MEMBER POWERS: That's a surprise.

MR. KING: Yes. Confidence level certainly is an issue that, I think, is important in a number of these issues we are going to talk about, it is not just on this issue.

CHAIRMAN APOSTOLAKIS: But already, I mean, if you look at the goals it seems to me that we are saying that accident prevention is a thousand times more important than mitigation, because you are saying 10^{-4} -- can you really do that? That's more of a feasibility issue; you can put even more emphasis on that side. I don't know how high, but it's pretty high, you know? It seems to me it would be easier to do more on the other side to make sure that mitigation is better than 0.1.

MR. KING: I think we can do better. I mean, what is the right ratio--

CHAIRMAN APOSTOLAKIS: Well, in the sense of -- if there is such a thing as a severe accident, then we can contain it, find it, with the probability, the condition probability of better than .1. It is fairly more feasible than working the prevention side.

But this is clearly a defense in depth issue which means a matter of uncertainty.

MEMBER BONACA: Although by designing the passive features, you are enhancing prevention.

CHAIRMAN APOSTOLAKIS: Actually my biggest uncertainties are on that side. I mean, even the AP600 reported something like a few 10 to the minus 7 for core damage frequency. I think there are uncertainties there. I mean, I couldn't find them at the time, but if you put yourself light water reactor history 30 years ago, there are a lot of things have happened since then, that we could not imagine. So the 10 to the minus 7 number is more suspect in my mind --

MR. KING: You are raising an interesting argument in terms of should we consider what is the balance, should we put a ratio to somehow quantify the balance for prevention and mitigation?

MEMBER BONACA: You know, if I could, the safety goal policy I was thinking about, actually, if you think about additional reactors and remember, we talked about four or five hundred, really, you have a viability of the industry objective that goes beyond the safety goal policy. I mean, that is not adequate any more.

CHAIRMAN APOSTOLAKIS: Yes, that is the whole point.

MEMBER BONACA: It would be more of an

industry issue.

CHAIRMAN APOSTOLAKIS: That brings up an interesting point. You know, people have been complaining from the beginning -- you should never have goals in terms of rates, because you run into these issues at some point. Per-year, per-whatever.

It has worked very well for us because we haven't built any more plants, but now maybe it is time to reconsider.

MEMBER KRESS: I hope we don't get tied up on this balance issue, because our real goal is to ensure the risk is not an undue risk. Whether it's achieved by a really good design that stops it from occurring or maybe not so good a design but has an extremely good containment. I don't think we should get tied up on that.

I think we should be interested in the overall number, and you need to worry about the uncertainties.

MEMBER ROSEN: What happened to defense in depth?

MEMBER KRESS: It is coming up.

CHAIRMAN APOSTOLAKIS: There are two or three slides in the presentation --

MEMBER ROSEN: But if you are saying we

should just be worried about the final number --

MEMBER KRESS: You heard me say, yes, I'd worry about the uncertainty in the determination, and that ought to be a consideration in how you do it. But I really think that is the risk that you should be worried about.

MEMBER ROSEN: I agree.

MR. KING: And that is your ultimate measure. But I still, I would give a lot more weight to prevention than mitigation.

CHAIRMAN APOSTOLAKIS: We already do.

MR. KING: And we already do. But is that good enough, or do we want to go further? The only other thing I want to point out --

MEMBER POWERS: My point was, I wouldn't say well, I got ten to the minus 7, but we're going to stick a .01 containment on it, too. That's what I was arguing against, the other direction. I think if you got good enough at the prevention end, you shouldn't get tied up on this balance.

MR. KING: You could carry that to the extreme and say all you need is prevention, you don't need --

MEMBER KRESS: And that is what I'm saying, you very well could get by with that in regulatory specs. As long as the uncertainties are not killers.

MEMBER ROSEN: But we are talking about a new reactors where the uncertainties are going to be large.

MEMBER KRESS: I say we've got to give some estimate.

MR. KING: The other thing I want to point out on this slide is the bottom item, implications for future LWRs. Most of these key considerations, depending on how they -- yes, whatever the outcome is for non-light water reactors, I think is going to have a bearing on the future of light water reactors. So that has to be kept in mind when you go to the Commission with a recommendation.

Defense in depth, that is the second overarching issue. I think the Committee was right in its letter of last July, in saying that is an overarching issue, not a sub-issue under some of these other things.

Right now, we talk about defense in depth in a lot of places, but we really don't have a good definition of what it is. It is not mentioned in the regulations. We have the 1999 white paper on risk-informed performance-based regulation that has a definition, but it reads more like a goal.

MEMBER POWERS: In truth, it is mentioned in the regulations, 50.48, and appendix R, both mention explicitly defense in depth.

MR. KING: Okay; I'm going to look at those. I don't remember seeing that in there.

MEMBER POWERS: Those are all fire protection regulations. The basic principle is prevention, suppression, and mitigation of consequences. And if you are desperate to find a definition of defense in depth, that is not a bad one. If you are looking for this rationalist baloney about compensating for uncertainties that we can't quantify or even articulate, you know, you're in more desperate shape. But I don't want to prejudice you with that point of view. I'm totally open-minded on this subject.

(Laughter.)

CHAIRMAN APOSTOLAKIS: Of course, when they mention fire protection and suppression, you know there was some sort of uncertainty advanced in their minds, because they don't do that for all fires. For some of them, they say that they are so low probability -- you don't do it for every single fire --

MEMBER POWERS: I'm really struggling to remember any of that, in 5048, or --

CHAIRMAN APOSTOLAKIS: It may not say it, whether you do the evaluation.

MEMBER POWERS: But when you are talking about the way the analysis is going back, I mean, yes, it is true that the approach to defense in depth is borne of uncertainty. But they circumvent the need to quantify them because in the end they are saying, "What if I'm wrong about all the analyses, including my analyses for my uncertainties?"

CHAIRMAN APOSTOLAKIS: Now they were wrong in Appendix R, when they demanded that things be near the ceiling, 20 feet above -- but as long you have 20 feet separation horizontally, it was okay. And then there was a search that showed that if you had a fire there was a hot plume that drives the gases up, and then you have a hot gas layer. So whether you have twenty feet or thirty feet, it really doesn't matter; because all of them are immersed in the hot gas layer.

Nobody asked, "What if we're all wrong?" And they were. So you know, there are limitations to that rationalist approach, too. In the scenario approach, it came out. In the scenario approach they identified the hot gas layer, and they said, "Gee, the horizontal distances don't really matter." There are limitations to both approaches.

MEMBER POWERS: I think you see what the prejudice was in setting this up. Yes, they took a conventional wisdom at the time and argued about 20 feet based on the radiation argument and not on hot gas.

But, you see the defense in depth says, first of all, you prevent that fire from ever occurring. Second of all, if that fails, you try to detect and suppress that fire. Now, the 20 feet was in fact and implementation of mitigating consequences.

CHAIRMAN APOSTOLAKIS: Well, but it could be prevented, depends on what you are trying to prevent. But you are saying prevention refers to the fire itself. But if you say "I'm trying to prevent core damage, then failed is a --

MEMBER POWERS: It is preventing damage to safety-related equipment, was the objective in that 24th thing there. But I mean that is compounding a lot of what fails on top of each other before you get there.

CHAIRMAN APOSTOLAKIS: The point I'm making is that just as you can criticize the argument that you should quantify your uncertainties and be rationalist, you can criticize the argument, I will be asking myself, "What if I am wrong?" because we may not ask that question at some crucial point, because you don't know. You don't ask, "what if I'm wrong" every single step of the way.

So maybe theoretically you can quantify the uncertainties like what the press wants, but theoretically, also, you can ask you know, "What if I'm wrong." But in both cases there are holes. That is why it should be risk-informed.

MEMBER KRESS: I think we ought to move on.

MEMBER POWERS: My only point was to say that it's not -- in the regulations, I mean, it is true in the sense that they don't speak of defense in depth for the bulk of the regulations, but there is an explicit mention defense in depth in connection with fire protection. And it is not a half-bad definition of a structuralist view toward defense in depth.

MR. KING: I will go look at that. There have been people that have tried to define defense in depth. IAEA and INSC are two of the most prominent in my mind, where they defined five levels that include design elements, as well as programmatic elements in fairly multi-paged documents that issued, that put those descriptions out.

I saw three options in trying to go to the Commission on this issue. One is we could just continue or previous practice of doing case by case reviews, and making judgements that defense in depth is incorporated into the design before we license it.

You know, that is a potential for some inconsistency, and it certainly has a lack of transparency in how those decisions were made, or has a potential for a lack of transparency.

We can try to develop a description or a policy statement on defense in depth that the Commission could issue that could try and define what those elements are.

We could, maybe, view it as trying to implement the definition that is in the risk informed performance based white paper, which I view more as a goal. And it could have structural elements, rational elements, it could have quantification on it, it could have any level of detail you want.

MEMBER POWERS: It was the case by case process of this committee to conduct a fairly thorough investigation of what it thought about defense in depth, and why the ability to do quantitative risk assessment.

And the problem we saw was that defense in depth was being used to undermine the use of risk information in the regulatory process, because it was always trumped by eliminating defense in depth over the years.

And so I guess I would look, my suggestion to you is don't present that, just that case by case thing, but you might want to consider another option, which says that in those cases where, at a fairly high level in the system, and not in the areas where there is quantitative risk analysis is actually pretty good for evaluating the systems, and what not.

In other words, I think there is more to this case by case than just looking at each subsystem, and what not. Because that is denying that you have this capability to look at a plant in an overall sense.

And I don't think you want to do that at this point.

CHAIRMAN APOSTOLAKIS: This is the so-called pragmatic approach in our paper. And I thought, I'm a little surprised that you don't mention option 3 here, because those guys have done a lot of thinking about it. And they did try to implement, as I recall, this pragmatic approach.

Because, you know, in our paper, between rationalist and structuralist we figure that neither one is really perfect, and you need this combination that Dana just described.

And having defense in depth of the highest level, without even questioning it, is a good thing to do with international mitigation. So I would suggest that we look at the option 3 documents, because they have done thinking about this.

MR. KING: I've looked at the option 3 documents and the discussion in REG guide 1174, I think that philosophy could be imbedded in that second option, if that is the way we decide to go.

CHAIRMAN APOSTOLAKIS: That is right.

MEMBER KRESS: But it raises the question, and I'm not the right person to raise this question, actually the Chairman is the one that should raise the question, but I will encourage him to raise it.

You said defense in depth up here, and not defense in depth philosophy. And maybe that distinction that we tried desperately to draw in 1.174 ultimately failing miserably, but that may be the way to ask the question, rather than casting it as strictly defense in depth.

CHAIRMAN APOSTOLAKIS: I agree.

MEMBER KRESS: I'm the ultra-rationalist in the crowd, and in defense in depth. So let me make a comment.

I think if you go to the option 3 concept you're stuck in this quagmire of prevention and mitigation, along with, perhaps, looking at individual sequence contributions, and not letting any one of them be too much.

But I think that is a problem, and what I think defense in depth ought to be, in the rationalist sense is, let's presume we have good PR risk assessments with uncertainty, and have goals on risk, not goals, you have acceptance criteria on risk, that are appropriate for the whole range of regulatory objectives.

And defense in depth ought to be focused on how these goals, how this thing is met. Is it met by a single element of design, or is it met by redundant systems, and is it met by reliabilities that are highly uncertain, or --

I think you ought to think along those lines for defense in depth. And then, maybe, you can factor into that the uncertainties associated with each element of how it is achieved.

And then say, well, there is too much

uncertainty here, we have to do something.

MEMBER BONACA: But I think, though, you can combine disciplines with what Dana has been saying, by simply calling it defense in depth philosophy.

In other words, you are pointing out that you have to worry about conventional mitigation. At the same time you are saying look at the uncertainties.

MEMBER KRESS: I was arguing against defense in depth philosophy being prevention --

CHAIRMAN APOSTOLAKIS: Well, I think it would be useful to give guidance how to do what --

MEMBER ROSEN: For example, I disagree, I don't like the inside approach, I can tell you that. Because by trying to define what it is, it really weakens the philosophy itself, that has been implemented in so many different forms, so many different judgements and areas, that -- and now if I can implement it with insights from PRA, clearly, then I can have a better defense in depth.

MEMBER KRESS: I really think if you look at the white paper definition, it is pretty good, it doesn't say prevention and mitigation, it says some -- yes, it doesn't say multiple barriers, it is multiple compensation.

And, you know, I think you can build a defense in depth on that.

MR. KING: I don't even think it says multiple. I will read it. It says: Defense in depth is an element of NRC safety philosophy. It employs successive compensatory measures to prevent accidents and mitigate damage if an accident or naturally caused event occurred with a nuclear facility.

Defense in depth philosophy ensures that safety will not be wholly dependent on any single element of the design, construction, maintenance, or operation of the nuclear facility.

The net effect of incorporating defense in depth in the design, construction, maintenance, and operation is that the facility or system in question tends to be more tolerant of failures and external challenges.

That is it.

MEMBER KRESS: That is a pretty good definition. And it doesn't really say anything about the balance between preventive and mitigation.

MR. KING: To me it says that is the goal of defense in depth, I have no quarrel with that. But if I was the designer I'm not sure how that would help me, other than, you know, you want to make sure you don't put --

MEMBER POWERS: Explain to me why it wouldn't help you. I mean, it seems to me that it is pretty explicit, it is not going to be dependent on the single element. So that tells me that I can't be absolutely dependent on passive natural circulation to keep my core cool.

MEMBER KRESS: And does it also tell you you can't be absolutely dependent on the fuel pellet?

MR. KING: Yes.

MEMBER BONACA: Ideally I think the rationalist approach makes sense.

MEMBER KRESS: Frankly I don't think we are well enough in technology, PRA technology and uncertainty to really implement the --

MEMBER BONACA: That is exactly the problem.

MEMBER ROSEN: Well, even though I think PRA is near perfect now I would still say there is still the question of what we don't know, there is this incompleteness uncertainty. Which by its very nature says, if you don't know it, you don't know it.

So you don't know how to quantify it. So because of that, even though of the near perfection in some PRAs, you still have to --

CHAIRMAN APOSTOLAKIS: This committee --

MEMBER ROSEN: -- back those new --

CHAIRMAN APOSTOLAKIS: This committee asks Joe to tell him what she doesn't know.

(Laughter.)

MEMBER ROSEN: I was thinking that Joe would tell us. He would be the only one who could meet on non-negotiable demands.

CHAIRMAN APOSTOLAKIS: Perhaps we have exhausted the --

MR. KING: Let me just talk about this third option. The difference I see between the second option, that is one where you would specify certain structuralist elements in defense in depth.

And you can have some rationalist elements in there, as well. But the third option, to me, is strictly a process that would sort of be a way -- describe a way to treat uncertainties, if that is how you view defense in depth, it would not have any structuralist elements in it.

So that is the difference between the second and the third. The key factors that affect the recommendation on this, certainly the scope of defense in depth, what we've been talking about all along.

Structuralist versus rationalists, should it include things, programmatic type things like QA, and EQ trains.

CHAIRMAN APOSTOLAKIS: But the reason why you make this distinction is the uncertainty, because the uncertainties have got the performance of physical elements, are smaller in general, than the uncertainties regarding the problems.

So this is, really, saying -- I would rather see something physical that I can touch, as a barrier, than have somebody tell me, make sure -- because that is more uncertain.

MR. KING: That is why we make the distinction.

CHAIRMAN APOSTOLAKIS: Because we have faced that before with, you know, reduce the risks. So some people say, okay, we will have better programs to make sure that the transient fuel is not coming to the room. And people saying, gee, we are already supposed to have those, I don't believe that.

Then somebody else says, well, you have these two trains, why don't we erect a barrier between them? And everybody goes, yes. The uncertainty now went down, this is physical.

MR. KING: But the counter argument to

that is you can put a barrier in, but if that barrier is poorly designed, and poorly constructed, and poorly maintained, what good is it?

CHAIRMAN APOSTOLAKIS: But still I think that the main difference between these, where you say versus, I think, is the level of confidence that we have, that one will work versus the other.

MEMBER KRESS: Well, I think there is also a difference, there, and some things can be handled by PRA, and also deterministic analysis, where others can't. Like QA, inspection, passive, all those are not well suited for PRA.

So you maybe just say, well, we are going to require QA, just like we now do, we are going to, for safety systems, we are going to require training, we are going to require inspection, testing, all those things are not quantified, we just require them.

MR. KING: But don't call them defense in depth, you mean?

MEMBER KRESS: Well, I would call them defense in depth. I would tell them, I would --

MR. KING: There is probably a whole set of those things, you call them good engineering practices, or something.

MEMBER KRESS: Yes, maybe do that.

CHAIRMAN APOSTOLAKIS: I think the latest insert to defense in depth -- good engineering practices is part of defense in depth. That is why I think it is important to say philosophy, rather than just defense in depth.

MEMBER KRESS: And I think the issue of redundancy and diversity is definitely defense in depth. And I would say there is some things where you ought to require redundancy.

Like, for instance, I think there is key safety functions that are reactor design independent. Like being able to scram the reactor.

MR. KING: Two independent shut down systems?

MEMBER KRESS: Two independent shut down systems.

MR. KING: I don't care what your PRA says, it --

MEMBER KRESS: -- like being able to have long term decay heat removal. You know, I think there are things like that that you can just say, redundancy and diversity is defense in depth, and we will require it.

Now, that begs the question of how reliable each one should be, and that is another issue.

MR. KING: You are arguing for putting together some sort of high level definition of defense in depth that says, these are the features that future plant has to have?

MEMBER KRESS: Yes, that would be part of my definition.

MEMBER BONACA: By the way, the first bullet on programmatic, it is -- I mean, try to replace an area, talk about the actuary. And that really has a foundation into a lot of operating experience.

MR. KING: If we do go and try and define defense in depth what is the approach we should take? Realize reactor oversight process cornerstones are one structure you could follow, if you want to try and write something down.

That brings in, potentially, things like security, security an element of defense in depth.

MEMBER ROSEN: It should be. Challenges from internal and external threats to the safety systems in the plant.

MR. KING: If you read the definition in the white paper it talks about external threats, that is true.

If you would write, try and develop such a definition of defense in depth, it could form the foundation for future licensing framework, the thing that Mary and her folks are going to be working on, might provide a nice skeleton, a structure from which to step forward and try and write that.

It could also be useful in other areas, like reg analysis guidelines, which don't say much about defense in depth. And you factor that into your reg analysis decisions.

Again, there is implications for future light water reactors, and there is the issue of coordination with non-reactor activities. You know, NMSS struggles with the issue of defense in depth, too, and you have to consider, do we want to write something that is strictly for reactors, or do we want to write something broader for the Agency?

MEMBER KRESS: I don't think we have anything else on the agenda, so we can -- I think this is an important issue, so we shouldn't give it short shrift.

CHAIRMAN APOSTOLAKIS: So you will not complain if we stay here until 7 o'clock? Tom, you have an open house here.

MR. KING: I will stop when you want me to stop.

CHAIRMAN APOSTOLAKIS: Let's take a break now for 11 minutes.

(Whereupon, the above-entitled matter went off the record at 3:45 p.m. and went back on the record at 3:57 p.m.)

CHAIRMAN APOSTOLAKIS: Let's go on, Tom.

MR. KING: We will move on to the third issue, which is called international codes and standards. To me the real issue here is, when you look at the future of design efforts, most of those are international efforts, in terms of consortium of organizations.

And the question is, and they are using international codes and standards in a number of them, in their design work. Should we actively get involved in looking at endorsing and using international codes and standards?

MEMBER KRESS: Things like ISO and --

MR. KING: Yes, those kinds of things.

MEMBER WALLIS: I was thinking if you look at current U.S. policy, --

MR. KING: Current U.S. policy is we should, yes.

CHAIRMAN APOSTOLAKIS: We should --

MEMBER POWERS: There is a lot of pressure to go to ISO2000.

MR. KING: And trust me, if you read NRC management directive 6.5, which is titled: NRC Participation in the Development and Use of Consensus Standards, it says that we should, as a first step, see if there are consensus standards out there were used before we develop our own standard.

And it also says it makes no distinction between domestic and international standards. So to me the management directive is pretty clear, we ought to be doing that.

It takes resources to do that, it takes a commitment --

CHAIRMAN APOSTOLAKIS: There is a difference, though, between what you say now, and what you said in the previous slide. Standards, okay, you can look at them, it is international, maybe carry some weight.

But you say reviewing those existing codes and standards were never practical. And you are going to go now and get the various codes that the European Union has developed, and France, and Germany, separately, and try to, without them coming to you?

Because typically in the United States

that is what happens, right? The Licensee comes to us first proposes something.

MR. KING: That is option one. We could sit back and when an application comes in, or pre-application, we can see, okay, what international standards are they using, and then we get involved in reviewing them, and endorsing them, if it makes sense to do that.

That is one way to do it.

CHAIRMAN APOSTOLAKIS: -- major undertaking to do that? I mean, reviewing the thermohydraulic code is a --

MR. KING: No, I'm not talking about thermohydraulic codes, I'm talking about things like the ASME Board, and pressure vessel code, ISO9000, design codes and safety standards, basically is what I'm talking about, not analytical codes.

CHAIRMAN APOSTOLAKIS: That makes more sense.

MR. KING: Again, the first option is just sit back and wait. Somebody comes in and says, we are using this, we will look at it.

MEMBER RANSOM: I have a question. I never really heard much in nuclear safety with the concept of fail safe, fail operational type design philosophies.

Is there a reason for that, or is that just inherent in what people do? These are concepts that were used in the aerospace program, and they were very successful. It enters into the basic design.

CHAIRMAN APOSTOLAKIS: We are trying to prevent fail dangers, we don't care about fail safe. That is the utility's job.

MEMBER RANSOM: That is an interesting concept.

CHAIRMAN APOSTOLAKIS: Because that creates unnecessary shutdowns.

MEMBER RANSOM: Because, for example, if you put a containment on something, there is nowhere for it to fail safe. It fails -- so maybe a containment isn't good for that.

MR. KING: It could fail open, you know, that is not fail safe. You know, your isolation valves don't close, it doesn't fail like a bomb, it just has a hole in it.

CHAIRMAN APOSTOLAKIS: And we really worry about that.

MEMBER RANSOM: But some of these recent designs, like the gravity driven cooling systems, you know, basically if they fail, they simply dump more water in the core. So that is kind of a fail safe concept.

And it can be carried further. But I was just curious.

CHAIRMAN APOSTOLAKIS: I think it is the terminology that is not being used, but the concept is. But the emphasis is always on dangerous failures, by the nature of the agency. We are not really designed the articles for operation, we make sure they are safe. It is somebody else's job to make sure that there are --

MEMBER ROSEN: The people who do design it can run it in a safe fashion.

