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& Probability Risk Assessment Joint
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NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARD

(ACRS)

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JOINT SUBCOMMITTEE ON THERMAL-HYDRAULIC PHENOMENA AND ON RELIABILITY AND PROBABILISTIC RISK ASSESSMENT

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FRIDAY, JANUARY 18, 2008

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ROCKVILLE, MARYLAND

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The Advisory Committee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2B3, 11545 Rockville Pike, Rockville, Maryland at 8:30 a.m., Sanjoy Banerjee, Chairman, presiding.

COMMITTEE MEMBERS:

SANJOY BANERJEE, Chairman
SAID ABDEL-KHALIK, Member
DENNIS C. BLEY, Member
WILLIAM J. SHACK, Member
JOHN D. SIEBER, Member
GIRIJA S. SHUKAL, Designated Federal Official

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ADJOURN:

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

8:33 a.m.

CHAIRMAN BANERJEE: The meeting will now come to order. This is a joint meeting of the ACRS Subcommittees on Thermal-Hydraulics Phenomena and Reliability and PRA. I'm Sanjoy Banerjee, Chairman of the Thermal-Hydraulics Phenomena Subcommittee. ACRS Members in attendance are Said Abdel-Khalik, Jack Sieber and William Shack. Girija Shukal of the ACRS staff is the designated federal official for this meeting.

The purpose of this meeting is to discuss the results of Cable Response to Live Fire, CAROLFIRE, testing and fire model improvement. Including staff's resolution of public comments. In addition, the Subcommittees will be briefed on the fire model phenomena identification and ranking table. We will also hear presentations from the NRC staff.

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

The rules for participation in today's meeting have been announced as part of the notice of this meeting previously published in the <u>Federal</u>

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

The transcript of the meeting is being kept and will be made available as stated in the Federal Register notice. Therefore, we request that participants in this meeting use the microphones located throughout the meeting room when addressing the Subcommittee. The participants should first identify themselves and speak with sufficient clarity and volume, so that they may be readily heard.

We will now proceed with the meeting. I call upon Mr. Mark Salley of the Office of Nuclear Regulatory Research to begin. Thank you. Mr. Salley?

MR. SALLEY: Yes, can somebody flip these slides? Good morning, gentlemen. We have two topics, somewhat different, that we would like to discuss with you today.

Next slide. CAROLFIRE, Cable Response to Live Fire. This is a very unique project that we have completed. CAROLFIRE originates as a user need from the Office of Nuclear Regulatory -- or excuse me, NRR. I'll just stick with the acronym. It is a response to RIS 2004-03, where after the expert committees had met and industry completed their testing, there was a number of cable configurations that were unknown as to how they were going to respond via hot shorts, so the user need drove that.

And also a very interesting thing with CAROLFIRE is we took the initiative in the Office of Research to look at the fire modeling. We also have fire modeling work that is ongoing. And when we look at how the fire models are used in RIS applications in the plant, one of the key targets that at the end of the day the analysis always gets down to is when do the cables fail? And that is an area that had a fair amount of uncertainty. I say uncertainty and I don't see George here.

CHAIRMAN BANERJEE: Yes, he is stuck in Boston.

MR. SALLEY: Okay.

CHAIRMAN BANERJEE: We just got an email at 12:45 last night.

MR. SALLEY: Okay.

CHAIRMAN BANERJEE: Thank you.

MR. SALLEY: But the idea of predicting cable damage using the fire models had an area of uncertainty. We took the opportunity with CAROLFIRE to look into that and I'll tell you a little more about that.

With today's meeting with CAROLFIRE, we would like to request a letter from the ACRS to go forth and publish. Like I said, we are complete. We have gone through all the steps and we would like to publish it and move on to our next project.

The second topic, again, I'm sorry George isn't here, but at a previous meeting we had informed the Committee that we were going to undertake the first of our knowledge, an actual PIRT to look at fire modeling. And the Committee asked to be informed of what we saw in the PIRT process. We have completed the meetings and we've got the write up started and we wanted to give you an information talk on how the PIRT went. Next slide.

CHAIRMAN BANERJEE: The letter that you are requesting is with regard to the three reports we have right now?

MR. SALLEY: The three volumes of CAROLFIRE.

CHAIRMAN BANERJEE: Right.

MR. SALLEY: And that's what I'll talk to a little bit.

CHAIRMAN BANERJEE: Now, two of those are final that we have seen in the sense that they -- Volume I and II have taken into account ACRS comments that you have had, public comments. What is the status of Volume III, which is this fire modeling?

MR. SALLEY: Volume III is also final.

CHAIRMAN BANERJEE: Okay.

MR. SALLEY: Okay. It's a contractor report. It is coming from NIST. And in the big scheme of things with CAROLFIRE, like I said, we had a user need that drove us. That was why we did the project. And we answered those questions in Volume I. So Volume I, basically, answers what NRR asked us on the circuit configurations.

We took the initiative to gather a lot of thermal data. When you look at cable response in fire, a lot of people for a lot of years have looked at things and there is no test standard. I can't put on ASTM this is how you do it. Every researcher went and did it a little differently. Where did you measure your temperatures? How did you measure your temperatures? How did you determine cable functionality?

These are things that the research community, everyone does a little different. We took the opportunity with CAROLFIRE to gather some high quality thermal data of how the cables were responding. We put that together and we assembled it as Volume II. Both those projects were done by Sandia National Labs.

As another partner on this project, we had NIST involved. They work a lot with us with the fire modeling. What Volume III does was it takes the data in Volume II and puts it into a practical tool that can be used to predict the cable damage. And that's the whole key of our work. In research, you know, our job is to create the tools for the other offices to use. And that's what Volume III will capture.

CHAIRMAN BANERJEE: So the sort of letter you are looking for is to say that we have reviewed it and whatever comments we have left to put them down and then, presumably, these results will be used in some way by NRR or whatever other organization, but they will come up with a methodology to use it and apply it and so on. We're not going to deal with that issue today, right?

MR. SALLEY: That is --

CHAIRMAN BANERJEE: It should be applied.

MR. SALLEY: -- correct. What Volume III does is Kevin McGrattan from NIST is going to address it and explain to you what he had done. He, basically, had done some of the research of taking the test data and the thermal data and putting it into a practical application that can be incorporated as a sub-routine into a fire model or we're actually looking if we could do it into a hand-type calculation in order to reduce the uncertainty with cable performance during fire.

CHAIRMAN BANERJEE: So you want a comment on that model, but beyond that, we noticed that there were quite a few comments from NEI regarding the applicability of this data and all that sort of stuff now.

MR. SALLEY: If my memory serves me correctly, and I have the guys here that actually went through each comment, NEI's focus was all on Volume I. I don't believe --

CHAIRMAN BANERJEE: And the forward of Volume I it seemed.

MR. SALLEY: Well, yes.

CHAIRMAN BANERJEE: Right.

MR. SALLEY: Yes, and they will explain to you our comment resolution.

CHAIRMAN BANERJEE: All right.

MR. SALLEY: The key with this document and like I said with CAROLFIRE is we have gone through an extensive review. Any review that I could have put this through, I believe we have exercised. We went through the formal research peer review process, which we can talk to you about and the different peer reviews we had.

We sent the document out for public comment. Industry requested more time for the public comments. We allowed them more time to give us the comments. They sent the comments in. The Office of Research submitted this to the ACRS to look at it on the quality aspect and you all performed a quality review on this.

And now, my final step, and I believe I have checked every box, is to ask for the letter to go forth, publish this and move on to the next project.

CHAIRMAN BANERJEE: Okay.

MR. SALLEY: So I believe we have covered everything on that. Next slide.

MR. KLEIN: Could I add something, Mark, please?

MR. SALLEY: Yes, Alex.

MR. KLEIN: My name is Alexander Klein. I'm the Fire Protection Branch Chief in the Office of Nuclear Reactor Regulations. And we will address the application of Volume I from NRR's perspective on a slide following the presentations by Steve Nowlen later on this morning.

CHAIRMAN BANERJEE: Okay.

MR. KLEIN: So hopefully that will, you know, answer some of these questions.

CHAIRMAN BANERJEE: But that doesn't necessarily become part of our letter. You are really looking for a letter, if I understand it, which comments on the publication of those three volumes?

MR. SALLEY: Yes. The letter is to --

MR. KLEIN: A PRA man.

CHAIRMAN BANERJEE: Oh, we have, excuse me, to introduce you, Dennis Bley, ACRS Member, who now presumably can say something about PRA. We don't have George here, Dennis.

MEMBER BLEY: George isn't here.

CHAIRMAN BANERJEE: Well, he is stuck in Boston.

MEMBER SHACK: He won't be here.

MEMBER BLEY: Oh, he won't be.

CHAIRMAN BANERJEE: Yeah.

MEMBER BLEY: Okay.

CHAIRMAN BANERJEE: So we have a PRA man. Okay.

MEMBER BLEY: Good.

CHAIRMAN BANERJEE: Yeah.

MR. SALLEY: Now, as Alex was saying, you know, the key in research is that we do the research that's necessary and we create the tools to allow the other offices, in this case NRR, to be successful. So I thank Alex and some of his staff will be here, because we can see the progression of the meeting. After we have done something, your questions would follow-on, but what is NRR going to do with it?

Hopefully, we've got the right people from Alex's branch here to say okay, this is how we tend to take this research product and to put it into actual play in the regulation arena. So Alex will do that.

CHAIRMAN BANERJEE: And once we have heard everything, then we discuss this.

MR. SALLEY: Okay.

CHAIRMAN BANERJEE: The matter of the letter again.

MR. SALLEY: Okay.

CHAIRMAN BANERJEE: Okay.

MR. SALLEY: Again, like I said, we are complete. We are on schedule to publish it. And it is a courtesy, because you had done so much work with us, that we wanted to come back to you and say hey, we're final, we're ready to go, are you comfortable with that too? Because it does have a lot of impact. I mean, it's research that is needed. It's things that the Agency is working through currently today.

The other topic that we put on here and we put this on again at your recommendation to be informed is, to the best of our knowledge, we performed the first ever Fire Modeling PIRT where we have done expert elicitations in fire modeling before. And people have done that. But we tried to take the formalized NRC process of doing a phenomena identification ranking table and to actually put that into the fire modeling arena.

So needless to say, when the -- Steve Nowlen will give you a discussion that. Sandia was our contractor. NIST with Kevin again supported us. This was new to the fire community. And we brought in the fire modeling experts to this and tried to explain to them what we were doing in the nuclear arena. So again, this will be something new and we just want to give this to you. You know, PIRT is what a PIRT is.

I mean, that's what the experts said, but we wanted to keep you informed of George's recommendation.

Next slide, please. You're going to hear principally from two people today. They are both active participants in these programs. Mr. Steve Nowlen, you all know Steve. He has burning cables now for 20-some odd years. And we burned a few more. But he will carry you thought a lot of the work that Sandia did.

We also have Dr. Kevin McGrattan from NIST. Our models, our partners, excuse me, in the fire modeling effort, which you are familiar with 1824 of the V&V that we had worked through. And Kevin is going to show you how we interpreted some of this CAROLFIRE data introducing the uncertainty with cable.

So those are the two prime people you will be hearing from today. As a final comment with this, with CAROLFIRE, especially, it's a very unique project. It was a very interesting project. And it was a collaboration from a lot of people. Of course, like we do in research a lot, we work with our prime contractor on this work, which is Sandia. We also had NIST involved to look at the fire modeling aspects. And we even took it a step further and we had the University of Maryland. One student actually did his PhD thesis on some of the distributions that he saw.

So we were sharing that data across this team and this team worked together as a unit. And when you look at the Volumes I, II and III, you will see Volumes I and II, obviously, done by Sandia. III was done by NIST. But I think the set comes together as a good coherent, cohesive approach from the beginning of this is the problem to this is the final resolution we have with it. So that was our intent to make this as a package.

And NIST actually picked their speed up a little bit. We expected Volume III somewhat later, but it did complete on time. So we were able to give you all three volumes, so you can see how the whole trilogy, if you will, worked out.

MEMBER SHACK: I just had a question. You are going to have CD with all the data on it.

MR. SALLEY: Yes.

MEMBER SHACK: What is the format of that going to look like?

MR. NOWLEN: I can address that.

MEMBER SHACK: You're going to be addressing that? Okay.

MR. SALLEY: Steve will address that, yes. We are going to put the data out there. So with that --

MEMBER SHACK: I also want to know what principles are they going to present?

MR. SALLEY: Oh, slide.

MR. NOWLEN: Yes, I saw that, too.

MR. SALLEY: All right. You got me.

Okay. It was never my strong point. Yeah, there you go. So with that, I would like to turn this over. Like I said, Alex Klein is going to have a couple of words. Like I said, it's only natural, you know, we are the tool makers. They are the ones who put the tools in place. We have asked Alex to say a couple of words.

CHAIRMAN BANERJEE: Does he want to speak now, Alex?

MR. KLEIN: Yes, but just a few minutes, if I could, please.

CHAIRMAN BANERJEE: All right. Sure.

MR. KLEIN: Thank you, Mark, I appreciate it. This is -- I'm Alex Klein again. I'm the Fire Protection Branch Chief at NRR. We're the organization that made the original user need request to the Office of Research to conduct these testing for us.

Just a little bit of background, but before I do that, I wanted to introduce a couple of my staff members here who will be here for the entire morning. Dan Frumkin sitting over there and Dr. Ray Gallucci against the wall there and Naeem Iqbal were primary staff members involved in this CAROLFIRE support.

I, unfortunately, have to leave right after my opening remarks here, but Dan Frumkin will provide you the NRR perspectives on the Volume I CAROLFIRE following the presentation by Steve.

As market indicated, this was an NRR user need request, as a result of a Regulatory Issue Summary 2004-03. Regulatory Issue Summary 2004-03 is inspection guidance for our inspectors when they perform their triennial fire protection inspections at the licensee's plant. And in there, we have got circuit configurations that are binned into three areas.

And Steve will get into a little bit of detail into that as he goes into his talk. But what I wanted to let you know is that the CAROLFIRE testing focused on the Bin 2 research that is outlined there. And again, Steve will get into each of those individual types of Bin 2 configurations that Sandia performed their testing on and that's outlined in the result, I believe, in Volume I of the CAROLFIRE test report.

So that's all I wanted to say, at this point, so I thank you for giving me this opportunity and I thank the Office of Research for performing the support.

MEMBER SHACK: Well, let me ask you.

MR. KLEIN: Yes.

MEMBER SHACK: Are you going to redo the RIS, at this point?

MR. KLEIN: Dan will speak about that.

MEMBER SHACK: Okay.

MR. KLEIN: If I may hold off on that response, but we do have some perspectives on what we will be doing with the Regulatory Issue Summary at a future date.

CHAIRMAN BANERJEE: Thank you.

MR. KLEIN: Thank you.

CHAIRMAN BANERJEE: We will go back now to Steve, right?

MR. KLEIN: Steve will now speak.

CHAIRMAN BANERJEE: Yes.

MR. NOWLEN: So I am Steve Nowlen. I'm a distinguished member of the technical staff at Sandia. As Mark says, I've been burning cables and doing other sorts of fire things for about 24 years now. I've been there a while. I was Sandia's principal lead on this effort. I was the technical lead. And I'll explain, you know, what Sandia's role was versus some of the other partners and everything. And then I really just want to go through and give you a stronger background on the CAROLFIRE Project and what we did and how we did it and what we found.

So as Mark has said, the project is, essentially, complete. At least Sandia's part of it is, essentially, complete. Our two-volume report has been through public comment now. The ACRS commented and those were treated as a part of the public comment response process. And a copy of the final pre-publication report, which was completed in early December, was provided to you for review. I expect that there will be a few final clean-up items on that and then we expect to go forward with publication promptly, we hope, and it should be very close to final, at this point.

So what I'm going to present today, and I have a pretty good chunk of time here on your schedule and I appreciate that, I'm going to give you a fairly detailed description of the CAROLFIRE Project. I think the presentations you have seen in the past have been fairly brief and quite abbreviated. So I'm really going to try and give you a lot more detail about what we did.

And then I'm going to go into a summary of the public comment process and, in particular, focus on the comments, the nature of the comments, how we responded to them and what sort of changes they resulted in in the report. And there were a good number of changes that we did implement in the report, based on the public comments.

Following my presentation, you're going to see a presentation from Dr. McGrattan about the complimentary work going on at NIST relative to the fire modeling. And so I think together our objective is really just to ensure that you have a clear and concise understanding of what we have done and the implications of the data, because they do go well beyond just the risk.

I think we did a -- in my own view, I feel like we did a good job of addressing the RIS issues. But we also went so far beyond those RIS issues with the information on the thermal response and the fire modeling work that we want to make sure that everyone really has a good appreciation for what this project is. We believe it has got life that will last quite a long time. We're far from done with this data. I think it is unique in the world and it will live for a while yet. So we're just really scratching the surface.

So with that, again, we have hit on this several times. There were these two major objectives of the CAROLFIRE Project. First and foremost, was resolution providing data to help NRR resolve these Bin 2 circuit configurations? That was clearly job one. That was the priority. I'm sorry, these Bin 2 issues came up as a result of, originally, the circuit work that was done by the Nuclear Energy Institute in collaboration with EPRI. They did a series of cable fire tests down in Texas looking at spurious operations. Based on their work, industry and NRC came together and held a public workshop to say how are we going to move forward with the circuit issues.

And as a result of that public workshop, which was February 2004, there was a list, basically, the circuit configurations were grouped into one of three bins. Bin 1 were things that we all agreed we should start looking at right away.

Bin 2, which is the real key for us, were those things that we really didn't understand very well. There was some indications that perhaps they were important. In some cases there were indications that they may not be important. But we didn't have enough data to really tell. So they were put in uncertain to be addressed by additional research.

And then there was actually a Bin 3 in the original and these were circuit configurations that everyone felt fairly comfortable we had enough evidence to say they were not significant.

CHAIRMAN BANERJEE: Can you give us an example of Bin 3? We know what Bin 2 is.

MR. NOWLEN: Yes, right. Bin 3, what was in Bin 3.

CHAIRMAN BANERJEE: Just one example.

MR. NOWLEN: Dan, do you remember? I didn't come prepared with that. These actually didn't make it in the final.

CHAIRMAN BANERJEE: Right. We're aware of that.

MR. NOWLEN: But --

CHAIRMAN BANERJEE: We're trying to understand how qualitatively you made that selection.

MR. FRUMKIN: Right. This is Dan Frumkin of NRR. For example, in these terms, I'm sure Steve will explain more thoroughly later, but an inter-cable short involving conductors in an armored cable, whereas a conductor must go through the armor, back through the armor and energize another cable through a conduit, multi-three phase hot shorts where each phase must hit the appropriate other phase in sequence without anything shorting the ground.

So these are the types that were

considered unlikely or least likely to fail.

CHAIRMAN BANERJEE: Now, in the public comments, I noticed that there was some comments related to armored cable.

MR. NOWLEN: Yes, there were. There were a couple of comments on the armored cable. And as Dan mentioned, one of the Bin 3 items was inter-cable, between two armored cables, hot short interactions occurring, because the armor is typically grounded. We said it's very, very low likelihood if not simply impossible to get through two shields of armor. So that wasn't a part of the Bin 2 issues. That was put as a Bin 3 item. You simply aren't going to get that.

But the comments that we got specific to the armored cables were that we didn't do armored cables as a part of CAROLFIRE. We explicitly excluded those because we were aware of the fact that Duke Energy was doing their own testing concurrent with our CAROLFIRE Project. And Duke is really the main plant that uses -- or the main utility that uses lots of armored cables.

CHAIRMAN BANERJEE: But that's proprietary data, right?

MR. NOWLEN: Yes, but NRC has access to it. It's --

CHAIRMAN BANERJEE: But other people with armored cable, do they have access to it?

MR. NOWLEN: I can't answer that question.

CHAIRMAN BANERJEE: Are there others, other than Duke, with armored cables?

MR. SALLEY: With the armored cable what made Duke unique was -- this is Mark Salley by the way. What made Duke unique is across their plant, they used armor exclusively. So if you look at a cable train at Duke Plant, instead of seeing the classic jacketed cables that we're used to seeing, in Duke you will see armored cable in there.

MR. NOWLEN: Right.

MR. SALLEY: So that made them very unique. The other plants, I think, for some small drops maybe to equipment, you will see pieces of seal-type or armor-type cable, but it won't be to the extent that Duke was exclusively using armor throughout the plant. So they had a unique problem. There is a report on it. Duke has asked us to keep it proprietary. I believe you will have -- you can get access to the one we had. One of our researchers was there and witnessed the test with Duke. So we were -- we are aware what Duke did.

MR. FRUMKIN: Yes, this is Dan Frumkin.

There is a public version of the report that is missing of the, you know, technical details. But yes, the NRC staff has the proprietary version. And I should say that if there is other plants that have access -- have a lot of armored cable, the Nuclear Energy Institute is a very good clearinghouse and I don't -- and that would be their means to go and contact Duke and try to get a copy of the proprietary report.

CHAIRMAN BANERJEE: Thanks.

MR. SALLEY: I would presume they will make the information available to others, but --

CHAIRMAN BANERJEE: Yes, okay.

MEMBER SHACK: Somewhere it says 7 percent of the cable is armored in the plants.

MR. SALLEY: Yes, I don't know what the basis for that is.

CHAIRMAN BANERJEE: This is in the public comment.

MEMBER SHACK: Well, it's in your report.

MEMBER SIEBER: What fraction is due.

CHAIRMAN BANERJEE: Or is it in the NEI comments?

MEMBER SHACK: No, it's a quote from the Volume I. I didn't go back and check the quote. I believed NEI, but they quoted you.

MR. NOWLEN: No, I think they are quoting someone else. But they did -- the basic gist of the comments that they made was that they felt we should make a stronger emphasis on the fact that we had excluded armored cables. And so -- because we had mentioned it once in the report, I think, that we had excluded armored cables. And so we strengthened that and we, basically, acknowledged as we didn't do armored cables.

We were in a little bit of a tight spot on that, because we can't reference the Duke report directly, because it's proprietary and NUREG/CR can't reference proprietary documents. So we were kind of dancing a little fine edge of saying well, they had done this without having a reference that we could cite that said, in fact, they did it.

So we ended up we were able to cite the nonproprietary version of the staff report, ultimately, because that had become available as we went forward. And so again, that was the gist of their comments was to strengthen the fact that we hadn't done armored cables. So it wasn't a real major comment, in our view, but we did accept it and address it.

So again, the Bin 3 configurations, those were good examples. You know hot shorts propagating from inside of the conduit to a cable outside the conduit. Again, the conduit is going to be grounded. You're just not going to be able to do that. So those were the types of configurations that made it in Bin 3. And again, we'll note that the Bin 3 items didn't, ultimately, make it into the final version of the list. They were sort of historically preserved in the minutes of the meeting and that's about it.

So then the second area is the fire modeling. And as Mark -- Mark covered this fairly well. The basic goal here was to try and reduce the uncertainty associated with predicting fire induced cable damage. As Mark said, when we get into a lot of these regulatory applications, whether it be PRA or inspection or whatever, plant changes, risk informed change evaluations, it usually comes down to fires damaging cables. That's what we worry about 98 percent of the time when we are doing this business.

So understanding how cables respond and how they fail and having tools that allow us to predict that with confidence is very, very important to our applications. And this has been an area that hasn't been a focus of past fire research. And so I think it's a very important thing and we have tried very hard to improve the situation there.

MEMBER SHACK: Well, it's more of a cable damage model. You sort of assume you know everything about the fire.

MR. NOWLEN: Yes.

MEMBER SHACK: And then you compute what it does to the cable.

MR. NOWLEN: That's exactly right. It's about the cables. How do the cables respond and when do they fail? Because that's really the key is, you know, electrical failure and being able to say when the --

MEMBER SHACK: No, but there is a lot of-- part of the fire model I have to know before I get to the cable damage.

MR. NOWLEN: That's right. This was not focused so much on understanding fire. This is focused on understanding how a fire impacts the cables. So you are absolutely correct there.

Okay. So now, I'm going to go through the Bin 2 items, since again that was job one for us. I don't know how familiar this particular Subcommittee is with these items, so if I'm boring you, please, let me know and we can move through these quickly.

The first of the Bin 2 items, which is just listed as A, they are A through F, and it's -- this is paraphrasing. In the RIS, you will see there is a rather long description, but to paraphrase it it's spurious actuations caused by inter-cable shorting for thermoset cables. Two key phrases here: inter-cable, that just means it's between two separate cables, thermoset cables, we broadly group cables into two groups, thermoplastics and thermosets.

Thermoplastic materials are materials that will melt when you heat them. So it becomes a liquid and it will flow. A thermoset material will not melt. It will char. It will burn. It will swell. It will bloat, but it won't melt. So there is -- what we see is between these two broad groups of materials, there are very, very different behaviors in terms of how they respond to fires.

Again, the whole melting behavior, melting, dripping, it's very different from charring, swelling, bloating, smoldering, burning.

MEMBER BLEY: Steve?

MR. NOWLEN: Yes?

MEMBER BLEY: Within each group, are they pretty consistent or is there a pretty wide range of response?

MR. NOWLEN: There is a fairly wide range of response. It's wider for thermosets than it is for thermoplastics. Thermoplastics tend to have a little bit narrower band of response. Thermosets have a very wide response band. It's quite --

CHAIRMAN BANERJEE: These are basically polymers, right?

MR. NOWLEN: Yes, they are all polymers. An example of a thermoplastic would be polyvinyl chloride, PVC. Very common in home wiring for example. Plastic plumbing, it's used everywhere, flooring. They use it for cables. Also, you add lots of plasticizers to make it more flexible, anti -- flame retardants, fire retardants and you can make a cable insulation. It's very, very popular for industrial applications, in particular, but it's also seen in nuclear power plants. So you will see one of our cables is a PVC insulated cable.

Typical thermoset would be a cross-link polyethylene. You know, again, it's a polymer, but it's a different polymer and the cross-linking is what really turns polyethylene into a thermoset. A straight polyethylene material would be a thermoplastic. But once you cross-link it, it no longer will melt and it becomes a thermoset.

Other thermosets that we tested are silicone, ethylene/propylene rubber, materials like that. The other -- we did test a polyethylene, a straight polyethylene thermoplastic material. The other one we tested is Tefzel. It's a teflon-based material. So there is a range of materials on both sides of this particular divide between thermoset and thermoplastic. And as you will see in a minute, we tested a range of both.

CHAIRMAN BANERJEE: Okay. Thank you.

MR. NOWLEN: So what -- where this one came from, why was this a Bin 2 item? What was done and again, we're specifically talking about shorts between two cables. When NEI did their testing, it was obvious that with the thermosets internal shorting within a single multi-conductor cable was leading to spurious operations. There was really no question about that. But they had done some testing to look at the possibility of cable-to-cable shorting as well.

And they used a configuration that was purposely designed to make it more likely that that might occur. They used single conductor cables located next to a multi-conductor cable, basically, tied together, strapped down to each other. They never saw a single case of a spurious operation due to an inter-cable short on their thermosets. They saw some interactions, but no spurious operations.

We looked at that as part of this panel meeting that the NRC had and said well, it seems like it's low probability, but is there enough data there to really say it's never going to happen? And the answer was no, therefore it ended up in Bin 2. It was fairly typical of the debates that took place on the Bin 2 items. Some indication, it probably isn't real high probability, but not enough to say it's never going to happen.

So now, you look at the behaviors that they saw and ask why. Why would you not see these interactions? That was another part of the debate is is there a reason we might actually suspect that that's a reasonable postulate that these are low likelihood or very, very, very unlikely. And in this particular case, again, it hinges on the behavior of the materials.

Since with the thermoplastic, the materials melt and flow. They basically can go away entirely and you can have nothing but conductors interacting with each other and it doesn't matter whether they came from one cable or two cables or three cables. Potentially, they could interact with each other fairly readily. And again, NEI bore that out.

But with the thermosets, because they don't melt, there is a charring behavior. One of the questions that was raised is is that char enough to keep the conductors from interacting? And so --

CHAIRMAN BANERJEE: Is the char conductive?

MR. NOWLEN: Not particularly. Once you get it wet, it is, but the char itself is not conductive. It's carbon, mostly carbon by the time you burn away all the plasticizers and whatnot, you're left with carbon char.

MEMBER SIEBER: But it's not as good as unburnt material?

MR. NOWLEN: Oh, no. No, it's very fragile, for one thing.

MEMBER SIEBER: Well, and there are leakage paths if it were --

MR. NOWLEN: There are leakage paths?

MEMBER SIEBER: -- instrument cable or very low current, you may --

MR. NOWLEN: High voltage also.

MEMBER SIEBER: Right. You may see a change in the characteristics.

CHAIRMAN BANERJEE: I guess a lot of this came out of the Brown's Ferry fire, right? I mean, the --

MR. NOWLEN: Everything came from Brown's Ferry, ultimately.

CHAIRMAN BANERJEE: Right. Now, what was found there?

MR. NOWLEN: Brown's Ferry, Mark, could you speak to Brown's Ferry?

MR. SALLEY: Yes, this is Mark Salley. What Steve is alluding to in that is in '75 in March when the Brown's Ferry fire occurred, PVC, as a matter of fact, PEPVC, polyethylene insulation, polymonochloride jacket was the cable of choice through the industry in the '70s.

CHAIRMAN BANERJEE: This was cross-linked?

MR. SALLEY: No, no. This was straight thermoplastic materials and it was easy to manufacture. It was cheap. And this is what the utilities were buying. So the Brown's Ferry fire showed that weakness of the thermoplastic-type insulations and jackets. And that really revolutionized the cable industry and the nuclear industry, that and EQ kind of rewrote the book on how cables are manufactured and why what is chosen for what application.

So the challenge we have and the reason we looked at his as such is all those Brown's Ferry plants, there are plants that are still operating out there, do have the installed thermoplastic materials and they are using them. Now granted, the newer stuff that was added to those plants as well as the plants that came later tended to go and the slang that was used was the IEEE 383 qualified, because that really was showing how cables could meet the fire performance and the EQ performance.

So our problem is, and Steve will get into the cable selection which was quite interesting, that we have a mixture out there. It's also an interesting point and, Steve, you know a little bit more about this than I, but a lot of the Europeans are still using thermoplastics today. So it does benefit people beyond the United States.

MR. NOWLEN: Yes, there really was a sea change in the U.S. relative to use of thermoplastics. Before Brown's Ferry, thermoplastics, as Mark said, were very common, especially outside containment where you didn't have the equipment qualification, the EQ issues that Mark mentioned. Outside containment, you didn't have to deal with those issues. Thermoplastic cables were adequate and they were less expensive.

Inside containment where you get into the equipment qualification issues, thermoplastic cables usually won't hold up to those kinds of environments and so they would make a switch to thermoset cables inside containment. For example, with TVA, the very common configuration was the polyethylene PVC cables outside and silicone-based cables inside containment. That was real common configuration.

Now, after Brown's Ferry, thermoplastic cables got a very bad reputation and the industry -- there were some standards coming out, IEEE 383 was in the process. That's mainly an equipment qualification standard. But as a part of it, there is -- they added a flammability test and that became the new standard for cables being installed post-Brown's Ferry. And so what you see is early plants were mainly thermoplastics outside containment. Newer plants are almost exclusively thermoset everywhere.

Thermoplastics really just became very unpopular. Now, as Mark says in Europe, that sea change never happened. They still use PVC insulated and polyethylene insulated cables quite extensively. Again, they have the same issues inside containment, there is an equipment qualification issue. You will find thermosets, but they are still very widely used in Europe.

So again, yeah, one of the things we have done here is we have really tried to look at a fairly broad mix of cables and I'll get into that one in a minute.

CHAIRMAN BANERJEE: What percentage of the U.S. plants use thermoplastics?

MR. NOWLEN: That's a very, very hard question to answer. We tried to do a survey several years ago and our estimate, at that time, was we were mainly looking at control room configurations, at that particular time, and we estimated that about 25 percent of the control rooms 15 years ago had thermoplastic cables in them.

What that meant for plants overall, I can't really say. What it means today, you know, there hasn't been particularly a concerted effort to replace thermoplastic cables in plants that have them. If they are installing new cables, they will typically install a thermoset, but that doesn't mean they are making a concerted effort to go and replace existing cables. That's a fairly arduous undertaking.

So they are out there. The exact percentage, I don't think anyone can give you a really good answer to that.

CHAIRMAN BANERJEE: But you give a rough number, right?

MR. NOWLEN: Rough number, I would say -- you know, again, our estimate, at the time, was 25 percent of control rooms still had thermoplastic. That's probably not a bad estimate of how many plants out there have thermoplastic, probably on the low end. It's probably a little higher than that.

CHAIRMAN BANERJEE: Let me just ask one more question.

MEMBER SIEBER: My guess is 50 percent.

MR. NOWLEN: You think 50? Well --

CHAIRMAN BANERJEE: All right. Jack, you had a number?

MEMBER SIEBER: Well, it seemed to me that after the Brown's Ferry fire, a lot of plants were under construction, at that point in time. They had warehouses full of cable and they had no test results other than boy, this bad thing happened. And so even after Brown's Ferry for a couple of years, this cable still went into the plants.

MR. NOWLEN: That's true.

MEMBER SIEBER: And the method of dealing with it was you can't separate once the plant is built. You have to put in fire barriers and so these methods of fire barriers were installed, but it doesn't deal with the temperature problem. You know, you still get into the insulation melting phenomena.

MR. NOWLEN: Right.

MEMBER SIEBER: So I know of no plant that has done a wholesale change out job.

MR. NOWLEN: I don't know of any plant that's done a wholesale change out either. And he's absolutely correct in that it depended a lot on where the plants were in their construction.

MEMBER SIEBER: Um-hum.

MR. NOWLEN: If they had already bought a warehouse full of cables, the chances are they used them. If they had not yet bought cables, they probably changed their orders right away. So it depended a lot on where plants were in their construction process at the time that Brown's Ferry happened and, you know, there were a lot of plants under construction, at that time.

CHAIRMAN BANERJEE: Let me ask you one other question. Do you distinguish between intra-cable shorting and inter-cable shoring?

MR. NOWLEN: Right.

CHAIRMAN BANERJEE: It's clear what that

means. What are the implications of intra-cable versus inter-cable shorting?

MR. NOWLEN: Well, it depends a lot on the specific circuit. For a lot of circuits, it's not much of a distinction, because within the single multi-conductor cable, you have what you need to cause a spurious operation. Basically, you need an energizing source, something that has the power and you need a target that if you hit it with the power, it's going to cause the spurious operation.

Most control circuits you will have that. The control circuit is typically contained within one multi-conductor cable. There are exceptions. People have taken source conductors out of a cable and put it in a different cable. There's no reason you can't do that. Simply run the power through a separate cable. So there are exceptions even within control, but when you get to power cables, it's a bit different.

Power cables, if you're looking at two power cables shorting together and spuriously operating a pump or something, that usually has to occur between cables. So there are various reasons why you would be interested in inter-cable as a unique failure mode as compared to intra-cable, within the cable. You know, either you have moved your sources out, so you need an external source or you're looking at power cables. Those are the two most common cases.

And with regard to, you know, well, so what, you know, who cares, we believe that there are reasons why intra-cable, within the cable, shorts are more common than inter-cable. The way cables are manufactured and we have got some samples here, we will pass them around, you will see that there is an inherent twist in the conductors as they manufacture. Usually, they run the individual conductors through an extruding machine that lays the insulation on and then the conductors are gathered together and the jacket is then extruded over the top of a group, set of conductors.

Well, as they go through these machines, they get a twist to them. And that twist tends to leave a little residual strain inside the cable. And one of my postulates for many years has been that the reason we see these intra-cable shorts is because of this residual tension and it has a tendency to bring the conductors together when the insulation materials begin to lose their integrity and strength.

So that's my own postulate. I think it holds. Now, what you are seeing here, these are individual -- actually the group represents all of the cables that we tested, the 15 different cables we tested, so each of you now has one of our 15. Most of these are control cable configurations, different number of conductors. They all have different insulation and jacket materials.

CHAIRMAN BANERJEE: So when you say, for example, PEPVC, this is a thermoplastic PE.

MR. NOWLEN: Right.

CHAIRMAN BANERJEE: And thermoplastic PVC jacket?

MR. NOWLEN: Correct. Yes, that is our --

CHAIRMAN BANERJEE: The PE is the internal insulation then or the external?

MR. NOWLEN: Correct.

CHAIRMAN BANERJEE: Okay.

MR. NOWLEN: Yeah, the PE, the standard jargon that we used was insulation/jacket. So PE/PVC with PE insulated, PVC jacketed, that particular one was our core thermoset in -- or thermoplastic, I'm sorry. That was our core thermoplastic as being most representative of what you will find in a typical U.S. plant for thermoplastic.

MEMBER SHACK: And there is one with the woven jacket here.

MR. NOWLEN: Yes, that might be the

silicone rubber.

MEMBER SHACK: Okay.

MR. NOWLEN: Is that the silicone or the--

CHAIRMAN BANERJEE: Silicone rubber.

MR. NOWLEN: Silicone rubber. That is one tough cable. We'll talk about that one.

CHAIRMAN BANERJEE: Silicone rubber, silicone rubber?

MR. NOWLEN: Yes.

MEMBER SIEBER: What is that?

MR. NOWLEN: Well, it's -- actually, it's a silicone rubber with a fiberglass internal weave over each of the individual conductors and the outer jacket, the black woven jacket is actually Aramid, which is a material used in bulletproof vests, believe it or not. It's a very tough cable.

CHAIRMAN BANERJEE: What is the material outside made of, Aramid?

MR. NOWLEN: Aramid.

CHAIRMAN BANERJEE: What is that?

MR. NOWLEN: It's an artificial fiber. I'm not enough of a fiber chemist to tell you exactly what it is.

CHAIRMAN BANERJEE: It's some sort of a polymer or is it --

MR. NOWLEN: I don't believe it's a polymer.

MR. KLEIN: It's like kevlar or nomax, the kind of material they use for bulletproof vests or fire fighter garments and so forth.

CHAIRMAN BANERJEE: It's carbon fiber or something?

MR. KLEIN: I don't think it's carbon.

MR. NOWLEN: I don't think it's carbon fiber. It's probably --

CHAIRMAN BANERJEE: A fiber?

MR. NOWLEN: -- some sort of a fiber. I don't know enough about it.

MEMBER SIEBER: Okay. It has to be more flexible than carbon.

MR. NOWLEN: Yeah.

MR. KLEIN: I'm pretty sure it's just a polymer.

CHAIRMAN BANERJEE: It's just a polymer.

MR. NOWLEN: Yeah.

MEMBER SIEBER: Okay.

MR. NOWLEN: Now, see in that particular one it's fairly typical of what you will find inside containment at a TVA plant, for example. That's why we picked that particular one.

CHAIRMAN BANERJEE: Well, when you say XLPE, X means it's cross-linked?

MR. KLEIN: Cross-linked polyethylene?

MR. NOWLEN: The XL, yes, is cross-linked and then the PE would be polyethylene. So that particular one was our core thermoset.

CHAIRMAN BANERJEE: That's a thermoset.

MR. NOWLEN: Yes.

MEMBER SIEBER: Now, these --

MEMBER SHACK: Is that the most common thermoset to cross-link polyethylene?

MR. NOWLEN: Yes, it seems to be. In particular, that one is a Rockbestos Firewall III product and that one right there is the most common single cable you will find out there. Rockbestos Firewall III cross-link polyethylene insulated, it's one of the most popular. Very, very common for plants built in the late '70s, early '80s.

CHAIRMAN BANERJEE: But when you say cross-link PO, that's polyolefins?

MR. NOWLEN: Olefin, yes, that's a cross-linked polyolefin. Polyolefins are somewhat a more generic designation.

CHAIRMAN BANERJEE: Right. So you don't exactly know what the olefin is there or do they --

MR. NOWLEN: No, they won't tell you.

CHAIRMAN BANERJEE: I see.

MR. NOWLEN: That particular one is a very modern cable type. You won't find too much of that in plants today. We tested that one as an example of what you might find in plants tomorrow sort of thing. That one is a zero halogen cable, so that they don't use any of the chlorine, iodine, bromine additives and fillers. And so it burns rather differently. It has an aluminum-based aluminum hydroxide filler, so that when you heat it up, you get a lot of steam off the thing instead of soot.

CHAIRMAN BANERJEE: But not hydrochloric acid?

MR. NOWLEN: But no hydrochloric acid, no bromines, no iodines, you don't get any of the halogens. The Navy, in particular, was driving manufacturers to produce these low halogen cables, because they have a lot of corrosion issues. I mean, you have a fire in a submarine, you can't exactly vent, so they end up with corrosion issues. And they have pushed the industry towards these low halogen cables and they are becoming more popular.

CHAIRMAN BANERJEE: Are they mainly polypropylene or what's the olefin, do you know?

MR. NOWLEN: I couldn't answer that. I mean, the manufacturers specifically won't tell you. Those are guarded secrets. They do not want you to know what's in any of these cables. They are trade secrets. They spend a lot --

MEMBER SIEBER: They don't want the other manufacturers to know.

MR. NOWLEN: Precisely. They spend a lot of money developing these formulations and --

CHAIRMAN BANERJEE: But they have superior fire protection capability, I presume?

MR. NOWLEN: In some senses, yes. They don't burn as easily is the main thing. It's harder to ignite them, because you are dumping out water. Water is a great fire suppressant. It's steam, but it's hard to burn a cable that's steaming. And so until you drive off all of the steam, they don't burn very well. So they behave very differently.

MEMBER SIEBER: Well, it's interesting to note that most of the spurious actuations come from control cables as opposed to power cables, because protection installed on devices such as differential ground, single phasing will stop spurious operation. And it's the control cables that seem more fragile, at least to me, than the power cables do. In there, you can -- you have no electrical defense against ground or a short within a power -- or control cable.

MR. NOWLEN: It depends a little on the circuit configuration.

MEMBER SIEBER: Yes.

MR. NOWLEN: If the control circuit itself is grounded, then you can still trip the fuses by a ground or you will get multiple shorts to ground. But yeah, the thing we see is that the control circuits seem to be the focus. Again, because you take a typical control cable and everything you need to cause it is right there. There it is. All I've got to do is get these two to work with each other and there it goes, you know, that's --

MEMBER SIEBER: And no defensive mechanisms.

MR. NOWLEN: Other than the fusing and the protection of the circuit and just that chance that, you know, maybe those two -- you know, it's usually two specific or, you know, a combination. There might be two alternative pairs that could come together. But it's usually a very specific combination that has to occur.

