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UNITED STATES NUCLEAR REGULATORY COMMISSION'S

ADVISORY COMMITTEE ON NUCLEAR WASTE

September 21, 2006

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON NUCLEAR WASTE (ACNW)

173rd MEETING

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THURSDAY,

SEPTEMBER 21, 2006

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VOLUME IV

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The Advisory Committee met at 8:30 a.m. in Room T-2B3 of the U.S. Nuclear Regulatory Commission, One White Flint North, 11555 Rockville Pike, Rockville, Maryland, DR. MICHAEL T. RYAN, Chairman, presiding.

MEMBERS PRESENT:

MICHAEL T. RYAN, Chairman

ALLEN G. CROFF, Vice Chairman

JAMES H. CLARKE, Member

WILLIAM J. HINZE, Member

RUTH F. WEINER, Member

NRC STAFF PRESENT:

CHRIS BAJWA

EARL EASTON

JOHN T. LARKINS, Executive Director, ACRS/ACNW

MIKE LEE

DEREK WIDMAYER

ALSO PRESENT:

HAROLD ADKINS, Pacific Northwest National Laboratory

I-N-D-E-X

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

(8:35 a.m.)

28) OPENING REMARKS BY THE ACNW CHAIRMAN

CHAIRMAN RYAN: We will come to order. This is the fourth day of the 173rd meeting of the Advisory Committee on Nuclear Waste. During today's meeting, the Committee will consider the following: disposition of public comments on spent nuclear fuel transportation package responses to tunnel fire scenarios, NUREG CR-6886 for the Baltimore tunnel fire and NUREG CR-6894 for the Caldecott fire.

We completed our discussions of letters on Monday. So we will not have any detailed discussions other than those appropriate to the creation of letters from the two-day working group that we had on modeling and monitoring.

The meeting is being conducted in accordance with the provisions of the Federal Advisory Committee Act. Mike Lee is the designated federal official for today's initial session.

We have received no written comments or requests for time to make oral statements from members of the public regarding today's sessions. Should anyone wish to address the Committee, please make your wishes known to one of the Committee staff.

It is requested that speakers use one of the microphones. In a small room, that might not be too hard to do. And speak with sufficient clarity and volume so they can be readily heard. It is also requested that if you have cell phones, you kindly turn them off. Thank you very much.

Without further ado, I'll turn the session over to our progressive member, Ruth Weiner. Ruth?

MEMBER WEINER: I can borrow an agenda?

CHAIRMAN RYAN: Please.

MEMBER WEINER: Our speakers today are going to be Earl Easton and Chris Bajwa, who will discuss the Baltimore and Caldecott tunnel fire studies. I understand the draft document was issued. There were comments on the draft document. And one of the points of the discussion will be the resolution of those comments.

<u>29) DISPOSITION OF PUBLIC COMMENTS ON</u>

<u>SPENT NUCLEAR FUEL TRANSPORTATION PACKAGE</u>

<u>RESPONSES TO TUNNEL FIRE SCENARIOS</u>

MR. EASTON: Good morning. Thank you, Dr. Weiner.

Today myself, Earl Easton with the Spent Fuel Project Office; Chris Bajwa; and Harold Adkins will be going over the responses to the two studies we did: one on the Baltimore tunnel fire, which was a rail tunnel fire; and the Caldecott tunnel fire.

These were published last fall. They were put out for publish. These were published in draft. They were put out for public comment. We did receive a number of comments, both from the public, from the ACNW, when we initially briefed you on the Baltimore tunnel fire. We had a number of internal staff comments. And, of course, the last thing we would like to focus on is your questions because they have always been helpful in guiding us.

To start with, we got comments from four sources from the public request. And they were from the Northeast High-level Radioactive Waste Transportation Project; the Brotherhood of Locomotive Engineers and Trainmen; the State of Nevada, their agency for nuclear projects; and one from a private individual.

I think we circulated these last night to the Committee electronically. And what I'm referring to is an appendix which will be in the back of the study, which is a more detailed discussion of how we addressed each specific comment with more detail than the ones that we're going to discuss today.

Today's approach is basically we sorted

the comments and sort of picked out what we thought were the major areas of focus. And those are the comments we got on the location, severity, and duration of the fire; the fact that the initial study did not consider lead melt for the NAC-LWT TCAST; the composition that we assumed for CRUD. We assumed it was all cobalt-60 for simplicity.

We had a comment on the potential loss of lead shielding. We had comments on how do you consider fuel that might be damaged or high burn-up, brittle at being shipped. We had some comments on the performance of cask seals.

And we also had some comments, "Well, this is just really basically looking at the consequences. Can you put it in some sort of risk perspective?" And, again, there were some individual comments in appendix G that are more specific topics that we won't really discuss unless a question comes up that you might have.

Again, just to set the stage, this is our basic model that we used. There was no spent fuel cask in either one of these accidents. So we're playing a "What if?" game. The model assumed a tank car, a buffer car, and as spent fuel car. And, of course, they're separated by about 20 meters in the model.

The fire started in a leak in the tank car and then engulfed the whole tunnel. Basically it burned in a pool area. And that fire heated the tunnel, which then re-radiated heat into the cask. And that's basically the model.

We use a duration of 7 hours followed by 23-hour cool-down. During that cool-down, of course, the tunnel is continuing to radiate heat. And we got the temperature profiles primarily from work done by the National Institute of Standards and Technology, NIST.

The first area that I am going to address it the location, intensity, and duration of fire. Comments basically were, did you put the cask close enough to the fire? Would it have been worse had you have placed the cask closer to the tank car?

The duration of the fire, couldn't it have been more than seven hours? Is that the appropriate length of time? And couldn't the fire have burned hotter?

First, addressing the location of spent fuel cask, we would call the attention of the Committee to requirements that DOT has on the placement of spent fuel and high-level waste in trains. They have a regulation -- it's 49 CFR 174.85 -- that requires a non-placarded, nonhazardous car to intervene between spent fuel casks and any other class of hazard, such as flammable liquid.

This is a depiction of an actual shipment, spent fuel cask in the middle. You see the two buffer cars. The tank car if it had been present in this shipment would have been on either side of those two box cars, but that's to give you an indication of the spacing.

When you apply that, when you look at what really happened at the tunnel -- and this diagram in the upper left-hand corner is modified from the National Transportation Safety Board report, but this is a sketch -- cars 47 through 55 derailed. Car 52 was the tripropylene tank car.

So had theoretically a spent fuel cask been in that manifest for that train, it would have been perhaps in site 54 or site 50 with 51 and 53 being the buffer cars. Okay?

Could you have gotten the tank car closer? Well, if you look at a schematic of the tunnel looking end on, you see that there is not really much room to go around a tank car. And there's not really much room, really, to go override a tank car for the --

should I say the buffer car.

If you look top view, we have 3 rail cars basically 60 feet -- dueling lasers here. We have 3 rail cars roughly 60 feet in length. The tunnel is about 15 feet. And even if you try to squeeze them together, you don't really get much closer. So we think, really, what this indicates is the effectiveness of the DOT rule. This is, indeed, why the rule was implemented.

The fire intensity. Let me just go over how we derived the intensity that was used in the study. When we had NIST actually go and analyze the fire, they calculated based on their models -- and, again, their models are benchmarked in actual tunnel fire experiments -- that the amount of heat input would have been around 1.7 times 10^8 Btu, or 50-megawatt, fire.

They predicted in the first half-hour to an hour that the fire would become oxygen-starved. And this is a picture from their report that they used to explain that. Fresh air is trying to come here, and it gets entrained here. And it's being forced back out on the sides. And it's being used, oxygen is being used, at a much faster rate than it can enter into the tunnel.

Again, this is in an unventilated tunnel. Some tunnels are ventilated. They predicted a peak temperature in the range of 1,800 to 2,000 degrees roughly. And the hottest temperature that their model predicted were really within the first half-hour but within the first hours, to be certain, was about 1,472 degrees Fahrenheit at the ceiling above the source of the leak. And the peak ceiling temperature at the cask surface, which is, again, some 60 feet down, only rose to 752.

This is their actual prediction modeling of the fire as it occurred. Okay. What did we use? We assumed an intensity ten times this high. We assumed a 500-megawatt fire, 1.7 times 10^9 Btu per hour. And how did we get that fire? Well, in the model we actually had to physically punch holes in the tunnel to get in enough oxygen. You know, this is stoichiometric for the chemical engineers in the audience.

We actually burned all the fuel. We know in the real accident that some of the fuel didn't burn. I know my colleague Chris has found news articles that a day or so later some sewer lids had popped because some of the propylene had migrated and had pockets. But NIST told us a lot of this probably just vaporized or soaked into the ground and really didn't participate in the initial fire.

We assumed that it was all burned and none lost to vaporization or seepage. That led to a peak temperature of 2,084 in the flame region, which is a little higher. And the temperature at the cask, where you have the ceiling, the brick ceiling, above the spent fuel cask, where it would have been placed, about 1,830-some degrees Fahrenheit. And that lasted for over three hours in their seven-hour model, seven-hour fire.

So we believe that we appropriately modeled an intensity that is realistic. The duration, the Baltimore tunnel fire lasted --

CHAIRMAN RYAN: Let me ask you a question. How is it realistic if it's ten times more the realistic envisions? It's a bounding case.

MR. EASTON: Right.

CHAIRMAN RYAN: A couple of things strike me. One is -- and, you know, I understand what you did, but you got very significant digits on temperatures, like three.

MR. EASTON: Right, right.

CHAIRMAN RYAN: And, yet, you assumed ten times higher. So some of the specificity that you have in your slides and then just jacking up by a factor of ten notes you will be exactly consistent.

MR. EASTON: Okay. Good question. When I say realistic, this tunnel was not ventilated. In real life, sometimes you have tunnels that are ventilated. You could get oxygen flow.

So what we did is we said if you got to all the oxygen flow that you needed to support the fire, how big would it be? And this is where we came up with a factor. It could be a factor of ten times higher. So it is more realistic if you have a ventilated tunnel.

Does that answer?

CHAIRMAN RYAN: It does. Does the document explain the basis for the factor of ten?

MR. ADKINS: Yes. It's in the NIST document, the document --

CHAIRMAN RYAN: It's in a different document. That's not as high-focused in your document. And you explain the basis.

MR. ADKINS: Actually, we have added verbiage over that. Harold Adkins from PNNL.

We have gone ahead and added verbiage to the document that explains the fact that it could have been a tunnel that involves ventilation, like current tunnels, because this tunnel is fairly old and then also the potential for the fuel not to seep or anything else like that into the ground or not participate in the combustion process.

CHAIRMAN RYAN: So the factor of ten is probably a realistic scenario --

MR. ADKINS: Yes.

CHAIRMAN RYAN: -- based on your other assumptions?

MR. ADKINS: Yes.

CHAIRMAN RYAN: Okay.

MR. ADKINS: If the fuel is not to seep or go below into the water drainage system or what have you and then there is enough oxygen to participate in the combustion process, those are the numbers that you would come up with.

CHAIRMAN RYAN: Okay. I think that's a very important distinction because when you say, "We assume ten times more," that sort of gives the impression that you're --

MR. ADKINS: Yes.

CHAIRMAN RYAN: -- in a world that's way above reality, but what I'm hearing now is we're probably on the center line of reality.

MR. ADKINS: Right. And we wanted to make sure of the potential, you know, if there was another tunnel or scenario that --

CHAIRMAN RYAN: Yes. If it was as clearly laid out in the document, I think that's helpful. But if it just looks like you assumed a factor of ten higher for no apparent reason, that's not good.

MR. ADKINS: Understandable.

CHAIRMAN RYAN: Okay. Great.

MR. EASTON: And I should mention that all of the comment areas that were gone over, substantial revisions were made to the document.

CHAIRMAN RYAN: Fair enough.

MR. EASTON: Okay. And then we tried to link it back to the original document, too.

The NIST analysis used pool size, a reasonable pool size, because that determines how fast the fuel was consumed. So it basically is roughly a 25-foot by 25-foot or the footprint of a tank car, a rail car as the pool size. And if you supply it with all the oxygen it needs, it would consume that in about 6.7 hours. We think that to be a reasonable proximation.

Just to give you a little linkage to some of the other studies that we have done, 6672 was a major examination of spent fuel shipment risk.

They have a table in that document that says 99 percent of large train fires last less than 7 hours. And they also have in there experimental data which say that a fully engulfing fire would under a rail cask last approximately 7 hours, too.

CHAIRMAN RYAN: What about those one percent?

MR. EASTON: What about the?

CHAIRMAN RYAN: The one percent? Are they three days or a week?

MR. EASTON: No. And, again, this in 6672 was an interpretation of FRA data. We have gone back and looked at FRA data.

CHAIRMAN RYAN: I lived in Augusta, Georgia, near Augusta, Georgia. And there was a train that burned for four days there. So, I mean, is it a big difference?

MR. EASTON: No.

CHAIRMAN RYAN: How do we know that?

MR. EASTON: Well, when you say that the fire lasted for four days, I think you've got to be very careful.

CHAIRMAN RYAN: Why not?

MR. EASTON: For example, the train --

CHAIRMAN RYAN: The train was engulfed,

all the cars, for four days.

MR. EASTON: Yes.

CHAIRMAN RYAN: It burned like crazy. Towns were evacuated.

MR. EASTON: Right. But that's not unusual because if you have, like, for example, a propane tanker on fire, it will get a hole and it will leak some out. And it will catch fire. And then the standard practice is not to put that fire out unless you can plug the leak. And sometimes these things take 15 days to burn out.

They look like they're fully engulfing. Firemen are cooling the other end to keep it cool so it doesn't levee. That's why you have people evacuated for the time length.

CHAIRMAN RYAN: Again, what I'm reaching for is all that rich detail which helps you understand that 99 percent of large train fire last 7 hours or less.

MR. EASTON: Right. We're going to get --

CHAIRMAN RYAN: I need to know about the other one percent to know I'm comfortable with that.

MR. EASTON: Okay. We're going to get to that a little later on.

CHAIRMAN RYAN: Fair enough.

MR. EASTON: We're going to get to that a little later on when we put it into risk perspective.

CHAIRMAN RYAN: Ah. Now we're talking.

MR. EASTON: Okay?

CHAIRMAN RYAN: I'll wait.

MR. EASTON: Okay.

CHAIRMAN RYAN: Now you know where I'm going.

MR. EASTON: Yes, yes. And that's where we were headed, too, I think.

CHAIRMAN RYAN: Great.

MR. EASTON: So, in conclusion, on these comments, we think that the location selected based on the regulatory requirements for shipments was realistic. We think the intensity and duration modeled exceeded those in the actual tunnel fire but adequately reflect maybe a more severe fire that could be fully oxygenated.

And we think that we -- well, we know that we amended the report to include a lot of this information. We put tables and charts and that sort of thing. So that's really how we handled that series of comments.

The next one I'm going to turn over to Harold, who was the chief modeler. And this addresses

I guess Dr. Weiner's comment on the lead melt.

MR. ADKINS: Musical chairs. Again, Harold Adkins from PNNL.

One of the comments issued by the ACNW is that within the reports of Baltimore and the analysis, of course, Baltimore and Caldecott tunnel fire studies, we didn't consider lead melt and that not modeling of lead melt could affect the outcome of the analyses in two ways. For one, it would yield non-conservative results from the shielding standpoint if you had lead slump and then an extra-conservative result from the perspective of internal temperatures within the cask.

We went ahead and updated. To address this question, we went ahead and updated the model of the LWT and to include the effect of lead melt.

What we have here, just to show, I guess, that we have the latent heat effusion taken into account is when you consider different points along the cask as a function of time as it approaches, as we consider locations where there's a little larger lead volume, going across the cask to points where there is also somewhat of an insulative barrier after the neutron shield ruptures, we get an arrangement where basically the temperatures rise, plateau, plateau off, and then we'll hold until they melt. And then after melting, we'll continue to rise again. And then, of course, on the way down, they'll plateau again and level off until the effects of the lead solidifying have gone away.

