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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

FUTURE PLANT DESIGNS SUBCOMMITTEE

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MEETING

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ROCKVILLE, MARYLAND

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TUESDAY

JANUARY 13, 2003

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The Subcommittee met in Room 2TB3 at Two White Flint North, 14555 Rockville Pike, Rockville, Maryland, at 8:30 a.m., Thomas S. Kress, Subcommittee Chair, presiding.

<u>PRESENT</u>

THOMAS S. KRESS, Subcommittee Chair
GEORGE E. APOSTOLAKIS, ACRS member
F. PETER FORD, ACRS member
GRAHAM M. LIETCH, ACRS member
VICTOR H. RANSOM, ACRS member
STEPHEN L. ROSEN, ACRS member

PRESENT (Continued):

WILLIAM J. SHACK, ACRS member
JOHN D. SIEBER, ACRS member
GRAHAM B. WALLIS, ACRS member

NRC STAFF

LAURA DUDES	NRR
BELKYS SOSA	NRR
DON CARLSON	RES
WALTON JENSEN	NRR
STEVEN JONES	NRR
JACK ROSENTHAL	RES
PATRICK SEKERAK	NRR
MARTIN STUTZKE	NRR
EDMUND SULLIVAN	NRR

AECL TECHNOLOGIES

JOHN POLCYN
PETER BOCZAR
PETER CHAN
RAJ JAITLY
VINCE LANGMAN
MARC LEGER
JULLIAN MILLARD
DAVID RICHARDS
STEPHEN YU

C O N T E N T S PAGE

PROCEEDINGS

(8:29 a.m.)

CHAIRMAN KRESS: Will the meeting please come to order?

This is a meeting of an ACRS subcommittee on future plant designs.

I am Thomas Kress. I am Chairman of this particular subcommittee. Members in attendance are practically everyone, which is good because that was my request. They included: George Apostolakis, Peter Ford, Graham Lietch, Victor Ransom, Steve Rosen, William Shack, Jack Sieber, and Graham Wallace.

The purpose of this meeting is to discuss the advanced CANDU reactor ACR-700 design features and the related pre-application reviews. The subcommittee will gather information, analyze relevant issues and facts, and formulate proposed positions and actions as appropriate for deliberation by the full committee.

Medhat El-Zeftawy is the designated federal official for this meeting.

Rules for participation in today's meeting have been announced as part of the notice of this meeting previously published in the <u>Federal Register</u> on December 22nd, 2003.

A transcript of the meeting is being kept and will be made available as stated in the Federal Register notice. It is requested, therefore, that speakers, number one, identify themselves, their name and organization they're with and speak mostly loudly enough that we can all hear, and be sure to use a microphone.

We have received no written comments or requests for time to make oral statements from any members of the public regarding today's meeting.

I'd like to point out to the committee members that this is a briefing and to acquaint us with the design and safety analysis approach of the ACR-700. We're not yet dealing in severe accident space at this meeting, and we don't expect to have a letter on this at this time.

But I'm sure that the AECL Canadian representatives would be interested if we have any early concerns. We could get them by voice here, and they could be then prepared to address them at some later meeting.

I'm not sure if we have any particular early concerns. My reading of the information we have so far, which is pretty extensive -- it took quite a while -- is some of the things we need to do is we need to look at the codes that they've used and their status of validation, what experiments they have done.

It looks to me like they have a good set of design basis accidents that are equivalent or even more stringent than what we have. I like their defense in depth. It looks very good to me. It looks like it's as appropriate as ours with the right diversity and redundancy on key safety tissues.

I like their use of what I call FC curves for acceptance criteria, and they look fully equivalent to some of our acceptance criteria. They're mostly in doses and design basis space.

I think we have to look at their PRA, which won't be part of this particular meeting yet, but maybe in the future. Particularly look to see if it meets our quality standards for PRAs.

I think their "design to" safety goals meet the U.S. expectations for higher level safety for advanced reactors. Those are just some of my early, early impressions of the written material. So I'm not at all negative about the design. I think there are some issues that we'll want to discuss and learn more about. Maybe if members have any, they can express them either now or later as we go through the meeting.

So do I hear any comments from other members before we get started?

(No response.)

CHAIRMAN KRESS: Seeing none, I'll turn to our agenda for today, which is long and tight, and I expect I will have to exercise some control over it this time. So I hope the members understand if I cut out some debate at this time. I don't want to inhibit some of our question asking, just some of our debate back and forth. We can do that later. But ask all the questions you like.

At this time I'd like to move to the second part of our agenda which is the introductory comments from the NRC staff, and I presume Laura Dudes will do that.

MS. DUDES: Good morning. I'm Laura Dudes. I'm the Section Chief for the New Reactors Group in the Office of Nuclear Reactor Regulation.

We are so pleased to come before the ACRS today to present our approach for the pre-application review for the ACR-700 reactor design. We consider this meeting an important step in a process that is going to take us down quite a few different roads and challenges in the next year.

We intend to discuss today our planned approach for our technical reviews, our approach to address regulatory infrastructure needs to a certain extent, and policy issues that may need to be communicated to the Commission.

I'd like to take this time to actually welcome AECL Technologies to this first ACRS meeting and also to acknowledge members of the Canadian Nuclear Safety Commission who are here today to observe this meeting as part of our ongoing international collaboration efforts on this project.

Briefly, the pre-application review began in mid-2002 and was divided into two phases. Phase one was a design familiarization process in which the staff participated in several informational meetings and facility tours in order to gain an understanding of the overall design and operation of the ACR-700. Phase one completed in the summer of 2003.

Phase two, which we're in now and which includes presentations to the ACRS as we go through this, includes the more specific review of the design features of the ACR-700. Phase two, however, will not necessarily draw regulatory conclusions on all issues reviewed during the pre-application phase.

The key focus topics that will be reviewed during phase two have been designated by the applicant, AECL.

The staff is presently in the early stages of their technical review, and our goals here today are simple. AECL will be presenting an overview of their design, and the staff hopes to discuss their technical approach to some of the more challenging issues and key focus topics; hopefully call out a process and a plan that we plan to use to approach regulatory challenges and policy issues that may need to go to the Commission in the future.

Thank you.

CHAIRMAN KRESS: I wonder if we could ask the Canadian safety --

MS. DUDES: Members to stand up?

CHAIRMAN KRESS: -- members to stand so we can know who they are.

MS. DUDES: Sure.

CHAIRMAN KRESS: I'm not sure we're familiar with all of them.

Wow. I won't bother to ask you to introduce yourself. We're very happy you're here, and please feel free to take part in any of the debate or discussion if you'd like.

Thank you very much.

MS. DUDES: As you can see, our international collaboration effort is going quite well on this project.

CHAIRMAN KRESS: Thank you, and with that, we'll get started with the meat of this meeting and turn it over to the AECL representatives for their introductory remarks.

MR. POLCYN: Good morning. My name is John Policy. I'm the President of AECL Technologies, which is the U.S. subsidiary of AECL. So I'm responsible for the deployment of the ACR-700 in the U.S., if you will.

Echoing Laura's words, I'd really like to thank you for the opportunity to come before you this morning and to talk about the ACR-700 and provide you an overview,

I want to acknowledge, too, Jim Lyons and Belkys Sosa on the NRC staff and project management for being so cooperative, so open with us. In terms of collaboration, we've had a lot of interaction. We've had visits by staff to our Chalk River laboratory and our White Shell facility.

One thing about the ACR-700. It is based on proven technology, on the CANDU technology. There's 34 plants operating, units operating throughout the world, 22 of which are just north of the border.

I want to acknowledge CNSC as well. We're kind of running a parallel path right now. We do have a high level of interest in Ontario for new nuclear generation. So I think it's very important that we do work collaboratively.

Relative to the U.S., I will tell you that we do have a couple of very serious customers. So going back to what Tom said, it's very important that we understand what issues you have and get those on the table and discuss them and come to -- you know, at least develop a road map for resolution of those issues.

We feel like we owe that to our customers because we certainly don't want to impact their schedules. We have been included in the envelope of the three early site permits that have been filed by Exelon, Intergy, and Dominion, and also continue to work with other utilities as well that have shown an interest in the ACR-700.

I will tell you that we feel like we're a little bit unique. We're very open. We have nothing to hide. We don't have all the answers. We want to work with you in a very collaborative, open basis, have a lot of interaction so that we do understand the issues and concerns and questions so that we can respond to them or come back to you with the appropriate answer and with the right people.

With that, what I'd like to do is just take a couple of minutes and introduce our technical experts that we brought with us today, and I would ask them to stand so that you can see them so that we don't have to do a jack-in-the-box and introduce each one individually as they come up.

I'll be turning this over to Stephen Yu, who's our program manager for the ACR product development. He's going to provide an overview of the ACR and its key features.

Following Stephen will be Vince Langman. Vince is our ACR design certification program manager. He'll review our pre-application scope and expectations from the staff and talk about the feedback from the pre-application program which is key to the continuation of our certification and future licensing resource expenditures here in the U.S.

Vince will be followed by Mar, Leger, who's the Director of Materials Engineering. He'll discuss the unique design of the ACR pressure tubes and fuel channels, and when I say unique, you'll see design features that are not incorporated into any PWRs or BWRs, but they're absolutely integral to the horizontal core and operational philosophy.

And I will remind everybody that we do consider the ACR-700 as a light water reactor that happens to use heavy water simply for moderation.

Following Mark will be Dave Richards, who is the manager of AECL Code Center and Software Performance. He'll discuss our computer code development and qualification, and as you'll hear in Vince's presentation, AECL has acknowledged that our computer software quality will be one of the key focus topics from the staff's review. So Dave will be able to address those concerns, those questions.

Following Dave will be Jullian Millard. He's our manager of ACR reactor and fuel handling who will discuss our on power fueling. This is another feature that's absolutely integral to the ACR, and that it makes possible the use of SEU and allows us to reach the high capacity fractures that our U.S. utility customers and worldwide customers have made the requirement.

Following Jullian will be Peter Chan. Peter is our team leader for ACR physics and fuel. He'll discuss a topic that has been of high interest to everyone, and that's negative void coefficient. That was the subject of much interest in the CANDU-3 days.

Following Peter will be Peter Boczar. Peter is our Director of Reactor Core Technology, and he will provide a more detailed description of the ACR fuel design, and ACR fuel being another design feature that substantially departs from PWR and BWR concepts here in the U.S.

And then lastly, Raj Jaitly, who's our manager of PSA and safety design, will discuss AECL's PRA methodology that we intend to use to design and evaluate the ACR on an ongoing basis.

And with that, I'll turn the program over to Stephen Yu, who will give you a design overview of the ACR.

Thank you.

MR. YU: I guess I will first sit down so that you can see the screen.

DR. WALLIS: That's the first test.

MR. YU: That's the first one.

CHAIRMAN KRESS: Why don't you hook up the portable one to him?

MR. YU: Good morning. In terms of the initial talk, it's to give an overview so that later on in the morning when they provide the discuss on the focus topic so that you know in what relationship to the rest of the main features of the ACR design.

I am in charge of a team that has been working on this for the last two and a half years now. The team is made up of NSPHN group (phonetic), plus the safety and licensing group, and so we have proceeded and defined the concept. We're now very much working plus the detail so that we will be able to put together a design control document for later submission on design certification.

So our work is nowhere complete, but we certainly have defined a lot of the design features that we are going to use. So there's still some optimization that's going on, which when we delve into details, some of the design details are being evolved taking into consideration of some of the initial feedback from the review as well as from constructability, operational feedback. We are incorporating some further design changes into them.

So the other item in my talk is mainly on the general design features like the fuel, which you will hear more about.

DR. WALLIS: I'm interested. How do you optimize the design? You've got various criteria for optimization, one of which is economics and one of which is safety. How do you trade these off in an optimization of a design?

MR. YU: Certainly the basic safety principles of ACR is inherently in the traditional way that we have done our safety criteria. We are following the regulatory guide that has been established for the design principles.

Certainly when you are trading off CANDU design features which are operational features, that's no different than what we have always been doing as to, you know, how much complexity do you introduce versus, you know, that how to simplify the design so that it's easier for it to operate.

Cost is certainly a consideration. A lot of them that we are looking at a specific cost target. Other pieces in the different parts of the plant. Certainly safety is paramount. We need to be able to make sure that we meet the safety acceptance criteria with margins.

DR. WALLIS: So they're a constraint. They're not part of the optimization costs?

MR. YU: They are the constraints that we need to meet, yes.

DR. APOSTOLAKIS: Did you also include, in addition to cost and safety, any of the other objectives that have been articulated by the Department of Energy for future reactors or you don't consider this a future reactor, like sustainability, security, and so on?

MR. YU: We look at in the GEN-4 studies --

DR. APOSTOLAKIS: Yes.

MR. YU: -- essentially we are looking at accessibility in terms of fuel cycles, in terms of the ability of CANDU to be able to burn different materials, and certainly we are looking at our features so to make sure that it's able to carry through.

I think certainly our change to light water coolant, as well as certain enriched uranium fuel, which is really a step in the direction that we'll be able to use MOX fuel and other fuel cycles. And that, in terms of your end utilization and so on, that would be an objective in the very beginning set in the concept.

But the details is really we take an evolutionary step, making some radical changes initially for the design concept, and then stick with that and proceed with the design by itself.

DR. APOSTOLAKIS: So these other objectives are sort of secondary here?

MR. YU: We want to make sure that we can move in that direction, but not essentially trying to optimize it for that at this point in time, but we are looking at major obstacles that might prevent us. Then we will look again.

So on to highlight some of the engineering safety features because that will be a key element of the safety design. I want to give a brief introduction of an approach in the severe accident features and the mitigation. This is a big subject. So I'm only touching the surface in this overview, and also some of the operational features in the design itself.

In terms of ACRS, I mentioned that we are doing an evolutionary extension of our CANDU 6 plant. The picture that you see are the two 600 megawatt design that's now operating in China, which is the latest version of the CANDU 6 design that we have.

We still have one unit under construction in Romania.

When we talk about the core of the design, this is the calandria, which is the equivalent of the reactor core vessel, but the calandria is really a low pressure vessel, and it contains the moderator, while you see the entity coming off on the ends. This is really the connection to the pressure tube within the reactor itself, and that's where the other connections to the reactor cooling system.

CHAIRMAN KRESS: I would have called the calandria -- I wouldn't have called it part of the reactor coolant pressure equivalent. I would have called the pressure tubes the equivalent of the reactor vessel.

MR. YU: The pressure tube would be the equivalent of the reactor vessel.

CHAIRMAN KRESS: Yeah, I thought you said the calandria was. I wouldn't have said that I don't believe

MR. YU: Thank you.

CHAIRMAN KRESS: So are we looking at the ends that would be connected to the refueling machine when we look at that picture?

MR. YU: Yes. As you can see here that the fueling machine would be connected to the ends of the fuel channel where the inputting and then connected to the pressure tube.

DR. ROSEN: The calandria operates at what pressure normally?

MR. YU: It operates at around 30 PSI.

CHAIRMAN KRESS: The refueling machines on each end become part of the reactor coolant system.

MR. YU: When it is connected to the reactor coolant system, yes, it forms the extension to the reactor cooling pressure.

MR. SIEBER: And the pressure there is about 2,000 pounds per square inch.

MR. YU: That is government (phonetic).

MR. SIEBER: Roughly, yeah.

DR. ROSEN: And you analyze loss of coolant accidents with the refueling machine in place and without?

MR. YU: The additional volumes in the refueling machine is such a small volume. So in terms of sterilize safety analysis, I don't think it's going to impact it.

Would they be assessed, Victor?

MR. SNELL: You analyze breaks in every -- I'm sorry. I'm Victor Snell, Director of Safety and Licensing for the ACR Project.

We analyze breaks in every pipe in the reactor coolant system. We analyze breaks which are initiated by the fueling machine, but if the fuel mission is on reactor and a break in another pipe occurs, as Stephen says, that role is not very important. What is important is whether the fueling machine actually can initiate a breach in the boundary, and that's part of the design basis. What is important is whether the fueling machine actually can initiate a breach in the boundary, and that's part of the design basis.

DR. ROSEN: Well, I was thinking more about whether the fueling machine can interact with a tube that fails while it happens to be on that tube and whether the effects of that interaction during a failure of the pressure tube or perhaps the end fitting has been analyzed.

MR. SNELL: We bound that by assuming one of the design basis accidents, assuming the fueling machine for some reasons backs off the channel without closing it.

DR. ROSEN: But then it would restrict the flow somewhat.

MR. SNELL: Well, the ejected containment.

CHAIRMAN KRESS: In your safety analysis, do you assume more than one pressure tube fails at a given time?

MR. SNELL: No. In fact, it's fundamental to the design that the pressure fuel failure must not propagate. It's fundamental to the pressure tube design.

CHAIRMAN KRESS: That's a design

objective.

MR. SNELL: It's a design requirement.

CHAIRMAN KRESS: It's not the biggest pipe anyway, is it? Your headers are bigger.

MR. SNELL: Yeah, the pressure tube is about that big around.

CHAIRMAN KRESS: And the headers are --

MR. SNELL: The headers are about eight inches.

CHAIRMAN KRESS: Okay.

MR. YU: The inlet, 20 inches; the outlet, 22 inches in diameter. So that really forms the biggest piping in the reactor coolant system.

DR. WALLIS: It looks beautifully simple until you put in all of the feeder tubes.

MR. SIEBER: Yeah.

(Laughter.)

MR. YU: Well, we do have quite a bit of connections.

So that's part of the optimization I did talk about. A change from natural uranium fuel with heavy water coolant and heavy water moderator in previous operating CANDU reactors to the use of light water as the coolant; I guess by virtue of that and the use of the enriched uranium that give us more fuel cycle flexibility, and also it does change the core size so that you can make it more compact, and the others that we are looking at similar designs, especially in the reactor coolant system that are operating at higher pressures and temperatures that give us a better efficiency.

And so that's what we have followed, the trend. And I think our operating pressures and temperature are still lower than the PWR, but the rest of the intrinsic CANDU features are retained.

So in terms of design features, Peter Boczar will give you more details on the fuel, but I think the characteristics of our fuel design has been, you know the half a meter long bundle and also our ability to change the fuel on power so that the two fueling machines are there to replace the fuel when the rich is burned up.

CHAIRMAN KRESS: You have several of these 1.6 foot long bundles in a tube. When they meet up with each other, is there any requirement that they meet up in a certain way?

MR. YU: No, because we have done all of our pressure job correlations, both totally in line as well as --

CHAIRMAN KRESS: As much off line as you

can get?

MR. YU: Yes.

CHAIRMAN KRESS: Okay.

MR. YU: So --

CHAIRMAN KRESS: So it doesn't matter how they meet.

MR. YU: That's right.

CHAIRMAN KRESS: This going to light water coolant and the increasing enrichment is an effective way, in my mind, to get rid of the negative void coefficient, the positive void coefficient. Did you get of it altogether?

MR. YU: Yes. That's one of our design requirements, is to have the negative void reactivity.

CHAIRMAN KRESS: Dysprosium in your second bullet there, is that a burnable poison?

MR. YU: It is a burnable poison, yes. It's one that we have quite a bit of experience in, in both using NRU and in some of the other experimental fuels that we have.

DR. ROSEN: Can you compare it for me with samarium?

MR. YU: I have to ask Peter to help me.

Peter Boczar.

MR. BOCZAR: Peter Boczar, ACL.

We chose dysprosium because its burnout characteristics matched the reactivity characteristics that were required for the ACR, and it was a naturally occurring fission product. So it turns out it is very compatible with the fuel.

DR. ROSEN: But samarium is more typically used than burnable poison, and so I'm just wondering why.

MR. BOCZAR: We considered a whole range of burnable poison, samarium, gadolinium, erbium, and this was the one that best matched the reactivity characteristics we needed for the ACR.

DR. WALLIS: You have no boron in the coolant?

MR. YU: No.

DR. WALLIS: So it's harder to detect leaks then?

(Laughter.)

CHAIRMAN KRESS: That's an inside thing.

MR. SIEBER: That's sort of a relative thing.

MR. YU: So further on the fuel, burn-up is around 21,000 megawatt days per ton. This is certainly about three times our current net uranium fuel burned up, although it's still much lower than the PWR fuel burn-up.

CHAIRMAN KRESS: Is there any limit in terms of core neutronics on what burn-up you could go to?

MR. YU: I don't think there's any limit in terms of core neutronics' viewpoint. I think, you know, that we want to have the more optimized uranium utilization, and that's how we arrived at it. Certainly it is the thoughts for the future we will be able to increase the burn-up of the fuel by adjusting the enrichment grading in the fuel bundles itself.

So this would allow also to get to, say, higher bundle power and lower rating than the current CANDUs.

MR. LEITCH: Did I understand you to say that there were 12 fuel bundles in a pressure tube; is that correct?

MR. YU: There are 12 fuel bundles in each channel, yes.

MR. LEITCH: Then I don't know if later we're going to discuss the fuel cycle. In other words, my question, when you get to the on-line refueling, do you change out all 12 or is there some kind of a stagger that is in effect there?

MR. YU: Certainly, you know, we will be

giving more details on that.

MR. LEITCH: Okay.

MR. YU: But we will be changing, you know, the two bundles from the front end, and then it will be moving progressively downward. So we're taking it from one end and putting the fuel bundles on one end.

MR. LEITCH: Okay. Thank you.

MR. YU: We have been looking at, you know, the different fuel replacement in the traditional operating CANDU. We have four bundle chips as well as eight bundle chips for the actual uranium, but for here, given the longer burn-up, so we are reducing the number of bundles that we need to replace each time because the rest in time in the core can be longer.

CHAIRMAN KRESS: Your clad, is it Zirlo?

MR. YU: The clad is Zircaloy, yes.

MR. LEITCH: So you're looking at two bundle shifts now?

MR. YU: Current reference, yes.

MR. LEITCH: So I think that's the direct answer to your question.

MR. YU: Two bundles, yes.

MR. LEITCH: Technically two of the 12

would be moved out.

MR. YU: Yes, that's right. We moved the higher burn-up one from the inner channel and then put new fuel in the front.

MR. SIEBER: That gives you a power peak toward one end of the reactor.

MR. YU: No, because our channels are oriented such so that one-half the core on alternate channel. You have the inlet going on one end, and the addition channel is at the outlet on the other end. So it does balance out.

MR. SIEBER: So each refueling machine can operate either as an inlet or an outlet machine?

MR. YU: That's correct, yes.

MR. SIEBER: All right.

MR. YU: It has the flexibility to be able to do that.

CHAIRMAN KRESS: How do you know? How are you able to decide which one of your fuel elements is defective if you're leaking fission products?

MR. YU: There is an overall detection knowing that there will be activity in the core, and then the fueling machine would be able to be located on the channels. It would be able to sample --

CHAIRMAN KRESS: Oh, you can sample from

any channel?

MR. YU: -- groups of channels or individual channels so that where --

CHAIRMAN KRESS: And so you can then narrow it down.

MR. YU: You narrow it down.

DR. ROSEN: Sample the coolant flow, yeah?

MR. YU: Sample the coolant flow.

DR. ROSEN: The outlet coolant flow.

MR. YU: Yes.

DR. FORD: In one of the articles I was reading, you would know this within two minutes, was the metric I heard. You can do this all in two minutes? Determine whether you have a leak in a tube within two minutes?

MR. SIEBER: Yeah.

DR. FORD: Is that right?

MR. YU: The leak in the tube, that's different from the fuel detection.

MR. SIEBER: Right.

MR. YU: And, yes, I think we're talking about a feature where we monitor the gas space in between the pressure tube and the calandria tube. I think I will be moving towards that.

By monitoring the gas space to detect

moisture, we'll be able to know whether there's any leak started in any of the --

DR. FORD: Okay.

MR. YU: So starting with shorter bundles it limits the amount of activity that contains noble gas within the bundles itself, and the clad of collapsible under the pressure of the reactor coolant system so as to enhance the heat transfer.

Also, because of the relatively low burn-up, obviously the internal pressure period should be small, and on the other hand, the fuel design is such that you look at the gas space allowance from within the pallet itself, between the clad and the pellet.

CHAIRMAN KRESS: How thick is your clad?

MR. YU: The clad? Peter? I

I don't know.

MR. BOCZAR: I'll give the answer when I give my presentation.

MR. LANGMAN: Vince Langman. It's the thicker clad, right? Yeah, I take it back.

CHAIRMAN KRESS: One reason for the question is I was wondering when you get the design basis space you have this requirement in our regulations that you can only oxidize a certain depth of the clad, but that's the U.S. fuel, and with its clad thickness and its type of clad, and I was just wondering how you'd -- I guess we'll get to that later, but how you deal with that issue if you have a different kind of clad thickness.

MR. LANGMAN: Right.

DR. SHACK: Have you changed cladding as you've changed cladding as you've gone from the CANDU 6 to the ACR?

MR. YU: No, it's immaterial.

DR. SHACK: It's Zirc-4 in both of them for the fuel clad?

MR. YU: Yes.

In the few channel design, it's where you can see this is the exact dimensions of a scale model of the pressure tube, which is the reactor coolant pressure boundary within the core and the calandria tube. The inner scarce space is where we monitor moisture. Normally we circulate through them.

CHAIRMAN KRESS: How did you decide on CO_2 in there? I was wondering perhaps why not --

MR. YU: Well, in earlier reactor design we had gone for nitrogen, but I think the isotopes that came out is not good. So coming to outside give us the best response. In terms of inner gas for insulation --

CHAIRMAN KRESS: Well, I guess helium would have a bad isotope, too, that you couldn't follow.

MR. SIEBER: Yeah.

CHAIRMAN KRESS: Okay.

DR. FORD: There's a whole range of materials degradation modes inherent in this graph, and this very sort of qualitative statements that have been made here, will those be covered later on as to the quantification of some of these items here and how that affects the kinetics of materials degradation?

MR. YU: Mark, can you answer whether they're going to be addressed further?

MR. LEGER: Mark Leger.

We will be addressing some of those degradation issues in the pressure tube presentation.

DR. FORD: Good.

CHAIRMAN KRESS: The only one you've observed so far has been erosion-corrosion?

MR. LEGER: No, in pressure tubes we don't see any erosion-corrosion.

CHAIRMAN KRESS: At the inlets?

MR. LEGER: At either end.

CHAIRMAN KRESS: Either end? I thought I read that somewhere.

MR. LEGER: We have had flow accelerated corrosion in --

CHAIRMAN KRESS: That's what I ready.

MR. LEGER: -- in other parts of the system.

CHAIRMAN KRESS: Yeah. Are these calandria in pressure tubes -- they're in a pretty high neutron fluence field. Are they subject to imbrittlement or will we discuss that later?

MR. YU: That will be part of the environment operating, yes, described further.

MR. SIEBER: I take the replacement tubes are replaceable then.

MR. YU: That's correct.

MR. SIEBER: All right.

MR. YU: And actually in current operating reactors, we have also replaced in some of the refurbishment projects we are also planning in some cases being able to replace the calandria tube as well if it needs be. But those are operating under low pressures anyway.

That is the relative comparison of the kind of changes that we have made and also the CANFLEX bundle with two different pin sizes. The bigger pin size is similar to what we have used before, but this is a smaller pin size which contains two rings in the CANFLEX bundle. This is what we have used in the ACR.

These fuel bundles have gone through reactor irradiation in one of the CANDU 6, despite the fact that it was using lesser uranium, but a lot of the elements have gone through lots of research environments to look at its performance and its behavior under different operating conditions.

CHAIRMAN KRESS: Have you subjected these to heat transfer tests to look at distribution of temperatures around the --

MR. YU: Yes, very much so.

CHAIRMAN KRESS: We ought to hear about that later maybe?

MR. YU: Yes.

CHAIRMAN KRESS: Maybe not this meeting but later-later maybe?

MR. YU: I think it will give you some high level view even at this meeting in terms of the measurements under, you know, the transient conditions. So the gap that I talk about, this larger gap as well.

DR. RANSOM: What is the pressure in the gap, the CO_2?

MR. YU: The pressure in the gap is

typically we just press around 30 psi as well, the celulor (phonetic). We just have it enough so that you would be able to circulate it using compressors around the different ends.

DR. RANSOM: So it's about the same pressure as the calandria then?

MR. YU: Yes. The operating pressure is about 10 psi. So it is within that design envelope, yes.

DR. ROSEN: And the eight internal rods are the only ones that contain the burnable poison; is that correct?

MR. YU: That's correct. The center rod is the only one that contained it.

DR. ROSEN: Only the center rod?

MR. YU: Only the center rod.

DR. ROSEN: Not the others of the -- any other rod in the bundle.

MR. YU: No. Only the center rod has the burnable poison. All the others just have the enriched uranium.

That gives you the range of operating pressures and temperature that we use in ACR. As I indicated, we extended our operating range to study higher, between 13.2 megapascal in the inlets of the pressure tube, while it's around 12 megapascal at the outlet pressure tube. Certainly when you have this (unintelligible) depending on where the pressure tube is located between the region.

Core (unintelligible) is around 2.5 millimeters thick. The diameter is around six inches.

MR. SIEBER: What is the peak clad temperature in normal operation at 100 percent power under these hydraulic parameters?

MR. YU: Normal operating peak clad temperature. Peter, can you please answer?

MR. BOCZAR: Peak clad temperature would be slightly above the coolant temperature.

MR. SIEBER: Okay. But we're really talking just a few degrees, right?

MR. YU: Yeah, normally it would be just a few degrees.

MR. BOCZAR: Yeah, Peter Boczar, ACL.

Peak clad temperature would normally be a few degrees higher than the peak coolant temperature.

MR. SIEBER: And you don't operate in a boiling position at all, right, or do you allow nucleate boiling?

MR. YU: We do allow boiling towards the end of the term.

MR. SIEBER: Okay.

MR. YU: And actually, our design condition is to have two percent quality at the outlet header, and so at the end of the channel, the last bundle, maybe a bundle and a half depending on channel power, would have some nucleate boiling.

DR. WALLIS: How is the power distribution across the channel? When you have this moderator on the outside and then you have slow neutrons coming in from the moderator, what's the difference between, say, the power per unit length of the center rod and the peripheral rods?

MR. YU: I think you can see a lot more of the details in the --

DR. WALLIS: We're going to see that later on?

MR. YU: -- in subsequent presentations

DR. FORD: You said at the end of the channel you do have some boiling. Obviously you haven't talked about the chemistry of the primary side here yet. We'll be discussing that and the impact of that if you have boiling?

Do you understand the question?

MR. YU: Yes, I understand the question. I think we didn't plan to get into the chemistry, in fact, for the reactor cooling system, but certainly the boiling impact on the fuel design on the heat transfer on the CHF, yes, it would be addressed.

DR. FORD: Okay.

DR. ROSEN: And the safety impact of the collapse of those voids under certain circumstances?

MR. YU: That's taking into consideration in the safety analysis.

DR. ROSEN: We'll hear more about that, too?

MR. YU: Victor, can you come?

MR. SNELL: I'm not sure you'll hear more about it -- this is Victor Snell -- I'm not sure you'll hear more about it at this meeting, but I'll give you a thumbnail answer, which is that we've kept the negative void reactivity fairly small in absolute terms for safety reasons. So actually the design center value is minus seven milli-K.

The amount of voice in normal operation is a very small fraction of that. There's not much boiling in the channels. So collapse of void in all operation has relatively small effect.

DR. ROSEN: Relative to the 7 MK?

MR. SNELL: Yes.

DR. ROSEN: What would you say? One

percent, ten percent?

MR. SNELL: I think it's about a milli-K or something to that. At most a milli-K. Peter?

Yeah, Peter is nodding. So it's about --

DR. ROSEN: So that would result in a positive reactivity insertion on void collapse of about one milli-K.

MR. SNELL: That's correct.

MR. YU: In terms of fuel channel, this gives you some more details of the end of the fuel channel itself. This is where the pressure tube rode (phonetic) into the end fitting, and we have two tube sheets in between. That's where the shooting for the end SEU (phonetic), and shooting for the surrounding is done by shooting water itself. So the end fitting is kind of anchored down onto the tube sheet using the positioning assembly.

In order to give the flexibility, the endless bellows is one that contains the gas boundary so that we would be able to give it the flexibility on relative thermal expansion, as well.

The connection to the reactor coolant system is through the what we call a feeder connection. Each of the piping that connects to the end fitting is on the side. It's not through the end.

The end is reserved for the fueling machine connection so that we have a channel closure that normally seals the reactor coolant boundary, and the fueling machine would be sequenced to take out the channel closure before and also take out the seal plug, which is the shooting (phonetic) at the end of the channel, and then the refueling action can take place after these two internals are removed.

So you will hear more details regarding the on-line refueling operation, but that is the basic sequence and the interfaces.

So the feeder connections are all identical at the entity itself, but the feeder routing at the reactor phase would be according to the relative where they were on the reactor phase itself.

DR. ROSEN: Before you get off this, I think that first bullet deserves some comment. This is a leak before break philosophy for the pressure tubes, usually before break, before piping, under certain cases as well, but we also include in the design basis space the instantaneous failure of the largest pipe in the system.

So do you take into account in safety case analysis a more stringent case than this?

MR. YU: Yes.

DR. ROSEN: The instantaneous failure of a pressure tube?

MR. YU: Yes. In the safety case, we do analyze the instantaneous rupture of the pressure tube and its effect on the injection into the calandria and also we even have to do a what if situation if it does break the calandria tube as well, although the design is such so that the moment is designed to contain the pressure tube rupture, but in the safety case we do analyze the other.

DR. ROSEN: The instantaneous case is analyzed in the safety case.

MR. YU: That's right.

DR. SHACK: Is this figure roughly to scale? Is the end fitting that long?

MR. YU: It is roughly. It is to scale.

DR. SHACK: To scale. Okay. Yeah, your drawing in your booklet isn't to scale, and I'm having a hard time reconciling the two.

MR. YU: I think what you see in the other case picture is from this tube sheet onwards because I think that, you know, you've got the two tube sheets. The only outer tube sheets can be seen.

DR. SHACK: Okay.

MR. YU: In normal operation, you know,

all of these would be inside a feeder cabinet as well so that when you look at the old review, you would not be able to see all of the details. So, yeah, P is a little bit shorter, especially the first picture you saw. It has, you know, the cover of the insulation.

So I think one thing I want to highlight is all our reactivity mechanisms, including the shutoff rods and also the poison injection, the past poison injection system, are all going into, they are located within the moderator space. So they are not in the high pressure system at all. So they go in between the lattice, outside of the calandria tube.

CHAIRMAN KRESS: I found it interesting that your control rods are separate from your shutdown scram rods, and you have, in addition to the scram rods, you have a separate boron injection system that will shut down the reactor.

MR. YU: We have a gadolinium injection system.

CHAIRMAN KRESS: Gadolinium, gadolinium, okay. So it's pretty good defense in depth, in my mind, from the standpoint of one of the key safety issues, and that is shutting off the reactor.

MR. YU: Yeah, we do have two safety grade fast shutdown systems, and in addition we do have, for normal power control, we have the additional rods so that we can have fast step-back, even to avoid the shutdown system to come in.

So that practically we do have the three means of shutting down.

DR. ROSEN: Why did you choose gadolinium for the injection system rather than boron?

MR. YU: Victor, can you?

MR. SNELL: I'm not 100 percent sure. My understanding is it's a lot easier to get out of the system once you put it in and that you'll gradually burn out as well, but I mean, that choice has gone back to the very early days of CANDU, and I think it was a matter once you get boron in the moderator, it's hard to get out again.

DR. WALLIS: So the thermal expansion of these tubes is quite a lot, isn't it? The pillars have to take up a lot of expansion.

MR. YU: yes.

DR. WALLIS: How much is that? It's quite a lot, isn't it?

MR. YU: Four inches?

DR. WALLIS: Four inches. It's quite -- well, that seems a lot to me.

MR. YU: Can you explain, please? Sorry.

Mark.

MR. LEGER: Mark, yeah.

The thermal expansion isn't very much, but there is some channel elongation that I'll be talking about.

DR. WALLIS: The elongation is due to neutronic effects?

MR. YU: Due to flux, yes.

DR. WALLIS: Change in the material itself.

MR. YU: Due to irradiation, it does creep with time. So I think into bellows they're to take up time.

DR. ROSEN: And that's a percent of the total elongation would you say that the neutron lengthening is 90 percent of 95 percent of the amount of lengthening you have to accommodate versus the thermal growth?

MR. YU: Thermal, thermal is very small in comparison. So I think certainly it will be five, ten percent at right range.

MR. LEGER: It's a relatively small fraction. I can work it out. I don't have it in my head.

DR. WALLIS: So the tubes, when they're

subject to all of this radiation decide to grow lengthwise rather than sag?

MR. YU: One thing that might be too small in here to show, we do have spaces. There are four spaces in the gap. We supported along the length, and they're fixing in place so that you do have interspacer small sag. That happens, and diametrically it will also creep.

DR. WALLIS: Don't spacers slide along the calandria tube?

MR. YU: Yeah, the spacers would slide along the calandria tube. It's tight around the pressure tube.

CHAIRMAN KRESS: The calandria tubes on the outside are not spaced. They can sag.

MR. YU: But the calandria tube is -- it's operating at a much lower temperature as well. So it hasn't got the pressure in it so that in terms of the formation, it would be much smaller.

DR. ROSEN: Well, does it grow lengthwise as well?

MR. YU: Mark?

MR. LEGER: It's not part of my presentation, but the calandria tubes don't change dimension very much in the reactor.

DR. ROSEN: Why is that? They're made of the same material.

MR. LEGER: No. The pressure tube is cold worked zirc-niobium, and the calandria tubes are annealed, stress relieved Zircaloy-4.

MR. YU: I think the operating temperature, as well as the pressure is subject to within the reactor coolant system, would thus create, you know, high stresses in making the creep bigger.

So in terms of core design, the on power refueling is also part for the long-term reactivity control because, you know, the channel fuel replacement would dictate how the core reactivity change would be. Typically a total of 9 milli-K in the control devices, and we have additional what we call control absorbers. They are used for fast power changes. If we need to step back to avoid the shutdown system from coming in, we don't need boron, as mentioned before in the reactor coolant itself.

The control rod ejection is not one of the analysis case that we need to look at because of the low pressure environment that it offered in, and it does not interact with the few.

DR. ROSEN: Now, if you have a pressure tube failure, clearly the calandria will go to a higher pressure.

MR. YU: Yes.

DR. ROSEN: But what is that higher pressure? Typically it operates at 30 psi, I think you said.

MR. YU: Yeah, roughly it is at the top of the calandria so that it would below at the design pressure itself.

DR. ROSEN: Which is?

MR. YU: Which is around the 30 psi. It's operating around ten.

DR. ROSEN: Oh, operating is ten?

MR. YU: Ten, 15, in that region.

DR. ROSEN: So if you lose a pressure tube, it will go to 30, and then the rupture disks will relieve.

MR. YU: Yeah. Temporarily it might be subjected to, you know, the pulse pressure, but then as soon as it's relieved --

CHAIRMAN KRESS: Where is it relieved into?

MR. YU: It is relieving into the vault (phonetic) itself, the reactor, the reactor building.

So this gives you --

DR. ROSEN: I mean, is that expected if

you have a pressure tube failure on the calandria?

MR. YU: No. I think, you know, that the expectation would be that it would pressurize the endless space between the calandria tube and the pressure tube, and then you would see possibly slow leaks through those small tubings were the gas normally circulates.

DR. ROSEN: Okay. So you don't expect the pressure -- calandria tube failure on a pressure tube failure?

MR. YU: Not normally, even though in analysis you assume that it might cause failure.

MR. SIEBER: Well, that's where the ballast is. Would it not --

MR. YU: The ballast would deform.

MR. SIEBER: Yeah, it would rupture that before it would rupture the tube, calandria tube?

MR. YU: It's possible, but I think, you know, that in terms of deformation pressure, you can take a lot more.

MR. SIEBER: Okay.

DR. WALLIS: So all of these tubes are unsupported over their length and the control system slides in between them?

MR. YU: The calandria tubes are not

supported along the length, no. It is relying on the two end tubes.

DR. WALLIS: So they must remain straight then. If they buckled in any way, they would interfere with your reactivity control devices.

MR. YU: That's correct. I think from operational reactivity viewpoint, some may say it would tie (phonetic), but that is small.

In terms of the reactivity mechanisms, they are all in the interspace between the lattice. So that's why, you know, in a gravity operation it would not interfere with the control mechanisms.

So certainly as part of the safety evaluation, you do assume the shutdown devices adjacent to the first pressure tube to be disabled. So it is apart of the analysis assumption that you assume that they are not affected.