MEMBER SIEBER: Right.

MR. NOWLEN: With the power cable, usually even on a single phase, you usually have to get two together.

MEMBER SIEBER: Right.

MR. NOWLEN: You know, and Dan mentioned the three phase, smart three phase shorts between two power cables, we put in Bin 3, because you've got to get three concurrent.

MR. KLEIN: Perfectly --

MR. NOWLEN: Perfectly aligned at roughly the same time or the circuit is going to trip.

MEMBER SIEBER: Right.

MR. NOWLEN: So that one is a little harder to see happening. So, you know, for various reasons that and the fact that with power cables you usually need things to happen between two cables, which we think is less likely for various reasons.

MEMBER SIEBER: Right.

MR. NOWLEN: So we've got lots of reasons we're focusing mainly on control.

CHAIRMAN BANERJEE: Steve, I don't want to interrupt this conversation, but you've got until 12:15, basically --

MR. NOWLEN: Yes.

CHAIRMAN BANERJEE: -- to get through your presentation with a 15 or 20 minute break in between.

You can pace yourself to where you want, but at 10:00, we'll take a break.

MR. NOWLEN: I understand.

CHAIRMAN BANERJEE: So get to whatever point you want to and we'll cut the conversation short, just to make sure that we get there.

MR. NOWLEN: Okay.

CHAIRMAN BANERJEE: Up to what point would you like to get?

MR. NOWLEN: Oh, I -- this --

CHAIRMAN BANERJEE: Are there any specific?

MR. NOWLEN: Not specifically, no.

CHAIRMAN BANERJEE: Okay.

MR. NOWLEN: I think there is -- you know, a lot of the conversations we're having here are --

CHAIRMAN BANERJEE: Have a bearing on what is going to happen, yeah.

MR. NOWLEN: -- have a bearing on what's coming.

CHAIRMAN BANERJEE: Right.

MR. NOWLEN: And again, since our objective is really to make sure you have an understanding of what we're doing, I'm perfectly good with these conversations. I have -- there is a lot of material later in the presentation that we can move through more quickly.

CHAIRMAN BANERJEE: Okay.

MR. NOWLEN: These fundamental discussions, I think, are so important I'll take all the time you want here.

MR. SALLEY: Yes, you know, our key here is to answer whatever questions you have. So, you know, we have laid out a presentation. Obviously, we would like to go with that. If you want to take it somewhere different on this subject, we're comfortable with that.

CHAIRMAN BANERJEE: But part of this --

MR. SALLEY: The three --

CHAIRMAN BANERJEE: -- is while we can look at these from a heat transfer and other point of view, we -- some of us, at least, need to be educated into the -- as to the context, which is what you are really -- the jack of this knows the context.

MR. NOWLEN: Yes.

CHAIRMAN BANERJEE: But others don't.

MR. SALLEY: You are absolutely right. And, you know, long ago and far away, a senior electrical engineer told me that if you're ever going to understand cables, you need to learn about polymers. And you can see the polymer signs, like Dupont sells, is a very big part of this cable construction. And there is a lot of it out there.

As we have talked with cables, the different things, there is a lot of trade offs. For example, you want low halogen-type cables, but halogens tend to be a good extinguisher. So if you're trying to build cables that have low flame spread, one of the things the industry tried was to put halogens in there, because they could become self-extinguishing-type cables.

So there is a lot of trade off. We recognized that in CAROLFIRE and if you noticed, we actually put in an appendix that one of our new interns, a chemical engineer, wrote to start educating people again into the field of polymers and that was the purpose for that to be added.

CHAIRMAN BANERJEE: Right. We also noticed that while you alluded to kinetics, you did not actually employ that in your sort of -- you looked for a different sort of criteria.

MR. NOWLEN: Yes, we're hoping we can do it in a simpler way.

CHAIRMAN BANERJEE: Okay.

MR. NOWLEN: Than chemical kinetics.

CHAIRMAN BANERJEE: All right.

MR. NOWLEN: And I think you will see from Kevin's presentation that simple seems to work fairly well.

CHAIRMAN BANERJEE: And for the better.

MR. NOWLEN: The simpler the better, yeah.

CHAIRMAN BANERJEE: Right.

MR. NOWLEN: Okay.

CHAIRMAN BANERJEE: Okay.

MR. NOWLEN: But again, absolutely, I -- you know, I absolutely want you all to be comfortable and understand where we are going and these fundamental concepts are so important to us, you know. The difference between thermosets and thermoplastics, it's like our whole world right now. So understanding that is really important to us. So I'll spend as much time on these as you want.

So again, Bin 2, Item A, inter-cable between thermosets. And I think we covered that. Item B was inter-cable shorting between one thermoset cable and a thermoplastic cable. So the thinking here, now NEI didn't do this configuration at all in their testing. They did either thermosets or thermoplastics, but they didn't do any mixed-types, mixed bundling.

So the idea here was that, in general, thermoplastic materials are thermally weaker than thermoset materials. The thermoplastic material may fail at 250 degrees centigrade. A thermoset material will probably fail somewhere closer to 400 degrees centigrade. So there is a very substantial margin between the vulnerability of a thermoplastic than that of a thermoset.

MEMBER BLEY: The failure modes are quite different, it sounds like.

MR. NOWLEN: Well, the failure mode is another thing. We still see intra-cable as the first primary failure mode. The thermoplastics seem to be more likely to interact with each other, between two, the intra -- inter-cable. The inter-cable seems more likely with thermoplastics, because of the melting.

MEMBER BLEY: Yeah.

MR. NOWLEN: But beyond that, the other thing we will see is the thermoplastics once they start going, they kind of cascade through all the fault modes more quickly. You know, the melting, everything just sort of comes together. Thermosets, you can get a more prolonged transition time. You get some initial shorting between a couple of conductors, it can hang in there for a while before further shorting occurs.

Thermoplastics tend to go a little more quickly. You will get that initial faulting, but they do tend to cascade more quickly. So gain that was all --

CHAIRMAN BANERJEE: Do you usually get an inter-cable short before your -- sorry, intra- cable short?

MR. NOWLEN: Yes, yes. Usually the first thing we see is shorting within the cable, intra-cable shorting that's first. Then -- now, again, that may not cascade through to all of the conductors being one big group, but usually that's first. We see interactions within the cable and then we will start seeing interactions with other cables. And again, I think that's a residual tension that comes from the manufacturing process.

CHAIRMAN BANERJEE: Right. You mentioned that point.

MR. SALLEY: Just some of you may have seen these before and maybe it's good that we just do a little -- go back and make sure that everybody has the concepts that he is talking about. We have some different cable samples that come out of some fire tests. These are from out of NEI's fire test. A couple of things I'll have you look at, these are the configurations that you heard Steve talking about.

Of course, the cable failing internally, you can see with the seven conductor versus two cables coming together. These two are classic thermoplastic. These are very interesting, because this is actual Brown's Ferry vintage cable that came out of some old PVA stock, so this is PEPVC, the same cables that failed at Brown's Ferry. And you can see the failure mechanisms of the melting that Steve described, which we see classically with the thermoplastic cables. So you can pass this around and look at it.

And again, you will see two cables coming together there for an inter-cable shorting. This is the classic thermoset failure. And again, you can see the charring, the bloating and almost like a piece of wood on a fire-type of combustion versus the liquidification and then burning. So you can take a look at these and pass them around. I think it may help a little bit. I hope it does.

MR. NOWLEN: Okay. So see again, you can -- I think on the sample of the thermoplastic, you can actually see one of the single conductor cables coming in contact with the multi-conductor.

CHAIRMAN BANERJEE: Right, right.

MR. NOWLEN: And that's an actual sample from their test.

CHAIRMAN BANERJEE: Interesting, yes.

MR. NOWLEN: Yeah. Now, you know again, whether or not that leads to a spurious operation all depends on what those two conductors do in the circuits. You know, if one is a source and one is a target, you've got a spurious operation, if not something else will happen. Now, these are good samples.

So again, this idea of shorting between a thermoset and a thermoplastic, which was not tested, the thought was because the thermoplastic cables are likely to fail more quickly than the thermosets, the chances are they will go through their whole cascading failure modes and -- before the thermoset ever really has a chance to get involved in any shorting.

CHAIRMAN BANERJEE: These Brown things there, they -- are these power cables or what are they?

MR. NOWLEN: They are small power cables.

CHAIRMAN BANERJEE: Power.

MR. NOWLEN: Very small single conductor power cables. And again, typically, what NEI did is they took the multi-conductor cable and they put three single conductors around it to try and look for the inter-cable interactions. And so those are the three single conductors that were wrapped around it. You know, you're not going to see that configuration at the plant. Again, they were purposefully trying to sort of heighten the probability that interactions would occur.

At the time, their thought, at least, was we're not going to see any spurious operation, so let's make it as conservative as possible and that way we can put the issue to bed. Well, it didn't quite work that way.

CHAIRMAN BANERJEE: Okay.

MR. NOWLEN: Okay. So that was -- the second issue is shorting between thermoset and thermoplastic cables, the second in Bin 2. And again, there was no data on this before CAROLFIRE, so many of our configurations used combined bundles of thermoplastic and thermoset and we explicitly looked for these types of interactions to occur. And we saw some interesting things here, so I'll get into that one.

CHAIRMAN BANERJEE: Did you use those sort of single, I don't recall now, cables? You never did, right?

MR. NOWLEN: No, we didn't. The 15 cables we used are in that bundle right there. They are all multi-conductor cables. Most of the -- we were trying to do something that would be more representative of what you would really see in the field. NEI was specifically trying to be conservative. We tried to be more realistic.

So ours were typically two seven conductor cables next to each other. And we were looking for interactions between those two seven conductor cables. One thermoplastic, one thermoset or in a number of cases it was two thermosets, because that was Item A. So again, we're after all of these Bin 2 items, we set up configurations that would allow for those interactions and then watched for them and see what happened.

MEMBER BLEY: Steve?

MR. NOWLEN: Yes?

MEMBER BLEY: In the thermoset cables.

MR. NOWLEN: Yes.

MEMBER BLEY: When you get intra-shorts, are they between adjacent conductors or is it random? It looks like it would be more likely to be adjacent ones in this cable.

MR. NOWLEN: It is, yes. It tends to

involve nearest neighbors. It tends to start in the outside row. You noticed on these there is an outside row and a core cable or a core conductor. Because the outside gets hot faster, it tends to occur first on the outer loop. I mean, we have, you know, multi-conductor cables that get very large and have many layers. But again, we would expect to see the outside ones become involved first. Yeah, it tends to be nearest neighbors interact first.

MEMBER BLEY: Has there been any discussions with perhaps designers about selecting conductors to avoid these kind of problems in future designs?

MR. NOWLEN: For future plants, it's worth thinking about. You know, for future plants, you have a lot of opportunity just to do things that aren't practical with an existing plant. You know, in my mind, removing the sources from your control cables and routing them separately would be even better. You know, if you don't have a source to energize the target, you won't get the spurious operations. So I think there is a number of things we can do in future plants.

Today, you know, rewiring plants is not so simple, so it -- and the difficulty we run into is that it's hard to take that factor into account. We know that is true, but to actually go into an individual control circuit and determine which conductors are doing what, is very challenging. It's not something we can do on a routine basis.

CHAIRMAN BANERJEE: In practical terms, what can be done with the existing plants to reduce the risk?

MR. NOWLEN: Well, they are doing -- well, I mean, first of all, we have to understand the risk.

CHAIRMAN BANERJEE: Right, right, right.

MR. NOWLEN: And we're still kind of --

CHAIRMAN BANERJEE: Imagine that you understand the risk.

MR. NOWLEN: If we understand the risk--

CHAIRMAN BANERJEE: What can you do?

MR. NOWLEN: -- various things. I mean, cable protection, you know, all of the traditional fire protection measures help, understanding what might happen in a particular scenario, so that you can plan and have appropriate operator procedures and whatnot to deal with the things that could happen, knowing what equipment is vulnerable and what might be spuriously operating, so that the operators can anticipate that. I think that those are all, you know, great.

CHAIRMAN BANERJEE: Knowledge is great in this, but --

MR. NOWLEN: Knowledge is king.

CHAIRMAN BANERJEE: Yeah, but other than things that operators can do and be aware of, are there any other measures that can be taken to improve the situation? If the --

MR. NOWLEN: We're really dancing into an area that --

CHAIRMAN BANERJEE: -- situation was --

MR. NOWLEN: -- I'm not the right one to ask.

CHAIRMAN BANERJEE: -- fire barriers and things like that.

MEMBER SIEBER: Well --

MR. NOWLEN: Fire barriers, yeah. All of the traditional fire protection measures help. Anything you can do to make fires less likely, to make damage to cables less likely, to make it more likely that you intervene before damage occurs, all those things reduce risk. Proper planning, good procedures, all those things help. Beyond that, I would really rather not speculate as to what --

CHAIRMAN BANERJEE: Right. Well, Jack

probably knows this stuff.

MEMBER SIEBER: Yeah, well, I think that's true. There is a lot of steps that one can take. It's a matter of the plant physical layout and separation that's available. For example, there has been some plants in the late 1970s that ended up rerouting cable, you abandon a cable in place and run it through another fire area. And that's practical if you're talking close to 200 cables. There are thousands of cables in the plant, so, you know, there is no wholesale fix like that, other than fire barriers. And you have capacity concerns and ventilation. It's a difficult problem and that's why everybody is excited about it.

MR. NOWLEN: Yeah, I know.

CHAIRMAN BANERJEE: I'm not excited about it.

MEMBER SIEBER: I am.

MR. NOWLEN: Well, there is a lot of activity in industry right now.

MEMBER SIEBER: Yeah.

MR. NOWLEN: And on, you know, an individual basis, if you find a particular combination that's very challenging to your operators, you can take individual actions and reroute cables, you know, redesign circuits, so that they are either not vulnerable or less vulnerable to the spurious operation occurring. There are things you can do. But again, on a wholesale basis, it's not practical for an existing plant. It's just too much.

But on an individual basis, if you are trying, if you have identified a specific risk scenario, one way to deal with it is to take some of the -- you know, relocate cables, redesign circuits, but that's got to be carefully thought out before you just jump in.

MEMBER SIEBER: You know, one of the --

MR. NOWLEN: It does get expensive. There is a whole EQ burden that goes with it, too.

MEMBER SIEBER: And one of the other problems is there are some plants that were built where they didn't utilize the technique of pull tickets, which tells you what racks and what conduits a specific cable goes through, you know, and a lot of plants have pull tickets and then you can sit down with your computer and say here is where the circuit goes and identify the conduit, the cable tray, whatever area it is in.

If you don't have that, you got a big problem.

MR. NOWLEN: Yes.

MEMBER SIEBER: And you have to deal with that problem in a different way than analytical.

CHAIRMAN BANERJEE: We have a suggestion, Steve, that --

MR. NOWLEN: Yes?

CHAIRMAN BANERJEE: -- we move through this with the aim of getting to the testing immediately after the break.

MR. NOWLEN: Okay. Very good.

CHAIRMAN BANERJEE: Okay. So move at whatever speed you need.

MR. NOWLEN: Sure. Okay. Let's see, let's cover these items then. Item C is concurrence spurious actuations associated with failures impacting three or more cables. Basically, the guidance was written to consider the spurious operations that might arise from failures impacting any two cables. And that we felt was reasonable given the probabilities that came out of the NEI test.

But when you get into multiple spurious operations, you get into a lot of issues. Do they overlap in time? How long do they persist? When do they occur? These things begin to reduce the likelihood that you are going to see three or four at the same time. So part of the objectives with CAROLFIRE was to try and get a better handle on the multiples. NEI gave us some information. Our tests have added to that. It's all building up to a better understanding of these likelihoods and likelihood of overlap.

How the effects of, you know, a cable located directly above the fire versus one that is off in the hot gas layer somewhere, how those are going to affect things. So that was Item C.

Item D is multiple spurious operations when you have a control circuit with a control power transformer in it. Control power transformers are these small power devices that they will use in powering the control circuit. Typically, if you are trying to run say a 480 volt motor operated valve, three phase valve motor, what they will commonly do is in order to get the control power, they will tap off two phases of the motor power and they will transform that down to say 120 volts AC and use that to power the control circuit.

So what the device that does that for them is the control power transformer. Now, these control power transformers are sized just big enough to run the circuit, the control circuit. So they are relatively small. They only give out a certain amount of power, say 150 volt amps. So if you draw too much power, you draw say 2 amps from a 150 volt amp transformer running nominally at 120, it can't sustain that 120 volts. So it will begin to degrade, the voltage will begin to degrade.

And if the voltage drops low enough, you can't get the circuit to actuate. It takes a certain minimum voltage. So there is a competing effect here of draining power from the control power transformer and providing enough power and voltage to actually actuate the circuit. And that seemed to have a fairly strong effect in the NEI test. They saw nominally half as many spurious operations given a small CPT in the circuit.

And so we were all kind of wondering well, what does that really mean? And as interim guidance, they said well, for the CPT circuits, let's just look at one at a time. We will think about multiples later. So again, we were addressing this through our testing.

Item E, this has to do with the persistence of a hot short. How long can a hot short last? And the guidance was fire induced hot shorts lasting more than 20 minutes will be deferred to additional research. In the NEI tests, the longest hot short they saw was about 11 minutes, a little more than 11 minutes. After that you see the faults propagate and continue to degrade and they go through additional failure modes and eventually things will go to ground, power supplies trip out. You just can't sustain a short forever in a fire environment.

So the guidance was based on nominally twice what NEI saw in their tests. The question was how good is that? So we did a lot of additional testing to try and see how long these things last. Now, this is hot shorts and the hot short is the actual interaction of a power conductor to a target. Now, if I -- the conductors could stay together, but if I trip the power, it's no longer a hot short. There is no power.

On certain devices, this doesn't necessarily mean the spurious actuation goes away, you have got a motor operated valve and you shift the valve to an open state say and then you cut the power, well, the valve stays open. So this is about the cable interaction. The actual I get a hot short, it persists for 20 minutes.

Now, for other types of valves, solenoid operated valve, air operated valve, if you lose power, the valve is going to return to its fail safe spot. So like a port. It's going to go closed. It's not going to stay open after you drop out the hot short. So this has implications for certain types of circuits. Important implications for certain types of circuits. And other circuits, it's -- it could be misinterpreted.

You have to be a little careful about motor operated valves, in particular. They will persist in whatever state they are left in when the power dies.

MEMBER BLEY: Were these longer hot shorts always in thermoset cables?

MR. NOWLEN: Most of them were, yeah. The thermoplastics, again, the hot shorts tended to be shorter duration. They were on -- the longest ones were on the order of a couple of minutes, 2, 3, 4 minutes at worst. And just jumping ahead, we saw similar sorts of behaviors, by the way.

Okay. Now, this is Item F. Item F is about cold shutdown circuits. Appendix R, of course, has requirements for achieving cold shutdown within 72 hours. You are allowed to make repairs, etcetera, etcetera. And so the question was raised well, what about the cold shutdown circuits? What are we going to do with those?

This was not a CAROLFIRE issue. This is not a testing issue. This is a system safety-type issue. So this particular item, Item F, was outside the scope of CAROLFIRE. It's not -- you know, if you look at a cold shutdown circuit, if there's a hot shutdown circuit, they are the same. The cables are, basically, the same. The circuit configurations are going to be, basically, the same.

So from an experimental standpoint, from a phenomena standpoint associated with cables, there is no difference here. So this was not a CAROLFIRE issue. This is being addressed separately outside of CAROLFIRE.

Okay. That takes me to the fire model improvement area. We still have a few minutes. Now, as background for this, I don't know if this Committee specifically has heard about it, but there are separate efforts doing verification and validation fire models. NRC Research has recently published a report on that. Kevin was involved in that as well. They collaborated with EPRI on that particular effort.

And CAROLFIRE was really designed to compliment those ongoing efforts. And verification and validation is, of course, an issue for the new

NFPA 805 standard, the fire -- the performance-based fire protection standard. It says you need to use fire modeling tools that have been subject to verification validation.

Well, for our applications, you know, five years ago, those didn't exist. Today, we have a much better handle on that, but one of the areas that was found to be difficult for these models, it hadn't really been validated, was the cable. How do cables respond and when do they fail? So CAROLFIRE is kind of taking it to the next step. One of the issues that came out of verification and validation was cable response failure. Let's start addressing that.

So we needed data to support the cable thermal response and electrical failure modeling, the development of the tools, the calibration of the tools and, ultimately, the validation. Right now, we're more focused on calibration of the tool.

CHAIRMAN BANERJEE: Let me get this clear. The stuff we have seen, some of us at least, have to do more with not modeling the source of the fire, but given a certain source, then what happens to the fluid motion and the heat transfer and, you know, this type of thing.

MR. NOWLEN: Right.

CHAIRMAN BANERJEE: But the source is sort of based on some form of empiricism. There is no attempt to model the burning process itself, in the sense that it would burn, as you said certain source term and then look at the convection or whatever goes on around it. But you are not actually looking at the combustion process in the wood itself.

MR. NOWLEN: Well, there is a --

CHAIRMAN BANERJEE: Is that correct?

MR. NOWLEN: -- mixed bag there. Not entirely.

CHAIRMAN BANERJEE: That's what we have seen.

MR. NOWLEN: Yes. For most modeling exercises, yeah, the fire is taken as a given input.

CHAIRMAN BANERJEE: Right.

MR. NOWLEN: But there are the simpler fire modeling or the simpler fire sources. For example, a liquid pool fire, we can predict that with reasonable accuracy. A spray fire, we can predict that with reasonable accuracy. The ones that become more challenging are things like electrical control panels where, you know, what's an electrical control panel? How do you a priori model something that complex and variable? That's a real challenge that, you know, maybe our grandchildren might want to take up.

It's -- you know, just the fundamental understanding of a very, very complex fuel source and trying to predict how a fire might start from recipient, no we can't do that today.

CHAIRMAN BANERJEE: Right. So what I'm trying to understand here is given a source of a fire somewhere else, you can sort of use these calculations to give you the environment around the cable, if you will.

MR. NOWLEN: Correct.

CHAIRMAN BANERJEE: The cable will be exposed to. Then you can do some analysis of what happens to the cable to short and stuff like that.

MR. NOWLEN: Correct.

CHAIRMAN BANERJEE: Can the cable itself catch fire?

MR. NOWLEN: Oh, absolutely, yes.

CHAIRMAN BANERJEE: Yeah. So if it catches fire then, that part of acting as a source term for the fire, that can't be done at the moment, right?

MR. NOWLEN: Again, we -- most approaches involve empirical modeling of how that secondary fire --

CHAIRMAN BANERJEE: Condition/process itself goes on.

MR. NOWLEN: Right, yeah.

CHAIRMAN BANERJEE: That's a pretty empirical model.

MR. NOWLEN: Fairly empirical for most. There are some modeling -- there is some modeling work going on to try and do solid surface claim spread, a priori first principles modeling. But in general, our applications, we're still looking at empirical models of the subsequent spread of the secondary fires, we would say.

CHAIRMAN BANERJEE: That's based on some experiments or whatever?

MR. NOWLEN: It's based on information extrapolated from experiments. You know, how quickly will a fire in a cable tray spread? There are some sort of rule of thumb numbers out there that we use.

CHAIRMAN BANERJEE: Well, let me ask another question here. The point at which you get cable failure or hot shorts or something, that doesn't necessarily involve the study of the combustion of the cable itself. I mean, given an environment, it's a thermal conduction model that you developed it looks like, you can sort of get it to the point where the temperature is high enough and the thing goes.

MEMBER SIEBER: Right.

MR. NOWLEN: Yes.

CHAIRMAN BANERJEE: Right. But now the cable itself could catch fire and act as a source term for other cables or whatever.

MR. NOWLEN: Absolutely.

CHAIRMAN BANERJEE: That part of it is not part of the model, right?

MR. NOWLEN: Correct.

MEMBER SIEBER: You can actually have a failure in the thermoplastic cable without a fire in that cable itself.

MR. NOWLEN: Oh, yes.

MEMBER SIEBER: And the fire dynamics tools, as I understand it, is the way you model situations where the combustion is here and the target is over here.

MR. NOWLEN: Yes.

MEMBER SIEBER: And what's the energy transfer and what's the dynamic response of the target.

MR. NOWLEN: Yes, there is a range of tools in our application. Again, the fire is typically treated as a known behavior.

CHAIRMAN BANERJEE: Environment, yes.

MR. NOWLEN: But that known behavior does accommodate ignition of the cables and the subsequent spread. You know, that has to be a part of what you assume the fire is going to do. How you actually do that is based on empirical rules, but then you will build that into your fire modeling and account for --

CHAIRMAN BANERJEE: Well, one of the things that struck me is these experiments you did. Potentially, it could be modeled if you know the -- if you assume something about the heat source, which is what we basically do here.

MR. NOWLEN: Yes.

CHAIRMAN BANERJEE: You could model it in its complete geometry with one of the tools that you people have developed.

MR. NOWLEN: Yeah, I think we're getting a head to Kevin's talk here.

MEMBER SIEBER: Yes, yes.

MR. McGRATTAN: This is Kevin McGrattan from NIST. I'll be happy to address all those questions during my presentation.

CHAIRMAN BANERJEE: Right.

MR. McGRATTAN: We did actually model his experiments and I can talk about that a little bit.

CHAIRMAN BANERJEE: All right. So when you talk about the fire model improvements here, you could use these experiments itself to validate and improve the actual fluid dynamic calculations that you do in your fire model.

MR. McGRATTAN: Yes.

CHAIRMAN BANERJEE: As well as just looking at the cable itself.

MR. McGRATTAN: Yes, yes.

CHAIRMAN BANERJEE: So it's a coupled problem in some sense.

MR. McGRATTAN: Yes.

MEMBER SIEBER: Absolutely.

CHAIRMAN BANERJEE: Right. But what you have presented to us in Volume III is just what happens to the cable, right?

MR. McGRATTAN: Right.

MR. NOWLEN: Yes. As I said, we're just scratching the surface so far. Even with Kevin's work, he has started with the simple. There -- this is going to have a long life. There is a lot more work to be done here.

CHAIRMAN BANERJEE: Yes, I think the high level question is whether you had sufficient measurements in these experiments, especially the intermediate scale experiments.

MR. NOWLEN: Yes.

CHAIRMAN BANERJEE: That actually serve as a validation for sort of fire simulations that you guys have been doing with LES or whatever.

MR. NOWLEN: Yes, and again, I think we were more focused on --

CHAIRMAN BANERJEE: Cables.

MR. NOWLEN: -- calibrating the model.

CHAIRMAN BANERJEE: Yes, yes.

MR. NOWLEN: Trying to get a fundamental understanding of whether we had this problem right. Validation is a more challenging task. And so I'm a little hesitant to think of this in terms of validating models. We're more in the development stage. We needed something to help guide the development of the models. Validation ultimately will still be another need.

CHAIRMAN BANERJEE: Well, I think the way we can put it is given that the environment around the cable or cable sets are known, then what you are trying to predict and the experiments try to give the data base for, when will that fail in certain modes from a potentially hot short or whatever it is. But at the moment, you are really just addressing failure.

MR. McGRATTAN: Right. And we are addressing this sub-model of cable failure.

CHAIRMAN BANERJEE: Yeah, yeah.

MR. McGRATTAN: Not the fire models.

MR. SALLEY: Let me give you a quick time line on that just to put things in perspective. We have actually come a very long way with this. When the STP was introduced into the inspection tools back in the late '90s, again, the key becomes when is the circuit damaged? When do I get the spurious actuation? When does this make something bad happen to the reactor systems?

We started that in the late 1990s. We had to first decide that there were two different types. Not all cables are created equal. There are things called thermosets and thermoplastics. So, you know, we had to start there and say that they fail at different temperatures. The early models that were run in the late '90s for risk applications, because at the end of the day, what was the risk, that's the main question people get to.

The best we could do was say that well, we know that around 400 degrees fahrenheit the thermoplastics fail. So if a model predicts a hot gas layer that hits 400, assume failure. And that's what we did into the late '90s.

In 1805, we looked at that because of comments that the failure isn't instantaneous. There is a thermal mass. There is going to be some heat soak. It's going to take some time for that failure to occur. Naeem, Steve, myself, we sat down, went through all the existing tests and we come up with a simple -- backed out an equation. We said yeah, here is for thermal lag and this how long it will take. And that's what is currently being used today.

CAROLFIRE is the next logical step. Okay? We have now got this data. We want to know the failure mode of the cable. That's what we are focusing in on. So this is our next logical step and that's what Kevin's presentation will be about this afternoon for you. So we have actually come quite a ways from the late '90s to today. I mean, it's not 10 years and you can see very clear advancements of how we do this.

MR. NOWLEN: And so what CAROLFIRE really tried to contribute to this was to gather lots and lots of data about how the cables responded to these fire environments. If you look through the literature on cable fires, there is really not very much of that out there. A little bit. You will find it here and there. But to really say how did these cables respond and then to correlate that to the electrical failure, that was a real missing link in terms of the data that Kevin had available to help him develop these models.

We had lots of tested cable failure. We had -- some of those provided some information on response. There is lots of tests of burning cables. A few of those gave information on electrical response. So there was this gap of being able to directly correlate thermal response and electrical response and that's the gap we really focused on filling.

MEMBER BLEY: And so your cable failures link to electrical failures along with time distributions?

MR. NOWLEN: Yes.

MEMBER BLEY: Okay.

MR. NOWLEN: Yes. That was the goal.

CHAIRMAN BANERJEE: Okay. So now --

MR. NOWLEN: But I think that's probably a good spot to take a break, if you would like.

CHAIRMAN BANERJEE: Right. So after this we will get immediately into the experiments.

MR. NOWLEN: Yes.

CHAIRMAN BANERJEE: As quickly as possible.

MR. NOWLEN: Yes.

CHAIRMAN BANERJEE: And we've got quite a lot of --

MR. NOWLEN: We've got lots of pictures to illustrate what we have done.

CHAIRMAN BANERJEE: And that has to be done by 12:15.

MR. NOWLEN: No problem.

CHAIRMAN BANERJEE: All right.

MR. NOWLEN: That's two more hours.

CHAIRMAN BANERJEE: Surprised. Okay. We'll take a break. 10:15, be back in 15 minutes.

(Whereupon, at 9:59 a.m. a recess until

CHAIRMAN BANERJEE: Okay. Let's go back into session. Back to you, Steve. And as people have planes to catch today, we'll try to get it done.

MR. NOWLEN: Absolutely.

CHAIRMAN BANERJEE: Okay.

MR. NOWLEN: We have lots of pictures after this, so we can move fairly quickly through this next set.

CHAIRMAN BANERJEE: Okay.

MR. NOWLEN: We've been through the

objectives now, so you know what we are trying to do, hopefully. I wanted to just one more time hit on the roles and responsibilities. This was a collaborative effort. Research was the sponsor in the overall responsibility for program direction. NRR did play an advisory role in this. They participated in most of our project conference calls during the period where we were planning these tests and through the process of running them as we were making decisions as to whether we were going to change things in the next test, if we were going to look for something different.

NRR participated fully in all of that as well as they reviewed the report as well. NIST and the University of Maryland, both had similar roles, although NIST was rather more involved. The University of Maryland had a similar involvement though, an advisory role for planning the experiments and helping us with data reporting. They did a lot of the initial work of looking at the data, kind of interpreting what they were seeing, giving us feedback for planning on the next tests.

And they had a particular emphasis on fire modeling improvement goals. They weren't especially interested in the Bin 2 items. They were, obviously, more interested in the modeling parts of it. And NIST was focused on fairly simple approaches, as you will see from Kevin. I mean, that's not the end of it, but that was his initial involvement.

The University of Maryland was more focused on statistical and advanced methods of potentially modeling this. And unfortunately, there is no one from Maryland here to represent their work, but there is at least --

CHAIRMAN BANERJEE: We had a copy of the thesis.

MR. NOWLEN: Did you? Okay.

CHAIRMAN BANERJEE: Yeah, we read that.

MR. NOWLEN: Yes, because there is at least one thesis out there so far. And I thought it was a nice piece of work.

MEMBER SIEBER: Yes.

MR. NOWLEN: And then our role, Sandia's role, we were the test lab. And so I -- our people were responsible for test design, the procurement and the actual execution of the tests. We were also responsible for the analysis of the electrical data for the Bin 2 issues. That was our job. But when it comes to the thermal modeling side, the fire modeling side, our responsibility was limited to gathering and reporting the data.

It was explicitly not our job to do extensive analysis of that data. Now, you will see in Volume II we actually did quite a bit. We did as much as we possibly could.

CHAIRMAN BANERJEE: Let me ask you a question here about experimental design. Of course, we had looked at the peer review and so on.

MR. NOWLEN: Right.

CHAIRMAN BANERJEE: But did NIST have a hand in planning the instrumentation that could be put in?

MR. NOWLEN: Absolutely, yes.

CHAIRMAN BANERJEE: In terms of characterizing things?

MR. NOWLEN: Yes, absolutely. In fact, jumping a head a little bit, but they recommended we drop some things that were in the initial plans related to heat flux, in particular.

CHAIRMAN BANERJEE: Yeah, I noticed that comment on the heat flux meters.

MR. NOWLEN: Yes. They really didn't feel they would be very useful. And so they recommended we drop them as very expensive and not very useful.

CHAIRMAN BANERJEE: And the cable itself

was a heat flux meter, right?

MR. NOWLEN: The cable itself is a slug calorimeter in effect. And so what we did is we dropped a lot of -- you know, we had originally planned for additional metal slug calorimeters and radiometers and things of that nature. And we dropped most of that, we kept a little. We dropped most of it in favor of doing more with actually measuring cable responses. So we did a lot more thermal response cables than we originally planned.

So instead of buying radiometers, we basically bought thermocouples and instruments and cables.

CHAIRMAN BANERJEE: But what about thermocouples in the various spaces and things itself?

MR. NOWLEN: Yeah.

CHAIRMAN BANERJEE: You didn't have too many of those?

MR. NOWLEN: We didn't have too many, but the -- it was felt that we didn't need very many, because it was a relatively small space. It was designed to be a hot layer exposure with a capture-hood, basically, and we will see that in a second. Again, the feedback from NIST was put a few in and that's good enough.

So we had ceiling. On the side walls we had -- there are actually quite a few air thermocouples near the cables, so each bundle would typically come with not only the cable thermocouples, but also an air thermocouple right next to the cables above and below. So there is more than it might appear, but again the feedback was, you know, don't worry about putting in 500 thermocouples under the hood. We just don't need that kind of data. That was not the focus.

CHAIRMAN BANERJEE: It would be the -- I don't think we are going to get into the environmental modeling part of this today, right? We're mainly going to talk about the cables.

MR. NOWLEN: Mainly, it's the cables, yes.

CHAIRMAN BANERJEE: And that issue would arise when we look at the environmental models around the cables?

MR. NOWLEN: Yes.

CHAIRMAN BANERJEE: At some point in time, I presume, that will be looked at?

MR. NOWLEN: Yes.

CHAIRMAN BANERJEE: When using a model.

MR. NOWLEN: Yes. I mean, all the data we gathered is there and there is a lot of air temperature data available. Like I said, all the cables also came with air thermocouples, in addition to raceways, conduits, cable trays, the tray runs, side rails. There is lots of that there. We haven't focused on that. Again, there is lots and lots of room fire data.

You know, people have done fires in rooms and measured thermal -- we have done it. NIST has done many, many tests. So that just wasn't perceived to be the need. The need we focused on was try and measure the environment near the cables and then measure how they respond to that environment. That's what they were really after and so that's where the focus is.

CHAIRMAN BANERJEE: Okay.

MR. NOWLEN: Okay.

CHAIRMAN BANERJEE: Let's go on, yeah.

MR. NOWLEN: So about understanding those roles and again, you will see that reflected in our Volume I, Volume II, some of the things that people asked for in comments were simply outside my scope, so I couldn't do that in my report. I simply didn't have the scope to do it.

So again, there was a peer review. And I guess you have seen that. We were responsible.

Sandia was responsible for developing the test plan, but all of our collaborative partners contributed to the peer review. We had Nathan Siu and I apologize for this name being misspelled there. Yeah, I'm sorry, I know Nathan and I know better than that.

MEMBER SIEBER: It's only three letters.

MR. NOWLEN: It's only three letters and I got two of them wrong, backwards.

MEMBER SIEBER: You only got one right.

MR. NOWLEN: I got all three right, just not the right order.

MEMBER SIEBER: Dyslexia.

MR. NOWLEN: Yeah. So and then NRR, we also had comments from Dan Frumkin and Naeem Iqbal. They both contributed to our peer review. Anthony Hamins at NIST, Mohammad Modarres, I'm sure you all know, at Maryland, and then at Sandia, one of my colleagues. We have another group that does fire work mainly for DOE and DoD applications. We had one of their people, Vern Nicolette review the test plan as well.

And then we also included one outside expert and that's Dan Funk of EDAN Engineering. And he was a very important contributor to our peer review. He was actually the author of the EPRI report, the documents the NEI tests, right, the original set of tests.

MEMBER SIEBER: Yeah.

MR. NOWLEN: He was the report author. So we had him. We actually hired him as a consultant to peer review our test plan and he actually gave us some really good feedback on the electrical circuit parts, in particular. So I think he was a real good contributor to our peer review.

So out of that, we ended up with our test plan. The test plan and now we're going to get into what was done. We did pursue two scales of testing. There is a small-scale test that were done that involved a fairly simple radiant heating exposure. Very -- the idea here was we can do lots of experiments quick and dirty and cheap and they are very well characterized, very easy to control. And again, when we're looking at just beginning the process of developing this response model, it's real nice data to help you calibrate what is happening to the cable. And again, most of the data correlates directly to electrical performance.

And then there is the intermediate-scale where we went to a more realistic scale of real, this is where the open live fire comes from. They were real fires in a more realistic configuration with real trays and conduits loaded and all of that. We also did test quite a broad range of cables. The 15 cables we tested are in the pile there. And they do represent a fairly broad range from, essentially, the most robust cables you will find out there in industry to effectively the least robust from a thermal damage standpoint.

And again, the point that we did not do armored cables because we knew Duke was doing that and so we simply didn't try and reproduce what they were already doing. So this is the list of cables. This is in the report. We don't need to go through it in detail. But, you know, people who know Rockbestos Suprenant, they are a major manufacturer who have been around forever for the nuclear industry, very, very common.

And this Firewall III line of cables, as I said before, single most popular brand name you will find out there. So this one of all, that's probably representative of the largest single set of cables you will find out there. Some of these others, a lot of these like general cable is a -- is now a conglomerate of a number of manufacturers that used to make nuclear plant cables. And they still do, but basically, general cable has been buying up smaller manufacturers. Tamaqua, Boston Insulated Wire, BIW, and a number of other small manufacturers that cater to the nuclear industry, they are all now under the general cable label.

So one of the materials, the cross-link polyethylene and the EPR cables, those are both still marketed under what is known as BICC, which doesn't mean it's -- it's one of those acronyms that doesn't mean anything. But they were a major manufacturer of nuclear plant cables in the '70s and '80s. So these product lines while still market -- while now marketed under general cable are really traceable back to what industry had.

Now, the rest of these are more general industrial-type cables, like PVC, PVC, these were acquired from general cable. They are just general industrial. They are not specifically nuclear-qualified. First Capitol was the supplier of our silicone cable. Again, it's not specifically nuclear-qualified, but we specified a configuration that would be typical of what we would find in a nuclear plant, but it does lack the specific qualification.

CHAIRMAN BANERJEE: Are all these cables used in nuclear plants today or supposed to be?

MR. NOWLEN: They are all --

CHAIRMAN BANERJEE: Or represented?

MR. NOWLEN: They are all representative of what's used in nuclear power plants today. Some of these are, like I said, the Rockbestos Firewall III and the BICC brand from General Cable are explicitly nuclear-qualified cables. The rest of the cables are just typical of what you would see.

CHAIRMAN BANERJEE: So the first floor are nuclear-qualified?

MR. NOWLEN: Yes. The first floor are nuclear-qualified. And this one here, the EPR/CSPE is nuclear-qualified. I'm sorry, this one is not. The cross-link polyethylene PVC is not. I apologize. The EPR is.

CHAIRMAN BANERJEE: What does nuclear-qualified mean?

MR. NOWLEN: It's certified to IEEE 383 and all its glory. All of the equipment qualifications, severe accidents, survival, radiation and thermal aging requirements, all of that.

MEMBER SHACK: This is not to say that these other cables couldn't pass that, they just haven't been through it?

MR. NOWLEN: Correct, yeah. Now, these

guys down here, the PVC cables --

MEMBER SIEBER: Probably wouldn't.

MR. NOWLEN: -- they wouldn't pass it. The silicone rubber almost certainly would. The cross-link polyolefin, don't know. Nobody has tested that one. Again, this cross-link polyolefin is one, you know, again, the cable you might see in the plants tomorrow. Nobody has tried to qualify it to my knowledge, so I suspect it would, but I don't know for certain.

CHAIRMAN BANERJEE: The CSP has a halogen?

MR. NOWLEN: Yes.

CHAIRMAN BANERJEE: And that's the reason -- I mean, the reason could be as a fire retardant, right?

MR. NOWLEN: Absolutely, that's why -- yeah, it's chlorosulfinated, so it's got a lot of chlorine.

CHAIRMAN BANERJEE: Yeah.

MR. NOWLEN: Yeah.

CHAIRMAN BANERJEE: Produce a lot.

MR. NOWLEN: There are a lot of -- actually, these all -- the CSPEs, the polyethylenes, those all have chlorine, bromine. PVC, you know, for comparison, is like 60 percent chloride by weight, by mass. You know, it's 60 percent chloride, yeah. It's huge. It's mostly chloride.

MEMBER SHACK: What's this proprietary Tefzel compound?

MR. NOWLEN: Tefzel? Tefzel is a teflon-based material, so it's a brand name produced by Dupont. One of the interesting things about Tefzel is that you buy Tefzel as a premanufactured material and you simply apply it to your cables. So Tefzel is Tefzel, basically. There is a couple of different formulations of it, but again, in contrast like a cross-link polyethylene, the manufacturers will compound that material using their own proprietary formulations.

Tefzel is unique in that Dupont sells it as precompounded. You simply apply it to your cable.

CHAIRMAN BANERJEE: But you extrude it with the cable?