The net effect of modeling this is we did obtain some margin, minor additional margin, on the peak clad temperatures for the time history. And what you see here is basically the dashed line is neglecting the thermal effects of lead melt and then, of course, including the effects of lead melt. And these are the peak clad temperatures in reference to the ruptured temperature.

MEMBER WEINER: Is that peak clad temperature the same one you had in the draft report?

MR. ADKINS: Yes. The neglecting right here, the dash.

MEMBER WEINER: Yes.

MR. ADKINS: Then the solid is, of course, including the lead melt. Average temperatures, there's a little more margin presented, of course. The last one I think we're about 100 degrees different. Here we're about 120 degrees different and, again, with quite a bit of margin to cladding rupture, which is primary containment boundary.

The next effect of the seals is somewhat negligible simply due to the fact that they are outboard on the outside surface of the cask for the most part with the exception of the cask closure lid seals. As you can see here, the plots almost identically overlay.

CHAIRMAN RYAN: Excuse me. Could you just refresh us a little bit on the heat load that permeated that curve? I noticed it's a 30-hour curve.

MR. ADKINS: Sure, sure. There it is. Let me make sure I understand the question. Mainly you're asking me what is causing the effect for the temperature rise from initiation of the fire --

CHAIRMAN RYAN: What were the input assumptions to make the temperature go up and then come back down? Is that a five-hour, six-hour fire or so?

MR. ADKINS: That's a 6.67-hour fire, yes. And what it was was the second case that Earl explained that you had questions on regarding the magnitude.

CHAIRMAN RYAN: Thanks.

MR. ADKINS: And I guess obviously including the lead melt provides a more realistic analysis and demonstrates additional margin with regards to the fuel cladding. And the report has been modified with the results and conclusions associated with those additional analyses. And a very good comment, Dr. Weiner. Thank you.

Next I believe it's Chris Bajwa. Are you back on stage? Thank you.

CHAIRMAN RYAN: Thank you.

MR. BAJWA: I am Chris Bajwa. I am a thermal reviewer in the Spent Fuel Project Office. And I am going to talk about something that's a little bit outside my area of expertise, but hopefully I can do well with it here.

One of the questions that we had from the ACNW was about the assumption that we made that 100 percent of the CRUD that can come off the fuel rods was cobalt-60, that that was the main radionuclide constituent of the CRUD. And the question is, is that a valid proximation? And how would it affect the doses in this case of any particular release?

We did a little homework on this. And much of the information that we found came from a Sandia report on the estimate of CRUD contribution to shipping cask containment requirements and that Sandia 88-1358. This table is actually right out of that particular report.

It turns out that you can see here that for a PWR assembly, which is what we're considering for the NAC LWT, the total activity decreases to about -- these numbers are in the report. And then I'll explain the graph that's there.

The total activity for a single PWR assembly decreases to three percent of that at discharge after five years. So this is discharge from a reactor to the spent fuel pool. And five years after that, you have only three percent of your total activity. And then it decreases to one percent after 13 years.

CHAIRMAN RYAN: Why is total activity up there?

MR. BAJWA: Why is total activity?

CHAIRMAN RYAN: Yes.

MR. BAJWA: Well, in this case, that's just a little background on --

CHAIRMAN RYAN: Oh, okay.

MR. BAJWA: -- what we're doing with this. And then the cobalt-60 in that accounts for 92 percent of that total activity at 5 years and then 99 percent of that total activity at 8 years.

So if you look at the graph here, you see these constituents: cobalt-58, manganese-54, and cobalt-60. The cobalt-60 is really the bad actor, so to speak. That's the one that you're most concerned with as time goes.

CHAIRMAN RYAN: Well, I've got to probe this a little bit if you don't mind.

MR. BAJWA: Okay.

CHAIRMAN RYAN: This is a whole bunch of other things, like the iron, manganese, magnesium, other things. And it is real easy just to collect them all up, analyze it.

I know cobalt is always picked on as the double gamma ray and it's the only one that's transmitted through, but I wonder about that.

MR. BAJWA: Okay. Well, part of the other thing, too, that we looked at is the fact that cobalt-60 is in this case a limiting A2 value as well when you're talking about dose. So the A2 value is sufficiently less than some of the other constituents here.

CHAIRMAN RYAN: I guess I'm making the point that it's real easy to know the exact inventory and then just calculate the transmission for everything. That way you're not guessing or compromising the inventory.

MR. BAJWA: That's true, yes. One of the

things, though, that we have seen in this calculation that we have done, too, is that the increase in the actual release will be very small, even if we did count those other constituents.

CHAIRMAN RYAN: Oh, we've got a release now. All bets are off. Cobalt is not important.

MR. BAJWA: Cobalt is not important?

CHAIRMAN RYAN: It's unimportant. Plutonium, curium, all things --

MR. BAJWA: Oh, yes, sure.

CHAIRMAN RYAN: What is the magnitude? So if you're looking at an internal exposure, the game is different.

MR. EASTON: He's talking about just the release of CRUD.

MR. BAJWA: Right, in this case.

CHAIRMAN RYAN: Release of CRUD to what?

MR. EASTON: To the outside.

MR. BAJWA: To the outside.

CHAIRMAN RYAN: All bets are off. Cobalt is not important.

PARTICIPANT: I think it's a simple release of CRUD without breach --

CHAIRMAN RYAN: Without breach?

MEMBER WEINER: Without breach of the --

CHAIRMAN RYAN: He said to the outside. So that's a whole different ball game. Cobalt is important. I'm backing up.

PARTICIPANT: We'll get to the others.

CHAIRMAN RYAN: All right. Fair enough.

MR. BAJWA: So consequently, just as another note, for five years of something that's called "five years," the hottest assembly that you could put in any of these casks that we're analyzing. So basically what we have presented here as far as CRUD, we think that it is a reasonable constituent.

This is the same thing for BWR assemblies with maximum CRUD spot activities. For BWR assembly, the total activity decreases to 31 percent of that at discharge after 5 years and a one percent after 30 years. And in this case, cobalt-60 accounts for 98 percent of that activity at 5 years.

CHAIRMAN RYAN: Can I ask another dumb question? Why is cesium not on the radar screen here?

MR. BAJWA: For the CRUD, I don't believe the cesium --

CHAIRMAN RYAN: It's still in the fuel.

MR. BAJWA: It's still in the fuel, yes, but for the --

CHAIRMAN RYAN: It's about 25 percent of

the total gamma ray transmission if you've got cobalt and cesium.

MR. BAJWA: Well, we actually are going to talk about what might come out of the fuel. And then cesium becomes the major player there. But for the CRUD, cobalt-60 is considered to be reasonable for CRUD deposits for --

CHAIRMAN RYAN: Again, I hate to be thick, but I'm struggling with release of CRUD. Release of what CRUD to where from where?

MR. BAJWA: Basically the CRUD that we're talking about is a deposit that is on the surface of the rods in the fuel assembly.

CHAIRMAN RYAN: Right.

MR. BAJWA: And so if there is a seal failure, in this case we're basically postulating that because the seals have breached their surface temperature, they go away. So there is a possibility that you could have some release from the internal cavity of the cask into the atmosphere. In this case, what we're taking into account for is --

CHAIRMAN RYAN: You just told me it's inside the cask.

MR. BAJWA: Inside the cask, right, inside the cask cavity. We're assuming intact fuel.

CHAIRMAN RYAN: Yes.

MR. BAJWA: So all we're having --

MR. EASTON: Cladding hasn't failed.

MR. BAJWA: Right. Cladding hasn't failed.

CHAIRMAN RYAN: That's the hook I needed. Okay. Thanks.

MR. BAJWA: Okay. And we do go into details as to the additional rationale for the selection of cobalt-60 to represent the CRUD in the report. So this is captured in the report.

And I'll let Earl take over and talk about loss of lead shielding.

CHAIRMAN RYAN: Thanks.

MR. EASTON: Musical chairs here.

Again, one of the comments that we got -- and this I think came primarily from the Brotherhood of Railroad Engineers and dealt with the protection and the safety of their workers -- was that we did not consider the possibility of loss of lead shielding; that is, the lead exceeding its melting point and somehow slumping because, again, this was not that type of accident that could result in any impacts that would breach the outer containment wall of the cask. So we're just talking about lead.

We went back and consulted primarily with Sandia National Lab, who had done some work in this area. And what we did is we talked to them about a particular model when they had analyzed this issue before. The model is pretty simplistic. It starts out before the fire. This is the lead shielding. And this is the one fuel assembly.

What we did as a result of the fire, we let the lead shielding expand. We held the inner wall constant in diameter. We let the lead expand. And we let that push out the outer wall. We didn't take any credit for when it cools down. That outer wall may come back and squeeze the lead back in place.

So the volume that the lead expanded to is basically this volume here. So we said that the lead sunk back down when it solidified as sort of a bounding case, and it left a void. Okay? We don't think that there are scenarios that a void would be bigger, larger than that in any particular area. It would be very unlikely.

And we did calculations based on the shielding. Sandia did calculations. We did independent calculations. We basically came up with the same answers.

What that showed is as a result of the

fire in this void, the dose rate went up at one meter from 14 millirem to hour to about 330. That was still within the regulatory limit that we allow after a hypothetical accident condition of 1,000. There is no regulatory dose rate at the surface, but you can see the surface rate did go up appreciably.

CHAIRMAN RYAN: Why are you using sieverts?

MR. EASTON: Why what?

CHAIRMAN RYAN: Why are you using the International Units? I didn't know the NRC had converted to this.

MEMBER WEINER: I think both of them.

MR. EASTON: Well, the transportation --

CHAIRMAN RYAN: No, not both of them.

MR. ADKINS: Here, right here.

MEMBER WEINER: Yes. You have millirems per hour and millisieverts per hour.

CHAIRMAN RYAN: Oh, it's 1,000 millirem per hour. Okay. Millisieverts. Okay. I'm reading. Sorry. The other challenge is, how can you have five significant digits? Please stop doing that to yourselves.

MR. ADKINS: You got me on that one. I surrender on that.

(Laughter.)

MEMBER WEINER: What did you use to calculate the shielding? Did you use microshield or --

MR. EASTON: Yes, microshield.

MEMBER WEINER: Okay.

MR. EASTON: Some of your I guess colleagues at Sandia use microshield to help.

MEMBER WEINER: Yes.

MR. EASTON: And we reran all the calculations to make sure. And we worked with Doug Ammerman to make sure that the structural modeling is internal.

And, again, this chart, these diagrams, are included in the report now in a discussion. So we believe -- and, again, this is --

MEMBER WEINER: Excuse me, Earl. Did you include the microshield model in the report?

MR. EASTON: You mean the actual data from the --

MEMBER WEINER: Yes, the actual. Yes.

MR. EASTON: No. We just basically put these tables in so we were in these calculations. And we didn't actually.

So we believe that even for the case of

lead melt and resolidification, that the doses would remain below the regulatory limits for hypothetical accident conditioned under Part 71. And we have revised the report to reflect that.

We do appreciate that comment. We think it was a good comment. We had focused only on the releases. And we think that was, again, a very good comment. And that made the report much more complete.

Okay. Chris is going to come back up and handle this tough one with the cesium, and I'll be here to help him.

MR. BAJWA: I always appreciate Earl's help on these things.

All right. So we're going to talk about the effects of damage and high burn-up fuel. In the original studies, we didn't deal with either high burn-up or damaged fuel.

We did have several comments on this, both from the public and from the industry. As we presented the results in different industry forums, the question came up. And so we decided that we definitely needed to take a look at this.

The releases that we're talking about are actually from the NAC LWT cask, which is in this case carrying a single PWR assembly. And the reason that we don't consider damaged fuel or high burn-up in the other casks that we looked at, the TransNuclear 68 and the HighStar 100, the TransNuclear 68 is not licensed to carry damaged fuel. So it would not have a payload that would include damaged fuel.

The HighStar 100 has an inner canister that is welded. And that in our analysis thermally did not fail. So there is nothing available for release from the HighStar 100, even if it was carrying damaged fuel. So that's why we're only looking at the NAC LWT here.

We went to NUREG 6672, which has been mentioned a couple of times. And in that document, they actually have an analysis that is done for truck cask in a severe fire. And they looked at the releases that could come from damaged fuel.

The fuel that they used in their analysis was high burn-up. It was 60 GWD per MTU. And they assumed that there was a 100 percent burst of all the fuel rods and that the temperatures were high enough to volatilize cesium.

So this is essentially worst-case scenario in terms of they didn't project that only a percentage of the fuel was failed. They said all of it was failed.

And so the release fraction that's calculated in that document for cesium-137, which we believe is the bad actor here, for severe fires is 100 percent rod burst at 1.7 times 10^{-5}. That particular release fraction is a number based on essentially a seven-factor formula.

And it includes the fraction of cesium present in the fuel assembly, in this case a single PWR fuel assembly, that's available for release, the fraction that plates out. So they assume that some of it does plate out before it gets out or is deposited on the internal cavity of the cask as well as the differential pressure between the cask cavity and the atmosphere and to allow the release.

EXECUTIVE DIRECTOR LARKINS: So what fraction of the cesium inventory does this represent?

MR. BAJWA: I think the number is -- well, it's 1.7 times 10^{-5} is the release fraction for cesium-137. So that's the fraction that you multiply by the total activity of the cesium in that PWR assembly to get the release, which in this case is 1.4 curies. So you take --

EXECUTIVE DIRECTOR LARKINS: Okay.

MR. BAJWA: It's in that formula. You take the release fraction. You multiply it by the total activity that you have for cesium-137 for a single PWR assembly. And that's how you determine what the release is.

MEMBER WEINER: What did you assume for the internal temperature of the cask to get plate out at the walls? Because if the internal temperature of the cask is the same as the external temperature, I don't see where anything is going to plate out. It has to be a little cooler.

So what kind of assumptions were made for the internal cask temperature? Was that during the seven hours of the fire the internal temperature hadn't reached the external temperature or what?

MR. BAJWA: In this case the calculation I think assumes a cooler temperature allow for the plate out. So I don't know exactly what -- it might have been assumed that the internal temperature is at the temperature of the fuel rods bursting, which I believe is 750 C.

And then the external temperature is the fire. And the interior would definitely be cooler to allow for the mechanism. Otherwise you wouldn't take credit for it. So that's a good point.

CHAIRMAN RYAN: Did you do any follow-up analysis with the 1.4 curies in terms of exposure scenario to individuals or how did you handle that 1.4-curie release?

MR. BAJWA: Well, basically the 1.4 curies is 10 times less than the A2 for cesium-137. And the A2 obviously is based on dose. So in this case, we are focused on the A2 value.

CHAIRMAN RYAN: So A2 was just the metric you stopped at?

MR. BAJWA: Pretty much.

CHAIRMAN RYAN: Okay.

MR. BAJWA: So the potential releases for damaged or high burn-up fuel are less than the regulatory limits. In this case, the A2 value is our benchmark that was established for transport safety.

And the report actually includes a new section that details this evaluation, goes into the calculation, explains the seven-factor formula and whatnot.

MEMBER WEINER: What happens if you don't assume plate out?

MR. BAJWA: Your release would increase.

MEMBER WEINER: Yes. Did you do that quantitatively, look at that?

MR. BAJWA: We did not do a sensitivity on plate out.

MEMBER WEINER: Okay.

MR. BAJWA: We just assumed that that is a reasonable mechanism. So we didn't look at that.

CHAIRMAN RYAN: Did you say you have got a margin of about a factor of ten between?

MR. BAJWA: Yes, the A2 for cesium-137 is 14, 14 curies.

CHAIRMAN RYAN: Right.

MR. BAJWA: So Earl will talk about performance with cask seals.

MR. EASTON: And, again, this whole issue of cesium is more fully described in the 6672, which is based on experimental studies, the vapor pressure on various cesium salts, temperatures and that sort of thing. So we just basically adapted that.

One of the comments we got is about the failure of seals. And, again, I would like to emphasize that we didn't take any credit for any of the seals in calculating these release fractions. We really took credit for the small clearances between the lid and the cask body.

And so we didn't really go too much into a discussion of cask seals, although we have talked to research about doing some additional confirmatory research, maybe about looking at how seals behave in severe fires or how those clearances behave in severe fires.

