**The Study Committee**

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February 14, 1997

Dr. Jared L. Cohon, Chairman
U.S. Nuclear Waste Technical Review Board
1100 Wilson Blvd.
Arlington, VA 22209

Dear Dr. Cohon:

Thank you for the opportunity to present my comments regarding the crash testing of nuclear spent fuel shipping casks. My comments were -- indeed -- too detailed and too lengthy for the comment period at the Board's meeting in Pahrump, NV, on January 29th.

I have enclosed a summary of material contained in Sandia report SAND77-1462, which was the principal basis for my comments. Other sources included private correspondence from R.M. Jefferson, former Manager, Nuclear Materials Technology at Sandia National Laboratories (now retired), and conversations with Dr. H. R. Yoshimura; these gentlemen were co-authors of SAND77-1462.

The attached summary does not include the rail cask crash-and-burn sequence. I have included some basic information on this test sequence as a footnote on page 5 of the summary; I do not have the Sandia report of this series, although I understand that such a report was written.

The copy of SAND77-1462 that I have is not of a quality that permits copying illustrations. I have a few crash test photographs, which are being copied; I will forward these as soon as possible.. The video referenced on page 4, footnote 8 is quite good, and other videos and films of the crash tests should be available from Sandia.

I have also inclosed a copy of a response by Robert Jefferson to an article published by the State of Nevada about the "crash tests." This is self explanatory, I believe. Please contact me if there are questions I might answer, or if I can be of any other help.

Sincerely,

Hal Rogers
Co-chairman

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# RESPONSE TO Nevada Nuclear Waste News ARTICLE

by
Robert M. Jefferson[1]
March 1992

An article, titled "Use of Crash Test Films in Ads Blasted," was published by the State of Nevada in the February 1992 issue of the "Nevada Nuclear Waste News." As detailed below, that article contains 43 accusations of misinformation or intentional misleading of the people of Nevada by DOE or the nuclear industry. This response addresses each of those accusations. Please excuse the length. It takes much more to respond responsibly than it does to hurl the accusation. For the sake of clarity the article is appended to this response and each accusation is quoted before the response is given.

## What they 'forget' to say

"In the fire test, the film fails to mention that 10 minutes after the reported 30 minutes of exposure to fire, the outer shell of the cask cracked open in two places, the lead shielding began to vaporize and the test was stopped as a result."

This accusation is distorted and misleading. As reported in the open literature, the cask subjected to the fire did develop two cracks in the outer shell but not until the cask had been engulfed in flames for 100 minutes not 40 as claimed. Two purposes of this test were to compare real cask temperature behavior to the calculated values and to drive the lead shield of the cask to complete melt. Fuel to the fire was shut off, not at 40 minutes but at 100 minutes, because the test objectives (temperature histories and complete lead melt) had been achieved. Because fuel remained in the pool below the cask after fuel cut-off, the fire continued to burn for another 25 minutes. The two cracks (about 6 inches long by 0.04 inches wide) were found after the test and molten lead had been extruded thorough one of these and was then was vaporized by the heat of the flames producing white smoke. Of importance is the fact that even though this represented a severe overtest of the cask, so little lead was expelled through these cracks that the shielding would still have met the regulatory criteria after the test. The fact remains that the cask did not fail to perform as intended.

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[1] Mr. Jefferson has been active in the nuclear field since 1954, and was the Manager of the Transportation Technology Center at Sandia when the crash tests were conducted. Since April of 1985 he has been an independent consultant in the packaging and transportation of radioactive materials.

1. "...crash tests of nuclear waste canisters .... are as much as 15 years old"

While that is true and sounds ominous, it technically makes no difference. The tests were conducted to calibrate calculational tools and accomplished that. Modern stress analysis methodologies and thermal analysis techniques have improved significantly since these tests were conducted, based primarily on the availability of greater computing capability. But, the basic calculational methodologies have been in existence for over a quarter of a century now and have not changed radically over that period. The test program provided a validation of the accuracy of these calculational tools (which were found to be quite accurate).

2. "...crash tests of nuclear waste canisters ... do not represent real life casks"

The casks used in the tests under question were real casks, which had been used to transport spent fuel and used the same design and construction features as modern casks. Since several casks were used, and since these were constructed of varying materials of varying thicknesses, the goal of the program was accomplished in that the calculational tools were evaluated over a range of design parameters. Having validated the methodology, that same methodology used for the design and evaluation of modern casks is accurate and effective. Based on that proven accuracy and effectiveness, it is possible to assure that current and future generation casks will be capable of retaining their contents even if they should ever be involved in a serious accident. Further, current and future generation casks will benefit from a the design and operational experience gained in the thirty years since the test casks were designed.

3. "...crash tests of nuclear waste canisters ... do not represent real-world accidents"

Here we agree but for very different reasons. The test scenarios were selected to represent conditions much more severe than would ever be experienced in the "real-world." Let me give two examples. First, the impact tests were conducted against a 690 ton concrete block, 20 feet thick, backed by 1760 tons of compacted earth. There is simply nothing along the highway or railroad right-of-way that is that strong a target. If, for example, the target had been a foot thick concrete wall backed by compacted earth, the damage seen would have been much less than the tests produced. Another example is the fire test where the cask was suspended 3 feet above the fuel so as to be in the hottest part of the flames. In the real world the cask would have been on (or partly under) the ground and covered with debris from the accident (see # 37 below). Under "real-world" conditions the heat input to the cask would have been much less. Besides, to produce the fire that burned for 125 minutes required about 36,000 gallons of fuel. Data from past severe accidents reveal that such a quantity of fuel, concentrated beneath the cask is simply not available in "real-world" accidents.

4. "cracks resulting from the staged accidents could have unleashed radioactivity on the public"

The only cracks created in the "staged accidents" conducted by Sandia occurred in the outer stainless steel shell of the rail cask during the fire test (see box above). Since these cracks did not involve the primary containment (or inner shell), there was no way radioactive material could have been released through those cracks. In the grade crossing test cracks were created on the cooling fins which are attached to the exterior of the cask These have nothing to do with containment or leakage.

5. "The clips in the ads showing crash tests ... were taken from films produced by Sandia ... in 1977 and 1978."

See # 1 above.

6. "The films purport to show casks in severe accident tests."

In a way this is a valid accusation since the tests produced environments well beyond severe accidents. See # 3 above.

