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D I S C L A I M E R

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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BRIEFING ON REGULATION OF TRANSPORTATION OF RADIOISOTOPES AND RESULTS OF THE MODAL STUDY

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PUBLIC MEETING

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Nuclear Regulatory Commission
Room 1130
1717 H Street, Northwest
Washington, D.C.

Thursday, January 21, 1988

The Commission met in open session, pursuant to notice, at 2:17 p.m., the Honorable LANDO W. ZECH, Chairman of the Commission, presiding.

COMMISSIONERS PRESENT:

LANDO W. ZECH, Chairman of the Commission
THOMAS M. ROBERTS, Member of the Commission
FREDERICK M. BERNTHAL, Member of the Commission
KENNETH CARR, Member of the Commission
KENNETH ROGERS, Member of the Commission

STAFF AND PRESENTERS SEATED AT THE COMMISSION TABLE:

S. CHILK

W. PARLER

V. STELLO

H. THOMPSON

C. MacDONALD

R. BURNETT

W. LAHS

PROCEEDINGS

CHAIRMAN ZECH: Good afternoon, ladies and gentlemen.

Today the Commission will be briefed by the Office of Nuclear Material Safety and Safeguards and by the Office of Research on the transportation of radioisotopes and the results of the modal study.

The modal study is an evaluation of the safety of certain radioactive material shipments. The Commission requested the staff to undertake this study to confirm its earlier determination that the NRC regulations provide a reasonable degree of safety and that no immediate changes were needed to improve safety.

The staff will also summarize current and planned activities related to the NRC certification of DOE shipping packages.

This is an information briefing this afternoon and no formal Commission vote is expected.

Do any of my fellow Commissioners have any opening comments?

[No response.]

CHAIRMAN ZECH: If not, Mr. Stello, you may proceed.

MR. STELLO: Thank you, Mr. Chairman. I will quickly introduce the people at the table. On my far left is Bob Burnett. Next to him, Bill Lahs, Hugh Thompson and Chuck MacDonald. Hugh Thompson will give us a briefing on the

activities associated with transportation issues in NMSS and will quickly give you an overview of the modal study along with Mr. Lahs from Research.

The transportation safety record, as you are aware, is excellent. We have not had any real problems. I think we are doing a good job yet it remains an issue of some controversy. I think we will identify recent congressional issues relating to transportation dealing with shipping casks for plutonium via air, which in terms of significance, impacts on the resources, both in dollars and FTE's. It can obviously be quite significant to our program.

Let me then get you started and we will start the briefing and at the appropriate time I will identify the most recent congressional action and what that could mean to the transportation program.

CHAIRMAN ZECH: All right. Thank you very much. Mr. Thompson, you may proceed.

MR. THOMPSON: Thank you.

As you know, transportation is one of the functions that we do have. It is an organization that is within our safeguards and transportation division. Since some new Commissioners have been added to the Commission since we briefed the Commission in this area, we thought we would take a few moments to cover some of the background of the interagency responsibilities in this area because it is one in which the

we, the Department of Energy and the Department of Transportation have some key programs on and a very close interface on our activities.

Could I have the next slide, please?

[SLIDE.]

MR. THOMPSON: The Department of Transportation has the overall fundamental responsibility for all hazardous material including the radioactive material. They are responsible for the routing activities, the carriers, those activities associated with let's say the safety of the drivers, their qualifications, and the qualifications of the carriers for this activity.

Because of our special expertise and that of the Department of Energy, there are certain shipments that have been negotiated through memorandums of understanding for our responsibility and review.

The Department of Energy is responsible for the transportation and certification of the radioactive material by their own activities and their contractors. NRC is responsible for both the transportation of the licensed radioactive material of significant quantities, and looking at this, the health and safety aspects. When we look at the Type B packages, we have a health and safety responsibility as well as sabotage or kind of a physical security responsibility for certain categories, Category I, special nuclear material and

some spent fuels. We do have some responsibilities in those areas.

We have health and safety responsibilities and physical security responsibilities. To understand how that is put into place in today's regulatory framework, the next slide identifies how the packaging is done.

[SLIDE.]

MR. THOMPSON: There are two types of DOT packaging. One is considered the bulk or strong, tight type packaging, which typically would have contaminated waste, smoke detectors, small medical test kits, small types of things which have a rather minimal health hazard and should be able to withstand most normal transient types of incidents but would not be expected to survive any major accident conditions.

If you look at the way the regulatory framework is established, the DOT transportation limits, the amount of radioactive material that would be in a package to such a small amount, the public health would be protected even if that material were released. NRC in our certification program provides its high integrity containers so there is no release from the packages and use that approach to protect the public health and safety.

There is a Type A package which is frequently considered a little stronger from the DOT aspects, low level resins, clean-up from the reactor waste and it would not again

present a serious hazard if the material leaked, but it does have a bit more capability than just the other strong bulk, tight one, and then again the Type B package that we have.

In our regulatory framework, the Type B package would be for spent fuel, high level waste, irradiated reactor components and some highly radioactive radiological devices. In these cases, you could have a rather serious health hazard if the contents of the material were spilled or leaked or had a criticality accident as part of the fuel shipment aspects.

In making our judgments in order to establish our criteria, they are kind of hypothetical accident conditions. There are things like a 30 foot drop test, certain fire tests, a puncture test. These are what we call performance standards, that we evaluate or actually test the packages to make our judgments that the material, the quality control of these packages are sufficient to adequately protect the public health and safety.

[SLIDE.]

MR. THOMPSON: The next slide identifies what we say is our memorandum of understanding, primarily with the Department of Transportation, which sets out the responsibilities not only for the licensing review but also what type of emergency response capabilities we have initially and for follow-up activities.

DOT does serve as the national competent authority

for transportation of radioactive material. They do develop the standards and requirements for the Type A and low specific activity packages that we just talked about.

NRC has the responsibility for the Type B and the fissile material packaging and the lead role in investigating accidents where damages occur on NRC approved packages. It is the review and evaluation of the packages that we have the responsibility for.

Again, our memorandum of understanding calls for exchange of information and inspection and enforcement programs in the various areas of jurisdiction.

Likewise, we have a memorandum of understanding with the Department of Energy.

[SLIDE.]

MR. THOMPSON: The next slide shows that primarily for the activities on the Nuclear Waste Policy Act, back in November of 1983, we established the framework where we in fact put into place our consultation arrangements for discussions with the Department of Energy and basically they indicated their intent to have NRC certify the DOE shipping casks for the spent fuel associated with the Nuclear Waste Policy Act.

Subsequently, as you probably know, Congress has enacted a requirement that in fact they are required, not just by the memorandum of understanding, but the law does now require that.

We establish periodic meetings to exchange information on technical issues, policy type assumptions and we meet about twice a year. I think the last meeting we had was in September where we just basically went over the status of their program, discussed various technical issues concerning the licensing of their casks. They have not got any casks in for us to actually review. We have had some preliminary meetings with DOE on those activities.

With respect to one of the key issues that we face in the transportation activity is the increasing desire by the Department of Energy to have NRC certify DOE casks. I think when we prepared these initial briefing slides, late last year, we had a proposal down to the Commission on ways to address some of the impacts this program might have on our own programs.

NRC certification is not required for DOE with the exception of the Nuclear Waste Policy Act casks. There has been a significant increase from the Department of Energy in applications for the timeframe, fiscal year 1988 to 1992. These include the Naval reactors program, West Valley high level spent fuel casks, the Nuclear Waste Policy Act, and recently the WIPP transportation casks for transuranics.

As you know, we maintain a fairly limited amount of resources in this area to review our actual applications. We have about 85 or so applications a year that we must review.

Again, we really had no formal procedures between NRC and DOE for package review except for the Nuclear Waste Policy Act.

[SLIDE.]

MR. THOMPSON: The next slide provides a projection of what this impact has potentially on our review activities. We normally have somewhere around 8 to 10 FTE's available to do these types of reviews. The peak workload for this coming year was such that we felt and we recommended to the Commission that it take some actions to assist in reducing and streamlining the process of our review of DOE applications, and the Commission has sent a letter to Secretary Herrington. We are still waiting for their response.

There is one activity that is identified on this chart which is the plutonium air shipment casks. This particular estimate of resources in FY89 was put in there prior to the recent action by Congress to have a much more stringent evaluation of that particular type cask than we currently have. The resources associated with that review right now, this is more of a consultation type review activity, based on our current review standards, and it would take significantly higher resources if we had to respond, assuming there is a foreign country that wishes us to respond to the new requirements.

COMMISSIONER BERNTHAL: Let's see, the original rather extraordinary language that has been proposed with

respect to those plutonium shipments was modified in the end considerably, so where are we now?

MR. THOMPSON: I guess the language is still fairly stringent.

MR. STELLO: I was wondering if general counsel was familiar with it.

MR. PARLER: General counsel heard about the issue you are talking about yesterday and he has somebody that is going to provide him with research and an interpretation of the Murkowski amendment as it was recently enacted by Congress. As I understand it, there are two schools of thought. Under the Murkowski amendment, the criteria are essentially the same as the Scheuer amendment which the Congress adopted either in 1975 or 1976, but with the aircraft test added to that, or whether the criteria in the Murkowski amendment are substantially beyond, more severe than in the Scheuer amendment. You have that problem to deal with as well as the aircraft test.

I am told the Murkowski amendment in its legislative history is fairly clear. What I am trying to find out is fairly clear in which one, the first one, which is pretty much the same as the Scheuer amendment plus the aircraft test, where the criteria have been substantially increased.

From what I have heard, these criteria are presumably thought to have been substantially increased. I am looking at that.

COMMISSIONER BERNTHAL: Yes. Certainly not to the extent as the original Murkowski proposal, which would have required half velocity crash tests.

MR. STELLO: There are two criteria as well as the two issues related to aircraft, one dropping and the other crashing aircraft.

COMMISSIONER BERNTHAL: The actual tests that would have been required were extraordinary. Those were dropped. They were changed in the final version.

MR. THOMPSON: They were slightly changed but they still had a significant requirement along the lines of full scale air crash tests, if we were not able to certify or have an independent body certify that the test conditions that we established were equivalent to a worst case scenario. I think that is what the general counsel is looking at.

MR. STELLO: There is also another issue, that unless clause does not apply to the case of dropping it from an aircraft, for example, or may apply.

MR. PARLER: We will get you an answer fairly quickly.

MR. THOMPSON: It is important that we do have a good reading on this. Based on my discussions with Harold Denton and others, there is still one country that is very interested in continuing to pursue this activity, so it is something we need to review and respond to fairly promptly. Since it is a

requirement that the country support financially those activities, we will need to assure that we have a program in place and that they know how we are going to carry this out. Otherwise, it will divert significant funds from review activities.

[SLIDE.]

MR. THOMPSON: This slide will essentially identify the steps the Commission has taken to assist us in evaluating the additional resources that we need. We have requested that DOE certify the packages prior to submittal and to prioritize their package review needs. There are a number of packages that have been in here some years. We typically in the past have been able to almost always meet DOE's requested date for their Naval reactor packages.

As you know, we intend to still work on their packages until DOE decides a different priority will be in place. I don't have right now a projected date to get a response. We do have a system in place, pending a response by DOE on this activity.

COMMISSIONER BERNTHAL: Do we have the authority to "require" DOE to certify those packages or is this a request?

MR. THOMPSON: This in essence is really a request. What DOE has the authority to do is to certify their own packages and once they are certified, they would be useful with the exception of the Nuclear Waste Policy Act shipping

packages.

COMMISSIONER BERNTHAL: We can't meet that mandatory directive?

MR. STELLO: General counsel may know.

MR. PARLER: The areas that we can direct DOE to come to us either to be licensed or to be certified are those areas that Mr. Thompson has already alluded to, that is the Nuclear Waste Policy Act as amended recently and that are covered in a particular section of the Energy Reorganization Act of 1974. There is nothing in the Energy Reorganization Act of 1974 as amended that I recall that would require DOE to come to us to get casks certified.

Therefore, other than the Nuclear Waste Policy Act, the thing is entirely voluntary on DOE's part. I would assume, but I do not know, that there would be substantial motivations on their part to come to this agency to get their casks approved, for fairly obvious reasons.

MR. THOMPSON: Obviously, there may be some exceptions to the thing if there is a particular need and one or two casks, for them to certify the casks first and we would be prepared to accept their judgments and their recommendations as to which to put the priority on. It may be the WIPP casks might receive priority or the Naval reactor casks, whichever one it would be. Until otherwise, we are putting our emphasis on the Naval reactor casks consistent with our past practice

and the resources we have available.

COMMISSIONER CARR: Let me make sure I understand this. You said there were 85?

MR. THOMPSON: Typically we will receive a total of applications for amendments or new cask reviews at about 85 reviews a year.

COMMISSIONER CARR: Different casks?

MR. THOMPSON: Different casks, different designs, same designs but maybe a different loading factor.

MR. BURNETT: Internal modifications to an existing cask.

MR. THOMPSON: I guess there is something like 225 approved NRC certified casks for various shipments, spent fuels --

COMMISSIONER CARR: I assume those approvals are generic in that if they meet that cask and that kind of loading, they can keep doing it without coming back.

MR. THOMPSON: That's correct.

COMMISSIONER CARR: It is an one time shot.

MR. THOMPSON: There is a five year renewal, each five years they would come back for renewal of that application.

COMMISSIONER BERNTHAL: Let's see, what about the response to the Commission's request that DOE certify their designs and give us priorities? Have they thus far responded

and indicated what they are going to do?

MR. THOMPSON: No, sir.

As I mentioned earlier, a second part of our responsibility deals with the physical protection requirements that we have on our shipments.

[SLIDE.]

MR. THOMPSON: The next slide identifies in summary that the two main areas requiring physical protection is the first category, Category I, and the spent fuel requirements. There are small differences with respect to the armed escorts, where the spent fuel does not automatically have armed escorts all the time. You would only have armed escorts in urban areas. The spent fuel does not necessarily have a specialized cargo vehicle and we do have unarmed escorts for the spent fuel in non-urban areas.

The two key areas that we have looked at from a sabotage or a physical material accountability control are the spent fuels and Category I materials. The Commission has proposed a rule at one time to relax some of the requirements on spent fuels based on an evaluation of the significance of a sabotage of a spent fuel shipment. We will be evaluating that in the years to come, as to whether or not that is an appropriate reduction in our physical protection capability of that material.

[SLIDE.]

MR. THOMPSON: The next slide identifies what we think is a key area with respect to the emergency response role of the NRC and essentially we really have a coordination role or a communication role as the primary function, in assuring the state agencies, the Department of Energy and other affected agencies informed of the accident. We provide specific information on NRC certified packages and we offer other technical advice as requested on protection of the public health and safety issues. We would only assume radiological control at an incident scene until state or local authorities arrive.

We have never had that occur. I wouldn't anticipate we would ever be the first on the scene for any particular reason, but that is the responsibilities that we have.

We experience each year a number of events that come into our incident response center, 25 to 30 type transportation accidents a year. Of the 25 events in 1985, four involved some material release. In fact, NRC Region IV responded to one which was a yellow cake collision with a train in North Dakota, which received a good bit of NRC oversight and attention at that particular time in 1985. In 1986, we really did not have to respond to any events that involved some material release.

COMMISSIONER CARR: When you say information on the NRC certified packages, that is packaging? We don't look at each package before they ship it, do we, as long as they are

meeting our requirements?

MR. THOMPSON: That's correct. It relates to the specifics of the design, the characteristics of the package, shielding characteristics, what material might be shipped in it.

COMMISSIONER CARR: The impression I got reading this was each package that is shipped, we have to okay it before it goes. That's not correct.

MR. THOMPSON: That is not the case. In fact, much of the inspection of the transportation activities is done by the states. They may occasionally spot check a transportation shipment through a state, particularly on spent fuel. Some states make an effort to inspect the package shipment at the border and inspect it carefully and may escort it through the state or the local transportation areas, which depends on the sensitivity to the area as to what the local authorities do.

CHAIRMAN ZECH: I know we don't have many of these incidents. My experience would lead me to believe that the NRC has responded rather promptly. I would hope that this is the case and we would continue to give priority to anything like this that happens. We should have an NRC responsible person on the scene just as soon as we can. I hope that is what we do. It looks like that is what we have done. I hope we will continue to do that.

MR. THOMPSON: Most of these are fairly small type

incidents. I believe there was one recently in Richland, Washington, where there was a truck overturned with some contaminated soil. We evaluate whether or not NRC's presence would be of assistance to either the state or local, we will consult with them, and if there is any need or request for our assistance, we respond promptly.

CHAIRMAN ZECH: If there is any doubt at all, if there is any question about it, we should go, whether we are asked or not. I would like to make sure that happens. The regions can do it and we should back them up if they need help from Headquarters.

MR. STELLO: As the slide also indicates, I guess there was at least one occasion when we were the first at the scene. When we are --

CHAIRMAN ZECH: We take charge until properly relieved.

MR. STELLO: That's right, until relieved by the state or local authorities.

COMMISSIONER BERNTHAL: At any given time on the average, how many shipments of spent fuel are in transport in this country?

MR. MacDONALD: Approximately 100 per year, 100 shipments per year.

COMMISSIONER BERNTHAL: Every third day on the average. Are you saying shipments per year? I am saying on

any given day, how many shipments are in transport?

MR. BURNETT: We are running about 100 to 200 shipments a year.

COMMISSIONER BERNTHAL: How many days on average does each shipment take?

MR. BURNETT: On an average, some of them are short like one day, some are two or three.

COMMISSIONER BERNTHAL: It sounds like that on the average, at least every day there is a movement.

MR. BURNETT: There is about 52 shipments coming in from abroad, coming into Portsmouth, Virginia. Most of those shipments go from that shipping dock into the Savannah River, which is less than a day away. That might give you some indication. There are some others.

COMMISSIONER BERNTHAL: I get the picture.

MR. THOMPSON: But the number of shipments obviously as we move to the high level waste repository are going to be significantly different and certainly to the extent that we have evaluated the environmental aspects associated with those, we will probably re-visit that in part of our update of our environmental assessment activities that we are planning to do in any event.

MR. BURNETT: The average days in transport is going to change because you will have a single repository and you can see the impact.

COMMISSIONER BERNTHAL: We are really beginning to develop a pretty good statistical base for expressing the safety of these casks, I would assume.

MR. THOMPSON: Bill may address some of the statistical bases. I think we didn't use our nuclear transportation shipments, to develop the accident rates because it was few compared to what I would say the gasoline tankers are. When you are really looking for significant statistical numbers, those numbers way outweigh ours. It is an important area because very careful records are kept, the accidents are evaluated.

One of the key issues that we keep facing, both in Congress and with our own individual reviews is the adequacy of our regulations. The history, the accidents, have always proven that the program that we have established has reached the highest degree of performance in protecting public health and safety.

As you may know, in 1977, we evaluated through an environmental impact statement, the adequacy of our regulations to consider whether we needed to make any significant changes to increase those. It was based on the information that had been developed, public comments were received on it and the safety record we had achieved to date.

The Commission concluded that the present regulations provided a reasonable degree of safety and no immediate changes

were needed to improve safety. Again, this was reaffirmed recently by the Office of Technology Assessment, when they concluded that the regulations provided a high level of public protection for spent fuel shipments, in fact, probably the highest level of any of the activities, hazardous material transported, and this was given that we implemented the quality assurance programs that were utilized and relied upon by the industry in developing and designing and building these casks.

In addition to those two studies, we have conducted some full scale studies, full scale testing. I guess there is a photo that many of you have probably seen. There is always the train and the cask meeting shortly at the intersection. Despite that aspect, and you may want to put that particular slide up, we felt it was important to do a modal study which looked at more than just the one point.

[SLIDE.]

MR. THOMPSON: All these casks performed sufficiently to adequately protect the material involved. The modal study gave a much broader review and a risk assessment review of the activities associated rather than just the one frame that you can see there, one dimensional hit, although it is a fairly dramatic one, it didn't really satisfy everybody's concerns with respect to the transportation cask issues.

Bill, you might want to talk a bit about what we were able to do in the modal study to further evaluate the adequacy

of our regulations.

MR. LAHS: You heard Hugh generally describe the approach to our transportation safety regulations. He has alluded to the radioactive material package performance requirements, including those directed at assuring that the proper protection is being provided in the event that one of our packages becomes involved in a severe transportation accident.

He just got done mentioning the 1977 environmental impact statement which provided a risk perspective on all radioactive material shipments in the United States including spent fuel.

I mention these items because they are really the starting point or reference point for the modal study discussion.

The principal use of the modal study is it was taken together with things like the full scale test that you just saw which I think provides information from which people can make a better judgment on the adequacy of our transportation regulations and also I believe upon which past Commission conclusions with regard to the adequacy of those regulations can be made.

As mentioned, the modal study focuses specifically on regulation adequacy with regard to spent fuel shipments, which could become involved in severe transportation accidents.

Just a brief background, when the Commission made its decision back in 1981 on the adequacy of the regulations, I think they recognized that for spent fuel and certain other shipments, that the nature and the quantity of the materials shipped dictated some need for some continuing action. They essentially told us to address two issues, which are shown on this first viewgraph.

[SLIDE.]

MR. LAHS: People always ask, what is the relationship between our existing performance standards, that is things like the 30 foot drop and the unyielding service, the fire test, the puncture test and the related acceptance criteria, and the environments that we can really see in real world accident situations.

Secondly, they asked, could we characterize what the potential radiological hazards might be if a spent fuel shipment became involved in what most people would consider a severe transportation accident.

[SLIDE.]

MR. LAHS: To respond to this directive, we decided that a study could be undertaken to evaluate the level of safety provided by spent fuel casks designed to our existing regulations, with the assumptions shown on the slide.

The general approach would be to try to evaluate the performance of those casks against severe accidents which have

historically occurred involving non-nuclear shipments using road/rail transportation.

Over the course of this study which lasted -- it started in 1981, there were essentially three different contractors involved, the latest of which was the Lawrence Livermore National Laboratory and it is their contractor report which is most frequently referred to by the modal study.

In doing the study, Livermore really had to give consideration -- had to address two main considerations. First of all, since we have a performance standard approach to our regulations, if you think of what do we have out there, we have casks of different designs. They all meet our regulations but you could have casks that ship BWR, PWR, assemblies, shielding material can be different, closure designs can be different. Any of those casks can be the one that some day, somewhere along the line could become involved in a severe transportation accident. That accident could also involve a wide variety of forces, both mechanical and thermal.

[SLIDE.]

MR. LAHS: The first step in the study essentially involved determining the magnitude and likelihood of the forces which we really could see in real world accident situations, focusing especially on those which had the possibility of compromising cask safety functions. That means containment integrity, shielding, criticality control. This information

was derived from a review of the historical record of all road and rail accidents and was supplemented by route and other informational type surveys.

What resulted from this was a distribution of accident scenarios which predicted the occurrence rate of cask interactions with a variety of targets. As this viewgraph shows, one of the main classes we divided things up into are what we call parts that were soft relative to the cask, things like people, you drive in your automobile, trucks, buses. There are classes of targets which can be hard, things like bridge columns, hard surfaces either adjacent to the roadway or maybe below bridges where a shipment could go through a bridge railing and fall to the surface below.

There were other parameters which were obviously important to characterize the magnitude of the forces which could be involved, both of a mechanical and thermal nature, and there are a lot of them addressed in the study itself. Several are illustrated in the brochure which you have a copy of.

The major ones as you might expect are things like velocity, impact angles, what is the object surface and whether there is a fire involved.

[SLIDE.]

MR. LAHS: The crucial step in the whole study was the next one. Remember that the level of safety is really provided in the cask designs themselves. The crucial step in

the study was to try to come up with a design definition of a cask or casks which could act as a surrogate to the level of safety that is being provided in the regulations.

Basically what was done is we defined a representative road and rail cask which had features common to the casks that are out there, but which had capabilities deliberately selected to only just meet the existing regulatory requirements.

Once that was done, the remaining steps really became more mechanical and that was essentially to evaluate the representative casks against the accident environments which had already been defined.

We used computer codes to essentially evaluate the degree of damage that these casks could sustain, both of a mechanical and thermal nature, and then looking at that damage, made a conservative assessment on what the radiological hazard was that could result, what that hazard could be and what the magnitude would be.

The hazards were essentially of two types.

[SLIDE.]

MR. LAHS: This is the first one. That involves the possibility obviously of a material release. For that to happen, you have to have an accident severe enough not only to rupture the cladding of the individual fuel routes within the assemblies to allow the material to escape to the inside of the

cask but you also have to have an accident severe enough to somehow cause a violation in the cask integrity.

The slide here really shows the possibility where you might have seal damage and release through a failed seal.

[SLIDE.]

MR. LAHS: This viewgraph shows the other type of hazard which could result and that is shield degradation. In our representative casks, we chose lead as the shield material and the illustration shows an example of where if you had a head on impact of one of these casks, you might get lead slump, lead could actually move forward causing a void in the shield and an increased radiation level external to the cask, even though the event might not lead to any material release from the cask.

