UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

SUBCOMMITTEE ON CLASS 9 ACCIDENTS

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

Thursday, August 28, 1980

The meeting of the Advisory Committee on Reactor Safeguards Subcommittee on Class 9 Accidents was convened, pursuant to notice, at 8:30 a.m.

MEMBERS PRESENT:

W. KERR, presiding
H. ETHERINGTON
S. LAWROSKI
J. C. MARK
C. P. SIESS

ACRS CONSULTANTS PRESENT:

J. LEE
R. SEALE
S. SIEGEL
G. SCHOTT
D. GREGORY
R. STREHLOW

DESIGNATED FEDERAL EMPLOYEE:

G. R. QUITTSCHREIBER

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PROCEEDINGS

MR. KERR: The meeting will come to order.

This is a meeting of the Advisory Committee on Reactor Safeguards, specifically the Subcommittee on Class 9 accidents.

My name is William Kerr. I am Subcommittee chairman. Other ACRS members here today are Mr. Etherington, Mr. Lawrowski, Mr. Mark and Mr. Siess. As consultants we have Messrs. Lee, Seale and Siegel. As invited experts -- I am not sure I know what the difference is -- we have Messrs. Shott, Strehlow and Gregory.

The purpose of the meeting is to discuss hydrogen generation and control. This represents an interesting departure from the usual in that we spend much of our time discussing the more complicated atoms, and I guess we have learned our lesson and we are going to start now looking more at simple atoms, and perhaps we can solve that problem.

We have as a continuing consideration the evolution and treatment of accidents more serious than the design basis accident, which I guess we refer to as the Class 9 accident. As a part of that consideration, we had originally planned today's meeting to look at some of the information available and some of the considerations associated with the production, distribution and possible consequences of hydrogen generation during accidents.

After the meeting was planned, we also received some specific questions from Commissioner Gilinsky having to do with the Sequoyah case specifically. I think you perhaps have those questions, but I might repeat them because part of our effort today will be to get information that may help the Committee to deal with those questions.

They are specifically: Does the Committee believe additional hydrogen control measures are necessary for ice condenser containments; and second, is the Committee reasonably persuaded of the effectiveness of distributed igniters in ice condenser containments? Can such igniters be counted on to keep pressure increases caused by hydrogen burns at suitably low values, which I would define as design pressures, during accident sequences involving TMI-like quantities of hydrogen?

We have received, those of us on the Subcommittee, the consultants and, I presume members of the Committee, eventually, rather voluminous information hydrogen, some of which deals specifically with the Sequoyah situation, some of which deals with the broader questions. This information varies from a so-called compendium on hydrogen which has been put together by Sandia, among others, to a set of SECY papers prepared by the staff for consideration by the Commission.

I would suggest that as we explore this question, both the Subcommittee and the Committee, we give continuing attention to an effort to understand the approach that the staff plans to take in eventually trying to deal with this question on a general basis.

I assume that will finally occur in the rulemaking hearings and in the process of rulemaking, and I would guess that the philosophy is now being developed. I have had some problems myself in understanding what approach the staff plans to take eventually.

I could get the impression in reading the SECY papers that the present approach of the staff and, perhaps, even the Commission, based on reading of transcripts of meetings, might be one which will make the generation of hydrogen due to x percent metal/water reaction -- where x is still undefined in y minutes, and where the number of minutes is also not completely specified -- on a non-mechanistic but conservative basis as a design basis accident and would then plan to require that a system exists which will keep the containment pressure produced thereby to an acceptable level where the acceptable level is still not thoroughly defined.

It might be some multiple of design pressure between perhaps 1 and 3. It is not yet clear to me on what basis one would require the operation of the mitigation system, whether one would talk about a single failure criterion or some probabilistic basis. That, insofar as I have seen, has not been made very clear, and indeed, I may be misinterpreting the approach. I have been trying to understand it.

Comments made by some of the staff and even some members of the Commission in the discussions I read might lead me to conclude that an event producing an amount of hydrogen equal to that produced at TMI, given in some cases as 200 to 300 kilograms of hydrogen, and in others to 30 to 50 percent of metal-water reaction, is likely with high probability to occur at each operating reactor during its useful life, and that those changes in equipment, procedure, training and staffing which have already been introduced, and some of which soon will be, have had little or not effect on the probability of occurence of a hydrogen-producing accident.

Again, I am not sure I am interpreting the discussion correctly. But that could be an impression on would get.

Also, it seems to me, in spite of all the comments that have been made since TMI-2 about early attendance to concentrate on low probability accidents and to ignore higher probability but presumably lower consequence accidents, I don't see a clear approach yet to an attempt to specify a consideration of scenarios or sets of accidents which are classified according to probability.

In fact, it seems to me that at least in the SECY paper, that the staff estimates of quantitative hydrogen production appear to be based on consideration of production of hydrogen by a large LOCA followed by failure of the ECCS. Again, I am giving my effort to interpret what I have seen, and I may be misinterpreting it.

What I am trying to suggest to you and to me and to each of us is that we try to explore and understand the ultimate approach that is going to be taken in deciding how one deals not just with the Sequoyah problem but with the hydrogen problem in general, and as it fits into consideration of Class 9 accidents.

Now, in the Sequoyah situation itself, as far as I can tell, a good bit of attention has been given to what at least TVA and the staff interpret to be a set of scenarios somewhat similar to TMI-2. It would be interesting to me, although I am not sure how feasible this is, to see attention given to scenarios chosen on the basis of probabilities, with a goal of trying to attach some sort of probability to the generation of some quantity of hydrogen.

It seems to me, and I am not sure this is feasible at all, that one can postulate sets of scenarios that will lead to generation of almost any amount of hydrogen up to that that would be produced by a metal/water reaction with all the zirconium and all of the steel in the system, if one wants to carry things that far.

So, it would appear to me that at some point one almost must deal with probabilities. Again, I recognize that this may be early in the game and that this may be an ultimate intention.

It also seems to me that at some point we need to try to deal with whether the changes that have been suggested and in many cases mandated by TMI have decreased the probability of hydrogen generation, and how much?

For example, has the probability, once these are in place, been decreased by a factor of 10 or 100 compared to what it was before TMI-2? Is it the same for all kinds of reactors, or does one need to give specific consideration? And is there some probability below which one does not worry about hydrogen generation?

It is also not clear to me that whether in the treatments we are seeing, we are taking a conservative approach or the staff plans to take a conservative approach or whether a best estimate approach is the one that is appropriate. Does the staff have an ultimate goal? And if it does, is this goal understood by licensees who have to deal with this problem?

That perhaps is enough of a set of comments from me, and I simply indicate these are some of the questions that have occurred to me as I have tried to read the information. I do think that the information made available to the Subcommittee represents quite a lot of work, and I find it quite useful, and I look forward to learning further as we go through the day.

You will note that we have scheduled a fairly full day's work. I have a plane schedule to leave at 6:15 this evening and I hope to be able to catch it, which means we probably will be finished by about 5 o'clock, if anybody has a tight schedule.

MR. MARK: Mr. Chairman.

MR. KERR: Yes, sir.

MR. MARK: One thing about your description I thought gives the picture very beautifully that bothers me is that those objectives which you referred to as perhaps being ultimately going to become clear, it is absolutely urgent that they become clear before one go into rulemaking or anything else.

MR. KERR: Thank you, Mr. Mark.

After those comments, I should remember to add that the meeting today is being conducted in accordance -- I have not mentioned that, have I?

MR. QUITTSCHREIBER: No.

MR. KERR: I must. -- with the the provisions of the Federal Advisory Committee Act and the Government in the

Sunshine Act and all other applicable rules and regulations.

Mr. Quittschreiber is the designated Federal employees. Rules for participation in today's meeting have been announced as part of a Federal Register notice on August 6 of this year.

A transcript is being kept and will be available as stated in the notice. Those speaking who want to be recorded should try to use microphones so that the recorder can understand what you say.

I gather that we have not had any written comments nor requests for time to make oral statements.

I will proceed now with the meeting; but before I do, I should ask, I am sure, if there are comments or specific questions with which members of the Subcommittee would like to deal at this point, or the consultants.

(No response.)

I see none. I will therefore call upon Mr. Butler of the NRC. Mr. Butler.

MR. RUBENSTEIN: My name is Lester Rubinstein. I am assistant director for core containment systems. As Dr. Kerr has mentioned, the staff is here to answer many of the questions which he has raised. I am not sure in this time period we will be able to answer all of the questions; however, we have prepared a comprehensive discussion on most of the issues he touched upon.

We do provide early in the discussion a perspective on the current state of affairs of hydrogen management in all containments. We touch briefly on this. We move on to place this in perspective with the current regulations and the plans that the staff has to deal with hydrogen management in the interim through the interim rule and the requirements for Sequoyah, and finally, with the long-term rulemaking hearing.

We have invited our consultants to give you a detailed presentation on the status of our work on the distributed ignition system, with particular attention to the Sequoyah plant.

Dr. Butler will lead off with an introduction which considers the agenda we will follow and some particular remarks on general containments.

(Slide.)

MR. BUTLER: Good morning. My name is Walter Butler of the NRC staff.

As Mr. Rubinstein described for you, we will follow as close as we can the agenda given by the Subcommittee. We have presenters today. Following myself will be Shapaker, Tinkler, instead of Phil Di Benedetto, we will just cover for his subject matter with respect to the response of equipment, and Messrs. Fleishman, Madeiros, Bowman and Cybulskis.

I thought it would be helpful to get started simply by putting on the board the agenda which each of you already have. The presentations we have are basically as prescribed here, which allows about an equal amount of time for questioning.

We will start off here with a background discussion and setting perspective of how we got to this point today. Some things have been moving very fast on the subject of hydrogen.

(Slide)

The second page of your agenda is shown there. We hope to conclude the NRC staff portion of presentation soon after lunch, with the statement of our view of where we stand on the general subject of hydrogen and on the specific nature with respect to the Sequoyah station.

This will be followed by a presentation by R&D Associates of Los Angeles on subject matter similar to what the staff will have previously addressed. Similarly, TVA will express its views on the same subject. The last hour here will be presented by Mr. Miller of EPRI.

(Slide)

I would like to discuss now the statement of the objectives as we view them for today's presentation. We would like to provide summary discussions of the general hydrogen issue as it affects all plants, including a description of our overall program to resolve the issue of hydrogen generation and control for all plants.

We would like to provide detailed discussions on the specific hydrogen issue as it affects the Sequoyah station, and also the specific attention to the interim resolution for the Sequoyah station.

It is my understanding that there are two issues that need some attention by the ACRS or on which the Commission would like the ACRS's views. One issue which will be dealt with today is the hydrogen issue and the response to hydrogen combustion. The other issue is the structural response -- the behavior of the structure to the pressures as a result of hydrogen burn.

The second issue will be addressed by another subcommittee on Tuesday the 2nd of September. We will only have a brief discussion here, simply for perspective reasons, a discussion of our view of the yield pressure and failure pressure for the ice condenser containments.

(Slide)

A slide that describes some of the background to how we got to this point today. First of all, the pre-TMI requirements, pre-TMI licensing requirements are prescribed in the regulations, 10 CFR, Section 50.44, and in the general design criteria number 50 of Appendix A to Part 50.

Following the TMI accident there was prepared the staff's Action Plan, NUREG-0660. Items relevant to hydrogen generation and control are dealt with in items II.B.6, 7 and 8 of the Action Plan, as well as the so-called RSSMAP studies of the Probabilistic Assessment Staff of Research.

Those entries in the Action Plan identify work that needs to be done on prescribed schedules dealing with hydrogen. The previously mentioned series of SECY papers, 107A and B, were prepared in response to item II.B.7 of the Action Plan. SECY paper 80-283 was prepared in response to the RSSMAP studies of the Probabilistic Assessment Staff.

There was a concluding paper prepared very recently, item 1.3.3 of that slide, Hydrogen Control for Sequoyah, which was considered during the Commission meetings of August 14 and 21, just these past two weeks.

There are also some related reports available, two R&D Associates reports, one dealing with structural response and the other dealing with a critique of the hydrogen generation and control work that was sponsored by the NRC staff. There are also a series of Sandia reports, including the compendium and a number of reports on selected topics that are available.

(Slide)

A slide of the chronology on the recent activities, starting with the February 22 issuance of SECY [illegible]107. That paper gave a general discussion of the responsiveness or sensitivity of the various types of containments to hydrogen generation and control. That paper concluded with staff recommendations that MARK I and MARK II containments on boiling water reactors be required to be inerted.

An interim rule that carries out or proposes to carry out that recommendation will be discussed later on in today's work.

On March 19 there was a Commission briefing on that general paper, followed by on March 28 a Commission request for certain additional information relative to the 107 paper. The requested informatin was furnished in SECY papers dated April 22 and June 20, the 107A and 107B papers.

On June 26 the Commission heard a briefing on the entire series again. There was a meeting with the ACRS on July 11, followed by the ACRS report on Sequoyah dated July 15. The last two entries there were the August 14 and August 21 briefings of the Commission.

(Slide)

It is my understanding that these issues will be considered again at the full committee meeting of the ACRS on September 4 and that there will be a Commission meeting soon thereafter. I am not sure whether it is the evening of that same day or the very following day, the 5th, but we should hear that very soon.

I thought it would be a good idea to briefly summarize where the different plants with different containments stack up. The MARK I BWRs we recommend and the draft interim rule would require that they be inerted. There are only two operating BWRs that are not currently inerted. These are the Vermont Yankee and Hatch-2 plants.

MARK II BWRs, because of their small size and low pressure - well, moderately low pressure design -- are also recommended for inerting. Ice condensers. The specific licensing requirements relative to hydrogen generation and control, as we all know, are under consideration by the Commission and are presently under discussion.

MARK III containments are in the same hydrogen sensitivity situation as the ice condensers, and licensing requirements for the MARK II relative to hydrogen generation and control are still under consideration by the staff.

The first plant to be licensed with a MARK III is the Grand Gulf station. Subatmospheric containments and dry containments, because of their large size and high design pressure, do not require hydrogen control requirements beyond Section 50.44, 10 CFR 50.44, pending the rulemaking proceeding that was discussed earlier.

On the subject of ice condenser plants, we have listed all ten of them here at five sites.

(Slide)

Their fuel load dates are indicated on the far right. Three operating plants include Cook-1 and 2 and Sequoyah-1. Though Sequoyah is at this time loaded to 5 percent power, all the others are in various stages of construction, with McGuire-1 being the very next plant scheduled for fuel loading. All the others are 1981 and forward.

(Slide)

A brief paper that characterizes design features important to hydrogen control. The structure of all ten ice condenser units are all freestanding steel, with the exception of the two Cook units, which are reinforced concrete. Design pressure: they are all at 15 pounds except Sequoyah and Cook which are at 12 pounds.

The net free volume of containment: they are all about 1.2 million cubic feet, about half the size of the large dry containments. The provisions for containment sprays: they are all in the upper compartments with the exception of D.C. Cook, which has the sprays in the lower compartment as well.

(Slide)

The staff approach toward developing resolution on the subject of hydrogen control, the staff has broken the program up into short-term and long-term. The object of the short-term is to define and implement those requirements to assure no undue risk to the health and safety of the public pending the rulemaking proceeding.

The long-term approach would require the owners of nuclear plants to conduct analyses and experiments where these studies should be designed to establish the data base for defining the design features that make the plant's response to degraded and melted core accidents acceptable.

We will also establish NRC-sponsored research and technical assistance programs to confirm the results obtained by LWR plant owners, and to establish the acceptance criteria for the design features we expect will be proposed for mitigating degraded and melted core accidents.

(Slide.)

A description of our short-term program for Sequoyah and for other ice condenser plants. We have technical assistance work underway with Livermore National Laboratory where they are charged with developing data to determine that the interim distributed ignition system proposed for Sequoyah will not degrade the safety of the plant, and that the igniters will in fact successfully lean mixtures of hydrogen, air and steam.

At Battelle-Columbus we have a program underway to assess the IDIS in terms of the extent to which that system can improve hydrogen control in ice condenser plants. At Sandia we have work underway to develop a data base on alternative systems. The point being that should the current efforts on the IDIS lead to a conclusion that they are not suitable for hydrogen control, we would like to have some backup system and efforts to understand potential backup systems are underway at Sandia. These are the halon system and the water fogging system.

At Ames Laboratory we have work underway to understand the structural response of various containments. Included in that program is a determination of the response of the structures to localized detonations. TVA and the other ice condenser owners have an association designed to study the sensitivity of ice condensers by use of the so-called CLASIX code. More details on that code will be discussed later today.

They will have programs underway to assess the accuracy and reliability of the CLASIX code. They will perform -- they have completed tests at the Singleton Laboratory and have just yesterday submitted the results of those tests. They will have an extended program of tests at the Fenwall Laboratory in Massachusetts, and that will be a subject of discussion by the staff later today.

Finally, part of the Fenwall tests will include an assessment of the response of selected vital equipment to the anticipated burn environment.

(Slide.)

The final slide I have here, to give you a perspective on the time in which we are doing the various things and selected pieces of milestones here, starting with September 2, next Tuesday, we expect to receive from TVA their safety analysis report on the IDIS. There will be the full committee meeting on September 4 followed by a Commission meeting on Sequoyah. October 1 we expect to have the testing at the Fenwall Labs completed, at least for the early series of tests. The work at Livermore will be completed October 30. The Sandia work on assessment of alternative hydrogen control measures, October 30.

Similarly, the Battelle-Columbus analyses, we expect to have that work completed by October 30 as well. Reports on all these activities should be available to the staff by November 15 with a target of a staff SER on the interim distributed ignition system by September 15. We expect to present the results of the staff review to the ACRS in January and brief the Commission soon thereafter.

MR. LAWROSKI: Will there be any test results available by the September 4 meeting?

MR. BUTLER: While there will be the results of the very elementary tests at Singleton Labs, it is a very small unit that just -- there will be results of the durability of the selected igniter system. There will be completed certain tests at Fenwall Labs, but data from them will not be too meaningful. They are just kind of checkout tests.

MR. LAWROSKI: I was referring to the expectation based on the Sequoyah hydrogen control plans report.

MR. BUTLER: I'm sorry. I did not hear the question.

MR. LAWROSKI: My question was based on a date I thought I saw in the --

MR. KERR: Will you use a microphone, Mr. Lawroski?

MR. LAWROSKI: I am now. Thank you, Bill.

I thought there was a date of the availability of such tests by August 15 according to the report -- draft report on hydrogen control for the Sequoyah nuclear plant, which bears no date unfortunately.

MR. BUTLER: Yes. We were expecting a safety analysis report from TVA by August 15. The safety analysis report -- there was material furnished August 15, but we felt it was not really a complete report with respect to what should be in a safety analysis report. We have since sent a letter to TVA identifying the topics that need to be addressed, and they intend to furnish a response to that by September 2, on Tuesday.

Nevertheless, those will not contain the results of any substantial testing. They are results primarily of analytical efforts.

MR. LAWROSKI: I want to correct myself. The report does have a date, August 13, 1980.

MR. BUTLER: Oh, yes, that is the -- that is the hydrogen control paper.

MR. LAWROSKI: Yes.

MR. BUTLER: But that submittal of August 15 was expected to be a safety analysis report which was not expected to contain results of experimental work.

MR. LAWROSKI: That is also mentioned. It is expected to be available by September, as well as some test results.

MR. KERR: Do you understand Mr. Lawroski's questions? I am not sure I do, but if you do it is okay.

MR. BUTLER: No, I don't understand the last question.

MR. LAWROSKI: He has answered the -- at least for me enough, the extent of the tests that will be available.

MR. KERR: Okay.

MR. MARK: Could you say in a very few words, just topic headings, what is in and what is not in the MARCH code?

MR. BUTLER: I think I will have to defer to Mr. Cybulskis or Charlie Tinkler.

MR. RUBINSTEIN: We have a presentation on that later in the afternoon.

MR. MARK: That will be fine.

MR. KERR: Does it say in a very few words what Mr. Mark wants?

MR. RUBINSTEIN: I cannot promise that.

(Laughter.)

MR. KERR: Please continue.

MR. BUTLER: The very next topic on the agenda is a discussion of the rulemaking proceedings, starting off with the interim rule by Mr. Fleishman, and he will be followed by Mr. Madeiros on the advance notice of rulemaking for the final rule.

MR. KERR: Mr. Butler, if your presentation is complete, on one of your transparencies labeled "Staff Approach Toward Developing Resolutions," I find that the long-term approach requires owners of nuclear plants to conduct analytical and experimental studies to establish a data base for defining those design features that make the plant response to degraded/melted core accidents acceptable.

Now, it would seem to me that in order to do that they would need a fairly clear definition of what degraded coremelt accidents they were protecting against. Is the staff in the process of developing a scenario or a design basis accident against which they are to mitigate?

The transparency does not mention this, and it would seem to me that that would be a fairly important part of the total picture.

MR. BUTLER: I believe the answers to that question will be the outcome of the rulemaking proceeding itself.

Now, there are a series of questions in that area contained in the advance notice of rulemaking, and Mr. Madeiros will describe the kinds of questions we are asking to adduce the necessary information.

MR. KERR: But you are not going into the rulemaking hearing blind, are you? The staff will have a position before it goes in -- a tentative position at least before it goes into rulemaking, won't it?

MR. BUTLER: I would rather defer to Mr. Madeiros to answer the question.

MR. KERR: Surely this is going to be an NRC position and not a Mr. Madeiros position.

MR. BUTLER: That is true.

MR. KERR: Well, does the NRC have a position now? Is it going into the rulemaking hearing with a tentative position?

MR. BUTLER: Well, I believe by the class of questions that we ask it indicates the direction we are taking.

MR. KERR: So that you will have a direction but nothing other than that.

MR. RUBINSTEIN: We do have a position going into the rulemaking hearing for the small containments such as the MARK I's, the MARK II's. We will have a position --

MR. KERR: The position that I see now is a position that says given that one has hydrogen in the containment, what does one do about it. But what I see written here is require owners to conduct analytical experimental studies to etablish a data base for defining design features that respond to degraded/melted core accidents.

Now, in order to do that it seems to me one has to know what kind of accidents one is designing against. And the position for Mark I and Mark II does not define the accident against one which is designing.

It is a non-mechanistic thing. It defines one has a certain amount of hydrogen, and what I am trying to get a picture of is that the sort of definition that you plan or -- I recognize the answer may be that you simply have not decided yet. And if that is the answer, then do you plan to decide by the time you go into rulemaking what at least the staff would consider to be a sensible approach to this?

MR. NORBERT: Jim Norbert from Office of Standards Development.

In the interim rule which Mort will be talking about here shortly there is a number that we are asking the vendors to do design studies on for the interim -- as part of the interim rule, a number on how much hydrogen release they should -- to look at as a basis. There is nothing fixed. It is not the staff's final position, but it gives them a bound to shoot for; and that is in the interim rule.

MR. KERR: I guess what I am reading from is labeled as a long-term approach.

MR. NORBERT: I was not quite sure about that with Walt either.

MR. RUBINSTEIN: The staff has not defined a set of scenarios which would lead specifically to severe core damage and large amounts of hydrogen generation, and we have had discussions, and TVA has identified for the Sequoyah plant four scenarios which would have the highest likelihood of leading to severe core damage.

We believe we have taken mitigation -- pardon me. We believe we have addressed those features in the Action Plan and through operating procedures and guidelines.

Our current approach that we are dealing with right now is -- I think you are right on target -- is mitigation consequences in dealing with Sequoyah.

MR. KERR: I am referring more to the long-term approach on Mr. Butler's slide.

MR. RUBINSTEIN: The staff does not have a position on sequences which would lead to severe core damage, and it is likely that we will look to the rulemaking hearing for guidance in this matter.

MR. KERR: Okay. So at this point one will not require the owners to do these studies until after rulemaking has been completed, is that correct?

MR. RUBINSTEIN: We want them to do studies and help us in the identification --

MR. KERR: How can they do studies to mitigate against something without knowing what they are trying to mitigate against, and they won't know this until after rulemaking. It seems to me that one has something of -- well, at this point since inflation has set in, it is probably a "Catch-33" situation.

(Laughter.)

I really --

MR. BUTLER: I recognize the question, and it is a valid question. In summary fashion you are asking if the staff will undertake a study program prefatory to the rulemaking to see if the staff can prescribe certain bounds or guidelines for the rulemaking.

At the present time the staff does not plan that kind of activity. It might be an appropriate activity for the staff to undertake. I guess the staff really has not decided it, okay.

Now, why don't we go through the discussion on the rulemaking, and if the questions continue to prevail, it might be an appropriate comment of the ACRS.

MR. KERR: Okay. Thank you, Mr. Butler.

MR. LAWROSKI: Are we having this discussion and then the rulemaking presentation?

MR. BUTLER: I believe I described what the present activities --

MR. KERR: I am satisfied with your answer.

MR. BUTLER: Thank you.

MR. KERR: Mr. Lawroski, more questions?

MR. LAWROSKI: It seems to me we have the cart before the horse, but maybe this is the way we arranged the agenda. I don't know.

MR. KERR: Your problem is you are living back in the horse-cart era.

(Laughter.)

MR. LAWROSKI: I see. Do you have an inflationary term for that?

MR. KERR: Please continue.

(Slide.)

MR. FLEISHMAN: My name is Mort Fleishman, and I am with the Office of Standards Development. I am going to describe the rulemaking on the interim rule that we are presently working on.

The staff is currently involved with two major rulemaking actions, one involving a longterm related to consideration of degraded or melted cores safety regulation, and the other one involving an interim rule on hydrogen control and certain degraded core considerations.

Now, the long-term rulemaking consists of four parts. One is an advance notice of proposed rulemaking which will be discussed by Mr. Madeiros after I am finished. That has already been sent to the Commission, and it is a SECY-80-357 paper. And we view this long-term rulemaking as a two to four year effort depending upon what questions or problems may come up during the course of the rulemaking.

There is a very good possibility that there will have to be a rulemaking hearing similar to what happened at the ECCS hearing, and depending upon what comes up there, that will dictate essentially how long the rulemaking will last.

The interim rule, which is the subject of my talk, has already been sent to the Commission via SECY-80-399. It was sent to the Commission this past week, and we look at that as going through just a proposed rule and an effective rule phase. Depending upon what the Commission decides, that rule could be made effective by early 1981.

Now, before going into the details of the rule I would just like to give a little bit of background on the rule. Following the TMI-2 accident there were a number of studies that were initiated which culminated in several documents of which most of you, I am sure, are familiar with.

The documents that were related to the Three Mile Island accident was NUREG-0578, which was issued in July of 1979 and essentially was a status report and summary of the short-term recommendations made by the Lessons Learned Task Force; and NUREG-0585 was issued in October 1979, which was their final report.

Based on these two reports, letters were sent to licensees of operating nuclear power plants and also applicants and other people that would be affected by that describing what followup actions should be taken resulting from the NRC reviews of the Three Mile Island accident.

(Slide.)

Clarifying letters were also sent out on October 30. After the September 13 letter regional meetings were held the week of September 24 to clarify the recommendations made. I believe the ACRS has already reviewed these documents. In fact, the September 13 letter had a number of recommendations in it that were attributed to the ACRS. In fact, the ACRS letter concerning that was included in the September 13 letter.

Some recommendations that the ACRS made were on accident monitoring and instrumentation such as containment pressure, hydrogen concentration, and things like that. In May 1980 the staff and the Commission reviewed and approved NUREG-0660, which was the TMI-2 Action Plan, and under Task II.B.8 of that Action Plan they describe the various rules that we are presently working on.

That is sort of the background, and it sort of gives you an indication of the relationship of the long-term rule and the interim rule to each other.

The interim rule itself consists of two major parts.

(Slide.)

The first part is based on the -- is related to hydrogen management in containment, and the other is related to design and other requirements.

Now, these design and other requirements were revealed from the TMI-2 accident and had been discussed in the various NUREG reports, and the licensees are already familiar with most of these requirements.

The recommendations that we have made -- that we have in this paper were already transmitted to the Commission. As far as our position on the NUREG, we have already discussed that, and we are codifying regulations which the staff feels should be put into place immediately to protect the public health and safety.

The staff believes that if these requirements are put into effect, it will improve the capability of nuclear power plants to deal effectively with TMI-2 type accidents. We don't have any specific quantification of just how much an improvement that will be, but essentially based on engineering judgment, we feel there will be an improvement.

(Slide.)

MR. KERR: Mr. Mark.

MR. MARK: In the interim rule it is certain degraded core considerations. You also mentioned TMI-2 type. Is it then clear and agreed that one is limiting one's attention to the sort of boiloff picture for TMI and nothing else?

MR. FLEISHMAN: In this interim rule that is correct.

MR. MARK: So this also involves hydrogen coming at a quite slow rate, like 1 percent reaction per minute. It has nothing to do with 107 which does not observe such restrictions, and the only thing uncertain is how much hydrogen was actually involved in TMI which no one yet knows.

MR. FLEISHMAN: I believe we feel the TMI-2 type accident was somewhere in the 25 to 50 percent metal/water reaction.

MR. MARK: I'm aware that you feel that, but I'm not aware of any evidence that really puts the finger on it.

MR. FLEISHMAN: That is correct.

MR. KERR: Please continue.

MR. FLEISHMAN: Okay. Relative to hydrogen managment, the interim rule has four items within the rule. We are going to require that the Mark I and II reactors -- BWR reactors be inerted. We are not saying anything at all about ice condensers or other pressurized water reactors in the rule.

It would mean that the Vermont Yankee and Hatch-2 reactors, which are not presently, will have to be inerted. This recommendation as made to the Commission by the staff in SECY-107(d) -- the whole SECY-101 series.

We are also requiring in the interim rule that design analysis studies be performed to look at various measures to handle large amounts of hydrogen. We are not specifying any specific accident scenario, but we are just saying that we want them to look at measures to study what they could do to handle various amounts of hydrogen.

We told them to look at hydrogen up to 75 percent metal/water reaction. The measure we are suggesting that they look at in the evaluation would include inerting, hydrogen recombiners, purge systems, halon suppressant systems, filtered vent systems, hydrogen combustion systems, water fog spray, or combinations of these.

Depending upon the results of these studies further requirements may turn out to be necessary in the long-term.

MR. MARK: Is it made clear in that connection anything about the suddenness of the appearance of this hydrogen; that is, does it come on at TMI-type rates or not come on in a delta function?

MR. FLEISHMAN: We say that -- in the rule that the hydrogen generated within the first eight hours, and we do not say anything in the rule about how fast that reaction rate should be. We just say hydrogen generated within the first eight hours, which would basically avoid having to look at long-term radiolytic composition.

MR. MARK: That, I think, is a good point, but there is still quite an important difference, it seems to me, and it seems to me it will seem so to the designers, if you assume that the hydrogen is bled out uniformly throughout the eight hours or comes on in the particular ten minutes during the eight hours.

MR. FLEISHMAN: The rule says nothing about that. We did not give any specific guidance on that in our --

MR. KERR: Don't you think you should?

MR. FLEISHMAN: What do you think about that, Walt?

MR. BUTLER: I think with respect to the lower bound -- Mort identified the upper bound of eight hours, and that will indicate clearly that they are not to rely on the heat removal systems.

With respect to the rapid rate of -- that is, the lower bound for a rate of hydrogen generation, I guess what we are trying to do is have them consider it to come out as fast as possible. Yet, we are not prescribing --

MR. KERR: Mr. Butler, I think the question was not what you are going to specify but whether you are going to specify something, and Mr. Fleishman says you are not giving any rate of hydrogen generation.

I think the question is shouldn't you, if you are asking designers to design something, give them some idea of what they are designing for? And apparently at this point nothing is said about the rate of hydrogen evolution. Wouldn't that have a significant effect on how one was going to handle it?

MR. BUTLER: If the rate comes out -- if you prescribe a rate that is very fast, it certainly will have an effect. It is our hope, though, in not prescribing it in the interim rule that that issue be considered during the final rule.

MR. KERR: But how can one do a design to handle this without knowing what one is designing for, Mr. Butler?

I don't understand.

MR. BUTLER: I think the problem is one with schedule. In the interim rule we are requesting that certain studies be conducted on a sensitivity basis. Those results will then be available for assessment during the final rule phase.

If after reviewing the results of those analyses it looks like additional studies are needed, those additional studies will have to be done.

MR. KERR: Then what you expect they will do is consider everything from an instantaneous release to a release uniformly over eight hours. Even though you have not asked for that, you expect that is what they will do.

MR. BUTLER: Well, I am not sure what to expect in the way of response. I guess questions will have to wait until answers come in.

MR. KERR: Well, I guess there is good biblical precedent for doing this sort of thing. I can remember Daniel and King Newbuchadnessar when the king called him in and asked him to interpret his dream, and the only problem was the king could not remember what the dream was.

So he asked Daniel to tell him what the dream was first. But I would hope that people would produce better results from a study if they knew what it was you wanted them to study.

MR. BUTLER: I might indicate that the reason we did not put the lower bound in was because we did not think that the analysis results was going to be very sensitive to any lower bounds, except for the terminal lower bound, and we were not ready to require that terminal lower bound pending receipt of the results of some of these studies.

So I guess any studies of any rate would be satisfactory, and as we get further into the rulemaking and we decide that we really want that end point, well, we want to defer that decision until we have the results of some of these early studies.

MR. ETHERINGTON: Are you assuming the same amount of hydrogen with the only difference being the temperature and steam content in the containment: that is, an immediate release of one cubic foot of hydrogen leads to the same end concentration as a release over a long period? Or are you removing some of that hydrogen in the interim?

MR. FLEISHMAN: The rule itself did not get that specific.

MR. ETHERINGTON: What is the concept? What is your concept?

MR. FLEISHMAN: We are asking for sensitivity analyses to be done, so we assume that they would look at various rates of generation and various scenarios.

MR. ETHERINGTON: And various rates of removal as well?

MR. FLEISHMAN: Depending on the systems we are asking them to look at, they would have different capabilities. Hydrogen combustion is one of the systems we are suggesting they look at. It is actually in the statement of considerations. We have given them essentially guidance on some of the areas we want them to look at. The hydrogen combustion system was one of the areas we suggested that they look at.

MR. ETHERINGTON: In other words, you will get a higher pressure from an immediate release than could be obtained with a long-term release, assuming that you have these hydrogen-relieving systems.

MR. FLEISHMAN: Yes. In other words, that would be the things they would look at, depending upon which system they would look at. It would affect the --

MR. ETHERINGTON: You are including immediate release but you are not insisting on that being in the criteria.

MR. FLEISHMAN: We have not specified it in the rule at this point. Now, when we start getting information in as a result of these studies, we may want to revise our guidance, revise the studies. This is going to be an ongoing thing. There is going to be interaction between the staff and the licensee, so depending on what comes in, there is going to be an interplay, and the studies, I am sure, will be modified.

There will be discussions between the staff and the licensees as to what action finally gets -- the rule itself is quite general, actually. It just says we want the studies to be done. The specifics of what is going to be done will vary from plant to plant as well as from licensee to licensee.

MR. KERR: Well, I think we have all been faced with the fact that there is a limited supply of manpower and resources available for these studies. Now, if we tell people to go study something which was not what we had in mind, and they spent a lot of effort studying something that was quite different from what we wanted them to study, it seems to me that that is not very efficient.

I recognize that perhaps you cannot know exactly what you want done until you have had some preliminary results, but it certainly seems to me that one could perhaps save manpower and resources if one could be more specific than just sort of saying go away and study the problem. I mean if you have in mind some limitations or some general guidance, it certainly seems to me it might be to everybody's advantage to provide it.

MR. BUTLER: What you say certainly is true. However, we did not want to cast in concrete in the form of a rule the specifics on what should be analyzed. It was our hope to maintain some measure of flexibility, so that when we start implementing the rule, we intend to meet quite frequently with the various owners group and at that point provide appropriate guidance as to scope of the studies.

MR. KERR: Please continue.

Excuse me. Mr. Etherington.

MR. ETHERINGTON: Regardless of the basis of calculation, you are going to calculate the pressure which you believe will result in combustion of a certain amount of hydrogen. Now, I was told recently that you use the specific heat and constant pressure in calculating the pressure from the combustion. I was told this.

Is this true; and if so, why don't you specifically use heat and constant volume?

MR. FLEISHMAN: I would defer to Mr. Tinkler on that.

MR. TINKLER: The calculations that you saw in the SECY paper 107 were done assuming specific heat of gases at constant volume.

MR. ETHERINGTON: Constant volume.

MR. TINKLER: Constant volume.

MR. ETHERINGTON: Then I was misinformed.

MR. TINKLER: There was a calculation presented at a meeting sometime ago. I do not recall the details of it.

Someone did present a calculation with pressure calculated using heat and constant pressure. But the calculations which you have seen to date in the SECY papers performed by the staff have been --

MR. ETHERINGTON: That is about 40 percent higher.

MR. TINKLER: If you do the calculation consistently, it may not be that much different. The calculations which you see are also done assuming the gas constants for the various gases as a relatively low temperature, so that it does contain some additional conservatism in that regard.

MR. ETHERINGTON: Not very much, though.

MR. TINKLER: Two thousand or three thousand degrees. It is 10 or 15 percent, yes.

MR. ETHERINGTON: Yes.

MR. LEE: Based on the present understanding of the amount of hydrogen generation, and even perhaps the rate of hydrogen generation, the interim rule would require interting for MARK I and MARK II BWRs.

MR. FLEISHMAN: That is correct. We feel it would be appropriate at this time to require the inerting at least until we have more information, which will be determined during the long-term rulemaking.

MR. LEE: But that decision would have assumed certain rates of hydrogen generation, I presume, which could have an instantaneous generation of a certain amount; or is it different from that?

MR. FLEISHMAN: Well, right now the way the regulations presently stand, most plants would not have to be inerted based on the way 50.44 is written. The regulations now call for no more than a maximum of 5 percent metal/water reaction to be considered by the regulations.

TMI-2 showed us that that was no longer accurate. So, in lieu of having any further information which is going to be determined in the long-term rulemaking, we felt it would be appropriate to require inerting right now. I guess the feeling is that inerting will be beneficial. Just how beneficial it is and what sort of reactions it can correct for, I don't think we know exactly.

MR. LEE: I guess my question is really related to one of the comments. General Electric Company has somewhere -- I can place where I read it in the bulk of documents I have -- but they were criticizing the staff position relative to the fact that in BWR systems you cannot expect hydrogen generation immediately nor a loss of coolant accident or anything like that.

So they feel there is no need to go inerting MARK I and MARK II containment systems.

MR. FLEISHMAN: That is correct. That is G.E.'s position.

MR. LEE: Staff has taken the position that regardless of comments, it would be necessary at this point to go to inerting.

MR. RUBINSTEIN: Let me address that. We did not do a mechanistic analysis of the generation of hydrogen in dealing with the BWR MARK I's and II's. For the interim, staff essentially assumed that hydrogen could be generated, looked at the structural response and design pressures, looked at the amounts of hydrogen which could be generated from a severely damaged core, and came to the conclusion that we had better prepare a mitigation scheme for this.

The benefit of inerting a MARK I and II was small, but so were the costs, and the interim we felt it was a prudent course of action.

MR. KERR: In that connection, Mr. Rubinstein, I would be interested in your comments on a document that is labeled "Decision Rationale for the Staff's Position on Inerting." On page 3 of the document I find the statement: "MARK I and MARK II containments should be inerted. The decrease in residual risk is small based on probabilistic analyses because the likelihood of this accident scenario is one to two orders of magnitude smaller than the dominant core melt containment failure accident scenario for BWRs."

Then this statement: "The persuasive argument for inerting, however, is not the magnitude of risk decrease.

It is rather there are no significant countervailing safety disincentives." I am not sure I know what that statement means. I guess it means that inerting will not make things any less safe. "The cost of inerting is small and there has been substantial satisfactory experience with inerting MARK I containments."

Now, except for the third statement, it seems to me one can make exactly the same arguments for painting the containment red, white and blue. There are no safety disincentives. It does not cost much. And one has had satisfactory operating experience up till now with red, white and blue containments.

But I would feel better if one -- I just cannot believe that the staff cannot come up with a better justification for doing something which does cost some money and does have some safety considerations than to say, well, there don't seem to be any safety disincentives and it doesn't cost much, so let's do it.

I don't think it is as persuasive. You must have other reasons for proposing what you have proposed.

MR. BUTLER: The subject of deciding whether MARK I's and II's ought to be inerted was a very difficult one to arrive at because we were faced with judgmental views that said they should be inerted because their sensitivity to hydrogen generation was very intense; they had a very small volume and it did not take but about 6 percent metal/water reaction to reach the detonable mixtures of hydrogen concentrations; and a prudent course of action would say: by golly, you can expect operators to do the wrong things at the wrong times and give you the adverse concentrations of hydrogen.

Nevertheless, we were faced with results from the Probabilistic Analysis staff that concluded with respect boiling water reactors that the dominant sequences rarely were the core melt sequences, and they found their analysis with their reactor safety methodology which led to their conclusion that inerting did very little to improve the safety of the BWRS.

So we had to provide some kind of justification there of a judgmental view that you needed to inert against some objective information that said if you believe probabilistic assessment approaches, then you would not require inerting because it did you very little good.

MR. KERR: I agree. I think it would be a good idea to provide some justification. But I believe if a licensee came in to you with the sort of justification that you have given, you would fall on the floor laughing. I mean I would.

Now, I recognize that you have a letter from the ACRS suggesting that these things be inerted also, and you have been kind enough not to mention that.

(Laughter.)

Well, I was just struck by what appeared to me to be a rather weak justifictation, and I have an idea that there must be better justifications than that.

Mr. Fleishman, we hav interrupted you periodically. Why don't we get back to you?

MR. FLEISHMAN: I have just one other comment. I think the justification is a result of committee decision. That is about what everyone could agree to.

The next item that we have relative to hydrogen control in the interim rule is we are going to require that for plants that rely upon external recombiners or venting to satisfy the hydrogen control requirements, that they have dedicated penetrations. In other words, the penetrations should be dedicated for that service only.

Finally, we have one other item that we are adding, and that is that plants that rely upon venting have to have external recombiner capability installed. Now, this was a minority recommendation of the Lessons Learned Task Force. However, the staff now believes that in order to reduce the likelihood of release of radioactive material to the environment, means other than venting should be available for control of hydrogen.

So, we are requiring in the rule that these plants have penetrations installed so that they could install external hydrogen recombiners if required.

MR. LEE: What kind of venting capacity do you have in mind when you have included these two items 3 and 4?

MR. FLEISHMAN: Right now the venting capacity and even the external recombiners only have to meet the requirements of Section 50.44, which is up to at most a 5 percent metal/water reaction. To actually take into account something like TMI-2, just how these plants should be modified, whether they should be backfit, what the new design should be: that is going to be the subject of the rulemaking.

MR. LEE: It is mostly having the recombiners on line, available on-line? Is that the main difference between the present requirements and these suggested rules?

MR. FLEISHMAN: The last one. Right now many, many plants just have venting. They do not have recombiner capability.

MR. LEE: But I thought oft-times most of them have had --

MR. FLEISHMAN: The plant licensed prior to November 5, 1970, I believe, did not have to have recombiner capability. Some of them did but not all of them did, I believe.

This is going to require that all plants now have recombiner capability.

MR. LEE: Thank you.

MR. MARK: Assuming what you mean by that is that there be such fixtures, nozzles, whatnot, outside that a recombiner could be brought from Columbus, Ohio and hitched on.

MR. FLEISHMAN: That is correct. Not only that; they have to have proper procedures and shielding available so that they can install the recombiners during and following an accident.

MR. KERR: Mr. Seale.

MR. SEALE: In this 5 percent metal/water reaction requirement, there still is not a rate specifically indicated there, is there?

MR. FLEISHMAN: That is correct.

MR. SEALE: As I recall the analysis of the capabilities of recombiners that were available at TMI, even a 5 percent availability would have swamped the capacity of the recombiners that were there.

MR. FLEISHMAN: Actually, I said up to 5 percent. Most recombiners probably are not required to meet the 5 percent because they have to meet -- I think the way 50.44 is written now, they have to be able to accommodate up to five times the metal/water reaction calculated that would occur during a design basis LOCA, which could be less than one percent, actually.

MR. SEALE: Well, I think this is a very good example of the kind of fix which is generic, which is tremendously sensitive to the input assumptions. In line with Dr. Kerr's earlier remarks regarding the effect of not being specific with regard to design requirements, it is almost inevitable that the first presentation is going to be a nonacceptable --

MR. RUBINSTEIN: Excuse me. The case of the recombiners are really directed toward mitigating the effects of a LOCA, which we do have this fix on. One of the alternatives I think Mort said was the facility had the option of either using a recombiner or purging.

The staff believed that it is possible in the future we would not find purging for the mitigation of LOCA hydrogen generation under 5 percent desirable, so we are asking for a dedicated penetration capability with the appropriate isolation and procedures for primarily dealing under 50.44 with the mitigation of the hydrogen generation for LOCA.

So it does not deal with the severe core damage and it is not a mitigation feature for TMI-type accident.

MR. SEALE: So this is one case where the rulemaking is more general than just the --

MR. RUBINSTEIN: This is an interim step to deal with the potential for purging from a LOCA-type design basis accident.

MR. SEALE: And then is more general than just the TMI kind of accident.

MR. RUBINSTEIN: It is for any accident which would generate hydrogen up to about 5 percent.

MR. KERR: Please continue, Mr. Fleishman.

MR. FLEISHMAN: The other aspect of this interim rule would require other design requirements and improvements.

(Slide)

I will not go into that very much because they are not related as much to hydrogen control, except for the first one, which would require high point vents in the reactor coolant system and the reactor vessel head to control noncondensable gas buildup. That is also a requirement that has been previously mentioned in the letters.

So we have items on protection of safety equipment in vital areas, implant iodine instrumenation, sampling capability, leakage integrity outside containment, accident monitoring instrumentation, detection of inadequate core cooling and training to mitigate degraded core accidents. These are all recommendations that had already been made in these letters, and we are just going to be codifying them.

And that is the interim rule.

The status of the long-term rulemaking will be discussed by Mr. Madeiros.

MR. LAWROSKI: Are there any criteria except for the recombiners?

MR. FLEISHMAN: The recombiners have to meet the criteria of Section 50.44. So in other words, they are the same recombiners that have been installed in all of the plants that meet 50.44 criteria.

MR. KERR: It seems to me the TMI situation with which this is dealing is a recognition that people would not want venting to occur under any conditions, so they are saying that although we are willing to consider venting in extreme situations before TMI, we are no longer willing to consider it.

Now, I have a little bit of a problem when I see that filtered vented containment is one of the alternatives for dealing with hydrogen, but that is a separate problem and I guess we need to keep problems separated.

MR. ETHERINGTON: Isn't the capacity of the recombiner so small that it would have no material effect on the Three Mile Island accident?

MR. KERR: I think that is true. That is what I am saying. We are dealing with accidents that we believed in before Three Mile Island, namely, the design basis LOCA.

MR. ETHERINGTON: The design basis LOCA. Also, the recombining is too slow to be effective, isn't it?

MR. KERR: The recombiner deals, I thought, with radiolytic decomposition, primarily?

MR. ETHERINGTON: It will get the other hydrogen down in time.

MR. KERR: But it will prevent a pressure buildup that might occur due to radiolytic decomposition. In other words, you might have to vent.

MR. ETHERINGTON: Are we talking about more than this at that time?

MR. FLEISHMAN: Not right now, no; but there are people who believe that these recombiners could have been beneficial during Three Mile Island also; that during a long-term buildup of hydrogen, that the recombiners could function and could mitigate to some extent the effects of the accident.

MR. ETHERINGTON: Are you talking days or hours?

MR. FLEISHMAN: Weeks.

MR. ETHERINGTON: Weeks, yes.

MR. FLEISHMAN: The fact that you have this recombiner capability could still help in something like TMI-2.

MR. ETHERINGTON: They had already had the explosaiton.

MR. FLEISHMAN: It would not have prevented the explosion.

MR. ETHERINGTON: Pardon?

MR. FLEISHMAN: It would not have prevented the explosion.

MR. ETHERINGTON: It would not have prevented the explosion, no.

MR. KERR: Are there other questions or comments? Is Mr. Madeiros up next?

MR. FLEISHMAN: Yes.

MR. KERR: Mr. Madeiros.

MR. MADEIROS: Good morning. My name is Manny Madeiros from the Office of Standards Development.

On May 9th I described and advance notice of proposed rulemaking being prepared by the staff concerning degraded cooling, and I will not repeat that presentation. But I did bring two slides with me from that presentation to kind of bring people up to speed because I see an awful lot more people here in the audience today and on the Subcommittee.

The first slide.

(Slide)

This briefly describes the problem. First of all, the degraded cooling and resultant core damage is treated unevenly in the regulations. You can go to various sections in the regulations and pull out numerous examples of where one place will discuss a 5 percent metal/water reaction, another place 1 percent hydrogen.

You get into Part 100, of course, and you are talking a substantial melting. The second point being the safety analysis stops short of the Class 9 accidents and therefore is inadequate and suggests that the designs are not adequate either and that currently --

MR. KERR: Excuse me, Mr. Madeiros. I don't know whether that microphone is at all directional, but if it is, I think you have it pointed away from your voice.

MR. MADEIROS: Okay. Lastly, I have on here an example of a related problem. I will not dwell in much detail on this because we have discussed that all on May 9th, unless there are questions.

(Slide)

Here I thought from some of the questions being asked this morning that it might be wise to discuss what an advance notice of rulemaking is. It defines the area of concern, explains the problem to the public. It provides the public an opportunity to advise. Normally we allow a 60-day comment period.

In this particular case for this advance notice of rulemaking, we have allowed 90 days. We elicit advice by asking questions. In this particular case we have asked 18 questions. Two of them have to do with hydrogen, and that is what I am going to get to here in a minute.

Then we use the public recommendations to shape a proposed rule. We do this at an early stage of development, and this answers somewhat, Dr. Kerr, your question a little bit earlier to these other fellows of why we did not have some specific numbers in mind.

The Commission has made the decision to start with an advance notice of rulemaking in this very important and complex area rather than start with a proposed rule. When you start with an advance notice of rulemaking, you are truly looking for the advice and recommendations of the public, of the regulated industry. And if you already have fixed numbers in your mind, I thing we somewhat make a charade of the --

MR. KERR: Mr. Madeiros, I insist that one can go in with recommendations that are not necessarily fixed. It has been my experience over the years that you get better advice from people if you ask them about something specific than if you just go out and sort of say what should I do?

MR. MADEIROS: That is what we intend to do at at the proposed rulemaking stage. We have just started with this one step earlier and have truly left the issue open for the best advice that we can get. We feel there is much room for imagination out there for the industry, and we are going to let the industry exercise its imagination in giving us good advice on the ANR, so that when we prepare a proposed rule and then perhaps have hearings, we will have fixed positions that we can defend logically technically.