DR. WALLIS: You're assuming that there is nothing to move them horizontally, but presumably if there is a flux distribution, they could have different irradiation on one side than the other, and if there are neutron effects changing the materials, this could lead to a change in the geometry of the tube.

MR. YU: I believe this is unlikely,

but --

DR. WALLIS: Well, presumably you have experience. I mean, you measured these things.

MR. YU: But operating experience is such that --

DR. WALLIS: So you don't really take the tubes every two years or something.

MR. YU: -- we have not observed those. We have not observed anything like that.

DR. WALLIS: Well, you may not have observed anything. You maybe observed something. It would be nice if you had observed something and you could bracket it.

MR. YU: Okay. In terms of numbers, we have a nine zone control, which is really for regional power adjustment, and we have full control of stubbers (phonetic). Those are the ones that that are used for fast power step-back or setback.

Shutdown system number one, we have 20 shutoff units, and there are six injection nozzles. In the safety system description I'll give you more details of that.

As already mentioned, the total (unintelligible) void is minus 7 million K.

DR. WALLIS: This prompt neutron lifetime, is the lifetime of a neutron from fission to absorption its whole lifetime, not just while it's prompt. I mean it's --

MR. YU: Peter, can you clarify?

DR. WALLIS: It must be its whole lifetime.

MR. CHAN: This is Peter Chan from the ACL Physics,

I believe our definition is the neutron, the lifetime from fission, from the fission born to being absorbed.

DR. WALLIS: Which is the whole lifetime.

MR. CHAN: The whole lifetime.

DR. WALLIS: So it's the neutron lifetime.

MR. CHAN: That's right, but for the plump part (phonetic).

DR. WALLIS: Yeah, yeah. There are so few of the delayeds.

MR. CHAN: That's right, yeah.

This is the neutron life and from the plump part of the neutron.

DR. WALLIS: Presumably also very closed the life of the delayed fraction as well once they've been emitted

MR. CHAN: Yeah, I believe so, yeah.

DR. ROSEN: And this total coolant void reactivity is if you lose all of the coolant in a channel; is that correct?

MR. SNELL: In the core itself, the entire core.

DR. ROSEN: The whole core.

MR. SNELL: The whole core. It's a full core void reactivity.

DR. ROSEN: All of the pressure tubes go dry.

MR. SNELL: That's correct.

MR. YU: Okay. I already mentioned about the two percent outlet quality in the reactor coolant system towards the other end, and the --

DR. WALLIS: Is this the equilibrium quality? So, in fact, because of subcooling, there would be a higher quality in terms of a fraction of steam.

MR. YU: No, this is the maximum quality that we're expected to operate.

DR. WALLIS: Is this the equilibrium thermodynamic quality or is it a physical quality taking account of subcoolant?

MR. YU: This is the fraction of steam weight quality in the reactor coolant system under steady state operation. I was going to say when the steam generator knew that it would have far more heat transfer, so initially all of our reactors operate in subcool conditions.

But this is design conditions, assume the design fouling (phonetic) for the steam generators before you arrive at that, based on operating experience that would arrive at, you know, at some time later, before you need to clean the steam generators and so on.

So I think this is the reference maximum.

DR. WALLIS: So the water leaving the tubes is saturated.

MR. YU: The water at the outlet header at saturation where the pressurizer is located, yes.

DR. WALLIS: I'm saying this because you know you realize that they could be subcooled and then it could condense on its way to the header. So I'm not --

MR. YU: No. I think in the reference design conditions, given two percent quality going into the inlet plenum of the steam generators, so we do have a condensation zone within the steam generator itself. So --

DR. WALLIS: This is an equilibrium.

MR. YU: -- heat transfer --

DR. WALLIS: It's essentially an equilibrium quality then.

MR. YU: Yes, yes, yes.

The last bullet references the fact that when you have a postulate to pressure tube and calandria tube rupture, the light water coolant would gain to the moderator that the mixing has the effect of reducing the reactivity. So it does smooth it in the right direction.

DR. WALLIS: Are the flow fluctuations with all of these parallel channels in operation?

MR. YU: Not according to our design. I think, you know, that actually in this diagram if you look at the interconnect between the two reactor header, its design function is to make sure that there is no channel-to-channel instability. So that's designed such so that you will avoid that.

Because it is a figure of eight loop, the reactor coolant goes through the core twice. Half of the channel has the inlet connected to one end. It comes out, and then it goes though a steam generator and heat transfer pump. And then it goes through the other half of the channel in the other direction.

CHAIRMAN KRESS: Now, these are staggered by the lines. One line would have one direction and the next line --

MR. YU: No. We have alternate channels both above and below. So if you look at the diagram, we have one going in the -- one next to it, both above, on the side, all four channels surrounding it in the opposite direction.

CHAIRMAN KRESS: Yeah, that's what I was saying.

MR. YU: Yes, that's right. On each roll that's what it is, and the adjacent roll is staggered.

CHAIRMAN KRESS: It's on each roll, right.

MR. YU: So the range of sizes that we have ranges from two inches on the reactor phase because of the space, and it goes to the three and a half inches for the outlet so as to balance the pressure drop. So we design each of the channels for equal pressure drop, sizes and lengths.

CHAIRMAN KRESS: How do you control the flow? Is it just because your headers are a big volume compared to the feeder lines?

MR. YU: That's correct. It's really a header --

CHAIRMAN KRESS: There's no individual orifice.

MR. YU: I think in the operating reactors you do. In this design I'm not too sure whether we need -- I don't think we need any orifices on this design. We have simplified it, especially the called profile is relatively flat for the ACR. We don't need to use orifices, but in CANDU 6 we have, to use for the outer channel especially. The TOX-4 file (phonetic) is more of the (unintelligible) across the reactor face.

So the parallel series palm (phonetic) arrangement, you always have two of these pumps operating in series. So on the prostrate pump issue, you still have the other pumps on the opposite end to push the coolant through the core.

These things are above the core so that when we analyze header breaks, that the remaining channels would still be refueled. Certainly after LOCA there's no preferred direction for the channel flow in the long term because the long-term cooling, which is the equivalent of the residual heat removal system, would be circulating the water through the header into each of the channels depending on where the postulated break is.

DR. RANSOM: The fuel tubes that are inside the matrix, are they spaced far enough apart, I guess, that the feeder pipes can flow, pass between the adjacent tubes?

MR. YU: Yes.

DR. RANSOM: In order for this coolant to get to the internal central, say, assemblies?

MR. YU: The space between the (unintelligible) is sufficient for oil (phonetic) feeders to conduct. So that has been our design for all of the CANDU reactors in the past. The layout is such that we would be able to, you know, given to unhook the feeders if we can to a single free channel replacement.

DR. RANSOM: Are you going to talk later about the seals that are -- you know, you have sealing between gas spaces, light water, then heavy water and, you know, passing through the shield tanks, as well as the calandrium. It seems like there are an awful lot of seals. I wonder if they're welded or if there are some bellows I know.

MR. YU: I think we will be talking about the row joints between the pressure tube and the entity, but that's really the only connection for the reactor cooling within the core itself. The other CUs are really to her self-contained boundaries because they are located in between, like the (unintelligible) is reoccupying the space in between. So from the bellow itself, it would have connection to the system for leak detection.

So I don't have a detailed diagram in here, but we can illustrate that further. Certainly you see some further cross-section of the boundary later on.

CHAIRMAN KRESS: Your feeder tube is Zirc-4?

MR. YU: No. Feeder tubes are stainless steel.

CHAIRMAN KRESS: And the headers are?

MR. YU: The headers are carbon steel.

CHAIRMAN KRESS: So this similar weld is where the feeder tube goes into the pressure tube?

MR. YU: Yeah. We have these similar welds at the top end here, close to the header.

DR. SHACK: Oh, so the whole feeder tube is stainless steel. I thought there was a transition to a carbon steel.

MR. YU: Yeah. I think we have been optimizing to see where would be for inspectability. So --

DR. SHACK: How about magnet type deposition of your steam generator tubes.

MR. YU: We did have that.

DR. SHACK: Yes.

MR. YU: In the current operating CANDUs. So I think in terms of erosion/corrosion, the original reference design to put all of the ICSIT (phonetic) as well as the bottom half of the feeders, all stainless steel, and then we have the challenge regarding the similar metal weld particularly from the inspection viewpoint as to how can we, you know, do good inspection, and we have been contemplating what is the best location for that.

So I think what we are hearing is really what our latest thinking is. It does not change the design itself, except that where the transition weld would be.

So it is now much closer to the header itself. It's still being finalized in terms of stress analysis, and then inspectability.

DR. FORD: So there's no decision about the details of these dissimilar metal welds between the carbon steel and the stainless steel structure?

MR. YU: The details have been worked out, except --

DR. FORD: So it will not be, I assume, a straight stainless steel to carbon steel weld. There will be some buttering. There will be some incanel alloys.

MR. YU: Well, I think it's a straight weld, but, Mark, can you clarify? I think it's a straight weld, but, Mark, can you clarify?

MR. LEGER: I don't have all of the details, but there would be involved -- it would have an intermediate metal, yeah.

MR. YU: So you will hear more about the on-power refueling, but this is the arrangement, how it is supported. The fueling machine head would be where the fuel bundle are being retrieved and stored and then take it out.

The way it is taken out is the fueling machine head would accept new fuel from the port at the containment boundary, and then going to the machine, and then once you have put into the reactor on the other side, it comes out and you put into the spent fuel receiving bay, and then the storage bay is where they would be stored.

CHAIRMAN KRESS: Is that storage bay inside your containment area?

MR. YU: No. The storage area is outside containment. That's our containment.

CHAIRMAN KRESS: Oh, that's your

containment.

MR. YU: That's our containment boundary.

DR. ROSEN: Now, these CANFLEX assemblies are in a horizontal position in the core, and they're moved out in a horizontal position.

MR. YU: That's right.

DR. ROSEN: Until they get to the spent fuel storage area, but then they have to be tilted, right?

MR. YU: That's right.

DR. ROSEN: Brought into the vertical position and slid down into the racks. Are you going to describe how you do that?

MR. YU: Well, I think you can explain that later in the on-line refueling. I think what we have done here is a little bit different from what it was before. In current operating reactors, they are stored in the racks, and they still remain in the horizontal position, but then when the transition to dry spent fuel storage, they are put into baskets and then put into the dry spent fuel storage.

So what we have done is to minimize the handling by designing the baskets within the bay so that they would be able to, you know, put into similar position and then so that it simplifies safeguards and so on.

DR. ROSEN: But you have to make the tilt, the up ending --

MR. YU: Yes, that is correct.

DR. ROSEN: -- in this operation, and that's what I'm interested in.

MR. YU: That is the fuel transfer system to be able to do that.

CHAIRMAN KRESS: While you've got that picture and it's on my mind, could you tell me a little about the containment, how bit it is in volume and pressure, design pressure?

MR. YU: The containment, it is 39.5 meters in diameter and 59 meters height to the bottom of the dome, and the containment thickness here is about 1.2 meters, and the dome thickness is around one meter, and the containment free volume is about 58,000 cubic meters. The design pressure --

CHAIRMAN KRESS: And it's a free standing steel structure?

MR. YU: It is a steel lined pre-stress containment. The design pressure is 450, which is really being dictated by the steam line break.

DR. SHACK: The impression I get is that this is different than the CANDU containment.

MR. YU: Yes.

DR. SHACK: What's the difference?

MR. YU: The CANDU 6 containment do not have a steel line. It has a plastic liner, and also the criteria for the peak pressure are different in our reference (unintelligible) environment. So it does be able to withstand the main peak pressure. So the design pressure is generally slower in the CANDU-6.

And also, CANDU-6, I must add that we do have a dousing tank which is to reduce the peak pressure at the top of the dome. For the ACR design we have adopted a dry containment.

CHAIRMAN KRESS: I hate to inhibit questioning, but we're getting already behind time. Can we go --

MR. YU: I think I need to go faster.

CHAIRMAN KRESS: I know it's our fault, but could you please.

MR. YU: Okay.

CHAIRMAN KRESS: And we'll try to restrain ourselves a little bit.

MR. YU: So shut-down systems, I think that, you know, it shows the reactivity mechanisms back here, and I'll give you a cross-section of the shutdown system number one. The absorber material is in the kind of flat, rectangular cross-section. Normally, you know, that is packed outside the core, and it is dropped by gravity into the core itself, and the mechanism to drive is really to raise it up to the reactor scram.

CHAIRMAN KRESS: There's 20 of those?

MR. YU: We have 20 of these, yes.

CHAIRMAN KRESS: And you only need ten of them to shut down the --

MR. YU: Sorry?

CHAIRMAN KRESS: You only need ten of them to actually shut down the reactor or do you need all 20 of them?

MR. YU: I think we do have margins, but not ten. We need to postulate some under testing or some other failed to operate single failure criterion.

CHAIRMAN KRESS: Yeah.

DR. ROSEN: Clearly these are packed outside the core, but are they parked outside the calandria as well?

MR. YU: They are, yes. This is the calandria shell. So they are normally --

DR. ROSEN: Normally above, the tip is above the outside of the calandria shell.

MR. YU: Yes, yes.

DR. ROSEN: So they see no neutrons in their normal operation.

MR. YU: No. For the shutdown system number two, we have six of these gadolinium injection tanks. They are injected by nozzles. They are located on the reflector region of the core so that we've got three on top and three on the bottom. Their performance is similar within less than a second. The poison would be injected into the core prior to shutdown.

CHAIRMAN KRESS: They are protected by gas pressure?

MR. YU: By helium gas pressure normally operating around 8 MPa.

So for emergency core cooling system we have the accumulated tanks and each one would be connected to the reacting headers. As part of the outlet headers, we have the emergency core cooling operation. They would be connected under that injection mode so that depending on where the break is, you always have flow through the core.

And for the intermediate mode, we have the reserve water tank, which is 2,500 cubic meter of water capacity. The majority of that water is used for flooding the sump, and that would be the initial cool water injection after the accumulated tanks are emptied.

CHAIRMAN KRESS: How does it get down to the sump?

MR. YU: Sorry?

CHAIRMAN KRESS: How does it get to the sump? Are there spray nozzles?

MR. YU: No. It's just a straight galkamer (phonetic) pipe. The valves open up, and then it just floods the sump.

The normal isolation between the accumulators, we use the one-way rupture disk so as to simplify the valve operation because this rupture disk would stand the full reactor coolant pressure during normal operation, and then on the much lower (unintelligible) pressure on the other end, then it would burst the disk.

These devices have been completely tested in our laboratories.

There's also the floating ball shutoff (phonetic) that would, you know, when the water gets down to low level, then you see the bottom of the tank that would prevent the gas from getting in.

CHAIRMAN KRESS: Will we see more about

the design details of that one-way rupture? How do you achieve a high pressure resistance in one direction and not in the other?

MR. YU: No, the idea is not to -- oh, it's a rupture disk that has a backing plate, and it's a full hose on that backing plate. So on the reverse direction it has all of the support by the backing plate and only in the forward direction. Then the full pressure is applied to the full diameter. So it's such a differential area that gives you the differential bursting.

So for the long-term cooling, this would be the part that would be used to flood the sump and then we have redundant pumps for each of the reactor and the header through the evolving arrangement.

DR. ROSEN: I'm sure you're following the discussions here in this country on pressurized water sump plugging effects.

MR. YU: Yes.

DR. ROSEN: And it seems that this design is susceptible to the same difficulties. Can you comment on that?

MR. YU: We essentially have followed the very earlier, every since the initial incident regarding insulation, plugging, faulty material, and sizing of the sump, whether, you know, it meets single failure or not.

So we have selected insulation materials appropriately. The latest that we have noticed, I think we are looking into that. Some of the chemistry effects which we are monitoring. So our designers are looking to the latest bulletin on this subject.

This is just a parameter that the ten wall units of 170 cubic meters in each of the two tanks; the pressure for injection is about 5 mph.

The containment I already mentioned about the sizes and the design pressure. We are using the air coolers that are located at the strategic places for heat removal. I do have a diagram to show that.

We use passive autocatalytic combiners for the core damage accident.

CHAIRMAN KRESS: And those are sufficient to deal with all of the hydrogen you might get generated in a severe accident?

MR. YU: The scenario that we posted, maybe, Victor, can you elaborate a little more if you need to?

MR. SNELL: This is an interesting area where we're actually trying to meld two regulatory philosophies. There is no need for hydrogen control mechanisms for design basis accidents. So these are put in for what's required. In Canada we're required to look at what's called dual failures. I guess we call it dual failures, but they're basically an accident plus an impairment or a failure of a safety system.

So in this particular case, you would be looking at loss of coolant with failure of the ECC to inject, and when you do that, you produce hydrogen through oxidation of the sheets. Although one would say that's a severe accident, we nevertheless provide design mitigation of it. That's why the hydrogen control is there.

CHAIRMAN KRESS: We'll probably hear more about that some time later.

Are these the European, German designs or are these your own design?

MR. SNELL: These are our own, passive autocatalytic combiners.

MR. YU: I believe we have supplied some of these to Finland as well for their use.

I talk about the local air vault coolers. This is really a schematic as you show where the normal circulation would be.

Severe accidents. The reserve water tank that I mentioned earlier not only supplied the water, but part of the water is for the make-up to the steam generators on lots of normal CBR heat sync makeup, and also it can provide makeup to the moderator, as well as the shield tank.

So this allows us, you know, to make up the water surrounding the reactor coolant system because the heavy water moderator is just on the outside of the calandria tube.

DR. APOSTOLAKIS: Why do you need to provide makeup water to the moderators?

MR. YU: This is part of our severe accident mitigation backup so that if you are on a severe accident scenario, if by any chance that your core is severely damaged, then it would be boiling off the moderator. So that in order to replace the water to allow it for a longer heat sync, then --

DR. APOSTOLAKIS: So it's really cooling.

MR. YU: Cooling, yes, for heat removal under severe core damage event. So you can see that the moderator is surrounding it, and then so when we provide the makeup, then our situation when the calandria tube is still intact, you'll still be able to remove the heat and on progressively more damage situation, then you still have the seal water (phonetic) surrounding it. That would be able to do the heat removal, can see the (unintelligible) water is about four times that of the calandria moderator water at least.

So the moderator system normally would remove the fission heat appearing in the moderator itself. So when it continues to operate, it will remove about five percent of the heat. So, therefore, it can be an emergency thing under severe core damage type of events.

I already mentioned that. In view of time, and because, as I mentioned, we have the control system was well as two independent shutdown systems, and we normally, when we look at the frequency of anticipated transients without scram, the frequency is so low that we don't normally analyze it.

But even in a sequence where the core damage is loss within the calandria, it would still be contained because, you know, that water is on the outside. And I did mention the makeup under the (unintelligible) water system.

Operation of features. As I mentioned, we do need to look at some of the features to provide more on-line terror. That's what our customers are demanding, certainly from the management team interface and reliability viewpoint that we need enhancement.

In terms of the operational error, we are paying more attention to the control design and also in terms of the control room, we have an improved alarm recognition system, as well as the last screen display.

DR. APOSTOLAKIS: But I thought you were going to say that you're giving more time to the operators to act. What is the shortest time they have to act? I mean, you just said earlier that severe core damage can be delayed for hours.

MR. YU: Oh, I think, you know, in terms of severe core damage events, it's way beyond 24 hours, if not longer. Victor?

MR. SNELL: Victor Snell.

I'll try and give a summary. On single events, what we were trying to do in this design is to give the operator about eight hours before he has to do something. Obviously a severe core damage event is a combination of many events, and there are exceptions to the eight hours, particularly things like if you have a steam generated tube rupture and you're then required to isolate the effect of the steam generator. That would need to be done before eight hours.

There's a couple of exceptions, but by and large, the automatic systems will take the operator through a single event, a single initiating event for about the first eight hours.

MR. YU: In terms of the control room, we have installed a prioritized alarm system with color coding so that it makes the operator be able to recognize the event faster in terms of screening out some of the duplicate alarms that come in on duplicated channels.

In terms of help monitor, we have more systems that would be able to look at the chemistry trends, for example, which is what we have the chemistry command system so that on any chemistry excursion we will be able to do support analysis, the variation as well regarding what's to be done and what chemicals need to be added for --

DR. FORD: Now, the last bullet is predictions. Predicting what, materials degradation?

MR. YU: In terms of material degradation and, for example, in terms of cleaning, what would be the plan versus, you know, the predicted time, whether you can restore the performance.

DR. FORD: So you have got the algorithm for amount of degradation of the pressure tube, for instance, as a function of time and as a function of various other parameters, operating parameters?

MR. YU: Not on the pressure tube itself. Mainly talking about in this particular case it's steam generators monitoring, for example, and even primary chemistry monitoring because I think we need to control it for the reactor coolant on a certain pH, as well as chemistry limits, and that will give you the monitoring of what's going on.

DR. FORD: So forget about pressure tube for the steam generator tubes, for instance. You've got algorithms of expected time to first failure as a function of secondary and primary water chemistries.

MR. YU: They are not really for safety monitor. This is really more for operational in terms of chemistry control, chemical additions, cleaning of the steam generator --

DR. FORD: Okay. So it's more operational predictions.

MR. YU: It's operational oriented, yes, not safety.

MR. LEITCH: If one is operating less than the four main reactor coolant pumps, must you be operating a particular combination of those pumps?

MR. YU: We do not design this to operate with partial pumps.

MR. LEITCH: So you must be operating all four pumps?

MR. YU: Yes.

MR. LEITCH: Not the right two. I mean you cannot operate with just the right two pumps?

MR. YU: At start-up we can operate with one pair initially until it gets up into higher temperature, and then you start the -- they start it in a staggered manner, but for pull power operation, that's not designed for partial pump operation.

DR. ROSEN: So you trip the reactor if you lose the coolant pump?

MR. YU: Yes.

MR. LEITCH: How is the --

CHAIRMAN KRESS: I honestly -- go ahead.

MR. LEITCH: How is the SCRAM System II initiated or the shutdown System II? How is that initiated, manually or --

MR. YU: No. IT's all relying also on the range of trip signals as well, like, you know, the low header pressure, high header pressures, and so on, neutronic trips as well as process trips for both of the shutdowns.

MR. LEITCH: But does the second system

operate only if the first one has failed?

MR. YU: No. They are independent parameters. The set points are such so that it can be avoided to come in that they would be. So that the first shutdown system has much tighter set point. So that they would prefer to come in earlier.

Like, for example, in high reactor system pressure, how reactor coolant system pressure. Then the STS-1 set point is lower and the STS-2 is higher.

MR. LEITCH: And I had one other question about the term ACR-700. Some of your figures here just say ACR. Does the 700 apply to a particular size of ACR or is that all we're discussing at the moment, the 700?

MR. YU: It's just too long to repeat that. Oh, I think it is talking about ACR-700 in our design.

MR. LEITCH: Okay. So every place I see "ACR," I should assume that's a 700.

MR. YU: Assume ACR-700, yes.

MR. LEITCH: Okay, okay. Thank you.

MR. YU: So that's a picture of the Qinshan Ming (phonetic) control room that we would certainly replicate the last display as well as the advanced alarm system. The operation interface on the panel are going to be modified further based on human factors improvements.

DR. ROSEN: Is this a digital control room, fully digital or is it a hybrid, analog and digital?

MR. YU: Yes, we are using PCS for our control, as well as the shutdown systems. They're all computerized as well.

DR. ROSEN: My question is: is this a fully digital control room or do you use a lot of analog instrumentation as well?

MR. YU: I think I can say that we are fully digital in a sense because it's difficult. All the systems, we do have computerized shutdown system, as well as computer control for reactor control. So whether they are in your sense fully digital, I'm not too sure whether. I don't want to answer a yes because I don't know what you're referring to, but yet all shutdown systems are digital, computers control, as well as the reactor control. So we have computer control, and we're going to a PCS as well.

MR. SIEBER: I think one feature that I think I read about was the fact that you separate your protection system from your control systems.

MR. YU: Right.

MR. SIEBER: And in a digital sense not everybody does that, but I think that makes a better design.

MR. YU: Yes, we do separate shutdown systems from the reactor control.

So in summary, we place on a lot of our operating experience as well as our R&D regarding our product. We talk a lot about optimization regarding the different aspects of the design, including the operation feature.

We introduce a number of passive features in our design for safety. Operational aspect, we pay a bit more attention to the operating needs as well.

DR. ROSEN: Now, what is the nominal operating cycle? I know you don't have to refuel on line. So there's no arbitrary limit, but certainly you have in mind a time frame before you will shut the plant down and do a full maintenance.

Do you have some nominal time frame in mind?

MR. YU: Well, we are aiming for three years.

DR. ROSEN: Three years.

MR. YU: For plan outages because a lot of the mentions we can do on line as well.

DR. ROSEN: But you can't maintain turbine on line.

MR. YU: No, not everything on line.

DR. ROSEN: So you have to on --

MR. YU: That's why every three years -- some inspections used to be done also in certain cycles as well. So I think three years would be the way that we input. We have access to containment areas as well.

DR. WALLIS: Now, you're not presenting a PRA to us today; is that right?

MR. YU: Yes, that would be --

DR. WALLIS: You will? You will. Okay.

MR. YU: There will be a PRA presentation.

DR. ROSEN: But you haven't done the whole PRA.

MR. YU: -- methodology.

DR. ROSEN: The methodology will be discussed.

MR. YU: Yes.

DR. ROSEN: But you haven't completed it.

MR. YU: No.

DR. WALLIS: Well, that puzzles me a bit because it's stated that you use the PRA in design. If the design constraint is that the core damage frequency be ten to the minus five while you're doing your optimization, then it is ten to the minus five, and you don't have to do a PRA again because you've already done it as part of the design.

So I'm not quite sure why it hasn't been done if it's --

MR. YU: We've done Level 1 PRA, and also we have utilized our experience from the PRAs that were done for the CANDU 6 before. So the supplementary design assist PRA has been done.

In terms of an integrated Level 1 and Level 2 PRA, we're still in the process of doing that. So I think that in areas that we are changing from the CANDU 6, we have done the specific scenarios to see whether we are moving in the right direction or not.

DR. WALLIS: So the PRA should come out as you intended --

MR. YU: Yes.

DR. WALLIS: -- to be ten to the minus five CDF.

MR. YU: It's a case of documentation and the detail work in order to get that.

MR. SIEBER: It's probably a mistake to ever say that a PRA is truly done.

MR. YU: That's right.

(Laughter.)

MR. SIEBER: You just keep on going and going.

DR. ROSEN: It's an oxymoron to say that this a completed PRA.

DR. APOSTOLAKIS: How do you conclude then that the ACR meets the NRC safety goals if the PRA is not complete? I mean that's what this document says that was sent to us earlier.

MR. YU: Well, we believe we have done enough to know that when the detailed documentations are done that we expect to be within the limits that we have set of the safety goal.

DR. APOSTOLAKIS: So if a PRA is submitted to us at some point?

MR. YU: Will be as part of the design certification.

DR. APOSTOLAKIS: By the way, the goals that you mentioned here are a little old, aren't they? We're not using ten to the minus five for core damage frequency, are we? It's four.

You remember OCRANT (phonetic) ranged an issue here some time ago that the goals were increased by a factor of ten without a formal process.

MR. SIEBER: That's right.

DR. APOSTOLAKIS: It's ten to the minus five for a larger list, but if you go way back, I think you will find ten to the minus six.

CHAIRMAN KRESS: Yeah,b ut there's this thing on the books that says the NRC has an expectation of a higher level of safety.

DR. APOSTOLAKIS: But it says goals.

CHAIRMAN KRESS: I know, I know, I know.

DR. APOSTOLAKIS: It's not expectations. Maybe that's something for us to worry about.

PARTICIPANT: That's why you've got to meet the goals.

CHAIRMAN KRESS: And I think the utilities require it.

DR. APOSTOLAKIS: It's not a problem. It's not a problem.

CHAIRMAN KRESS: Yeah, the utilities' requirements document calls for --

DR. APOSTOLAKIS: Now, I also tried to get some of the references that you list in this document by going to --

MR. YU: May I ask what document are you --

DR. APOSTOLAKIS: Well, it says "Safety Characteristics of the Advanced" --

MR. YU: Oh, okay, yes. We can search for an item if --

DR. APOSTOLAKIS: Yeah, that's what I'm getting at. I was able to get a couple of them, but References 5, 6, and 7 I was unable to get. Can you make sure?

MR. YU: Yeah.

DR. APOSTOLAKIS: And eight, five, six, seven, and eight. Can you make sure we get copies?

CHAIRMAN KRESS: Could you send those to Ahmed and he'll see that those get distributed?

MR. YU: Okay.

DR. ROSEN: Now, while we're talking about additional needs for information, I read in Section 2.8 in this same document, the safety characteristics of events, CANDU reactor designs by Waddington and Rogers that discussion of incorporation of past experience, and that a formal review had been done of past experience within each engineering discipline, which resulted in 475 feedback issues to review and 1,175 suggestions for improvement.

I'm very interested in that. I would like to pursue this some more. Where would I go to do that?

MR. YU: In what way you want to pursue

that?

DR. ROSEN: Well, to know what the 475 feedback issues were, for example, and what had been done with them. Perhaps the same for the 1,175 suggestions for improvement.

At some point I'll fatigue, but at least I would like to start.

MR. YU: Okay. Well, I think we can give a status report.

DR. ROSEN: You must have some compilation.

MR. YU: Yeah, yeah. We have, in fact, tied into a feedback database, and so certainly they have been scanned for the applicability, and also, you know, each of the disciplines would be using that as part of the design input to make sure that we would avoid the previous problems.

DR. ROSEN: It's a very good start for a new design, avoiding the problems you know about.

MR. YU: Yeah.

DR. APOSTOLAKIS: Since we are going to talk about the information needs, there is a sentence here that intrigues me. "Reliability of the safety critical software is demonstrated through trajectory based random testing."

Would you send me a document to educate me about this? I'm sure that you have something somewhere. I mean these are really impressive words.

(Laughter.)

CHAIRMAN KRESS: It's a trajectory.

DR. APOSTOLAKIS: This is in Section 3.6 of this report by Worthington and Rogers.

MR. SNELL: Yeah, we can send you that. It was also done on CANDU 9, and I believe we made a submission to our own regulatory on that time.

DR. APOSTOLAKIS: Okay. So you have concluded -- I mean, I don't know when we're going to discuss this. I mean, the safety system reliability, you set a target of ten to the minus three. It says here years per year. I don't know what that means. Probably per year only, right?

MR. YU: Per year.

DR. APOSTOLAKIS: Years per year?

MR. YU: It is one.

DR. APOSTOLAKIS: No, there is an S.

And then you say that this was chosen to insure that the likelihood of a larger lease is extremely low and all of that. I mean, this is a very interesting application.

MR. YU: It's part of the regular

philosophy to set a reliability target and for operational reactor, they have to demonstrate the reliability of the system to meet that target. of ten to the minus three.

DR. APOSTOLAKIS: This ten to the minus three comes from the regulator?

MR. YU: Yes.

DR. APOSTOLAKIS: Is it also true that if you show that your reliability is ten to the minus five you don't get any credit for that, that it stays at ten to the minus three because the regulator says so?

See, I don't understand --

MR. YU: No, no, no, no, no, no.

DR. APOSTOLAKIS: No? I remember vaguely reading something like this years ago, that you cannot claim more credit than we allow you to claim.

MR. YU: Oh, yes, the system has to demonstrate that it meets that minimum reliability limit.

DR. APOSTOLAKIS: Right.

MR. YU: Obviously you need to achieve better than that before you can show that your testing has demonstrated the reliability requirement has been met.

But in safety analysis, especially in dealing with fuel failures, you cannot credit each of the shutdown systems to be more reliable than the ten to the minus three. I think that's maybe what you're referring to.

DR. APOSTOLAKIS: Anyway, I'd like to see more information on this, how you implement it, if there is any. Otherwise maybe this is it.

MR. YU: Well, I think we can show you what needs to be done. We need to do operational testing of the control logic, as well as the hardware, to make sure that the failure rate is demonstrated. This is really through the testing.

DR. APOSTOLAKIS: Now, I have a question on something else. I managed to download your policy on human factors, and it's very interesting that essentially what it says is do a good job.

Is there another document that tells you how to do a good job? Because we have big reports that give guidance to the licensees regarding human factors, and this is really impressive. It's only two bullets. It says, "Take into account human factors that could impact upon the Commission's mandate for protection."

Well, how do you do that?

MR. YU: For us, certainly there are inter-Canadian regulatory guidelines, and for our design we have established an engineering human factors plan, and from the plan we have established design guides.

DR. APOSTOLAKIS: So there is a regulatory guide that implements this policy or you don't use it where it's a regulatory guide?

MR. YU: Well, there's a regulatory document for guidelines. You're guiding what is needed, and we have an entering (phonetic) human factors plan for the implementation as well as the more detailed entering practices that are needed in order to demonstrate that they are met.

It's a different framework, but the ideas are the same. For designers, you know, certainly they have the entering guide they use for the day-to-day design, as well as a section in each of the design documents that are addressed.

DR. APOSTOLAKIS: At some point somebody will tell us what the major differences between the two regulatory systems are so we don't have to figure them out ourselves? You're using the same words like defense in depth and all of that, but are there any major challenges somewhere there that we do and you don't do or you do and we don't do?

MR. YU: I believe the challenges are very similar.

DR. APOSTOLAKIS: Get the core damage frequency below ten to the minus five, right?

MR. YU: That's right.

CHAIRMAN KRESS: I hate to interrupt this. Patience with us. We were scheduled for a break at 10:30, and we're a half hour behind schedule. Rather than go to the next item on the agenda, I suggest we take a break now and be back in about 15 minutes.

DR. APOSTOLAKIS: Twelve o'clock.

CHAIRMAN KRESS: No, no, 10:45. I'll give you an extra few minutes. Be back at 10:45.

(Whereupon, the foregoing matter went off the record at 10:25 a.m. and went back on the record at 10:45 a.m.)

CHAIRMAN KRESS: We will move to Roman numeral five on the agenda, ACR pre-application scope, rationale and expectations.

Vince Langman.

MR. LANGMAN: Hi. I'm also the designated catch-up player because I think we can actually --

CHAIRMAN KRESS: That will be helpful. Thank you very much.

MR. LANGMAN: We can go through this presentation fairly quickly.

I've also been asked. There was one point that I thought was fairly important that wasn't quite right. The free containment volume is actually 48,000 cubic meters, not 58. Okay?

Also, I'd like to take this opportunity to introduce three other people that we brought with us. Nick Popov, if you could just stand up in the back. He's actually the licensing manager for the ACR effort in Canada, but he has also been very key on the technical side with regards to the PIRT exercise that's going on with the NRC at the current time and also on the computer code validation side of the house.

And Al Stretch, who is ACL's expert on codes and standards and safety design philosophy.

And last but not least Robert Ion, who is my right hand and left hand, and is one of the people who makes all of this exchange of information possible, which has been, as you'll see, although I'll flip through it very quickly, has been an extensive amount of information exchange in what I consider to be a reasonably short period of time.

So I was asked to talk fairly briefly

about how do we come up with this pre-application scope, and what were some of our expectations, and as Laura mentioned earlier, we started the pre-application review in mid-2002 and kind of wrapped it up at the end of the summer of 2003.

We had a pretty good idea from our perspective as to what some of the CANDU specific focus topics needed to be. Through discussion with the NRC staff, we actually added one, which was the actual confirmation of void reactivity.

One of the big feedback items that has been mentioned is from the CANDU 3 days. It was very clear coming in this time that a positive voice coefficient was a nonstarter, and so we incorporated that feedback right from the beginning.

We've had extensive familiarization meetings, have submitted a number of large tomes related to the technology base and the design, and we've started the process of responding to the staff's request for additional information.

As Laura also mentioned, we sort of morphed into Phase 2 September of this past year and expect to hopefully finish Phase 2 by September of 2004. We have a pretty aggressive schedule of additional technical meetings on the key focus topics especially, and I'll mention what those key topics are. That's really what we're here to provide some more technical information on.

We are participating; ACL is participating to the fullest extent on the NRC PIRT meetings that are being held, the subpanel work that's being done on reactor analysis, severe accidents, and thermal hydraulics.

There are a number of additional reports that we are also intending to deliver, and we expect that there will be a lot more requests for information from both the staff and, as was evident from before the break, from the ACRS members as well.

So it was pretty simple. There are a number of CANDU specific aspects of the ACR that are not easily addressed or not addressed at all by the current NRC regulations, and so what we really went after in terms of key focus topics were basically things in the design that if the NRC don't like them or can't handle them -- probably "don't like them" is a better phrase -- then there's no sense in going forward.

If you tell us that, you know, zirc-niobium is not a good pressure tube material and you've got to make it out of something else, we'll say thank you and we'll go home. I don't think that will be the case, but you know, we have to be clear. There are certain aspects of the design that aren't currently handled.

There are also certain issues as well that have prohibitively large monetary or schedule impacts. For example, computer codes and the extent of validation. If you were to say, well, no, we really need a fully validated TRAC or RELAP model for the CANDU system and that's what we want you to use in your safety analysis, that would be a pretty major schedule and monetary effort on ACL's part, and certainly there has been a lot of code validation and development work done over the decades at ACL specific to CANDU.

So these are a matter of record. So --

DR. APOSTOLAKIS: So I don't understand this. What do you think the NRC staff should do when it comes to points that may be prohibitively large monetary expenses?

MR. LANGMAN: If you'll give me a minute, I'll get to that. We state it pretty clearly.

DR. APOSTOLAKIS: You can even have two.

MR. LANGMAN: Okay. For those who know me, that may not be enough.

(Laughter.)

MR. LANGMAN: I don't intend to go through all of these. They are a matter of record. The key ones that we have come prepared to discuss are the Class I pressure boundary, computer codes and validation adequacy, the whole concept of on power fueling, including the fuel design and acceptance of the fuel design.

That actually, I think, will be broken out into a separate key focus topic, albeit it brings the total to 13, but we'll do that anyway, and confirmation of the negative void reactivity.

DR. ROSEN: Are you implying that there's some degree of contentiousness about these three? For instance, on power fueling, is there some view that you have that the staff is against on power fueling as a matter of religion or --

MR. LANGMAN: Oh, no, no. It's more the fat that it is definitely different, and we have to show you what it's all about and there are no, I don't think, any real requirements in the current Code of Federal Regulations that deal with fueling on power, and I think it's more of the fact that one needs to come up with those.

I'm not saying that these are key because we think they can't be solved. I'm saying they're key because they have to be solved. Okay?

There are certain things that are nice to have on some of the focus topics, but if we don't get those, then we can go ahead anyway, but there are certain areas like roll joints, which is one of my favorite ones. I mean, roll joints are not part of the current Class I accepted kind of process, but they're absolutely critical to the whole concept of CANDU and the fact that you can change channels out during operation, you know -- not during operation, but during a maintenance effort.

But not that we expect we have to, but it is something that's rather key to the design.

DR. ROSEN: Well, no, you do expect to do it once in the life of --

MR. LANGMAN: Yes, at 30 years we change out the whole core.

So this was just meant to impress people with the fact that we did have a lot of familiarization meetings in Phase 1. The NRC staff stalwartly braved the Canadian winter in Chalk River in December 4th and 5th, and we dutifully had a good snowstorm for them.

CHAIRMAN KRESS: At least you didn't have any mosquitoes.

MR. LANGMAN: No, no. That was supposed to be in White Shell.

We, also, had a meeting on the details of the RD-14(m) results in June. That was when the mosquitoes were supposed to come in. Unfortunately it was a very dry summer in Manitoba, and so there weren't that many.

CHAIRMAN KRESS: When we have dry summers down here, it makes the mosquitoes worse.

MR. LANGMAN: Ah, okay. Anyway, we had a whole series of meetings and around about the end of the summer, as I mentioned last year, we sort of jointly decided that these big, familiarization meetings had served their purpose, and we were now at a stage where we wanted to get the specific technical experts at ACL together with the specific reviewers on the NRC side and get into more detail.

There is a list here just for your information of the type of information that has been submitted during pre-application. I should note that we have provided any of the computer codes that people want to look at. We've provided the source versions of these codes and input decks, and there has been how one actually utilizes these thermal hydraulics codes, and there's a physics code similar meeting coming up in February back in --

DR. APOSTOLAKIS: Well, all of these thermal hydraulic codes and basic structure are very much the same, aren't they?

MR. LANGMAN: Yeah, I would think so. I'm a fuel guy more than a thermal hydraulics person, but, yes. But every code has its idiosyncracies, and we're just trying to make the familiarization process faster.