In the final steps of the evaluation, the package response and accident force likely analyses were combined. Estimates were made that given that an accident occurred, what would be the damage sustained by the representative casks. That damage was placed into various categories as shown in the next viewgraph.

[SLIDE.]

MR. LAHS: This slide is really a damage magnitude diagram, where if you are working from the bottom left to the upper right, you are seeing increasing levels of damage. As you go up, you are seeing increasing levels of mechanical

damage, which in the study was characterized by a measure of the maximum strain achieved in the containment shell of the cask. As you go out the abscissa, what you are seeing is thermal damage which is being characterized by a measurement of the maximum temperature at the center line of the shield.

Through this process of taking these representative casks and subjecting them repeatedly to the loading conditions which we established for the real accident forces, for each individual case, we were able to generate the information necessary we felt to characterize a relationship between our regulations and some baseline level of safety that is being provided.

At this point, I am going to discuss some of the results of the study.

[SLIDE.]

MR. LAHS: The study provides three perspectives on the safety that is being provided by our existing regulations. First, the study results are as to cask accident likelihoods, in terms which compare the potential radiological hazard to values which currently exist as acceptance criteria in our existing regulations in Part 71. Secondly, we have a perspective which is a risk calculation, which is similar to what was done in the 1977 environmental impact statement. That was done for all materials but spent fuels was singled out. Here we are just focusing on risk from spent fuel accidents.

Finally, to give people some feeling for how casks could respond to say a serious accident, a very severe accident, what we did is try to evaluate how our representative cask would respond if it had been involved in several severe accidents that are actually on the historical record.

[SLIDE.]

MR. LAHS: Here the results indicated that if our representative cask over a period of time was involved in 1,000 accidents, the time estimate would be something like 50 to 100 years, depending on shipment mileage, and of those 1,000 accidents, 994 would result in forces being applied to the cask which would be probably less than the forces that are being applied by our hypothetical accident conditions. Therefore, we wouldn't expect any radiological hazard to be created.

COMMISSIONER BERNTHAL: 950, not 994.

MR. LAHS: I am going to the bottom. 994 is correct. 994, we would expect no radiological hazard but even in the remote event that something did happen, we think the hazard would still be far below the hazard that is applied by our acceptance criteria.

The 994 is made up of two components. First, there is 950 of those 1,000 events roughly that would involve cask interactions with soft targets, and therefore it is those targets that would be taking most of the damage.

If you talk about the other targets, harder classes

of targets which could be hard, even in that class, there are 44 events which essentially would cause damage which would probably lead to no radiological hazard. Why?

For example, you might hit a bridge column, maybe the velocity is less than 30 miles an hour, or maybe you hit a column at 70 miles an hour but it is only a glancing blow, or even with hard classes of targets like bridge columns, there are certain sizes of columns which are soft relative to these casks. The column is going to fail before the cask will.

Even though there might be a fire, which could be hot enough and long enough, you always have the question, is the cask really involved in that fire. That is how we get the 994.

How about the remaining six?

[SLIDE.]

MR. LAHS: The study showed that of the six remaining accidents, four fell in the second box on the left side, which is an area where we are predicting minor cask damage. What does "minor" mean? If you look at the structural response, we are talking about maximum strains between .2 and 2 percent, not a lot of damage.

The hazard that could be created by such an event might be seals, the seals could fail so you could get maybe some release of radioactive gases and some volatiles. Again, when we evaluated the situation, the radiological hazard that is created is still far below the values that are stated as our

acceptance criteria.

Only when we get to the next box up, when we think about the possibilities of major damage and it really only applies to accidents where we are talking about the much larger strains, 10 percent and above strain accidents, could we predict radiological hazards which could equal or might exceed by factors of four or so the values that are currently in our acceptance criteria.

In the outer range, the striped area, you are talking about extremely rare events. You are almost guessing. To give you a feeling for what that means, we estimated that maybe 1 in 100,000 accidents would fall into that striped area. To give you a feeling in terms of time, that would be like an event roughly every 500 years.

Because of that open area, we tried to provide a second perspective shown on the next viewgraph.

[SLIDE.]

MR. LAHS: We subjected our representative cask design to a selected number of real world severe accidents. I am not going through all the accidents. The point of this slide is that when we did that, we found out that 3 of the 4 led to predictions that the damage would fall in that lower left box. The Caldecott Tunnel fire was kind of a borderline case. Only in one event, and that was the Livingston train yard fire accident in Louisiana in 1982, could we come up with

predictions where we could say, there could have been major damage to the cask. That particular accident involved a derailment of a number of vinyl chloride and petroleum tank cars. The fire lasted for several days or a couple of explosions. We essentially put our representative cask in that accident environment and we came up with predictions that if cask had been at the right place, we could have gotten temperatures ranging from 600 to 720 degrees.

Finally, the last perspective --

COMMISSIONER BERNTHAL: What exactly is the physical damage that occurs in that box?

MR. LAHS: In that box, for our representative cask, remember our cask had a lead shield, and you are obviously talking about lead melting, so you could either partially lose the shield, the shield could melt, when it contracts, voids could be created, you could have an increased direct radiation hazard and because of the fire you could have seal failure. You could have actual radioactive material releases out through the seals.

COMMISSIONER BERNTHAL: There are no dangers from the lead melting of structural damage to the internals that you could begin to compromise --

MR. LAHS: The expansion or something like that?

COMMISSIONER BERNTHAL: Such that you could get criticality or anything like that.

MR. LAHS: No. When we looked at criticality, it is mentioned briefly in the brochure, but the safety that is being provided against criticality accidents is such that the estimates that we were making on criticality events were numbers that are just not believed, 10 to the minus and I can't remember the number offhand, but it was like 10 to the minus 13 or 14, it is hard to honestly believe that such an event is critical.

COMMISSIONER BERNTHAL: Seal failures would occur from over pressure if they occur?

MR. LAHS: From either mechanical damage or some of these seals could degrade as the temperatures get higher than say 550, depending on the type of seal you are talking about.

MR. THOMPSON: Even in these cases, the radiation dose levels are not so significant, they are like four times the regulatory limit, that is like four rems per hour for a shielding loss and it is a little more complicated with the more aerosol release but it is still, making a lot of assumptions, like less than 25 rem dose to somebody who would be like 100 feet away who might be in the cloud. That is a high dose level but it is not like you are going to have a lethal dose.

MR. LAHS: That is a fair characterization. Obviously as you are getting up, as you go to the upper levels, the uncertainties, what if, and it is difficult.

COMMISSIONER BERNTHAL: In aged fuel like this, aged spent fuel, what is the principal remaining volatile component? Obviously if the iodine we tend to worry about is all gone, many of the noble gases I guess are all gone.

MR. LAHS: Cesium, which is also --

COMMISSIONER BERNTHAL: It is not really a volatile.

MR. LAHS: It can be. Krypton is around as a gas.

[SLIDE.]

MR. LAHS: The last chart is the third perspective which is a risk perspective, a study similar to what was done in the 1977 environmental impact statement. Again, just focusing your attention on the bottom line, the 1977 study estimated that if you looked at accident risk associated with spent fuel transportation, they came up with a number of .0004 of latent cancer fatalities per year.

We think the study that Livermore did is a little more precise, a little more accurate. Our re-evaluation led to a figure that was about one-third of that value.

All of what I talked about today is available in a published report, NUREG/CR-4829. It was peer reviewed by the Denver Research Institute. I honestly believe that taken together with other things, that the study does provide some new insights for people to make judgments on their own on the adequacy of the regulations. The brochure you have was produced with the expectation that the study's results could be

more accessible and comprehensible, not only outside the agency but within the agency.

MR. THOMPSON: We congratulate Bill. I know it is a popular document. I think we have provided thousands of these documents primarily to the state liaison officers for their use in advising the Governors, and to state legislators. I think Bill has made presentations to the state legislators. It is a well received report and one that I have found to be very useful in trying to communicate to the public in what the risk with respect to transportation of spent fuel is today. It is a very, very volatile issue, particularly in the states that are trying to look for reasons to be opposed to anything dealing with the spent fuel high level waste repository.

There are still some issues that we have before us that we are looking at this year in coordination with Research, such as the nodular cast iron material, which is a non-specification material that is subject to more brittle fracture concerns. We use and have licensed some of these casks for independent spent fuel storage applications but not in transportation because of the brittleness.

Other countries have licensed these casks and there has been some attempt at one time to involve NRC in agreeing to the approval of that type of cask design. We had a research project look at this activity and we concluded that some additional information may be necessary, certainly we have

serious doubts right now based on the information that we have, that it is useful to try to use nodular cast iron as part of the material. I think Research will be providing us with information shortly on what our expectations would be, whether it is worth pursuing.

I don't believe we have a license application before us and it is probably not useful to spend a lot of NRC money in this activity at this time.

COMMISSIONER BERNTHAL: Is that the German design?

MR. THOMPSON: Primarily the German design.

COMMISSIONER BERNTHAL: The concerns are both about mechanical integrity under stress and response to high temperatures? What is the principal concern?

MR. THOMPSON: Certainly brittle fracture.

MR. MacDONALD: Not so much the temperature as the fracture and toughness of the material. As Bill went through the modal study, using some strains of 10 percent or so, and higher than that for the materials that are currently used in spent fuel casks, the nodular cast iron casks would not have that type of ductility, you may not be able to develop the full strength of that material before you would have a failure. The concern would be of having a cask breaking open. We believe this should be looked into before proceeding in that area.

There are concerns about the material, reproduceability of the material and the material being a non-

specification, not having a specification for that material. The code such as the ASME code would not accept that material for nuclear application. There are a lot of questions that would remain before we would see moving into an area of using a material which certainly on appearance would be an inferior material.

COMMISSIONER BERNTHAL: On what basis has Germany approved it? Do they have less stringent standards than we are applying?

MR. MacDONALD: I really do not know.

MR. THOMPSON: The next two issues primarily relate to using the current type of material we have and either going with a different design, which is the rectangular design, and I think most of the casks you have seen are basically circular and the question is you may get a greater capacity in a cask resulting in fewer shipments, but you again have a more difficult time being able to demonstrate it meets our structural requirements in Part 71.

Likewise, the credit for fuel burn up. We talked earlier about criticality issues and our ability to really understand what our safety margin is from a criticality aspect. In transportation, we do not have and do not give credit right now for fuel burn up. That is one of the issues we will continue to look at. People feel they can get increased storage capability in the existing cask if we will give them

credit for that.

There are questions on accountability, recordkeeping, measurements, different criticality in the rod, if you knew you had a general burn up, being able to know what it is in the various physical locations within the rod itself, spent fuel rod itself. Those are some of the issues that are important.

Finally, the issue of the plutonium in the air transport. I think that is the one we talked about earlier. It is one which could take a significant amount of agency resources to do. Certainly depending on what the general counsel comes up with on what the requirements really are, it could require us to develop new criteria and then conduct various testing associated with those new criteria.

COMMISSIONER BERNTHAL: What is the credit for fuel burn up? I understand in principle. Can you give me a 20 word or less summary?

MR. THOMPSON: I will let Chuck MacDonald give you a 20 word or less.

MR. MacDONALD: Our hope is to increase the fuel load capacity in the cask, by increasing the capacity, you reduce the number of shipments that you would have to make.

MR. THOMPSON: I think it is a criticality issue. The question is how much of the fuel, if you had fresh fuel in there, you have certain poison type barriers as part of the basket structure that you place the spent fuel in and ship it

in, such that if you put that in even a pool of water, just for loading and unloading, that you won't have a criticality accident. That is it has to be flooded. The time that you really flood the transportation cask, unless you have an accident, it is really loading and unloading.

MR. MacDONALD: As far as the function that the fuel basket would perform. It would hold the fuel assemblies, there would be a neutron absorber as part of that fuel basket and there would be some spacing in there for moderation of the neutrons so they could be absorbed, and if you can do away with the neutron absorbers, do away with some of the spacing --

COMMISSIONER BERNTHAL: For high burn up fuel?

MR. THOMPSON: That's correct.

MR. MacDONALD: For higher burn up as the reactivity would decrease. It certainly is not an issue that as fuel comes out of the reactor, that it does have less reactivity.

COMMISSIONER BERNTHAL: I guess I am surprised it makes such a difference going from regular burn up to what we call high burn up. Maybe it does.

MR. THOMPSON: No, we don't give credit for any burn up.

MR. STELLO: We assume it is fresh.

COMMISSIONER BERNTHAL: You assume all fuel is fresh.

MR. STELLO: Highest reactivity you can get in a fuel

is assumed. Then you have to add absorbers, poison, to accommodate the --

COMMISSIONER BERNTHAL: The question before you is whether to offer a credit for the burn up.

MR. STELLO: You give them a credit if you can get more fuel back in and take out some of the poison.

COMMISSIONER BERNTHAL: That is extraordinarily conservative.

COMMISSIONER CARR: You want to make sure they don't unload a recently loaded fuel.

MR. THOMPSON: The question is how you would go about having assurances. There is no clear measure that you can make that says this is 10 percent burn up or 1,000 megawatt day burn up.

MR. STELLO: Your accounting and recordkeeping system if you do this is going to be very, very significant.

MR. THOMPSON: Perhaps we could back off some, but if you back off some, is it worth it to go through the whole process.

MR. STELLO: We don't know but that's the end of our briefing.

[Laughter.]

COMMISSIONER BERNTHAL: You didn't know that, did you?

MR. THOMPSON: No, I didn't. Again, just to re-

emphasize it, transportation is probably the area in which the public comes in closest contact with it and it is one where almost every state has an area of interest and one that I think will be before the Commission for some time. We wanted you to be aware of the things that we were working on and to let you know that we think this is a program which has achieved a very high level of safety and assurance of adequate protection of public health and safety.

CHAIRMAN ZECH: Thank you very much. Any questions from my fellow Commissioners? Commissioner Roberts?

COMMISSIONER ROBERTS: No.

CHAIRMAN ZECH: Commissioner Bernthal?

COMMISSIONER BERNTHAL: I don't really have many questions, I guess. I also want to compliment Bill, the author of this study, on the work he has done, in two respects. One, although I wouldn't attempt to analyze the technical details of the product here, you presented it in a way that I think is very good. It is a very good educational document, to say the least.

I also like the fact that the name of the author is on the document. That is something that we have talked about very often in connection with research work that comes out of this agency. That is not just because I especially want to contribute to his publication list, which is fine. It cuts both ways. That means he is accepting responsibility for this

product and it is not under the sometimes gray imprimatur or the U.S. Nuclear Regulatory Commission only.

I would encourage that sort of thing. Let's get the authors' names on it and let them stand by their work.

The one other item I would mention is there must have been a good deal of rather detailed technical work that is behind this somewhat more popularized version here. Have you published that work and do you intend to?

MR. LAHS: That is the NUREG document.

COMMISSIONER BERNTHAL: It is only published as a NUREG. Are you going to put it in a journal? Are there appropriate portions for a journal?

MR. LAHS: The people at Livermore have published some papers on the study. In general, the results of this study have been published.

COMMISSIONER BERNTHAL: Again, I would encourage you to the extent, both for your own professional good and to maintain the principle here, that those parts that are publishable, you be encouraged to put them in a standard line journal.

MR. STELLO: We will go back and make sure there isn't any further work that we can publish.

COMMISSIONER BERNTHAL: Again, I compliment you on a nice job.

MR. LAHS: To be fair, a lot of Hugh's people worked

very hard and you have a great graphics department, too.

COMMISSIONER BERNTHAL: We ought to be doing more of that sort of thing for public education as well as for other reasons. It is a great contribution to helping the public to focus on where the real risks are in this business and also are comparing the risks in this business to many other risks that we live with on a daily basis.

That is really all I have to say. It was a good briefing. Thank you.

CHAIRMAN ZECH: Commissioner Carr?

COMMISSIONER CARR: No questions.

CHAIRMAN ZECH: Commissioner Rogers?

COMMISSIONER ROGERS: Just one question. What is the material of the outer shell?

MR. LAHS: Stainless steel.

COMMISSIONER ROGERS: I just want to reinforce what Commissioner Bernthal just said. I think this publication is very attractive. I think it is a good thing to represent the Commission by and I would like to compliment you on a fine job.

MR. LAHS: Thank you.

CHAIRMAN ZECH: As we all know, a number of states, as you mentioned earlier, have been very interested in transportation matters on a continuing basis for nuclear materials that will be going through their states.

Are we working close enough with the Department of

Transportation, do we need to develop any new guidance or policies as far as transportation is concerned?

MR. STELLO: We have very good relations with them and work very closely. We have made changes over the years. Quite frankly, if some of the legislation that is at issue prevails, it will drive the Department of Transportation and us to do considerable work. The bill provides for specific regulations to be developed jointly.

CHAIRMAN ZECH: We do have a continuing relationship.

MR. THOMPSON: Our relationship has been good. I think we have no communication problems that I am aware of. It is important that we do this, we maintain that type of communication.

CHAIRMAN ZECH: We haven't had many serious problems occur in these packages. Every so often, we have a problem. We have had a few. Is there any additional things you are aware of that we should be doing on packaging of radioactive wastes? Do you think the casks and our responsibilities are adequately taking care of the radioactive waste responsibilities that we have or are there other things we should be doing?

MR. THOMPSON: We are very comfortable with the level of protection of the public that we have with our current cask designs. The area that is being pushed by the industry to a certain respect is getting credit for fuel burn up. They would

like to maybe reduce some of that margin. We obviously are being very careful and thorough in our review before we elect to reduce any of this margin that we have to reach the level of protection we have today, just to make sure that we don't back away from it.

There are also questions concerning the need for continued guards for the spent fuel. That is the other area where there is some pressure by DOE and the industry, that we should not continue that level of protection for that material. As long as we feel it is appropriate to do that, we will continue to do it, to keep that level of protection.

It gets into emergency response. If there is one area that a question keeps coming up, it is the adequacy of the local people who are trained or would be first on the scene of an accident with a radiological consequence. If a spent fuel shipment was involved in a transportation accident, what is the appropriate local response.

We believe and I think DOE in the recent law will find a need to have an increased level of training at state and local emergency response organizations. I think our role has been to focus just on the adequacy of the cask design in those areas. I am comfortable with ours. There will still continue to be an issue with the state and locals on that.

COMMISSIONER CARR: Do we have a feedback and lessons learned from the accidents we have had?

MR. MacDONALD: Our accident experience as far as Type B packages are concerned has been there has been no release from those packages. That involves some 50 accidents for a 15 year period or so. Spent fuel casks have been involved in accidents but they perform as designed.

The smaller packages that are not designed to retain their contents in an accident, they do release the contents in accidents. However, the contents are limited so that it is not a significant health and safety hazard.

The system does seem to be working.

COMMISSIONER CARR: I would hope we do review them for lessons learned, if there are any.

MR. STELLO: I think the answer is yes but the lessons learned are more as to how to respond to the accidents. The typical accident you have is --

COMMISSIONER CARR: All I am saying is look at them and make sure there is not something we can learn.

MR. STELLO: From the point of view of how to deal with them; yes.

CHAIRMAN ZECH: Wasn't there a recent incident involving radioactive waste from TMI II material?

MR. THOMPSON: I remember one where there was a train collision. I want to say in St. Louis.

CHAIRMAN ZECH: A rerouting problem.

MR. BURNETT: It was up in Minnesota and it

accidentally got put on an off track, misrouting and it was picked up later.

MR. THOMPSON: I believe a train hit.

CHAIRMAN ZECH: What is the most significant accident to one of our casks that we have had?

MR. BURNETT: Chuck, how about the one a few years ago out west where the cask was actually thrown off the truck?

MR. MacDONALD: Yes. That would probably be the one outside Oak Ridge, Tennessee, which contained an overfuel cask. The truck took some evasive action to avoid a collision. The package went into the side of the ditch. The driver was a fatality. The cask separated from the vehicle and slid some 200 feet and came to rest. The people out of Oak Ridge National Laboratory responded to the scene and recovered the package, took it into the National Laboratory. It was inspected and it was only superficial damage to that package.

CHAIRMAN ZECH: No radiological release?

MR. MacDONALD: No releases. We have had cases where there are heavy concentrated loads, where problems with the trailers may crack and have weld failures. In this case, the cask essentially carries the trailer. The safety is not really dependent upon that trailer and you see the industry coming back to redesign the trailers in that type of equipment.

CHAIRMAN ZECH: Let me thank you very much for a very interesting and valuable presentation. I agree with the

recognition that has been given to you, Bill, for your contribution to our agency and to our country.

The modal study represents a significant body of work and I think the findings represent certainly some confirmation that our regulations do provide a reasonable level of safety in the transportation of radioactive material. I think the study was very useful in that regard.

It is important that we continue our close association with the states and with the public regarding transportation of radioactive material. I do believe we should continue a close relationship with the Department of Transportation and the Department of Energy also, especially with regard to our safety responsibilities.

This is a matter that we don't discuss at this table very often. It is very important. I think all the Commissioners agree with me that certainly we all feel a very keen responsibility in this area of nuclear materials as well as the reactor programs.

I think the briefing today was very useful, very helpful and very professional. Thank you very much. We stand adjourned.

[Whereupon, at 3:30 p.m., the meeting was adjourned.]

REPORTER'S CERTIFICATE

This is to certify that the attached events of a meeting of the U.S. Nuclear Regulatory Commission entitled:

TITLE OF MEETING: Briefing on Regulation of Transportation of Radioisotopes and Results of the Modal Study

PLACE OF MEETING: Washington, D.C.

DATE OF MEETING: Thursday, January 21, 1988

were held as herein appears, and that this is the original transcript thereof for the file of the Commission taken stenographically by me, 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 events.

Suzanne B. Young

Ann Riley & Associates, Ltd.

TRANSPORTATION

OF

RADIOACTIVE MATERIALS

REGULATORY RESPONSIBILITIES

AGENCY	SCOPE
DOT	TRANSPORTATION OF ALL HAZARDOUS MATERIAL INCLUDING RADIOACTIVE MATERIAL. RESPONSIBLE FOR ROUTING OF SHIPMENTS.
DOE	TRANSPORTATION OF RADIOACTIVE MATERIAL BY DOE AND ITS CONTRACTORS.
NRC	TRANSPORTATION OF LICENSED RADIOACTIVE MATERIAL. RESPONSIBLE FOR ROUTING SAFEGUARDS FOR LICENSED MATERIAL.