MEMBER RANSOM: However, by specifying defense in depth, you know, in effect you are telling people how they have to be designed.

CHAIRMAN APOSTOLAKIS: To be safe.

MEMBER RANSOM: Not specifically, but at least as far as the overarching concepts are concerned, in order to be safe or licensed.

MR. KING: It should have certain features in it, for example. Maybe I can talk about the options.

Like I said, the first one is we sit and wait, we review what we are asked to review. The second one is to go out and try to take a look at what is out there, in terms of existing codes and standards, and anticipate maybe this is something we can use.

Now, when it says whenever practical, I really had non-LWRs in mind, in the sense that you take HTGRs, we don't have reg guides, or design standards for HTGRs. But perhaps maybe the Germans, or the Japanese, or somebody do.

Maybe it would make sense to go target those areas where we don't really have an infrastructure, and go do that. The same thing on the third option, which is more than review what is out there, we would actually participate in the development of what is needed.

Because there are development efforts under way in some of these areas. Should we jump in and participate in those?

And then the fourth one is, going even further, and that is trying to harmonize with other regulatory bodies in terms of what the requirements ought to be, at least the standards that should be used.

So that is sort of the range of options. As I said, the management directive 6.5 is pretty clear that we ought to try and use international, or domestic and international standards wherever we can.

As I said, that does, if we are going to do that, that does require resources, and commitment of some stability. You can't just jump in and out of that kind of thing.

If we did that it might have some public confidence type aspects to it. We could say, hey, we are using international standards, you know, all the other major countries are using the same standards.

To me that might have some influence on public confidence. And I think if we did that it could be useful, an efficient and effective way of beefing up our infrastructure where we don't have it, particularly in these non-LWRs.

So those are the considerations for dealing with that.

MEMBER WALLIS: Well, if you look at our reaction to environmental standards world-wide, or something, we always seem to say we do whatever we like. And I think that is what we do here.

If the standards, internationally, get too strict, we will withdraw.

MR. KING: That is always a possibility. But when I read the management directive it is pretty clear to me that we are to get engaged in that kind of thing.

MEMBER KRESS: Well, I think you are likely to come in to some foreign reactors with designed to certain code and standards, and you will have to know what those are, to see whether they are acceptable to you. So I think it is more --

MEMBER WALLIS: Well, you don't mean something like a CDF or --

MEMBER KRESS: No, that is --

CHAIRMAN APOSTOLAKIS: Well, in fact, this morning, because now from ACL, suggested that maybe since the ACR 700 is being reviewed by the Canadian authorities, and possibly by the UK authorities, that the NRC may want to take advantage of that, and not repeat the work.

So some of the foreign designers are, in fact, urging us to start doing that. So hopefully we will accelerate the process.

MEMBER KRESS: Yes, and it might even go further, for example, if you look at the UK acceptance criteria for things like safety, they are probably different than ours. But you might be able to look at them and say, okay, if they meet these, they very well meet ours also, or something like this.

So it would be kind of -- for that case, it might be well worth your while to check and see what they are doing.

MEMBER ROSEN: Well, as a minimum, if they are licensing, for instance, the ACR700 in UK, one could clearly read the British licensing documents and see whether or not they go to reducing the workload on the Staff, simply by saying, okay, these are reasonable analysis and we will accept them, use them in part for the basis of our work.

MEMBER KRESS: So I think we are supporting some sort of activity.

MR. KING: Again, the paper in December is not going to go to the Commission and say, well, we ought to work on these ten standards, or whatever. It is more to get the direction to then go explore, work out the deals.

Fourth issue, events, what we call event selection.

MEMBER KRESS: Design basis events?

MR. KING: And events for emergency planning purposes. The MHTGR 10, 15 years, came in with a scheme that defined events using some probabilistic criteria, and then depending on the event category there were acceptance criteria.

Those related acceptance criteria that went along with it. The pebble bed folks pretty much picked up that same concept, and I understand that GTMHR is doing the same thing.

It is pretty much a probabilistic-based approach. We had looked at that, back in the MHTGR days, and went to the Commission with the position, a recommendation on how to deal with that.

There was a SECY paper issued back in 1993, '93 or '92, and the Commission issued an SRM. And the Commission basically back then said, let's use a deterministic approach for the MHTGR, but supplement it with PRA insights.

Which, to me, basically said let's pick our design basis accidents deterministically, then look at the PRA and see if there is anything else we want to add in there, because the PRA --

MEMBER POWERS: Why do you have to have a design basis accident?

MR. KING: Why do you have to have one?

MEMBER POWERS: Yes.

MR. KING: What are you going to design the plant for? At some point --

MEMBER POWERS: I'm not going to design a plant, are you?

MR. KING: I'm not going to design the plant, but somebody is going to design the plant.

MEMBER POWERS: That is fine, let them design it. What you are concerned about is what the risk is to the public. You are not concerned, at all, about accidents that, by design, have extraordinarily low probabilities.

You are worried about the accidents that will occur, that have a reasonable probability. You may find those out with a PRA approach.

MR. KING: How do you decide, as a regulator, where you draw the line? I want them to consider these, and I don't want them to consider those? At some points you are going to have to --

MEMBER POWERS: I want them to consider anything that can happen.

MR. KING: Anything that can happen, but?

CHAIRMAN APOSTOLAKIS: Let me phrase it in a different way, because there is a disagreement here.

After I do my PRA, and I do everything Dana wants, then I say, a design that results in this risk to the public health and safety is acceptable. It seems to me the next charge to us is to make sure that the review process of the application is efficient.

So after I do the PRA and identify these things, I'm saying now, now designer, if you do this, and this, and this, and that, then we will review these elements, and then you have met the goals.

In other words, the design basis envelope here will be really a means to facilitate the review, which is what you said, what do you design for? I think it is the same question put in a different way.

But it will not be a deterministic approach where you define the envelope, and then you postulate that anything else that may happen is covered by the envelope, because you are doing your PRA first.

You identify the sequences, and so on, and then after everything is settled, you say, now I need to define a number of events that I will call design basis. So that when they come to me I will tell my people what to look for.

MEMBER ROSEN: What you do is you tell the designer that below a certain frequency we are going to have this kind of treatment for your systems, and above this frequency there will be another kind. Or maybe there will be three, I'm not sure.

And then he goes and designs the plant and does the calculation, I have this design, I have too much stuff in the high frequency category. I want to do something a little different so that I can get less regulatory oversight, so I'm going to put some more barriers here, or some more robustness here or there.

So it is -- the PRA becomes a design tool, it could be used in lots, and lots of different ways. And then the regulator comes, when he is all done, then the regulator comes in and does exactly what he told the designer ahead of time.

He verifies, of course, that the PRA is adequate and correct, and then he applies a regulatory controls to the things that, as Dana said, can happen and have consequences. In other words, have frequency that are reasonably high, and have some consequences.

By the way, that is risk --

MEMBER KRESS: Let's look at this in another point of view. You are allowed to have these reactors come to you, already with a conceptual, pretty good conceptual design. And they all have a good idea of what accidents are likely to happen, events, and how they can go.

And what they are going to say to you is, hey, I want to consider these in my design basis, pick some of them and say, we are going to try to conform to your chapter 15 with these.

And you are going to be faced, then, with saying are those the right ones for the tubes, and how are we going to choose them, and how are we going to decide whether those are the right design basis accidents?

And they might have picked them on some basis of frequency like the PBMR did. And I think your only option here is to start and say, well our purpose is just what Dana said, we want to have a design that has acceptable risk, and has maybe some acceptable depths in terms of whatever that means.

But we would like to have design basis accident because it gives them something to design to, and determines their design licensing basis. And it is like George said, it facilitates the review for any future plant, and things of that nature.

So what I would suggest you have to do is you say, all right, we will, tentatively, we will let you use those that you choose for the design basis events. But after you give me a design that is based on those, you are also going to give me a PRA.

And you are going to show me that you meet my risk acceptance criteria. But you have to have these risk acceptance criteria, and they can't just be CDF and --

MEMBER WALLIS: I don't agree with that.

MEMBER KRESS: And then you tell them, if you don't meet my criteria, you have to include something else in the design basis.

MEMBER WALLIS: I don't agree with that for this reason. It is a perfectly logical way to go until you start saying, now those are your design basis events. To me that says that is basing a whole, something foreign onto this analysis.

You've got an analysis that ranks all the sequences, and all the events. And now to say, well these are design basis doesn't make any sense. It is anachronistic, it is going back to the way that we used to do things, and trying to paste it on a new --

CHAIRMAN APOSTOLAKIS: No, that is not the way we used to do things. We selected the design basis events first, and that makes a big difference, that makes a huge difference.

Let's not forget that there will be a number of reactors, we hope, applications of a particular type. Let's say the ACR700. After you have gone through your PRA, and you have reviewed it exhaustively with the Staff and so on, why is it inconceivable that the licensee and the agency say, in order now to achieve these goals that you and Dana have identified, make sure that the risk is so low, and so on, you have to do A, B, C, D.

And the benefit of that is that you are removing the burden of confirming the PRA and working in uncertainty, from the lower level engineers who run the reviews.

Otherwise you are going to have interminable discussions regarding the validity of the PRA, what do we do here and there. That will be done, once and for all, by senior staff, and the Applicant, and then they agree that this will be the design envelope for this plant.

And if you do these deterministic things you have met the probabilistic goal.

MEMBER BONACA: At some point there will have to be an agreement between the regulator and the designer of which transients, or whatever are going to be considered, and -- because it is very unlikely that all the consequences are -- or whatever.

CHAIRMAN APOSTOLAKIS: It facilitates the review.

MEMBER ROSEN: Well, if you put all these sequences and events down, and --

MEMBER BONACA: I'm not going to call it design basis, so I --

MEMBER ROSEN: -- down and, say, CFR order, or most -- but at some point, I agree, that someone draws a line that says, above these you have to consider them, below these you don't.

But there is an alternative to even that. If someone draws a line and says above this you have to apply all of the standards in 10CFR, whatever, below this line you can do it selectively, or you can do it in some reduced or graded manner.

So at no point in that discussion do you say design basis.

MEMBER KRESS: You guys are presupposing a whole new regulatory system. I think these things are going to have fit into what we have. And what we have is design basis events, we have conservative specifications on how you meet them.

We have figures of merit they have to meet. And I think they are going to have to fit into that.

MEMBER ROSEN: You are right, I'm presupposing a different way of doing business.

MEMBER KRESS: Okay, but I think when we worry about recent certifications that are going to come in, we are going to have to fit them into what we have.

And we are going to have to choose design basis events, and they are going to have to be calculated with thermohydraulic codes, and figures of merit --

MEMBER ROSEN: Now, I ask Tom, is that correct? Is it true that we will have to pick design basis events? Because if so there is no point discussing this.

MR. KING: The options I'm talking about are, do we want to revisit the Commission decision of ten years ago that said for MHTGR pick the events that the plant is to be designed for in a deterministic basis, look at the PRA and see if you missed anything, and fill in the gaps.

What I'm suggesting is, going back to the Commission, and if we agree that doesn't make sense any more, because we are more of a risk informed agency, maybe we want to start with the PRA, and define some probabilistic criteria, somehow we have to figure out how we are going to take that PRA and give guidance to a designer so that he can go do the design.

MEMBER ROSEN: I think what you said is exactly right. You have three options up there. The first one is the way we are doing business now in the

-- we are using deterministic approach supplemented by PRA, that is what south Texas did in the risk informed world.

The third option is what I think I'm arguing for, and I want to speak to Dana, but I think that is what I hear from him, too. Is to use a probabilistic approach, and you supplement it with engineering judgement.

CHAIRMAN APOSTOLAKIS: But at some point you have to define some deterministic criteria that will guarantee that the probabilistic --

MEMBER POWERS: I think we are not -- from a point of view I think we are very consistent. What you are talking about is the next step. It is having done the PRA, and said gee, it looks like you are getting very sensitive station blackout.

So when you build your plant you want to make sure that your diesel generators are in good shape, okay? And whatever it takes to do that. And I don't think I have any objections to that.

CHAIRMAN APOSTOLAKIS: And the form of the design basis accident doesn't have to be the same as it is now, because I think that bothers some people. We can formulate them in a different way.

MEMBER POWERS: The fundamental problem I have is that we spent an entire day yesterday talking about behavior under design basis accident conditions. And those accidents pose very, very little risk.

CHAIRMAN APOSTOLAKIS: I agree.

MEMBER POWERS: And we are spending a huge amount of money on it.

CHAIRMAN APOSTOLAKIS: I want to sensitize the committee to the issue of doing something in relatively large scale. And an analogy is -- the most successful one is, this thing that the Supreme Court has asked police officers to read the rights to a suspect.

The objective is to make sure that the guy knows his rights. And that is all that the Supreme Court says. If you don't read his rights the guy is free, even if he is guilty.

That is a deterministic criteria. Because the police cannot go and say, but he is a lawyer, he knows his rights. The Court says, no, you didn't read them, he walks.

Why do they say that? Because you apply this principle to a country of 260 million. You can't rely on every police officer, everywhere, to make a judgement whether the guy knows his rights.

So they impose a strict deterministic

criteria. And it seems to me that if you are planning to license more than one reactor, you have to have deterministic criteria. You can't expect all these people who get involved in the licensing process to make judgements whether the probabilities are low, and so on.

That judgment has to be made once and for all by a select group of people that says, yes, for this type of reactor if you meet these criteria, then the risks are low.

MEMBER ROSEN: We are not as far apart as we may have seemed. Because I'm arguing exactly for that, using the PRA approach -- use the PRA approach, have a select group of people in the licensing process make that determination, codify it in a way that everybody in the design group, and the maintenance group, and the construction group can understand it.

You don't -- in South Texas they didn't give out the PRA to everybody and say, go out there and get your special treatment. The derivative of the PRA is something that they use every day.

CHAIRMAN APOSTOLAKIS: So I think we are almost in agreement. The more we talk, the more we agree.

MEMBER BONACA: I had noticed, about ten

minutes ago, that you guys were all in agreement.

MEMBER KRESS: We are all in agreement except one of us.

MEMBER ROSEN: And you know who that one is.

CHAIRMAN APOSTOLAKIS: Let's move on.

MR. KING: All right. If you take the probabilistic approach it can apply to more than event selection. It can apply to classification equipment, it can replace the single failure criteria. These are things that are being looked at under risk informing option 3, to various aspects.

And it would seem reasonable to look at them under a risk informed approach to non-light water reactor future plant licensing. So those are caught up in this issue, as well.

Certainly the more you use PRA you get into issues of PRA quality, completeness, document control, perhaps bringing the PRA into the licensing basis. And you have to deal with issues of level of confidence.

MEMBER POWERS: That level of confidence is the one that continues to irk. And I mean maybe diverting us from the main topic here. But we continue to see people come in and present probabilistic assessments for all point values.

And we absolutely cannot judge level of confidence. I have not seen a PRA yet that we can judge level of confidence on.

Now, I'm not even sure how you go about doing it.

MR. KING: Because it is incomplete, you mean?

MEMBER POWERS: No, let's -- if we stipulate that whatever PRA they have for operational events is complete, just for the sake of argument, we don't ever get anything that allows us to judge the level of confidence on that.

People come in and say we've gone through the peer review process and so it is good. I mean, it is a good quality. But they give you a number, and you just have no idea what to do with that number, because you don't know whether it is a mean, a median, or an accident, or what.

Because there is nothing to judge level of confidence from.

MEMBER ROSEN: But you can force that. If you just tell someone to go back home and come back with that, they will. They are getting away with not telling you that number. But if forced they can give you the number, they just don't want to.

Because, typically, it is going to be in order of magnitude around the value they gave you.

MEMBER POWERS: On this pressurized thermal shock we were beating the people over the head over what they meant by their distribution. It turns out computer code calculates out exactly what I was after. All they had to do is write it down.

MEMBER ROSEN: That is right, and George knows that, and I know that. The only question is we haven't forced them to give you that. It is embarrassing, because when you come back and I tell you that the numbers weren't even -- I have to tell you it is really 5 --

(Off the record discussion.)

MEMBER ROSEN: If somebody tells me less than that I would be interest in having a look at how they got --

MEMBER SIEBER: I think your confidence in the answer for an advanced reactor -- so it is going to be hard to apply the principles where you rely on the PRA first, without putting some deterministic overlay on top.

MEMBER ROSEN: You are absolutely right. Which means that once you have that understanding, then you have to say, okay, where does the defense in depth go to help you with --

MEMBER SIEBER: If you don't have a good PRA then you are picking up the deterministic criteria that is pretty arbitrary, too.

MEMBER WALLIS: It is going to be arbitrary --

MEMBER SIEBER: Just because it is a solid naught, because it is a number doesn't mean that it is better. On the other hand, you know, you could come up with a -- because the numbers are really great from a PRA standpoint, and you can conclude you don't need a containment.

So there is an element in defense in depth that disappears. It is not engineering judgement --

MEMBER WALLIS: Not if the structuralists have their way.

MEMBER SIEBER: Of course you put the containment there.

CHAIRMAN APOSTOLAKIS: I even asked that question at the PSA conference this week. A fellow stood up and asked the NRC folks present, on what basis did you decide to force the AP600 design when the PRA results show that we don't need it? And the answer was defense in depth.

MEMBER POWERS: But that was an erroneous answer.

CHAIRMAN APOSTOLAKIS: Why?

MEMBER POWERS: It was a question of confidence.

CHAIRMAN APOSTOLAKIS: -- defense in depth? I asked myself, what if I'm wrong?

MR. KING: Fifth issue, source term. Back when we were looking at the MHTGR Dave proposed using a scenario specific source term, not taking a source term representative of a core melt, or a sever core damage accident, and using that for the purposes of citing under chapter 15 analysis.

The Commission accepted that position back in their SRN of July of '93, basically said, that is okay provided we have sufficient knowledge of the behavior of the plant, and the behavior of the fuel.

Which implied that there had to be a lot of work to make sure we had the confidence to be able to do that. That is different than what Fort St. Veraine did. Fort St. Veraine basically assumed an uncontrolled core heat-up, and had, other than the timing, had releases similar to the TIB source term.

Fort St. Veraine didn't have passive heat removal, and so forth, it needed active systems.

Really we are revisiting this issue with the Commission to see if they still accept that position.

To me the fundamental policy shift is one of -- it really departs from past practice where we've used source term representative of severe core damage accident for licensing, including Fort St. Veraine.

And maybe that is -- should that be considered an element of defense in depth? You will assume severe core damage for licensing purposes, for citing purposes. That is a question, not a conclusion.

Certainly puts more burden on understanding plant behavior. Follow some extensive research to have the confidence, and maybe some extensive monitoring of the plant, and the fuel fabrication process over the life of the plant, to make sure you are getting the quality you need.

So it has some hooks in it, it is not a quick and easy solution to do that.

MEMBER KRESS: I think this question is tied to the previous one about event selection. And in the current system all we do is we select these design basis events, and specify how they are to be dealt with, to some extent.

And one of the ways that they are dealt

with is the source term. You assume there is a pretty severe source term. And the reason we do that, in my mind, is that by doing it you are putting enough conservatism in your calculations, for these design basis events, that you render the plant at acceptable risk level.

And the only way you know that it is rendered an acceptable risk level is you go back and do a PRA with scenario-specific source terms. So we use, we actually should be using both, in my mind.

If you are going to go to the design basis accident concept, I don't care what you use for the source term, as long as what you use renders an acceptable risk level, and acceptable confidence level.

So, you know, you could use a scenario specific ones, or you could use a bounding one, and might treat them differently in terms of how you specify the design basis.

In my mind the way we've just selected design basis events, with the single failure criteria, the specified source terms, and with the figures of merit that they have to meet, like peak clad temperature, and this sort of -- not all those have source terms in them.

In fact the source term only shows up in few of them like that. I guess it shows up in the LOCA, reactivity and source events, and it shows up in containment.

MR. KING: You know what we have now for light water reactor, we have a plant that has ECCS systems to prevent the core from melting, yet we assume the core melts anyway, when we calculate containment performance. So we have conservatism on top of conservatism.

MEMBER KRESS: I think my point is that in order to arrive at bounding source term you have to kind of know what scenario specific source terms are in a given reactor design. And the two are tied together, you can't just say option one is bounding, and option two is scenario specific. You have to have both of them, and you use one -- it is all right to use the bounding one if you use the scenario specific ones to decide what your bounding one is.

And the final result is you have to meet some sort of risk acceptance criteria at a particular confidence level.

MEMBER SIEBER: The TIB source term is not necessarily bound --

MEMBER KRESS: Well, bounding in the sense that if you use it along with a specified design basis accidents, you render the plant to an acceptable confidence.

MEMBER SIEBER: That is right, but it relies on --

MEMBER KRESS: So it is bounding, in essence.

MEMBER SIEBER: -- water and partitioning, and all that.

MEMBER KRESS: That is not all you can get out. It serves the purpose that you want.

MEMBER SIEBER: For light water reactors.

MEMBER KRESS: And I think that is --

MEMBER SIEBER: On the other hand, a different kind of fuel is going to have a different source term, it is usually bigger, right?

MR. KING: This issue will certainly drive the containment issue, depending on which way this goes, it is going to drive the containment issue. That is why the designers are interested in it.

They would like to not have to impose this source term representative of a severe core damage because they say our plant isn't going to have severe core damage, or it is such a low probability, we don't need to worry about it. And they want us to buy into that.

MEMBER KRESS: Well, my basic philosophy would be, if you are going to use a design basis concept, and a source term along with it, choose the one that lets you have an acceptable risk. You have to do both, risk and the -- and, you know, it may very well be that an accident involving air ingression in a PBMR leaves you a huge source term, but it is risk that might still be acceptable if you use a real small source term in your design, and your design accommodates in terms of frequency, for example.

But it doesn't have to use that source term.

MEMBER SIEBER: It doesn't have to. But if you are engineering *** there isn't all that data out there, the correlation --

MR. KING: To me it gets back to it is a fundamental question of defense in depth. Does the Commission want to maintain that policy of saying I don't care what your design --

MEMBER SIEBER: That is where it comes down to.

MEMBER BONACA: And the question is, do you allow the PRA to derive the elements of defense in depth?

CHAIRMAN APOSTOLAKIS: But it's not only whether it's a handicap to design, but I mean what does it do for us?

MEMBER KRESS: No, but I don't think --

MEMBER BONACA: But look at the elements of defense in depth, the cumulative examples --

CHAIRMAN APOSTOLAKIS: Only because it was interpreted as a single hardware --

MEMBER BONACA: The others, if you look at those, still, clearly they suggest that you can have separation, you will have no diversity. So to the degree to which you integrate, you know, some prescription of defense in depth based on the size of your PRA, I think that defense-in-depth ultimately is going to be what you will get.