7. "The films have been criticized by the Nuclear Regulatory Commission..."

See # 24 below.

8. "The films have been criticized by the ... National Transportation Safety Board ..."

See # 23 below

9. "The films have been criticized by ... numerous transportation experts..."

The only other "experts" that I know of, besides the two cited above, who have criticized the tests are persons like Messrs. Audin and Resnikoff. Both Messrs. Audin and Resnikoff have spent their careers campaigning against the nuclear option. Their papers attacking the safety of spent fuel transport over the past decade have been systematically

refuted on several occasions.

10. "The films have been criticized ... as misrepresenting real accident conditions..."

Again, in a sense this accusation is correct since the tests were much more severe than real accidents (see # 3 and # 6 above).

11. "The films have been criticized ... as ... falsely presenting a picture of casks that will not leak or release radioactivity under severe conditions."

The film produced by Sandia does say that the tests show "how rugged these casks really are." And, they are rugged by any measure. But, it is not the Sandia film that says the casks will not leak or release radioactivity under severe conditions. That statement comes from an NRC study (called the Modal Study - see # 21 below) which reviewed all of the very severe transportation accidents that have occurred in the United States and concluded that none of these to date would have produced damage sufficient to cause the spent fuel shipping casks to release any radioactive material. The film has been used to provide the visual imagery to support that finding.

12. "The films of the tests mislead the viewer in three basic ways: a) Illusion - mistaken impressions are created that are not clarified."

From a person who does his best to convince people that spent fuel shipping casks are still shipped with large quantities of water in them (see # 17 below), this is an interesting accusation. It might serve to put this accusation in perspective to point out that these tests were open to the public. Before each test Sandia told those visitors who showed up, exactly what had been predicted to happen. Among the audience were many skeptics who truly wanted to see the predictions proven wrong. These visitors were taken to the test site and allowed to watch the test after which they were allowed to inspect the wreckage (they could touch the cask if they so desired). Following the tests, extensive documentation of the results were published in the open literature. Under those conditions it is difficult to create the illusions that Lindsay Audin claims.

13. "The films of the tests mislead the viewer in three basic ways: b) Diversion - the viewer's attention is focussed on characteristics and conditions that are not the most likely to yield a release of radiation."

It is difficult to determine what Mr. Audin means by this accusation. It is hard to imagine conditions more severe than unyielding surfaces or totally engulfing fires (requiring

suspension of the test cask above the flames) There is no such thing as an unyielding surface. The unyielding surface is an engineering term requiring that all of the energy of the impact be absorbed by the package. Any denting, crumbling, deformation, or movement of the impact surface means that some of the energy is being absorbed by the impacted surface and thus not available for creating damage in the cask. Besides, the purpose of the test program was to validate the calculational tools used to design and evaluate these containers and not to proof test those casks.

14. "The films of the tests mislead the viewer in three basic ways: c) Censorship - important information is withheld, making an educated assessment of the film's validity impossible."

This accusation cuts to the quick since one primary objective of these tests was to be open and above board. That approach began by making the tests open to the public. Following that there have been approximately 60 technical articles, published in the open literature, on these five tests. Every possible bit of information available to Sandia has been shared with the public and the technical community. The film is but one very small part of the total effort. Indeed, all the information available to Mr. Audin came from Sandia. Censorship is hardly a valid assertion!

15. "Modifications made to the casks and their contents ... are much like magic acts where the audience has no idea that special props will be used to create illusions."

Some of the casks used in the tests were modified. The original impact limiters on the truck casks used were replaced with impact limiters then (and now) in use. Early impact limiters were essentially stainless steel egg crate structures and between the certification of these casks and the conduct of the tests, the industry had changed over to balsa wood impact limiters. So balsa impact limiters were installed on the casks to make them more representative of then current casks. Since the purpose of the tests was to validate analytical tools, such modifications were considered necessary. The rail cask was not modified but, was tested in the same configuration as had been while in service. The casks used in the tests were loaded with dummy fuel elements in an attempt to provide realistic loading to the interior of the cask during impact. Since the tests were not intended to evaluate fuel elements, the use of dummy elements was perfectly acceptable. Sandia did however, in an attempt to be totally open about the information available, report the damage to these dummy fuel elements. Mr Audin would have people believe that this openness was an attempt to mislead. Only one other feature of the test can possibly be included in this accusation. Prior to the first test, Sandia heated the cask to simulate the heating that would be present if the cask had been carrying spent fuel. Following the test some critics complained that such heating improved the ability of the cask to withstand damage (heating improves ductility or the ability of metals to bend without breaking). So,

on subsequent tests the casks were not heated. Take your pick of which way you think is best.

16. "During the drop test, a crack actually formed along a weld leading directly to the cask's inner cavity where fuel is held, creating a potential pathway for leakage."

The Sandia test series did not include any drop tests. The event evidently referred to was a test conducted by Oak Ridge National Laboratory. As a result of the drop test on that cask (without an impact limiter) there was a crack created in the outer shell of the cask. The report of that test indicates that the crack led to the shielding cavity (not the fuel cavity). Evidently, Mr. Audin confused the shielding cavity (the space between the outer and inner shells which is filled with lead in the cask tested) with the fuel cavity (the void space inside the inner shell). The crack created in that test did not compromise the ability of the cask to provide the protection intended. Damage is not equivalent to failure.

17. "Had there been real spent fuel in the cask, and the resultant water, radioactive crud and steam, the crack would have been sufficient to cause releases."

Since the crack was in the outer shell of the cask, this extension by virtue of induced steam pressure is nonsense. But, this is the premiere claim of the anti-nuclear activists. Water in the cask will provide the driving force to create the failure needed to expel radioactive material into the atmosphere. There is one small glitch in this argument though. All casks in use for transporting spent fuel in the United States, now or in the future, will be shipped "dry" meaning the water has been drained from the cask after loading. When confronted with this fact, as Mr. Audin and others have been repeatedly, they claim that you cannot get all the water out of the cask so what remains will, when heated by the spent fuel, vaporize and thus pressurize the cask. But, draining the cask removes enough water so any possible steam generation from the remaining water will not produce sufficient overpressure to cause the cask to leak (or the pressure relief device to release anything). Thus, accusations such as this are more misleading to the public than anything imagined by Sandia.