DR. FORD: Vince, just to make sure I understand, on the previous, two previous, when you say the documentation given to the staff, that documentation is enough to back up the definitive statements made in these documents? For instance, the materials, there's a statement saying there will be no problem with the late hydride cracking or words to that effect. There had been documentation given to the staff to back up that statement?

MR. LANGMAN: For example, on the pressure tube side, we provided a rather large document on sort of everything you've wanted to know about pressure tubes but were afraid to ask. It was done in a very technology base oriented way. So it was kind of a lot of the R&D related to the understanding of pressure tubes.

I think what's coming up and what is still required is for us to also provide how we think one could actually review and accept pressure tubes like the way we do in Canada in the United States. We haven't got to that tough part yet, but we are working on it.

DR. FORD: Okay, okay.

MR. LANGMAN: And it's intended that that type of information if it isn't provided prior to our submission of design certification, it will be included either by reference or will be included in our design control document that we submit for design certification.

So we do recognize that we have to provide that kind of information. I'd say we're maybe a little over half-way to two-thirds of the way there because the technology base, one of the focus topics that seemed kind of odd was the technology base. We did want to take an appropriate amount of time to show the amount of research and development that is behind the statements that are made, and I think, you know, ACL is a bit unique in that regard as a reactor vendor because they also are the people that are responsible for the nuclear lab in Canada at Chalk River and White

Chalk.

And so there is a large technology basis there, and we wanted to make sure that everyone understood what was available.

These are just more of the things that we've provided. We have provided a rather lengthy comparison on the quality assurance side. We've also gone through an initial assessment of the generic safety issues. That's more a screening in terms of which ones may be applicable to the ACR, and that has been provided to the staff as well.

So what do we expect out of all of this? Well, we certainly hope that the staff will identify whether there are any impediments to actually licensing the ACR in the U.S. not only on the specific topics that we've chosen, but if we have, indeed, missed some, we would assume that they would talk to us about those as well.

We're looking to have success paths identified for any unresolved focus topics that occur or that may not be resolved during pre-application, and I think Laura stated it correctly that it's not expected that we'll be able to come to a regulatory resolution on a lot of these pre-application focused topics, but we do want to make sure that we have a common understanding of how we can get from there to here.

MR. SIEBER: Maybe I could ask a question that I should have asked 60 seconds ago.

MR. LANGMAN: Sure.

MR. SIEBER: As far as QA is concerned, does AECL use the Appendix B type of QA or ISO 9000 series QA?

And if you use ISO 9000, would that be acceptable?

MR. LANGMAN: I'm not as familiar with ACL's current status on ISO 9000. So I'll ask Stephen if he knows about that in a minute.

MR. SIEBER: Okay.

MR. LANGMAN: But certainly ACL uses a series of standards, the Canadian Standards Association that have been compared to the U.S. requirements, and actually on the QA side even though it hasn't been listed as a focus topic, you may have noticed there was actually a familiarization meeting for about two --

MR. SIEBER: Yes, there was.

MR. LANGMAN: -- and a half days in December, and it's my understanding that there has been considerable progress made between the staff, the

NRC staff, on the QA side with our staff, and although I'm not a QA guru, I think it's fair to say my feeling is that there is a lot of meeting of the minds and it looks like it's not going to be a major issue.

MR. SIEBER: Well, perhaps when it's the staff's turn they could address that same question in a sentence or two.

MR. YU: Stephen Yu here.

The only thing I can add is, yes, we follow the CAC standard, but, on the other hand, we also have seeked (phonetic ISO 9002 registration, and so we have been subjected to that kind of audit, and so we did meet the requirements.

So the basis of our QA menus and so on are based on the standard that we have subject to other audits.

MR. SIEBER: Okay. Thank you.

MR. LANGMAN: I think I've also alluded to the third bullet, which is the assessment of the completeness of our R&D program and technology base. We do have tests specific to the ACR actually in progress and over the next couple of years, and as well as a rather extensive R&D program that supports the sort of CANDU specific aspect of the ACR design.

And last, but not least, we were hoping

that we would be able to get some estimate of the cost and schedule that the staff field would be required for actually performing the design certification review of the ACR by the end of pre-application.

This is an expectation, but it's in recognition of the fact that there is a concurrent pre-licensing process going on on the ACR both in Canada and in the United States, and this is in our mind an excellent opportunity for synergy between two mature and knowledgeable regulators, and so we have tried to set this up in a way that there are common major documents for review, similar time frames for those reviews, and we're hoping that basically this will lead to what I refer to as a common North American technology, technical basis for licensing the ACR in Canada and the U.S.

We do recognize that the nature of the law in Canada and the U.S. require that certain things may be treated differently, but we believe it's very important that both regulators have a common understanding of what the issues are and what the actual technical basis and what the design is so that when you apply those separate requirements, they're applied to a common understanding of what the machine actually looks like and is.

And that's basically it for my preamble on that. I have a very brief introduction to the key focus topics.

Class I pressure boundary design. Some of these I was a little concerned when I wrote these, but I decided that we wanted to make sure that it was very clear what we were looking for from the NRC. So they sound a bit presumptuous, but here goes.

I mean, for this particular issue we're looking for the staff to accept the principal design features of the pressure boundary. We don't say how, but we're looking for them to accept them somehow.

The use of zirc-niobium pressure tubes or the use of zirc-niobium as pressure tube material --

DR. SHACK: So you're not planning on running off and getting a code case, for example, from the ASME? That's not part of the game plan?

MR. LANGMAN: That is not part of the game plan, neither for roll joints or closure plugs, 403 stainless steel end fittings and fueling machines as components of a Class I pressure boundary.

MR. SIEBER: Well, actually your pressure boundary is an ASME 8 class pressure boundary?

MR. YU: For a fuel machine, the boundary of the head that handles the fuel, which is connected to the fuel channel, are Class I.

MR. SIEBER: Okay. But the pressure tubes, the steam generators, all of those headers and all of that. It seems to me I read someplace where you're using the ASME code as the code of record.

MR. YU: Yeah, that's correct.

MR. SIEBER: Okay.

MR. LANGMAN: We use ASME wherever we can in our process, and when CANDU specific issues arise, that tends to be where the Canadian Standards Association standards have been developed and are in use.

The of note part is just with respect to what we've actually submitted and some notes to make, and one of them is we have provided the CSA standards related to the use of these materials and components.

The fitness for service guidelines, there was a question earlier with regards to how do we monitor the fitness or the pressure tubes. There is actually a rather extensive assessment that's performed on an ongoing basis to insure that the pressure tubes are fit for service, information on pressure tube inspection or the fact that we have rather extensive pressure tube inspection technology, and pressure tubes really are an area.

I was talking to Mark Leger at the break, and we were trying to do a rapid mental calculation, which is always a danger, about how many person-years we've actually spent in Canada on pressure tubes, and we place it possibly in excess of 1,000 person-years, I mean, in terms of research and development. I mean, there has been a lot of work done over the last four, five decades on pressure tubes. They're an integral part of our design concept, and they were something we knew right from the beginning we had to understand very well.

And so there is a lot of information, and it's actually why this is the number one focus topic, because I think this is an absolutely key area, and it is also one that there's so much information that it's a challenge to get through it all to come up with the types of requirements that would be needed in the U.S. to allow this to happen.

DR. WALLIS: So these are your desired outcomes.

MR. LANGMAN: Yes.

DR. WALLIS: Does the staff agree that these are reasonable outcomes to AMAT at this stage in the process and in a reasonable period of time?

MS SOSA: I'd like to address that.

Belkys Sosa, the project manager for the ACR at site.

Their use of "the staff accepts" is always something that we had several discussions over, and I think what they are expressing here is the desired outcome, big picture. When we're talking about pre-application review, we're simply going to identify showstoppers; technical areas that will need to be looked at in more detail; essentially provide feedback for them in time to incorporate in their design certification obligation.

We don't expect to resolve these safety issues on any of these focus topics in the next year. This stuff needs to come up to speed on familiarizing themselves not just with CANDU technology, but ACR specific designs.

DR. WALLIS: So rather than accepting, you're going to not reject.

MS. SOSA: Yes.

(Laughter.)

DR. WALLIS: You don't give them the rubber stamp that says, "We accept all of these things." You're just saying, "We have not rejected."

MS SOSA: Yes, and we will also hopefully identify the issues that will need to be resolved. I think that's a big plus.

DR. WALLIS: Yes.

MS. SOSA: The pass-forwards he refers to it.

MR. LANGMAN: I would hope that the success path could be defined pretty clearly because at the end of the day, you know, two thirds of the way through design certification and X tens of millions of dollars or hundreds of millions of dollars later, it's like, "Oh, by the way, we can't get our head around two and a half percent niobium," I'm going to have to fall on my sword somewhere, you know, because that's part of the reason to focus on these, was to sort of try to wrestle with the hardest issues right up front to see if there really is something that is a showstopper rather than assuming we'd be able to work our way through everything, quite frankly.

Focus topic number three, computer codes and validation adequacy. Since CANDU 3, there was about a six-year integrated effort in Canada involving all the Canadian utilities and ACL with regards to formal validation of our computer codes used in safety analysis, and we've been sharing with the NRC staff the outcome of those assessments, and basically we're looking to have the staff accept the computer codes as fit for purpose for analyzing the ACR 700, which is a little different than saying they're just certified.

Like we really want to focus, to begin with, on do they agree that they're put for purpose for the actual analysis of the ACR 700 as opposed to CANDU reactors in general. Okay?

CHAIRMAN KRESS: If we're talking about, let's say, thermal hydraulics codes, is your approach going to be an Appendix K approach or a best estimate approach, if you know what the difference between those two are.

MR. LANGMAN: Oh, yeah. What we have currently in Canada is something we call limit of the operating envelope approach, and my understanding is there is a DOE funded project ongoing currently with INEEL that is actually evaluating our limit of the operating envelope approach to LOCA analysis against Appendix K, evaluation models.

We have done uncertainty analysis in the past and best estimate plus uncertainty analysis, but the intention was not to go that route for this particular application.

So I guess the most direct answer I can give you is that we're probably a little bit in the middle.

DR. WALLIS: I wish you would go to

realistic, and do it right and show us how it should be done.

MR. LANGMAN: Point taken.

DR. RANSOM: Does the plan include submitting your computer codes to the NRC for their review?

MR. LANGMAN: Oh, yes. Actually as part of pre-application we've submitted the major work horse codes, the CATHENA code, which is our system thermal hydraulic code, and the physics code sweep (phonetic). As part of the fuel design review, we'll also be submitting the fuel codes that we use in analysis, as well as severe accident codes eventually, but yes.

To begin with though we focused on thermal hydraulics and physics and felt that if we could work out sort of the process for review and what the staff need to see and what's helpful to them with those two code sweep or the one code and the other code sweep, then we could apply that to the other codes and make it a bit more of an efficient process rather than trying to hit them with all ten or 12 codes at once, but the intention is yes.

DR. WALLIS: Well, I think to go farther in what I just said, I mean, if you try to make your

ACR fit something like Appendix K, there are all kinds of hidden conservatisms and things in Appendix K which are really specific to the designs that we have in this country.

MR. LANGMAN: Yeah. We don't have a reflood philosophy.

DR. WALLIS: Right, right.

MR. LANGMAN: Yes, that is true.

Focus topic number eight, the third key focus topic on power fueling, and I've got in brackets "including fuel design." I believe this will actually become a separate key focus topic. I think both the staff and us have recognized that this is a pretty major item, as well, to actually review and approve the CANDU fuel design, the ACR fuel design, and it's really the fact that our fuel design is different.

You know, just when you compare the physical size of a PWR fuel assembly to a CANDU fuel bundle, and we do have a full mock-up of CANDU fuel bundle for ACR and the pressure tube and calandria tube is somewhere in One White Flint, right? It's not in Two. So it is around. You have one in your possession right now if you ever want to look at it.

DR. WALLIS: Pick it up.

MR. LANGMAN: Yeah, yeah, even when it's

loaded with fuel, it's about 50 pounds. I won't steal Peter Boczar's thunder, but he's going to talk a bit more about the fuel design.

You know, obviously we have had extensive successful experience with the various fuel designs that have been developed over decades. There's been a whole lot of effort put into CANDU fuel as well, probably a little less on pressure tubes, but on a similar order of magnitude, and we have had on CANDU fuel extensive experience with on power fuel, and so we don't expect any problems in that area as well, but Jullian Millard will be addressing that more fully in a moment.

And last but not least, the confirmation of the negative void reactivity. This was one where I quickly learned that a lot of the staff are from Missouri. I figured when we pulled these together, you know, the void reactivity is going to be negative. So that's not really a key focus topic because, darn it, you know, it's going to be negative.

And basically it was mentioned that this would probably be a very good idea to have this as a key focus topic to make sure that we do confirm that it is a negative void reactivity. We take that very seriously.

There are a number of R&D programs underway to provide ACR specific validation for the physics code sweep that will help with the technology basis for this, and Peter Chan will be walking you through a bit about how we came to a negative void coefficient.

So with that, oh, one last thing. This is not a key focus topic, but we thought it was an appropriate time to talk a bit about our PRA methodology. My understanding which is really sketchy on this is that we are -- our methodologies are very similar to the U.S. approach, but I'll leave that for Raj Jaitly to further expound upon.

And we --

DR. APOSTOLAKIS: I'm surprised it's even a focus topic. I mean, what's so special about it?

The others I can understand, but this one doesn't seem to me to belong here.

MR. LANGMAN: You know, you could be right actually on that one. The more we think about it, I mean, we are looking at the sort of frequency goals, ten to the minus five, ten to the minus seven, but we felt -- well, okay.

DR. ROSEN: Even trees, fault trees.

MR. LANGMAN: Yeah.

DR. WALLIS: That's not the problem.

DR. ROSEN: Success criteria scenarios, all that stuff.

MR. LANGMAN: Yeah, Raj is nodding his head.

DR. ROSEN: What's new?

MR. LANGMAN: Well, we'll hear.

DR. WALLIS: Well, the problem is the indefinable to some folks measure of quality of the PRA.

DR. APOSTOLAKIS: Yeah, but that's not the special focus issue here. I mean, there's no difference --

DR. WALLIS: Well, there has to be agreement about how good it has to be.

MR. SIEBER: You have different phenomenology.

MR. LANGMAN: Yes. That was the one aspect of this, was the actual different severe accident phenomenology, and that was a part of like the actual focus. A lot of the focus of the familiarization meetings was more on the actual technology basis for understanding the phenomena associated with severe accidents.

MR. SIEBER: Well, required.

MR. LANGMAN: The actual methodology of doing the analysis, I guess.

MR. SIEBER: It requires the adaption of the results of severe accident codes and thermal hydraulics codes in PRA terms in order to make it realistic, and that's no easy thing to do.

DR. WALLIS: Well, there may be more model uncertainty, for instance, or less, less model uncertainty because --

MR. SIEBER: Yeah, but you have to be able to --

DR. WALLIS: -- particular codes and physical events.

MR. SIEBER: You have to be able to define that in order to know what the uncertainty really is.

CHAIRMAN KRESS: I would guess one of the issues would be what kind of fission product source term is involved in the various sequences.

DR. APOSTOLAKIS: Yeah, but it doesn't sound to me like it's at the same level as the Class I pressure boundary design.

CHAIRMAN KRESS: No, I don't think so.

MR. LANGMAN: Oh, that's why it's not actually a key focus topic.

CHAIRMAN KRESS: A focus topic, not key.

DR. APOSTOLAKIS: Ah.

MR. LANGMAN: Sorry. No, it's not a key one.

DR. SHACK: It's not safety related. It's just the extent to which you meet goals.

DR. ROSEN: It's nice to put it up there. The ACRS has had more than a passing interest in the PRA technology.

DR. SHACK: So what is the meaning now of going from one to three to eight and from nine to 11? There were others that were settled or --

MR. LANGMAN: No. There were other topics that were part of a previous list.

CHAIRMAN KRESS: If you go on the previous list, there's about 11 or 12 topics. A number of them aren't key, and he just picked out the ones that were key and gave them the same number.

MR. LANGMAN: So without further ado, I guess Mark Leger is the first person up.

Thank you.

DR. WALLIS: So you've really caught up in time, haven't you?

MR. LANGMAN: That's my job.

CHAIRMAN KRESS: You did good.

DR. WALLIS: So let's see. Where are we

now?

MR. LEGER: Good morning. I'm Mark Leger, and I'm going to be talking about the Class I pressure boundary.

I've outlined the talk here. I wanted to talk about some of the major features of the pressure boundary. I'm going to talk a fair bit about our CANDU experience actually. I'll say some things about leak before break and how this fits into our philosophy for pressure tubes, and then I'm going to talk about some of the fuel channel standards on pressure tubes and fittings, some of the issues with regard to channel closures for on power refueling and a few words about inspection and material surveillance.

So in terms of the pressure boundary features of the ACR, as was mentioned just a few minutes ago, with regard to the piping valves and pressure vessels, all of these are designed to the ASME code, Section 3 code, and the feeder pipes as well.

We've got these multiple, small diameter pipes that join the headers in the fuel channels. They're also designed to the same standard, ASME Section 3, NB.

DR. WALLIS: Does this include design for inspectability?

MR. LEGER: We are --

DR. WALLIS: Because you've got this forest of feeder tubes. You have to get devices in there to inspect for whatever may be going on.

MR. LEGER: We are considering inspecting. How inspection will be done for these, as was mentioned before with regard to the dissimilar metal weld, the location of this weld is an issue with regard to our ability to be able to do inspection.

MR. SIEBER: Well, you're just inspecting the joint. So the complexity of all of these tubes going to the header, you really are only looking at two places, which is where it connects to the pressure tube and where it connects to the header.

MR. LEGER: Well, in some cases there will be other welds within the system.

MR. SIEBER: Oh, within the tube? Yeah. Well, that does make it tough.

MR. LEGER: But these are low risk welds. So as you can see, we've got the headers at the top here and all of these feeder pipes that go down and join onto the end fittings, but all of the components at the top here are all right down until you get to the fuel channel, it's all designed with ASME standards.

DR. WALLIS: Is all of this enclosed in insulation of some sort?

MR. LEGER: Yes. There is an insulation cabinet.

DR. WALLIS: Stuffed in or is there a box that fits --

MR. SIEBER: There's a box.

MR. LEGER: It's basically boxed in. At least it is in the current CANDU 6.

DR. ROSEN: When you get a leak out there, you don't know where it's coming from. It's in the box someplace.

MR. SIEBER: Well, you take the box off.

DR. ROSEN: In the header. You get one of these tubes leading from the header to the face of the machine. That leak will just appear in the box, right?

MR. LEGER: It would appear in the box, yes.

MR. SIEBER: Yeah, I would think a visual examination there would be difficult. You can't see every place because there's a lot of obstructions there.

DR. FORD: Somewhere in one of the documents, I think one of the documents that was sent to us before this meeting, this question of inspectability came up, and it was admitted, I guess, that there are areas where you cannot inspect. You just physically cannot inspect it.

Has there been analysis done of the consequence if you have a failure in one of these complex piping geometries as to whether you have just got to inspect it or what?

MR. LEGER: Well, the single feeder covered by a safety analysis --

MR. SIEBER: That's one of your design bases.

MR. LEGER: Yes, that's right.

MR. SIEBER: You're supposed to be able to tolerate that with a fuel main.

DR. FORD: So, in other words, you've specifically designed this spaghetti of tubing such that those critical piping areas can be inspected.

MR. LEGER: That's right.

DR. FORD: Is that true?

MR. LEGER: That's right. That's what we would like. That's what we're trying to achieve.

DR. FORD: And those that you can't

inspect, you say, no, never mind.

MR. LEGER: That's right.

DR. FORD: Is that right?

MR. LEGER: That's the goal of the detail design.

MR. SIEBER: That would be a goal.

DR. ROSEN: That means that clearly a 90 degree bend, just a 90 degree bend has got to be a non-risk significant --

MR. LEGER: That's right. We would judge it to be non-risk significant. It would be low --

DR. ROSEN: Because you can't possibly inspect every 90 degree bend.

MR. LEGER: That's right.

DR. FORD: And that's why you're opting to go to stainless steel bends? These are the cold form bends, and presumably you will have erosion/corrosion at those

MR. LEGER: Any bends that are sufficiently small radius would be stress relieved.

DR. SHACK: Okay. Let me come back here again. If I design these feeders to the ASME code standards and I have seven welds per feeder, you're going to go for a risk informed inspection plan then rather than a standard ASME code inspection? That's how you're going to get around the seven welds?

MR. LEGER: That's what we would like to do.

DR. SHACK: Okay. That's sensible enough.

MR. LEGER: Yes.

DR. ROSEN: Well, if it's good enough to do for operating reactors.

DR. SHACK: Well, it's not quite ASME in the usual sense.

DR. ROSEN: Well, only in that we didn't do that when we built our reactors. We did it after the fact.

DR. APOSTOLAKIS: Is a risk informed approach acceptable in Canada?

MR. LEGER: We haven't been using a detailed risk informed approach for the inspection of the -- we have a standard for inspection that includes the Class I pressure boundary, and that's the N-285.4, CSA N-285.4 standard, and it is based on an assessment of sort of a judgment of the risk of various parts.

DR. ROSEN: Well, now, correct me if I'm wrong. We've got an ASME code, and we've got a system of code cases, which means if you meet a code case, you meet the code. And a risk informed inspection is a code case, correct? An approved code case.

So if you do risk informed inspection you're meeting the ASME code. I mean, I could be wrong, but I think that's what it's --

DR. APOSTOLAKIS: That means automatically it's acceptable in Canada?

DR. ROSEN: Oh, I don't know about Canada.

MR. LEGER: Our inspection is done through our CSA standard. It does refer in some places to the ASME in terms of acceptance criteria and so on, yes.

MR. SIEBER: But prior to that, there was always a selection process going on within a ten-year interval. When you wrote your ISI plan, you would name all of the welds and then describe places where you couldn't inspect and seek exemptions from those, and then through each interval you would take a certain percentage of those with the goal of at the time you decommissioned the plant, you have inspected everything in it, you know.

So the risk informed is just another mechanism for more intelligently choosing the places to inspect at each interval or each refueling.

DR. APOSTOLAKIS: But the regulators have to agree with that.

MR. SIEBER: Absolutely.

DR. APOSTOLAKIS: It's more intelligent.

DR. ROSEN: The Canadian regulators. Now, in the U.S. we accept the ASME code and the code cases. So that has already been done for risk informed inspections.

MR. SIEBER: Well, we accept it through a review process.

DR. APOSTOLAKIS: Yeah, and it's not --

MR. SIEBER: -- 55(a).

DR. ROSEN: Right.

MR. LEGER: Of course, one of the major differences between --

DR. FORD: Oh, I'm sorry. Could you go back to the previous slide? I think just skimming through your presentation you don't deal with this later on.

What we understand now is stainless steel feedwater pipes are welded to the header, which is carbon steel, 106 presumably.

MR. LEGER: There will be an intermediate weld within the feeder.

DR. FORD: Okay.

MR. LEGER: That's what we were talking about, the location of this transition between the stainless steel and --

DR. SHACK: So you will have a stainless

steel stub on the header where?

MR. LEGER: No, it would be a carbon steel stub on the header. That's right.

DR. FORD: But the weld from the stainless steel to the carbon steel presumably will involve a nickel base butter.

MR. LEGER: It would involve --

DR. FORD: Of some sort?

MR. LEGER: Yes, that's right.

DR. FORD: And this is at 325 degrees C.?

MR. LEGER: Yes.

DR. FORD: Hot side temperature.

MR. LEGER: The outlet temperature.

DR. FORD: Yeah. What sort of nickel based alloy will you use?

MR. LEGER: I'm not right up on the detail at this moment. I could get that for you.

DR. FORD: Okay, but obviously you're going to take into account all of the problems we've had.

MR. LEGER: That's right. We won't be using the IA-182.

DR. FORD: Good.

MR. LEGER: It will be something akin to the --

DR. FORD: And you mentioned early on you've got a lot of extensive experience. You do have a lot of extensive experience in ultimate nickel based weld alloys, 690-whatever it might be, 152. Well, 152.

MR. LEGER: No. In the current CANDUs, it is an I-82 material that has been used on the inlet feeders for the flow orifices.

DR. FORD: Okay.

MR. SIEBER: Well, the design itself for these, the headers and the feeder tubes is not unique to the ACR 700; is that correct?

MR. LEGER: Well, in the current CANDU it's all carbon steel.

MR. SIEBER: Right. Okay.

DR. SHACK: But your document in 4.6 says they are stainless to carbon steel welds. Are you telling me that there are none of those now?

MR. LEGER: Well, it is a stainless to carbon steel weld, but the weld material is something different. That's what Peter's point was.

DR. SHACK: Oh.

MR. YU: Stephen Yu here.

The feeders themselves, the low feeders, as I mentioned, are stainless, and then there will be a transition weld from that to carbon steel feeder, but how sort it is, that still remains to be determined, and then you have a pooling also from the header where it is connected on the upper feeders.

MR. LEGER: All right. So most of the rest of the talk deals with fuel channels, and the fuel channel is designed, of course, to Canadian standards, but it's designed to meet the intent of ASME with accommodation for the particular aspects of pressure tube and the requirement to be able to refuel.

So the zirc-niobium material, of course, isn't an ASME code material, and the stainless steel end fitting, which is a modified 403 stainless steel, Martensitic stainless steel, that is also not ASME, and there are some other design differences. There are roll joints as we talked about between the pressure tube and the end fitting, and we have a channel closure as a part of the boundary that's accessed by the fueling machine.

So this is sort of an overview of the ACR channel, and as you can see, we've got two channels here basically, one that you can see from the outside and one that's in a cross-sectional view. And I guess the features that I'd like to point out here is that at the end we have a channel closure that's accessed by the fueling machine, and then the feeder pipes are connected to the end fitting here, and then within the end fitting there's a liner tube that distributes the flow.

So the flow into the channel would come in through the feeder pipe and be distributed by a liner tube which would be similar at both ends of the channel.

So here we've got the flow going this way in this channel and this way in this channel. All the other feeder pipes are located here between the adjacent channels. So the feeder pipes pass in the spaces between the end fittings along the reactor face.

The end fitting here, which goes from here to here, is this stainless steel single piece forging, and it's held in location by this position assembly which is attached to the end shield at the outside of the end shield. And then there's a rolled joint here between the stainless steel and the pressure tube. So this is the pressure tube here in this location here, and the pressure tube itself is contained within a calandria tube. Then the calandria tube, as Stephen was describing, separates the pressure tube from the cool moderator which is on the outside, the moderator water.

The calandria tube is rolled into the inner tube sheet here, and the pressure tube is supported vertically within the calandria tube on spacers that are spaced along the length of the channel. So there are nominally four spacers along the length of the channel that allow the channel to accommodate axial displacement. Because of thermal expansion and so on, the channel is fixed at one end, and during operation when you heat up, it expands and it moves on the bearings which are within this lattice tube in the end shield. So the end fittings are supported on bearings within the end shield, and if this end is fixed, then the thermal expansion is accommodated by the bearings on this end and also during operation, the channel elongates due to the irradiation that we were talking about before, the neutron irradiation.

DR. ROSEN: Now, before you go on, let's focus on this rolled joint for a minute.

MR. LEGER: I'm going to talk about the rolled joint later, but we --

DR. ROSEN: Oh, okay. Well, I just wanted to know a little bit dimensionally how long it is.

How long does the roll actually --

MR. LEGER: It's about ten centimeters.

DR. ROSEN: Really?

MR. LEGER: A little bit less than ten centimeters.

DR. ROSEN: It's very long. It's a very long role compared to the roll of, for instance, a steam generator.

MR. SIEBER: Pretty high pressure.

DR. ROSEN: A steam generator tube and a USBWR rolled into the tube sheet is quite a bit shorter.

MR. LEGER: It's not a normal roll joint. I'll get into some of that.

MR. SIEBER: Before you flip the channel closure, is that a threaded plug?

MR. LEGER: No. The details here are being looked at in detailed design, but Jullian Millard can answer more details about the channel closure.

MR. SIEBER: That's subject to the full RCS pressure, right?

MR. LEGER: Yes, that's right, but it's designed to take it.

DR. SHACK: Is it any different than in a

CANDU 6?

MR. SIEBER: Well, I don't know what that is.

MR. LEGER: Stephen, maybe you would like that.

MR. YU: Stephen Yu here.

What we have got is a semi-modified conditions of a CANDU 6 sealed closed design because of the end fitting diameter, because they are different. So dimensionally, it is very different, but functionally in terms of the sealing mechanism and the sealing phase and the principles of how it is sealed by the reactor coolant pressure are the same as the CANDU 6.

DR. FORD: Could I ask a question? The fact that you've got boiling of the hot end of the pressure tube, is that a new feature for the ACR 700?

MR. LEGER: No, the current CANDU 6 also has boiling at the end. In fact, it has a higher level of boiling at the outlet end.

DR. FORD: And is there any extent --

MR. SIEBER: Well, let's clarify that just for a second. The statement that was made before was that you had two percent quality factory boiling during a main steam line break, which is pretty severe. The steam plug (phonetic) is very high.

MR. LEGER: No, no. We have two percent boiling during normal operations.

MR. SIEBER: During normal operation, okay.

MR. LEGER: Up to two percent.

MR. SIEBER: Well, that clarifies that for me.

MR. LEGER: Yes.

DR. FORD: Well, my next question is there's not that many CANDU 6s out there. If that's the first model that had boiling at the hot end of the pressure tube --

MR. LEGER: No, no. Some of the other -- Darlington also has boiling at the outlet end and some of the Bruce channels have boiling at the outlet end.

DR. FORD: There presumably has been inspection of those.

MR. LEGER: Yes.

DR. FORD: And do you see any extensive corrosion?

MR. LEGER: We don't see any effect on the pressure tube or on the feeders basically related to boiling.

DR. FORD: And they are all zirc, two and a half niobium?

MR. LEGER: They're all zirc, two and a half niobium.

DR. ROSEN: No deposition of any kind?

MR. LEGER: No. There's very, very little heat transfer at the pressure tube surface. It's not like fuel.

DR. RANSOM: These bearings that you mentioned for the axial growth, they have seals to prevent the CO_2 from --

MR. LEGER: Well,the bellows here is on the end, and it seals to the end fitting. It's a shrink fit and a weld.

DR. RANSOM: So the bellows primarily seals the CO_2 from surroundings?

MR. LEGER: Pardon?

DR. RANSOM: It primarily seals the CO_2 from the surroundings.

MR. LEGER: That's right. The annulus gas is a closed system.

DR. WALLIS: And as the tube grows, those bellows expand.

MR. LEGER: That's right.

DR. WALLIS: But presumably then the tube must stick out further because I don't see any way of accommodating the growth of the tube itself.

MR. LEGER: That's right.

DR. WALLIS: So presumably --

MR. LEGER: The end fittings --

DR. WALLIS: -- the fueling machine backs off a bit.

MR. LEGER: That's right. The end fittings move axially outward.

DR. WALLIS: The whole thing grows out.

DR. SHACK: And the feeder tube bends.

MR. LEGER: And the feeder tube bends.

DR. WALLIS: That's right. I was going to ask that, too. Right.

And since one is held at a different end, so --

MR. LEGER: No, no, no. At any one time at one end they're all fixed.

DR. WALLIS: They're all fixed at one end.

MR. LEGER: So all of the motion is at the other end of the reactor. And then part way through life in the current CANDUs you fix the other end and allow the channel the grow the opposite way.

DR. FORD: And so presumably there has been a fatigue analysis done of that feeder tube to pressure tube joint because presumably if you're going to load follow, you're going to have a cyclic stress on that. No?

MR. LEGER: Well, the number of heat-ups and cool-downs is taken into account in the design, yes.

DR. FORD: From a fatigue perspective.

MR. LEGER: From a fatigue perspective.

DR. FORD: And what sort of design curve do you use for stainless steel feeder tube versus cycles? Do you use an ASME III code?

MR. LEGER: Yes, it would be. It would be done according to ASME III.

DR. FORD: Taking into account the latest information about fatigue of stainless steels in reducing environments?

MR. LEGER: It will be looked at, yes.

DR. FORD: Okay.

MR. LEGER: All right? Any others?

DR. ROSEN: You said you promised me a discussion of the rolled joint, but I don't see it in your presentation. Is it in some other place?

MR. LEGER: There's a picture of the rolled joint, and I was going to talk a little bit to that picture.

DR. ROSEN: All right.

MR. LEGER: So this is just a summary of what experience we've had with CANDU. We've had 41 years of experience with pressure tube reactors in the CANDU community. There's approximately 400 reactor years of operation of large CANDUs worldwide, starting sine Pickering II in 1971, and the longest operating zirc-niobium pressure tubes that are currently in service have 150,000 hours of operation on them.

As we talked before, the pressure tubes change dimensions over their lifetime, and just to give you a sense of what these changes are, for ACR, we're expecting that the maximum diametrical strain seen in any pressure tube would be four, four and a half percent diametrical expansion over the 30-year life.

And associated with that, there's an elongation and a seven percent wall thinning expected during the 30-year pressure tube life. This phenomenon is due to the irradiation treatment growth of the anti-strophic material under the neutron array fast flux that it sees during operations.

DR. WALLIS: Does this change the actual nature of the material?

MR. LEGER: It does have some changes it affects. It has some changes on the microstructure.

It changes the strength of the material. The strength actually increases.

DR. WALLIS: So there are a lot of atoms which are knocked around by neutrons and reattached to things or move around in the lattice.

MR. LEGER: They move around in the lattice. Every atom in the pressure tube gets displaced on average about once a year. That's the sort of --

DR. WALLIS: Pretty severe bombardment.

MR. LEGER: But the microstructure looks the same even after 20 years of irradiation. It looks very similar, except it has --

PARTICIPANT: It's displaced, but it doesn't go very far.

MR. LEGER: It doesn't go very far. All of these dimensional changes are accommodated by design, and we have methods of calculating what the deformation would be based on the experience that we've had, and on a large program of research and development that has been going on for some time.

So the experience in the R&D programs cover the range of ACR conditions that we're going to be having.

The elongation itself is accounted for in all of the feeder clearances and so on and in the stresses in the feeders. The impact of the diametrical expansion for fuel cooling is also something that is taken into account.

DR. FORD: Is there a good database for radiation hardening of this particular material?

MR. LEGER: We have a substantial database of material removed from CANDU 6 reactors, yes.

DR. FORD: I'm just thinking, for instance, the changes in K1C for stainless steel.

MR. LEGER: Yes.

DR. FORD: Which is a lot of material out there, is incredibly scattered as a function of fluence. Is that the same? Do you have well behaved relationship between K1C and fluence, for instance?

MR. LEGER: We've measured the fracture toughness of pressure tubes using both small specimens and burst tests of material removed from pressure tubes taken out of reactors. So we have a substantial database. We have tested more than 1,000 small specimens of different pressure tubes over a number of years, and we have a significant database of material characteristics after radiation.

DR. FORD: Okay, and there's not a big scatter. What's the uncertainty of these calculations?

MR. LEGER: Well, there are differences between different pressure tubes that we're making progress in identifying the causes of all the differences, and that was one of the reasons for changing some of our chemistry specifications for the material, and now we've got a material that maintains its fracture toughness much better than some of the tubes that are currently installed in CANDU reactors.

DR. FORD: Okay.

MR. LEGER: Just to give you a sense of how our predictions work, for example, for diametral strain rates, this is just a plot of predicted strain rates using our design equation versus measured strain rates for pressure tubes installed in quite a number of different reactors, all with slightly different coolant temperature conditions and neutron fluences.

So some of this variability that you see here is material variability and some is variability that isn't -- no, I'll just say it's material variability.

So our expectation with regard to despite these significant strains that we're seeing, we don't see any issue with pressure tube ductility limits. The material is deforming under a radiation, and that's in a condition with very low stress exponent, that's close to one, and under these conditions, you expect to get a behavior that's almost super plastic.

So we don't see anything in the microstructures of tubes removed from service that have significant diametral strains to indicate that there's any creep ductility limit that's being approached here.

DR. WALLIS: Very high strain. We're probably indicating such as a clarian tube.

MR. LEGER: Pardon?

DR. WALLIS: Very high strain. It would probably bring it up in contact with the clarian tube.

MR. LEGER: No, the clearances there are much greater than four percent.

DR. WALLIS: But the failures. Sorry. So you mean it's to incipient failure. It's not as it begins to fail you get the very high strain. You mean it allows a creep strain. Your very high strain refers to a creep strain rather than a strain when it begins to burst?

MR. LEGER: Yeah. With regard to this, I was talking about creep strain; that we're not expecting that creep strain will be an issue with regard to creep ductility.

PARTICIPANT: Does that strain rate increase or decrease with time?

MR. LEGER: It tends to increase very slightly with time.

DR. RANSOM: So with these time is going on your plot --

MR. LEGER: Sorry. These were just comparisons of the measured strain rate. Yes, these are strain rates. Sorry.

DR. RANSOM: But they're in a series.

MR. LEGER: In some cases the measurements have been made over time.

DR. RANSOM: And so time is going to the right?

MR. LEGER: Sorry, no. In this plot, I think I'm going to have to perhaps answer that question --

DR. APOSTOLAKIS: Time has nothing to do with this plot.

MR. LEGER: No, these are predicted strain --

DR. APOSTOLAKIS: Pressures measured.

MR. LEGER: -- rates versus measured strain rates.

DR. RANSOM: Well, on the same material

then, which is each one of the points --

MR. LEGER: No, the strain rate, if you're at the left on this plot, you're at a very low neutron fluence. The flux rate would be low, and if you're at this side, the flux is higher and the strain rate is higher.

DR. RANSOM: Oh, so the flux is varying.

MR. LEGER: That's right.

DR. APOSTOLAKIS: But the C61a nd so on, these are different materials?

MR. LEGER: They're different tubes.

DR. APOSTOLAKIS: They're different tubes.

MR. LEGER: They're different tubes, data from different tubes.

DR. APOSTOLAKIS: Because there seems to be some consistency there. There is no variability is there?

MR. LEGER: Well, single tubes behave, tend to behave in one way.

DR. APOSTOLAKIS: Right.

MR. LEGER: I mean, when you go to a different tube, the material variability makes that tube creep, for example, a little bit faster or a little bit slower than some other tube, but the whole tube would be creeping at a particular rate --

DR. APOSTOLAKIS: Right.

MR. LEGER: -- depending on the material, but different parts of the tube creep at different rates because the neutron fluxes are different along the tubes.

DR. FORD: In that particular algorithm presumably the two inputs are stress and temperature, and those are the only two?

MR. LEGER: It's stress and temperature and neutron fluence, neutron flux.

DR. FORD: Flux, not fluence?

MR. LEGER: It's neutron flux. It's a neutron flux term.

DR. WALLIS: So this is a plot of material behavior that doesn't need a log scale in order to put the points on the piece of paper?

(Laughter.)

DR. WALLIS: That's an inside joke.

MR. LEGER: Let's see. I went through that.

In terms of our experience with pressure tube integrity, we've had no pressure tube leaks due to design or material performance since 1986. We did have some early leaks in zirc-niobium pressure tubes in the Pickering reactors. This was back in 1974 and

'75 due to delayed hydride cracking near rolled joints.

So the rolled joints had high residual stresses, and that resulted in a cracking problem.

There also was a rupture of a Zircaloy-2 pressure tube in a Pickering reactor that happened at power, and that was due to contact between the pressure tube and the surrounding calandria tube that resulted in hydride blistering and a crack developing from blisters. And the pressure tube ruptured at power, but the calandria tube remained intact. The reactor was shut down safely without any of the safety systems having to be brought into action.

We had one rupture at cold conditions from a long manufacturing flaw that started at one of these rolled joints that had high residual stress, but the issues that led to these early failure have been solved basically. We've developed low residual stress joints that eliminate these high residual stresses in the pressure tubes. We have new channel spacer design that prevents the spacers from moving and prevents the pressure tubes from coming into contact with the surrounding calandria tubes.

We've improved our manufacturing practices, and we have better inspection during manufacturing to reduce the chance of having a long manufacturing flaw in a pressure tube.

DR. FORD: Now, the thickness of your tubes have changed for the ACR 700 versus the CANDU 6.

MR. LEGER: That's right.

DR. FORD: Which all impact onto these various engineering changes you've made, the creep rates and touching the calandria tube, the residual stresses in your rolled joint.

MR. LEGER: Yes.

DR. FORD: So how certain are you that you're not going to have a problem with some sort of probability aspect.