/

PACKAGING CONSIDERATIONS

PACKAGE TYPE - - - - AGENCY	SAMPLE CONTENTS	CONSEQUENCE OF PACKAGE FAILURE	DESIGN CRITERIA
BULK OR STRONG, TIGHT - - - - DOT	URANIUM ORE AND CONCENTRATE,PLASTIC AND PAPER WASTES FROM CONTAMINATED AREAS, SMOKE DETECTORS, MEDICAL TEST KITS	MINIMAL HEALTH HAZARD	MUST WITHSTAND CONDITIONS INCIDENT TO TRANSPORT 49 CFR PART 173
TYPE A - - - - DOT	MEDICAL ISOTOPES, LOW LEVEL RESIN CLEAN-UP WASTES FROM REACTORS	DOES NOT PRESENT A SERIOUS HEALTH HAZARD IF CONTENTS RELEASED	MUST WITHSTAND NORMAL CONDITIONS OF TRANSPORT 49 CFR PART 173
TYPE B - - - - NRC	SPENT FUEL, HIGH LEVEL WASTE, IRRADIATED REACTOR COMPONETS, RADIOGRAPHIC DEVICES	SERIOUS HEALTH HAZARD IF CONTENTS RELEASED, SHIELDING IS LOST, OR CRITICALITY CONTROLS FAIL	MUST WITHSTAND NORMAL TRANSPORT AND SEVERE ACCIDENT CONDITIONS 10 CFR PART 71

DOT/NRC MEMORANDUM OF UNDERSTANDING

JULY 2, 1979

DOT

- SERVES AS NATIONAL COMPETENT AUTHORITY FOR TRANSPORTATION OF RADIOACTIVE MATERIAL
- DEVELOPS STANDARDS / REQUIREMENTS FOR TYPE A AND LSA PACKAGES

NRC

- DEVELOPS STANDARDS / APPROVES TYPE B AND FISSILE MATERIAL PACKAGES
- LEAD ROLE IN INVESTIGATING ACCIDENTS WHERE DAMAGE OCCURS TO NRC APPROVED PACKAGES

DOT AND NRC

- INFORMATION EXCHANGE, CONSULTATION AND ASSISTANCE WITHIN AREAS OF SPECIAL COMPETENCE
- INSPECTION AND ENFORCEMENT PROGRAMS WITHIN INDIVIDUAL AREAS OF JURISDICTION

NRC/DOE PROCEDURAL AGREEMENT FOR NUCLEAR WASTE POLICY ACT SHIPMENTS

NOVEMBER 3, 1983

* ESTABLISHES WORKING RELATIONSHIP FOR TRANSPORTATION ACTIVITIES UNDER THE NUCLEAR WASTE POLICY ACT

* EXPRESSES DOE'S INTENT TO USE NRC CERTIFIED PACKAGES

* PROVIDES FOR PRE-LICENSING CONSULTATION ON PACKAGE DESIGN, DEVELOPMENT, AND TESTING

* ESTABLISHES PERIODIC MEETINGS TO EXCHANGE INFORMATION ON TECHNICAL ISSUES AND POLICY ASSUMPTIONS

NRC CERTIFICATION OF DOE PACKAGES

* NRC CERTIFICATE NOT REQUIRED FOR MOST DOE SHIPMENTS, DOE HAS OWN CERTIFICATION PROGRAM

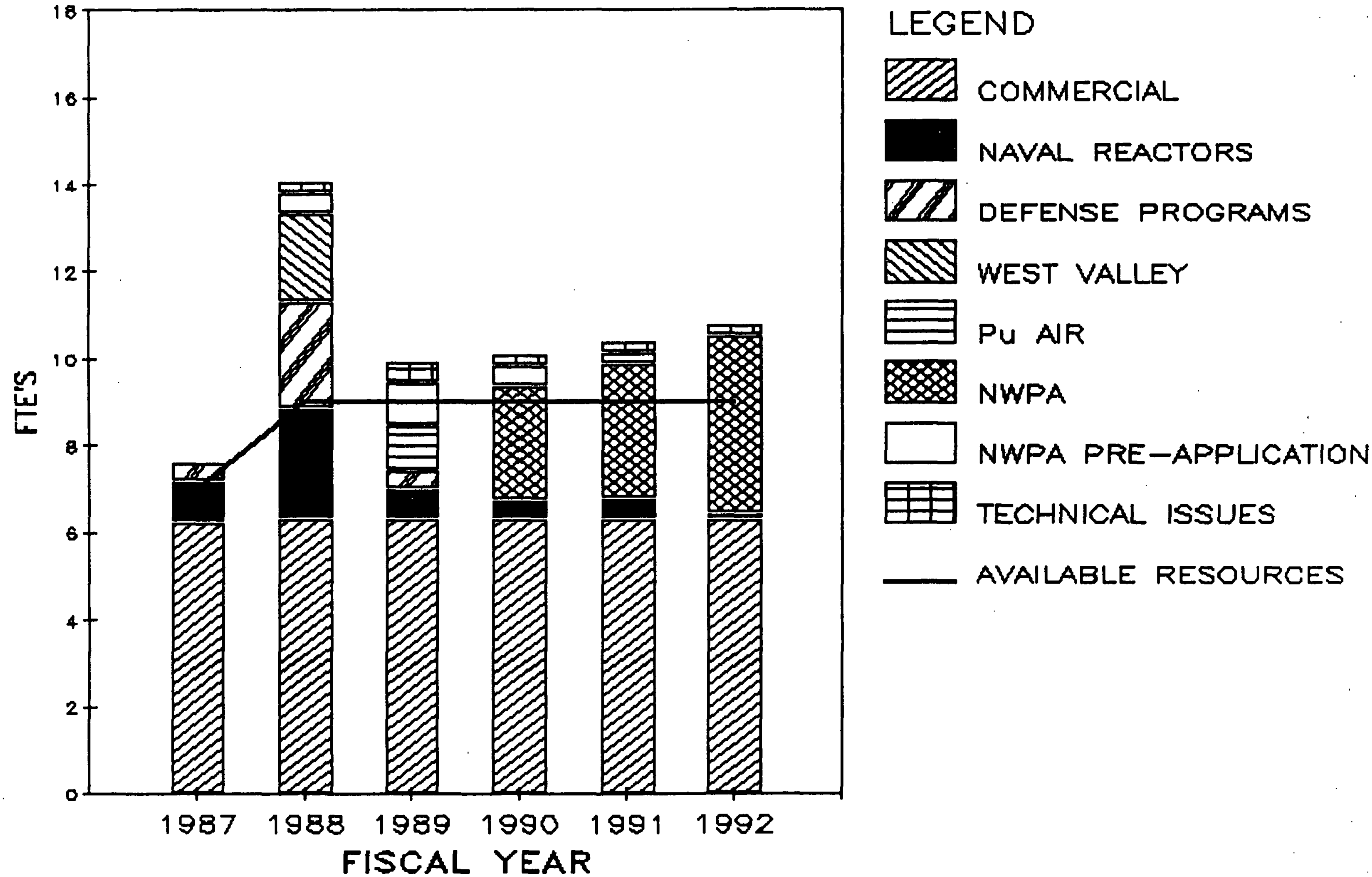
* RECENT LEGISLATION REQUIRES USE OF NRC CERTIFIED PACKAGES FOR NWPA SHIPMENTS

* SIGNIFICANT INCREASE IN DOE APPLICATIONS IN FY 88 - FY 92 (NAVAL REACTORS, WEST VALLEY, NWPA AND WIPP)

* LIMITED RESOURCES TO REVIEW INCREASED DOE CASELOAD

* NO FORMAL PROCEDURE EXISTS BETWEEN DOE AND NRC FOR PACKAGE REVIEW (EXCEPT FOR NWPA)

PROJECTED TRANSPORTATION CASEWORK



MEASURES TO MANAGE EXPECTED SHORTFALL IN NRC RESOURCES

* REQUIRE DOE TO CERTIFY PACKAGES PRIOR TO SUBMITTAL.
  - SHOULD RESULT IN MORE COMPLETE APPLICATIONS

* REQUIRE DOE TO PRIORITIZE PACKAGE REVIEW NEEDS

* CONTRACT OUT FOR TECHNICAL ASSISTANCE FOR PACKAGE REVIEW.
  - WOULD REQUIRE ADDITIONAL RESOURCES

* CONSIDER REPROGRAMING OF FTE'S IF POSSIBLE.

SUMMARY OF PHYSICAL PROTECTION REQUIREMENTS

		CAT I [1]	CAT II [2]	CAT III [3]	SPENT FUEL [4]
1.	ADVANCED ROUTE APPROVAL	✔			✔
2.	ARMED ESCORTS	✔			
3.	ARMED ESCORTS IN URBAN AREAS				✔
4.	COMMUNICATION CENTER/CALL-INS	✔			✔
5.	ADVANCED LEA COORDINATION	✔			✔
6.	RADIO TELEPHONE/CB BACKUP	✔			✔
7.	SPECIALIZED CARGO VEHICLE	✔			
8.	IMMOBILIZATION OF CARGO VEHICLE	✔			✔
9.	UNARMED ESCORT IN NONURBAN AREAS				✔
10.	ADVANCED NOTIFICATION	✔	✔		✔
11.	TRAINING, PROCEDURES AND INSTRUCTIONS	✔			✔
12.	NO CASUAL STOPS/SURVEILLANCE	✔			✔
13.	PROTECTION OF SCHEDULING INFORMATION	✔			✔
14.	CONVENTION NOTIFICATION	✔	✔	✔	✔

NOTES

1. MORE THAN 5 KGS OF HIGHLY ENRICHED URANIUM (HEU) OR MORE THAN 2 KGS OF Pu.
2. 1 TO 5 KGS OF HEU; 500 GRAMS TO 1 KG Pu.
3. 15 GRAMS TO 1 KG HEU; 15 TO 500 GRAMS Pu.
4. MORE THAN 100 GRAMS OF IRRADIATED URANIUM MEASURING 100 REM'S AT THREE FEET UNSHIELDED.

EMERGENCY RESPONSE ROLE OF THE NRC

* ASSURES THAT STATE AGENCIES, DOE AND OTHER AFFECTED AGENCIES ARE INFORMED OF THE ACCIDENT
* PROVIDES INFORMATION ON NRC-CERTIFIED PACKAGES
* OFFERS OTHER TECHNICAL ADVICE AS REQUESTED
* ONLY ASSUMES RADIOLOGICAL CONTROL OF THE INCIDENT SCENE UNTIL STATE OR LOCAL AUTHORITIES ARRIVE

ADEQUACY OF REGULATIONS

* COMMISSION REAFFIRMED ADEQUACY (46 FR 21219) AS RESULT OF NUREG – 0170

* OFFICE OF TECHNOLOGY ASSESSMENT CONCLUDED REGULATIONS PROVIDED A HIGH LEVEL OF PUBLIC PROTECTION

* FULL SCALE TEST RESULTS

* MODAL STUDY

ISSUES ADDRESSED BY "MODAL STUDY"

* RELATIONSHIP BETWEEN EXISTING PERFORMANCE TESTS AND REAL-WORLD ACCIDENT ENVIRONMENTS

* CHARACTERIZATION OF POTENTIAL RADIOLOGICAL HAZARDS WHICH COULD BE CAUSED BY LOW PROBABILITY SEVERE ACCIDENT EVENT

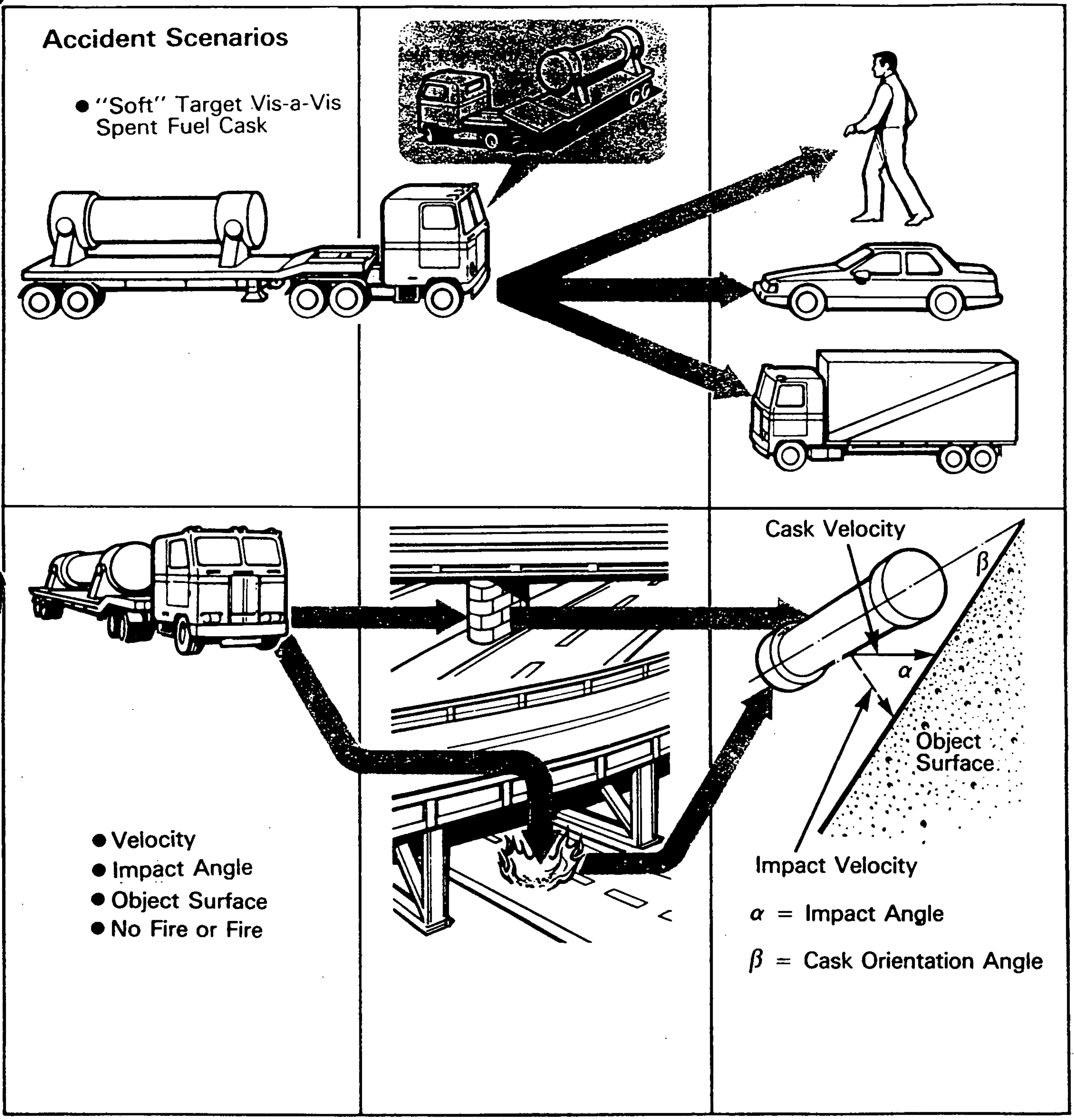
SHIPPING PACKAGE (CASK) RESPONSE TO SEVERE HIGHWAY AND RAILROAD ACCIDENT CONDITIONS

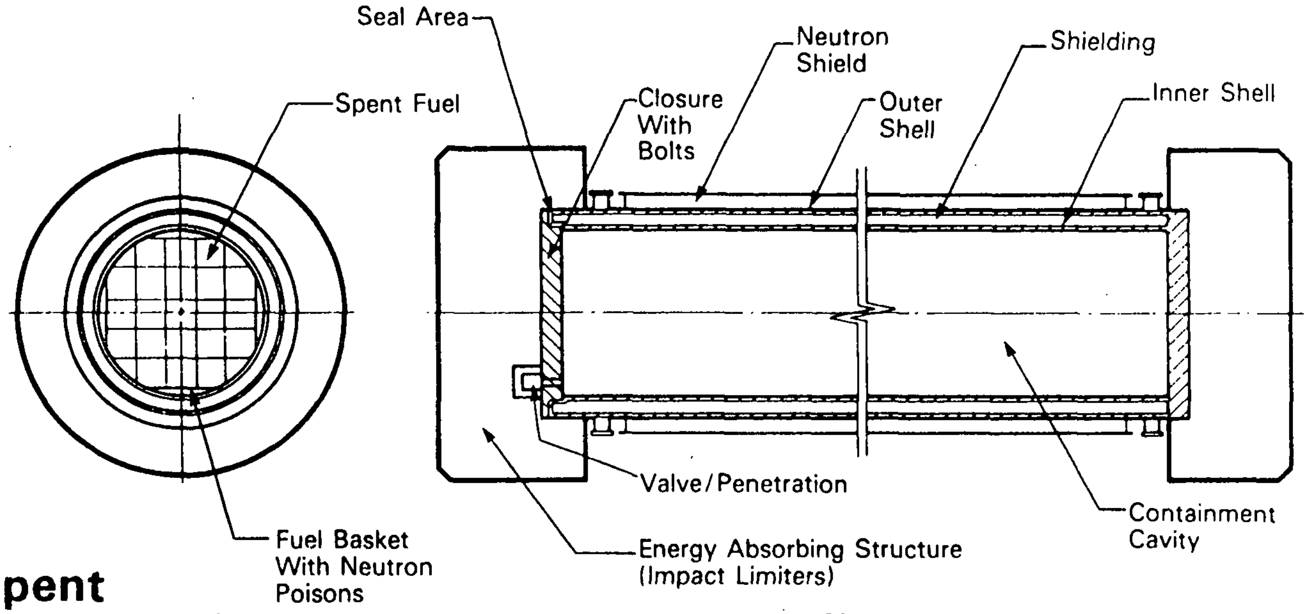
OVERALL OBJECTIVE

EVALUATE THE LEVEL OF SAFETY PROVIDED FOR U.S. SHIPMENTS OF COMMERCIALLY GENERATED SPENT FUEL – FOCUS ON TRANSPORTATION ACCIDENTS AND CONSIDER THE "NEAR FUTURE" INCREASES IN SPENT FUEL TRAFFIC.

GENERAL APPROACH

EVALUATE THE PERFORMANCE OF SPENT FUEL CASKS, LICENSED UNDER THE EXISTING REGULATORY REQUIREMENTS, WHEN SUBJECTED TO LOADINGS ASSOCIATED WITH TRANSPORTATION ACCIDENTS.


Accident Scenarios
● "Soft" Target Vis-a-Vis Spent Fuel Cask
● Velocity
● Impact Angle
● Object Surface
● No Fire or Fire
Cask Velocity
β
α
Object Surface
Impact Velocity
α = Impact Angle
β = Cask Orientation Angle



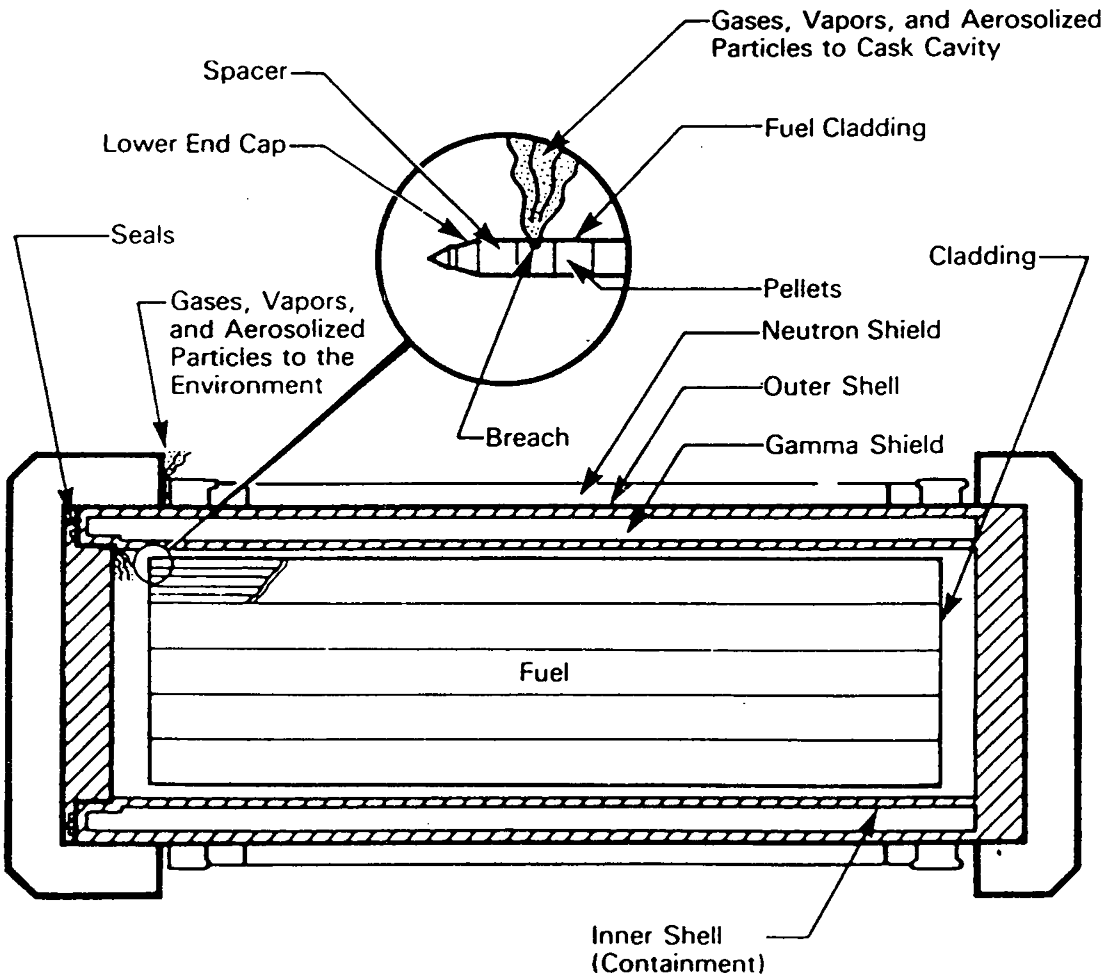
Schematic of Spent Fuel Cask

Typical Radioactive Material Release Pathway

Presumed if either:

(1) Cask containment vessel strain between 0.2 and 30 percent, or

(2) Centerline gamma shield temperature between 500°F and 1050°F

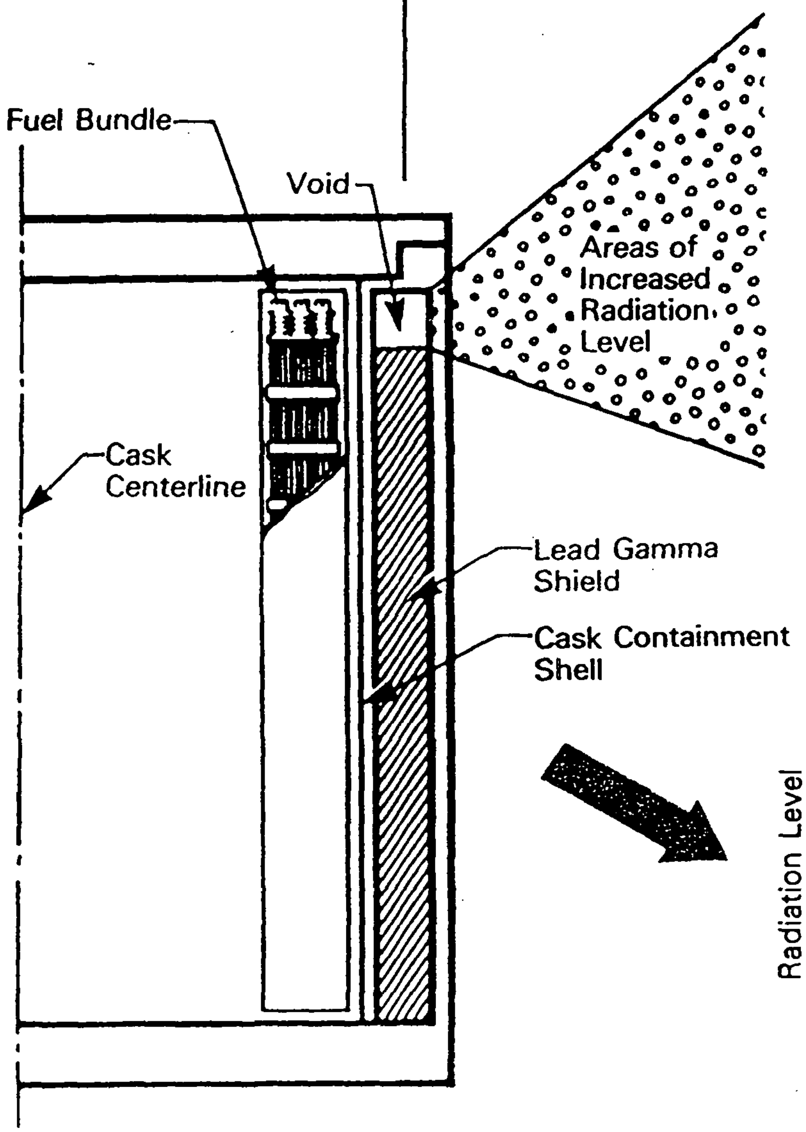


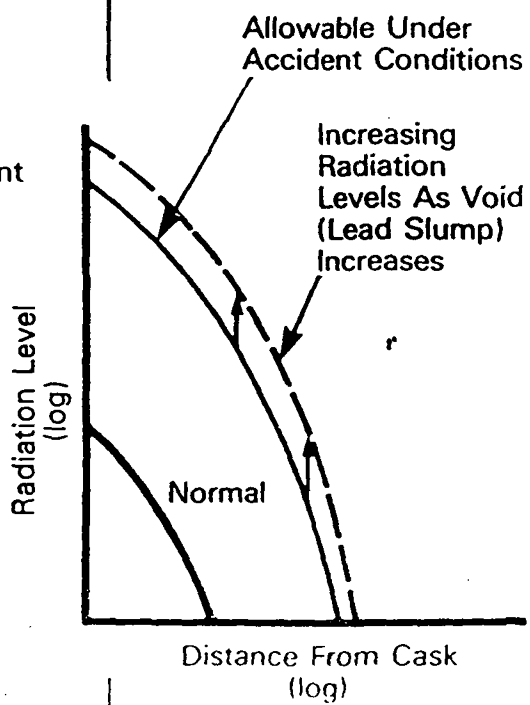
Typical Radiation Level Increase as a Result of Lead (Gamma Shield) Slumping

Presumed if either:

