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NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS (ACRS)

SUBCOMMITTEE ON FUTURE PLANT DESIGNS

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THURSDAY, JULY 17, 2003

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MONROEVILLE, PENNSYLVANIA

The Subcommittee met at the Westinghouse Energy Center, 4350 Northern Pike, Monroeville, PA, at 1:00 p.m., Thomas Kress, Chairman, presiding.

SUBCOMMITTEE MEMBERS:

THOMAS KRESS - CHAIRMAN

GRAHAM WALLIS - MEMBER

JOHN SIEBER - MEMBER

GRAHAM LEITCH - MEMBER

VICTOR RANSOM - MEMBER

F. PETER FORD - MEMBER

ALSO PRESENT:

MEDHAT EL-ZEFTAWY
MIKE CORLETTI
TERRY SCHULZ
ED CUMMINS
TOM HAYES
DAN FREDERICK
RALPH CARUSO
JIM SCOBEL
SELIM SANCAKTAR
JUN LI
JIM GRESHAM
M. KHATIB-RAHBAR
MIKE ZAVISCA
SUD BASU
H ESMAILI
JOELLE STARFOS
RICHARD ORR

C-O-N-T-E-N-T-S

P-R-O-C-E-E-D-I-N-G-S

1:00 p.m.

CHAIRMAN KRESS: Let's get started if we can, please. The meeting will now please come to order. This is a meeting of the ACRS Subcommittee on Future Plant Design.

I'm Thomas Kress, Chairman of this Subcommittee. The other ACRS members in attendance are Peter Ford, Graham Leitch, Victor Ransom, Graham Wallis, and I presume Jack Sieber will be here shortly.

For today's meeting the Subcommittee will review and discuss the AP1000 instrumentation and control design concept, the manned machine interface design acceptance criteria, human factors issues, and the open items regarding the design reviews.

The Subcommittee will gather information, analyze relevant issues and facts, and formulate proposed positions and actions as appropriate, for deliberation for the full Committee.

Mr. Medhat El-Zeftawy is the cognizant ACRS staff member, staff engineer, for this meeting. The rules for participation in today's meeting have been announced, as part of the notice of this meeting, previously published in the Federal Register, on July

8th, 2003.

The transcript of this meeting is being kept, and the transcript will be made available as stated in the Federal Register Notice. It is requested that speakers identify themselves, and speak with sufficient clarity and volume, so that they can be readily heard.

We have received no written comments, or requests for time to make oral statements from any members of the public. I don't have any particular introductory comments, so with that I will turn it over to Mike, to get it started.

MR. CORLETTI: Thanks, Tom. The presentations that we are going to have for the next day and a half are geared to providing you information that has either been -- the Committee has expressed an interest in seeing, a more detailed presentation, or related to the Draft Safety Evaluation Report.

And we've got our first presentation today, it is on the ADS Squib valve reliability, which was an issue that was raised at the PRA Subcommittee meeting.

The first presentation is with Terry Schulz.

MR. SCHULZ: Good afternoon. I'm going to start this off, we will be talking a little bit about the system design and concentrating on the requirements for the stage 4 ADS squib valves. Then Tom Hayes will talk about the instrumentation control of the ADS 4 squib valves.

And then Dan Frederick is here from the valve vendor that makes these kinds of valves, and is our expert witness on how these valves are being designed, what has been their experience in the past.

And then, to wrap it up, we will have Selim Sancaktar talk about the PRA modeling, and in particular some -- considering some newer information on valve reliabilities, and what means to the PRA.

You've seen this picture before, I don't want to really belabor it, but the four valves that we are talking about are the four squib valves connected to the hot legs, which we have been talking about, from a thermal-hydraulic performance, extensively.

These valves are normally closed. There is an upstream, normally opened, motor operated valve. That valve provides isolation capability, in case there is any leakage through the squib valve, which is an extremely unlikely situation to happen.

They also provide an ability to isolate the valve, if it had opened in an accident, and you are in a recovery mode.

CHAIRMAN KRESS: Do those things ever fire off accidentally, and open up?

MR. SCHULZ: We will --

CHAIRMAN KRESS: That is part of the reliability questions.

MR. SCHULZ: Yes. Tom Hayes, in particular, will be talking about the details of the INC, I will talk a little bit about the logic, and the interlocks, and permissives that we have in the design from a logic point of view, and Tom will talk, very much, about the potential, or how the valve is controlled.

And, in fact, he will go into fire hazards issues and how we will prevent that from inadvertently opening the valve.

MR. CUMMINS: Just to review the open item. Was the ACRS comment that the AP1000 PRA relied significantly on the performance of the 4 stage ADS valves, and could we please present why they will open when we want them to open, and why they won't open when we don't want them to open, and that is the title of this presentation, really.

CHAIRMAN KRESS: The question was, where did you get the reliability number that goes in the

PRA.

MR. SCHULZ: Yes, and why is that a good number to have. If you step back a little bit, I was not involved with the certification of the AP600.

MEMBER LEITCH: But as I understand it, it did not have a valve such as this?

MR. SCHULZ: No, it did.

MEMBER LEITCH: It did?

MR. SCHULZ: The configuration, as you see on this picture, was both for AP600 and AP1000.

MEMBER LEITCH: Okay.

MR. SCHULZ: There were two of the four squib valves are shown here, AP600 had four squib valves. The only difference is these are bigger than AP600. These are 14 inch pipe, the AP600 were in a ten inch pipe.

Now, that doesn't really connect them to the IDS, but they are bigger for AP1000. There also are squib valves in the injection lines, and the recirc lines. We are not specifically going to talk about those today.

But most of what we are talking about, or will talk about, is applicable to those valves, also, in terms of their reliability and the simplicity of their design and operation.

MEMBER LEITCH: Okay, thank you.

MR. SCHULZ: The ADS 4 valves are -- their function is to work in a loss of coolant accident, because they are not needed, or intended to be used in non-LOCA accidents.

They are -- they play a role in getting the plant down to the low pressures required for the gravity drain from the IRWST, as was talked about in the last day and a half in the Therma-Hydraulic Subcommittee meetings.

That is a very important function of these valves. The whole ADS system, as we -- as you see here, actually involves four separate stages. Three of them are connected to the pressurizer, discharge into the IRWST from a sparger. Those are motor operated valves.

I show three stages here, there is actually two groups of those, there is a total of six flow paths. There is four stage 4 valves, they are actually kind of in a sequence. This valve opens, and then about a minute later the second stage 4 opens in both pairs, too.

And the whole purpose of the staging of the ADS is to control and smooth out the transient that the reactor cooling system goes through, in going from high pressures down to very close to atmospheric pressure.

The ADS valves are controlled by their core make up tanks level. That is what actuates them. The core make up tank level was a good indication, in our plant, of how much high pressure inventory, safety injection inventory is still available.

So as the inventory gets depleted, then in a kind of a LOCA sequence, then, we actuate ADS. And stage 1 is actuated on what we call a low 1 core make up tank level. That is about two-thirds volume set point.

That is sent by four level sensors in each core make up tank.

CHAIRMAN KRESS: What are those level sensors?

MR. SCHULZ: What kind of sensors?

CHAIRMAN KRESS: Yes. Are they weight --

MR. SCHULZ: They are DP switch, actually. They are very simple. We've actually used the switches because to keep them somewhat different from some of the other DP sensors that we have in the plant from a PRA point of view.

So there is a narrow range set of four DP sensors for the low 1. There is a separate set of narrow range DP sensors for the level 2. And one of the reasons why we use that level narrow range, is because we can run into significant density differences in the safety water, depending on whether it is recircd or not.

Initially it is cold, high density water. We could have gone through, in a very small LOCA, substantial recirculation period, the water could heat up. And because of that the density could be reduced.

And to minimize the impact on the set point we came up with a very narrow range sensors. These sensors, of course, go into the protection system to actuate the valves.

The second and third stage are controlled by the low 1 set point plus timers. So that the stage 2 will always go off a minute or so after stage 1; and stage 3 will go off three minutes after stage one, kind of sequencing.

Stage 4 the CMT level is --

MEMBER LEITCH: Restored? Will that stop the action of ADS 2 and 3?

MR. SCHULZ: No.

MEMBER LEITCH: So once the sequence is started you are going to get 1, 2, and 3?

MR. SCHULZ: That is right. Now, you

won't necessarily get 4.

MEMBER LEITCH: I understand.

MR. SCHULZ: It is a separate set point. And that set point is low, more like 20 percent volume of the core make up tank. And the fact that the operators take the recommended emergency procedure actions, which is to turn the normal RHR system, which can act like a low head safety injection pump.

If they take that action, and that system works, and it is not a safety system, so we can't guarantee that it will work. But if it does work then what it does is it slows down the core make up tank injection and stops it, because of a favorable interaction in the wake of RNS pump flow comes in, it comes in here, goes through this orifice.

Which then, if these pumps are running, and replacing the core makeup tank flow, the back pressure stops the core makeup tank injection, the water stays in the core makeup tank, so it is available should the RNS system quit, or be shut off inadvertently later on.

But if the RNS does get started, and keeps running, then the CMT level will not drop down to actuate stage 4. Because you don't really need it with RNS pumps running, because they provide enough pressure, with ADS 1-3 to adequately cool the core.

There are, of course, manual controls both through the projection system, and the diverse actuation system. Either one of those systems, there are separate controls, in the control room, to control the ADS valves.

In both cases it requires two switches to be actuated, to minimize the chance of inadvertent actuation. The power supplies, each stage 4 has three separate sets of wires coming to it, coming to three separate igniters that are located in the valve. Two of those sensor wires are coming from the protection system. So any one of the four squib valve either has a train A and train C wire coming through it, or a train B and D.

This minimized, improves the reliability, minimizes the consequences of a single failure. So in that whole ADS system, the worse single failure is a single stage 4 valve. You cannot have a single failure that will affect stage 1, 2, and 3, and stage 4, for example.

In addition each stage 4 valve has a third set of wires coming to it, coming from the diverse actuation system. This is a diverse INC system, the DAS control of the ADS is only manual, there is no automatic.

And we did that, partly, to minimize the chance of inadvertent actuation, and partly because it wasn't needed to be automatic, based on our PRA insights.

Now, I will talk a little bit about the logic that controls the automatic signals. In order to get an automated protection system actuation of stage 4, we first need to actuate the core makeup tanks, this is basically an S-signal, like low pressurizer pressure.

You will also need the core makeup tank level to drop, to this low 1 set point, and then you need timers to go through to give a permissive for the low 2 level, and then you need the low 2 level to have occurred.

And you will also need to be below a specified RCS pressure. This is about 1,300, 1,200 psi. This is where you would go to in a small LOCA, and it is a little bit below the set point. Excuse me, the set point is a little bit above the steam generator safety valve set point.

So in a case where passive RHR is going to be moving all the decay heat, which can happen shortly after an accident, that is where the plant will tend to go with the leak.

But it also gives us an additional interlock to prevent inadvertent actuation at high pressure. So you need all these things to take place, from a logic point of view, and in order for the stage 4 valve to be automatically actuated.

MEMBER LEITCH: Are the instrument lines connected to these level switches, are they independent all the way into the CMT? In other words, or do you have multiple instruments hanging off the same set of instrument lines? Maybe that is a detail that hasn't been worked out.

MR. SCHULZ: You are talking about the tubing sensors going into the tank?

MEMBER LEITCH: Yes. In other words you talked about four different level switches.

MR. SCHULZ: Yes.

MEMBER LEITCH: But are they independent all the way to the penetrations into the tank?

MR. SCHULZ: They actually are not. And we've gone through an evaluation of the consequences of (unintelligible) out of all those lines. Remember there are two tanks, and either core makeup tank can actuate ADS.

In addition to that -- I would have to go back and look at -- I know we looked at that very carefully to make sure that was okay. We lock open the valves, so they can't inadvertently be closed, the root isolation valves.

MEMBER LEITCH: I understand yes.

MR. SCHULZ: And we have gone through evaluations of what is going to happen here, leaks going out of the --

MEMBER LEITCH: -- drops off on one of those root isolation valves, or something like that.

MR. SCHULZ: Yes.

MEMBER LEITCH: But you do have another complete tank which would also actuate the system?

MR. SCHULZ: In either tank can actuate ADS.

MEMBER LEITCH: Yes.

MR. SCHULZ: -- both tanks have level sensors for low 1 and low 2.

MEMBER LEITCH: Yes. Okay, good, thanks.

MR. SCHULZ: So from a point of view of a real inadvertent signal coming through to the valves, we think it is incredibly low with all the interlocks and permissives that we have, and redundant switches.

Tom Hayes will --

MR. HAYES: -- were for sensors, too.

MR. SCHULZ: Yes, when I say four sensors, there is A, B, C, D division for each set, okay?

MR. HAYES: And we do it two out of four votes.

MEMBER RANSOM: What protection do you have against sabotage?

MR. CUMMINS: Tom will address it is some respects.

MR. SCHULZ: These valves are, of course, inside containment.

MEMBER RANSOM: Right. So it is very hard to get to them.

MEMBER RANSOM: And where are the switches?

MR. SCHULZ: The switches are in the control room.

MEMBER RANSOM: Are they located right together, or do they have any interlocks, or any way to prevent --

MR. SCHULZ: The switches for the protection system, there is two safety handles in the plant, in the control room. They are not located next to each other. And you have to actuate a switch on both panels, so one person can't do it.

The DAS is a little bit different, but

there is two switches on a panel that are close together, but there is a separate power switch that you have to turn on to actuate, turn power on to the manual controls.

And that is physically separate from the valve control switches. This just gives you a picture of how much bigger the piping and valves get when going from AP600 to AP1000. You can also get a feeling, here, for some of the advantages of the squib valves, relatively compact, compared to a motor operated valve.

And a motor operated valve, really, wouldn't meet the functional requirements for this valve, it wouldn't open fast enough. They also wouldn't be diverse from stages 1, 2, and 3. So you probably would have to go to something a bit more exotic than a motor operated valve as an alternative.

MEMBER RANSOM: I have a design question. Why isn't the motor operated valve located downstream of the squib valve?

MR. SCHULZ: Because we want the squib valve to discharge directly to the containment, to maximize its performance, piping downstream.

MEMBER RANSOM: I would think from a leakage point of view -- well, the other thing is maintenance, the motor operated valve, don't you have to once in a while actuate that valve?

MR. SCHULZ: No, because it has no safety function.

MEMBER RANSOM: But you want it to close.

MR. SCHULZ: We would want it to close, but we would not -- there is no in-surface testing requirements for that valve, because it is no safety function valve.

Would the valve be exercised? Probably, not necessarily at power.

MEMBER RANSOM: Well, you are clearly not at power.

MR. SCHULZ: The valves are also flanged in, and with the valve located at the end of the pipe, it is easier to take the valve apart, because you don't have a flange on both sides of the valve, you only have it on the one side.

So if you ever actuated the valve, and then wanted to refurbish it, rebuild it for operation again, you have to take the upstream part off, and it is a little easier to do it in this location.

MEMBER RANSOM: Well, this is a shear valve, so that you destroy the valve if you open it?

MR. SCHULZ: No, it doesn't destroy the

valve.

MEMBER RANSOM: Well, it destroys its seal?

MR. SCHULZ: It cuts part of the valve, engineered shear section inside the valve. We will be showing you what that looks like.

MEMBER SIEBER: I presume --

MR. SCHULZ: This is a view --

MEMBER SIEBER: -- that there are substantial pipe restraints on the ADS lines, too, because of the reaction force, if you use them?

MR. SCHULZ: There are.

MR. CUMMINS: Put your picture back up.

MEMBER SIEBER: Yes, the drawing doesn't show any restriction.

MR. CUMMINS: -- the little lips on the end there, those are forced numbers that go right to the steam generator well, so if it goes off, we've designed them so that it could go off at operating pressure, and it wouldn't cause the pipe to wet.

MEMBER SIEBER: Right.

MR. SCHULZ: This shows you a view of the functional requirements. I mentioned that it is a 14 inch pipe. The hole going through the valve has a nine and a quarter inch ID.

And, of course, it is a safety seismic class one design, full system pressure design. It is designed to open at full system pressure, and it is also designed to open at very low pressure, which is actually more challenging than the high pressure.

Expected opening pressure, as you heard from hydraulic, is somewhere 100 psi, or in fact a little bit lower. The normal water temperature, up against the valve will be hot. It won't be full system pressure because there is a partial loop seal in front of the valve.

We are requiring the valve to be designed so that it can tolerate full hot leg pressure. It is flanged upstream, both up and downstream, and it is stainless steel construction.

I talked about several of the aspects here of why we selected squib valves. We actually didn't originally have squib valves in AP600. We were thinking of using some gas piston valve of some kind. But we became concerned when we actually started talking to valve vendors about the availability of those valves, and the development issues.

So we ended up selecting the squib valves partially, a very strong reason, was that they are very reliable valves. And, of course, this is an important PRA safety function, so that reliability is very important.

The ability to use the three independent control circuits, all the ways through the valve, is a unique and very beneficial function. They are very diverse from the motor operated stage 1, 2, and 3 valves, again, a PRA benefit.

They have a very low chance of inadvertent opening, or leakage. That is a very beneficial function. The in-service testing and inspection is simplified versus motor operated, or air operated valves.

They actually are less expensive than air operated valves that we looked at. Even though there is some development costs in coming up with these valves for the ADS-4, there is in our minds less uncertainty and the cost will be lower, than coming up with the -- an alternate valve.

And as a final thing, the US utilities who are working with us, when we were developing AP600, actually suggested this to us, and supported the use of the squib valves.

The last two slides I have deal with in-service testing and inspection. Both are being -- will be performed in accordance with ASME requirements.

Basically ASME says that for squib valve you should take 20 percent of the valves, of a given function or design, and every two years replace the propellant, and put it in a test fixture, and fire it, make sure that the pressure developed would have been sufficient to actuate the valve.

CHAIRMAN KRESS: So you take one valve every two years and do that?

MR. SCHULZ: No, we only have four, so it is actually 25 percent of the valves, because we have four valves.

MEMBER RANSOM: What do you do if you find one that doesn't fire?

MR. SCHULZ: Then you need to look at, you know, the whole parts of the quality control. And this is, when you make the propellant, initially, you make it in batches, and you do testing of that before you even put the propellant in the valve, to make sure that this was a new manufacture to start with.

So there is, also, a propellant that is designed, it is over-designed so that it will work with 80 percent, or something like that, of the design amount of propellant that you put in.

So it is very unlikely that that will

happen, but not impossible. If something like that happens you need to try to find out what the root cause of the problem was.

MEMBER RANSOM: Do you go back and replace all the ones that came from that batch?

MR. SCHULZ: That is a definite possibility. If you can't figure out what the problem is, or if you do figure it out, and it is for something with aging, or that was different than when you first made it. So there are some alternatives there that you can take and certainly one of them is to replace the propellant in the other valves.

MEMBER LEITCH: One thing that we always did in other squib valve applications was in the storeroom you would test one from each batch before you used it, in actual application, to be sure that that batch did, indeed, fire properly.

MEMBER RANSOM: I imagine the manufacturer did something similar --

MEMBER RANSOM: Perhaps, I'm not sure what the manufacturer's practices were, but --

MR. HAYES: We have a manufacturer here that you can ask.

MEMBER RANSOM: Yes.

CHAIRMAN KRESS: The test fixture that you test this in, what measures the force, the charge, it measures the --

MR. SCHULZ: -- the pressure?

CHAIRMAN KRESS: -- the pressure, maybe.

MR. FREDERICK: Yes, I will get into the details when I give my presentation, if that is okay.

MR. SCHULZ: Another thing that we do is that when we disconnect the wiring from the propellant, and reconnect it, we will do a continuity check to make sure everything is hooked back together and, in fact, that the firing circuit inside of the valve is intact, and it is all connected together.

And, of course, the valve position sensor, that is -- in-service inspection, now this relates to, primarily, inadvertent opening of the valve, somehow cracking, rupturing of the valve opening.

The shear cap, which we will be seeing in a little bit, is the main issue here. The valve body is a massive chunk of stainless steel, and I don't think there is any issue with it breaking.

The flange is connecting the valve body to the piping, are very robust also. So I think that the focus of question of in-service inspection, and potential leakage/rupturing is with the shear cap.

And one of the things that we would

concentrate on in-service inspection, we would look at that, take the valve apart, inspect it from a dimensions point of view, make sure there was no thinning.

We would also look for any cracking in that shear cap. And if there is any problems we will replace it. Once you've got the valve apart it is not that big of a deal.

And we anticipate that although this will be done every ten years, that it probably wouldn't be done all four valves every ten years, it would be some kind of a staggered, it would give you intermediate data.

CHAIRMAN KRESS: Have you made some sort of analysis to see if that valve is thermally cycled? When you have a dead end off of a hot thing with a -- sometimes these things can get thermally cycled, and are you having -- do you have temperature measurements on it, or --

MR. SCHULZ: We do not --

CHAIRMAN KRESS: -- way to monitor it?

MR. SCHULZ: -- measurements in the plant. The piping is big piping.

CHAIRMAN KRESS: Yes, 14 inch.

MR. SCHULZ: To make it up the top of the hot leg.

CHAIRMAN KRESS: Yes.

MR. SCHULZ: So we anticipate that it will be uniformly hot.

CHAIRMAN KRESS: It is full of liquid, you drain any air out?

MR. SCHULZ: That is right.

CHAIRMAN KRESS: So you have a dead end with hot liquid coming off the hot leg?

MR. SCHULZ: Yes.

MR. CUMMINS: If I may, Tom? For AP600, where we did such an evaluation for the dead end pipes like that, for thermal stratification, for AP1000, where we were using the DAC approach, that is a commitment to perform that assessment as part of the final piping design.

CHAIRMAN KRESS: Okay.

CHAIRMAN WALLIS: You have to vent this pipe, don't you?

MR. CUMMINS: I'm sorry?

CHAIRMAN WALLIS: Don't you have to vent it, you get electrolytic pulls because you are letting off the gases, the noble gases --

CHAIRMAN KRESS: -- hydrogen get up there?

CHAIRMAN WALLIS: -- get up there? It

probably would. You have to vent any kind of a dead end like that. Otherwise you are likely to accumulate, over a long period of time, hydrogen.

MR. SCHULZ: Well, two things. One I don't see that as being a problem.

CHAIRMAN WALLIS: It doesn't matter if it pulls the hydrogen --

MR. SCHULZ: If there is some up there --

CHAIRMAN WALLIS: -- expose the mixture, too, it is radiolosis.

MR. SCHULZ: We have some other high points where we do actually have an isobaric chart inlet which is in the CMT inlets, both of those where the presence of hydrogen might, adversely, interact with the natural circulation of the system.

We have high point, not only high point vents, but high point gas chambers on top of high points to level sensors, that actually measure. Now, we don't anticipate actually seeing anything up there, okay?

But in those -- those functions are much more sensitive to the presence of hydrogen.

CHAIRMAN WALLIS: If it did fill up with the explosive mixture of hydrogen and oxygen, and you set off the squib valve, you might set that off, too?

You probably would.

MR. SCHULZ: I don't think so.

CHAIRMAN WALLIS: Why not?

MEMBER FORD: -- explosions occurred in some PWR plants, hot legs of PWR plants. But there, I think, there has been an explosive mixture of hydrogen and oxygen, oxygen in your case. And you also need an ignition source.

And I'm not too sure, unless the motor operated valve is moving --=

MR. SCHULZ: I don't know --

MEMBER FORD: Probably the PWR explosion, it doesn't mean --

(Everyone speaks at the same time.)

MEMBER SIEBER: -- very rapid rate, sometimes it self-ignites when you do that. But these valves start off with hydrogen, and also leaps pretty good, these valves are just a single valve.

And no matter how good the manufacturer is, they are probably going to leak a little bit, too, so the hydrogen will probably leak.

MR. SCHULZ: I don't think these valves will leak.

MEMBER SIEBER: I've never seen a valve that didn't leak a drop or two every month.

MR. SCHULZ: Well, these aren't your regular valves. Now, two of these valves actually have the --

MEMBER SIEBER: Better off --

MR. SCHULZ: -- connection off of them. And that would be the ADS 4 tees off horizontally, passive RHR goes straight up.

CHAIRMAN KRESS: Yes, but that collects hydrogen.

MR. SCHULZ: So that will tend to collect it for that, if it does exist.

CHAIRMAN KRESS: The actual design, it would be important, but you can still have thermal stratification in there.

MR. SCHULZ: Yes, which we said would be something to look at. That is the end of my portion. Tom Hayes will now talk about the controls of the valves.

MR. HAYES: Good afternoon, I'm Tom Hayes from Westinghouse. I'm an electrical engineer, so most of what you are talking about, so far, is foreign to me.

I'm here to try to answer the questions about why do we think this valve --

CHAIRMAN KRESS: What you say will

probably be foreign to us.

MR. HAYES: Okay, good. But I'm focusing on the actuation circuit of these valves, and pointing out what we have done to ensure that the valves will receive an actuation signal when necessary, and will not receive an actuation signal when they should not.

As Terry mentioned, each of these ADS 4 squib valves can be actuated by either of two protection system channels, protection system that carry the initials PMS, but that is the safety grade system.

It is a four channel system. So, as Terry mentioned, two of these four valves get an AMC signal, and two of the valves get a B&D signal. And for each of those valves, one of those signals will cause the valve to actuate.

The protection system has both automatic and manual means of generating that signal. And then there is a diverse actuation system that also has a manual way of actuating that valve.

Each one of these circuits are energized to actuate, driven primarily by the characteristics of the valve. It is not like an AOD that you can have be a fail open valve. It needs energy so that it can actuate, that is just the design of the valve.

So I would like to first address the issue of the reliability to actuate when you want it to. And we address this by the three separate signals that go to the valve.

What I have here is a block diagram of a single ADS 4 valve, the circuits that would actuate it. There are three of them, they are independent all the way out to the valve. Each one of these valves will have three actuators, or three igniters at least, so that any one of those igniters will open the valve.

MEMBER WALLIS: What kind of a signal do you send?

MR. HAYES: It is a pulse of current.

MEMBER WALLIS: One pulse of current?

MR. HAYES: One pulse of current.

MEMBER WALLIS: So some kind of a fire that caused a short might send a pulse of current?