So basically we just pointed out again that we didn't take any credit for seals. One might ask, why are the seals really there if you don't take any credit?

Well, remember when you ship under normal conditions, the release rate is based on the very strict health physics model, where you have to be in close proximity for a year and you count up everything over that year. So it has had a very, very tight release rate. And to get that, you have to have a very, very sensitive seal. And you have to have a strong clamping force.

So a lot of the function of the seal is to make sure you comply with normal conditions of transportation. We had that extra margin to extend it out to hypothetical accident conditions, but a lot of the containment is providing and keeping the cladding intact and keeping that clearance small and fast. And we did add some language to the report.

I just wanted to emphasize here that we only got one comment on the Caldecott tunnel fire. And that comment focused on -- I guess we got a comment from an individual that was with the

California Highway Patrol and commented that the report in NTSB was different and could we reconcile that.

And I think we said, "Well, we're going to steer clear of reconciling that" and tried to depict the accident as accurately as we could and with the bounding-type analysis.

So that was the only comment, but many of the comments we got on the Baltimore tunnel fire have applicability to the Caldecott. So we looked at all the BTF comments and made changes in the Caldecott as appropriate. Okay? We just assumed they were comments also on the Caldecott.

CHAIRMAN RYAN: Were there any differences in the CHP versus the NTSB report as well?

MR. EASTON: Do you want to get into that?

MR. BAJWA: Okay. All we really know because we didn't really pursue it is that there were differences in how the accident actually happened. And what we were told by the individual from the CHP was that NTSB admitted that -- well, NTSB never admitted that there were any differences. And they stuck by what they thought the accident, as described in their report -- how it happened. And CHP just thought that their version was more accurate.

CHAIRMAN RYAN: What are the differences, I mean, in terms of --

MR. BAJWA: We never asked what the differences were.

MR. EASTON: I think they were more focused on the sequence of the accident --

MR. BAJWA: Exactly.

MR. EASTON: -- and cause, the root cause.

MR. BAJWA: Right, not within --

CHAIRMAN RYAN: That's really the focus of my question, some assumption that would change what you assumed the analysis. I mean, that's a weakness, but --

MR. BAJWA: I don't think it --

CHAIRMAN RYAN: The differences that you talked about don't have an effect on your assumptions. I assume that you took these differences of that context into --

MR. BAJWA: I think when we just described how the accident happened, somebody said, "Well, it may have happened a little differently, but the consequences are the same." So we didn't get involved in --

CHAIRMAN RYAN: And you said that in your report?

MR. BAJWA: Well, we can --

MR. EASTON: I think we said it in our --

CHAIRMAN RYAN: I think it is important. I'm just trying to think about how to close this up. If you say, "Well, there might have been slight differences in the sequencing, but in terms of your assumptions for impact analysis that didn't have any bearing, that's important for you to make an assessment on that.

It sounds like you have done that. You ought to just say it.

MR. EASTON: Yes. I think we're going to say it in appendix G, which is attached.

CHAIRMAN RYAN: Okay.

MEMBER CLARKE: Earl, while we're on that, could I ask a question about the heavy carbon fuel? You have on slide 6, I guess, 7, tripropylene, a specific hydrocarbon fuel. Does that matter? I mean, have you bounded the case? Obviously it could be other hydrocarbon fuels.

MR. EASTON: Yes. I mean, I --

MEMBER CLARKE: Were they different in these situations? Is this actually the fuel that was in one of the --

MR. EASTON: No.

MEMBER CLARKE: Because you have a --

MR. EASTON: This was actually the fuel. So a lot of the details were based on that fuel, but --

MEMBER CLARKE: For both fires?

MR. EASTON: The fire for the Caldecott was gasoline.

MEMBER CLARKE: Sorry. I guess what I'm asking is your analysis doesn't really matter what the fuel is. You've --

MR. EASTON: We were told given all the parameters, that, you know, the exact nature of the fuel was not all that dominant. We were told that.

MEMBER CLARKE: Yes. I just wanted to see how you --

MR. ADKINS: The flammability rating of the tripropylene is directly parallel to that of the fuel that was involved in the Caldecott tunnel fires.

MEMBER CLARKE: But other hotter fuels that could change your analysis or have you bounded that?

MR. EASTON: I think these are typical of -- this is like no mean. You know, there are like all different chains. I think this is the typical mean for a hydrocarbon. I think it would be tweaking and not really that much.

MEMBER CLARKE: Not that important to the analysis.

MR. EASTON: I'm a chemical engineer. So I didn't trust them. I went back and pulled the numbers.

CHAIRMAN RYAN: That's all reflected in your report?

MR. EASTON: No, not this. This is my --

MEMBER CLARKE: I just wanted to probe you on that because you were mentioning a specific fuel and a specific fire.

MR. EASTON: Do we have a specific argument about generalizing the hydrocarbon fuel? I know the NIST report.

MR. BAJWA: Basically what we understand from NIST -- and Dr. Kevin McGrattan did the original FDS models. In fact, he's just next door in an ACRS meeting.

In general, hydrocarbons behave very, very similar when you put them in full fire situations. So the differences that would be between tripropylene and some of the other hydrocarbons that could be transported on a rail or would be transported on a rail would not change the numbers very much at all.

MEMBER CLARKE: I guess what I am suggesting is you might want to put a little bit about that in your report.

MR. BAJWA: Okay. That is a good question.

MEMBER WEINER: As a matter of fact, all you will get, the biggest difference you would get, would be the heat of bond rupture from the mother carbon-hydrogen bond during another couple of those. And that would be lost in your other heat loss.

MEMBER CLARKE: I think that probably merits an explanation.

MR. BAJWA: Okay.

MEMBER CLARKE: So we'll --

MEMBER HINZE: Let me ask a related question if I might relate to the location of the fire. If you look at a petroleum tank farm, what you see are the tanks. And each one will have a dike around in case there is a fire, the flow the petroleum product is confined to within the dike.

Have you considered the possibility of a rupture of a tank and then the leak-out, the run-out? And so that the fire will actually be in greater proximity to the spent nuclear fuel.

MR. EASTON: You mean like a stationary

tank?

MEMBER HINZE: Yes. Well, you have the tank rupture. And if there is insufficient oxygen, you won't have or you will have run-out of the fuel. And that fuel could get much closer to your canister. And, therefore, your temperatures would be higher. Have you considered that?

MR. EASTON: I don't know if we've done that exactly analysis of a stationary tank rupturing. We have gone back and looked at all the train accidents. And some of those involved tank cars, where you have rupture and run-out.

And what we have done -- I guess I had a couple of different graphs here. We have actually gone back in some of these accidents and taken the graphics of how the tank cars end up. And you usually always get a buffer car the way that these things accordion.

In every accident we see, you get a buffer car between the actual tank car in the spent fuel casks. So if it's burning at the site of the tank, you usually have something intervening.

MEMBER HINZE: But the run-off could still go underneath the car.

MR. EASTON: It could, but --

MEMBER HINZE: It would move beyond the buffer car.

MR. EASTON: But you would have to get a pretty fully engulfing fire under the whole tank car because these are pretty big heat sinks if I'm following.

MEMBER HINZE: Yes, I understand.

MR. EASTON: And, you know --

MEMBER HINZE: But you also get run-off. And that fire could be in much greater proximity than you're assuming by this buffer car.

MR. EASTON: Yes. Well, this again is just focused on tunnels and focused on rail accidents.

MEMBER HINZE: Which would be even more confining. It would confine the run-off.

MR. EASTON: Well --

MR. ADKINS: One of the things that I think might be prudent to be mentioned is if you did have migration of the fuel, potentially what you could get is a larger pool.

And when we did some sensitivity evaluations, you know, one of the things that worked against us is the fact that the fire did last seven hours because these casks have a tremendous amount of thermal inertia.

So if the fuel burns up abruptly, it's actually less damaging to the actual cask and the contents itself. So if the fuel were to migrate, you would have a high potential that the fuel would be potentially larger and yield a lesser effect than what we have studied here.

Pool, the pool size that was selected in a square area as well, there was a lot of thought, I guess, regarding the selection of that particular square area to work against us from the standpoint of working with the time constant associated with the cask.

MEMBER HINZE: But did you also take into consideration the proximity of the fire, then?

MR. EASTON: Yes. And, in fact, I'm glad we're back on that. There were a couple -- you know, Kevin McGrattan gave us quite a bit of data, as you would imagine, for the particular fire.

And Chris and I actually went through and looked for, prior to the buffer car discussion looked for where we were going to witness one of the higher heat fluxes associated with the location of where the fuel would be and where the cask could potentially be.

Oddly enough, with the exception of being directly in the fuel pool, by the way the flaming product migrates and the way the tunnel is oriented and the way the cask was potentially situated, at least the rail car location, the 20-meter location was actually one of the worst where we witnessed one of the highest heat fluxes just due to the fact that the combustion process was quite a bit more efficient at that particular location.

MEMBER HINZE: Does that get into the report, then, that thinking?

MR. EASTON: In a sense, yes, from the regard that we have touched on it. And also a lot of these details have been included in the NIST report.

MEMBER WEINER: What happens in the event of a dual track tunnel, where you could actually have -- I noticed that was one of the comments, but if you have a tank car on the other track, so to speak, then you don't have the accordion.

MR. EASTON: We're getting to that, yes, --

MEMBER WEINER: Okay. If that's --

MR. EASTON: -- unless you want me to give you the answer now.

(Laughter.)

MEMBER WEINER: Well, if you're getting to that, I'll wait. It's tough, but I'll wait.

MEMBER HINZE: We suckered you into that one, didn't we?

(Laughter.)

MR. EASTON: We are going to get right into it. Okay?

MEMBER WEINER: Okay.

MR. EASTON: And, again, we're trying to put this again in some risk perspective. As you know, when Kevin Crowley came to brief you on this, he said that basically the outstanding safety issue if there was one was long-duration fires. And so we went back, and we looked at long-duration fires, fully engulfing fires. And the tunnel was a component of that.

The Baltimore tunnel fire, the Caldecott tunnel fire, our general survey of FRA accident data, and some actions we have taken with the Association of American Railroads all are geared towards addressing this report. So that's really how we're going to use the Baltimore tunnel fire as one piece of data in the end that we're going to use to address the NAS conclusions on long-duration fires.

I hope I don't bore you. Some of you have probably heard some of this a little bit before. I'll go through it real quick. We went through 30 years of data, 21 billion train miles. In that time, there had been 1,726 releases of hazmat from vapor to multiple tank cars. We went and assessed those accident reports. Based on that assessment, we think we have less than ten where there have been severe fires.

MEMBER WEINER: Could you go back to the preceding slides, then? You actually have 11 significant figures on number of train miles.

MR. EASTON: I just added up the data from FRA.

(Laughter.)

CHAIRMAN RYAN: That's actual addition. That's fine.

MEMBER WEINER: Yes, that's fine.

CHAIRMAN RYAN: In relation to where we're going, it's not. I heard you say you added up the actual figures.

MR. EASTON: Right.

CHAIRMAN RYAN: I'm okay with it.

MR. EASTON: Approximately 21 billion miles. Okay.

Now, real quickly, to set up the answer to Ruth's question, when you look at these rail accidents -- and these are events per million miles -- you see that railroads in general have become safer, but this purple area, most of the accidents are derailments of single trains. Okay? Very few collisions. And others, as you know, in rail yards and that sort of thing.

Why is that important? Well, in collisions, you usually don't get long-duration fires. And the reason why is trains have regulations that if they're long enough, the first hazmat car has to be like six cars back from this end and six cars. And trains usually collide in the front and the back.

When you side swipe, you only usually get one or two cars at most involved. It turns out that most times that you have a fire, it's a train with 10 or 12 cars going off the track and getting jumbled up.

Okay. The other point, again, this is accidents. These are total number of accidents now because we're in rail yards. It's hard to do by miles. Half of the accidents happen in rail yards, and half are outside rail yards.

So of all of these accident that we looked at, again, looking at the approximately 21 billion miles of train travel, most were derailments of a single train. We could only find one really severe fire that occurred in the tunnel. We have been studying that for five years now.

It is likely that in all of these

accidents, what we have found is that there haven't been fully engulfing long-term fire that fully engulfed a cask because either the placement of a spent fuel cask, where that would have ended up, we have gone back and actually mapped the location of the cars and numbered them and say, "What if you picked spent fuel?"; that sort of thing.

The nature of the flammable material, a lot of these are flammable gases which either BLEVE into a big fireball and it's over very quickly or burn and they burn back to the tank car and they let those burn for days and evacuate whole towns for days and they won't let anybody back into those towns until those tank cars are empty because they don't want an explosion.

So it's really not the fire danger. It's often an explosion danger. And the most severe parts of the fires are over very quickly. And in almost every case, we have found that emergency response people were there very quickly. Okay?

Now, do these three factors work well in tunnels? Well, you can't get in a tunnel to do emergency response. The nature of the flammable things, the gas just eats up the tunnel. And the placement of spent fuel casks, well, I don't think that's too bad. So maybe tunnels are a little unique. That is what we found out.

So is there a simple fix perhaps to all of this? Well, most big shipping campaigns we think, like DOE, will use dedicated trains. So if you derail a single dedicated train with no flammable liquid, you probably have pretty much eliminated that.

We went to the Association of American Railroads, and we said, "What happens if you have flammable liquids in a tunnel with spent fuel at the same time? Is there a way that we could put on operational controls on the railroad to prohibit them?"

And we did that because we're not the experts because if we prohibit shipment, we might make something else less safe, you know. So we said, "You're the experts. Can you do that?"

We approached them in March. In July they changed their rules. The rule says that when you have a tunnel with two tracks, single bore, you're not allowed to have a train with run-over liquids and spent fuel at the same time. The exact wording is given in one of the backup slides. Okay? That's OT-55, revision I.

And we think with that, that is about the best operational control you can have to eliminate tunnel fire. So we think dedicated train tunnel fires takes what is really a low probability event as close to zero as we can practicably achieve, as close to zero as we can practicably achieve.

So that's what really came out of this study and the NAS study is we do have an operational control through the Association of American Railroads that would prohibit that. They're probably less than ten of these type tunnels in the whole country; that is, double tracks in the door. And so they said it was not an undue --

CHAIRMAN RYAN: Really? There are only ten like that in the country.

MEMBER WEINER: Most of them have dual doors.

CHAIRMAN RYAN: I understand.

MR. EASTON: There were a number, a higher number, at one time, but most all of them had the second track removed and the other track located in the center to accommodate higher cargo.

CHAIRMAN RYAN: Interesting.

MR. EASTON: And where you have a lot of traffic, the trend has been to do a separate door.

CHAIRMAN RYAN: This is just an

off-the-wall question, but, I mean, are any of these last ten dual tracks anywhere near where spent fuel would be shipped?

MR. EASTON: That I don't know.

CHAIRMAN RYAN: If they're all in North Dakota, it's not a big deal for anybody.

MR. EASTON: I think there may be one or two located in the Northeast, but generally they route around them.

CHAIRMAN RYAN: Interesting.

EXECUTIVE DIRECTOR LARKINS: I just have a general question. You said half of these occur in the train yards. Have any of these gone from simple deprivations to detonations or have they had any more energetic types of events other than just the simple pool fire?

MR. EASTON: Yes. And I won't bore you, but I have a whole presentation on that with maps and rail yards and everything. There have been a few where initially you have BLEVEs, you have a puncture and you have it explode. And then usually it catches some sort of cargo on fire, like, you know, if you have tires, they burn, but they're not fully engulfing as with respect to a spent fuel car. They are with respect to the tires or the paper. And we have gone back to one in Akron, Ohio, where you had a BLEVE.

The best thing for spent fuel casks is to probably go ahead and let the thing explode, but that's not the best for a lot of other cases. So primarily how these accidents work is you either get a puncture and you get a muted explosion or you get a fire that burns with some intensity and then burns back to the tank car.

There's one famous example, Weywauga, Wisconsin, where they had an evacuation for 15 days. And it burned for 15 days. But there are cases where the firemen had to go back and relight the fires because some of the fires were going out.