MR. KING: What you're really arguing about is that considering a large source term is an evolution, and that that is not the right way to look at it.

MEMBER POWERS: I think that, I mean, I don't agree with the Committee at this level, but I think that the structuralist point of view used the analyses that you've done, the flow assessments you've done. I want to know what happens in this -- what is contained in the engineering safety systems that you've got if you put a large source term back in that containment.

MEMBER KRESS: What do you mean by "large"?

MEMBER POWERS: That's a big one, yes. I don't have difficulty with the approach that they've taken in the development of NUREG 1465, which is not different in kind from what they did with TID 1434. They've said, okay, here's the kind of source term that you have to deal with. They use those particular source terms because they're not going to be applicable to all reactors. For instance, a pebble bed modulated reactor, I think, would probably have a little different-looking source term than I would put in the -- I like the idea of having both gaseous and particulate material and debris in there.

I don't know what the exact mix is going to be, but you have something that was never anticipated that dumps a whole lot of reactivity into the containment.

MEMBER KRESS: I don't think I'm disagreeing with you, but my point is, that when we did 1465, what we actually did was we took a set of scenario-specific accidents and calculated releases, and then we kind of took a conservative part of those and said, "Just sit."

I think you could do the same think with the pebble bed modular reactor. If you had enough database for the fuel, and you a description of the accidents it could go through, you could CRA-specific accidents and say, "Here are the source terms I get out of that." Now one of the accident sequences might be an air-ingression accident. But then you've got to use judgment, like we did in 1465. Is that an accident sequence we really ought to have to deal with in terms of the specification of the source term?

MR. KING: But all the accident scenarios that went into making 1465 were core melt scenarios.

MEMBER KRESS: Yes, they were core melt, but they weren't coolant core melt.

MEMBER POWERS: I think he's hinting at the problem I have. You had the advantage for the current generation of reactors and you could get into similar accidents. The people developing these gas-cooled reactors come in and say it's not possible. And they throw up a lot of reasons, none of which do I swallow, for why they can't. And yet, I'm doing this because I'm saying, one of these days, nature will prove these guys wrong.

I'm not sure that I am happy with them going through their accident sequences and doing what we did for 1465 because they'll come up with minuscule source terms and they'll sum them up and take a conservative limit on a minuscule source term, and it's still a minuscule source term. Yet what I'm worried about is that all those analyses are wrong.

I think what we did was just fine for existing reactors, but I don't think that is the prescription I would put on everybody else. I would say give me a decent-size source term that has a mix of particular gaseous materials and show me how you contain it. And I would do that, the guy came back and said, "Here, I've done this mechanistically, I've looked at all my reactor accents. I get a pretty healthy source term on some of them, and it's a mix, and I like using that."

He goes through the analysis much like AP 600 * did; they didn't think their core was going to melt either. They went ahead and came up with a mix. They adjusted their ways from 1465 and went ahead and did the analysis, and I think we were happy with that. We didn't like the numbers they came up with, but clearly you were happy with that.

If the guy did that, I think I would be content. I wouldn't say, "Oh, well, you didn't get 50% of the iodine out; I think you're going to fail." That's not terribly important to me. It's more important to me that the mix is substantial.

CHAIRMAN APOSTOLAKIS: I think the equivalent of what you are saying is, as you said, the mix. At that level, you don't know what your volume is, going to a high temperature. Just to protect myself --

MEMBER POWERS: I give PRA where PRA is due. There's no strong numbers up at this level; I freely admit that someday there will be, but it's not there right now.

CHAIRMAN APOSTOLAKIS: I think that's an important point, and if you put it in that language, you've always talked about confidence language. So what Dana is saying when it comes to the source term, forget about the mean and the median. I don't want you to go with the 90th percentile; some sort of a mix of the very bad case with the standard cases. So you can always play something --

MEMBER WALLIS: You'll be in real conflict with the designers, because they're going to come back and say, "Our source term is minute. That's the whole idea of this wonderful reactor is it has a very small source term. That's why it's so safe and good for the public."

MEMBER POWERS: That's what they're going to say, exactly.

MEMBER WALLIS: They're going to say that.

MEMBER POWERS: And that's just not good enough for me.

CHAIRMAN APOSTOLAKIS: No, but if you can figure out a way to get something that is larger -- Dana is allowing for a mix.

MEMBER WALLIS: But you've got to be realistic. You can't just figure out something that's absurd; you've still got to be --

CHAIRMAN APOSTOLAKIS: Well, that's why it's not an easy problem. But the idea, though, is not bad, that at some point you get away from the mean or the best estimates, and say I want higher confidence now, because this is the end of the line. And the other thing is, of course, Tom mentioned security evaluation; make that part of the whole process. Then maybe the reason why you need the containment is not the source term; to keep things outside, not inside.

MR. KING: Or maybe there is a way or a scenario that PRA isn't amenable to, through the security concerns at least.

CHAIRMAN APOSTOLAKIS: That's right, that's right, so we have to risk-inform the security process.

(Laughter.)

CHAIRMAN APOSTOLAKIS: Well, we gave you extra time, Tom, but come on.

(Laughter.)

MR. KING: You guys are lucky; my wife's out of town, so I don't have to be home at any special time.

Alright, containment, sixth issue, versus confinement. This was an issue raised back on the MHTGR days. What the Staff recommended and what the Commission endorsed was you could have a design, they didn't say it had to have a containment -- they said it must do two things. One, it must meet the release limits, whatever they are in the regulations; and it must for 24 hours have a performance that you can show that its leak rate, whatever leak rate you assumed in the safety analysis, will not be exceeded in the first 24 hours. So if you've got a confinement, and you can show that in the first 24 hours it's going to work the way it's supposed to work for a containment, you could make the case for a confinement.

Again, I think this is a fundamental defense-in-depth issue. It certainly is dependent upon the event selection and source term issues, how they turn out.

Some designers will argue that having the containment on an HTGR makes it less safe because you make the heat removal more complicated. The passive systems have to be more complicated, you have to have active systems.

That's certainly one argument that we will hear. Another one is that you'll retain that hot helium and you'll have a pressurized building and that provides a driving force for any fission products that are in there. That makes it less safe. There have been designs approved in other countries without containment buildings, most notably Germany.

On the flip side, I see that containment is -- can be a way where you don't have to worry so much about fuel performance and heat removal system performance. You don't have to worry so much about air ingress. It can have some positive aspects. So I think looking at the design both with and without the containment might be a reasonable criteria to impose to see what are the safety benefits. Does it really detract from safety or does it really maybe improve safety?

I'm just sort of speaking out loud here, thinking about additional criteria that we might want to think about before going forward to the Commission.

Saying, do they want to stick with their 1993 position, or do they want to embellish the criteria or take a different position?

MEMBER KRESS: This certainly is tied in with everything that's going on.

MR. KING: Yes. If the Commission decides big source term, then I think that settles this one. If they decide scenario-specific, small source term -- there could be other reasons; public confidence is probably something they'll think about.

MEMBER WALLIS: I wonder if that's right. I mean I'm sitting here, you're raising all these questions. You're somehow assuming that the Commission is magically going to be wise enough to make a good choice?

MR. KING: Yes.

MEMBER KRESS: That's their job.

MEMBER WALLIS: No, I don't. I think you've got to lay out the rationale for why they ought to make the various choices.

MEMBER KRESS: I think it's incumbent upon these guys to give them lots of information.

MEMBER WALLIS: And they've got to give a way of thinking as well as just letting them --

CHAIRMAN APOSTOLAKIS: They usually do.

They usually do. They don't just give them all the same arguments.

MR. KING: Our plan is to give a recommendation. Here are the options we considered; here's the pros and cons. Here's what we recommend. Here's why.

CHAIRMAN APOSTOLAKIS: That's why you come here before us.

MR. KING: Yes, that's what I want to talk about, is the steps to do that. Let me just touch on the last issue and then we can talk schedule.

Emergency planning. Again, the HTGR designers are saying we don't need to have off-site emergency planning --

MEMBER POWERS: What's EAB?

MR. KING: Exclusion area boundary; that's the fence around the plant. They say they'll never exceed one rem at the fencepost; therefore, you don't need to evacuate people. This was looked at again ten years ago with the MHTGR. What the Commission said was, they did not agree to making any change to emergency planning at that time. They said what they would need before they would make a change to emergency planning was, get some operating experience on these plants to see if all their safety claims really, in fact, pan out.

They may want to retain that position today, or they may want to reconsider. I don't know. We'll lay out the options and the pros and cons and see where they want to go. To some extent, you could consider this: emergency planning is the last line of defense-in-depth, and if you're going to back off in those other areas, maybe you don't want to back off there until you really do have some operating experience. To me it's a reasonable position.

MEMBER LEITCH: As long the only sites being considered are existing sites, it's kind of a moot point.

MR. KING: For existing sites, it's probably a moot point; I agree. But again, it's also something where, if you do want to change it later, it's not like you have to change the plant design. You could change the emergency planning plans later without -- you know, put a containment on the plant or something.

Schedule. We'll be having this workshop. The next step after the workshop, in a couple of weeks, is to then start formulating recommendations, draft recommendations. I would like to come back to you -- Subcommittee, Full Committee -- certainly, at the latest, at the Full Committee meeting in December. So in closing, think about the schedule, Subcommittee, Full Committee, leading up to the December Full Committee Meeting. Thank you.

(Whereupon, the proceedings went off the record at 4:00 p.m.)

CERTIFICATE

This is to certify that the attached proceedings before the United States Nuclear Regulatory Commission in the matter of:

Name of Proceeding: Advisory Committee on Reactor Safeguards 496th Meeting

Docket Number: N/A

Location: Rockville, Maryland

were held as herein appears, and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission taken by me and, thereafter reduced to typewriting by me or under the direction of the court reporting company, and that the transcript is a true and accurate record of the foregoing proceedings.

/s/ Rebecca Davis

Rebecca Davis
Official Reporter
Neal R. Gross & Co., Inc.

EPRI Topical Report on Reactivity Initiated Accidents

Undine Shoop
Office of Nuclear Reactor Regulation
October 10, 2002

RIA Criteria History

- Agency Program Plan for High Burnup Fuel – July 6, 1998
  - Industry will have to provide the Criteria, Data base, and Models for Burnup > 62 GWD/MTU
  - Industry will have to perform the research necessary to develop the data base to support extended burnup ranges > 62 GWD/MTU
  - RES will confirm criteria for burnup < 62 GWD/MTU

NRC Preliminary Review Plan Purpose

- To focus resources appropriately to provide a detailed review and identify all the elements needed to complete the review

NRC Preliminary Review Plan Elements

- Data Verification
  - Correct application in the methodology
  - Correct application in a manner consistent with the methods used to generate it
  - Statistically sound combination of the data sets
- SED/CSED Theory and Model
  - Investigation and verification of the equivalence of SED/CSED model to Rice's J/Jc formulation
  - FRAPTRAN independent verification
- Fuel Rod Failure Threshold
  - Validation of this application
  - Review of applicability to current and future proposed fuel types
- Core Coolability Limit
  - Application verification

NRC Preliminary Review Plan Elements – Cont.

- FALCON Code
  - Review of the code
- Fuel Dispersal
  - Review data for applicability of the phenomena to the proposed safety limit
- Uncertainty and Conservatism
  - Data uncertainty verification
  - Conservatism confirmation
- Limitations of the Criteria
  - Review data for limits of applicability which would create limitations of the methodology application
- Safety Evaluation Conditions of Acceptance
- Revision of associated RG and SRPs

Future Activities

- Final Review Plan – December 31, 2002

United States Nuclear Regulatory Commission

UPDATE ON ISSUES IN 1998 AGENCY PROGRAM PLAN FOR HIGH-BURNUP FUEL

Ralph Meyer
Office of Nuclear Regulatory Research

ACRS
October 10, 2002

ORIGINAL LIST OF ISSUES

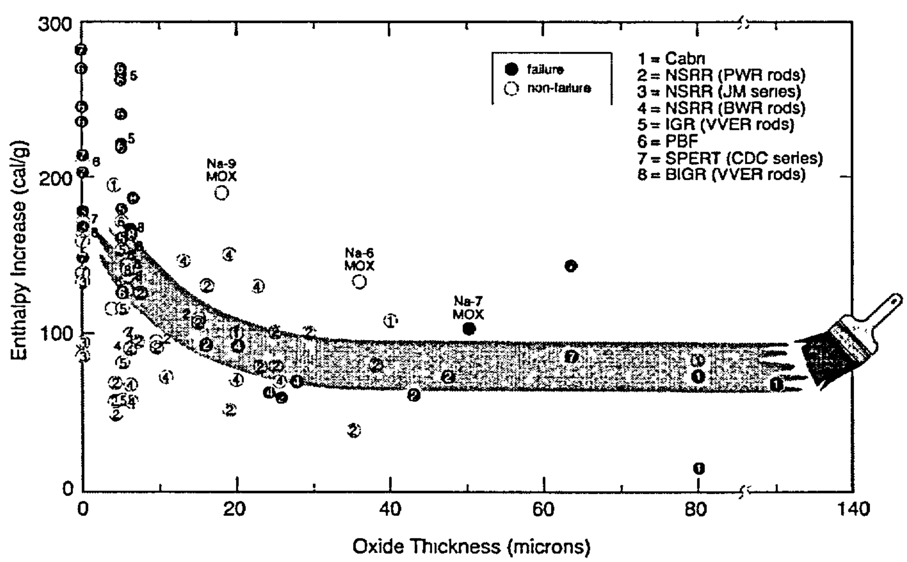
1	Cladding Integrity and Fuel Design Limits	Resolved in original plan (no further discussion)
2	Control Rod Insertion Problems	Resolved in original plan (no further discussion)
3	Criteria and Analysis for Reactivity Accidents	NRC confirmatory assessment at 62 GWd/t, early 2005. Revision of Reg. Guide 1.77, TBD.
4	Criteria and Analysis for Loss-of-Coolant Accidents	Zircaloy criteria and models at 62 GWd/t, 2004. New performance-based criteria possible.
5	Criteria and Analysis for BWR Power Oscillations (ATWS)	Schedule to be determined
6	Fuel Rod and Neutronic Computer Codes for Analysis	Resolved
7	Source Term and Core Melt Progression	Technical issues essentially resolved. Revision of Reg Guide 1.183, TBD.
8	Transportation and Dry Storage	Research Information Letter, 2004
9	High Enrichments (>5%)	No activity needed now (no further discussion)

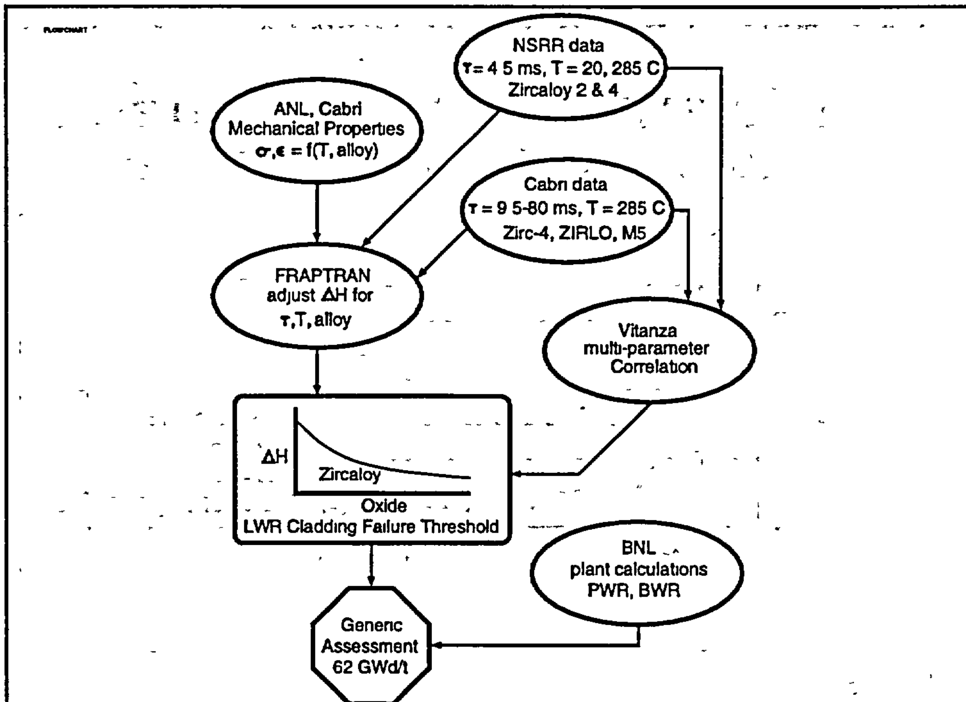
CRITERIA AND ANALYSIS FOR REACTIVITY ACCIDENTS

ISSUE: 280 cal/g regulatory limit in Reg. Guide 1.77 is not adequate for high-burnup fuel. New limit needed.

METHOD: (see following slides)

SCHEDULE:
Cabri test(s) late 2002 (early 2003)
ANL Zircaloy mechanical properties 2003
NSRR Zirc. tests in high-temp. capsule late 2004
NRC confirmatory assessment 62 GWd/t early 2005





R Meyer – ACRS 5 10/09/2002 8 14 AM

Correlation for the RIA Failure Threshold (Vitanza 2001)

$$H_F = \left[200 \cdot \frac{25+10D}{Bu} + 0.3\Delta\tau\right]\left(1 - \frac{0.85OX}{W}\right)^2$$

- **H_F = Fuel Enthalpy Failure Limit (maximum of 200 cal/g)**
- **Bu = Burnup in MWd/kg**
- **D = 0% (brittle) to 1% (ductile) cladding hoop strain limit**
- **$\Delta\tau$ = Pulse Width (maximum of 75 msec)**
- **OX = Oxide thickness in (um)**
- **W = Cladding wall thickness (um)**

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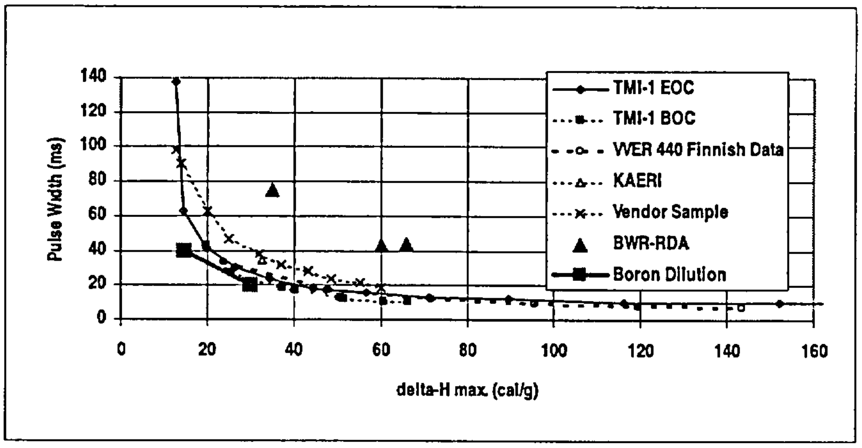
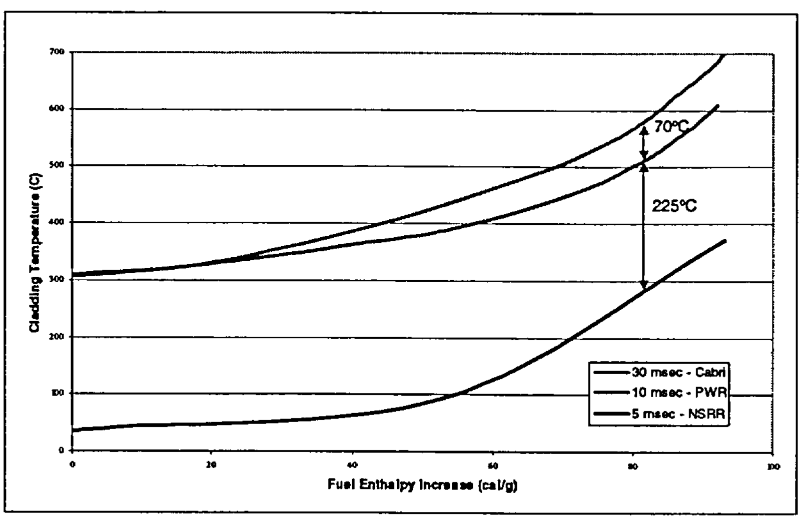
PULSE WIDTH FROM PWR AND BWR ANALYSIS OF DIFFERENT RIAs



PULSE WIDTH

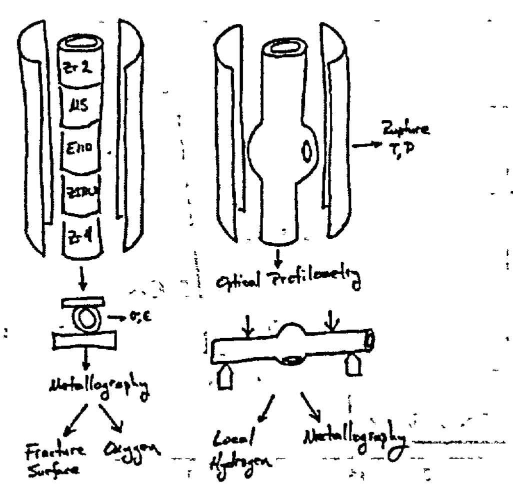


CRITERIA AND ANALYSIS FOR LOSS-OF-COOLANT ACCIDENTS

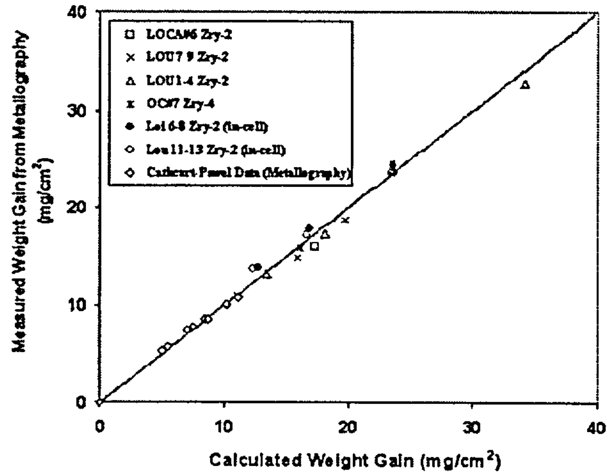
ISSUE: Embrittlement criteria in 10 CFR 50.46 and related evaluation models are probably affected by burnup and alloy. Check and revise if necessary.

