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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

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SERVED NOV 27 1984

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| In the Matter of | ) | Docket No. 50-289 |
| | ) | (10 CFR 2.206) |
| GPU Nuclear Corporation | ) | |
| (Three Mile Island Nuclear | ) | |
| Station, Unit 1) | ) | |

ORDER

Pursuant to 10 CFR 2.772, the time within which the Commission may act to review the Director's Decision is extended until December 3, 1984.

It is so ORDERED.

FOR THE COMMISSION

JOHN C. HOYLE
Acting Secretary
of the Commission

Dated at Washington, DC
this 26th day of November 1984



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# UNITED STATES
# NUCLEAR REGULATORY COMMISSION

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**IN THE MATTER OF:**

METROPOLITAN EDISON COMPANY

(Three Mile Island Nuclear Station, Unit No. 1)

**DOCKET NO:** 50-289SP

(Restart Remand on Management)

**LOCATION:** HARRISBURG, PENNSYLVANIA **PAGES:** 28436 -28573

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

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| In the Matter of: | ] | |
| | ] | |
| METROPOLITAN EDISON COMPANY | ] | Docket No. 50-289SP |
| | ] | |
| (Three Mile Island Nuclear Station, Unit No. 1) | ] | (Restart Remand on Management) |
| | ] | |

Room 156
Main Capitol Building
Harrisburg, Pennsylvania

Friday, November 16, 1984

The hearing in the above-entitled matter was convened, pursuant to adjournment, at 9:00 a.m.

BEFORE:

JUDGE IVAN W. SMITH
Chairman, Atomic Safety and Licensing Board

JUDGE SHELDON J. WOLFE
Member, Atomic Safety and Licensing Board

JUDGE GUSTAVE A. LINENBERGER, JR.
Member, Atomic Safety and Licensing Board

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APPEARANCES:

On behalf of the Licensee:

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On behalf of Witness Zebroski:

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1333 New Hampshire Avenue, N.W.
Washington, D.C. 20036

C O N T E N T S



E X H I B I T S

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P R O C E E D I N G S

JUDGE SMITH: On the record.

You may proceed, Mr. Blake.

MR. BLAKE: Our next witness is Edwin Zebroski. Mr. Zebroski has not been previously sworn.

MR. McBRIDE: Mr. Chairman, members of the Board, my name is Michael F. McBride, with the law firm of LeBoeuf, Lamb, Leiby & McRae, 1333 New Hampshire Avenue, Northwest, Washington, D.C.

JUDGE SMITH: Is your microphone on?

MR. McBRIDE: Yes. Did you hear me?

JUDGE SMITH: Yes, with some difficulty.

MR. McBRIDE: My name is Michael F. McBride, with the law firm of LeBoeuf, Lamb, Leiby & McRae, 1333 New Hampshire Avenue, Northwest, Washington, D.C., 20036.

I simply wanted the record to reflect that I am present this morning as personal counsel for Dr. Zebroski.

As the Board knows, I have previously entered an appearance on his behalf because of some procedural issues that have arisen.

I don't expect to have to participate this morning, but I simply wanted the record to reflect that I am present.

JUDGE SMITH: Dr. Zebroski, would you stand and accept the oath, please?

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Whereupon,

EDWIN L. ZEBROSKI

was called as a witness and, having been first duly sworn, was examined and testified as follows:

DIRECT EXAMINATION

BY MR. BLAKE:

Q. Dr. Zebroski, would you please state your full name and business address?

A. My name is Edwin --

Q. Dr. Zebroski, before you commence, there is a button on the microphone in front of you which, if it is turned in the right direction, turns on a red light; and then you will want to pull the microphone as close to you as possible. It doesn't pick up over a distance at all, so put it very close up.

Again, if you will just state your name and business address.

A. My name is Edwin L. Zebroski. My business address is Electric Power Research Institute, 3412 Bellevere Avenue, Palo Alto, California, 94303.

Q. Dr. Zebroski, do you have before you a copy of a document dated November 1, 1984, and entitled "Testimony of E.L. Zebroski"?

A. I do.

Q. Was this document prepared by you?

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A. Yes.

Q. Do you adopt this as your testimony in this proceeding?

A. I do.

MR. BLAKE: Mr. Smith, I ask that the document entitled "Testimony of E.L. Zebroski" comprised of 12 pages be accepted as Dr. Zebroski's testimony in this proceeding and be physically incorporated into the record just as though read.

JUDGE SMITH: Are there objections?

MS. BERNABEI: Yes. I at this time move to strike the testimony in its entirety. I don't think it is relevant to any issue before the Board.

Mr. Zebroski, as is clear from his testimony, did not arrive on site until March 31. The only possible relevance that I see is the conversations with Mr. Dieckamp after he arrived on site on March 31.

I think given that other testimony has not been permitted on that subject, his should not be. Therefore, I would move to strike the entirety of his testimony on the grounds of irrelevance other than the specific portions on his conversations with Mr. Dieckamp, which I would move to strike on the grounds of irrelevance.

JUDGE SMITH: The testimony is clearly relevant. There may be portions of it specifically which you might have

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legitimate objections to, but in its entirety the overall is clearly relevant and your objection on that basis is overruled.

Do you have further objections?

MS. BERNABEI: I had two objections. One was on the grounds that it was not relevant; the second is that his conversations with Mr. Dieckamp should not be permitted in the record if Dr. Gilinsky and Mr. Bradford's recollections are not.

JUDGE SMITH: I'm sorry; I thought you said that his conversations with Mr. Dieckamp should be accepted.

If that is your objection, that is overruled, too, and the testimony is received. It will be bound into the transcript.

(The document follows:)

November 1, 1984

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

| | | |
|---|---|---|
| In the Matter of | ) | |
| | ) | |
| METROPOLITAN EDISON COMPANY | ) | Docket No. 50-289 SP |
| | ) | (Restart-Management Remand) |
| (Three Mile Island Nuclear Station, Unit No. 1) | ) | |
| | ) | |

TESTIMONY OF E. L. ZEBROSKI

My name is Edwin L. Zebroski. My current position is Chief Nuclear Scientist at the Energy Study Center, a part of the Electric Power Research Institute (EPRI) in Palo Alto, California. EPRI is the research arm of the electric utility industry. Prior to joining EPRI, I held various design and development positions in Stanford Research Institute, (Physics Department), and in the General Electric Company, Research Laboratory, and in the Nuclear Energy Division. My training includes degrees in Science from the University of Chicago and the University of California. I am a registered Professional Engineer, and a member of the National Academy of Engineering. I have authored or co-authored over 120 technical publications and patents relating to the basic and applied science of nuclear energy. A major area of my specialization during the period 1965-1976 was the behavior of nuclear fuel under various operating conditions, including transients and accidents.

The purpose of my testimony is to cover three main points, based on my personal observations and involvement as a member of the Industry Advisory Group, convened at Three Mile Island in the early days following the accident:

1. The extent to which there was a rapid learning curve evident in the days immediately after the accident, in respect to organizing, and interpreting, the large volume of plant data, and in sorting out different views and speculation as to the extent and nature of the damage to the reactor, by focusing on generation of hydrogen as illustrative of this learning curve.

2. The extent to which related uncertainties remained for months after the accident, reflecting the limited general state of knowledge of severe core accidents at that time.

3. The extent and nature of the involvement of Mr. Herman Dieckamp in the activities and technical discussions of the Industry Advisory Group during the period of my observation.

At the time of the TMI-2 accident, I was Director of the Nuclear Systems and Materials Department at EPRI, which conducts research and development programs aimed at improved lifetime, reliability, and cost-effectiveness of components, fuels,

and systems of Nuclear Power Plants. (Mr. Dieckamp was generally aware of these programs through his participation in prior years in two of the advisory committees which serve EPRI.) At a Research Advisory Committee meeting in Scottsdale, Arizona, Dr. S. Bartnoff of GPU reported to the Committee on March 29 and again on the morning of March 30, that an incident had occurred at TMI-2. Later in the morning of March 30, Mr. Culler, the President of EPRI, reported to the same meeting on a phone call from Mr. Dieckamp which indicated that the situation had deteriorated relative to the perceptions on the previous day and that technical support help from EPRI was needed. Mr. Culler agreed to send technical assistance to TMI, initially consisting of Mr. Milton Levenson, then Director of the Nuclear Division at EPRI, and myself. Mr. Dieckamp outlined four basic tasks which needed technical support; I was asked to undertake the first task which was Core Damage Assessment.

After a conference call on March 30 with Mr. Robert Keaten of GPU, I traveled to TMI, arriving on the morning of March 31. Office and conference space was made available at the National Guard Armory adjacent to the Harrisburg airport. An initial meeting to review the situation was organized and the technical review discussion was led by Mr. Dieckamp on the afternoon of March 31. Sometime during March 31, I became aware of the pressure spike which occurred shortly before 2:00 p.m. on March 28, 1979. I remained at TMI intermittently for the next four weeks, serving as co-leader of the Industry Advisory Group

which was assembled to provide calculations, and evaluation of options for maintaining control and safety of the reactor system.

My investigative efforts on core damage at TMI during the initial days following the accident centered on several questions: namely, (1) the postulated hazard from the gas bubble in the reactor, (2) the possible extent of core damage, and (3) possible means for removing the gas bubble.

The gas bubble evident in the reactor was postulated to be potentially subject to ignition and explosion creating a sense of immediate potential for catastrophe. This potential apparently was first postulated about March 30th, and was reported in the national media with banner headlines. Various people from national laboratories discussed the explosive potential. The President's Science Advisor was reported to have commented that New York City and Philadelphia might be exposed to severe radiation if the bubble were to explode. A helicopter reportedly was dispatched to bring sacks of oxygen-absorbing chemicals (like sodium hyposulfite, a chemical used in photography).

In the telephone call with Mr. Robert Keaten of GPU on March 30 (mentioned earlier) he noted that he had become aware of a gas bubble in the reactor vessel but did not know its source or its full composition. He hypothesized that it might contain some air, from air dissolved in the borated water used to assure safe nuclear shutdown of the reactor.

I stated to Mr. Keaten my belief that oxygen could not be present in the reactor vessel and that no explosion was possible. I repeated this position later in meetings with NRC people on site (Stello, Vollmer, and Mattson) during the period March 31 to April 2, quoting the extensive literature on this subject dating to the 1950's and 1960's. The basic scientific information was that the presence of even small amounts of hydrogen suppressed the effect of radiation on water. (In the absence of excess hydrogen, radiation acting on water can produce hydrogen and oxygen in a volume ratio of 2 to 1, which is an explosive mixture.)

Apparently none of the staffs or the officials of the various government agencies involved were aware that since the mid-1950's, hydrogen was routinely used in all pressurized water reactors -- both Navy and civilian power -- to prevent the formation of oxygen-hydrogen mixtures by radiolysis. I urged the NRC representatives to make telephone calls to the national laboratories (Brookhaven, Argonne, and Oak Ridge) where the scientific and test work had been done to check out this information. This work was widely published in technical papers, and covered in textbooks on nuclear engineering.

By about April 2nd or 3rd, the NRC decided that the evidence against the possibility of a hydrogen-oxygen explosion was indeed unquestionable, and the bubble was disappearing. This was announced publicly, with the comment that previous

concerns of possible explosion were due to overly conservative calculations. (It was later evident that the earlier inquiries to the national laboratories did not indicate that hydrogen was present in the reactor vessel.)

During the same days I was also continuing my efforts to estimate the extent of core damage. The prevailing state of knowledge on possible reactor core damage as of 1979 was the analysis in the report Wash-1400. This report, and the related NRC calculations used in licensing, postulated that if cooling water was lost, the fuel would fail (distort and leak) due to high temperature, and that the reactor core would then proceed to melt down with extensive spread of the bulk of the radioactive elements in the fuel (up to 70% of the total). The information available to me March 30 through April 4 did not correspond to such a degree of severity. The observations available March 30 and 31, (including the pressure spike and the indications of high levels of gaseous radioactive elements, but only small amounts of iodine and cesium) was that a significant fraction of the fuel was certainly perforated, releasing most of the rare gases. The apparent evidence that only a small fraction of the iodine and cesium were released was consistent with perforation of fuel cladding, but not necessarily gross disruption or melting of fuel. If major core damage were present, a large fraction (up to 70%) of the iodine and cesium would be expected to be volatilized -- according to the prevailing calculations accepted by the NRC.

The pressure spike was evidence of the probable presence of enough hydrogen to burn, but of itself was not evidence of how much had been produced. Small amounts of hydrogen -- as low as 4% in air, are known to be capable of ignition -- which would result in a pressure pulse, even if there was simply burning rather than explosion. I was aware that hydrogen gas from gas cylinders is routinely used to provide a small amount of hydrogen dissolved in the reactor coolant. As noted earlier, the dissolved hydrogen is used to prevent the decomposition of water by radiation (radiolysis), which would otherwise form oxygen and hydrogen. There was an evident need to determine whether some hydrogen cylinders or piping might have leaked hydrogen into the containment, which then could be ignited when a relay or motor was actuated or started.

Another possible source of hydrogen was recognized to be from the reaction of zirconium with steam at high temperatures. This was also plausible but did not of itself necessarily imply more extensive fuel damage than just perforation from localized overheating. Localized overheating alone could cause clad ballooning and rupture, with or without the added effect of oxidation of zirconium.

One of the major technical surprises of the subsequent investigations of the TMI accident has been the low extent of mobility of iodine and cesium, despite what we now know to be major core damage, with oxidation of a large part of the

cladding. On the basis of the licensing analyses prevalent at the time of TMI, major core damage should have been accompanied by the release of large fractions of iodine and cesium (up to 70% of total inventory) to the primary system, and from there to the containment building air, and to any leakage paths to the auxiliary building. It is now known scientifically (although not yet fully accepted for regulatory purposes), but was not known or accepted then, that iodine and cesium, under conditions prevailing in a PWR loss-of-coolant accident, have a very strong affinity for water. The relatively large amounts (over 5%) which are now believed to have escaped from the fuel at TMI-2, have remained almost entirely in the water.

The small amount of iodine that did escape to the air (a small fraction of 1%) was readily detectible in the containment building and the auxiliary building. Had the postulated amounts of iodine been released, much larger emissions of iodine to the containment, and via leakage paths to the auxiliary building, would have been expected. In the absence of such observations, the expectation that core damage was limited to leakage or perforation of some fuel was plausible. If the fuel were only perforated, then it would still be possible to remove it and replace it using conventional underwater mechanical handling equipment. A small degree of fuel perforation ("leakers") is often present in the normal periodic refueling operations.

The question of how much hydrogen was evolved was the key to determining whether the core damage was limited to perforation or whether there had been more extensive or even severe disruption of the core structure. The first solid evidence of the amount of hydrogen produced came from the analysis of gas samples taken from the containment building on March 31 at 0600. These showed significant oxygen depletion (4.4% to 5.2% below the normal value in air, respectively). This corresponds to extensive reaction of zirconium (later calculated to be 45 to 52% of the core inventory). However, at the time, these results were questioned. Eight more gas samples were taken on April 1 and April 2. These showed substantially smaller oxygen depletion (average value of 2.3%, but with a wide scatter, some samples showing normal oxygen levels or higher). Later samples have confirmed that the initial values from the samples of March 31 are most likely to be valid. (There is an apparent possibility that in-leakage of air to the gas samples caused the error and scatter in the April 1-2 samples.)

Even with 50% cladding oxidation, the preservation of much of the core structure was judged to be possible. This assumed that the oxidation of the zirconium cladding produced a layer of oxide, but leaving a metal tube intact under the oxide. (Somewhat analogous to rusted iron pipe with an average of half of the iron still intact.) The near-normal readings on thermocouples in the core region also seemed to indicate that the core structure was mostly intact.

After the situation at TMI had been stabilized, late in April, 1979, the EPRI Board of Directors authorized EPRI to set up an investigation team to assess the facts, causes, and lessons learned from the accident.

This led to the organizing of the Nuclear Safety Analysis Center (NSAC) at EPRI in May, 1979, for which I was named the Director. In the next few months, a total of 80 technical people were enlisted in the investigation for a total of 12 man-years of effort. This effort produced a report (NSAC-1) issued July, 1979 on the sequence of events, with supplements in succeeding months. A final report including the supplements was distributed in March 1980. Many other investigations were proceeding which involved exhaustive interviews with plant personnel. These interviews apparently were finding a considerable range of conflicting recollections and perceptions. It was decided that the NSAC study should rely on the detailed analysis of instrument records and to avoid reliance on recollections or interpretations by plant personnel.

Accordingly, we did not interview any of the plant personnel. (We did have full support and help from GPU and plant personnel in finding and copying any instrument records and logs. This eventually amounted to over 50,000 pages of records).

Some months later, in Palo Alto, analysis of the instrument records brought out awareness (in NSAC) of an apparent

thermal shock to the reactor core, possibly from a rise of water level in the core at about 7:47 a.m. on March 28. The nuclear instruments also showed a change in readings which could be interpreted as relocation of fuel by slumping or collapse of fuel rods previously embrittled by oxidation of the cladding. (I was aware of the results of two incidents in which experimental fuel was operated without adequate cooling and which resulted in fragmentation of the fuel rods.)

The NSAC analysis reported in NSAC-1 suggested that roughly the upper two-thirds of the core had been uncovered and subsequently overheated. Given that about 50% of the total zirconium was converted to oxide, the local oxidation in the upper part of the core would have to be near 100%. The fuel cladding in this region would be almost completely converted to a ceramic oxide. The sudden cooling of a hot brittle ceramic can result in fragmentation. The likelihood that core structure was preserved in this region was then recognized to be small. From this emerged the hypothesis published in NSAC-1 report, that a region of the core shaped like an inverted bell, reaching to within about 3 to 5 feet of the bottom of the core, was most likely fragmented into a rubble bed. (This analysis was confirmed conclusively only in July-August 1982, when a TV camera was lowered into the reactor core region.)

During the period that I was at TMI, Mr. Dieckamp continued to keep in touch with me and Mr. Levenson and to

participate in the technical discussions after the initial meetings of the Industry Advisory Group (IAG), to which I referred earlier. There was also an operating support group at TMI led by Mr. William S. Lee (of Duke Power) for a time and then later by Mr. Byron Lee (of Commonwealth Edison Co.). Mr. Levenson and I met with this group daily to review our findings and recommendations. Mr. Dieckamp participated actively in these discussions. There were also daily meetings with the principal NRC representatives (led by Mr. Victor Stello) to discuss our findings and recommendations, also with active participation by Mr. Dieckamp.

