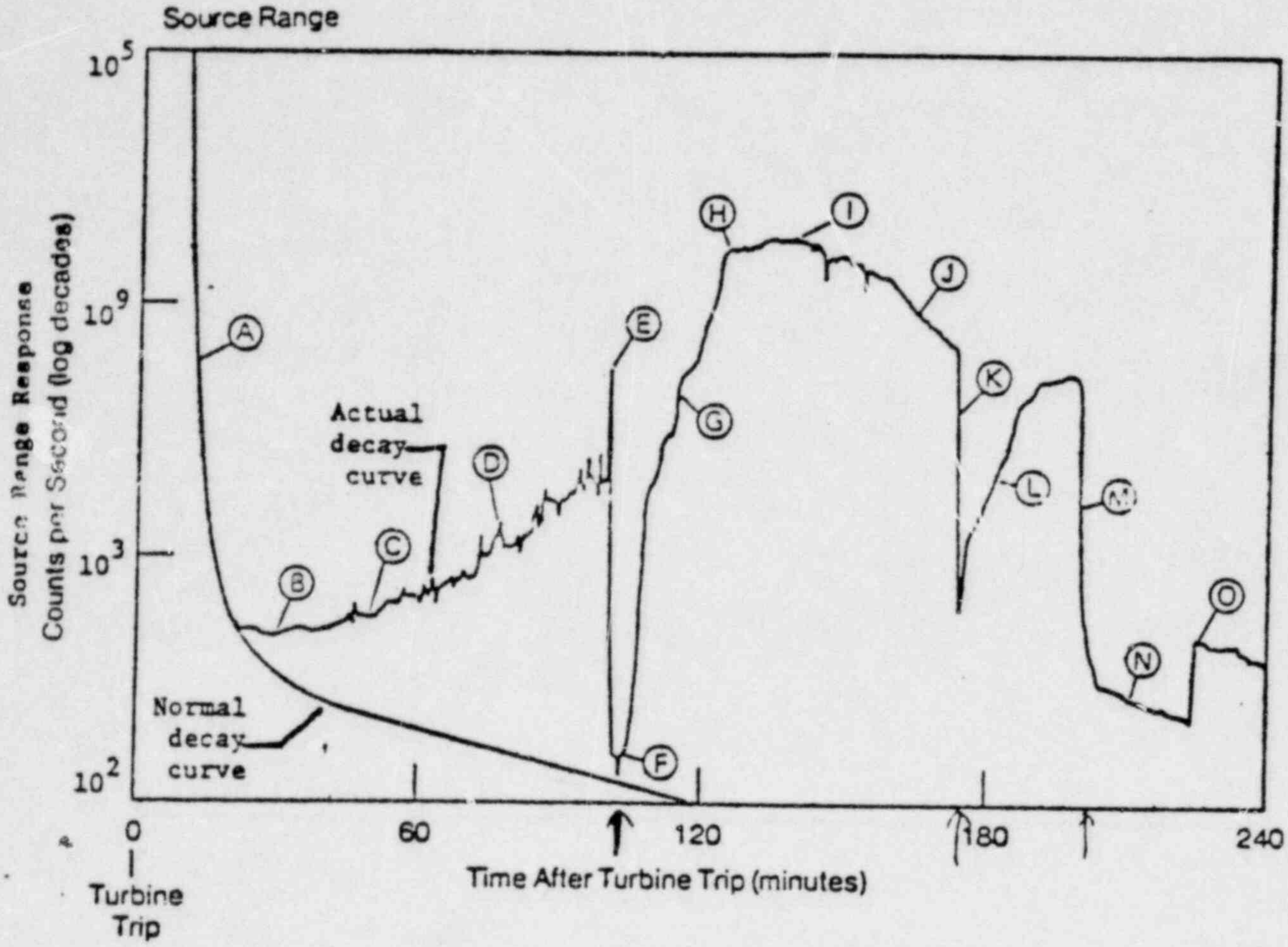
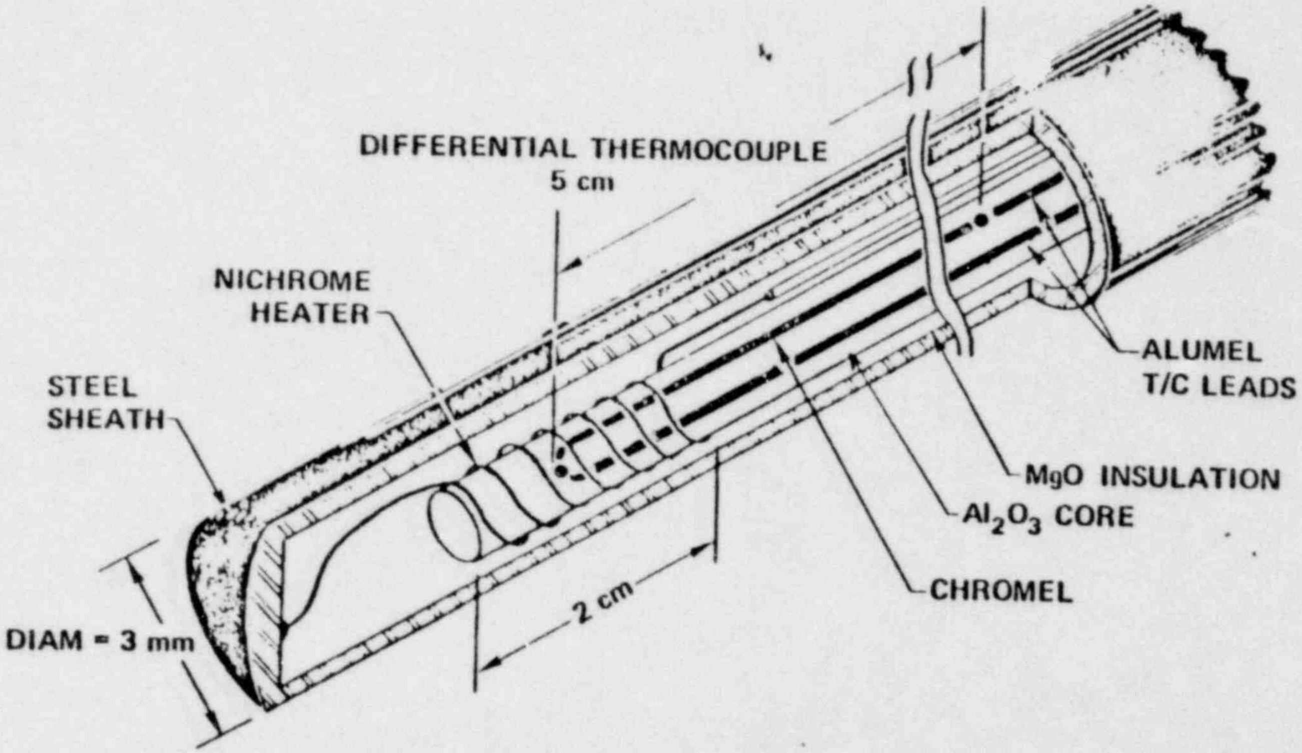


Figure 4. Source Range Detector Reading as a Function of Time after Turbine Trip

ORNL-DWG 79-20442B

UNION CARBIDE
ORNL

HEATED TC COOLANT SENSORS ARE SMALL AND USE REACTOR-COMPATIBLE COMPONENTS



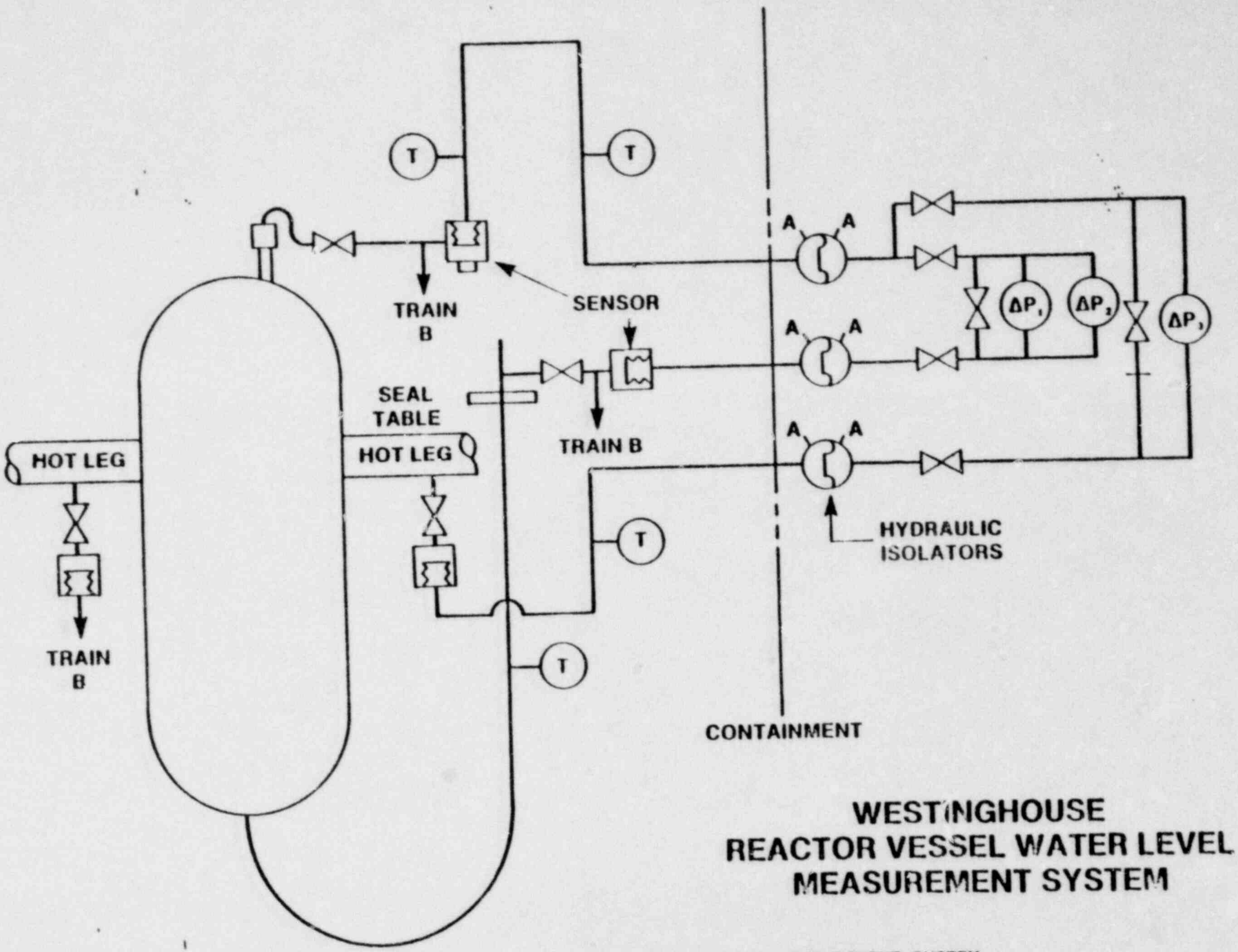


FIGURE 6. WESTINGHOUSE REACTOR VESSEL WATER LEVEL MEASUREMENT SYSTEM

	DATA QUALITY	DURABILITY	RETROFIT	OPERATIONS	RELIABILITY	REMARKS
Electrical Impedance LLD	+	−	−	+	−	Not recommended.
Sonic/Ultrasonic Propagation	−	+	±	+	−	Could be used now when calibration is available.
Sonic Propagation on Vessel	−	+	+	+	−	A possible backup system.
Sonic Pressure Pulse Reflection	−	+	−	+	+	There may not be available space for wave guide.
Microwave	+	−	−	+	+	Needs to be proven.
Time Domain Reflectometery	+	−	−	+	−	Not recommended.
Ultrasonic Ribbon	+	+	+	+	+	Needs development. Promising.

(CONTINUED)

	DATA QUALITY	DURABILITY	RETROFIT	OPERATIONS	RELIABILITY	REMARKS
SPND	+	−	+	−	−	Not recommended.
γ-Beam	−	+	+	−	−	It is still a viable alternative. May be useful after R&D.
Exterior Neutron Detector	−/+	+	+	+	?	Top/bottom location not proving side string promising.
Neutron Thermalization Moisture Gauge	?	−	−		?	Not proven.
Weighing	−	+	−	+	−	Not recommended.
Heated T.C.	+	+	+	+	+	A good local measurement.
Δp Cell	±	+	+	−	±	A viable method; BWR is using it.

SUMMARY CONCLUSIONS

- CRITERIA BASED ON RELIABILITY AND PRACTICALITY HAVE BEEN DEFINED FOR ICC INSTRUMENTATION
- MULITUDE OF TECHNIQUES HAVE BEEN CONSIDERED, BUT ONLY FEW ARE FEASIBLE
- NRC/RSR IS TESTING SELECTED TECHNIQUES UNDER SIMULATED LOCA CONDITIONS
- HTC SEEMS PROMISING FROM TEST RESULTS

MODERN MEASUREMENT TECHNIQUES FOR INADEQUATE COOLING OF NUCLEAR REACTOR CORES

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Division of Reactor Safety Research
U.S. Nuclear Regulatory Commission
Washington, D.C. USA

ABSTRACT

A reliable and unambiguous monitoring of reactor vessel liquid level, which can detect inadequate core cooling (ICC), was an important item from the Three Mile Island (TMI) Lessons Learned survey.

A multitude of methods was proposed by many parties involved. They could be divided in two main groups: intrusive and nonintrusive, regarding the penetration of the reactor pressure boundary. Some of the methods considered are proven in similar or nonnuclear systems, such as static head/differential pressure, heated thermocouples, sonic/ultrasonic devices, microwaves, etc., while others are in a developing stage, although based on proven principles. Several methods from this second group would be: gamma attenuation, neutron diffusion (both locally applied), neutron/gamma activation (n-gamma and gamma-n) reactions, traversing probes signal and noise analysis, etc.

Applicability of various methods should be considered in conjunction with factors, such as reactor operating state (steady power, transients, or shutdown) and sensing field (upper plenum and core region).

This paper lists all realistic candidate methods in a systematic way and evaluates their relative merits and drawbacks based on several criteria, such as: feasibility study and test results, power plant retrofit possibility/convenience, mounting cost and time needed, instrument longevity/survival in the adverse conditions of the reactor environment, operability, reliability, unambiguity of data, serviceability, and other features.

1. INTRODUCTION

Until recently, the water inventory in a pressurized water reactor (PWR) vessel was not directly measured. Various investigation groups [], 2 , 3] identified this as a major contributor to the TMI-2 accident of March 1979. In order to protect the health and safety of the public, the U.S. Nuclear Regulatory Commission (USNRC) set requirements for both new and existing PWRs to provide direct, unambiguous methods to detect inadequate core cooling (ICC) in PWR vessels. Although there are several promising techniques, very few have been adequately evaluated. It is not known to what extent they meet NRC requirements or whether they can be backfitted in a practical manner. To meet this need, the NRC, Division of Reactor Safety Research (RSR), organized several meetings to explore feasible methods and sponsor limited evaluation studies.

The basic approach of evaluating the various candidates for liquid level measurement is to formulate a set of criteria against which the performance of each method can be judged as to its feasibility for application as a power plant instrument. These criteria are data quality, survivability, reliability, retrofit, and operation.

Once the criteria is established, the merit and shortcoming of each proposed method will be evaluated. Several staff meetings were held, and experts were solicited to establish a concensus of evaluation on those more established methods. In addition, a specialist's meeting was held in October 1980 at the WRSR information meeting where proposers of more novel approaches were invited to present their cases for peer review [4].

A few methods considered more feasible are being subject to bench and system tests in NRC experiment facilities under the conditions simulating those expected to exist in reactor accidents or transient.

This paper summarizes several techniques that may be used to measure the core cooling ablity of power reactors. Evaluations of these techniques, based on testing and engineering judgment, are also presented.

It should be emphasized that evaluations reported in this paper reflect only the technical opinion of some of the instrumentation staff in the Reactor Safety Research Division. As such, it should in no way be considered as the NRC official position.

2. CRITERIA FOR EVALUATION

Although many proposed techniques appear good in principle, one must carefully consider many important factors before actually installing them in nuclear power plants. Some of these factors are NRC licensing requirements, data quality, reliability, ability to survive during operation and abnormal conditions, and impacts on existing reactors and plant operations when retrofitted. These considerations can be used as criteria to evaluate proposed techniques.

2.1 NRC Licensing Requirements

The NRC licensing requirement for the ICC instrument is part of the post-TMI Action Plan [5], Section II.F.2. A follow-on document provides guidance on how one can meet this requirement [6]. Some of the points worth mentioning are: The measurement must be unambiguous and easy to interpret under various phenomena with the coolant pumps on and off; it must cover the entire length of the vessel; it must give advance warning of the approach of ICC; and it must meet all of the qualification requirements for safety-related electrical equipment. However, NRC allows combining the new instrument with existing in-vessel instruments, such as core-exit thermocouple and subcooling meters, if the new instrument cannot meet all the requirements by itself.

2.2 Data Quality

Inherent measurement characteristics. Each technique has its own inherent advantage and limitations; these should be carefully recognized in the feasibility evaluation. The measurement should be unambiguous, the need for data inference should be minimal, and its function should not rely too much on other measurements. It should cover the normal operation conditions of the reactor and abnormal conditions. This means the instrument should perform whether the core is critical or scrammed. Also the performance should not be affected by boron concentration, coolant pump operation, or by fission products in the coolant.

Unlike instruments used for research studies, the emphasis of ICC instruments should be placed on qualitative trend indications under the above conditions. This means that precision and fast response (faster than one minute) are not as critical.

In-vessel environments. A power reactor operates under a wide range of conditions between startup and full power. For example, the PWR system pressure ranges from 0 to 20 MPa and temperature ranges from 50-350°C. Thus the thermal properties of the coolant vary over a wide range. Likewise, the pH of the waster chemistry changes from 4.5 to 10.5, thus the conductivity of the primary coolant can vary from 1 to 30 micromho/cm. Depending on the control rod position and boron concentration, the neutron flux in the core vary at least 10 decades.

The reactor vessel itself is typcially 20 cm thick steel, inside it is the downcomer filled with a blanket of water. These conditions plus noise such as vibration, electromagnetic noise from pump motors, and control rod drive mechanism can challenge the quality of the data from most of the techniques.

Sensing region. A typical PWR vessel is about 14 meters high. Internally, it can be divided into upper head, upper plenum, core, and lower plenum. The thermal-hydraulic and neutronic conditions in each region are different. Thus it is difficult to rely on one device to cover the whole vessel. A more realistic approach to the problem is to determine where a particular measurement technique can best function and to combine it with other instruments to form a total ICC detection system.

2.3 Survivability and Qualification

Since ICC instrumentation serves a vital function, it should meet all of the requirements applicable to safety-related electrical equipment in nuclear power plants. These requirements are environment- and seismic-qualification related. They are specified in standards such as IEEE standard 323-1974, IEEE-394-1975, Reg. Guide 1.89 and 1.100, NUREG-0588, etc. The typical range requirement for essential instruments in the reactor vessel are:

temperature:	Coolant - 400°C (750°F), in-core - 1260°C (2300°F)
pressure:	21 MPa (3000 psig)
radiation:	10^7 R/hour (in containment)
boron content:	0 to 6000 ppm

2.4 Reliability

A reliable instrument for ICC should perform well under any factor conditions: this means it does not give spurious alarms during normal plant perturbations; the instrument should function whether the coolant pumps are running or not and during abnormal conditions (including small-break LOCA). However, during a large-break LOCA, the reactor is protected by the Emergency Core Cooling System (ECCS) and very little operator action is needed. Thus, we do not feel it is important for the instrument to perform equally well in these conditions; but the instrument should survive the transient and function after reflood.

2.5 Retrofit

Many techniques are sound and nearly ideal when they are incorporated into the design of new plants, but they are not suitable for existing plants without severe impacts. Some of the considerations for retrofitting are as follows:

(a) It should require minimum penetration or utilize existing penatrations.

(b) It should minimize modification to existing NSSS design, and it should not require any modification to the fuel bundles.

(c) The sensors should be mounted at stable locations and require no attention during the operation.

(d) It should not impact the operation cycle of the reactor, including refueling.

(e) It should last at least the life of the fuel, and should be easily replaced after that.

(f) The downtime required for its installation and periodic checking should be minimal.

2.6 Operation and Maintenance

The objective of this new instrument is to help the operator clearly understand the status of the reactor, not to burden him with more data and additional actions. This means the measurement should be as direct and simple as possible. The display should be unambiguous, requiring no interpretation from the operator. The sensors and data reduction system should be calibrated and fixed so that the operator will not need to manipulate them during operation. The instrument should be event independent (i.e., using the display, the operator will understand cooling conditions without having to speculate about the status of the reactor). Human factor consideration and operator's input should be taken into the system design and implementation.