MR. NOWLEN: Yes. You extrude it on to the conductors and then if you are jacketing it, you would extrude it over the jacket as well. So that one is quite unique. When you buy Tefzel, Tefzel is Tefzel. All the rest of them are proprietary manufacture formulations. And that's because Tefzel is a, you know, registered trademark brand name with

Dupont.

CHAIRMAN BANERJEE: Now, you say it's a thermoplastic.

MR. NOWLEN: Yes.

CHAIRMAN BANERJEE: But it would be a higher melting thermoplastic, wouldn't it?

MR. NOWLEN: It is a higher melting thermoplastic. It is still a thermoplastic.

CHAIRMAN BANERJEE: Yes. It's --

MR. NOWLEN: It does melt.

CHAIRMAN BANERJEE: -- teflon-based.

MR. NOWLEN: Yes.

CHAIRMAN BANERJEE: Yes.

MR. NOWLEN: Yeah, it's more robust than the other PE and PVC, yeah. Not all that much. I've actually got a plot for you in the back here. It's not all that much tougher, but it's a little tougher.

Now, these others, the cross-link polys, the EPRs, they are substantially more robust. And this one, the silicone rubber, and this one here, the Vita-Link, that's another trade name product out of Rockbestos, that one was actually donated to us. Those are -- the Vita-Link is also a silicone-based material. These guys, when it comes to just plain heat, are tough. We put these in our radiant heating test at 700 degrees centigrade for an hour and they wouldn't fail.

Now, I mean, that's severe. They would burn and, you know, they were -- there wasn't much -- you know, you wouldn't install it once it has been through that test, but they -- electrically they just sort of snubbed their nose at us.

Now, we had heard that before. We had heard that from industry that, you know, thermally they will stand up, but once you get them wet, they will fail. And indeed that's what happened. We went to the intermediate scale, we put them in a number of the tests and we had a small sprinkler in the facility, so at the end of the test, these things would still be functioning, but just as soon as we hit the water, down they would go. They would short out.

So those two are very interesting. The silicone materials, they seem to be very, very tough from a thermal standpoint, but again, once you burn them up, you hit them with water and, you know, with fires we usually do have water around, you know, we're trying to put the fire out, so those were the interesting ones, most interesting.

Okay. So again, the idea is a range from the best to the worst in some senses. This is a picture of them. Again, that's just that set of samples. Just to give you an idea, you know, one of the things we were trying to do is you see like this is a typical seven conductor with a core cable or a core conductor and six surrounding it. Here is another one. These are roughly the same size, but two different materials.

We tried to pick up like say this one here is a three conductor with an uninsulated drain wire. We tried to pick up -- this is where we talked about having more copper, less plastic, more plastic, less copper, that ratio and they are specific numbers now.

CHAIRMAN BANERJEE: But when you say power control and instrumentation, which is the function, what is the correlation of the characteristics of these with the function?

MR. NOWLEN: Um-hum, right. The instrument cables are like this guy, two very small conductors with a shield and drain. Small wires, you are carrying minimal power. It's not trying to -- you know, you are carrying like a millie amp level signal.

CHAIRMAN BANERJEE: Okay.

MR. NOWLEN: So you only need a minimal size of a conductor. That's one of our instrument wires. This is the other one right here. The control cables are more than intermediate sized conductors. In our case, they were 12 or 16 gauge, which is -- you know, that's kind of typical of what you find in your house.

MEMBER SHACK: Okay. That's real wire to me.

MR. NOWLEN: Now, you will see a cable like that is used in what we call a light power, like a lighting circuit in your house. That would be --

MEMBER SHACK: Yes, that's 12.

MR. NOWLEN: -- there, but --

CHAIRMAN BANERJEE: Is that the second one? The control cable?

MR. NOWLEN: This one, this one, this one, these two on the end, actually, this one here is also a seven conductor. So all of these were -- this one was one of the lightest wire gauges right here, that's a 12 conductor. Now, let's see, this one here, that's a three conductor and it's a heavier gauge. So this is what we would call a light power cable. You are going to carry upwards of say 30 amps on that circuit. These 12 conductors, you're going to be looking more at 15 to 20 amp-type circuits in a tray application.

And then there -- let's see where is that, this is the other power cable here. Again, this one was a three conductor and it had what's called a drain wire. It's basically a ground wire. But that's another light power cable. We didn't go with the upper end. I mean, power cables can, you know, get this big. They can get huge, inches across. We didn't try and do that.

What we were really looking for here was, again for Kevin's purposes, to try and sort of vary the copper to plastic ratio, so that he could get a feel for how important that was to how they respond. And so that's why the focus was really on these seven conductor control cables. That was the focus. But the others, the 12 conductor and the light power cables were that variation on a theme to try and give Kevin a little more insight into how that affected things.

MEMBER BLEY: Is it likely to use results that would extrapolate to the larger size cables, power cables?

MR. NOWLEN: I'll leave that to Kevin.

MEMBER BLEY: Okay.

MR. NOWLEN: I would guess yes.

MEMBER BLEY: Please, talk about that when you are up, in case I forget.

MR. NOWLEN: I would think so, you know.

Okay. So the small-scale test, these were done in a facility we call Penlight. This actually had a life in the past. It was originally developed for the NRC Research Program in the early '80s. And in that day it had the name SCETCH, the Severe Combined Environment Test Chamber, and it was used in a range of tests for hydrogen burn environments.

We actually had an apparatus that we could simulate a rapid pulse hydrogen burn, pressure transmitters were tested in here for high temperature steam environments. We did some cable thermal damage testing in here, so it had a life before. It is now being maintained by our other fire group out at Sandia used for a variety of purposes. But basically, it's an array of heating lamps. These shiny aluminum looking cylinders. Each one of those represents a quartz lamp.

So then the quartz lamps are 24 inches long. They go back into the plant and they surround--inside of here there is a metal shroud. So what we do is we use the lamps to heat the shroud and the shroud acts as a grey-body source that then heats whatever is inside of it. So, you know, the problem with quartz lamps is they don't give you the right spectrum for a fire. They are too hot. They are too high in the spectrum.

So what you do is you turn it into more of a thermal spectrum by having this intermediate shroud. So again, the idea is the ability to run lots of tests in a very, very well-characterized environment. We did this with cable trays. This shows you a typical cable tray arrangement, so you can see the shroud here. Now, those lamp ends are now hidden behind this metal plate. The metal plate was there to protect the electric on the lamps, keep them clean. We didn't want the smoke dirtying up the lamps.

MEMBER ABDEL-KHALIK: But the majority of the experiments were run with the end covers closed?

MR. NOWLEN: Yes.

MEMBER ABDEL-KHALIK: What is the fraction of experiments that were done with the ends open?

MR. NOWLEN: We did the first end, I think. The preliminary tests were done mostly with open ends. We wanted to see what was happening, basically, there. And then as we got towards the end where we were doing some of the larger bundles, we decided to go back to an open end, because it seemed like the closed ends were restricting the natural burning of the cables.

MEMBER ABDEL-KHALIK: Um-hum.

MR. NOWLEN: So I think probably of the total set of Penlight tests, about 20 percent were done open and the other 80 percent were done closed.

MEMBER ABDEL-KHALIK: Now, for the open ended tests, how well do you know the axial heat flux distribution?

MR. NOWLEN: We know the radiant input well. What you don't know is with the open end you have this sort of unknown in/out connection flow.

MEMBER SIEBER: Yes.

MR. NOWLEN: And that complicates the problem. We didn't attempt to characterize that and so again, that was the main reason that most of the tests were done closed. And we had no problem. Like this is a test of -- you see, this is connecting to the electrical monitoring system. So this cable on the right is actually there thermal response cable. So it has got thermocouples on it.

This one is the electrical response. With a test like this where it was two single cables, it was no problem running closed. The behaviors weren't affected and for Kevin's purposes, again, to get rid of that unknown convective behavior, he really wanted it closed up as well as possible. It's not sealed, but you can see from this picture it's pretty well closed.

MEMBER ABDEL-KHALIK: Well, okay. So for the open tests, I guess you agree that you don't really know the axial heat flux distribution that well.

MR. NOWLEN: Not as well. There is an unknown convective effect that we didn't attempt to characterize.

MEMBER ABDEL-KHALIK: So for the closed tests, this thing is 2 feet long.

MR. NOWLEN: Yes.

MEMBER ABDEL-KHALIK: And roughly the L over D is close to 1. Even for the closed test, how well do you know -- how uniform is the axial heat flux distribution?

MR. NOWLEN: Kevin, you seem dying to -- I don't -- we have data on the uniformity. You know, there is -- we know that temperature -- you know, for example, there is a temperature distribution across this shroud, just because it's heated in the, you know, across its length, but it -- there is conduction off to --

MEMBER ABDEL-KHALIK: But actually, in most of experiments, you, essentially, collected data from one thermocouple TC-11 or something like that.

And even though in earlier experiments when you had more thermocouples, they showed significant axial variation in temperature.

MR. NOWLEN: Yes.

MEMBER ABDEL-KHALIK: And yet in the end you opted to only collect and store data from one thermocouple.

MR. NOWLEN: Yes.

MEMBER ABDEL-KHALIK: So --

MR. NOWLEN: There's a couple reasons for that. What were -- what we find with cables is the hot spot drives the failure. Because the thermal response of the insulation tends to be exponential with temperature, so insulation resistance drops exponentially with linear increases in temperature. So what we see is that the failure behavior, and we have seen this in past testing, is driven by the behavior at the hot spot.

The center in this case is the hot spot. So we focus mainly on that center point with a good number of experiments run without board thermocouples, you know, towards either end, so that we would have data to understand how much axial variation there was in the thermal response.

MEMBER ABDEL-KHALIK: But --

MR. NOWLEN: And what Kevin has found, I think, is that his results do correlate very well with the sub-jacket thermocouples measured at the center. That seemed to work well.

MEMBER ABDEL-KHALIK: Wouldn't the heat flux be a part of our boundary conditions?

MR. McGRATTAN: Yes. I'll talk about this more, but I actually modeled in a very crude way that apparatus and then embedded within it this simple cable failure model. So I did capture the spacial variation of the heat flux.

MEMBER ABDEL-KHALIK: With your crude model rather than in a verified way using experimental data?

MR. NOWLEN: Well, we do have experimental data, just not for all the tests. We -- you know, again, this was one of the things that we consulted with NIST on is early in the process, we were running multiple thermocouples along the length and Kevin was looking at that data and Marilyn was looking at that data. And then they said okay, we've got enough of that, you know, you can stop. It's not helping us any more. We got what we need.

Then we shifted our focus to primarily a thermocouple at the center. So there was feedback among the modelers and when they gave us the high sign that they had gotten enough of that data, we shifted and just for efficiency purposes --

MEMBER ABDEL-KHALIK: So I guess we'll just revisit this when you talk about your model.

MR. McGRATTAN: Sure.

MEMBER ABDEL-KHALIK: Thank you.

MR. NOWLEN: And the covers that he is speaking of --

CHAIRMAN BANERJEE: Now, you had an estimate of the heat flux from the quartz lamps and knowing the power going in or whatever?

MR. NOWLEN: Yes.

CHAIRMAN BANERJEE: So you had a direct measure of the heat flux. But you didn't know how uniform it was, that's the real issue.

MR. NOWLEN: Well, we have -- what we have is a measure of the surface temperature of the shroud.

MEMBER ABDEL-KHALIK: Right.

MR. NOWLEN: And we have that. Typically, we stopped recording all of it. There is actually thermocouples on the top, both sides and the bottom. And there is a few tests where we measured all of the data.

CHAIRMAN BANERJEE: How uniform was it?

MR. NOWLEN: It's fairly -- well, gosh, how uniform? That's a qualitative question. It does vary from end to end and there is a couple of plots that illustrate that. There is -- the hot spot is maybe, you know, 20 degrees centigrade higher than the very end out here on the wings. And there is a little variation just because of the natural convection effect between the top and the bottom.

MEMBER ABDEL-KHALIK: Right.

MR. NOWLEN: 5 degrees centigrade sort of thing.

MEMBER ABDEL-KHALIK: But axial is a variation with significantly more than that.

MR. NOWLEN: Axially, like I say, between the center and the outboard position, about 20 degrees centigrade on the shroud. Now, the cable you will see that axial either -- is a fairly substantial variation. And again, we have plots in the report to illustrate that. The cable responds differently, because, you know, essentially part of its radiant environment is this unheated end.

CHAIRMAN BANERJEE: Right. Because, obviously --

MR. NOWLEN: You have to understand that.

CHAIRMAN BANERJEE: -- even a 20 degrees

change is significant, because it goes to the fourth power.

MR. NOWLEN: Yep. Yeah, I mean, it's critical that people understand this when they interpret the data. You've got to understand that these are all true effects. And they -- you know, to whatever extent, they need to be accounted for. But again, we seem to see good correlation with the behavior at the hot spot, that seems to be the key. It seems to work.

MR. McGRATTAN: Yeah, I mean, one thing I'll mention is that in the tests in which they ran a conduit through there, in some sense, the temperature of that conduit served as a perfect way of measuring the heat flux.

CHAIRMAN BANERJEE: Because you had multiple embedded thermocouples.

MR. NOWLEN: Right.

CHAIRMAN BANERJEE: But then you would have to know the thermal conductivity of the materials rather well, right?

MR. McGRATTAN: Well, we do know the material properties of the conduit.

MR. NOWLEN: Generic.

MR. McGRATTAN: And the simple

calculations that I did, I mean you could pull out of a basic heat transfer book --

CHAIRMAN BANERJEE: Right.

MR. McGRATTAN: -- will predict that conduit temperature fairly accurately.

CHAIRMAN BANERJEE: So if you knew the thermal physical properties, and you trusted your thermocouples --

MR. McGRATTAN: Yes.

CHAIRMAN BANERJEE: -- which could be exposed to some radiant effects --

MR. McGRATTAN: Right.

CHAIRMAN BANERJEE: -- on the surface.

MR. McGRATTAN: Right.

MR. NOWLEN: Yeah. I've got a photo that illustrates the thermocouples. We tried to deal with that.

MR. McGRATTAN: Yes, the conduit -- the point of the conduit was not to serve as a --

CHAIRMAN BANERJEE: Heat flux meter.

MR. McGRATTAN: -- heat flux gauge.

CHAIRMAN BANERJEE: Yeah.

MR. McGRATTAN: But after the fact did a good job of it.

MR. NOWLEN: It actually did, yeah. All

these passive targets could be looked at like slug calorimeter. I mean, we build a lot of calorimeters that look like a big piece of pipe with ends on it and throw them in fires. So it's not a bad analog. I mean, it wasn't what we set out to do. It's not why we did it, but it worked pretty well. And I do have later --

CHAIRMAN BANERJEE: So you do need an independent --

MR. NOWLEN: -- later I have got a picture of it.

CHAIRMAN BANERJEE: -- measure of the heat flux or at least --

MR. NOWLEN: Well, we didn't do it for this program, but it has been done for the facility before. And that's why we were able to produce the plot that gives you emissivity as a function of temperature for the shroud, because this is a very well -- this facility is actually its primary use these days is calibrating heat flux cables. That's what they use it for.

And so they have characterized it very, very well, so that they can actually use it as a calibration source when they calibrate a heat flux gauge. So this is --

CHAIRMAN BANERJEE: That heat flux you measured using the conduit are in line with the estimates that you make?

MR. NOWLEN: Yes. I think that's a true statement, yes.

MR. McGRATTAN: Um-hum.

CHAIRMAN BANERJEE: Okay.

MR. NOWLEN: So this illustrates --

CHAIRMAN BANERJEE: On this point, there are no -- if you did a fluid dynamic simulation, you don't see any convection patterns set up by all these non-uniformities?

MR. McGRATTAN: Oh, you do.

CHAIRMAN BANERJEE: How significant are they?

MR. McGRATTAN: But they are -- well, very insignificant. I mean, the rate to have heat flux in that apparatus is driving everything.

MR. NOWLEN: It's a very radiantly dominated facility.

MR. McGRATTAN: Right.

MR. NOWLEN: Even when it's relatively open, it's predominantly radiant.

MR. McGRATTAN: I mean, that's why I like working with this data most of all, because it is probably the best characterized data that we have related to cables. Even more so than putting these cables into an oven.

MR. NOWLEN: Yes, ovens -- we have done ovens.

MR. McGRATTAN: They have their own problems.

MR. NOWLEN: Yes, they have their own problems. Very difficult to characterize the radiant versus the thermal effect.

MR. McGRATTAN: Emissivity and so forth.

MR. NOWLEN: Yeah.

CHAIRMAN BANERJEE: Now, your preferred motive heating these cables, obviously, was radiant, because that's most characteristics, I guess, of fires, rather than convective?

MR. NOWLEN: Well, fires involve both.

MR. McGRATTAN: Right.

MR. NOWLEN: What the objective with Penlight was to do something that was very well-characterized, albeit, not necessarily fully representative of what happens in a fire. We felt that, you know, radiant is a dominant behavior in fires, no doubt. Convective can be important. For example, plume exposures. Convection is very important. We weren't trying to argue that this is a fire, that this is a plume exposure. This is more like a hot gas layer exposure.

It's -- but it doesn't involve the convective piece of it. Now, again, one of the questions you might ask is does that make an effect on how the cables respond? We don't believe so. We think that the effect of the cables is an overall heating effect. So whether it comes from radiant versus convective would affect timing, but not necessarily mode of failure, you know.

CHAIRMAN BANERJEE: Well, you can get very different heat fluxes in convective conditions.

MR. NOWLEN: Yes.

CHAIRMAN BANERJEE: Compared to radiant.

MR. NOWLEN: Which gets to the timing, you know.

CHAIRMAN BANERJEE: Right.

MR. NOWLEN: It's going to longer to heat the cable to its failure threshold if it's a more convective environment, a nice aggressive radiant environment like these were, it will tend to lead to earlier failures. Now, again, we tuned the heat flux to give us failure times in the sort of 10 to 20 minute range. We considered that to be more representative of what we see in applications. That 10 to 20 minute damage range is somewhat representative and it becomes risk important.

You know, we begin to have the issue of can we put the fire out that quickly? So we tuned these heat fluxes for each of the cables to reach what we considered a reasonable failure of time. But again, it's an idealized configuration. The real configuration is the intermediate-scale, where we have real fires, the open live part of CAROLFIRE. That's the more representative of what really happens in fire.

This is an idealized case that is aimed -- you know, a lot of the Penlight tests were aimed squarely at the fire modeling. A lot of these Penlight tests with the single cables -- you know, if I'm doing a single cable, that doesn't tell me anything about inter-cable.

CHAIRMAN BANERJEE: Fire modeling is a term. I think cable response under it given heat flux is what you're talking about.

MR. NOWLEN: Yes.

MR. McGRATTAN: Cable response modeling, sure.

CHAIRMAN BANERJEE: Yeah.

MR. NOWLEN: Yes. And that's really -- Penlight, probably 60 percent of the Penlight tests were explicitly for that purpose as opposed to the Bin 2 items. We did do bundles. When you get into the bundle tests, those are starting to attack the Bin 2 items. But most of these tests in Penlight were very simple configurations, single cables and they were aimed squarely at fire modeling. And just well-characterized, idealized conditions.

This just shows you the airdrop. Some of the tests were run with no raceway basically. We just supported them on each end and then covered it up with the same cover we used for the conduit. So again, remove the raceway as an element. These were all single cable tests. So again, you know, simplifying Kevin's life, get rid of the blockage introduced by the cable tray. It's purely 360 surround on heat flux. So simplifying again.

CHAIRMAN BANERJEE: Because it makes the calculation of the heat flux simpler.

MR. NOWLEN: Yes. Again, the idea of calibrating the model. Can we do the simple case? If we can't do the simple case, we're in trouble already. Well, the simple case we can handle. Let's step it up. Let's go to something like a conduit where it's fairly -- it's going to the cable transfer, it's complex geometry, so, you know, and then let's go to bundles. So it's continuously stepping up in complexity, but starting real simple.

MR. SALLEY: Keep in mind, please, that at the end of the day, you know, we're looking at fire risk. Okay. And the world Dennis comes from and the PRA, the questions that we are asked with the cables and it will become quite simple from the inspectors is what temperature does it fail? You said, well, I just can't throw you a temperature out there. I mean, there is a temperature and a time.

You know, we're looking at the cable failure. And the simple question they want answered is, they don't -- the heat transfer part, yes, it's fascinating in and of itself. But the goal here for Kevin was to give us a tool that at what time and temperature can we start to expect these failures? So again, it's driven by the risk part of it and that's the question the PRA people want.

I've got this kind of cable, when does it fail?

MEMBER ABDEL-KHALIK: Yes, but to get from here to there, you have to have a reliable verifiable model.

MR. SALLEY: Yes, you do. And I think Kevin --

MEMBER ABDEL-KHALIK: That's what we're asking.

MR. SALLEY: -- will get to that. If you are familiar with fire protection, the concept that this set out on, if you look at a sprinkler head, there is millions of sprinkler heads installed. And the sprinkler head has a temperature rating. An ordinary head is 165 degrees fahrenheit. Does that mean that it goes off at 165 degrees? Okay. This was a question 20 some years ago the fire protection community, in general, asked. Why do I put a 165 versus a 225 versus a 500 degree sprinkler head in there?

The concept they came up with was response time index. And this is what is commercially used. Fire risk today is to when suppression systems operate. The same is true with thermal detectors that operate suppression systems. We tried to take that same concept with that same rigor for the cables. So that was our model in setting this up, but I'm sure Kevin is going to get a lot more into it this afternoon and we will get to some of this detailed heat transfer for you. So, you know, if -- that will be Kevin's presentation.

MR. NOWLEN: And just to illustrate, cables did burn in Penlight. You know, one of the things we typically see with cables is they will fail first and then ignite right away. And we have seen that before. We saw it again here.

CHAIRMAN BANERJEE: When you say right away --

MEMBER SIEBER: In seconds.

CHAIRMAN BANERJEE: -- is there a -- within minutes, seconds or --

MR. NOWLEN: Seconds.

CHAIRMAN BANERJEE: Seconds.

MR. NOWLEN: It's fairly common that the electrical arcing that occurs when the cables short acts as a pilot that ignites a flame. These things -- occasionally, when we ran these at pretty high flux, they would poof, burst into flame. That did occur. We ran a number of tests where that occurred. But more commonly, with these longer term heating, they won't just burst into flame, but once they electrically fail, that arc triggers the fire. It's the pilot that starts the flame.

MEMBER SIEBER: Or gives you a heat impulse.

MR. NOWLEN: Yes, it gives you that trigger that, you know, there are off-gassing, there is all kinds of flammable materials coming out just from the off-gassing, but you need something to trigger them to ignite. You need that extra little spark of energy and it's usually the electrical spark in our cases that we have seen. And we saw it again, so Penlight and one of the things we did later in the test with the larger bundles, we felt that the closing up the chamber was really choking off the normal burning behavior.

So towards the end, we decided to reopen the chamber. Kevin has to sacrifice the unknown heat flux and convective term that comes in, but we didn't want to restrict the normal burning.

CHAIRMAN BANERJEE: But why was burning important if it usually failed before it burned?

MR. NOWLEN: Well, because if one cable fails and ignites a bundle, how will that affect the subsequent behavior of the other cables? That was the question. And many of our Bin 2 issues were related to inter-cable interactions.

CHAIRMAN BANERJEE: I see.

MR. NOWLEN: We weren't just interested in that first one.

CHAIRMAN BANERJEE: Not just intra-cable. So you did inter-cable.

MR. NOWLEN: A lot of inter.

CHAIRMAN BANERJEE: Okay.

MR. NOWLEN: So the bundles are aimed at the inter-cable behavior. We didn't want to restrict that natural behavior too much, so we opened it back up and sacrificed the uncertainty of convection.

MEMBER BLEY: Steve, we were looking at some new plant yesterday. Do the cables, the insulation, does it produce any oxygen? If this was in an inner environment, would you actually burst into flame?

MR. NOWLEN: No.

MEMBER BLEY: Of course, you wouldn't have the fire to start with, would we?

MR. NOWLEN: It shouldn't. No. Well, no.

MEMBER BLEY: But you could have a major short that created real high currents.

MR. NOWLEN: No. You don't get oxygen off of these as --

MEMBER BLEY: Okay.

MR. NOWLEN: -- a product. Not any of the times I'm aware of.

MEMBER SIEBER: Not out of convection.

MR. NOWLEN: Unless they are doing something odd with their low halogen. But I can't imagine their generating oxygen. That would be not a good thing from a fire perspective.

MEMBER SIEBER: That's sort of backwards.

MEMBER BLEY: I'm sure it wouldn't.

MEMBER SIEBER: Fire consumes oxygen.

MR. NOWLEN: Yeah. The oxidation process here is clearly oxygen-based. So no, they shouldn't burn in an inner environment, even if they fault. You shouldn't get an ignition.

MEMBER BLEY: And in an inner environment, we wouldn't have the inter -- the inter-cable factors will be quite different.

MR. NOWLEN: Your fires are just different. So if you -- you know, the question is can you get a fire that is big enough to cause multiple failures from one cable starting the whole thing off, you have internal faulting overload whatever on one cable, can you actually create a fire that would then propagate? It's going to be -- it's a challenge even in a non-invert environment, especially with the newer cable types. In an inert environment, I'm speculating, but yes, I think no oxygen gets to that. It's going to be tough.

I should be careful, because there is always Hinesdale. The Hinesdale Switching Center fire. If you haven't looked into that one, it's very interesting. But I don't think we want to divert there.

CHAIRMAN BANERJEE: Well, I guess, the issue is not whether it produces necessarily a fire, although that's a rapid heat release. If there is any decomposition reaction which produces a lot of heat, I mean, that's really the issue, which could then move to the next cable.

MR. NOWLEN: Right. And short of oxygen, no. It's an oxidation process. You know, polymer is --

CHAIRMAN BANERJEE: There is no decomposition?

MR. NOWLEN: Not that I'm aware of, no.

CHAIRMAN BANERJEE: No, usually polymerization is atomic.

MR. NOWLEN: Yes, right.

CHAIRMAN BANERJEE: Was breakdown is --

MR. NOWLEN: Right. But that's a part of the formulation process.

CHAIRMAN BANERJEE: Yeah.

MR. NOWLEN: Once it comes out of the

manufacturer, that's all taken place.

CHAIRMAN BANERJEE: Yes.

MR. NOWLEN: Okay. Here is a typical illustration before and after of the thermoplastic. So here you see the melting behavior and Mark had some cables that showed that nicely. But you can also see, you know, the number of thermocouples that are installed. Several -- you know, we would take them down to the cable, but the thermocouple would be located in between.

This would be a typical setup with a thermal response cable and electrical response cable. You know, we don't want to stick thermocouples on the one we are measuring for electrical performance, because that could affect the electrical performance. So we run these side-by-side and then again, aftermath of a typical thermoplastic, they look like that. Lots of melting, gooey stuff dripping down.

In contrast, this is the -- before it looks the same. You can't really tell the difference, but afterwards, this is more typical of a thermoset. You have this ash that's left behind. The cables char and burn, but, you know, you don't get that melting material dripping all over the place. So that's very typical of those two cable types. You know, I think you can begin to see why we classify them that way, because these behaviors are so different.

This was a typical bundle. You can see a bundle now. We had a limit to how many cables they would let us actually burn in this small-scale apparatus. It wasn't really designed to take large burning. So we weren't able to do two bundles side-by-side.

MEMBER ABDEL-KHALIK: Could you go back to Slide No. 22?

MR. NOWLEN: Back to 22?

MEMBER ABDEL-KHALIK: It's two slides.

MR. NOWLEN: You'll have to tell me. Two slides?

MEMBER ABDEL-KHALIK: Right.

MR. NOWLEN: This one?

MEMBER ABDEL-KHALIK: This one, right.

MR. NOWLEN: Yes.

MEMBER ABDEL-KHALIK: So you have, essentially, two identical cables subjected to identical conditions?

MR. NOWLEN: Correct.

MEMBER ABDEL-KHALIK: One you, essentially, get the electrical response and the other one you monitor the thermal response?

MR. NOWLEN: Correct.

MEMBER ABDEL-KHALIK: You know, when you examine these two cables afterwards, do they really look identical? Looking at this picture.

MR. NOWLEN: For the most part, yes, but the one difference you see is the tape that we used to secure the thermocouples. The tape is -- it's actually a fiberglass tape and it's pretty strong. It's pretty robust. It holds up pretty well. So other than the fact that that tape spot looks a little different than the rest, yes, they do look very much alike.

You know, for example, you look at this, this is actually two cables. The one in the back was a thermal response and the one in the front was an electrical performance. And qualitatively, they are very, very similar. But that tape, you know, you have to secure the thermocouple somehow and the tape is part of the reason we don't want to do that to our electrical cable.

We don't want to mess with the electrical cable at all. We want it just to be a cable.

CHAIRMAN BANERJEE: Is there an independent way of measuring surface temperature looking at say the infrared or something?

MR. NOWLEN: We didn't try to do that, no. With this facility, because it's so strongly radiant.

CHAIRMAN BANERJEE: Yes. No, it would be difficult.

MR. NOWLEN: It would be quite a challenge. I mean, you're going to see the background no matter what angle you get.

MEMBER SIEBER: I don't think you could do it.

MR. NOWLEN: You're going to see the background, which is going to be the shroud and it's going to dominate.

CHAIRMAN BANERJEE: Unless it was very focused.

MEMBER SIEBER: Well, no.

MR. NOWLEN: No, infrared is --

MEMBER SIEBER: The cable is too small.

MR. NOWLEN: Yes, the cable is -- yeah, these cables, you can see the sizes we are dealing with here. They are on the order of a half inch to three-quarters of an inch.

CHAIRMAN BANERJEE: So this was the only way you could measure temperature?

MEMBER SIEBER: Yes.

MR. NOWLEN: yes, thermocouple, yes.

MEMBER SIEBER: You could probably measure the temperature of the Penlight chamber itself.

MR. NOWLEN: Oh, and we did.

MEMBER SIEBER: Yes.

MR. NOWLEN: And we did.

MEMBER SIEBER: With an optical.

MR. NOWLEN: Oh, you can do it optically. They -- you know, again, that's all part of the validation that they have done for Penlight at the facility --

MEMBER SIEBER: Right.

MR. NOWLEN: -- is, you know, using -- they have used infrared and looked at it.

MEMBER SIEBER: But you couldn't do the surface?

MR. NOWLEN: It wasn't --

MEMBER SIEBER: Anything dealing with picking it out.

MR. NOWLEN: -- practical in this case. Yeah, because -- just because it was very small with a very radiantly dominant shroud all around it.

MEMBER SIEBER: It's like looking at the sun.

MR. NOWLEN: Yeah. Like trying to measure the temperature of Mercury as it transits the sun, it's very difficult.

So in the intermediate-scale test, this is just a representation of the facility. I've got some pictures to illustrate this. Basically, we had a capture-hood. The upper dark section is covered and enclosed roof. The rest of it down below is open. And the idea here is one of the things we saw in the NEI test was they had a closed -- it was actually a plate steel room, a quarter inch thick plate steel, kind of atypical, but it only had a small door in one end of it.

And they ran into multiple cases where they were in oxygen limited burning. They couldn't get enough air into the facility to support the full burning. And it really impacted their results. Their temperatures never got up as high as they expected. And so one of the things we did is we went more open. We wanted this to look more representative. You know, in a real plant, rooms are big. And we wanted it to look more like a big room, but we did want to be able to capture the products, create a gas layer that would be sufficient to damage cables that weren't directly above the fire.

So the compromise was this facility, you can see -- well, you probably can't see the dimensions here, but it's about 12 feet. In this dimension, eight feet back and forth and about 10 feet high. The upper 4 feet is enclosed. The lower 6 feet is open. And then this was all put inside of a larger test facility. And again, I've got some pictures.

We picked this. You know, we wanted a more realistic testing scale, but when you go to the scale, you're, obviously, losing control of what is going on. You know, you are in a more random fire -- real fire environment. The hood is roughly the size of an ASTME 603 standard room fire test. We made it a little bigger. But that was sort of our model for it. But it's also more open. The open bottoms to ensure that we got full burning behavior as we would normally expect.

We used propene and that's not a typo, propylene, as the burner, rather than something like propane or natural gas. Propene creates a sooty, smokey fire when you burn it the way we did as a diffusion fire. You don't pre-mix it with oxygen. You send the gas out, you let it naturally mix with the oxygen in the air and burn. That creates a sooty, smokey fire, which again in our plants, that's what we expect to see, sooty, smokey fires.

So we used that gas. Particularly, it's

controllable. We can measure it. We can get a good idea of its heat release properties. But it creates a nice smokey fire for us. So that's why we chose that. Then again, we did the cables and trays and conduits and airdrop configurations.

This is a picture of -- so here is our hood right here. This is the upper part. And we placed it inside of a larger burn facility. The larger burn facility was about 50 feet long, 18 feet high at the peak. It had a stack that came out of the ceiling. And so this is inside of that larger facility. This is the burner here, basically, right under the middle of the thing. You can see here this is probably right after the test, because everything is very dirty, but this is a typical cable tray going through the fire. It would have been under the middle, so there was a tray here in the middle, one on each side.

MEMBER ABDEL-KHALIK: Is there any explanation for the pulsating nature of the flame in these experiments?

MR. NOWLEN: Yes, yes. That is -- yeah, that was another question we got in the peer review. It's an expected behavior when you are doing one of these diffusion fires. We wanted a fire that would bring us up into the turbulent regime. You don't want a nice little laminar bunsen burner.

CHAIRMAN BANERJEE: Turbulent where?

MR. NOWLEN: I'm sorry?

CHAIRMAN BANERJEE: Turbulent where? Turbulent flame?

MR. NOWLEN: Turbulent plume. Yeah, the flame is on, the plume is on, it's turbulent. And so it's really the pulsation is a reflection of those turbulent eddies that you generate that will propagate up. So it kind of -- it looks like a pulsating behavior and it's -- we expected it. It wasn't something that was unexpected or unusual. We had mentioned it in the report and there was a comment on that.

And so we have clarified in the report that that was, in fact, an expected behavior for this type of burner.

CHAIRMAN BANERJEE: Well, why did you want turbulence in your flame? I mean, what --

MR. NOWLEN: Well, it's --

CHAIRMAN BANERJEE: -- difference does it make?

MR. NOWLEN: Well, most big fires are going to be turbulent.

MEMBER SIEBER: Right.

MR. NOWLEN: So again, we were trying to be representative of, in this case, what we would expect to see. We didn't -- you know, a bunsen burner, you can get a laminar flame. Almost anything else that you burn is going to give you a turbulent flame. And we wanted to make sure we were in the turbulent regime. And so in effect, the pulsation behavior that you see is evidence that you have made the transition you're in.

CHAIRMAN BANERJEE: I have to understand the objectives of this experiment now, because really, you've got a situation because it's turbulent, obviously, it's very hard to characterize, because nobody knows anything about turbulence, right? And the difficulty then becomes how do you handle this problem in terms of modeling?

MR. NOWLEN: Well --

CHAIRMAN BANERJEE: Because you get very, very non-uniform effects, fluctuating.

MR. NOWLEN: Well, there are -- okay. Yes, I'll let Kevin, because there are advanced models that deal with turbulence.

CHAIRMAN BANERJEE: Well, I know that.

MR. McGRATTAN: The point of this exercise is to address the Bin 2 issues.

CHAIRMAN BANERJEE: Right.

MR. McGRATTAN: Okay. So this setup is just trying to mimic, in a fairly reproducible way, hot upper layer in a room. It was -- this is not designed to be a validation experiment. I mean, we may use some of the data in that way, but this was not the primary purpose of these experiments.

CHAIRMAN BANERJEE: You create that hot upper layer in a much more, let's say, reproducible way. And you could do it with multiple laminar flames where you would know precisely the fluxes and things, because, obviously, it's very difficult to model a turbulent flame, particularly, one that is producing a lot of soot, you know. You don't even know --

MR. NOWLEN: Well, but again, it's kind of --

CHAIRMAN BANERJEE: -- how much is burning.

MR. NOWLEN: -- the objective of these tests was not to characterize a turbulent flame and develop a model of turbulent flames.

CHAIRMAN BANERJEE: No, no. I understand.

MR. NOWLEN: It was to help --

CHAIRMAN BANERJEE: I'm saying --

MR. NOWLEN: -- support in part the modeling of fire -- of cable responses in fire environments. And the goal here was partly to go to a more realistic fire environment. It's a real fire. This is a fire. It's a turbulent fire. Yes, it's challenging from that perspective, but it's real. You know, Penlight was highly idealized. Very well-controlled, very well-characterized, but highly idealized.

This, you are losing control, but you are getting much more representative of what's really out there when you deal with fires.

MR. McGRATTAN: Right.

CHAIRMAN BANERJEE: Well, but if you're talking about this hot gas layer, after all, I mean, the radiation properties of this fire, this, that and the other, it's a different issue. But if you're talking about the hot gas layer, you could create it in many different ways.

MR. NOWLEN: Yes.

CHAIRMAN BANERJEE: Clearly and they could be representative of what you see in many fires. The difficulty with this, of course, is that you don't know the source term very well, because of what's happening is that -- well, I don't even know what degree of combustion you're getting, how much soot you're getting. I mean, there's all sorts of issues here, which you --

MR. NOWLEN: There are. But again, you have to look at what we were trying to do. And from the Bin 2 perspective, we needed to get real. If we didn't get real, we would have been subject to all kinds of criticisms for running idealized oven tests and not getting real. You know, we needed our results to be arguably representative of real configurations. And that's what we argue this is.

CHAIRMAN BANERJEE: This is a real configuration to that approach?

MR. NOWLEN: I think this is a reasonable analog for something like either an electrical control panel --

MEMBER SIEBER: Fire in a big room.

MR. NOWLEN: -- cabinet fire, a liquid fuel spill fire or any other. You know, I mean, I can come up with a range of scenarios that this would be a reasonable analog. Again, idealized in some regards, but, you know, an oil pool fire will look a lot like this if it's confined to the same sort of space.

MEMBER SIEBER: Right.

MR. NOWLEN: You know, there are --

MEMBER ABDEL-KHALIK: I'm trying to physically understand what is meant by pulsating flame with a periodicity of 1 to 2 seconds. If I were to take a picture like the one you have right now --

MR. NOWLEN: Yes.

MEMBER ABDEL-KHALIK: -- and take a picture half a second later, what would that picture look like?

MR. NOWLEN: Yeah, part of it is the picture is doing a little bit of averaging. Okay. Because you have got -- you know, we're looking through a smokey room right now at the fire burning. So there is a bit of averaging.

What you will see are, you will see large eddies forming and so you will have a pulse that will come up and it's a pair of large eddies or, you know, a ring of a large eddy coming up and then another one forms and another one forms, so that is very typical behavior. You get these -- that's what I meant by pulsating.

MEMBER ABDEL-KHALIK: So what is the mechanism that would give you a 1 to 2 second periodicity?

MR. NOWLEN: I don't have it.

MR. McGRATTAN: The buoyant plume. The

frequency is typically 1 over the square root of the diameter.

MEMBER ABDEL-KHALIK: Yes.

MR. McGRATTAN: If you measure the diameter in meters, that gives you the frequency. That's rough rule of thumb. I think it's 1.5 over the square root of the diameter. That's typically seen with buoyant plumes and with fire.

MEMBER ABDEL-KHALIK: Now, does that mean that the heat flux also varies?

MR. McGRATTAN: Sure.

MEMBER ABDEL-KHALIK: With the same kind of frequency.

MR. McGRATTAN: Sure. Because the flame height, the visible flame is going to change its height and that will be reflected in the heat fluxing that you are on around the surrounding surfaces.

MEMBER ABDEL-KHALIK: And that time constant is significantly smaller than the shortest time constant of any test piece that you are actually looking at.

MR. McGRATTAN: Right.

MEMBER ABDEL-KHALIK: Is that correct?

MR. McGRATTAN: Right.

MR. NOWLEN: That is correct also, yes.

MEMBER ABDEL-KHALIK: Okay.

MR. NOWLEN: Yeah. Again, when we talked about the pulsating fire, we were really trying to say to people who, you know, do fire testing that this is just the kind of fire you would expect to see from this burning. That's really what I was trying to say. But it didn't come across very well, obviously.

MR. McGRATTAN: Yeah, and that's important for credibility, that when you show this to fire protection engineers, I mean, seeing multiple laminar flames might be better for a validation experiment, but they are going to question, just as much as you're questioning why you used that fire, why you use the laminar flame.

CHAIRMAN BANERJEE: Yeah, I guess, there is an issue here where knowing the heat flux and the degree of combustion more precisely would have given you the possibility of having a heat balance in the system, which we don't have, because we just don't know how much is burned.

MR. McGRATTAN: Right. But let me throw a wrench into all of this. We originally planned on modeling these tests, the whole thing, you know, the fire, the heat transport and the cable failure. However, the problem is that in almost all of these tests, cables burned. And as Steve talked about in the beginning, we don't have the thermal physical properties of these cables with enough detail to actually make prediction of the burning rate.

Steve isn't measuring the heat release rate, except via a fuel flow to that burner. So we only know the, at best, you know, given the uncertainty in the efficiency of the fire, heat release rate from the fire plus or minus about 10 or 15 percent. Once the cables start burning, in terms of model validation, game over.

Now, we anticipated this as a problem from the very beginning, because most practical fire tests involve burning real stuff. And fire modelers don't actually like to burn real stuff, because it's hard to predict the burning rate of real stuff.

CHAIRMAN BANERJEE: The point I made right at the beginning.

MR. McGRATTAN: Yes, exactly. But what Steve and Frank did was they put thermocouples, not only in the cables, but they surrounded each tray or conduit or what have you with a couple of thermocouples in the gas. So given that this is a fairly hot black layer, we know the surrounding temperature, that's what we really needed to validate our cable response model.

Even if we could predict those near temperatures with our fire model, okay, that would say the fire model is working fine, but ultimately it's that exposure temperature surrounding the tray that we really needed as the boundary condition for our cable response calculation.

MEMBER ABDEL-KHALIK: Is it really temperature independent of heat flux?

MR. McGRATTAN: Well, we simply used the temperature. We assume the layer was black. Sigma T^4, plus a convective effect.

MEMBER ABDEL-KHALIK: So you ignored convective effects?

MR. McGRATTAN: No, we added it, but we used a simple convective heat transfer coefficient.

MR. NOWLEN: You can -- the thing is --

CHAIRMAN BANERJEE: How did you know that --

MR. NOWLEN: -- is that --

CHAIRMAN BANERJEE: -- without knowing the velocities?