They were trying to vent the tanks, instead of actually going back and relighting. And I pictured them standing on top of the tank cars relighting them. And this is one that many critics cite, and they evacuated for 15 days, but after about the first 3 hours, the fire is under control. And these are all what they call pressure fires, and they come back.

But they evacuated that town for 15 days. By the eighth day, you had people standing on the tank cars with pipes out fighting them. So, anyway --

MEMBER WEINER: Can you go back a second?

Okay. The AAR has made a rule. And, admittedly, even the situation where this could occur isn't going to happen very often.

How can you be assured that the trains are going to abide by the rules? It's one thing to make a rule. We all know that the rules are broken now and again.

MR. EASTON: That's a very good question. We asked that question. First we approached the Federal Railroad Administration to see if they were interested in regulation.

MEMBER WEINER: Yes. And they said no?

MR. EASTON: And they said no. The best way to do it, the most efficient way to do it, really, the rules that are as ironclad as you can get are the circulars that AAR put out because they control the five or six major railroads. And it's the top executives that agreed to the rules. And these are pretty much the law of the land.

Now, we take that on faith from the Federal Railroad Administration a little bit, but they said, you know, it's in their interest to do it. I've heard that before, too. And since there are only about ten of these tunnels, it's not a big burden. They've been sensitized to this.

In the circular, it says the NRC has requested that this action be taken. And so the railroads know that we have requested it, we feel serious about it. But it does not have the force of law or regulation, but it's the most expedient way we could go. And we have asked the Federal Rail, who is in charge of this area. They did vent this, like I say, with all the major railroads. They did change it.

MEMBER HINZE: Earl, how much monitoring would there by the NRC, DOE, et cetera, in the transport of these special trains, these dedicated trains, to eliminate the kind of possibility that this is bringing out?

MR. EASTON: My experience has been there will normally be quite a bit of monitoring of these. States have stopped trains to inspect them, to go to that length. The Federal Railroad Administration has special protocols in to double check equipment on a more frequent basis, double check tracks.

I don't know if this has made it in because this is July 16th, but we have made all the states aware of this. And in the end, it will be up to the railroads to apply the circular.

Since it's not a regulation, it would be up to then the states to I guess use the bully pulpit to really make this happen or another important thing, since there are so few of these and states -- this is for Yucca Mountains -- states are now actively engaged and DOE in deciding the routes, the preferred routes, as you know. And they may very well decide to use this as a factor.

MEMBER WEINER: Yes. Let me correct one thing, which DOE keeps bringing up at these meetings. The states will not decide the routes. DOE will decide the routes.

MR. EASTON: That's correct.

MEMBER WEINER: And the states can say that they have preferred routes. And, actually, when you look at it, if you look at most of these routes, which go across the country, there are very few choices. At most through any particular state or region, there are three possible, three, four at the outside possible routes that you can take because they have to connect.

MR. EASTON: Right.

MEMBER WEINER: So I did want to correct that.

MR. EASTON: And you're right. States don't pick the routes. DOE and shippers pick the routes, railroads. They are sensitive. And they are doing studies now in an advisory capacity to DOE. These are the routes.

MEMBER WEINER: These are routes.

MR. EASTON: A lot of them in the Midwest don't go through many tunnels. A lot of the tunnels in the mountains in the west are single bore. And I think you will just find a very few choke points at dual. And I think that they will consider that in routing. That is probably the best and quickest we could do to even reduce what I want to emphasize is a very small risk.

We didn't find any cases of fully engulfing fire. Our conclusions on the tunnel fire are that it's relatively benign. But, despite that, if there's a simple rule that you can sensitize people to, then we think it basically eliminates it.

CHAIRMAN RYAN: Okay. Are there any other questions?

MEMBER WEINER: No.

VICE CHAIRMAN CROFF: Yes. Can I take you back to slide 11? I've got a question about that first bullet. Are water mains commonly in these tunnels? And what would have happened if there wasn't a water main to the accident?

MR. EASTON: I don't know that they're common in this tunnel. It just happened to be collocated with the water main. It basically put out the fire. If we wanted to model the Baltimore tunnel fire correctly, we would have modeled a three-hour fire, but we didn't want to take any credit for the water main. That's why we --

VICE CHAIRMAN CROFF: Oh, so your scenario didn't take any credit for that?

MR. EASTON: No, sir. That's just historical. Sorry. That's just historical data. That's the way it happened: something major intervening that was over primarily in three hours. But we went and said, what would it take to consume the whole tank there?

VICE CHAIRMAN CROFF: The second question, the buffer cars that are normally used, are they normally box cars or flat cars? The picture you showed I think showed flat cars I remember.

MR. EASTON: If I remember, I think it was actually -- well, I think the buffer cars are actually the box cars in this picture. See, what you are looking at, the spent fuel cask sits in the middle of a long car. So that space there is just the end of that flat car.

VICE CHAIRMAN CROFF: I was seeing something else there.

MR. EASTON: But if your question is it could be either, it could be a flat car, but, then again, that holds basically -- it would be a long space. But the space between the box car and the --

VICE CHAIRMAN CROFF: The reason for the question is the overriding, cars overriding, issue. It seems a flat car would be a bit easier to override.

MR. EASTON: Yes because I guess a flat car with the ends might come up to where that arrow says on eight feet maybe, you know, cut that off, something like that, because, you know, you usually have ends on them.

VICE CHAIRMAN CROFF: Yes.

MR. EASTON: And you could conceivably get a tank car up over that, but it would be -- you know, these are very heavy. And you sort of have to angle it right. Again, this was not a collision. It didn't have much force.

And, again, these go into a coupler. And those couplers have been strengthened within the last couple of years to not let that fall apart. The most likely mode is now, from what FRA tells me, that the couplers don't give, but the rail cars just fall over together and try to remain coupled. Really, that's one of the focuses: to keep those couplers together.

One of the biggest cause of accidents up until that time was the couplers coming apart and puncturing. So they worked on keeping those connections as strong as they can.

CHAIRMAN RYAN: All set?

MEMBER WEINER: Jim?

MEMBER CLARKE: I just think it's important in the casks to clarify that you have looked at the identity of the different hydrocarbon fuels and you get to bond to that situation or your analysis is such that it's insignificant just to show --

MR. EASTON: We'll put in that. Good comment. We'll put in that.

MEMBER WEINER: I've got three questions. If it's true that in the model that you have you never really get to the clad rupture temperature, what about damaged fuel? What would you significantly rupture, get into the actual fuel if you had damaged fuel to begin with?

MR. EASTON: If you had damaged fuel to begin with, I'm assuming that most of the krypton and all of that is gone, right?

MEMBER WEINER: Yes.

MR. EASTON: And so the cesium, rather than being volatile if you're not talking the temperatures, is more of a particulate. And it's just trying to get particulate out through a closure. Is that where you are?

MEMBER WEINER: I'm just asking the question. The cesium would be cesium chloride, --

MR. EASTON: Right.

MEMBER WEINER: -- no matter where it is. And I was just wondering if you had -- well, let's take the case of de-clad fuel.

MR. EASTON: Right.

MEMBER WEINER: What would happen at these temperatures?

CHAIRMAN RYAN: De-clad fuel?

MEMBER WEINER: Well, they have some that don't -- I know.

MR. EASTON: Chopped-up fuel?

MEMBER WEINER: Yes, chopped-up fuel.

CHAIRMAN RYAN: That's not de-clad, though.

MR. EASTON: Well, yes. And I think probably 6672 addressees that to some extent.

MEMBER WEINER: If they do, I apparently don't remember.

MR. EASTON: The reason we chose the particular analogy or reference to 6672 is because we thought cesium becomes a bad actor if it's at a higher temperature and you have a vapor temperature and you have something that can get through small clearances. And I think at lower temperatures, you don't have that. What is the melting point for cesium? It's up over 1,000 degrees for most cesium. Vapor pressure is pretty low, too.

That is what this model is really based on, the vapor pressure of cesium. I think if you had lower temperatures, it works in your favor. You're just trying to get the particulates out. It's hard to get through tight clearances. But we didn't really look at that.

MEMBER WEINER: Could you have a pool fire in the tunnel? How likely is that?

MR. EASTON: A pool fire in the tunnel?

MEMBER WEINER: A pool fire in the tunnel.

MR. EASTON: I think it's more likely to have a pool fire in the tunnel than not in the tunnel because outside the beds are generally raised and there's poor substrate. Conceivably you could have a concrete floor or something like that.

But when you think about what it would

take for a fully engulfing fire for a long period of time -- this burns about what, 11 inches per hour? So if you wanted to have a fire, you would need 70 inches of fuel. And so you have to feed that pool, you know, at that rate to keep the pool right under that cask.

Most of these tunnels have what, a three percent grade? So you dump all the fuel out. And it's going to spread over a wide area. And that area will determine how fast it burns. And if it burns up faster, you know, away from the cask, it probably gets you more attuned to what we analyzed with the radiation coming from the tunnel.

So we didn't see that as a particular issue because this was a low probability that we thought that would happen. That is, it runs out that small hole and it goes all the way down 60 feet and forms a pool. And it's just that right configuration for that period of time.

MEMBER WEINER: Finally, the test sequence in 71.73, you think that that is adequate to cover this particular concern? I know that question has been raised from time to time in the past.

MR. EASTON: Well, my opinion is yes because we did an analysis for a much longer time than what that test is, although it's not the exact condition. And we didn't find that you really get significant releases.

So I think any time you ask if the regulation is adequate, we're really protecting against real-life accidents and go back and look at real-life accidents. And if you study real-life accidents, you would find that nothing bad happens because you have a cask designed to a standard. I think that's sort of where you want to be.

CHAIRMAN RYAN: Well, I think that's one of the strengths of your study is you really have a pretty robust database of miles of accidents. You know, you've got a mile of gasoline. You go back years and years. There's nothing left out.

So that's a strength, and I think that is something to emphasize in your report. If you're not making up an accident scenario, you have developed that accident scenario from actual experience over many, many gazillions of miles. So that's a plus.

The one area I think -- it's just a question more than anything. I remember a few years ago we talked. And Milt Levinson asked about DOD and DOE experience on miles with these kinds of shipments. Is that in your database?

I know you're looking at what's in

commerce. And this, of course, wouldn't be in commerce, but as a fraction of the total, DOD and DOE have put a lot of stuff on the rail.

MR. EASTON: Well, I will double-check that, but I believe it is because naval reactor shipments for most DOE do use commercial carriers.

CHAIRMAN RYAN: And I think if you could just qualify and say that is included or that's not included or part of it is and part of it's not, that would be an enhancement to the power of your scenario development.

You know, it's not just commercial nuclear power fuel that's going from A to B. It includes the broad spectrum of radioactive material shipments in this arena. And if you just qualify that a little bit, I think it would be a real -- you know, would bolster your case.

MR. EASTON: I don't remember if DOE has any secret trains that they know, but they're probably not in the database.

CHAIRMAN RYAN: Yes.

MR. EASTON: I know Navy reactors, they go out and hire Union Pacific. And that's all answered.

MEMBER WEINER: Staff, questions?

MR. WIDMAYER: Well, I have one.

It's Derek Widmayer, ACNW staff. I'm not advocating --

CHAIRMAN RYAN: Could you come up to the table, please?

MR. WIDMAYER: Should I kneel?

(Laughter.)

CHAIRMAN RYAN: You can if you want.

MR. WIDMAYER: I'm not advocating this as part of the study but just a curiosity. As Dr. Ryan said, it seems like you have a tremendous amount of data on accidents and you have covered your bases. Did anybody ask you to extend that, think out of a box, and think about if somebody attacked the train and did this on purpose and --

MR. EASTON: Well, we have another whole independent effort that looks at somebody attacking casks or security systems. I guess --

CHAIRMAN RYAN: That's a separate area we probably should just leave right there.

MR. CAMPBELL: This is Larry Campbell.

That's really outside the scope of this study. And now you're into safeguard space and classified space. So that's outside the scope of this.

CHAIRMAN RYAN: Thanks for your question, Derek.

MR. WIDMAYER: Okay.

MEMBER WEINER: Other questions?

(No response.)

MEMBER WEINER: Nobody? Well, thanks very much.

CHAIRMAN RYAN: This is great follow-up. It really is good, and I'm pleased to hear that some of the comments you have received from the public have --

MR. EASTON: We'll have to come back on this one.

(Laughter.)

CHAIRMAN RYAN: Thank you very much.

With that, we're a little bit ahead. We'll go ahead and take a break and resume at 10:30. By the way, this will conclude our formal part of the record. We're going to be considering letter writing and other activities. So the record will close here. Thank you.

(Whereupon, the foregoing matter was concluded at 9:59 a.m.)

CERTIFICATE

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

Name of Proceeding: Advisory Committee on Nuclear Waste 173rd Meeting

Docket Number: n/a

Location: Rockville, MD

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

Charles Morrison
Official Reporter
Neal R. Gross & Co., Inc.

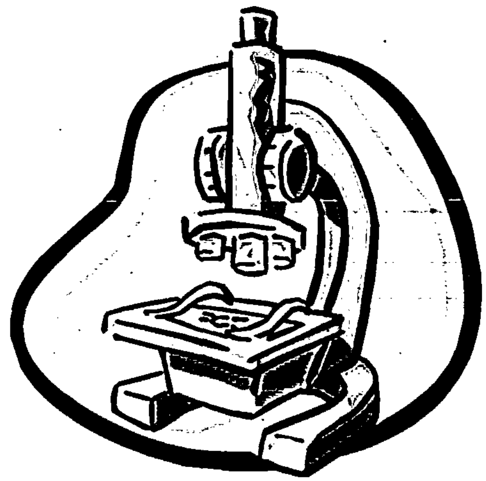
Baltimore and Caldecott Tunnel Fire Studies Response to Comments

173th Meeting of the
Advisory Committee for Nuclear Waste
Rockville, Maryland
September 21, 2006

Chris Bajwa and Earl Easton
Spent Fuel Project Office
U. S. Nuclear Regulatory Commission

Harold Adkins
Pacific Northwest National Laboratory

Focus of Today's Presentation

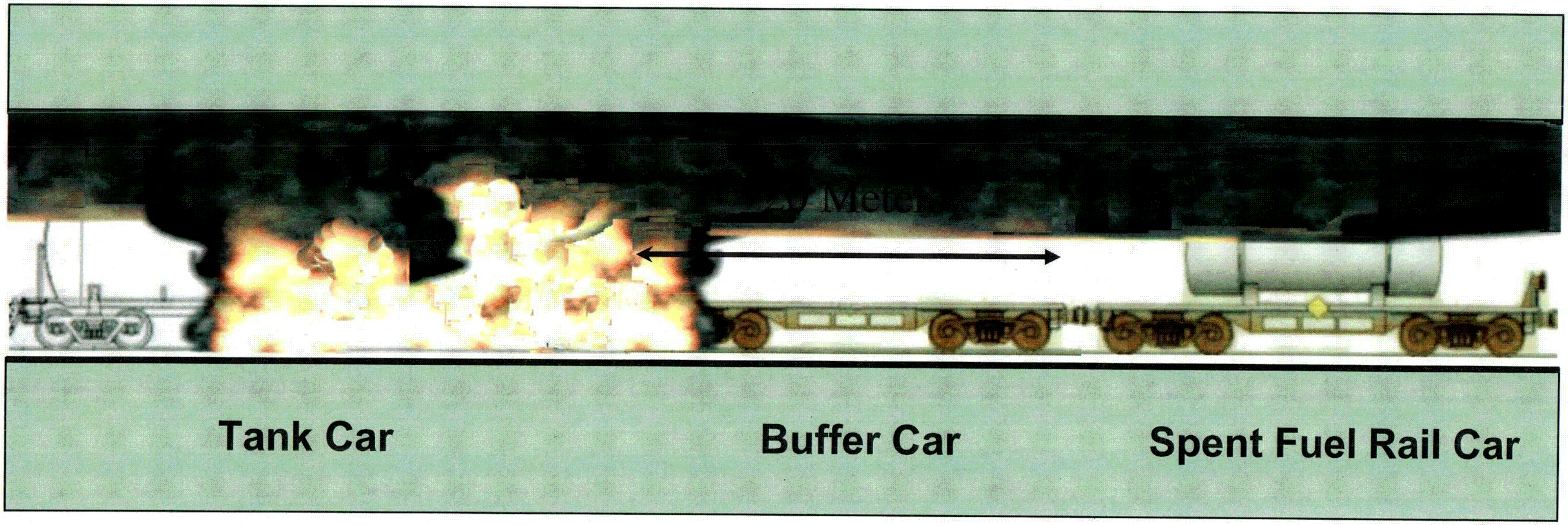


- Public Comments
- ACNW Comments
- Internal Staff Comments
- Your Questions

Major Comments

- Location, severity and duration of fire.
- Modeling of lead melt.
- Composition assumed for CRUD.
- Potential loss of lead shielding.
- Effects of damaged and high burn-up fuel.
- Performance of cask seals.
- Risk perspective.