The instrument should have periodic inservice verification and calibration capability. The routine maintenance requirement should be minimal. The sensors output should be accessible for spot-check or emergency situations.

3. CLASSIFICATION OF MONITORING TECHNIQUES

3.1 Intrusive vs Nonintrusive/Interference Criteria

The strict interference criterion for any instrument in question is whether any behavior of the system being measured can be affected by the existence and operation of that instrument. This is a rigorous definition of a nonintrusive instrument.

We separate the add-on instruments into three catagories based on their relationship to the reactor vessel and the fluid.

a) Nonintrusive - These instruments are placed outside the vessel pressure boundary.

b) Intrusive - These instruments are placed inside the reactor vessel. Therefore, they usually disturb reactor operation when retrofitted. One example is adding a new instrumented pipe in the upper head.

c) Semi-intrusive - Even though these instruments required some penetration on the vessel pressure boundary, they do not interfere with reactor operation. Examples are pressure taps for dp and more sensors into existing incore process tubes.

3.2 Parameters Measured

Directly measured parameters. They can be obtained from sensors without interpretation. Examples are pressure, temperature, gamma and neutron fluxes, electrical properties such as impedance, capacitance and inductance, operation noise, etc. These parameters are measured directly with designed sensors.

Indirectly determined parameter. The parameters are not available from sensors directly. Through basic physical laws and direct sensors, these parameters can be determined in a straight-toward manner. Examples are density, radiation at remote location of known distance, heat transfer coefficient, etc.

Derived Parameters. These parameters must be interpreted by combining the sensor information with sophisticated algoriths. Examples are flowrate measurement, DNB at some distances from the sensor, liquid and gas inventory, etc.

4. EVALUATION OF TECHNIQUES CONSIDERED

In this section, each method will be briefly described. The past experience of performance, if available, will be discussed and the main points will be identified. All the methods and their evaluation against the criteria will be summarized in a table.

Nonnuclear Methods

4.1 Pressure Differential for Static Head

This method measures the collapsed liquid level in the reactor vessel through pressure taps near the bottom of the vessel and above the core. In some cases, additional taps are provided for levels above the core. The dp system has been widely used in systems other than in nuclear reactor vessels. For reactor application, Westinghouse has developed a dp system (Fig. 1) that is now undergoing tests. The advantage of the dp system is its simplicity and well-understood principle. The disadvantages are:

1. Large error when the pump is running;
2. Need of penetration of vessel to install taps; and
3. Measurement gives the collapsed level, not froth level that can still perform cooling function.

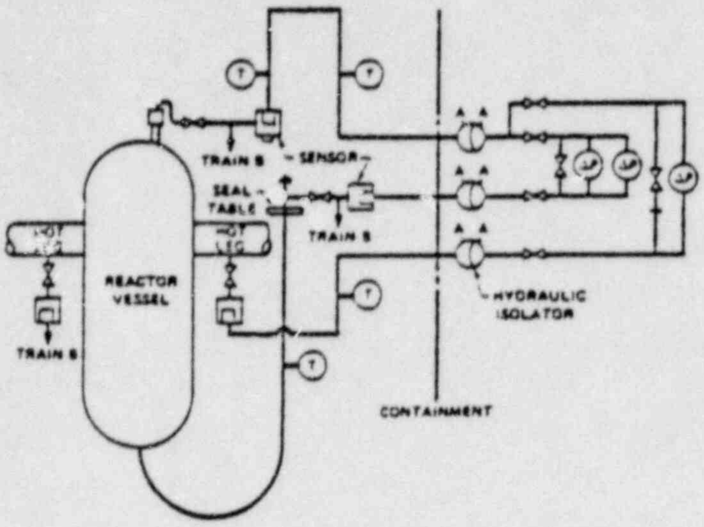

Fig. 1. Westinghouse DP Level System.

4.2 Heated Thermocouples HTC and Heated RTD

The basic principle of a heated thermocouple or heated RTD as a liquid level indicator is the high-heat transfer coefficient of water verses that of steam. Thus, a HTC with a heating source will register a rapid rise of temperature when the probe is uncovered. However, the water could be either in the form of a froth, mist droplets, or "solid" water with heat transfer coefficients varying for two or more orders of magnitude. Many different variations of design are in existence and have been used in industry and in naval applications. For reactor application, Combustion Engineering, EG&G, FCI, and ORNL have developed their own design (Fig. 2) [7, 8]. These devices are being tested.

The advantages of heated thermocouples are:

1. It measures directly the cooling capability of the fluid including froth level and droplet flow; and

2. The instrument is rugged and the operating principle is simple.

The disadvantages are:

1. The measurement is of local (point) phenomena. Thus, it can only tell whether froth is at the given location unless an array of sensors is used; and

2. There is some difficulty in differentiating high quality, high flow cooling and flow cooling.

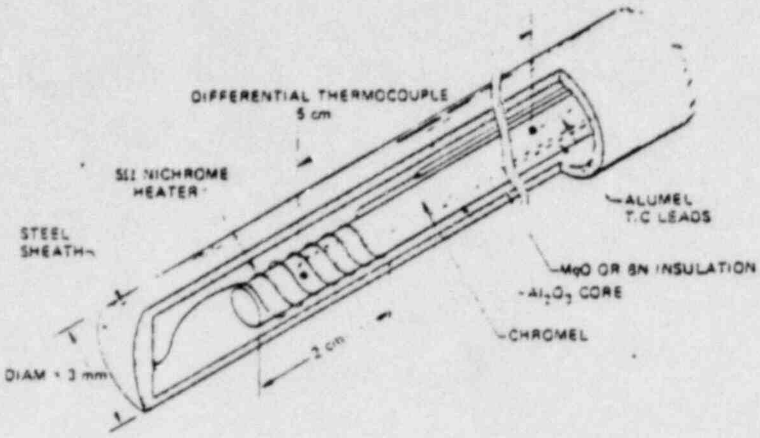

Fig. 2. ORNL HTC Liquid Level Detector.

4.3 Impedance Effect and Wave Propagation in Solid

When ultrasonic or sonic waves are traveling in the solid (such as a vessel wall or wave guide), the surrounding medium affects the solids impedance to wave motion. Since liquid has a higher density than steam, the change of acoustic impedance at the liquid-gas interface causes the wave to be reflected at different time delays. The location of the interface can then be identified. This is the principle for the use of the ultrasonic ribbon as a reflectometer. It is under evaluation of ORNL [7].

Another method based upon this principle is to determine liquid distribution from the noise pattern picked up by sensors distributed on the outside wall of the vessel for waves transmitted either from the vessel or from known transmitters [9].

The advantages of these impedance mismatch methods are:

1. The ability to obtain detailed and continuous distribution of density; and

2. The relative simplicity for retrofit (either inserting a ribbon through guide tube thimbles, or installing a transmitter/receiver at the external wall of the reactor).

The disadvantages are:

1. More complicated to interprete the measurements, especially for the noise pattern method, since it is subject to interference from extraneous and spurious sources; and

2. Need to compensate for temperature effect. (Note: This temperature compensation was taken care of in ORNL ultrasonic ribbon using torsional wave for density and tensional wave for temperature.)

4.4 Sonic and Ultrasonic Waves Through Fluids [10]

The waves emitted can be ultrasonic pressure or acoustic waves. They can be emitted either upward from the bottom or downward from the top. Waves reflected from liquid-gas interface are picked up by the sensor. From traveling time and wave velocity, the location of the interface can be determined. If there is a motion of interface, its velocity can be determined from the Doppler shift.

The advantage of the echo system is its simplicity. The disadvantages are:

1. The wave is subject to the interference of structures, and also spurious noise sources; and

2. The method requires penetration of the vessel and retrofit.

4.5 Microwave

The microwave method is essentially a radar that measures the time delay of the reflected wave. Instead of directly measuring the time with a paused system, which would require an extremely short pluse for the distance of about 3-10 meters, the proposed method is based upon the swept frequency radar technique [11]. As shown in Figure 3, the output of a swept microwave oscillator is a linear ramp function of frequency as a function of time. The frequency difference between the emitting wave and the reflected wave can be determined by comparison and the time delay can then be determined by proportionality. The signals are being processed by a fast Fourier Transform.

This microwave technique seems to be promising, but it still untried. The advantages are:

- It gives a continuous reading of liquid level and the water content in steam;

- It gives detailed, on-line, information of all pertinent phenomena along the beam.

The disadvantages are:

- Need a distinct steam/water interface that does not exist in pumped flow;

- Interference of internal structures.

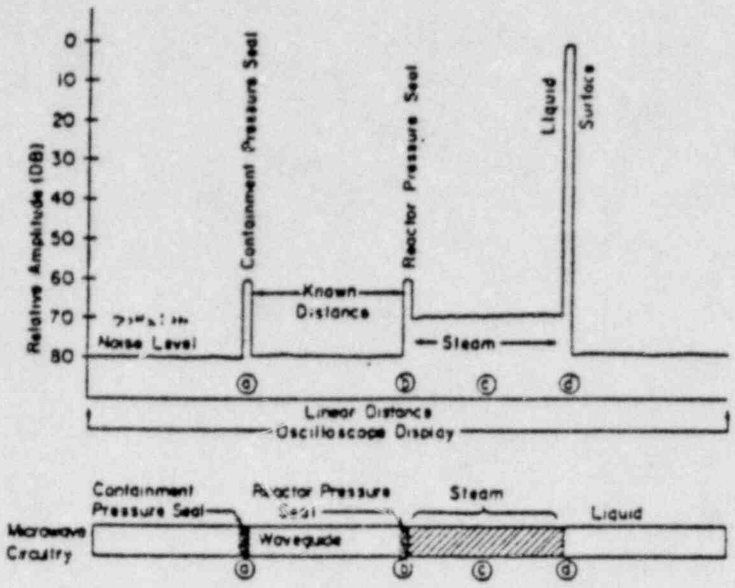

Fig. 3. DAVCO Microwave Level Measurement

4.6 Electrical Impedance Probe

The principle of this method is the large difference between impedances of water and gas. The measured quantities can be either conductance, capacitance, or the two combined as impedance. The probe can use electrode-to-electrode, or electrode-to-ground circuitry.

Many electrical probes have been developed and used in reactor safety research to measure coolant density and liquid level [12], the latter only qualitatively (in LOFT, 3D test facilities, etc.). The advantages of such devices are:

1. They employ well-understood principles,
2. They have been used in the reactor safety community, and
3. Detailed density distributions can be mapped when a sufficient number of probes is used.

The disadvantages are:

1. The insulation seal and eletrodes degradation,
2. The measurement is intrusive and retrofit is difficult and expensive,
3. The accuracy is affected by the water chemistry.

4.7 Weighing of the Vessel

In principle, this nonintrusive approach is about the simpliest method of all. The only things needed are an optical extension meter or strain gauges to determine the total weight of the vessel plus the inventory.

Disadvantages are:

1. the need to isolate the vessel from the rest of the system so that load is not also shared by connecting structures;

2. the need to compensate for temperature effect; and

3. the need to eliminate numerous sources of noise and vibrations.

4.8 Radioactive Measurements

There are many methods proposed, using neutron or gamma activities, to deduce water inventory. The major ones are:

- Gamma measurements using existing detectors in guide tubes;
- Gamma measurements using detectors outside of vessel;
- Use of existing self-powered neutron (gamma) detectors (SPND);
- Neutron thermalization moisture gauge, using additional sources in guide tubes; and
- Neutron detector outside of vessel.

The advantages of these radioactive methods are their nonintrusiveness (external devices) or the use of existing devices.

The major disadvantages are:

- Low signal-to-noise ratio;
- Effect of fission products in masking the signal;
- Effect of boron concentration on the neutron signals; and
- Reactor vessel (steel walls) presents a powerful, slow decaying gamma source.

In the following sections, each proposed method will be briefly described. Their performance record, if available, will be cited. Advantages and disadvantages, in addition to those just listed, will be discussed.

Incore gamma detectors. This method uses standard densitometry techniques to measure coolant density [13]. Existing guide tubes will be used for insertion of detectors. In many reactors, insertion of these detectors can only be done during refueling. Also, calibration represents a problem since the Gamma-activity varies with time during the fuel cycle.

External gamma detectors. This proposed method involves using movable, well collimated gamma detectors mounted outside the vessel. The idea is to scan the vessel to detect the sharp changes of activities [14]. This design involves moving machinery and it is particularly susceptible to noise background and to interference from internal structures. No performance history can be cited.

Self-Powered Neutron Detector (SPND). The basic element of SPND is the cobalt emitter in which Co^{59} is transmitted to Co^{60} upon neutron irradiation. The de-excitation of Co^{60} results in the prompt emission of several capture gamma rays: These gamma rays interact with the emitter to create Compton or photo-electrons and thus form a current. The current in the reversed direction is also formed by externally originated gamma ray. Thus, the instrument acts also as a gamma detector. A decrease of water density in the core reduces the neutron activity, especially in the lower energy range where the Co neutron absorption cross-section peaks. Thus, reducing water density causes reduction of SPND neutron current. On the other hand, low density causes reduction in absorption and attenuation of [illegible] rays increasing their flux, which helps the reversal current flow. The [illegible] result is lower current with lower water density. The relationship is shown in Figure 4, from LOFT test data (LCE L2-2, L2-3). It appears that SPND tracks liquid level well during initial quench and during reflood. However, the L2-2 and L2-3 large breaks were tests with a measurable neutron flux still present during the first few minutes after break. For a small break, the neutron flux will be negligible compared to the gamma flux and the existing SPND should be replaced by a detector more sensitive to gamma activities.

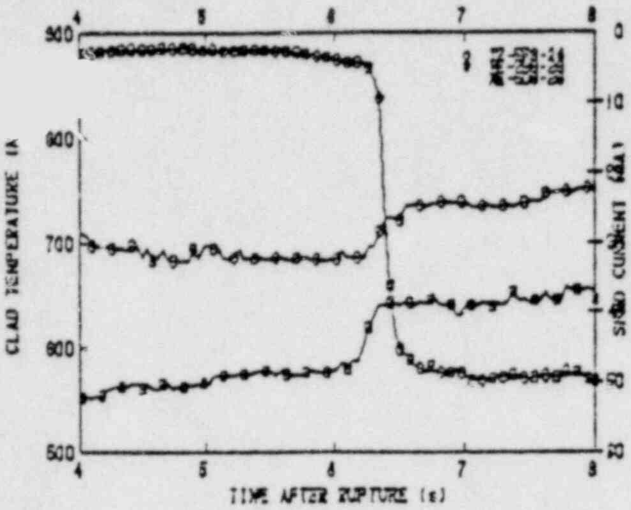

Fig. 4. LOFT SPEND Response Compared to
Clad Thermocouple Response.

<u>External neutron detectors</u>. Two methods were proposed. One method, advanced by INEL [15] would put two arrays of thermal neutron detectors outside the vessel, but inside the primary shield tank. One of the arrays would be on the inside wall of the tank and the second array a little distance into the tank, in a cation that is near the maximum thermal neutron flux. The peak intensity would change when the amount of moderator changes (i.e., when the downcomer water level changes). From the ratio of the signals from the detectors at two positions, the peak signal location and water level is determined.

This method is not proven. In addition, it monitors the level in downcomer, which may not be the same as liquid level in core.

Another method was advanced by the National Nuclear Corp (NNC) and tested under sponsorship of EPRI [16]. Neutron detectors He and BF_3 type, FM___ were deployed at the top and bottom of the vessels.[3] Tests were conducted at NCC laboratory, and then at Prairie Island, Rancho Seco, Trojan, and more recently at LOFT. The test results indicate an increasing count rate with decreasing gaseous absorption, e.g., with the lowering of the water level. However, results from power plant tests (-0.00115 cps/ft) are not as optimistic as the laboratory tests (-0.589 cps/sc.). The required counting interval of 1000 seconds is a very long period. LOFT results are not encouraging, but they are still under analysis at this reading.

A more promising method is that proposed by Penn State University [18]. The method involves deploying a string of external neutron detectors along the height of the reactor vessel. To account for the effects of changing activities, boron concentration, and water in the downcomes, at least four detectors are needed. Among these, two are reference detectors, one near the bottom level of the core, the other at a level above core. Two others are positioned along the core elevation. Variation of all signals, corrected by reference detection readings, indicates the change of liquid density along the height, thus inferring liquid level.

Neutron thermalization water level detector. This method was proposed by Science Applications, Inc. [19]. The principle is to use existing neutron thermalization moisture gauge with 1-20 μg 252 CF neutron source and 235 U-lined fission counter.

Tests with sand-water mixtures showed that the counts/seconds versus the depth will indicate the water level (Figure 5). It was proposed that a string of such detectors be inserted in guide tubes. However, no tests with steam-water under reactor conditions have been performed.

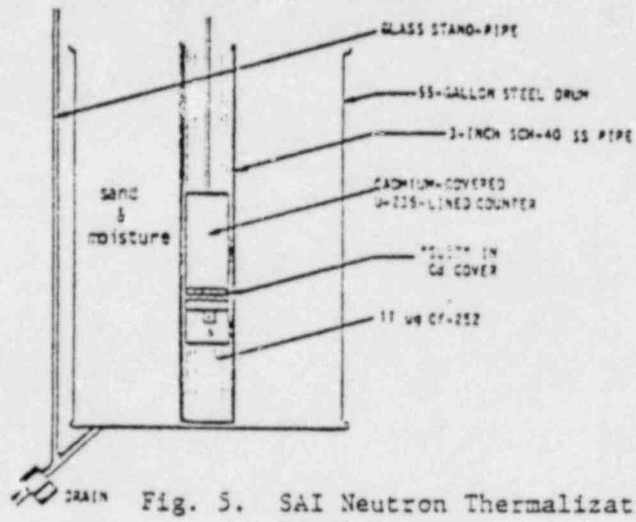

Fig. 5. SAI Neutron Thermalization Water Level Detector.

5. SUMMARY OF SURVEY AND EVALUATION

Based upon the survey described in Section 4.0 and the criteria formulated in Section 2.0. A table is constructed to summarize the merits of each measuring system. It should be noted that this table is based upon present knowledge of the state of the art, as understood by the NRC Reactor Safety Research staff in charge of advanced instrumentation. As more tests and more knowledge becomes available, the table may be subject to revision. Furthermore, this table does not necessarily reflect the opinions and criteria of the licensing staff of NRC.

TABLE 1

	DATA QUALITY	DURABILITY	RETROFIT	OPERATIONS	RELIABILITY	REMARK
Electrical Impedance LLD	Discrete points.	Seal insulation and electrodes are exposed to reactor water. Cannot last for 30 years.	Insert during next refuel period.	Okey.	Sometimes the signals are difficult to interpret.	Not recommended.
Δp Cell	Uncertainty due to dynamic head.	Failure rate of Δp cell in reactor application is high.	Use existing penetration in the bottom of the vessel.	Need to bleed during depressurization to eliminate bubbles.	Possible flashing interference.	A viable method; BWR is using it.
SPND	Okey with calibration and software.	May not last in high temperatures.		Complicated.	Neutron activities reduce after SCRAM.	Not recommended.
γ-Beam	Not clear.	N/A	External.	Needs a strong beam.	Beam has to pass through all the interior structure. May cause confusion. Need to sort out different energy level.	It is still a viable alternative. May be useful after R&D.
Sonic/Ultrasonic Propagation	Not clear.	N/A	Use existing internal structure as wave guide. Transducers are external.	Relatively easy.	Need insitu calibration.	Could be used now when calibration is available.
Ultrasonic Ribbon	Continuous temperature and density profile.	Yes.	Insert through thimbles guide tube.	Simple, but needs software.	Okey.	Needs development. Promising.

TABLE I (CONTINUED)

	DATA QUALITY	DURABILITY	RETROFIT	OPERATIONS	RELIABILITY	REMARK
Heated T.C.	Discrete points. Not clear under high flow.	Qualified material is available.	Could be installed in next refueling period.	Easy.	Reliable.	A good local measurement.
Sonic Pressure Pulse Reflection	Interference by structures.	Durable.	Need to put a pressure pulse emitter and receiver and an empty tube as wave guide.	Simple.	Reliable.	There may not be available space for wave guide.
Time Domain Reflectometery	Okey.	Electrical insulation may not last long.	Need to put in a rod.	Easy.	Interpretation may be difficult.	Not recommended.
Sonic Propagation on Vessel	Downcomer interference.	N/A	External accelerometers.	Easy.	Interpretation needs computer software and checkout on plant.	A possible backup system.
Microwave	Good.	Insulation exposed to high temperature steam.	Needs window.	Okey.	Okey.	Needs to be proven.
Weighing	Large error.	N/A	Difficult.		Calibration is different. Interference from connecting structure.	Not recommended.
Neutron Thermalization Moisture Gauge	?	Not sure.	Needs insertion.	?	?	Not proven.
Exterior Neutron Detector	Gives liquid level.	N/A	Exterior	Simple.	Needs interpretation and reference.	Top/bottom location not proving side string promising.