MR. LEGER: Well, the changes have been made in a direction that should improve things, in fact.

DR. FORD: Yes.

MR. LEGER: Because the stresses are reduced. The stresses in the pressure tube are reduced relative to what they are in the CANDU, for example. The rolled joints here in the stages of going through a development process for the rolled joint because of the different thickness so --

DR. FORD: I guess my question is really you had two failures, Bruce and Pickering due to failures because of stress or whatever it might be. We'll come to that in a minute or two. And you said that you've improved things from that early experience.

MR. LEGER: Yes.

DR. FORD: Different material, thicker material, and it's a qualitative feeling that things are better?

MR. LEGER: No, it's the --

DR. FORD: And you're never going to have another Bruce or Pickering incident?

MR. LEGER: Well, we are required to be certain that we won't have pressure tube/calandria tube contact, for example. That's one of the requirements of the standard.

DR. FORD: So presumably you've got a fairly extensive database of all interactions between DHC and irradiation and temperature and stress and material.

MR. LEGER: We have a large database of --

DR. FORD: And those interactions to be certain that you would never have a contact between the tube and the calandria?

MR. LEGER: Well, the contact between the tube and the calandria depends on the creep of the channel and on whether the spacers remain in their design locations, and so the spacers for ACR will be not exactly the same spacers as --

DR. FORD: I guess why I'm asking the question, as you know, in this country we have had 40-odd years of many, many manhours of experience of saying that austerlic (phonetic) alloys, nickel based stainless steels will never crack, and yet even now we're still getting unpleasant surprises.

And so when you say that you're certain that something will not happen, I'm interested to know why the certainty.

MR. LEGER: We think it's a very low probability.

DR. FORD: Okay, okay.

DR. ROSEN: So you're taking "certain" back?

DR. FORD: Well, the design is intended to address all of these issues. The safety analysis covers the potential that it doesn't.

DR. SHACK: You're so certain that you're going to change them out at 30 years.

DR. FORD: I want to know what the criteria are.

MR. LEGER: The 30 years has to do with

the limits on, for example, diametral expansion that you can tolerate.

In terms of the cracking mechanism that we've studied over time, the cracking mechanism by delayed hydride cracking is something that we have been studying for quite a long time. We understand it very well, and we know that cracking won't be possible at operating temperatures, given that the hydrogen content of the tube remains below the solubility limit in the material.

And we avoid crack initiation by having these low residual stress joining techniques and by preventing debris flaw formation in the system by keeping it clean.

Any cracking that could potentially occur at low temperature where the solubility of hydrogen is exceeded, the cracking is avoided by having lower pressures.

In zirc-niobium material, of course, hydrogen goes into solution. This is just a plot of the hydrogen concentration on a log scale versus the one over T because it's a sort of thermally activated process. So there's a solubility limit. As long as the hydrogen concentration is below this limit, then hydrides won't form in the material and you can't have delayed hydride cracking.

So we currently have experience up to CANDU 6 temperatures. The ACR is slightly higher temperature. The pressure tubes do pick up hydrogen through the corrosion reaction that occurs on the inside surface with the coolant. So a fraction of this hydrogen generated by the reaction is picked up by the material.

And if you do get into a situation where dydrides are present, then there is a potential that there could be a fracture concern.

DR. FORD: But your thesis is hydrogen is necessary, but it is not the only criterion. For instance, Bruce and Pickering have failed and, therefore, they --

MR. LEGER: Yes, but that's hydrogen.

DR. FORD: I'm puzzled then because what --

MR. LEGER: All of the cracks that have occurred in pressure tubes have been attributed to delayed hydride cracking.

DR. FORD: Okay. So if you don't have hydrides, then you can't have cracking, and yet Pickering and Bruce did.

MR. LEGER: They didn't crack at reactor

operating temperature. They cracked when the reactors were shut down due to these high residual stresses in the rolled joints.

DR. FORD: Okay. And we're not going to have this problem with the ACR 700?

MR. LEGER: No, no. The target is to keep the hydrogen concentration below this solubility limit in the main body of the pressure tube during reactor operation.

DR. FORD: Okay.

DR. WALLIS: How about the water chemistry side? You control the hydrogen?

MR. LEGER: Yes, the water chemistry is controlled. It has its -- lithium hydroxide is added to keep the pH up for the carbon steel parts of the system, and the hydrogen is added at levels that are in the range of three to ten cc's per kilogram.

DR. WALLIS: That's to weed out the oxygen in the water.

MR. LEGER: That's right.

DR. WALLIS: And then that hydrogen doesn't affect the --

MR. LEGER: No. The hydrogen doesn't seem to --

DR. WALLIS: It doesn't have an impact.

MR. LEGER: No, it doesn't.

DR. FORD: And so just to follow on my concern, I grant you that under operating temperatures and operating conditions you don't have a problem, but during an accident situation where you may lower the temperature, it's really like a PTS situation for current pressurized water reactors. You could have a problem then, couldn't you, with the zircaloy?

The temperature goes down, i.e., goes to the right on that plot --

MR. LEGER: Yes.

DR. FORD: -- and then you would have a problem of cracking as happened at Bruce and Pickering?

MR. LEGER: I don't know exactly what scenario you're thinking about. I mean, if you are under low temperature conditions where you have high stresses and you've got a crack that could potentially grow --

DR. FORD: Yes.

MR. LEGER: -- then the crack could grow at a rate that would be determined by the delayed hydride crack velocity curve, which we have in detail.

DR. FORD: I guess my concern is on that plot you're saying anything below that thick line, no problem at all with DHC, and yet we did have cracking at two --

MR. LEGER: At the operating temperature.

DR. FORD: That's my point.

MR. LEGER: Yes.

DR. FORD: And you explain away the Bruce and Pickering experience of cracking as happened at low temperature. Now I'm asking the question, well, that could happen with the ACR 700, could it not?

MR. LEGER: Well, at low temperature, as I was indicating before, the reason why it happened at low temperature was because there were still some very high residual stresses present in those tubes, and so there was a driving force at low temperature. In ACR --

DR. FORD: You won't have that.

MR. LEGER: -- we won't have that.

DR. FORD: Okay.

MR. LEGER: Again, in terms of how much hydrogen gets picked up, well, in CANDU reactors, the corrosion of pressure tubes so far after 20 years of operation, we have oxide thicknesses on the inside of the pressure tube that are in the range of 20 to 30 microns, and the maximum hydrogen that's picked up, although it's picked up as deuterium in our current

CANDU 6 reactors, it's equivalent to about 20 parts per million of hydrogen after 20 years of operation, except near the rolled joints where there's higher hydrogen pickups.

So the rolled joints, the areas of the rolled joints do pick up some higher levels of hydrogen.

MR. SIEBER: Why is that?

MR. LEGER: Well, we think it's a galvanic interaction between the pressure tube and the end fitting that's causing the pickup in the pressure tube.

MR. SIEBER: Oh, okay. Could you describe what this low stress rolling technique is?

MR. LEGER: Well, the low stress rolling technique is basically a technique that in the current CANDUs -- and as I said, we are going through a development program for the ACR to demonstrate that we'll be able to achieve the same good flow stress rolled joint which is different because of the differences in the wall thickness and so on.

But in the current CANDUs, the rolled joints are what are called a zero clearance rolled joint, and in order to make the rolled joint, the end fitting is heated up, and the pressure tube is inserted. It's actually an interference fit within the rolled joint, and then the rolling takes place.

And that leaves the material in the pressure tube just on the inside of the rolled joint where it's not supported in a compressive stress situation rather than a tensile stress.

MR. SIEBER: Thank you.

MR. LEGER: So we have models of corrosion and hydrogen pickup that are based on experimental programs, and these models are compared with the observations that we have from surveillance from reactor.

We have models for both how hydrogen gets picked up in the rolled joints and in the main body of the tube. This is a plot of how hydrogen behaves in CANDU 6 reactors at the five meter location, which is five meters from the inlet end. It's the position that has the highest pickup rate in the CANDU 6 channel.

This is deuterium concentration. So you have to divide these numbers by two to get hydrogen basically, and this is time in hot years. So ten hot years is 87,600 hot hours of operation, and so the model that was derived from experiments and from lab experiments is the solid middle line, and the measurements from reactor are shown here.

So there's some variability again, which is material variability primarily, and some reactor-to reactor variability as well.

But for our predictions for ACR, we use an upper bound of these curves. So getting to pressure tube leak before break, leak before break is seen as a defense in depth for normal operation. The annulus gas system is used as a leak detection system. So the gas is circulated through the gas annuli between the pressure tubes, and if there is a leak, it picks it up. The gas system is monitored continuously for moisture content.

In ACR the response time of this system is going to be significantly improved relative to what is currently in place in the other reactors that we have.

We know that fracture toughness and crack growth rates are, pressure tube material, and leak before break basically means that you have to be able to demonstrate that using your upper bound crack growth rates and your lower bound fracture toughness values, that you have a database for it that you can show that if you do get a leak, that you will have time to be able to detect that leak, have the operator react to that leak, shut down the reactor, and maintain the pressure boundary in a satisfactory condition without the crack becoming unstable.

So leak before break for a reactor is demonstrated by a sequence of events analysis. So you postulate that you have a crack, that it's growing, that it starts leaking. We have models for what the leak rate will be and what the response of the system will be in terms of detection, operator action, and so on, and we know what the crack growth rates are. We know what the minimum instability crack length is, and so we can demonstrate that we have leak before break for pressure tube in the reactor.

DR. FORD: Obviously the veracity, if you like, or the supporting documentation to come up with that end conclusion, you've got to go into the whole question of the scatter of the pressure mechanics data and the crack growth rate data.

MR. LEGER: That's right.

DR. FORD: Plus whether it's an axial versus circumferential crack. Has all of that data been made available to the NRC so that they can come to their own independent view on that?

MR. LEGER: Some of the data has been made available, but I don't think that -- I'm not sure whether we've given all of the data. We made a presentation in December of 2002 where we showed all of the data, but in terms of what's actually been transmitted, we have a lot of significant quantity of the data in this document on the technology of fuel channels that was given to the U.S. NRC.

But in terms of whether -- I don't think even in here it includes all of the data out to the highest fluences that we have because this is a public document.

DR. SHACK: In addition to the leak before break, do you do a volumetric inspection, ultrasonic or eddy current under pressure tubes?

MR. LEGER: Well, they're inspected during manufacture.

DR. SHACK: Right, but I mean in service.

MR. LEGER: In service we have a program of in-service inspection, but it inspects the fraction of the tubes in general, the small fraction of the tubes. So the --

DR. SHACK: And small fraction is 20 percent?

MR. LEGER: In current reactors it's less than 20 percent. I think the current standard is being rewritten to increase the amount of inspection that's done, but the amount of inspection that's required is quite small. It's a small number of tubes, and basically --

DR. SHACK: Is this an eddy current probe on the surface?

MR. LEGER: It's basically an inspection to detect a generic degradation problem that could affect a large number of channels rather than a specific channel inspection because all of the channels are basically operating in the same condition.

All right. The fuel channel standards, the pressure tube is designed to this CSA Canadian standard, CSA N-285.2. So the tubes meet a material standard which is an N-286.6, and additional ACL technical specifications. So the standard is a general standard. ACL has some additional requirements on the pressure tube material that are in our technical standards.

Zirc-niobium material is an ASTM material. It's in the ASTM standard B-353 as UNSR-60901 material, and basically for these standards we've used an ASME type of criteria to establish the allowable design stress levels. So the allowable design stress level is determined by the minimum strength of the material, either the UTS or the -- it's actually the

UTS. It's one-third of the UTS that's used as the design stress level, stress allowable level.

The tubes that we produce basically are consistent, high quality product. The current tubes that are being produced have improved properties relative to earlier production and these improved properties have been established through the research programs that have been done over the years. One of the major factors, I think, that I mentioned before was this improved fracture toughness after irradiation.

That resulted from an R&D program that identified chlorine as being a bad thing to have in pressure tube material. It really had an impact on how the fracture toughness decreased effluence, but now we have manufacturing methods that reduce the chlorine content so that we get very high fracture toughness.

DR. ROSEN: Who actually makes these tubes?

MR. LEGER: Pardon?

DR. ROSEN: Who actually makes them?

MR. LEGER: The tubes are made -- in Canada the tubes are manufactured by NUTECH, which used to be Chase Nuclear in the States, but the material itself, we've had two sources of material, well, actually more than two sources, but two sources of material over time. The material is supplied by Wa Chang (phonetic) in Albany, Oregon, or for the Qinshan project the pressure tubes were -- the material was supplied by a Chepetski (phonetic) plant in Russia.

The tubes are actually manufactured in Arnprior, Ontario, by NUTECH Precision Metals.

Just in terms of the rolled joints, the rolled joints also meet a Canadian standard, and this standard is made to reflect the ASME code requirements of design by analysis. So we're looking at being able to show that the stresses in the joint are acceptable and so on.

The resulting joint is this strong joint. It has to be able to -- the code requires it to be able to withstand three times the design condition axial load, including pressure. The qualification program is carried out with production grade joints, and each reactor joint when the reactor is actually assembled, each joint is checked to make sure that the wall thickness reduction that has been achieved by the rolling is within the range of acceptable wall thickness reductions for the pressure tube rolled joint and the leak rate of the joint is checked using a helium leak detection system.

DR. ROSEN: This is field operations, right?

MR. LEGER: It's a field operation. That's right, although in ACR the reactor, including the pressure tubes -- maybe, Stephen, you could say something about that.

MR. SIEBER: It's a factory assembly.

MR. LEGER: It will be a module.

MR. YU: Even on recent reactor construction that we have, a facility for the installation the rolled joint, so it's a clean environment for doing that. I think in the module concept we would do very similar, whether it is in the location off site or on site. They would still be the same clean environment for the rolled joint installation.

DR. ROSEN: Well, the difference is whether or not there are transportation stresses, whether the rolled joint is made in the place where it's going to operate or whether it's made remotely and then shipped. So that's all I was asking. And you're saying it could be made remotely and shipped as part of a module.

MR. YU: That's correct.

DR. RANSOM: After 30 years you change out this tube, right?

MR. LEGER: that's right.

DR. RANSOM: How is that taken out? Just cut them and then --

MR. LEGER: The tubes would be cut and removed, yes.

DR. RANSOM: And the bells are rewelded when you put it back in, I guess.

MR. LEGER: Well, the process for ACR, does anyone have the details of the process that will be used for ACR? I don't.

MR. YU: Well, in general, one of the emptying would be removed, and then, you know, after the rolled joint is cut, the next picture will show that we have two sets of rolled joints in there, grooves ready so that after the two ends are cut, then the pressure tube can be removed, and they are removed and then collapsed to reduce the volume of waste, and then the new pressure tube we put in with the end fitting on the end where the end fitting was removed.

So it's just two joints in the pressure tube that the pressure tube is new material. We reuse the end fittings.

DR. RANSOM: I guess the rolling process

is rolled from the interior.

MR. YU: That's right.

DR. RANSOM: And expanded into the --

MR. YU: That's correct. I think the rolling is taking place from within.

DR. ROSEN: And now here's the picture you promised me, and you're going to take me through that slowly.

MR. LEGER: Yes. Here's the picture. So these are the --

DR. ROSEN: Including the heat treatment and all the rest.

MR. LEGER: Pardon?

DR. ROSEN: Including the heat treating.

MR. LEGER: The heat treating?

DR. ROSEN: Didn't you say it was heated up?

MR. LEGER: Well, the end fitting, to make the current zero clearance rolled joints, the end fitting is heated up for CANDU 6 reactor. The end fitting is heated up, and then the pressure tube is inserted, and then it is cooled down, and then the rolling takes place, the mechanical rolling. The rollers are inserted, and a tapered plug is pushed in as the rolls take place. So it's a propulsive rolling technique, and the tube is rolled and the pressure tube actually gets extruded into grooves in the end fitting, and it's these grooves in the end fitting and the pressure tube extrusion into these groves that gives the rolled joint its very good strength characteristics. So that's where the strength comes from.

And this is an ACR designed rolled joint. So as Stephen mentioned, this set of groovers would be used for the initial pressure tube that was put in, an then the pressure tube would be cut here, and this pressure tube would be removed. The original pressure tube would be removed, and the new pressure tube would be inserted and rolled into these groups. That's the intent.

MR. SIEBER: You have to move that end fitting out of the way to get the tube in though. Does that mean --

MR. LEGER: One end fitting would be left.

MR. SIEBER: You'd have to cut the feeder pipe.

DR. ROSEN: Now, you're very careful to say that for CANDU the end fitting is heated up. Does the ACR also heat up the end fitting?

MR. LEGER: Well, we're in the midst of

going through a development program for the rolled joint to be able to demonstrate that we've got all the characteristics that are required.

DR. ROSEN: What does that mean? What did you just say? Did you just say you don't know yet?

MR. LEGER: Well, we haven't -- the detailed rolled joint, the demonstration that we've got that the rolled joint has been developed to a satisfactory level, it's a development program for the ACR rolled joint.

DR. ROSEN: Okay. We're all speaking the English language now, and what you're saying --

MR. LEGER: What i'm saying is that we have a CANDU 6 rolled joint, that the ACR geometry is going to be different because the pressure tube is thicker and because some of the clearances and so on are different, and so we have to go through a development program for the ACR rolled joint which is not yet completed.

DR. ROSEN: Do you envision that it will be like the CANDU?

MR. LEGER: Yes, it will be similar, but it's not going to be identical. Does that -- maybe Jullian. Can you elaborate on that at all?

MR. MILLARD: We've actually got quite an extensive program going on, including using -- sorry. I'll go near the microphone.

We've got quite an extensive program going on using a combination of computer based tools and static testing where we use a program LS Dinez (phonetic) and Design-aid, which we took out of the automotive industry. It's used for crash tests, and we've got a series of tests going on looking at different variations of groove geometry and clearances and fitting thicknesses and fitting shrink.

If you look on the outside of the end fitting you'll see that we've got a shrunk reinforcing ring there.

DR. WALLIS: Yeah, I was going to ask about all of these other colors you've got here.

MR. LEGER: Well, these are the bearings in the lattice tube. This is the lattice tube, which i snot part of the fuel channel. This is the bearing, and this is the --

DR. WALLIS: It's the reinforcement?

MR. LEGER: This green part is the stainless steel 403 forging, and this is the pressure tube.

DR. WALLIS: That yellow thing is a reinforcement?

MR. LEGER: The yellow thing is a reinforcement.

MR. MILLARD: Yeah, it's an inconel reinforcement that we would like to find a way of designing out, but just now we've got it in there.

CHAIRMAN KRESS: That's so you don't deflect that part when you do the pressure tube rolling.

MR. MILLARD: Yes. Basically it gives us --

CHAIRMAN KRESS: It keeps it in place.

MR. MILLARD: It gives us an interference fit and alters the stress in site.

DR. ROSEN: Well, before you get this certified we'll have a chance to see hat you're really going to do here.

MR. LEGER: That's right.

DR. ROSEN: This is a design detail of crucial importance.

MR. LEGER: That's right, but the intent is to make a rolled joint that meets our CSA standard that has these characteristics of high pull-out strength and no residual stress in the pressure tube and so on.

DR. ROSEN: And in the broad outline it

will involve an end fitting that's heated up and then an inconel -- I mean a zirc-niobium tube that's extruded into that heated up end fitting, which then is allowed to cool. Am I correct?

MR. LEGER: No, the sequence is different. The rolling for the current CANDUs, the rolling takes place after the whole thing has been cooled. All right?

DR. ROSEN: Okay, and what you're saying for ACR, the rolling will place hot.

CHAIRMAN KRESS: No, he says he doesn't know yet. Probably cold.

DR. ROSEN: I give up. I don't know what you're going to do.

MR. SIEBER: It's the same

CHAIRMAN KRESS: It's the same.

MR. MILLARD: Basically we've got a heat shrink of the yellow sleeve, which is actually inconel just now. So we heat shrink on that the whole end fitting, push it over the end of the pressure tube, allow it to cool slightly so that the operators can get clear without burning their fingers, and then we put in the rolling tools and expand out, and we measure out our expansion as we go, and then we measure the leak rate around it to make sure that our deformation is okay and our leak rate is okay, and we do qualification where we do example rolls, where we cut apart and do pull tests on to prove the process in general.

So we prove the process off line and then monitor key parameters in that process during installation in the reactor.

DR. FORD: And one of the acceptance criteria will be that the residual stress for this new design, whatever it is going to be, is not going to be sufficient. They're going to push it over the boundary for delayed hydride cracking.

MR. LEGER: That's right.

DR. ROSEN: And this may or may not be done in the field.

MR. SIEBER: It's going to not be done in the field, except for the replacement.

CHAIRMAN KRESS: Except for 30 years, 30-year replacement.

DR. ROSEN: Initially it may or may not be done in the field; is that correct? Because I asked the question and then I got the answer, "Well, it's a module that could be fabricated off site."

MR. MILLARD: When we do that the first time in the field, it's done in controlled environment where quite often they build a tent around so they can control the environment, but it's still field work really.

MR. SIEBER: Now, the coefficients for thermal expansion for the two tube materials is such that when you heat the plant up the joint gets tighter, right?

MR. LEGER: The expansion coefficients are different.

MR. SIEBER: Yes, they have to be.

MR. LEGER: But the actual expansion coefficient for the pressure tube is slightly less than the end fitting, but the joints do remain tight.

DR. ROSEN: So it relaxes a little.

MR. LEGER: It relaxes a little. The interspatial stress would go down, although I'm not sure with the inconel.

MR. SIEBER: So when you test the strength of the joint, do you test it hot or cold?

MR. MILLARD: Test it hot, yeah. You test leak rate hot and below strength hot.

MR. SIEBER: Right.

MR. LEGER: So the end fitting I think we've gone through some of that before. It's a single forging. It's high strength. It has good fracture toughness, and we've not identified any issues with it.

In terms of the channel closure, channel closures are these removable components that allow us to do the on power fueling. The actual closures themselves are designed to satisfy ASME Class I design rules, but they do satisfy the requirements of the Canadian standard in 285.2.

DR. WALLIS: How do they attach?

MR. LEGER: Pardon?

DR. WALLIS: How do they attach?

MR. LEGER: Jullian has it.

MR. MILLARD: It's Jullian Millard again.

Our attachment of channel closures is by a series of jaws which go out into the end fitting. Some of our reactors use a breach log for CANDU 6, Pickering, and ECR will use this jaw construction.

CHAIRMAN KRESS: We'll get into the details of that later.

MR. MILLARD: I think I left my presentation at too a high a level. So I don't think I showed a slide of that.

CHAIRMAN KRESS: Okay.

MR. MILLARD: It can be supplied at a subsequent date.

CHAIRMAN KRESS: We can put this off until later to find out about that.

DR. WALLIS: It's just that all of these places where you might lose the pressure boundary I think need to be understood.

MR. SIEBER: That one is a key one.

MR. LEGER: The requirements of the code, of the Canadian code, require that the closure has to be locked in place to prevent it from being inadvertently removed, and the closures have to be leak tested each time they're installed during operation, like when you do a fueling operation, you have to leak test the closure before the fueling machine is removed from the channel.

CHAIRMAN KRESS: Are these sealed by O rings?

MR. LEGER: Pardon?

CHAIRMAN KRESS: Are these metal O ring seals?

MR. LEGER: It's a metal-to-metal seal, yes. The --

DR. ROSEN: So you're proving before you back away from the face --

MR. LEGER: Yes.

DR. ROSEN: -- that even when you back

away it's already sealed.

MR. LEGER: That's right.

DR. ROSEN: And while you're sealed hooked to it --

MR. LEGER: While the fueling machine is still hooked to the channel, hooked on the channel, locked on the channel, a pressure test is done to --

DR. ROSEN: Your basically depressurize a space.

MR. LEGER: That's right.

DR. ROSEN: And check to make sure there's no leakage into that space.

MR. LEGER: That's right.

DR. ROSEN: And that the pressure is not rising in that space.

MR. LEGER: That's right.

DR. ROSEN: And then when you're convinced that you've made a good seal --

MR. LEGER: Then you can remove the fuel test. And there are interlocks in place. The code requires that there are interlocks in place to prevent the fueling machine from disengaging before the closure is in place.

MR. SIEBER: I take it there's no flow and no pressure while the actual refueling is taking place? Has to be or the fuel element would have --

MR. LEGER: May Jullian can answer that. I know in the current fueling machines there is flow, a small amount of flow injection into the channel during refueling.

MR. SIEBER: I would think that you would need normal flow.

MR. LEGER: Well, no, the whole channel is undergoing normal flow.

MR. SIEBER: Right, okay.

MR. LEGER: But in addition to that, the fueling machines inject a small amount of fluid into the channel at the same time.

MR. SIEBER: Right. That's good enough for an answer.

DR. ROSEN: Now, that additional flow is process system flow, call it, that actually comes from an external system; is that correct? And comes through flexible hoses and somehow is injected into the channel. Am I correct about all of that?

MR. LEGER: That's right, yes.

DR. ROSEN: So that those hoses are actually part of the reactor system, the pressure boundary during this operation.

MR. SIEBER: There's a check valve in

there.

DR. ROSEN: Is that right?

MR. LEGER: That's right, yes.

DR. ROSEN: And so those hoses are designed to ASME Section 3, Class 1?

MR. LEGER: Those hoses are designed to the Canadian standards, CSA and 285.2, and there are --

DR. ROSEN: Because I never heard that there was a --

MR. LEGER: -- requirements; there are --

DR. ROSEN: -- set in that Section 3, Class 1.

MR. LEGER: There are requirements on the hoses as well. Jullian knows more about that than I do.

MR. MILLARD: Basically, the injection flow is -- Jullian Millard from ACR again.

We have got isolation valves and check valves on the heads, which allowed us to have a good isolation boundary. So we try and have our hoses below ASME Section 1 because it's very expensive to have equivalent of ASME Section 2 hoses and ASME just now does not cover flexible hoses, which is why we have additional requirements in our CSA code both on manufacturing checks and on calculation of service live.

DR. ROSEN: So how much flow is going through these hoses and check valves? Are we talking about gallons per minute or --

MR. MILLARD: It's normally about 20 gallons per minute that we're putting into the end of the channel compared to I was thinking metric; is it 25 kilograms a second of flow going down the channel? So it's a relatively small percentage. It's basically a flush and flow that we're putting in to make sure we don't get fuel channel fluid coming into the fueling machine head even though the fueling machine head is using process fluid from the pressure and inventory control system of the new transport system. We try and run the fueling machine heads cold.

DR. ROSEN: And you say there were check valves. If one of these hoses failed --

MR. MILLARD: Yeah.

DR. ROSEN: -- you're relying on the check valve, right?

MR. LEGER: We've got isolation valves and check valves.

DR. ROSEN: But the isolation valves are automatic isolation? I mean, they would sense that the delta P or how does this work?

MR. MILLARD: Just now we've got flow fuses which are flow based check valves that come in, and we've also got isolation valves under operator control.

DR. ROSEN: Manual?

MR. MILLARD: Manual control, and then we've got flow measurement so the operators can see it. They would also see the spray of water coming out on the vault cameras, but the flow rates are relatively small, and because that fluid is not coming out of the channel, it's fluid to do with the fueling machine system

DR. ROSEN: Has that ever happened in existing machines where you had a failure of a hose?

MR. MILLARD: I gather many, many years ago they did have a failure of a hose, and since then more stringent quality control was put on the hoses and also better calculation of service life from the radiation --

CHAIRMAN KRESS: I think I'm going to have to move this on a little bit. We're getting way behind.

MR. LEGER: I think that was pretty much it.

CHAIRMAN KRESS: At this time before they close the cafeteria, I propose we shorten our lunch period a little to catch up if you guys don't mine, and I suggest we try to be back here at one.

PARTICIPANT: At one?

CHAIRMAN KRESS: Well, I'll tell you what. I'll give you till 1:15. That will put us 15 minutes behind. So 1:15 we'll recess.

(Whereupon, at 12:34 p.m., the meeting was recessed for lunch, to reconvene at 1:15 p.m., the same day.)

AFTERNOON SESSION

(1:18 p.m.)

CHAIRMAN KRESS: At this time we're going to change the order of presentations a little bit and instead of computer codes and validation, we're going to hear on-power fueling.

So you know where to turn to in the slides.

MR. MILLARD: Good afternoon. I'm Jullian Millard from the Reactor Fuel Handling Branch in ACL.

I'm going to give you a quick overview on on-power fueling. Obviously it's a fairly big subject. Apart from presentations we've handed over, we've given a fairly large document giving a lot of the background data on the technology basis and the safety background to off-power fueling.

And there are a number of meetings coming up where we're handing over other detailed information to NRC staff on this.

Basically I'm going to discuss the advantages of on-power refueling on the CANDU reactor design and how the equipment is used. Basically we do it to keep t he core reactivity low and give us a lot more flexibility in station outages. So basically outages don't need to be at a fixed time. They can be taken at basically a time that the market wants, which operators prefer a lot.

We have been safely and successfully doing on-power fueling for many decades now in 45 reactors, and the ACR design is an evolutionary design building on the best features of our past designs.

Basically this is an overview of the reactor building. This is the fueling machine bridge down here, and this is the reactor face with our forest of feeders as you called it down in here in the red headers, and this is actually SDS-2 here, shutdown system 2 coming at the site, and SDS-1 is in the deck on the top here, just to give you an idea of scale.

Our ACR-700 reactor, as Stephen says, it's evolutionary, and we use the small stuff constantly over the year instead of a larger complement for a refueling outage.

The plan here in the same building, that last section was a section from this site. So this is just show the air lock site, which is the main maintenance air lock site of the building where we've got our fuel bays for fuel reception and our what we call maintenance locks, but they're really locks into which we move the fueling machines for transfer onto spent and refuel ports.

In the center we've got our coolant supply for normal operation for the fueling machine.

In terms of our fueling scheme, basically fueling is used as the high level method of keeping core reactivity at about four and a half milli-K, which works out at 5.6 bundles per full power day for daily refueling. Of course, we don't actually do daily refueling normally. Most of our reactors work on four days of fueling and three days for maintenance and other activities, maintenance activities, et cetera, Christmas holidays where they fuel ahead using our zone controls to give them a bit of buffer to allow the fueling staff to have some time off, holidays.

CHAIRMAN KRESS: Does your refueling machine have to have a flexible hose connected to it from the cooling line?

MR. MILLARD: Yes. I'll show you those in subsequent pictures.

Each two bundle shift replacement gives us about .2 milli-K of increase in reactivity in the channel, and our physics staff select the channel based on the overall core balance where they're taking about 20 months for fuel to pass through.

And it also allows us to take out

defective fuel promptly. As soon as we get any detection through the heat transport system that we have defect gases in there, we can go in and home in on the channel and home in on the bundles and pull them out.

DR. ROSEN: What can you say about fuel experience? Has there been a lot of fuel, one percent, tenth of one percent, defective fuel or --

MR. MILLARD: I should probably refer that to Peter Boczar. My memory is at .1 percent fuel bundles, and it's typically one element for each of those bundles.

DR. ROSEN: A tenth of one percent typically. Is that what you said?

MR. MILLARD: A tenth of one percent, and that typically relates to manufacturing defects.

DR. WALLIS: How long before you reach a steady state? There must be a starting transient with this fuel.

MR. MILLARD: I should refer that to the other Peter Chan here.

MR. CHAN: I'm Peter Chan from physics.

It will take approximately a year for us to discharge all of the bundles in the first start-up core.

DR. WALLIS: It's a year, but the typical fuel residence is 20 months. So you get some unburned fuel. You're just --

MR. CHAN: It's 600 days is the typical drill time, residence time in the reactor.

DR. WALLIS: But you're refueling day by day, whereas this initial batch really gets old together.

MR. CHAN: The initial batch has lower enrichment. It will stay in the reactor a lot less time than the normal fuel.

DR. WALLIS: I see. Okay.

MR. SIEBER: How many bundles are resident in a reactor typically?

MR. CHAN: Pardon me?

MR. SIEBER: How many bundles are resident in the reactor typically?

MR. CHAN: Oh, right now we have 284 channels. Each channel has 12 bundles.

MR. SIEBER: Times 12.

MR. CHAN: Yeah.

MR. SIEBER: Okay. A lot of them.

MR. MILLARD: As I said, we have got names which give us control of spatial reactivity across the reactor and also give us some method for building these nice windows for all of these fuel handling stuff. You can tell it's fuel handling and not physics, and we've got our full control absorbers for para-setbacks (phonetic).

So basically this picture you've seen before. You've got the end fitting with its channel closure. There's a shield plug in here, which is actually more of a fuel support than a shield plug because we don't rely on the shielding characteristics of it, but it does provide some small shielding during shutdowns, and our reactivity mechanisms which were totally separate.

There's an absorber guide on the outside of each reactivity mechanism. So basically should anything happen on the calandria tubes moving, the calandria tubes would move into the guide. They wouldn't move on to actually stopping the absorber in its operation.

But I've never seen instances of the calandria tubes moving to that degree.

DR. WALLIS: Do these tubes all stick out? Are they supported at the ends in some way? Are they just sticking out like that?

MR. MILLARD: They're literally just sticking out like that. The picture I'll show you later because the insulation cabinet comes on at this level here, you only actually see a small stub sitting out beyond the --

DR. ROSEN: But they're cantilevered. There's no support, right?

MR. MILLARD: It's cantilevered. We take the official support to be coming from here. Even though there is some loading and support coming through the heater, everything is designed to be taken at the root of the fuel channel through the bearings here and for axial movement on this restraint. So we've got a pair of bearings which are sliding bearings to allow our axial -- and then the restraints in there.

DR. ROSEN: Do you ever measure the vibration at the end of that to see if you had any displacement?

DR. RANSOM: We expect the ends of the fuel channels to deflect. There is no actual vibration that we see. I know we've done some measurement of heat transport system vibration, but we don't normally see vibration of the end of the end fitting itself in normal operation.

The fueling machine control system keeps a log of the positions of the end fittings, and it has got a homing system that allows it to basically latch on should the end fitting have deflected out of position.

DR. ROSEN: But you see no deflection. The cantilevered, it could be -- if there was some sort of forced vibration in the building or the --

MR. MILLARD: Yeah.

DR. ROSEN: -- it would be going like this all the time and you'd worry about fatigue eventually.

MR. MILLARD: Yeah, I know. We haven't seen anything like that. In part, I suspect because it's very stiff because it has to take the seismic loads from the fueling machine during seismic events. So the structural load or the structural strength we've got for that keeps it relatively --

DR. RANSOM: Does the refueling machine actually hang onto the fuel channels?

MR. MILLARD: The fueling machine is ported off the bridge, but it's spring loaded, and it's in several axes on the bridge and clamps firmly onto the channel with its 60,000 pounds of force. So it is very firmly clamped onto the end of the channel, and then there's a lock that goes in, physically locking it on to make sure it can't move while it's part of the pressure boundary.

This is just an end view of the reactor showing the STS-2 shutdown nozzles here, which is way up into the reflector region and down into the channels and the numbering of the channels. This numbering also appears on the reactor face so that your reactor operators can see it while they're fueling through their TV camera views.

So apart from the physics staff telling them which channel to refuel and seeing the automatic sequences to go to that channel, these numbers then appear later on you'll see in the picture of the reactor face.

This is the more detailed picture of the fuel channel assembly. You can see there's a groove here on the end fitting that we clamp onto here, and then we have a sealed face on the outside here that we seal with a metallic seal between the --

DR. WALLIS: So isn't this a symmetrical end then?

MR. MILLARD: You mean both ends?

DR. WALLIS: Or maybe it's just the numbering scheme that's not symmetrical.

DR. ROSEN: I was looking at the face. Go back then.

DR. WALLIS: You've got eight on one end

and nine on the other. It's just the numbering scheme. It's not symmetrical. Okay. Did you miss out number nine, do you? There must be a nine under the J.

MR. MILLARD: Yes.

DR. WALLIS: Okay.

MR. MILLARD: Yeah, there's a nine under the J.

DR. WALLIS: Okay. That's all right.

MR. MILLARD: So basically you can see our restraint here going into the fueling tube sheet. The bellows here, which are seal welded on the outside, and then attached to the end, the end fitting. The shield plug here, which is the main fuel support which we pull out to move the fuel string and change bundles, and the closure plug at this end that we take out with the central stem. You can't really see the jaws in this view though. It's much too small.

MR. LEITCH: Does the unit continue to operate at full power while this is ongoing?

MR. MILLARD: Yes, yes.

MR. LEITCH: And must there be some adjustments in reactivity after you make one of these moves or is what you're doing on any given day so small that you can't really see it?

MR. MILLARD: The operator doesn't normally do anything to adjust the reactivity, but the zone controls themselves may adjust automatically, slightly to compensate should you end up with -- because as you refuel over a day when you're refueling several channels, you're refueling in different parts of the core. So you're changing the core balance. So the zone controls will automatically adapt for that.

MR. LEITCH: And where does the operator -- where is he positioned? Does he have any unusual radiation exposure while doing this operation?

MR. MILLARD: Not really. The operator is in the control room.

MR. LEITCH: So this is all done remotely then?

MR. MILLARD: It's all done remotely. Most stations do send operations staff on walk-throughs through the reactor building where they'll look at some aspects of the system while it's operating, but they don't go anywhere near the reactor face.

MR. LEITCH: Sure, yeah.

MR. MILLARD: They'll be looking at the process system underneath the air lock and some other parts of the system, but they won't go into the actual radiation zone.

DR. ROSEN: You just said something that surprised me. That is that this operation is controlled from the main control room. It's not a separate refueling control room.

MR. MILLARD: Correct. It's controlled --

DR. ROSEN: I misunderstood that.

MR. MILLARD: Yeah, because the main control room under control of the main reactor operator. I'll show you later a picture showing you where the fuel handling panel sits and the fuel handling operators sit.

MR. LEITCH: Is there a TV monitoring then of the engagement?

MR. MILLARD: Yes.

MR. LEITCH: Okay.

MR. MILLARD: So we have TV monitoring and all the redundant sensors on the refueling machine itself.

MR. LEITCH: Okay. Thanks.

MR. MILLARD: So we've got drive sensors, redundant sensors, and we've got the TV picture.

DR. WALLIS: This feeder connection in this drawing looks like a bracket rather than a pipe.

MR. MILLARD: This one.

DR. WALLIS: Yeah, what is that?

MR. SIEBER: That's the feeder connection.

DR. WALLIS: Yeah, but it's not a pipe that's welded on. It's a bracket of some sort.

MR. MILLARD: Yeah, the pipe gets welded on here. We're actually doing some detailed design optimization in this area of the port area.

MR. SIEBER: That's a cut-away view.

MR. MILLARD: So this is a cut-away view across our port. Just trying to minimize the pressure drop that's now as part of our detailed design work.

DR. WALLIS: So it's not just the pipe which is welded directly to the pressure tube. There's something else there.

MR. MILLARD: This one shows a bolted connection.

DR. WALLIS: Yeah, something else there. Okay.

MR. MILLARD: So the fuel channel interfaces --

DR. WALLIS: Why do you need a bolt if you've got a welded?

MR. MILLARD: This one goes back in many ways to our CANDU 6 Pickering-Bruce history. All of our historical CANDUs have been bolted at this place with metallic seals.

DR. WALLIS: So it's not a weld. it's a bolted, sealed connection that can be disconnected.

MR. MILLARD: And we considering going back to bolting in this region because we think we can get some advantages from it.

MR. SIEBER: It makes it easy to replace pressure tubes.

MR. MILLARD: Yes.

MR. SIEBER: You know, because you just undo the bolts, and it slides right out. Otherwise you've got to cut the pipe.

MR. MILLARD: Yes.

DR. WALLIS: So it's yet another place where there is a seal.

MR. SIEBER: Yeah.

MR. MILLARD: Yes.

MR. SIEBER: It's a potential leak.

MR. MILLARD: It's one of the few seals we've actually got.

DR. SHACK: Is that a metallic seal?

MR. MILLARD: Yes, it is metallic.

DR. WALLIS: Well, the seal, there are a lot of places where there are pressure boundaries which are not welded.

MR. MILLARD: yes, yes.

DR. WALLIS: You may call some of them seals. Others are plugs.

DR. ROSEN: This one has a gasket. It's a gasketed seal.

MR. MILLARD: Yes, it is a gasketed seal.

DR. ROSEN: But it 's not very big. It's two inches.

MR. MILLARD: Yeah.

MR. SIEBER: Now, what keeps the fuel from just walking right back out of the pressure tube?

MR. MILLARD: It's basically the shield plugs which are latched in place.