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JUDGE SMITH: Off the record.

(Discussion off the record.)

JUDGE SMITH: Back on the record.

MR. BLAKE: Judge Smith, Dr. Zebroski is available for cross-examination.

I would observe at this juncture what I have previously observed at the prehearing conference earlier this week, that insofar as arguments are going to be made as to objective evidence of the strategies of cooling throughout the day on March 28, that Dr. Zebroski is a principal to the NSAC report, a detailed analyses of the event. He is here; he is available and is offered as well for questions on this objective evidence by any of the parties or the Board as to the understanding of the sequence and what the objective evidence indicates.

JUDGE SMITH: So I understand then, you have no objections to intervenors' cross-examination on the sequence beyond the scope of the direct examination?

MR. BLAKE: That is correct, particularly this repressurization area. However, I would note that Ms. Bernabei, in her opening statement, says that the industry's analysis of the events that afternoon would support her position regarding repressurization and then she refers to objective evidence in that regard.

We have an interpreter here, and maybe one of the

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best interpreters of that objective evidence. I not only would not object, but I would encourage the parties to take this opportunity to ask Dr. Zebroski of that sequence and what occurred in the afternoon regarding pressurization, re-pressurization, et cetera.

MS. BERNABEI: I appreciate Mr. Blake's concern, but I think we should be allowed to present the case we wish, and I think the report is clear on its face. And while I appreciate Mr. Blake's concern for proving our case, I think we can do it better ourselves.

So, thank you, Mr. Blake, but we did not have the intention to question Dr. Zebroski on the report. Obviously, that is open to the Board.

MR. BLAKE: I think it's open to the other parties and the Board. And, as I have indicated before, to the extent subsequent to Dr. Zebroski's appearance here today there are attempts made to argue from that objective or, more importantly, to call other witnesses to talk about the NSAC report in which Dr. Zebroski played a role, I will object to the calling of those witnesses if Ms. Bernabei does not take advantage of the opportunity here today to determine whether or not -- with the witness here in the room she can elicit what she needs.

MS. BERNABEI: It appears to me that I am free, just as Mr. Blake, to question any witness which appears, who has

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a reason to appear, on the NSAC report. We do not have to prove our case through the licensee's witnesses, and we have not chosen to do so in this case.

Mr. Blake can state whatever he would like to object to, but outside of the context of a particular objection situation, I think it is worthless argument.

JUDGE SMITH: Is the report to which you refer, the NSAC report, the same report which was received in the evidence? I believe it is; the final report, the final version of it.

MR. BLAKE: It may have been during the technical phase to which I was not a party, so it might be that Mr. Dornsife would be a better historian on this than I.

But, in fact, the NSAC report of July, 1979, and the supplement to that of October of '79 are item numbers 63 and 64 in part C of the joint party stipulation.

JUDGE SMITH: So, in any event, it is available for findings in this phase; that was the thrust of my question.

MR. BLAKE: Yes; that's correct.

JUDGE SMITH: And I have some familiarity with the report if, indeed, it is the same one; and I think it certainly must be.

MR. BLAKE: Yes, sir.

JUDGE SMITH: There is nothing before the Board to rule on with respect to the dialogue between Mr. Blake and

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Ms. Bernabei, except that we should note that the offer has been made, and we do recognize Dr. Zebroski as an unusually well-informed person on the EPRI endeavors and report; we would take that into account should the need be asserted later in this hearing for additional access to that report.

(Pause.)

JUDGE SMITH: You may proceed, Ms. Bernabei.

MS. BERNABEI: May we approach the witness?

JUDGE SMITH: For what purpose?

MS. BERNABEI: To question him. It is just a little easier to do it from down there.

CROSS-EXAMINATION

BY MS. BERNABEI:

Q. Dr. Zebroski, you work for the Electric Power Research Institute; is that correct?

A. That's correct.

Q. We can't hear you, sir.

A. That is correct.

Q. And that is an industry research group, that is, a research group for the nuclear industry; is that correct?

A. That is partially correct.

Q. It's partially correct?

A. Yes. It is not restricted to the nuclear industry.

Q. But it is largely a research group for the nuclear industry; that is a large part of its work?

j9

A. Less than one-fourth.

Q. It is a large part of your work, is it not, sir?

A. It is a large part of my work.

Q. You were the director and principal author of the National Safety Analysis Center or industry report on the accident; is that correct?

A. If I may correct your wording, it is correct; it is Nuclear Safety Analysis Center, not National.

Q. Okay, Nuclear Safety Analysis Center.

A. Yes.

Q. You issued a report in July of 1979?

A. That is correct.

Q. You'll have to speak up, and I'll try to speak up a little also, Dr. Zebroski.

A. I'll get a little closer to the mike.

Q. You are here today, are you not, as part of the undertaking of that investigative endeavor and report, that is, the NSAC analysis?

A. Yes.

Q. When did you learn of the Three Mile Island accident or transient?

A. I heard radio accounts of an accident driving to work on the 28th, I believe. There were newspaper accounts on that same day.

Q. When did you next learn of any information about

j10

the severity or seriousness of the accident?

A. There was a more extended newspaper account on the 29th and then I received phone calls from Arizona from my immediate superior, Mr. Milt Le enson, who said that we should plan to get some staff together on the following day to discuss the situation.

Q. There was a meeting of the Research Advisory Committee of EPRI in Arizona on March 29 and March 30; is that correct?

A. That is correct.

Q. You reference that in your testimony on page 3; is that correct?

A. That's correct.

Q. You were not at that meeting, were you?

A. No, I was not there.

Q. You were not there on the 29th or the 30th; is that correct?

A. Correct.

Q. You made note in your testimony about a certain statement made on the 30th about the TMI accident; is that correct?

A. It would help if you would refer to the place in my testimony.

Q. Page 3; specifically, a report by Mr. Culler of EPRI to the Research Advisory Committee meeting.

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A. I see the place. May I have the question again?

Q. Yes. Mr. Culler made a statement to the Research Advisory Committee meeting, did he not, about the TMI accident?

A. Strictly speaking, several; not a statement, but several.

Q. How did you learn what Mr. Culler said about the accident at that meeting?

A. I only learned that he had said something; I didn't learn the context of it in any detail.

Q. Did you learn the content of his statements in any detail prior to writing and submitting your testimony?

A. Only the notations in the reference -- I submitted as evidence the minutes of the meeting, which were typed in formal form, and also the handwritten notes of the secretary of the meeting in which, at a particular time, toward the very end of the meeting, Mr. Culler then made some statements; and my knowledge of those statements derives entirely from those notes.

Q. You make a statement in your testimony that Mr. Culler reported a telephone call from Mr. Dieckamp about the accident; is that correct?

A. Correct.

Q. And I presume from your testimony that Mr. Culler's statement about the accident is derived from this telephone

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call from Mr. Dieckamp at some previous time.

A. Correct.

Q. And your testimony is that Mr. Dieckamp had indicated "that the situation had deteriorated relative to the perceptions on the previous day;" is that correct?

A. That statement is derived from the written notes of Mr. Elsaesser which I submitted.

Q. I'm asking you, Dr. Zebroski, isn't this what you said in your testimony: that Mr. Culler told RAC of EPRI that Mr. Dieckamp had said to him that the situation at TMI had deteriorated relative to the perceptions of the previous day? That is your testimony, is it not?

A. Yes.

Q. If you know, what was your understanding or Mr. Culler's understanding of the situation the previous day, that is, March 29?

MR. GOLDBERG: Objection; it is a compound question.

Could counsel please separate it and state one question?

MS. BERNABEI: I assume from his testimony that Dr. Zebroski's understanding derives from Mr. Culler's. That's why I stated it as I did.

MR. GOLDBERG: The question is his or Mr. Culler's. If we just get an answer that would state some explanation, not knowing whether it was Dr. Zebroski's or Mr. Culler's --

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I just want one question.

JUDGE SMITH: It can be cleared up. He will explain the source of his information at that time I'm sure.

BY MS. BERNABEI:

Q. What was your understanding of that phrase which you used in your testimony?

A. I became aware of that phrase as it is specifically referred to only within recent weeks as I looked at Mr. Elsaesser's notes of that meeting.

At the time I had only the instruction both from my immediate superior and the later call from Mr. Culler that the situation needed investigation and we should get some staff together to work on it.

Q. So you drafted this testimony and this understanding after your review of notes or minutes of those meetings?

A. Correct.

Q. Do you know whether these are Mr. Dieckamp's precise words to Mr. Culler or Mr. Culler's precise words to the EPRI group on March 30?

A. I have no direct knowledge of that.

MS. BERNABEI: Are we on TMIA Exhibit 5?

JUDGE SMITH: No.

MS. BERNABEI: 6?

JUDGE SMITH: Exhibit 5 is the Cherry/Dieckamp memo.

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We are on 6.

MS. BERNABEI: I would like to mark as TMIA Exhibit 6 what would appear to be minutes of a March 29-March 30 EPRI Research Advisory Committee meeting.

(Whereupon, the document referred to was marked as TMIA Mailgram Exhibit No. 6 for identification.)

BY MS. BERNABEI:

Q. Dr. Zebroski, do you have what has been marked as TMIA Exhibit 6 for identification before you?

A. Are you referring to the handwritten or the typed version?

Q. The handwritten.

A. TMIA 6; yes, I have it.

Q. Are these the handwritten minutes of the meeting to which you referred earlier in your testimony?

A. Yes.

Q. And you reviewed these minutes, did you not, in preparation of your testimony, specifically, that portion which appears on page 3?

A. That's correct.

Q. It is fair to say that the typewritten minutes for this meeting do not mention a presentation by Mr. Culler about the TMI accident; is that correct?

j15

A. They mention that it was discussed. They do not mention the content.

Q. So the handwritten minutes are the only now-existing minutes which discuss the accident and the substance of the discussion of the accident.

A. To my knowledge, yes.

Q. Now, if you can -- referring you to page 4, the last four lines -- moving backward for a moment: who is the author of this record of the meeting?

A. Mr. Lewis Elsaesser, who serves as the secretary of this group.

Q. So it is fair to say that these are in the nature of official minutes of that meeting?

A. The typed version is.

Q. Well, these notes are the notes from which he prepared the typed version I assume.

A. I believe so.

Q. And these are maintained in EPRI files currently; is that correct?

A. Yes.

Q. The last four lines on page 4 of TMIA Exhibit 6 is the description which Mr. Culler gave to the EPRI group on March 30; is that correct?

A. Correct.

Q. If you could read with us, what were his exact

j16

words on that date, at least as reflected in these minutes?

A. "FLC" are the initials of Mr. Culler, Floyd L. Culler -- "re: 3-Mile Island -- very serious." That's underlined.

The next lines are somewhat garbled in the copies, but I think I can make them out and I believe it's correct. The next line reads "significant core damage apparent."

The next line reads "I," which is the chemical symbol for iodine, "leakage likely."

The next word is very hard to make out, but I interpret it as "emergency think teams on-site and in California." Of course, the last word is abbreviated."

Q. Now, if my understanding is correct, this was Mr. Culler's report to the EPRI group of his previous conversation with Mr. Dieckamp; is that correct?

A. Correct.

Q. So one could assume that what appears in these minutes is Mr. Dieckamp's assessment that he communicated to Mr. Culler of the situation at Three Mile Island?

A. That is an inference, but I'm sure Mr. Culler also heard the radio and newspaper reports which had been going on for two days, and he also had heard from the earlier discussion with Mr. Bartnoff, which I also referred to.

It is not clear to me that this would be exclusively derived from that telephone conversation. But if I may carry

j17

on a little bit, the "very serious" words are a very distinct change in signal from the presentation which Mr. Bartnoff had given the previous day, the 29th, and also earlier in the morning on the 30th.

We have subsequently gotten the time of that telephone call as being around 9:00 Arizona time on the 30th, and Mr. Bartnoff had talked to people earlier that morning, apparently, and the previous evening, and there was clearly a change in perception.

That is my interpretation that I have in my testimony; that between the Bartnoff information and the later call from Mr. Dieckamp, there was a clear change in perception. Those were my words in the testimony.

Q That's not quite what you say, though, is it, Dr. Zebroski? On page 3 you say "Mr. Culler...reported to the meeting on a phone call from Mr. Dieckamp," and then presumably the clause which follows indicates what Mr. Dieckamp reported to him, "that the situation had deteriorated relative to the perceptions on the previous day." Is that correct?

A That is correct that that's what the words say, but I have to say that at least part of that is my projection from reading the record of the minutes of the meeting. I'm not sure that either party actually said those words.

Q Now, it is fair to say that part of the report

j18

of Mr. Dieckamp was "significant core damage apparent;" is that correct?

A. That's Mr. Elsaesser's notes; correct.

Q. And "iodine leakage likely;" is that correct?

A. That's Mr. Elsaesser's notes also.

Q. In your testimony you did not state, did you, that Mr. Culler had received this assessment of the situation from Mr. Dieckamp and reported it to the meeting on March 30?

A. (No response.)

Q. That portion of the report you did not include in your testimony, did you?

MR. BLAKE: Objection. The testimony speaks for itself. We all have the testimony in front of us.

MS. BERNABEI: This is cross-examination.

MR. BLAKE: I know it's cross-examination.

THE WITNESS: I'm sorry; I don't understand the question.

JUDGE SMITH: I guess that disposes of it.

MS. BERNABEI: That's fine; I'll repeat the question.

BY MS. BERNABEI:

Q. Dr. Zebroski, you did not include in your description of Mr. Culler's report to EPRI that Mr. Dieckamp had reported significant core damage apparent or that iodine leakage was likely?

A. That was the purpose of appending the minutes and

j19

the handwritten notes, to make that point. I didn't put it in my --

Q. For your reference, that is not a portion of your testimony; that is not included as a portion of your testimony in this proceeding.

A. I'm sorry; that's a technical distinction I don't understand.

Q. What I'm asking you now is about the written testimony, which is the only evidence we now have before us in this proceeding from you, Dr. Zebroski.

A. Yes.

Q. What I have stated to you is that you nowhere in the written version of your testimony, which again is the only thing before the Board at this point, -- we nowhere have a description of the meeting, that is, the meeting which indicates what Mr. Dieckamp said to Mr. Culler, which states that there was significant core damage apparent in Mr. Dieckamp's assessment.

A. I don't believe there was a meeting with Mr. Dieckamp.

Q. No; no. I'm saying in the Culler rendition of his conversation with Mr. Dieckamp, as reported in your testimony, you nowhere state that Mr. Dieckamp told him significant core damage was apparent.

A. (No response.)

j20

Q. Those words do not appear in your testimony.

A. That's correct.

Q. And, in fact, the sense of those words do not appear in your testimony; is that correct?

A. I don't agree with that statement. "Deteriorated," "call staff together to work on it," it seems to me, was a very strong indication of seriousness. We were all aware of the newspaper and radio reports.

Q. And you believe that that includes an indication or an implication that Mr. Dieckamp had indicated that there was significant core damage at TMI on March 30 or by March 30?

A. To me the word "deteriorated" has that indication.

Q. Were you informed of Mr. Dieckamp's assessment of significant core damage at TMI at the time you began your assignment?

A. If you define the time of the assignment I can answer your question.

Q. Yes; March 30.

A. I would say that would only be a possible inference, but not a knowledge.

Q. So Mr. Culler did not tell you Mr. Dieckamp's assessment at the time he outlined for you your role in the analysis?

A. That is correct.

Q. Do you today know the basis for Mr. Dieckamp's

j21

assessment on March 30 that there was significant core damage?

A. Not really. I can infer it from a great deal of the testimony that has been transcribed, but not directly of my own knowledge. I don't have a basis for that.

Q. When did you receive an assignment to undertake a core damage assessment? That is referenced on page 3 of your testimony.

A. I think in the sense of a general assignment to participate or at least to get knowledgeable, that occurred, well, in a limited extent in the call from Mr. Levenson on the evening of the 29th to basically get a team together and start working.

Q. What did Mr. --

A. May I finish the answer, please?

Q. I'm asking for the first time now.

A. That's what I'm trying to define. As I understood, however, at that point it may have amounted to no more than to spend a couple of days at the blackboard and accumulate the information to do something about it. There was no necessary implication of spending some time at Three Mile Island or the extended study which actually followed. Those assignments came in stages. So, strictly speaking, the assignment -- there was not an assignment; there was a series of assignments.

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I am responding to your question on the first assignment, which I think is really limited to: get knowledgeable and get a meeting together tomorrow morning.

Q. What did Mr. Levenson say was the condition of TMI-2 on the evening of March 29 when he spoke to you?

A. We had no technical discussion. He was aware that I was aware of the radio and newspaper reports, and he said: let's get together and get more informed on it.

Q. I believe -- what did he say was the condition of TMI-2 at that time in terms of core damage?

A. To my knowledge, there was no technical discussion at all in those telephone calls.

Q. No technical discussion.

A. No.

Q. What did you understand your assignment from Mr. Levenson to be?

A. To gather information.

Q. On what?

A. On the situation at Three Mile Island, which had had many confusing reports in the media.

Q. So you were supposed to talk to the newspapers about the condition of TMI-2?

A. No; to gather information directly from the plant sources.

Q. For what purpose?

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A. It was related -- EPRI, among other things, had testing programs on fuel behavior under both normal and abnormal conditions, so this related to that.

Q. Were you to do any assessment of core damage? Was that any part of your assignment as given to you by Mr. Levenson?

A. At that time that was not mentioned. There was no technical discussion in those telephone calls.

Q. So the idea, according to your testimony, is you were supposed to do general research activities at EPRI somehow related to the incident or accident at TMI-2 on March 29?

A. In a sense, yes. Our research objectives are defined by real world observations, and in that sense being informed will enable you to direct the research better. So, initially that was the objective.

Q. Were you to provide technical assistance in any sense to the site?

A. That step came in the telephone call from Mr. Culler, who recounted that he had a request for assistance from Mr. Dieckamp.

Q. Did Mr. Culler, after his call to Mr. Dieckamp, then give you an assignment, a second or different assignment?

A. Not really. I think he simply echoed the "get informed." It is hard to define an assignment when nobody really knows the situation.

j24

Q. At what time did he tell you to get informed?

A. I'm sorry.

Q. At what time did he tell you to get informed?

A. I haven't been able to place the time of that call. I can place Mr. Levenson's call as rather late in the evening on the 29th, but I can't place the time of Mr. Culler's call.