Assumptions Used to Define the Tunnel Fire Environment



- Casks located one rail car length from fire source.
- Duration of fire – seven hours; 23-hour cool down.
- Temperature profiles developed by National Institute of Standards and Technology (NIST).

Location, Intensity and Duration of Fire (Public Comment)

- The spent fuel cask could be located closer to the source of the fire.
- The duration of the fire could be longer than the seven hours analyzed.
- Fire could burn hotter.

Location of Spent Fuel Casks

DOT requires that radioactive materials be separated by buffer cars from other hazardous materials (49 CFR174.85)

Possible Locations of Spent Fuel Casks based on DOT Regulations

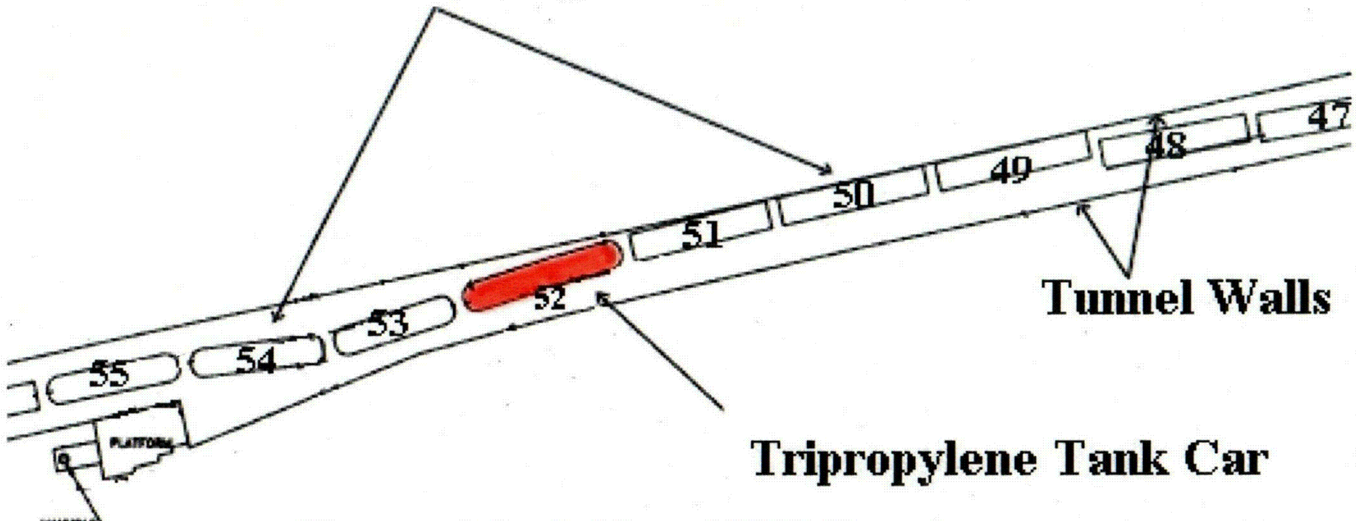
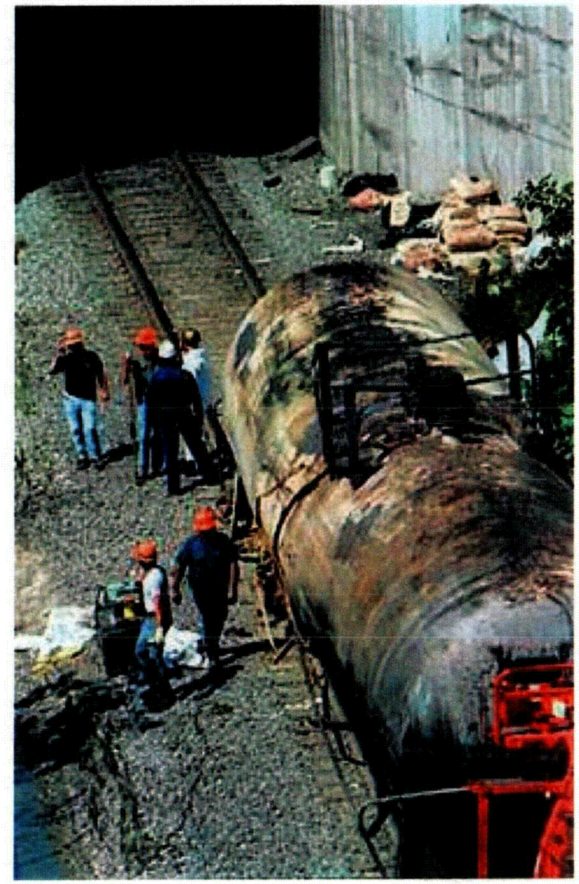
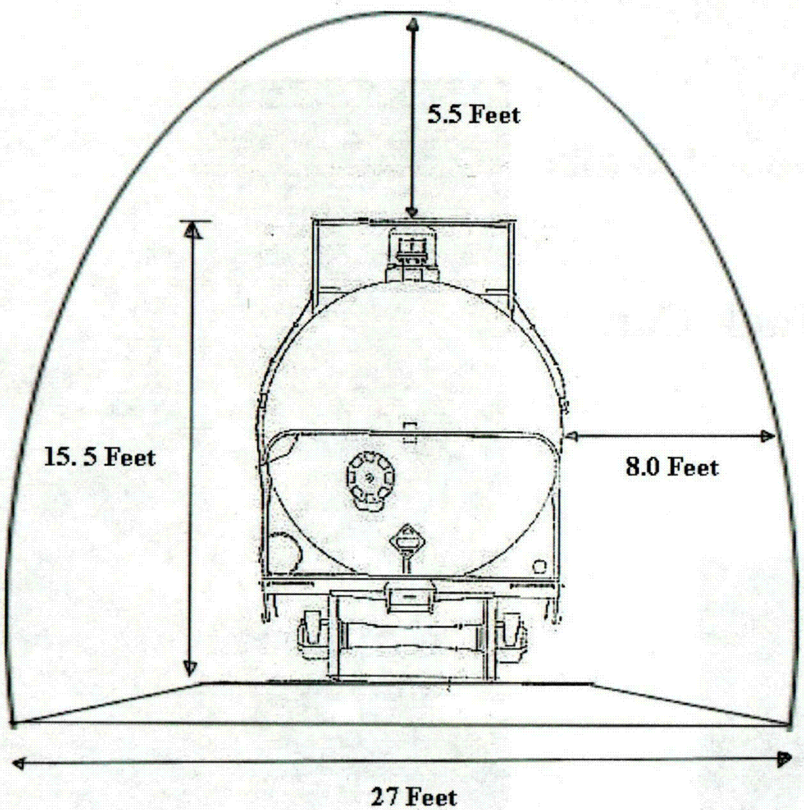


Diagram Adapted from NTSB Report

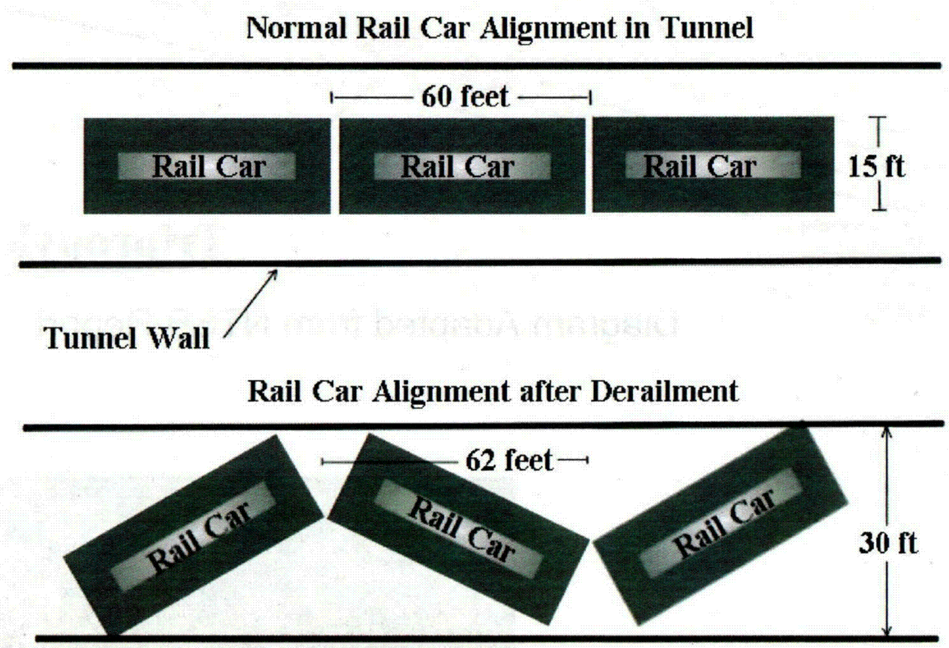


Hole in Tripropylene Tank Car

Location of Spent Fuel Casks



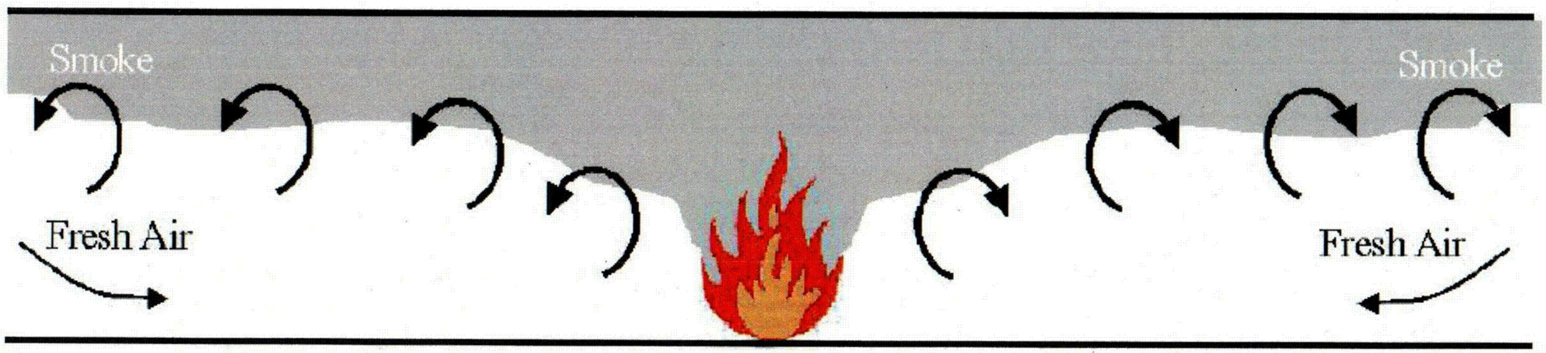
End View



Top View

Fire Intensity

- NIST analysis of the actual fire predicts
  - Intensity to be no more than 1.7 x 10^8 Btu/hr (50 MW).
  - Fire is oxygen starved.



  - Peak temperatures of 1832 – 2010 ^{0}F in flame region.
  - Hottest temperatures occur within first hour.
    - Peak ceiling temperature at source - 1472 ^{0}F
    - Peak ceiling temperature at cask - 752 ^{0}F

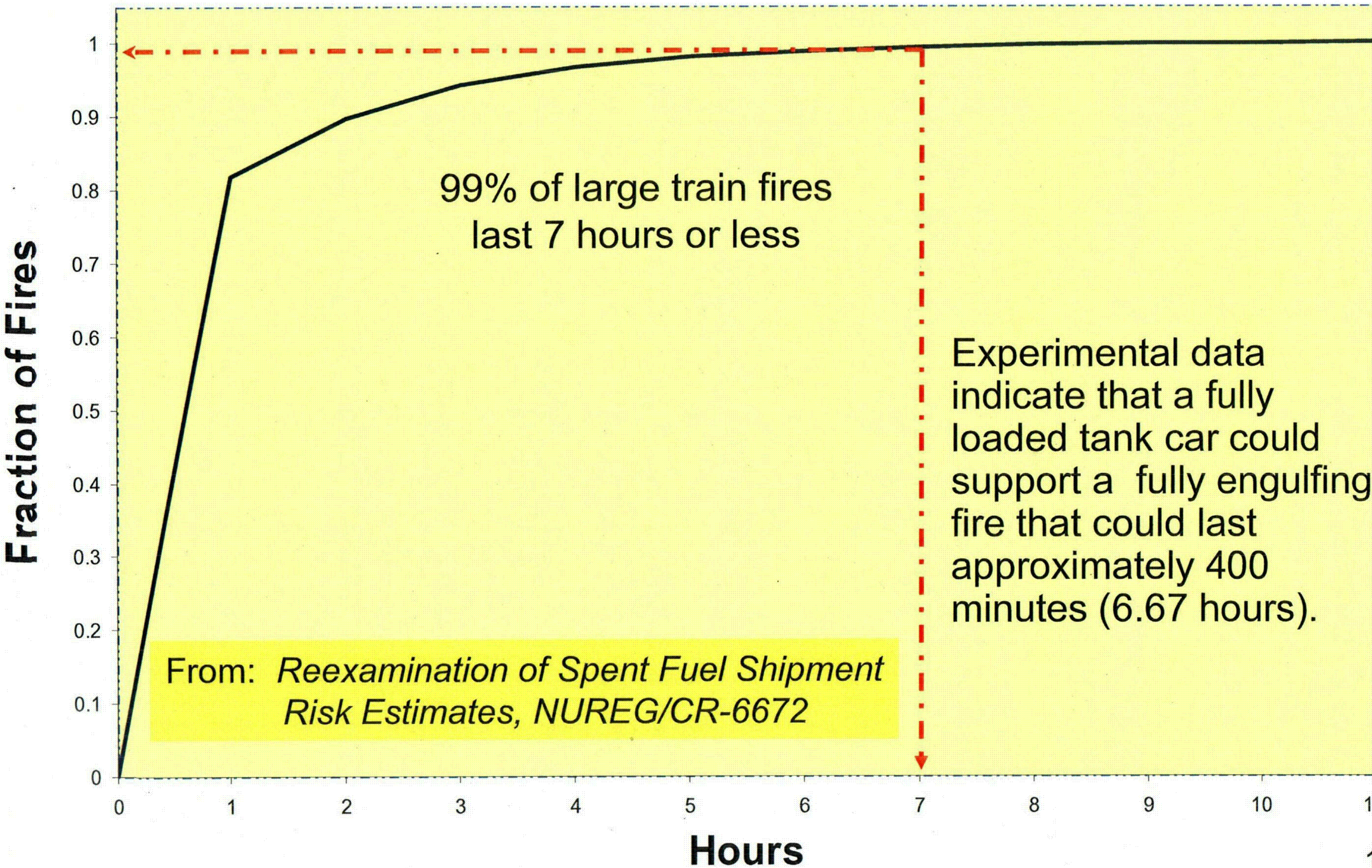
Fire Intensity

- NIST/PNNL analysis assumes
  - Intensity of BTF of 1.7×10^9 Btu/hr (500 MW). Factor of 10 higher than for actual fire.
  - Fire is oxygenated. (Artificial holes in tunnel).
  - All fuel is burned (None lost to evaporation or seepage).
  - Peak temperatures of 2084 ^{0}F in flame region.
  - Hottest temperatures calculated
    - Peak ceiling temperature at cask - 1832 ^{0}F (lasts for over 3 hours).