(Slide)

Now, the features of the ANR have not changed. ANR from the first line -- that is advance notice of rulemaking. The feature of the advance notice of rulemaking have not changed materially since we discussed them in Chicago on May 6th. Briefly they are here.

We will require a coherent consideration of core damage in design and review. We will analyze a broad range of accidents within and outside traditional design envelopes. And I might take on the controversial point you raised in your opening remarks, I guess, about whether the staff is leaning towards the end of spectrum only kind of accident, and clearly the answer is no.

This advance notice of rulemaking covers the whole range of accidents, as I discussed with you earlier, from clad perforation to small amounts of hydrogen up to release of gap activity, up through large amounts of hydrogen release, and then on to melting. But we are asking that the -- we will consider accidents lesser than design basis accidents, historically consider, and accidents within the envelope.

So it is not just the end of spectrum problem that we are interested in, and that is kind of what my third point is there so I will not repeat it. Basically the reason is my fourth point, because we will be considering multiple failures and operator errors.

This brings me to the item of particular interest.

MR. KERR: Can you tell me whether the staff at this point plans to take a mechanistic as contrasted with a probibilistic approach?

MR. MADEIROS: That has not been decided. My guidance on it would be, as much as I have to do with it, to take a mechanistic approach because I do not feel that the probabilistic approach is developed enough to be very practical. The probabilistic approach deals primarily with failure rates.

MR. KERR: I think I understand the probabilistic approach. I just wanted to know which one the staff was likely to adopt.

MR. MADEIROS: I thought I would explain a little bit because this is not the trendy view in the Commission or the ACRS. Anyway, I will skip that.

MR. ETHERINGTON: There seems to me a problem if you take a mechanistic view, with the statement, I believe by one of the commissioners, that containments ought to be able to handle as much hydrogen as was developed at Three Mile Island because that has already happened. That puts you on a real spot, doesn't it?

MR. MADEIROS: Yes, it does on that one, perhaps. What I had in mind more, Mr. Etherington, was that the probabilistic approach just does not deal very well with stupidity, with operator errors, with design deficiencies, that sort of thing. It deals primarily with component failure rates. That kind of information is so skimpy in this business as to almost make that worthless from that standpoint.

It is not a procedure or a method or a methodology or whatever buzz words you like to use these days. It cannot deal with the operator. It cannot deal with the mistakes an operator would make.

MR. ETHERINGTON: I sympathize with your position entirely. I merely point out that this criterion puts you on the spot.

MR. MADEIROS: So again, then, it will require imagination is what you are saying, and I think the Commission can rise to the occasion, or the staff.

I will now go to the item of particular interest here, and that is the question concerning hydrogen.

(Slide)

There are 18 questions in the advance notice of rulemaking. Most of them have to do with analysis and design improvements. Two have to do with hydrogen, and these are the two that are in the advance notice of rulemaking that I expect to be published soon. I will give you a schedule on that in a moment.

"Are you in favor of requirements to incorporate into containment design systems for controlling combustion of hydrogen?"

"Do you favor methods of control that suppress combustion, or do you favor controlled burning?" If you favor suppression of combustion --" here we are talking about the inerting on demand idea, the halogen suppression schemes, the fogging schemes, the steam injections steams that Mort spoke of and others earlier -- let's see -- "or if you favor controlled burning, do you recommend open flames, spark plugs, catalytic combustors, igniters, these glow plugs we have been talking about?"

The idea is with this piece of the question that ignition sources in containment are unavoidable so you might as well control them as leave ignition to chance. That is kind of the idea behind of, I think, all of our work when I speak of igniters. And then what percent of the core's zirconium being oxidized, and at what rate would you design for?

We would be looking for some good advice to come up with some of the numbers, Mr. Seale, that you were asking about a little bit ago.

And then would you respond differently for different reactor or containment types; and if so, what differences do you recommend?

And then we would get into the question of inerting. Can everybody see that? I will push it up a little bit.

Would you recommend that all nuclear plants operate with a nitrogen-enriched containment atmosphere as some BWR plants currently do? Why or why not; and if not, which types of containment, if any, would you limit nitrogen enrichment to?

I think one of the ideas throughout this advance notice of rulemaking, and particularly here, is that you don't want to do things that take away from safety. We have heard arguments -- I am not sure how completely valid they are, but they seem to have some validity -- that some things like inerting could decrease safety rather than increase it. So we would be interested in those kinds of thoughts in response to this question.

Now, as of today two commissioners have approved the advance notice of rulemaking. I expect the other two to approve it shortly. As soon as the full Commission approval is received, we will publish the advance notice of rulemaking is the Federal Register for a 90-day comment period. Assuming we were able to do that by the end of September, we would still then by the end of December this year have the advice and response from the regulated industry, from the public that would allow us immediately to start on a proposed rule, and which I expect will take several months to not only prepare but to process through the staff and on its way to the Commission.

Now, I believe the Subcommittee has a copy of SECY 80-357, which Mort Fleishman mentioned earlier, that contains all of the questions. One of them, Dr. Kerr, I am sure you will be interested in particularly. In Chicago you suggested that and advised that a question be added weighing the costs of this work against improvements, so I added this question: Would you consider useful or appropriate comparisons between nuclear power plant risks and other risks to which people are exposed? That was the suggestion of this subcommittee in Chicago, and it has been added to the rule.

One of the things yoiu raised in your opening remarks was whether the staff was leaning towards a conservative approach in the design of mitigating systems or design improvments or a realistic approach or best estimate approach, I think were your words.

This question is part of the question, so again, I don't come with an answer today but I come with a statement that that is in the advance notice of rulemaking. We ask that specific question of the public, and within a short time expect to have the advice that with our own thoughts would let us go forward with a firm position at the proposed rulemaking stage.

Let me see. Well, there was another controversial point you raised and I don't know whether I should take it on or not, but I guess I will. You wondered whether it was the staff's view that the training changes and some of the instructions to operators and that sort of thing would lead us -- I cannot remember your exact words -- but perhaps to go slower or take a less stringent view of some of the mitigating --

MR. KERR: What I wanted to find out is whether the staff thought the probability of producing a certain amount of hydrogen had been significantly decreased as a result of the changes that have occurred and will occur as a result of TMI-2.

MR. MADEIROS: Okay. That is right.

MR. KERR: And if this is being taken into account in deciding what one should finally do about mitigation or prevention.

MR. MADEIROS: And that is being said quite often. Many publications, a lot of pronouncements have that view that what has been done in these areas as a result of Three Mile Island should result in less hydrogen production. My point of view is I don't think that is so. I think that is more wishful thinking than anything else.

MR. KERR: Well, Mr. Madeiros, if all the money and effort that has been spent since Three Mile Island has had no influence on the probability of hydrogen production, it seems to me that we are certainly wasting a lot of resources.

MR. MADEIROS: I did not say it had none.

MR. KERR: Well, I will say no significant.

MR. MADEIROS: No significant.

MR. RUBINSTEIN: Mr. Chairman, I believe that represents his personal opinion.

MR. MADEIROS: That is correct.

MR. RUBINSTEIN: It is the staff's viewpoint, and we have slides prepared in our summary to take that into account, that there have been significant changes which contribute to the reduction of risk.

These have been partly the basis for our recommendations, our general recommendations before we got into mitigation devices or distributive ignition systems and halon, to go forward with the ice condensers without modification. That was a very important part of our considerations and we will address this in a moment.

MR. MADEIROS: I think we should wait for his detailed comments.

With that, I do not think the advance notice of rulemaking work to date answers any of the other points you raised at the beginning. If you have further questions, I would be glad to try to answer them.

MR. KERR: Mr. Lee.

MR. LEE: The way you envision the schedules for the proposed rulemaking hearings, potential hearings that might take place, by that time do you think you may be able to draw upon some of the results that staff might have performed in their risk assessment analysis, probabilistic assessment and so on?

MR. MADEIROS: Perhaps. It depends on what direction this takes after we get the advice. There is a predominant view in the Commission that mitigation is the nature of the game today, that we have reached the point of diminishing returns with regard to prevention, and so mitigation is where we ought to put our work.

I personally do not believe that, but it may be so. We may get advice from the public, from the regulated industry that convinces us otherwise, that there is much to be done in the area of prevention. If that turns out to be the case, then I do not see the need perhaps as much for thes probabilistic analyses and the research and the kinds of things I think you are suggesting as would be if you were to lean more heavily toward the mitigating things like core catchers and controlled filtered vents and those kind of way-out --

MR. LEE: I do not understand why you think prevention would require or prevention could use the probabilistic assessment results while mitigation does not.

MR. MADEIROS: Maybe I can give you an example, maybe. Let's suppose that the public advice is that we could get a step increase in improvement in safety by requiring strict literal requirements with operating procedures, for example, and that there should be an effort to do that.

There does not need to be a lot of probabilistic risk assessment done or research or study to require that operators operate these plants in strict compliance with operating procedures. That could well be suggested by the regulated industry in lieu of something like a controlled filtered vented scheme.

I am not saying that they will, but it could be. And from my point of view that is a very strong need in this business, but that is another subject.

MR. LEE: I thought a certain amount of operator actions could perhaps be factored into probabilistic risk assessment analyses.

MR. MADEIROS: I don't think so. I don't think probabilistic risk assessment will ever come to grips with the operator.

MR. LEE: Even on a relative comparative risk analysis basis.

MR. KERR: I don't think you are going to convince him. He does not believe in it.

(Laughter.)

MR. LEE: I was not trying to convince him about that, but what I was interested in was really whether you would be able to at least utilize, or do you plan on utilizing some of the results that might be available?

MR. RUBINSTEIN: May I help in this regard? The staff looks to probabilistic risk assessment to be a very complementary and powerful tool to our deterministic analysis in safety. In the particular instance where Dr. Kerr was talking about in his introduction, for example, if we identified a scenario either through failure modes and effects analysis or very high risk scenario to event tree or fault tree, we would want to go ahead and fix that in the plant, and in this way we would couple deterministic and probabilistic.

This is why when we talk about scenarios which would lead to severe core damage -- and we try to identify them -- if we identify those with significant contributions to risk, our first step would be to fix them and reduce the risks.

MR. KERR: I think it is fair to say that the non-PAS part of the staff looks on risk assessment somewhat like one should look upon perfume: it is okay to smell it but you should not swallow it.

(Laughter.)

MR. SIEGEL: In one of your slides you emphasized that you are providing the public an opportunity to advise. I am really concerned about how the public is identified in your mind. It certainly needs to be larger than the industry and the Union of Concerned Scientists. I would be very disappointed if those were the only responses you received.

MR. MADEIROS: I guess I would, too. What we do to make sure we don't have that kind of disappointment is first of all you publish it in the Federal Register and hope people see it there.

MR. SIEGEL: That is a rather vague and really hopeless hope.

MR. MADEIROS: In a lot of respects it is. But what we do in addition, then, and the advance notice of rulemaking states this, is we prepare a long list for selected mailings. We try to get in everybody that is a licensee, potential licensee. We try to get the architect engineer. We try to get all public interest groups. We try to get universities.

We try to get on this list of hundreds of people anyone that has expressed an interest in the past in areas to do with nuclear power. They are recorded in a special group in the Commission that keeps track of those kinds of things.

MR. SIEGEL: I really hope it would be something more than an invitation to comment, but in some way appoint a delegation of responsibility that organizations, for example, like certain identified professional engineering societies --

MR. MADEIROS: We cannot demand the American Nuclear Society will comment.

MR. SIEGEL: You cannot demand, but you can make a pointed request to the current president that he has a responsibility to get on the ball and do something about it, or other engineering organizations, different groups than are the convention active responders, so you really involve the public.

MR. MADEIROS: We will try. That is the best I can tell you. We will accept any suggestions for improvement there as well. We personally suggest that these technical society meetings, that they get copies of these things and read them and comment to us. We announce to maybe scores of people at some of these meetings that have not seen the Federal Register notice. We have a special list that I mentioned.

We use every means that we have been able to think about so far, and we will accept any additional help we can get in that area.

If there are no more questions, that is all I have, gentlemen.

MR. KERR: Thank you, Mr. Madeiros.

Although the schedule does not call fo .t at this point, I am going to declare a ten-minute break.

(Recess.)

MR. KERR: We will reconvene and continue with the subject of licensing efforts, and the name I have associated with that is Mr. Shapaker.

MR. SHAPAKER: Yes.

MR. KERR: How close did I come in my pronunciation?

MR. SHAPAKER: Very good. My name is Jim Shapaker. I am with the Containment Systems Branch. I want to discuss briefly the status of the design and testing of the distributed ignition system at the Sequoyah Plant.

(Slide)

It is felt that after studying various concepts, that TVA feels the distributed ignition system is a very promising concept for improving hydrogen control capability in the event of a degraded core accident.

The purpose of the system is to mitigate the consequences of the hydrogen release to the containment under degraded core accident conditions by inducing controlled burns, preferably in the lower compartment, to permit active and passive heat removal systems to dissipate the combustion energy and thereby maintain the containment response within the containment structural design capability.

Now, associated with this effort is design, testing and analytical efforts, and I will talk briefly about the design of the system and the testing that is going on, and the analytical efforts will be discussed subsequently.

(Slide)

TVA has a short-term program and a long-term program, and their short-term program is concerned with the distributed ignition system. There are essentially three developmental phases that they have identified. There is an interim phase which deals with the system installation and operation and testing, and I understand the system has been installed.

However, before the system is made operable, prior Commission approval is needed. With respect to the system design itself, the system as it now exists is not a safety grade system, and it consists of 30 glow plugs that are distributed throughout the containment. There are eighteen in the lower compartment, five in the lower plenum of the ice condenser, four in the upper plenum of the ice condenser, and three in the upper compartment.

The glow plug that is currently being tested is the GMAC 7-G diesel engine glow plug. The system will utilize standby lighting circuits, and these circuits are of seismic design. They are powered from the emergency buses, and as a result, emergency diesel generator power is available to them and the system will be remote manually controlled from the auxiliary building.

The standby lighting cabinet is about 150 feet from the main control room, and they have proposed emergency operating instructions which will instruct an operator to initiate the system in response to the automatic actuation of any safeguards equipment.

As a result, the decision to actuate the system will not be left up to the operator.

(Slide)

I have a picture of the Sequoyah containment. I just wanted to give you a feel for the relative locations of these igniters. On the right are given the elevations at which they are located, and the number beneath is the number of glow plugs at each elevation. As you can see, there are 14 in the lower compartment region. At the 731-foot elevation, there are four more in the lower compartment.

The remaining five are located in the lower plenum of the ice condenser. There are four in the upper plenum of the ice condenser and three in the dome area.

(Slide)

This just briefly is how the electrical circuit looks. The glow plug device is represented by this here (indicating), and there is a transformer which sets down the voltage from 120 volts to 14 volts, and the glow plug is shown there.

MR. LEE: Excuse me. How large are the glow plugs physically?

MR. SHAPAKER: The glow plug itself, probably about that long (indicating).

MR. LEE: The size does not matter.

MR. SHAPAKER: This is what the box looks like that contains the transformer.

(Slide).

It is about a foot long by six inches wide, eight inches high.

MR STREHLOW: Is that designed to be explosion proof, the box itself?

MR. SHAPAKER: I don't know.

MR STREHLOW: Because is you want the glow plugs to work twice --

(Laughter.)

MR. STREHLOW: -- the box better be explosion proof or maybe it will crush.

MR. BUTLER: In respose to that, I think the objective of the glow plug, of course, is to ignitiate a combustion rather than any severe detonation Now, the boxes, of course, are designed in a rather rugged fashion. It is a strong box. We hope to have a sample of that box available next Thursday to show to the committee.

MR STREHLOW: If the box is crushed by the external explosion, you are in trouble for the next ignition. It should be tested to be strong enough to withstand that sort of pressure.

MR. KERR: I think that if that box is crushed by the initial explosion, then we are in trouble, period.

MR. RUBINSTEIN: The point of the glow plugs is to initiate a controlled combustion as opposed to detonation.

MR. STREHLOW: I am talking about a pressurizer, 25 psi, which might crush a weak box.

MR. SIEGEL Do you have any indication where the glow plugs are located with respect to the specific places where one might expect the gas to be released? I mean you have them shown in a rather general volume. They must be much more specifically located than that.

MR. SHAPAKER: Yes. TVA does have some more detailed slides where they are specifically located at each elevation. They are located around the reactor vessel within the lower compartments here.

(Slide)

And they are also in the annular regions outside the shield wall at each elevation, and the ones at the 731-foot elevation are just right at the operating deck but in the openings as they go up into the steam generator dog houses. And, of course, the ones in the lower plenum would see any hydrogen sweeping through as it was forced out through the ice condenser.

MR. SIEGEL: Does the reactor primarily boundary itself have any new vent on it, say in the upper regions, near which a vent could possibly be opened and near which several igniters specifically could be located?

MR. SHAPAKER: There will be a reactor coolant system vent. I don't know exactly --

MR. RUBINSTEIN: That will vent into the containment. But TVA will go into some greater detail this afternoon and has Vu-graphs prepared on the distribution of igniters and some of these other design details.

MR. SIEGEL: Good.

MR. ETHERINGTON: It is true, I suppose, that the igniters will not become effective until you have 6 percent of hydrogen, and therefore you will have an explosion, is that right?

MR. SHAPAKER: I am not sure I understand. If there is an indication of an accident as a result of some automatic actuation of various equipment, the operator is instructed to initiate the system. Therefore, it will be ready. And if there is then a hydrogen release --

MR. ETHERINGTON: There will be an explosion. The nitrogen will not just burn because you have these things on. It has to get up to the combustion --

MR. RUBINSTEIN: The probability --

MR. SHAPAKER: There is a concentration at which they will become effective.

MR. RUBINSTEIN: We have a graph of the flammability and detonation limits in terms of composition of the air, steam and hydrogen, and 5 percent --

MR. ETHERINGTON: We are all familiar with that. I wanted to make sure there was not any misconception. There is going to be an explosion. That is right, isn't it?

MR. KERR: I think there is at least one misconception. I don't know on which side at this point, but I don't think Mr. Rubinstein thinks there will necessarily be an explosion.

MR. SIEGEL: I would like to hear the point discussed a little more. I hear words like control burn, detonation, explosion. What are we talking about?

MR STREHLOW: If I could comment, you would expect the glow plug to oxidize hydrogen near its surface at all times no matter what the concentration of hydrogen is, but that would be so slow that you would never rid of the hydrogen by that process. You would expect that when you get to about the 4 percent limit, you would start getting upward propagating flames.

You might end up just having a continuous 4 percent burn with small pressure rises associated with it at that point. Hydrogen burn is very funny at the lean limit. When it burns upward, it does not burn everything completely.

It only burns downward at about 9 percent, then it burns everything completely, both upward or downward. But at 4 percent hydrogen, 5 percent, 6 percent, you might only burn 10 percent or 20 percent of the hydrogen in your apparatus in one burn. The flame will propagate to the ceiling and go out. It won't propagate laterally outward. It does not do that.

So that if you have the glow plugs on continuously, you have to expect a slow burn to occur at 4 to 5 percent hydrogen wherever the concentration was at that level. And when the concentration gets back to that level, it would do the same thing again.

MR. SIEGEL: Meanwhile, you could have other volumes where the hydrogen concentration was rising into the detonability limit.

MR STREHLOW: That is a possibility. You might have a very high hydrogen concentration at the top of the reactor in the dome and have very low concentrations down below; but if you have glow plugs up in the dome, you are taking care of that, too, because the hydrogen concentration will go up to 5 percent and you will start getting burning.

MR. LEE: But I thought you said you will not see much of a lateral propagation.

MR STREHLOW: Not between 4 or 6 or 7 percent.

MR. LEE: So you would see what you term controlled burn around the --

MR STREHLOW: They are propagating up.

MR. LEE: Vertically around the location.

MR STREHLOW: It might grow a little bit in size.

MR. LEE: That is why I was interested in the size of the glow plugs and so on.

MR. RUBINSTEIN: We have some specific insight to the Sequoyah Plant and mixing and combustion. I think Mr. Tinkler can address some of these questions.

MR. TINKLER: I would like to say that we will address burning at various concentrations a little later on when we talk about the analytical work. There is some concern over the definition of explosion here. That seems to be one of the problems. If you could define relative flame velocities that you are talking about, then we could probably confirm whether we agree with your statement or not.

MR STREHLOW: If you are talking about just flame propagation through the system, then the rate of pressure rises as a function of a normal burning velocity in the system. The large systems have very slow pressurizers like Three Mile Island, only 10 seconds or so, and that was with a moderate flame velocity, I imagine.

MR. TINKLER: Do you consider that an explosion?

MR STREHLOW: I call that an explosion, yes.

MR. TINKLER: In that event, then, we are in effect calculating similar types of transients, and the term "explosion" can be used for a burn where it takes 10 seconds, for example.

MR STREHLOW: In my opinion, that is true.

MR. TINKLER: And we will provide results of calculations where burns occur in 10 seconds.

MR STREHLOW: You have to be careful between the difference between an explosion and a detonation.

MR. TINKLER: You don't mean detonation when you say explosion.

MR STREHLOW: No, not necessarily.

MR. TINKLER: You mean a relatively quick pressure rise.

MR STREHLOW: Yes.

MR. TINKLER: And I think the igniter will be tested within a vessel that will be -- where the hydrogen will be burned at varying concentrations and some of the concentrations will be high enough so that you will see rapid pressure rises.

MR STREHLOW: If you do this in a small vessel, you will be able to tell what pressure you see in a large vessel for that same concentration of hydrogen.

MR. TINKLER: Like I say, I can only respond that we will be testing hydrogen, various concentrations.

MR STREHLOW: What size vessel?

MR. TINKLER: Jim will talk about this in a little more detail. It is on the order of 100 cubic feet, one of the vessels.

MR STREHLOW: Okay.

MR. TINKLER: But we are testing at various concentrations and we would expect that we would get flame propagation in some cases upward and sideways and spherical.

MR STREHLOW: Yes.

MR. KERR: Are we now all of one mind? Good. Please continue.

MR. SHAPAKER: With respect to the glow plug testing, the have conducted some initial tests at the TVA Singleton Laboratory.

(Slide)

The purpose of these initial tests were to screen alternative igniters and demonstrate that igniters can be used to detonate hydrogen. Some of the characteristics of the plugs that they found were that they determined the glow plug's temperature was a function of applied voltage, and at 14 volts they got a temperature of about 1720 degrees Fahrenheit.

MR. KERR: You say that they did experiments to determine that glow plugs could ignite hydrogen? Was there some doubt about that?

MR. SHAPAKER: Well, since they were not used for this purpose before, they wanted to run some initial tests and confirm in their own mind and give themselves some confidence that they are on the right path.

MR. KERR: Sounds reasonable.

MR. SHAPAKER: Okay. They also wanted to determine the durability of the glow plugs, and they have operated a specimen successfully at 1720 degrees Fahrenheit for six days, and this particular glow plug was used in the hydrogen burn test. They also wanted to determine the reliability of the glow plug as an ignition source, and they introduced different concentrations of hydrogen and they did achieve ignition in dry air at a 12 volume percent and 7 volume percent hydrogen mixture.

They wanted to determine the completion of hydrogen burn, and at the 12 volume percent mixture they essentially got 100 percent combustion. The volume of this vessel was about .04 cubic feet. It was a very small vessel.

(Slide)

MR. KERR: .04 cubic feet?

MR. SHAPAKER: Yes.

MR. KERR: How did they get the glow plug inside?

(Laughter.)

MR. SHAPAKER: Well --

MR. KERR: Anyway, they did. Okay.

MR. SHAPAKER: They have now a subsequent testing program that will continue to be scoping in nature and verify that the glow plugs are a useful concept and to better understand the combustion phenomena using these glow plugs in different environments.

The purpose of the test will be to demonstrate that the igniter will initiate a volumetric burn for different environmental conditions, and the different environmental conditions that they are going to select are including a steam environment, and they want to define the hydrogen concentration range over which a volumetric burn will be initiated with these different environmental conditions.

In general, the acceptance criteria for the tests are that they are looking for consistency in the data, confirmation of theoretical predictions, and reliable ignition at the high concentrations, around 12 volume percent with essentially complete combustion.

In other words, the purpose of these tests will be such that there is no surprise, that they fully understand what phenomena are going on. The test facility that will be used is a spherical vessel. It is about six feet in diameter. It will be heated electrically. It will be equipped with an internal fan to promote mixing and create a draft at the igniter surface.

The purpose of creating this draft is to determine what effect the flow of a mixture past the igniter would have on its reliability and effectiveness.

MR. LEE: I have a question. I do not understand your rationale for suggesting 12 percent by volume of the hydrogen concentration in your acceptance criteria. I thought you were talking about the control burn which produced low pressure so you would like, perhaps, to somehow initiate ignition at lower concentrations of hydrogen, I thought.

MR. CHAPAKER: With the glow plugs on, it will begin to ignite the mixture or whatever will support a flame.

MR. GREGORY: Did you test that? Have you tested the glow plug action as the hydrogen concentration rises from zero up through the lower flammable limit? It seems to me that you tested getting it up to 12 percent and then putting on the glow plug. That is not representative of what will happen inside the containment.

MR. KERR: Is TVA going to discuss the tests?

VOICE: Yes, sir, we are.

MR. KERR: Okay.

MR. LEE: Could you also perhaps comment, if you would, at this stage on the status of the theoretical models for predicting this type of phenomenon and how it compared, for example, with the often quoted triangular diagram and so on?

MR. SHAPAKER: Well, this is what they are -- by conducting these tests, they are fully expecting that their burns will occur. In keeping with that turnery diagram --

MR. BUTLER: I think we will defer to a later presentation by Mr. Bowman when he describes the test program that he planned at the Livermore test facility.

MR. KERR: Please continue.

MR. SHAPAKER: Okay. They will be monitoring the atmospheric temperature and surface temperature of the vessel, and they will have their vessel pressure also, and it will have hydrogen and oxygen analyzers to measure the pre and post-burn concentrations.

(Slide)

Just briefly, the first series of tests TVA is planning looks like this. You can see the various temperature, pressure and hydrogen concentrations that they want to achieve in the vessel initially, and the degree of mixing that they want to induce inside the vessel.

(Slide)

Based on the outcome of these tests, they are contemplating the need for possible further testing, and also what they have in mind is to measure the temperature response of the different components and steel or concrete objects.

Now, with respect to measuring the temperature response of components, they are planning to submit to the staff in early September plans for their testing to determine the effects of a hydrogen burn on essential components, and the Environmental Qualification Branch is taking an active part in this effort in scoping out this program.

MR. ETHERINGTON: What is meant by saturation temperature on the previous slide? What temperature, what pressure is that?

MR. SHAPAKER: I guess that would be the saturation temperature corresponding to the total pressure.

MR. ETHERINGTON: What pressure?

MR. SHAPAKER: The total pressure in the vessel.

MR. ETHERINGTON: The pressure that develops in the burn?

MR. SHAPAKER: No, for the initial conditions.

MR. ETHERINGTON: I see. All right.

MR. SIEGEL: The pressure is in the next column.

MR. ETHERINGTON: Oh, yes, I see. I did not see that.

MR. SHAPAKER: They also want to investigate ways to simulate a spray droplet entrainment in the atmosphere so they can determine to what extent a spray system would have on the effectiveness of the igniters. The schedule for the testing is not quite as shown on this slide.

(Slide)

We just got additional information last night. The facility is being prepared and they do have to install some heaters and instrumentation yet; and as a result, the test series number 1 schedules is from 9/8 to 9/12, and further tests being planned for 9/15 to 9/28, with a test evaluation from 9/15 to 9/19, and a test report on 10/1.

Presumably this test report would not include the results of further tests. It would probably only include the results of their series number 1.

(Slide)

There is also a Phase II to this program, and this is sort of an improvement phase. These improvements will proceed along with their long-term degraded core task force program, and some of the improvements that will be implemented include providing individual control from the main control room for each igniter, installing additional hydrogen and oxygen monitors to guide the operators so they know more precisely what is going on in the containment within the various compartments.

They want to install a plant computer to warn of hydrogen concentrations reaching the detonation limit. The backup diesel power supply will continue to be included in any design improvements. And they want to determine the environmental qualification of the distributed ignition system components. And also they want to determine the effects of the hydrogen burn environment on other components.

These two items will be covered in part in this next series of testing in the larger vessel for this vessel. It is large enough to physically contain the glow plug rig that was described earlier.

They are also going to be looking into alternate and/or additional igniter locations based on a better understanding of the characteristics of combustion and whatever they find out from these tests.

They are also contemplating installing hydrite converters near the reactor vessel vent, PORV discharge nd air return fans.

MR. LAWROSKI: What is a hydride converter?

MR. SHAPAKER: I believe it consists of certain metals that have an affinity for forming a hydride at an elevated temperature as hydrogen would pass over it. So it would serve as an initial getter for any hydrogen being released from the reactor coolant system. They are also contemplating --

MR. SIEGEL: Will we hear more about those later?

MR. SHAPAKER: Possibly from TVA when they discuss their longer-term efforts.

MR. SIEGEL: In that same paragraph, what is the reactor vessel vent?

MR. SHAPAKER: This would be the vent prescribed by the TMI Action Plan, I presume.

MR. SIEGEL: Doesn't that exist now?

MR. SHAPAKER: I don't know if that one is installed or not.

MR. KERR: Is there a TVA representative who can respond to the question of whether the vent now exists?

VOICE: Dr. Kerr, our engineering design people just came in. If you could repeat the question we could probably get an answer.

MR. KERR: I should give them a chance at least to sit down, I suppose.

The question is whether the reactor vessel vent as prescribed by the Lessons Learned at TMI now exists and is ready to be operable on Sequoyah.

VOICE: It has not been -- the system has not been installed.

MR. KERR: It has not been installed, but what --

VOICE: It has not been installed, but the drawing has been issued. The hardware is not in the plant itself.

MR. KERR: It is in process. Thank you.

Do you want to add something, Mr. Rubinstein?

MR. RUBINSTEIN: This was originally slated for January 1, 1981, but it is a requirement which is coupled with the inadequate core cooling and reactor vessel level requirement, and both of these items have been slipping, partially because of material unavailability, for the pressure drop systems, for the inadequate core cooling reactor vessel, and partially because the staff has only started to undertake a review with the Westinghouse owners' group on the reactor coolant system vent itself.

So I visualize this requirement being, in effect, late in the year, perhaps December of 1981.

MR. KERR: Thank you.

Mr. Lawroski.

MR. LAWROSKI: Are we going to hear more about hydride converters this afternoon?

MR. KERR: Yes.

Please continue.

MR. SHAPAKER: As a result of trying to improve the diagnostic capability within the containment, additional containment penetrations may have to be installed, so that is another item in their improvement phase.

(Slide).

The third phase consists of final modifications that will be implemented at the completion of TVA's long-term degraded core task force program. Of course, these remain to be defined as their study continues. The degraded core task force program is a two-year effort, and they have identified some major tasks, and they plan to continue with their study of controlled ignition.

They also plan to study ultimate concepts, and they mentioned the use of halon suppressants or possibly fogging systems, and they plan to following along the rulemaking proceeding with their own efforts in risk assessment and core behavior, with hydrogen generation and transport, and with their studies of hydrogen burning and analytical efforts and containment response, and also the structural response of the containment.

MR. LEE: A question. Are they going to have both controlled ignition system and some suppressant system, or choose one or the other?

MR. SHAPAKER: They will probably have to choose one or the other. They are continuing to study alternate concepts in the event that their current study of the distributed ignition system does not prove to be that desirable.

MR. BUTLER: Let me add to that, Jim. They have an interim distributed ignition system in place now. They hope to have it operational with staff approval shortly. However, there are continuing studies under way not only to study further the glow plug efficacy, but also to study other alternative approaches.

If the alternative approaches prove better, they will be used in lieu of or even in addition to. It is subject to future determination. Right now they are just going forward with the burning system, the igniters. They might later add or substitute another system.

MR. LEE: Those are two conflicting systems. One is to suppress burning; the other is to initiate burning. That is why I am somewhat curious at this stage.

MR. BUTLER: You certainly would not use the igniter with the halon system, that is true.

MR. LEE: Okay.

(Slide)

MR. SHAPAKER: This concludes my discussion of the distributed ignition system. I have two other slides on their hydrogen sampling system and mixing systems. I don't know if you want to hear that right now or not.

MR. KERR: I think we probably do not unless you think it contributes.

Let me ask you if you would be willing to comment on Mr. Gilinsky's question, which is, if I may paraphrase: Is the staff persuaded of the effectiveness of distributed igniters in ice condenser containments?

MR. SHAPAKER: Well, I guess I can say it looks promising; but this next series of testing will really provide the most useful information.

MR. KERR: You are not yet persuaded but you are willing to be persuaded if the evidence is persuasive.

(Laughter.)

MR. SHAPAKER: We are keeping an open mind.

MR. RUBINSTEIN: The preliminary evidence is quite persuasive, particularly from the very limited Singleton Laboratory work. And we look forward to reaching our full conclusion in December, after the submittal.

MR. KERR: Is the staff going to try to determine if the igniters can keep pressures below design pressures if one is faced with TMI quantities of hydrogen?

MR. RUBINSTEIN: The staff will discuss analyses this afternoon which deal with the initial hydrogen content and the final hydrogen content as determined experimentally from our work as it is placed in both the MARCH code, and TVA will address it as it is in the CLASIX code, and sequential burns, which deal with both pressure and temperature.

MR. KERR: Thank you.

MR. GREGORY: Is the concept you have in mind to keep the igniters running continuously at all times, or only to activate them in the event of an accident?

MR. SHAPAKER: They will not be powered at all times. They will only be actuated when certain events occur which cause the automatic initiation of different safety equipment. Then the operating instructions will be for an operator to then immediately go and actuate this system.

MR. GREGORY: I would be interested to learn what criteria, what triggers the decision to turn on the igniters and what safeguards are being put in to make sure that they get turned on before you possibly have built up to the detonable limit.

MR. KERR: Can the TVA representative hear the question? What I really want to know is whether you plan to address this question in your presentation.

MR. LAI: I can address it now. TVA has an emergency procedure written, but of course we are not activating it, pending the NRC staff approval to use the system. The procedure called for in the emergency operating instruction is that you would activate this system immediately after the ECCS system is activated and the emergency core cooling system is initiated.

The next step is to make sure the system is on and functional.

MR. KERR: Does that respond to your question, Mr. Gregory?

MR. GREGORY: Yes. I would have some concern that the controlled ignition system could in certain events cause a detonation if it was not activated soon enough after a hydrogen release. I think some attention ought to be paid to that.

MR. KERR: Thank you.

MR. SEALE: I assume you are also going to determine that it is really on, and not that the switch has just been flipped.

MR. KERR: I will accept that as a gratuitous remark.

(Laughter.)

MR. KERR: But an appropriate one.

Mr. Etherington.

MR. ETHERINGTON: The first Vu-graph referred to this as the most promising interim concept. To me it looks like the most promising concept that we have seen. If this is approved and installed, is TVA looking at the possibility of devising an interim -- a periodic testing of individual plugs?

MR. LAI: The answer is yes.

MR. ETHERINGTON: Good.

MR. KERR: With hydrogen, I assume.

MR. ETHERINGTON: Yes.

MR. LAI: We did not plan to test the igniter in place with hydrogen.

(Laughter.)

MR. ETHERINGTON: I realize you are not going to fill the containment with hydrogen. Surely you can put a box around it or something.

MR. LAI: No, sir. We do not plan to test the igniter inside the plant with any hydrogen. It would be off-site testing.

MR. KERR: Are there other questions?

(No response.)

MR. KERR: Thank you, Mr. Shapaker.

I show a presentation by Mr. Tinkler at this point.

MR. TINKLER: I am Charles Tinkler. I work in the Containment Systems Branch.

This portion of the presentation will deal with the overall NRC efforts to address those technical questions which are related to the issue of hydrogen control.

(Slide)

Those efforts are primarily in three areas: short-term efforts principally directed towards an evaluation of igniters for degraded core accidents. These efforts are principally being monitored by NRR. The long-term efforts on hydrogen control are being conducted through the Office of Research, and their research will deal with both degraded and melted core accidents.

In addition, earlier this year the staff began its studies on the Zion/Indian Point plants in which hydrogen control was also a topic.

(Slide)

MR. KERR: Mr. Schott.

MR. SCHOTT: For general information or orientation, are the Zion and Indian Point things MARK III's or are they ice houses or what are they?

MR. TINKLER: They are large drive PWRs.

Under the short-term efforts we have a rather large program to evaluate the igniters. We have obtained technical assistance from a number of labs in order to complete our evaluation in a timely manner. Livermore is participating in the igniter evaluation by performing tests on the igniters that have been proposed by TVA for their interim distributed ignition system.

Livermore will also conduct a survey of hydrogen detection in plants currently in operation. The igniter tests, as has been talked about previously -- and the tests will be described in much more detail by Mr. Bowman of Livermore later on, but principally the idea is to determine the effectiveness of the igniters in varying atmosphere mixtures, the ability to ignite the hydrogen in varying concentrations of steam.

Columbus-Battelle is participating in this program, and they are performing analysis using the MARCH code for the Sequoyah containment in an attempt to analytically determine the effect of use of igniters. Sandia will perform an evaluation of igniters and principally focus on alternative systems in the case that igniters do not eventually end up being very promising.

MR. LEE: Mr. Tinkler, what kind of result do you expect to get out of MARCH analysis for the controlled ignition systems and so on?

MR. TINKLER: We think the MARCH code represents a substantial improvement over calculations which have been provided, for example, in SECY papers. It provides the capability to do a transient calculation of hydrogen release to the containment and the transient burning of hydrogen.

MR. LEE: How about the controlled burning igniters? Are you trying to model that?

MR. TINKLER: The data that we learn from tests will be used as the basis for parameter studies and analysis

-- the ignition set points, quantity of hydrogen that is burned, for example.

Now, we feel that we need a data base from which to do our analysis.

MR. LEE: So it is from your experimental tests you expect to get --

MR. TINKLER: How much of the hydrogen will burn for a given concentration, and those parameters are input options into the codes that we are talking about. We are able to initiate hydrogen combustion and the burndown limit in the codes so that we can model the heat addition to the atmosphere.

MR. LEE: I am still not sure the information that you have has to really come from your experimental efforts.

MR. TINKLER: The experimental efforts will verify. It will also provide the basis for future analyses to determine how effective they are in mitigating the consequences of various accidents.

MR. LEE: I am particularly interested in what kind of volume a particular igniter could perhaps control, what kind of a volume of hydrogen and what rate and so on. Unless you have this information to put into the MARCH code or any other code, you cannot expect to get any meaningful information.

MR. TINKLER: I think the information we will get from the test program will be sufficient to model the calculation in the codes that we have available. Like I say, the tests are designed to determine whether the hydrogen will ignite at various concentrations. That will be bounded for analytical purposes.

MR. KERR: The MARCH code does not itself model the microscopic behavior of the burn. If I understood Mr. Lee's questions, they had to do with flame propagation that might occur at low hydrogen concentration. Suppose you get an ignition. How much burn do you get? Where does it go? Don't you need that sort of information to have a good understanding of the energy input from a burn, for example, and how extensive the burn is; or is that too detailed? Maybe you only need a broad brush.

MR. TINKLER: I don't think that we need to know the precise definition of the flame front in order to perform the bulk of the containment calculations. We are principally concerned with how much hydrogen is burned and how much energy addition to the containment atmosphere results.

MR. KERR: But the MARCH code does not tell you how much hydrogen is burned, does it? You have to input that.

MR. TINKLER: Yes.

MR. KERR: If you input it, how do you know what to input unless you know something about the behavior of the igniters in a lean mixture of hydrogen?

MR. TINKLER: We intend to test the igniters in a lean hydrogen mixture. You have seen data on that at 8 and 12 percent, okay? But the igniters will be tested in leaner atmospheres.

MR. LEE: The data base is still quite limited.

MR. TINKLER: Yes. That is why we are doing the testing.

MR. LEE: The six foot diameter test volume still is quite limited, in my opinion, compared to the large containment.

MR. TINKLER: One of the test vessels will be approxmately ten cubic feet. One of the test vessels will be approximately slightly more than 100 cubic feet.

MR. LEE: That is a six foot diameter vessel you are talking about, and I don't know how many glow plugs you have for that 100 cubic foot volume. I don't know whether it makes sense. I have no idea whatsoever at this stage. And to rely on -- oh, I am not saying that you should not try to exercise the MARCH code or anything like that, but I am just curious what kind of information you envision getting out of such an exercise of the computational program.

MR. TINKLER: One more try here. I think the numbers from the test data -- you know, we cannot guarantee them to be precise for the plant applications; but with a little judgment we can bound those numbers in order to determine the effects of hydrogen burning at various concentrations. That is the best we could hope to do in any situation where we have conflicts between test data and actual configurations.

MR. LEE: That might well be perhaps the best you can do, but I am still interested in what general information you can get out of running the MARCH code that you don't already have from your test program.

MR. TINKLER: The calculations you have seen in the SECY papers are hand calculations for an adiabatic heat addition. The MARCH code is a substantial improvement over that type of calculation. Unless we do a transient calculation which takes credit for heat removal mechanisms in the containment, we won't see benefit from any mitigation devices.

MR. LEE: I agree with your assessment to a certain extent. As far as hydrogen generators are concerned, perhaps what the MARCH code predicts might be somewhat more accurate or more reliable. As far as the efficacy of the disributed igniters is concerned, I am not sure what additional information a code like the MARCH program can provide.

MR. TINKLER: I gave it my best shot.

MR. BUTLER: It might be helpful. I think the thrust of your prior question, Mr. Lee, was more in the area of distribution of hydrogen concentrations before you turn on the glow plug, and the concern presumably is you might have appropriate distributions away from the glow plug but no hydrogen near the glow plug. Is that the thrust of your question?

MR. LEE: Yes, certainly. That would be my concern.

MR. BUTLER: It might be helpful here to indicate that there are return air fans that assist quite a bit to mixing the air in the upper and lower compartments. These are 40,000 CFM fans that give you one complete air change in the lower compartment every five minutes.

Now, it is true that the hydrogen addition could conceivably be a point source, and we are trying to engage a consultant to examine the heterogeneity question of hydrogen distributions by postulating point sources and determine how that hydrogen would provide various concentrations as a function of space away from the point source.

MR. LEE: That is just one part of my concern, perhaps. The second part was related to what Dr. Strehlow mentioned earlier about the lateral versus vertical propagation of flame, which I am willing to wait and learn a little bit more about a little bit later. But if that type of phenomenon cannot be simulated in a code like the MARCH code and the code is not certified to be a design-type of code -- and I understand the model is not really detailed at this stage -- what additional information can we get out of the code?

I still have that concern.

VOICE: I agree with most of your comments, Mr. Lee. The MARCH code certainly does not do the microscopic studies. But I think maybe the point should be made that given certain amounts of information on the efficacy or effectiveness of the igniters under different conditions, things that the MARCH code can tell you are what is the effects of that type of ignition in a large system as opposed to the idealized experiments.

MR. LEE: How can you tell? I am curious, if you could educate me a little.

VOICE: I would just as soon not take too much time at the moment since I am scheduled to be on in a little while. Perhaps I can address that point a little later. But basically what the MARCH code will tell you is, given ignition under these conditions, what is the effect in the full-scale system.

MR STREHLOW: Mr. Butler, your comment raised another question in my mind. With those return fans, they are ducted? The air is ducted by those fans through ducts to circulate?

MR. TINKLER: Yes, it is.

MR STREHLOW: They can be very dangerous as far as transition is concerned. If you do a burn, a long duct with a fan that is making nice, turbulent flow can be extremely dangerous in causing transition to detonation. This may not happen at 4 percent. It probably would not. But if you got up to 8 percent and those fans are running, you might have a real good time with a detonation going down those ducts.

MR. KERR: Please continue.

MR. TINKLER: I don't believe I mentioned I&D Associates, but they are involved, and they will participate with Livermore in an evaluation of data. Another lab not listed here is Brookhaven, which has participated in the Zion/Indian Point studies and has done work on hydrogen.

MR. SEALE: I have not heard anything yet, and I was just interested in this one point; and that is, you are putting some igniters in or at least you are examining the possibilities. There are a lot of igniters that are apparently already in there, switches, and maybe even those fan motors you were talking about. And I wonder if there is any evaluation of other ignition sources in such systems?

It seems to me that there is very likely going to be ignition whether you put those igniters in there or not. Maybe not as often or as regularly, if you will, or continously, but there will be some ignition.

MR. TINKLER: The idea of adding the ignition system is to more or less improve the reliability which you feel will occur, okay? It is recognized there are random ignition sources inside containment.

MR. SEALE: The reason I brought it up, I guess, is you speak of other things besides ignition as an approach, and the idea that anything else might be incompatible with the ignition; and yet, if there are ignition sources there anyway, you really are going to have to accommodate that problem.

MR. TINKLER: That would have to be factored into an evaluation of the other mitigation systems.

MR. SEALE: Okay.

MR. STREHLOW: I might comment on that point. The glow plugs are probably a very strong source of ignition. There is a large surface area. They are very high temperature. If I remember correctly, Three Mile Island went off at 8 percent or something like that hydrogen.

That indicates to me that the ignition sources present are not strong sources, and it turns out when you go towards the limit, the strength of the ignition source has to increase markedly, otherwise you will not get flame propagation. So the installation of glow plugs might be a very good thing to do, because you might induce relatively slow burns over a long period of time which will not cause any appreciable pressure rise in a system.

MR. SEALE: If they are not there you still --

MR. STREHLOW: We don't know until the experiments are done.

MR. KERR: It seems to me we may be converging on the TVA position.

(Laughter.)

MR. SIEGEL: I have kind of a basic difficulty with this approach. I don't know if this is the right time to ask the question, but let me pose it now.

It seems to me the objective of this distributed igniter effort and the test program is to demonstrate that you can safety ignite several hundred kilograms or several tens of kilograms of hydrogen. But it seems to me a better objective would be to say that you can safely handle so many kilograms per second of hydrogen coming from some hopefully plausibly identified sources so you'd never tens or hundreds of kilograms in the containment.

I don't see any signs that either the test program or the concept is addressed toward this latter question.

MR. TINKLER: In the event that we have to provide some sort of system to mitigate the consequences of a degraded core accident, we cannot avoid the introduction of hydrogen in those quantities.

MR. SIEGEL: I agree. You need the other as a backup system. But I would like to see some evidence that you have a pilot light near the place where the flame is likely to start rather than have a light bulb in the kitchen which will blow it up when you have it there.

MR. TINKLER: What I would like to point out is this is the interim distributive ignition system. Further review of this system, you know, as yet to take place, and the location and number of igniters is one of the subjects that we intend to review in more detail.

MR. SIEGEL: Well, frankly, I guess I have expressed my reservations about this being the preferred interim system.

MR. KERR: That is not a question.

(Laughter.)

MR. TINKLER: Okay. The Sandia short-term program, which is being monitored by the Office of Research, as I said previously, will concentrate on alternative systems. They will look at deliberate ignition systems also; and to take the things they will look at under deliberate ignition, they will look at ignition strategies, whether you want to igniters on and leave them on, or whether you want to have intermittent operation. And they will look into analytical verification of igniter effectiveness to see if they could determine from existing test data at what concentrations you burn hydrogen and so forth.

Halon systems, some of the issues to consider are concentrations necessary to prevent deflagration or detonation, the effects of recombiner operation in this halon atmosphere, post-accident handling of the halon atmosphere -- the halon only suppresses the burn; it does not remove the hydrogen -- what would a halon system look like, the design concept. And they would evaluate it as a short-term solution to the issue of hydrogen control.

Water fog, similar type issues will be investigated -- the design concept, what would a system look like, how much water would have to be supplied to the containment, what droplet size in order to suppress, what is its effectiveness in -- to prevent hydrogen burning, what effects would it have by immediately reducing steam concentrations perhaps and thereby changing the flammability characteristics, what would a long-term recovery look like for a containment with a water fog system, since again presumably this only works as long as it is operating, and what aspects of this would lead you to believe that this is a short-term solution to solving the hydrogen control problem.

(Slide.)

MR. KERR: What is the significance of the term that appears in two of those short-term feasibility --

MR. TINKLER: We believe the issue of hydrogen control will be studied for some time in conjunction with the rulemaking, in conjunction with ongoing studies that the staff --

MR. KERR: I am not making my question specific enough. Does that mean you are trying to determine whether it would be feasible to implement those very soon?

MR. TINKLER: At Sequoyah.

MR. KERR: That is what short-term feasibility means.

MR. TINKLER: Yes. Could they reasonably hope to install a water fog system at Sequoyah in this time frame.

MR. LEE: Are hydrogen -- are there any systems under study by anybody at the present time?

MR. TINKLER: I would say that hydride converters are not -- they are not being strongly considered by the staff at this time. TVA has indicated they will look into this area, but it is a technology about which we do not know a great deal.

The ultimate capabilities to observe hydrogen are not well understood.

MR. GREGORY: I would suggest that you might consult the people at Brookhaven who have a tremendous background on various hydrides.

MR. TINKLER: Okay. Brookhaven has suggested hydride converters in connection with the Zion/Indian Point study. Brookhaven continues to work in that area.

MR. GREGORY: I would think, just off the top of my head, that it would be difficult to find a hydriding metal that is tolerant to air, because if you have an inerted containment, it would be relatively easy to pull the hydrogen out with a hydride, but with an air-filled containment, I think the hydriding metals are likely to oxidize.

MR. TINKLER: Long-term efforts principally being directed by the Office of Research, the last time, I suppose, the staff reported on this, we indicated that a user's request was being prepared or had been prepared for additional research on control or mitigation of melted core accidents. Since that time a user's request has been issued, and to repeat the objective of it, was to provide technical support for conducting a rulemaking on degraded/coremelted accidents.

We had hoped to investigate the filter vented containment system designs and hydrogen control systems for generic types of lightwater reactors, various containment types. We had suggested that the research initially focus o hydrogen controls for the ice condenser in the Mark III containment, since they seem to be more sensitive to hydrogen generation.

MR. KERR: Have you given the RES any specifications? I mean, for example, on a filter vented containment design. Have you specified any rough criteria for behavior that these have, or is that part of the research program to establish criteria?

MR. TINKLER: Part of the research program is to establish the criteria under which these systems must, you know, operate and what their function will be. We have not specified detailed criteria that we think a filter vented containment system must have.

MR. KERR: How about non-detailed criteria? Have you given any --

MR. TINKLER: We identify criteria against which we think all the systems should be judged -- cost-benefit sort of items, reliability.

MR. KERR: For example, have you specified flow rates that you expect that these may have?

MR. TINKLER: No. If we had done that, then we would have identified the accident scenarios.

MR. KERR: That is so logical that I must agree with you.

(Laughter.)

MR. TINKLER: And we have not identified the accident scenarios for which they must operate. Okay. And we discussed this before, so --

MR. BUTLER: Let me add to that, Charlie.