Q. Was it on the 29th or on the 30th?

A. I believe it was on the 30th.

Q. Do you remember whether it was before or after his presentation to the EPRI Research Advisory Committee?

A. I didn't know the time of that meeting, so I can't answer your question.

Q. Do you know if it was in the morning or in the afternoon?

A. I can't really place that either.

Q. Now, after Mr. Culler gave you the instructions to get informed, what did you do?

A. I believe we placed some calls to people at GPU. I am not clear whether I called there or they were calling us because they also had instructions to work with us, I believe. But, in any event, a conference call with Mr. Keaten developed, as my notes show.

Q. Do you know what time that call from Mr. Keaten was?

A. My notes submitted also in the testimony -- I have

j25

to refer to this -- it's around 9:00 in the morning California time, or about noon New Jersey time.

Q. Dr. Zebroski, for your information none of these notes were submitted with your testimony; these notes were submitted in the discovery portion of these proceedings. They are not before the Board unless they are entered in the record.

A. Then I will answer directly.

MS. BERNABEI: I would like to have marked as TMIA Exhibit 7 a portion of the 3/30/1979 notes of, apparently, Dr. Zebroski's morning conversation with Mr. Keaten.

(Whereupon, the document referred to was marked as TMIA Mailgram Exhibit No. 7 for identification.)

THE WITNESS: On those notes I marked the time as 9:15, March 30, 1979. I presume that's a.m.

BY MS. BERNABEI:

Q. It is fair to say that whatever time you talked to Mr. Culler was prior to your conversation with Mr. Keaten?

A. Again, I am not quite sure of that. I had already had sufficient indication from Mr. Levenson to expect that we would be discussing with the people in Pennsylvania and New Jersey --

Q. Let me just interrupt for a moment. What was your

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understanding of the purpose of your conversation with Mr. Keaten at 9:15 on March 30?

A. To try to get a less confusing picture than we had heard through the radio and the media accounts.

Q. You say that you at this time did not have an assignment from Mr. Culler; is that your testimony?

A. As the assignment eventually developed, the answer is no, as the assignment as I described in the first question was clearly an assignment to get informed and there was an implication that we might be prepared to do more later; but that was not yet assigned.

Q. Did you know that you were to undertake a task which you call core damage assessment at the time that you talked to Mr. Keaten?

A. I did not know that in the sense of an instruction, but Mr. Culler did mention that Mr. Dieckamp had suggested four tasks, one of which was core damage assessment. And since the behavior of fuel and components was part of our normal responsibility, the inference was fairly obvious.

Q. Is it fair to say then that at the time you talked to Mr. Keaten at 9:15 a.m. on March 30, you knew you would undertake an assessment of core damage; that is one of the four tasks that Mr. Dieckamp had set out?

A. Yes, but the extent of that assessment was certainly not defined.

j27

Q. Some assessment.

A. Spending time at the island and so on was not defined.

Q. But some assessment you would do.

A. That's correct

Q. During this conversation with Mr. Keaten, he gave you a briefing on the status of the reactor; is that correct?

A. Yes.

Q. And it is fair to say that he wanted to bring you up to speed on what had occurred up to that time?

A. That was the purpose, yes.

Q. To that degree you were told of the sequence of events up until Friday morning?

A. At the time I would have said yes. I think in retrospect I have to say it was fragmentary.

Q. Mr. Keaten was also -- one of the purposes was to inform you about the bubble in the reactor vessel; is that correct?

A. Correct.

Q. And the state of information about that bubble?

A. Correct.

Q. And that is reflected in your notes, TMIA Exhibit 7; is that correct?

A. Yes.

Q. You have certain information noted here, and I

j28

would like to ask you for what period of time this information was gathered.

There is a notation in the beginning of your notes which says: one RCP, reactor coolant pump, was running; one S/G, steam generator, was running; is that correct?

A. That's correct.

Q. And then there is a notation that that was true on Thursday; is that correct?

A. That is my interpretation of my scrawl, yes.

Q. Was it your interpretation at the time you wrote these notes that that was the situation on Thursday?

A. That's what I had been told, yes.

Q. There are certain notations that appear, certain parameters that appear later: 1000 psi; 260 to 280 degrees Fahrenheit; is that correct?

A. Yes.

Q. What are those parameters.

A. I would interpret them as applying to the same Thursday night time interval that applied in the previous two lines: during the night, large quantities of gas in primary system. I presume that means Thursday night, but he's talking Friday morning; so that's the implication that that is as current as his information was.

Q. Do you have any more specific information or knowledge about when those parameters were mentioned, that is,

j29

the 1000 psi, the 260 to 280 degrees Fahrenheit?

A. I do not, except from the later investigation, of course. At that time the answer is I did not.

Q. Dr. Zebroski, what was your understanding of what these pressure and temperature readings indicated? Could those be the reactor coolant system pressure and temperatures?

A. That would be my interpretation.

MS. BERNABEI: I would like to have the parties and the Board refer to TMIA Mailgram Exhibit 2, which is a part of Mr. Seelinger's log for March 29, 1979.

BY MS. BERNABEI:

Q. Dr. Zebroski, I think I may show you my copy of this exhibit and ask you to refer to what has been marked as page 7 of TMIA Mailgram Exhibit 2.

JUDGE LINENBERGER: Are you referring to the joint exhibit?

MS. BERNABEI: No. It's one of the exhibits we introduced, I believe, with Mr. Lowe. We introduced it and then entered into a stipulation, so it is not in evidence.

JUDGE SMITH: Where are we on this exhibit?

MS. BERNABEI: I believe it's marked page 7. It's the fifth page of the exhibit, but it is marked page 7. There is pressure and temperature at the bottom of that page.

Judge Smith, may I be allowed to share the exhibit with the witness? We did not make additional copies.

j30

JUDGE SMITH: Let's see if the Board can't share.

(Document passed from Judge Smith to Ms. Bernabei.)

BY MS. BERNABEI:

Q. Dr. Zebroski, the entry which appears on the bottom of page 7, that is, the reactor coolant system temperature and pressure, appear to be the same readings which Mr. Keaten gave you on the morning of March 30; is that correct?

A. May I take a little time to look at that?

Q. Certainly.

(Witness perusing documents.)

A. Well, there is partial overlap. There is a number of things on page 7 which are not in my telephone notes.

Q. Right, but I am just sticking right now to the reactor coolant system temperatures and pressures -- excuse me; temperature and pressure, the 280 degrees and the 1000 psi.

A. That seems to coincide.

Q. It appears from the notes, does it not, to be the conditions or parameters of the reactor at 1330, that is, 1:30 p.m., on March 29?

A. I can't really make that out on my document.

MR. BLAKE: I'm sorry; are you reading that as 1330?

MS. BERNABEI: Yes.

THE WITNESS: I would interpret it as 1830.

j31

BY MS. BERNABEI:

Q. As 1530?

A. 1830 I think it would read, because the previous entry is 1745.

Q. 1830.

A. Yes.

Q. In any case, 1830 would be 6:30 in the evening; is that correct?

A. Yes, but I can't tell from this what day.

Q. On the front of the notes it says March 29, so we will assume for the moment that it is March 29.

A. These aren't my notes. I'm getting very skittish about trying to interpret somebody else's notes.

Q. No. I understand that. I'm just saying that these are the same reactor coolant system temperatures and pressures as noted in your notes; is that correct?

A. Two of the numbers coincide; there are many others which don't appear in my notes.

Q. You have a notation in your notes, returning to somewhat more solid ground, your notes, which is TMIA Exhibit 7 -- you have a notation that at that time there was an understanding that there was approximately 1500 cubic feet of gas in the pressure vessel and pressurizer?

A. That's what my notes show.

Q. I believe it is your testimony that at that time

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neither GPU nor others understood the composition of that gas bubble; is that correct?

A. On the fourth line from the bottom it says: "don't know what is in gas." I presume I got that from the telephone conversation.

Q. Was one of the considerations that this bubble could be a steam bubble? Was that a consideration at this time?

A. I wouldn't interpret it that way. I think when people say gas, that does not usually imply steam.

Q. Is it fair to say that the consideration at that time was that the bubble was non-condensable gas, possibly hydrogen?

A. Yes. Again, if I could clarify, I think there are two levels of understanding here, the level of understanding which I had at the time that I wrote these notes --

Q. I understand.

A. -- which left that question very ambiguous. Our later knowledge made it very clear that it was hydrogen, or substantially a mixture of hydrogen and steam, and perhaps traces of other things.

Q. At any time in your analysis did you come to learn that there was a concern about a steam bubble prior to March 30, that is, prior to the time you learned of the status of TMI-2?

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A. May I repeat the question to make sure that I understand it? You're asking me if prior to March 30 I knew that there was a steam bubble in the reactor?

Q. No. At some time during your involvement, up to the present, did you learn that there was a concern on site about a steam bubble in the system or in the reactor vessel?

A. Taking knowledge up to the present?

Q. That's correct.

A. Oh, yes, indeed.

Q. Did you understand this concern to exist on March 29, or do you understand --

A. I have no direct knowledge of that.

Q. I asked you if you had any knowledge up to the present time.

A. From the analysis?

Q. Yes.

A. I think our analysis suggests that by the 29th, yes, that was understood to have been a steam bubble.

Q. That was a steam bubble in the reactor vessel?

A. Somewhere in the vessel head certainly, and possibly, in the steam generator.

Q. It's fair to say that it would not always be clear whether a bubble in the reactor vessel were a steam bubble or a hydrogen bubble, is that correct, or non-condensible gas is perhaps a better way of phrasing it?

A. Strictly speaking, you could have both simultaneously; the bubble could be partly gas and partly steam. In fact, at all times it was a combination of gas and steam.

Q. What I'm talking about is primarily a steam bubble, a primarily hydrogen non-condensible gas bubble. It's fair to say that knowing there was a bubble in the reactor vessel, one could be unsure as to whether it was primarily a steam bubble or primarily one of non-condensible gas.

A. Could you add to the question. Understanding as of now or as of March could be very different.

Q. As of March.

A. As of --

Q. Perhaps I should clarify. My question is: on March 28 or March 29, one could be unsure whether a bubble that was seen in the pressure vessel was of hydrogen or non-condensible gas primarily or was a steam bubble.

A. I am having a hard time coming to grips with that question.

Q. There was a concern about the bubble in the pressure vessel on March 29; is that fair to say?

A. That's correct.

Q. What I'm asking you is: isn't it true that that concern could be based in part on an uncertainty of whether it was a steam bubble or a non-condensible gas bubble or a hydrogen bubble?

A. Certainly as time went on, there was an increasing understanding that it was not just a steam bubble. In fact, even the occurrence of the steam bubble at that time was not part of the general training and understanding and analysis on reactors; so even that was a surmise for those people. And as we know from other matters, it had only been recognized in the NRC analysis and the B&W analysis, but not yet communicated to the people at the site.

Q. In any case, there could be uncertainty if one were to know there were a bubble in the pressure vessel whether it was non-condensible gas or steam?

A. Yes, indeed.

Q. Assuming for the moment -- again, I'd like to stick for the moment to what people knew back on March 28th and 29th.

If one were to assume there were a steam bubble in the reactor vessel and that there were a reactor coolant pump operating, would you not have been led to believe that after a certain period the steam bubble would be collapsed or condensed such that it would disappear after a certain point?

A. That would be true only if there was a source of water at a sufficient pressure. Simply running the circulating

pump wouldn't ensure that. It would also require the heat pump be running and not be throttled back.

Q. Now, you're talking about HPI?

A. Yes.

Q. What flow in HPI would be necessary in order to cause this condensation of a steam bubble?

A. Any flow in excess of the letdown would eventually accomplish that. If it was only slightly in excess of letdown, it would take weeks. If it was done at full flow of the pump, it could take perhaps half an hour.

Q. Full flow of one pump?

A. No, three pumps.

Q. Full flow of three pumps. What pressure conditions would be necessary?

A. I believe the pumps are capable of providing pressures up to 2,600 psi. So they have the capacity of collapsing the bubble, the steam bubble, regardless of the system pressure.

Q. So it's fair to say that if all three reactor coolant pumps were running at full flow for about a half an hour, they would be capable of collapsing a steam bubble?

A. I have to back off on the half hour. It depends on how big the bubble is. Let me answer the question this way: if the bubble is of X cubic feet, then three times the maximum pump flow divided into the X cubic feet will give you

the minutes approximately of the collapse.

MR. BLAKE: Ms. Bernabei, would you agree to just correcting the record at this point in your question that you meant high pressure injection pumps rather than random fuel pumps when you referred to all three pumps running?

THE WITNESS: I referred to high pressure injection. I agreed with Ms. Bernabei when she identified the pumps and specifically --

MR. BLAKE: Excuse me, Dr. Zebroski. Ms. Bernabei, would you agree that that was what you were referring to in your question?

MS. BERNABEI: Yes.

BY MS. BERNABEI:

Q. In terms of the reactor coolant pump, could the flow from the reactor coolant pump similarly collapse the steam bubble in the reactor vessel?

A. If you specified a great many more conditions, it is possible; but in general the answer would be no, that alone would not do it.

Q. What condition would you need to specify in order to make that determination or evaluation?

A. You would have to specify the amount of residual heat in the system -- that is to say the heat capacity of the vessel -- how much make-up flow you were providing from high pressure injection, how much letdown flow was occurring and

the initial size of the bubble.

Q. Excuse me?

A. And the initial size of the steam bubble.

Q. From your analysis -- and I would like you to assume now from the depth of knowledge which you gained during your analysis -- assuming the conditions of one reactor coolant pump running, assuming also the make-up and letdown flow that existed on Thursday afternoon at TMI, and assume --

A. May I write this down, because it is going to be hard to juggle all of these?

One circulating pump running.

Q. Reactor coolant pump; right?

A. Yes.

Q. And assume the make-up and letdown flow that you know to have existed on March 29th.

A. I am sorry. That makes it impossible for me to answer without referring to the documents, because I don't know from my memory what the flow was on March 29th.

Q. You'll certainly be allowed to do that. And the size of the bubble which you came to know or you have come to know existed on Thursday.

A. Yes.

Q. And my question is: if possible, how long would it take to collapse a bubble if it were a steam bubble believed to have existed in the reactor vessel? If you need to refer

to --

A. Well, qualitatively, let me see if I can get the intent of the question. If I miss the intent, please correct me.

Q. Sure.

A. I think that scenario of high pressure injection to collapse a steam bubble I believe had already been tried before, and the fact that the bubble had not collapsed and condensed indicated that it was the non-condensible gas. presumably hydrogen.

So had it been a steam bubble--I think I can bypass the qualitative subject-- it would have collapsed already. Was that the thrust of your question?

Q. Yes. When had that attempt been made to collapse the bubble? Was it sometime on Thursday; is that fair to say?

A. Well, the make-up pumps, I believe -- let me refer to another exhibit here.

Q. Sure.

A. The block valve was closed and remained closed at about not quite 15 hours into the accident, and the high pressure injection pump was turned on -- and this still leaves me at a loss because I don't have the March 29th information here. But it is my impression that at one point, the high pressure injection was left on for a fairly long time and the reactor coolant pump was started.

Had you had only steam there, then certainly by sometime on the 29th a steam bubble, if that was the only gas that was present, would have been collapsed. The system pressure was raised sufficiently. Enough water was going in.

Q. There is evidence that the reactor coolant pump started I believe at 7:20 or 7:40 in the evening of March 28th and stayed on at least through the evening period of March 29th.

By what time would you expect the steam bubble to have collapsed on March 29th?

A. That's an extremely complicated question. It also would depend on the condition of the steam generators as to heat sink. So you would really have to specify a lot more.

Q. Assume that there was at least one steam generator running.

A. If you had a steam generator filled and the pump that was running was feeding that side, and if you had only the steam bubble, then you would expect the steam bubble to collapse fairly quickly.

The operation has been done a number of times since then in similar instances.

Q. When you say "very quickly," how much time?

A. Again, it would depend on the parameters. I think I gave a rough way of estimating it before. Certainly it won't collapse any faster than you supply the volume of water equivalent to the bubble. It may collapse more slowly than

that if the capacity is higher.

Q. Assuming that the reactor coolant pump is started in the evening, 7:20 or 7:40 p.m., on March 28th and that there is one steam generator running in that period or shortly thereafter, when you say "very quickly," how quickly could you expect the steam bubble to collapse?

A. Please define the conditions once again. I can't juggle them all.

Q. Yes. Assume the conditions you knew existed in the evening of March 28th as well as the fact that a reactor coolant pump was started I believe at 7:20 p.m., 7:40 p.m. that evening. Assume also that there was HPI that was on and remained on and increased to the extent that you know at 5:30 p.m., and that there was one steam generator running.

How long would it take to collapse the steam bubble?

A. To make a qualitative estimate, it would be less than a couple of hours. That is really not based upon any direct calculation of that system but knowledge of other systems like the Crystal River incident in 1980.

Q. Returning for a moment to your notes for March 30th, I believe it's your testimony that at this point Mr. Keaten at GPU knew or indicated to you they knew that the bubble was a non-condensible gas bubble and not a steam bubble; is that correct?

A. That is partly inferable from my notes, but I

think it is also part of my recollection. The notes say: "Don't know what is in gas. Borated water with air in it." So it implies the concern that some of the gas may be air.

Q. Do you know when Mr. Keaten or GPU came to the conclusion that the bubble in the reactor vessel was not condensible gas?

A. I have no direct personal knowledge of that. I have seen various testimony which appears plausible in terms of the sequence of things that happened. That perception arose sometime during the 29th.

Q. Did you ever analyze or study when there was an understanding within GPU of the bubble as being one of non-condensible gases? Was that part of your study or analysis of the accident?

A. No. I think as our report stated, we had already heard so many contradictory perceptions from the operating people, that we were trying to stick entirely to the hard record, the recorders and so on.

Q. I believe it's your testimony that the first time you were aware of the pressure spike was on March 31st; is that correct?

A. I cannot place it for you that accurately. That's a guess.

Q. That was at the first meeting that you attended at the TMI site concerning your duties regarding analyzing the

accident?

A. Again, I have to say that's a guess. It was sometime in the period of those two or three days, but I couldn't place it as to that particular afternoon.

Q. It is your testimony, though, is it not, that sometime during March 31 you became aware of a pressure spike?

A. As I say, I can't place the time. That's a guess. That's my best guess.

Q. You attended a meeting, an orientation meeting, did you not, on the afternoon of March 31st?

A. Right.

Q. Mr. Dieckamp was present at that meeting; is that correct?

A. Correct.

Q. Was there any assessment provided of core damage at that meeting?

A. I think in the strict sense of the word, no. I think the circumstances were described, and I think it was intended that the groups with the various assignments make their own assessment. So I think we were not led into conclusions, as near as I can recall.