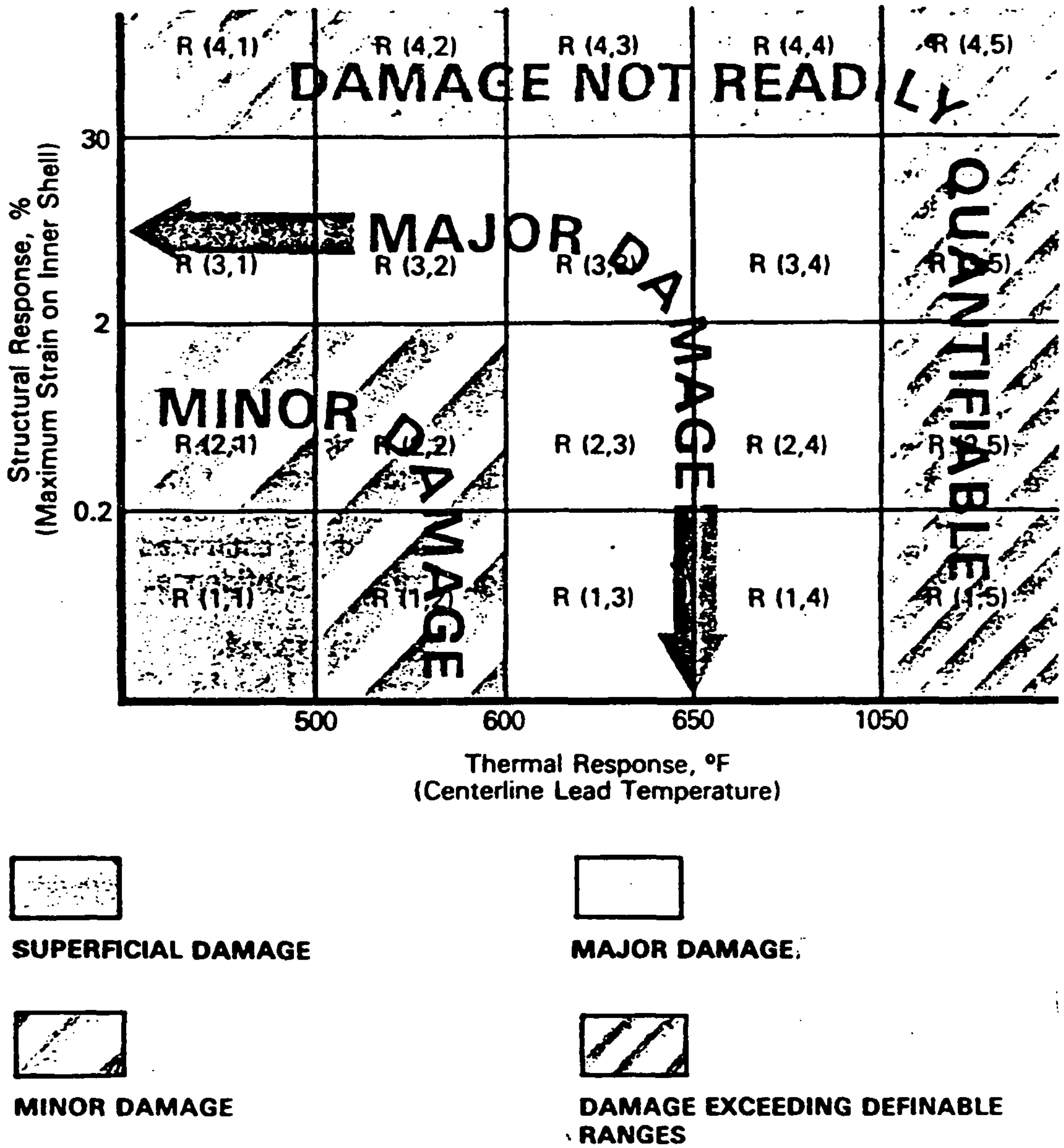
(1) Cask containment vessel strain exceeds 0.2 percent, or

(2) Centerline gamma shield (lead) temperature exceeds 600°F





Cask Response (Damage) Regions



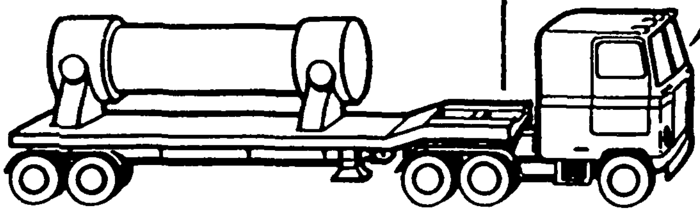
THREE PERSPECTIVES PROVIDED BY MODAL STUDY RESULTS

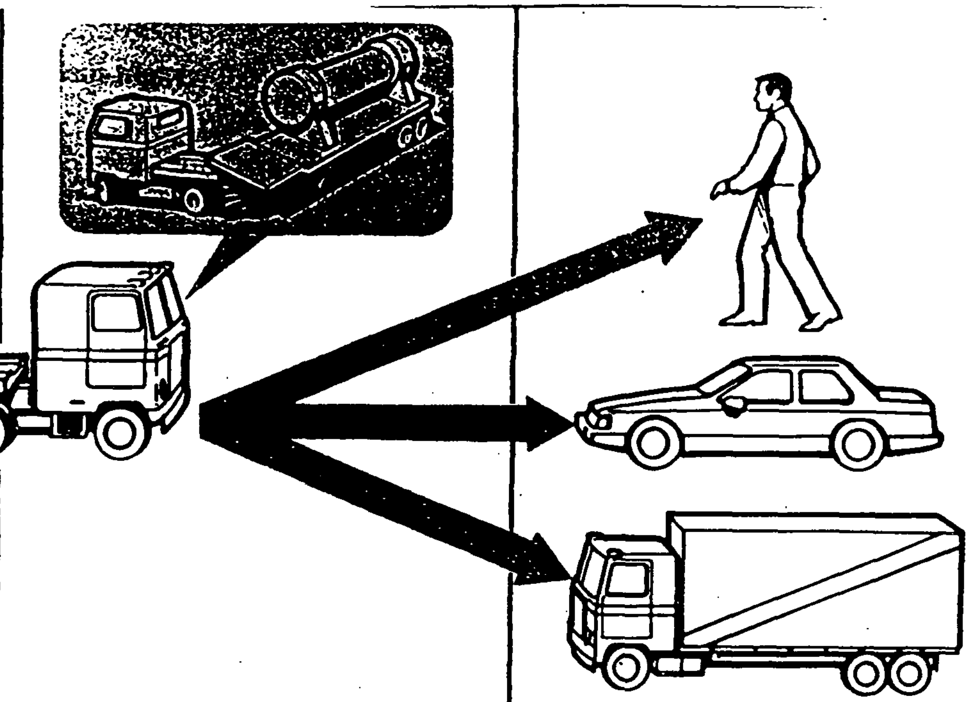
* ACCIDENT LIKELIHOODS PRESENTED IN TERMS WHICH COMPARE POTENTIAL FOR A RADIOLOGICAL HAZARD TO VALUES SPECIFIED IN CURRENT PACKAGE ACCEPTANCE CRITERIA

* TOTAL ANNUAL ACCIDENT RISK

* PROBABLE RESPONSE OF REPRESENTATIVE CASKS TO SEVERE ACCIDENTS ON RECORD

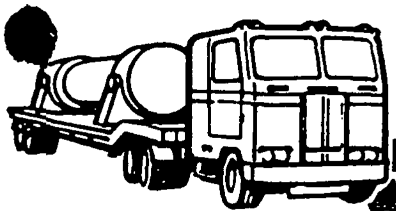
Accidents With No Expected Radiological Hazards

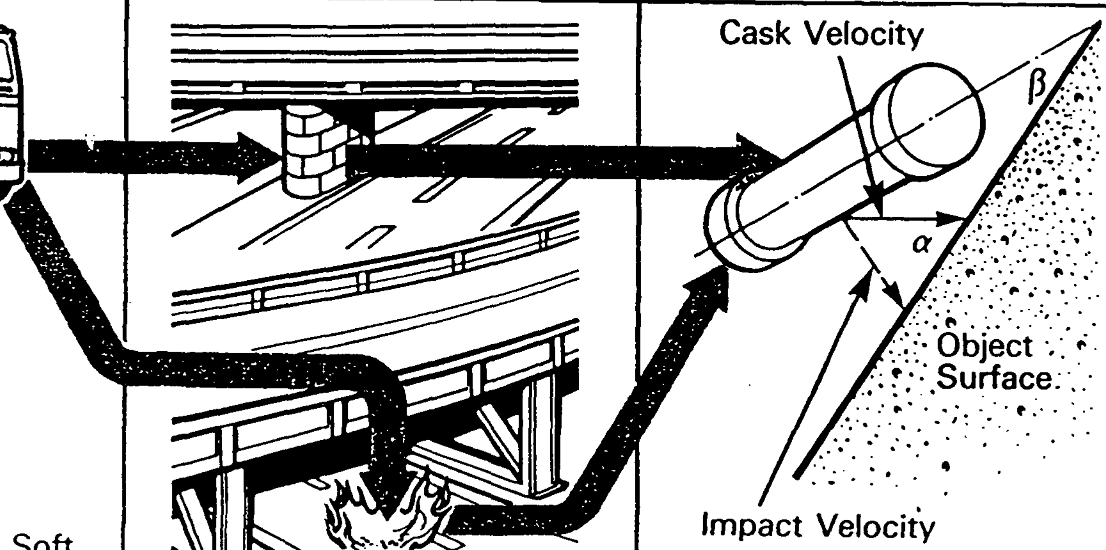




~950 of Every 1000 Accidents

- "Soft" Target Vis-a-Vis Spent Fuel Cask
- No Fire or Fire of Either Limited Extent, Temperature, or Duration





α = Impact Angle

β = Cask Orientation Angle

~44 of Remaining 50 Accidents

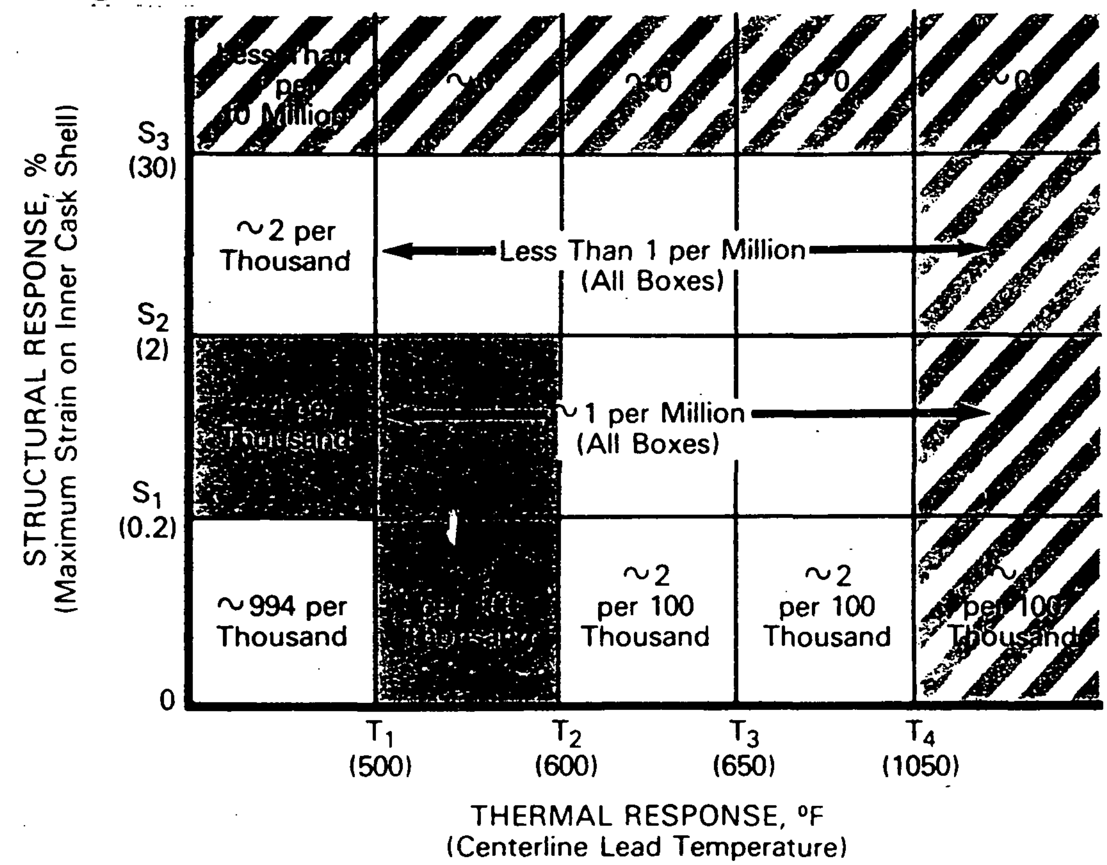
One or More of the Following Apply:

- Velocity Too Low
- Impact Angle Too Shallow
- Object Surface Too Soft
- No Fire or Fire of Either Limited Extent, Temperature, or Duration

Conclusion:

994 of Every 1000 Truck Accidents Generate Forces Incapable of Causing Cask Functional Damage.

Fraction of Truck Accidents Involving Spent Fuel Shipments that Cause Cask Responses Within Each Response Region



Predicted Cask Response to Selected Historical Accident Events

CALDECOTT TUNNEL FIRE - 4/82

- 3-Vehicle Collision — Gasoline Truck-Trailer, Bus and Automobile
- 8,800 Gallons of Gasoline
- Fire of 2 Hours and 42 Minutes - 40 Minutes • 1900°F

Predicted Cask Response

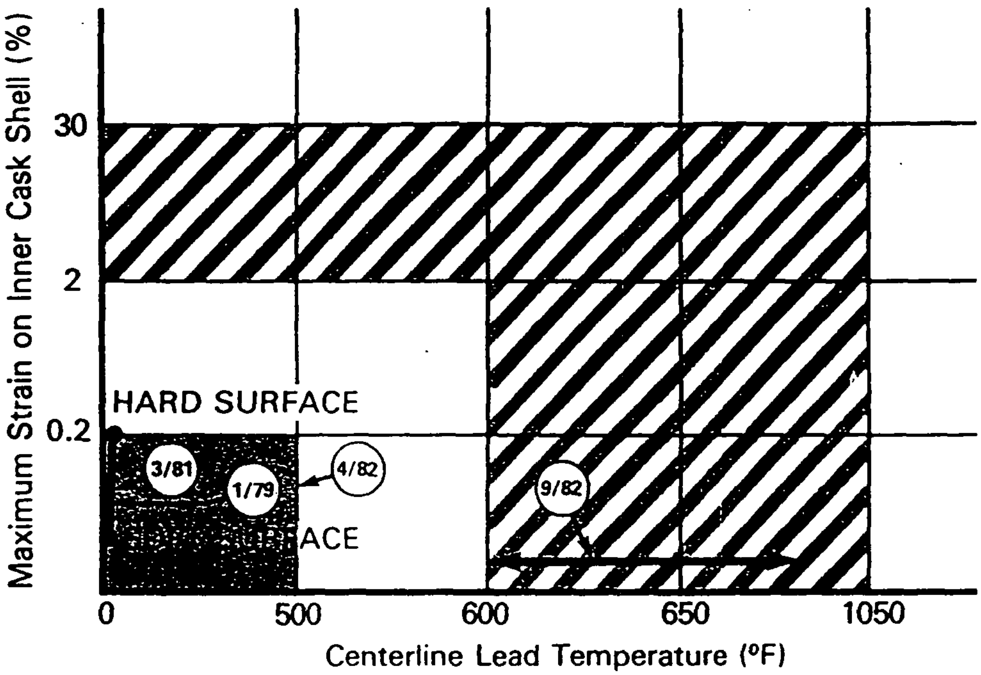
- No Significant Impact Damage - "Soft" Objects
- 45 Minutes • 1900°F Causes 500°F Centerline Temperature

I-80 BRIDGE ACCIDENT - 3/81

- Collision With Pickup Truck and Fall from 64-Foot High Bridge Onto Soil

Predicted Cask Response

- 44 mph Impact
- No Significant Impact Damage

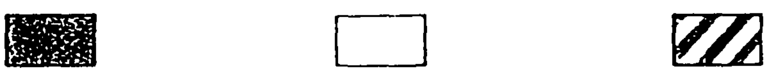


LIVINGSTON TRAIN FIRE - 9/82

- Derailment of Vinyl Chloride/ Petroleum Tank Cars
- Large Fires for Several Days Moved Over Large Area
- 2 Explosions

Predicted Cask Response

- Maximum Probable Cask Exposure to Petroleum Fire - Between 82 Hours and 4 Days
- No Significant Damage from Explosion
- Centerline Shield Temperature Between 600°F and 720°F Dependent on Degree of Cask Involvement



No Radiological Hazard | Radiological Hazard Approximates Compliance Values* | Radiological Hazard Exceeds Compliance Values By Up to a Factor of 4

DERAILMENT ON ALABAMA RIVER BRIDGE -1/79

- Plunge Off 75-Foot High Bridge
- Railcar Impacts Into Water and Mud

Predicted Cask Response

- 47 mph Impact in Soft Target
- No Significant Impact Damage

RISK RESULTS - COMPARISON WITH PAST FES EVALUATION

	FES (NUREG-0170) ESTIMATES	LLNL STUDY RESULTS
Fraction of Transportation Accidents Involving Spent Fuel Shipments Causing Any Radiological Hazard	0.09 (Truck) 0.20 (Rail)	0.006 (Truck) 0.006 (Rail)
Fraction of Transportation Accidents Involving Spent Fuel Shipments Causing Largest Estimated Radiological Hazard	0.004 (Truck) 0.002 (Rail)	0.00001 (Truck) 0.00013 (Rail)
Overall Annual Risk From Transportation Accidents Involving Spent Fuel Shipments	0.0004 Latent Cancer Fatalities Per Year	Less Than 1/3 of FES Value

NEW ISSUES

* NODULAR CAST IRON
* RECTANGULAR SHIPPING CASKS
* CREDIT FOR FUEL BURNUP

Barbiniq Loc. #9

NRC TRANSPORTATION EVENT RESPONSE

SOURCE: REPORTABLE EVENT DISCRIPTIONS COMPILED BY AEOD FOR 1985-1986

1985 : AEOD CHARACTERIZED 25 EVENTS AS TRANSPORTATION RELATED; 9 INVOLVED VEHICLE ACCIDENTS - OTHERS INCLUDED HANDLING DAMAGE, LEAKING PACKAGES, ETC.

* OF 25 EVENTS, 4 INVOLVED MATERIAL RELEASE; NRC (REGION IV) RESPONDED TO ONLY ONE (YELLOW CAKE TRUCK COLLISION WITH TRAIN IN NORTH DAKOTA)

1986 : 33 TRANSPORTATION EVENTS; 9 VEHICLE ACCIDENTS, 4 INVOLVED PACKAGES FALLING FROM VEHICLES, OTHERS INCLUDED HANDLING DAMAGE, THEFT OF VEHICLES, ETC.

* OF 33 EVENTS, 4 INVOLVED MATERIAL RELEASE; NRC DID NOT RESPOND TO ANY OF THESE EVENTS

Bechhoefer #10 2-7-2

ADEQUACY OF REGULATIONS

OFFICE OF TECHNOLOGY ASSESSMENT REPORT

* EXAMINED TRANSPORTATION OF HAZARDOUS MATERIAL

* CONCLUSIONS ON SPENT FUEL TRANSPORT :

  " NRC PERFORMANCE STANDARDS YIELD CASK DESIGN SPECIFICATIONS THAT PROVIDE A HIGH LEVEL OF PUBLIC PROTECTION, MUCH GREATER THAN AFFORDED IN ANY OTHER HAZARDOUS MATERIAL SHIPPING ACTIVITY. "

  " THE PROBABILITY OF AN ACCIDENT SEVERE ENOUGH TO CAUSE EXTENSIVE DAMAGE CAUSED BY RADIOLOGICAL RELEASE FROM A PROPERLY CONSTRUCTED CASK IS EXTREMELY REMOTE. "

Backup for #10 1032

ADEQUACY OF REGULATIONS

NUREG – 0170

BASED ON:

* INFORMATION DEVELOPED
* PUBLIC COMMENT RECEIVED
* SAFETY RECORD

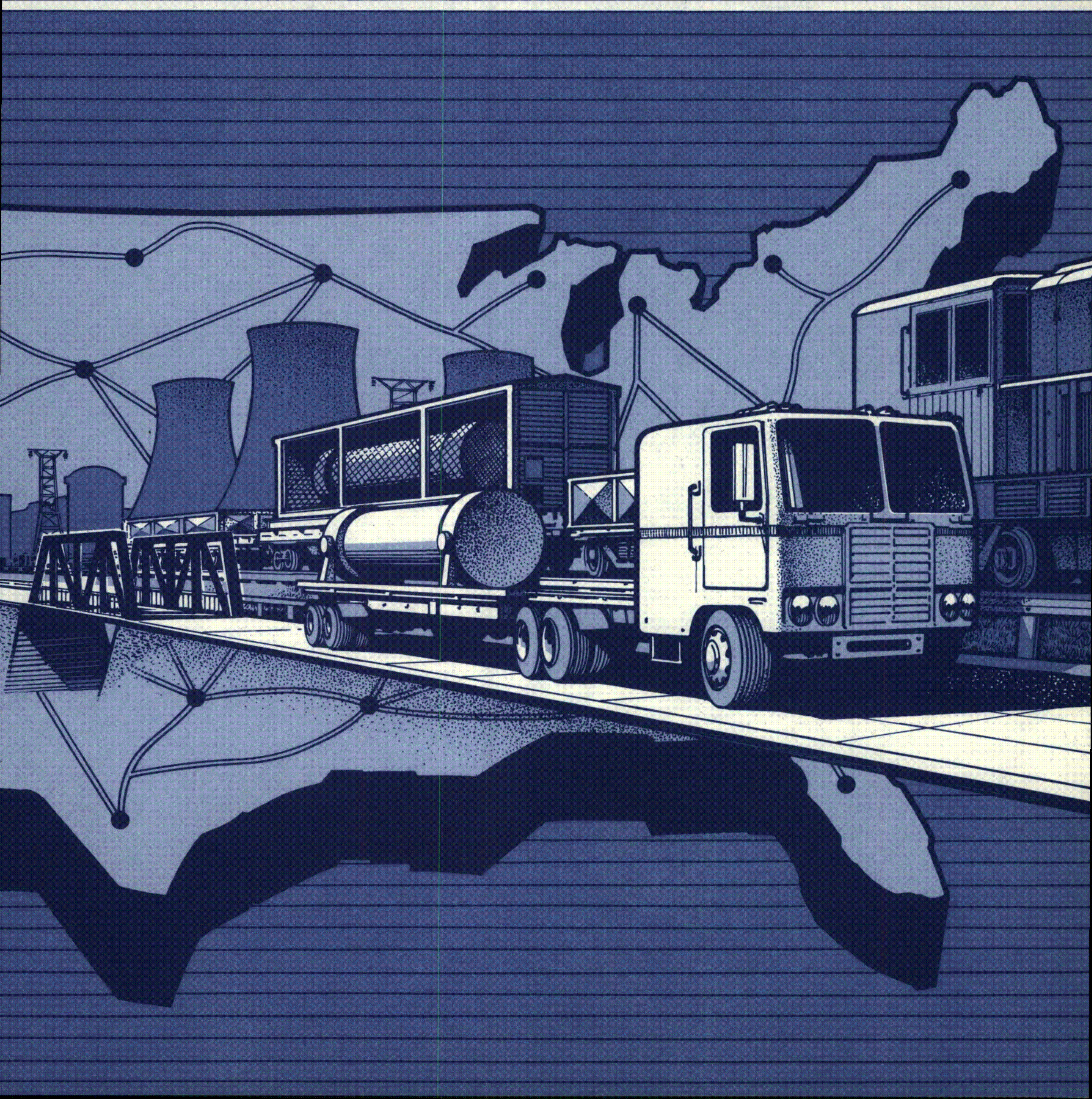
THE COMMISSION CONCLUDED THAT:

PRESENT REGULATION PROVIDES A REASONABLE DEGREE OF SAFETY AND THAT NO IMMEDIATE CHANGES ARE NEEDED TO IMPROVE SAFETY (46 FR 21219)

U.S. NUCLEAR
REGULATORY
COMMISSION

Transporting Spent Fuel

Protection Provided Against Severe Highway and Railroad Accidents



J.S. NUCLEAR
REGULATORY
COMMISSION

Transporting Spent Fuel

Protection Provided Against Severe Highway and Railroad Accidents

March 1987

Author: William R. Lahs

Division of Regulatory Applications
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

TABLE OF CONTENTS

INTRODUCTION

This report summarizes the results of a study conducted for the Nuclear Regulatory Commission (NRC) to determine the level of safety provided during shipments of spent fuel from U.S commercial nuclear power plants. The study focuses on the protection provided for shipments that may be involved in truck or railroad accidents.

During shipment, the cask and the form and structure of the spent fuel being shipped provide the primary physical means for containing radioactivity and for limiting radiation levels outside the cask. These functions must be maintained at acceptable levels even under the wide range of forces the cask and fuel could be subjected to during an accident.

Spent fuel shipments are regulated by both the Department of Transportation (DOT) and the NRC. The NRC evaluates and certifies the design of the shipping casks used to transport spent fuel, while DOT regulates vehicles and drivers.