MR. McGRATTAN: Well --

CHAIRMAN BANERJEE: That's Reynolds to the .8 or something again.

MR. McGRATTAN: Right. In the different kinds of models, some times you will have a velocity, for example, in a CFD calculation, but in the calculations that we envisioned this cable response model to be embedded in, you don't even have that. So typically, with simple calculations, you just assume a fixed convective heat transfer coefficient.

CHAIRMAN BANERJEE: Well, how do you actually get the heat flux in the model in which you are embedding this?

MR. McGRATTAN: So I mean, literally?

CHAIRMAN BANERJEE: Right.

MR. McGRATTAN: Literally, if I assume the layer is --

CHAIRMAN BANERJEE: Do you know what heat flux --

MR. McGRATTAN: -- black, Sigma T^4, plus H Delta T.

CHAIRMAN BANERJEE: And the H is assumed?

MR. McGRATTAN: Assumed.

MR. NOWLEN: Empirically-based.

MR. McGRATTAN: Yes.

CHAIRMAN BANERJEE: And the T external is assumed?

MR. McGRATTAN: Yes. T external is what--

MR. NOWLEN: No, it's predicted.

MR. McGRATTAN: -- Steve would measure or what a fire model would predict.

CHAIRMAN BANERJEE: Okay. So how does the fire model predict it? That's what I'm really getting at.

MR. NOWLEN: That has been a body of work that has been in all --

MR. McGRATTAN: Yeah.

MR. NOWLEN: -- ongoing.

CHAIRMAN BANERJEE: T external.

MR. McGRATTAN: I'm going to talk about the different types of fire models in my presentation and I'll give you a brief overview of how these different models --

CHAIRMAN BANERJEE: It includes the loop somehow, right?

MR. NOWLEN: Yes.

CHAIRMAN BANERJEE: I mean, at the end of the day --

MR. McGRATTAN: Oh, absolutely.

MR. NOWLEN: But ultimately --

MR. McGRATTAN: Absolutely.

MR. NOWLEN: -- we can say that the ability to predict the environmental temperature near these cables is a fairly well-handled task. There is the issue of predicting the fire itself, but if you understand the fire, predicting what a temperature response is going to be at a particular spot in the room isn't too difficult. We have models that do that.

So we were really taking it to the next step saying given that I know the temperature at that spot, now can I predict how the cable responds? And so in my case, since I'm not predicting, I'm actually measuring the temperature at that spot and measuring how the cables respond. And so I'm kind of putting the fire behind me. I'm saying I'm not attempting to create a fire you can model, because, for various reasons, we wanted cables to burn. That's a very uncontrolled behavior.

And we focused for fire modeling on that other part. Measure the temperatures near the cable, measure the response of the cable and give Kevin that next piece of the pie.

MEMBER BLEY: Sanjoy?

CHAIRMAN BANERJEE: Yes?

MEMBER BLEY: The morning is passing away. It seems to me that this line of questioning deals more with our topic for this afternoon in relevance to the modeling. The issues of systems response and that sort of thing, we haven't even touched on yet.

MR. NOWLEN: Yeah.

MEMBER BLEY: And I would sure like to hear some of that.

CHAIRMAN BANERJEE: Okay. Okay.

MR. NOWLEN: Yeah, let's move forward. I'll -- there are more photos in there of the different setups. This one shows one of the more complex setups with several trays. Actually, you can see here this is a slow calorimeter. It's a metal slug held in an apparatus with thermocouple embedded down the middle. So we had a couple of those, but again, there was somewhat limited.

Here is some typical setups of trays, bundles, individual cables. The one on the bottom is a random fill tray. These are individual bundles. This is a thermal bundle with two electrical bundles. You know, here again, you can see these are thermocouples above and below. You know, this right here is a thermocouple above and below that cable.

So, you know, big focus on the environment near the cable and then the response of the cables coupled to these electrical cables, so we also know when they would have electrically failed. This one here is just a typical tray. This one is an airdrop that we simulated similar to Penlight where the cable is just going through. We kind of used the tray to hang it at each end, but within the facility, there is no support.

So here again, we sort of repeated the things we had done in Penlight. Here is some typical after. You can see these things are pretty messy. There is not a lot left. That's copper, this is insulation, that's copper. There is not a lot left. These things burn. Most of the cables in most of the tests burned. This shows you a cable tray. This was one of our random fill trays. It basically burned up entirely.

You know, just looking at the conditions, these are mostly thermosets that I happened to pick. This one is the silicone. It leaves behind this funny fuzzy white char. It's kind of interesting. So we did instrument for thermal response. I think we have covered this adequately.

The cable electrical response, there were two systems used. One is an insulation resistance measurements device that Frank Wyant and I actually patented after the NEI tests. And it is a very detailed look at cables. The other is the Surrogate

Circuit Diagnostic Units. A fancy name for a circuit simulator. It's very similar to what NEI had done. And again, the Duke tested a very similar approach.

This gives you an idea of one of our sub-jacket thermal, because you can see this is the 12 inch mark on the thermocouple lead wire. So the thermocouple is actually embedded down here inside the cable. We make a small slit and slip that cable -- that thermocouple underneath the jacket. And so we get away from -- that's what I was referring to earlier. We get away from these tape marks. We don't want the thermocouple right there. We need to close up the hole.

What we can do is we can get these things slipped down to here and cover up the hole back here. And we get a pretty good idea of what is going on down here that's lining up the --

CHAIRMAN BANERJEE: How do you know how far down it is?

MR. NOWLEN: We put a mark on them. This is just a 12 inch mark before I start. I mark a known spot, so I can tell how far in I've gotten. You can also see, with a lot of them, sort of see the little bead kind of working its way down through. So it's imperfect, but again, the idea that we were -- and this we think is the best measure of the temperature response is just below the jacket, what's the cable doing? That seems to be the best correlation.

Again, for the reasons we talked about before, it's that outer layer of conductors that fails first. That's a pretty good measure of what those outer layer conductors are seeing.

We did do others where we embedded them more deeply into the cables and taped to the surface. There is all kinds of different data for that. This one illustrates the conduit. You can see the thermocouples here, here and here on the conduit. These are -- actually what you do is you take a metal jacketed thermocouple, a very small 40 mil diameter, and you actually weld a small piece of stainless steel over the top of it down to the conduit to get fairly intimate contact between the thermocouple and the conduit itself. And that's real common.

So when we look at the conduit temperatures, we're pretty solid that these things didn't separate away. This is the insulation resistance system. I'm not sure I want to go into too much detail. Basically, you have a cable under test with multiple conductors. It could be multiple cables, one cable, whatever, but each individual conductor is hooked up to a set of input relays and output relays.

And what we can do is we energize one conductor on this side, so we feed it power and then we can monitor whether there is any leakage to any of the other conductors. And we do it systematically. And basically, through that, first, you energize one and monitor, say, No. 9 and then you can energize No. 9 and monitor No. 1 and you know have two equations, you know, and you have all your unknowns and you can solve for the individual insulation resistances in the system.

There is two resistances to ground and a resistance between the two conductors and that's how that system works. So it's a very detailed look at how each individual conductor is interacting with all of the other conductors and the ground plane that's present. So that's one.

The other one was the circuit simulators and this was the generic picture. We basically can put in three target devices of whatever type we want. We have anywhere from zero to three energized source conductors. We can ground as many as three conductors by selecting these different switches. I can ground one, two or three conductors. So basically, we can set up a range of different types of control circuits and see how a specific control circuit configuration would respond.

And I just hooked my test cable up out on this end of it and I can then simulate. Now, the typical arrangement is shown here. This is the MOV circuit. We have two energized sources. We have a dummy. We have a resistor that's simulating a non-energized indicator lamp. We have the two actuator relays that would position the valve open and closed. Then we have another relay that would be simulating the normally lit indicator lamp.

So this is our typical MOV. Here is the control power transformer. We have an input power, output power to the circuit. So again, this is that little 150 volt amp or whatever power transformer.

And this one gives you -- you know, now, what happens is that I'm looking for the sources one or two to hit the targets four or five, in particular. You know, if I get a short between one and four, I just spuriously actuated that actuator. One and five actuates that one. So that's what we're looking for.

Now, in this case, it's a grounded circuit. If that shorts to ground, I would blow the fuse. So, you know, we have all of these things built into this and we can look at a more representative configuration of a control circuit to see what happens. So those were both used.

MEMBER BLEY: You are monitoring those circuits?

MR. NOWLEN: Yes.

MEMBER BLEY: The test is being run.

MR. NOWLEN: Yes.

MEMBER BLEY: And at the same time, are you monitoring the insulation resistance or is that separate?

MR. NOWLEN: That would be a separate cable.

MEMBER BLEY: Okay.

MR. NOWLEN: Some cables had insulation resistance monitoring. Some were hooked up to this.

MEMBER BLEY: Okay.

MR. NOWLEN: But each of these lines, each individual line has an amp meter and a volt meter in it. So we are, basically, measuring all the voltages and currents throughout this circuit as a function of time throughout the test.

So now, I can jump into the results. We're there. Item A was thermoset-to-thermoset. If you remember, our first Bin 2 item. This is one case where -- now, these are a little confusing. A, B and C are cables. Cable A, Cable B, Cable C. Each of these cables was set up with two conductors on the IR system. So basically, we grouped them. We took the outside group of six, we tied them together in alternating pairs, so you have 1, 3, 5 and 2, 4, 6 are ganged together --

MEMBER BLEY: Um-hum.

MR. NOWLEN: -- in each cable. So what we were looking for is we were looking for the relative timing of, say, the group one to group two versus Cable C to Cable B. Right? So it's a little confusing, but the bottom line here is this blue line right here is C to B. This is Cable C interacting with Cable B.

CHAIRMAN BANERJEE: Remind us again about C and B an A.

MR. NOWLEN: C is one cable. B is another cable. This is inter-cable shorting between two thermoset cables. In this particular test, that's the first thing that we saw happen. This is insulation. this is, basically, the insulation resistance, so this is on the IRMS. So we're looking at the IR system. And, you know, we're down here to below 100 ohms between these two cables.

CHAIRMAN BANERJEE: C5 to B4.

MR. NOWLEN: Right. That -- well, Cable C was 5 and 6, those two groups. B was 3 and 4. A was 1 and 2. So it's A1, A2, B3, B4, C5, C6. Those were the groups we had. The first thing we saw was C interacting with B, that's the bottom line, at this point.

MEMBER SHACK: Rather than C interacting with C?

MR. NOWLEN: Exactly, exactly.

MEMBER BLEY: And these are actually fairly slow. I mean, it has taken 2 or 3 minutes as you get into the range or where you will start to actually see an interaction.

MR. NOWLEN: Right.

MEMBER BLEY: So it isn't --

MR. NOWLEN: That's right.

MEMBER BLEY: -- precipitous. I had always thought it would go very quickly.

MR. NOWLEN: Well, it all depends on how hot -- how fast you heat them, you know. And we were specifically shooting for failure times that weren't seconds, but were minutes instead. We didn't want things going so quickly that it wouldn't be representative.

MEMBER BLEY: Okay.

MR. NOWLEN: We wanted things to be happening in minutes, not necessarily hours, but minutes. And so, you know, we have achieved that.

MEMBER BLEY: And what you were saying earlier, what you are getting is you begin to get a little current flow as the resistance drops off and getting that gradually increasing current is where you had troubles with the transformers?

MR. NOWLEN: Right.

MEMBER BLEY: Well, not troubles, where it actually had an impact on the circuit.

MR. NOWLEN: To have an impact, yeah.

MEMBER BLEY: Yes.

MR. NOWLEN: Right, yeah. Now, this is the IR system, so again, what we are looking at is here is pretty clear cut evidence --

MEMBER SHACK: Of the short.

MR. NOWLEN: -- that however unlikely, it can happen. You cannot entirely dismiss thermoset-to-thermoset shorts. This was the only really truly clear cut case we had. We had some others where I would, for example, see one of the conductors shorting internally and then shorting to another cable. You know, we saw various ones of those, but we did see this one. It's unequivocal. It's clearly the first failure mode. You can't argue with this one, so you have to say it's plausible.

What's the probability? Well, that's something else again. I don't know what happened here. That's something else again, but you can't throw it away. So our recommendation --

CHAIRMAN BANERJEE: But most of your other ones were within -- there was the inter-cable short first, I remember that.

MEMBER BLEY: Intra-cable.

MR. NOWLEN: Intra-cable.

MEMBER BLEY: Intra.

CHAIRMAN BANERJEE: Intra, sorry. Intra-cable.

MR. NOWLEN: That's all right.

CHAIRMAN BANERJEE: I get mixed up. Yeah, intra was for --

MR. NOWLEN: I've been doing this for years and I get mixed up. Yes, most of them, you know, it was more typical to see like C5, C6.

CHAIRMAN BANERJEE: Right.

MR. NOWLEN: You can see that one actually falls way out here towards the end, but, you know, I focused on what C did. But it was more common to see

B4, B5.

MEMBER SIEBER: Intra-cable.

MR. NOWLEN: They go together. A1, A2, they go together. And then we start seeing other things happen.

CHAIRMAN BANERJEE: B4 --

MR. NOWLEN: So again, our conclusion --

CHAIRMAN BANERJEE: -- to ground, for example.

MR. NOWLEN: Yes, B4 went to ground. You know, that's like here not too long after it had interacted with 5, it went ahead and shorted to ground.

MEMBER ABDEL-KHALIK: Now, these cables where presumably an intimate contact before --

MR. NOWLEN: Yes. They were in a bundle together, sort of a little triangular.

MEMBER ABDEL-KHALIK: And how were they pressed against each other?

MR. NOWLEN: They weren't.

MEMBER ABDEL-KHALIK: There were not? They were just sort of --

MR. NOWLEN: We used nylon ties to kind of hold the bundle together, but they were basically just there together.

MEMBER SHACK: They were bundled the way you would normally bundle a --

MR. NOWLEN: The way you would normally bundle cables.

CHAIRMAN BANERJEE: And these were hanging? These had no RIS failures or what?

MR. NOWLEN: This was in a tray.

CHAIRMAN BANERJEE: This was in a tray?

MR. NOWLEN: This particular test was in a tray.

CHAIRMAN BANERJEE: Okay.

MR. NOWLEN: Yeah, it was in a cable tray. And again, this was the most clear cut case we saw for Bin 2, Item A.

MEMBER SHACK: So you had one primary and then several secondary and tertiary?

MR. NOWLEN: Exactly. And this was the one case where we definitely saw a primary inter-cable fault. So, you know, again, our recommendation is low probability, but not entirely implausible.

CHAIRMAN BANERJEE: Did you try to reproduce this very experiment and see if it happened?

MR. NOWLEN: We did do a number of repeated tests. And in terms of thermal response, there is clearly good correlation. When we repeat a test, we get very similar results and we've got some stuff to illustrate that. But in terms of the circuit faults, no, like I said, we saw this once. That's the only time we saw it as a true hard --

CHAIRMAN BANERJEE: It's much more random.

MR. NOWLEN: -- primary fault mode. So that's a lot more random, yeah.

CHAIRMAN BANERJEE: Yeah.

MR. NOWLEN: Item B was kind of interesting, too. This, Item B, was the thermoset-to-thermoplastic inter-cable interactions. And a lot of this played out the way we expected. What you have here, this is a thermoplastic cable on top. And this is a thermoset cable on the bottom. And these were together in one of these bundles.

Now, this is our circuit simulators. So that's why there are so many plots. There are seven traces, voltage, current. We have tried to sort of sort it out. But the bottom line here, forget all the rest of it, the thermoset -- or the thermoplastic cable, see I even get them confused, failed after about 10 minutes. Okay. It went belly up, shorted to ground, lost all power.

It went through some spurious operations on the way, but, ultimately, it was dead after 10 minutes. We saw this interesting little blip on the thermoset cable around the same time. Hum, I wonder what that is? Well, it didn't spuriously actuate or anything. We did see something. But then look what happens. This is the thermoset cable now going through its failure modes and we see a spurious operation in this case and then voltage degrading.

But look at what happens to the thermoplastic cable while the thermoset cable is failing. We're clearly getting voltage. This voltage is dead. The only place it's getting voltage is from here. So what was happening is the thermoset cable still had voltage and it was beginning to impose voltage and current on the thermoplastic cable, which had already failed.

So again, you look at that and say well, it doesn't seem very likely that a thermoplastic cable is going to energize a thermoset, because it's probably going to be dead, but you are still going to have this possibility of the later failure in the thermoset, possibly, energizing the co-located thermoplastic.

MEMBER BLEY: Interesting. I think you said this earlier. Was it typical that the thermoplastic time period when you were getting activity before it went dead was maybe twice as long as for the thermoset?

MR. NOWLEN: No. No, it wasn't that clear cut.

MEMBER BLEY: This is unusual or just one case out of many?

MR. NOWLEN: Well, what we tended to see is the longest sustained faults tended to be associated with the thermosets.

MEMBER BLEY: Okay.

MR. NOWLEN: Okay. So you know, like the 10 minute.

MEMBER BLEY: Yes, that's what you said earlier.

MR. NOWLEN: Tended to be thermoset, right.

MEMBER BLEY: And that's different here, yeah.

CHAIRMAN BANERJEE: Well, it has to be how quickly it reaches a specific temperature, presumably.

MR. NOWLEN: Yeah, and the conditions it is under.

MEMBER BLEY: Which conductors it touched when.

MR. NOWLEN: Yeah, where it is in the

bundle, how close to the ground plane it is. Lots of things seem to affect it. But this one, you know, you're seeing, you know, over the course of what a minute or so, those were more typical. The more typical faults last a short period of time, you know, less than a minute. And then they cascade onto further fault modes.

MEMBER BLEY: Yes.

MR. NOWLEN: And actually Ray reminded me that he did an -- Ray Gallucci had done an analysis of this and when you take away the longer duration ones that tend to be associated with thermosets, the shorter duration ones all kind of don't seem to be statistically different. Thermoplastic and thermosets see lots and lots of shorter duration shorts. The longer ones do tend to crop up in the thermosets. So maybe that clarifies that earlier comment.

CHAIRMAN BANERJEE: If you superimpose -- sorry, go ahead.

MEMBER BLEY: Am I reading something improper into this? The top one over there on the right we have a red plot.

MR. NOWLEN: Right.

MEMBER BLEY: Is that a conductor or a piece of the circuit that hadn't been active earlier that is still probably intact and is being now interacted with the thermoset version?

MR. NOWLEN: No, it's a part of the circuit that had failed earlier. It's actually a spare conductor in this particular circuit. It wasn't hooked to anything, except our monitor.

MEMBER BLEY: Okay. I didn't see the red over here, so I thought maybe it was one that hadn't been active in the others.

MR. NOWLEN: It's in there --

MEMBER BLEY: Oh, is it?

MR. NOWLEN: -- but it didn't play much of a role.

MEMBER BLEY: Okay. But it was there, it has failed?

MR. NOWLEN: It was there, yeah.

MEMBER BLEY: Or at least it has lost power, that's what we're seeing.

MR. NOWLEN: Yeah. And these are on the same time scale by the way. You know, 600 seconds here is 600 seconds here. These are -- if I superimposed them completely, you -- it would be completely washed out, but this is the same test, same time scale, two co-located cables.

CHAIRMAN BANERJEE: If you superimpose the temperature on this?

MR. NOWLEN: That comes up a little later. Yes, we can do that.

CHAIRMAN BANERJEE: Will you show us the clock?

MR. NOWLEN: Yeah. Okay. So Item C. Item C was --

MEMBER BLEY: I'm sorry, just one last question.

MR. NOWLEN: Okay. Sure.

MEMBER BLEY: You don't have to go back to that one. Well, since you did, when -- these are voltage plots you're showing us?

MR. NOWLEN: Actually, there is voltage and current. This particular one is current.

MEMBER BLEY: Okay.

MR. NOWLEN: Two currents on --

MEMBER BLEY: So they are just different meters on the different parts of the circuit?

MR. NOWLEN: Yes, this is current and this is voltage. It's --

MEMBER BLEY: But we don't know if a particular -- what has happened to a particular conductor. We just know that it no longer has power applied to it?

MR. NOWLEN: Mostly, yeah. With this -- because this is a circuit simulator, you know, once you blow the fuse, the power goes away and you lose any information.

MEMBER BLEY: Yeah.

MR. NOWLEN: Until something like this happens and we start seeing these voltages coming back on that circuit.

MEMBER BLEY: So at least it's intact.

MR. NOWLEN: Well, it's somewhat intact. It hasn't gone 100 percent to ground.

MEMBER BLEY: Yeah.

MR. NOWLEN: It's interacting and I don't know what else it was interacting with, but, you know, the lesson was when this one went down, it imposed some voltage and current on that one.

MEMBER ABDEL-KHALIK: So what quantitative --

MR. NOWLEN: That's why we do spurious operation, to get the right ones involved.

MEMBER ABDEL-KHALIK: -- data would you record in an experiment like this?

MR. NOWLEN: Well, the quantitative data is the timing of the failures, you know, when this failed. The behavior is this blue one right here, this blue trace, it's actually one of my targets. And so this was an actuation target. So actually, this one saw a spurious operation on that particular target. I get information on the quality of that interaction. In this case, it was just barely enough to trigger it here. It wasn't enough to trigger it there.

You know, again, my voltage degraded. It wasn't enough voltage. But here I got a relay lock-in. I can tell how long that relay locked in for. I can tell that it kicked in and out a couple of times. So I can get a lot of information on how that particular target responded and I can tell actually by looking at some of the other data which of the sources hit that target. Was it No. 1 or No. 2?

I can tell when it shorted out to ground. So there is a lot of data buried in these circuits and similar data down here. You know, again, the blue one is a spurious actuation target. So down here I also saw a spurious actuation. So there is a lot of data buried in these plots that because there are so many superimposed, it gets a little lost, but I was trying to deal straight to a particular point.

CHAIRMAN BANERJEE: They are qualitative in some sense, I guess, because if you reproduce this experiment, you won't necessarily get that behavior.

MR. NOWLEN: No, there is a random factor involved here.

CHAIRMAN BANERJEE: So in some sense, they give you qualitative behavior, but it doesn't give you -- I mean, when it comes to some deterministic model, it will probably be the temperature at which that thing occurs, which is probably the only thing.

MR. NOWLEN: No, no, I would just -- because again, one of the issues we talk about is how long these things last. I've got quantitative information about how long these things persisted in a range of tests that I can now consolidate into a statistical model of the future. I mean, you know, one test only gives you one little piece of information. 50, 60, 80, 90 tests give us a statistical distribution.

CHAIRMAN BANERJEE: So if you reproduce this experiment, let's say, 10 or 15 times --

MR. NOWLEN: You get a distribution.

CHAIRMAN BANERJEE: -- you get -- yeah, you would get a different behavior. But you would get something which qualitatively had the same behavior.

MR. NOWLEN: Yes.

CHAIRMAN BANERJEE: It may not be the same conductors exactly or whatever, but --

MR. NOWLEN: I begin to build a base of information that we can do statistical assessments and develop distribution of behaviors. Just like any other uncertain parameter, I can now treat it as a distribution. You know, we didn't take this that far yet, that's one of those gold mines that underlies CAROLFIRE that we haven't dredged up yet.

CHAIRMAN BANERJEE: But if you did --

MR. NOWLEN: But it's there.

CHAIRMAN BANERJEE: -- very different experiments, you know, many of them, then you may not have enough data to build a distribution.

MR. NOWLEN: Well, there is a point to that, because we have to understand, you know, what are the critical factors that influence the distribution. One of the things we pursued here that's different from what NEI did is cables in different locations, in different routing configurations, bundled in different ways with mixed types and so, you know, we're trying to build that understanding of what is really critical to these behaviors and building up a base of information that would then allow us to develop these statistical distributions and that's the direction, ultimately, I see us going.

You know, the probability of spurious operation is no longer .3, it's now a distribution centered at about .27 with an uncertainty and, you know, da, da, da. I can begin to treat these in a more sophisticated way, at least, and I can begin to treat and quantify my uncertainties as to what the real behavior will be, because clearly there is uncertainty. You know, I could run this twice and get two different results.

CHAIRMAN BANERJEE: Right.

MR. NOWLEN: That's an uncertainty. You know, it's just inherent in the nature of the fire.

MEMBER BLEY: But even at this point, we're seeing things, like you pointed out.

MR. NOWLEN: Yes.

MEMBER BLEY: Cases where before when we were thinking about the risk, we might have said that's just so unlikely we will never see that happening.

MR. NOWLEN: Right.

MEMBER BLEY: And then well, we're seeing some of it.

MR. NOWLEN: Yes, and we agree. Well, it is unlikely, but you can't say never.

MEMBER BLEY: And these time distributions on how long the faults last were things we -- guess is not the best word I would like to use, but really estimated from very minimal experience. And this will go a long way.

MR. NOWLEN: Yes. We have well more than doubled our knowledge-base relative to spurious operations.

MEMBER BLEY: When you have no data, a little goes a long way.

MR. NOWLEN: A little goes a long way, yes. We had NEI.

MEMBER BLEY: Certainly --

MR. NOWLEN: We had 14 tests.

MEMBER BLEY: -- I should see things that you --

CHAIRMAN BANERJEE: All right. Let's move on.

MR. SALLEY: Dennis is absolutely correct though and that's the important point. Remember the question that we were asked from NRR when this all started. Can this happen? I mean, that was the big question. What did Harry Truman say? "Those who don't read history are doomed to repeat it" or something?

That's what we have seen with circuit failure. If you go back to the NEI test when they started this, the premise was Appendix R was unrealistic. These circuits do not fail this way. That's where they set their ship to sail and we ended up in this world. So understand again, we're coming back to the "can this happen" type question here.

MEMBER ABDEL-KHALIK: That was not Truman, by the way.

MR. SALLEY: Wasn't it Truman?

MEMBER ABDEL-KHALIK: That was Santiago.

MR. SALLEY: Santiago said it, but Truman put a spin on that also.

MEMBER SHACK: We will assume Truman was quoting George.

MR. NOWLEN: Okay. So Item C, if you recall Bin 2, Item C, was concurrent spurious operations arising from the failure impacting three or more cables. This one is tough, because it gets into statistics and we haven't really got great statistics, even today, but you have to observe that every single test program that has looked at this, and that includes NEI, us and the Duke test, because we have seen what they have, they saw as many as 4 out of 4 simulated circuits spuriously actuate during the course of the test.

Okay. CAROLFIRE, included. We saw cases where all four of ours spuriously actuated. We did explore different exposure locations and conditions. And what we did see is that, you know, a cable right above the fire versus one in the hot gas layer, even a cable in a conduit versus a cable in a tray, very, very different timing. So the timing is the real critical factor here that we need to get a handle on.

And, you know, ultimately, it's hard to say two cables at a time is enough. Statistically, you are in a weak position there. So at some level, we need to think about more, but before we just jump in whole hog and say you've got to do them all, I think we really need to think harder about our ability to deal with the timing and the duration issues that CAROLFIRE clearly highlighted were important and variable, depending on where the cable was, what kind of cable it was, how it was routed.

So we have come down somewhat soft on this particular one, but, ultimately, you have to come back to this. We have all seen 4 out of 4 go. So, you know, we're going to have to figure out how we're going to deal with that and that has been our recommendation.

Item D was concurrent spurious operations given the properly sized CPT, remember the control power transformer. This is a really strange one. We were not able to reproduce the effect that NEI had seen in their tests. We did not see the same effect of CPTs reducing the spurious actuation likelihood. We did not see these cases of voltage degradation leading -- you know, preventing the spurious operation. We can't --

MEMBER SHACK: Did your consultant have any opinions on this?

MR. NOWLEN: We did talk to people. There was one aspect of our test that in hindsight fouled us up a little bit. We had intended to do smaller CPTs and we specifically went to a manufacturer and bought actuation devices that required a certain power load to operate, 100 volt amps. Okay. And that's the way the manufacturer advertised them. So we bought 100 volt amp CPTs, we bought 150 volt amp CPTs and 200 volt amp CPTs. You know, 100 percent, 150 percent, 200 percent.

Well, we were looking at our data and trying to figure out what's going on. We're not seeing what we expected to see. So we went back and actually measured these relays that we had bought. It turns out they weren't really 100 volt amp CPTs. They were more like 75 to 80 volt amps.

CHAIRMAN BANERJEE: Right. I recall that statement in your report, yeah.

MR. NOWLEN: Yeah. So we had to go back and reinterpret our data and our 100 volt amp CPTs were really closer to 150 percent of power and larger. But even though we had 150 volt amp CPTs, which is exactly what NEI used, 150 percent of required circuit power, we did not see the same effect. So there is something more going on here that we don't understand.

Now, our recommendation has been we don't have any basis to question what NEI did and the results. There clearly was something going on there, but we were unable to reproduce the effects, so this is something that we just don't understand quite.

CHAIRMAN BANERJEE: It has to be resolved, right, in some way?

MR. NOWLEN: We're going to have to -- well, right now, it's a factor of 2 that we applied for CPT circuits at 150 percent or less. We apply a reduction of 2. So, you know, in the RIS world, the factor of 2 is not a huge factor here. But yeah, ultimately, I mean, there is --

CHAIRMAN BANERJEE: You're saying it's not a very important effect?

MR. NOWLEN: Well --

MEMBER SIEBER: It is --

MR. NOWLEN: -- there are a lot of other more dominant effects that are going to drive this answer as opposed to CPTs.

MEMBER SIEBER: It's an important effect if you are counting on the failure to clear the circuit.

MR. NOWLEN: Yeah.

MEMBER BLEY: And counting on failure is a tough --

MEMBER SIEBER: Yeah. And the problem is manufacturers look at the rating a different way. They say I don't want it to fail until well beyond what the rating is.

MR. NOWLEN: Yes, right.

MEMBER SIEBER: And so they make the devices much stronger.

CHAIRMAN BANERJEE: 150 or whatever.

MEMBER SIEBER: Yeah, right, or 200.

MR. NOWLEN: Well, it was the combination of that and the relays. You know, they are conservative. Well, you need 100 volt amps to run this thing. Well, you only need 80.

MEMBER SIEBER: Right. They go the other way.

MR. NOWLEN: Yeah.

MEMBER SIEBER: That way nobody can make a mistake except you.

MR. NOWLEN: Right. So, you know, and it does raise the question of, you know, what do we mean by properly sized? You can't just look at the label on the device. There is more to it than that. And so again, we're talking about a factor of 2, but we don't understand that factor very well today.

MEMBER BLEY: Do you know if their markups used the same control circuits that you used and powered them the same way?

MR. NOWLEN: They used the same configuration, but they used a different set of relays. And I don't know whether they used the same brand of control power transformers. We bought them from a nationwide supplier. You know, we bought them from a supply house. We went based on, you know, we were looking for a very specific power rating and so we selected ours that way.

The others that have been done, they pulled them out, basically, of stock. You know, they had the relay and everything and they used those. In hindsight, I kind of wish I had a few of those in stock and had used them instead, you know, but hindsight is always 20/20.

CHAIRMAN BANERJEE: Move on.

MR. NOWLEN: Yes. The last one, hot shorts lasting more than 20 minutes. In our case, the longest one we saw was 7.6 minutes. So we fall back on the NEI was 11.3. Overall, that appears to be not a bad estimate of what the worst case you might see, probably conservative.

MEMBER SIEBER: Yep.

MR. NOWLEN: And but all the data everyone has gotten seems to show that what we expect that once you get into these fire degradations, everything is going to keep cascading down until it's all gone.

CHAIRMAN BANERJEE: This is when the cable catches fire, right?

MR. NOWLEN: No, this is the hot short. This is the two conductors and energized conductor contacting a target.

CHAIRMAN BANERJEE: But by the time --

MR. NOWLEN: And holding that energized --

CHAIRMAN BANERJEE: -- it's -- when it fails and shorts, it catches fire?

MR. NOWLEN: It burns.

CHAIRMAN BANERJEE: Right?

MR. NOWLEN: It catches fire. It's not going to go out right away.

CHAIRMAN BANERJEE: Yes.

MR. NOWLEN: The fire is going to continue to cause further degradation.

CHAIRMAN BANERJEE: Right.

MR. NOWLEN: It's eventually everything is going to go to ground. It all washes out. 20 minutes doesn't seem like a bad estimate of how long that is going to take, worst case.

CHAIRMAN BANERJEE: Were there any cases where you had hot shorts where you didn't have a fire following it?

MR. NOWLEN: Yeah, yeah, there were a few in Penlight. In the intermediate-scale, no, pretty much everything burned eventually. It's a little hard to tell when things ignited relative to shorts, because we just didn't have that good of view into the smokey room. But with Penlight, certainly, we saw a number of cases where we got shorts without burning or burning well after the shorts had occurred. We saw cases where the burning occurred first. So it -- you know, all three.

Okay. So that's where we came down on that. Which takes me to the public comments.

CHAIRMAN BANERJEE: And this takes account of everything, thermosetting, thermoplastic, right?

MR. NOWLEN: Yes, yes.

CHAIRMAN BANERJEE: So which have the longest periods?

MR. NOWLEN: The thermoset cables. When you look at the longer duration hot shorts, they tend to be associated with thermosets.

MEMBER SIEBER: Yes.

MR. NOWLEN: When you look at the shorter duration faults, which were predominant, most of the faults last a minute or less, they are relatively short duration, those tend to be all mixed up. The thermosets and the thermoplastics seem to be pretty similar.

MEMBER SIEBER: Yes.

MR. NOWLEN: But there is the sort of tail out there wagging the thermoset dog with longer hot shorts.

CHAIRMAN BANERJEE: Was that what NEI saw as well?

MR. NOWLEN: Yes. The longer ones there were also generally associated with thermosets, although they saw some thermoplastic ones that were a little longer duration than ours. NEI tended to have very long failure times. You know, a lot of their failures occurred after an hour. They were very long. They tended to have --

CHAIRMAN BANERJEE: They had a much lower heat flux than you or what?

MR. NOWLEN: Well, again, it was just oxygen-limited burning thing. They would tend to get their enclosure right up into that range we expect to see failures and then they would hover there for an hour or so until eventually something finally failed.

MEMBER SIEBER: Um-hum.

MR. NOWLEN: So I think that kind of contributed to their shorts also tending to be a little longer in duration. It wasn't quite as an aggressive exposure and so things took a little longer to go through that ultimate cascading behavior. Ours tended to go a little more quickly, because our environments were a little more aggressive in general. We never got to oxygen-limited burning. We always had plenty of air to burn whatever wanted to burn.

CHAIRMAN BANERJEE: Okay.

MR. NOWLEN: Okay. So we have about 20 minutes left. I will try and bang through the public comments here. There were, of course, two sources, industry submitted comments and those were all collected and submitted through NEI and the ACRS review provided us with comments. And that was really it. There were no other sources of public comment.

We did get some internal comments from NRR and the Research staff, but the public comments were from those two sources. The majority of comments were editorial in nature and there was a draft report and there were definitely a lot of typos and stuff in it. Hopefully we have cleaned those up. We basically accepted all of those and revised the document accordingly.

So and there were a good number of those. I think well over half of the NEI comments were editorial in nature. For example, some of the comments, and this included both ACRS comments and ones from industry, suggested expanding on the data analysis and reporting. And again, we have taken some of these and we have expanded what is in Volume II, in particular. There is a number of new tables and figures that we have presented to try and get at some of the key things people had asked for and some of those were, you know, great suggestions.

But we were just really limited in how far we could go with that. My role, Sandia's role, explicitly excluded that. And so we had to stay within our scope. We did what we could. And as I say, you will see that there are a number of areas where we expanded. And I think it was a good quality addition to the report. But we could just only go so far. And I have mentioned this before.

CHAIRMAN BANERJEE: So you have given us a very detailed outline of how you have responded to each comment, right?

MR. NOWLEN: Yes, yes. You have a specific sheet where we went through each comment and provided a specific response and outlined how we were going to change it, so you have that. Another area, there were a number of comments from NEI, in particular, about, you know, what does this mean to regulation? And I'm a NUREG/CR, I'm sorry, I don't do that. So basically, we have referred those to NRR and I think Dan is going to chat a little bit about that probably right after lunch.

Basically, those are just things I can't address by definition. I just can't.

CHAIRMAN BANERJEE: Well, it's also really beyond the scope of this meeting.

MR. NOWLEN: Yes.

CHAIRMAN BANERJEE: Yes.

MR. NOWLEN: Some of the significant revisions as was noted here this morning, there were a lot of comments on the foreword. And there was, in particular, an objection taken to the wording that said, you know, "We have enough information to say these could be risk-significant." And so what was done, and there were several comments on that particular phrasing, is the words have been modified and clarified somewhat.

It now says "Under certain circumstances, they could be risk-significant." Because it is a circumstance. It's a very specific sort of configuration that creates this as potentially risk-significant. You have to have a cable that's vulnerable. You have to have a cable that's susceptible to spurious operation.

It has to impact something that you care about in terms of say shutdown. You've got to have a fire source that can get it. You have to look at the probability that your active suppression and your manual fire brigade and all those measures, I mean, so again, we have clarified the words. We do feel that as it is written now --

CHAIRMAN BANERJEE: Is it necessary to, I mean, even say those things, because --

MEMBER SIEBER: Yeah.

CHAIRMAN BANERJEE: -- the report stands by itself. But I don't know --

MR. NOWLEN: Well --

CHAIRMAN BANERJEE: -- to give it to -- put it in a context maybe, you have to, I don't know.

MEMBER SIEBER: The bottom line, it's a bottom line.

MR. NOWLEN: That was the intent is to put it -- this is the staff foreword. So this is the NRC's foreword to introduce why should you care about this report, I guess in a sense, that's the way I see it. And I think that's a big part of it is that, you know, we know enough today to say that under certain circumstances, these could be risk-important. And so I believe the staff is simply trying to put the whole report into the perspective of why should anyone care.

MEMBER SIEBER: Um-hum.

MR. NOWLEN: I mean, so I think from that perspective and I believe staff concluded that from that perspective it's a valid statement. And so it was clarified, but largely --

CHAIRMAN BANERJEE: Well, I think as long as you take NEI's comments into account in some way, it will be okay.

MR. NOWLEN: And we did. I think we did. I suspect that they will be happier with the new language. I think it's fair language. And so I agreed with the staff on their --

CHAIRMAN BANERJEE: Then I guess in this case it's in the eyes of the beholder.

MR. NOWLEN: Yes, that's true.

CHAIRMAN BANERJEE: NEI might not, but nonetheless.

MR. NOWLEN: Agreed.

CHAIRMAN BANERJEE: Yes.

MR. NOWLEN: Agreed. Okay. Let's see, other revisions. There were a number of comments that came in. We had used the term "in the body of the report." So we're outside the foreword now. We're into the stuff that I wrote. And I had used the term "risk-relevant." And I was -- I hadn't really defined that term, what I really meant by it and so people thought well, what do you mean risk-significant?

No, I specifically didn't mean risk-significant. I meant this is something that might be a factor when you start looking at risk. That's all I meant. There might be something you would need to consider. You would want to consider. So I have clarified that in the report. We offered a definition. We actually -- I believe it is in a footnote. We put a footnote in that says "This is exactly what we mean and we don't mean this. We don't mean risk-significant." You know, so hopefully that will address those comments.

And like I say, there were -- NEI said I think there were three or four separate comments that touched on that same phrase. What do you mean by this? So we did that.

CHAIRMAN BANERJEE: Okay.

MR. NOWLEN: Let's see, there was a request for more information on cable physical characteristics. And this was one ACRS had requested, others did as well. We're in a tough spot on this one. We did add specific information on the relative content of copper versus plastic for each of the cables. You will now see that there is both a mass fraction and volume fraction for every cable we tested and those were compliments of NIST. They had measured that.

So I was expecting it to show up in Kevin's report. I hadn't put it in mine. Well, we brought it over and we have now put it into my report as well. The Volume II contains that. But beyond that, when you get into things like thermal conductivity, thermal diffusivity, density, I don't have them. The manufacturers won't give them to me. We tried very hard to get them. And particularly, the University of Maryland pestered the manufacturers for months trying to get the information and we could not get it.

And we didn't have the wherewithal to measure it for -- you know, try and measure thermal conductivity of one of those insulation materials, given that is your sample. It's not practical, not feasible. So basically, our hands were tied on some of those. I think you will see from Kevin's work that the generic information, there is a lot of generic information out there in handbooks and whatnot, Hilado's book is a good one, Flammability Handbook for Plastics. That seems to work well for Kevin.

CHAIRMAN BANERJEE: Did you put in your report, I don't recall, a table of the properties you used?

MR. McGRATTAN: In my report? Well, as you will see in my talk, the only properties I use is K row and C. And K and C I'm just using constant values that I am pulling from the literature.

CHAIRMAN BANERJEE: Yeah. So those

literature values are tabulated for the different materials?

MR. McGRATTAN: No.

MR. NOWLEN: He's got a generic.

MR. McGRATTAN: You use constant value for all.

CHAIRMAN BANERJEE: Oh, you just --

MR. NOWLEN: It doesn't make much difference.

MR. McGRATTAN: That's the whole -- that's the point of the model.

MR. NOWLEN: They are all fairly similar anyway. I mean, when you look at these.

CHAIRMAN BANERJEE: Yeah. They are all polymers.

MR. NOWLEN: These polymers. There is not a huge variability.

CHAIRMAN BANERJEE: Is there a difference between thermosetting and thermoplastic?

MR. McGRATTAN: There is nothing in my model that distinguishes. It's really a bulk thermal calculation.

CHAIRMAN BANERJEE: But it just gets up to two different temperatures and --

MR. McGRATTAN: Yeah.

CHAIRMAN BANERJEE: -- thermoplastics burn?

MR. McGRATTAN: Yes, when they fail, it's different.

CHAIRMAN BANERJEE: Yes.

MR. McGRATTAN: But not how they get there.

CHAIRMAN BANERJEE: Okay. All right.

MR. NOWLEN: Okay. Another thing we added to the report was a summary table for the Penlight results. And in particular, we looked at the single cable test where we do the direct correlation between temperature and electrical response. And we made a lot of talk about how you can correlate those, but again, we hadn't done it. We have gone back and for the Penlight test we have added a table that summarizes how those correlate thermal response.

You know, the temperature at the time of failure, so that was a good suggestion and we definitely incorporated that. You will see that in the report. There is also a number of new plots that provide additional overlays of the thermal response and electrical performance, so that you can see the correlated behaviors. Again, we were kind of limited in how many of those we could do just because of time constraints, but we added a number of them to further illustrate that.

