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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

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WORKING GROUP ON STRUCTURES AND MATERIALS
FOR CLINCH RIVER BREEDER REACTOR

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

Thursday, August 19, 1982

The Working Group convened, pursuant to notice, at 8:30 a.m., PAUL SHEWMON (Chairman of the Working Group) presiding.

PRESENT FOR THE ACRS:

PAUL SHEWMON, Chairman
HAROLD ETHERINGTON
MAX CARBON
CHESTER SIESS
ROBERT AXTMANN

CONSULTANTS:
S. BUSH
Z. ZUDANS

DESIGNED FEDERAL EMPL[illegible]

ANTHONY CAPPUCCI

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PROCEEDINGS

MR. SHEWMON: This is a meeting of the ACRS CRBR Working Group on Structures and Materials. I am Paul Shewmon, Working Group Chairman. We will proceed with the meeting as we had on the agenda before we covered the first two items from this morning's agenda, and we are now ready for the Applicant's presentation on containment properties, according to my agenda, does that fit with yours?

MR. DIXON: Yes.

MR. SHEWMON: Are you Mr. Gale?

MR. GALE: Yes, I am Richard Gale, with Westinghouse. This is a presentation on the containment analysis.

The regulations require that we have compliance with ASME Code Section 3, subsection NE. Our PSAR is consistent with the ASME Code. However the code did not at that time, and still does not, address buckling for complex geometries and loadings that we have in this vessel. Therefore, we must consider several areas of buckling, namely, the cylinder, the dome, the ring stiffner, and also address thermal interaction.

We have addressed the adequacy of this buckling design by two methods: the ASME Code rules and the buckling criteria that we have inserted in the PSAR, Appendix 3.8-A. We have many conservatisms in this buckling criteria which I will illustrate.

I will first address the cylinder. In the PSAR, the cylindrical buckling criteria was fundamentally adopted from that of Sequoyah, and we have adopted it for our applicable conditions. There are some few differences.

The dome was based on Welding Research Council Bulletin 69 for buckling of shells with double curvature, and we have also based it on the Sequoyah with slight variations, variations that are due to some small geometric differences.

The ring stiffeners were designed to the ASME Code rules, and we have also checked all of those rules with Mr. C. D. Miller of CBI who is a well-known, respected expert in the buckling field. These were all confirmed to be adequate in his opinion.

The thermal interaction equations were primarily based on the BOSOR analysis, and it has been demonstrated that the critical failure mode for this vessel was due to yielding rather than any critical buckling.

We have limited the critical thermal buckling stress to 80 percent of yield for SSE and 67 percent for

OBE. The thermal stresses were all treated as primary stresses in the buckling interaction equation, and we combined them with concurrent axial hoop, shear, and torsion stresses.

MR. SHEWMON: Excuse me, but I am disoriented somehow. We are talking about a containment which normally is around the vessel and normally does not get too hot. You are talking about a failure mode of thermal buckling. Does this postulate some accident in which the gas gets very hot inside the containment?

MR. GALE: It is by yielding. We have to consider all of the conditions and temperature is a portion of those conditions. We do not have high temperatures. We only go to a maximum of 150 degrees, less than 150, 130 degrees in the accident mode.

MR. SHEWMON: Fahrenheit?

MR. GALE: Yes. But we must consider it. It is not that our failure as a result of the thermal condition, but what I am saying is that we have do hae temperature rise, and we have considered it.

MR. SIESS: Could you back off a little bit and tell us what load the structures are subjected to that you are analyzing. You assume that we know that, but it probably wouldn't hurt.

MR. GALE: The loads that the vessel is

subjected to are primarily those resulting from the crane loads. The crame is supported off of the vessel in a support. I have a backup viewgraphs, if we do need that.

We do have crane loads, and the prime loads that the vessel is subjected to are those loads transmitting from the loads on the crane through the vessel shell wall, down through the skirt, and obviously those loads are increased significantly during an earthquake event, and those are the significant loads that we must address. There are some other incidental loads. We have some internal design pressure, which in those cases helps because the internal pressure releases the pressure on the shell.

MR. SIESS: But that would not exist necessarily during an earthquake, would it?

MR. GALE: Correct.

MR. SHEWMON: The crane loads would exist during an earthquake because the crane itself is so heavy even if it is not lifting anything?

MR. GALE: We are postulating all crane loads including live loads. We are considering a 125 ton load being suspended on the crane during an earthquake.

MR. SHEWMON: You also postulate that the reactor is at full power?

MR. GALE: Yes.

MR. SHEWMON: You consider what happens when the containment buckles and that 125-ton load falls?

I guess if I have a 125-ton load on the crane, and I have an earthquake, and nothing else happens, you shut the thing down and repair it. Does the containment have a safety related function 24 hours a day, seven days a week?

MR. GALE: You are slightly out of my area. Let me try to answer my portion of it.

First off, we have designed the vessel so that we have adequate amount of margin, so that there will not be a buckling failure as such time as we have a 125-ton load on the polar crane. Therefore, we are designed for that, and that can't happen.

To go beyond that, to determine what the systems are doing, I need help from the systems people, whether or not we have postulated the 125-ton load falling from the crane in an earthquake.

Can you answer that, Paul. The question is, whether or not we have postulated 125-ton live load falling from the crane in an earthquake.

MR. SIESS: Can you back off a little bit and give us the safety significance. Are you interesting in buckling of containment as something that can affect the health and safety of the public.

MR. GALE: That is a conservative position. although it is not demonstrated that buckling would result in a failure of containment function, nevertheless, we have taken the position that we will prevent buckling because that is a conservative approach to demonstrating that you will not fail the containment function.

MR. SIESS: It doesn't answer my question. Is somebody prepared to answer the question why we are concerned with the buckling. How conservative something is has to be judged in terms of the consequence, and I don't have any feel for the consequences of buckling of the containment, so I have no way of judging How conservative is enough. Do you understand?

MR. DICKSON: I believe I understand the question. As I understand it, your thought is that an earthquake causing a buckling and failure of the containment does not necessarily endanger the health and safety of the public, assuming no other failure. That is correct. For conservatism, however, we have designed the containment to remain integral during and after an earthquake so that it can perform its containment function.

MR. SHEWMON: One simple question before we get to yours.

Having it at full power when you are carrying maximum load, which sounds like something that you could get around carrying administratively, but is that something that you expect to do, or is that again a "Gee Whiz, why not, it is conservative"?

MR. DICKSON: I don't think that it is quite a "Gee Whiz, why not." Whether the reactor is at full power makes very little difference to the load on the containment, if any difference at all.

MR. SHEWMON: It would make a lot of difference in the safety consequences, and that is what I have in mind.

MR. DICKSON: that is correct, and that could be categorized as a "Gee Whiz, why not." It is a fact that the containment, not the crane, that sometimes will be carrying loads of that magnitude. If we should have an earthquake, we don't want that containment to buckle under those circumstances, whether the reactor is at full power or simply removing decay heat.

MR. ZUDANS: I have a different question completely. You are explaining what is required and what what is done in terms of stress limits. What we would like to see first, at least I, is which specific loads did you include in the containment buckling analysis, because there is no buckling problem unless you can show that there are some stresses generated either in one or both of the directions.

I would like to see first and ask you what are those things specifically. That is all we really need, all the other discussion is just argument.

MR. GALE: Let me try to answer your question. We do have the dead load of the weight of the vessel.

MR. ZUDANS: Plus the weight of the crane.

The weight of the crane, the weight of some attachments to the vessel, such as cable-trays, et cetera things that are attached to the vessel. That is the first item. The live load is the crane load. We do postulate that we do have a 125-ton live load suspended from the crane. Obviously, these are the two earthquake events that are really multipliers of these.

MR. ZUDANS: They are not multipliers, they are additives.

Go ahead, next.

MR. GALE: We also assume thermal loading at that time.

MR. ZUDANS: The thermal loading is the design basis accident.

MR. GALE: And in this case it is about 130 degrees shell temperature.

MR. ZUDANS: That is a uniform temperature you assume.

MR. GALE: No, we have analyzed it for varying temperatures depending on what the accident conditions are.

MR. BUSH: May I pursue that a little bit. When we look at the Sequoyah type plant about 15 years ago, our concern was that you break pipe, a secondary pipe, and when you get a jet of steam, you are certainly not going to have a nice uniform temperature. You will have a very high temperature. By and large, there was an indication under those circumstances that you would get buckling.

Now, whether the buckling meant anything from a safety point of view, that is another point of view. It doesn't sound to me as if your buckling calculations would be bounding by any stretch of the imagination.

MR. GALE: Our thermal loads are very, very minimal. The thermal load that we design for as a result of an accident is down in the lower levels of the vessel, down in the concrete structures, finds its way to the environment above the operating floor and several paths. It gets very uniformly distributed.

We also have insulation inside of the

containment vessel from the operating floor, some nine feet up to the first girder, to mitigate the effects of any thermal irregularities on the cell at the point of discontinuity where the shell enters the concrete. We have extremely uniform heat and very minor heating, and the heating is through the atmosphere inside the cell structure from the operating floor to the vessel.

MR. BUSH: I am not a believer of major pipe breaks, but I must confess that if you did break a pipe, the insulation wouldn't serve much purpose because the jet loads from that would take care of the insulation in no time at all.

MR. GALE: We don't have those pipes.

Mr. Dickson would like to speak to you.

MR. DICKSON: We are not sure that we brought out the configuration, but all the sodium pipes are below the operating floor inside lined rooms that are furthermore lined with concrete some distance before you get to the containment.

The containment area that he is talking about getting hot is above the operating floor, and the heat from the cells below the operating floor has worked its way. Any steam lines that we have are outside of containment and cannot impinge on containment either. There is no way for any thermal loads to apply directly on containment in our design.

MR. ZUDANS: I think you are right. There is really nothing that could create asymmetric temperature patterns within the steel portion of the shell. Is that correct?

MR. SIESS: Does the containment play any role in the HCDA?

MR. DICKSON: Yes.

MR. SIESS: It would get any thermal loads?

MR. DICKSON: In the TMBDB, thermal margin beyond the design basis, it does have thermal loads. It gets hotter than it does during the design basis accident.

MR. ZUDANS: Okay, now we see the picture.

MR. GALE: All the postulated accidents are taking place down in here, and it is through various and sundry stairways and other paths that the heat finds its way up into this area. So the heating of the shell is not by any direct action from any jet stream or any pipe break, or anything that you are normally accustomed to looking at. It is only by heating this entire area that we heat the shell, therefore we get extremely uniform heat into the shell.

We do have that question from the staff, and I don't recall the number at the moment, but we have prepared an analysis of that and have responded to that question from the staff.

MR. ZUDANS: That is all right. The other load that you have marked on that other slide as PE, what is that load?

MR. GALE: We have designed for external pressure. Even though it is a conservative design, we have designed for it way back in the beginning. Before we had our design analysis so detailed, we did feel that it was conservative to include some PE. All of our design is based on an external conservative number of 0.5 psig.

MR. ZUDANS: If I read this slide correctly, with this combination of loads, you think will not --

MR. GALE: This slide is not intended to be shown at this time. It is only to give you the analysis on the right side that I will demonstrate to you later.

MR. ZUDANS: This is what we want to see, and you can explain the results afterwards.

MR. SIESS: What is the source of the external pressure?

MR. GALE: There is none. We assume a 0.5 psig external pressure for design purposes only. There is some minimum amount of external pressure that can result many, many hours into the accident as a result of the cool down from a sodium fire. But we have relief valves on the vessel that are designed to open at three inches of water. Therefore, there is no possible way to ever achieve 0.5 psig external pressure.

MR. BUSH: You said something I am interested in. You assume a sodium fire, and I would think that in a sodium fire you might have much higher temperatures than from a thermal point of view with regard to buckling.

MR. GALE: No, we do not. The maximum shell tempeature in a sodium fire is 130 degrees.

MR. BUSH: I would like to see those calculations, I am afraid that I don't believe those.

MR. ZUDANS: You assume the sodium fire is below the floor.

MR. GALE: The logic for that -- Appreciate that I am not the one to answer this question, but I will attempt to give you some general logic. Logic is that this is all taking place down here, and we have done detailed analysis. There are people on the project who obviously can answer that question for you, but remember that we have insulation here.

Because the continuity between the shell and this concrete is our critical area, so we have insulated this to reduce the thermal stresses, and the maximum temperature on the shell is 130 degrees. It is not uniform and we have developed those gradients, and we have analyzed those gradients. But there is no local heating, it is very general heating.

MR. SHEWMON: What is the primary defense against tornadoes? You said half a pound external pressure, which you can begin to get that with --

MR. GALE: That is complete enclosed by confinement.

MR. SHEWMON: That fends off any wayward airplane and tornado?

MR. BUSH: No, that is not big enough for an airplane.

MR. SHEWMON: But you do feel that it does take care of tornadoes.

MR. DICKSON: It will certainly stop it.

MR. SIESS: It will slow down an airplane.

MR. SHEWMON: Okay.

MR. GALE: I heard a comment a earlier that what you wanted to hear was something else. Do you want me to go over this presentation anyway?

MR. ZUDANS: Go ahead.

MR. GALE: Let me see if I remember where I was. I believe I was about here, where I was talking about, we have combined the thermal stresses in combination with the axial hoop, shear, and torsion stresses.

MR. ZUDANS: I don't understand your second bullet. Could you explain what that means? What is the thermal buckling stress, if you don't have any thermal loads to create compression?

MR. GALE: Yes, we do have some thermal loads.

MR. ZUDANS: What does thermal buckling by itself mean? You can't have thermal buckling without having dead weight at the same time. What does 80 percent mean in this case?

MR. GALE: Don Griffith, can you handle that?

~~MR. GRIFFITH: We are talking about the~~ combined seismic.

MR. ZUDANS: So why do you use thermal, and what is the significance of 80 percent of yield, what does it mean?

MR. SHEWMON: They mean that if the combined stresses got to 80 percent, it buckles.

MR. ZUDANS: I want them to explain what is the buckling load. You compute some buckling load by some method, and say this is the buckling load. If the buckling load exceeds the yield, it is not good, you have to complete it by a different way.

MR. GALE: Perhaps what we have not done here is to demonstrate what the purpose of this presentation was. We have intended to communicate to you all of the parameters that we have utilized in the development of our criteria, and that is the question that we are attempting to answer up front, which is were all your assumptions, where did you criteria come from, and why do you that those criteria. This entire presentation at front end is geared toward that response.

MR. ZUDANS: That is exactly what I want to understand. What does it mean?

MR. DICKSON: I believe I can add that most of those were developed as criteria before we knew exactly what the parameters would be. At that time we did not have the analyses that showed that the design basis accident would only get 130 degrees. Does that help?

MR. ZUDANS: It only helps if you strike out that second bullet, because it is meaningless.

MR. SHEWMON: Let's assume it is struck for a minute, and see what else he can tell us.

MR. GALE: We also performed an ASME buckling check for compression of the overall seismic effects, and we included the dead load and external pressure.

We also verified, using an equivalent external pressure with the hoop comprssive stresses, and we considered pressure and added that to the seismic loading. That is what you were just asking a moment ago that we explain here.

We checked the ring stiffeners under the ASME code rules, and we then checked the buckling by the rules applicable to stiffened vessel under external pressure. We designed all the penetrations for the shell under the ASME rules.

MR. ZUDANS: I would like more explanation to the second and last bullet. Let's go to the last one first. When you talk about shell penetration, it is not a buckling design. You are reinforcing the shell according to the ASME rules, is that what you mean?

MR. GALE: We have used the area replacement rules.

MR. ZUDANS: That has nothing to do with buckling.

MR. GALE: There are no ASME rules for buckling for penetration designs.

MR. ZUDANS: That is understood. Now, the second, how did you create this equivalent external pressure? The code does not provide you with rules on that.

MR. GALE: Don, can you help me on that, or Richard?

MR. GRIFFITH: What code are you referring to?

MR. ZUDANS: It says ASME code rules, and it has nothing to do with ASME code rules.

MR. GRIFFITH: The ASME code rules, the Section 3 rules deal with certain kinds of components, as you are well aware, spheres and cylinders under certain external pressure. They don't cover bending of cylinders, and the critical region is the bending problem. So you have to go, in the analysis, beyond what is provided by the code to meet the intent of the code for limits.

Code 1047, which is not applicable here, but it gives you the current concepts, that throws it over into a complete analysis. If you go then into 284, it is a different concept.

MR. ZUDANS: Don, if you mean that this bullet is supposed to tell me that interaction analyses were made with some brief computer codes, the highest compressive meridian location was found, and that was used for code rules, then it is all right.

MR. GRIFFITH: Yes.

MR. ZUDANS: All right, but it is not expressed that way.

Proceed.

MR. SIESS: Did you understand that?

MR. ZUDANS: Yes. I just want to make sure that we all understand what they have done.

MR. SHEWMON: Not all, just some.

MR. SIESS: I am still sitting here trying to figure out why we are concerned with satisfying an ASME rule that doesn't exist. Is there some legal reason?

I was told at least five times that the ASME doesn't cover this, but still you are going to meet it. The ASME rules don't cover cylinder bending. Why don't you stop worrying about ASME, why don't you go up somebody else?

MR. SHEWMON: We have somebody trying to answer.

MR. SIESS: Is this somebody who knows something about buckling of cylinders or bending?

MR. GRIFFITH: May I talk?

MR. SHEWMON: Yes.

MR. GRIFFITH: It is not that the ASME code doesn't want you to guard against buckling. If your geometric and loading conditions don't meet the conditions that they cover, the intent of the code certainly is that where buckling is a failure mode, that you must guard against it. In certain cases where they know what to give you, they give you some simple design charts to avoid that.

In the cases where you cannot generalized very simply in the form of charts, the intent certainly is that you still avoid buckling by a combination of tests and test verified analysis. That is very clear in code case N-37 for the genuine buckling failure mode, but it is for the owner to specify.