The matter of filter vented containments has been under study for a couple of years at least, and in conjunction with that work sponsored by research, the NRR staff has met with the research people and the Sandia people and expressed its comments with respect to containment systems' needs in regard to the filter vented containment.

MR. KERR: One of the reasons I ask is because any good research organization is not dedicated to solving problems. They are dedicated to finding new problems. I mean, you know, that is what a researcher does. So unless you give him some idea of the problem you want him to solve, he will not try to solve problems; he will try to find problems.

At some point it seems to me somebody is going to have to define what the problem is in order so someone can look for a solution. Maybe it is too early to do that.

MR. BUTLER: It is our expectation that we will have frequent meetings with the research people as well as with the laboratory support people. It is indeed a bit too early to do that. We still have to meet with the research people in their response to our user's request.

MR. TINKLER: Since that time a draft RSR program plan for severe accident phenomenology and mitigation research has been drafted. The logic of the program is similar to the WASH-1400 reactor safety study and the Zion/Indian Point study.

About the most I can say is the program is currently under review, and this draft program also deals with much more than hydrogen control. It deals with broader aspects of the severe accident mitigation.

(Slide.)

The relationship to Zion/Indian Point studies, as previously mentioned, the Zion/Indian Point studies did consider generation and release of hydrogen, and the severe accident to the containment, and the ultimate combustion of that hydrogen.

As a result of the Zion/Indian Point studies, Sandia compared a compendium of hydrogen behavior in a post-accident environment, and there were various studies of mitigation features. These studies were done for the Zion/Indian Point plants, so application of all these studies to the Sequoyah plant are not easily made.

The general conclusion from the technology exchange meetings and the bulk of the work was that the large dry containments may survive a hydrogen deflagration for degraded core accidents.

You might argue what is large, but it does appear for the dry containments they would be able to survive a hydrogen deflagration simply due to the high volume.

MR. KERR: In fact, you could almost say large containments would, couldn't you, whether they were dry or wet?

MR. TINKLER: Yes.

MR. GREGORY: May I go back to the previous slide with your issuing requests for research, and ask you to -- ask what mechanisms are you using to solicit new concepts, new ideas from the research community on methods of either preventing hydrogen release or observing hydrogen or combustion techniques?

Are your requests going out in such a form that the universities, the industrial contracting labs may respond, or are you addressing these only to the potential users and the national labs?

MR. RUBINSTEIN: We have a representative from research here who can address that question.

Mr. Hotzen.

MR. HOTZEN: The current work, we are planning to use Sandia Laboratories as our center for the hydrogen work. They in turn may funnel work out to universities or other research laboratories, but they are going to be our center for the hydrogen research work.

MR. GREGORY: It occurs to me that there are surely a number of research operations around the country that might have ideas to offer in this respect, but they may not even be aware of this kind of problem.

MR. HOTZEN: Yes. We are currently talking about possibly holding a conference at Sandia in December and inviting the broad community to attend that for two reasons: one, to inform them of what Sandia is doing, and second, to find out what each of the organizations are doing.

As someone mentioned earlier, the hydrogen problem has come up pretty quick. There are a lot of people running in a lot of different directions, and we need to find out what each other are doing.

MR. GREGORY: As a member of the industrial contract research community, we scan the Commerce Business daily for requests for proposals in areas that we think we have technology to offer, and I do not recall having seen anything relating to this advertised to the research community.

I would just like to make the comment that you do have a mechanism of getting out to the hungry research public, and it might give you fast response on new ideas if funding would be available.

MR. HOTZEN: At the moment the main job -- we have been through the compendium at Sandia which raises a lot of interesting areas where research could be done from the scientific point of view. The next step we have to do is find out where that research would be of interest in the nuclear safety area; and that is the next part of the work we are going to do.

After that we will be in a position to get a better handle on the specific experiments that we might advertise for assistance on.

MR. KERR: Please proceed, Mr. Tinkler.

MR. TINKLER: This concludes my presentation at this time.

I would like to introduce Mr. Bowman.

MR. KERR: Before you conclude completely, back to the MARCH code, does the staff feel fairly confident of the results or the applicability of the results you are getting from that code, or are you using it because it is the best you have, or what is your attitude toward the results insofar as they apply to, say, Sequoyah and other operating plants?

MR. TINKLER: It's the best we have, okay. But we feel that any of the results calculated to date are preliminary in nature, okay. The codes that have not been used for this application --

MR. KERR: Is "preliminary" a euphemism for "semi-lousy,", or do you mean "early?"

(Laughter.)

I don't know.

MR. TINKLER: If anything, it is a euphemism for a lot better than anything else we can do, and we think they are reasonable calculations. Whether we think they can predict pressures within one psi, for example, we cannot say that with any confidence.

MR. KERR: What about 10 psi?

MR. TINKLER: I think that is the ballpark we are talking about, how much lower we can get it. On MARCH -- we need to learn a little more about it.

MR. KERR: I'm not trying to be critical. I'm just trying to understand how you view the results of the code, because I do not -- I do not know.

MR. TINKLER: I can only say that based on my limited exposure to the code, I have to say -- repeat it is a substantial improvement over what we had before. I think the code does a reasonable job of modeling the transient. Whether it could do a better job is debatable at this time; but we think it is valuable in determining the effectiveness of the igniters.

We surely need to use something like it, or the CLASIX code which is being used by TVA.

MR. RUBINSTEIN: May I add to this? We recognize MARCH and CLASIX as essentially unverified in terms of experimental bases, and we will be doing at Battelle with the MARCH code verification through other codes where possible. And I believe that TVA will discuss to some degree their verification program and their code later this afternoon.

MR. KERR: Thank you. Thank you, Mr. Tinkler.

MR. TINKLER: As I said, Mr. Bowman will discuss the igniter program at Livermore.

MR. BOWMAN: My name is Barry Bowman. I am from the Lawrence Livermore National Laboratory. I am going to give you a brief overview of the hydrogen igniter program that we have going on right now at the laboratory. We are doing this under contract to the NRC, and the overview will cover the following items.

(Slide.)

Very briefly I will go through the program objective, the status of the hydrogen monitoring device survey, a description of the experimental design and instrumentation, and experimental conditions and brief account of the procedures we intend to use to conduct the experiment, and finally, a program schedule to give you an idea of how soon we intend to get everything done.

(Slide.)

The objectives of the program are fairly explicit. There are three major objectives. The first of these is to test the thermal igniters proposed for use at Sequoyah by TVA in various mixtures of hydrogen, air and steam.

Bill Lowry is the project engineer. He is here today.

The second objective is to survey and report on the state of the art methods and devices for hydrogen protection, being conducted by Bill Lye, and then to conduct a literature survey of the hydrogen combustion, particularly that conducted by the U.S. Bureau of Mines.

To date there are no publications or data available for hydrogen combustion in substantial amounts of steam, so this represents a new work from that standpoint.

The igniter itself -- I brought one along to give you an idea of the size of what we are dealing with.

MR. SIEGEL: When you say test the thermal igniters, what does that mean -- to see if they light the gas, or to see how the phenomenon of gas combustion goes on in some chamber which has been initiated by the igniters? What does to test thermal igniters mean?

MR. BOWMAN: It implies that we will confirm whether igniters will or will not function for various combinations of air, hydrogen and steam. How we detect the burn will be from a detection of pressure rise in the vessel. I will go into that in a little while.

MR. SIEGEL: It is literally a test of the igniters, as you say, not a test of the phenomenon of hydrogen combustion as initiated by these igniters.

MR. BOWMAN: That is right. Before I cover that, here is where we are in the hydrogen monitoring systems.

(Slide.)

This is not an all-inclusive list. There are four basic types that we have uncovered -- catalytic device manufactured by these companies: a semi-conductor device; a volume expansion device; and electrochemical oxidation type device.

The catalytic device essentially detects the hydrogen by increasing temperature of the catalyst. The semi-conductor device detects it by a change in the current of the conductor. The volume expansion device is a mechanical device; as the hydrogen adsorbs it actually increases in size. And the electrochemical oxidation is basically an electrolyte absorption process where the hydrogen increases or decreases the output of a little battery.

(Slide.)

The general characteristic of the available systems, they depend on diffusion of the hydrogen. They are fairly slow in response. "Slow" here means 3 to 30 seconds for the first two devices that I mentioned, catalytic and semi-conductor, and from 7 to -- let's see -- 30 to 7 minutes for the volume expansion device. Electrochemical oxidation is also the --

MR. KERR: What sort of time response does the NRC think should be available?

MR. BOWMAN: Why don't you ask the NRC?

MR. KERR: They have not told you?

MR. BOWMAN: No.

MR. KERR: All right. I will ask them later.

MR. BOWMAN: The indications were that was adequate, 30 to 30 seconds, but I will --

MR. GREGORY: What is the response time of the electrochemical?

MR. BOWMAN: Three to 30 seconds, somewhere in that time frame. It's a matter of seconds, not minutes. The slowest is the volume expansion device. Some are subject to contamination if you do have other hydrocarbons in the system, or if you have a fair amount of water in this system, then they also pick up that. The pores on a catalytic detector can actually be plugged by condensation of water.

Some are limited in the range of hydrogen detection. Of the devices I mentioned, the catalytic and semi-conductor devices have a range of about .02 percent by volume of hydrogen up to about what is called the lower explosion limit or sometimes referred to as the lower flammability limit of 4 percent or so.

The volume expansion device and electrochemical oxidation devices don't have any apparent upper limit. The lower limit for the volume expansion device is on the order of a tenth of a percent, and the electrochemical oxidation is roughly half that, .05 percent.

MR. SIEGEL: Are any of those devices based on the thermal conductivity of the gas?

MR. BOWMAN: Of the gas? I am not sure.

MR. SIEGEL: That is sort of the classical way of measuring hydrogen.

MR. BOWMAN: I suspect the semi-conductor device refers to that. I don't know the details. I know the least about that one, so you probably know more than I do.

MR. RUBINSTEIN: I believe that type of conductor is in Sequoyah. TVA can answer that.

MR. KERR: Is it the view of Livermore that existing devices are adequate for the purpose for which they may be needed in a nuclear plant?

MR. BOWMAN: We don't know. It depends on what you mean by "detection" in a nuclear plant.

Okay. Right at this point what we are trying to determine, first of all, what is available commercially, what range of --

MR. KERR: I guess I don't see what difference it makes what is available commercially unless you know what you want. I mean, you could go to a catalog and find out what is available commercially. I assumed that Livermore was looking for something that would do a job, and it had some idea what the job was.

MR. BOWMAN: Let me describe the job a little bit. If you are going to detect hydrogen concentrations that are burnable by these thermal igniters, you need something that will detect normally 4 percent. If you want an opinion, the catalytic converter, if that is the upper bound, if you get concentrations that exceed that, you are going to pick that device almost every time.

So in the selection of a device we are not involved in the selection, but we could be involved in making recommendations as to which devices are or are not usable within a plant, and we will do that.

MR. KERR: But you are not yet prepared to do that.

MR. BOWMAN: Not yet, no. We started this whole process August 1. This is sort of a status report as to where we are.

MR. KERR: Thank you.

MR. BOWMAN: A description of the experimental apparatus, I have some pictures that will show you better what the system is like. This is a schematic, but the orientation and basic configuration are correct.

(Slide.)

This is the hydrogen supply, air supply and steam generator that we are going to use to provide various concentrations within this vessel. This is a 10 cubic foot diameter -- test chamber. It is an ASME steel pressure vessel. It is normally 20 inches in diameter and about 60 inches in length. We have access points at the side and the top which are about eight inches, and at this end through which protrudes a mixing fan which is about four inches in diameter.

Okay. The instrumentation and the glow plug itself are in the system at these approximate locations.

(Slide.)

We have several thermocouples installed throughout the vessel at the bottom, top, and sides. We have them sticking into the vessel, normally an inch or so, and attached to the internal wall and the outside wall to measure the heat transfer through it.

We are also measuring the ambient conditions. We have static pressure transducers located on the end flange and right now on the top flange, and dynamic quartz-type pressure transducers which are flush-mounted to the sidewall of the containment.

These two will detect any substantial strength pressure wave that is propagated through the system. We initiate combustion at a higher concentration. We have taken gas samples periodically on the ends, both above and below the center line, to determine the homogeneity of the mixture within the containment vessel at the top, and then periodic samples that are mounted to this flange plate on the side.

The glow plug itself is on an extendable rod that sits down inside the vessel through this upper flange. It can be moved up and down so that we can locate it anywhere vertically within the pressure vessel that we like.

There is also a differential pressure transducer which just measures the hydrostatic head of the condensate that we are going to get through the process of conducting the experiment.

MR. MARK: In the slide before and what you have said, you are prepared to mix hydrogen, air and steam. As soon as one of these igniters has burned a little and the flame is out and the hydrogen keeps coming, do you no longer have normal air to look at?

You have nitrogen contaminant probably more than steam. Is there any plan on the part of research or Livermore or NRR to add nitrogen fraction contaminate to the system, because it is certainly going to affect the ignition the second or third time that you call on it.

MR. BOWMAN: Not specifically, no. We are going to rely on that to tell us what is in the volume at any particular time prior to ignition, immediately after ignition, and any subsequent firings of the glow plug. So you are right. It will be --

MR. MARK: If you are going to be subsequently igniting the used air, then you will get these data points free.

MR. BOWMAN: Right. We are getting a lot of data points free by this experiment which I think you will see.

MR. STREHLOW: Are you going to change the elevation of the glow plug?

MR. BOWMAN: We had not planned on changing that. Right now it is sticking down, okay. We can change the orientation of both the glow plug and the entire system if we want.

MR. STREHLOW: And are you planning to put the gases in an then turn the glow plug on?

MR. BOWMAN: We plan on precharging the vessel, all right, and I will go through that in a little bit.

MR. STREHLOW: Okay, sure.

MR. BOWMAN: Any other questions on that? I have some photographs that we took just before we left. This will give you an indication of a couple of things -- what it looks like and where we are in assembly.

(Slide.)

This is the vessel itself. You can see the various penetrations for the pressure transducers at the top and thermocouples. The dynamic pressure transducers come out here and here (Indicating). This is the side eight-inch flange, and then the flange on the end (Indicating).

(Slide.)

The igniter itself is mounted on this rod that we can control its vertical position (Indicating). The igniter that I passed around is sticking right up here on the end. Everything that goes into the vessel itself is from this type thread forward to the left (Indicating).

(Slide.)

The mixer itself is an air-driven fan that pokes in the end wall, and the gas sampling bottles we are just starting to assemble. They are normally 70 cubic centimeter bottles with an isolation valve here. They remotely operate a solenoid valve. We have to do all of the experimentation remotely in a bunker just in case we make a mistake.

(Slide.)

Some of the characteristics of the glow plug that we have arrived at are shown on the vu-graph. We applied various voltages. Incidentally, I did not mention it, but the glow plug itself is instrumented for current voltage and surface temperature.

(Slide.)

The first four tests are normally with 13 to almost 16 volts pressed across the glow plug itself. Surface temperatures are on the order of 1770 to 1800 degrees. This is the RMS voltage. In rise times it was the order to 20 to 30 seconds to come up to that peak temperature.

In the subsequent tests below this blue line you will see there is some inconsistency in the data, and this may reflect a breakdown in the plugs, since the voltage was impressed across it. That was well above the design value of 12 volts.

(Slide.)

An experimental region of interest that we are going to be looking at, here is the famous turnery diagram. I'd like to point out a couple of things. These are not really very strict lines. They are more or less broad bands across here, and this lower detonation line is subject to how the tests were actually conducted, because it is dependent upon the --

MR. MARK: Is that a typo on the slide about the hydrogen fractions?

MR. BOWMAN: Let me look here. No.

MR. MARK: Four-tenths to nine-tenths sounds pretty high.

MR. BOWMAN: That is not percent by volume.

VOICE: That is a typo.

MR. MARK: Under the experimental region by your right hand, maybe a zero would have cleared it up.

MR. BOWMAN: I am losing you somewhere. Yes, I am sorry. It is a typo. It is .04 to .09. Yes, in this region here. So 4 to 9 percent by volume.

MR. MARK: Do you know what your tank will stand? I mean, can you fill it with two hydrogens and one oxygen and light it and still have the tank there?

MR. BOWMAN: We think so, but we are conducting tests in a bunker.

(Laughter.)

The design pressure on the tank is 200 psi. I think detonation calculations show that we could generate a pressure wave when the pressure is about 5 to 6 atmospheres, if I recall, overpressure.

MR. SCHOTT: It is more than that.

MR. BOWMAN: I will check that for sure. That was in the presence of a substantial amount of water vapor.

MR. STREHLOW: It sounds awfully low.

MR. BOWMAN: A relatively low concentration of hydrogen.

MR. KERR: Well, they do have the bunker.

MR. STREHLOW: Yes.

MR. BOWMAN: That is right.

MR. SEALE: It may be a 50 cubic foot volume.

(Laughter.)

MR. BOWMAN: Experimental procedures, we are relying on some of our pretest thermodynamic calculations.

(Slide.)

We are going to meter the air, precharge the tank with air, and then put in the hydrogen by allowing it to reach equilibrium with a precharged bottle, precharged volume of hydrogen, so we do not inadvertently get more than we want and create this situation.

We then inject saturated steam from the steam generator to a precalculated pressure and temperature that is outside of these predicted combustion limits, allow the steam to condense on the side walls, and periodically fire the glow plug, sampling gases just before and just after each firing. This gives us a measure of what the condensation rate on the walls is by post-determination of the water vapor in the samples.

After we get an ignition which will detect the pressure in the system, then we will grab a final sample and decide to go on to subsequent firings.

(Slide.)

MR. LEE. There is no way of measuring the pressure around the glow plug during the -- during the firing process or right after on continuous basis?

MR. BOWMAN: No.

MR. LEE: So you have to get the pressure difference before and after.

MR. BOWMAN: That is right. We are looking at the equilibrium pressure for the tank before and after, and then the quartz impact gauges essentially may give us a peak pressure.

MR. LEE: How much time do you feel that you have to give after the firing -- burn was initiated before you reach that pressure in the tank?

MR. BOWMAN: I am not certain, okay. That is one of the things that we will find out. The complexity that contributes to that is continuing condensation within the tank of revaporized water vapor; so we don't know.

MR. LEE: Presumably from small tests set up like this you could go to a larger containment system, or is that too much to ask?

MR. BOWMAN: I don't know, and that is a question I think that comes up: what is the applicability of these tests to an extrapolation to a larger test system or to a containment itself. And Roger --

MR. STREHLOW: If you have a small vessel, in other words, almost a round vessel, the extrapolation is straightforward. The maximum rate of pressure rise times the volume to the third power is a constant, so if you determine it in this vessel -- and I think this vessel is large enough -- you should be able to get a realistic pressure time curve. Assuming that there is no flame acceleration due to structural interactions and things like that, you will get the lowest value for pressure rise with time.

MR. LEE: How about the fact of the condensation on the walls and so on? Is that going to affect anything?

MR. STREHLOW: That is what this big matrix code takes care of. What was the name of the code, the one we were arguing about it?

MR. KERR: The MARCH code.

MR. STREHLOW: That takes care of the condensation effects in the main vessel. It handles all the losses to the load itself, which you would not do in an adiabatic calculation.

MR. LEE: But I have -- I have a concern about what a code can do in lieu of experimental data.

MR. KERR: But your answer is that the experiment does not handle that problem.

MR. STREHLOW: The experiment will handle the problem. He will get condensation.

MR. KERR: It does not handle the extrapolation problem.

MR. STREHLOW: The code would -- well, I don't know how to answer that. The main thing that happens, I think, if you have losses is that the maximum pressure is different, that the rate of pressure rise will still be about the same probably, and that can be done by the extrapolation of these experiments here by the maximum pressure. If you do -- you are probably going to do an adiabatic calculation for maximum pressure, aren't you, on this system for complete combustion?

MR. BOWMAN: That is right.

MR. STREHLOW: You will see a volume that is less than that during the experiment, and you can attribute that to partial combustion, and you can get samples so you can tell how much did burn. In that case you will mix the gas thoroughly before you draw that final grab sample, won't you?

MR. BOWMAN: We will turn the fan on prior to combustion.

MR. STREHLOW: But I mean after -- you should recirculate it afterwards because you might draw a false sample if you have only partial combustion.

MR. SIEGEL: On your chart about experimental procedures, you show that you inject saturated steam, and then you allow the steam to condense slowly, and then periodically the glow plug is fired. Do you know the steam conditions at the time that combustion is occurring? Are those steam conditions varying during the combustion process?

MR. BOWMAN: During the combustion process you are going to generate water as a combustion product, and you will also revaporize some of the condensate; so we will not know precisely until we post-process our gas samples what we had at the time just prior to combustion.

MR. SIEGEL: Will you know the steam conditions at the time of initiation of combustion?

MR. BOWMAN: We will know from the pressure and temperature measurements that we made, so we can infer about where we are on the diagram, but not exactly.

MR. LEE: Will you also be able to somehow infer the pressure pulse that might occur based on the pressure that you measure later on?

MR. BOWMAN: I'm not sure I understand your question.

MR. LEE: The pressure on the glow plug when the maximum temperature is reached, it may be different from the particular pressure that --

MR. STREHLOW: There are no waves in this system. The pressure is spatially constant. It is temporally changing, but it is spatially constant. The velocity of sound is 1,000 feet per second, and that thing is only 10 feet long. It takes a hundredth of a second, so there is no pressure gradient in the system at all, not with this kind of condition.

MR. LEE: Not even with the condensation and so on taking place on the wall?

MR. STREHLOW: No way. You will change the pressure with time, but you will not have spatial gradient. So if you measure pressure at the wall, and you measure accurately, you are measuring the pressure at the glow plug.

MR. LEE: No, but I am interested in the temporal variation of pressure.

MR. STREHLOW: That you will get with those gauges and --

MR. LEE: The special --

MR. STREHLOW: A megacycle of pressure fluctuation, but you won't see that in this system because the pressure rise is slow.

MR. SIEGEL: What is the time scale for the pressure rise? Is it short compared to condensation or evaporation times? I am still concerned about the steam presence.

MR. BOWMAN: I think it is short compared to condensation rate. The sort of temperatures we see externally at the test site, the condensation rates are such that we could condense from 70 percent steam down to 30 percent steam in the course of about an hour. Okay. Pressure increase within the vessel itself occurred much more rapidly, a matter of seconds, seconds or subseconds.

MR. SCHOTT: Can we expand a bit on the temperature control that you do or do not have on the test vessel? It is unheated, uninsulated, but the injection of steam will allow its temperature to go up after?

MR. BOWMAN: That is right. The injection of steam will preheat the vessel, all right, and then we just let it cool down. And the control of the experiment really is, you might say, almost uncontrolled, but our control takes place as the steam condenses and the volume of hydrogen comes up naturally.

We have some calculations that predict what that volume fraction decrease in steam should be. Some of the tests we are going to conduct in the shakedown period, of course, and we can verify that. There is a mechanism to get the water vapor concentration up to some appreciable value by injecting enough steam to heat the metal and still permit an appreciable water vapor in event ambient condition.

MR. BOWMAN: Absolutely.

MR. SCHOTT: Seventy degrees or something like that.

MR. BOWMAN: Sure.

MR. SCHOTT: Another clarification on the tests that have already been done and are being reported here in this extensive graph. On the glow plug temperature I can see how it is easy enough to monitor current voltage continuously to these glow plugs in operation.

What instrumentation is laid to these righthand column peak temperature figures?

MR. BOWMAN: We had a thermocouple welded to the surface of the glow plug itself.

MR. GREGORY: Your experimental procedure is obviously designed to get a matrix of data on combustion under these conditions, but I am concerned it does not seem to include a set of conditions that represent what would happen in the real case of hydrogen in a reactor containment.

My concept here is that the reactor containment is filled with a mixture of air and steam, and then you have a steady injection of hydrogen coming from the core. And the glow plugs will be on before you reach the flammable limit, and you are hoping that you will get a lightoff of the hydrogen, a partial burn, but then the hydrogen keeps on coming, and so you get another one and another. And you want to make sure that the glow plug is going to ignite every time before you reach detonation.

You are not running that kind of test in your experiment. You are working with a constant ratio of oxygen to hydrogen, and just letting the steam partial pressure drop.

MR. BOWMAN: There is a more fundamental question to be answered, all right, and which this whole program really addresses: will the glow plug function if the concentration around the glow plug itself reaches such and such combination of concentrations, all right?

So the answer to the more extensive question that you ask is almost implicit in what you get out of this in terms of the glow plug will function under these concentrations locally. All right. If it will function subsequently at different concentrations, if we measure those, then we do have confirmation yes, that it will or not. If the concentration, you know, changes into some range where we have not conducted an experiment, then the question is again open.

MR. GREGORY: I think I would be happy if I could see experimental results that show the -- in effect, determine the lower flammability limit of hydrogen in the presence of a glow plug and in the presence of a lot of steam. You are really not determining the flammability limit. You are just determining whether the glow plug will ignite the hydrogen when it is about that limit.

MR. BOWMAN: It really is a test of the functionability of this particular device rather than a reproduction of the flammability limit curves.

MR. KERR: Mr. Gregory has a point in that if it functions the way you hope it will, it will first light off when one has reached something that turns out experimentally to be the lower flammability of hydrogen in that situation. Maybe you don't have to determine what that is to make certain it will operate. That is precisely the way it will operate, it seems to me.

MR. BOWMAN: That is exactly what we will determine.

MR. STREHLOW: If this glow plug had a rapid rise time for temperature, I would be suspicious of doing the experiment this way, but it takes 30 seconds for the thing to get hot, and under those circumstances you have a convective field around that glow plug which actually reproduces the same convective field that you would expect to have with a hot plug being contacted by a gas which has the proper composition to burn.

So you have a quasi-steady experiment here, and it should model what is happening in a reactor as the concentration is changing. If this thing had a rise time of a tenth of a second, then I would say no, you have to watch your step because you are not duplicating conditions; but this thing is going to have a nicely defined convective flow field around it at all times in this experiment.

Now, one thing it should look at it is when it goes off relative to where this 30 second rise is. If it goes off after ten seconds, then you are igniting under worse conditions than the steady state conditions.

MR. BOWMAN: We will be monitoring that during the course of the experiment. We know previous experience of data available indicates what the temperature threshold is or even the energy threshold and --

MR. SCHOTT: Recognizing that presently planned and financially provided for and manpower provided for experiments at Lawrence Livermore are of the preset mixture switch on the glow plug rather than the continuous injection of fuel type, it still makes -- there is an important aspect to be investigated by the present mode of experimentation, to work with not only accumulated steam but also accumulated nitrogen in place of air.

Carson Mark has made this point earlier, but I want to hammer on it. One will not have conditions with a lot of steam. One could, but the function of the deliberate ignition system and hardware for burns subsequent to a first burn is important, and so the reduced oxygen situation can and should be investigated by this mode of investigation.

MR. BOWMAN: You are suggesting we fire the glow plug after initial indications of ignition, correct?

MR. SCHOTT: That is one way to go about it. The more deliberate way is to start from scratch with extra nitrogen.

MR. KERR: Other questions or comments? Please continue.

MR. BOWMAN: The experimental schedule, to give you an idea of what we're doing and where we are, is we started this schedule in August. We expect to be complete with at least this series of tests by October 30.

The design and assembly, you have already seen some of the pictures of where we are there. We are right on schedule or even a little bit ahead. We anticipate we will start checkout about the middle of September, as indicated.

We provide a quick report on the data acquired by October 30 and then a final report some three months subsequent to that, and also the conceptual design for a spray system in this particular configuration, if it is deemed necessary and important.

We will also report on a review of the hydrogen detection systems and the literature survey by about the October 30 deadline date.

Some of the problems we have already considered that have already come up is what is the influence of glow plug location on combustion -- this refers to the tendency for the stuff to propagate upwards in the presence of concentrations below eight percent -- whether or not a turbulent atmosphere in the tank is desirable; whether you want to leave the fan on or shut it off; the revaporization of the condensed water adversely affecting sampling -- we have already addressed that -- the homogeneity of the mixture, we get an indication of that by sampling at various points within the containment vessel itself. And then the last question, of course, which is one of prime importance, how this can be extrapolated for use in representing a real containment.

What we intend to deliver to the NRC is a report of the hydrogen detection monitoring methods, the results of our combustion literature survey, and for the various concentrations of hydrogen, air and steam which should be able to tell you, okay, whether or not the glow plug will function -- function meaning will it light the mixture up.

We do that by providing the pre- and post-ignition temperatures and the concentration of the major constituents, and we will make an attempt that if some high pressure wave does propagate through the system -- finally, the energy input to the igniter and its temperature (Inaudible).

That is all I have to say.

MR. SIEGEL: Will there be any thermal instrumentation on the glow plug during the course of the test?

MR. BOWMAN: Just a thermocouple, yes.

MR. SIEGEL: You ought to be able to tell from the thermocouple whether ignition is occurring. That will tell you instantaneously whether ignition is occurring.

MR. BOWMAN: With the response time of the thermocouple. We probably pick it up on the pressure indicators sooner.

MR. KERR: As I look at the schedule and after conferring with Mr. Tinkler, who assures me that the next presentation will require at least an hour, it seems to me this is a sensible time to break for lunch. So I am going to break and reconvene at 1:30.

(Whereupon, at 12:30 p.m., the meeting was recessed for lunch, to be reconvened at 1:30 p.m., the same day, Thursday, August 28, 1980.)

AFTERNOON SESSION

(1:30 p.m.)

MR. KERR: It has been called to my attention that there are people who think it is rather warm in this room. And the conclusion, after careful investigation, is that you people are making too much heat. So I want to urge that everybody think cool for the rest of the day, and we will therefore not overload the air conditioning system quite as much.

If air conditioning only means cooling to you, you have a limited perspective. It also can mean heating. And I think, I think that's what's happening to ours.

Mr. Tinkler and Mr. Jenz, perhaps --

MR. TINKLER: No, Mr. Cybulskis.

MR. KERR: Mr. Cybulskis, okay. You lead off? Or does he lead?

MR. TINKLER: I'll lead off.

MR. KERR: Okay. And he, he comes in as a relief pitcher.

(Pause)

MR. TINKLER: This portion of the presentation will deal with the analytical efforts which have taken place to date in order to evaluate the role of the igniter system and mitigating the consequences of a degraded core accident, specifically, for the Sequoyah plant.

As a point of reference, we're showing a slide which outlines the capability of the Sequoyah containment, as calculated by various organizations. TVA calculated a yield of 33 and an ultimate strength for the containment of approximately 43 psig. Ames (?) calculated a slightly higher yield pressure. R&D Associates calculated a slightly lower yield pressure, using minimum code values for the yield strength of steel. And the Office of Research calculated a similar number for the yield pressure as compared to TVA.

As I say, this, this slide, is presented as a point of comparison for the presentations that will proceed after this.

To date, the bulk of the analysis has been done by Battelle/Columbus, using the MARCH code, and by TVA through OES, using the CLASIX code.

At this time, Mr. Cybulskis, from Battelle/Columbus, will provide a discussion of the results obtained for the Sequoyah plant using the MARCH code.

After that, I'll return and discuss the CLASIX results.

(Pause.)

MR. CYBULSKIS: Good afternoon. My name is Peter Cybulskis. I am with Battelle's Columbus Laboratories. And this afternoon I would like to describe briefly the very short study on the behavior of the Sequoyah containment assuming intentional ignition, using the MARCH code.

I had described the MARCH code to the Committee, July 2nd, in Los Angeles. So I really hadn't intended to get back to that point. But since there were a number of questions raised, let me very briefly say at least a few words about what MARCH does as intended to do.

The initials "MARCH" stand for Meltdown Accident Response Characteristics. MARCH is an outgrowth of the work that we did for the reactor safety study, in which there were a limited number of computer pools developed to treat the meltdown accident. Since that time we have done substantial additional work, which has led to the development of MARCH.

What MARCH tries to do is the thermal hydraulics of a core meltdown accident, starting from the initiation of the event, through core heat-up, core meltdown, pressure vessel melt-through, and interaction of the core debris with the concrete ultimately. Throughout the course of the core heat-up history, MARCH is continuously coupled to the containment, where it keeps track of the containment pressure, temperature, composition of the atmosphere, what have you, taking into account static heat sinks and those engineered safety features that might be applicable, which may include spallies (?), containment coolers, ice condenser, et cetera.

It is a systems code more so than a detailed code in any one area. As I said before, it attempts to treat the entire meltdown accident scenario. It does have a lot of approximations in it, for various reasons, sometimes because the knowledge is not adequate to describe things exactly; or in some cases we have included bounding matters, in other cases we have included approximations for convenience; and at other times there are phenomena that we feel are not important, so we have not chosen to treat them in great detail.

In the limited time here, I don't want to get into great detail on MARCH, unless there are some specific questions.

In terms of the treatment of the containment, MARCH is a -- has a capability of treating the containment as a multi-volume system. However, and the inherent assumption in MARCH is that the -- most of the pressure rises within the containment take place slowly and that the pressures can equilibrate three compartments. There are some exceptions to that approximation, particularly when we get into the areas of containment plumbing and the containment failure. But, in general, the assumption is made that the inputs into the containment and the pressure rises are slow enough that the pressure within the entire containment structure goes up and down essentially uniformly.

With those brief words on MARCH, let me get on to the work related to Sequoyah.

MR. KERR: Excuse me, Mr. Cybulskis, would you be willing to comment briefly, at least, on where those assumptions make sense for the ice condenser containment and the problem being addressed? That is, how good an approximation do you feel that is, in light of this structure and the problem?

MR. CYBULSKIS: The -- I don't have any great difficulty with applying MARCH to the type of structure that we have here. With regard to the specific problem that we are discussing today, the hydrogen burning issue, you do run into limitations. And the limitations have to do with the duration of the burn, or, if you will, the flame velocity. If the flame velocity is relatively slow and the burn takes 10, 20, 30 seconds, then that is more than adequate time for the pressures to be essentially equal in all compartments. When you start talking about flame speeds corresponding to burn times of one second or less, or of that order, then I would have to question the effective equilibrium approximation.

MR. KERR: Thank you.

MR. LEE: I may come back to that point once more, you did indicate earlier in the morning that, indeed, using

MARCH code you perhaps differentiate or extrapolate, like you say, from a small test environment to a large containment as to the special effect whether the burn front could be assumed to propagate heat, especially, and so on.

MR. CYBULSKIS: No, I'm sorry, that is a misunderstanding. We do not treat the details of the propagation of the burn front in the MARCH code. In the MARCH code the composition of each compartment is assumed to be homogeneous.

Now, the thing that we can do in MARCH, and I will get into that in the things that we have done, is, for any given composition of, say, hydrogen or steam, we can make assumptions about the point of hydrogen ignition and the completeness of burning. And this is where the small-scale experiments, hopefully, will come into play. Right now we have taken basically a parametric study, using perhaps a certain amount of judgment and using the information that is available in the literature as to the burning characteristics.

Doing the small-scale experiments we discussed earlier give us some data points. For example, at 6-percent mixtures only half the hydrogen would burn. Then we would input those parameters into MARCH in specific places and track the effect of that type of burning throughout the entire containment volume.

The thing that you -- that MARCH does that the small-scale experiments don't tell you is what is the effect on the entire system of burning, say, in one compartment and then expanding through the ice condenser into the other compartments. If you -- we can go ahead and make the assumption that all compartments have the same composition and everything burns at once, then the MARCH results, say, in terms of peak pressure, should be very similar to the experiments in small scale.

But that, I don't think that would really be particularly interesting. I think the point of interest is, given ignition, say, in the lower compartment, what happens in the system as a whole. That is the type of thing that we need a code like MARCH or CLASIX or some other code.

Did I answer the question?

MR. LEE: To a certain extent. But one of the concerns I raised was: if the burn was propagated more or less in a vertical column of some kind, without a lot of lateral propagation --

MR. CYBULSKIS: Yeah. Let me --

MR. LEE: -- then what does a code like MARCH tell in such a scenario?

MR. CYBULSKIS: Well, let me -- this is somewhat of an aside, but let me throw up a transparency, for example, that perhaps might shed some light on it.

This is data paperback, Furno et al., U.S. Bureau of Mines data, that I'm sure many of you have seen. And as far as I know, there are not too many people that argue with this, this particular data. But what it indicates is volume percent hydrogen versus the pressure increase. This particular curve is a calculated constant volume burning curve. It's easy to reproduce. It's a fairly straightforward calculation. You can even do it with a slide rule if you're so inclined. A home calculator works better.

And this, this is the experimental data under a particular set of conditions and using a particular ignition source. And without going into great detail, what this curve tells you is that the next region, here, if you get a composition in this region, given this ignition source, you will get complete combustion. The flame will propagate upward, downward, sideways; there is no problem, the mixture is rich enough.

In this mixture here, between 4 and approximately 8 percent, you will only get upward propagation and incomplete combustion. And this is the point that was made earlier this morning.

And right in the steep part of the curve, the -- it's the tricky part, where you may or may not get complete combustion, depending on a lot of factors, including the ignition source, and, in fact, it may not be as reproducible as you would like to have.

In the -- as I understand the program, in the small-scale experiments, what it will be attempted to do, if you will, is definition of a similar curve, but it wasn't presented in this context, using the particular glow points then as igniters. And if it takes a 12 percent composition to ignite reliably, then I think we would feel fairly confident that the ignition will go to completion, whether the compartment is large or small.

MR. LAWROSKI: Is that a sub 1 atmosphere at the start?

MR. CYBULSKIS: This particular atmosphere --

MR. LAWROSKI: A little pressure?

MR. CYBULSKIS: Yes.

MR. LAWROSKI: What could you say about it if you started out with, say, three or four atmospheres?

MR. CYBULSKIS: I think, based on what has been published in the literature over the years, the pressure itself has only a small effect on the flammability limits.

Of course, the final pressure would be higher, depending on what initial pressure is. But that's again a very straightforward calculation. There's nothing particularly secretive about that.

MR. STREHLOW: If I can answer that, any flame system that has a low flame temperature, and this limit flames are low-flame-temperature systems, there's hardly any dissociation. And that means that if you doubled the initial pressure, you'd double the final pressure, essentially; I mean, you'd raise the final pressure by the same amount proportionally. It's almost one-to-one; there's hardly any deviation from that.

MR. SEALE: So these delta-Ps would just sit on top of any residual?

MR. STREHLOW: Well, if you have two atmospheres exactly, you end up with twice the delta-Ps.

MR. MARK: Could you just give a simple, one-word answer: Does MARCH calculate the hydrogen generation or take it as input?

MR. CYBULSKIS: MARCH calculates the hydrogen generation. And --

MR. MARK: Taking account of the amount of steam?

MR. CYBULSKIS: Taking into account the amount of steam, the temperature of the core, the conditions in the core at the time, it generates the hydrogen in the primary system, releases it from the primary system to the --

MR. MARK: How does it handle the fact that the steam might not be -- I mean, your reaction rate at 4000 degrees -- it'll calculate the hydrogen-steam mixture coming out of the top of the tube, for instance.

MR. CYBULSKIS: Yes.

MR. MARK: And one could get the input state of the gas, and you do get that when you go into the lower compartment?

MR. CYBULSKIS: Yes. The -- what MARCH attempts is, in terms of the hydrogen or steam or whatever is coming off the top of the core, it would come out at a particular temperature, and if the core is very hot, these gases are very hot, they would mix with the gases that are already in the system and transfer heat to structures, et cetera, and then, depending on the accident sequence, in a large break you would have an easier path to the containment than you would in a small break, but it tries into account the path that it has to take to the containment and introduces the gas at the appropriate conditions -- at the calculated conditions.

MR. MARK: So if there's only little steam coming, then there'll be very little hydrogen generated?

MR. CYBULSKIS: That is correct. And, in fact, that is what we find in most of our calculations, that the extent of reaction, or really the rate of reaction, is controlled by the availability of steam, except for the initial phases of the accident.

Now, I must footnote that, or asterisk that, in the sense that most of the calculations we do, of course, are meltdown accidents, where we define an accident sequence and let it takes its natural course, if there is a natural course; we generally do not try to arrest the melt.

MR. LAWROSKI: Could you put that curve back on again, please?

If I increased the starting pressure, would not the -- what you show there as taking off rapidly, at about 8 percent, wouldn't that drift to the left more?

MR. CYBULSKIS: Not -- not necessarily. It depends -- if you raised the pressure uniformly and you did not change the composition of the gases, it would not drift very much.

And let me see if I can lay my hands on -- on another slide, which you have seen many times, and this is the, basically the Shapiro-Moffette curve. And this, this, the dark line, is at one atmosphere. And the other lines are, one is increased temperature only, and the second line is increased temperature and pressure. And as you can see, the flammability limits -- or the -- built very rapidly with -- with increasing pressure, the temperature does somewhat.

Any other questions or comments?

MR. LEE: Can you end up with a very hot hydrogen gas, depending on the accident sequence?

MR. CYBULSKIS: Yes, you can, depending on the accident sequence. And if the hydrogen enters the containment at a very high temperature and there's oxygen present at the point of entry, you could expect ignition to take place without any other events.

MR. LEE: (WORDS UNINTELLIGIBLE) number?

MR. CYBULSKIS: I'm sorry?

MR. LEE: Can you venture to give a typical number for that?

MR. CYBULSKIS: I believe the spontaneous ignition temperature of hydrogen in air is a number that is fairly widely available, and if my memory serves me correctly, it's around 1100 degrees Fahrenheit.

MR. LEE: And hydrogen temperature, typically, you get in the --

MR. CYBULSKIS: That would have to be the hydrogen temperature to get spontaneous ignition upon contact with air.

MR. LEE: Right. But I mean the temperature of hydrogen that you get typically out of MARCH code?

MR. CYBULSKIS: They can be -- in our -- it would depend on how you defined the problem. If you defined a large LOCA hot leg break, then you would, essentially, come out into the containment maybe with 3000 degree Fahrenheit. If you define a small break or transient where the gas goes through a long length of pipe and through the steam generator, then the temperature would be down, controlled by the structural heat sense; it may be 500 or even less.

MR. LEE: TMI-2? Can you venture --

MR. CYBULSKIS: In TMI-2, as we analyzed the accident, all the releases took place through the pressurizer water, so they would have been at the pressurizer water temperature, which was relatively low.

MR. STREHLOW: If I could interject an answer to Mr. Lawroski's question, Gary and I were just talking about this, and if you're talking about an ordinary flame, like propane or something like that, the lean limit is unaffected by pressure, essentially. The problem is that the -- this steep change in curve behavior there is due to a number of different phenomena than are usually apply -- or, usually occur in an ordinary flame, so we don't know which way it would go.

MR. LAWROSKI: Okay.

MR. STREHLOW: The answer is: you'd have to do experiments at high pressure. There's buoyancy forces involved; there's preferential diffusion involved. Both of these are pressure-dependent. And it's toss-up in the air now and ask which way the wind is blowing.

MR. KERR: You're saying a very thorough long-range research program should be carried out in this area?

MR. STREHLOW: Yes.

MR. LAWROSKI: Preferably in Illinois. But thank you.

MR. CYBULSKIS: The work that I'm about to describe is a relatively short effort. And I understand, from discussions with the NRC representatives, that we will -- they will be asking us to do further work. So, in that sense, we have run a finite number of computer runs; we have not run perhaps as many as we would like, or as many as we're going to; in that sense, the results are preliminary.

Just for reference, this is a cross-section of the Sequoyah containment. In our MARCH modeling we represented it as a two-volume system, the lower compartment and the upper compartment. The volume of the ice condenser in our, the way we modeled it was included with the lower compartment. And the ice condenser -- or the heat removal flux associated with the ice condenser we modeled at the junction between the two. And just for reference, the dividing line between the two compartments is roughly like this.

I don't recall the numbers exactly, but I believe it's something like 390,000 cubic foot in the lower compartment and about 900,000 cubic feet in the upper compartment, give or take a little.

The accident sequence that we used as the -- for the basis of analysis was S2D sequence, which is a small break, the failure of the emergency core cooling injection system. As I indicated before, the sequence is that it ran, we let the sequence proceed, to meltdown, failure of the vessel head, and a dropping of the core into the reactor cavity. This is really not a point of interest, as I understand it, to the discussion here; however, that, we made no attempt to arrest the accident, at least, not in the short-term effort.

And just to give the perspective of what we're talking about, we have the core, given this type of accident, we have core uncovery at 43, top of the core beginning to uncover at 43 minutes into the accident, start of melt at 62 minutes, and slumping of the core approximately a half hour later. The time required for the entire core to slump into the bottom of the reactor vessel is a function of modeling assumptions. This represents a particular set of assumptions. It could be different. That's one area where we don't know very much now.

Going on, this is just the pressure transient for this accident, without any hydrogen burns, just again to put things in perspective. And we're primarily interested in this region here where the pressure is staying constant. At this point the reactor vessel fails and you're in a different sort of situation.

There a number of slides for this accident sequence in the handout. I won't bother to go through those unless there's particular interest in any of them.

Having done the no-burning case, then we looked at the -- what would happen under different burning assumptions, different ignition limits, et cetera. And let me just give a series of slides that are more or less typical, before I get into the overall results.

All right. This particular -- here again we have pressure time history in the containment for a particular sequence: ignition assumed at 10 volume percent; hydrogen burning to completion -- a burn time of five seconds, I believe, burning only in the lower compartment. And on the time scale that the computer spits out, you can barely see the little blips, these are the 10 percent burns that you see, you get very small pressure releases under these assumptions. The large pressure spike is associated with the head failure and release of large amounts of containment to -- hydrogen to the containment.

Corresponding temperature courses, this is again in the lower compartment, you see whenever you get the burn, you get something like 2500 degree temperatures in the atmosphere of the lower compartment; they are rapidly reduced by the action of the recirculating fans blowing the air around through the ice condenser, et cetera.

Just for interest, if we look at the partial pressure of hydrogen, which just repeats what we've seen in the other slides, it builds up to our assumed ignition limit, burn to completion, builds up again, burn to completion.

The particular case that I'm talking about here, as I indicated, was ignition at 10 volume percent hydrogen. And let me go on to the mass of ice in the containment for this particular case. During the boil-off phase of the accident, the ice is depleted at a relatively slow rate, because the input into the ice bed is controlled by the hole size, effectively. When you get into the hydrogen burn regime, you see small stuff releases in the amount of iceage down by the burn; and of course when the head fails and there's a large burn, you deplete the ice bed completely.

MR. LEE: Do I understand correctly from the series of slides that a hydrogen burn in this particular sequence of action doesn't make whole lot of difference?

MR. CYBULSKIS: Under this particular set of assumptions, you get very small pressure increases in the containment if you burn at 10 volume percent in the lower compartment.

MR. LAWROSKI: Did you say that this is the result when the head fails?

MR. CYBULSKIS: When the head fails and releases the rest of the hydrogen into the compartment, it's well above 10 percent, it burns, and you get a very high pressure spike. But that assumes complete core meltdown, which is basically what the MARCH calculation is intended to do, as I indicated before. We -- for the purposes of this brief study, we made no attempt to arrest the accident in any way.

MR. LEE: Short of complete core meltdown, what kind of impact could we expect from hydrogen burn?

MR. CYBULSKIS: Well, that -- let me get on to my summary of results and that perhaps will answer your question.

Let me just throw up one other slide. This is for a slightly different -- well, for a case where we assumed ignition at 8 volume percent and only burned down to 4 volume percent, the burn limit. And you would get more spikes, obviously, since you're burning less hydrogen in each start and with that particular set of assumptions. You're starting to approach the -- more or less a continuous combustion of the hydrogen.

Let me throw on this very busy slide here. And those of you that don't have handouts may not be able to read it. Apologize for that. That's basically a summary of the runs that we conducted for this initial study.

What we looked at were the assumed ignition point in terms of volume percent hydrogen -- we looked at 10, 12, 8, 4 percent -- and the assumed burn limit in terms of how far down in hydrogen concentration. We burned -- in most of the cases, as you can see, we assumed complete combustion of the hydrogen. In a number of the cases we assumed that it burned down to the nominal flammability limit.

We also looked at the duration of the burn, or the burn time, which corresponds to some assumptions about flame velocity, and within the context of what we're doing here, it didn't seem to make an awful lot of difference (WORDS UNINTELLIGIBLE). But in the presence of the ice, the ice tends to overwhelm the energy release and you don't see much of an effect.

Next factor that we looked at was the flame propagation. Since the hydrogen is released -- from one compartment to the other, so flame propagation from compartment one to two or vice versa -- since the hydrogen is released into the lower compartment, you would always reach your set point, or your ignition point, in the lower compartment first before you would reach it in the upper compartment. So what happens is, you burn the lower compartment down to zero, if that's the case, and then some of the hydrogen in the upper compartment, which is not at 10 percent, blows back down, you generate some more hydrogen, so the lower compartment keeps building up to 10, while the upper compartment tends to lag behind, though its level of hydrogen increases in a period of time.

So in most of the cases we assumed ignition only in the lower compartment. In some of the cases we assumed that the flame would propagate into the upper compartment. That was an assumption, that, in fact, it would propagate; there's no mechanistic calculation to indicate that it would or would not, though, in fact, if, say, you're talking about 10 volume percent hydrogen, in the upper compartment you would probably be talking about significant levels -- I'm sorry, if you have 10 volume percent in the lower compartment, you would have significant levels in the upper compartment also.

And looking at the results we get, I think they're fairly straightforward. What we see is, if we burn only in the lower compartment and let the hot gases expand through the ice bed into the upper compartment, we get very nominal pressure rises. And that's not too surprising, since the lower compartment is a smaller volume, you're burning a relatively small amount of hydrogen there, you're taking advantage of the ice heat sink as well as expansion volume in the upper compartment. And the pressures that we're talking about here are just a few psi pressure rises.

If you make the assumption that the flame propagates into the upper compartment, then you get significantly higher pressure rises.

The -- in the last three cases in the table, we arbitrarily reduced the amount of ice in the containment, to see what we would predict in the absence of ice. So, in these three cases, the ice was gone long before the hydrogen came along. In the case 17, we still get a modest pressure rise compared to what it would do if it were, say, an adiabatic combustion. Case 18, we modified the treatment of our suspended water droplets in the atmosphere, basically, reduced the amount of water in the atmosphere, and we get some increase in predicted pressure but still a relatively modest increase. And in the last case there, we let the flame propagate into the -- both compartments, once it started, and then you get some relatively high pressure generated again.

But I think the conclusion, based on this relatively limited set of runs, is: given ignition, and if the burn takes place only in the one compartment, your pressure, overall pressure releases are quite modest. And if you compare the column marked "PT," which is, if you will, the actual pressure, against the "PNEW," which is the adiabatic pressure that you would conduct, you'd see quite a significant effect of the containment sprays and the ice on the pressures that we calculated.

That is -- I will stop there.

Yes, sir?