And we also added three plots illustrating sort of summarizing those correlations results and what we saw. Here are some examples of that. I don't know. These probably don't show up all that well. But here is an example of an overlay of temperature response with indication of the time of failure and time of ignition for that particular test, so you can see exactly where -- in this case, the cable ignited slightly before it failed electrically, but again, there are a couple of these.

CHAIRMAN BANERJEE: Is that a thermoplastic or what is it?

MR. NOWLEN: This one --

CHAIRMAN BANERJEE: I'm trying to read the scale, but can't see.

MR. NOWLEN: -- is 500 C, that's a thermoset.

CHAIRMAN BANERJEE: Thermoset.

MR. NOWLEN: That's not a thermoplastic.

CHAIRMAN BANERJEE: C or K, I can't --

MR. NOWLEN: C. 500 C.

CHAIRMAN BANERJEE: Okay.

MR. NOWLEN: On the scale. Now, these are summary plots that show the measure temperature at the time of failure for different test cases. In this case, these are all the cross-link polyethylene cables under different conditions, the tray tests, the conduit tests and the airdrops. These are the larger conductor cables in a tray. These are the larger conductor cables in a conduit.

So you begin to get a sense of where these things are failing. You know, again, this is from 380 to 470 degrees C. You begin to -- you know, and there is a fair degree of consistency across these. We've got some outliers, but there is a fair degree of consistency across here. And we did a similar plot. These are for all of the different thermoplastic types. It happened we had a question about the Tefzel. These are the Tefzel out here.

Your scale runs from what 250 to 400? So the Tefzel are up in that sort of 300 C range. These are the polyethylene insulated. They are in the 250. These are the PVC. They are more down in the 200 to 240 range. So we have added these. And there is a third plot like that that covers the miscellaneous cable types.

CHAIRMAN BANERJEE: Now, if you took one of those and you read it that test, let's say the first test, what would be the range of temperatures? Let's say the top one.

MR. NOWLEN: Yes, well, like if you take these three tests right here.

CHAIRMAN BANERJEE: Yes.

MR. NOWLEN: These are a direct repeat set. So that's three tests reproducing the exact same conditions over cable in a cable tray. That's as close as we can reproduce. Not too bad. This set over here was also a matched pair. This set here was a matched pair.

CHAIRMAN BANERJEE: So those outliers may not be actually outliers, right?

MR. NOWLEN: Well, no. Actually, like some of these, these were early tests where the heat fluxes were quite high. So one of the things you are seeing in that particular test and this one as well, these were under very high flux conditions, very short duration tests.

CHAIRMAN BANERJEE: Right. They might be real.

MR. NOWLEN: They might be real, yeah.

CHAIRMAN BANERJEE: I mean, because heat flux is high, the response is --

MR. NOWLEN: Yeah, I'm getting a more -- a less uniform response within the cable, so the outside is hotter. By the time the inside gets hot enough to really fail, the outside got really not.

CHAIRMAN BANERJEE: Yeah.

MR. NOWLEN: So yeah, there is definitely explanations for some of these outliers.

MEMBER ABDEL-KHALIK: Now, where do these error bars come from?

MR. NOWLEN: The error bars represent tests where I had multiple thermocouples and that simply represents the range of the thermocouples that were measuring response for a given -- and then the dot is just the average. Some of these, there was only one thermocouple or the thermocouples are so closely aligned that you can't tell the difference. But others, there were multiple thermocouples, so it simply reflects the multiple --

CHAIRMAN BANERJEE: Does the thermal model capture this?

MR. NOWLEN: Not really.

MEMBER ABDEL-KHALIK: It's not a detailed uncertainty.

CHAIRMAN BANERJEE: It's thermal?

MR. NOWLEN: No, it's not detailed at all.

MEMBER ABDEL-KHALIK: Nothing about this.

CHAIRMAN BANERJEE: It doesn't particularly --

MR. McGRATTAN: The thermal model only takes this as an input.

CHAIRMAN BANERJEE: Yeah.

MR. McGRATTAN: These are the so-called failure temperatures that you would input to the thermal model.

MR. NOWLEN: So Kevin might, for example, choose to assume a failure threshold between 420 and 430 C for the cross-link polyethylene cable. That becomes an input to his model. And when he predicts that the inside of the cable has reached that temperature, he will say now we have got failure. This is actually a fairly important little piece of information that we added that is a real good suggestion.

You know, a lot of -- this may be what gets quoted more than anything else in the report.

MEMBER BLEY: But from one thing you have said there, it goes back to what Said had asked you earlier, I think. You're saying those two high points were cases with higher heat flux, so that the heat flux is important in addition to the temperature and may be, I didn't look at the two temperatures, a fair amount.

MR. NOWLEN: A fair amount, yeah.

MEMBER BLEY: 20 degrees.

MR. NOWLEN: Yes.

MEMBER BLEY: Okay.

MR. NOWLEN: Well, and again --

MEMBER BLEY: It's not enormously --

MR. NOWLEN: -- you have to interpret those in context of the exposure. So you know, we talk about those in the report. But, you know, again, you -- there is uncertainty here. There is no doubt. And you know, exactly what contributes to those much higher temperatures, might take us a little while to explain.

Well, let's see, we're almost done and we're almost out of time. We added some discussions relative to the use of the cables with the thermal targets. We've got a number of questions about the heat fluxes. And, you know, again, from our perspective, all those cables are in effect heat flux gauges. They are cable-specific heat flux gauges. So we haven't done that analysis to the invert and say what has been the heat flux to the cable.

You know, it was outside our scope. But we have added an additional discussion to really clarify that. And, you know, you can say a similar thing about the conduits as Kevin mentioned. We also added the discussion about the pulsing fire behavior. I think we covered that. And we also added some additional discussion on burner efficiency, because that clearly is one of our -- it is the most important uncertainty when it comes to characterizing the fire, what was the actual efficiency of that burner?

Unfortunately, we couldn't measure it. We didn't measure it. And so -- but we have added to the discussion to explain how it affects it and what we think the range might be.

So in summary, we are to the last slide. Good timing. CAROLFIRE has contributed to our two critical areas, I think, in a very important way. Resolution of those circuit configurations that we call Bin 2 and improving the fire modeling capability. I mean, we still have a long ways to go there certainly. I think we have made a really good start. We have provided some data that no one ever had before. Kevin now has something to work with to develop the data or to develop a model, rather.

Our status, we have the two-volume test report. It is in the final stages of publication. You have got a copy of that. We do expect to be doing some more final editorial clean-up as the NRC print room goes through it. They will always find a few more things in there. But we do expect that it will be published. This -- I'll get back to the question that was asked three hours ago.

The format of the data, we are releasing all of the raw data and all of our process data. It is going to be provided in the form of Excel spreadsheets with raw and processed data on different sheets. All of the plots that we generated for purposes of the report are in the Excel spreadsheets. Each sheet also provides details on the conditions of the test, specific thermocouple layouts, placements, numbering, how the circuits were configured, their summary of the circuit failure modes observed.

There is a time line for each test. So they are fairly elaborate Excel spreadsheet files. And again, we are intending to provide each and every one of those with the final report probably in the --

CHAIRMAN BANERJEE: You mean on CD-Rom or something?

MR. NOWLEN: Probably two CD-Roms. We have enough stuff we will probably fill two. Because we are also going to include all of the photographs.

MEMBER BLEY: Or one DVD.

MR. NOWLEN: One DVD. Well, I'm not sure the NRC has gone DVD yet. It would fit on one DVD. But we're also going to be providing all of the photographs. We took a lot of photographs during this. I mean, obviously, we can't put all those in the report, but we will be providing all of those and we're working with staff to finalize those CDs as well.

Now, NIST has the third volume, which you have now seen as well, and he is going to present, Kevin, on that after lunch. And we mentioned the University of Maryland has at least one PhD thesis. I haven't touched base with Maryland lately, so I'm not sure exactly where they are at on other -- whether they are following up on this or not. But there is one thesis that came out that I thought was a nice piece of work looking more at the detail.

And I really feel myself that this data is really a gold mine. And we have just barely scratched the surface. There is so much data here and we're already working with staff to talk about what we might be able to do, looking further into the data. And so I think that this data is going to live a long time. And I think you will hear more about it in the future.

And with that, I'm done.

CHAIRMAN BANERJEE: Well, thank you, Steve. You have helped a lot and we'll take a little break now.

MR. FRUMKIN: Yes, Steve, I'm sorry.

CHAIRMAN BANERJEE: yes.

MR. FRUMKIN: NRR has one slide to wrap-up what we intend to do with the CAROLFIRE results and I can just do -- throw that up and --

CHAIRMAN BANERJEE: Sure.

MEMBER BLEY: While you are getting that, did -- Steve, did you get comments from vendors for AEs in addition to --

MR. FRUMKIN: Yes, I'll just come up to the front.

MR. NOWLEN: No.

MEMBER BLEY: -- industry groups? None at all?

MR. NOWLEN: No, no. NEI and ACRS that was all.

MEMBER BLEY: Oh.

MR. NOWLEN: None of the cable manufacturers or anything, none of the suppliers.

MEMBER BLEY: Do you know if they are following it?

MR. NOWLEN: No, I don't.

MEMBER SIEBER: They don't subscribe to the Federal Register.

MR. NOWLEN: I suspect it's kind of specialized for them, I suspect.

CHAIRMAN BANERJEE: Go ahead.

MR. FRUMKIN: So my name is Dan Frumkin. I'm on the Fire Protection Branch in NRR, the Office of Nuclear Reactor Regulation. And I'm just going to give you some insights to where we see using this information.

The RIS, the Regulatory Issue Summary, for inspection guidance is all Bin 2 items is not as likely as the Bin 1 items that are currently in the inspection procedure, but perhaps more plausible, more likely than the Bin 3 items that are either considered unlikely or incredible. CAROLFIRE confirmed that they were right there in between.

But due to some of the questions, the information -- the likelihood, you know, and the rare events that, you know, one out of many tests had a thermoset-to-thermoset failure, that kind of information. NRR doesn't see, at this time, elevating the results to the inspection procedure. We feel that we have the vast majority of fire risk using risk considering, you know, configurations and so forth are already in the inspection procedure and it's not our intent to dilute that with some items which actually haven't been quantified with RIS, but based on the information that we have available are generally considered less likely than the current inspection guidance.

And we intend to work with an RES to quantify the failure modes that Steve was referring to along the lines of mining that data. There is other tools, specifically, expert elicitations perhaps or some more perhaps small-scale testing or whatever tools we come up with or research and NRR comes up with to quantify this, because only through that quantification can we really use this information in determining risk through the significant determination process or even fire PRA, because we don't have -- it would be very complicated to put a thermoset-to-thermoplastic configuration into a fire PRA, because we don't know what number necessarily to use.

So those -- that's our path forward. We're very happy to have gotten this information. It confirmed the meeting that we had a number of years ago and we do see more work on this going forward.

MEMBER SIEBER: Thank you.

MR. FRUMKIN: Okay.

CHAIRMAN BANERJEE: Thank you.

MR. FRUMKIN: Yes.

MEMBER SHACK: Mark, does it -- is it useful, do you get a lot of information out of this that can quantify the intra-cable hot shorts? I mean, I assume you got lots of data here that you didn't have before. You know, we have sort of never -- we don't really talk about that, because the focus wasn't on it, but I assume that's one of the things that can be mined. You have a much better quantitative understanding of that or at least possibly out of this set of tests.

MR. SALLEY: Yes, and Steve can answer that directly. You know, we saw a lot of that. Things that the NEI tests already said were probable, we didn't bother to go back and keep piling that on. If you wanted to get a better --

MEMBER SHACK: Yes, if I wanted distributions, for example --

MR. SALLEY: Yes, you could now go back and this is the gold mine that Steve was talking about. You know what the NEI stuff has. You saw the figures that came out that are currently being used today. You could go back in mine this data out and expand that set, yes.

CHAIRMAN BANERJEE: Okay. If there are no more questions, I'm going to break for lunch. Okay. So we come back at 1:00.

(Whereupon, the meeting was recessed at 12:17 p.m. to reconvene at 1:06 p.m. this same day.)

A-F-T-E-R-N-O-O-N S-E-S-S-I-O-N

1:06 p.m.

CHAIRMAN BANERJEE: We are back in session. Kevin McGrattan will tell us all about THIEF. That's a nice name. We're trying to finish slightly early, because several Members have planes to catch and things. It's not me, so I don't care, but some of the colleagues.

MR. McGRATTAN: Well, I have 13 slides. You can make this as long or as short as you want.

CHAIRMAN BANERJEE: We want to make it --

MEMBER SIEBER: Don't challenge us.

CHAIRMAN BANERJEE: -- just right.

MR. NOWLEN: When do you want to adjourn for the day?

CHAIRMAN BANERJEE: I think 4:30 would be good, if we can finish it.

MR. NOWLEN: Okay.

CHAIRMAN BANERJEE: I think we can do that.

MR. NOWLEN: Yeah.

MEMBER SIEBER: I think we'll take it out of the PIRT's hide.

MR. NOWLEN: That's fine.

CHAIRMAN BANERJEE: We would rather --

MR. NOWLEN: You guys are the kings of PIRT, so --

CHAIRMAN BANERJEE: -- listen to you guys.

MR. NOWLEN: -- talking about PIRT is a little uncomfortable anyway, but you're kings.

CHAIRMAN BANERJEE: Okay. Go for it.

MR. McGRATTAN: Well, let me introduce myself again. My name is Kevin McGrattan. I work in the Building and Fire Research Laboratory at the National Institute of Standards and Technology. And you have already seen the title of my presentation is a clever acronym. All clever acronyms, by the way, are the doings of Mark Salley, who spends a lot of time coming up with nice names for things. We didn't know what to call this model, because it's, as you'll see, fairly straightforward heat conduction.

And yet the name implies Thermally-Induced Electrical Failure. Meaning it's really just a thermal model. And the electrical part of it Steve has already talked about.

CHAIRMAN BANERJEE: You could have called it TUF, oh, never mind.

MR. McGRATTAN: Okay. Just as some background for how we came about developing this model. I just want to fill you in on what the current methodology is for cable failure. This is listed in NUREG 1805, which some of you may know as these fire spreadsheet calculations of the FDTs, the Fire Dynamics Tools.

MEMBER SIEBER: Um-hum.

MR. McGRATTAN: And the basic idea is if you have predicted via your various types of calculations what a compartment or room temperature is, shown here on the left, we'll call that an exposing temperature, then the black and the red curves give you an estimate of when a cable, either a thermoset in black or a thermoplastic in red, will fail. So this is based on a lot of data that has been collected over the years.

Steve has probably been responsible for half of it or maybe all of it. And in fact, I think these curves are developed by you.

So now, this is nice in the sense that if you are an engineer and you have a rough estimate of what your compartment temperature is going to be, here is a great way to estimate your cable failure time. The problem is as we go forward in developing our fire models, there's a couple of problems with this.

One is these curves don't even consider the bulk properties of the cable. You know, you passed them around this morning. Some are thin, some are thick, some have multi-conductors, there's no consideration at all. This is all just based on lots of test data with lots of different kind of cables and these curves, in some sense, are conservative bounds on all the test data.

And in fact, the points that you see up there are from the Penlight series and CAROLFIRE. So it demonstrates that these curves that are currently being used are fairly conservative.

The other problem with these curves is they don't account for time dependent exposures. And now the fire models as they become more sophisticated give us time history or temperature history, function of time. You don't just deal with one compartment temperature any more. And also with these curves, you really can't expand this beyond the simple cable independent of anything else.

So if you put a conduit around it, if you put an armored jacket on it, there is nothing to account for that in the current methodology. So we need to go beyond this simple set of rules. But the question is how far down the road do we want to go in developing a fire model?

Well, consider the types of models that we currently use in fire protection. There are, basically, three types. The simplest kind of model has been around the longest, those are what we call the hand calculations. A lot of these hand calculations are now codified in spreadsheets. So the FDTs, for example, the Fire Dynamics Tools, use a lot of these empirical correlations that have been developed over the years.

Here is one of the most popular correlations used in fire that gives you the temperature of a compartment as a function mainly of the heat release rate Q dot along with some other constants having to do with the geometry of the compartment.

Then in the early 1980s and throughout the '90s, the so-called Two-Zone models were developed. These are the models where you look at a more or less rectangular compartment with a specified or a fire of a fixed heat release rate. And these models will typically conserve mass and energy between two zones, an upper zone and a lower zone, so you have, basically, an estimate of an upper layer temperature and a lower layer temperature.

Now, in the 1990s and through today, we're now looking at using CFD models for fire calculations and that's shown here on the right. This is an example of the fire model that I'm part of the developers. This is the fire dynamic simulator.

Now, in the last couple of years and I think some of you on the Committee have seen some of this work. The NRC has conducted verification/ validation studies of these different kinds of models. What I'm showing here are the experiments that we looked at, all of which are mocked-up in the CFD model, but there are comparable sketches of these compartments in the other models.

I include these pictures here because I want to point out what a typical fire model calculation consists of in the nuclear arena. So what you see here on the left here, this is a 19 meter high test hall in Finland, which you have a fire in the middle of the space and smoke filling it up. This was the closest set of experiments we could come to a turbine hall fire.

These are some experiments that Steve conducted about 20 years ago now. In fact, at Factory Mutual in Rhode Island, the tests were conducted by Sandia at Factory Mutual's facilities. This was a mock-up of a control room with various fires of various sizes and various ventilation rates in the compartment.

These were some experiments done at my laboratory about four years ago in which you have a geometry that's typical of any number of compartments in a nuclear plant, again with fire in the middle of the space, some cable trays hanging in various locations. These were some experiments done when my lab used to be called The National Bureau of Standards, some 20 years ago.

Here we are just looking at the movement of smoke and hot gases from one compartment into a hallway and back into another compartment. And these were some experiments done in Germany probably about four or five years ago in a test furnace with a fairly large liquid pool fire inside.

Now, in all of these calculations, you are very limited in what amount of detail you can put in. Most of these calculations are focusing on moving smoke and hot gases from a fire of a known size throughout a space and ultimately predicting the response of targets. Targets could be a cable, sprinkler, smoke detector or any number of things.

Now, when you look at these calculations, you have to consider two things. What can the calculation provide to a sub-model, for example, a sub-model of cable failure? What information can we get from the large scale and also how accurate are these models? Because it's the accuracy of the models and the information that they can provide that's going to dictate in some sense the level of detail that you can incorporate into your cable failure model.

MEMBER SHACK: You just have to get used to the process. It happens.

MR. McGRATTAN: I'm sorry. I know there's one screen going blank. Okay. Well, in a nutshell, what this slide shows are some of the results of the V&V Study that the NRC conducted several years ago. And it is written up in NUREG 1824. These two quantities, in particular, the hot gas layer temperature and the radiation heat flux would be important as inputs to any sub-model of cable failure.

So what these charts basically show is they compare for all of the test data that we looked at, a comparison of the measurements shown on this axis with the predictions of the various models. And the various models shown by the different colors are the hand calculations shown in yellow, the zone models shown in the pink and then the CFD model shown in the blue.

So the first thing you will notice is that as the model gets more sophisticated, the answers tend to get more accurate. These dashed lines, by the way, represent the experimental uncertainty. So the goal of any fire model is to try to get at least within the experimental uncertainty bounds.

If you look at the radiation heat flux, you actually see a little bit more scatter, because this is an even more difficult prediction to make than a hot gas layer temperature, with again, the most inaccuracy going to the hand calculations. A little bit more accurate shown by the zone models and then, ultimately, the most accurate shown by the CFD models.

So as a result of 1824, we have a fairly good handle on what kind of accuracy you can get out of these models. We know from the previous pictures what kind of information you can get from the models. Basically, you can get a bulk temperature in the vicinity of the cable. A CFD model might give you -- well, it will give you a velocity, but the other models won't.

You will get some indication of the blackness or lightness of the smoke, if you want to do an emissivity calculation. But by and large, if you had to summarize things, you are probably going to know the thermal conditions in the vicinity of the cable to something like 20 percent accuracy. Okay.

CHAIRMAN BANERJEE: 20 percent absolute temperature or what?

MR. McGRATTAN: 20 percent --

CHAIRMAN BANERJEE: 20 percent heat flux?

MR. McGRATTAN: -- temperature. I would say 20 to 25 percent in the heat flux and 10 to 15 percent in the temperature rise over ambient.

Okay. Now, as Mark alluded to before, this isn't the first time that sub-models have been developed for fire models, specifically for fire models, because there are fire protection devices that we, obviously, want to incorporate into our models. So over the past 30 years, things like sprinklers and smoke detectors have been put into most practical models.

Now, these are the current models for these two devices, models of activation. If you look on the -- if you look over here, a sprinkler is really nothing more than predicting when a thermal device, known as a link, T_l is going to reach a certain temperature and you use this simple convective heat transfer equation to predict it. Okay.

Only information that you need from the larger scale fire model is a velocity, a gas temperature and this empirical constant known as an RTI. So just a handful of numbers from your fire model, one empirical constant and, ultimately, a temperature which the sprinkler is rated to activate at and that's your model.

This was done probably 25 years ago at Factory Mutual by Gunner Heskestad. He developed a similar model for a smoke detector, except now instead of a thermal lag, there is a hydrostatic lag due to the fact that it takes time for smoke to penetrate into the interior of a smoke detector. But again, from the fire model, you get a velocity. There is an empirical link scale, a smoke concentration and then the interior concentration of smoke is predicted with this simple equation.

So when we set out to develop a model of cable failure, we thought well, we should have something like this, because, if you think about it, just like these models, our cable failure model is not going to have much more information to work with than what you see on this slide here.

So then came the THIEF model and another reason why we call it the THIEF model is that we didn't really invent this. Actually, Joseph Fiore invented it originally and then a couple of researchers at SP Fire in Sweden, which is basically our sister lab in Sweden, were interested in cable failure just like us. And they had just solved the 1-D heat transfer equation.

And we called it the THIEF model, because we stole their idea. Now, we had originally thought that we could use something like the equation that is used for a sprinkler. The problem with the sprinkler link equation is that it assumes that the sprinkler link is thermally thin. We really can't make that assumption with a cable. We have to assume that these cables are thermally thick, so the next level of complexity is just to look at 1-D heat conduction into a cylindrical object without going into any detail of the complexity inside.

That's what the big idea that Andersson and Van Hees had was to not worry about the complexity of the interior. Don't worry about the number of cables, the amount of copper, just treat it as one lumped capacitor and see how well solving this equation can predict when that cable is going to fail.

Now, what do we need for this model? Well, shown here in blue, the boundary condition is we need the radiative and the conductive heat flux from the room. Okay. The fire model in which this sub-model is embedded will have to provide this information. The density of the cable, and we're assuming that this is homogeneous, is just going to be obtained from the mass per unit length divided by the cross-sectional area.

So the cross-sectional area and the mass per unit length, those are essentially given by the manufacturer and if they are not, you can just go weigh a piece of cable and get this information.

The P_s, the specific heat and the thermal conductivity, these, as was discussed before, these are not numbers that are easily obtained from the manufacturers. They simply do not want to give us this information and I think, in truth, they don't even actually have this. They don't necessarily have to measure these things when they develop the cables. There is no standard test. There is nothing that they have to provide to an authority when they develop a cable.

So we took from some experiments that we had done several years ago, some of the bulk properties of the cables that we were using, at that time, in which we measured. We actually sent to a lab to have measured for that particular cable, the specific heat and the thermal conductivity. And even though these were actually functions of temperatures, we just decided to take the fixed values at 1.5 kj/kg/K for the specific heat and .2 W/m/K for the thermal conductivity.

We thought that we would just start with those numbers and then see how it goes. Those were sort of the initial values, initial guesses and as we went on we found out that we really didn't have to change them. The results were adequate, as I'll show now.

Steve showed some photographs of the Penlight apparatus. And this is just to give you an indication of how well the model works in this simple configuration. So what is shown here in black is the temperature of the cylindrical shroud of the Penlight apparatus. So that's something that is dialed into the model, the exposing temperature. The solid red and the dashed red lines are the temperatures of the thermocouples just underneath the jacket in the middle of the apparatus. And shown by the dotted line are the predictions of the model.

Now, note that the model predicts well the temperature inside the cable. What the model cannot predict though is what's happening right here, and that is the cables are igniting. There is nothing in the model that talks about ignition. The model only just tracks the interior temperature. There's also nothing in the model that says that the cable failed here.

This dashed line is when the cable failed in the experiment, but there is nothing in the model that says it will fail.

CHAIRMAN BANERJEE: Why does the model go through a peak there?

MR. McGRATTAN: Go through a peak here?

CHAIRMAN BANERJEE: Right.

MR. McGRATTAN: It's just following this temperature. Okay. So the model knows nothing about the fact that those cables actually ignited in the real experiment.

Now, predicting when cables ignite and how cables burn, that is something that we're interested in, but for the moment with this simple model, we're not even addressing those issues, because the model can't possibly address those issues.

Now, I talked before about we wanted a model that had some flexibility. We didn't want to just calibrate the model for a single cable all by itself, because we know that cables never exist all by themselves in a plant. They are -- sometimes they are surrounded by something like a conduit or thermal lag or whatever it is. We want to be able to continue doing heat transfer calculations, even in a more complex configuration.

So with a conduit, there it's very easy to extend the model to, first, predict the conduit temperature, which is what we're doing here in this experiment. The solid blue line is the measured conduit temperature in the middle of the Penlight apparatus. The blue line is the predicted temperature based solely on the thickness of the conduit, the properties of steel and that's it.

And then, of course, the solid red, dashed red, those are the measured interior cable temperatures. And then the dotted red is the prediction of the model.

MEMBER ABDEL-KHALIK: Back to the previous slide. Presumably, the onset of ignition is a function of temperature.

MR. McGRATTAN: Yes.

MEMBER ABDEL-KHALIK: And therefore, wouldn't it be a fairly simple extension of the model to add a volume metric heat generation term at a given temperature?

MR. McGRATTAN: Um, the problem is that

ultimately when the entire cable try is involved, we're no longer dealing with just a single cable.

MEMBER ABDEL-KHALIK: Okay.

MR. McGRATTAN: And the rate at which these cables are going to burn is going to be a function of the radiative heat feedback from the fire itself and the details of the heat transfer cable to cable. So when I say our model has nothing to say about having multiple cables arrayed in a tray, and the heat transfer between these cables, it's sort of akin to when you have a fire in your fireplace. What sustains the combustion is the radiation back and forth between the logs and the walls of the fireplace.

If you were to pull one of those logs out of the fireplace, combustion typically stops, because of the heat losses. So accounting for that complex interaction of the heat transfer amongst all the cables, that's something that if we wanted to truly predict the burning behavior of the cables, that's what we would have to start incorporating into a model and that's much more complex than we're prepared to do here.

This model is only aimed at predicting when that cable is going to fail, because in a large-- a large majority of the hazard calculations and PRA calculations that are done, correct me if I'm wrong, those who actually do this sort of thing, they are interested in when the first failure is going to occur. I mean, another thing I should say about this model, Steve talked about all these -- all of the failure modes that would occur for a given cable. We are only interested in the first one with this model.

MEMBER ABDEL-KHALIK: You know, the black curve on this --

MR. McGRATTAN: Um-hum.

MEMBER ABDEL-KHALIK: -- this is a boundary condition.

MR. McGRATTAN: Yes.

MEMBER ABDEL-KHALIK: And can -- this boundary condition, even in the experiment, is affected by the onset of combustion.

MR. McGRATTAN: Yes, yes.

MEMBER ABDEL-KHALIK: And therefore, you can't have it both ways.

MR. NOWLEN: Well, it's -- you know, you're right. I mean, in theory, we could, for example, say that given that the cable has failed, there is a probability that we get ignition concurrent with that and so you could, you know, see some time adding that in as a mechanism for propagating cable fires.

We have now ignited a specific point, one location on one cable and the more difficult problem is then to say well, how does that then affect its neighbors? How quickly does it spread? How does it spread from one tray to another? Those get into some very, very complex and difficult problems for fire models to deal with today. And that's what Kevin is really alluding to.

I mean, in theory, sure you can see this going further.

MEMBER ABDEL-KHALIK: Well, it --

MR. NOWLEN: But you know, it's baby steps, I think, is where we're at.

MEMBER ABDEL-KHALIK: I look at your model as sort of a very small just, you know, one dimensional transient conduction of a cable.

MR. McGRATTAN: Um-hum, um-hum.

MEMBER ABDEL-KHALIK: And for that, you need the boundary conditions.

MR. McGRATTAN: Yes.

MEMBER ABDEL-KHALIK: And what this affects, what this happens is that there is a direct coupling between your model and the boundary conditions.

MR. McGRATTAN: Absolutely.

MEMBER ABDEL-KHALIK: And therefore, I'm not sure how you get good boundary conditions for your model --

CHAIRMAN BANERJEE: He doesn't care.

MEMBER ABDEL-KHALIK: -- in real life.

MR. McGRATTAN: Well, as Steve alluded to that ignition often coincides with failure --

CHAIRMAN BANERJEE: That's right.

MR. McGRATTAN: -- at which point, game over for this model.

MR. NOWLEN: Yes.

MR. McGRATTAN: Now, then you could introduce some more sophisticated model of burning or you can look at a lot of fire tests that have been conducted that were specifically designed to get burning rates for different types of cables. So within 1805, for example, there are, for the different classes of cable and different types of cable, actual burning rates here, heat release rates per unit, length of cable tray.

And the model work that I do actually have all the mechanisms within the model that I have developed to predict the burning rate. However, there are so many uncertainties in that prediction that I'm, at this stage, still more comfortable using the empirical burning rates, rather than trying to predict them myself.

I mean, long-term, sure, that's what I want to be able to do. I want to be able to predict from first principles the rate at which real materials burn, but, at this point, we still have to rely on empiricism.

MR. SALLEY: And that is future work. If I ever get out of the CRs and get the money, we -- seriously, if you are ever at NIST, you will see that we have two trailers that are loaded with cables that are leftover actually from Brookhaven from the EQ days, so we have started to amass cables and that. And we're only as good as the state of the art. If you took the Fire Protection Engineering Handbook today and you opened it up to things like cable trays, for example, heat release rate.

Heat release rate is the driver for our fire models. How big is the fire? You go back and look at the work that Factory Mutual did, Archie Tewarson, over the years, it was done 20 some years ago and it is crude rough data, but that's where the state of the art is. We have future projects. Like I said, if we get past the CR and the funding to actually go and look at these things for flame spread, because of the PRA world, it becomes very important for them how fast the fire is propagating down the trays.

So this is future work that we do have scheduled. The key of this presentation was the question, the most prominent question, when does the cable fail and I get my hot short? So that's the piece. We have recognized those other areas. I think you will see some of that in the PIRT, too, this afternoon.

MR. NOWLEN: Yeah, and the way we will use this is we will look at a fire scenario that has a source and a number of targets that are usually cables, so I may have cable here, here, here and over there. Now, I can take and I can model each of those as a part of the model and say well, this one is going to fail then and then this one and then this one and then sometime later that one. But because of the state of the art, I'm going to treat the fire as empirically determined.

I'm going to say based on all of the experimental data we have, this is what I think the fire is going to do. And I'll feed that in as an input to his model. Now, I can get these predictions of time to damage and I can start building up target sets and assessing the likelihood of suppression within. You know, by the time I get the first three targets, what's the likelihood I put the fire out?

Now, my fourth target is way over here, so it's a much longer time. I add that to the target set, but I have a much better chance of putting the fire out before it ever gets there. So we begin to weigh these things against risk and the likelihood of suppression. But again, we're still treating fire as the source itself, which includes the burning of the cables based on these empirical experimentally drive perceptions of how a cable fire is going to grow. We're not quite there yet with the models to where we have confidence in our ability to a priori predict that sort of behavior.

MEMBER BLEY: But I would think even if you could model at the level you are hinting at, we're lucky if we know which cable tray the cable is in. Where in the cable tray, we don't have any idea.

MR. NOWLEN: Where in the --

MEMBER BLEY: And some of them have a lot of cables in a cable tray.

MR. NOWLEN: We're getting a lot better about knowing which tray it is in and where the room the tray is.

MEMBER BLEY: Oh, yeah, the newer plants you have that.

MR. NOWLEN: Yes. Well, and even as a part of the reconstitution efforts that people are going through for Appendix R and the 805 transition work that is going on, people are tracing cables. We know a lot more about where cables are today than we did a few years ago and it is getting better and better all the time. So that part of the problem, we're actually getting a pretty good handle on.

But, you know, like you said, within a tray, where is the cable within a tray? We have --

MEMBER BLEY: Some trays have an awful lot of cables.

MR. NOWLEN: Oh, yeah, yeah, you know, 50 cables in a tray and they all look the same from outside. You don't know which one is which.

MEMBER BLEY: Well, what do you do with this model when you come to a bundle of cables?

MR. McGRATTAN: We're going to get to that.

MEMBER BLEY: Oh.

CHAIRMAN BANERJEE: Talking of single cables, right?

MR. NOWLEN: Single so far.

MR. McGRATTAN: Single so far, right. And I will summarize the results of Penlight. So there were some 30 tests done in Penlight with just single cables that we used to test the model. And here is a summary of the results. On this axis, the measured time to some prescribed threshold temperature, because again, this doesn't predict what temperatures the cables fail at, and the predicted time of that same threshold temperature, the dashed lines represent the average of the predictions and a standard deviation.

This just gives you some indication of the spread of the predictions. And as you can see here, we're doing pretty well in predicting these very simple cable configurations. So this gives us confidence that we can use this model --

CHAIRMAN BANERJEE: With a constant thermal conductivity?

MR. McGRATTAN: -- in practice. And again, with constant C and constant K all of those results were obtained.

MEMBER SHACK: Universal constant.

MR. McGRATTAN: Universal constants.

CHAIRMAN BANERJEE: Like the gas prices.

MR. McGRATTAN: Right. Well, if you're

actually -- regardless of whether it is a thermoset or a thermoplastic, you actually look at the K and the C for this, so they are fairly comparable.

CHAIRMAN BANERJEE: Actually, if you divide them by each other, you just get one constant.

MR. McGRATTAN: Okay.

CHAIRMAN BANERJEE: They are both outside the derivatives.

MR. McGRATTAN: Yes, yes. Now, the question is okay, so you can predict one cable in this very ideal setting. What happens when you have a real cable in a real setting? So let's look now at the intermediate-scale tests. Steve introduced the setup. And as I said before, we wanted to apply the model here exactly the same way that we had applied it in Penlight.

So regardless of the specifics of the configuration, we just applied this cable model in a very simple way. So regardless of whether the cable was buried within a random pile, as you see here, if it were in a conduit, we treated the conduit the exact same way that we did in the Penlight. Here are the bundles that Steve talked about before. This is a six cable bundle and this was a 12 cable bundle.

I believe that with the six cable bundle it was E that was instrumented thermally and with the 12, I think, it was the A. Is that right, Steve?

MR. NOWLEN: Yes, generally.

MR. McGRATTAN: Yes, yes. Now, we mentioned this morning that in Steve's experiments the rounding of any of these cable configurations were thermocouples say here and here, here and here, here and here and here and so on, that would measure the surrounding gas temperature, okay. And these measurements are what I used as input, because I wanted to test the sub-model. I wasn't interested in this case in testing the fire model, per se. I wanted to see how well we could predict cable failure if all that we knew was the surrounding gas temperature.

CHAIRMAN BANERJEE: Now, how did you get a heat flux from that? You explained that before, but can you do that again?

MR. McGRATTAN: Okay. So --

CHAIRMAN BANERJEE: Because that's the boundary condition.

MR. McGRATTAN: Right. So it's just Sigma T^4 of the gas temperature minus Sigma T^4 of the cable with emissivity in there.

CHAIRMAN BANERJEE: You lump the cable as single surface temperature, right?

MR. McGRATTAN: Yeah, yeah, because this is all one unit.

CHAIRMAN BANERJEE: Whether it is buried or not, it doesn't matter?

MR. McGRATTAN: No, it doesn't matter.

CHAIRMAN BANERJEE: But --

MR. McGRATTAN: It doesn't matter.

MEMBER SHACK: The mass is just the mass of that whole bundle?

MR. McGRATTAN: No, the mass is the cable. It's as if the --

MEMBER BLEY: The rest of the bundle isn't there.

MR. McGRATTAN: -- bundle doesn't exist. Yes.

MEMBER SHACK: Oh, okay.

MR. McGRATTAN: Now --

CHAIRMAN BANERJEE: What about if it's buried?

MR. McGRATTAN: -- that's an imperfect assumption and that's why you see more scatter in the predictions here.

MEMBER SHACK: Right.

MR. McGRATTAN: The good news though is that if you look at these yellow points which are the greatest under-predictions of cable failure, those come from these experiments. So in other words, when your cable is actually buried within a pile, if you don't include that pile in your calculation, you are going to fail the cable quicker with your model than it would in reality. And that's what we want this model to do.

If it's going to make a mistake, we want it to make a mistake on the conservative side. So anything on this side of the line is a conservative prediction.

CHAIRMAN BANERJEE: Okay.

MEMBER ABDEL-KHALIK: I guess, logically, that's sort of counterintuitive, right?

MR. McGRATTAN: Okay.

MEMBER ABDEL-KHALIK: In a sense that you were -- you are ignoring something that is, essentially, protecting the cable of interest --

MR. McGRATTAN: Yes, yes.

MEMBER ABDEL-KHALIK: -- in your model.

MR. McGRATTAN: That's exactly it.

MEMBER ABDEL-KHALIK: And yet, your model predicts that it will fail earlier.

MR. NOWLEN: No, that's --

MR. McGRATTAN: All the model is getting

is that exposing temperature and it doesn't get any of the benefit of the heat sink or the protection of the surrounding cables.

CHAIRMAN BANERJEE: It's like a single exposed cable.

MR. NOWLEN: Yes.

MR. McGRATTAN: Yes.

MR. McGRATTAN: Because if you think about it, go into a plant and you see in a tray often times the cable will be buried amongst its neighbors, but, at some point, it may pop out.

MEMBER BLEY: Now, these are in the hot gas area?

MR. McGRATTAN: If it's going to fail, it's probably going to fail where it pops out. And so in our hazard calculations, we want to account for the fact that it is possible that that cable is not always going to be protected by its neighbors. I'm sorry, what were you saying?

MEMBER BLEY: Steve answered me. The heating is coming from the hot gas layer?

MR. McGRATTAN: Yes.

MEMBER BLEY: And in fact, that's right, in the real world this cable could be in the middle in one place and on the edge in another place.

MR. McGRATTAN: Yes, yes. And we were also interested and the question came up this morning about the difference between the radiative heat flux of the Penlight apparatus and the real conditions of hot gases in an upper layer. I modeled both the Penlights and these experiments just taking that exposing temperature and the model behaved very similarly, because there were experiments in the intermediate-scale in which there were only single cables.

And in those cases, those single cable results in the intermediate-scale, based on that exposing gas temperature, were very similar using the model and the same set of assumptions to in Penlight. So I inferred from this that that Penlight apparatus was doing a good job of mimicking heat flux that a real cable would see in a real fire.

MEMBER ABDEL-KHALIK: I guess I am a little confused. What is the $_s$ on page 7?

MR. McGRATTAN: Oh, I'm sorry. Yeah, I just used that for solid, because I -- most of my calculations aren't gas-phased and I always penned a little s to represent a solid. So a solid -- the density of the solid as opposed to the gas, the thermal conductivity of the solid. That's it.

At this point, we have our results. We are pleased with them. We have written up our report. We're currently working with the NRC staff to embed this model into the various fire models that are currently used. The fire models that were V&V several years ago, we want to incorporate this simple cable failure model into each one of them. The hand calculations, the zone model and the CFD calculations.

MEMBER BLEY: I lost track of one thing in your explanation, way back in your first picture when you talked about you don't have combustion in the model.

MR. McGRATTAN: Right.

MEMBER BLEY: So it doesn't explain the real line jumping up, but the dash line jumps up the same way.

MR. NOWLEN: No, it --

MR. McGRATTAN: Oh, I'm sorry. The --

MEMBER BLEY: It's a different dashed line up at the top?

MR. McGRATTAN: No, these -- Steve would always put two thermocouples inside the cable jacket, one on either side.

MEMBER BLEY: Okay.

MR. McGRATTAN: Just to sort of test the

variability.

MEMBER BLEY: So both of those are data. I'm sorry.

MR. McGRATTAN: Both those are data.

MEMBER BLEY: I thought you said the dashed one was --

MR. McGRATTAN: Yeah. And I like that, because it shows in some sense, both the repeatability and the variations.

MEMBER BLEY: But the little dashed one is the --

MR. McGRATTAN: It's the little --

MEMBER BLEY: -- bottom one.

MR. McGRATTAN: Yeah, the dots, I'm sorry, they don't show up very well in this.

MEMBER BLEY: I didn't -- I should have looked at the picture here.

MR. McGRATTAN: That's a prediction.

CHAIRMAN BANERJEE: So how deep inside the solid to you -- is that temperature? Is it right at the surface?

MR. McGRATTAN: It's underneath the jacket.

CHAIRMAN BANERJEE: Okay.

MR. McGRATTAN: So it's input to the

simple model --

CHAIRMAN BANERJEE: The jacket thickness?

MR. McGRATTAN: -- we need to know the jacket thickness.

CHAIRMAN BANERJEE: So then you don't even need to solve it in cylindrical coordinates, we just do a 1-D.

MR. McGRATTAN: Right, right. But because, as you see, for example, in this case, it can take quite a long time to reach failure. For example, here the first short in this conduit test was 23 or 34 seconds from start. So like 40 minutes. And so --

MR. NOWLEN: Yes, 40 minutes.

CHAIRMAN BANERJEE: Time significant.

MR. McGRATTAN: Yeah, I mean, we --

CHAIRMAN BANERJEE: Heating of the interior.

MR. McGRATTAN: It doesn't cost us anything to do it in cylindrical coordinates. I mean, this is a cheap calculation.

CHAIRMAN BANERJEE: Well, the only thing is that --

MR. McGRATTAN: We might as well do it.

CHAIRMAN BANERJEE: -- you did it in -- as a slab you could just write an analytical solution and be done with it.

MR. McGRATTAN: Well, the Swedes actually have an analytical solution for the cylindrical coordinates.

CHAIRMAN BANERJEE: Does that involve vessel function?

MR. McGRATTAN: Yes, exactly.

CHAIRMAN BANERJEE: I assume your computer can, too.