MR. HAYES: We will talk about that in just a minute. You are getting ahead. If you want me to jump ahead, I would be willing to. That would get us back on schedule if I do that.

(Laughter.)

MR. HAYES: Let me first address how we are addressing the issue of reliability to actuate, and then we will talk about the reliability to not actuate, when you don't want it to, which is what you are asking about.

MEMBER WALLIS: A lightning strike, or anything that sends a --

MR. HAYES: Certainly a lightning strike would set one of these off.

MEMBER WALLIS: It would?

MR. HAYES: Inside containment, it has to be inside containment.

MEMBER WALLIS: No, no, outside, surge.

MR. HAYES: Outside, no. I'm talking about lightning striking through the steel containment into this valve.

Okay, so in effect we are triple redundant, and there are three different ways of actuating this valve, three way redundant, two way diverse. The two top halves we show here are from the protection system, the energy for this current that would open the valve comes from the class 1E power --

MEMBER WALLIS: The supposed current level is not -- are you talking about what goes from the controller to the valve? I was talking about what comes to the controller, what comes from the side of PMS division to the controller.

Is this a piece of digital information, or is it a pulse of current?

MR. HAYES: Oh, okay. When you talk about what the controller is -- this box that I have labeled squib valve controller is, basically, a capacitor with interlock circuits, okay?

So you charge it up, let's talk about how the controller works. Each controller has what we call an arm and a fire circuit. Now you are getting into this -- the reason we did that is to do everything we can to preclude spurious actuations.

Now, what the arm circuit is relatively low current compared to the five amps it takes to fire this valve, it would be something in the less than one amp range, that would charge a capacitor in the controller.

When the capacitor is charged, and the armed circuit has been de-energized, there is interlocked circuits to look for that, then the fire circuit, if the controller sees an energy on the fire circuit, this control grade signals --

MEMBER WALLIS: Just a pulse of some current in the fire circuit?

MR. HAYES: These are not -- the pulse is out here on the fire side. These are just normal digital signals.

MEMBER WALLIS: So there is a digital signal that is an encoded signal, with quite a bit of information?

MR. HAYES: No, no, it is just an on and off. A digital, to me, is on versus off. It is not, well it is a continuous current.

MEMBER WALLIS: It is a very simple thing I'm getting at.

MR. HAYES: Yes.

MEMBER WALLIS: If it were an encoded digital --

MR. HAYES: No, it is not encoded.

MEMBER WALLIS: -- signal, then there is much less chance of it being fudged by a short. But if you have just a current, then that could easily be fudged by a short.

MR. HAYES: Sure, I understand that. But these are simple signals. It is either energy there, or not energy there.

But, remember what I said about this control, what it is, is the capacitor that will charge up. It gets its current from the arm signal, so it gets a half an amp or so, for 30 seconds or so, and charges up the capacitor.

And then, when that capacitor is charged, the fire signal will release that pulse of current to go out to the valve.

MEMBER SIEBER: I picture what you are describing as a capacitor, SPD switch on it?

MR. HAYES: Well, it is a little more than that. Let's talk a minute about what that is.

CHAIRMAN KRESS: Okay.

MR. HAYES: So each controller has two inputs, an arm signal and a fire signal, and the arm signal is where it gets its energy to charge the capacitor.

Now, what are the interlocks we have associated with that? First of all the intended operational sequence is to the arm circuit, to be energized long enough to charge the capacitor, for the arm signal to go away, and then the fire signal to appear. And that will release the energy.

Now, in that process we have an indication and alarm to the operator when that capacitor is charged. There are times he wants it charged. Obviously right before he wants the style to open. There are times he wants it not charged, which all the other times.

So you need an alarm on that to say that that capacitor got charged, and you didn't mean for it to. So we have a capacitor there that normally it sits there de-energized. We have interlock circuits in this controller box, that says there is nothing you can do on either one of those signal lines to make this capacitor discharge.

You send it the fire signal to charge, it will try to discharge, but it has nothing to discharge. You send it the arm signal, with no fire signal, it will charge up the capacitor, and that capacitor will stay charged if that arm signal is still there, but it will never fire, there is never a fire signal.

MEMBER WALLIS: It won't let you fire when it is partially charged?

MR. HAYES: It will let you try to fire it if you partially charged it, and the arm signal has gone away. You can try to fire it. But it won't stay partially charged, it won't stay charged, or even partially charged very long.

It is a matter of minutes, it has a lead resistor that discharge the capacitor back down.

MEMBER SIEBER: I take it that it is a big electrolytic capacitor?

MR. HAYES: Yes.

MEMBER SIEBER: So it has a lifetime, you have to change them out every ten --

MR. HAYES: Sure.

MEMBER SIEBER: -- or so? Okay.

MR. HAYES: They will be tested every refueling for degradation, and probably changed every ten years even if they don't show degradation.

MEMBER SIEBER: I would.

MR. HAYES: I would too. That is a plant operator issue at this point.

MEMBER LEITCH: I'm still a little confused. Can you back up to the level switches? I mean, the level is going down, and at the same level do you actuate both the arm and the fire?

MR. HAYES: Well, yes. The level tells the protection system it is time to open the ADS 4 valves.

MEMBER LEITCH: Right.

MR. HAYES: Then what the protection system does, with its own internal timers, is it actuates the arm signal for 30 seconds, then deactivates the arm signal, and then actuates the fire signal.

MEMBER LEITCH: Okay. If the arm signal is not de-actuated will it fire?

MR. HAYES: No.

MEMBER LEITCH: Okay.

MR. HAYES: It has to be a coordinated sequence of things that happen into that control. Now, most of this --

MEMBER LEITCH: Back up to that again, to the level switches. I'm still a little confused about the logic there. Four level switches?

MR. HAYES: Right.

MEMBER LEITCH: And they are arranged like in an H pattern, one out of two --

MR. HAYES: Two out of four.

MEMBER LEITCH: Two out of four, okay. Okay, thanks.

MR. HAYES: So you have -- the idea of this controller, now, and it is driven very much by concerns about shorts resulting from fires. Now, we are into the shorts resulting from fires question that came up.

If we go back to the picture one more time, I will just pick one of these. If you have a fire that is causing this circuit to hot short. And, by the way, this is what we call a two pole circuit, so it has both wires there, and they are both broken on the upstream end.

But you get smart hot short. Both of

those conductors short to two conductors somewhere else. You can't get an arm signal. And when that arm signal gets in there, and charges the capacitor, the operator will get unarmed.

Now it is possible for a fire to cause that to happen. It is possible for that fire to then burn enough to break the conductors and make this an open circuit. It is possible for a fire to, then, cause this fire circuit to do the same thing, two smart hot shorts.

However, it is not possible for that to happen instantaneously. That takes a little bit of time. In the meantime there are fire detectors in the room where this might happen, smoke alarms, and the operators have procedures that tell them to go turn the power off in that room if there is a fire.

So if you look, from a fire actuated point of view, if you are looking from this box forward, there is nothing to short to. This is all passive stuff with no energy stored.

These cables are in trays and could, conceivably, short to another cable, but they are in instrument trays. Instrument circuits are 4 to 20 milliamps, 20 milliamps won't fire one of these valves.

So there is -- although it would be potentially possible for those wires to short to something, there is nothing for them to short to, within the trays they are in.

The fire would have to take those wires out of the trays they are in, put them in a different tray, and have these two conductors short. And that is just beyond design basis, in my mind.

Now, upstream from these controllers, we now are in areas where there are wires that you could conceivably short to, but that is where you start meeting these coordinated shorts, in multiple places in a single room, or in multiple rooms.

And that is where we get into the, by the time that happens, somebody has noticed their plant is on fire, and they've turned the power off. Now, I think I just went through about the next five slides.

MEMBER SIEBER: That is good.

MR. HAYES: These are just some more of the interlocks that are in the box. Basically attempting to prevent any spurious, reasonable spurious things that could happen as a result of inadvertent things happening.

Upstream of the squib valve we have the arm and fire signal coming from two different places, so they are physically separated, at least in the room that they are coming from. The rest of the story I've been through, you turn the power off.

This is all energized, actuate stuff, turn the power off when there is a fire. These manual actuation switches, and Terry has already mentioned it, are located at minimum two different places in the control room, where somebody has to be bumping into a switch.

The switches are going to be covered. This is, obviously, not a switch you want to have so that the guy can't even inadvertently bump one of them. He is going to have to bump two, and they are going to be in two different places.

The only other issue that I can think of, that could cause a problem for spurious actuation is, the protection system is a computer based system. And software does screw up. And what I have to tell you is that this is the best software you are going to get.

It is protection grade software, it is class 1E software, and Bill Gates was not involved. Again, I emphasized, the squib valve controller itself has no power, has no stored energy, except for the potential, if you could come up with some possibility that the capacitor gets energized, but that is alarmed.

So under normal conditions the controller is sitting there with no energy, no power, no way to generate a signal, absolutely none. I don't care how smart your little rodent that gets in there, or your fire, or whatever.

Failures downstream of the controller. Yes, here, what we are looking for is some way of generating the five amps that it takes to actuate one of these valves in some kind of cable to cable fault.

And we are simply saying there are no adjacent cables that have the ability to generate five amps. Those circuits just aren't there, they are in other trays.

MEMBER SIEBER: Actually, the way I think, it would be better to know what the voltage is, because the amperage is determined by the resistance of the detonator, right?

MR. HAYES: Well, the voltage is 48 volts, it is at 24/48.

MEMBER SIEBER: Thanks.

MR. HAYES: But 24 volts could, I mean, the detonator has very low resistance. So what we have, though, is a power supply internal impedance, and 24 volts won't get you five amps.

Again, this is basically a summary of what I've been repeating. So, basically, we believe the old possibilities of fires, operator error, equipment failures, and have at least some reasonable belief that this is not likely to have a problem.

MR. CARUSO: Are there any on-line monitoring and continuity to this normal operation?

MR. HAYES: We are not going to do that because we are worried that that is more dangerous from a spurious actuation point of view.

MR. CARUSO: You made a conscious decision not to --

MR. HAYES: We made a conscious decision to do that check right after we have done our refueling. The INC system guys are going to make me check the continuity, check all the way up to the squib valve.

So what I believe will happen, at the refueling, is a connector will be pulled, we will put on a test device, we will test fire all the way out, so we know the INC is good up to there.

MR. CARUSO: A lot of applications in these valves now that put a very small current through, and then they measure continuity.

MR. HAYES: I know. And those things have all kinds of problems. It is a great theory. In actual practice we are finding that they do, occasionally, generate a spurious trip.

Do you have any more questions before I sit down?

(No response.)

MR. HAYES: Okay. I will introduce Dan Frederick from Conax Corporation, who is the manufacturer of these types of valves.

MR. FREDERICK: As was mentioned, I'm Dan Frederick, I'm Vice President of engineering for Conax, and I work directly in design and development of fire wells. So I have a pretty long history of dealing with devices similar to what we are going to discuss today.

It is a fine agenda that has been put forth here, is the overview, first of all, by Conax Florida Corporation, just to give you an idea that yes, we have a building, and do exist.

Then we will get into the GE development program, follow that up with the AP1000 valve design, and the squib valve reliability will be taken care of at the end.

As you can see that is the plant, there is actually three buildings involved, and it in St. Petersburg, Florida. Just a quick overview of the company.

Conax was founded in 1948, the first development of elector-explosive devices was in the early 1950s. Conax Florida subsidiary was formed and moved to Florida in 1982, it became ISO 9001 certified in 1997.

We were purchased by Cobham of England in 1998. We have about 150 employees, our annual sales about 30 million dollars. And, as previously noted, we are in St. Petersburg.

CHAIRMAN KRESS: Who are your customers?

MR. FREDERICK: Virtually all major aerospace corporations, Air Force, Navy, Lockheed, Boeing, etcetera, etcetera.

CHAIRMAN KRESS: Is Pyronetics one of your brand names?

MR. FREDERICK: I personally came from Pyronetics originally. And so I was there for many years, when Pyronetics was relocated in Denver in 1980. Time frame, I headed up the engineering for many, many years, I was with OEA until about 1999, actually.

During that time frame Pyronetics was,

quote, absorbed into OEA, because we were in the same building as OEA, Incorporated. And then the aerospace side became OEA Aerospace, because at the same time the airbag industry was starting, and we had the initiator designs for many of the automotive type companies.

And, therefore, it became OEA Aerospace. Since that time Aerospace has been purchased by UPCO, which is now located in Fairfield, California, and that is where I was at before I decided to move down and take the position with Conax.

CHAIRMAN KRESS: So it is a different company?

MR. FREDERICK: So right now Conax is, obviously, separate from the original Pyronetics, OEA, UPCO. However, we have a license agreement, and we are working directly with them on the sale of pyrotechnic valves.

CHAIRMAN KRESS: But one reason for asking who your customers were is they -- the customers generally require some sort of QA/QC specs. And we were interested in what sort of QA and QC you have to have on these.

And I presume, from these particular customers, that is --

MEMBER SIEBER: That is what ISO 9001 --

MR. FREDERICK: ISO 9001, and certified ISO 2000 by October, November time frame of this year. So we are moving forward in the next phase of the ISO certification process.

A quick list of some of the products. In addition, we call them, pyrovalves, for the most part pyrovalve and squib valve are virtually the same, they have the same kind of design features.

Stored gas systems, water activated systems, pin pullers and cutters, actuation systems, and we even take lots of complex "build to print" jobs in some cases.

The advantages of squib valves, they are very fast acting, you have the solid metal seals, you don't really have to worry about leakage over time. They are reliable, environmentally durable, and NASA sponsored and qualified many programs.

We build valves because they came to us and said, well, we want these valves to fly on certain missions, and we designed them that way. The other advantage that wasn't noted there, typically a fire valve, just from the nature of it, you are getting so much work from so small an energy source, that you have a very lightweight component, compared to what anything else could put out there, that would do something in similar fashion.

We have a Class 10,000 clean room, we get involved with electronic assembly on our lot of our life support programs. We have a model shop that we use for a lot of our prototyping and development work. We do a lot of gas purity testing, we have pure gas bottles if you want to model the main missile systems that are produced today.

And we have our own environmental testing that we do in-house, as far as vibration, and altitude testing, etcetera. Obviously it is not to the size you would need for this valve.

MEMBER SIEBER: Do you build the controller that Mr. Hayes discussed?

MR. FREDERICK: No.

MEMBER SIEBER: So that comes from some place else?

MR. FREDERICK: I believe it comes from Westinghouse right? Yes, we don't do that.

MEMBER SIEBER: And you manufacture the detonator, or do you buy that from someone?

MR. FREDERICK: What we are going to be doing, on the detonator, which I was calling an initiator, my background, and booster charge, which is the main propellant source, we will be going back to UPCO, who built it previously, for all practical purposes, and they will do it again.

MEMBER SIEBER: So these are the -- it will be the same as the General Electric water valves?

MR. FREDERICK: Yes, that is exactly right. In fact, I was directly involved with the valve many years ago, and the design activity.

Just a brief list, I mean, obviously there is a lot more data up there, and I won't go through those items, but you can see it is a pretty extensive list of things that we are directly involved in.

Certification, as I mentioned earlier, we are ISO 9001, in November of 1997, and in January 2001, again. And getting into the GE valve development program, just to give you a little history, is what this amounts to.

Originally General Electric went out to seven potential bidders to provide a product that would do the work that they needed done. And for all practical purposes that obviously wasn't just going to somebody that made squib valves. That included, from what I recall, going to the Japanese, and getting some kind of a pneumatic system, etcetera, etcetera.

But what it really came down to is that at the time we proposed a two inch ID valve that would be upscaled to the required seven inch valve, as the recommended approach for them to use.

And we even provided, at that time, a list of our customers. They went out and contacted a bunch of customers because, you know, obviously if you are moving into a big development program on valve, it is always nice to get some input from the people that say we have been working with to understand where we were coming from, that we had the potential to design something of that size.

So then we received a contract, and then we moved out to design a seven inch valve. And the Westinghouse AP600 valve is, in fact, the same ID as the GE valve, and the AP1000 valve, the plan would be to scale up the existing GE seven inch valve, to accommodate the slightly larger 9.24 inch ID diameter for the AP1000 valve.

This valve, I will just give you a brief description of. This is the two inch valve that led to the GE valve. And from a quick design description here, we will go through the design description here.

You can see, on the top of the valve, right at that cavity, which is really not real clear to everybody, where the initiator is located in that valve. There is actually two of them.

So if you located it around the other direction you would have one sticking out this side, and one out that side. So they have redundancy built in from two initiators to do the -- just to cover in case you ever had to have two.

But in reality the valve was designed to work with one initiator. And this particular valve, based upon the way it was designed, didn't even require booster charge. And so when you fired the initiator you get ballistic pressure that will build up in this cavity.

It would build up a high net plunger right here. So when you got to a control pressure, that it took to break that shear section, then this part right here would stroke down, causing this sheared out section to move down, contact the support plate at the bottom, and then just rotates over down to the bottom, creating a full flow open flow passage.

MEMBER SIEBER: Is that hinged at the bottom?

MR. FREDERICK: Yes, it is, that is a hinge, yes.

MEMBER SIEBER: So it doesn't go shooting across the room?

MR. FREDERICK: No, no, it is totally contained just like the GE valve that I will show you here in just a second.

And in this particular case, which we didn't need on the GE valve, you can see there is metal belts around the outside, because they wanted to prevent any potential for pyrotechnic materials to get out into the system, they were concerned about downstream of the valve.

CHAIRMAN KRESS: This thing wouldn't work if you put it in backwards?

MR. FREDERICK: That is correct. Yes, it was never intended to be pressurized on this side.

MEMBER SIEBER: Well, it wouldn't work anyway.

MR. FREDERICK: Depends on what you put in it.

MEMBER SIEBER: You would have a hard time bolting it up. There is no flange on the other end.

MR. FREDERICK: That is where it all started, that was the valve that we said, hey, we can take that valve and we can stay with that. So let's go to the next slide.

So then we took on the design activity, moved forward, and developed the valve that is before you. You can see there is a very large amount of similarity to the two inch valve.

MEMBER WALLIS: I presume you made it very high pressure you would have a problem, because you must not fail in tension, but it must fail in shear?

MR. FREDERICK: That is correct.

MEMBER WALLIS: And so you have been through all that, so there must be some sort of limit to this design if the pressure is too high in the system.

MR. FREDERICK: Well, if you got extremely high, you would have a real problem from the standpoint that the higher the pressure, and the bigger the diameter here, the thicker that section --

MEMBER WALLIS: That is right, and you have to be able to shear it off.

MR. FREDERICK: And then what happens is that you could, but the amount of booster charge up in here, and the size of the valve would be very large. So you just have to work into that.

I mean, you could get there if you really wanted to. I'm pretty confident we can open up anything we need to open. But this valve, as I pointed out earlier, is based upon the two inch, and you can see that you have a shear section, again, at this location.

You have a hinge pin, where this thing rotates over --

MEMBER WALLIS: So you shear it, but you don't first break the hinge?

MR. FREDERICK: No. There is a slot right here --

MEMBER WALLIS: It impacts on the bottom, then?

MR. FREDERICK: It impacts on the bottom, and then it just rotates over with this surface contacting that surface. And you are, again, full open.

A tension bolt was added up to the top, and you can see that we have a tension bolt here that you didn't see in the prior valve. And the reason for that is because when you go to the much thicker shear section here, we didn't want to rely on static pressure in order to drive the section open.

So we gave it a little dynamic impact, as a result of backing it up, and putting a control depth, or distance, between the bottom of the ramp, or piston, and the top of the part that you are trying to shear.

This valve, also, although it didn't have the bevels to prevent any flow lines, in particular case of the nuclear environments, we went to all-metal seals. So all the interfaces on all the assembly has metal type o-ring seals. So you don't have any rubber components on the entire design.

And just a little more information on it. The requirements at that time was that there was an external temperature that the valve had to be exposed to, an internal temperature that was in the pipe. And the goal was to keep the booster propellant below 280 degrees fahrenheit, which was the set limit for the program, and cooling fans were on the top as well.

And we went through the testing and met all the requirements, in that regard, as well. On the bottom, which I don't believe you need on the Westinghouse valve, but it was on the GE valve, ins an electro-mechanical switch.

And what that did is it told somebody in the control room that if the valve ever did fire, it would send a signal back into the control room.

Here is what it looks like in -- you can see up here the bolts are broken, but the sheared section actually rotates over center, and the contact to the valve body is down here.

The valve is designed to be refurbishable.

The requirement on the prior programs, within 24 hours you had to take apart the valve, remove all the parts that needed to be replaced, put the valve back together.

And so you can see, when you look at the valve, that part obviously has got to be replaced because you sheared out the section. The tension bolt was broken, and there is a few seals, and that type of thing, that go into the refurb process.

But GE actually did take the parts that were in Wiley, when we shipped them to Wiley, and actually did do a refurb, and it met the requirement of the 24 hour with no problem.

The key feature there is that you can fire the valve, you can do some surveillance testing, and whatever you need to, and you can save all the real high dollar product of parts that are associated with the valve.

MEMBER WALLIS: How thick is the shear, the ring of material that is sheared, how thick is it?

MR. FREDERICK: This is going from memory. I believe it is a quarter inch on the seven inch valve. And, of course, it would be scaled up because of the bigger diameter and slightly high pressure for the 10 inch in the AP1000 valve.

Now I will give you a little summary of some of the testing that was done on the previous program, on some of the things that we would go through in order to ensure that we can meet the basic requirements associated with any new program.

Of course you always have the examination of product because, obviously, you want to start with meeting your intent and your requirements. We did hydrostatic testing on the sheared out sections, as well as the valve housing.

Leakage testing was performed in the inlet pressurizer. We did the thermal exposure testing, which is one I mentioned earlier, where the inlet was at 550, surrounding air at 190, and the booster at the top of the valve had to be below 280, which it was.

MEMBER WALLIS: What is the nipple made out of?

MR. FREDERICK: In the prior program it was made out of 304L, because that was the material that was chosen at the time. For the AP1000 we have been discussing going to 316L, which is more compatible with what has been used by Westinghouse.

But if you look into the material properties, both are very, very close. I mean, 316L, 321, 304L are all common materials used in the aerospace business.

Other items, we had verification to make sure that everything was the way it was supposed to be. We did development testing. One valve was fired twice, another valve was fired once. And then the units were delivered to GE for additional testing, subsequent to pyronetics testing at that point.

If I'm going to fast, let me know, I know we have a real time constraint.

CHAIRMAN KRESS: You are doing good.

MR. FREDERICK: Some of the testing that is done, or performed, on initiators and boosters, what is called a closed bomb testing. And that is performed at temperature and in some, not all cases, it is performed with unders, and in some other cases perhaps overloaded boosters.

Now, closed bomb testing is where you actually put the booster with the initiators in it, and to a metal enclosure of a control volume, you put in a couple of pressure transducers, one on each side of the bomb. You fire the unit, and what you do is you establish what the pressure time curve is.

And that data is important because if you get out there, let's say three or four years, after we delivered the first batch of boosters and initiators, you can actually go back, pull those out, put them in a closed bomb, if you choose to do that, run a sample test, and verify you have had no degradation of performance as a result of pressure time data curves that are established during the upfront time to the program.

In addition, before we would ever ship any boosters, we would also run an in-house, what we call mod acceptance test, where we would pull some samples out of the batch and verify that those units, indeed, do meet the pressure time performance requirements.

Under lot sample testing, this is something that you don't normally have to do, most of the time. But you do do it occasionally. And generally you would do it, like if you had a nuclear program, or you are trying to verify that the material properties would go through what you needed them to, under a nuclear condition, or if you are trying to establish a new propellant.

CHAIRMAN KRESS: That first bullet just measures the increase in weight with time?

MR. FREDERICK: Yes.

CHAIRMAN KRESS: And that is a measure of either oxidizing, or picking up moisture?

MR. FREDERICK: Yes, that is right. Yes,

what you are doing here, by running it through this thermal test, and the scanning test, what you are really doing is just looking at this weight loss test.

In each of these cases what you are really doing is trying to establish, through that, is there anything unusual that is happening, that gives you an idea that you really don't want to use those materials.

And so there are guidelines, that you are looking toward, when you are running those tests, as far as acceptance criteria, so you know what you are going into, and what you are coming out with.

And then in this particular case some radiation testing was performed on the boosters, and on the position switch and cables. And those, you can see, is indicated there.

In addition boosters were subjected to accelerated thermal aging testing, 25 days at 360 fahrenheit would simulate a four year normal life. And the cable assemblies went through a similar type test program. And then a reliability testing is where a lot of boosters were manufactured.

And, as I recall, it was over 80. They went through a whole series of tests, they came back to us, we fired them all in closed bombs, and verified that performance was as it should have been.

CHAIRMAN KRESS: When you did the radiation testing, what sort of source did you use?

MR. FREDERICK: GE did that.

CHAIRMAN KRESS: GE?

MR. FREDERICK: Yes, we shipped them the product and they ran the testing.

MEMBER WALLIS: I presume they are way over designed. You actually had much more booster than you would need to shear off the average nipple, just to make sure that you shear off the more stubborn nipple, you have enough --

MR. FREDERICK: Well, that section is extremely controlled by dimensional requirements. And we always size valves to function properly with an 80 percent minimum charge.

And so we actually demonstrate that, by testing, that we do comply with that requirement.

CHAIRMAN KRESS: Is there a potential to have too much charge?

MR. FREDERICK: The only potential there would be that yes, you could have too much. And, again, what we would normally do is control it on the top end, which typically is 120 percent maximum.

Because, obviously, if you put way too

much, you would drive that thing right out of the bottom, and it wouldn't function quite right. So you have to control all those parameters pretty closely.

MEMBER FORD: Has anyone, on the sheared nipple, and before, in the closed state, there is a fairly small ligament. What is the tensile state on that ligament, under operating conditions?

MR. FREDERICK: That sounds like a simple question, but it isn't, because it depends on all the conditions that you have at the time, because you are designing that particular section, based upon your diameter, and your pressure.

MEMBER FORD: Right.

MR. FREDERICK: So, again, I'm going from memory. If you go back to the GE valve, it was designed more toward the stress at the yield level, than it was ultimately, because the material strength for 304L, the yield value was extremely low, compared to the ultimate.