18. "The actual forces encountered by the cask during the tests were overstated by the way the tests were conducted. The actual force of the cask hitting the wall in the truck test was only 29 mph because it was slowed by the shock absorbing effects of the truck cab."

Well, almost. As stated, the cask actually impacted the wall at 29 mph after being slowed by the crush of both the tractor and the nose of the trailer. Since the arrangement of the cask on the tractor trailer rig was exactly as it would be during transport today, the

same effect would take place in a "real" accident. Further, the analysis performed before the test predicted impact at that speed. What Messrs. Audin and Resnikoff fail to point out, and what they well know, is the fact that this is the result of the 61 mph impact test. The damage to the cask was so slight that the same cask was repainted, mounted on another tractor trailer rig and tested a second time at 84 mph. In this second test the cask actually impacted the wall at 65 mph as had been calculated in advance. Interestingly enough, these anti-nuclear activists repeatedly refuse to tell the public about this more severe test. One wonders about who is guilty of misleading the public.

19. "The rail cask test similarly overstates the speed and intensity of the impact."

The cask and railcar used in this test were exactly the same as had been used to transport spent fuel for almost a decade. Other than painting and the installation of instrumentation, nothing was altered on the cask or railcar. The impact velocity of the railcar was reported as accurately as could be determined (two methods were used). Any accident that might have occurred with that cask would have included the railcar so how could the speed and intensity of the impact be overstated unless one speculates that the cask might somehow be mounted on the car without any constraint. While modern rail casks are carried on less robust railcars than the one used in the test, modern casks do have impact limiters, which the test cask did not have.

20. "After each test, the film sound track states that no radiation would have been released. But two of the tests did cause leakage of water that had been added to the cask."

In the first test in which the truck was impacted into the 690 ton concrete block at 61 mph there was no damage to the cask at all. There could have been no release of radioactive materials even if the cask had contained spent fuel. In the second test, in which the truck impacted the concrete block at 84 mph there was also no leakage of water. Because there was concern about leakage by those conducting these tests, the water inside the cask contained a colored dye to make detection of any leaks easier. As said before, there was no leakage detected after the test. When recovering the cask from the wreckage a wire rope sling was placed around the cask and a crane used to pull the cask loose from the wreckage. During the time the cask was under the strain from this sling there began a leak at a rate of about one drop every two seconds. As soon as the cask was placed on another trailer and the tension on the sling released, the leak stopped. Based on the time and the leak rate it was estimated that about one cup of water leaked from the cask. Had

there been spent fuel in the cask the pressure in the cask (the test cask was pressurized to 6 psi, roughly equivalent to the expected operating pressure) would not have created any different condition to produce a leak. Under the then applicable NRC regulations casks are allowed to release limited quantities of water coolant if involved in an accident. The reason this was allowed, in spite of claims to the contrary, was that release of the liquid would not have represented a release of radioactive materials sufficient to create a public health problem.

The only other water filled cask, in the test series, was the rail cask. During the impact test there was no damage to the cask sufficient to cause a leak. In fact the rail cask was pressurized to 10 psi prior to the test and retained that pressure after the impact test. Since there was no loss of pressure there could not have been a leak. In the fire test the temperatures inside the cask did increase to the point that the pressure caused the relief valves to open and release steam. Again, this had been predicted and was a design feature of the cask allowed under the then applicable regulations.

21. "The Sandia presentations withhold and distort information showing that the consequences of transportation accidents could be significantly more severe than claimed by DOE and the nuclear industry."

There is no doubt that someone is withholding and distorting information. As shown in other paragraphs of this analysis, it appears to be Messrs. Audin and Resnikoff with the help of the State of Nevada. No competent authority has ever found the risk of transporting spent fuel to be greater than stated by the film in question. NRC has, over the past couple of decades, commissioned a series of studies on the adequacy of the regulations. The earliest of these studies was WASH 1238 (An Environmental Study of the Transportation of Radioactive Material to and from Nuclear Power Plants), published in 1972. That study found that the regulations were adequate to provide proper protection to the public. Following that study the NRC commissioned another study published in 1977 as NUREG 0170. This study (Final Environmental Study on the Transportation of Radioactive Material by Air and Other Modes), looked at the entire country as might be impacted by shipments of radioactive material. Concerns were expressed that cities had not been adequately considered. So, another study (NUREG/CR 0743) was initiated evaluating the impact of an accident involving a spent fuel cask in a crowded metropolitan area (New York City). This third study (The Transportation of Radionuclides in Urban Environs; Draft Environmental Assessment) concluded that the regulations again provided adequate protection. In fact, the "Urban Study" concluded that the risk of transporting spent fuel was less than had been calculated by NUREG 0170. Still, cries of concern expressed the very point made by the article being studied here; there must be more severe accidents than those that have been studied. So, again NRC initiated another study (NUREG/CR 4829, Shipping Cask Response to Severe Highway and Railway Accident Conditions) directed at compiling data on severe accidents (whether they involved radioactive material or not) and

comparing the environments produced with the level of protection offered by spent fuel casks meeting the NRC Regulations. Again it was found that the risk of shipping spent fuel was low; in fact it was only about one-third what had been found in the 1977 study published as NUREG 0170. So, after extensive study, by several competent laboratories, it has been found that the fears (of consequences significantly more severe than studied by DOE), are unfounded. Note too, these studies were done by NRC, not DOE.

22. "Such productions can be fairly called 'propaganda' and are clearly out of place in an honest debate over nuclear transportation safety."

After what is revealed in # 21 above it is quite brash of Messrs. Audin and Resnikoff to challenge anyone's honesty. In this debate it appears that anything offered by those who support the politically correct Nevada viewpoint is called information and everything offered by the industry or DOE is called "propaganda." In fact, both views might be labeled "propaganda," defined as the methodical propagation of a doctrine. One doctrine is that radioactive waste should not be buried in Nevada no matter what. The other doctrine is open evaluation of the facts. DOE and the industry have, from the beginning, attempted to be honest and open with the data available from testing and analysis of the safety of transporting radioactive materials in this country. It appears from the article published in the Nevada Nuclear Waste News that this honesty and openness is one sided.

23. "In 1989 Ludwig Brenner of the National Transportation Safety Board said "it is the misuse of these films to represent that the casks are safe that is objectionable ... The high-speed collision tests represent only two of a larger number of accident scenarios that need to be analyzed to assess the safety of spent fuel cask transportation."