MR. SIEBER: But that's way at the end. You've got --

MR. MILLARD: Both ends.

MR. SIEBER: -- a pretty long distance here between the calandria tube sheet where the fuel, the active fuel starts and the end of that plug. That looks --

MR. MILLARD: Oh, you mean the feeder here and here.

MR. SIEBER: -- like there would be three or four feet sticking back. So why doesn't the fuel -- you know, you've got a lot of flow going through there. Why doesn't the fuel sort of follow the flow?

MR. MILLARD: The fuel does follow the flow. Normally it's held in place by these shield plugs, fuel hard against the downstream shield plug which is latched in place and with a gap on the upstream shield plug. And then when you start to fuel, when you fuel from downstream, when you take out the plug, the whole fuel stream follows the plug down.

MR. SIEBER: Okay.

MR. MILLARD: And then when you push the shield plug back in place, the string goes back with it.

MR. SIEBER: And you were getting field growth, assembly growth while burn-up is proceeding.

MR. MILLARD: Yes.

MR. SIEBER: And that's what the gap is for. I take it the gap is maybe an intercept, a couple of centimeters.

MR. MILLARD: About an inch. Mark probably knows or Victor will probably remember the gap.

DR. WALLIS: That's why you have holes in the shield plug, to line up with the holes in the liner tube (phonetic).

MR. MILLARD: Yes, as we pull it back out.

MR. SIEBER: Okay. that's not important if you don't know.

MR. SNELL: Just to clarify, Victor Snell speaking. The gap is about an inch or two. One of the reasons of the gap, in a loss of coolant accident, you want to make sure that the expansion of the fuel stream isn't constrained by the two shield plugs.

MR. SIEBER: Right. Okay. Thank you.

MR. MILLARD: So the fuel channel is restrained, which reacts the fueling loads and the seismic loads because the biggest seismic loads that the fuel channel end fitting sees are when the fueling machine is attached. It has got this removable shield plug which locates the fuel string itself. It has got removable closure plugs which provide the pressure boundary, and it has got this end fitting interface which allows the head to latch on and clamp to it, acidual (phonetic) faced with a seal to allow us to extend the pressure boundary out into the fueling machines.

MR. SIEBER: And I take it for the standard design the seismic loading, I assume, would be a .3 G?

MR. MILLARD: We've got a lot of stuff going on to do with seismic, particularly to do with one site, but I'm not sure how much I'm supposed to say to do with that. I know our standard design reference was .3 G, but we'd be happy at looking at some higher loads to do with specific site spectra.

MR. SIEBER: Okay, but the standard design will have a standard seismic loading assumption which would apply to a majority of sites, I presume, and then you would have to do special work, special analysis for a seismically active site.

MR. MILLARD: I have a suspicion that some of the special work may be done up front because of one customer.

MR. SIEBER: Okay.

MR. MILLARD: I should let Stephen answer that.

MR. YU: Well, we certainly apply the .3 G as our equivalent to SSE adequate level, and the soil conditions, you know, to look at the range of site soil conditions, and we do the envelope for the standard design. I think, you know, there might be special issues that is being currently, you know, addressed like the northeast region on the high frequency special seismic problem.

But as far as the Center of Design is concerned, that's the approach, no different than other reactor types.

MR. SIEBER: Thank you.

MR. MILLARD: So fueling, we've got our string of 12 fuel bundles. We normally take our radiated fuel downstream putting fresh bundles upstream, which allows us to use flow for fueling, which is much more gentle on the bundles.

We are capable of fueling mechanically to go the opposite way if we have to, but we try not to fuel mechanically on power.

We discharged the irradiated bundles by our fuel port going through the containment boundary into the bay in the reactor auxiliary building, which is the square building around the main reactor building.

We bring in new fuel via fuel ports also through the containment boundary.

CHAIRMAN KRESS: And these are our locks so that the containment is not ever really open?

MR. MILLARD: Yeah.

CHAIRMAN KRESS: It's always really closed.

MR. MILLARD: It's always really closed

with a series of multiple valves on each one that we shuffle through.

And the fueling machine, as we've discussed, is this movable Class I pressure vessel that either connects to the fuel ports and fuel channels and sequence, as well as we've also got some ancillary ports and some other equipment for maintenance.

DR. WALLIS: So this fueling machine is going up and down, reactor pressure down to zero several times a day.

MR. MILLARD: Yes, yes.

DR. ROSEN: And you can take it out and maintain it when you're done with the fueling for the day; is that right?

MR. MILLARD: Yes.

DR. ROSEN: And move it to a place where you actually can go in, go in and get at it with your hands.

MR. MILLARD: Yes. Basically you can move it into this maintenance lock. A shield door comes across and then locks out, and then maintenance staff can come in there, do maintenance. They can unbolt the head, take the head off to a maintenance facility and put in a new head. They can do general inspection. They can do servicing.

MR. SIEBER: Could you -- I guess the next slide probably covers it -- but tell us what the design basis accidents are related to the fueling operation?

MR. MILLARD: Yeah, I can quickly go through this. I know the bulk of the design basis accidents, but I should probably have one of our safety staff, Victor, actually go through them in more detail.

MR. SIEBER: Obviously you have a LOCA associated with it, but there's probably some mispositioning accidents.

MR. MILLARD: Yeah, there are mispositioning accidents to do with the potential for the fueling machine to contact end fittings as it moves across the face.

MR. SIEBER: Right.

MR. MILLARD: I'm usually more concerned with all of the safety features we've got in to make sure this never happened in the actual details of the accidents that are being postulated.

MR. SNELL: But just to answer the rest of the question, of course, in safety you ignore all of that stuff that Jullian has put in and you make sort of bounding assumptions -- Victor Snell speaking, by the way -- you assume -- I'm going to memory -- but you assume the fueling machine can back off from the reactor without closing the plug. You assume severance of the inlet and outlet hoses, which actually provide cooling to the fuel while it's in the fuel bundle. You look at accidents with the refueling machine off reactor where it loses cooling in your transfer from the reactor to the spent fuel port. That's about the range of things, I think.

We do look at seismic events for the fueling machine on reactor, which really imposes a design requirement on qualification of the fueling machine which is already mentioned.

DR. ROSEN: If you do take two hot bundles into the fueling machine and then back away from the face and then have your accident where your cooling is severed, your hoses are severed, you're going to end up with two hot bundles with no cooling. Am I right?

MR. SIEBER: Right.

MR. SNELL: In some of the earlier designs you would boil off the water in a fueling machine and then you'd damage the bundles in the machine over a period of I think tens of minutes if my recollection is correct. I believe on ACR there's backup cooling provided in the cooling machines in transit. So Biofueling Confront (phonetic), I believe, made improvement to the machine in that respect.

(No response.)

And there's also multiple errors that you've got, which is not tens of minutes. It's multiple errors because we've got ten tons of steel and water to heat up with the fuel load. so --

DR. ROSEN: Wait a minute now. Are we talking about just having two spent assemblies right fresh from the reactor --

MR. MILLARD: Yes.

DR. ROSEN: -- in the machine?

MR. MILLARD: Yes.

DR. ROSEN: And then the machine is disabled and loses cooling?

MR. MILLARD: Yes, yeah.

DR. ROSEN: Where does this ten tons of water come from? I don't get it.

MR. MILLARD: The fueling machine head mass of steel plus water is about ten tons. So you've got to heat up not just the water in the magazine, but the magazine shell itself, which is multiple tons.

DR. WALLIS: Do you have pictures of this machine somewhere in here?

MR. MILLARD: Yeah.

MR. SIEBER: The transfer coefficient between the fuel bundle and the machine walls isn't going to be very good with the water mix, and so the temperatures of the fuel bundle will probably go pretty high.

MR. MILLARD: The water doesn't get lost out of the fueling machine head for many hours normally because all of our connections are high up on the machine. So basically you can't drain down the fueling machine head below the level that the fuel sits.

MR. SIEBER: But it is boiling away.

MR. MILLARD: Yes, but it takes many hours to boil away.

DR. ROSEN: So if the hose is severed, the water spills out in the hoses, but that's all.

MR. MILLARD: Yeah.

DR. ROSEN: The water in the machine is still there.

MR. MILLARD: It's still there.

MR. SIEBER: I would have to look at that more carefully.

MR. MILLARD: We have multiple hose

connections so we have redundant --

MR. SIEBER: Well, I would think that that would be an opportunity to exercise defense in depth.

MR. MILLARD: Yes. Now, the principal safety features on our fueling are well proven and have been developed over the years with the Canadian standard also being developed as we gain more information. Our pressure boundary components, we use ASME criteria and ASME code in full whenever we can, only enhancing it where we needed to, where there was a gap that wasn't covered. For instance, the NF support of the actual vessel, ASME doesn't take into account a moving vessel with median standards association codes governing those features, and we've got a lot of interlock, mechanical locks, and backup systems in there to make sure everything is safe.

And we've also got this benefit of lower reactor coolant activity because of the fact that we're able to take out defect bundles very promptly, which helps keep the reactor coolant system activity low, which makes maintenance easier.

MR. SIEBER: Could you tell us if there have been incidents or accidents with refueling machines in CANDU reactors of any design, and if so, maybe a simple characterization of what happened?

MR. MILLARD: There have been a number of incidents primarily in the earliest CANDU reactors to deal with fueling machines. A number of them were to do with operator error of operators by passing out information. In subsequent reactors, interlocks were then improved to stop that happening.

For instance, many, many years ago in Pickering, I believe, they forgot to put a thing called a guide sleeve, which is a piece of tube which keeps the bore of the end fitting constantly going into the fueling machine.

MR. SIEBER: Right, right.

MR. MILLARD: Basically the channel closure is a larger diameter, this guide sleeve.

MR. SIEBER: Right.

MR. MILLARD: So this time they forgot to put the guide sleeve in, and then they were able to put a fuel bundle into that gap. It cost a lot of trouble to get over. The precautions to stop that ever happening again are a lot more rigorous, and there's detail of a lot of that stuff in the submission that we did.

MR. SIEBER: Okay. Thank you.

MR. MILLARD: As far as features to enhance safety, we've got our latching snout mechanism with additional safety lock to make sure that we can't unintentionally or have an unsafe release from the fuel channel to make sure RCA's integrity is always maintained.

We've got a lot of qualifications of our controls and instrumentation to make sure it functions properly following earthquakes, loss of coolant accidents or main steam line breaks.

We've got a seismically and environmentally qualified emergency water system to make sure we keep fuel cooling in the fueling machine head when we're off channel for those bundles to make sure we don't get into the boil-off state.

And we've also got special baskets for maintaining criticality because we've increased the enrichment over past CANDUs. We've got to have more features in for criticality protection. So we've got absorbing sleeves in all of our storage baskets and the same types of storage sleeves of steel sleeves in all of our magazines in new fuel and spent fuel in the fueling machine itself to make sure we have our criticality as well.

I can't go through all of the safety features, but in terms of the inadvertent release features, we have got the snout to end fitting clamping mechanism itself, the protection in that. We've got a safety lock which is totally passive in its operation and it's engaged by channel pressure. So operators can't override it to make things go wrong.

We've got these checks on the fueling machine snout and the general end fitting prior to removal of the channel closure in the first place, to make sure everything is okay.

We've got further interlocks on pressure and status of the safety lock. We've got another series of interlocks on the bridge drives and related brakes to make sure the bridge is locked into position when we're extending the pressure boundary.

We've got limited force of the carriage drives as well to make sure that the carriage has got the minimum chance of doing any damage. We've got a further check on partial channel blockage prior to installing the channel closures so that we make sure when we have fueled that we have fueled properly and we haven't inadvertently started to block the channel in any way, and then we've got further checks for integrity of the seal between the channel closure and the end fitting before we unclamp.

So we've got an excellent safety record so far to do with fueling. We've got over 400 years of operation with no accidents.

DR. FORD: That's really reactor years.

MR. MILLARD: Reactor years.

DR. ROSEN: That's how many fuel assemblies do you think you've actually transferred? Probably hundreds of thousands?

MR. MILLARD: It's hundreds of thousands. In the CANDU 6s alone it's 43,000 fueling cycles that we've been through. That's channels refueled. So over the other types of reactors, it's into the hundreds of thousands. So we've got a huge body of data to build on operational experience.

The CANDU 6 stations improved on the alley stations on their safety performance as I alluded to, and ACR is further built on in its design on the CANDU 6 stations with more safety features and using a lot of data from the feedback system to further optimize the design.

In terms of the actual equipment, I'll give you a quick run-through, showing you the new fuel storage that we go through into new fuel transfer, into the fueling machine itself with its head, its carriage, its bridge, the catenaries, the fluid systems that supply through the catenaries and the control system into the spent fuel transfer system and into spent fuel storage, both there and dry storage because historically the CANDU plants take fuel out of the pay when it's cooled enough and moves it into long-term dry storage.

Basically new fuel starts in this secure storage and is only moved into the transfer room as required. So quantities are limited in that area, and as I said, we store the fuel with features to prevent inadvertent criticality even in the worst conditions.

DR. ROSEN: And all fuel assemblies are identical. You don't vary the enrichments or anything like that?

MR. MILLARD: All of our normal fuel is identical. The first load, as Peter talked about, is slightly different, but subsequent to that, once you're past that stage everything is the same.

DR. ROSEN: So there's no chance of a mix-up of a new bundle or anything. They're all the same.

MR. MILLARD: Yes. So then when the containment valve is closed, we inspect the fuel before we put it in. We load it into the transfer magazine, and then we close isolation valves and transfer the fuel across through containment into the fueling machine head.

This is a very rough schematic just showing we've got this loading trough, a loading ram, isolation valve, the magazine or isolation values and a transfer tube going through.

I show you a much more cluttered picture here from a CANDU 6 station. This is the magazine here. The ram is here. The trough is underneath this cover here, and these are simple manual controls for local operation of the thing. We've also got this hoist here which is used. So the staff don't need to pick up a bundle by themselves. They've basically got a grapple on the hoist that they use.

MR. SIEBER: A magazine.

DR. FORD: And that's the ten ton --

DR. WALLIS: No, no, no. It's outside containment.

DR. FORD: Oh, okay.

MR. MILLARD: There's very little capacity.

DR. FORD: This isn't the fueling machine yet. This is this exact --

MR. MILLARD: No, this is just nuclear transfer to get it in the first place and to get it somewhere where we can do our final inspection to make sure there has been no damage between the fuel storage and before it goes in.

The fueling machine itself, we've got the head, which is a Class 1 pressure vessel, which has got a snout assembly with drives in it to connect to the channels and ports. It has got separators which are fingers to both sense the movement of things going through the snout and also to provide some separation motion so we can split apart fuel strings before we retain magazines.

There's the magazine which holds fuel and tools, and we have got a latching ram assembly which is a compound ram which moves the fuel and hardware around.

Then there's a carriage that supports the head and gives it local motions, including the motions onto the reactor face and back off.

There's the bridge which supports the carriage and also is used to support inspection and maintenance. It is used as a big lift basically during a lot of the shutdown inspections and initial build of the reactor.

We've got the catenary system, which is for power and fluid systems, which is all redundant. We've got the control system with viewing and safety interlocks, and we've got this process system for our pressure control and cooling to go between the different pressure states on the reactor and lower pressure on the fuel transfer ports.

This is just a high level picture with a lot of the walls cut away showing the tracks inside the maintenance lock, the catenary itself, the fueling machine head, the carriage, the bridge system here, and the columns which support the bridge.

This is an equivalent CANDU 6 fueling machine which is a lot more complex on the structure on it because it uses all hydraulics to do with it. So there's a lot of idle controls here instead of electrical controls, but you can see isolation valves on the site of the fueling machine here. You can just see the magazine in here. You can see the boundary of it, and you can almost see the snout there and see the round (phonetic) here.

And then there's the catenary here with fluid and electrical connections going across into the maintenance lock. This is the shield door area where the shield door being out of the view on this site, and you can see the shield cabinets here with just a small bit of end fitting sticking out.

DR. WALLIS: Now, this refuel operation, does the operator just sort of do something to initiate it and then all of the sequence of events occur automatically or does the operator have to initiate each one of them in sequence or what?

MR. MILLARD: Certain sequences happen automatically, but there are certain safety critical ones which where a pause is forced, and in many instances the reactor operator has to come in and say, yes, it's okay to, for instance --

DR. WALLIS: To move on.

MR. MILLARD: -- reach the pressure boundary and, yes, it's okay to start moving fuel through the core. So the reactor operator knows at that time so if there is a reactivity transient, he can see it. He can see the things happening.

So it's basically under the control of the reactor operator with the automatic sequences just being used to give more consistency between them.

DR. ROSEN: Is there constant communication in the control room between the operating staff and the fueling staff?

MR. MILLARD: yes.

DR. ROSEN: Where the fueling staff says, "Now, we're going to latch onto so-and-so and so-and-so"?

MR. MILLARD: Yes.

DR. ROSEN: And the plant operators outside the fueling staff say, "Yes, I understand."

MR. MILLARD: You can do it.

DR. ROSEN: "If you're going to latch onto so-and-so, please go ahead."

And the other guy says --

MR. MILLARD: Yes.

DR. ROSEN: -- "Roger that. I'm going to go ahead."

MR. MILLARD: Yes. It's very much under the control of the main operator, as I'll show you in a picture we've got later. They are basically side by side in the control room.

DR. ROSEN: So it's not -- although it's in the same room, it's not proceeding like it's separate from the main operation.

MR. MILLARD: No.

DR. ROSEN: It is the operation of the station.

MR. MILLARD: Yeah.

DR. ROSEN: It's what the station is doing then.

MR. MILLARD: Yes, and it's basically the station is always under control of the main operator and the fuel handler.

This is just a cut-away view of the ACR fueling machine head to make it slightly easier to see the magazine here with its tubes, which also provides for criticality protection and the ram sticking out the back.

And this is the ram.

DR. ROSEN: Are these matters just good practice , what we just discussed, or are they required by regulation? The formal commuunications and the control of these manipulations. How deep does that go in your regulatory scheme?

MR. MILLARD: I'm not actually sure how deep that goes. I know there's a lot of sign-off, and I know the qualification of the operators includes control of that, but I'm not sure where it's enshrined.

DR. ROSEN: See, what I'm getting at is these are reactivity manipulations.

MR. MILLARD: Yes.

DR. ROSEN: And they get the highest level of attention in our system.

MR. MILLARD: Yes.

DR. ROSEN: But they are clearly of a different kind than we have, but they are fundamentally change in delta K, and that means rigid, riveted attention on it.

MR. MILLARD: Yes.

MR. SNELL: Let me give you a somewhat incomplete answer to your question -- Victor Snell again -- because a lot of this goes over into operating utilities.

The way it works in Canada, an operating utility has to prepare operating policies and procedures and submit those to the regulatory agency for review and approval before they can operate and become part of the plant license, and those would have to describe the responsibilities of the various operators in the control room.

I believe what Jullian is saying is correct, but I think to be 100 percent sure, you need to actually look at what a particular utility does. So the way the regulation is done is through approval of the operating policies and principles that a utility submits to our CNSC.

Once they're approved, they're bound to them, and they would describe the relationship that Jullian is describing.

DR. ROSEN: And those policies would then be embodied in practices which are procedures.

MR. SNELL: Well, they're part of the

license, and they would be --

DR. ROSEN: And then they become part of the license which they are required to follow.

MR. SNELL: That's correct.

DR. ROSEN: And so any inspector could come in and see if they're following at any time.

MR. MILLARD: And they basically have administrative logs and computer logs in the fueling machine systems showing all of the operations of the plant.

The spent fuel port in the maintenance log also is an extension of local pressure boundary there, and basically we transfer a straight through into the bay in water. So for ACR it's waterborne transit all the way. So there's no cooling issue at all in that.

And as was talked about earlier, we're going straight into baskets as part of that process, moving the fuel from horizontal into the vertical position so we can store the fuel in basically a larger --

DR. ROSEN: How can you do that? I mean, you can't -- grabbing it with a tool or anything, it has got to have some sort of an up ender that goes like that doesn't it?

MR. MILLARD: The current plants have got a relatively simple up ender. We're still actually in detail design of our ACR equivalent because as part of that we have to drop it down into a solid tube. In the current ones they can go upright, and they're only going into a partial tube in the dry store baskets whereas we have to go into a solid tube, but we have to do it very gently.

So we don't have all of the detailed design of that sorted out just now.

DR. ROSEN: But in the current plants it's some kind of tray into which this bundle is pushed, and then it's pinned at one end presumably in a hydraulic arrangement or a check drive that pulls it upright.

MR. MILLARD: That pulls it upright.

MR. LEITCH: Jullian, if I'm getting the picture correctly, there are really two fueling machines, one in each end.

MR. MILLARD: Yes.

MR. LEITCH: Now, when you're discharging the fuel versus inserting new fuel, do you have to change the positions of those machines or the one machine can serve both functions?

MR. MILLARD: Each machine can serve both functions.

MR. LEITCH: Okay.

MR. MILLARD: Many of the utilities try to do on a single day everything all in one direction, which our physics colleagues don't always cooperate on that.

MR. LEITCH: So there's no detrimental effect then with running for a day or so with only ten bundles instead of twelve in that particular tube?

MR. MILLARD: No. We always take out and put in one channel at a time.

MR. LEITCH: Okay.

MR. MILLARD: We don't run the machines independently.

MR. LEITCH: Okay.

MR. MILLARD: We do take out and put in at the same time. So we always keep 12 bundles.

MR. SIEBER: You actually have 14 during that operation.

MR. MILLARD: On CANDU 6 they end up with more, but for ACR, we don't.

MR. SIEBER: Oh, really?

MR. MILLARD: Because the enriched fuel we take out before we put back.

MR. SIEBER: Okay.

MR. MILLARD: So it's a maximum of 12 for

ACR.

MR. SIEBER: But once you get outside the moderator area, other than the difficulty of making the calculations, you're pretty much guaranteed criticality.

MR. MILLARD: yes.

MR. LEITCH: Now, I'm picturing the machine on one end getting out of kilter with the machine on the other end. Is that possible or is there some kind of interlocks other than just administrative to prevent that from occurring?

MR. SIEBER: They're both in the same tube.

MR. MILLARD: They're controlled from the same control room with redundant controls, and there are usually two fuel handling operators watching to making sure that you're on the right place with also camera views from both ends, which show you which channel you're on.

And there's a TV monitor apart from just being on the control panel in front of the fuel handling operator. There's a bigger monitor higher up so other people in the control room can see are they getting out of kilter.

It's more an economic penalty if they did get out of kilter because of the reactivity change from one channel is relatively small So you're just --

DR. ROSEN: What do you mean by "out of kilter"?

MR. MILLARD: Instead of being one channel, if someone tried to put new fuel into one channel while taking fuel out of another channel, for instance, adjacent channels.

DR. ROSEN: Well, it wouldn't work, right? I mean the channel that you were trying to put it in, there wouldn't be any room.

MR. SIEBER: You would have to push hard.

MR. MILLARD: The fuel would go into the channel, but it wouldn't go into the core area, and then the shield plug wouldn't go back into place. It would be basically just drop out, but it doesn't have enough force to do any damage.

DR. ROSEN: Now, on the other end you could take some bundles out and not replace them.

MR. SIEBER: And you could forget about it.

MR. MILLARD: Yes.

MR. SIEBER: You could forget about it, and that would be --

DR. ROSEN: But that would just be an economic penalty.

MR. SIEBER: Well, to achieve 100 percent power you've got to raise the power someplace else so you end up with a --

MR. MILLARD: But I gather our physics people would rather we didn't operate with empty channels or partial empty channels.

MR. SIEBER: Yeah, right.

DR. ROSEN: The physics people are really in charge of this operation.

MR. MILLARD: Yes.

DR. ROSEN: They give you a fueling order, I assume of some kind.

MR. MILLARD: Yes.

DR. ROSEN: A written document that says or a computer document that says, "Do this."

MR. MILLARD: "Do this."

DR. ROSEN: And then the main control room chief, the unit op. station manager, or the shift manager says, "Okay. This looks like a valid order from the right people; seems reasonable to me, and we'll do this," and he gives it to the fueling people.

MR. MILLARD: Yeah, and then he watches them do it.

DR. ROSEN: So there's a chain of command here.

MR. MILLARD: I know, and he also watches them doing it at key stages to make sure they're opening the right channels. So there are levels of checks and balances to make sure you don't start doing it on different channels.

MR. LEITCH: Earlier you talked about this operation proceeding perhaps four days a week. Is that four around-the-clock days or is it done in four or five hours a shift?

MR. MILLARD: Most of the plants do it during a day shift. They have two days of fueling, a day of maintenance, two days of fueling. Bruce operates more -- the Darlington stations just now operate around the clock, but they are larger cores, and they have more flexibility in their maintenance, but for ACR we'd be following CANDU 6 Pickering type practice.

DR. ROSEN: Graham's question is an interesting and useful one, and I don't think I got the answer I expected. For that day that they're refueling, do they work a 24-hour day?

MR. MILLARD: No.

DR. ROSEN: How many hours during the day of the day that they're actually working?

MR. MILLARD: From memory, we need to check, but I think it's around about four hours of actual operation. I would need to dig back through some of our operational stuff.

DR. ROSEN: So on a fueling day of 24 hours, they only are actually moving fuel for four hours of that 24.

MR. MILLARD: Yeah. Yeah, because you don't get a full seven and a half hour shift of actual operating time in the breaks and the time going to and from the control room.

DR. ROSEN: And there's plenty of time to take your time is the other time I'm interested in.

MR. MILLARD: Yes.

DR. ROSEN: This operation, while it must proceed, can proceed in an orderly manner.

MR. MILLARD: Yes.

DR. ROSEN: A measured pace.

MR. MILLARD: Yeah, and if you don't do things one day there's enough reactivity control that you can do it in the next. So you've got multiple days of what's normally referred to as shim that you can use up if you want to, if you don't fuel for any reason.

MR. SIEBER: What's the burn-up in megawatt days per metric ton of the typical spent bundle?

MR. MILLARD: For ACR, Peter can probably confirm, but I think it's 20.5.

MR. CHAN: About 20.5 or 20,500 megawatt day per ton, somewhere.

MR. SIEBER: Thank you.

MR. MILLARD: And typically a lot of our stations use dry store more for economic reasons for taking the fuel out of the fuel bay for a certain period.

The spent fuel transfer basically is done under water with containment valves using flow to move the fuel across so that we've got very gentle movement with a series of containment valves.

And then we move into these baskets which are stored in racks. The exact shape of some of this basket structure is currently the optimized in detail design. So you may see some changes as the years go on in the process of the application, well, over the next year before the ACD submission goes in.

MR. SIEBER: Is there any reason why you chose to put a hat shaped basket in a rectangular slot?

MR. MILLARD: This picture is actually quite old. I think it was done originally for simplicity of the seismic support or for the basket, for some particularly high seismic zone areas.

MR. SIEBER: Thank you.

MR. MILLARD: The fuel handling operators, basically the senior nuclear operator is in control. He's got to give approval when we're clamping onto the channel, when we take the channel closures out, when we're moving or transferring the fuel, or when there are any manual operations going in there, when they divert from sequences for any reason.

DR. ROSEN: Is your senior nuclear operator equivalent to our senior reactor operator or a unit supervisor or shift supervisor? Why is his equivalent here? Do you know? Is he the top guy on the shift, the highest level or the next highest?

MR. MILLARD: I'm far from the expert on the operator. Stephen, do you?

MR. YU: I believe they're equivalent.

DR. ROSEN: I didn't understand.

MR. YU: I believe the two are equivalent.

DR. ROSEN: Senior nuclear operator is the same as senior reactor operator in the U.S.?

MR. YU: In U.S., yes.

MR. MILLARD: Yes. And fuel handling panel operators. There's a fairly rigorous program of about 18 months before they can actually do anything, and even then they're under the control of someone else.

This is a view of the control room from Qinshan showing the central table and the panels for the main reactor control, but showing the fuel panel on one site. Basically it is split down the middle here with one site being for one fueling machine and the other side for the other fueling machine, and there's a back-up TV screen at the top here.

Some of the plants have actually put in bigger displays to give a better view of what's going on.

MR. LEITCH: So there's no conflict between fueling and normal reactor operations? For example, if the plant trips while this, there may be distractions, but there's no restraint with regard to doing it.

MR. MILLARD: Well, no. Basically everything happens as it normally would. The reactor operator is in control of it all.

DR. ROSEN: What do you mean it happens as it normally would? They continue fueling or --

MR. MILLARD: No. Fueling stops. Fueling stops. If they haven't taken a closure plug out, they wouldn't take it out, and if anything, they would try and get the fueling machine off and clear. If the fueling machine is in operation, they would stop until a safe time, until they're told to bottle up that channel and get the closure plug in.

MR. LEITCH: Is the fuel machine provided with normal AC power or is there any kind of emergency power supply?

MR. MILLARD: Typically they have been run off Class III. There's still a debate going on for ACR reading through the U.S. regulations if where we will end up, and so I'm not quite sure where we are, if we've deviated yet on that.

So the fuel handling operators follow many practices to guard against errors. They never start fueling unless they've got full increment redundancy available on the redundancy inside the fueling equipment. They never perform operations on their RAD until they have been tested first and rehearsed, and there's a high emphasis on human performance and qualification with automation used for consistency, and we've got extensive software checks and software interlocks to do with the automation, and independent and separate interlocks on hardware to make sure things aren't done wrong.

Now, the maintenance is done on line. We've got full redundancy in everything. We've got a predictive preventive maintenance program going on, and there's a fuel emission maintenance area outside that is used for all of this maintenance. So basically there are no scheduled outages for fueling purposes. It's all for maintenance of the other equipment because the fuel handling equipment tends to be used in outages for getting at the reactor phase.

So the on power refueling capability of ACR reactors completely splits us from fueling requirements on our outages. It gives us a lot of flexibility and safety margins. It gives us local reactivity, removal of defect fuel. We've got computer control and automation to make sure everything happens safely and with optimum fuel usage, and we've got defense in depth all the time with multiple barriers.

DR. RANSOM: When defective fuel is detected, what do you, remove the entire channel?

MR. MILLARD: On current stations they remove the entire channel, but for ACR I suspect we are going to end up taking out the individual bundles because of the different performance of fuel. Peter could probably explain that better.

There's also a bigger economic penalty on ACR than on the previous natural uranium CANDUs where fuel is extremely cheap.

DR. RANSOM: You have a method, I guess, for finding out which bundle it is in the channel that's leaking?

MR. MILLARD: We start off by telling down to the channel, and even in doing so because we know the high stress title in the fuel, which is during fueling shifts, we know pretty well which bundle is going to be because it will be one of the earlier bundles going through the channel.

When we actually pull the fuel out through the fueling machine head, we have got detection associated with the fueling machine head, and we can also see the drop on defect gases coming through the reactor coolant systems itself, through measurement in the headers.

So we can tell when the defect bundle leaves the core, as well as looking to see defect bundles in the fueling machine itself.

And then we've got further diagnostics going through fuel transfer so that we can handle it appropriately and make sure the defect gases don't get into the bay.

DR. RANSOM: Just out of curiosity, a fueling machine can take out more bundle at once, more than one bundle at once or --

MR. MILLARD: It normally handles pairs. It's capable of emptying a complete channel because it empties complete channels during shutdowns for inspection of panels.

DR. RANSOM: And it also has sort of a Gattling type cartilage, I guess, that you can load them into?

MR. MILLARD: Yes, yes. So we designed to take out a complete channel in pairs.

MR. LEITCH: I don't see any provision for recycling a fuel bundle; is that correct, or did I miss something? Once it's out, it's out?

MR. SIEBER: Right.

MR. MILLARD: Normally once it's out we have got the ability to put shield plugs back and forth between it, but the fuel staff don't want us to put fuel back.

CHAIRMAN KRESS: Is all of your spent fuel storage on site at every reactor? I mean, you don't have a central storage at Yucca Mountain?

MR. MILLARD: No, we don't have the equivalent of a Yucca Mountain. Each station up to now has been taking care of their own stuff. The multiple unit stations have got central facilities associated with those multiple unit stations.

So, for instance, the Bruce site has got one dry store facility, as has the Pickering site.

CHAIRMAN KRESS: Are those essentially like the dry storage units?

MR. MILLARD: Yeah, and also Pickering has got some centralized bays where it can move things out.

CHAIRMAN KRESS: I guess we'll now move on to the computer code validation adequacy.

MR. RICHARDS: Yeah, I'm just going to have a brief overview on our computer codes and validation adequacy. I'll start by talking about our software quality assurance program, SQA program; talk a little bit about our validation methodology; then talk about what we call our industry standard tool set and the key ACR computer codes.

I can't concentrate on a range of codes. So I've chosen thermal hydraulics as an example in my presentation. So I'll focus in on thermal hydraulics later in the presentation, and I'll give some examples of CATHENA validation, which is our thermal hydraulics computer code.

The software quality assurance program that we operate under are under predefined QA procedures and they're based on the Canadian Standards Association, CSA, quality assurance of analytic, scientific and design computer programs for nuclear plants. That is N-286.7, published in '99.

And subsequent to this, ACL published its own quality assurance manual which is compliant with the standard, and that was revised again in March 2001.

CHAIRMAN KRESS: When we talk about QA and validation of software here, the staff, NRC staff, focuses very strongly on the process, how it is put together and the specifications, rather than final product, these standards here.

MR. RICHARDS: They're very process driven. So if you look at like the design, you'll start out with the problem definition. You'll have a development plan, and you'll go through the stages until you get to design and then coding, and then each one of those will have a verification step.

CHAIRMAN KRESS: Okay. That's very much like what we do here.

MR. RICHARDS: Yeah.

DR. APOSTOLAKIS: Well, but they do more than we do.

CHAIRMAN KRESS: Well, I'm waiting for --

DR. APOSTOLAKIS: I believe you use some formal language. At least for Darlington, the specifications are formulated in terms of formal language; is that correct?

MR. RICHARDS: For the computer programs we use for safety and licensing analysis, it's done under the standard. Now, Darlington, the OPG, Ontario Power Generation, they've developed a manual similar to what we have, and it is quite detailed, quite prescriptive on the things that you have to do through the software development cycle and the documentation you must have in place for the user.

MR. LANGMAN: Excuse me, Dave. Vince Langman, ACR.

I think what you're referring to is the safety critical software work that Darlington does, and that is a very algebraic, formal verification.

DR. APOSTOLAKIS: Right, right.

MR. LANGMAN: You know, you prove from first principles that the code doesn't do anything that it shouldn't do. We're talking about safety analysis computer codes. So it is --

DR. APOSTOLAKIS: It's very different, right.

MR. RICHARDS: So the way that we maintain compliance with our procedures is we verify it through internal third party and regulatory audits.

DR. APOSTOLAKIS: Well, but why would it be different? If one method is very useful in one area, why isn't it in another? This is just a development of the code. It has nothing to do with what the code does. So I'm curious why in the safety critical area you do one thing and for thermal hydraulics you do something else.

Well, thermal hydraulics is, of course, easy. So it's not --

(Laughter.)

MR. LANGMAN: No, no, but I think our approach to verification and validation is very similar to that in the United States. For the safety critical software work --

DR. APOSTOLAKIS: I thought you were doing better than we were.

MR. LANGMAN: Well, maybe for safety critical software. It is an algebraic and very rigorous verification process that took for -- I was involved in it a bit way back when. I mean, it took probably 100 person-years to formally validate 3,000 lines of code, and we generated piles of functional tables that proved, you know, from first principles that the code was perfect.

But, you know, applying that, I think system thermal hydraulic codes tend to be a little longer than 3,000 lines, too.

MR. SIEBER: Well, we have the same situation of V&V requirements under Reg. Guide 1.182 are very stringent and require detailed methodology, but they apply to instrument and control codes, protection codes as opposed to design codes.

MR. RICHARDS: Yes, but what I'm talking mainly here is analytic, scientific and design computer programs. So programs we use in safety and licensing analysis where we have to.

MR. SIEBER: A lot of the validation there is based on test data.

MR. RICHARDS: Yes, which I'll be getting into in a little bit.

MR. SIEBER: Right.

MR. RICHARDS: Within Canada we have what we call industry standard tool set. I guess some five years ago we realized the formal qualification of safety and licensing code. We recognized that it would require significant investment, and if we could develop a standard tool set, it would result in you wouldn't have redundancies and inconsistencies if undertaken separately by each organization.

So the Canadian utilities and ACL worked together to qualify a standard set of computer codes. We all agreed to meet the common processes of our standard CSA N-286.7, and we agreed to share effort on code development qualification and support.

If we look at key ACR computer codes, I won't go through them all but essentially have physics, panel, containment, and fission product transport, and severe core damage.

So I'll be talking about validation methodology, and it applies to all of these codes, but what I will do is I will just use CATHENA as an example, which is our system thermal hydraulics code.

DR. APOSTOLAKIS: What does it stand for?

MR. RICHARDS: CATHENA is Canadian Algorithm for Thermal Hydraulic Analysis.

MR. SIEBER: Not related to Athena

MR. RICHARDS: Athena, no.

MR. RICHARDS: Pardon me?

DR. WALLIS: What's the E for?

MR. RICHARDS: Thermal, t-h-e.

DR. WALLIS: Oh, that's the thermal part. Okay.

MR. RICHARDS: Yeah, we just chose the letters.

DR. WALLIS: So where does analysis start?

MR. RICHARDS: CATHENA, okay, code for thermal hydraulic analysis.

DR. WALLIS: This is a non-analysis, and that -- well, never mind.

(Laughter.)

MR. RICHARDS: Canadian algorithm for thermal hydraulic analysis. Canadian, C, algorithm, A, T-H-E, thermal, T-H-E-N, analysis.

DR. WALLIS: N is a bit -- well, never mind.

CHAIRMAN KRESS: What's in a name?

MR. RICHARDS: So the CATHENA model is a nonequilibrium model, six equation. You have two velocities, two temperatures, two pressures, and you can also include noncondensibles.

We have flow regime dependent, constitutive relations which couple with the two-phase model, and CATHENA can interface to other codes through PVM, like fuel behavior, plant control physics.

So one of the important things that the code has to be able to do is to predict the behavior in the CANDU channel, which could involve stratification of the code.

CATHENA has quite a detailed what we call solid heat transfer model.

DR. WALLIS: It's a one dimensional -- excuse me -- it's just a one dimensional code presumably?

MR. RICHARDS: It is a one dimensional code, yeah, but when you look at the channel here, it's like pseudo two dimensional that you can infer a level in the stratified flow.

So the heat transfer model will identify if you are in the stratified flow where the level is and which pins would be above that level and which pins would be below that level, and that will determine the heat transfer.

So you could have multiple surfaces for thermal hydraulic code. You can model radial and circumferential conduction, and as I mentioned before, you have to consider stratified flow. When the --

DR. RANSOM: Does that stratification model consider that boiling may be occurring in the liquid collapsed layer so that you have some voids below the interface and perhaps even entrainment above the interface?

MR. RICHARDS: We do have a model, a level swell (phonetic) model that's not normally used.

DR. RANSOM: Not in a transverse direction though?

MR. RICHARDS: Yeah. No, the assumption right now is that the way the code is normally used is that the bottom layer is strictly liquid.

DR. WALLIS: Does it get into this stratified mode only during an accident or is it running in this mode?

MR. RICHARDS: No, no. When you're under normal operating conditions, the flow are some 20 to 30 kilograms per second and you don't see stratified --

DR. WALLIS: You don't.

MR. RICHARDS: -- conditions. We have a number of test programs that demonstrated that.

MR. SIEBER: And you probably don't see a level either.

MR. RICHARDS: well, you wouldn't see a level, but you can always infer a level in that you can look at the thin temperatures.

DR. RANSOM: Well, what sort of void is produced under normal operation? I thought that was relatively small.

MR. RICHARDS: It is small, and that would be in a mixed flow because of the flow rate. It would be high.

DR. ROSEN: So you don't really have a level in this tube during all operations.

MR. RICHARDS: This is strictly under -- CATHENA is used for LOCA analysis mainly.

DR. WALLIS: Dissolution conditions or --

MR. RICHARDS: Under natural circulation.

DR. WALLIS: There's no question which way it wants to go and that sort of thing.

MR. RICHARDS: Yes. We can model the deformed geometry, the pressure tube. I'm talking now of the code is used quite extensively for the CANDU 6 system, and in that you can get deformation of the pressure tube and calandria tube, and that can be modeled.

DR. RANSOM: Is that from swelling, you mean, that the --

MR. RICHARDS: During accident conditions where you have the pressure tube heating up and you still have pressure within the pressure tube. As I say, this is used mainly for existing CANDU analysis where you can have this type of thing happen.