So you design it down here, because you don't want it to yield, either. And so if the number would have been, say, 28000 as an example for yield, it would have been designed to meet that.

Whereas in a lot of the valves that we deal with, we are more concerned not at the yield level because the customer would say, here is approved pressure you have to put on it, here is an ultimate burst pressure.

In which case if I'm using titanium, the yield is 120, and the ultimate is 130 so, really, proof is a piece of cake, and the ultimate test is the one you are concerned about.

MEMBER FORD: But it is a question to the Westinghouse people. But I agree that 316L is a pretty good choice of material for the primary system. But you can crack 316 L, especially if it is cold worked in any way.

Has there been any materials design review taken that this is not going to crack during operational conditions?

MR. CORLETTI: Will you be here tomorrow?

MEMBER FORD: Why, is there a lot of questions we --

(Laughter.)

MR. CORLETTI: Can we save that question?

MEMBER FORD: Absolutely, of course.

MEMBER RANSOM: While we are on that, though, is that valve nipple satisfy all the ASME safety requirements for personnel to be around it, at operating pressure?

MR. SCHULZ: You can't have people around after --

MEMBER RANSOM: Well, presumably startup, things like that, you don't have any people there?

MEMBER RANSOM: But it is designed to ASME code, which --

MR. FREDERICK: Well, the valve is designed to ASME code, you know, it is a class 1 requirement. So there would be no reason why somebody wouldn't be around it. It is just like any other class 1.

MEMBER RANSOM: It has sufficient safety margin that you could be around that pressure.

MEMBER FORD: Is there any special machining considerations to that nipple region? I mean, are there any criteria put on you as to limiting the final machining operations?

MR. FREDERICK: The only thing I can say there is that we control the actual shear-out section. On the inside, obviously, it is a straight section. On the outside it is a curved section, and it is extremely tightly controlled, dimensional.

MEMBER FORD: Is it ground, or is it --

MR. FREDERICK: That is something that we haven't established on this particular program.

Because if I go back to this program with GE that was not an issue at the time. The issue there is verify the design concept.

So that is some of the things that we would have to work out with when on, exactly, the controls associated with that particular --

MEMBER WALLIS: The nipple is made from one piece, or is it a tube that is welded in?

MR. FREDERICK: This is one piece, right here, this entire section. So that is a machine made section.

MEMBER WALLIS: Machined from solid, or what?

MR. FREDERICK: Yes it was. It had to meet certain roundness associated with the program. I believe it was a hot forced --

MEMBER WALLIS: Just looking at that beautiful squared edge at the end of that -- to --

MR. FREDERICK: Yes, right here?

MEMBER WALLIS: Yes.

MR. FREDERICK: That is where the sheared out section is -- and this part here is attached from the other side in order to assemble, because you couldn't get it through otherwise.

MEMBER FORD: What about machine notched, you have a high strength concentrator, plus the environment?

MR. FREDERICK: That is correct.

MEMBER FORD: Plus a machined surface for which we don't have the specifications for the machining. I mean, you could have have put residual stress in at that point. It is a beautiful combination.

MR. FREDERICK: Yes, in designing valves, you are designing strength.

MEMBER FORD: Is that for operating in high temperature water?

MR. FREDERICK: That is exactly right.

MEMBER FORD: That is my concern. I'm not concerned about mechanical failure, I'm concerned about stress --

MR. FREDERICK: That is some of the details that I think we need to look at, as a separate issue.

CHAIRMAN KRESS: I just want to interject a comment relative to the cracking issues. One of the points is, and they may address some of this. But the other part was in Terry's presentation, you point out that we will be inspecting it, as part of the inspection process.

So if there is any indications I think, you know --analysis done as to what is causing it. So I think it is important to realize that it is not just sitting --

(Everyone speaks at the same time.)

MEMBER FORD: You might have enough damage occurring in the 18 month cycle --

MR. FREDERICK: You wouldn't want that.

MEMBER FORD: You wouldn't want that, correct.

CHAIRMAN KRESS: How does that -- the hinged part? Is it welded?

MR. FREDERICK: Not in that particular configuration it wasn't. It was threaded in with a straight machine from one side.

CHAIRMAN KRESS: You put the valve in first then put the pin?

MR. FREDERICK: Right.

MEMBER SIEBER: We probably know more about these valves than we ever wanted to.

MR. FREDERICK: And, lastly, we went through the vibration testing actuation and flow testing, that was done at Wiley.

Now getting into the AP1000 valve, just to give you a comparison between the seven inch and the new AP1000 valve. You can see, initially here, the ID is going from 7 to 9.24, and we discussed the material.

Safety and seismic class is the same, the design pressure is higher than previously, the temperature is slightly higher. And the external temperature is quite a bit less.

The radiation level for ten years as identified here, versus four year requirement that was on the prior valve. The inlet as previously mentioned, you are down to 1 psi operation. And the design life of boosters here is eight years as a target, and previously they were just shooting for a four year target.

MEMBER WALLIS: Go back to the materials, is there some requirement on the chemistry of the water that is in contact with this thing?

MR. CUMMINS: It is primary water chemistry --

MEMBER WALLIS: Does this valve have some specs that says it has to withstand an environment that sets the chemistry for this period of time?

MR. CORLETTI: Yes. But are you saying does the valve impose additional functional requirements?

MEMBER WALLIS: Another functional requirement here about the chemistry of the water, and the boron, and all that stuff.

CHAIRMAN KRESS: That goes into the initial selection of materials.

MR. SCHULZ: This is obviously a small subset of the requirements, many other things that we have specified already.

MEMBER WALLIS: Have these things ever been in a reactor environment before? Survived for a long period of time?

MR. CUMMINS: I think GE uses squib valves, Westinghouse doesn't.

MEMBER WALLIS: Actually in there, so they have been in there for a while?

MR. CUMMINS: In their plants. I believe they are small ones, three inch or less.

MR. FREDERICK: Moving on to the AP1000 design. I mean, obviously it is going to be a scaled up design from the original. Analysis design report for the --

MEMBER WALLIS: You no doubt have all the pipe groups, have you?

(Laughter.)

MEMBER SIEBER: -- question about your

hydrostatic test. If I look at the way the valve is built, the shear section is part of the pressure boundary. And so when you do a hydrotest, if you test it to failure, the place that it will fail will be the shear section.

And have you done that, and how much overpressure can this valve take before you get a failure in the shear section?

MR. FREDERICK: We didn't take it to destruction.

MEMBER SIEBER: How far have you got?

MR. FREDERICK: That I don't know off hand.

MEMBER SIEBER: -- which is one and a half, I guess. And not actually prove too much. I guess it is satisfactory, but I was just curious about what kind of margin you have to avoid a failure of the shear section without the actuator working.

Because, you know, if that valve operates your plant is in trouble, I think.

MR. FREDERICK: Well, we did some hydrostatic testing at whatever the margin was over and above the --

MEMBER SIEBER: Do you test -- you test to code, then, right?

MR. FREDERICK: -- to code, yes. ADS 4 development prototype -- in charge sizing, and hydrostatic, and leap testing, and vibration, and of course actuation with over and under loaded that would be required.

Getting into reliability, some of the things that we look at, this is just sort of a heading, and I will discuss it here shortly. High reliability requirements, I mean, most of the aerospace industry, for many, many years, including missile, satellites, and everything else, used pyrovalves because they are highly reliable devices.

Failure modes and specs analysis is a standard process that you go through. Ignore that, that was originally a preliminary sample provided to Westinghouse for their review, but it is not in your packet, so if you look for it, it won't be there.

So I don't want you to think you are going to find something that maybe isn't there. Look at the design shear section a little more, reliability of squib valves, and then we will get into replacement of charges at the end.

First of all, what our customers require is basically higher reliability. We are working on life support programs, aerospace programs. And the consequences of failures are high. I mean, it is not always dollars, so to speak, but it is also people.

Because a lot of the devices we build are used for life support, and life saving type features. Our procedures control higher reliability. And, as mentioned earlier, we are certified in every way we should be, to meet our standards.

Custom valve designs and upscaling is a standard process. The simple valve design reduces problems. I think the key thing there is, like anything else, the fewer parts you have of anything the better off you are.

And if you go back and compare a squib valve with anything else that you might use as a substitute, you will find that you have a lot less parts to deal with and, therefore, that reduces your potential for problems.

The development process that we have been going through, for many years, is to deliver highly reliable valves, and then it has been proven with what we've shipped.

Some of the things that we go through, as far as how to build in high reliability, we look at past experience, lessons learned. We performed design analysis, I call it design analysis here because generally in prior valve, it was a design analysis report, a lot of customers would call up, like stress analysis report where you are doing the same type of thing.

Examination and analysis of the drawings in the FMEA, and reliability analysis, obviously, is required. Under testing --

MEMBER WALLIS: Do you do the --

MR. FREDERICK: We do. We have an AFSCRAM program that we have some people that --

Under testing, we get involved with development and prototype units. Margin testing, as I've mentioned over and under loads. Obviously we have to do acceptance and qualification tests.

Acceptance being something you would do on everything you build, and then qualification testing is generally samples that you pull out of that acceptable batch.

MEMBER WALLIS: To get back to my question, I would think you would have to control that sharp corner pretty carefully, the way you machine that little sharp corner.

MR. FREDERICK: That shear out section is really not a corner, as such, it is a radius.

MEMBER WALLIS: It must be a radius.

MR. FREDERICK: But it is a radius, it is very well --

MEMBER WALLIS: And you specify that very clearly?

MR. FREDERICK: Yes. Under design for shear out section, the shear section is a standard pyrovalve design feature. Again, it has been in valves as long as I have worked on valves.

So it even dates back, even some of the valve designs that I incorporated in 1980, date back to the late '60s, that were designed for Lockheed Martin and some of the early space programs.

The concept has been proven many times, thousands of times with valves. To my knowledge there is no leakage ever reported on a delivered product, through the sheared out section, or the shear section. And I have designed valves as small as three-thousandths of an inch, in some applications for pyrovalves.

The concept proposed for the AP1000 is really the same as the AP600, and the SBWR, same design there, as far as the design concept. And the designs, the basic design proposed would meet the ASME codes, as identified.

And there would be a design by analysis

for NB3200.

CHAIRMAN KRESS: What is the propellant? Is it proprietary?

MR. FREDERICK: Technically it is. It does show up in the Department of Transportation, I believe, or the Department of Energy report someplace along the line. But it was intended to be a proprietary item.

So even though you know the name it is not a big deal, because you still have to know how to put it together to get there. So I won't bring that out here, so it is originally considered to be a proprietary item.

Getting into corrosion affects, we have discussed this somewhat and I think we all agree that there is more work to be done in that area, as far as corroding effects, and any effects of 316L and the intended application.

And in-service inspection, obviously, is something that we have discussed, and obviously there has to be something in place to cover that.

Under reliability summary I have it listed here, and I have to give you a few specifics on what the numbers mean, otherwise they won't mean what you think they mean.

Under UPCO reliability, again, I gave you the track record of what UPCO means relatively to what we are doing today. But they have manufactured more than 64,000 valves, fired 5,300, and the reliability numbers are stable.

Under Conax reliability, what I did, was accumulated a bunch of numbers. Conax had not kept records from the beginning of time on valves. So what I had to do is try to accumulate as much information as I could.

And there is at least greater than 25,000 initiators that have been put out in the field, which went with basic valves at the same time, to no reported failures coming back associated with the valve itself.

Sandia reliability numbers, I've included those in there, that is input information that was given to me by Westinghouse, and I just inputted that for information purposes, and it is the intent of Westinghouse to get more details into some of the Sandia information, which will be forthcoming after my presentation.

CHAIRMAN KRESS: Is that based on the same 25,000 and no failures? It is just a different statistical analysis?

MR. SCHULZ: We don't know. Sandia has a data base, the manufacturers have a data base, there is some overlap.

MR. FREDERICK: This is what I was given probably, I don't know, maybe a month or two ago, prior to all the new information that was just received from Sandia, to support this meeting.

MEMBER FORD: I think, since it is on the record, I should just mention, you can crack 316L in PWR primary water, dependent on what the stress is, what the surface condition is.

And as you correctly pointed out, more work needs to be done.

MR. FREDERICK: Finally here, squib valves have high inherent reliability. I think that is safe to say based upon the thousands of units that are out in the field.

Reliability for smaller valves is applicable for larger valves. And, again, some more discussion will follow my presentation in that regard. The same design standards that are basically established for programs, you have engineering analysis, various test requirements, we've got those identified.

And design concepts, similar shearing

material in all cases. It is a standard squib valve design characteristic that you want to have.

And, lastly, again to my knowledge, no failures associated with shear section cracking under constant high pressure and temperature. To qualify that, in the applications that we worked in, obviously.

CHAIRMAN KRESS: Thank you very much.

MR. FREDERICK: That is it for me.

MEMBER LEITCH: I have a question. Reliability data is based on the thousands that are commonly manufactured, and I take it that is normally about two inches, or do you have considerable experience with anything larger than that?

MR. FREDERICK: Two inches is generally about the largest that we have made. I may be able to backtrack in Conax, and they may have one that is two and a half or something.

But, again, it is different, it is a little bit different, but it is the same type of thing where you are shearing off --

MEMBER LEITCH: The seven inch valve you referred to is not in the --

MR. FREDERICK: No, I don't even include that --

MEMBER LEITCH: -- manufactured? Yes, okay.

MR. FREDERICK: Thank you.

(Telephone interruption.)

MR. SANCAKTAR: My name is Selim Sancaktar, I'm in the reliability and risk assessment group at Westinghouse.

I wanted to summarize, for you, a few thoughts and facts. I can keep it as short as you want, you can catch up if you want.

But we previously discussed with, at least, the PRA, what we did with AP1000. And summarize it on some of my slides. Afterwards basically -- I will give you first the high level summary.

We sought, by function, and all of that information came from Conax. The other part of the information, we went to Sandia Laboratories, and we commissioned them to review what we are doing, and what they are doing in the squib valve area, and tell us what they think of what we are doing.

They contact the clients --

(Laughter.)

MR. SANCAKTAR: But I don't know what they talk about. Sandia sent us a report, unfortunately it arrived two days ago. So I'm not going to present that, can't give it a fair representation. They also sent us a presentation slides, which you have in your hand, right?

CHAIRMAN KRESS: When you say Sandia, do you have a name associated with that?

MR. FREDERICK: Yes, it was Ruby Latham was the name of the person. They wanted to make sure that it was independent from the NRC contracts that they had.

MR. SANCAKTAR: So all of these slides, the things I noticed are, first of all, unfortunately there are no slide numbers here, but towards the end, there are two tables like this. And included at the bottom there is a failure risk assessment of two minus four, which is equal or lower than their previous estimates, which we used for AP1000.

In fact, in their report, they use these numbers to estimate the failure probability we used for AP1000, and it goes down a little bit. So the point is, if you look at it numerically, things are as good as before, or better, according to Sandia's information available to Sandia.

Before you asked whether their 25,000 valves is the same as Conax 25,000 valves. I don't think there are many manufacturers, so I'm sure there are only so many valves around.

Sandia did a subset that includes Conax', and UPCO's, and so on, so it is all the same information --

MR. FREDERICK: Sandia, over the years, have been directly involved with their own type of analysis that -- so how it all ties together, I don't know. But I don't believe the numbers I put out are totally different.

MR. SANCAKTAR: So the bottom line of the Sandia report is, what they said before, and we used, is still valid, or even better. Moreover, they looked at the concern about the structural, possible structural failures, and upscaling failures.

And, again, their conclusions, they didn't find anything new. They don't think there is a problem in upscaling, or with respect to the operating temperatures and pressures, which coincide with what Conax also said.

So the bottom line is, we still believe that AP1000 calculations are reasonable and the conclusions based on the AP1000 PRA about the risk, contribution to plant risk of these valves is still valid.

And my personal opinion is that I feel more comfortable, I think, with this slightly better. But not enough information exists to make a big deal out of it.

MEMBER FORD: Except that none of these tests that they evaluated have been conducted where high temperature water has been one side of the seal, is that correct?

MR. SANCAKTAR: Well, obviously a lot of testing has been done under various conditions, but not to the temperatures that we are talking here. I mean, when we build valves with pyro pressures than 24, 2,500, we have a valve with 10,000 psi operating.

MEMBER FORD: These are the reliability of the valves in the highest produced condition, not in after-service? Do you understand the difference? After-service. So my question still stands, then.

None of these data points relate to after-service in high temperature water.

MR. SCHULZ: The boiling water reactor or the --

(Everyone speaks at the same time.)

MR. SCHULZ: -- concern of failure to open after service?

MEMBER FORD: No, I'm really concerned

about premature opening. Okay, I didn't understand the --

MR. SCHULZ: These are addressing the issue of reliability to open on demand.

MEMBER FORD: Got you, okay.

MR. SANCAKTAR: But they also tell us something about other failures, lesser failures of that nature, that they didn't show themselves yet. So we are not certain about (unintelligible) ten minus four.

But there aren't any best crossed line beyond what has been reported. So we know they are ten to minus two or three. So we know the level, the threshold that are established with other failures. But how much we know, we don't know.

They may be equal to, or it might be (unintelligible). That it is ten minus twelve, or anything like that.

So, now, the best, I think go through the presentation, or I can let you ask questions. I will give you a choice, whatever you like.

MR. SCHULZ: You could skip to the premature opening, the structural valve --

(Everyone speaks at the same time.)

MR. SANCAKTAR: I just addressed, the last two minutes the --

MR. SCHULZ: Right.

MR. SANCAKTAR: It is telling us that the structural failure aspect that cannot be purely addressed. We have addressed it with situations in generalized operational proportion, and design proportions, and (inaudible).

And then you also -- lack of evidence says that it is at the level of whatever evidence they give us for a lot of failure model (inaudible) report.

But just for the sake of getting a feeling for it, if you say that these valves are as reliable as a piece of pipe, as a segment of pipe (unintelligible) of a ten foot piece.

So if you say that this is like a segment of pipe, each valve, and you only have definitions of failures, and so on, you follow the same process for these valves. We will end up with, four the four valves, for the year, six times minus six previous failure, from just some catastrophic structural failure.

This is about ten percent of what we have assigned now. So this might be -- so if you say, go back and say this is twice as bad as a pipe, so you get stresses. If you say it is ten times as bad as a pipe, you will get -- this number will be about six times to the sixth, which is, which will be equal to what we assigned to premature opening due to spurious signal.

So we have the same orders of magnitudes. And then we have other slide -- there, that is the one. And what would that mean? For example, if we double the failure to open (unintelligible) we see a 15 percent increase in the base PRA.

If you don't reach your opening we see an increase of about twelve percent. So if you (unintelligible) a factor of two, about the 25 percent increase, you must be estimated.

CHAIRMAN KRESS: Is this small, is this large, is the next question. I will leave it to you, it is not small, it is not large either.

MR. SANCAKTAR: I've seen people worrying about small percentages (unintelligible) to me is -- by a factor of two we are in the same, we agree.

CHAIRMAN KRESS: About 10 to the minus 6? Ten to minus 7, that is pretty small.

MEMBER FORD: Would you mind going back to slide 32? It should be ten -- eight times (unintelligible) for R?

MR. SANCAKTAR: Yes.

MEMBER FORD: And the first bullet, and I'm trying to -- I read the phrase, squib valve considers some of the pipe segments. What are the assumptions in that?

MR. SANCAKTAR: If they were, let's say it this way, if they were, assumed to be as (inaudible) that is what I would tell them, with the same assumptions of other numbers in the same PRA, just to get some sort of a point to refer to.

I'm not saying they are, I'm not saying they are not. But once you get this number, then I can move up and down and say, well, they are not -- obviously I cannot say they are more reliable than a piece of pipe.

CHAIRMAN KRESS: But you are saying even if it is ten times less reliable it doesn't matter?

MEMBER WALLIS: Clearly it is not a pipe.

MR. SANCAKTAR: So I have to relate it to something that is existing in the PRA, but the number for it, and try to get some numerical thing out of it, other than there is no other intention. Does that answer your question?

MEMBER FORD: Yes, I just read the statement, and my natural thought was to challenge it. I'm not really sure why I'm challenging it.

(Laughter.)

CHAIRMAN KRESS: That is always his natural thought.

(Everyone speaks at the same time.)

MEMBER FORD: I can understand your reasoning, and I can understand Tom's reasoning and say, even if you increase it by a factor of ten, but what about a factor 1,000? Because of stress concentrators, whatever.

MR. SANCAKTAR: Yes.

MEMBER FORD: And I hadn't thought it through.

MR. SANCAKTAR: I mean, if it is a thousand times worse, it is worse, then we would be in a domain where we would start seeing failures in other places.

So the conclusions basically are that we don't have any new information that considerably differs from what had calculated, because we had calculated slightly (unintelligible) failing to open, valves prematurely opening, it is a good as estimate, as best estimate as you can come up with without too much (unintelligible).

CHAIRMAN KRESS: These 25,000 valves are part of the data base, are they two inch valves?

MR. SANCAKTAR: Yes.

CHAIRMAN KRESS: So they are small compared to --

MR. SANCAKTAR: Yes. And for me the important things that gave me confidence were that both parties are mentioned, said that upscaling was not a problem, and then they didn't see (unintelligible) in this particular case, a subject that would really make a big difference.

CHAIRMAN KRESS: So by both parties you mean Conax and Sandia?

MR. SANCAKTAR: And Sandia, right. So we think that the conclusions of the, for the AP1000 PRA with respect to (unintelligible) failure of squib valves are still valid, it is reasonable.

Just as a side point, if there is a spurious opening, MOVs are three, can be (unintelligible), and we don't want to be in that situation.

MEMBER WALLIS: They can close on the full flow? They have to close on the full flow?

MR. SCHULZ: They are not designed to do that, no. So I'm not sure (unintelligible). And squib valve opening.

MEMBER WALLIS: So they wouldn't shut it

in time to do any good?

MR. SCHULZ: It probably would get you into a --

MEMBER WALLIS: -- stay open, because once you are into that LOCA you want to stay --

MR. SCHULZ: It is a large break LOCA for us.

MR. SCHULZ: Eventually you can close one or --

(Everyone speaks at the same time.)

MEMBER WALLIS: Well, it seems a bit -- let's see, fragile, the reasoning. Fragile reasoning. This thing is not a pipe, it is more like a disk, or something. There is no reason that experience with pipes has anything to do with the experience with squib valves.

MR. SANCAKTAR: And we do use it. I mean, we know the AP1000 --

MEMBER WALLIS: You don't use it anyway?

MR. SANCAKTAR: Anyway.

MEMBER WALLIS: So let's forget it.

MR. SANCAKTAR: I just want to give you a feeling about the numbers --

MEMBER WALLIS: -- is what you would get?

MR. SANCAKTAR: Yes, just to give you

(unintelligible). Just to give you a feeling, but I don't have a number to give you. So (unintelligible) on the table --

CHAIRMAN KRESS: But basically the reliability numbers come from 25,000 two inch squib valves, out there, in operation, none of which have failed, gives you a reliability for that, and expectation that scale-up wouldn't change that, nor the operational conditions would change that.

So that is the --

(Everyone speaks at the same time.)

MEMBER WALLIS: -- but the opening unexpectedly is different.

CHAIRMAN KRESS: Yes, it is a different thing too, yes.

MR. CORLETTI: We have addressed at least part of it in regards to the (unintelligible).

MEMBER WALLIS: Let the PRA people argue about it.

MR. CUMMINS: I just want to be able to explain this to Steve --

(Everyone speaks at the same time.)

CHAIRMAN KRESS: Are we ready for a break, then? We will take a 15 minute break, and be back by 20 after.

(Whereupon, the above-entitled matter went off the record at 3:05 p.m. and went back on the record at 3:20 p.m.)

CHAIRMAN KRESS: I guess we are ready to start again, and now we will talk about aerosols in the containment? I guess this was, primarily, a question that came from Dana Powers, where he was a bit astounded that the size of the lambda they used, to remove aerosols from containment, and in particular I think he was questioning the diffusio-thermophoresis part of it.

Partly because it wasn't clear to him that the rate of steam condensation on the walls was always there at the same time the aerosols were. But, anyway, I just thought I would throw that perspective out, as to where the concern came from. So with that I will turn it over to Dr. Li.

MR. LI: Good afternoon. My name is Jun Li, an associate at Polestar Applied Technology. Today I'm going to talk about the calculation, the QA calculation of post-LOCA containment aerosols deposition for AP1000.

As an introduction, I would like to mention a few things first. First of all, Polestar has performed a QA calculation for the containment aerosol deposition which also is referred to as a containment Lambda.

Several years ago for AP600, as a part of AP600 design certification in that calculation the lambda for the best estimated scenario to consider, at the same time an extensive study of the sensitivity of the radial parameter that will affect the containment lambda has also been performed.

So we will talk about that later. And similar to AP600, as we all know, that AP1000 containment has a very large steel shell that is cooled from outside. So that we will expect very much higher heat transfer rate as compared to AP600 operating framework, where the walls (unintelligible).

As a result of that, we would expect a much higher natural aerosol removal than what would exist in -- from the sedimentation alone.

MEMBER WALLIS: That depends on the ratio, it is not obvious that condensation is going to drag aerosols to the wall, which I suppose is what you are talking about, faster than sedimentation, until you look at the relative rates of the --

MR. LI: Yes, that is true. But for everything given the same, for example, the same amount of aerosol, the same volume, and so on and so forth, if you only have sedimentation, you don't have a condensation, then the lambda is going to be smaller than the case where you have both.

MEMBER WALLIS: You don't know about how much?

MR. LI: Yes, we don't know about how much. That is the purpose of this calculation.

CHAIRMAN KRESS: But the containment effective height for AP1000 is bigger than AP600. So that reduces your sedimentation level?

MR. LI: Yes, you can now say that without kind of assumption, for example, if you have same amount of aerosol --

CHAIRMAN KRESS: Yes, for the --

MR. LI: -- certainly your sedimentation is going to be smaller. But if you have, you increase the volume, but at the same time you increaSe more the amount of aerosol, the sedimentation lambda (unintelligible).

So it is not like a -- yes, in this case it just so happens the AP600, the AP1000 has a 75 percent more thermal energy, as well as 75 percent more aerosol -- I mean, diffusion -- therefore, you know, 75 percent higher, 75 percent more aerosol in the containment than AP600.