MR. McGRATTAN: Yes, our numerical solution is far simpler than that. And we don't want to be bothering the guys at NRC with vessel functions in the spreadsheets.

CHAIRMAN BANERJEE: No, yes, but on the other hand, the slab solution is just going to involve simple functions.

MR. McGRATTAN: Right. But sometimes these cables can be fairly small in diameter. So we don't want to rule anything out with that assumption. I mean, because the numerical solution is so cheap and easy, we just do it.

MEMBER ABDEL-KHALIK: If I go back to Slide No. 7.

MR. McGRATTAN: Are we going back or forward?

MEMBER ABDEL-KHALIK: Back.

MR. McGRATTAN: There?

MEMBER ABDEL-KHALIK: Right.

MR. McGRATTAN: Okay.

MEMBER ABDEL-KHALIK: Now, the second equation is about a condition, right?

MR. McGRATTAN: Yes.

MEMBER ABDEL-KHALIK: It tells you, essentially, the heat flux in the solid at the surface is equal to the instant heat flux.

MR. McGRATTAN: Yes.

MEMBER ABDEL-KHALIK: So this dT_s by dr is a local value at the surface?

MR. McGRATTAN: Yes.

MEMBER ABDEL-KHALIK: Right?

MR. McGRATTAN: Yes.

MEMBER ABDEL-KHALIK: Now dT_s by dr in the conduction equation up there is not the local value of the surface or is it?

MR. McGRATTAN: It is.

MEMBER ABDEL-KHALIK: It is?

MR. McGRATTAN: Well, no, this is a partial differential equation.

MEMBER ABDEL-KHALIK: Right. T_s is the function of both r and time.

MR. McGRATTAN: Time, yes.

MEMBER ABDEL-KHALIK: But dT_s by dr in the second equation? That is a local value at --

MR. McGRATTAN: Yes, local value.

MEMBER ABDEL-KHALIK: -- r = R.

MR. McGRATTAN: Cap R = the actual radius of --

MEMBER ABDEL-KHALIK: Right.

MR. NOWLEN: That's exact boundary conditions.

MR. McGRATTAN: That's the boundary conditions.

CHAIRMAN BANERJEE: I guess you should write r = --

MEMBER ABDEL-KHALIK: Say r = R, right.

MR. McGRATTAN: Yes, okay.

MEMBER SHACK: Now, suppose I took the old fashion empirical correlation and applied it to the conduit tray. What am I -- or, you know, would my scatter now look about the same as your model? Have you lost all the advantages of your model when you -- I mean, you're now so far from reality, it's hard to imagine you are better than the purely empirical one.

CHAIRMAN BANERJEE: The time -- the first curve you showed.

MR. NOWLEN: The old correlation would give you very conservative results in comparison to the measured data.

CHAIRMAN BANERJEE: The second or third slide.

MR. McGRATTAN: Yep.

MEMBER ABDEL-KHALIK: So it's even better for the bundle.

MR. NOWLEN: Yes.

MEMBER ABDEL-KHALIK: I mean, I can understand why it is better for a single cable. Why it's better for a bundle almost boggles my mind, but if that's the way it works, that's the way it works.

MR. McGRATTAN: Well, the gases do penetrate in the interior of these bundles.

MEMBER ABDEL-KHALIK: Ah, okay.

MR. McGRATTAN: I mean, they are not --

MEMBER ABDEL-KHALIK: It's not a conduction problem. It's a gas?

MR. McGRATTAN: It's gas. These are gases in there.

MR. NOWLEN: These are porous.

MEMBER ABDEL-KHALIK: Okay. Okay.

CHAIRMAN BANERJEE: The boundary condition.

MEMBER ABDEL-KHALIK: Okay. So the real resistance in here is not until I actually hit my God damn cable.

MR. McGRATTAN: Yes, yes.

MEMBER ABDEL-KHALIK: Yeah.

CHAIRMAN BANERJEE: The boundary isn't it actually written as Sigma T G^4 minus Sigma T_s r = r^4, right?

MR. McGRATTAN: Yes. Yes, you can use -- now, I leave it somewhat vague here, because each type of fire model is going to have a different way of coming up with these numbers. For example, in the spreadsheet calculations, there is a separate calculation that gives you a radiative flux from a point source. So there your q''r is going to be some-- you know, 1 over 4 pi r^2 type estimate. Whereas, the zone model and field model, they will give you a Sigma T^4 minus and so forth.

Yes, I was surprised when I read the paper by the Swedes. I mean, I thought that there would be more to it. I thought that we would have to include at least something about the copper content. You know, the volume, the mass per volume and all that sort of thing, but I've looked at the results and where we were over-predicting or under-predicting was complete insensitive to a lot of the details of the interior.

CHAIRMAN BANERJEE: But at some point in the report, the experimental reports, there was an effect of the copper to mass ratio.

MR. McGRATTAN: Right.

CHAIRMAN BANERJEE: I remember that.

MR. NOWLEN: There's some. We show some plots that there is --

CHAIRMAN BANERJEE: Yeah.

MR. NOWLEN: -- a little bit of it. You can see some noticeable difference in terms of the thermal response. There is a little.

MR. McGRATTAN: Right. And we do account for it indirectly in the sense that we use the mass per unit length.

MR. NOWLEN: Right.

MR. McGRATTAN: So a heavier cable is going to have --

MR. NOWLEN: A slower response.

MR. McGRATTAN: Yeah, a slower response.

MR. NOWLEN: And you will see that in the data and he accounts for it through that mass per unit length. So and that seems to do a pretty good job of handling that particular variable.

MR. McGRATTAN: But the specific mass or volume fraction of copper or the insulating materials, I was surprised that the thickness of the insulation material didn't seem to have any effect.

CHAIRMAN BANERJEE: If you go back to the overall correlation, your second to the last slide or something, yeah. Now, when you are looking at showing those data now, let's say, let's take the blue, which is the six bundle.

MR. McGRATTAN: Yeah, sure.

CHAIRMAN BANERJEE: Now, are those mainly cables which are buried or on the surface?

MR. McGRATTAN: Well, here in the six cable, it's this E. So it's not completely buried.

CHAIRMAN BANERJEE: Okay.

MR. McGRATTAN: It's seeing the hot gas.

MR. NOWLEN: Yeah, in effect, if you look at that bundle, none of the cables in the six bundle are truly buried. They are all exposed somewhere around the perimeter, some more than others.

CHAIRMAN BANERJEE: If you look at the minus 33 percent line, there are a whole bunch of blue around that, towards the low temperatures. Go down, yeah.

MR. McGRATTAN: Down here?

CHAIRMAN BANERJEE: Yeah, a little bit higher as well. They more or less lie on that.

MR. McGRATTAN: Yes.

CHAIRMAN BANERJEE: And then almost at the same conditions, you see there is a sort of a jump up.

MR. McGRATTAN: Right.

CHAIRMAN BANERJEE: Are those -- that's the same cable though, right? What's the --

MR. McGRATTAN: It's the same cable, but these bundles were in different locations in the rig. So for example, sometimes they were here directly over the fire, and correct me if I'm wrong, I forget exactly where --

MR. NOWLEN: Right.

MR. McGRATTAN: -- things were. And sometimes they were in various locations. So sometimes they were actually intimate with the fire and sometimes they were a little bit further away.

MR. NOWLEN: Right.

MR. McGRATTAN: So --

CHAIRMAN BANERJEE: So now, going back to that figure, I'm just trying to understand.

MR. McGRATTAN: Yes.

CHAIRMAN BANERJEE: That sort of change, is that always associated with a cable being close to the fire or far from the fire? Is there some trend there?

MR. McGRATTAN: To be honest, I don't know. I haven't looked at it in that regard to see -- that is when I plotted this up, I didn't distinguish-- I only looked at the different configurations, but I knew it would be interesting to see what is the difference between that point and that point.

CHAIRMAN BANERJEE: Yes, I think there is also an issue, yes, certainly that's one of them, because they are more or less exposed on the same conditions, right?

MR. NOWLEN: But they are also different types of cables. These are all mixed thermoplastic, thermosets, you know, EPRs, cross-link polyethylene.

CHAIRMAN BANERJEE: Right.

MEMBER BLEY: Each one of the points is a different composition.

MR. NOWLEN: Is one.

CHAIRMAN BANERJEE: Right.

MEMBER BLEY: Okay.

MR. NOWLEN: The one --

CHAIRMAN BANERJEE: Which is really the second point I was coming to, is whether you can explain this by some change in the properties of the cable or proximity to the fire. That's really --

MR. McGRATTAN: My guess would be this here has to do with proximity to the fire, because remember, our boundary conditions are these gas temperatures.

CHAIRMAN BANERJEE: Right. And so there's no radiation.

MR. McGRATTAN: In measuring that gas temperature, these were bare beads.

MR. NOWLEN: Bare bead thermocouples.

MR. McGRATTAN: These are bare bead thermocouples in the fire.

CHAIRMAN BANERJEE: Right.

MR. McGRATTAN: And to what extent that represents a true explosion temperature, I mean, that's subject to another couple of hours.

CHAIRMAN BANERJEE: Right. But I mean, when you see that trend, if you could correlate it to some sort of a positional effect, then that would give more confidence in the use of a single constant to perimetries this equation.

MR. McGRATTAN: Um-hum, um-hum.

CHAIRMAN BANERJEE: Whereas, if you actually found that that was not in proximity to the fire, but it depended on the type of cable or something --

MR. McGRATTAN: Right, right.

CHAIRMAN BANERJEE: -- that would suggest there's another parameter in the problem.

MR. McGRATTAN: Okay.

CHAIRMAN BANERJEE: Not just a single parameter.

MR. McGRATTAN: Yes, well, certainly that group as distinguished from that group --

CHAIRMAN BANERJEE: Right.

MR. McGRATTAN: -- that's definitely something to take a look at.

CHAIRMAN BANERJEE: Yeah.

MR. McGRATTAN: Along with all the other breakdowns and colors. This is part of Steve's data mining.

MEMBER ABDEL-KHALIK: Well, if I remember correctly, thermal conductivity of copper is somewhere between 300 and 350 W/m/K.

MR. McGRATTAN: Yes.

MEMBER ABDEL-KHALIK: And the value that you are using in your equation is .2.

MR. McGRATTAN: Correct.

MEMBER ABDEL-KHALIK: Which presumably reflects the thermal conductivity of the insulating layer.

MR. McGRATTAN: Yes.

MEMBER ABDEL-KHALIK: And so what is the range of applicability over which you are solving this equation? What is the range?

MR. McGRATTAN: Well, at the moment, that's the range.

MR. NOWLEN: This is the range.

MR. McGRATTAN: Because that's the -- those are the cables that we validated against.

MEMBER ABDEL-KHALIK: No, I -- you have a differential, a partial differential equation in time and position, right?

MR. McGRATTAN: Yes.

MEMBER ABDEL-KHALIK: So what is the range of -- I understand the range of time, right?

MR. McGRATTAN: Right.

MEMBER ABDEL-KHALIK: Until you get to a certain point. But what is the range in r that you are solving this equation for?

CHAIRMAN BANERJEE: The temperature we're moving into the -- how far in has it got from the cable failure?

MR. McGRATTAN: Yeah, I would have to sit down and do some work on that.

CHAIRMAN BANERJEE: The first layer, I suspect.

MR. McGRATTAN: Yeah, I mean, that's --

MR. NOWLEN: It probably is.

MR. McGRATTAN: We're assuming throughout this analysis that the first failure is occurring at the outer most ring of conductors. If you remember from looking at these, there are often layers of conductors in the 7 and 12 conductor cables. And we are assuming that since the failure is thermally --

MEMBER ABDEL-KHALIK: Well, this is the direction your temperature is radiant.

MR. McGRATTAN: Thermal wave is penetrating and it's our first level. So that heat transfer is dictated mainly by the plastic of the jacket and the insulation material. In that, the copper is coming into play only as sort of this giant heat sink that we are accounting for via the bulk density of the cable.

MEMBER ABDEL-KHALIK: You know, I'm trying to balance time constants here. And you know, you're predicting time responses in the hundreds, sometimes thousands of seconds.

MR. McGRATTAN: Yeah.

MEMBER ABDEL-KHALIK: And yet, the time

constant of all these layers, presumably over which you are solving this heat conduction equation is very short.

CHAIRMAN BANERJEE: Well, we take the square root of the thermal diffusivity. Let's look at the thermal diffusivity K by Row CP. What does that come to? Let's look at that and then we can answer his question.

MR. NOWLEN: I think, you know --

CHAIRMAN BANERJEE: What is the time constant?

MR. NOWLEN: -- the density of these is pretty high. These are high density materials, because there is a lot of copper here. The density is high. Thermal conductivity is low, because he is focusing on the insulation.

CHAIRMAN BANERJEE: Well, I can --

MR. NOWLEN: I think --

CHAIRMAN BANERJEE: -- roughly give you an answer.

MR. NOWLEN: -- you know, you are getting deep into the problem and, you know, that's what we struggled with, too. How deep do we have to dig into this before we get a reasonable prediction of the thermal response? And what his overall results are showing is you really don't have to go to this level. You don't need it, because, in most of these cases, the very, very simple representation works with reasonable uncertainty and that's the key lesson is we don't need to go there.

CHAIRMAN BANERJEE: What is it row roughly?

MR. NOWLEN: So let's go with it.

CHAIRMAN BANERJEE: What is row?

MR. McGRATTAN: Row?

CHAIRMAN BANERJEE: Yeah.

MR. NOWLEN: Density.

MR. McGRATTAN: It's density of the cable.

CHAIRMAN BANERJEE: No, but how much.

MEMBER ABDEL-KHALIK: 5.

CHAIRMAN BANERJEE: 5?

MR. McGRATTAN: 5 grams per cc on average. It's going to be less than that. I think it's going to be 2 or 3.

MEMBER ABDEL-KHALIK: That's fine. Depending on the copper, too.

MR. McGRATTAN: Yeah.

CHAIRMAN BANERJEE: Well, I have to change this to a side unit, since you've got everything else.

MR. McGRATTAN: I mean, well, 2,000

kilograms per meter cubed, that's usually the unit I work with.

CHAIRMAN BANERJEE: Is that enough? Not 5,000?

MR. McGRATTAN: No, 5,000, no. Copper is 5,000 or 6,000.

MEMBER ABDEL-KHALIK: Okay.

MR. NOWLEN: Solid copper.

MR. McGRATTAN: Yes.

MR. NOWLEN: This is half plastic.

MEMBER ABDEL-KHALIK: I mean, the thing I'm struggling with is that you're presenting, you know, a fairly straightforward heat conduction model that gives it legitimacy. Yet, when you look at it, it really is just a hodgepodge of different things. Right? You're modeling conduction in an inhomogeneous region. You're assuming the conduct -- you're using the conductivity.

MR. McGRATTAN: Right.

MEMBER ABDEL-KHALIK: The homogenized conductivity of the region in which you are solving this equation.

MR. McGRATTAN: Yeah.

MEMBER ABDEL-KHALIK: And yet, you are using the conductivity of a sub-region, right? And

I'm not sure exactly how that works.

MR. NOWLEN: Well, actually, the number for conductivity that he is using is we have actually measured a bundle of cables like this and done a conductivity experiment to measure the bulk thermal conductivity, if you just pretended this were a bulk medium, it's about the number you get.

MR. McGRATTAN: Yeah.

MR. NOWLEN: It really is dominated by the conductivity of the insulation materials, not the copper.

MR. McGRATTAN: Yeah, once the jacket --

CHAIRMAN BANERJEE: How thick is the jacket?

MR. NOWLEN: We did that back in the days where we were doing how fast it degraded.

CHAIRMAN BANERJEE: How thick is the --

MR. McGRATTAN: The C times the row is what you really have to look at.

MR. NOWLEN: Right.

MR. McGRATTAN: Not C and row, but those two multiplied together. And then a lot of the sort of mystery goes away.

MEMBER BLEY: Isn't this a little simpler? You know, when you -- you're showing us the threshold, the time to the threshold temperature. I'm assuming, because I don't remember what I read in here, that the threshold temperature you are using is the temperature you showed us before when you had failures. Both cases, you are measuring that temperature right under the jacket.

MR. NOWLEN: Right.

MEMBER BLEY: Yes?

MR. NOWLEN: Yes.

MEMBER BLEY: So that's really what this is.

MR. NOWLEN: Yes.

MEMBER BLEY: It's the temperature around 400 for one of them right under the jacket, so the temperature here is the one under the jacket, which is the place you measured, right, his cable failed. So it's the same thing.

MR. NOWLEN: Right.

MEMBER BLEY: So it's really just calculating through that outer jacket.

MEMBER ABDEL-KHALIK: Right. But when you look at this, I mean --

MEMBER BLEY: Why should it give you good results?

MEMBER ABDEL-KHALIK: No, the temperature distribution in the copper is pretty much uniform.

MR. McGRATTAN: Absolutely.

MEMBER ABDEL-KHALIK: And equal to that inside surface temperature. So well, it works, I guess.

MEMBER BLEY: The copper has got another layer of insulation around it.

MR. McGRATTAN: Yes.

MR. NOWLEN: Yes, the copper is separated out. There is individual pieces of copper distributed through the mass.

CHAIRMAN BANERJEE: What is delta in your problem, the thickness?

MR. McGRATTAN: The thickness of the jackets.

CHAIRMAN BANERJEE: The jacket?

MR. McGRATTAN: Which you can see here.

MR. NOWLEN: You can see it here.

MR. McGRATTAN: In millimeters.

CHAIRMAN BANERJEE: Yeah.

MR. NOWLEN: Yeah.

(Multiple people speaking at once.)

CHAIRMAN BANERJEE: You are right. There is a problem.

MEMBER ABDEL-KHALIK: Some are real thin.

CHAIRMAN BANERJEE: If you do the transient --

MEMBER ABDEL-KHALIK: L squared to Alpha.

CHAIRMAN BANERJEE: Yeah.

MR. McGRATTAN: Yeah.

CHAIRMAN BANERJEE: What is happening is that it comes to be --

MEMBER ABDEL-KHALIK: Much smaller than these times.

MR. McGRATTAN: Yeah.

CHAIRMAN BANERJEE: It is. Actually, it shows that your conduction layer is almost a centimeter, by my rough hand calculations, in a thousand seconds. I could be wrong. I could have made a mistake.

MR. McGRATTAN: Right, right.

CHAIRMAN BANERJEE: But it shows roughly that, the penetration depth in a thousand seconds would be about a centimeter.

MR. McGRATTAN: Yeah, right, yeah. Well, I can include in the report a little bit of numbers or analysis or something like that.

CHAIRMAN BANERJEE: Yeah.

MR. McGRATTAN: That would demonstrate --

CHAIRMAN BANERJEE: Yes.

MR. McGRATTAN: -- I think this is why this is working.

CHAIRMAN BANERJEE: Yeah. It's funny that you can actually ignore the copper, but I suppose --

MR. NOWLEN: Well, you don't ignore its mass, but you ignore it as --

CHAIRMAN BANERJEE: It's conductivity.

MR. McGRATTAN: You ignore its spacial distribution.

MR. NOWLEN: Yeah.

CHAIRMAN BANERJEE: Yeah.

MR. McGRATTAN: And indeed, I actually have the ability in the numerical solver that I wrote to do the layers. So I actually first started doing a layer of plastic and then a layer of copper.

MR. NOWLEN: The result didn't change.

MR. McGRATTAN: And I thought that that was unnecessarily complicated.

CHAIRMAN BANERJEE: Well, let's put it this way. That if the results did not change, it would be worth showing those results to demonstrate that it doesn't matter.

MEMBER ABDEL-KHALIK: Yeah.

CHAIRMAN BANERJEE: You see?

MR. McGRATTAN: Yes.

CHAIRMAN BANERJEE: I think that point, it sets this issue to bed.

MR. McGRATTAN: Yes, yes.

CHAIRMAN BANERJEE: Because you can actually do a two layer model. I mean, it's a trivial calculation.

MR. McGRATTAN: Right.

MR. NOWLEN: Well, and actually, with the University of Maryland work, they were actually pursuing a fully two dimensional representation of the individual components with the fillers and the copper and the insulation and, you know, the whole bit, as a full, you know, 2-D finite difference type representation or not to be allotted nothing, you know. It didn't make much difference.

CHAIRMAN BANERJEE: But you know, all this -- in a way what you are really saying is that there are scaling factors in this phenomena which allow you to use a simple model. And therefore, whatever you validate this against, say numerical work or whatever, demonstrates that this is a defensible position.

MR. McGRATTAN: Right.

CHAIRMAN BANERJEE: Makes the case stronger for this.

MR. McGRATTAN: Right. And even more so

when we show this plot.

CHAIRMAN BANERJEE: Yeah.

MR. McGRATTAN: Because we want -- if the model is going to err, we want it to err on the conservative side.

CHAIRMAN BANERJEE: Right.

MEMBER ABDEL-KHALIK: I mean, in a sense, instead of having a scaler empirical model, you have a differential empirical model.

MR. McGRATTAN: Yeah.

MR. SALLEY: Yeah, and it's important to point out the state of the art. I've stole, Kevin has stolen slides before and spoke to industry and let me give you a real question and Dennis I'm sure you have seen this. If I have a cable that's in a cable tray or I have a cable that's in a conduit, and I'm trying to predict in a PRA for a given fire and a given compartment, when do I see damage, everyone will tell you well, the one in the conduit will fail later, because it's protected by the conduit.

The conduit has mass. It takes time to heat that up. Where the cable tray, it is exposed. And everybody says yeah, we agree. But then you asked the question how much longer? And no one answers is out there. If you see from one of Kevin's slides, you know, that slide in itself to industry is worth a lot, because it starts telling you this is what a cable and a conduit buys you.

So, please -- you know, the state of the art, we're making progress good, but this is where the state of the art is today. And we expect to see this get better over time. And that's why you only saw one PhD thesis and not two, because the last time we saw the fellow that was working the 2-D heat transfer, he couldn't get the properties and he was banging his head off the wall over in Maryland somewhere trying to finish a thesis. So we're comfortable.

CHAIRMAN BANERJEE: Well, there is -- you know, I think it's what's -- doing a little work on this figure, which is very interesting. The inverted red triangle is also at the same sort of conditions show quite a bit of scatter, if you will, and one of them is not conservative and one is very conservative.

MR. McGRATTAN: Right.

CHAIRMAN BANERJEE: So there has to be something associated, whether it is the position within the random fill or whatever, I mean.

MR. NOWLEN: Well, a lot of these ones down where the damage times are very short would be the cable trays directly above the fire. So you are probably seeing the effect there. And at the longer time, you are going to be the ones that are off in the wings.

MR. McGRATTAN: Right.

CHAIRMAN BANERJEE: Well, that would be a good explanation.

MR. NOWLEN: Yeah.

CHAIRMAN BANERJEE: But I think, you know, it's what is working on this a little bit to strengthen. No, I think for this report.

MR. McGRATTAN: Right.

CHAIRMAN BANERJEE: I'm talking about.

MR. NOWLEN: Oh, um-hum.

CHAIRMAN BANERJEE: For this report, it might be worthwhile trying to understand some of this in a little bit more scientific way. I mean, yeah, it's conservative, but, you know, we want to make sure that this thing holds water if somebody like Vizad looks at it and he says, you know, what the hell is this.

MR. McGRATTAN: Right.

CHAIRMAN BANERJEE: You know, so you don't want to get shot down --

MR. McGRATTAN: Right.

CHAIRMAN BANERJEE: -- without bringing

forward the rationale as to why it works.

MR. McGRATTAN: Right, right.

CHAIRMAN BANERJEE: And what the scatter is.

MR. McGRATTAN: Right. But keep in mind with that point, that point and that point, that's -- this --

CHAIRMAN BANERJEE: Random, yeah.

MR. McGRATTAN: -- tray is a couple feet above a 300 kilowatt fire.

CHAIRMAN BANERJEE: Right, right.

MR. McGRATTAN: And there is a certain amount of -- in the way that those cables were put into the tray was very random. So to try to, you know, get a better prediction of those results --

CHAIRMAN BANERJEE: Just a better explanation. I mean, is it that in that case the right hand side, lowest one, is it that it was buried, that's why it is so down?

MR. McGRATTAN: Yeah.

CHAIRMAN BANERJEE: I mean, if that's the case, fine.

MR. McGRATTAN: Yeah.

CHAIRMAN BANERJEE: We buy that. If it was not buried and you got that --

MR. McGRATTAN: Right.

CHAIRMAN BANERJEE: -- then it would be a little suspicious. So each of those outliers, if we numbered them 1, 2, 3, 4, 5, 6 or whatever, it would be good to have an explanation as to why that's the way it is.

MR. McGRATTAN: Right.

CHAIRMAN BANERJEE: You know?

MEMBER BLEY: That would take it away from just data scatter.

MR. NOWLEN: Yeah.

MEMBER BLEY: That's close to what I wanted to ask. I think you have answered this for me. If I look at just the three cable bundles, the black triangles, you've got a whole string of those going up on your chart.

MR. McGRATTAN: Yes, right there, yes.

MEMBER BLEY: As I go up, each different black triangle is a different run with different materials and a different position in the cable tray, perhaps?

MR. McGRATTAN: Well, it would be a conduit. It wouldn't be a cable tray.

MEMBER BLEY: Oh, I'm sorry, yes.

MR. McGRATTAN: And the conduit, I

believe, was more or less in the same location every time. The conduit was here and here?

MR. NOWLEN: Yeah, it was usually off to the side location.

MR. McGRATTAN: Yes, the conduits were not in the fire.

MEMBER BLEY: So they are pretty much in the same place.

MR. NOWLEN: No, no. It moved a little bit, but they -- it was more consistent than the trays were.

MR. McGRATTAN: It was here and here.

MEMBER BLEY: But the difference in the time then has to do with the materials?

MR. NOWLEN: Materials?

MEMBER BLEY: It's a nice -- it's a pretty uniform spread of time.

MR. McGRATTAN: Well, the fire --

MR. NOWLEN: It's also the intensity of the fire.

MEMBER BLEY: Oh, that varied every time, too?

MR. NOWLEN: Yeah.

MEMBER BLEY: Okay.

MR. NOWLEN: Some fires involved,

essentially, the gas burner and one sparsely loaded tray. Some fires involved the gas burner and three random filled trays that created quite a large fire. So that had a huge influence on the time to damage.

MR. McGRATTAN: The report actually has a plot of every single point. So you can, in the report -- I think what I have to --

MEMBER BLEY: I was just looking.

MR. McGRATTAN: -- be able to do is be able to go from point to plot and that will help to explain why you are seeing what you are seeing.

MEMBER BLEY: That would be real helpful, yeah.

MR. McGRATTAN: Yes.

MEMBER SHACK: Just when you do the conduit calculation now, do you then assume the temperature of the conduit and then you radiate into the cable?

MR. McGRATTAN: Exactly. This is almost as if the conduit is now the exposure.

MEMBER SHACK: Is now the exposure.

MR. McGRATTAN: Yeah.

MEMBER SHACK: Okay. So that's the difference between the conduit calculation and the tray calculation?

MR. McGRATTAN: Yeah. And the conduit calculations are very accurate, because assuming you can calculate conduit temperature, now, you've got a really nice exposure.

MEMBER SHACK: Yes, you actually -- you've got a problem you can really handle.

MEMBER BLEY: And except for the short exposure, a few down there, they fall almost on the line.

MR. McGRATTAN: Yes.

MR. NOWLEN: Right.

MR. McGRATTAN: Yeah. I wish all cables could be put into conduits.

MEMBER ABDEL-KHALIK: So do a lot of people. So what goes along with this model is essentially a table saying the threshold temperature that you have to worry about for this kind of cable is X and for that kind of cable is Y.

MR. NOWLEN: Well, that's an input. It isn't required, but yes. You have to pick a threshold temperature.

MEMBER ABDEL-KHALIK: Okay.

MR. NOWLEN: And again, we've got this -- a couple of the plots I showed right at the end show you where we can start pulling some of those threshold temperatures from. We're getting a pretty good idea where these are. And there are other tests that give us thresholds for different types of cables. So we've got a fair amount of information about if a cable reaches a certain temperature, it's going to fail. We've got a lot of data on that one. We weren't especially after that, although we have added to it.

MEMBER ABDEL-KHALIK: But I think like Sanjoy was saying, it would be a good idea to include some explanation, because to me this model is sort of incongruent. It's a mixture of different things and yet, it works.

MR. McGRATTAN: It's a fortuitous mixture.

MEMBER ABDEL-KHALIK: Right, correct.

MR. McGRATTAN: I think some real analysis would be the right way to go.

CHAIRMAN BANERJEE: Okay. All right.

MR. SALLEY: I have a question on that before we leave. We're asking for a letter from you and I also have a schedule to publish. Will you be able to give us a couple detailed comments on if you would do A, B, C in Volume III would make it a better type document, because my goal is to get the highest quality document out on time. When would you say that we would be getting a letter from this group?

MEMBER SHACK: I assume we will be writing a letter on this in February.

MR. SALLEY: So in February I'll be seeing a letter?

MEMBER SHACK: Well, yeah, at the end of February, right.

MR. SALLEY: Okay.

MEMBER ABDEL-KHALIK: So are they scheduled to make a presentation to the Full Committee?

MEMBER SHACK: I'm trying -- I was just looking at that. Girija should know, he knows the agenda better than I do.

MR. SHUKAL: I think so, yes.

MEMBER SHACK: I've got it right here. I'll tell you --

MEMBER ABDEL-KHALIK: You do?

MEMBER SHACK: -- in a second. Yeah.

MEMBER ABDEL-KHALIK: I'm sure I have it actually.

MR. SALLEY: We had a date and it was indeterminate whether they were going to want us to appear for the Full Committee.

MEMBER ABDEL-KHALIK: I mean, you should probably know whether or not you are on the agenda for the February Full Committee meeting.

MEMBER BLEY: Yes, it doesn't sound too promising, does it? The February meeting --

MEMBER SIEBER: Maybe we should start at 5:00 a.m. on Saturday.

MEMBER SHACK: You are on from 3:15 to 5:00 p.m. on Thursday.

MR. SALLEY: 3:15 to 5:00.

MEMBER SHACK: Now, it's just the -- no, briefing by discussion with representatives, NRC staff and its contractors. So you guys are up.

MR. NOWLEN: What date?

MEMBER SHACK: Let me just make sure I get it right here. Thursday, February 7th.

CHAIRMAN BANERJEE: 7th, yeah.

MEMBER SHACK: At 3:15 to 5:00 p.m.

MR. NOWLEN: I'll be in Paris, so you guys will have to go.

MR. SALLEY: Again, I wanted to get your comments. The discussion that came up here, could I possibly get, you know, hey, these are the couple, three things that you guys need to do in Volume III to really improve the quality? Then we will start work on that is what I'm saying. I want to get the highest quality document out. And I value your comments.

MEMBER SHACK: Certainly you can get, you know, comments from individual Members. It can be almost directly emailed either through your -- or you know, we don't have to wait for a meeting for that. You know, if the Members feel they have comments they would like to see, you can take them as individual Member's comments.

MEMBER SIEBER: Right or the public.

MEMBER BLEY: But I think that one Sanjoy just made is --

CHAIRMAN BANERJEE: Or we can -- if we end up meeting today, we can just jot down these comments. There is no formal process to write a letter with comments.

MR. SALLEY: Okay. If you could give us those comments, like I said, we can get started on those and we can still keep our schedule on this. So I would appreciate that if you could.

CHAIRMAN BANERJEE: Okay.

MR. SALLEY: I'm assuming Volumes I and II are pretty much as is. We have some internal comments for Steve that he is going to take back and tweak it here and there, but nothing major. Volume III, this is the first time we've really discussed it with you. If we could get those comments, that would help us.

MEMBER ABDEL-KHALIK: Okay. All right. I guess our Chairman is out for a minute, so it is 2:15. We will take a break until 2:30. Okay. All right.

(Whereupon, at 2:13 p.m. a recess until 2:31 p.m.)

CHAIRMAN BANERJEE: Back in session. And we will now hear about the PIRT from Steve.

MR. NOWLEN: Yes. Well, I'll let Mark do a quick introduction here.

CHAIRMAN BANERJEE: Okay. Just tell us.

MR. SALLEY: Just quick one minute on the PIRT. A while back, a couple -- three years ago in front of the Committee when we talked about the plans of what we are doing in fire research and, occasionally, we would sit down and share with you the different areas we're working in, we brought up the idea of the PIRT. And it was just bringing the subject up for fire modeling.

It had a little debate, if you remember, amongst the Members. For example, I remember George, he knew that we were well deep into a V&V Program and his thought was you're halfway done with the V&V, why are you bothering with PIRT, which is a reasonable thing. If you're doing a V&V, don't even waste your time on a PIRT. You've got solid real test data that you are balancing against, you know, do that.

People who do PIRTs don't have test data, which is why they do PIRTs. Which is -- it's a fair opinion and it does hold some water. We thought about that and we said yeah, that does make some sense. However, there is other benefits that we may be able to gather out of a PIRT. It's not a big exercise. It's not -- it takes some time, but it's not hugely involved like an experimental set.

Is there anything that can help us by doing a PIRT? We said yes, there are some things that the PIRT could be a help to us. For example, when we run experiments, if we're going to go and look at some compartment type fires and that, it would be nice if we had some metric that was developed that would say hey, you've done enough fires of this type, here is where you're lacking in knowledge. Here is where you should focus on.

So if for nothing else but a pool to look at where we go with future experiments, we said that's a good reason, a valid reason to do a PIRT. So with that in mind, and the fact, too, the fire modeling, to our knowledge, no one had ever done a formal PIRT before. We did find that Sandia had done one on their weapon side. And they said hey, it wasn't a bad exercise. It did help us out a little bit with some of the models we used in our fire protection weapons work.

So again, that was another point that we said yeah, maybe we should do this. So with that spirit, we went and we did the PIRT. Another thing that was interesting about the PIRT is when we looked at it, it's a fire modeling PIRT. And in our minds, when we say fire models, we think of something. If we think of fire models, Kevin immediately goes to the FDS-type models or the 1805 spreadsheets that we use or some fire modeling.

But it was interesting that when some of the people we assembled looked at fire modeling, they actually looked at it broader. Some of the PRA-types wanted to get in there and say now, hey, that's part of what we do. So again, we saw some different things.

The group we assembled Steve will talk about that. And again, it was interesting because of the group, this, I believe, some serious fire research type people -- and this is the first time they were ever involved in one of these. To make it a little more complex, the majority of them had no nuclear experience. We tried to get fire modeling experts, so we were trying to take them into the nuclear world, which of itself presented quite a challenge, because the non-nuclear world looks at fire different than the nuclear world does.

For example, one of the things with exits. You put people into any of their equations, their only thought, the people, get them out of the building. How fast can we exit, egress? Our job is a little different. Now, we've got operators who want to stay in there and do things. So there were some real challenges in our PIRT, which makes it somewhat unique.

Nevertheless, we ran a PIRT and we want to update you a little bit and tell you what we saw in this PIRT and what, if anything, we can gather from it. Okay. So that's the spirit that we are bringing this to. We have got the -- the main part of the work is done. Now, it's the idea of package and everything and putting the report out.

Okay. So that's the spirit that this project was done under. Steve?

MR. NOWLEN: Okay.

CHAIRMAN BANERJEE: Thank you. Steve, we want to get through this, so that we can have a little time for discussion and closing remarks.

MR. NOWLEN: When would you like me to wrap it up?

CHAIRMAN BANERJEE: If you can wrap -- sorry?

MEMBER SHACK: 4:45 would be good.

CHAIRMAN BANERJEE: Hum?

MEMBER SHACK: 4:45?

CHAIRMAN BANERJEE: Yes, if you can wrap it up by 4:00, then we will have about half an hour.

MR. NOWLEN: That's more than plenty. More than plenty time.

CHAIRMAN BANERJEE: Okay.

MEMBER SHACK: Perfect.

MR. NOWLEN: It will depend a lot on your questions, of course, but I can easily wrap it up that quickly, perhaps a little earlier.

CHAIRMAN BANERJEE: Okay.

MR. NOWLEN: So again, the idea here is just to give you a --

CHAIRMAN BANERJEE: Just a matter of schedules.

MR. NOWLEN: Yes, understood. And, you know, this --

MEMBER SHACK: Well, especially, since you are, essentially, through the PIRT. I hadn't quite realized that.

MR. NOWLEN: We have had the meeting. And, you know, we just want to give you an idea where we went and where we have been and what you will probably expect to see. We're going to be working the report here over the next few months, so I'm guessing you'll hear from us again. So really, I think, this is just an opportunity to introduce our PIRT to you. And, you know, next time we'll probably have more detail for you.

I have focused here on a fairly high level view of the PIRT. You know, who was involved in it and some of the preliminary results we have seen come out of it. We'll talk a little about the scenarios, but, you know, we can easily wrap-up well sooner than the current schedule.

CHAIRMAN BANERJEE: Great.

MR. NOWLEN: No problem.

CHAIRMAN BANERJEE: We can do it justice and the earlier we can do it, the better.

MR. NOWLEN: Absolutely, yes.

CHAIRMAN BANERJEE: Okay.

MR. NOWLEN: Okay. So again, the content, I'm going to give you a little bit about our objectives and actually Mark has given you a little bit of that already and status, a little more detail on status. I'm going to give you a description of the make-up of our PIRT panel. It actually was a fairly impressive group of people to get together in a room.

I'll tell you a little about our meeting schedule and how we ran our meetings. I'm assuming this group is pretty well-familiar with the PIRT process, so I don't expect to spend a lot of time on that. I don't want to, you know, teach grandmother to suck eggs sort of thing. And then I'll tell you a little bit about the process instruction specifically that we gave the PIRT and, in particular, the terms we defined for them to use.

And then I'm going to give you a little bit about the scenarios we considered and some of the preliminary results we're seeing coming out of it. And again, our objective is just to give you some update of where we are at and where we have been and I expect you will hear more from us as we get closer to publication.

So again, the idea was to perform a Phenomena Identification Ranking Table exercise specifically for fire modeling in the nuclear power plant applications, because Mark said Sandia has internally used the PIRT process in some of the weapons work associated with the fire model work Sandia is involved with. We have a fire model of our own that is used in the weapons complex.

And to help with this whole process of, you know, we no longer test nuclear weapons, so we do everything by analysis. And the PIRT was helping them. They have conducted PIRTs to help them guide the development of their own models. So we were supportive of NRC's interest in doing a PIRT. And we really saw it as a compliment to the V&V work that was going on. They were pretty deep into that before we really started on this, but they saw some really interesting things when they took their report out to the broader fire protection community and asked for comments.

You know, they had done this from the perspective of those of us involved with nuclear plants and Kevin working from this side, but when they went out and approached the general community, I think they got some really interesting insights back from that community that were a little unexpected from a little bit different perspective. And so we thought the same thing would happen here.

Bring in some of the non-nuclear experts and see what they think of what we're doing and where they think we should go. So it was interesting from that perspective. I think it was very successful from that perspective as well. And again, the objective of any PIRT is to provide input to planning for future activities. So research will take the input and incorporate it into their future plans.

Now, when we say nuclear plant applications, the kinds of things we were thinking listed here, rather, fire PRA, the NFPA 805 Transition process and the whole structure of that, the change analysis, the underlying risk analysis that most plants are bringing in, the inspection process, the fire protection SDP, for example, Significance Determination Process, exemption requests, you know, and on and on.

Those were the kinds of applications we had in mind. So as we get to the scenarios, you will see we tried to write scenarios that were typical of what we see in those kinds of applications and then have the team look at those.

So our status, our PIRT panel meetings have been completed. We ran them over the course of the summer. We had three meetings. Each meeting was basically a week long. Those have been done. Sandia has completed the first draft of the project report.

We have submitted that for staff review. We do expect to go to the PIRT panel for them to actually review and comment on the report and we will be revising it accordingly and providing an updated draft and then we'll go on through the publication process.

I'm hoping we will see that happening this spring, that's our schedule. Whenever you are dealing with expert panels, there is a little uncertainty there, but that's our hope.

So the make-up of the PIRT panel. We had a total of seven members. We drew five people from the U.S. community. We had one individual from the University of Edinburgh and one person from IRSN in France, one of their researchers. And they did represent a good mix of academia, research and field application. You will see a number of, in particular, our U.S. experts were people who deal with these sorts of issues.

For example, DOE facilities, other non-nuclear facilities and we had one or two who had some background with nuclear plants analyses as well. Primarily from other fields though, from other aspects of fire protection.

So I was the facilitator and so here is a mini resume for me. I've been involved with the NRC

Fire Research Program for 24 years now. I've got lots of publications, including 24 NUREG/CR reports. And I have been involved in sort of all aspects of nuclear plant fire protection over the years. I started, you know, I cut my teeth on fire experiments, burning cables, electrical panels, cable damage-ability. I got involved in risk assessment. I've been -- I was one of the principals on the consensus method for EPRI research.

I was a member of the ANS Fire PRA Standard Writing Committee. I was involved as a member of the senior review board in IEEE days. So, you know, I have been around a while and I've got a pretty strong background when it comes to the nuclear side.

And so they asked me to facilitate this exercise, which was an interesting thing for me. I haven't particularly been into expert elicitation, but it was a very interesting process for me. And I felt fairly comfortable in this role.

So to the members of our PIRT panel, the first member is Dr. Vyto Babrauskus. Vyto currently is basically his own consulting firm, Fire, Science and Technology, been out there about 10 years in that role. And he has some interesting background. Vyto was actually the first person ever awarded a PhD in fire protection engineering. Number one, the very first guy. That's a pretty impressive --

CHAIRMAN BANERJEE: From where?

MR. NOWLEN: From the University of California, Berkeley. He worked with, the name is on the tip of my tongue. Well, after getting his PhD, he came to NIST. And Vyto was actually the father of the cone calorimeter, which is a very widely known and widely used standard test apparatus. You will find them all over the world today. So Vyto is the guy who developed that apparatus.

He was a contributor to the Hazard I model, one of the very early NIST fire modeling tools. He has been involved in furniture calorimetry work, developing a furnished model. So, you know, really this is a guy who, you know, you talk to people in the fire community and say the name Vyto Babrauskus and they know exactly who you are talking about.

So Vyto was one of our strongest members, I think, in terms of his research background and his credentials in the general community. He -- actually right now, he is very strong in forensic sciences, expert testimony and fire reconstruction and things of that nature. That's sort of his bread and butter these days.