Fire Duration

- The severest part of the BTF lasted only 3 hours (due to water main break).
- NIST analysis predicts that:
  - Based on a reasonable pool size (600 sq. ft.), a well ventilated fire would consume 28,700 gallons of hydrocarbon-based fuel in about 6.7 hours.

Duration of Large Fires involved with Train Accidents (Derailments)



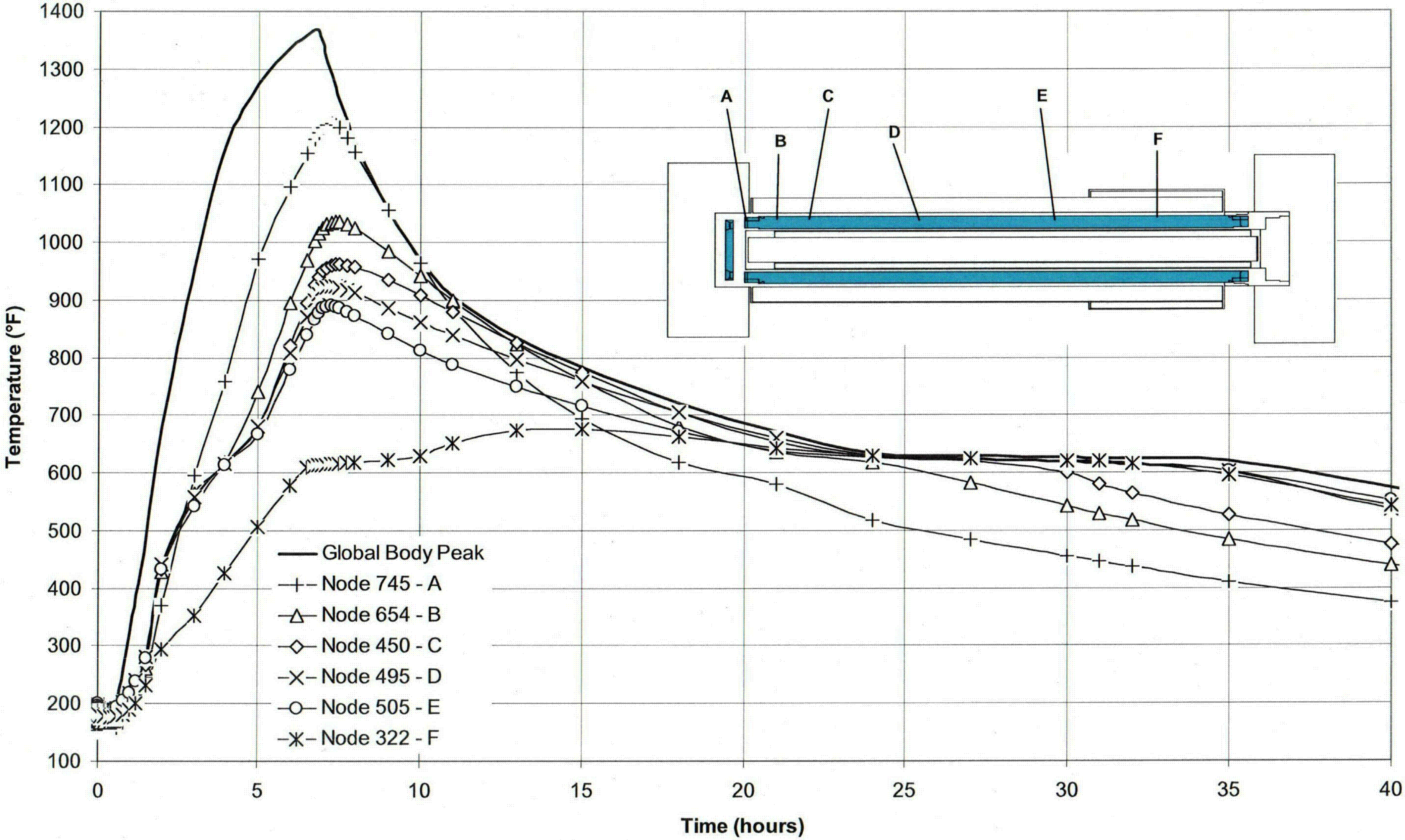
Location, Intensity and Duration of Fire

- The location selected for a spent fuel cask in the BTF study is realistic.
- The intensity and duration of the fire modeled in the BTF study exceeded those in the actual tunnel fire, but adequately reflect more severe tunnel fires that may not be oxygen starved.
- Report amended to include additional information including figures and text.

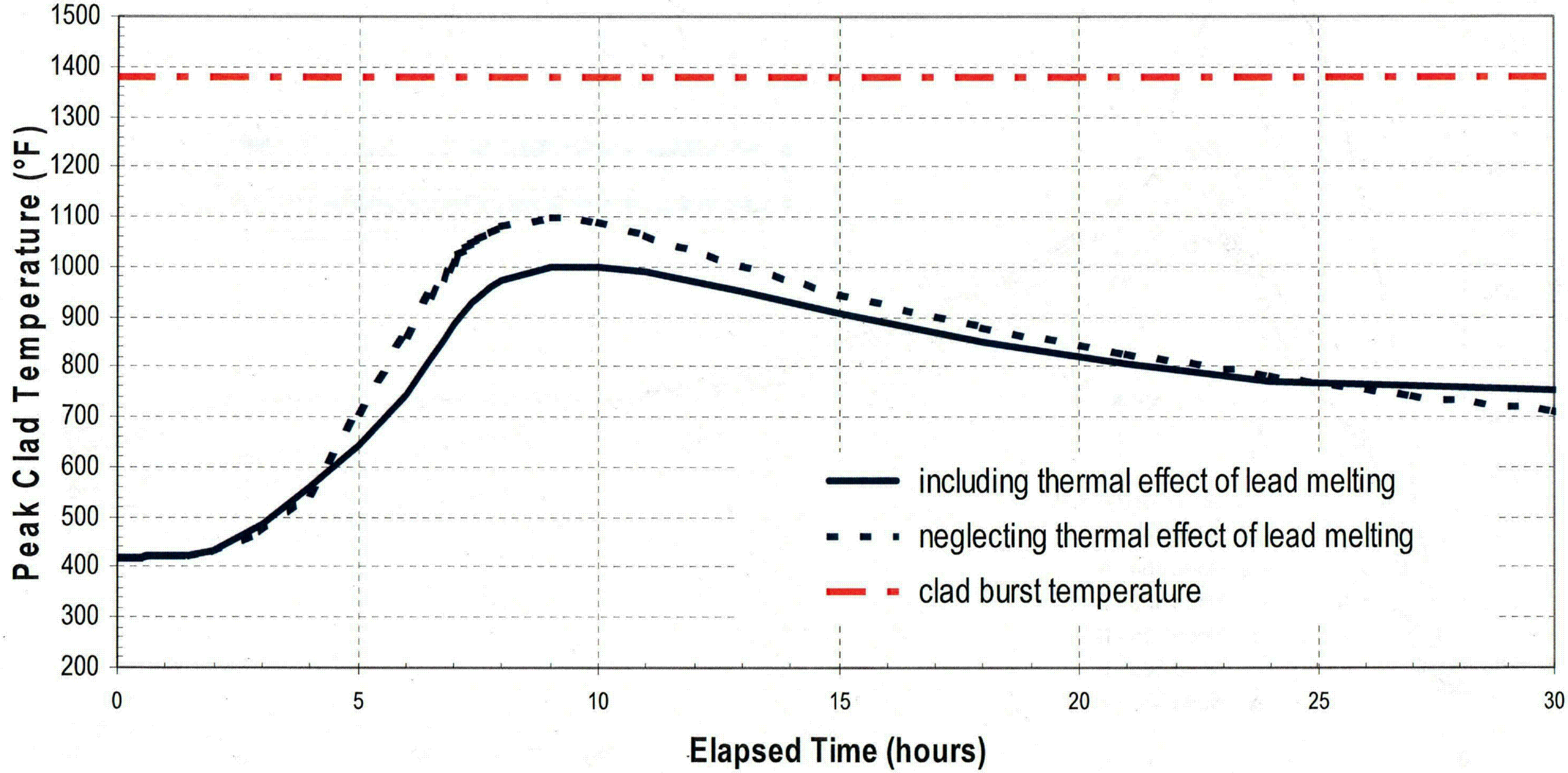
Modeling of Lead Melt (ACNW Comment)

- The Baltimore and Caldecott Tunnel Fire Studies did not consider lead melt. Not modeling lead melt could effect the outcome of the analyses.

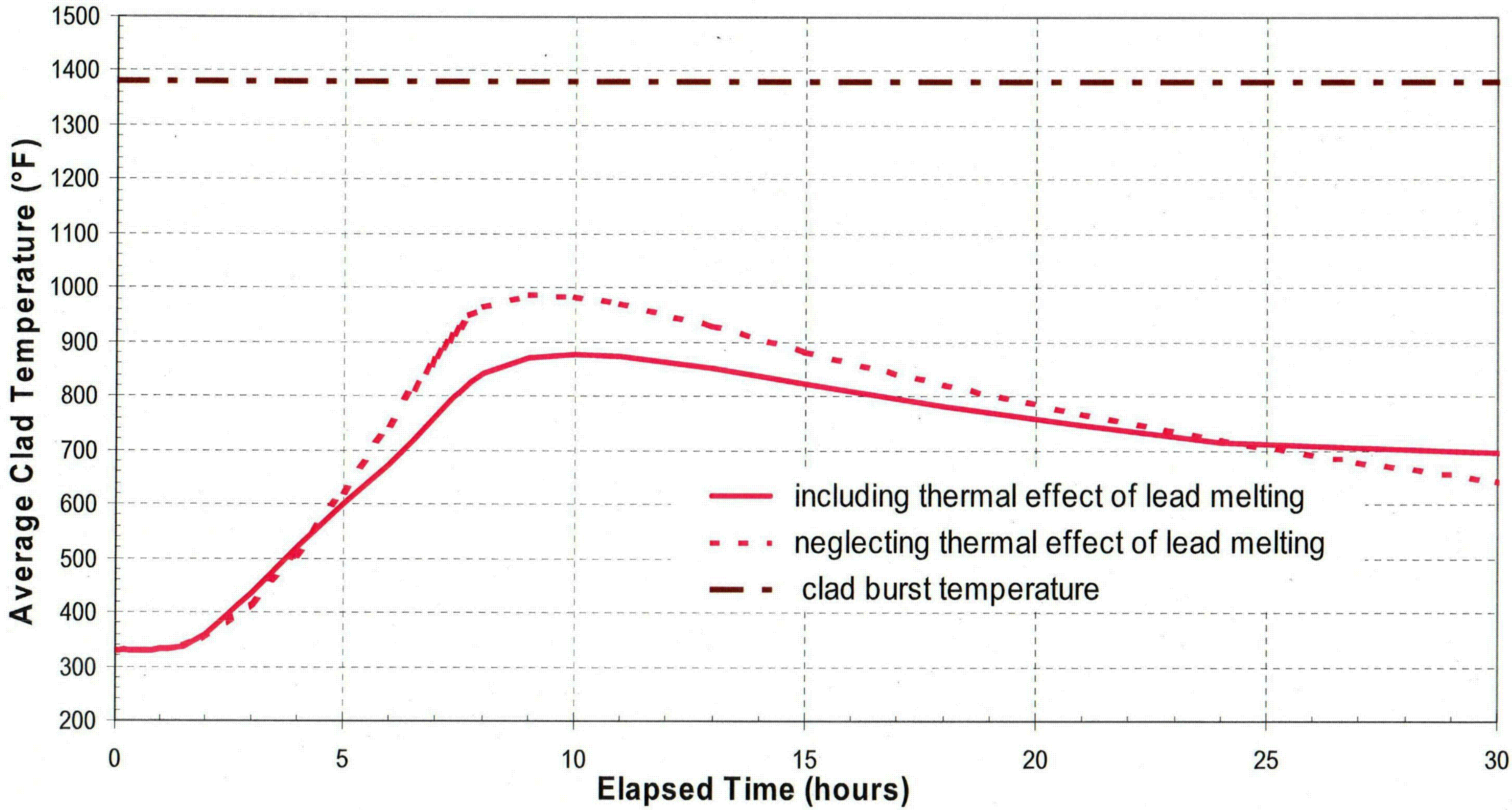
Lead Temperature as a Function of Location and Time



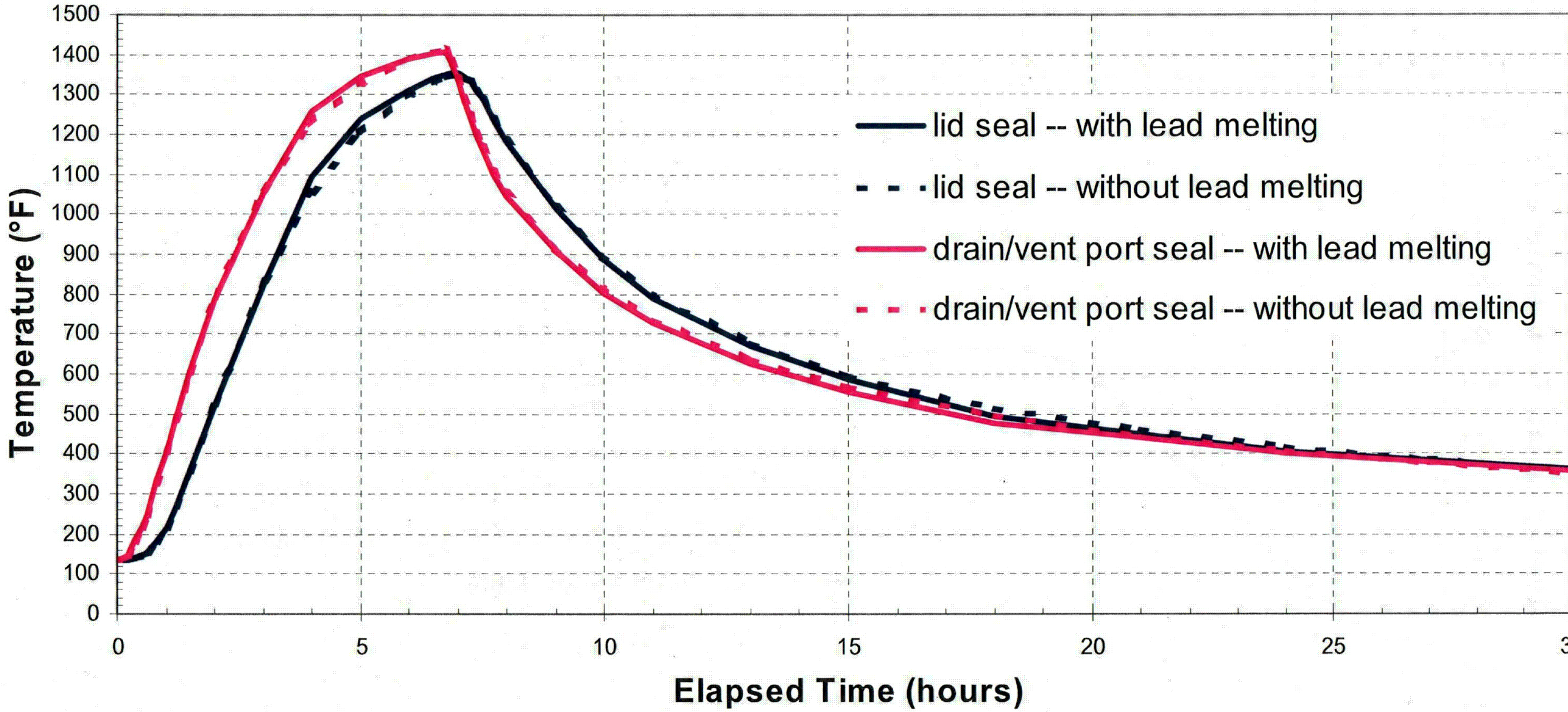
Peak Clad Temperature History in NAC LWT with and without Lead Melting