Current NRC regulations require that shipping casks meet certain performance standards. The performance standards include normal operating conditions and hypothetical accident conditions a cask must be capable of withstanding without exceeding specified acceptance criteria that (1) limit releases of radioactive material and radiation levels outside the cask and (2) assure that the spent fuel will remain subcritical (that is will *not* undergo a self-sustaining nuclear reaction).

The study, conducted by Lawrence Livermore National Laboratory (LLNL),* began with an assessment of the possible mechanical and/or thermal forces generated by actual truck and railroad transportation accidents. The magnitudes of forces from actual accidents were compared with forces attributed to the "regulatory-defined" hypothetical accident conditions. The frequency of the accidents that can produce defined levels of thermal or mechanical forces was also developed. With this information, the study results show that for certain broad classes of accidents, spent fuel casks provide essentially complete protection against radiological hazards. For extremely severe accidents, those that could conceivably impose forces on the cask greater than those implied by the hypothetical accident conditions, the likelihood and magnitude of any radiological hazard were conservatively calculated. The study also contains an evaluation of the radiological risk from transportation accidents. Risk represents the summation of the products of the magnitude and likelihood of all accident outcomes. The purpose for making the risk calculations was to compare the resulting values with those previously used by NRC in judging the adequacy of its regulations.

The purpose of this summary, prepared by the NRC staff, is to present the results of the LLNL study to a broad range of readers who may possess varying degrees of knowledge on the technical subjects covered in the LLNL technical report. As a result, this summary focuses on the overall approach and major results of the study. Although this summary describes many important assumptions and insights, a complete understanding of the scope and meaning of the LLNL work would require, as a minimum, frequent reference to the main LLNL report and its supporting appendices.

For the reader interested solely in the results of the LLNL study, the figure on the next page, the foldout on page 29, and the discussion under "Summary of Objective and Results" should be consulted. Readers wishing to understand the logic of the approach and the basis for major assumptions should refer to the main body of this summary report, which presents a step-by-step explanation of the separate tasks required to meet the study's objectives.

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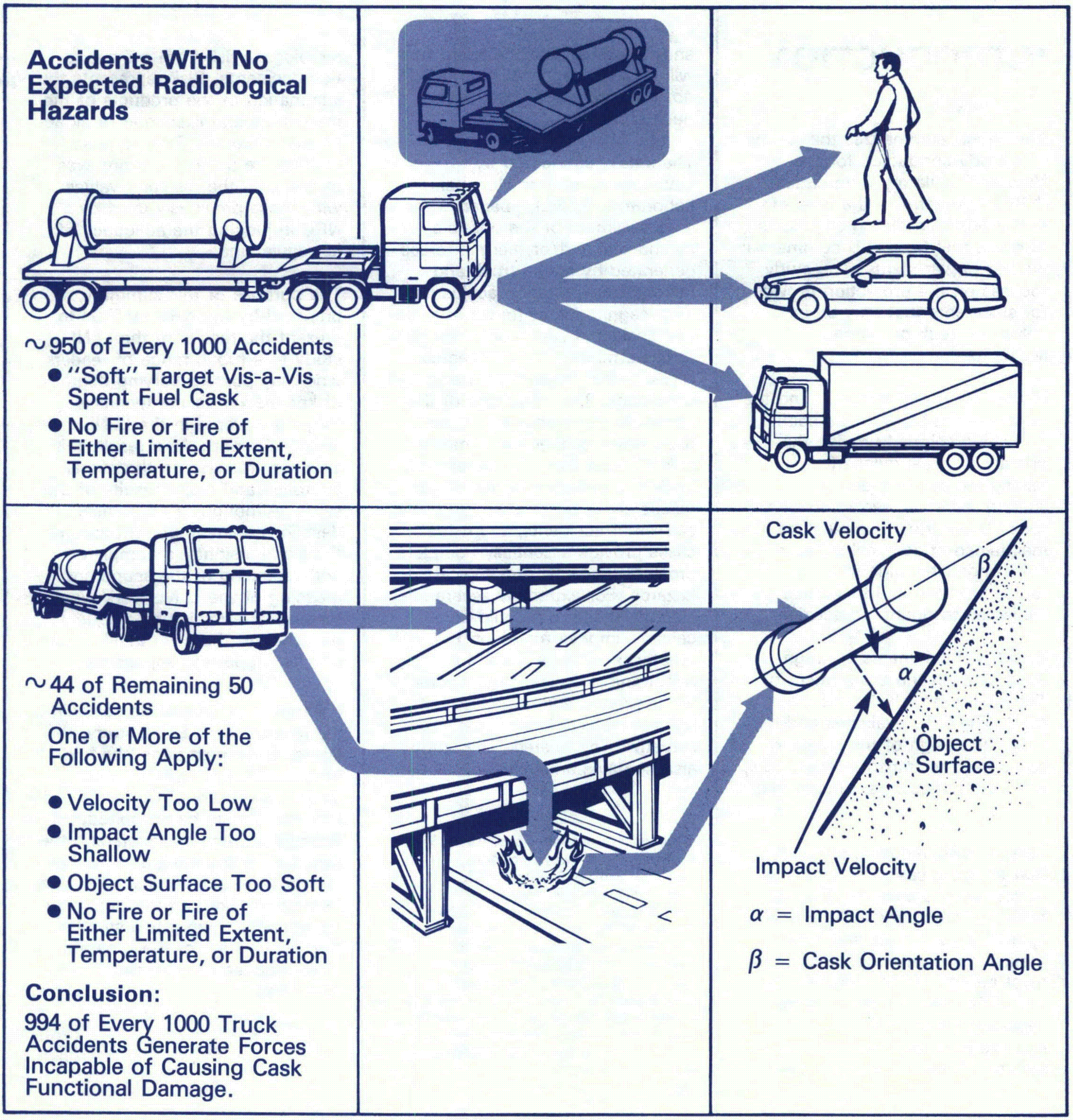
* "Shipping Container Response to Severe Highway and Railway Accidents," NUREG/CR-4829, February 1987. This report underwent peer review by the Denver Research Institute. The LLNL report and documentation resulting from peer review are available for inspection and copying at the NRC Public Document Room, 1717 H Street, NW, Washington, D.C. Formal NRC reports are available for purchase through the Superintendent of Documents, U.S. Government Printing Office, Post Office Box 37082, Washington, D.C. 20013-7082.

OVERVIEW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Cask Velocity
β
α
Object Surface
Impact Velocity
α = Impact Angle
β = Cask Orientation Angle

Summary of Objective and Results

The objective of this study was to characterize the level of safety for commercial spent nuclear fuel shipments should they become involved in severe transportation accidents. Researchers evaluated a broad spectrum of severe, historically documented, truck and rail accidents that caused death, injury, or significant property damage and assessed the minimal level of performance that should be achieved by NRC-licensed spent fuel shipping casks. The results, illustrated in the figure on the opposite page, indicate that no radiological hazard would be expected in at least 994 of every 1000 severe transportation accidents. In only about one accident every 40 million shipment miles (or once every 13 years assuming 3 million shipment miles per year) would minor functional cask damage be expected. If any radiological hazards were created, their magnitude would be expected to be less than currently-defined compliance values in existing regulation. In only about one accident every 80 million shipment miles could cask damage be significant enough to cause a radiological hazard which could equal or slightly exceed existing compliance values.

The data from documented severe accidents had to be extrapolated to characterize extremely severe accidents for which experience provided no models. This process led to the finding that in about 1 in 100,000 truck accidents and 1 in 10,000 rail accidents, extensive damage to cask and fuel could occur. In these situations, engineering judgment was used to conservatively estimate the resulting radiological hazard; however, predictions made under such unlikely accident conditions are subject to uncertainty.

In an attempt to gauge this uncertainty, the study assessed the potential for a radiological hazard in extremely severe accidents by assuming that a spent fuel shipping cask with minimally acceptable capabilities was involved in the four documented severe accidents shown on page 29. The most likely outcome in three of these four accidents would be minor or superficial damage to the cask and no radiological hazard. In the fourth, and under some circumstances in two of the three previous accidents, a radiological hazard could occur. Its magnitude would be less than or comparable to the hazard implied by compliance values in existing NRC regulations.

As a final point of reference, the risk of spent fuel shipments was evaluated and compared with previous estimates used in assessing the adequacy of existing regulations. The resulting risk level was less than one-third of past estimates.

BACKGROUND

Over the last 10 years, thousands of shipments of commercially generated spent nuclear fuel have been made throughout the United States without causing any adverse radiological consequence to members of the public. In the near future, the number of these shipments is expected to increase. More than 40,000 spent fuel assemblies have been used at nuclear power plants in the United States and are currently being stored in underwater "fuel pools" at these sites. Under the terms of the Nuclear Waste Policy Act (NWPA) of 1982, these spent fuel assemblies will be placed in a Federal Repository for permanent storage beginning in 1998. Shipments from reactor sites to the Repository for ultimate disposition will require increased rail and road movement of spent fuel.

In part, because of the projected increase in the number of spent fuel shipments, the U.S. Nuclear Regulatory Commission (NRC) decided to reassess the level of safety provided by casks designed to existing regulations.

In large measure, the safety associated with spent fuel shipments, especially in the event of a transportation accident, is provided by the casks that contain the spent fuel during shipment. These casks must meet performance requirements specified in the *Code of Federal Regulations* (10 CFR 71) and their design must be certified by the U.S. Nuclear Regulatory Commission.

OVERVIEW

Other elements of safety are provided by the Department of Transportation's operating requirements for vehicles and drivers. These operating requirements are defined under Title 49 of the *Code of Federal Regulations*.

What Is Spent Nuclear Fuel?

Spent nuclear fuel refers to uranium-bearing fuel elements that have been used at commercial nuclear power reactors. This spent (used) fuel contains radioactive material resulting from the fission process that takes place within the reactor. The radioactive material is formed within ceramic fuel pellets about the diameter of an aspirin tablet but twice as thick. These pellets are contained in 15-foot-long sealed metal tubes or rods—a few hundred per rod. From about 50 to 400 of these rods are grouped in a square array to form a spent fuel assembly.

When spent fuel is removed from the reactor, the self-sustaining fission process has stopped; however, spent fuel assemblies still generate significant amounts of radiation and heat. This heat and radiation are caused by the "radioactive decay" of the products of the fission process. The actual material emitting the radiation is, for the most part, still contained within the ceramic fuel pellet. Some material, however, mainly in gaseous or volatile form, can leave the pellet. This material is normally contained within the metal fuel rods that surround the pellets.

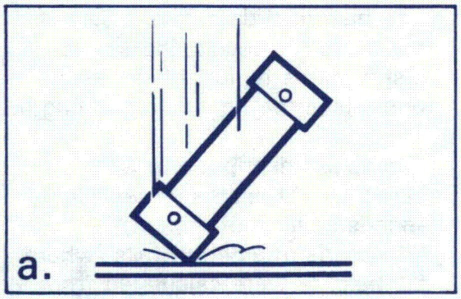
The heat and radioactivity in spent fuel necessitates that any shipment be made in containers or casks that provide the necessary degree of public protection. In practice, this means a cask must shield and contain the radioactivity and dissipate the generated heat.

How Is Safety Achieved?

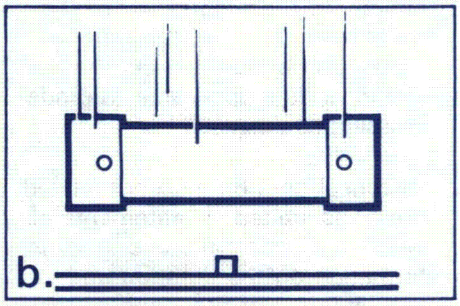
Safety in the shipment of spent nuclear fuel is achieved by a combination of factors including the physical properties of the spent fuel itself, the ruggedness of the container or cask containing the fuel, and the operating procedures and controls applicable to both the cask and the vehicle transporting the cask. If a transportation accident should occur, safety is primarily assured by the integrity of the spent fuel shipping cask. The design of all casks used to ship commercially generated fuel in the United States must meet performance-oriented requirements specified in Federal and international regulations. The performance requirements include the definition of a series of "hypothetical accident conditions," described on the opposite page. All licensed casks must be capable of withstanding the mechanical and thermal loadings imposed by these conditions and still meet specified acceptance criteria.

These acceptance criteria include: (1) stringent limits on both the maximum allowable release of radioactive material and the radiation levels outside of a cask and (2) requirements regarding cask configurations which assure that subcriticality of the spent fuel is maintained.

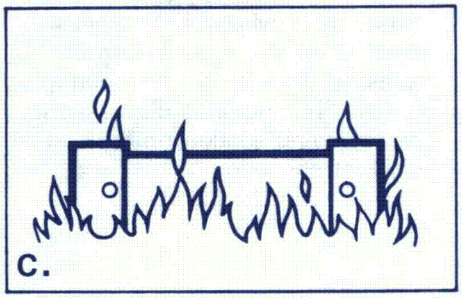
In practice, NRC verifies conformance with these acceptance criteria by analyses demonstrating that essentially no permanent deformations or excessive temperatures occur within a cask's containment shell following the sequentially applied loadings imposed by hypothetical accident conditions. Demonstrations that casks can withstand these conditions, coupled with information about cask designs and construction materials, suggests that casks should be capable of withstanding far greater mechanical and thermal loadings during an accident than those caused by hypothetical accident conditions without causing any significant radiological hazard. The LLNL quantifies this capability through two supporting analytical assessments. The first identifies actual documented accidents in which mechanical and thermal loads would be less than those implied by the hypothetical accident conditions. The second identifies accidents (and their likelihood of occurrence) in which loads could exceed those specified in the regulations and evaluates the capability of a cask to continue to function safely under such conditions.



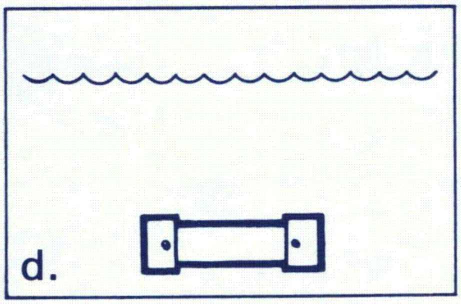
a.



b.



c.



d.

Standards for Spent Fuel Casks

For certification by the NRC, a cask must be shown by test or analysis to withstand a series of accident conditions. These conditions have been internationally accepted as simulating damage to spent fuel casks that could occur in most severe credible accidents. The impact, fire, and water-immersion tests are considered in sequence to determine their cumulative effects on one package. A separate cask is subjected to a deep water-immersion test. The details of the tests are as follows:

Impact

Free Drop (a) — The cask drops 30 feet onto a flat, horizontal, unyielding surface so that it strikes at its weakest point.

Puncture (b) — The cask drops 40 inches onto a 6-inch-diameter steel bar at least 8 inches long; the bar strikes the cask at its most vulnerable spot.

Fire (c)

After the impact tests, the cask is totally engulfed in a 1475°F thermal environment for 30 minutes.

Water Immersion (d)

The cask is completely submerged under at least 3 feet of water for 8 hours. A separate cask is completely immersed under 50 feet of water for 8 hours.

Insights on the Safety Provided by Typical Spent Fuel Shipping Casks

Over the last decade, considerable experimental and analytical evidence has been gathered to provide insights into the safety provided by spent fuel shipping casks. The most dramatic evidence has involved full-scale crash tests carried out both in this country and in Great Britain. Trucks and rail cars carrying casks have been run head-on into massive concrete barriers at speeds from 60 to over 80 mph. Casks have also been struck by locomotives travelling at 100 mph and have been immersed in fires in which temperatures have been deliberately kept high. In all tests, the resulting cask damage ranged from superficial to very minor. These results certainly attest to the overall ruggedness of the casks tested and the general integrity of their design. From an analytical standpoint, the most notable effort to provide insights into the safety of spent fuel shipments involved the preparation of a generic environmental statement on the shipment of all radioactive materials, including spent fuel.* This study included an evaluation of the risks from transportation accidents involving shipments of radioactive material. Risk is a measure that multiplies all potential radiological hazards by

* "Transportation of Radioactive Material By Air and Other Modes," NUREG-0170, December 1977.

their individual likelihood of occurrence and sums the results. The risk associated with all radioactive material shipments was so small that the Nuclear Regulatory Commission judged that its regulations regarding the packaging of these materials were adequate and not in need of immediate change. The Commission did call for continuing efforts to further understand the hazards and risks posed by the transportation of radioactive material. The LLNL study is one result of that effort.

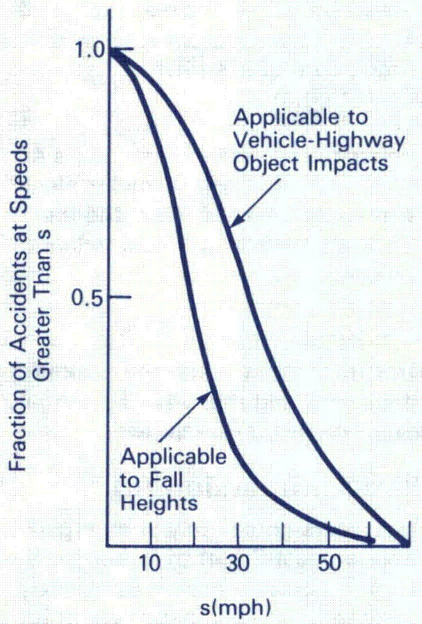
Accident Scenarios

Spent fuel shipments could be subjected to a variety of transportation accident situations or scenarios. Identifying these potential scenarios began with the historical data from typical truck accidents that involved deaths and injuries or those that exceeded certain levels of property damage. Data from minor accidents (e.g., fender benders) were excluded.

Highway

Most of the information on the likelihood of single and multi-vehicle accidents in the figure on the opposite page is based on historical data. The solid lines show accident scenarios derived from the historical data whereas the dashed extrapolations consider the potential effects of cask impacts with a variety of hard objects or surfaces. Impacts with these types of objects or surfaces have the greatest potential for causing damage. The extrapolation was made by merging documented accident data with statistical data representing highway terrain and adjacent structures. This data was obtained from recorded information and by surveying hundreds of miles of typical interstate highway to determine how frequently surfaces and objects such as large bridge columns or hard rock surfaces occur. Most spent fuel shipments will be made over such interstates.

TRUCK ACCIDENT SPEEDS



The historical data also provided the basis for developing speed distributions typical of the accidents (see the figure on this page).

The speed distributions were based on (1) estimated vehicle speeds at time of impact; (2) speeds attained in falls (where fall heights were calculated from a survey of bridge heights along interstate highways); or (3) combinations of these speeds. For the truck-train scenario, the train speed distribution reflects the historical data applicable to grade-crossing accidents.

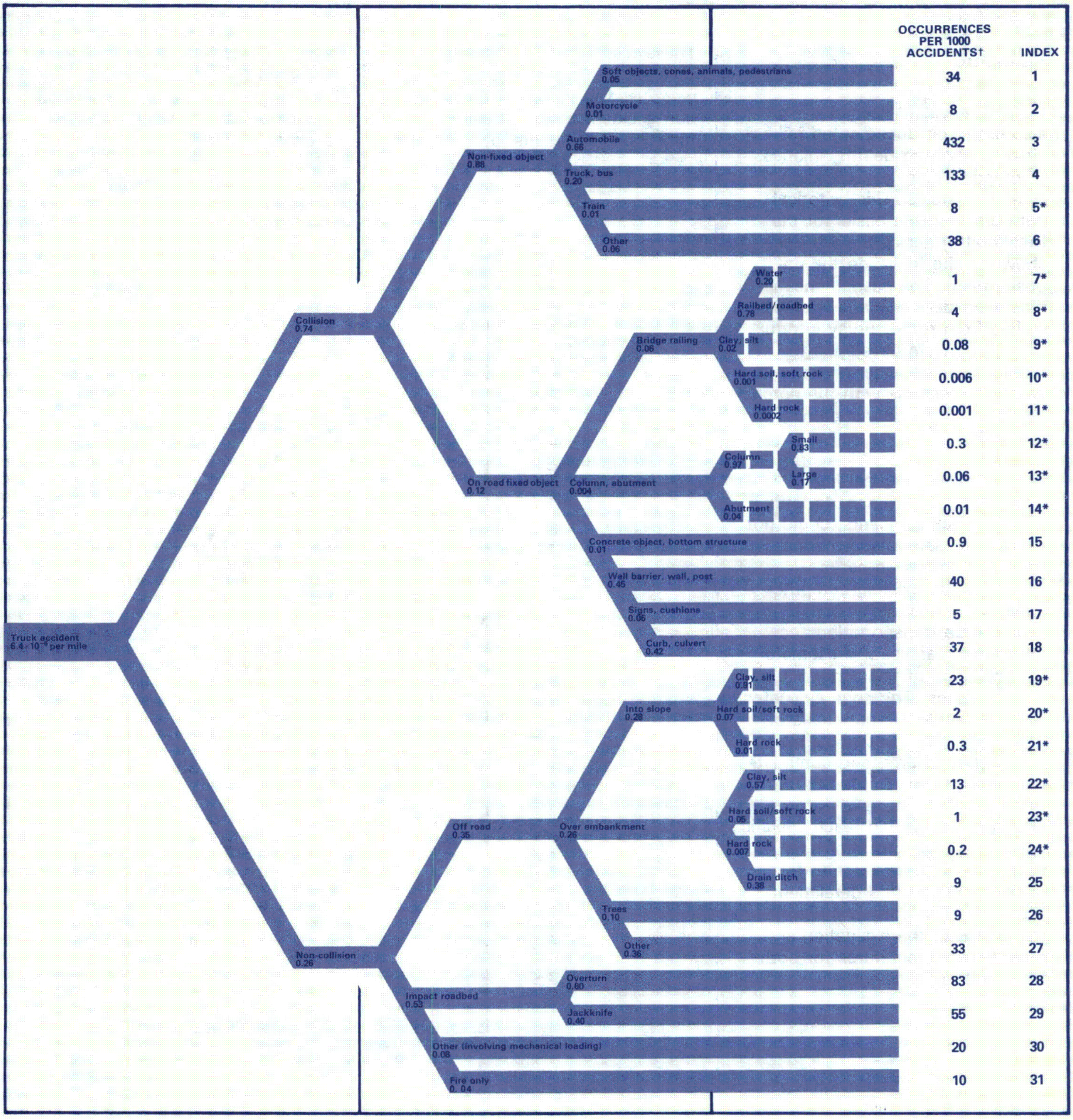
Historical data on accident-related fires was limited to statements of whether or not a fire occurred. Information on the duration and temperatures of fires, and of their location with respect to a vehicle's cargo was extremely sparse. As a result, the environments typical of accident-related fires had to be assessed through an engineering model. This model is discussed in the following section on railroad accident scenarios.

Occurrence Rates for Truck Accident Scenarios

† Rounded values

* Accident sequences subsequently shown to have the most likely possibility of causing cask damage

■■ Developed extensions of historical scenario data



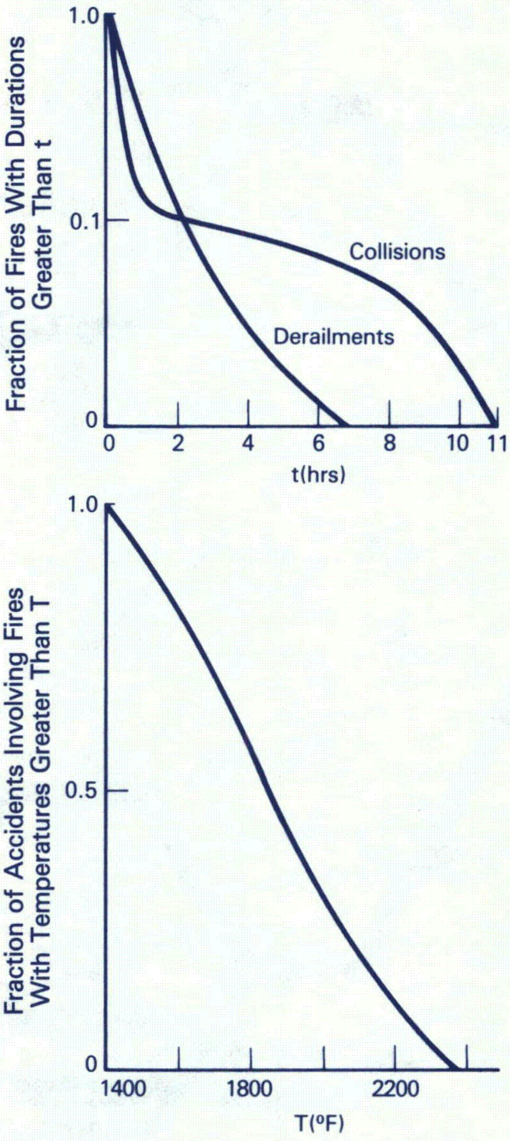
Railroad

Railroad accident scenarios were also based on documented rail accidents involving deaths, injuries, or property damage exceeding small thresholds. This historical data provided the bases for the likelihood of accident scenarios shown in the figure on the opposite page. The dashed lines indicate accident scenarios derived mainly from route survey information. They were developed to more accurately determine the types of accidents with the potential to cause functional damage to the cask.