Q. Was any assessment made of core damage at that meeting? Perhaps I should say: was any assessment expressed at that meeting?

A. If we define the terms as we discussed in the

deposition, there was certainly clear awareness of fuel damage. Core damage, as we discussed before, has a wide spectrum of interpretation. So with that distinction made, there was no discussion of core damage.

Q. And the way you are choosing to interpret it, if I am correct, is there was no assessment of structural core damage?

A. That's correct.

Q. But there was an assessment, was there not, of fuel damage -- core damage in the sense of fuel damage?

A. Not so much assessment as the fact that there were radiation observations.

Q. And that assessment was, was it not, that there was at a minimum 15 percent failed fuel?

A. That number was bandied about. I think it was recognized that it had very little basis. In fact, it was a guess from the radiation level.

Q. You testified at a prior time that the assessment at that point of core damage, meaning fuel damage, was at a minium 15 percent? That was the working figure that was used. It may have ranged higher.

A. I guess you are referring to the deposition. Shall we say, as a normal human being, in any situation you have an intuitive guess of the situation.

Q. No, no, no --

A. As an investigator --

Q. I'm talking about what was expressed at that meeting. Have you ever testified that expressed at that meeting was an assessment that core damage in the sense of fuel damage was at least 15 percent?

A. I am trying to answer that question.

Q. Can you answer it yes or no, Dr. Zebroski?

A. No, ma'am, I can't.

Q. Did you ever testify at a prior time that the range of possibilities discussed at that meeting in terms of core damage defined as fuel damage was 15 percent with an undefined higher range?

A. In my understanding of the word "assessment," I would have to say no. As an investigator, we consider a range of possibilities, and certainly in that sense of the word a range of possibilities was expressed. As an assessment, clearly no.

Q. That range of possibilities which was expressed was for 15 percent core damage defined as fuel damage upward; is that correct?

A. I believe, if I recall what I said was that I had no reason to dispute a number which everyone recognized to be very vaguely based on a guess.

As a working number to start with, clearly there was a radiation level and clearly there was some fraction of fuel

leaking; and when you hear people who are acquainted with the situation some days longer than you have giving a number, you have no reason to dispute it, but I also didn't believe it particularly.

Q. Mr. Dieckamp appeared in agreement with this possibility of 15 percent or upward of failed fuel or core damage defined as failed fuel.

MR. BLAKE: Was that a question?

MS. BERNEBEI: Yes, it is a question.

MR. BLAKE: Can you repeat it, please?

THE WITNESS: I have no way of --

JUDGE SMITH: Wait a minute, please.

MR. BLAKE: Could you repeat the question?

JUDGE SMITH: I didn't understand that as a question.

MR. BERNEBEI: It was a question, but I'll lay some foundation to alleviate Mr. Blake's objection.

BY MR. BERNEBEI:

Q. Mr. Dieckamp was at this meeting, was he not, on March 31st?

A. (Witness nodding affirmatively.)

Q. You will have to say yes or no, sir, for the record.

A. Yes.

Q. Was he in agreement to your knowledge with this estimate of 15 percent or greater fuel damage or core damage?

A. I can't really tell. I can only say he didn't

either agree with it or disagree with it. It was discussed, and I presume that had he felt strongly about it in either direction, he would have made that known. There was a working assumption recognized by all as being highly uncertain.

Q. The working assumption was that there was at least 15 percent fuel damage; is that correct?

A. I am not even sure that the "at least" was present. The number was bandied about with recognition that it was on a very conservative basis.

Q. Have you testified at a prior time that the working assumption was 15 percent ranging up to an undefined upper limit of core damage?

A. I --

JUDGE SMITH: Wait a minute, please. Ranging --

MS. BERNEBEI: Up to an undefined upper limit. That is ranging upward without limit. The words were not good, I agree.

THE WITNESS: I believe --

BY MR. BERNEBEI:

Q. Is that your prior knowledge? Is that your prior testimony, Mr. Zebroski?

A. May I decompose the question? As an assessment, no. As a working basis for an investigator, yes.

Q. So your working basis was at a minimum there was 15 percent core damage?

A. No. I can't even say as a minimum. That was a

central value around which a lot of uncertainty existed in both directions.

Q. Would you refer to pages 43 and 44 of your deposition? Do you have that in front of you?

A. I think I can find it.

MS. BERNEBEI: For the record, that is a deposition that was taken of Dr. Zebroski on November 6th, 1984 to this proceeding.

THE WITNESS: Ye , ma'am; I have it.

BY MS. BERNEBEI:

Q. I would like to refer you now to the question starting on page 43, line 19. Question: Can you then tell me what was the range of possibilities that you had in your mind at that time? Answer: I don't think I can put an upper limit on it. I would say that the 15 percent minimum seemed very plausible, and I had no feeling for an upper limit.

Was that your testimony at that time?

A. That is what the record shows.

Q. On pages 5 and 6 of your testimony, you talk about, if I am characterizing it correctly, a misconception within the NRC staff about the possibility or the likelihood of a hydrogen explosion at TMI on March 30th; is that correct?

A. I don't see that on pages 5 and 6 -- oh, the testimony. Yes, ma'am; I have it now.

Q. You talk in those two pages about a misconception

that you perceived within the NRC staff about the possibility of a hydrogen explosion, is that correct, on March 30th?

A. Is there a particular line or paragraph that I should --

Q. I'm talking generally about the discussion on page 5, the paragraph continuing to the top of page 6.

(Witness perusing document.)

A. Now, what was the question, please?

Q. You discuss in the portion of your testimony I pointed out generally a misconception within the NRC staff in your mind which existed on March 30th as to the possibility of a hydrogen explosion at TMI.

A. Yes, I believe that was a misconception.

Q. That is generally what you discuss, a misconception within the NRC staff?

A. Yes.

Q. If I understand, you are not contesting in this discussion that there was, in fact, hydrogen present in the pressure vessel at TMI on March 30th?

A. No, I don't.

Q. Your contention is essentially there was not oxygen present such as to cause combustion or an explosion?

A. Correct.

Q. If I understand from your later testimony the basis for your analysis is that the hydrogen which was present

suppressed to some degree the radiolysis such that oxygen was not produced to create an explosion; is that correct?

A. Yes, ma'am.

Q. Referring you to the last sentence of the paragraph -- excuse me; the paragraph which continued onto page 6 which talks about inquiries to national laboratories, I would like to read the sentence and ask you some questions about it.

You say: "It was later evident that the earlier inquiries to the national laboratories did not indicate that hydrogen was present in the reactor vessel."

Now, you're talking here about inquiries from the NRC staff to national laboratories?

A. I believe so.

Q. Do you have any direct knowledge of what inquiries the NRC made to national laboratories concerning the hydrogen bubble in the TMI reactor vessel on March 30th?

A. As we discussed in the deposition, I have no direct knowledge of the specifics of those inquiries, but can only infer this from the answers given.

Q. Whatever information you have about inquiries to national laboratories comes essentially from the responses of the national laboratories back to the NRC staff; is that correct?

A. Correct.

Q. You are not stating in your testimony, are you, that the inquiries from the staff to the national laboratories were wrong in that they indicated hydrogen was present in the reactor vessel?

A. In that they failed to indicate that hydrogen was present.

Q. Your testimony is that those inquiries failed to indicate that hydrogen was present in the reactor vessel?

A. I --

Q. I'm just asking for an explanation of your testimony.

A. Yes, I'm coming to that. There were two related questions being asked and there wasn't sufficient distinction made between them. One is the radiolysis in the sump where there is also known to be radiation from the failed fuel and radiolysis in the vessel where the presence in the atmosphere of hydrogen was very different from the situation in the sump. And the answers that they received clearly indicate that those two conditions were not well discriminated in the posing of the question.

Q. But insofar as this sentence states the NRC staff did not indicate hydrogen was present in the reactor vessels in inquiries to national laboratories, that is not correct; they did, in fact, so indicate that, did they not?

A. In the context of the question on the expected

radiolysis rate, the situation of the hydrogen was clearly not made clear because the people who answered the question on the radiolysis rate, had they been asked, would have also answered that there was a very high recombination rate under the same circumstances. So by not giving that answer, it's clear they were not asked that question.

Q. But what you're saying is inferring now from the answer of the labs, not the direct inquiries, you're inferring that the representation or the description of the hydrogen present in the reactor vessel was not accurate, not that the staff told these national laboratories there is no hydrogen; is that correct?

A. I can only infer that the presence of the hydrogen was not called to the attention of the people who were being asked the question about radiolysis.

Q. Your testimony is that you have no direct knowledge. You only have what knowledge you gained from the answers of the national laboratories?

A. Correct.

Q. At page 6 of your testimony, you speak about your efforts to estimate the extent of core damage, and I think you base your observations in this and the following portions of your testimony on the information available to you from the March 30 through April 4 period; is that correct?

A. Approximately, yes.

Q. And if I understand --

A. Well, including whatever information we had on the 28th and 29th, of course, also.

Q. I am talking now about your assessment of the seriousness of core damage. You base that assessment, as described in your testimony, on what was available to you from March 30th to April 4th?

A. Yes. The assessment at that time was based on the knowledge at that time.

Q. It was not the information available to GPU generally or site personnel generally but to you. That's what I'm trying to --

A. Oh, I see what you're saying. Well, I think we were granted access to most knowledgeable people. So I had to at least assume that we had the information.

Q. Right; but whatever opinions you express in your testimony is on the basis of what you had available to you?

A. Yes, ma'am.

Q. Now, I believe you say that based on the information available, you came to an assessment that core damage -- and I'm talking about your assessment in the early period through April 4th -- your assessment was that the core damage was not as serious as would be expected from the analysis in Wash-1400 and the NRC licensing criteria?

A. Correct.

Q. Now, with 20/20 hindsight, in fact, the extent of core damage at that time was as great as would be expected in an analysis in Wash-1400 and the NRC licensing criteria; is that correct?

A. That is not correct. There is no such analysis in Wash-1400.

Q. I would like to read you the second sentence of the testimony on page 6, the first full paragraph: "The prevailing state of knowledge on possible reactor core damage as of 1979 was the analysis in the report Wash-1400."

I am asking you if you applied the prevailing state of knowledge in the Wash-1400 analysis --

A. Yes.

Q. --and the related NRC calculations that were used in licensing at that time --

A. Yes.

Q. -- you would reach a more correct assessment of the degree of core damage at TMI than you, in fact, reached based on the information available to you March 30 through April 4; that is that there was serious core damage? I am talking with hindsight now.

A. As a speculation, I certainly had to consider that possibility based on the state of knowledge at that time. I would be hard pressed to give good reasons for it.

Q. I'm not asking you about what you did at the time.

I'm saying: given what we know today about the extent of core damage at TMI-2, isn't it true that whatever analysis would be reached through the information available in Wash-1400 and the NRC calculations used in licensing would be closer to the mark in your assessment based on the information available to you in this early period? That is there was more serious core damage than you understood.

A. No. I am afraid that is seriously wrong, because some of the very basic information didn't arrive until a day or two later.

Q. I am talking about right now.

JUDGE SMITH: I recognize several time periods implicit in your questions, and I think the witness is having trouble sorting out your time periods.

MS. BERNABEI: Okay; let me try to clarify it. I agree with you, Judge Smith.

BY MS. BERNABEI:

Q. You talk in your testimony about how your evaluation through the period of about April 4th that there was less serious core damage than would be believed if one applied the analysis in Wash-1400 and the related NRC licensing calculations; is that correct? I'm just talking about what your testimony says.

A. (No response.)

Q. Isn't that the import?

A. Let me read it.

Q. Sure; page 6, the first full paragraph.

A. I see it.

(Witness perusing documents.)

I wouldn't change those words, because there was really -- between the situation of either a small or a large number of fuel leakers and the situation of extensive melting of the fuel, there was no discrimination in Wash-1400.

Wash-1400 specifically states -- and then the appendix qualifies that there is a large degree of analysis that was not done -- basically states that if the fuel gets somewhere over 2000 F you go to meltdown and then describes the consequences of meltdown. But it makes no description of the intermediate states. In fact, the means for making those calculations did not exist in 1979. The basic data on which to make those calculations did not exist.

Q. I think the question I asked you was a little more simple, Dr. Zebroski. The question is: if one applied the Wash-1400 analysis or knowledge gained in the Wash-1400 and also if one assumed what you call the NRC calculations used in licensing and reached an estimate based on the conditions you knew at that time, wouldn't one reach a closer estimate to the degree of core damage than you reached in your analysis with the information available to you; that is that there was serious core damage?

A. I tried to answer that several times. As my personal speculation, because I have done test work which carried fuel through extensive damage, I haven't considered that as a real possibility for the investigation. But as a reasonable thing that one would write down as a conclusion or an assessment at that time, we didn't have the information yet.

Q. Isn't it true that a new Department of Energy study has indicated, in fact, a portion of the fuel at TMI melted?

MR. BLAKE: Objection.

THE WITNESS: That was also --

MR. BLAKE: Objection, Dr. Zebroski.

JUDGE SMITH: When an objection is made, we want to avoid your answering until there has been a resolution on it.

THE WITNESS: All right.

MR. BLAKE: The nature of my objection is relevance. I don't see it.

JUDGE SMITH: What is the relevance?

MR. BERNABEI: I assume in the context of his testimony Dr. Zebroski -- his testimony is being offered to show the low rate of understanding -- not rate -- the low level of understanding of core damage at the time of the TMI-2 accident.

It appears to me that some of the NRC reports and calculations he criticizes in his analysis were, in fact, closer to assessing and understanding the extent of core damage at

TMI than his own. And I think given that he has chosen to criticize the NRC staff's understanding of core damage and understanding of the accident that that is fair ground to ask him: given what we know today, weren't they perhaps closer to the mark than you were in your analysis. That's really the extent of it.

JUDGE SMITH: The way you jump around in time periods, it is very, very hard for me to follow the logic of your question.

MS. BERNABEI: I frankly don't see the relevance of a great deal of this, but since it has been at least for questioning allowed in this proceeding, I think it's fair to ask Dr. Zebroski whether or not those NRC regulations and reports which he criticizes were, in fact, closer to assessing core damage than his own assessments at this period. That's what I understand the import of his testimony to be.

JUDGE SMITH: Even if that were the case, then of what value is it to you, to the witness and to the Board, a newspaper clipping of last week?

MS. BERNABEI: I don't think it's a newspaper clipping. It's a Department of Energy study that was --

JUDGE WOLFE: In any event, what is the importance of it?

MS. BERNABEI: I frankly don't see the importance of this testimony, but it seems to me that the credibility of his

testimony is open to question and the scundness of his testimony is open to question given that the Board is going to consider it and did not strike it as I moved.

JUDGE SMITH: Certainly his testimony is not going to be impeached based upon any Department of Energy newspaper account of last week. So from that point of view, it's irrelevant.

MS. BERNABEI: I just proffer that I think the Department of Energy study was not a newspaper account but in fact a study that was either authorized, directed or otherwise recommended by the NRC --

JUDGE SMITH: I'm sorry; I was careless in my speech. The only thing that the Board knows about the study that you are talking about is a newspaper account.

MR. McBRIDE: Mr. Chairman, I hadn't expected to have to participate, but I have to note that I think it is quite wide of the mark for Ms. Bernabei to comment about a witness' credibility, a man as distinguished as Dr. Zebroski.

JUDGE SMITH: Mr. McBride, I am afraid we will have difficulty. I agree that Dr. Zebroski would under certain circumstances have independent rights not to be badgered, not to be ridiculed, not to be mistreated, and your presence here for that purpose is welcome. However, when he agreed to testify, he put in issue his expertise, his credibility and the believability of his testimony.

Counsel for Licensee, short of abuse of the witness, will be the only one having standing -- well, of course, the parties will be the only ones who have standing. So I would appreciate it if you would reserve your comments about his status and his believability and credibility until you perceive personal abuse, and then by all means when that happens, please bring it to our attention.

MR. McBRIDE: I will just say that I am not trying to interject. The only reason I did it is --

JUDGE SMITH: Wait. We've run out of tape. We'll take a 10-minute recess.

(Recess.)

JUDGE SMITH: On the record.

Mr. McBride, you may complete your remarks.

MR. McBRIDE: I don't see any need to say anything further, Judge Smith.

BY MS. BERNABEI:

Q. I would like to refer you down to the portion of your testimony on page 6, the middle of the first full paragraph in which you speak about the information available to you March 30 through April 4.

You had available to you in that period information about the pressure spike and the related hydrogen calculations, is that correct?

A. That is correct.

Q. I believe you also had available to you some reactor coolant samples?

A. I would have to consult the record to know exactly what the timing of that is. I recall the timing on the gas samples. I don't recall -- oh, I do recall that there was somewhat conflicting information on coolant samples, so that there had been some analysis. The test value was not resolved.

Q. Is it your testimony that you do not know what reactor coolant samples you had available to you in that period, that is from March 30 to April 4?

A. In the literal meaning of your question, the answer is no. In the sense of having some idea of the result, the

answer is yes.

Q. Did you have available to you all reactor coolant samples that had been taken prior to March 30, and during the period March 30 to April 4?

A. The word "all" in that question, I can't certify whether we had all or some. I clearly had some. Whether I had all is unknown.

Q. Isn't it true that today you cannot identify which reactor coolant samples -- that is, which reactor coolant samples were taken at one time -- you had available to you during this period?

MR. BLAKE: Objection. Asked and answered. The witness has answered the question. He said, without consulting the record --

MS. BERNABEI: The question wasn't whether he had seen them all, but whether or not he knew those that he had seen, that is the dates for the reactor coolant samples he had available in the period March 30 to April 4.

My question was a leading question; that is: you do not know the dates of the reactor coolant samples you had available to you during that period.

MR. BLAKE: I agree with your statement of the question. My objection stands.

MS. BERNABEI: I haven't asked the question. Maybe someone else has.

JUDGE SMITH: I don't recall it being asked in that subset form.

MR. BLAKE: Then I'll withdraw the objection.

BY MS. BERNABEI:

Q. Do you remember the question?

A. Let me restate the question to make sure I understand it. Do I have knowledge of the times and samples drawn? I have no firsthand knowledge of the specific times and samples drawn. My specific recollection is that as fast as the results came in, they were communicated to us either by telephone or somebody put it on the blackboard.

Q. Is it fair to say that you --

A. But I can't recall the specifics, since there were many bits of data coming in. I can't recall the specifics of when and what.

Q. It is fair to say you do not know today whether or not you had available to you in this period all the reactor coolant samples preceding and included in that period -- that is, from March 28 through April 4?