Average Clad Temperature History in NAC LWT with and without Lead Melting



Temperature History of Seals in NAC LWT with and without Lead Melting

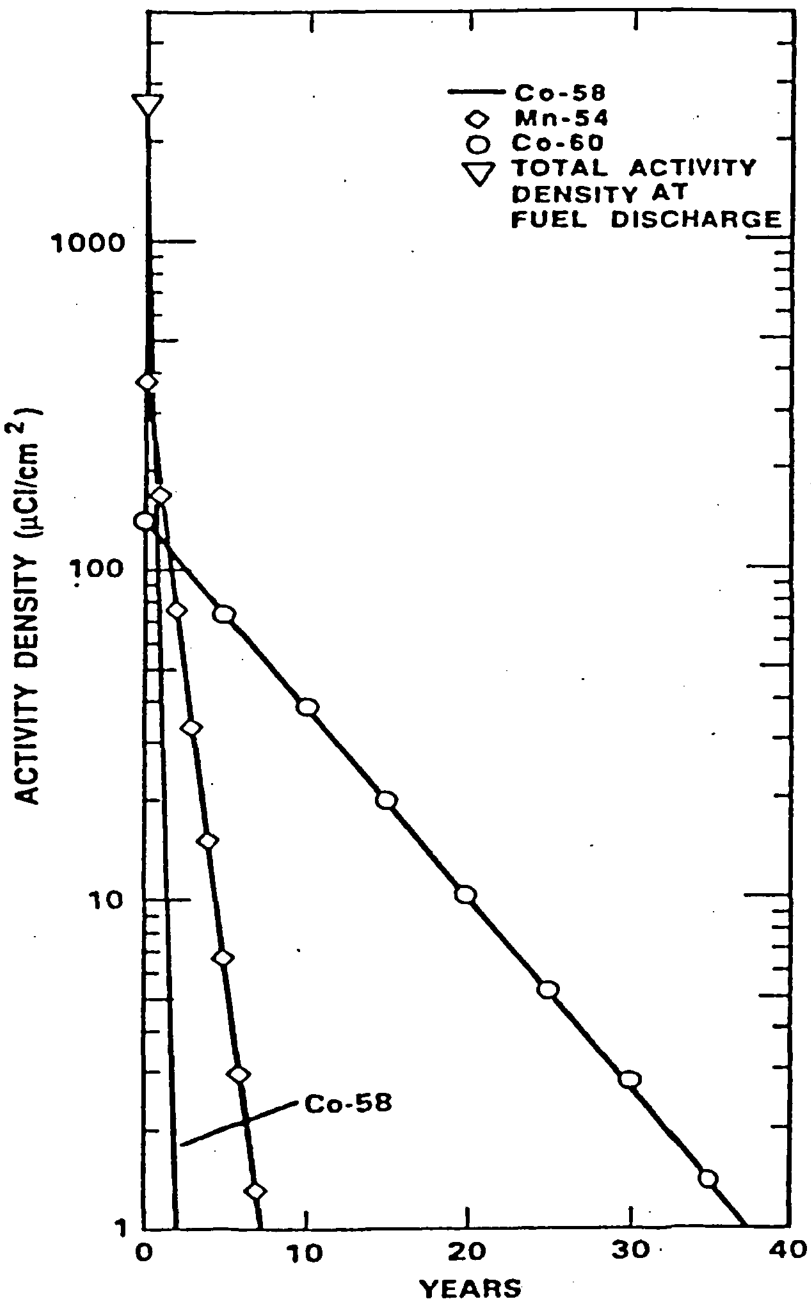


Modeling of Lead Melt

- Including lead melt provides a more realistic analysis and demonstrated additional margin.
- Report has been modified with additional text and figures.

Composition Assumed for CRUD (ACNW Comment)

- The Baltimore and Caldecott Tunnel Fire Studies assumed that the composition of CRUD on the fuel rods was 100 % Co-60. Is this a valid approximation and how would it affect doses?



Activity Density for Major Isotopes for PWR Assemblies with Maximum CRUD Spot Activities

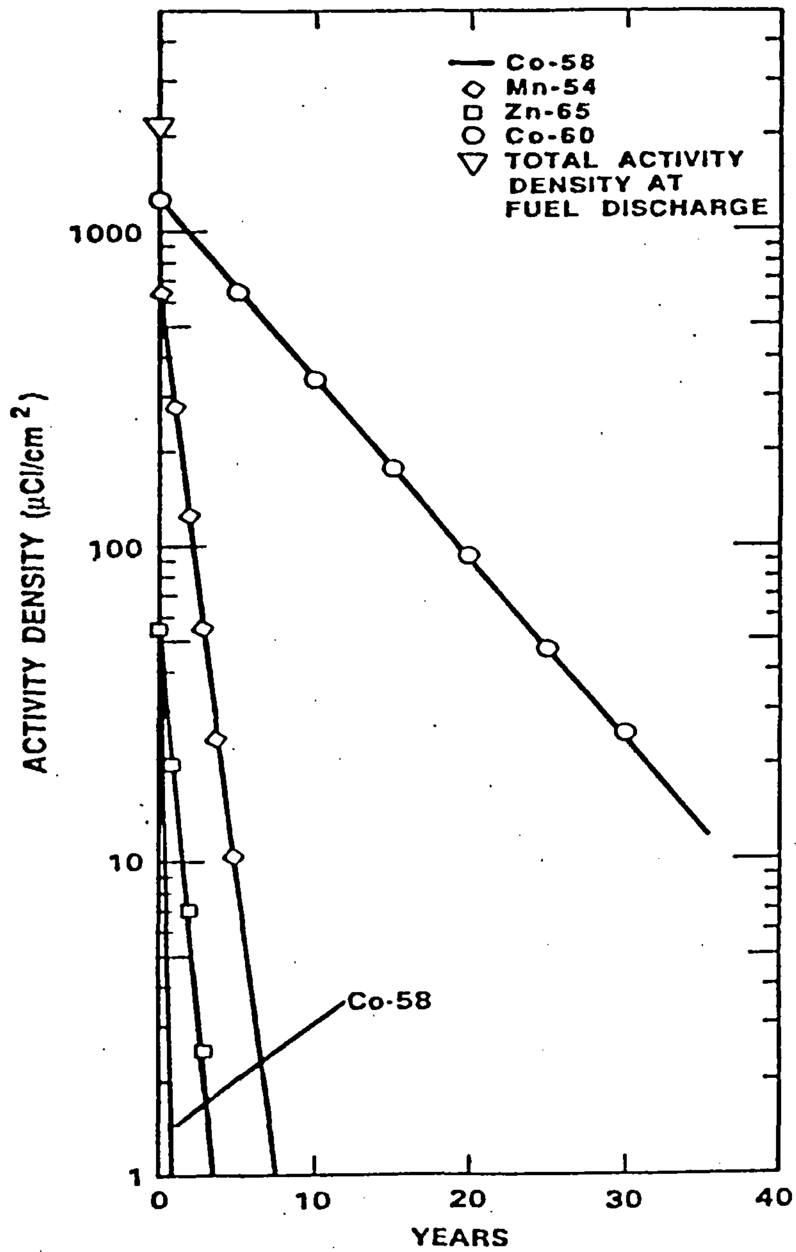
- Total activity decreases to 3% of that at discharge after 5 years and to 1% after 13 years.
- Cobalt-60 accounts for 92% of the activity at 5 years and 99% at 8 years.

From: *Estimate of CRUD Contribution to Shipping Cask Containment Requirements*, SAND88-1358

Activity Density for Major Isotopes for BWR Assemblies with Maximum CRUD Spot Activities

- Total activity decreases to 31% of that at discharge after 5 years and to 1% after 30 years.
- Cobalt-60 accounts for 98% of the activity at 5 years.

From: *Estimate of CRUD Contribution to Shipping Cask Containment Requirements*, SAND88-1358



Assumption for CRUD Composition

- Cobalt-60 considered to be reasonable for CRUD deposits for fuel five years or older.

- Report provides additional rational for the staff's selection of Cobalt-60 to represent CRUD.

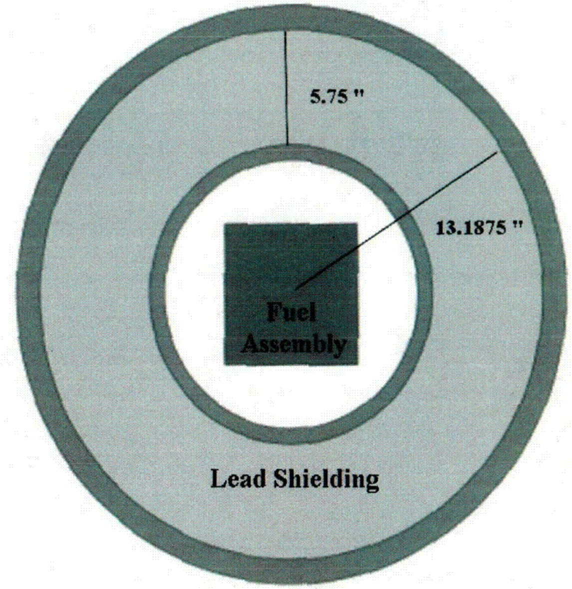
Potential Loss of Lead Shielding
(Public Comment)

- The Baltimore and Caldecott Tunnel Fire Studies did not consider the possible consequence of a loss of lead shielding.

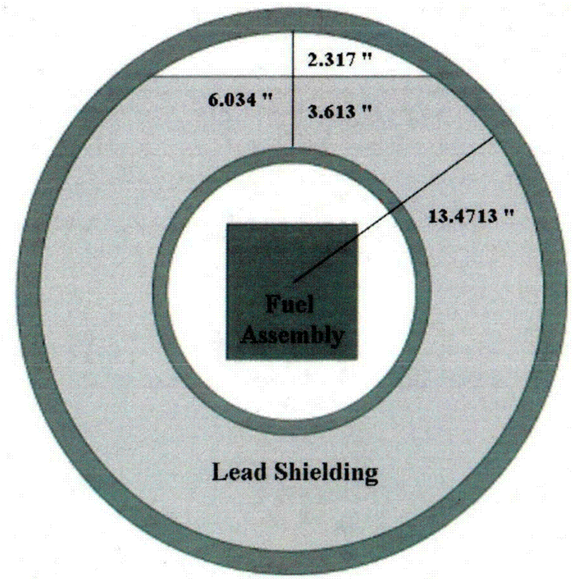
Potential Doses with Loss of Lead Shielding

Location	Intact Cask mrem/hr (mSv/hr)	After lead melt mrem/hr (mSv/hr)	Regulatory Limit* mrem/hr (mSv/hr)
Surface	55.71 (0.5571)	1216 (12.16)	
1 m	14.99 (0.1499)	331.3 (3.313)	1000 (10)

*from 49CFR173 and 10 CFR 71.51(a)(2)



Before Fire



After Fire

Potential Loss of Lead Shielding

- Doses remain below regulatory limits for any probable loss of shielding due to lead melt.
- Report has been revised to include discussion and diagrams of staff analysis of potential shielding loss.

Effects of Damaged and High Burn-up Fuel
(Public/Industry Comment)

- The Baltimore and Caldecott Tunnel Fire Studies did not consider the effects that damaged or high burn up fuel has on calculating the potential releases from the NAC-LWT cask.

Effects of Damaged and High Burn-up Fuel

- Potential releases from NAC-LWT bounded by fire analyses done for truck cask in NUREG/CR-6672.
  - Truck cask modeled after NAC-LWT cask.
  - Assumes fire severe enough to burst 100% of fuel rods and volatilize cesium.
- Release fraction calculated for Cs^{137} for severe fires (100 % rod burst) ≈ 1.7 $\times 10^{-5}$.
- Total release of Cs^{137} ≈ 1.4 curies.

Effects of Damaged and High Burn-up Fuel

- Potential releases for damaged or high burn-up (60 GWD/MTU) fuel are less than the regulatory limits established for transport safety.
- Report includes new section detailing this evaluation.

Performance of Cask Seals
(Public Comment)

- Analyses in Baltimore and Caldecott Tunnel Fire Studies do not take credit for cask seals remaining intact.
- User Need with RES initiated to examine seal performance in severe fires.

Caldecott Tunnel Fire

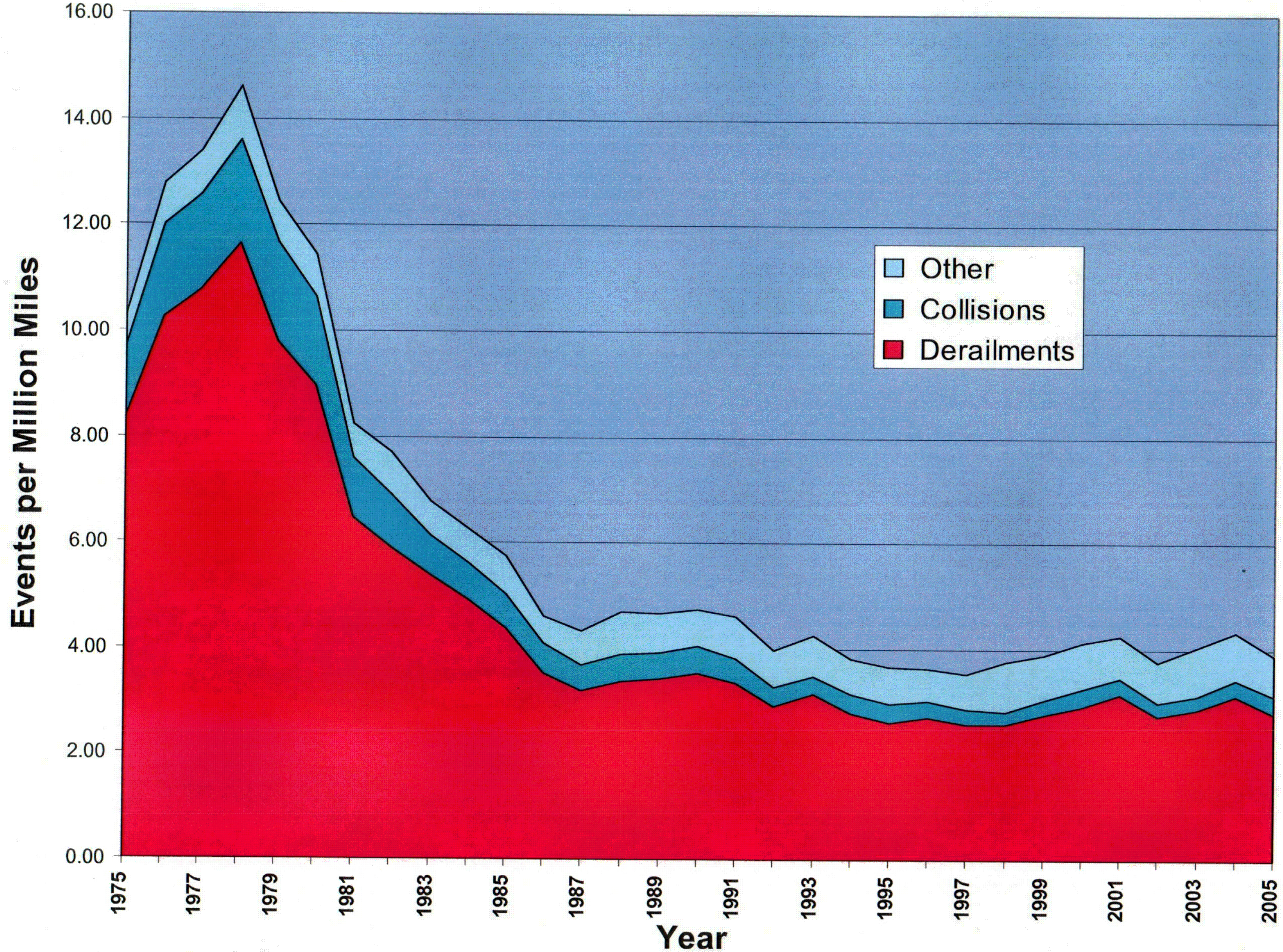
- Comments on NUREG/CR-6886 on the Baltimore tunnel fire will be rolled into NUREG/CR-6894