MR. SHEWMON: Okay, onward.

MR. GALE: That is we had to develop Appendix 3.8-A, because how to do it was not defined. We therefore developed that appendix to provide for loading cases and geometries beyond the ASME design formulas. We used some established classical buckling analysis that is consistant with the ASME approach. We did consider imperfections due to knock down factors, and we considered the combinations of different buckling stress components. This is one of the things, incidentally, that is stated anywhere.

We have applied conservatism in our design in this fashion. We have assumed that the maximum stresses acting uniformly around the circumference even though the maximum stress only occurs locally.

We assumed the maximum stress acting uniformly over the length of the panel, even though those appear only in limited areas.

We have used equivalent static stresses for peak responses from dynamic analysis.

We have designed for 125-ton live load on the polar crane during an SSE, which is an extremely unlikely event, as the question was asked earlier.

We did not take credit for the concurrent tensile stresses in the cylindrical shell. We did not take credit for internal pressure, for instance, as an aid against the stresses resulting from polar crane loads.

We incorporated significant conservatism in the buckling analysis in an effort to get a very conservative design.

A summary of this portion, therefore, is that the PSAR criteria is consistent with the previously licensed, Sequoyah being our model, however, Sequoyah was also used elsewhere.

The design conforms to these criteria. However, the NRC has requested a comparison of the PSAR to the 1980 code and to the code case N-284, which is part of the reason why we are talking about it, because the staff has asked about it. N-284 deals primarily with buckling.

We recently provided this comparison -- I said, recently, but that is not quite the fact. At this moment, I have produced it out of my shop. It is in review in the project, and it has not the project yet, but will be shortly presented to the staff.

We have also evaluated the significant changes both in the 1980 code and N-284, again, in that package that is not yet there, but soon will be with the soon be there.

We continue to believe that the design is safe and adequate even after all of these reviews and comparisons, but we are continuing this dialogue with the NRC to reach some agreement with them that we in fact have the conservative safe design that we feel we have.

It is now time to show this in total. As a part of this on-going effort with the staff, and the questions particularly about code case N-284, and these buckling issues, we have done some analysis. What we have done with the BOSOR4 program was to combine these loads and use an N-284 analysis code case. The code case is a code case that came out in the 1980 time frame, and that is a case dealing only with buckling.

We have run that at the critical area of the portion of the shell immediately above the operating floor and below the first girder. That is the general consensus of opinion as to where the critical area of buckling would be on the vessel.

We have run that analysis in that N-284 type framework, and we have a safety factor of 1.9 as compared to that required by code case N-284 of 1.67 under SSE loading conditions. Under OBE loading conditions, we have a safety factor of 2.5 as compared to N-284 of 2.0.

MR. ZUDANS: I have a couple of questions. The BOSOR analysis can analyze asymmetric loads. Can you pick the worst meridian in this case, and use that proposal for buckling. Then in order to comply with N-284, are you required to pick out a knock down factor. What was the knock down factor on the scale?

MR. GALE: This work was performed by a consultant in our company, Richard Orr, who has some recent experience in dealing with the buckling issue. Mr. Orr is in the audience here, prepared to answer your detailed question with regard to that analysis.

At this point, Richard, could you come to the microphone please?

MR. ZUDANS: I didn't expect to see you here.

MR. ORR: In response to your question, the knock down factors used in the analysis for the first phase, for the axial stresses, we used a knock down factor of 0.275; for the bay just above that, it is

0.33, and for the bay almost up by the crane girders, it is 0.309. These magnitudes are all calculated using code case N-284. In the group direction, the knock down factor is 0.8 at all locations. When we combined it with the shear structures, we used a knock down factor on the shear of 0.712.

MR. ZUDANS: The factor of safety that you indicated at 1.67 says that you assume this to be a --

MR. ORR; A service C condition.

MR. ZUDANS: How did you arrive at that justification, or was it given to you as an analyst?

MR. ORR: No, we basically defined the service level C condition. Typically, service level A on the containment is the design basis accident. Service level B is the design basis accident plus the operating basis earthquake. Service level C is the design basis accident with the safe shutdown.

MR. SIESS: The second case, with the OBE, is that related to service level C also?

MR. ORR: It is related to service level B, which has the same allowables as service level A.

MR. BUSH: I notice that you have assumed a value of zero for PE in this one, whereas in the other calculation, the early one, you used a 0.5. What would be the implications with regard to the safety factors that you had from the calculations with the 0.5?

MR. ORR: It would reduce safety factors by something less than 10 percent.

MR. BUSH: What was the buckling stress level compared to in the worst case?

MR. ORR: The maximum axial stress is just less than 4000 psig.

MR. ZUDANS: I think that we can dispense with the rest of the presentation, as far as I am concerned.

MR. GALE: Therefore, we have designed for the ASME code. We do meet the code. We have developed additional criteria, and we do meet that additional criteria. We still believe that everything is safe. However in response to the staff's question, we have gone into code case N-284 in somewhat greater detail. As I mentioned before, we are presenting that to the staff. We believe that we will reach a favorable conclusion on that.

We have presented the numerical comparison that I have just showed you that demonstrates that our design does in fact, in the critical areas, still meet the conditions of code case N-284.

That concludes my presentation.

MR. ZUDANS: I would like to ask the staff a question.

Do I understand that the staff has approved code case N-284, or is in the process of reviewing it? Do you know that?

MR. CHEN TAN: The N-284, our branch has not approved it. N-284, the load test that they use as a safety factor of 2, but according to the code it is a factor of 3. So we have this problem under study by Los Alamos National Laboratory, and also Los Alamos is doing tests on the buckling of the containment.

MR. ZUDANS: We had a presentation at Los Alamos, and they indicated that the cylinders are reinforced in accordance with the ASME rules, and the buckling capability was not reduced. One of the Reg Guide stated that the factor of safety should be 2. Has this been changed?

MR. CHEN TAN: The basic problem is that the code is not clear about the knock down factor. Does the factor of 3 include enough knock down factor or not.

MR. ZUDANS: The knock down factor in this code case is similar to NASA reported knock down factors which is based on actual load and bounds of test results.

MR. CHEN TAN: Bushnell is also studying this problem, and we have an interim range for the buckling that he looked at. There is a true concern with it. So we want him to do a more detailed review by Bushnell in coordination with Los Alamos. For this buckling, we have not determined criteria yet.

MR. SHEWMON: Thank you.

Mr. Boasso.

MR. BOASSO: Good morning. I am Cliff Boasso from Westinghouse, and this morning I would like to give you an overview of the gas leak detection system that we have in the Clinch River plant.

The function of liquid metal/gas leak detection is continuous monitoring of liquid metal systems for leakage into surrounding gas spaces; detection of small leaks prior to significant corrosion of crack propagation; and detection of larger leaks prior to significant loss of liquid metal inventory or onset of significant economic damage.

In the plant, we have aerosol detectors monitoring the environment of the cells. We have aerosol detectors monitoring the environment between piping and the insulation surrouding the piping. We also have aerosol detectors monitoring the annular space between components and the broad vessel surrounding the components.

We also have different types of detectors, and I will get into this in my next viewgraph, for detecting different types of leakage as well as leakage between large components, heat exchangers, and the insulation, as well as leakage in valves. These detectors will generate alarms that go to local panels in the plant, and the information is transmitted from these local panels to the main control room.

This is a brief overview of the logic.

Typical requirements for the primary heat transport system: Detection sensitivity, we detect 100 grams per hour or greater in less than 250 hours. Leakage of 30 gallong per minute or greater will be detected in less than five minutes.

In the primary heat transport system, we have a system which is diverse in nature. We have different principles for detecting the leakage. Leak location on a cell basis, a major component basis -- the pump, the heat exchange or the reactor -- and also piping section, the hot leg and cold leg.

We have leak confirmation via the different signals, via signals from different detectors. We have a seismic category II system, and we have alarms and indicators in the main control room.

MR. SHEWMON: Yesterday I was asking questions about how you decided how many leak detectors you needed per running furlong, or something like that, and I was asked to wait until today. Do I wait for your next talk, or do you want me to ask about it now?

MR. BOASSO: Now would be fine, if you would repeat it for me please.

MR. SHEWMON: You say all these good things, and my question has to do with whether you sort of put one off in the corner of the cell, whether to do this you have to have one every yard along every pipe inside the insulation, or what the density of detectors has to be to perform, and how you go that frequency?

MR. BOASSO: For the system that is interrogating the annulus between the pipe and the insulation, we locate the sniffers at 25-foot intervals, and we have a maximum of eight sniffers going to one detector. We have performed verification testing to assure us that this particular design will indeed detect leakage of this magnitude.

With respect to the cell itself, we have determined that it makes no difference where you put the detector with respect to the dispersion of the aerosols. The logical place would be to put them in the vicinity of the return to the cooling system, obviously.

MR. SHEWMON: Have you had an exchange with the staff on this matter yet?

MR. BOASSO: We have spoken with staff in the past on our leak detection system. We have made a presentation to the staff, yes, sir.

MR. SHEWMON: The reason I bring it up is that I remember a rather unproductive exchange when FFTF was up in which the staff and the applicant hadn't reached agreement, and were not communicating very well. So if the staff, at least, has some opinions on what the basis for those will be, I think you will find it more productive.

MR. BOASSO: I can't speak for the staff, obviously, but we have discussed it with the staff.

MR. SHEWMON: You feel you have a good technical basis for why 25 feet is good enough?

MR. BOASSO: Yes, we have verified that with the test program.

MR. BUSH: Let me ask you a question in this respect. In particulate monitors, I am assuming this is an activity monitor.

MR. BOASSO: We have three different types of detectors, and I will show you in the next two viewgraphs.

MR. BUSH: Let me ask a question, and you don't have to answer it right now. Particulate monitors, their reliability at time interval is markedly affected by the background. Therefore, a plant that is operated, as you build up a substantial level of background radiation, you can mask it substantially. That certainly has been the case in the water reactor. By analogy, I would expect that the possibility exists here. So when you get to the right place, I would like you to address that question.

MR. BOASSO: Very briefly, the different types of detectors that we utilize in the plant. We have the contact detector that we insert in the valve bellows for detecting leakage, and if we find a leakage of liquid metal into the valve bellow, we a short to ground and a signal going to the control room indicating the leak.

The same basic principle for cable detectors, a short circuit would be indicated with liquid metal reaching the particular indicator.

The aerosol detectors contain a 0.S micron filter membrane. The gas is drawn across that membrane via a vacuum pump system, and we monitor the differential pressure across that membrane. Upon increase of about two inches of water gauge, we will get an alarm in the control room indicating a potential leak.

Another system that is utilized is sodium ionization detector where we thoroughly ionize the particulates, create a current, and get an alarm in the main control room.

These two systems are the primary systems in the plant. In addition, for those cells containing radioactive sodium, we have a radiation particulate monitor, where we cell gas going into a scintillation detector, we interrogate that, and feed an alarm into the main control room.

MR. SHEWMON: Can we go back to the previous slide now. In response to Dr. Bush's question, then, the first two are what used to be called sparkplugs up above, and there are no background problems there. There is no background problem on the filter, I presume.

MR. BOASSO: That is correct.

MR. SHEWMON: But there could be on the ionization one

MR. BOASSO: No, sir. The next one would be a potential background problem.

MR. SHEWMON: For radiation, but there are other kinds of background.

MR. DICKSON: Could I add to that.

MR. BOASSO: Yes.

MR. DICKSON: If you are used to thinking of water plants, water is not sensibly radioactive compared to the background in the cell. Primary sodium becomes very radioactive because of the activation of the sodium itself. So it is a very strong gamma signal, readily detectible from many general contaminations you might have in the plant.

MR. SHEWMON: Let me again say that I am talking about background radiation. I am talking about it the way an electrical engineer or an analytical chemist would talk about it. If I look at the ionization detector, there is still the question of whether you are likely to have enough background sodium around that isn't radioactive, or whether your filtering system would get in trouble if you indeed have poor housekeeping.

I don't quite know what I am searching for here, but the question is, in an LMFBR, how much background sodium is there likely to be?

MR. BOASSO: I would expect none. Where those detectors are located, we have no valves. In the primary heat transport there are no valves. I would not expect any leakage from the piping system.

MR. SHEWMON: When I was a beginning graduate student, I went to the lady who ran the stockroom and I said that I wanted some pure copper, or something. The young lady was incensed that I would suggest that any of her copper wasn't pure, or any of the other metals.

So to say that there isn't any sodium there, it does not strike me that you were trained as an analytical chemist.

MR. BOASSO: We would not expect it.

To give you an idea of how the plant is instrumented, we have 169 plugging filter aerosol detectors, eight sodium ionization detectors, 62 cable detectors, and 213 detectors monitoring various leakage throughout the plant, as well as seven radiation particulate monitors.

MR. SHEWMON: Your contacts are sparkplugs?

MR. BOASSO: Yes.

MR. AXTMAN: Are all of these detectors tested in a radioactive sodium environment?

MR. BOASSO: The plugging filter aerosol detectors and the sodium ionization detectors, which do not depend upon radioactive sodium for detection, have been tested with sodium aerosols.

The radiation particulate monitor is a standard radiation monitor produced to discover gas leaks, and it is well known in the industry. So we didn't think it would be necessary to go through an extensive test program to demonstrate the response characteristics. It is strictly a scintillation type detector.

We have extensive and comprehensive liquid metal to gas leak detection, covering a wide range of leak size and utilizing a variety of techniques in Clinch River.

I would like now to give you a brief overview of sodium spill accidents for cell structural design.

The basis for spill selected is from the largest or highest pressure liquid metal pipe in the cell at the location producing the worst case spill on a cell basis.

We postulate a pipe leakage based on a moderate energy system fluid break, which is one-fourth the diameter of the pipe times the thickness as defined in Branch Technical Position MEB 3-1. Leakage is assumed with liquid metal system operating at maximum normal operating temperature and pressure.

Our methodology -- cell pressure and temperatures are calculated with sodium/NaK fire computer codes accounting for spray and pool burning aspects.

We have a nodal networks giving temperature distribution through the cell lines into the structural concrete. Mr. Palm, in his presentation later, will give you more details. We assume zero gas leakage from the inerted cells to maximize pressure challenge. We assume that the maximum oxygen concentration in the inerted cell is 2 percent, which is the maximum operating level.

MR. SHEWMON: How do you plan to put out fires, if they do start?

MR. BOASSO: In our inerted cell, the basic inerting of the cell is a suppression mechanism which would preclude a large sodium fire, a minimum oxygen concentration.

In the inerted cell, we have very little burning. Because of the small oxygen concentration, you quickly into a classical heat transfer. There is very little burning. For the PHTS cells, the primary heat transport system cells, we burn something like maybe four pounds of sodium.

MR. SHEWMON: What happens next. You can't go away and say that you will come back next year. You have a bleeding primary system. You isolate that part of it, and then what?

MR. BOASSO: With respect to the leak scenario and what takes place when you postulate the leak?

MR. SHEWMON: Yes. It is not burning, but you aren't doing anything about it yet. Now what happens?

MR. BOASSO: In my next viewgraph, I will get to that.

The typical results for the inerte cells, and I would like to talk about the primary heat transport system.

We postulate a break in a pipe, and I would like to talk specifically about the scenario for the primary heat transport system cells. The sodium is being discharged in the system at approximately 950 feet. We get a reactor scram on low level sodium in the reactor vessel from our PPS probes. That results in a shut down of the main pump. We go on pony model flow, and we remain on pony model until the fluid has been discharged from the system. There is no more sodium to be discharged. That is basically the scenario.

MR. SHEWMON: This is discharging on the floor of the cell.

MR. BOASSO: Yes, it goes right on to the floor of the cell.

MR. BUSH: Incidentally, your slides and ours don't track. It would be nice if there were one set of good slides, because you have some that we don't have. In fact, about a third or more of yours.

MR. SHEWMON: This particular slide is not in the handout.

You now have thousands of gallons of sodium on the floor of the cell. What happens now?

MR. BOASSO: We discharge sodium into the cell, and we analyze the spray phase. We assume all the fluid is converted to a spray, and this gives us about a 700 degree gas temperature in the cell. Then as we go through the thermal hydraulic profile, we shut the pump off and go on pony model flow. Then the gas temperature will vary accordingly.

Gas and fluid is being discharged into the cell, and the heat is being absorbed by the cell structure.

MR. SHEWMON: The scenario can't be done when you are sitting there with so many hundreds of gallons of sodium on the floor. Can somebody tell me what happens next.

MR. BOASSO: To the sodium on the floor of the cell, or to the system itself?

MR. SHEWMON: To the sodium on the floor.

MR. DICKSON: What Cliff is trying to do is to set the stage for the next presentation to be made by Bob Palm.

MR. SHEWMON: Does he know some chemistry? Does he know how to get it off the floor?

MR. BOASSO: How we clean off from the spill?

MR. SHEWMON: What he is telling me, I guess, is that we are not going to melt down the piping, so it is okay. Is that the bottom line?

MR. DICKSON: He is telling you that you don't melt down the piping, or you violate the cell liner. The cell liner will be discussed in the next presentation. What he is discussing is the thermal conditions.

MR. SHEWMON: So the sodium lays on the floor and cools down gradually. It eventually solidifies.

MR. ETHERINGTON: It finally turns into carbon steel.

MR. ZUDANS: On this graph, how did the heat gas temperature go from 700 to 450 degrees, how did it go down that quick?

MR. BOASSO: This is basically when the pump scram, and you go from 1,000 GPM flow rate to something like about 100 GPM flow rate.

MR. ZUDANS: It is due to flow rate reduction?

MR. BOASSO: Yes, it is flow rate dependent.

MR. SHEWMON: What is that first little blib?

MR. BOASSO: I can't recall all the details on it.

MR. SHEWMON: What about the last blip?