METHOD: (see following slides)

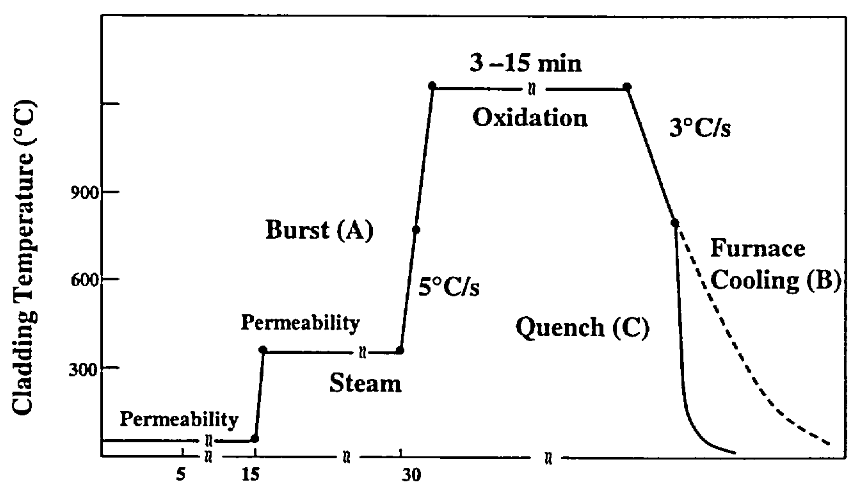
SCHEDULE: Zircaloy criteria and models at 62 GWd/t in 2004

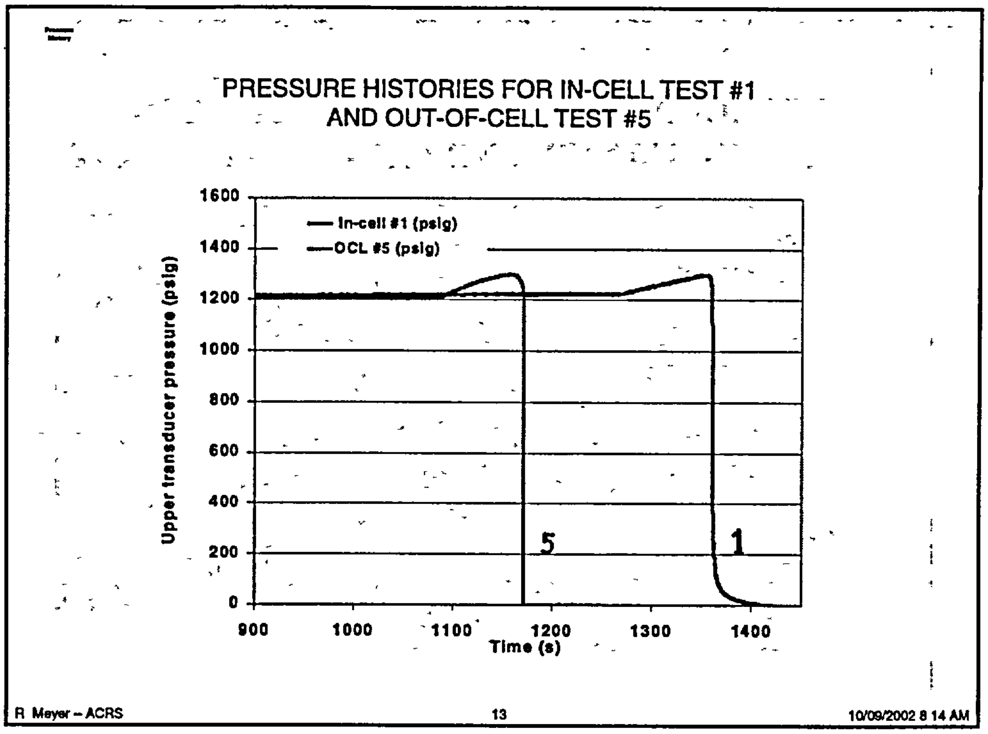


Measured Weight Gain from Metallography for Irradiated and Unirradiated Zry-2 and Zry-4



LOCA INTEGRAL TEST SEQUENCE





PRESSURE HISTORIES FOR IN-CELL TEST #1
AND OUT-OF-CELL TEST #5
In-cell #1 (psig)
OCL #5 (psig)
Upper transducer pressure (psig)
1600
1400
1200
1000
800
600
400
200
0
900
1000
1100
1200
1300
1400
Time (s)
5
1
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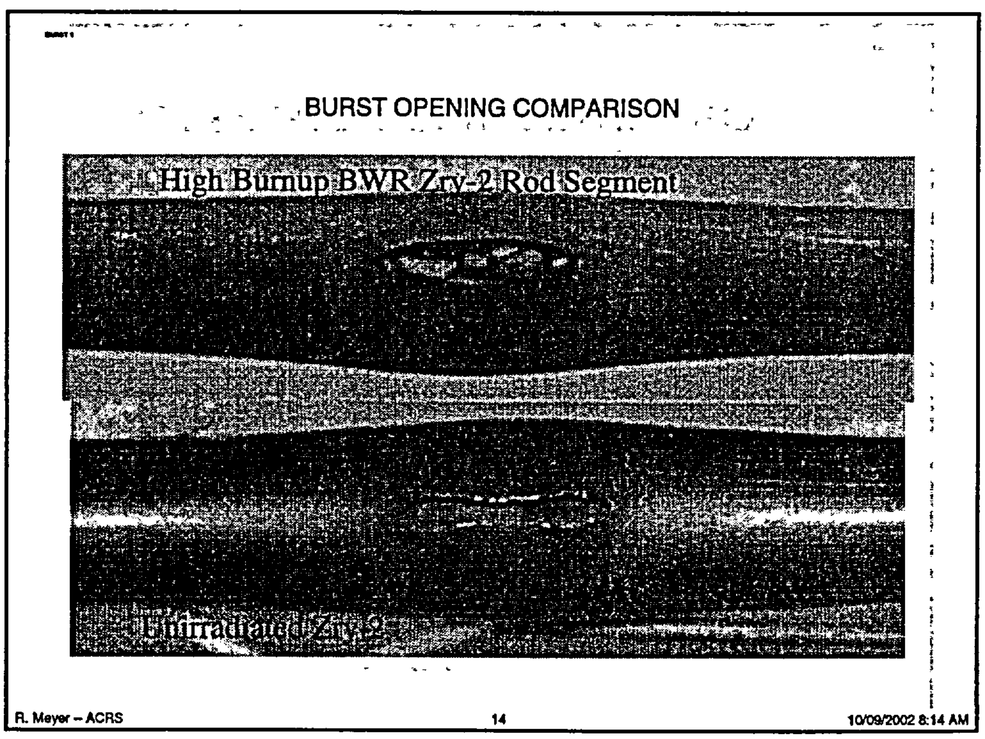

BURST OPENING COMPARISON
High Burnup BWR Zry-2 Rod Segment
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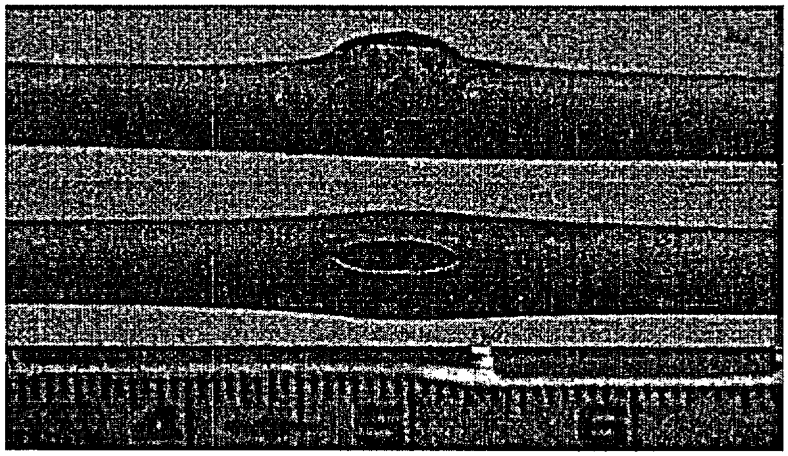
14
10/09/2002 8:14 AM

LOCA INTEGRAL TEST (PHASE B)
HIGH-BURNUP BWR BALLOON & BURST



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LOCA INTEGRAL TEST (PHASE B)
HIGH-BURNUP BWR FUEL PARTICLES

Fuel Particles (4 g)
≈15% Released
during Test;
≈85% Released
during Transfer

30×30 mm Jar
Cross-section

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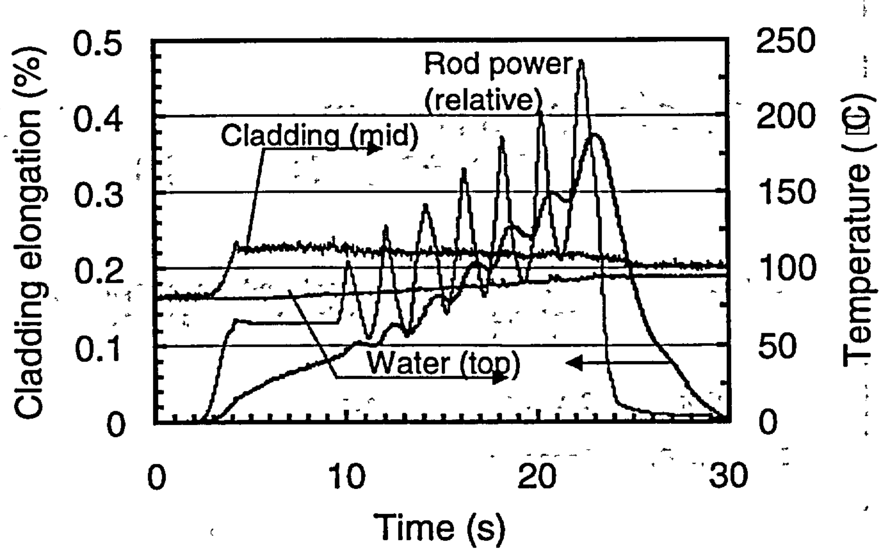
CRITERIA AND ANALYSIS FOR BWR POWER OSCILLATIONS (ATWS)

ISSUE: 280 cal/g limit currently used may not be adequate to ensure benign result in PRA for "successfully" terminated oscillations

METHOD: Analytical + some experimental separate effects

SCHEDULE: TBD



FRAPTRAN-GENFLO CODE ANALYSIS

- Coupled codes installed at PNNL in early September 2002
- Sample cases have been run by PNNL and NRC staff
- Analytical plan to be developed in 2003

FUEL ROD AND NEUTRONIC COMPUTER CODES FOR ANALYSIS

ISSUE:	NRC codes did not have high-burnup capability and were needed to help review vendor codes for high-burnup applications.
METHOD:	Develop, assess, peer review
SCHEDULE:	Resolved

SOURCE TERM AND CORE MELT PROGRESSION

ISSUE: Applicability of NUREG-1465 source terms to high-burnup fuel

METHOD: Expert elicitation, more data

SCHEDULE: Expert elicitation completed in June 2002
VERCORS, PHEBUS, VEGA data as available
Revision of Reg. Guide 1.183 TBD

TRANSPORTATION AND DRY STORAGE

ISSUE: What is the effect of burnup on fission product inventory (shielding, heat source, activity) and cladding degradation (removal from storage)?

METHOD: Direct tests and measurements

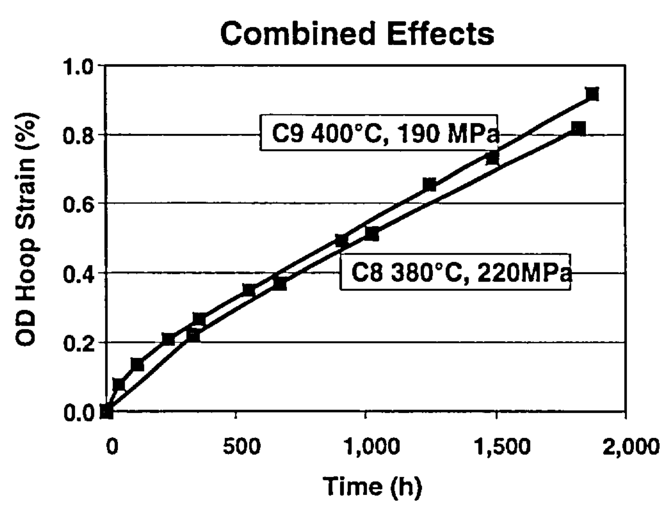
SCHEDULE: ANL tests on Zircaloy in 2003
Research Information Letter in 2004

Surry Thermal Creep Tests

- Summary Results

Test No.	Temp. (°C)	Stress (MPa)	Duration (hrs)	Avg. Strain	Failure	Strain Rate (%/hr)
1	380	220	2180	1.10	No	4.5×10^{-4}
2	380	190	2348	0.35	No	8.8×10^{-5}
3	400	190	1873	1.03	No	4.9×10^{-4}
4	400	250	693	5.83	No	$>4.9 \times 10^{-3}$
5	360	220	3305	0.22	No	4.2×10^{-5}

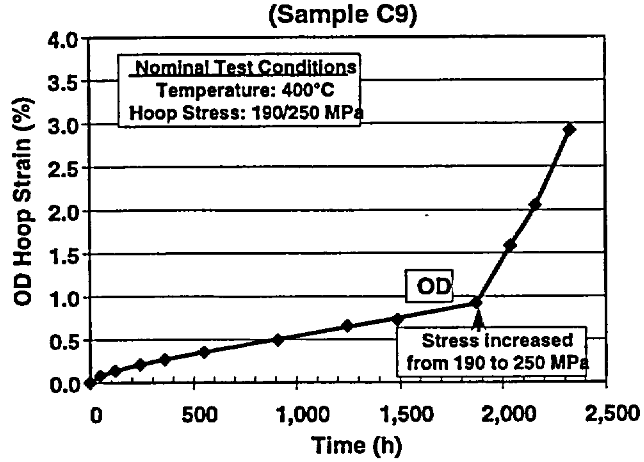
Summary Test Results



Summary Test Results

Effect of Increased Stress

(Sample C9)



Preliminary HBR Creep Matrix

(07/12/02 Version)

H-content wppm	Temp. °C	Stress MPa	Time h	Predicted Strain, %
650±50	400	220	TBD	TBC
650±50	400	190	TBD	TBC
650±50	400	160	TBD	TBC
650±50	420	160	TBD	TBC
650±50	380	220	TBD	TBC
650±50	380	190	TBD	TBC
650±50	380	160	TBD	TBC
650±50	360	220	TBD	TBC
650±50	360	190	TBD	TBC

Proposed Test Matrix/Schedule Cabri Project

- CIP-0 series: Two tests in the Na-loop in 2002
- CIP-Q :Qualification test for the water loop in 2005
- CIP-1 : Tests in water loop, comparison tests of CIP-0 tests, 2006+
- CIP-2: High burnup UO2 fuel, >80 GWD/T
- CIP-3: Mechanistic understanding on effects of pulse width, fuel microstructure, etc
- CIP-4 Study of high burnup MOX fuel, > 60 GWD/T
- CIP-5 To be defined

CIP0 Tests Will Determine Future Scope Of RIA

- RIA criteria proposed was based on Zircaloy clad
- Two additional RIA tests in CABRI Na-loop in 2002
  - CIP0-2
    - M5 rod (~ 20μm, ~73 GWd/T)
    - Test will be performed in 10/02
    - 30 ms, with enthalpy of ~95 cal/g (based on calculations)
  - CIP0-1
    - ZIRLO rod (~ 100μm, ~73 GWd/T)
    - Test will be performed in 11/02
    - 30 ms, with enthalpy of ~90 cal/g (based on calculations)
- New parameters involved
  - Higher burnup, 63 GWD/T 73 GWD/T
  - New alloys, M5 and Zirlo

New Reactor Licensing
Presentation to the ACRS

October 10, 2002

James Lyons, Director
New Reactor Licensing Project Office
Office of Nuclear Reactor Regulation

New Reactor Licensing Schedule

Timeline: 2002 (Qtr 1–Qtr 4), 2003 (Qtr 1–Qtr 4), 2004 (Qtr 1–Qtr 4), 2005 (Qtr 1–Qtr 4), 2006 (Qtr 1–Qtr 3)

ID	Task Name	
1	**Early Site Permits**	
2	Exelon	
3	Entergy	
4	Dominion	
5	**Design Certifications**	
6	**AP1000 Certification**	
7	Application submitted	03/28
8	Request for Additional Information	09/30
9	Draft Safety Evaluation Report	06/16
10	Final Safety Evaluation Report	July 2004
11	Final Design Approval	October 2005
12	Rulemaking completed	December 2005
13	**ESBWR pre-application**	
14	kickoff meeting	6/20&21/02
15	Phase 1 completed	August 2002
16	Request for Additional Information	June 2003
17	Draft Safety Evaluation Report	September 2003
18	Phase 2 complete	December 2003
19	ESBWR Design Certification Applic.	DC application - Early CY 2004 (projected)
20	**ACR-700 pre-application review**	DC application late CY2004 (projected)
21	**SWR-1000 pre-application review**	Preapp submittal mid 2004 - design cert app late 2005 (projected)
22	**GT-MHR pre-application review**	DC application late CY2004 (projected)
23	**IRIS pre-application review**	DC application late CY2004 (projected)
24	**PBMR pre-application review**	DC early CY2006 (proj)

ESBWR Design and Technology Overview

(1390 MWe natural circulation with passive safety systems)

A.S. Rao

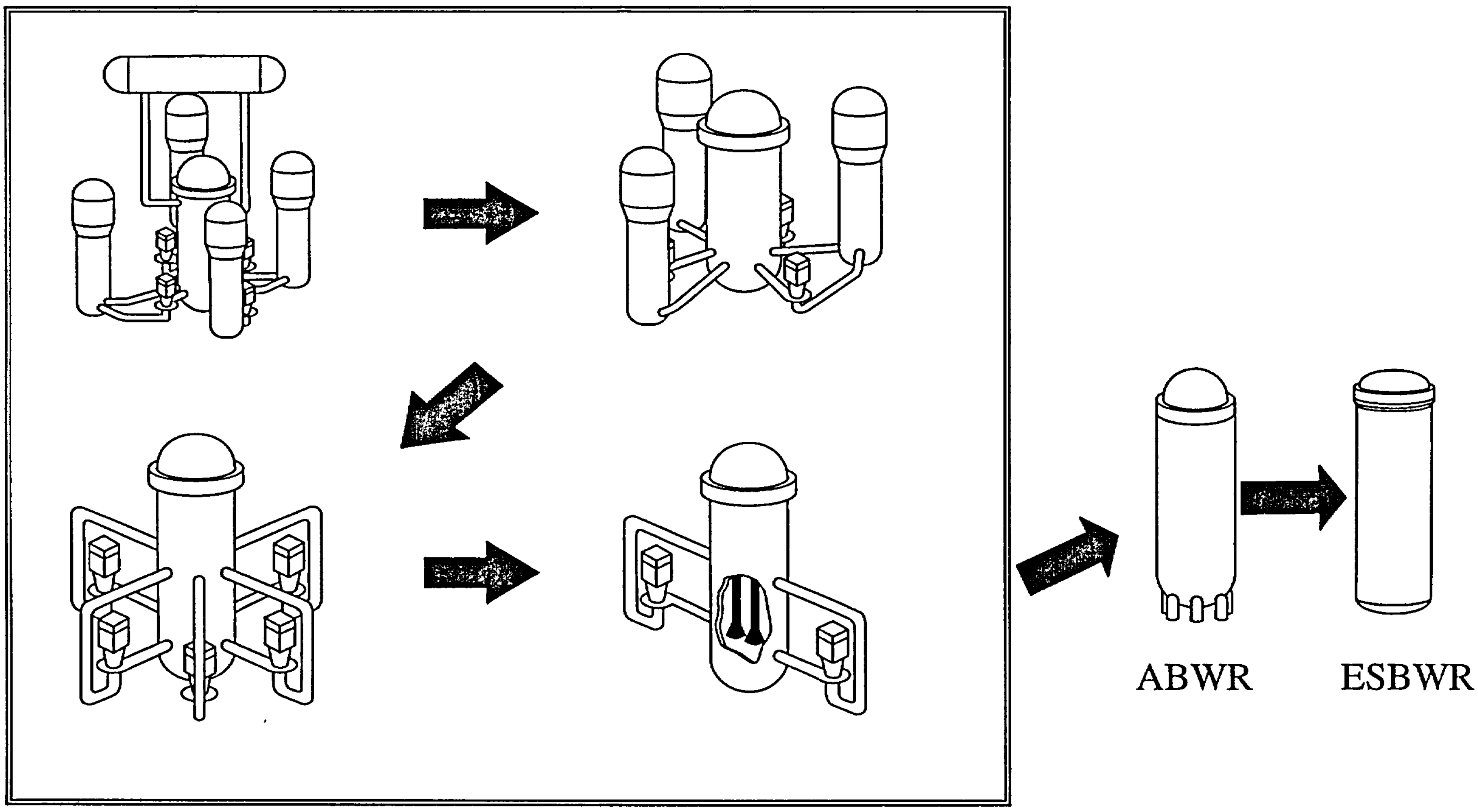
October 10, 2002
ACRS Meeting
Rockville, Maryland

Outline

- ***ESBWR evolution***
- ***Design summary***
  - ***Design philosophy***
  - ***Vessel and passive safety systems***
  - ***Containment and buildings***
- ***Features that improve plant performance***
- ***Technology programs and methodology***
- ***Summary and Conclusion***