First, Mr. Brenner made the statement on behalf of himself and not the National Transportation Safety Board and second, he made the statement in 1979 not 1989. Further, Sandia agrees with Mr. Brenner. That is the very reason the tests were conducted; so that the technical community would have validated calculational tools that could be used to analyze many different accident possibilities. And, that is exactly what is done in the design and regulatory evaluation of shipping casks. It is also the reason that requiring testing of full scale casks does not make technical sense. If testing was the only means of evaluation, there would have to be multiple tests of each design. But, because of the proven accuracy of design and evaluation methods such as scale model testing and computer based analysis, full scale cask testing is not necessary. Without such engineering tools, the alternative would be endless testing to meet ever more severe scenarios lacking any relationship to reality.

24. In a June 1989 report, the Nuclear Regulatory Commission said that "[the tests are]

interesting , but inapplicable for irradiated zircalloy fuel assemblies."

This statement is found in a June 1979 NRC report (not 1989 as claimed) and met with agreement by Sandia at the time. The tests conducted by Sandia were intended to evaluate the design and analysis techniques used for spent fuel shipping casks and had nothing to do with the fuel itself. The NRC was quite right in objecting to the use of the very inexact data (i.e., visual observations) on stainless steel clad elements and applying it to zircalloy clad elements.

Additional comment on # 23 and # 24: The use of the wrong date indicates either very sloppy handling of the facts or intentional deception.

25. " 'it was the truck that had the impact,' not the cask."

First, note that the words 'not the cask' are not part of the original quote but have been added by the author of this article. For further comment see # 18 above.

26. "The casks are not the same as are used today, or are they the type to be used for dump shipments."

Again, the purpose of the test series was to evaluate the accuracy of analytical tools used to design and evaluate thick walled structures (spent fuel shipping casks) subjected to extreme environments. Having accomplished that, it makes no difference whether the casks today are exactly the same as those tested or not (See argument at # 1 and # 2 above). Of interest is the fact that the casks tested were what are called steel:lead:steel, meaning that the cask consists of two concentric shells of steel (or stainless steel) containing a layer of lead between them. Modern casks still use that same arrangement so the casks tested were quite like modern casks from that standpoint. Other design features of the casks tested were also similar to modern casks making the calculational models used directly applicable to modern cask designs.

27. "The casks in the films could carry at most one early fuel assembly, which is considerably smaller than the assemblies used in the newer and larger nuclear power plants."

First, the rail cask shown in the films was designed to carry ten fuel assemblies, not one as claimed in the article. The truck casks were designed to carry one Pressurized Water Reactor or up to four Boiling Water Reactor fuel elements. Secondly, these casks were used to transport fuel elements roughly the same size (slightly smaller, not "considerably" smaller) as those used in later plants. For purposes of verifying the analysis, these differences would have no effect.

28. "In the train collision film the cask was thrown off the truck rig, but it is very likely that the modern cask would end up absorbing a large amount of the kinetic energy of the train."

This contention has been around a long time but is a distortion of reality. First, there are two points in this comment; one is the retention of the cask on the trailer and the other is the amount of energy available for damage. The available energy will be addressed in # 36 below. Truck casks are mounted on the trailers in bolt-on saddles and tied down using clamps on the lifting trunions. NRC Regulations (10 CFR 71.45) requires the tiedowns be capable of withstanding a 2 G vertical force and a lateral 5 G horizontal force without failure of the tiedown system. The cask tiedown system used in the test met those requirements so it is difficult to understand how modern casks would behave any differently. A modern cask, struck by a railroad train would be expected to be thrown off the rig in the same manner the test cask was thrown off.

29. "The NRC Regulations allow for testing of a quarter-scale model. The small casks in the movies would not even qualify as a quarter-scale model of the modern casks under design."

The models shown in the film were not intended to meet NRC criteria since those criteria were not in place at the time of the tests. In some measure the existence of the NRC criteria is tribute to the success of the scale modelling done by Sandia even though most of it was one-eighth scale. There is no doubt that the scaling laws are easier to follow at one-quarter scale than smaller scale but, the results of carefully prepared one-eight scale models is accurate enough for the purposes Sandia used them for. Scale models were used for initial verification of the analysis and for scoping studies to determine parameters and instrumentation for the full scale tests. It might be noted that the DOE cask design program calls for testing of a one-quarter scale model of the rail cask and a one-half scale model of the truck cask.

30. "Repository casks will be lighter and less heavily shielded and will not have cooling fins and other appendages which serve as impact absorbers."

Total weight of the loaded casks will remain very close to the same value as those tested. What will change, as suggested, is the weight of the empty cask. For example, in the truck casks tested the total weight was 50,000 pounds of which the spent fuel contributed about 1,250 pounds. In other words, the packaging, including the water in the cavity, contributed 97.5% of the weight. Modern truck casks will still weigh about 50,000 pounds but, will carry approximately 5,000 pounds of spent fuel elements. In this case, the cask will represent 90% of the total weight, which is less. Despite this reduction in empty weight

from 48,750 pounds to 45,000 pounds (a modest change), the cask must still meet the same design requirements as those casks tested. Further, each cask is fitted with special impact absorbers on each end to provide additional protection. Whatever little protection afforded by the fins on the older casks has essentially been replaced by the similar protection offered by the neutron shield on modern casks (missing on the test casks). Because of advances in manufacturing techniques and the NRC imposed requirements for more quality control, modern casks are more competent than those tested by Sandia.

31. "The film casks were produced in very limited quantities and were almost entirely hand made, limiting the opportunities for manufacturing flaws."

It is true that the casks tested were manufactured in small numbers but, they were not subject to the stringent Quality Assurance requirements in place today. In fact, it was manufacturing defects that caused the cracks that developed in the fire test of the rail cask (see box on page 1). The implication that modern casks will be less competent because of sloppy manufacturing techniques is just not true.

32. "They (the next generation casks) will be produced in extremely large numbers in a production line fashion, creating greater opportunities for error and faulty construction."

This statement reveals a total lack of understanding of manufacturing processes. Manufacturing in a production line fashion allows the use of jigs and fixtures as well as standardized procedures, all of which contribute to improved quality. While the larger numbers of modern casks that will be manufactured will allow the utilization of modern production techniques, the casks to be produced for shipping spent fuel to a repository will not be required in "extremely large numbers." Unless, of course, one considers less than 100 as "extremely large numbers." Quite contrary to the claim stated by the article, modern casks will be of significantly higher quality than those tested by Sandia.

