Immediately after the test, of course, we pulled the basket out to see what was going to be left, and we noticed that -- we took the basket out in the lab, and parts of the basket which was outside the point of contact, there was no permanent set of the basket.

And anywhere there was a point of contact during the contact, the deformation was minor. None of the rows had any signs of permanent set, none of the lip bolts failed, the environment was maintained, the criticality.

And that is only a part of the story. We obviously had to fix whatever we had to fix. We went back and did a whole series more of 30 foot drop tests, took the cask back from the lab, no permanent set.

So what we have concluded is we have actually taken a 30 foot actual drop, it is only supposed to occur one time, and we actually turned that into a normal operational condition, which is only a one foot drop.

So we felt like there was a massive amount of conservatism -- next slide, please -- in the design. Not just on the basket, but also on the cask body as well. And not just on the cask body, but in the bolts and the lid, as well.

So, in summary we feel like the methodology shown is adequate, we showed the results, and we feel that there are inherent conservatisms in the methodology.

One, one of the largest that we see, is the ASME code methodology, we are using elastic analysis, neglecting the ductility of the stainless steel. And the inherent conservatism of the structure evaluation using acceleration beyond that which we see in the test.

And the other one that we feel that there is conservatism is that very few things are rigid in this world, especially when you have a quarter million pound object impacting.

So we feel like this demonstrates that the current designs that we have, have a large margin of safety during the transport.

Thank you very much.

MEMBER LEVENSON: Thank you. Any of the --

VICE-CHAIRMAN WYMER: I have sort of a general question, whichever one of you chooses to stab at it.

There are three different kinds of gamma shielding material. You talked about stainless steel, lead, depleted uranium. And I would expect there to be differences in the performance, and the cost.

Would anybody care to tackle the gamma shielding materials?

MR. YAKSH: I would like to take the first stab. Mike Yaksh, NAC international.

The DU is on cask NI-1/2, we didn't renew it under BU85. So it is phasing in time, as it were. So that is probably not a good comparison. TE NI-1/2 was an innovative cask in its time, but it is frozen. So we primarily use the lead, it is easy to pour.You

MR. SINGH: Do you want me to supplement it?

VICE-CHAIRMAN WYMER: Please.

MR. SINGH: All right. Well, in the cask you have two competing considerations. You have to maintain a certain diameter, which is the most you will make about 8 feet, 96 inches, and you have to have certain gamma attenuation capability.

Now, lead has a much greater density than stainless steel, or any form of steel. And, therefore, you are able to provide much more gamma shielding capability in a small diametrical space.

However, lead is a very weak structural

material, it tends to creep under sustained loads. And, therefore, if you were to make the cask out of steel instead, or stainless steel, or any form of steel, you have gamma shielding, as well as structural capability.

If you were to use lead, a lot of lead, and less steel, you will have more effective gamma shielding capability in the same diametrical extent, but you will have less structural capability.

Our cask is all steel, we do not use any lead.

VICE-CHAIRMAN WYMER: What cost?

MR. SINGH: The cost depends on the extent of welding you do in the cask, the manufacturing cost. The material cost is fairly constant. I mean, if you use lead, for example, and you were to pour lead, which is heated, temperature control operation, it is more expensive than installing lead bricks, which are pre-manufactured.

There are competing considerations. I guess the maximum, the most significant cost element, in making the cask, is the extent of joining, the welding work that you do, and maintain the dimensions that is where most of the expense is.

VICE-CHAIRMAN WYMER: Yes. One of the

things that occurs to somebody who doesn't know anything about this business is that something like lead in an impact, from an accident, or a test, it might tend to flow a little bit, and change the position of the weight.

MR. YAKSH: NAC International, Mike Yaksh, I don't agree with that. We have done extensive testing, we exposed it to five times the G-load, we didn't see any slumping, we didn't see any bulging of the outer shell, or bulging of the inner shell.

VICE-CHAIRMAN WYMER: That is what I was trying --

MR. YAKSH: You would have thought, we would have seen that in the five times the G-load, but we didn't see that, because we did metrology measurements of the insides, as well, of the STC, so I would say I don't see any --

I know with some designs if you have a weakened shell you might have slumping, some damage. But since we are aware of that, that is not a problem. Thank you.

MR. SHIH: This is Peter Shih from Transnuclear. Kris is right, you know. Normally if we don't have a dimension constraint, like our TN-68 dual purpose cask, and we are only design for transport in the United States, so we use steel.

However, like our new NP-197, because we try to use this particular cask not only in the United States, but also in Europe, you know, so we had outside diameter constraints, we do have a lead filled, and it is lead filled stainless steel.

I just mentioned moments ago, I said, steel. But we do have a lead filled stainless steel.

VICE-CHAIRMAN WYMER: Thank you.

MEMBER LEVENSON: What you are really saying is that the regulators sometimes control the technology, the economics. There are different requirements for your European shipments than your American shipments, so you end up with a different design?

MR. SHIH: Yes.

MR. SINGH: The regulators contribute to the technology, of course. In a positive way, one would think.

MEMBER LEVENSON: John?

MEMBER GARRICK: I'm very impressed with your confidence in scale model testing. From two points of view, one is the point of view of demonstrating safety, and that is to say cask integrity. And, two, the point of view of authenticating your analysis models.

Let me ask the question another way. Is there anything that we can learn from full scale tests, with respect to those two points, that you can't learn from scale model testing? Any of you can talk about that.

MR. SINGH: Well, you know, when you scale in any physical test, if you scale a structure, or a component, you use certain scaling algorithm, you will scale mass, you will scale volume, you will scale local rigidity of the materials.

But there are compromises involved. You don't have a direct, unless you are doing the test, for one specific loading, and one specific orientation, any scale model you will make would be ideal for that particular test, but it will be approximate, or depart from the scaling that you have done, for other loadings.

MEMBER GARRICK: Full scale test would have the same problem. For one particular angle, one particular load, etcetera, etcetera.

MR. SINGH: That is correct, but the full scale test, whichever loading you apply to it, will give you the response of the structures it would.

What I'm saying is that when you scale

anything down to a quarter scale, or a scaled structure would replicate, you will be able to scale up the response to the full size structure for that specific load, or for approximately for loads which are close to it in their nature and application.

But once you go you try to deal with a wide variety of loads that you want to study. Well, then you will depart from it. So scale models do serve a function, they do have -- they are much, much less expensive, and you can run many of them.

For example, we have numerous scale model tests when we were qualifying to license HI-STAR. We couldn't do all those many tests on a full scale, of course, that you will end up destructively modifying the cask in the process of testing.

So scale models have their place under the sun, but I think that to have, if you were to run a full scale test, you would have a much higher level of confidence. There are limitations when you scale down a structure.

MR. SINGH: But it sounded like what you were saying is that that may be true with respect to demonstrating the integrity of the cask. But as far as models are concerned, analytical models, scale models usually, can they not, do a very good job of giving you what you need to analyze a full scale design?

MR. SINGH: To benchmark model, yes.

MEMBER GARRICK: Yes, to benchmark the model.

MR. SINGH: It will give you a useful tool. And that is what we do today. We have a scale model, we have scale model test results, and we have benchmark the analytical model to predict the cask response using the scale model.

And that is a satisfactory way to do things.

MEMBER GARRICK: But the question is, from an investment standpoint, is it worth the extra expense to go to full scale model to reduce, maybe, the uncertainty in your analytical model, by ever so small, if you really forthright in presenting the uncertainties in the first place?

MR. SINGH: Well, I don't mean to suggest that you cannot do scale model test and pull up a very high level of confidence with respect to the ultimate performance of the structure.

But it is a case of available funds versus the level of exactitude, or rigor, or quality of information you are looking for. I do -- I would love to do a full scale test, as a scientist and as an engineer. But it is very expensive.

And scale models serve the function to establish a high level of confidence in the behavior of the structure.

MEMBER GARRICK: We engineer a lot of things without full scale models, of course. And somehow we've managed to, in most of those cases, do it right. And so I'm just very curios as to the experts here, as to what added benefit we get from full scale tests.

Maybe somebody else would like to talk about it?

MR. YAKSH: As Kris said, the scale modeling has its place under the sun. To us it has allowed us to benchmark our methodology to which we would do a full scale. And I think something needs to be pointed out more, is that in our experience we look at the quarter scale model not only just confirming, but also any kind of manufacturing details that need to be worked out, it is much easier to work them out on a quarter scale model than when you are dealing with something that weighs 4 tons, it is much easier to work with something that weighs 100 pounds.

So we look at the quarter scale modeling not only as a means of benchmarking the methodology, but this is how we want to build it, because it is easier to work with a quarter scale, than it is to work with a full scale.

So it is really a dual purpose, it is just not benchmarking data, it is how we want to build that full scale. Because, ultimately, you are not going to transport the quarter scale model, you are going to transport the full scale.

And what everybody has been focused on is, primarily, I want to get back the results. The important thing is if you want to build a full scale, how you build a full scale, and influence your results. So you want to work all those wrinkles out, and details out, in accordance with scale model testing.

That is why, at this point, I don't know how much more testing we want to do, I don't know what we would learn if we did any more testing. We've built so many of these quarter scale models, learning so many things in fabricating, that I don't see any more how we would learn any more, if we were to go to a full scale.

MEMBER GARRICK: Thank you.

MR. SHIH: This is Peter Shih, from

Transnuclear. Basically in my presentation, page 64, I list about three report, and in each report I have studied, extensively, between the scale, radiation shielding between the scale model and a full scale.

And based on the conclusion of these three report, you know, if your scale factor is one quarter, or greater, then the correlation is excellent. And, also, the CEGB, the full size cask, before, they also have a scale model test.

And based on the information I learned from those, you know, they have a camera, high speed camera, one-third scale model, and a full scale model. And it do a drop, and they behave almost identical, you know?

I don't have the report now, but this is based on my knowledge, you know, that third scale test, and the full scale test are almost identical. Thank you.

VICE-CHAIRMAN WYMER: Thank you.

MEMBER RYAN: I was going to ask a question, again, back at design. At least for highway casks, weight is really your limiting feature, is it not?

MR. YAKSH: Actual highway?

MEMBER RYAN: Yes, road versus rail.

MR. YAKSH: No, you can get higher than 52,000.

MR. SHIH: You can have an overweight truck.

MEMBER RYAN: Sure, you are always kind of constrained to make that decision, either stay within the 8,000, or go over.

MEMBER LEVENSON: Maybe one more question on the modeling issue. It is a little bit philosophical, but maybe I can get three different opinions.

And that is, if you were making rather drastic changes in the design, so you don't have a lot of background, and you are starting with a relatively new model, the casks are designed, would you feel more comfortable if you had one test at full scale, which lets you test one data point, or you have multiple tests of small scale models, where you have multiple data points, but at a scale.

Which would give you a bigger sense of confidence?

MR. YAKSH: This is Mike Yaksh, International. I would rather have more data points, because if there is variability in manufacturing I will never pick it up with one data point, I will pick it up with multiples.

And in all the tests we've done, whatever variability is there, we've observed it. And that gives us greater confidence. When we build the full scale, we will build it like we say we would build it.

MR. SINGH: I agree with Mike. The -- a single test, you know, a cask is not an isotropic homogenous body. So if you run one test, in any given direction you are going to get response for that particular loading.

The actual cask, of course, in real life has infinite number of loadings, directions it can be loaded. So a number of scale model tests, scale tests, gives you the ability to benchmark your model much more accurately than you could with one full scale test.

MR. SHIH: Again, I tend to agree. The reason is the cask, basically, you drop in different orientation, and a different part of component of the cask will respond differently.

Like for the basket, you know, the worse case would be a side drop. However, for the lip the worse case would be the seat drop through the lid. So basically, you know, I think for one drop in full scale, probably, you cannot represent the entire load issue. Thank you.

MEMBER LEVENSON: It is interesting, the three of you agree. Historically back at the Manhattan project days, there was a physicist by the name of Sam Untermier, who is really I guess is the inventor of the boiling water reactor, in later years.

But he argued it was never necessary to get more than a single data point, because physicists could understand everything from first principles, at one point you just knew where to put the curve, the shape of the curve came from theory. But you don't really agree with that.

Any questions for the Staff? Any of the other presenters have questions?

MR. AMMERMAN: Doug Ammerman, Sandia National Labs. And I would like to make a comment on the scale modeling. What the vendors said is exactly correct for structural testing.

But if you go and do thermal testing, and you want to relate the test results of the scale model to a full scale, it is impossible. You could use scale model to benchmark code, you can use the code to the full scale, directly compare the results of the scale model test, to the result of the full scale test.

For example, in Mike's presentation, for structural impact he said Gs were this, and you simply had to divide by four, in order to -- what the Gs would be for a full scale.

That works fine for structural, but it is not the same correlation for thermal testing. The other area that doesn't scale is leak testing. If you do a scale model testing and say the leak rate was X, it doesn't tell you anything about what the leak rate would be, or very little about what the rate would be for the full scale.

Which is why when people do scale model testing they say the leak rate is zero. I know how that correlates to full scale, it is still zero.

MEMBER LEVENSON: Any comments or questions?

MR. BRACH: Bill Brach, NRC. Just one additional comment I want to add. Earlier this morning we were talking about full scale testing, or scale model testing, and we were discussing some of the needs, or benefits, or reasons coming from either a science perspective, or a safety perspective.

I juts want to mention there is one other aspect that we didn't discuss this morning, but although it was evident in at least one of the comments we heard, there also is a public interest perspective.

And I will just mention that within the NRC, in our strategic plan, I'm sure you are aware where strategic goes, is to increase public confidence. So speaking from the Staff's perspective, we do have to take into context those considerations, in addition to the earlier discussion we had on the science and safety.

MEMBER LEVENSON: Well, I think it is much broader than that, Bill. I think the Committee is well aware that while we much prefer to focus on the technical aspects, what you have to do, in operating an agency, is partially technical, and partially legal, and partly political, partly public opinion.

But we are trying to focus on the technical aspects. I think we realize that everything you do isn't purely technical, and it gets modified by all the other pressures.

And if it is an act of Congress it is somewhere at the top of the pecking order. But we are trying to separate.

MEMBER GARRICK: Mill, I want to draw Doug out a little bit on his observation about thermal versus structural.

Is the difference because it is more difficult to constrain a thermal test? Otherwise I don't quite -- pardon?

MR. AMMERMAN: No, it is because there is different regimes in a thermal test. The heat transfer is done by three modes, radiative, convective, and conductive. And not all those modes scale the same manner.

The radiative heat transfer scales with temperature of the force, conductive scales with temperature, with temperature. And so the -- you have a mixed mode of heat transfer scaling laws become too complex.

If you wanted to say I'm going to ignore two of those modes, I'm only going to look at, say, radiative because it dominates, then you can do scale model testing. Do a scale fire. Actually, it is still not very easy, you have to scale temperature and scale time to do a scale fire.

In reality you have a similar situation with testing. That when you do a quarter scale test you actually have a 4G field. But we say that that is not important. So instead of doing quarter scale test, dropping it from a quarter scale distance, we do a quarter scale test dropping it from a full scale distance, in a 1-G field, instead of a 4-G field.

It ends up with the same impact velocity. But where the quarter scale model doesn't behave the same as the full scale, it is in rebound. The quarter scale will rebound much higher, rebounding in a 1-G field, instead of a 4-G field, it is going to rebound four times as high as you expect it to, scale the rebound height for full scale.

MEMBER GARRICK: That is partly what I mean by constraining, though, is that you design an experiment where you understand those differences between the different parameters.

It seems to me if you could do that, then you ought to be able to get the same benefit. It sounds like, in the early days of reactor kinetics we had some of the same problems, of trying to properly constrain the transient experiments in such a way that we could really do a proper matching of the neutronics with the thermal hydraulics.

And as we learn more and more about how to do that, and how to constrain the experiment, then the concept such as scaling phenomena seem to fall in line more.

And I was just wondering if it was the same kind of thing here.

MR. AMMERMAN: Yes, it is a similar kind of thing. You do a replica scale for heat transfer, it is not actually the best way to do it, because what we would really like to do, your replica scale, you have to scale temperature.

Fires don't come in a wide range of temperatures, you get what you get. So to solve that problem you scale the conductivity. But you can't do that with the same material, you have to change material.

So a scale model that you would build for an impact test may not be the same scale model that you would use for a fire test.

MEMBER GARRICK: Yes, okay, thank you.

MR. FISCHER: I'm a little bit concerned because it seems like we've gotten into scale model testing just using like the pi theorem, and so forth. So I was talking about physical codes in scale model testing.

And when you use a physical model, these things are taken into consideration. I would like to think your PRONTO, and so forth, is a physical code, not just a scale code. I mean, they are doing physical phenomena.

So when you are using a good physical

code, you get the right answers. The only reason why you do the scale model testing is just to kind of see what is going on, and what regions are important to look at, and that you understand how bolts actually go in place, and friction between bolts, and will they untorque on you, how do these things react.

And if you went through scale I think you are close enough to say, yes, I benchmarked my code, just like when we do criticality analysis. We don't have the exact configuration of what you have in your cask, but you have something close.

And so I don't want to hear us going down the road of our scale model testing the way we used to do. We wrote an extensive report on that. Jerry Mach was the primary author on that.

And we spent a lot of time on that, and it never came out as NUREG because there was too much controversy, and so the bottom line is you better be using a physical computational code, or otherwise I don't trust scale model testing.

You have the inertia problem, and so forth, and that sort of thing. So there is not -- that is a different type of test. That is what we used to do 15 years ago.

MEMBER GARRICK: This is when the workshop gets interesting. We've come a long way.

MEMBER LEVENSON: That is why we have workshops, rather than a bunch of just presentations. Questions from the committee members, or the other presenters?

MR. RESNIKOFF: I appreciate your allowing us to -- Marvin Resnikoff. I have just two quick questions. One involves the presentation that was made by, I think, NAC.

And it showed that the deceleration of 188, 86-G, I think. And now I remember Lawrence Livermore study that Holtec, or PFS presented at the hearing, where it said that the cladding would be damaged at 63-G.

In other words, it looks like the impact of 186-G would severely damage the cladding. Is that your understanding, is the question.

MR. YAKSH: I understand your question. Is the full scale see 188-Gs? The answer is, no, it doesn't. What you looked at there was the quarter scale. And as Doug pointed out, in order to see what the full scale G-load would be, you would divide 188 divided by 4, which is much less than 63.

See, if you are transporting the fuel quarter scale fuel, you don't transport quarter scale fuel, you transport full scale fuel, in a full scale cask. Therefore the acceleration that would be up there for the full scale would be one-fourth of that value.

MR. RESNIKOFF: In other words, if you dropped a full scale cask a 30 foot drop, it would only have a deceleration of 40-some G? Is that your understanding?

MR. YAKSH: Yes, sir.

MR. RESNIKOFF: I don't believe that is true.

MR. YAKSH: Yes, sir, it is. I have two experts over there that will agree with me, sir.

MR. FISCHER: That is what you designed it for, and I'm sure it does it. That is the problem when we start talking about scale tests. And as a rule of thumb we can divide by four, or whatever, or multiply.

But, again, when we get down to the real physics, we need a physics code to run it.

MR. RESNIKOFF: I'm back to the drawing boards, then.

MEMBER LEVENSON: There is another thing we have to remember, and that is that the number of Gs that the vehicle sees, or the cask sees, is not identical to what fuel sees. There is significant energy absorption, many places between here and there.

MR. RESNIKOFF: The other quick question involves the type of carriage that the Holtec cask is going to be on. Maybe Mr. Fronczak is going to address this point.

I noticed in one of your views you had two double axle carriages at each end, that is where the airplane engine impacted the cask. But in another view you had single double axle carriages at each end.

And so my question is, is it the single double axle carriage at each end? And if so, are those movable carriages, or are they rigid?

MR. SINGH: Marvin, we are not designing the rail car. The portion of the structure that we designed is the cradle that is connected to the rail car. The car, for modeling purposes, was modeled, the platform was modeled, and the wheels were modeled.

In this model it was considered a rigid body. The one that you saw, with the engine impacting it, it was modeled as a rigid body. We wanted to see if there is no energy dissipation through deformation at all, would the cask separate from the rail car.

We did not focus on the railroad design aspect of the car.

MR. RESNIKOFF: Well, maybe Mr. Fronczak will be talking about that.

MR. SINGH: I'm sure he will enlighten us, later, on these things.

MR. FRONCZAK: We see one design.

MR. RESNIKOFF: What did you say?

MR. FRONCZAK: During my presentation you will see at least one design, which is the private fuel storage design.

MR. RESNIKOFF: One of your, I forget the name of the company, TT something or other, is the one that tests these casks, and are they associated with the Association of American Railroads?

MR. FRONCZAK: Yes, TTCI, it is Transportation and Technology Center, Incorporated, is a wholly-owned subsidiary, for-profit subsidiary, of AAR.

MEMBER LEVENSON: Any other questions or comments?

(No response.)

MEMBER LEVENSON: If not we will take a break a couple of minutes early, and reconvene sharply at 3:30.

(Whereupon, the above-entitled matter went off the record at 3:14 p.m. and went back on the record at 3:31 p.m.)

VICE-CHAIRMAN LEVENSON: I think we're ready. Our first speaker after the break is Chris Bajwa from the SFPO. Chris?

MR. BAJWA: Thank you.

Before I start, I just want to make a small, short announcement. In the packages you received today, there are a set of slides for my presentation. Please disregard those slides that are in there. There is a handout that has the version that I will be presenting right now. We have extra copies of that handout up here on the corner of the table right next to Tim. They handed them out. So just about everyone should have gotten one. If we run out of those, we can make more copies for anyone who needs them.

All right. My name is Chris Bajwa. I am with the Spent Fuel Project Office. I am a federal engineer. Today I am going to talk to you about the staff review and analysis of the 2001 Baltimore Tunnel fire event.

In this presentation, I am going to cover several topics. First of all, I am going to tell you a little bit about the Baltimore Tunnel fire. Then I will talk about the staff's coordination with the

National Transportation Safety Board, who has primary responsibility for investigating transportation accidents.

I will tell you about a preliminary scoping analysis that the staff did. I will also tell you about a National Institutes of Standards and Technology fire model that was done to model the Baltimore Tunnel fire. I will tell you a little bit about the validation of that NIST model. I will also tell you about a refined cask analytic model that the staff did based on the NIST data. And, finally, I will have some conclusions. My goal is to get through all of this without putting anyone to sleep. So we will see if we can accomplish that today.

Next slide. Well, they say a picture is worth 1,000 words. So I have four pictures up here. That's 4,000 words. I figure I probably don't have to say anything more for the entire presentation.

Anyway, these are some pictures that were taken during and shortly after the Baltimore Tunnel fire that happened last year, July 2001. It took place at the Howard Street Tunnel, which is in downtown Baltimore, right next to Camden Yards.

That particular tunnel is a single-rail tunnel. It's about 1.65 miles in length. And, just to go through the pictures here, this is the east portal of the tunnel. The train that was traveling through that tunnel at the time was a CSX freight train. It derailed. And a fire ensued after the derailment.

It was traveling through. This is the entrance, the east portal. This particular car was removed after the fire. This car is a triprophylene tanker car. Triprophylene was the fuel that actually spilled out and ignited.

This is a hole that was in the car. It's about 1.5 inches in diameter. That hole was punched in the car when the car itself derailed. It was believed that the braking mechanism broke, flipped up, and punched a hole in the car. And that is where the triprophylene spilled out.

This picture up here was taken at the west portal during the fire itself. Obviously you can see there is a fair amount of smoke. And down there this is the west portal after everything was cleaned up. And you can see the difference between these two pictures. This is the same portal.

Next slide. As I said before, the NTSB is the lead agency for investigating transportation accidents. The commission and the staff requirements memorandum asked the staff of FSPO to look at and analyze the Baltimore Tunnel fire and see if it had any impacts on transportation of spent nuclear fuels specifically and also if there were any regulatory implications for this particular event.

We met with NTSB and have met with them several times. The first time we met with them was in September of 2001. At the time, NTSB indicated that they would look into the fire and wanted to quantify the thermal conditions that were found in the fire.

Later they decided that the derailment, the cause of the derailment, was actually a primary concern to the NTSB. They kind of changed their minds and decided they would not look into the fire, which makes sense because the derailment caused the fire. And so the cause of the derailment is what the NTSB was interested in.

So the staff decided that our main interest was the fire because we believe that would have the biggest impact on the spent fuel transportation cask. So we decided that we would look at the fire and analyze that.

The NTSB provided information, data, technical expertise on rail events. They also made the rail cars that were taken out of the tunnel after the fire available for our inspection. And we were able to take some samples and look at the damage that was done.

Now, in order to get our hands around this particular accident, we decided that we wanted to do a preliminary scoping analysis to kind of see how a spent fuel transportation cask might react if exposed to a severe fire. We also wanted to make sure that there wasn't an immediate concern over the performance of the cask if it were in, say, a tunnel fire accident.

We selected the Holtec HI-STAR cask, which Kris Singh told you about earlier. So you obviously have a lot of detailed information on what that cask looks like. Part of the reason we picked it is it's a certified cask, one that the NRC has certified for use.

The second reason is that it's likely to be extensively used. Specifically, if private fuel storage at that particular site is licensed and operational, there will be hundreds of shipments using the Holtec HI-STAR cask. I developed a HI-STAR analytic thermal model using the anisys finite element analysis program.

You heard probably a little bit about 10

CFR Part 71 and specifically Section 73, which talks about the hypothetical accident condition for spent fuel transport casks. This condition is a fully engulfing fire at a flame temperature of 1,475 degrees Fahrenheit for 30 minutes. That is what every cask that the NRC certifies has to meet. That's a condition in the regulations.

What I did for this particular analysis is I chose 1,500 degrees Fahrenheit. And I ran this analysis for seven hours. So the spent fuel cask that I was analyzing was fully engulfed for 7 hours at 1,500 degrees Fahrenheit.

The schematics that Mr. Singh showed you are a little bit nicer than mine. So I am just going to run quickly through these. This is the HI-STAR cask. The MPC, the multi-purpose canister, is where the fuel is actually stored. That is a welded, seal welded, pressure vessel. This is the over-pack in which the MPC resides. What is missing from this picture obviously is the impact limiters.

Next slide. For this preliminary scoping analysis, we had boundary conditions of convection and radiation on the outside. And internally conduction, radiation, and convection were also accounted for. The initial steady state thermal conditions, normal conditions for transport, were 100 degrees Fahrenheit. We let the cask reach a steady state temperature on the inside with 100-degree ambient temperature on the outside. There is a 20-kilowatt heat generation on the inside.

Given that we didn't know the thermal conditions that were present in the tunnel at that time, we chose the engulfing flame temperature to be 1,500, which is slightly above the 7,173 requirement. For the fire, we increased the convection heat transfer on the surface of the cask in order to simulate the fire environment, which is a turbulent fire environment.

Next slide, please. Our conclusions from that particular preliminary analysis were the following. We determined that there would be no cladding failure for the fuel that was in that spent fuel cask that was in that fire. That was based on the temperature limits, short-term temperature limits.

There's no canister failure based on stresses at temperature and on the creep criteria. And if those two are true, then there would be no radioactive release, which is what we believe would be the case for this particular analysis. So now what do we do?

Having completed a scoping analysis, we got a general feel for what the cask might do when exposed to severe fire. We wanted to get a better picture of what actually happened in the Baltimore Tunnel as far as what kind of a fire there was.

In order to get a better picture of that, we went to the National Institute of Standards and Technology. We contracted with them to quantify the thermal conditions that existed in the tunnel during the event.

For this, NIST used the fire dynamic stimulator code. It is a computational fluid dynamics code that models combustion, heat release rates, and gas flow in a variety of fire environments. It has been used with very high success on the reactor side to model fires in the reactor nuclear power plants.

For this project, the analytic model used by NIST was validated using data obtained by the Federal Highway Administration in their Memorial Tunnel test program. FHA tested several different sizes of fires in an abandoned tunnel in order to quantify what kind of temperatures you would see, what kind of flow regimes you would see in tunnels. So NIST validated the code using data from these experiments.

The analysis results from the NIST fire model were input into the staff's revised cask analysis model. I will be talking a little bit more about this in a few minutes.

The Howard Street Tunnel fire model. What exactly did NIST do? First of all, they used a computational grid that extended the entire length of the Howard Street Tunnel. So they modeled 1.65 miles of the tunnel in FDS. They obviously used a finer grid in the areas of concern surrounding the fire and in the rail car areas immediately in the vicinity of the fire.

They modeled the rail cars in the derailed configuration. The NTSB provided a diagram that showed how the rail cars were laid out after the derailment had happened. And NIST used that in order to model the rail cars in their fire model.

The combustion of hydrocarbon fuel, which triprophylene is essentially a hydrocarbon fuel, that was modeled also. There was no ventilation in the tunnel at the time of the accident. The ventilation system was not operating. So the NIST model did not use any ventilation.

Finally, the NIST model reached essentially spent fuel steady state conditions in about 30 minutes. As soon as they lit that fire off, it took about 30 minutes for it to teach its steady state conditions; in other words, the maximum temperature conditions.

Next slide. This is an animation of the Howard Street Tunnel fire model from NIST. I don't know exactly why that is not working, but we do have the .avi of that if you want to see that. I don't know why it is not working at this point.

The tunnel fire model, what you would see if it were working, basically the triprophylene pool was right here. The fire was flaming up between two cars. There were two cars on either side, this being the triprophylene tanker car. I don't know why it's not working. Anyway, we do have some data from that in a later slide. So I will be able to show that to you.

One of the thing that you will notice is that the temperatures in this particular fire model were obviously at the highest up here at the top of the tunnel. Because the fire was shooting up between these two cars, it was impinging directly on the tunnel and then spreading out along the length of the tunnel.

The one thing to say about this model is that it does have a grade. Going from this direction to this direction, there is a slight upward grade. So the temperatures of the fire would actually be a little bit higher on this side of the car than on the down wind side.

Next slide. Now, unfortunately, I couldn't show you an animation of that, but we did want to make sure that we would confirm the NIST results. What did we have there to help us confirm the NIST results? We had physical evidence from the tunnel itself.

There was a fire. There were burned rail cars. There were bricks that had fallen down during the fire. There was a lot of physical evidence. We contracted with material and fire experts at the Center for Nuclear Waste Regulatory Analysis to analyze samples from the tunnel and also samples from the rail cars that were removed from the tunnel.

The center staff performed metallurgical analyses on several material samples and components removed from the rail cars that were in the tunnel during the fire. So the center's experts were able to look at what came out of the tunnel and determine what kind of temperatures those particular physical witnesses to the fire had seen

The analyses conducted by the center indicated that the temperatures predicted by the NIST model were consistent with the physical evidence that was analyzed. So we had a reality check on the NIST model, and it looked like the NIST model was consistent with the physical evidence that we saw from the tunnel.

Next slide. So now we have some data from NIST. What do we do with that? We applied the data from NIST to two separate assessments of a spent fuel transportation cask finite element analysis model. The first assessment was with the cask center 20 meters, or approximately one rail car length, from the fire. The reason we chose that is that per federal regulations, any radioactive material package must be at least one box car away from any hazardous materials package. So, in reality, because the Howard Street Tunnel was a single rail car tunnel, it would be very unlikely for a spent fuel cask traveling through that tunnel to come any closer than one box car's length away from a fire.

Now, just to put a little bit of a bound on that, we also looked at the cask located adjacent to the fire, five meters from the fire to the center of the cask.

Models we used are 2D cross-section models. I will show you some details of that in the next few slides. We did also model the support cradle, which Holtec, Mr. Singh showed you in the Holtec presentation.

Finally, we have a 3D model that is under development to better characterize the conditions that were in the tunnel and how they would affect the spent fuel cask.

Next slide. This is the refined cask model. We actually have a 24 fuel assembly basket. This particular model has about 27,000 elements. It explicitly models all of the gaps and the various features of the basket: the MPC, or multi-purpose canister; the gamma shields, gamma plates, which are carbon steel plates, the whole Type A neutron shield, and the stainless steel outer skin.

Next slide. This is a closeup of one of the fuel cells, fuel assemblies. We do use a homogenization for the fuel assembly itself and use an effective thermal conductivity that is based on verified with data.

This is some of the basket details. These here are the basket supports. And then you have the stainless steel support plates. This in here is helium. And then on the sides here, you have the boral plates held with criticality control.

Next slide. Now, this graph is actually a little bit hard to see. It will be a little bit better in your packets. What this plot shows is the maximum temperatures that we derived from the NIST data. It is actually more to show you the trend and how we applied our boundary conditions to our refined cask model.

You see up here that you have the maximum temperatures at the top of the tunnel. This is from the upward slope is in this direction. The fire is at zero. That is where the fire is located, zero meters. And then there is a scale on each side of distance, the top of the tunnel, top of the rail cars, sides of the tunnel, wall temperatures. And then you go down to the floor of the tunnel down here.

As you can see, temperatures are higher on the upward side of the fire. That is to be expected because there is a little bit of flow.

MEMBER GARRICK: Chris, what would you expect those curves to look like if your model assumed ventilation?