MR. BLAKE: Objection, asked and answered.

MS. BERNABEI: I don't think he answered the question. That's why I asked it again.

JUDGE SMITH: I am having difficulty following. Do you perceive the question as having been answered?

THE WITNESS: I gave a kind of an answer to it, which is

that --

JUDGE SMITH: Wait a minute.

MS. BERNABEI: I would appreciate a yes or no answer, if possible.

JUDGE SMITH: See, the real harm in asking a question again which has already been answered is that the witness perceives different in a question he has already answered. If it is put to him again, he perceives that there is a different purpose.

MS. BERNABEI: No, no. It was the same question; I don't believe it was answered the first time. What I am actually requesting is a yes or answer: does he know today whether he had available to him in this period all reactor coolant samples taken up to this date, April 4.

I think a yes or no answer is appropriate to that question.

JUDGE SMITH: That's not the point. The question is, was it asked and answered before. And I don't believe that that particular subset of items was asked before.

But if we go much farther along this line, I am going to be totally confused, as opposed to partially, the way I am now.

MS. BERNABEI: What I addressing is, what information was available for him to make his opinions on page 6.

JUDGE SMITH: You may answer.

THE WITNESS: When you put the word "all" in, there is

no way of knowing by anybody whether all information on any subject, even near and dear to his heart, is available. It is an unanswerable question with the word "all." However --

Q. Dr. Zebroski --

A. If you would allow me, I would like to answer the thrust of your question.

JUDGE SMITH: Let him finish.

MS. BERNABEI: I would like him to answer yes or no.

JUDGE SMITH: No. I will allow him to finish in his way, because the problem has been brought about by your series of questions, the confusion about the series, the distinction between one question and another.

And the only way it can be prevented is to allow him to answer narratively.

THE WITNESS: My impression was that the sample handling, transmittal and analysis was being supervised by the NRC, and work was being done at the national laboratories.

It would be extremely implausible to me that that information was not fully, comprehensively made available to everybody.

So, my inclination, without the direct chapter-and-verse knowledge, is that "all" is very probable. The answer to the "all" question is in reality, in all probability, yes, even though I can't prove it.

BY MS. BERNABEI:

Q. You in fact have no direct knowledge that you were given all reactor coolant samples; is that correct, direct knowledge -- not your general knowledge of what was occurring on that date?

A. I can only say it was a very strong presumption. I have no direct knowledge of any subject in life when the word "all" is put on it. It's an unanswerable question.

Q. Do you have any direct knowledge or information that you received the reactor coolant sample that was taken at approximately 6:45 a.m. on March 28?

A. Without consulting the record, I can't be that specific.

Q. Can you consult the record, whatever information you have available to you?

A. We have answered the NSAC-1 document, so I would have to consult that. I don't have that available.

Q. I can give you a copy, here.

A. I think Mike has a copy, or Dave.

(Document handed to the witness by Counsel Bernabei.)

JUDGE WOLFE: Could I have the number on that, please?

MS. LEWIS: Item 63.

MR. BLAKE: We have at least one here, if the Board would like to use additional copies.

MR. DORNSIFE: I have a copy here.

JUDGE SMITH: We have nothing.

THE WITNESS: I need to decompose the question as to a matter of time frame. In the time frame of the investigation which went on in the following year, there is no question that all stones were turned. I think that's the thrust of your question, what access we had in the days immediately following the accident.

BY MS. BERNABEI:

Q. It's very specific, Mr. Zebroski. It's in the period March 30 through April 4 on which you base your opinions presented on page 6 of your testimony.

A. I'm sorry. NSAC-1 would have no relevance to that time, since it didn't exist at that time.

Q. My question to you is: in the period March 30 through April 4, did you have available to you as a part of the information available to you a reactor coolant sample taken on March 28 at 6:45 a.m.?

A. There were a number of conflicting samples. I am sure that was one of them. I don't know of any exclusion. I know of no record that says any samples were excluded from our information at that point.

Q. Isn't it true that you testified at a prior time that you have no knowledge whether or not you received all reactor coolant samples taken in that period, and in fact you know of no specific reactor coolant sample that you received

during that period?

A. I received no samples. I did receive results.

Q. Is that your prior testimony?

A. I made that distinction in the deposition. We received zero samples --

Q. Let me start over --

A. -- but we did receive results.

JUDGE SMITH: Don't cross-talk. Let him finish his answer.

BY MS. BERNABEI:

Q. Is it your prior testimony or is it not your prior testimony, Dr. Zebroski, that you do not know today that you received all reactor coolant sample measurements or results that were taken in the period of March 28 through April 4 during the period of March 30 through April 4?

MR. BLAKE: Objection, on two grounds. First, we are not here merely to test the witness' memory. If there is some prior piece of testimony that she wants to ask Dr. Zebroski if he would stand by today, that is one thing. That is not what she is doing.

Second, I think that the way she has at least characterized the prior piece of testimony, whatever she's referring to, is precisely what his testimony has been today. He can't certify all. He was aware of what he was aware of.

MS. BERNABEI: That is exactly what I am trying to

demonstrate. He offered certain opinion based on information available to him in the early part --

MR. BLAKE: His --

MS. BERNABEI: Mr. Blake, if you will allow me to finish -- Dr. Zebroski has offered a certain assessment of core damage based on the information available to him in the early aftermath of the accident.

I believe his testimony is to the effect that there was not sufficient knowledge available to assess to any accurate degree the extent of core damage.

I believe we are entitled to check or to test whether or not he had adequate information available in this period to make the assessments he did, and whether he had available to him the knowledge and information available to the licensee.

And if he did not, then I think that discredits to some degree his opinions as offered in his testimony. That is what we're trying to do.

JUDGE SMITH: That is a very complicated chain of logic, and the trouble I have following through from beginning to end is that we begin with the premise that he did not have information. Then you are trying to establish that, contrary to that testimony, he did not have information. That's where I fall down. And then from there on in it only goes downhill.

MS. BERNABEI: What we are trying to demonstrate is, he did not have the information available to the licensee in the

early aftermath of the accident.

JUDGE SMITH: There was information, but that he did not have it?

MS. BERNABEI: That's correct. That is what we are trying to establish: what information was available to him to draw the conclusions and make the analysis he did in the early days after the accident.

JUDGE WOLFE: I have a problem with your question, because I think the witness has already made it known that he distinguishes between the word "samples" and the word "results."

Your question posed "results or samples." He has already made that distinction.

MS. BERNABEI: I amended the question to conform to his terminology. My last question, I amended that so we were understanding each other.

JUDGE SMITH: Let's sort things out one at a time. You understand Judge Wolfe's concern that the inquiry put to you encompasses results?

THE WITNESS: Yes, sir.

JUDGE SMITH: That's put to rest.

JUDGE LINENBERGER: Excuse me. Before you proceed, Ms. Bernabei, I should like to ask the witness a question that will clarify something in my mind.

Dr. Zebroski, as you now reconstruct the events in the past, do you recall ever being in a situation in which you

concluded that your assessment of the extent of core damage could have been accomplished more effectively if certain information that you knew existed had been made available to you, but indeed was not made available to you?

THE WITNESS: The answer to that is unequivocably no.

And if I may clarify one other terminology question, the lack of information that I am alluding to -- which I do allude to a lack of information -- what I am saying is that the state of art of interpreting the radiation levels, even if you had 100 percent knowledge and measurement of it at that time and had 100 percent assurance of accuracy, which was not available in this period, even with that information, the ability to interpret that in terms of core damage is what was lacking.

That's the information I said was lacking, not the sample information. I have no doubt at all in my mind that we had total access to the sampling.

JUDGE LINENBERGER: Thank you.

JUDGE SMITH: Now, what you wish to do, Ms. Bernabei, is test his last statement that there was total access to the sample reports and sample results.

MS. BERNABEI: That's correct.

JUDGE SMITH: And you also wish to test the opinion expressed in response to Judge Linenberger's question, that even if they had a certain totality of all information, it would not change his view or his opinion.

As I understand where we are right now, it is that because of the state of science at that time, the omission of some information would not have changed the analysis.

Now, do you want to test both of those premises?

MS. BERNABEI: I think that's a fair characterization.

JUDGE SMITH: And have I fairly summarized what has passed by in the last several minutes?

THE WITNESS: Yes.

JUDGE SMITH: Do you agree, Mr. Blake?

MR. BLAKE: I believe you have, Judge Smith. My question is whether or not Ms. Bernabei is allowed to test the first of the two purposes you have identified, and if so how in this proceeding, and what relevance and materiality it may have.

JUDGE SMITH: Well, that's the bigger problem I have about the whole line. I don't know how to do deal with that. I guess I can see an indirect relevance.

Your point is that the corporation was sitting on information --

MS. BERNABEI: That's correct.

JUDGE SMITH: -- that he didn't have, and you want to impute that information somehow to Mr. Dieckamp, and this exculpating testimony then will be somehow to no avail. Is that the basic strategy?

MS. BERNABEI: Dr. Zebroski offers a number of opinions

about the low level of understanding of core damage. What I am suggesting is that he did not have information available to him to render this opinion; and that to the degree he talks about Mr. Dieckamp's informing and involvement, then I think we can impute that to Mr. Dieckamp.

JUDGE SMITH: Going that route, I don't see much point in the testimony.

MS. BERNABEI: I don't see much point in his testimony, period. It seems to me the only relevance his testimony has, as far as I can tell, is conversations he may have had with Mr. Dieckamp and Mr. Dieckamp's understanding of the analysis of core damage.

His general testimony about the low understanding of core damage, of accidents of this severity and the resulting core damage does not appear relevant to Mr. Dieckamp state of mind, and that was our original objection.

Given that the Board is allowing in his testimony as to technical personnel and others' low understanding of the degree of core damage at TMI in the aftermath of the accident, I think we are entitled to challenge the basis for his evaluation or assessment, and that is what we're trying to do.

JUDGE SMITH: Yes, you can do it, but you have to understand toward what end. The end that I thought we were going to, which has some relevance, was that he testifies about the ambiguous information and the uncertain analysis.

And I thought you were going to say, "Okay, that may have been your perception, but the corporation and in particular Mr. Dieckamp had hard information that you didn't have."

MS. BERNABEI: That's correct.

JUDGE SMITH: Therefore, this exculpatory testimony should not operate to excuse Mr. Dieckamp.

MS. BERNABEI: Exactly.

JUDGE SMITH: But when I suggest that to you, you go another route and you say, the purpose of this testimony is to explain Mr. Dieckamp's involvement in the activities that Dr. Zebroski is testifying to.

And you are trying to demonstrate something by that route which I don't understand the relevance of.

MS. BERNABEI: I was not clear. That is not our intention with this line of questioning.

JUDGE SMITH: Your purpose is as I first stated it?

MS. BERNABEI: That is correct.

JUDGE SMITH: With that, then, I think that you should be allowed to go to the particular piece of information to which you allude and put it to the witness and see what happens, which is a particular reading at a particular time.

BY MS. BERNABEI:

Q Is it fair to say that you do not know today --

JUDGE SMITH: Aren't you going to pursue that? We're going all the way back now, several questions. There was a

particular question as to what we had been debating, and that is: did he know about a particular --

MS. BERNABEI: That's right. That's the question.

JUDGE SMITH: All right.

BY MS. BERNABEI:

Q. You do not know today, do you, whether you had available to you March 30 through April 4 the reactor coolant sample taken at 6:45 a.m. on March 28?

A. With the full knowledge of all the investigations that have looked at this question, I know of nothing that we knew subsequently that would have changed our state of understanding at that time.

Q. I am asking for a yes or no answer.

JUDGE SMITH: Counsel is entitled, Dr. Zebroski, if it is possible, for you to answer yes or no. There will be opportunities for explanation, for whatever counsel wants to do, and indeed for whatever you want to do.

THE WITNESS: I understand.

JUDGE SMITH: But for our purposes, she is entitled to develop a line of logic and have your direct answers to it.

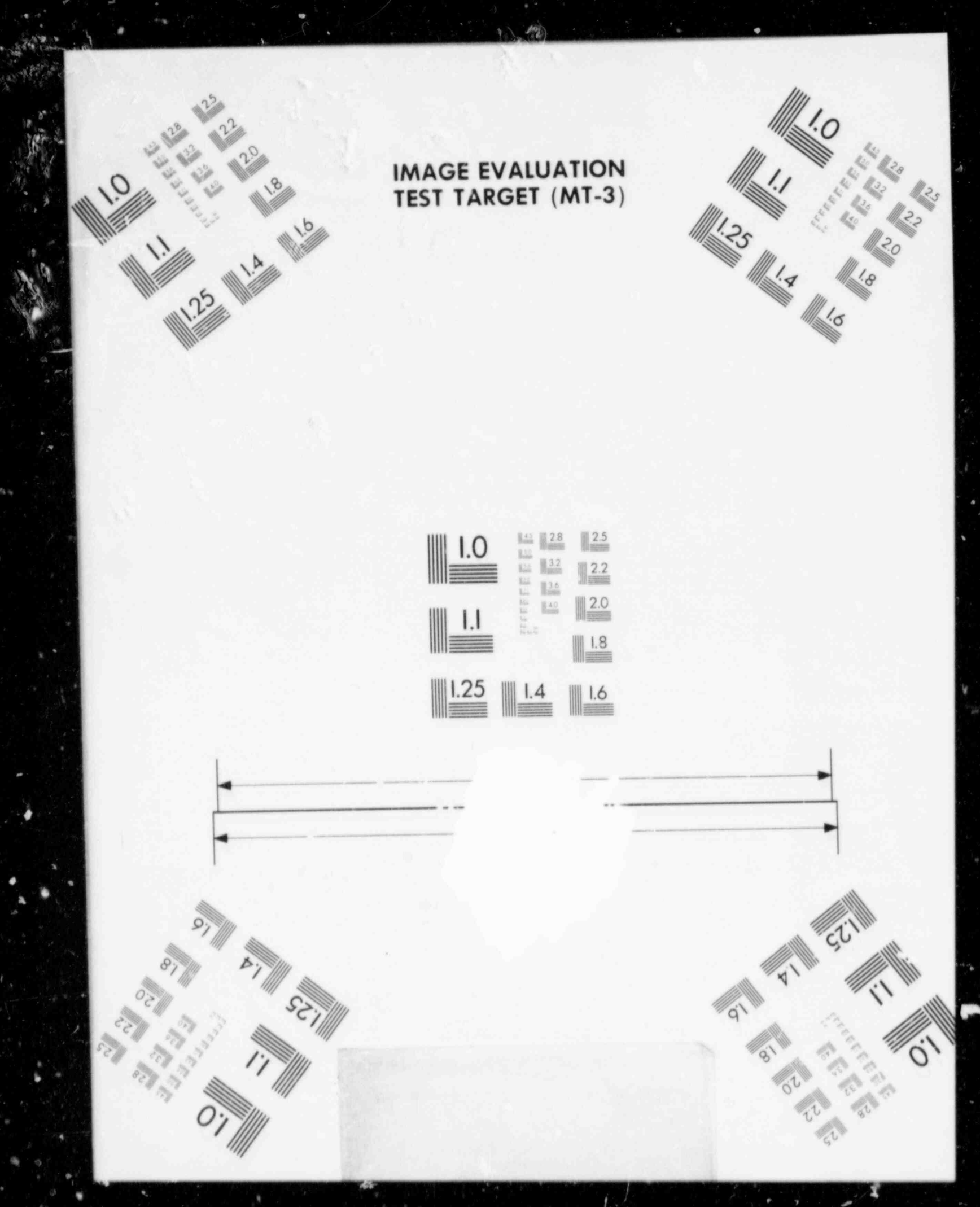
THE WITNESS: No.

BY MS. BERNABEI:

Q. Your answer is no?

A. That's what I said.

Q. And is fair to say that you do not know today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whether or not available to you in this period immediately after the accident you had all the reactor coolant samples taken during that period? And I would like a yes or no answer.

MR. BLAKE: Objection. Asked and answered about four times.

JUDGE SMITH: That indeed has been asked and answered, and we have ruled that in the context of this long series of questions, his narrative explanation would be permitted. He has given it. The objection is sustained.

BY MS. BERNABEI:

Q. I'll go back to the deposition. Didn't you testify at a prior time that in fact you could not state that you had available to you all the samples taken in that period?

A. With the word "all," I have to say yes.

Q. I believe it is your testimony that you had available to you certain thermocouple data from March 31; is that correct?

MR. BLAKE: I'm sorry, what testimony?

MS. BERNABEI: His prefiled testimony.

BY MS. BERNABEI:

Q. Specifically referring you to page 9, the last sentence, you had available to you certain thermocouple temperature readings; is that correct?

A. Where on the page?

Q. Last sentence.

A. Yes, ma'am.

Q. It is fair to say, is it not, that you in your testimony state you had access to certain in-core thermocouple temperature readings in this period?

A. Correct.

Q. And I believe the readings or the near-normal readings to which you referred at the bottom of page 9 are readings taken on March 31?

A. Yes.

Q. Did you have available to you at any time in this early period of your assessment the full set of 51 or so readings taken of in-core thermocouple temperatures on March 28?

A. No.

Q. In fact, you did not receive those until approximately six weeks after the accident, is that correct?

A. Correct.

Q. Did you have available to you in-core thermocouple temperature readings taken on March 29 or March 30?

A. When?

Q. All the questions are in the period March 31 through April 4.

A. Information, yes. The exact paper, no.

Q. Did you have before you all in-core thermocouple temperature readings for those days?

A. Not all.

Q. I believe it's your testimony that the first reactor building atmospheric sample which you are aware of was taken at approximately 6:00 a.m. on March 30, is that correct?

A. I am not sure. I see another record that says 4:00 a.m. Our record says 6:00.

Q. At any case, the early morning of March 31 was the first one of which you know?

A. Yes.

Q. And if I am correct, you directed or instructed that that be taken, or your group instructed that that be taken?

A. That was my impression, which I believe now on the record is not correct. Other people had already initiated that, I think. We simply endorsed it.

MS. BERNABEI: If you will allow me just one moment?

(Pause.)

BY MS. BERNABEI:

Q. Dr. Zebroski, is it fair to say that you know of no reactor building atmospheric sample taken on March 29? That's the gist or import of your prior testimony?

A. I know of no sample taken on March 29.

Q. Do you know of any sample that was directed to be taken on that date?

A. I know only what's in the record.

Q. I would like to show you what appears at the bottom of page 6 of TMIA Exhibit No. 2. It is the fourth page of that

exhibit.

(Document handed to the witness by Counsel Bernabei.)