MR. SIEGEL: Siegel. Some of your latter curves, I think it's, well, like the fourth from the last, which shows the temperature in compartment number two, and there's a period of, oh, like, five minutes after that precipitous rise where the atmosphere is up around 1500 degrees Fahrenheit, as I read what I see there. What else is up at this temperature? And how much of the model that's used in calculating this is disappearing during those five minutes?

MR. CYBULSKIS: I'm sorry.

MR. SIEGEL: I mean, are there fans, sprays, and so forth?

MR. CYBULSKIS: This, the ice condenser, if the ice is there, is available to remove heat, basically, in proportion to the flow through it; the sprays are on in this particular accident sequence, so they would be available except for those times when the -- there is ice available. Basically, we can't -- the way the code is set up, we can't have the ice and the spray both.

MR. KERR: I think Mr. Siegel has some concern about the fans operating at 5000 degrees Fahrenheit.

MR. CYBULSKIS: Well, the -- the -- the numbers that you see there, the 1500 or 2000, whatever, is the temperature of the gases.

MR. SIEGEL: Yeah, I know. But in five minutes some recalibration will occur.

MR. CYBULSKIS: Let --

MR. SIEGEL: If it's just a narrow spike, I can understand; it's just the atmosphere.

MR. CYBULSKIS: Let me put on a slide that might perhaps shed some light on that question.

I'm not -- I don't believe this in your handout; and perhaps it should have been. But this is for, I think, the previous case 17, where we had the reduced amount of ice. These are the surface temperatures of the various structures in the compartment. The shell in the upper compartment and the iron and concrete structures in the upper compartment -- lower compartment. And basically, what we're seeing is, in this region, very modest temperature rises, and then when you get the head failure it increases.

But the heat capacity of the atmosphere is very low compared to the heat capacity available. So, basically, the temperatures that you see are of very short duration in the atmosphere and they're rapidly dissipated by the available heat sinks.

So this is perhaps indicative of what you might expect given this set of assumptions.

MR. SIEGEL: The other question I have is related to this. On one of your charts dealing with the mass of ice, I'm really quite impressed with the disappearance of a million pounds of ice in a very brief period. That, too, looks like a glacier falling off or something.

MR. CYBULSKIS: It's a direct result of the energy input into the ice. Now, there I would suspect that there may be room to question some of the assumptions of our treatment of the ice condenser, whether, in fact, you conduct that much heat to the ice. But the rapid disappearance of that ice, if, in fact, it is a direct result of the large energy input associated, one, with the release of the high-pressure and -temperature steam that's in the primary system, release of the remaining hydrogen and the combustion of that hydrogen, in a short period of time, those represent rather substantial amounts of energy.

MR. SIEGEL: Well, how was the ice subdivided in its initial state?

MR. CYBULSKIS: The -- the -- our treatment of the ice condenser is based on the experiments that were done with Westinghouse -- or, by Westinghouse in the development of the concept. And in the tests -- and there may be Westinghouse people that could probably describe it better than I can -- but in the tests that were conducted, they measured -- they put steam through the ice and measured the effluent coming out of the top. And basically, what we have done is represented the temperatures inlet and outlet, the ice condenser is almost like a heat exchanger with fixed outlet conditions, based on the experiments.

Now, I -- as I say, there are probably people better qualified here to answer about the details of the ice condenser itself (WORDS UNINTELLIGIBLE).

MR. MARK: Could I ask what is just meant by your use of the term "head failure": is that melt-through of the bottom of the vessel or something?

MR. CYBULSKIS: Yes. That is the --

MR. MARK: Okay.

MR. CYBULSKIS: -- failure of the reactor vessel bottom.

MR. SCHOTT: And that is, that triggers release of -- there's a considerable mass of hydrogen that's been, already been -- represents the oxidation of zirconium --

MR. CYBULSKIS: Right. That's --

MR. SCHOTT: -- which is withheld from the system.

MR. CYBULSKIS: That is correct.

MR. SCHOTT: But it's -- what? In solution in the --

MR. CYBULSKIS: Right. It's not in solution. It's just that it's released to the primary system, and as your water level in the core drops down, your boil-off rate of steam drops down, and, effectively, there is no, little or no motive force to pump that --

MR. SCHOTT: It's just the volume that's --

MR. CYBULSKIS: That's --

MR. SCHOTT: -- that's about that time been shielded off by --

MR. CYBULSKIS: Right.

MR. SCHOTT: -- (WORD UNINTELLIGIBLE) that was attacked.

MR. CYBULSKIS: And when you're -- now, remember, this is a small break case, the particular sequence we're talking about; it's a two-inch break. You now open up the entire bottom head and you empty the system.

MR. RUBENSTEIN: Peter, maybe you ought to place in perspective severe core damage in relationship to the time scale of whether the head fails. Severe core damage primarily deals with scenarios which are terminated. And S2D-2 is a scenario which is unterminated.

MR. CYBULSKIS: That is the point I tried to make in my opening remarks, that basically we made no attempt, as a matter of convenience, in this thing in pointing to some results of, say, terminating it; we just ran the code as we normally do it, which is a unterminated, or, if you will, just let -- follow the sequence and whatever, wherever it leads without terminating it short of meltdown.

And, in fact, the results following head failure represent complete core meltdown, complete metal-water reaction.

MR. SIEGEL: Do they include a core-concrete reaction?

MR. CYBULSKIS: In the particular calculations that I presented today, there is no core-concrete reactions. They would take place, well, basically, at about the time that the calculation ended they would start, to compound it.

MR. KERR: Mr. Schott?

MR. SCHOTT: Just two specifics here. The sets of Vu-graphs in the handout deal with two cases, S2D-B and S2D-2. What's the --

MR. CYBULSKIS: Okay.

MR. SCHOTT: -- major distinction between these two?

MR. CYBULSKIS: The S2D-B, in this case the "B" stands for "base case": no hydrogen burning whatsoever; the hydrogen is generated, it sparked through the system, but we did not burn it.

In the case of -- "2" is the one where we burned it. Case 2 in that case corresponds to case 2 in the table of the kinds of conditions under which it was burning.

MR. SCHOTT: And the other general matter: in these calculations there is considerable pressure excursion, in the lower chamber where the burn takes place, that's relieved on some time scale. Is the lower chamber really stronger than the total containment by some distinct amount?

MR. CYBULSKIS: I would defer that question to representatives of Sequoyah. Perhaps they would care to comment on that.

MR. TINKLER: Are you referring to -- can you tell us what curve you're referring to?

MR. SCHOTT: I'll try.

MR. TINKLER: Is it case two?

MR. SCHOTT: Well, it is -- it says --

MR. CYBULSKIS: What are the labels? I --

MR. SCHOTT: Maybe I can't -- maybe I'm -- was misinterpreting something --

MR. CYBULSKIS: What are the labels in the graph?

MR. SCHOTT: Let's see. I may have missed, just missed, missed the significance of something as it went by. The temperature in compartment one, that gets high, but, presumably, the -- is the supposition there that the density is low?

MR. CYBULSKIS: No, there is --

MR. SCHOTT: That the material has vented?

MR. CYBULSKIS: There is no supposition. The temperature does, in fact, get high, but it goes on --

MR. SCHOTT: But is the pressure not high when that is so?

MR. CYBULSKIS: No, the -- the pressure is not correspondingly high, because the pressure is venting into the ice condenser and the gases are being cooled.

MR. SCHOTT: Okay.

MR. KERR: Mr. Lee, you have a question?

MR. SCHOTT: Probably it's --

MR. CYBULSKIS: What I tried to indicate, if you will look at that PNEW column, that represents the adiabatic burn pressure.

MR. SCHOTT: So are the --

MR. CYBULSKIS: In that particular compartment. So if you want to look at it as being a limiting pressure condition for that compartment, that will give you some indication as to how high the pressure might be if it were not venting into the other compartment.

MR. SCHOTT: Probably what I've done here is just -- is followed something too late to the head rupture. There is something here called "pressure in containment volume number one," which is this lower probably, going up to almost 140 psi at 90 (WORDS UNINTELLITGIBLE) --

MR. CYBULSKIS: That is following head failure.

MR. SCHOTT: That is. Okay, thank you.

MR. KERR: Mr. Lee?

MR. LEE: I guess I still don't understand the distinction between hydrogen burn pressure and partial-pressure hydrogen in compartment number two and so on?

MR. CYBULSKIS: The partial pressure of hydrogen is just that: the partial pressure that the hydrogen would have at that particular point in time. That's just the --

MR. LEE: With or without the burn?

MR. CYBULSKIS: Without the burn. That is just the hydrogen occupies some --

MR. LEE: All right.

MR. CYBULSKIS: -- some space; therefore, it has some partial pressure associated with it.

MR. LEE: But for the same case when you say "hydrogen burn pressure," what does it mean then?

MR. CYBULSKIS: The hydrogen burn -- or the -- let -- let me make sure -- the hydrogen burn pressure in -- as it's labeled in -- let me see if I can find a appropriate graph perhaps -- is really the adiabatic burn pressure that you would get if there were no heat removal mechanisms.

MR. LEE: And if you had hydrogen burn?

MR. CYBULSKIS: Yes.

MR. LEE: But you just said there is no hydrogen burn, because the partial pressure indicates it's zero practically.

MR. CYBULSKIS: Okay. Which graph are you looking at?

MR. LEE: Okay. I'll refer to it. Here's one that shows Sequoyah S2D-B.

MR. CYBULSKIS: Right.

MR. LEE: And the ordinate is partial-pressure hydrogen in compartment number two.

MR. CYBULSKIS: Okay, that's -- it's not this graph that you're looking at?

MR. LEE: No.

MR. CYBULSKIS: No.

MR. LEE: No, that gets at what I'm most interested, that's my second one.

MR. CYBULSKIS: Well, the one that says "partial pressure," there is no burn, but there is, obviously, hydrogen.

MR. LEE: But, then, if there is no burn, what is it -- where do we get the burn pressure?

MR. CYBULSKIS: The -- in case B, the adiabatic pressure is calculated if it burns: if it burns what would be the pressure.

MR. LEE: Is that for lower compartment, upper compartment?

MR. CYBULSKIS: For both compartments, if it were to burn at any instant in time, this is what the adiabatic pressure would be.

MR. LEE: But when the --

MR. CYBULSKIS: It gives you some perspective as to how significant the hydrogen might be, so that when you run the next MARCH case you know whether to run a case with burning or not.

MR. LEE: Are we looking at the results of two different cases, then, although they are all, both labeled case B?

MR. CYBULSKIS: Case B is the same case -- as I said, this is a "what if" pressure; we did not actually burn it, but we asked the computer what would it be if it burned.

I don't think you -- you still look puzzled.

MR. LEE: So the -- let me try to go at it once more -- so the effect of the -- or, the increase in pressure due to hydrogen burn over the initial part of the assumed accident is something like 20 psi? Is that what?

MR. CYBULSKIS: I'm -- I'm still --

MR. LEE: From this. From this transparency you had.

MR. CYBULSKIS: Just looking at this graph --

MR. LEE: The first 60 minutes --

MR. CYBULSKIS: Right.

MR. LEE: -- the increase in pressure due to possible hydrogen burn is 20 psi or thereabouts?

MR. CYBULSKIS: It's -- it's -- no, in this particular case it's zero, so that this really represents, is the pressure. There is no burning.

MR. LEE: But if you had burning?

MR. CYBULSKIS: It can't burn in this point of time. So there's no contribution of burn up to this point. It becomes flammable at this point here.

Now, if it were to burn at this point, adiabatically this is what it would be.

MR. TINKLER: I think it ought to stay there.

MR. CYBULSKIS: Okay.

MR. KERR: Are there other questions?

Please continue.

MR. CYBULSKIS: I -- that concludes my discussion, except perhaps to say that we are planning some further studies, perhaps a little more parametrically than we have done, to try to better define the limiting conditions, if you will, under which the containment may or may not be able to accommodate hydrogen burns. The details of those particular parametric studies are yet to be defined other than they're in the works.

I don't know whether you want to add anything to that, Les?

MR. RUBENSTEIN: Well, we have the capability of assuming certain hydrogen generation rates and burns, and what we're going to try and do is anticipate a matrix which we can plug our data from the Livermore and the Fenwall experiments into, to get some insight into what the pressures and temperatures would be as calculated by MARCH.

MR. KERR: At various points, you and others have pointed to the fact that this is an unverified code and that it has some approximations and assumptions in it and that it is a systems code which attempts to handle a good many phenomena simultaneously.

If you were going to assign confidence, would you say that that part of the code that is treating the hydrogen burn and the consequences thereof is more, or less, or about the same as -- here, in a sense, one is treating hydrogen almost as a human input; although the code does calculate it, it calculates it under a rather special set of circumstances. But given that you have hydrogen, is it your feeling that the burn and the pressure calculations in, say, a Sequoyah-type containment are fairly accurate? Or do you have any comment on that?

MR. CYBULSKIS: I -- I feel fairly comfortable about the way we treat the hydrogen burn itself and the -- say, the pressure asssociated with a burn in the specific volume given, the specific composition. That part of it, I think, is fairly straightforward.

Now, we do include heat sinks in our subroutine. The slab heat sinks, the spray heat sinks, again I feel reasonably comfortable; I think those are fairly straightforward.

The one heat sink -- and which, unfortunately, may be the most important one -- I have some misgiving is, and that's the ice bed. While the ice bed has been proven to be quite effective in handling, say, steam blow-down, and I have no reason to question that, the way we have modeled the ice bed, for also these hydrogen calculations, is the same way as we did for the blow-down, and whether, in fact, the ice bed is equally effective in creating, say, the energy removal from the hydrogen flame, I don't know and I don't have any basis for assessing it right at this moment.

MR. KERR: Well, it appears to me that that is a fairly crucial part of the calculation. And if there's a large uncertainty in that, I would think that one would want to investigate that. How does the staff look at this part of the calculation?

MR. RUBENSTEIN: We feel much the same way.

I think, Peter, you want to talk about the second half of the work that you'll be doing for us, which is towards the verification. And I don't want to use the word in the literal sense that Dr. Tong uses it experimentally, because I think we'll do code comparison, but we will be looking at that.

MR. KERR: You're going to compare two unverified codes with the assumption that if they both give the same answer something or other has then been demonstrated -- and I'm not sure what.

MR. RUBENSTEIN: We'll try.

MR. CYBULSKIS: Let me just make a couple of comments, if I may, in this verification area. There are facets of the MARCH code that are fairly easy to verify, and some of this has been done. There are facets that perhaps never will be verified. Let me just point out, for example, that the structural heat sink models that we use are the, essentially the same as they are in the CONTEMPT code, which, I believe, is an approved code. The heat transfer coefficients from the atmosphere to the structural heat sinks, I forget whose correlation we use, my memory fails me for the moment, but this particular correlation has been shown by a number of people to be conservative insofar as it does not transfer as much heat to the containment -- to the structure as has been experimentally observed.

In terms of, say, the blow-down pressures that we might predict, we have some highly simplified blow-down models in our code that would predict the containment response if we put steam in among other things. And the results that we get are consistent with what we see for sample problems for CONTEMPT, for example.

So a number of these things are really, either have been or, in fact, are, easy to verify. The areas that are difficult to verify and may never be verified, I think, are some of the areas I alluded to in some of my earlier presentations to the committee, namely, the core slumping models and that type of things. In those areas the only hope that you have of any kind of verification is a comparison with somebody else's code. Hopefully, we won't have too many data points.

MR. RUBENSTEIN: But they're beyond the range of interest, core slumps.

MR. CYBULSKIS: In the particular discussion at hand --

MR. RUBENSTEIN: This time --

MR. CYBULSKIS: -- that is correct.

Obviously, the -- in the work that I presented here, we just made assumptions that the hydrogen ignites at certain levels and burns down to certain levels. These were assumptions of convenience, for the purposes of the study. And the experimental program that was described earlier will, hopefully, shed some light into these areas. We can then go back and feed that experimental data and repeat the calculations and see what it would make.

So, I guess, in summary, as far as the verification is, there are parts of the code that are, in fact, verified or easily verifiable, there are parts of the code that are not as easily verified.

MR. KERR: Well, as I have grasped the mass of material that I have heard today, I get the feeling that the MARCH code, given an energy input which would come from burning uniform distributions of hydrogen and air, can probably calculate the pressure fairly accurately.

MR. CYBULSKIS: Yes.

MR. KERR: That there's going to be an experimental program to determine if igniters will ignite. But at some point, it seems to me, one also has to determine whether given ignition, one gets an amount of burning necessary to produce the energy input which goes into the MARCH code, that is, given a burn in the vicinity of an igniter, how does it propagate. And the code -- and you certainly have not claimed that the code will tell you anything about that. It isn't clear to me that the experiments are going to tell one very much about that. Where does that information come from?

MR. CYBULSKIS: I think the --

MR. KERR: Or I'm missing something.

MR. CYBULSKIS: The point that I tried to make, by showing my first slide, which was really not in my planned presentation, the Furno data, was that above certain levels of hydrogen in air, in particular, perhaps not in steam mixtures, there has been data showing that the combustion will go to completion. And I'm not sure -- to the best of my knowledge, that is an accepted conclusion -- I'm not sure that we have to prove that again.

MR. KERR: So that you're saying that at some point one will accumulate a sufficient concentration of hydrogen so that given an ignition at that point one has a burn?

MR. CYBULSKIS: Yes. And the burn will go to completion. And I think the experiments that Livermore is doing will shed some light on this for the particular set or igniters.

If I might make a passing comment with result to the -- with respect to the Furno slide that I showed, I believe, if I remember the source correctly, those data were shown for a single spark in a particular mixture. And what they found: that given a single spark in those very lean mixtures, it did not burn at all, and you got these little flamelets that were mentioned earlier, little balls of fire that sort of just rose up.

Another part of that particular paper, which isn't perhaps as well known, is that they did do some experiments with repeated sparking. And when they did the experiments with repeated sparking, they, in fact, found that they could get more complete burning than they did with just a single spark, though the number of experiments in that area is very limited.

So, I guess, the only thing I'm trying to point out there is that we're not completely in the dark on hydrogen behavior. There is a base of knowledge available.

MR. KERR: Thank you.

Mr. Lee?

MR. LEE: Based on your MARCH calculations, can you somehow give me a rough idea what kind of benefit, or reduction in pressure in containment, we can expect if we have functional distributed igniters?

MR. CYBULSKIS: Well, I come back, if I may, to the, what perhaps is, to me, basically much of a basic conclusion, though I'm not sure that everybody would agree with me, but if you let hydrogen accumulate to significant quantities in a containment of this type and then get ignition, for whatever reason, a la Three Mile Island, or whatever, at a significant concentration, then you have a very high probability of failing the containment. And the whole point of the intentional ignition effort, as I understand it, is to make sure that you never reach those very high concentrations of hydrogen that can, in fact, fail containment. What you're trying to do is to keep the hydrogen concentration down to manageable levels. And the manageable levels may not be well defined, but basically what you're trying to do is keep the pressure within some envelope. And a good way to do that is to make sure that the hydrogen doesn't accumulate to a high level.

MR. RUBENSTEIN: One of the next presentations will address some specifics in terms of pressure and temperature with the CLASIX code for Sequoyah.

MR. CYBULSKIS: Well, I won't keep you waiting.

MR. KERR: Thank you, Mr. Cybulskis.

That brings us, I believe, to a presentation by -- or you, you're next up. Okay.

MR. TINKLER: This portion of the presentation will deal with the analysis that has been provided by TVA, principally performed by OPS.

This slide says some of the same. It indicates that TVA believes that the study of igniters will continue for about a year and they will determine sensitivity to critical parameters for various accident scenarios, which they are waiting for us to identify, in order to determine the containment response for distributed ignition system.

The bulk of the calcualations have been done using the CLASIX code. The code is under development. But to summarize, we think the code contains the models that are necessary to perform a calculation of the containment response. It contains features typical for containments and features unique to ice condenser containments.

This is a list of some of the capabilities that CLASIX has. CLASIX is a multivolume containment code. It is not restricted to equal pressures. It can calculate different pressures in different rooms. It has the capability to model a vent from the upper compartment into either the environs or can model a vent path directly from the upper compartment to the lower compartment, which would bypass the ice condenser.

It has an ice condenser model slightly more refined than the MARCH code presently uses. The ice condenser model is similar to that used in the LCTIC 3 code, which is a licensing code used by Westinghouse CPS to perform design analysis on ice condensers. And the ice condenser heat transfer model is taken principally from the Walt's Mill (?) test data.

It has the capability to model the recirculation fans which draw suction in this case from the upper compartment and discharge to the lower compartment in the dead-ended regions in the containment. It has the capability to model both the lower inlet and intermediate deck doors. This is one of the reasons why you may get different pressures, because they act as check valves in reverse direction.

It has the capability to model individual atmosphere constituents -- oxygen, hydrogen, nitrogen and steam. It uses ASME values for saturated steam. It has the capability to model sprays. It will model sprays whether the ice is there or not.

Input to the code can be in the form of hydrogen, nitrogen or pure heat additions, and input would also be break flow, steam water. It has several burning control options in order to determine the sensitivity to the ignition criteria or setpoints that you choose to investigate.

As I stated earlier, the TVA has provided preliminary analytical results. These results are for the small break LOCA with a failure of ECCS, the S_2D sequence. The rate of hydrogen release to the containment was based on a MARCH calculation provided to Westinghouse.

Onset of hydrogen release was approximately one hour after accident initiation, and the hydrogen continued to be releasead for approximately 3000 seconds. They released approximately 1550 pounds of hydrogen, representing about 70 percent of the zirc reaction.

The base case, which we will be looking at a little bit later, assumed hydrogen combustion when 10 volume percent hydrogen was reached in the various compartments. They have done a number of sensitivity studies regarding the air return fan, burning parameters and ice availability.

This is a list of the base case parameters that we used. As I said, the CLASIX code calculation begins when hydrogen is released to containment, when hydrogen is generated. Up until that time, in order to initialize the CLASIX code, results from the LOTIC code, which is a review and approve code.developed by Westinghouse, and the initial conditions, volumes, temperatures, pressures, the ice mass at the start of the CLASIX calculation, heat transfer properties, are taken from the LOTIC analysis.

Burn parameters, and we have several of them listed, are user options. They are hydrogen for ignition within a compartment, hydrogen concentrations necessary for propagation of the hydrogen burn into adjacent compartments, and the oxygen levels necessary to sustain the ignition. Those are the values that we used in the base case.

The air return fans were modeled, both of them, in the base case, assuming a constant capacity of 40,000 CFM. The spray system was modeled with a flow rate of 6,000 GPM at a temperature of 125 degrees. Sprays are modeled as droplets and modeled, a film coefficient to the droplets, a value of 20.

The ice condenser drain temperature was conservatively assumed to be 32 degrees. As I have said, break release data was obtained from results using the MARCH code to calculate the primary system response. The CLASIX code does not model the primary system; it is simply a model of the containment.

This is a figure of a ice condenser model as seen by CLASIX. The Sequoyah model was also a four-volume model. The fan was modeled, took suction from the upper compartment and discharged into both the dead-ended volumes and the lower compartment volume, and they also modeled the flow path from the upper compartment to the lower compartment through the operating deck drain holes, which is a bypass.

The ultimate capacity of the code is seven volumes.

This shows the hydrogen release that was used in the CLASIX calculation as calculated from a MARCH analysis for the S$_2$D transient. As we said, the onset of hydrogen production occurs in roughly an hour after accident initiation and proceeds for approximately 3000 seconds. This represents -- at the top of the curve -- this is integrated mass release and it represents about 70 percent of the core reaction.

At this time the core slumped and they terminated the calculation because they consider this evaluation of degraded core accidents.

This is a plot of some of the results obtained using the CLASIX code for the base case. This is a plot of the temperature in the lower compartment. What we see here is a series of nine burns in the lower compartment. The igniters are turned on. Hydrogen concentration reaches 10 percent and the hydrogen is burned off.

Hydrogen concentration then builds up until the 10 percent setpoint is reached, and again it burns. The temperature hovers around 2200 degrees for each of the nine burning cycles. During each cycle, approximately 100 pounds of hydrogen are burned, resulting in about 6 million Btus released to the containment.

MR. KERR: Mr. Tinkler, you mentioned sprays earlier. Are these calculations made assuming that the sprays are operating?

MR. TINKLER: Yes.

MR. KERR: What turns them on?

MR. TINKLER: Containment high pressure setpoint.

MR. KERR: That setpoint, then, is not reached until the pressure --

MR. TINKLER: It would have been reached long before the onset of hydrogen generation. It is reached at about, I think it is, 2.5 to 3 psig.

MR. KERR: I thought in TMI-2 it was -- one of the evidences for detonation was that sprays aren't turned on until one reached a fairly high pressure.

MR. TINKLER: Well, TMI-2 has a considerably higher spray setpoint, too.

MR. KERR: The ice containment is a very low --

MR. TINKLER: Ice condensers have lower containment spray setpoints.

MR. KERR: Thank you.

MR. TINKLER: Because of lower design pressures.

This is another temperature plot. From this plot we see that the first burn in the lower compartment does propagate into the ice condenser volume and it results in a temperature excursion in the ice condenser of around 1200 degrees. The remaining burns did not propagate into the ice condenser volume simply because the concentration of hydrogen was sufficient to meet the criteria of the analysis.

This is a plot of the temperature in the upper compartment volume. Again, you see one departure from the normal transient in that the temperature rises briefly to about 150 degrees. This is due to the fact that one of the burns did occur and did propagate into the ice condenser and results in a higher exit temperature from the ice condenser, so you discharge hotter gases into the upper compartment and it raises the upper compartment temperature.

I don't think you could see that phenomenon necessarily from MARCH, depending on how the calculation was done.

This is a series of pressure plots. The total pressure in the lower compartment. Pressure prior to hydrogen burning is approximately 22.5 psia, and it arises to approximately 26.5 for the first burn. The pressure transient closely resembles the temperature transient, and the peaks are obviously occurring when the hydrogen is burning.

The pressure is decreased from the peak pressure calculated each burn in approximately two minutes. The first pressure peak is slightly higher than the others because the concentration of hydrogen, while it is at 10 percent for each of the burns, the absolute magnitude of hydrogen present in the lower compartment can vary simply because the mass of various constituents in the lower compartment varies during the transient.

So you may have had slightly more actual pounds of hydrogen in the lower compartment for the first burn.

This is a plot of the pressure in the upper compartment. It is very similar to the lower compartment. There is a slightly different pressure because the burn did propagate into the ice condenser.

This is a plot of the lower compartment oxygen, partial pressure. From this figure it looks like the oxygen concentration in the lower compartment at the start of the transient is on the order of 10 percent and decreases during the burn as oxygen is depleted, and oxygen is returned to the lower compartment via fans and the cycle is allowed to start over again.

This is a plot of the hydrogen partial pressure in the lower compartment. First burn occurs when the hydrogen concentration is 10 percent and the partial pressure is correspondingly around 2.3 psi.

This is a plot of the steam partial pressure in the lower compartment.

This is a plot of the ice mass. As can be seen, during each burning cycle we get a very rapid change in the ice mass, although the overall transients are rather smooth. As a matter of fact, the shape doesn't really change that drastically from the beginning of hydrogen burning to the end, but that may vary due to steam release rates from the primary system also.

One can roughly estimate the efficiency of the ice in removing energy due to hydrogen burning by looking at the slope of this transient during a burn cycle. You could extrapolate the slope at the higher points in order to estimate roughly how much energy of the burn is being removed by the ice.

After the transient is over, we have about 3000 pounds of ice which should represent at least 40 million Btus of energy removal capability. As I say, this was done conservatively, assuming the drain temperature to be 32 degrees. The hotter the drain temperature, the more ice that would be left following the transient.

TVA has provided a number of sensitivity studies to indicate trends that they see. The first case, as I said, was the base case. There was a total of 900 pounds of hydrogen burned. There was a series of nine burns, 100 pounds per burn. The peak temperature in the lower compartment was approxmately 2200 degrees. The icebed saw a peak temperature of 1200 degrees. The upper compartment saw a peak temperature of only 150 degrees, with peak pressures of 26.5 and 28.5.

They performed a case assuming that the hydrogen was ignited at 8 percent and that the burn would propagate into other compartments at 9 percent. This case resulted in slightly more hydrogen being burned, with less hydrogen being burned at a time.

This case also saw approximately 26 total burns within the containment, the bulk of them occurring in the lower compartment, but there were also burns in the ice condenser and a burn in the upper compartment. You see, the upper compartment temperature is substantially higher than the base case. It rises to about 260 degrees.

But the sprays were effective in removing heat addition to the upper compartment in this case.

TVA has performed a case assuming one air fan in operation. The base case assumed both air fans, and there was a negligible change in the results.

TVA has also performed a case assuming no ice in the ice condenser exists after the first two of seven burning cycles. This is a nonmechanistic analysis in that if they do the S_2D transient, they have ice in there. But this case was done in order to indicate what type of sensitivity they may have to varying accident scenarios, although you would have to precisely look at the accident scenario to determine at what time you ran out of ice.

There are obviously scenarios where ice is depleted, but you would have to balance that against the energy that would be remaining in the core along with the releases to the lower compartment.

This case burned 350 pounds of hydrogen, not significantly different. They burned slightly more hydrogen each time. They had only seven burning cycles, all of which were determined to have occurred in the lower compartment. The peak pressure for this case was 41 psia.

The final case shown here is a case with no air fans, where mixing of the atmosphere constituents is simply based on pressure differentials between compartments. That is how flows are calculated. Without the air fans, there is a great deal of difficulty in predicting beforehand where the hydrogen will end up.

In this case a great deal of hydrogen accumulated in the upper compartment, resulting in a burn in the upper compartment with a very high pressure of 92 psia.

MR. ETHERINGTON: Is that kind of pressure difference on the ducts effective without the fans?

MR. TINKLER: Yes. If you have a delta-p between the upper and lower compartment, it will drive it through that to the ducts and to the fans.

MR. ETHERINGTON: So you don't really -- that means if you have no fan system.

MR. TINKLER: Well, this burn may occur, say, on the order of 10 to 20 seconds. I can't say it is guaranteed, but it is doubtful that the pressure could be equalized between those two compartments through the fan system in 10 seconds.

MR. ETHERINGTON: Isn't that equally true if the fans were running?

MR. TINKLER: Yes.

MR. ETHERINGTON: So the fans don't really make much difference one way or the other.

MR. TINKLER: As far as differential pressures there?

MR. ETHERINGTON: Yes.

MR. TINKLER: No, they don't make much difference, I wouldn't guess. What they do make a difference in is mixing the hydrogen.

MR. ETHERINGTON: Yes, yes.

MR. TINKLER: The no fans case also -- I think at one point the lower compartment was oxygen depleted or there was not sufficient oxygen to sustain the ignition.

MR STREHLOW: I am curious on one point. You say when one chamber burns, and the other doesn't burn. Is that what you actually do in the code, you allow combustion only in one chamber and nothing happens in the other chamber?

MR. TINKLER: You specify conditions under which the burn will propagate. You specify the condition at which the burn in one compartment will propagate to another, and you can specify a propagation delay time.

MR STREHLOW: But it always propagates, in other words.

MR. TINKLER: Excuse me?

MR STREHLOW: It always propagates?

MR. TINKLER: No.

MR STREHLOW: I have a problem with that, because if the pressure rises from 15 psi initial pressure to 26 psi --

MR. TINKLER: It rises from approximately 22.5 to about --

MR STREHLOW: About 4 psi, right?

MR. TINKLER: 4 psi.

MR. STREHLOW: The point is you are going to displace some of the gas from the chamber that contains adequate hydrogen to the chamber that doesn't. It is not going to mix with that gas; it is going to burn in that chamber. The flame will propagate after it. I mean if you have a vented vessel, for example, that has got combustion going on in it, you get a tremendous fireball outside that vessel.

So that when you pressurize this vessel and gas is transferred to the second vessel to pressurize it, some of that gas contains the hydrogen. And you don't have any flame arresters in there, so the flame will get up in there. Now, it won't burn all of it because there is not that much hydrogen up there, but there will be combustion in the second chamber if there is combustion in the first chamber, at all times.

MR. TINKLER: I understand.

MR STREHLOW: But that is not what the code does, right?

MR. TINKLER: The code can do that by specifying a -- you could ultimately model that by specifying a low setpoint for propagation.

MR STREHLOW: But it doesn't at the present time.

MR. TINKLER: Well, these runs did not. It could.

MR STREHLOW: Okay, that is the answer.

MR. TINKLER: Like I say, it is anticipated that sensitivity studies into the ignition criteria that are used in the analysis will continue for some time. There is no claim that we have searched out and found the worst case for ignition criteria. That wasn't the intent in these cases.

The intent was to pick parameters they thought were reasonable. I believethat would be the case. I believe at 10 volume percent, which was the base case, they believed that the combustion will be fairly complete, and therefore it is a reasonable calculation.

MR. MARK: Did I catch correctly that this Case 5 is the one in which you have still nine cycles but --

MR. TINKLER: No. The case with no fans. It is not quite the same because the burning occurs in different places at slightly different times. This case was not run until completion.

MR. MARK: It is the no ice that had nine cycles, two with ice and seven without.

MR. TINKLER: The no ice case had seven cycles, two with ice, five without. I will provide you some slides on that a little later. As a matter of fact, right now.

This is the case with no ice. Again, it's a non-mechanistic analysis, which is conservative. This is the total pressure in the upper compartment; pressure in the lower compartment. Very similar.

MR. KERR: Mr. Tinkler, I'm beginning to run into a problem in that I have about three more hours of presentation and only about two more hours of time.

MR. TINKLER: I only have a few more slides.

MR. KERR: Okay. I was just going to suggest that if you could talk 30% faster --.

MR. TINKLER: Okay. Like I said, the transient looks very similar to the other transients you've seen. You see the two pressure peaks for the cases where ice is remaining, and the two cases where ice has been removed.

You would expect the pressure in the containment to rise after the ice has melted out, irregardless of hydrogen burning, because you've lost the heat sink, and you see that in a normal design basis LOCA analysis. But the pressure is approximately 41 psi, which is still far below the yield pressure containment.

This is a plot of the temperature in the lower compartment; about 23, 2400°F. We were burning slightly more hydrogen in the cycle.

MR. ETHERINGTON: Do you consider 41 psi below the yield?

MR. TINKLER: The yield was estimated between 27 psig using a conservative value for the yield strength, and between 27 and 36 I believe psig. We calculated 41 psia.

MR. LAWROSKI: Mr. Tinkler, in view of what happened in the case 5 with no air fans to the upper compartment peak pressure, how comfortable would you be with a system that only has two air fans?

MR. TINKLER: You could argue that anything that increases reliability of the air fans would be an improvement. Since they are sensitive to it.

As we tried to emphasize, this is all work that has been done on a rather short timeframe, and we have many things that we're going to continue to review. Some of these topics include the location and number of igniters. It may be that we decide we will want additional igniters located in some strategic places where high point vents are, the pressurizer release valve or whatever. Hydrogen monitoring and mixing, those systems were designed for what is on the docket as a design basis accident. Are they adequate or suitable for this kind of accident mitigation?

We need to know more about the ability of igniters to function in a turbulent flowing atmosphere. Procedures and strategy for igniter operations; we need to learn more about CLASIX, the solutions scheme, models in the containment, specific details, that is, and the input parameters. Analysis results need more review. Mixing of constituents, sensitivity studies, burning criteria and the effects of different hydrogen generation rates.

We do think the no-ice case does demonstrate some insensitivity to the accident scenario.

The effects of local detonations need more work done, they need more review.

MR. KERR: Excuse me, when you say the effects of, are you able now to predict the possibility of local detonations?

MR. TINKLER: We don't calculate concentrations that are detonable in the analysis we've done.

MR. KERR: Is your model capable of doing that?

MR. TINKLER: Of doing a detonation calculation?

MR. KERR: Of doing a calculation which would find pockets of detonable mixtures, if they existed, in this structure?

MR. TINKLER: If we picked a small, a very small, volume, we have 7-node capacity, and if we picked a very small node and we introduced hydrogen in a node adjacent to it, we could force the code possibly to calculate it.

MR. KERR: Do you plan to make an effort to explore for this possibility? Do you consider it a serious problem or unlikely?

MR. TINKLER: We consider the problem of local detonations to require more work by both the applicant and the staff. Preliminary calculations and judgments are that they can withstand local detonations. Presumably, concentrations may be higher in the lower compartment, but it's a smaller volume. If you could withstand a detonation of a local pocket, you could most surely withstand equilibrium pressure after the detonation, because we're talking about smaller quantities of hydrogen. But in any event, it does need more work.

Protective measures for essential equipment; we need to learn a little more about the response of equipment to the temperature transients and what may be necessary to insure that they'll be operable. Whatever equipment is needed, that is.

Conclusions. The preliminary conclusion is that the distributing ignition system has significant potential as a short-term solution to the problem of hydrogen control. It should be stressed that the system is most useful when operating in conjunction with existing heat removal systems. If you don't have other heat removal mechanisms, burning it with igniters is not a great advantage.

And we intend to explore various aspects of both igniters and possibly additional heat removal methods.

MR. KERR: Thank you sir. Are there questions?

MR. MARK: When you say the very short term, do you mean something that can be implemented quickly or something you'll try to get away from quickly?

MR. TINKLER: Something that could be implemented quickly. TVA has indicated that this is an an interim distributing ignition system and they will continue to study other measures for hydrogen control.

MR. MARK: But there may not be any very good reason to change if you learn a little more about it.

MR. TINKLER: That is correct. That's not to say it couldn't be the final system.

MR. GREGORY: I have a concern about the curve which shows depletion of oxygen in the lower compartment. If you drop the oxygen pressure by about half for a short period of time, it, in effect, is putting the hydrogen-oxygen ratio up and your conditions for initiation of ignition will be quite different during that period while oxygen is coming back into the system. You, in effect, conceivably increased or you've certainly altered the hydrogen-oxygen ratio in the gas.

MR. KERR: How do you remove oxygen while at the same time removing hydrogen?

MR. GREGORY: You remove both, but they'll come back in at different rates because they're coming back from different sources. The oxygen, I assume, is coming in from the upper compartment and the hydrogen is coming from a break in the lower compartment. And they're coming in at different rates and it will be pretty complicated to model but it ought to be looked at.

MR. TINKLER: It does look like, though, that the oxygen is returned to their ignition setpoint much more quickly than the hydrogen is built up, just based on the next slide.

MR. KERR: If the igniters work, as one might predict that they will, is that a problem? One would simply get a flammability limit earlier than otherwise might occur.

MR. SCHOTT: In the regime that's being deal with here in this series of calculations, it appears that depletion of oxygen -- rather, depletion of hydrogen at the immediate time of the burn is quite complete; that of oxygen, while it looks serious, like down to half, is not for any useful period of time or a dangerous period of time so complete as to prevent burning of any hydrogen that might accumulate. That is, one is always in the regime where there is more than enough oxygen to handle however much hydrogen may be present. And as long as that is so, the 10% criterion on hydrogen is the limiting one, and even that is just an assumption.

It appears to me that the series of calculations that have been done both with the CLASIX and the MARCH codes are severe cases of the pressure and temperature transierts in that they have not -- they have worked with hydrogen accumulation up to this 10% level, or 8% --

MR. TINKLER: That was a point that we battered around this morning.

MR. SCHOTT: Which one is sure will burn rather completely, whatever is in short supply, which in every instance is the hydrogen. So it's a conservative test of the ability of a repetitive burn system to accommodate a rather small number of burns with rather substantial, 100 pound, accumulations of hydrogen each. And the real situation that may result from having --. It's as though the igniters were triggered at will at this 10%, which is not what's actually being proposed to be done.

MR. TINKLER: But you're saying then that they hydrogen may be burned at even a slower rate, smaller quantities at a time.

MR. SCHOTT: More continuously in time. And probably mixing -- to the point where mixing becomes the limitation instead of what's now -- the set of parameters that now are governing the calculations.

MR. KERR: Other questions or comments?

MR. LEE: I'm still somewhat puzzled. Is there any accident scenario that could get us to the upper flammability limit instead of the lower flammability limit?

MR. TINKLER: Are there any?

MR. LEE: Yes. Or should they consider those sequences?

MR. TINKLER: It's difficult for me to say whether there's --. Seventy percent of the core reaction is what we showed as the endpoint for our calculation in some definition of a degraded core accident. That represents near 17% hydrogen, 17%-18% hydrogen concentration in the containment at dry atmosphere. So --

MR. LEE: Seventeen percent of --?

MR. TINKLER: No. Seventy percent of the core corresponds to 17% molar concentration of hydrogen in the containment uniformly.

MR. LEE: In a mixture of air and hydrogen?

MR. TINKLER: Yes, it's primarily a dry atmosphere. More steam reduces the concentration.

MR. MARK: But you will go through the upper limit. You have hydrogen and steam coming out the end of a pipe, and it's a low percent hydrogen as far as the air is concerned. Now you'll add air.

MR. TINKLER: In a local region we could. That's based on bulk containment.

MR. KERR: Are there any other questions?

MR. SCHOTT: That 70% based on zirconium, is that hydrogen that is all released through the vent, or is some hunk of that 70% still harbored in the unburst reactor?

MR. TINKLER: That 70% is in the containment.

MR. KERR: Thank you, Mr. Tinkler. Mr. Butler? I show you for 10 minutes now.

MR. BUTLER: I'd like to make some conclusory remarks for the staff's portion of today's presentation. I certainly appreciate the comments and also some of the answers and questions raised by the members of the committee and its consultants. We covered a lot of ground today, covering different programs, each with different objectives. We've dealt with long-term programs and short-term programs; generic issues, generic criteria, as well as specific issues and specific criteria for Sequoyah for the near term. I recognize it's somewhat difficult for those new to the issue and the problem to keep these different programs and issues separated, but I think it's important that an effort be made.

We did cover a lot of the generic and overall kinds of issues. But for us, that kind of matter can await further developments in further meetings. For us, the urgent thing is the near-term issue, Sequoyah; the interim distributed ignition system and whether it is good enough for an interim period pending further understanding of the characteristics of the IDIS.

The program has moved very fast. We had a meeting with the ACRS July 15th. Subsequent to that meeting, all this stuff we discussed today was prepared. We wrote work statements, contracted with a number of labs and got them well underway with their programs. I think you can understand that the staff has worked very vigorously, and certainly the TVA applicant has worked harder and faster. They have limited time to present their story, additional to those things that we presented based on their input to us.

Now, let me go through some of the slides, just to refocus on the stuff I showed you earlier today and the urgency of our schedule. Starting with the September 2 date --

MR. KERR: If you read those things one by one, I'm going to --.

MR. BUTLER: I won't. You've seen it this morning. Starting with the September 2 date we have the mini-PSAR, and we expect to conclude all our activities by December and meet again with the ACRS in January and with the Commission also in January. We need a tentative decision next week with respect to whether Sequoyah can reasonably be authorized to run at full power for this interim period pending further understanding of the issue.

This slide simply summarizes the status for all the classes of containments, and you'll note in here for the ice condensers that the specific criteria and measures for hydrogen control are under consideration. We hope to conclude that matter within the next few days.

I have one slide on staff position and then the staff conclusions. The staff position is that the existing provisions at Sequoyah which satisfy Section 50.44 are sufficient near-term requirements to warrant full power licensing. We have accelerated programs, both staff and applicant, to qualify and implement measures additional to those of 50.44. The timeframe is during the next four months. These additional measures, if found effective and appropriate for Sequoyah, will be considered as requirements also for other ice condenser plants.

In conclusion now, since the TMI short-term Lessons Learned items have been implemented at Sequoyah, and placing the

Sequoyah plant in the same risk space as Surry and the Peach Bottom station, both of which are operating; since aggressive applicant and staff programs are in place to improve the hydrogen management capability at Sequoyah in the timeframe of the next four months; since preliminary work shows the integrated distribut ignition system to be a very promising approach, at least for a substantial fraction of scenarios that lead to degraded cores; furthermore, since backup programs are in place, should the IDIS prove unacceptable, the staff concludes that full power licensing of Sequoyah need not await completion of these near term studies and experiments.

MR. KERR: Are there questions?

Thank you very much, Mr. Butler. The agenda now has scheduled a presentation by RDA Associations. Mr. Hubbard, are you going to start?

MR. GREGORY: May I ask a question before we start. is it my understanding that the Commission is recommending allowing Sequoyah to run at full power without the ignition system we've been talking about? Is that fair?

MR. KERR: I think it has reached the position that they are going to recommend this to the Commission, I believe.

MR. RUBENSTEIN: That's true. Between now and December the startup program is such that I wouldn't even want to hitch on December. We feel confident that the changes made by the action plan have improved the risks to Sequoyah and placed it equal with other plants. But in any case, until the resolution of the interim distributed ignition system occurs in December, potentially 25 effective full power days of operation will occur.

MR. KERR: Mr. Hubbard?

MR. HUBBARD: My talk is going to be very short, which the Chair will be glad to hear, I'm sure, as much to catch an airplane as any other reason, however. But I made the talk length proportional to the length of time RDA has been involved in this subject of containment safety, which would be about a minute.

Our involvement came through a request from Commissioner Gilinsky to respond to a set of fairly specific questions about Sequoyah containment. And although we have a group of people at RDA who are intensely interested in the subject, we have spent a very short time on it. The total effort was about four man weeks and split between a look at the structure and hydrogen problems. So I think it's probably a little unlikely that we're going to be able to say anything to you that you haven't heard before, other than our opinions on the matter.

The first thing that struck us was, of course, that one is constrained by rates, and that at some rate of zirconium reaction and burning of hydrogen, igniters don't do anything for you. And we took the base case of no ice present and 1% per minute zirconium reacting, and that saturates the heat removal capacity of the plant.

So whatever else we have to say about it, we're talking about what can one do if the rate of production is lower than that, and I don't know of any data that limit the rate to that value. In case the ice is present, I understand that Donald C. Cook's study indicated about twice that value to saturate the heat removal capacity.

So, one might ask then what next, assuming that the rate is lower than that. What one would like to do is use the pilot light approach rather than the light in the kitchen, and that is to surround all the possible sources of hydrogen production with a little flame so that you get it immediately, before it can build up in concentration. And, of course, probably that's how the igniters will be distributed somewhere near. But as a practical matter, you can't accomplish that goal, so gradually the concentration of hydrogen will build up in the containment, and there's probably no way to avoid that.

Therefore, there seemed to be two ways to go with igniters, that being the case. One would be to try to keep the concentration below 9% or 10%, whatever is the value, wherein propagation is rapid. The other would be --. And in that case, I haven't heard any data that exist that would give you information that tells you how many you need in that case. I'm sure it's not 30. I mean I'm sure, but after all, if you spread them uniformly, that's 30 in 30,000 cubic meters. It stretches the imagination that one per 1000 cubic meters is going to suck in all the mixture and burn it.

The other approach is to say well, we'll keep track of the concentration and let the igniters go when you reach some limit at which burning is more rapid, 9% or 10%. And in which case, then, you are stuck with burning whatever is in the compartment that's isolated. You know, the structure is compartmentalized and the problem with that, as I see it, is the upper compartment is very large and 10% of it is like 2000 cubic meters. A 10% concentration is like 200 kilograms of hydrogen; that will create -- you know, burning that will create a pressure too rapidly for the heat removal equipment to handle. It looks like two-thirds of the case that we examined at 300 kilograms of the whole containment, which would be close to four atmospheres.

So it seems to us that because of the uncertainty in the production rate and the uncertainties in the mixing in the lower containment; after all, it's produced rich and becomes lean as mixing takes place, probably largely in the ice compartment, the uncertainty of where you ought to put the igniters -- until you know those facts and the lack of information about igniters, we concluded that it's probably not a reasonable thing to expect that igniters could play a role of pressure control until those data were available, at least on the slow burning.

There's another thing that has to be added to that, some of the judgment that went into that has to do with kind of, I would say, a pathological task that RDA, against accepting the output of large systems' computer codes, without the adjunct of a large experimental program to go with it, and I haven't any experimental data that would be needed for this use. So that was the reason -- I mean, that in a nutshell summarizes our feelings about the subject.

In addition, I think one should point out that if the ice is there, and if the sprays are working, they do remove steam from the hydrogen-steam mixture that's produced. And it seems to me any fluctuations in the containment have a chance, therefore, for leaving you with a dried out mixture that's rich enough to possibly detonate. And it was just mentioned -- I'd be very leery of detonating 10 kilograms of hydrogen next to the containment wall.

MR. SCHOTT: As a gas?

MR. HUBBARD: You don't think so? The energy content of 10 kilograms is several hundred of high explosive, and just on an energy basis alone --. And if you have a thick enough layer, I mean, the speed that counts is not the detonation speed, you know it's a very sharp spike, but it's just the sound speed. So you'll have a pressure there for a few milliseconds and that's something that really ought to be looked at.

So the other part of the question that we were asked to speak on was what about alternatives. And it's very clear that nobody likes inerting a containment, which would solve this problem and create a lot of others, I guess. And I must say, as was pointed out before, it's an awful lot easier to find the problems than it is to come up with solutions. And I guess our total time on this specific problem was maybe a couple weeks, so I think we really can't add anything to the programs that are ongoing here already.

MR. KERR: Are there questions?

MR. GREGORY: You indicate, I think, in your written material, and you were alluding verbally, that you might prefer to go the inerting route rather than the combustion route.

MR. HUBBARD: I mean, it just avoids the problem. That was the point. It raises a lot of other problems.

MR. GREGORY: May I ask if the containment will fail or not with the pressure rise that's brought about simply by the release of the extra gas? If we get something like 70% of the cladding material reacted, and all that hydrogen comes out into the containment, just the pressurized use of the extra gas that's in there, will that cause the containment to fail or not?

MR. HUBBARD: I don't think so, no. It's just the energy released in producing the hydrogen that's split evenly between hydrogen production and burning. It's the added energy, it's not the gas.

MR. KERR: I think the answer is no, but I expect it depends on the scenario that one postulates.

MR. BUTLER: That particular problem was considered and reported in SECY 80-107, wherein we made the determination that pressure, although above design pressure, is well below the failure pressure of the ice condenser.

MR. KERR: Thank you very much, Mr. Hubbard. That brings me to TVA, and I expect having listened this long, you would like to be heard. In fact, the parenthesis says "new information".

My name is Wang Lau with TVA, Nuclear Engineering Branch. We also have a few people from Westinghouse, Offshore Power and also from our home office here today. They can answer questions later.

We were asked to give a 15 minute talk about new information. Since we have not talked with this particular sub-committee we weren't sure exactly what new information was or old information. But I heard from this morning and this afternoon, a lot of questions were asked, a lot of information was presented. Of course, I will not duplicate that information. I do intend to cover some of the things that were not covered this morning. Not with the intention of presenting a complete story in 15 minutes because that's not possible to do, but I will try to use my presentation to kind of stimulate your questions so that some of the questions that were asked this morning if they were not answered properly, you can try me again and see if I can do a little bit better.