MR. BAJWA: Well, ventilation would introduce obviously more oxygen to the fire. Most likely fire temperatures would be higher if you introduced more oxygen.

Next slide, please. Again, this slide, unfortunately, will be a little hard to see, but it is in your handouts. This is the maximum ionic temperatures as a function of time for the 20-meter case.

Basically, the thing to look at here, a couple of things to point out. For the fuel temperature, the fuel really doesn't start heating up for about 15 hours into the fire transient when it's displaced 20 meters from the fire source.

The fuel exceeds the 1,058 short-term temperature limit, 1058 Fahrenheit, at about 116 hours into the transient. That's, of course, assuming the maximum fire temperature for that entire length of time.

Next slide, please. These are the maximum component temperatures as a function of time for the five-meter distance. Obviously if you move closer to the fire, your temperature is going to go up. That is what we see happen here. It is not unexpected.

One thing to point out is that fuel temperatures still take about ten hours before they start to rise from their normal condition temperatures. In this case, we extend the 1,058 short-term temperature limit at 37 hours. Again, that is for continuing the fire at its maximum temperature for that amount of time.

One of the things to point out is that the short-term temperature limit is by no means the temperature at which the fuel bursts open. The short-term temperature limit is actually determined experimentally where they exposed fuel cladding to that temperature for an extended period of time. And for periods of time from 30 days to 70 days at 1,058, they saw no significant cladding degradation or failure. So it is not a limit where you reach it and you blow up, but that is the limit that we currently accept for short term.

Next slide. This is basically just a summary of what I just told you. For 20 meters, we are at over 100 hours for exceeding the short-term temperature limit. For five meters, we are over 30 hours.

And time to canister failure is also something that you want to look at because if your canister fails, then you have a possibility of radioactive release. If you fail your fuel and you don't fail your canister, most likely nothing is going to come out. It will be a heck of a mess to clean up, but you won't have a radioactive release.

Using stress and creep standards from ASME to look at time to failure for the canister, which is a welded pressure vessel. For the 20-meter case and the 5-meter case, it's about the same. We are looking at over 30 years at temperature before this thing is going to fail. So we don't believe that that in this particular case is a problem.

Okay. Let's see if this one works. Would you click on it? Not working. Could you try using the pad other than the mouse? Give that a shot. They were working earlier.

Anyway, what you would see, this is an animation of the five-meter case. What we ended up doing here is we took the top third of this particular cask and applied the boundary conditions at the top of the tunnel. Then we took the third side, one-third of the side, and used the wall conditions from the NIST data. Then for the bottom, we used the conditions from the bottom of the rail car from the NIST data.

Now, what is interesting about this is this particular cradle is basically a box. So you have convection going on inside that box due to the temperature. So that was models in our particular model.

The other thing to note is when you are five meters away from the fire, most likely the flames are going to be traveling over the impact limiter and will have a direct view of the cask itself. We model that in this particular model, and we get it running and are able to show you.

What you will see is that the tops of the cradle actually heat up because they have a direct view of the flames poring over the impact limiter. It has a direct view of the cask, middle of the cask.

Next slide, please. It is clear from this analysis that for this particular fire case, the particular fire that we analyzed, the cask maintained structural integrity. And fuel failure is not expected until well within the transient, if at all.

Currently it is believed that the most severe portion of the fire in the Howard Street Tunnel was within the first three hours and that the burning that occurred after that time was actually in the nonhazardous cargo. There were a number of box cars that had paper, paper products in them. Those obviously ignited at some point and burned but at a much lower temperature than the triprophylene.

The consequences of a spent fuel cask

being involved in a fire such as the one that occurred in the Howard Street Tunnel are minimal. And, as a result, the health and safety of the public would have been protected if such an event had occurred, such a fire had involved a spent fuel transportation cask.

Further, the Association of American Railroads has developed a performance standard for transporting spent nuclear fuel by rail. And that standard will most likely prevent hazardous materials, such as triprophylene or kerosene, from being shipped on the same train as a spent fuel cask. Bob Fronczak is going to talk about that. So I won't steal any more of his thunder.

The staff's preliminary conclusion is that additional regulatory requirements are not required to protect spent fuel shipping casks from severe fires if current regulations are followed. Following the AAR performance standard for shipping of spent fuel will add an additional margin of safety to the shipment of spent nuclear fuel.

VICE-CHAIRMAN LEVENSON: Thank you.

Mike?

MEMBER RYAN: Chris, this is a question out of my own ignorance. Would you tell me a little bit more about this 1,058 criteria? I realize it's a criteria, but how does that relate to fuel failure ultimately in a fire circumstance? Do we know that?

MR. BAJWA: Bill may be able to add to what I would say. The 1,058 criteria is what we currently use in our reviews as the short-term temperature.

MEMBER RYAN: "Short-term" being how long?

MR. BAJWA: "Short-term" being 30 days.

MEMBER RYAN: Okay.

MR. BAJWA: That is a short-term length. It was verified experimentally since that fuel did not fail or it did not degrade noticeably for periods of 30 days. So that's where the 1,058 comes from.

As far as temperature at which spent fuels, there are burst pressures that can be calculated. I don't know exactly what those are.

MEMBER RYAN: So the 1,058 is not a threshold failure number? It's a regulatory number that has conservatisms in it?

MR. BAJWA: That is correct. Yes.

VICE-CHAIRMAN LEVENSON: John?

MEMBER GARRICK: Were your results pretty much independent of the age and burn-up of the fuel and the possibility of damaged fuel?

MR. BAJWA: The analysis that we did took into account the fuel that was certified to go into the cask. So we did not look at damaged fuel. We did not specifically look at high burn-up fuel.

MEMBER GARRICK: Okay. Thank you.

VICE-CHAIRMAN LEVENSON: Others? Go ahead.

MEMBER WYMER: I have a question. The Holtec cask uses aluminum honeycomb impact limiters wrapped in steel. What assumptions, if any, did you make about what happened to the aluminum at those temperatures?

MR. BAJWA: We were looking at the center line temperature of the cask. So the aluminum impact limiters didn't actually play into the analysis per se. We were looking at a cross-sectional.

MEMBER WYMER: I would think they would have because if the aluminum had, for example, melted -- I don't remember them melting aluminum -- then the whole thing would have sagged. It would have been a different geometry, would have checked the fire.

MR. BAJWA: It is possible. The other one actually melts at 600 degrees. The cradle itself supports. I don't believe that that design rests on the impact limiters. I believe the cradle supports the cask. So they could melt, and they would in this case. But the cask itself probably would not move from the cradle.

MEMBER WYMER: The cat's cradle. One other question. Suppose there had been a lead shield at the cask. How would that have changed the results since it circulated?

MR. BAJWA: Probably the biggest result -- and this is kind of speculation because we didn't look at it, obviously. The biggest result would be that you would melt the lead and lose your shielding capability. I could not say what kind of structural consequences there would be to lead.

The one thing, though, is that the lead would absorb quite a bit of heat trying to melt. So you would have a heat sink, at least for a certain amount of time, while lead was melting in there.

MEMBER WYMER: Thanks.

VICE-CHAIRMAN LEVENSON: Questions from the ACNW staff? Any questions? Come to the microphone and identify yourself.

MR. HODGES: I'm Wayne Hodges from the Spent Fuel Project Office.

One thing that is crisp he kind of mentioned in passing but is probably important to point out a little bit, the calculation he did was assuming that this maximum fire temperature went on essentially indefinitely. In the Baltimore fire, we know that based on what events occurred, that the intense fire lasted probably for about three hours.

If it had not had a water main break, which tend to cool things down, based upon how much fuel you had in the tank car, the fire probably would have lasted maybe six and a half hours.

So even for the worst case, where you got to burn all of the fuel in the tank car, it is not going to go on indefinitely. And, if you recall from his analyses, you didn't start eating the fuel up until for the case where you are a tank car away until ten or more hours in the tank. In the real world, you are already out of fuel by that time and things are starting to cool down a little bit.

So, even though it is a better analysis than what was done initially, it is still somewhat a very bounding analysis and shows a lot of margin there.

MR. BAJWA: Thanks, Wayne. That is a very good point.

MR. REZNIKOFF: Marvin Reznikoff. I have a quick question. First of all, I found the analysis very impressive. happened to the neutron shield that was around the cask? How would the neutron doses increase if that material melted? And what would be the effect on fire-fighters?

MR. BAJWA: Very good question. Most analyses assume that the neutron shield melts during the fire. And then they will assume --

MR. REZNIKOFF: Your analysis assumed that?

MR. BAJWA: I believe that we actually left the neutron shield intact during the fire to increase the amount of heat that was getting into the cask. Sometimes what is done is it will be replaced by air, which actually gives you a more insulative boundary to the heat that is moving into the canister. So I believe for the fire analysis, we actually left it intact.

MR. REZNIKOFF: In a real-life situation, it might melt?

MR. BAJWA: If it reached the melting temperature, certainly, yes, it would.

MR. REZNIKOFF: Then I know one consideration is what would happen to the fuel. That is what you are looking at. But I was asking another question. What would happen to emergency responders. How close could they get to a cask? That is why I was asking that question.

MR. BAJWA: We obviously didn't look into that in this analysis, but that is definitely something that should be considered in the future.

VICE-CHAIRMAN LEVENSON: Any other questions?

MEMBER KOBETZ: Hang on a second. We're going to be able to show you this picture.

MR. GRUMSKI: I just have one more point. I think that the importance of this presentation is that the administrative controls that are put on shipments and, like any nuclear power plant, if you worked in a nuclear power plant, there are engineering controls, which would represent the cask design and protection of the cask; and there are administrative controls, which is how you ship spent fuel.

You are not going to ship spent fuel with that type of shipment in a tunnel like that. It is probably going to be in private train service and special train service. Those controls are regulated not only by DOT, the NRC, but also the shipper.

So something he really needs to bring out in his presentation is that scenario is very unlikely in a real world on the train shipments because it just won't happen. There won't be that train next to that car. And I think that needs to be brought out.

Oh, I'm sorry. My name is Ken Grumski.

MR. FRONCZAK: Bob Fronczak with AAR.

The scenario he brings up is very possible if we were to ship in regular train service under the current just general regulatory scheme. I agree with you, and I am glad you pointed out that had you followed our performance standard and shipped in dedicated trains, you wouldn't have had that fuel source there. But if you were to ship just in regular freight service under a current regulatory scenario, that is a very real possibility.

MR. BAJWA: Well, look at that. All right. This is what I wanted to show you before. This is the NIST fire model. Obviously the source of triprophylene is down here at the base of this car, in between these two cars here.

What I was explaining before was you see the fire impinging directly on the top of the tunnel and then spreading out. What you are not seeing here, of course, is temperatures. And you're not really seeing flow. But you can see sort of how the fire behaves given the flow regimes that are being experienced there

CHAIRMAN HORNBERGER: Not seeing

temperature, not seeing flow, what are we seeing?

MR. BAJWA: You are seeing a visualization of what is combusting in there. Okay? Now, what you are going to see here is the top of the cask is obviously going to heat up the quickest because that is going to be the highest temperature regime. Down on the sides, there will be a lower temperature regime.

Then down on the bottom, towards the beginning of the fire, you actually have some cooling down here because the fire is sucking some air in in order to feed itself. So you have air flowing past this cradle and actually cooling it down a little bit. Here on the sides, you see the heating up of the cradle due to the direct view that it has of the flames that are on the top of the cask.

This simulation was run for 150 hours. You can see when you consider 150 hours, it takes quite a while for that heat to work its way down into the fuel. The fuel itself obviously and the cask, this whole unit, has a very high thermal inertia if you want to use that word. It takes a long time to heat it up and get the heat to go through the different layers and into the fuel basket.

That's it.

VICE-CHAIRMAN LEVENSON: Thank you.

Our next presentation is by -- oh, I'm sorry. Microphone, please.

MR. GUTHERMAN: Brian Gutherman from Holtec.

I just wanted to add a little more perspective to the 1,058 temperature. The value for ECCS in operating reactors is 2,200 degrees Fahrenheit to give you some perspective that there is almost 1,000 degrees there or 1,200 degrees. The melting point, zirconium or zircalloy cladding, is some number of degrees above that. So I just wanted to offer that up for perspective.

VICE-CHAIRMAN LEVENSON: Thank you.

MS. GUE: Could I comment?

VICE-CHAIRMAN LEVENSON: Yes.

MS. GUE: Sorry. I'll be quick. Lisa Gue with Public Citizen again.

I guess I just wanted to take issue here with the conclusion statement that the health and the safety of the public are protected. I understand that it is a very important consideration, the impact of this kind of long-duration fire on the fuel itself, but the way this study has been presented, just as a blanket conclusion that there would be no radiation released that could be damaging to the public when it hasn't even been taken consideration the effect on the shielding and how that might impact energy response efforts is another example of how I think the NRC loses the confidence of the public in the studies that it does by presenting somewhat misleadingly the studies that are carried out.

So I guess I just want to put that out there as an example for the purposes of public communication, how it's really important to clearly communicate what was being studied, what was being tested, and limit the conclusions, then, to those parameters.

Thank you.

VICE-CHAIRMAN LEVENSON: Any other comment?

(No response.)

VICE-CHAIRMAN LEVENSON: If not, our next speaker is Robert Fronczak from AAR.

MR. FRONCZAK: Hopefully we have got these technical difficulties solved by this late hour. I am very impressed with the number of people that are still here.

My name is Bob Fronczak. I am not a testing expert. I am not a modeling expert, though I have been around the railroad industry for about 25 years. So I know a little bit about railroads.

First slide, please. What I am here to talk about or what I have been asked to talk about is testing. I want to cover some of the AAR cask testing, at least analysis work that we did, focus on four things that we came up with as issues, crush loads, collisions with structures and falls, thermal event frequencies, and structural strength of rail cars, and then go a little bit into our performance standard for spent nuclear fuel.

Next slide. As far as cask integrity goes, we for many years -- and some of you may remember this -- had a recommended practice in the rail industry where we recommended spent fuel ought to be shipped at 35 miles an hour with a standing pass rule, which means that if one train met another train carrying spent nuclear fuel, one train needed to stand while the other one passed it no faster than 35 miles per hour.

That was all based on the 30-foot drop test, which accelerates a cask to 30 miles an hour. Railroads are very conservative, and we felt that this was kind of a bet the company kind of issue.

With upcoming shipments, figuring that

Yucca Mountain was going to open in 1996 or 1998, we commissioned a couple of reports to analyze what we felt was the state of the art on communicating to the public what testing, what the NRC testing, means to the actual environment. So we looked at the modal study very closely.

We commissioned two reports. One was done by Transys or Gordon English, et al. The other was done by Jim Rock at the Texas Transportation Institute. Both of those have already been presented or given to NRC. I think I talked about this in preparation for the package performance study about two years ago.

Next slide. The conclusion of those reports. The Transys report was that there are some accidents that might not be able to withstand forces in railroad accidents. One thing, to change our recommended practice, that was not good enough. So we commissioned another report.

What we looked at is the consequences of an accident if one were to occur with the release. That report determined that if you did have a release, that public health wouldn't be affected in a major way. Again, that is assuming that nobody is right next to the cask if that incident were to occur.

Next slide. Some of the things that we do question or at least we think a little bit more work ought to be done on, -- and, again, I talked about this a couple of years ago -- crush loads. Crush loads are not required by NRC tests presently. Rail by definition is multiple packages being transported altogether. In derailment, we feel that crush loads are a very real possibility. So we do feel that crush loads ought to be considered.

One study looked at frequency of incidence of crush loading at one-tenth of that of impact loading. And only .8 percent experienced impact with a coupler or significant frame member of other vehicles.

Next slide. You can slice this many different ways. One way to look at it is that three percent of trains and accidents in 2001 derailed more than five cars, many of the accidents, 70 percent, less than 5 cars but 3 percent more. As the speeds increase in derailments, you derail more cars. So, again, you can go through this many different ways. As the speeds increased, those would be the accidents that would be of more interest.

So that is one area we feel needs a little bit more work. Perhaps some of that work is already being done as a result of our previous comments.

CHAIRMAN HORNBERGER: Robert, out of ignorance, my own ignorance, that is, by "crush loads," are you talking about one car piling on top of the other? Is that the mechanism?

MR. FRONCZAK: That's exactly what we are talking about, yes. Again, it's a requirement for small packages. I think the idea is that the likelihood of a crush load with a large package is pretty small, but we feel in a North American rail environment that that is a real possibility. You're talking about fairly heavy loads. I mean, the standard rail freight vehicle is centered in 63,000 pounds today going to 286.

MR. FISCHER: I do want to point out in the modal study, we looked at a G.E. locomotive landing on top of the cask. It did nothing to it, very little. That is in the report. I think that was a three or four hundred ton locomotive. So we did look at it. We felt a locomotive was the heaviest thing that could land on it. So we did look at it.

MR. FRONCZAK: And it was a crush accident?

MR. FISCHER: Yes.

MR. FRONCZAK: Okay. That is not what our consultant found.

Similar sources of information that we can go to to look at this, this topic, is the FRA database. That includes the number of cars involved in derailments. Also, there is the AAR-RPI tank car safety research and test project. That is an over-30-year database of over 30,000 damaged tank cars.

To get at the data that we are looking at would require going through -- we don't want to have a search for crush loads in that database that would require going through individual records manually to get at that data, but it is available.

Next slide. The modal study used highway data to evaluate impacts with structures and falls. We feel that the railroad environment is a lot different by road. Roads go basically according to whatever the grade is. It will go over hill. And by rail, you can't do that. Rail, the maximum grade is about two, two and a half percent. So there are a lot of cuts and fills. We figured that we probably underestimated frequency of rock cuts, frequency of impact with embankments, water crossings, and large structures.

Next slide. As far as thermal event

frequencies, the mobile study looked at 81 percent fires less than one hour, 99 percent of the fires less than 7 hours. Although the Eggers data was actually evaluated and not used, they looked at 50 percent of the fires less than 11 hours and 9 percent of the fires less than 130 hours. We felt that the Eggers data would have been a more conservative choice.

Point to one railroad incident, which in 1996 the fire lasted 18 days or 360 hours. That was in Weyauwega, Wisconsin. It was an LP gas derailment. We had the town evacuated for that amount of time.

Next slide. As far as the structural strength of rail cars, the modal study used 100,000 pounds per foot or a million pounds for a 10-foot-wide locomotive and 1.6 million pounds for a 16-foot-long cask. The locomotives are designed to withstand one million pounds of force at the coupler without permanent deformation. Our finite element analysis indicated that three million pounds would be applied at the coupler height and ten million pounds at the frame's neutral axis.

Next slide. The next thing I wanted to talk about is our performance standard for spent nuclear fuel trains. This standard is a little bit different than most other standards that we have in our manual standards and recommended practices in that it includes all the cars on the train. Most new cars, the car itself, need to be designed and tested. This one, all the cars in the train, including buffer cars and locomotive and security cars, will be tested.

Require static and dynamic modeling before construction requires full-scale characterization, both static and dynamic testing of each car and the train. That is all done at a test facility before the car is actually approved by AAR Equipment Engineering Committee. And then it needs to be analyzed or at least a report needs to be submitted after 100,000 miles of operation just to make sure that it is still meeting the standard.

Next slide. The road worthiness criteria or performance requirements in the standard exceed standard freight car designs today. So you need an enhanced performance truck to meet the design criteria in this new performance standard. It also requires electronically controlled pneumatic breaks. That reduces stopping distance significantly. In a loaded coal train, you are talking about 30 percent benefit in stopping distance.

We envision a fairly short dedicated train. So you wouldn't get all of that benefit in stopping distance. What that does provide you is a conduit between all the cars in the train for on-board monitoring of some defect parameters.

Next slide. The performance standard requires monitoring for things like truck hunting, where the trucks will actually go back and forth. Again, that is a mode of derailment. Wheel flats, you might hear that as cars go by, as that wheel pounds. That is another mode of derailment.

Braking performance, vertical, lateral longitudinal acceleration. So as that thing is going up and down or sideways on the track, we will be monitoring that.

Bearing conditions. We have hot box detectors, spaced periodically along the tracks to look for hot bearings. This will monitor the actual bearing temperature on board and will be able to stop that train if there were an increase in temperature before anything were to occur as well as speed and ride quality.

Next slide. This is kind of a schematic diagram of how we envision the system. Showing two locomotives here, that is not necessarily because it needs it for weight but primarily for redundancy in case you had a failure en route.

You are looking at a buffer car between any occupied vehicle and a first cask car. That needs to be of consistent size and weight of the other cars in the train because you are looking at a 200-ton locomotive here and a 200-ton spent nuclear fuel cask car over here.

Then a security car at the end. We believe that the security car ought to be a personnel car or actually probably a retrofitted passenger car to allow permanent occupancy of the people that would be escorting the shipments. You don't have to get those people on and off en route. And then you have got the enhanced performance truck and then the defect detection equipment throughout the entire train.

Next slide. There are some other performance features that we have implemented to be able to allow us to rescind our 20-some-year-old recommended practice. One of those is OT-55, "These shipments will be done in accordance with OT-55." That is our recommended operating practice for hazardous materials.

In OT-55, there are increased track and equipment inspection requirements, increased defect monitoring. In other words, there are wayside hot bearing detectors spaced more frequently than on other sections of track, increased maintenance frequency, increased employee training, and there is a maximum speed limit of 50 miles per hour. So, whereas, before we were recommending 35 miles an hour with a standing pass, now we are recommending 50 miles per hour with no restriction, passing restriction.

Tomorrow I don't know what Kevin Blackwell has to talk about, but FRA has got their safety compliance oversight plan. That has a bunch of other I guess extra-regulatory kind of requirements for inspection of spent nuclear fuel, high-level waste shipments.

Next slide. The Private Fuel Storage is the first organization to design to the new performance standard. Their cask car is being manufactured or it has been manufactured, the prototype, by Trinity Industries. The overall weight of that cask car-cradle combination is 476,000 pounds. It's very much heavier than a typical rail car.

The modeling and characterization have been done. The on-track testing is currently being performed out at our transportation technology center in Pueblo, Colorado, hope to finish that this year.

The performance standard does not require dedicated trains. The reason it doesn't require dedicated trains is because the Supreme Court won't allow us to require dedicated trains. In fact, you lose a lot of the operating or a lot of the benefits of this performance standard if you don't ship it in dedicated trains because the on-board defect detection will be negated.

Private Fuel Storage is designing their system as a dedicated train system with all of the I guess requirements of the performance standard.

Next slide. This is what that car looks like at TTC. You can see it's a span bolster, eight-axle vehicle. There is a truck, two-axle truck here, two-axle truck here, the same thing on the other side. It's depressed well. And that's what it looks like.

Next slide. In summary, we feel that there are some issues that ought to be looked at as far as testing goes related to crush load, collision with structures, et cetera. NRR is committed to incorporating improvements in technology into the transportation of spent fuel and high-level waste. We will continue to do that as technology comes up that we feel could benefit.

That was all I had to say.

VICE-CHAIRMAN LEVENSON: Okay. Thank you.

Mike?

MEMBER RYAN: Thanks.

I learned a lot about rail shipments today. A couple of questions, though. Are there any materials in transport now under a dedicated train arrangement?

MR. FRONCZAK: In actuality, most of the shipments of spent nuclear fuel have been made by dedicated train, whether they have been requested to be dedicated train or not. For instance, the Navy requests regular train service. Union Pacific will not ship that. BNSF will not ship that in just regular train service. They ship that in dedicated train.

MEMBER RYAN: So that is the railroad's choice, rather than the shipper's choice?

MR. FRONCZAK: It is not always that way. That is the way the Navy does it.

MEMBER RYAN: Right.

MR. FRONCZAK: By contrast, most of the Department of Energy shipments have been made by dedicated train at their request. For instance, the foreign research reactor shipment that was made out of Concord, California, FINEEL in -- I don't know -- '88 or something, '86, that one in dedicated train -- no.

'96 I think.

The same thing with the West Valley shipment. That was planned. Had that occurred, it was planned for dedicated trains.

MEMBER RYAN: I guess the question is you described a dedicated train with enhanced monitoring and all of those kinds of things. Is there any other material in commerce that is shipped under that kind of enhanced protection system now?

MR. FRONCZAK: No.

MEMBER RYAN: The other question is more generic. I mean, you gave a lot of statistics about accident rates and so forth. I assume that is for the industry as a whole and not for this dedicated train segment, which I guess I am assuming. Help me understand better. Are their performance numbers for a dedicated train segment much better?

MR. FRONCZAK: In other words, would the derailment rate, for instance, for a dedicated train be --

MEMBER RYAN: All the performance indicators of tip-over, derailments, and car failures, and all that sort of stuff. I mean, I would assume that if you had a dedicated train service, the basic statistics would be better or not? I don't know.

MR. FRONCZAK: The problem with that is that we don't have very much data with a dedicated train. We have got reams of data with regular trains.

MEMBER RYAN: It might be interesting to separate that out. Even though it is maybe not a lot of data, it would be interesting to see because that is really the question, "What am I buying?"

MR. FRONCZAK: Right, right. Exactly.

MEMBER RYAN: Thanks.

MEMBER GARRICK: Yes. I wrote a paper on this about 20 years ago and concluded that you're not buying anything.

What I wanted to ask you is I participated in some hearings with the ICC way back in the '70s. And the issue was whether there should or should not be special trains. The conclusion of those hearings was that there was no scientific basis for dedicated trains for the shipment of radioactive materials. What has happened between then and now that would cause the American Railroad Association to feel as strongly as you evidently do about special trains?

That was really a very high-level ventilation of all the scientific information in the '70s. And there was representation from all the major railroads and your association as well as the scientific community. This whole issue was washed pretty thoroughly at that time, and that was the conclusion. Has there been something happen in the meantime that this should be an issue?

Now, I think that if the user wants to finance a dedicated train, that should be their privilege. But what we have to deal with is scientific evidence.

I think Mike's question is a very good one. If you incorporate today's contemporary thinking about risk and apply that to the different kinds of cargoes that are on the railroads and you had 100 hazardous cargoes, probably the nuclear from a risk standpoint would come out at the top in terms of being the most safe.

And so when you start talking about dedicated trains for nuclear, aren't you really opening up a hornet's nest with respect to sending the message to the public that there ought to be dedicated trains for all of the other extremely hazardous materials?

MR. FRONCZAK: We feel that -- and our members have felt this for years -- there are things that we can do to make these shipments safer. We feel that we owe it to the public to do that. We don't feel like they're asking that much. Incidents that get blown out of proportion, like the Baltimore Tunnel fire, in a dedicated train scenario because the fuel would not be there.

Now, FRA has been asked to do a dedicated train study. That was mandated by Congress for completion in 1994. And that study has still not been published. And Administrator Rudder from FRA indicated that that was going to be done this year. In my understanding, it has been quite controversial. And that is why it has not been published. So I guess we will find out by the end of the year.

MEMBER RYAN: Maybe I can extend the question a little bit. You know, just in simple terms, things like chlorine and ammonia are shipped all the time, every day, in much larger quantities. So on a risk basis, you could think about the idea that if you made an incremental improvement there in terms of transportation safety overall, that would be a big win compared to an incremental improvement for something not in commerce very often, relatively speaking. So how does your organization prioritize the risks that you face an industry?

MR. FRONCZAK: We do it by risk assessment, risk management. There have been tremendous improvements in chlorine tank cars over the last 20 years. There have been tremendous improvements in LP gas transportation. That derailment that we had in Weyauwega, Wisconsin had that happened 30 years ago, there would have been dead people as a result of that.

The safety improvements, the safety vents that we put on the cars, the thermal protection we put on the cars, the bottom and top outlet protection we put on those cars, all of those things have been done by industry initiatives, industry-funded research, where the safety of that transportation of those materials have been improved tremendously.

We have had, what, maybe 3 fatalities in the last 15 years caused by hazardous materials transportation by rail. Highway, there are probably 18 to 20 fatalities per year. So we feel like we have done a lot to improve transportation of hazardous materials by rail.

CHAIRMAN HORNBERGER: I also have a follow-up question on this because I was actually impressed with you said that OT-55D was for hazardous waste.

MR. FRONCZAK: Hazardous materials.

CHAIRMAN HORNBERGER: Hazardous materials.

MR. FRONCZAK: Right.

CHAIRMAN HORNBERGER: Not hazardous waste. Hazardous materials. I would, therefore, infer from that that if you are recommending dedicated trains, it would be for all hazardous material.

MR. FRONCZAK: No. Like I said, we believe that the transportation of spent nuclear fuel ought to be done by dedicated trains. I didn't want to get into the reasons for that here, and I haven't really because there are a lot of reasons for that. Efficiency is one of those reasons.

We have locomotives that cost less than these casks cost. We are very hyper about having those things used all of the time. I don't think you guys want these things sitting around yards for 48 hours waiting to be switched into another train. You don't want your guards sitting around yards, rail yards, for 48 hours waiting to be picked up by another train. There is a whole bunch of other reasons I haven't even touched on about the dedicated trains.

CHAIRMAN HORNBERGER: But all of those reasons -- and they are all very sensible reasons. Obviously you wouldn't want to do it that way, and I would imagine that the user want to do it. They have nothing to do with safety.

MR. FRONCZAK: I would argue that there is going to be less of a probability of derailment. Now, you can argue all you want about what would happen if that derailment were to occur. I guarantee you the public is concerned about that. We are very concerned about that. We don't want that incident to occur on our railroads.

CHAIRMAN HORNBERGER: I agree with that. But, again, if you want to talk about risk, as Mike said, then your comment is exactly the same for ammonia and chlorine and natural gas.

MR. FRONCZAK: That's why if we had a dedicated train, you would have fewer derailments.

CHAIRMAN HORNBERGER: Okay. But the public is very familiar with those kind of shipments, and they're not with this stuff.

MEMBER WYMER: No, that's enough been said.

CHAIRMAN HORNBERGER: Maybe too much.

VICE-CHAIRMAN LEVENSON: I guess, with that, maybe I shouldn't.

On this business of the dedicated train, since you don't have any data to indicate that it is really safer, is your recommendation based on a risk analysis or intuition?

If it is risk analysis, I have some interest-taking observations, like if the crush load is really an important thing, you are much safer if you don't because the largest crushing load you have got in your whole system is a cask. Three or four casks in a row generate a much larger risk than one cask in the middle of an ordinary train.

So has there really been a risk analysis done to support this recommendation or is it just "We think it's a good idea," et cetera?

MR. FRONCZAK: We have looked at a lot of data as far as under the current railroad design criteria, what derailment rates would be for that versus what we would expect it to be if it were designed to the new performance standard. And our analysis would indicate that it's safer or we would have less derailments with dedicated trains.

Now, you're right. If you've got more than one package together or one cask together, there is a possibility of those casks impacting on each other. And that is why the performance standard requires double shelf couplers so that those cars stay together when they are derailed.

MEMBER RYAN: Have you published that analysis you mentioned?

MR. FRONCZAK: No.

MEMBER GARRICK: See, we don't mean to be hard on you on this, and you have done a good job of stating largely why you are doing what you are doing. It has a lot to do with the public and their views and things. And that has to be a major consideration.

What we are really focused on is what is the technical basis. And, as I say, the Interstate Commerce Commission, the Supreme Court, et cetera, et cetera, have not seen sufficient scientific evidence to support the view of dedicated trains for nuclear materials. We're still searching for that.

And, yet, the railroad industry appears to continue to believe very strongly that dedicated trains are in order for a material that is probably much less of a risk to the public safety than many other materials that you routinely ship on the basis of the technical evidence and the scientific evidence. We're just trying to search for that and see if there has been a change in the last 20 years that would account for your position.

MR. FRONCZAK: All I have to say is that the Private Fuel Storage is convinced that that is the way it ought to be shipped. So they see some benefit in it. As a matter of fact, most all shipments are made by dedicated train.

VICE-CHAIRMAN LEVENSON: Okay. Any ACNW staff members there?

MEMBER KOBETZ: I want to follow up with something that Larry said about the crush and the engine dropping on a cask in the modal study or somehow crushing it. What was that based on? Obviously there hasn't been any testing of that type. And there are a lot of variables with the train landing or crushing. What was the scenario of the study?

MR. FISCHER: Basically I think it dropped a few feet on top of the cask.

MEMBER KOBETZ: How in-depth was the analysis? Again, something like that, it seems there are a lot of variables as far as where it hits.

MR. FISCHER: Well, what we saw is that there wasn't much damage done. So we decided not to look longer into that scenario because there were other scenarios we thought were much more significant, more credible.

MEMBER KOBETZ: Was it a direct hit, then, on top of --

MR. FISCHER: Yes. It was laying on top of it, yes. Right. As for the couplers, your couplers are made to disconnect at about 1.3 million pounds. That's why we use 1.6. They disable themselves because they don't want to puncture the car in front of them. So that was the basis for the study, not the capability of the whole chassis.

When we looked at the capability of the whole chassis, the coupler was gone. And by that time, you got a dynamic situation. And as the train hits the cask, it accelerates the cask so you don't see the full static ten million pounds load because you're accelerating the cask and it's pulling away.

CHAIRMAN HORNBERGER: Unless it's --

MR. FISCHER: The train is pretty big, too, because it is going to hit whatever the cask hit.