MR. BOASSO: This is where no more fluid is being discharged. This is the termination of the analysis. The sensible heat is just disappearing.

MR. ZUDANS: It means that somehow heat is being taken out.

MR. BOASSO: This is the end point for discharge fluid from the system. In another viewgraph, I will show you the long-term heating effects as to how the concrete heats up. This is only discharging fluid from the system as a function of time.

MR. ZUDANS: Here you are indicating, I assume, that this is a correct graph. What causes the temperature to drop down that fast?

MR. BOASSO: The analysis stops at this point.

MR. ZUDANS: So why do you show the blip going down?

MR. BOASSO: I show the blip where the analysis ends.

MR. BUSH: Let me ask a quick one, since we discussed this earlier. I presume that the liner in the cells is attached by slugs, because you certainly have the classic condition for thermal buckling.

MR. BOASSO: Mr. Palm will get into that in detail.

The corresponding pressure increase, we have a pressure resulting of about 14.5 psig, peak pressure in the cell which is well below its design pressure of 30 psig.

The long term effects, after we conclude this brief phase, and we look at the pool of sodium sitting in the cell, and the cell is absorbing the energy, obviously you are going to have a decline in temperature as a function of time with heat going into the structures, and the maximum concrete temperature is below 100 degrees Fahrenheit.

MR. SHEWMON: Let me go back to the slide before. You have got a gosh awful large break in this thing, which is spraying that hot sodium, and the pressure in the cell falls. Is that because the ventilating system relieves it.

MR. BOASSO: Just the sensible heat transfer going into the cell. This is a very short time frame when you have the spray phase. You have some oxygen being consumed as a result of the spray burning, which gives you a peak pressure cell, the pumps scram, and then the sensible heat --

MR. SHEWMON: The pump scrams, and how many gallons do you postulate in this accident gets sprayed into the room?

MR. BOASSO: The total sodium spray in the cell is 35,000 gallons, approximately.

MR. SHEWMON: So you have sprayed 35,000 gallons of very hot sodium into a room whose temperature is 25 degrees C, and it doesn't raise the gas pressure, it actually cools that gas below the pressure.

MR. GROSS: That starts off at zero, and it goes to less than 15, and then falls down as the rate of fluid changes.

MR. SHEWMON: In 15 seconds, or something so short, I can't see it on that graph, you have sprayed 35,000 gallons.

MR. BOASSO: At this point, we have sprayed something on the order of a few gallons.

MR. SHEWMON: So all the time you are spraying gas into there, which should tend to heat up, since you are spraying hot sodium much hotter than the temperature of the gas in the room, is that right?

MR. BOASSO: Yes.

MR. SHEWMON: You get one pressure pulse, but you don't get a significant temperature rise after that. Why is it that if you spray hot sodium into a cold gas container, the gas pressure doesn't rise?

Go back to the temperature graph, we need to get to that first, the burning of the oxygen, when the oxygen quits and the sodium continues to go in.

MR. BOASSO: The majority of the oxygen is consumed very early into the scenario. We have pumps spraying for four and a half minutes. In the scenario, we go from a flow rate of 950 GPM down to something on the order of 150 GPM, so we have significantly reduced the amount of sensible heat transfer going into that cell. From then on, it is really dumping hot sodium into the cell for increasing the cell pressure. We have the spray phase.

MR. SHEWMON: The sudden cooling comes from the fact that you have a lot of cold structure around there?

MR. BOASSO: We have a large cell of 110,000 cubic feet. We have cold structures. Yes, sir.

MR. SHEWMON: You have sprayed, for every cubic foot, a third of a gallon of hot sodium into it. So you are telling me that heat transfer from the gas into whatever is sitting there is enough to cause that sudden cool down. Now are you spraying more sodium during this couple of thousand seconds.

MR. BOASSO: Yes, sir, we are discharging the majority of the sodium from this point to this point.

MR. ZUDANS: It is like ten hours.

MR. SHEWMON: That doesn't raise the gas temperature hardly at all.

MR. BOASSO: That is correct.

MR. SHEWMON: Because you have so much cold structure around asborbing heat, is that it?

MR. BOASSO: That is right.

MR. ZUDANS: That doesn't strike me as correctly right.

I think when we heard the previous presentation on the function of leak protection system, that behind that that liner was used a cooling system as well.

MR. BOASSO: Excuse me.

MR. ZUDANS: Behind the liner, you have a gap which is used to monitor the leak of that liner.

MR. SHEWMON: That is a pipe, and here he is in a cell.

MR. ZUDANS: The cell liner has a gap between the liner which is washed with some gas that is used as a detection medium, and also the cooling.

MR. BOASSO: No, sir. We do not have a detection system behind our cell liners.

MR. DICKSON: Could I interject here. REmember, we had that confusion before. The cooling is actually caused, the flow is into and out of the cell, and behind the cell. The primary cooling is right into and out of the cell. There is also another factor. The sodium temperature that started around 1,000 degrees and dropped down to 600 long before the scenario is closed. So you are adding sodium that is just about 600 and dumping it into the cell liner, the sensible heat, and all the components, and some going into the concrete which, as Cliff said, doesn't get above 200.

MR. ZUDANS: So the sodium is no longer 1,000 degrees.

MR. DICKSON: I don't know how long it takes to get to 600, but I think it is two hours. It drops down fairly rapidly from the 1,000.

MR. ZUDANS: What is behind the liner?

MR. DICKSON: There is an annulus, but it is not the primary cooling.

MR. ZUDANS: The annulus is monitored?

MR. DICKSON: No.

MR. LONGENECKER: There is a gap between the concrete and the liner, and there are vent lines, so that if there are any moisture coming out of the concrete, it is going to be drained off.

MR. SHEWMON: Mr. Boasso, is this a hot leg or a cold leg?

MR. BOASSO: This is a hot leg.

MR. SHEWMON: The hot leg is normally at 1100 F.

MR. BOASSO: It is 985.

MR. SHEWMON: It gets dropped down to 600 before you can control the spray by the back in scram to reactor, and the intermediate heat exchangers are still working. Is that how you got this temperature down to 600 or whatever?

MR. DICKSON: Yes, sir, it automatically goes down to 600 with the rescram.

MR. CARBON: One point of clarification. The gap behind the liner is stagnant air?

MR. DICKSON: Yes, sir.

MR. ZUDANS: It is not blocked off, there are outlets.

MR. DICKSON: Yes.

MR. BOASSO: PHTS cells have been designed to accommodate a conservative spectrum in a design basis liquid metal spill event.

This concludes my presentation.

MR. AXTMAN: Yesterday I asked the question on what the probability, despite all this well engineered system, of a sodium fire. What I meant was that in neutronic circuits, we have all kinds of redundancies and checks. Is it not conceivable that there is a scenario something like an anticipated transient without scram where a relay that turns off the pump, reducing the pressure in the cell, does not turn off the pump?

Has this system, which seems really to threaten the entire operation, been subjected to probability calculations of its efficiency and operability?

MR. BOASSO: I think I will refer to Dr. Dickson for that.

MR. DICKSON: I ascertained from Cliff this morning that such a leak is sort of improbable. It is not in the design basis that was analyzed in Chapter 15. It would also be considered in the PRA analyses that is ongoing and not yet completed, which I believe is the PRA analysis to which you are referring, which would include failure of the probability to scram. The scram signal, of course, is part of the plant protection system and depends upon safety grade equipment.

MR. AXTMAN: I am speaking about the scram of the pump.

MR. DICKSON: When the reactor scrams, it automatically shuts down the three pumps.

MR. ZUDANS: To phrase the thing differently. Is the probability of the pump remaining running greater than the probability of the reactor staying on.

MR. AXTMAN: This spill that was described now was preconditioned with the assumption that the large motor will shutdown the pump.

MR. DICKSON: You realize that we are not shutting off just one pump to one given cell. The three pumps are tripped by the plant protection system with the same signal that trips the scram rods.

MR. ZUDANS: All assumptions being the same, would the cell temperature go up to 900?

MR. DICKSON: The cell temperature would not go up significantly more if the pumps continue to run, but you might have a problem with excess of lost sodium, and that is what will be covered in the PRA. The system would terminate itself by running out of the ability to transport sodium in that one look alone, and the other two loops continue.

MR. ZUDANS: But it spills that sodium much faster.

MR. DICKSON: That is correct, it would raise the temperature more.

MR. ZUDANS: The cooling effect that brought the sodium from the 900 to 600, instead of two hours, it would maybe in five minutes, and you could have a cell temperature of 900. Maybe that should be the design basis accident.

MR. DICKSON: No, that is beyond the design basis accident. The plant protection system trips the pumps, as well as it scrams the reactor.

MR. ZUDANS: I understand that.

MR. AXTMAN: Are there ways to test the system without activating it?

MR. DICKSON: Test it for what?

MR. AXTMAN: Probability that the circuit that would turn the pump on. the relay that knock out the pump.

MR. DICKSON: Yes, the plant protection system is checked out regularly on a routine basis.

MR. AXTMAN: To this detail?

MR. DICKSON: Yes, sir. The trip signal that shuts it off is a trip on a low sodium, the sodium probe in the reactor vessel. It is not sensing anything in any cell. It sees a low sodium level and it shuts the reactor down, and shuts the pumps.

MR. SHEWMON: Mr. Palm, please begin.

MR. PALM: Good morning, gentlemen. My name is Bob Palm, and I am with Burns & Roe, we are the architect-engineer for the Clinch River Project. As the AE, we have the responsibility for the design of the structures inside of the safety related buildings.

Primarily this morning I will be covering lined cells in the reactor contaiment building. This is a follow-on to Mr. Boasso's presentation, how large sodium spills and accident fires are accommodated in these cells.

So far as the provisions of designs, there were two basic elements in the structures that the design effort has concentrated on. One is the cell liners, and the concrete cell structures behind the liners that form the basic cells where the sodium spills could occur. When I talk about sodium, I am talking about radioactive sodium.

I will concentrate on cell liners, for the first few minutes of this presentation, in the reactor containment building, not necessarily the primary heat transport system cell.

First of all, the cells are inerted with nitrogen, as Mr. Boasso explained, and this is primarily to limit the sodium burning in the cells in the event of a large or a small spill. Because the cells are inerted with nitrogen, the resultant accident effects will be limited, that is, any pressure and temperature build up.

The liners themselves are primarily, and they are classified as engineered safety features for the Clinch River design, to provide a continuous barrier against sodium concrete reaction. Since all of these cells are reinforced concrete structures, and because of these liners and because of limiting or preventing sodium concrete reaction, the effects are minimized.

First of all, hydrogen generation is precluded, and the pressure temperature effects and potential radioactive release is controlled.

There are some other features here which are probably not safety related. There is one, however, that is quite primary to the design, and that is that the cell liners will maintain the structural integrity of these radioactive system sodium cells.

Another feature of the cell liners is that because of the inclusion of insulated concrete behind the liner, we will control the amount of temperature build up in the concrete structures. I will get into that in more detail a little later insofar as the concrete structure design is concerned.

Incidentally, I don't plan to get into details on the criteria or functional requirements. They are all in the PSAR in detail, I believe it is Appendix D, Section 3.8.

MR. SHEWMON: We don't promise not to ask you questions on it, but go ahead. That is a good first line of defense.

MR. PALM: Before getting into the result of the analysis, this is a basic description of the liner. The wall and ceiling panels are made up of a continuous three-eighths of an inch carbon steel plate. They are made up in large prefabricated sections. There is a four inch thick insulating concrete material behind the liner.

We have a cut-away here of the corner of two walls intersection with the floor. This is known as tri-plan corner. This is your continuous wall liner plate. This is the floor liner plate. This is all made up of three-eighth inch carbon steel material.

Behind the liner we have, as I said, this four inch insulating concrete made up of precast lightweight perlite. Between the insulating concrete and the liner plate is this air gap that everybody has been talking about. It is preformed during the prefabricating process. At the same time, we have Nelson studs that are welded at 15 inches on center to the liner, and they run through the air gap, through the insulating concrete, and they are anchored into the structural concrete.

In this one-quarter inch air gap there are a series of vent pipes. By a series of vent pipes, I mean, there are a minimum of two vent pipes per floor panel or ceiling panel that will vent any gases that could be generated from the heating up of the concrete to relieve any pressure build up behind the liner plate, because any pressure build up behind the liner plate would be a condition that could jeopardize the integrity of the liner. Hence we have this pressure relief vent system.

This is a passive system, as somebody mentiond before. This is routed to an uncritical area of the building.

MR. ZUDANS: I have a question. The corner that you left untouched shows that you have two I-beams making up the corner and a liner plate. Is every corner made that way?

MR. PALM: That is right. The typical panel anchors are these Nelson studs. At the corners, we do have continuous T sections with angles that are welded at the corners, both the vertical corners and the horizontal corners.

MR. ZUDANS: What would be the concrete temperature in this section. There is no ventilation, there are no air gaps. Have you calculated the temperature in that beam area?

MR. PALM: We have calculated the conductivity of temperatures through the anchors --

MR. ZUDANS: What about the concrete surrounding this?

MR. PALM: I don't have the specifics, but they are higher than typical concrete temperatures.

MR. ZUDANS: Do you expect them to be identical to the space air temperature?

MR. PALM: Generally, we talk about a gas temperature on the order of 600 F. The liner temperature in the welded area, we have used 1,000 degrees in the early phases, and then of course cool down over the long term. The temperatures in these areas are on the order of 300 to 400 degrees.

We consider this a local area, and this is consistent with the ASME Code Division 2, where you are allowed, under accident conditions, to build up allowed temperatures of up to 600 degrees for local areas.

MR. ZUDANS: Elsewhere you are protected with that insulating four inch precast layer. In the corners, you are not.

MR. PALM: There is an air channel into there. I will tell you another feature, which is not on here, and that is primarily because of this potential problem that we did include or add Nelson stud anchors to these two sections to carry the anchorage back further into the structural concrete.

MR. ZUDANS: Of course, your Nelson studs will also be hot, and they will heat up the concrete, unless they are longer than you would normally use.

MR. PALM: They are 18 inches long. They are very long. When we talk about Nelson studs, we normally associate anchorage lengths of about six inches. In this case, we are talking about 18 inch long anchors.

MR. SHEWMON: It would take a while to heat those up.

MR. ZUDANS: That is right.

MR. PALM: But you did point to a particular problem area in the design.

Another feature of this liner, getting to the corners, is that it is a rigid system. If buckling does occur, or if deformation does occur, at the corners, the main force for reactions that were generated due to heat up of the liner is taken by these corner anchorages and transported into structural concrete.

MR. SHEWMON: On the side, you show the perlite panel between the steel line and the surrounding concrete. On the bottom it looks like you have nowhere the build up between the perlite liner and the structural concrete.

MR. PALM: Maybe I had better show you another figure. The floor liner is different than the wall liner. There are a series of continuous I-beam sections similar to what we see here in the corner, and this is very similar to containment bottom liner anchorage design.

MR. SIESS: Those I-beams sit on the structural concrete, and then there is a fill of maybe nine inches, and then the perlite panel

MR. PALM: That is right.

MR. SIESS: So the heat transmission from the I-beam would be mostly the non-structural concrete.

MR. PALM: Let me show you this viewgraph. This is a detailed section of the floor liner, and your question is the conductivity. That nine inches of concrete that you saw is basically this portion in here.

MR. SIESS: Okay. Is all that cast monolithically.

MR. PALM: No, sir, all this is cast monolithically.

MR. SIESS: The reinforcement is down below the I's. The depth comes to about the height of the I-beam.

MR. PALM: Not necessarily. We have some of the reinforcing here. In some areas, we do have additional layers of reinforcing. Of course, we have more reinforcing on the opposite face.

MR. SIESS: Why is that different? Why do you have the bottom different from the sides?

MR. PALM: Because of construction. We can't prefab these panels with Nelson studs and set them in the structural floor, because the structural floor will be in place. But the walls and ceilings we can. The liner system is like a tank, you pour the main rebar, the walls and ceiling are placed, and then the concrete is placed.

MR. SIESS: So you will put the I-beams and then pour the concrete around them about up halfway, and then place the perlite panels, and then put the plate on. The bottom panel will be prefabricated and placed?

MR. PALM: First of all, the concrete will be precast in sections, and they will be placed. Then the liner plate will be cut to fit each of these.

MR. SIESS: The side panels are prefabricated?

MR. PALM: That is correct.

MR. ZUDANS: Could you put that previous slide on?

This rigid frame structure that you referred to.

MR. PALM: Did I say a rigid frame structure?

MR. ZUDANS: It is a rigid structure. Do your calculations consider the loads developed by the spray heat?

MR. PALM: Yes. Certainly it is a very primary load, and when I do get into the discussion of the concrete structure, this is unique to breeder plant designs.

MR. SHEWMON: If you do this over a period of the next week, and when I asked what happend to the sodium, he said that it freezes. I assume that to freeze it in that well insulated cell means that it takes a long time. So you have run this through to where you get the worst set of stresses, and you design your hold-down bolts to keep cleaner. Is that basically what you have done?

MR. PALM: Yes. That is, again, another unique consideration in the design of these structures, in that the amount of heat that is carried or conducted into the concrete structure is a lot, and since the duration of the heat load is over many hours before you reach sort of an equilibrium in the thermal gradients through these concrete structure.

MR. CARBON: Can you say something about this insulating concrete. How much less is the thermal conductivity than the other, and what are its temperature characteristics in terms of giving off gases?

MR. PALM: It does give off gases. It is a perlite concrete. Its mass is approximately a third of structural concrete. It is about 85 pounds per cubic foot. Its thermal conductivity value, I don't know the fundamental difference between that and structural concrete.

MR. CARBON: I was trying to get a feel for how much insulation this provides.

MR. PALM: Let me answer you this way. The amount of temperature is on the order of 500 F in the unwelded area. The temperature that we design for is 1000 degrees. I believe the calculated temperature is about 600 or 700 degrees, and the concrete behind it is about 200 degrees, we have a drop off between the air space and the insulating concrete of about 400 degrees F.