Q. I am representing for the moment that this has been identified previously as Mr. Seelinger's notes or logs for that day, March 29.

It indicates, does it not, that there is a concern or indication that a reactor building atmospheric sample was to be taken?

(No response.)

Q. Sir, you'll have to answer yes or no, I think, for the record.

MR. BLAKE: Could I have the question repeated, please? You're referring the witness to page 4?

MS. BERNABEI: Perhaps the reporter could read it back--it's page 6 of TMIA Exhibit No. 2, which is the fourth page of that exhibit.

JUDGE SMITH: Okay, Exhibit No. 2. We may have one

MS. BERNABEI: We may have one of the Board's copies of that exhibit.

THE WITNESS: Could I have the question again, please?

BY MS. BERNABEI:

Q. Yes. It indicates, does it not, that there is a concern or instruction to take a reactor building atmospheric sample on March 29, that entry?

MR. BLAKE: Objection.

JUDGE SMITH: We're still trying to find the exhibit. Just stop, please.

MS. BERNABEI: Here is another copy.

JUDGE SMITH: We're in Exhibit No. 2, page 4?

MR. BLAKE: Page 6, number 6, which I believe is the fourth page in the exhibit.

JUDGE SMITH: Now, disregard the question and the objection and start again.

BY MS. BERNABEI:

Q. Referring you to the bottom portion of that page, Dr. Zebroski, and assuming for the moment --

JUDGE SMITH: Please specify the page. I'm confused between page 4 and page 6.

MS. BERNABEI: Page 6 is the number that appears at the top righthand corner of the page.

JUDGE SMITH: Wait until he gets that page.

BY MS. BERNABEI:

Q. You are with me on that page of that exhibit, is that correct?

A. Yes.

Q. Now, referring you to the bottom portion of that page, it indicates, does it not, that there is a concern about taking a reactor building atmospheric sample on that date?

A. I read the words, "Need RD atmosphere or atm sample."

Q. You have no information, do you, about an atmospheric

sample that was taken on that date, March 29?

A. Correct.

Q. You speak in your testimony about in-core thermocouple data which indicated near-normal levels. That is, just to confirm the date, March 31, is that correct, the bottom of page 9?

A. Correct.

Q. Were you aware on March 29, two days previous, that there was a concern about high in-core temperatures both within the NRC and within GPU?

A. Can you specify when, when that awareness? Your question is unclear as to time.

Q. Yes; in the afternoon of March 29?

A. Definitely not.

Q. I would like to refer you now to the same Exhibit No. 2 which you have before you. Did you have any indication or knowledge that five in-core readings were in the range of 500 to 600 degrees Farenheit on the afternoon of March 29?

A. No. You mean on March 29? The answer is no. If you mean on some other date, the answer is yes.

Q. All my questions are referencing now the period between March 31 and April 4, on which you base your opinion. Were you aware then --

A. Oh, then, that's different. I misunderstood your question to be, did you realize on March 29, and the answer is

no. If you said, did you know later, depending on when "later" is, it could change the answer.

Q. "Later" in all my questions is March 31 through April 4. With that understanding, did you know first that there was a concern about thermocouple temperatures within the NRC and B&W and licensee about high in-core temperatures on that date?

A. Was there a concern by those people in the time frame of March 29?

Q. Right.

A. I believe at some later time we did gain that perception, but I don't know when.

Q. Is it fair to say that you testified during your deposition that in fact you did not know in the March 31 through April 4 time frame of this concern on March 29 of high in-core temperature readings?

A. No, that is not correct. If I stated it, I will retract it, because we had at least hearsay evidence that some high readings had been obtained, but also some very low readings that we discounted. But we did not actually --

JUDGE SMITH: Does Dr. Zebroski have access to his deposition as these questions are being put to him?

MS. BERNABEI: We will certainly provide him with access, yes.

BY MS. BERNABEI:

Q. Were you aware of five to six in-core temperatures reading in the 500 to 600 degree range on March 29? Again, were you aware in the period March 31 through April 4?

A. I believe in my deposition I stated that we had -- the core thermocouple temperature maps then current were supplied to us immediately in the first review meeting.

And then over the next days, I think we also got technical information about it which showed this scattered pattern of high and low temperatures.

My sentence in the testimony in question stands, that some of them were near-normal, and that led to the confusion.

Q. That was not my question. Let me ask the question, and you can answer yes or no. I would appreciate a yes or no answer.

Were you aware of a concern on March 29 among the NRC staff, among B&W personnel, among licensee personnel that in-core temperatures, at least five, ranged in the area, in the range of 500 to 600 degrees? Can you answer yes or no, Dr. Zebroski?

A. Can I ask for one bit of interpretation, of the word "concern"? If the question is to have me project the state of mind of someone else, the answer is clearly no.

Q. Was there a concern that these readings were still high on March 29 at approximately 3:30 p.m.? Do you know of

any concern expressed about that?

A. With that level of specificity, the answer is no.

Q. Did you know of any concern expressed about high in-core temperatures, off-normal, high, in-core temperatures in this range on March 29?

A. We were generally aware that there was concern of high in-core temperatures, yes, but this specific five, I couldn't say.

Q. I'd like to refer you to page 6 of Mr. Seelinger's notes. Again, that is page 4 of TMIA Exhibit No. 2. It indicates, does it not, Mr. Seelinger noting --

JUDGE SMITH: That's page 6, the fourth page?

MS. BERNABEI: That's correct.

BY MS. BERNABEI:

Q. -- a concern among NRC, B&W personnel and licensee personnel that there were measured in-core temperatures in the range of 500 to 600 degrees Farenheit?

A. I read those words, yes.

Q. Were you aware of concern on the NRC's part on March 29 about 9:30 p.m. of hot spots in the core?

A. No.

Q. Were you aware that in-core thermocouple readings for March 29 and apparently March 30 had a wide variation; some read high and some read low?

A. Yes.

Q. And that would indicate to you, would it not, that in fact there was structural core damage? It would be one indicator of that?

A. No.

Q. It would not?

A. It would indicate doubt on the heat calibration of the thermocouples, but not necessarily structural damage.

Q. It is one indicator, if the thermocouples are operating properly, of structural core damage; is it not?

A. In the light of later months of analysis, that is a totally accurate statement. At the time, we could not draw that inference.

Q. At the time, if one believed the thermocouples were functioning properly and one saw a wide variation in the high and low measurements for in-core temperatures, one could conclude at that time that there was structural core damage?

A. It would be a highly doubtful conclusion.

Q. I'm asking you to accept my premises for the moment; the thermocouples were functioning properly. If one assumes --

A. Accepting that highly doubtful premise, the answer is yes.

Q. Assuming, Mr. Zebroski, that you had available to you at the time you made your assessment of core damage which you describe on page 6, assuming that you had available to you in the March 30 to April 4 time period in-core thermocouple

temperature readings from March 28, the 51 or so readings; assuming that you had available to you all the reactor coolant samples that had been taken up to that point; assuming you also had available to you all the reactor building atmospheric samples taken, including the ones with which you are now familiar, would that change your opinion or assessment as to the degree of core damage?

A. I guess I have lost the point of, at what time of that perception?

Q. March 30 through April 4.

A. Assuming you had full knowledge of the subsequent months on March 30, is that the question?

A. No. Assuming you had additional knowledge to the one that you had testified you did have. Assuming you had the in-core temperature for March 28, that is the set of 51 readings --

A. Yes.

Q. Assume that you had all the reactor coolant samples that had been taken up to and through that period.

A. Yes.

Q. Assume also you had the existence of any reactor building atmospheric samples other than the one you had mentioned.

A. Yes.

Q. Would that change your assessment as to the degree

of core damage as expressed on page 6?

A. In the sense of ability to analyze it at that time, the answer is no, it wouldn't change.

Q. Referring you to page 7, the last sentence of the first full paragraph, you state in the sentence,"There was an evident need to determine whether some hydrogen cylinders or piping might have leaked hydrogen into the containment...."

Was there at that time or any later time any evidence that that had occurred, that is that hydrogen had been leaked into the containment from hydrogen cylinders or piping?

A. The evident need simply says that there was an intent to investigate. The result of the investigation --

Q. Can you answer my question yes or no? Was there any evidence at that time or any later time that that in fact had occurred?

A. The implication of the question is that it was ridiculous to investigate --

Q. Dr. Zebroski, you do not have the right to interpret or otherwise rephrase my questions. If you can answer my --

JUDGE SMITH: Yes, he does have that right. He has a right to understand the question before he is called upon to answer it. He has that right and duty.

MS. BERNABEI: I do not think he has a right to comment on the question. May may not think it's appropriate --

JUDGE SMITH: Let's begin again.

BY MS. BERNABEI:

Q. Did you have any evidence in the aftermath of the accident or at any time up to the present that there was any hydrogen cylinder or piping leaking hydrogen into the containment?

A. Upon investigation, the answer is no.

Q. Did you have any evidence before your investigation?

A. It was just a reasonable question to ask.

Q. So, the answer is no?

A. Well, the evidence that possibly a burn had occurred, you had to look at all possible sources of hydrogen.

MS. BERNABEI: May I request that the witness be directed to give a yes or no answer?

JUDGE SMITH: No, I don't think so. The difficulty is, you are using the word "evidence." And he has trouble, I believe, with using that word. It's an imprecise term. I don't think he can do any better than he is doing. So, I deny your request.

BY MS. BERNABEI:

Q. Dr. Zebroski, on page 10, you describe the organizing of the Nuclear Safety Analysis Center in May of 1979; is that correct?

A. Was the organization correct, or was the page correct?

Q. Listen carefully, please. On page 10, you describe,

do you not, the organizing of the Nuclear Safety Analysis Center in May of 1979?

A. It is correct that I so describe it.

Q. And it is fair to say that you were the director of this effort?

A. I was appointed director.

Q. You were the director?

A. I was appointed and served.

Q. When were you appointed?

A. I have asked that question, too. The only objective evidence I have is that I issued a letter to organize the study about May 3. So, sometime before May 3 I was appointed.

Q. This study and the resulting report relied on hard data -- that is, the analysis of instrument records and not operator interviews; is that correct?

A. That was the intention.

Q. You state on page 10 that you had the full support and help from GPU and plant personnel; is that correct?

A. Three people were assigned to us, yes.

Q. Now, there were two supplements issued to the original NSAC report, is that correct?

A. That is correct.

Q. The original report was issued in July of 1979?

A. Strictly speaking, there were many supplements. There were two supplements issued prior to the March, 1980

version which was believed to complete the description of the sequence of events.

There has been a series of roughly 25 reports over the years delving into the research implications of some of these things.

Q. Let's start with the report you referenced. The first report, NSAC-1, was issued in July of 1979; is that correct?

A. Correct.

Q. The first supplement was issued in October of 1979; is that correct?

A. Correct.

Q. Now, starting with the first report, in this report you did not have available to you, did you, certain primary system hot-leg temperatures in compiling this report?

A. Since you asked that question at the deposition, I did investigate that. To the best of our knowledge now, we did have that information on film but didn't reduce it to a plot because of the very fuzzy nature of the data. It wasn't reduced to a plot until later.

Q. It is fair to say it was not included in the NSAC-1, that is Figure TH-1, primary system temperatures?

A. It was not included, but it's implied in the work in progress listed in the index.

Q. Let me try once more. Those temperatures -- that is,

the measurements of those temperatures -- are not included on any graph or plot which occurs in NSAC-1; is that correct?

A. Correct.

Q. Now, those temperatures are, however, included or plotted in the first supplement issued October, 1979?

A. Correct.

Q. Now, is there any reference or other substantiation of your view that you had available to you at that time those specific temperature measurements?

A. Yes.

Q. Where in NSAC-1?

A. It's not present in NSAC-1. If I may answer the thrust of your question, there was a great deal of work in progress --

Q. Let me just clarify --

A. -- that we did not publish --

Q. Can I just clarify, Dr. Zebroski, it does not appear in NSAC-1; is that correct?

A. That's correct.

MR. BLAKE: Would you allow the witness now to complete his answer, Ms. Bernabei?

MS. BERNABEI: I just wanted an answer to my question. I don't think there's a pending question.

THE WITNESS: May I call to your attention, though, that we now know that we had it on film before that; we just hadn't

reduced it to a plot.

JUDGE SMITH: How are you progressing?

MS. BERNABEI: I am almost done.

BY MS. BERNABEI:

Q. I just have one further set of questions. You state in your testimony that you were aware, to cause ignition of hydrogen, it was necessary that the amount of hydrogen reach 4 percent of the total containment volume; is that correct?

A. That is not correct.

Q. That is correct?

A. That is not correct.

Q. Let me refer you to page 7. Does it not indicate that hydrogen as low as 4 percent in air is known to be capable of ignition?

A. That is clearly not the total for containment volume.

Q. Excuse me?

A. That is clearly not referring to the total containment volume.

Q. Let me ask you the question directly, then: isn't it true that in order to have an ignition of hydrogen in the containment, one would require around 4 percent of the total volume?

A. Definitely not.

Q. We aren't talking about localized ignition.

A. I'm talking about localized -- the answer to your question implies that localized is an option. You cannot have independent knowledge that it's homogeneous when it can't be.

Q. Assuming for the moment that it is not localized ignition or combustion, in order to have ignition of hydrogen-- Dr. Zebroski, if you would --

A. Do I have to accept assumptions which are contrary to common scientific knowledge?

JUDGE SMITH: You might have to. That, I am afraid to say, is sometimes the course of legal proceedings. But when those assumptions are contrary to all scientific knowledge, I certainly hope that you will bring that to our attention.

THE WITNESS: Thank you, sir.

JUDGE SMITH: However, you do have to allow Ms. Bernabei to approach her case in her way and do it the way she sees fit. We would appreciate it if you would do that.

BY MS. BERNABEI:

Q. Mr. Zebroski, assuming for a moment that we are talking about combustion in the entire volume of the containment, one would need to reach 4 percent volume of hydrogen in the total volume of the containment to cause any ignition or combustion; is that correct?

A. Yes, given your assumptions.

JUDGE SMITH: I might explain, I appreciate your frustration in the scientific --

THE WITNESS: I am just trying to be accurate, sir.

JUDGE SMITH: Here's how it works. She can ask you statements based upon assumptions. You give an answer, and you say, "Well, jiminy, that's not a very good assumption. I'm afraid we're going to mislead."

But when she gives you that assumption, if she doesn't establish that that assumption is correct somewhere else in the hearing, then the exchange is without value.

THE WITNESS: That helps a lot.

MS. BERNABEI: I could just represent that in fact Mr. Lowe has already represented that the assumption in this question is correct.

BY MS. BERNABEI:

Q Assuming for a moment --

MR. BLAKE: I beg your pardon. I cannot let that go by without at least saying that the record will stand for itself with respect to Mr. Lowe.

MS. BERNABEI: I think it will.

JUDGE SMITH: I am only trying to make Dr. Zebroski feel a little more comfortable in what he perceives to be an illogical process.

MS. BERNABEI: If I can just note, I think Mr. Lowe's testimony will stand for his understanding --

JUDGE SMITH: I don't even want to argue that point.

MS. BERNABEI: I don't, either.

JUDGE SMITH: I'm talking to Dr. Zebroski.

BY MS. BERNABEI:

Q. Assuming that there is at least a 4 percent amount of hydrogen in the total volume of the containment -- you're with me?

(Witness nodding affirmatively.)

Q. Assuming that is a fact, what amount of zirconium -- and assuming that that hydrogen was produced in a water-zirconium steam reaction, what amount of the zirconium cladding or zirconium elements in the core would need to react in order to create that amount of hydrogen, 4 percent of the total containment volume in TMI-2?

A. I won't try to do the calculation in my head, but a related calculation is in one of the exhibits which I submitted which actually showed a larger amount than 4 percent was finally analyzed, and 4 percent would be the proportional amount to the amount which was finally analyzed.

Q. And what is your answer, Dr. Zebroski?

A. As I say, I can't do the calculation in my head. I can give you a method for deriving the answer, that it is a substantial portion of the actual amount which is listed in that appendix, and you can look at that if you would like.

Q. We don't have your exhibits before us, and I reminded you of that before. Haven't you testified in your deposition that a rough estimate of the zirconium elements

which would need to react in order to create 4 percent hydrogen would be approximately 15 percent of those elements?

A. If you had to make a first guess, short of a calculation, we would expect that to be within a factor of two or three.

Q. We're talking about 15 percent?

A. 15, yes.

Q. And I believe that's what you testified in your deposition, is that correct, a ballpark figure of 15 percent?

A. Yes, with the understanding of the word "ballpark."

Q. I believe you testified that that is zirconium elements, not necessarily zirconium cladding; is that correct?

A. It would be the total inventory of the zirconium, yes.

Q. But the large majority of that would be the cladding, zirconium cladding?

A. If you add end plugs, I would agree with that; cladding alone -- a large fraction.

Q. It's fair to say that in order to create a volume of 4 percent hydrogen in the total containment of TMI-2, one would need to see, in a gross sense, 15 percent oxidation of the zirconium elements, primarily zirconium cladding?

A. Of that order, yes, a ballpark figure.

Q. From your testimony, I also understand that you do not believe that 15 percent oxidization of the zirconium cladding would necessarily indicate core damage; is that correct?

A. That's correct. My testimony says that if it was uniformly distributed you would still have the metal structure intact, as an analogy to the rusty iron pipe.

Q. What scientific basis, what scientific articles or authority do you have to make the statement that 15 percent oxidization of the cladding would not necessarily indicate core damage?

A. I don't think a paper on that subject would be accepted in any journal since it is common sense that if you take 15 percent of the pipe 85 percent is still there.

Q. This is common sense?

A. If you don't know whether the distribution is uniform or localized, you would have to start off with the assumption of uniform; so the presumption --

Q. Have you --

A. -- is the the metal core remaining is the starting point for the investigation.

Q. Are there any NRC regulations which address whether or not oxidization of 15 percent of the cladding would indicate core damage?

JUDGE SMITH: You are skipping the caveats that he

puts in his answers each time, and that is uniformly distributed.

MS. BERNABEI: I understand.

JUDGE SMITH: So long as everybody understands that that is implicit in each question and answer along the line.

MS. BERNABEI: I don't think that is an accepted principle of analysis in this area, but he can state that that is his understanding; but that's not the premise for my questions.

JUDGE SMITH: It had better be. The premise for your question had better purport with his understanding of the question. Otherwise we are not going very far.

MS. BERNABEI: Okay, I will be very clear as to the premise of my question.