6. PROGRESS REPORT ON RSR-TESTED INSTRUMENTS, TEST RESULTS, AND PLANNED WORK

While conducting loss-of-coolant accidents (LOCA) related to thermal hydraulic research in the past years, the USNRC/RSR has acquired a great deal of two-phase flow instrumentation expertise and many LOCA simulation facilities. These unique capabilities have been utilized to evaluate the ICC instrumentation. The RSR research program evaluates prototypes of selected methods for feasibility assessment and conducts confirmatory tests and evaluations of vendor-proposed methods for licensing. Some of the highlights are summarized in the following sections:

6.1 Heated Thermocouples (HTC) and Heated RTD

The NRC/RSR tested several types of HTCs at Oak Ridge National Laboratory (ORNL) [20]. They are: U.S. Navy type; ORNL prototype; Combustion Engineering (CE) prototype, which is similar to the ORNL one; and a commercially available heated RTD. The tests were under simulated pump-off natural convection conditions and pump-on two-phase flow conditions.

Steady-state high-pressure high-temperature natural convection test. A pressurizer was used to test the Navy type HTC, the ORNL HTC, and the heated RTD for pressures up to 10 MPa (1500 psia). The results for each of them are shown in Figures 6. We can see that they indicated clearly whether the medium was water or steam. However, we can also see that as the pressure increased, the properties of water and steam were similar. The temperature different of the HTC becomes smaller. This can be improved by increasing the heater power. Another important observation was the effect of drops in the steam. As the drops wetted the probe, the signal fluctuated. This problem was overcome by protecting the sensors with droplet shields.

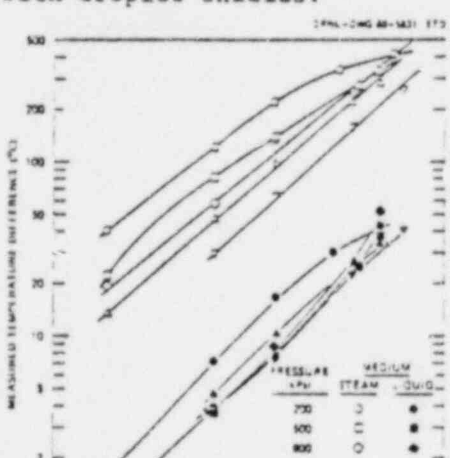

Fig. 6. ORNL HTC Natural Convection Test Results.

Forced convection steam-water flow test. A steam/water instrument test loop used to investigate the ability of an HTC to detect velocity and quality change. In the loop, the steam and water were separately metered, and the flow was measured independently by dosimeter and turbine flow meter. The result shows that the HTC is sensitive to both velocity and quality change.

Small-break LOCA steady-state film boiling experiment at thermal hydraulic test facility (THTF). THTF is a high pressure, single-loop separate-effects LOCA test facility for heat transfer studies. It has an 8x8 full-length electrically heated rod bundle. It was well instrumented for void fraction, velocity, and fuel temperature measurements, as shown in Figure 7. The HTC provided by CE was tested in a small-break LOCA film boiling experiment. The result shows that the HTC indicated poor cooling for velocities up to 3 meter/sec [21].

System effects test under accidents. Several HTCs will be installed at the Semiscale facility at Idaho National Engineering Laboratory in mid-1981. Different small-break LOCA tests will be run, and the results will be reported later.

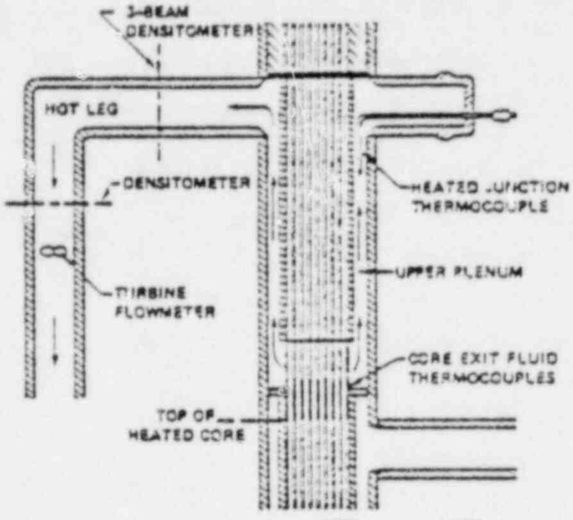

Fig. 7. HTC Test at ORNL THTF Facility.

6.2 Pressure Difference (Dp) System

The system as shown in Figure 1 was proposed by Westinghouse. It has just been installed and calibrated at the Semiscale facility. Tests will begin in March 1981.

6.3 Ultrasonic (vibrating) Ribbon Probe

The ultrasonic probe built by ORNL was tested in the pressurizer. The most recent breakthrough was the temperature effect compensation for the waveguide.

7. CONCLUSION

In this paper, we have considered methods proposed for reactor vessel water level measurement. We established a set of criteria based on power plant operation considerations as well as data qualities. The proposed methods are evaluated against these criteria. From the evaluation, we can see that the complexity of power plants and other considerations rule out many otherwise attractive methods.

Meanwhile, the NRC/RSR utilized its LOCA experiment facilities and two-phase flow instrumentation expertise to evaluate a few prototypes. These tests under simulated PWR transient conditions are necessary because many techniques may appear attractive in steady state or in bench tests but may not perform well under realistic reactor conditions. The test results reported here and elsewhere will provide a basis for NRC licensing decisions. These results are also useful to the nuclear community in considering full scale application. We want to remind the readers that the opinions expressed in this paper are our own and should not be taken as the NRC's final position.

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PRESENTATION OUTLINE

- Objectives and background
- Overview of devices and test programs
- Highlights of thc tests
- Summary

STATUS OF NRC/RES RESEARCH ON

REACTOR VESSEL WATER LEVEL MEASUREMENT

PRESENTED TO THE ACRS

MAY 28, 1981

BY

ANDREW L. M. HON

EXPERIMENTAL PROGRAMS BRANCH

DIVISION OF ACCIDENT EVALUATION

OFFICE OF NUCLEAR REGULATORY RESEARCH

Background

. TMI Lessons Learned; Redirected RES two-phase instrumentation program

. Capabilities

. . LOCA RES instrumentation development experience

. . Unique LOCA test facilities

. . Two-phase flow thermal hydraulic expertise

Relationship With Other Activities

. TMI Action Plan; Work with NRR to evaluate vendor proposed techniques

. "Piggyback" LOCA experiments

OBJECTIVES AND SCOPE OF STUDY

- ID suitable techniques for unambiguous detection of ICC
- Proof of principle testing of promising techniques and limited refinements
- Technology transfer
- Confirmatory testing of vendor proposed techniques in LOCA
- ID potential problem and improvement needs

WE DO NOT CONSIDER

- Equipment qualifications
- Human factor

TESTS PERFORMED AT ORNL

. NATURAL CONVECTION - PRESSURIZER 14-1500 PSIA

HTC - ORNL, NAVY

HRTD

ULTRASONIC

. TWO-PHASE FLOW FORCED CONVECTION - STEAM/WATER INSTRUMENT DEVELOPMENT LOOP

HTC - ORNL

. LOCA TRANSIENT SIMULATION - THTF FILM BOILING TESTS

HTC - CE

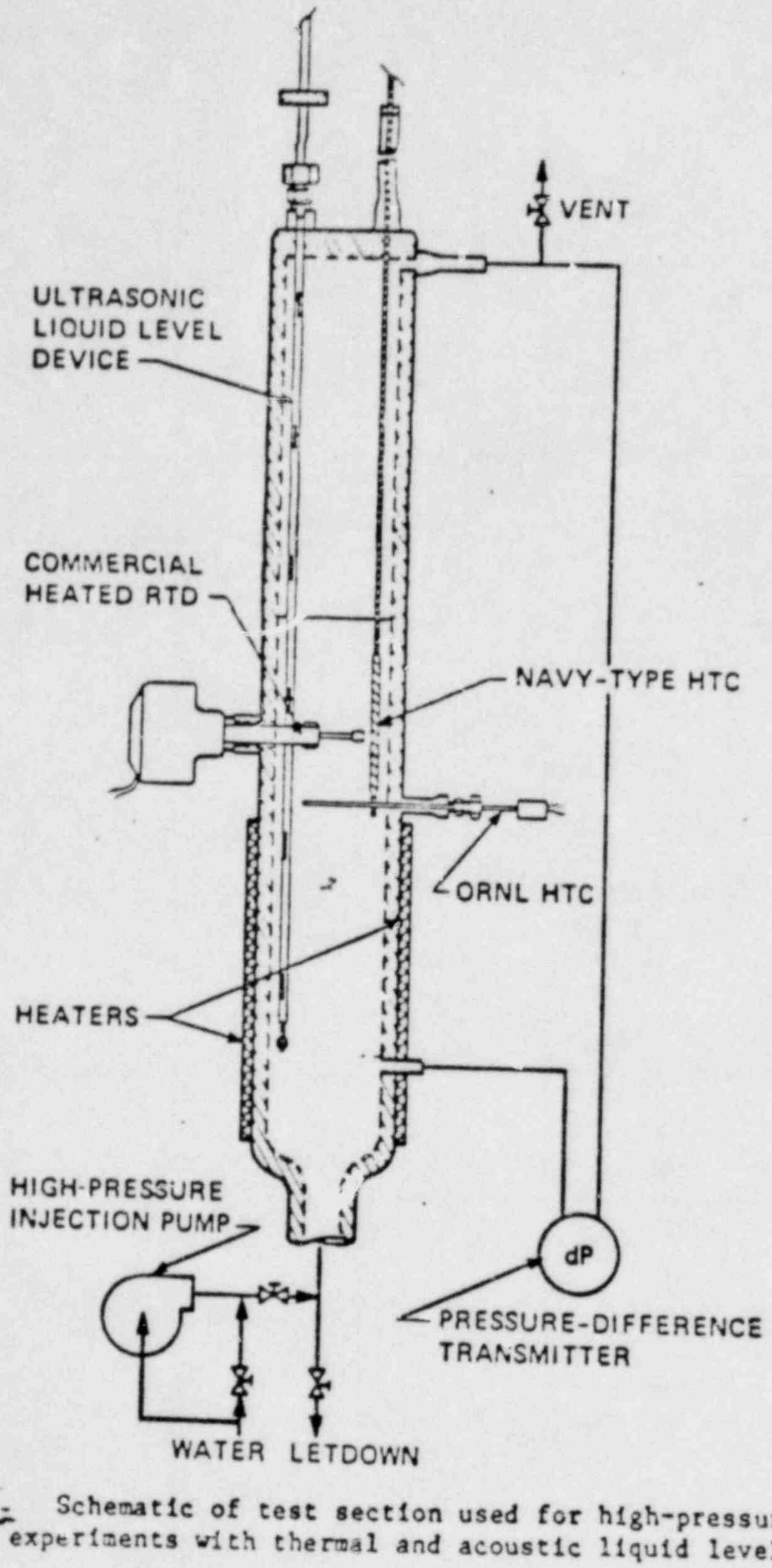
- ORNL-ELECTRICAL PROBLEM DURING TEST

ACCIDENT EVALUATION TEST PROGRAM FOR ICC INSTRUMENTATION OVERVIEW

(LIQUID LEVEL DETECTORS)

	Test Facility \ Device	ORNL HTC	NAVY HTC	ORNL ULTRASONIC	INEL HTC	FCI HRTD	CE HTC	EPRI NEUTRON MONITOR	W ΔP
ORNL	PRESSURIZER	Good*	Good*	Good*		Good*			
ORNL	STEAM-WATER	Good*							
ORNL	THTF	Shorted During Test					Good* for V < 10 ft/sec		
INEL	SEMISCALE	After 05/81					?		After 03/81
INEL	LOFT							Failed to indicate	
INEL	AUTOCLAVE				Good*				

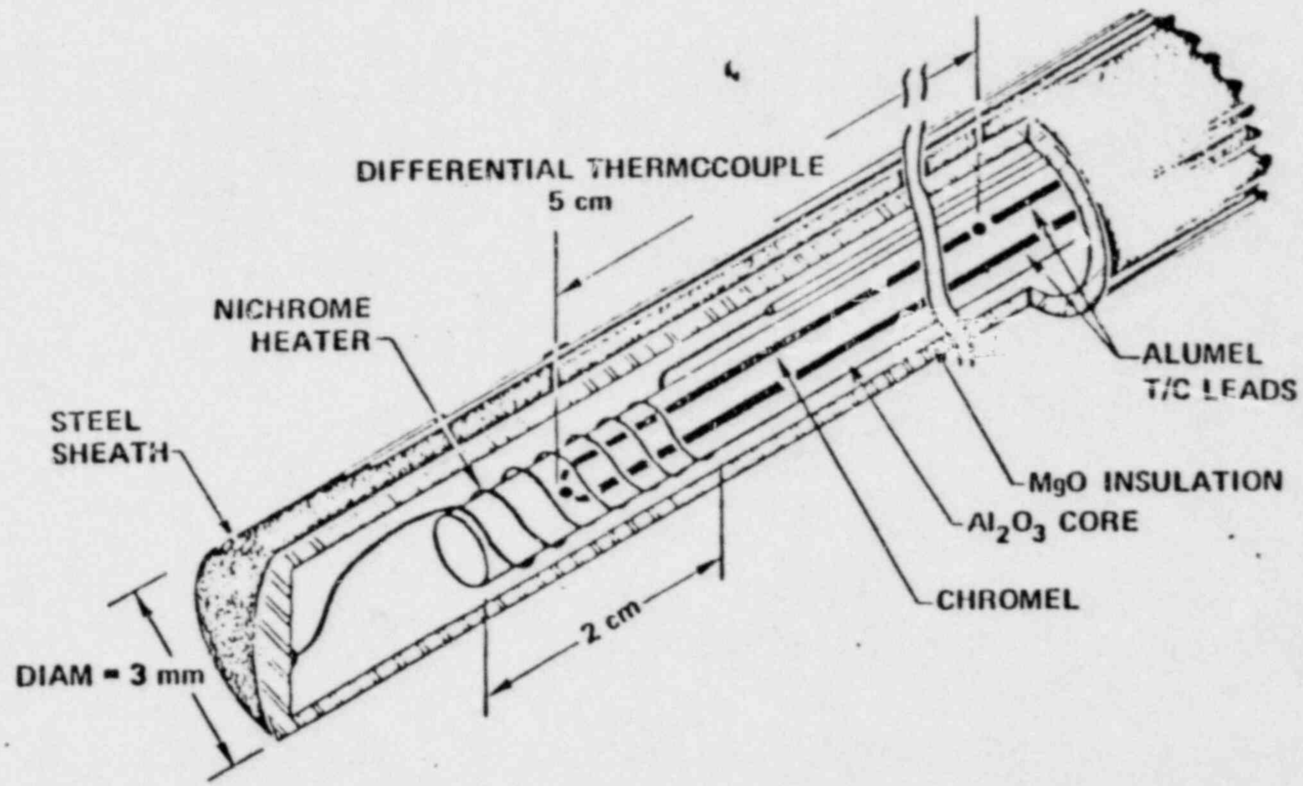
*With droplet shield



Schematic of test section used for high-pressure natural convection experiments with thermal and acoustic liquid level sensors.

UNION CARBIDE ORNL

HEATED TC COOLANT SENSORS ARE SMALL AND USE REACTOR-COMPATIBLE COMPONENTS



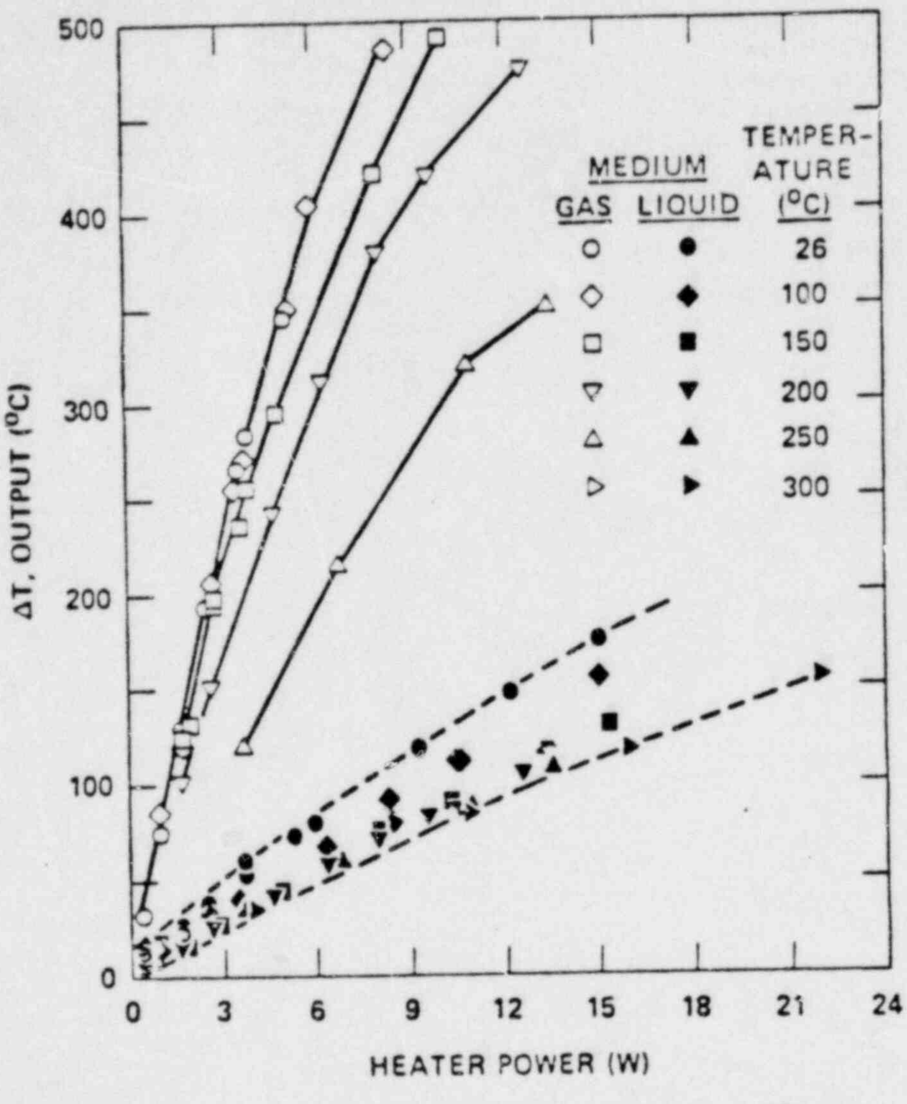


Fig. 3. Steady-state ΔTs recorded from Navy-type HTC sensor in natural convection to steam and water. Data are plotted vs power produced in probe heater with system temperature and medium surrounding probe as parameters.