The first thing I want to cover is the igniter system a little. Let me tell you some of the major topics I will cover and I want to cover the installation and operation of thermal igniters, locations and things like that. And I will briefly mention spark igniters that we considered at one time, and about the Singleton Lab tests, the Fenwall tests, a little bit about the halon study and some information about degraded core.

The igniter system looks something like this. It has a General Motors type diesel igniter with a transformer in there to drop it to the proper voltage; a little ring shield at the top to stop the containment spray from getting to it directly, and the assembly is pretty rugged. We have sent samples of these igniters with the whole assembly to Livermore and to NRC and to Fenwall and, of course, our own Singleton Lab for testing.

This is just a simple electrical circuit.

MR. LAWROSKI: That will do it for our Chairman, anyway.

MR. LAU: I beg your pardon?

MR. KERR: He is alluding to the fact that at one point I was known as an electrical engineer, and he thinks that will be the one thing that I understand about today's presentation.

(General laughter.)

MR. LAU: We have some electrical engineers in our task force and I do have to keep them busy, you know.

(Laughter.)

This is a rough outline of our Sequoyah plant, and you notice there are six different elevations. These elevations are sealevel elevations. This is a very busy diagram. I'll show a little bit better one.

This gives you a little better view. I also intend to show you this one later. Now, 669 is the floor level, basement level, and you can come up. This elevation is directly under the air return -- I mean, the ice condenser. These numbers are the number of igniters at these elevations, in those particular planes. There's four in the ice condenser in the upper plennum; five in the lower plennum; six directly under the ice condenser; and those are in what we call the deadend volume, but they are pretty wide open really. Notice the colors, because going to the next picture, it will show you a little about the detonation thing you will consider.

The four yellow ones are the steam generators. These four are, of course, air coolant pumps; this is the pressurizer, this is the reactor cavity. The ice condenser goes 300° around this -- may even go down to 60° for refueling and other things. These two locations are the air return fan locations, and they are not under the ice condenser, they are just within the 60° opening and they suck directly from the upper compartment into there.

This is the pressurizer joint tank. This is where the reactor vessel vent discharge point is. Those are the locations of interest.

MR. SIEGEL: What is the reactor vessel vent?

MR. LAU: Yes, we have a reactor vessel vent since TMI, and that is just an opening in case you have that bubble that we talk about like at TMI inside the reactor vessel. We can vent it out. It doesn't get trapped inside. That's a new feature.

MR. SEIGEL: That can be controlled from the control room?

MR. LAU: Yes, sir.

MR. SCHOTT: Is that up or down in this picture here? Downward into here?

MR. LAU: It's vented out to the lower compartment just outside the ice condenser doors, near the ice condenser doors. In this picture, it would be around elevation 700, plus or minus. Okay?

MR. SCHOTT: That's a duct from someplace.

MR. LAU: There is the reactor vessel vent.

MR. SIEGEL: Where is the nearest igniter to that?

MR. LAU: Okay. Let's see if I can remember all those figures. Same color as the igniter, orange. This is one elevation, that's 689, the basement. To give you a rough idea, the orange dots are the igniters. Those numbers don't really mean a whole lot. The A, B, C means the reclose(?) of the diesel generator because it is backed up by emergency power and seismic and all that. The Glow represents the glow plug. L is the emergency lighting fixture that we are not using.

MR. SEALE: All of the G's on here are glow plug locations, right?

MR. LAU: Yes, sir. And this is at the basement. The (?) was scattered, and this is a little high elevation, 700 under the ice condenser. That's 731. You'll recall that 731 is around there, inside the ice condenser in the lower plennum. It's kind of like a manifold as far as the ice condenser is concerned.

MR. SIEGEL: Are you saying that the nearest plug is inside the ice -- the nearest plug to the reactor vent is --

MR. LAU: No, sir. We've got -- The nearest plug to the reactor vessel vent? Nearest plug to what?

MR. SIEGEL: To the exit from the reactor vessel vent.

MR. LAU: No, there are a few in the lower compartment. The reactor vessel vent is venting to the lower compartment, and there are --.

MR. KERR: What is the nearest glow plus? One foot, 10 feet? 20 feet?

MR. LAU: Let me see. In this drawing, this is 90°, so this is around 45° at around 731 elevation. So let's take that 731 elevation at 45°; I would say the igniters are located in this area. This area is about 65 feet, so this is about, oh, say about 20 feet.

MR. KERR: Okay. Is that a good enough estimate? Good.

MR. SCHOTT: It's a good enough estimate but it's not close enough.

MR. LAU: This elevation, 792, has something interesting in one corner, and that is the location of the control panel in the auxiliary building. And this control panel is approximately 100 feet from the main control room. You can run out there and throw the switch and run back. But these igniters are manually controlled, not from the main control room. You do have to get out there, but there's no radioactive stuff at that elevation; there are electrical things.

MR. KERR: I should point out that it's very unlikely that any hydrogen would ever come out of that vent. So if you're going to put the glow plugs there to catch the most likely exit spot of hydrogen, that's probably not it.

MR. GREGORY: I thought I heard somebody say that the purpose of the vent was to let out the " bubble."

MR. KERR: Well, that was the Three Mile Island bubble which maybe was there and maybe was not. But remember, at Three Mile Island there was a lot of hydrogen released and it didn't come out through a vent. And it may not come out through it --. In fact, I think it somewhat unlikely that it will come out the vent the next time.

MR. SIEGEL: It came out of a vent which happened to be the exist from the pressurizer, but if you provide another more suitable vent, why shouldn't it come out there?

MR. KERR: But this suitable vent is only the vent in case one develops a bubble in the top of the vessel and can't get rid of it.

MR. GREGORY: So if you ever use the vent, you will get hydrogen coming out.

MR. KERR: That's true.

MR. GREGORY: And I would not like to operate a kitchen range, for example, where the pilot light is 20 feet away from the burner. That doesn't seem to be --

MR. KERR: I defer to your wisdom.

MR. SEALE: I think Dr. Kerr's point might be, though, that it's equally important to ask whether or not there's a glow plug near the relief valves for the pressurizer.

MR. KERR: I'll take credit for that viewpoint.

(Laughter.)

MR. LAU: Of course, there's a pressurizer relief in Sequoyah that relieves to the reactor coolant drain tank, the tank that I showed earlier, and from there, there is a rupture. Just like in TMI. I mean, that rupture -- the hydrogen will be dispersed in the lower compartment.

MR. SIEGEL: Do I understand that the location of the glow plugs is really constrained by the location of your emergency lighting system?

MR. LAU: I'm not so sure that constrained is the proper word, but this is --

MR. SEIGEL: Determined by?

MR. LAU: In the interim system, the first phase, we do want to go in there and use whatever is available. Our reason is that the emergency lighting circuit is usually located in a place, by design, that is wide open to give good illumination of what is going on. So the couplingis pretty good because of that. And the conduit is there, it is seismic and backed up by diesel and the location (?) is good, and that's what we used.

Later on, in our future study if we do find out that there are better locations such as -- we might reroute the reactor vessel vent, we might put the igniters further away and we might put them closer.

MR. KERR: Mr. Lau, I think if we get answers this long to every question that we ask; I think he has the answer to his question now.

MR. LAU: Thank you. Three more in the very top dome.

I have here a drawing showing the approximate -- it's a hydrogen scheme, designed for that purpose -- to collect hydrogens at various locations especially at the deadend volume and the steam generator enclosures and things like that. So we can use the air return fans to kind of circulate the hydrogen burner. Get better mixing.

As Mr. Butler said earlier, the air return fan has something like 40,000 cfm speed and you would have a complete air change in the lower compartment in about four or five minutes. So it is a highly turbulent, well mixed case.

I heard a lot of questions this morning and this afternoon about pocketing, detonation and so on and so forth. I think we should keep in mind that the flammability lower limit is around 4%, and you'll get a lot better chance of igniting at, say, 8% or 10%. The detonation limit we're talking about, 18% and higher.

Now, there is a margin of, say, about 10%. We are therefore talking about concentration gradient in space of around 10%. With this kind of mixing and with the wide open areas and with all the turbulence inside and in the upper compartment we have the sprays, of course people can always argue with me, but I really think that we have pretty good mixing, such that that kind of concentration gradient is not exceeded, considering we have 30 igniters and they are not that far away. Okay? But right now I do not have any numbers to back up what I've mentioned about this concentration gradient.

Any questions so far? Okay. We'll talk a little bit about some of the Singleton tests we have. We have endurance tests and it looks like -- you can always fail a plug. If you intentionally put overvoltage on it, we have successfully ruined a few of them at at 16 volts or so. But if the reactor coolant fails, it usually fails within about the first 30 minutes or so. At a bout 14 volts we are pretty successful in keeping it alive. Now, some of the old plugs we bought they fail. I think it's because of the shelf life or maybe there's some moisture in them or something like that. But all the 1979 plugs are pretty successful, and I guess the Lawrence Livermore people use the plugs and they're okay, too.

The endurance tests -- we are planning more tests. We are buying large samples, a kind of quality assurance sampling test to establish some kind of confidence level on an igniter. We use, of course, a future installation of an igniter or a replacement igniter and we prove it would work.

We feel very comfortable with the temperature requirements we've put on the igniters. That's important because we want to prove that the igniter works.

The staff mentioned this afternoon that the spontaneous ignition temperature in the ideal situation, dry air, is around 1100°F. Now, we are using about 1700°. Something above 1500° is our criterion, so there's plenty of margin there. The steam concentration does not affect the spontaneous ignition temperature that much; according to some of the published literature from the British research, the steam concentration in the range we are talking about might add about 50°C or maybe 100°F to the spontaneous ignition temperature. So we have plenty of margin, we feel very comfortable with the fact that you will ignite. Certainly at the 8% and 10% range. And, of course, we'll confirm those in our future testing.

MR. STREHLOW: I've got a comment here. Remember we said that if you have a 2% hydrogen mixture you'll probably get low localized chemical reaction in the neighborhood of the glow plug; they hydrogen would not burn but would be decomposed, it would oxidize; it wouldn't really be a flame. There's a possibility that this might shorten the life of the plug considerably, and if you're considering putting these plugs on and leaving them run for weeks to make sure that there's no hydrogen buildup that's going to go to explosion, and you soak them in a 2% hydrogen mixture, they may burn out in a few days. And that's one --

MR. KERR: You do not intend to leave them on --?

MR. LAU: We have some of the igniters in the lab and we've been burning them for over a week.

MR. STREHLOW: In a hydrogen atmosphere?

MR. LAU: Not in a hydrogen atmosphere.

MR. STREHLOW: That's the point I'm making. I'm making the point that if you put them in a hydrogen atmosphere of 2% or 3%, the plug's temperature will be higher than the temperatures that you measure because of the oxidation reaction occurring at the surface. And this will cause the plug temperature to rise above the temperatures. And the thing that burns those things out is to get them too hot.

MR. KERR: This could be a problem in the long term evolution of hydrogen, but I would guess that it's more likely that that will be slow and would be thought of as being taken care of by recombiners, if recombiners are still in existence.

MR. SIEGEL: My impression was that this could be a serious point. If you're doing this for a couple of days, you're in a time that's short compared to where recombiners are in place but long compared to a deterioration time of the plug.

MR. KERR: You may be right.

MR. DILWORTH: This is George Dilworth, TVA. Recombiners in our containments are in place. They're inside the containment, two of them, part of the design basis for this plant. And we do not intend to run the igniters for extended periods of time. When the hydrogen is produced through the S2D situation that we've been talking about today, after that's over with, those 9 burns, the igniters will not be left on. The recombiners are sufficiently capable of taking care of any small residual hydrogen that might be released.

MR. KERR: However, one should not ignore the fact that nature does not necessarily recognize all of the S2D as a possible method of evolving hydrogen, and it seems to me it is possible that one might get something slow compared to that and fast compared to recombiners.

MR. LAU: At one time, we considered spark igniters. They are definitely a very efficient ignition source. We kind of dropped it for our Phase 1 program, interim program, because we were not sure of the effect due to electromagnetic interference, and we are contracting people to make a study and go ahead with a design of a (?) or something of that nature and maybe if it's successful we'll pick it up again. But, of course, we have to worry about electromagnetic shield. We might also have a magnetic effect on the flame burning. So that's being studied.

MR. LEE: Are these glow plugs used in any major ways other than in diesel engines?

MR. LAU: I do not know of any.

MR. LEE: Just diesel engines? That's where they are used?

MR. LAU: Yes.

MR. LEE: Are any controlled ignition devices in use for controlling hydrogen in any industry?

MR. LAU: Of course, the Bureau of Mines has a lot of -- something of this nature with igniters, but they're not for hydrogen. They're for various types of gases. And there are other industries, the chemical industry uses igniters, but not for the purpose of hydrogen that I know of.

The Fenwall test will have a seven foot diameter test vessel. We intend to push droplets in it later on, and we intend to have a fan circulating the atmosphere inside to make sure that the burning is still there.

By the way, a couple days ago we had a kind of shakedown demonstration at Fenwall. I hesitate to call it a test because it was not one of the scheduled tests. And they put about 12% hydrogen in there in dry air, and they got ignition. They measured pressure pounds, and don't quote me on the final pressure we got because I don't know anything about calibration or pressure sensors or anything like that. But they received about a 67 psi gauge, which is pretty much what you'd expect in an adiabatic burn in a closed volume with no venting. 12% hydrogen. The pressure rise was about.4 second. Since the vessel was 7 feet in diameter --.

MR. LAWROSKI: Where was the decimal on the second?

MR. LAU: Zero point four (0.4). Since it was a seven-foot diameter, the igniters were put in the center, so the distance from the center to the sides is about three or four feet, so that would give you a flame speed of approximately 10 feet per second, plus or minus. That's exactly the kind of thing we're talking about.

MR. DILWORTH: Wang, just a minute. This is George Dilworth again. To save time, we're going to have a more detailed presentation on the 5th to the full Committee of the Fenwall test. I think it would be better to wait until that time rather than receive a lot of questions on those tests today.

MR. LAU: Okay. Our schedule for those tests is in the handout, and we intend to have a first phase of the testing done by approximately the last part of September.

The halon study. We have contracted a contractor to study halon with Duke and ADP joining in that study. The major thing to study, of course, is the biological effects if it's virtually activated, and also, whatever the decomposition product may do to your system.

MR. KERR: That doesn't [illegible] a lot of study, does it?

MR. LAU: It's a very funny thing. This decomposition product I understand will reach some kind of equilibrium. At least, that's what the chemical engineer told me.

I want to conclude by saying that we are using the S2D or MARCH code to study. We do not know that certainty evolved in the MARCH code because TVA does not have the capability to generate the MARCH data. We are using the CLASIX code to make the containment study. We are testing to make sure that igniters work.

Our approach is that we want to make sure that a hydrogen source be used that will find a fair range of accidents. We want to make sure that the containment analysis using the CLASIX code predicts situations that we can stand in our containment, and we want to make sure by testing and whatever, the literature and available data, to prove that our assumptions and things like that used in the computer model are accurate. And we believe that that's a logical approach to the solution.

MR. KERR: Thank you, Mr. Lau. Questions? This brings us to a presentation from NSA by Mr. Miller.

MR. MILLER: My name is Al Miller. I am summarizing the workshop that we held in Palo Alto back in March, where we gathered a bunch of experts to talk about containment stability.

There is a summary of that workshop available to anyone who wants it. I will leave this one here for the committee if they would like.

I will race through these first slides. I think that we will see the purpose. This is the hydrogen burn. We have a little more detail on that showing the apparent pressure rate followed by a generalized increase in temperature all the way around the containment, somewhat implying a generalized burn throughout the containment, and the tree balance showing somewhere around 50 percent metal water reaction taking place there.

These are all in the document, if you would like more detail. I will not dwell on them. The conclusions from our workshop -- these are conclusions from our workshop, and not necessarily NSAC conclusions. The first conclusion was that the Three Mile containment was not challenged by the hydrogen burn. It would not have been challenged if there had been 75 percent or even 100 percent metal water reaction.

The second conclusion was, there is some insecurity in being able to predict the pressure rises in large containments. There are scale effects, and these should be studied further. I will go into what Avery is doing with respect to that a little bit later.We will talk about that a little bit later.

The most important conclusion was the third that the highest probability for successful mitigation of hydrogen accumulation problems was controlled ignition, perhaps coupled with the use of water sprays.

The filler venting concept received almost no support. Spark ignition of hydrogen in concentrations less than 8 percent was unreliable. There is some data by Rockwell that show that they had some difficulty igniting hydrogen concentrations less than about 8 percent in a reliable manner.

The inerting of containment atmosphere is a possible option but there is very great concern because of the occupational hazards that it poses. The experience in India was mentioned where they lost a few people.

The use of halon to suppress detonations was talked about, but again the questions that were raised by TVA were again raised here.

MR. LAWROSKI: The regular halon.

MR. MILLER: Halon 1301 is the one that the data is on.

MR. LAWROSKI: They may to date not have been very serious.

MR. MILLER: Halon is used quite a bit. I know Three Mile has a halon system.

A few final words on the work that will be done at Avery, or what we are proposing to do at Avery.

We are proposing some large scale testing, probably at the Nevada test site, probably in a 50-foot diameter sphere, 100 psi steel sphere, looking at the scale effects. There will be room to put in fans, obstructions, promoting turbulence, testing different kinds of ignitions, ignitions of various sources, different percentages, perhaps going up to detonable mixtures by using subatmospheric conditions.

That in a nutshell is about what I have to say.

MR. KERR: Thank you, Mr. Miller.

Referring to one of your conclusions that ignition is unreliable in concentrations of hydrogen less than 8 percent for spark ignition, did you consider only spark, or did you talk about glow-plugs, for example?

MR. MILLER: Yes. Some of that data is in the blue bound volume. Spark ignition via the AI work, the Atomic International work was not reliable, whereas using a detonable mixture to ignite was reliable, and using a flame to ignite was reliable at those regions, even down to 3 or 4 percent.

MR. KERR: Did the glow plug get any consideration.

MR. MILLER: The work there was to look for pressure response, and not ignition types.

MR. KERR: Did you workshop talk any about what was deemed to be an appropriate way of considering the amount of hydrogen involved? Is there a consensus that one ought to consider, 100 percent metal water reaction, or 50 or 70, or 20? Is there an approach to how one might decide on an appropriate amount to consider; or do you have any suggestion for the committee?

MR. MILLER: That was a subject of the workshop. The workshop was, you have got it, now what do you do with it, what are the responses.

MR. KERR: Your conclusion is that burning looks like a promising approach, but more questions need to be answered before one is certain of that?

MR. MILLER: Exactly, yes.

MR. KERR: Are there other questions?

MR. LEE: This unreliability of ignition at around 8 percent or below that, in light of one of these slides that we saw earlier in the afternoon which indicated a steep increase in pressure somewhere around 8 percent concentration, does that mean that we have a very narrow window in which we should operate our glow plugs?

MR. MILLER: The work at AI dealt with sparkplugs.

MR. LEE: I understand that.

MR. MILLER: Small sparkplugs, 120 sparks per second sparkplugs, and the correlation between that and the glow plugs is questionable.

MR. LAWROSKI: May we not also forget getters, too, hydrogen getters?

MR. MILLER: We talked about getters at the workshop.

MR. LAWROSKI: If you get one that is truly good, you are going to have problems with oxygen.

MR. MILLER: We talked about them at the workshop, and they did not receive too much support. The R&D types are excited about it because it is a fantastic R&D project.

(General laughter.)

MR. LAWROSKI: They have their place at the battery. You have an inventory of hydrogen. If you have a getter for this purpose, wouldn't you agree that you are kind of fighting the battle between something that is going to take the hydrogen out without getting goofed up.

MR. GREGORY: I think that if you are not going to inert the containment, then the best thing to do with hydrogen is to burn it in a controlled way. If you are going to inert the containment, then you still have to get rid of the hydrogen somehow, and then you would use a getter.

MR. LEE: In order to get this type of benefit out of our sprays, what kind of spray system do we need compared to what we have right now?

MR. MILLER: These nozzles were standard. The numbers are in here, but they were standard BWR nozzles in existence. I have forgotten the number. They were standard nozzles giving you a 500 micron droplet.

MR. LEE: So we don't have anything other than guaranteeing that the sprays will work.

MR. MILLER: I am sure that you could optimize that. But there was no attempt made in this study to optimize.

There were questions concerning the actual heat sink supply is not really big enough to give you that pressure suppression. So there were questions concerning, was there a mechanical energy transfer; was a lot of the energy of that deflagration going into actually breaking the droplet apart as opposed to actually heating up and vaporizing the droplet. You really could not account for that presssure decrease just in a heat transfer heat sink type mode.

There is certainly a lot of room for optimization. This was just using standard BWR spray nozzles.

MR. LAWROSKI: My acquaintance with the suppressants -- were there any really good ones that were talked about at the workshop?

MR. MILLER: Von Alby was there, and the one mentioned by him was the Halon 1301, the CF3BR. I think that is the one most commonly in use today.

MR. SEALE: I would assume your big Nevada site test with the big container, and so on, will include some glow plug work?

MR. MILLER: Yes. A variety of ignition sources are planned to be evaluated. I can virtually guarantee you that the IVA ones will be used as one of the options. It is not my project, but i can almost guarantee that they will be used.

MR. SEALE: Okay.

MR. MILLER: The schedule on that is that we are hoping to be starting initial testing next summer, next September, somewhere in that area. Money has been allocated by our task forces. It hasn't been allocated by our Board of Directors. We are looking for co-funding. There are a bunch of options in the mill.

MR. KERR: Is your work coordinated with, in the sense that you are going to take full account of the work being done by Livermore?

MR. MILLER: Yes. We are trying to stay closely involved with all of the work, the Livermore, the Sandia, and Fettel-Frankfurt.

MR. KERR: Are there further questions.

(No response.)

MR. KERR: Thank you, Mr. Miller.

(Whereupon, at 4:15 p.m., the Committee went into executive session.)

EXECUTIVE SESSION

MR. KERR: The executive session is now in session. It is an open executive session.

I would like your comments on the two questions raised by Mr. Gilinsky, if you have any at this point, since we must deal with these as a committee at our next meeting. Do you have any suggestions for me, or the subcommittee?

Do those members of the subcommittee have any suggestions as to appropriate comments in response to Mr. Gilinsky's questions, the first one being, "Does the committee believe additional hydrogen control measures are necessary for ice containments?"

MR. SIESS: Additional to what?

MR. KERR: I don't know. I assume that it is additional to what now exists.

MR. SIESS: By what now exists, do you mean what was required of Sequoyah?

MR. KERR: I am not sure.

MR. SIESS: We wrote two letters in whatever month it was, July. We wrote one letter on Sequoyah. We wrote a letter to Mr. Gilinsky in response to a question he had raised separately. Did we say anything in those letters about hydrogen control measures for ice condensers?

MR. KERR: We commented, I think, about the approach that TVA was taking, and said that it seemed reasonable.

MR. SIESS: We had a letter from Mr. Gilinsky and a response to him at the July meeting. I don't have that in my collection here, so I am not quite sure about that. I thought the committee had a position that we did think something additional was required for ice condenser containments over what was already there before Sequoyah started talking about igniters.

MR. KERR: My interpretation of the letter, which is probably not as good as yours --

MR. SIESS: I am not trying to interpret the letter. I said, a position, but whether we have written it down anywhere, I don't know.

MR. KERR: We don't have a position until it becomes written down.

MR. SIESS: I know.

I think that in some of the letters we have written on other things, we have talked about hydrogen control for ice condensers. But specifically, I guess, the question from Mr. Gilinsky is whether either of the letters we wrote on July 15, or whatever it was, made a clear position, or whether we can cite something else, or whether we should write another letter.

MR. KERR: He refers to the letter of July 15th to him on hydrogen control measures at Sequoyah.

MR. SIESS: That is the letter I don't have in front of me, or the Sequoyah letter, for that matter, right at the moment.

What do you think the committee's position is on hydrogen control measures for ice condenser containments? Didn't we write a letter? Have we aid anythig about Mark I or Mark II containments on hydrogen.

MR. KERR: We have written a letter on TMI lessons learned in which we agreed with the staff's recommendation on inerting Mark I and Mark II containments. I don't remember our having mentioned ice condensers in that same letter.

MR. SIESS: My recollection is that we did.

MR. KERR: We did not recommend inerting them, did we?

MR. SIESS: No. We recommended that they be looked at.

MR. KERR: Yes.

MR. SIESS: There was a strong indication that at least we thought that there might be something needed to be done about ice condensers.

MR. KERR: I think that that is the case, yes.

I don't know whether Mr. Gilinsky is talking about the general case or about Sequoyah. I guess we can find out by asking, maybe.

MR. LAWROSKI: When we talk about Sequoyah, that is the immediate model?

MR. KERR: It seems to me that that would make some sense.

MR. LAWROSKI: We must not forget that there will be at least 10 of these things. Sooner or later we are going to have to bite the bullet.

MR. SIESS: In the letter to Mr. Gilinsky, we simply said, regarding the control of large amounts of hydrogen "is discussed to some extent in the committee's Sequoyah letter." So that takes care of that. We can now look at the Sequoyah letter.

I think that somebody needs to look back further because I thought I sensed a position by the committee that ice condensers, at least, had a problem.

MR. KERR: There certainly has been a concern about ice condensers.

MR. SIESS: The Committee in its March 11, 1980, report on the NTOL items recommended the licensees develop reliability assessments for their plants, and that design studies of possible hydrogen control in filter vented containments be required. This was mentioned in the Sequoyah letter.

I don't see any position in here. I see an awful lot of words, but no position.

MR. KERR: Do any of our consultants have advice for us at this point that they would be willing to volunteer?

MR. SEALE: I don't know whether it is advice, but it is some comments.

It seems to me that the ignition approach is the right way to go. I really shudder to think of all of the as yet unresolved engineering problems you would get into if you tried to do inerting, and so on, at this stage of the game in a system that was designed the other way. It does not seem like a good idea.

I am a little concerned about a problem that was mentioned by, I believe, Dr. Strehlow, regarding the possibility of the ducts and the turbulent mixtures in those ducts serving as a sort of a quasi-containment, I guess, for directing some flame fronts, or something like, from one region to another. I am not sure if I am saying it quite right, but I think that that the is the substance of what he said.

To me it is kind of interesting that the location of the plugs at this stage seems to be a question of convenience rather than maybe the most strategic place in which they might be located. I think that that can be a dangerous convenience to accept. I would hope that the TVA people would look at it in more detail and if there wasn't a more systematic way of going about locating those things.

Certainly, the glow plugs look like the right approach. I think sparkplugs would cause all kinds of problems in control instrumentation and things like that that we have not even thought about yet just because of the electro-magnetic interference effects.

In general, I think the idea of going ahead as the staff recommends, recognizing that at some point fairly soon down the road some decisions are going to be available with the glow plug approach, and hopefully putting the glow plug in a more propitious set of locations is the reasonable and prudent thing to do.

MR. SIEGEL: I more or less second the comments that Seale has made. I think the glow plugs are an appropriate interim solution to be adopted. I feel rather strongly that the vent system -- you cannot move the glow plugs, the exists from the vent system ought to be somehow adapted to be located closer to one or more glow plugs. I personally would emphasize the more or so, to give some redundancy.

As you said, Dr. Kerr, I don't think we can fully identify where the hydrogen is going to come from in the next event, but at least there are some plausible places where it might be planned for. I think that those plans should be coordinated with the locations of the glow plugs.

If it is too hard to move the plugs, then let's adapt the vent system, but combine them in some reasonably logical fashion.

If this can be done in a timely way so that the proposed operation at one percent power can occur more or less simultaneously with the installation of this combined vent and glow plug system, then I have no reservations about the recommendations of the staff.

On the other hand, I would dislike seeing the thing being an interim-interim measure where 100 percent operation continues for some extended period before even the glow plugs come into availability.

MR. KERR: If I understand the staff's recommendation, they are willing to recommend that Sequoyah be permitted to go to 100 percent power with the idea that since they are in a testing phase the total amount of 100 percent power operation between now and the glow plug approval time is likely to be something like not more than a month full power days.

MR. SIEGEL: What concerns me about that particular recommendation is whether operation at 100 percent power would impede any additional, hopefully, minor modifications to the glow plug array or the installation of some additional vent system. I would rather have those changes added to the interim plan, rather than to have those changes impeded by the 100 percent operation even for a brief period.

DR. KERR: I think the points you are raising are very good. I don't know enough about the ignition system to know where the plugs should be put. It occurs to me that if you put them too close to the source of hydrogen, at least it seems to me in principle, to be possible that you will be igniting the hydrogen in a situation in which the concentration is considerably greater than if it were permitted to diffuse somewhat, which might be an argument against putting it near a vent. On the other hand, if you put it near the vent, then you are more likely to ignite it earlier.

What I am saying is that there are possible trade-offs here which I would not know how to answer on the basis of what I have heard so far.

MR. SIEGEL: I fully agree with you. There is some optimum place, and that optimum place would be -- It would be extremely fortunate if that optimum was where the emergency lightbulb happened to be.

MR. LEE: May I make some comments?

MR. KERR: Please.

MR. LEE: I feel somewhat less encouraged, perhaps, about the ignition system than the two gentlemen who have commented on the system, for a couple of reasons.

One is, even with the addition of the ignition system, one may not be able to disregard the possibility of local detonations, and with all the compartments, and so on, one might have to contend with.

The second point, perhaps, Brookhaven National Lab people reported that one might have to worry about some of the foam padding or cover that exists around the ice condenser, and so on, and not based on my expertise at all, which is practically nothing in this area, but my gut feeling is to rely on flame, even at low propagation speed, I feel a little bit uneasy about it. I would like to explore the possibility of using some suppressant, halon 1301 or some other mechanism, or a combination of several possibilities.

Those things, perhaps, should be explored a little bit more, perhaps as actively, although I feel the issue of ignition system perhaps has gone far along so that we should certainly try out more either in the test facilities or also in the actual plant in some way.

I feel somewhat uneasy about the ignition system partly because in response to one of my earlier questions, if this type of system had ever been used with hydrogen, the answer was no. To try it out on a large containment for the first time, I feel somewhat uneasy.

MR. SIEGEL: I would like to add a comment, or a question that Mr. Lee's comments reminded me of. In reading the description, I, too, was concerned about this one word description of the foam insulation around the ice condenser. In view of the things that we have heard about in airplanes and in the BART system, that can be a very suspect material, particularly if you have an atmosphere that is up at 1500 degrees for a few minutes.

We did not hear anything about that today in response to my concerns about what else happens when the atmosphere gets up to 1500 degrees for several minutes.

MR. KERR: Mr. Gregory?

MR. GREGORY: I would like to agree with the general comments that were made over here that an ignition system does seem to be the way to go, and more consideration should be given to the design placement of the igniters.

In general, there are two standard ways of dealing with flammable gases leaking into spaces. One is to deliberately eliminate the ignition sources, and the other is to deliberately ignition sources in a place where you ignite the flammable gas before it gets out of control.

The obvious example that we are all familiar with is in our own gas domestic appliances, the pilot flame, or the spark igniter is always located very, very close to the burner. I think we have to look at the same philosophy in the system.

It should be possible to make some pretty educated guess as to where the most likely place is that hydrogen will come out into the containment in the event of various types of accidents, and to make sure that there is an ignition source right there.

I would like to make one observation that would bother me a little bit about glow plugs. Glow plugs are not normally used in hydrogen ignition or flammable gas ignition systems, whereas standing pilots and spark ignition system have got a record of being used for this kind of thing.

We are embarking on an ignition technique which perhaps is not well established in the industry, it just occurs to me that a sparkplug in an engine operates many, many millions of time in its life, and a glow plug only operates for a few thousand times in its life. I just wonder if the spark system should not be, perhaps, reconsidered.

MR. KERR: Any further comments on that?

MR. SEALE: I will just observe that IEEE 279 control rod circuits are a beautiful antenna, and more than once reactors have been scrammed because of high frequency electro-magnetic disturbances.

MR. SIEGEL: But hopefully the reactors have been scrammed when these things go on.

MR. SEALE: That is right.

MR. KERR: Are there any other comments?

(No response.)

MR. KERR: Let me thank all of you for your attendance and participation. The meeting is adjourned.

(Whereupon, at 4:30 p.m., the meeting was adjourned.)

NUCLEAR REGULATORY COMMISSION

This is to certify that the attached proceedings before the

ACRS Subcommittee on Class 9 Accidents

in the matter of:

Date of Proceeding: August 28, 1980

Docket Number:

Place of Proceeding: Washington, D. C.

were held as herein appears, and that this is the original transcript thereof for the file of the Commission.

David R. Parker

Official Reporter (Typed)

(SIGNATURE OF REPORTER)

NUCLEAR REGULATORY COMMISSION

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Suzanne Babineau

Official Reporter (Typed)

Suzanne Babineau

Official Reporter (Signature)

Tape 1/5RB
+2

HYDROGEN BURNING IN ICE CONDENSER CONTAINMENT

by

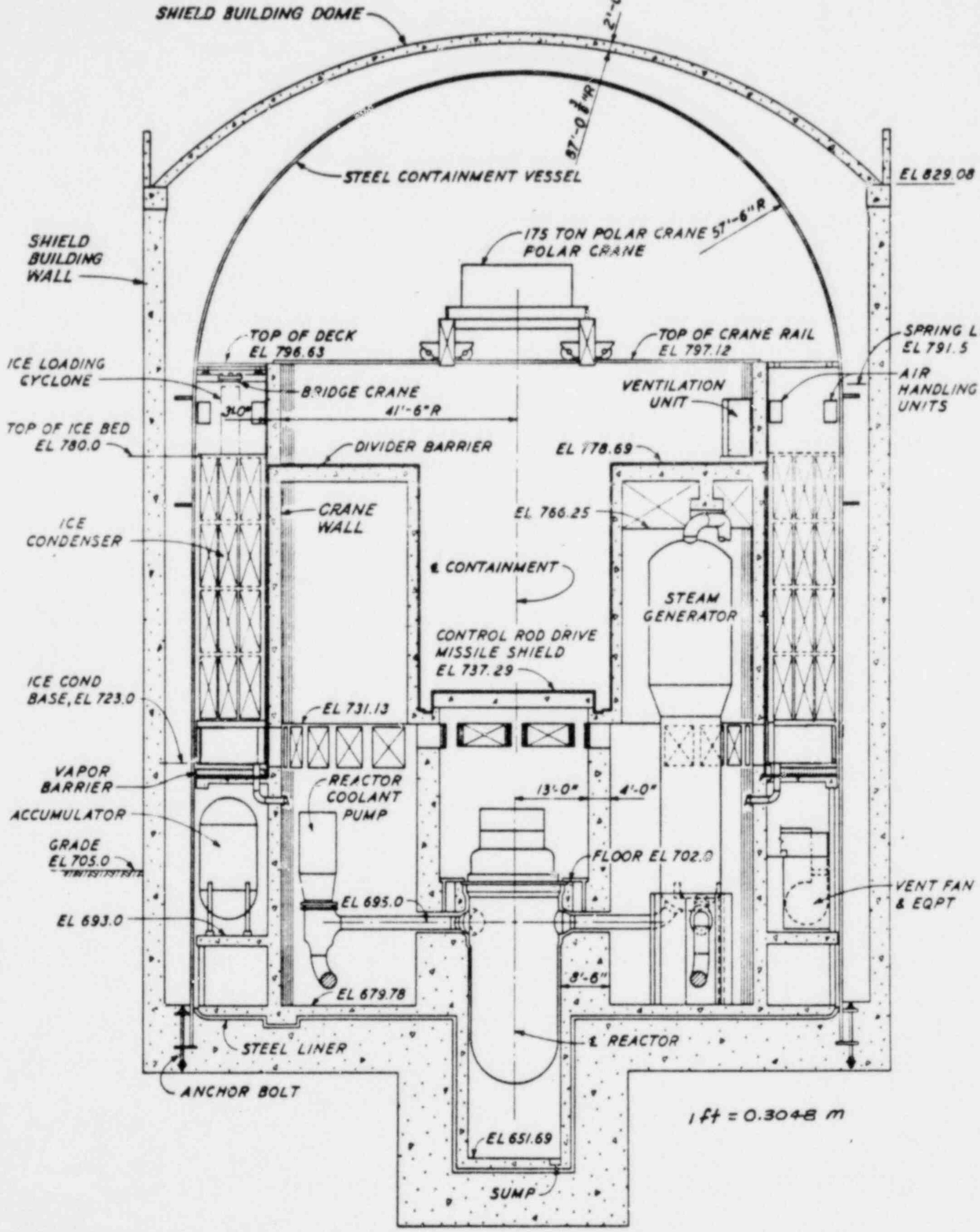
Peter Cybulskis

Presentation to:

ACRS Class 9 Accident Subcommittee
Washington, D.C.

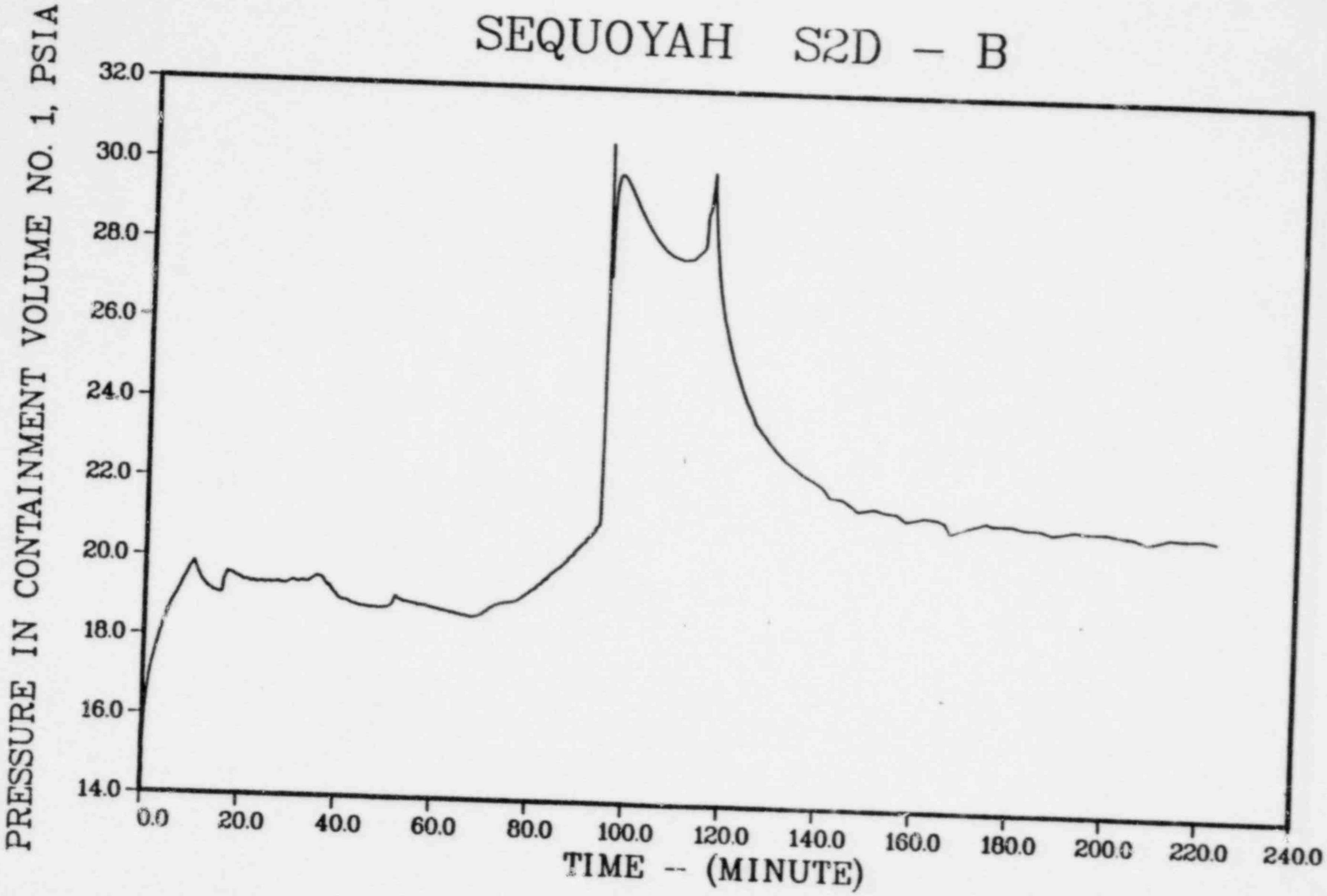
August 28, 1980

BATTELLE
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201

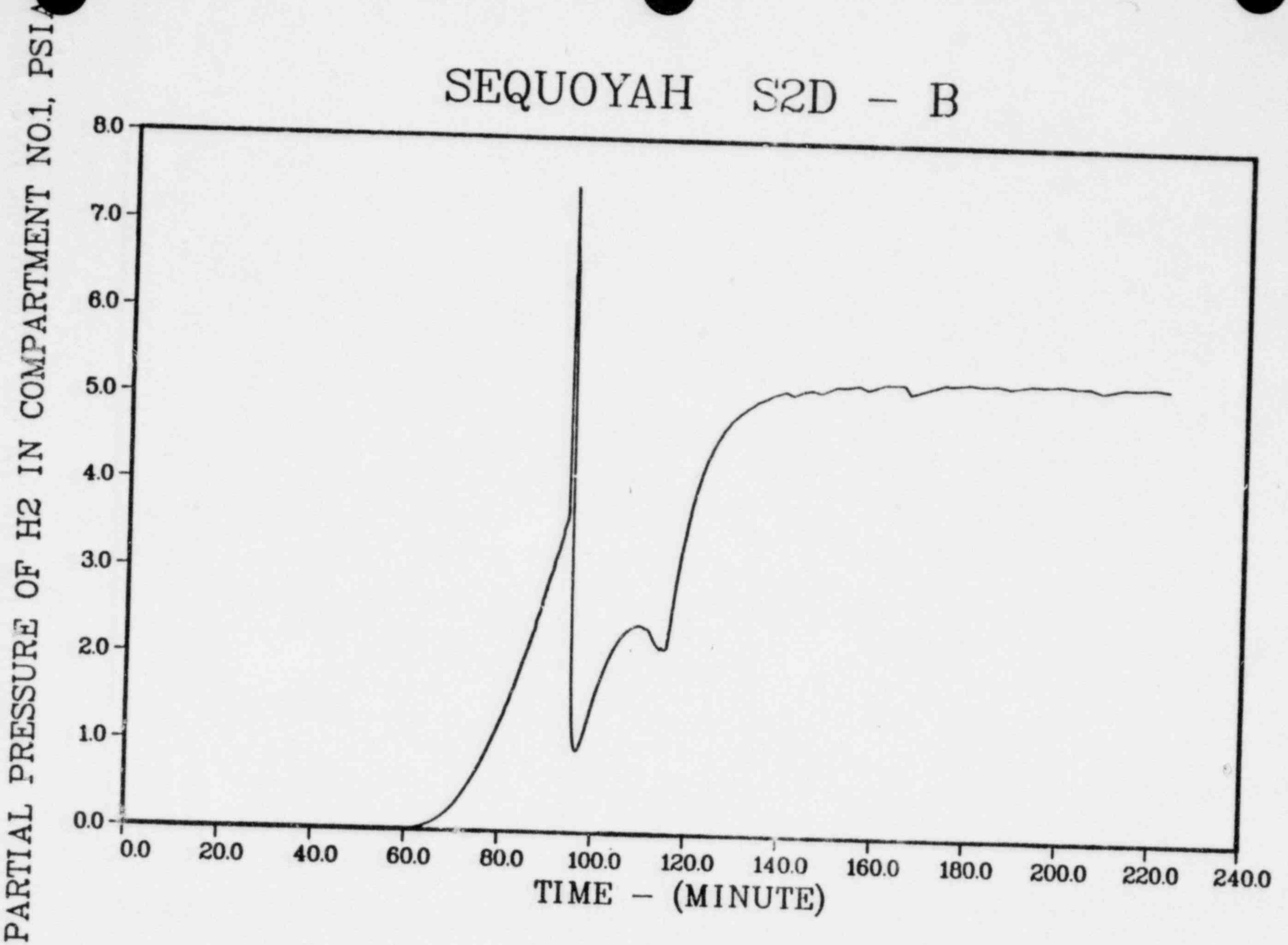


1 ft = 0.3048 m

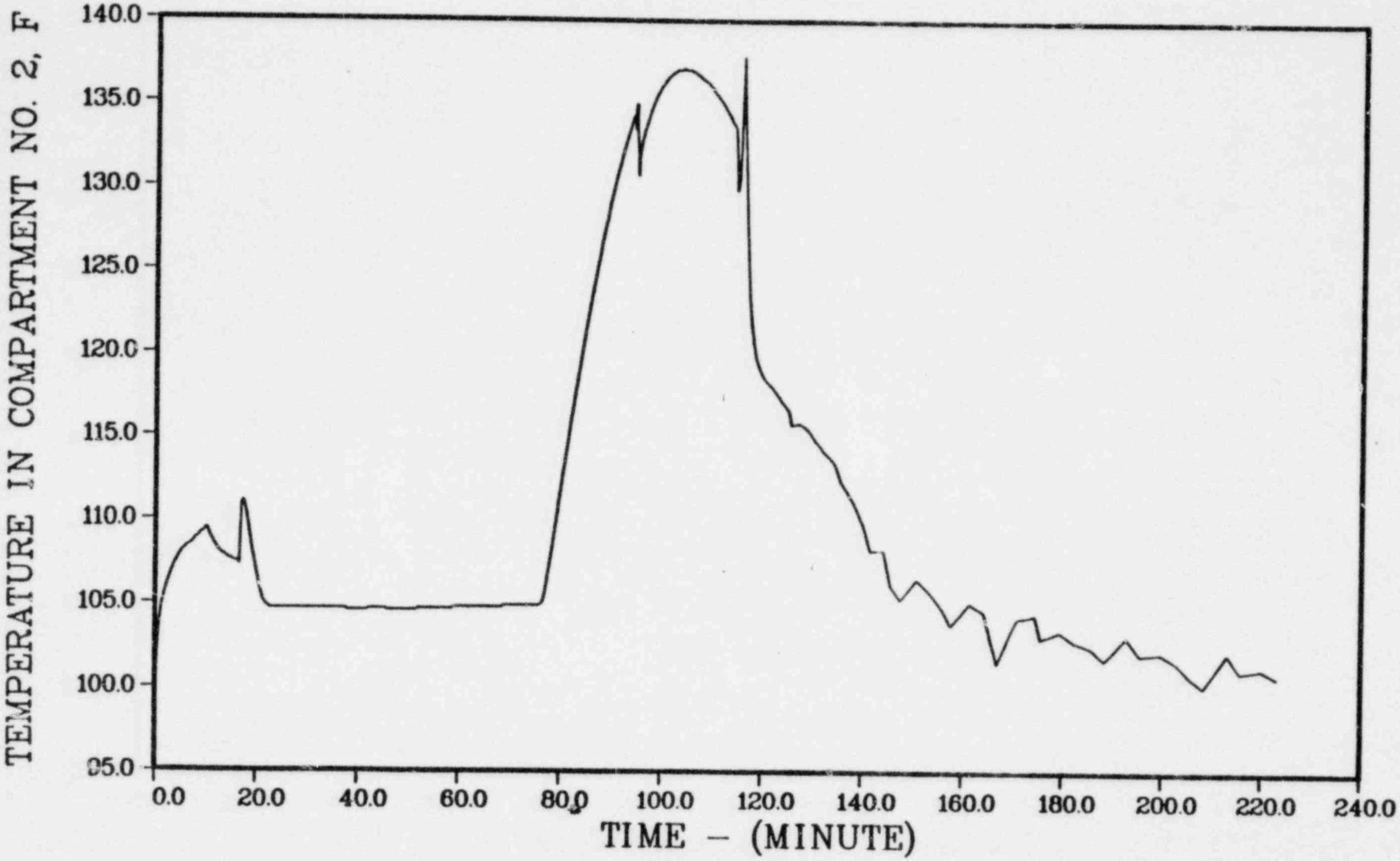
Figure 3.8.1-1 Reactor Building Elevation

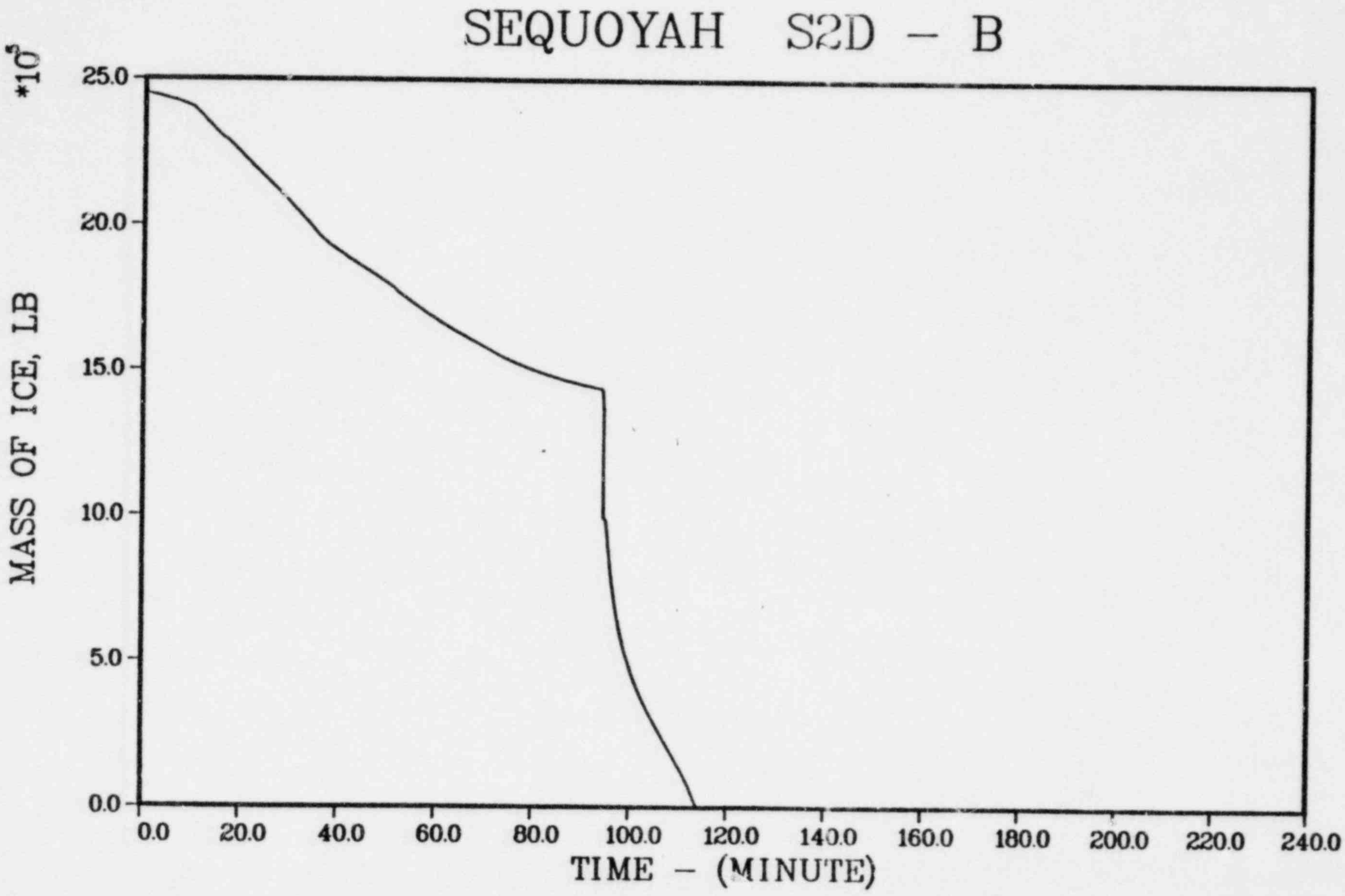


SEQUOYAH S2D - B


SEQUOYAH S2D - B

SEQUOYAH S2D – B




SEQUOYAH S2D - B
*10^5
MASS OF ICE, LB
25.0
20.0
15.0
10.0
5.0
0.0
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
180.0
200.0
220.0
240.0
TIME - (MINUTE)