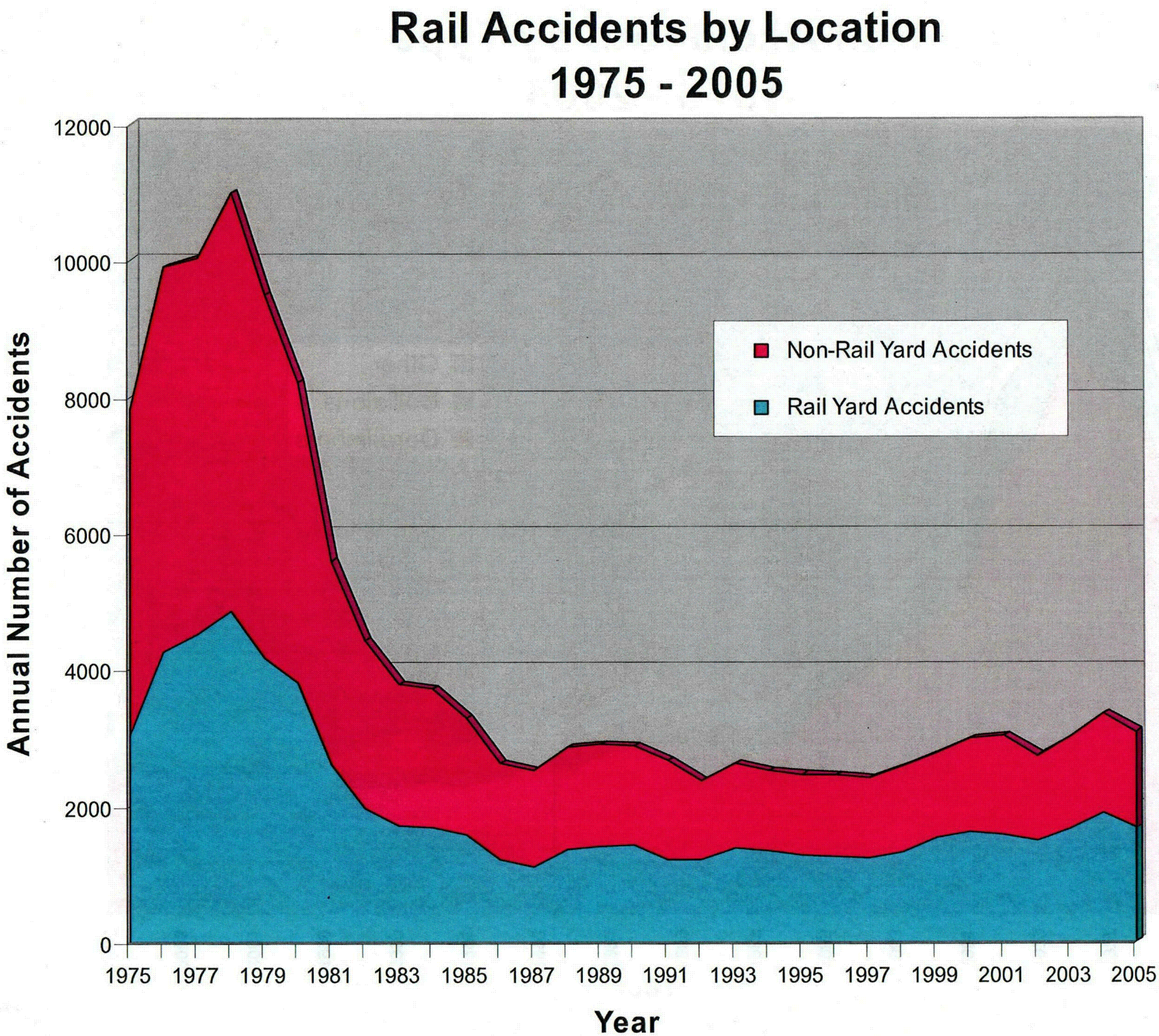
- One comment received pertaining to differing accounts of the accident between CHP and NTSB

Risk Perspective on Rail Accidents
(Internal Comment)

- For US rail accidents the risk from severe fires is very low.
- From 1975 through 2005
  - a total of 20,790,273,841 train miles have been logged on U.S. railways.
  - there have been 131,875 reported incidents.
  - there have been 1,726 reported releases of hazardous materials.
  - based on our preliminary re-assessment less than ten have involved severe long duration fires.

Rail Accidents by Type
1975 - 2005

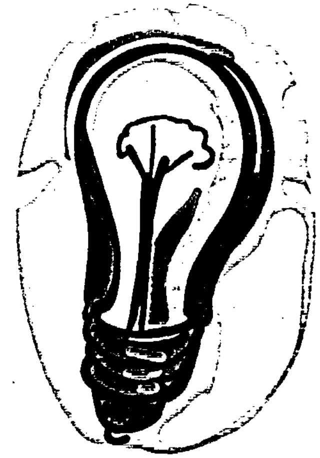



Rail Accidents by Location
1975 - 2005
12000
10000
8000
6000
4000
2000
0
Annual Number of Accidents
Non-Rail Yard Accidents
Rail Yard Accidents
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
Year

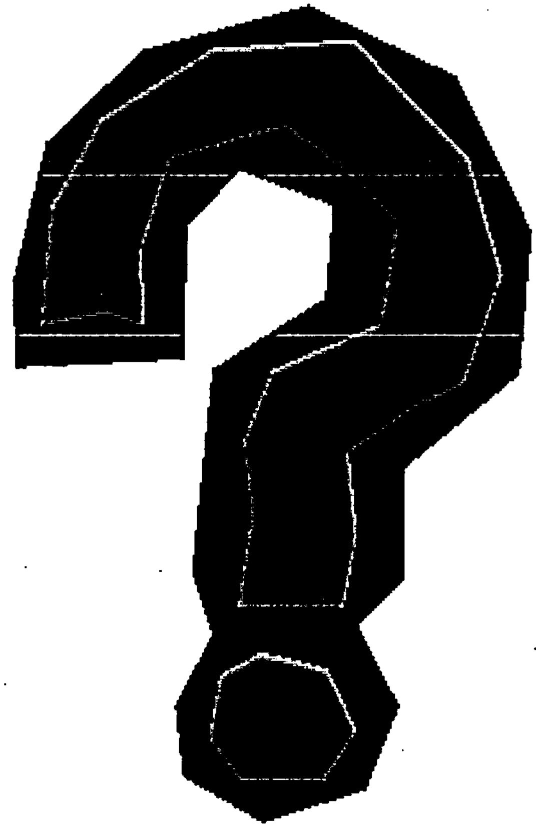
Risk Perspective on Rail Accidents (continued)

- Of these accidents, most were derailments of a single train.
- One occurred in a tunnel.
- It is likely that in all of these accidents, a spent fuel cask would not have been in a fully engulfing long-term fire because:
  - the placement of the spent fuel cask,
  - the nature of the combustible material,
  - and actions taken during emergency response.

A Simple Fix ?



- Can simple operational controls make an already low risk even lower?
- General use of dedicated trains
  - Severe fires result most often from derailment of single trains
- No pass rule in tunnels
  - Tunnel fires are the most credible accidents that could result in "fully engulfing" fires
  - AAR revision of Circular OT-55 includes "No Pass Rule"

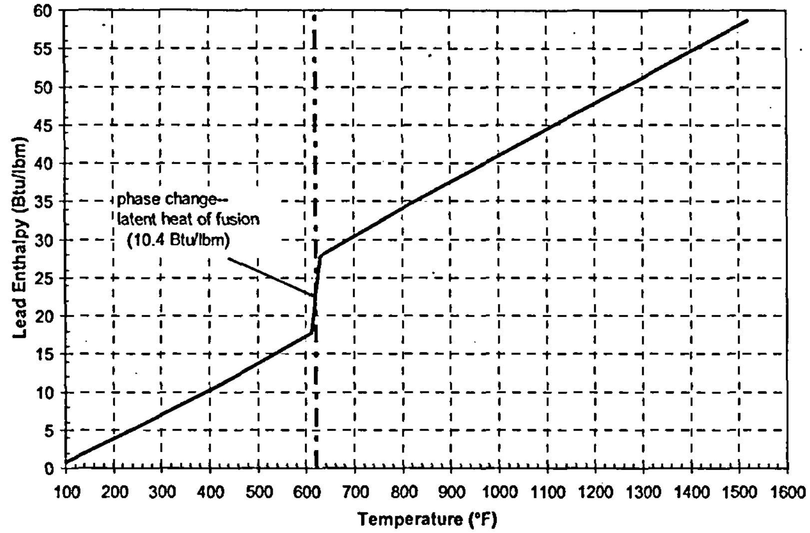


Backup Slides

Thermal Properties of Lead

- Thermal conductivity of molten lead approximately 50% lower than for solid

- Latent heat of fusion for lead:
  - 10.4 Btu/lbm (24.2 kJ/kg)



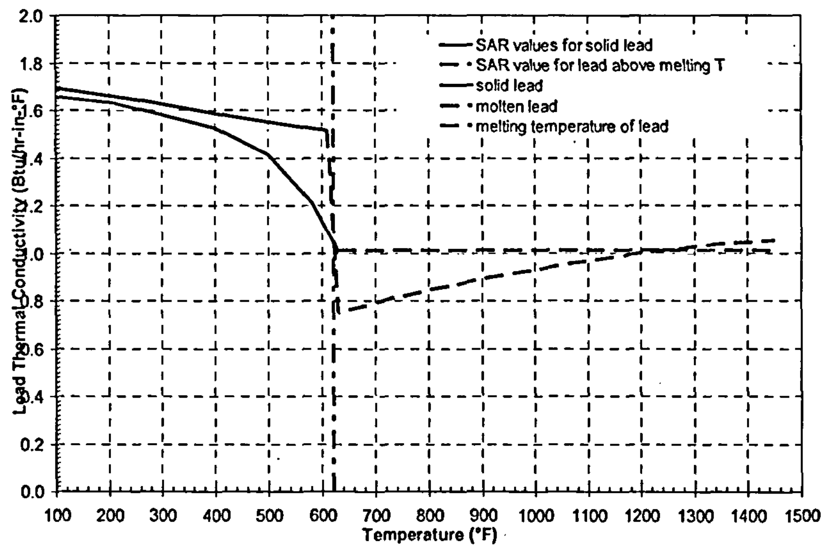


Table 7.9 Generic High Burnup, Three-Year Cooled, Fuel Assembly Inventories for RADTRAN Calculations (Ci/assembly)

Generic BWR Assembly	
Nuclide	**Amount (Ci)**
Co-60	6.40e+01
Kr-85	1.74e+03
Sr-90	1.59e+04
Y-90	1.59e+04
Ru-106	1.42e+04
Cs-134	2.15e+04
Cs-137	2.59e+04
Ce-144	1.03e+04
Pm-147	8.49e+03
Pu-238	1.67e+03
Pu-239	7.44e+01
Pu-240	1.36e+02
Pu-241	2.91e+04
Am-241	2.05e+02
Am-242M	8.09e+00
Am-243	1.22e+01
Cm-242	1.82e+02
Cm-243	1.42e+01
Cm-244	2.95e+03

Generic PWR Assembly	
Nuclide	**Amount (Ci)**
Co-60	5.78e+01
Kr-85	1.74e+03
Sr-90	5.36e+04
Y-90	5.36e+04
Ru-106	4.43e+04
Cs-134	6.99e+04
Cs-137	7.90e+04
Ce-144	3.87e+04
Pm-147	2.58e+04
Eu-154	8.42e+03
Pu-238	4.81e+03
Pu-239	2.14e+02
Pu-240	4.28e+02
Pu-241	6.52e+04
Am-241	4.36e+02
Am-242M	1.33e+01
Am-243	2.51e+01
Cm-242	3.76e+02
Cm-243	2.88e+01
Cm-244	5.62e+03

Calculation of Fission Product Release for Burst Fuel Rods

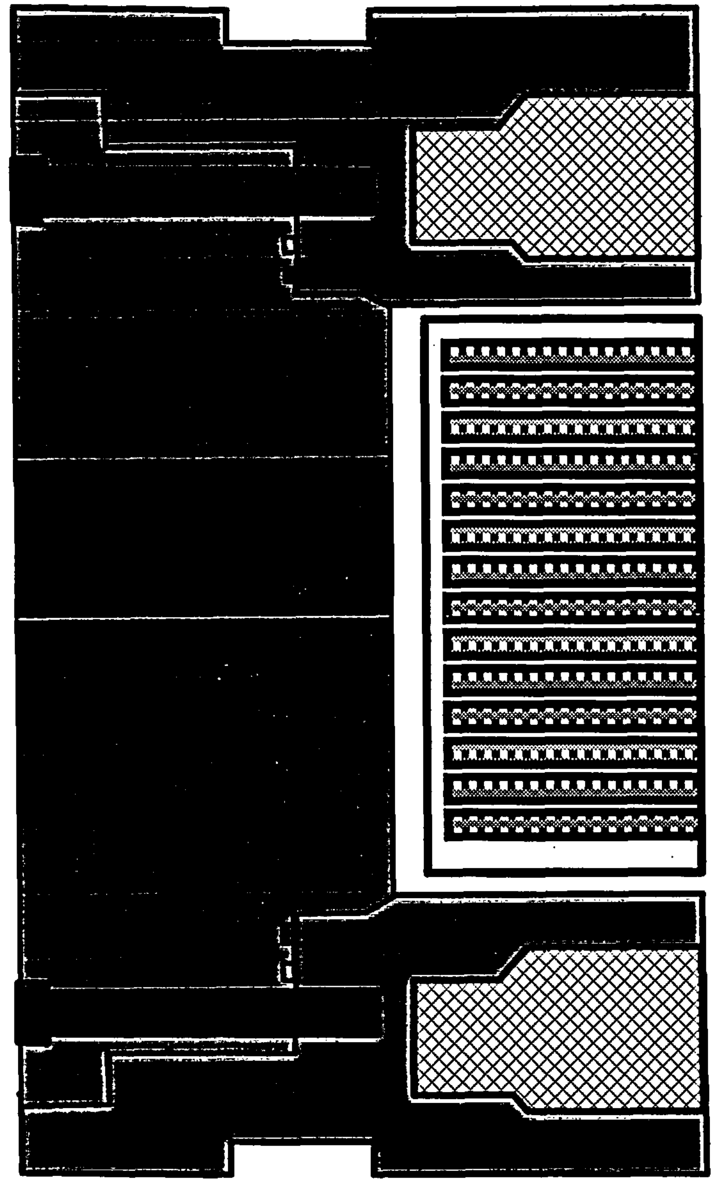
$$f_{rel} = f_{bur} f_{RCf} \left(1 - f_{dep}\right)\left[1 - \frac{p_{atm}}{p_b}\frac{T_b}{T_f}\right]$$

where :

f_{rel} = total release fraction for release of fission products from failed rods to the environment.
f_{bur} = fraction of rods failed by thermal burst rupture.
f_{RCf} = release fraction for fission products to the cask interior from a rod failed by thermal burst rupture due to a fire.
f_{dep} = fraction of the materials released from failed rods to the cask interior that deposits rapidly onto cask internal surfaces.

p_{atm} = atmospheric pressure
p_b = cask pressure after rod failure due to burst rupture

T_f = average fire temperature (1000°C)
T_b = rod burst temperature (750°C)



From: *Reexamination of Spent Fuel Shipment Risk Estimates, NUREG/CR-6672*

ASSOCIATION OF AMERICAN RAILROADS

Circular No. OT-55-I
Effective July 17, 2006

Recommended Railroad Operating Practices For Transportation of Hazardous Materials

VIII Special Provision for Spent Nuclear Fuel (SNF) and High Level Radioactive Waste (HLRW)

When a train carrying SNF or HLRW meets another train carrying loaded tank cars of flammable gas, flammable liquids or combustible liquids in a single bore double track tunnel, one train shall stop outside the tunnel until the other train is completely through the tunnel.