The available historical fire-accident data, pertinent to both rail and truck accidents, could not be used to determine potential thermal loadings on casks. Therefore, an existing computer code, previously developed to characterize transportation accident fires, was used to estimate the likelihood of fire temperatures and durations. The code evaluated data on accident type, cause of fire, availability of combustibles, fire-fighting efforts, and combustible burning rates to predict the likelihood that fire temperatures and durations would reach specific values. The top graph on this page shows this evaluation for railroad collision and derailment accidents. The bottom graph gives the results of the evaluation applicable to temperatures for both truck and rail accidents.

These results, which included several conservative assumptions, were used to represent transportation accident fires. For example, for railroad accidents involving collisions, about 10% of all fires were estimated to last longer than 2 hours. Temperatures in over half of such accidents were estimated to exceed 1800°F.

FIRE DURATIONS AND TEMPERATURES



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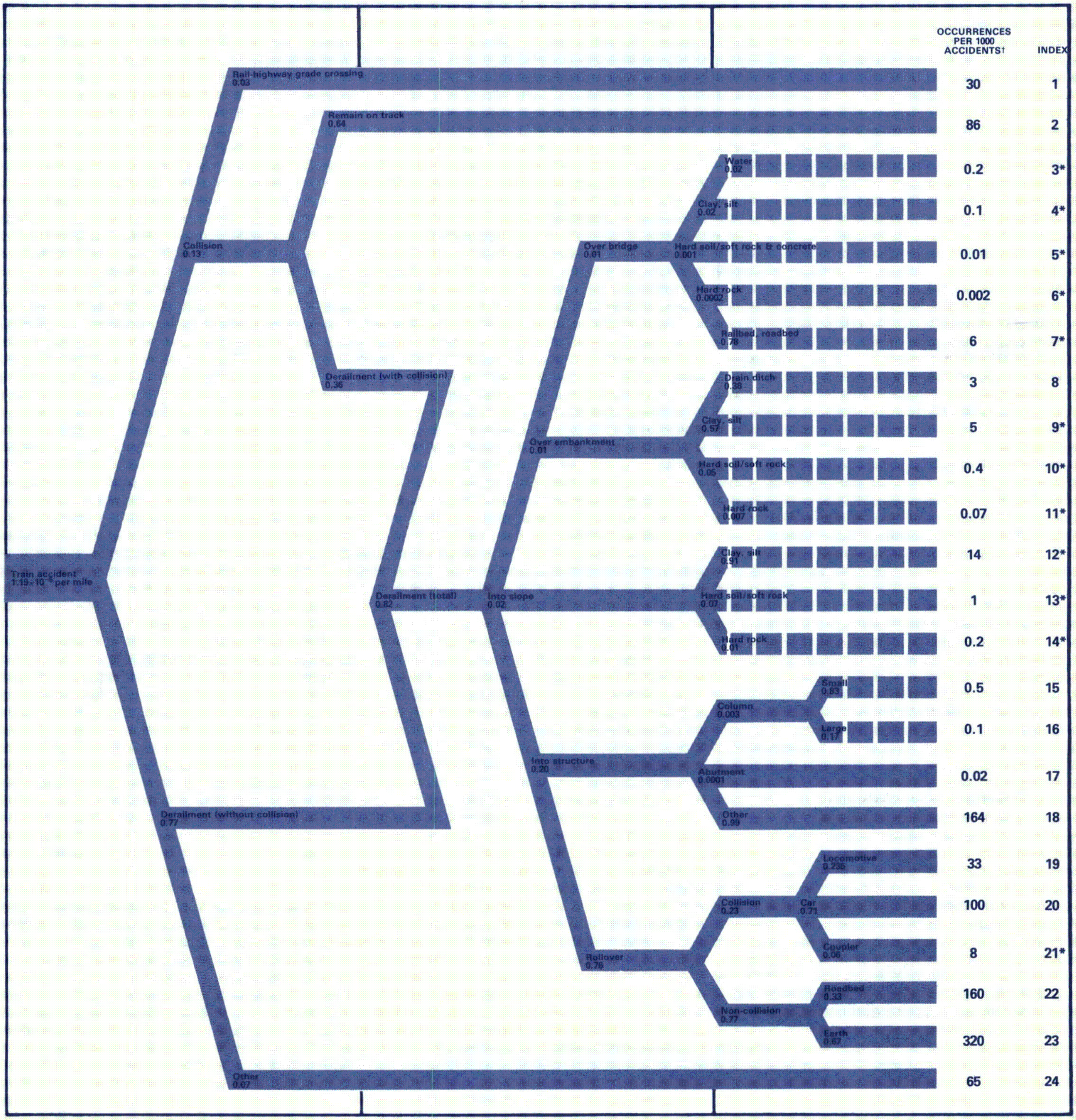
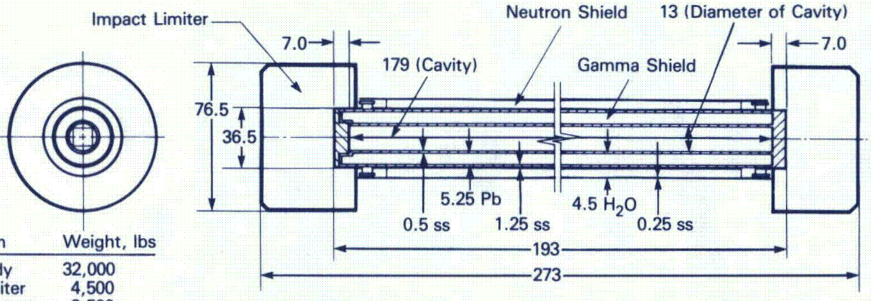


CASK CHARACTERISTICS AND RESPONSES

Can Cask Safety Be Characterized in Real-World Accidents?

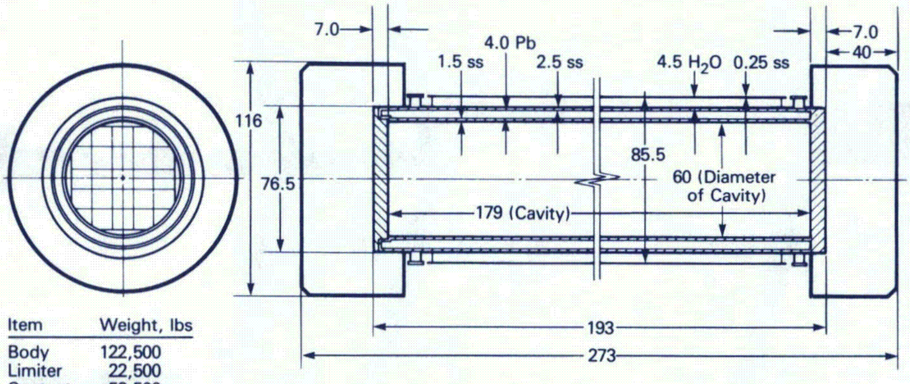
This question was critical to the credibility of the LLNL study. The answer was "Yes." An approach to the problem could be followed to allow fair characterization of the minimal level of safety that would be meaningful to an assessment of the adequacy of existing regulatory requirements. The first step taken in this approach was to define two representative cask designs—one for truck shipments and one for rail shipments. In both cases, the casks were designed to just meet "regulatory" acceptance criteria following an accident with mechanical, thermal, and water-immersion accident conditions depicted on page 5. The cask designs included only those features absolutely necessary to determine a cask's ability to achieve its primary safety functions. (These safety functions and the cask features that achieve these functions are discussed briefly on pages 11 through 13.)

Representative Designs for Truck and Rail Casks



Item	Weight, lbs
Body	32,000
Limiter	4,500
Contents	2,500
	39,000

TRUCK CASK



Item	Weight, lbs
Body	122,500
Limiter	22,500
Contents	52,500
	197,000

RAIL CASK

All Dimensions in Inches

ss = Stainless Steel
Pb = Lead
H_2O = Water

Note:
The representative truck and rail casks consist of stainless steel cylindrical shells that enclose a ring of lead shielding material. A water jacket surrounds this cylindrical structure. At each end of the cask, an "impact limiter" is provided to protect the cask against impact forces.

CASK CHARACTERISTICS AND RESPONSES

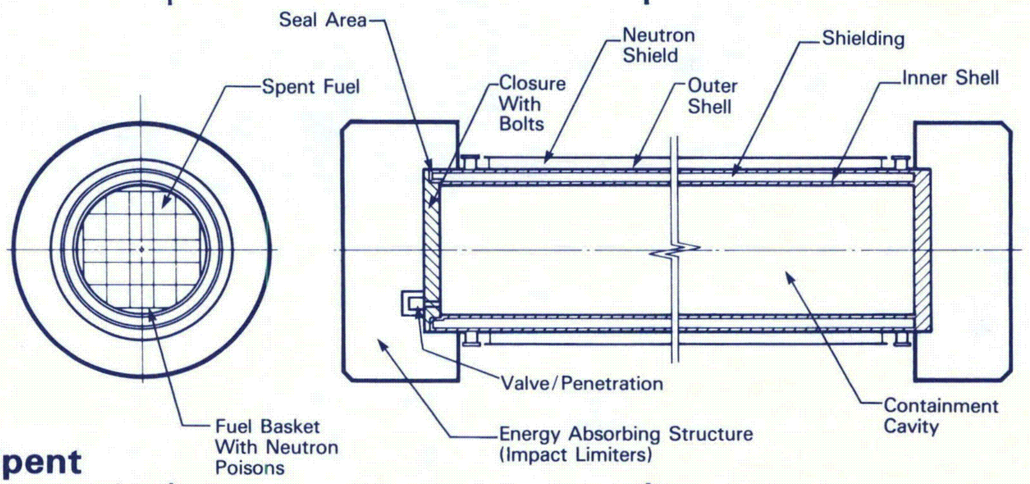
Once these representative cask designs were defined, they were subjected to the most damaging accident scenarios identified on pages 6 through 9 to determine their structural response. By measuring structural response, researchers estimated their potential for a radiological hazard. If the potential existed, the magnitude of the radiological hazard was conservatively evaluated. Through this process, that fraction of severe rail and truck accidents capable of causing a specified radiological hazard was estimated. The radiological hazard was then compared with compliance criteria in existing NRC regulations.

As an additional point of reference, the radiological risk of shipping commercial spent fuel was compared to documented estimates used by the NRC in making its past judgment on the adequacy of existing regulations (see insert on page 5).

Cask Safety Functions and Representative Cask Design Features

The primary cask safety functions include: (1) containment of radioactive material, (2) shielding against the radiation emanating from the spent fuel, and (3) assurance that subcriticality of the fuel is maintained.

Containment is achieved by retaining the radioactive material within a closed vessel. Typically, containment is provided by the integrity of the spent fuel cladding and by the cylindrical steel containment vessel or inner cask shell (see figure below). The vessel is provided with a bolted-end closure to permit loading and unloading. The closure contains a seal between the cask cavity and the environment that prevents leakage. Piping penetrations, which terminate in protected enclosures, are also provided for operational purposes. The required containment safety function is achieved by these features. Furthermore, the successful functioning of these features is promoted by (1) an externally located, energy-absorbing structure designed to protect the cask against impacts, and (2) the integration of the containment features into an overall cask design that maximizes protection provided against outside forces. In defining a representative cask, the complexities associated with various designs for containment closures, penetrations, and seals were not modeled. The failure of these features was assumed if the containment or inner shell was calculated to incur any significant permanent structural damage.

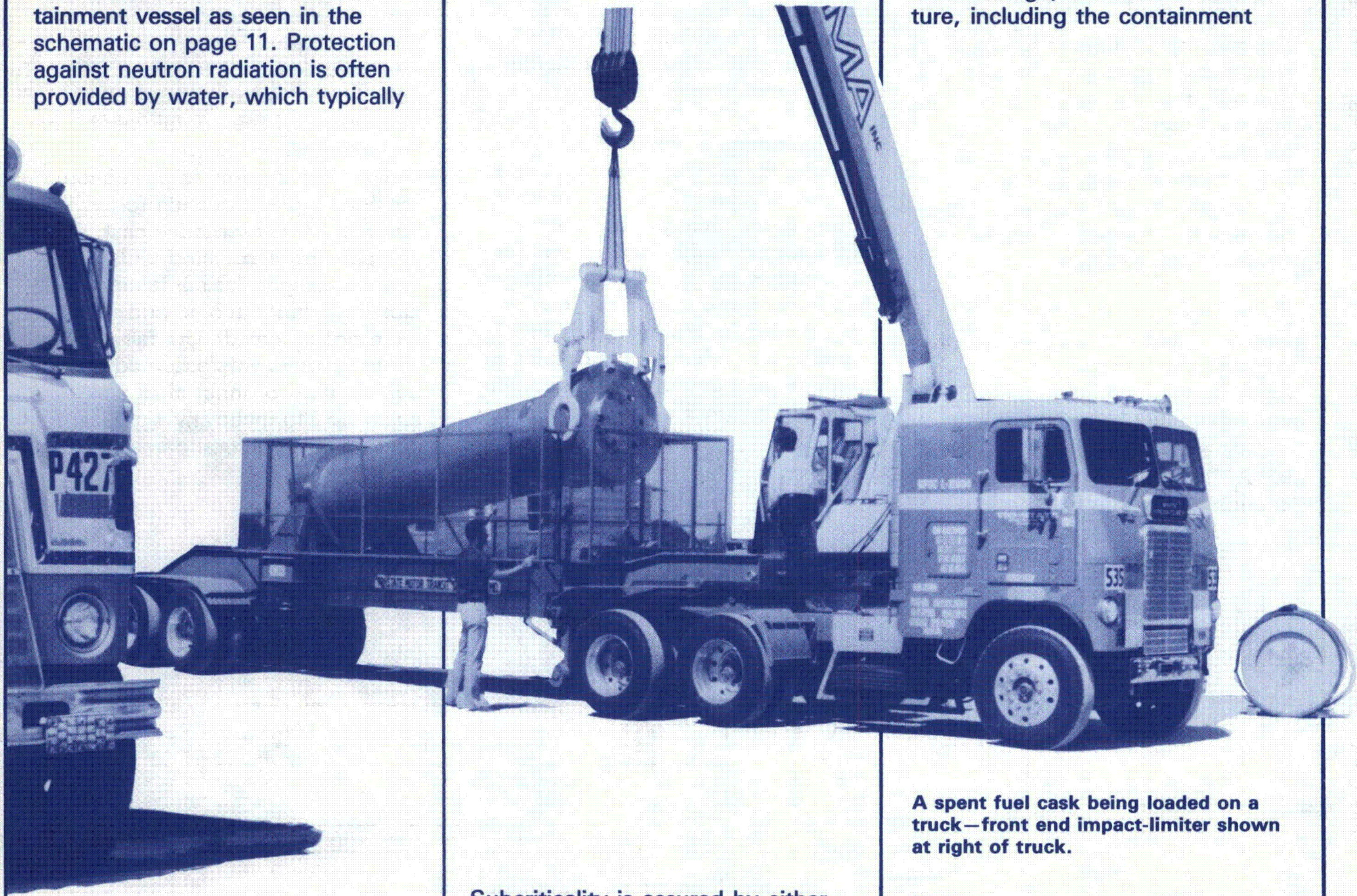


Schematic of Spent Fuel Cask

CASK CHARACTERISTICS AND RESPONSES

Shielding is provided against **gamma** and **neutron** radiation. Protection against gamma radiation which is very penetrating is most important and is achieved through use of heavy materials such as lead, uranium, or steel that reduce the radiation level. This material surrounds the containment vessel as seen in the schematic on page 11. Protection against neutron radiation is often provided by water, which typically fills a jacket surrounding the main cask body. Loss of the neutron shield normally results in a small increase in external radiation levels, but to a value that is within regulatory limits for transportation accidents. Failure of the neutron shield was assumed to occur for all accidents considered in this study. As a result, only the lead gamma shield was modeled in some detail in the representative cask designs.

Subcriticality is assured by either limiting the amount of spent fuel being shipped or by maintaining control of the spent fuel configuration during shipment and including "neutron poisons" in cask structural materials. The "poisons" are typically included in the solid structure or "basket" holding the fuel assemblies and absorb emitted neutrons, thereby making a "chain reaction" impossible and thus assuring subcriticality. Before the fuel basket can incur any significant damage, the total cask structure, including the containment



A spent fuel cask being loaded on a truck—front end impact-limiter shown at right of truck.

Note:
Actual spent fuel casks like the one shown in this figure are expected to perform their intended safety functions during an accident better than the representative cask designs assessed in this study.

shell, would have to be severely damaged. However, physical damage alone does not affect a cask's ability to maintain subcritical conditions. A material like water must surround the cask and fill the area between individual fuel rods and fuel assemblies before criticality would be possible. For these reasons, the features to assure subcriticality are not specifically modeled in the representative cask designs. Instead, an upper-bound estimate of the likelihood of criticality is provided in the LLNL report. The estimate is based on the type of accident that could substantially deform a cask in the presence of a material, like water, that would promote criticality. A brief discussion of this estimate is presented in the section on potential hazards and risks on page 26.

What Constitutes a Severe Transportation Accident?

In this study, a severe accident is one that could compromise one of three basic cask safety functions: (1) any loss of containment of spent fuel material, (2) a degradation or reduction in cask shielding capability, or (3) a loss of subcriticality control. Any of these occurrences could potentially create a radiological hazard.

Severe accidents typically involve impacts with massive and hard objects or surfaces or exposure to high-temperature fires of long duration. The scenarios shown on pages 7 and 9 are those that could compromise a cask's safety functions and potentially cause a radiological hazard.

Given the ruggedness and massiveness of spent fuel casks, a severe accident in this study would *not* include tragedies involving collisions between the vehicle transporting the cask and an automobile or bus in which several people might be killed or injured. Although potentially serious to the occupants of such vehicles, collisions with automobiles and buses at any speed involve forces that would **not** seriously compromise cask safety functions. Any deaths or injuries from such accidents would not be caused by the radioactivity of the spent fuel cargo.

Establishing a Scale to Measure Cask Response

Mechanical Loads—Measure of Cask Response

A cask and the nuclear fuel it contains can undergo various types of damage when subjected to mechanical loads. The most significant damage would include material yielding, dimensional changes, and rupture of the cask. The most common engineering guidelines used to characterize structural damage are stress, strain and displacement. Strain, particularly on the inner "containment" shell of the cask, was selected as the best single indicator to characterize cask damage following a transportation accident. Sensitivity studies established a relationship between the strains at different cask locations and the maximum strains experienced in the cask containment shell. As a result, it was possible to use a specific strain in the cask shell to estimate damage to cask components such as seals, closures, and penetrations.

Three discrete levels of strain were defined to encompass four broad ranges of cask and fuel damage, as shown in the figure on the following page. The significance of the 0.2-, 2-, and 30-percent strain values, in terms generally indicative of cask and fuel damage, is also illustrated on page 14.

CASK CHARACTERISTICS AND RESPONSES

Thermal Loads—Measure of Cask Response

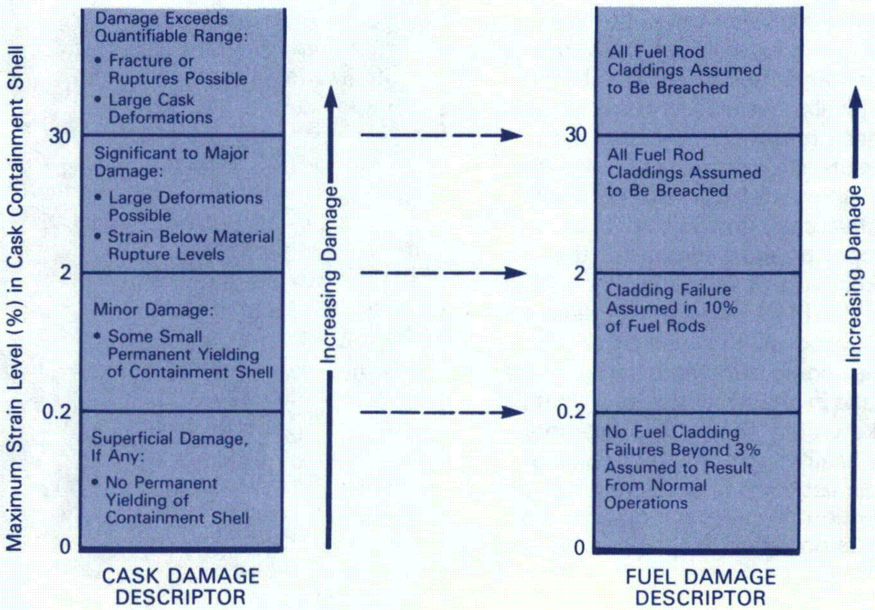
Heat from a fire can conceivably damage cask components, the cask structure itself, or the spent fuel. The more important types of damage can involve degradation of cask seals, melting of the lead gamma shield, or structural failures. The significance of high temperatures on spent fuel is that it can eventually cause the fuel rods to rupture and release radioactive material into the cask.

The temperature at the centerline of the cask's gamma radiation shield is the indicator most likely to reveal the extent of cask damage from fires associated with transportation accidents. Four temperature levels are defined to categorize five ranges of cask and fuel damage. These response ranges are indicated in the next column at the bottom of the page.

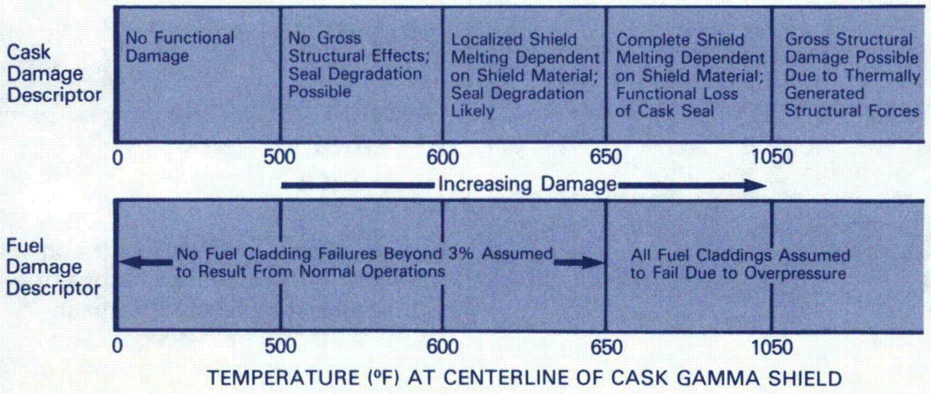
What Does Strain Measure?

When subjected to a force, the steel used in the cask containment shell can change dimension. The change in dimension of any segment of the steel shell along a given direction, when divided by the original length of the segment in that direction, is termed "strain." Strains experienced by materials under design loads are typically small, except for a few

Measures of Cask and Spent Fuel Response to Mechanical Loads



Measures of Cask and Spent Fuel Response to Thermal Loads



materials such as rubber. For a given material, the measure of strain can indicate whether a material will remain elastic and not deform or permanently yield or fracture and result in a rupture.

What Does Temperature Measure?

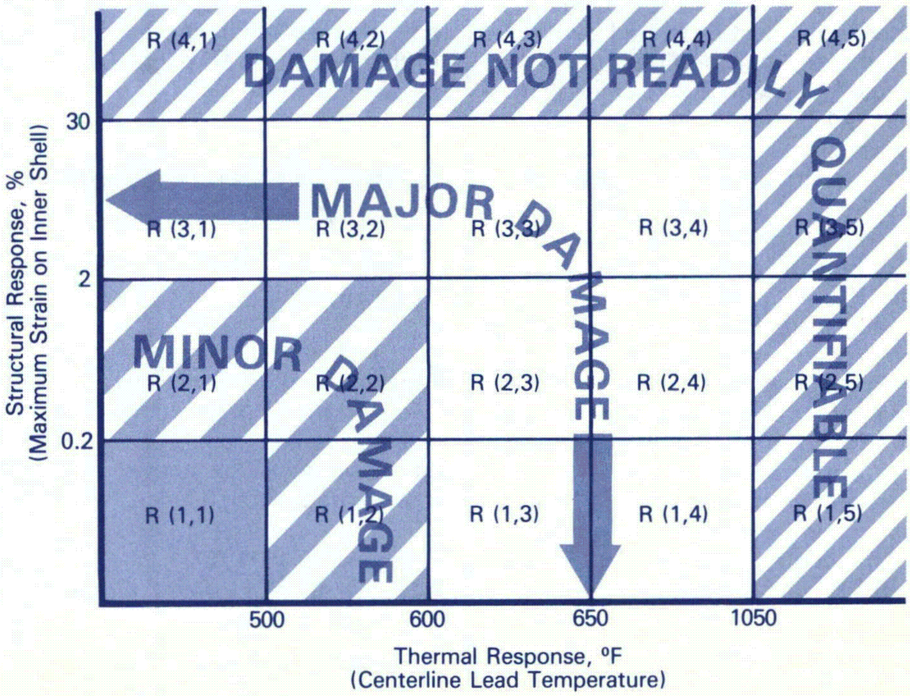
The temperature at points within a massive spent fuel cask can indicate the amount of heat absorbed from external sources such as fires and can also indicate potential cask or fuel damage. The cask can be damaged by the degradation of seals or the melting of the gamma radiation shield. For the spent fuel, the pressure of gases within the fuel rods, and the strength of the fuel cladding is strongly influenced by temperature. If temperatures become high enough, fuel rods could rupture and release radioactive material inside the cask.