CHAIRMAN HORNBERGER: So to follow up, then, on Tim's question, does this whole analysis depend upon the cars being launched airborne? We are really talking about an impact kind of situation and not a static load.

I am trying to think of the difference. Is it just a different impact? It's not just one laying on top of the other and crushing it, then.

MR. FISCHER: No. It's laying down on top of it with a dynamic load factor.

CHAIRMAN HORNBERGER: Dynamic load factor.

VICE-CHAIRMAN LEVENSON: Not a 30-foot drop.

MR. FISCHER: But not a 30-foot drop. That's correct. No.

MR. YAKSH: I would like to make a comment on that. Mike Yaksh, AAC. Keep in mind all of these weigh about 200,000 pounds, roughly all designed at 60 G's. These things are designed to take 60 G's. We got a 300-ton locomotive. It nowhere comes close to 60 times 250,000 pounds. So if you just put it in perspective.

And the other thing, the locomotive is not a rigid item. So the loads will pass through. And the transport task is public supported. A load will pass through. So that is why it is nowhere near a controlling case.

MR. FISCHER: In fact, if you looked at what happened to the locomotive when the British ran it into the cask, the locomotive was destroyed. The engine actually was torn up. And then the intervenors claim that they took the bolts loose before they ran the test. So it goes on and on.

If you don't want to believe, you don't want to believe. That's okay. But it's not worth arguing over. And, by the way, G.E. didn't want to ship dedicated train. But when it got time to get those spent fuel out of those pools, they were on dedicated train, and they were gone. You lost more money arguing than just doing.

MR. FRONCZAK: It's our right-of-way. It's our property we're trying to protect.

VICE-CHAIRMAN LEVENSON: Well, like I mentioned earlier to Bill in connection with the regulatory agency, railroads have a lot of different things other than technical issues on which they base decisions. I think we have to recognize that. It doesn't mean the committee has to involve itself in the economics and the efficiency. We're trying to focus on the technical issues.

I hope you understand we appreciate all of these things may be more important in any case. We're just trying to look on our chart.

Any other questions? Go to the microphone and identify yourself.

MR. McCARVILLE: Hi. I'm Dave McCarville from Booz Allen Hamilton. Formerly I worked for Ed, Low, and Ashland and managed quite a few spent fuel shipments by rail.

The buffer cars were always empty. In here, I see you have got a 100-ton buffer car. You should explain what analysis was done to come up with that recommendation and what configuration and how it would be procured if there were to be such an item.

MR. FRONCZAK: The reason for the loaded buffer car -- Union Pacific actually did this as a result of the Navy requiring their shipments to be done at the end of regular trains. What happens is that you get in-train forces that are so large that you can actually lift a lighter car off the track and cause a derailment. So that's the reason you want a car of consistent weight with the other cars in the train and not just a really lightly loaded or empty car as a buffer car.

MR. McCARVILLE: I assume some analysis between the security car and locomotive with personnel in it and crush testing. Has that been analyzed as well?

MR. FRONCZAK: I'm sorry? What?

MR. McCARVILLE: If the 100-ton buffer car is right next to a personnel car, wouldn't there be some crush testing safety effects there to look at?

MR. FRONCZAK: The one thing the performance standard requires is that the personnel car has to meet the same sort of design requirements as a freight car. And freight cars have been analyzed for those kind of loans.

MR. McCARVILLE: You say there is a report that analyzed that 100-ton requirement?

MR. FRONCZAK: Not specifically, but there is a report that analyzes the Navy situation.

MR. McCARVILLE: One more question. What would a 100-ton buffer car look like as far as a configuration? Has there been any thought into how it would be laid out?

MR. FRONCZAK: My thought is it's a gondola car with ballasts in it, something like that.

MR. McCARVILLE: Thank you.

VICE-CHAIRMAN LEVENSON: Someone else?

MR. GRUMSKI: Ken Grumski from MHF.

Bob, two questions, actually. What is the cost, average cost, per mile of a dedicated train?

MR. FRONCZAK: I can't answer that question. I am with the industry association.

MR. GRUMSKI: You don't know what the average is?

MR. FRONCZAK: We don't get involved in costs at all. Our members do that. And we are restrained by antitrust to talk about cost.

MR. GRUMSKI: Okay.

MR. FRONCZAK: Now, there is some

information out there. For instance, the Three Mile Island shipments, that information is in a report. I can't remember off the top of my head what that is. I've got that report in my office, and I can find it for you if you want to call me.

MR. GRUMSKI: I am curious because regular train service versus dedicated train, I am sure there is a huge cost difference. And I just wanted to know what --

MR. FRONCZAK: Well, it's a matter of transporting 100 cars versus however many you have in a dedicated train and the crew.

MS. GUE: Hello again. Lisa Gue with Public Citizen.

I appreciated your presentation. And I just had a quick question about the AAR. Does the association have an enforcement capability with these performance recommendation?

MR. FRONCZAK: I guess, yes, we do. Now, who is the AAR? The AAR is an industry association, nonprofit industry association. Our members are the Class 1 railroads. That is Burlington Northern Santa Fe. Amtrak is one also, Canadian National, Canadian Pacific, CSX Transportation, Norfolk Southern, Kansas City, Southern Union Pacific Railroad basically.

We set voluntary standards because we have to interchange equipment with each other. Equipment gets interchanged all the time. If you didn't have couplers the same height, you couldn't interchange that equipment. If you didn't have tracks that had the same gauge, you couldn't move cars between railroads.

So yes, our standards are enforceable if you want to transport something in what is called free interchange in the U.S. rail network. Now, there are private agreements between carriers.

MS. GUE: Let me just specify a little bit more. Of course, there are things like the size of the railway track. Of course, there is not much flexibility there. But in the case of this performance recommendation, if a particular carrier wanted to travel faster than 50 miles per hour being paid on delivery, is there something that the AAR would do about that the way the DOT or the NRC would if they were federal regulations?

MR. FRONCZAK: I don't know that there is anything we could do since they're our members. If a member chose to ignore something, I don't know that we would just say, "Okay. You are no longer a member." I would have to think about that.

Generally speaking, these are all recommended practices, though that the members have agreed to. So all of our members have agreed that this is the way they want to do it. They wouldn't agree to it if they didn't do it or want to do it.

MS. GUE: I guess there is some experience with industry self-regulatory arrangements in other fields where that has been somewhat of a limiting factor. I would just express some concern from a public interest perspective to in relying on industry self-regulation, as important as your input obviously is, and we would certainly like to see some of these recommendations adopted by the federal regulatory agencies, including the NRC, than have the enforcement capabilities and the oversight abilities as well.

And you have heard me make this comment many times before, but I would be remiss if I didn't comment on this discussion of relative risk management or what might also be referred to as safety triage.

It is clear, I hope, to everybody that the large-scale shipment of high-level nuclear waste such as being contemplated to Yucca Mountain does pose unusual risks and that high-level nuclear waste is not the same as a number of other hazardous materials that are currently being shipped and, furthermore, that what we have to be worried about is the combination of those risks.

So shipping on a non-dedicated train introduces the possibility that was dismissed by one of the comments in the discussion of the Baltimore train tunnel fire of having both an explosive or a flammable material in combination with a cask of high-level waste in the same accident situation.

So I guess from a public interest perspective, again, I am always concerned to hear those kinds of recommendations made about risk assessment that seem to imply that we are trading between two risks when, in fact, we are discussing adding an additional risk and that everything should be done by the regulatory agencies as well as the various industries involved to minimize those risks to avoid being exposed to like two additional risks.

MEMBER GARRICK: I don't want to get into a debate here, but I think that you should be held accountable in the same way that others are held accountable when it comes to make those kinds of observations.

You have made a pretty dramatic observation about the risk being unique with respect to what we are talking about here today. I guess my comment to you is what is your evidence for this from a risk perspective?

I am an analyst. And I believe that analysis has to be based on real evidence. There is no evidence to support what you just said except opinions. I think if your cause is to be well-represented and you make those kinds of claims, it is time for you to come forth with the evidence that supports those claims because it is not in existence.

MS. GUE: Well, I guess the I think non-debatable evidence is just the nature of the substance that we're talking about here. Unshielded, a ten-year-old fuel assembly releases enough radiation to be lethal from just a few feet away within a matter of minutes.

I realize we are not talking about shipping unshielded fuel assemblies, of course, but I think it is very important to acknowledge the intense danger of the material itself, in part, to underscore the need for these regulations, for safety and the shipment of nuclear waste. If we pretend that this material is cotton balls, I don't think that anybody would be in favor of that. I think it is important to keep in mind what it is that we are talking about shipping.

Another thing I just wanted to say -- and this is I guess more general because I think this is the final; this comment doesn't really relate to this particular presentation, but I think it would be very useful for the NRC to recommend to the Department of Energy that that released the specifics of the transportation plan with respect to Yucca Mountain because it becomes difficult to analyze some of these risks I think without the information about which routes will be used, which mode of transportation will be used. And it would be very good to know how many tunnels comparable to the Baltimore Tunnel are actually on the routes that might see high-level waste shipments in the Yucca Mountain campaign.

Finally, I was surprised that the agenda seems to have focused only on the impact tests and the fire tests. And I am wondering why the committee has not examined also the drop test and the submersion issues, particularly since we seem to be assuming a preference for train shipments here, which according to the Department of Energy will also include some as of yet unusual barge shipments of waste on the waterways. We would hope that the committee would also look into that.

Connected to that, of course, we're, as you know, concerned about the lack of inclusion in the regulatory requirements as well as in the package performance study outlines that have been released so far of consideration of explosive impacts, the terrorist vulnerability of these shipments. So I don't know if that might be something that is going to be looked at in the next couple of days of this or not.

Finally -- sorry. I have already said, "Finally." Really finally this time. I just did want to point out that with all of the conversation about the importance of public confidence on the relevance of these discussions, these regulatory activities, and test activities for public confidence, it does seem strange that the only presenters from outside the agencies were representatives of the industry, various industry interests. And I guess I would recommend to the committee to include in this type of fora in the future representatives of some of the public interest organizations with a stake in this process.

Thank you.

VICE-CHAIRMAN LEVENSON: I think one of the reasons the speakers are limited, as I tried to make clear earlier, the committee is trying to focus only on the technical issues. There are many, many public issues. That is a whole different agenda.

If there were a public interest group that had a research organization, had technical data, I think we would be interested in hearing. We are trying to limit our discussion to technical.

Let me ask you one question, which may seem strange but as a follow-up to the discussion we just had of multiple risks. Mention was made of explosives added to other things. Do you allow trains to have box cars full of dynamite, TNT, on the same train that carries ammonia and liquid petroleum and so forth?

MR. FRONCZAK: Yes.

VICE-CHAIRMAN LEVENSON: Okay.

MR. REZNIKOFF: I just had one quick point. Actually, the Navy sometimes ships exclusive use trains when they're carrying some of their missiles, some of their torpedoes. There have been some horrendous accidents where it is only a train full of missiles and torpedoes. I just thought I would mention that in support.

I wanted to support what Lisa mentioned concerning sabotage. I think it would be very helpful if the NRC looked into this issue and published something about this issue. I mention this because Dr. Singh earlier showed pictures of a jet engine striking a cask. We would agree with him since we did the work for Utah a jet engine would not penetrate a transportation cask.

Furthermore, it's an almost impossibly low probability. The horizon is low to have a jet plane hitting a cask car that is horizontal. It is almost impossible to hit the Pentagon without the plane hitting the ground first and then hitting the Pentagon.

So think of a horizontal car. It is almost impossible. But it is important to consider anti-tank missiles and bridge. That is an important issue. This is not an issue that was looked at at the modal study because there is not an issue that you can easily assign a probability to. And, therefore, you cannot easily assign a risk. Nevertheless, it is an issue that should be investigated by the NRC.

VICE-CHAIRMAN LEVENSON: Let me just comment to both you and the previous speaker. Because there is nothing on terrorism activities in this workshop does not mean it is not being looked at. It means it is being looked at in a classified manner. There are lots of things underway that can't be discussed in public meetings like this.

I want to remind everyone if you still have some sitability, this workshop will reconvene here tomorrow at 12:30. We have a conflict with room and space. And we have other commitments. So tomorrow morning will be the regular ACNW meeting in the regular location at 10:00 o'clock, but the workshop will reconvene here at 12:30.

I turn the meeting back to our chairman.

CHAIRMAN HORNBERGER: The meeting is adjourned.

(Whereupon, at 5:07 p.m., the foregoing matter was adjourned.)

CERTIFICATE

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

Name of Proceeding: Advisory Committee on Nuclear Waste - 138th Meeting

Docket Number: N/A

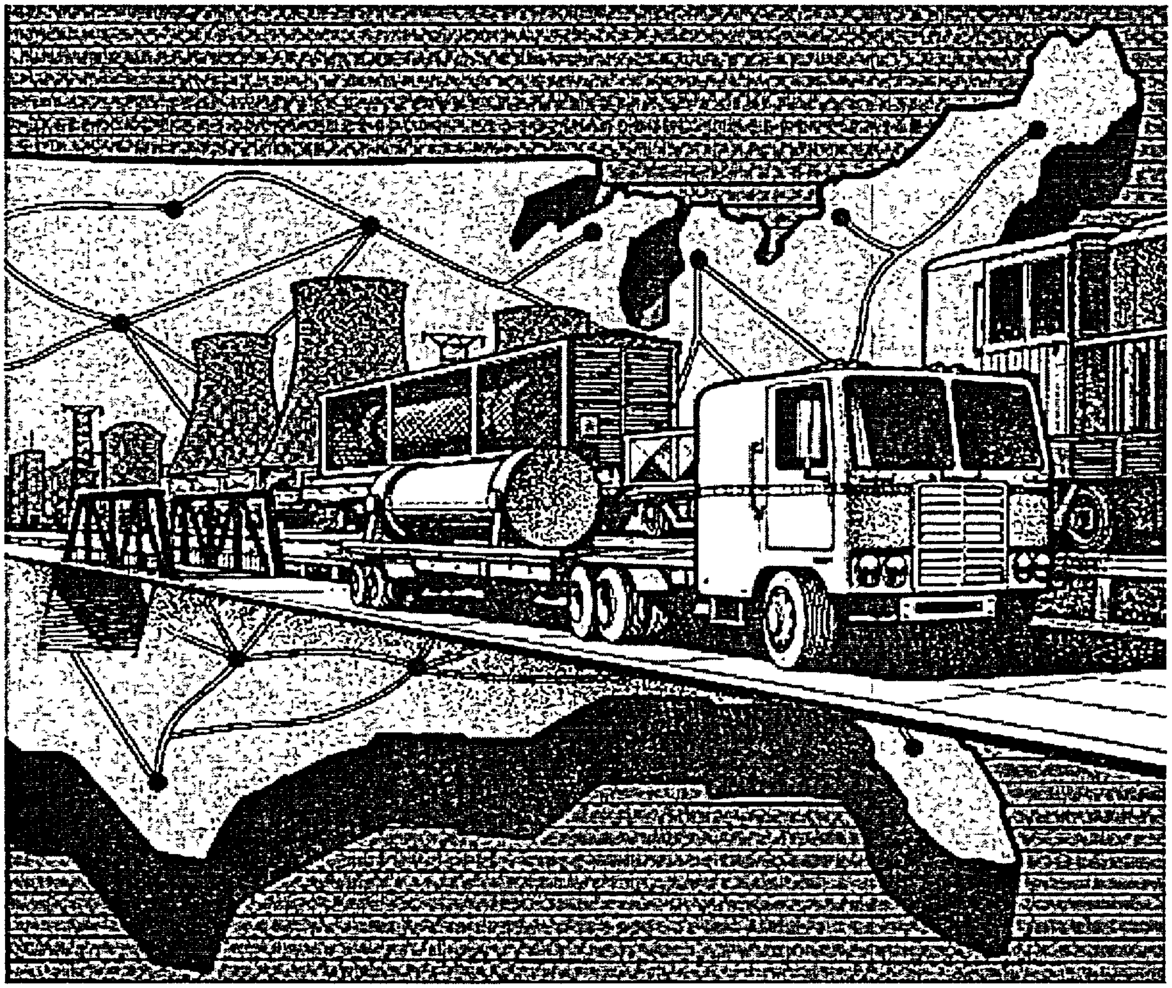
Location: Rockville, Maryland

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

/s/ Heather Craycraft

Heather Craycraft
Official Reporter
Neal R. Gross & Co., Inc.

Spent Fuel Transportation Package Analysis and Testing



Transportation Working Group
Workshop
Session I

November 19, 2002

TABLE OF CONTENTS

ADVISORY COMMITTEE ON NUCLEAR WASTE
TRANSPORTATION WORKING GROUP WORKSHOP
NOVEMBER 19 & 20, 2002,
TWO WHITE FLINT NORTH, AUDITORIUM, ROCKVILLE, MARYLAND

Contact: Tim Kobetz (301-415-8716, tjk1@nrc.gov)

-PROPOSED SCHEDULE-
NOVEMBER 19, 2002

	Topics	Presenters	Time
I.	Opening Remarks	G. Hornberger, Chairman, ACNW M. Levenson, ACNW	8:30-8:40 a.m. (10 min)
II.	Analysis and Testing		
a.	Overview of Research Program Objectives	E. William Brach, SFPO	8:40-9:00 a.m. (20 min) Presentation Time 9:00-9:20 a.m. (20 min) Discussion Time
b.	Summary of Sandia National Laboratory Research	Doug Ammerman, Sandia	9:20-10:05 a.m. (45 min) Presentation Time 10:05-10:35 a.m. (30 min) Discussion Time
	BREAK		10:35-10:50 a.m.
c.	Summary of Lawrence Livermore Laboratory Research	Larry Fischer, LLNL	10:50-11:35 a.m. (45 min) Presentation Time 11:35 a.m.-12:05 p.m. (30 min) Discussion Time
d.	Public Comments		12:05-12:30 (25 min)
	LUNCH		**12:30-1:30 p.m.**
e.	Vendor Analysis and Testing	Kris Singh, Holtec International Peter Shih, Transnuclear Michael Yaksh, NAC Intl.	1:30-1:50 p.m. (20 min) Presentation Time 1:50-2:10 p.m. (20 min) Presentation Time 2:10-2:30 p.m. (20 min) Presentation Time 2:30-3:15 p.m. (45 min) Discussion Time

17

	BREAK		**3:15-3:30 p.m.**
f.	Analysis of Fires	Chris Bajwa, SFPO	3:30-3:50 p.m. (20 min) Presentation Time 3:50-4:10 p.m. (20 min) Discussion Time
g.	Comparison of Analysis and Testing to Actual Railway Experience	Robert Fronczak, AAR	4:10-4:30 p.m. (20 min) Presentation Time 4:30-4:50 p.m. (20 min) Discussion Time
h.	Public Comments		4:50-5:15 p.m. (25 min)
i.	Committee Discussions	Milt Levenson, ACNW	5:15-5:45 p.m. (30 min) Discussion Time

12

Overview of Research Program Objectives

UNITED STATES NUCLEAR REGULATORY COMMISSION

E. William Brach, Director

Spent Fuel Project Office
U.S. Nuclear Regulatory Commission

Overview

- Spent Fuel Transport Safety
- Scope of Spent Fuel Transportation
- Role of Research - Risk Assessments and Transport Studies

3

Key Messages

- NRC ensures that casks are robust
  - *Regulates design and construction*
  - *Reviews designs and independently checks ability to meet accident conditions*
  - *Ensures containers are built, maintained, and used properly*
- Exemplary industry compliance with safety regulations, resulting in strong transport safety record
- Supported by confirmatory research

NRC Yucca Mt Transport Role

- Nuclear Waste Policy Act Section 180
  - *DOE must use NRC certified cask*
  - *DOE must apply NRC advance notifications*
  - *DOE must provide training and funds to local and Tribal governments along routes*

Scope of Spent Fuel Transportation

- Historical/Current:
  - ~1300 shipments in NRC certified casks in 20 yrs; 4 accidents but no releases
  - Currently about 10 SNF shipments/yr
- Private Fuel Storage (40,000 MTHM)
  - ***~50 rail shipments/yr @ 4 casks each*** for 20 yrs
- Yucca Mountain (63,000 comm. MTHM)
  - *Mostly rail scenario (FEIS):* ***~130 rail shipments/yr @ 3 casks each + 45 truck shipments/yr for 24 yrs***

Transportation Studies

- NUREG-0170 (Final Environmental Statement, 1977)
  - *All radioactive materials by all modes*
  - *NEPA basis for Part 71 & 49 CFR*
  - *Resulted in 1981 Commission Policy Finding: Transport regulations adequate, subject to close and continuing review*
- Modal Study (NUREG/CR-4829, 1987)
  - *First incorporation of cask finite element analyses & detailed thermal/impact response*

Transportation Studies (cont'd)

- NUREG/CR-6672 (2000)
  - *First incorporation of sampled ranges for input parameters*
  - *Updated assumptions*
- Package Performance Study (1999-2005)
  - *First incorporation of confirmatory testing, model validation*
  - *Public participatory process*

Transportation Studies (cont'd)

- Baltimore Tunnel Fire study (2002)
  - *Assess hypothetical performance of spent fuel cask in real-world accident*
  - *Coordinated with NIST and NTSB*
- National Academy of Sciences study
  - *Expert panel review of societal and health risks of spent fuel transport*
- Non-NRC sponsored studies & tests
  - *1970s Sandia demonstrations*
  - *1980s U.K. operation smash hit*

Conclusion

- High confidence in safety provided by transportation regulations
- Transportation research programs
  - *Confirmatory in nature*
  - *Consistent with Commission direction*
  - *Valuable insights into cask performance & release estimates*
  - *Developed the approaches used for key Environmental Reviews for licensing*
  - *Support Public Confidence*

7

Summary of Sandia National Laboratories Research

Presented at:

Advisory Committee on Nuclear Waste
Transportation Working Group Workshop

Doug Ammerman
Sandia National Laboratories
November 19, 2002

Outline

- Review Past Significant Test Programs at Sandia
  - 1970s Crash Test Program
  - Defense High Level Waste (DHLW) 1/2-Scale Cask Testing
  - TRUPACT-II Full-Scale Tests
- Analysis Methodology
  - Structural Modeling/Analysis Codes
  - Thermal Modeling/Analysis Codes
- Linking Analysis to Testing
  - Code Verification and Validation
  - Examples of Analysis vs. Testing
- Conclusions - Where are the Gaps?

Past Test Programs at Sandia

- Sandia has, since its beginning, been involved in systems level testing.
- Transportation package testing has been going on for over 30 years.
- Different test programs had different purposes and goals.
- The goals define the way the tests are conducted.

1970s Crash Test Program

- Purpose
  - Assess and demonstrate the validity of analytical tools and scale modeling techniques for predicting damage in accident environments by comparing predicted results with actual test results
  - To gain quantitative knowledge regarding extreme accident environments by measuring the response of full scale hardware under actual crash conditions
- Approach
  - Mathematical analyses, scale model testing and full scale tests

1970s Crash Test Program

- Extent of instrumentation on scale model and full scale hardware
  - Accelerometers – measure accelerations of the package and transport system
  - Strain gages – measure strains on various cask and transport system components
  - High-speed photography – record cask and transport system response

1970s Crash Test Program

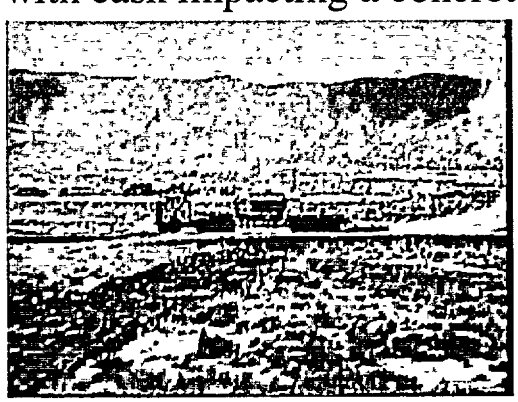
- Truck cask impacted by a locomotive

1970s Crash Test Program

- 80 mph grade crossing impact
  - Truck cask impacted by a locomotive (SAND79-2291)
  - Utilized 18 high-speed (400-2500 fps) cameras
  - Seven strain gages on cask body
  - Four piezoresistive accelerometers
  - An accelerometer on the locomotive
  - Data was acquired via a telemetry system

1970s Crash Test Program

- Truck with cask impacting a concrete barrier

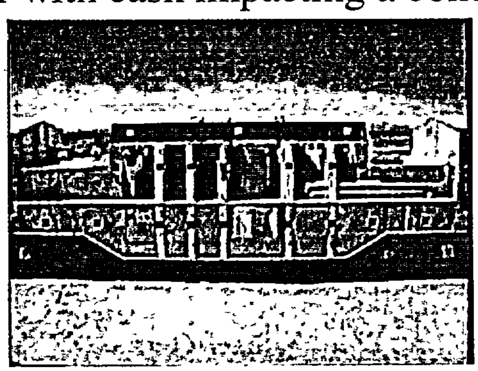


1970s Crash Test Program

- 60 and 84 mph truck cask impact tests
  - Truck with cask impacting a concrete barrier (SAND77-0270)
  - Test was monitored with about 14 high speed cameras (framing rates between 400 and 3000 fps)
  - Five active accelerometers were placed on the cask body
  - Strain gages were placed on the cask head
  - Pressure transducers were placed inside the cask cavity

1970s Crash Test Program

- Rail car with cask impacting a concrete barrier



1970s Crash Test Program

- 80 mph impact of special railcar
  - Rail car with cask impacting a concrete barrier (SAND78-0458)
  - Monitored with numerous high-speed cameras (up to 3000 fps) placed above, on the sides, and at various angles
  - Active accelerometers were placed on the rail car frame, rail car cage cover, and on the cask, as well as on the target
  - Strain gages were installed on the railcar frame, the cask body, and on two fuel rods inside the cask

1970s Crash Test Program

- Rail car with cask in a fully engulfing fire

1970s Crash Test Program

- Rail car with cask in a fully engulfing fire
  - Instrumented with numerous thermocouples to measure thermal response of cask exterior and interior

1970s Crash Test Program

- Results
  - Indicated that current (at the time of the tests) analytical and scale modeling techniques could predict vehicular and cask damage in extremely severe accident environments with reasonably good accuracy
  - Much data was collected on response of transport systems in accident environments
  - Tests indicated that spent fuel casks are extremely rugged containers capable of surviving very severe accidents

1970s Crash Test Program

- Is there any additional information that can be gleaned from these tests?
  - The 3D finite analysis computer codes and computational hardware available today provide more detailed information about the response of packages and transport systems than the lumped parameter and 2D finite element models of the late 1970s. Some of this data could be used in benchmarking present day codes, for example, locomotive-cask impact test.
  - There have been tremendous improvements in data collection instrumentation and sensors since these tests were performed. Future full-scale tests would be better documented.

DHLW Cask Tests (1986)

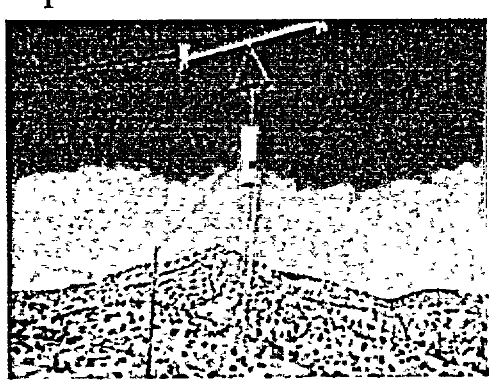
- Purpose
  - Certification impact and puncture test sequence
  - Provide test data on accelerations and strains to compare with analysis results
  - Define the damage state to use as an initial condition for the hypothetical fire analysis
  - Test sequence included 5 drops and 2 punctures

DHLW Cask Tests

- Extent of instrumentation
  - Accelerometers - varied from 6 to 15, depending on test orientation
  - Strain gages - varied from 4 to 24, depending on test orientation
  - Strain gage bolts - varied from 0 to 8, depending on test orientation
  - LVDTs - varied from 0 to 6, depending on test orientation

DHLW Cask Tests

- End drop test at -31°C



DHLW Cask Tests

- Results
  - Package was leak-tight after each test
  - Closure deformations were very small (< 0.004 in)
  - Peak strain measured was 0.0033
  - Peak acceleration measured was 2200 Gs
  - Analysis results were generally conservative

DHLW Cask Tests

- Is there any additional information that can be gleaned from these tests?
  - This test series was very thorough and can be used as a demonstration of the types of information that can be obtained from a drop test.
  - The tests were performed in 1986, and it would be difficult to resurrect any of the digital data from the tests.
  - The test results could be compared to modern analysis results.

TRUPACT-II
Full-Scale Tests (1989)

- Purpose
  - Certification test sequence - drop, puncture, fire
  - Multiple tests of each type performed
  - Package certified by full-scale testing

Slide 21 ACNW/TWGW/Nov 19 2002

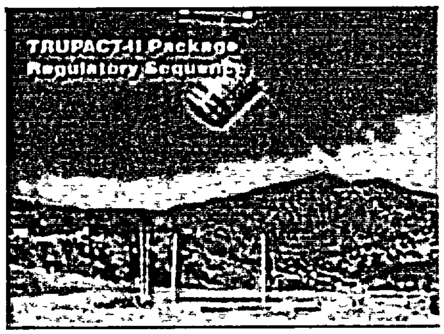
TRUPACT-II
Full-Scale Tests

- Extent of instrumentation
  - Very little dynamic data taken
  - Post-test leak checks were performed
  - Photometric coverage

Slide 22 ACNW/TWGW/Nov 19 2002

TRUPACT-II
Full-Scale Tests

- Regulatory test sequence was performed



TRUPACT-II
Full-Scale Tests

- Results
  - Package remained leak-tight following all tests
  - The relatively flexible package experienced visible deformations

TRUPACT-II Full-Scale Tests

- Is there any additional information that can be gleaned from these tests?
  - The lack of instrumentation during this test sequence makes it difficult to compare the test results to analyses.
  - Extent of test sequence demonstrates the expense of relying on testing to demonstrate regulatory compliance.

Analysis Methodology

- Cask vendors rely on analyses to some extent to demonstrate package response to the hypothetical accident tests.
- Conservatisms introduced into analysis methods (or assumptions) for design certification are not always applicable for test predictions.

Structural Modeling/Analysis Codes

- Sandia uses transient dynamic finite element codes with explicit integration of the equations of motion.
  - **HONDO** - 1st code of this type, developed at Sandia
  - **DYNA** - developed at LLNL, available commercially
  - **PRONTO** - developed at Sandia
  - **ABAQUS/Explicit** - commercially available
  - **PRESTO** - Newest Sandia code in this family

Thermal Modeling/Analysis Codes

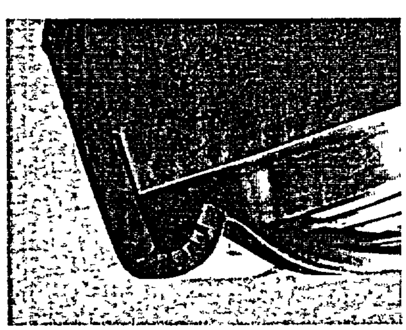
- Sandia uses CFD and finite element codes to solve fire dynamics and heat transfer problems.
  - **CAFE** - developed at Sandia; designed to model large fires engulfing a package, coupled to P/Thermal
  - **MSC P/Thermal** - commercially available, FE code used to solve heat transfer problems
  - **SODDIT** – a Sandia developed one-dimensional direct and inverse heat transfer code
  - **Vulcan** - CFD code developed at Sandia used to solve a broad range of fire problems
  - **COYOTE** - FE code developed at Sandia used to solve a broad range of heat transfer problems
  - **CALORE** - Newest Sandia FE heat transfer code

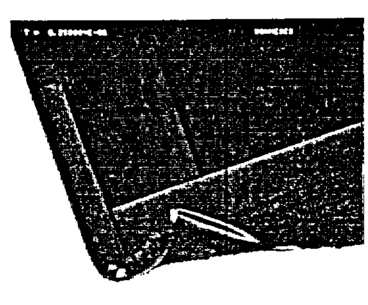
Linking Analysis to Testing

- Code verification and validation
  - Verification and validation provide high confidence in the computational accuracy of simulations, demonstrating the predictive capability of the codes and their underlying models.
  - Verification is the process of determining that a computational software implementation correctly represents a model of a physical process.
  - Validation is the process of determining the degree to which a computer model is an accurate representation of the real world from the perspective of the intended model applications. Validation makes use of physical data and results from previously validated computer codes.