ORNL-DWG 80-5831 ETD

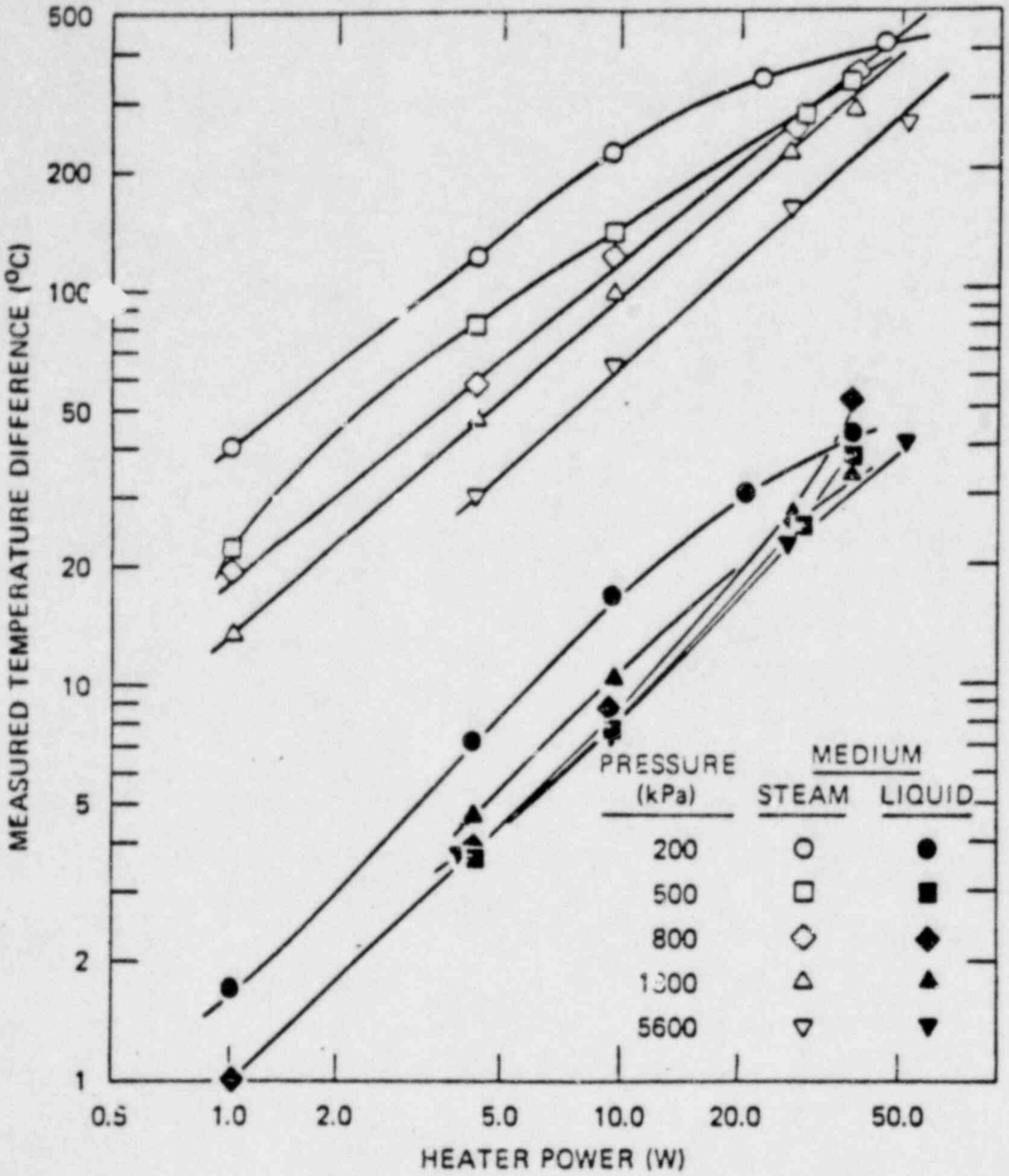
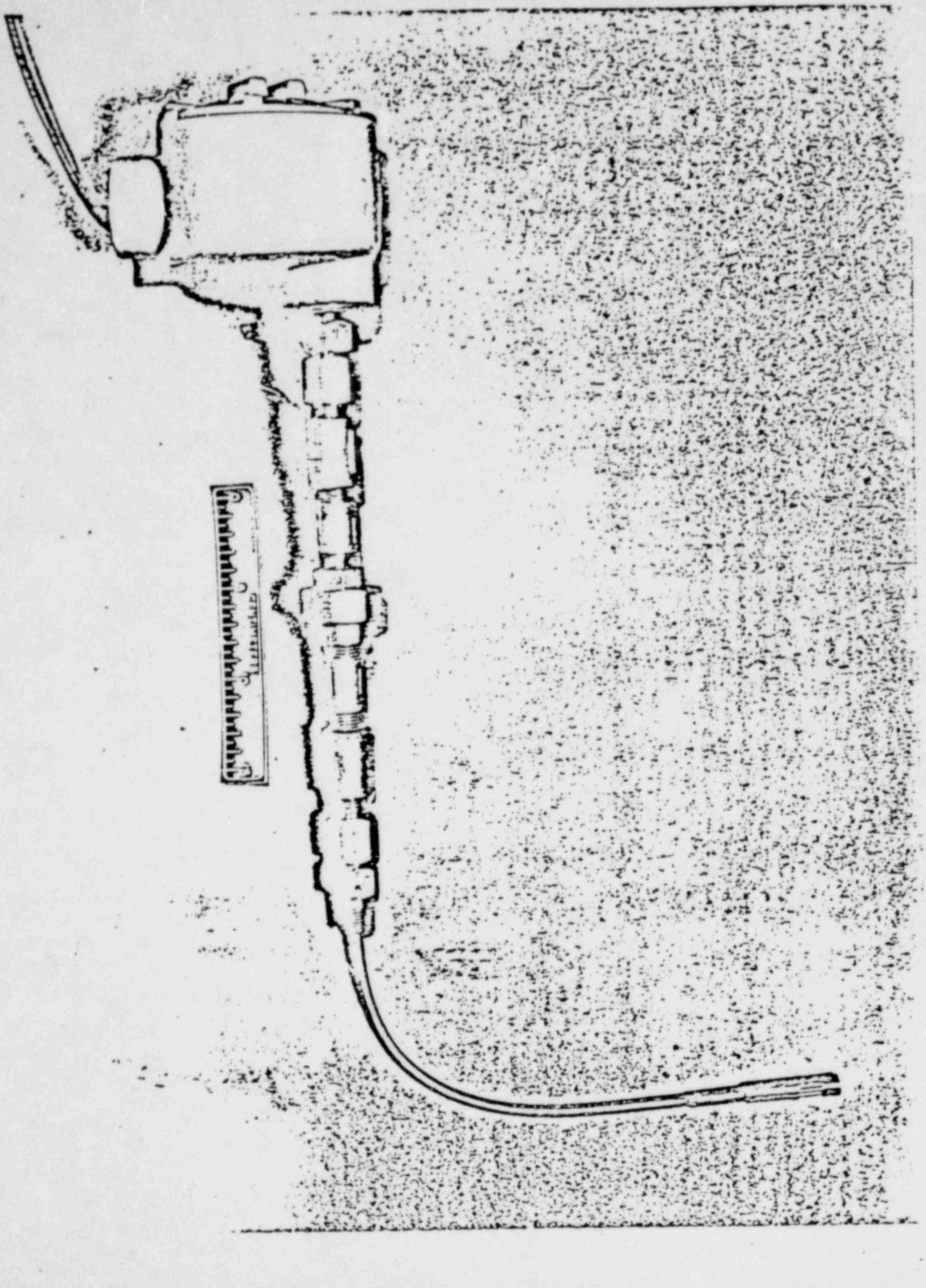


Fig. 2. Steady-state temperature differences recorded from HTC probe ORNL I in natural convection to saturated steam and water. Data are plotted vs power produced in probe heater with system pressure and medium surrounding probe as parameters.



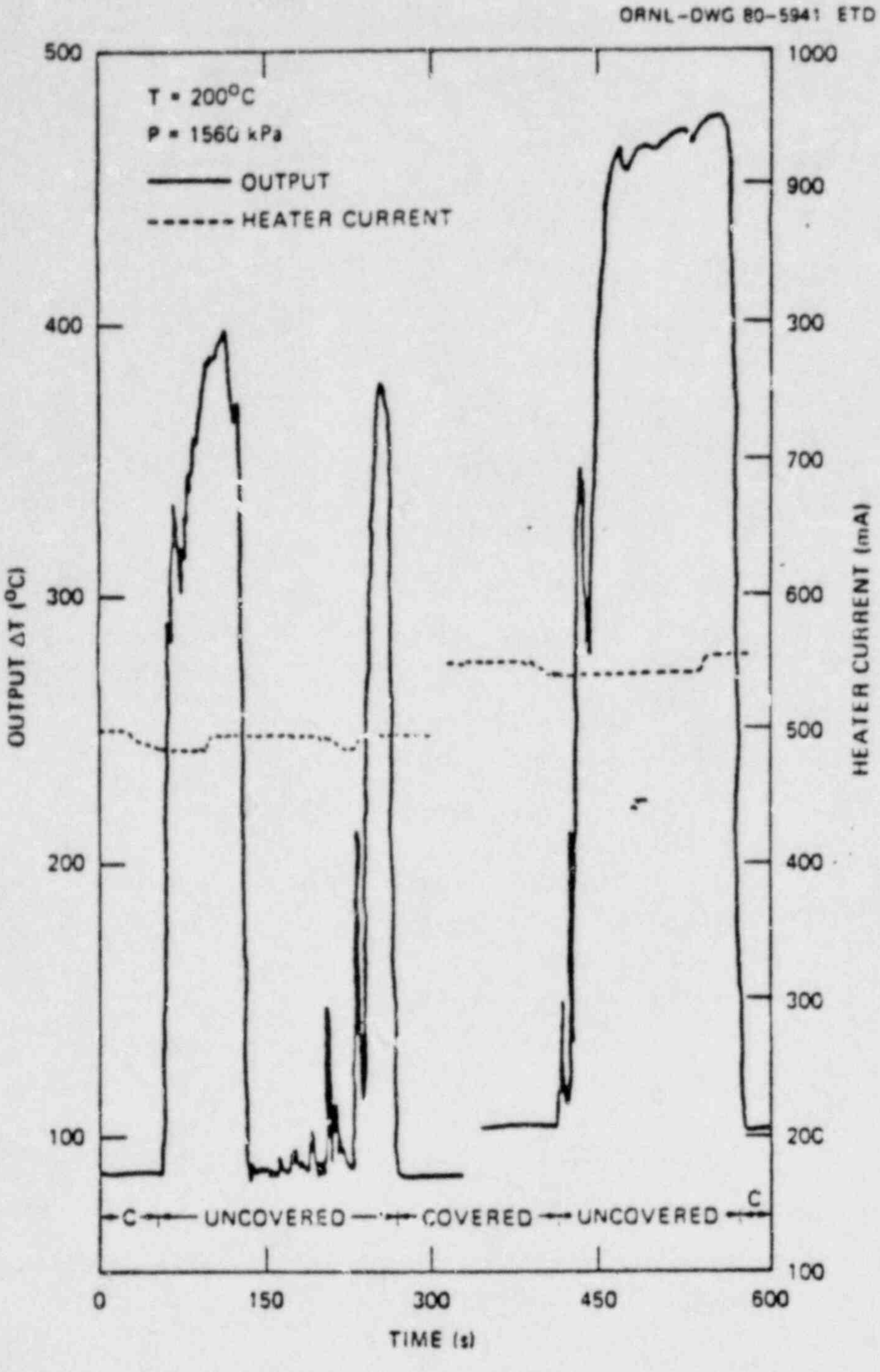


Fig. 4. Navy-type HTC output recorded vs time during natural convection tests at 200°C. Heater current ranged from ~500 to ~550 mA. During period denoted as covered, active part of probe was immersed in saturated liquid. During uncovered period, probe was immersed in saturated steam.

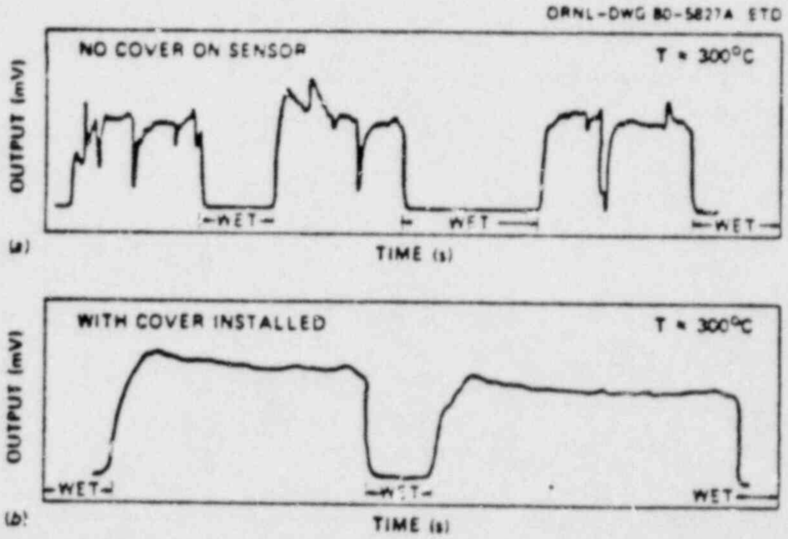


Fig. 7. Time-dependent output obtained from heated RTD device during natural convection experiments performed at ~300°C (pressure =8.6 MPa). (a) Data obtained with bare sensor head shown in Fig. 5, (b) data obtained while sensor head covered as described in text.

ORNL-PHOTO 6473-80A

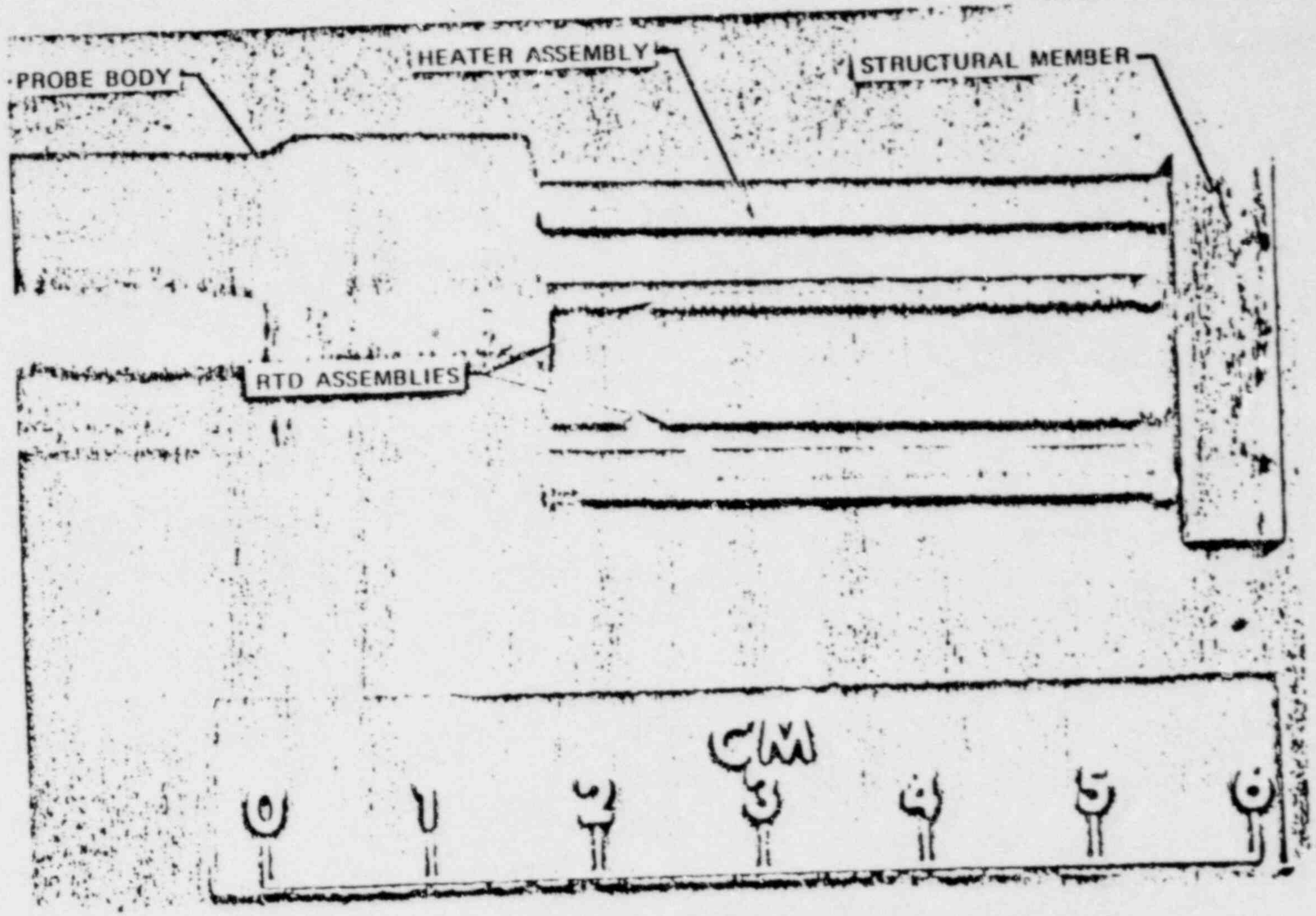


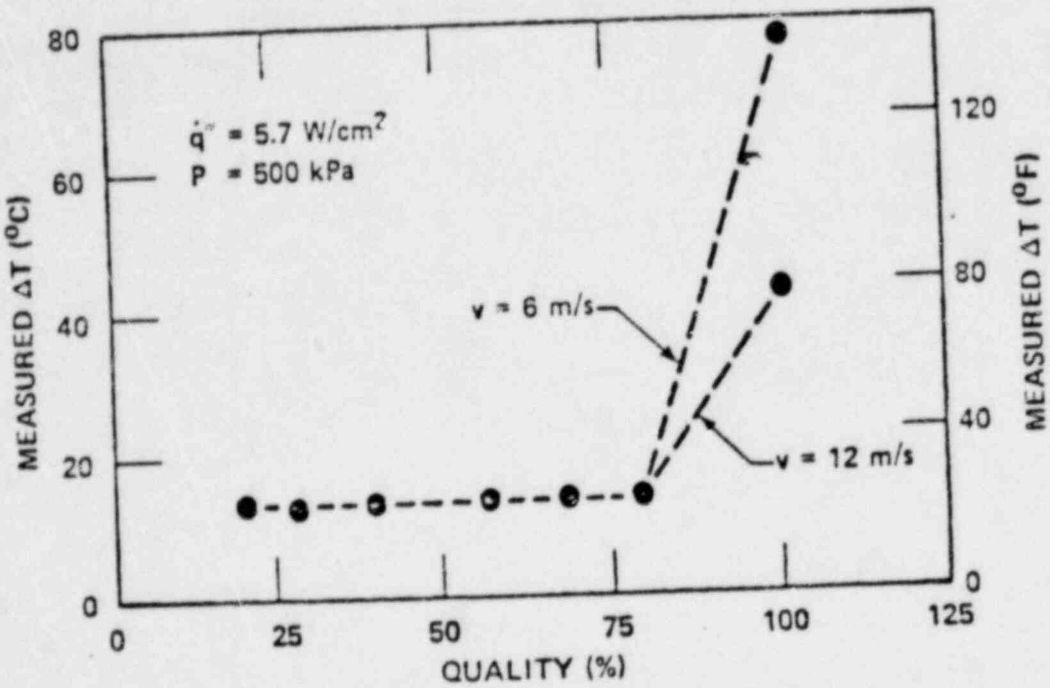
Fig. 5. Sensor head of commercial heated RTD device tested in high-pressure natural convection. Device was installed for testing as in plan view shown.

ORNL-DWG 80-5291 ETD

ORNL HTC

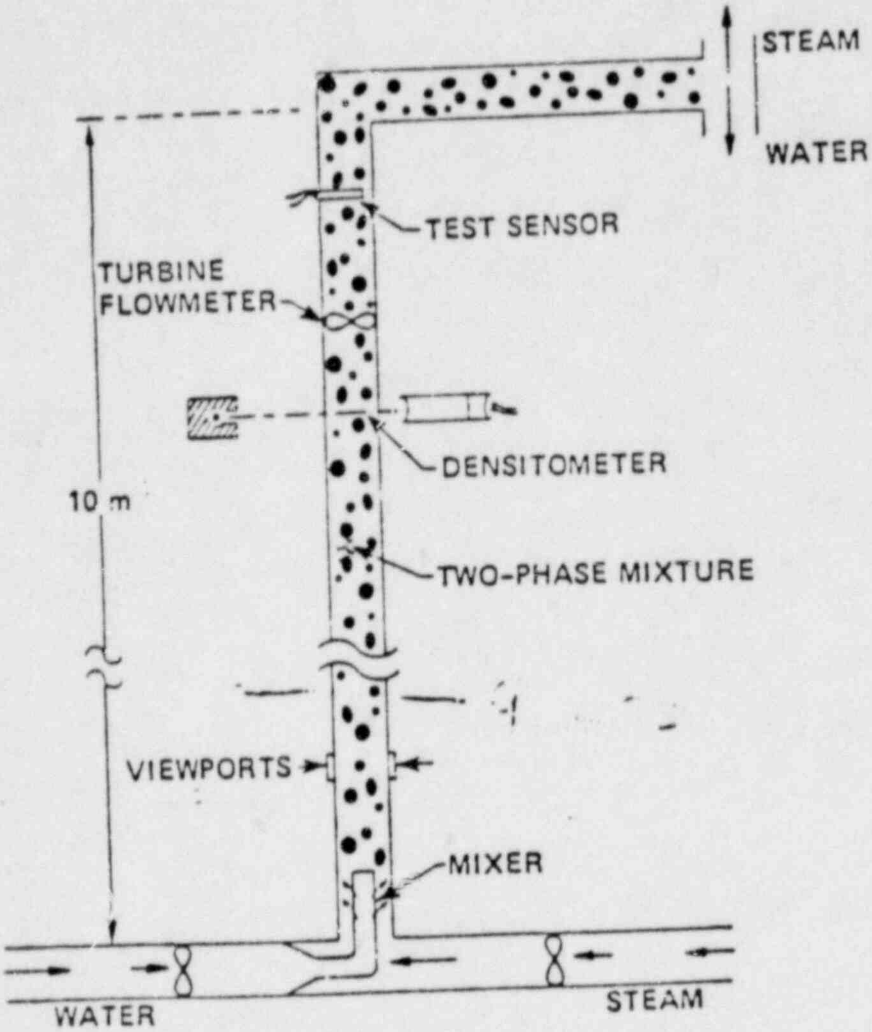
UNION CARBIDE ORNL

IN FORCED CONVECTION TESTS, MEASURED ΔTs INDICATED THAT COOLING CAPACITY WAS GOOD



UNION CARBIDE ORNL

ANOTHER TEST FACILITY IS USED FOR HTC TESTS WITH FORCED CONVECTION STEAM-WATER FLOW AT MODERATE PRESSURES



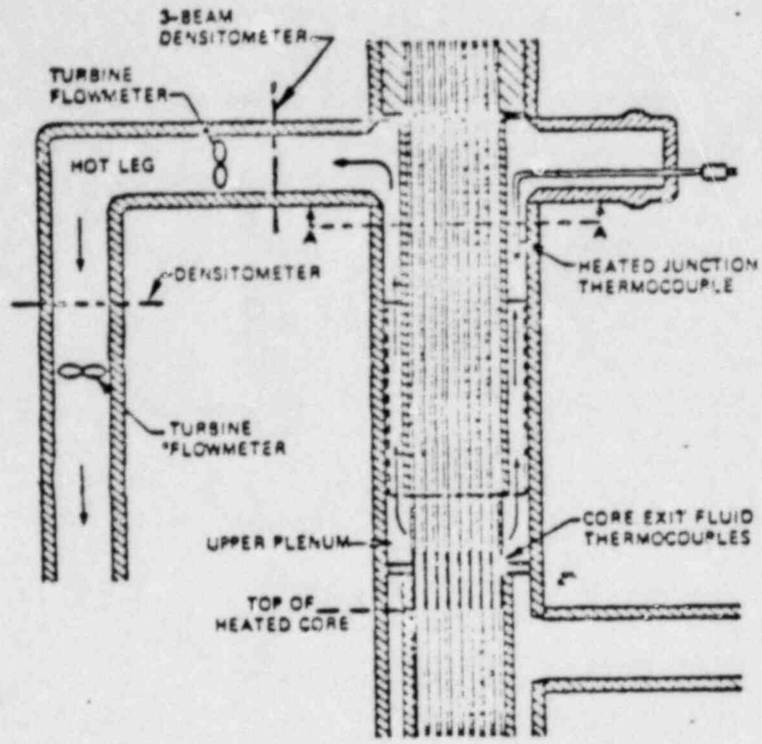


Fig. 3a. Schematic of upper part of THTF test section and outlet piping showing locations of HTC and other instrumentation.