Evaluating Cask and Spent Fuel Response to Accident Loads

On the previous two pages, cask containment strains and centerline shield temperatures were defined separately to characterize broad categories of cask and fuel damage. In real transportation accidents, however, a cask could undergo a combination of mechanical and thermal loads. The "cask response matrix" shown on this page therefore combines the

Cask Response (Damage) Regions

Note:
The size of each region or group of regions has no relationship to the likelihood of accidents causing the described damage level.



SUPERFICIAL DAMAGE—No permanent deformation to containment vessel. Temperatures too low to degrade material. Strains and temperatures less than or equal to values considered acceptable following imposition of "regulation-defined" hypothetical accident conditions.

MAJOR DAMAGE—Large containment vessel deformations without gross fractures or ruptures. Temperatures high enough to melt lead shielding.

MINOR DAMAGE—Limited permanent containment vessel deformations. Temperatures approaching the range where the lead shield could melt and the seals could degrade.

DAMAGE EXCEEDING DEFINABLE RANGES—Fractures or ruptures possible. Temperatures sufficiently high to affect cask and spent fuel integrity.

CASK CHARACTERISTICS AND RESPONSES

structural and thermal responses to categorize cask damage from all possible combinations of mechanical and thermal loads.

The process of categorizing cask response for a specific accident scenario is best described by an example. From the figure on page 7, scenario 20 indicates that about 2 of every 1000 truck accidents are expected to result in an impact into a slope consisting of hard soil or soft rock. Cask damage from this type of accident can be estimated (in terms of maximum containment vessel strain) if truck velocity, angle of impact, and cask orientation at impact are specified. Similarly, if a fire occurs during this accident (an event expected in about 1 of every 100 slope-impact accidents), damage to the cask can be estimated in terms of temperature at the centerline of the lead shield if the fire temperature, duration, and cask location relative to the fire are specified. The overall cask damage for the entire spectrum of transportation accidents characterized by cask impact with a soft rock slope can be calculated and placed into one of the response regions shown on page 15.

Two further steps are then required to complete the evaluation of the level of safety provided for spent fuel shipments. First, each response region must be considered in terms of the radiological hazard that could result from the specified level of cask damage. This relationship is described on pages 16 through 19. Second, the likelihood that the specific accident scenario (for example, impact into soft rock slope) can lead to a cask response within a particular region must be evaulated. This part of the evaluative process is further described on pages 20 through 27.

Relationship Between Cask Response and Potential Radiological Hazards

For most cask responses to transportation accident loads, any resulting radiological hazards can be conservatively estimated with a high degree of confidence.

Relationships of Mechanical Loads, Cask Response, and Radiological Hazards

For accidents causing small structural strains in the cask containment shell, no radiological hazards would be expected since, for less than 0.2 percent strain, no significant permanent deformation would occur in the containment shell.

Strains in the 0.2- to 2-percent or the 2- to 30-percent ranges were presumed to cause containment functional failure, but without gross rupture of the containment (see figure on opposite page). The lack of any gross rupture is a reasonable expectation based on the known ductility (that is, the ability to stretch without fracturing) of the stainless steel material typically used in cask containment shells. At these strain levels, however, the impact loads could cause the lead gamma shield material to "slump." Where voids or gaps in the shield occur, radioactivity inside the cask could increase radiation levels outside the cask (see figure on page 19).

The major difference between accidents causing 0.2- to 2-percent strain as opposed to 2- to 30-percent strain involves the behavior of the fuel rod cladding that contains the spent fuel within the cask. The lower range was assumed to cause failure of up to 10 percent of the fuel rod cladding, whereas at the higher range, all rod claddings are assumed to fail. In either case, experimental information on radioactive releases from failed fuel rods is used to establish the fraction of gaseous, volatile, and solid radioactive material that could escape from each fuel rod. For the purpose of this study, all of this material was assumed to be released from the cask, although in reality, a large but undefinable fraction would "plate out" or adhere to surfaces within the cask.

What Types of Radiological Hazards Could Be Possible in Transportation Accidents?

The fuel assemblies used in commercial power reactors contain solid ceramic uranium oxide (UO_2) fuel pellets. During reactor operation, the uranium fuel fissions creating radioactive fission and activation products. Physically, most of the radioactive material remains in solid form within the pellets, although the pellets may exhibit some degree of fracturing. However, a small fraction of the fission products are gases or are in volatile form (the amount of volatiles being dependent on temperature). The radiological hazards that could conceivably be created by this material can occur through two distinct cask-damage mechanisms: (1) a release of material from a damaged cask or (2) an increase in the external radiation level emanating from material within the cask.

Material releases can occur in gaseous, volatile, or in solid form. The solids can be small airborne particles or larger pieces. Solid particles that could be inhaled can pose a significant hazard to people.

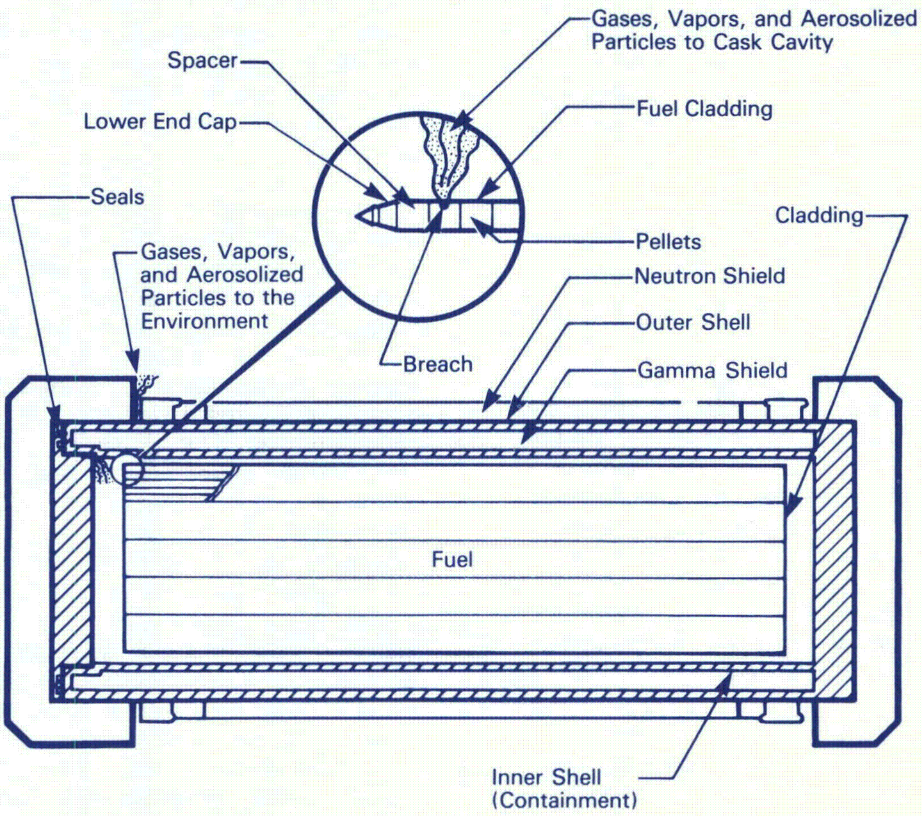
Increased radiation levels from material still within the cask could occur as the result of voids in the cask shielding due to mechanical forces or temperatures high enough to cause shield materials to melt.

Typical Radioactive Material Release Pathway

Presumed if either:

(1) Cask containment vessel strain between 0.2 and 30 percent, or

(2) Centerline gamma shield temperature between 500°F and 1050°F



CASK CHARACTERISTICS AND RESPONSES

The radiological hazards from accidents causing cask strains greater than 30 percent could not be precisely predicted because of the extensive and potentially varied nature of cask and spent fuel damage. In these situations, all gaseous material was presumed to be released while radioactive material in volatile and solid form was arbitrarily assumed to increase by a factor of 10 over the values predicted for accidents causing strain in the range of 2 to 30 percent. Only a very small fraction of truck or rail accidents, beyond any known accidents, could be severe enough to cause strains greater than 30 percent in the cask containment shell.

Relationships of Thermal Loads, Cask Response, and Radiological Hazards

Fires resulting from transportation accidents can affect a spent fuel cask and its contents. If the fire does not cause 500°F temperatures at the cask shield centerline, no radiological hazard would be expected since cask structural components are not susceptible to thermal deterioration or damage at temperatures below this level.

If temperatures at the shield centerline should reach between 500°F and 600°F, certain cask seal materials could degrade and lose their capacity to function. The spent fuel within the cask, however, would not reach temperatures high enough to fail the fuel rod cladding material. As a result, any potential radiological hazard created by a release of radioactive material from a cask would be limited to gaseous and volatile materials that have escaped from fuel rods whose cladding has failed during or before the accident for reasons other than the fire. Based on past experience, 3 percent of the fuel rods in a shipment were assumed to have cracks or breaks as a result of their use in the reactor, handling and storage before shipment, or vibrational loads during normal shipment.

At centerline shield temperatures between 600°F and 650°F, two types of radiological hazard could be created if lead is used as the gamma shield material (as is the case for the representative cask designs). Lead melts at 621°F and expands in volume during the melting process. This expansion can cause structural stresses that can result in loss of the cask's containment function. When the lead cools and resolidifies, its contraction can cause voids or gaps to form in the gamma shield. These gaps degrade cask shielding capabilities and so increase radiation levels outside the cask, as shown in the figure on the opposite page. In this study, a cask's loss of shielding capability was calculated as a function of temperature. A cask configuration that maximizes lead slump and subsequent voids, thereby maximizing radiation levels outside the casks, was also assumed.

Between 650°F and 1050°F, release of radioactive material from the cask or increased radiation levels outside the cask from contained material are more likely to occur and the magnitude of the resulting hazard could become larger. The major factor affecting the potential radiological hazard is the fraction of fuel rods experiencing cladding failures. For shield temperatures in this range, fuel rod temperatures can cause cladding failures; therefore, any radioactive material in mobile form could be released from the fuel to the cask. If cask containment is compromised, this material could reach the environment. Experimental information on the release of radioactivity from spent fuel has been used to estimate the magnitude of the potential radiological hazard. The conservative assumption was made that any material released inside the cask would escape from the cask to the environment.

If centerline shield temperatures exceed 1050°F, a cask's functional capabilities could be affected by several complex chemical, thermal, and structural processes that cannot be precisely predicted. In these situations, all gaseous radioactive material was presumed released to the environment whereas the release of radioactive material in volatile or solid form was arbitrarily assumed to increase by a factor of 10 over values

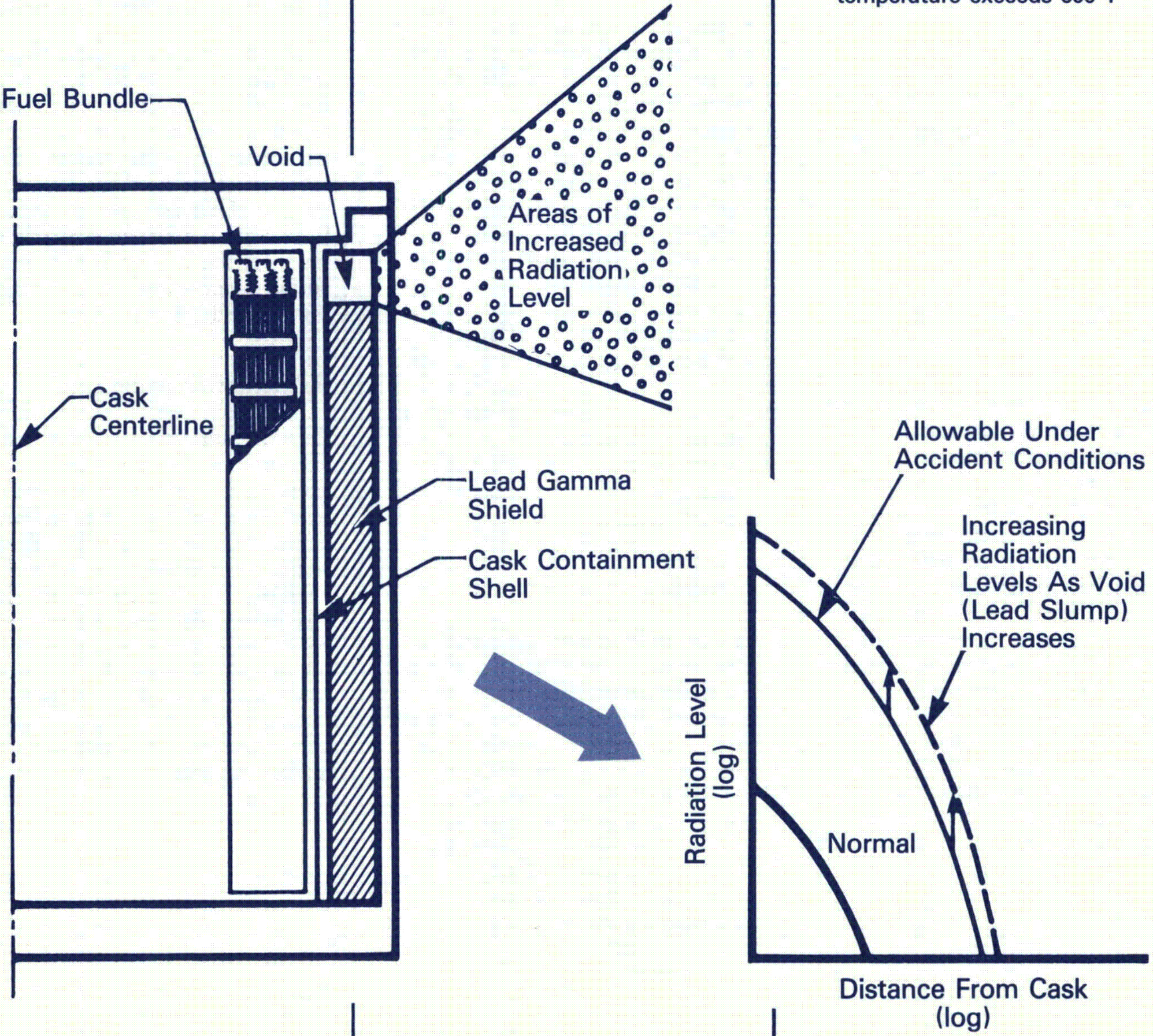
CASK CHARACTERISTICS AND RESPONSES

Typical Radiation Level Increase as a Result of Lead (Gamma Shield) Slumping

Presumed if either:

(1) Cask containment vessel strain exceeds 0.2 percent, or

(2) Centerline gamma shield (lead) temperature exceeds 600°F



CASK CHARACTERISTICS AND RESPONSES

assigned for temperatures in the 650°F to 1050°F range. As is the case for accidents causing extremely large structural strains, no historical truck or rail accident could be specifically identified that would have the potential to cause shield temperatures above 1050°F.

Cask Damage—What Accident Conditions Are Important and How Are They Defined?

Damage Caused by Mechanical Loads

The most important accident conditions used to define the mechanical loads imposed on a cask during an accident are those associated with various impacts. Because of the large weight, hardness, and rigidity of spent fuel casks, loads caused by crushing, by projectiles, or by other mechanisms have been demonstrated to be far less damaging than loads caused by impacts with hard, massive objects. As in any impact involving a motor vehicle or train, the damage sustained would depend on vehicle speed, the angle of impact (a head-on or a side-swiping impact), the hardness and massiveness of the object struck, and the orientation of the vehicle or object at the time of impact (front, rear, or side impact).

● **Velocity at Impact**

Potential cask velocities on impact were principally based on records of truck and rail accidents. The truck information shown on page 6 was derived from a sample of truck accidents causing fatalities or injuries reported by the California Highway Patrol. The rail information was derived from mainline accident data available from the Federal Railroad Administration. For accidents involving falls, the velocity of impact was based principally on a survey of bridge heights along a typical section of interstate highway. The velocity of trains involved in truck impacts was derived from rail-highway grade-crossing accident information.

● **Angle of Impact**

The angle of impact between a cask-carrying truck or rail car and the object or surface hit was estimated for each of the accident scenarios shown on pages 7 and 9. For example, head-on impacts with objects such as bridge abutments and columns were estimated to be far more likely than a side-swiping impact. Specifically, about 40 percent of all impacts with columns or abutments were assumed to occur at an angle less than 20° from head on. About 21 percent were estimated to occur within 10° of head on.

● **Hardness of Object Struck**

The hardness and massiveness of the object struck was determined, for the most part, by the information from the accident scenarios described on pages 7 and 9. Surfaces, such as hard rock, soft rock, and clay/silt, were modeled to provide a conservative representation of the variety of possible surfaces occurring within these three "earth" classifications.

● **Orientation at Impact**

Cask orientation on impact was estimated for each accident scenario similar to the process used to determine the possible angles of impact. For impacts with slopes or in impacts with other vehicles, any orientation was considered equally likely. For impacts with bridge columns and abutments, all orientations were considered possible, but the most likely orientation was estimated to involve an impact with the front end of the cask.

Damage Caused by Thermal Loads

The temperature of an accident-generated fire is the most important consideration in assessing potential cask functional degradation. The cumulative heat affecting a cask depends not only on the temperature and duration of the fire but also on the extent to which the cask is exposed. Data on fire temperatures and durations are not readily available in accident records; however, conservative estimates of fire temperatures and duration can be calculated based on pertinent information about the accident. For example, the thermal loading to a cask involved in a collision with a tanker carrying flammable cargo can be estimated by knowing the maximum volume carried by a typical tank truck and the nature of the product being shipped (for example, gasoline). For accidents involving trucks or trains carrying nonflammable cargo, knowledge of fuel tank volumes and the types and amounts of combustible material typical of truck or rail car construction is sufficient to allow similar conservative estimates to be made.

The only accident condition that could not be based, even qualitatively, on recorded accident data was the location of a cask relative to a fire resulting from a transportation accident. In the absence of recorded data, the researchers provided estimates that would be prudently conservative. The result was a presumption that in all accidents involving fires, a truck cask would be located at or within 31.5 feet of the fire center, the chance of any specific location within this range being equally likely. For rail casks, this location parameter was broadened slightly to encompass a range of 0 to 43 feet. Beyond these ranges, the thermal loads were not significant.

POTENTIAL HAZARDS AND RISK

Fraction of Accidents Without Any Expected Radiological Hazards

For every 1000 truck or rail accidents involving spent fuel shipments that are capable of causing injury, death, or significant property damage, 994 would be expected to cause no significant radiological hazard. This estimate took into consideration cask responses to both mechanical and thermal accident loadings.

Mechanical Forces

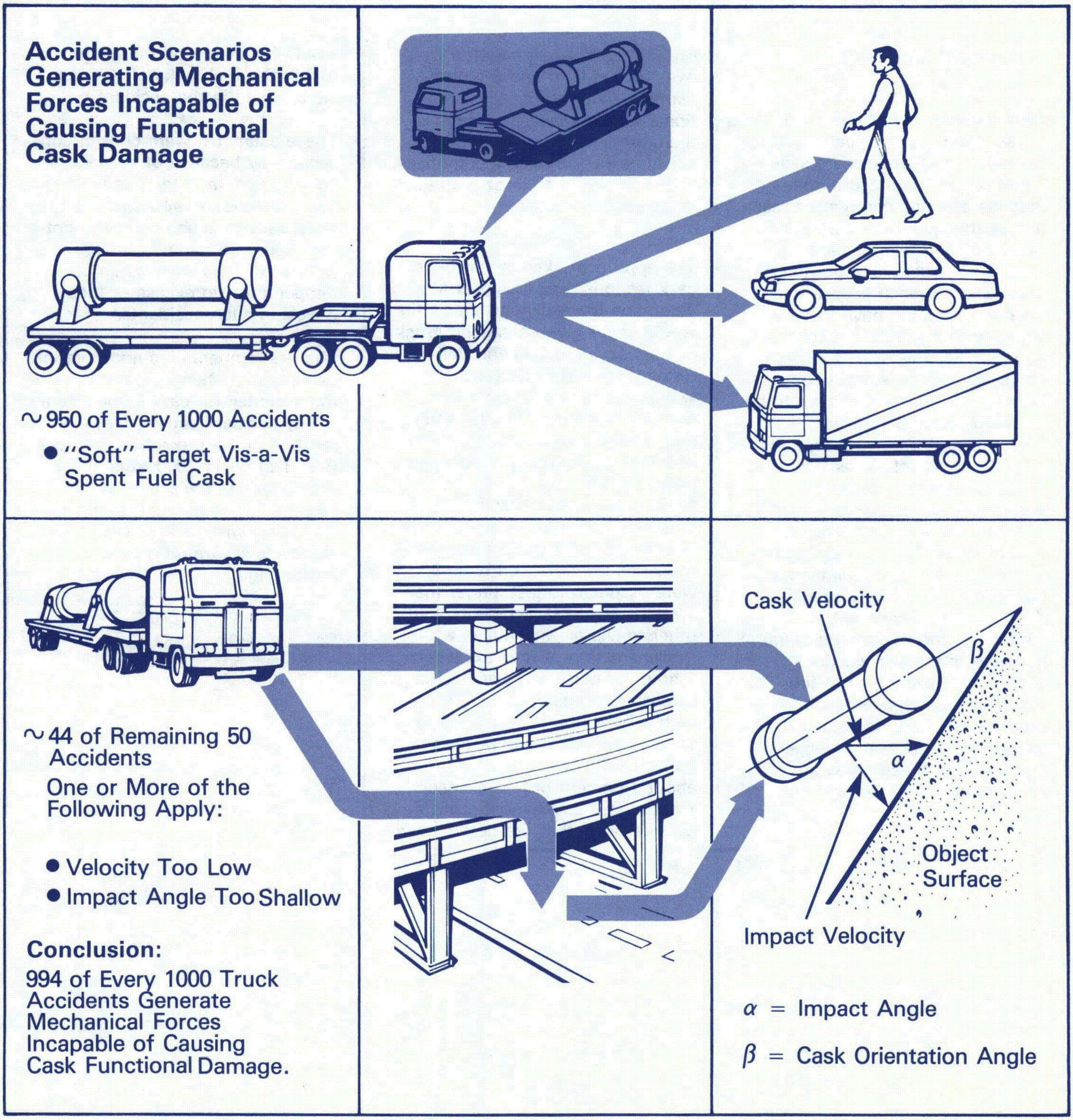
- **Responses to "Non-Severe" Transportation Accidents**

How the cask responded to mechanical forces was first considered for the objects identified in the accident scenarios described on pages 7 and 9. Estimates were made of the maximum forces that could be generated by each object or surface when struck at any impact velocity. These estimates were compared to the force necessary to cause a cask's containment structure to begin to permanently yield or deform. Through this comparison, many scenarios involving impacts with "soft" targets are shown to cause no functional damage to a cask (see opposite page). (These scenarios are shown without an asterisk on pages 7 and 9.) To illustrate this process, consider damage to a truck caused by a variety of collisions with animals and pedestrians; motorcycles; automobiles; other trucks; and, finally, fixed objects. Collisions with animals, pedestrians, motorcycles, and, to some degree, with automobiles typically cause little truck damage. These objects are "soft" relative to the truck, and as a result incur most of the damage sustained in the accident. Shipping casks are massive, heavy structures so that the objects so indicated on pages 7 and 9 are indeed "soft" relative to the cask.

Summing the accident rates for truck accident scenarios involving impacts with a "soft" object provides a basis for concluding that these accidents describe about 950 out of every 1000 truck accidents. Such accidents would be unlikely to cause any functional cask damage. For the railroad accident scenarios, "soft" object impacts would occur in about 960 of every 1000 railroad accidents.

- **Responses to "Hard" Object Impact Accidents**

In accidents involving cask impacts with potentially massive and/or hard objects (see the scenarios marked with asterisks on pages 7 and 9), the possibility of cask functional damage is controlled by accident-specific parameters. For example, a truck carrying a spent fuel cask could hit a bridge column at 60 miles per hour. If the truck and cask side-swipe the column, however, the effective impact velocity (cask-vehicle velocity perpendicular to the column) could be only a few miles per hour and the resulting forces would be insufficient to damage the cask functionally. A second possibility is that the truck hits the bridge column or abutment head on but the truck and cask are traveling at less than 30 mph. Because current regulations require that a cask be subjected to a 30-mph impact on an unyielding surface without sustaining unacceptable damage, any impact of less than 30 mph on a generally flat surface would not be expected to cause functional damage. When these combinations of possible accident parameters are taken into account, at least 44 out of every 50 accidents involving impacts with "non-soft" objects or surfaces would be expected to cause no functional damage to a cask. The same outcome is anticipated for railroad accidents: conversely stated, a maximum of about 6 accidents out of every 1000 have the potential to cause some degree of cask functional damage.