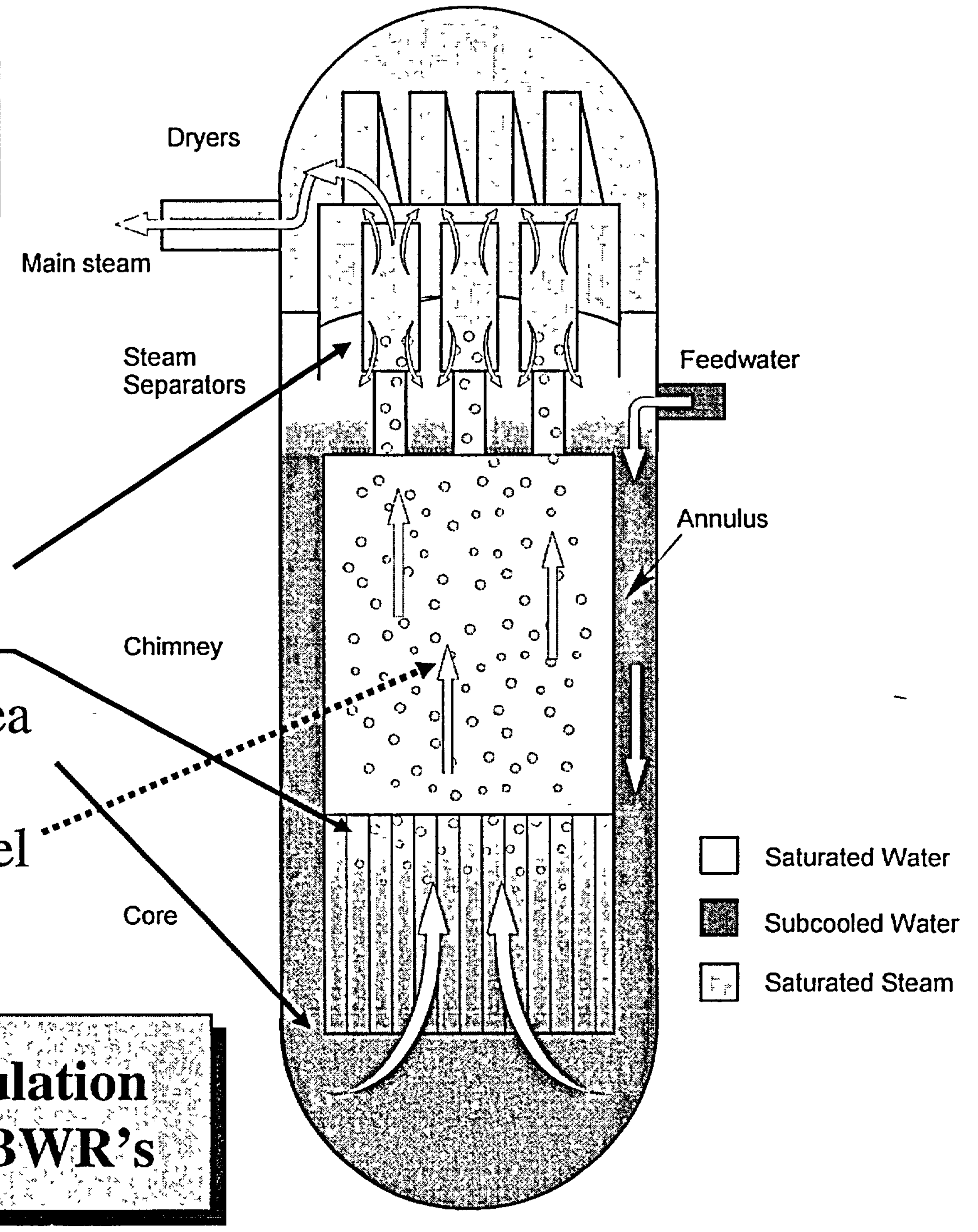
Pre-application review is a 12 month plan to close technology issues

Evolution of the ESBWR Reactor Design



Evolution and Innovation Towards Simplicity

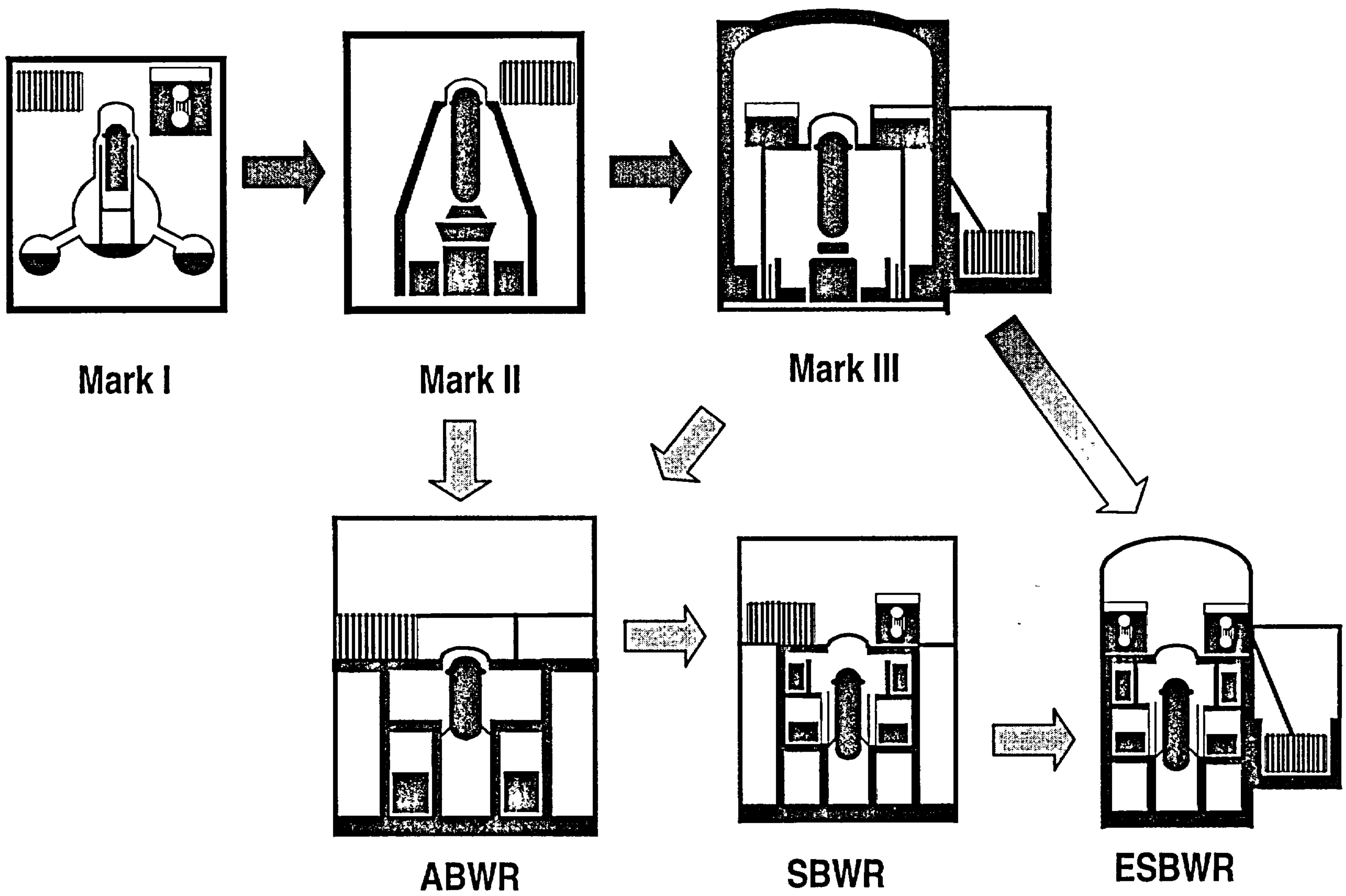
No pumps needed for normal operation



- Reduced flow restrictions
    - improved separators
    - shorter core
    - increase downcomer area
- Higher driving head
    - chimney and taller vessel

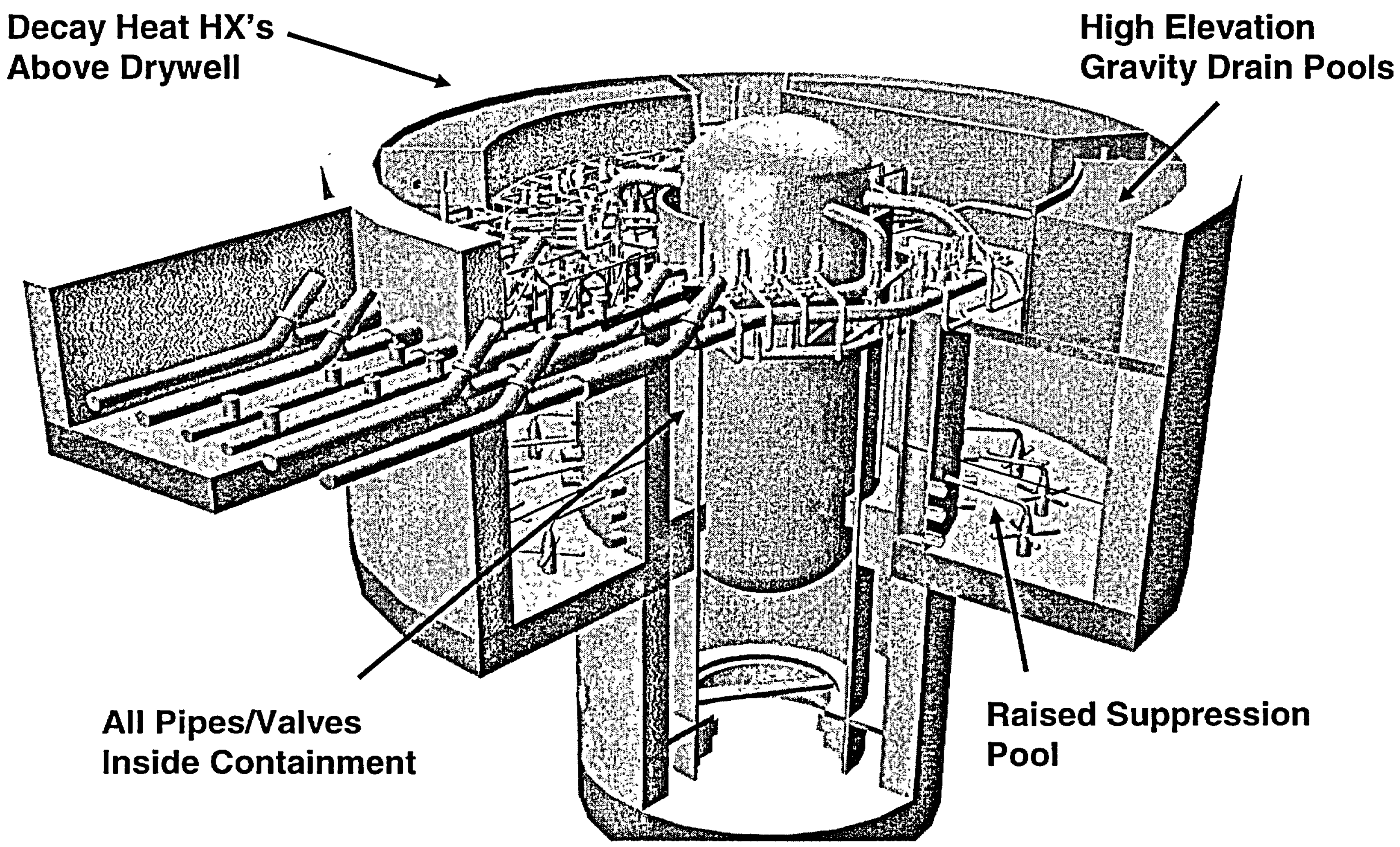
Enhanced Natural Circulation Compared to Standard BWR's

Evolution of BWR Containments



Evolution and Innovation Towards Simplicity

Passive Safety Systems Within Containment Envelope



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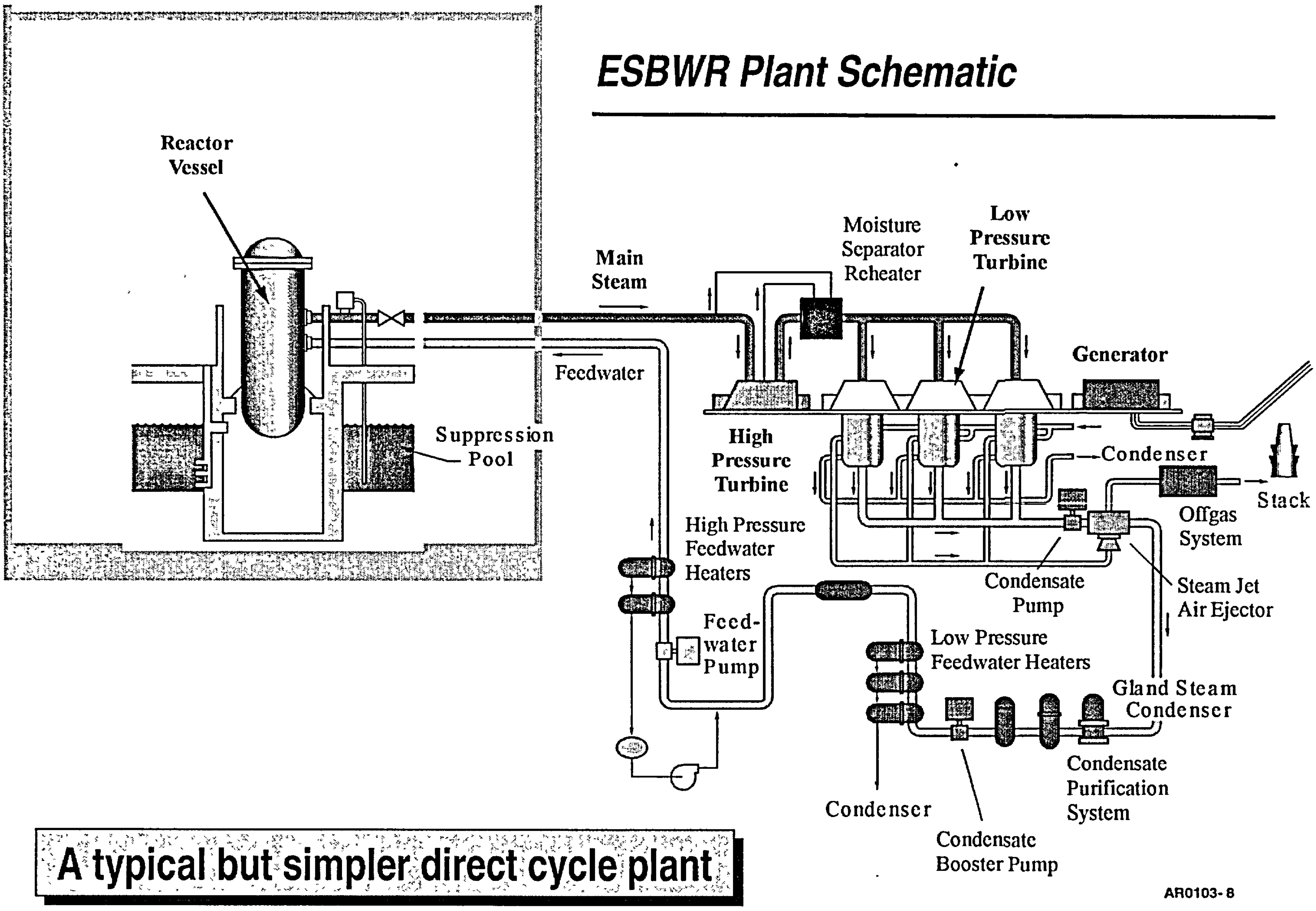
Comparison of key ESBWR parameters to operating BWRs

Parameter	BWR/4-Mk I (Browns Ferry 3)	BWR/6-Mk III (Grand Gulf)	ABWR	ESBWR
Power (MWt/MWe)	3293/1098	3900/1360	3926/1350	4000/1390
Vessel height/dia (m)	21.9/6.4	21.8/6.4	21.1/7.1	27.7/7.1
Fuel Bundles (number)	764	800	872	1020
Active Fuel Height (m)	3.7	3.7	3.7	3.0
Power density (kw/l)	50	54.2	51	54
Recirculation pumps	2(large)	2(large)	10	zero
Number of CRDs/type	185/LP	193/LP	205/FM	121/FM
Safety system pumps	9	9	18	zero
Safety diesel generator	2	3	3	zero
Vessel pressure, Mpa	7.1	7.1	7.1	7.1
Safety Bldg Vol. (m^3/MWe)	115	150	160	70

Evolution within a small range minimizes operational risks

ESBWR Plant Schematic



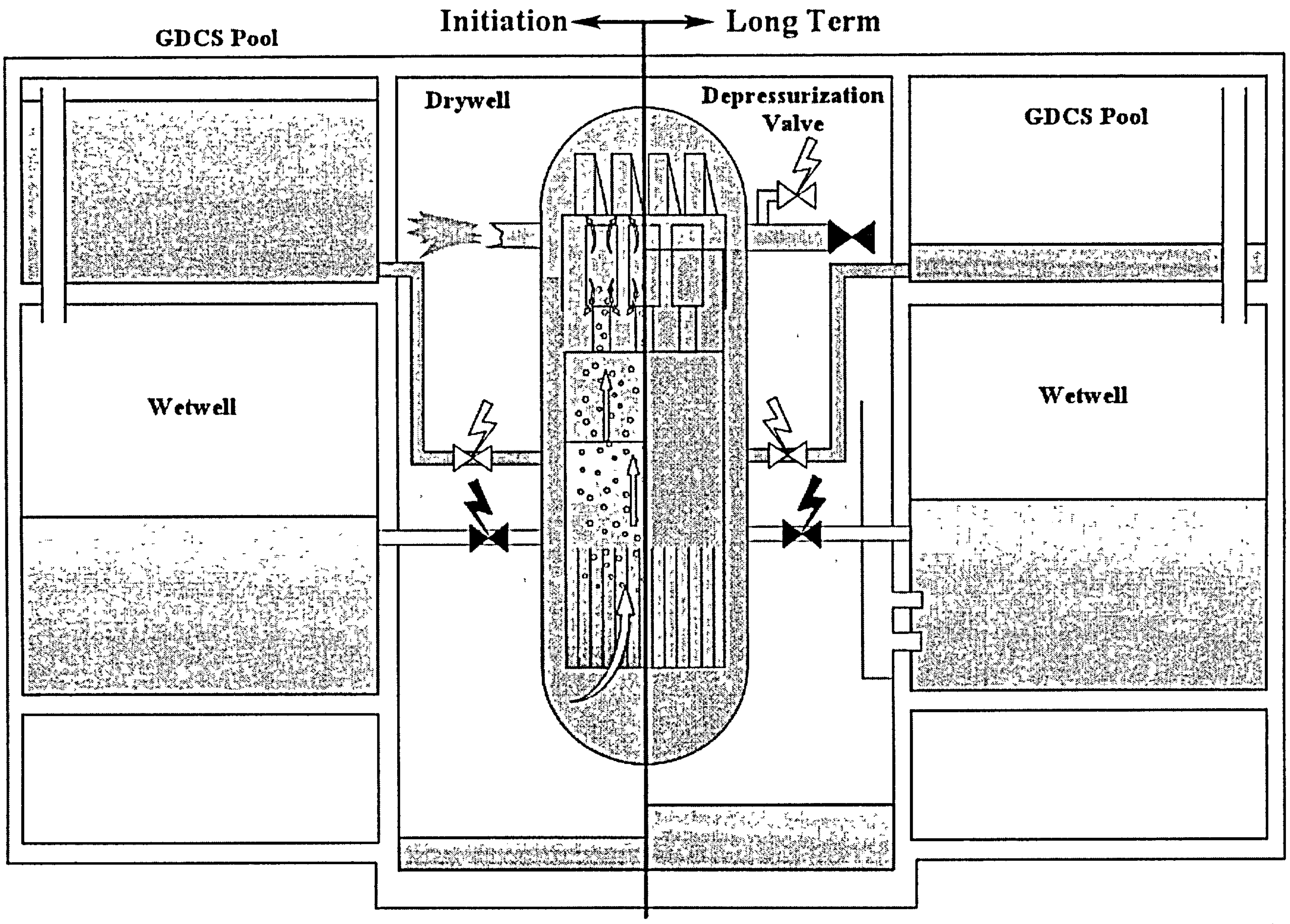
A typical but simpler direct cycle plant

Design philosophy for core cooling

- ***Increase inventory in the vessel***
  - Use taller vessel - NEW
  - Increase amount of subcooled water - NEW
- ***Minimize inventory loss from the vessel***
  - Eliminate large pipes below the core and minimize other pipes - NEW
- ***Keep core covered after initial blowdown***
  - Shorter core lower in the vessel - - NEW
- ***Provide inventory makeup – low head using gravity***
  - Provide diverse depressurization system for high reliability - NEW
  - Required makeup rate is very low
    - Multiple tanks rely on gravity
  - No high capacity systems needed
  - Fewer systems interactions
- ***Utilize improved BWR analyses tools*** - NEW

Design features improved the plant response

Gravity Driven Cooling System (GDCS) - Main Steam Line Break



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Design Philosophy for decay heat removal

- ***Remove Decay Heat From Vessel***
  - **Main Condenser**
  - **Normal shutdown cooling system – a full pressure system - NEW**
  - **Isolation condensers - NEW**
  - **Remove vessel heat through relief valve opening**
- ***If Needed, Remove Heat From Drywell***
  - **Passive containment cooling (PCC) Hx (safety-grade) - NEW**
    - Always available and drywell/wetwell pressure difference drives the flow through the heat exchangers
    - Condensed steam returns to drywell/vessel, non-condensables collect in the wetwell airspace
    - No operator action needed for 72 hours
  - **Suppression pool cooling (non-safety)**

Several Diverse Means of Decay Heat Removal

Decay Heat Removal from Containment - How it works

- ***Initially steam (blowdown energy) flows to large heat sink in containment (suppression pool) and through heat exchangers***
- ***Longer term (decay heat) steam flows to heat exchanger (based on pressure differences) and heat is transferred outside containment***
    - ***Vertical tube heat exchangers in a pool of water***
- ***Containment pressure determined by non-condensables in wetwell airspace and vapor pressure***

Concept is simple, reliable - extensive testing and analysis provide high confidence in the design margin