MR. CARBON: What would you have if you had ordinary concrete?

MR. PALM: It would be halfway between maybe 100 to 200 degrees difference, on that order. We have looked at this in evaluation studies in the early phases of the design.

MR. CARBON: Sometime, I would appreciate finding out how much insulation that really provides.

MR. SHEWMON: In terms of relative conductivity?

MR. PALM: We have all the data.

MR. SHEWMON: I have great trouble with this viewgraph that we were shown but didn't get on temperature rise, just how it doesn't violate the first law of thermal dynamics. But with regard to what you said of the sodium coming in was 500, if the temperature of the cell goes to 600 degrees F, even 700 in the initial stage, the design you have would cope with it? I don't know about the pressure, but at least with regard to other things, the cell would be okay. Is that your conclusion?

MR. PALM: That is right.

MR. SHEWMON: Fine.

MR. ZUDANS: I am a little bothered with that, but not with your point, with the heat transfer point. If the concrete stays at 200 a certain distance away, it means that there is no heat being conducted away from the cell, therefore, everything that would be in there would, gradually with time, build up to the temperature that is inside the cell. So where does this heat really go when the temperature goes down? There is no conduction through the walls.

MR. DICKSON: Could I add something. One of the gentlemen here just made a back of the envelope calculation, taking this cell volume of 120,000 feet, and the cell surface area, he came to the conclusion that the steel in the liner was 225,000 pounds, which is about 22,500 Btus per degrees F. Taking also the 35,000 gallons is 245,000 pounds, roughly, the same amount as the weight of the cell liner. Again, assuming the specific heat is about 0.1, I think it is a little higher in sodium, but if we assume the 0.1, it is the same as the steel, which is also about 24,500. So the heat up of the steel would be a degree for every cool down of the sodium.

If all of this was dumped at 600 degrees, without any loss into the concrete, and of course there is some, the temperature would settle at, assuming we started at 100, at two-thirds of 500, or around where it is shown to be. Some of the sodium comes in a little higher than the 600, and some of the heat goes into the concrete.

MR. SHEWMON: That is vary helpful.

The other thing is, if the cell could cope with 600, and that is the main temperature at which most of the sodium comes in, then it doesn't make a great deal of difference.

MR. PALM: Westinghouse has done an analysis as part of the thermal transient gradients, and they are a couple of hundred hours anyway on the basic state of equilibrium.

The qualification of this liner system design, we have done rigorous analysis using ANSI's computer program. If we get into some detailed questions, I have backup viewgraphs, but I don't know how much time we are talking about this morning.

But we have done a lot of analyses and we have had several meetings with NRC staff on the liner design. The basis for formulating the material properties to be examined, we have completed a high temperature test program to establish the stress/strain characteristics of the carbon steel plate material of temperatures from ambient on up to approaching 2000 degrees F. The reason we have gone that high is because we utilized this in our analysis for events beyond the design basis, the core melt through condition.

On the basis of these curves, we have established these material properties for examination under all of the various cell liner accident conditions. We are talking about many cells, on the order of 40, between the containment building and the reactor.

On the basis of this, we have established the criteria which is presented in the PSAR which is generated on the basis of the Von Mises strains criteria, using tri-axial stress/strain conditions. We have established allowable limits that are related to ultimate strength of the material.

From this, we have in our analysis calculated the strain conditions at critical points in the liner, whether it would be at a corner or at mid-point, on the floor or wherever.

We have examined a full gamut of conditions, I don't have a viewgraph on it, but again they are in the PSAR, considering imperfection, liner corrosion, local hot spots, penetrations, imbedments, and discontinuities certainly at the corners, all of this sort of thing. We have determined where these maximum strain conditions do occur, and in all cases we have not exceeded the allowable limits established.

MR. ZUDANS: What are the allowable limits?

MR. PALM: The allowable limits, I have a viewgraph on them, maybe I will just show it to you, 0.5 of the ultimate strain, which is under load. We have other strain limits for various load combinations, for construction, and the construction conditions, and other load combinations that are not as critical as combination D. D is for the maximum spill in any given cell. For conditions up to, not including D, we are using Division 2 liner criteria as far as strain and strain are concerned.

For the maximum sodium spill condition, we are using 0.5 of the ultimate for membrane only, and 0.67 of the ultimate for combined membrane and bending.

MR. ZUDANS: How much strain did you get in the calculation?

MR. PALM: Roughly, the maximum is about half of this.

MR. ZUDANS: Was it three percent, four percent?

MR. PALM: About the same. The maximum is on the order of 8.

MR. ZUDANS: It corresponds to 400 degrees delta T. When you did that, did you look at the studs and see if they would stay on the liner or would be sheared off, because you must assume that one of the panel is going to buckle.

MR. PALM: We have done buckling analyses, and we are doing some additional analyses in support of NRC questions.

MR. ZUDANS: The scenario is that you have a panel that buckles and an adjacent panel didn't buckle. This promotes a zippering event that shears off the studs, and continues shearing off all the other studs.

MR. PALM: The answer to the question is, the zipper effect, we have examined this and it will not occur. However, we are doing a more detailed analysis of this. We have not finished it, but it is in response to some NRC questions.

MR. SIESS: How would the liner fail?

MR. PALM: It is not going to fail.

MR. SIESS: This is interesting because if you were analyzing it for some kind of loading, you could simply increase the loading to the point of failure, and see how it would fail and see what your margin was. I guess the kind of loading you have here is a temperature and pressure load.

MR. PALM: Yes.

MR. SIESS: Do you visualize increase those loads to a failure in any way to see what your margin is?

MR. PALM: Under CDA conditions, and the motor failure, there is a break down of concrete in the outward zone where the anchors will put, where you will lose the anchoring capacity to hold the liner in plane.

MR. SIESS: The concrete would deteriorate with temperature enough that the buckling loads would tend to pull the studs out of the concrete.

MR. PALM: That is correct. It would tend to basically pop it right now, because you have this buckling effect.

MR. BUSH: I am assuming that your corners or the edges, the welds are not only plate to plate but also well into the I-beams, is that correct?

MR. PALM: Right.

MR. BUSH: Therefore the probability of the zipper tear at the junction point is reduced markedly as compared to a straight weld.

MR. SIESS: If every step failed, the liner can continue to buckle indefinitely, and pretty soon it gets to where there is no membrane stress in it, if it moves out far enough.

MR. PALM: That is right.

MR. SIESS: It is not really failure, it is an intact liner. So the question is, can it tear loose at the corners?

MR. PALM: It is a classical question, everything gets to the corners, and that is our design, really. We have accommodated a full load.

MR. SIESS: When you get to the corner, you have the rotation there on that weld, but it is very ductile material. Does the weld in the corner fail if you go far enough?

MR. PALM: Not with the design that we have. I don't have a blow up of this.

MR. SIESS: I don't think that you could make it fail.

MR. SHEWMON: Let him get on with his concrete cell structure that comes next now.

MR. SIESS: I have a lot more questions when you come to the concrete.

MR. SHEWMON: That is why I sort of tried to entice you on.

MR. SIESS: The ultimate failure is actually concrete.

MR. ZUDANS: There is another question along the same lines. After you put this liner in, let me ask you, did you say that in time the wall is prefabricated. one complete wall?

MR. PALM: No. Let's assume that this is a 40-foot length of wall, this would be in about three sections. The sections are basically about 10-foot wide by 25-foot high.

MR. ZUDANS: That is three-eighth inch thick carbon steel plate, that is what it said on the slide. It is welded in the field.

MR. PALM: That is right.

MR. ZUDANS: And to the corner beams.

MR. PALM: Yes.

MR. ZUDANS: When you finish welding, without any sodium in it, how do you assure yourself that you don't have cracks and leaks and different conditions?

MR. PALM: Preoperational inspection. We also have an in-service inspection.

MR. ZUDANS: It has to be very well inspected because it is a complicated shape, and I don't know how you do that.

MR. BUSH: Can't you pressurize it because you have a leakage detecting system built into that ?

MR. PALM: We will have a pressure test in these cells.

MR. SHEWMON: Basically, in the pressure test is your weld leak?

MR. PALM: No. It will be a magnetic particle vacuum box testing of all the liner seams.

MR. SHEWMON: How do you magnetic particle with a vertical weld?

MR. PALM: It is a combination. We can't do it overhead. It is a vacuum box, basically.

MR. SHEWMON: The floor is for cracks in the vertical welds. It is for leaks, is that it?

MR. PALM: Also cracks, and whatever.

MR. CARBIN: What sort of in-service inspection are you going to have?

MR. PALM: I have a viewgraph on that.

MR. SHEWMON: Can it be checked for leaks periodically after it is in service?

MR. PALM: We are going to define critical areas in the cells that we will go in and inspect on a periodic basis, or if some abnormal event occurs in the cells during the plant operation.

MR. ZUDANS: In the previous meeting, I was obviously wrongly impressed with this space of a quarter-inch between the liner and the insulation concrete was in fact being filled with inert gas.

MR. SHEWMON: With the weld, you have local yielding around these corners where that gets taken up, and how well is at least an interesting question.

MR. ZUDANS: It is very likely that the box will crack during fabrication.

MR. SHEWMON: If it does crack, how do you repair it?

MR. AXTMAN: You heat it up, you set up the same stresses and you crack it.

MR. PALM: Would you like to see the viewgraph?

MR. CARBON: Will they be inspecting these cells once every year, or every five years?

MR. PALM: I believe that it is on the order of once --

MR. DICKSON: Why don't we use this chance for a break. Dr. Kaushan has found the relative conductivities. While Cliff is looking for that, perhaps we can get him to give these conductivities.

MR. KAUSHAN: There is a range of conductivities in perline at 200 degrees Fahrenheit, the conductivity is 0.08 Btu per hour per foot per degree Fahrenheit. At 1500 degrees, that number for perlite concrete is 0.13. For structural concrete for comparison, the numbers are 200 degrees, 1.0, at 1600 degrees, 0.58. There is a certain scatter around that data, and I have given you the mid-range numbers.

MR. CARBON: Thank you.

MR. SHEWMON: Let's get on because we are dragging this out a lot.

MR. PALM: The in-service inspection we are talking about is once every ten years, which is in accordance with Section 5 of the ASME Code. We will also be inspecting -- There are all lined cells. There will be three pre-selected cells in both the RCB and RSB, a total six cells -- at least twice in the ten year period, and these will be conducted during maintenance.

MR. ETHERINGTON: What is the access to the cells?

MR. PALM: We have sealed doors.

MR. ETHERINGTON: They are real doors, and not overhead hatches?

MR. PALM: Some cells have an overhead hatch, but for the most part they are electrically operated door, or manually operated doors.

MR. SHEWMON: Can we get on to the concrete.

MR. PALM: As far as the concrete qualification, there was a large scale sodium dumped in the RT-1 test. This is a cross-section of the reactor containment building, and the cells, as Rick Gale pointed out, are below the operating floor. The cell configurations do vary.

This is a typical PHTS cell. These cells are comprised of a continuous integral reinforced concrete structure. By that I mean, all these cells are interconnected through reinforced concrete walls or floors.

The design of these concrete structures is in accordance with ACI code. We first started the design of this plant, we were following ACI 318, and then we gradually converted over to ACI 349. We now are designing in accordance with ACI 349 in line with the current regulatory guide, which I believe is 1.142.

In addition, we, of course, are following the normal concrete design requirements for nuclear power plants, the SRP regulations, et cetera. We have developed supplemental requirements because of the high temperature design conditions encountered in these sodium cells.

Primarily, we are talking about temperatures that exceed 150 degrees, which is the normal accepted practice long term temperature for structural concrete design. As it was pointed out before, some of these temperatures do get up to 200, and in some cells they approach 300 degrees.

So the thermal effects on the structure are key to the duration of the heat load, which again we had discussed before, because of this duration, the resultant penetration of the heat load that exceeds 150 degrees into the concrete structure.

The design properties of the concrete and the reinforcing steel are influenced by these higher temperatures. Because of that, we have through a comprehensive test program, have generated high temperature properties for all of the design properties for the structural concrete and the reinforcing steel.

In addition, we have established thermal properties, some of which Nino Kaushan has pointed out, and structural concrete under the range of temperatures that are considered in this plant design, and they do vary with temperature.

To continue on the concrete structures, another important point, is that as the cells fill up, they do tend to expand as forces are generated. Because of that, we have to consider the interaction between the cells because of an accident occurring in one cell, what happens to this thermal expansion effect. This is accounted for in our detailed analysis.

The allowable ACI stresses are reduced in accordance with the high temperature. Material properties have been generated from the tests, and these are checked against the calculated stresses from the loading combinations, and these are the normal loading combinations considered in any nuclear power plant: design pressure, temperature, seismic, and whatever.

The cell structure analysis, we have used the MASTRAM program, and in some cases we have used STARDIME, depending on the cell configuration, type of analysis that we have been doing, or had to do. We have used ANSI in some areas.

Using finite element techniques, we have considered the interaction effects due to the interconnection of these models of the cells, to determine the influence of the heat up from the sodium spill accident.

MR. SIESS: Are the time dependent effects included in the analysis?

MR. PALM: That is correct.

MR. ZUDANS: In a static sense. It takes snapshots in time.

MR. PALM: We select certain time increments.

MR. ZUDANS: If you had a heated cell like the one you showed before, how many additional cells do you put in your model?

MR. PALM: It depended on the conditions in the adjacent cells, whether they were lined or unlined, whether they were small, large. I have some typical models that I can show you.

MR. ZUDANS: Show one, the worst one.

MR. PALM: In fact, I will show you two, I think that will be a little bit better.

This is one of the cell itself. It is three-dimensional. This happens to be cell 107-B. This is down at the mat level and continues on up to the operating floor, so we have considered the adjacent cell above this, the cell where the accident occurs, and we haven't taken these cells on the side here because this happens to be on the outside of the containment. We have a larger model for that, and I will show that in a minute.

MR. ZUDANS: What were your typical conditions? Like at the very bottom, do you expect them to be built in the mat, the boundary conditions?

MR. PALM: Yes.

MR. ZUDANS: Does it have additional level walls?

MR. PALM: This particular one, no.

MR. ZUDANS: What about the other side?

MR. PALM: The only thing we have -- this is a very large open cell. This is one particular one where we do have interconnection.

I will show you just one more, which is quite a different kind of a model. It is more extensive. This is a three-dimensional model. This is the outer-containment wall, and these are intersecting cell walls. We have taken these one stage further back into the interior cells.

This is representative of a quadrant of the outer or interior concrete structures. We have three other models that are representative of the other quadrants, because each of the quadrants, only of them are the same and two others are different, so we have three models similar to this.

What we also do, we break out this curve into a separate model with liner mesh.

MR. SHEWMON: Qualitatively what you do is if one of those joints yields, then that is failure because of the lack of ductility of the concrete, or if it yields, it cracks and you take the shear strength of the concrete plus that of the rebar as the code does?

MR. PALM: Yes, it will crack.

MR. SHEWMON: Once that cracks, it is failure?

MR. PALM: No.

MR. SHEWMON: When it cracks, does it yield to rebar?

MR. PALM: The rebar is designed to control the cracks. If we exceed the allowable stress, it is considered failure if the cracking is to such a point that the reinforcing is overstressed. It is not actually yield, it is something less than that.

MR. BUSH: If you degrade the properties of the concrete sufficiently.

MR. PALM: There are other considerations. If we get cracking to the point where it jeopardizes or compromises the integrity, yes.

MR. SHEWMON: Does this finish your presentation?

MR. PALM: I have one more viewgraph on the results of the analysis, and this is combined liners and concrete. I think the key element here is that the analyses have determined that the containment boundary will not be compromised, and this is a part of what we are doing to determine that and come to that conclusion. The concrete thickness and reinforcing are designed to accommodate the most severe combination of loads.

MR. CARBON: If you have the knowledge of which concrete is supposed to be poured in the LWA-2 --

MR. PALM: I will show you another slide that is simpler. The LWA-2, as I understand, that we would key the basemat going up to the operating floor.

MR. ZUDANS: Don't you have another cut?

MR. PALM: I will show you another one.

MR. CARBON: Is that foundation mat that you are looking at going up to about elevation 730.

MR. PALM: It is an 18-foot section.

MR. CARBON: So it is just up to elevation 730.

MR. LONGENECKER: In essence, you have a 100-foot deep hole, and you are going to pour about the 18 feet of that structure.

MR. PALM: It is 18 feet here, and it is 16 feet inside the containment.

MR. CARBON: I am not sure of what you just said. You pour the foundation up to elevation 730.

MR. LONGENECKER: It does not include insulation of the liner.

MR. CARBON: Then do you pour anything in your walls?

MR. PALM: No, it is not planned in this activity. This slab will be integral with the walls.

MR. SHEWMON: Any other questions?

MR. ZUDANS: I have one. I am looking at this picture, and I am wondering, what did you connect the elevation 816 to the building?

MR. PALM: This connection here, that is a diagram that is primarily the transmission of seismic load. This is to vent differant seismic behavior of the containment building and the surrounding structure. It is the seismic tie, basically.

MR. BUSH: So you think that they may respond to different frequencies that interact.

MR. PALM: Yes.

MR. ZUDANS: It would also affect the building.

MR. SHEWMON: What I would like to do is to take a break and come back, and have our closing discussion

MR. KAUSHAN: I would like to correct the record. I said yesterday in response to a question that had to do with the steam bypass. I said that it was 100 percent bypass and 80 percent relief. I turned the numbers around a little bit. It is 85 percent bypass, and 80 percent relief.

MR. SHEWMON: Let's take a ten minute break, and then we can come back and see what needs to be done.

MR. SHEWMON: Gentlemen, would you take you seats so we might tie this thing up?

Let me ask, Mr. Stark, did you get what you wanted?