Linking Analysis to Testing

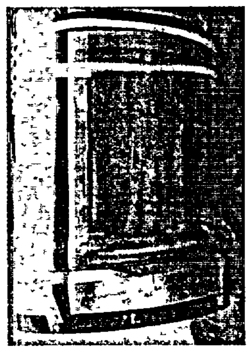
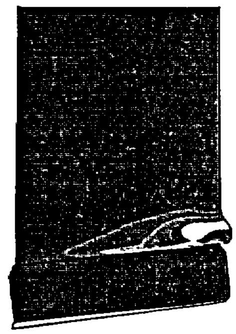
- Comparison of analysis to testing
  - DHLW notched impact limiter





Linking Analysis to Testing

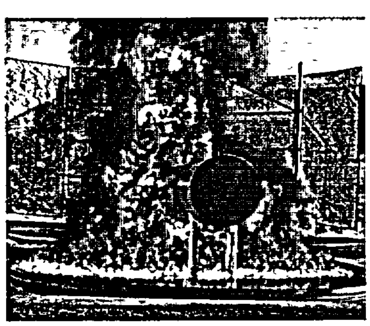
- Comparison of analysis to testing
  - SETU 60-MPH corner impact

Slide 31 ACNW/TWGW/Nov 19 2002

Linking Analysis to Testing

- Comparison of analysis to testing
  - Truck-Cask-Size Calorimeter




Slide 32 ACNW/TWGW/Nov 19 2002

Conclusions - Where are the Gaps?

- Certification tests (e.g. DHLW,TRUPACT-II) do not involve significant plastic deformation in the closure region.
- SETU tests were not full-scale and did not involve a complete cask system.
- Crash Test Program had little instrumentation to compare to analysis results and used casks that were obsolete in the 1970s.
- There is no data on surface heat flux incipient onto a rail-cask like object in an open pool fire.
- There is no data available on the response of spent fuel to severe transportation environments.
- There is no demonstrated comparison between the analyses used in risk assessments and full-scale high-speed-impact and fire tests.

FESSP

Fission Energy and Systems Safety Program

Summary of Lawrence Livermore National Laboratory Research on Transportation

Presented to:
Advisory Committee on Nuclear Waste Transportation Working Group

Larry Fischer

November 19, 2002

Lawrence Livermore National Laboratory

Making History
Making a Difference

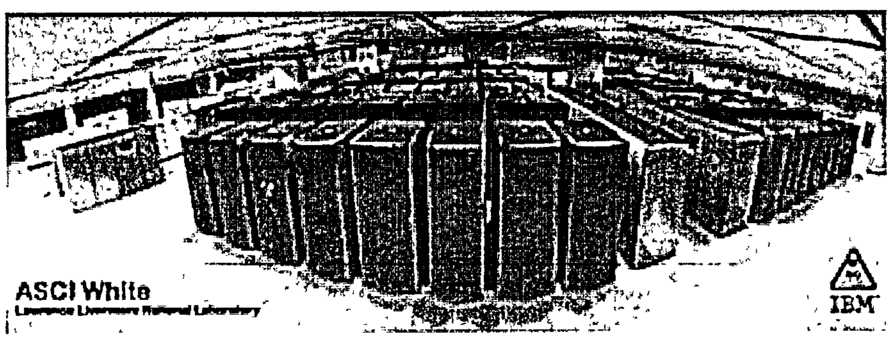
1952-2002

This work was performed under the auspices of the U S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

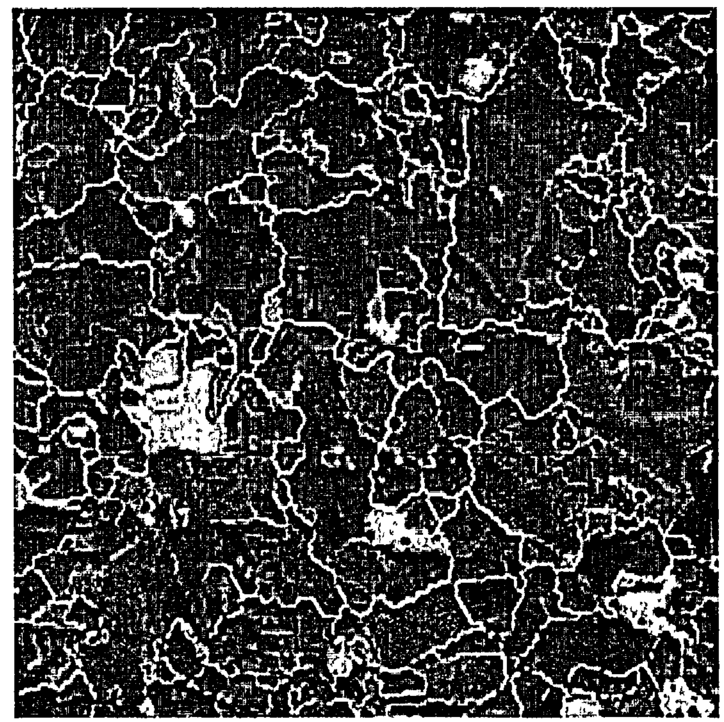
25

LLNL's stockpile stewardship programs resulted in state-of-the-art computational models

When underground nuclear testing was suspended in 1991, the stockpile stewardship program emerged. One of the cornerstones of the program was the development of high speed computing, greatly expanded memory, and multi-scale, multi-physics computer modeling.



High Speed Computer
with Expanded Memory



Multi-scale, Multi-physic
Modeling

Outline

- Background
- Shipping container response to severe highway and railway accident conditions – (Modal Study) – 1986/1987
- Shippingport reactor shipment – 1988
- Plutonium Air Transport Certification (PATC) – 1992
- Low velocity impact tests of solid steel billet onto concrete pads – 1998
- Summary and conclusions

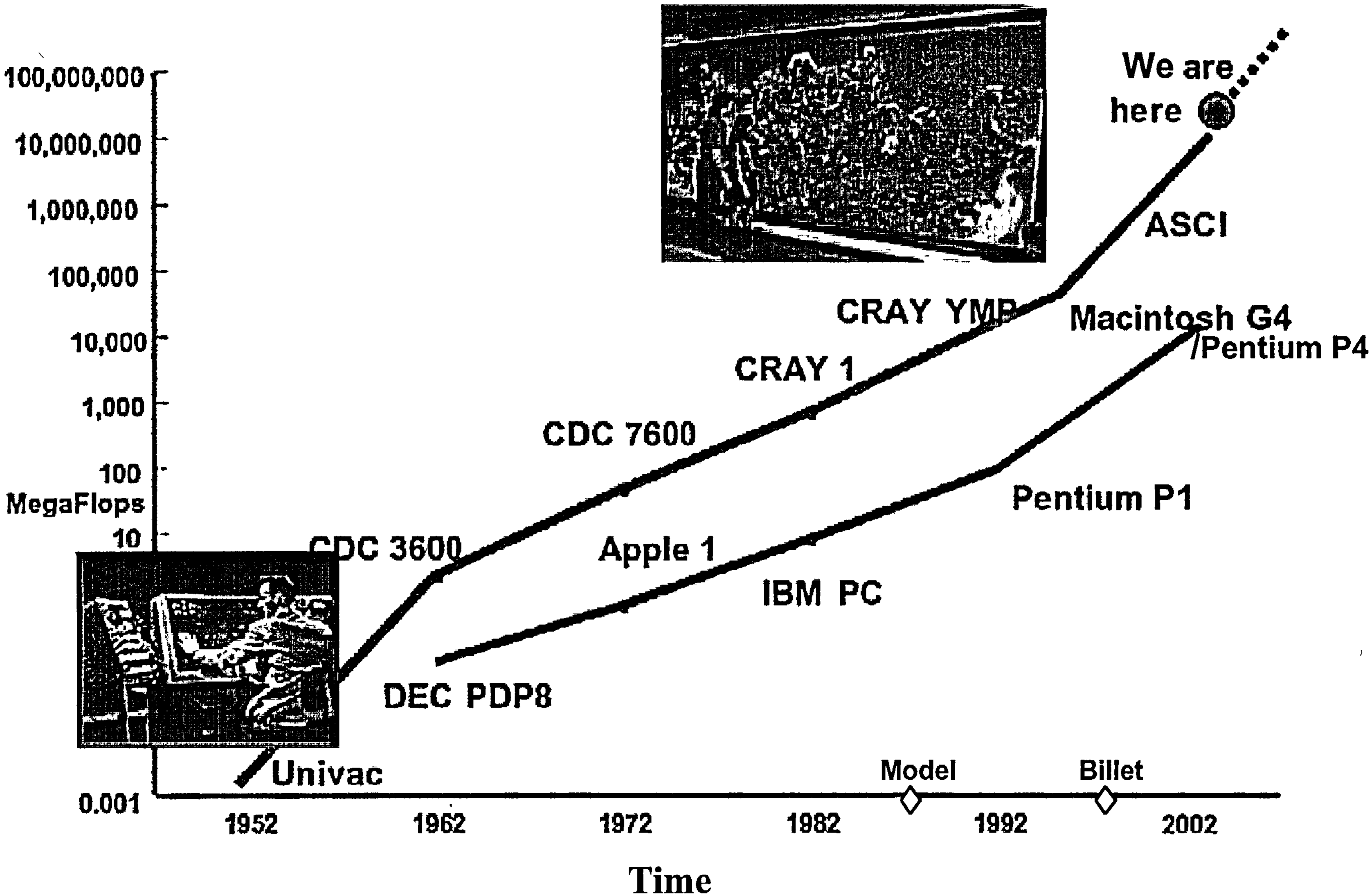
27

Background

LLNL has used computational analysis combined with testing for over fifty years to evaluate and understand physical phenomena

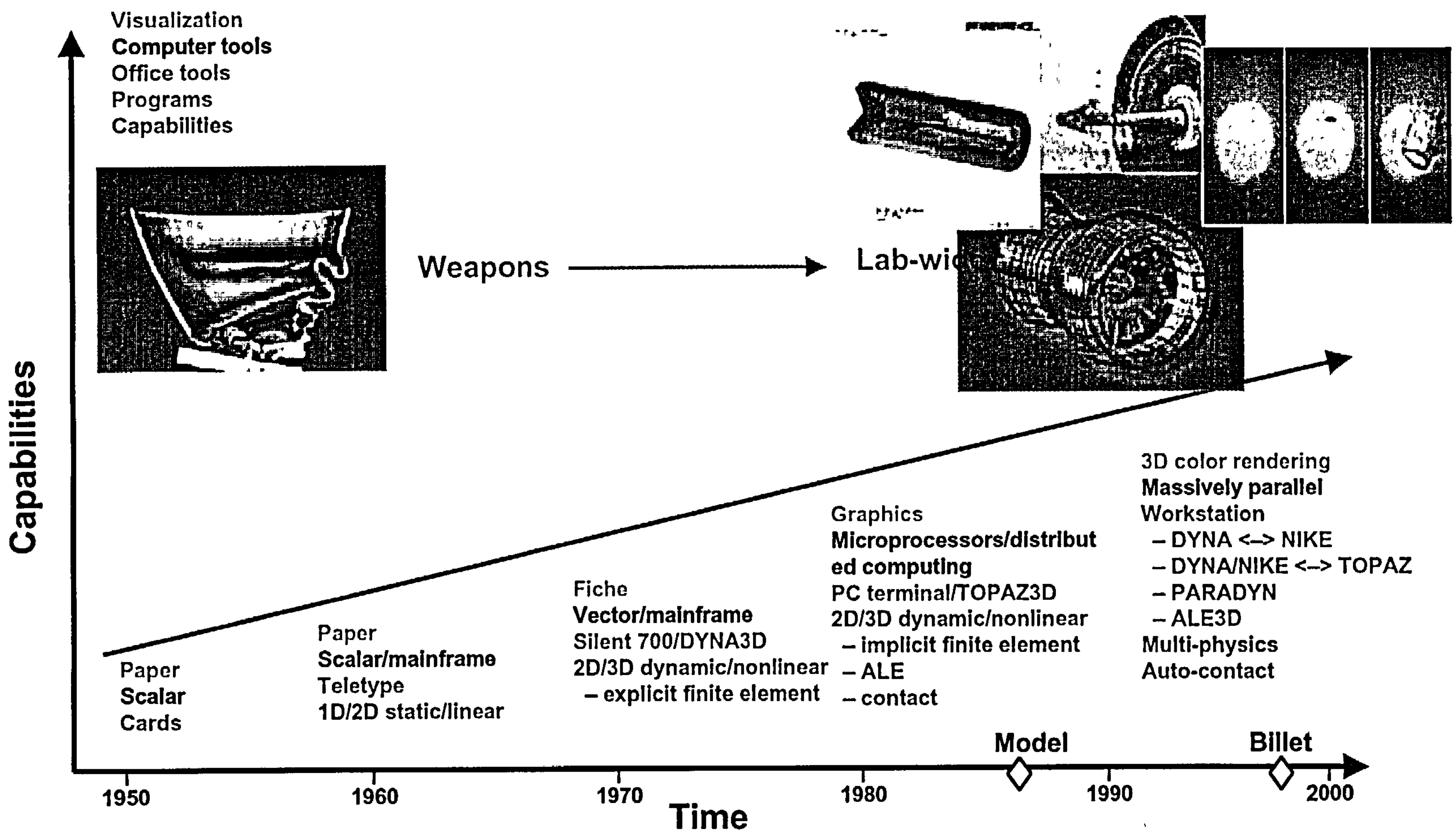
- Developed in the late 1960's and early 1970's computer codes for structural, thermal, and nuclear transport analyses
- Combined test and analysis to benchmark computer codes in order to use to evaluate system performance, postulated accidents, natural phenomena, and sabotage
- Recent exploration of massively parallel processing and multi-scale, multi-physics modeling has led to unprecedented computer simulation capabilities and has reduced the need for large scale expensive testing

1980s: Exploration of massively parallel processing has led to unprecedented simulation capabilities



69

Computer code modeling and graphics capabilities also increased dramatically



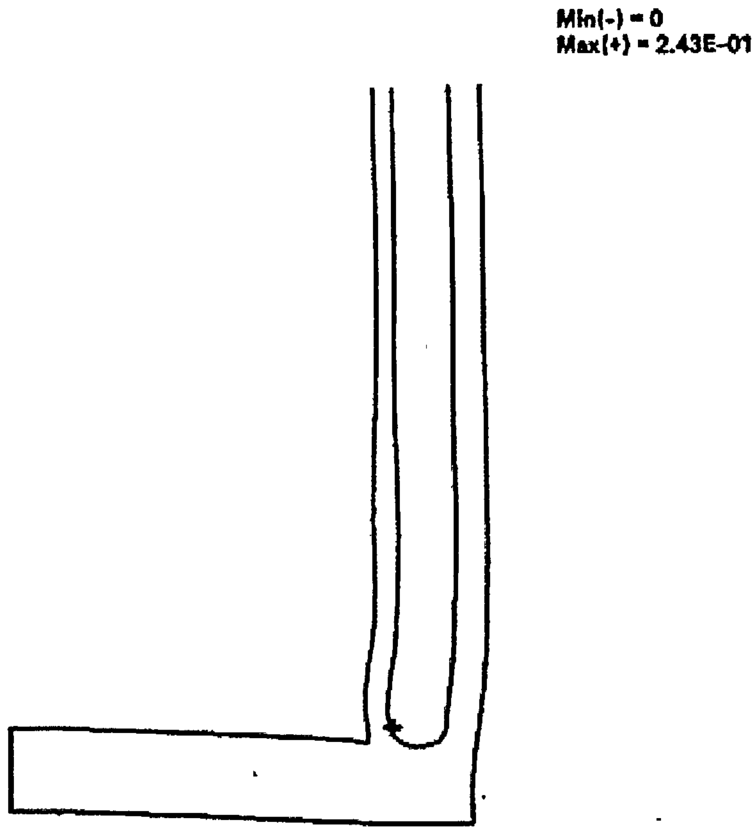
Modal study was performed in 1986 using the Cray 1

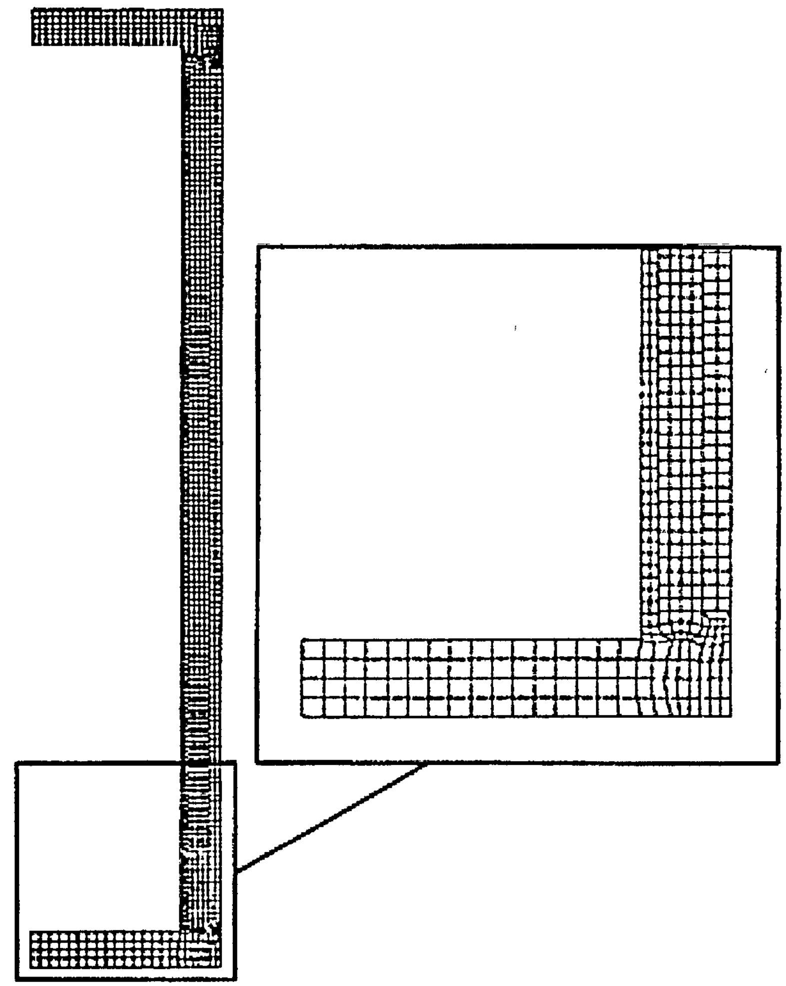
The Modal Study was performed for the NRC to evaluate the level of safety provided under severe accident conditions for spent fuel casks

- **Used quantitative computational modeling and analysis to evaluate responses of representative casks to severe accident condition to estimate radiological releases**
- **Used Cray 1 machine (1 Gigaflop) to perform primarily 1D and 2D analyses and a single 3-D analysis to reduce computational time and costs. Most analysis were performed for unyielding surfaces (consistent with 10 CFR 71 requirements).**
- **Benchmark of computer codes were limited primarily to weapons components and closed form solutions**

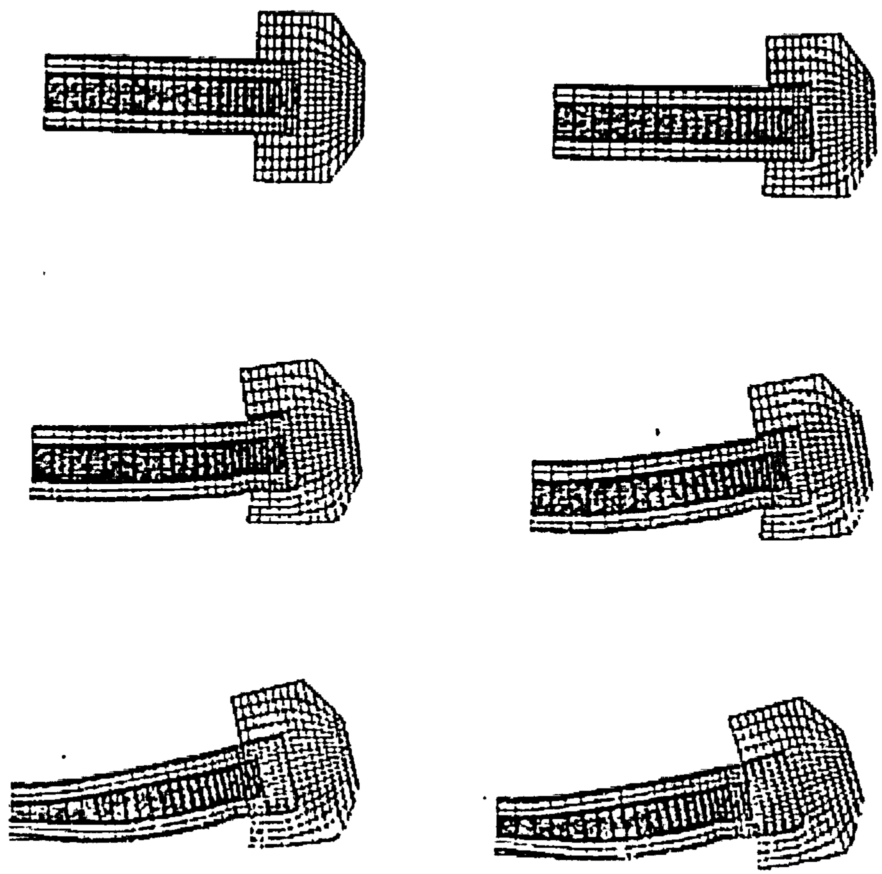
JG

Rail cask finite element 2D model and strain results for cask impact at 90 mph





Truck cask finite element 3D model and deformation results for cask impact at 60 mph



33

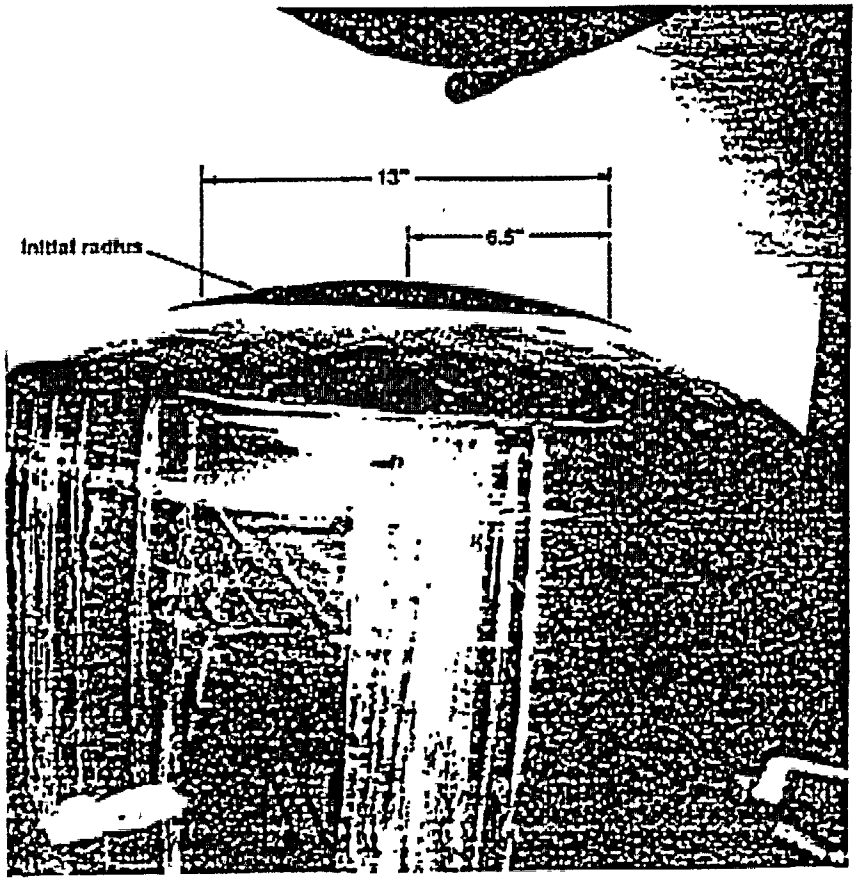
Shippingport analyses were performed with the Cray-YMP in 1988

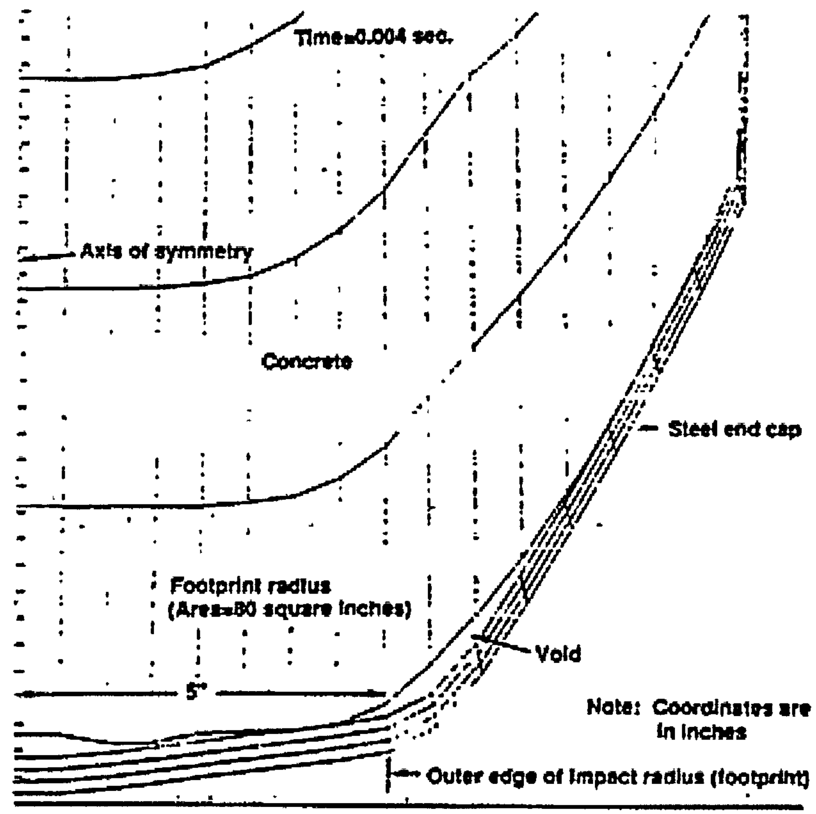
Computational analysis with scale model testing was used to obtain certification of the Shippingport reactor package for shipment

- Important package features were included in 1/10 scale model for drop and puncture bar tests
- Fair agreement (~30%) was demonstrated between scale model testing and computational analysis
- Using the benchmarked Dyna 3D code, the reactor vessel package was shown to meet regulatory drop requirements with good safety margins

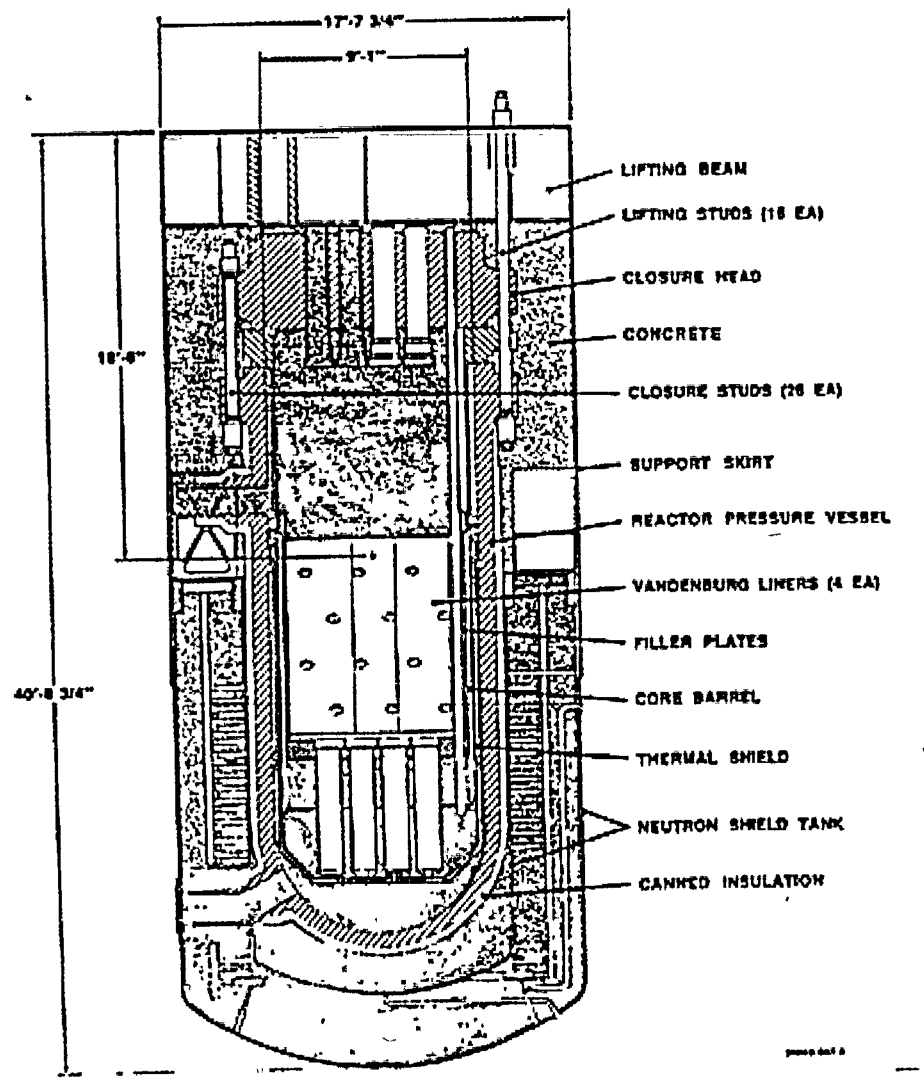
134

Shippingport forty-five foot drop test and analysis of 1/10 scale model



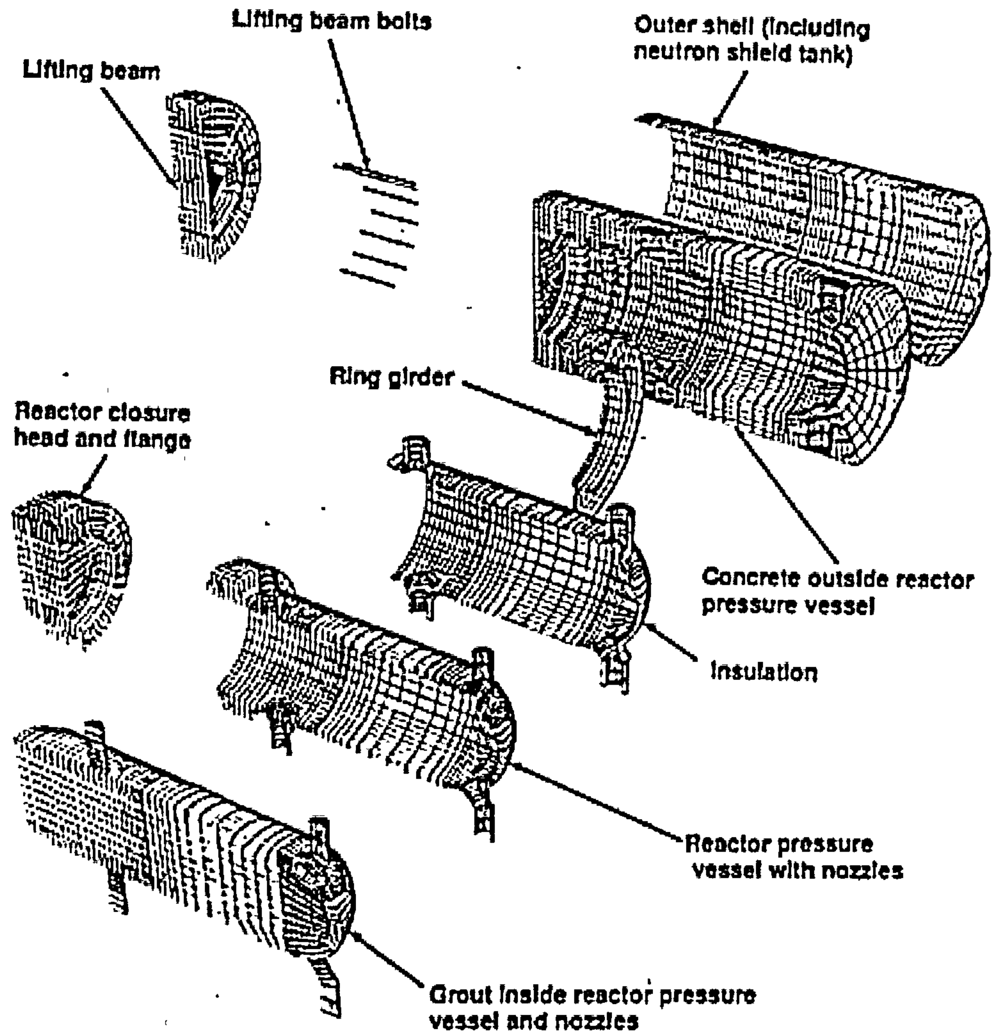


Shippingport reactor package



36

Shippingport Dyna 3D finite element model



37

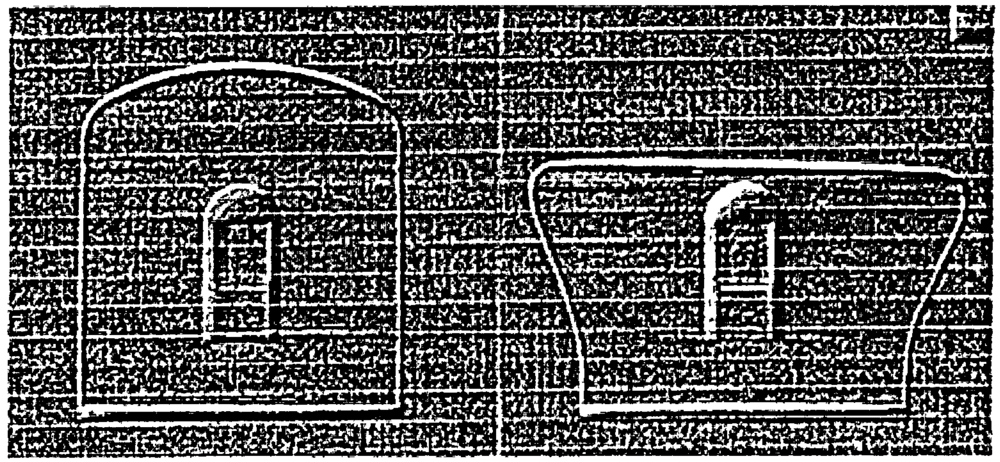
PATC tests – 1992 SGI workstation

High velocity impact tests of a 1/6 scale air transport package were performed to benchmark a computer code to be used to evaluate impacts on real surfaces