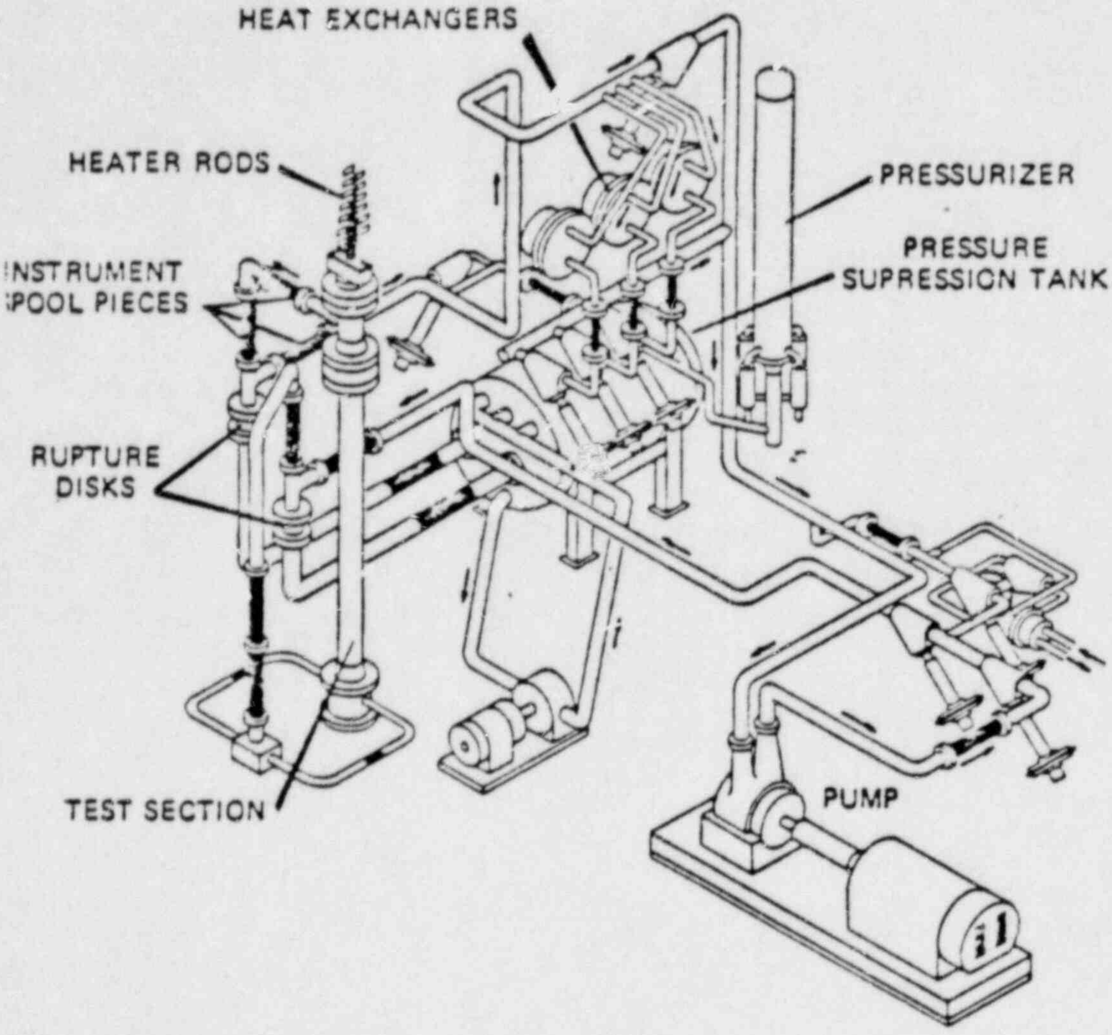


Fig. 1. Isometric drawing of Thermal Hydraulic Test Facility.

A SINGLE CE HTC SENSOR WAS EVALUATED DURING THTF STEADY STATE FILM BOILING EXPERIMENTS

- FLOW RATES AND CORE POWERS SIMULATED SMALL BREAK LOCA
- SINGLE HTCs LOCATED IN UPPER PLENUM, NEAR TEST SECTION OUTLET
- OUTPUT ΔT MONITORED BEFORE, DURING, AND AFTER PERIODS OF FILM BOILING IN ROD BUNDLE
- RESPONSE OF TEST SENSOR RELATED TO FRS TEMPERATURES AND FLUID CONDITIONS AT TEST SECTION OUTLET

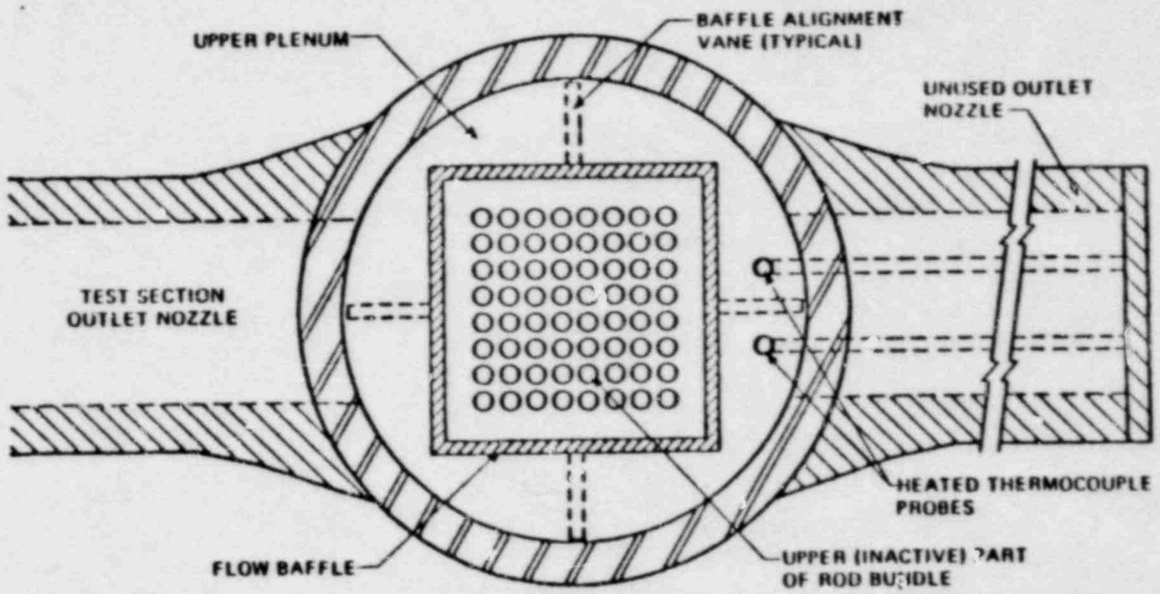
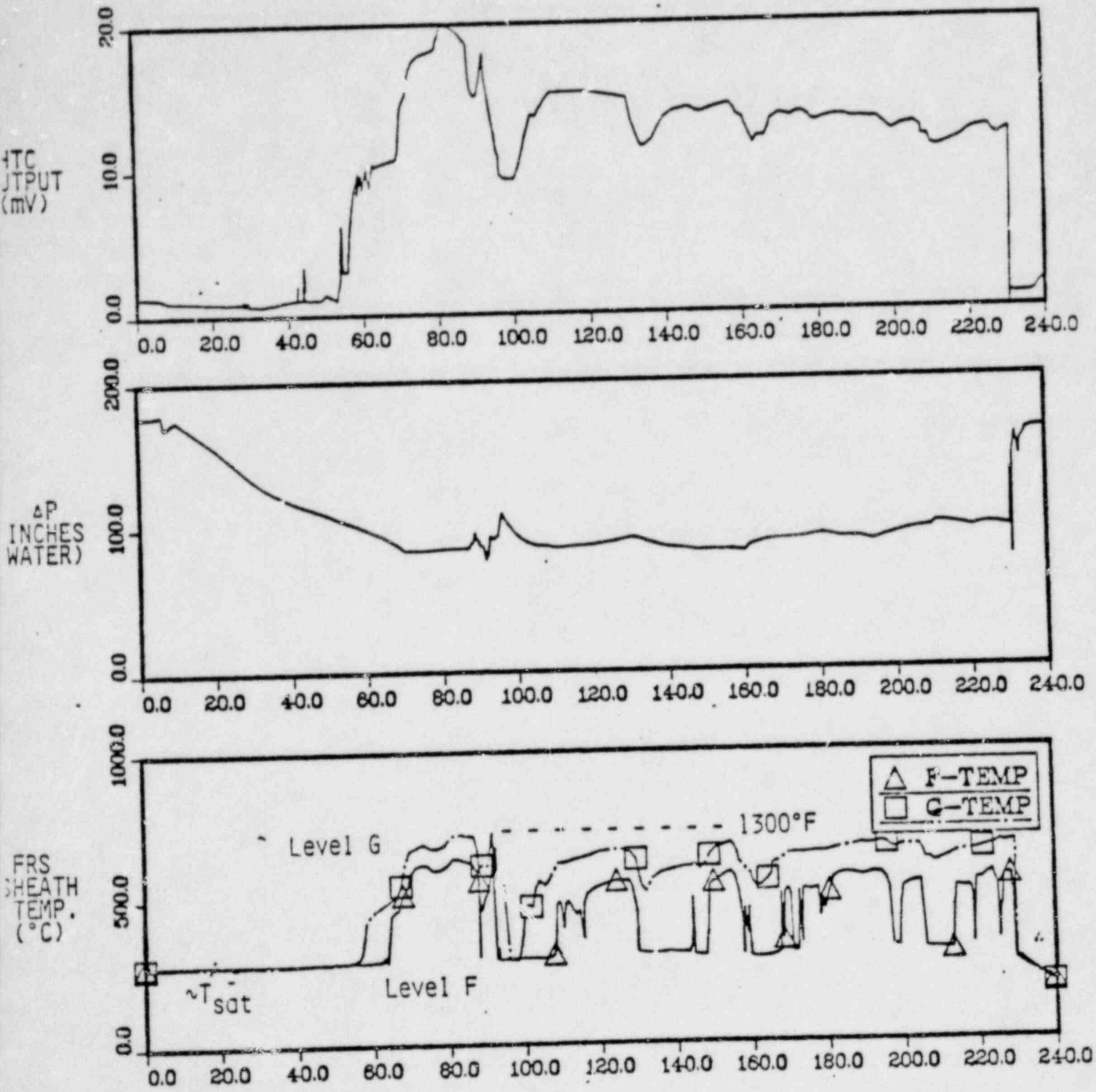


Fig. 3b. Cross-sectional view of THTF at plane A-A.

HEATED THERMOCOUPLE, PRESSURE DIFFERENCE, AND FRS SHEATH TC RESPONSE TO REPEATED BOILOFF AND REFLOOD IN THTF



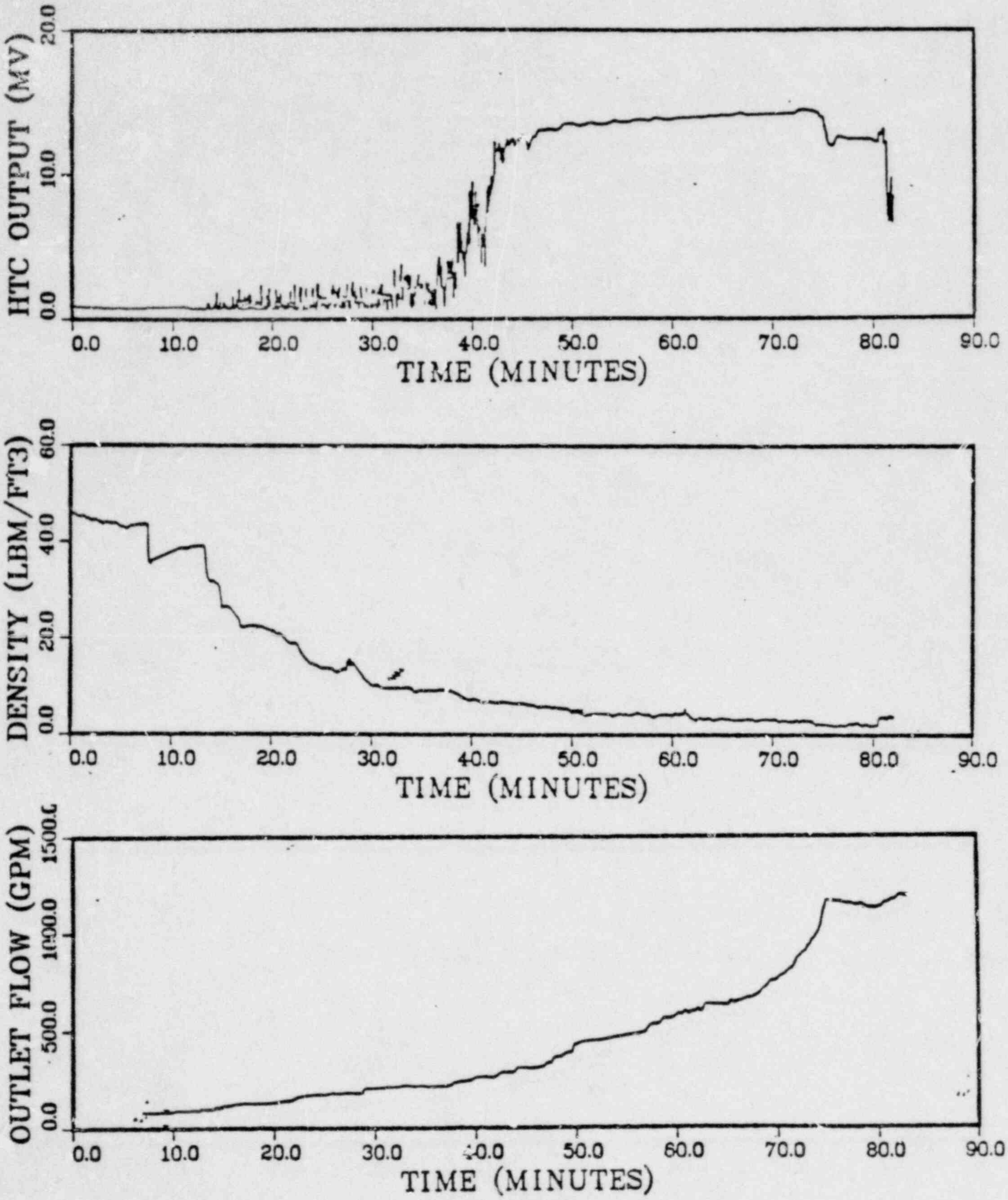
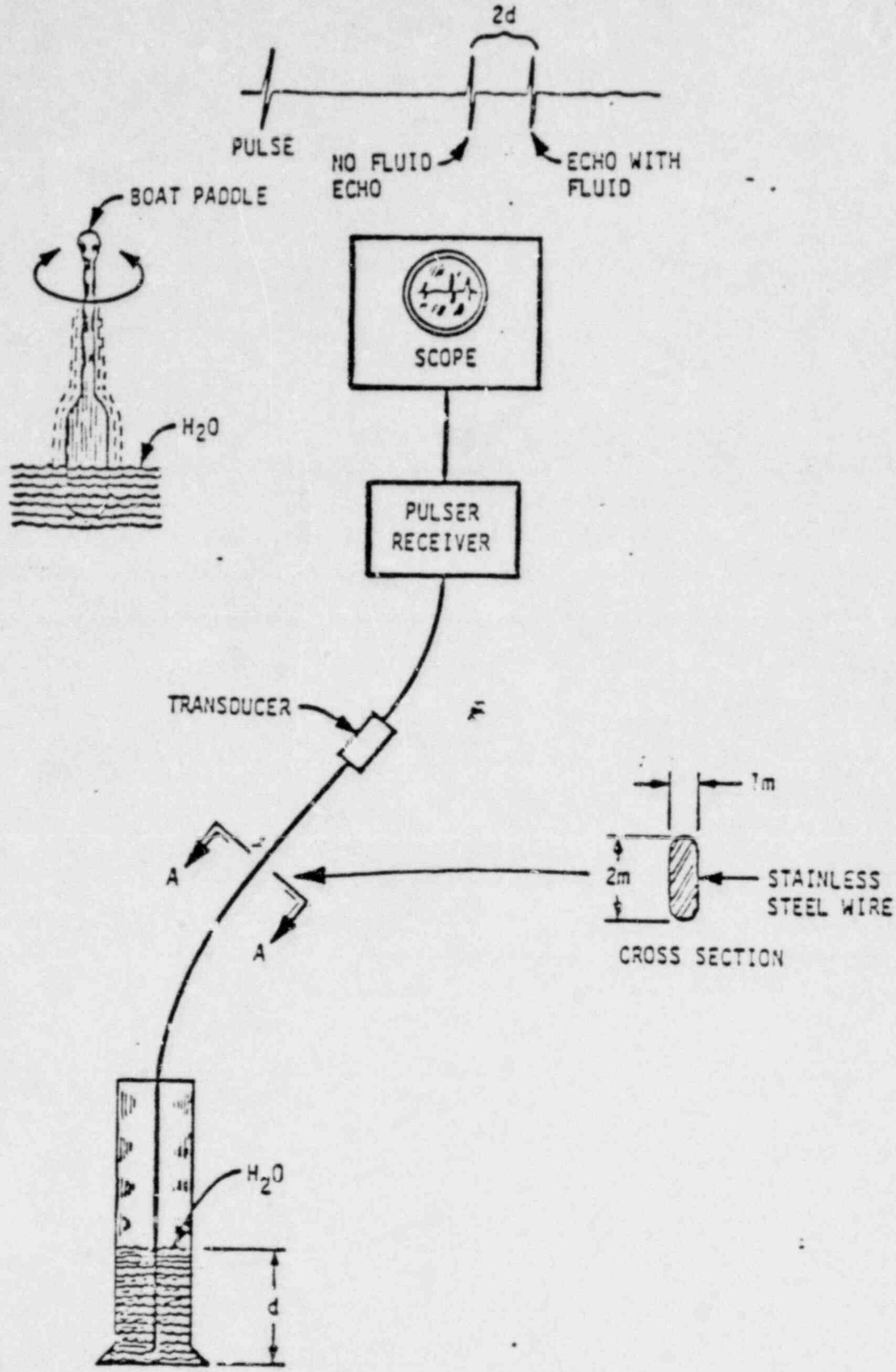


Fig. 6. Heated thermocouple output, measured density, and measured volumetric flow at test section outlet beginning at 19:14 on 9/11. Level F was in film boiling from about 70 min to 80 min.