Our validation methodology, we have what we call a technical basis document, and then the technical basis document relates the safety concerns to phenomena governing behavior during a phase of an accident, a given accident, and then we have validation matrices which relate phenomena to data sets. There are validation matrices for the various disciplines.

So this is code independent. For a given code you would generate a validation plan before you start any validation without code. You would then conduct a number of validation exercises, and you would summarize those in a validation manual, and I'll talk about thermal hydraulics as an example next.

DR. RANSOM: One thing I'm kind of interested in, the standard you talked about at first in terms of the code satisfying those, there are really two issues that come up. One is the code coded correctly in terms of it representing, you know, what the analysts presumed it to represent, and then the third one, of course, is whether that model fits data or can be assessed.

But is there anything done to assure

correctness of the coding irrespective of the model that it represents?

MR. RICHARDS: The standard talks mostly about the development of software. It does say that the qualification or the validation will take place through validation process, and it doesn't say exactly how you would do it. It just says that you will validate your code. You'll make sure that it represents reality.

This right here is what we've developed within our industry, and it gives a more descriptive way of doing it.

DR. RANSOM: Are these all FORTRAN codes?

MR. RICHARDS: Yes, the largest majority.

DR. RANSOM: And they comply with some standard version I would guess.

MR. RICHARDS: Most are done with FORTRAN 77, though we're moving somewhat to FORTRAN 90. They would adhere to that, to those coding requirements.

So once again, technical basis document, we're given accident category, that this document will identify the key safety concerns. The expected phenomena governing the behavior that evolves with time during identical phases of the accident. It establishes a technical relationship between the technical disciplines, the safety concerns associated with the phase of an accident governing physical phenomena, and the relevant validation matrices.

So just an example, thermal hydraulic example, early in the LOCA you would expect great discharge charge characteristics and critical flow to be a primary phenomenon. I think in your terminology it was a high ranking of importance phenomenon, whereas during ECC injection, you would have quench/rewet characteristics as becoming a primary phenomena or one of the high ranking importance.

Validation matrices, and I'll be talking about one in the next few slides. Identify and describe phenomena relevant to the discipline. Rank the phenomena according to their importance in the accident phases, and that's consistent with the PIRT-like process, and it identifies data sets and cross referenced phenomena, and I'll be talking about the type of data that you can use, separate effects experiments, integral and/or scaled experiments, analytical solutions for inter-code comparisons, and it would include CANDU-specific data and otherwise international.

So this is just a sample of the table where along here we have what are phenomena, and I've only given ten. Our thermal hydraulics validation matrix has 23. I was doing the first ten, and then across the top here, this is for an existing CANDU, by the way. It's not for the ACR. A validation matrix has been largely developed for the ACR system, but it hasn't been finalized yet.

So we have the thermal hydraulic phenomena. We have the accident scenarios, and then you identify the phenomena as either primary or of high importance, secondary importance, or having very little importance.

The second part of the validation matrix looks at the data sets and the phenomena can be validated. It's in the data sets.

DR. RANSOM: I didn't see counter current flow limiting on there, and I thought that was a very important phenomena.

MR. RICHARDS: Yes, it is. It occurs farther down in the list.

DR. RANSOM: Oh, really?

MR. RICHARDS: I've just given the first ten. I had to sort of compress this. There would have had to be two more slides to get it.

DR. RANSOM: I thought that was quite an important thing in the CANDU type reactor --

MR. RICHARDS: Yes.

DR. RANSOM: -- because of these small tubes, you know, feeding.

MR. RICHARDS: But if I did go down for that, you would see for those, for each of these accident scenarios, you would see --

DR. RANSOM: It's judged to be even lesser importance.

MR. RICHARDS: These phenomena are not ranked in order of importance.

DR. RANSOM: Oh, okay.

MR. RICHARDS: Okay. I'll try to move along a little more quickly. For experimental database we use for validating our codes -- and I'm just talking about thermal hydraulics -- we'll make use of quite a bit of international data: Edwards, Marviken, Christensen, Tess, and quite a few others. So we have gone through the literature, and we will use what we can that is available internationally.

When we look at CANDU specific tests, we can subdivide it into small scale experiments, component experiments, integral experiments, and we do have some CANDU plant transients.

And I'll just note here that the majority of existing data supporting current CANDUs can be used for validation of the ACR.

Where we found gaps to exist, and it's mainly at higher pressures and temperatures of the ACR, new experiments have been completed and others have been planned which we'll carry out.

DR. WALLIS: Don't you have some special phenomena like natural circulation with multiple tubes that give rise to some interesting things that you don't get from this sort of background of data that's available? You have to do your own experiments.

MR. RICHARDS: Yes, we'll be getting to that. So if we look at CANDU specific experiments, we conducted quite a large number. Flooding is important in the feeder system downstream of an elbow in the feeder system. That's where the flooding will occur. So we've conducted experiments to characterize that.

We've done experiments characterizing pressure tube calandria to heat transfer experiments; horizontal tube rewetting/refilling experiments; and also pressure tube circumferential temperature distribution experiments.

DR. WALLIS: These are all sort of separate effects tests?

MR. RICHARDS: Yeah, we call them separate effects, small scale experiments, yeah. So you're just looking at one particular effect.

If you look at full scale experiments, component experiments, we have test facilities that can look at feeder refilling, channel stratification, header studies, pump characterization, and end fitting. There are specific facilities, and these are generally full scale. They're not full scaled.

This is an example of --

DR. WALLIS: They are not full scale in the number of feeders, for instance.

MR. RICHARDS: No, but for instance, we can look at this. This is the cold water injection test facility. It has a CANDU typical channel here. It has CANDU typical end fittings, and it has a feeder system that is representative of what you would see in an actual CANDU system.

So the inlet and outlet headers would be scaled, but in this you could look. You can devise experiments where you can void the channel and initiate refill and monitor the refill through the system.

DR. RANSOM: Is that part of the Penoloff (phonetic) facility?

MR. RICHARDS: No, this exists at Stern Laboratories in Hamilton. This is just an example of a component test, and all of these are full scale. All that you're missing is the interaction between the channels.

So then you go to RD-14M, which is an integral facility, and it has not as many channels as an actual CANDU, but it has ten channels. So this facility has full elevation changes between major components and full venue dimensions of a CANDU type system. It has reactor typical heat and mass transfer rates, ten full length electrically heated channels, a total of 11 megawatts. That's a fairly large facility.

It has simulation of all primary side components, end fittings, feeders, headers, and steam generators, and in it you can generate full pressure and temperature conditions. That's for current CANDUs and ACR.

And in here you do, in fact, see under natural circulation that you do get interaction between the headers, and you can study it in this facility.

DR. RANSOM: Now, is that the facility building, Penelon (phonetic).

MR. RICHARDS: White Shell, yes.

DR. RANSOM: Yeah, White Shell.

MR. RICHARDS: Just some example validations of CATHENA, the type of validation that we perform, and start with the Marviken test. Essentially you have the CATHENA calculated mass flow rate, measured mass flow rate, and these are your data points. So the discharge model does reasonably well in CATHENA.

And you go through a range of conditions, top blow-down steam, bottom blow-down water.

These are some experiments that we performed looking at the actual void in the RD-14M channel, and the only way we could get the void with the accuracy we wanted and the time resolution was to use a neutron scatterometer which we developed, which actually looks right through the channel.

And in it you can see the experiment and the CATHENA prediction.

DR. WALLIS: And you don't have enough flux or something to get good resolution, which is why it jumps around so much?

MR. RICHARDS: Yes. Yeah, and with gamma, if you use a gamma densitometer, the uncertainty would be --

DR. WALLIS: It's just the statistics of the radiation.

MR. RICHARDS: Yeah.

DR. WALLIS: So that the void fraction bigger than one is simply an artifact.

MR. RICHARDS: Or less than zero, yeah. It's within the air bounce.

DR. WALLIS: That's interesting. Usually it's the code that jumps all over the place, but in this case the code is very --

MR. RICHARDS: Well, no. It turns out if you look at it, the code is just looking at voiding, and essentially we have in the channel, we have 12 nodes. So it would be over a .5 meter. So you wouldn't expect things to happen, voiding to happen that quickly. Other things, perhaps, condensation, but as for voiding, during this you have essentially blow-down. You'll have emptying of the channel, flashing. Those phenomena are not -- well, we see this as being smooth and with the other calculations. We get condensation with the deal.

DR. RANSOM: Data is from the RD-14?

MR. RICHARDS: RD-14M, yes.

This is a natural test in a CANDU 6 pump where they tripped one pump, and they looked at -- they measured the run-down speed, and again, we can simulate that with CATHENA and get quite reasonable results.

So just in conclusion, we use a range of CODES in our ACR analysis, and they are developed and qualified under a formal SQA program. I've talked a little about the validation methodology. I've used thermal hydraulics and CATHENA as an example. The same is true for the other codes that I showed in an earlier slide, and we do have quite a bit of experimental information to use in our validation.

That's essentially it.

DR. WALLIS: There was a question of how much do you need in terms of data in order to answer the questions you're asking. It always seems to be a very judgmental thing.

MR. RICHARDS: At the end of the validation, our QA procedure says that the analyst should look at it and the analysts at least will say, "Are we getting most of these" or "was the validation successful or are there serious gaps?"

And if there are serious gaps, they're noted and we will try to look to other experiments.

DR. WALLIS: Ideally you'd like your data to tell you what the uncertainties are that you're going to put into something like that. A code, which eventually affects the PRA in some methodical way.

You probably aren't that far along.

MR. RICHARDS: The validation, I believe you can use the validation of the code to get that uncertainty. For a lot of the validation, at least in the thermal hydraulics code, we do look at -- there is a portion of the validation that looks at uncertainty. We look at how does, for instance, if you alter the heat transfer coefficient within the range of its uncertainty, how does it affect this variable you're looking at.

So we are on our way towards it.

DR. WALLIS: Maybe at some time we'll have a smaller group of us look at that in some detail perhaps, if we get that far. A year or two?

CHAIRMAN KRESS: At this time, I'd like to note that we're so far behind that we've decided to postpone the discussion on the fuel design and the discussion on PRA methodology to some later meeting yet to be scheduled.

And at this time, before we get to the NRC staff presentation, which will be the next on the agenda, I would like to take about a 15 minute break.

DR. APOSTOLAKIS: Are we going to receive any documents of the actual PRA before we have that meeting?

CHAIRMAN KRESS: I would like to have it before we have the meeting, yes.

DR. APOSTOLAKIS: Are there any plans for us to receive anything?

CHAIRMAN KRESS: There are slides in here on the overview of the PRA.

DR. APOSTOLAKIS: Yeah, I know, but it's just methodology, a high level discussion.

CHAIRMAN KRESS: Yeah.

MS. SOSA: Today you will hear from the NRC staff on PRA and what are the plans and process as for the pre-application review.

DR. APOSTOLAKIS: But you don't have it yet. You don't have the document.

MS. SOSA: I guess to answer that question I would refer to --

DR. APOSTOLAKIS: He said no already.

CHAIRMAN KRESS: But that would be a document we would want before that next scheduled meeting.

DR. APOSTOLAKIS: Sorry?

CHAIRMAN KRESS: We would want that document before that next scheduled meeting, George.

So let's take a 15 minute break.

(Whereupon, the foregoing matter went off the record at 2:56 p.m. and went back on the record at 3:17 p.m.)

CHAIRMAN KRESS: I forgot we are also putting off the discussion on the negative void reactivity coefficient until a later time also.

So we're going to move at this time to the NRC staff presentation, and I'll ask Laura Dudes to introduce us to that.

MS. DUDES: Well, first I'd just like to say what a fantastic meeting this has been so far. I think we really appreciate the enthusiasm to which we have approached this topic. I think it's consistent with the Commission's advanced reactor policy statement and a lot of these questions, which I think they envisioned us engaging vendors early on these challenging issues and new technology.

As AECL has presented to us in one of their first slides, they may have over 50 years of operating R&D experience, but a lot of this technology is new to us, and so we're still in a heavy questioning mode.

The two project managers, Belkys Sosa and Jim Kim, are going to lead off this presentation, and then we also have several of our technical staff to speak with you this afternoon.

As I said, AECL has about 50 years of R&D. The staff has had a few months. So they're going to be talking to you about their approach to their technical review, how they're going to try and ferret out regulatory and policy issues, and I'm not sure where we'll be in level of detail, but hopefully we can get some insights on what you think of our approach to the project.

Belkys.

DR. WALLIS: Could you give us any preliminary sort of insights or conclusions?

MS. DUDES: I don't think we're going to be at that level of detail today. However, from this meeting I know we'll all be together several occasions in the near future.

MR. SIEBER: Well, maybe we could ask a similar question. Are there some real hard spots that the staff is concerned about? If so, what are they?

MS. SOSA: Good afternoon. I'm Belkys Sosa.

DR. WALLIS: The other question is: have you done any real work yet?

(Laughter.)

MS. SOSA: Before I get to my presentation, I'd like to address a few comments. The pre-application review in general terms is a voluntary process. A lot of the issues, well, all of the issues really are raised by the applicant, and the staff, through the pre-application review so far, Phase 1, has been a familiarization phase, basically just coming up to speed, reading a lot of the material that has been submitted, attending meetings, developing RAIs, that sort of thing.

Phase 2, which is what we're currently in, it's really the beginning of the review process, and as we said many times today, pre-application is not going to close out or resolve the issues that we've seen today. These are not easy things. This is basically all of the difference that this design has in comparison to what we normally see in the --

DR. WALLIS: But you have developed RAIs?

MS. SOSA: They have developed RAIs in thermal hydraulics, in neutronics,

DR. WALLIS: Have they got any answers?

MS. SOSA: -- PRA.

You will hear from the staff on the issues, the key focus topics. So I would --

DR. WALLIS: So we will hear on that.

MS. SOSA: Yes.

DR. WALLIS: Okay.

MS. SOSA: You will hear from the staff, and in some cases their review is more advanced than others. It depends on the issues. So please bear with us.

Today we're here for information mostly. We're not ready to present results or even speculate on what the issues are at this point. Everybody has ideas, but we're not there yet. So please bear with us. There will be other subcommittee meetings where we would get into a lot of the details, and I'm sure all of the important stuff will come up.

What I'd like to request from the committee is to give us feedback on our process and what the plan is for pre-application review, and also this is big picture. We don't want to forget the ultimate goal, which is the signed certification. Even though by September of this year, we will be developing what we call the safety assessment report, which is the deliverable that the NRC will be providing to AECL. This will include the identification of the technical issues that have been identified on this pre-application review, policy issues, regulatory issues, the schedule, and the resource estimates.

But, again, it will not bring to closure as far as a safety evaluation, but will simply be a snap picture in time, and hopefully will provide valuable feedback to the applicant. We believe so.

Well, let me go to my slides, and I won't go through all of them. I'll try to be brief. I think that you've heard a lot of these points already from AECL and others.

Because the ACR-700 is a unique design, there are unique features, and the approach and criteria to be applied in a design review is going to be different in some cases to that of conventional live water reactors. Their review will identify where new staff positions, regulations and regulatory guidance is needed to address the unique characteristics of the design.

For instance, pressure tubes --

DR. APOSTOLAKIS: What does that mean, new regulatory guidance? That may take a long time.

MS. SOSA: Well, we may find that out. It's not necessarily clear. Like I said, in a lot of these issues, for the key focus topics you will hear from the staff today on what their plan is.

DR. APOSTOLAKIS: So is it possible you will say we cannot certify this design because we need three new rules? I mean, I don't understand because that --

MS. SOSA: They have brainstormed on that issue, and in particular for the Class I pressure boundaries one of the most critical areas that we're looking at for this topic, and you will hear from them on the best approach that they have so far, and there are many ways to do it, but they figure out a way where we can do this relatively within the time frame that it will be the best solution, if you will.

So I would ask you to please wait until --

MR. FLACK: Yeah, excuse me, George. Part of the purpose of the pre-application review is to flesh out any policy issues ahead of time without waiting for the design certification process to take place. So a lot of it is to look at what's different with this plant and how we would go into the licensing design certification with this plant and then raise those up as policy issues if we see differences or discrepancies between the two.

So it's really a fundamental purpose of the pre-application review.

CHAIRMAN KRESS: Well, let me ask you a specific question about that. I gathered from what I've heard so far that their LOCA thermal hydraulic analysis is somewhat akin to Appendix K, but I would be surprised if they're using the Moody blow-down model, and I would be surprised if they're using the decay heat curve that we specify in Appendix K.

What will you do about things like that?

MS. SOSA: Well, today you will hear from Walt Jensen. He's the lead on the thermal hydraulics review, and if you like an answer now, I can ask him to get up.

CHAIRMAN KRESS: No, no, no.

MS. SOSA: You can wait. Thank you.

DR. APOSTOLAKIS: But we can ask the Canadians to pay for our changing our regulatory structure.

CHAIRMAN KRESS: That would be a good deal.

DR. APOSTOLAKIS: That would be a good deal.

(Laughter.)

CHAIRMAN KRESS: Maybe we could use their FC curves.

DR. WALLIS: But all of the presentations seem to be about things you're going to do, and that's so obvious. Read all documents and think about them. What are you going to tell us?

MS. SOSA: Well, (pause) --

MS. DUDES: Part of the things and the reason why we're here today -- excuse me, Belkys -- is to tell you and to actually get to Minsites (phonetic) because as I think you see here, we're going to have regulatory infrastructure issues. We're going to have policy issues.

Part of the review is to identify them, develop a plan to get those to the Commission, and again, yeah, we may find in this pre-application review that we will need additional infrastructure, regulatory infrastructure, or policy decisions, and our plan here at the subcommittee is to present this approach and get insights for particular topics, if you have insights on which way we should be leaning and developing these policy or infrastructure needs.

MS. SOSA: Thanks, Laura.

In the application of exhibit regulation and guidelines, the staff may need to interpret guidance developed for live water reactors for application to non-live water reactor concepts.

CHAIRMAN KRESS: Now, you're doing this as a non-LWR?

MS. SOSA: No. I'm saying that there are certain areas that are not --

CHAIRMAN KRESS: Not applicable or can't

do.

MS. SOSA: Exactly.

CHAIRMAN KRESS: But still it's an LWR.

MS. SOSA: Yes, sir. Thank you.

DR. WALLIS: Now, you way you have an equivalent level of safety. I thought that they were trying to get a higher level of safety in these advanced reactors.

MS. SOSA: Well, I would like to have --

DR. WALLIS: It's up to you to figure that out. It's your regulations.

MS. SOSA: Well, at this point it's -- what I have on the slide is the equivalent level of safety.

CHAIRMAN KRESS: I gather from that that you meant when you look at their analysis of the design basis accidents, that they will have design basis accidents that are almost equivalent except for ones that can rule out, and that they will meet the regulations we have on the books now for those.

MS. SOSA: Yes.

DR. WALLIS: Yeah.

CHAIRMAN KRESS: That's the way I interpret that.

But the equivalent level of safety being greater will be that maybe they'll have more margins, and maybe they'll have a PRA that shows that --

DR. APOSTOLAKIS: But they don't have to. The Commission has expressed a wish. They didn't issue a regulation.

CHAIRMAN KRESS: I think that's a pretty strong decision.

DR. APOSTOLAKIS: But they already claim that they have better core damage frequency and --

CHAIRMAN KRESS: Sure. I think they probably do. Okay.

MS. SOSA: Okay. What you have here is the focus topics that you heard about extensively this morning, and the underlined items are the key focus topics. As you see, I've added the fuel design separately already, which is what we've agreed so far.

And as far as the status, we've completed Phase 1. We're now in Phase 2, and this includes per panels, some thermal hydraulics of neuron accidents and neutronics, and you will hear a little bit of that today.

DR. APOSTOLAKIS: I'm a little confused as to what the difference is between pre-application and application. I mean, it seems you're doing everything that you would be doing.

MS. SOSA: That's a good question.

DR. APOSTOLAKIS: You call it safety assessment report as opposed to safety evaluation report?

MS. SOSA: Yes. That's a good question, and that was also a result of a lot of discussions with the staff. In some areas it's not so simple. They don't have acceptance criteria that can readily apply. So they feel a little reluctant to use the same safety evaluation report as normally. So they felt comfortable with the safety assessment report.

In our mind it's a review, and it's the same type of review. It's not going to be anything different. In some areas as far as when we're done with pre-application, we will be a little farther in the process than in others, but we see it as something that can easily be transitioned to the design certification once the application comes in, and that's the plan.

Today we're hoping to hear, to get some feedback on what you think of the plan and the process.

CHAIRMAN KRESS: Well, to me, George, the pre-application gives the applicant a signpost that says, "How am I going to go any further than this?"

and it's the place for him to make that decision. You know, if it were just in an application for certification, you wouldn't have to figure out when to do that. You could still do it. I think you can withdraw an application, but this gives them a point to stop and look at things and decide whether they're going forward with this.

MS. SOSA: I think it was a very smart decision of AECL to bring this pre-application forward when they did. It gives the staff an additional period to look at the issues and try to come up with a plan that would be useful, and also the main goal of pre-application is to facilitate the ultimate design certification review.

DR. APOSTOLAKIS: So that would be a good idea then for Gen-4 reactors, if they ever ask for certification.

DR. WALLIS: Your product is a safety analysis assessment report?

MS. SOSA: I'm sorry? What was the question?

DR. WALLIS: I'm just wondering what a safety assessment report is.

CHAIRMAN KRESS: That's the end point of Phase 2, right?

DR. APOSTOLAKIS: She's saying it's the same as SER.

MS. SOSA: Yes.

CHAIRMAN KRESS: It's not exactly an SER because they don't have to have an SER.

DR. WALLIS: That's the product of the pre-application review.

MS. SOSA: I have a slide here, and let me go to that, that it has the main sections of what the ultimate report is going to contain, and it's not consistent exactly with the safety evaluation report, but it's along the same lines. It's substantial, we feel, that this is what AECL really needs to have by the end of September in order to --

DR. WALLIS: Is AECL going to respond to their desired outcomes?

MS. SOSA: They stated in there these are outcomes; the word "acceptance" a lot, and we struggled with that, and we told them that we didn't think that we could accept and give them a definitive safety determination by the end of pre-application. That was not what we saw.

What we could give them is what we have here. Essentially as far as the material that the staff has been able to review and what has been submitted to date, that we could review that to the extent that the guidance exists, and we would identify technical issues that will require further data or analysis, as well as identify the regulatory issues, such as rules, rulemaking, or exemptions that will need to be resolved; policy issues; and hopefully in the conclusion we would give them a discussion on the feasibility of completing this review, as well as provide them with a schedule and resource estimates.

Now, the schedule and resource estimate would be to cover these focus topics, you know, essentially 12/13 items that you heard today. It won't be scheduling a resource estimate for the entire design certification. We will give them that estimate after we get a chance to review the application and see what it looks like.

There has been a lot of concern from the staff on, well, are they going to give it to us the way we are used to looking at it. So we hear from AECL, yes, you're going to get something that looks the same, the same type of format than what you're accustomed to. So we feel confident that that's what we'll get.

Now, Phase 2 of pre-application is scheduled to complete on September of this year. So we have an aggressive schedule. This is an informational briefing. So please keep that in mind when you address the staff, and we'd love to get feedback today on what you think of our process and our plans.

And that's all I have.

Oh, I believe there was a question on QA that I'd like to address before --

DR. WALLIS: It would be useful if you had some milestones or something where you say what you want to achieve by the end of Phase 2 instead of the meetings you're going to have and what's the output of Phase 2? And what does it lead to? That would help me.

MS. SOSA: Yes. Kim, the other PM, will be addressing the schedule and highlighting some of the major milestones that's scheduled for the end of the presentation. So he will summarize that.

DR. WALLIS: Okay.

MS. SOSA: As far as the QA, I'd like to address the comment that was made earlier this morning. QA is an area where we feel very confident. In fact, we're actually doing more than what the applicant requested of us in their pre-application.

In some areas we're exceeding the scope of the pre-application, and we've told AECL this, and they seem to be okay with that, and we are working closely with our counterparts in the Canadian Nuclear Safety Commission, and they will be conducting audits in parallel, and there is a lot of work currently ongoing.

So we feel that that's one area where at the end of pre-application we will actually have more than what the applicant requested.

DR. APOSTOLAKIS: Will the staff request an ACRS letter at some point?

MR. SIEBER: Yes.

MS. SOSA: At some point, yes, but not for the pre-application.

CHAIRMAN KRESS: Usually what we do, usually, George, if we think there are showstoppers that are not forced in either the staff presentation or the things, we like to let them know that. It's not necessarily a letter. We can tell them verbally in the meetings, but sometimes we'll write a letter saying, "Here are some ACRS areas of concern and we'd like to hear more about." We'll do that sometimes.

But the real letter comes after we review the SER.

DR. APOSTOLAKIS: Which means when we

actually are --

CHAIRMAN KRESS: That's the one that says we agree with the staff or we don't agree with the staff.

DR. APOSTOLAKIS: But we will not evaluate the safety assessment report because that's pre-application.

CHAIRMAN KRESS: Well, I think we can look at that, yes, and give them feedback.

MS. SOSA: We have plans to provide a draft safety assessment report in July and come back to you for a full committee in September, early September. So whether that requires a letter.

CHAIRMAN KRESS: It depends on whether we think everything is fine or whether we think there are problems. We could have a letter then.

MS. SOSA: Now, we are also working with your staff on arranging for subcommittee meetings on several areas. Probably materials will be one. PRA may be another. Thermal hydraulics. It's not clear exactly what your needs are going to be, but you will see more of this.

DR. FORD: So your hope is that if you're going to have an SER coming out in September, that before then, i.e., today you need us to flag to your prime stuff for doing these various sections, "Hey, I want to see more of this, this, this, and this in July."

Anything we're going to get in July, your draft report in July, I want you to cover these items. Is that correct?

MS. SOSA: If you feel that that's consistent with the approach for pre-application and, you know --

DR. ROSEN: Let me be sure I understand. Did you say you wanted subcommittee meetings with a PRA subcommittee, materials and metallurgy subcommittee?

MS. SOSA: That's what we're currently planning.

DR. ROSEN: With Human Factors Subcommittee perhaps? Who knows what all?

MS. SOSA: Committee meetings we can fit between now and July.

CHAIRMAN KRESS: We may combine some of those.

MS. SOSA: It's something that we need to do.

DR. ROSEN: But it's something that really, in fact, I think the suggestion is a good one.

I mean, you're not going to get the level of detailed review that you need until you assemble those subcommittees and give them enough material to dig into.

MS. SOSA: Yes.

DR. ROSEN: And George's earlier comment about the PRA, yeah, well, the RPA subcommittee will do a thorough review if it has a PRA to look at. If it doesn't, well, it will just --

CHAIRMAN KRESS: Med and I are working out with Jim Lyons and the staff some sort of schedule for having meetings. You know, we're having things in mind like the next one might be a physics and fuel design, and then there might be a PRA combined with severe accident and almost surely be a thermal hydraulic subcommittee.

DR. ROSEN: Sure.

CHAIRMAN KRESS: And from there I'm not sure. There will be a materials maybe, but that might take five days or something.

DR. APOSTOLAKIS: But the rest of the committee has to agree on that.

CHAIRMAN KRESS: Yeah, but that's about the extent of it. You know, that's like four right there.

MS. SOSA: Yes.

CHAIRMAN KRESS: That may be it. We'll have to review the SER. That's not coming out until next year some time.

MS. SOSA: No, no. This year.

CHAIRMAN KRESS: The SER?

MS. SOSA: This year. SAR.

CHAIRMAN KRESS: Oh, SAR we'll review.

DR. ROSEN: We're going to have to be done by July --

CHAIRMAN KRESS: We'll review the SAR.

DR. ROSEN: -- with all those subcommittees.

MS. SOSA: Yes.

DR. ROSEN: But give you the input you need, and that means we've got to get a lot of information through the subcommittee chairman and members of the subcommittees before then.

CHAIRMAN KRESS: We won't have that many subcommittees before July.

DR. ROSEN: It's very exciting, a very exciting time in which the ACRS will be devoting most of its attention to nothing but this.

DR. WALLIS: But we're not going to do all of the work. You guys have to come up with some results to us.

CHAIRMAN KRESS: Yeah, we can't have these meetings until they're ready for it.

MS. SOSA: That's right.

MR. FLACK: And this is John Flack again.

Just to add to that, it's also looking at our own infrastructure and what our needs are as well. So it goes in two places.

CHAIRMAN KRESS: Yes, right.

MS. SOSA: Thank you.

At this time I'd like to turn it over to Mr. Sullivan, and he will be addressing the first key focus topic. That's the Class I pressure boundary.

DR. ROSEN: Now, Ed, before you sit down, let me just tell you I looked ahead on your slides, and Slides 8 through 13 just repeat what we've already heard, but in your district. So why don't you skip to 14 unless you think there's absolutely something that's burning that needs to be said in the interest of time. Fourteen is where you start talking about what the issues are.

MR. SULLIVAN: I would like to summarize what comes ahead of it though. I realize there's a lot of repetition, but --

DR. ROSEN: There's plenty of repetition.

MR. SULLIVAN: -- in our particular area, which may be different from some of the other reviews which I think you'll see this afternoon, what we feel that we need to do is see where this design, to the extent that we have information on it, does not meet our existing regulations.

What regs. do we know are going to need exemptions from or something like that, and what other areas are we going to need, as Belkys said, supplementary criteria, staff positions, requirements, whatever?

It's not going to be our intent in the pre-application review to try to resolve the issues. Our intent is to try to point out to AECL where we need additional information in their application, and to the extent we can, identify the kinds of things they asked for, namely, what might be a showstopper, that sort of thing.

So with that introduction, I'm probably going to not be very helpful in Slides 14 and 15 because we're really not prepared to discuss them in any depth. These are just issues that, to the extent we've been able to familiarize ourselves with this design, they're things that we want to look into further.

And you can ask questions, but I'm not sure we're going to be prepared to answer them. There are several people in the room that have been assisting in this review.

DR. FORD: But if you look at the list of comments on 14 and 15, all of the potential issues, they're all absolutely bang on. You've hit the pin on the head, but they all need numbers. We need, you know, some data, some prediction algorithms, some consequences, interactions, and that's all going to be done by July.

Is it going to be done by July?

MR. SULLIVAN: No, it's not. it's not possible. I'm not sure we even have enough information to the review, and that's why I said a few minutes ago that one of the things that we're going to need to identify to AECL not just for pre-application, but also for the application, is what additional information we need to do the review.

DR. APOSTOLAKIS: But I'm a little confused though, Peter. I mean, there have been lots of CANDUs around the world. There must be a lot of data on these things and some arguments from AECL. It's not that they are starting from scratch.

So it could be done by July.

MR. SULLIVAN: We don't have enough resources to do it by July.

DR. APOSTOLAKIS: Ah, that's different.

MR. SULLIVAN: And we don't have the information in hand, and we haven't communicated yet to AECL what additional information we need besides the main report which they have, which is the technology of the fuel channels.

DR. ROSEN: These are technical issues, by and large, but don't they have a border in some respects on policy issues and legal issues? And don't you have to bring in the OGC at some point?

MR. SULLIVAN: Yes, and that's one of the things that Belkys was communicating with the structure of the way the SAR is going to look. I think in our area we may be identifying safety issues that are also regulatory issues that may require policy direction.

DR. FORD: Forget the policy aspects for the time being, important though they are. For instance, some of the changes that the applicant had said they're going to make, thicker, thicker tubes, changing the alloy, these are all in the right direction, but it's qualitative. It doesn't tell you what is the factor of improvement going to be to counteract the bad effect of increasing the pressure and temperature, for instance.

I mean this is not a Nobel Prize winning exercise that has to be gone through. I mean, you don't have to do years of research. You've just got to look at the data and assess whether their case, qualitative case -- can you put a number on it, on the fact of improvement?

That's their job to do, to present to you.

MR. SULLIVAN: We also need to somehow develop acceptance criteria in order to evaluate this information. I grant you I think it must exist and some of it ACL is in the process of developing because I know that they're doing additional research in areas where they've had to extend the application for the ACR-700 design.

DR. FORD: So does it come down to the fact that you've got an agenda that by July of this year you've got to come out with a draft, but there's a whole lot of information you won't have; therefore, you're going to have to sign off in a state of un-knowledge, if that's the right word?

DR. APOSTOLAKIS: They're not signing off in July.

MR. SULLIVAN: We're not signing off.

We're trying to identify issues. We're not really intending to resolve them. That's for the --

DR. APOSTOLAKIS: -- evaluation report.

MR. SULLIVAN: In other areas from the staff, I think you'll see some differences. In other areas the staff is getting into the review. They have the criteria they need to some extent or by and large. I'm not sure. They'll have to answer that, and their review is different from this one.

DR. ROSEN: And I would characterize what you'll be trying to do this year as a best efforts view, the best efforts to help AECL. If you come up with something else in November of this year that's not in your SAR, that's just the way it goes. It's not like there's any finality.

DR. FORD: So the way you are right this instant, January whatever it is, you're foreseeing that in July your report on these issues will be saying, "Hey, these are the issues."

DR. ROSEN: "That we see now."

DR. FORD: "This is where I want to be in a year's time," or whatever it is. "Mr. Licensee, please supply this data to me."

DR. APOSTOLAKIS: Plus certain issues have been resolved.

DR. FORD: Oh, yes.

MR. SULLIVAN: We can also add in the meantime we're going to be trying to interact and provide information or documentation needs, and so forth. We're not going to wait until July or September if we can identify information needs before then.

DR. FORD: Sure, sure. Good.

DR. WALLIS: But if you don't start resolving some of these things, they're going to get pretty despondent. If all you do is keep asking for information and say these are issues without resolving anything, I would be pretty despondent as an applicant and say, "When is anything going to end?"

CHAIRMAN KRESS: I think our experience with the staff has been that when they do these things, if their intention is to resolve the issues, they'll get there depending on the resources.

DR. WALLIS: I would think you'd want to take one or two to see what kind of things come up. Then you'd all know more what kind of game you're playing.

CHAIRMAN KRESS: That might be a good suggestion.

MR. FLACK: Yeah, if I could just add to

that, I mean, certainly it's important to do as much as we can on the pre-application review, but a lot of it is asking the right questions, and in order to ask the right questions, you have to probe and see what's out there, where the limits are.

And I think that is very important in the pre-application phase because that tells you how big the mountain is going be to climb, and the best way we can define that mountain, the better off we can be when we go into this.

So a lot of it is not to jump into trying to look at one issue in depth, but try to see how difficult all of these issues are and what are the most important ones to deal with as soon as we can.

So I don't want to underestimate that effort in trying to understand those issues and being able to ask the right questions.

MS. SOSA: So at this time I'd like to turn it over to Jack Rosenthal. He'll be presenting the PIRT process.

DR. APOSTOLAKIS: What qualifies you to --

CHAIRMAN KRESS: Yeah, do we know you?

MR. ROSENTHAL: My name is Jack Rosenthal. I'm the Branch Chief of the Safety Margins and Systems Analysis Branch, and I'm qualified as a supreme generalist, and they put me up here because I know an awful lot about a broad area and very little about any one. So we could have a reasonably fast presentation.

The researcher's job is to build tools that the regulator can use for independent analysis. So we are in the tool building business.

CHAIRMAN KRESS: Are we going to try to use space for this?

MR. ROSENTHAL: I'll get to that.

CHAIRMAN KRESS: Oh, okay. Sorry,

MR. ROSENTHAL: So we have to decide what numerical tools we could use, what data we have, what experimental facilities we have or might need in order to build validated tools.

I want to emphasize that this is a research program. Okay? We're not doing a design review of ACR-700 itself. That keeps coming up, but rather we're exploring ACR-700 to find out what we need to do to modify our codes in order to be able to do an independent analysis.

DR. APOSTOLAKIS: So you don't have to be done by July.

MR. ROSENTHAL: I don't have to be done.

DR. APOSTOLAKIS: Period.

MR. ROSENTHAL: We picked three areas, and

I will explain why I think that these areas are important, neutronics, thermal hydraulics, and severe accidents, and as you see from the names, I think we really have a prestige group of people doing their work

DR. ROSEN: This is called Powers, Powers.

MR. ROSENTHAL: Dana Powers, your (pause) -- you recognize him.

CHAIRMAN KRESS: Is that a male or a female.

(Laughter.)

MR. ROSENTHAL: Here we're using the people that we think have the best knowledge to advise us independent of whether they have some involvement in the plan itself.

Bob Henry, for example, is a key developer of MAP, and the Canadians use MAP in their analysis, but I think that he is also a very knowledgeable guy, and we want to take advantage of that expertise.

DR. WALLIS: This has all just occurred. This is all --

MR. ROSENTHAL: All for the PIRT.

DR. WALLIS: And probably going to conclude that, therefore, AECL's PIRT is good.

MR. ROSENTHAL: Perhaps. BNL is the

overall contractor. I'd like to say that the regulator, Canadian Nuclear Safety Commission, is participating in the PIRT, and we're learning from them; they're learning from us, and I welcome their involvement.

AECL has been very, very, very generous in supporting the PIRT, and I should publicly acknowledge that. They have provided a number of documents and have subjected themselves to the inquiring minds of people like Zuber.

(Laughter.)

MR. ROSENTHAL: In the PIRT process you need to -- let me stop with the thermal hydraulics for a second. NRC codes think vertical, and we have to teach our codes to think horizontal, and that's a major, major undertaking.

Walt Jensen is doing some analysis with CATHENA to familiarize himself with it. The Koreans have modified RELAP to look like a CANDU reactor, and we're building a RELAP deck for ACR-700, which we will give to NRR for their use. That will not address critical subchannel issues.

And then we will invest a little bit longer range in TRACE. Things like AP-600 have the advantage of the Apex facility as well as Rosa and other facilities. See, you have multiple, integral facilities at differing scales to benchmark your work.

Here much of the data comes from RD-14M. My staff has been up there. It is a very fine facility, but it's one facility. So we have to decide whether that data generated from that facility is adequate or would we need another facility, and that's big bucks and big time, and where would it be done and by whom, et cetera?

So that's why we decided to go with the PIRT process, to try to get some early advice on is the current database adequate. If additional data is needed, does it have to be done on a large scale integral or could it be done small scale?

AECL, I'm sure, would be more than willing to run some additional experiments at RD-14M. They've been very cooperative that way, but if something else is needed at a differing scale, maybe a smaller scale, maybe some university lab bench stuff to balance off the bigger scale stuff, but we've got to find out now.

Yes, sir.

DR. ROSEN: It could be one of those showstoppers.

MR. ROSENTHAL: Yes.

DR. ROSEN: This could be the showstopper.

I mean, we haven't heard one yet today, but here's one that flops out like a big, ol' fish on the table. If you decide you need a whole other integral effects facility, not the money, but the item alone might be the showstopper.

MR. ROSENTHAL: Right, but so I think we've got the right people to advise us.

DR. ROSEN: All right.

MR. ROSENTHAL: Okay. They have to pick a break, and they pick this -- there is one critical break in which you get stagnant conditions in a flow channel, and so that may not be the riskiest break, but it's rich in -- and I don't know what the riskiest break is -- but it's rich in thermal hydraulic phenomena. So it's a good sequence to explore.

Of course, a figure of merit is fuel temperature versus time. As I say, we're going to have problems because we have to teach our thoughts, our databases, and our codes how to think horizontal. The PIRT process, you pick a sequence; you look at the systems and components; you rank stuff by importance.

And what we are asking for the PIRT panel to do is to identify high, medium and low, what's important and what's the knowledge base, high, medium, and low. A high-high is okay. It's very important.

If I have a lot of knowledge about it, I can live with that.

A low-low is also okay. The showstoppers are a high-low, that is, where it's important phenomenologically, and the data, the knowledge base, the collective knowledge base is low. That knowledge base could be in the general literature. It could be for proprietary experiments. It doesn't have to be from another facility. We just need a sufficient amount of data.

So what we have to do by this spring is to identify if the experimental database is adequate, if the data is adequate. The writing of the computer codes if the data is there is far more tractable.

Okay. Let me just go on with the neutronics for a second. They're using codes like WIMS-8. We're familiar with the nuclear codes that the Canadians use, and that's just fine, although I don't think that Americans are familiar with dysprosium which is the burnable poison they use instead of gadolinium or something else. But that should be conceptually straightforward.

I mean, you know, how you go about doing calculations, getting cross-sections, et cetera, but what is super important, what I call in my mind, just my mind, a quintessential issue is, in fact, do they have a negative coolant void reactivity coefficient.