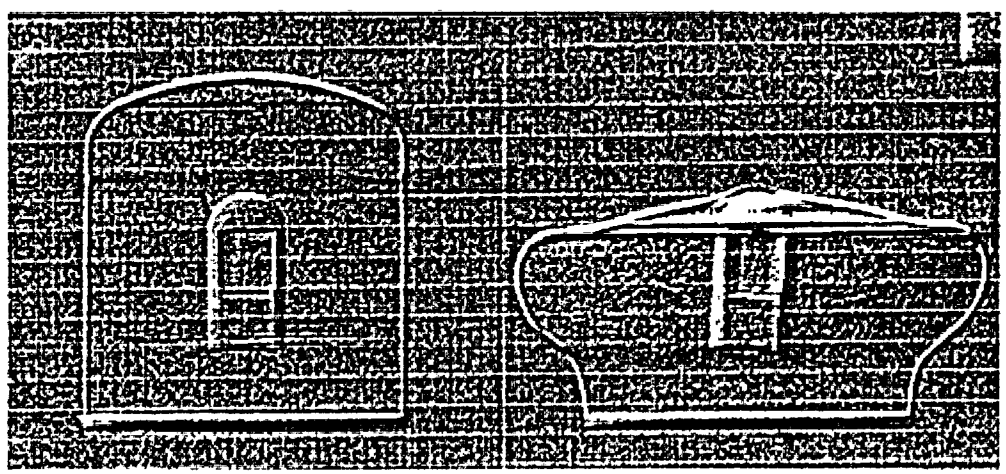
- Package used grout as impact limiter material and a high strength containment system. An aluminum ball was used to measure peak g forces.
- The test impact velocities varied from 17 to 157 m/s on steel surface and 206-208 m/s on concrete surface
- Good agreement with impact limiter deformation was demonstrated between scale model testing and computational analysis

38

High velocity impact tests



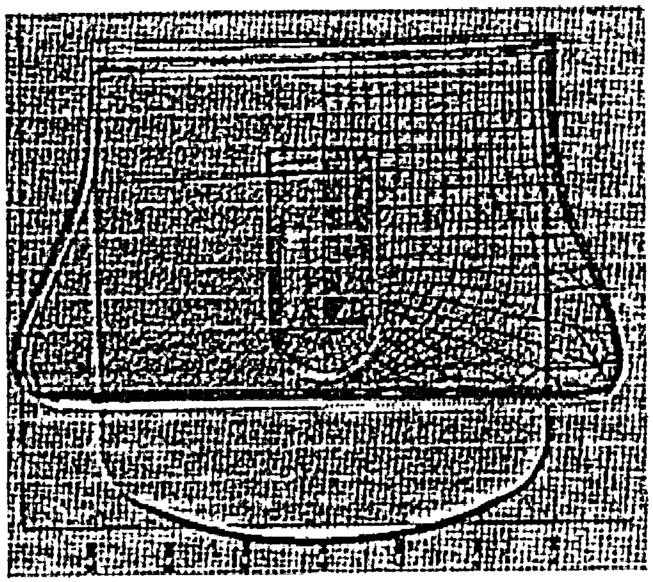
Radiograph of test model after impact on steel plate at 167 m/s (516 ft/s)



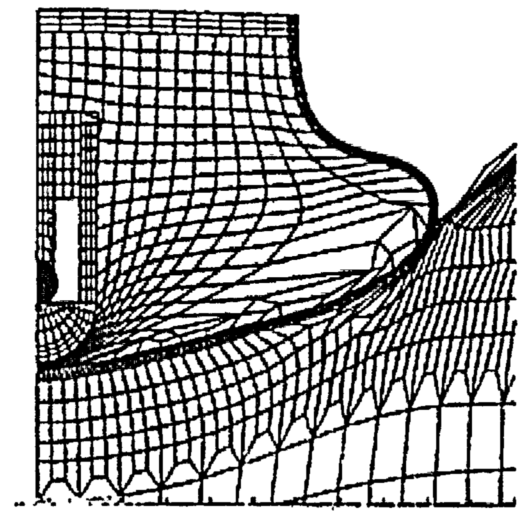
Radiograph of test model after impact on grout block at 288 m/s (945 ft/s)

39

High velocity impact tests (cont.)



Overlay of computer simulation on radiograph results of test package, impact on unyielding surface at 143.6 m/s



Simulated test package deformed shape with grout damage curve invoked, 288 m/s impact on soft rock

40

Billet testing performed in 1998 on an SGI workstation

Low velocity impact tests of a solid steel billet were performed to develop a method to use finite element analysis of storage cask drop and tipover onto a concrete pad.

- Impact onto an unyielding surface required the use of impact limiter on top of storage cask. Concrete can absorb energy and may eliminate need for impact limiter.
- Used 1/3 scale model of storage cask (steel billet) and reinforced-concrete pad.
- Used precision accelerometers and developed method for determining cut off frequency for them. Computational analysis was used to benchmark the Dyna 3D code.
- Good to excellent agreement was demonstrated between scale model testing and computational analysis.
- Using the benchmarked Dyna 3D code, a typical storage cask impacting concrete did not need an impact limiter to meet drop and tipover structural integrity requirements.

17

Billet testing

Maximum Billet End Drop Deceleration Test vs. Simulation

Test # / Channel #	Test data, filtered at 450 Hz	Finite element analysis simulation, filtered at 450 Hz
Test #1/ Channel A1	70.8 g	
Test #2 / Channel A1	78.7 g	
Test #1 / Channel A5	103.8 g	99.5g
Test #2 / Channel A5	88.0 g	

Maximum Billet Side Drop Deceleration Test vs. Simulation

Billet drop height / (Test #)	Test data from channel A3, filtered at 450 Hz	Finite element analysis simulation, filtered at 450 Hz
45.7 cm (18 inches) (Test #3)	108.2 g	
45.7 cm (18 inches) (Test #5)	86.0 g	105.0 g
45.7 cm (18 inches) (Test #10)	125.5 g	
91.4 cm (36 inches) (Test #4)	110.0 g	
91.4 cm (36 inches) (Test #7)	not available	142.7 g
91.4 cm (36 inches) (Test #9)	125.2 g	
1.83 m (72 inches) (Test #6)	206.7	
1.83 m (72 inches) (Test #8)	197.0	190.1 g

Hz

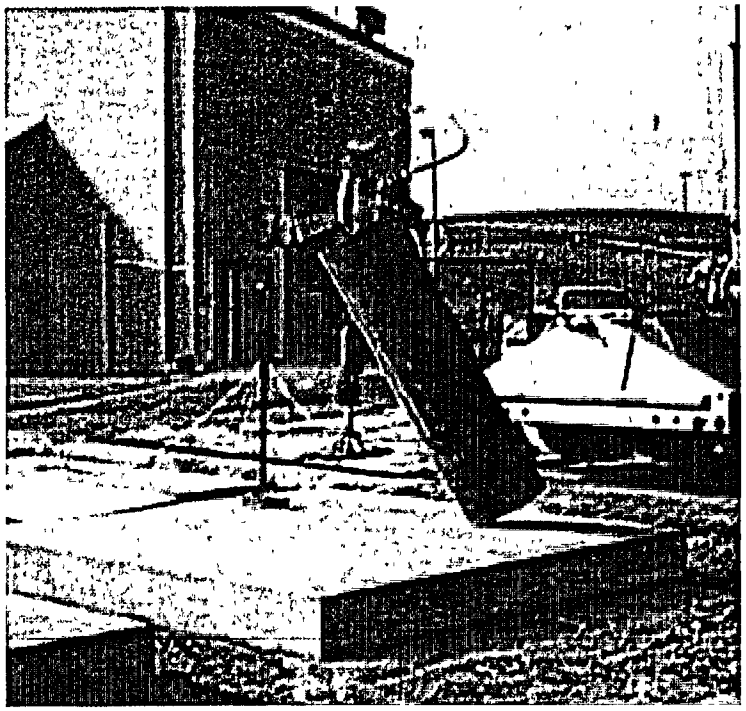
Billet testing (cont.)

Maximum Billet Tipover Deceleration Test vs. Simulation

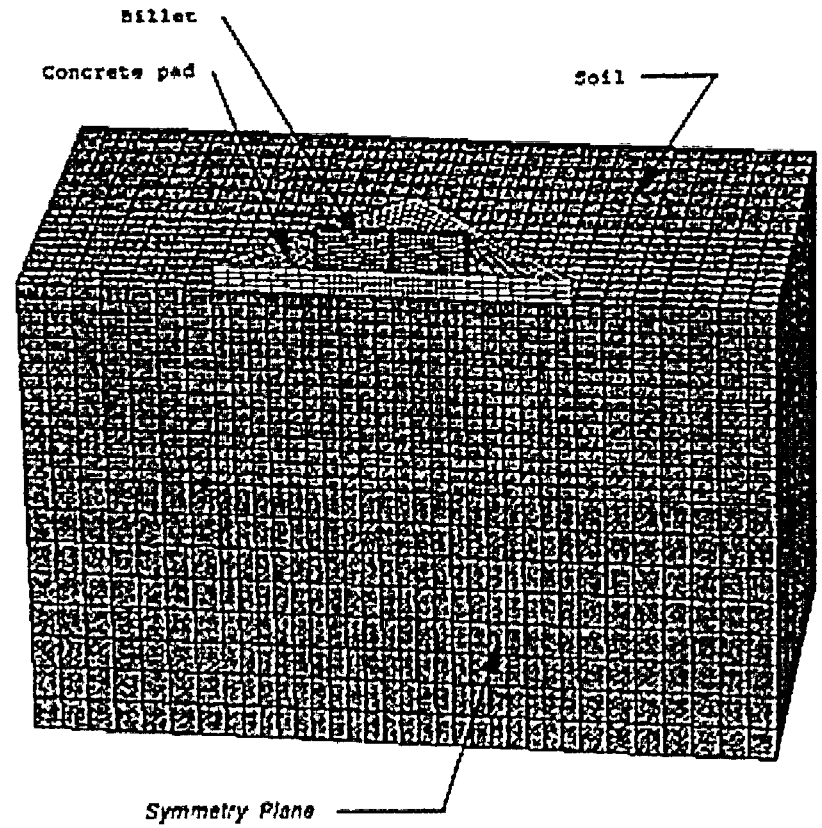
Test # / Channel #	Test data, filtered at 450 Hz	Finite element analysis simulation, filtered at 450 Hz
Test #11/ Channel A1	237.5 g	244.7 g
Test #12 / Channel A1	213.6 g	
Test #11 / Channel A5	231.5 g	
Test #12 / Channel A5	213.0 g	

43

Billet tipover test and finite element model of test

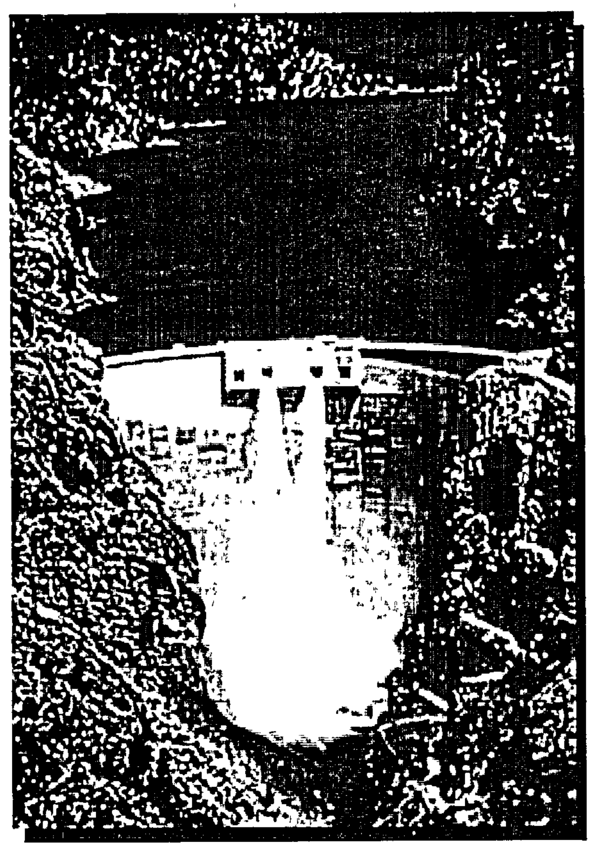


Billet Tipover Test



Finite Element Model

Seismic analysis of Morrow Point Dam



Charles R. Noble

15

Today's analytical capabilities allow more comprehensive analyses of shipping packages

To understand the package design margin, additional analyses are needed

- Residual stresses are created during cask fabrication
  - Metal bending
  - Machining
  - Welding
  - Lead/depleted uranium pouring
  - Annealing
- Detailed analysis of bolted closures requires large, complex computer models
- Contemporary high speed computers allow many analyses of a shipping package
- State of the art visualization tools allow engineers and members of the public to understand computer simulations

Recommendations

- Perform drop and thermal tests on a typical transportation cask per 10 CFR 71 hypothetical accident requirements
- Use state of the art instrumentation to record cask response, particularly in the closure and weld regions
- Benchmark at least one finite element code against the tests recordings
- Drop and thermal testing can use scaled cask models of at least 1/3 scale
- Perform drop and thermal testing simulations for full size cask
- Use high speed advanced computer system and physics codes for analyses
- Provide methodology and data such that applicants can benchmark their own finite element codes and perform analyses for their casks

DESIGN ATTRIBUTES AND STRUCTURAL CHARACTERISTICS OF THE HI-STAR TRANSPORT PACKAGE

by
Dr. K.P. Singh
President and CEO
Holtec International
555 Lincoln Drive West
Marlton, NJ 08053

HOLTEC INTERNATIONAL

A presentation to Advisory Council on Nuclear Waste
White Flint, MD
November 19, 2002

Components of the Transport Package

1. The HI-STAR dual purpose overpack
2. The Multi-purpose canister (MPC)
3. A set of two impact limiters
4. Transport cradle
5. Rail car
6. Personnel barrier (non-structural)

HOLTEC INTERNATIONAL

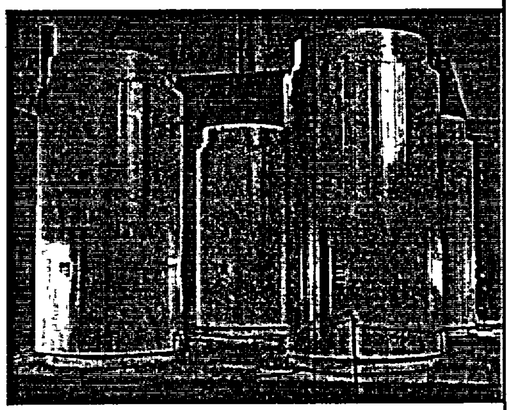
2

The HI-STAR Dual Purpose Overpack

- Storage (10 CFR 72) docket No.: 72-1008
- Transport (10 CFR 71) docket No.: 71-9261

Performance Mission:

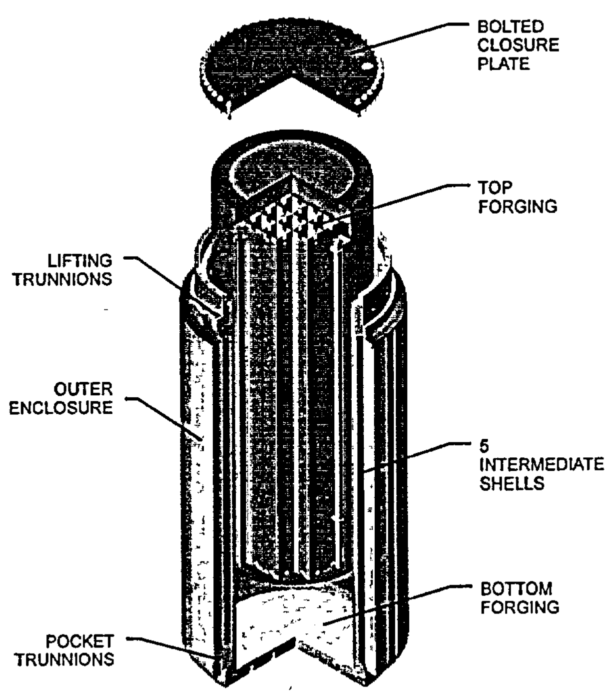
- Provide a virtually impregnable physical barrier to protect the stored MPC.
- Ready to transport on railcar at as low as -40°F ambient temperature.
- Capable of being stored on an ISFSI pad free-standing or anchored.
- Gross Weight ≤ 125 tons.



HOLTEC INTERNATIONAL

3

HI-STAR 100 Overpack with MPC Partially Inserted



HOLTEC INTERNATIONAL

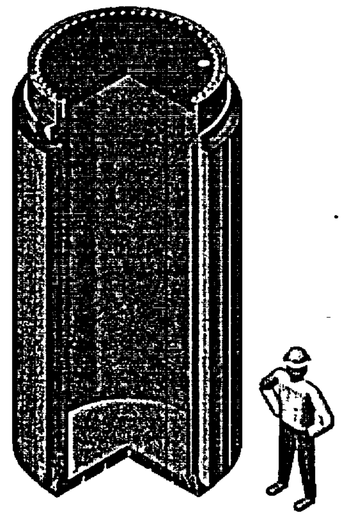
49

HI-STAR Design Features

Diameter:
- Bottom (footprint) - 83 1/4 inches
- Top (top lid) - 77 3/8 inches
- Mid-height - 96 inches

Weight:
- Empty - 154,000 lbs
- loaded w/MPC-32 - 243,000 lbs

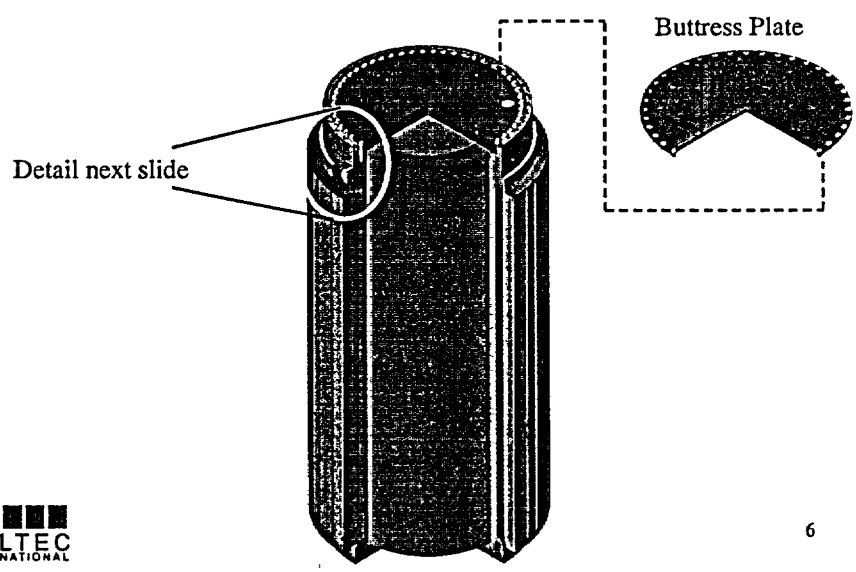
Height: - 203 1/4 inches



HOLTEC INTERNATIONAL

5

Design Features to Protect Against Accidents

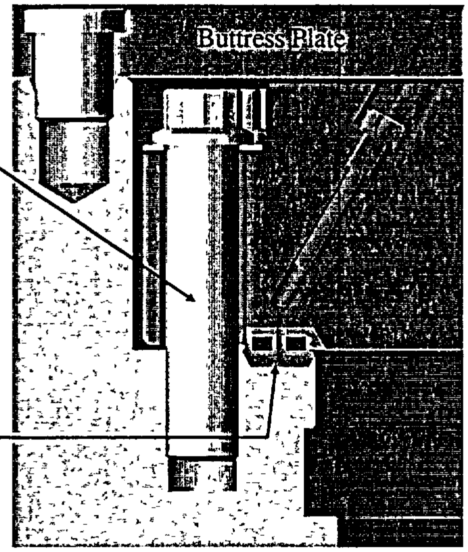


HOLTEC INTERNATIONAL

6

Design Features to Protect Against Accidents

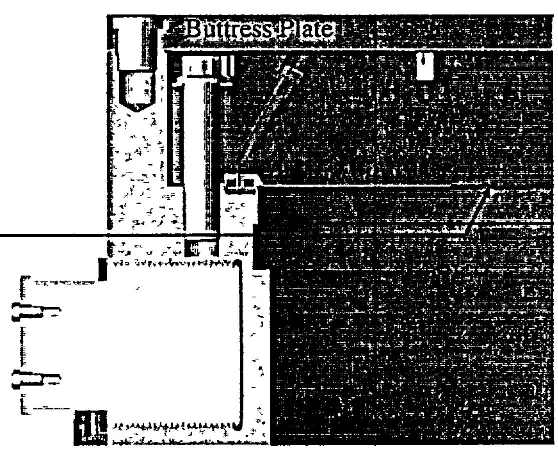
- Lid bolts are protected against lateral impact
- Dual gasket closure



HOLTEC INTERNATIONAL

Design Features to Protect Against Accidents

- Top Lid Recessed to mitigate effect of a massive impact.



HOLTEC INTERNATIONAL

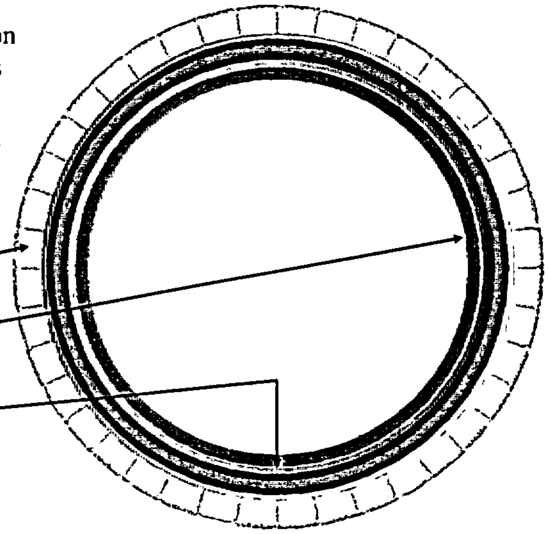
Design Features to Protect Against Accidents

- Multi-layered shell construction prevents propagation of cracks and provides a natural barrier against fuel heat-up under fire.
  (cross section shown at mid-height)

Holtite (Neutron Shield)

Inner Shell

Layered Shell (Five Layers)



HOLTEC INTERNATIONAL

9

HI-STAR Materials

Part	Material	Thickness
Bottom forging	Ni - steel	6 inches
Top lid	Ni - steel	6 inches
Containment (inner-most shell)	Ni - steel	2.5 inches
Gamma shells (4 total)	Carbon steel	1 1/4 inches each
Outer shell	Carbon steel	1 inch

HOLTEC INTERNATIONAL

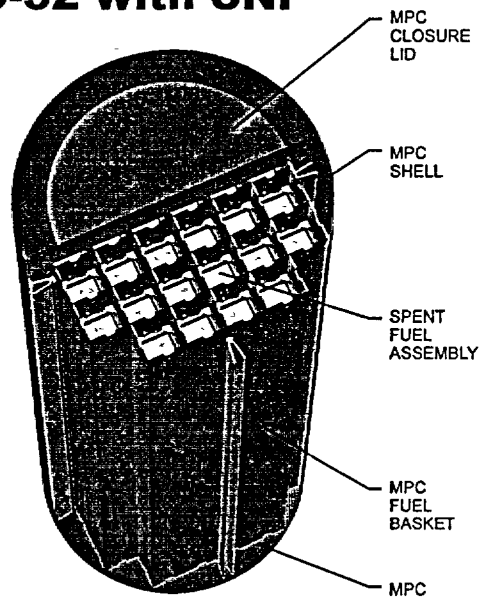
All HI-STAR load bearing materials qualified to remain fracture resistant @ < 40°F

10

MPC-32 with SNF

• The fuel is protected by the MPC enclosure vessel; the MPC is protected by the HI-STAR overpack.

• The MPC Enclosure Vessel is an all-welded, stainless steel pressure vessel.



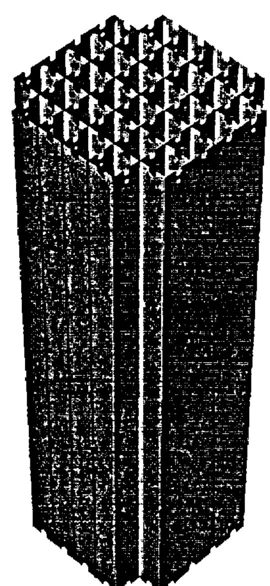
HOLTEC INTERNATIONAL

11

MPC-32 Basket

•The fuel basket, an egg-crate of stainless steel plates, orthogonally arrayed and full-length welds at all plate-to-plate intersections.

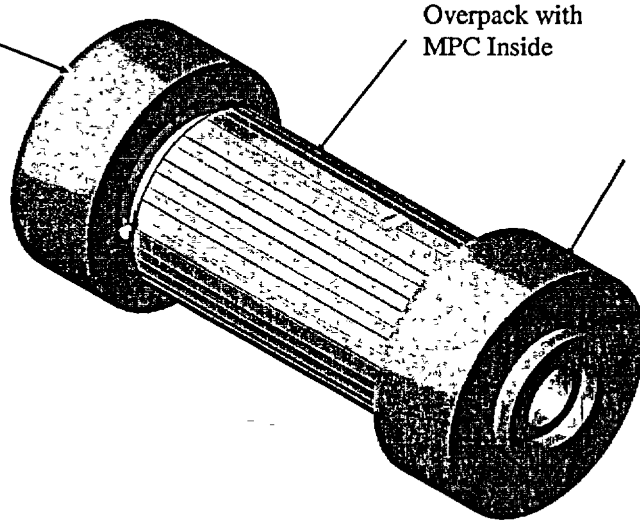
•The fuel basket is engineered to withstand impact freefall without exceeding ASME code stress limits.



HOLTEC INTERNATIONAL

HOLTEC Patent Nos 5,898,747 and 6,064,710

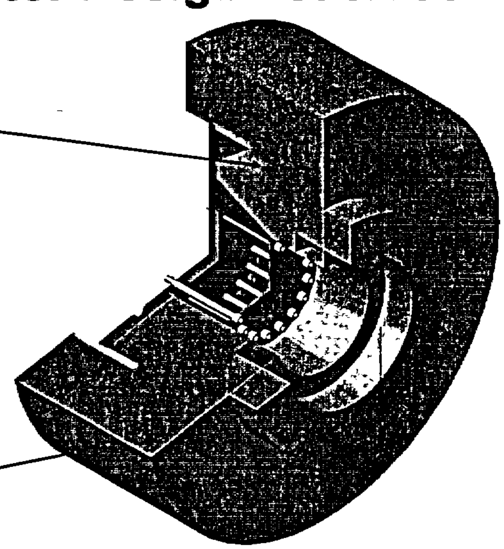
HI-STAR Package with Impact Limiters Installed



HOLTEC INTERNATIONAL

13

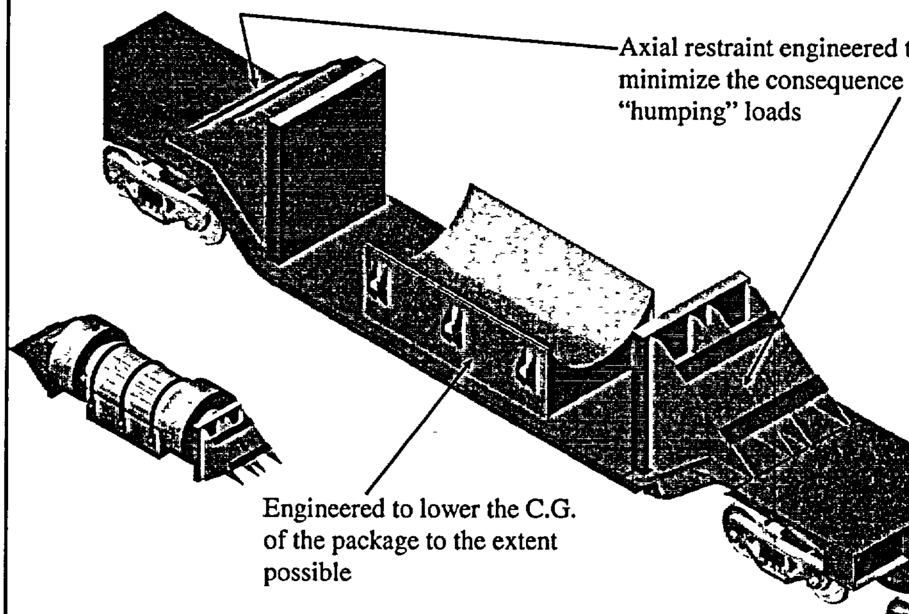
Impact Limiter Design Features



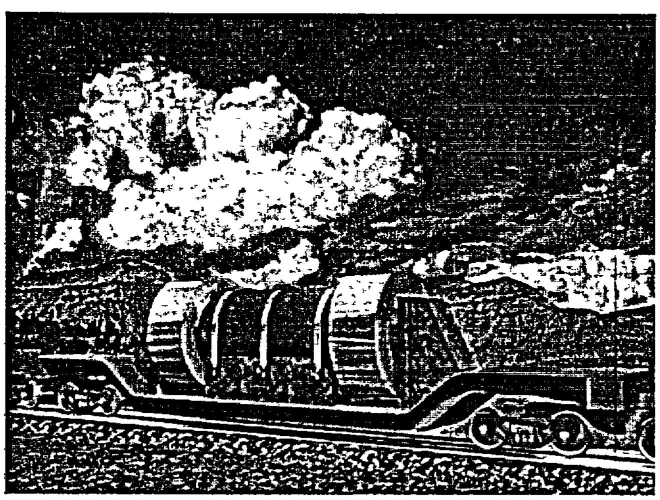
- Made of aluminum honeycomb
  - All-aluminum impact material eliminates weather (humidity and temperature) concerns
- Outer skin made of stainless steel

HOLTEC INTERNATIONAL

HI-STAR 100 Transport Cradle



The HI-STAR Transport Package (shown without Personnel Barrier)



HOLTEC INTERNATIONAL

16

Availability & Use

Thus far, eight HI-STARs have been manufactured.

- 4 HI-STAR 100 casks are in use to store MPC-68 (BWR) fuel at Exelon's Dresden Station.
- 3 HI-STAR 100 casks are in similar use at Southern Nuclear's Plant Hatch.
- 1 HI-STAR 100 overpack was built as a full size prototype; similar in all respects to its production unit, available from Exelon for testing purposes.

Exelon Executive responsible for the sale of HI-STAR is V.P. Kevin Yessian (630-657-3650, kevin.yessian@exeloncorp.com)

HOLTEC INTERNATIONAL

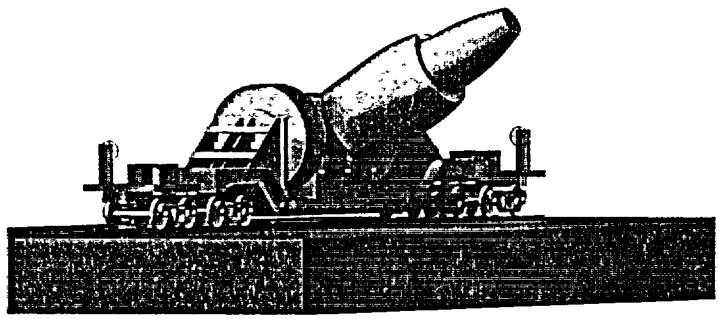
17

GLOBAL DYNAMIC MODEL OF IMPACT

- TRANSPORT PACKAGE, SUPPORTS, RAIL CAR, IMPACTOR SIMULATED FOR DYNAMIC ANALYSIS.
- IMPACTOR - 767 ENGINE AT 500 OR 250 MPH AT 30 DEGREE ANGLE WITH HORIZONTAL; ENGINE WEIGHT = 13,000 LB.
- TARGET - TOTAL ROLLING WEIGHT ON RAILS ~ 475,500 LB.
- ASSUMPTIONS:
  - PACKAGE; RR CAR (with package support saddles,trucks); ENGINE SIMULATED AS 3 RIGID BODIES
  - DAMAGE AT IMPACT LOCATION SIMULATED BY "COEFFICIENT OF RESTITUTION" (COR) - KINETIC ENERGY TRANSFERRED TO PACKAGE (COR = 0.25 OR 0.0).
  - COEFFICIENT OF FRICTION =0.5 SPECIFIED AT WHEEL/GROUND OR WHEEL/RAIL INTERFACE
  - PACKAGE HELD TO RR CAR SUPPORTS ONLY BY FRICTION FORCES; PACKAGE TIE-DOWNS CONSERVATIVELY NEGLECTED.
- OBJECTIVE: DOES THE PACKAGE REMAIN WITH THE RAIL CAR??
- NEXT SLIDES SHOW MODEL AND TWO "MOVIES" CONSTRUCTED DIRECTLY FROM RESULTS OF SLIGHTLY DIFFERENT DYNAMIC SIMULATIONS.