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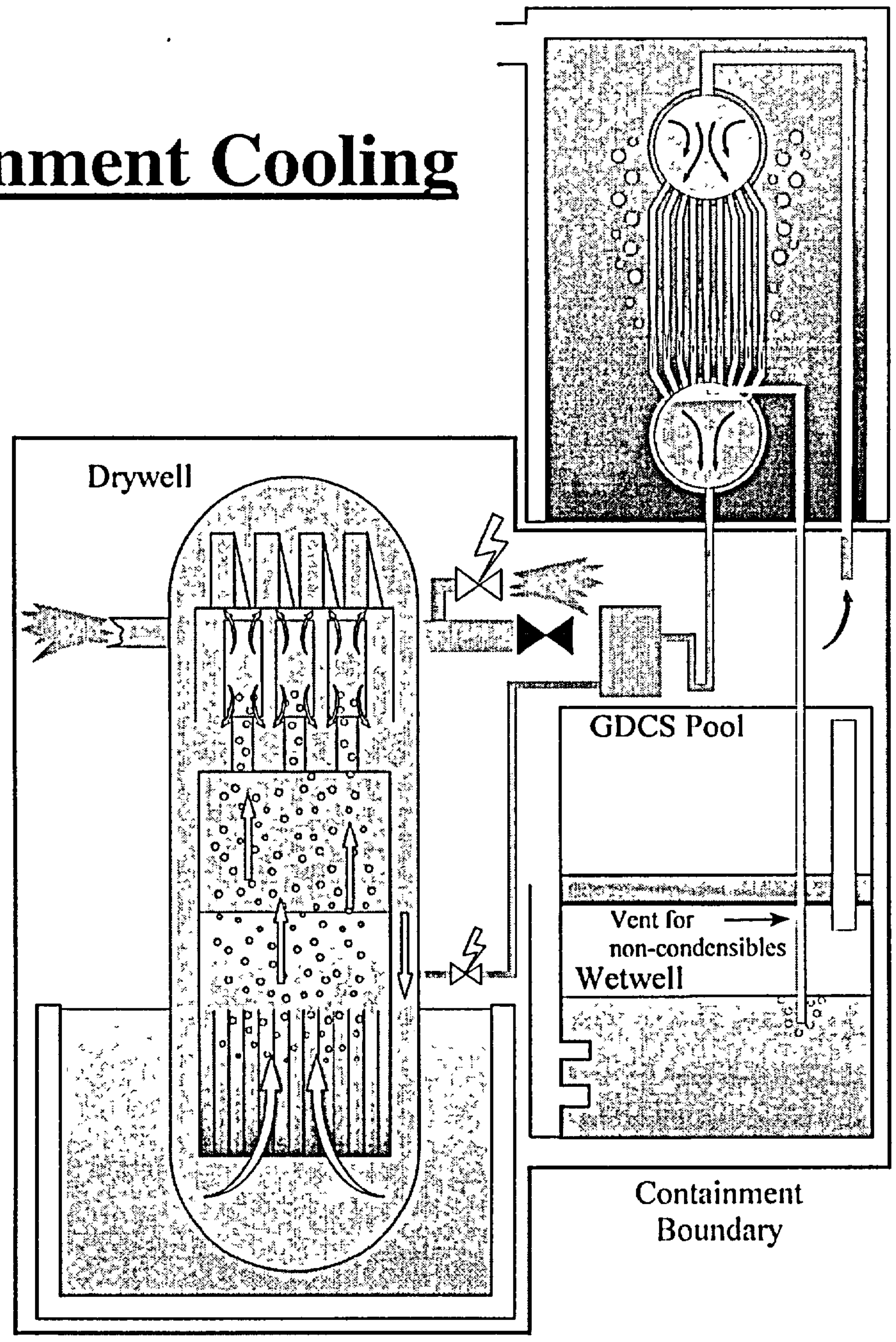
Passive Containment Cooling



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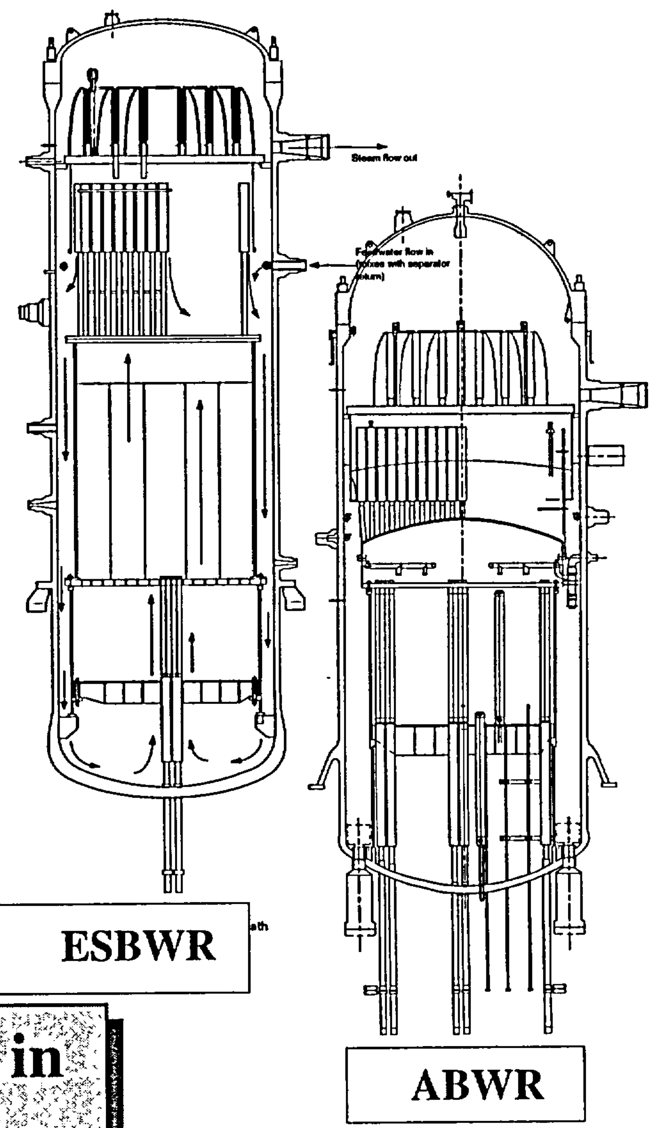
Design Features Affecting LOCA Response

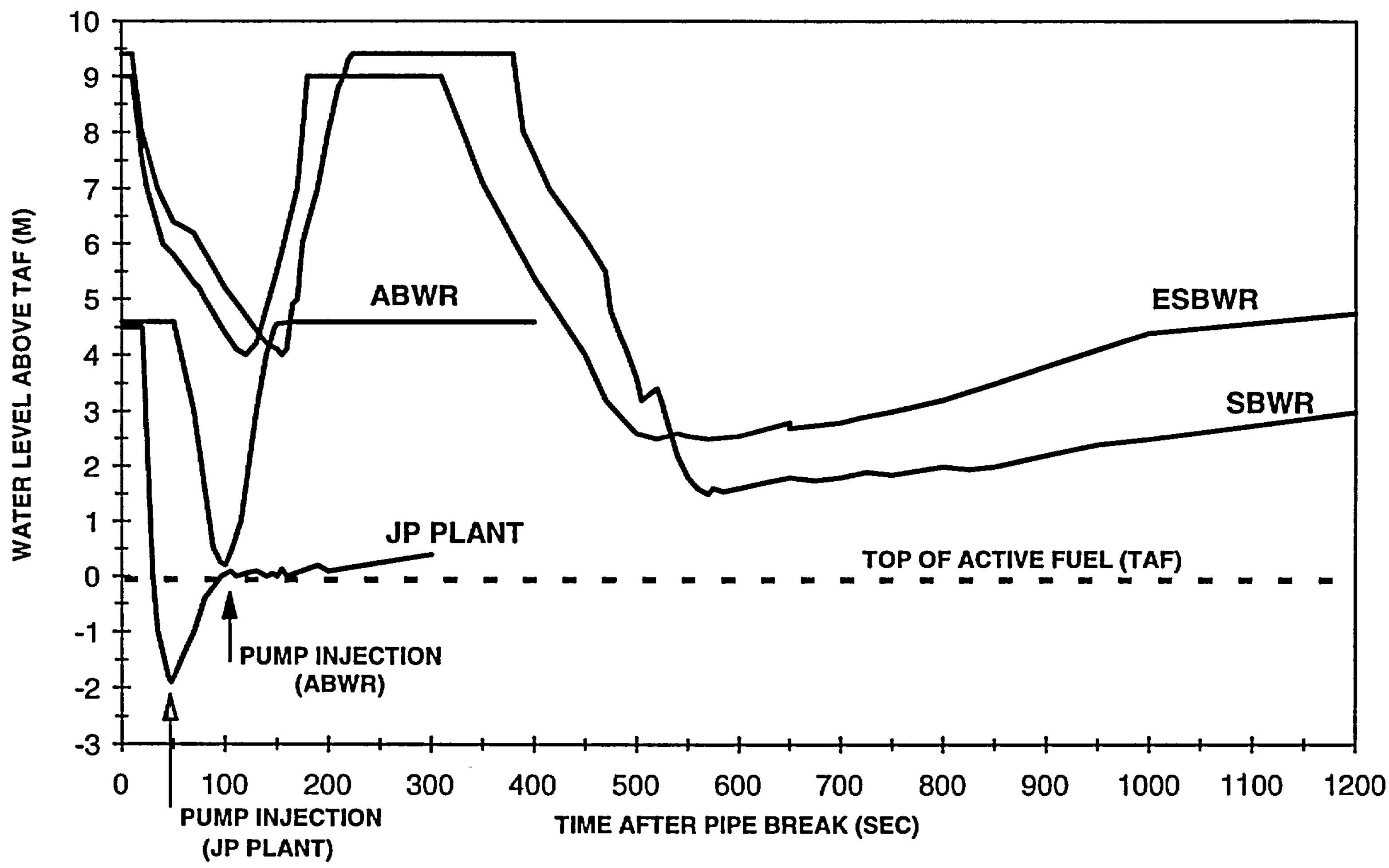
	ESBWR	*ABWR*	*BWR5*	*BWR4*
Large pipes below core	*No*	*No*	*Yes*	*Yes*
Core height, m	*3.05*	*3.66*	*~3.66*	*~3.66*
TAF above RPV bottom	*~ 1/4*	*~ 1/2*	*~1/2*	*~1/2*
Separator standpipes	*Long*	*Short*	*Short*	*Short*
Vessel height, m	*27.7*	*21.1*	*~21.9*	*~21.8*
Water volume outside shroud (above TAF), m^3	*222*	*88*	*94*	*92*



ESBWR's greater water inventory results in improved plant LOCA performance

Water Level in Shroud Following a Typical Break

(values are intended to show typical trends for limiting breaks)



Margin to core uncovery – 3m ± 0.3m

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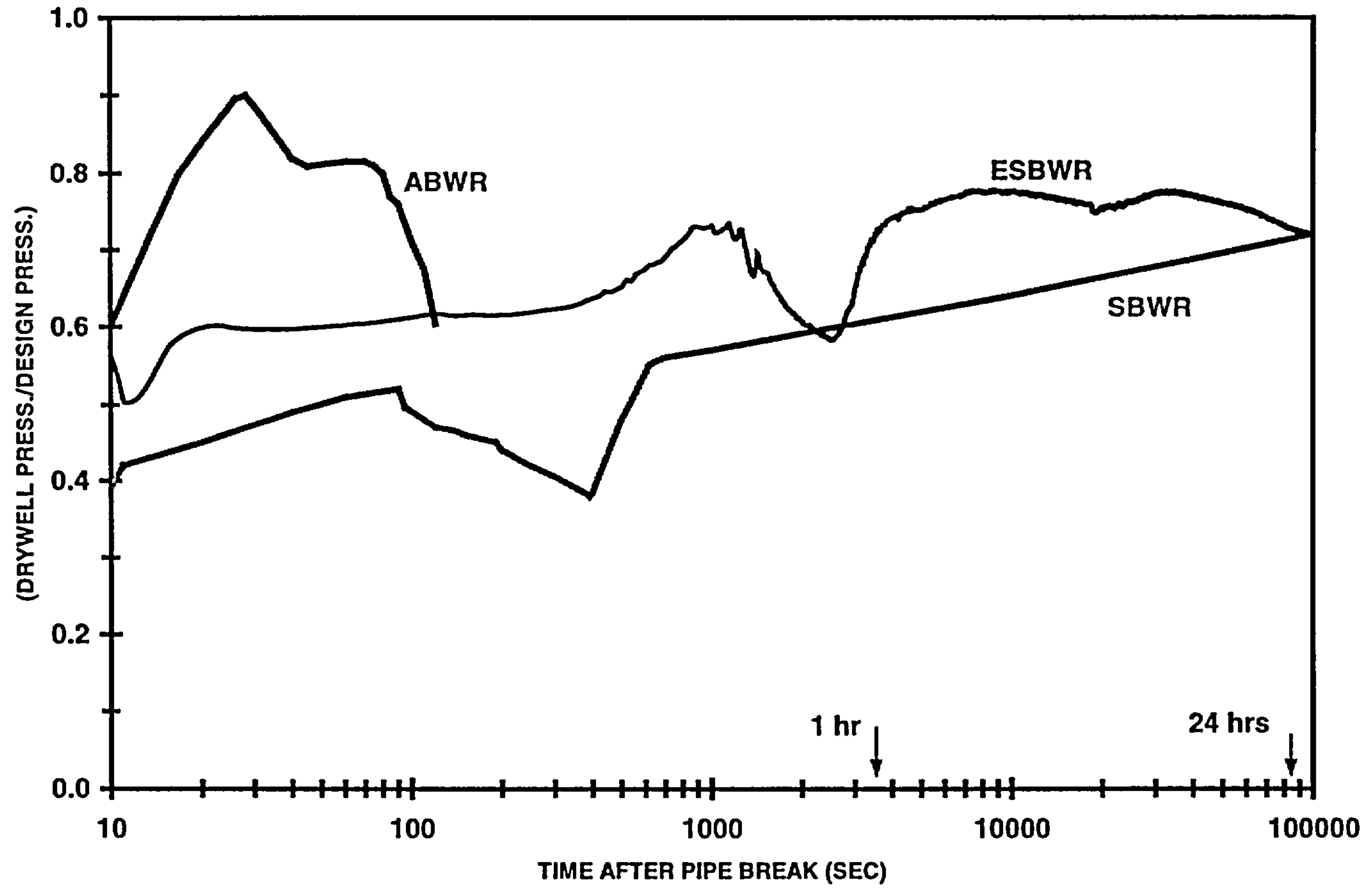
Containment Pressure Following a Pipe Break

(values are intended to show typical trends for limiting breaks – ESBWR has lower design pressure than SBWR)



Large margin to design pressure

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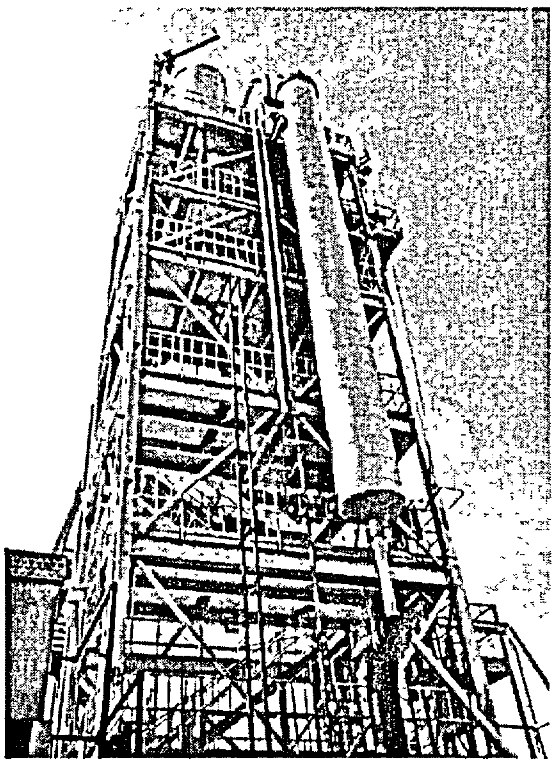
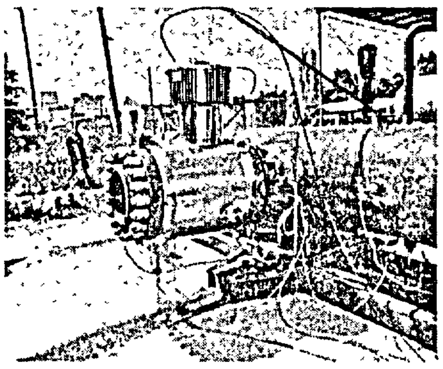
Technology Program for Features New to SBWR/ESBWR



- ***Component tests***
  - Full scale components tests – DPV valves and vacuum breaker
  - Full scale isolation condensers & PCCS heat exchangers,
- ***Integral tests***
  - Integral tests at different scales – 1/400 to 1/25
  - System interaction tests
  - Large hydrogen releases
- ***Testing used to qualify computer codes***
- ***Extensive international cooperation***
- ***Extensive review and participation by NRC staff***
  - Test matrix
  - Running of actual tests
- ***Decay Heat Removal – additional ESBWR tests***
  - 8 Integrated system tests run in PANDA

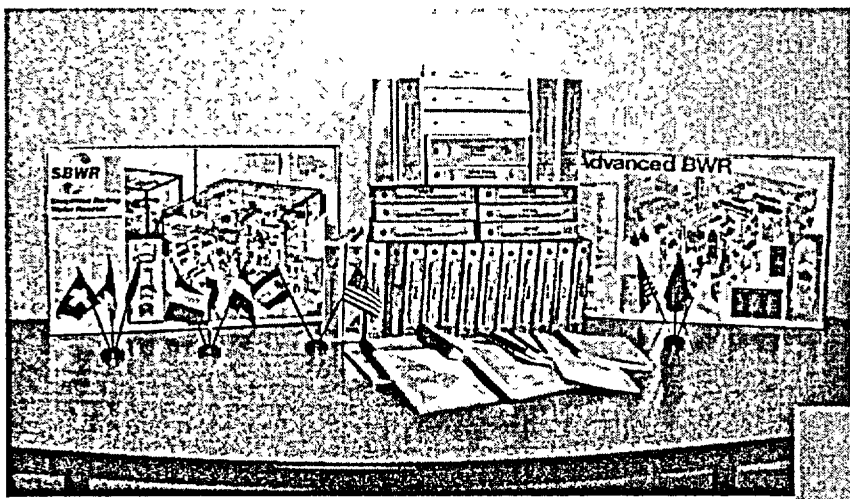


Reactor Depressurization Valve in the Test Facility

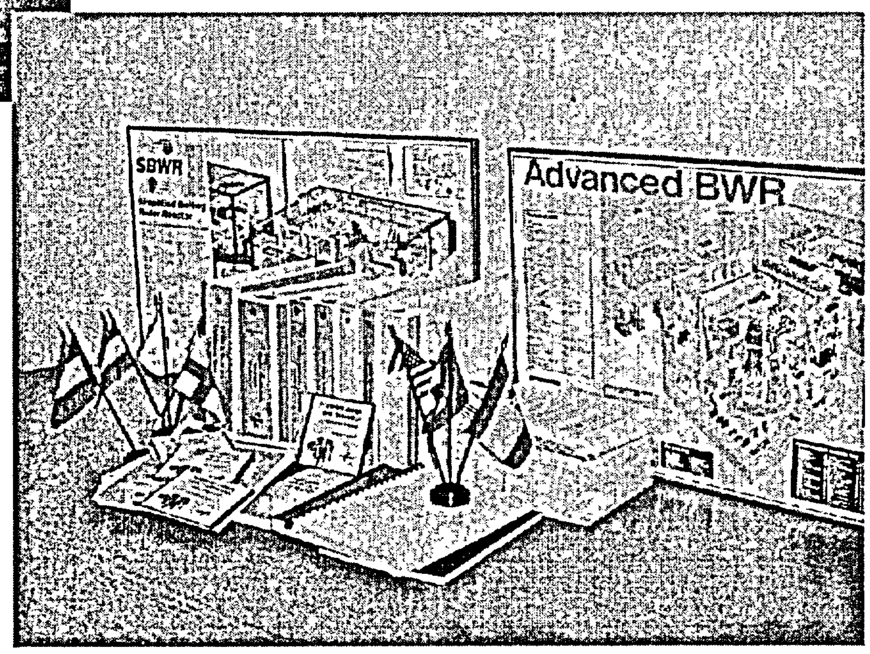
A complete, multi-year technology program supports the design

ar02-17

ESBWR Design/Technology based on SBWR and ABWR

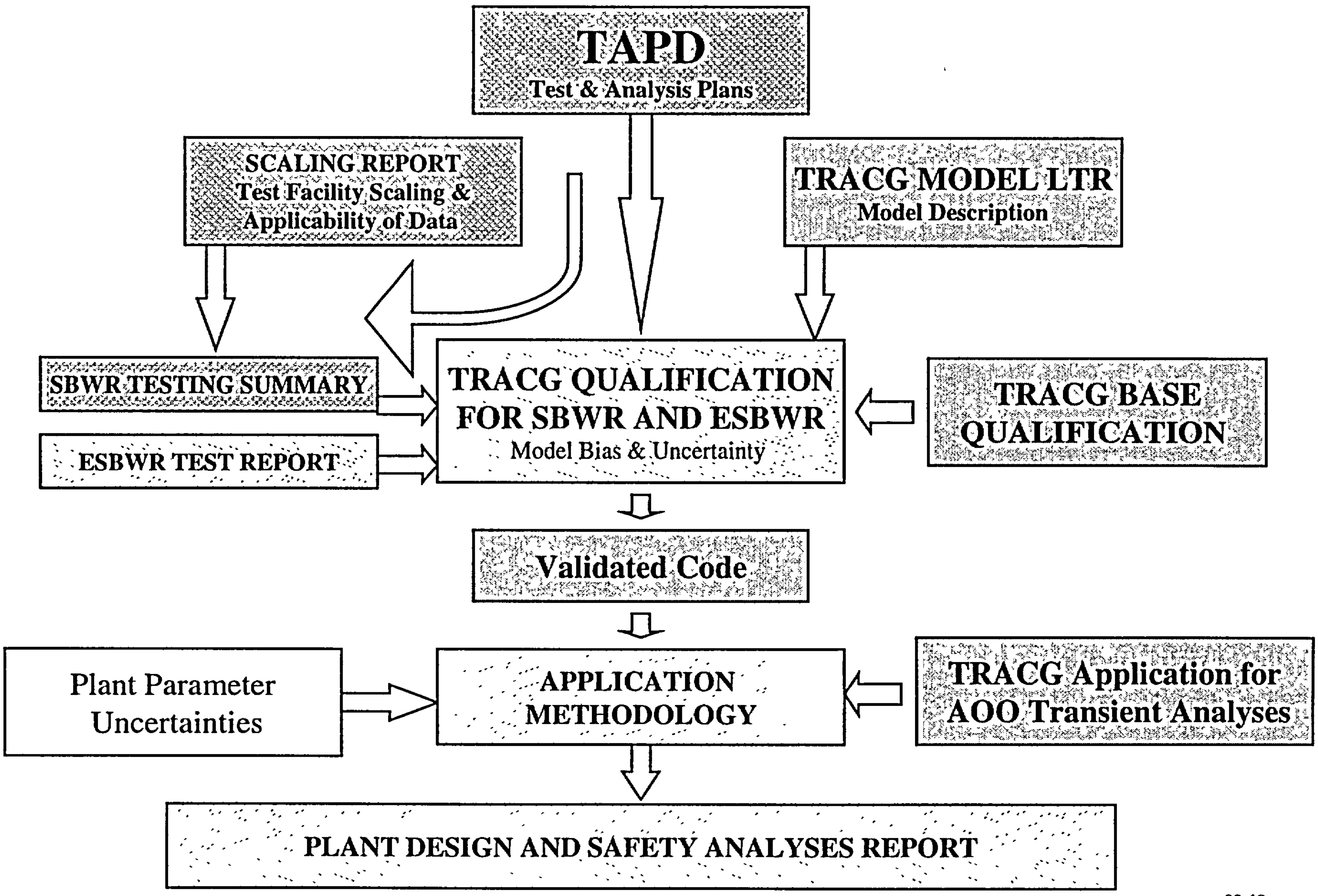


Extensive new submittals



Extensive SBWR submittals and reviews, new test data and reports, coupled with design changes to add margin