Now, for the volume only increase by 20 percent. Therefore --

CHAIRMAN KRESS: So you have the initial concentrations?

MR. LI: Initial -- yes, the concentration actually is higher, therefore the sedimentation lambda will be higher.

CHAIRMAN KRESS: Yes, they will cross over, you are right.

MR. LI: Yes. So we will talk about, because as I said, you know, the third point I want to make is that since the AP1000, and the AP600 have similar design, so this calculation is pretty much the repetition of AP600 calculation, except that we use AP1000 parameters, like a geometry surface, modeling, and the amount of aerosol that (unintelligible) to AP1000 design.

At the same time we use AP1000 thermal-hydraulics, because the AP1000 the thermal power is higher, so the thermal-hydraulic condition is going to be different.

But in terms of the sensitivity of containment lambda, we are going to rely on our sensitivity study done on the AP600, which we will discuss later, to asses the possible variation on the

AP1000.

CHAIRMAN KRESS: Westinghouse does this for the --

MR. LI: Yes.

CHAIRMAN KRESS: They use a code, they are using -- you use the containment code?

MR. LI: Yes, it is --

CHAIRMAN KRESS: For the aerosols.

MR. LI: For aerosol we use what is called STARNAUA, QA code, which is the one we use for the AP600 calculation.

CHAIRMAN KRESS: Which code was it to use? What is the name of the code, again?

MR. LI: The name of the code is STARNAUA.

CHAIRMAN KRESS: Is that one that you guys at Polestar developed?

MR. LI: Yes, that is right.

CHAIRMAN KRESS: I'm not familiar with it.

MR. LI: It is the one -- the last three pages summarize the --

CHAIRMAN KRESS: The model?

MR. LI: The STARNAUA -- originally from (unintelligible) which --

CHAIRMAN KRESS: Oh, it comes from the NAUA?

MR. LI: Yes.

CHAIRMAN KRESS: Okay, I'm sorry, I didn't understand.

MR. LI: Yes, it is -- then it becomes a, actually when I was at Stanford, but I took the NAUA code, because EPRI was the sponsor of my program. So we basically changed the NAUA code to include other kind of --

CHAIRMAN KRESS: Well, basically the aerosol models there are the same ones that are in containment?

MR. LI: Yes, exactly, exactly. It was just additional feature like -- in STARNAUA we start to consider a spray.

So now I would like to, also as a part of introduction, I would like to put the aerosol removal in some kind of perspective. Basically we -- what we have here is tightly sealed containment, which the design is 1.183 percent that was given by Westinghouse.

Then we have this, the larger containment, outside we have a water plume to cool the containment. And on the inside we also have a condensate plume running on the inside surface.

And as a result we have a pretty high heat transfer, which I think some early (unintelligible) talks to that. And then in the containment there will be steaming, turbulence situation, and we can kind of visualize that there is a pretty favorable environment for aerosol removal, as we will show, you know, in the calculation later.

Basically because of the (unintelligible), we are basically arguing that there is no way the aerosol can bypass those mechanisms to leak out directly, because they have to get to the surface. And the leakage, there is a leak (unintelligible), and it has to be at the surface.

So if you have a warning the aerosol stay there, then it cannot leak. So once there is a leak, then it gets to the surface and this (unintelligible) starts to take place.

Now, we are going to basically use the AP600 calculation that we have done previously, as a basis to explain what we did for AP1000. So this is the time that we want to show the comparison, and so we will know what we are looking for.

Now, compared to AP600, as I said earlier, the thermal power is at 75 percent higher. And, therefore, the amount of aerosol is 75 percent more. Volume is increased by 20 percent, which I was told that it just makes that taller, therefore the sedimentation area doesn't change.

So now we certainly know, with higher -- with higher thermal powers mean that higher decay heat, therefore there is higher total heat transfer out of the containment, and we expect a higher diffusiophoresis, and a higher thermal phoresis.

CHAIRMAN KRESS: At the same time?

MR. LI: No, not at the same time, because sometimes -- it is a competing process. But it is just that conceptually --

CHAIRMAN KRESS: Conceptually, if you have thermophoresis, if you have diffusional phoresis you don't have thermal phoresis, so if you don't have thermophoresis, you can have thermal phoresis?

MR. LI: Yes. I think that usually those mechanisms are -- the combined mechanism tends to be like one minus, you know, something and .1 minus, the other -- you know, it is not like -- it is a product, rather than --

MEMBER WALLIS: What is thermal phoresis?

MR. LI: Thermal phoresis is the particle movement driven by the temperature gradient.

MEMBER WALLIS: So how about the condensation, doesn't that drag particles to the --

CHAIRMAN KRESS: Absolutely, that is why diffusional phoresis --

MR. LI: Yes, that is called --

MEMBER WALLIS: That is actually dragging by flow?

CHAIRMAN KRESS: Yes, that is -- it is misnamed, it should be called step and flow --

MR. LI: Yes.

CHAIRMAN KRESS: It is misnamed.

MEMBER WALLIS: Diffusion takes place, anyway, and --

MR. LI: Exactly, which is the reason why it is not --

(Everyone speaks at the same time.)

MEMBER WALLIS: -- account of the condensation?

MR. LI: Yes, exactly.

MEMBER WALLIS: Another question, is this aerosol charged?

CHAIRMAN KRESS: That is always a question that is never answered. The feeling is with all the steam in there, that it sort of dilutes the charge.

MEMBER WALLIS: Does it?

CHAIRMAN KRESS: Well, the aerosols are hygroscopic, and they are sort of wet, and that tends to do something to neutralize the charge.

MEMBER WALLIS: Well, the charges on them, it doesn't come off, unless it leaks off somewhere?

CHAIRMAN KRESS: Well, they are venting all that water, it sort of neutralizes it.

MEMBER WALLIS: It doesn't neutralize it unless there is an equal and opposite charge of some sort, from somewhere. So there is probably a charged cloud in there, I don't know.

CHAIRMAN KRESS: Well, that has always been an unanswered question in the aerosol business, are these things charged, and do they affect anything if they are.

And that has never been answered.

MR. LI: So basically all of the three mechanisms increase the removal rate, rather than decrease it. Therefore we would expect higher containment level for AP1000 than for the AP600.

Now, how do we do the calculations? The procedure is like this. First of all, we would select an accident sequence for AP1000 based on relatively high probability. In this case we choose a (unintelligible) -- sequence out of that.

And also the sequence has a timing, in terms of aerosol release, that matches, are similar to

NRC Regulatory Guide 1.183, timing for PWR fission product release. So that is the criteria.

So we selected a sequence, and we used what is called MAAP4 computer code. Actually it is done by Jim in Westinghouse to simulate the accident to produce the thermal-hydraulic conditions.

And once we get the thermal-hydraulic condition, then we use that and input, and use the Polestar QA code, STARNAUA, which I talk a little bit about earlier, to calculate the natural aerosol removal under those conditions.

CHAIRMAN KRESS: Now, when you look at Reg Guide 100, it specifies a fission product fractional release, and has an option for the timing for that, and it specifies you use the large break LOCA sequence to get the pressure, and the thermal-hydraulics.

Is that what you did here?

MR. LI: Yes, we used the NRC Reg Guide 1.183. You use the release fraction, and the release timing for -- which is the (unintelligible) release of 25 percent.

CHAIRMAN KRESS: So this is a design basis space you are dealing with?

MR. LI: Yes, exactly. And a maximum release for 1.3 hours, then a release fraction like iodine 25 percent, cesium hydroxide 35 percent. So we use the fraction as the -- for our aerosol specification.

CHAIRMAN KRESS: Now, in the PRA space there is no need to do all this, the MAAP code calculates all that for you, right?

MR. LI: Yes.

CHAIRMAN KRESS: So this is strictly dealing in the design basis?

MR. LI: This is design basis.

MR. SCOBEL: I think the answer to your question is thermal-hydraulically we did not use the design basis LOCA environment, we used the severe accident environment. I think that was the question that you asked --

CHAIRMAN KRESS: Yes, that would --

MR. SCOBEL: -- pressure and the temperature --

CHAIRMAN KRESS: Yes, that was one of the parts of the question.

MR. SCOBEL: We didn't use the design basis LOCA, we used the severe accident. That is why we used the MAAP code to generate the environment.

CHAIRMAN KRESS: And I guess the question is, is that acceptable way to deal with design basis space, to you guys over there? I mean, it is a departure from -- it is almost a redefinition of large break LOCA.

MR. SCOBEL: But it is actually the same methodology that we used for AP600, to separate the lambda for AP600. And the reasons, actually, that we did that to relate what you were saying were Dr. Power's concerns, where he didn't think that there would be as much condensation at the time when you would have the aerosol, in a small basis LOCA, that is not true, you always have the condensation.

CHAIRMAN KRESS: Yes, it is all at the same time, isn't it, in design basis?

MR. SCOBEL: Well, we don't have these kind of aerosols generated in a design basis LOCA for the very reason that you have core cooling going on the entire time.

But in a severe accident, when you are melting the core, then you tend to not be producing so much steam because you --

CHAIRMAN KRESS: -- space.

MR. SCOBEL: Right. So you have a drop in the mole fraction of steam in the containment, and your condensation rate goes down, which you can actually see in the package of the thermal-hydraulic conditions.

CHAIRMAN KRESS: So, basically, you are actually picking an accident that probably is worse than the design basis space?

MR. SCOBEL: If we had used the design basis we would have gotten better lambdas, that is correct, exactly.

CHAIRMAN KRESS: Okay, thank you for that clarification.

MEMBER WALLIS: I would think that if you can predict the condensation rates you have a pretty good handle on the diffusiophoresis.

MR. LI: Sure, that is exactly --

MEMBER WALLIS: The particles are dragged by the steam, there is no mechanism for giving any relative velocity, or anything.

CHAIRMAN KRESS: That is right. If you have this condensation rate, you can pin down the diffusiophoresis. So that is the secret there, have you got the right condensation rate.

MEMBER WALLIS: Well, you know the rate at which you are boiling, and that is the rate you are condensing, pretty well. If you say state --

CHAIRMAN KRESS: Yes, pretty much, you are right.

MEMBER WALLIS: So just from the decay heat --

CHAIRMAN KRESS: But if the pressure is going to change, and there may be some --

(Everyone speaks at the same time.)

MEMBER WALLIS: Is this benchmarked by TMI, or anything like that?

CHAIRMAN KRESS: It has been benchmarked by large aerosol containment tests, but not TMI. There were no aerosols in TMI.

MEMBER WALLIS: Not at all?

CHAIRMAN KRESS: No.

MEMBER WALLIS: Wonderful, it didn't get that far.

CHAIRMAN KRESS: Had some noble gases.

MR. LI: So, as I said, we have -- so using the MAAP code, we can get into (unintelligible) for the containment vessel removal calculation. And, also, since we know that the removal process also depend on the aerosol characteristics, we sample (unintelligible) certainly the heavier, the larger particle, the faster they will settle.

And so in our calculation those are the assumptions we made.

CHAIRMAN KRESS: That is the log normal

distribution?

MR. LI: Yes, it is log normal distribution, because this is also the assumption we used for AP600. And there is log normal situation, the geometric mean really is .22 micron, sigma is 1.8, which produced a mass mean diameter of 1.3 micron.

And we could do this pretty much conservative, because even in the Sandia National Lab study, done by Dana Power, the mass mean diameter they used an extension of 1.5 microns to 5.5. So we used the smaller in the lower end.

The efficient power ratio is 1.5 to 1, and we basically neglected the hygroscopicity, because we know that there is a controversy about, you know, what kind of a chemical form this aerosol particle will be.

But if there were cesium iodide, we know those are soluble materials, but we neglected the hygrospicity. The packing fraction, we used .8.

CHAIRMAN KRESS: And that translates into dynamic shake factor?

MR. LI: Yes, that translates into -- because of, you know, there is a concern that the particle, even though they are the type they are --

CHAIRMAN KRESS: Basically is reduced to density by that much?

MR. LI: Yes, exactly, to reduce the density. Because we believe, you know, those aerosol will generate at very high temperature, which they are pretty much liquid and then, when -- you know, so that it should be close to one, but which was .8 at the best estimate, and we do a sensitivity study.

CHAIRMAN KRESS: What that does is reduces, actually, your lambda, doesn't it?

MR. LI: Yes, that is right.

CHAIRMAN KRESS: It makes it smaller?

MR. LI: Yes.

CHAIRMAN KRESS: What was your sensitivity study on that, too?

MR. LI: The release fraction and timing, as I said earlier, that we used an NRC Regulatory Guide 1.183 --

CHAIRMAN KRESS: Now, the question I have about that is, when did you start it, in the accident sequence, to MAAP?

MR. LI: We started at -- the (unintelligible) we take it is from Reg calculation, we start at the core uncovery, the MAAP started at core uncovery.

CHAIRMAN KRESS: You waited until core uncovery?

MR. LI: Yes, because what happened is that before that, if there is a lot of steam, a lot of condensation --

CHAIRMAN KRESS: Yes, that is when you get all that --

MR. LI: -- credit for that, because the core is not even uncovered. So all the time you see in a tape, the --

CHAIRMAN KRESS: And you say at the point of core uncovery, do you mean top of the active fuel, or bottom of the active fuel, or --

MR. SCOBEL: It would be top of active fuel.

CHAIRMAN KRESS: Top of active fuel.

MR. SCOBEL: -- mixture level to dryout.

MR. LI: Now, the removal mechanism I think is pretty much a standard -- basically (unintelligible) as I said, there is also a removal by spray, into the STARNAUA, but that wasn't used.

So the screen mechanism is a sedimentation diffusiophoresis, and thermophoresis. So we can see that the sedimentation is the one that is pretty much sensitive to the sides.

And if that is a spherical solid (unintelligible), then fine, the denominator is one.

(Everyone speaks at the same time.)

MR. LI: If the packing fraction is smaller than one, then the phi is going to be larger than one, that is going to affect the sedimentation.

Now, as we can see that the diffusiophoresis and the thermophoresis are not that sensitive to the particle side, especially the diffuser. Thermophoresis, there is some small dependency on the particle side, as you can see it, because the number is in there.

But other --

MEMBER WALLIS: Now, this has nothing about condensation?

MR. LI: Yes, the Q (unintelligible) is --

MEMBER WALLIS: Just like conduction. I don't see any HFG, or anything like that.

MR. LI: HFG?

MEMBER WALLIS: This doesn't come into it, the latent heat of the --

MR. LI: That will come into the --

(Everyone speaks at the same time.)

MEMBER WALLIS: Why? Doesn't that affect thermophoresis? Where is that in the thermophoresis? Or the diffusiophoresis? That is where it is, okay.

MR. LI: That doesn't come out --

MEMBER WALLIS: I'm sorry, now I understand.

MR. LI: Yes.

CHAIRMAN KRESS: The temperature gradient is carried forward --

(Everyone speaks at the same time.)

MR. LI: So basically what it says is acceptable sedimentation, the diffusiophoresis, and the thermophoresis are pretty much dependent on the decay heat.

So whatever amount of decay heat you have, as long as you want to let those heat out of the containment, that is going to drive particle. So what you make the lambda calculation, pretty much robust, because we all know that, you know, sooner or later it is the decay heat that basically -- and the removal process is directly related to that.

So there are some dependency on the pressure and temperature, because they will affect the coefficient. But the dependency on the temperature pressure is not as high as on directly the heat transfer rate, on the condensation line.

So this is the calculated result. The red curve is for AP1000, and the green curve is for --

CHAIRMAN KRESS: Now, do you have that

broken down by components for these three mechanisms?

MR. LI: Not for this curve, but in the next one, yes.

MEMBER WALLIS: I don't understand fraction per hour. And if you remove a faction of one it is all gone. So what are you talking about?

CHAIRMAN KRESS: It is a fraction of what is left.

MR. LI: Whatever fraction --

(Everyone speaks at the same time.)

CHAIRMAN KRESS: It is either the amount of --

(Everyone speaks at the same time.)

CHAIRMAN KRESS: It is like a decay --

MR. LI: If there is no source, only by removal, then the concentration is going to decrease, N is equal to N at a time certain, certain time --

(Everyone speaks at the same time.)

MR. LI: -- to the minus lambda T.

MEMBER WALLIS: But one is a pretty high number then, isn't it?

MR. LI: One is -- let me give you some -- I know you probably heard that LACE experience performed, and so they measured the concentration as function of time, in their -- for example, LACE (unintelligible).

And their measurement was that the lambda for insoluble particles, which is magnum oxide is around 1.3, 1.4. And the lambda for the soluble material, which is cesium hydroxide, is 1.8.

MEMBER WALLIS: But you have a lambda of 1 here, for AP1000.

MR. LI: Yes.

MEMBER WALLIS: Which means in four hours it is turned down to eight to the minus four, presumably?

MR. LI: Yes.

CHAIRMAN KRESS: That is about right.

MEMBER WALLIS: Something like that?

MR. LI: Again, in the LACE, as example, they call it half life -- 23 minutes everything cuts by half. So it is a -- yes, you are right.

MEMBER WALLIS: Well, this is like a very rapid removal rate.

CHAIRMAN KRESS: It is pretty rapid.

MR. LI: It is, it is. And, as I said, that is what --

MEMBER WALLIS: Most of it by the condensation?

CHAIRMAN KRESS: I think in general most

of it is sedimentation, but here it may be the condensation.

MR. LI: Yes. In LACE experience it is pretty much done by sedimentation because LACE is kind of a heat transfer, insoluble and soluble.

Now, if you want to see the contribution from different removal mechanisms, on the right hand side is AP600, and on the left side is AP1000. Now, for AP600, it just so happen that three mechanisms, basically they kind of contribute.

But for AP1000, because as I said earlier, in the presentation, because we have a 75 percent higher heat transfer rate, therefore basically during the competing process, the heat transfer rate basically removes most of the particles, which this is the result.

MEMBER WALLIS: So what is this Q double dash?

MR. LI: Q double dash is a sensible heat transfer.

MEMBER WALLIS: It can't be condensation, it must be just the sensible.

MR. LI: Yes, it is sensible, yes. It is basically driven by --

MEMBER WALLIS: I just wanted to be sure

you weren't using the total heat transfer.

MR. LI: No.

MEMBER WALLIS: I'm surprised it is so big.

MR. LI: It is. But if the sensible heat transfer drops, then the condensation has to come out, because they have to, the decay heat has to get out. So --

MR. SCOBEL: I believe one of the things that you are seeing here is that because you do have, for a period of high aerosol concentration, you have a drier containment due to --

(Everyone speaks at the same time.)

MR. SCOBEL: -- the sensible heat transfer go up.

CHAIRMAN KRESS: And I can see why the sedimentation may be a little lower, because it is pretty high effective containment, and that is --

MR. LI: Actually because we are assuming it is well mixed, so --

(Everyone speaks at the same time.)

MR. LI: -- doesn't play much role.

CHAIRMAN KRESS: Yes, it does, it is directing the lambda. Even though you are well mixed, you still get H -- you still have to follow that height?

MR. LI: Yes, that is right. In fact, the assumption is actually making it worse, because --

CHAIRMAN KRESS: And it would come out faster.

MR. LI: Yes, because basically, you know, part of the basis is we move downward. So we are assuming well mixed, so basically it put them up again. Every time, you know, they move down a little bit, and --

CHAIRMAN KRESS: That is why the height enters into it?

MR. LI: Yes, that is right, yes. But as I said, because there are more -- if you see the equation, in the end it is (unintelligible) in the containment.

CHAIRMAN KRESS: Well, what enters into the exponential is the ratio of the volume to the area.

MR. LI: Yes, that is right.

CHAIRMAN KRESS: And you call that height?

MR. LI: Yes.

(Everyone speaks at the same time.)

MEMBER WALLIS: It seems to me it doesn't make any difference. Well, I guess you are superimposing the mixing on the surface sedimentation?

CHAIRMAN KRESS: Yes.

MEMBER WALLIS: It is not as well mixed as the drift relative to the sedimentation.

MR. LI: Yes.

MEMBER WALLIS: -- also there is a drift going on.

MR. LI: Yes, if there is not, one reason is -- pretty much more concentrated --

MEMBER WALLIS: -- do it all mixed up so much there is only a little air near the bottom, which is kind of stagnant, where you get sedimentation at all.

MR. LI: But actually what happened is one mix, then you have a removal rate down there, so it is just the velocity times the temperature -- the --

MEMBER WALLIS: Superimposed, yes.

MR. LI: Yes. So if this get removed, so you have a, you know, an air that has no particle any more, but then the well mix is going to provide particle. So in that sense --

CHAIRMAN KRESS: It comes out because you are removing aerosols as particular velocity, on a particular area. But you are removing those out of the -- so it is volume over air, it looks like a height.

MR. LI: Yes.

CHAIRMAN KRESS: And that is where it shows up.

MEMBER WALLIS: Yes, so you have bigger area, you get more out of it.

CHAIRMAN KRESS: Yes. That is interesting.

MR. LI: So about sensitivity, as I said earlier, we didn't do a sensitivity study for AP1000, because we are going to borrow the result from AP600. So let's take a look at the sensitivity for the AP600.

MEMBER WALLIS: Sorry, isn't there some of alutriation, that the big particles come out first, and the tiny particles are left behind?

MR. LI: Yes.

MEMBER WALLIS: It is not just quite so simple.

CHAIRMAN KRESS: Yes, you get a lambda for each particle size. Now, what they are doing is getting an average lambda --

(Everyone speaks at the same time.)

MEMBER WALLIS: Check the average.

CHAIRMAN KRESS: What they get is find out total mass, and then back out the lambda from the total mass.

MR. LI: Yes, exactly. What we did is we divide the aerosol distribution into multiple bins.

MEMBER WALLIS: Okay, now it makes sense.

MR. LI: So each bin you calculate its own removal, and the total removal of lambda --

MEMBER WALLIS: The effects of lambda are averaged over these things, but the change in the weight, because you have different proportions in the bins as you --

MR. LI: Yes, that is right. But remember that the particle also agglomerate.

MEMBER WALLIS: Yes, I was going to ask you that, too.

MR. LI: Yes. And so the --

MEMBER SIEBER: Well, how do you treat that? How do you treat the agglomeration? Because then you are --

MEMBER WALLIS: It is a random process, where they --

MR. LI: It is not a random process, actually -- originally --

(Everyone speaks at the same time.)

MR. LI: The original German code, you know, distribution, by sedimentation, and pretty --

CHAIRMAN KRESS: There is some turbulence?

MR. LI: Yes, turbulence.

MEMBER WALLIS: What is the source of the turbulence?

CHAIRMAN KRESS: It is natural convection. And you have to characterize the turbulence level from the --

MR. LI: So for sensitivity study we changed the diffusion path to inner mass ratio from .5 to 3.

CHAIRMAN KRESS: Just out of curiosity, what did you use for a sedimentation area?

MR. LI: Sedimentation area?

CHAIRMAN KRESS: Yes. The cross section of the containment, or did you actually look at all horizontal surfaces? So you did do that, and looked at all horizontal surfaces?

MR. LI: Yes. That tends to --

MEMBER SIEBER: Did you consider angular flow?

CHAIRMAN KRESS: You can take the horizontal, the grid is in there, and there is equipment that had horizontal surface, you can gather all those up.

MEMBER WALLIS: Do you have convection

flowing down the walls --

MR. LI: Yes.

MEMBER WALLIS: I imagine a few feet a second. And as you concentrate particles in that boundary, they don't all go to the walls, some of them go down along the floor?

MEMBER SIEBER: Right.

MEMBER WALLIS: And then they are more likely to settle out as they are closer to the floor?

MEMBER SIEBER: Well, making the turn.

MEMBER WALLIS: Making the turn to the inertial separation.

(Everyone speaks at the same time.)

MR. LI: -- because of the void fraction. And the things blow out of the core, you know, that they --

CHAIRMAN KRESS: Probably coming out the ADS 4 valve?

MR. LI: Yes. So we thought that was a conservatism. And, also, even when they got to the past and we believed, you know, when it goes through the tortuous path, there should be some -- you know --

CHAIRMAN KRESS: Actually, this is design basis space, and they specify an aerosol source that they should use. And in picking that source the Staff rightly decided that there would be things like that, so they don't really use the full core inventory, they've reduced it quite a bit.

But they take into account this inertia stuff that they don't know how to calculate, and take account for things like that. So it is built into -- that kind of thing is actually built into the source that is specified.

MEMBER WALLIS: It must be very sensitive to the size of the particles.

CHAIRMAN KRESS: Yes, but that gets speared out real fast by the agglomeration process. I mean, you can put them in small, but they will change in a hurry. They don't get that big. Some of them are like 10 to 20 microns, they get pretty big.

MEMBER WALLIS: Unless you want to keep them out going around, scrubbing out more.

CHAIRMAN KRESS: Well, that has been proposed, that you artificially put aerosol --

MEMBER SIEBER: For a small break, though, the biggest hole you have in the system is the ADS 4, which is -- which is a chimney. So you are going to have a big circulation --

CHAIRMAN KRESS: You have plenty of natural convection.

MR. LI: The sensitivity result for AP600, because of the way -- we think that the NRC time for the diffusion path, but we also know that there will be inner material that will also be releasing the contaminant, not equal to a more inner material that would tend to make the concentration higher, so you have a higher agglomeration that you have to remove.

So the -- how many we will allow into the containment to calculate the lambda will have some effect. So in our -- as I said, we've assumed 1.5 in the ratio, but we did a sensitivity study by changing the -- I'm sorry (unintelligible) mass ratio from .5 to 3, and we see the change of 5 to 6 percent in total leakage.

Now, we didn't compare the lambda, because lambda is basically a function of time. But after the wall we are actually more interested in the leakage out of the containment. So the lambda can change in time, but this is like integral effect on --

MEMBER WALLIS: Where is it leaking from?

CHAIRMAN KRESS: That is unspecified.

MEMBER WALLIS: This is just design --

MR. LI: Yes, it is .1 and --

(Everyone speaks at the same time.)

CHAIRMAN KRESS: In design basis space you take this design basis leak rate, like .1, but you up the leak rate by the pressure that you get out of design basis LOCA. And I was just wondering if you guys actually did that, too.

MR. GRESHAM: The containment leak rate is design basis is based on operation, or based on conditions --

MEMBER SIEBER: It is the LOCA peak pressure.