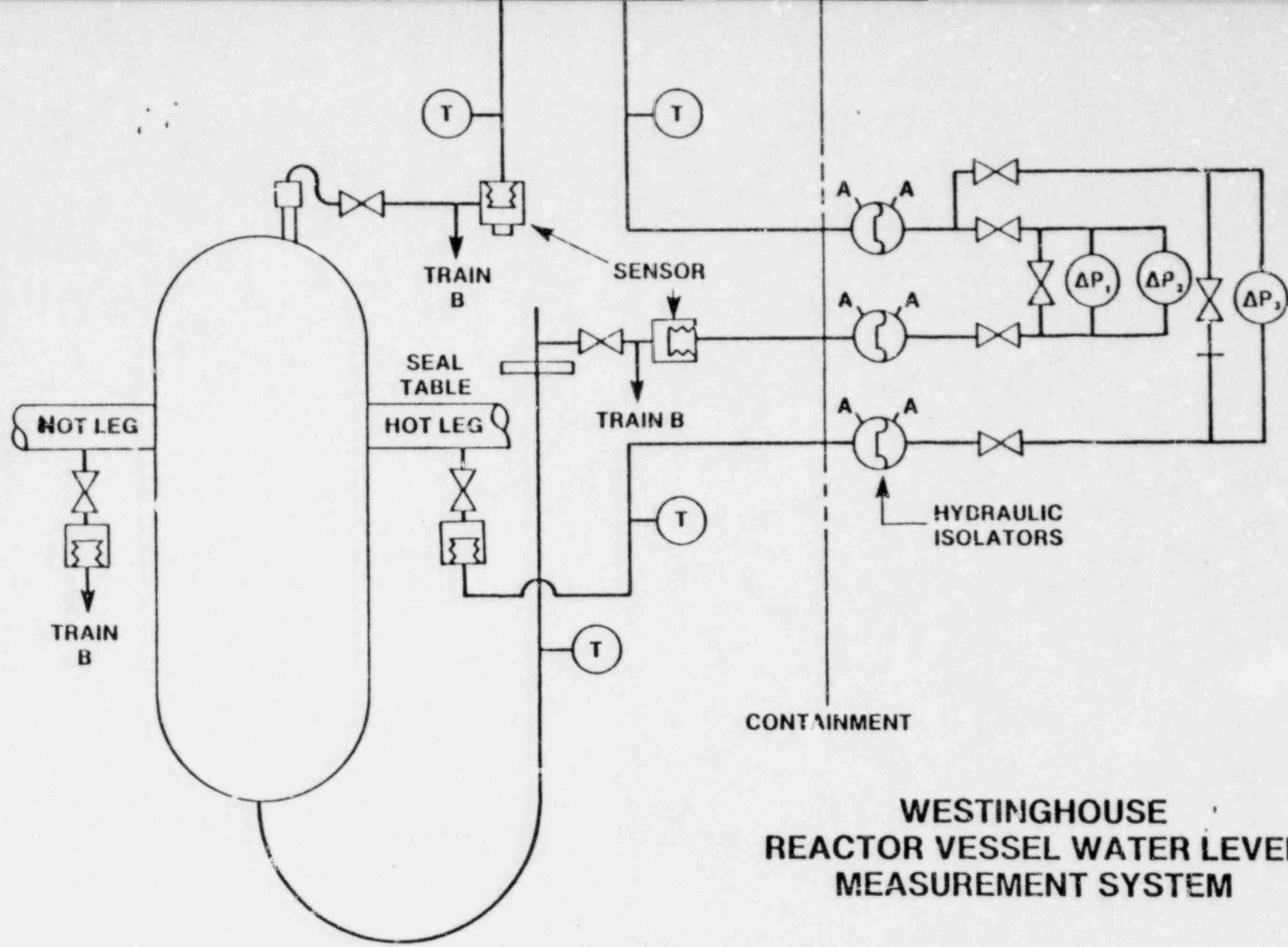
water at low flow rate



TORSIONAL PULSE ON FLATTENED WIRE IS DELAYED BY DENSE MEDIUM MUCH LIKE A BOAT PADDLE IN WATER.

TEST RESULTS FROM THTF FILM BOILING EXPERIMENTS WITH HJTC PROBE

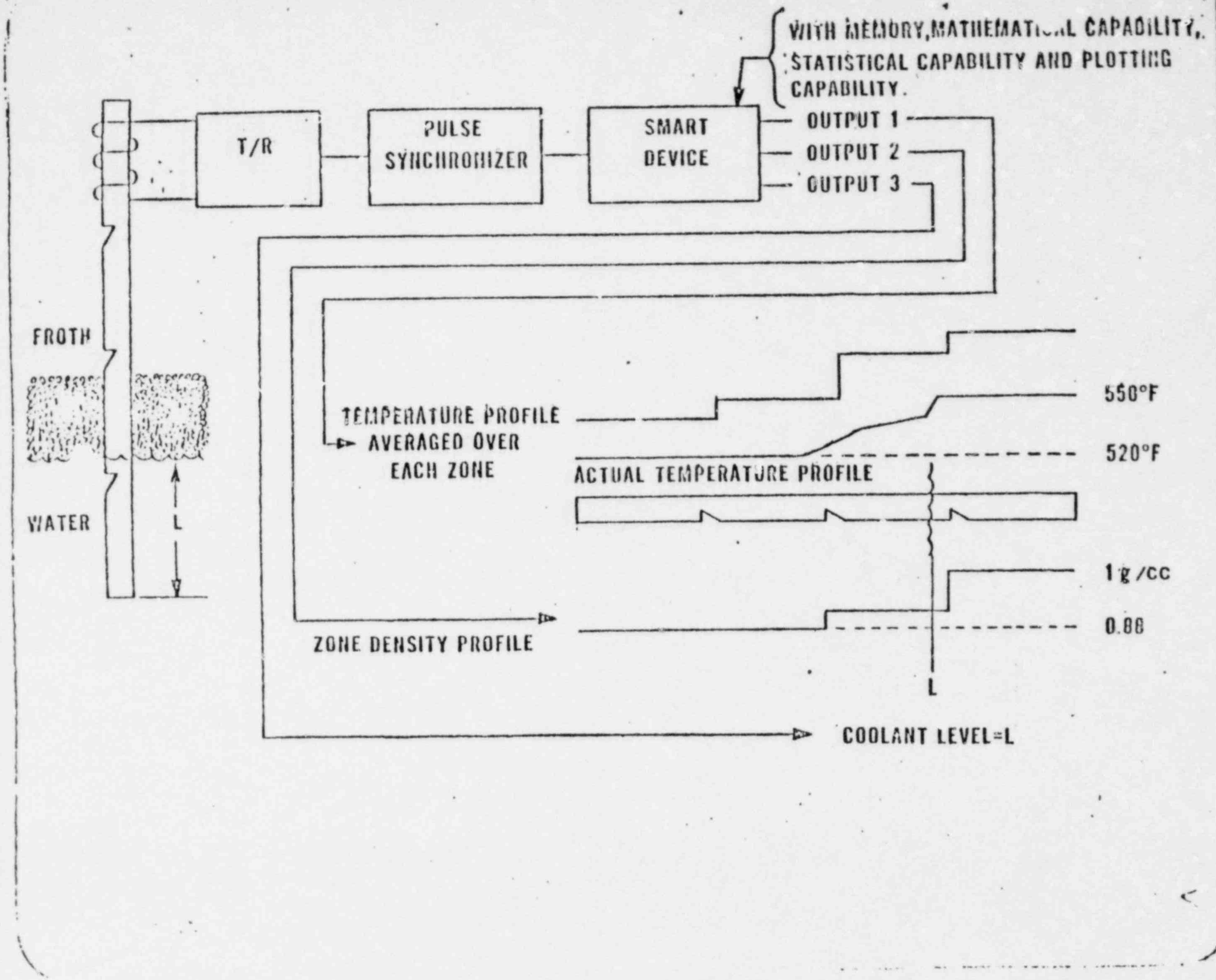
- SENSOR OPERABLE AFTER >40 h AT LOCA CONDITIONS
- INDICATED POOR COOLING PRIOR TO AND DURING ROD BUNDLE CHF AT 600, 900, 1200 AND 1800 psi WITH OUTLET VELOCITIES UP TO ~10 fps



**WESTINGHOUSE
REACTOR VESSEL WATER LEVEL
MEASUREMENT SYSTEM**

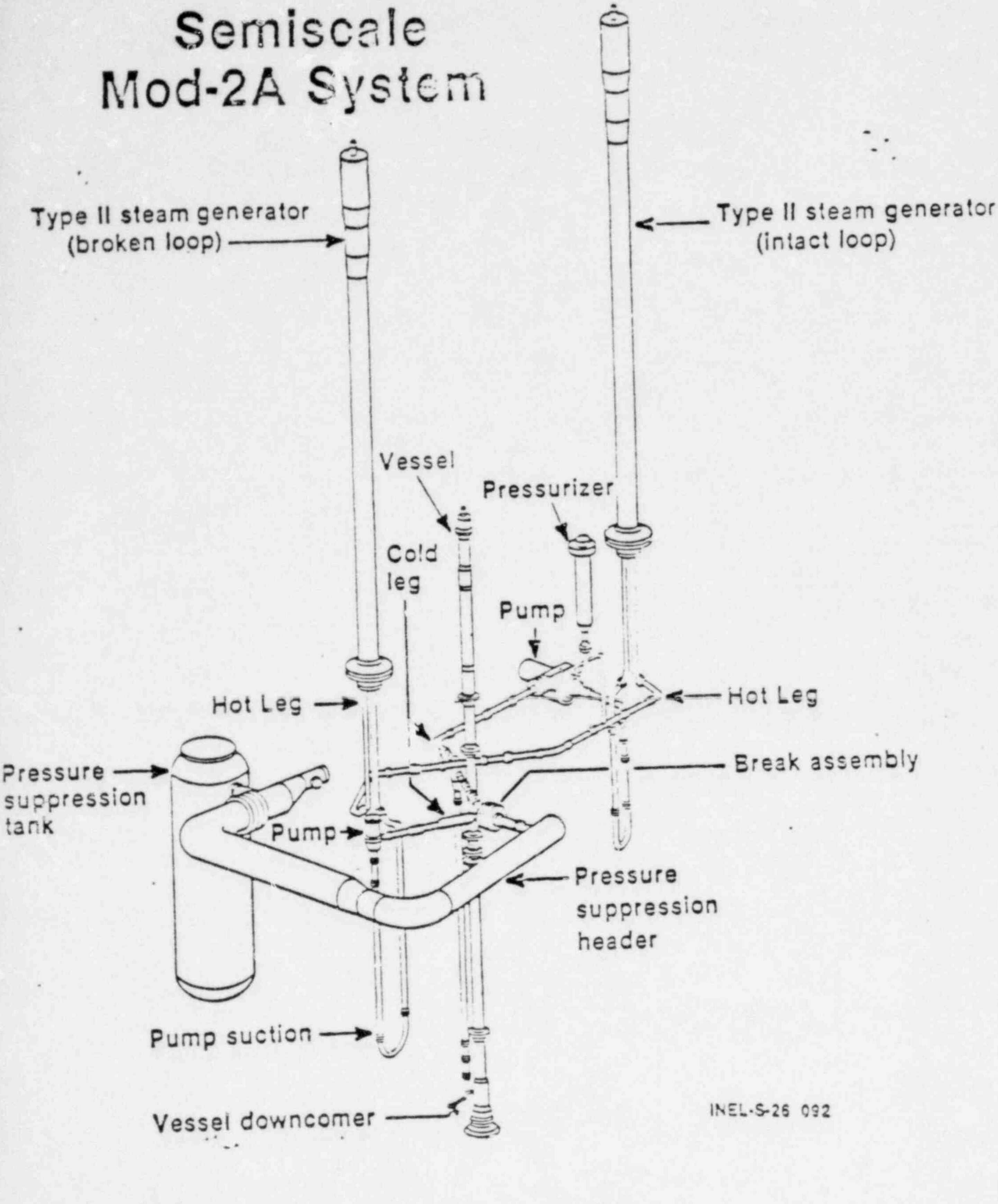
at

... probe and fitting, and (c) probe internals.

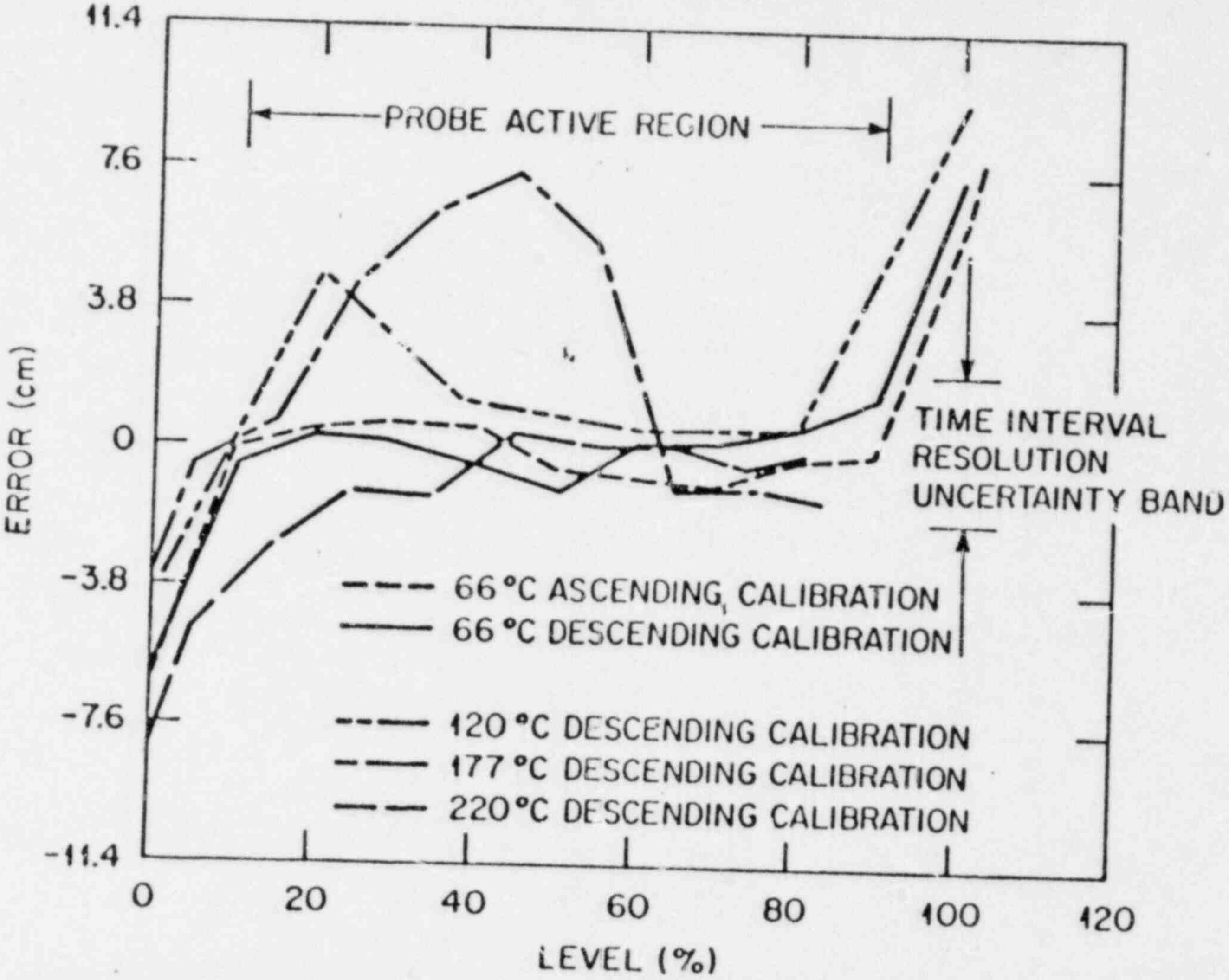


WITH MEMORY, MATHEMATICAL CAPABILITY, STATISTICAL CAPABILITY AND PLOTTING CAPABILITY.
T/R
PULSE SYNCHRONIZER
SMART DEVICE
OUTPUT 1
OUTPUT 2
OUTPUT 3
FROTH
WATER
L
TEMPERATURE PROFILE AVERAGED OVER EACH ZONE
550°F
520°F
ACTUAL TEMPERATURE PROFILE
1 g /cc
0.88
ZONE DENSITY PROFILE
L
COOLANT LEVEL=L

Semiscale Mod-2A System



PROBE WELL BEHAVED IN ACTIVE REGION



SUMMARY

. RES/EXP. PROG. BR. IS EVAL. ICC INSTR. SINCE TMI

. PROOF OF PRINCIPLE TEST SHOWED HTC AND ULTRASONIC PROMISING

. EXCELLENT COOPERATION AMONG RES, VENDORS, NAT'L LABS

. PERFORMANCE TESTING

  . . @ ORNL - THERMAL DEVICES FROM NAVY, ORNL CE, FCI

  . . @ INEL - W DP (SEMISCALE) NEUTRON DET. (LOFT)

. PROGRAM COMPLETION PLANNED FOR DEC. 31, 1981

TESTING W DP AT SEMISCALE

ARRANGEMENT

- W PROVIDES AND CHECKS OUT ALL DP HARDWARE
- INEL CONDUCTS REGULARLY SCHEDULED BLOWDOWN TESTS AND RECORDS DATA, DRAFT DATA REPORT
- ORNL ANALYZES THE TEST DATA INDEPT. TO EVALUATE THE PERFORMACE
- RES/EXP. PROG. BR. PROVIDES OVERALL COORD. AND MANAGEMENT