MR. STARK: You mean the money?

(Laughter.)

MR. SHEWMON: I guess the question now is, what requests, questions, what happens now, and one of the things that we didn't get was the materials, leak before break, in-service inspection, that sort of a presentation, and you said would get me an idea as to when that might be ready.

MR. STARK: That's correct. Felix is here now, and some members of the applicant, and I guess what I recall you mentioned yesterday, you requested a similar session to discover or to discuss the status of the materials review, and you, I think, specifically mentioned the leak before break status of the staff review.

I mentioned that briefly to Felix this morning, and I guess the reason why he is here is to see if you want anything else in that session, and I guess we were talking about a session a month or six weeks from now, based on what Felix said.

MR. SHEWMON: The title of the program is

Materials and Structures, and we've got structures pretty well, but nothing for materials from the staff, and maybe what we needed from the applicant, but I suspect a review might bring up some other questions, so I am really trying to get an idea as to when that part of the review is likely to be in shape.

MR. STARK: A review is not an integrated review, and basically most groups are writing their findings, and though they are the only group in existence, and then we are trying to blend it together. So I suspect in order to help you we should put a materials presentation together.

MR. SHEWMON: If we could see a copy of their review, we could see what questions got treated. When do you expect to have that written?

MR. FELIX: We have completed the SERs on the core reactor and the core support structures.

The control rod drive materials, the reactor vessel materials, and the primary heat transport system, we are reviewing right no. We should have those three sections written within the next two weeks, two or three weeks.

MR. SHEWMON: What happens with regard to cracks that are benign and whether you allow them to assume a leak before break?

MR. FELIX: We have accepted the leak before a break several years ago, actually in the FFTF review. The cold leg has been acceptable. The hot leg, there is some question about it, and we are reviewing that now.

MR. SHEWMON: Why is the hot leg more of a problem?

MR. FELIX: There are certain positions that have to be ironed out with other groups in terms of our review. I think the materials are acceptable for both hot and cold leg. However, some of the branches have not accepted the hot leg loading situation so far.

MR. SHEWMON: What about frequency of inspection?

MR. FELIX: In terms of in-service inspection, we have not accepted the division 3 of the ASME code. We believe that there should be more of an in-service inspection and pre-service inspection requirement than is in the code, and we have told the applicant this. We really think that the internal structure should be examined, whether this is done autosonically or by vibrational methods. I think that that has to be worked out, but we are not satisfied at all with the in-service inspection requirements that have been in the PSAR at this time.

MR. BUSH: It seems to me that you could use

IWAE somewhat beneficially by analogy. The containment section, admitted of the water reactor part of it, is in pretty good shape. I think both in the examination of the places to be examined point of view, it would be applicable.

MR. SHEWMON: What is IWAE for the record?

MR. BUSH: IWAE is the containment section in ASME 11. It is a totally independent section that deals exclusively in this instance with steel containments.

MR. FELIX: I think that you are right. I think there are certain inspections that should be done on the containment, particularly the cell liners, that are not in the PSAR.

I think that the cell liners that are required to hold sodium should be inspected very thoroughly as a prerequisite for their acceptance.

But in terms of the in-service inspection, our position has been that the same philosophy as the 77 code should be given to the in-service inspection program, namely, that the piping system components should be analyzed, and the most highly stressed welds examined periodically.

MR. SHEWMON: There was some discussion yesterday about the support cone.

MR. FELIX: This has me worried. There are two areas in the internals that I have examined, that thee are some questions about. One is the horizontal buckling, the section that separates the lower from the upper section, and the weld in the core support. I think something should be done to periodically inspect those areas.

I am not talking about those dissimilar welds, those should be examined, too. I am talking about the core support welds internal, and the horizontal plates.

MR. ETHERINGTON: All those welds would have high residual stresses. Stainless steel doesn't relax very fast.

MR. SHEWMON: Max, did you want to bring up your review of the safety margins, or the completeness of that.

MR. CARBON: Yes. I would like to raise the following question.

Dr. Trifunac has looked at a return frequency for the SSE and he comes up with numbers, the way he calculates it, of a return of something like 1640 years. I really don't know how significant this is. I don't know how significant calculations like this are, but it does raise a question.

We have the same question for LWRs, the return frequency for the SSE is in the neighborhood of 10 to the four tiers, or something like that, and it is considered in principle not to be good enough, long enough. But everyone seems to be convinced that we have considerable structural margin in LWRs, so that we really don't have to worry very much about that. We have adequate safety there.

But the question comes up here, do we have comparable adequate safety, comparable built-in margin? Suppose that the return frequency were 1600 years or less, or something like that. It of course means that we can have higher acceleration values or some perhaps unacceptable frequency.

The question is: What is the built-in margin, how do we determine it? How much is needed for this particular plant at this particular location? How much credence do we give to these calculations. I don't know the answer to these questions.

If the calculation of 1640 years is a reasonable thing, then I think we have quantified safety questions, even though I realize that this puts the staff in an awkward position.

MR. SHEWMON: Let me ask a different question. If we wanted to review the margins of safety of the SSE and be sure that they were uniformly there, how could we get a review of it?

Do you want to suggest that we have a separate meeting on that, or ask the staff to at least assemble things of that sort that we can review particularly?

MR. CARBON: It would seem to me a very worthwhile way to go at it, I don't know if it is the only one, if the staff could assemble information, if we had a meeting to review this built-in margin. If it turns out that we have got lots of margin, it seems to me that it could take care of it right there in an excellent fashion.

MR. SHEWMON: Chet, do you have any comments?

MR. SIESS: The margins over and above the return period come in several places, they are not just in the structural resistance. The conservatisms that are built in the soil structure interaction. In other words, there are conservatisms in the analytical methods.

What we need to look at, I guess, is whether there are things being done differently on the CRBR than on light water reactors. Whether those conservatisms that are built into the process are likely to be different in the CRBR than in light water reactors. That would be the only way that I would see that it would make much sense.

MR. CARBON: You are saying, basically, show that we have the same conservatisms here as elsewhere, and that we have the same answer.

MR. SIESS: Is there anything different about the plant with the way these conservatisms come out, or is there anything different about the way it is being analyzed, the margins that are being used for design, etc. Otherwise, we can't open a completely new can of worms with the CRBR compared to the light water reactor, I don't think. We have already opened up one can.

MR. STARK: Dr. Okrent brought this question up in a different fashion.

He was not so much referring to margin, and I guess this is my interpretation of Dr. Okrent's comment. When it comes to structures, I think he believes that there is a good deal of similarity, and we could use light water reactor procedures and techniques.

But when it comes to piping systems, where you have high temperatures and thin walls, what is concern was, in the light water business, we are arrived at a position and it is based on a lot of experience, and there is some confidence in the margin.

He was looking at how we were going to display the equivalent confidence in whatever margin we put in. If we argue that it is the same margin, how do we give confidence that it is the same margin based on the limited experience both on the staff and in the industry.

So the question has come up. I am probably not the best expert on this, but we are looking at it in phases, in basic pieces of equipment, where we can use the light water reactor technology, we are going to try to use it, and where we can't, that is going to be the challenge.

MR. BUSH: I rarely agree with him, but this is one case where I agree completely. I think that you should decouple structures from systems and components, and look at them separately.

I believe that the output from the steering committee on piping systems, which is examining rather carefully this whole business of response under loads for seismic with regard to more realistic mapping factors, should have a positive feedback in the next six to 12 months, and could well have an impact from the point of view of system response, particularly piping.

MR. SHEWMON: Is this particular group under the SSMRP?

MR. BUSH: This is totally different from this. It is one I chair under the Pressure Vessel Research Committee, but it is in close cooperation with

NRC. In fact, we went to the Commission level, and the Commission has authorized it, the idea being to look at piping systems, particularly as you get rid of a lot of the supports.

Because the arbitrary limitations, my personal opinion is, even though you have less experience because of the characteristics of the system, you ought to have damping in these relatively thin and lower pressure systems.

MR. SHEWMON: It seems to me that it would be closer to the petroleum where they build such rigid systems.

MR. BUSH: That is what we are using, the experience that is coming out of industries such as the petro-chemical where you have systems either at varied pressures and varied temperatures, with minimal supports, they sort of flap in the breeze, and factoring this into them from the point of view of response.

MR. SIESS: Actually, there are three areas that you might want to think about:

The structures area, we have already mentioned; the piping that we were discussing; the other one that has come up in discussion has to do with the function of the particular electrical equipment where the valves won't function during and certainly after the earthquake.

The questions that came up on electrical equipment were things like breaker chatter or relay chatter that could send all sorts of unusual signals to various things during an earthquake if the equipment did not have some margin beyond the SSE on chatter. We saw some reports where they had quite a margin on structural resistance, or ability to function after.

So there are three kinds of things, the structures, piping, and the other components.

MR. ZUDANS: I would like to hear one answer. Bob Orr is here, and he could tell us what fraction is the buckling stress in the seismic analysis.

MR. ORR: In the analysis for the actual stress just above the operator deck, two-thirds of the actual stress is due to seismic effect. It is a significant percentage.

MR. SIESS: Mr. Orr, if you didn't have a fully loaded polar crane, or didn't have the crane fully loaded at that point in time, what would happen to that?

MR. ORR: That analysis has not been done. In my judgment, it is fairly minor because the dead weight of the crane is signicantly greater.

MR. ZUDANS: It also tells you that it is not a significant margin in terms of SSE input to the buckling mode failure of the containment because two-thirds of the load the containment was subjected to. So if you reduce that one, you reduce the safety factor which was 1.9, I understand.

MR. ORR: 1.9 is the required safety factor, but theirs is 1.67. It is a fairly conservative evaluation of buckling. There is some degree of margin there, but I can't tell you quite how much.

MR. ZUDANS: During the intermission, I was informed of a misstatement that I made that reinforcing improves the buckling capability. It improves it, as compared but never quite restores. It is not better than 80 percent. That is what a gentleman from Lawrence Livermore told me just now.

MR. ORR: I believe that it does not restore it based on the theoretical calculations to the buckling value.

MR. ZUDANS: The gentleman from Lawrence is here and he could comment, because I don't want to misinterpret him.

MR. BUTLER: I am Tom Butler of Los Alamos. The experiments we have run on steel cylinders show that if you take a fabricated steel cylinder without a penetration, you will get a certain buckling mode. If you put a penetration in, it knocks it down further. As you start putting reinforcement background around the penetration, it brings it up, but it never brings that same cylinder up to its unpenetrated value. I told Dr. Zudans that it is on the order of 80 percent.

MR. SIESS: 80 percent means code reinforcement. If you put more than that, can you bring it back up to where it was, or could you never get it back up?

MR. BUTLER: You probably never will be because you have an imperfection that grossly disturbs your stress field. C.D. Miller at CBI ran the same type of experiments on plastic cylinders, and his experiments show that you did get back up to the non-penetrated value.

MR. SHEWMON: What is a plastic cylinder, when you are talking about a piece of steel.

MR. SIESS: It is a plastic insert.

MR. BUTLER: A lot of the buckling work that we have done has been in plastic cylinders, but you have to be a little careful.

MR. ZUDANS: It is a different finding by Miller compared to what you found, is that because his cylinders were perfect essentially?

MR. BUTLER: We have tossed around various ideas between ourselves as to why, but we don't have any answer.

MR. ZUDANS: What it really says is that the knock down factor used, I really don't whether N-284 uses knock down factors which envelope the lower bounds, then it woulin't matter if they had any perforated. If they didn't, the knock down factors might have to be reduced by 20 percent.

MR. GRIFFITH: I think that it might be kept in mind that it is a rather generic statement, but the actual reduction in the buckling mode that you would get for the penetration would be a function of the size of the penetration relative to the wavelength of buckling mode and where your stiffeners are relative to the penetrations, and where the penetrations are relative to your peaks.

MR. ZUDANS: We are talking about clean cylinders, no stiffness, just what the hole does by itself.

MR. BUTLER: I might mention that in our experiments, it was a model of a typical equipment hatch penetration.

MR. GALE: Our equipment hatch is also reinforced with structural steel, and not simply built in accordance with the ASME code area replacement because of the side of the hatch is also stiffened with vertical stiffeners and horizontal stiffeners.

MR. SIESS: Another thing about the equipment, it is not just a hole with reinforcement around it. There is something filling that hole that also stiffens it. Is that your point?

MR. GALE: My poing was, primarily, that we have additional stiffening over and above the ASME code rules. We have structural steel, both vertical and horizontal.

MR. SHEWMON: But part of the comment is that if you have a hole, no matter how much reinforcement you have around, you have a defect, unless the hatch itself strengthens it up. I don't know whether that was in here or not.

MR. BUTLER: I think I need to make one more comment. Even though I didn't get back to the unreinforced value, it covered the value we got.

MR. ZUDANS: That is very important and that what I didn't know.

MR. BUTLER: The knock down factors covered the value. The only point is that you cannot bring it back to the unpenetrated value.

MR. SHEWMON: Did you have a hatch in your experiment, or is that not the way it is done?

MR. BUTLER: No, we just put the reinforcement in.

MR. SHEWMON: You left it as an open hole and gradually added reinforcement around the inside.

MR. BUTLER: Yes.

Gentleman, are there any other questions that we would like to see the staff come back to us on, particular things that you would like to bring up at this point?

MR. AXTMAN: I would wonder if the staff has had a chance to evaluate the GAO's recent blast on the steam generators.

MR. SHEWMON: They do and they gave a presentation to the Commission. I did not ask that it be presented here this morning, but you probably can get a handout, or you can get a brief summary.

MR. STARK: I can attempt to summarize it.

The findings that the GAO made, we have reviewed, basically we find that while the comments are correct in the GAO report, they are of such a minor nature.

For example, one of the comment is that the prototypic steam generator is a good prototype of the design steam generator. It is certainly true what they are saying, but I think it might be 95 percent or 99 percent prototypic at this time.

There is an element of truth to almost everything they have said in there. We have attempted to factor it into our review. For example, the design changes, we see them as increasing the availability of the steam generator. We don't see they help or hurt chapter 15 analysis, which envelopes both steam generators, for example.

I think one of their comments was that they shouldn't place the order for the steam generator, but that is history. The applicant has already placed an order. I forget what the other two points were.

We looked at it and we factored it into our review. From a personal standpoint, I don't see any great significance. Nothing added or detracted from safety in my point of view based on what I have seen.

MR. AXTMAN: I think a major conclusion, if you follow their logic, was that chances of having an operable plant on the schedule, with the history of steam generators, particular CRBR, the LMFBR steam generators, would not necessarily make a full scale steam generator available. That is what I got out of it.

MR. STARK: If a steam generator, basically, is unreliable, it is not going to be an availability problem. Our action is to shut the plant down and repair it. If it is down an awful lot, it won't demonstrate a ver reliable product, but it will not be an unsafe activity, or an event.

MR. ETHERINGTON: Some of these problems that look like operating problems do have safety significance. All the failures that we have had in the water reactors, most of them have occurred in areas where NRC has felt it not their business to investigate.

MR. STARK: Let me give you a bit more information. If you compare the steam generator to a light water steam generator, you will find that by and large there aren't any radiological consequences to a massive failure.

While there is a bit of tredium in the intermediate loop, it doesn't have the inventory of radioactive particles that the PWR has. That is one of the measures that we have not really faced.

The other one is that if you postulate a steam break in the PWR, you get a pretty significant reactivity insertion. The negative temperature coefficient that exists in the particular plant is so small that it doesn't show up as a significant accident.

The only safety feature that is in common with the PWR is that it is the preferred decay heat removal path using the steam generator, and in that sense it has a safety related function, and we are reviewing in that fashion.

I should point out that it has three loops and any one of the loops is sufficient, at least based on what we have seen so far, to accomplish that. So while they might have one loop down, we think at least from what we have seen so far, that you can simply close the plant down. We think we have enveloped it with the accident analyses that have been postulated in Chapter 15 where we have analyzed multiple tube breaks, and looked at their consequences.

MR. SHEWMON: Bob, another thing that bothered me with that is that the information was that the project didn't have the engineering judgment to learn anything from their prototypic tests, thus could not make any improvements in the next one that they ordered. I have a lot of difficulty with that sort of a conclusion.

ARe there other questions?

(No response.)

MR. SHEWMON: If not, we will adjourn the meeting.

Thank you very, Mr Dickson, for bringing up your group. It has been a good meeting.

(Whereupon, at 11:15 a.m., the meeting adjourned.)

NUCLEAR REGULATORY COMMISSION

This is to certify that the attached proceedings before the

____

in the matter of: ACRS/Working Group on Structures and Materials for Clinch River Breeder Reactor

Date of Proceeding: August 19, 1982

Docket Number: ____________________

Place of Proceeding: Washington, D. C.

were held as herein appears, and that this is the original transcript thereof for the file of the Commission.

Patricia A. Minson

Official Reporter (Typed)

Patricia A. Minson

Official Reporter (Signature)

CLINCH RIVER BREEDER REACTOR PLANT

CRBRP PROJECT

BRIEFING FOR

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS (ACRS) WORKING GROUP

STRUCTURES AND MATERIALS

AUGUST 18 & 19, 1982

CRBRP STRUCTURES AND MATERIALS

BRIEFING FOR

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS (ACRS)

CONTAINMENT BUCKLING ANALYSIS

PRESENTED BY:

RICHARD E. GALE
SYSTEMS INTEGRATION,
WESTINGHOUSE - OR
CRBRP PROJECT

AUGUST 19, 1982

ASME CODE RULES

- ASME BUCKLING CHECK CONSISTED OF AXIAL COMPRESSION CHECK OF THE OVERALL SEISMIC EFFECTS, THE DEAD LOAD AND EXTERNAL PRESSURE.
- THE CODE EXTERNAL PRESSURE BUCKLING CRITERIA WERE VERIFIED BY DEVELOPING AN EQUIVALENT EXTERNAL PRESSURE FOR THE HOOP COMPRESSIVE STRESSES. THESE STRESSES CONSISTED OF THE EFFECTS OF EXTERNAL PRESSURE ADDED TO SEISMIC LOADING.
- RING STIFFENERS CHECKED PER CODE RULES FOR STIFFENED VESSEL UNDER EXTERNAL PRESSURE.
- BUCKLING WAS CHECKED BY RULES APPLICABLE TO STIFFENED VESSEL UNDER EXTERNAL PRESSURE.
- SHELL PENETRATIONS ARE DESIGNED IN ACCORDANCE WITH ASME RULES.