MR. GRESHAM: It is at peak pressure containment, yes.

MEMBER SIEBER: And so it starts at that.1 and goes down, as containment depressurizes.

MR. GRESHAM: The NRC's guidance is assume the design basis for the first 24 hours. And then no further reduction.

MR. LI: Now, if you cut the sedimentation area in half, then you can increase the leak rate by 13 to 14 percent. And, remember, this is for AP600, where the sedimentation, it will only affect sedimentation.

Now, the sedimentation in AP600 calculation contribute about 30 percent. So if we cut this sedimentation area by half, the leakage increase by 13 to 14 percent, which means you cut the sedimentation in half, because 30 percent times .5 is around 14 percent.

So we know, for AP1000, it is going to be five percent, because it only contribute (unintelligible). Another thing we did is reducing the packing fraction from .8 to .1, which kind of exaggerate a little bit. Then it increases the liquid about 14 percent.

Again, sooner, because it only affect the -- pretty much only affect the sedimentation. So for AP1000 we expect to be five percent, too.

Now, in smaller value of RG, because already I said that, you know, we use RG and sigma, that is already at the lower end of the Sandia that has been looking, we reduced that further, we get the leakage increase by an order of five percent, which is small.

Then, again, if for AP1000, because it is also the fact that, again, only sedimentation, and it should be like two percent, three percent. So that is why we are saying that AP1000 lambda derivation should be lower than on the average.

Now, the conservatism that we think in this lambda calculation, on top of that we think, you know, by neglecting the hygroscopicity, our lambda is a conservative, because we know cesium hydroxide and cesium (unintelligible) are solid.

And we also neglected the inertial impaction on wet surface, and we will discuss that. And we also neglected the aerosol retention in the leak paths, when they leak out through the (unintelligible).

CHAIRMAN KRESS: That is not exactly neglected, because some correction to the source term is built into it. The actual specified source term has some recognition that there was some retention in the leak path.

MR. LI: You mean in the leak path?

CHAIRMAN KRESS: Yes. I'm sorry, you are talking about leaking out of the containment? I'm sorry.

MR. LI: Yes, in there they haven't considered the retention in the primary section. We only take what is coming out of the primary system into the containment.

CHAIRMAN KRESS: Okay, I'm sorry.

MR. LI: And our purpose are that we choose to use a small set (unintelligible) we use the MMD=1.3 micron, and the Sandia work assumes, you know, 1.5.

So the conclusion is that we saw that the lambda for AP1000 is 1.1 per hour. The result is robust because there is a combination of removal mechanisms, and we discussed this around the conservatism.

So again, that is the end of my presentation.

CHAIRMAN KRESS: There is no surprise to me there is the large contribution to thermophoresis. And I guess your explanation of that, the dry phase, and you still have to get the decay heat out, and do you have higher power than AP1000, does make sense.

MR. LI: Actually I have thermal-hydraulic data, it connects --

CHAIRMAN KRESS: It is strictly a matter of plugging in that thermophoresis equation to the thermal-hydraulics.

MEMBER WALLIS: Well, presumably you have radioactive material which is gaseous, which is not in the form of aerosols. Not just noble gases, but other things that have vapor pressure enough to evaporate --

CHAIRMAN KRESS: No, just the --

(Everyone speaks at the same time.)

MEMBER WALLIS: Only the noble gases. It seems to be because noble gases, you know, you sort of vent them anyway.

MR. GRESHAM: After 24 hours the noble gases are down to about one percent of their --

MEMBER WALLIS: Just because of the leakage?

CHAIRMAN KRESS: Yes, they are leaking.

MR. GRESHAM: No, because of decay.

(Everyone speaks at the same time.)

MR. GRESHAM: However, even when the small fraction of iodine seems to be in organic form, and thus gases are at 5 percent, there still is a formidable source.

CHAIRMAN KRESS: And the aerosols have settled out, and unless you control the PH of that water, the iodine can come back out. So it is not a question of can you open it just --

(Everyone speaks at the same time.)

CHAIRMAN KRESS: It could be, that element is organic.

MEMBER WALLIS: You want to solidify once it gets to --

CHAIRMAN KRESS: It would be nice to hold it there.

MR. SCOBEL: I have a presentation at this time, the analysis currently in the AP1000 is not based on this calculation of removal coefficients, it is based on the removal coefficients that were calculated for AP600. So there is --

CHAIRMAN KRESS: I see, you went ahead and used the same lambda?

MR. SCOBEL: We used the same lambda.

CHAIRMAN KRESS: So you are saying you would be in the conservative --

MR. SCOBEL: Well, I'm just saying, it is conservative. We have this information earlier --

CHAIRMAN KRESS: But you still meet the criteria?

MR. SCOBEL: Yes.

CHAIRMAN KRESS: So that is all you --

MR. SCOBEL: We have --

(Everyone speaks at the same time.)

MR. SCOBEL: I have a presentation on the thermal-hydraulics of what we use if you feel that you want to see that. It just discusses the sequence that we used, why, which I've already told you, and then have a presentation of the plot, and with a comparison to AP600, they look a little different, and there is some reason.

But if you want to see that I would be glad to present it. If you don't, we can move on.

CHAIRMAN KRESS: I think the consensus here is we would like to hear that.

MR. SCOBEL: Sure.

MR. GRESHAM: I think before Jim starts the presentation it would be worth -- it is worth pointing out that all the curves on here, that have a time of zero hours, that is zero hours is the time when you have uncovery of the active fuel. It is initiation of the accident.

MEMBER WALLIS: I was just looking at the handout from Polestar. We have this heat transfer rate, which has these mountains in it, peaks?

MR. GRESHAM: That is what Jim is going to talk about.

MEMBER WALLIS: So I'm always ahead of you.

(Everyone speaks at the same time.)

MR. SCOBEL: Like I said, we used the severe accident environment to generate the environments for the containment, because it addresses the dragging -- it reduces condensation and heat transfer.

And it is also the same methodology that we use for the AP600. We used the dominant core damage sequence from the risk assessment, because it is a double-ended break in the DVI line. The RCS is fully depressurized, and you fail gravity injection.

There is successful cavity flooding on the outside of the vessel to prevent the vessel from failing. And as a result you reflood back into the reactor vessel, through the break. And in the sequence we also produced a significant amount of hydrogen, and the hydrogen ignitors are turned off.

MEMBER RANSOM: -- the injection phase, just assumption, or --

MR. SCOBEL: This is what creates the severe accident, as opposed to a data base accident.

MEMBER WALLIS: Is there any mechanism that --

MR. SCOBEL: The mechanism is that it is the dominant sequence in the PRA, the failure --

(Everyone speaks at the same time.)

MR. SCOBEL: -- the squib valves, there is squib valves in that line, in that gravity injection line. And you have simultaneous failure of multiple squib valves.

And this is just a list of the T&H input parameters required for the NAUA code. The first one is containment temperature, and the spikes you see there, that is hydrogen burning at the igniters.

And as opposed to the AP600 case where, apparently, we did not have the igniters turn on. The next one is containment pressure. And this one is kind of interesting. There is -- you know, you can see this difference between AP600 and AP1000, and it is kind of -- you would expect AP1000 to be higher than AP600, and also you have this depression here, that is different than AP600.

And the reason for that is that AP1000 has a higher core power density. And what you see, then, in the results is that the core melt, at the time that you reflood the core, is a lot more severe, and the core is all kind of plugged up, and blocked up.

And so you end up cutting off your water ingression into the core debris, in the core, inside the vessel. And so in AP600, where you had a pressurization due to heat transfer from the core debris to the water, in AP1000 what you are seeing is you are not getting that heat transfer.

And so the pressure is coming down because the steaming is going down. So this is, actually, with respect to creating steam, is conservative. But now you have more superheat in the --

MEMBER WALLIS: This is a gauge pressure, isn't it?

MR. SCOBEL: This is the atmosphere.

MEMBER WALLIS: So it goes almost down to one atmosphere?

MR. SCOBEL: Yes. Because you are not getting much steam from the core region at that point. And you can see that in the steam low fraction going out here.

The other thing I wanted to mention about the pressure is that we also have an effect from hydrogen combustion, because you are taking the partial pressure of hydrogen, which you had almost 1,000 kilograms of hydrogen in the containment.

You are taking that out of the containment, and it is also taking oxygen out of the containment, so it had an effect on the containment pressure over all, during meltdown.

So, anyway, during this initial period of time with the aerosols, before four hours, you can see that there is a substantial decrease in the condensation rate, due to the fact that we are not getting the steaming.

CHAIRMAN KRESS: It is interesting, all these hydrogen burns helps you here. It gives you more condensation, it gives you more thermophoresis, and doesn't affect your sedimentation.

MEMBER WALLIS: It stirs things up.

MEMBER SIEBER: Why does it give you more condensation, just because of --

MR. SCOBEL: Say that again?

MEMBER SIEBER: Why does it give you more, the hydrogen burn, you get the water from the burn?

CHAIRMAN KRESS: You get steam, you get hydrogen, you get steam from the --

MEMBER SIEBER: The burn?

(Everyone speaks at the same time.)

MEMBER WALLIS: How much oxygen is there in there to burn all this hydrogen?

MEMBER SIEBER: It is a big containment.

MR. SCOBEL: There is enough to burn that amount of hydrogen.

MEMBER WALLIS: A thousand kilograms?

MR. SCOBEL: Sorry?

MEMBER WALLIS: A thousand kilograms sounds like a --

CHAIRMAN KRESS: They keep track of the oxygen content, and that is when they decide when this is going to burn, is when the hydrogen oxygen -- well, I think that the thousand is spread out over --

(Everyone speaks at the same time.)

CHAIRMAN KRESS: When you get up to 12

percent --

MR. SCOBEL: The hydrogen, also, it would be about 4 to 6 percent.

CHAIRMAN KRESS: Four to six, that is right, you are just burning, you are not exploding.

MR. SCOBEL: I've actually seen calculations where you have poor concrete interaction, and stuff going on, and you have containment heat removal that is really substantial, and you start to get negative pressures in the containment.

You actually have a continuous hydrogen source, over several hours, because the core is still -- you still have multi core -- even though it is flooded with water, the water is not getting into this core mass, kind of like TMI.

MEMBER WALLIS: And it suddenly gets in and you produce --

MR. SCOBEL: No, you are accumulating it in the containment as it is being produced.

(Everyone speaks at the same time.)

CHAIRMAN KRESS: Burns real fast.

MEMBER WALLIS: But it has to produce a certain concentration before you get ignition again?

MR. SCOBEL: Yes, you have to have the right combination of hydrogen and oxygen.

MEMBER WALLIS: It seems to me that you have just about enough oxygen --

MR. SCOBEL: The oxygen will come down, yes, significantly.

MEMBER WALLIS: What is the rough order of magnitude calculation?

MR. SCOBEL: I have actually seen calculations where you have poor concrete interaction, and stuff going on, and you have containment heat removal that is really substantial, and you start to get negative pressures in the containment for hydrogen.

MEMBER SIEBER: Right. Now, you are assuming this debris all stays in the vessel?

MR. SCOBEL: All the debris is in the vessel.

MEMBER SIEBER: And you don't have any core interaction?

MR. SCOBEL: And, in fact, you would expect -- the sequence is flooded both inside and outside the vessel, it is not just -- it is not the classic sequence that you are --

CHAIRMAN KRESS: You are right, it is not flooding in both places?

MR. SCOBEL: Yes, it is flooded inside and out.

CHAIRMAN KRESS: Yes, you are right.

MEMBER SIEBER: Well, again, the break is at the direct injection nozzle?

MR. SCOBEL: A direct injection line break, yes. And you end up flooding the compartment.

MEMBER SIEBER: Up to that, and then it goes into there.

MR. SCOBEL: The PXS compartment floods, and then you refilter through the break.

CHAIRMAN KRESS: Actually these hydrogen peaks in the heat transfer rate, probably have almost negligible effect on the thermophoresis -- sharp compared to the -- I would suspect you get more thermophoresis just from the averaging them out. The time they are there is so short.

MR. SCOBEL: Any way, thank you.

CHAIRMAN KRESS: Thank you.

MEMBER WALLIS: Thank you.

MR. ZAVISCA: I'm Mike Zavisca from ERI, and I hope to give you a brief overview of some of the general results of the severe accident analysis that we performed using MELCOR 1.85.

MR. ZAVISCA: We performed a number of severe accident analyses for a number of AP1000 core damage sequences, in order to support the NRC in formulating positions on a number of severe accident issues.

But if I were to list some of the main objectives we were after in these analyses, it would be -- first of all, we wanted to obtain some data to support our independent analysis of the IVR issue.

Second, we wanted to look at what the results would be of molten core concrete interaction, get a picture of what the containment conditions would be, relevant to the hydrogen combustion issue.

CHAIRMAN KRESS: Did Westinghouse specify the type of concrete they were going to use?

MR. ZAVISCA: We -- well, we performed sensitivity to a number of different types of concrete. And in addition, just to get a general idea of the timing of the accident progression, and a number of other general issues.

We selected a number of sequences for analysis, which we named according to the definition of ASME as used by Westinghouse. We had four base cases, and a number of sensitivities in addition.

Our 3BE scenario was a safety injection line break. And this is similar to the scenario that Jim just described. It is a scenario which is expected to lead to successful in-vessel recovery. So this scenario will be used -- we ran mainly to support the IBR analysis.

And we also had a number of sensitivities to this case, regarding things like efficiency of PCCS operation. Then there was a traditional large LOCA type sequence to 3BR, which is similar to one of the top sequences in the PRA.

I should say that in this table we analogized some of our sequences, to sequences that show up in the Westinghouse PRA, however, they are not identical in all respects.

First of all because some details of system availability in the PRA were, in some cases, not mentioned, or left ambiguous, we just did not have information on those, so we had to guess. Or, in some cases, we adjusted things deliberately in order to be able to look at aspects we wanted to examine.

An example of which is for the 3BE scenario, where Westinghouse allowed water ingress back into the vessel. We disallowed that because we wanted to obtain boundary conditions for no water ingress.

And we have a set of 3D scenarios, which are spurious opening of ADS valves. These are partially depressurized sequences which, therefore, would not be expected to lead to successful in-vessel recovery, so you have injection of debris to the containment.

And these are the scenarios we mainly used to analyze multi core concrete interventions in a number of sensitivities to this, with regards to things like concrete type, conditions in the cavity, etcetera.

So you have injection of debris to the containment. And these are the scenarios we used to analyze multi core concrete interventions in a number of sensitivities, with regard to things like concrete type conditions in the cavity, etcetera.

And then, lastly, high pressure transient, initiated by loss of heat water, designated sequence (inaudible).

Just a few brief words about the MELCOR model employed. We -- I guess the main point here is that we modeled all safety systems, documents, and the general level of the organization, of the RCS and containment, is basically equivalent to that, that was used in the MELCOR model used by Westinghouse.

And the information used in developing this model came from the various design documents. In some cases from parameters in the MELCOR model, and specific responses to RNX.

One thing that was not included was molten of the core barrel, during the core damage progression. And this has something to do with some boundary conditions for the lower plenum (inaudible).

We also did some things to enhance conductivity in the lower debris, in the debris in the lower plenum to model --

MEMBER WALLIS: -- the chemical reactions with the debris, from the shroud?

MR. ZAVISCA: That is right. So we are underestimating the amount of steel that is in danger as a result of that. This is one of the things we mentioned as future work, which could be done later.

CHAIRMAN KRESS: Can you explain that last slide justa little more. When we made that mixing of the -- does that mean the question is whether or not you have stratified steel, or metal over ceramic, or what do you mean by the mixing?

MR. ZAVISCA: This is really related to the fact that in the MELCOR model of the lower plenum, it has a number of radial rings, and basically mixing between those rings is only done in order to equalize the level.

There is no sort of advective mixing of the molten debris between rings. We wanted to model a little bit of the effect somehow equalizing the composition and decay heat content of the material between the rings of the lower --

CHAIRMAN KRESS: Is that to decide whether the --

MR. KHATIB-RAHBAR: Let me explain this. This is the molten core convection in a sense, because MELCOR does not model multiple convection. The idea was to get a mixing of the debris, because if you do not have the conductivity, you get debris side by side with very different --

CHAIRMAN KRESS: So this is to decide when it melts through the vessel?

MR. KHATIB-RAHBAR: Yes.

CHAIRMAN KRESS: That is what it is for, okay, now I understand.

MEMBER WALLIS: How do you know how much to enhance the conductivity?

MR. KHATIB-RAHBAR: Well, this actually does not affect the result, if you look at that separate IBR issues of this -- it does not affect any of the things that we do later. This was just done because we wanted to get somewhat of a realistic vessel wall temperatures, otherwise it would confuse temperatures far exceeding the vessel melting temperature.

This is not official (inaudible) and without this it would compute large temperature gradients within the neighboring parts of the lower plenum.

We just do it to get (unintelligible).

MEMBER WALLIS: In order to get a pretty uniform temperature?

MR. KHATIB-RAHBAR: Precisely.

MEMBER WALLIS: And this is realistic?

MR. KHATIB-RAHBAR: No. Well, realistic yes, from the standpoint of mixing in -- next presentation.

MEMBER WALLIS: In fact this may be the worse case scenario, is that right? What is the implication of having that restriction?

MR. ZAVISCA: The implication of that in MELCOR is that we have less -- the implication of -- in the MELCOR model is, of course, we have less steel in the melt. But as we will see later, that assumption was not carried over into the IVR analysis.

So we did not assume, in the IVR --

MEMBER WALLIS: But it is not necessarily conservative, steel reacts --

CHAIRMAN KRESS: It is not conservative with respect to -- it is not conservative with respect to the MCCI. So I think that is why they are telling us they didn't do it.

MR. BASU: But I think it is conservative with respect to the focusing effect.

CHAIRMAN KRESS: Yes, with respect to the focusing and melting through the vessel is conservative, so it depends on what you are interested in.

MEMBER RANSOM: We actually want to look at that, because that is -- this is not tested as part of the code, so we didn't want to do something --

MEMBER WALLIS: Does MELCOR use oloearian representation of these core materials? Oloerian?

MR. ZAVISCA: It is actually very simple, it is a point model, so it doesn't do any of that sophistication. It takes a particular mass, it heats it up. And you divide it up into nodes --

(Everyone speaks at the same time.)

MR. ZAVISCA: -- after the LOCA. It reaches the -- it goes down to the next one.

MR. KHATIB-RAHBAR: Exactly, to the next node.

MR. ZAVISCA: Automatically.

MEMBER RANSOM: So it is an olearian representation?

MR. ZAVISCA: Pseudo, yes. The next slide is a schematic to sort of give an idea of -- our first objective to obtain boundary conditions to the IVR analysis. I showed you some of the main results.

Actually I say here these are 3BE, but these were -- when in the MELCOR column these are results of low pressure best cases we performed in MELCOR.

And I show the comparison, the range of MELCOR MAAP4 results that we documented for the DBE IVR classes. And I don't want to say that we are -- we performed these -- we did not perform this analysis in order to perform an exclusive comparison with MAAP, we didn't intend to do that. But this is just for information purposes, we want to see how it compares.

So core progression between one and two hours, core plate fails at 2.6-3.7 hours, at which time the debris, you get the first relocation of debris to the lower plenum, that is 2.6-3.7 hours.

Later you get gross melting of the core plate, 3 to 4 hours. Dryout of all the water in the lower part of the RPV shortly thereafter.

MEMBER WALLIS: Does the core plate fail by melting, or by softening, or by stresses in breaking, or what?

MR. ZAVISCA: Well, in the MELCOR model it simply is assumed to fail to provide structural supports once it reaches a certain temperature.

MEMBER WALLIS: So it softens then?

MR. ZAVISCA: Yes.

MEMBER WALLIS: It becomes very weak, and it doesn't have to melt?

(Everyone speaks at the same time.)

MR. ZAVISCA: So at the time of the core plate failure, in MELCOR, we get 80 percent of the core, which is then in the form of debris, sitting on top of it, slumps down into the lower plenum.

And this mass contains about -- includes about 27 tons of steel, and 11 to 12 tons of unoxidized zirconium metal.

MEMBER WALLIS: About 100 tons, or something?

MR. ZAVISCA: This is -- I think there are about 100 tons.

MEMBER WALLIS: Something like that, a rough order --

MR. ZAVISCA: Some of the corresponding

figures I couldn't extract from the MAAP results. But, as I mentioned, we did not model core rationality here, so this figure is kind of low.

I think in the Rome analysis that was done by Westinghouse, they had between 50 and 70 tons. It is basically the lower support plate, and some small mass of structural steel inside the core.

The scenario is analyzed from the standpoint of multi core interactions, mainly partially depressurized spurious ADS sequences, which included a number of sensitivities to a concrete type. And conditions in the reactor cavity.

And I think I will skip ahead to this slide, because the overall penetrations, concrete penetrations distances we observed, and also a comparison with the Westinghouse results from MAAP4.

And this shows that the main difference between our results is we are predicting much lower penetration, much lower concrete penetration as compared with MAAP4.

MEMBER WALLIS: No source of groundwater, or anything like that?

MR. ZAVISCA: No.

MEMBER WALLIS: Just like a big difference, presumably.

MR. ZAVISCA: As far as I could tell the initial conditions, and the boundary conditions for these were identical between ours and the MAAP analysis.

CHAIRMAN KRESS: Now, MAAP tends to eat down and across, and MELCOR just goes down. Is that the end of --

(Everyone speaks at the same time.)

CHAIRMAN KRESS: Yes, but MAAP does it more, I think.

MR. BASU: That depends on the concrete diversity --

MEMBER WALLIS: So how far does it go in a year?

CHAIRMAN KRESS: It stops.

MEMBER WALLIS: Looks like quite a long way.

MR. KHATIB-RAHBAR: Yes, the model is not designed to calculating such a long time.

MEMBER WALLIS: I know.

MR. ZAVISCA: So basically within about 60 hours one meter penetration in MELCOR, about 2.5 maximum in MAAP4. We reiterated here that the graph was for limestone based concrete.

For the softest concrete we get, again,

significantly less penetration in MELCOR, as compared with MAAP4. Core concrete interactions debris between roughly 1 and 3 tons of hydrogen within 60 hours. Also large quantities of carbon monoxide and carbon dioxide.

The larger quantities of hydrogen results from the use of the basaltic concrete. And latest containment pressures in the presence of CCI between two and --

MEMBER WALLIS: Doesn't the concrete break into chunks and flow to the surface?

CHAIRMAN KRESS: No, it melts.

MEMBER WALLIS: It actually melts, it doesn't interact with the water in the concrete?

(Everyone speaks at the same time.)

CHAIRMAN KRESS: It goes up as gas. The water gets released and gets converted to CO and CO2, reacting with the --

MEMBER WALLIS: The thermal stresses don't just shatter the concrete?

CHAIRMAN KRESS: No. Basically it is melting. They did it at Sandia, it was pretty accurate.

MR. ZAVISCA: With regard to hydrogen deflagration, in most of these sequences we observed a general early behavior at the release, the initial release occurs to some part of the lower containment, IRWST, or the access compartment, or one of those confined compartments in the lower containment.

And so hydrogen initially develops at higher concentrations there, and burns there. Eventually it will migrate up to the -- the open part of the containment and possibly burn there.

So in the early phase we typically see lots of very small burns occurring in the --

MEMBER WALLIS: If each one is 10 percent H2, then you can calculate just how much oxygen you are removing with each burn.

MR. KHATIB-RAHBAR: That is how we did it.

CHAIRMAN KRESS: That is automatic.

MR. ZAVISCA: We did some calculations assuming -- but in the MELCOR it will still burn whenever it reaches a specified concentration within a particular compartment, 7 percent, or 10 percent.

In the scenarios that involve multiple core concrete interactions, we get vast quantities of hydrogen and carbon monoxide in the late time frame, so you observe one or more relatively large degradations in the late time frame, in the upper part of the containment.

Because sometimes some of the hydrogen results, across the different MELCOR calculations that we performed, you get between 44 and 65 percent equivalent core zirconium oxidized, which corresponds to around 420 to 650 kilograms.

And the MAAP4 results are similar, there are many more calculations that they performed, so there is a wider range. But averages --

MEMBER WALLIS: -- by water, steam?

MR. ZAVISCA: This is oxidation of the cladding during --

MEMBER WALLIS: Steam?

CHAIRMAN KRESS: Steam.

MR. ZAVISCA: Containment loads as a result of early combustion were never higher than three and half, that we observed. In the probabilistic AICC calculations that Westinghouse performed it was an upper bound of 4.3.

CHAIRMAN KRESS: Now, does that containment design 60 psi? I'm trying to remember.

MR. BASU: It is 59.

CHAIRMAN KRESS: So we didn't even get up to the design pressure, much less --

MR. ZAVISCA: That is correct. Now, in the late time frame, with all this additional gas release from MCCI, we sometimes calculate some relatively large deflagrations in the upper containment.

CHAIRMAN KRESS: Now, that is getting close to two times design pressure?

MR. ZAVISCA: Well, this is -- this limit here corresponds, approximately, to the service level C, which is about 1 percent condition of probability of containment failure.

But this is what we obtained. What determines this upper limit is the amount of available oxygen. Take all the oxygen in containment and burn it all at once in the late time frame, that is about what you get, that is the upper limit.

As far as the general timing of events, some of these have been mentioned before. One additional thing we did for the high pressure scenario was calculate a time to rupture of the steam generator tubes using integrated time to failure from -- with failure parameters.

And we determined that the tubes would fail around 7.4 hours, which is a little longer than was calculated, but a little later than was calculated by MAAP. But we reached the same conclusion, that for the high pressure sequences, and pre-rupture of the tubes is a likely outcome prior to vessel -- reactor vessel failure.

CHAIRMAN KRESS: Well, but that doesn't create a bypass, or does it?

MR. ZAVISCA: Yes. In the PRA I believe there are sequences of one hundred percent chance --

MEMBER WALLIS: What is in the secondary at that time when you bypass --

MR. ZAVISCA: It is dry.

MEMBER WALLIS: It is dry?

MR. ZAVISCA: Yes. And the late containment loads, except for brief loads caused by hydrogen combustion, they are generally below 2 bar, very low.