BY MS. BERNABEI:

Q Assuming that you know that there has been 15 percent cladding failure oxidation of the zirconium cladding, do you know of any NRC regulation which defines or guides you in terms of whether that is serious core damage?

MR. BLAKE: Objection. I don't understand what the purpose of such a question is. The witness hasn't been offered as an expert on NRC regulations or otherwise.

Time is getting short; we are all trying to finish. I object.

JUDGE SMITH: You are going to go to 5054 and say:

ah hah; how about that?

MS. BERNABEI: Right.

JUDGE SMITH: He's going to say: well, I told you uniform. And there we are.

Let's get there quickly.

Overruled.

BY MS. BERNABEI:

Q. Do you know of any regulations including the acceptance criteria for the emergency core cooling system that would indicate that 15 percent oxidization of cladding failure -- or 15 percent oxidization of cladding or cladding failure would indicate core damage?

A. I am aware that such criteria exists.

Q. These criteria would indicate, would they not, that 15 percent oxidization of cladding indicates core damage?

A. It definitely would not.

Q. That's not the way you read those regulations?

A. I think they are silent on the question of core damage. They really address the question of what would good engineering practice be. Good engineering practice wouldn't be to allow your pipes to rust 15 percent either. It sometimes happens, and then you have some margin of safety.

JUDGE SMITH: At this point I think there should be a limit on your debate about the meaning of that regulation.

MS. BERNABEI: That's fine.

BY MS. BERNABEI:

Q Just to make sure I understand: you do not have any scientific basis or authority, scientific article or journal which supports your belief that 15 percent oxidization of cladding would not necessarily indicate core damage?

MR. BLAKE: Objection; asked and answered.

JUDGE SMITH: Yes.

THE WITNESS: I'm sorry. I didn't hear the last part. Shall I answer or shall I not?

JUDGE SMITH: It is sustained. You should not answer.

MS. BERNABEI: I have no further questions.

JUDGE SMITH: Mr. Au?

MR. AU: Mr. Dornsife has a few questions.

JUDGE SMITH: May I inquire, Mr. Goldberg, how much questioning you might have?

MR. GOLDBERG: I would estimate 15 or 20 minutes.

JUDGE SMITH: Mr. Dornsife?

MR. DORNSIFE: Likewise or less.

JUDGE SMITH: You may proceed.

CROSS-EXAMINATION

BY MR. DORNSIFE:

Q Dr. Zebroski, these questions are referring to your knowledge of what occurred after you wrote the NSAC Report, not at the time of it, not during the early period but your full understanding of what happened.

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First of all, what is your understanding of how hydrogen would have been released to the containment building early on in the accident?

A. My understanding is that it would have come out through the tailpipe of the PORV and initially be in the compartment containing the tank that would receive that material, and indeed initially be contained within that tank. So the presumption of localization would have to be made until and unless proven otherwise.

Q. Are you aware that the rupture disc on the tank had gone early on?

A. Yes.

Q. And would it have into the containment?

A. Yes.

Q. Is it possible, based on that release pathway that there could have been a localized phenomenon, a localized burn creating this same transient that appeared in the reactor building?

A. Depending on the time that was involved -- the stratification of hydrogen is a well-known phenomenon. It does not mix uniformly unless you have some sort of either a fan or some sort of a gradient driving that mixture.

So the assumption that you would have a localized concentration is always a worry in industrial safety, and we take precautions against stratification, so on that basis

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I would have to take that as starting assumption.

Q. My question was: assuming that indeed there was a stratification of a localized burn, would it be possible to get the containment response, the pressure spike, that occurred from a localized burn?

A. Depending on the magnitude of the spike. There were a great many pressure oscillations in the earlier record on that same recorder, and they were of a similar amplitude. Since there are two pens on the same recorder, a wide range and a narrow range pen, many of those earlier oscillations were of the same amplitude as the ones which were later interpreted as 28 psi. But that assignment can only be made after you were able to clearly distinguish which pen was which.

And I have on hear -- I haven't seen the record, but I have on hearsay that the two operator entries in the log listed that pressure spike as being interpreted from the narrow range as in the range of 3 or 4 psi, which is in the same range as the earlier oscillations that had preceded for several hours.

Q. Isn't it correct that, indeed, a pressure spike well in excess of 3 or 4 would initiate ESF?

A. That I know of my later knowledge. I couldn't make that distinction at the time.

Q. I'm asking you: could a localized burn create a pressure spike that could indeed initiate ESF?

A. I would expect that, but I guess I need to say that I have to have two different personae in this. One is from the state of mind of an investigator who keeps options open until he has a comprehensive picture, and the other is with the full knowledge of access to all data over all times and the analysis that goes with it.

In the personae of an investigator I would be happy to say: how close to the pressure sensors did the potential load block reach? If they were far away, then I would have to agree with the assumption of a wide spread pr ssure spike. If they were nearby, then, as you know, hydrogen in a burn has a flame front which has both a pressure and a temperature chart -- a pressure and temperature gradient. So if you had a sensor that was nearby, it would respond without necessarily requiring that the entire containment see those conditions.

Q. Then could, indeed, assuming now that we had some zirconium cladding reaction and it was allowed to build up over time in the pressurizer, and upon the opening of the blocked valve this hydrogen bubble or whatever you want to call it, the hydrogen burp, was released in the containment, could, indeed, the operators at the time have recognized some sort of a chemical reaction, or whatever you want to call it, a hydrogen burn chemical reaction, but not necessarily associate it with severe core damage?

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A. My general answer to that question is no, at two levels. The first level is that that whole area -- the first level is that you could have assessed fuel damage in the sense of deterioration of individual fuel rods over some area. You could not have determined,except as a question of investigating, whether that led to structural damage. At the second level I believe that the question of hydrogen generation and combustion was only very peripherally involved in anything that the operator was exposed to in their training and education.

They probably had more information on worrying about hydrogen explosions from a battery than they had from a hydrogen explosion here, since the hydrogen question would enter only if they had studied the basis for the ECCS criteria, which is to try to get the water in fast enough to limit the hydrogen generation to around a percent or so.

As a design criteria, they might have recognized that the hydrogen was a consideration. I think the issue on vapor adjust in Appendix K would generally have been beyond the trend in the perceptions of the operators. So definitely I would consider it only a wild guess; even if one of them or several of them made that guess, it would not be -- a jury of their peers would be very skeptical of that guess.

Q. I guess I am not asking you about their training or their recognization; I am asking: would it have been

physically possible to have had a hydrogen combustion in the containment without necessarily having severe core damage?

A. I believe so, yes; in the sense of structural damage, I believe you could have generated hydrogen without structural damage.

Q. This is based on your knowledge now after you have done all of the analysis?

A. Yes.

Q. Following the pressure spike that occurred at about 1400 on March 28th, what was the operator's response after that particular time?

A. There were quite a number of actions with the block valve and with the make-up pump and, to the best of our knowledge -- it is not recorded -- the let-down. And all those actions indicated a continuing degree of confusion on the issue of low inventory. If you understood that the system was starving for water, then you wouldn't have opened the block valve periodically. You wouldn't have shut off -- and maintained the make-up pumps in the throttle conditions, and wouldn't have continued let-down, because all those actions are contrary to maintaining adequate inventory.

Q. So there is no evidence of any change in strategy at that point as far as cooling is concerned?

A. Well, over a period of many hours the strategy

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changed because the normal shut-down objective of going to low pressure injection and natural convection cooling, after ten or twelve hours it became abundantly evident that it wasn't going to work. At least my recollection is that several people stated that they were telephoning or yelling into the control room to turn on the pumps, turn on the injection pumps; so at some point we had to try to get to that.

Specifically, there was quite a bit of testimony that Dick Estelle was telling them to get those pumps turned on. I assume that referred to the make-up pumps. So since the official training strategy was now changed, the actions were finally taken; but certainly in the immediate three or four hour time frame, I think that the actions manifest continuing confusion on the inventory and the significance of the pressurizing.

Q. Based on your knowledge of the general knowledge of the industry at that particular time frame, and also the training that was given concerning severe core accidents, what do you think would have been the operators' response had they have known that there was significant -- that that ignition, that pressure spike was caused by a gross hydrogen detonation or burn?

A. I think if that had been understood clearly, then it would have forced the conclusion that the total inventory was very low. That's the only way you could expose a lot of

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the core to the steam, was to have a much lower than normal inventory of water, and you would take all actions possible toward restoring that inventory of water. Those are the actions which I see as being confused, and delayed for many hours, even after the hydrogen spike.

Q. Do you think that it is credible to assume that the top plant managers, knowing there was severe core damage, would have left the plant site and told the operators not to make any changes in the system, had they been aware at that point?

A. Well, I have to be even-handed in my answers. In the sense of projecting what the people felt, I would be reluctant to try to answer that. As a personal feeling, I would be inclined to say that they couldn't have regarded the situation as terribly serious if they left the plant.

JUDGE SMITH: I think you are stretching the witness' expertise beyond that for which he was offered, and for what he claims.

BY MR. DORNSIFE:

Q. In your testimony on page 3 you state that Dr. Bartnoff of GPU was talking to the research advisory committee on March 29th and again on the 30th?

A. Yes, sir.

Q. Do you recall any notes or minutes of that meeting or what he discussed in general?

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A. No, I can only infer that he did not communicate-- based on his telephone conversations, with the plant, he did not communicate the level of seriousness which developed out of the phone call the following morning. His early statements were: we have an incident; we have had a transient; we have lost -- some valves were closed that shouldn't have been closed. So he had a little bit of the sequence of events, but clearly not any of the consequences perceptions in light of what he stated.

Q. Were you, in fact, at those meetings?

A. No, sir.

I have that only through the notes of the meeting and through the comments of Mr. Levenson, who was there.

Q. On page 5 of your testimony you talk about the NRC's evaluation of the problem with the hydrogen bubble in the reactor vessel, and how that was made aware to the public. Are you aware of at any time the NRC informing the public that there was never a problem from the potential explosion of that hydrogen bubble in a reasonable time after the event occurred?

A. Yes, I am aware of that. There was a statement on television by Mr. Denton to the effect that our calculations had been conservative, and I believe the report has the exact time and phrasing of that statement.

I was just refreshing my recollection by scanning this here.

pl3

Q. But it was never stated positively, as you stated it, that it was not a possibility?

A. It was never stated that way.

Q. Going to your Exhibit TMIA Number 2, page 9 --

A. Yes.

Q. -- this is again based on your knowledge at this time of what the sequence of events was. Do you see an entry at 2130 that says: $H_2$ in reactor building, instance of loading of equipment which could cause a spark?

A. I'm sorry, I'm don't see that.

Q. "$H_2$ in RB."

A. I've got you.

Q. Then turn to page 10, the next page. Look at 2100, the entry at 2100. It says: evolving significant gas in MUT, which I assume means make-up tank; correct?

A. I would interpret it that way.

Q. "Burped MUT to vent header, area monitors came up." To your knowledge of the plant, where does the gas go once it gets in that vent header?

A. I have only fragmentary knowledge of that. Some of that gas obviously appeared in the fuel tunnel and in the auxiliary building through pathways which were not well understood at the time. I think we have a chapter called "Pathways," which addresses that.

Q. You misunderstand my question. The design, when

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the gas gets into the vent header, where is the gas supposed to go?

A. I am not sure of the answer to that. Eventually it goes to the atmosphere.

Q. If I said the waste gas decay tank, would that refresh your memory?

A. That is probably the primary intended target. What I am saying is that I also know that some of that went other places.

Q. I am talking about leaks.

A. All right, yes.

Q. Would you go to page 11, please; at the top of the page there appears to be a time of 2115. This is apparently instructions to Biehl to get a hydrogen sample and to get an $H_2$ in the decay tanks.

Apparently then Floyd after that says: path to decay tank, hydrogen to building. Assuming for a minute that those notes are out of sequence and indeed the notes at 2100 and 2115 lead up to the note at 2130 on page 9, would it not be possible to infer from that sequence, assuming that were the proper sequence, that the mention of hydrogen in the reactor building,Bensel looking at equipment could mean that the proposed strategy was to evacute the decay tanks back to the reactor building?

A. I don't get the connection of that 2130.

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Q. Well, it says $H_2$ in the reactor building.

A. I see.

Q. Going back to page 10 -- or page 11, it says under instruction to Floyd, second entry: path for decay tank $H_2$ to building.

A. Yes.

Q. Assuming that "building" means reactor building --

A. Yes.

A. -- is it possible that the note at 2130 -- assuming that the notes are out of sequence -- that that could refer to a proposed strategy to vent hydrogen from the decay tanks into the reactor building?

A. Yes.

Q. Is this also consistent with your understanding of the sequence of events?

A I would have to study it a lot harder to give a clear answer on that, but I think it does illustrate one other point, that the concern on localization of hydrogen was well-placed because in that case we clearly would have been venting hydrogen in a limited volume.

Q. Thank you, Mr. Zebroski. I have no other questions.

JUDGE SMITH: Mr. Dornsife, what did we learn from that exchange?

MR. DORNSIFE: Do you mean the last exchange?

JUDGE SMITH: Yes. I just didn't follow it.

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MR. DORNSIFE: I think there was earlier testimony that that $H_2$ in the reactor building meant that somebody was concerned about hydrogen from some source in the reactor building, and my postulate -- I don't know who numbered the notes, but if indeed they are out of sequence, that may then be a false assumption.

JUDGE SMITH: I see. All right.

Mr. Goldberg?

CROSS-EXAMINATION

BY MR. GOLDBERG:

Q. Dr. Zebroski, on the first page of your testimony in the last sentence you talk about the major area of your specialization during the period of 1965 to 1976 was the behavior of nuclear fuel under various operating conditions, including transients and accidents.

Does that area of specialization include fuel damage resulting from transients or accidents.

A. Yes.

Q. On page 6 of your testimony you mention the analysis which is contained in Wash-1400. Could you briefly describe what is the subject matter of Wash-1400?

A. "Briefly;" that's a tough assignment, but it is an attempt to make an analysis of all of the events which would be conceived to lead to a release of radioactive activity to the containment and to the environment; and

specifically since the cushion of release to the environment was the dominant safety question, it focused upon sequences which could lead to core meltdown, and specifically did not investigate intermediate states of damage which did not involve core meltdown. And I believe that one of the appendices noted that that was an area for future investigation and was beyond the state of the art to analyze at that time.

Q. Was the TMI-2 accident which occurred on March 28, 1979, as we know it now, one of those intermediate states which were not considered by Wash-1400?

A. I believe that is correct.

Q. Nor was it considered by any other publication to your knowledge; is that correct?

A. The "any other" -- well, I am aware that at the level of individual fuel rod damage experiments connected with ECCS, that individual fuel rods had been driven to extensive damage, even to fragmentation. I think the PRTR reactor had had an accidental channel blockage, and that both severely oxidized and actually fragmented some fuel rods, so there was the possibility of doing that if you had prolonged mismanagement through heat production and cooling.

At that level, the fuel element level, the research community was investigating for those kinds of phenomena. That had not yet entered the access analysis community, per se.

Q. On pages 6 and --

A. May I supplement that statement?

Q. Yes.

A. I would like to respond also to a point raised by Ms. Bernabei that I criticized the NRC. I definitely did not criticize the NRC. I was criticizing the state of the art of that topic at that time, acknowledged by all the people in the field; so this, in my thinking, did not constitute a criticism of any agency. My criticism, if any, was restricted to the question of perception of generation of oxygen in the presence of excess hydrogen. I think that percerption was well known in the textbooks, and I think that within the NRC staff itself there is a good deal of rueful regret on that subject.

Q. On pages 6 through 8 of your testimony, you talk about the amounts of iodine that were detected on March 28th, March 29th and March 30, in that time frame in 1979. Based on the prevailing state of knowledge that existed in that time frame of 1979, were the iodine readings which were actually taken indicative of core damage?

A. I guess the short answer is no. May I explain my answer?

Q. Yes, please.

A. On the Wash-1400 basis you would have expected a release of the iodine content of the pellet body, itself,

rather than just the iodine in the fuel clad gap. If you had a perforation of the cladding you would expect that there would be easily available iodine in the fuel clad gap, which is a small percentage of the total inventory. If you have the structure of the melting of the pellet, under the then-state of the art knowledge we would expect a very large fraction of the iodine, 57 percent or perhaps even more; and that clearly is not the case.

That explains my answer, that you would not incur structural damage,at that state of knowledge.

Q. You were asked a number of questions by Ms. Bernabei concerning thermocouple readings in the period of, I believe, March 31st to April 4th and your knowledge of those thermocouple readings.

Do you have any idea as to how many thermocouples there were at TMI-2?

A. I would say in plants in general the numbers would be many hundreds.

Q. Do you have any knowledge as to the frequency with which readings were taken in that time period of March 31st to April 4th, 1979?

A. Most of the significant thermocouples are on recorders or can be queried by the plant computer. Some are multipoint recorders and are not routinely read out in the control room. Again, I can't make a distinction by presenting

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a fraction. It varies from plant to plant.

Q. Are you aware of thermocouple readings being taken by the Nuclear Regulatory Commission in the period of March 31st through April 4th?

A. No. We understood that such information would be gathered. That was one of the few bits of information which we knew was not available to us.

Q. At this time are you aware that during that time period the NRC in fact were taking thermocouple readings?

A. Only as hearsay. I have no solid knowlege of that.

Q. I would like to direct your attention to TMIA Exhibit 6, which are the notes, the RAC notes of March 29th and 30th of 1979. Do you have that document in front of you?

A. Yes.

Q. I would like to refer you to page 4 of that document. Ms. Bernabei asked you a number of questions about the phrase "significant core damage." Do you see that phrase there?

A. Yes.

Q. Did I understand your testimony correctly earlier to be that you have no knowledge of whether Mr. Dieckamp actually made an assessment that there was significant core damage apparent as of the date of these notes of March 29th and 30th?

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MS. BERNABEI: I am going to object. That is a mischaracterization of his prior testimony.

MR. GOLDBERG: That's what I am trying to get, an understanding of his prior testimony. That's how I understood it, and I would ask the witness to explain if that was his prior testimony.

MS. BERNABEI: I object, that that is a mischaracterization.

JUDGE SMITH: Based upon Mr. Goldberg's explanation of his question, I don't think that you have any objection. He is trying to establish the testimony.

Overruled.