CYLINDER

- PSAR CYLINDRICAL BUCKLING CRITERIA (APP. 3.8-A) ADOPTED THE BUCKLING CRITERIA FROM SEQUOYAH PSAR (SAME AS FSAR) FOR APPLICABLE CONDITIONS

CRBRP CONTAINMENT VESSEL BUCKLING ANALYSIS

- REGULATIONS REQUIRE COMPLIANCE WITH ASME CODE SECTION III SUBSECTION NE
- PSAR CONSISTENT WITH ASME CODE
- CODE DID NOT (DOES NOT) ADDRESS BUCKLING WITH COMPLEX LOADINGS AND GEOMETRY
  - CYLINDER
  - DOME
  - RING STIFFENER
  - THERMAL INTERACTION
- ADEQUACY OF BUCKLING DESIGN WAS CHECKED BY TWO METHODS
  - ASME CODE RULES
  - BUCKLING CRITERIA OF PSAR (APP. 3.8-A)
- CONSERVATISMS IN BUCKLING CRITERIA

CYLINDER

- PSAR CYLINDRICAL BUCKLING CRITERIA (APP. 3.8-A) ADOPTED THE BUCKLING CRITERIA FROM SEQUOYAH PSAR (SAME AS FSAR) FOR APPLICABLE CONDITIONS

DOME

- BASED ON WELDING RESEARCH COUNCIL BULLETIN 69 FOR BUCKLING OF SHELLS OF DOUBLE CURVATURE
- BASED ON SEQUOYAH WITH SLIGHT VARIATION

RING STIFFENER

- DESIGNED TO ASME CODE RULES
- PSAR CRITERIA WERE CHECKED BY EQUATIONS DEVELOPED BY C. D. MILLER OF CBI FOR ALL LOADS (AND CONFIRMED TO BE CORRECT)

THERMAL INTERACTION

- PSAR CRITERIA WERE BASED ON TEST RESULTS AND ANALYSIS BY BOSOR4. THE RESULTS DEMONSTRATED THAT FOR GEOMETRIC PROPORTIONS TYPICAL OF CRBRP CONTAINMENT VESSEL, THE CRITICAL FAILURE MODE FOR A FIXED END CYLINDER SUBJECTED TO A TEMPERATURE RISE WAS BY YIELDING RATHER THAN BY CRITICAL BUCKLING.
- CRITICAL THERMAL BUCKLING STRESS IS LIMITED TO 80% OF YIELD STRESS FOR SSE AND 67% FOR OBE.
- THERMAL STRESSES WERE TREATED AS PRIMARY STRESSES IN THE BUCKLING INTERACTION EQUATION IN COMBINATION WITH CONCURRENT AXIAL HOOP, SHEAR, AND TORSION STRESSES.

ASME CODE RULES

- ASME BUCKLING CHECK CONSISTED OF AXIAL COMPRESSION CHECK OF THE OVERALL SEISMIC EFFECTS, THE DEAD LOAD AND EXTERNAL PRESSURE.
- THE CODE EXTERNAL PRESSURE BUCKLING CRITERIA WERE VERIFIED BY DEVELOPING AN EQUIVALENT EXTERNAL PRESSURE FOR THE HOOP COMPRESSIVE STRESSES. THESE STRESSES CONSISTED OF THE EFFECTS OF EXTERNAL PRESSURE ADDED TO SEISMIC LOADING.
- RING STIFFENERS CHECKED PER CODE RULES FOR STIFFENED VESSEL UNDER EXTERNAL PRESSURE.
- BUCKLING WAS CHECKED BY RULES APPLICABLE TO STIFFENED VESSEL UNDER EXTERNAL PRESSURE.
- SHELL PENETRATIONS ARE DESIGNED IN ACCORDANCE WITH ASME RULES.

BUCKLING CRITERIA OF PSAR

APP. 3.8-A

PROVIDES FOR:

- LOADING CASES AND GEOMETRIES BEYOND ASME DESIGN FORMULAS
- USE OF AN ESTABLISHED CLASSICAL BUCKLING ANALYSIS WHICH IS CONSISTENT WITH THE ASME APPROACH
- CONSIDERATION OF IMPERFECTIONS BY USING KNOCKDOWN FACTORS
- CONSIDERATION OF COMBINATIONS OF DIFFERENT BUCKLING STRESS COMPONENTS

CONSERVATISMS IN BUCKLING CRITERIA

- ASSUMED MAXIMUM STRESSES ACTING UNIFORMLY AROUND THE CIRCUMFERENCE EVEN THOUGH THE MAXIMUM STRESS OLY OCCURS LOCALLY.
- ASSUMED MAXIMUM STRESS ACTING UNIFORMLY OVER THE LENGTH OF THE PANEL (EXCEPT AT GROSS STRUCTURAL DISCONTINUITIES) ALTHOUGH MAXIMUM STRESS OCCURS ONLY ON A LIMITED AREA.
- USED EQUIVALENT STATIC STRESSES FOR PEAK RESPONSES FROM DYNAMIC ANALYSIS.
- DESIGNED FOR 125 TON LIVE LOAD ON POLAR CRANE DURING SSE WHICH IS AN EXTREMELY UNLIKELY EVENT.
- NO CREDIT WAS TAKEN FOR CONCURRENT TENSILE STRESSES IN CYLINDRICAL SHELL. (ADDED IN ABSOLUTE TERMS WHICH IS CONSERVATIVE).
- SIGNIFICANT BUCKLING CONSERVATISM HAS BEEN INCORPORATED IN THE DESIGN BY INCORPORATING THESE CONSERVATIVE APPROACHES.

SUMMARY

- THE PSAR CRITERIA IS CONSISTENT WITH PREVIOUSLY LICENSED PLANTS
- THE DESIGN CONFORMS TO THESE CRITERIA
- NRC HAS REQUESTED COMPARISON OF THE PSAR TO THE 1980 CODE AND TO N-284
- CRBRP HAS RECENTLY PROVIDED THIS COMPARISON
- CRBRP HAS ALSO EVALUATED ALL SIGNIFICANT CHANGES
- CRBRP CONTINUES TO BELIEVE THAT THE DESIGN IS ADEQUATE AND SAFE
- NRC DIALOG IS CONTINUING TOWARDS A MUTUAL AGREEMENT

CRBRP STRUCTURES AND MATERIALS
BRIEFING FOR

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS (ACRS)

OVERVIEW OF SODIUM SPILL ACCIDENTS FOR CELL STRUCTURAL DESIGN

PRESENTED BY:

CLIFF J. BOASSO
SYSTEMS INTEGRATION,
WESTINGHOUSE–OR
CRBRP PROJECT

AUGUST 19, 1982

LIQUID METAL/GAS LEAK DETECTION
TYPICAL REQUIREMENTS (PHTS)

- DETECTION SENSITIVITY
    - LEAK 100 GRAMS/HR OR GREATER-- LESS THAN 250 HR
    - LEAK 30 gpm OR GREATER--LESS THAN 5 MIN
- DETECTION DIVERSITY
- LEAK LOCATION
    - CELL
    - MAJOR COMPONENT (PUMP, HEAT EXCHANGER, REACTOR)
    - PIPING SECTION (HOT LEG, COLD LEG)
- LEAK CONFIRMATION
- SEISMIC CATEGORY II
- ALARM AND INDICATOR IN CONTROL ROOM

TYPICAL RESULTS
FOR INERTED CELLS

ANALYSIS METHODOLOGY

- CELL PRESSURE AND TEMPERATURES CALCULATED WITH SODIUM/NaK FIRE COMPUTER CODES ACCOUNTING FOR SPRAY AND POOL BURNING EFFECTS
- NODAL NETWORK GIVING TEMPERATURE DISTRIBUTION THROUGH CELL LINERS INTO THE STRUCTURAL CONCRETE
- ZERO GAS LEAKAGE FROM INERTED CELLS TO MAXIMIZE PRESSURE CHALLENGE
- 2% OXYGEN CONCENTRATION IN INERTED CELLS

SODIUM SPILL ACCIDENTS

CODES UTILIZED	APPLICATION
• SPRAY-3B	SPRAY BURNING
• SOFIRE	POOL BURNING (ONE CELL)
• GESOFIRE	POOL BURNING (TWO CELL)
• SPCA	SPRAY-POOL BURNING
• HAA-3	AEROSOL BEHAVIOR

CRBRP STRUCTURES AND MATERIALS

BRIEFING FOR

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS (ACRS)

OVERVIEW OF LIQUID METAL/GAS DETECTION

PRESENTED BY:

CLIFF J. BOASSO
SYSTEMS INTEGRATION,
WESTINGHOUSE–OR
CRBRP PROJECT

AUGUST 19, 1982

LIQUID METAL/GAS DETECTION

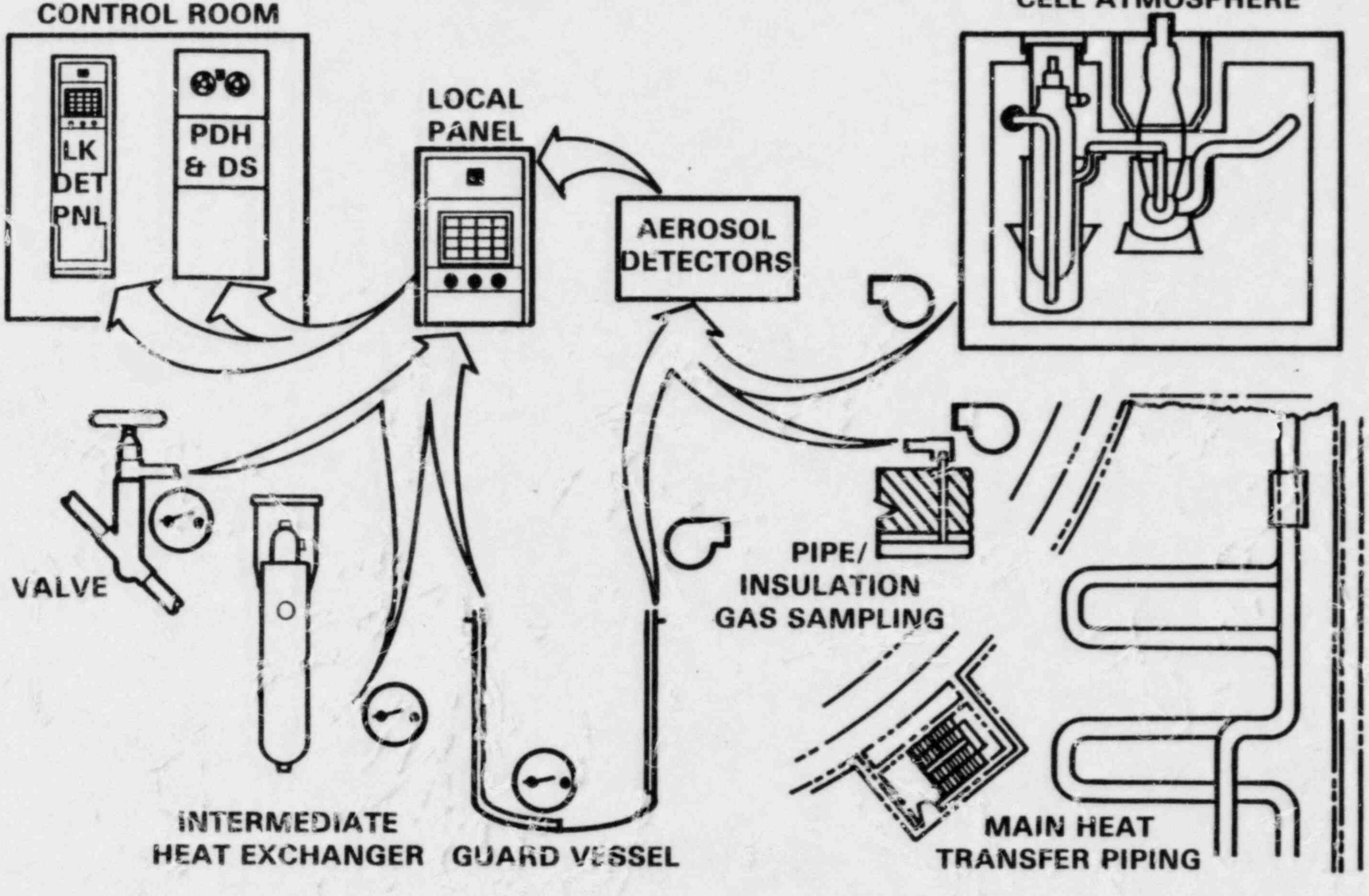
BREAKDOWN OF DETECTOR QUANTITIES

PFADS	SIDS	CABLE	CONTACT	RADIATION PARTICULATE MONITOR
169	8	62	213	7

BASIS FOR SPILL SELECTED

- SPILL SELECTED FROM LARGEST OR HIGHEST PRESSURE LIQUID METAL PIPE IN CELL AT LOCATION PRODUCING WORST CASE SPILL ON CELL BASIS
- PIPE LEAKAGE BASED ON MODERATE ENERGY SYSTEM FLUID BREAK (1/4 DT) AS DEFINED IN BRANCH TECHNICAL POSITION MEB 3-1
- LEAKAGE ASSUMED WITH LIQUID METAL SYSTEM OPERATING AT MAXIMUM NORMAL OPERATING TEMPERATURE AND PRESSURE

LIQUID METAL TO GAS LEAK DETECTION INSTRUMENTATION SYSTEM



CONTROL ROOM

LK DET PNL

PDH & DS

LOCAL PANEL

AEROSOL DETECTORS

CELL ATMOSPHERE

VALVE

PIPE/ INSULATION GAS SAMPLING

INTERMEDIATE HEAT EXCHANGER

GUARD VESSEL

MAIN HEAT TRANSFER PIPING

CRBRP STRUCTURES AND MATERIALS
BRIEFING FOR

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS (ACRS) WORKING GROUP

LINED CELL ANALYSIS

PRESENTED BY:

BOB PALM
CIVIL/STRUCTURAL ENGINEER,
MANAGER
BURNS & ROE
CRBRP PROJECT

AUGUST 19, 1982

LINED CELL ANALYSIS

- Provisions in design to accommodate liquid metal spills in inerted cells
- Cell Liners
- Concrete Cell Structures

CELL LINERS

CELL LINER DESIGN TO ACCOMMODATE A NA SPILL

GENERAL FUNCTIONAL REQUIREMENTS

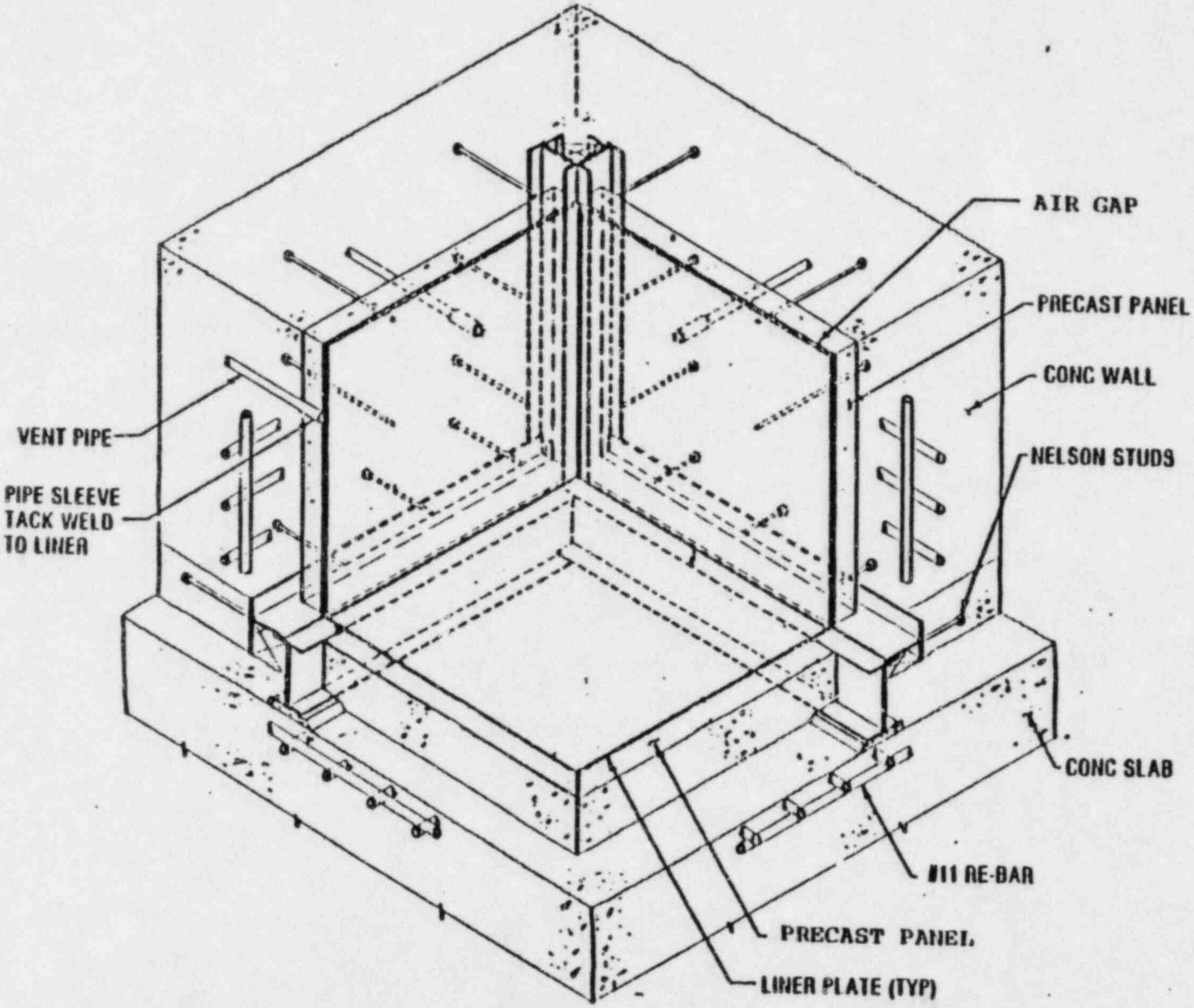
1. Cells Inerted With Nitrogen to:
   - o LIMIT NA BURNING
   - o LIMIT CELL PRESSURE/TEMPERATURE
2. Cell Liners Provided To:
   - o PREVENT SODIUM - CONCRETE REACTIONS
     - PREVENT HYDROGEN GENERATION
     - MINIMIZE PRESSURE/TEMPERATURE EFFECTS
     - MINIMIZE RADIOACTIVE RELEASE POTENTIAL
   - o CONSERVE NITROGEN MAKE-UP DURING NORMAL OPERATING CONDITIONS
   - o MAINTAIN STRUCTURAL INTEGRITY AFTER SPILL
   - o PROVIDE THERMAL PROTECTION TO LIMIT STRUCTURAL CONCRETE TEMPERATURE
   - o FACILITATE DECONTAMINATION AFTER SPILL