ESBWR Technology Program Elements



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Summary and Conclusions

- ***Passive safety systems have simplified the plant design***
- ***Plant evaluations are simpler***
  - Less complex analyses
  - Low parameter uncertainty - ± 0.5C for PCT!
- ***Substantial margins exist in the design***
  - Improved mechanistic codes show better performance
  - Defense in depth systems provide additional back-up
- ***Extensive qualification of TRACG***
- ***Technology issues extensively studied***
  - Independent studies provide confidence in technical bases

Performance improved by design features
Improved performance measured by qualified methods

ar02-20

FRAMATOME ANP

SWR 1000 Design Overview

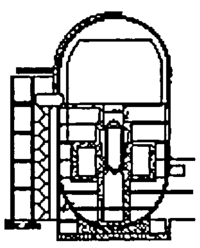
Roger Stoudt

October 10, 2002
Advisory Committee on Reactor Safeguards
Rockville, MD

FRAMATOME ANP

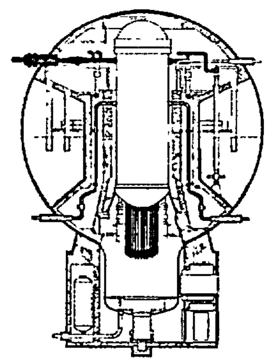
Evolution of Framatome ANP's BWR Technology

- Kahl
- Gundremmingen A
- Lingen (1st Fine Motion CRD - 1968)



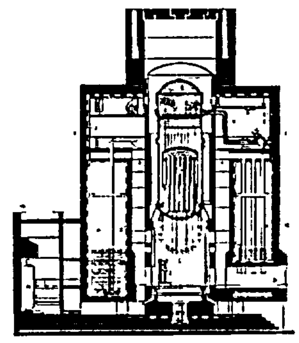
Full pressure containment - 61

- Würgassen
- Brunsbüttel (1st Internal recirc pump - 1977)
- Philippsburg 1
- Isar 1
- Tullnerfeld
- Krümmel

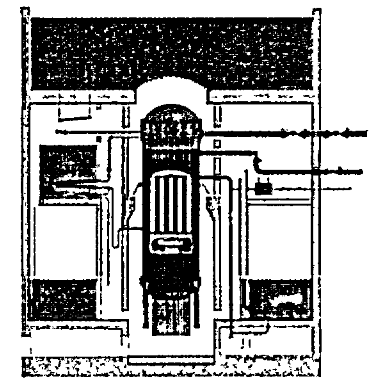


Product Line 69

- Gundremmingen B/C (3 train RHR & prestressed concrete containment - 1984/85)



Product Line 72



SWR 1000

FRAMATOME ANP

SWR 1000 Plant Parameters

> Thermal Power	3370 MW
> Electric Net Power	1253 MW
> Number of 12x12 fuel elements	664
> Inner Diameter of RPV	7.12 m (23.4 ft)
> Fuel Element Active Length	3.0 m (9.84 ft)
> Number of control rods	157
> Number of main recirculation pumps	8
> RPV pressure	75 bar (1088 psia)
> Number of Safety Relief Valves	8
> Emergency Condenser (EC) Capacity	4 x 66 MW
> Containment Cooling Condenser	4 X 4.8 MW
> Number of Passive Flooding Systems	4
> Containment Diameter	32.0 m (105 ft)
> Maximum Containment Pressure	7.9 bar (115 psia)

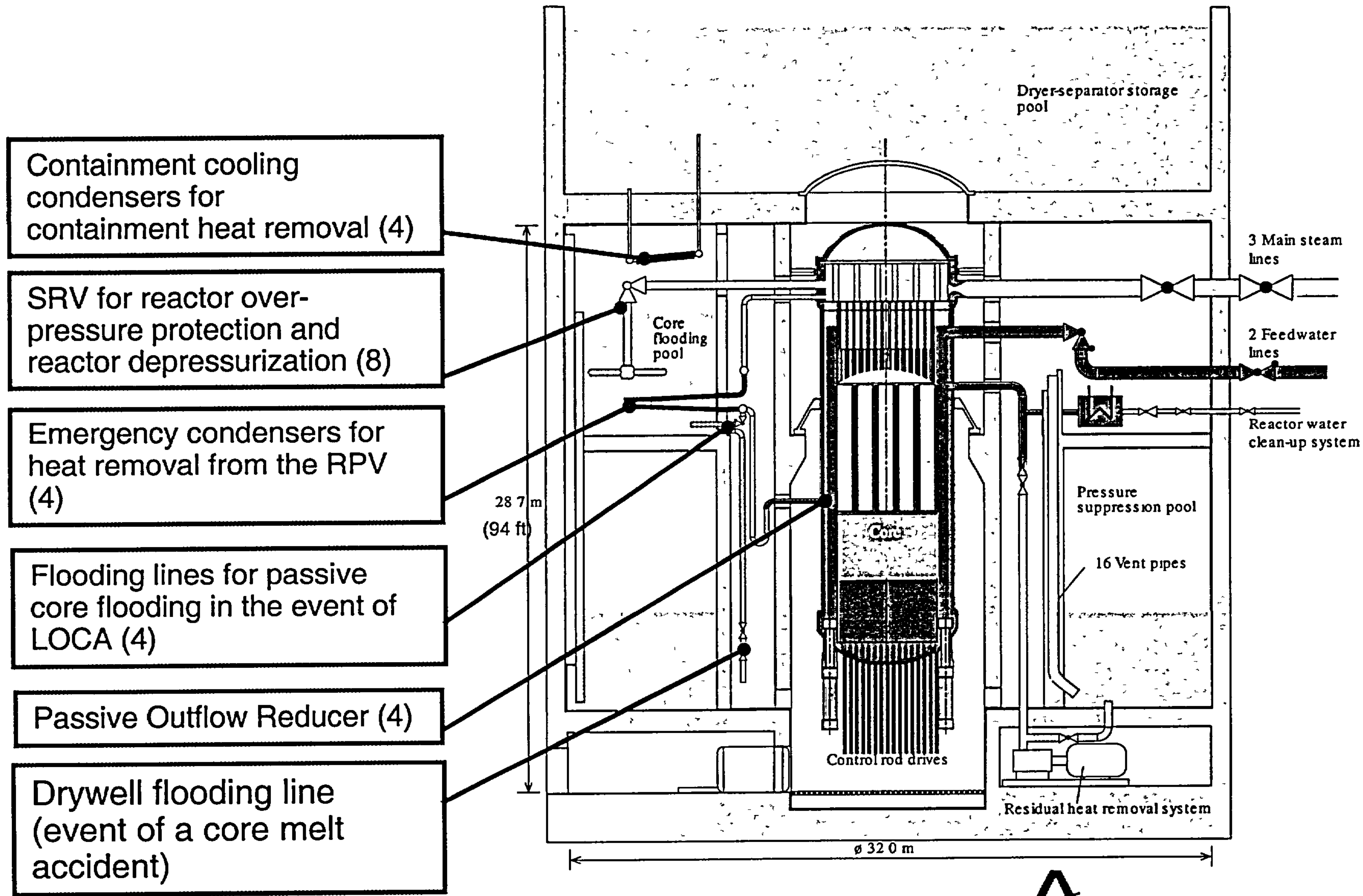
FRAMATOME ANP

Safety Approach

> All active systems have passive safety-related backup to perform nuclear safety functions

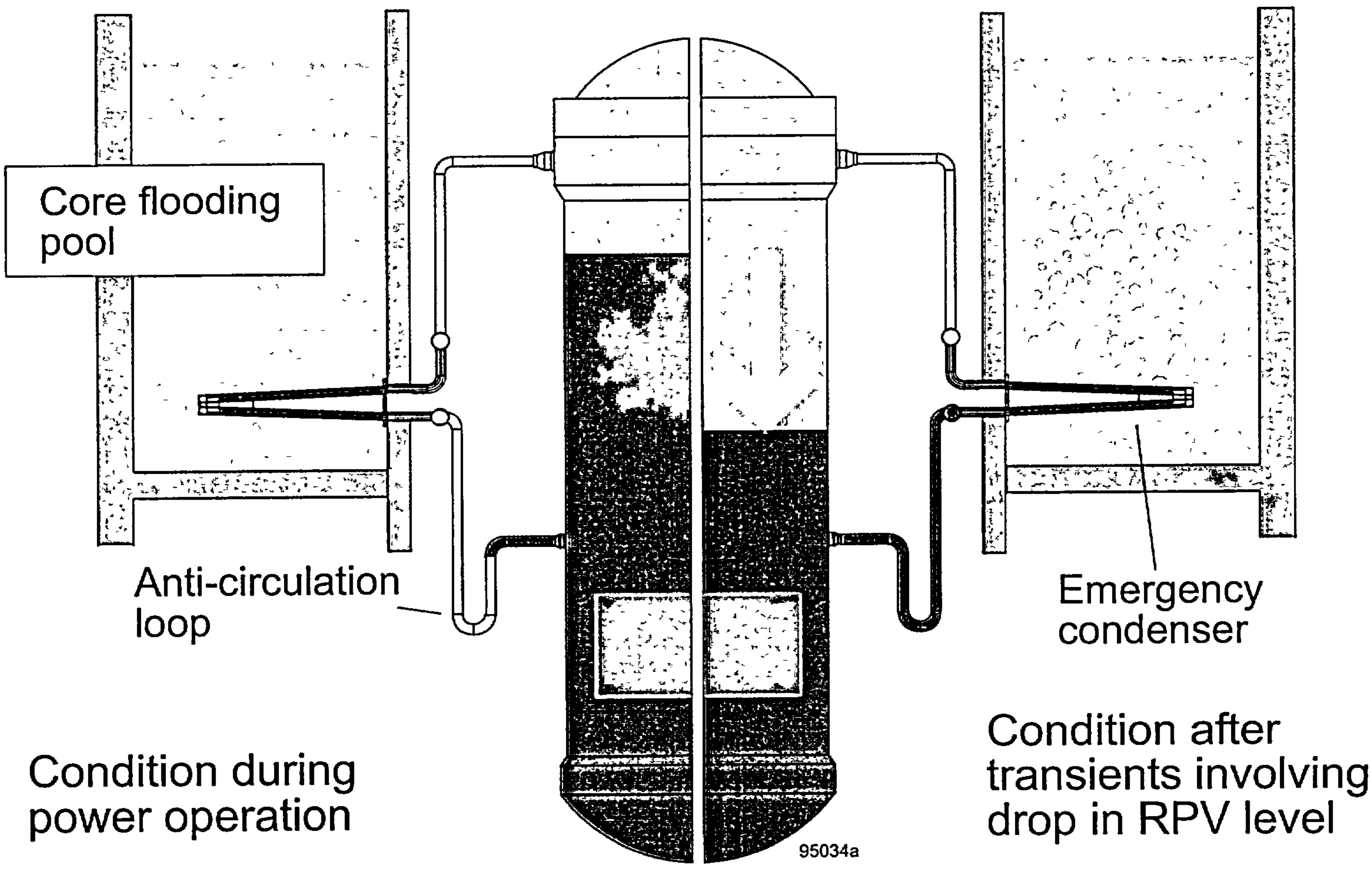
> SWR 1000 defense-in-depth design incorporates safety-related passive systems that are designed to meet all nuclear safety criteria without reliance on active systems

SWR 1000 Passive Safety Concept

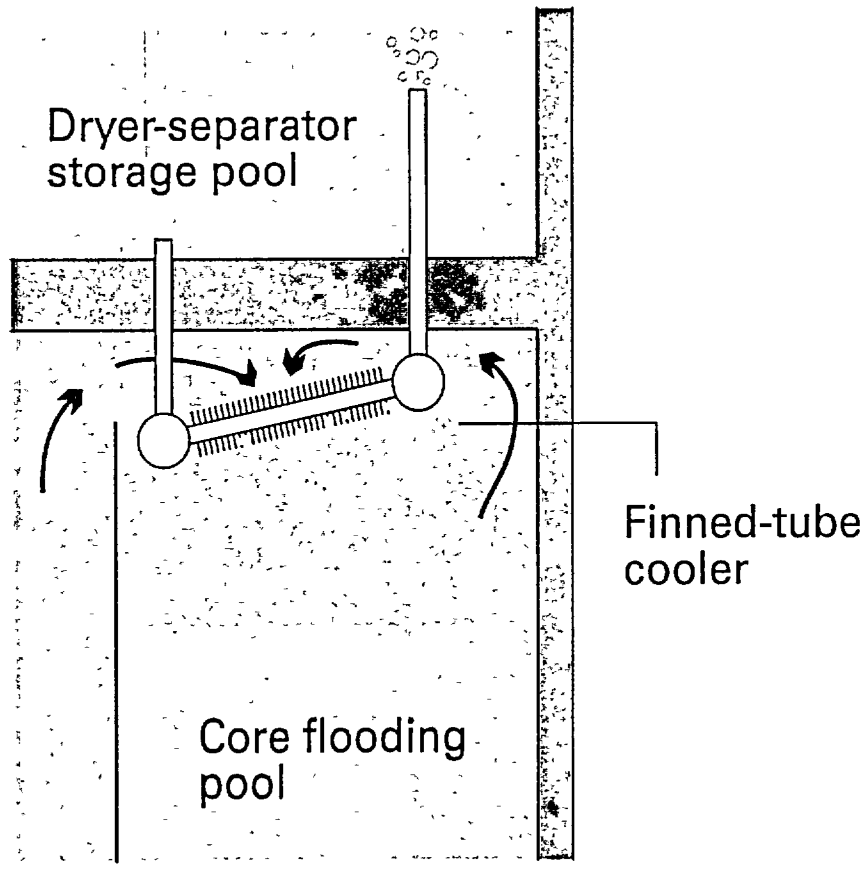


FRAMATOME ANP

Passive Safety Systems: Emergency Condenser

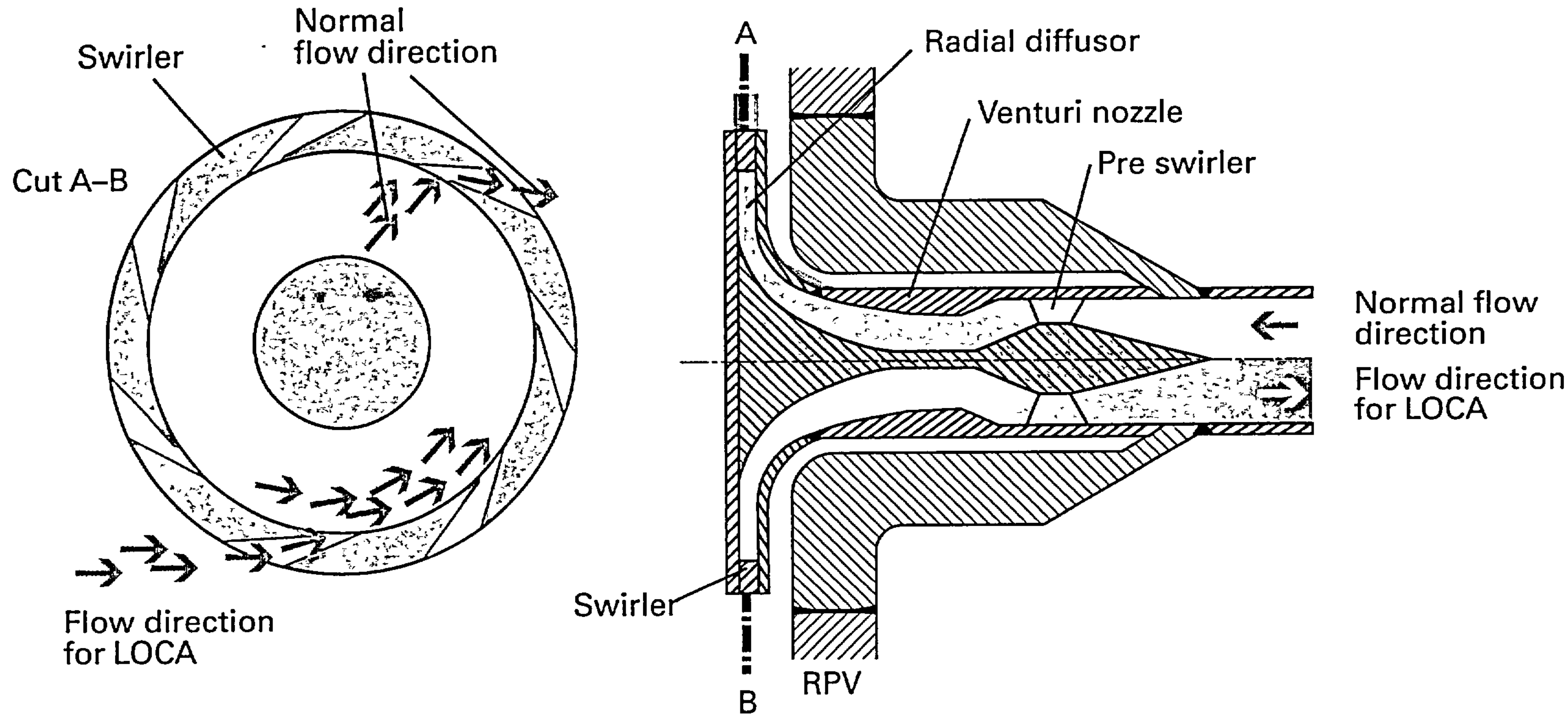


Passive Safety Systems: Containment Cooling Condenser



Containment Cooling Condenser

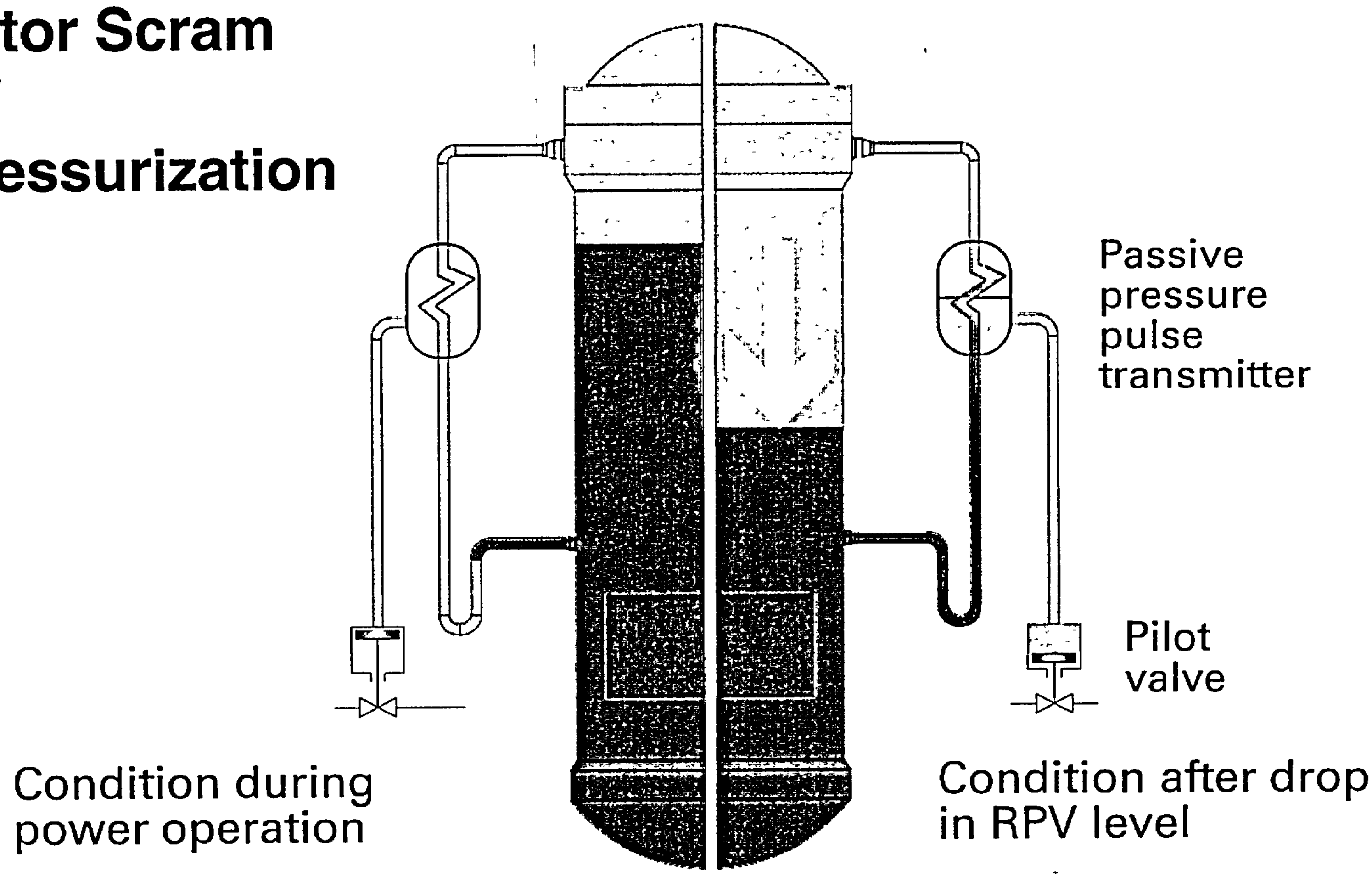
Passive Outflow Reducer



FRAMATOME ANP

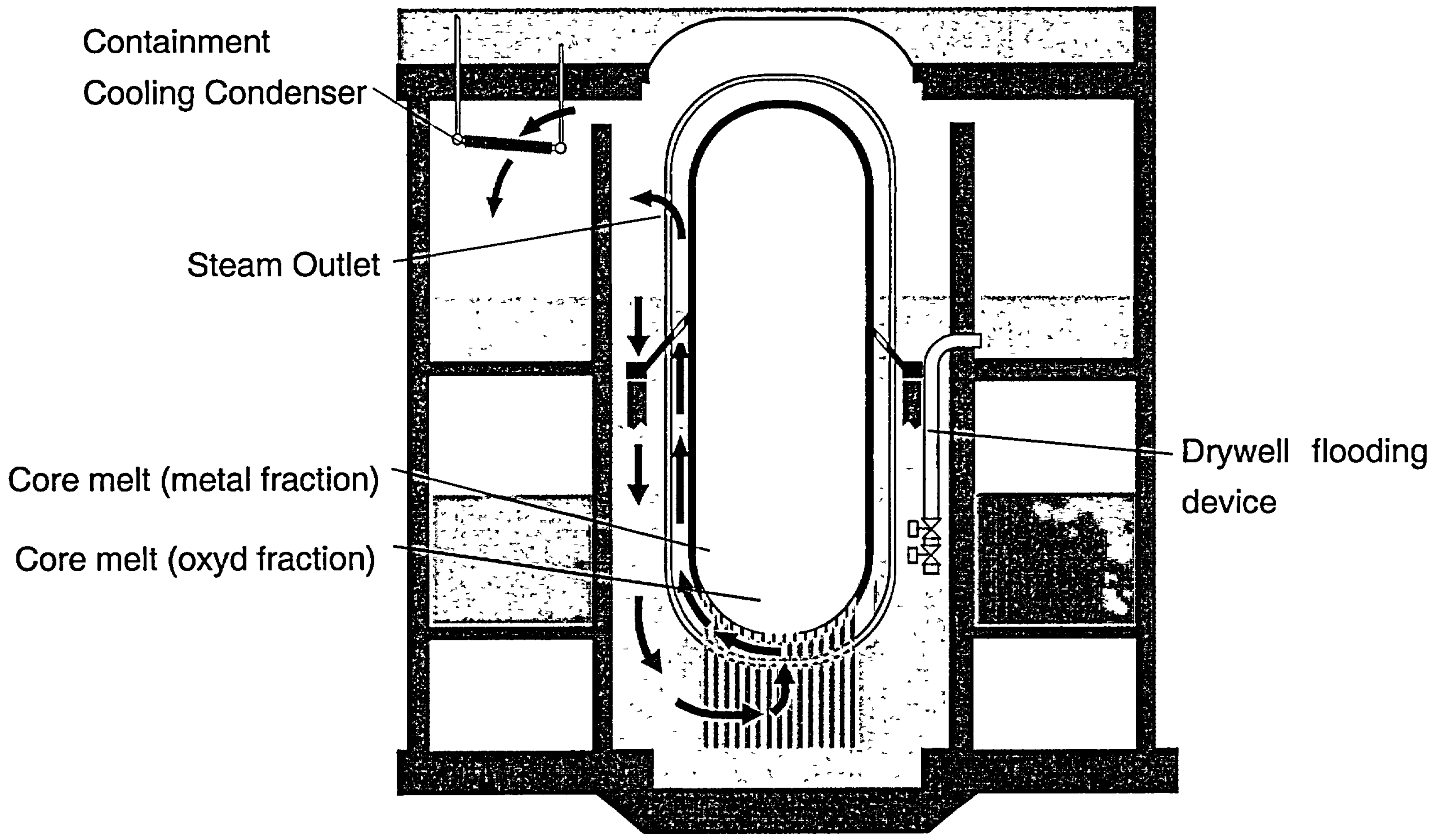
Passive Pressure Pulse Transmitter: Passive Safety System Actuation Device (Patented)