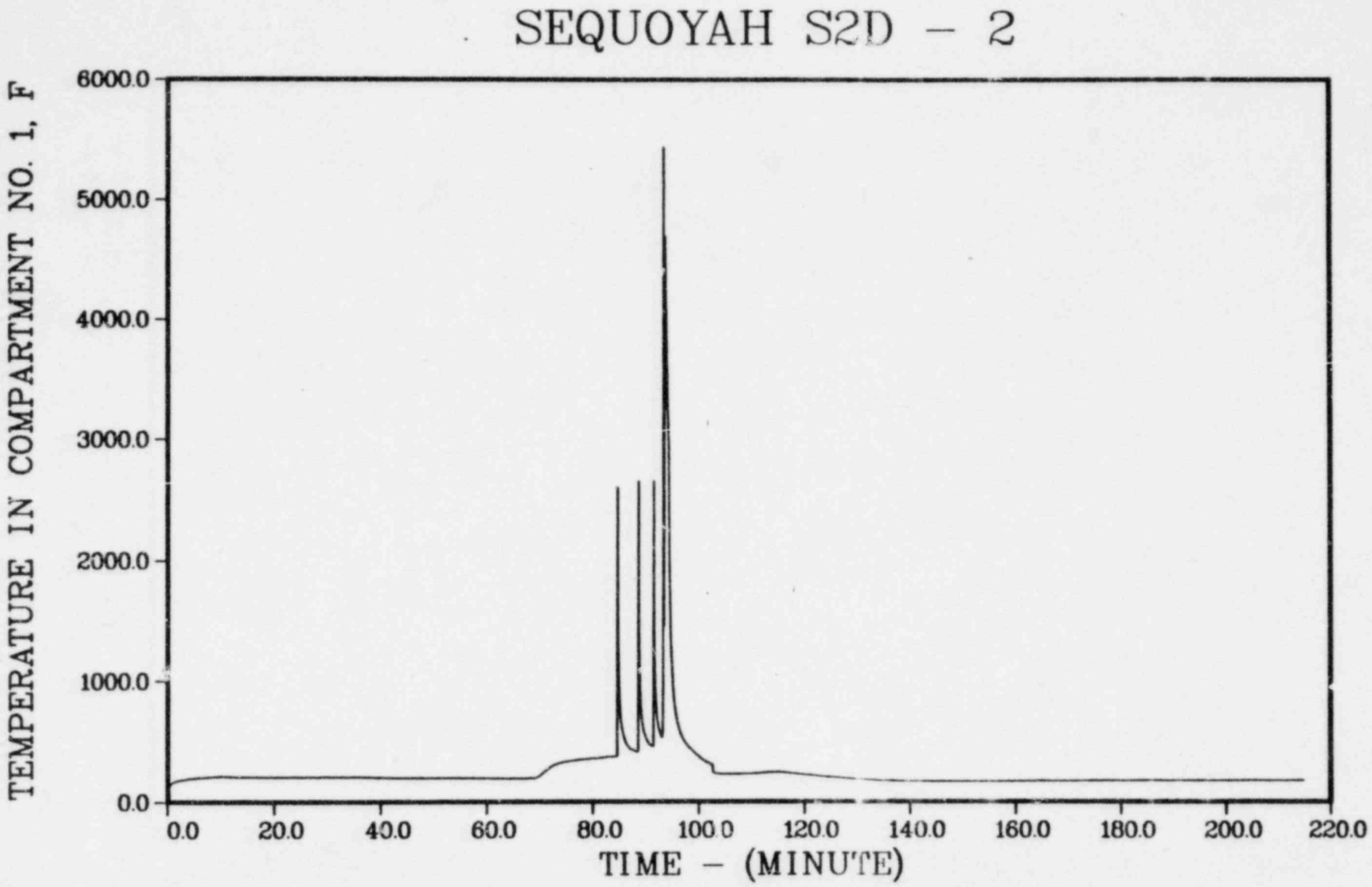
SUMMARY OF RESULTS

Case	Ignition Point v/o H_2	Burn Limit v/o H_2	Burn Time, sec	Flame Propagation 1 ⇅ 2	PT psia(1)	PNEW psia(2)	PMAX psia(3)
1	10	0	1	no	23	58	141
2	10	0	5	no	23	58	136
3	10	0	25	no	22	58	131
1X	10	0	1	yes	44	58	126
1X(5)	10	0	1	yes	53	66	150
4	10	4	1	no	22	44	122
5	10	4	25	no	22	44	114
6	12	0	1	no	24	64	141
7	12	0	25	no	23	64	137
6X(5)	12	0	1	yes	60	71	181
8	8	0	1	no	22	51	132
9	8	0	25	no	22	51	127
10	8	4	1	no	22	36	120
11	8	4	25	no	21	36	110
10X	8	4	1	yes	27	36	112
1B	4	0	1	yes	24	41	111
17(4)	10	0	1	no	31	79	146
18(4,5)	10	0	1	no	35	68	223
19(4,5)	10	0	1	yes	50	66	149

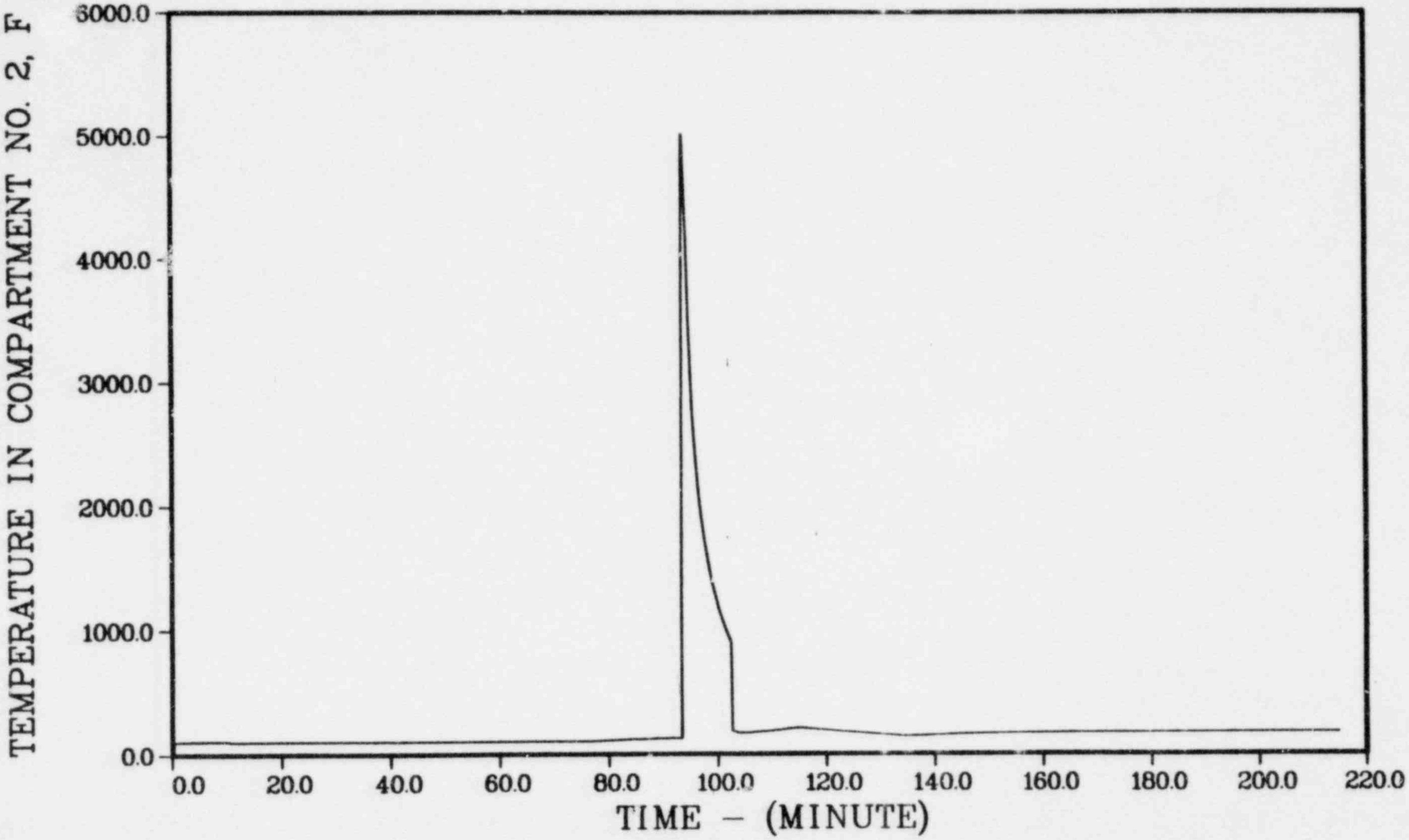
(1) Peak pressure prior to core slump
(2) Peak adiabatic H_2 burn pressure prior to core slump
(3) Peak containment pressure after head failure
(4) Ice melt complete at 21 minutes
(5) Modified treatment of suspended water droplets

Battelle
Columbus Laboratories

PLOT 2 19.40 RI 8 AUG, 1980 JOB-SEQUOKR , BATTELLE BCC DISSPLA VER 8.



LOT 5   19.41.[illegible] RI 8 AUG, 1980   JOB-SEQUOKR , BATTELLE BCC DISSPLA VER 8.2



SEQUOYAH S2D – 2

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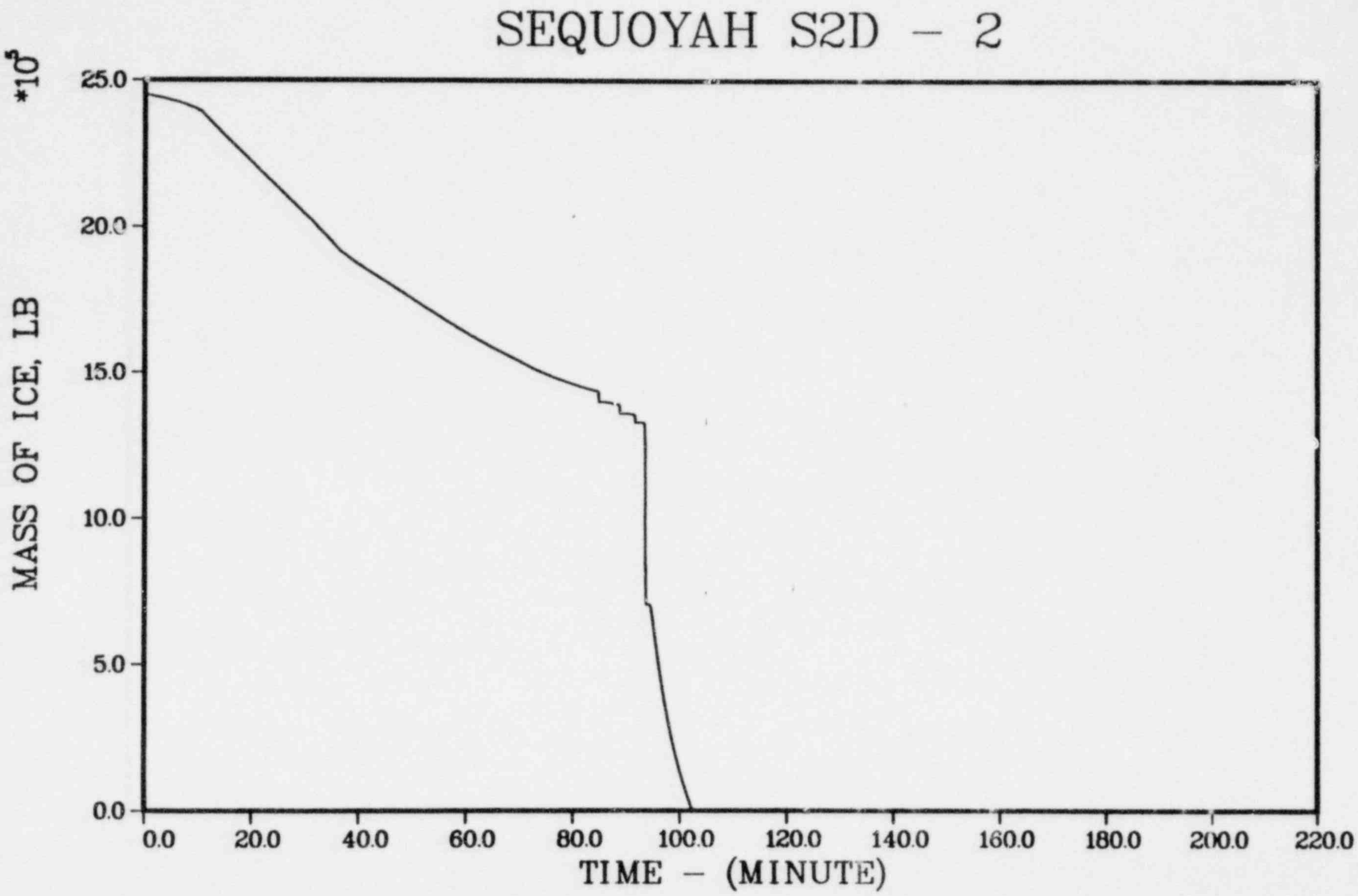


Tape 3

TVA ANALYSES

- Analytical Effort
  - Westinghouse/Offshore Power Systems
  - About/year study of critical parameters for various accident scenarios to determine containment response
  - Using CLASIX code (under development)

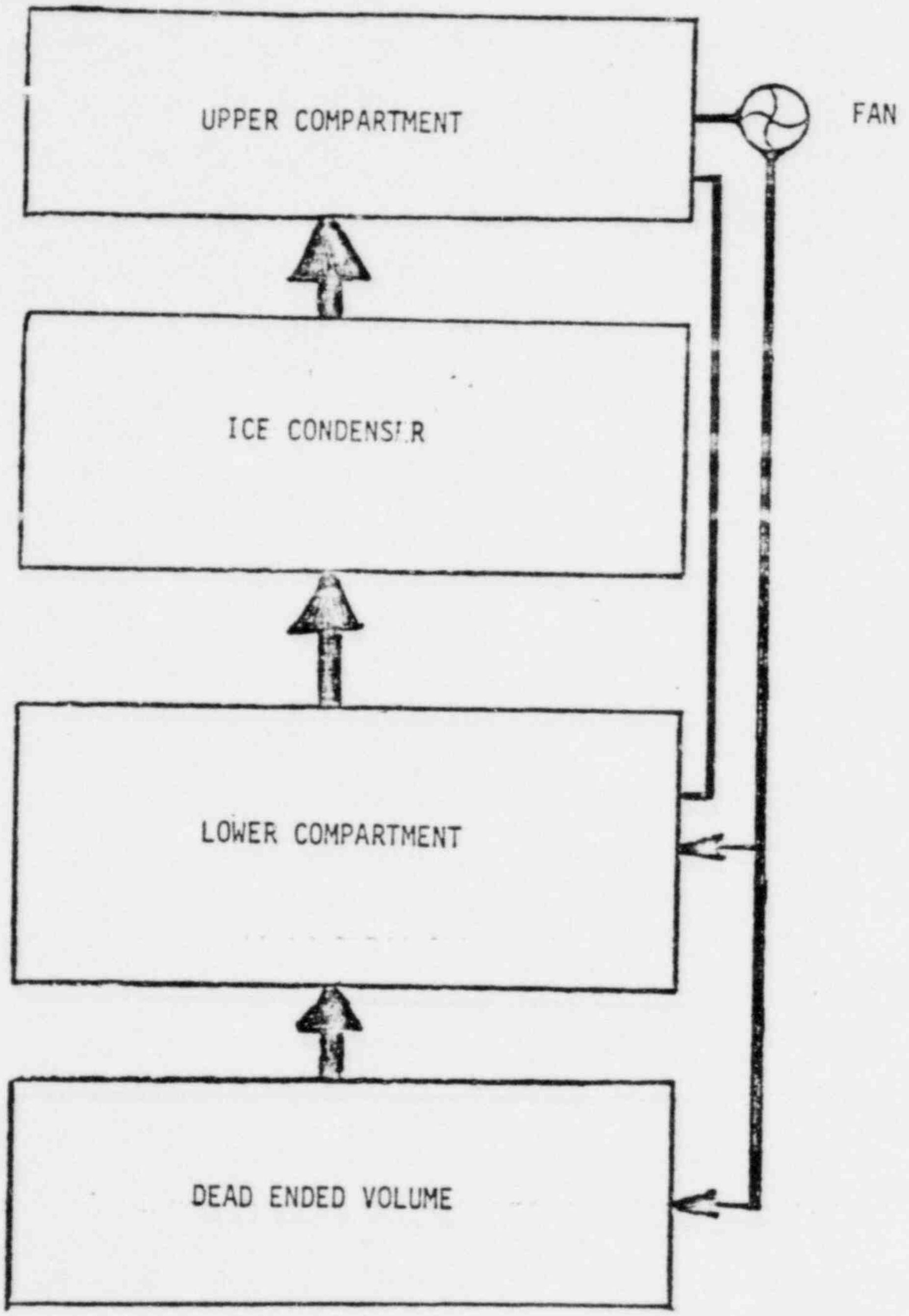
CLASIX CAPABILITIES

1. VENT FROM UPPER COMPARTMENT
2. ICE CONDENSER
3. RECIRCULATION FAN
4. DOORS - LOWER INLET AND INTERMEDIATE
5. INDIVIDUAL REPRESENTATION OF O_2, H_2, N_2 AND H_2O
6. SATURATED AND SUPER-HEATED STEAM
7. SPRAYS
8. H_2, N_2 AND HEAT ADDITIONS
9. BREAK FLOW
10. BURN CONTROL

- Preliminary analytical results
  - selected small break LOCA resulting in degraded core cooling (S_2D sequence of WASH-1400)
  - Rate of hydrogen release based on MARCH code calculation (onset of hydrogen release 3500 sec after accident initiation and assumed to continue unimpeded for 3000 sec, resulting in reaction of about 70% of total zirconium in core)
  - hydrogen combustion assumed when 10 volume percent hydrogen reached
  - varied assumptions regarding air return fan and upper compartment spray performance, and ice availability.

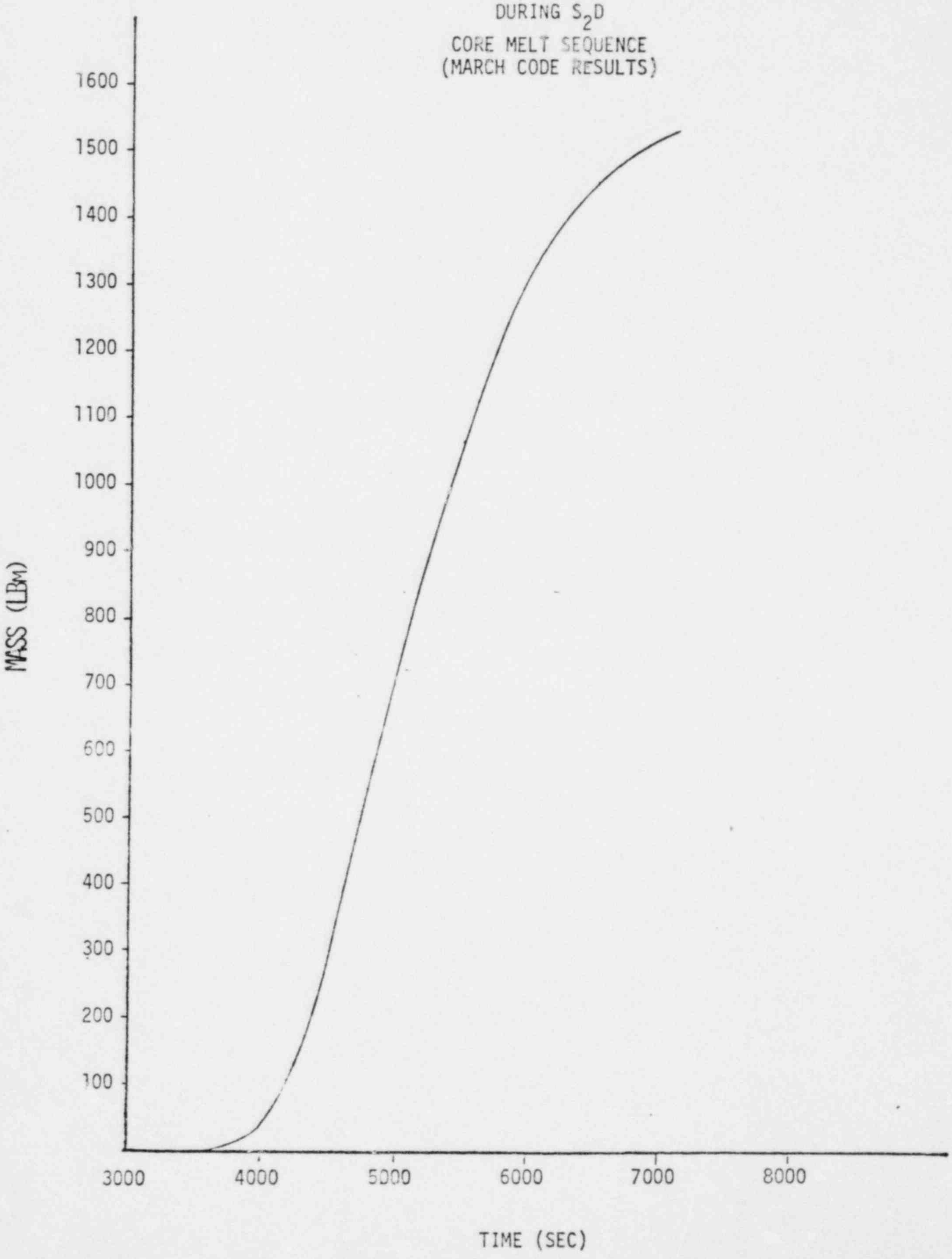
BASE CASE PARAMETERS

1. INITIAL CONDITIONS:	VOLUMES	
	TEMPERATURES	
	PRESSURES	LOTIC
	ICE MASS	CODE
	ICE HEAT TRANSFER AREA	
2. BURN PARAMETERS:	H_2 FOR IGNITION	10 V/O
	H_2 FOR PROPAGATION	10 V/O
	O_2 FOR IGNITION	5 V/O
3. AIR RETURN FANS:	NUMBER OF FANS	2
	CAPACITY OF EACH FAN	40000 CFM
4. SPRAY SYSTEM:	FLOW RATE	6000 GPM
	TEMPERATURE	125 F
	HEAT TRANSFER COEFFICIENT	20 BTU/HR FT^{2}F
5. ICE CONDENSER DRAIN TEMPERATURE		32 F
6. BREAK RELEASE DATA		MARCH CODE



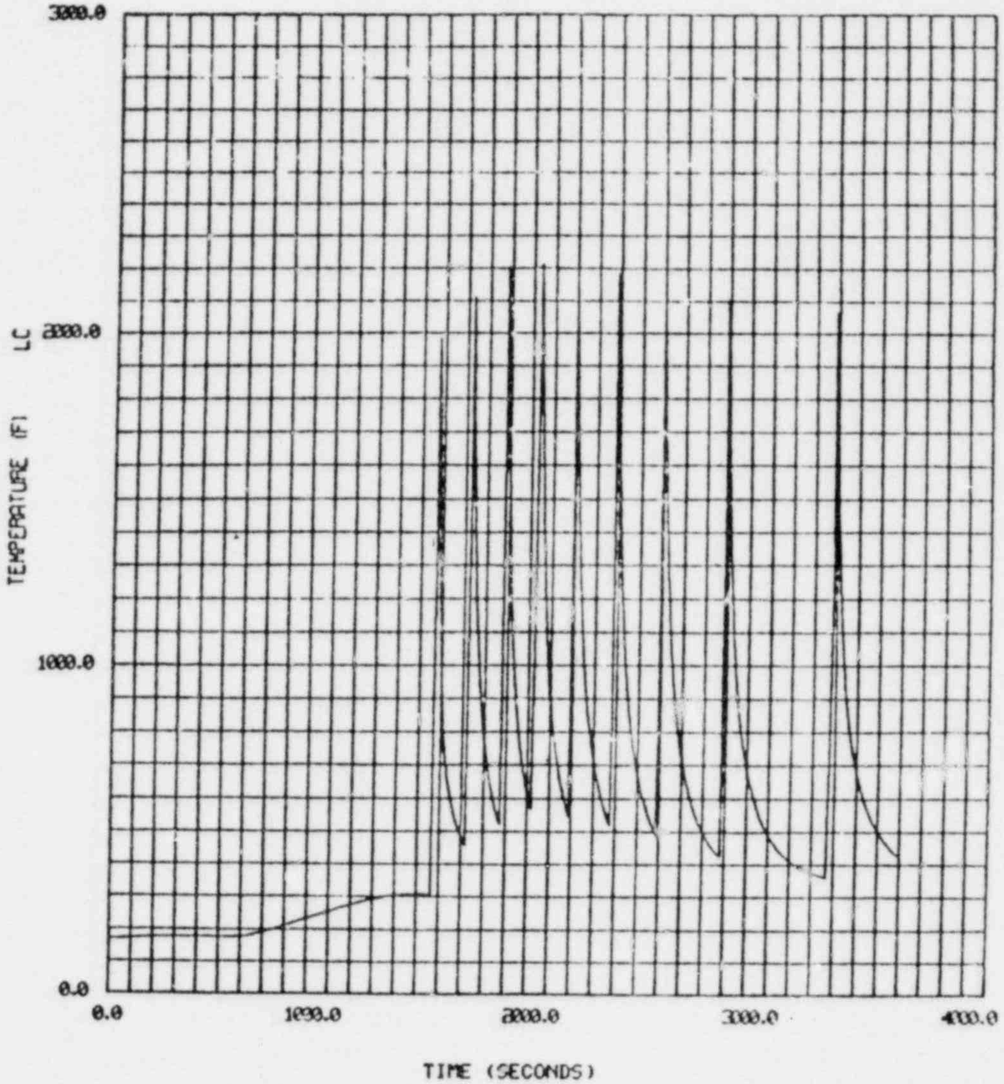
CLASIX MODEL OF ICE CONDENSER CONTAINMENT

HYDROGEN PRODUCTION
DURING S_2D
CORE MELT SEQUENCE
(MARCH CODE RESULTS)