And what we obtained from this, first of all, what will deflagration does not challenge the containment in any case. Even the maximum theoretical possible burn only barely reaches the --

MEMBER WALLIS: You store up hydrogen and then you wait for it to go?

MR. ZAVISCA: PCCS is successful in preventing lower pressure containment, as determined by the low late quasi-static load can be calculated. And based on penetration, it is not predicted within 3 days, which is the longest calculation that we performed.

We predict, actually predict the steel liner will be reached within about 30 hours, I think, but full penetration (inaudible). And in general there are no surprises from accident timing or general results.

CHAIRMAN KRESS: This MCCI calculations assume dry --

MR. ZAVISCA: They are both dry and with wet --

MR. ESMAILI: Tom, if you know, in the MELCOR world it makes a little difference if it got wet or not?

CHAIRMAN KRESS: -- unless you do an aerosol calculation, but in effect -- so what we get from this is using MELCOR you get results that are not too different than MAAP, and that severe accidents that involve a multitude of reactor vessel, don't really challenge containment very much?

MR. ZAVISCA: That is correct.

CHAIRMAN KRESS: So this turns into some sort of a -- this kind of thing, when you look at all the accident sequences, converts into an initial containment failure probability that is pretty low?

MR. SCOBEL: It is .08.

CHAIRMAN KRESS: That is what I thought.

MR. ZAVISCA: The most challenging thing we ever observed was one of those late --

CHAIRMAN KRESS: This just is a confirmation that what they do with MAAP is probably pretty good, is that your message?

MR. ZAVISCA: I think in most cases, if anything, the MAAP results will be more conservative.

CHAIRMAN KRESS: Very good.

MR. ESMAILI: My name is Esmaili, I'm from ERI, and I will be talking about the in-vessel retention of core decay externally cooled by the cavity water, and the potential impact of excess of steam explosions or fuel coolant interactions through the vessel failure.

Now, the objectives of the study were two-fold. The first one was to examine the IVR issue in order to determine the likelihood and the location of vessel breach.

Following this IVR analysis we also found that it provided some insights into this type of a failure. The second objective was to formulate the FCI scenarios, and quantify the impulse loads on the cavity wall, and on the pressure vessel itself.

And the approach that we used in this for

AP600, AP1000, was basically the same as the approach that we used for AP600 over six years ago.

Now, the first step was to develop a one-dimensional mathematical model based on our ERI two dimensional model that we used for AP600, and we had to modify this in order to be able to compare our results with the DOE results that they did for AP600, and the INEEL results.

Basically we are looking at two configurations. The first configuration that you see here is a molten pulse surrounded by a crust, a solidified crust, in an overlying molten-like metal layer on top of it.

Now, this was the base model that we used in AP600 and DOE used for AP600 also. Now, the second configuration is a little bit more challenging. This involves a molten ceramic pool that is sandwiched between heavy metal layer at the bottom, right here, and a light molten metal layer on the top of it.

CHAIRMAN KRESS: Now, in Dr. Powers' -- this was strictly a thermal analysis, or did you have metal interactions with --

MR. ESMAILI: This was strictly a thermal analysis. I'm going to mention later on --

MEMBER WALLIS: In reality the steel

interacts with the ceramic, doesn't it?

CHAIRMAN KRESS: Not much.

MEMBER WALLIS: Isn't there a thermal reaction with the --

MR. ESMAILI: That is true. The uranium dissolved in oxidized zirconium, it makes it heavier, it sinks to the bottom. But you are looking at a quasi-steady process by the time that the relocation has occurred and, you know, there is heat transfer to the vessel wall, and the cavity wall.

So we are looking at it strictly from a thermal point of view.

CHAIRMAN KRESS: Now, the outside of the vessel you used the same heat transfer that you got for the AP600? The boiling on the outside?

MR. ESMAILI: On the outside it is -- I'm going to get to that discussion on the next slide.

If it does not exceed the critical heat flux, so --

CHAIRMAN KRESS: Yes.

MR. ESMAILI: Now, for the critical heat flux they sued the lower head configuration V. At the time that they did the study, the data and correlation was not available for this lower head configuration.

But we assumed that CHF was higher by a

factor of 1.44, compared to configuration 3 that was reported by Westinghouse. And the reason we did that was that in general that configuration IV was higher by about 20 to 30 percent, the CHF was higher between 20 to 30 percent compared to configuration III.

And, overall, configuration V was higher by 20 percent, compared to configuration IV. So that is why we used this factor of 1.44. And this is, as you can see, the comparison between -- I apologize, this is the configuration of the CHF for configuration of III, and the higher CHF for configuration V, which is at an angle of about 90 degrees is about 2.1 megawatts per meter square.

CHAIRMAN KRESS: This is responsive of the angle from the bottom --

MR. ESMAILI: From the bottom of the vessel all the way to -- yes, exactly. That is all the way up to the top of the vessel.

MEMBER LEITCH: I don't understand what you mean by these various configurations.

MR. ESMAILI: This is the configuration of the insulation around the vessel lower head, but they changed it so they make it more streamlined, so that they would increase the critical heat flux.

MR. SCOBEL: The configurations relate to the open tests that were bounded to determine this critical heat flux, and configuration V actually does a good job of modeling the geometry of the AP1000 reactor vessel insulation, and the vent at the top of the insulation, which a higher critical heat flux that we need to get for AP1000, over AP600.

MR. KHATIB-RAHBAR: It is not to be confused with the ERI melt configuration, we have two configurations, I and II. So there are Westinghouse configurations, and ERI configurations. So keep that in mind.

MR. ESMAILI: Now, as far as the heat transfer in the molten pool region for configuration I, all the model PRI, DOE, and INEEL, basically used for the top metal layer, we used the Globe-Dropkin for the heat transfer to the vertical, to the horizontal surfaces.

And Churchill-Chu for the vertical surfaces, for the side wall of the reactor vessel. For the ceramic pool, at the time of the study for AP600, they used Mayinger's correlation for heat transfer downward into the ceramic pool, and the Kulacki-Emara correlation for the heat transfer upward towards the top metal layer.

Now, DOE used the correlation, the Mini-

ACOPO correlation, which was a one-eighth scale test facility, and subsequently used the ACOPO correlation which increased the range of the numbers, and that was a one-half scale facility.

MEMBER WALLIS: What is the problem -- is it very small, or something?

MR. ESMAILI: The problem number for ceramic materials is typically about .5, .6, or -- for metal it is very low, it is about .1, yes. It is about .12 for a metal.

Now, the solution method for configuration I was based on the non-linear Newton-Raphson method, and we also allowed for a temperature dependence of viscosity in the molten pool, and in the steel layer.

And this was just to be consistent with DOE and INEEL models. The material properties that we used basically the INEEL has documented them very, very well. And we just used those material properties along with the uncertainties in the material properties in the report for AP600.

The decay heat partitioning was based on the amount of uranium that was in the ceramic layer, and in the bottom metallic layer, the heavy metallic layer.

Now, the first was to verify a model,

benchmark our model against the DOE and INEEL results, and in order to do that we basically used the DOE heat transfer correlation, and you see the comparisons for the heat flux to water, and the vessel wall thickness here.

Now, we did another additional calculation where we used our own default, which was heat transfer correlation. And all that does is just shift the distribution of heat flux inside the ceramic pool.

So where there is lower heat transfer in the ceramic pool, there is a higher heat transfer in the metallic. So that is all it does. But since we got our data from the INEEL reports, of the comparison of our predictions, shows excellent agreement with the INEEL results.

But there is some discrepancy between the DOE results. As a matter of fact I saw the same discrepancy in the metallic layer, as we can see here.

MEMBER WALLIS: This is all theory?

CHAIRMAN KRESS: No.

MEMBER WALLIS: Is this all theoretical?

CHAIRMAN KRESS: No, the correlations come out of experiments.

MEMBER WALLIS: There is no data --

MR. ESMAILI: That is correct.

MEMBER WALLIS: I don't understand the other figure about vessel wall thickness.

MR. ESMAILI: This is -- you see here, because of the heat flux is lowest at the bottom of the vessel, and highest towards 90 degrees, towards the top of the molten pool.

So that is why you see the vessel thickness is about --

CHAIRMAN KRESS: What is happening is the vessel is melting to -- and getting thinner to accommodate the heat flux.

MR. KHATIB-RAHBAR: -- heat transfer on the --

MEMBER WALLIS: It looks to me that you are predicting the vessel thickness, which you already know.

CHAIRMAN KRESS: No, this is thickness versus position to accommodate the heat flux at that location.

MEMBER WALLIS: So it is actually melting?

MR. ESMAILI: It is actually melting, right.

MEMBER WALLIS: This is how far it would melt given that heat flux, until it --

MR. ESMAILI: About 6 centimeters less.

CHAIRMAN KRESS: And that is what is left to have structural integrity. And the question is, now, do the loads on that fail?

MR. KHATIB-RAHBAR: That is the key issue here, how much of the vessel wall do you have.

CHAIRMAN KRESS: Yes.

MR. ESMAILI: Okay. We also predicted the metal pool temperature within a few degrees of both INEEL and DOE results. And, as a matter of fact, the top at the crust, the interface between the ceramic pool and the metal layer was within --

MEMBER WALLIS: Must be a pretty happy vessel with that temperature inside, and boiling water on the outside.

(Laughter.)

MEMBER WALLIS: There must be thermal stresses --

CHAIRMAN KRESS: They are accounted for in the loads.

MR. ESMAILI: We can see the top of the vessel is melting, you know, the inside temperature of the vessel can reach up to 1,600, 1,700. And on the outside it is practically saturation temperatures of about 400.

MEMBER WALLIS: There are no

discontinuities, this is just a nice hemispherical -- penetrations, or anything like that?

CHAIRMAN KRESS: Not in the AP1000.

MR. SCOBEL: There is a drain right in the middle. You have a drain line somewhere in the --

CHAIRMAN KRESS: I must be thinking of --

(Everyone speaks at the same time.)

MR. ESMAILI: Now, as far as uncertainties in the late phase progression, some differences in design between AP1000 and AP600, specifically the power is increased by about 75 percent to 3,400 megawatts in AP1000.

Now, the reflector in the AP600 is replaced by a thinner core shroud in AP1000 to allow for a lower core site, and there is a thicker lower core support plate.

As I showed you before, we considered two bounding melt configurations. Melt configuration I was the molten ceramic with an overlaying metal pool. The second configuration, the melt configuration II is the ceramic pool sandwiched between two metallic layers, one is heavier than the other.

Now, INEEL also considered a third configuration, and that was the configuration where there is a ceramic pool, there is a thin metal layer, and there is an additional ceramic pool on top of that.

We did not consider that very important and the reason is because, you know, the challenge to the vessel is really due to the thin metal layer associated with the focusing -- so you have to take care of, you know, the thin metal layer first.

CHAIRMAN KRESS: How did you decide how much material was in the bottom heavy metallic layer?

MR. ESMAILI: Yes, I'm coming to that, it is coming.

CHAIRMAN KRESS: Okay.

MR. ESMAILI: Now, this is the -- when we talked about the ERI, it only accounts for thermal interactions, chemical reactions with the vessel wall is not considered, we have not considered it. And we may have to do it some time in the future, but at this point we have not --

MR. KHATIB-RAHBAR: Let me add something. Due to chemical energy addition, as you will see later on, with configuration II, which is the heavier metal layer in the bottom, because of the ratio of the heat flux is so small, even if you were to add the chemical reaction heat it would not make a big difference. But the eutectic issue still remains.

MEMBER SIEBER: Since you don't consider the chemical reactions of the fuel, and internals when they are melting, would you expect largely different compositions in layer thicknesses, from an actual melt experiment that included chemical reactions, as opposed to one that just looks at thermal effects?

MR. ESMAILI: Well, they do consider chemical reaction during the core melt progression.

MEMBER SIEBER: Chemical reactions with other things, but not within the core itself?

MR. ESMAILI: Not within the core, right. Once the pool is formed you assume a quasi-steady. Now, it is possible that because of chemical reaction, heat-up reaction, etcetera, there are periods that the actual, the heating of the material may produce some temperature excursion, but --

MEMBER WALLIS: But isn't the eutectic thing that Dana is worried about the real source of heat, isn't it?

CHAIRMAN KRESS: Yes, one of the things, but --

(Everyone speaks at the same time.)

CHAIRMAN KRESS: -- question I always had about that is it does have crust layer protection from that.

MR. KHATIB-RAHBAR: And the ceramic layer is actually the whole issue, the crust affects the vessel.

CHAIRMAN KRESS: Yes. You have a crust there, too. Well, maybe -- maybe not.

MR. ESMAILI: We basically considered four uncertainty distribution. The first one as the decay heat, because that is where we define the four relocations to the lower plenum.

The second was the amount of zirconium oxidation, the third one was the actual amount of core relocation to the lower plenum, and the fourth one was the metal content. And the metal content is really the molten core uncertainty here.

In terms of the decay heat, our decay heat distribution was based on the results of plant-specific MELCOR calculations that showed, if you remember from the previous presentation, that the timing of core relocation varied from two and a half to three and a half hours, 3.6 and 3.7 hours.

And that is how we based our most probable range in terms of power density. We also considered a high power density up to about three cubic meter, and that is because we relied on the MAAP4 calculation that showed an earlier relocation, about two hours into the lower plenum.

But here we considered only the residual property for this higher power.

CHAIRMAN KRESS: How did you decide on the distribution, that is not normal --

MR. ESMAILI: No, it is not normal. It is, actually, if you go back -- yes, it is -- okay, we assume the most probable range was between, let's say, in terms of the core flow decay, between 23 megawatts and 29 megawatts, okay?

And it assigned lower probability anything above 29 megawatts, also about 38 megawatts, depending on the core relocation. Also combined the timing of core relocation decay heat to come up with this distribution for -- it is an accumulated probabilistic distribution, for the Westinghouse is a probability density function.

But this showed that the lower bound of decay heat is 1.3 compared to Westinghouse and our analysis, as a matter at the median is also 2.1 megawatts and it is the same for Westinghouse.

But, as I mentioned to you, because we considered relocation we have a higher upper bound here. Now, the second uncertainty distribution oxidation fraction in vessel, is also based mainly on the results of MELCOR calculation that we just saw earlier, that showed that the most probable range was about 50 percent for that, but there is a different calculation that showed that it could range from 44 all the way to 65 percent.

So we assigned a most probable range between 40 to 60 percent, but we also assigned some probability for 60 to 70, and a residual probability between 70 to 80 percent. And the reason we stopped at an upper bound of 80 percent was because under very degraded core conditions there is a limited amount of steam and the core is really degraded, so there is not a lot of chance for oxidation of the entire zirconium.

CHAIRMAN KRESS: What I don't understand is how you decided what probability to assign. You just got a bunch of people together and --

MR. KHATIB-RAHBAR: No.

CHAIRMAN KRESS: How did you come up with that .5?

MR. ESMAILI: This one here?

CHAIRMAN KRESS: Yes.

MR. ESMAILI: This was based on the results of MELCOR calculation. The MELCOR calculation that we did mostly predicted 50 percent zirconium fraction oxidation.

MR. KHATIB-RAHBAR: Tom, I just thought of something similar to what -- where you say my most likely regime was that zirconium oxidation is going to be between 40 percent to 60 percent.

CHAIRMAN KRESS: So then you reduce a factor of 10 to get the --

MR. KHATIB-RAHBAR: Exactly.

CHAIRMAN KRESS: Now I understand what you did.

(Everyone speaks at the same time.)

MR. KHATIB-RAHBAR: -- that form the probability level. But in order to show them here, because people have a difficult time understanding what the probability level means, we converted it to power density function, which is more --

CHAIRMAN KRESS: Most people understand probability -- but this was decided on, just like --

MR. ESMAILI: Absolutely, yes.

CHAIRMAN KRESS: Now I understand.

MR. ESMAILI: And now we have this 30 to 40 percent range, if you remember the math calculation that showed that the zirconium oxidation factor can be as low as 30 percent, although it has a lower probability.

Now, one of the most important condition is the relocation of ceramic material to the lower plenum. Now, the MELCOR calculation predicted about 80 percent --

(Telephone interruption.)

MR. ESMAILI: The MELCOR calculation predicted that about 80 percent of the core melt and relocation to the lower plenum.

We also 25 probabilistic distribution, we also relied on some insights from the SCDAP/RELAP calculation that they did for AP600 at the time. Now, SCDAP/RELAP calculation for AP600 showed that the initial relocation of the debris can take only about 50 percent of the core debris.

Subsequently the second debris relocation involved an additional 35 percent. So the final relocation was about 85 percent. But what is important is the timing between the first relocation and the second relocation, depending on how -- the modeling approach you use in this code, this can be between 13 minutes to over an hour, depending on how you model this.

So, therefore, we said okay, the most probable range for our core relocation to the lower plenum is somewhere from 60 percent to 80 percent, but we cannot rule out the lower relocation, because there is enough time for the debris to form, you know, to dry out the lower plenum and reformat the molten pool.

So, therefore, we provided some probability in the 50 to 60 metric ton range. And this is in light of the fact, actually, because the vessel, the entire vessel is cooled, so there is heat transfer from the entire vessel by radiation to the core --

MEMBER WALLIS: So that is a RELAP5?

MR. ESMAILI: So that might delay the timing of the second debris relocation.

I'm going to talk about the MAAP4 calculation, also about the initial relocation, and about 50 percent of the core, but the relocation was more gradual and eventually a greater proportion of the core relocated downwards.

Now, one of the most important uncertainties is the amount of metal. Now, since this directly has to do with the focusing effect, we felt that the amount of steel in the lower plenum had to be dependent on the amount of core that relocated into the lower plenum.

Now, if there is not sufficient amount of ceramic material in the lower plenum, it does not touch the lower core support, so in that case the amount of steel would have to be limited.

And this one we assigned somewhere from 50 to 60 metric tons, we assigned 3 metric tons to 8 metric tons of steel. Now, the lower 3 metric tons is just the steel that is in the lower head.

And the addition of 5 metric tons, over 8 metric tons, is due to 25 percent melting of the core barrel. In the MAAP calculation the testing they predicted that 25 percent of the core barrel on the AP1000 PRA has melted and come down.

Now, you need about 50 metric tons of ceramic material to touch the --

(Pause due to computer problems.)

MR. ESMAILI: Okay. Now, as soon as you reach threshold for the core ceramic material, about 60 metric tons, it starts to touch the core support plate, and the lower metallic blocks. So if you go a little bit further it is possible to melt the entire core support plate, and substantial amount of the lower blockage.

So that is why you see this shift of the steel metal from about 60 metric tons to about 40, and then it goes all the way up to about 60 metric tons. And the way we came up with this 40 to 60 is we said, okay, and we assumed that --

(Telephone interruption.)

MR. ESMAILI: And so for the 60 to 80 metric tons what we have is that we assumed the entire lower plenum melts along with the core support plate, and 50 percent of the core shroud, the barrel. And, of course, this is not very important, but for the upper bound they include the entire mass of steel in the reactor vessel, which is about 70 metric tons.

Now, just to give you a comparison, you see that in Westinghouse's, the height of this metallic layer varies from .6 meter all the way to about 1 meter, okay? So this is a very thick metal layer.

Because of the thin metal layer assumption that they used, and associated with low ceramic relocation, in our case this red line here is the height of the metal layer that varies somewhere from .2 meters all the way to 1 meter.

Now, the one meter in both cases are the same, because the amount of steel is the same. But the important thing is that we have some probability of very, very thin metal layers.

MR. SCOBEL: Are you saying that when -- you are assuming that when the oxide touches the lower support plate, that you only get a part of the lower support plate in through the --

MR. ESMAILI: I'm just saying because the core support plate is a solid material, so you just need very, very little -- I mean, once you hit it at the bottom, it is a very, very little amount of UO2, or ceramic material to really submerge the lower support plate.

MR. KHATIB-RAHBAR: I think Jim is asking a different question. He is concerned about the lower bound metallic plate, right?

MR. SCOBEL: Yes, I'm looking at the metal mass as a function of the UO2 mass, and it gradually increases from 60 up to 80 percent. And I was just trying to understand, so you are saying when you contacted at 60 percent, when you contact the lower support plate at 60 percent, you are saying that it actually gradually melts into --

You know, at 60 percent if you contact the lower support plate, I would say that you are going to have the lower support plate, and the core shroud down there really fast, because --

MR. ESMAILI: That is why I think -- I don't know whether -- that is why you see -- at 50, you know, it is --

MR. SCOBEL: Oh, I see.

MR. ESMAILI: Do you see what I'm saying? So there is this discontinuity.

MR. SCOBEL: I'm sorry, I see.

MR. ESMAILI: Yes.

CHAIRMAN KRESS: The probability you have in the next curve are actually the probabilities of having the given amount of core melt, and you just -- you take the correlation and translate it into --

MR. ESMAILI: Exactly. It translates into this, correct. It translates into this type of probability for the height of the metal layer.

So you can see for that

MR. KHATIB-RAHBAR: What it shows is that you need to reach, first you need to reach the bottom of the core plate. Once you reach it, then they become very similar. That is why you see this double hump behavior.

MR. ESMAILI: And this one here corresponds to that --

CHAIRMAN KRESS: Sixty percent?

MR. ESMAILI: Right. Now, in order to study this, probabilistically, of course we used the LHS computer code, and we generated about 1,000 random samples from those four distributions that I showed you earlier, in addition to the uncertainties in the material properties.

These have all been fed into the one-dimensional heat transfer model, and these are the final results. This is a probability, this is a critical, this is the heat flux ratio that is the ratio of the local heat flux to the critical heat flux, and this shows the probability at three different regions.

One is at the bottom of the vessel, so that you can see that this is at the bottom of the vessel, you know, in the ceramic pool. The red line is at top of the oxide layer.

Still in the oxide layer, but at the top, where the heat flux is degraded. But even then you can see that the heat flux does not even reach .8. So there is no probability of failure in the ceramic pool region.

But you can see, in the top metal layer, the critical heat flux reaches 1 at about .85. So --

CHAIRMAN KRESS: Now, this is your case for --

MR. ESMAILI: That is configuration 1, that is right, the two layers, one is the ceramic, and one is the metallic layer, right.

And so the estimate of condition of

failure probability, and the figure of merit here is exceeding critical influx of .151. That means that out of these 1,000 samples, out of these 1,000 calculations, 150 of these resulted in failure of the vessel, because the critical heat flux was exceeded.

Now, we also did some sensitivity calculations to bound this range of the failure probability. The first thing we did, actually, was to add a decay heat in the top metallic layer, and using the approach that was proposed in the report for AP600, we assigned 10 percent to 20 percent of the decay heat that was residing in the top metallic layer.

Now, the first thing to notice is that if you compare case -- because there are three things here to notice. One is the focusing effect. That means that the probability of having a very, very low thin metal layer.

And this we can see by comparing case 1 and case 5, or case 6 and case 9. In case -- well, let's concern the cases with the decay heat in the top metal layer.

The case six is the base case plus the decay heat in the top metal layer. The CFT is about .27. But if I decrease the probability of load max relocation, essentially saying that we have a very low probability of having a very thin metal layer, the failure probability is decreased by four-fold, from 27 percent to about 7 percent.

This is true whether you have decay heat in the upper metal layer, or you don't. The second thing is that in the base case we did not have decay heat in the metal layer.

And the presence of the decay heat always increases the -- always increases the failure probability, but it also depends on what heat transfer correlations you use.

Now, if you compare cases 6, 7, and 8, which was our heat transfer correlations, the DOE and INEEL heat transfer correlation, you see that the failure probability increases from 27 percent to 31 percent.

After some point it is difficult to increase the failure probability, because what you do is that instead of having the decay heat in the ceramic pool, you are putting this into the metallic pool, so you are actually decreasing the amount of heat that is coming from the bottom into the metallic pool.

So at some point it -- yes?

MEMBER WALLIS: CFP is the conditional failure probability?

MR. ESMAILI: That is right.

MEMBER WALLIS: And this is saying that the vessel is going to fail at the metal layer?

MR. ESMAILI: At the metal layer, right, the metal layer. Because the critical heat flux is exceeded here. But there is no CFP for the ceramic layer, it is basically zero.

Another thing would be that, you know, the density did not consider any variations in material properties, you know, there were like 20 material properties in there. And there is a very, very insignificant change in terms of, you know, failure probability.

So the material property does not play an important role. And this is very obvious here. The only thing that makes a difference here is the amount of steel that is relocated in the lower plenum, and this is how we quantify it.

Now, the case 2 with the melt configuration 2, where we have a ceramic pool sandwiched between a heavy layer, and a light metallic layer, is a little bit more challenging.

Now, we did a parametric calculation for this particular case, we assumed a conservative estimate. It said that, okay, in case that there is a decay heat in the lower metallic layer, the worse that you can -- the temperature has to -- the highest temperature has to occur at the interface.

So, therefore, in the limit, the top surface of the bottom layer has to be insulated, okay? So all the decay heat that is generated in the bottom metallic layer have to be going into the vessel.

So this is how they did the parametric calculation. But they also required some additional condition which -- in order to make sure that the saturation is greater than one, so that bottom metallic layer is heavier than the outside layer.

And the mass fraction of the uranium in the bottom layer was 6.4, this was in response to the peer review of the original AP600 by one of the peer reviewers.

And all they had to do was just change the fraction of the U that is in that oxide form, that means change how much uranium is in the bottom layer, versus what is in the ceramic pool.

And the partitioning of decay heat was based, was proportional to mass ratio of uranium. And here are the results. For this faction of U in oxide form that translates into the mass of uranium in the bottom layer, changing from 3,000 kilograms, all the way to about 9,000 kilograms.

And for this , the three-fold increase in the mass of uranium, you see that the critical heat flux ratio, the heat flux ratio, varied from .22 to .36. So there is not a big difference in terms of heat flux ratio.

As a matter of fact, even under -- at the upper bundle, at about 36.36, it is well below one. So, therefore, we conclude that the failure of the lower head, at the bottom location is not likely.

MR. KHATIB-RAHBAR: And this also is a typical reaction issue, adding additional heat would probably not do very much.

CHAIRMAN KRESS: Yes, I can see it.

MR. ESMAILI: There is a big margin in terms of --

CHAIRMAN KRESS: You have a lot of margin to critical heat flux.