33. "The accident scenarios portrayed in the film, while appearing dramatic and severe, do not represent worst case, real-world accident conditions."

While Messrs. Audin and Resnikoff have repeatedly made this claim, they have never identified the requirements they would consider more representative of the "real world" than those derived by the international experts who defined the requirements now in use. As stated in # 21 above, the NRC sponsored Modal Study looked at worst case, real-world accidents that have actually taken place in the United States and found none that would have damaged these casks sufficiently to cause a release of radioactive material.

34. "The forces exerted on the cask in many real-world situations could easily exceed those experienced during the filmed tests. These could include higher and more intense impact velocities, hotter and longer burning fires, and longer and more damaging drops from bridges, canyons, etc."

Three claims centered on severity are made here. First is the claim that the impact velocities in the Sandia Tests were not as high as might be expected in the real-world. Department of Transportation data on highway collision velocities reveals that by the time you reach 65 mph, 99.99% of all collisions are included. There are no highway collisions where the change in velocity exceeded 70 mph. Since one of the truck tests was conducted at 84 mph it would appear that highway collisions were covered. For rail accidents, the entire spectrum of collision accidents is covered by the time you reach 80 mph. Again, the rail car collision at 81 mph should encompass that. As for the "intensity" of the impacts there is simply no way to impart more energy into the cask (and therefore cause more damage) than to use an unyielding target. This includes the head-on collision of two maximum allowable weight tractor-trailer rigs at the speed which the vehicle hit the target in the Sandia tests. There are no "real-world" situations which exceed those shown in the tests.

Second, is the claim about hotter and longer burning fires. Several real-world arguments serve to reveal the fallacy of that point. Simplest of these is the availability of fuel. The fire test in the film consumed 36,000 gallons of JP-4 (jet engine fuel). It would take almost two rail tank cars to provide that much fuel. The pool of fuel must be on the order of 60 feet in diameter and centered on the cask in order to completely engulf the cask and the rail car as in the test sequence. But, the fuel must not soak into the ground or run off and away from the cask (no ditches and level ground). In order to allow for such real-world considerations would require at least doubling the quantity of fuel needed to 72,000 gallons. Further, the cask would have to end up, after the accident, suspended above the center of this pool of fuel. But, studies of severe accidents shows that the heavier objects end up on the bottom of the wreckage not the top. There is certainly nothing heavier than the cask on the railroad train (see # 37 below). Considering all these real-world factors makes the exposure to a fire more severe than the test fire essentially impossible. The temperature of fires is another matter. For each pound of fuel burned in an ideal fire there is about 3.6 pounds of Oxygen required or about 17 pounds of air. A fire of the required size is burning 1,700 pounds of fuel per minute which would require 29,240 pounds of air. In more understandable terms, it would require about 362,000 cubic feet of air per minute or 6,000 cubic feet of air per second. Air being sucked into the fire would have to reach velocities of over 20 mph at the base of the fire. All of this explanation is to show that large pool fires are oxygen starved and therefore burn cooler than the theoretical combustion temperature. Another proof of this is the fire test shown in the Sandia film. Calculations performed before the test used two radiating temperatures for the flames. One that was calculated was 1,475°F (the regulatory temperature) and the other calculated was 2,000°F (the measured temperature of JP-4 combustion). During the first two-thirds of the fire test,

the heating of the cask closely followed the profile predicted by the regulatory temperature. Hotter fires of the size required are not "real-world" events.

Finally, when it comes to "real-world" drops from bridges and canyons there are again some factors to consider. Often cited is the fact that the Royal Gorge bridge is 1300 feet above the canyon floor. But, casks do not cross the Royal Gorge bridge since the only thing on the other side is a traffic circle. In fact, casks, which are required to be transported on Interstate Highways, do not cross any bridges of extreme height. But, they might cross a few rivers and canyons that are greater than 30 feet deep from the bridge. Tracing the experience to date of heavy trucks going off high bridges reveals this is an extremely rare event. Further, the surfaces below the bridge are not unyielding and not perpendicular to the path of the cask. These conditions reduce the severity of the impact. Tests comparing target hardness effects indicate that targets such as weathered rock would require impact velocities on the order of three times that of the unyielding target to produce equivalent effects. To achieve a 90 mph impact the cask would have to drop 272 feet, a distance greater than any bridge or canyon along the route.

Even though the tests were not conducted as proof tests but were performed to validate the analytical tools used in the design and evaluation of casks, they did encompass the real-world accident spectrum.

35. "In the train accident film, the locomotive did not have fuel; it was accelerated by means of small jets or rockets and its fuel tanks were empty. The accident did not allow for a fuel fire following the collision."

Fuel was not included in the grade crossing test because the only purpose it would have served was to obscure what was being studied. Fuel tanks may or may not have ruptured but suppose they did. The result would have been to spread diesel oil from the point of impact forward to the point the locomotive stopped. No pool would have been formed and it is debatable whether or not the diesel oil would have ignited. Even if it had ignited, the fire would have been a low temperature event of short duration and would not have included the cask considering where it came to rest. This accusation shows the care exercised in obtaining accurate data in these tests, not any omission.

36. "The accident was not conservative. The amount of kinetic energy available for destruction was the kinetic energy of the locomotive. A real collision would more than likely involve a train which would have 100 times the kinetic energy of a single locomotive."

This factor was considered in calculations before the test. Those calculations showed that the locomotive frame would buckle upon impact forming a ramp that would lift the

cask into the superstructure. As soon as the locomotive structure buckled the additional energy available for further damage to the cask is limited. The addition of 100 or more rail cars would have no effect on the energy available for damage. Proof of this fact was provided by the British rail impact test which did include cars behind the locomotive. The impact energy in that test was that produced by the locomotive alone; the rail cars added nothing to the severity of the collision. A second proof is the fact that the locomotive was still moving following the impact thus still had remaining kinetic energy. The impact itself had transmitted all of the energy available for damage of the cask; had there been 100 rail cars added to the locomotive, the amount of energy transmitted to the cask would have remained the same.

37. "The amount of energy available for damage in this accident would be significantly greater than depicted and it is likely the cask would be buried beneath other derailed freight cars."