HOLTEC INTERNATIONAL

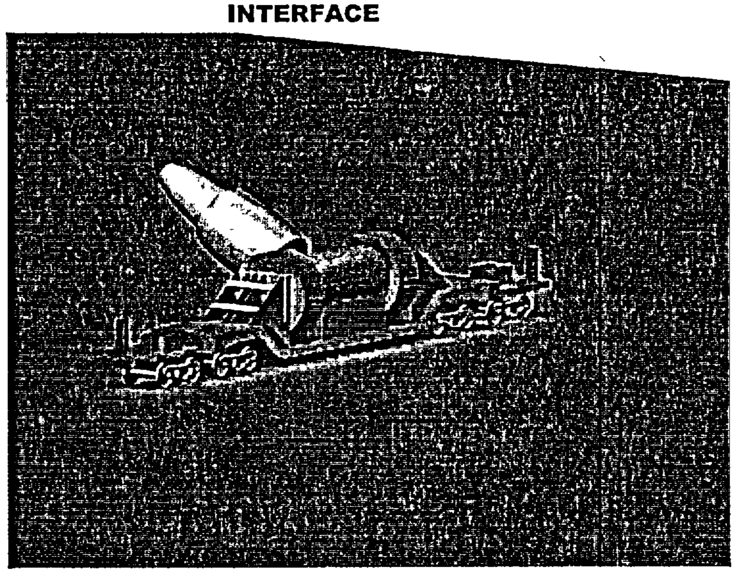
18



HOLTEC INTERNATIONAL

19

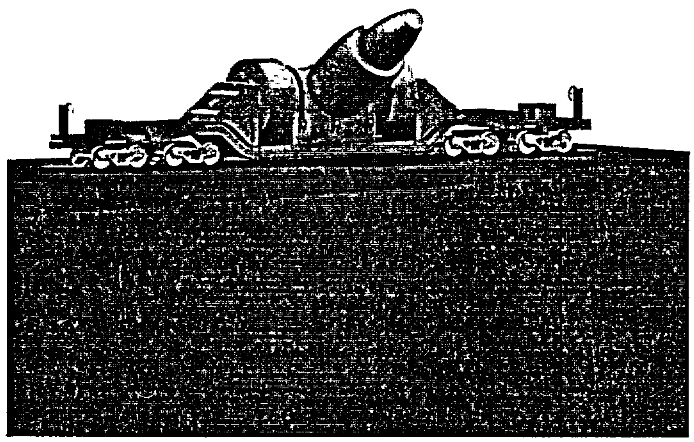
RAIL NOT INCLUDED - IMPACT SPEED 500 MPH; COR=0.25 AT IMPACT LOCATION; COF =0.5 AT WHEEL/GROUND INTERFACE



HOLTEC INTERNATIONAL

20

RAIL INCLUDED, 250 MPH SPEED; COR=0.0 AT IMPACT LOCATION; COF=0.5 AT WHEEL/RAIL INTERFACE -TIE DOWNS INCLUDED BUT DEACTIVATED



HOLTEC INTERNATIONAL

Post Impact Responses

- Package remains with vehicle during rollover for specified engine impact angle, speeds, and "cor" values.
- Adding different contact algorithms, adding interfaces (Engine/Package, Car Body/Trucks, Wheel/Rail, Rail/Ground), and separating connected rigid bodies, would permit simulation of local energy absorption without significantly adding to simulation times.
- Companion LS-DYNA3D model of complete system(engine is approximated) has been developed to include local deformation.

HOLTEC INTERNATIONAL

22

ADVISORY COMMITTEE ON NUCLEAR WASTE
TRANSPORTATION WORKING GROUP
WORKSHOP
NOVEMBER 19 & 20, 2002

Analysis and Testing Associated with Spent Fuel Transportation Casks

Peter Shih
Structural Analysis Manager

COGEMA GROUP
TRANSNUCLEAR

OVERVIEW

> Introduction
> Transport Cask Design Compliance
- US Design Criteria Based on Part 71, NUREG, and ASME Code
- European Design Criteria Based on IAEA and ASME Code
- Analysis
  - Methodology
  - Analysis Codes
- Testing
  - Acceptance Testing
  - Scale Model Impact Testing
  - Full Scale Tests

> Transnuclear Transport Cask Design & Licensing Experience
> Conclusions

59

INTRODUCTION

Over Thirty Years Experience in:

Design, Licensing, Fabrication and Operation of Packaging for Both Storage and Shipping of Spent Fuel, Radioactive Waste and Other Radioactive Material.

Experience Includes:

- **Design**
- **Analysis**
- **Testing**
- **Fabrication**
- **Certification**
- **Operation**

COGEMA GROUP

TRANSPORTATION WORKING GROUP WORKSHOP NOVEMBER 19 & 20, 2002

TRANSNUCLEAR

US Transport Cask Design Criteria

Design Basis:

- **10CFR Part 71**
- **Regulatory Guide 7.6**
- **Regulatory Guide 7.8**
- **ASME Section III, Subsections NB and NG**
- **ASME Section III, Subsection WB**
- **NUREG/CR-6007, Stress Analysis of Closure Bolts for Shipping Casks**

COGEMA GROUP

TRANSPORTATION WORKING GROUP WORKSHOP NOVEMBER 19 & 20, 2002

TRANSNUCLEAR

European Transport Cask Design Criteria

Design Basis:

- **IAEA Regulations as Adopted into Law by Specific Countries**
- **ASME Section III, Subsection NB and NG (as Applicable)**
- **European Transportation Constraints**

COGEMA GROUP

TRANSNUCLEAR

US Transport Cask Design Criteria

Acceptance Criteria:

- **Normal Conditions**
  - **Meet ASME Section III, Service Level A Allowables**
  - **Maintain Containment**
- **Accident Conditions**
  - **Meet ASME Section III, Service Level D Allowables**
  - **Maintain Containment**

COGEMA GROUP

TRANSNUCLEAR

61

US Transport Cask Analysis Methods

> Structure and Thermal
  - Finite Element Analysis Using ANSYS
  - Accepted Analytical Methods
> Criticality
  - Evaluated Using KENO-Va Within Scale 4.4 System
> Containment
  - Leakage Calculations in Accordance with ANSI 14.5
> Shielding
  - Gamma Dose Rate (MCMP)
  - Neutron Dose Rate (MCMP)

COGEMA GROUP

TRANSNUCLEAR

Acceptance Testing (Fabrication)

> Pressure and Structural Tests
  - ASME Code Hydrostatic Test (1.5 Times MNOP)
  - Trunnion Load Test (ANSI N14.6)
> Containment Test
  - ANSI N14.5 Leakage Test
  - Helium Mass Spectrometer (for leak tight or near leak tight requirements)
> Shielding Test (Optional)
  - Neutron Shield Test
  - Gamma Shield Test
> Neutron Absorber Test
  - Thermal Conductivity Testing
  - B10 Areal Density Testing
> Functional Test

COGEMA GROUP

TRANSNUCLEAR

Scale Model Testing

- > **Validate the G Value Predicted by Computer Analysis**
- > **Demonstrate That Crush Depths are Acceptable**
- > **Demonstrate Confinement of the Energy Absorption Material After Drop**
- > **Demonstrate Adequacy of the Impact Limiter Attachment Design**
- > **Evaluate the Effect of Low Temperature on the Crush Strength and Dynamic Performance of the Impact Limiter**
- > **Evaluate the Effect of a 40 inch Drop onto a Scaled Six inch Diameter Puncture Bar on a Previously Crushed Impact Limiter**

COGEMA GROUP

TRANSPORTATION WORKING GROUP WORKSHOP NOVEMBER 19 & 20, 2002

TRANSNUCLEAR

Scaling Relationships

Length	$L_{scale} = (1/\lambda)\ L_{full}$
Weight	$W_{scale} = (1/\lambda^3)\ W_{full}$
Energy Absorbed During Drop	$E_{scale} = (1/\lambda^3)\ E_{full}$
Velocity at Beginning of Impact	$V_{scale} = V_{full}$
Force During Impact	$F_{scale} = (1/\lambda^2)\ F_{full}$
Deformation	$D_{scale} = (1/\lambda)\ D_{full}$
Impact Duration (Time)	$T_{scale} = (1/\lambda)\ T_{full}$
Impact Deceleration	$G_{scale} = (\lambda)\ G_{full}$

COGEMA GROUP

TRANSPORTATION WORKING GROUP WORKSHOP NOVEMBER 19 & 20, 2002

TRANSNUCLEAR

Scale Model Drop Tests

> Justification

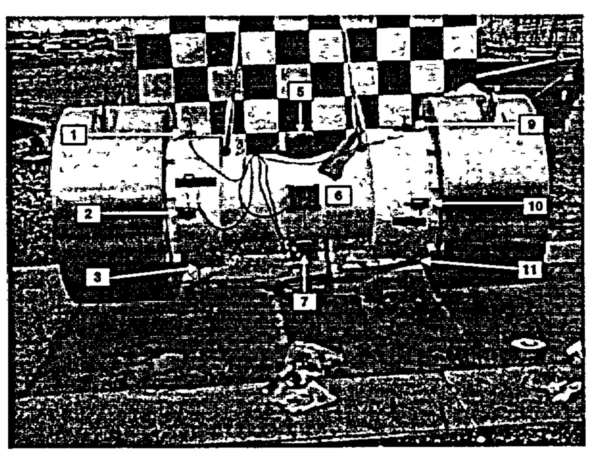
- **The Validity of the Scale Model Test and the Scaling Relationships Have been Studied Extensively by Several Experts**
  - "Drop Testing of Package Using Scale Model" (LLNL)
  - "Design and Testing of Scale Model Transport System" (Sandia)
  - "Study of Mechanical Strength of Cask with Scale Model" (Ecole Polytechnique)
- **Scale Model Testing is Authorized by IAEA and Historically Accepted by USNRC**
- **Scale Model Testing is Widely used for the Qualification of Type B Packages Throughout the World (USA, France, Germany, UK, and Japan....)**

> Advantages

- Reduce Fabrication Cost
- Reduce Cost and Potential Difficulties on Schedule due to Availability of the Target
- Reduce the Potential Difficulties of Performing the Test

1/3 Scale Model and Accelerometer Locations

(NUHOMS - MP197 Transport Cask)



Impact Limiter Testing Orientation

(NUHOMS - MP197 Transport Cask)

Test Number	Drop Orientation	Drop Height	Remark
1	0° Side Drop	30 Feet	
2	20° Slap Down	30 Feet	Bottom Impact Limiter Chilled to –20°F
3	90° End Drop	30 Feet	
4	90° End Drop	40 Inches	Drop Onto a Scaled Six Inch Diameter Punch Bar

COGEMA GROUP

TRANSNUCLEAR

0° Side Drop Test Set Up

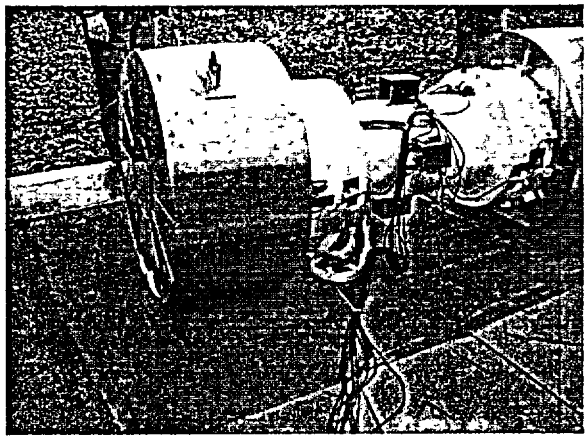
(NUHOMS - MP197 Transport Cask)

COGEMA GROUP

TRANSNUCLEAR

65

NUHOMS-MP197 Scale Model and Impact Limiter After 0° Side Drop

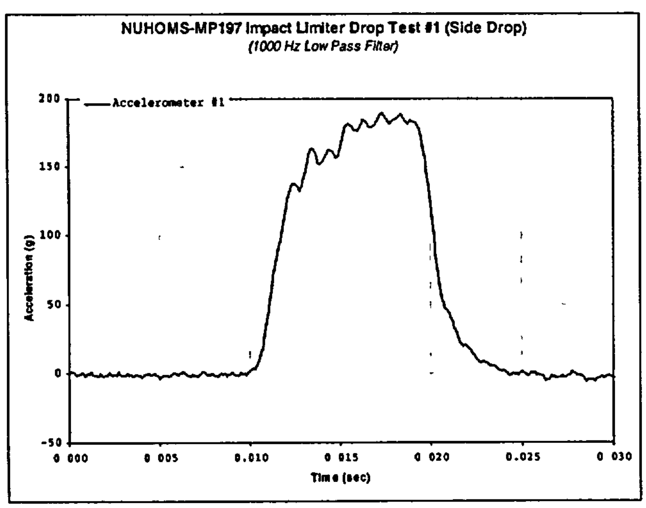


COGEMA GROUP

TRANSPORTATION WORKING GROUP WORKSHOP NOVEMBER 19 & 20, 2002

TRANSNUCLEAR

NUHOMS-MP197 1/3 Scale Model and Impact Limiter After 0° Side Drop Acceleration Time History

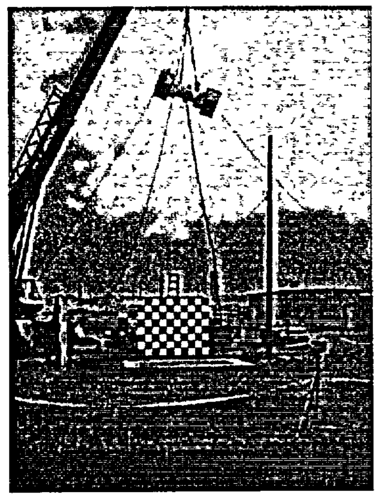


COGEMA GROUP

TRANSPORTATION WORKING GROUP WORKSHOP NOVEMBER 19 & 20, 2002

TRANSNUCLEAR

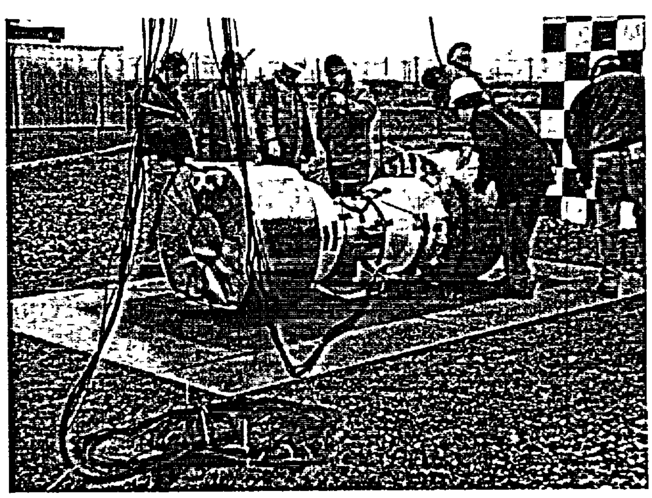
20° Slap Down Test Set Up
(NUHOMS - MP197 Transport Cask)



COGEMA GROUP

TRANSNUCLEAR

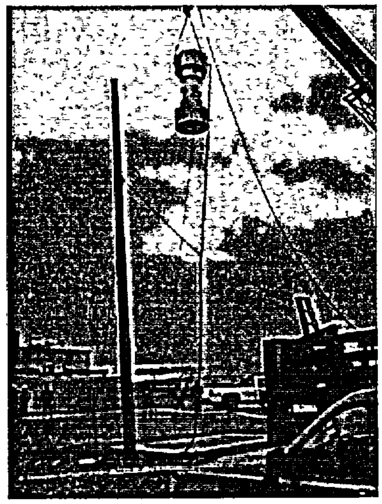
NUHOMS-MP197 Scale Model and Impact Limiter After 20° Slap Down Drop



COGEMA GROUP

TRANSNUCLEAR

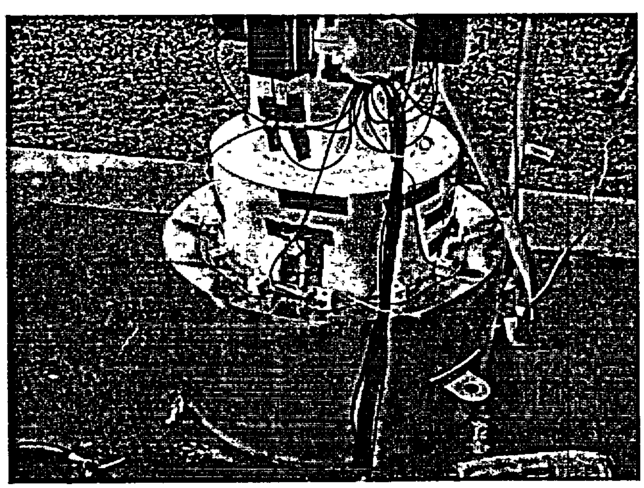
90° End Drop Test Set Up
(NUHOMS - MP197 Transport Cask)



COGEMA GROUP

TRANSNUCLEAR

NUHOMS-MP197 Scale Model and Impact Limiter After 90° End Drop

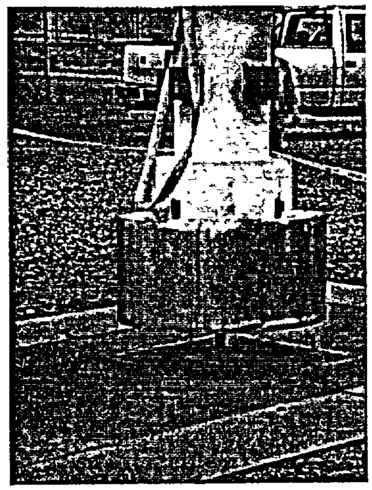


COGEMA GROUP

TRANSNUCLEAR

68

NUHOMS-MP197 Scale Model and Impact Limiter After 40 inch Puncture Drop



COGEMA GROUP

TRANSPORTATION WORKING GROUP WORKSHOP NOVEMBER 19 & 20, 2002

TRANSNUCLEAR

Comparison of Measured vs. Calculated g Loads

(NUHOMS - MP197 Transport Cask)

Drop Orientation	G Loads Measured by Drop Test	Input Loading Used in Structural Analysis
0° Side Drop	61G Normal	75G
20° Slap Down	32G Normal 53G Rotational	60G 196G
90° End Drop	65G Axial	75G
90° End Drop (Puncture Test)	N/A	N/A

COGEMA GROUP

TRANSPORTATION WORKING GROUP WORKSHOP NOVEMBER 19 & 20, 2002

TRANSNUCLEAR

69

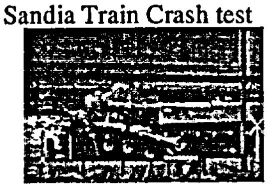
Full Size Package Testing

> Scale One Testing Has been Performed on Spent Fuel Casks

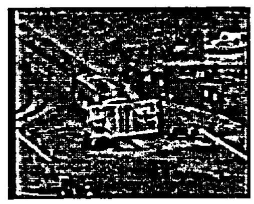
> These Tests were Primarily Used for Public Acceptance

> Sandia Test

Sandia Train Crash test



> CEGB Test



COGEMA GROUP

TRANSNUCLEAR

CEGB Full Scale Test

> Test on a 50T MAGNOX Spent Fuel Cask in 1984

> Test Program Used a Production Cask and Included 30 ft Drop (Identical to Regulatory Conditions)

> Regulatory 30 ft Drop Confirmed the SAR Results which were Based on Scale Model Tests

> A 240T Locomotive Traveling at 100 mph was Crashed into a Full Scale Cask Placed on Railtracks

> The Cask Survived the Train Crash Without Leakage

> Impact Forces From the Train Crash were Less Than the 30 ft Drop Test

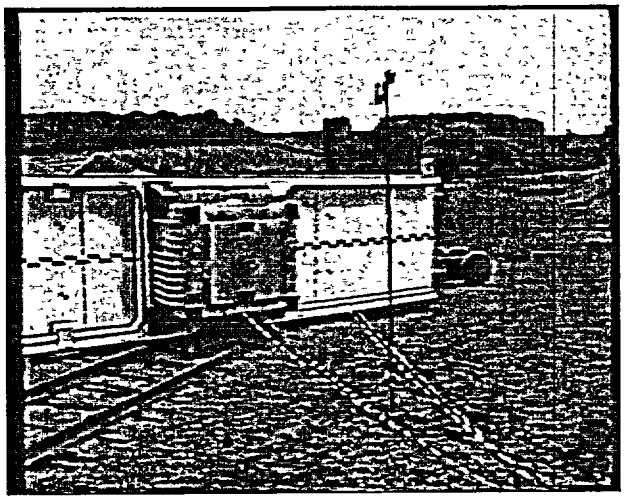
> Full Scale Testing Gave Public Confidence and Confirmed That Regulatory Tests are Realistic when Compared to Real Accidents

COGEMA GROUP

TRANSNUCLEAR

70

MAGNOX Spent Fuel Transport Cask
(Operation Smash Hit)

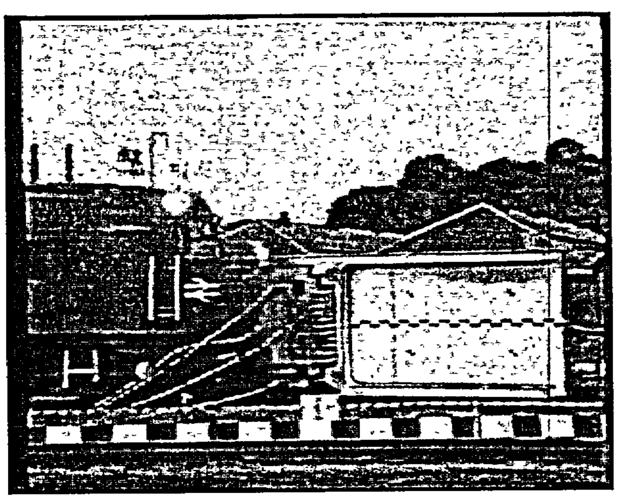


COGEMA GROUP

TRANSPORTATION WORKING GROUP WORKSHOP NOVEMBER 19 & 20, 2002 25

TRANSNUCLEAR

MAGNOX Spent Fuel Transport Cask
(Operation Smash Hit)



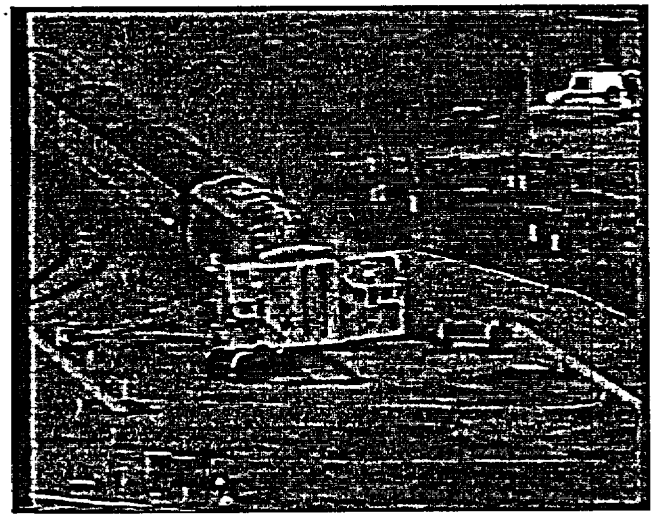
COGEMA GROUP

TRANSPORTATION WORKING GROUP WORKSHOP NOVEMBER 19 & 20, 2002 26

TRANSNUCLEAR

71

MAGNOX Spent Fuel Transport Cask
(Operation Smash Hit)



COGEMA GROUP

TRANSNUCLEAR

Transnuclear Experience in High Speed Impact Testing

> Aircraft Crash Tests Performed on TN Dual Purpose Casks
  - Impact of F16 Fighter Jet
  - Impact of an F18 Fighter Jet
  - The Tests were Performed on Models with Missiles Representing the Real Hardness of a Jet Engine Under Impact Conditions
  - Impact Velocities were Between 336 & 481 mph

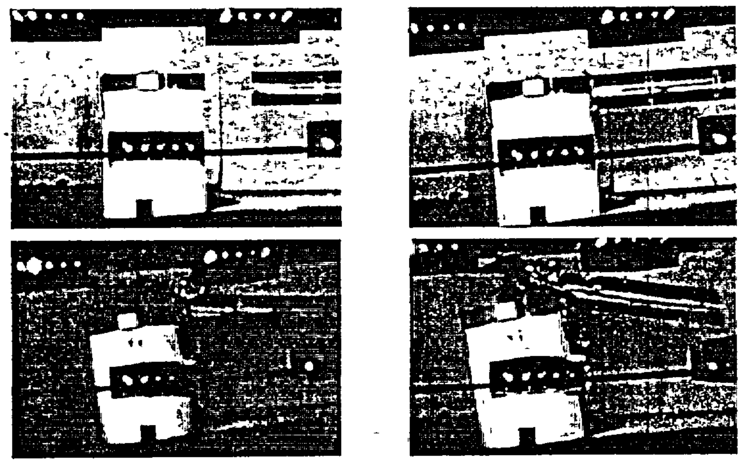
> Tests were Performed Using 1/3 Scale Models of a TN24D & a TN24G Cask
  - External Steel Shell
  - Neutron Shielding
  - Containment Vessel: Forged Steel Shell & Welded Bottom, Bolted Lid with Metallic Seals

COGEMA GROUP

TRANSNUCLEAR

72

Transnuclear Experience in High Speed Impact Testing (TN 24D Aircraft Crash Test)



COGEMA GROUP

TRANSNUCLEAR

Transnuclear Experience in High Speed Impact Testing (Aircraft Crash Test Results)

> Test Results

- The Part of the Cask Outer Shell Struck by the Missile was Locally Deformed but There was no Significant Loss of Shielding
- No Deformation of the Forged Containment Vessel or the Closure lid
- Leak Tightness was Unchanged After the Impact

> Conclusion

- Dual Purpose Casks can Survive Very Severe Impacts

COGEMA GROUP

TRANSNUCLEAR

73

Summary of Transnuclear Cask Licensing Experience (US)

Package	Testing Scale	Transport Mode
TN-8, 8L	1/2	Truck
TN-9	1/2	Truck
TN-BRP	1/3	Rail
TN-RAM	Use results from TN-BRP Testing	Truck
TN-REG	1/3	Rail
TN-FSV	1/2	Truck
TN-68 (Dual Purpose Cask)	1/3	Truck /Rail
NUHOMS-MP187	1/4	Truck /Rail
NUHOMS-MP197 (Part 71 & IAEA)	1/3	Truck /Rail

COGEMA GROUP

TRANSNUCLEAR

Summary of Transnuclear Cask Licensing Experience (European)

Package	Testing Scale	Transport Mode
TN 9	1/4	Truck/Rail
TN 12/1	1/3	Truck/Rail
TN 17T	1/3	Truck/Rail
TN 17/2	1/3	Truck/Rail
TN 24D	1/3	Truck/Rail
TN 24G	1/3	Truck/Rail
TN 24P	1/3	Truck/Rail
TN 24GET	1/2	Truck/Rail
TN 28	1/3	Truck/Rail
TN 97L	1/3	Truck/Rail
TN 1300	1	Truck/Rail
MTR	1/2	Truck/Rail

COGEMA GROUP

TRANSNUCLEAR

74

Conclusion

Transnuclear's World-Wide Experience in Cask Licensing Including Regulation Scale Model Testing and High Speed Impact Testing Has Shown That :

- **Analytical Method can Accurately Predict Cask Behavior**
- **Scale Model Test Results Provide Valuable Benchmarking Data**
- **Reduced Scale Model Testing is Fully Justified, Scale One Test on Large Package is Unnecessary**
- **Full Size Cask Public Demonstration Tests Prove That the Current Regulations Give Adequate Safety Margins Under Real Accident Conditions**

COGEMA GROUP

TRANSNUCLEAR

NAC INTERNATIONAL

NAC International Transport Cask Analysis and Testing Experience

Dr. Michael C. Yaksh

November 19, 2002

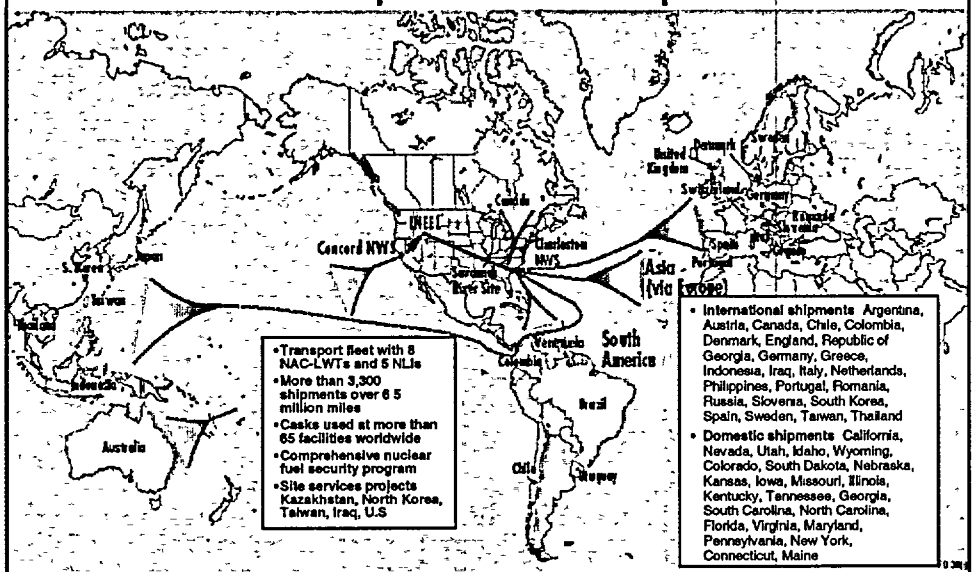
Atlanta Corporate Headquarters 3930 East Jones Bridge Road Norcross, GA 30092 770-447-1144 Fax 770-447-1797 www.nacintl.com

NAC Transport Cask Licensing Experience

Cask Designation	CoC No.	No. of CoC Rev./Application	NRC or IAEA Approval
NLI-1/2	71-9010	39/Transport	NRC/IAEA
NAC-1	71-9183	13/Transport	NRC/IAEA
NLI-10/24	71-9023	8/Transport	NRC/IAEA
NAC-LWT	71-9225	23/Transport	NRC/IAEA
NAC-STC	71-9235	2/Transport	NRC/IAEA
NAC-MPC	71-9235	2/Transport	NRC/IAEA
UMS®	71-9270	Transport	NRC/IAEA
Advanced UMS®	Pending	Transport	NRC/IAEA

76

NAC Transportation Experience



NAC INTERNATIONAL

Overview

- NAC does not perform 10CFR71 cask licensing by testing, but by analysis with confirmatory testing
- Demonstration of integrity of the cask system uses both testing and analysis
  - Testing confirms required structural response where analysis methods may need validation
  - Analysis allows loading conditions to be examined in which testing is not practical
- Testing confirms analysis methodology

NAC INTERNATIONAL

Overview (continued)

- A number of systems are required for maintaining cask integrity, which may involve more than a containment requirement
  - Impact limiter to absorb energy due to impact with a rigid surface
  - Robust cask body shells, lids, bolts and seals to maintain containment
  - Robust internal structure to maintain geometrical location of the fuel for criticality control
- NAC history of designs / testing / usage for transport applications is extensive

NAC INTERNATIONAL 5

NAC Cask Testing Experience

System	Design Weight (lb)	Impact Limiters	Test Type *	Test Location
NAC-UMS	260,000	Redwood/balsa	1, 2	Naval Surface Warfare Center; Oak Ridge National Lab; Sandia National Lab
CY-STC	260,000	Redwood/balsa	1, 2	Naval Surface Warfare Center; Oak Ridge National Lab; Sandia National Lab
NAC-STC	250,000	Redwood/balsa	1, 2, 3	NAC International; AEA, Winfrith, UK
NAC LWT	52,000	Honey comb	1, 2, 3	Hexcell; Oak Ridge National Lab
NLI 1 / 2	52,000	Balsa	None	None
Californium	52,000	Foam	1 (NS-4-FR)	NAC International

(*) 1. Materials testing.
2. Scaled cask body and impact limiters.
3. Scaled basket within scaled cask body.