MR. ESMAILI: Not only that, you will see that even if the vessel fails at the bottom, you know, the FCI loads are more benign than --

CHAIRMAN KRESS: How did you decide that?

MR. ESMAILI: We make a calculation, I

will show you. We assumed that even if the vessel fails at the lower head, at the bottom of the vessel, because of the difference on the cavity wall, that the loads on the cavity walls are much lower than if it fails at the side wall location. I will show you the results.

Now, the specifications of the issue and boundary conditions for ex-vessel FCI, we used the calculation for the IVR analysis that we did. So as far as core composition, and core temperature was concerned, this was -- this came directly from the IVR analysis that shows that the core has to be metallic, the temperature we estimated at slightly over 2,000K.

Now, the lower head failure size we used lower head failure size of about 40 centimeter. And the reason we did that was our best estimated decay heat density, power density, we can have a metal layer as thick as about 35 centimeters, 40 centimeters, and still fail the vessel.

But that is why for the base we assumed a 40 centimeter failure site. Now, the containment pressure was, according to MELCOR calculation, and the cavity water was 50 degrees subcooled, and lower head was fully submerged, there was a deep water level up to about, I think, a depth of about six meters.

MEMBER WALLIS: Does this make sense? The vessel suddenly failed with a hole of four meters, or doesn't it slowly grow?

(Everyone speaks at the same time.)

CHAIRMAN KRESS: When that molten stuff goes through that hole it just goes, shooo, like this.

MR. ESMAILI: The whole thing could come down, the whole thing could come zip. There are different scenarios, the whole thing could come zip and come down, it would unhinge.

But as far as the FCI is concerned, their only concern is with the first second or so. You know, because most of the explosion occurs once the --

MEMBER WALLIS: Very quickly.

CHAIRMAN KRESS: Yes.

MEMBER WALLIS: It flows it right back into the vessel.

(Laughter.)

MR. ESMAILI: -- hydrostatic nothing might come out, so that is another possibility.

For the calculation matrix, for the AP600 we did a lot of calculations for FCI. In this case, because the lessons learned from the AP600, we only did five calculations, actually.

This involved the most important

uncertainties in terms of melt progression uncertainties that involves melt pour composition, and failure size, and variability in the modeling of the fuel coolant interactions.

We used the PM-ALPHA/ESPROSE computer code to calculate the impulse loads on the cavity walls. Now, the case one was the best case, case two was the assume the ceramic pool at high temperature of 3,100. That means that the -- ceramic material.

Case three was a failure size of .06 meters. The reason we showed this .06 meter is -- well, it worked out fine because of the nodalization of the lower head. But at the same time at the higher, at the upper end of the decay heat, you can support a metal layer as thick as 53 centimeter, and still retain the vessel.

So we went to the larger pool size of about 60 centimeters. Now, case 4 had to do with the modeling, different particle diameter of .1 compared to .01 in the base case, and the fragmentation rate of 400 kilogram per second, compared to 4 --

MEMBER WALLIS: When it comes out, it is assumed it has a diameter of .4 meters? It is a big jet, and then it has to shatter it.

MR. ESMAILI: Yes, but once it goes in the water, presumably, it breaks up, the particles break up, the jet breaks up.

Now, there is another code, there is a one-dimensional Texas computer code, actually, that we used for AP600. And that one predicts, you know, the particle breakup.

So we came up with this particle size based on the particle size that was predicted with the Texas code. So as the jet goes through the water it breaks up into these small particles, according to the calculation.

Now, the case 5 is the bottom failure of the lower head, the one I just discussed. Now, the problem nodalization was similar to the AP600. The model said high vessel lower head, up to a distance of about 6 meter.

The only difference was that the lower head was now about -- only about one meter away from the cavity flow, so we had to drop the lower head. This blue line that you see here, these are the actual boundaries of the computation, okay?

It is supposed to be the boundaries of the reactor vessel itself. Now, inside here I should mention that I show this -- inside the vessel itself we don't do any calculations, because it is just solid, okay? So all the calculations are done outside of the boundaries of the reactor vessel.

I think we are running out of time, so I will just show you -- I will go over this very quickly, these are the results of the three mixing calculations in terms of --

MEMBER WALLIS: Well, what are the units on this --

MR. ESMAILI: Pardon?

MEMBER WALLIS: What are the units on --

MR. ESMAILI: This is a melt point fraction, of the melt. In the (inaudible) I think the discussion came up from the previous. So you have to specify the melt volume fraction.

MEMBER WALLIS: In what, in the water?

MR. ESMAILI: You don't see the vessel wall here, because it is yellow, but -- these are the results of the explosion calculation, and you can see that the explosion starts right here and it propagates to the water.

MEMBER WALLIS: What are the colors here, these are still --

MR. ESMAILI: No, these are not -- these are the pressures.

MEMBER WALLIS: I thought they must be,

yes.

MR. ESMAILI: These are the pressures, and I was just going to go over this very quickly.

This is about a millisecond, there is still no -- at one millisecond these are the pressures, there is no explosion.

CHAIRMAN KRESS: What triggers the explosion?

MR. ESMAILI: What triggers the explosion? The trigger is the high pressure cell at the bottom of the vessel.

CHAIRMAN KRESS: When it hits the bottom of the vessel?

MR. ESMAILI: Yes, yes.

MEMBER WALLIS: Now, what kind of explosion is this?

CHAIRMAN KRESS: It is just a thermal explosion.

MEMBER WALLIS: A thermal explosion?

(Everyone speaks at the same time.)

MR. KHATIB-RAHBAR: Rapid heat transfer. We have a particle that punches and transfers all the heat to the water, and you have --

MEMBER WALLIS: You can see it.

MR. ESMAILI: This is at two milliseconds, three milliseconds, four milliseconds, and goes all around the vessel, you know, and then from the -- up around the vessel.

Now, here you can see that these are the wall pressures, these are a location of the function of time. You can see the pressures of the lower half, and the interaction between cavity wall and --

CHAIRMAN KRESS: What would happen if that melt didn't trigger, when it hit the bottom, that more and more came up, and built up, and then you've got --

MR. ESMAILI: Yes, but that is the thing. Because more and more can settle on the cavity floor. But it is very, very -- one of the conditions required for a steam explosion is to mix this melt.

CHAIRMAN KRESS: It has to be mixed with what?

MR. ESMAILI: Mixed with water right. Now, you have a stratified -- on the cavity floor you would have a stratified situation. You know, there is not a mixing involved in melting for the water --

CHAIRMAN KRESS: Well, that is debatable, because I just -- it comes down you have container instabilities, and you have --

MR. ESMAILI: Absolutely, yes.

CHAIRMAN KRESS: And you have other

instabilities that entrap water in there. And there could be some water mixed in with that bottom layer.

MR. ESMAILI: It could be, but I think stratified explosions are always more benign than --

CHAIRMAN KRESS: Well, that has been the experience, you are right.

MR. ESMAILI: Another thing is that a lot more time for it to cut down, you would produce much higher vapor void fraction. And which increases the -- you know, there is vapor there, so there is no --

CHAIRMAN KRESS: But basically the hole size, with the jet coming down, and the distance to the bottom fixes the amount of melt that interacts after that?

MR. ESMAILI: That is right.

MR. KHATIB-RAHBAR: That is why this is lower, as you will see, the bottom failure, they are low in AP600 because the distances.

CHAIRMAN KRESS: Distances, sure.

MR. ESMAILI: The area under the curve so I get the impulse loads that we use. For the best case you see about 85 kPa-s. And finally - now, for these five scenarios, the impulse -- see the bottom failure of the lower head is about 9 kPa-s. So you basically do not have any challenge to containment.

And compared to the 85 and using ceramic melt at a higher initial internal energy, of course you get much higher, about 300 kPa-s.

Now, these results, the only --

MEMBER WALLIS: Go back, what does that mean? The bottom head failure that number means what?

MR. ESMAILI: This number?

MEMBER WALLIS: Yes.

MR. ESMAILI: This is just the impulse load.

MEMBER WALLIS: That is what is required to break the --

CHAIRMAN KRESS: That is the location of the failure, and that is the impulse load you get, it is not saying what impulse load has failed.

MR. ESMAILI: No, I'm not saying that at all. That is the calculation. This just shows what the wall experiences in terms of --

CHAIRMAN KRESS: It is sort of the maximum in --

(Everyone speaks at the same time.)

MR. ESMAILI: Now, for AP600 we did a calculation for this scenario for the subcooled pool with the RPV model. For the AP600 we saw that the maximum impulse load was about 600 Kpa-s.

Now, consistently the results of AP1000 showed that it is a -- it is a factor smaller than AP600. And the reason is because the vessel is sitting a little closer for AP1000, and also the initial reaction of the melt coming into the water was higher in the AP600 because of a higher initial pressure inside the RCS. So velocity was higher by a factor of 2, also.

Finally, so the results of the

(Everyone speaks at the same time.)

MR. ESMAILI: -- focusing effect for configuration 1, so we have more --

CHAIRMAN KRESS: So you end up with more melt, that is why we saw --

MR. ESMAILI: Yes, absolutely. So we see that the likelihood of failure goes from 4 percent to 30 percent. There is no likelihood of failure for the bottom layer. And the side failure of the lower head always results in a higher impulse load, and the bottom failure is not reached.

CHAIRMAN KRESS: And did you decide what impulse load the cavity could take, or is that somebody else's job?

MR. KHATIB-RAHBAR: That is somebody else's job.

MR. BASU: For AP600 the impulse load showed -- that it still lower than --

CHAIRMAN KRESS: Lower than --

MR. BASU: So if you compare the AP1000, I don't know what the -- presuming it is the same. It is even better.

CHAIRMAN KRESS: Thank you.

MR. CUMMINS: One comment, the slide that we have just seen made a statement that these slides may contain information proprietary to Westinghouse. Westinghouse has reviewed these slides, and they do not contain proprietary information.

CHAIRMAN KRESS: Thank you. So we can take them and show them to people?

MR. CUMMINS: Yes.

CHAIRMAN KRESS: Where are we -- we have another hour to go?

MEMBER SIEBER: We are just getting started.

MR. CUMMINS: The next presentation is on seismic and structural design --

CHAIRMAN KRESS: Does that announcement get kicked out, the one over the PA that said we had 15 minutes left?

(Pause.)

MR. ORR: My name is Richard Orr, I'm responsible for the structural design and seismic analysis, responsible for AP600 and now for AP1000. It seems I always get the end of the agenda, so I will do my best to -- I know I can't meet adjournment by 5:30, but I will try not to go for an hour.

I will go fairly quickly. If you have questions please interrupt and let me know.

What I want to cover is the Staff structural configuration changes from the AP600. We have an excellent staffing point with e AP600 design, there were relatively few changes, and so we were able to do our seismic analysis, and structural design with a good start.

I will then cover the structural design basis, the seismic analysis of the nuclear islands, I will get into the structural design of come of the critical sections, and I will briefly talk about the Staff review, and the remaining open items, and a few slides at the end for seismic margins.

CHAIRMAN KRESS: Now, some of the members have expressed concern about how structure with a heavy mass of water on top --

MR. ORR: I have a little bit in the presentation on it, I will try to sort of emphasize it when I get to it.

CHAIRMAN KRESS: Okay, thank you.

MR. ORR: The primary change for AP1000 from the structural point of view, is that we have to increase height of containment. Containment is increased in height by 25'6", the shield building went up with it.

And because of the increase of heat loads we increased the size of the PCS tank to 800,000 gallons. We made minor changes at the air inlets, we got exactly the same air flow, but we made the opening slightly higher by 25'6", 12' wide, and 16', in order to get more column in between the air inlets.

The capacity of the polar crane increased because the steam generators are much heavier. And this is, primarily, the bridge itself. It probably has the same capacity, and the load is the same.

All of the RCS equipment increased in size, and the walls, the shield walls above the operating deck, around the steam generators and the pressurizer compartment, the steam generator walls were raised 5 feet, the pressurizer wall was 7 feet.

There was a minor change in the elevation of the fuel pit floor, because the fuel is 14 feet, instead of 12 feet.

We use these slides to show that there is really no changes in the --

CHAIRMAN KRESS: Now this --

MR. ORR: -- is AP600, the right-hand one is AP1000.

CHAIRMAN KRESS: Now, this is more vulnerable than the east-west direction?

MR. ORR: Yes. In the east-west direction the footprint from this wall, the east side to the west side, is about 160 feet, or so. The containment is about 150 outside of the shield building. And so this is about 165 in the north-south direction it is 256 feet.

So most of the seismic results are worse in the east-west direction than in the north-south direction. This just shows a comparison in elevation. Again, the cross sections are pretty much the same. The containment vessel has increased in height, the shield group has gone up.

The auxiliary building is virtually identical. And one thing to mention, when we get into structural configuration behavior, we have tied the walls and floors of the auxiliary building directly into the shield building cylinder.

The containment vessel is separate from

the shield building, there is a 4 foot 6 gap between the containment vessel, and the concrete cylinder. The containment vessel sits in the base mat, and the containment internal structures sit inside the containment, the bottom head.

Above grade the structures, the containment internal structures, the containment vessel, and the shield building are independent.

MEMBER SIEBER: Why is the bottom of the containment building rounded?

MR. ORR: Because we -- the containment vessel is an ASME vessel. The steel head is capable of taking pressure on its own. If it weren't surrounded by concrete, the steel head would be adequate for 59 psi.

The other option is to put, effectively, a flat head, design it as a reinforced concrete base mat, and we looked at it a little bit. Some of the details you get into, are try to anchor down a steel vessel into concrete, are difficult to construct.

Changes to the containment vessel, the diameter is the same. The height, as I said, went up 25 foot 6. Design code is the same. Material has changed. For AP600 we used SA537 material. Here we've got SA738 grade B.

One of them is 18 KSIA ultimate, the SA738 is a 85KSI ultimate, so there is a slight increase in allowed stress. This was a material that was not in the code in the mid-'90s. It is a material being used successfully by CPI on a lot of non-nuclear vessels, and effectively is going to be replacing the SA537 material that would have been used for AP600.

We increased the thickness from an inch and five-eighths on AP600 to inch and three quarters on AP1000. This is the maximum with heat treatment, and in response to one of the NRC's issues, we have actually increased the thickness of the lowest course from inch and three quarters, to inch and seven eighths, to provide additional margin in the transition region, where the vessel is imbedded, and goes down into the concrete.

We did the same thing on AP600, but we were only going up to an inch and three quarters, so we didn't have any increased -- this is just two views of the PCS roof tank. As I said, we went from 540,000 gallons to 800,000 gallons.

We did this by increasing the diameter from 80 feet to 89 feet. The height is pretty much the same, but because it slid down, the conical roof, we get slightly more volume.

The seismic design basis, firstly it is generally the same as AP600, 0.30gSSE. However, for current design certification purposes, we are only looking at hard rock sites.

CHAIRMAN KRESS: This prevents you from building one in Japan?

MR. ORR: No, in Japan almost all of their sites are hard rock. Oh, .3, yes. We have actually looked at cases with seismic isolation, there were also the options of operating it a little bit.

We have used the same response spectrum, parameter response spectrum, as we used for AP600. This was REG guide 160, which was in existence in the mid '80s and used for most plants. We reviewed it, and then in 1990, and we put in some application of high frequencies, particularly at 25.

Some of the recent data in east coast site shows that there is significant amplification around that frequency. We did a series of finite element models for AP1000.

This was a similar approach to what we did on AP600. We do finite element models of the buildings, and I will show you two typical ones, shortly, that are used in static analysis, and also in model analysis, and we use those model analysis results to come up with a simplified stick model of the, for dynamic purposes.

These stick models are created individually for the auxiliary and shield building, for the containment internal structures, for the containment vessel, and polar crane, and for the reactor coolant loop.

The stick models have been combined in the time history analysis.

This now is the typical finite element model of the shield building, and the auxiliary building, which has been described. These are integral structures. It extends all the way from the base mat up to the top of the shield building group, where the refinement of the model sufficient for dynamic behavior.

We did a more detailed model that we used in the static analysis.

CHAIRMAN KRESS: Are the dots on there where you concentrated --

MR. ORR: Yes. The stick model, the dots represent either masses or in some cases just the connecting links between a series of sticks. The circles are masses, the open circles are the centroid of the section, and the X's are the shear centers.

We developed a similar model inside containment, very detailed, and the same model was used both in the dynamic analysis, the model analysis, and the static analysis.

This particular view represents the portion of concrete inside the containment vessel, and all of the concrete structures, including the module structures that you saw in the presentation at lunch time.

The seismic analyses that were done, firstly, on the fairly detailed finite element models, we do model analysis to get frequency and effective mass of the dynamic properties.

We also use those models to create properties for the simplified sticks, and we check the stick models, the frequencies, and the mass in the stick models against those in the detailed shell models.

The stick models are used in a modal analyses time history that results in responses at each of the models, time history responses. The typical responses we look at are maximum acceleration and relative deflection of the load relative to the ground.

And we create floor response spectra from the acceleration time histories for use in equipment design. This typical flow response spectra is at the top of the shield building roof, in the horizontal direction.

At the zero period acceleration this is, effectively, the maximum acceleration response of the structure. We have an acceleration of about one point HG at the top of the shield building roof.

The response spectra represent the response of a single degree of freedom attached to the structure. If it is in resonance with the structure, for instance here at about 3 hertz, you get very large amplification.

This 3 hertz frequency is the fundamental frequency in the east-west direction of the shield building. The smaller peak, at about 8 hertz, 7 or 8 hertz, is a local mode of the shield building roof. This is the tank rocking on the conical roof.

So when we looked at the design of the tank we are looking at, effectively, these accelerations for the structure, of about 1.7G, and we qualify the building structure for that.

In addition we looked at the water in the tank, and we looked at the slushing mode of the tank, and we see movement of the free surface, I think it is about 4 or 5 feet.

But we have that amount of freed water in the tank, so it does not impact on the outer side.

MEMBER SIEBER: You could have added baffles in there, right?

MR. ORR: We could have added baffles, yes. I'm not sure how effective they would be, because right now the frequency of the water slushing is at .13 hertz, about 8 seconds. As you get baffles it is going to increase that frequency.

We are very well off by the fact that the frequency is so low, that it does not get excited by the 3 hertz contents of there shear.

MEMBER SIEBER: Okay.

MR. ORR: For AP600 we had extensive structural design. And in our review, with NRC, we established a series of critical sections that were really based on our judgement. We said this is going to be the locations, most congested, most difficult to design.

We did the detail design calculations, NRC reviewed those. We have done the same thing for AP1000. There are 22 critical sections. This is just some examples of the shield building roof, and there are actually three critical sections here.

One is the columns between the area, and that is -- the second is immediately above them, is what we call the tension range, running around immediately above the air inlets. And then there is the lower portion of this cylindrical wall.

We do static calculations on the detailed finite element models, using the accelerations from the time history analysis. This is just one example of models that we created from the shield building roof.

We actually also have models, this is 180 degrees, we have models at 360 degrees, we have models at 90 degrees. The one at 90 degrees is the one we used in the detailed design calculations, with considerably more requirements than shown in this portion.

From the detailed plant model we get a number of forces in all of the elements, and go into hand calculations and processes, to calculate the amount of reinforcement.

This is an example of the reinforcement in this tension rail, and in the column between the air inlets. They are congested, but that won't be feasible. This was redone for AP1000, but really the changes are not that significant in the quantities of reinforcement between the two plants.

In the early stages of AP1000 we had a pre-application review,a nd I think at that time I presented something to ACRS. We were requesting that we could do much of the seismic analysis and the structural design to the combined license applicant.

And we had lots of discussion and we were permitted to do that work. So that is the work that we did last year, and we had extensive meetings with NRC. First we had a one week meeting in November, secondly the one week meeting in April.

The first meeting was primarily seismic analysis, the second meeting was primarily the structural design. Resulting from that there are still a few open items, but we think we made excellent progress.

In the areas that I am responsible for firstly there are five open items in chapter 2 that address the goetechnical interface of the site. Most of that is that we maintain the information from AP600 in the interim there was a new standard review plan that was issued, so we have now revised the DCD to reflect the new standard review plan, that should be resolved with no great problem.

In the section on seismic analysis,

section 3.7, there are seven open times. We have responded to all of them. The most significant one was a discussion we had with the Staff, actually since the beginning of this year, that we resolved in a meeting in April, related to the assumption of the stiffness of concrete to be used in the seismic analysis.

And after extensive discussion we agreed to do additional analyses, and having done those additional analyses we have actually revised all of the seismic results in the DCD.

Changes, we have reduced the stiffness of the concrete by a factor of .8, the changes, the frequencies by about 10 percent, and changes to some of the responses more than 10 percent.

Because we changed the stiffness of the concrete we do not change the stiffness of the steel vessel, and the relative frequency between the two now changes, and that does change the overall response.

MEMBER SIEBER: I don't know hardly anything about concrete, except that I always was under the impression that it doesn't bend. And, therefore, how do you change the stiffness?

Is there differences in composition, or are you really looking at rebar --

MR. ORR: No, this is an analysis assumption of the material property of the concrete, the elastic --

MEMBER SIEBER: The space it --

MR. ORR: -- is used in the past, in most analyses. Recently there has been a change in the state of the art, various FEMA documents that recommend something less, and we have now sort of used actually the 80 percent.

MEMBER SIEBER: Okay.

MR. ORR: I think it is probably giving us a better estimate of expected behavior than we got in the past.

MEMBER SIEBER: If it is a better estimate, does that mean you are better off, or worse off?

MR. ORR: Not really. If it is more likely to be -- it is a best estimate, and then we broaden the floor response spectra plus minus 15 percent from that.

MEMBER WALLIS: Does the concrete fail, do they get pulled back --

MR. ORR: Well, what happens is -- the only reason we have reinforcemnt is because we know that concrete cracks. If it didn't crack, we wouldn't need reinforcement.

MEMBER WALLIS: For these transients, does it actually open up and then close?

MR. ORR: Yes.

MEMBER WALLIS: It does, okay.

MEMBER SIEBER: Well, I always sort of pictured it as the rebar being the basic structural element with the concrete being a lot of mass that is hanging on the rebar.

MR. ORR: From a strength point of view you are relying entirely on reinforcement. From a stiffness point of view, generally, the concrete is more significant than the reinforcement.

MEMBER SIEBER: Right. But it is the mass of the concrete, as opposed to the continuity of it, right?

MR. ORR: Well, it is also the continuity because what happens is you get cracks every two or three feet.

MEMBER SIEBER: Right.

MR. ORR: Between that you've got uncracked concrete. So you've actually got a combination of --

MEMBER SIEBER: A series of plates.

MR. ORR: -- uncracked concrete and

cracked concrete.

MEMBER SIEBER: Right, okay, thank you.

MR. ORR: The third section is the structural design DCD sections 3.8. There we have 14 open items on all of the seismic and the structural open items we have provided a response to NRC. We believe that those responses are substantially adequate.

We will have at least one further meeting with NRC staff. One of the open items relates to design of containment vessel. We had not presented as much design of the vessel as NRC staff felt was necessary.

Since then we have done additional work and the information is available for them to review.

CHAIRMAN KRESS: Is the purpose of the seismic to develop some sort of confidence in the probability that the containment will fail? That is the basic purpose, right?

MR. ORR: Of the design work?

CHAIRMAN KRESS: Of the calculations and the design.

MR. ORR: We have originally said that the level of information for containment vessel would basically be design specifications, similar to an ASME design specification and all of their allowable stresses.

NRC staff wants to -- wants a demonstration that the vessel can be designed to those requirements meeting ASME. So that is what we are now doing.

As part of the application in the PRA report there is a section related to seismic margins. We did an evaluation for AP600, we updated it for AP1000, and this report is in the PRA report.

As part of that we established the high confidence low probability of failure values for each of the safety related structures, and for the systems and components.

For the buildings we have evaluated the shield building, and the auxiliary building, the containment vessel, and the interior containment structure. That is also the IRWST tank, because the tank is integrated into the structure.

MEMBER SIEBER: Are you folks designing pipe supports, or does somebody else do that?

MR. ORR: We have, in the seismic margins evaluation, we include piping and pipe supports.

MEMBER SIEBER: For the modules?

MR. ORR: Everything, yes.

MEMBER SIEBER: But there are other parts of the plant that aren't really built as modules, right?

MR. ORR: This is -- so not just the modules.

MEMBER SIEBER: Okay.

MR. ORR: We evaluate mechanical equipment, a lot of this is based on generic data, and the valves and the electrical equipment. The basic requirement is that we demonstrate that we meet, at least a review level of .5G.

What we found for AP1000 is generally our margins are a little lower, because we have higher response for the AP1000. But it is not significantly different.

And .5G we have a number of items there. We think the lowest one, same as on AP600, is around .5.

MEMBER SIEBER: Let me ask you the question that goes way back to the beginning. You are designing for a hard rock site, and it is my understanding that more than half of the sites, the potential sites in the U.S. are hard rock.

On the other hand you can take one that superficially is in hard rock, and put in franki valves, and things like that. Is that an acceptable alternative to finding a near surface hard rock formation?

MR. ORR: One of the open items in the DSER that we just responded to relates to that. That we had the capability in AP600, and we now put it into AP1000, that allows the combined license applicant to do site-specific analyses of AP1000, and make comparisons of floor response spectra at certain key locations.

MEMBER SIEBER: Okay.

MR. ORR: If he can demonstrate that these spectra are less than that, or he can demonstrate that any exceedences he has made appropriate changes, then this design can be applied directly.

MEMBER SIEBER: But do you know the margins? You know, you are going to find, perhaps, exceedencs of your findings, which aren't exceedences of the overall criteria, right?

So the licensee, the COL licensee is allowed to use your margins, correct?

MR. ORR: As far as I know.

MR. CUMMINS: Say your question again.

MEMBER SIEBER: I picture -- you have multiple structures here. And if you look at, for example, selected equipment, or selected buildings, you are going to find some better able to withstand a .5G seismic event, than other ones.

So all the COL licensee applicant has to do is to make sure that those areas that don't -- that are on his site exceed your hard rock analysis, are still within the .5G.

MR. ORR: This seismic margin is different. This is the one that says, okay, you've designed for an SSE of .3G. I want you to demonstrate that you are not right at the edge of a cliff, and if the earthquake is .31G everything falls down.

So you are demonstrating, all the way up to .5, that the plant hangs together.