READY-

FRAME 01 ,

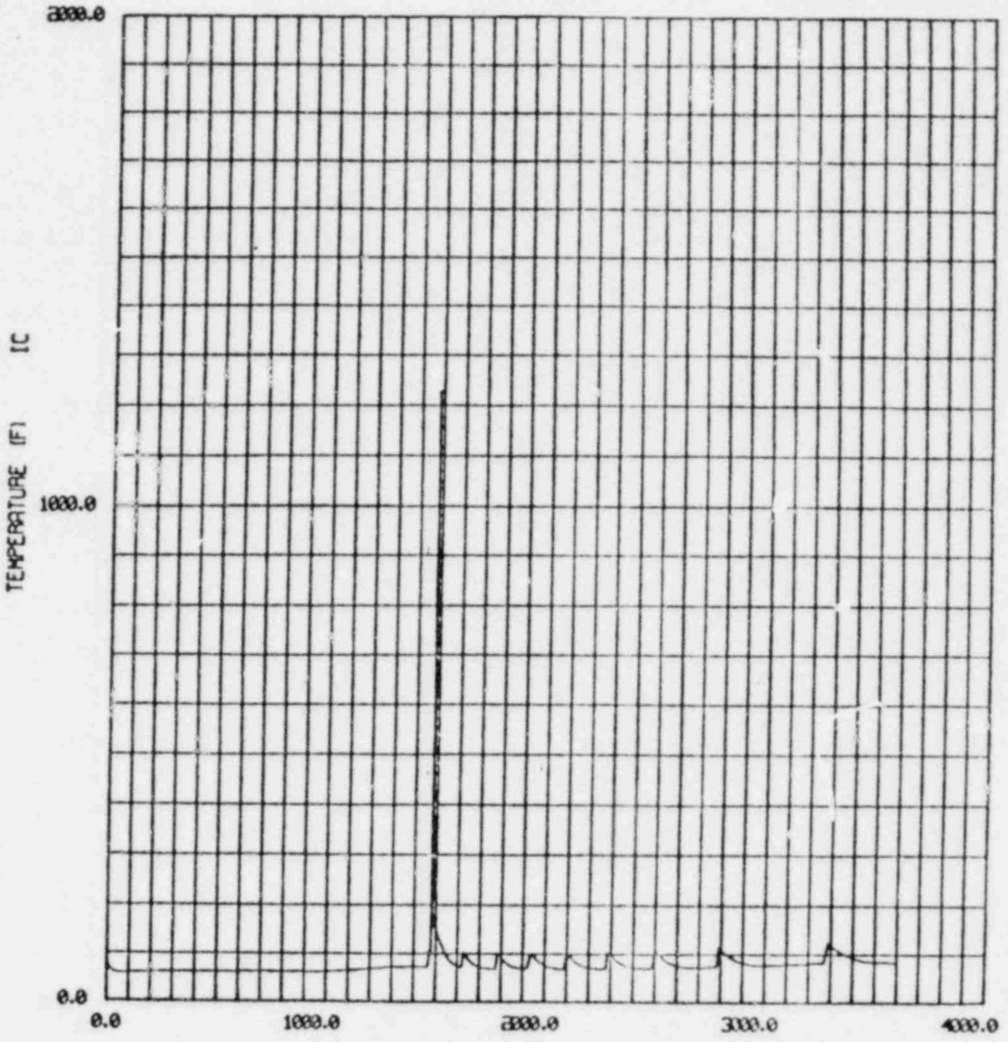


TVA S2D CASE1 2 FAN 1 SPRAY BURN 100 PCT AT 10 V 0 6FPS T+3480 BASE1

LOWER COMPARTMENT TEMPERATURE

READY-

FRAME #2

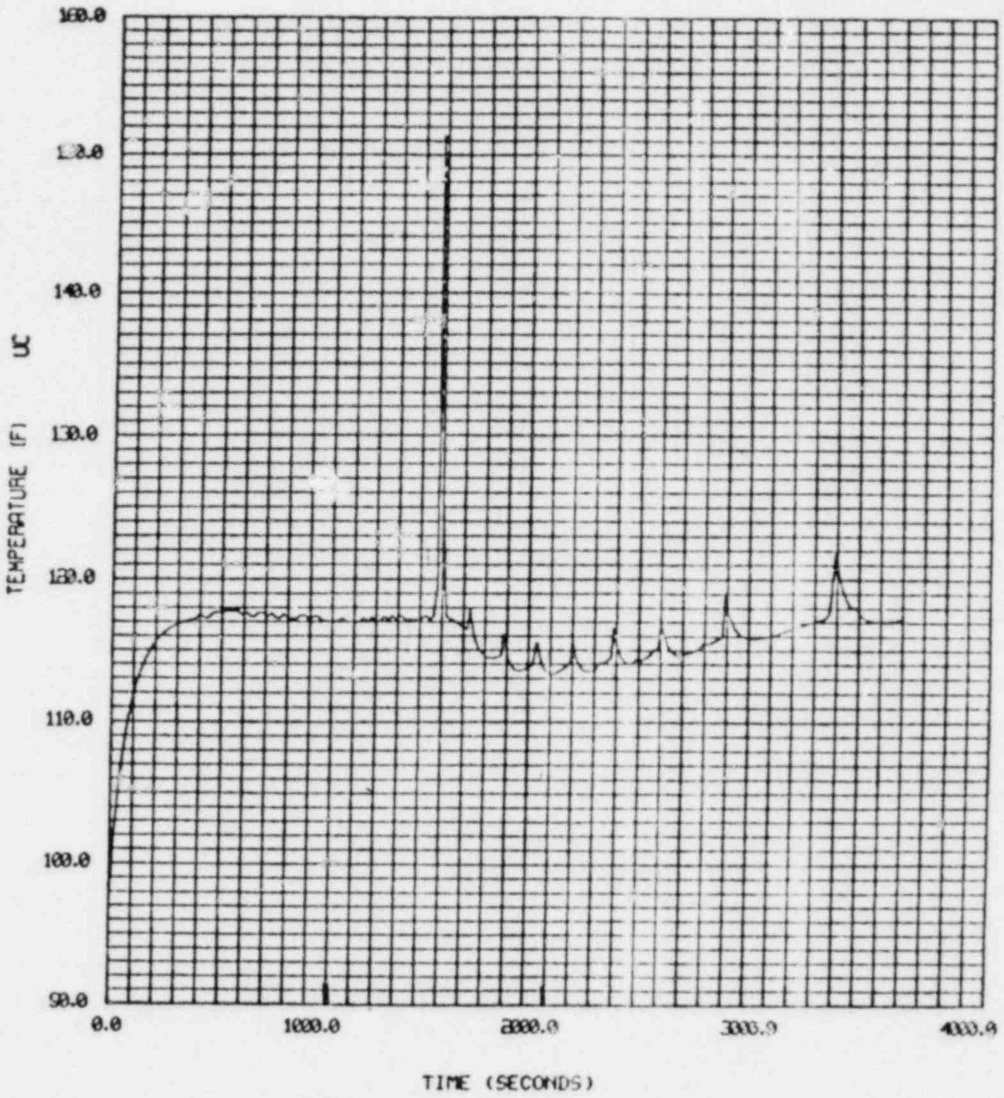


TVA S2D CASE1 2 FAN 1 SPRAY BURN 100 PCT AT 10 V 0 6FPS T+3480 BASE1

ICE CONDENSER TEMPERATURE

READY-

FRAME 03

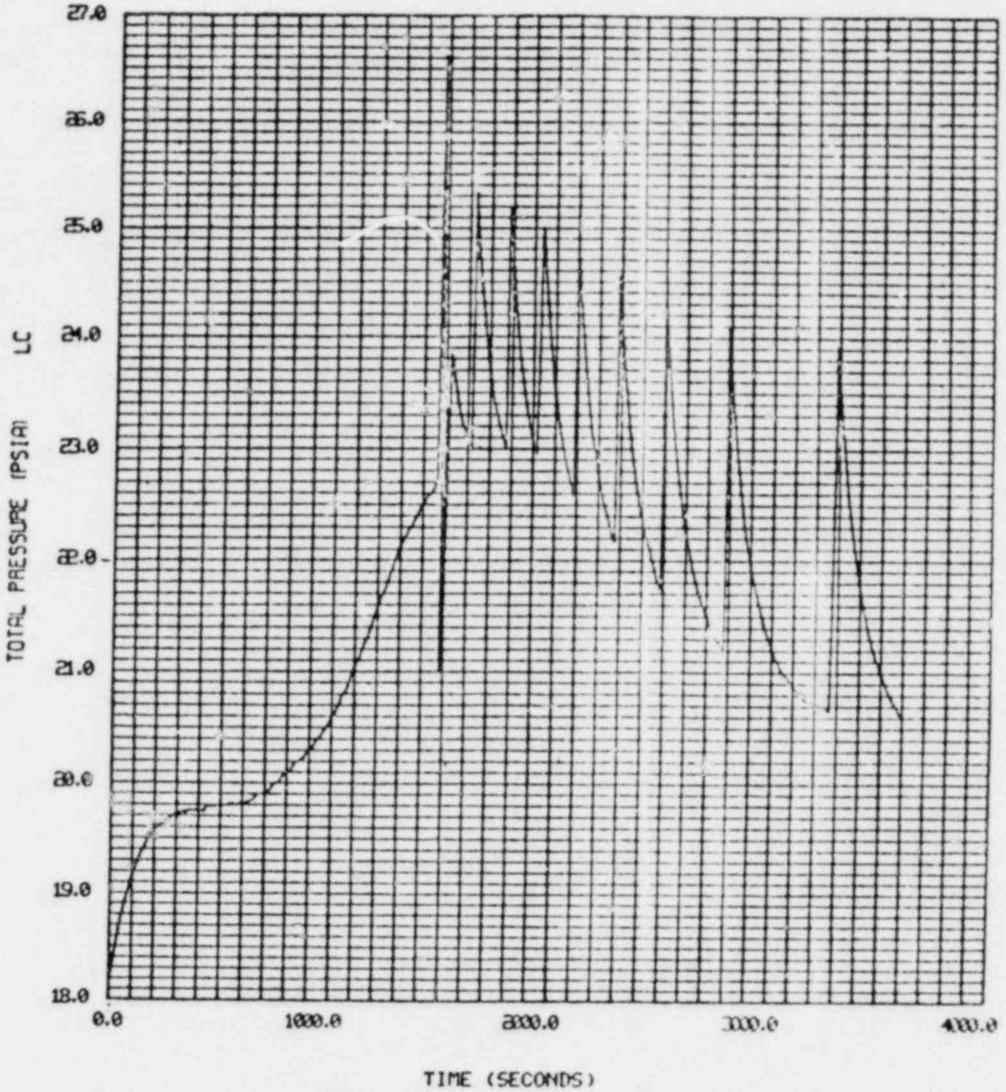


TVA S2D CASE1 2 FAN 1 SPRAY BURN 100 PCT AT 10 V @ 6FPS T+3490 BASE1

UPPER COMPARTMENT TEMPERATURE

READY-

FRAME 05 F,5

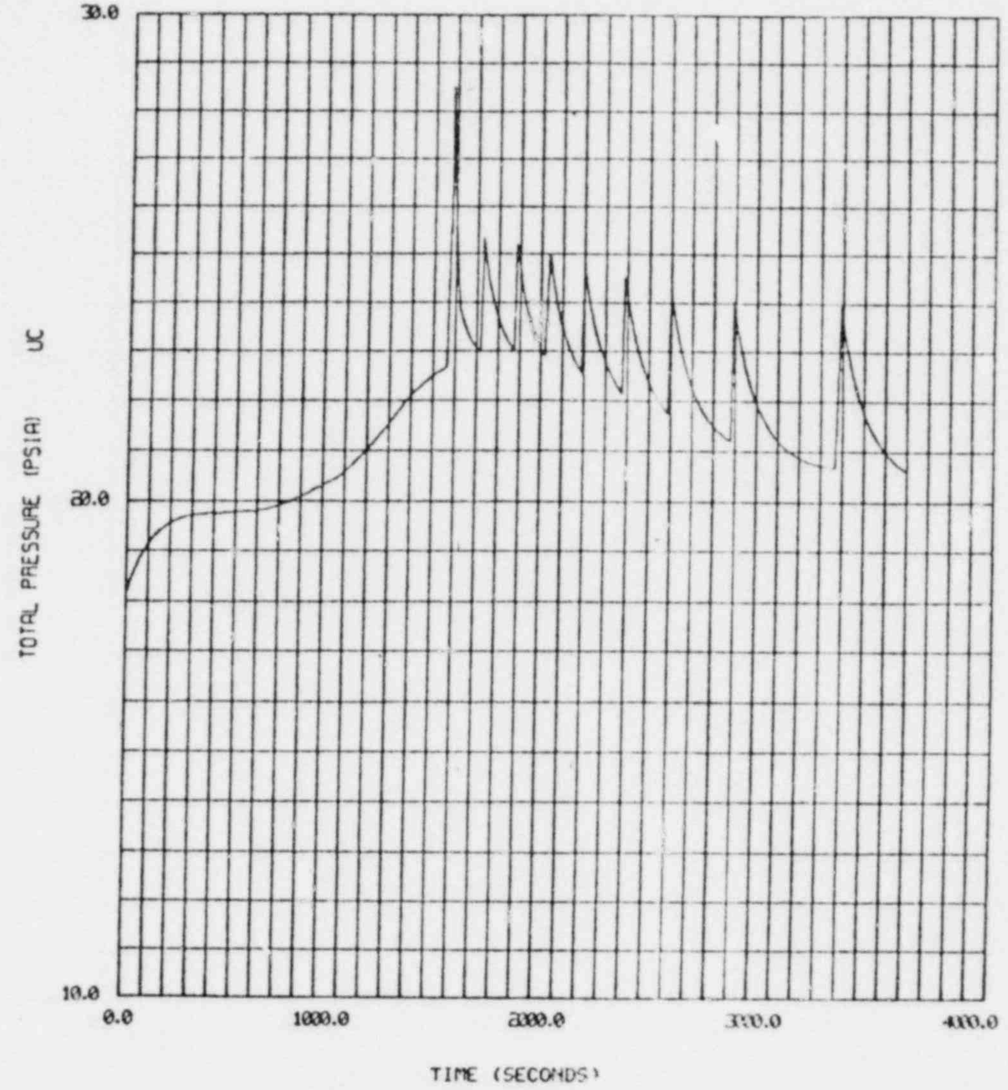


TVA S2D CASE1 2 FAN 1 SPRAY BURN 100 PCT AT 10 V 0 FPS T+3480 BASE1

LOWER COMPARTMENT PRESSURE

READY-

FRAME 07 1

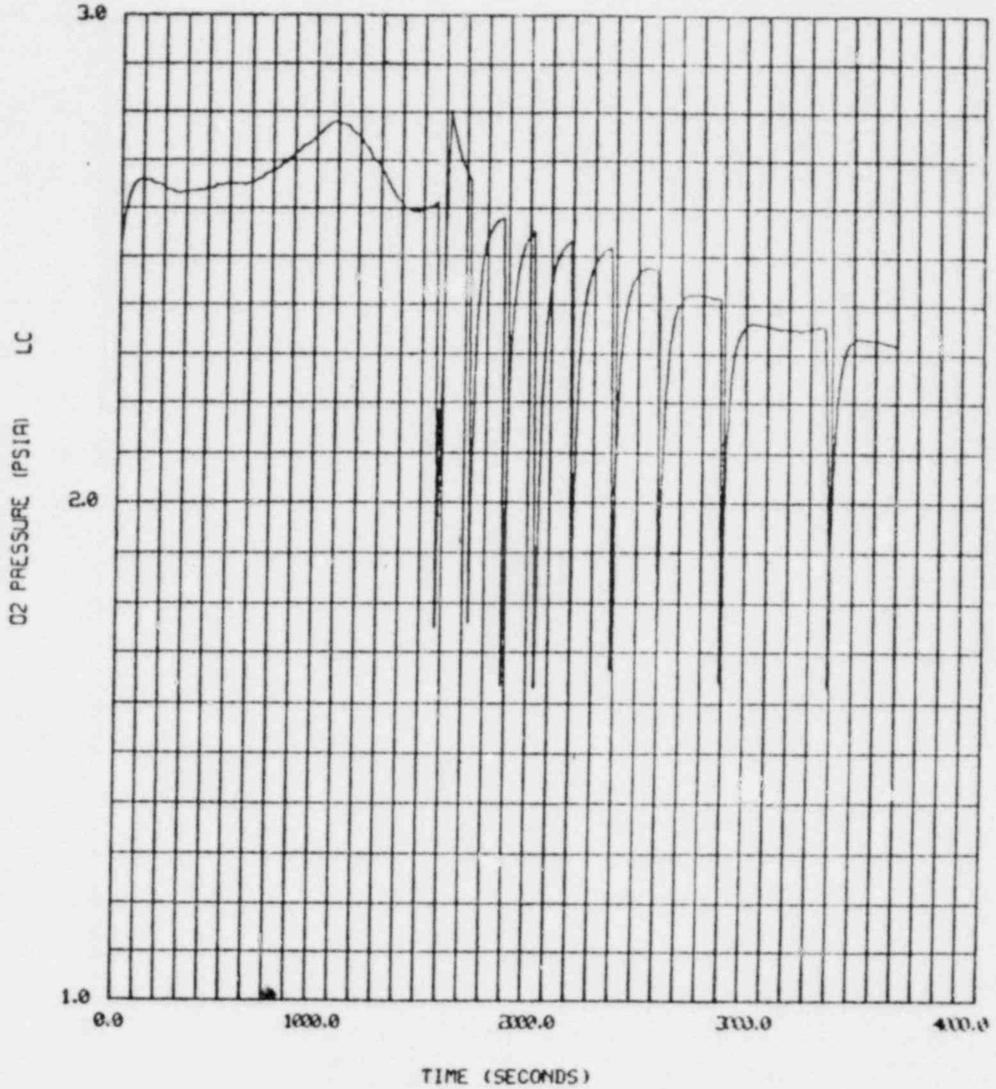


TVA S2D CASE1 2 FAN 1 SPRAY BURN 100 PCT AT 10 V 0 6FPS T+3480 BASE1

UPPER COMPARTMENT PRESSURE

READY-

FRAME 09

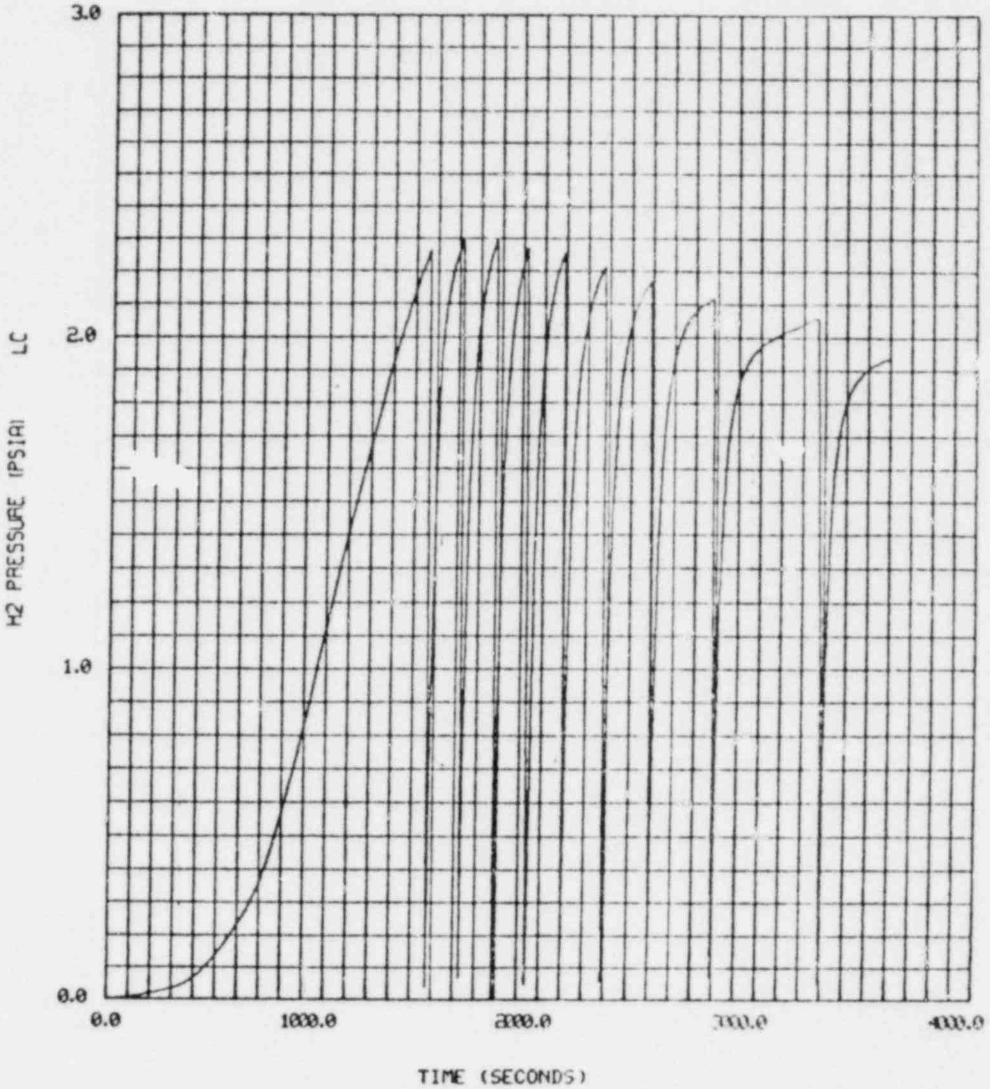


TVA S2D CASE1 2 FAN 1 SPRAY BURN 100 PCT AT 10 V 0 6FPS T+3480 BASE1

LOWER COMPARTMENT OXYGEN

READY-

FRAME 17 F,17

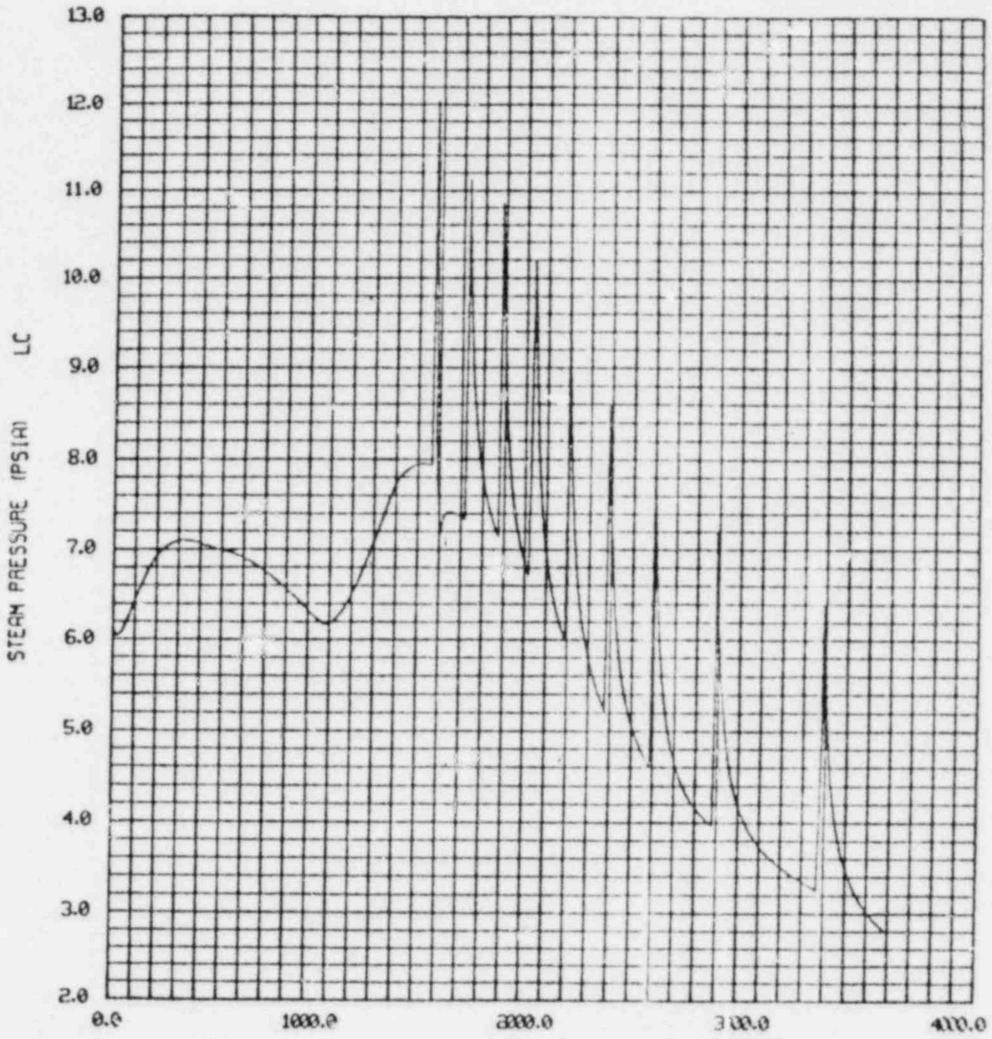


TVA S2D CASE1 2 FAN 1 SPRAY BURN 100 PCT AT 10 V 0 6FPS T+3480 BASE1

LOWER COMPARTMENT HYDROGEN

READY-

FRAME 21 F.21

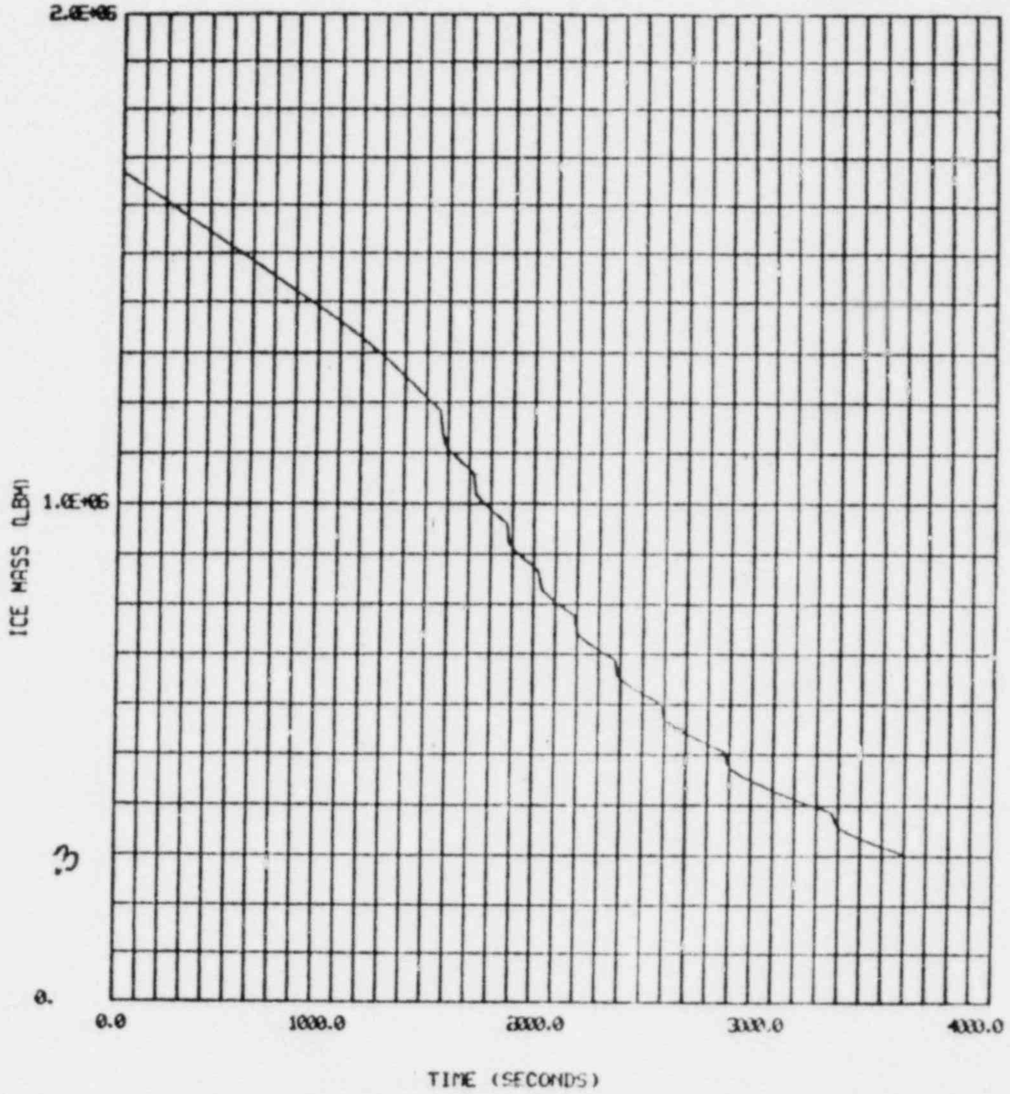


TVA S2D CASE1 2 FAN 1 SPRAY BURN 100 PCT AT 10 V 0 EFPS T+3480 BASE1

LOWER COMPARTMENT STEAM

READY-

FRAME 41 F,41



TVA S2D CASE1 2 FAN 1 SPRAY BURN 100 PCT AT 10 V 0 6FPS T+3480 BASE1

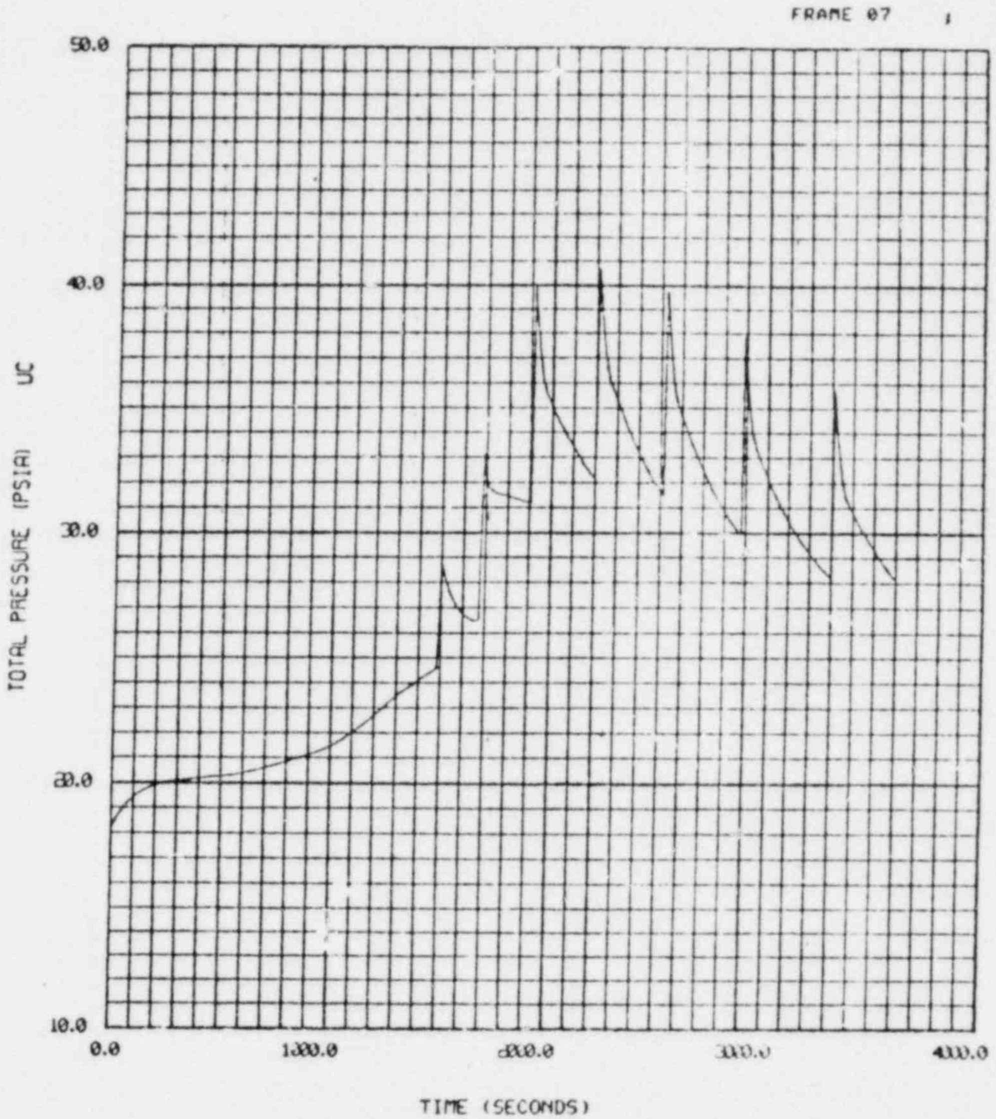
ICE MASS

TABLE 1. PRELIMINARY CONTAINMENT ANALYSIS SENSITIVITY STUDIES

	TOTAL H_2 BURNED (LB)	PEAK TEMP. (^{o}F)			PEAK PRESS (PSIA)	
		LOWER COMPARTMENT	ICE BED	UPPER COMP.	LOWER COMP.	UPPER COMP.
1. BASE CASE	900	2200	1200	150	26.5	28.5
2. H_2 IGNITION AND PROPAGATION @ 8%	1050	1200	700	260	28.5	30.5
3. 1 AIR FAN	900	2200	1350	160	26.5	29.5
4. NO ICE*	850	2400	2000	270	41	41
5. NO AIR FANS	1200	2370	2580	1090	46.4	92.4

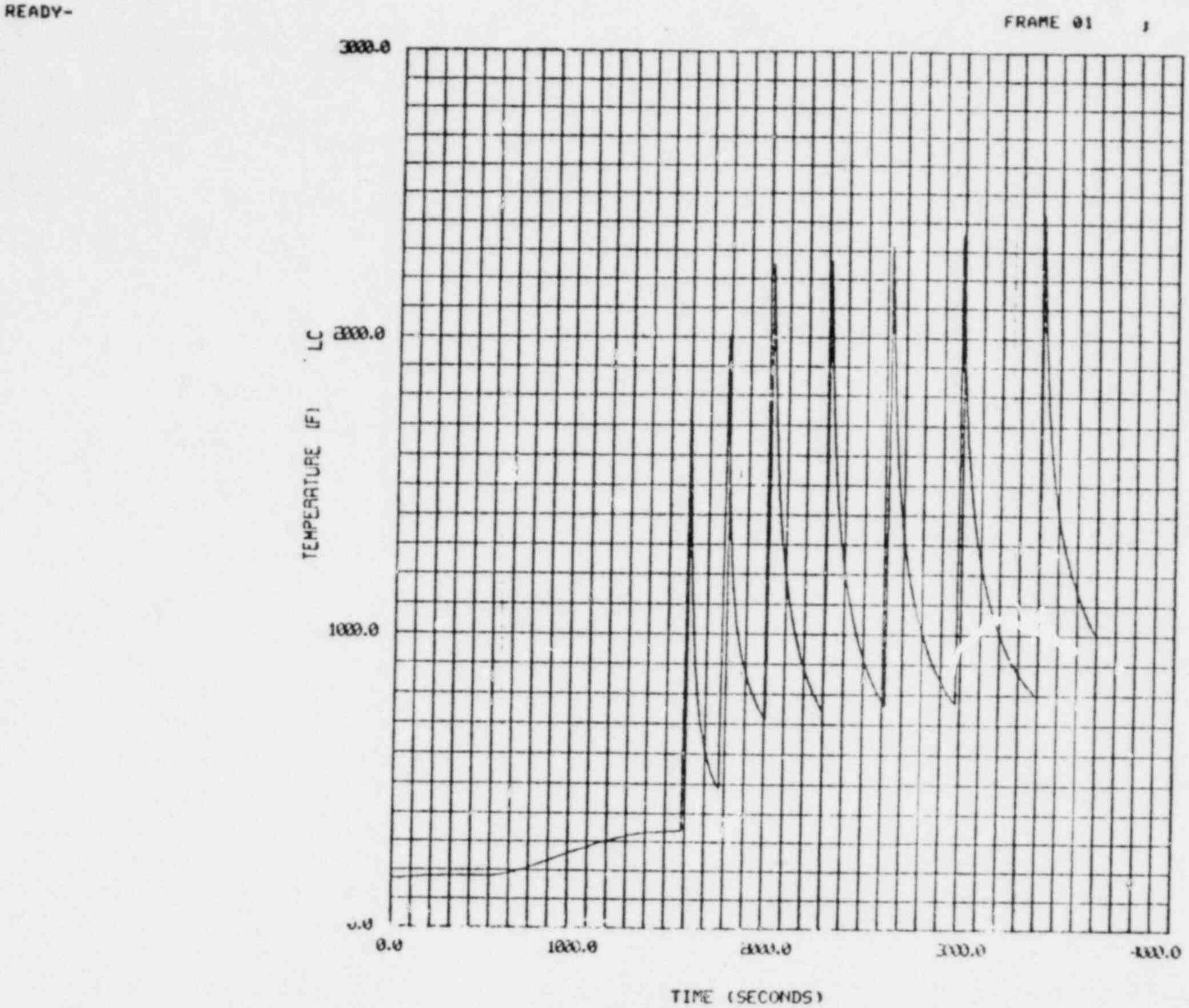
* ICE EXISTS ONLY FOR THE FIRST TWO OF 7 BURNING CYCLES.

READY-



TVA S2D CASES 2 FAN 1 SPRAY BURN 100 PCT AT 10 V 0 6FPS T+3480 -ICE

UPPER COMPARTMENT PRESSURE



TVA S2D CASES 2 FAN 1 SPRAY BURN 100 PCT AT 10 V 0 6FPS T+3480 -ICE

LOWER COMPARTMENT TEMPERATURE

TOPICS FOR FURTHER REVIEW

1. LOCATION AND NUMBER OF IGNITERS

2. H_2 MONITORING AND MIXING

3. ABILITY OF IGNITERS TO FUNCTION IN TURBULENT, FLOWING ATMOSPHERE

4. PROCEDURES AND STRATEGY FOR IGNITER OPERATION

5. ANALYSIS MODELS
   CLASIX

   A. SOLUTION SCHEME
   B. CONTAINMENT MODELING
   C. INPUT PARAMETERS

6. ANALYSIS RESULTS
   A. MIXING OF CONSTITUENTS
   B. SENSITIVITY STUDIES

      I. BURN CRITERIA
      II. DIFFERENT H_2 GENERATION RATES

7. EFFECTS OF LOCAL DETONATIONS OR RAPID BURNS USING CLASIX. INPUT AS A BOUNDARY CONDITION TO CLASIX, START FROM DETONATION.

8. PROTECTIVE MEASURES FOR ESSENTIAL EQUIPMENT

DELIBERATE IGNITION SYSTEM (DIS)

PRELIMINARY CONCLUSION: SIGNIFICANT POTENTIAL FOR MITIGATING THE CONSEQUENCES OF DEGRADED CORE ACCIDENT WHEN OPERATING IN CONJUNCTION WITH EXISTING CONTAINMENT HEAT REMOVAL MECHANISMS.

Tape 4 -

HYDROGEN PROBLEMS IN SEQUOYAH CONTAINMENT

INTRODUCTION

This letter report completes the RDA response to a request from the Nuclear Regulatory Commission to critique the ultimate strength analysis of the Sequoyah containment. This second report deals with the last two tasks of the work statement.

1. How would the analyses and results be altered if the stresses are caused by ignition/detonation of 300-600 Kg of hydrogen distributed uniformly and nonuniformly in the containment?
2. To what extent can distributed ignition sources mitigate the effects of hydrogen?

A preliminary discussion of these topics was attended by Commissioner Gilinsky and Dr. John Austin at RDA on 18 July 1980.

RESULTS

1. a) 300 kg of H_2 gas mixed uniformly with the air and steam (if less than 40 percent steam) in the Sequoyah containment volume following an accident would be completely combustible if ignited (see Figure 1). This complete combustion could occur so rapidly as to exceed the capacity of the available heat removal processes, and could produce a pressure as high as 5.5 atmospheres, thus rupturing the containment (see Table 2). The combustion of 600 kg of H_2 would of course have more severe consequences.

   b) A nonuniform distribution of 300 kg of H_2 present in the containment would consist of parcels of gas richer in H_2 than the uniform distribution. If these separated parcels formed while the blowers were operating, they would probably be mixed, combustible and perhaps detonable. If they were all detonable and all ignited, the damage to the containment would be worse than that due to ignition of a uniform mixture. If the gas parcels were not detonable, the pressure upon combustion would probably be at least as high as the uniform distribution. Under some circumstances, it would be possible to collect pockets of gas too rich in H_2 to burn. As the outer edges of such pockets mix with air, partially combustible mixtures would form. The results of igniting such a distribution would clearly depend on the sizes of the parcels and the timing.

It should be noted that harmless mixtures of H_2, air and steam may become highly combustible or detonable as steam is condensed out (see Appendix B). Thus one mechanism employed for removing heat from the containment also removes the combustion inhibitor from the containment.

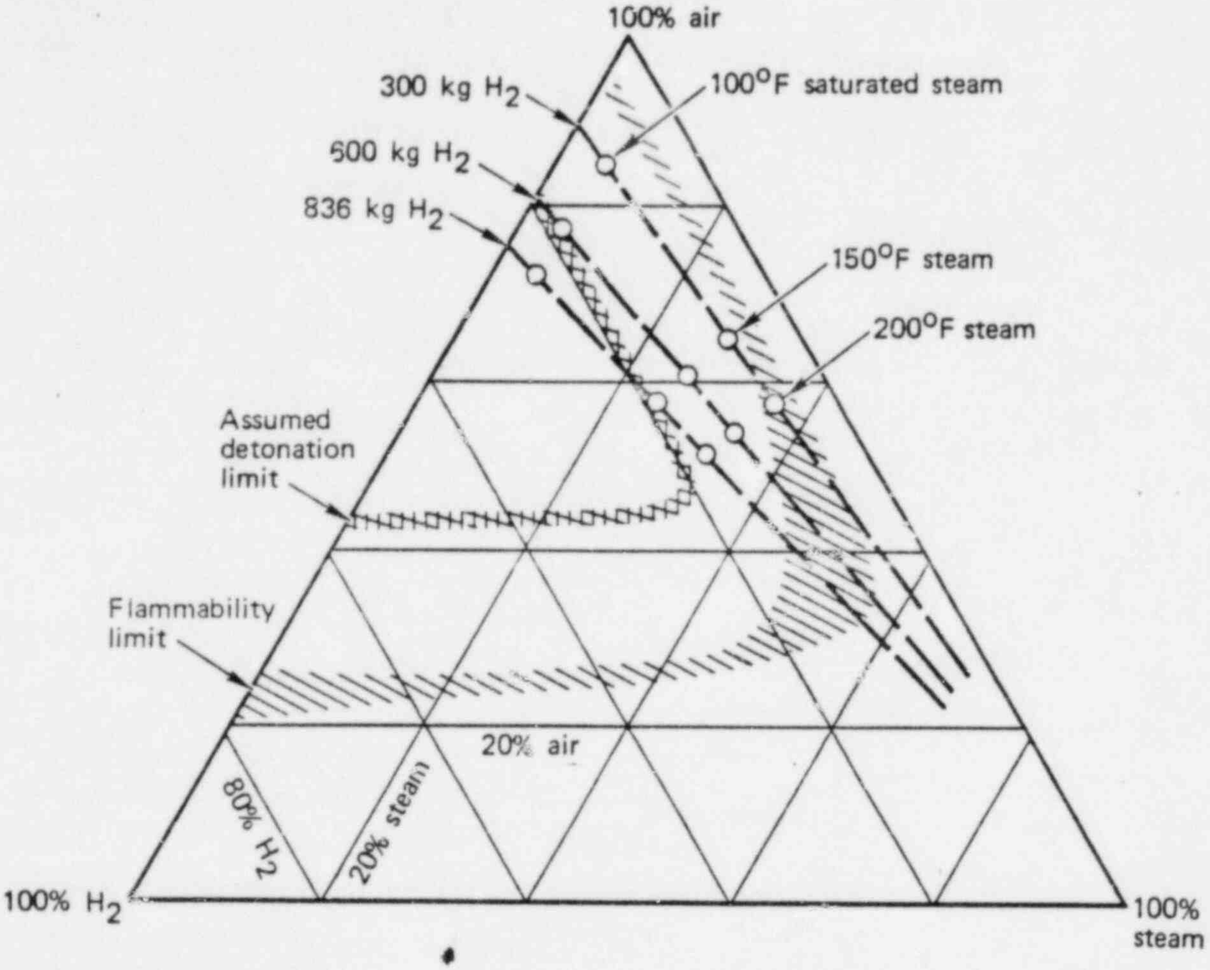
2. If the rate of hydrogen formation is sufficiently low, and the mixing of H_2 is complete and rapid so that all the gas in the containment gradually increases in H_2 concentration, then the presence of enough igniters could prevent overpressurizing the containment. This would be accomplished by releasing the heat of combustion at low concentrations over a long enough period of time to be handled by the heat removal equipment. However, if the Zr reaction rate is high relative to heat removal processes, then igniters might only delay containment failure. Table 3 shows that a 1 percent per minute Zr reaction rate, accompanied by the burning of hydrogen at its rate of formation, would match the steady-state heat removal capacity of the RHR equipment.

If the H_2 is not thoroughly mixed, then there is a possibility of igniting a detonable pocket of gas with an igniter. If left to its natural end, such an H_2-rich pocket could disperse below the detonation limit (∿20 percent H_2) when its ignition would cause less of a problem.

Since the possible rates of generation of H_2 following an accident and the rate, place, and degree of mixing with air are highly uncertain, the use of igniters can only be an uncertain means of pressure control. Improper use might be detrimental rather than helpful. On the other hand, if it is assumed that there are many unavoidable ignition sources in the containment, it is certainly true that control of the time and place of ignition is preferable to chance. In this sense the use of igniters seems beneficial.

COMMENT

It is our opinion that the uncertainties in H_2 generation and mixing are so dependent on hardware details and scenarios that they are unlikely to be greatly reduced by further work. For this reason we believe it may be a better use of resources to explore thoroughly the feasibility of using an inert atmosphere in the containment, so as to avoid the hydrogen burning problem.



Limits of flammability and detonation based on Shapiro and Moffette WAPD-SC-545, as reproduced in WASH 1400.

Figure 1. Uniform mixtures in the Sequoyah containment vessel.

TABLE 1. INPUT DATA FOR SEQUOYAH PLANT

1.	Free volume of containment vessel[a]	3.2×10^4 m^3
	Weight of contained air at 27°C, 1 atm.	3.7×10^4 kg
	Gram moles of air	1.3×10^6
	Gram moles of oxygen	2.7×10^5
2.	Weight of zirconium in core[b]	1.9×10^4 kg
	Gram moles of zirconium	2.1×10^5
3.	Yield of 100% Zirconium-water reaction	
	Weight of hydrogen	836 kg
	Gram moles of hydrogen	4.2×10^5
	Heat of reaction[c], $Zr + H_2O$	1.1×10^{11} joules
	Heat of H_2 burn[d] (to form liquid H_2O)	1.2×10^{11} joules
	Total heat of reaction + burn	2.3×10^{11} joules

4. Molar quantities and partial air pressure of saturated steam in containment

At 100°F (38°C) vapor = 8.1×10^4 moles = 0.06 atm.
150°F (66°C) = 5.9×10^5 moles = 0.25 atm.
200°F (93°C) = 8.4×10^5 moles = 0.78 atm.

NOTES:

(a) Sequoyah Nuclear Plant, Preliminary Safety Analysis Report (PSAR), Table 5.2-1 gives the total containment active volume as 1,142,000 ft^3, comprised of 730,000 in the upper compartment, 125,000 in the ice compartment, and 287,000 in the lower compartment.

(b) Sequoyah PSAR, Tabel 1.3-1, gives the clad weight as 41,993 lb.

(c) G. W. Keilholtz, ORNL-NSIC-120, Annotated Bibliography of Hydrogen Considerations in Light-Water Power Reactors, Feb. 1976, Table 1, Heat of Reaction = 122 to 137 kcal/mole Zr.

(d) Lewis and Von Elbe,
p. 685, 68.3 kcal/mole H_2O.

TABLE 2

		H_2 Quantity	
	300 kg	600 kg	836 kg
1. Percent Zr Reaction	36%	72%	100%
2. Moles H_2	1.5×10^5	3.10^5	4.2×10^5
3. Partial Pressure @ 300°k (atmospheres)	0.12	0.23	0.32
4. Molar Ratio $\frac{H_2}{Air}$, Uniform Distribution	0.11	0.23	0.32
5. Detonatable (D) or Combustible (C)[a] Mixture, no steam present	C	D	D
6. H_2 Concentration Multiplier Required relative to uniform mixture[a]			
a) to reach detonation regime	2.0	1.0	1.0
b) to reach stoichiometric ratio of 0.42:1 for H_2:air	3.8	1.8	1.3
7. Steam Vapor Pressure Required:[b]			
a) to prevent detonation of uniform mixture	0	0.1 atm	0.4 atm
b) to prevent combustion of uniform mixture	0.9 atm	2.0 atm	2.3 atm
8. Energy Release in 100% Combustion, Joules (liquid water product)	4.3×10^{10}	8.6×10^{10}	1.2×10^{11}
9. Final Absolute Pressure in Adiabatic Combustion (Initial ~~Air~~ Partial Pressure 1 atm, Initial Temperature 300°k)[c]			
a) No steam, 100% combustion	5.5 atm	10.0	13.3 atm
b) No steam, 50% combustion	3.3	5.8	7.3
c) Steam @ 190°F, 50% combustion	4.1	6.5	8.3

NOTES:

(a) Approximate, based on regimes outlined in Figure 1.

(b) Approximate, based on regimes outlined in Figure 1, plus molar concentrations of saturated steam as a function of pressure.

(c) Assuming products of combustion behave as ideal gases, and assuming a constant-volume reaction.

TABLE 3. HEATING AND COOLING RATES IN SEQUOYAH CONTAINMENT

Time when Fission Product Heat (Cumulative) Equals Total Heat of Reaction	3000 sec
Rate of Heating at the 1% per min Zr Reaction Rate	
Zr Reaction	18.0 MW
H_2 Burning	20.0
Total	38.0 MW
Rate of Fission Product Heating at 2 hours (when ice has been melted in DBA)	27 MW
Steady-state Cooling Capacity of the 2 RHR Heat Exchangers[a]	67 MW
Net Margin of Cooling Capacity (Beyond Chemical Reactions @ 1%/min and Fission Product Heating)	2 MW

NOTES:

(a) Sequoyah PSAR, Table 6.3-2 cites 2 heat exchangers, each having a capacity of 1.15×10^8 BTU/h at specified conditions.

APPENDIX A

LITERATURE SEARCH ON EXTENT OF HYDROGEN BURNING AND FLAMMABILITY LIMITS FOR MIXTURES OF H_2, AIR, AND STEAM

In considering the effects of 300 kg to 600 kg H_2 in the Sequoyah containment vessel, questions of lean mixture flammability limits and the extent of combustion are important. The 1976 literature survey by Keilholtz (1) provided citations for most of the sources used in this brief study, and provided much of the available data on flammability and extent of combustion.

EXTENT OF COMBUSTION

Keilholtz states that combustion of 100 percent of the hydrogen will not occur until the hydrogen comprises about 10 vol percent of the H_2-air mixture. A partial combustion data point of 50 percent combustion is quoted for a 5.6 vol percent H_2 mixture in air. This point is attributed to Shapiro and Moffette (2), a reference that we were unable to obtain in the available time. However, Furno, et al. (8) indicate about 90 percent combustion for an initial mixture of 8.5 percent H_2 as compared with 5-10 percent combustion for mixtures of 6.9-7.4 percent H_2. If 300 kg H_2 were uniformly distributed throughout the active volume of the Sequoyah Unit 1 containment vessel, it would constitute a 10 vol percent mixture with air (neglecting steam), and hence could burn completely.

FLAMMABILITY LIMIT

The lean mixture threshold of flammability is given by Keilholtz as 4.1 vol percent H_2 in air but at this concentration, Egerton (3) as well as Keilholtz point out that the flame front is not coherent, and flame propagation is upward only.

Downward propagation begins with a hydrogen concentration of about 9 vol percent (1), (3). Drell and Belles (4) state that a 9 percent mixture will burn completely (a point to be compared with the Keilholtz 10 percent mixture for 100 percent combustion). Even the lean mixture non-coherent flames are postulated to burn a mixture that is richer than the original mixture, because the high diffusion rate of H_2 permits access of additional H_2 to the flame (4). The diffusion rate of H_2 is also important to the dispersal of segregated pockets of hydrogen, and will be discussed later.

STEAM DILUTION

The effects of dilution by steam are potentially important. Drell and Belles (4) state that inert diluents have scarcely any effect on the lean-mixture limit of flammability, where 300-600 kg of H_2 in Sequoyah would be, if uniformly distributed. They claim water vapor has effects similar to CO_2, and they show data of Coward and Jones (5) (which we were unable to obtain) such that only after more than half the mixture is CO_2 does the fraction of H_2 required for flammability begin to increase. These findings are consistent with the ternary mixture chart of Shapiro and Moffette for H_2, air, and steam, wherein the lean mixture flammability limit is at a nearly constant H_2 fraction as the steam content increases from zero to about 50 vol percent.

DETONATION

Shapiro and Moffette indicate a triangular shaped detonation regime in their ternary mixture chart, a regime bounded approximately by a 19 vol percent H_2 line at the lean mixture boundary and a 45 vol percent air line at the rich mixture boundary. Although the original reference was not available to us, it appears that the authors constructed the detonation regime by extrapolating from data on dry mixtures of H_2 and air. We note that Drell and Belles show the range of detonability of H_2 in air from 18.3 vol percent to 50 vol percent H_2. We could find no information on the effects of inert diluents on the detonability of hydrogen-air mixtures, and we note the caption on the Shapiro-Moffette ternary mixture chart: "Assumed Detonation Limits." We conclude that the effects of steam on detonability of H_2-air mixtures are essentially unknown. The nearest information we could find was cited by Keilholtz, and this pertains to detonations in Knallgas-team mixtures (6). Knallgas is a stoichiometric mixture of H_2 and 0_2. In reference (6), experiments indicated that a minimum of about 65 vol percent Knallgas in saturated steam at 100°C was required for detonation. This would correspond to about 44 percent H_2.

The occurrence of detonation is also influenced by the size and configuration of the vessel, and the nature of the walls (4,7), which further complicates efforts to predict detonation precisely.

REFERENCES

1. G. W. Keilholtz, "Annotated Bibliography of Hydrogen Considerations in Light-Water Power Reactors, ORNL-NSIC-120, Feb. 1976.

2. Z. M. Shapiro and T. R. Moffette, "Hydrogen Flammability Data and Application to PWR Loss-of-Coolant Accident," WAPD-SC-545, 1957.

3. Sir Alfred C. Egerton, "Limits of Inflammability," Fourth Symposium (International) on Combustion, the Williams and Wilkins Co., Baltimore, 1953, pp. 4-13.

4. I. L. Drell and F. E. Belles, "Survey of Hydrogen Combustion Properties," National Advisory Committee on Aeronautics Report 1383, 1958.

5. H. F. Coward and G. W. Jones, "Limits of Flammability of Gases and Vapors," U. S. Bureau of Mines, Bulletin 503, 1952.

6. J. A. Luker and E. C. Hobaica, "Effect of the Initial Mixture Density on the Formation of Detonation in Knallgas Saturated with Water Vapor," Journal of Chemical and Engineering Data, 6, 2 April 1961, pp. 253-256.

7. L. B. Adler, E. C. Hobaica, and J. A. Luker, "The Effect of External Factors on the Formation of Detonation in Saturated Knallgas-Steam Mixtures," Combustion and Flame, 3, 481, 1959.

8. A. L. Furno, E. B. Cook, J. M. Kuchta, and D. S. Burgess, "Some Observations on Near-Limit Flames," Thirteenth Symposium (International) on Combustion, 1971.

APPENDIX B

HYDROGEN-AIR MIXING BY FAN

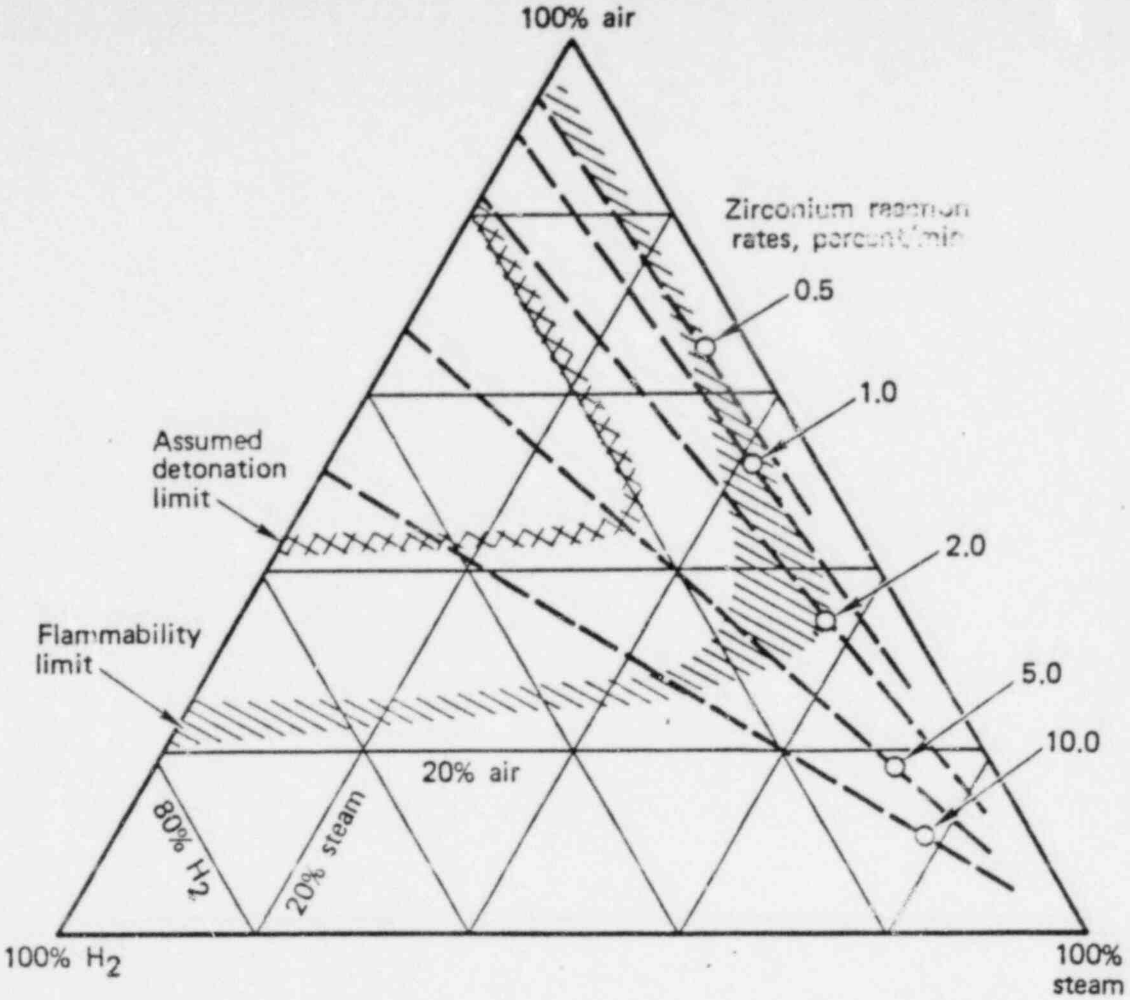
Air recirculation fans are provided in the Sequoyah containment for returning air to the lower compartment after a postulated blowdown. Two such fans are provided, each having a rated capacity of about 40,000 cfm. The purpose of the fan-induced recirculation is to convey steam produced by residual heating to the ice condenser, if the emergency core cooling system should fail (failure of the ECCS is also a situation that could permit a zirconium-water reaction and hydrogen generation). The design basis for the recirculation system is an air flow rate of 40,000 cfm, corresponding to the operation of one fan. Some parameters related to mixing and burning of hydrogen in an air flow of 40,000 cfm have been calculated, and are presented in Table 4.

The air velocities in the ice condenser and upper plenum are low. Nevertheless, the flow would be turbulent in the upper plenum of the ice compartment, so the flow entering the upper compartment should be well mixed. If hydrogen were being generated by a 1% per minute reaction of zirconium (as an example), the rate of hydrogen flow would be about 10% of the air flow, giving a mixture containing about 9% H_2. This would be combustible, according to the literature cited elsewhere in this report.

A reference calculation is illustrated in Figure 2, where mixtures of 40,000 cfm air and the hydrogen yields of various rates of zirconium reaction are plotted on the ternary mixture chart. Each reaction rate corresponds to a straight-line locus, with steam rate determining the position on any line. The one point plotted on each line is for a steam rate that corresponds to the heat release rate of the $Zr\text{-}H_2O$ reaction and the latent heat of vaporization of water. It can be seen in Figure 2 that the yield of $Zr-H_2O$ reaction rates in excess of 2% per minute can produce detonable mixtures with 40,000 cfm of air if the steam content is sufficiently low. Rates of several percent per minute were calculated for some accident scenarios in WASH 1400.

Table 4. Air Circulation Parameters

Design Data From Sequoyah PSAR	
Number of Blowers	2
Capacity of Each Blower	40,000 cfm
Ice Condenser: Flow Area (net)	1,326 ft^2
Height	48 ft
Annular Thickness	11 ft
Effective Circumferential Length	267 ft
Lower Compartment Active Volume	2.87×10^5 ft^3
Total Containment Active Volume	1.24×10^6 ft^3
Derived Parameters, for One Blower Operating	
Air Velocity: a) In Ice Bed	30 ft/min
b) In Upper Plenum of Ice Compartment	14 ft/min
Air Reynolds Number in Upper Plenum (kinematic viscosity of air @ 50°C = 1.15×10^{-2} ft^2/min)	2.6×10^4
Air Residence Time in: Ice Compartment	1.6 min
: Lower Compartment	7.2 min
: Total Active Volume of Containment	31 min



Limits of flammability and detonation based on Shapiro and Moffette WAPD-SC-545, as reproduced in WASH 1400.

Figure 2. Locus of state points for mixtures of 40,000 cfm air with the hydrogen yield of various Zr reaction rates.

Lau
Tape 4

1. Controlled Ignition Phase 1 Program Status

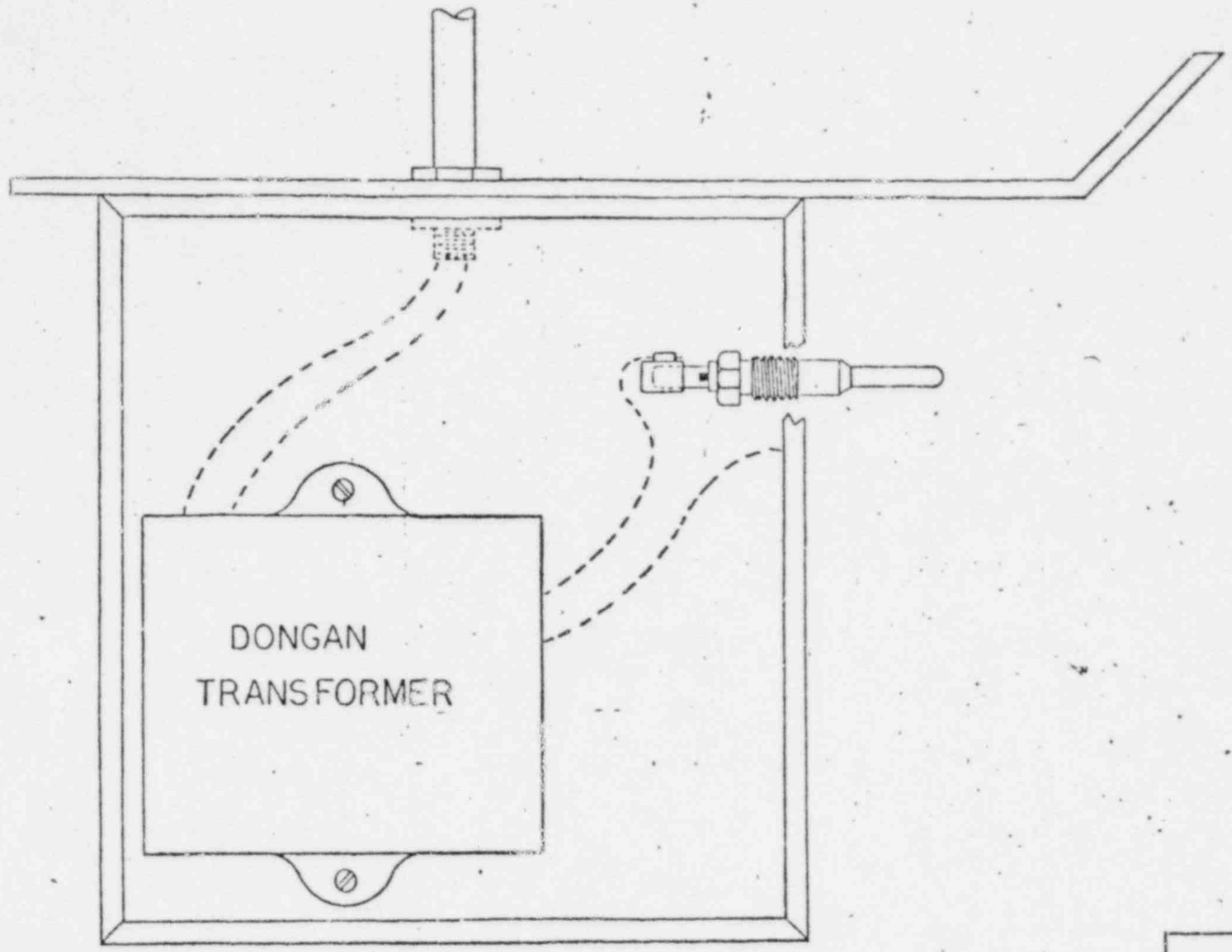
   - Description, installation, and operation of thermal igniters.
   - Spark igniters and electromagnetic interferences

2. Singleton Lab Tests

3. Fenwall Tests

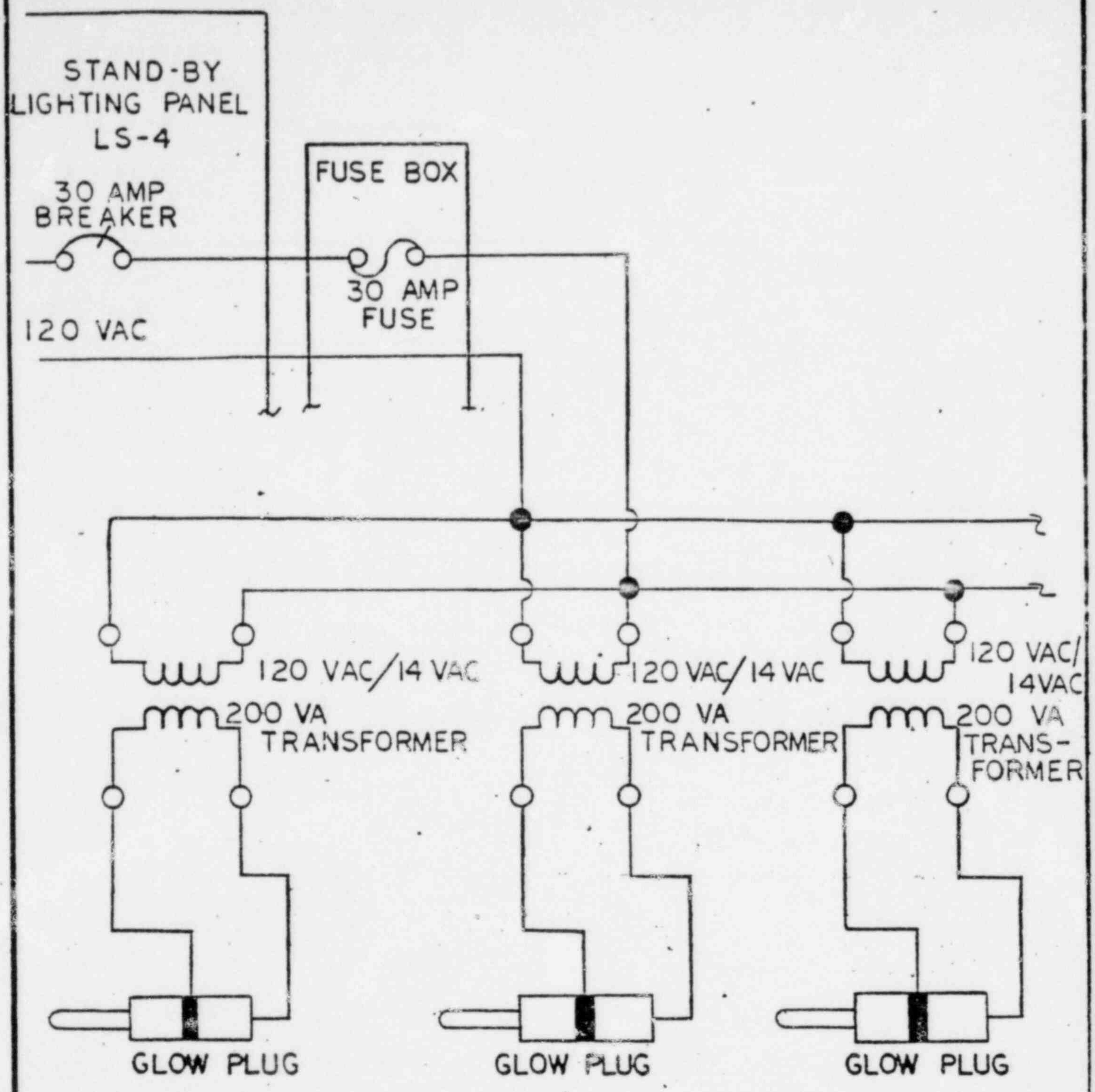
4. Halon Study

5. Degraded Core



SEQUOYAH NUCLEAR PLANT
FINAL SAFETY
ANALYSIS REPORT

PRELIMINARY PHASE I
MOUNTING DETAIL
FIGURE 6.2-147



- TYPICAL OF ONE CIRCUIT

(NUMBER OF GLOW PLUGS PER CIRCUIT VARIES FROM ONE TO EIGHT)