MIDYEAR REVIEW OF

DEVELOPMENT OF LIQUID LEVEL DETECTORS FOR NUCLEAR REACTOR VESSELS

PRESENTED BY

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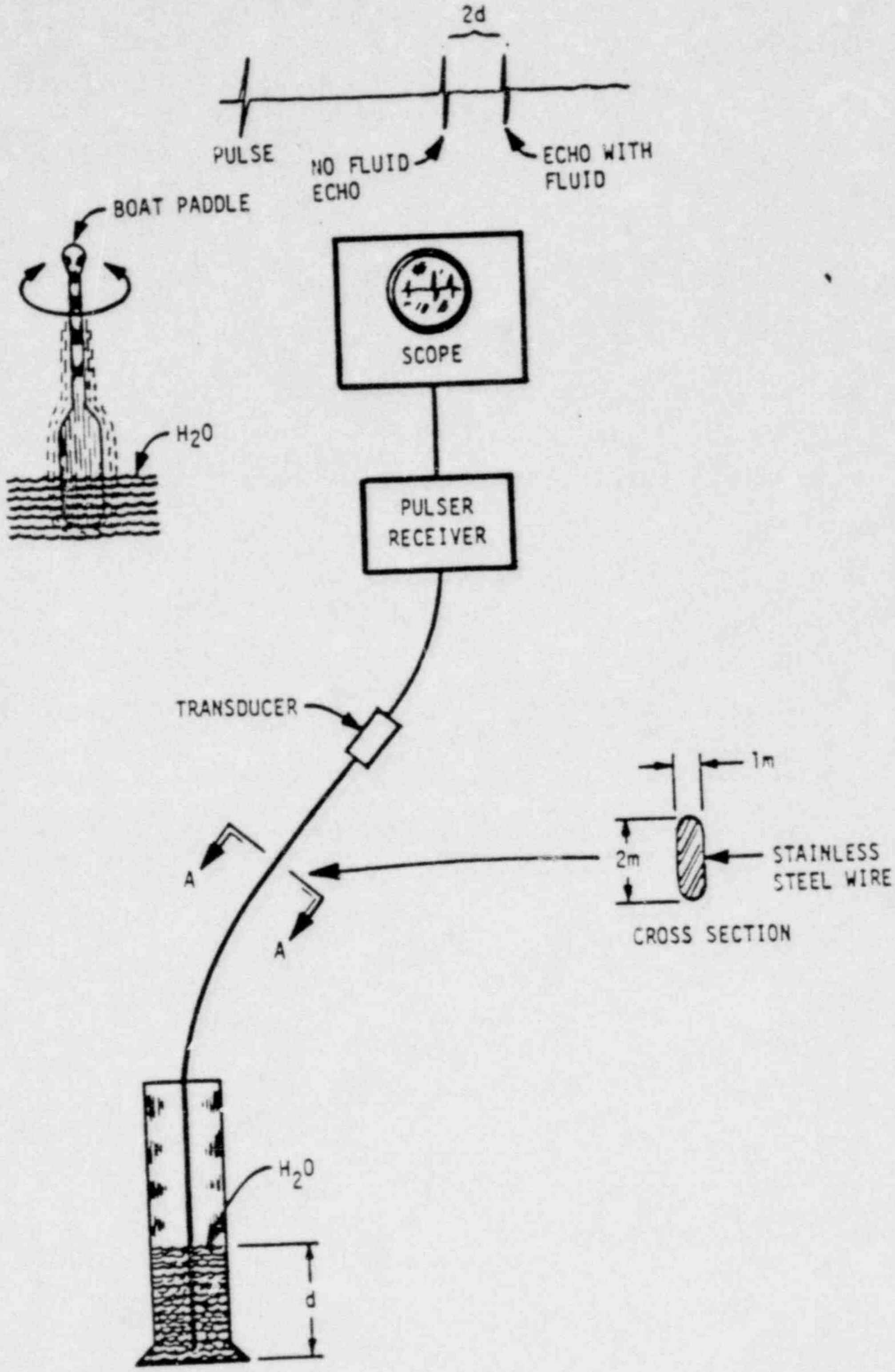
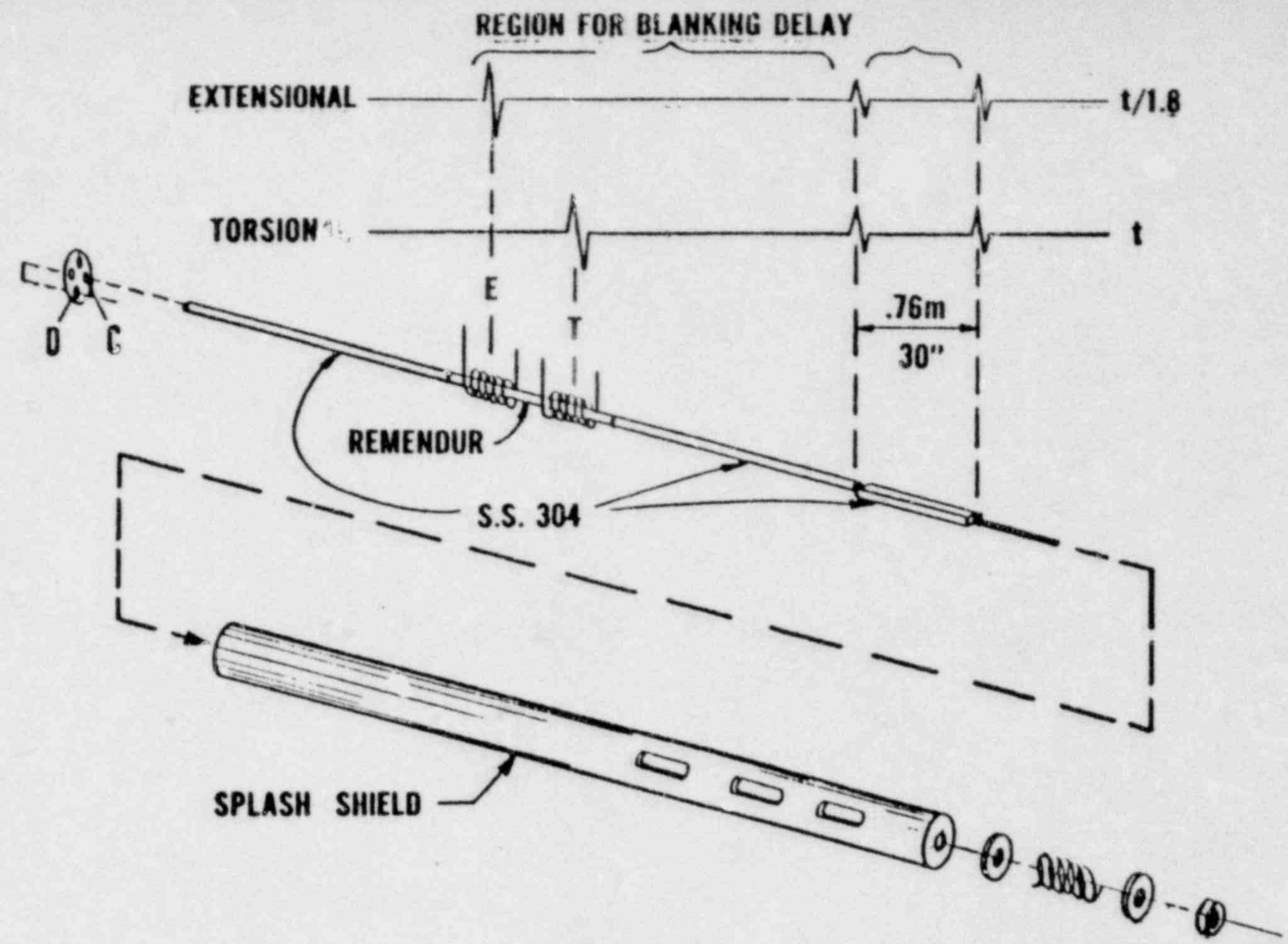
CONTENTS OF THE FOLLOWING PRESENTATION INCLUDE:

- o REVIEW OF ULTRASONIC LEVEL PROBE AS OF LAST REPORT (7/80)
- o NEW PROBE DESIGN
- o PROBLEM AREAS
- o ACTION ITEMS
- o FUTURE PLANS



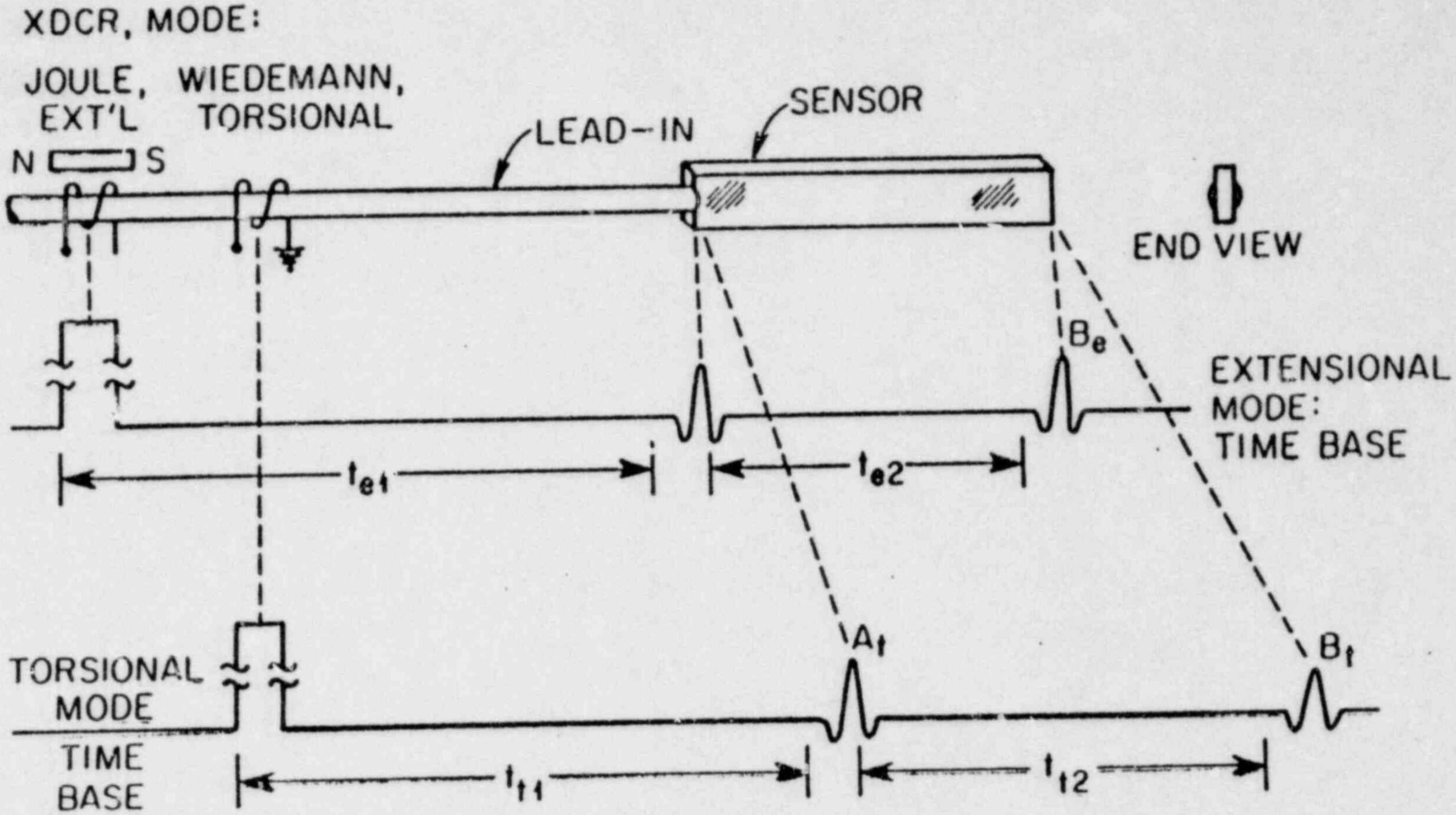
TORSIONAL PULSE ON FLATTENED WIRE IS DELAYED BY DENSE MEDIUM MUCH LIKE A BOAT PADDLE IN WATER.



DRAWING OF PROBE

FIGURE 1.

FOUR BLANKED INTERVALS t_{e1}, t_{e2}, t_{t1}, t_{t2}.



The velocity of torsional ultrasonic waves in a rectangular waveguide is dependent on the *density* of the surrounding medium.

$$v = K\sqrt{\frac{\mu}{\rho}}\left[1 + \frac{\rho}{2\rho_s}\left(1 - \frac{1}{K}\right)\right]$$

The velocity of an extensional wave is:

$$v = \sqrt{\frac{Y}{\rho_s}}$$

where ρ = density of surrounding medium
ρ_s = density of sensor material
μ = shear modulus
Y = Young's modulus
K = shape factor (less than one)

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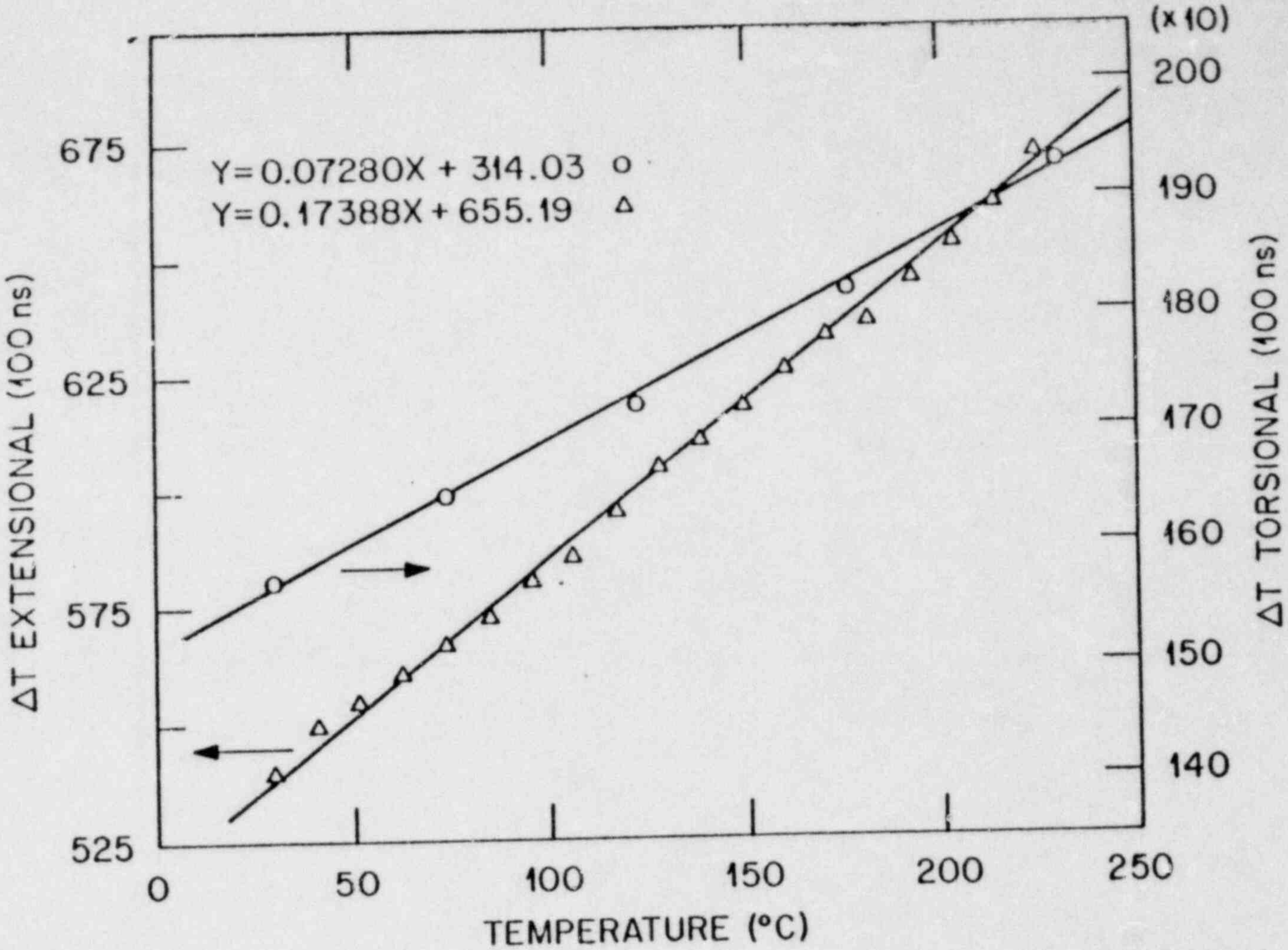
APPROXIMATED BY LINEAR CURVES



PRESENT METHODS UTILIZE LINEAR APPROXIMATIONS
BASED ON REFERENCE CALIBRATION DATA

- TEMPERATURE COMPENSATED TORSIONAL TRANSIT TIME

$$\tau_{TL} = \tau_{TM} - (\tau_{EM} - \tau_{ER}) * K_1$$

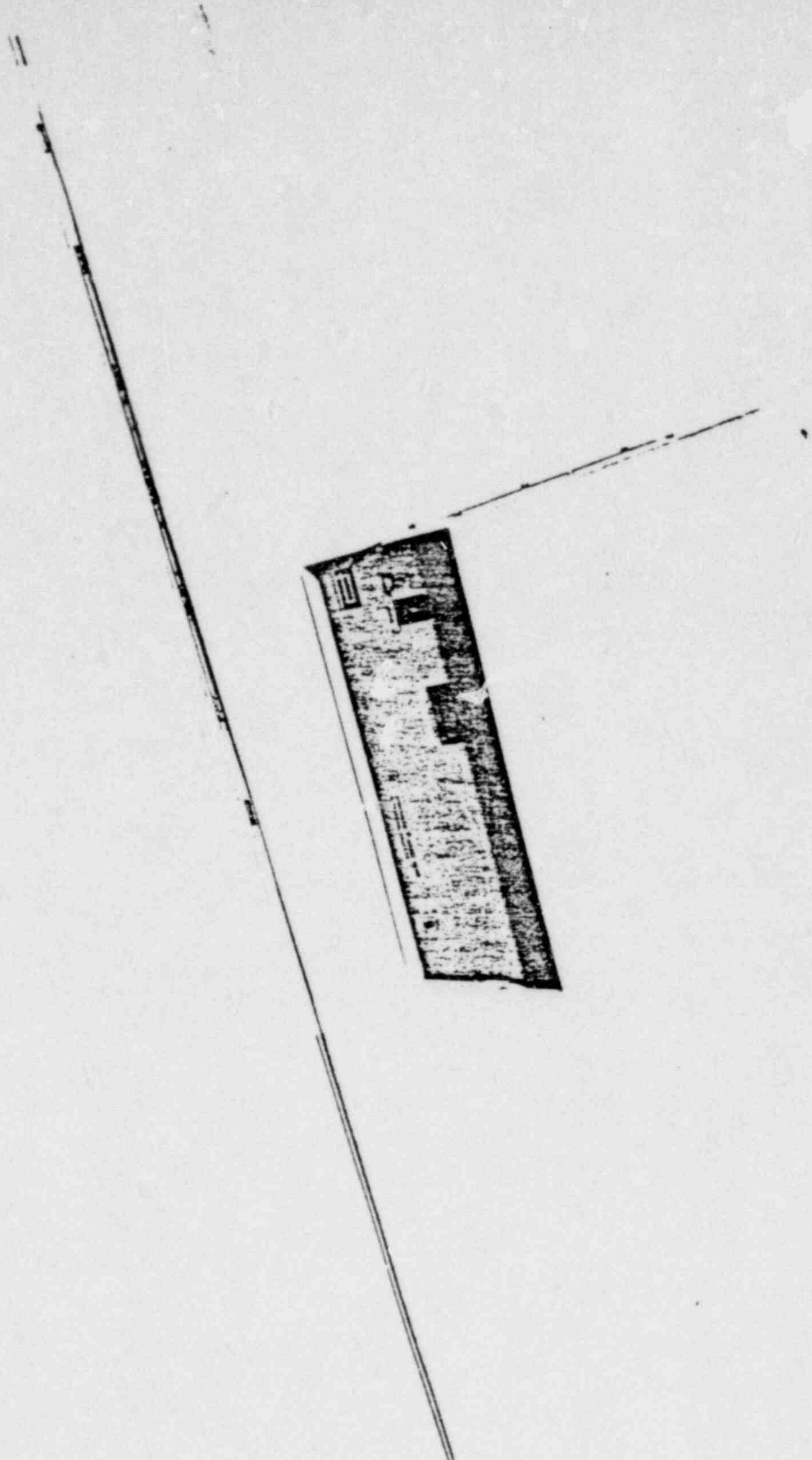
- CALCULATED LEVEL

$$L = (\tau_{TL} - \tau_{TR}) * \frac{F}{K_2}$$

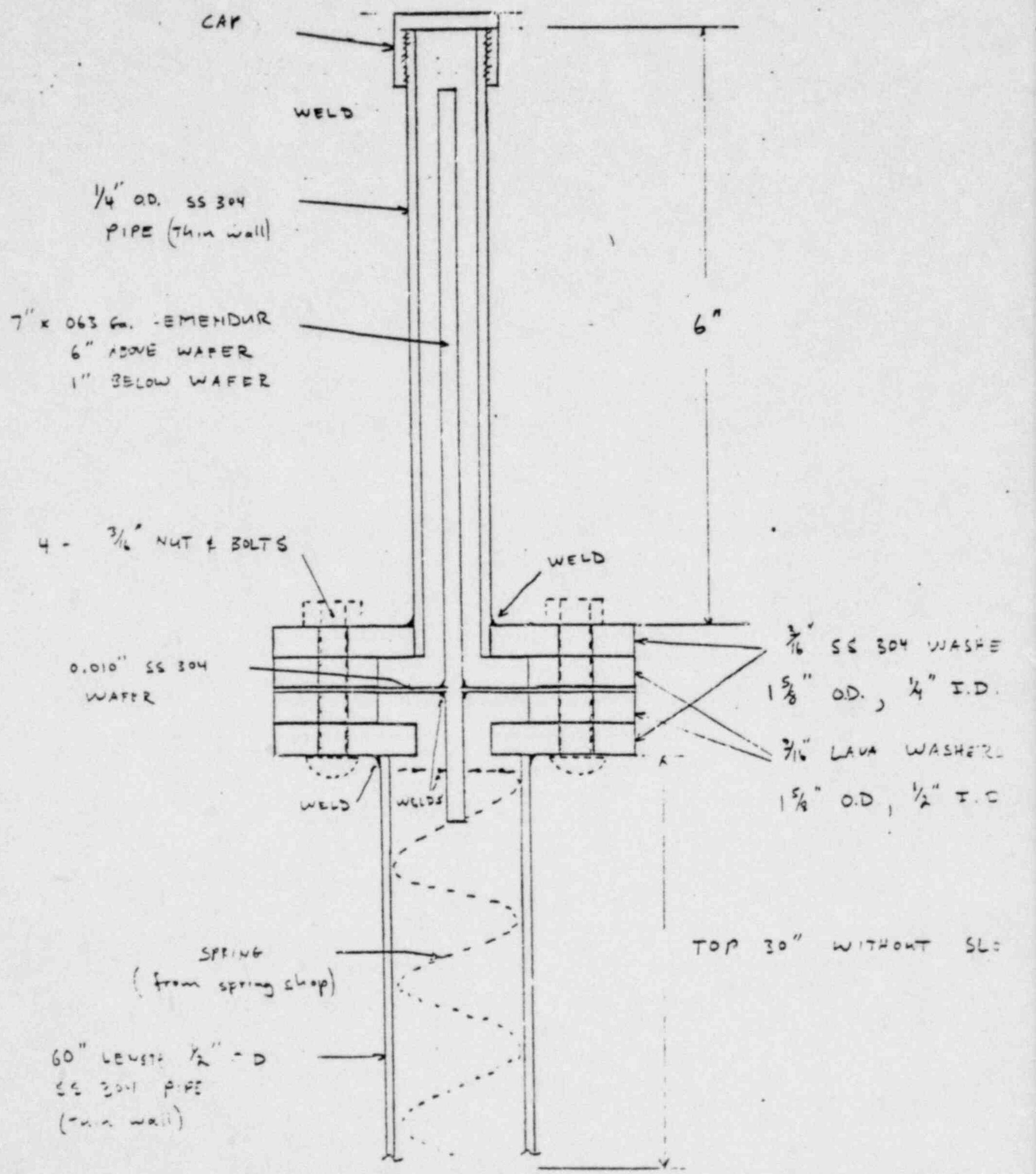
τ_{TM} = MEASURED TORSIONAL TRANSIT TIME
τ_{EM} = MEASURED EXTENSIONAL TRANSIT TIME