MR. CUMMINS: And you have to still do that at COL stage. So the margin is really owned by the NRC, not by the applicant, and their customers.

MR. ORR: If you have a site .5G, and our design is .3G, then you've got that margin to play with in some manner.

Some of our evaluation of seismic margins now is based on a paper plot, and so there are certain commitments that are required for the combined license applicant. He is, obviously, going to demonstrate that the seismic response at his site is lower or equal to the ones we've used in design.

There are certain equipment choices still to be made, one of them being the electromechanical relays, that he has to demonstrate are robust. And then as you build it, there are always some changes, there are always some things you find, as you do the first walk-down.

And so the combined license applicant is required to do the seismic walkdown exactly as has been done on many of the existing plants.

MEMBER SIEBER: But that is really intended to do things like tie switch gear together, and --

MR. ORR: It is also --

MEMBER SIEBER: -- as opposed to a reanalysis?

MR. ORR: It is also to do a walkdown and see, well, are there certain other interactions there that you didn't quite realize when you were doing the design.

MEMBER SIEBER: Right, okay.

MR. CUMMINS: But it is not supposed to be reanalysis.

MEMBER SIEBER: Right. But there might be in some instances.

MR. CUMMINS: Yes.

MR. ORR: We are continuing some work on the seismic margins in response to the open items. As I mentioned, we have changed the assumption of stiffness of concrete, and hence we have changed some of our seismic results.

We are looking to see if that affects the seismic margins.

MEMBER SIEBER: Let me ask another real quick question. You probably do your seismic pipe design in hangars by analysis. But you can't possibly review every pipe in the plant. What is the minimum size pipe that you do by analysis, as opposed to using templates, or something like that?

MR. ORR: I believe that the -- we are analyzing all of the large bore, greater than two inch. I think some of the less than two inch high energy lines we do analysis on, others will be a space table type of --

MEMBER SIEBER: But all the way down to two inches?

MR. ORR: Yes, sir.

MR. CUMMINS: I think your answer is for safety related piping.

MR. ORR: Yes.

MEMBER SIEBER: Right.

MR. CUMMINS: This is seismic one piping.

MEMBER SIEBER: Right, which is better than top --

MR. ORR: I believe all --

MEMBER SIEBER: And that is better than industry practice had been up to this point, in plants under construction, to my knowledge.

MR. ORR: The last item we are doing, as we review the seismic margin, we are updating some of the calcs because we now have better design information on AP1000 than when we did the original seismic margin update.

What I would expect is that this is going to increase many of our HCLPFs. We will still meet the requirement of .5.

I think I managed to get through in less than my allotted time.

CHAIRMAN KRESS: We are adjourned.

(Whereupon, at 6:22 p.m., the above-entitled matter was adjourned.)

CERTIFICATE

This is to certify that the attached proceedings before the United States Nuclear Regulatory Commission in the matter of:

Name of Proceeding: Advisory Committee on Reactor Safeguards Subcommittee on Future Plant Designs

Docket Number: n/a

Location: Monroeville, PA

were held as herein appears, and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission taken by me and, thereafter reduced to typewriting by me or under the direction of the court reporting company, and that the transcript is a true and accurate record of the foregoing proceedings.

Donna Willis

Donna Willis
Official Reporter
Neal R. Gross & Co., Inc.

SQUIB VALVE

CONAX florida
A Cobham plc company

AGENDA

- Overview of Conax Florida Corporation
- GE SBWR ADS (AP600 ADS 4) Valve Development
- AP1000 ADS 4 Valve
- Squib Valve Reliability

CONAX florida
A Cobham plc company

OVERVIEW OF CONAX FLORIDA CORP.

CONAX florida
A Cobham plc company

CORPORATE OVERVIEW

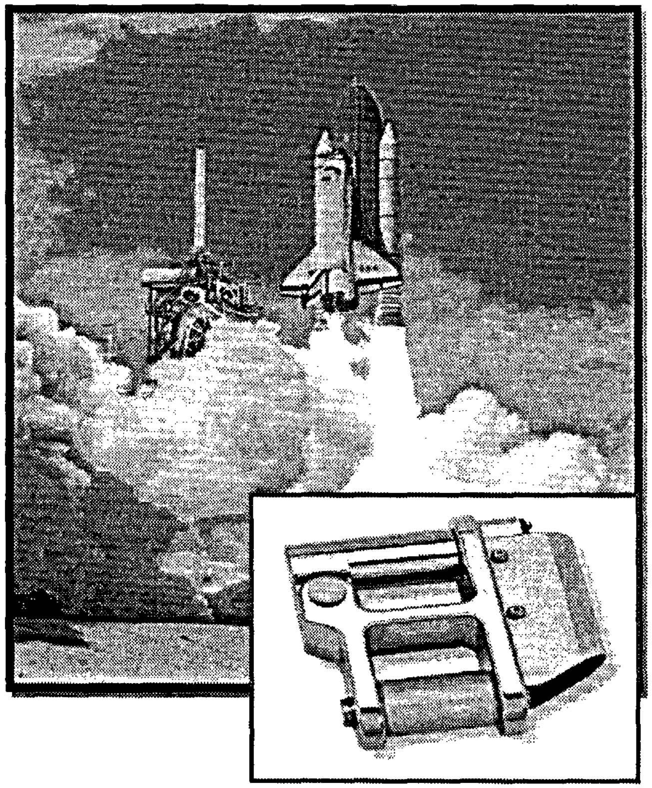
- Conax was founded in 1948.
- First developed electro-explosive devices in early 1950's.
- Conax Florida subsidiary was formed and moved to Florida in 1982.
- Facility was ISO 9001 certified in September 1997.
- Conax was purchased by Cobham plc of Dorset, England in 1998.
- Employ approximately 150 people.
- $30 million in annual sales.
- Located in St. Petersburg, Florida

CONAX florida
A Cobham plc company

Aerospace Systems

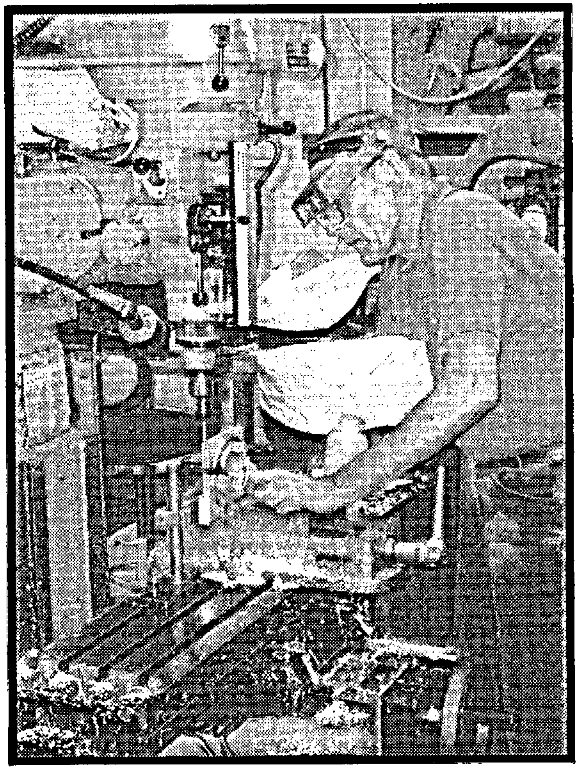
- Utilize Conax's proprietary electro-explosive technology to actuate and control critical systems.

- Conax Products Include:
  - Pyrovalves
  - Stored Gas Systems
  - Water Activated Systems Systems
  - Pin Pullers & Cutters
  - Actuation Systems
  - Complex "Build to Print"

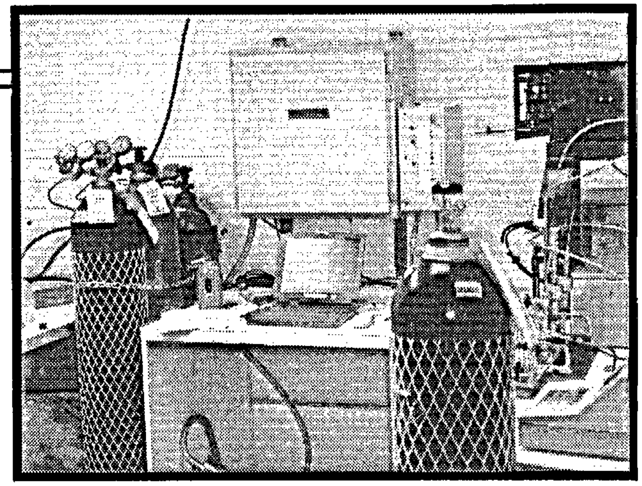


- Advantages:
  - Fast Acting
  - Solid Metal Seal
  - Reliable & Environmentally Durable
  - NASA Sponsored & Qualified

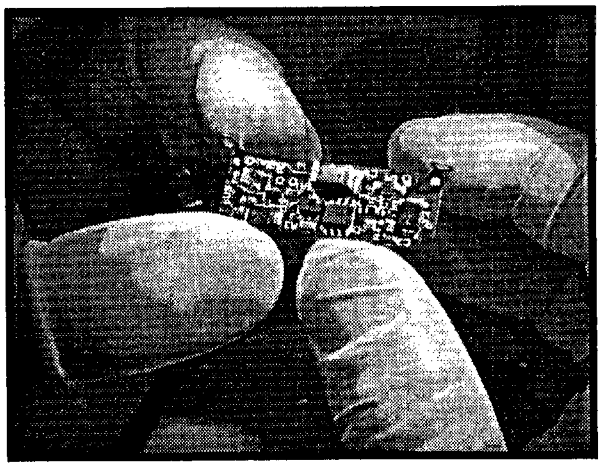
Class 10,000 Clean Room



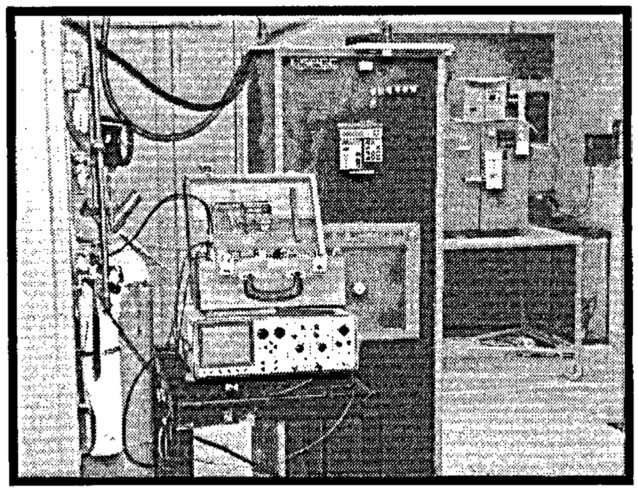
Prototype Shop



Gas Purity Testing



Electronic Assembly



Environmental Testing

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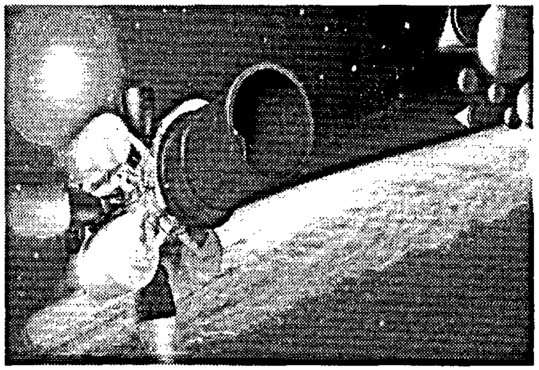
CONAX MAJOR PROGRAMS

Space Systems
Atlas
Titan
Space Shuttle
Centaur
EELV
Delta
Taurus
Pegasus
AXAF
A2100
HS601
HS702
Mars Surveyor
PanAm Sat
NSTARC

Under Sea
MK-46 Torpedo
MK-48 Torpedo
MK-50 Torpedo
MK-67 (SLMM)
ADCAP Mine Torpedo
Arctic Buoy
CCAPS

Build To Print
Acoustic Counter-Measure
Submarine Separable Cover
Javelin Flex Assy.
Torpedo Nose Assy.
Smoke Generator

Missile Systems
Javelin
EKV
BAT
THAAD
Tomahawk
Tactical Tomahawk
Standard Missile
Minuteman
MX



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CONAX QUALITY ASSURANCE

Certification

- Quality Assurance System ISO-9001 Certified
  - November 1997
  - January 2001
- Quality System in Compliance with AS-9100
  - International Aerospace Quality Group

GE SBWR ADS VALVE DEVELOPMENT

- General Electric initiated contact with established valve suppliers throughout the world (7 bidders)
- Pyronetics proposed valve simplest design approach
  - Based upon Pyronetics 2" ID flow passage valve
- General Electric provided a list of Pyronetics customers
  - Some of Pyronetics customers contacted
- General Electric concluded OEA Pyronetics was capable of designing, manufacturing and testing squib valves (7" ID)
- Contract awarded to Pyronetics
- Westinghouse AP600 ADS 4 is same ID as GE valve
- Westinghouse AP1000 ADS 4 is simply scaled-up AP600 / GE SBWR valve

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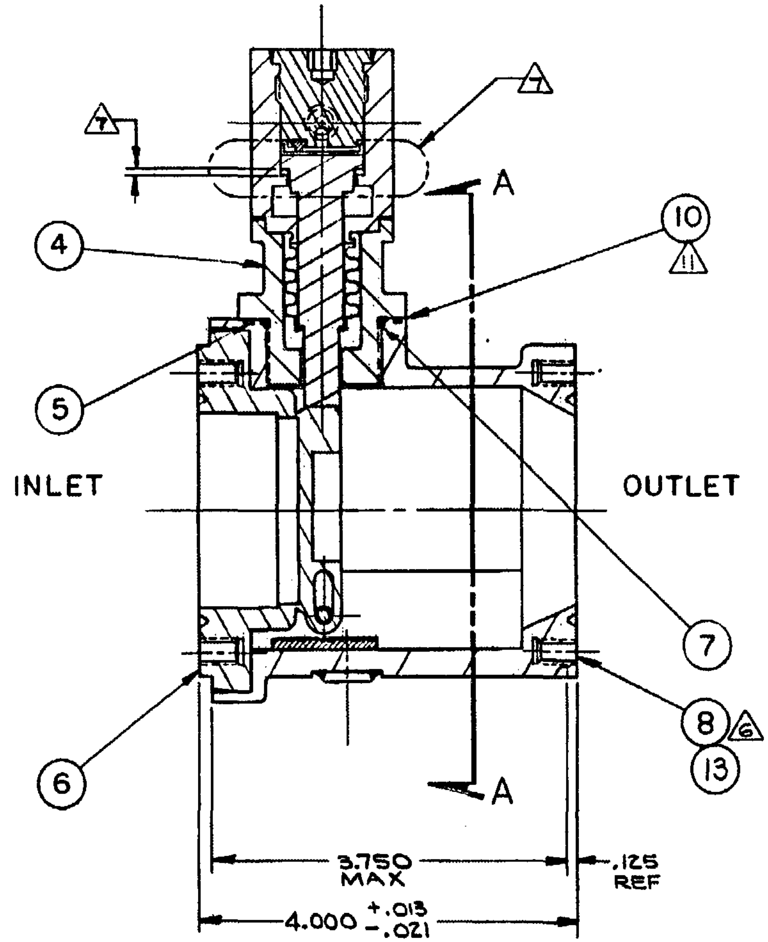
2" ID OEA DESIGN

Design of 2" ID flow passage valve



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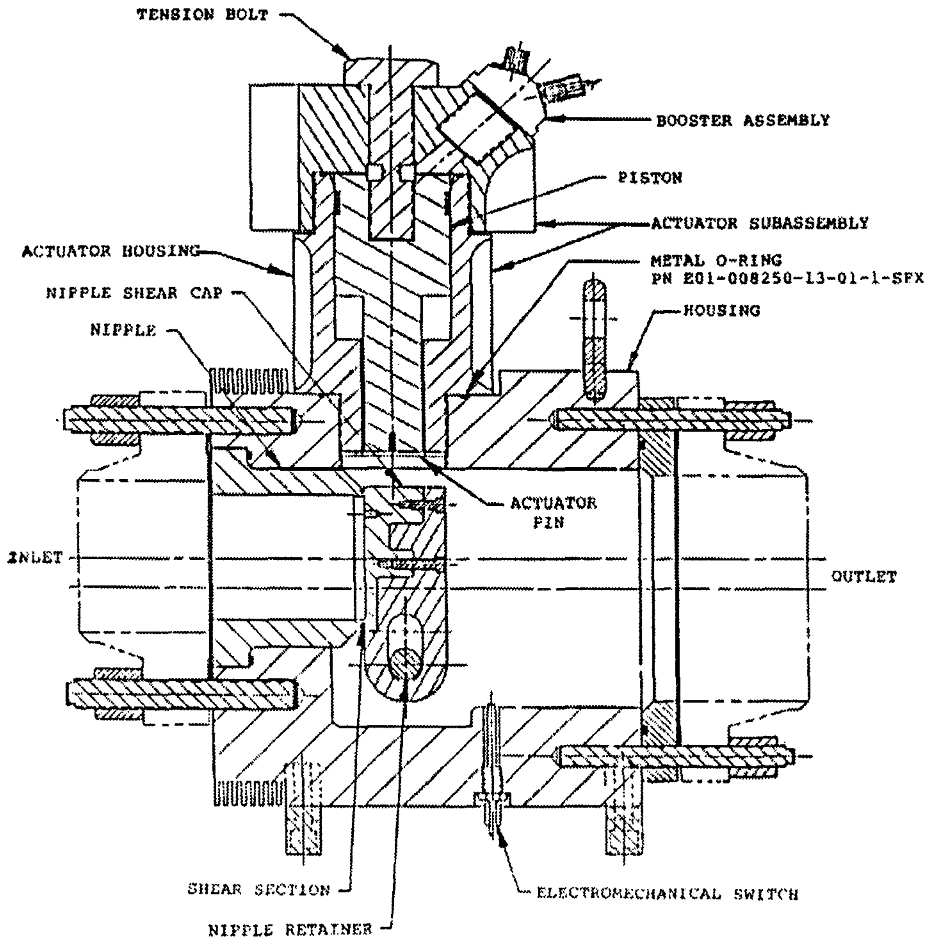
GE SBWR ADS DESIGN

Design of SBWR ADS (7" ID) - closed



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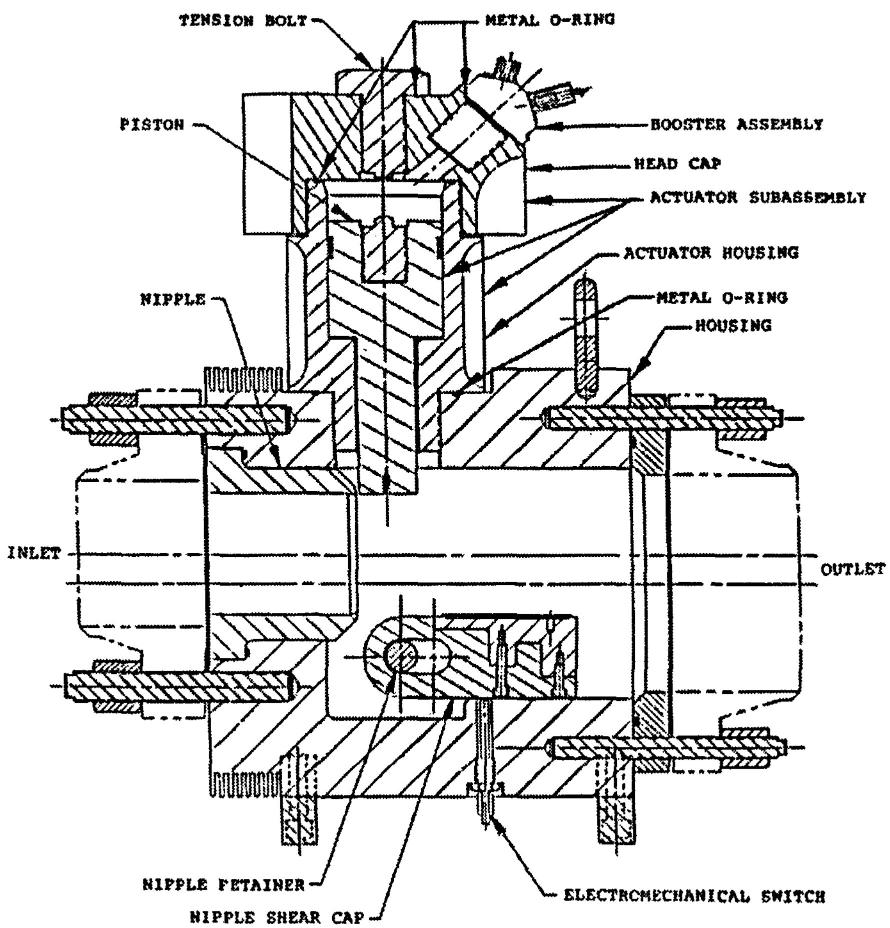
GE SBWR ADS DESIGN

Design of SBWR ADS (7" ID) - open



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TEST PROGRAM PERFORMED

Acceptance Tests

- Examination of Product (full size, pressure rating)
- Hydrostatic Testing
- Leakage (inlet pressurized)
- Thermal Exposure – Inlet conditioned to 550°F and surrounding air temperature 190°F (actuator met <280°F requirement)
- Cleanliness Verification

Valve Development Test Sequence

Development Tests (1)	SERNO 1	SERNO 2
First Actuation	1	1
Second Actuation	2	

(1) Both units delivered to GE for additional testing subsequent to Pyronetics testing

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TEST PROGRAM PERFORMED ON INITIATOR BOOSTER

Closed Bomb Testing:

- At temperature
- 100% and 80% booster load

Lab Samples Testing:

- Thermo Gravimetric Analysis (TGA) scans to determine thermal degradation as a function of time and temperature,
- Differential Scanning Calorimetry (DSC) tests to determine change of state temperature and temperature regimes of interest,
- Isothermal tests to determine the amount of weight loss.

Radiation Testing:

- Boosters: 2.31×10^7 rads Total Integrated Dose (TID)
- Position switch and cables 5.6×10^7 Rads TID

INITIATOR/BOOSTER TESTING (con't)

Accelerated Thermal Aging:

- Boosters: 25 days at 360°F (simulating four year normal life)
- Cable Assemblies: 69 days at 374°F (simulating ten year normal life)
  - Did not meet requirement. Design changed to use different epoxy.
- Position Switch: 54 days at 360°F (simulating ten year normal life)

Reliability Testing:

- All units met performance requirements

SBWR ADS VALVE TESTING

Seismic and other dynamic loads evaluated

- Vibration Testing
- Actuation / Flow

AP1000 ADS 4 VALVE

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PERFORMANCE REQUIREMENTS

	AP1000 ADS 4	SBWR ADS
Nominal Size	Inlet: 14 inch Min ID: 9.24	Inlet: 8 inch Min ID: 7.00
Valve Body Material	SS (316L)	SS (304L)
Safety/Seismic Class	1 / 1	1 / 1
Design Pressure	Inlet: 2485 psig Temp: 650°F	Inlet: 1500 psi Temp: 595°F
Seat DP, Forward	Inlet: 2500 psig	Inlet: 1500 psig
External Temperature Range, Normal	120°F to 50°F	190°F
Radiation Level	.5x10^7 RAD (ten years)	2.31x10^7 RADS (four years)
Open Pressure Range	Inlet: 1 to 2500 psig	Inlet: 1 to 1500 psig
Design Life of Booster	8 years target	4 years

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AP1000 ADS 4 VALVE DEVELOPMENT

1. Design

   - Scale up design from SBWR ADS valve
   - Analysis Design Report (ASME Code)

2. Development/Prototype

   - Testing similar to previous SBWR ADS program.
   - Tests planned:
     - Charge sizing
     - Inspection
     - Hydrostatic and Leak Testing
     - Vibration
     - Actuation (over and under loaded boosters)

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RELIABILITY

- **High Reliability Requirements**
- **FMEA (preliminary sample)**
- **Design Shear Section**
- **Reliability of Squib Valve**
- **IST Replacement of Charges**

HIGH RELIABILITY IS REQUIRED

- Our customers require high reliability
  - Life Support programs
  - Aerospace programs
  - Consequences of failures are high

- Conax procedures control high reliability

- Custom Valve Designs / Up-Scaling is Standard Process
  - Simple valve design reduces problems
  - Development process is able to deliver highly reliable valves

HIGH RELIABILITY IS BUILT IN

Design / Analysis

- Past experience with similar products (lessons learned)
- Design analysis of new design
- Examination and analysis of drawings
- FMEA
- Reliability analysis

Testing

- Development and prototypes units
- Margin testing (over and under loaded boosters)
- Acceptance and qualification
- On propellants (powder form and in initiators and booster)

Quality Assurance: ISO 9001 Certification

DESIGN SHEAR SECTION

Design:

- Shear section is standard pyrovalve design feature
- Concept proven on thousands of valves
  - No leakage ever reported on delivered product
  - Thickness as small as 0.003 inch and thicker
- Concept same as for AP600 / SBWR ADS
- Designs meets ASME code Section III, Class I
  - NB3200, Design by analysis

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DESIGN SHEAR SECTION

Corrosion Affects

- 316 L Material selected for the con-o-cap (i.e. shear section):
  - Material compatible with planned system media
  - Not subject to stress corrosion cracking like numerous other materials

In Service Inspection

- Designed for ease of removal for inspection

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RELIABILITY SUMMARY

- UPCO reliability of:
  - .999568 at 90% confidence
  - .999437 at 95% confidence
    - Valves manufactured: 64,690
    - Total quantity fired: 5,324

- Conax reliability of:
  - .9998169 at 90% confidence
  - Based upon:
    - Total initiators >25,000
    - Valves manufactured: >25,000

- Sandia reliability of:
  - .999839 at 90% confidence
  - Based upon:
    - Initiators manufactured: 25,000

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RELIABILITY

- Squib valves have high inherent reliability
  - Reliability for smaller valves applicable for larger valves
    - Same design standards established
      - > Engineering Analysis
      - > Proof and Leak Testing
      - > Over and under loaded boosters used during testing
      - > Design concept similar (shearing material) in all cases.
  - No failures associated with shear section cracking under constant high pressure and temperature

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