The energy available for damage is addressed in # 36 above. On the matter of burying the cask by other freight cars, that is precisely the point made in # 3 and # 34 above. After the accident the cask is at the bottom of the wreckage, covered by other wreckage, protected from fire and cushioned from any additional impact that might be imagined.

38. "A very serious accident would be one involving a dedicated train consisting of perhaps 10 freight cars carrying 10 casks. The DOE has at times considered such a transportation system. The piling up of 10 casks could result in the breaking of several casks and the release of significant amounts of radioactivity."

Before addressing this point it might be informative to comment on the use of the word "radioactivity." Radioactivity is a property of a material, like weight or beauty or size. You don't release weight or beauty or size and radioactivity is not released. The proper terminology is the release of radioactive material. This is conceptually important since the radioactive material involved in this debate is spent fuel; a ceramic solid not a powder or liquid. Further, this solid is contained in a zircalloy cladding from the time it is manufactured until it is finally disposed of as waste. It takes considerably more than a "leak" to allow this material to escape from a cask. In contrast, the use of the term "radioactivity" implies something smaller than the eye can see; something which can actually flow through any crack and can insidiously creep around any barrier. Those who wrote the article being reviewed should know better. If they do know better they are guilty of intentionally misleading the public; if they don't know better they are not qualified to make the assertions they have.

DOE has indeed considered such dedicated train shipments and may someday use

such an approach. In almost any conceivable accident, only a portion of the train would leave the tracks. Therefore, it is difficult to conceive all ten casks "piling up" as postulated. Even if all ten did leave the tracks and begin to jackstraw (e.g., the cars hinge on the couplers and fold together side to side), this process of "jackstrawing" will absorb much of the initial energy. Even if several of the casks do bump into each other, the cask presents no more severe an impact than the impact into the unyielding surface which they are designed to survive.

39. "It is doubtful that current clean-up crews have any expertise or know-how to deal with such a large catastrophe."

Large transportation accidents occur every year or so. Current "clean-up crews" have experience with such events. Further, as the result of years of planning, there are emergency response plans in place for just such a contingency. By the time any MRS or repository opens these plans will be further refined. An accident involving spent fuel casks would not be any different than other severe accidents that have been experienced as long as there was no release of radioactive material. Studies have shown that there are no accidents within the real-world experience that would cause the magnitude of release hypothesized. As soon as it had been determined (by DOE, the NRC, State, or local personnel) that there had been no release of radioactive material, the private "clean-up crews" would begin clearing the wreckage. DOE would be responsible for determining the disposition of the casks based on NRC regulations.

40. "The use of clips of these films in the ANEC ads is just another example DOE's and the nuclear industry's efforts to distort and misrepresent facts to try sell the nuclear dump to Nevadans."

There is no doubt of efforts to distort and misrepresent facts. The fault lies with those who produce and publish articles of the type analyzed here.

41. "If anything, the film clips in the ads are even more dishonest and misleading than the original films, since the clips rely solely on the dramatic imagery of trucks and trains crashing into walls and each other to divert peoples attention away from the real issues of safety."

Again, the most dishonest and misleading part of this whole exchange is the article being analyzed. Its purpose is to sensationalize the situation through misinformation and thus divert people's attention away from the real issues of safety and what has been done to study the safety of shipping spent fuel. The films are what they are; no retakes; no doctoring. Anyone who does not come away impressed with the severity of the tests just has

no perception of the violence of the test accidents. This is not imagery, it is fact. Messrs. Audin and Resnikoff are the guilty parties to confusing the situation in an effort to distort the safety record of the industry and the effort DOE and the industry devote to assuring that safety record stays unblemished. There is no other human activity with the record of safety amassed by those involved in the shipping of spent fuel.

42. "There could be as many as 140,000 individual truck shipments of nuclear waste streaming through Nevada if a dump is built here."

This alarming number assumes that each fuel element to be placed into the repository, should it ever be built, will be shipped in its own cask. But, as was hinted at in the accusation in # 27 above, several systems are under consideration ranging from truck casks which would hold four to nine elements to rail casks capable of shipping 21 to 52 fuel elements. If all the fuel was shipped by truck it is estimated to take about 21,500 shipments. Over a 28 year period that would average 770 shipments a year or one every 11.3 hours. If all the shipments were made by rail the numbers of shipments drops to 7,000 or about 250 per year or one every day and a half. Obviously the figures used in the article are intended to alarm rather than to inform.

Counting the box on the first page, this reply addresses a total of 43 misleading, distorted or incorrect allegations. The issue here is who is telling the truth. After reading this, you might conclude that one side is and the other side is not. Maybe the people of Nevada need to reassess the information being furnished them by their State officials.

# Crash test films branded misleading

(Continued from Page Five)

Other criticisms of the ad films:

- The casks are not the same as are in use today, or are they the type to be used for dump shipments. The casks in the films could carry at most one early fuel assembly, which is considerably smaller than the assemblies used in the newer and larger nuclear power plants.
- In the train collision film the cask was thrown off the truck rig, but it is very likely that the modern cask would end up absorbing a large amount of the kinetic energy of the train.
- The NRC's regulations allow for testing of a quarter-scale model. The small casks in the movies would not even qualify as a quarter-scale model of the modern casks under design.
- Repository casks will be lighter and less heavily shielded and will not have cooling fins and other appendages which serve as impact absorbers.
- The film casks were produced in very limited quantities and were almost entirely hand made, limiting the opportunities for manufacturing flaws. They will be produced in extremely large numbers in a production line fashion, creating greater opportunities for error and faulty construction.
- The accident scenarios portrayed in the film, while appearing dramatic and severe, do no represent worst-case, real-world accident conditions. The forces exerted on the cask in many real-world situations could easily exceed those experienced during the filmed tests. These could include higher and more intense impact velocities, hotter and longer-burning fires, and longer and more damaging drops from bridges, canyons, etc.
- In the train accident film, the locomotive did not have fuel; it was accelerated by means of small jets or rockets and its fuel tanks were empty. The accident did not allow for a fuel fire following the collision.
- The accident was not conservative. The amount of energy available for destruction was the kinetic energy of the locomotive. A real collision would more than likely involve a train which would have 100 times the kinetic energy of a single locomotive.
- The amount of energy available for damage in this accident would be significantly greater than depicted and it is likely the cask would be buried beneath other derailed freight cars.
- A very serious accident would be one involving a dedicated train consisting of perhaps 10 freight cars carrying 10 casks. The DOE has at times considered such a transportation system. The piling up of 10 casks could result in the breaking of several casks and the release of significant amounts of radioactivity.
- The cleaning up procedure would require much special equipment currently unavailable, and a considerable amount of time. It is doubtful that current clean-up crews have any experience or know-how to deal with such a large catastrophe.
- The use of clips of these films in the ANEC ads is just another example of DOE's and the nuclear industry's efforts to distort and misrepresent facts to try to sell the nuclear dump to Nevadans.
- If anything, the film clips in the ads are even more dishonest and misleading than the original films, since the clips rely solely on the dramatic imagery of trucks and trains crashing into walls and each other to divert people's attention away from the real issues of safety.