REV NO.	ECN NO.	DATE	DSGN	DRWN	CHKD	SUPV	ENGR	INSP	SUBM	RECM	APPD

DSGN
DRWN
CHKD
SUPV
INSP
ENGINEER

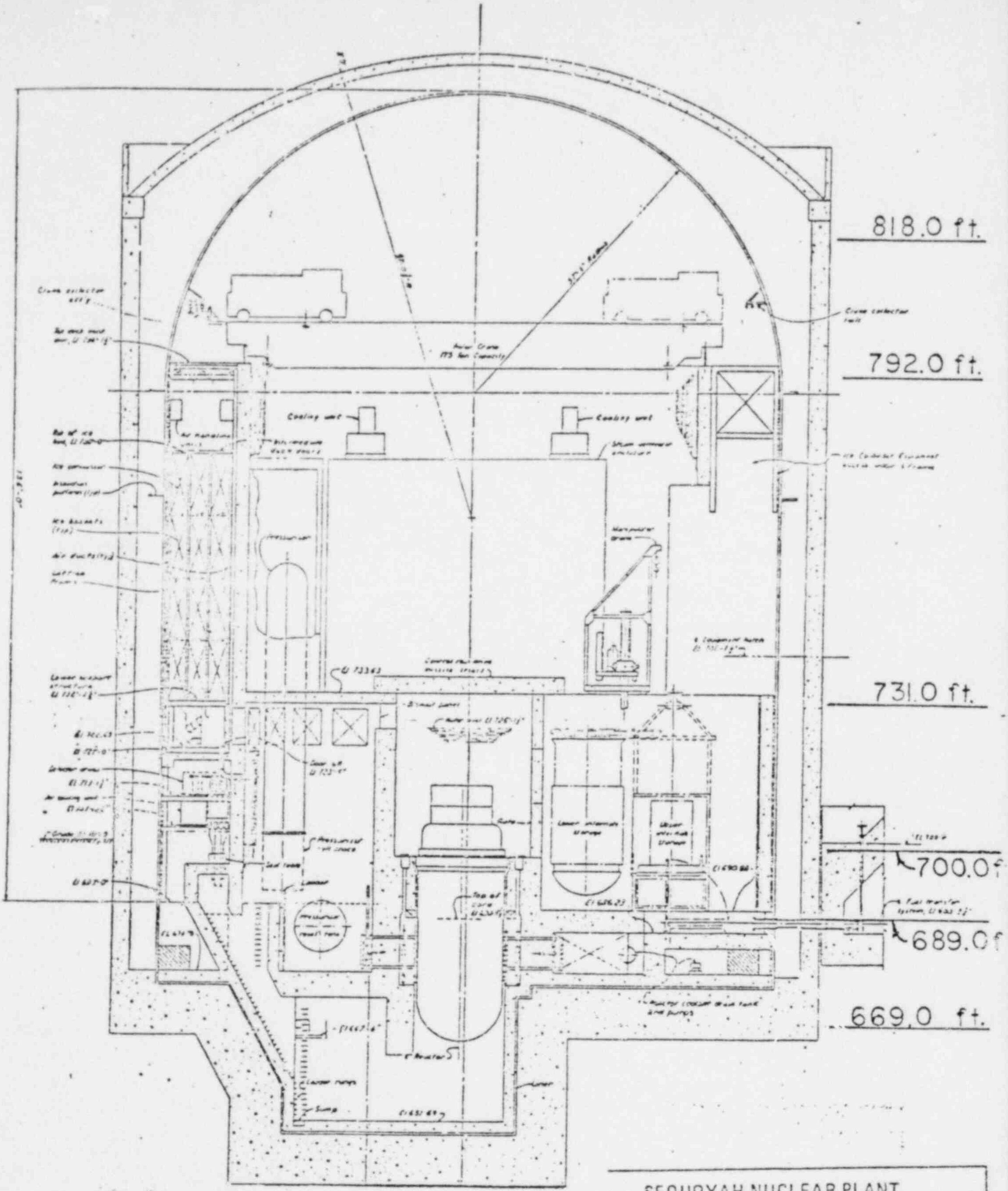
ELECTRICAL SCHEMATIC
FIGURE 15

TENNESSEE VALLEY AUTHORITY
DIVISION OF ENGINEERING DESIGN

SUBMITTED
RECOMMENDED
APPROVED

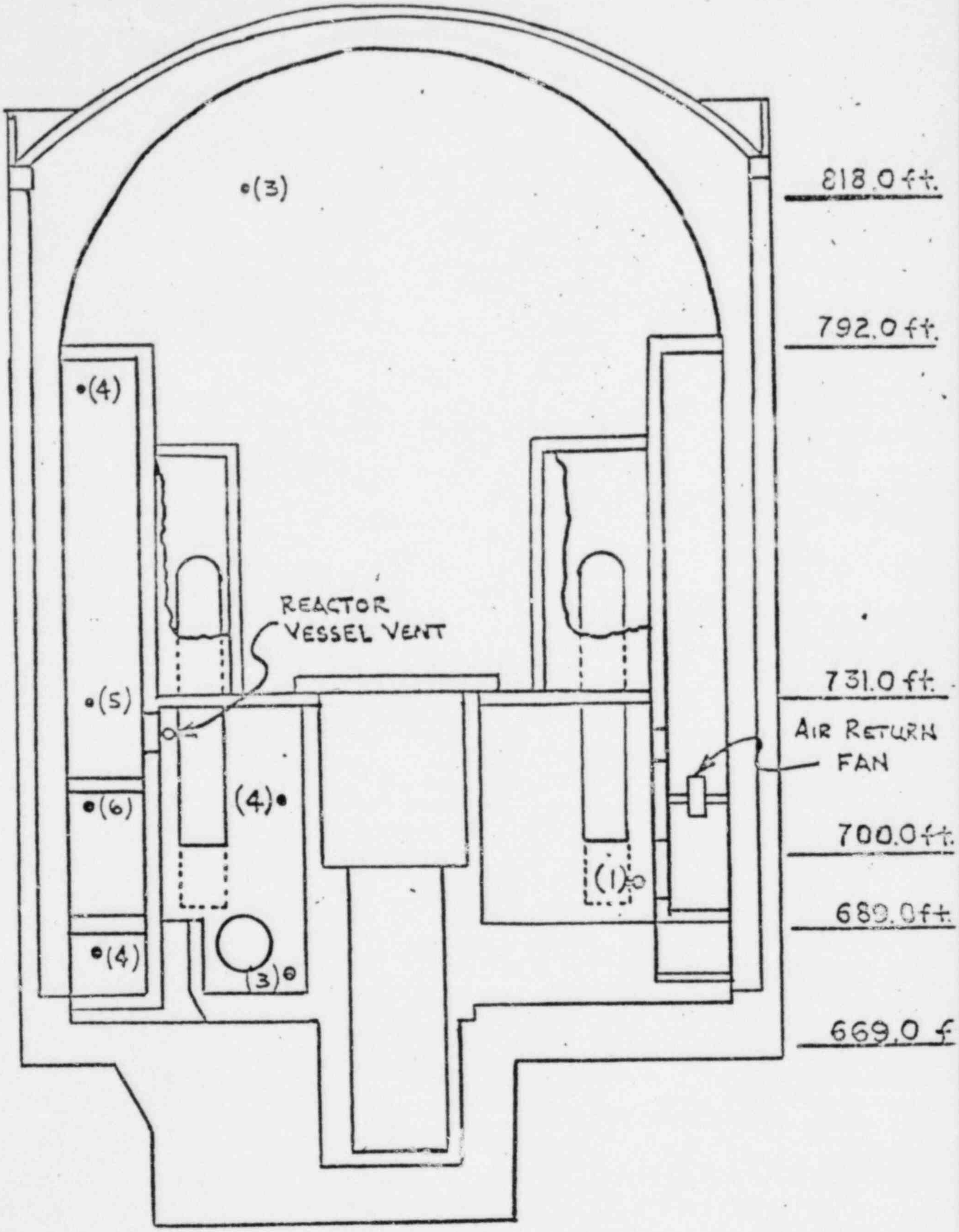
KNOXVILLE

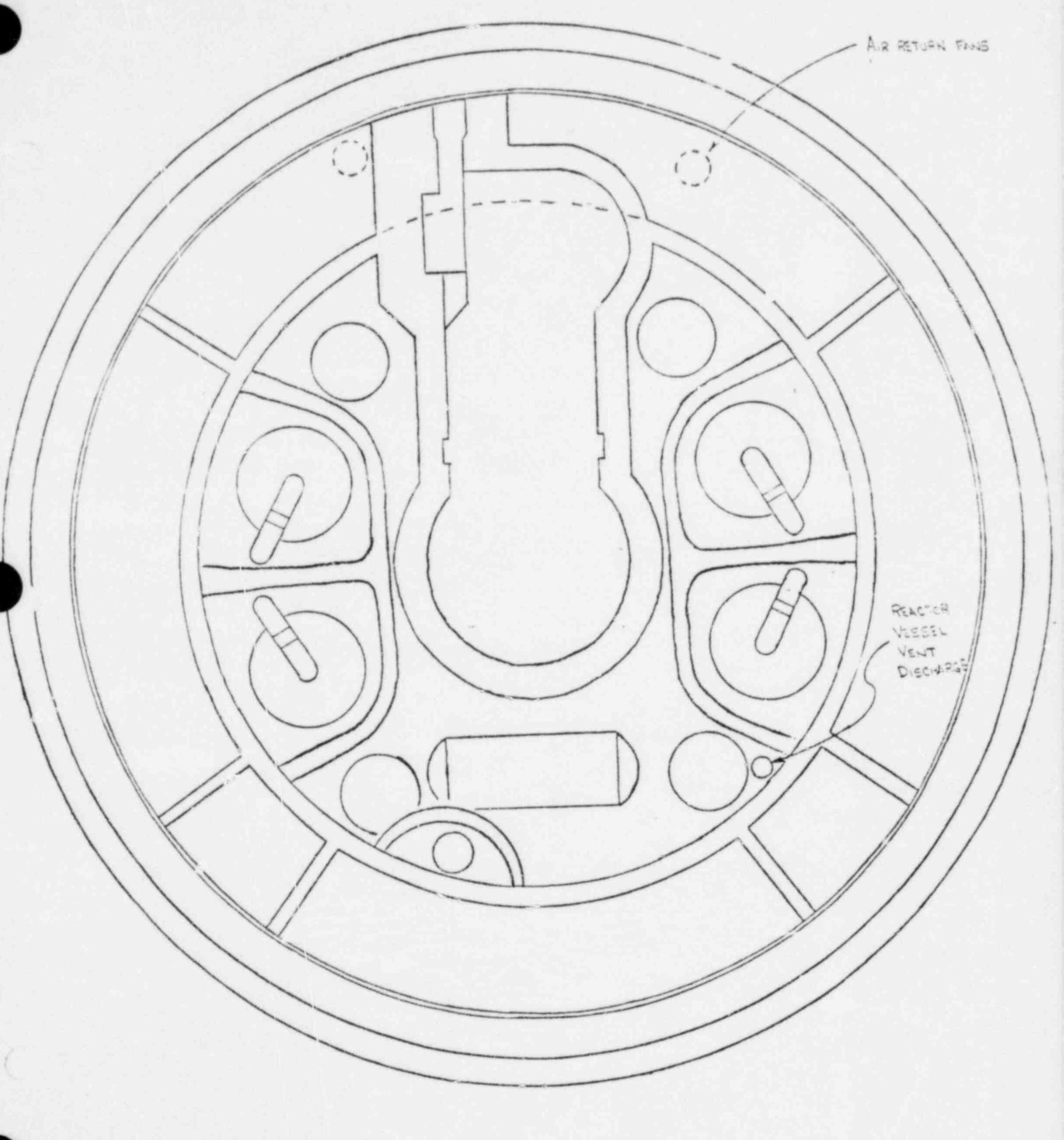
RECORD DRAWING AS CONSTRUCTED

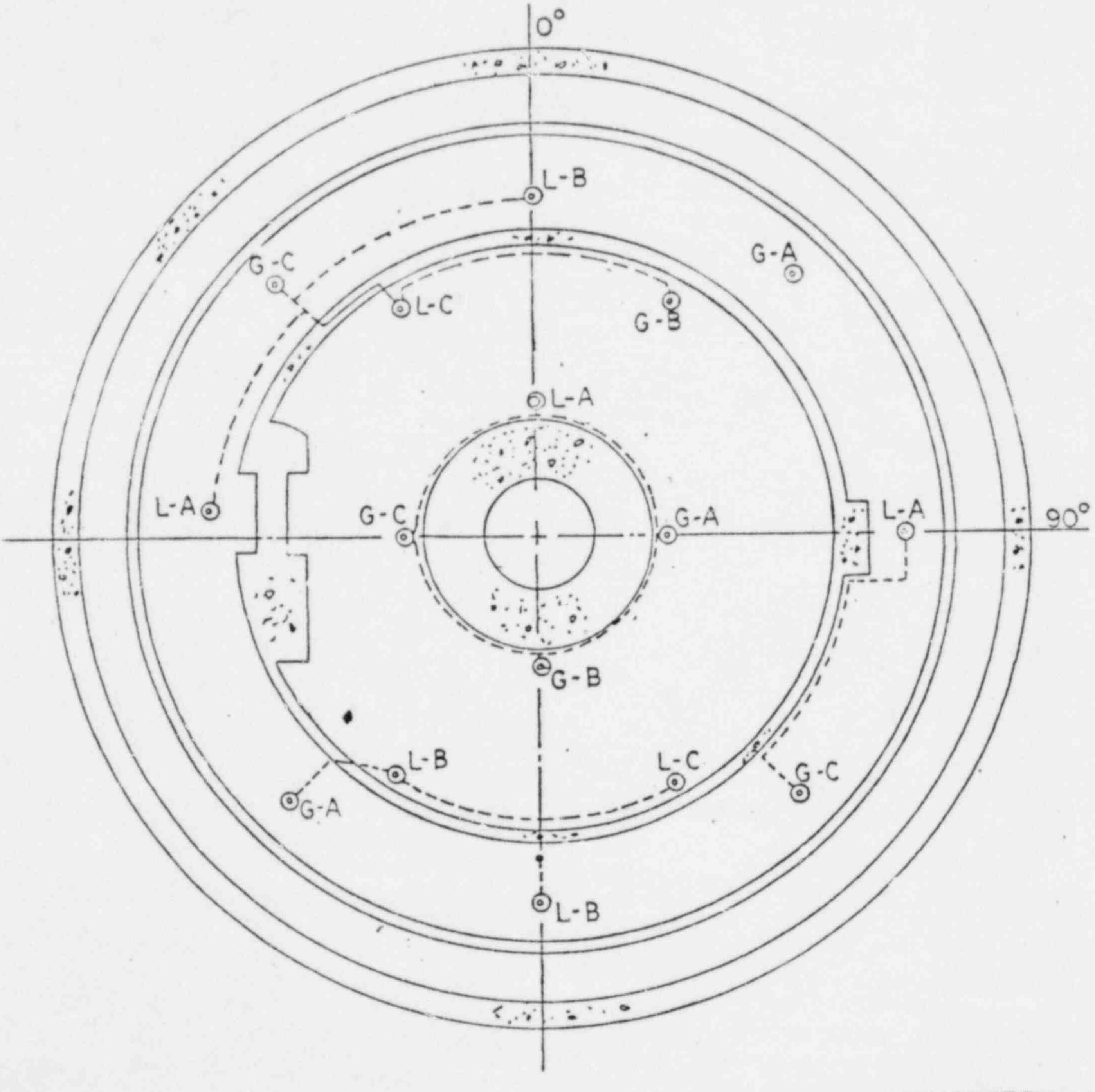


SEQUOYAH NUCLEAR PLANT
FINAL SAFETY
ANALYSIS REPORT

CONTAINMENT LIGHTING
FIXTURE ELEVATION
FIGURE 6.2-141

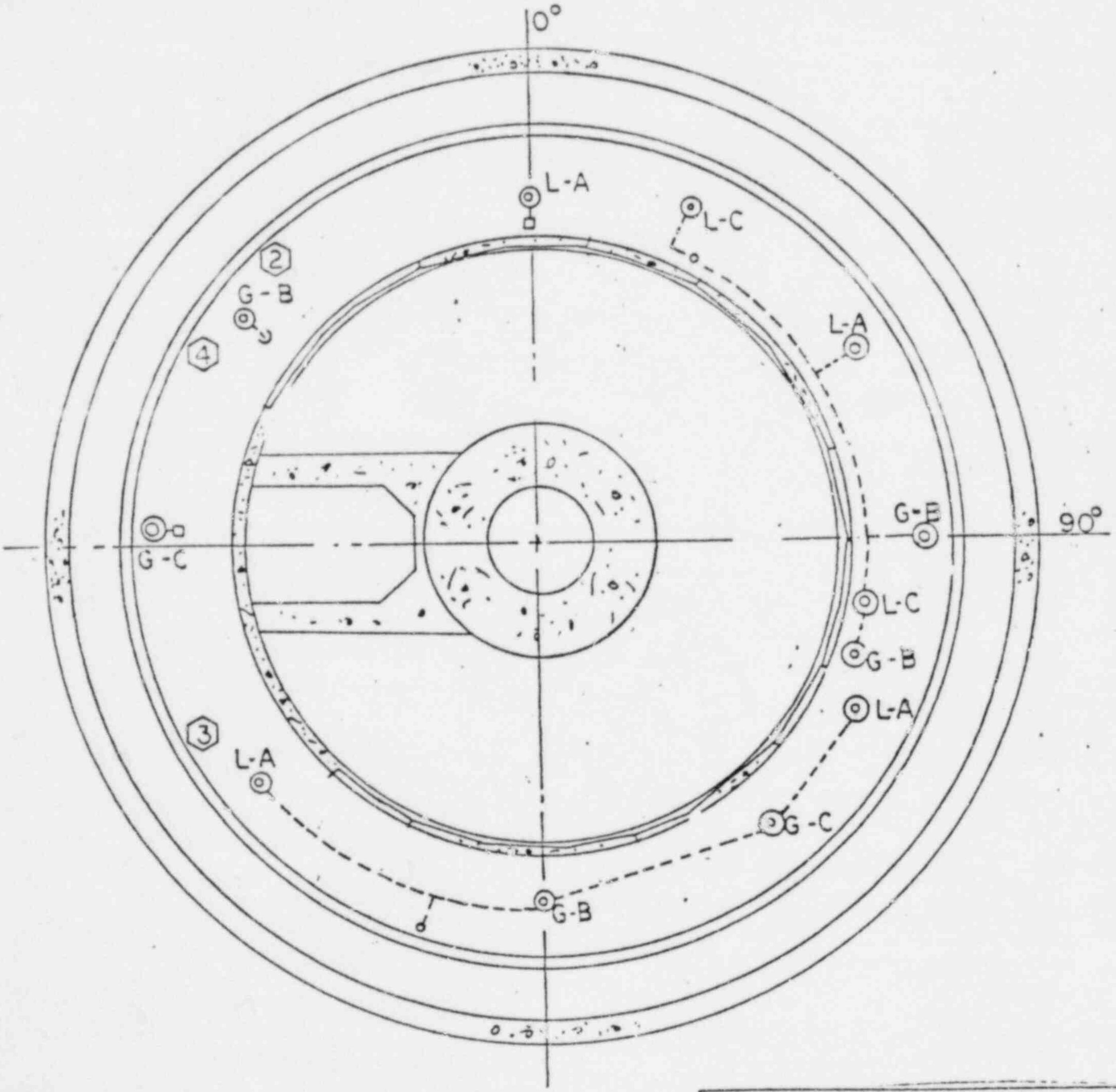

•(3)
818.0 ft.
792.0 ft.
•(4)
REACTOR VESSEL VENT
731.0 ft.
•(5)
AIR RETURN FAN
•(6)
(4)•
700.0 ft.
(1)○
689.0 ft.
•(4)
(3)•
669.0 f


AIR RETURN FANS
REACTOR VESSEL VENT DISCHARGE



SEQUOYAH NUCLEAR PLANT
FINAL SAFETY
ANALYSIS REPORT

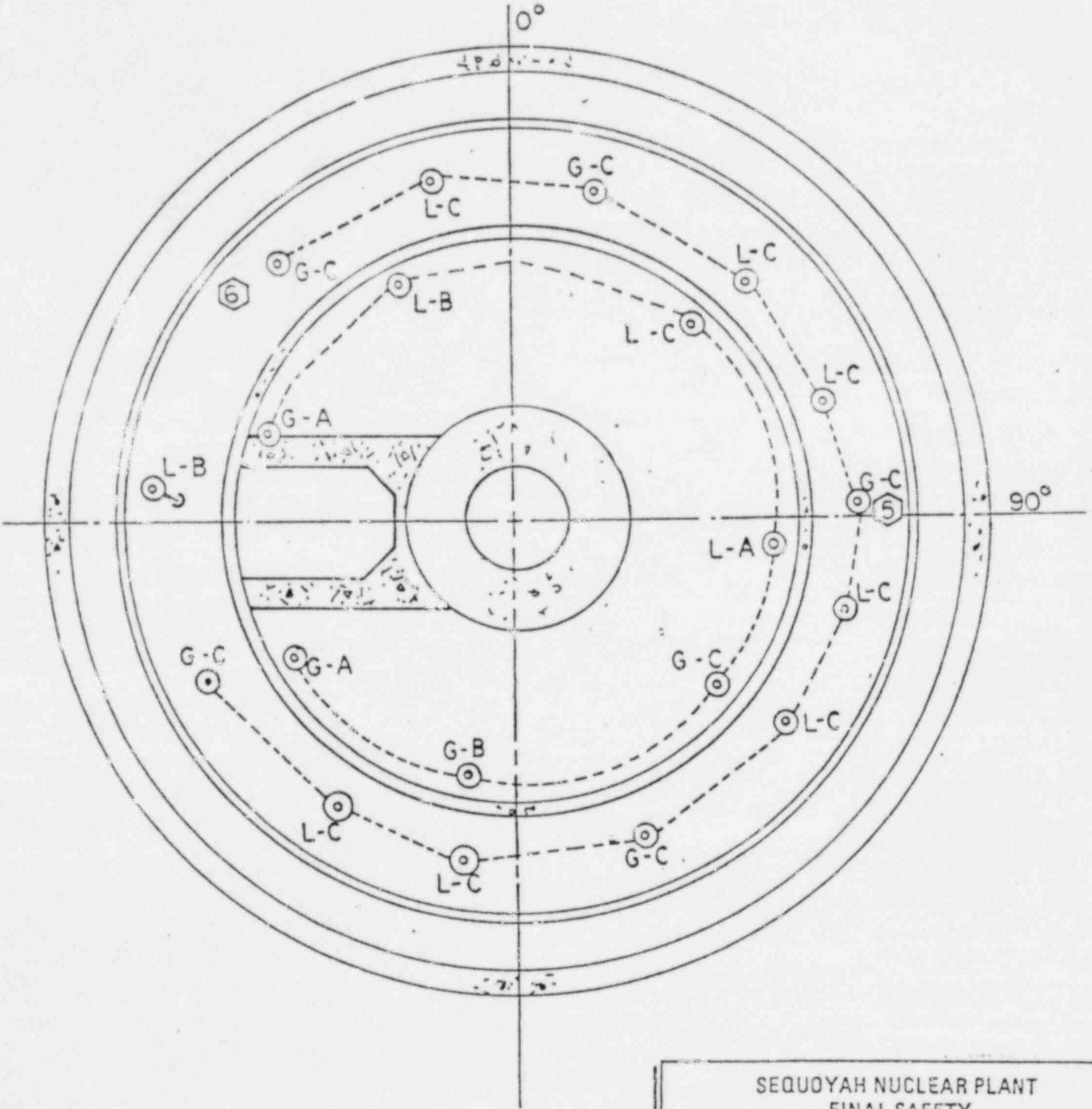
CONTAINMENT LIGHTING FIXTURES
EL. 689.0'
FIGURE 6.2-142



SEQUOYAH NUCLEAR PLANT
FINAL SAFETY
ANALYSIS REPORT

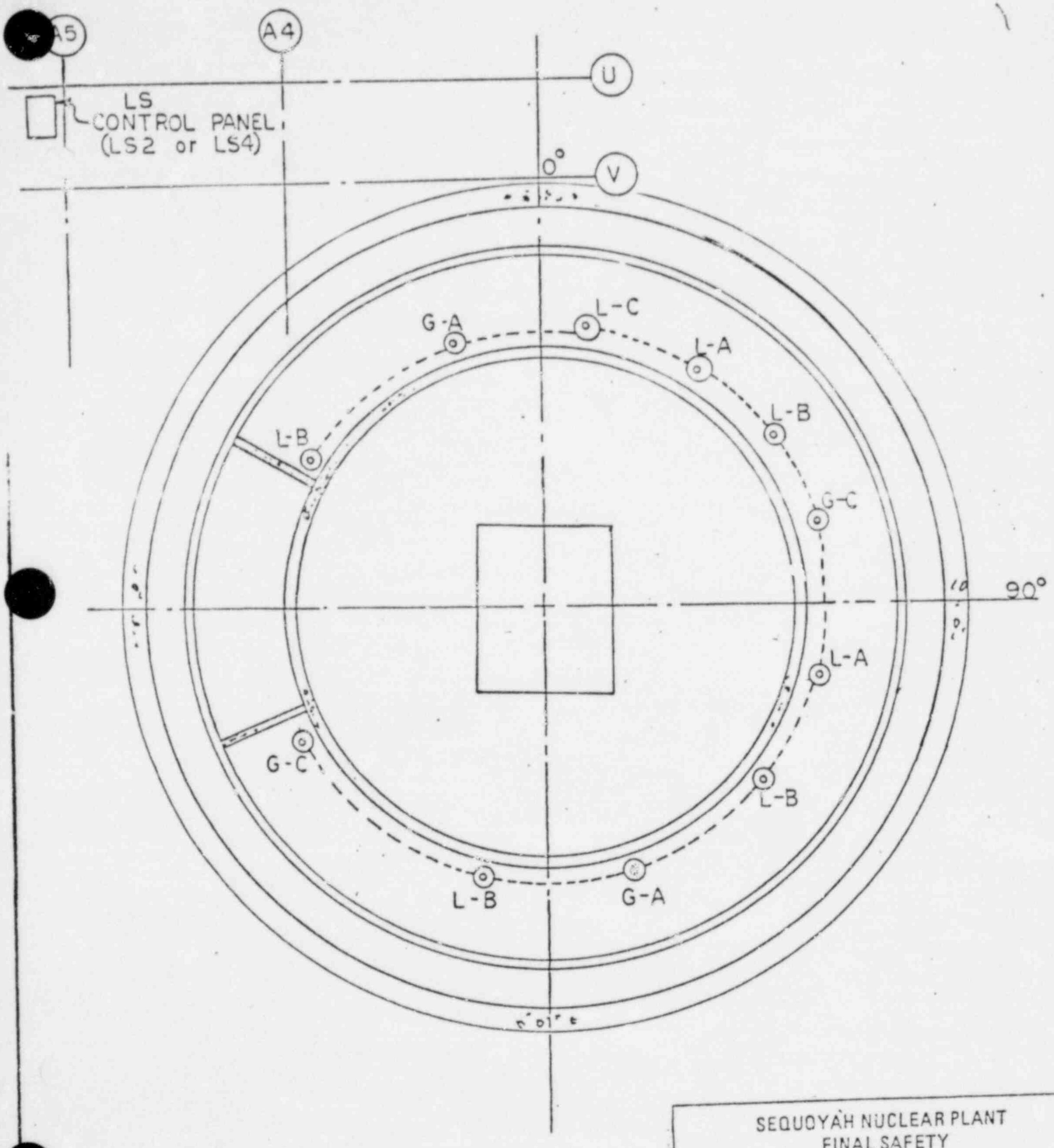
CONTAINMENT LIGHTING FIXTURES
EL. 700.3
FIGURE 6.2-143

1



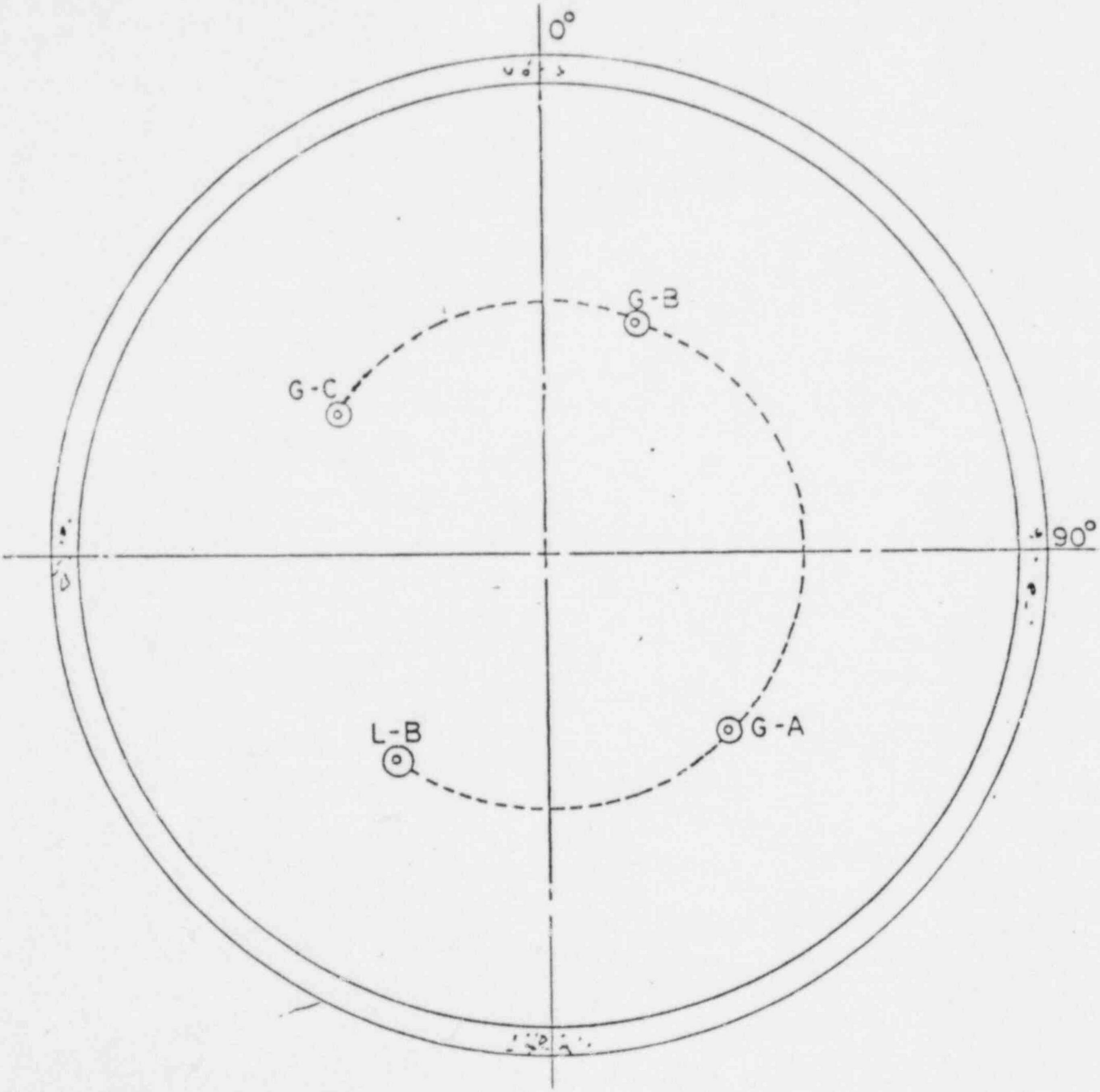
SEQUOYAH NUCLEAR PLANT
FINAL SAFETY
ANALYSIS REPORT

CONTAINMENT LIGHTING FIXTURES
EL 731.0'
FIGURE 6.2-144



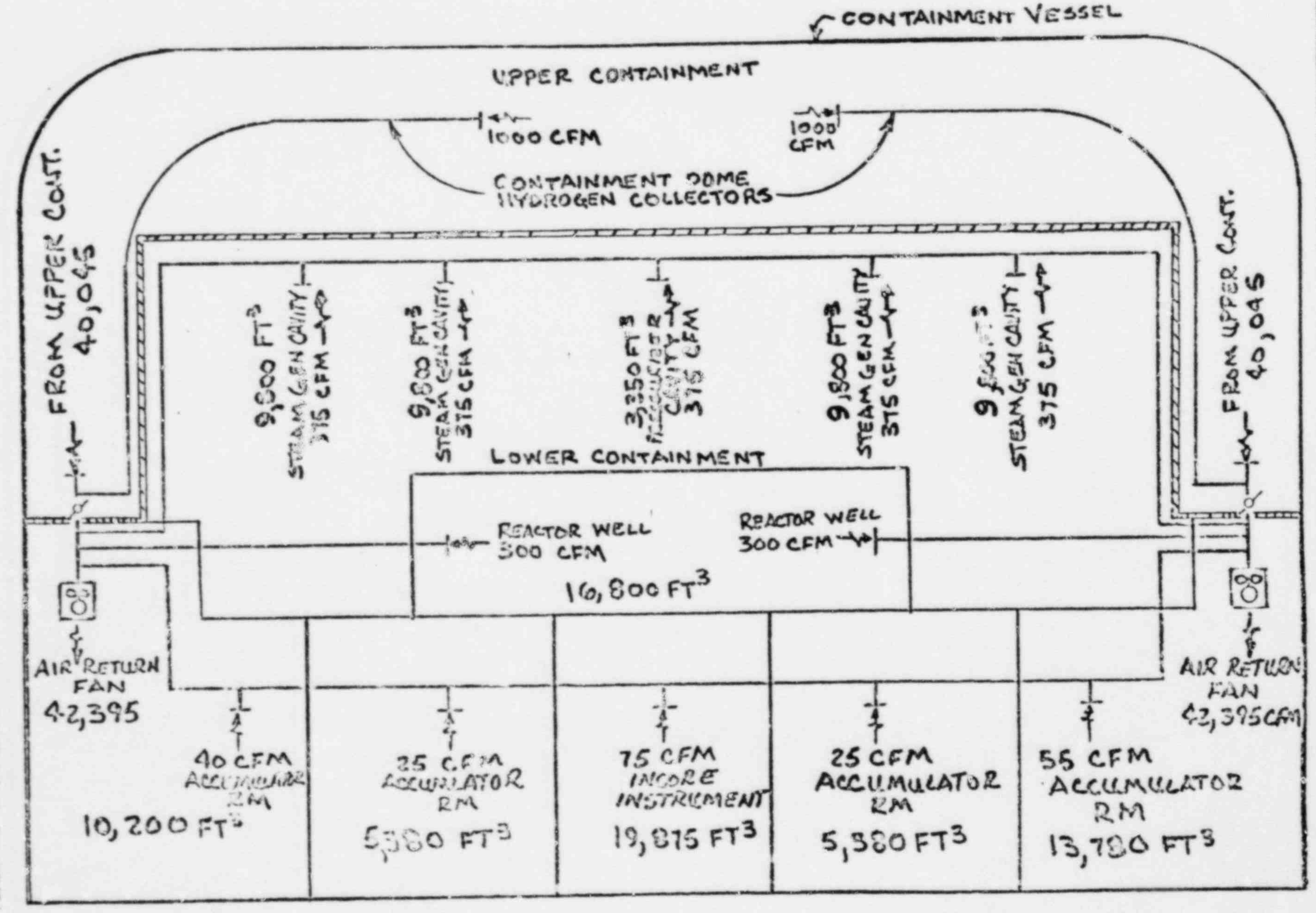
SEQUOYAH NUCLEAR PLANT
FINAL SAFETY
ANALYSIS REPORT

CONTAINMENT LIGHTING FIXTURES
EL 792.0'
FIGURE 6.2-145



SEQUOYAH NUCLEAR PLANT
FINAL SAFETY
ANALYSIS REPORT

CONTAINMENT LIGHTING FIXTURES
EL 818.0'
FIGURE 6.2-146


CONTAINMENT VESSEL
UPPER CONTAINMENT
1000 CFM
1000 CFM
CONTAINMENT DOME HYDROGEN COLLECTORS
FROM UPPER CONT. 40,045
FROM UPPER CONT. 40,045
9,800 FT³ STEAM GEN CAVITY 375 CFM
9,800 FT³ STEAM GEN CAVITY 375 CFM
3,350 FT³ PRESSURIZER CAVITY 375 CFM
9,800 FT³ STEAM GEN CAVITY 375 CFM
9 [illegible] FT³ STEAM GEN CAVITY 375 CFM
LOWER CONTAINMENT
REACTOR WELL 300 CFM
REACTOR WELL 300 CFM
16,800 FT³
AIR RETURN FAN 42,395
AIR RETURN FAN 42,395 CFM
40 CFM ACCUMULATOR RM 10,200 FT³
25 CFM ACCUMULATOR RM 5,380 FT³
75 CFM INCORE INSTRUMENT 19,875 FT³
25 CFM ACCUMULATOR RM 5,380 FT³
55 CFM ACCUMULATOR RM 13,780 FT³

PRELIMINARY TESTING TO IDENTIFY
COMMERCIALLY AVAILABLE IGNITERS

TESTING CONDUCTED AT TVA'S

SINGLETON LABORATORIES

1.0 Introduction

TVA has a testing program which is being conducted at TVA's Singleton Laboratory to obtain preliminary information about the performance of commercially available igniters. The purpose of these tests was to screen alternative igniters and to gain a degree of confidence that the igniters could ignite hydrogen. The tests were not run under normal laboratory test conditions since the objective was to identify which igniters, if any, were most promising as subjects for more detailed testing and evaluation. Nontheless, TVA gained considerble information and assurance that commercially available igniters could ignite hydrogen.

2.0 Preliminary Screening

A number of igniter types were evaluated, ranging from high energy spark igniters to large diameter (1-1/2" I.D.) heater coils. Although the spark plug type igniter was considered an excellent candidate for this application, it was rejected prior to preliminary testing due to potential problems with electromagnetic interference (EMI) with critical instrumentation. TVA's Electrical Engineering Branch is researching the problems associated with EMI generators, and spark type igniters may be considered at a later date for use in Sequoyah unit 2 or Watts Bar.

Two other potential candidates, both coil heaters, were rejected after the first one, a large diameter (1-1/2" I.D.) coil, could not reach sufficient surface temperature, and the second one failed at the connector in less than five minutes. Therefore, testing was restricted to diesel engine glow plugs, since they were known to be capable of achieving the 1500°F minimum surface temperature desired by TVA and because of their rugged design.

TVA determined that at 12 volts ac, acceptable surface temperatures could be achieved but that considering line losses, variances in system voltages, possible plug cooling due to high humidity, and other effects, TVA would need to operate the plugs at 13 volts ac ± 1 volt.

Since the possibility existed that TVA could overstress the plugs by overvoltage, TVA consulted glow plug manufacturers and identified two types of failure modes which could be expected. The first type of failure caused by overstressing would be the failure of the heater wire within the glow plug sheath. This type of failure due to the breaking of the circuit would outwardly cause the plug to discontinue glowing. The second type of failure caused by overstressing would involve offgassing of the glow plug tip. Unlike the first type of failure after offgassing, the glow plug may continue to glow; however, the surface temperature would drop significantly.

3.0 Description of Glow Plugs

Glow plugs manufactured by three different companies have been levels both on the primary and secondary side and at the plug were measured by a digital voltmeter (Fluke model number 8024A), and the current levles were measured by an amp meter (Triplett model number 10 type 2). The surface temperature of each of the glow plugs was measured by either a thermocouple (type S) connected to a potentiometer (Leeds and Northrop model number 8690-2) in contact with the surface of the plug or by an optical pyrometer (Pyro model number 85). A total of 12 plugs have been tested to date.

4.2 Surface Temperature

A GMAC model 7G plug was operated at 12, 14, and 16 volts ac. Surface temperatures as measured by the thermocouple were 1480, 1550, and 1650°F, respectively. Since the thermocouple would be expected to increase local heat loss and hence reduce the measured local surface temperature of the thin-walled plug sheath, these valves were probably somewhat lower than actual surface temperatures. This conclusion was supported by later readings with the pyrometer while testing another GMAC model 7G at 14 volts ac and getting 1720 ± 15°F.

A Bosch plug has been tested at 13 volts ac. It produced a surface temperature of 1700°F as measured by an optical pyrometer. Based on these results, TVA concluded that the diesel glow plugs could produce the desired surface temperatures.

4.3 Voltage Tests

Voltage tests have been completed on only the GMAC model 7G plugs. Based on tests on 5 GMAC 7G plugs, reliable operation at 14 volts was confirmed by two other 7G plugs failed at 16 volts ac after a few minutes.

Inconclusive testing on 2 Bosch plugs resulted in failure when operated at 14 volts ac; however, one Bosch plug operated satisfactorily at 13 volts ac. One Isusi plug was tested at 14 volts ac but lasted for only 30 minutes.

4.4 Extended Operation

Endurance tests have been performed on only two plugs for extended periods of time. A GMAC model 7G plug was operated continuously for 148 hours without failure and was later used in the hydrogen burning tests. A Bosch 10.5 volt plug was operated at 13 volts for 90 hours, then cooled down for two hours and turned back on. It has been running continuously after being reenergized since August 20, 1980, at 10 a.m.

5.0 Hydrogen Testing

One igniter (AC 7G) was installed in a "PARR" (229HC6-T316-031579-

5142) pressure vessel in order to determine feasibility of igniting hydrogen in a sealed container. The vessel lid has a silicone rubber sealed gas injection sampling port. Hydrogen concentrations in the vapor phase were determined before and after ignition intervals. An ignition interval is the time current flows through the igniter circuit. The hydrogen was measured by a Perkin-Elmer gas chromatograph equipped with 3920 thermal conductivity dector and an M-2 integrator. The chromatic graph was standardized with hydrogen and air mixtures prepared from research grade hydrogen and laboratory air.

Temperature measurements were made with a mercury and glass (484635, ASTM 9C) thermometer. Temperatures reported are ambient for tests 1 through 3. Prior to tests 4-10, 100 grams of water was added to the vessel. The vessel was heated by a temperature adjustable hot plate to saturation temperature of the water and maintained throughout the test. The reported temperature is the water temperture after completion of the test. Results of the 10 ignition tests are given in table 1.

6.0 Future Tests at Fenwall Laboratories

TVA and Westinghouse have contracted with Fenwall Laboratories to perform hydrogen burn testing on the AC igniter and its mounting enclosure in an enclosed vessel. Attachment 1 is the proposed Test Plan for the testing. The final test plan is being prepared by Fenwall and should be available in the near future. These tests are designed to prove the effectiveness of this igniter assembly to burn a volumetric quantity of hydrogen in environmental conditions which approximate postulated accident conditions inside containment.

7.0 Conclusions and Summary

The purpose of these tests at Singleton was to select a commercially available igniter that was capable of igniting hydrogen. From the results obtained, the GMAC model 7G glow plug produces more than adequate temperatures at a range of voltages that can be provided inside the Sequoyah containment.

In addition, the plug seems capable of extended operation at high temperatures and has been shown in small tests to be able to ignite 12 percent and lower volumetric quantities of hydrogen. Although it has not been tested as thoroughly, the Bosch plug appears like it may also be an optional igniter.

TABLE 1

HYROGEN IGNITION TESTS

Test No.	Vessel Contents	Temp. (°F)	Initial Hyd. Conc. (% Hyd.)	Final Hyd. Conc. (% Hyd.)	Ignition Intervals (Min.)
1	Hyd., Air	90	12.5	0.1	5
2		80	7	0.1	5
3		80	3.5	0.1	5
4	Hyd. Air, Water	120	12	0.1	3
5		180	14	0.5	3
6		180	4	2.5	1
7		180	2.5	1.5	1
8		180	1.5	1.3	1
9		180	11	5	1
10		180	5	2	1.3

Vessel Volume 1.1 dm^3 (0.039 ft^3)

Operating Voltage 12V dc

ATTACHMENT 1

SUMMARY

SEQUOYAH PLANT

HYDROGEN IGNITER TEST PLAN

1. Introduction

The following describes tests to be conducted on a type of hydrogen igniter to be installed in the Sequoyah Nuclear Plant. The igniter consists of a "glow plug" as used in diesel engines, the surface of which exceeds 1500° F and serves as a hot surface to initiate hydrogen burning, and a power transformer and an enclosure for the unit. The function of the igniters in the nuclear power plant containment is to burn hydrogen, in accidents where it could be released, when it reaches a burnable concentration thereby precluding its buildup to high concentration levels. The tests will be conducted by Fenwall, Incorporated, at their facilities in Ashland, Massachusetts. The unit, consisting of glow plug and enclosed transformer, will be placed in a test vessel and subjected to a range of environmental conditions (including hydrogen concentration, temperature, pressure, and steam), and its hydrogen ignition performance monitored.

1.1 Purpose of Tests

The primary purpose of the tests is to demonstrate that the igniter will initiate a volumetric burn of the hydrogen for the specified environmental conditions (pressure, temperature, water vapor). A secondary objective of the tests is to narrow down the hydrogen concentration range for which a volumetric burn of hydrogen will be initiated.

1.2 Acceptance Criteria

For the initial set of tests, the following acceptance criteria will be used:

1. Data generated are internally consistent (i.e., ignition at 8% consistently produces low pressure rise).
2. Data gathered confirm theoretical predictions.
3. Igniters reliably ignite mixtures at high (12%) concentration and provide relatively complete combustion.

2. Description of Igniter

The igniter is a General Motors Ac Division Model 7G glow plug (thermal resistive heating element) requiring 14V ac supply at a maximum of 8-1/2 amps. The surface temperature of the plug as measured by an optical pyrometer should be a minimum of 1500° F. TVA has measured 1720° F surface temperature on one of the glow plugs at their facilities. The igniter is powered by 120V ac stepped down to 14V ac. The power transformer is a Dongan Electric, Incorporated, Model 52-20-187 specially wound transformer having the following characteristics:

120V RMS AC on primary side
14V RMS AC on secondary side
200V A Min.
Class H (High temperature insulation)
Open style with 18" flexible leads
Certified capability that transformer will operate at 220° C.

The igniter and transformer are mounted as a unit as shown in Figure 1 with the glow plug extending from the side. The unit is encased in a 1/8-inch steel plate box type casing and sealed with a rubber seal for water tightness.

3. Description of Test Facility

The tests will be conducted by Fenwall, Incorporated, at their facilities in Ashland, Massachusetts.

3.1 Test Vessel

The igniter unit will be tested in a spherical vessel in excess of six feet in diameter. The internal volume of the test vessel is 1000 gallons (134 ft^2). The vessel is constructed of carbon steel (exterior) and is lined with stainless steel. The vessel is designed for a working pressure of 500 lb/ft^2. The vessel is equipped with five diameter access ports (four on circumference, 90° apart,

and fifth at the top), one of which is drilled to attach to a manifold with valves and connecting lines to air, steam, and hydrogen makeup sources.

The vessel is heated externally via electrical heaters. The vessel will be equipped internally with a fan to promote mixing and also to create a draft at the igniter heating surface during testing when desired.

3.2 Instrumentation and Measurements

The vessel is instrumented with two pressure transducers to monitor the pressure including the pressure transient during the hydrogen burn. The output is carrier amplified and feeds to an oscillograph device. Thermocouples are provided which will monitor vessel atmosphere temperature prior to and after a burn. In addition, a thermocouple will be used to measure the temperature of its heated surface. Gas mixtures will be formed using pressure instrumentation and a partial pressure method in which a given gas is added until the appropriate partial pressure is indicated. Sampling capability exists via a 1-inch by 1-foot lecture bottle. Hydrogen and oxygen analyzers will be provided to measure pre- and post-burn concentrations of these gases:

	O_2 Analyzer	H_2 Analyzer
Manufacturer	Hays Republic	Hays Republic
Model	A 00632	SH-A-00643D
Range	0-5%/0-20%	0-5%/0-20%
Accuracy	± 1% F.S.	± 2% F.S.

4. Test Plan

4.1 Identification of Tests

The unit consisting of the glow plug and encased transformer will be positioned in the test vessel (via 18-inch port) with the glow plug heating surface located near the center of the test vessel. Various mixtures of H_2, steam, and air will be adjusted with pressure and temperature as specified and then the igniter turned on. The pressure transient will be recorded and the mixture analyzed for H_2 and O_2 content prior to and after the burn. The test matrix for the first series of 12 tests is shown in Table 1. Initial total pressures of 15, 21, and 27 lb/ft^2 a will be covered at hydrogen concentrations of 8 and 12-volume percent. Initial temperature wil vary from 180° F (dry case) to 350° F (superheated steam) with most of the tests being conducted at saturation temperature corresponding to the pressure to be tested. In addition, a fan will be located in the test vessel to provide drafts of 5 and 10 FPS in the vicinity of the glow plug to simulate turbulence which may be developed in the vicinity of the igniters.

Further testing will be developed based on the outcome of test series #1, and may include addition of an instrumented transmitter and steel or concrete surfaces with thermocouples attached to measure temperature response on hydrogen burn. In addition, means to simulate spray droplet entrainment in the atmosphere are under investigation.

4.2 Test Procedure

The basic procedure is to adjust mixture concentration temperature and pressure, then energize glow plug and record the pressure and temperature transient. Hydrogen concentration after the burn will be measured to assess completeness of burn. The steps for the different tests are as indicated in Table 2. In one of the tests with a steam environment, the glow plug will be energized after the steam, pressure, and temperature environment conditions are reached, but before hydrogen is added, and allowed to stand for two hours. Then the glow plug will be deenergized, hydrogen adjusted, and then the glow plug energized. The purpose of this is to allow for preburn exposure to the environment.

4.3 Test Schedule

The test schedule is tentatively planned as follows:

Facility Preparation	8/18 through 8/29
Test Series No. 1	9/1 through 9/5
Subsequent Tests	9/8 through 9/12
Test Evaluation	9/15 through 9/19

DE01;SQNHYD.AA

TABLE 1

TEST SERIES NO. 1

Test	Temp (^{o}F)	Total Pressure* (Gauge)	Hydrogen Concentration (Volume Percentage)	Fan Induced Flow Speed (fps)
1	180	0	12	0
2	180	0	8	0
3	Sat temp	6	12	0
4	Sat temp	6	8	0
5	Sat temp	12	12	0
6	Sat temp	12	8	0
7	Sat temp	6	12	5
8	Sat temp	6	8	5
9	Sat temp	6	8	10
10	Sat temp	6	12	10
11	350	12	12	0
12	350	12	12	10

*This is the total pressure due to air, hydrogen, and steam. For tests 1 and 2, the pressure will be higher than 0 due to the added hydrogen partial pressure and the evaluated temperature.

PROPERTIES OF HALON 1301

- LOW BOILING POINT (-72°F)
- LOW TOXICITY (UL GROUP 6)
- INSOLUBLE IN WATER (0.0095 W/O)
- INERT
- LOW RADIOLYTIC DECOMPOSITION (0.00023 g/d/R/h)
- NO LONG TERM ACTIVE MIXING REQUIRED AFTER INJECTION

SUITABILITY OF HALON 1301

- PREVENTS HYDROGEN IGNITION AT SUFFICIENT CONCENTRATIONS.

- ATLANTIC RESEARCH CORPORATION REPORT SHOWED HALON 1301 SUITABLE FOR USE IN A MARITIME REACTOR CONTAINMENT.

- INITIAL STUDY BY ARC FOR AEP/DUKE/TVA INDICATES HALON 1301 SUITABLE FOR USE IN ICE CONDENSER CONTAINMENT.

AREAS OF FURTHER STUDY BY ARC FOR AEP/DUKE/TVA
ON HALON 1301

- EFFECT OF HALON 1301 AND ITS DECOMPOSITION PRODUCTS ON CONTAINMENT MATERIALS
- TEMPERATURE AND PRESSURE EFFECTS ON CONTAINMENT DUE TO INADVERTENT ACTUATION
- POTENTIAL PROBLEMS ON LONG TERM ACCIDENT RECOVERY
- EFFECT OF HIGH CORE TEMPERATURES ON HALON 1301 DECOMPOSITION
- POTENTIAL FOR NON-INERTED HYDROGEN POCKET DETONATION TO INITIATE COMBUSTION IN INERTED MIXTURES
- PERSONNEL HAZARD DUE TO INADVERTENT OPERATION
- SYSTEM DESIGN AND INCORPORATION

Degraded Core

- TVA is following the state-of-the-art developments at national laboratories (Battelle, Columbus, Brookhaven, Oak Ridge), AIF, EPRI, etc.

- TVA is building the capability to use MARCH as a starting point.

- MARCH is not intended for design.

- TVA has set a goal to obtain a hydrogen generation rate curve (into the containment) for a fair range of core damage accidents.

STATEMENT IN RESPONSE TO QUESTION -

DO ICE CONDENSERS NEED ADDITIONAL HYDROGEN MITIGATION SYSTEMS?

The nuclear power industry and NRC have identified many lessons in the TMI-2 event. As a result of studies by the staff, the Kemeny Commission, consultants, ACRS, and others, including TVA's own Nuclear Program Review, a large number of changes have been identified. Some were implemented almost immediately, some are in various stages of implementation, and others are the subject of intensive study or planned rulemaking. The issue of the effects of hydrogen generation from degraded cores was considered by many, including TVA, as one of the more important raised.

We are addressing all of our containment designs; while the lower design pressure is a disadvantage for this issue, the ice condenser containment also has definite advantages, including a large, passive heat removal capability.

As a result of its Nuclear Program Review, TVA committed to:

> Study ways to contain larger amounts of hydrogen and to backfit feasible features into the Sequoyah design. (TVA Nuclear Program

Review: Sequoyah Nuclear Plant and the report of the President's Commission on the accident at Three Mile Island, November 1979.)

TVA moved immediately to fulfill that commitment by committing significant resources to the issue. That effort continues and at this point has resulted in a significant study of degraded core accidents and their mitigation, in a long range plan to further study and act on the recommendations of that study, and in installation of an interim distributed ignition system. We feel that the steps taken and planned to reduce the likelihood and minimize the extent of core damage events, when coupled with the plants' inherent capability to withstand substantial core damage (about 25% metal-water reaction), would provide a sufficient degree of safety for the short term until TVA's and others' studies could be completed. However, since TVA is committed to make feasible improvements in the safety of our plants, we proceeded to install the interim distributed ignition system once we were convinced that it would not reduce plant safety and had the promise of increasing the amount of metal-water reduction that the plant could withstand. Our efforts are being placed on determining how much increase in capability the interim system affords and on our long term program which addresses other alternative measures in addition to controlled ignition.

TVA believes: that Sequoyah can be safely operated at least in the short term until our studies can be completed; that the plant already has significant capabilities to withstand a range of core damage events; and that the interim distributed ignition system increases this range of capability. We are firmly committed by policy, by staff opinion, and by actual work to take the lead on this safety issue.