CRBRP LINER SYSTEM COMPONENTS

1. PREFAB WALL AND CEILING PANELS
   - 3/8" CARBON STEEL PLATE
   - 4" PRECAST INSULATING CONCRETE PANEL
   - CONTINUOUS BEHIND THE LINER VENT SYSTEM
   - NELSON STUD ANCHORAGES

2. FLOOR LINER SYSTEM
   - 3/8" CARBON STEEL PLATE
   - EMBEDDED STRUCTURAL ANCHORS
     - VENT HOLES
   - 4" PRECAST INSULATING CONCRETE PANEL
   - CONTINUOUS BEHIND THE LINER VENT SYSTEM

3. BI-PLANAR AND TRI-PLANAR CORNERS
   - USE OF FIXED SQUARE CORNERS



TYPICAL CELL LINER ISOMETRIC - CORNER DETAIL

LINER SYSTEM QUALIFICATION

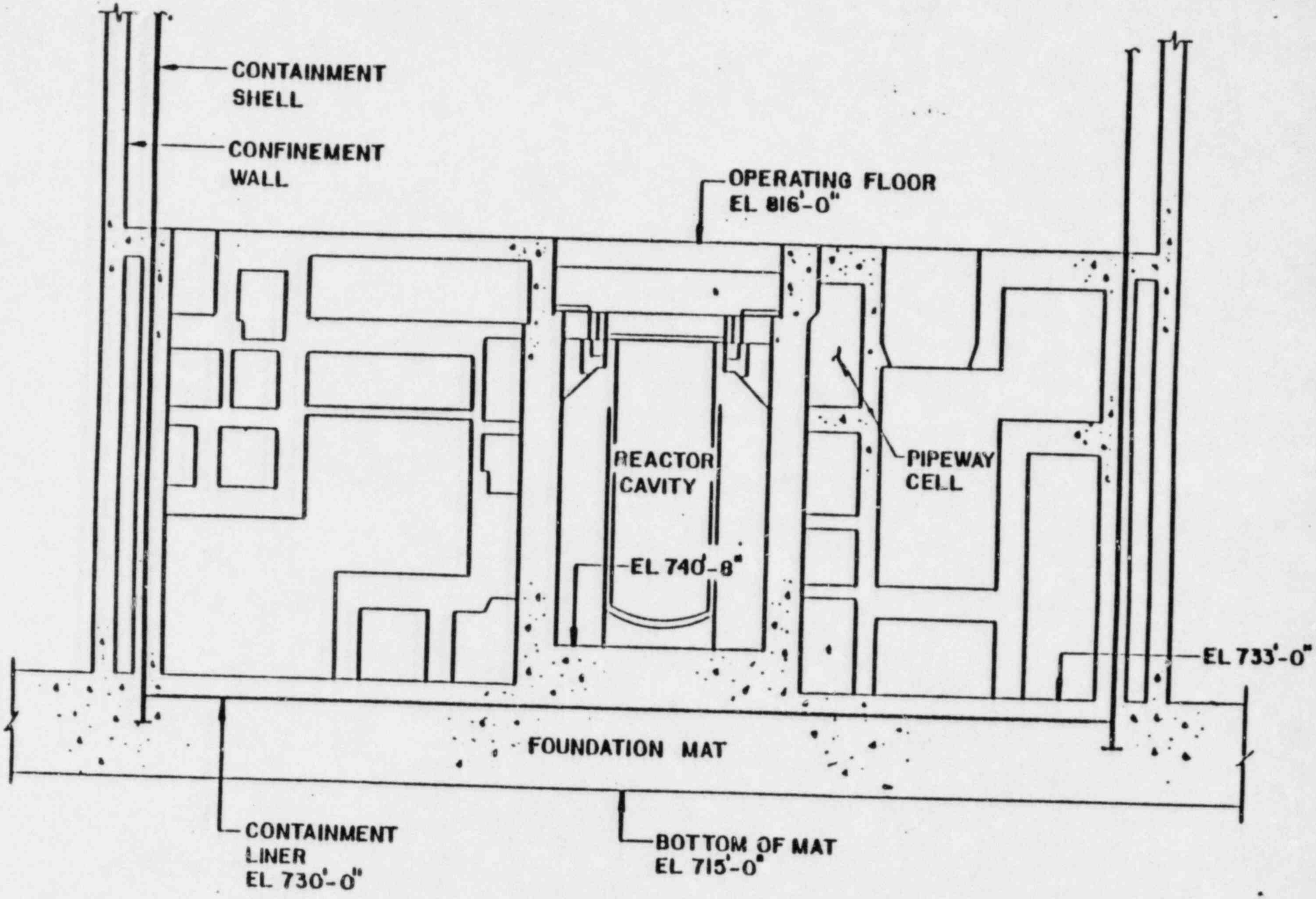
ANALYSIS

- Elastic-Plastic Analysis using the computer program ANSYS
- Stress-Strain curves at temperature developed from testing performed on SA516 Grade 55 carbon steel
- von Mises strains calculated and compared with allowable limits

TESTING (LT-1)

- Large scale sodium spill qualification test performed with CRBRP cell liner

CONCRETE CELL STRUCTURES



RCB CROSS SECTION

CONCRETE CELL STRUCTURES

- Concrete design conforms to ACI Code and NRC requirements
- Supplemental requirements for high temperature concrete design
  - Developed for Na spill conditions where concrete temperature exceeds 150°F
  - Thermal effects on structure are dependent on duration of heat load and resultant penetration into concrete
  - Design properties of concrete and rebar are influenced by high temperatures
- Design considers temperature dependent properties for concrete and rebar
  - Strength
  - Modulus of Elasticity
  - Stress-Strain relationship
  - Shear and bond strength
  - Coefficient of thermal expansion
- Comprehensive testing of CRBRP concrete established high temperature properties

CONCRETE CELL STRUCTURES (CONTINUED)

- ALLOWABLE ACI STRESSES REDUCED IN ACCORDANCE WITH TEMPERATURE/STRENGTH RELATIONSHIPS
- LOADING CONDITIONS AND LOAD COMBINATIONS ARE IN ACCORD WITH SRP AND ACI
- CELL STRUCTURE ANALYSIS
  - FINITE ELEMENT APPROACH USING NASTRAN CODE
  - INTERCONNECTED CELL MODELS USED TO DETERMINE INFLUENCE OF NA SPILL EFFECTS

- Results of Analyses
    - Na spill effects are controlled and contained within each cell
    - Containment boundary is not compromised by any Na spill or the DBA
    - Concrete thicknesses and reinforcing are designed to accommodate the most severe combination of loads

CRBRP STRUCTURES AND MATERIALS
BRIEFING FOR

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS (ACRS)

OVERVIEW OF LIQUID METAL/GAS DETECTION

PRESENTED BY:

CLIFF BOASSO
SYSTEMS INTEGRATION,
WESTINGHOUSE-OR
CRBRP PROJECT

AUGUST 19, 1982

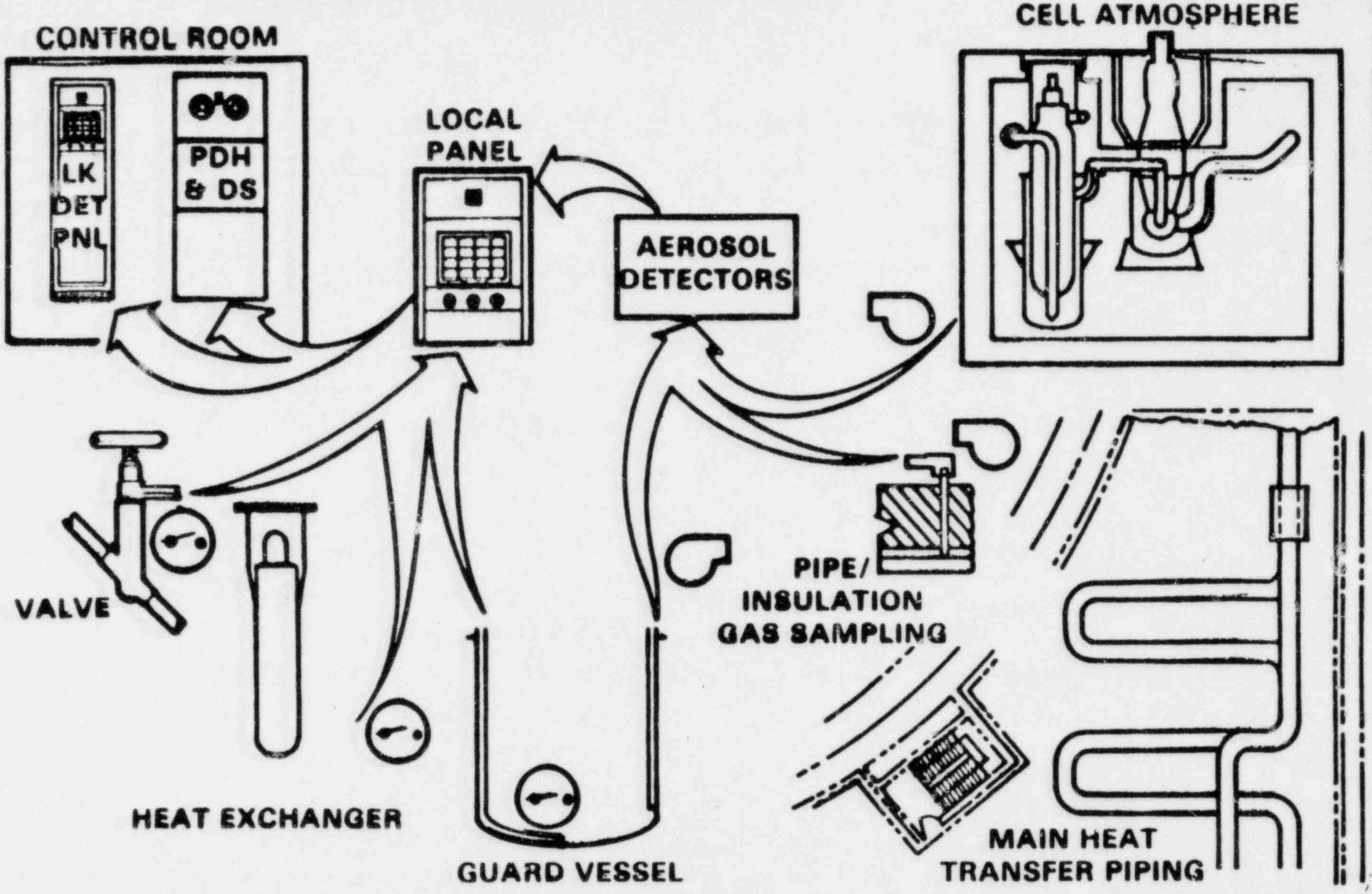
LIQUID METAL/GAS LEAK DETECTION
FUNCTION

- CONTINUOUS MONITORING OF LIQUID METAL SYSTEMS FOR LEAKAGE INTO SURROUNDING GAS SPACES

- DETECTION OF SMALL LEAKS PRIOR TO SIGNIFICANT CORROSION OR CRACK PROPAGATION

- DETECTION OF LARGER LEAKS PRIOR TO SIGNIFICANT LOSS OF LIQUID METAL INVENTORY OR ONSET OF SIGNIFICANT ECONOMIC DAMAGE

LIQUID METAL TO GAS LEAK DETECTION INSTRUMENTATION



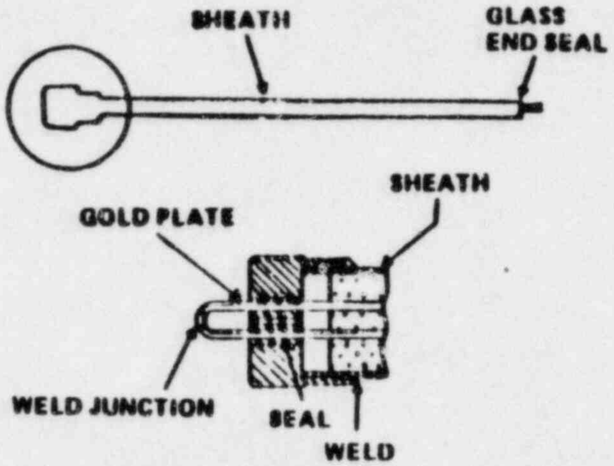
VISUAL NO. ______________ SUBJECT ______________

SUBJECT ______________

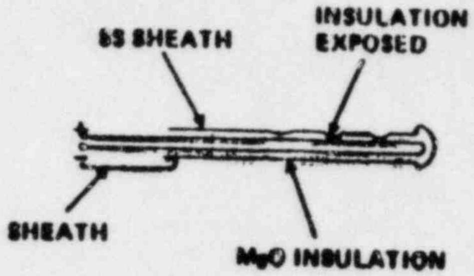
LIQUID METAL/GAS LEAK DETECTION
TYPICAL REQUIREMENTS (PHTS)

- DETECTION SENSITIVITY
  - LEAK 100 GRAMS/HR OR GREATER--LESS THAN 250 HR
  - LEAK 30 gpm OR GREATER--LESS THAN 5 MIN
- DETECTION DIVERSITY
- LEAK LOCATION
  - CELL
  - MAJOR COMPONENT (PUMP, HEAT EXCHANGER, REACTOR)
  - PIPING SECTION (HOT LEG, COLD LEG)
- LEAK CONFIRMATION
- SEISMIC CATEGORY II
- ALARM AND INDICATOR IN CONTROL ROOM

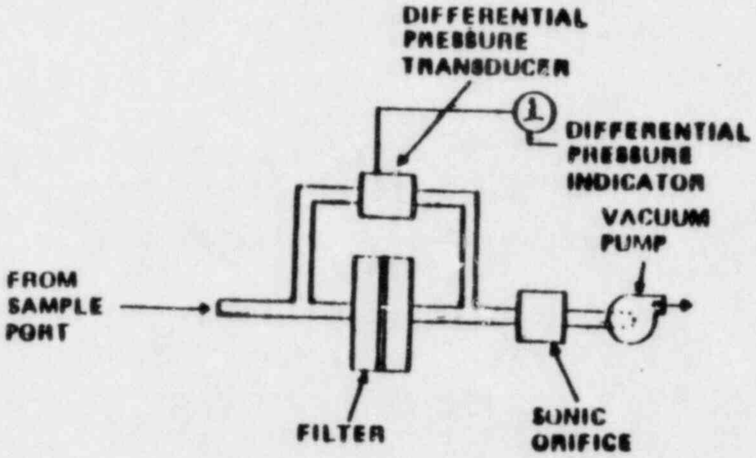
LIQUID METAL/GAS LEAK DETECTION



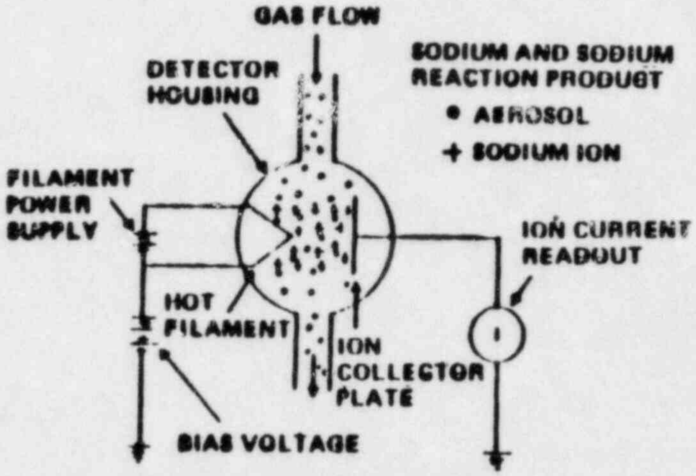
a. CONTACT DETECTOR



b. CABLE DETECTOR



c. PLUGGING FILTER AEROSOL DETECTOR

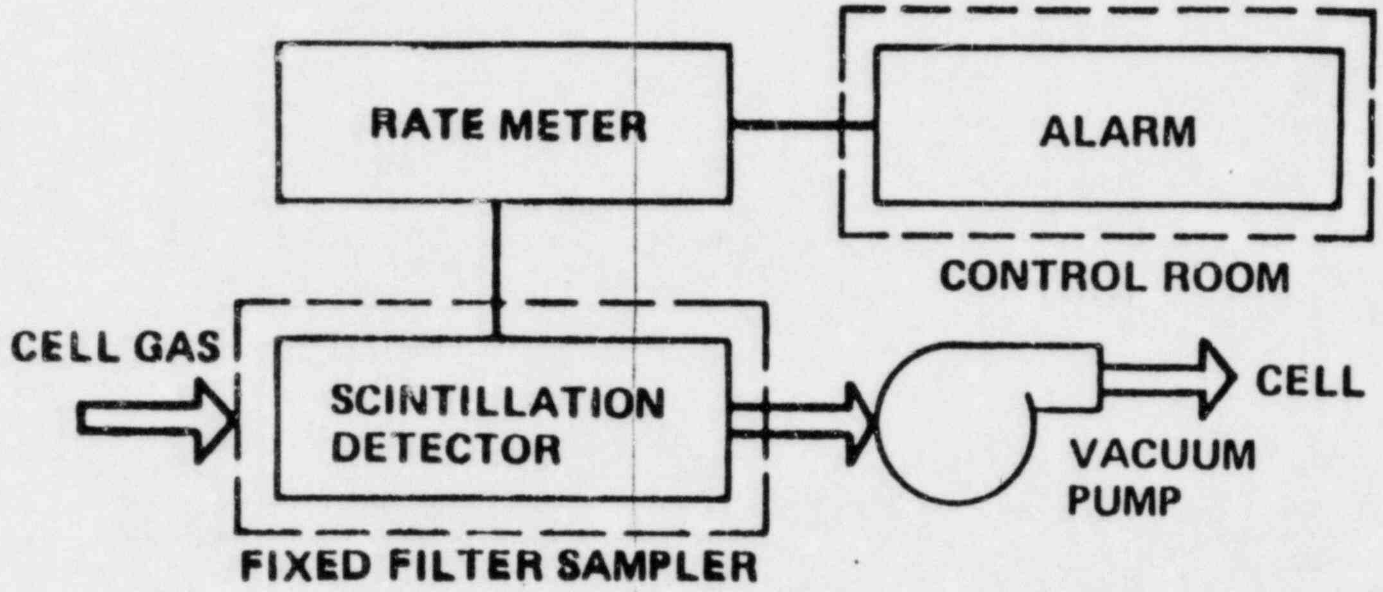


d. SODIUM IONIZATION DETECTOR (SID)