Loux said the safety aspects of transportation are of supreme importance, since 90 percent of the commercial nuclear power reactors are east of the Mississippi River, and thus would have to be shipped over long distances.

There could be as many as 140,000 individual truck shipments of nuclear waste streaming through Nevada if a the dump is built here.

That amounts to up to 5,000 truck shipments a year, or one every hour and 45 minutes for 28 years, the proposed length of time for burying the tens of thousands of tons of radioactive waste from the nation's nuclear power plants.

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# A Summary : Crash Testing Nuclear Fuel Shipping Containers, 1975 Through 1977 (Four Tests)

ABSTRACT:

In an attempt to understand the dynamics of extra severe transportation accidents and to evaluate state-of-the-art computational techniques for predicting the dynamic response of shipping casks involved in vehicular system crashes, ERDA (The Energy Research and Development Administration ) undertook a three-part test program: 1 The use of computational methods to predict accident environments and the damage incurred by shipping casks; 2 Testing of 1/8-scale models of cask systems, studying the damage incurred by instrumentation and high speed photography, and correlating the results; 3 Conducting full-scale crash events at Oak Ridge and Sandia, involving representative hardware, both casks and carriers.([1])

PROGRAM OBJECTIVES:

The ERDA test program had two major objectives:

> 1: To assess and demonstrate the validity of analytical and scale modeling programs for predicting damage in accident conditions by comparing predicted results with actual test results, and . . .
>
> 2: To gain quantitative knowledge of extreme accident environments by measuring the response of full scale hardware under actual crash conditions.

"The tests are not intended to validate present regulatory standards (i.e., regulations promulgated by the U.S. Nuclear Regulatory Commission, and the Department of Transportation, and/or the International Atomic Energy Agency)." ([2])

*Program objectives have been, and are still frequently distorted.*

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[1] Data and information have been summarized from Sandia document SAND77-1462, by Robert M. Jefferson and H. Richard Yoshimura. (Mr. Jefferson has retired; I believe Dr. Yoshimura is still with Sandia Laboratories. The referenced document is a preprint of a presentation made before the 1978 Annual Meeting of the National Academy of Science's Transportation Research Board, Washington, D.C.. Other sources are noted.

[2] Quoted from SAND77-1462, page 4.

ERDA approached this full scale test program in three separate phases:

1. Mathematical analyses;
2. Scale model testing, and;
3. Full scale tests.

The referenced report (SAND77-1462) contains descriptive material regarding the analyses phases (1 & 2) of the ERDA program, including both lumped-parameter and dynamic finite-element models, and scale model testing. Discussion of these phases is omitted here, since we are primarily interested in the full scale testing program. Note that tests were limited to repeatable tests; no roll-overs or skids.

PRELIMINARY TESTING:

The ERDA conducted drop tests of obsolete shipping casks to prepare for full scale testing of spent nuclear fuel shipping systems. Two free-fall drop tests were conducted in 1975 using obsolete casks. ([3],[4]) Both drops were from helicopters at about 2000 feet.

#1 Impacted hard, undisturbed prairie surface at 396 kph (246 mph), penetrating the soil 2.4 meters with no measurable deformation of the cask. An identical cask dropped the standard 10 m (about 33 ft) onto an unyielding surface at the Oak Ridge drop tower facility suffered deformation and weld failures in the outer shell of the cask.

#2 Had been used to ship and store spent fuel from an Oak Ridge research reactor. It impacted the ground at 371 kph (230 mph). This cask suffered superficial deformation.

These tests demonstrated that the regulatory 10 meter ("30 ft") tests were more severe than the free-fall tests, even though the free-fall velocities were higher. Both casks would have safely contained their contents after impact, without release.

FULL SCALE TEST EQUIPMENT:

As usual, financial constraints affected both test definition and equipment. Out-of-service and older shipping cask systems, used commercial truck tractors, and a military surplus locomotive were obtained and modified (e.g., added cask impact limiters), to make them more representative of current designs.

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[3] Ivan G. Waddoups, Air Drop Test of Shielded Radioactive Material Containers, SAND 75-0276, Sandia Laboratories, Albuquerque, NM (September 1975)

[4] Casks were considered obsolete because they did not meet the then current fire test requirements.

Casks Used in These Tests: The casks weighed from 20 to 62 metric tons (tonnes), and were of the same basic construction: Each had an inner and outer steel shell, with the annular region between filled with lead for beta-gamma shielding. The heads were bolted to the cask bodies. The casks used in the test program were similar in weight to modern casks, and -- where they differ -- the weight difference has been shown to be of little significance in the accident environment.([5])

Impact Test Target: The target for impact tests was designed to be very massive and rigid. It consisted of a heavily reinforced 626 tonne concrete structure, backed by more than 1,580 tonnes of earth. An object of this size and weight would be very rare along truck or railroad routes. For all practical purposes, considering the masses and velocities involved in the tests, this target was essentially unyielding.

## TRUCK IMPACT TESTS:

For the truck-cask impact tests, a spent fuel cask weighing 20.5 tonnes, and its normal transport trailer with tiedowns were obtained. The cask was mounted with its head facing forward, as are most modern truck casks. The cask was secured on the trailer by bolted connections at either end of the cask. Balsa wood impact limiters were added to evaluate the effectiveness of such devices. A standard cabover, tandem-axle, diesel-powered tractor was procured for the test. Although used, the structural members of the tractor were in excellent condition.

First Truck-Cask Test: The first truck-cask impact test occurred on January 18, 1977. The cask was loaded with an unirradiated Savannah Core II reactor fuel assembly, ballasted to the weight of a typical PWR fuel assembly, with the test cask heated to 66°C. About 160 kg of water was included in the cask to simulate its normal shipping environment.([6]) The truck-trailer rig was propelled by rocket motors.