It's like 100 milli-K, some number like that, is the total void coefficient. So the number is very, very close to zero and is very difficult to measure it, but you'd like to have a negative number.

What we need to do, I don't need to have computed the number precisely by this spring, but I have to have enough exploratory work done that I have confidence that either the coefficient is, in fact, negative or could be made negative.

Now, just within, I'd say, the last six months to a year the designers have tweaked the enrichment and the burnable poison in order to give them a slightly more negative void reactivity coefficient for confidence, and you can always tweak these numbers again after all of this has taken place.

CHAIRMAN KRESS: Do we have a regulation?

MR. ROSENTHAL: But you have to be able to get there.

CHAIRMAN KRESS: Do we have a regulation on the book that says, "Thou shalt have a negative" --

MR. ROSENTHAL: I think we've got a GDC.

CHAIRMAN KRESS: A GDC says, "Thou shalt have a negative void coefficient"?

MR. ROSENTHAL: Don? Go ahead.

MR. CARLSON: We have a general design criterion 11, and I can read that to you.

CHAIRMAN KRESS: Please.

MR. CARLSON: Basically it's often interpreted as calling for a negative power coefficient, but the exact words are, "GDC 11 reactor inherent protection. The reactor core and associated coolant systems shall be designed so that in the power operating range the net effect of the prompt inherent nuclear feedback characteristics tends to compensate for a rapid increase in reactivity."

MR. ROSENTHAL: Now, as I say, the codes that are being used here we're somewhat familiar with. They have done benchmarks. They're perfectly competent engineers, but here's a case where I think that it's a sufficiently important issue that we'd like to be able to do independent analysis and independently confirm the values.

And I think that of all things, I don't see this as a conceptually impossible problem. I mean, we know how to go about doing it. We've got the data; we've got the cross-sections; we've got the computer codes. It's a piece of work that we have to do, but I think that it's an important enough issue that we ought to be able to independently confirm that it's negative.

DR. WALLIS: It's all a paper subject, too. You're not going to build one and prove it. So eventually --

MR. ROSENTHAL: Well, we'd be relying here on things like criticals, benchmarks to criticals.

DR. WALLIS: Well, at all times you're going to rely on a paper study.

MR. ROSENTHAL: Well, here you've got benchmarks to criticals. Here you have separate effects and integral tests. So it's not totally paper at all. And severe accidents also has some experimental work.

Now, let me just talk about severe accidents for a minute. For some accident sequences, AECL says that, okay, what will happen is that you'll have a single channel that that could fail, and you'll quench, and you won't propagate, and that's the end of that event for that particular sequence.

That's very different from a U.S. light water reactor. We assume propagation TMI more than half the core melt (phonetic). So that's a very, very, very important issue, and if you can convince me that you'll never fail more than a channel worth of fuel, which is less than one percent of the fuel and you have a large dry containment, which they do have, then this is a very, very, very nice design.

So the focus then becomes on would the failure be a propagating failure. Similarly, if you have a whole core event, are you going to quench in the shield tank the event? You have a large dry containment, and the action is terminate in containment. Nice.

So the focus of me and the severe accident people is -- I keep pointing at the screen, and I know that doesn't do any good.

(Laughter.)

MR. ROSENTHAL: Just the super issue is do I have propagating failures or not because if I don't have propagating failures or if I can arrest the sequence in containment and it is the large dry containment, I think you're really in very good shape.

CHAIRMAN KRESS: Are steam explosions on the list for the severe accidents?

MR. ROSENTHAL: Only on the sense that what they're looking at is within the context of would you have a propagating failure, and in fact, if you're reliant on this hot molten stuff from a channel falling into the moderator as a way of terminating this, then the potential for steam explosion would truly be there.

CHAIRMAN KRESS: So that is on the table.

MR. ROSENTHAL: Yes. Now, in terms of fission products sought -- and so the focus here is more on accident progression, and we're going to have to teach Melcor how to do accident progression on this horizontal --

CHAIRMAN KRESS: You can't teach an old dog new tricks.

MR. ROSENTHAL: As distinct from --

CHAIRMAN KRESS: You don't have to worry about this candling down the fuel?

MR. ROSENTHAL: Don't have to worry about candling. Have to worry about quenching now. Different issues.

But in terms of source term, I see this as more of an action progression issue rather than a source term issue for two reasons. On one end, they have this big, nice containment, and the other thing is that things like the Canadians took actually a leadership role in an ISP, international standard problem, involving iodine, and so I think that they have some expertise in that area.

CHAIRMAN KRESS: Chemical effects or was

that release from fuel?

MR. ROSENTHAL: It was chemical effects.

CHAIRMAN KRESS: They have a pretty low burn-out.

MR. ROSENTHAL: Yes.

CHAIRMAN KRESS: So that to me is a real plus.

MR. ROSENTHAL: A plus also. So at least conceptually in severe accident, within the severe accident real, my issues and I think the PIRT's issues involve accident propagation as the important issues.

CHAIRMAN KRESS: How much fuel is actually involved?

MR. ROSENTHAL: And if, in fact, it's -- or for many of the sequences we're talking about a single channel or less. Then you really are in very good shape.

CHAIRMAN KRESS: I agree with you.

MR. ROSENTHAL: Now, they are going to -- there is an experiment where they're going to -- I may need some help here -- they're going to put it's like 100 kilograms of molten core in the water, and the initial experiments are actually being designed at Argonne and then the larger scale work will be done in --

CHAIRMAN KRESS: That's like one channel.

MR. ROSENTHAL: Yeah. Am I getting the numbers all wrong? I have the numbers entirely wrong. I have the concept right and the numbers wrong.

MR. RICHARDS: So it's right. The formulation of the material that will melt is being done to Argonne.

MR. ROSENTHAL: And that's 25?

MR. RICHARDS: There will be first an experiment done at five kilograms, then 25.

MR. ROSENTHAL: Okay.

CHAIRMAN KRESS: Twenty-five is about one fuel change.

MR. ROSENTHAL: And then you're planning the larger test after Argonne is done?

MR. RICHARDS: Yes.

MR. ROSENTHAL: It will be how big?

MR. RICHARDS: The tested Argonne are done in a bursting a pressure tube into an air atmosphere. The experiments that are done at Chalk River will be looking at that material being injected into a calandria leak containment.

MR. ROSENTHAL: And that gets right to your issue.

CHAIRMAN KRESS: Well, the question I

would have about that is how much of the zirconium are you going to have in that mixture. Does it melt and join in with the UO_2? That would be the issue to me.

MR. ROSENTHAL: The experiments are it's a mix.

CHAIRMAN KRESS: Yeah, because I think that is a key element to determine the energy.

DR. WALLIS: Well, this study is new experiments; they haven't done them in the past? They don't have a database?

MR. ROSENTHAL: They've done some experiments. I'm now starting to run out of steam. So we'll stop. I mean, they've done some experiments, and there is some body of knowledge that pertains to this reactor also, but I think that the planned experiments will be crucial.

The plan is that we have had the second PIRT meeting already. We're going to have a third meeting, the physics guys in January and the thermal hydraulic guys and severe accident guys in February. We'd like to come out with some preliminary understanding in terms of the need for additional thermal hydraulic facilities in the March-April time frame based on our then understanding with a formal report in June.

In parallel with that, I have a small effort going where co-developers are digging through subroutine by subroutine through code and not to modify the code, but just to figure out what has to be done because these are a rather large undertaking.

So that's where research stands.

CHAIRMAN KRESS: You had a slide that looked a little strange to me, and it said that -- Slide 21 -- a large break of an inlet or an outlet header voids all fuel channels within one to three seconds. Is that true?

MR. ROSENTHAL: I believe so.

CHAIRMAN KRESS: Voids every pressure tube in one to three seconds.

DR. WALLIS: Gets dry?

MR. ROSENTHAL: No.

PARTICIPANT: "Void" it says.

DR. WALLIS: No, it's dry.

MR. ROSENTHAL: I need help again. David. There's Don Carlson standing behind you.

MR. CARLSON: Yeah, we're repeating what we heard from AECL in terms of the rate of voiding. A large complete break, double ended break of an inlet or outlet header we were told would void half of the channels, that is, the channels emptying into the affected header in about one second and drain the remaining channels in about one or two more seconds. A total of three seconds.

If AECL wants to elaborate on that or correct that, please speak up.

MR. SNELL: Victor Snell.

It sounds sort of half familiar. It will avoid the downstream channels, that is, half of the channels in the order of seconds. I think it takes much longer to void the opposite pass. That's my recollection.

MR. ROSENTHAL: Let's leave that up to the --

DR. WALLIS: Jack, thinking about interactions for the ACRS, particularly the thermal hydraulic subcommittee, presumably there's a good time for you guys and maybe the other guys, Jensen and company and whoever else is doing thermal hydraulics to meet with us. Would it be about the middle of the year or is that too late for you?

Maybe you'll let us know.

MR. ROSENTHAL: Yeah, I would think -- Belkys, I'm looking you in the eye right now -- I would think about April we would have something to say. I mean, there's no sense --

MS. SOSA: Between April and June is what we have on our milestones schedule, and again, the dates have not been set, but that's what we're aiming for.

MR. ROSENTHAL: Okay. Then I would think that, well, by May the PIRT panels will have met, have come up with their tables which we could present.

DR. WALLIS: I think when you have done enough work to know what the issues are and to know the scope of them rather than just that there are some, then it will be appropriate, but we don't want to meet you if you're going to tell us all about what you're going to do.

MS. SOSA: Yes, I agree with that. That's the plan.

DR. WALLIS: So let's work at that. Let's work at that.

DR. RANSOM: I'm curious. Wasn't the CANDU ever considered for licensing in the U.S.?

CHAIRMAN KRESS: They had a tentative thing that was withdrawn, I think, because --

MR. ROSENTHAL: It's my understanding it was withdrawn because of their reactivity coefficient, and --

CHAIRMAN KRESS: I think that was the

showstopper.

MR. ROSENTHAL: --and here is a major difference. You're going from natural uranium to a big difference.

CHAIRMAN KRESS: And light water instead of heavy water.

MR. ROSENTHAL: Well, that heavy water, too

CHAIRMAN KRESS: Well, yeah, but light water in there where it matters.

MR. ROSENTHAL: Heavy water moderator.

CHAIRMAN KRESS: That makes a big difference in the void because it's more of a poison than it is a moderator.

MR. ROSENTHAL: Didn't we decide that something like 90 percent of the slowing down occurs in the moderator? That's one reason we have such a small void coefficient, is that the moderator which doesn't participate in the void can play such a large role.

MR. FLACK: Yeah, this is John Flack.

I believe it was looked under pre-application review. There was a policy issue on the positive void, but they had withdrawn before the Commission acted on that, and I think Don Carlson could add to that. I think that's probably --

MR. CARLSON: Yeah, about ten years ago for the pre-application review for the CANDU 3 design, at that time the staff highlighted the strongly positive coolant void reactivity of that design as a policy issue, brought it to the Commission, but shortly after AECL submitted the design certification application, they withdrew it for economic reasons, plus some uncertainty about that positive coolant void issue.

MR. ROSENTHAL: But now that you've gone to an enriched core, at least conceptually I think that there's some combination of enrichment level and burnable poison level that will give you a negative number, and in all likelihood they've done it right, and I think that it is something that we ought to be able to independently analyze.

MS. SOSA: I would like to turn it over to Mr. Jensen, and he will be going over the computer codes and validation focus.

MR. JENSEN: Good afternoon. I'm Walt Jensen, Reactor Systems Branch, and I see an up arrow and a down arrow, and I see a map.

(Laughter.)

MR. JENSEN: Let's see. Let's do a down

arrow. Yes, here we are.

Unfortunately, I'm just going to talk about mostly what we're going to do because we've been doing a lot of review and done a little code analysis, but we're just getting started.

So the first slide is comparing what the AECL's desired outcome is to what I look on as our minimum objectives. So we're doing a review; we're looking for strengths and weaknesses. We are working on a list of REIs for the codes. We're looking for showstoppers; haven't found any showstoppers yet.

CHAIRMAN KRESS: Did they use the CSAU process in their code validation?

MR. JENSEN: It's similar. We're going to try to -- the PIRT process is part of that. I think it's not going to be a best estimate methodology, but it's going to be a limiting bounding methodology perhaps using Appendix K as much as they can. The part of Appendix K that certainly doesn't apply at all that I think was mentioned was the flooding rate guidance in Appendix K. If you've got less than one inch per second, you're supposed to do certain things and use of flat data, that just doesn't apply at all.

They have the Moody correlation within the CATHENA code.

CHAIRMAN KRESS: Oh, they did put that in?

MR. JENSEN: It's in there. It's an option. There are many options in the CATHENA code, and we're asking for a methodology adopting that specifies exactly which options will be used for these Chapter 15 analysis that haven't been submitted yet.

Now, as far as --

CHAIRMAN KRESS: Do they have their own decay heat period?

MR. JENSEN: They have the --

CHAIRMAN KRESS: It's different than the ANS?

MR. JENSEN: They have the ANS 7 to 9 standard. I'm not real sure about the 71 standard. They could put that under the table if they wanted to. They do have that capability. So I'm not really sure about that.

They have for the existing CANDUs. They run the CATHENA code in conjunction with the three dimension physics codes because it's really important to get the physics right for a LOCA because of the positive void coefficient.

Okay. So this is what we're trying to scope out what needs to be done, and besides that, we want to develop independent audit capability so we can run some of these same analyses that are important, and we can learn by looking at the results.

It's a lot more efficient to run the code ourselves and look at the results than ask them for that information.

DR. WALLIS: This would be running their code or running your codes or both?

MR. JENSEN: Both. I think we'll be running our code. I'd rather run our code because I understand it a lot better.

DR. WALLIS: Are they going to submit a working copy of the code so you can run their code?

MR. JENSEN: They have and we have. We have run their code. I hope not to run very many complex cases of the CATHENA code because I don't understand it. I've had about four days of hands on training with CATHENA, and I'm really a layman, but I have run what is called the critical inlet paddle break (phonetic), and I'm looking at that and we're --

DR. WALLIS: Give it to some young intern who will learn it in a day.

(Laughter.)

DR. RANSOM: Did they provide the source code to you?

MR. JENSEN: I don't have the source code.

I just have an executable.

DR. RANSOM: I'm wondering if you would need that if you wanted to look at any specific -- I know that's a pretty big job, but --

MR. JENSEN: We may ask for that. I certainly wouldn't want to get in and try to change the code. I would be afraid I would screw it up.

All right. Let's see. Moving on, we do plan to use the guidance of the draft reg. guide.

DR. ROSEN: Do you still draft guides? I mean there have been drafts for six years or something. Are they still drafts?

MR. JENSEN: Well, this is a new version of the draft. I was told when I first did this slide I had the older version from the year 2000. It was Reg. Guide, I think, 1070 something, and I've updated it, put the current draft reg. guide, which we have, and it's good guidance, and I think industry has a difficult time with it, but we plan to use it.

We have the CATHENA theoretical manual. It's not for the current version of the code. There have been a few changes in it. So we want to find out about the latest code version.

DR. WALLIS: Does it look significantly different from the things you're familiar with, the other codes that vendors have or that you have? Isn't it much the same?

MR. JENSEN: Much the same except for as Jack mentioned, it's turned over on its side, and in addition to --

DR. WALLIS: There's nothing about the conservation laws or stuff that says anything about the orientation of the reactor.

MR. JENSEN: That's right.

DR. WALLIS: Basically the questions are all the same presumably.

CHAIRMAN KRESS: There's no gravity involved in neutron --

DR. WALLIS: You might consider a few more phenomena.

MR. JENSEN: Like the heat transfer from the fuel channel to the calandria tube, the swelling and creep of the fuel channel and how it made -- how it would come in contact with the calandria tube and then the transfer of heat out to the moderator tank, which is, I understand, an extra source of heat removal for the plant. I believe AECL feels that under certain conditions that the pressure tube would swell against the calandria tube and can remove all of the heat out of the fuel channel without causing additional overheating.

CHAIRMAN KRESS: What happens to those spacers then?

MR. JENSEN: That's a good question. There are four spacers, and there are springs separating the two tubes, and between the two spacers I suppose it could seal and make contact, but not the spacers. No, I don't suppose so. So that's something that we'll have to look at.

Resources. I'm getting a lot of help in this review for the CATHENA. We have the technical manuals and a number of presentations by AECL. We have the CATHENA executable and at an input deck. I've run it, am looking at the results.

We have a preliminary RELAP model. This is under a contract by the Office of Research, and we were given the RELAP input deck last Friday. I haven't run it yet.

I attend all of the PIRT panel meetings, and I'm getting a lot of valuable insight as they go over the phenomena that will be most important to analyzing LOCAs.

And then RES is helping us again with experimental facilities to decide whether the facilities are scaled correctly and if additional experimental data needs to be obtained, and they're going to provide that in the course of the preliminary review and perhaps hopefully by next spring.

Neutronics, well, this is being led by Dr. Tony Attard who is also in my branch, and he's following pretty much the same approach that I am with the CATHENA code. The main physics code is the RFSP code, which has been coupled with CATHENA for the operating CANDU plants to look at the power series where they carry out the LOCA, and that's the WINS and the DRAGON code that produce cross-sectional input to RFSP.

We may not need to couple physics and thermal hydraulics codes to the degree that they have been on for past CANDUs, operating CANDUs because of the positive model coefficient is no longer present. So we may be able to do a lot more with running RELAP by itself perhaps using point kinetics, but we have asked the Office of Research to develop a PARCS model that can be hooked into RELAP and then later into TRACE as the TRACE model is developed.

We also have a contractor at Brookhaven helping us review the physics equations in the three codes.

DR. WALLIS: It seems to me you might have a problem. This CATHENA code has probably had some tuning already to CANDU type reactors and horizontal flows and all of that. You have codes which are being developed for other purposes that have been tuned to other kinds of situations, and yo may have a real problem with that depending on what kind of correlations to use or fudge factors or whatever.

MR. JENSEN: There has been some work with that. The South Koreans have given us some models to put into RELAP, which are in RELAP, that they've designed specifically to model the Korean CANDU 6 reactor, and we have, in fact, -- there has been some benchmarking between RELAP and CATHENA for the ACR, and they seem to be doing pretty well.

The fuel channel model and RELAP does define a level. I'm not sure how good it is, but it defines a level so that the fuel pins that are above the level then overheat, and the fuel pins are lower than occurred, and let's see what else?

Other resources for both thermal hydraulics and neutronics, we're working with the CNSC. We're setting up for a protocol for aiding each other in our review. We have a thermal hydraulics meeting tomorrow afternoon that we're going to try to see how we can aid each other's review.

And of course, we have insights and guidance from the ACRS -- we will have -- which we always listen to. So then --

DR. RANSOM: Walt, is the theory manual proprietary?

MR. JENSEN: Yes, it is.

DR. RANSOM: But I guess the ACRS could have a copy and look at it if they wanted to?

MR. JENSEN: Yes.

CHAIRMAN KRESS: As long as we treat it as proprietary.

DR. RANSOM: It has quite a different numerical method and a somewhat different model, and it would be interesting to see what the latest really is.

MR. JENSEN: I suppose, Belkys, could we get the ACRS?

MS. SOSA: Yes, anything that we have available to us that's been docketed is certainly available for you. So I'll work with making arrangements.

DR. WALLIS: Well, it sounds like a lot of work, and I just wonder what the minimum amount of work necessary is that might get you there by July. I don't have a good feel for it, but just hearing all of the things you guys want us to look at, it seems like a lot of work.

MR. JENSEN: Well, we're not going to be done by July.

DR. WALLIS: But you're going to write a report anyway.

(Laughter.)

MR. JENSEN: Well, yes, I guess it will be kind of -- the only reports I know how to write are SERs. I've written so many of those, and so it's going to look an awful lot like an SER, but there will be some places that probably say we have asked for more information here, and AECL has agreed to supply it.

We don't understand this. We need something else here, and at least it will document where the holes are, and then I suppose as we progress in the review perhaps several years, we'll slowly fill those holes in.

MS. SOSA: Thank you.

At this time I'd like to turn it over to Mr. Carlson, and he will be addressing the negative void reactivity review.

MR. CARLSON: I'm Don Carlson. I'm in the Office of Research in the Advanced Reactors Group. My work is technically in the area of nuclear analysis, but I'm also coordinating the overall research involvement in the pre-application review for ACR-700.

I'm going to ask the committee members to look at the handout package for AECL. My talk really assumed that we would go through AECL's talk on the coolant void reactivity first. The way I would like to do my talk is just to refer back to a couple of key slides from the AECL presentation to help you understand what I'm talking about in my slides.

So that's the yellow tab, negative coolant void reactivity in the AECL handouts.

So this work is in response to AECL focus topic number nine, confirmation of negative void reactivity. AECL's desired outcome is staff confirmation, or their word is "acceptance," that the coolant void reactivity is negative over a range of operating conditions.

Regulatory context of that is as came up during Jack Rosenthal's talk, is the void reactivity is key to evaluating the design in relation to general design criterion 11, reactor inherent protection.

The aim, as stated by AECL, is to have a negative coolant void reactivity so that it satisfies that requirement, GDC 11.

Furthermore, whether the void reactivity is positive or negative, it can have a significant impact on the progression of analyzed transience and accidents.

Now, before I get into my own slide, I'd like you to look at the third slide of AECL's presentation. That introduces you to how they go about changing the design. This is the first CANDU design that tries to have a negative coolant void reactivity, and so that slide shows the top figure, natural uranium, a conventional CANDU lattice with a pitch of 28.6 centimeters center to center between fuel channels, and a ratio of 16.4.

In their new design, the ACR-700 that we are reviewing in the pre-application phase, the lattice pitch has been reduced to 22 centimeters center to center, giving a greatly reduced moderator to fuel ratio of 7.1.

In addition to reducing the pitch, they have also increased the diameter of the calandria tube. That is they have increased the gap between the pressure tube and the calandria tube. All of that helps reduce the amount of heavy water moderator in the lattice and gives them a more compact core in the process.

DR. WALLIS: Doesn't it matter where the void is?

MR. CARLSON: The void is in the coolant, which is --

DR. WALLIS: Yeah, but where in the coolant?

MR. CARLSON: The coolant is next to the fuel pins.

DR. WALLIS: But is it at the end or in the middle or is it a subcooled void or what kind of a void is it? Doesn't it make a difference? It's not as if this void is everywhere at the same time.

MR. CARLSON: Actually in CANDU analysis, and this was true for CANDU 3 ten years ago and is true in the way CANDUs are analyzed around the world, they talk about coolant void reactivity, which is the difference between effective voided and cooled. So voided, I mean all of the coolant is gone.

DR. WALLIS: It's all completely void.

MR. CARLSON: Yes.

DR. WALLIS: Okay. That I understand. Okay. Then I don't have to worry about where the void is. It's everywhere.

MR. CARLSON: Now, there's a void coefficient that you can derive from that, and it's not a straight line, but they often talk about coolant void reactivity as a way of focusing on what that coefficient is.

And during Jack's talk, i think he misstated, and I think during the AECL talks they did mention that the nominal coolant void reactivity for the equilibrium core as it is presently designed is minus seven milli-K.

DR. WALLIS: That's when all of the coolant has gone.

MR. CARLSON: That's right. So the difference between K effective, operating conditions cooled and voided is seven milli-K.

DR. RANSOM: Well, would this be demonstrated with a code by maybe forcing a void initially and seeing if it dies away, you know, if the power decreases?

MR. CARLSON: Are you talking about in a reactor?

DR. RANSOM: Well, in like CATHENA or CATHENA coupled with a neutronics code. You perturb it more or less like voiding a channel and then proving that it decays away.

MR. CARLSON: Well, they do calculations and we will be doing calculations and have started doing some calculations to predict what the coolant void reactivity is, and their code is RFSP, their reactor code, and that is coupled to CATHENA. If we move forward, we would couple our PARCS code with TRACE and/or RELAP, but the PARCS code needs to predict accurately what the negative void reactivity is, assuming that it is negative.

MR. SIEBER: I take it the idea to have a negative void coefficient is to design the core so that it is under moderated.

MR. CARLSON: Yes.

MR. SIEBER: During normal operation so that the void formation further exacerbates the under moderation, which provides a slowing down.

MR. CARLSON: Yes. The applicant has stated that with the current lattice that it is under moderated with respect to the light water coolant.

MR. SIEBER: And with regard to temperature coefficient, it's the combination of enrichment and poisoning that will change that coefficient.

MR. CARLSON: As AECL would point out, the magnitude of the coolant void reactivity is very sensitive to the fuel design.

MR. SIEBER: That's right.

MR. CARLSON: And the fuel design that they are presently using -- and this changed during Phase I of the pre-application review -- during the beginning of Phase I the fuel enrichment was 2.0 percent, and it had, I think, 4.8 weight percent dysprosium in the center pin, and in about June of last year, June 2003, they changed that to 2.1 weight percent and 7.5 weight percent dysprosium.

MR. SIEBER: And that should make a pretty --

MR. CARLSON: Well, it went from minus five milli-K to minus seven milli-K.

MR. SIEBER: Okay.

MR. CARLSON: And that was in part, I think, a reaction to our Phase 1 discussions where they felt that they needed to make it more negative to increase confidence that it is, in fact, negative.

MR. SIEBER: Because, too, that you're basically wasting neutrons.

MR. CARLSON: I think their nominal average burn-up went from 20 gigawatt days per ton to 21.

MR. SIEBER: Okay. Well, you get some of it back.

MR. CARLSON: And so in Jack's talk he

said that we understand that it can be made negative. If we don't agree that the present design is fairly negative with confidence under all operating conditions, they can further modify the fuel to make it more negative.

MR. SIEBER: Well, it seems to me that that's a fact, that with enough design changes, and some of them are pretty subtle because it's just enrichment and burnable poison strength, that you can make it have whatever characters that you want.

The question is: can you calculate it accurately enough to feel confident that you're really negative.

CHAIRMAN KRESS: Yeah, that's the third yellow sub-bullet on there, which I think is a very interesting question.

MR. CARLSON: Well, before I go into that slide, I wanted you to take a quick look at slide number nine. That's on the third page of the ACL presentations in the upper left-hand corner. It's a table of major contributors to the coolant void reactivity, milli-K in ACR, and there are two read numbers, which are the positive contributions to negative void reactivity, and a series of green numbers, which are the negative contributions to coolant void reactivity, as calculated by AECL.

DR. WALLIS: So you need your plutonium.

MR. CARLSON: Yes. It becomes more negative with burn-up, with the buildup of plutonium and the depletion of the positive effect of U-235.

DR. WALLIS: If you enrich it more, it makes it worse. Do you get more 235?

DR. RANSOM: No.

MR. CARLSON: Well, you need more dysprosium to balance out the effect of enrichment, and that's --

DR. WALLIS: It just about balanced, right?

MR. SIEBER: Yeah.

DR. RANSOM: Does this balance mid-life or end of life type imbalance?

MR. CARLSON: Peter chan can correct me, but I think it's based on a simple lattice calculation with the WIMS code for mid-burn-up fuel, mid-cycle burn-up fuel, and to that they've added a reactor leakage. So these are not firm numbers, but they're illustrative numbers.

MR. SIEBER: Well, these change constantly throughout the cycle, whatever you call a cycle.

MR. CARLSON: Well, they don't have a

cycle. They have an equilibrium core.

MR. SIEBER: Right.

MR. CARLSON: And our review at this point is focusing exclusively on the equilibrium core because the initial and transitional cores have not been designed yet.

MR. SIEBER: Okay, but the challenge may be greater for the initial core. It could be.

MR. CARLSON: Yeah. It's an interesting question.

DR. ROSEN: Well, because you're not in plutonium.

MR. SIEBER: Well, on the other hand, you can choose the parameter levels, the constituent levels to force it even in the initial core.

MR. CARLSON: Yes, that's what AECL has told us. They're confident that they can --

MR. SIEBER: I believe that.

MR. CARLSON: -- they can tune it to what it needs to be in the initial and transitional cores, but we haven't seen exactly how they're going to do that.

DR. WALLIS: The bit red term is this hydrogen, the water.

MR. CARLSON: Yes.

DR. WALLIS: If you blow the water out, it becomes much more reactive.

MR. CARLSON: I'd like to point out because this is a common misconception, and I've heard from numerous sources, people who are new to this design say, "Oh, they've gone to light water cooling." Well, our light water reactors have negative power coefficients and negative moderator temperature coefficients.

MR. SIEBER: And that's because the enrichment is way up there.

MR. CARLSON: But, in fact, going to light water did not help AECL -- and they'll confirm this -- does not help. In fact, it would be easier to make the coolant void reactivity negative if they had stayed with heavy water cooling.

MR. SIEBER: That's right.

MR. CARLSON: And the big effect there, as you see, is that 31.5 read number for loss of absorption by light hydrogen in light water.

DR. RANSOM: DY is deuterium, I guess?

MR. CARLSON: No, EY is dysprosium with the burnable poison.

DR. WALLIS: That's the one that cancels out the 235.

DR. RANSOM: What is the effect of the calandria

MR. CARLSON: Well, it's zirconium. So the neutronic -- it's pretty transparent to neutrons.

MR. SIEBER: It's invisible.

MR. CARLSON: But we're discussing that in our PIRT discussions, and I'll be flying to Brookhaven tomorrow morning, as Jack indicated, to have the third PIRT meeting for neutronics.

MR. SIEBER: So the real issue is not can you calculate it and have enough confidence that you know that you got a reasonably good answer.

MR. CARLSON: Exactly. So let me go through my slide here.

AECL's nominal value of the coolant void reactivity is only slightly negative, that is, an informal definition of coolant void is K, that is, the neutron multiplication factor voided. Minus K cooled is minus .007 or minus seven milli-K. A more formal definition is one over K cooled minus one over K voided. Numerically they're the same when the cooled K effective if one.

Anyway, it's only slightly negative. The coolant void reactivity is also a combination as we saw in that table from the AECL of large positive and large negative and small negative effects, and it is sensitive to core design. As I just said, slightly changing the enrichment and increasing the burnable poison, changed it from minus five to minus seven milli-K, and it's also somewhat sensitive to operating parameters. If there is a poison in the moderator, which they don't usually have but would have in the unusual case of restarting after long shutdown, they would have a small amount of boron in the monitor. That makes the coolant void reactivity less negative.

Another key observation is because of these factors, the evaluation of bias and uncertainty in the calculated CVR predictions, i.e., validation, will figure quite prominently in the staff conclusion and also how we model it. But validation of our models is key.

Interesting to note is that there will be no in reactor measurements of coolant void reactivity. They are difficult to do and they are not planned by AECL. That kind of measurement would basically call -- the straight measurement would call for you to have an operating or plant that's ready to operate and take out all of the coolant.

MR. SIEBER: Yeah, they just melt it.

MR. CARLSON: So there would be some

reluctance and difficulty in doing that.

This is not to say that we're closing the door on any way of doing in reactor measurements, but we do acknowledge that it's difficult and there's no obvious way to do it, and it is not planned by AECL a this time.

DR. WALLIS: No one will ever know.

MR. CARLSON: So, therefore, we're stuck with what we predict, and those prediction methods will be validated based on some ACR specific benchmark measurements in the ZED-2 facility at Chalk River Lab. It's an AECL facility. We've been there, and we've seen it.

DR. RANSOM: Is that at zero power?

MR. CARLSON: This is a zero power critical facility.

CHAIRMAN KRESS: That's an interesting bullet about how confident are you.

MR. CARLSON: So the validation question becomes --

CHAIRMAN KRESS: A more interesting question to me is how confident do you have to be.

MR. CARLSON: Well, yeah.

CHAIRMAN KRESS: Is that a policy issue?

MR. CARLSON: Potentially, potentially.

So, yeah, the question is when code calculations predicate a small negative CDR, how confident are we that the actual CDR will, indeed, be negative in view of prediction bias and uncertainty? Again, as determined by benchmarking against some semi-prototypic experiments.

Now, the experiments that AECL has done for validating the neutronic predictions for conventional CANDUs really don't help us here. They really have to do a set of ACR specific benchmarks because the neutronic phenomenology in this design is quite different from that in conventional CANDUs.

They have started doing some of those tests, and the majority of them will be finished in the next year or so. They're planning to complete them in 2005.

So as I alluded to a moment ago, a significant result from a Phase 2 pre-application activities was that in June 2003, AECL did change the fuel designed to make the coolant void reactivity more negative.

Some of the pre-application interactions we've had on coolant void reactivity, we've had some technical exchanges on coolant void reactivity analysis and validation, including facility tours of the ZED-2 facility, and in Vince Langman's earlier slide he said those were in December of '03. They were actually in December of '02, over a year ago now.

We developed a set of RAIs in March of last year, and AECL responses were provided and supporting document in June of last year, and in November and another set just came in last month, and there's more information coming as they solidify their program description and actually conduct their experiments.

We received our first information, detailed information, about the physics design of the core in that June response, but they immediately changed their design. So we have yet to receive that level of detailed information about the current design.

I provided established report in September of last year to Research -- well, I'm in Research -- to NRR, and NRR forwarded that to AECL in September. We started our NRC PIRT activities in September and had our first meeting in October, our second meeting in December, and our third neutronics PIRT meeting later this week.

AECL has been very helpful with the presentations that they've made at those meetings and with the follow-up information that they were requested by the panel members during the meetings.

We've also had helpful participation by the CNSC staff as observers in those PIRT meetings. The CNSC, the Canadian regulatory staff, has also been making progress on their own in trying to do independent calculations of coolant void reactivity and we'll be hearing about that from them soon.

DR. WALLIS: What is the typical uncertainty in these calculations? When I went to the university a long time ago, the uncertainties were fairly high in these CVR calculations. Are they now narrowed to the point where when you say 15.1 you're pretty sure it isn't 13?

MR. CARLSON: That's a very good question, and I don't think it's quite that good, but we'll see. We're going to --

DR. WALLIS: You don't know?

MR. CARLSON: We're in the learning stage.

DR. WALLIS: You must know what's typical. Say what the odd is now. What's the sort of typical uncertainty in these numbers? Does anyone have a handle on that?

MR. CARLSON: Well, frankly, I'm not involved in light water reactor analysis.

DR. WALLIS: But somebody is.

MR. CARLSON: But yet we do have people in NRR and in Research who are. So if anybody wants to speak up. My feeling is that ten to 20 percent --

DR. WALLIS: That's much too much.

MR. CARLSON: -- uncertainty --

DR. WALLIS: That's much too much to be sure with minus seven and these big numbers.

MR. CARLSON: For the moderator temperature coefficient. Uncertainties on that, in that general order of magnitude, somebody can correct me if I'm wrong.

DR. WALLIS: Not hearing a correction, we take it that each one number 31.5 is within --

MR. CARLSON: Oh, you're looking at that table? I would say, yeah, we have an uncertainty associated with plutonium. I don't know exactly what it is, but obviously we can't predict with absolute accuracy what the inventory of plutonium is as a function of irradiation.

And on top of that, we don't know with absolute accuracy what the effect of it, given the amount of plutonium in the fuel is on coolant void. The ZED-2 experimental benchmarks will give us a handle on that. Otherwise our analysis tools are pretty good, but just how good remains to be demonstrated in this context.

DR. WALLIS: So you don't have a feel for how good they are now? I would think you could look at somebody with an expert eye who knows these things and makes these calculations, could look at these numbers and say, "Gee, whiz, I'm not particularly confident," or, "I'm really sure that they're pretty close to minus seven because I know you can do these things accurately."

MR. CARLSON: We've been having these discussions in the context of the PIRT in the first two meetings of the PIRT, and our experts are kind of on the fence as to whether we can real prove with confidence that when it's minus seven milli-K that it really is negative.

MR. FLACK: Yeah, I believe that knowing what drives the uncertainty is what really is important in understanding what that really is going to be, and I think that a lot of it is where we're trying to understand what would be driving that uncertainty and whether it would overlap.

MR. CARLSON: This is enough different from light water reactor physics that we know that I think experts just won't immediately come up with an answer of what they think the expectation is for accuracy like you're asking. But we could talk qualitatively about I think there may be substantial uncertainty in Plutonium-239 and U-235 terms because the inventory as a function of burn-up is not perfectly known, for example.

MR. FLACK: Why don't we just take this as a take-away? We'll be meeting more on this in the future and let's come back on that one.

MR. SIEBER: Let me ask just one other question. There's a lot of resonances in the cross-section diagrams in the energy range that you're dealing with here, and when you have one of these voids, you end up with a pretty good size spectral shift which steps you through those resonances, which depending on where you are during that transient will change whether the coefficient -- what the level of it is.

MR. CARLSON: Well, you'll see that the dominant resonance absorber, of course, is U-238.

MR. SIEBER: Right.

MR. CARLSON: And in their table it's a minus 15 milli-K effect. The change in absorption in U-238 upon coolant voiding is minute 15 milli-k.

MR. SIEBER: Then it comes down like this, and then there's a bunch of resonances and then it goes to essentially a mean value again.

MR. CARLSON: What's happening is that when you remove coolant from the channel, more of the neutrons do their slowing down out in the moderator away from the fuels who have reduced resonance absorption.

MR. SIEBER: Right, but the burnable poison has the same phenomenon. If you had gadolinium it's even wilder than --

DR. WALLIS: But that would make it even more reactive, wouldn't it? If you get less absorption, you get more reactivity, not less. It think it must be because you lost the light water coolant that you --

MR. CARLSON: Yeah, I'm thinking about CANDU here. Excuse me, yeah.

DR. WALLIS: I think you've got more resonance absorption because you've lost the hydrogen that's doing some slowing down for you in the channel itself, but again, we're debating stuff. You're going to sort it out.

MR. CARLSON: Yes. So that the coolant void reactivity is the initial focus of our neutronics PIRT, and it will be completed in the March-April time frame.

So for completing Phase 2 of the pre-application review activities on coolant void reactivity, we'll provide, research will provide an initial -- we'll apply input on the status and initial results and plans for coolant void reactivity, confirmatory analysis to NRR in May, and that will be used by NRR in responding to AECL in the SAR.

DR. WALLIS: Well, tell me. These PIRTs don't really tell you very much. they tell you that some experts think that some phenomena is important. That's fine -- are important. That's fine.

But until you actually evaluate it, you haven't really learned much.

MR. CARLSON: Well, in a way our PIRT panel has not become expert yet in this particular design, and really at this point the only experts on the design are at AECL. The rest of us have a steep curve to climb.

So anyway, this is kind of PIRT in the dark. We have technical discipline area experts, but they all acknowledge that they have much to learn on the specifics.

DR. WALLIS: So even when you have a good PIRT, you still have a long way to go.

DR. ROSEN: Of course, the PIRT, all it does is tell you what to focus on.

DR. WALLIS: Right.

MR. CARLSON: Yeah.

MR. SIEBER: That's right.

MR. CARLSON: So as we learn more, we will refine what we learned from our initial PIRT.

DR. WALLIS: I think the real thing is can the staff calculate the things that matter with this design with enough confidence to make a decision. Now, I don't have any measure of that from what I've heard today. I know it's difficult.

MR. CARLSON: Well, and we see it as being difficult, and we will not provide an answer that, yes, it is negative during pre-application review.

DR. ROSEN: That is kind of a problem for AECL, isn't it, trying to decide whether to go ahead with an application? And if it turns out you don't believe that you can confidently say that it's negatively, that may be a show stopper.

MR. CARLSON: Well, the emphasis of our early activities continuing into the design certification phase will be to identify gaps in their experimental database that would make it difficult for us to conclude with confidence that it is negative for the current design or any modified design.

MR. FLACK: But, again, I think what we're trying to do is to see where we're headed as a final conclusion. Again, the pre-application is part of being prepared, having the staff prepared, trying to put the tools in place that will answer that question, and then when we get to the end of this, we will go forward with whatever position we're in at that time with the basis for it.

So it could evolve to a policy issue, uncertainties are large, and we're not as confident as we believe we could be, but that is to be seen. What we're at a phase now is just putting in place those things that will get us that answer, and Don has been going through with you all of the areas he's looking at, and we'll continue to look at this as part of pre-application, and when we come back later this year, we'll give you our assessment of where we are at that time. That's about the best we could say at this point.

MR. SIEBER: But it's just as likely that you can conclude that it's okay as it is that you would conclude that it's not okay at this point in time.

MR. FLACK: As a basis for either answer.

MR. SIEBER: That's right.

MR. CARLSON: We know how to get there, but there's a number of things we have to do.

MR. SIEBER: You know you have to cross fences. You just don't know how high they are.

DR. WALLIS: What I'm concerned about is you're going to be so uncertain that you won't really know what you're saying about whether it's okay or not.