THE WITNESS: This is third-hand evidence because in the first hand Mr. Dieckamp says something, and in the second hand Mr. Kunder understands something, and in the third hand the secretary writes something down, and in the fourth hand we read it here; and we further recognize the imprecision of the use of the word "core damage" versus "fuel damage." So I can only say that I see those words, but certainly on present assessment it was not possible, even if somebody had been able to read and integrate all of the 2,000 signals in the control room, to make that statement with any degree of confidence. You could only state that there was clearly fuel leakage and release of some fission gases and some iodine, but it would only be a surmise that there was core structural

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damage; and I am using "core damage" in the sense that we discussed at the deposition and earlier today, that core damage means core structural damage so you would have to go through and replace it.

Q. Even as a surmise, do you have any first-hand knowledge that Mr. Dieckamp ever made that statement, as reflected in these notes?

A. As I say, I have only fourth-hand knowledge.

JUDGE SMITH: I hope you are not going to go very far. It would be very unfortunate if your questions along these lines generated another round of questioning, a very highly unreliable round of questions and answers such as we developed this morning. I think that the information -- I just hope you don't go very far.

MR. GOLDBERG: We will not.

JUDGE SMITH: We have spend an awful lot of time on puff, you know.

MR. GOLDBERG: That's exactly right, Judge Smith, and the record will show that this morning during Ms. Bernabei's questioning she repeated that after Mr. Zebroski testified that he had no first-hand knowledge that Mr. Dieckamp actually made that statement. She repeatedly mischaracterized his statement as if he knew that Mr. Dieckamp made that assessment, and that's the purpose of my --

MS. BERNABEI: Let me just --

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JUDGE SMITH: Wait a minute; I am not criticizing Mr. Goldberg. I am just trying to tell the parties: enough already, you know. We have heard all we want to hear.

MS. BERNABEI: Let me just state for the record the reason I asked Dr. Zebroski about these particular minutes is he relied on them and represented what they said in his testimony specifically on page 3.

JUDGE SMITH: No, Ms. Bernabei. I understand your point. My point is much more narrow, and that is we have spent too much time on non-probative testimony in this particular hearing.

BY MR. GOLDBERG:

Q. Dr. Zebroski, you were asked a number of questions concerning the steam bubble that may have been suspected on March 29th. Do you have any knowledge of whether Mr. Kunder reported to the NRC on March 28th in the morning about 9:25 that there was in fact a steam bubble in the primary system?

A. I have no such knowledge.

Q. When you use the phrase "core damage," what do you mean by that phrase?

A. I think you can define about eight shades of gray between normal fuel and the fuel leakers and so on and core melt. I think the simplest and most powerful distinction in that gray scale, it seems to me, is the level of structural damage where you can no longer remove the fuel and replace

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it. If you have anything substantially short of that, you would have a radioactive problem in clean-up, but, in principle, the fuel could be pulled out in a matter of days or weeks after you had access to the core, replaced and the plant would still have operability as a power plant.

Once you have that level of fuel that the fuel starts to fragment and collapse, you are in an entirely different regime and so forth; and so in the measure of the seriousness of the event, given that the radiation release reaches relatively high levels early in that gray scale, then that is already serious. If you then talk in terms of the plant viability, there is an enormous step in seriousness when you have the gross structural damage so you can't replace the fuel.

Q. One final question, Dr. Zebroski: again with respect to steam bubbles, do you know, is there a termperature of steam above which the HPI pumps could not collapse the steam bubble?

A. Yes.

Q. Is there a term for that temperature?

A. Critical temperature.

MR. GOLDBERG: Thank you. I have no further questions.

MS. BERNABEI: I'm sorry. I didn't hear that last answer.

THE WITNESS: Critical temperature.

(Pause.)

JUDGE SMITH: Dr. Zebroski, the Board has no questions of you; however, we do wish to give you an opportunity to consider whether you felt that any of your answers -- that you were not permitted to give a complete answer to any questions, if there was something that was left dangling because of the objections and interchange among the lawyers here.

THE WITNESS: Yes. I have two points. I think it was the series of questions on when the thermocouple data was available to us. I have reviewed that with the people who were gathered.

We had an EPRI employee stationed at TMI working with two GPU people who were assigned to establish an archive and gather all of the data, and we also had an individual designated to receive and disseminate and interpret what was available as soon as it was received and hang it in our war room and make it available to the analytical group.

I talked with all but one of those people directly and through some secondhand also with that missing person, and they all assert that they have no evidence that the hot-leg data was treated in any different way than any other data. That is it was made available to us as fast as it was possible to duplicate it and film it. We, in fact, had it for some time before we knew we had it because it was on microfilm and very difficult to read and only after people had invested

quite a bit of effort in deciphering the cloud of points was the hot-leg data which ranged from up to 800 degrees and over plotted as a single line as it appears on our report in the supplement and in the March, 1980 edition.

And furthermore, had we considered that data critical to any of the analysis, we would have put much greater effort into pursuing it sooner. As it turned out, it really had no quantitative bearing. Our understanding of the situation was already ample that the temperatures were above saturation temperature for a substantial period of time, and our report plots those time intervals explicitly. So that information was used explicitly in the analysis right from the beginning.

So I will make two points. There is no evidence that there was any delay or withholding of that information. I believe there was some confusion either in my mind or Ms. Bernabei's mind in the deposition whether we are talking about a delay on the hot-leg temperature or a delay of the in-core thermocouples. So there is no question that the in-core thermocouple data was not available until it was discovered sometime in May.

Again, as evidence of due diligence on the other side, I think as soon as that piece of paper appeared -- and I tracked the paper trail on that by some telephone calls -- that it got out to California in a matter of a couple of days.

So again, we have no indication that we got other than

the full cooperation that they had promised us.

Furthermore, on the 51 thermocouple readings, the in-cores, we had hearsay awareness from the plant people that somebody had measured extremely high temperatures on the day of the accident; they couldn't find the actual paper; but that that knowledge was available to us, and that they had to measure the knowledge that they were accompanied by some low measurements which appeared incredible because they were lower than the general temperature of the system which was also available.

We came to believe the high temperatures fairly quickly, but at least the explanation of why those high temperatures were initially not believed, which is the appearance side by side of incredibly low temperatures, at least that was understood as part of the confusion.

The fact that we later got the entire 51 readings did not have any bearing on our understanding or analysis of the thing. I think everybody felt that had those really entered into the perception of those people that some of those readings were very high and had to be explained, the seriousness of the situation might nave come a day earlier.

So that certainly was a regrettable lapse in that transmission of data, but the data, which I understand was communicated clearly -- that is: we got two high and two low readings; we don't know what to believe -- we knew that story. We came

to believe the high readings were at least very strongly indicative, even without knowing the exact numbers, of a powerful saturation temperature and confirmed the other evidence that people eventually uncovered.

When we finally had the detailed readings, they did not really contribute to the analysis. What they did contribute to was we undertook a study of how, given the fact that temperatures above the melting temperature of stainless steel were very likely to have occurred, how could you still be getting any kind of readings on these things.

Experimentally, we asked Oak Ridge Natural Laboratory to attempt to reconstruct those conditions; and when they put thermocouples under melting conditions -- that is steel melting conditions -- they couldn't get them to rejoin and function as thermocouples. There were many tries. So there is still a mystery of where those junctions exist and how it is that they are functioning. Some of them are reading very near the right temperatures even today I understand. So that's the subject of investigation.

The second point: I would like to respond to the allegation that I was critizing the NRC in any broad way. I would like to make it very explicit that the criticism was limited to question of the flammability or explosion potential of the hydrogen bubble by the mechanism of radiolysis producing oxygen under those conditions. I think that is

fairly basic information in reactor operation.

I think it is regrettable that responsible people, including people with technical director titles were unaware of that very basic fact, which is the basis for the putting of hydrogen into all pressurized water reactors from 1955 on. That regret I think you get even with talking with the staff. We should have known that. It is readily admitted.

The implied criticism of Wash-1400 or the licensing analysis was not a criticism of analysis. It was a criticism of the -- it was alluding only to the state of the art at that time which had not treated the subject of the intermediate stages between fuel perforation and core melt. That omission both in analysis and data and testing and the state of the art generally was alluded to explicitly in the appendix to Wash-1400. So I think there is not the slightest scintilla of implication of criticism. It is simply a recognition of a widely recognized state of the art at that time as seen from the perspective of the present time.

To buttress that point a little more clearly, there had been five years -- at least the last three years have been very intensive -- of research on the subject of the serious accident analysis, the in-core program in the industry, and a corresponding effort in the NRC and DOE laboratories and overseas --

JUDGE SMITH: I might say that we perceive no

perjorative connotation in your testimony at all. I think we understood right from the very beginning that you were demonstrating a different historical perspective. I am concerned about your explaining the testimony, but I'm also concerned about going in the direction in this record in which we have no jurisdiction or no concern.

THE WITNESS: I was responding --

JUDGE SMITH: We saw no perjorative connotation, however, in your explanation.

THE WITNESS: Well, I felt a perjorative connotation in the implication that I was disagreeing and second-guessing the NRC at that time. There was no such connotation in my statement.

I am trying to make the point that anyone even in the NRC staff today I believe would agree that there has been a need for these five years of research of which three years have been very intensive and many tens of millions of dollars to define, among other things, these intermediate stages of core damage.

The implication was that we couldn't do that because somebody was withholding data is what I am alluding to. I am trying to make the point that the inability to analyze it was a lack of the state of the art to be able to analyze it --

JUDGE SMITH: I think your testimony has made that abundantly clear.

THE WITNESS: Thank you, sir; and I am through.

JUDGE SMITH: Before we go to Mr. Blake's redirect, do you wish to follow on Dr. Zebroski's explanation?

MS. BERNABEI: You're talking now about the criticism of the NRC staff?

JUDGE SMITH: Yes. After we gave him a chance to explain any areas he felt remained unexplained, we wish to give you an opportunity if you see a need for it.

MS. BERNABEI: We may offer rebuttal testimony to Dr. Zebroski's in terms of withholding information, but --

JUDGE SMITH: That's not my point.

MS. BERNABEI: No further questioning.

JUDGE SMITH: All right.

Mr. Blake.

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REDIRECT EXAMINATION

BY MR. BLAKE:

Q. Dr. Zebroski, Mr. Goldberg, NRC staff counsel, asked you a question about your definition of core damage. The detailed answer that you gave as a definition, is that your definition of how you would use that term today?

A. I hope I don't have to give a yes or no answer to that. I think it would depend upon the context of the use of the term, but in general, yes.

Q. Was there such a detailed or commonly understood definition in being at the time of the TMI-2 accident?

A. No. The term was used loosely.

Q. That is the term "core damage" by you or your peers at your level of expertise or individuals in the operating environment; the host of people who came to comment or make observations about the TMI-2 accident, in your view, would not have had a common definition of that term, "core damage"?

MS. BERNABEI: I object to the form of the question. It's a leading question.

JUDGE SMITH: Are you waiting for a ruling?

MR. BLAKE: Yes.

JUDGE SMITH: It may be leading; however, it's not likely that Mr. Blake will suggest an answer to Dr. Zebroski. It's efficient. We are running out of time.

Off the record for a moment.

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(Discussion off the record.)

JUDGE SMITH: Back on the record.

Go ahead.

THE WITNESS: Will you restate -- whether that was common terminology at the time?

BY MR. BLAKE:

Q. That's correct; yes.

A. The pragmatic historical answer was that we had a meeting of all the known experts we could round up, including the NRC people, on Thursday of the first week of April, and they began to make that distinction between field damage and structural damage in that meeting.

But as common practice prior to that time, I would say no. It was the gray scale that was not understood.

Q. Dr. Zeborski, there were a number of questions asked of you regarding EPRI's or the industry advisory group's access to or availability of information to those groups in a timely way.

Are you aware of any instance in which the industry advisory group or, subsequently, EPRI, was delayed in receiving information or otherwise did not have information made available to it in a timely way where Mr. Dieckamp could have possibly played a role?

A. Given the last phrase, the answer is clearly no. Our evidence, objective evidence, was that Bob Arnold issued

a directive to the staff that they make all of the total information available as promptly as possible to the archival group under Bob Long; and Bob Long in turn had a directive to make that available as promptly as possible to us. We were allowed to station a person there to help with the compiling of the information.

MR. BLAKE: I have no more questions, Judge Smith.

JUDGE SMITH: Ms. Bernabei.

RECROSS-EXAMINATION

BY MS. BERNABEI:

Q. I believe in a question posed to you by Mr. Goldberg you stated that you did not believe the iodine readings taken on the date of the accident would necessarily be indicative of core damage; is that correct?

A. That is correct.

Q. Do you know whether or not GPU management interpreted iodine readings to indicate core damage on March 28?

A. I do not know the answer to that.

MS. BERNABEI: I would like to mark as TMIA Exhibit 8 what has been identified in depositions as the notes of Richard Lentz, the GPU service corporation engineer involved in management meetings at GPU service corporation on the morning of March 28.

(Whereupon, the document referred to was marked as TMIA Mailgram Exhibit No. 8 for identification.)

BY MS. BERNABEI:

Q Dr. Zebroski, referring to the second page of what has been marked as TMIA Exhibit 8, specifically item 10 which appears on that page, that indicates, does it not, a linking of high iodine levels to possible core damage?

A Excuse me; I'm just getting to that page.

JUDGE SMITH: Give me time to write down the exhibit number, get to your page, and --

MS. BERNABEI: I'm trying to expedite things. I apologize.

THE WITNESS: I'm ready.

JUDGE SMITH: Wait a minute. Just a moment. These are Lentz's notes you said.

(Pause.)

JUDGE SMITH: All right, now start in.

BY MS. BERNABEI:

Q These notes would indicate, specifically at page 2, item 10, would they not, that there was a link, at least assuming you use Mr. Lentz's notes, of high iodine level to core damage?

A Certainly questionable.

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Q. In response to another question by Mr. Goldberg you talked about critical temperatures in which the makeup or HPI would not collapse a steam bubble; is that correct?

A. (Witness nodding affirmatively.)

Q. That temperature, what are the ranges of critical temperature?

A. It's within a degree or so of 700 Fahrenheit.

Q. It is fair to say that those temperatures did not exist in the evening of March 28 or thereafter at TMI, that is, temperatures of that magnitude.

A. That's not a determinable question. It might have existed at some spots locally. But in the context of your question, whether the pump had collapsed the bubble, they did not exist over any substantial volume in the system so as to prevent the bubble from collapsing.

Q. And that would be from the evening or late afternoon of March 28, thereafter?

A. Correct.

Q. I believe in your statement that you were invited by the Board to make you talked about the 51 thermocouple readings. I think your testimony was that that information from those readings was available to you even though you didn't have the hard data so to speak; is that correct?

A. The fact that mixed high and low observations had been made was available.

Q. Now we're talking about the complete or 51 thermocouple readings; is that correct?

A. Correct.

Q. Is it your impression or your understanding that that complete set of the 51 thermocouple readings was also available to site personnel on the first day of the accident?

A. It is my impression that it was available to the technicians who made millivolt measurements, but I have a strong inference that nobody actually completed the conversion of those millivolts to temperatures at the time. In fact, the evidence is that it was done on two occasions in the first week of May, once by people working on the archive work under Bob Long, and again by the recorder in Palo Alto at our request.

Q. Let me ask you the question again. I believe your answer is yes. You believe that site personnel had available to them, whether in millivolt readings or in temperature readings, a full set of in-core data, that is, the 51 or so readings.

A. The 51 readings existed, but to discriminate site personnel and those in charge in the control room, I think the answer is no.

Q. What is the basis for your information?

A. Because there was no evidence that I'm aware of that the millivolts were converted to temperatures at that

time.

Q. Other than --

A. The sheet that we got was millivolt readings without temperatures. Beyond that I won't speculate.

Q. The basis for your opinion that it was not available to site management was that the temperatures were not converted; is that correct?

A. That's correct.

MS. BERNABEI: I have no other questions.

JUDGE SMITH: Any further questions?

MR. AU: No further questions.

JUDGE SMITH: All right, Dr. Zebroski. Thank you very much, sir.

(Witness excused.)

JUDGE SMITH: We will meet then Monday at the library of the University Center at 10:00.

MS. BERNABEI: Judge Smith, before we adjourn, there are a number of exhibits which I would like to move into evidence. If the Board wishes, we can do that on Monday morning.

JUDGE SMITH: I think if we can move along, we should do it today while our memory is fresh.

MS. BERNABEI: They are specifically TMIA Exhibits Nos. 2, 6, 7 and 8.

MR. McBRIDE: Excuse me, just one moment, Ms. Bernabei.

Judge Smith, would you object if Dr. Zebroski and I absent ourselves at this point?

JUDGE SMITH: Dr. Zebroski is excused.

JUDGE WOLFE: Those numbers again, Ms. Bernabei?

MS. BERNABEI: Yes; 2, 6, 7 and 8. I was going to go one by one and describe them.

MR. BLAKE: Would the Board object to doing this on Monday as the first order of business? I'm searching here; I can't even find all the numbers yet.

MS. BERNABEI: I can identify them and assist Mr. Blake.

JUDGE SMITH: I suspect it is going to take some debate and argument. We may have the advantage then of the transcript, and I think perhaps it would be better to wait until Monday morning to argue your exhibits.

MS. BERNABEI: I have one other request. It does not appear at this time that we have the joint exhibits despite Mr. Blake's representation, and I would request permission to use the Board's copy, unless the Board intended to use it this weekend.

JUDGE SMITH: I think it would probably please Mr. Lewis if you were to do that. We have no objections to it.

MS. BERNABEI: Unless the licensee will provide us a copy. We do not appear to have it at this time.

JUDGE SMITH: You would understand that you wouldn't

mark on them or anything. I don't want any messages on the exhibits.

MS. BERNABEI: I promise.

JUDGE SMITH: Do you have any objections to that?

(No response.)

JUDGE SMITH: All right; that's fine.

Anything further?

(No response.)

JUDGE SMITH: We're adjourned until 10:00 a.m. on Monday.

(Whereupon, at 1:17 p.m., the hearing was adjourned, to be reconvened at 10:00 a.m. on Monday, November 19, 1984, in Harrisburg, Pennsylvania.)

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# CERTIFICATE OF OFFICIAL REPORTER

This is to certify that the attached proceedings before the UNITED STATES NUCLEAR REGULATORY COMMISSION in the matter of:

NAME OF PROCEEDING: Metropolitan Edison Company
(Three Mile Island Nuclear Station, Unit No. 1)

DOCKET NO.: 50-289SP
(Restart Remand on Management)

PLACE: Room 156, Main Capitol Building
Harrisburg, Pennsylvania

DATE: Friday, November 16, 1984

were held as herein appears, and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission.

(Sigt) John A. Kelly
(TYPED)
John A. Kelly
Official Reporter

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