VISUAL NO. ____________ SUBJECT ____________

LIQUID METAL/GAS LEAK DETECTION

RADIATION PARTICULATE MONITOR



LIQUID METAL/GAS DETECTION
BREAKDOWN OF DETECTOR QUANTITIES

PFADS	SIDS	CABLE	CONTACT	RADIATION PARTICULATE MONITOR
169	8	62	213	7

LIQUID METAL/GAS LEAK DETECTION

SUMMARY

- EXTENSIVE AND COMPREHENSIVE LIQUID METAL-TO-GAS LEAK DETECTION, COVERING A WIDE RANGE OF LEAK SIZES AND UTILIZING A VARIETY OF TECHNIQUES IS PROVIDED FOR CRBRP

CRBRP STRUCTURES AND MATERIALS

BRIEFING FOR

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS (ACRS)

OVERVIEW OF SODIUM SPILL ACCIDENTS FOR CELL STRUCTURAL DESIGN

PRESENTED BY:

CLIFF BOASSO
SYSTEMS INTEGRATION,
WESTINGHOUSE-OR
CRBRP PROJECT

AUGUST 19, 1982

BASIS FOR SPILL SELECTED

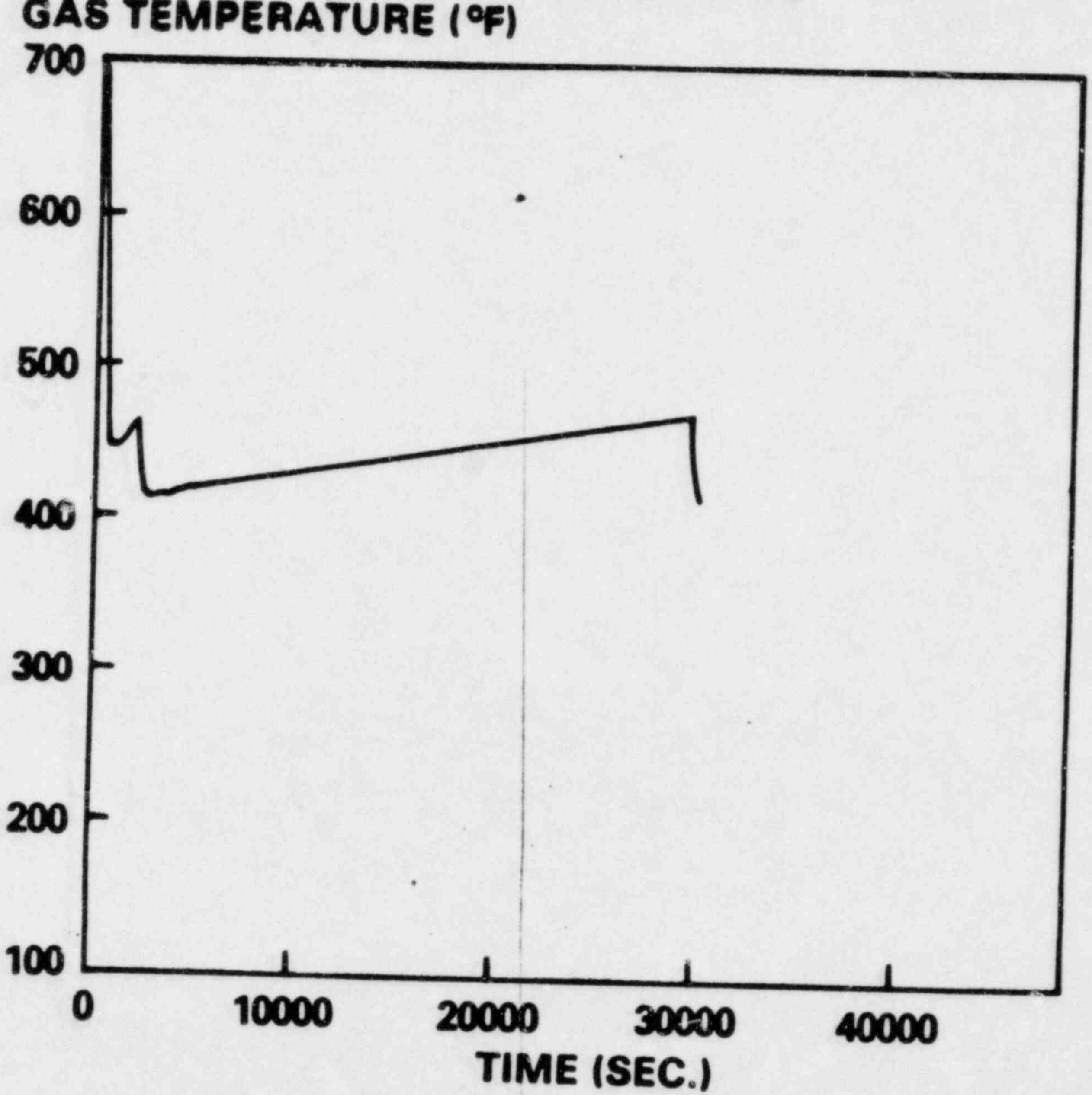
- SPILL SELECTED FROM LARGEST OR HIGHEST PRESSURE LIQUID METAL PIPE IN CELL AT LOCATION PRODUCING WORST CASE SPILL ON CELL BASIS
- PIPE LEAKAGE BASED ON MODERATE ENERGY SYSTEM FLUID BREAK (1/4 DT) AS DEFINED IN BRANCH TECHNICAL POSITION MEB 3-1
- LEAKAGE ASSUMED WITH LIQUID METAL SYSTEM OPERATING AT MAXIMUM NORMAL OPERATING TEMPERATURE AND PRESSURE

ANALYSIS METHODOLOGY

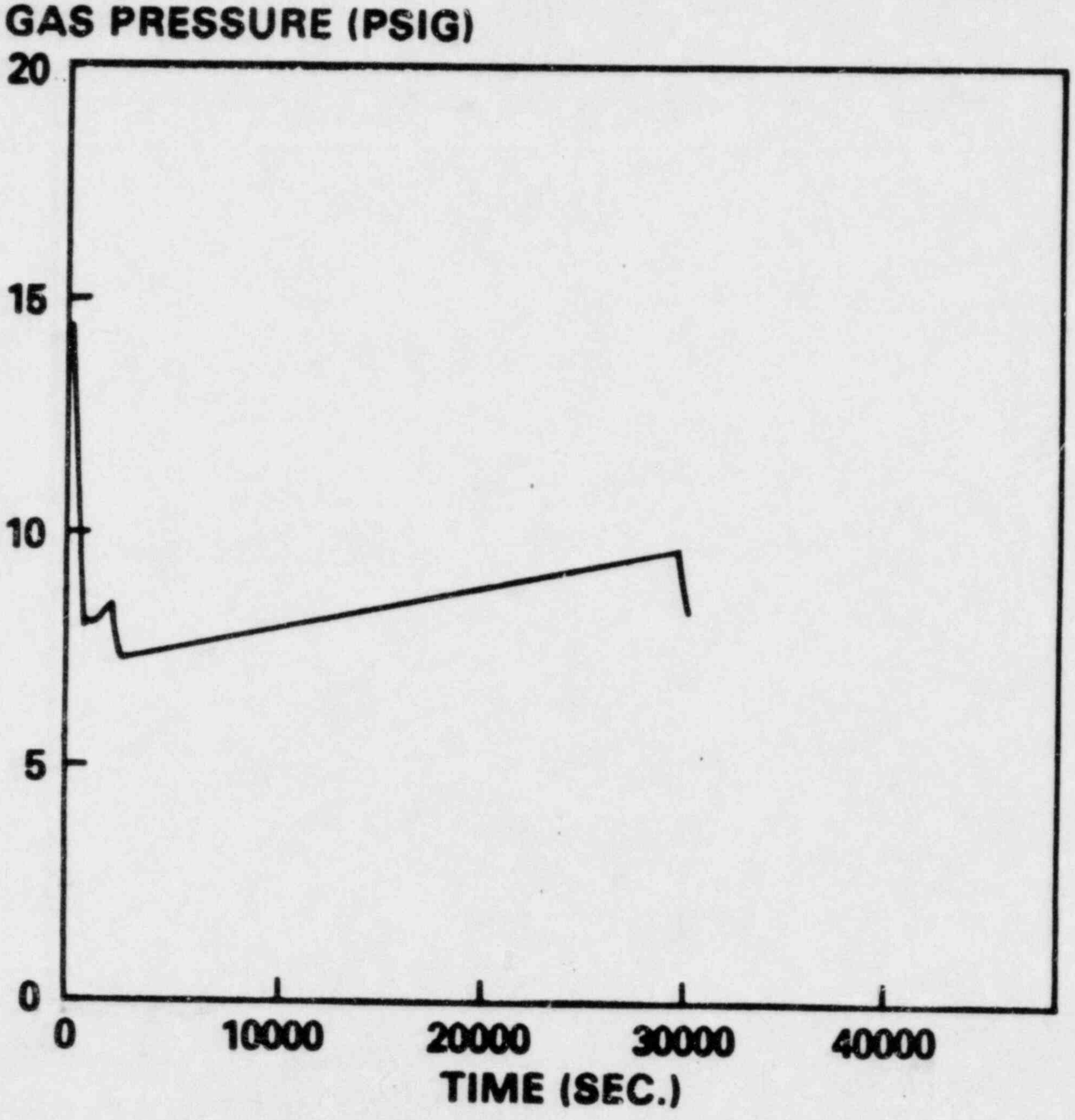
- CELL PRESSURE AND TEMPERATURES CALCULATED WITH SODIUM/NaK FIRE COMPUTER CODES ACCOUNTING FOR SPRAY AND POOL BURNING EFFECTS
- NODAL NETWORK GIVING TEMPERATURE DISTRIBUTION THROUGH CELL LINERS INTO THE STRUCTURAL CONCRETE
- ZERO GAS LEAKAGE FROM INERTED CELLS TO MAXIMIZE PRESSURE CHALLENGE
- 2% OXYGEN CONCENTRATION IN INERTED CELLS

TYPICAL RESULTS FOR INERTED CELLS

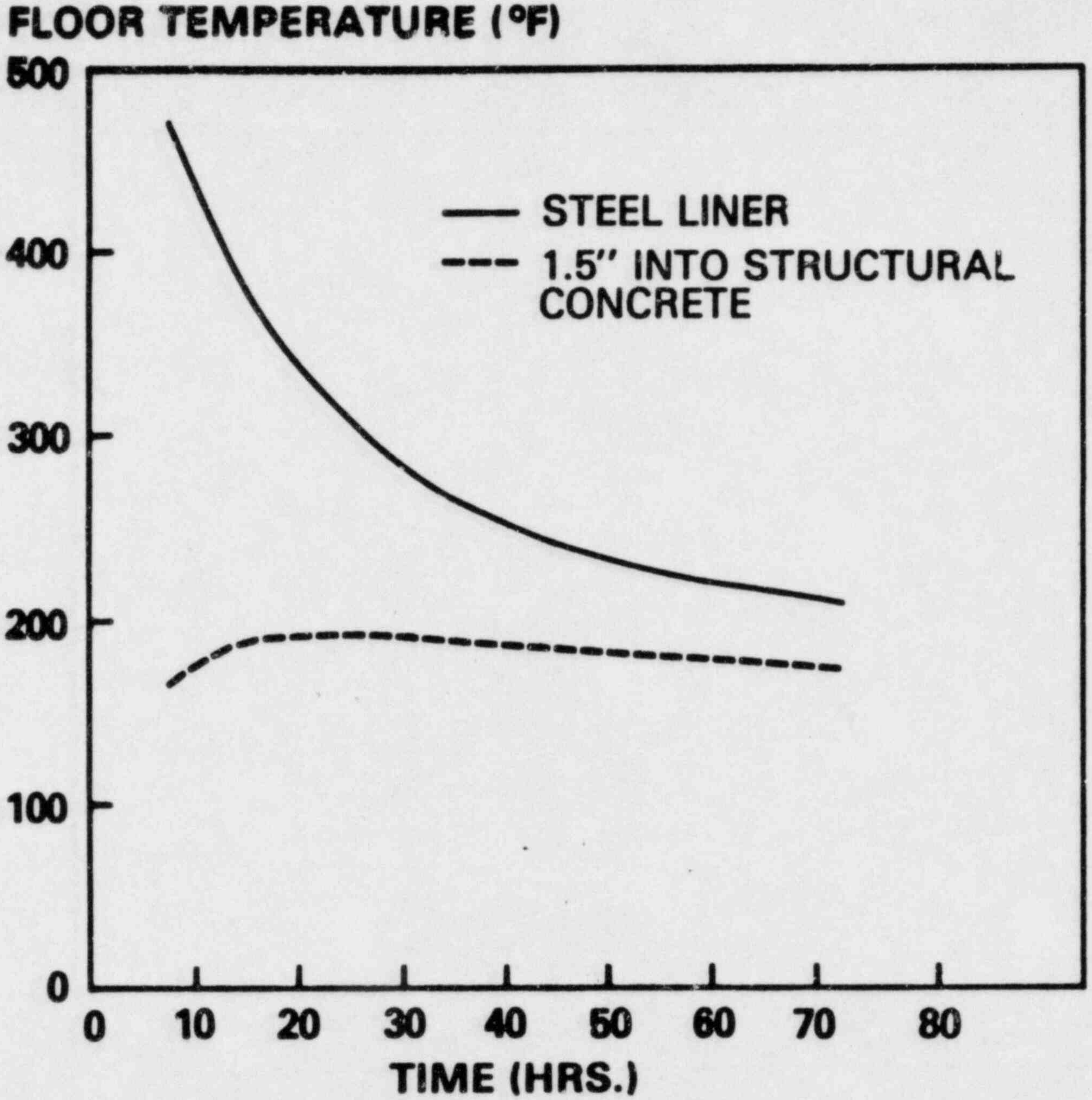
PHTS CELL GAS TEMPERATURE (SPRAY PHASE)



PHTS CELL GAS PRESSURE (SPRAY PHASE)



PHTS CELL FLOOR TEMPERATURE



SUMMARY OF EVALUATIONS

- PLANT CELL STRUCTURES DESIGNED TO ACCOMMODATE CONSERVATIVE SPECTRUM OF DESIGN BASIS LIQUID METAL SPILL EVENTS.

VISUAL NO. ____________ SUBJECT ____

BUCKLING EVALUATION ADJACENT TO OPERATING DECK

LOAD CASE	FACTOR OF SAFETY	
	BOSOR4 ANALYSIS ADJUSTED FOR SHEAR	REQUIRED BY CODE CASE N-284
DL + LL + SSE + THERMAL + P_E	1.9	1.67
DL + LL + OBE + THERMAL + P_E	2.5	2.00

$P_E = 0$ FOR THIS ANALYSIS

CONCLUSIONS

1. THE CONTAINMENT VESSEL HAS BEEN DESIGNED TO MEET THE ASME CODE AND SUPPLEMENTAL BUCKLING CRITERIA IN EFFECT AT THE TIME THE E-SPECIFICATION WAS CERTIFIED (MID 1975).

2. COMPARISON OF PSAR CRITERIA AGAINST CURRENT CRITERIA INCLUDING CODE CASE N-284 HAS BEEN PREPARED BY THE PROJECT.

3. NUMERICAL COMPARISON OF THE MOST CRITICAL LOCATION OF THE CONTAINMENT VESSEL (BASED ON ISSUED DESIGN REPORT) HAS BEEN CONDUCTED AGAINST CURRENT CRITERIA AND HAS SHOWN THAT THE DESIGN MEETS THE CRITERIA.