MR. SIEBER: Well, you can calculate your uncertainty, too, to some extent.

MR. FLACK: We'll have to come to decisions in light of whatever uncertainties there are at that time, and it will tell us --

MR. CARLSON: We can discuss this more on the next bullets in the next slide.

So we'll be providing initial -- we'll also be providing a report, the third bullet here on initial insights and plans for assessing the neutronics validation data for the coolant void reactivity, which means evaluating bias and uncertainty in those predictions and perhaps treating biases and uncertainties in the safety analysis.

No conclusions, just thoughts and observations based on where we are now in the pre-application review and where we will be a few months from now.

And then as in all areas, we'll be coming up with inputs on estimated resources and schedules for confirmatory analysis of the coolant void reactivity and validation and related work to establish core models with the PARCS code for ACR-700, and that will be in the May-June time frame as well.

My last slide, here's our thinking on the continuation of confirmatory analysis activities for coolant void and related work from henceforth and into the design certification phase.

Three major activity areas, the first one being independent static calculations of nominal values of coolant void reactivity using detailed models with existing state of the art methods, i.e., the MCNP code. MCNP is a Monte Carlo exact geometry continuous energy point-wise energy code, but it solves the item value problem static. It's not a dynamic code. So we will be doing static calculations of the difference between K effective voided minus K effective cooled. We started some of that and will be continuing some of that.

So MCMP modeling with in-house cross-checking against another code, AECL is also using

MCNP. There's another code called MONK. It's from the U.K. It's very similar to MCNP, but different, but independent, and uses different cross-section libraries. They have libraries from Jeff and Jendel, as well as ENDFB.

The second sub-bullet. The results of the MCMP analysis will reflect and supplement the phenomenology insights from the PIRT panel.

And the final bullet, the detailed MCNP modeling studies will help qualify the more proximate models and methods to be used by the NRC nuclear code suite for reactor transient analysis, SCALE plus PARCS.

The second major bullet, validation and benchmark analysis to evaluate coolant void reactivity bias and uncertainty. As I said early on, we expect bias and uncertainty, the validation question to weigh heavily on our conclusions in this area.

The NRC and DOE have put significant effort over the last eight years in developing sensitivity and uncertainty analysis methods for us in validation in the criticality safety realm. We're considering adapting and applying those methods and perhaps other sensitivity and uncertainty methods to help us assess the applicability and coverage of the set of semi-prototypic ZED-2 benchmarks, and from those benchmarks derive the bias and uncertainty in predicting coolant void reactivity in the reactor.

A related exercise is to review and assess the measurement techniques for ACR benchmarking in ZED-2. Thee are some rather unique approaches they use for those measurements, and we started to understand them, but the measurements themselves have potentially significant uncertainties.

And the early emphasis of all of these activities is to try to identify gaps in associated needs for additional integral data and possibly also differential data, cross-section data or cross-section covariance data.

The final major bullet. We'll be providing SCALE lattice data as input to our PARCS core models for simulating ACR-700 operations and transience. The substeps include adapting and applying SCALE, the SCALE Triton code to Model ACR-700 fuel lattices in another yet to be determined sequence in scale to treat the three dimensional problem of the transverse reactivity devices. That is, the absorber rods are perpendicular to the fuel channels, in between the fuel channels. So that's a three dimensional problem that we are not used to dealing with. We do lattice physics in two dimensions for our current reactors.

The corresponding tools in AECL code suite are WIMS and DRAGON. The second sub-bullet, adapt and apply PARCS to model the core with lattice data provided by SCALE, and RFSP is the corollary code for AECL.

And then integrating and testing the resulting scale data is used in the PARCS models and then coupling with TRACE and/or RELAP.

Once those models are in place, we'll use those in addition to the AECL codes to analyze the impacts of postulated CDR variations or uncertainties. On the progression of cooling transience, the reactivity response to cooling transience in ACR-700.

That concludes my talk. Are there any questions?

(No response.)

MS. SOSA: Thank you, Don.

At this time I'd like to turn it over to Mr. Steve Jones, and he will be discussing the on-power refueling focus topic review.

MR. JONES: Good afternoon. I'm Steve Jones in the Plant Systems Branch of NRR. I just wanted to speak briefly about the on-power refueling topic, a little bit more regulatory basis than technical than perhaps the last couple of presentations have been.

Obviously, on-power refueling has been previously licensed before in the United States. So our body of regulations has left some gaps. The objective is to really fill those gaps with regard to design criteria, accident evaluation, and, in particular, the codes and standards that would be applied to the on-power refueling mechanisms.

Now, as Belkys went over, our end report will deal with regulatory issues, policy issues. That's probably at times policies just with a small "P," just dealing with what level of risk is acceptable for the on-power refueling design.

And then develop the regulatory and policy framework to support --

DR. WALLIS: Is that going to be the basis for it, is to use a risk approach? Are you looking at things that can go wrong and how they could affect core damage rather than writing a lot of new regulations that are ad hoc and the old style?

MR. JONES: Our regulations, as I said, really leave quite a big gap. So it seems like consistent with our risk informed policy that we would be using risk to develop any new design criteria that would apply to on-power refueling.

And really the on-power refueling topic is really a small scale version of the entire design certification of the plant in that you have a small pressure vessel that contains irradiated fuel that's moving around inside containment and then interfaces with other systems. It affects the reactor accident frequency because for a time it's part of the Class 1 pressure boundary.

But then, again, when it's separate from the reactor coolant pressure boundary, one previous speaker mentioned you're only deal with 12 fuel assemblies, which is one channel, less than one percent of the core. It doesn't pose a great deal of consequences considering that that's inside containment.

CHAIRMAN KRESS: But don't the Canadians have a design basis accidents related to the --

MR. JONES: Yeah.

CHAIRMAN KRESS: One approach might be to look at those and say those would be acceptable design basis concepts?

MR. JONES: Yes. We'll get into that in a later slide. They have provided some design basis accidents. I'll start at the highest two with our regulations under Part 50 and Part 52. I gave a couple of examples where there's some clear applicability in 10 CFR 5055(a) in codes and standards, and you've been asking quite a few questions of AECL regarding the design and the different points where seals or flexible hoses become involved in the pressure boundary design of this plant.

And Patrick Sekerak in the Division of Engineering will be talking about that aspect of on-power refueling in a moment.

One other example is criticality accident requirements, and that's in Part 5068. It's not likely to be a real technical issue, but evaluating how exactly to apply or exempt the on-power refueling from that particular requirement could be a policy issue or regulatory issue we need to deal with.

The next area is developing a design criteria, and that's really very well integrated with the types of accidents that could happen and their frequency. There's a lot of existing criteria in Part 50, Appendix A that we could apply. Also I'm sure AECL has developed some criteria that they've used in designing their own private refueling to date.

The areas we're looking at include criticality prevention, fuel cooling, residual heat removal, mechanical handling of the fuel, instrumentation control systems with regard to those interlocks and other devices associated with the on-power refueling machine; to what extent emergency cooling is required and to what extent containment integrity is maintained during the fuel transfers.

And then from those identify issues, policy issues which may require high level guidance or Commission involvement.

DR. WALLIS: Has AECL left this up to you? I would think that in their submission they would say, "Here's our reactor, and this is why it meets your general design criteria."

MR. JONES: We did have actually our first technical meeting yesterday regarding our on-power refueling, and we discussed that it would greatly simplify matters to get their proposed design criteria and just evaluate whether or not those are acceptable, but as we have already a set of design criteria in Appendix A, it doesn't seem entirely out of the scope of our work to also propose some for this type of application.

DR. WALLIS: I just thought they would

have already come in saying all you had to do is see whether you accept it or not. It doesn't seem that is the case.

MR. JONES: In the documents I have reviewed to date, I haven't seen any set of design criteria specifically --

DR. RANSOM: It seemed like that would want to trade off the risk due to decay heat removal and low power operation, which I understand there are significant risks in conventional plants versus not having to go through that phase.

MR. JONES: That's true. That would be an opportunity.

DR. ROSEN: Well, not having to go through that phase as often.

DR. RANSOM: Pardon?

DR. ROSEN: Not having to go through that phase as often.

DR. RANSOM: Right, right.

DR. ROSEN: We do have to shut down at some point, and then they have shutdown risk issues, not the same ones we have, clearly, but there do shut down after three years.

MR. JONES: I guess the dominant contributor as far as mid-loop operation with fuel still in the reactor vessel would largely be avoided in this design. So that's a big part.

The other issues, as Dr. Kress mentioned, with review of operating experience and failure modes analysis of their basic design to identify proposed design basis events and bring risk elements in to see how likely any one of those design basis events were, and from that establish acceptance criteria for the accident analyses involving the fuel handling machine.

Again, there may be some policy issues that arise out of that. Since we're dealing with a very small fraction of the core, the risk or the consequences are relatively low. However, they are different from what we have licensed in current plants where we're only looking at mechanical damage of, for instance, one PWR assembly which is at least on the same order of magnitude as far as amount of irradiated material, but we're only looking at gap releases in those type of events, filtered through some amount of water, whereas it seems as though at least accidents in this refueling machine could involve thermal damage to fuel that involves a larger release, and we'd just have the containment boundary as a protected mechanism.

Regarding technical issues as far as

that's really the methods of review and analytical tools, I really don't see many issues in that area. Right now this is pretty traditional accident analysis work or risk evaluations, but we'll be looking for those items and identifying any in the safety assessment report.

And that concludes my portion of the presentation.

Mr. Sekerak from Division of Engineering will talk briefly about the Part 5055(a) code and standard applicability to on-power refueling.

MS. SOSA: Thank you.

MR. SEKERAK: Good afternoon or good evening might be more appropriate. My name is Patrick Sekerak. I'm from NRR, Division of Engineering, Mechanical Engineering Branch.

And my part of this review is specifically related to review of the qualification and design of the mechanical equipment that's associated with the on-power refueling system, and much of what Steve provided you just before is applicable to my area, but what I wanted to concentrate on in the interest of brevity was the specifics of what I'm particularly concerned about in reviewing the mechanical design basis of the components and component supports that comprise on-power refueling equipment.

So far the most detailed document that has been submitted by AECL for on-power refueling is the AECL report, "The Technology of On-power Refueling." What this document provides is a very good, general description of the qualitative portions of the system and how the system works, how the components relate to each other, and it's a good general description, and it also provides some reference to CSA standards that are supplementing the ASME design standards that we use as part of our regulations.

And in that regard, it's useful because it provides some basis for our understanding of a design, quite frankly, that I'm very unfamiliar with. However, what it does not provide is the level of quantitative design basis information that I need to pass judgment on the design basis for the equipment it constitutes, the on-power fueling system.

That kind of information, and I refer to 10 CFR 5247 for reference, that type of information is by this litany of information that I have under the second paragraph, which should not be interpreted as all inclusive by any means, but gives a representation of the type of detailed design criteria and information that I'm going to need in order to do a technical review for design certification purposes.

Now, the path forward for staff review of this kind of information is Chapter 3 of the standard review plans, the NUREG 0800, and it's represented primarily by standard review plans, such as 3.2.2, 3.9.1, 3.9.2, 3.9.3, and 3.9.6.

That is the plan that I will be using for review of the design adequacy of this kind of equipment and supports, and one thing I'd like to highlight. Probably the most important thing that those standard review plans rely upon is the ASME boiler and pressure vessel code as the document that defines the acceptance criteria and design basis for mechanical equipment.

And the policy issue, although I list it as a policy issue, it could be a regulatory issue, but I'll consider it a policy issue for now because it concerns me because what we've been told is that there are a number of departures from 10 CFR 5055(a) which constitutes the adoption of the ASME design code as the rule for design of components that provide pressure boundary, Class 1 pressure boundary, and supports for the Class 1 pressure boundary, and we're told that there are a number of CSA standards that are being used as proposed alternatives to these ASME code requirements.

I know that there are a number of components in the on-power fueling system that fall into that category. There are also some components that will be affected in the Class I pressure boundary design, and there may be others. I'm not sure of the full extent of where those alternatives to the ASME code really are applicable.

I know that in the Class I pressure boundary design and on-power fueling equipment design that they are applicable, and what I'm concerned about is that there has to be some reconciliation formally of these CSA standards when they provide for either replacement of ASME standards or supplementation of ASME standards or provision of new standards, adding to the ASME code requirements.

The first thing that I would have to do when it comes actually time to write a safety evaluation report, the first paragraph that I'm going to write is what are the acceptance criteria. Ordinarily that would be fairly easy. I'd just refer to the general design criteria, standard review plan guidelines, the regulatory guidelines, and then I could proceed to the detailed review of the kind of information that I would expect from the second category of the slide, the 5247 design information.

But I've got a problem right away. In the first paragraph of the safety evaluation report that I'm writing, I've got to reconcile somehow the acceptability of the CSA standards. Now, 10 CFR 5055(a) provides for the NRC review and acceptance of proposed alternatives to 10 CFR 5055(a).

But what I'd like to emphasize is that it also suggests that the burden of proof of the acceptability of those standards in providing an acceptable level of quality and safety to codes that it is replacing, that burden of proof rests with the applicant. And I would emphasize that for AECL consideration.

What we would expect, what the staff would need in order to proceed with this kind of review in an efficient manner is to have those proposed alternatives or exemptions of whatever form they take, proposed in the process adjusted by 10 CFR 5055(a), and especially with regard to providing justification that the CSA standard provide an acceptable level of quality and safety to the provisions of the ASME code that it is replacing or supplementing.

As I mentioned before, the AECL report, "Technology of On-power Refueling," I find to be a very useful document to provide an overall orientation. However, for my purposes it's long on system description; short on technical details. And before I can really proceed any further, I would need much more detailed technical design basis information and also a basis to establish an agreed upon acceptance criteria where there are departures from the ASME boiler and pressure vessel code which includes not only Section 3, but Section 11 and the operation and maintenance codes, which are also adopted by reference in 10 CFR 5055(a).

DR. ROSEN: And the code cases.

MR. SEKERAK: And code cases that would be applicable.

DR. ROSEN: Well, one was mentioned this morning, risk informed code case, risk informed inspection code case.

No, I think your analysis here is very useful, very thoughtful, and difficult obviously for AECL implications. But there is another way for AECL to approach it perhaps just as hard or even harder unfortunately and that's for them to go to the ASME code and get that reconciliation adopted in code cases, which would solve your problem, wouldn't it?

MR. SEKERAK: It would in theory.

However, in practice, having participated in the ASME process as a new code committee member, the process sometimes is very lengthy. I would be concerned about the length of time that it would take to get code cases approved to support the kind of scheduling that both AECL and the project is --

DR. ROSEN: Oh, I agree with you 100 percent. I just think that if you just leave the time scale off the axis for a moment, but stepping through that process, if AECL was to identify the deviations or differences with the code, the ASME boiler and pressure vessel code and its O&M cases and the rest of it, identify those, go to the code communities, get code cases that say, yes, it's acceptable if you do this or that and whatever the conditions are; then you're back in what you said. When you sit down, you can evaluate it.

MR. SEKERAK: I would agree that ignoring the pressures of schedule, that would be a good way to proceed because it would address ASME, who would really have the depth of knowledge to address the differences and to be able to make judgments about whether or not the applicable CSA standards had the same design basis that the code does, the same implicit factors of safety, and the various other technical provisions that I would be looking for as a justification that the CSA standards provide equivalency to the ASME standards.

DR. ROSEN: And leaving out the time scale, which brings in the consensus process, which is very useful.

MR. SEKERAK: Yes, it does, and the ASME code, obviously, has developed as a consensus code over decades. We're familiar with it. Many of us have used it. We participate in the consensus review process. So we're comfortable with it.

When standards that deviate from it are introduced in our review, that provides another challenge, and I'm not saying that that necessarily is a showstopper. I don't even know enough about the CSA standards to even suggest that.

But it provides an additional challenge right up front to agree on acceptance criteria which would otherwise be very clear for us, and I would certainly like to have that acceptance criteria tied down specifically before I even spend an hour on reviewing a design certification, the details of a design certification application.

So those are the major points that I wanted to emphasize in my view of what I have done in this regard so far. So if there are any other questions, I'd be glad to try to answer them if I could.

MS. SOSA: Before we move from this topic I'd like to clarify a couple of things. Part of the issues that you heard today from Mr. Sekerak are things that we are addressing in Phase 2. The main objective of Phase 2 is to provide the type of feedback that he expressed here today.

So hopefully we will come to good solutions. There are multiple ways to resolve this issue. However, the schedule is a very important consideration.

So we're hoping to proceed with a plan that works.

DR. ROSEN: Schedule is very important for AECL, clearly, but overriding it is the question of the consistency of this design with our requirements and the ability to find confidently that the design does meet those requirements. So, I mean, that has to be first, and then if you can do that on their schedule, so much the better, but first things first.

MR. SEKERAK: And this is especially important since a major section of our regulations are devoted to this very topic. The ASME code has become enshrined in the basis for our regulations for a long time, and I would need some detailed information about reconciliation of requirements that would convince me that any new CSA standards that are proposed, in fact, do have a sound design basis.

And if there are departures from design factors, for example, implicit in the ASME III code, then I would expect some justification of why those design standards or departures from those design factors are compensated for by other provisions.

And without belaboring that point too much, just to provide an example, the ASME III code has implicit in it a design factor of approximately three, which is measured by the allowable stresses that are specified by the code compared to the minimum material properties that are measured in the code approved materials.

If a design standard is provided that has a smaller design factor implicit in it, it would not necessarily be unacceptable, but there would have to be a justification of why that lower design factor is -- what compensates for that particular lower design factor? Is it more stringent requirements on material procurement, material inspection, fabrication requirements? What are the compensating factors that would allow me to accept a design code that has a lower implicit design factor?

And that's just an example of the kinds of detail that I think would be necessary in order to justify departures from 10 CFR 5055(a) requirements.

MS. SOSA: Thank you.

MR. SEKERAK: Thank you.

MS. SOSA: And last on today's agenda we have Mr. Martin Stutzke, and he will be presenting the staff review for the PRA.

MR. STUTZKE: Hi. I'm Marty Stutzke. I work for the Probabilistic Safety Assessment Branch in the Office of Nuclear Reactor Regulation. I have been there about seven months now. Prior to that I had 17 years as a private consultant doing PRAs.

So my perspective may be a little different, and my boss is helping me to learn.

DR. WALLIS: Are you just learning from your boss or is it the other way around?

(Laughter.)

MR. STUTZKE: Hopefully it's mutual.

I have two major things I'd like to present to you today. First of all is our plan to conduct our review, the objectives, the guidance, the various assignments and schedules and things like that.

The second thing is what I will label to say potential policy issue concerning risk acceptance guidelines for core damage frequency.

The objectives are pretty much as you would expect. We want to determine that the PSA methodology will produce a PSA with adequate scope, adequate level of detail, and technical acceptability. Along the way, as Belkys has told you, we need to identify potential issues, technical regulatory policy.

Finally, we've been asked to generate a schedule and resource estimate for actually reviewing the PRA when it has been submitted. As you point out now, what we have to work with are PRA methodology documents. We have a reference analysis for the CANDU 6 and the CANDU 9. I have not seen any PRA or any PRA results for the ACR-700 as of this time.

Finally, we need to learn about the ACR-700 design, the plant layout, the construction. The systems are somewhat similar, and deceivingly different sometimes.

When I was a private consultant, I did PRA work in Romania on a CANDU plant. So what I learned by that exercise was if you go in with preconceived notions, you generate the wrong answer and identify the wrong risk contributors.

So we need to be a little bit careful that we understand how it works before we try to attack how it fails and model that correctly.

DR. FORD: Did you say that you haven't received the PRA from the applicants for this ACR-700?

MR. STUTZKE: That's correct.

DR. FORD: And yet you're supposed to write something by July?

MR. STUTZKE: I'm supposed to write on the methodology of the PRA.

DR. FORD: Ah.

MR. STUTZKE: Yes, it's a little sporty.

DR. WALLIS: There's nothing there about their competence to use the methodology? I can say I'm going to use all the best textbooks and all of the best methods, but I may be totally incompetent in my use of them.

MR. STUTZKE: Let me address that when we talk about the PRA quality issue because I think that has some bearing on this.

The next couple of slides I will just flip through them with your permission because they talk about the general sorts of guidance that I'm using to help do my work.

Notice with respect to PRA quality, the sections out of Reg. Guide 1.174, the standard review plan Chapter 19 and specifically Chapter 19.1; the ASME and ANSI standards on PSA; and last but not least, Regulatory Guide 1.200. This was formerly draft Regulatory Guide DGL 1122 whose publication is imminent I've been told.

PARTICIPANT: It's more. The Reg. Guide 1.200.

MR. STUTZKE: So here's what's been done before. First of all, you should realize this is a joint effort between our branch and the PRA branch and the Office of Research being head up by John Ridgely over there.

We've issued an RAI concerning PSA quality. They had a short chapter in their methodology document, and I asked some questions, how they intended to do this.

Very recently, between Christmas and New Year's, we issued some advice or guidance on our expectation. Specifically what I did was identify to them when Regulatory Guide 1.200 had been entered into the ADAMS system so that they could access it and become acquainted with it like this.

I advised AECL that we have a project in our branch called the PRA quality pilot projects where we intend to test the regulatory guide with five or six applications. I'm certain you're aware of that. It has been coordinated through the NEI, and I wanted to make AECL aware that this was going on.

CHAIRMAN KRESS: Does that guide give guidance on how to do uncertainty?

MR. STUTZKE: No.

CHAIRMAN KRESS: Well, that would be a --

MR. STUTZKE: It's not a methodology document per se. It says you should do uncertainty, and here are the types of uncertainties to come.

CHAIRMAN KRESS: It doesn't tell you. Does the methodology document have any guidance?

MR. STUTZKE: The methodology document constrains itself to parametric uncertainty, variations in failure rates and propagating, that sort of thing.

Within the next six weeks research will give me their draft report where they have reviewed the generic methodology and the generic PSA analyses, the so-called reference analyses, as well as the ACR PSA methodology report. I understand research has engaged a contractor to help them out; is that right?

I think it's somebody at Oak Ridge, but I don't know the details. It's not important.

Towards the middle of April we'll get together with research and the contractor and finalize their report so that they will have met their deliverable to me.

Towards the middle of May I will complete our review of the ACR PRA methodology. Another report, which is the "Phenomenology of Limited and Severe Core Damage Accidents." The review here is not nitty-gritty details of Level 2 PSA. It's more towards understanding what phenomenology accident progression really looks like to make certain we understand what they're telling us.

An additional report in here AECL will prepare, the latest target date is March 1st, is a document that discussed how they've used the PRA and the design ACR. That was originally scheduled, I believe, this fall, and it has been slipped for some time. We are very interested to see this document.

So towards the end of April, we'll complete our schedule and resource estimate, and then at the end of March or -- excuse me -- the end of June here complete our deliverable to the project manager of Belkys.

Okay. Here's our potential policy issue. Staff requirements memorandum on SECY 9016 specifies a core damage goal of ten to the minus four per year for evolutionary and advanced reactor designs. The ten to the minus four per year, Professor Apostolakis addressed that earlier today. AECL has a target of ten to the minus five per year. Okay? So they're designing to one order of magnitude lower than what we think is necessary.

I shouldn't say "what is necessary." To our current acceptance guideline.

MR. SIEBER: Like this so you can make it more risky.

DR. WALLIS: Of course, making it safer is totally unacceptable.

DR. ROSEN: You should use the words "frequency goal." Don't try to interpret it. It gets you in big trouble. It's the goal.

DR. WALLIS: Not even to be achieved.

DR. ROSEN: Goals are good things.

MR. STUTZKE: Now, for the ACR-700, as in other CANDUs, AECL has divided the core damage accidents into two broad categories: limited core damage accidents where the progression of the accident has arrested within the fuel channels, okay, so that you're talking about single channel sorts of problems.

DR. WALLIS: Is that core damage or not core damage?

MR. STUTZKE: This is the root of my question.

DR. ROSEN: To the operator that's core damage.

CHAIRMAN KRESS: To the PRA it's not.

MR. STUTZKE: Severe core damage --

MR. SIEBER: It's short of core damage.

MR. STUTZKE: -- it's traditional LWR accident progression.

CHAIRMAN KRESS: The definition of core damage in the U.S. involves significant amounts of fission product.

DR. WALLIS: That's my understanding, too.

MR. STUTZKE: That's my question, is how significant is significant.

Let me continue a little bit.

DR. WALLIS: Maybe you guys should give an answer to it.

MR. STUTZKE: In their PRA methodology, they define ten plant damage states. Okay. That with actually one plus exception they map to either limited or severe core damage categories. They have a plant damage state number nine that pertains to tritium release that does not involve any fuel damage at all. Okay?

For example, what if you get a pipe break in the moderator system? What if you get a hydrogen fire or explosion in the surge tank to the moderator system? Things like this.

The plus I had talked about is what about refueling accidents. Okay? They're single channel, that volume of fuel, but they could be inside the reactor core; they could be outside the core or somewhere in between like this.

Now, my understanding of their methodology is they have the capability of calculating frequencies for each one of these plant damage states because they are nothing more than the end states. So it's a matter of telling the computer go ahead and calculate the answer.

I have also, as part of one of my RAIs, requested they try to calculate the uncertainties for each one of these things. My purpose here is I wanted to understand what the magnitude of the frequencies were and what the risk drivers were for each one of these point damage state directives at this point.

This leads me to a question. How do I

interpret the ten to the minus four core damage guideline? In AECL's thinking, and I think in most of our branches' thinking, the guideline applies to severe core damage. Okay?

It raises the question: well, what about the limited core damage frequencies? Do we merely calculate them? Do we try to compare them to some sort of a target? If so, what target?

CHAIRMAN KRESS: My advice there would be go to the regulatory framework for risk informed regulations and see if you can find a target there.

MR. STUTZKE: I appreciate that. Yeah, we'll look.

On the other hand, if it applies to the total, you have the question on the other end: do you need a percentage sort of thing, say, severe is some percentage for the total core damage?

My personal leaning, as I said, is towards the interpretation above the first interpretation that severe core damage frequency target.

The second question that I have is: what about these accidents that involve potential releases but no fuel damage at all, like tritium releases? Okay. My instinct tells me they're probably of a much smaller consequence than severe core damage, but the frequency may be higher. I just don't know at this point in time.

CHAIRMAN KRESS: That needs to be looked at.

MR. STUTZKE: It needs to be looked at.

CHAIRMAN KRESS: And I think you're going to need some sort of acceptance criteria. Otherwise your safety analysis is not complete.

MR. STUTZKE: That's correct. That's my feeling.

Any other questions?

DR. ROSEN: Acceptance criteria that doesn't lead to success criteria for the mitigating systems and track back into the analysis.

MR. STUTZKE: Yeah, slowly.

MR. SIEBER: Well, that really just boils down to what health effects there are, in other words, fatalities, and depending on the level of tritium release, I guess if you do anything there is some latent effect, but do you consider the whole world?

CHAIRMAN KRESS: Well, the --

MR. SIEBER: You end up with one.

CHAIRMAN KRESS: That's one of the things that they wrestled with in the risk informed framework.

MR. STUTZKE: Yes.

CHAIRMAN KRESS: And they have guidelines in there, and it would apply to the tritium just as well.

MR. STUTZKE: Right.

MR. SIEBER: I think that's the way to resolve that.

CHAIRMAN KRESS: Yeah. Those aren't regulations.

MR. SIEBER: No, they aren't.

CHAIRMAN KRESS: You may be faced with you don't have the information.

MR. STUTZKE: But it's some guidance.

MR. SIEBER: It's the rationale that has been used before. That's about the best you can say.

MR. STUTZKE: But correct me if I'm wrong. That guidance is in terms of dose.

CHAIRMAN KRESS: Since there's a dose and that's what made you apply it to these things, and it's a frequency associated with giving doses.

MR. STUTZKE: Yes, sir.

CHAIRMAN KRESS: It's almost an LF type curve like they can use anyway, but it would be well worth checking into to see if you can use it.

MR. SIEBER: Yeah.

CHAIRMAN KRESS: It doesn't have the power regulation.

MR. STUTZKE: But I think it's better than nothing.

Okay. That's all I have for you.

DR. ROSEN: Well, I have a question --

MR. STUTZKE: Yes, sir.

DR. ROSEN: -- about using the -- you listed all of the standards, the ASME internal event standard and the ANS low power and shutdown standard. Buried in that ASME internal event standard is a requirement for peer review.

MR. STUTZKE: Yes, that's correct, and I asked as part of my RAI what is AECL's intentions with respect to some sort of peer review, specifically to ACR or has other of their work ben peer reviewed, something that we can point to that may demonstrate compliance with the standard.

We have a meeting with AECL. I believe it's February 5th to discuss these questions.

DR. ROSEN: I'll be interested in the answer.

MR. STUTZKE: And me, very much.

MS. SOSA: Last, in summary, we'll present the schedule and the major milestones, and that presentation will be by Jim Kim.

MR. KIM: This is Jim Kim from the NRR, your reactors project office.

If I look at the presentation, I look back at the AECL and I'll just thank for their presentations and I also like to thank committee members for the feedback on these subjects.

As we know we are already in Phase 2 of the pre-application phase and so far up to date, ACR has been submitted more than 160 documents in support of the pre-application review. And we have requested REIs on physics, thermal hydraulics, and quality assurance, and PRA, and also we requested additional information in support of the PIRT process, and so far we have received the responses on thermal hydraulics, physics, and PIRT, and we'll be receiving QA responses in two weeks, which is end of January.

DR. FORD: There have been no RAIs on materials?

MR. KIM: We are expecting several more RAIs, especially on pressure boundary design and several other subjects.

We have to request the RAIs by end of March in order to get the responses from AECL by the end of April. That is the time frame that we have at this time.

And today we are conducting ACRS information briefing, and we have a window of opportunity between April and June in order to conduct the ACRS subcommittee meetings on possibly thermal hydraulics and PRAs and possibly material issues.

And the end product of the pre-application is to produce a draft safety assessment report by end of July, and we are currently forwarding the draft SAR to both ACRS Committee and OGC for their concurrences.

And we will conduct the full committee meeting in September, and after concurrences will issue the final SAR to the AECL.

CHAIRMAN KRESS: We will try to accommodate your needs for the ACRS review.

MR. KIM: Thank you.

CHAIRMAN KRESS: Because we consider this one of the more important things.

MS. SOSA: Thank you.

CHAIRMAN KRESS: Did you want to?

MS. SOSA: Yes. I'd like to give an opportunity to Mr. Jim Lyons to express some closing remarks.

MR. LYONS: Thank you.

It's good to see I'm appreciated some

places.

I'm Jim Lyons. I'm with the new reactor licensing project.

I'd like to thank you all for your time and attention today. We've got through a lot of material, and we've seen a lot of really good questions and a lot of good issues discussed here.

I'd like to reemphasize that this pre-application review is meant to address those technical and policy issues that AECL has identified for the most part and in some cases we've identified that should be resolved prior to them actually coming in for a design certification application.

As you've seen, we're in various stages of our review on different focus topics. On some of the issues we've had a lot of interactions and we're fairly far along. On some we're just really getting started. And so a lot of what you're hearing from the staff today is trying to understand how are we going to review the ACR-700 which was designed, you know, without our regulations in mind and trying to apply our regulations.

And so a lot of it is reconciling those differences, and so that's one of the challenges that the staff is faced with and that I think you're hearing as we go through here, and I think it's something that we're going to continue to work on.

And AECL has been very good about giving us as much information as we need, as we've asked for. We're very happy with that. We're moving forward.

We're trying to work this -- I shouldn't say "trying" -- we're working well with the Canadian Nuclear Safety Commission to have them help inform us on what some of the key issues we should be looking at and trying to help us focus our reviews and to give us the benefit of their experience with the CANDU design.

So with that, again, I'd like to thank everyone for their time and attention.

CHAIRMAN KRESS: We'd like to thank everyone for these very good and informative presentations. Very useful to us.

At this stage in a subcommittee meeting, quite often we'll go around the table and seek initial comments from members on what they think so far. I think this may be too early a phase to do that.

So instead what I'll do is give anybody on the committee the opportunity to speak up if they have some sort of thoughts that they'd like to express or burning issues or they see anything so far that they wish to comment on.

So I'll throw it open to you. I'm not going around the table and say, "You, you, you, and you."

DR. WALLIS: Am I allowed to say something then?

CHAIRMAN KRESS: Well, definitely.

DR. WALLIS: I was really fascinated by the AECL presentation. I think it was a good presentation. You know, from their point of view, this is something they have a lot of experience with, and it looks like a nice design.

I just think that you've probably underestimated the need you have to cost your application in terms of the language and the terms and the measures that these fellows here in Washington are familiar with. You have to make a lot of effort to turn it into things they understand. Otherwise they just keep coming back asking you questions, and you won't reach resolution.

So you've got to make more of an effort, I think to understand what it is and the language that they speak and the way that they think.

And I'm really uncertain from hearing about what the staff said. I understand and I was pleased to hear that many of these members realize what they're up against. I can't see whether or not they're going to be able to resolve some of these issues. I mean, they raise the questions, but they don't give me any measure of how likely it is that they're going to be resolved. So this is very much an open -- it's sort of a suspense story without an indication of where it's likely to go for me.

And I almost feel there's a need for sort of a regulatory interpreter between these two sides of saying, "Can't we do it this way for the NRC so that they can understand what you're doing? And can you do it this way for the NRC so they can understand it?"

So it's something sort of in between.

CHAIRMAN KRESS: That would be a good job for Ken Rogers.

DR. WALLIS: Ken Rogers, yeah. I was thinking of Ken Rogers, yeah, right.

Because it would be a real pity that just because, as you speak different languages, in technical languages or regulatory languages you can't sort of get an agreement about something which may well be a nice technical piece of equipment.

CHAIRMAN KRESS: I appreciate those comments.

Yes, sir.

DR. FORD: Could I make a comment because both the --

CHAIRMAN KRESS: Does it have anything to do with materials?

DR. FORD: It sure does.

(Laughter.)

DR. FORD: Because both the staff and the applicant asked for advice as they go into this, finish their pre-application stage.

Someone asked are there any burning materials issues which are drop dead. I don't see that there are any issues which are drop dead issues at this stage. The ACR-700 is an evolutionary design. It has got good CANDUs. It has got a good operational record.

The staff are asking the right questions as far as materials issues. I'm astonished, however, that there have been no RAIs at this stage. The concern I have is the complete lack of quantification on both sides to quantify the kinetics of materials degradation and their consequence.

All of the materials degradation modes delay hydrogen cracking, erosion-corrosion, test corrosion, corrosion fatigue, they've all been highlighted, and they must increase in probability of occurrence because of the increase in temperature. All of them are thermally activated processes.

The remedial actions of changing material and/or the dimensions are the right direction to go, but I see no quantification as to the fact of improvement of going in those directions, and I think that at this stage from both the regulatory point of view and operational point of view, you need to quantify those kinetics, not only the individual modes of degradation, creep, DHC, et cetera, but the interaction of those modes, start-up, shutdown, and also for accidents.

the other area that I was dismayed at not having a lot of information is inspection criteria. I like the reference to the risk informed, but I saw no data to back up that hope.

Those are the hopefully constructive comments I have to make.

CHAIRMAN KRESS: Anybody else feel compelled to say some words?

MR. LEITCH: Yeah, I had a question. I didn't hear a whole lot about emergency electric power supply. I suppose there are diesels required, but I don't know how big they need to be, what the starting requirements, starting times for those diesels are.

So I guess at some future time I'd like to hear a little bit more about the emergency electric power supply.

Also, I didn't hear -- and this may be beyond the scope of our discussion here, but I didn't hear anything at all about considerations regarding safeguards and security. You know, at this early stage of design, this may be a time when some significant progress could be made in designing the plants to take into consideration some of the safeguards and security issues.

CHAIRMAN KRESS: Yeah, I had in mind the potential vulnerability in the spent fuel pool there.

MR. LEITCH: Yeah.

CHAIRMAN KRESS: The containment looks like it's pretty good.

MR. LEITCH: And I guess I'd like to hear a bit of a sales pitch, a commercial. I mean, I see the advantages of on-power refueling and the operating flexibility that that achieves, but I didn't hear any discussion -- and, again, maybe it's beyond the scope. It's not really a safety issue perhaps -- but why should a utility be interested in buying one of these machines? Is it low construction cost, low operating cost, load following capability or just maybe there are some of those advantages that are just not clear to me. They just haven't been emphasized. I'm just not sure what those --

MR. SIEBER: I think that's probably beyond the agency's concern.

MR. LEITCH: Well, as I say, maybe it may not be a safety issue, and it may be --

MR. SIEBER: It certainly isn't.

MR. LEITCH: -- beyond the scope of this discussion, but I'd like to hear a little bit about the advantages of this particular design.

CHAIRMAN KRESS: Spoken like a good ex-V.P.

MR. LEITCH: Yeah, right.

MR. SIEBER: There was a discussion of the emergency power in the CD that was sent to us. There was a whole chapter on it.

CHAIRMAN KRESS: Yeah, that too was an attempt.

MR. LEITCH: Yeah, there were two sentences.

MR. SIEBER: Well, they got it.

MR. LEITCH: It said, "Do you need diesels?" But I mean, I don't know the capacity or the speed with which they are required, those kinds of issues.

MR. SIEBER: Maybe they don't know it either at this point.

MR. LEITCH: That's really all I had.

CHAIRMAN KRESS: Anybody else?

DR. RANSOM: Well, one observation that I had that's kind of off the wall probably, but this seemed to be the first CANDU 3 reactor that we've looked at that did not provided for making it very difficult to uncover the core. You know, even under accident situations the others seem to have designed features such that the containment was flooded to the point that the core could not be uncovered.

Now, it may be from a risk point of view there's nothing added by incorporating a feature like that, but it would be interesting to know why not.

CHAIRMAN KRESS: Anybody else?

Well, seeing as how you guys are obviating my comment about going around the table, I feel compelled to say some few things, too.

I do think it's a little early for us to make judgments on what the issues are now. That's why I did it this way, but I have a list of some of the issues I think might be important to resolve, and one on my list is the confirmation of the negative power core, including uncertainties.

I think there are some material issues that need to be addressed.

Well, at one time when we get to the severe accident part and the PRA part, I want to see more about the energetic fuel coolant interactions and the potential for propagation of a failure of one pressure tube to others.

I would like to see the termination of the amount of hydrogen produced during severe accidents compared to the capacity of the autocatalytic converters and/or the strength of the containment.

I think there was an issue dealing in Appendix K space with the thermal hydraulics code and what is the actual conservatism in the codes being used; what is the required conservatism, what are the margins and what are the figures of merit going to be?

I mean, is this going to be oxygen produced, hydrogen, or is it going to be heat clad temperature or departure from nuclear boiling water? I think the figures are going to be different because they relate specifically to U.S. reactors.

I'm looking forward to reviewing the core mount progression and source term. I think it's important for confirming the PRA results.

I think very important, another important issue is the potential need for any additional integral and/or separate effects testing, and I don't think that's been resolved yet. That to me could be a potential showstopper if there's substantial needs there.

I think staff will have to give some sort of detailed review and acceptance, if that's the right word of the code kit that's being used by AECL. It doesn't look like a trivial ask if you're going to review all of those codes and pass judgment on them.

In terms of PRA, I think there is a question of quality and whether or not they ought to think about having an industry peer review pretty much like the ones in the U.S., and I'm particularly interested in how to deal with uncertainties in there, more than just parametric uncertainties. I want to see some discussion of what model uncertainties might do to you.

I think another issue for the staff is the set of design basis accidents that AECL has. Are they good enough? Are they equivalent to what we have in a sense, and is that good enough? And is there a dose acceptance criteria acceptable compared to what we have?

And you know, I would like to see more thought given to their what I call frequency consequence acceptance curves. I think they look like very useful things. How do they compare with what we have in the U.S., and would they be useful for this last set of issues when we talked about needing acceptance criteria for limited core melt accidents and tritium release and other kinds of accidents that aren't full core melt.

That's kind of a set of issues. I don't see -- they're just things I'm interested in. I don't think they represent any shortcomings or anything. I don't want to give that impression.

So I think we'll hear more later, and I want to thank the staff once again and AECL people for a very informative discussion, even though we had to depart from the agenda a little bit. We'll have to make that up.

Yes, sir? Oh, that's a good question. If there are members of the public here that wish to make any comments, they're welcome to do so at this time.

Seeing none, I think at this time we will adjourn this meeting.

(Whereupon, at 6:06 p.m., the Advisory Committee meeting was adjourned.)