As predicted, the truck struck the target at 97.8 kph (60.8 mph); the cask struck the target at 45 kph (28 mph; about 20 g's). The truck cab area was totally destroyed; the trailer was badly damaged but continued to support the cask. The fuel element was undamaged, and there was only superficial damage to the cask external fins and piping.

The cask sustained so little damage that the same cask was used for the second crash test. It was again loaded with a Savannah Core II fuel assembly and water, and heated to 66°C, as for the first test. The cask was equipped with balsawood impact limiters and attached to its standard shipping trailer by front and back bolted tiedown fittings.

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[5] Although considered obsolete, both the truck and rail cask types used in these tests were reported to be in service in the latter part of the 1970's. They are obsolete now.

[6] Today, all spent fuel shipments are normally dry shipments, with an inert atmosphere.

The second test was conducted on March 16, 1977, at a velocity of 135 kph (83.9 mph); the cask impacted at 104.6 kph (65 mph). As predicted by pretest analyses, the tractor and trailer were demolished, and portions of the forward impact limiter in contact with the cask were completely crushed. The tiedowns held until the final stages of impact. Both cask and trailer remained in an approximately horizontal position after the crash.

While removing the cask from the trailer remains, seepage at a rate of about two drops per minute was detected from the cask head, releasing about 100 cc of water by the time it stopped. Inspection of the cask showed that the head was peened onto the cask and that the front of the cask had bulged. Several dents found on the surface of the cask head were caused by impact with the trailer fifth wheel pin. Slight bending of the front portion of the cask occurred due to nonsymmetric impact conditions. As predicted, the front portion of the cask was permanently deformed (bulged). The cask head was removed with great difficulty. Inspection of the fuel assembly revealed deformation at the impact end. Some fuel rod buckling occurred, but no clad (fuel rod) failure was detected. The overall response of the cask transport system agreed well with pretest analytical predictions.

If the casks had been loaded with spent fuel, neither crash would have resulted in danger to the public from released radioactive material.

GRADE CROSSING TEST:

An analytical investigation of a grade-crossing accident was performed.([7]) This indicated that with the then current shipping cask configurations, either a glancing frame or superstructure impact would occur in a two-track rural grade-crossing collision. The glancing frame impact, the more severe case, was selected for the full scale test. The impact forces generated by the frame would be limited by crippling of the locomotive's I-beam members (the main, longitudinal structural members), and therefore the effect of increasing the locomotive or train mass would be negligible in increasing damage to the cask.([8])

The locomotive grade-crossing test was conducted on April 24, 1977. The test cask was loaded with a fresh Savannah Core II fuel assembly. The 109 tonne locomotive was accelerated to test speed, impacting the cask at 131 kph (81.4 mph). As predicted, the frame of the locomotive was crippled, forming a ramp that lifted the cask into the superstructure of the locomotive. Two 2.5 mm depressions were formed in the cask where the I-beams had scraped away the cask fins, but the cask shell was not ruptured. After superstructure crush-up, the cask rolled off to the right side of the locomotive, tumbled in the dirt, and came to rest between the rails. The deformation was very similar to that predicted by scale model testing. Leak testing of the cask after impact indicated a small leak in the head seal when the cask was pressurized. This leakage would have caused essentially no risk to the public. The fuel assembly was intact, with some bowing of the fuel pins but with no clad failure. The

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[7] A.W.Dennis, Analytical Investigation of a Grade Crossing Accident Between a Rail Train and a Spent Nuclear Fuel Cask , SAND 74-0317, Sandia Laboratories, Albuquerque, NM; January 1975.

[8] The English conducted a test (or "demonstration") using an IAEA cask and a full train -- a locomotive and several cars -- impacting at more than 100 mph. See DOE tape, OCRWM Compilation Video; Five Full Scale Cask Tests.

overall damage to the cask agreed with pretest analytical and scale model predictions. Again, an accident of this magnitude would present no risk to the public.([9])

ACCIDENT SEVERITIES AND PROBABILITIES:

The test scenarios selected generally fall within the "extra severe" or "extreme" categories described in the 1972 AEC report, WASH 1238.([10]) Assuming that 3500 truck shipments (3200 km each, year 1990 estimates) are made each year, the probability of occurrence for the 100 kph truck impact into a massive barrier is once every 70 years; and for a velocity of 130 kph, approximately once every 1000 years, or no more than once every $1.13 \times 10^7$ km traveled (about 7,021,686 miles). Using the same shipment conditions for a grade-crossing accident, the probability is that for a velocity of 130 kph (80.8 mph), the predicted frequency of occurrence is somewhat less than once every 4500 years.([11],[12])

CONCLUSIONS:

Quoted from SAND77-1462: "The program objectives have been successfully met thus far. It has been shown that current analytical and scale modeling techniques can predict vehicular and cask damage in extremely severe accident environments. In addition, much data have been collected on the response of transport systems in accident environments. These tests have shown that the spent fuel casks tested are extremely rugged containers capable of surviving very severe accidents. The strong implication is that modern casks, designed and constructed to more rigid requirements, will survive equally well. Moreover, the capability to predict their survivability without full scale testing has been shown to be feasible through mathematical analysis and/or scale model testing."

We will be happy to respond to any questions.

Hal Rogers, Co-chairman, The Study Committee

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9 Of interest, if the cab of the truck in this test had been occupied, it is likely that the drivers would have survived!

10 WASH 1238, Environmental Survey of Transportation of Radioactive Materials To and From Nuclear Power Plants, US Atomic Energy Commission, Washington, DC (1972)

11 The final of the planned tests involved the impact into the previously described target of a special railcar with Yankee-Rowe rail cask (about 70 tons with its standard mounting frame). No significant impact damage to cask. This was followed by an engulfing fire: 2200° flame, 1475° radiating temperature. Test plan called for termination at 90 min. - all lead molten; fuel to fire pit turned off. With radioactive cargo, no release would have occurred. Probability calculations for a shipment distance of seven million miles indicate that for a velocity of 115 kph (71.5 mph), the probability of occurrence is about once every 5900 years, and for a velocity of 130 kph (80.78 mph), no more than once every 18,000 years.

12 I do not have the Sandia report describing the impact-followed-by-fire test; it was successful -- no release of contents.