NAC INTERNATIONAL 6

78

Typical Methodology for Impact Limiter Energy Absorbing Materials

- Material Testing
  - Material testing is performed on samples to define the stress-strain curves
    - For a range of strain rates to be expected in the impact
    - Temperature variation is from –40°F to 200°F
    - Multiple directions of material orientations
    - Multiple tests to observe variability of the properties
    - Material tested by NAC: redwood, balsa, foam, aluminum honeycomb, NS4FR neutron shielding

NAC INTERNATIONAL

Typical Methodology for Impact Limiter Energy Absorbing Materials (continued)

- Material Testing (continued)
  - The testing is used to define the extent of variability of parameters associated with material
  - Material testing is required to produce accurate analysis results required by NRC
    - Maximum acceleration agreement between analysis and testing
    - Agreement of acceleration time histories between analysis and testing

NAC INTERNATIONAL

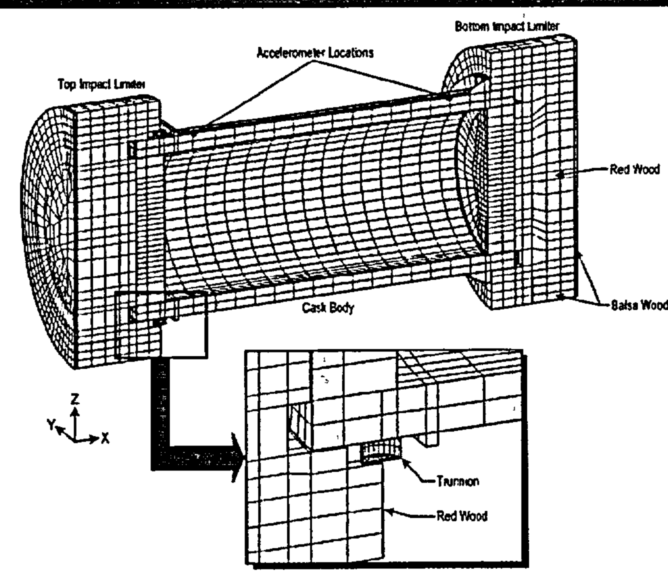
Analysis Methodology

- Objective of the analyses
  - Full scale cask analysis: to ensure that the design objectives are met
    - Acceleration limitations are specified to allow limited decoupling of the evaluations
    - Evaluation using the maximum temperature ranges is performed
    - Cask drop orientation is varied
    - Sensitivity studies are performed
  - Scale model cask analysis: to permit the methodologies to be benchmarked for scale model testing
    - Analytical methods
    - Manufacturing methods

NAC INTERNATIONAL

Analysis Methodology (continued)

NAC uses LS-DYNA to perform the evaluation of the full-scale and scale-model cask response



NAC INTERNATIONAL

80

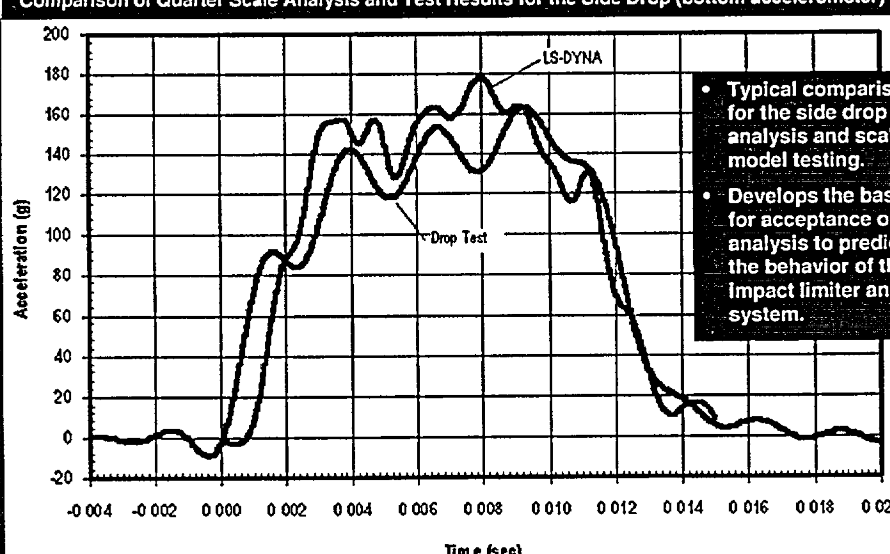
Scale Model Testing

- Scale model manufacturing employs the same procedures and methods as required for the full scale design
  - Material requirements
  - Material orientation
  - Assembly of the components
  - Acceptance criteria for the material
- Scale model testing produces data for comparison with analytical predictions
  - Extent of crush of the impact limiter
  - Maximum accelerations
  - Overall acceleration response of the system
  - NRC requires conformance of testing to maximum accelerations <u>and</u> time history of cask accelerations predicted by analysis

NAC INTERNATIONAL 11

Scale Model Testing (continued)

Comparison of Quarter Scale Analysis and Test Results for the Side Drop (bottom accelerometer)



- Typical comparison for the side drop for analysis and scale model testing.
- Develops the basis for acceptance of analysis to predict the behavior of the impact limiter and system.

NAC INTERNATIONAL 12

Inherit Conservatisms and Margins in the Design

- Drop testing uses a rigid surface backed by a semi-infinite mass
- Loading is concentrated at the ends and not along the cask
- Force deflection curves from the scale model testing show 20 - 30% more capacity than required for the full-scale cask design
- Stress analyses of the system use accelerations which are larger than those obtained in the test and predictions
- Most analyses employ ASME Code methodology for the accident evaluation for the basket and for the containment
  - Neglects ductility of stainless steel
  - Uses Code acceptance criteria (very conservative with respect to "failure")

NAC INTERNATIONAL 13

Inherit Conservatisms and Margins in the Design (continued)

- Conservativism of NAC's approach has been demonstrated in one side drop test of the NAC-STC at Winfrith, U.K.
  - Cask body and basket model was a quarter scale of the full scale design
  - Cask body and basket were subjected to 5 times the design accelerations (300g full scale)
  - Basket at point of impact showed minor deformation
  - Basket outside the point of impact showed no permanent set
  - No cask body containment welds exceeded yield
  - No lid bolts failed; cavity environment was maintained
  - Criticality configuration was maintained

NAC INTERNATIONAL 14

82

Summary

- Analysis methodologies have been shown to adequately and conservatively predict the impact limiter response
- Inherit conservativism exists in the methodologies
  - ASME Code methodologies
  - Impact limiter margin
  - Inherit conservativisms in the structural evaluation
  - Drop testing on essentially unyielding surface
- Design and testing methodologies demonstrate that current NAC cask designs provide large margins of safety during transport

Staff Review and Analysis of the Baltimore Tunnel Fire, July 2001

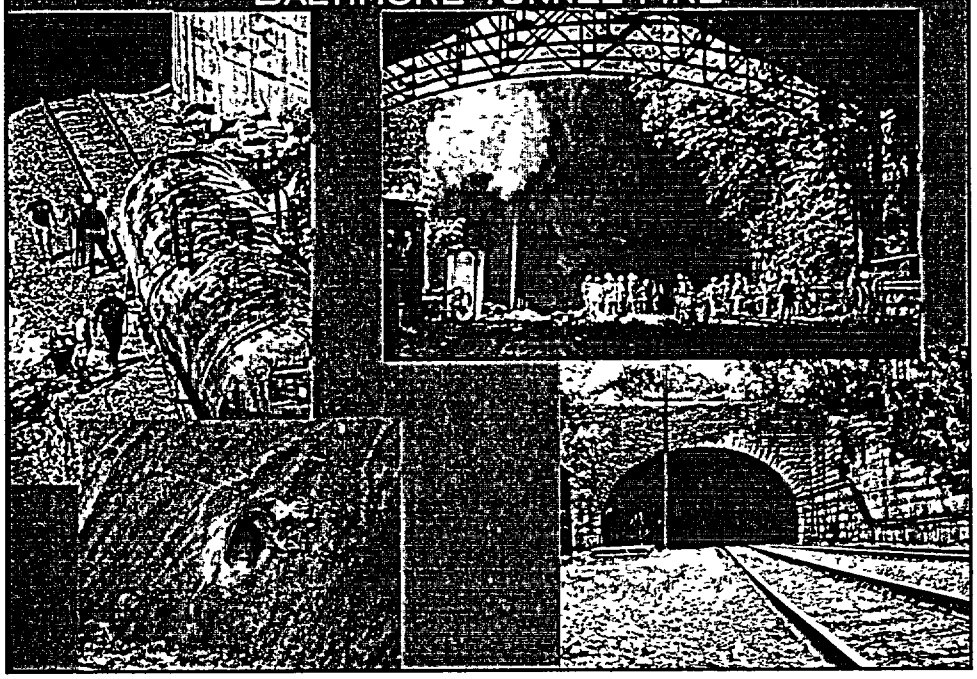
CHRISTOPHER S. BAJWA
SPENT FUEL PROJECT OFFICE
OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS
U.S. NUCLEAR REGULATORY COMMISSION
TRANSPORTATION WORKING GROUP WORKSHOP
NOVEMBER 19, 2002
ROCKVILLE, MD

INTRODUCTION

- BALTIMORE TUNNEL FIRE
- PRELIMINARY ANALYSIS
- TUNNEL FIRE MODEL
- REVISED ANALYSIS
- CONCLUSIONS AND FUTURE WORK

2

Baltimore Tunnel Fire

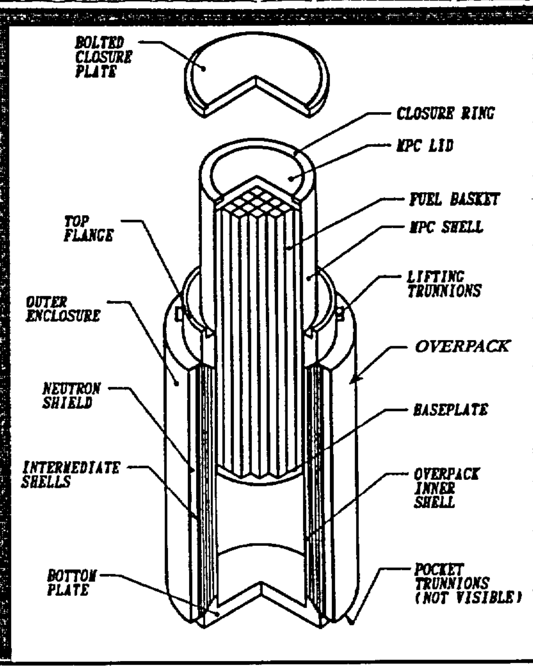


Preliminary Analysis

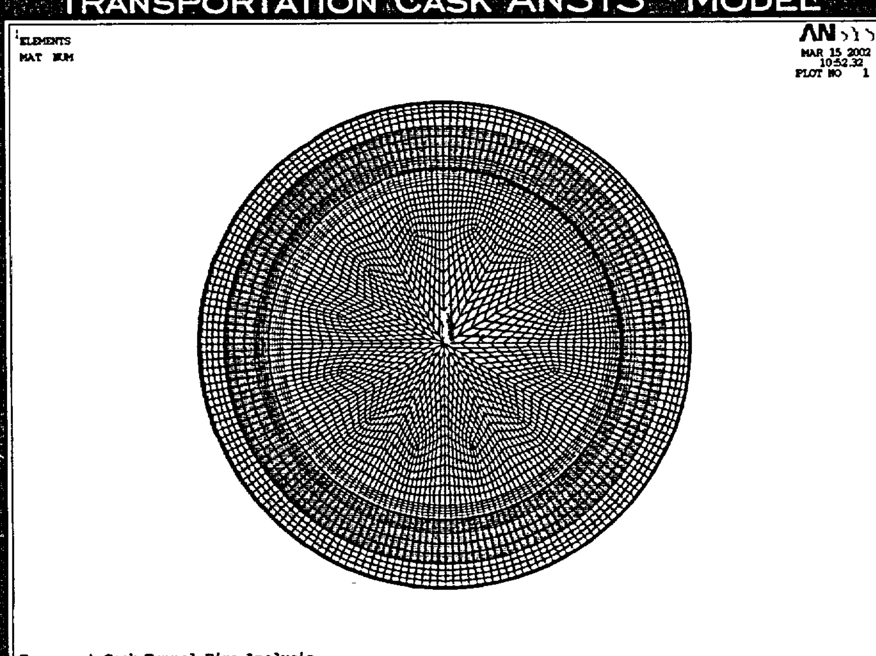
- Meeting with NTSB
- Spent Fuel Transportation Cask
- Finite Element (ANSYS®) Model

4

Spent Fuel Transportation Cask



Transportation Cask ANSYS® Model



Boundary Conditions

- Convection; Radiation
- Normal Conditions for Transport
- Fire conditions (1500°F, 7 Hours)

8

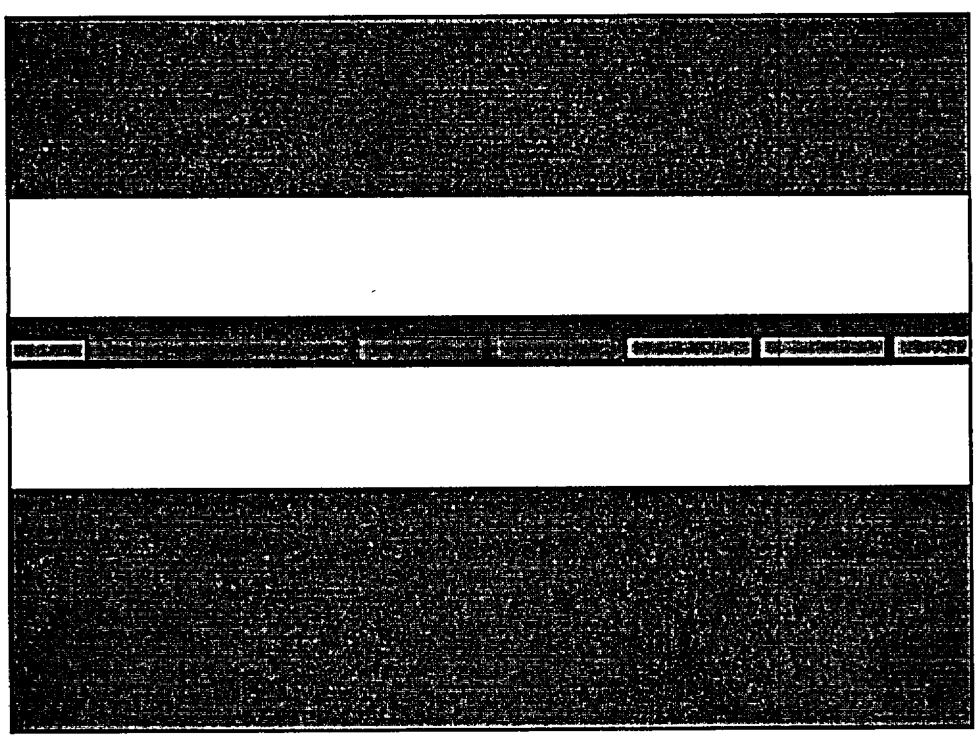
Preliminary Results

- No cladding failure
- No canister failure
- No radioactive release
- Conservative assumptions

13

NIST Tunnel Fire Model

- Fire Dynamics Simulator (FDS)
- Memorial Tunnel Test Program
- Maximum Predicted Temperatures



Revised Analysis Based on NIST Data

- Temperature and flow within tunnel
- Relation of cask to fire
- 2D Cross-Section
- 3D model Under development

Refined Cask Model

Results From Revised Analysis

- Time to exceed short term limits
  - For 20 Meters over 100 hours
  - For 5 Meters almost 30 hours
- Time to MPC failure
  - For 20 Meters
  - For 5 meters

Conclusions

- Cask Performance
- Consequences of fires
- Health and Safety of the Public Protected

ACKNOWLEDGEMENTS

- MR. BRIAN KOEPPEL
- MR. HAROLD E. ADKINS, JR.

PACIFIC NORTHWEST NATIONAL LABS

- DR. KEVIN MCGRATTAN (NIST)
- MR. JAY KIVOWITZ (NTSB)

Comparison of Analysis and Testing to Actual Railway Experience

Association of American Railroads

By: Bob Fronczak
AVP Environment and Hazmat
Of: Association of American Railroads
For: U.S. Nuclear Regulatory Commission
Rockville, MD
November 19, 2002

1

Outline

Association of American Railroads

- Testing Issues
  - AAR Cask Integrity work
    - Crush loads
    - Collisions with structures & falls
    - Thermal event frequencies
    - Structural strength of railcars
- Performance Standard for SNF Trains

2

92

Cask Integrity

Association of American Railroads

- AAR commissioned two reports:
  - "Rail Transport of SNF - A Risk Review," G.W. English, et.al., July 1995 (revised 11/95; 6/96; 12/97) (Report #1)
  - "Railroad Transport of SNF," James Rock, et.al, May 27, 1998 (Report #2)
- Sent to NRC January 2000

3

Report Conclusions

Association of American Railroads

- Conclusion Report 1:
  - SNF Casks might not be able to withstand forces conceivable in all railroad accidents.
- Conclusion Report 2:
  - Agreed with 1st report but, determined that public health would not be affected in the event of an accident.

4

93

Issues Raised in Report 1

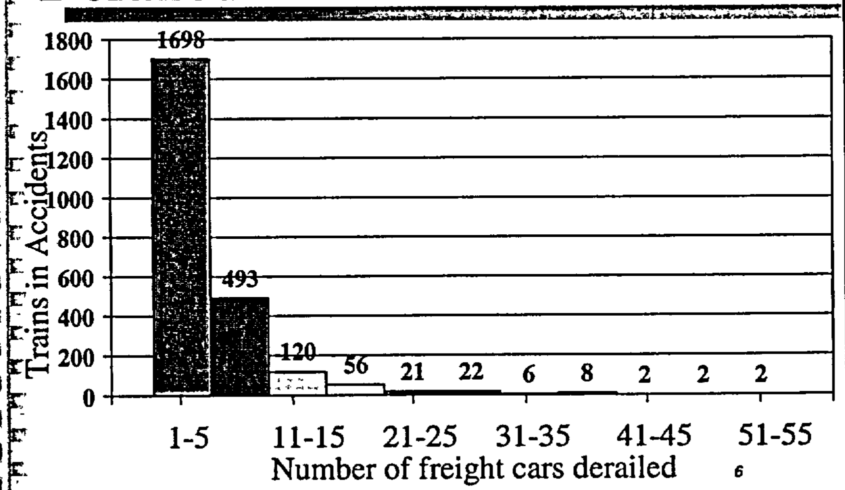
Association of American Railroads

- Crush loads:
  - Not required for large packages (only if mass less than 227#)
  - Rail cask = 125 tons (250,000#)
  - Real probability in rail accidents
    - By definition, rail transport involved multiple vehicles
- Modal Study:
    - Frequency of incidence of crush loading was assessed as one-tenth that of impact loading
    - Only 0.8% experience impact with a coupler or significant frame member of other vehicles.

5

30% of Trains in Accidents in 2001 Derailed More Than 5 Cars

Association of American Railroads



6

94

Sources of Information

Association of American Railroads

- FRA database includes the number of cars involved in derailments
- AAR-RPI Tank Car Safety Research and Test Project
  - Over 30,000 damaged tank cars in database (over 30 years of data)
  - Could be used to determine percentage subject to crush loads
  - Will require manual search of records

7

Collision with Structures and Falls

Association of American Railroads

- Modal study used highway data to evaluate impacts with structures and falls
  - Railroads different (more cuts and fills)
  - Underestimates:
    - Frequency of rock cuts,
    - Frequency of embankments,
    - Frequency of water crossings and
    - Possibly the frequency of large structures

8

95

Thermal Event Frequencies

Association of American Railroads

- Should evaluate thermal event frequencies more closely
- Modal Study
  - 81% fires < 1 hour
  - 99% fires < 7 hours
- Eggers
  - 50% fires < 11 hours
  - 99% fires < 130 hours
- Eggers would have been the more conservative choice
- Weyauwega WI 1996 fire lasted 18 days (360 hours)

Structural Strength of Railcars

Association of American Railroads

- Underestimated in Modal Study
  - 100,000 lb / foot
  - 1 million lb for a 10 ft-wide locomotive
  - 1.6 million lb for a 16 ft long cask
- Locomotives designed to withstand 1 million lb force at the coupler without permanent deformation
- Finite element analysis indicates that:
  - 3 million lb if applied at coupler height
  - 10 million lb if applied at the frame's neutral axis

10

96

Performance Standard for Spent Nuclear Fuel Trains

Association of American Railroads

- Includes all cars in the trains including buffer cars, security cars
- Requires static and dynamic modeling before construction
- Requires full scale characterization, static, and dynamic testing of each car and the train
- 100,000 mile evaluation period

11

Performance Standard for SNF Trains (cont.)

Association of American Railroads

- Roadworthiness exceeds standard freight car requirements
  - Enhanced performance trucks
- Requires Electronically Controlled Pneumatic (ECP) Brakes
  - Reduced stopping distance
  - Provides conduit for on-board defect detection

12

97

System Safety Monitoring

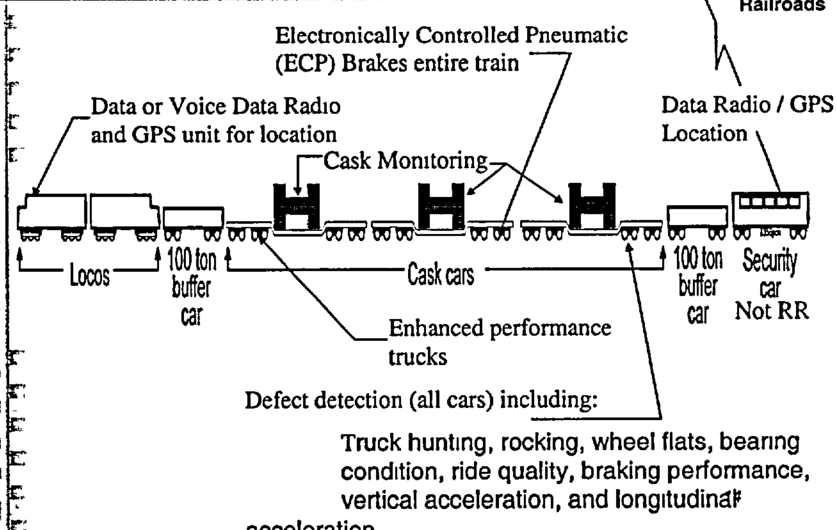
Association of American Railroads

- **On-Board Monitoring Systems**
  - Location Determination
  - Truck Hunting
  - Wheel Flats
  - Braking Performance
  - Vertical, Lateral, Longitudinal acceleration
  - Bearing Condition
  - Speed, Ride Quality

13

Diagram of SNF Train

Association of American Railroads



98

Other Enhanced Safety Actions Affecting SNF Transportation

Association of American Railroads

- AAR OT-55-D
  - Track and Equipment Inspection
  - Defect Monitoring
  - Increased Maintenance Frequency
  - Increased Employee Training
  - Maximum Speed Limit (50 MPH)
- FRA Safety Compliance Oversight Plan Policy for HLRW and SNF Shipments

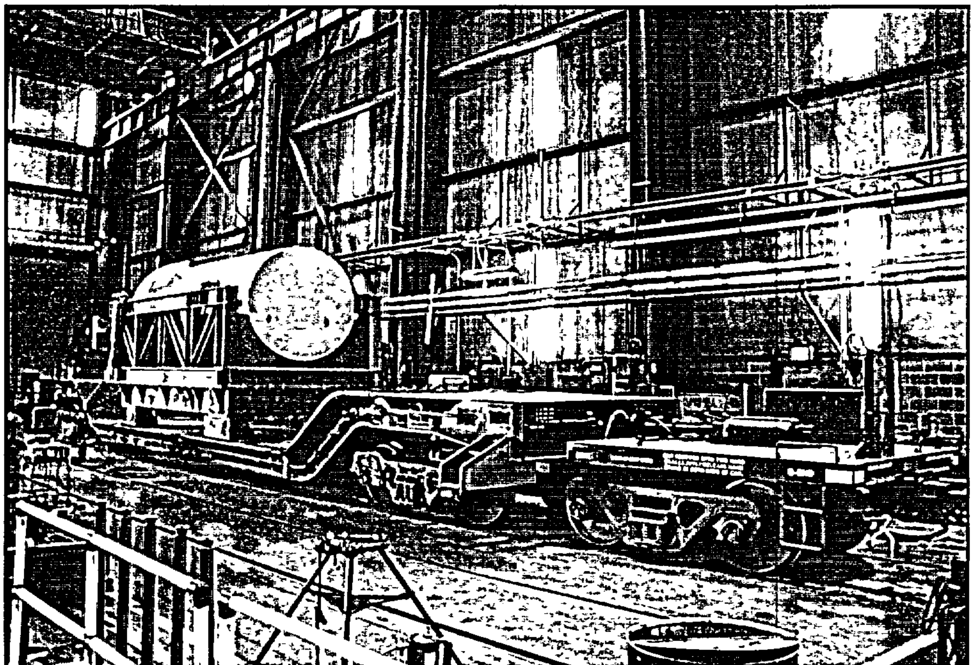
15

Private Fuel Storage LLC

Association of American Railroads

- First Shipper to Build SNF Equipment to AAR's New Performance Standard
- Cask Car Manufactured by Trinity Industries
- Overall Weight of Car, Cask, Cradle, and Impact Limiters is Approx. 476,200 lb.
- Modeling and Characterization Testing Complete
- Static and Dynamic Tests Planned for 2002

16



PFS Railcar at TTCI for Testing

Summary…

Association of American Railroads

- There are testing issues that should be addressed:
  - Crush loads
  - Collisions with structures & falls
  - Thermal event frequencies
  - Structural strength of railcars
- AAR is Committed to Incorporate Technological Improvements in Rail Transportation Designed to Enhance the Safety of SNF Shipments

18

Staff Review and Analysis of the July 2001 Baltimore Tunnel Fire Accident

Christopher S. Bajwa

Spent Fuel Project Office, NMSS

U.S. Nuclear Regulatory Commission

Presentation to the Advisory Committee on Nuclear Waste

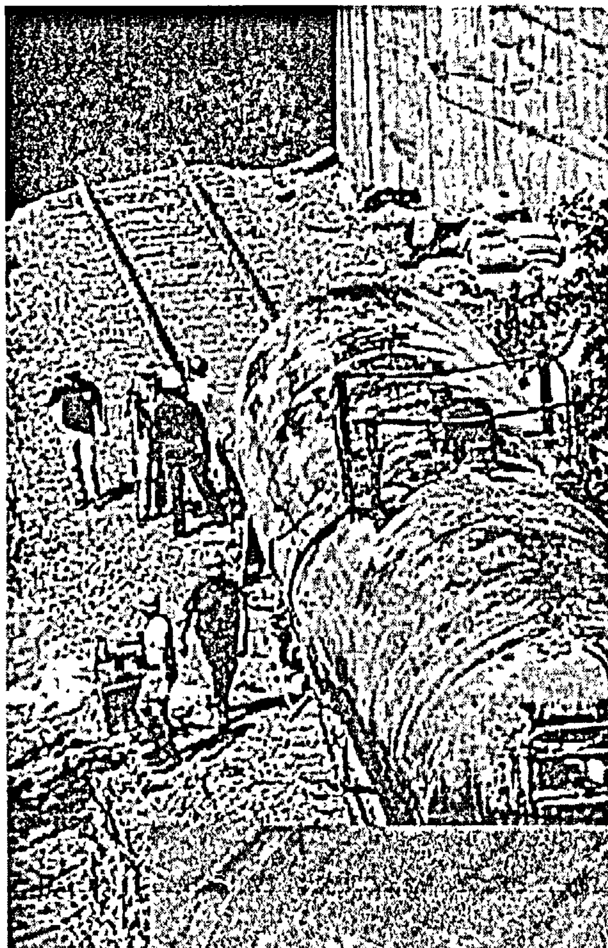
November 19, 2002

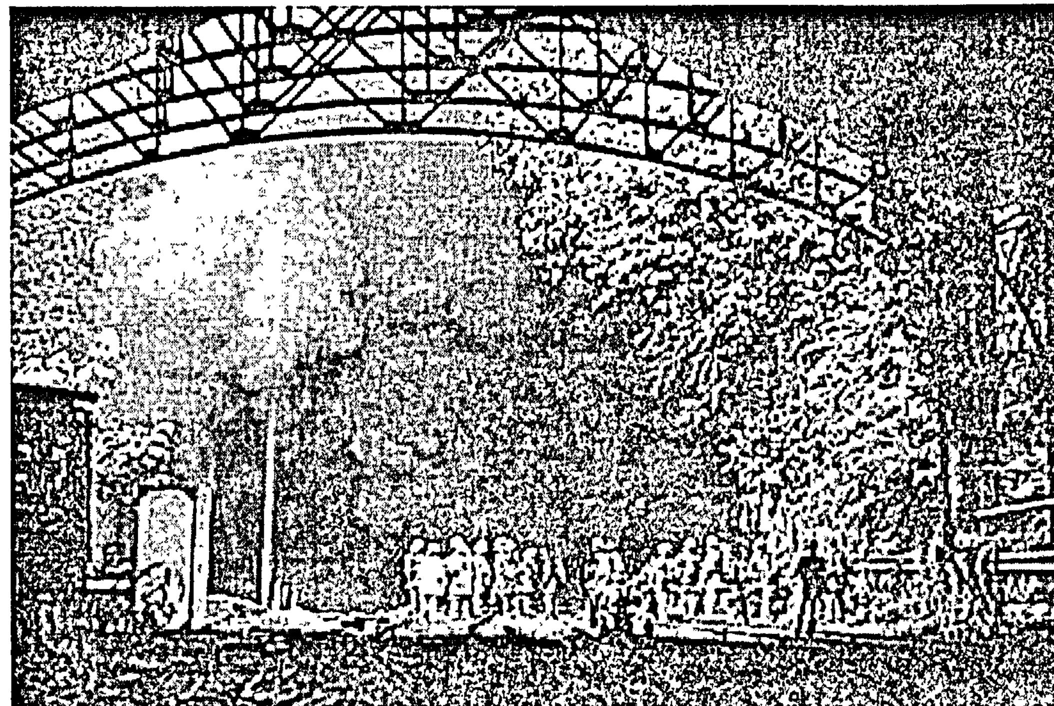
Rockville, MD

Introduction

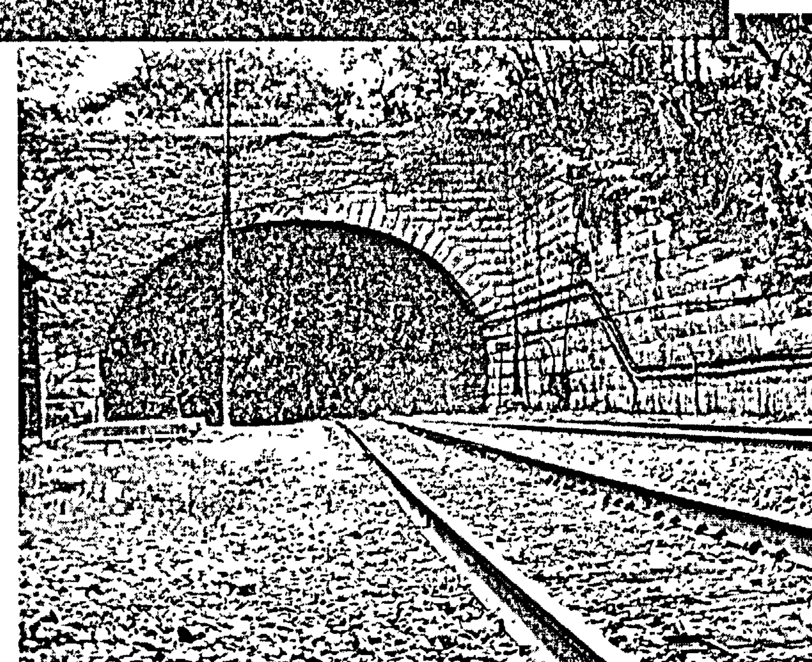
- Baltimore Tunnel Fire Accident
- Coordination with NTSB
- Preliminary Scoping Analysis
- NIST Tunnel Fire Model
- Validation of NIST Fire Model
- Refined Cask Analytic Model
- Conclusions