Our second panelist was Dr. Craig Beyler. He is now a technical director at Hughes Associates. And Hughes Associates is deeply involved with DOE work. They have had a lot of involvement in the DOE facilities, Savannah River, Hanford, places like that. Also a lot of DoD work. They are becoming more and more involved in the nuclear plant work supporting some of the 805 Transition work.

But Craig is basically a senior manager there. And he is responsible for overall management of their fire protection design research and development projects. So he's a fairly high level guy. Again, he has also been strong in his previous work with method development, fire dynamics, fire chemistry, mathematical fire modeling, that's all part of his early career.

He has chaired various committees and associations associated with SFPE and others, the International Association for Fire Safety Science. He is the current chair there. He has been very active with SFPE, a current member of their Technical Steering Committee, past president of the Steering Committee. He is also a member of -- the chairman, in fact, of the Task Group on Engineering Practices. And he has had involvement with various other task groups for SFPE as well.

He is on a number of university guidance committees, governance and advisory boards and whatnot, editor for various journals. Again, a very well-known name, very active in the community and a fairly broad background in both model development and more recently in applications and whatnot. So another very strong member in terms of the kinds of things we were looking for.

The next one is Doug Carpenter. Doug is with Combustion Science and Engineering. And Doug has a pretty good background in investigations and reconstruction, again, the sort of forensic science side of fire protection. He has also been -- had a lot of work in the application of quantitative fire hazard tools, which includes fire modeling.

And his role has been in a fairly broad range of facilities and applications. It goes from -- he has had some background with nuclear plants, but also looking at transportation, commercial manufacturing facilities. He has actually done a good bit of work on new airport designs, large atrium settings for things like hotels and office buildings, transportation fire safety, tunnel fires, so, you know, kind of a broad brush across a very wide range of facilities and applications.

And his role has been as the analyst. You know, he is taking the tool. He is trying to get an answer that he can trust and believe in and sell to a regulator in one setting or another. He has also been involved in developing flame spread models for, in particular, vehicle fires. He has got into some of his transportation work where they were looking at tunnel fires. The Europeans especially have issues with tunnel fires up in the Alps. They have had some bad ones, so there has been a lot of interest. He has been involved in that.

He also has a background as an instructor in various settings. He does continuing education programs for SFPE as an instructor. ICBO is -- I have to remember that acronym. I'll have to -- it will come to me.

MR. SALLEY: Building officials?

MR. NOWLEN: Yes, building officials, yes. It's the International --

MR. SALLEY: Congress.

MR. NOWLEN: -- Congress of Building Officials. So this is more the hospitals, hotels, office structures, theaters, that sort of thing. And also at the University of Maryland, he is teaching a series of courses at the University of Maryland in fire protection. So a good background. He is a certified fire and explosion investigator with the National Association of Fire Investigators. Again, this gets into his forensic sciences, fire reconstruction. That's not an easy thing to do. That's a fairly significant certification process.

And he also has a pretty broad set of publications, including a number of peer review journal articles. So again, a good strong background and fairly varied.

Next, Dave Evans is our next member. He is actually currently the Executive Director of the Society of Fire Protection Engineers, but he was also a past researcher and manager at NIST in the Fire Protection Research Program. He was Chief of the Fire Safety Engineering Division for several years. He performed original work in the study of smoldering, the effects of response time and fire sprinklers and fire test measurement systems, performance of fire sprinkler systems in fires of various types.

And he was one of the co-developers of the original DETACT Code, which is a sprinkler response time code. One of the -- again, another one of your early NIST fire modeling codes. He is a fellow and past president of SFPE. And he has got -- also another person with a very long publication list in a range of areas.

So, you know, Dave really brought the perspective of the general fire protection community. He hadn't had any past involvement with the nuclear industry, in particular, but quite a broad involvement with the larger community of fire protection in more general settings.

Brian Melley, a professional engineer. He is with the Triad Fire Protection Engineering Group, vice president and principal engineer there. He has been a manager of the Fire Protection Program at PECO. So here is a guy with nuclear plant experience. He was actually responsible for the fire protection at four nuclear power plants when he was with PECO. So he was the Fire Protection Program manager for them.

So a good solid background here on the nuclear side. He has got 28 years of experience in fire protection engineering. He had been around through fossil energy, general industrial facilities, eventually the nuclear angle with PECO. He has been involved in the development of various fire hazard analysis methods, design and evaluation of fire suppression systems, fire protection inspections, audits, code analysis and interpretational, a lot of that comes from his PECO work where he was, in fact, responsible for the PECO fire protection submittals and analyses.

Also, more recently involved with again reconstructive analysis on fires, hydraulic modeling of water supply systems and things of that nature. He has also been heavily involved with SFPE. And in particular, he has been a peer reviewer on a lot of the hydraulic software, you know, for analyzing hydraulic systems associated with fire protection systems.

He has been a peer reviewer on that software for them. And again, another person with a fairly long list of publications. Especially, I was surprised at his publications given how much he had spent in industry. You don't usually see the industry people publishing a lot of journal articles and papers and things. Brian has been active as a publisher of papers and journal articles throughout his career. So I found that to be especially interesting with Brian.

Laurence Rigollet was -- is the individual who was provided to us by IRSN. They provided her complimentary, you know, they paid for her time and travel and whatnot, so that was very nice of them and very generous. Laurence is --

CHAIRMAN BANERJEE: Her or him?

MR. NOWLEN: Her.

CHAIRMAN BANERJEE: Laurence?

MEMBER SHACK: Laurence?

MR. NOWLEN: Laurence is French. It's not Laurence. It's Laurence. And she is currently the head of the Fire Research and Development and Uncertainty Simulation Methods Laboratory. This is basically IRSN's fire modeling group down in Cadarache. You know, they have -- I don't know if you are familiar with Jon Marc Such. He formerly was the head of this group. Laurence has taken his position and Jon Marc has moved up a notch.

It's a very good group. They are doing a lot of work down there. The French IRSN has an interest in developing independently their own analysis tools. You know, the utility there has their set of analysis tools. IRSN likes to develop an independent capability. And this is the group that is basically doing this. They are developing both a zone model and a CFD model. They are fairly well along in that work. They actually have working models and Laurence is the head for that group.

She has a staff of 15 folks working for her. She has been involved in pretty much all aspects of the work. She came up through the group doing experimental work and eventually leading the group. And she is fairly widely published as well in the fire modeling development validation, especially, and again she was provided compliments of IRSN.

The last member of our panel is Dr. Jose Torero. He is currently a Professor of Fire Safety Engineering at the University of Edinburgh. And in terms of academic credentials in fire protection engineering, you won't come across anyone who can beat Jose. He has been around. He has been an adjunct professor in a number of places. He is currently an adjunct professor with the University of Cantabria, I'm probably pronouncing that terribly, in Spain.

He is a former instructor at the University of Maryland. The Worcester Polytechnic Institute, he has been an instructor there. He has taught in Chile. There is -- in Britain the structure is a bit different, in the United Kingdom, but he is the Director of the Building Research Establishment Centre for Fire Safety Engineering.

It's basically a research center that was certified by the British government to support them in a range of applications mainly looking at building safety. So not particularly nuclear power plant oriented, but more general building life safety issues. And that's a fairly prestigious appointment for him in his field.

He has had past research in tunnel fire safety, structural behavior. He got quite deeply involved in the post-9/11 world of, you know, people suddenly realized fires could potentially represent a structural threat to a facility. You know, towers come down sort of thing. He was extensively involved in the post-9/11 research that is being conducted in Europe looking at structural response of steel, in particular, to fire. So he was a real interest to us from that perspective.

He has also been looking at a lot of advanced concepts and fire protecting engineering and fire management, fire service management, coordination of fire services, communication, that sort of thing. He is also a member on the advisory board for Worcester Polytechnic, the whoopies of the world. And also Glasgow University. And he has been -- he has taught numerous short courses on various subjects, fire investigation included, fire safety engineering design, da, da, da.

And again, very widely published. He is active on several editorial boards, fire safety journals and others. And again, a very -- in the academic world, they don't come much -- with much better credentials than Jose has got.

So that was our panel.

CHAIRMAN BANERJEE: Let me ask you a question.

MR. NOWLEN: Sure.

CHAIRMAN BANERJEE: So, obviously, from the make-up of the panel, it was rather focused on fires rather than combustion, if I understand this. Fires of things.

MR. NOWLEN: In a sense. You know, all of these people have backgrounds in -- well, I shouldn't say all. Most of these folks have backgrounds in combustion chemistry, that includes combustion chemistry. For example, when you get into these reconstructive forensic science type fields, you know, explosion and fire safety investigation, you have to have the combustion background. You have to understand combustion kinetics.

You have to understand the chemistry associated with combustion to get that problem right. So Jose, Vyto, Craig, Brian, Doug Carpenter, to some extent, all have good strong backgrounds in combustion chemistry as well. But yes, and we --

CHAIRMAN BANERJEE: Well, you see what the results of the -- sometimes the PIRTs reflect the people on them.

MR. NOWLEN: Sometimes only? You mean they don't?

CHAIRMAN BANERJEE: The topics which are seen to be important, let's go through it.

MR. NOWLEN: Yes, absolutely. We saw that very strongly here. There were some very strong personality interactions on this panel that were very interesting to watch. Especially for someone like me, where I'm not exactly a weak personality either and I tend to be opinionated and I'm not shy about expressing my opinions. And so, you know, I had to kind of step back and watch these interactions take place. It was very interesting.

Individual agendas, occasionally, come through. We had cases where the panel could not agree. They just would not agree on a particular ranking for a particular phenomena. And often times it was a conflict between, for example, the more academic side and the more practical side. People who were out in the field trying to do this and say, I don't care if it's 15 seconds or 40 seconds, you know, I'm talking minutes. I don't care. It's not -- well, but we're not doing -- so there were some very interesting personalities here.

And again, I think the panel really did represent a good mix from pure academia to nearly pure application oriented folks.

CHAIRMAN BANERJEE: Well, pure academia I would have liked to have seen somebody like -- well, I don't know if he is still active, Forman Williams or, you know, even Tony Oppenheim's student, Bonheim, more on the academic side.

MR. NOWLEN: Jose is a strong academic here. And a number of our panelists also have credentials in academia with teaching continuing education, teaching at University of Maryland, teaching at Worcester.

CHAIRMAN BANERJEE: Do you have any interactions with Paul Linden, one of my colleagues at UC San Diego?

MR. NOWLEN: I don't know him very well.

CHAIRMAN BANERJEE: He does these things. He was at Cambridge and then he is now the chairman at UC at San Diego.

MR. NOWLEN: Well, we -- Williamson, Brady

Williamson.

CHAIRMAN BANERJEE: Not form -- no. Forman Williams.

MR. McGRATTAN: I know who Forman Williams is.

CHAIRMAN BANERJEE: This is --

MR. McGRATTAN: He has been on a number of these kinds of panels.

CHAIRMAN BANERJEE: Right.

MR. McGRATTAN: On fire combustion.

CHAIRMAN BANERJEE: Forman is pretty almost retired now.

MR. McGRATTAN: Yes, but he does a lot of this type of work.

CHAIRMAN BANERJEE: Yeah.

MR. McGRATTAN: When we did the World Trade Center investigation, he was on the advisory panel for that.

CHAIRMAN BANERJEE: Well, Paul Linden and I guess Sheshadre, you know, there was Paul Libby there as well.

MR. McGRATTAN: Yes.

CHAIRMAN BANERJEE: They have a very strong combustion group.

MR. McGRATTAN: Yeah, I know who these

people are.

CHAIRMAN BANERJEE: Yeah. Anyway, let's move on.

MR. NOWLEN: Well, we wanted to keep the panel at a reasonable size, too, and I'll tell you seven was about as many as I think I could have managed at one time. It was occasionally a challenge.

Okay. So basically, we did hold three panel meetings, May, July and August. Each one lasted three days. And at our first meeting, we did the introductions. None of these panelists had ever been involved in a PIRT before. So we had to introduce the concept, introduce the structure and they even rebelled against that on occasion. You know, they wanted to know why are we doing it this way? We need to do it -- we want to go this way. And we said no, no, no. You have to work within the structure of how a PIRT works.

You know, this is the rules and you have to play by the rules. So it was interesting, but again, our first meeting, basically, the whole first half day was devoted to introducing them to the concept, introducing them to some of our nuclear power plant issues and what not. There was a presentation by Jennifer Uhle, who, at that time, was your division director.

MEMBER SHACK: Our division director.

MR. NOWLEN: And Mark was the project lead, also provided some NRC perspectives. I gave them an overview on the process and how we wanted this all to work to find the terms for them.

CHAIRMAN BANERJEE: Who was the division director now?

MR. SALLEY: Christiana Lou Fermino.

CHAIRMAN BANERJEE: Who is Jennifer?

MR. SALLEY: She is the Division of Engineering. We resorted, went back to three divisions in research. Went three to two and now we're back to three.

CHAIRMAN BANERJEE: Okay.

MR. NOWLEN: And then we also had technical area experts to support the process. They weren't members of the panel, but they were available to answer questions. Kevin was one. We also had Francisco Joglar-Biloch from SAIC. They were available to -- you know, they are both -- Kevin is very active in fire modeling, obviously, a long time involvement there.

Francisco has been deeply involved in nuclear power plant analyses for SAIC. He was a member of our team on the fire PRA method, for example. He was a member of the writing team for the NS standard. So we had them available, not as panelists, but as technical area experts to support the panel if questions came up.

And all three of our meetings did involve scenario descriptions and discussions. And, you know, as we went along, things obviously as they got more comfortable with it, it picked up speed and they kind of -- in the first meeting, it was kind of a struggle to get them to take ownership of the process. You know, I'm not going to stand up here and give you the answer. You are supposed to sit there and give me the answer.

And getting that concept across to them, it took us most of the first meeting, but by the end of the first meeting, they were taking over. They were beginning to take ownership. They were beginning to drive the process the way we wanted to. And then by the time we got to the second meeting, they really took control. And they really took over and we were now recording. We were, you know, taking their input and writing it down and that's exactly what we wanted.

So it took us a while to get there, but we did get there. They really did take ownership of the process and that was good.

So the format was typical of a PIRT, you know, facilitated discussions. We would present a scenario to them. Each scenario had a defined figure of merit, that is a goal or an objective to be achieved through the application of fire modeling tools. And I'll give you those in a minute as we go through these.

The technical area experts were available to support the discussions, but the panel would then identify all of the relevant phenomena, just the laundry list, top to bottom, give us all the phenomena. We would then go back through and make a pass, rank each of them for importance as measured against the scenario and the figure of merit. And then we went back and we made another pass to do the state of knowledge assessment.

And a couple of things that might have been a little unique here, you know, we did the adequacy of the existing model, you know, how good are the models today and the input data. Do we have the data we need? But we also asked them about feasibility of getting new data. If they said the data were not real good, if they ranked them as poor or moderate, we would say okay, well, how hard is it going to be to get new data?

I'm not sure I have seen that in a lot of other PIRTs, it's something Sandia has incorporated into the PIRT they did for our fire modeling and it was an interesting additional input. You know, is this something that we can -- well, you will see our definitions in a minute, but the idea is is this something that is going to be easy to do or is this something that's a real challenge and we don't -- we really don't know how we would do it? So that was sort of an added thing I haven't seen in some of the other PIRTs that we reviewed going in here.

The other thing we added to it is there was a lot of discussion early in our process about what's a phenomena versus what's a parameter? And, ultimately, I think they resolved that to our satisfaction. We kind of made them -- we have them what we thought the right answer was and they kind of went around a couple times and eventually they decided we were okay with that. But they wanted to know where these parameters fit in.

And so another added element was we said okay, if we get down to a phenomena and you have ranked it as important and you have said we don't have a real good state of knowledge, if you think there are key parameters here that are what's driving our ability or inability to treat this phenomena, we will mark those down as well and take notes about what those key parameters are.

So you will see way off on the end of our tables, there is this listing of parameters and that's what that's all about. And some of those were interesting. A lot of them turned out to be fairly obvious in the end, but some of them were actually quite interesting when they came across.

So again, I mean, into the process, we don't need to go too deep into this. We did ask them to be very inclusive about phenomena. You know, list all of the relevant phenomena, whether you think they are important or not. You know, don't -- when you are ranking -- when you are listing phenomena, don't worry about importance, we will get to that later.

And some interesting things came out of that as well. We had -- occasionally, for example, they would dive into things that we wouldn't -- you know, Mark mentioned, when you say fire model, he has a certain perception. Kevin has got a perception. I have a perception of what's a fire model. They took it in interesting directions.

How do the operators make a decision to --

whether or not they are going to abandon the control room, for example, in one of our scenarios? How are they going to make that decision? You know, how -- what's the process? And we said well, how does that relate to a fire model? Because I'm not sure where you are headed. We will write it down, you know, and so in our minds we're kind of thinking wow, they're going in a very interesting direction.

You know, ultimately, some of these wrapped up as unimportant, but it was very interesting to see the way they went and just the way they thought about what a model might constitute and what they think a model might be able to do in the longer run.

In terms of ranking the phenomena for importance, we did allow for disagreements among the panel. We asked them to strive for consensus and part of my job was when we had a disagreement, I said okay, well, why do you say high, why do you say low? Does that change anyone's opinions? You know, do we have a consensus? Is it because we don't understand the way we have defined the phenomena or do we truly disagree on how important this is?

And in some cases, we would end up redefining the phenomena, because it was just people saw it differently. Other times, there were legitimate differences in opinion and yes, we understand the phenomena. We just don't agree as to how important this would be. So we saw both of those. But ultimately, we said if you disagree, we will accept the disagreeing views.

When we came to state of knowledge, we did ask them for a consensus position. We said we want you to come as a panel to a consensus as to where you think we are relative to this and that actually worked out reasonably well.

So now, in terms of fire model, we did put some bounds on this as well. We asked them to consider a range of models that is anything from these handbook correlations on through to the CFD-type codes, the full 3-D Codes. Even to the point of considering statistical models, you know, we have statistical models for certain phenomena, like ignition and the spread of cable fires, they are basically statistical models. They are empirically derived from data.

And we asked them to consider those. You know, is that good enough? Is that a good enough model of what is going on? In some cases they weren't impressed, other cases they thought it was okay. So that was kind of interesting. We also asked them to consider modeling tools that are readily available. Our aim was the kinds of applications we see coming from plants.

Okay. So if you've got some super duper proprietary model that no one can get to, it's not really fair game for us. We wanted to know what is the state of the art given readily available tools. Now, there were some discussions where people were aware of things going on that were in a proprietary domain that might eventually find their way into a more public domain and those were factored into some of the comment fields, but ultimately the rankings are based on the kinds of models that are readily available.

And in particular, that knocked out the Sandia model, because our model is not what we would consider readily available. We don't give it away. We don't -- it's not a public -- it's not a proprietary, per se, but it's not a public code. You can't go to Sandia's website and download our fire model. So our fire model was a priori not considered in this process. And there are others like that. You know, things that are proprietary property of a particular group.

Now, the thing is --

CHAIRMAN BANERJEE: Well, how would you consider say a code like fluent or something which has some fire capability, modeling capability, but you have to license it?

MR. NOWLEN: We did not consider the need to pay a licensing fee, a barrier to availability.

CHAIRMAN BANERJEE: If a commercial code like that could --

MR. NOWLEN: Commercial code was fair game. That would have been fair game.

CHAIRMAN BANERJEE: Though you can't go and download it, obviously.

MR. NOWLEN: No, no.

CHAIRMAN BANERJEE: You've got to pay.

MR. NOWLEN: But like take Sandia's code, you can't pay me a licensing fee and get it either. In order to get Sandia's code, you have to come to Sandia and be trained on the model and be a certified-user. You have to generally be associated with a federal agency and then you can gain access to the code.

CHAIRMAN BANERJEE: This code is different? I mean, it's --

MR. NOWLEN: You can go to the NIST website and download FDS, CFAST, they are fully public.

MR. SALLEY: It's public domain.

MR. NOWLEN: Yes.

CHAIRMAN BANERJEE: Both of them, open source as well?

MR. NOWLEN: Open source, yes.

CHAIRMAN BANERJEE: That's a good idea. Also smart people working on it.

MR. McGRATTAN: It sounds like it's the way to go.

CHAIRMAN BANERJEE: It's strong in some ways.

MR. SALLEY: Their way is the smart way.

MR. NOWLEN: Perhaps.

CHAIRMAN BANERJEE: Well, it's hard work for you, but it probably improves the code.

MEMBER SIEBER: I do when I have the free time.

MEMBER BLEY: How many emails per day do you get with --

MR. NOWLEN: Well, that's the problem. I can download FDS and I don't consider myself an expert on the ins and outs of CFD modeling, but I can download it and I can get an answer. Do you trust it? If you're smart, you'll say no. CFAST, yeah I can handle CFAST. I'm pretty good at CFAST. But FDS, I don't know the FDS. I have never exercised it.

CHAIRMAN BANERJEE: So you actually make the source code available too?

MR. NOWLEN: Yes.

MR. McGRATTAN: In my opinion, if you're doing risk assessment calculations, you have to divulge the calculation method to anyone who wants to see it.

MR. NOWLEN: Yeah. It's a visibility thing. NRC --

CHAIRMAN BANERJEE: Well, I think that's a very important point, so that you can actually look at the details yourself.

MEMBER SIEBER: Of the code, yeah.

MR. NOWLEN: You know, there --

CHAIRMAN BANERJEE: This is one of the issues I have with the use of commercial codes or broad activities by the NRC where they are using commercial codes, which are not completely transparent and that we can't actually look at.

MR. NOWLEN: When you are using a black box and you're not sure what's inside that box, it's hard to judge the merits of what you see, other than by your judgment or other things you can compare it to. But again, Sandia made a decision a long time ago that --

CHAIRMAN BANERJEE: My colleague, Graham Wallace, calls it color fictional dynamics.

MR. NOWLEN: I mean, our tool was -- you know, for example, we made a specific choice because of our rule and our traditional customers. And, you know, the nuclear weapons complex is a very highly specialized subject that isn't something that is really as subject to public scrutiny as power plants. You know, so we have a very different audience and so we had the luxury of making a different choice in terms of availability of our model. And so we control it very strongly.

NIST has a very different role and, you know, their model is widely available and they are generally the benchmarks that most people use. So, you know, it is a choice, but there is the downside. The other side of the sword is that an unqualified user can also get a hold of it and so garbage in, garbage out. It doesn't matter how good the code is if the user is no good.

CHAIRMAN BANERJEE: Look, they can do that with commercial codes, too.

MR. NOWLEN: That's right. That's exactly right.

CHAIRMAN BANERJEE: And it happens very often.

MR. NOWLEN: Yes. So you just have to deal with that.

CHAIRMAN BANERJEE: Right.

MR. NOWLEN: And, you know, for example, NFPA 805 says people running your fire model have to be qualified to run the fire model and you are responsible for demonstrating that. So, you know, you address it through that direction. But again, this idea that readily available codes certain codes that may be out there like ours are not a part of this. They were not assessed in terms of this.

And in fact, you know, none of the panelists on this particular panel knew much about Sandia's code and we didn't bring one of our own people into the panel. We didn't want our people on the panel. We wanted a different group. We wanted a separate group. So it's just something to recognize about the limits of what we did.

CHAIRMAN BANERJEE: Move on.

MR. NOWLEN: Yes.

CHAIRMAN BANERJEE: Time is --

MEMBER BLEY: Well, now, as your experts

picked the phenomena to address, I assume they picked the phenomena not so much from a knowledge of these codes as from their knowledge of the problem.

MR. NOWLEN: Yes, absolutely.

MEMBER BLEY: So it really doesn't matter so much. Now, are they evaluating against particular codes somehow along the way? I'm not sure --

MR. NOWLEN: Yes.

MEMBER BLEY: -- how that factors in. Oh, okay.

MR. NOWLEN: Well, when you look at -- you know, you ask them a question are the existing codes adequate to deal with the problem given the context you are trying to meet?

MEMBER BLEY: Okay.

MR. NOWLEN: Then yeah, obviously, they are weighing it against their knowledge of what is out there.

CHAIRMAN BANERJEE: It's not in the importance ranking. It's in the adequacy of the database?

MR. NOWLEN: The adequacy.

CHAIRMAN BANERJEE: Or the adequacy of the two.

MR. NOWLEN: The phenomena are ranked for importance, independent of what model you might apply. This is just how important is smoke development to assessing cable damage, for example. But when you get to the model adequacy, yeah, it's absolutely based on their knowledge of the models that exist, readily available models that exist in the community today. And again, that was the big reason we were really after people who had experience with models. They knew what is out there. They had experience with the NIST Codes and with what the French Codes were doing and others.

MEMBER BLEY: In the table, do they evaluate against the specific models or is it generally against the generally available codes?

MR. NOWLEN: The generally available codes. You can see -- well, we'll get into it. The next one --

MEMBER BLEY: So differences could well be due to differences in the code somebody is thinking about?

MR. NOWLEN: Yes. And there were cases of that where someone said well, I don't know of anything like this and someone else would say oh, but I know, they have got this and they've done it. Oh, okay. And the minds would change. Their ranking would change based on one or two individual's knowledge of a particular area. That was quite common actually.

I'll give you our rankings in just a second on that one. Let me do this one. This is the importance ranking in terms of you've got a phenomena, how important? These were the definitions we gave them. We had pulled this out of the Sandia PIRT that we did, were involved with. The first order of importance to the figure merit, secondary importance.

CHAIRMAN BANERJEE: Give them the scenarios or they developed the scenarios?

MR. NOWLEN: We gave them scenarios.

MR. SALLEY: We spent -- that was the key with this is we took a lot of real scenarios that we had seen over the years. Quite truthfully, we had, you know, in our experience, seen people struggle with trying to model, so --

CHAIRMAN BANERJEE: So you specified the scenarios of interest and then they --

MR. SALLEY: Yes, we had EPRI also, that's how IC got into this is EPRI, who we have an MOU with and we work with, that's where Francisco was supplied by EPRI. We had a number of meetings before this ever took place, before we ever contracted Steve with NIST, NRC, NRR, Research and EPRI. We said what kind of scenarios can we develop?

So we tried to develop some real hard and fast scenarios to keep them in bounds and asked them okay, given you have this problem and we brought you in say as a consultant, that's a role I needed these people to play. How well could you do this? And that's how we tried to box the scenarios to keep it uniquely --

CHAIRMAN BANERJEE: Otherwise it would go -- it would take you three meetings just to develop the scenarios.

MR. SALLEY: Yes.

CHAIRMAN BANERJEE: Yes.

MR. NOWLEN: Now, we did see as we went through scenarios, we found we had to add more detail, because they would ask questions, you know, very specific questions about well, how high above the fire is this sprinkler? They assumed 10 feet or, you know, and tell me why you think that's so important. Okay. So there was a bit of that, but we basically had a set of scenarios we went in with and they worked from those.

CHAIRMAN BANERJEE: So just for the mechanics, they would come to the meeting and then go home and probably do some homework and fill in these tables and send it to you? Is that how it worked?

MR. NOWLEN: It was some of that. We had hoped for more of that. You know, for example, before each meeting, we gave them preparatory work to do before the meeting. You know, think about -- we had given them the scenario and say we would like you to think about this before you come, maybe develop a preliminary list of phenomena. Honestly, that didn't work out too well.

CHAIRMAN BANERJEE: It was mainly at the meeting then.

MR. NOWLEN: It was mainly at the meetings. Now, after the meetings we did route the information we had developed. We would develop the tables at the meeting and fill them out as we went. We would route those to the panel and say, you know, please, check these over. Does it reflect your discussions and your recollection of what we did?

And in some cases, we got some feedback, but again, experts like this --

CHAIRMAN BANERJEE: Did they have to give a reason?

MR. NOWLEN: I'm sorry?

CHAIRMAN BANERJEE: Did they have to give a reason for choosing something high or medium?

MR. NOWLEN: Yes. Oh, yes, we always pursued why is that your answer.

CHAIRMAN BANERJEE: So there was a consensus developed rather than individual reasons?

MR. NOWLEN: We preferred a consensus, but it wasn't always. You know, some people had differences of opinion. They would agree it's high, but for slightly different reasons. And we marked those down. And again, we saw a consensus, say, well, you know, you have heard their explanation, does that change your view? You know, they didn't always agree, but in a lot of cases we did reach a consensus. Most cases we reached consensus. There is a few outliers in a couple of very specific areas that were near and dear to one panelist or another that are the outliers.

So again, we had definitions for importance. Here is your model adequacy rankings, which gets to your question, Dennis. You know, for high, we said there is at least one mature physics-based or correlation-based model out there that is believed adequately to represent the phenomena over the full parameter space.

MEMBER BLEY: Let me ask you a question. I'm not real familiar with this curve, this topic. But it strikes me when I see that and now you explained you might have an argument, somebody said I don't know any of this and somebody said yes, there is one. What good is this if I'm looking at it and I don't know which one code out there can handle this problem?

MR. NOWLEN: Well, we --

MEMBER BLEY: Or which half of them can.

MR. NOWLEN: -- tried, you know, to capture that through we had this extensive comment field that, you know, we would capture all of the discussions and if they said there is -- you know, hey, university of so and so has this handle, no problem. We tried to capture that. We didn't run into that. In general, they stuck to the pretty well-known CFAST, FDS, the handbook correlations, SFPE, NFPA handbooks, occasionally some of the other zone models that are out there.

They stuck to things that were pretty widely known. Nobody really came forward with anything that was --

CHAIRMAN BANERJEE: Esoteric.

MR. NOWLEN: -- esoteric, out there, nobody knew about.

MEMBER BLEY: Okay. The purpose of this is to help NRC decide where to focus its research?

MR. SALLEY: Future research.

MEMBER BLEY: Future research. Okay.

MR. NOWLEN: Right.

MR. SALLEY: For example, if you had something that came out as being very important and you had a low state of knowledge, you know, that would trigger something.

MEMBER BLEY: Okay.

MR. SALLEY: If you had a hand in something that was very important and we had a lot of work done, we don't want to redo the same work. So this will give us a matrix.

CHAIRMAN BANERJEE: Typically following this would be what we would call a scaling study.

MR. NOWLEN: Yes.

CHAIRMAN BANERJEE: To see how well the important phenomena is scaled and in experiments and that sort of a thing. So there is a systematic process.

MR. NOWLEN: Right.

MEMBER SIEBER: You're not evaluating existing methods as much as you are identifying which phenomena will solve the problem that's come up.

MR. NOWLEN: Right.

CHAIRMAN BANERJEE: How well we understand it.

MR. NOWLEN: Right.

MEMBER SIEBER: And maybe you know a code that does that --

MEMBER BLEY: And to do the work to fill it in.

MEMBER SIEBER: -- right now.

MR. NOWLEN: Right. And we had a number of those. I mean, you will see. I'll go through the -- you know, the ones that bubble to the top are high state or high importance, low state of knowledge, bubble to the top. And so I've got a preliminary list of some of those for our scenarios. And that would be the things this particular panel would recommend as areas ripe for more investigation.

MEMBER SIEBER: I presume though that in the process of identifying something that's important where you don't have a good state of knowledge, the panel would say give you direction. These are the phenomena that are important to solving this kind of a problem, so that you can start off and say how is that phenomena related to the answer that I want to achieve?

MR. NOWLEN: Yes.

MEMBER SIEBER: How does this all come

together?

MR. NOWLEN: Yes.

MEMBER SIEBER: And then that says I can go and buy a code. I can take an existing code and modify it or I can start from scratch. Now, perhaps even with an experimental program, too, you know, get a baseline of data.

MR. NOWLEN: We didn't necessarily take them that far, but again, because the panel tended to stay in the domain of pretty well-known tools, you know, there aren't that many out there. They stayed pretty well in the domain of well-known tools, so we had a good understanding of, you know, when they said something was poor, they were looking across the range from everything from these handbook correlations to FDS.

MEMBER SIEBER: Well, how do they know it's poor? They work a code and then the thing burns down or it didn't burn down the way they expected it?

MR. NOWLEN: That's the nature of expert opinions. You know, this is all expert opinions.

CHAIRMAN BANERJEE: I think it's more qualitative than what you are looking for, Jack.

MR. NOWLEN: Oh, absolutely, yeah.

MEMBER SIEBER: Yeah.

MR. NOWLEN: Yeah.

MEMBER SIEBER: Well, I've seen PIRTs in other areas that approach it in a different way.

MR. SALLEY: We did throw them some curves, too. You know, this was a real learning experience for everybody involved that were the first time with PIRT. And we tried starting out with what we thought was a simple problem. We all agreed was simple and maybe it wasn't so simple, because they wanted to get a lot more into it. But there was --

MEMBER SHACK: They made it complicated.

MR. SALLEY: Yeah. That did happen. Right. It's not that --

MEMBER SHACK: Did water flow down from that tank?

MR. SALLEY: Well, the fact was it was simple. This ought to take you a half hour to --

CHAIRMAN BANERJEE: You can count the --

MR. SALLEY: This is simple. You guys ought to get through this in an hour or two, okay. It's a simple problem and you are at the second to the second day still at that first problem and you're going wait a minute, you know, because the other one is really complex.

MEMBER SIEBER: You changed the panel.

MR. NOWLEN: Well, there again, this gets into that. You know, the panel was shy at first, which surprised me given some of the personalities on this panel. But they were a little shy. They were a little reluctant to, as I see it, take ownership. I didn't want to stand there and well, what about this and what about that? I didn't want to feed it to them. I wanted them to feed it to me.

CHAIRMAN BANERJEE: Sorry to interrupt this flow, but if we get to the -- if we are to get to the results --

MR. NOWLEN: Yes.

CHAIRMAN BANERJEE: -- and discuss them, you've got to move along.

MR. NOWLEN: Yes. We're doing okay.

CHAIRMAN BANERJEE: Yeah.

MR. NOWLEN: We're doing okay. So again, we had data. We had descriptors for the high, medium, low on data adequacy as well. And in terms of developing new data, we also gave them descriptors, because again, we wanted to ask how hard this is going to be? You know, is it readily obtainable? A high probability of getting it or is it, you know, it would require significant development of new capability?

So I don't even know how to do this today.

I would have to develop an instrument. And I think that's something that's perhaps unique to this one, but I wanted Mark to see that and say, you know, gosh, if you're going to go after this, recognize that you are taking on a pretty challenging task. So that's really what this one was aimed at.

So now, our first scenario. This first scenario that we did was an electrical cabinet fire in a main control room back panel. So here is our main control room. It's a typical complex. These were specified as cable risers behind this control room with a concrete wall and different structures. We said there is a little restroom here. The kitchen area is over here.

So fairly common two unit. You know, we have the main horseshoe down here in orange. And our fire cabinet is this red one in the back. So we told them there is a fire in that cabinet. And what we want you to do is use your fire model to predict if and when the operators would be forced to abandon the main control room.

It seemed like a pretty straightforward one to us. And --

CHAIRMAN BANERJEE: It doesn't seem that straightforward.

MR. NOWLEN: Well, it --

CHAIRMAN BANERJEE: All right.

MR. SALLEY: There is our eighth panel member right there.

MR. NOWLEN: There he is.

MEMBER SIEBER: It depends on the operator.

CHAIRMAN BANERJEE: We try to take --

MR. NOWLEN: Yes. What we left out of this scenario is anything to do with components, cables damage. We just said your target is the people and we assume that the panel, from the community that they come from, they ought to be pretty familiar with how fire impacts people. So we thought this would be a real straightforward for one to start with. It took us two days to get through this one.

But, you know, again, I think a lot of it was just a learning process. And really even in hindsight, this was a great one for them to start with, because it gave them something that was fairly familiar that they could kind of work around to get themselves familiar with the process and get to the point where they were comfortable with really taking on ownership of this whole thing.

CHAIRMAN BANERJEE: What is that lower

diagram there?

MR. NOWLEN: This is a picture that we showed them of a typical control cabinet, what it might look like. You can see there is bundles of cables here, lots of control cabinets, relays and, you know, the rats nest sort of thing of the individual conductors being pealed out of the larger cables, another bundle here, some excess cable in the bottom.

We showed that to them and said, you know, assume this is the sort of panel you have burning. There is ventilation openings in the doorway. This is actually a panel fire out of a plant, so it's not made up. It's actually a plant panel.

So we gave them that and some other pictures. We had other pictures for them to look at that sort of said here is what you are dealing with. This is the nature of the scenario.

And in this case, it was just one scenario. We originally had a sub-scenario that added in the concept of the damage target, but after it took them two days to get through this, we decided to move on. What we got out of this, the areas that they ranked as being highly important for the most state of knowledge, the effectiveness, timing and level of control of the manual fire suppression.

This is one of those areas where they got into something that we wouldn't, us, normally consider to be in the realm of a fire model. You don't model per se the fire brigade. But they really felt, you know, they ranked this as highly important. Clearly, the fire brigade is the one who is going to come put the fire out. And so they ranked it as highly important and said our modeling of that is really poor.

You know, right now, we basically have statistical models, so ultimately, they looked at the quality and pedigree and our statistical model.

CHAIRMAN BANERJEE: It wouldn't be some operator with a fire extinguisher trying to put it out?

MR. NOWLEN: Well, he might take a shot at it, but if the fire grows beyond his ability to put it out, they are going to rely on the fire brigade as a fall back.

MEMBER BLEY: Which has happened.

MEMBER SIEBER: Yes, the first shot is electrical isolation if you can do it.

MR. NOWLEN: Yeah.

MEMBER BLEY: This panel is --

MR. NOWLEN: The control room, you're not going to be able to --

MEMBER BLEY: Panels are hard to isolate.

MR. NOWLEN: -- do that, you know.

MEMBER SIEBER: A lot of nice switches.

MR. NOWLEN: These ones would be.

MEMBER BLEY: The ones I knew worked.

MR. NOWLEN: So again, you know, they brought that forth and, you know, when we kind of thought fire brigade, modeling the fire brigade, wow, okay, well, yeah, that brings in our statistical model. We have a statistical model for fire brigade performance based on past fires.

So we presented that. They weren't particularly impressed.

MR. SALLEY: Right. We wanted to go down in the world of physics and here is the first thing they hit on which is the heat reliability analysis we're doing time line.

MR. NOWLEN: Yeah.

CHAIRMAN BANERJEE: Well, having skirted that one then.

MR. NOWLEN: Yeah.

CHAIRMAN BANERJEE: The second one is also --

MR. NOWLEN: The second one, the human

sensing the fire. Now, this one is a little different, because -- and we acknowledge it even in the PRA method. Humans make great fire detectors. Your nose is one of the best smoke detectors you will ever find. Chances are you will pick it up before the -- you know, you smell your wife burning dinner before the smoke detector goes off, at my house at least.

MEMBER SIEBER: Not mine.

MR. NOWLEN: And not that it happens often. My wife, my apologies to her. But they felt that in this particular -- especially the way we had set up the conditions where the smoke detectors were in the general space, they really felt that the humans were likely to detect the fire before those smoke detectors ever went off. And they said well, since that triggers the whole time line, you know, that could be very, very important.

And, you know, the fire models can't do that. So they ranked it as poor state of knowledge, but potentially, a very important phenomena. So they actually picked up on something we had seen before. And this one is a little different than when we got into the decision making process of how the operators would decide to abandon and things. This was more legitimate.

I mean, you could see, for example, a model that would predict, you know, when do the pyrolysis products in the room reach a threshold where the human nose would detect it? I can almost see that happening some day. It's certainly not there today. So I think they got this one spot on. This was a good one.

Impact of the open-grate false ceiling. We specified a ceiling just like this one right here. The egg crate sort of ceiling as, you know, the same reason it's here, it's a human comfort sort of thing. We specified that for this control room and they thought that was really important. It's behavior, the potential effect it could have on the plume development, the fact that it could melt and become a fuel that's now involved in the fire.

All of that. They ranked that as something that we don't understand and could be important. Characterizing the cabinet fire itself and they actually came down into this one at a fairly high level of detail. Some of these you begin to see sort of the academic transition of the fire from the incipient stage to open flaming.

You know, that whole process of an overheating component smoldering and eventually turning into an open flame. They ranked that as highly important and poorly understood. Some of the others, this was one we had disagreement on. Some of the panel said I don't care. I want to know what happens when it's burning, it's flaming. That's what comes to me. So this was one where we had a lot of disagreement.

But then this was actually a common theme through all of them. Characterizing the fire source was always highly important. And it generally ranked from low to medium. They rarely ranked our ability to model that as high.

CHAIRMAN BANERJEE: That's sort of evident. It's largely empirical.

MR. NOWLEN: Right. Largely empirical, that's right. And being able to model that. We talked about that a lot this morning, our ability to model it is still fairly crude. That was very common.

In this case, they also brought the acid gas production up. They ranked other things like CO production and HCN, hydrogen-cyanide production. They ranked a number of things as phenomena, but they were less important, because we specified they had breathing apparatus. So ultimately, they came down to well, the acid gas and the tearing of the eyes, that

that could induce, could be a real strong factor here.

We probably don't understand acid gas production from cables very well. So they felt they had a pretty good handle on the smoke, that we could do the smoke distribution. We could estimate smoke production. But acid gas was something they felt we didn't have as well and because it can cause tearing, they felt that could be really important. They might get that before they have a chance to put their masks on. So that's what basically came out of our control room scenario.

Our second scenario took us into a switch gear room. And we specified, we gave them again some pictures. This is a real plant. So you can see there is a stepped ceiling here. There is a lower region and a higher region. You can see it kind of in the plan view or in the drawing back here. We specified a fire in a cabinet section back underneath this lower ceiling. And then we gave them different figures of merit.

In two of the scenarios, the figure of merit was to predict when -- if and when failure would occur to a cable right down here. So back in the corner. We didn't put it right above the panel. We put it down the tray at the end of the bank. And said you need to know when the safe shutdown cable down here fails.

In the other case, we moved the cable up underneath the upper level ceiling up here and said what happens up there?

The other variation here is in 2b. We told them this was no longer just your average slowly growing thermal fire. This is now a high energy arc fault reminiscent of the San Onofre arc fault event that I assume you all have heard about. You know, this cabinet goes boom and spills its guts and you know have a fully developed fire in a very short order.

And so we gave them that as basically three variations on a theme for the same general configuration. This was at our second meeting and they took up ownership and they ended up, at this meeting, they started rolling phenomena up at a much higher level. They decided that they way they had broken out the first scenario was just way too deep, just way too -- they got into the minutia of things and they really felt that didn't work well for them.