τ_{TR} = REFERENCE TORSIONAL TRANSIT TIME
τ_{ER} = REFERENCE EXTENSIONAL TRANSIT TIME

K_1 = RATIO OF $\Delta\tau_{TM}$ TO $\Delta\tau_{EM}$ AS A FUNCTION OF TEMPERATURE
K_2 = TOTAL TIME CHANGE
F = SPAN OF LEVEL MEASUREMENT



FABRICATION DRAWING OF MOISURE SEAL



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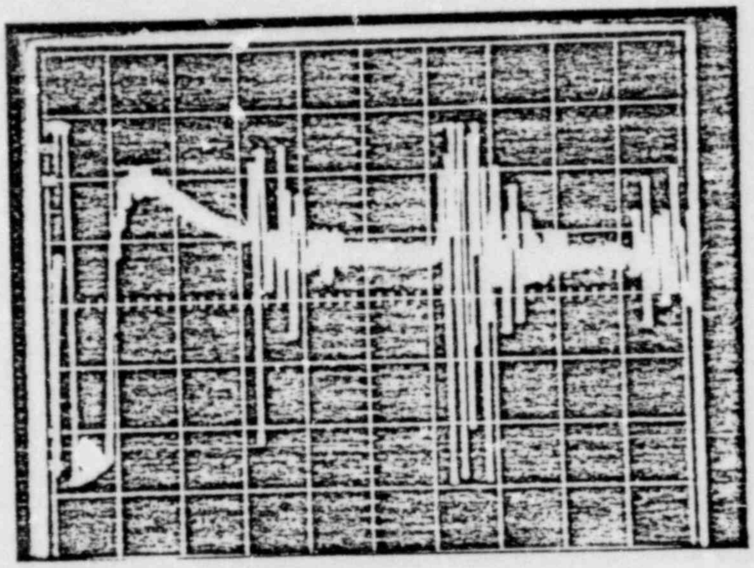
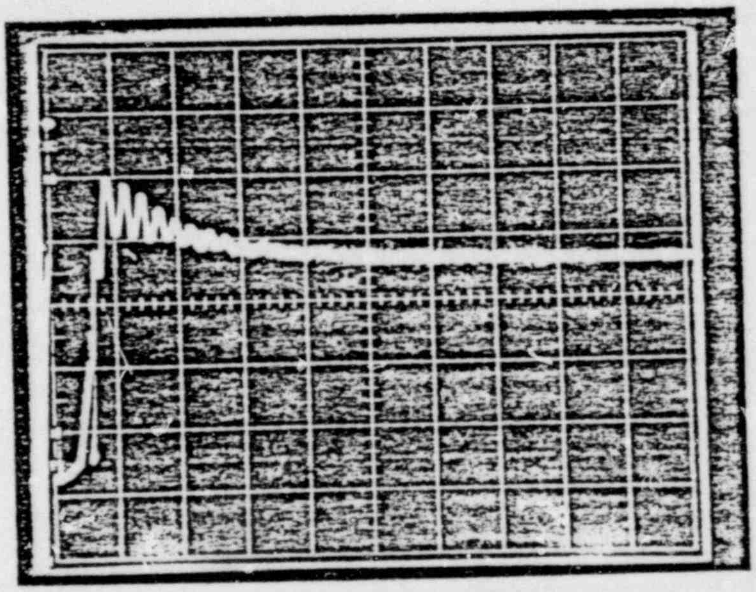
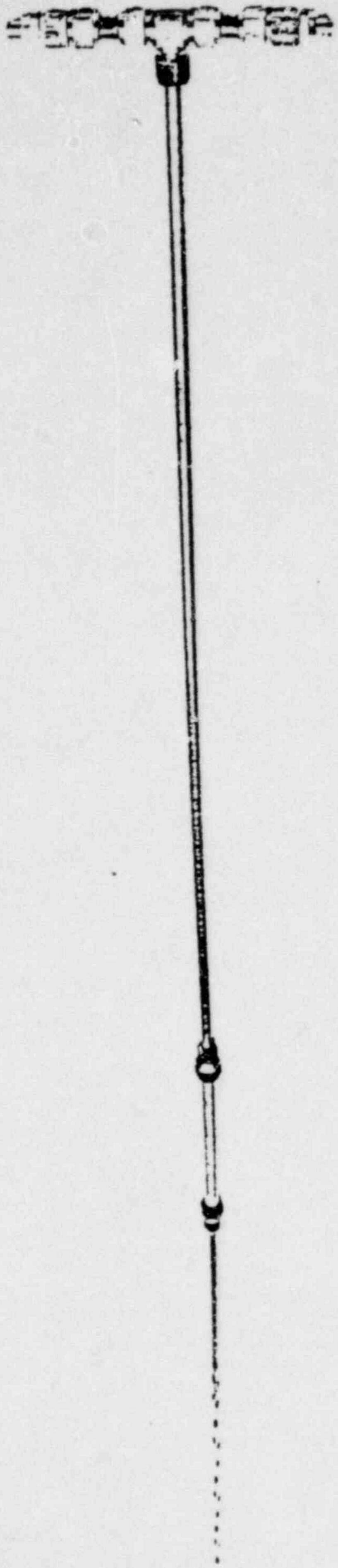
TRANSMITTED EXTENSION WAVE (UPPER)
AND ATTENUATED TORSION WAVE (LOWER)
WITH .25 MM MOISTURE SEAL

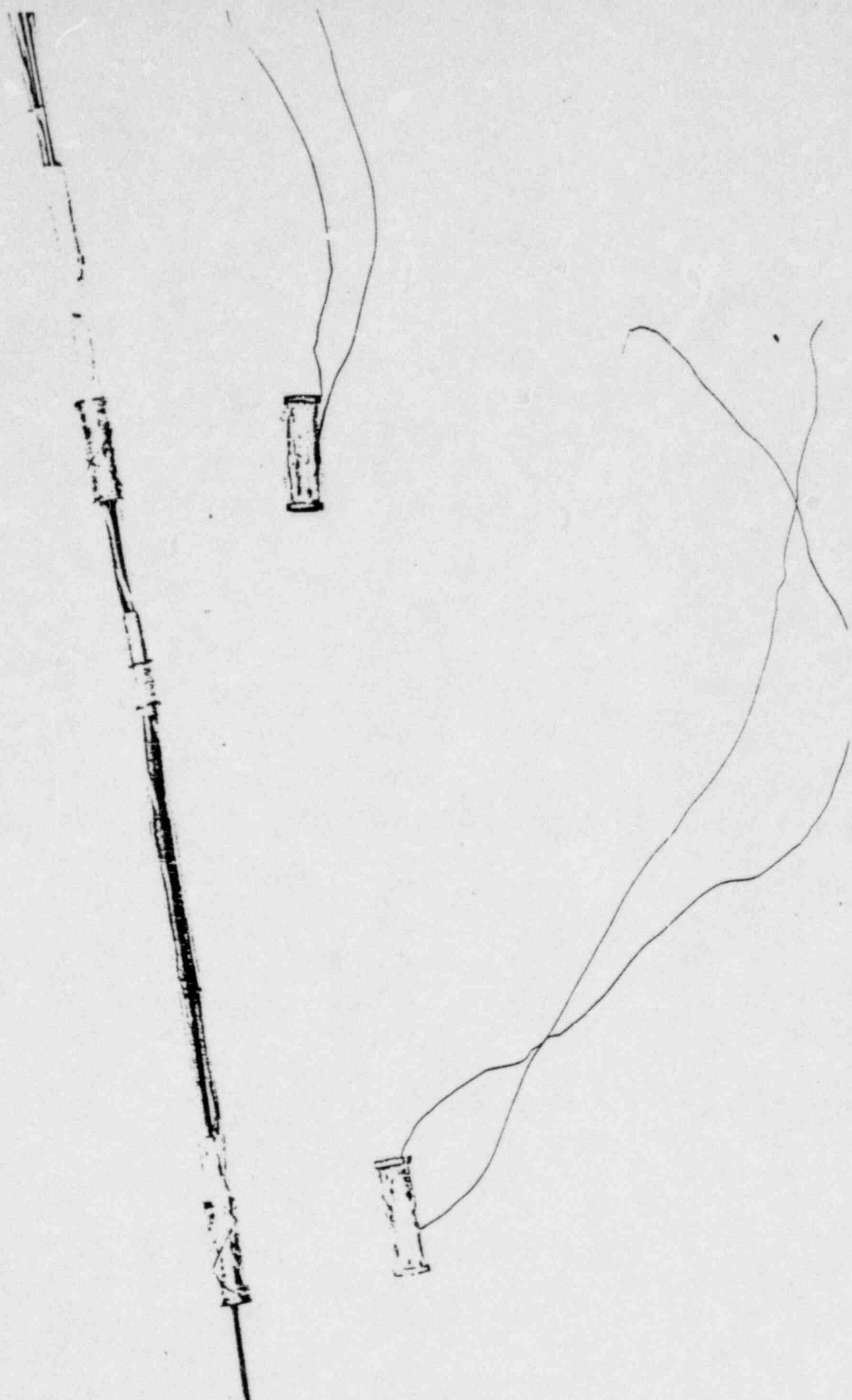




IMPROVED MEC' NICAL DESIGN EXTENDS TEMPERATURE RANGE

- o HEAT TREATED LAVA COIL FORMS (1100°C)
- o NICKEL PLATED CERAMIC INSULATED MAGNETIC WIRE (850°C)
- o NEW WAVEGUIDE WITH WELDED JOINTS (1350°C)
- o CONTINUOUS FLUID COMMUNICATION WITH SPIRALED SLOTS
- o SPRING INTERFACE BETWEEN WAVEGUIDE AND SHROUD PROVIDES SUPPORT WITH NO REFLECTION





DATA PROCESSING ENHANCED WITH SMART DEVICE, FAST ELECTRONICS

- o HP 85 COMPUTER
  - A. STATISTICAL AVERAGING OF SAMPLED DATA
  - B. PROCESSING DATA WITH CURVE FITTING CAPABILITIES
  - C. OUTPUTS OF TEMPERATURE PROFILE, DENSITY AND LEVEL IN ENGINEERING UNITS
- o PANAMETRICS 5010C INTERVALOMETER
  - A. MULTIPLEXING TORSIONAL/EXTENSIONAL SIGNALS
  - B. MULTIPLE ZONE/MULTIPLE PROBE INTERROGATION
  - C. 20 MHz CLOCK YIELDS 50 NS RESOLUTION
    1. 3 MM RESOLUTION FOR TORSIONAL
    2. .7°C RESOLUTION FOR EXTENSIONAL

SEVERAL PROBLEM AREAS HAVE BEEN IDENTIFIED

- ATTENUATION (100%) OF TORSION WAVE AT MOISTURE SEAL OF .25 MM THICKNESS
- ELECTROMAGNETIC SHIELDING WITH COILS OUTSIDE PRESSURE BOUNDARY IF THICKNESS > .4 MM
- EDDY CURRENT EFFECTS DUE TO PROXIMITY OF TRANSDUCER HOUSING TO MAGNETIC COILS
  - A. 1.5 MM RADIAL CLEARANCE → 10 DB ATTENUATION
  - B. 4.5 MM RADIAL CLEARANCE → 3.4 DB ATTENUATION
- TEMPERATURE EFFECTS OF REMENDUR MAGNETOSTRICTION
  - A. 250°C → LOSS OF HELICAL MAGNETIZATION
  - B. 980°C → LOSS OF MAGNETOSTRICTION (CURRIE TEMP.)

DEVELOPMENT ACTION ITEMS

- o REMENDUR TEMPERATURE PROTECTION
    - A. ISOLATION AND COOLING
    - B. REMAGNETIZATION
    - C. MODE CONVERSION
- o CROSS CORRELATION OF WAVEFORM RATHER THAN ZERO-CROSSING METHODS
- o HP 85 INTERFACE
    - A. STATISTICAL METHODS
    - B. ALGORITHMS DEVELOPED
    - C. BETTER COMPENSATION
- o VOID FRACTION MEASUREMENTS
- o DENSITY CALIBRATION

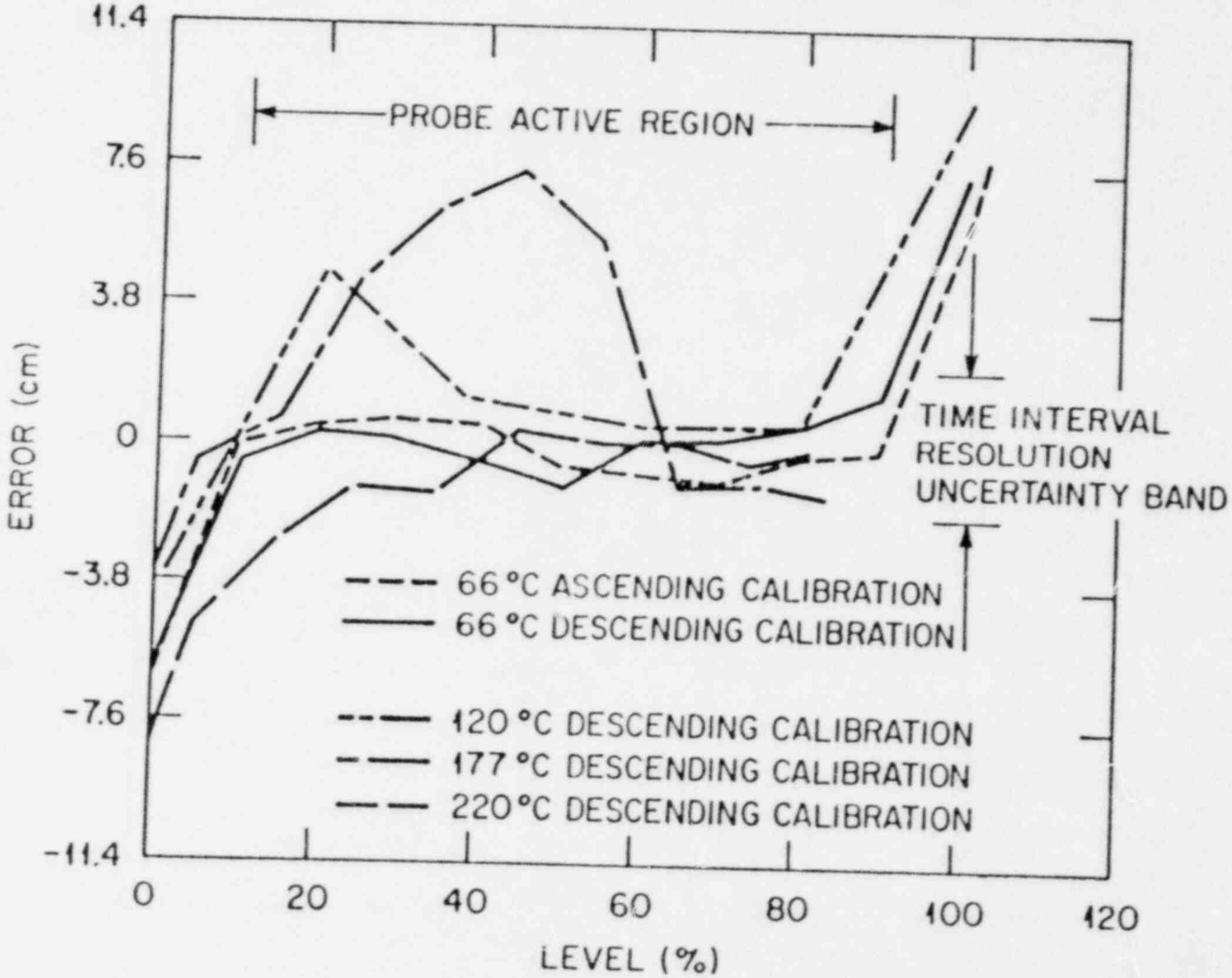
ADDITIONAL TESTS ARE REQUIRED FOR FURTHER DEVELOPMENT

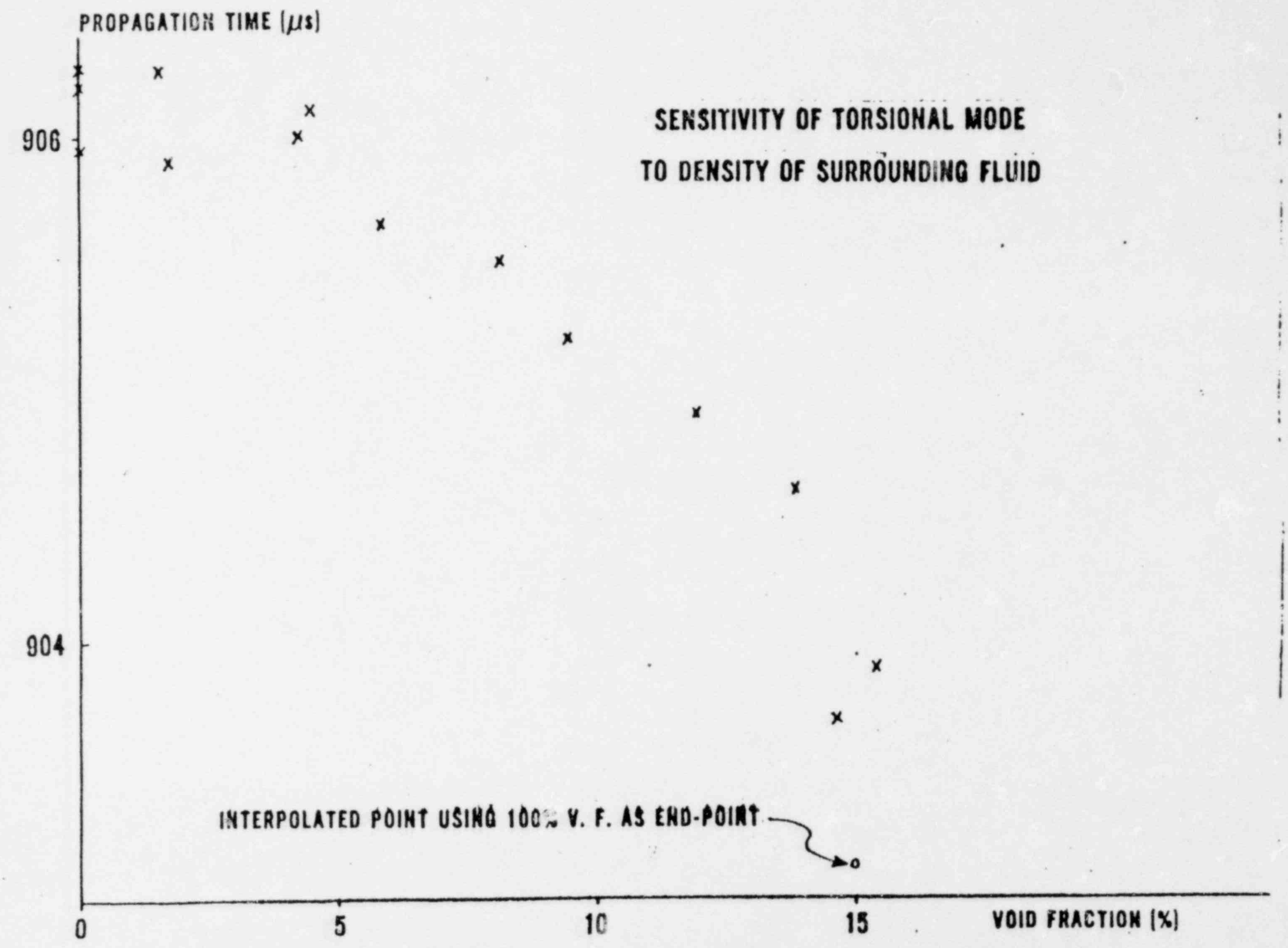
- TWO-PHASE (STEAM/WATER) TESTS
- FLOWING CONDITIONS
- SEMI-SCALE

ACCOMPLISHMENTS SINCE LAST REVIEW

- HIGHER TEMPERATURE PROBE DEVELOPMENT
- HP85 INTERFACE 65% COMPLETED
- MODIFIED PANATHERM 5010C
- SEVERAL TESTS RUN
- EVALUATED SEVERAL PRESSURE SEAL DESIGNS

PROBE WELL BEHAVED IN ACTIVE REGION





SENSITIVITY OF TORSIONAL MODE
TO DENSITY OF SURROUNDING FLUID
PROPAGATION TIME (μs)
906
904
0
5
10
15
VOID FRACTION (%)
INTERPOLATED POINT USING 100% V. F. AS END-POINT