Accident Scenarios Generating Mechanical Forces Incapable of Causing Functional Cask Damage
~950 of Every 1000 Accidents
• "Soft" Target Vis-a-Vis Spent Fuel Cask
~44 of Remaining 50 Accidents
One or More of the Following Apply:
• Velocity Too Low
• Impact Angle Too Shallow
Conclusion:
994 of Every 1000 Truck Accidents Generate Mechanical Forces Incapable of Causing Cask Functional Damage.
Cask Velocity
β
α
Object Surface
Impact Velocity
α = Impact Angle
β = Cask Orientation Angle

POTENTIAL HAZARDS AND RISK

Thermal Forces

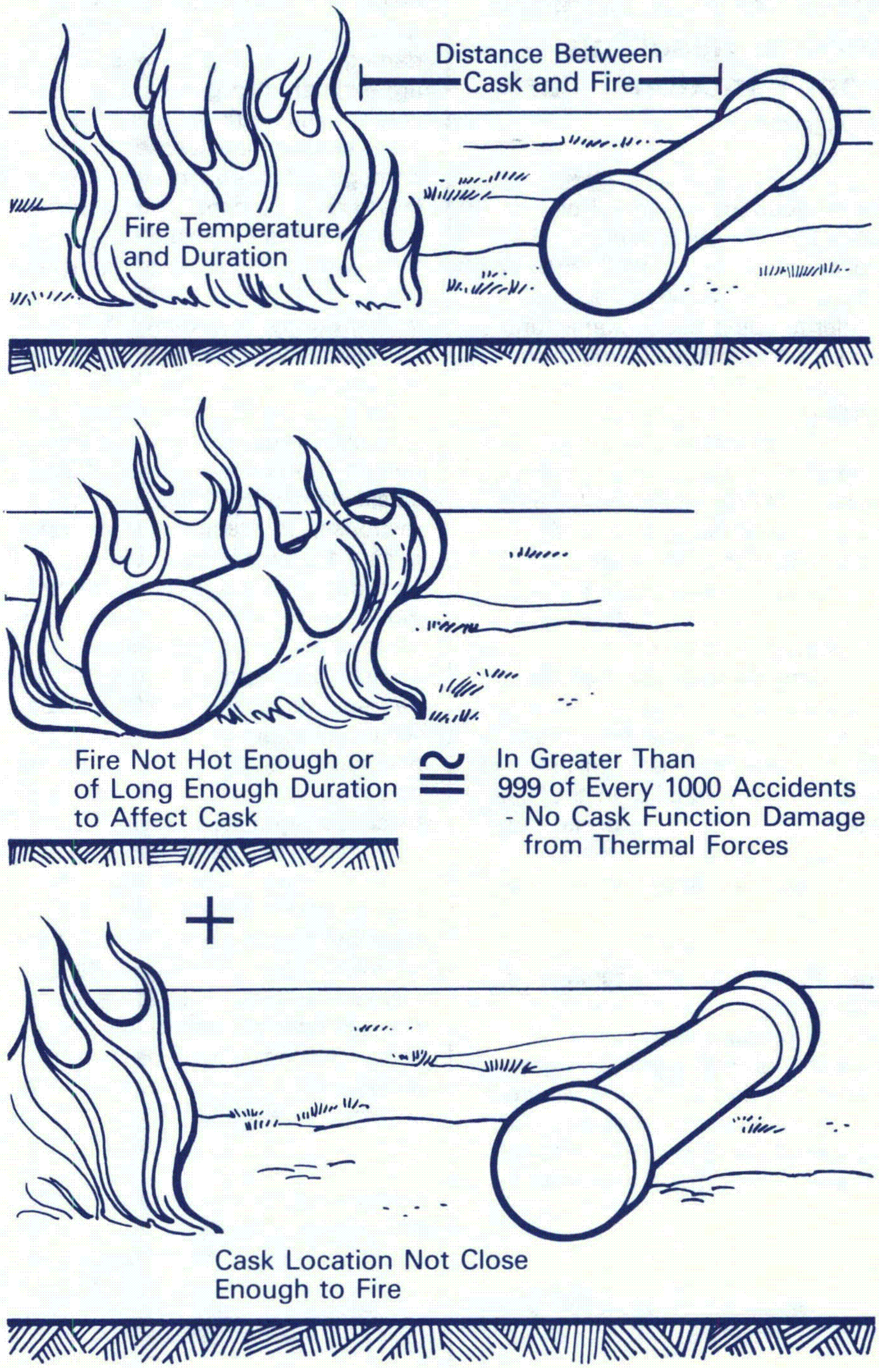
Cask damage from fires could cause melting of the lead shield or degradation of the closure seal. Either form of damage requires that the affected component reach temperatures in excess of 500°F. The mass and heat capacity of spent fuel casks are large. For a truck cask to reach such a temperature, it would have to be engulfed in a 1700°F fire for over an hour. For the larger representative rail cask to sustain equivalent damage, it would have to be engulfed for an estimated 1.35 hours. With few exceptions, only about 1% of the accidents in the truck and rail accident scenarios listed on pages 7 and 9 involve fires. Many of these fires would be fed by diesel or gasoline fuel from the truck or other vehicle involved in a highway accident, or from diesel fuel, lubricants, and rail car structural materials in railroad accident scenarios. These types of fires would not be expected to generate the heat necessary to cause functional cask damage. Furthermore, these types of fires are generally localized and not likely to completely engulf a cask over 16 feet long and 5 feet in diameter. The potential for functional cask damage from fires is therefore limited to accidents involving tanker trucks, locomotives, and tank cars with large quantities of flammable materials.

The approach taken to calculate cask responses to fires was to determine the likelihood that a fire would occur given a specific truck or train accident scenario defined on pages 7 and 9. Each scenario was assigned one of eight fire duration estimates (five for truck and three for rail accidents), two of which are shown on the upper figure on page 8. For rail accidents, a significant fraction of fires were assumed to have long durations (1 of 8 for the accident scenarios illustrated on page 9 were assumed to last longer than 1 hour). For truck accidents with other trucks or with trains, a similar fraction of fires exceeded 1 hour. Only for truck accidents involving no collision, a collision with a fixed object or a collision with an automobile were the fire durations limited so that only about 1 percent or less exceeded 1 hour. This assessment reflects the likelihood that fire durations would be limited by the amount of fuel in the fuel tanks of the vehicle involved in the accident.

These estimates were chosen conservatively because of the lack of actual accident data. The likelihood distribution applicable to fire temperatures is shown in the bottom figure on page 8. A large fraction of fires were assigned temperatures in excess of those typical in such accidents.

The fire temperatures and duration parameters, when considered with the potential for cask involvement in any accident-caused fire, resulted in the prediction that less than 1 of every 1000 truck or rail accidents has the potential to cause a fire capable of compromising cask safety. This conclusion is illustrated on the opposite page.

Accident Scenarios Generating Thermal Forces Incapable of Causing Functional Cask Damage



POTENTIAL HAZARDS AND RISK

Potential Radiological Hazards Resulting From Functional Cask Damage

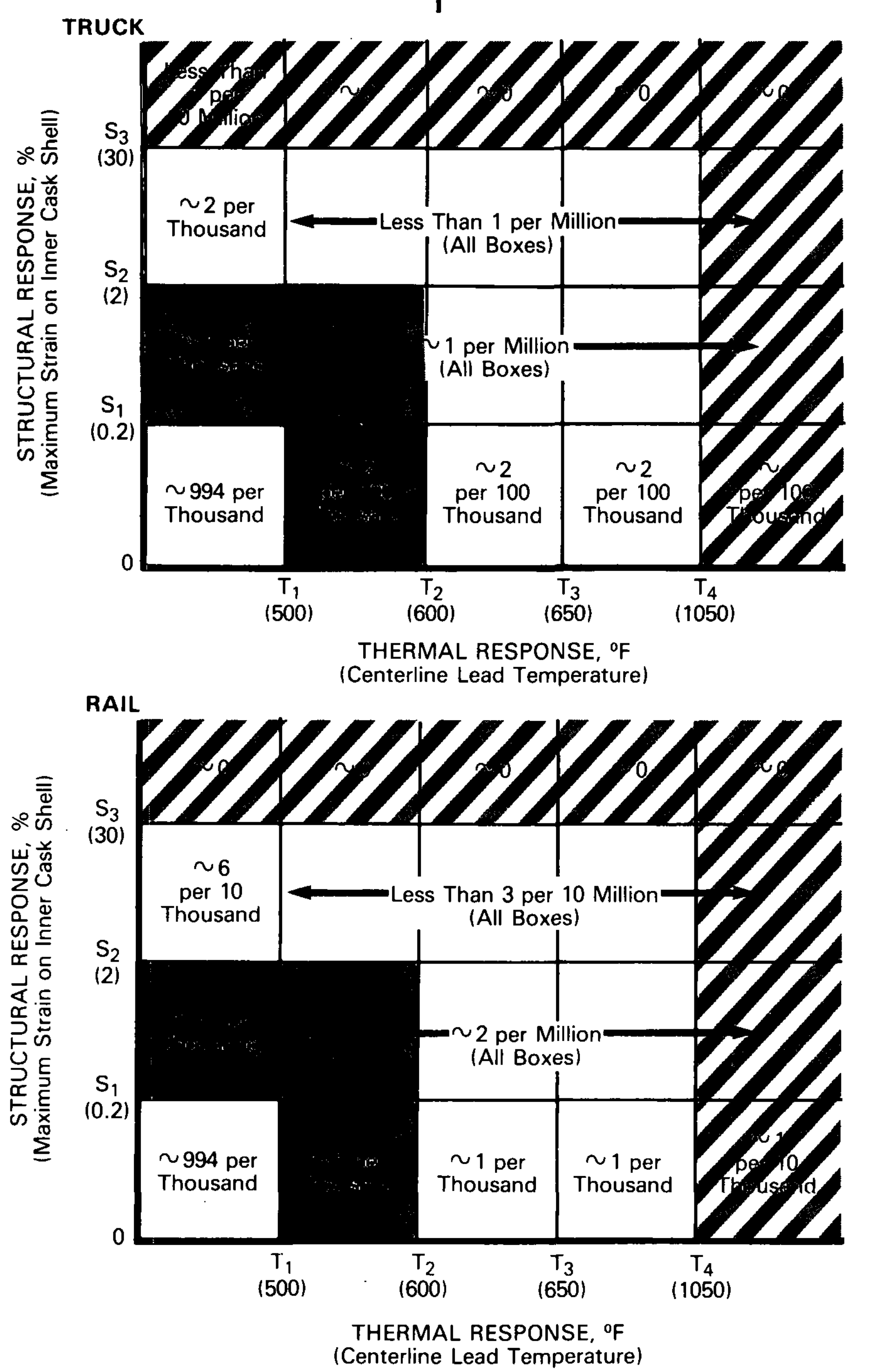
The evaluations described on pages 22 through 25 indicate that less than 6 of every 1000 truck accidents and 6 of every 1000 rail accidents could cause some functional cask damage. Damage to the cask could lead in turn to radiological hazards caused by either (1) the release of radioactive material from the cask's containment, or (2) an increased level of radiation emanating from the spent fuel within the cask caused by a degradation in a cask's shielding. The magnitude of any radiological hazard will vary depending on the extent of the cask's damage—the hazard tending to increase in magnitude as cask damage increases. In order to evaluate this variability in the potential hazard, three broad areas of cask response were characterized (see the figure on the opposite page).

Most of the accidents capable of causing any functional cask damage produce the limited responses shown within the gray area of the figure. In fact, of the 6 truck accidents out of every 1000 capable of causing any functional damage, about 4 are estimated to result in a cask response within this region. Similarly, 4 of the 6 damage-producing rail accidents are estimated to generate similar levels of damage. In this gray area, containment vessel structural damage is limited (to strains of less than 2 percent) and cask gamma radiation shield temperatures within the body of the cask are typically below melting temperatures (less than 600°F compared with the lead-melt temperature of 621°F). Note that other casks which do not use lead as a shield material would be expected to experience little, if any, shield damage. At this level of response, any radioactive materials released from the cask would exist as a gas and only a small fraction would occur either in volatile form or as small solid particles in an aerosol. Furthermore, little degradation of the cask's shielding would be expected since the mechanical and thermal forces imposed on the cask are insufficient to cause significant shield "slump" or voiding. In quantifying the potential magnitude of any radiological release created by responses in this area, researchers estimated that the magnitude of any release was likely to be *less* than compliance values applied to casks after they have been subjected to the hypothetical accident conditions described on page 5.

In the large open area, structural damage to a cask's containment could be significant, although gross rupture of the cask's containment shell would not be expected. The heat could melt lead in the shield, resulting in voids and increased external radiation levels. For cask responses in the large open area, radioactive material releases and/or external radiation levels potentially could slightly exceed existing regulatory compliance values. Just about 2 of every 1000 truck and rail accidents involving a spent fuel shipment are conservatively predicted to be capable of causing this level of radiological hazard.

Finally, only about 1 in every 100,000 truck accidents and 1 in every 10,000 rail accidents are calculated to lead to cask damage as described in the outer ring of response regions. No documented accident can be specifically identified that can cause this degree of cask damage. As indicated on pages 16 through 20, the radiological consequences of events in the outer ring were hypothesized because of the extensive and potentially varied nature of cask and spent fuel damage. Similarly, the potential for a loss of the cask's subcriticality function would be expected to be restricted to a small fraction of the "outer ring-type events" in which sufficient quantities of water were physically present.

Fraction of Truck and Rail Accidents Involving Spent Fuel Shipments that Cause Cask Responses Within Each Response Region



Note: Numbers have been rounded off.

POTENTIAL HAZARDS AND RISK

Interpretation of the Relationship Between Potential Radiological Hazards and Real-World Severe Accidents

Predicting the likelihood and magnitude of any radiological hazard in a severe transportation accident is not an exact science. The forces applied to the spent fuel shipment in extremely severe accidents are based on extrapolations of historical accident data, the evidence from physical tests, and predictions from engineering models using conservative assumptions. What is clear is that as the severity of accidents increases, the extent of possible damage to casks and spent fuel also increases.

This summary report has described the processes and results used to assess the level of safety for spent fuel shipments. To better understand the results, two further interpretations of the level of safety can be made. First, an illustration of the relationship between potential radiological hazards and some understandable accident parameters is provided in the illustration on the opposite page. The illustration applies to truck shipments of spent fuel subjected to mechanical forces. The expected yearly accident event frequencies, indicated on the figure, include consideration of predicted spent fuel shipment activity and a truck accident rate of 6.4 accidents per million truck miles. It is important to remember that the statements on event likelihoods apply to the performance of the defined representative cask designs—real cask designs are expected to provide a greater level of safety in transportation accidents.

The second interpretation involves the prediction of the performance of the representative cask designs if they had been involved in certain historically documented, severe transportation accidents. Four specific events were selected from about 400 severe accidents that, in turn, were selected from a much broader DOT data base. The description of the four events and the predictions of cask response are illustrated on a portion of the figure on the opposite page.

Together, these results are believed to present a fair picture of the minimum level of safety provided during shipments of spent fuel. The reader is encouraged to refer to the LLNL report for a complete interpretation of the studies approach and results.

Risk Estimate for Spent Fuel Shipments

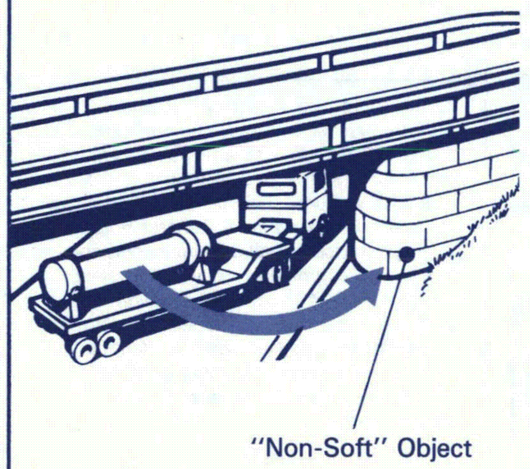
"Risk" and "expected value" are two of several measures used to predict future occurrences based on past experience in fields ranging from safety to sports. In this study, historical information on truck and rail accidents was supplemented by route survey data to predict the occurrence frequency of severe transportation accidents. Engineering models were then used to predict how a spent fuel shipment would respond in these accidents and what magnitude of radiological hazard might be created. A risk measure was determined by multiplying the magnitude of each potential hazard by its occurrence frequency and summing all the resulting values.

This type of risk measure has a regulatory precedent applicable to this study. In December 1977, a study that evaluated the risk for all radioactive material shipments, including spent fuel, was published as a Final Environmental Statement (FES).* The evaluations contained in the FES indicated a radiological risk from transportation accidents of one latent cancer fatality every 59 years for all projected 1985 radioactive material shipments. Most of this risk was associated with shipments of medical radioisotopes. The contribution from spent fuel shipments was 2.5 percent of this estimate.

* "Transportation of Radioactive Material by Air and Other Modes," NUREG-0170, December 1977.

Accident Scenarios Generating Mechanical Forces Potentially Capable of Causing a Radiological Hazard

Occurrence Rate
= 6 Events per 1000 Accidents
= One Accident Expected Every 10 Years (Assuming ~3 Million Shipment Miles Per Year)



POTENTIAL MAGNITUDE OF RADIOLOGICAL HAZARD

Cask Velocity Normal to Surface or Object - Between 32 mph and 50 mph

4 Events per 1000 Accidents or 1 Expected Event Every 14 Years

- Material Releases (Primarily Gases and Volatiles) Less Than Compliance Values*
- No Significant Increase in External Radiation Levels

~2 Events per 1000 Accidents or 1 Expected Event Every 35 Years

Cask Velocity Normal to Surface or Object - Between 50 mph and 75 mph

- Material Releases (Primarily Gases and Volatiles) Could Exceed Compliance Values* by a Small Factor (i.e., 2 or 3 Times)
- External Radiation Levels Could Equal or Slightly Exceed (by a Factor of ~3) Compliance Values*

Less Than 1 Event per 10 Million Accidents or No Expected Events During Repository Shipments

Cask Velocity Normal to Surface or Object - Exceeds 75 mph

- Material Releases Estimated to Exceed Compliance Values* by About a Factor of 20 Dependent on the Specifics of the Accident
- External Radiation Levels Estimated to Exceed Compliance Values* by a Factor of 30 Dependent on the Specifics of the Accident

*Compliance Values as Defined in Current Regulations

Predicted Cask Response to Selected Historical Accident Events

CALDECOTT TUNNEL FIRE - 4/82

- 3-Vehicle Collision — Gasoline Truck-Trailer, Bus and Automobile
- 8,800 Gallons of Gasoline
- Fire of 2 Hours and 42 Minutes - 40 Minutes @ 1900°F

Predicted Cask Response

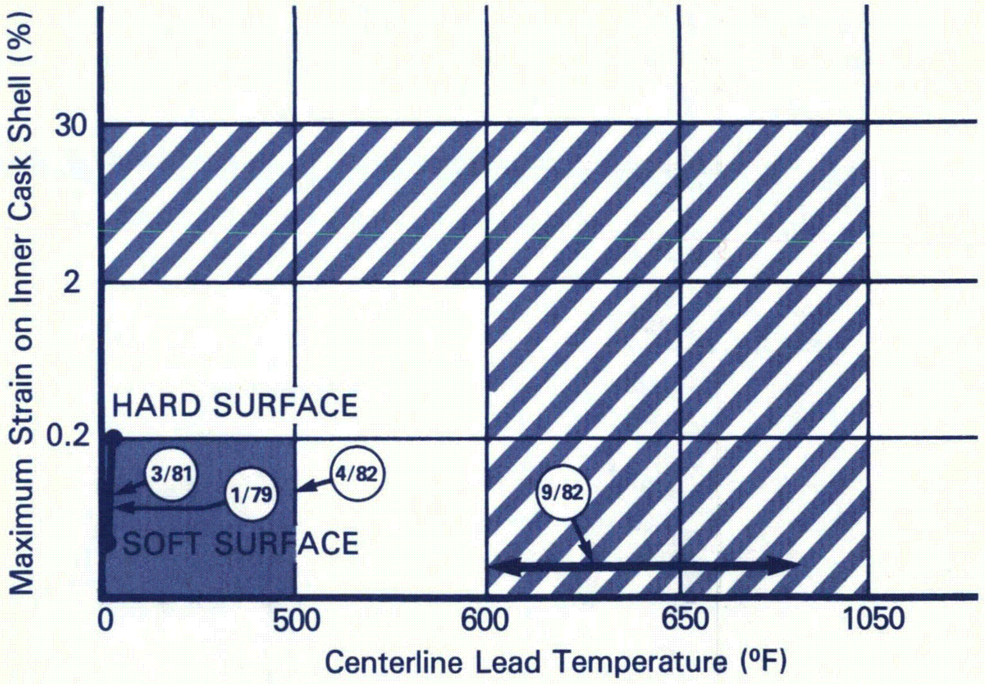
- No Significant Impact Damage - "Soft" Objects
- 45 Minutes @ 1900°F Causes 500°F Centerline Temperature

I-80 BRIDGE ACCIDENT - 3/81

- Collision With Pickup Truck and Fall from 64-Foot High Bridge Onto Soil

Predicted Cask Response

- 44 mph Impact
- No Significant Impact Damage



No Radiological Hazard

Radiological Hazard Approximates Compliance Values*

Radiological Hazard Exceeds Compliance Values By Up to a Factor of 4

LIVINGSTON TRAIN FIRE - 9/82

- Derailment of Vinyl Chloride/ Petroleum Tank Cars
- Large Fires for Several Days Moved Over Large Area
- 2 Explosions

Predicted Cask Response

- Maximum Probable Cask Exposure to Petroleum Fire - Between 82 Hours and 4 Days
- No Significant Damage from Explosion
- Centerline Shield Temperature Between 600°F and 720°F Dependent on Degree of Cask Involvement

DERAILMENT ON ALABAMA RIVER BRIDGE -1/79

- Plunge Off 75-Foot High Bridge
- Railcar Impacts Into Water and Mud

Predicted Cask Response

- 47 mph Impact in Soft Target
- No Significant Impact Damage

POTENTIAL HAZARDS AND RISK

In the FES, the predicted performance of radioactive material packages was based, for the most part, on engineering models and conservative engineering judgments. The LLNL study, on the other hand, focused entirely on spent fuel shipments and provided a detailed engineering analysis of package or cask performance under severe transportation accident conditions. The table on this page compares the results from the two studies.

The LLNL study included a more detailed approach to the calculation of radiological hazards that involved the consideration of releases of radioactive material as small inhalable particles. Any solid material release from a cask would require the creation of a direct release pathway from both the containment provided by the fuel rod and the cask (that is, a pathway much more direct than one needed for gaseous or volatile material releases). With the assumption of such a pathway and the presumed release of solid material,* the risk, as calculated in the LLNL study, is shown in the following table to be less than one-third of the values estimated in the FES. Therefore, to the extent that the Commission's conclusion on the adequacy of NRC regulations were initially valid and were dependent on the FES risk estimates, the LLNL study has not identified any increase in risk that would change the Commission's conclusion.

RISK RESULTS - COMPARISON WITH PAST FES EVALUATION

	FES (NUREG-0170) ESTIMATES	LLNL STUDY RESULTS
Fraction of Transportation Accidents Involving Spent Fuel Shipments Causing Any Radiological Hazard	0.09 (Truck) 0.20 (Rail)	0.006 (Truck) 0.006 (Rail)
Fraction of Transportation Accidents Involving Spent Fuel Shipments Causing Largest Estimated Radiological Hazard	0.004 (Truck) 0.002 (Rail)	0.00001 (Truck) 0.00013 (Rail)
Overall Annual Risk From Transportation Accidents Involving Spent Fuel Shipments	0.0004 Latent Cancer Fatalities Per Year	Less Than 1/3 of FES Value

*A shipping cask has been subjected to attack by explosive to evaluate cask and spent fuel response to a device 30 times larger in explosive weight than a typical anti-tank weapon. This device would carve an approximately 3-inch-diameter hole through the cask wall and contained spent fuel and is estimated to cause the release of 2/100,000 of the total fuel weight (~10 grams of fuel) in an inhalable form. No transportation accident can be identified that would impose anywhere near the energy per unit volume caused by this explosive attack.

Notes

NUREG/BR-0111