So they started rolling things up and, you know, the things that rolled out, behavior of the fire spread along the cable tray. And we talked about that this morning. They definitely keyed on that as something that is poorly understood, relative to the current models, but very important, especially given the scenario we had. It's about propagation down that tray.

They also were looking at propagation from the tray back down to the adjacent panels and whether that would occur, you know, for example, if they were thermoplastic cables and they were dripping. Well, is that going to ignite the next panel? We said well, if it does, then we're going to propagate this thing a lot faster. So they brought that one in.

And again, characteristics of the original cabinet fire. In particular, they brought out the blast dynamics and the ignition of materials due to the initial fault associated with the high arc fault fire. So again, fairly good choices, in my view, but it was interesting that they came up with it independently.

Our next scenario took us into the turbine building. And here is the graphic we presented to sort of show a dual unit turbine building. You have the turbine generator sets, two turbine generator sets for this unit. We showed them this as a picture of a typical lube oil storage tank. We placed that storage tank in an elevation below the main operating deck. And we said our fire source involves this thing.

And we gave them, again, a couple of variations on a theme. Two of the scenarios just involved a leak in the low pressure side of this tank. The oil pools up in the berm below the tank and gets ignited. So big pool fire.

The second one -- the third one we gave them though was that we have a break in the high pressure side of the thing and we get a spray fire that could perhaps then subsequently pool, but we definitely have a spray fire.

We also gave them a little bit of variation in the figure of merit in two of the scenarios, one of the pool fire and one with the spray fire. We said there has been an inspection finding and there as a part of an inspection they found that there was an unsealed hole in the wall between the turbine building and the main control room.

We told them the main control room was in this structure adjacent to the turbine building and there was an undetected leak, an undetected hole that shouldn't have been there. It's supposed to be a three hour barrier.

CHAIRMAN BANERJEE: How big?

MR. NOWLEN: I don't remember the exact size we gave them. We gave them a relatively small size in terms of square inches of surface. It wasn't a giant hole. You know, it was something like this. Unsealed cable tray penetration sort of size.

And so we said the figure merit for those cases was predicting if and when you would see any component failures for equipment inside the main control room due to this big fire in the turbine building.

The third case was to predict structural failure of the structural steel in the turbine building. Collapse of the building. And for that one, we went back to the pool fire.

So we showed them, you know, additional pictures of the kind of structural steel we had in mind. These again come directly from a plant. You know, the idea that the operating deck may be this sort of steel grading that you see all over the place. These windows, we showed them pictures of these windows in the upper part of the turbine building that bring daylight in and all. These turned out to be real interesting for us, that was an interesting discussion. I'll get to it.

But also, we gave them other pictures that showed, for example, some of the piping obstructions. There is a bridge crane up above here. You know, all these things kind of came in to their discussion. So we tried to give them a lot of, you know, real life pictures of what these things look like.

So what they came up on this one, they said the performance of the sprinklers. We specified that there were sprinklers under the operating deck. They really thought, you know, these sprinklers had a good chance of controlling, in particular, the pool fire. But whether they would really work for this scenario was considered uncertain.

We had this huge tank sitting right above the fire that's a blockage. There was all kinds of other obstructions. They really keyed in on that and whether or not these systems would work under these conditions. They had the flow path itself to the main control room, the geometry of that. They felt like we probably didn't have a very good handle on how much smoke and heat would actually get through the two rooms.

In particular, we specified that the control room was typically pressurized. You know, just for habitability issues. It is typically a little higher pressure. And they felt that really complicated the problem of the transport through that leaking hole.

CHAIRMAN BANERJEE: I can see that the next one, Bill is going to make a comment on.

MEMBER SHACK: No, no.

MR. NOWLEN: The behavior of the windows was a real interesting one. They felt, you know, there wasn't really any question that the windows would break. It was timing, because we also said there is roof vents in this turbine building. There typically are, you know, smoke vents. And they said well, the real key here is do the smoke vents open up first or do the windows break? Because they felt that would really have a big impact on the dynamics of the fire.

So they were actually a little reluctant to go here, because there has been a good deal of work on window breakage in fires, but they really felt given this configuration it was uncertain what the timing would be. That one they were fairly -- for one of their high important, low state of knowledge, they were real soft on this one. They --

CHAIRMAN BANERJEE: There is no pressure waiver associated with this, right? So --

MR. NOWLEN: No.

CHAIRMAN BANERJEE: -- what --

MR. NOWLEN: It's differential.

CHAIRMAN BANERJEE: -- is it --

MR. NOWLEN: The glass won't take much of a transient --

CHAIRMAN BANERJEE: -- thermal stresses?

MR. NOWLEN: -- or a heat gradient, no.

MEMBER BLEY: Well, what -- I'm just curious. What was the big difference in how the fire progressed whether the windows burst or the vents opened?

MR. NOWLEN: Well, you open up all this ventilation --

MEMBER SIEBER: You get more oxygen.

MR. NOWLEN: -- that would allow --

MEMBER BLEY: A lot more air through the windows than you would through --

MR. NOWLEN: Yeah.

MEMBER BLEY: But if the vents open, that will cool and you won't get the windows breaking?

MR. NOWLEN: Well, the vents will draw off the smoke from up above, but won't affect the overall building flow quite as much.

MEMBER BLEY: Okay.

MR. NOWLEN: They felt like the windows --

MEMBER SIEBER: Cool the windows.

MR. NOWLEN: -- because the windows were such a large space and where they were located --

MEMBER BLEY: I guess that must be the --

MR. SALLEY: We also have the challenge here with that main lube oil tank. You're talking quite a big fire.

MEMBER SIEBER: Yes.

MR. SALLEY: Many, many megawatts.

MEMBER SIEBER: Pool fire.

MR. SALLEY: Your model is going to dance, too. My oxygen limit and my fuel is limited, so when people have tried this in the past, when they started getting oxygen limited, they wanted to break out windows to allow additional combustion oxygen. So if you get to that state, the key is do these windows break and if so, when? So what's the state of your fire? Is it oxygen limited or not?

MR. NOWLEN: Yeah.

MR. SALLEY: And then that turns into a challenge.

MR. NOWLEN: And they kind of felt that if the roof vents opened up, then chances are the windows wouldn't break.

MEMBER BLEY: Would survive.

MR. NOWLEN: But if the roof vents didn't open up first, the windows would break. So that was--

MEMBER BLEY: If the vents open, it's primarily heat going out.

MR. NOWLEN: Yeah.

MEMBER BLEY: Rather than a lot of air coming in.

MR. NOWLEN: Right. Yes, you are kind of channeling that hot smoke right up out the roof.

They also keyed in on CO and particulate production. We questioned them on that. Why are you concerned about the -- the particulate was -- you know, they were concerned about particulate getting into the control room and damaging the equipment, soot deposition, because they were control components. They felt that was important. They were never really able to give us a good answer for why CO, but they stuck by their ranking.

So we'll probably follow-up a bit on this review process. Can you really explain this one to me? We tried a couple of times.

They also felt like the heat release rate for the spray fire was something we probably couldn't handle very well. And again, it was keyed on the fact that it was a highly obstructed fire and we had these sprinklers that would go off and how much of an effect the sprinklers would have on the heat release rate of the fire, rather than simply we don't understand spray fire. They thought it was really the specifics of this scenario that made it more uncertain.

MEMBER BLEY: Do the operators have SCUBA breathing apparatus in the control room or do they have access to instrument there?

MEMBER SIEBER: No, no, it's in the control room and the emergency squadron.

MEMBER BLEY: Do they have lines that they just -- like the SCUBA, which is like half an hour or something?

MR. NOWLEN: Well, it depends on the plant. Some plants are tied to a central air source, whether or not that is instrument air or not, I'm not certain. Others have SCUBA and they have replacement bottles, so they can change it out. The fire brigade definitely has self-contained breathing.

MEMBER SIEBER: SCUBA.

MR. NOWLEN: Full apparatus.

MEMBER SIEBER: Right.

MR. NOWLEN: But again, yeah, typical bottles. You've got 30 minutes per bottle. They can change them out.

MEMBER SIEBER: They're just breathing air, not oxygenated.

MR. NOWLEN: Right. Yes, typically. There was one interesting outcome that came out of this one. On 3c, clearly, we're looking at the structural steel problem, you know. We aimed them right at it. They said oh, we can handle that. You know, that's no problem.

MEMBER SIEBER: Yeah.

MR. NOWLEN: Since 9/11, we know that problem.

MEMBER SIEBER: Yes, changing.

MR. NOWLEN: We've got that in the bag. So they ranked it as highly important, but they said it's also high state of knowledge. So that was one of the things we had specifically aimed that scenario at. That came up fairly interesting.

MEMBER SIEBER: But the typical power plant engineer or fire protection engineer in a power plant could not solve that problem?

MR. NOWLEN: No, right.

MEMBER SIEBER: As to whether the building would remain erect or not.

MR. NOWLEN: No. But they felt there are readily available models for that out in the community. Now, they may not have found their way to that Part A.

MEMBER SIEBER: Yes, you better do it before the fire starts.

MR. NOWLEN: Right. But they can hire, you know, the smart boys, the Qs to answer that problem. They really felt strongly that that was a well-understood problem at this point. There have been so much research in the last 10 years or well, probably in six years.

MEMBER SIEBER: You can tell from --

MR. NOWLEN: Yeah, they got that one.

MEMBER SIEBER: -- the temperature how weak the steel is getting. The question is tell me what the temperature really is and that's where the fire modeling comes in.

MR. NOWLEN: Yeah.

MEMBER SIEBER: And the geometry makes a big difference in it, too.

MR. NOWLEN: They felt they had -- well, the structural -- from a structural standpoint, the geometry effects, they felt they had it pretty good. And yeah again, if you can predict the response of the steel, they felt that for most conditions, they could, in fact, predict the response of the steel and understanding the collapse.

Like I say, they strongly felt this was a well-understood problem, at this point.

MEMBER SIEBER: Well, it took NIST a little --

MR. NOWLEN: Oh --

MEMBER SIEBER: -- some effort to do the World Trade Center.

MR. NOWLEN: Sure. But all of that has fed the current understanding.

MEMBER SIEBER: Yeah.

MR. NOWLEN: So it's based on that and the work that is going on in Britain, in particular, that they were quoting.

MEMBER SIEBER: And that report was a good report.

MR. SALLEY: And the Harvard Code has been out there for how many years now? 20 some years maybe?

MR. NOWLEN: Yeah.

MR. SALLEY: You know, the Harvard e-transfer for the steel with the fireproofing. So that's pretty much established knowledge.

MR. McGRATTAN: It's not the heat transfer that's the problem. It's will the structure come down, given weakened steel?

MEMBER SHACK: So it's really a structural analysis problem.

MR. McGRATTAN: Yeah.

MR. NOWLEN: That's the way they expressed it, too, and they felt there had been a large body of work in Britain that looked specifically at that part of the problem. They felt it was well-handled.

MEMBER BLEY: You didn't actually have structural engineers though on this?

MR. NOWLEN: Well, he had -- Jose Torero was deeply involved in that work. He is the one who brought to the panel and we actually had him give us references that we could pass out to the panel that they could look at. But he was the guy who had the strong knowledge there and he convinced the rest of the panel that -- to go with him on that one.

He carried the whole panel. And ultimately, like I said, he provided the references and they all looked at them and they said wow, this is good stuff.

So okay, our last scenario and then we will get you out of here. Scenario 4 was a self-ignited cable fire in the annulus region inside containment. And what we gave them is a pair of cable trays. One ignites in the redundant tray with separation between the two. So in this case, it was what is if and when these -- the redundant tray and cables would be damaged.

And again, containment is one of those areas where separation tends to be --

MEMBER BLEY: Weakest.

MR. NOWLEN: -- weaker. So they tackled this one as the last one. There was really only one key phenomena that came out of this one and that was the sprinklers. We had specified that there was a sprinkler. This is a header that goes around the annulus and there were sprinkler heads coming down out of that header. And this is something we see and they put a heat collector plate above the sprinkler head, so that in theory the heat collects under the plate and causes the sprinkler to activate.

And we got a good laugh out of that one from them. They laughed heartily about that. But then they said well, you know, given the configuration, would this sprinkler activate and if it activates, would it really control the fire here? That was the one thing out of this scenario that they really keyed on. They felt like, you know, in this case, the configuration vertical array of cables, we could probably handle that pretty well.

It is mainly a radiation problem between these two. We don't really have the convective problem. They felt we could handle the radiation heat transfer pretty straightforward. But they really felt what we don't know and what we can't predict well is how that sprinkler is going to respond.

So that was really the only one that came out of that.

MEMBER SHACK: Well, they had the sprinkler for the turbine fire, too.

MR. NOWLEN: We had the sprinkler for the turbine fire. Yeah, they pulled that one out. That one was more of an effectiveness with obstruction.

MEMBER SHACK: Obstruction.

MR. NOWLEN: They felt it would go off. They just weren't sure --

MEMBER SHACK: Graded ceiling.

MR. NOWLEN: Yes, and the graded ceiling.

MEMBER SHACK: And this one was whether it would actually go off?

MR. NOWLEN: Whether it would go off and if it went off, whether it would be effective. But mainly, whether it would go off or not, that was where they really keyed.

MEMBER SIEBER: Let me ask a question. It's my understanding that if you install sprinklers to code requirements, you don't necessarily know that you have enough sprinkler capacity to handle the combustibles that it is supposed to be protecting. Is that true?

MR. SALLEY: Yes and no. How is that for an answer, Jack?

MEMBER SIEBER: No good.

MR. SALLEY: You know, if you go back into the older sprinkler design --

MEMBER SIEBER: Yes, the old 1900s type.

MR. SALLEY: Yeah. If you go back to the 1970's codes, we were doing a lot of not hydraulically calculated back then, but a lot of it was called grid systems.

MEMBER SIEBER: Right.

MR. SALLEY: Where you would have 10 foot centers and you had nice uniform grids, which that was a challenge putting into plants. But a part of that code that nobody bothered to read was that you had to go and look at your occupancy to decide on what your density was.

MEMBER SIEBER: Right.

MR. SALLEY: Because your density was now driven then by the size of the sprinkler head and the size of the pipe array. They were all calculated at one time. And across the board, the industry kind of said we're all ordinary hazard group one. And yeah, kinda sorta.

So if you were in a heavy -- what I'm saying, if you get a heavy congested cable area like maybe the cable spreading room --

MEMBER SIEBER: Right.

MR. SALLEY: -- you really may be stretching the limits there. Where if you are in a more open area with less combustibility, you're okay.

MEMBER SIEBER: Was there -- isn't this an important area since you really rely on sprinklers in a lot of places where additional investigation ought to take place or maybe additional regulation?

MR. SALLEY: There have been studies done.

MEMBER SIEBER: I know.

MR. SALLEY: Sandia, as a matter of fact, did the key one. How much do you need to extinguish, for example, deep seated fires and gang cable trays? And for the standard sprinkler design, you are pretty good. Now, the key there, too, though is sprinkler theory is not designed for extinguishment. It's designed for control.

MEMBER SIEBER: Right.

MR. SALLEY: So you --

MEMBER SIEBER: If the sprinklers go off, you don't say the fire went out.

MR. SALLEY: Right. But you controlled the fire and --

MEMBER SIEBER: It's just somebody else can go put it out.

MR. SALLEY: -- it's just the --

MR. NOWLEN: Yeah.

MR. SALLEY: Yeah, that -- the --

MEMBER SIEBER: Now, insurance companies, I notice nobody on this panel is from an insurance company, but they have a lot of ideas about how many sprinklers you ought to have and where they ought to be. And I'm wondering why there is nobody from insurance companies on the panel?

MR. SALLEY: That did come up in Scenario No. 3, the turbine building.

MEMBER SIEBER: Yeah.

MR. SALLEY: Because the very question you're asking, when you design a turbine building system, I've done a couple of these, the insurance company gives you very prescriptive --

MEMBER SIEBER: Yes, they do.

MR. SALLEY: -- density requirements, because of the oil hazard.

MEMBER SIEBER: Yep.

MR. SALLEY: And you actually have to design --

MEMBER SIEBER: You've got 5,000 or 6,000 gallons of oil per turbine.

MR. SALLEY: Right. And they give you that. And we -- as a matter of act, that came up to the panel. The question what was the system designed to? And we actually gave them standard American Nuclear Insurers' criteria.

MEMBER SIEBER: Right.

MR. SALLEY: Of the dual density systems.

MEMBER SIEBER: Right.

MR. SALLEY: And we provided that with them. But the key that would tend to hang them up in both Scenarios 3 and 4 was that you didn't have the flat ceiling like Sprinkler C in commercial appliances.

MEMBER SIEBER: Right.

MR. SALLEY: We always get this oddball ceiling. In the turbine building, we had the grate. So the question becomes do you now get enough heat that comes up in the convective plume? Does it strike the grate and come over and give you a velocity past the sprinkler head that operates the sprinkler head? Well, kinda no.

MEMBER SIEBER: Well, my guess is it rages like it wasn't there.

MR. SALLEY: And that's the kind of things that that --

MR. NOWLEN: They didn't feel we understood that one.

MR. SALLEY: Scenario 4 was a setup.

MEMBER SIEBER: Okay.

MR. SALLEY: And I'll tell you guys that. Scenario 4 was a setup, because if you go and look at the classic exemptions, that has come in for Appendix R, there is a number of them out there for Scenario 4 and people have been very creative on how they said that that's adequate. And one of the ways was if I put a sprinkler between the trains, the sprinkler must go off before the other train is taken out and into --

MEMBER SIEBER: The only way you can do that is to put a roof in.

MR. SALLEY: Well, they put the little heat collectors.

MEMBER SIEBER: Yeah, but that's not good enough, I don't think, right?

MR. NOWLEN: Well, we got a good laugh out of that one.

MEMBER BLEY: That's what you get.

MEMBER SIEBER: Because the heat all goes around the corner and not up to the top.

MR. SALLEY: And we have written information notices out on the problems with them, but that's not to say there ain't a few thousand of them out there.

MR. NOWLEN: Well, I've got four minutes, so I better get back here.

MEMBER SIEBER: Okay.

MR. NOWLEN: So --

MR. SALLEY: The bottom line was the scenarios were all heavy discussions between us and there was -- we spent a lot of time developing scenarios, I think you'll see that.

MR. NOWLEN: Yes. Now, I wanted just to close out 4, they basically dismissed the other -- the importance of most of the other phenomena, because this area is inaccessible. So things like detection, you know, accessibility, the spread rate of the fire, it's like well, you know, who cares? I mean, if the sprinkler doesn't put the fire out, nothing else is going. So it's all about the sprinklers, so that's where they came down.

And this was another one where we had disagreement. We actually had three of the panelists just, you know, said forget it. These sprinklers aren't going to work. You know, I don't --

MEMBER SIEBER: I don't see that.

MR. NOWLEN: -- think they are important at all, because they are not going to work. And the other three panelists said well -- or the other four said well, I'm not so sure. I think we -- you know, they could be important. They might work. So this was another one where we had some disagreement.

MEMBER BLEY: You didn't have anybody saying it would work for sure, it doesn't sound like it.

MR. NOWLEN: I'm sorry?

MEMBER BLEY: Nobody was saying that it would work for sure?

MR. NOWLEN: No one was willing to say that.

MEMBER SIEBER: Not saying that.

MR. NOWLEN: Four of them felt that they had a chance of working and -- but then our ability to predict whether or not they would work was -- they all agree that was true. You know, once we got past how important it is, they all said, yeah, well, we don't know how to do it. So that they agreed on.

So to wrap it up right on time here, we did this PIRT exercise. I think it was very interesting. We did complete the meetings. We are drafting our report. There were a number of phenomena. I think some surprises did come out of it. We did have some disagreements among the panel and I think you just have to accept that. That's just the nature of the process.

We do have our draft report for review. We are going back to the panel for their review before we publish. We do want them to buy in on the report. So we expect some more changes there. But we are hoping to publish this spring. And that is it.

MR. SALLEY: And the facilitator is good at herding cats. He is a good facilitator, because I'll tell you a lot of frustration when they would start spreading out to try to get everybody back on mission. That was --

CHAIRMAN BANERJEE: So what will be the take-home messages from this?

MEMBER BLEY: Did you learn something useful? Would you do this further? Did you learn how you would do it a little differently?

MR. SALLEY: Oh, yeah, any time you do anything the first time, if we did a second one, I think we have a lot of key insights how we would do a second one. Yeah, I mean, if you want to talk about our inexperience with this, like I said, we spent a lot of time with NIST and that. In our simple minds, the people who do this every day, we had over 12 scenarios, each one with multiple things.

And then we were questioned, did we have enough scenarios? What if we get into the second meeting and we run out of scenarios? So you can see that --

MR. NOWLEN: Yeah.

MR. SALLEY: -- we were totally leaning, you know, these guys are going to bang these out and, you know, what if they run out of problems.

MR. NOWLEN: Yeah, and I had been warned. I had talked to people and they said if you get through one scenario in your first meeting, you're doing well. So I was like well, don't worry about 10 and 12, get 1 and 2 right, you know. So they -- yeah, it was a learning process for that, too.

CHAIRMAN BANERJEE: So you learned how to do PIRTs in a way?

MR. NOWLEN: Yeah.

CHAIRMAN BANERJEE: To some extent.

MR. NOWLEN: Yeah.

CHAIRMAN BANERJEE: But that -- this is probably going to be the case for any PIRT if you start with a new panel.

MR. NOWLEN: Well, and I think again, unless you have a panel that has already been through this before and they know what to do, for us the first meeting was all about educating the panel and getting the panel. You know, again, my phrase is to take ownership of the process. This is your input. I don't -- I'm not going to tell you.

CHAIRMAN BANERJEE: Do it again.

MR. NOWLEN: You can.

CHAIRMAN BANERJEE: You probably want to use something like the current panel or some approximation.

MR. NOWLEN: It would be good to have at least one or two people on the panel who have been through it before. You know, none of our folks had been through this before. And so they were all struggling. What we did see, you know, there were certain dominant personalities on the panel. And you know, at our first meeting, one of our panelists couldn't make the first day and, you know, so there was one dominant personality. And then the second day, our missing panelist showed up and the whole dynamics changed. And they ended up like this a lot of times.

So there were a lot of very interesting dynamics among the panel. And ultimately, they worked well together. I mean, ultimately, they did take over. We truly were just the facilitators and they did take over.

CHAIRMAN BANERJEE: So what would be, like I said, the take-home message from this program?

MR. SALLEY: For program, you know, I think we're going to --

CHAIRMAN BANERJEE: Learn something new.

MR. SALLEY: Yeah. What I think we will use this for again, and the key piece will be, if you watched how we're doing fire dynamics and fire modeling, it has been a very stepped out process. Okay. We start out with a document like 1805 and said okay, here is the introduction to fire dynamics and how this is going to play out in the fire plan. Okay. And we have got that done.

The next thing you see we go to is like the fire model V&V. You know, how good are these fire models? Yeah, you are getting numbers, but are you off by 5 percent or 50 percent? That matters in the end. So we went through and we did the V&V Project. So now, we've got a handle on how good the models are predicting.

The third piece for us was this PIRT and to get a feel of well, what's the expert opinion of what we know, what we don't know, what's important and what's not.

And there is a fourth piece that we're currently working on now. It is going to take us about a year to get it and it's the key that you get down to. It's not just a model. How good is the modeler? And we have talked to you all before about this with the V&V and we have got a big project going right now with a nuclear power plant fire model users guide, to say, hey, you know, if you get the ceiling that looks like this, this is how you do it.

Okay. And go through a bunch of those examples or this is how you take the V&V and apply it to a real problem with nondimensional parameters. So that fourth piece we need to get done. I think when we have that, we will then look and say where do we go with future resource?

We have already got -- here is another thing about the PIRT. Me, as a branch chief, I've got ideas where I want to go. And some of my staff members, they have ideas where they want to go. Is it where we need to go or is it where I, you know, Mark Salley want to go? And I think it would be better, it would be much more wise use of resources if we say something like flame spread on cable trays.

I'm saying we need to do some work on there. And we now have the PIRT saying you guys don't know much about flame spread on cable trays. You really ought to look at that. So I think it will be used that way to help us guide where we go in the future with fire research.

CHAIRMAN BANERJEE: Okay. I think that's fair enough.

MR. SALLEY: That's the big take away I want out of this.

CHAIRMAN BANERJEE: Yes. So in order to wrap this up now, because I see restless people on my left and right.

MEMBER SHACK: Yeah.

CHAIRMAN BANERJEE: We want to sort of get -- elicit some comments which might help Mark Salley and Steve and others with the Full Committee meeting. I guess we want a letter for the Full Committee, right?

MR. NOWLEN: Yes, Mark wants a letter.

CHAIRMAN BANERJEE: Yeah.

MR. SALLEY: I would like a letter, especially on the CAROLFIRE. The PIRT piece, I'm not too worried about. PIRT is what it is.

CHAIRMAN BANERJEE: I think it's CAROLFIRE that you will get the letter on.

MR. SALLEY: CAROLFIRE, I would.

CHAIRMAN BANERJEE: Yeah.

MR. SALLEY: Because it has been through every checking balance.

CHAIRMAN BANERJEE: So --

MR. SALLEY: Except for --

CHAIRMAN BANERJEE: -- I think there has to be some sort of a shorter presentation, obviously, made at the Full Committee meeting. I don't know how much time we have for it. Do you know?

MEMBER SIEBER: An hour and a half or something like that.

MR. SALLEY: Do you have the agenda?

CHAIRMAN BANERJEE: An hour, two hours. Two hours.

MR. SALLEY: Yeah.

CHAIRMAN BANERJEE: Oh, okay, we have two hours set.

MR. NOWLEN: That's a significant --

MR. SALLEY: I think it's a little closer to an hour and a half.

CHAIRMAN BANERJEE: Yeah.

MEMBER SIEBER: Yeah.

MR. SALLEY: But --

CHAIRMAN BANERJEE: That's a significant amount of time.

MR. SALLEY: That's a significant amount.

MEMBER SIEBER: Do you want comments now?

CHAIRMAN BANERJEE: Yes, I think that's why it would be very helpful to get some comments.

MEMBER SIEBER: All right.

CHAIRMAN BANERJEE: From the Members.

MEMBER SIEBER: Well, if you want them from me, I can say a few things about what I have heard today. And I guess the purpose of any research is to accomplish some regulatory objective. And the objective is to determine whether you are safe or not. And that may require changes in the rules or changes in the inspection techniques or some kind of good feeling that says I'm doing the right thing in the inspection pattern that I now have and the rules that now exist.

And that sort of determines the -- how

much effort you put into the research that you do. I think this is a difficult problem to solve, the problem of cable fires, because there is a lot of variables. Every cable fire configuration is a little different from every other one.

On the other hand, it appears you've got consistent results that are fairly predictable and fairly useful to at least answer the regulatory question. Do I need new rules or do I have to change enforcement or can I just forget about it and say okay?

And so I think from the standpoint of what we accomplish, we accomplish the right thing. I think it could -- you could have put a lot more effort and money and time into it and maybe done a little better, even though I even sort of doubt that, because of the variabilities, measurements and configuration and so forth.

I think that we have satisfied the objectives as I have seen them. In addition to establishing a regulatory strategy as to how one deals with the closure of these kinds of fire protection issues, I think that I see as an outcome of the research that has been done is a handle on the timing as to when fires start, when things fail and that's important to determine the overall risk to the plant, you know, CDF, if you're doing a fire PRA.

In fact, it's not clear to me that if you involve cable fires how you can do a fire PRA without that. And so I think there is another good benefit that comes out of that.

And I really don't see any downsides that are worth picking on, at this point, so I would consider the project as a successful project.

CHAIRMAN BANERJEE: We're going to have to give a letter.

MEMBER SIEBER: Right.

CHAIRMAN BANERJEE: So are there any specific points you want them to address --

MEMBER SIEBER: Other than --

CHAIRMAN BANERJEE: -- for the Full Committee?

MEMBER SIEBER: -- satisfy the objectives.

CHAIRMAN BANERJEE: Yes.

MEMBER SIEBER: That's it.

CHAIRMAN BANERJEE: All right. Dennis?

MEMBER BLEY: Now, I was very interested in this. It looked like really good work. I think it has already eliminated some myths that have been sitting around that have been affecting fire risk assessment work. I think it has potential with a lot more looking at the data to allow much better modeling of some of the other phenomena and gives us a much better idea of time frames than we have had before.

With respect to the report, in all three volumes, there are data points on curves that, as you were talking earlier, if they can be explained a bit, I think it would really make it much more useful to any reader to understand why the points are like they are. It's not transparent when you look at those why a couple of things are higher and a couple are low. Does that mean you have got to have data? And it sounds like no. It sounds like you have pretty good explanations for most of them. I think that would help a lot.

And I don't know where you go in the future with mining the data, but once you make it available, a lot of other people are going to be mining the data, too. And it's not good potentially.

CHAIRMAN BANERJEE: So, Dennis, would you be able to, in this case, help with the ACRS letter in clarifying some significance it might have?

MEMBER BLEY: Sure.

CHAIRMAN BANERJEE: From the PRA point of view?

MEMBER BLEY: Sure. And both -- of course, George can help on that too.

CHAIRMAN BANERJEE: Of course, yes. Both are missing at the moment, so you have to carry the --

MEMBER BLEY: Yeah. One of the stories start -- probably jumped in to when you said something, Jack, because there is a plant in Switzerland where he and several engineers spent almost a year tracing down almost every important cable.

MEMBER SIEBER: That's right.

MEMBER BLEY: And I don't know of anywhere else anybody did that to support an analysis like this.

MR. NOWLEN: We have.

MEMBER SIEBER: Well, you know it's the plant, right? You already know where the cables are.

MEMBER BLEY: If you did it right now.

MEMBER SIEBER: No, if you did it right in 1980.

CHAIRMAN BANERJEE: Well, this is probably like --

MEMBER SIEBER: I'll give you five years to learn.

CHAIRMAN BANERJEE: Bill?

MEMBER SHACK: Well, just in terms of the presentation to the Full Committee, I think you do need to set this stage by reminding the Members about the RIS, because many of them will be ready for it. So, I think, you know, if you set it up that here is the RIS, you know, you've got the program. Let's address the problem. Obviously, you are going to have to skip a lot of the details that you went through today.

You probably do spend more time with the model, because people like models. You know, we're ACRS guys. You know, we're academics and researchers, so, you know, that sort of gets them off. So that's--

CHAIRMAN BANERJEE: A couple of people who run a few plants, but that's all right.

MEMBER SHACK: Yeah. I think it was an interesting piece of work, you know. You, obviously, addressed the problem. I think you have got a lot of useful data out of it.

MR. NOWLEN: Yeah.

MEMBER SHACK: I'm impressed that the model works as well as it does, but, you know, that's a good model.

CHAIRMAN BANERJEE: Simple as you get.

MEMBER SHACK: It's simple as you can make it and still have it explain what it needs to explain. That's good. In your reports, you could make the lines instead of the half pixel a full pixel, so that you can actually see the bounds on the --

CHAIRMAN BANERJEE: Color handouts as well.

MEMBER SHACK: Yeah.

CHAIRMAN BANERJEE: Instead of black and white.

MEMBER BLEY: I was going back to document, because I could tell on the handouts.

MEMBER SIEBER: I think the PIRT discussion should --

CHAIRMAN BANERJEE: Any other comments?

MEMBER SIEBER: -- lead it to -- you know, I think there should be some clarification on the THIEF model of exactly how you handled the bundling. I mean, I'm down to practical -- you know, it's almost Mark's user manual here, you know. And, you know, when I handle a bundle, I really ignore the bundle and it's the cable. And I looked at the report and I guess maybe it's clear in there, but you might just look at those words a little bit, you know, and how you handle the conduit.

MR. McGRATTAN: You know, Mark had

actually made that same suggestion to make the report more like a user's manual.

MEMBER SHACK: A user's manual.

MEMBER SIEBER: Yes.

MR. McGRATTAN: Which I hadn't intended in the beginning, but it makes sense. Why not?

MR. SALLEY: And my fear is that we're going to put this on. It is in this report in the U.S. and you realize every time we put this out, every other regulatory body around the world looks at us.

MEMBER SIEBER: True.

MR. SALLEY: And they are going to grab this and start incorporating it into their models. And if they do that, I would like them to do it at least right.

MEMBER SHACK: Yeah.

MR. McGRATTAN: Yeah, me, too.

MEMBER SHACK: That's a good idea. I mean, a chapter that's almost a user's manual kind of thing would be helpful.

MR. McGRATTAN: Yeah.

MEMBER SHACK: I'm sure that Sanjoy and Said will have other suggestions.

CHAIRMAN BANERJEE: Said?

MEMBER ABDEL-KHALIK: A lot of work went

into this project. I appreciate the time and effort that was put into it. There is a lot of data, experimental data. As you said, this is going to be very useful for a long time to come. And not just for simple models, but perhaps for much more advanced models in the future.

The one thing I would have liked to see is an estimate of the uncertainty in the experimental data, because that would be very helpful. And that is really what is missing in the data. As far as the model is concerned, I really would like to see a list of the underlying assumptions in the model and a justification for those underlying assumptions, because without that, it just seems like just another empiricism, albeit, a little fancier than an Algebraic formula.

MEMBER SHACK: Right.

MEMBER ABDEL-KHALIK: And therefore, you know, this will require some thought as to what are the underlying assumptions? If you just go by the physical properties that you are using in the model, the row, the C and the K values, and you just basic transient conduction you estimate with the --

MR. SALLEY: Yes, um-hum.

MEMBER ABDEL-KHALIK: -- you know, the

time constant is it's nowhere near what you are actually getting in this. And so why does that work? What are the underlying assumptions? I think that would go a long way towards making the model more believable, rather than a fortuitous sort of result that just happens to model the experiments that have been done.

MR. SALLEY: Right, right. That's fine.

CHAIRMAN BANERJEE: Yes, I think you have got a picture. We -- the Committee has discussed the report before, as you know. And we have responded and I think we have got most of the points we have brought up covered. I would say the point that Said brought up about the uncertainty is -- was also in our assessment of these two reports. It needs to be addressed pretty much head-on, whatever it takes, even if you look at those numbers of the temperatures versus, I forget the thermosetting materials and different things.

You come up with replicated experiments, which show good agreement, but there are few outlier points, which are high heat fluxes, whatever they are. I mean, I think if those are outliers for a good reason, they should be stated. And it should be clarified why they are outliers, because the ACRS is going to get into the details.

If you show that curve, they are going to ask you why are these outliers? And the reports have to reflect that in some way, because people are going to get into the technical details, you know. That is what is going to happen at the Committee meeting. You know how it goes.

So you have to have a pretty good explanation. Now, as we have already discussed the reports, I think the new report is Volume III, which is what will get probably the most attention, because we have already looked at the other two. And, you know, it's important that you present the material briefly and so on, but as you addressed our issues already and you issued the -- addressed the public comments, I think you have gone a long way towards satisfying the ACRS on that.

So it will be Volume III, which I think is relatively new material, and it would be useful to present that in a way which will sort of explain why this thing works, in spite of its simplicity. And that's exactly what Said is saying. He is saying, you know, yeah, it probably works. You know, but why? Tell us that.

MEMBER ABDEL-KHALIK: What are the

assumptions?

CHAIRMAN BANERJEE: Yeah. And I think a little bit more work there to even look at the data and sort of bin it into --

MR. SALLEY: Right.

CHAIRMAN BANERJEE: -- why the trends are there. The second thing would be, as he says, to justify some of the assumptions. If you run it with a copper core and you don't get any difference in the results --

MR. SALLEY: Right.

CHAIRMAN BANERJEE: -- I mean, that's -- then you have to say why you don't get a difference in the results.

MR. SALLEY: Right.

CHAIRMAN BANERJEE: I mean, you know, it's not enough to just show it numerically. It's necessary to put the physics in there. And that's what the Committee is going to be after.

MR. SALLEY: Um-hum.

CHAIRMAN BANERJEE: I'm sure. Once they understand the physics, I think it's going to be --

MR. SALLEY: Right.

CHAIRMAN BANERJEE: -- easy sailing on this.

MR. SALLEY: Right.

CHAIRMAN BANERJEE: Okay. So --

MEMBER ABDEL-KHALIK: Somebody just looking at the --

MR. SALLEY: So for the Full Committee, if I understand it, we have what an hour and a half?

MEMBER SIEBER: Um-hum.

CHAIRMAN BANERJEE: Well, you have two hours, but, you know --

MEMBER SHACK:Probably an hour and a half.

CHAIRMAN BANERJEE: But look at it this way. There will be so many questions, that if you even plan for an hour, it will probably take two hours.

MR. SALLEY: Okay. We want to -- let me see if I have your recommendation. I want to do a quick recap on the Volume I and II and say this is what we've got.

MEMBER SIEBER: While you --

CHAIRMAN BANERJEE: And the RIS, and the RIS.

MR. SALLEY: And the RIS. And here is how the Bin 2 items, basically, shook out and in pretty much of a summarily type approach.

MEMBER SIEBER: Here are the results.

MR. SALLEY: And I want to leave more time for the Volume III, which will be new material and spend a little more time going through Volume III for a whole host of reasons with the group. Is that the--

CHAIRMAN BANERJEE: And we'll try to move it along.

MR. SALLEY: Okay.

CHAIRMAN BANERJEE: But, you know, otherwise, in the first two slides, you're going to get stuck for half an hour, of course.

MR. SALLEY: Of course. And the PIRT, we will just leave that at the sub-Committee level?

MEMBER SIEBER: Right.

CHAIRMAN BANERJEE: Right now --

MR. SALLEY: You've been informed on the PIRT.

MEMBER SIEBER: Yeah.

MR. SALLEY: And you know what we did.

MEMBER SHACK: There is certainly enough to get through at the Full Committee without trying to bring that in, I think.

MR. SALLEY: Okay. So the PIRT won't even be on it, right?

CHAIRMAN BANERJEE: And anyway, when you finish the report on the PIRT or something, that would be the right time probably, if you want the Full Committee to look at it.

MR. SALLEY: I don't even know that we would need that. I mean, PIRT is what it is. I can't go back to the experts with a sharp stick and say change your answer, you know.

MEMBER SIEBER: No, we can't.

MR. SALLEY: I'm stuck.

CHAIRMAN BANERJEE: Yes, so the PIRT is the PIRT.

MEMBER ABDEL-KHALIK: You would, of course, need to describe both the small-scale and the intermediate-scale experiments.

MR. SALLEY: Yes.

MEMBER ABDEL-KHALIK: Just so that people will -- would know physically what was done, what the experiments were about.

CHAIRMAN BANERJEE: Yes, the PIRT, of course, if it leads to some impact on your proposed research and things like that in the future, and if you have any wish to consult with ACRS on that, that might be of interest to me.

MR. SALLEY: Yeah, I think that's where it is going to be used in the future or three years from now and I'm sitting here telling you about the experiments that we're running. The question will be coming up how did your PIRT rank that this far? And I think that's where I see it being used down the road to be truthful.

CHAIRMAN BANERJEE: Okay.

MEMBER SHACK: Just to back up to Said's thing on the uncertainty and even your comment, you know. People are going to use this data. So when they look at those failure times and they have got those ones way up high there, you know, if those -- if there's a reason why those really shouldn't be on that plot, they should probably even vanish from the plot.

MR. NOWLEN: Understood.

CHAIRMAN BANERJEE: I would keep them on with an explanation.

MR. NOWLEN: With an explanation.

MEMBER SHACK: Yeah.

CHAIRMAN BANERJEE: All data is --

MEMBER BLEY: Well, I know, but if somebody is going to take an average for a failure time by going through that curve --

MEMBER SHACK: That's not a good idea.

MEMBER BLEY: -- it's not a good idea.

MEMBER SHACK: I mean, that just got me nervous about thinking that, you know, this is going to be out there.

MEMBER BLEY: Well, I think that should be --

MEMBER SHACK: People don't read the fine print. They -- I mean, there is at least a third dimension there, if not four, and most can cover that if they are on the figure.

MR. NOWLEN: I'll let --

MEMBER SHACK: Don't want to leave it out there naked.

CHAIRMAN BANERJEE: I think it was very useful. This was a very good meeting and I would like to thank you. We were very happy to hear about CAROLFIRE and, you know --

MEMBER SHACK: And bring your toys along.

CHAIRMAN BANERJEE: Yes, definitely.

MR. SALLEY: Oh, absolutely, yeah, yeah.

CHAIRMAN BANERJEE: All of the aids you can get.

MR. SALLEY: All right.

CHAIRMAN BANERJEE: Sorry.

MEMBER BLEY: One last thing.

CHAIRMAN BANERJEE: Yes.

MEMBER BLEY: You told us some this morning and I guess I chatted a little with you at lunch, and I don't remember what was in the report on this, but the difference between the previous tests and this one, I think, people would be very interested in at least what you have told us here.

MR. NOWLEN:Yeah, because there is actually a section in the report that covers what is unique about these tests. And we had to -- you know, NEI didn't want to say they were bad, we were better. So we adjusted all of that a little bit. But there are comparing contrasts, what's different about ours compared to the earlier tests and why did we do it that way.

MEMBER SIEBER: Some of them were moved.

MR. SALLEY: We actually --

MR. NOWLEN: So we tried to --

MR. SALLEY: -- had --

MR. NOWLEN: I didn't cover that here.

MR. SALLEY: We actually had a big thing and it kind of painted a picture like maybe we were heros and maybe those before us were less than heros.

MR. NOWLEN: Unintended, of course.

MR. SALLEY: Unintended. You know, one series did this and we did this and here is the difference and why. And I think we removed that.

MEMBER SIEBER: Yes, because you're

preparing for the cost.

MR. NOWLEN: Put some of it out. We softened a lot of the --

CHAIRMAN BANERJEE: Well, still it motivates what you're doing, so --

MR. SALLEY: It is a natural evolution. Whoever comes second, if they paid attention to what the people did first, they would learn. I mean, that's just the evolution of research.

MR. NOWLEN: In a sense, we are trying to sort of preempt those comments and would say oh, none of this is real. This is all so fake, it's ridiculous. Why are you even thinking it? We were kind of trying to head that off and we probably went a little too far. So they said oh, quite beating up our tests so bad.

CHAIRMAN BANERJEE: Okay. I think we are done then. So thank you, gentlemen.

MEMBER SIEBER: Thank you.

CHAIRMAN BANERJEE: Thank you. We're going to adjourn.

MR. SALLEY: Thank you.

CHAIRMAN BANERJEE: We're adjourned.

(Whereupon, the meeting was concluded at 4:22 p.m.)