Baltimore Tunnel Fire





Hole in Tanker Car



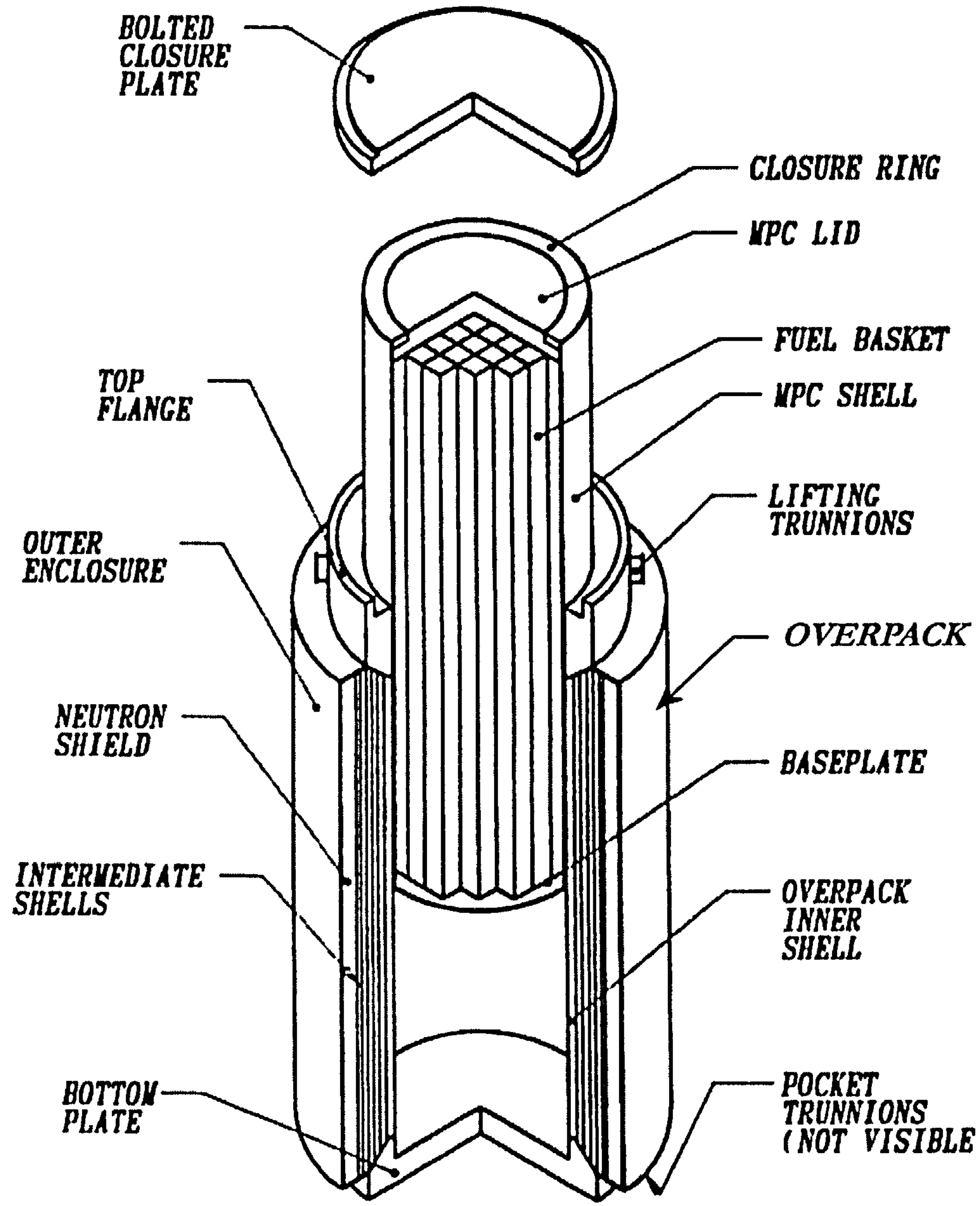
Coordination with NTSB

- NTSB – Lead investigative agency
- Derailment was primary concern
- NTSB Provided Information, Data and Technical Expertise on Rail Events
- Provided Access, through CSX, to Rail Cars & Tunnel

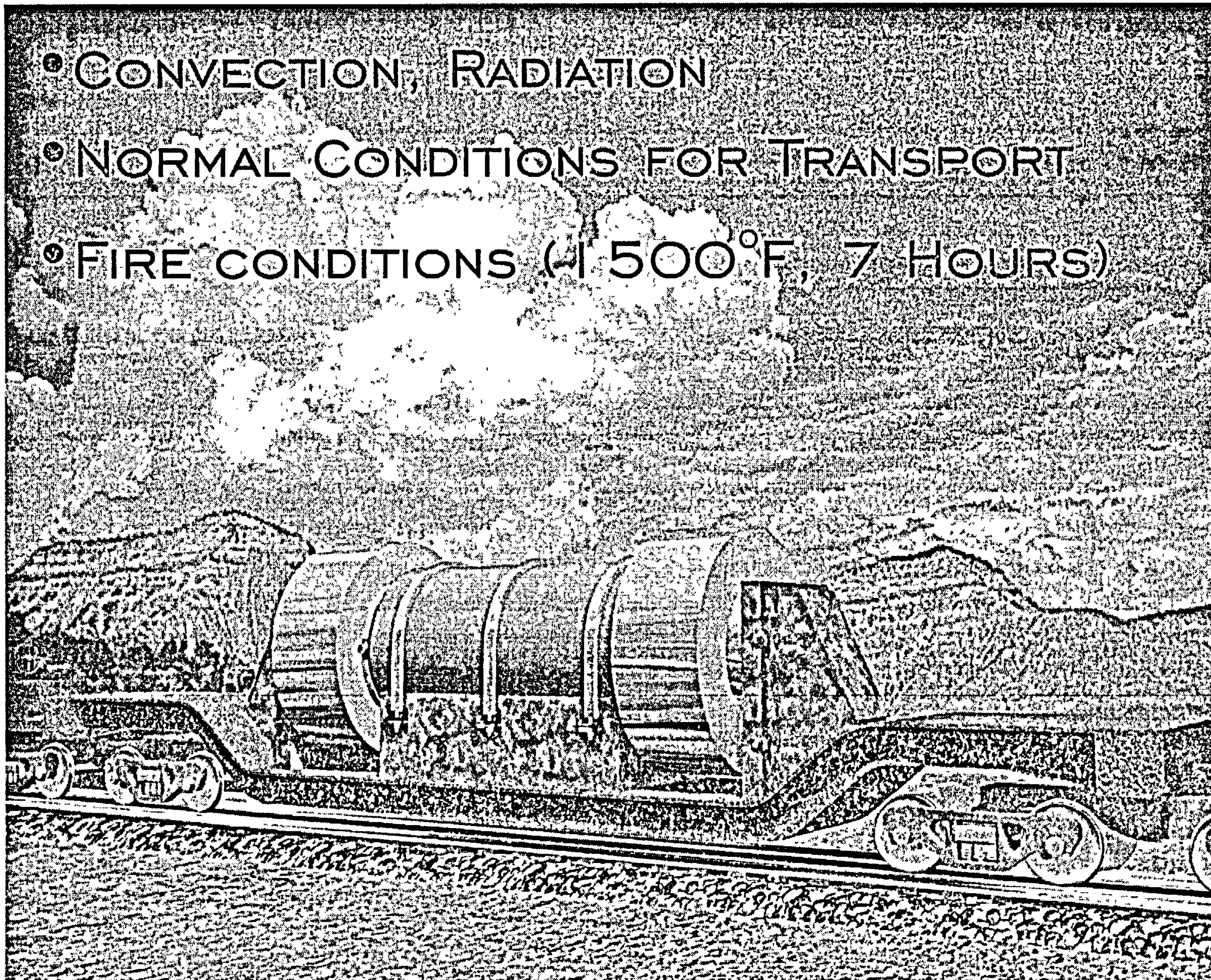
Preliminary Scoping Analysis

- Selection of a Spent Fuel Transportation Cask
- Finite Element (ANSYS®) Model
- 10 CFR 71.73 Requirements
- 7-Hour Bounding Analysis

Spent Fuel Transportation Cask



Boundary Conditions



PRELIMINARY RESULTS

- NO CLADDING FAILURE (BASED ON TEMPERATURE)
- NO CANISTER FAILURE (BASED ON STRESSES AT TEMPERATURE AND ON CREEP CRITERIA)
- NO RADIOACTIVE RELEASE

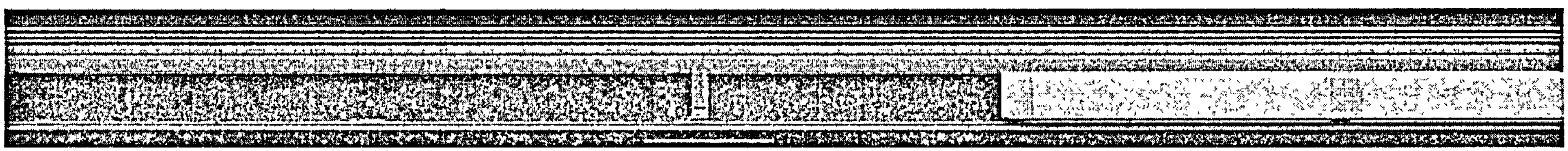
NIST Tunnel Fire Model

- Fire Dynamics Simulator (FDS)
- Validated with Memorial Tunnel Fire Test Program Data
- Results used as input to revised analysis

Howard Street Tunnel Fire Model

- Railcars in derailed position
- Grade of tunnel modeled
- Tripropylene pool used as fuel
- No ventilation in model
- Steady State conditions reached 30 minutes into simulation

NIST Howard Street Tunnel Fire Model



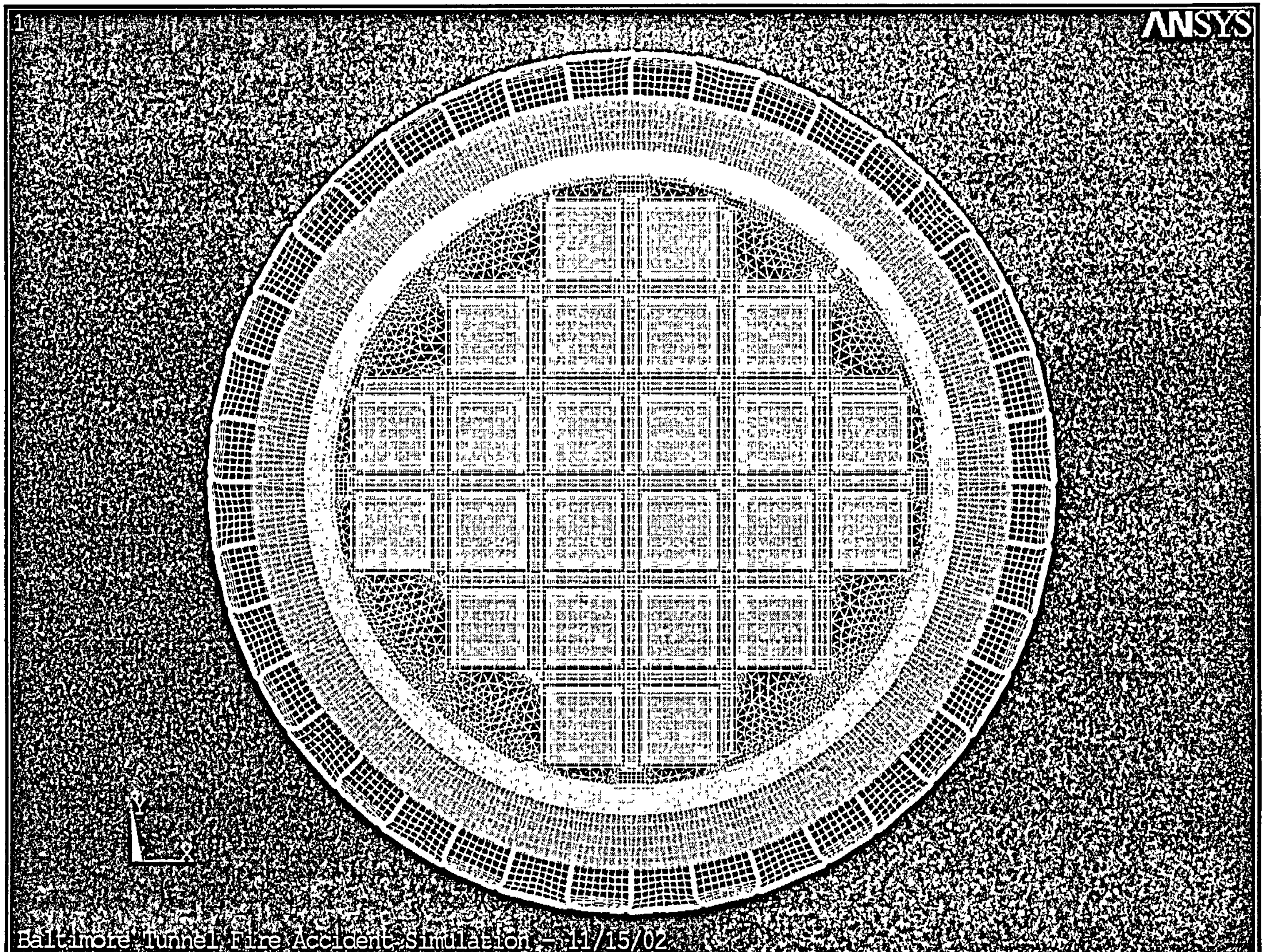
Analysis of Physical Evidence

- Further data to support NIST results
- CNWRA Material and Fire experts
- Samples obtained from Rail Cars
- Metallurgical Analyses Conducted
- Results reported by CNWRA consistent with NIST temperature results

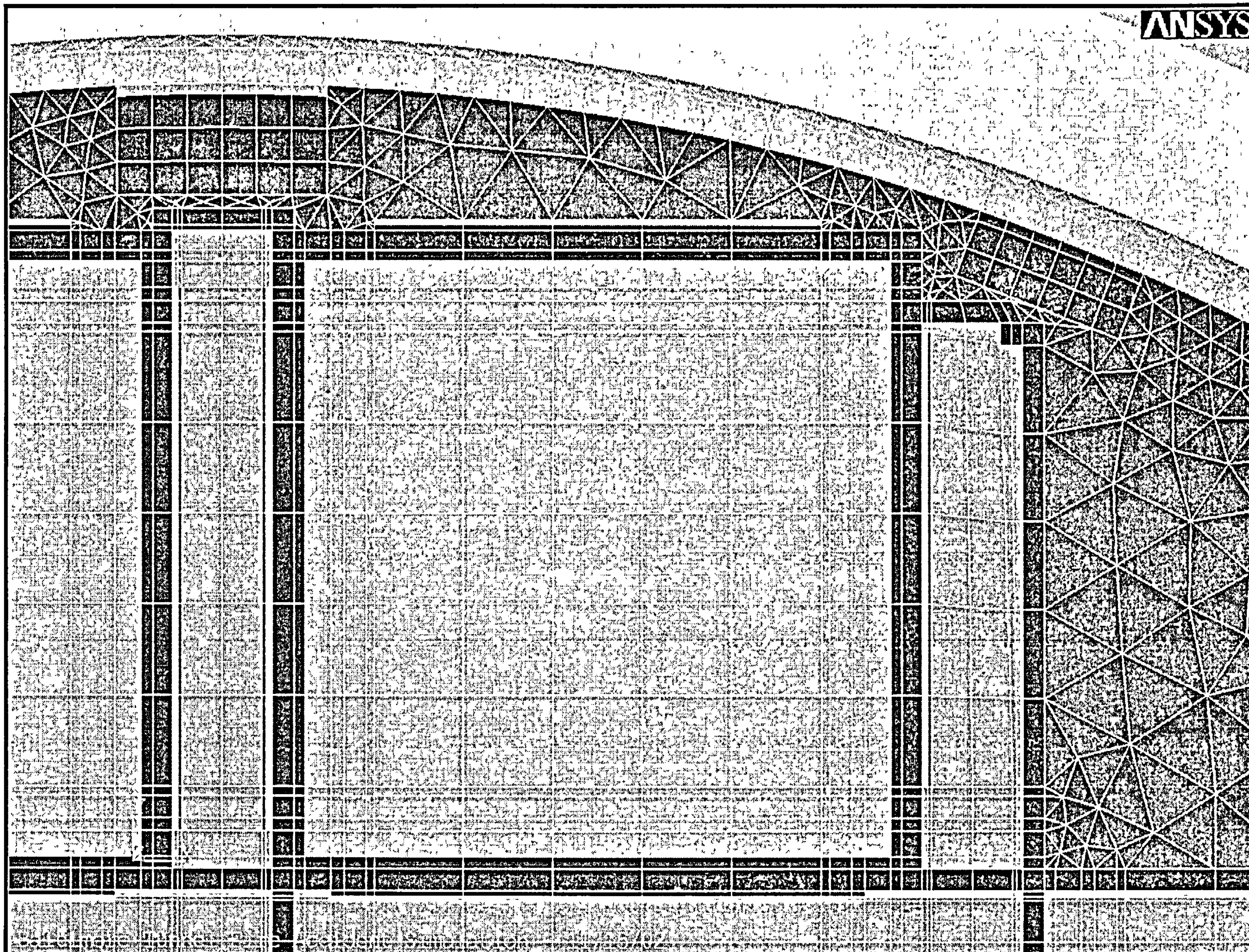
Revised Analysis Based on NIST Data

- Assessments Applied NIST Data (temperature and flow)
- Assessment – 1: Cask center 20 Meters (one rail car length) from fire per federal regulations (49 CFR 174.85)
- Assessment – 2: Cask located adjacent to fire (5 meters from fire to center)
- 2D Cross-Section with support cradle
- 3D Model under development

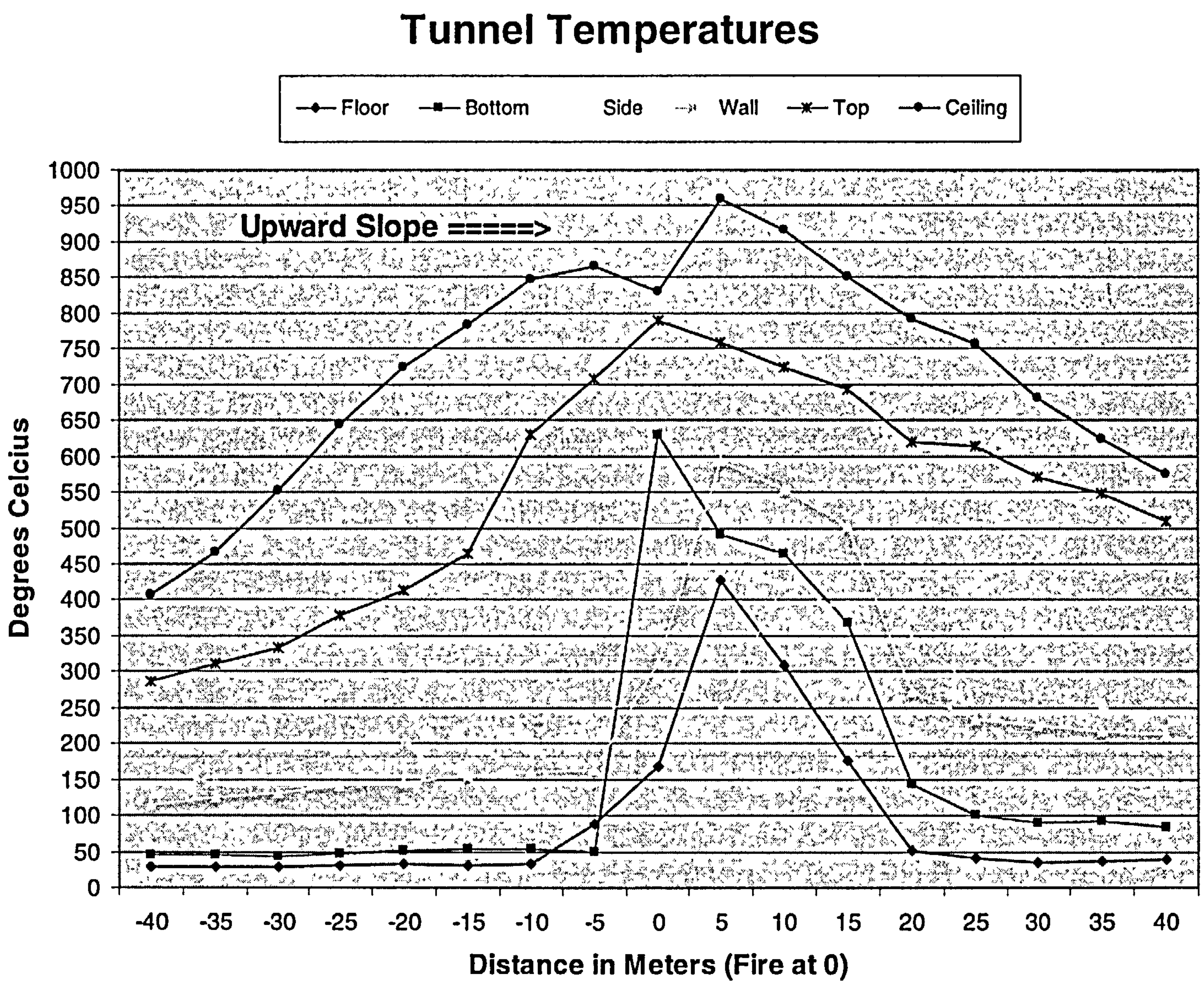
Refined Cask Model



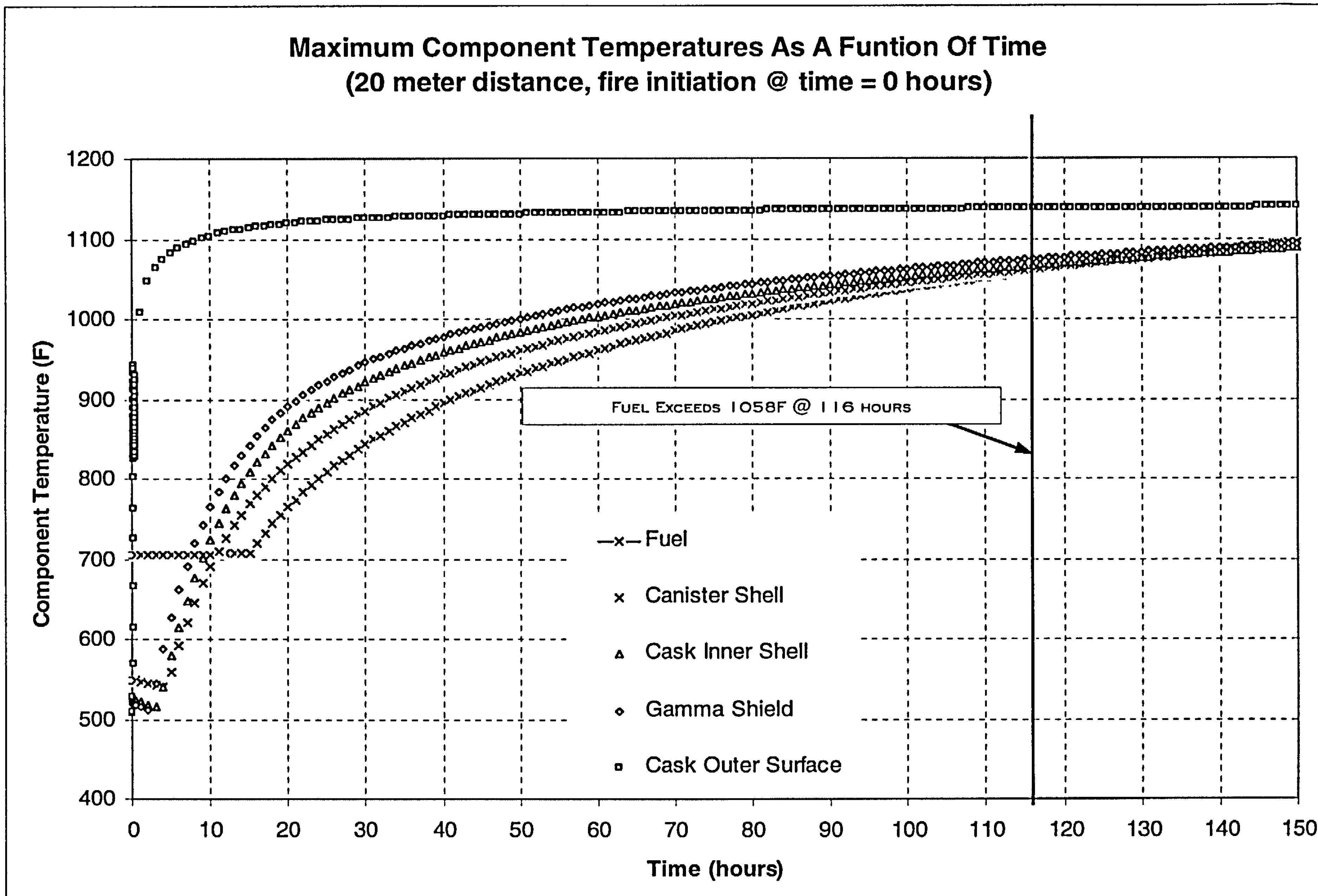
REFINED CASK MODEL



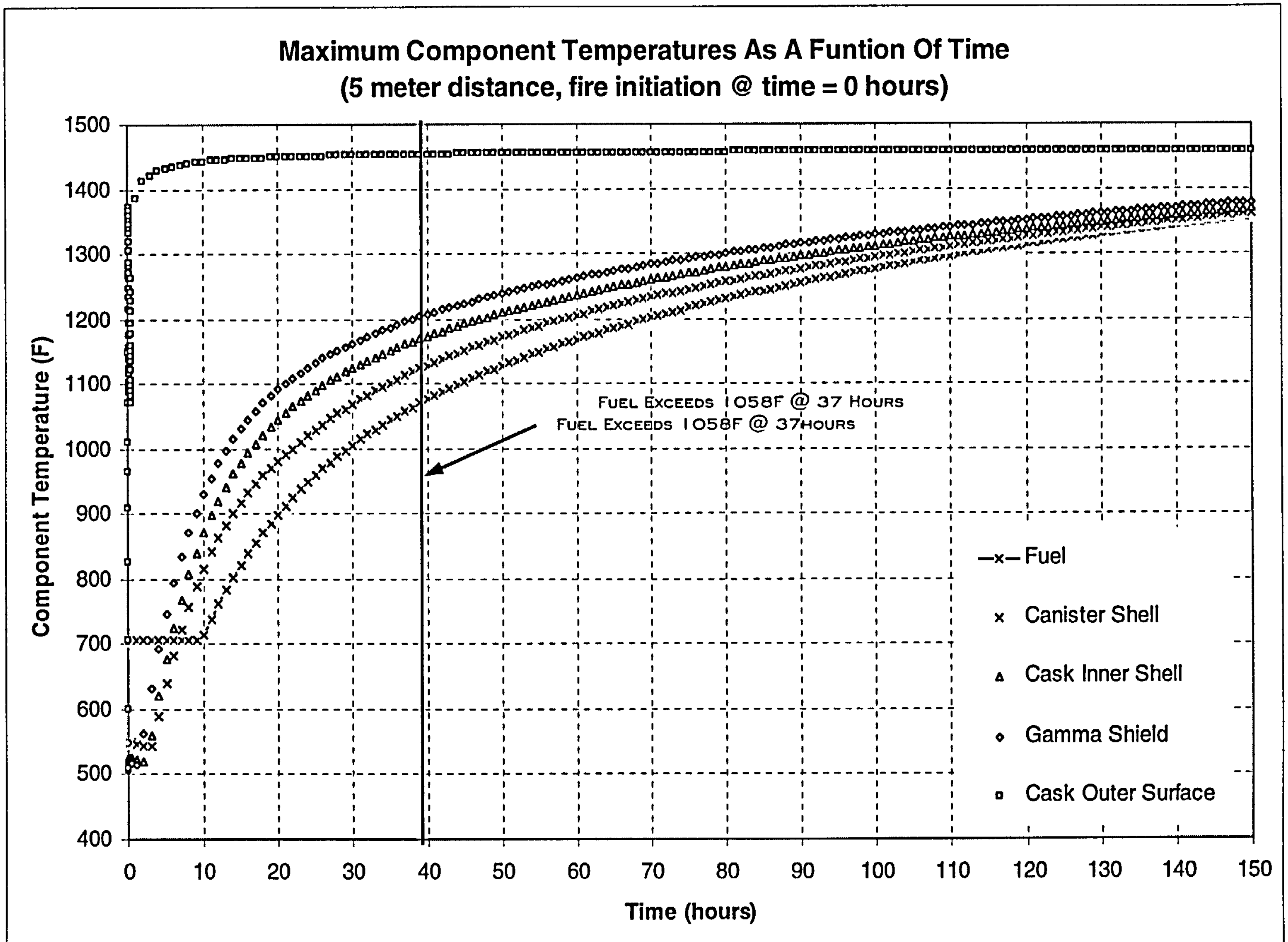
NIST Temperature Data



20 M Results From Revised Analysis



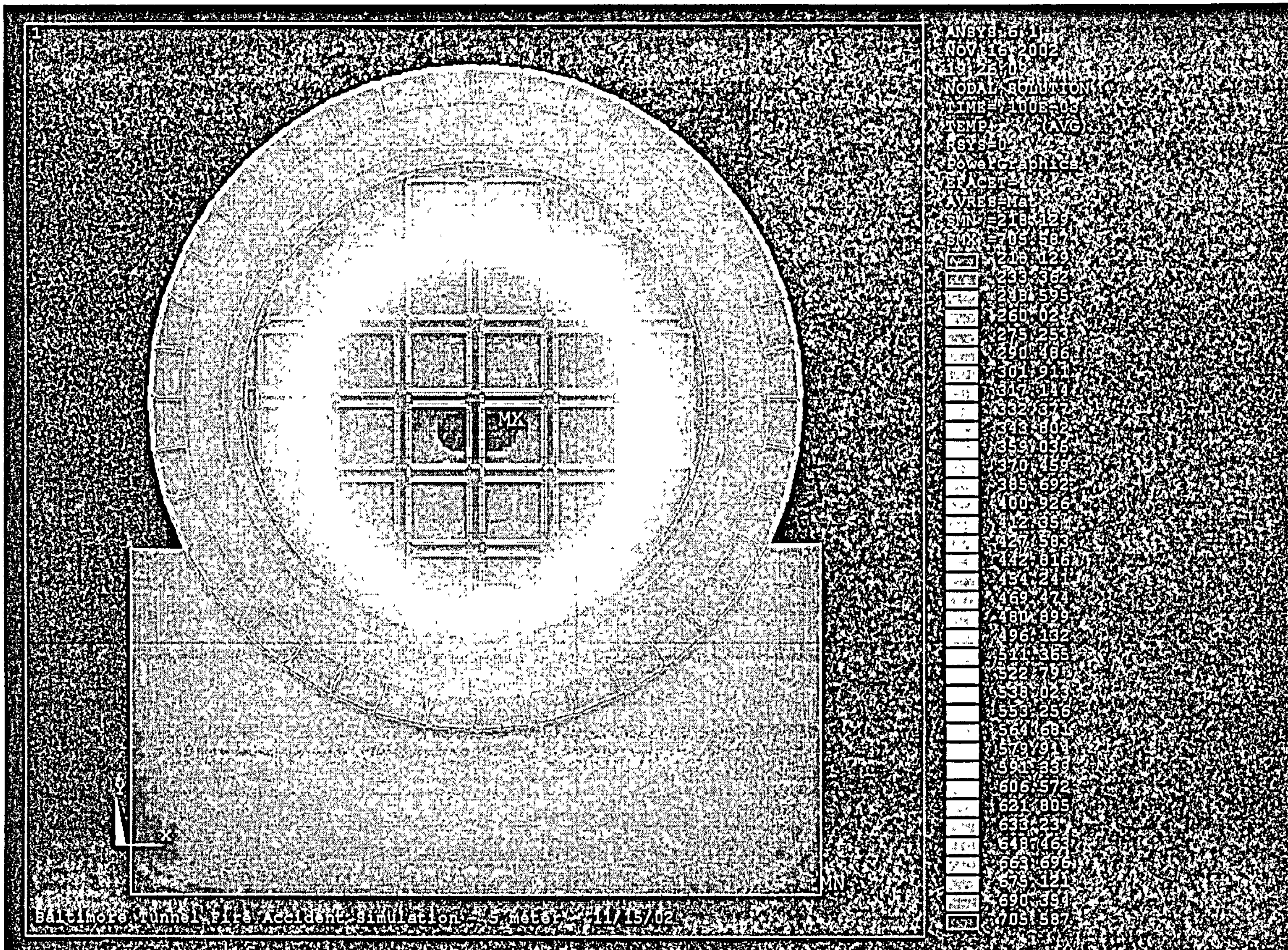
5 M Results From Revised Analysis



Results From Revised Analysis

- Time to exceed short term fuel temperature limits (1058°F)
  - For 20 meters over 100 hours
  - For 5 meters over 30 hours
- Time to canister failure
  - For 20 meters over 30 years
  - For 5 meters over 30 years

Animation of 5 Meter Results



CONCLUSIONS

- CASK PERFORMANCE
- CONSEQUENCES OF FIRES
- HEALTH AND SAFETY OF THE PUBLIC PROTECTED
- AAR PERFORMANCE STANDARD FOR TRANSPORTING SPENT FUEL BY RAIL
- PRELIMINARY CONCLUSION: ADDITIONAL REGULATORY REQUIREMENTS NOT NECESSARY IF CURRENT REGULATIONS AND AAR PERFORMANCE STANDARDS ARE FOLLOWED

ACKNOWLEDGEMENTS

- MR. HAROLD E. ADKINS, JR. (PNNL)
- MR. BRIAN KOEPPEL (PNNL)
- DR. KEVIN MCGRATTAN (NIST)
- MR. JAY KIVOWITZ (NTSB)