PPPT actuates
- **Reactor Scram**
- **MSIV**
- **Depressurization**



FRAMATOME ANP

Severe Accident Control
Core Melt Retention in the RPV



FRAMATOME ANP

Summary

> Important SWR 1000 Features
  - Large water inventory inside the RPV
  - Large water inventories inside the containment for heat storage and flooding
  - Nitrogen-inerted containment atmosphere
  - Passive equipment for heat removal from the RPV and containment
  - Passive actuation of key safety functions
  - Passive, external cooling of the RPV and melt retention within the RPV in the case of severe accidents

> In the event of transients or LOCAs and utilizing only passive systems, stable conditions can be established without outside intervention of personnel for several days.

Testing

> Tests Performed
- Emergency Condenser (EC)
- Containment Cooling Condenser (CCC)
- Passive Pressure Pulse Transmitter (PPPT)
- Passive Outflow Reducer (POR)
- RPV Flooding Line
- Reactor Pressure Vessel Exterior Cooling
- CONGA - CCC heat transfer in presence of aerosols
- SCRAM Tank

> Future Tests
- Fast Acting Boron Injection System
- Spring Support Check Valve (RPV Flooding Line)
- Vent Pipes and Quenchers
- Control Rod Drives

FRAMATOME ANP

Advanced CANDU Reactor
(ACR™)

Presentation to the
Advisory Committee on Reactor Safeguards
October 2002

Dr. V.G. Snell
Director, Safety & Licensing
ACR

AECL
TECHNOLOGIES INC.

Advanced CANDU Reactor
(ACR™)

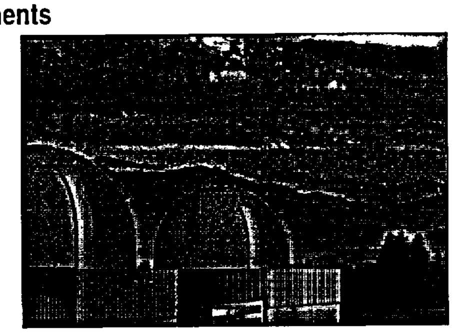
Presentation to the
Advisory Committee on Reactor Safeguards
October 2002

Dr. V.G. Snell
Director, Safety & Licensing
ACR

AECL TECHNOLOGIES INC.

Outline

1. What is ACR?
2. Meeting Customer Requirements
3. Technical Summary
4. Safety Improvements
5. Technology Base
6. Status
7. Licensing Opportunities
8. Conclusions



AECL TECHNOLOGIES INC.

1. What is ACR?

- The ACR is an evolutionary extension of the proven CANDU 6, which has eight units in operation on four continents, two units currently under construction, and one which went critical in September 2002

2. Meeting Customer Requirements

Specific overnight capital cost:	$1,000/kWe
Construction schedule:	36 months
LUEC:	$30/MWh
Capacity factor:	>90%
Plant Operating Life:	60 years

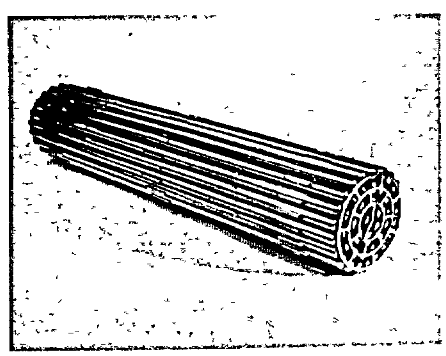
AECL TECHNOLOGIES INC.

Achieving Low Capital Cost

- Current operating CANDUs:
  - Natural uranium fuel
  - Heavy water (D_2O) coolant
  - Heavy water (D_2O) moderator
- ACR - relax constraint of Natural Uranium Fuel and --
  - Use light water coolant
  - Reduce core size & reduce amount of heavy water moderator
  - Increase pressure tube thickness
    - Increase reactor coolant system (RCS) pressure
    - Increase thermal efficiency
- Retain intrinsic proven CANDU features

3. Technical Summary - Fuel

- 0.5m (1.6 foot) long CANFLEX fuel bundle
- On-power refueling
- 43 fuel rods
  - 2.0 wt% ^{235}U SEU in 42 rods
  - NU + 4% dysprosium in central rod
- Fuel burn-up 20,500 MWd/MT (U)
  - higher than NU CANDU average
  - modest vs. LWRs
- Higher bundle power, lower rod rating



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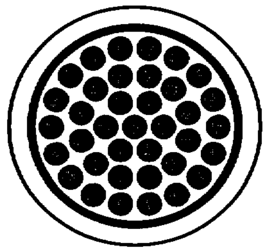
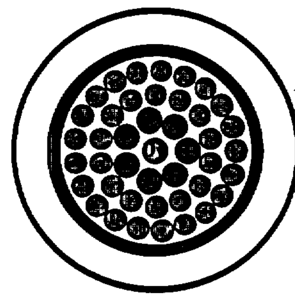
Fuel Channel

CANDU 6



ACR

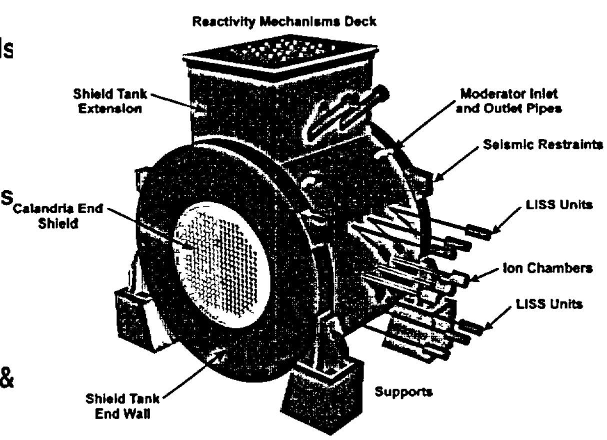


- 37-rod NU fuel
- Zr – 2.5% Nb pressure tube
- Zr-2 calandria tube
- Insulating gap between pressure tube and calandria tube

- 43-rod SEU fuel
- Thicker Zr – 2.5% Nb pressure tube
- Stronger Zr-4 calandria tube
- Larger gap between pressure tube and calandria tube

Reactor

- Horizontal fuel channels surrounded by low temperature, low pressure moderator
- Steel calandria contains moderator & supports fuel channels
- Shield tank surrounds calandria and contains light water for thermal & biological shielding
- All reactivity devices in moderator



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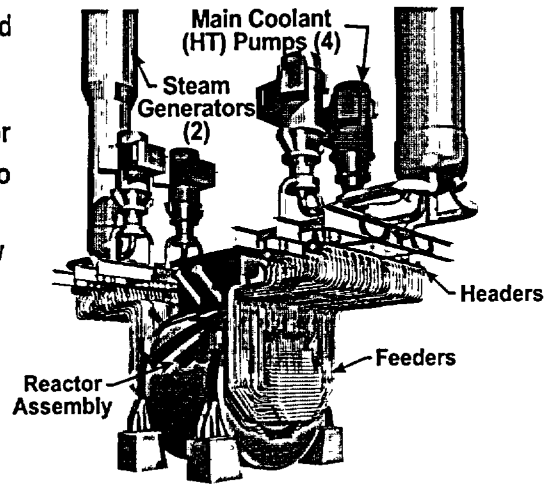
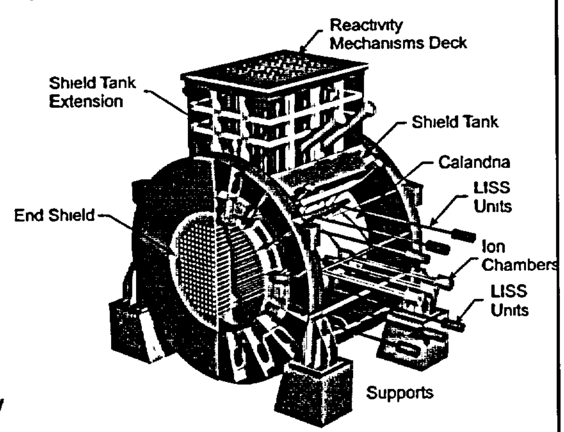
Reactor Coolant System

- Each channel is connected at its inlet and outlet by small (feeder) pipes to headers, above the reactor
- Above headers – similar to PWRs
- No large pipes at or below core level
- Tolerates pump seizure
- Natural circulation, even with some void



Safety Systems

- Two fully independent shutdown systems
  - SDS1 – rods drop in moderator
  - SDS2 – liquid absorber injected into reflector
- Two stage Emergency Core Cooling System
  - Initial injection from pressurized tanks
  - Long term pumped recovery
- Steel-lined dry pressure containment



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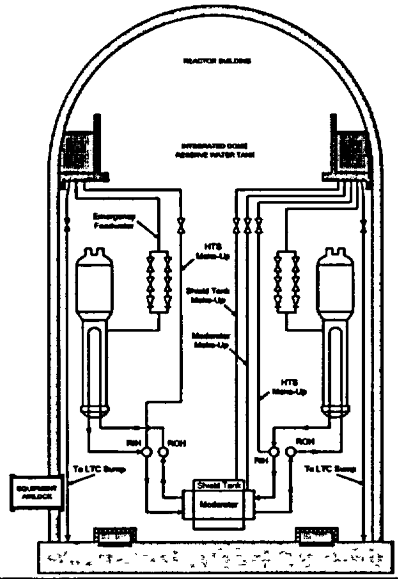
Severe Accident Resistance

Elevated Reserve Water Tank can add water by gravity to:

- Reactor coolant system
- Steam generators
- Moderator
- Shield tank

Moderator can remove decay heat from fuel channels without UO_2 melting

Shield tank can slow down or arrest graceful severe core damage progression



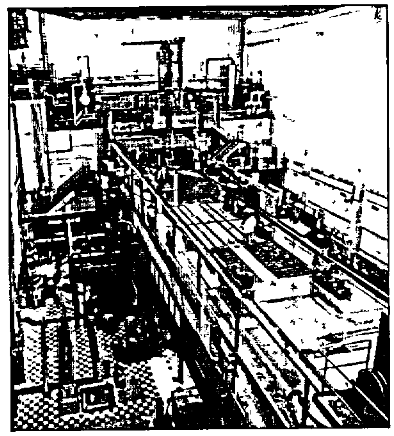
4. Safety Improvements

- Small negative void coefficient
- More negative power coefficient over operating range
- Larger thermal margins due to CANFLEX fuel
- Pressure-tube failure contained within calandria tube
- Improved heat sink reliability
- Inter-unit ties enhance reliability of safety support systems
- Inherent shutdown on single channel failure
- Steel-lined dry containment
- Extended seismic qualification
- Severe accident prevention & mitigation
- Design insights from generic CANDU PRA; ACR design-assist PRA

5. Technology Base

- ACR is an evolutionary improvement of operating CANDUs
- CANDU technology base developed & maintained by AECL & CANDU utilities
  - 2000 people at Chalk River Laboratories
- ACR R&D is anticipatory
  - Modest extension of databases to ACR conditions
  - Confirm code validity
  - Confirm performance of modified components

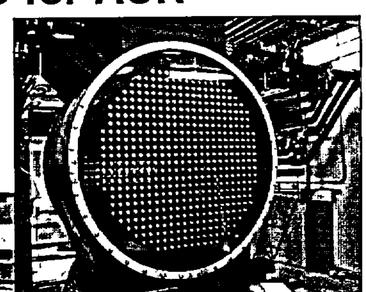
NRU Reactor – Fuel, Materials & Safety Tests

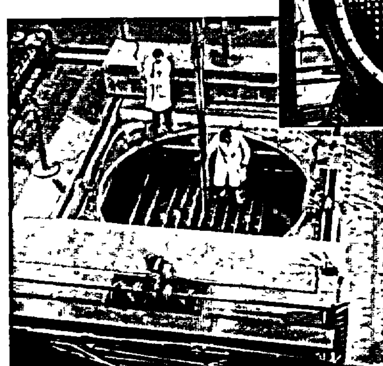


Anticipatory R&D for ACR

- Fuel
- Fuel channel
- Fuel handling
- Components
- Safety code qualification

Moderator test facility





ZED-2 Reactor

AECL TECHNOLOGIES INC.

6. Status

- ACR-700 concept complete (reference design); ACR-1000 being considered
- Non-site-specific engineering complete 2005
- Hitachi investing in BOP optimization and plant-wide modularization
- Construction strategy and schedule defined
- Working with Canadian, US and UK utilities to bring ACR to commercialization

Status – Licensing

- Pre-application review started with USNRC; expect 2 years
  - Application for Standard Design Certification and/or COL
- Pre-licensing review also started in Canada to confirm licensability under Canadian regulations
- Possibility of pre-licensing review in UK

7. Licensing Opportunities

- Use of extensive Canadian regulatory, R&D & operating experience in NRC review
  - Acceptance of equivalence in meeting safety requirements
- Flexibility of NRC requirements to accommodate a technology both similar to and different from LWRs
- Co-operation with parallel regulatory reviews in Canada and possibly UK
  - Extent of common ground & consistency

8. Conclusions

- ACR is an evolutionary design building on proven CANDU 6 design and operation
- ACR meets the market economic, schedule and risk requirements
- SEU CANFLEX fuel contributes to improvements in both economics and safety
- R&D is anticipatory; modest extension of conditions and components
- NRC review requirements and processes could take advantage of prior CANDU licensing experience, and parallel reviews in Canada (& possibly UK).

AECL
TECHNOLOGIES INC.

Technical Related Policy Issues for

Future Non-Light Water Reactors

Presentation to ACRS-Full Committee
October 10, 2002
T. L. King, NRC/RES
301-415-6345

Objective of Briefing

- To discuss the schedule and options for resolution of the seven policy issues for future non-LWRs described in SECY-02-0139:
  - Expectations for safety
  - Defense-in-depth
  - Use of international codes and standards
  - Event selection
  - Source term
  - Containment vs. confinement
  - Emergency preparedness
- To solicit verbal feedback from the Committee regarding the options, including advantages and disadvantages, and to discuss plans for future meetings with ACRS

Background

- Current regulations are a combination of generic and LWR oriented requirements

- Previous licensing of non-LWR designs was based upon:
  - A review of the design against the regulations current at that time
  - A case-by-case determination regarding the applicability of the regulations
  - The need for additional requirements to address any unique aspects of the design/technology

- Pre-application reviews are an opportunity for early review and guidance on licensing/safety issues

Background

Continued

- **Useful to get Commission guidance early:**
  - **To support case-by-case reviews**
  - **To support development of a generic approach (framework)**

- **Pre-application work to date on PBMR and GT-MHR has identified technical issues with potential policy implication for non-LWRs**

- **Some of these issues had been raised in previous pre-application reviews (e.g., MHTGR)**

- **Scope of issues**
  - **Reactor design**
  - **Reactor operation**

Schedule

- **Public Workshop**
  - October 22-23, 2002
  - Doubletree Hotel, Rockville
- **ACRS**
  - November/December
  - Subcommittee/Full Committee
- **Paper due to Commission**
  - December 30, 2002

Expectations for Enhanced Safety

- **<u>Issue</u>: How to implement the Commission's expectations for enhanced safety (as expressed in the Commission's Policy Statements on Advanced Reactors and Severe Accidents)**

- **<u>Options</u>:**
  - Require current level of safety
    - With expectation that applicants will provide enhanced safety
  - Require enhanced level of safety
    - e.g., more stringent CDF
  - Require enhanced level of confidence
    - e.g., additional testing, additional oversight
  - Encourage industry to implement enhanced safety

Expectations for Enhanced Safety

Continued

- **Key Considerations:**
  - Additional reactors
    - Per site
    - Nationwide
  - Safety Goal Policy
    - Risk to individuals around a plant vs. site?
  - Performance Goal
    - Maintain safety - impact of more plants nationwide on performance measures?
  - Role of enhanced accident prevention in compensating for larger uncertainties in severe accident area?
  - Implications for future LWRs?

Defense-in-Depth (DID)

- **Issue: How to specify DID for non-LWRs**
  - Mentioned in Commission policies, but no articulation as to the elements of DID
  - Commission definition provided of DID in 1999 RIPB regulation white paper
  - IAEA and INSAG have description of DID

- **Options:**
  - Case-by-case determination, depending upon:
    - Plant design
    - Uncertainties
  - Develop description or policy statement articulating the elements of DID
  - Develop description or policy statement articulating DID as programmatic process

Defense-in-Depth (DID)

Continued

- **Key Considerations:**
  - Scope of DID?
    - Programmatic vs. physical elements
    - Reactor design vs. Other factors
  - RROP Cornerstones?
  - Foundation for future licensing framework?
  - Guidance for areas other than licensing e.g.:
    - Reg Analysis Guidelines?
  - Implications for future LWRs?
  - Coordination with non-reactor activities?

International Codes and Standards

- **Issue:** How should NRC requirements for non-LWRs relate to international safety standards and requirements?

- **Options:**
  - No specific initiative
    - Review on an as necessary basis as part of an applicant's licensing submittal
  - Review and endorse existing codes and standards, whenever practical
  - Participate in the development of codes and standards and endorse, whenever practical
  - Attempt to harmonize requirements with other regulatory bodies

International Codes and Standards

Continued

- **Key Considerations:**
  - NRC Management Directive 6.5
    - Public Law 104- 113
    - Office of Management & Budget Circular A-119
  - International nature of future design efforts and marketing
  - Usefulness in compensating for areas where there are gaps in NRC expertise or infrastructure?

Event Selection

- <u>Issue</u>: **To what extent can a probabilistic approach be used to establish the licensing basis:**
  - Event selection?
  - Safety classification?
  - Replace single failure criterion?

- <u>Options</u>:
  - Use a deterministic approach, supplemented by PRA
  - Use a probabilistic approach
  - Use a probabilistic approach, supplemented by engineering judgement

Event Selection

Continued

- **<u>Key Considerations</u>**:
  - Previous Commission guidance
    - SRM of July 30, 1993
  - Probabilistic criteria for event categories?
  - Probabilistic criteria for safety classification?
  - Probabilistic approach to replace the SFC?
  - PRA quality, completeness, document control?
  - Level of confidence?

Source Term

- **Issue: Under what conditions should scenario specific accident source terms be used for licensing decisions?**

- **Options:**
  - Develop a deterministic bounding ST
  - Allow the use of scenario specific ST

Source Term

Continued

- **Key Considerations:**
  - Previous Commission guidance
    - SRM of July 30, 1993
  - Scenario specific approach may depart from practice where ST is based upon core melt
  - Role of robust ST in DID?
  - Scenario specific approach puts more burden on understanding plant, fuel and fission product behavior over the life of the plant
  - Level of confidence?

Containment vs. Confinement

- **Issue: Under what conditions can a plant be licensed without a pressure retaining containment building?**

- **Options:**
  - Require a pressure retaining building
  - Allow a design without a pressure retaining building

Containment vs. Confinement

Continued

- **Key Considerations:**
  - Previous Commission guidance
    - SRM dated July 30, 1993
  - Related to resolution of event selection and ST issue
  - Should a pressure retaining building be a fundamental element of DID?
  - Impact on safety?
  - What criteria should be met to allow a design without a pressure retaining building?

Emergency Preparedness

- <u>Issue</u>: **Under what conditions can the EPZ be reduced, including a reduction to the EAB?**

- **<u>Options</u>:**
  - No reduction from current requirements
  - Allow a reduction in the EPZ
  - Allow a graded approach within the EPZ

Emergency Preparedness

Continued

- **<u>Key Considerations</u>:**
  - Previous Commission guidance
    - SRM of July 30, 1993
  - Related to defense-in-depth
    - last line of DID
  - Related to resolution of event selection, ST and containment issue
  - What criteria would be used to reduce the EPZ?
  - Credit for long response time?